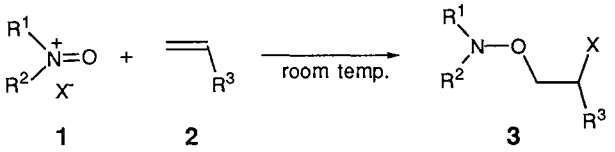
Electrophilic 1,2-Addition of Oxoammonium Salts to Olefins

Toshikazu Takata,† Yasunori Tsujino,† Saburo Nakanishi,† Kazuaki Nakamura, Eri Yoshida, and Takeshi Endo*
Research Laboratory of Resources Utilization, Tokyo Institute of Technology, Nagatsuta-cho, Midori-ku Yokohama 226-8503
†*Department of Applied Chemistry, Graduate School of Engineering, Osaka Prefecture University, Gakuene-cho, Sakai, Osaka 599-8531*

(Received May 31, 1999; CL-990461)

A new reaction of oxoammonium salt is demonstrated. Addition of oxoammonium salts (**1**) to electron-rich olefins (**2**) such as vinyl ethers and enamines rapidly proceeded to give corresponding 1,2-adducts (**3**) in high yields. The adducts **3** formed were further transformed by treatment with sodium ethoxide to isolable substitution products (**4**) in one pot reaction.

Oxoammonium salts (**1**) which are commonly prepared by one-electron oxidation of corresponding stable nitroxyl radicals are often utilized as excellent one or two electron oxidants for a variety of substrates such as alcohols, diols, hydroxide ion, benzyl ethers, and tertiary amines.[1~3] Electrophilic reactivity of **1** accompanied by O-C bond formation is confirmed only by Golubev *et al.* in the reaction with a Grignard reagent.[4] As our study on nitroxyl radical and related redox species,[1,5] we previously reported that **1** having low nucleophilic counteranions can serve as an initiator for cationic polymerization of vinyl monomers.[6] To investigate the electrophilic nature of **1** is of significance from viewpoint of not only clarification of the reactivity but also transformation or synthetic use of **1**. We have recently found a new O-C bond forming reaction of **1**, i.e. addition to C=C bond. This paper describes selective 1,2-addition of **1** with nucleophilic counteranion to electron-rich olefins affording corresponding alkoxyamines.

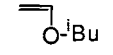
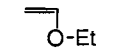
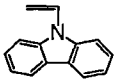
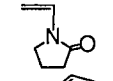
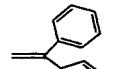
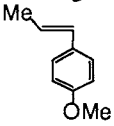
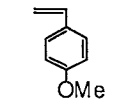
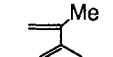
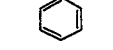


1 **2** **3**

To a solution of isobutyl vinyl ether (**2a**, 0.18 mmol) in $CDCl_3$ (0.5 mL) in a flask was added 4-methoxy-1-oxo-2,2,6,6-tetramethylpiperidinium chloride **1a**[7] (0.20 mmol) at room temperature. ^1H NMR spectrum of the mixture measured just after the addition suggested the formation of the adduct (**3a**). The structure of **3a** was established by the derivation to the stable acetal which is mentioned later, in addition to the spectral data (IR and ^1H NMR)[8]. In the ^1H NMR was observed a characteristic triplet signal at 5.60 ppm assignable to the chloromethine proton. The yield of **3a** was 89% from the ^1H NMR using benzene as internal standard (run 1, Table 1).

A variety of electron-rich olefins similarly reacted with **1a** (Table 1). Besides **2a**, vinyl ethers (**2b**, **2c**) including cyclic one, enamide (**2e**), and a few styrene derivatives (**2g** ~ **2i**) were converted to the corresponding *N*-alkoxypiperidine derivatives (**3**) in 50 ~ 97% yield. In the case of enamine (**2d**), adduct **3d** was obtained in 94% yield by the reaction at -20 °C, whereas no adduct was obtained at room temperature. Little adduct was formed from styrene, alkyl group-substituted ethylenes, and enol silyl ether. Inspection of the data of Table 1 seems to reveal that the yield of **3** depends on stability of carbocationic species formed by the initial attack of C=C bond at oxygen atom of **1a**. Use of excess amount of olefins (5 eq.) resulted in a certain yield increase and in quantitative yields of the adducts in a few cases (runs 2, 4, and 6).[9]

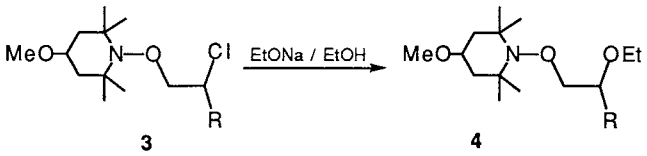
Table 1. Reaction of **1a** with various olefins **2**[a]

Run	Olefin (**2**)		Time / min	Yield (**3**) / %
1		**2a**	5	89
2		**2a**	3	96[b]
3		**2b**	5	80
4		**2b**	3	97[b]
5		**2c**	5	82
6		**2c**	3	95[b]
7		**2d**	3	94[c]
8		**2e**	15	79
9		**2f**	5	56
10		**2f**	5	61[b]
11		**2g**	5	60[d]
12		**2h**	30	50
13		**2i**	5	50[d]
14		**2i**	5	54[b]

[a]Reaction conditions: solvent $CHCl_3$; room temperature; molar ratio **1** : **2** = 1.1 : 1.0. Yield of **3** was determined by ^1H NMR. [b]Molar ratio **1** : **2** = 1 : 5. [c]Reaction at -20 °C. [d]Isomer ratio was not determined.

The isolation of **3** was usually difficult by chromatography, because **3** was fairly unstable α-chloro ethers or related species. However, relatively stable **3c** could be isolated as follows: the reaction mixture was concentrated by evaporation and the residue was carefully chromatographed on amine-treated silica gel (eluent: chloroform) to yield **3c** as colorless oil (30% yield as pure part). The *cis* : *trans* ratio was 1 : 4 by the ^1H NMR.

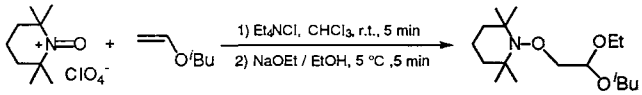
To demonstrate the reactivity of **3** and to determine the structure of **3**, successive treatment with sodium ethoxide in one-pot reaction was carried out to afford substitution products **4** in good yields. Namely, to the reaction mixture of **1a** and **2a** (0.91 eq.) was added ethanolic sodium ethoxide (2.0 eq.) at 5 °C. The product purified by preparative HPLC was acetal **4aa** (73% yield) of which structure was established by the spectral and analytical data.[10]



3 **4**

Reactivity of several oxoammonium salts (**1a** ~ **1f**)[5,11] were examined to find the effect of the structure of **1**. The results are listed in Table 2. Somewhat stable **1a** and **1b** similarly afforded the corresponding adducts in good yields independent of the structure of olefins (**2a** ~ **2c**). Although stable oxoammonium salts were not obtained, both **1c** and **1d** formed in situ from nitroxyl radicals and gaseous chlorine also reacted to produce the adducts **4**.

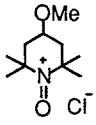
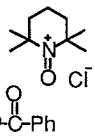
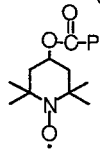
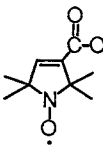
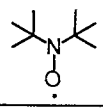
Since oxoammonium salts **1** with low nucleophilic counteranion are stable and easy to prepare,[5,11] it is desired to apply such oxoammonium salts directly to the addition reaction. Thus, the addition of **1** with low nucleophilic counteranion to **2** was employed in the presence of highly nucleophilic counteranion such as chloride ion. As depicted in the following equation, the adduct **4ba** was obtained in 45% yield, probably by overcoming the competitive polymerization of **2a**.[6] However, *N-oxo*-bis(2,4-dimethoxyphenyl)ammonium perchlorate (**1f**) hardly afforded corresponding adduct under the same conditions.



1b **2a** **4ba**, 45%

In this paper we have demonstrated a new reaction of oxoammonium salts (**1**) which undergo the electrophilic 1,2-addition to olefins to yield corresponding adducts *N*-alkoxyamines (**3**). The adducts further reacted with sodium ethoxide to give the stable substitution products (**4**) in one-pot reaction. The reaction can be regarded to have potential utility[12] as olefin functionalization, since alkoxyamine N-O bond is cloven by zinc reagent system.[13]

Table 2. Electrophilic addition of several **1** to selected olefins

Run	Oxoammonium Salt **1**[a] (Reactn. Conditn.)[b]		Reactn. Conditn. with				Yield of **4**
			2a[b]	**2b**[b]	**2c**[b]	NaOEt[b]	/%[c]
1		**1a**	C			E	90[d]
2		**1a**	C			E	73
3		**1a**		C		E	77
4		**1a**			C	E	69
5		**1b**	C			E	97
6		**1b**		C		E	63
7		**1b**			C	E	57
8	 (A)	**1c**	C			E	43
9	+ Cl_2 (A)	**1c**		C		E	65
10	(A)	**1c**			C	E	46
11	 (A)	**1d**	C			E	9
12	(B)	**1d**	D			F	42
13	+ Cl_2 (B)	**1d**		D		F	54
14	(B)	**1d**			D	F	44
15	 + Cl_2 (G)	**1e**	-[e]			-[e]	0[e]

[a]Both **1c** and **1d** were prepared in situ by the reaction of nitroxyl radicals with equimolar amount of gaseous chlorine. [b]Reaction conditions. A: $CHCl_3$, rt, 5 min. B: $CHCl_3$, -40 °C, 5 min. C: $CHCl_3$, rt, 5 min. D: $CHCl_3$, -40 °C, 5 min. E: EtOH, 5 °C, 5 min. F: EtOH, -40 °C, 5 min. G: CCl_4, rt, 5 min. [c]Isolated yield by column chromatography on silica gel. [d]Excess olefin 2 (10 eq.) was used. [e]Formation of **1e** was not confirmed.

References and Notes

1 Reviews see: M.Yamaguchi, T.Miyazawa, T.Takata, and T.Endo, *Pure Appl. Chem.*, **62**, 217 (1990); T.Endo and T.Miyazawa, *Yuki Gosei Kagaku Kyokaishi*, **44**, 1134 (1986); J.M.Bobbitt and M.C.L.Flores, *Heterocycles*, **27**, 509 (1988).

2 M.Yamaguchi, T.Takata, and T.Endo, *Tetrahedron Lett.*, **29**, 5671 (1988); M.Yamaguchi, T.Takata, and T.Endo, *J. Org. Chem.*, **55**, 1490 (1990); J.M.Bobbitt, *J. Org. Chem.*, **63**, 9367 (1998) and references cited therein.

3 T.Miyazawa and T.Endo, *J. Org. Chem.*, **50**, 3930 (1985).

4 V.A.Golubev and E.V.Kobylyanskii, *J. Org. Chem. USSR*, **8**, 2657 (1972); V.I.Rozenberg, V.K.Piotrovskii, V.A.Golubev, K.I.Gron, V.A.Nikanorov, Yu.G.Bundel, and O.A.Reutov, *Bull. Akad. Sci. USSR, Chem. Ser.*, **24**, 2508 (1975).

5 For examples: E.Yoshida, T.Takata, T.Endo, T.Ishizone, A.Hirao, and S.Nakahama, *Chem. Lett.*, **1994**, 1827; E.Yoshida, T.Ishizone, A.Hirao, S.Nakahama, T.Takata, and T.Endo, *Macromolecules*, **27**, 3119 (1994); E.Yoshida, T.Takata, and T.Endo, *Macromolecules*, **26**, 554 (1993); E.Yoshida, T.Takata, and T.Endo, *Macromolecules*, **25**, 7282 (1992).

6 E.Yoshida, K.Nakamura, T.Takata, and T.Endo, *J. Polym. Sci., Part A: Polym. Chem.*, **31**, 1505 (1993).

7 T.Miyazawa, T.Endo, S.Shiihashi, and M.Okawara, *J. Org. Chem.*, **50**, 1332 (1985).

8 Spectral data of **3a**. IR (NaCl, cm^{-1}) 2957, 2876 (C-H), 1387(N-O), 1097, 1028(C-O); ^1H NMR (60 MHz, $CDCl_3$) δ 5.60 (t, 1H), 4.13 (d, 2H), 3.35 (d, 2H), 3.28 (s, 3H), 3.80 ~ 2.90 (m, 1H), 2.00 (d, 2H), 1.76 (d, 2H), 1.62 (m, 1H), 1.27 (s, 6H), 1.20 (s, 6H), 0.93 (d, 6H).

9 This result agrees with that the addition reaction is competitive with the decomposition of **1a**, since **1a** decomposes slowly under the conditions.[2]

10 Spectral and analytical data of **4aa**. IR (NaCl, cm^{-1}) 2974, 2820, 1469, 1375, 1361, 1099, 1074; ^1H NMR (90 MHz, $CDCl_3$) δ 4.59 (t, 1H, *J*=5.4 Hz), 3.84 (d, 2H, *J*=5.4 Hz) , 3.75 ~ 3.15 (m, 5H), 3.31 (s, 3H), 2.00 ~ 1.00 (m, 8H), 1.23 (s, 6H), 1.15 (s, 6H), 0.93 (d, 6H, *J*= 6.7 Hz); ^{13}C NMR (22.4 MHz, $CDCl_3$) δ 100.9, 78.1, 73.9, 71.8, 62.2, 60.0, 55.7, 44.7, 33.2, 28.7, 21.0, 19.4, 15.4; Anal. Found: C, 65.03; H, 11.25; N, 4.47%. Calcd for $C_{18}H_{37}NO_4$: C, 65.21; H, 11.25; N, 4.23%.

11 E.G.Rozantsev, "Free Nitroxyl Radicals," ed by H.Ulrich, Plenum Press, New York (1970).

12 For example, K.Saigo, K.Kudo, Y.Hashimoto, H.Kimoto, and M.Hasegawa, *Chem. Lett.*, **1990**, 941.

13 Y.Shishido and C.Kobayashi, *J. Org. Chem.*, **57**, 2876 (1992).