CHEMISTRY LETTERS, pp. 1193-1196, 1991.

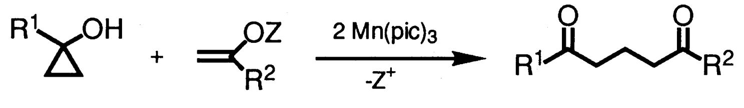
Generation of β-Keto Radicals from Cyclopropanol Derivatives by the Use of Manganese(III) 2-Pyridinecarboxylate as an Oxidant and Their Reactions with Olefins

Nobuharu IWASAWA, Satoshi HAYAKAWA, Koichi ISOBE, and Koichi NARASAKA*
Department of Chemistry, Faculty of Science, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113

Various β-keto radicals are generated from cyclopropanol derivatives such as 1- or 2-substituted cyclopropanols and a cyclopropanone hemiacetal by the use of manganese(III) 2-pyridinecarboxylate, and their reactions with electron-rich olefins give cross-addition products in good yields.

Cyclopropanes are known to have olefinic properties,1) and cyclopropanol derivatives are expected to show analogous characters to such enol compounds as silyl enol ethers and 1,3-dicarbonyl compounds which generate α-keto radicals by the reaction with manganese(III) acetate2) ($Mn(OAc)_3$) or ammonium cerium(IV) nitrate3) (CAN). But the oxidative generation of β-keto radicals from cyclopropanol derivatives are not explored extensively,4,5) and especially utilization of thus generated β-keto radicals for carbon-carbon bond formation is scarce.6-8) In these reactions, Fe^{III} or Cu^{II} compounds are employed as oxidants and electron-deficient olefins such as acrylonitrile or ethyl acrylate are used in excess as radical acceptors. However, the yields of cross-addition products are not sufficiently high, and the use of electron-rich olefins such as silyl enol ethers is thought to be difficult because they are easily oxidized by Fe^{III} compounds.

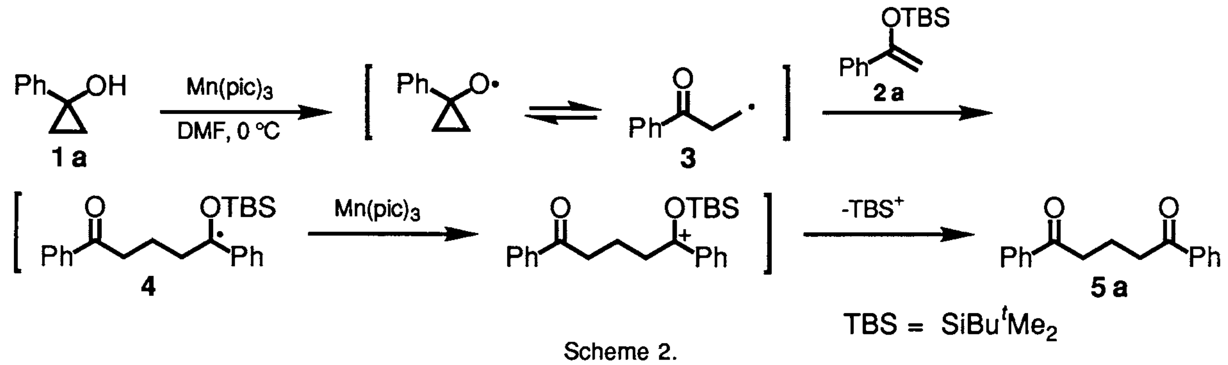
Previously, our laboratory reported the generation of α-keto radicals from β-keto carboxylic acids using manganese(III) 2-pyridinecarboxylate ($Mn(pic)_3$) as an oxidant, and their addition reactions with electron-rich olefins.9) This oxidant can be also employed in the generation of cation radicals from silyl derivatives of *aci*-nitroalkanes.10) As another application of this mild oxidant to radical reactions, we would like to report the generation of β-keto radicals from cyclopropanol derivatives and their addition reactions to various electron-rich olefins (Scheme 1).



Scheme 1.

We first examined the reaction of 1-phenylcyclopropanol (**1a**) and α-(*t*-butyldimethylsiloxy)styrene (**2a**) with $Mn(pic)_3$ as an oxidant. When a DMF solution of **1a** and 1.5 mole ratios of **2a** was added to 2.4 mole ratios of $Mn(pic)_3$, the reaction proceeded smoothly (0 °C, 0.5 h) and the cross-addition product **5a** was obtained in a high yield (89%) without accompanying self-coupling products of **1a** or **2a** (Scheme 2).11)

In this reaction, a β-keto radical **3**, generated oxidatively from the cyclopropanol **1a**, reacted with the electron rich olefin **2a** to give a radical intermediate **4**, which was further oxidized by $Mn(pic)_3$ affording the

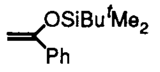
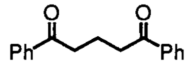
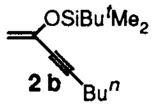
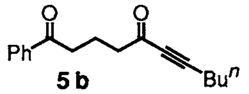
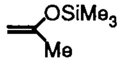
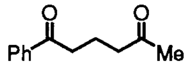
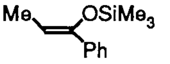
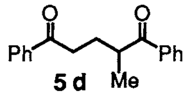
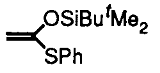
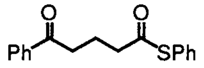
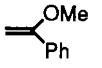
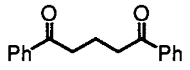


Scheme 2.

addition product **5a**. Other oxidants such as $Mn(OAc)_3$, $Fe(NO_3)_3$, and $CuCl_2$ were also examined, however, much inferior results were observed in these cases.

Since **1a** reacted smoothly with **2a** in the presence of $Mn(pic)_3$, the reaction of **1a** was further examined with various olefins. As shown in Table 1, a conjugated silyl enol ether **2b** also gave the corresponding product in a high yield (Entry 2). And, in addition to silyl enol ethers, electron-rich olefins such as a ketene thioacetal **2e** and a vinyl ether **2f** gave the adducts in good yields (Entries 5 and 6).

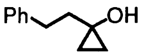
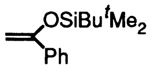
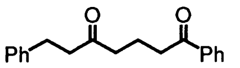
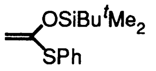
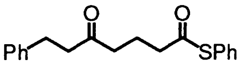
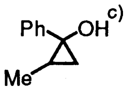
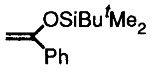
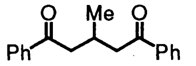
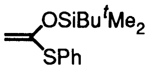
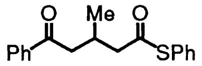
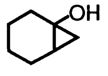
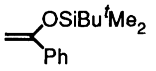
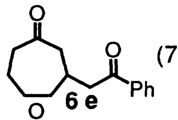
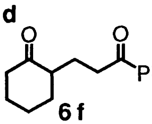
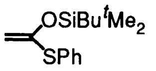
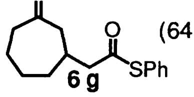
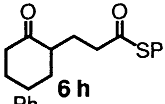
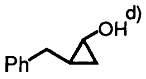
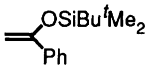
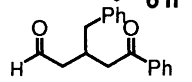
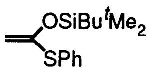
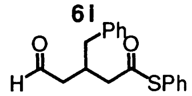
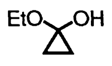
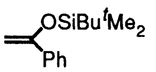
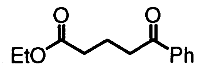
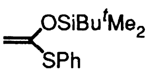
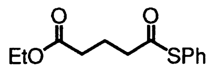
Table 1. The Reactions of 1-Phenylcyclopropanol (**1a**) with Various Olefins[a)]

Entry	Olefin	Amount of reagent / mole ratio[b)] $Mn(pic)_3$	Olefin	Product	Yield / %[b)]
1	 **2a**	2.4	1.5	 **5a**	89
2		2.4	1.5		88
3	 **2c**	2.6	3.1	 **5c**	14
4	 **2d**	2.9	1.7		41
5	 **2e**	2.5	2.6	 **5e**	66
6	 **2f**	2.4	1.5	 **5a**	72

a) Reaction conditions: DMF, 0 °C, 0.5-5 h. b) Based on **1a**.

Next, the reactions of various other cyclopropanol derivatives were examined with the representative olefins **2a** and **2e**. As shown in Table 2, a tertiary cyclopropanol **1b** reacted with the olefins **2a** and **2e**, and the corresponding adducts were obtained in moderate to high yields (Entries 1 and 2). In case of 2-substituted cyclopropanols **1c**, **1d**, and **1e**, secondary radicals were generated preferentially (Entries 3-8). Especially notable is the fact that bicyclo[4.1.0]heptan-1-ol (**1d**) was oxidized to give the ring-expanded radical affording the seven-membered adducts **6e** and **6g** as major products (Entries 5 and 6).[12] Furthermore, a secondary cyclopropanol **1e** and a cyclopropanone hemiacetal **1f** could be employed as β-formyl and β-alkoxycarbonyl radical sources in this reaction, and the corresponding aldehydes and esters were obtained in good to high yields (Entries 7-10).

Table 2. The Reactions of Various Cyclopropanols with Representative Olefins[a]

Entry	Cyclopropanol	Olefin	Amount of reagent / mole ratio[b]		Product (Yield / %[b])
			Mn(pic)$_3$	Olefin	
1	 **1b**	 **2a**	2.4	1.5	 **6a** (80)
2		 **2e**	2.4	2.7	 **6b** (59)
3	 [c] **1c**	 **2a**	2.4	1.3	 **6c** (78)
4		 **2e**	2.7	2.3	 **6d** (66)
5	 **1d**	 **2a**	2.4	1.5	 **6e** (77)  **6f** (5)
6		 **2e**	2.4	2.4	 **6g** (64)  **6h** (10)
7	 [d] **1e**	 **2a**	2.0	3.4	 **6i** (78)
8		 **2e**	2.0	3.4	 **6j** (33)
9	 **1f**	 **2a**	2.4	1.5	 **6k** (85)
10		 **2e**	2.0	1.5	 **6l** (63)

a) Reaction conditions: DMF, 0 °C, 0.5-2.5 h. b) Based on **1**. c) *cis*-Form. d) *trans*-Form.

A typical procedure is as follows: To Mn(pic)$_3$ (0.15 g, 0.36 mmol) was added a DMF (1 cm^3) solution of **1a** (20 mg, 0.15 mmol) and **2a** (53 mg, 0.23 mmol) with stirring at 0 °C under an argon atmosphere. After being stirred for 30 min, the reaction was quenched with phosphate buffer (pH 7), and the resulting mixture was filtered through Celite. Organic materials were extracted with ether, and the combined extracts were washed with brine, and dried over Na_2SO_4. The solvent was removed under reduced pressure and the residue was purified by preparative TLC (hexane / ethyl acetate) to afford the desired product **5a** (34 mg, 89% yield).

The present work was partially supported by Grant-in-Aid for Scientific Research on Priority Areas (Multiplex Organic Systems) from the Ministry of Education, Science and Culture.

References

1) M. Charton, "Olefinic Properties of Cyclopropanes," in "The Chemistry of Alkenes," ed by J. Zabicky, Interscience Publishers, London (1970), Vol. 2, Chap. 10, pp. 511-610.

2) See for example; E. Baciocchi, G. Civitarese, and R. Ruzziconi, *Tetrahedron Lett.*, **28**, 5357 (1987); E. Baciocchi, A. Casu, and R. Ruzziconi, *ibid.*, **30**, 3707 (1989).

3) See for example; S. A. Kates, M. A. Dombroski, and B. B. Snider, *J. Org. Chem.*, **55**, 2427 (1990).

4) S. E. Schaafsma, H. Steinberg, and Th. J. de Boer, *Recl. Trav. Chim. Pays-Bas*, **85**, 70 (1966); S. E. Schaafsma, H. Steinberg, and Th. J. de Boer, *ibid.*, **85**, 73 (1966); B. H. Bakker, H. Steinberg, and Th. J. de Boer, *ibid.*, **95**, 274 (1976); B. H. Bakker, Th. R. Bok, H. Steinberg, and Th. J. de Boer, *ibid.*, **96**, 31 (1977); S. Torii, T. Okamoto, and N. Ueno, *J. Chem. Soc., Chem. Commun.*, **1978**, 293; I. Ryu, M. Ando, A. Ogawa, S. Murai, and N. Sonoda, *J. Am. Chem. Soc.*, **105**, 7192 (1983).

5) Y. Ito, S. Fujii, and T. Saegusa, *J. Org. Chem.*, **41**, 2073 (1976); Y. Ito, S. Fujii, M. Nakatsuka, F. Kawamoto, and T. Saegusa, *Org. Synth.*, Coll. Vol. VI, 327 (1988); L. Blanco and A. Mansouri, *Tetrahedron Lett.*, **29**, 3239 (1988).

6) For the self-coupling reactions of the generated β-keto radicals, see; C. H. DePuy, W. C. Arney Jr., and D. H. Gibson, *J. Am. Chem. Soc.*, **90**, 1830 (1968); C. H. DePuy and R. J. Van Lanen, *J. Org. Chem.*, **39**, 3360 (1974); I. Ryu, M. Ando, A. Ogawa, S. Murai, and N. Sonoda, *J. Am. Chem. Soc.*, **105**, 7192 (1983).

7) For the cross-addition reactions of the generated β-keto radicals, see; S. E. Schaafsma, E. J. F. Molenaar, H. Steinberg, and Th. J. de Boer, *Recl. Trav. Chim. Pays-Bas*, **87**, 1301 (1968); S. E. Schaafsma, R. Jorritsma, H. Steinberg, and Th. J. de Boer, *Tetrahedron Lett.*, **1973**, 827.

8) β-Keto radicals are also generated indirectly from cyclopropanol derivatives via electrophilic cyclopropane ring opening by $Hg(OAc)_2$ and reduction of the generated organomercuric compounds. Cross-additions of these β-keto radicals with electron-deficient olefins are reported: B. Giese and H. Horler, *Tetrahedron*, **41**, 4025 (1985) and references cited therein.

9) K. Narasaka, N. Miyoshi, K. Iwakura, and T. Okauchi, *Chem. Lett.*, **1989**, 2169.

10) K. Narasaka, K. Iwakura, and T. Okauchi, *Chem. Lett.*, **1991**, 423.

11) When **1a** was treated with $Mn(pic)_3$ in the absence of the olefin **2a**, propiophenone and 1,6-diphenyl-1,6-hexanedione, the self-coupling product of the β-keto radical **3**, were obtained in ca. 30% and 50% yields, respectively. When **2a** was treated with $Mn(pic)_3$ in the absence of the cyclopropanol for 3 h at 0 °C, the self-coupling product of **2a** was not detected by ^1H NMR, and **2a** was recovered.

12) Seven-membered products are also obtained from 1-trimethylsiloxybicyclo[4.1.0]heptane derivatives by $FeCl_3$ oxidation (Ref. 5).

(Received April 5, 1991)