Tetrahedron Letters,Vol.26,No.41,pp 5061-5064,1985 0040-4039/85 $3.00 + .00
Printed in Great Britain

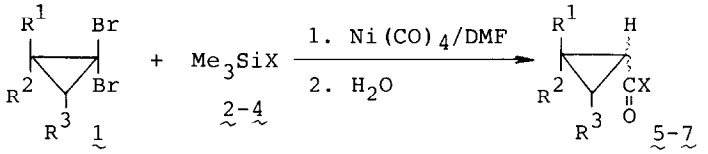
NICKEL ENOLATES IN THE $Ni(CO)_4$-INDUCED CARBONYLATION OF GEM-DIBROMOCYCLOPROPANES WITH SILYLAMINE OR SILYLSULFIDE

Toshikazu Hirao,* Shinichiro Nagata, Yoshihiro Yamana, and Toshio Agawa
Department of Applied Chemistry, Faculty of Engineering, Osaka University
2-1 Yamadaoka, Suita, Osaka 565, Japan

Summary: Silyl compounds (N,N-dialkyltrimethylsilylamine, 1-(trimethylsilyl)-imidazole and phenylthiotrimethylsilane) were successfully used in the $Ni(CO)_4$-induced carbonylation reactions of gem-dibromocyclopropanes. The nickel carbenoid and enolate complexes are considered to be involved as key intermediates. Protonation afforded the cyclopropanecarboxylic acid derivatives. The presence of an electrophile achieved another stereoselective carbon-carbon bond formation via the nickel enolate intermediate.

The chemistry of transition metal enolates has been scarcely explored although their synthetic utility is promising.[1] The previous paper reported the $Ni(CO)_4$-induced reductive carbonylation reactions of gem-dibromocyclopropanes with amines or alcohols.[2] The potential importance of this method is represented by facilitating difficult introduction of a functional group to a cyclopropane ring. We describe here a successful utilization of silylamine and silylsulfide in $Ni(CO)_4$-induced carbonylation reactions, in which nickel enolates are considered to be generated as key intermediates. This finding contributes one-step gem-functionalization of cyclopropanes.

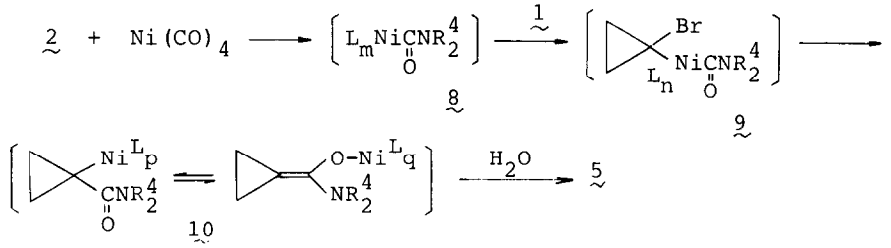
Treatment of the gem-dibromocyclopropane 1 with the silylamine 2 in the presence of $Ni(CO)_4$ in DMF followed by workup gave the cyclopropanecarboxamide 5, in which hydrogenolysis of the C-Br bond and introduction of the carbamoyl group are performed. A variety of gem-dibromocyclopropanes were subjected to



2, X=NR^4_2; 3, X=N⟨N; 4, X=SPh 5, X=NR^4_2; 6, X=N⟨N; 7, X=SPh

this reductive carbonylation reaction (Table I).

Silylamines are mainly used as silylating agents especially towards alcoholic hydroxyl groups.[3] The most powerful silylating agent, 1-(trimethylsilyl)imidazole (3) also underwent the similar type of reaction to give the corresponding 1-acylimidazole 6. These reactions might represent the first instance to use silylamine as a nucleophile in metal carbonyl induced carbonylation reactions. The plausible reaction path is depicted in the following scheme.[4] At the first step, $Ni(CO)_4$ is assumed to contact with 2 to generate 8 as proposed in the carbonylation reaction of vinyl bromides.[5] The attack of 8 to 1 forms the nickel carbenoid complex 9. The migration of the carbamoyl group gives the enolate 10, protonation (workup) of which completes the reaction path.



The reaction of 1,1-dibromo-2-phenylcyclopropane (1a) with N,N-dimethyltrimethylsilylamine (2a) gave a small amount of the 1-(trimethylsilyl)cyclopropanecarboxamide (9%) together with the desired cyclopropanecarboxamide 5a. The former formation might be explained by the capture of the enolate 10 with a silyl-containing species. The intermediacy of the unique transition metal carbenoid complex 9 is ascertained by following the reaction of 1a although 9 has not been isolated as a concrete complex. 1-Bromo-2-phenylcyclopropane (11a) was obtained as a byproduct which is considered to be derived by protonation (workup) of 9a. The ratio of 11a to 5a decreased gradually as the reaction time was prolonged (Table I).

Use of silyl compounds in the present carbonylation is also realized in the reaction with silylsulfide. Treatment of 1a with phenylthiotrimethylsilane (4) and $Ni(CO)_4$ resulted in the selective formation of the cyclopropanecarbothiolate 7a. This finding is in sharp contrast to the reaction with thiophenol; substantial amounts of byproducts such as phenyl-(2-phenylcyclopropyl)sulfide and S-phenyl 2-phenyl-1-phenylthiocyclopropanecarbothiolate are essentially obtained.[6] The silylsulfide 4 is regarded as a selective reagent for reductive carbonylation. Silylethers did not work as an initial nucleophile under the conditions employed here.

The generation of nickel enolates is characterized by the new method based on carbonylation of gem-dibromocyclopropanes. The absence of proton source in these reactions with the silylamine 2 permits new bond formation between another electrophile and the generated nickel enolate 10 because nickel enolates

Table I. Preparation of Cyclopropanecarboxylic Acid Derivatives 5-7

R^1	1 R^2	R^3		Me_3SiX X	eq	$Ni(CO)_4$ eq	reaction time, h[a]	isolated yield of 5-7, %[b]		5a/(5a+11a)
Ph	H	H	1a	NEt_2	1.2	1	0.5	5a	22 (5)	81
	1a			NEt_2	1.2	1	3	5a	50 (9)	85
	1a			NEt_2	1.2	1	6	5a	77 (1)	99
	1a			NEt_2	1.2	3	3	5a	85	
COOMe	Me	H	1b	NEt_2	1.2	3	3	5b	73	
n-Hex	H	H	1c	NEt_2	1.2	3	3	5c	73	
H	$-(CH_2)_4-$		1d	NEt_2	1.2	3	3	5d	55	
	1a			N⟨ ⟩	1.2	3	1.5	5e	80	
	1a			NMe_2	1.2	3	3	5f	39[c]	
Me_3SiCH_2	H	H	1g	N⟨ ⟩N	2.5	3	7	6g	65	
	1a			SPh	2.5	6	20	7a	47	
Me_3Si	H	H	1h	SPh	2.5	6	6.5	7h	38	

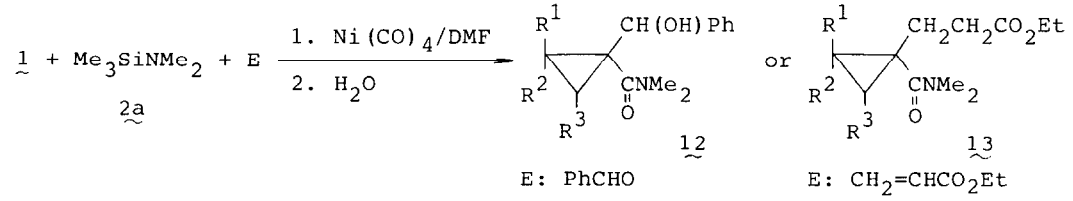
[a]Reaction temperature, 70°C. [b]The yield of 11a was shown in parenthesis. [c]N,N-Dimethyl 1-(trimethylsilyl)cyclopropanecarboxamide (9%) was produced.

Table II. Preparation of the Amides 12-13[a]

R^1	1 R^2	R^3		electrophile[b]	reaction time, h[c]	isolated yield of 12-13, %	
Ph	H	H	1a	PhCHO	6	12a	62
COOMe	Me	H	1b	PhCHO	6	12b	40
	1a			CH_2=CHCOOEt	3	13a	35[d]
	1b			CH_2=CHCOOEt	3	13b	40

[a]Me_3SiNMe_2 (1.2 eq) and $Ni(CO)_4$ (3 eq) were used. [b]Electrophile, 3 eq. [c]Reaction temperature, 70°C. [d]Ethyl 3-(1-bromo-2-phenylcyclopropyl)-propionate was obtained in a small amount.

are generally nucleophilic.[1i,j] Actually, the $Ni(CO)_4$-induced reaction of the gem-dibromocyclopropane 1 with the silylamine 2a was carried out in the presence of benzaldehyde to give the 1-(hydroxymethyl)cyclopropanecarboxamide 12.[7] Some



results are summarized in Table II. Of interest is the high stereoselectivity of the nucleophilic attack to bezaldehyde. In these cases, only one isomer was produced exclusively with respect to the geometry of the carbamoyl group[8] although it was not determined yet. The present method is evaluated as one of novel aldol reactions of electronegatively substituted cyclopropyl anions because their generation is fairly difficult.[9]

This interesting elaboration led us to try the Michael addition into ethyl acrylate. Only by mixing four compounds together, the gem-dibromocyclopropane 1 was successfully converted to the requisite adduct 13 through the high stereoselective bond formation[8] as observed in the attack to benzaldehyde (Table II). Formation of ethyl 3-(1-bromo-2-phenylcyclopropyl)propionate is assumed to be explained by the reaction of the nickel carbenoid complex 9 with ethyl acrylate.

The stereocontrolled introduction of two different groups based on the generation of the nickel enolate offers a simple and versatile method for gem-functionalization of cyclopropanes.

Acknowledgement This work was partially supported by the Grant-in-Aid for Scientific Research from the Ministry of Education, Science, and Culture.

References and Notes

1. a) H. O. House, D. S. Crumrine, A. Y. Teranishi, and H. D. Olmstead, J. Am. Chem. Soc., 95, 3310 (1973). b) T. Mukaiyama, K. Banno, and K. Narasaka, ibid., 96, 7503 (1974). c) E. A. Jeffery and A. Meisters, J. Organometal. Chem., 82, 315 (1974). d) Y. Ito, T. Hirao, and T. Saegusa, J. Org. Chem., 43, 1011 (1978). e) Y. Ito, H. Aoyama, T. Hirao, and T. Saegusa, J. Am. Chem. Soc., 101, 494 (1979). f) Y. Yamamoto and K. Maruyama, ibid., 104, 323 (1982). g) T. Hirao, N. Yamada, Y. Ohshiro, and T. Agawa, Chem. Lett., 1982, 1997. h) T. Hirao, Y. Fujihara, S. Tsuno, Y. Ohshiro, and T. Agawa, ibid., 1984, 367. i) I. Rhee, I. Ryu, H. Omura, S. Murai, and N. Sonoda, ibid., 1979, 1435. j) J. H. Nelson, P. N. Howells, G. C. DeLullo, and G. L. Landen, J. Org. Chem., 45, 1246 (1980).
2. T. Hirao, Y. Harano, Y. Yamana, Y. Ohshiro, and T. Agawa, Tetrahedron Lett., 24, 1255 (1983).
3. E. Colvin, "Silicon in Organic Synthesis"; Butterworths: London, 1980; pp 179-181.
4. Initially, reduction of 1-bromocyclopropanecarboxylates was proposed from the reasons mentioned in the previous paper.[2]
5. M. F. Semmelhack and S. J. Brickner, J. Org. Chem., 46, 1723 (1981).
6. T. Hirao, Y. Yamana, and T. Agawa, unpublished results.
7. A typical procedure is as follows. A mixture of the gem-dibromocyclopropane 1 (1 mmol), the silylamine 2 (1.2 mmol), $Ni(CO)_4$ (3 mmol), and benzaldehyde (3 mmol) in DMF (2.4 mL) was stirred under nitrogen at 70°C for 3 h. After the removal of excess $Ni(CO)_4$ under the reduced pressure, the mixture was diluted with ether and filtered on celite 545. The ethereal solution was concentrated and flash chromatographed to give the 1-(hydroxymethyl)cyclopropanecarboxamide 12.
8. This selectivity was checked by spectometry. For example, 13b: IR (neat) 1740, 1730, 1640 cm^{-1}; ^1H NMR (90 MHz, $CDCl_3$) δ 0.82 (d, 1H, J=3.4 Hz), 1.65 (t, 3H, J=4.8 Hz), 1.50 (s, 3H), 1.8-2.3 (m, 3H), 2.5-2.8 (m, 2H), 3.00 (s, 3H), 3.10 (s, 3H), 3.78 (s, 3H), 4.32 (q, 2H, J=4.8 Hz); ^{13}C NMR ($CDCl_3$) δ 15.0, 15.9, 26.3, 27.7, 30.9, 32.8, 36.1, 37.7, 38.5, 52.8, 61.3, 170.7, 173.8, 174.4; MS m/e 285 (M^+). Anal Calcd for $C_{14}H_{23}NO_5$: C, 58.93; H, 8.12; N, 4.91. Found: C, 58.95; H, 8.12; N, 4.84.
9. Quite recently, desilylation of α-(trimethylsilyl)-substituted cyclopropanes has been developed for their generation method: L. A. Paquette, C. Blankenship, and G. J. Wells, J. Am. Chem. Soc., 106, 6442 (1984).

(Received in Japan 23 July 1985)