THE NOVEL REDUCTION OF PYRIDINE DERIVATIVES WITH SAMARIUM DIIODIDE

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Abstract — Pyridine was rapidly reduced into piperidine with samarium diiodide in the presence of water at room temperature in excellent yield. On the similar reactions of pyridine derivatives bearing chloro, amino and cyano functionalities with samarium diiodide—H_2O—THF system, these functionalities were partly eliminated with this system to afford pyridine or piperidine. Furthermore, pyridinecarboxamides were reduced with this system to give the corresponding methylpyridines and 2-pyridinecarboxylic acid was reduced to give 2-methylpyridine as the major products.

INTRODUCTION

In general, compared with the reduction of other heterocyclic compounds, pyridine ring is hardly reduced to piperidine with the ordinary reducing agents under mild conditions except for a few methods, such as sodium—boiling alcohol (the Ladenburg reduction),[1] catalytic hydrogenation over platinum oxide,[2] Raney nickel[3] or copperchromium oxide[4] and aluminum hydride.[5] Taking into account of the utility of direct reduction of pyridine and its homologues to the corresponding piperidines, the discovery of a milder and convenient method has been desirable from a synthetic viewpoint.

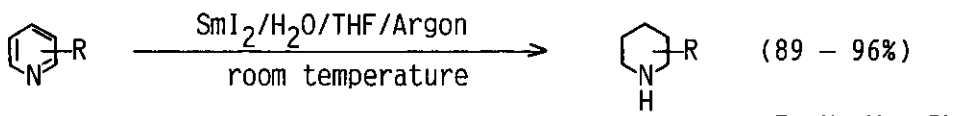
Recently, the use of samarium diiodide (SmI_2) in organic synthesis has been of interest from the standpoint of reducing property.[6] SmI_2 presents a high coordination number,[7] a great affinity for oxygen and nitrogen atoms and the highest reduction potential among species soluble in an organic medium. It is assumed that the electron donor ability of SmI_2 can be enhanced with basic ligands of SmI_2 since it would be expected to facilitate relatively the release of electron from metal ion when a sufficient electron is supplied from ligands around metal ion. In fact, the remarkable effect of HMPA,[8] base[9] and acid[9c] was observed in the reduction of organic compounds with SmI_2.

Little work has been reported on the reduction of pyridine derivatives with SmI_2. It has been previously reported that the addition of acid or base highly accelerates the single electron

donor ability of SmI_2, and these systems rapidly reduced a variety of organic functionalities.[9] Base on this reasoning and previous observations,[9] our first trial was conducted with the reaction of heterocyclic compounds by SmI_2 having the strong ability as Lewis acid. However, on the reactions of pyridine with SmI_2 (6 mol eq.) in the addition of acids such as 85% H_3PO_4, 35% HCl, 10% HCl and saturated HCl in ether at room temperature, the mixture of piperidine, tetrahydropyridine and their dimers were obtained in the any system. Furthermore, the similar reduction in the presence of NaOH, $LiNH_2$ or LiOMe was required the longer reaction time even though piperidine was obtained in good yield in the each systems. Then, considering a similar enhancement of the electron donor ability of SmI_2 by the addition of H_2O, our next trial was conducted with the similar reaction in the presence of H_2O. We report herein the novel reduction of pyridine and its homologues with SmI_2 in the presence of H_2O under the neutral and extremely mild conditions.

RESULTS

Reduction of Pyridine Derivatives with SmI_2–H_2O System. As can be seen in Table 1, the reductions of pyridine (**1**) and methylpyridines (**3** – **5**) did not proceed with SmI_2 alone and unchanged substrates were recovered even after 3 hours (Entries 1 and 8-10). Only trace amount of 2-phenylpiperidine (**10**) was obtained from the similar reaction of 2-phenylpyridine (**6**) (Entry 15). Then, expecting an enhancement of the electron donor ability of SmI_2 by the addition of H_2O, next the reaction of SmI_2–H_2O system toward pyridine derivatives was examined. Interestingly, pyridine (**1**) was rapidly reduced to piperidine (**2**) with SmI_2 (6 mol eq.) in the presence of H_2O at room temperature in excellent yield (Entries 2 – 4). However, adding alternately a solution of pyridine (**1**) in H_2O to a THF solution of SmI_2, the reduction proceeded within 2 – 3 minutes but the yield of piperidine (**2**) was decreased (Entries 5 – 7). In the reduction of pyridine with this system, the addition order of H_2O (additive) was important factor affecting the yield of piperidine and also an additional amount of H_2O was correlated with the rate of reaction. Thus, the results adding H_2O to a mixture of pyridine and SmI_2 in THF was far better than those of the addition of a mixture of pyridine and H_2O to a THF solution of SmI_2, and the yield of product was satisfactory when 55 – 83 mol eq. of H_2O (9.2 – 13.8 mol eq. of H_2O for SmI_2) was used (Entries 3 and 4).



Scheme 1

Table 1. Reduction of Pyridine, Alkyl- and Arylpyridines with SmI_2[a)]

Entry (No.)	Py-R R (No.)	Py-R (mmol)	SmI_2[b)] (mmol)	H_2O (mmol)	Time (min)	Product (No.)	Yield[c)] (%)
1	H (1)	1	6	None	180	Recovery of 1	—
2	H (1)	1	6	28	90	Piperidine (2)	95
3	H (1)	5	30	278	8.5	Piperidine (2)	96
4	H (1)	1	6	83	4	Piperidine (2)	94
5[d)]	H (1)	1	6	28	3	Piperidine (2)	68
6[d)]	H (1)	1	6	55	2.5	Piperidine (2)	59
7[d)]	H (1)	1	6	83	2	Piperidine (2)	59
8	2-Me (3)	1	6	None	210	Recovery of 3	—
9	3-Me (4)	1	6	None	310	Recovery of 4	—
10	4-Me (5)	1	6	None	240	Recovery of 5	—
11	2-Me (3)	0.5	3	28	6	2-Methylpiperidine (7)	89[e)]
12	3-Me (4)	0.5	3	28	18	3-Methylpiperidine (8)	95[f)]
13	4-Me (5)	0.5	3	28	14	4-Methylpiperidine (9)	92[g)]
14	2-Ph (6)	0.5	3	None	290	2-Phenylpiperidine (10)	2
15	2-Ph (6)	0.5	3	28	6	2-Phenylpiperidine (10)	97

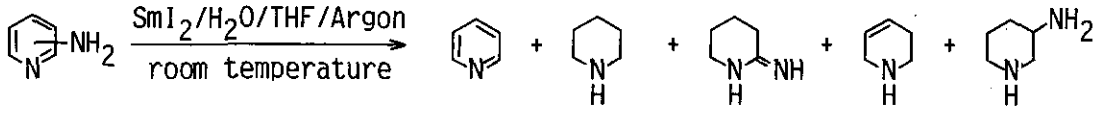
a) H_2O was added to a solution of substrate and SmI_2 in THF and reactions were carried out at room temperature under argon. b) 0.1 M solution in THF. c) Yield was isolated yield (yields of Entries 12 and 13 were determined by gas chromatography). d) A solution of pyridine (1) in H_2O was added to a THF solution of SmI_2. e) By-products; 2-methyltetrahydropyridine dimer (6%) and 2-methylpiperidine dimer (4%) (from mass data, unidentified). f) By-product; 3-methyltetrahydropyridine dimer (4%) (from mass data, unidentified). g) By-product; 4-methyltetrahydropyridine dimer (3%) (from mass data, unidentified).

Similarly, methylpyridines (**3** — **5**) and 2-phenylpyridine (**6**) were rapidly reduced with this system to afford the corresponding methylpiperidines (**7** — **9**) and 2-phenylpiperidine (**10**) in high yields (Entries 11—13 and 15).

Reduction of Aminopyridines with SmI_2—H_2O System. Furthermore, the reactions of some substituted pyridines with SmI_2 were examined in the presence of H_2O at room temperature. As shown in Table 2, reductions of aminopyridines (**12** — **14**) with SmI_2 alone did not entirely proceed (Entries 1—3).

However, in the reactions of aminopyridines (**12** and **14**) with SmI_2 (10 mol eq.)–H_2O (46 mmol) system, the amino group was unexpectedly eliminated with this system at room temperature to afford piperidine (**2**) in excellent yield (Entries 8 and 15). Contrary to these results, the similar reaction of 3-aminopyridine (**13**) gave 1,2,3,6-tetrahydropyridine (**11**) and 3-aminopiperidine (**16**) (Entry 9 or 10).

Table 2. Reduction of Aminopyridines with SmI_2–H_2O System[a)]



(**1**) (**2**) (**15**) (**11**) (**16**)

Entry	Py–R[b)]	SmI_2[c)]	H_2O	Time	Product / Yield[d)] (%)					Recovery
(No.)	R (No.)	(mol eq.)	(mol eq.)		(**1**)	(**2**)	(**15**)	(**11**)	(**16**)	(%)
1	2-Amino (**12**)	6	None	170 min						100
2	3-Amino (**13**)	6	None	180 min						100
3	4-Amino (**14**)	6	None	180 min						100
4	2-Amino (**12**)	2	11	5 sec	4	2	36			52
5	2-Amino (**12**)	4	24	2 min		52	45			
6	2-Amino (**12**)	6	28	4 min		51	29			
7	2-Amino (**12**)	8	37	6 min		82	16			
8	2-Amino (**12**)	10	46	10 min		94	2			
9	3-Amino (**13**)	6	28	1 min				66	26	7
10	3-Amino (**13**)	10	46	9 min		4		69	27	
11	4-Amino (**14**)	2	11	10 sec	8	1				90
12	4-Amino (**14**)	4	22	50 sec	2	7				81
13	4-Amino (**14**)	6	28	2 min	43	12				43
14	4-Amino (**14**)	8	37	3 min		87				12
15	4-Amino (**14**)	10	46	9 min		93				trace

a) H_2O was added to a solution of aminopyridine and SmI_2 in THF. The reactions were carried out at room temperature under argon. b) Substrate; 0.5 mmol. c) 0.1 M solution in THF. d) Yield was determined by gas chromatography.

Reduction of Chloropyridines by SmI_2 or with SmI_2–H_2O System. As shown in Table 3, both 2- and 4-chloropyridines (**17** and **19**) were reduced to pyridine (**1**) with SmI_2 in the absence of H_2O in good yield (Entries 1 and 3). However, the similar reaction of 3-chloropyridine (**18**) afforded only trace amount of pyridine (**1**) (Entry 2). Contrary to these results, chloropyridines (**17** – **19**) were reduced with SmI_2 (8 mol eq.)–H_2O (37 mol eq.) system to give only one product piperidine (**2**) in good yield (Entries 5, 7 and 9).

Table 3. Reduction of Chloropyridines with SmI_2–H_2O System[a)]

Entry (No.)	Py–R[b)] R (No.)	SmI_2[c)] (mol eq.)	H_2O (mol eq.)	Time	Product (No.)	Yield[d)] (%)
1	2-Chloro (**17**)	6	None	5 h	Pyridine (**1**)	78
2	3-Chloro (**18**)	6	None	4.5 h	Pyridine (**1**)	3
3	4-Chloro (**19**)	6	None	5 h	Pyridine (**1**)	76
4	2-Chloro (**17**)	6	28	10 min	Piperidine (**2**)	79
					Pyridine (**1**)	2
5	2-Chloro (**17**)	8	37	23 min	Piperidine (**2**)	92
6	3-Chloro (**18**)[e)]	6	28	28 min	Piperidine (**2**)	15
					Pyridine (**1**)	23
					3-Chlorotetrahydropyridine[f)]	4
7	3-Chloro (**18**)	8	37	38 min	Piperidine (**2**)	90
8	4-Chloro (**19**)	6	28	13 min	Piperidine (**2**)	62
					Pyridine (**1**)	7
9	4-Chloro (**19**)	8	37	18 min	Piperidine (**2**)	98

a) H_2O was added to a THF solution of substrate and SmI_2 at room temperature under argon. b) Substrate; 0.5 mmol. c) 0.1 M solution in THF.[2] d) Isolated yield (yields of Entries of 4, 6 and 8 were determined by gas chromatography. e) Recovery; 25%. f) From mass data (unidentified).

Reduction of Cyanopyridines by SmI_2 or with SmI_2–H_2O System. Interestingly, as can be seen in Table 4, cyano group of 2- and 4-cyanopyridines (**20** and **22**) was unexpectedly reduced to H or Me group with SmI_2 alone or SmI_2–H_2O system. In contrast to these results, cyano group of 3-cyanopyridine (**21**) was unaffected by SmI_2 or SmI_2–H_2O system.

Thus, in the reaction of 2- and 4-cyanopyridines (**20** and **22**) with SmI_2 alone, cyano group was unexpectedly eliminated at room temperature to give pyridine (**2**) accompanied with trace amount of 2- or 4-methylpyridines (**3** or **5**), respectively (Entries 1 and 7).

However, the similar reaction of 3-cyanopyridine (**21**) afforded only trace of the dimers of pyridine (**1**), piperidine (**2**) and 3-methylpyridine (**4**) (Entry 5). On the other hand, both nitriles (**20**) and (**22**) were more rapidly reduced with 2 mol eq. of SmI_2 in the presence of H_2O (11 mol eq.) to give pyridine (**1**) in excellent yield (Entries 2 and 8). On the similar reactions of nitrile (**20**) and (**22**) using of SmI_2 (6 mol eq.)–H_2O (28 mol eq.) system, piperidine (**2**) was obtained as the major product in moderate yield accompanied with by-products, respectively (Entries 4 and 10). Regarding the reductive elimination of cyano group in these reactions, cyano group at 3-position was unaffected with both SmI_2 alone and SmI_2–H_2O system, compared with those cyano group at 2- and 4-positions.

It has been previously reported that nitriles except for cyanopyridines were reduced into the

corresponding amines with SmI_2–base or acid system.[9] In contrast to the previous results, the present reductive cleavage of cyano moiety of pyridine ring with this system was the remarkable result similar to those of aminopyridines.

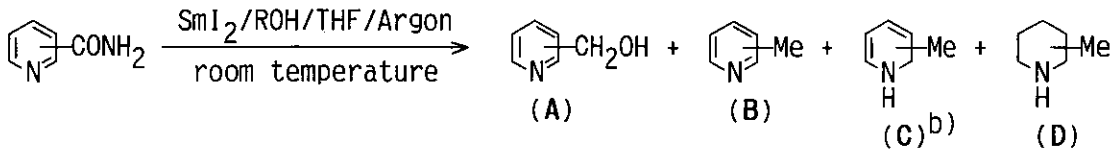
Table 4. Reduction of Cyanopyridines with SmI_2–H_2O System[a)]

Entry (No.)	Py–R[b)] R (No.)	SmI_2[c)] (mol eq.)	H_2O (mol eq.)	Time	Product (No.)	Yield[d)] (%)
1	2-Cyano (**20**)	6	None	2 h	Pyridine (**1**)	94
					2-Methylpyridine (**3**)	2
2	2-Cyano (**20**)	2	11	2 sec	Pyridine (**1**)	96
3	2-Cyano (**20**)	4	22	10 sec	Pyridine (**1**)	90
					2-Methylpyridine (**3**)	8
4	2-Cyano (**20**)	6	28	2 min	Piperidine (**2**)	65
					2-Methylpyridine (**3**)	4
5[e)]	3-Cyano (**21**)	6	None	4 h	Mixture of dimers[f)]	trace
6[g)]	3-Cyano (**21**)	6	28	20 min	3-Methylpyridine (**4**)	trace
7	4-Cyano (**22**)	6	None	4 h	Pyridine (**1**)	92
8	4-Cyano (**22**)	2	11	3 sec	Pyridine (**1**)	95
9	4-Cyano (**22**)	4	22	30 sec	Pyridine (**1**)	98
					4-Methylpyridine (**5**)	trace
10	4-Cyano (**22**)	6	28	3 min	Pyridine (**1**)	18
					Piperidine (**2**)	53
					4-Methylpyridine (**5**)	3

a) H_2O was added to a solution of cyanopyridine and SmI_2 in THF at room temperature under argon. b) Substrate; 0.5 mmol. c) 0.1 M solution in THF. d) Yield was determined by gas chromatography. e) Recovery; 63%. f) The mixture ratio of dimers of pyridine (**1**), piperidine (**2**) and 3-methylpyridine (**4**) : 1/1/4.5. g) Recovery; 45%.

Reduction of Pyridinecarboxamides with SmI_2–H_2O System. Pyridine-2-carboxamide (**23**) was reduced with SmI_2 alone at room temperature to afford 2-pyridylcarbinol (**26**) in good yield accompanied with 2-methylpyridine (**3**) (Entry 2 in Table 5). Though the reaction of pyridine-4-carboxamide (**25**) using 4 mol eq. of SmI_2 afforded 4-pyridylcarbinol (**28**) as the major product (45%) (Entry 4), the similar reaction using 6 mol eq. of SmI_2 gave 4-methylpyridine

Table 5. Reduction of Pyridinecarboxamides with SmI_2–H_2O System[a)]



Entry (No.)	Py–R[c)] R (No.)	SmI_2[d)] (mol eq.)	H_2O (mol eq.)	Time	Product (No.)/Yield (%)[e)] (A)	(B)	(C)	(D)	Recovery (%)
1	2-$CONH_2$ (**23**)	4	None	1.5 h	(**26**) 83[f)]				12
2	2-$CONH_2$ (**23**)	6	None	2 h	(**26**) 89	(**3**) 8			
3	3-$CONH_2$ (**24**)	6	None	5 h	(**27**) 3[g)]				92
4	4-$CONH_2$ (**25**)	4	None	1.3 h	(**28**) 45[h)]				50
5	4-$CONH_2$ (**25**)	6	None	3 h	(**28**) 4	(**5**) 92[i)]			
6	2-$CONH_2$ (**23**)	4	22	3 sec	(**26**) 3	(**3**) 58	(**29**) 19		18
7	2-$CONH_2$ (**23**)	6	28	3 sec		(**3**) 78	(**29**) 21		
8	2-$CONH_2$ (**23**)	4	22[j)]	5 sec	(**26**) 60	(**3**) 23			15
9	2-$CONH_2$ (**23**)	6	28[j)]	1 min	trace		(**29**) 18	(**7**) 41	
10	3-$CONH_2$ (**24**)	6	28	17 min		(**4**) 53		(**8**) 6	40
11	4-$CONH_2$ (**25**)	4	22	3 sec		(**5**) 77			23
12	4-$CONH_2$ (**25**)	6	28	3 sec		(**5**) 99			
13	4-$CONH_2$ (**25**)	4	22[j)]	10 sec		(**5**) 95			
14	4-$CONH_2$ (**25**)	6	28[j)]	7 min		(**5**) 38		(**9**) 56	

a) Reactions were carried out at room temperature under argon. b) 2-Methyldihydropyridine (**29**) (from mass data) was not identified. c) Amide; 0.5 mmol. d) 0.1 M solution in THF. e) Yield was determined by gas chromatography. f) By-product; 2-formylpyridine 4%. g) By-product; nicotinaldehyde 3%. h) By-product; 4-formylpyridine 5%. i) By-product; 4-formylpyridine 2%. j) MeOH (1 ml) was added.

(**5**) in good yield (Entry 5). In these reactions with SmI_2 alone, small amounts of the corresponding formylpyridines were obtained. Compared with the reactions of 2- and 4-pyridinecarboxamides, pyridine-3-carboxamide (**24**) afforded only small amounts of 3-pyridylcarbinol (**27**) and nicotinaldehyde under the similar conditions (Entry 3). On the other hand, amide (**23**) was immediately reduced with SmI_2 (6 mol eq.)–H_2O (28 mol eq.) system to give 2-methylpyridine (**3**) accompanied with methyldihydropyridine (**29**) (from mass data)

(Entry 7), and the similar reaction of amide (**25**) afforded 4-methylpyridine (**5**) in quantitative yield (Entry 12). However, compared with these results, the similar reaction of amide (**24**) gave 3-methylpyridine (**4**) in the lower yield and the reaction time was taken 17 minutes (Entry 10). Adding MeOH to this system, the reduction of amides (**23**) and (**25**) proceeded further and afforded methylpiperidines (**7**) and (**9**) as the major products, respectively (Entries 9 and 14).

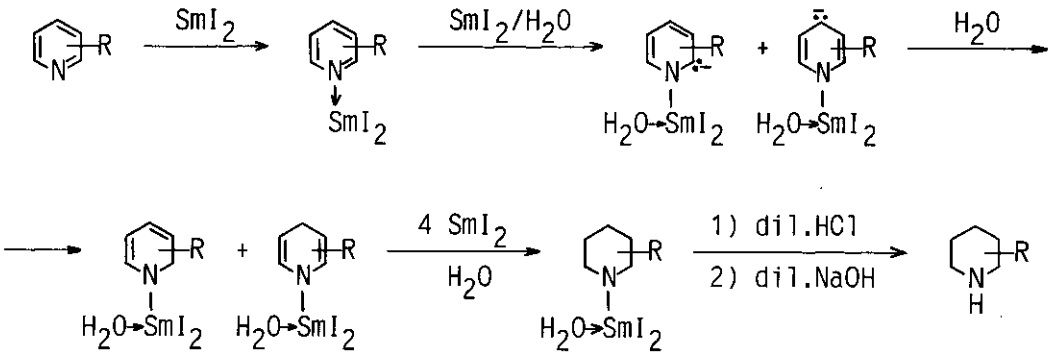
Reduction of Pyridinecarboxylic Acid with SmI_2–H_2O System. 2-Pyridinecarboxylic acid (**30**) was reduced with SmI_2 (6 mol eq.)–H_2O (28 mmol) system for 10 minutes at room temperature to give 2-methylpiperidine (**7**) (68%) and pyridine (**1**) (31%). However, the similar reaction in the absence of H_2O afforded only small amount (2%) of 2-pyridylcarbinol (**26**). It has been previously reported that pyridinecarboxylic acids were rapidly reduced with SmI_2–H_3PO_4 system to the corresponding methylpyridines alone in moderate yields.[9] Compared with these results, it is interesting in this regard that the present results exhibited the difference of electron donor ability between SmI_2–H_3PO_4 system and SmI_2–H_2O system.

MECHANISM

As described above, the single electron donor ability of SmI_2 is strongly affected by the nature of ligands around SmI_2 and it would be expected to facilitate relatively the release of electron from SmI_2 when a sufficient electron is supplied from ligands around SmI_2. Throughout the present reductions, adding alternately a THF solution of pyridine derivatives and H_2O to SmI_2, the yield of products decreased generally (these comments are given in the footnotes a) and d) in Table 1 and the results are illustrated by Entries 5–7) and the electron donor ability of SmI_2–H_2O system is greater than that of SmI_2 alone. These causes may be due to the enhancement of release of one electron from SmI_2 by the addition of H_2O to SmI_2. Accordingly, in the reduction of pyridines with this system, it is assumed that pyridine forms firstly the coordination bond with SmI_2 of strong Lewis acid, next H_2O acts as ligand with Sm in this complex and the decrease of reduction potential results consequently at the conjugated 2- and 4-positions in this intermediate. In fact, it was apparently recognized the difference of reactivity in 2- , 3- and 4-substituted pyridine, such as the reductive elimination of amino and cyano moieties in pyridines bearing these functionalities at the 2- and 4-positions, and the low reactivity toward the substituents at 3-position in pyridine ring. These causes could be the difference of resonance stability of radical or carbanion intermediates between the conjugated 2- or 4-position and the unconjugated 3-position for the nitrogen of coordinated pyridine ring to SmI_2, as above.

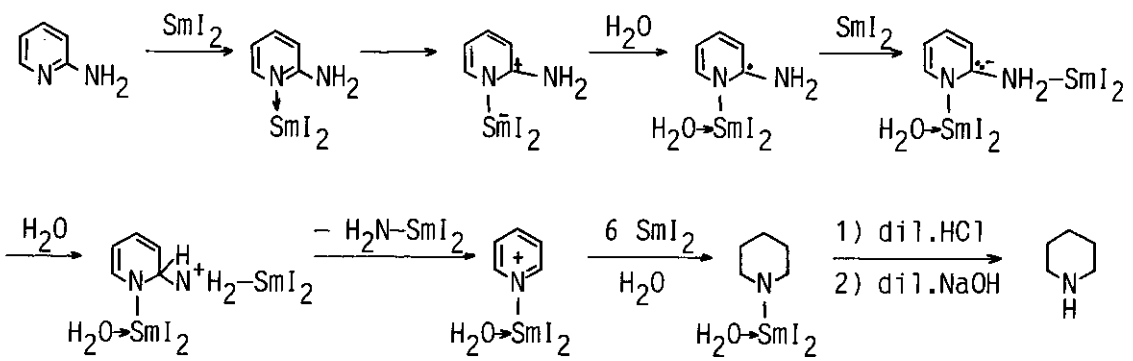
Though the reductant of this system has remained obscure at the present stage, it is presumed that reductant may also be coordinated SmI_2 ($SmI_2[H_2O]_n$) to form by the addition of H_2O to THF solution of SmI_2, therefore the electron transfer process of SmI_2 to the pyridine ring highly accelerates by SmI_2–H_2O system leading to piperidine. In order to rationalize the

reduction of pyridine ring, we propose the following reaction path (Scheme 2), which may explain the experimental results.



Scheme 2

Regarding the elimination mechanism of aminopyridines at the present stage, it is a speculation at best that the aminopyridines coordinates firstly to the SmI_2, and electron transfer occurs from SmI_2 to pyridine ring by the coordination of H_2O to the SmI_2. The next step is the formation of carbanion with two electron donors from two equivalents of SmI_2. After the protonation by H_2O, the elimination of $H_2N{-}SmI_2$ occurs concomitantly from the dihydropyridine intermediate, as shown in Scheme 3 (2-position is indicated).

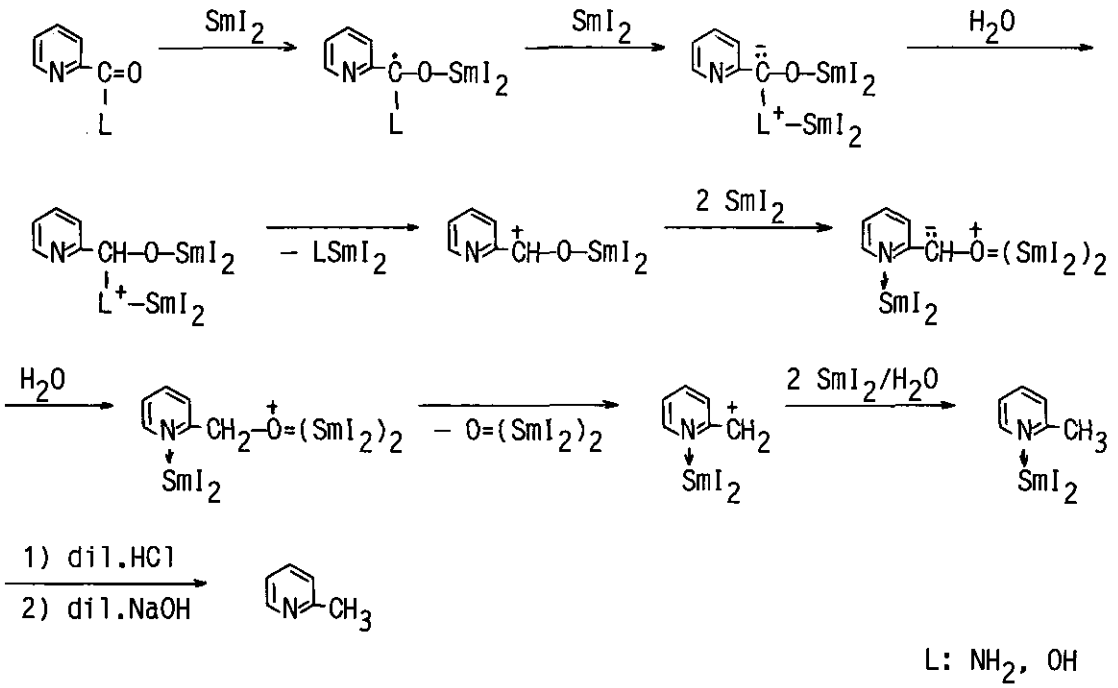


Scheme 3

Though the detailed mechanism of the elimination of cyano group at 2- and 4-positions in pyridine have remained obscure, it seems that this cause may be due to the preferential

supply of electron at the conjugated 2- or 4-position for the coordinated pyridines to SmI_2 as above, so cyano group is eliminated from pyridine ring.

Regarding the reduction of carbamoyl and carboxyl functionalities into methyl group, it is also assumed that H_2NSmI_2 or $HOSmI_2$ is similarly eliminated from the coordinated intermediates with this system to give the next intermediates of $PyCH_2OSmI_2$ and this is reduced further with this system followed by the elimination of $O(SmI_2)_2$ to afford methylpyridines, as shown in Scheme 4 (2-position is indicated).



Scheme 4

CONCLUSION

The electron donor ability of SmI_2–H_2O system observed greater than the use of SmI_2 alone. Accordingly, it is assumed that the highly promoted electron transfer from SmI_2 would be enhanced by the coordination of H_2O to SmI_2. The present results of pyridine derivatives by the SmI_2–H_2O system were shown as follows; 1) the rapid reduction of pyridines into piperidine derivatives at room temperature in high yield, 2) the reductive elimination of amino and cyano functionalities at 2- or 4-position of pyridine ring, 3) the reduction of carbamoyl and carboxyl moieties of pyridines into methyl group. The present reductions can be performed under mild and neutral conditions, so this SmI_2–H_2O system provides a useful and simple synthetic route for the reduction of pyridine and its derivatives.

EXPERIMENTAL

Commercially available fresh SmI_2 (0.1 M solution in THF, Aldrich and Strem) was used throughout this work, and all reactions were carried out at room temperature under argon with magnetic stirring. Melting points were determined on a Yanagimoto micro-melting point apparatus, model MP-S3, and uncorrected. Ir spectra were measured in Nujol mulls or as liquid films with a JASCO A-100 (Nihon Bunko) infrared spectrophotometer. Ms and GCms spectra were recorded on a JMS-D100 and JMS AX505W mass spectrometer. Gc analyses were performed with a CBP5-S50-050 (50 m, 0.33 mm, Shimadzu) capillary column connected with a Shimadzu GC-14A. Gas chromatography-fourier transform infrared spectrometry (GC-FTir) were performed with a CBP5-S50-050 (50 m, 0.33 mm, Shimadzu) capillary column connected with a Shimadzu GC-17A-IRG 8000. Nmr spectra were recorded on the JEOL FX90-Q spectrometer (Nihon Denshi). Products were characterized by comparison with authentic samples and with their ir, gc, ms, GCms, GC-FTir and/or nmr spectra.

General Procedure for the Reduction of Pyridine (1) with SmI_2–H_2O System In a typical procedure, a solution of SmI_2 (0.1 M in THF, 30 mmol) was added to a solution of 5 mmol of pyridine (**1**) dissolved in 1 ml of THF with the use of a syringe, then 5 ml of H_2O (278 mmol) was added all at once with stirring by the use of a syringe at room temperature under argon. After the deep blue color of the reaction mixture changed to pale yellow (for 8.5 min), a chilled 10% HCl (25 ml) was added to the resulting solution and the reaction mixture was stirred at room temperature for 10 min. After ether (50 ml) was added, the separating organic layer was removed and aqueous layer was exhaustively washed with ether, basified by the addition of 20% NaOH, saturated with NaCl, and extracted exhaustively with ether. The combined ether layer was dried over $MgSO_4$ and the solvent was evaporated at 40–50°C. The residue was purified by column chromatography (alumina) using ether as an eluent to give piperidine (**2**) (Entry 3 in Table 1). Products were characterized with the authentic samples by gc, GCms, ir, GC-FTir and nmr spectra. Alkyl- and arylpyridines were similarly reduced with this system and the results are listed in Table 1. The yields were determined by GC-FTir data after the identification with authentic samples on the basis of comparisons of their GC-FTir and GCms spectra.

General Procedure for the Reduction of Aminopyridines (12 – 14) with SmI_2–H_2O System In a typical procedure, a solution of SmI_2 (0.1 M in THF, 30 mmol) was added to a solution of 5 mmol of aminopyridine dissolved in 2 ml of THF, and 5 ml of H_2O (278 mmol) was added all at once with stirring by a syringe at room temperature under argon. After the deep blue color of SmI_2 disappeared, the treatment as above was similarly carried out to give reduction products. Products (**12**, **15** and **16**) were identical with the authentic samples on the basis of comparisons of their gc, GCms, ir, GC-FTir and/or nmr spectra. Products and reaction conditions are listed in Table 2. The yields were determined by GC-FTir data after the

identification with authentic samples on the basis of comparisons of their GC-FTir and GCms spectra.

Reduction of Chloropyridines (17 and 19) by SmI_2 A solution of SmI_2 in THF (0.1 M, 3 mmol) was added to a solution of 2(or 4)-chloropyridine (**17**) (or **19**) (57 mg, 0.5 mmol) in THF (0.5 ml) with stirring at room temperature under argon. After the deep blue color of the reaction mixture disappeared (5 h), the similar treatment as above was carried out to give pyridine (**1**). Results and reaction conditions are listed in Table 3 (Entries 1 and 3). The yields were determined by GC-FTir data after the identification with authentic samples on the basis of comparisons of their GC-FTir and GCms spectra.

General Procedure for the Reduction of Chloropyridines (17 – 19) with SmI_2–H_2O System In a typical procedure, after a THF solution of SmI_2 (0.1 M, 4 mmol) was added to a THF(0.5 ml) solution of 2-chloropyridine (**20**) (57 mg, 0.5 mmol), 0.66 ml of H_2O (37 mmol) was added all at once by a syringe with stirring at room temperature under argon. After the deep blue color of SmI_2 disappeared, the similar treatment as above was carried out to afford piperidine (**2**). Results and reaction conditions are listed in Table 3. The yields were determined by GC-FTir data after the identification with authentic samples on the basis of comparisons of their GC-FTir and GCms spectra.

Reduction of Cyanopyridines (20 and 22) by SmI_2 A THF solution of SmI_2 (0.1 M, 3 mmol) was added to a THF (0.5 ml) solution of 2(or 4)-cyanopyridine (**20**) (or **22**) (52 mg, 0.5 mmol) with stirring at room temperature under argon. After the typical deep blue color of SmI_2 disappeared, the treatment as above was similarly carried out to give pyridine (**1**). Results and conditions are tabulated in Table 4. The yields were determined by GC-FTir data after the identification with authentic samples on the basis of comparisons of their GC-FTir and GCms spectra.

General Procedure for the Reduction of Cyanopyridines (20 – 22) with SmI_2–H_2O System In a typical procedure, after a THF solution of SmI_2 (0.1 M, 3 mmol) was added to a THF (0.5 ml) solution of 2-cyanopyridine (**20**) (52 mg, 0.5 mmol), 0.5 ml of H_2O (28 mmol) was added all at once by a syringe with stirring at room temperature under argon. After the deep blue color of SmI_2 disappeared (1.5 min), the similar treatment was carried out to give piperidine (**2**) and 2-methylpyridine (**3**). Results and reaction conditions are listed in Table 4. The yield were determined by GC-FTir data after the identification with authentic samples on the basis of comparisons of their GC-FTir and GCms spectra.

Reduction of Pyridinecarboxamides (23 and 25) by SmI_2 A THF solution of SmI_2 (0.1 M, 3 mmol) was added to a THF (2 ml) solution of 2-pyridinecarboxamide (**23**) (61 mg, 0.5 mmol)

with stirring at room temperature under argon. After the typical deep blue color of SmI_2 disappeared, the reaction mixture was carried out following the similar treatment as above. 2-Pyridylcarbinol (**26**) and 2-methylpyyridine (**3**) were obtained by chromatographic purification on an alumina column using ether as an eluent, respectively. These products were identical with authentic samples on the basis of comparisons of their gc, GCms, ir and GC-FTir spectra. Results are listed in Table 5. The yields were determined by GC-FTir data after the identification with authentic samples on the basis of comparisons of their GC-FTir and GCms spectra.

General Procedure for the Reduction of Pyridinecarboxamides (23 – 25) with SmI_2–H_2O System In a typical procedure, a solution of SmI_2 (0.1 M in THF, 6 mmol) was added to a solution of pyridine-2-carboxamide (**23**) (122 mg, 1 mmol) in THF (2 ml), then 1 ml of H_2O (28 mmol) was added all at once by a syringe with stirring at room temperature under argon. After the typical blue color of SmI_2 disappeared (3 s), the treatment as above was similarly carried out to give reduction products. The products were purified by column chromatography (alumina) using ether as an eluent to give 2-methylpyridine (**3**) and methyldihydropyridine (**29**) (from GCms data). Results and reaction conditions are listed in Table 5. The yields were determined by GC-FTir data after the identification with authentic samples on the basis of comparisons of their GC-FTir and GCms spectra.

Reduction of 2-Pyridinecarboxylic Acid (3o) by SmI_2–H_2O System After a THF solution of SmI_2 (0.1 M, 3 mmol) was added to a THF (2 ml) solution of 2-pyridinecarboxylic acid (**30**) (62 mg, 0.5 mmol), 0.5 ml of H_2O (28 mmol) was added all at once with stirring at room temperature under argon. After the deep blue color disappeared (10 min), the reaction mixture was similarly treated as above to give 2-methylpiperidine (**7**) (68%) and pyridine (**1**) (31%). The yield was determined by GC-FTir data after the identification with authentic samples on the basis of comparisons of their GC-FTir and GCms spectra.

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Received, 7th June, 1993