

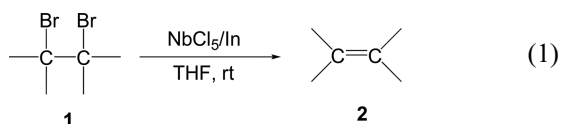
Efficient and Selective Debromination of *vic*-Dibromides to Alkenes with NbCl₅/Indium System

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The debromination of *vic*-dibromides to alkenes is a valuable synthetic transformation in organic chemistry as a double bond protection-deprotection strategy.¹ Accordingly, a good number of methodologies have been developed for the debromination of *vic*-dibromides to alkenes.² However, many of these methods lack the desired chemoselectivity when other reducible functional groups are present and often require long reaction times, or involve elevated temperatures. As a result, there still exists a search for new improved methods for this conversion. The chemical reactivity of NbCl₅/M system (M = Zn, Mg, Al) has been the subject of considerable interest and the reducing ability of these systems has been extensively studied.³ Recently, it has been reported that NbCl₅/Zn system is used as a reagent for reducing sulfides, epoxides, and amine *N*-oxides.⁴ Because indium and zinc closely resemble each other in several aspects, including first ionization, we considered that a combination of NbCl₅ with indium could serve as a protocol for the reductive debromination of *vic*-dibromides. Over the past years, indium metal has been the subject of active interest because of its unique properties such as low toxicity and high stability in water and air compared to other metals.⁵ In connection with our interest in exploring the utility of metal-metal salt binary systems for organic transformations,⁶ we herein wish to report an efficient and chemoselective method for the debromination of *vic*-dibromides **1** to alkenes **2** using NbCl₅/indium system at room temperature. The reaction can be generalized as shown by Eq. (1). To the best of our knowledge, this is the first study in which a NbCl₅/indium system has been employed for the debromination of *vic*-dibromides to alkenes.



The new reducing system was generated by the addition of indium powder to a stirred solution of NbCl₅ in THF under sonication.⁷ The generation of low-valent niobium species was examined with an excess of indium metal at room temperature. The appearance of a black color was judged as the formation of low-valent niobium complexes. Encouraged by the convenient generation of low-valent niobium

complexes from reduction of NbCl₅ with indium metal, we have investigated the reactions of NbCl₅/indium system with various *vic*-dibromides and found that the reductions generally proceeded with high yields and showed good selectivity over other labile substituents. In an attempt to characterize the low-valent niobium species that presumably participates in the electron-transfer process, we conducted an experiment that showed that NbCl₅ was ineffective in debromination when no indium was present. And the reaction was also not very effective with indium metal without NbCl₅. Thus, it is clear that a combination of indium and NbCl₅ is essential to carry out the debromination. We examined a series of functionally and structurally diverse *vic*-dibromides and the representative results of the reactions are summarized in Table 1. Clearly a broad range of functional groups (ester, carboxyl, aldehyde, methoxy, bromo, chloro, and ketone) were tolerated under the reaction conditions. It is worth commenting that the sensitive carbonyl group remains intact without any further reduction (entries 5-11). In comparison with other procedures, the present procedure reduced *vic*-dibromides more rapidly in higher yields and showed a good chemoselectivity. The high yields of the debromination products demonstrate the efficiency of this new method. Furthermore, only *trans* olefins were obtained and no overreduction of the produced alkene was observed with any substrate.⁸ Although the reaction mechanism of the method has not yet been established, the reaction can be envisaged to proceed in two steps. In the first step, NbCl₅ is probably reduced by indium to form a low-valent niobium species, which in the subsequent step would debrominate the *vic*-dibromides **1** to give the corresponding alkenes **2** through a SET (single electron transfer) process. The reducing property exhibited by metal-metal salt combinations proceeds through the transfer of one electron from the metal surface to the substrate. In such combinations the elementary metal part should be more electropositive than the metal part of the salt. The notable advantages of this methodology are mild reaction conditions, fast reaction time, high yields, and tolerance of various functional groups compared with existing reagents. We have demonstrated the utility of a NbCl₅/indium system in effecting chemoselective debromination of *vic*-dibromides.

In conclusion, we have found that *vic*-dibromides treated with NbCl₅/indium system are efficiently converted into the

Table 1. Reductive debromination of *vic*-dibromides using a NbCl₅/indium system

Entry	Substrate	Product ^a	Time (min)	Yield (%) ^b
1			10	95
2			10	91
3			10	92
4			15	94
5			15	89
6			10	93
7			10	95
8			20	88
9			10	92
10			20	90
11			30	89
12			10	93

^aThe products were characterized by comparison of their spectral data with authentic samples. ^bIsolated yields.

corresponding alkenes in high yields under mild conditions.

Although the scope and limitations were not fully established, the present method could be a practical alternative to the conventional method with its mildness, rapidity and chemoselectivity as well as high yields. Further work on the application of the NbCl₅/indium system is in progress.

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References

- Greene, T. W.; Wuts, P. G. M. *Protective Groups in Organic Synthesis*, 2nd ed.; New York, 1991.
- (a) Buther, T. S.; Detty, M. R. *J. Org. Chem.* **1998**, *63*, 169. (b) Li, C. J.; Harpp, D. N. *Tetrahedron Lett.* **1990**, *31*, 6291. (c) Malanga, C.; Mannucci, S.; Lardicci, L. *Tetrahedron* **1998**, *54*, 1021. (d) Tanata, R.; Negoro, N.; Yanada, K.; Fujita, T. *Tetrahedron Lett.* **1996**, *37*, 9313. (e) Ranu, B. C.; Guchhait, S. K.; Sarkar, A. *J. Chem. Soc. Chem. Commun.* **1998**, 2113. (f) Mathai, I. M.; Sching, K.; Miller, S. I. *J. Org. Chem.* **1970**, *35*, 1733. (g) Ranu, B. C.; Jana, K.; Miller, R. *J. Org. Chem.* **2005**, *70*, 8621. (h) Ranu, B. C.; Das, A.; Hajra, A. *Synthesis* **2003**, 1012. (i) Xu, X.; Zhang, Y. *Synth. Commun.* **2000**, *30*, 1917.
- (a) Arai, S.; Takita, S.; Nishida, A. *Eur. J. Org. Chem.* **2005**, 5262. (b) Arai, S.; Sudo, Y.; Nishida, A. *Chem. Pharm. Bull.* **2004**, *52*, 287. (c) Kataoka, Y.; Takai, K.; Oshima, K.; Utimoto, K. *J. Org. Chem.* **1992**, *57*, 1615. (d) Kataoka, Y.; Takai, K.; Oshima, K.; Utimoto, K. *Tetrahedron Lett.* **1990**, *31*, 365. (e) Fuchibe, K.; Akiyama, T. *J. Am. Chem. Soc.* **2006**, *128*, 1434. (f) Fuchibe, K.; Oshima, Y.; Mitomi, K.; Akiyama, T. *Org. Lett.* **2007**, *9*, 1497.
- Oh, K. S.; William, E. K. *Tetrahedron* **2009**, *65*, 2966.
- For review: (a) Nair, V.; Ros, S.; Jayan, C. N.; Pillia, B. S. *Tetrahedron* **2004**, *60*, 1959. (b) Lubineau, A.; Auge, J.; Queneau, Y. *Synthesis* **1994**, 741. (c) Li, C. J. *Tetrahedron* **1996**, *52*, 5643. (d) Cintas, P. *Synlett.* **1995**, 1087.
- (a) Yoo, B. W.; Song, M. S.; Park, M. C. *Synth. Commun.* **2007**, *37*, 3089. (b) Yoo, B. W.; Park, M. C.; Shin, J. I. *Bull. Korean Chem. Soc.* **2009**, *30*, 1927. (c) Yoo, B. W.; Min, S. K. *Synth. Commun.* **2011**, *41*, 2993. (d) Yoo, B. W.; Kim, D. I.; Kim, H. M.; Kim, S. H. *Bull. Korean Chem. Soc.* **2012**, *33*, 2851. (e) Yoo, B. W.; Kim, S. H.; Min, G. H. *Bull. Korean Chem. Soc.* **2012**, *33*, 27.
- A typical procedure for the debromination of *vic*-dibromides is as follows: Indium powder (230 mg, 2.0 mmol) and NbCl₅ (238 mg, 1.0 mmol) are mixed in THF (4 mL). The resulting mixture is sonicated in an ultrasonic cleaner⁹ for 30 min and a solution of the low-valent niobium-indium complex is formed. 1,2-Dibromo-1,2-diphenylethane (170 mg, 0.5 mmol) is then added to this solution and the reaction mixture is stirred for 15 min at room temperature. The solvent is removed under reduced pressure and the residue is extracted with ethyl acetate, washed with brine, and dried over anhydrous Na₂SO₄. The crude product is purified by silica gel column chromatography (hexane:ethyl acetate = 10:1) to afford *trans*-stilbene (85 mg, 94%).
- (a) Hudlicky, T.; Sinai-Zingde, G.; Natchus, M. G. *Tetrahedron Lett.* **1987**, *28*, 5287. (b) Khurana, J. M.; Gogia, A.; Bankhwal, R. K. *Synth. Commun.* **1997**, *27*, 1801. (c) Yanada, R.; Bessho, K.; Yanada, K. *Synlett.* **1995**, 443.
- Sonication was carried out in a BRANSONIC ultrasonic cleaner bath, which produced a 47 Hz wave, with a fixed electrical power of 125 Watts.