ABSTRACT

This thesis deals with synthetic and mechanistic investigations on the hydroboration of olefins with various borane Lewis base complexes. It comprises of three chapters. Each chapter is subdivided into three parts: Introduction, Results and Discussion and Experimental Sections.

The first chapter describes the studies on the hydroboration of olefins with Hg(OAc)$_2$/NaBH$_4$ and RCOOH/NaBH$_4$ systems. It was found that Hg(OAc)$_2$/NaBH$_4$ and CH$_3$COOH/NaBH$_4$ systems hydroborate olefins. The hydroboration of olefins with these systems are relatively slow and only one equivalent of olefin reacted after 12 h at r.t. Although the hydroboration of olefins with CH$_3$COOH/NaBH$_4$ system has been reported earlier, the system has not been extensively studied. Utilization of the CH$_3$COOH/NaBH$_4$ system for selective hydroborations and controlled hydroborations was studied. The slow hydrobating nature of the CH$_3$COOH/NaBH$_4$ system was exploited in the selective hydroboration of olefins in the presence of other reducible functional groups. Selective hydroboration of olefinic moiety when it is present along with a carboxylic group in a molecule is difficult with BH$_3$.THF as the reduction of carboxylic group by this reagent is faster than hydroboration. This objective has been achieved in the past by protecting the carboxylic group as an ester or by utilizing two equivalents of hindered disiamylborane as the hydroborating agent. During the present studies, it was observed that the hydroboration of olefinic moiety present in a molecule along with a carboxylic acid group can be readily achieved by adding NaBH$_4$ to the olefinic acid (Scheme 1).
Hydroboration of olefins with CH₃COOH/NaBH₄ system followed by carbenoidation using the simple CHCl₃/NaOMe reagent and oxidation with H₂O₂/NaOH give symmetrical dialkylketones (Scheme 2). This transformation was earlier carried out under relatively more exotic reaction conditions. In addition to providing a simple synthetic method for the conversion of olefins to dialkyl ketones, the present transformations also throw some light on the nature of the species involved in the processes.

Scheme 2

Hydroboration of terminal alkenes with CH₃COOH/NaBH₄ system followed by oxidation with CrVII/(CH₃)₃COH reagent give the corresponding carboxylic acids in 30% to 75% yields. Although the yields are very modest in some cases, this method serves as a simple one pot procedure for the conversion of terminal alkenes into the corresponding carboxylic acids.

In the 2nd chapter, the studies on the synthesis and application of borane and iodoborane N,N-dialkylaniline complexes are described. Various methods reported for the generation of diborane were reviewed
in order to select a simple method for the generation of diborane for utilization in the synthesis of amine-borane complexes. The method reported by Freeguard and Long in 1965 involving the utilization of NaBH4/I2 system in diglyme appeared to be simple (eq. 1, 2). These authors trapped the liberated diborane in a series of liquid nitrogen traps using vacuum line technique. However, this simple system has not been extensively utilized for diborane generation, despite the facts that the starting materials are relatively simple to handle and the advantage over the diborane generated utilizing BF3·OEt2/NaBH4 system has been demonstrated.

\[
2\text{NaBH}_4 + \text{Hg}_2\text{Cl}_2 \xrightarrow{\text{diglyme}} \text{r.t.} 2\text{Hg} + 2\text{NaCl} + \text{H}_2 + \text{B}_2\text{H}_6
\]  

\[
2\text{NaBH}_4 + \text{I}_2 \xrightarrow{\text{diglyme}} \text{r.t.} 2\text{NaI} + \text{H}_2 + \text{B}_2\text{H}_6
\]  

During the present studies, it has been observed that the diborane can be readily generated utilizing the NaBH4/I2 system using the equipment similar to that utilized for the NaBH4/BF3·OEt2 system. The diborane generated by the above method was utilized for the synthesis of N,N-diethylalaniline borane complexes, for hydroboration of olefins, reduction of amides, imines and carboxylic acid groups. The N,N-diethylalaniline borane complex was utilized for symmetrical dialkyl ketone synthesis from olefins via hydroboration-carbenoidation-oxidation and synthesis of unsymmetrical dialkyl ketones via sequential hydroboration of two different olefins was also attempted.

Mono iodoborane-N,N-diethylalaniline complex was prepared in benzene by the reaction of I2 with the corresponding amine borane complex and its synthetic utility was explored (Scheme 3).
In chapter 3, the mechanistic studies on the hydroboration of prochiral olefins with various borane-chiral Lewis base complexes are described. In the introductory section, contributions by various research groups to the mechanistic studies on the hydroboration reaction are reviewed. Three different mechanistic proposals can be visualised from these reports (Scheme 4).
1. $S_1$ like mechanism: Involving free 'BH$_3$' monomer formation in an equilibrium step.

\[
\begin{align*}
\text{BH}_3\text{LB} & \rightarrow \rightarrow \text{BH}_3 + \text{LB} \\
\text{CH}_2=\text{CH}-\text{R} + \text{BH}_3 & \rightarrow \left[ \begin{array}{c} \\
\text{H}_2\text{B}---\text{H} \\
\vdots \\
\text{CH}_2-\text{CH}_2-\text{CH}-\text{R} \\
\end{array} \right] \rightarrow \text{R-CH}_2-\text{CH}_2-\text{BH}_2
\end{align*}
\]

2. $S_2$ like mechanism: Without any intermediate.

\[
\begin{align*}
\text{CH}_2=\text{CH}-\text{R} + \text{BH}_3\text{LB} & \rightarrow \left[ \begin{array}{c} \\
\text{H}_2\text{B}---\text{H} \\
\vdots \\
\text{CH}_2-\text{CH}_2-\text{CH}-\text{R} \\
\end{array} \right] \rightarrow \text{R-CH}_2-\text{CH}_2-\text{BH}_2
\end{align*}
\]

3. Mechanism with $\pi$-complex intermediate.

\[
\begin{align*}
\text{CH}_2=\text{CH}-\text{R} + \text{BH}_3\text{LB} & \rightarrow \left[ \begin{array}{c} \\
\text{BH}_3 \\
\vdots \\
\text{CH}_2-\text{CH}-\text{R} \\
\end{array} \right] + \text{LB} \\
\text{R-CH}_2-\text{CH}_2-\text{BH}_2 & \rightarrow \left[ \begin{array}{c} \\
\text{H}_2\text{B}---\text{H} \\
\vdots \\
\text{CH}_2-\text{CH}_2-\text{CH}-\text{R} \\
\end{array} \right]
\end{align*}
\]

The obvious difference between the $S_1$ like mechanism and $S_2$ like mechanism is the absence or presence of the Lewis base in the transition state of the $\text{B-H}$ addition to the olefin. Although it is not clear whether the Lewis base will have any influence during $\text{B-H}$ addition in the mechanism involving $\pi$-complex intermediate, the influence (if any)
will be only little since the $\text{B-H}$ addition here is an intramolecular rearrangement. Accordingly, it was thought that the problem (i.e. whether the Lewis base is present or absent in the transition state) can be examined by utilizing BH$_3$-chiral Lewis base complexes for the hydroboration of prochiral olefins.

The chiral Lewis base auxiliaries (2,3,4,5) were synthesized following modified literature procedures. The commercially available acid (1) was also utilized.

Hydroboration of prochiral olefins (6 to 9) were carried out with these chiral RCOOH/NaBH$_4$ systems and chiral amine borane complexes. The corresponding alcohols with optical inductions 0.3%ee to 19.2%ee were isolated after oxidation of the resulting organoborane with $\text{H}_2\text{O}_2$/NaOH. These results were considered in the context of mechanisms (Scheme 4) proposed by various workers for the hydroboration reaction. The present results along with the existing data in the literature indicate that
there is a spectrum of mechanisms possible for the hydroboration reaction, depending on the reactivity of the substrates. The results are discussed by taking into account of the frontier orbital interactions and steric factors involved.