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AMINOALUMINUM HYDRIDE AS NEW REDUCING AGENTS. II. SELECTIVE REDUCTION OF ESTERS OF CARBOXYLIC ACIDS TO ALDEHYDES

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It was found that esters of carboxylic acids are reduced to the corresponding aldehydes in good yields by diaminoaluminum hydrides such as bis(4-methyl-1-piperazinyl)aluminum hydride and dimorpholinoaluminum hydride at room temperature or under refluxing.

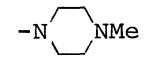
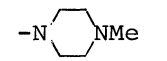
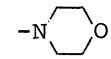
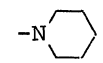
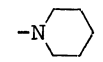
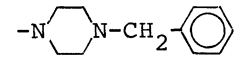
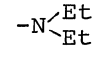
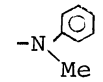
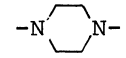
In the preceding paper,[1] it was shown that diaminoaluminum hydride especially bis(4-methyl-1-piperazinyl)aluminum hydride (BMPA) is very useful in reducing free carboxylic acids into aldehydes. We now report a convenient method for the reduction of esters of carboxylic acids to aldehydes by use of the above mentioned diaminoaluminum hydrides.

The synthesis of aldehydes from carboxylic acid derivatives is one of the most important reactions in organic synthesis. Therefore, many good reducing agents have been reported, such as lithium tri-t-butoxyaluminum hydride,[2] diisobutylaluminum hydride,[3] and sodium aluminum hydride[4] for the preparation of aldehydes from esters of carboxylic acids. Of these hydrides, it was shown that lithium tri-t-butoxyaluminum hydride reduces phenyl ester of carboxylic acids to aldehydes but is not applicable for the reduction of alkyl esters. When diisobutylaluminum hydride and sodium aluminum hydride were used as reducing reagents, various conditions should be carefully controlled in order to obtain aldehyde in essentially good yield and the yields of aromatic aldehydes are lower than those of aliphatic ones.

It was found that diaminoaluminum hydrides, prepared from one mole of aluminum hydride and two moles of secondary amines, especially BMPA, dimorpholinoaluminum

hydride (DMA), and dipiperidinoaluminum hydride (DPA) are effective for the reduction of esters of carboxylic acids to the corresponding aldehydes without accompanying alcohols. On the other hand, when the reaction mixture was hydrolyzed before the completion of the reduction, carboxylic amide produced from the ester and the amine was obtained along with the aldehyde. The results of the reduction of ethyl palmitate with diaminoaluminum hydrides, prepared from aluminum hydride and various secondary amines,[1] in tetrahydrofuran (THF) under reflux for 6 hr are summarized in Table 1.

Table 1 Yields of Palmitaldehyde in the Reduction of Ethyl Palmitate by Diaminoaluminum Hydrides

Diaminoaluminum Hydrides $HAl(X)_2$	Ratio (Reagent/Ester)	Palmitaldehyde[a] (%)	Others[a] (%)
X =  (BMPA)	1.5	50	
 (BMPA)	2.0	80	
 (DMA)	2.0	75	
 (DPA)	1.5	61	27[b]
 (DPA)	2.0	74	
	1.5	57	16[c]
	2.0	29	
	2.0	19	57[d]
X_2 = 	2.0	42	

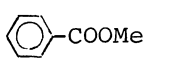
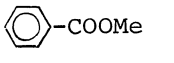
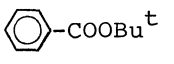
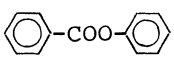
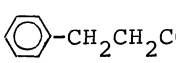
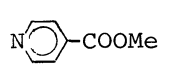
a) By isolation. b) N-Palmitoylpiperidine.
c) N-Benzyl-N'-palmitoylpiperazine. d) N-Hexadecyl-N-methylaniline.[5]

Among the secondary amines examined, diaminoaluminum hydrides derived from cyclic amines gave favorable results for the preparation of palmitaldehyde from ester as compared with alkyl or aromatic amines similar to the results obtained in the cases of the reduction of carboxylic acids to aldehydes.

The following experiment provides details of a typical procedure of the reduction of ester to aldehyde. N-Methylpiperazine (3.19 g, 32 mmol) was added to a 0.64 M

solution of aluminum hydride in THF[6] (35 ml, 16 mmol) over a period of 3 min in an ice-bath under argon and the solution was stirred for 1.5 hr at room temperature. A solution of ethyl hydrocinnamate (1.43 g, 8.0 mmol) in THF (10 ml) was added to the cooled solution of the reducing reagent and refluxed for 6 hr. The resulting clear solution was quenched with water (0.9 ml, 50 mmol) at 0°C to precipitate solid. The suspension was warmed to 70°C and the solid was filtered off and washed with THF. In some cases, the solid was repeatedly treated with water and washed with THF. The filtrate and washings were combined and the solvent was removed in vacuo. The residue was dissolved in ether, washed successively with water, 5 % H_2SO_4 and water, and dried over Na_2SO_4. The solvent was removed to give a crude oil. The oil was purified with column chromatography to give the pure oil of hydrocinnamaldehyde 820 mg (76 %): IR 1720 cm^{-1}; NMR ($CDCl_3$) δ 2.3-3.0 (m, 4H), 7.10 (s, 5H), 9.55 (s, 1H); 2,4-dinitrophenylhydrazone, mp 147-149°C (ref.[7] mp 149°C).

Table 2 Yields of Aldehydes[8] in the Reduction of Various Esters of Carboxylic Acids by Diaminoaluminum Hydrides.

Esters of Carboxylic Acids	Diaminoaluminum Hydrides	Ratio of Reagent/Esters	Conditions	Aldehydes[a] (%)
$n\text{-}C_5H_{11}COOEt$	BMPA	2.0	refl. 6 hr	(78)
$n\text{-}C_9H_{19}COOEt$	BMPA	2.0	refl. 6 hr	86
$n\text{-}C_{15}H_{31}COOEt$	BMPA	2.0	refl. 6 hr	80
$n\text{-}C_{15}H_{31}COOEt$	BMPA	4.0	refl. 6 hr	78
$n\text{-}C_{15}H_{31}COOEt$	DMA	2.0	r.t. 20 hr	73
	DMA	1.5	r.t. 15 hr	(50)[b]
	BMPA	2.0	refl. 10 hr	(72)
	BMPA	2.0	refl. 10 hr	(64)
	BMPA	2.0	refl. 10 hr	(75)
	BMPA	2.0	refl. 6 hr	76 (84)
	BMPA	2.0	refl. 6 hr	56

a) Yields by analysis with 2,4-dinitrophenylhydrazine are shown in parentheses.
b) N-Benzoylmorpholine was obtained in 37 % yield.

Treatment of a mixture of one mole of ester with two moles of the BMPA or DMA in THF either stirring for 1 day at room temperature or refluxing for 6 hr, followed by hydrolysis afforded the corresponding aldehyde in good yield. The yields of aldehydes in the reduction of various esters of carboxylic acids with BMPA or DMA are summarized in Table 2.

It is noted that diaminoaluminum hydrides such as BMPA, DMA, and DPA reduce ester of carboxylic acid to aldehyde in good yield very smoothly without accompanying alcohol. This new aldehydes synthesis should provide a convenient alternative route for proceeding from ester of carboxylic acid to the corresponding aldehyde.

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5) W.B. Wright, Jr., J. Org. Chem., 27, 1042 (1962) reported that 1-benzylpiperidine was obtained in 85 % yield from piperidine, ethyl benzoate, and lithium aluminum hydride (molar ratio, 1:3:1.5) but alkylation of arylalkylamines were low yields.
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8) All aldehydes were identified with IR and NMR spectra and as 2,4-dinitrophenylhydrazone.

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