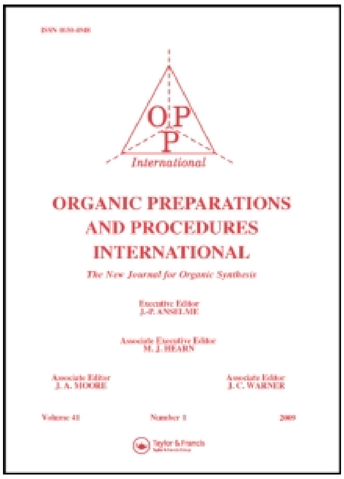

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REDUCTION OF CARBOXYLIC ACIDS TO ALDEHYDES BY THEXYLALKOXYBORANES

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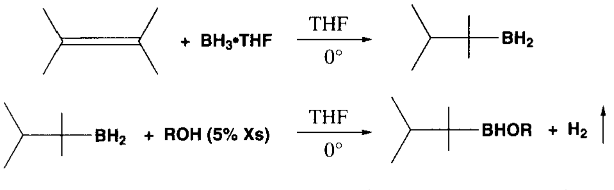
Thexylhaloborane-dimethyl sulfide (ThxBHX-SMe$_2$) complexes appear to be exceptionally valuable reagents for the selective hydroboration of carbon-carbon multiple bonds[1-4] and for the direct transformation of carboxylic acids into aldehydes.[5-6] Such exceptional ability must arise from the structural fitness of thexyl group in these hydroboration and reduction reactions. Very recently, we synthesized various thexylalkoxyboranes (ThxBHOR) and utilized them in the selective hydroborations of alkenes and alkynes. Like ThxBHX-SMe$_2$, these alkoxy derivatives achieved the selective hydroboration with high regioselectivity at room temperature.[7] In addition, in the course of exploring the reducing action of ThxBHOR, we observed that aliphatic carboxylic acids are reduced to aldehydes in good yields. This intrigued us. Accordingly, we decided to apply these alkoxy derivatives for the direct conversion of carboxylic acids to aldehydes. This communication describes the application of these newly synthesized reagents, ThxBHOR, for such conversion of carboxylic acids to the corresponding aldehydes.

The reagents are conveniently prepared by a simple reaction between thexylborane (ThxBH$_2$) and the corresponding alcohols in tetrahydrofuran (THF) solution (Eq 1). The solution of ThxBH$_2$ in THF can be readily prepared by the monohydroboration of 2,3-dimethyl-2-butene with BH$_3$-THF.[8]



(1)

R = Et; ThxBHOEt, R = i-Bu; ThxBHO^{i}Bu, R = i-Pr; ThxBHO^{i}Pr,
R = s-Bu; ThxBHO^{s}Bu, R = t-Bu; ThxBHO^{t}Bu, R = Ph; ThxBHOPh

In general, the reactivity of ThxBHOR[9] toward organic functionalities is much weaker than that of ThxBHX. Nevertheless, the reducing action of the alkoxy derivatives is very similar to that observed previously for the halogen analogues.[6a,10] A similar trend was also observed in the reduction of carboxylic acids with the alkoxy derivatives:although the alkoxy derivatives show a much lower reactivity than the halogen analogues toward carboxylic acids, the reagents can reduce carboxylic acids to aldehydes at 25° in good yields.

TABLE 1. Yields of Aldehydes in the Reduction of Representative Carboxylic Acids with Thexylalkoxyboranes in Tetrahydrofuran at 25° [a]

Acids	Yields of Aldehydes, %[b]					
	ThxBHOEt	ThxBHO^{i}Bu	ThxBHO^{i}Pr	ThxBHO^{s}Bu	ThxBHO^{t}Bu	ThxBHOPh
Butyric	86	84	90	93	34	82
Hexanoic	86, 81[c]	85, 84[c]	92, 90[c]	90, 93[c]	36, 38[c]	82, 78[c]
Octanoic	82	88	96	95(82)[d]		72
Decanoic	83	88	92	92		82
Pentadecanoic	80	83	91	93		81
Palmitic	87	82	94	98(87)[d]		79
Isobutyric			79	80		
Isovaleric	75	74	79	82		69
Pivalic			78	81		
Cyclopropanecarboxylic	69	72	78	80		70
Cyclohexanecarboxylic			80	83		
1,10-Decanedicarboxylic			89	92		
Benzoic	52, 48[c]	53, 55[c]	65, 62[c]	64, 68[c]	30, 33[c]	45, 43[c]
1-Naphthoic			63	65		
o-Toluic	43	45	62	60		40
m-Toluic	47	52	68	69		48
p-Toluic	34	40	58	52		38
p-Anisic			54	53		
Terephthalic			48	49		

a) Reacted with 5% excess reagent (2.1 equiv for monocarboxylic and 4.2 equiv for dicarboxylic acid) for 2 days with ThxBHOEt, 2 or 3 days with ThxBHO^{i}Bu, 3 or 4 days with ThxBHO^{i}Pr, 4 days with ThxBHO^{s}Bu, 4 or 5 days with ThxBHO^{t}Bu, and 3 days with ThxBHOPh after the hydrogen evolution at 0°. b) Yields are estimated as the 2,4-dinitrophenylhydrazones. c) Reacted with 50% excess reagent (3.0 equiv). d) Isolated yield.

As shown in Table 1, all the ThxBHOR, except the *t*-butoxy derivative, are sufficiently powerful to reduce carboxylic acids. The *t*-butoxy derivative does not attack carboxylic acids efficiently. Among the derivatives, ThxBHO^{i}Pr and ThxBHO^{s}Bu, like ThxBHCl[5] and ThxBHBr,[6] efficiently convert carboxylic acids to aldehydes. The reagents reduce straight-chain aliphatic carboxylic acids to aldehydes in approximately 4 days at 25° in yields of 90-98%. Branched-chain derivatives, such as isobutyric acid, isovaleric acid and pivalic acid, are reduced to the corresponding aldehydes in around 80% yields. Alicyclic derivatives, such as cyclopropanecarboxylic acid and cyclohexanecarboxylic acid, work equally well. Dicarboxylic acids, such as 1,10-decanedicarboxylic acid, provide the corresponding aldehydes in around 90% yields.

Just as in the reduction of carboxylic acids with ThxBHCl[5] or ThxBHBr[6], the reduction of aromatic acids with ThxBHOR is much more sluggish and the yields of aldehydes are significantly lower. Thus, both benzoic acid and 1-naphthoic acids give yields of 60-65%; toluic and anisic acids provide the corresponding aldehydes in yields of 52-69%. Finally, aromatic dicarboxylic acids, such as terephthalic acid, afford the corresponding aldehydes in around 50% yields.

ThxBHOR can be synthesized from various alcohols, thus allowing control of the steric and electronic environment of these reagents, and hence enhancing their versatility. Therefore, they might be the reagents of choice for the chemoselective reduction of carboxylic acid group to aldehyde in complex molecules. The general reducing properties of the reagents will appear shortly.

EXPERIMENTAL SECTION

All glassware used was dried thoroughly in a drying oven, assembled hot, and cooled under a stream of dry nitrogen prior to use. All reactions and manipulations of air- and moisture-sensitive materials were carried out under a dry nitrogen atmosphere. All chemicals were commercial products of the highest purity which were carefully purified by standard methods before use. The carboxylic acids were commercial products and purified either by distillation or recrystallization. Tetrahydrofuran (THF) was distilled from benzophenone -sodium ketyl. Sodium borohydride ($NaBH_4$) and 2,3-dimethyl-2-butene were used directly as received from Aldrich Chemical Co. All of the compounds prepared have been fully characterized by ^{1}H and ^{11}B NMR spectra. Yields reported in all cases are of analytically pure compounds. ^{1}H NMR spectra were recorded on a Varian EM-360 A instrument. ^{11}B NMR spectra were recorded on a Bruker AMX 300 spectrometer. GC analyses were carried out using a Varian 3300 FID chromatograph equipped with a Varian 4400 integrator.

Preparation of Thexylalkoxyboranes in THF.- The procedure for preparation of thexyl-*s*-butoxyborane (ThxBHO^{s}Bu) is representative. To an oven-dried, 250-mL flask fitted with a side arm and a stopcock leading to a mercury bubbler was added 110 mL of a 0.91 M solution of $ThxBH_2$[11] (100 mmol) in THF; the solution was cooled to -25°. To this solution was added 7.8 g of 2-butanol (105 mmol, 5% excess) dropwise with vigorous stirring. The mixture was then stirred for an additional 1 h after the complete evolution of hydrogen. The concentration of the resulting ThxBHO^{s}Bu solution in THF estimated by hydrolysis with a mixture of methanol-glycerol-water (1:1:1) was found to be 0.83 M. The ^{11}B NMR spectrum of the solution showed a clean doublet centered at δ 50 (J_{BH} = 125 Hz).[12]

Reduction of Carboxylic Acids.- The following reductions are typical of the procedure utilized in the quantitative analysis with 2,4-dinitrophenylhydrazine.

Hexanoic acid (0.58 g, 5 mmol) was placed in an oven-dried, 50-mL flask fitted with a side-arm and a bent-adaptor was connected to a mercury bubbler. The flask was immersed in an ice-water bath and to this was added 2 mL of THF. 12.7 mL of a 0.83 M solution of ThxBHO^{s}Bu (10.5 mmol, 5% excess) in THF was added dropwise with vigorous stirring. After the complete evolution of hydrogen, the ice-water bath was removed, and the reaction mixture was immersed in a water bath at 25° and stirred for 4 days. The whole reaction mixture was subjected to analysis with 2,4-dinitrophenyl-hydrazine, showing a yield 90%, mp of the hydrazone, 102-103°, lit.[13] 104°.

Isolation of Product Aldehydes.[5b]- The procedure for the isolation of octanal in the reaction mixture is illustrative. After reaction of octanoic acid (50 mmol) with ThxBHO^{t}Bu for 4 days at 25°, the reaction mixture was hydrolyzed with 25 mL of 2 N HCl. The mixture was then saturated with sodium chloride and the organic layer was separated. After neutralizing with a small quantity of solid sodium bicarbonate, the organic layer was poured into 75 mL of a saturated aqueous sodium bisulfite solution and 170 mL of THF was added. The mixture was stirred for 1 h. At this time, the crystalline bisulfite adduct of octanal was apparent. The solution was cooled in an ice-water bath to ensure complete crystallization of the adduct. The adduct was then collected by filtration and washed with 3 x 25 mL of pentane and dried. The solid adduct was placed in 50 mL of a saturated aqueous magnesium sulfate solution and then 50 mL of pentane and 8 mL of a 37% formaldehyde solution were added. The mixture was stirred for 1 h. The pentane layer was separated and dried over anhydrous magnesium sulfate. Evaporation of all volatile materials gave a 91% yield of the nearly pure product. Distillation gave 5.3 g of pure octanal (82%), bp 62-63°/15 mm; n_D^{20} 1.4182.

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REFERENCES

1. a) H. C. Brown, J. A. Sikorski, S. V. Kulkarni and H. D. Lee, *J. Org. Chem.*, **47**, 863 (1982); b) J. A. Sikorski and H. C. Brown, *ibid.*, **47**, 872 (1982).
2. G. Zweifel and N. R. Pearson, *J. Am. Chem. Soc.*, **102**, 5919 (1980).
3. J. S. Cha, S. J. Min, J. M. Kim and O. O. Kwon, *Tetrahedron Lett.*, **34**, 5113 (1993).
4. J. S. Cha, S. J. Min and J. M. Kim, *Bull. Korean Chem. Soc.*, **15**, 478 (1994).
5. a) H. C. Brown, J. S. Cha, B. Nazer and N. M. Yoon, *J. Am. Chem. Soc.*, **106**, 8001 (1984); b) H. C. Brown, J. S. Cha, N. M. Yoon and B. Nazer, *J. Org. Chem.*, **52**, 5400 (1987).
6. a) J. S. Cha, J. E. Kim and K. W. Lee, *J. Org. Chem.*, **52**, 5030 (1987); b) J. S. Cha, S. Y. Oh and J. E. Kim, *Bull. Korean Chem. Soc.*, **8**, 301, 313 (1987); c) J. S. Cha, K. W. Lee, M. S. Yoon and J. C. Lee, *ibid.*, **9**, 384 (1988); d) J. S. Cha, *Org. Prep. Proced. Int.*, **21**, 451 (1989).
7. J. S. Cha, W. W. Seo, J. M. Kim and O. O. Kwon, *Bull. Korean Chem. Soc.*, **17**, 892 (1996).
8. a) H. C. Brown and A. W. Moerikofer, *J. Am. Chem. Soc.*, **84**, 1478 (1962); b) H. C. Brown and G. U. Klender, *Inorg. Chem.*, **1**, 204 (1962).

9. The full scope of reducing characteristics of ThxBHOR is under investigation.

10. H. C. Brown, B. Nazer, J. S. Cha and J. A. Sikorski, *J. Org. Chem.*, **51**, 5264 (1986).

11. The solution of $ThxBH_2$ in THF was prepared by hydroboration of 2,3-dimethyl-2-butene (525 mmol) with BH_3-THF (1.1 M, 500 mmol) at 0° (See, ref 8). The solution of BH_3 in THF was prepared by reaction of sodium borohydride (300 mmol) and dimethyl sulfate (315 mmol) in THF at 0° (See, N. M. Yoon and J. S. Cha, *J. Korean Chem. Soc.*, **22**, 37 (1978)).

12. The ^{11}B NMR spectra for other derivatives are as follows:ThxBHOEt, δ 51 (J_{BH} = 127 Hz); ThxBHO^{i}Bu, δ 51 (J_{BH} = 121 Hz); ThxBHO^{i}Pr, δ 50 (J_{BH} = 126 Hz); ThxBHO^{t}Bu, δ 48 (J_{BH} = 126 Hz); ThxBHOPh, δ 51 (J_{BH} = 128 Hz).

13. *CRC Handbook of Tables for Organic Compound Identification*, 3rd ed., CRC Press Inc., Cleveland, 1967.

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