References

1. Scribner, R. M.; Sausen, G. N.; Prichard, W. W. *J. Org. Chem.* **1960**, *25*, 1440.
2. Bestus, J.; Castells, J. *J. Proc. Chem. Soc. (London)* **1962**, 216.
3. Lee, J.-Y.; Hall, H. K., Jr *J. Org. Chem.* **1990**, *55*, 4963.
4. Ramberg, L.; Wideqvist, S. *Arkiv. Kemi.* **1937**, *12A*(22).
5. Ramberg, L.; Wideqvist, S. *Arkiv. Kemi.* **1941**, *14B*(37).
6. Hart, H.; Freeman, F. *J. Org. Chem.* **1963**, *28*, 1220.
7. Hart, H.; Kim, Y. C. *J. Org. Chem.* **1966**, *31*, 2784.
8. Kim, Y. C.; Hart, H. *J. Chem. Soc. (C)* **1969**, 2409.
9. Lee, J.-Y.; Cho, S.-O.; Mun, G.-S. *Bull. Korean Chem. Soc.* **1992**, *13*(1), 99.
10. Lee, J.-Y.; Cho, S.-O.; Padias, A. B.; Hall, H. K. *Jr. Bull. Korean Chem. Soc.* **1991**, *12*(3), 271.
11. Lee, J.-Y.; Kim, K.-A. *Bull. Korean Chem. Soc.* **1994**, *15*(6), 418.
12. Moore, A. H. F. *Org. Syn. Coll. Vol. 4.* **1963**, 84.
13. Griffin, A. C.; Bhatti, A. M.; Hung, R. S. in *Nonlinear Optical and Electroactive Polymers; Am. Chem. Soc. Symp.* Prasad, P. N.; Ulrich, D. R. Ed.; Plenum Press: New York, 1987; pp 375-391.
14. Hesse, B. C. *J. Am. Chem. Soc.* **1986**, *18*, 723.

Synthesis of 2-Substituted-4-chloromethylfurans Using 2-(Chloromethyl)-3-(trimethylsilyl)propene

Jong Sun U and Kyung-Tae Kang*

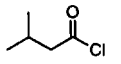
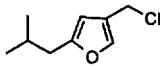
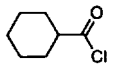
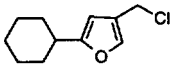
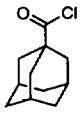
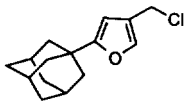
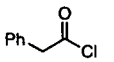
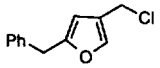
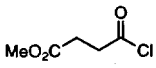
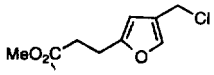
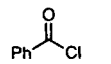
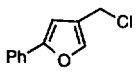
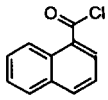
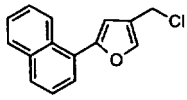
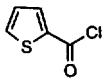
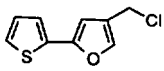
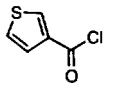
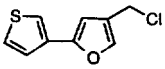
Department of Chemistry, Pusan National University, Pusan 609-735, Korea

Received July 27, 1994

The 3-furylmethyl moiety is present in various natural products such as perillene,[1] dendrolasin,[1] amilol-A and B,[2] anonene,[3] pallescensin-1,2,3, and A,[4] pleraplysillin-1,[5] nakafuran-8 and 9.[6] Most of them were synthesized from 3-chloromethylfuran. 3-Chloromethylfuran itself has been synthesized.[1a,7] However, the reports on alkyl or aryl substituted 3-chloromethylfurans are rare.[8] Though numerous synthetic routes to furans have been developed,[9] a regioselective preparation of highly substituted furans is still demanding. We describe here a general, convenient preparation of 2-substituted-4-chloromethylfurans **5**, which are useful for the synthesis of the substituted furanosesquiterpenes.

The epoxycarbonyl compounds, good precursors of furans, have been prepared from homoallylic alcohols by epoxidation followed by oxidation.[10,11] And the homoallylic alcohols have been synthesized from the reaction of allylic chlorides with aldehydes in the presence of magnesium or zinc.[12] However, these synthetic routes have some limitations for the preparation of variously substituted epoxycarbonyl compounds. Recently, we found that allylic ketones, which were obtained from the Lewis acid-mediated reactions of allysilanes with acid chlorides,[13] could be transformed to epoxycarbonyl compounds by epoxidation with m-chloroperoxybenzoic acid (MCPBA). Following this procedure, 2-substituted-4-chloromethylfurans **5** were prepared from the allysilane, 2-(chloromethyl)-3-(trimethylsilyl)propene (**1**)[14] as shown in the Scheme.

Table 1. Synthesis of 2-Substituted-4-chloromethylfurans **5**[a]

Entry	Acid Chloride **2**	Furan **5**	Overall Yield,[b] %
a			57
b			49
c			44
d			47
e			35
f			43
g			42
h			46
i			53

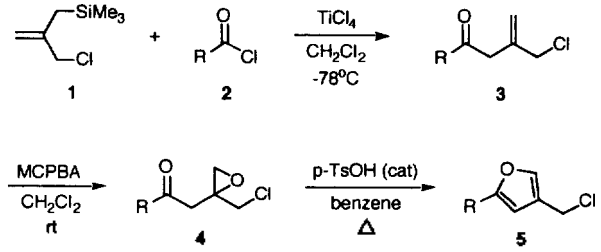
[a] The three step reactions were carried out consecutively without isolation of the intermediate products (See text). [b] Isolated yields (not optimized).

Reaction of allysilane **1** with isovaleryl chloride (**2a**) in the presence of one equiv of $TiCl_4$ at -78 ℃ in CH_2Cl_2 led to the allylic ketone **3a** in 92% yield after chromatography (SiO_2, hexane : ether = 8 : 1). The possible formation of conjugated enones coming from an acidic isomerization of **3** was not observed under our experimental conditions. Epoxidation of **3a** with MCPBA (2 equiv) in CH_2Cl_2 at 0 ℃ ~ room temperature gave the epoxide **4a** in 85% yield after purification (SiO_2, CH_2Cl_2). When a benzene solution of **4a** with a catalytic amount of p-toluenesulfonic acid was refluxed for 1 h, 2-isobutyl-4-chloromethylfuran **5a** was produced in 66% yield after purification by molecular distillation. The furan products **5**, especially aryl substituted ones, were lost significantly during chromatography on silica gel and alumina.

The three step procedures, the $TiCl_4$-promoted reaction of allylsilane **1** with an acid chloride, epoxidation with MCPBA, and cyclization process could be performed successively

Table 2. Spectral Data of 2-Substituted-4-chloromethylfurans **5**

Furans	^{1}H NMR ($CDCl_3$) δ, *J* (Hz)	^{13}C NMR ($CDCl_3$) δ	MS m/z (rel. intensity, %)
5a	0.93 (6H, d, *J*=6.6), 1.89-2.03 (1H, m), 2.45 (2H, d, *J*=7.0), 4.43 (2H, s), 6.05 (1H, s), 7.30 (1H, s)	22.3, 27.8, 37.1, 37.6, 106.4, 122.8, 138.9, 157.1	174 (M+2, 11), 172 (M^+, 32), 137(25), 129 (100)
5b	1.2-1.4 (5H, m), 1.6-1.8 (3H, m), 1.95-2.05 (2H, m), 2.45-2.6 (1H, m), 4.40 (2H, s), 5.97 (1H, s), 7.26 (1H, s)	26.0, 26.2, 31.4, 37.3, 37.5, 103.7, 122.6, 138.5, 162.2	200 (M+2, 18), 198 (M^+, 55), 163 (43), 155 (100)
5c	1.2-2.0 (15H, m), 4.45 (2H, s), 5.98 (1H, s), 7.31 (1H, s)	28.2, 34.6, 36.7, 37.8, 41.0, 102.3, 122.3, 138.5, 165.9	252 (M+2, 11), 250 (M^+, 39), 215 (10), 193 (26), 84 (100)
5d	3.93 (2H, s), 4.41 (2H, s), 6.05 (1H, s), 7.21-7.34 (6H, m)	34.5, 37.4, 107.0, 123.0, 126.6, 128.5, 128.7, 137.5, 139.6, 156.1	208 (M+2, 2), 206 (M^+, 8), 171 (9), 128 (13), 84 (100)
5e	2.65 (2H, t, *J*=15.0), 2.94 (2H, t, *J*=15.0), 3.69 (3H, s), 4.43 (2H, 1s), 6.10 (1H, s), 7.32 (1H, s)	23.5, 32.2, 37.4, 51.8, 106.2, 123.0 139.4, 155.6, 172.8	204 (M+2, 3), 202 (M^+, 10), 167 (11), 149 (29), 129 (28), 84 (100)
5f	4.49 (2H, s), 6.69 (1H, s), 7.2-7.7 (6H, m)	37.2, 105.4, 123.5, 123.8, 127.8, 128.7, 130.3, 140.0, 155.1	194 (M+2, 5), 192 (M^+, 15), 157 (16), 128 (22), 84 (100)
5g	4.55 (2H, s), 6.74 (1H, s), 7.45-7.54 (3H, m), 7.61 (1H, s), 7.67-7.70 (1H, m), 7.80-7.86 (2H, m), 8.31-8.35 (1H, m)	37.1, 124.2, 125.3, 125.6, 126.0, 126.4, 126.7, 128.2, 128.6, 129.1, 130.5, 134.1, 140.3, 154.9	244 (M+2, 17), 242 (M^+, 53), 179 (44), 119 (100), 84 (92)
5h	4.45 (2H, s), 6.53 (1H, s), 7.0-7.4 (4H, m)	37.0, 105.4, 123.1, 124.3, 124.6, 127.6, 133.1, 139.4, 150.5	200 (M+2, 10), 198 (M^+, 27), 163 (15), 135 (36), 84 (100)
5i	4.48 (2H, s), 6.52 (1H, s), 7.3-7.5 (4H, m)	37.2, 105.2, 119.6, 124.0, 124.6, 126.3, 132.1, 139.3, 152.1	200 (M+2, 6), 198 (M^+, 15), 163 (14), 135 (24), 84 (100)



without isolation of the intermediate products. The consecutive procedure afforded the furan **5a** in a little improved yield (57%, Table 1, entry a) compared to the intermediate isolation procedure (52%). The furans **5** which were prepared by the consecutive procedure are presented in Table 1. The method is general in scope since it has been applied to the synthesis of 2-aliphatic-(**5a-d**), 2-carbomethoxyethyl-(**5e**), 2-aryl-(**5f-g**), and 2-heteroaromatic-4-chloromethylfurans (**5h-i**). The structure of products was established by spectral characterization (Table 2).

In summary, the present reaction sequence offers a facile route to various substituted furans by using properly designed allylsilanes.

Experimental

^{1}H NMR spectra were recorded on a JEOL JSX 270 (270 MHz) spectrometer using tetramethylsilane as an internal standard. ^{13}C NMR spectra were obtained on a JEOL JSX 270 (58 MHz) spectrometer with $CDCl_3$ as solvent and internal standard. GC-MS analyses were performed with a Hewlett-Packard 5971 A spectrometer using a HP-1 column.

General procedure for the synthesis of 2-substituted-4-chloromethylfurans. The synthesis of 2-isobutyl-4-chloromethylfuran **5a** is typical: To a dichloromethane (5 *ml*) solution of $TiCl_4$ (1.25 g, 6.6 mmol) a mixture of isovaleryl chloride (**2a**) (0.78 g, 6.5 mmol) and 2-(chloromethyl)-3-(trimethylsilyl)propene (**1**) (1.02 g, 6.3 mmol) in CH_2Cl_2 (4 *ml*) was added slowly at −78 ℃. After 1 h, the mixture was quenched with 3 N HCl and extracted with ether. The ethereal extract was washed with sat. aq $NaHCO_3$ and brine, dried over Na_2SO_4, and concentrated *in vacuo*. The crude product **3a** (1.13 g) was treated with MCPBA (50%, 4.48 g, 13.0 mmol) in CH_2Cl_2 (10 *ml*) at 0 ℃ ~rt for 18 h. After removal of the solvent, benzene (10 *ml*) and p-toluenesulfonic acid (10 mg) was added, and refluxed for 1 h. The reaction mixture was partitioned between sat. aq NH_4Cl solution and ether, and the aqueous layer was separated and extracted with ether. The combined organic phases were washed with water and dried over Na_2SO_4, filtered, concentrated, and distilled (Kugelrohr, bp 70-72 ℃/0.04 mmHg) to afford 618 mg (57%) of **5a**.

Acknowledgement. This work was supported by the Korea Science and Engineering Foundation through the Organic Chemistry Research Center. We also acknowledge Mr. Chi Hyo Park of Lucky Ltd., for GC-MS and NMR spectra.

References

1. (a) Tanis, S. P. *Tetrahedron Lett.* **1982**, *23*, 3115. (b) Sheffy, F. K.; Godschalx, J. P.; Stille, J. K. *J. Am. Chem. Soc.* **1984**, *106*, 4833.
2. Walker, R. P.; Faulkner, D. J. *J. Org. Chem.* **1981**, *46*, 1098.
3. Ferrari, M.; Pelizzoni, F.; Ferrari, G. *Phytochemistry*, **1974**, *13*, 208.
4. (a) Nasipuri, D.; Das, G. *J. Chem. Soc. Perkin Trans 1*, **1979**, 2776. (b) Matsumoto, T.; Usui, *S. Chem. Lett.* **1978**, 105.
5. Scott, W. J.; Crisp, G. T.; Stille, J. K. *J. Am. Chem. Soc.* **1984**, *106*, 4630.
6. (a) Schulte, G.; Scheuer, P. J.; McConnell, O. J. *Helv. Chim. Acta.* **1980**, *63*, 2159. (b) Tafiis, S. P.; Herrinton, P. M. *J. Org. Chem.* **1985**, *50*, 3988.
7. (a) Sherman, E.; Amstutz, E. D. *J. Am. Chem. Soc.* **1950**, *72*, 2195. (b) Parker, K. A.; Johnson, W. S. *Tetrahedron Lett.* **1969**, 1329.
8. (a) Stone, K. J.; Greenberg, M. M.; Blackstock, S. C.; Berson, J. A. *J. Am. Chem. Soc.* **1989**, *111*, 3659. (b) Munzel, N.; Schweig, A. *Angew. Chem. Int. Ed. Engl.* **1987**, *26*, 471.
9. (a) Lee, G. C. M.; Holmes, J. M.; Harcourt, D. A.; Garst, M. E. *J. Org. Chem.* **1992**, *57*, 3126. (b) Kataoka, Y.; Tezuka, M.; Takai, K.; Utimoto, *K. Tetrahedron*, **1992**, *48*, 3495, and references therein.
10. Cormier, R. A.; Grosshans, C. A.; Skibbe, S. L. *Synth. Commun.* **1988**, *18*, 677, and references therein.
11. An alternative synthesis of 2-acetonyloxiranes from the palladium-catalized reaction of α-haloketones with acetonyltin reagents was reported; Pri-bar, I.; Pearlman, P. S.; Stille, J. K. *J. Org. Chem.* **1983**, *48*, 4629.
12. (a) Maurer, R. A.; Hauser, A. *Tetrahedron Lett.* **1984**, *25*, 1061. (b) Hegde, S. G.; Wolinsky, J. *J. Org. Chem.* **1982**, *47*, 3148.
13. (a) Kang, K.-T.; Lee, J. C.; U. J. S. *Tetrahedron Lett.* **1992**, *33*, 4953. (b) Kang, K.-T.; U. J. S. *Synth. Commun.* **1994**, *24*, 1507.
14. Lewis acid-mediated reactions of 1 with aldehydes have been conveniently empolyed in the synthesis of methylenetetrahydrofurans and methylenebutyrolactones, D' Aniello, F.; Taddei, M. *Synlett.* **1993**, 119.

Conversion of Nitriles into Aldehydes by Diisobutylaluminum Hydride-Dimethyl Sulfide Complex

Jin Soon Cha*, Oh Oun Kwon, Min Kyu Jeoung, and Eun Ju Kim

Department of Chemistry, Yeungnam University, Kyongsan 712-749, Korea

Received August 11, 1994

The conversion of nitriles into aldehydes is one of the most desirable means in organic synthesis. Numerous useful methods have been proposed to achieve such purposes.[1] Especially noteworthy is that some reagents, such as potassium 9-*sec*-amyl-9-borarabicyclo[3.3.1]nonane (K-9-*sec*-Am-9-BBNH),[2] lithium tris(dihexylamino)aluminum hydride (LTDHA)[3] and sodium tris(dihexylamino)aluminum hydride (STDHA)[4], nicely achieved the chemoselective reduction of aromatic nitriles to the corresponding aldehydes in which aliphatic nitriles remain intact.

Very recently, we prepared diisobutylaluminum hydride-dimethyl sulfide (DIBAH-SMe_2) complex by a simple addition of dimethyl sulfide to the solution of diisobutylaluminum hydride (DIBAH)[5] (Eq. 1).

$$(i\text{-Bu})_2\text{AlH} + \text{SMe}_2 \xrightarrow{\text{toluene}} \underset{\text{DIBAH-SMe}_2}{(i\text{-Bu})_2\text{AlH-SMe}_2} \qquad (1)$$

The complex, DIBAH-SMe_2, is very stable and possesses unique reducing characteristics. Accordingly, we have examined the reducing characteristics of the complex systematically in order to enlarge the scope of applicability as a reducing agent.[5] In the course of this systematic study, we found that DIBAH-SMe_2 converted both benzonitrile and capronitrile into the corresponding aldehydes in higher yields than those obtained by DIBAH itselt. Consequently, we decided to investigate a full scope of such transformations. This paper reports the results for the reduction of nitriles by utilizing DIBAH-SMe_2 in a limiting amount at 0 ℃, along with the results obtained previously by DIBAH itself[6] for comparison.

In general, as shown in Table 1, the yields of aldehydes by DIBAH-SMe_2 are better than those by DIBAH itself which is well known as a superior reagent for synthesis of aldehydes from nitriles.

DIBAH-SMe_2 in toluene reduced unsubstituted aromatic nitriles, such as benzonitrile and naphthonitrile, to the corresponding aldehydes in yields of 90-91% in 3 h at 0 ℃. Dinitriles, such as phthalonitrile and terephthalonitrile, were reduced to dialdehydes in yields of 92-99%. Ring substituted derivatives are readily accommodated. Thus, chloro-and dichlorobenzonitriles were converted into the corresponding aldehydes in yields better than 90%. Tolunitriles, regardless of the position of the methyl substituent, were also readily reduced to give the aldehydes in better than 92% yields.

The reagent also reduced aliphatic nitriles to aldehydes in yields of 71-99% in 3h at 0 ℃. Alicyclic derivatives, such as cyclopropanecarbonitrile, worked equally well. α,β-Unsaturated nitriles, such as crotononitrile, provided the corresponding aldehydes in a yield of 97%. Finally, it is also possi-