JOC*Note*

Removal of Thiazolidinethione Auxiliaries with Benzyl Alcohol Mediated by DMAP

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Abstract: In the presence of DMAP, a range of *N*-acylthiazaolidinethiones carrying different substituents were smoothly converted into the corresponding benzyl esters.

Chiral 4-monosubstituted thiazolidinethiones derived from inexpensive/readily available amino acids are useful[1] auxiliaries in asymmetric synthesis. Compared with their oxazolidinone and oxazolidinethione counterparts, removal of the these auxiliaries from the *N*-acylthiazolidinthiones after completion of the chiral induction is generally easier.[1a,b] Such a feature has great merits in the synthesis of complicated "fragile" molecules containing many different functionalities.

However, removal of the 4-monosubstituted thiazolidinethione auxiliaries is not always as trouble-free as one might deduce from the examples[1a,b,f,h,i] in the literature. With increasing the steric crowding around the *N*-acyl group, removal of the auxiliary becomes increasingly difficult. The cleavage[2] can be even further complicated when the *N*-acylthiazolidinethione contains a β-hydroxyl group. An additional factor that still further reduces the number of potential choices is that the sulfur-containing auxiliaries are readily oxidized and thus destroyed under Evans' H_2O_2/LiOH[3] conditions. Thus, it appears that new mild/efficient methods for converting *N*-acylthiazolidinethiones to corresponding esters or carboxylic acids are still in great need. Here in this Note we report the first systematic investigation on the conversion of *N*-acylthiazolidinethiones to the corresponding benzyl esters.

Our main results are outlined in Table 1. All the runs were carried[4] out in CH_2Cl_2 with DMAP[5,6] (4-(dimethylamino)pyridine) as the catalyst. From these data it appears that the removal of the thiazolidinethione auxiliaries is affected mostly by the size of the substituent at the α-carbon. For those substrates carrying a methyl group at the α-carbon, the yields were generally high (entries 1−4, 7, 12, and 13).

A larger substituent at the α-carbon has a negative effect on the reaction (entries 5, 6, 8, and 9). Similarly, "branching" of the linear chain also reduced the yield of the benzyl ester, even if the "branching point" was two CH_2 groups away from the α-carbon (entry 10). If the branching occurred at a position very close to the α-carbon, the cleavage of the auxiliary was completely shut off (entry 17).

When the α-substituent is larger than a methyl group, a delicate effect of changing the substituent on the auxiliary may also manifest itself (entries 8 and 9). The less satisfactory result with **13′** compared with that of **13** probably reflected that the Bn group in **13** blocked the entry of the attacking BnOH more effectively than the rigid Ph group in **13′**.

The effect of the β-substituent did not seem to be as prominent as that of the α-substituent. However, drastically increased steric crowding at the carbon β- to the acyl carbonyl group still may have a discernible influence on the cleavage reaction. (entry 6 vs 11).

The cleavage of **23** was exceptionally difficult (yielding benzyl isovalerate along with other unidentified side-products). However, it was possible to enlarge the rate difference between the desired cleavage and the side-reaction(s) and thus improve the yield of **24** through careful "tuning" of the experimental conditions (entry 14). It is interesting to note that if the acyl group on the β-hydroxyl group was removed (i.e., **25**) essentially no desired benzyl ester was formed (entry 15). Some unidentified side-products (of relative high polarity and showing strong fluorescence under 254 nm UV light) were generated instead. With an allyl group to replace the TES (entry 16), the situation was improved slightly.

The effect of the quantity of DMAP utilized in the reaction is not always straightforward. For most substrates examined in this work only a catalytic amount of DMAP was sufficient. Slight variation[7] in the amount of the added DMAP only led to changes in the reaction rate, but not the yield. However, a so far unexplainable

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[1] See, e.g.: (a) Crmmins, M. T.; King, B. W.; Tabet, E. A.; Chaudhary, K. *J. Org. Chem*. **2001**, *66*, 894−902. (b) Crimmins, M. T.; Chaudhary, K. *Org. Lett*. **2000**, *2*, 775−778. (c) Evans, D. A.; Downey, C. W.; Shaw, J. T.; Tedrow, J. S. *Org. Lett*. **2002**, *4*, 1127−1130. (d) Wu, Y.-K.; Shen, X.; Tang, C.-J.; Chen, Z.-L.; Hu, Q.; Shi, W. *J. Org. Chem*. **2002**, *6*, 3802−3810. (e) Wu, Y.-K.; Shen, X.; Yang, Y.-Q.; Hu, Q.; Huang, J.-H. *Tetrahedron Lett*. **2004**, *45*, 199−202. (f) Cosp, A.; Romea, P.; Talavera, P.; Urpi, F.; Vilarrasa, J.; Font-Bardia, M.; Solans, X. *Org. Lett*. **2001**, *3*, 615−618. (g) Hart, D. J.; Patterson, S.; Unch, J. P.; *Synlett* **2003**, 1334−1338. (h) Cosp, A.; Larrosa, I.; Vilasis, I.; Romea, P.; Urpi, F.; Vilarrasa, J. *Synlett* **2003**, 1109−1112. (i) Larrosa, I.; Romea, P.; Urpi, F.; Balsells, D.; Vilarrasa, J.; Font-Bardia, M.; Solans, X. *Org. Lett*. **2002**, *4*, 4651−4654. (j) Ambhaikar, N. B.; Snyder, J. P.; Liotta, D. C. *J. Am. Chem. Soc*. **2003**, *125*, 3690−3691. (k) Crimmins, M. T.; McDougall, P. J. *Org. Lett*. **2003**, *5*, 591−594. (l) Efremov, I.; Paqutte, L. A. *J. Am. Chem. Soc*. **2000**, *122*, 9324−9325. (m) Zhang, Y.-C.; Phillips, A. J.; Sammakia, T. *Org. Lett*. **2004**, *6*, 23−25.

[2] In this paper, cleavage refers only to those conversions of auxiliary acyl compounds into the corresponding esters or carboxylic acids. Reductive cleavage is not included.

[3] Evans, D. A.; Britton, T. C.; Ellman, J. A. *Tetrahedron Lett*. **1987**, *28*, 6141−6144.

[4] Because most of the runs were performed in the winter, the ambient temperature was low and varied considerably. The results appeared to be similar at 20 °C (entry 1).

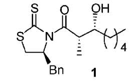
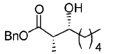
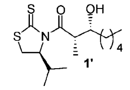
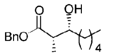
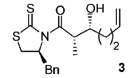
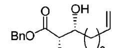
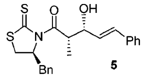
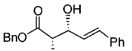
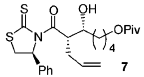
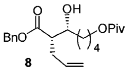
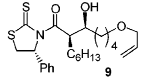
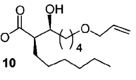
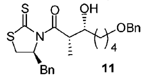
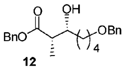
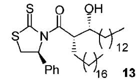
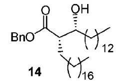
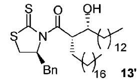
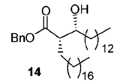
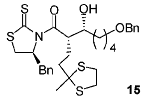
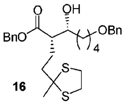
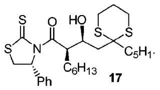
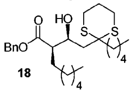
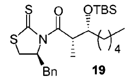
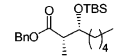
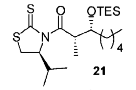
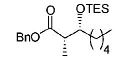
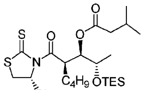
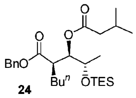
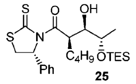
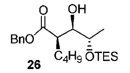
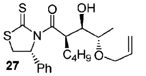
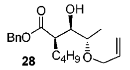
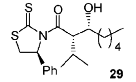
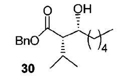
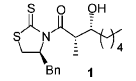
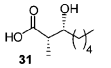
[5] Su, D.-W.; Wang, Y.-C.; Yan, T.-H. *Tetrahedron Lett*. **1999**, *40*, 4197−4198.

[6] Yan's procedure (ref 5) has been recently applied to the removal of 4-isopropyl-thiazolidinethione by the Romea−Urpi group (see refs 1f, 1h, and 1i, where the conversion of the acyl-thiazolidinethiones to methyl/ethyl esters was only very briefly mentioned).

[7] For some substrates, stoichiometric amounts of DMAP must be utilized in order to obtained the desired benzyl esters in synthetically useful yields (entries 12−14). Using significantly smaller amounts of DMAP in these cases resulted in very sluggish cleavage and extensive side-reactions.

10.1021/jo049204e CCC: $27.50

TABLE 1. Conversion of Various *N*-Acylthiazolidinethiones to Corresponding Benzyl Esters

entry	substrate	BnOH (equiv.)	DMAP (equiv.)	time (h)	temp. (°C)	product	yield
1[a]	 1	2.0	0.1	13	5	 2	93%
2	 1'	1.5	0.2	9	10	 2	90%
3	 3	1.5	0.1	17	10	 4	94%
4	 5	1.5	0.2	9	10	 6	91%
5	 7	1.5	0.1	21	13	 8	88%
6	 9	1.5	0.1	32	7	 10	80%
7[b]	 11	1.5	0.1	16	10	 12	91%
8	 13	2.0	0.1	16	10	 14	77%
9	 13'	2.0	0.1	30	15	 14	64%
10	 15	1.5	0.2	34	10	 16	80%
11[c]	 17	1.5	0.3	32	7	 18	63%
12	 19	1.5	1.0	45	10	 20	93%
13	 21	1.5	1.0	45	10	 22	91%
14	 23	1.2	1.0	12	25	 24	82%
15[d]	 25	1.5	1.0	16	12	 26	0%
16[e]	 27	2.0	1.0	25	10	 28	40%
17[f]	 29	2.0	0.2	20	8	 30	0%
18[g]	 1	(H₂O) 2.0	0.5			 31	82%

[a] Similar result (94%) was also obtained at 20 °C, with the auxiliary quantitatively recovered. [b] Another 0.1 equiv of DMAP was added after 9 h. [c] About 23% unreacted **17** was recovered. [d] Several unidentified compounds were obtained. [e] Along with several so far unidentified, more polar side-products (with strong fluorescence under 254 nm UV light), which were almost inseparable from each other. [f] Most of the **29** remained unreacted. [g] In this run, 2.0 equiv of water was utilized in place of the BnOH.

exception was also observed. When we treated **13** with 0.2 equiv of DMAP (instead of 0.1 equiv as in entry 8), the benzyl ester **14** was formed in only 26% yield. Most of the **13** was converted to other unidentified side-products.

It should be noted that in those successful runs, the free auxiliary could be recovered in high yields. From entry 1, for instance, (*R*)-4-benzyl-thiazolidinethione was recovered essentially quantitatively.

For the purpose of comparison, we also briefly examined a few other catalysts/conditions: K_2CO_3/MeOH, which worked very well[8] (affording corresponding methyl esters) for some other *N*-acylthiazolidinethiones that did not contain a β-hydroxyl group, led to extensive formation of side-products within 1 h. Imidazole/MeOH[1a,b] was inert on those hindered substrates. 2,6-Lutidine/BnOH was also completely inactive in such cleavage reactions. DBU behaved similar to DMAP. However, the reactions were not as clean as those using DMAP. With water to replace the benzyl alcohol, it was possible to cleave[9] the nonhindered *N*-acylthiazolidinethiones in good yields as exemplified by entry 18. However, the reaction completely failed for those hindered substrates.

Experimental Section

All the substrates were prepared by $TiCl_4$-mediated asymmetric aldolization as reported by Crimmins[1a,b] and co-workers. The TBS or TES protection of the β-hydroxyl group in the Crimmins aldols was realized by treatment with TBSCl or TESCl in the presence of 2,6-lutidine. Acylation of the β-hydroxyl group (**23**) was achieved with the corresponding acid chloride in pyridine under the standard acylation conditions. All ^{1}H NMR spectra were recorded in $CDCl_3$ (with Me_4Si as the internal reference) on NMR spectrometers operating at 300 MHz.

General Procedure. A solution (ca. 0.2 M for the substrate) of the substrate, BnOH, and DMAP in CH_2Cl_2 was stirred at the ambient temperature. The reaction was monitored by TLC. When the reaction was complete, the mixture was diluted with ether, washed with 1 N HCl, water, and brine, and dried over anhydrous Na_2SO_4. The crude residue after removal of the solvents was chromatographed on silica gel (eluting with a mixture of EtOAc/hexanes of proper ratio) to afford the pure product.

Data for Compound 1. A colorless oil: $[\alpha]^{20}_D$ +119.8 (*c* 5.0, $CHCl_3$). ^{1}H NMR δ 7.38−7.26 (m, 5H), 5.35 (ddd, J = 4.2, 6.7, 10.6 Hz, 1H), 4.48 (dq, J = 2.9, 6.9 Hz, 1H), 3.96−3.90 (m, 1H), 3.40 (dd, J = 7.3 Hz, 1H), 3.22 (dd, J = 4.0, 13.2 Hz, 1H), 3.04 (dd, J = 10.6, 13.3 Hz, 1H), 2.91 (d, J = 11.5 Hz, 1H), 2.67 (d, J = 3.3 Hz, 1H), 1.59−1.28 (m, 8H), 1.25 (d, J = 6.9 Hz, 3H), 0.89 (t, J = 6.8 Hz, 3H). FT-IR (film) 3447, 1694, 1455, 1164, 702 cm^{-1}. EI-MS *m/z* (%) 365 (M$^+$, 2.1), 332 (20.1), 314 (3.7), 276 (15.8), 20 (100), 118 (87.5), 91 (58.2). EI-HRMS cald for $C_{19}H_{28}NO_2S_2$ (M$^+$ + 1) 366.1556; found 366.1584.

Data for Compound 1′. A colorless oil: $[\alpha]^{27}_D$ +162.1 (*c* 0.50, $CHCl_3$). ^{1}H NMR δ 5.18 (ddd, J = 1.3, 6.6, 7.7 Hz, 1H), 4.47 (dq, J = 2.7, 7.1 Hz, 1H), 3.92−3.88 (m, 1H), 3.51 (dd, J = 7.9, 11.9 Hz, 1H), 3.04 (dd, J = 1.3, 12.0 Hz, 1H), 2.96 (d, J = 2.6 Hz, 1H), 2.34 (dt, J = 20.5, 6.7 Hz, 1H), 1.52−1.20 (m, 8H), 1.26 (d, J = 6.6 Hz, 3H), 1.06 (d, J = 6.8 Hz, 3H), 0.97 (d, J = 6.7 Hz, 3H), 0.88 (t, J = 6.5 Hz, 3H). FT-IR (film) 3446, 1694, 1466, 1160 cm^{-1}. ESI-MS *m/z* 318 ([M + 1]$^+$). ESI-HRMS calcd for $C_{15}H_{27}NO_2S_2Na$ ([M + Na]$^+$) 340.1375; found 340.1390.

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(8) See, e.g.: (a) Yamada, S.; Misono, T.; Ichikawa, M.; Morita, C. *Tetrahedron* **2001**, *57*, 8939−8950. (b) Nagao, Y.; Hagiwara, Y.; Tohjo, T.; Hasegawa, Y.; Ochiai, M. *J. Org. Chem.* **1988**, *53*, 5983−5986.

(9) Similar results were obtained using THF as the solvent. It is interesting to note that the reaction in CH_2Cl_2 seemed to be faster, although water is not soluble in this solvent.

Data for Compound 2. A colorless oil: $[\alpha]^{19}_{D}$ +11.1 (c 0.4, CHCl$_3$). ^{1}H NMR δ 7.38−7.26 (m, 5H), 5.14 (s, 2H), 3.93−3.89 (m, 1H), 2.58 (dq, J = 3.5, 7.1 Hz, 1H), 2.46 (d, J = 4.7, 1H, OH), 1.48−1.27 (m, 8H), 1.20 (d, J = 7.1 Hz, 3H), 0.88 (t, J = 6.8 Hz, 3H). FT-IR (film) 3449, 1731, 1456, 1171, 698 cm^{-1}. ESI-MS m/z 265.25 ([M + 1]$^+$). ESI-HRMS calcd for $C_{16}H_{24}O_3Na$ ([M + Na]$^+$) 287.1618; found 287.1628.

Data for Compound 3. A colorless oil: $[\alpha]^{25}_{D}$ +129.4 (c 0.65, CHCl$_3$). ^{1}H NMR δ 7.38−7.26 (m, 5H), 5.28 (ddt, J = 10.0, 16.8, 6.9 Hz, 1H), 5.36 (ddd, J = 3.5, 6.9, 10.5 Hz, 1H), 5.05 (br d, J = 16.8 Hz, 1H), 4.98 (br d, J = 10.1 Hz, 1H), 4.47 (dq, J = 3.3, 6.8 Hz, 1H), 3.95 (br dt, J = 11.5, 3.1 Hz, 1H), 3.40 (dd, J = 7.2, 10.5 Hz, 1H), 3.21 (dd, J = 3.7, 13.2 Hz, 1H), 3.04 (dd, J = 10.7, 13.3 Hz, 1H), 2.90 (d, J = 11.5 Hz, 1H), 2.76 (d, J = 3.3 Hz, 1H), 2.29−2.07 (m, 2H), 1.67−1.62 (m, 1H), 1.27−1.21 (m, 1H), 1.22 (d, J = 6.5 Hz, 3H). FT-IR (film) 3530, 1691, 1265, 910 cm^{-1}. EI-MS m/z (%) 349 (M$^+$ + 1, 3.3), 331 (2.2), 316 (23.8), 210 (100), 118 (62.3), 91 (42.7). ESI-HRMS calcd for $C_{18}H_{23}NO_2S_2Na$ ([M + Na]$^+$) 372.1062; found 372.1088.

Data for Compound 4. A colorless oil: $[\alpha]^{24}_{D}$ +3.83 (c 1.4, CHCl$_3$). ^{1}H NMR δ 7.41−7.34 (m, 5H), 5.82 (ddt, J = 10.5, 17.4, 6.5 Hz, 1H), 5.16 (s, 2H), 5.16−4.97 (m, 2H), 3.98 (dt, J = 3.8, 9.1 Hz, 1H), 2.60 (dq, J = 3.8, 7.2 Hz, 1H), 2.49 (br s, 1H, OH), 2.35−2.05 (m, 2H), 1.61−1.44 (m, 2H), 1.22 (d, J = 7.1 Hz, 3H). FT-IR (film) 3495, 1732, 1640, 1456, 1173 cm^{-1}. ESI-MS m/z 249.1 ([M + 1]$^+$). ESI-HRMS calcd for $C_{15}H_{20}O_3Na$ ([M + Na]$^+$) 271.1305; found 271.1318.

Data for Compound 5. A colorless oil: $[\alpha]^{27}_{D}$ +116.1 (c 0.75, CHCl$_3$). ^{1}H NMR δ 7.57−7.26 (m, 5H), 6.64 (d, J = 15.7 Hz, 1H), 6.20 (dd, J = 5.8, 15.6 Hz, 1H), 5.23 (ddd, J = 3.4, 6.3, 10.3 Hz, 1H), 4.80−4.56 (m, 2H), 3.23 (dd, J = 3.4, 10.3 Hz, 1H), 3.19 (dd, J = 6.6, 11.3 Hz, 1H), 3.03 (dd, J = 10.9, 13.5 Hz, 1H), 2.82 (d, J = 11.5 Hz, 1H), 2.67 (br s, 1H, OH), 1.32 (d, J = 6.3 Hz, 3H). FT-IR (film) 3445, 1698, 1601, 1495, 1342, 1137 cm^{-1}. EI-MS m/z (%) 364 (M$^+$ − 33, 15.7), 265 (10.2), 210 (42.7), 160 (33.2), 131 (36.2), 118 (93.6), 91 (100). ESI-HRMS calcd for $C_{22}H_{23}NO_2S_2Na$ ([M + Na]$^+$) 420.1062; found 420.1094.

Data for Compound 6. A colorless oil: $[\alpha]^{27}_{D}$ +4.75 (c 0.30, CHCl$_3$). ^{1}H NMR δ 7.60−7.26 (m, 5H), 6.64 (d, J = 16.0 Hz, 1H), 6.17 (dd, J = 6.2, 16.1 Hz, 1H), 5.16 (s, 2H), 4.60−4.58 (m, 1H), 2.76 (dq, J = 4.7, 7.1 Hz, 1H), 2.69 (br s, 1H, OH), 1.20 (d, J = 6.7 Hz, 3H). FT-IR (film) 3462, 1731, 1600, 1496, 1455, 1137, 749, 695 cm^{-1}. EI-MS m/z (%) 296 (M$^+$, 0.5), 205 (16.7), 187 (5.4), 180 (10.8), 133 (35.1), 131 (34.9), 115 (12.7), 91 (100). ESI-HRMS calcd for $C_{19}H_{20}O_3Na$ ([M + Na]$^+$) 319.1305; found 319.1333.

Data for Compound 7. A colorless oil: $[\alpha]^{24}_{D}$ +115.3 (c 0.20, CHCl$_3$). ^{1}H NMR δ 7.42−7.27 (m, 5H), 6.26 (d, J = 8.4 Hz, 1H), 5.76 (ddt, J = 17.6, 10.0, 6.7 Hz, 1H), 5.07−4.99 (m, 1H), 4.96 (br d, J = 17.0 Hz, 1H), 4.92 (br d, J = 10.1 Hz, 1H), 4.06 (t, J = 6.4 Hz, 2H), 3.97−3.90 (m, 2H), 3.07 (dd, J = 1.5, 11.4 Hz, 1H), 2.55 (br quint, J = 7.5 Hz, 1H), 2.45−2.36 (m, 2H), 1.19 (s, 9H). FT-IR (film) 3490, 1723, 1641, 1480, 1137, 698 cm^{-1}. ESI-MS m/z 464.2 ([M + Na]$^+$). ESI-HRMS calcd for $C_{24}H_{33}NO_4S_2Na$ ([M + Na]$^+$) 486.1743; found 486.1766.

Data for Compound 8. A colorless oil: $[\alpha]^{27}_{D}$ +7.69 (c 0.50, CHCl$_3$). ^{1}H NMR δ 7.38−7.33 (m, 5H), 5.78 (ddt, J = 17.3, 10.1, 7.0 Hz, 1H), 5.14 (s, 2H), 5.06 (br d, J = 17.0 Hz, 1H), 5.00 (br d, J = 10.0 Hz, 1H), 4.03 (t, J = 6.5 Hz, 2H), 3.89−3.80 (m, 1H), 2.60 (dt, J = 5.3, 8.7 Hz, 1H), 2.46−2.34 (m, 2H), 1.17 (s, 9H). FT-IR (film) 3514, 1727, 1642, 1480, 1158, 698 cm^{-1}. ESI-MS m/z 377.2 ([M + H]$^+$). ESI-HRMS calcd for $C_{22}H_{32}O_5Na$ ([M + Na]$^+$) 399.2142; found 399.2152.

Data for Compound 9. A colorless oil: $[\alpha]^{27}_{D}$ −99.2 (c 0.85, CHCl$_3$). ^{1}H NMR δ 7.41−7.26 (m, 5H), 6.26 (dd, J = 1.2, 8.1 Hz, 1H), 5.92 (ddt, J = 17.1, 10.5, 5.7 Hz, 1H), 5.28 (br d, J = 17 Hz, 1H), 5.17 (br d, J = 10.5 Hz, 1H), 5.02 (dt, J = 9.1, 4.0 Hz, 1H), 3.98−3.88 (m, 4H), 3.44 (t, J = 6.2 Hz, 2H), 3.05 (dd, J = 1.7, 11.4 Hz, 1H), 2.31 (br s, 1H, OH), 1.89−1.38 (m, 8H), 1.25−1.08 (m, 8H), 0.85 (t, J = 6.8 Hz, 3H). FT-IR (film) 3440, 1699, 1600, 1496, 1158, 698 cm^{-1}. EI-MS m/z (%) 430 (M$^+$ − 33, 4.1), 404 (8.7), 234 (8.5), 209 (17.0), 196 (48.1), 41 (100). ESI-HRMS calcd for $C_{25}H_{37}NO_3S_2Na$ ([M + Na]$^+$) 486.2107; found 486.2129.

Data for Compound 10. A colorless oil: $[\alpha]^{25}_{D}$ −48.9 (c 1.00, CHCl$_3$). ^{1}H NMR δ 7.42−7.25 (m, 5H), 5.91 (ddt, J = 17.3, 10.3, 5.6 Hz, 1H), 5.26 (br d, J = 17 Hz, 1H), 5.17 (br d, J = 10.7 Hz, 1H), 5.15 (s, 2H), 3.96−3.94 (m, 2H), 3.81−3.77 (m, 1H), 3.41 (t, J = 5.8 Hz, 2H), 2.48 (dt, J = 10.4, 4.5 Hz, 1H), 2.43 (d, J = 4.3 Hz, 1H, OH), 1.69−1.23 (m, 16H), 0.86 (t, J = 5.6 Hz, 3H). FT-IR (film) 3445, 1732, 1456, 1157, 1107, 698 cm^{-1}. EI-MS m/z (%) 317 (M$^+$ − 59, 0.6), 263 (2.3), 211 (6.2), 143 (18.0), 91 (100). ESI-HRMS calcd for $C_{23}H_{36}O_4Na$ ([M + Na]$^+$) 399.2506; found 399.2520.

Data for Compound 11. A colorless oil: $[\alpha]^{25}_{D}$ +70.0 (c 0.45, CHCl$_3$). ^{1}H NMR δ 7.37−7.26 (m, 5H), 5.34 (ddd, J = 3.6, 6.5, 10.5 Hz, 1H), 4.50 (s, 2H), 4.50−4.43 (m, 1H), 3.95−3.92 (m, 1H), 3.48 (t, J = 6.3 Hz, 2H), 3.39 (dd, J = 7.2, 11.4 Hz, 1H), 3.21 (dd, J = 13.4, 3.6 Hz, 1H), 3.04 (dd, J = 10.2, 12.8 Hz, 1H), 2.86 (d, J = 6.7 Hz, 1H), 2.76−2.72 (br s, 1H, OH), 1.65−1.38 (m, 6H), 1.24 (d, J = 7.0 Hz, 3H). FT-IR (film) 3445, 1694, 1602, 1495, 1164, 742, 700 cm^{-1}. ESI-MS m/z 480.30 ([M + Na]$^+$). EI-HRMS cald for $C_{25}H_{31}NO_3S_2Na$ ([M + Na]$^+$) 480.1638; found 480.1665.

Data for Compound 12. A colorless oil: $[\alpha]^{25}_{D}$ −2.08 (c 0.45, CHCl$_3$). ^{1}H NMR δ 7.39−7.26 (m, 5H), 5.15 (s, 2H), 4.51 (s, 2H), 3.93−3.89 (m, 1H), 3.49 (t, J = 6.2 Hz, 1H), 2.97 (br d, J = 4.1 Hz, 1H, OH), 2.58 (dq, J = 4.1, 7.3 Hz, 1H), 1.79−1.48 (m, 6H), 1.21 (d, J = 6.9 Hz, 3H). FT-IR (film) 3450, 1731, 1601, 1497, 1455, 1101, 737, 698 cm^{-1}. ESI-MS m/z 357.20 ([M + 1]$^+$), 379.25 ([M + Na]$^+$). ESI-HRMS calcd for $C_{22}H_{28}O_4Na$ ([M + Na]$^+$) 379.1880; found 379.1898.

Data for Compound 13. A colorless oil: $[\alpha]^{24}_{D}$ +61.0 (c 0.35, CHCl$_3$). ^{1}H NMR δ 7.42−7.27 (m, 5H), 6.27 (br d, J = 8.2 Hz, 1H), 5.02 (dt, J = 8.7, 4.3 Hz, 1H), 3.95−3.88 (m, 1H), 3.92 (dd, J = 8.3, 11.2 Hz, 1H), 3.05 (dd, J = 1.6, 11.2 Hz, 1H), 2.23 (br d, J = 3.6 Hz, 1H, OH), 1.82−1.05 (m, 58H), 0.86 (t, J = 6.7 Hz, 6H). FT-IR (film) 3447, 1700, 1465, 1155, 697 cm^{-1}. EI-MS m/z (%) 507 (M$^+$ − 195, 3.1), 488 (4.7), 462 (8.8), 195 (100), 135 (86.4). ESI-HRMS calcd for $C_{43}H_{75}NO_2S_2Na$ ([M + Na]$^+$) 724.5131; found 724.5148.

Data for Compound 13′. A colorless oil: $[\alpha]^{27}_{D}$ +39.0 (c 0.95, CHCl$_3$). ^{1}H NMR δ 7.37−7.26 (m, 5H), 5.39 (ddd, J = 3.4, 6.6, 10.6 Hz, 1H), 5.00 (dt, J = 9.7, 4.0 Hz, 1H), 3.92−3.81 (m, 1H), 3.36 (dd, J = 7.2, 11.8 Hz, 1H), 3.23 (dd, J = 3.6, 13.0 Hz, 1H), 3.05 (dd, J = 10.9, 13.2 Hz, 1H), 2.86 (d, J = 11.1 Hz, 1H), 2.15 (br s, 1H, OH), 1.95−1.80 (m, 1H), 1.80−1.00 (m, 57H), 0.88 (t, J = 6.5 Hz, 6H). FT-IR (film) 3505, 1702, 1466, 1190, 703 cm^{-1}. ESI-MS m/z 716.8 ([M + 1]$^+$). ESI-HRMS calcd for $C_{44}H_{77}NO_2S_2Na$ ([M + Na]$^+$) 738.5288; found 738.5266.

Data for Compound 14. A white crystal: mp 70−71 °C. $[\alpha]^{18}_{D}$ −5.01 (c 0.65, CHCl$_3$). ^{1}H NMR δ 7.38−7.25 (m, 5H), 5.15 (s, 2H), 3.72−3.85 (m, 1H), 2.47 (dt, J = 10.2, 4.7 Hz, 1H), 2.33 (br d, J = 4.5 Hz, 1H, OH), 1.69−1.19 (m, 58H), 0.88 (d, J = 6.6 Hz, 3H). FT-IR (film) 3444, 1727, 1469, 1456, 1157, 698 cm^{-1}. ESI-MS m/z 637.70 ([M + Na]$^+$). ESI-HRMS calcd for $C_{41}H_{74}O_3Na$ ([M + Na]$^+$) 637.5530; found 637.5552.

Data for Compound 15. A colorless oil: $[\alpha]^{27}_{D}$ +66.1 (c 1.95, CHCl$_3$). ^{1}H NMR δ 7.38−7.25 (m, 10H), 5.34 (ddd, J = 4.2, 7.0, 10.7 Hz, 1H), 4.91 (dt, J = 8.0, 4.0 Hz, 1H), 4.50 (s, 2H), 3.96−3.87 (m, 1H), 3.48 (t, J = 6.3 Hz, 2H), 3.43−3.22 (m, 6H), 3.06 (dd, J = 10.6, 12.9 Hz, 1H), 2.52 (d, J = 11.7 Hz, 1H), 2.25 (br d, J = 3.5 Hz, 1H, OH), 2.20−1.80 (m, 4H), 1.78 (s, 3H), 1.86−1.42 (m, 6H). FT-IR (film) 3442, 1694, 1602, 1495, 1162, 700 cm^{-1}. EI-MS m/z (%) 556 (M$^+$ − 33, 1.0), 480 (0.9), 209 (20.0), 119 (68.5), 91 (100). ESI-HRMS calcd for $C_{30}H_{39}NO_3S_4Na$ ([M + Na]$^+$) 612.1710; found 612.1704.

Data for Compound 16. A colorless oil: $[\alpha]^{24}_{D}$ +1.81 (c 1.4, CHCl$_3$). ^{1}H NMR δ 7.41−7.28 (m, 10H), 5.18 (s, 2H), 452 (s, 2H), 3.92−3.83 (m, 1H), 3.48 (t, J = 6.0 Hz, 2H), 3.39−3.24 (m, 4H), 2.51−2.47 (m, 1H), 2.11−1.13 (m, 10H), 1.73 (s, 3H). FT-IR (film) 3448, 1727, 1465, 1365, 1101, 735, 697 cm^{-1}. ESI-MS m/z 489.3 ([M + 1]$^+$), 511.2 ([M + Na]$^+$). ESI-HRMS calcd for $C_{27}H_{36}O_4S_2Na$ ([M + Na]$^+$) 511.1947; found 511.1939.

Data for Compound 17. A colorless oil: $[\alpha]^{25}_{D}$ −94.0 (c 1.00, CHCl$_3$). ^{1}H NMR δ 7.41−7.26 (m, 5H), 6.26 (d, J = 8.5 Hz, 1H), 5.03 (dt, J = 8.7, 4.5 Hz, 1H), 4.36−4.22 (m, 1H), 3.94 (dd, J = 10.2, 8.9 Hz, 1H), 3.52 (br s, 1H), 3.05 (d, J = 11.2 Hz, 1H), 3.07−2.92 (m, 2H), 2.78−2.73 (m, 2H), 2.40 (dd, J = 9.2, 15.1 Hz, 1H), 2.04−1.80 (m, 5H), 1.75−1.18 (m, 15H), 0.91 (t, J =

6.8 Hz, 3H), 0.85 (t, $J = 6.7$ Hz, 3H). FT-IR (film) 3444, 1699, 1602, 1495, 1158, 756, 698 cm^{-1}. EI-MS *m/z* (%) 537 ($M^+ - 16$, 5.2), 430 (5.7), 358 (10.5), 287 (23.8), 195 (42.5), 189 (100), 135 (51.1). EI-HRMS cald for $C_{28}H_{43}NO_2S_4Na$ ($[M + Na]^+$) 576.2069; found 576.2035.

Data for Compound 18. A colorless oil: $[\alpha]^{24}_{D}$ −18.9 (*c* 0.35, $CHCl_3$). ^{1}H NMR δ 7.39−7.26 (m, 5H), 5.16 (s, 2H), 4.09 (br t, $J = 7.2$ Hz, 1H), 3.76 (d, $J = 2.9$ Hz, 1H, OH), 3.01−2.82 (m, 2H), 2.80−2.68 (m, 2H), 2.54 (q, $J = 7.0$ Hz, 1H), 2.35 (dd, $J = 9.4$, 15.1 Hz, 1), 2.05−1.68 (m, 6H), 1.60−1.18 (m, 14H), 0.89 (t, $J = 7.5$ Hz, 3H), 0.85 (t, $J = 7.4$ Hz, 3H). FT-IR (film) 3431, 1731, 1456, 1158, 697 cm^{-1}. EI-MS *m/z* 467.3 ($[M + 1]^+$). EI-HRMS cald for $C_{26}H_{42}O_3S_2Na$ ($[M + Na]^+$) 489.2468; found 489.2462.

Data for Compound 19. A colorless oil: $[\alpha]^{25}_{D}$ +76.7 (*c* 0.40, $CHCl_3$). ^{1}H NMR δ 7.33−7.22 (m, 5H), 5.14 (ddd, $J = 3.9$, 6.7, 10.4 Hz, 1H), 4.52 (dt, $J = 12.1$, 6.6 Hz, 1H), 3.96 (dd, $J = 5.2$, 10.6 Hz, 1H), 3.35−3.23 (m, 2H), 2.99 (dd, $J = 10.9$, 13.1 Hz, 1H), 2.84 (d, $J = 11.1$ Hz, 1H), 1.52−1.15 (m, 8H), 1.09 (d, $J = 6.8$ Hz, 3H), 0.83 (s, 9H), 0.83 (t, $J = 7.3$ Hz, 3H), 0.00 (s, 6H). FT-IR (film) 1699, 1456, 1163, 836, 775, 702 cm^{-1}. ESI-MS *m/z* 480.2 ($[M + 1]^+$). ESI-HRMS calcd for $C_{25}H_{41}NO_2S_2SiNa$ ($[M + Na]^+$) 502.2240; found 502.2254.

Data for Compound 20. A colorless oil: $[\alpha]^{27}_{D}$ +9.83 (*c* 0.35, $CHCl_3$). ^{1}H NMR δ 7.34−7.29 (m, 5H), 5.11 (d, $J = 12.5$ Hz, 1H), 5.03 (d, $J = 12.5$ Hz, 1H), 3.98 (dd, $J = 5.5$, 11.2 Hz, 1H), 3.35−3.23 (m, 2H), 2.56 (dq, $J = 2.1$, 7.2 Hz, 1H), 1.46−1.21 (m, 7H), 1.16 (d, $J = 7.4$ Hz, 3H), 0.95−0.70 (m, 1H), 0.84 (s, 9H), 0.00 (s, 6H). FT-IR (film) 1733, 1462, 1255, 836, 775, 697 cm^{-1}. ESI-MS *m/z* 379.3 ($[M + 1]^+$). ESI-HRMS calcd for $C_{22}H_{38}O_3SiNa$ ($[M + Na]^+$) 401.2482; found 401.2499.

Data for Compound 21. A colorless oil: $[\alpha]^{27}_{D}$ +103.3 (*c* 0.50, $CHCl_3$). ^{1}H NMR δ 4.99 (t, $J = 6.6$ Hz, 1H), 4.51 (dt, $J = 13.1$, 6.6 Hz, 1H), 3.99 (dd, $J = 5.3$, 10.8 Hz, 1H), 3.45 (dd, $J = 7.9$, 11.6 Hz, 1H), 3.04 (d, $J = 11.3$ Hz, 1H), 2.41 (dt, $J = 20.4$, 6.7 Hz, 1H), 1.49−1.25 (m, 8H), 1.22 (d, $J = 6.6$ Hz, 3H), 1.07 (d, $J = 6.8$ Hz, 3H), 0.97 (d, $J = 8.0$ Hz, 3H), 0.96 (t, $J = 8.0$ Hz, 9H), 0.59 (q, $J = 7.6$ Hz, 6H). FT-IR (film) 1694, 1465, 740 cm^{-1}. ESI-MS *m/z* 432.2 ($[M + 1]^+$). MALDI-HRMS calcd for $C_{21}H_{41}NO_2S_2Si$ ($[M + 1]^+$) 432.2421; found 432.2429.

Data for Compound 22. A colorless oil: $[\alpha]^{27}_{D}$ +7.32 (*c* 0.20, $CHCl_3$). ^{1}H NMR δ 7.36−7.24 (m, 5H), 5.13 (d, $J = 12.5$ Hz, 2H), 5.10 (d, $J = 12.5$ Hz, 1H), 4.01 (dd, $J = 5.5$, 10.9 Hz, 1H), 2.58 (br quint, $J = 6.1$ Hz, 1H), 1.45−1.24 (m, 8H), 1.15 (d, $J = 7.0$ Hz, 3H), 0.93 (t, $J = 8.0$ Hz, 9H), 0.57 (q, $J = 8.0$ Hz, 6H). FT-IR (film) 1736, 1457, 742 cm^{-1}. ESI-MS *m/z* 379.2 ($[M + 1]^+$). ESI-HRMS calcd for $C_{22}H_{38}O_3SiNa$ ($[M + Na]^+$) 401.2482; found 401.2500.

Data for Compound 23. A colorless oil: $[\alpha]^{18}_{D}$ −197.8 (*c* 1.35, $CHCl_3$). ^{1}H NMR δ 7.38−7.27 (m, 5H), 5.94 (d, $J = 7.5$ Hz, 1H), 5.42 (dt, $J = 10.5$, 2.5 Hz, 1H), 5.05 (dd, $J = 7.7$, 3.1 Hz, 1H), 4.10 (dd, $J = 10.9$, 7.3 Hz, 1H), 3.95 (dq, $J = 5.8$, 11.8 Hz, 1H), 3.02 (dd, $J = 0.8$, 11.0 Hz, 1H), 2.19 (d, $J = 5.9$ Hz, 2H), 2.03−2.15 (m, 1H), 1.90−1.75 (m, 1H), 1.60−1.45 (m, 1H), 1.40−1.10 (m, 4H), 1.16 (d, $J = 6.0$ Hz, 3H), 1.04−0.92 (m, 9H), 0.64 (br q, $J = 8.0$ Hz, 6H). FT-IR (film) 1733, 1703, 1455, 1163, 744 cm^{-1}. ESI-MS *m/z* 588 ($[M + Na]^+$). Anal. Calcd for $C_{29}H_{47}NO_4S_2Si$: C, 61.55; H, 8.37; N, 2.48. Found: C, 61.72; H, 8.48; N, 2.35.

Data for Compound 24. A colorless oil: $[\alpha]^{30}_{D}$ +14.5 (*c* 1.37, $CHCl_3$). ^{1}H NMR δ 7.41−7.24 (m, 5H), 5.14 (dd, $J = 5.2$, 7.3 Hz, 1H), 5.14 (d, $J = 12.5$ Hz, 1H), 5.08 (d, $J = 12.5$ Hz, 1H), 3.78 (br quint, $J = 5.5$ Hz, 1H), 2.68 (ddd, $J = 14.3$, 8.3, 3.7 Hz, 1H), 2.19 (d, $J = 5.8$ Hz, 2H), 2.03−2.13 (m, 1H), 1.72−1.40 (m, 2H), 1.10 (d, $J = 6.0$ Hz, 3H), 0.95 (d, $J = 6.5$ Hz, 6H), 0.91 (t, $J = 7.9$ Hz, 9H), 0.54 (q, $J = 7.9$ Hz, 6H). FT-IR (film) 1740, 1453, 1164, 746 cm^{-1}. ESI-MS *m/z* 501.3 ($[M + Na]^+$), 479.2 ($[M + 1]^+$). ESI-HRMS calcd for $C_{27}H_{46}O_5SiNa$ ($[M + Na]^+$) 501.3007; found 501.3030.

Data for Compound 25. A colorless oil: $[\alpha]^{29}_{D}$ −166.7 (*c* 1.03, $CHCl_3$). ^{1}H NMR δ 7.42−7.25 (m, 5H), 6.28 (d, $J = 7.8$ Hz, 1H), 5.03 (dt, $J = 7.7$, 5.7 Hz, 1H), 3.92 (dd, $J = 8.3$, 11.2 Hz, 1H), 3.83 (br quint, $J = 6.0$ Hz, 1H), 3.74 (br ddd, $J = 5.4$, 5.4, 2.9 Hz, 1H), 3.06 (dd, $J = 1.8$, 11.2 Hz, 1H), 2.60 (d, $J = 2.5$ Hz, 1H, OH), 1.83−1.72 (m, 2H), 1.21−1.16 (m, 4H), 1.18 (d, $J = 5.9$ Hz, 3H), 0.97 (t, $J = 7.9$ Hz, 9H), 0.77 (t, $J = 6.7$ Hz, 3H), 0.62 (br q, $J = 8.0$ Hz, 6H). FT-IR (film) 3519, 1698, 1456, 1162, 744, 697 cm^{-1}. ESI-MS *m/z*: 482.4 ($[M + 1]^+$). ESI-HRMS calcd for $C_{24}H_{39}NO_3S_2SiNa$ ($[M + Na]^+$) 504.2033; found 504.2019.

Data for Compound 27. A colorless oil: $[\alpha]^{19}_{D}$ −123.7 (*c* 1.07, $CHCl_3$). ^{1}H NMR δ 7.41−7.27 (m, 5H), 6.28 (br d, $J = 7.7$ Hz, 1H), 5.91 (ddt, $J = 10.7$, 17.3, 5.0 Hz, 1H), 5.30 (dd, $J = 17.3$, 1.7 Hz, 1H), 5.19 (dd, $J = 1.8$, 10.6 Hz, 1H), 5.13 (q, $J = 6.3$ Hz, 1H), 4.08 (br dd, $J = 12.7$, 5.3 Hz, 1H), 3.97−3.84 (m, 3H), 3.45 (quint, $J = 6.2$ Hz, 1H), 3.04 (dd, $J = 11.2$, 1.6 Hz, 1H), 2.40 (br d, $J = 3.7$ Hz, 1H, OH), 1.21 (d, $J = 5.9$ Hz, 3H), 1.20−1.13 (m, 4H), 0.77 (t, $J = 6.5$ Hz, 3H). FT-IR (film) 3469, 1694, 1495, 1455, 1152, 1045, 698 cm^{-1}. ESI-MS *m/z*: 430 ($[M + Na]^+$). ESI-HRMS calcd for $C_{21}H_{29}NO_3NaS_2Na$ ($[M + Na]^+$) 430.1481; found 430.1480.

Data for Compound 28. A colorless oil: $[\alpha]^{27}_{D}$ +2.65 (*c* 0.35, $CHCl_3$). ^{1}H NMR δ 7.38−7.26 (m, 5H), 5.85 (ddt, $J = 17.8$, 11.2, 5.8 Hz, 1H), 5.24 (br d, $J = 17.4$ Hz, 1H), 5.14 (br d, $J = 11$ Hz, 1H), 5.13 (s, 2H), 3.98 (qt, $J = 1.7$, 6.0 Hz, 1H), 3.90−3.83 (m, 2H), 3.31 (dt, $J = 11.0$, 6.3 Hz, 1H), 2.57 (ddd, $J = 3.7$, 7.3, 10.4 Hz, 1H), 2.46 (d, $J = 2.5$ Hz, 1H), 1.83−1.60 (m, 4H), 1.14 (d, $J = 5.7$ Hz, 3H), 0.85 (t, $J = 7.0$ Hz, 3H). FT-IR (film) 3440, 1732, 1456, 1249, 697 cm^{-1}. EI-MS *m/z* (%) 263 ($M^+ - 57$, 0.1), 235 (9.0), 91 (100). ESI-HRMS calcd for $C_{19}H_{28}O_4Na$ ($[M + Na]^+$) 343.1880; found 343.1894.

Data for Compound 29. A colorless oil: $[\alpha]^{24}_{D}$ −94.7 (*c* 0.60, $CHCl_3$). ^{1}H NMR δ 7.38−7.26 (m, 5H), 6.31 (br d, $J = 8.4$ Hz, 2H), 5.23 (dd, $J = 5.5$, 8.7 Hz, 1H), 4.03−3.98 (m, 1H), 3.91 (dd, $J = 8.4$, 11.2 Hz, 1H), 2.16−2.09 (br m, 2H), 1.60−1.19 (m, 8H), 1.06 (d, $J = 6.6$ Hz, 9H), 0.96−0.82 (m, 6H). FT-IR (film) 3508, 1736, 1694, 1605, 1160, 698 cm^{-1}. ESI-MS *m/z* (%) 379.2 (M^+, 0.5), 361 (0.5), 346 (7.1), 320 (11.2), 292 (16.3), 275 (26.9), 263 (42.8), 248 (55.9), 196 (84.4), 180 (100). ESI-HRMS calcd for $C_{20}H_{29}NO_2S_2Na$ ($[M + Na]^+$) 402.1532; found 402.1548.

Data for Compound 31. A colorless oil: $[\alpha]^{23}_{D}$ +8.13 (*c* 0.55, $CHCl_3$). ^{1}H NMR δ 6.20−5.40 (very br lump, 1H), 3.97 (m, 1H), 2.61 (dq, $J = 7.1$, 3.2 Hz, 1H), 1.49−1.31 (m, 8H), 1.20 (d, $J = 7.1$ Hz, 3H), 0.89 (t, $J = 6.4$ Hz, 3H). FT-IR (film) 3445, 1736, 1460, 1379, 1181 cm^{-1}. ESI-MS *m/z* 197.1 ($[M + Na]^+$), 192.1-($[M + NH_4]^+$). EI-HRMS calcd for $C_9H_{18}O_3$ (M^+) 174.1256; found 174.1243.

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Supporting Information Available: ^{1}H NMR spectra of all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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