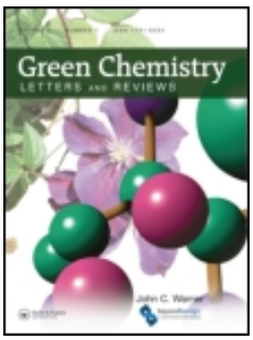

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RESEARCH LETTER

Silica sulfate as an efficient recyclable catalyst for protection of α-hydroxy acids with cyclohexanone

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Silica sulfate has been found to be an effective catalyst for protection of α-hydroxy acids under mild reaction conditions. Although the reaction can be carried out in diethyl ether, a remarkable rate enhancement was observed when the reaction was carried out under solvent-free condition. The catalyst could also be recovered and reused without any significant loss of reactivity. A wide range of α-hydroxy acids could be protected using cyclohexanone derivatives in high yield in presence of silica sulfate catalyst at room temperature.

Keywords: protection; α-hydroxy acid; silica sulfate; catalyst; cyclohexanone

Introduction

Protection of functional groups is an important and routinely utilized transformation in organic synthesis (*1*). In many organic synthetic methods, protection of α-hydroxy acids is a necessary process to carry out a multistep organic synthesis (*2–9*). In these cases, $BF_3.Et_2O$ has been used for the protection of α-hydroxy acid. However, this procedure has to be carried out using 1.5 equivalent of $BF_3.Et_2O$. Moreover, $BF_3.Et_2O$ is moisture sensitive, toxic, and expensive. Other acids including Lewis acids have also been used to catalyze the condensation of an α-hydroxy carboxylic acid with an aldehyde or ketone (*10, 11*). Yamamoto and others (*12*) used scandium trifluoromethanesulfinimide and scandium trifluoromethanesulfonate for protection of aldehydes and ketones using α-hydroxy acids. However, metal triflates are expensive and toxic. Moreover, azeotropic removal of water or addition of additives such as $MgSO_4$ is necessary in this process. Similarly, the protection of aldehydes and ketones with mandelic acid using $CuSO_4$ (*13*) and iodine (*14*) as a catalyst have also been reported. However, all these procedures were reported under homogeneous conditions. To best of our knowledge, there is no report of protection of α-hydroxy acids using a heterogeneous catalyst. With increasing environmental concerns, the need of environmentally benign synthetic chemistry has assumed significant importance. In line with the principles of green chemistry, synthetic methods should be designed to use substances that exhibit little or no toxicity to human health and the environment (*15*). In this regard, the use of heterogeneous catalysts and solvent-free condition are vital factors to address green chemistry requirements. In this communication, we describe for the first time a heterogeneous catalytic method for protection of α-hydroxy acids using silica sulfate as a reusable catalyst (Scheme 1) under solvent-free condition.

Results and discussion

The catalyst silica sulfate was made using a reported procedure (*16*). A solution of chlorosulfonic acid in dichloromethane was added drop wise to a mixture of silica gel in dichloromethane. The mixture was stirred at room temperature for 30 minutes. The silica sulfate thus prepared was then separated, kept under vacuum for 6 h, and finally dried in a desiccator for 24 h.

To determine the optimum amount of catalyst, tests were performed varying the concentration of the catalyst taking mandelic acid as a model substrate. The results are summarized in Table 1. In a typical reaction, silica sulfate was added to a mixture of mandelic acid (1 equiv) and cyclohexanone (1 equiv) in diethylether (5 mL) at room temperature. Cyclohexanone was purified by distillation prior to use. After 20 h of reaction, the protected hydroxyl acid was isolated in good yield (Table 1). Use of 40 wt% of silica sulfate was found to give a 88% yield of the corresponding protected acid. When the reaction was performed without solvent, a sharp increase in

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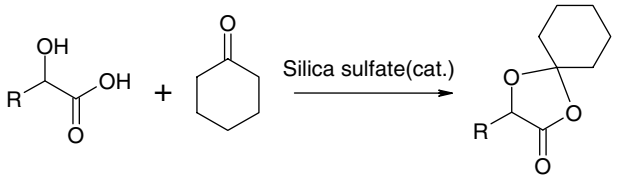


Scheme 1. Protection of α-hydroxy acids with cyclohexanone.

the rate of reaction was observed. In this case, a mixture of α-hydroxy acid (1 mmol) and ketone (1 mmol), silica sulfate was pulverized in a mortar at room temperature (Table 1, entries 7 and 8). We observed that the reaction completed in 25 minutes in presence of 25 wt% of the catalyst. We have also tested the reaction in a watch glass in place of mortar and pulverized with a glass rod. The reaction takes the same time for completion with similar yield (Table 1, entry 9). It was further observed that with simple silica gel the reaction does not produce any product, even after 12 h of reaction (Table 1, entry 10). This indicates that surface functionalization of silica is essential for catalytic activity.

The solvent-free process was further extended to reactions involving a variety of α-hydroxy acids which are described in Table 2. The general efficiency of this reaction is evident from the variety of hydroxy acids, which react in high yields within a short time. We have also examined the reaction with different cyclohexanone derivatives. The reaction was successful in all the cases. However, the yield for reaction of 4-*tert*-butyl cyclohexanone was found to be relatively low. When we attempted to protect 2-hydroxy-4-methylpentanoic acid and 2-hydroxy -3-methylbutanoic acid with cyclohexanone, there was significant product loss due to evaporation during solvent removal. In this case, the reaction was carried out only with 4-*tert*-butyl cyclohexanone. The reaction could also be carried out using other ketones such as acetone instead of cyclohexanone. We found that protection of mandelic acid with acetone takes longer time to achieve good yield (Entry 16, Table 2). In general, 25 mole% of catalyst is sufficient to push the reaction forward with high yield. However, in case of malic acid, 40% of catalyst is necessary for completion of reaction with high yield. Reusability of the catalyst was examined in case of mandelic acid. The recovered catalyst was dried under vacuum oven at 60°C for 6 h and then kept in a desiccator over P_2O_5 overnight before use. The catalyst was reused for two times without significant loss of activity (85% yield in both cases).

Experimental section

All the chemicals used were that of analytical grade. Melting points were determined in open capillaries in paraffin bath and are uncorrected. IR spectra were recorded using a Perkin Elmer Spectrum RX I FT-IR spectrometer. Mass spectra were recorded using a Perkin Elmer Clarus 600 C mass spectrometer. ^{1}H and ^{13}C-NMR spectra were obtained in $CDCl_3$ using a Bruker 300 MHz and 400 MHz instrument. The elemental analysis was carried out using a Perkin Elmer Series II CHNS/O Analyser.

General experimental procedure

A mixture of α-hydroxy acid (1 mmol) and ketone (1 mmol), silica sulfate (0.25 mmol) was pulverized in a mortar at room temperature. The reaction was monitored by TLC by taking a small amount of sample in DCM. After completion of the reaction,

Table 1. Protection of mandelic acid with cyclohexanone under different conditions.[a]

Entry	Catalyst	Amount (mol%)	Solvent	Time	Yield (%)[b]
1	SiO_2-OSO_3H	5	Diethyl ether	20 h	72
2	SiO_2-OSO_3H	10	Diethyl ether	20 h	75
3	SiO_2-OSO_3H	15	Diethyl ether	20 h	77
4	SiO_2-OSO_3H	20	Diethyl ether	20 h	71
5	SiO_2-OSO_3H	30	Diethyl ether	20 h	83
6	SiO_2-OSO_3H	40	Diethyl ether	20 h	88
7[c]	SiO_2-OSO_3H	30	–	20 min	90
8[c]	SiO_2-OSO_3H	25	–	25 min	89
9[d]	SiO_2-OSO_3H	25	–	25 min	88
10	Silica gel	25	–	12 h	0

[a]Reaction conditions: mandelic acid (1 mmol), cyclohexanone (1 mmol), diethylether (5 mL), rt;
[b]Isolated yield.
[c]Reaction carried out in a mortar.
[d]Reaction carried out in watch flask.

Table 2. Protection of various α-hydroxy acids in presence of silica sulfate as catalyst.[a]

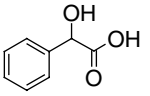
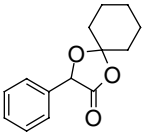
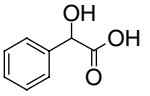
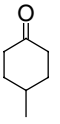
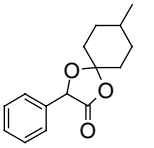
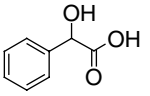
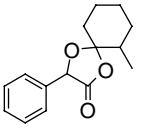
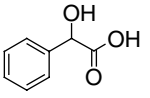
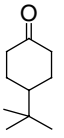
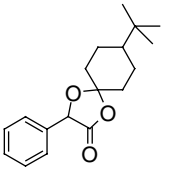
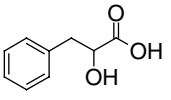
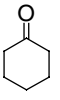
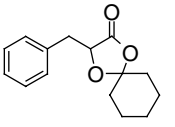
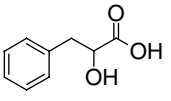
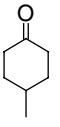
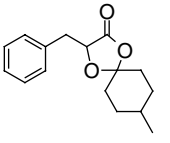
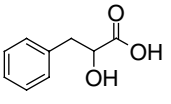
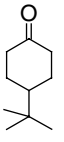
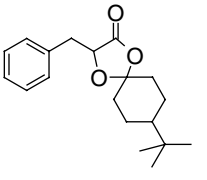
Entry	α-Hydroxy acid	Ketone	Product	Time (min)	Yield[b] (%)
1	 **1a**		 **1b**	25	89
2	 **2a**		 **2b**	30	86
3	 **3a**		 **3b**	30	84
4	 **4a**		 **4b**	35	82
5	 **5a**		 **5b**	40	87
6	 **6a**		 **6b**	60	87
7	 **7a**		 **7b**	90	70

Table 2 (*Continued*)

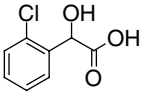
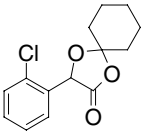
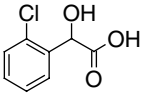
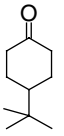
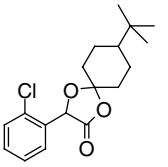
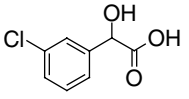
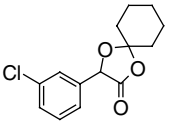
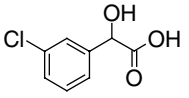
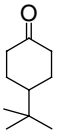
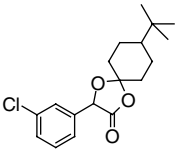
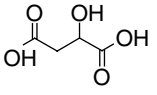
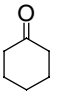
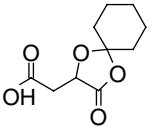
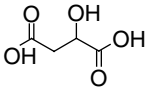
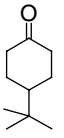
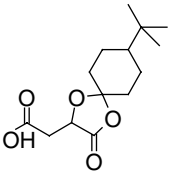
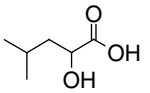
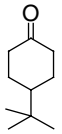
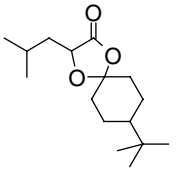
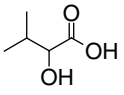
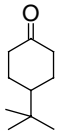
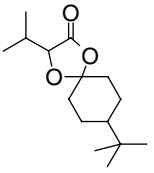
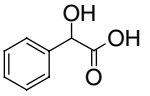
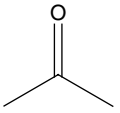
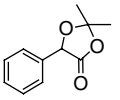
Entry	α-Hydroxy acid	Ketone	Product	Time (min)	Yield[b] (%)
8	 **8a**		 **8b**	50	87
9	 **9a**		 **9b**	75	59
10	 **10a**		 **10b**	45	86
11	 **11a**		 **11b**	80	66
12	 **12a**		 **12b**	90	75
13	 **13a**		 **13b**	120	63[c]

Table 2 (*Continued*)

Entry	α-Hydroxy acid	Ketone	Product	Time (min)	Yield[b] (%)
14	 **14a**		 **14b**	60	75
15	 **15a**		 **15b**	60	73
16	 **16a**		 **16b**	130	79

[a]Reaction conditions: α-hydroxy acid (1 mmol), ketone (1 mmol), silica sulfate (0.25 mmol), rt.
[b]Isolated yield.
[c]40 mol% of catalyst was used.

diethyl ether was added to the reaction mixture and filtered to remove the catalyst. The filtrate was washed with $NaHCO_3$ solution, water and brine, and then dried over anhydrous $NaSO_4$. After evaporation of the solvent, the crude product was purified by column chromatography over a short pad of silica gel (60–120 mesh) using petroleum ether–ethyl acetate mixture as eluent. Products **12b** and **13b** were purified by recrystallization from diethylether.

Spectral data of compounds

*3-phenyl-1, 4-dioxaspiro [4.5] decan-2-one (**1b**):* White solid. Mp. 60–61°C; IR (KBr, cm^{-1}) *v* 1808; ^1H NMR (300 MHz, $CDCl_3$): δ 1.25–1.45 (m, 2H), 1.5–1.69 (m, 2H), 1.7–1.88 (m, 2H), 5.27 (s, 1H), 7.1–7.3 (m, 3H), 7.32–7.39 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 24.2, 35.4, 36.4, 75.2, 111.4, 126.1, 128.4, 128.6, 134.6, 171.2; GC-MS (m/z%): 233 (1) $[M+1]^+$, 188 (74), 105 (33), 91 (100), 77 (33), 55 (66), 41 (45).

*8-methyl-3-phenyl-1,4-dioxaspiro[4.5]decan-2-one (**2b**):* White solid. Mp. 74–75°C; IR (KBr, cm^{-1}) *v* 1803, 1787; ^1H NMR (300 MHz, $CDCl_3$): δ 0.98 (d, $J=6.3$ Hz), 1.28–1.62 (m, 3H), 1.75–2.15 (m, 6H), 5.42 (s, 1H), 7.38–7.46 (m, 3H), 7.47–7.6 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.27, 30.54, 35.6, 36.3, 75.3, 111.7, 126.2, 128.5, 128.7, 134.6, 171.3; GC-MS (m/z%): 247 (1)$[M+1]^+$, 202 (63), 161 (11), 105 (25), 91 (100), 77 (23), 55 (90), 41 (36). Anal. Calcd. For $C_{15}H_{18}O_3$: C, 73.15; H, 7.37%. Found: C, 73.02; H, 7.28%.

*6-methyl-3-phenyl-1,4-dioxaspiro[4.5]decan-2-one (**3b**):* White solid. Mp. 80–82°C; IR (KBr, cm^{-1}) *v* 1787; ^1H NMR (300 MHz, $CDCl_3$): δ 1.04–1.1 (m, 1H), 1.15–1.5 (m, 2H), 1.55–1.86 (m, 5H), 1.9–2.19 (m, 2H), 2.2–2.45 (m, 1H), 5.33 (s, 0.5H), 5.34 (s, 0.5H), 7.3–7.41 (m, 3H), 7.42–7.5 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 13.7, 22.9, 31.5, 31.6, 38.0, 40.8, 75.1, 114.0, 125.8, 128.6, 128.9, 135.4, 171.7; GC-MS (m/z%): 247 (1)$[M+1]^+$, 202 (88), 112 (89), 91 (87), 68 (100), 55 (88), 41 (81). Anal. Calcd. For $C_{15}H_{18}O_3$: C, 73.15; H, 7.37%. Found: C, 73.06; H, 7.30%.

*8-tert-butyl-3-phenyl-1, 4-dioxaspiro[4,5]decan-2-one (**4b**):* White solid. Mp. 104–105°C; IR (KBr, cm^{-1}) *v* 1793; ^1H NMR (400 MHz, $CDCl_3$): δ 0.89

(s, 9H), 1.0–1.12 (m, 1H), 1.3–1.6 (m, 2H), 1.7–1.9 (m, 3H), 1.9–2.2 (m, 2H), 2.2–2.4 (m, 1H), 5.35 (s, 0.5H), 5.41 (s, 0.5H), 7.3–7.4 (m, 3H), 7.4–7.5 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 23.9, 27.5, 35.1, 36.2, 46.5, 75.4, 111.4, 126.3, 128.7, 128.8, 134.6, 171.5; GC-MS (m/z%): 289 (1) $[M+1]^+$, 244 (65), 161 (21), 107 (33), 91 (99), 57 (100), 41 (64), 28 (18). Anal. Calcd. For $C_{18}H_{24}O_3$: C, 74.97, H, 8.39%. Found: C, 74.88; H, 8.31%.

3-benzyl-1,4-dioxaspiro[4.5]decan-2-one (***5b***): White solid. Mp. 62–63°C; IR (KBr, cm^{-1}) *v* 1788; ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.2–2.12 (m, 10H), 3.0–3.14 (m, 1H), 3.15–3.28 (m, 1H), 4.62–4.21 (m, 1H), 7.15–7.22 (m, 5H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 24.3, 35.7, 36.4, 37.7, 74.6, 111.6, 126.9, 128.3, 129.8, 135.8, 172.6; GC-MS (m/z%): 246 (38) $[M^+]$, 148 (13), 99 (67), 91 (100), 81 (42), 55 (63). Anal. Calcd. For $C_{15}H_{18}O_3$: C, 73.15; H, 7.37%. Found: C, 73.25, H, 7.31%.

3-benzyl-8-methyl-1, 4-dioxaspiro[4,5]decan-2-one (***6b***): White solid. Mp. 68–69°C; IR (KBr, cm^{-1}) *v* 1788; ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.88–1.11 (m, 3H), 1.18–1.55 (m, 4H), 1.57–2 (m, 5H), 3–3.32 (m, 2H), 4.6–4.85 (m, 1H), 7.15–7.65 (m, 5H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.0, 21.5, 30.4, 35.5, 37.7, 74.4, 111.5, 126.8, 128.2, 129.8, 135.7, 172.3; GC-MS (m/z%): 260 (28) [M +], 203 (30), 175 (28), 113 (45), 91 (95), 55 (79), 28 (100). Anal. Calcd. For $C_{16}H_{20}O_3$: C, 73.82; H, 7.74%. Found: C, 73.73; H, 7.82%.

3-benzyl-8-tert-butyl-1,4-dioxaspiro[4,5]decan-2-one (***7b***): White solid. Mp. 120–121°C; IR (KBr, cm^{-1}) *v* 1788, 1714, 1451, 1367, 1222, 1121, 950; ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.86 (s, 9H), 0.98–1.12 (m, 1H), 1.2–1.48 (m, 3H), 1.5–1.8 (m, 4H), 1.82–2 (m, 1H), 2.98–3.12 (m, 1H),3.14–3.25 (m, 1H), 4.6–4.72 (m, 1H), 7.23–7.38 (m, 5H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 23.9, 27.4, 36.1, 36.2, 37.7, 46.4, 74.5, 111.7, 126.8, 128.2, 129.9, 135.7, 172.4; GC-MS (m/z%): 302 (6) $[M^+]$, 203 (55), 175 (77), 155 (32), 139 (32), 98 (38), 91 (100), 55 (92), 41 (65). Anal. Calcd. For: $C_{19}H_{26}O_3$: C, 75.46; H, 8.67%. Found: C, 75.59; H, 8.76%.

3-(2-chlorophenyl)-1,4-dioxaspiro[4.5]decan-2-one (***8b***): White solid. Mp. 66–67°C; IR (KBr, cm^{-1}) *v* 1803; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.4–1.6 (m, 2H), 1.65–1.85 (m, 4H), 1.88–2.05 (m, 4H), 5.4 (s, 1H), 7.3–7.45 (m, 3H), 7.5–7.58 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 24.5, 35.7, 36.8, 75.5, 111.8, 126.5, 126.7, 128.6, 128.7, 128.9, 134.8, 171.6; GC-MS (m/z%): 267 (1) $[M^+]$, 222 (58), 187 (38), 139 (31), 125 (100), 98 (60), 55 (95). Anal. Calcd. For $C_{14}H_{15}ClO_3$: C, 63.04; H, 5.67%. Found: C, 62.94; H, 5.59%.

8-tert-butyl-3-(2-chlorophenyl)-1,4-dioxaspiro[4.5]decan-2-one (***9b***): White solid. Mp. 99–100°C; IR (KBr, cm^{-1}) *v* 1755; ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.88 (s, 9H), 1.05–1.28 (m, 1H), 1.3–1.55 (m, 2H), 1.65–1.98 (m, 4H), 2.07–2.25 (m, 2H), 5.77 (s, 0.5H), 5.83 (s, 0.5H), 7.29–7.32 (m, 2H), 7.41–7.47 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 23.1, 23.2, 24.5, 35.7, 36.8, 75.5, 111.8, 126.5, 126.7, 128.6, 128.7, 128.9, 134.8, 171.6; GC-MS (m/z%): 323 (1) $[M^+]$, 278 (33), 243 (17), 195 (19), 139 (33), 125 (65), 57 (100), 41 (66). Anal. Calcd. For $C_{18}H_{23}ClO_3$: C, 66.97; H, 7.18%. Found: C, 66.90; H, 7.14%.

3-(3-chlorophenyl)-1, 4-dioxospiro[4.5]decan-2-one (***10b***): White solid. Mp. 88–90°C; IR (KBr, cm^{-1}) *v* 1788; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.40–1.58 (m, 2H), 1.62–1.80 (m, 4H), 1.82–1.98 (m, 4H), 5.37 (s 1H), 7.25–7.54 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 23.1, 35.7, 36.7, 74.6, 112.1, 124.5, 126.3, 129.9, 134.6, 136.8, 170.8; GC-MS (m/z%): 266 (2) $[M^+]$, 222 (74), 187 (40), 141 (61), 125 (97), 98 (90), 67 (78), 55 (100), 41 (72). Anal. Calcd. For $C_{14}H_{15}ClO_3$: C, 63.04; H, 5.67%. Found: C, 62.99; H, 5.61%.

8-tert-butyl-3-(3-chlorophenyl)-1, 4-dioxaspiro[4.5]decan-2-one (***11b***): White solid. Mp. 70–71°C; IR (KBr, cm^{-1}) *v* 1797; ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.9 (s, 9H), 1.08–1.2 (m, 1H), 1.32–1.6 (m, 2H), 1.70–1.95 (m, 4H), 2.0–2.15 (m, 2H), 5.33 (s, 0.5H), 5.39 (s, 0.5H), 7.34–7.45 (m, 3H), 7.48–7.52 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 23.4, 27.6, 32.3, 35.1, 46.4, 74.6, 112.4, 124.3, 126.3, 129.0, 129.9, 134.7, 136.6, 170.9; GC-MS (m/z%): 323 (1) $[M^+]$, 278 (22), 195 (11), 139 (29), 125 (25), 57 (100), 41 (51). Anal. Calcd. For $C_{18}H_{23}ClO_3$: C, 66.97; H, 7.18%. Found: C, 66.88; H, 7.11%.

(3-oxo-1,4-dioxaspiro[4,5]dec-2-yl)acetic acid (***12b***): White solid. Mp. 92°C; IR (KBr, cm^{-1}) *v* 1729; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.93–1.50 (m, 8H), 2.90 (d of AB, $J = 4.04$, 6.57, $J_{AB} = 17.18$), 4.70 (dd, $J_1 = 3.79$, $J_2 = 6.31$, lH), 9.78 (bs, lH), 1.30–1.50 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 22.90, 24.36, 35.29, 36.12, 69.97**,** 112.22, 171.96, 175.12; GC-MS (m/z%): 214 (8) $[M^+]$, 171 (19), 143 (7), 98 (99), 80 (31), 69 (46), 55 (100), 42 (48), 27 (17). Anal. Calcd. For $C_{10}H_{14}O_5$: C, 56.07; H, 6.59%. Found: C, 56.18; H, 6.51%.

(8-tert-butyl-3-oxo-1,4-dioxaspiro[4,5]dec-2-yl)acetic acid (***13b***): White solid. Mp. 133–134°C; IR (KBr, cm^{-1}) *v* 1728; ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.86 (s, 9H), 0.98–1.1 (m, 1H), 1.27–1.46 (m, 2H), 1.56–2.04 (m, 6H), 2.77–2.90 (m, 1H), 2.94–3.02 (m, 1H), 4.63–4.75 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 23.3, 23.9, 27.6, 32.3, 34.7, 36.0, 36.3, 46.6, 70.0, 112.0, 172.0, 174.8; GC-MS (m/z%): 270 (2) $[M^+]$, 199 (27), 171 (77), 143 (27), 139 (24), 98 (43), 71 (39), 57 (100), 41 (52), 29 (16). Anal. Calcd. For $C_{14}H_{22}O_5$: C 62.20; H, 8.20%. Found: C, 62.10; H, 8.33%.

*8-tert-butyl-3-(2-methylpropyl)-1,4-dioxaspiro[4.5]decan-2-one (**14b**): Liquid.* IR (KBr, cm^{-1}) *v* 1803; ^1H NMR (400 MHz, $CDCl_3$): δ 0.85 (S, 9H), 0.92–0.98 (m, 6H), 1.00–1.09 (m, 1H), 1.25–1.45 (m, 2H), 1.50–2.03 (m, 9H), 4.2–4.2 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.7, 22.8, 23.4, 23.9, 24.9, 27.6, 32.2, 34.6, 36.8, 40.8, 46.5, 72.4, 111.0, 174.0; GC-MS (m/z%): 268 (4) [M^+], 197 (26), 169 (68), 141 (62), 98 (34), 69 (46), 55 (100), 41 (62), 29 (26). Anal. Calcd. For $C_{16}H_{28}O_3$: C, 71.60; H, 10.52%. Found: C, 71.83; H, 10.74%.

*8-tert-butyl-3-(propan-2-yl)-1,4-dioxaspiro[4.5]decan-2-one (**15b**): Liquid.* IR (KBr, cm^{-1}) *v* 1789.9; ^1H NMR (400 MHz, $CDCl_3$): δ 0.84 (s, 9H), 0.92–0.98 (m, 3H), 1.01–1.08 (m, 4H), 1.20–1.43 (m, 2H), 1.52–1.97 (m, 6H), 2.03–2.12 (m, 1H), 4.19 (dd, $J = 3.8$ Hz, 25.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$): δ 16.5, 18.4, 23.3, 23.9, 27.5, 30.2, 32.2, 34.9, 36.2, 46.5, 78.1, 110.5, 172.7; GC-MS (m/z%): 254 (7) [M^+], 183 (30), 155 (90), 139 (24), 127 (100), 98 (48), 83 (32), 55 (75) 57 (81), 41 (73), 29 (25). Anal. Calcd. For $C_{15}H_{26}O_3$: C, 70.83; H, 10.30%. Found: C, 70.56; H, 10.14%.

2,2-dimethyl-5-phenyl-1,3-dioxolan-4-one (**16b**) Liquid. IR (KBr, cm^{-1}) *v* 1777; ^1H NMR (300 MHz, $CDCl_3$): δ 1.59 (s, 3H), 1.76 (s, 3H), 5.39 (s, 1H), 7.34–7.48 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 25.4, 26.6, 75.3, 110.3, 126.1, 128.2, 128.4, 134.2, 170.9; Anal. Calc. For $C_{11}H_{12}O_3$: C, 68.74; H, 6.29%. Found: C, 68.44; H, 10.02%.

Conclusions

We have developed an efficient heterogeneous catalytic protocol for protection of α-hydroxy acids in presence of 25 mole% of silica sulfate. The method is suitable for various α-hydroxy acids to obtain the protected acid in high yield.

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References

(1) Green, T.W.; Wuts, P.G.M. *Protective Groups in Organic Synthesis*; 3rd ed.; John Wiley and Sons: New York, 1999.
(2) Hanessian, S.; Tehim, A.; Chen, P. *J. Org. Chem.* **1993**, *58*, 7768–7781.
(3) Schinzer, D.; Bauer, A.; Schieber, J. *Synlett* **1998**, 861–864.
(4) Schinzer, D.; Bauer, A.; Schieber, J. *Chem. Eur. J.* **1999**, *5*, 2492–2500.
(5) Denmark, S.E.; Yang, S.-M. *J. Am. Chem. Soc.* **2002**, *124*, 15196–15197.
(6) Song, H.Y.; Joo, J.M.; Kang, J.W.; Kim, D.-S.; Jung, C.-K.; Kwak, H. S.; Park, J.H.; Lee, E.; Hong, C.Y.; Jeong, S.W.; Jeon, K.; Park, J.H. *J. Org. Chem.* **2003**, *68*, 8080–8087.
(7) Phukan, P.; Sasmal, S.; Maier, M.E. *Eur. J. Org. Chem.* **2003**, 1733–1740.
(8) Winneroski, L.L.; Xu, Y. *J. Org. Chem.* **2004**, *69*, 4948–4953.
(9) Suzuki, K.; Takayama, H. *Org. Lett.* **2006**, *8*, 4605–4608.
(10) Farines, M.; Soulier, J. *Bull. Soc. Chim. Fr.* **1970**, 332–340.
(11) Chapel, N.; Greiner, A.; Ortholand, J.-Y. *Tetrahedron Lett.* **1991**, *32*, 1441–1442.
(12) Ishihara, K.; Karumi, Y.; Kubota, M.; Yamamoto, H. *Synlett* **1996**, 839–841.
(13) Ferrett, R.R.; Hyde, M.J.; Lahti, K.A.; Friebe, T.L. *Tetrahedron Lett.* **2003**, *44*, 2573–2576.
(14) Banik, B.K.; Chapa, M.; Marquez, J.; Cardona, M. *Tetrahedron Lett.* **2005**, *46*, 2341–2343.
(15) Anastas, P.; Warner, J.C. *Green Chemistry: Theory and Practice*, Oxford University Press: Oxford, 1998.
(16) Li, Z.; Ding, R.; Lu, Z.; Xiao, S.; Ma, X. *J. Mol. Catal. A: Chemical* **2006**, *250*, 100–103.