Generation and Synthetic Application of Metallated Methyl Isopropenyl Ether, A Substitute for Acetone Enolate

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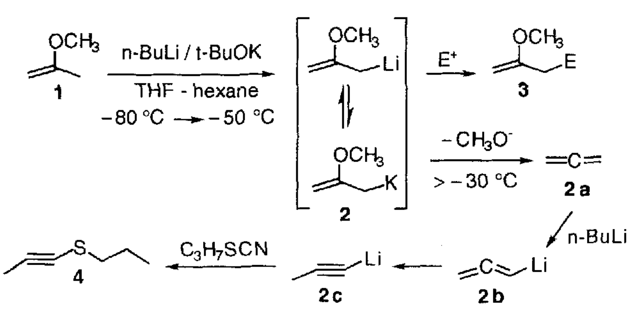
Methyl isopropenyl ether (**1**) has been metallated at low temperature with a 1:1 molar mixture of *n*-BuLi/*t*-BuOK in THF-hexane, and subsequently functionalized with a variety of electrophilic reagents. At temperatures higher than −30°C, the metallated methyl isopropenyl ether (**2**) decomposes with formation of allene. When the suspension of **2** is allowed to warm up to room temperature in the presence of an additional equivalent of *n*-BuLi, the intermediary allene is converted into 1-propynyllithium (**2c**), which reacts with propyl thiocyanate to give 1-propylthio-1-propyne (**4**). Some of the functionalization products were subjected to acidic hydrolysis affording the expected methyl ketones.

In organic synthesis, enolate anions derived from ketones are very useful intermediates. Although some reactions such as coupling with carbonyl compounds can be conveniently carried out with ketone enolates, other electrophiles, for example alkyl halides react sluggishly. Moreover, the functionalization with the latter reagents mostly gives a mixture of mono- and polyalkylation products[1,2]. The present paper deals with the metallation of commercially available methyl isopropenyl ether (**1**), its reaction with a number of electrophiles, and acid hydrolysis of some of the functionalization products. The successful performance of this sequence of operations as described here shows that metallated **1** can be considered as a synthetic equivalent of the acetone enolate.

Results and Discussion

A. Conditions for the Metallation of **1** *and Stability of the Intermediate* **2**: In order to optimize conditions for the metallation of **1**, this compound was allowed to interact with a number of base-solvent systems at temperatures ranging from −80 to 20°C. After a sufficiently long reaction time, the mixture was treated with *n*-octyl bromide and the product mixture examined. The following base/solvent combinations were tried. **a**: *n*-BuLi/THF and hexane, −30 → 20°C, **b**: *n*-BuLi/TMEDA and hexane[3], −20 → 20°C; **c**: *n*-BuLi and *t*-BuOK/TMEDA (1:1:1) and hexane[4], −30 → 10°C; **d**: *n*-BuLi and *t*-BuOK/THF and hexane[5], −80 → 10°C. The reaction with conditions **a**, **b** and **c** afforded only octyl bromide or a mixture of this halide and dodecane, indicating that the metallation had not occurred. Only when applying method **d**, was the alkylation product[6] found, together with *n*-octyl bromide. In a subsequent series of metallation experiments with the combination **d**, varying the temperature range of the metallation and the amount of methyl isopropenyl ether revealed that a threefold molar excess of **1** was necessary to ensure a complete conversion within a reasonable time (about 1 h), while the most favorable temperature range appeared to be −80 to −50°C. When the temperature of the metallation mixture was allowed to rise to higher levels, yields of the alkylation product were considerably lower and much of the octyl bromide was recovered. Practically all octyl bromide was recovered when the metallation mixture was stirred for a limited period at room temperature. From these experiments we concluded that the intermediate **2** has a limited thermal stability; furthermore, we suspected that upon temperature increase methoxide is eliminated with initial formation of allene. In order to prove this assumption, **1** was added at −80°C to a 2:1 molar mixture of *n*-BuLi and *t*-BuOK in THF-hexane; then the temperature was allowed to rise to room temperature. The extra equivalent of BuLi was used to convert the expected allene (**2a**) into allenyllithium (**2b**), which upon temperature increase could rearrange to 1-propynyllithium (**2c**). In order to detect the latter, propyl thiocyanate was added, leading to the formation of 1-propylthio-1-propyne (**4**) (identical with a sample prepared from propyne, BuLi in THF-hexane and C_3H_7SCN) in a reasonable yield (Scheme 1).

Scheme 1



B. Functionalization of Metallated Methyl Isopropenyl Ether (**2**): After having found the optimal conditions for the metallation of **1**, we carried out derivatizations with a number of electrophilic reagents (Scheme 1). All of the electrophiles reacted smoothly with the suspension of **2** within the temperature range of −60 to −45 °C, giving in most cases the expected products in good to excellent yields (Table 1). In the cases of the enolizable ketones, acetone, and pinacolone, however, the results were poor, presumably due to deprotonation of these ketones by the strongly (in a kinetic sense) basic intermediate **2**. Satisfactory yields of the expected alcohols were obtained, if prior to the reaction with the ketone, intermediate **2** was converted into the corresponding magnesium derivative by addition of an excess of $MgBr_2 \cdot OEt_2$. The product from **2**, or its derivative, and aldehydes or ketones in general, underwent decomposition at elevated temperatures, presumably due to elimination of water. Only the alcohol formed from $CH_3C(=O)-t\text{-}C_4H_9$ and $H_2C=C(OCH_3)CH_2MgBr$ was obtained pure by distillation.

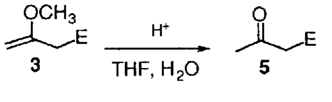
Table 1. Functionalization of the potassiated methyl isopropenyl ether (**2**)

Entry	Electrophile E^+	Product No	E	Yield (%)[a]
1	$Br(CH_2)_7CH_3$	**3a**	$-(CH_2)_7CH_3$	85
2	$Br(CH_2)_4Br$	**3b**	$-(CH_2)_4-$	95
3	$Br(CH_2)_3Cl$	**3c**	$-(CH_2)_3Cl$	83
4	Cyclopentyl bromide	**3d**	Cyclopentyl	64
5	1,2-Epoxyhexane	**3e**	$-CH_2CHOHC_4H_9$	85
6	Epoxycyclohexane	**3f**	2-Hydroxycyclohexyl	70
7	$ClCH_2C_6H_5$	**3g**	$-CH_2C_6H_5$	91
8	C_2H_5SCN	**3h**	$-SC_2H_5$	80
9	$ClSi(C_2H_5)_3$	**3i**	$-Si(C_2H_5)_3$	91
10	$BrCH_2CH(OC_2H_5)_2$	**3j**	$-CH_2CH(OC_2H_5)_2$	74
11	$t\text{-}BuCOCH_3$	**3k**	$-C(OH)t\text{-}BuCH_3$	64
12	t-BuCHO	**3l**	$-CH(OH)t\text{-}Bu$	89[b]
13	PhCHO	**3m**	$-CH(OH)C_6H_5$	90[b]
14	CH_3COCH_3	**3n**	$-C(OH)(CH_3)_2$	95[b]

[a] All distilled products **3** were >95% pure (300 or 90 MHz ^1H-NMR and GLC). – [b] yields of undistilled products.

C. Conversion with Products **3**: A number of products **3** were readily converted into the expected ketones by acid hydrolysis (Scheme 2).

Scheme 2



In the case of E = Et_3Si (**3i**, Table 1) the corresponding product **5i** was not isolated, presumably because the silyl group is split off under the acidic conditions giving acetone and Et_3SiOH. From compound **3j**, E = $CH_2CH(OEt)_2$, an intractable tarry product was obtained. The other results are summarized in Table 2.

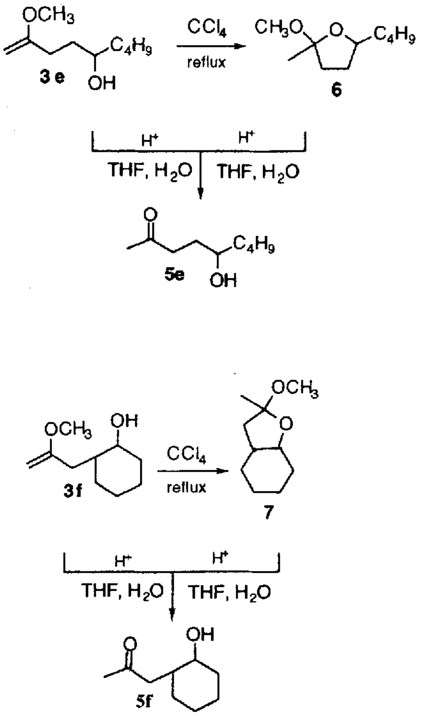
Table 2. Preparation of methyl ketone derivatives **5**

Entry	Starting material No	E	Product No.	Yield (%)[a]
1	**3b**	$-(CH_2)_4-$	**5b**	94[b]
2	**3c**	$-(CH_2)_3Cl$	**5c**	85
3	**3e**	$-CH_2CHOHC_4H_9$	**5e**	91
4	**3f**	2-Hydroxycyclohexyl	**5f**	84
5	**3g**	$-CH_2C_6H_5$	**5g**	89
6	**3h**	$-SC_2H_5$	**5h**	90

[a] All distilled products **5** were >95% pure (300 or 90 MHz ^1H NMR and GLC). – [b] yield after crystallization.

During recording the ^1H-NMR spectra of products **3e** and **3f** we noticed that the intensity of the vinylic signal decreased while a new signal appeared at about δ = 1.4. NMR and mass spectroscopic analysis showed that cyclization to derivatives of tetrahydrofuran had occurred. The cyclization with formation of **6** and **7**, respectively, could be easily carried out with excellent yields by heating a mixture of **3e** or **3f** and impure CCl_4 (technical quality) for 10 min under reflux. Treatment of **6** and **7** or their precursors **3e** and **3f** with a mixture of aqueous hydrochloric acid and tetrahydrofuran resulted in the formation of hydroxy ketones **5e** and **5f**, respectively (Scheme 3).

Scheme 3



From the successful performance of the sequence metallation of **1**, functionalization and aqueous hydrolysis of the derivatization products, it may be concluded that **2** can be considered as the synthetic equivalent of acetone enolate. We could not find other substitute synthons (for synthetic equivalents see ref.[7]).

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Experimental Section

All reactions were performed under dry nitrogen in flame-dried glassware, unless otherwise described. THF was freshly distilled from sodium-sand/benzophenone under a dry nitrogen atmosphere. Other reagents were commercially available, of analar grade and were used without further purification. Nuclear magnetic resonance (NMR) spectra were recorded on a Bruker AC 300 (^{1}H: 300 MHz, ^{13}C: 75 MHz) using deuteriochloroform as solvent and internal standard or on a Varian EM 390 instrument (90 MHz) using 20% solutions in CCl_4. Chemical shifts are given in δ values downfield from tetramethylsilane. Mass spectra were recorded on a Jeol JMS-AX 505 W, GC-MS combination.

Metallation of Methyl Isopropenyl Ether (**1**): A solution of 0.10 mol of *n*-BuLi in 65 ml of hexane (1.6 M) was added to 40 ml of THF with cooling below 0°C. After further cooling to about −90°C, 28.8 g (0.4 mol) of freshly distilled methyl isopropenyl ether was added over a few minutes while keeping the temperature between −90 and −85°C. Subsequently, a solution of 11.2 g (0.10 mol) of *t*-BuOK in 70 ml of THF was added dropwise for 10 min with efficient stirring, and cooling betweeen −95 and −85°C. The resulting thick, light-yellow suspension was stirred for an additional 30 min at −75°C and subsequently for the same period at −50°C.

2-Methoxy-1-undecene (**3a**): Most of the functionalization reactions were carried out using the following typical procedure, unless otherwise described. Octyl bromide (17.4 g, 0.09 mol) was added to the suspension of metallated methyl isopropenyl ether for 5 min with cooling between −60 and −50°C. After stirring for an additional period of 10 min at about −50°C, the cooling bath was removed and the temperature of the reaction mixture was allowed to rise above 0°C. Water (150 ml) was then added with vigorous stirring, the layers were separated and the aqueous layer was extracted with ether (3 times). The combined organic fractions were dried over K_2CO_3 and concentrated under reduced pressure. Distillation of the remaining liquid through a 30-cm Vigreux column gave **3a** in about 85% yield. B.p. 104−105°C/15 Torr; n_D^{20} = 1.4370. − ^{1}H NMR (90 MHz): δ = 0.86 (t, 3H), 1.0−1.5 (m, 14H), 1.9−2.1 (m, 2H), 3.48 (s, 3H), 3.73 (s, 2H). − ^{13}C NMR (75 MHz): δ = 14.0, 22.6, 23.9, 29.3, 29.4, 29.5, 29.9, 31.9, 34.9, 54.6, 79.9, 164.5.

2,9-Dimethoxy-1,9-decadiene (**3b**): The product was obtained in 90% yield from 0.10 mol of **2** and 0.04 mol (8.64 g) of 1,4-dibromobutane. B.p. 74°C/1 Torr; n_D^{21} = 1.4524. − MS (EI$^+$): 198, exact mass: calcd. for $C_{12}H_{20}O_2$ 198.1620, found 198.1645. − ^{1}H NMR (90 MHz): δ = 1.12−1.66 (m, 8H), 1.85−2.15 (m, 4H), 3.44 (s, 6H), 3.71 (s, 4H). − ^{13}C NMR (75 MHz): δ = 27.2, 28.9, 34.8, 54.5, 79.9, 164.4.

6-Chloro-2-methoxy-1-hexene (**3c**): The product was obtained in 83% yield from 0.10 mol of **2** and 0.102 mol (19 g) of 1-bromo-3-chloropropane. B.p. 65−66°C/14 Torr; n_D^{21} = 1.4563. − ^{1}H NMR (300 MHz): δ = 1.60−1.68 (m, 2H), 1.73−1.80 (m, 2H), 2.11 (t, 2H, J = 7.3 Hz), 3.51−3.55 (m, 5H), 3.86 (s, 2H). − ^{13}C NMR (75 MHz): δ = 24.0, 33.5, 44.4, 44.8, 54.0, 80.6, 163.5.

3-Cyclopentyl-2-methoxy-1-propene (**3d**): The product was obtained in 60% yield from 0.10 mol of **2** and 0.09 mol (13.41 g) of bromocyclopentane. B.p. 61−62°C/15 Torr; n_D^{21} = 1.4514. − MS (EI$^+$): 140, exact mass: calcd. for $C_9H_{16}O$ 140.1201, found 140.1149. − ^{1}H NMR (300 MHz): δ = 1.15−1.20 (m, 2H), 1.51−1.63 (m, 4H), 1.69−1.75 (m, 2H), 2.06−2.12 (m, 3H), 3.51 (s, 3H), 3.83 (s, 2H). − ^{13}C NMR (75 MHz): δ = 26.0 (2 C), 32.3 (2 C), 37.8, 41.1, 54.5, 80.5, 164.0.

5-Hydroxy-2-methoxy-1-nonene (**3e**): After the addition of 0.12 mol (12.0 g) of 1,2-epoxyhexane to 0.10 mol of **2** for 5 min with cooling between −60°C and −50°C, the reaction mixture was stirred for 20 min at −45°C. The mixture was then worked up following the procedure described for the alkylation of **2** with octyl bromide. The product was isolated in 85% yield. B.p. 70°C/0.5 Torr; n_D^{20} = 1.4514. − MS (EI$^+$): 172, exact mass: calcd. for $C_{10}H_{20}O_2$ 172.1463, found 172.1355. − ^{1}H NMR (300 MHz): δ = 0.88 (t, 3H, J = 7.0 Hz), 1.27−1.44 (m, 6H), 1.51−1.67 (m, 2H), 1.77 (s, br, 1H), 2.17−2.46 (m, 2H), 3.52 (s, 3H), 3.58−3.60 (m, 1H), 3.87 (dd, 2H, J = 1.9 and 8.9 Hz). − ^{13}C NMR (75 MHz): δ = 14.0, 22.7, 27.8, 31.3, 35.1, 37.1, 54.7, 71.3, 80.6, 164.0.

2-(2-Methoxy-1-propene-3-yl)cyclohexanol (**3f**): The product was obtained in 70% yield from 0.10 mol of **2** and 0.15 mol (15.0 g) of epoxycyclohexane according to the procedure described for the reaction of **2** with 1,2-epoxyhexane. B.p. 81−82°C/2 Torr; n_D^{20} = 1.4822. − ^{1}H NMR (300 MHz): δ = 1.11−1.24 (m, 4H), 1.69−1.74 (m, 4H), 1.90−2.0 (m, 1H), 2.04 (dd, 1H, AB, *trans*, J = 6.9 and 14.0 Hz), 2.25 (s, br, 1H), 2.16−2.43 (dd, 1H, AB, *cis*, J = 5.1 and 14.0 Hz), 3.26 (m, 1H), 3.54 (s, 3H), 3.92 (dd, 2H, J = 1.9 and 4.1 Hz. − ^{13}C NMR (75 MHz): δ = 24.9, 25.6, 31.0, 35.1, 39.1, 43.8, 54.8, 74.8, 82.1, 163.0.

2-Methoxy-4-phenyl-1-butene (**3g**): The product was obtained in 91% yield from 0.10 mol of **2** and 0.09 mol (11.40 g) of benzyl chloride. B.p. 57−58°C/≈1 Torr; n_D^{20} = 1.5185. − MS (EI$^+$): 162, exact mass: calcd. for $C_{11}H_{14}O$ 162.1045, found 162.1000. − ^{1}H NMR (300 MHz): δ = 2.48−2.54 (m, 2H), 2.9−2.95 (m, 2H), 3.97 (s, 2H), 7.25−7.40 (m, 5H). − ^{13}C NMR (75 MHz): δ = 30.7, 48.1, 54.1, 80.7, 126.8, 128.3 (2 C), 128.5 (2 C), 141.8.

3-Ethylthio-2-methoxy-1-propene (**3h**): The product was obtained in 80% yield from 0.10 mol of **2** and 0.10 mol (8.70 g) of ethyl thiocyanate. B.p. 65−66°C/15 Torr; n_D^{20} = 1.4775. − MS (EI$^+$): 132, exact mass: calcd. for $C_6H_{12}OS$ 132.0609, found 132.0542. − ^{1}H NMR (90 MHz): δ = 1.23 (t, 3H), 2.64 (q, 2H), 3.0 (s, 3H), 3.51 (s, 3H), 3.87−4.0 (m, 2H). − ^{13}C NMR (75 MHz): 14.6, 17.5, 29.6, 54.6, 88.7, 165.0.

2-Methoxy-3-triethylsilyl-1-propene (**3i**): The product was obtained in 91% yield from 0.10 mol of **2** and 0.09 mol (13.65 g) of chlorotriethylsilane. B.p. 80°C/16 Torr; n_D^{21} = 1.4565. − MS (EI$^+$): 186, exact mass: calcd. for $C_{10}H_{22}OSi$ 186.1440, found 186.1461. − ^{1}H NMR (90 MHz): δ = 0.36−0.68 (m, 6H), 0.8−1.1 (m, 9H), 1.57 (s, 2H), 3.45 (s, 3H), 3.58−3.7 (m, 2H). − ^{13}C NMR (75 MHz): δ = 4.8 (3 C), 7.5 (3 C), 20.7, 53.8, 84.0, 163.0.

5,5-Diethoxy-2-methoxy-1-pentene (**3j**): The product was obtained in 74% yield from 0.10 mol of **2** and 0.09 mol (17.75 g) of 2-bromo-1,1-diethoxyethane. B.p. 91−92°C/15 Torr; n_D^{20} = 1.4284. − MS (EI$^+$): 188, exact mass: calcd. for $C_{10}H_{20}O_3$ 188.1412, found 188.1406. − ^{1}H NMR (300 MHz): δ = 1.08−1.20 (m, 6H), 1.77 (t, 2H, J = 5.9 Hz), 2.14 (t, 2H, J = 6.0 Hz), 3.44−3.52 (m, 2H), 3.50 (s, 3H), 3.59−3.67 (m, 2H), 3.84 (s, br, 2H), 4.47 (t, 1H, J = 5.8 Hz). − ^{13}C NMR (75 MHz): 15.3 (2 C), 30.2, 31.2, 54.6, 60.9 (2 C), 80.3, 102.3, 163.6.

4-Hydroxy-2-methoxy-4,5,5-trimethyl-1-hexene (**3k**): To 0.10 mol of **2** was added dropwise for 10 min about 0.15 mol of a mixture of $MgBr_2$ and ether (40 ml, prepared from magnesium and 1,2-dibromoethane) with cooling between −80 and −70°C. After stirring for an additional 10 min at about −55°C, pinacolone (10 g, 0.10 mol) was added dropwise for 5 min. The reaction mixture was stirred for 15 min at −50°C, after wich the cooling bath was removed and the temperature allowed to rise to 10°C. The mixture was worked up as described for the alkylation of **2** with octyl bromide. The product was obtained in 64% yield. **B**.p. 80−82°C/15 Torr. − MS: $[M - CH_3]^+$ *m/z* 157; exact mass: calcd. for $C_9H_{17}O_2$ 157.1229, found 157.1327 and $[M - H_2O]^{+\bullet}$ *m/z* 154; exact mass: calcd. for $C_{10}H_{18}O$ 154.1358, found 154.1371. − ^1H NMR (300 MHz): δ = 0.95 (s, 9H), 1.10 (s, 3H), 2.20 (d, 1H, AB, *J* = 12.0 Hz), 2.43 (d, 1H, AB, *J* = 12.0 Hz), 2.80 (s, 1H), 3.56 (s, 3H), 3.99 (d, 2H, *J* = 34.0 Hz). − ^{13}C NMR (75 MHz): δ = 21.6, 25.3, 37.6, 41.5, 54.8, 75.3, 84.5, 162.1.

3-Propylthio-2-propyne (**4**): Metallated methyl isopropenyl ether was generated according to the procedure described above, starting from 65 ml of *n*-BuLi in hexane (0.10 mol, 1.6 M), 20 ml of THF, 14.5 g (0.2 mol) of methyl isopropenyl ether, 5.6 g (0.05 mol) of *t*-BuOK in 35 ml of THF. Subsequently, the temperature of the reaction mixture was allowed to rise to 10−20°C. After stirring for 15 min at this temperature, the resulting dark-yellow solution was cooled to −70°C and propyl thiocyanate (5.05 g, 0.05 mol) was added dropwise for 5 min, while keeping temperature between −60°C and −50°C. After an additional 10 min at −50°C, the cooling bath was removed, and the temperature was allowed to rise to 10−20°C. The dark-orange solution was worked up in the usual way, giving product **4** in 56% yield. B.p. 47°C/16 Torr; n_D^{20} = 1.4822. − MS (EI$^+$): 114. − ^1H NMR (90 MHz): δ = 1.01 (t, 3H, *J* = 6.6 Hz), 1.69 (q, 2H, *J* = 6.6 Hz), 1.90 (s, 3H), 2.51 (t, 2H, *J* = 6.6 Hz). − ^{13}C NMR (75 MHz): δ = 13.9, 14.2, 21.8, 30.3, 62.7, 85.3.

2,8-Decanedione (**5b**): To a solution of 9.9 g (0.05 mol) of **3b** in 60 ml of THF was added 30 ml of 10% HCl. After stirring for 5 min at room temperature, the reaction mixture was diluted with 50 ml of water. The water layer was extracted with diethyl ether (3 times). The combined organic layers were dried over K_2CO_3 and then concentrated under reduced pressure. The residue was crystallized in hexane/ethyl acetate. The product was obtained in 94% yield. M.p. 65°C. − ^1H NMR (300 MHz): δ = 1.21, 1.29 (m, 4H), 1.46−1.55 (m, 4H), 2.07 (s, 6H), 2.35 (t, 4H, *J* = 7.3 Hz). − ^{13}C NMR (75 MHz): δ = 23.6 (2 C), 28.9 (4 C), 43.6 (2 C), 210.0 (2 C).

6-Chloro-2-hexanone (**5c**): To a solution of 4 g (0.02 mol) of **3c** in 20 ml of THF was added 15 ml of 10% HCl. After 30 min of refluxing, the reaction mixture was worked up according to the procedure described for hydrolysis of **3b**. The product was obtained in 85% yield. B.p. 79°C/15 Torr; ref.[8] 85°C/16 Torr), n_D^{21} = 1.4441.

5-Butyl-2-methoxy-2-methyltetrahydrofuran (**6**): A mixture of compound **3e** (10.98 g, 63.85 mmol) and 50 ml of CCl_4 was heated for 10 min at reflux temperature. After concentration of the reaction mixture under reduced pressure, distillation yielded 90% of compound **6**. B.p. 41°C/ca. 2 Torr; n_D^{21} = 1.4273. − MS (EI$^+$): 172, exact mass: calcd. for $C_{10}H_{20}O_2$ (major isomer) 172.1463, found 172.1412 and calcd. for minor isomer ($C_{10}H_{20}O_2$) 172.1463, found 172.1387. − ^1H NMR (300 MHz): δ = 0.89 (t, 3H, *J* = 6.9 Hz), 1.30−1.51 (m, 9H), 1.65−1.81 (m, 2H), 1.95−2.1 (m, 2H), 3.21 (s, 3H), 3.22 (s, 3H), 3.93−4.06 (m, 1H). − ^{13}C NMR (75 MHz): δ = 13.9, 21.7, 21.8, 22.7, 28.0, 28.5, 30.2, 30.8, 35.3, 37.0, 37.7, 38.7, 48.2, 78.5, 80.9, 107.1, 107.2. The presence of two isomers gives rise to double signals.

5-Hydroxy-2-nonanone (**5e**): A solution of compound **6** (7 g, 40.69 mmol) in a mixture of 40 ml of THF and 20 ml of H_2O was stirred for 5 min at room temperature in the presence of the catalytic amount of chlorotrimethylsilane (ca. 2 ml). After a addition of 30 ml of H_2O, the water phase was extracted (3 times) with pentane. The organic layers were combined and dried over K_2CO_3. After concentration under reduced pressure, the residue was distilled. Compound **5e** was obtained in 91% yield. B.p. 64°C/1 Torr; n_D^{20} = 1.4415. − ^1H NMR (300 MHz): δ = 0.88 (t, 3H, *J* = 6.8 Hz), 1.27−1.45 (m, 6H), 1.58−1.68 (m, 1H, AB), 1.73−1.81 (m, 2H), 2.15 (s, 3H), 2.57 (dt, 2H, *J* = 7.0 and 1.3 Hz), 3.55 (s, br, 1H). − ^{13}C NMR (75 MHz): δ = 13.9, 22.6, 27.8, 29.9, 30.9, 37.3, 40.0, 71.1, 210.

7-Methoxy-7-methyl-1-oxabicyclo[4.3.0]heptane (**7**): The procedure as described for **3e** was used for the cyclization reaction of 10.53 g (61.86 mmol) of **3f** in 50 ml of CCl_4. Compound **7** was obtained in 90% yield. B.p. 53°C/2.5 Torr; n_D^{21} = 1.4561. − MS (E$^+$): 170. − ^1H NMR (300 MHz): δ = 1.03−1.34 (m, 8H), 1.85−1.61 and 1.46−1.37 (m, 16H), 2.04 (dd, dd, 4H, *J* = 5.9, 7.2 and 12.3 Hz), 3.18 (dt, 1H, *J* = 3.7 and 10.5 Hz), 3.25 (s, 3H), 3.28 (s, 3H), 3.34 (dt, 1H, *J* = 3.9 and 10.5). − ^{13}C NMR (75 MHz): δ = 23.8, 24.2, 24.2, 24.3, 25.7, 28.6, 28.8, 31.3, 31.7, 43.0, 43.8, 44.3, 44.5, 48.7, 49.0, 82.2, 83.9, 106.8, 107.3. The presence of two isomers gives rise to double signals.

1-(2-Hydroxycyclohexanyl)-2-propanone (**5f**): The procedure as described for **6** was used for the hydrolysis of 7.27 g (42.76 mmol) of **3f**. Compound **5f** was obtained in 84% yield. **B**.p. 85°C/1 Torr; n_D^{19} = 1.4733. − MS (EI$^+$): 156. − ^1H NMR (300 MHz): δ = 0.98−1.27 (m, 4H), 1.63−1.84 (m, 4H), 1.92−2.0 (m, 2H), 2.17 (s, 3H), 2.28 (dd, 1H, AB, *J* = 5.9 and 16.5 Hz), 2.68 (dd, 1H, *J* = 5.9 and 16.5 Hz), 3.15 (s, br, 1H). − ^{13}C NMR (75 MHz): δ = 24.9, 25.4, 30.5, 31.8, 36.0, 41.4, 48.3, 75.1, 210.3.

4-Phenyl-2-butanone (**5g**): Compound **5g** was obtained in 89% yield (ref.[8c] 53%) from 8.1 g (50 mmol) of **3g**, 55 ml of THF, 25 ml of 10% HCl, according to the procedure described for the hydrolysis of **3b**. B.p. 104°C/15 Torr (ref.[9,8c] 217°C/760 Torr), n_D^{19} = 1.5120.

3-Ethylthio-2-propanone (**5h**): Compound **5h** was obtained in 90% yield from 6.6 g (50 mmol) of **3h**, 40 ml of THF, 20 ml of 10% HCl, according to the procedure described for the hydrolysis of **3b**. B.p. 50°C/15 Torr; n_D^{19} = 1.4692. − ^1H NMR (300 MHz): δ = 1.14 (t, 3H, *J* = 6.0 Hz), 2.21 (s, 3H), 3.41 (q, 2H, *J* = 6.0 Hz), 3.15 (s, 2H). − ^{13}C NMR (75 MHz): δ = 14.1, 26.0, 27.6, 41.6, 203.9.

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