# Nucleophilic Ring-Opening of Chlorooxiranes: A New Synthesis of α-Hydroxy α′-Substituted Ketones from Carbonyl Compounds and 1-Chloroalkyl *p*-Tolyl Sulfoxides

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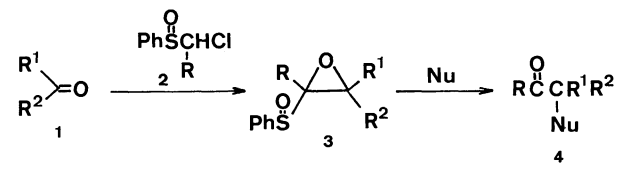
(Received December 19, 1990)

The addition of 1-chloroalkyl *p*-tolyl sulfoxides to carbonyl compounds gave adducts which were then converted to chlorooxiranes in two steps with good overall yields. The treatment of the chlorooxiranes with various nucleophiles gave α-hygroxy α′-substituted ketones or α-hydroxy ketones in good yields.

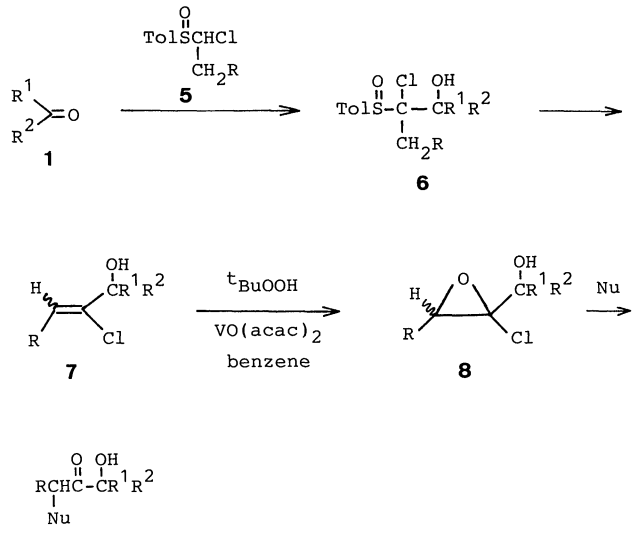
The homologation method of carbonyl compounds from lower carbonyl compounds by carbon–carbon coupling reactions is now one of the most important and extensively used methods for obtaining desired carbonyl compounds.[1] Recently, we reported a method to synthesize α-substituted carbonyl compounds **4** from carbonyl compounds **1** and 1-chloroalkyl phenyl sulfoxides **2** through α,β-epoxy sulfoxides **3** (Scheme 1).[2] In this method the carbonyl carbon of **1** was acylated and



Scheme 1.

the carbonyl oxygen was replaced by nucleophiles.

In a continuation of our study on the use of 1-chloroalkyl aryl sulfoxides in organic synthesis, we describe here a novel method for the synthesis of α-hydroxy α′-substituted ketones **9** from carbonyl compounds **1** and 1-chloroalkyl *p*-tolyl sulfoxides **5** through chlorooxiranes **8** (Scheme 2).[3] It is worth noticing that in this method **5** acted as an α-substituted acyl anion equivalent.

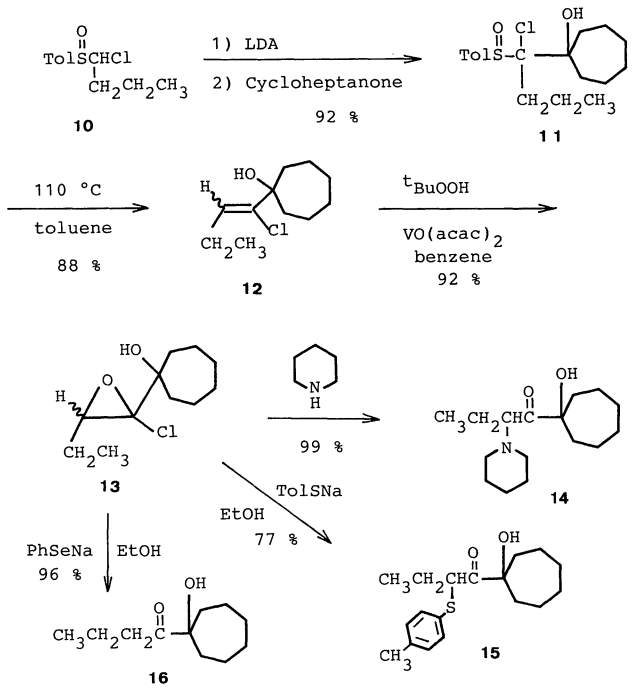


Scheme 2.

## Results and Discussion

The representative example of this procedure using 1-chlorobutyl *p*-tolyl sulfoxide **10**[4] and cycloheptanone as a carbonyl compound is as follows. The treatment of **10** with lithium diisopropylamide (LDA) in THF at −60°C and then with cycloheptanone gave chloro alcohol **11** in 92% yield. The sulfinyl group of **11** was found to be prone to eliminate under heating; refluxing **11** in toluene for 5 min cleanly gave the desired vinyl chloride **12** in 88% yield. Among the procedures reported for epoxidation of allylic alcohols[5] we selected a *t*-butyl hydroperoxide (ᵗBuOOH)-vanadyl acetylacetonate ($VO(acac)_2$) system for the epoxidation of vinyl chloride **12**, since the product chlorooxirane **13** was presumed to be unstable under acidic conditions.

The epoxidation of **12** was carried out by adding a solution of ᵗBuOOH (1.2 equivalents) to a dry benzene solution of **12** and $VO(acac)_2$ (0.12 equivalents) at room

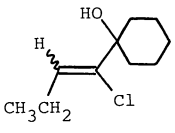


Scheme 3.

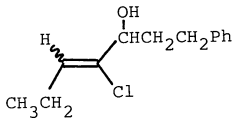
temperature (**Method A**). A slightly exothermic reaction took place to afford the desired chlorooxirane **13** in 92% yield. Chlorooxirane **13** was found to be stable under these reaction conditions and the usual workup system; it is storable for a few months in a refrigerator without any detectable decomposition.

We next investigated the reactivity of **13** with some nucleophiles. The treatment of **13** with piperidine[2c] without a solvent at room temperature gave the desired α-hydroxy α′-piperidino ketone **14** in quantitative yield within 10 min. The treatment of **13** with sodium *p*-toluenethiolate[2b] in ethanol at room temperature gave α-*p*-tolylthio ketone **15** in 77% yield within 10 min. The treatment of **13** with sodim benzeneselenolate[2a,6] in ethanol at room temperature gave α-hydroxy ketone **16** in 96% yield. From these results it became apparent that the reactivity of chlorooxirane **13** with the nucleophiles was quite similar to that of α,β-epoxy sulfoxides **3**.[2]

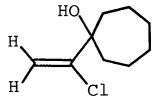
Encouraged by these results, we synthesized vinyl chlorides **17**—**20** from **10** or 1-chloroethyl *p*-tolyl sulfoxide (**5**; R=H) with cyclohexanone, cycloheptanone, 3-phenylpropanal, and decanal in a similar way to that described above.



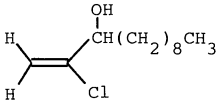

**17**



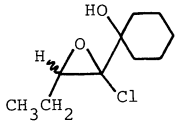

**18**



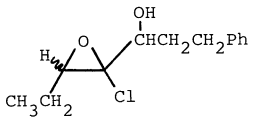

**19**



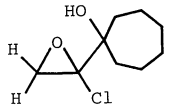

**20**



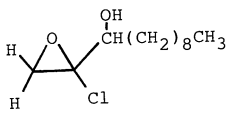

**21**




**22**




**23**



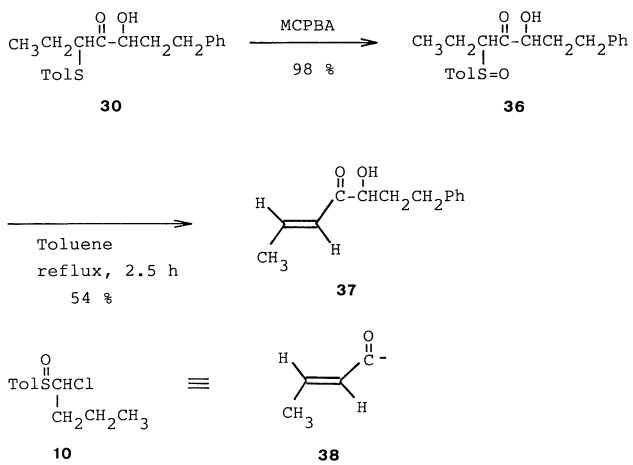

**24**

The epoxidation of **17** using **Method A** took place smoothly to give chlorooxirane **21** in 86% yield. The reaction of **21** with several nucleophiles gave α-hydroxy α′-substituted ketones **25**—**28** in high yields (see Table 1; Entry 1—4). Even sodium methoxide reacted with **21** at room temperature for 3 h to give α-hydroxy α′-methoxy ketone **27** in good yield (Entry 3).

We came across a problem in the epoxidation of vinyl chloride **18**—**20**. The epoxidation of **18**—**20** using **Method A** gave either no or an incomplete reaction; unfortunately, those vinyl chlorides (**18**—**20**) and chlorooxiranes (**22**—**24**) have the same (or quite close) $R_f$-value on silica-gel TLC, respectively. The other procedures reported for the epoxidation of allylic alcohols were unsuccessful. For instance, the epoxidation of **19** with $^t$BuOOH–titanium(IV) isopropoxide or *m*-chloroperbenzoic acid (MCPBA) both gave mainly cycloheptanone and some unknown products.

After several investigations we found that the treatment of vinyl chlorides with $^t$BuOOH and a very low concentration of $VO(acac)_2$ gave the desired chlorooxiranes in good yields. Thus, for example, to a solution of **18** and $^t$BuOOH in benzene at 50 °C was added a dilute solution of $VO(acac)_2$ in benzene over a period of 1 h (**Method B**) to give **22** in quantitative yield as a low melting point solid. Monosubstituted chlorooxiranes **23** and **24** were synthesized by **Method B**; however, the yields were rather low compared with the disubstituted ones (**13**, **21**, and **22**). Chlorooxirane **23** was found to be unstable; it decomposed slowly, even on storage in a refrigerator. However, if it was used immediately after being prepared, the desired α-hydroxy α′-substituted ketones (**32** and **33**) were obtained in high yields without any problem. Representative examples for the synthesis of α-hydroxy α′-substituted ketones from carbonyl compounds are summarized in Table 1.

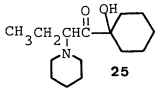
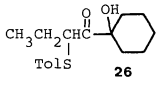
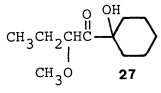
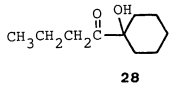
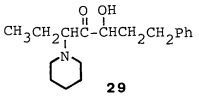
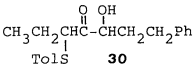
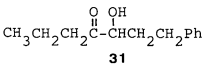
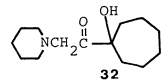
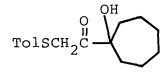
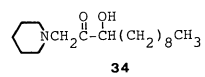
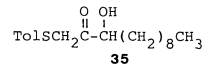
Nucleophilic ring-opening was investigated using some alkylmetals as carbon nucleophiles. The treatment of chlorooxirane **21** with *n*-butyllithium (3 equiv; −55 °C, 1 h), methylmagnesium bromide (3 equiv; −40 °C, 2 h), or lithium dimethylcuprate (3 equiv; 0 °C, 1.5 h) gave almost no reaction.




**30** **36** **37** **10** **38**

Scheme 4.

Table 1. Synthesis of α-Hydroxy α′-Substituted Ketones **9** from Carbonyl Compounds through Chlorooxiranes **8**

| Entry | Vinyl chloride (Yield/%)[a] | Epoxidation method[b] | Chlorooxirane (Yield/%) | Nucleophile | Product (Yield/%) | |
|---|---|---|---|---|---|---|
| 1 | **17** (93) | A | **21** (86) | Piperidine |  **25** | (95) |
| 2 | | | | TolSNa |  **26** | (92) |
| 3 | | | | $CH_3ONa$ |  **27** | (83) |
| 4 | | | | PhSeNa |  **28** | (98) |
| 5 | **18** (82) | B | **22** (98) | Piperidine |  **29** | (52) |
| 6 | | | | TolSNa |  **30** | (99) |
| 7 | | | | PhSeNa |  **31** | (60) |
| 8 | **19** (90) | B | **23** (74) | Piperidine |  **32** | (92) |
| 9 | | | | TolSNa |  **33** | (99) |
| 10 | **20** (91) | B | **24** (62) | Piperidine |  **34** | (95) |
| 11 | | | | TolSNa |  **35** | (92) |

a) Two-step overall yield from 1-chloroalkyl *p*-tolyl sulfoxide and carbonyl compound. b) See text.

The application of this procedure to a synthesis of α-hydroxy α′,β′-unsaturated ketone was made with **30** (Scheme 4). The α-tolylthio ketone **30** was oxidized with MCPBA to sulfoxide **36** in quantitative yield as a diastereomeric mixture. Heating **36** in refluxing toluene for 2.5 h afforded (*E*)-5-hydroxy-7-phenyl-2-hepten-4-one **37** in 54% yield. In this entire sequence **10** acted as an α,β-unsaturated acyl anion equivalent **38**.

In conclusion a new and versatile procedure for the synthesis of α-hydroxy α′-substituted ketones has been developed from 1-chloroalkyl *p*-tolyl sulfoxides and carbonyl compounds through the reaction of chlorooxiranes with nucleophiles. Because of its simplicity and the good overall yields obtained, we believe that the presented method will prove to be valuable in the synthesis of α-hydroxy ketones, α-hydroxy α′-substituted ketones, and α-hydroxy α′,β′-unsaturated ketones.

## Experimental

All of the melting points are uncorrected. The $^1H$ NMR spectra were measured in a $CDCl_3$ solution with a JEOL FX-100 spectrometer. Electron-impact mass spectra (MS) were obtained at 70 eV by direct insertion. Silica gel BW-127 ZH (Fuji-Devison) containing 2% of fluorescence reagent 254 and

a quartz column were used for column chromatography; products having UV absorption were detected by UV irradiation. In experiments requiring dry solvents, THF was distilled from diphenylketyl; benzene, toluene, and diisopropylamine were dried over $CaH_2$ and distilled. $VO(acac)_2$ was recrystallized from acetone.

**1-(1-Chloro-1-butenyl)-1-cycloheptanol (12).** A solution of **10** (1.15 g; 5 mmol) in 3 ml of dry THF was added dropwise to a stirred solution of LDA (6 mmol) in 6 ml of THF at −60 °C. The mixture was then stirred at −60°C for 10 min; cycloheptanone (0.71 ml; 6 mmol) was then added to the reaction mixture. After 10 min the reaction was quenched with sat. aq $NH_4Cl$. The entire mixture was extracted with ether–benzene. The usual workup followed by silica-gel column chromatography gave chloro alcohol **11** (1.58 g; 92%) as a colorless oil, IR (neat) 3400 (OH), 1070, 1040 (SO) $cm^{-1}$.

A solution of **11** (1.3 g) in 15 ml of toluene was refluxed under $N_2$ for 5 min. The solvent was evaporated under vacuum and residue was separated by flash chromatography (hexane–AcOEt=20 : 1) to give 680 mg (88%) of **12** as a colorless oil. IR (neat) 3410 (OH), 1655 (C=C) $cm^{-1}$; $^1H$ NMR $\delta$=1.01 (3H, t, $J$=7 Hz), 1.2—2.1 (13H, m), 2.21 (2H, quintet, $J$=7 Hz), 5.78 (1H, t, $J$=7 Hz); MS $m/z$ (%) 202 ($M^+$, 22), 173 (73), 145 (96), 41 (100). Found: $m/z$ 202.1127. Calcd for $C_{11}H_{19}ClO$: M, 202.1124.

**1-(1-Chloro-1,2-epoxybutyl)-1-cycloheptanol (13).** $^t$BuOOH (anhydrous, 3 M solution in 2,2,4-trimethylpentane, 1 M= 1 mol $dm^{-3}$; 3.3 mmol) was added dropwise to a solution of **12** (527 mg; 2.6 mmol) and $VO(acac)_2$ (93 mg; 0.35 mmol) in 12 ml of dry benzene. A slightly exothermic reaction took place; the reaction mixture was stirred at room temperature for 1 h. The reaction mixture was passed through a short pad of Florisil. The solvent was evaporated and the residue was purified by silica-gel column chromatography to give **13** as a low melting point solid. IR (neat) 3480 (OH) $cm^{-1}$; $^1H$ NMR $\delta$=1.06 (3H, t, $J$=7 Hz), 1.4—2.3 (15H, m), 3.32 (1H, t, $J$=7 Hz); MS $m/z$ (%) 219 ($[M+H]^+$, trace), 189 ($[M-C_2H_5]^+$, 0.8), 113 (100).

**1-(1-Hydroxycycloheptyl)-2-piperidino-1-butanone (14).** A mixture of **13** (113 mg) in 2 ml of piperidine was stirred at room temperature for 10 min. The piperidine was evaporated and the residue was dissolved in benzene. The solution was washed once with water, and then dried over $MgSO_4$. The usual workup followed by silica-gel column chromatography gave **14** (137 mg; 99%) as an oil. IR (neat) 3250 (OH), 1710 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.78 (3H, t, $J$=7 Hz), 1.2—2.2 (21H, m), 2.50 (4H, m), 3.58 (1H, dd, $J$=10, 3 Hz); MS $m/z$ (%) 266 ($M^+$, 0.2), 238 (0.1), 210 (0.1), 154 (0.3), 126 (100). Found: $m/z$ 266.2118. Calcd for $C_{16}H_{28}NO_2$: M, 266.2118.

**1-(1-Hydroxycycloheptyl)-2-(*p*-tolylthio)-1-butanone (15).** To 3 ml of EtOH at room temperature was added NaH (0.78 mmol) and then *p*-toluenethiol (105 mg; 0.85 mmol). A solution of **13** (85 mg; 0.39 mmol) in 0.5 ml of EtOH was added to a solution of the thiolate; the reaction mixture was stirred at room temperature for 10 min. Powdered $NH_4Cl$ was added to this mixture, and the EtOH was evaporated under vacuum. The residue was extracted with benzene and the usual workup was followed by silica-gel column chromatography, giving 92 mg (77%) of **15** as colorless crystals. Mp 70—72 °C (AcOEt–hexane); IR (KBr) 3525 (OH), 1690 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.92 (3H, t, $J$=7 Hz), 1.3—2.2 (15H, m), 2.33 (3H, s), 4.03 (1H, t, $J$=7 Hz), 7.0—7.3 (4H, m). Anal. Calcd for $C_{18}H_{26}O_2S$: C, 70.55; H, 8.55; S, 10.46%. Found: C, 70.57; H, 8.60; S, 10.40%.

**1-(1-Hydroxycycloheptyl)-1-butanone (16).** $NaBH_4$ (153 mg; 4.05 mmol) was added to a solution of diphenyl diselenide (630 mg; 2.03 mmol) in 9 ml of EtOH at room temperature. After all of the $NaBH_4$ reacted, a solution of **13** (147 mg; 0.67 mmol) in 1 ml of EtOH was added to the benzeneselenolate solution. The reaction mixture was stirred at room temperature for 10 min; powdered $NH_4Cl$ was then added. The EtOH was evaporated under vacuum and the residue extracted with benzene–ether. The organic layer was washed once with sat. aq $NH_4Cl$ and the usual workup followed by silica-gel column chromatography gave 119 mg (96%) of **16** as a colorless oil. IR (neat) 3480 (OH), 1700 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.92 (3H, t, $J$=7 Hz), 1.3—2.0 (14H, m), 2.52 (2H, t, $J$=7 Hz); MS $m/z$ (%) 184 ($M^+$, 0.25), 167 (0.15), 113 (100). Found: $m/z$ 184.1468. Calcd for $C_{11}H_{20}O_2$: M, 184.1462.

**1-(1-Chloro-1-butenyl)-1-cyclohexanol (17).** This vinyl chloride was synthesized from **10** and cyclohexanone in a similar manner as that described for **12** in 93% overall yield. Colorless oil; IR (neat) 3410 (OH), 1655 (C=C) $cm^{-1}$; $^1H$ NMR $\delta$=1.01 (3H, t, $J$=7 Hz), 1.2—1.9 (10H, m), 2.22 (2H, quintet, $J$=7 Hz), 5.80 (1H, t, $J$=7 Hz); MS $m/z$ (%) 188 ($M^+$, 50), 159 ($[M-C_2H_5]^+$, 100). Found: $m/z$ 188.0965. Calcd for $C_{10}H_{17}ClO$: M, 188.0966.

**Vinyl Chloride (18—20).** These vinyl chlorides were reported in the previous paper: see Ref. 7.

**1-(1-Chloro-1,2-epoxybutyl)-1-cyclohexanol (21).** This chlorooxirane was synthesized from **17** in a similar manner (**Method A**) as that described for **13** in 86% yield. Colorless low melting solid. IR (KBr) 3525 (OH) $cm^{-1}$; $^1H$ NMR $\delta$=1.06 (3H, t, $J$=7 Hz), 1.4—2.0 (13H, m), 3.30 (1H, t, $J$=7 Hz); MS $m/z$ (%) 175 ($[M-C_2H_5]$, 0.3), 146 (3), 99 (100).

**4-Chloro-4,5-epoxy-1-phenyl-3-heptanol (22).** A solution of $VO(acac)_2$ (106 mg; 0.4 mmol) in 50 ml of dry benzene was added dropwise to a stirred solution of **18** (440 mg; 1.95 mmol) and $^t$BuOOH (4.5 mmol) in 10 ml of dry benzene at 50 °C over a period of 1 h (**Method B**). The reaction mixture was passed through a short pad of Florisil and the solvent evaporated. The residue was purified by silica-gel column chromatography to afford 457 mg (98%) of **22** as a low melting point solid. IR (KBr) 3400 (OH) $cm^{-1}$; $^1H$ NMR $\delta$=1.07 (3H, t, $J$=7 Hz), 1.4—2.4 (5H, m), 2.6—3.0 (2H, m), 3.14 (1H, t, $J$=6 Hz), 3.86 (1H, dd, $J$=8, 4 Hz), 7.22 (5H, m); MS $m/z$ (%) 240 ($M^+$, 0.5), 205 (2.5), 193 (2), 104 (100). Found: $m/z$ 240.0918. Calcd for $C_{13}H_{17}ClO_2$: M, 240.0916.

**Chlorooxirane (23, 24).** These chlorooxiranes were synthesized from **19** and **20** in a similar manner as that described for **22** (**Method B**).

1-(1-Chloro-1,2-epoxyethyl)-1-cycloheptanol **23**: Colorless oil; 74% yield; IR (neat) 3475 (OH) $cm^{-1}$; $^1H$ NMR $\delta$=1.4—2.3 (13H, m), 3.01 (1H, d, $J$=5 Hz), 3.24 (1H, d, $J$=5 Hz); MS $m/z$ (%) 149 (0.5), 113 ($[M-C_2H_2ClO]^+$, 100).

2-Chloro-1,2-epoxy-3-dodecanol **24**: Colorless oil; 62% yield; IR (neat) 3425 (OH) $cm^{-1}$; $^1H$ NMR $\delta$=0.87 (3H, t, $J$=6 Hz), 1.0—2.2 (16H, m), 3.07 (2H, s), 3.82 (1H, m); MS $m/z$ (%) 235 ($[M+H]^+$, 0.3), 234 ($M^+$, 0.1), 198 (2), 155 (40), 83 (100).

**1-(1-Hydroxycyclohexyl)-2-piperidino-1-butanone (25).** Colorless oil; IR (neat) 3280 (OH), 1720 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.87 (3H, t, $J$=7 Hz), 1.0—2.0 (18H, m), 2.50 (4H, m), 3.54

(1H, dd, $J$=10, 4 Hz); MS $m/z$ (%) 253 ($M^+$, trace), 252 (0.2), 126 (100). Found: $m/z$ 253.2026. Calcd for $C_{15}H_{27}NO_2$: M, 253.2039.

**1-(1-Hydroxycyclohexyl)-2-(*p*-tolylthio)-1-butanone (26).** Colorless crystals; mp 63—64 °C (AcOEt–hexane); IR (KBr) 3510 (OH), 1700 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.90 (3H, t, $J$=7 Hz), 1.4—2.0 (12H, m), 2.32 (3H, s), 4.04 (1H, dd, $J$=8, 7 Hz), 7.0—7.3 (4H, m); MS $m/z$ (%) 292 ($M^+$, 14), 222 (3), 194 (16), 166 (58), 124 (100). Anal. Calcd for $C_{17}H_{24}O_2S$: C, 69.82; H, 8.27; S, 10.96%. Found: C, 69.58; H, 8.21; S, 10.85%.

**1-(1-Hydroxycyclohexyl)-2-methoxy-1-butanone (27).** NaH (1 mmol) was added to dry methanol (2.5 ml); a solution of **21** (62 mg; 0.3 mmol) in 0.5 ml of methanol was then added to the methoxide solution. The reaction mixture was stirred at room temperature for 3 h. Powdered $NH_4Cl$ was added to the reaction mixture, and the methanol was evaporated under vacuum. The residue was extracted with benzene–ether. The solution was washed once with water. The usual workup followed by silica-gel column chromatography gave **27** (50 mg; 83%) as a colorless oil. IR (neat) 3510 (OH), 1720 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.95 (3H, t, $J$=7 Hz), 1.4—2.0 (12H, m), 3.33 (3H, s), 4.10 (1H, dd, $J$=6, 5 Hz); MS $m/z$ (%) 200 ($M^+$, trace), 173 (0.3), 172 (3), 99 (100). Found: $m/z$ 200.1430. Calcd for $C_{11}H_{20}O_3$: M, 200.1411.

**1-(1-Hydroxycyclohexyl)-1-butanone (28).** Colorless oil; IR (neat) 3510 (OH), 1710 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.92 (3H, t, $J$=7 Hz), 1.0—1.9 (12H, m), 2.53 (2H, t, $J$=7 Hz); MS $m/z$ (%) 170 ($M^+$, 0.4), 159 (0.5), 99 (100). Found: $m/z$ 170.1303. Calcd for $C_{10}H_{18}O_2$: M, 170.1305.

**3-Hydroxy-1-phenyl-5-piperidino-4-heptanone (29).** Diastereomeric mixture with respect to the two chiral carbon (ratio about 1 : 1). Colorless oil; IR (neat) 3450 (OH), 1715 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.81, 0.85 (each triplet, $J$=7 Hz), 4.0—4.3 (1H, m), 7.21 (5H, m); MS $m/z$ (%) 288 ($[M-H]^+$, trace), 261 (0.2), 204 (4), 126 (100).

**3-Hydroxy-1-phenyl-5-(*p*-tolylthio)-4-heptanone (30).** Diastereomeric mixture (ratio about 2 : 1). Colorless oil; IR (neat) 3510 (OH), 1710 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.97 (3H, t, $J$=7 Hz), 1.5—2.2 (4H, m), 2.31 (3H, s), 2.72 (2H, m), 3.50 (2/3H, t, $J$=7 Hz), 3.76 (1/3H, t, $J$=7 Hz), 4.22 (1/3H, m), 4.56 (2/3H, m), 7.0—7.4 (9H, m); MS $m/z$ (%) 328 ($M^+$, 20), 205 (5), 165 (100). Found: $m/z$ 328.1495. Calcd for $C_{20}H_{24}O_2S$: M, 328.1495.

**3-Hydroxy-1-phenyl-4-heptanone (31).** Colorless oil; IR (neat) 3500 (OH), 1715 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.91 (3H, t, $J$=7 Hz), 1.4—2.3 (4H, m), 2.39 (2H, t, $J$=7 Hz), 2.76 (2H, m), 4.12 (1H, dd, $J$=8, 3 Hz), 7.21 (5H, m); MS $m/z$ (%) 206 ($M^+$, 2), 134 (12), 117 (20), 102 (46), 91 (100). Found: $m/z$ 206.1302. Calcd for $C_{13}H_{18}O_2$: M, 206.1305.

**1-(1-Hydroxycycloheptyl)-2-piperidino-1-ethanone (32).** Colorless crystals; mp 87—89 °C (AcOEt–hexane); IR (KBr) 3225 (OH), 1720 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=1.2—2.0 (18H, m), 2.45 (4H, m), 3.29 (2H, s); MS $m/z$ (%) 239 ($M^+$, trace), 211 (0.7), 149 (0.3), 98 (100). Anal. Calcd for $C_{14}H_{25}NO_2$: C, 70.25; H, 10.53; N, 5.85%. Found: C, 70.42; H, 10.58; N, 5.94%.

**1-(1-Hydroxycycloheptyl)-2-(*p*-tolylthio)-1-ethanone (33).** Colorless oil; IR (neat) 3510, 3410 (OH), 1705 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=1.4—2.0 (12H, m), 2.31 (3H, s), 3.89 (2H, s), 7.0—7.4 (4H, m); MS $m/z$ (%) 278 ($M^+$, 10), 166 (31), 138 (73), 124 (100). Found: $m/z$ 278.1335. Calcd for $C_{16}H_{22}O_2S$: M, 278.1338.

**3-Hydroxy-1-piperidino-2-dodecanone (34).** Colorless oil; IR (neat) 3370 (OH), 1720 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.87 (3H, t, $J$=7 Hz), 1.0—1.9 (22H, m), 2.42 (4H, m), 3.24 (2H, s), 4.22 (1H, m); MS $m/z$ (%) 283 ($M^+$, 0.1), 282 (0.3), 196 (1), 155 (10), 98 (100). Found: $m/z$ 283.2490. Calcd for $C_{17}H_{33}NO_2$: M, 283.2509.

**3-Hydroxy-1-(*p*-tolylthio)-2-dodecanone (35).** Colorless crystals; mp 69—71 °C (AcOEt–hexane); IR (KBr) 3550, 3380 (OH), 1720 (CO) $cm^{-1}$; $^1H$ NMR $\delta$=0.88 (3H, t, $J$=6 Hz), 1.0—1.9 (16H, m), 2.31 (3H, s), 3.72 (2H, s), 4.40 (1H, m), 7.0—7.4 (4H, m); MS $m/z$ (%) 322 ($M^+$, 32), 137 (48), 124 (100). Anal. Calcd for $C_{19}H_{30}O_2S$: C, 70.76; H, 9.38; S, 9.94%. Found: C, 70.69; H, 9.44; S, 9.70%.

**(*E*)-5-Hydroxy-7-phenyl-2-hepten-4-one (37).** MCPBA (2.75 mmol) was added to a stirred solution of the sulfide **30** (820 mg; 2.5 mmol) in 30 ml of $CH_2Cl_2$. The reaction mixture was stirred at −50 °C for 30 min; the mixture was then diluted with $CH_2Cl_2$ and the solution washed successively with 5% NaOH and sat. aq $NH_4Cl$. The usual workup followed by silica-gel column chromatography afforded a diastereomeric mixture of sulfoxide **36** (840 mg; 98%).

A solution of **36** (830 mg) in 20 ml of toluene was refluxed under $N_2$ for 2.5 h. The solvent was evaporated under vacuum and the residue purified by silica-gel column chromatography (hexane : AcOEt=20 : 1) to afford 265 mg (54%) of enone **37** as a colorless oil. IR (neat) 3470 (OH), 1690 (CO), 1630 (C=C) $cm^{-1}$ ; $^1H$ NMR $\delta$=1.6—2.3 (2H, m), 1.90 (3H, dd, $J$=7, 1 Hz), 2.76 (2H, m), 4.32 (1H, dd, $J$=9, 4 Hz), 6.17 (1H, dq, $J$=16, 1 Hz), 6.96 (1H, dq, $J$=16, 7 Hz), 7.20 (5H, m); MS $m/z$ (%) 204 ($M^+$, 0.6), 117 (12), 100 (90), 91 (100). Found: $m/z$ 204.1147. Calcd for $C_{13}H_{16}O_2$: M, 204.1149.

We are grateful to Dr. Mikio Takeda, Tanabe Seiyaku Co., Ltd., for the elemental analysis, and to Noriko Sawabe and Fukiko Hasegawa of this laboratory for the NMR and MS measurements. This work was supported by a Grant-in-Aid for Scientific Research No. 01571168 from the Ministry of Education, Science and Culture, which is gratefully acknowledged.

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