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1. Cyclobutanones *via* the (1-Oxycyclopropyl)methanol Route

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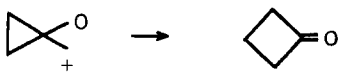
(21. VI. 76)

Summary.

A variety of alcohols of the 1-oxycyclopropyl structure, prapared mostly from α-alkoxy-α,β-unsaturated ketnnes and esters by way of reductinn and *Simmons-Smith* reaction of the resultant α-alkoxyallyl alcohols, are shown to rearrange into cyclobutanones on acid treatment (*cf. Scheme 1*).

Introduction. – As part of the development of the chemistry of oxycyclopropanes for utilization in the synthesis of organic natural products [1] it was pointed out recently that the exploitation of the (1-oxycyclopropyl)methyl cation rearrangement into cyclobutanones **1** might be a worthwhile endeavor in this connection [2]. The acid-induced conversions of alcohols **2a** and **2b** into the bicyclic ketones **3a** [2] and **3b** [3], respectively, represented early examples of such cyclobutanone synthesis, and soon were followed by a large array of conceptually similar processes [4]. The present communication illustrates further syntheses of cyclobutanones, based on *Scheme 1*, which were needed for terpene synthesis.

Scheme 1



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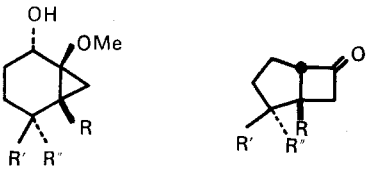

2 **3**

a: R = Me, R′ = R″ = H **b**: R = H, R′ = R″ = Me **c**: R = R′ = R″ = H

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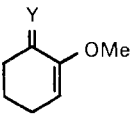
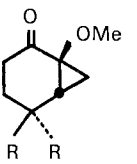
Results and Discussion. – Unsubstituted bicyclo[3.2.0]heptan-6-one (**3c**) could be prepared in the following manner. 1,2-Cyclohexanedione was converted into its methyl enol ether **4a** [5] on treatment with methyl orthoformate in acidic methanol [6] and the product reduced with lithium aluminium hydride. Cyclopropanation of the resultant allyl alcohol **4b** yielded **2c**, whose acid hydrolysis produced the bicyclic ketone **3c** [7]. This constitutes a high-yielding, five-step transformation of cyclohexanone into a bicycloheptanone.

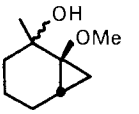
Scheme 2



4a: Y = O
b: Y = H, OH



5a: R = H
b: R = Me



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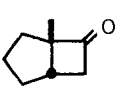

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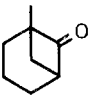

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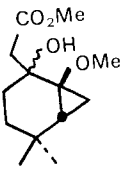
Collins oxidation of **2c** gave ketone **5a**. Treatment of the latter with methyllithium yielded a mixture of sensitive alcohols **6**, which, without purification, were transformed into a *ca.* 9:1 mixture of bicycloheptanones **7** [8] and **8** [9], respectively, on acid treatment. Whereas all bicyclo[4.1.0]heptanols had led exclusively to bicyclo[3.2.0]heptan-6-ones heretofore [2] [3], the formation of **8** as minor product in the acid hydrolysis of **6** represents the first case of the liberation of a bicyclo[3.1.1]heptan-6-one in such a rearrangement process. In the absence of other data it is difficult to assess the reason for the co-production of **8**, *e.g.* the extra substituent at C(2) of **6** affecting the transition state of the rearrangement or the configuration at C(2) determining which cyclopropane bond is to migrate. However, the new experience emphasizes that care must be exercised in predicting the structure of the final bicycle.

Collins oxidation of **2b** produced ketone **5b**. Addition of methyl lithioacetate, prepared by the interaction of methyl acetate with lithium dicyclohexylamide [10], to **5b** produced a stereoisomer mixture of alcohols **9** whose exposure to acid yielded ketoester **10**.

Scheme 3



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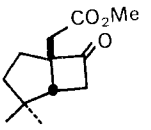

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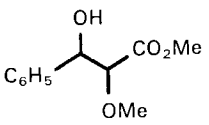
In view of all the above (1-oxycyclopropyl)methanols having been derived from 2-alkoxy-2-cyclohexenones (*e.g.* **4a**) it was of interest to broaden the scope of the method of cyclobutanone synthesis by operating on α-alkoxyacrylic ester systems, and as a consequence to develop a new procedure for their preparation. It could be shown that the strong lithium amide bases react with methyl methoxyacetate to form the lithium salt of the ester which attacks readily the carbonyl groups of benzaldehyde and cyclohexanone, yielding esters **11** and **14**, respectively. Dehydration of **11** with benzenesulfonyl chloride and triethylamine gave methyl 2-methoxycinnamate (**12a**), but similar dehydration of **14** unfortunately yielded the β,γ-unsaturated ester **15**. However, an equivalent of the desired conjugated ester **16** had been reported earlier [11], and even had been reduced to the α-alkoxyallyl alcohol **17**.

Treatment of the cinnamic ester **12a** with lithium aluminium hydride led to overreduction, but the reaction of the ester with diisobutylaluminium hydride afforded alcohol **12b**. *Simmons-Smith* reactions with **12b** and **17** produced the (1-oxycyclopropyl)methanols **13b** and **18**, respectively.

Scheme 4



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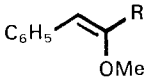

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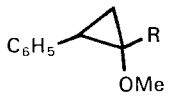

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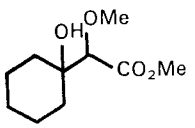
a: R = CO_2Me
b: R = CH_2OH



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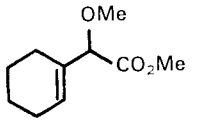

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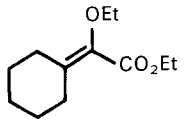

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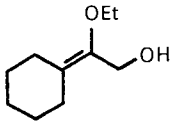

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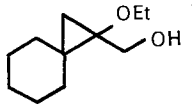


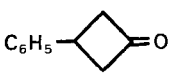
18

Hydrolysis of **13b** in aqueous acid yielded a 4:1 mixture of 3-phenylcyclobutanone (**19**) [12] and 4-phenyl-3-butene-2-one (**20**). Even though the production of the side-product could have been the consequence of acid-induced unravelling of the major product, the stability of **19** towards the reaction conditions under which ketones **19** and **20** were obtained precluded this pathway for the formation of **20**. Thus the latter must be the result of the (1-oxycyclopropyl)methanol **13b** behaving also as a (2-

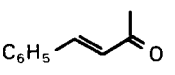
phenylcyclopropyl)methanol and decomposing to some extent *via* a 2-methoxyallyl phenyl carbenium ion intermediate.

Aqueous acid hydrolysis of **18** afforded the cyclobutanone **21** [13]. Thus simple, four-step syntheses of 3-substituted cyclobutanones are now on hand.

Scheme 5



19



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Finally, it was hoped to develop an alternate route to (1-oxycyclopropyl)methanols such as **13b** by way of esters (*e.g.* **13a**), based on the reported preparation of ethyl 1-methyl-2-phenylcyclopropanecarboxylate through the interaction of diethyl sodium methylmalonate with styrene oxide [14]. When the sodium salt of dimethyl methoxymalonate [15] was reacted with styrene oxide, ester **13a** was obtained, albeit in very low yield. Whereas the latter could be reduced into **13b** with lithium aluminium hydride and hence used for the synthesis of **19** (*vide supra*), the low yield of **13a** precluded this route from being a viable method of synthesis of cyclobutanones.

The American authors acknowledge gratefully financial support from the *Eli Lilly & Co.*

Experimental Part

General. M.p. uncorrected, determined on *Reichert* micro hot stage; IR. spectra recorded on *Perkin-Elmer* 137 spectrophotometer (absorptions in cm^{-1}); ^{1}H-NMR. spectra (internal TMS standard) obtained on *Varian Associates* A-60, EM-360 and HR-220 spectrometers (δ values downfield from TMS, J values in Hz); high resolution mass spectra (MS.) recorded on *AEI.* MS-9 spectrometer; analytical GC. performed on *Varian* Aerograph Hy-Fy and 1200 chromatographs (carrier gas: nitrogen; director: flame ionization); preparative GC. executed on *Varian* Aerograph Autoprep instrument (carrier gas: helium; detector: thermal conductivity); column chromatography carried out with *G. F. Smith* 50–200 mesh silicagel or *Woelm* neutral alumina. Abbreviations: i.V. = *in vacuo*, RT. = room temperature.

2-Methoxy-2-cyclohexen-1-ol (**4b**). A solution of 3.84 g of 1,2-cyclohexanedione, 5.46 g of trimethyl orthoformate and 5 drops of conc. sulfuric acid in 10 ml of anhydrous methanol was maintained under nitrogen at 85° for 5 h. It then was evacuated to 10 Torr and the heating continued for another 5 h. The mixture was poured into 5% K_2CO_3-solution, and extracted with CH_2Cl_2. The extract was washed with saturated brine solution, and dried ($MgSO_4$). Evaporation i.V. yielded 3.39 g of 2-methoxy-2-cyclohexenone (**4a**). – IR. (neat): 1690*s* (C=O), 1630*m* (C=C). – ^{1}H-NMR. ($CDCl_3$): 1.96 (*m*, J = 6, 2*H*, 2H–C(5)); 2.41 (*d*×*d*, J = 6, 2H, 2H–C(4)); 2.49 (*t*, J = 6, 2H, 2H–C(6)); 3.58 (*s*, 3H, OMe); 5.82 (*t*, J = 5, 1H, H–C(3)).

A solution of 12.6 g of **4a** in 100 ml of anhydrous ether was added dropwise to a stirring suspension of 4.50 g of $LiAlH_4$ in 600 ml of ether under nitrogen, and the mixture stirred 12 h. $Na_2SO_4 \cdot 10\ H_2O$ was added cautiously and the mixture shaken and then filtered. Evaporation of the filtrate i.V. and distillation gave 11.7 g of alcohol **4b**, b.p. 46°/0.1 Torr. – IR. (neat): 3320*m* (OH), 1660*m* (C=C). – ^{1}H-NMR. ($CDCl_3$): 0.9–1.7 (*m*, 6H, 3 CH_2); 2.99 (*s*, 3H, OMe); 3.54 (*m*, 1H, H–C(1)); 4.20 (*t*, J = 4, 1H, H–C(3)).

$C_7H_{12}O_2$ (128.10) Calc. C 65.60 H 9.44% Found C 65.47 H 9.52%

endo-*1-Methoxy-bicyclo[4.1.0]heptan-2-ol* (**2c**). A mixture of 80.4 g of CH_2I_2, 32.6 g of zinc copper couple [16] and 3 crystals of I_2 in **1** l of ether was heated under reflux and nitrogen for 2 h. A solution of 12.0 g of **4b** in 200 ml of dry ether was added slowly to the stirring suspension and the heating continued for 16 h. A saturated NH_4Cl-solution (50 ml) was added slowly, the ether solution then decanted, the aqueous layer extracted with ether, and the combined organic solutions washed with 5% NaOH-solution, and dried ($MgSO_4$). Evaporation i.V. led to 14.8 g of **2c** sufficiently pure for further reactions. Chromatography on SiO_2 and elution with ether gave liquid **2c**. – IR. (neat): 3470*m* (OH). – ^{1}H-NMR. ($CDCl_3$): 0.56 (*t*, *J* = 6, 1H, H–C(7)); 0.88 (*d*×*d*, *J* = 6 and 10, 1H, H–C(7)); 0.9–1.5 (*m*, 5H, H–C(6) and 2 CH_2); 1.7–2.0 (*m*, 2H, CH_2); 3.31 (*s*, 3H, OMe); 4.36 (*t*, *J* = 7, 1H, H–C(2)).

$C_8H_{14}O_2$ (142.11) Calc. C 67.57 H 9.92% Found C 67.47 H 9.76%

Bicyclo[3.2.0]heptan-6-one (**3c**). A mixture of 2.50 g of **2c** in 50 ml of ether and 50 ml of 3N HCl was stirred at RT. for 5 h. After separation of the two-layer system the ether solution was washed with 5% $NaHCO_3$-solution, and dried ($MgSO_4$). Distillation yielded 1.80 g of ketone **3c**, b.p. 168–170° ([7]: 164–165°). – IR. (neat): 1780*s* (C=O). – ^{1}H-NMR. ($CDCl_3$): 1.1–1.9 (*m*, 5H); 2.02 (*d*, J = 7, 1H); 2.46 *d*×*t*, *J* = 18 and 4, 1H); 2.8–3.6 (*m*, 3H).

1-Methoxy-bicyclo[4.1.0]heptan-2-one (**5a**). A mixture of 49.5 g of CrO_3 in 78.2 g of pyridine (distilled from BaO) and 1.2 l of CH_2Cl_2 was stirred at RT. for 15 min. It then was cooled to 0°, and a solution of 11.7 g of alcohol **2c** in 30 ml of CH_2Cl_2 added quickly. The mixture then was stirred at 0° for 10 min and concentrated i.V., and the residue partitioned between 5% NaOH-solution and ether. The latter phase was washed with 5% hydrochloric acid and thereafter 5% $NaHCO_3$-solutions, dried ($MgSO_4$), and evaporated i.V. Distillation of the residue produced 2.9 g of liquid **5a**, b.p. 46–48°/0.05 Torr. – IR. (neat): 1690*s* (C=O). – ^{1}H-NMR. ($CDCl_3$): 1.3–2.4 (*m*, 9H); 3.37 (*s*, 3H, OMe).

$C_8H_{12}O_2$ (140.10) Calc. C 68.55 H 8.63% Found C 68.62 H 8.65%

Bicyclic ketones **7** *and* **8**. 5.8 ml of a 1.9M ether solution of CH_3Li were added slowly to a stirred solution of 1.28 g of ketone **5a** in 30 ml of ether under nitrogen and the mixture then heated under reflux for 50 h. Water was added, the mixture shaken, and the aqueous phase extracted with ether. The combined organic solutions were dried (K_2CO_3), and evaporated i.V. To a solution of the residue, 1.30 g of **6** [IR. (neat): 3480*m* (OH). – ^{1}H-NMR. ($CDCl_3$): 3.32 (*s*, 3H, OMe); 3.38 (*s*, 3H, OMe of other isomer)], in 30 ml of ether at 0° there were added 30 ml of 5% HCl-solution, and the mixture stirred at RT. for 18 h. After separation of the layers the aqueous solution was extracted with ether, the combined organic solutions were washed with saturated brine solution, and dried ($MgSO_4$). Removal of the solvent by distillation through an efficient column, and distillation of the residue yielded 0.70 g of a 9:1 mixture of liquid ketones whose separation by preparative GC. on 15% Carbowax 20 M/Chrom W columns afforded pure 1-methylbicyclo[3.2.0]-heptan-7-one (**7**) as major product and 1-methylbicyclo[3.1.1]heptan-6-one (**8**) as minor component. Their structures were established by the identity of their IR. and ^{1}H-NMR. spectra with those of authentic samples [8] [9].

1-Methoxy-5,5-dimethyl-bicyclo[4.1.0]heptan-2-one (**5b**). A solution of 14.2 g of alcohol **2b** [3] in 70 ml of CH_2Cl_2 was added quickly to 138 g of CrO_3 pyridine complex in 1.4 l of CH_2Cl_2 (*vide supra*), and the mixture stirred at RT. for 90 min. The mixture was filtered and the filtrate concentrated to 200 ml i.V., diluted with 700 ml of ether, and washed with 3% HCl-solution. The washings were extracted with ether, and the combined organic solutions washed with 5% NaOH-solution, dried (K_2CO_3), and evaporated. Crystallization of the residue, 8.2 g, from pentane at –78° yielded crystalline ketone **5b**, m.p. 39–40°, b.p. 61–63°/0.1 Torr. – IR. (neat): 1695*s* (C=O). – ^{1}H-NMR. ($CDCl_3$): 1.08 (*s*, 3H, H_3C–C(5)); 1.11 (*s*, 3H, H_3C–C(5)); 1.3–1.7 (*m*, 5H, 2H–C(4), H–C(6), 2H–C(7)); 2.25 (*m*, 2H, 2H–C(3)); 3.35 (*s*, 3H, OMe).

$C_{10}H_{16}O_2$ (168.13) Calc. C 71.39 H 9.59% Found C 71.33 H 9.60%

5-Methoxycarbonylmethyl-2,2-dimethyl-bicyclo[3.2.0]heptane-6-one (**10**). A solution of lithium dicyclohexylamide was generated by the introduction of 4.43 ml of a 1.58M heptane solution of *n*-butyllithium into a stirred solution of 1.27 g of dicyclohexylamine in 10 ml of tetrahydrofuran (distilled from K) at –78° under nitrogen, and the mixture stirred for 10 min. Then 518 mg of

methyl acetate were added, and the mixture was stirred for another 10 min. Thereafter it was transferred into a swirling solution of 642 mg of ketone **5b** in 10 ml of tetrahydrofuran at –78°. After 5 min the mixture was allowed to warm up to RT., diluted with 1.4 ml of conc. HCl-solution, poured into water, and extracted with CH_2Cl_2. The extract was washed with 5% hydrochloric acid and saturated brine solutions, dried ($MgSO_4$), and evaporated i.V. A solution of the residue, 793 mg of **9** [IR. (neat): 3500*m* (OH), 1720*s* (C=O)], and 3 ml of conc. HCl-solution in 10 ml of methanol was kept at RT. for 20 h. It then was poured into 200 ml of water, and extracted with CH_2Cl_2. The extract was washed with water, dried ($MgSO_4$), and evaporated i.V. Preparative GC. of the residue, 290 mg containing a trace of side product (presumably the methoxycarbonyldimethyl derivative of **8**), on a 15% Carbowax 20 M/Chrom W column yielded liquid ketoester **10**. – IR. (neat): 1735*s*, 1780*s* (C=O). – ^{1}H-NMR. ($CDCl_3$): 1.02 (*s*, 3H, H_3C–C(2)); 1.05 (*s*, 3H, H_3C–C(2)); 1.5–2.3 (*m*, 5H, H–C(1), 2H–C(3), 2H–C(4)); 2.40 (*d*, J = 16, 1H, H–C(7) or H–C(1')); 2.57 (*d*, J = 16, 1H, H–C(7) or H–C(1')); 2.67 (br. *d*, J = 6, 1H, H–C(7) or H–C(1')); 2.9–3.2 (*m*, 1H, H–C(7) or H–C(1')); 3.64 (*s*, 3H, OMe).

$C_{12}H_{18}O_3$ (210.15) Calc. C 68.55 H 8.63% Found C 68.56 H 8.70%

Methyl 2-methoxycinnamate (**12a**). A solution of 48.0 ml of a 2.0 M hexane solution of *n*-butyllithium was added to a solution of 13.1 g of cyclohexylisopropylamine in 250 ml of dry tetrahydrofuran at –78° under nitrogen, and the mixture stirred for 10 min. Thereupon 10.0 g of methyl methoxyacetate were added slowly, and the stirring mixture kept below –65° for 15 min. Then 10.0 g of benzaldehyde were added and the mixture stirred below –65° for another 15 min. Finally, 17.7 g of benzenesulfonyl chloride were added, the mixture kept at the low temp. for 30 min, and then permitted to warm up to RT. over a period of 2.5 h. It was diluted with ether, washed with water and with saturated brine solution, dried ($MgSO_4$), and evaporated. A mixture of the residue and 40 ml of triethylamine was heated under reflux for 30 min, diluted with ether, washed with 3% HCl-, 5% NaOH- and saturated brine solutions, dried ($MgSO_4$), and evaporated. Distillation of the residue gave 13.3 g of liquid ester **12a**, b.p. 85°/0.2 Torr. – IR. (neat): 1715*s* (C=O), 1630*m* (C=C). – ^{1}H-NMR. ($CDCl_3$): 3.72 and 3.80 (2*s*, 3H each, 2 OMe); 6.88 (*s*, 1H, H–C(3)); 7.1–7.8 (*m*, 5H, arom. H).

$C_{11}H_{12}O_3$ (192.10) Calc. C 68.74 H 6.29% Found C 68.46 H 6.44%

When the reaction sequence was interrupted just prior to the addition of benzenesulfonyl chloride and followed by the usual work-up, a 1:1 stereoisomer mixture of esters **11** was obtained.

Liquid isomer A: IR. (neat): 3200–3700*m* (OH), 1735*s* (C=O). – ^{1}H-NMR. ($CDCl_3$): 3.36 and 3.59 (2*s*, 3H each, 2 OMe); 3.86 (*d*, J = 5, 1H, H–C(3)); 4.86 (*d*, J = 5, 1H H–C(2)); 7.28 (*s*, 5H, arom. H).

$C_{11}H_{14}O_4$ (210.11) Calc. C 62.85 H 6.71% Found C 62.66 H 6.55%

Liquid isomer B: IR. (neat): 3200–3700*m* (OH), 1735*s* (C=O). – ^{1}H-NMR. ($CDCl_3$): 3.32 and 3.62 (2*s*, 3H each, 2 OMe); 3.94 (*d*, J = 5, 1H, H–C(3)); 4.90 (*d*, J = 5, 1H, H–C(2)); 7.28 (*s*, 5H, arom. H).

$C_{11}H_{14}O_4$ (210.11) Calc. C 62.85 H 6.71% Found C 62.67 H 6.94%

2-Methoxy-3-phenyl-2-propenol (**12b**). A solution of 2.1 g of ester **12a** in 10 ml of benzene was added to 16 ml of a 1.59 M benzene solution of diisobutylaluminium hydride, and the mixture stirred under nitrogen at RT. for 2 h. At 5° 1.5 ml of methanol and then 1.0 ml of water were added. The precipitate was filtered off, and the filtrate evaporated i.V. The oily residue, 1.6 g, crystallized on standing yielding alcohol **12b**, m.p. 39–40°. – IR. (neat): 3100–3600*m*, 3080*w* (OH), 1645*m* (C=C). – ^{1}H-NMR. ($CDCl_3$): 3.62 (*s*, 3H, OMe) 4.05 (*s*, 2H, 2H–C(1)); 5.38 (*s*, 1H, H–C(3)); 6.8–7.4 (*m*, 5H, arom. H). – Mol.-wt. (MS.): $C_{10}H_{12}O_3$ Calc. 164.0836, Found 164. 0836.

(1-Methoxy-2-phenylcyclopropyl)methanol (**13b**). A mixture of 1.67 g of Zn and 260 mg of CuCl in 15 ml of dry ether was heated under reflux and nitrogen for 30 min, 6.80 g of CH_2I_2 were added and the mixture was heated under reflux for 2 h. Then a solution of 940 mg of alcohol **12b** in 2 ml of ether was added, and the mixture heated under reflux for 10 h. It was filtered and saturated NH_4Cl-solution added cautiously to the filtrate. The organic solution was washed with 5% NaOH- and saturated brine solutions, dried ($MgSO_4$), and evaporated i.V. Chromatography of the residue on alumina (activity III) and elution with ether/hexane 3:1 yielded 840 mg of liquid

alcohol **13b**. – IR. (neat): 3100–3600*m* (OH), 1605*w* (C=C). – ^{1}H-NMR. (CCl_4): 1.0–1.2 (*m*, 2H, 2H–C(3′)); 2.00 (*d*×*d*, *J* = 7 and 10, 1H, H–C(2′)); 3.14 (*s*, 3H, OMe); 3.50 (*d*, *J* = 12, 1H, 1H–C(1)); 3.70 (*d*, *J* = 12, 1H, 1H–C(1)); 7.05 (*s*, 5H, arom. H). – Mol.-Wt. (MS.): $C_{11}H_{12}O$ (M^+-H_2O) Calc. 160.0888, Found 160.0888.

$C_{11}H_{14}O_2$ (178.11) Calc. C 74.13 H 7.92% Found C 73.56 H 7.98%

A solution of 120 mg of **13a** in 15 ml of ether was added slowly to a solution of 25 mg of $LiAlH_4$ in 30 ml of anhydrous ether, and the mixture refluxed for 3 h. Then $Na_2SO_4 \cdot 10\ H_2O$ was added, the mixture shaken and filtered, and the filtrate evaporated i.V. Treatment of the oily residue, 80 mg, as above gave 55 mg of **13b**. – IR. identical with IR. of the above sample.

Methyl 1-methoxy-2-phenylcyclopropanecarboxylate (**13a**). A solution of 10.0 g of dimethyl methoxymalonate in 25 ml of anhydrous benzene was added dropwise to a suspension of 1.48 g of NaH in 70 ml of dry benzene and the mixture stirred under nitrogen at RT. for 2 h. A solution of 7.46 g of styrene oxide in 20 ml of anhydrous benzene was added dropwise over a 2 h period to the stirring mixture at 40°, and the suspension heated under reflux and nitrogen for 72 h. It then was filtered and the filtrate evaporated i.V. Chromatography of the red, oily residue, 6.20 g, on SiO_2 and elution with hexane/ether 32:1 led to the recovery of 1.20 g of styrene oxide, while elution with $CHCl_3$ gave 4.7 g of unidentified γ-lactone esters [IR. ($CHCl_3$): 1777*s*, 1740*s* (C=O), 1602*w* (C=C)], and then a 240 mg fraction whose rechromatography on SiO_2 and elution with $CHCl_3$ produced 160 mg of liquid **13a**. – IR. ($CHCl_3$): 1730*s* (C=O), 1642*w* (C=C). – ^{1}H-NMR. ($CDCl_3$): 1.59 (*m*, 1H, H–C(3)), 1.75 (*m*, 1H, H–C(3)); 2.81 (*t*, *J* = 6, 1H, H–C(2)), 3.17 and 3.75 (2*s*, 3H each, 2 OMe); 7.18 (*s*, 5H, arom. H). – Mol.-wt. (MS.): $C_{12}H_{14}O_3$ Calc. 206.112, Found 206.102.

Methyl (1-hydroxycyclohexyl)methoxyacetate (**14**). A 1.58 M hexane solution of *n*-butyllithium (6.33 ml) was added to a solution of 1.81 g of dicyclohexylamine in 15 ml of dry tetrahydrofuran at –78° and the mixture was stirred for 15 min. Methyl methoxyacetate (1.04 g) was added, and the stirring continued at –78° for 10 min. The mixture was transferred under nitrogen pressure through a stainless steel tube into a solution of 1.96 g of cyclohexanone in 15 ml of tetrahydrofuran at –78°, the stirring continued for 5 min, and the mixture then permitted to warm to RT. After the addition of 2 ml of conc. HCl-solution the mixture was poured into 150 ml of water, and extracted with CH_2Cl_2. The extract was washed with 5% HCl-, saturated $NaHCO_3$- and saturated brine solutions, dried ($MgSO_4$), and evaporated i.V. Distillation of the residue yielded 1.53 g of a liquid whose chromatography on alumina (activity III) gave ester **14**, b.p. 90°/0.05 Torr. – IR. (neat): 3200–3600*m* (OH), 1730*s* (C=O). – ^{1}H-NMR. ($CDCl_3$): 1.2–1.7 (*m*, 10H, 5 CH_2); 3.38 and 3.76 (2*s*, 3H each, 2 OMe); 3.59 (*s*, 1H, H–C(2)).

$C_{10}H_{18}O_4$ (202.15) Calc. C 59.39 H 8.97% Found C 59.20 H 9.04%

Methyl (1-cyclohexenyl)methoxyacetate (**15**). A solution of 180 mg of ester **14** and 191 mg of *p*-toluenesulfonyl chloride in 1 ml of pyridine was heated under reflux for 1 h. The heating was continued for 15 min after the addition of 0.3 ml of isopropyl alcohol. The mixture was poured into 5% HCl-solution, and extracted with CH_2Cl_2. The extract was washed with 5% HCl-solution and water, dried ($MgSO_4$), and evaporated i.V. Distillation of the residue produced 87 mg of liquid whose preparative GC. on a 15% Carbowax 20 M/Chrom W column led to ester **15**. – IR. (neat): 1740*s* (C=O). – ^{1}H-NMR. ($CDCl_3$): 1.5–2.1 (*m*, 8H, 4 CH_2); 3.28 and 3.71 (2*s*, 3H each, 2 OMe); 4.07 (*s*, 1H, H–C(2)); 5.80 (*s*, 1H, H–C(2′)).

$C_{10}H_{16}O_3$ (184.12) Calc. C 65.19 H 8.75% Found C 64.90 H 8.63%

(1-Ethoxyspiro[5.2]oct-1-yl)methanol (**18**). A mixture of 3.90 g of zinc copper couple (*vide supra*) and 16.1 g of CH_2I_2 was heated under reflux for 5 h. A solution of 1.73 g of alcohol **17** [11] in 50 ml of ether then was added slowly, and the heating continued for 12 h. Saturated NH_4Cl-solution was added cautiously. The organic solution was washed with 5% NaOH- and saturated brine solutions, and dried ($MgSO_4$). Evoporation of the solvent i.V. led to 1.84 g of alcohol **18**. – IR. (neat): 3100–3600*m* (OH), 3060*w* (cyclopropane CH). – ^{1}H-NMR. ($CDCl_3$): 0.28 (*d*, *J* = 5, 1H, 1H–C(2′)); 0.55 (*d*, *J* = 5, 1H, 1H–C(2′)); 1.15 (*t*, *J* = 7, 3H, CH_3CH_2O); 1.5–1.6 (*m*, 10H, 5 CH_2); 3.48 (*q*, *J* = 7, 2H, CH_3CH_2O); 3.75 (*d*, *J* = 12, 1H, H–C(1)); 3.92 (*d*, *J* = 12, 1H, H–C(1)).

$C_{11}H_{20}O_2$ (180.13) Calc. C 71.70 H 10.94% Found C 71.41 H 11.18%

3-Phenylcyclobutanone (**19**). A mixture of 120 mg of alcohol **13b** and 7 ml of 10% HCl-solution in 5 ml of ether was stirred at RT. for 100 h. The separated organic layer was washed with saturated $NaHCO_3$- and brine solutions, dried ($MgSO_4$), and evaporated i.V. GC. chromatography (Carbowax 20M/Chrom W column) of the residual oil, 95 mg, showed a 4:1 ratio of isomers. Preparative TLC. on SiO_2 gel (hexane/ether 4:1) yielded 10 mg of ketone **20** identical in IR., ^{1}H-NMR. and GC. behavior to an authentic sample, and 50 mg of the major isomer, **19**. – IR. (neat): 1780*s* (C=O), 1600*w* (C=C) (IR. identical with lit. [12]). – ^{1}H-NMR ($CDCl_3$): 3.1–3.7 (*m*, 5H, H–C(3), 2 CH_2); 7.20 (*s*, 5H, arom. H).

Cyclobutanone **19** was found to be stable in the above acid medium of its formation at RT. for 100 h.

Spiro[3.5]nonan-2-one (**21**). A mixture of 200 mg of alcohol **18** and 3 ml of conc. HCl-solution in 8 ml of ether was stirred at RT. for 6 h. The separated organic solution was washed with 5% NaOH- and saturated brine solutions, dried ($MgSO_4$), and evaporated i.V., yielding 125 mg of ketone **21** [13]. – IR. (neat): 1780*s* (C=O). – ^{1}H-NMR. ($CDCl_3$): 1.3–1.8 (*m*, 10H, 5 CH_2); 2.68 (*s*, 4H, 2H–C(1), 2H–C(3)). – Mol.-wt. (MS.): $C_9H_{14}O$ Calc. 138.1044, Found 138.1050.

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