stretch); nmr ($CDCl_3$) τ 2.73 (m, 15 $(C_6H_5)_3C$), 4.05 (d, 1, $J_{1,2} = 4.0$ Hz, H-1), 5.47 (t, H-4), 5.72 (d, 1, H-2), 6.78, 6.99 (q, 2, $J = 4.0$ Hz, epoxy, CH_2AB), 8.44 (s, 3, isopropylidene, CH_3-*endo*), 8.66 (s, 3, isoproylidene, CH_3-*exo*). A quantity of **2c** (0.392 g, 0.9 mmol) and 0.190 g (5 mmol) of lithium aluminum hydride in 10 ml of dry ether was refluxed for 10 hr. Water (*ca.* 1.0 ml) was added dropwise to the reaction mixture, the ether layer was drawn off, and the aqueous phase was extracted with four 20-ml portions of ether. The combined extracts were dried over magnesium sulfate and the filtered solution was evaporated to dryness. The foamy residue (0.286 g) was judged to be *ca.* 90% pure on tlc (ethyl–acetate petroleum ether, (1:4) but could not be crystallized from the usual solvents. The material was applied to two plc plates and the mixture was resolved with the same solvent system. The major fraction (**3c**, 0.194 g) showed a single spot on tlc and readily crystallized from petroleum ether as a colorless solid: wt 0.130 g (33% yield); mp 130–131°; $[\alpha]^{23}D$ +70.4°, $[\alpha]^{25}{}_{365}$ +247.4° (*c* 1); ir (CCl_4) 3510 cm^{-1} (OH) 1380 (geminal CH_3); nmr (pyridine d_5) τ 3.96 (d, 1, $J_{1,2} = 3.7$, H-1), 5.60 (d, 1, H-2), 5.67 (m, 1, H-4), 6.32 (m, 2, H-5, H-5′); mass spectrum *m/e* 446 (M^+).

Anal. Calcd for $C_{28}H_{30}O_5$: C, 75.31; H, 6.77. Found: C, 75.19; H, 6.83.

4,5-Dideoxy-1,2-*O*-isopropylidene-3-*C*-methyl-5-*O*-trityl-α-D-heptoseptanose (10).—Substance B, when subjected to glpc at a gas flow rate of 64.5 ml/min, was found to consist of one major and two minor components exhibiting retention times of 33, 27, and 23 min, respectively. A solution of 0.675 g of B in 10 ml of dry tetrahydrofuran containing 0.190 g (5 mmol) of lithium aluminum hydride was refluxed for 8 hr. The work-up of the reaction mixture was the same as that described for **3c**. The product, obtained as a foam (0.507 g), was applied to two plc plates which were developed in ethyl acetate–petroleum ether (1:4). The principal band was eluted with acetone and the filtered solution was evaporated to dryness. The residue crystallized from petroleum ether to give 0.205 g of a colorless solid: mp 129–130°; $[\alpha]^{23}D$ −44.6°, $[\alpha]^{23}{}_{365}$ −138.3° (*c* 1, $CHCl_3$); ir (KBr) 3420 (OH), 1380 cm^{-1} (geminal $-CH_3$); ir (CCl_4) 3570 cm^{-1} (OH); nmr ($CDCl_3$) τ 2.62 (m, 15, aromatic), 4.46 (d, 1, $J_{1,2} = 5.0$ Hz, H-1), 5.95 (d, 1, H-2), 6.70–8.22 (m, 6, CH_2 envelope), 8.35 (s, 3, 3-CH_3–), 8.63 (s, 6, $(CH_3)_2C$–); mass spectrum *m/e* 474 (M^+), 416 ($M^+ - (CH_3)_2CO$).

Anal. Calcd for $C_{30}H_{34}O_5$ (mol wt 474):[26] C, 75.92; H, 7.22. Found: C, 75.77; H, 7.16.

4,5-Dideoxy-1,2-*O*-isopropylidene-3-*C*-methoxymethyl-5-*O*-trityl-α-D-heptoseptanose (11).—A solution of 0.309 g of B in 55 ml of methanol containing 6 ml of 10 *N* sodium hydroxide was refluxed for 3 hr. The cooled solution was neutralized (phenolphthalein) with dilute acetic acid and evaporated to dryness. The residue was dissolved in ether previously equilibrated with water and the ether layer was washed with a dilute solution of sodium bicarbonate, and then dried over magnesium sulfate. The filtered solution was evaporated to dryness and the residue was crystallized first from ether–petroleum ether and then from ethanol to give 0.253 g of the product: mp 145–147°; $[\alpha]^{23}D$ −47.2°, $[\alpha]^{23}{}_{365}$ −148° (*c* 0.25); ir (CCl_4) 3550 cm^{-1} (OH); nmr ($CDCl_3$) τ 2.68 (m, 15, aromatic), 4.46 (d, 1, $J_{1,2} = 5.0$ Hz, H-1), 5.70 (d, 1, H-2), 6.60 (s, 3, CH_3O), 6.68–8.32 (m, 8, CH_2 envelope), 8.38 (s, 3, isopropylidene, CH_3-*endo*), 8.66 (s, 3, isopropylidene, CH_3-*exo*); mass spectrum *m/e* 504 (M^+), 489 ($M^- - CH_3$).

Anal. Calcd for $C_{31}H_{36}O_6$ (mol wt 504):[27] C, 73.78; H, 7.19. Found: C, 73.99, H, 6.90.

Registry No.—Diazomethane, 334-88-3; **1c**, 20590-54-9; **2c**, 24515-45-5; **3c**, 24467-32-1; **7b**, 24467-33-2; **7c**, 24467-36-5; **10**, 24467-39-8; **11**, 24467-40-1; **14a**, 24467-37-6; **14b**, 24467-38-7.

Acknowledgment.—The authors are indebted to Dr. Jiří Zemlička for his timely advice and criticisms during this work. We wish to thank Mr. Nikolai Cvetkov of this laboratory for assistance with ir and nmr spectra. We are also grateful to Professor Don C. DeJongh and Mr. David Brent, Department of Chemistry, Wayne State University, for mass spectral data.

(26) Calcd for $C_{29}H_{32}O_5$ (mol wt 460): C, 75.62; H, 7.00.

(27) Calcd for $C_{30}H_{34}O_6$ (mol wt 490): C, 73.44; H, 6.99.

The Synthesis and Birch Reduction of 2-Isoamyl-3-methyl-4-methoxy-2,3-dihydrobenzofurans and Related Compounds[1]

L. H. BRANNIGAN AND D. S. TARBELL

Department of Chemistry, Vanderbilt University, Nashville, Tennessee 37203

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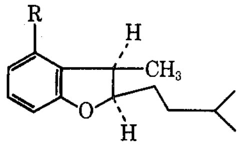
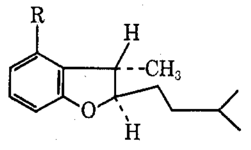
Conditions have been found by which Birch reduction, followed by hydrolysis of *cis*-2-isoamyl-3,4-dimethyl-2,3-dihydrobenzofuran (**1a**), gave 75% of α,β-unsaturated ketone. Stereospecific catalytic reduction of the carbon–carbon unsaturation could not be attained. 4-Methoxy-2-isoamyl-3-methyl-2,3-dihydrobenzofuran (**9b**) was prepared in good yield, and was converted into *cis*-2-isoamyl-3-methyl-4-keto-2,3,4,5,6,7-hexahydrobenzofuran in good yield. Mass spectral fragmentation patterns for perhydrobenzofurans and related compounds have been determined.

The synthesis and proof of configuration of *cis*- and *trans*-2-isoamyl-3,4-dimethyl-2,3-dihydrobenzofurans (**1a** and **2a**), which were needed for syntheses in the fumagillin series, were reported recently.[2] The present paper describes a study of the Birch reduction of the *cis* compounds **1a** as well as the synthesis and Birch reduction of the corresponding 4-methoxy compound **1b**; the *trans* compound **2b** was also prepared.



1a, R = CH_3
b, R = OCH_3



2a, R = CH_3
b, R = OCH_3

The *cis* compound **1a** was prepared by catalytic reduction of the corresponding 2-isoamyl-3,4-dimethylbenzofuran, using platinum and hydrogen in ethanol; the product, obtained in 92% yield, was 98% pure by vpc. Reduction of **1a** with 16 g-atoms of lithium in liquid ammonia, *t*-butyl alcohol, and ether,[3,4] followed by methanol, gave a product which showed no aromatic protons in the nmr, and showed a deficit of vinyl

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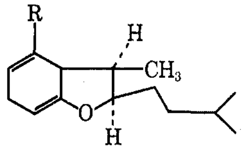
(1) Aided by Grant AI-08424 from the National Institutes of Health.

(2) E. C. Hayward, D. S. Tarbell, and L. D. Colebrook, *J. Org. Chem.*, **33**, 399 (1968).

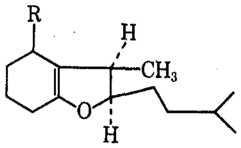
(3) A. L. Wilds and N. A. Nelson, *J. Amer. Chem. Soc.*, **75**, 5360 (1953); H. L. Dryden, Jr., G. M. Webber, R. R. Burtner, and J. A. Cella, *J. Org. Chem.*, **26**, 3237 (1961).

(4) D. P. Brust and D. S. Tarbell, *ibid.*, **31**, 125 (1966).

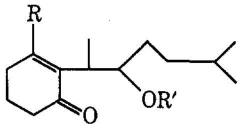
protons, indicting some overreduction. This was evidently a mixture of the expected tetrahydro compound **3a** (with possible double-bond isomers) and the hexahydro[5] compound **4a**. Hydrolysis of this mixture with oxalic acid in aqueous dioxane, followed by chromatography on alumina, gave a mixture of hexahydrobenzofurans, such as **4a**, judging from the nmr spectrum; there was also obtained a smaller amount of saturated and α,β-unsaturated keto alcohols, such as **5a**, and the corresponding saturated keto alcohols **6a**.



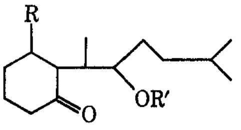
3a, $R = CH_3$
b, $R = OCH_3$



4a, $R = CH_3$
b, $R = O{=}$



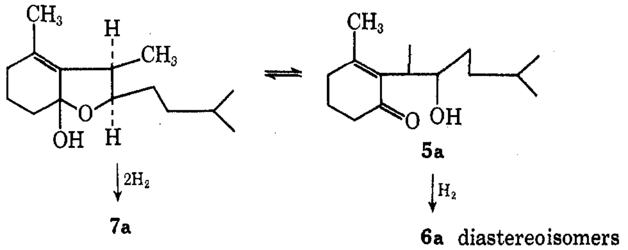
5a, $R = CH_3$; $R' = H$
b, $R = CH_3$; $R' = Ac$



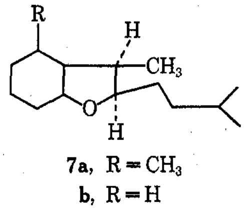
6a, $R = CH_3$; $R' = H$
b, $R = CH_3$; $R' = Ac$

The Birch reduction using only 5 g-atoms of lithium gave a mixture containing, after hydrolysis with aqueous acid, about 75% of α,β-unsaturated ketone; acetylation, followed by chromatography on alumina, yielded 10% of starting material **1a**, and in addition a mixture containing about three parts of α,β-unsaturated keto acetate (such as **5b**) and one part of saturated keto acetate **6b**. The mixture of conjugated and unconjugated keto acetates was hydrogenated with 30% Pd–C as catalyst; the product, from its ir spectrum, consisted only of saturated keto acetates.

The keto alcohol **5a** could exist in equilibrium with the cyclic hemiketal. Hydrogenation of the double bond of the hemiketal form should give only one diastereoisomer of the corresponding **6a** cyclic tautomer, the direction of hydrogenation being controlled by the *cis* methyl and isoamyl groups.



Mass spectrometry[6] of the peaks from a vpc column allowed an identification of seven out of nine peaks. Three were stereoisomeric perhydrobenzofurans **7a**, one was a saturated keto alcohol, and three peaks (two major and one minor, ratio 3:3:1) were saturated keto acetates of structure **6b**.

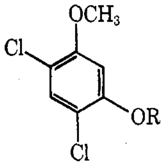


7a, $R = CH_3$
b, $R = H$

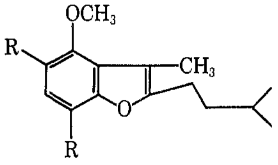
When the procedure was varied by following the Birch reduction and hydrolysis by Pd–C catalytic reduction, and then by acetylating, the examination by vpc–mass spectrometry showed 17 peaks, of which 4 were perhydrobenzofurans (**7a**), 2 were saturated keto alcohols (**6a**), 3 were saturated keto acetates (**6b**), 2 were unsaturated keto acetates (**5b**) or double-bond isomers, and 2 were probably β,γ-unsaturated keto alcohols.

The procedure using 5 g-atoms of lithium, in which the acetylation precedes the Pd–C reduction, is obviously the best one, giving a more homogeneous product and only two major stereoisomeric products of the keto acetate formula **6b**. Repeated attempts to cyclize the keto alcohols **6a** to the cyclic ketal with methanol or to the analogous cyclic pyrrolidino compound, a reaction which goes well with less highly substituted compounds,[7] or to a cyclic hemiketal, were all unsuccessful. The formation of two diastereoisomeric keto alcohols (**6**) or acetates in roughly equal amounts by these procedures indicated that control of the stereochemistry was not promising in this series.

The 4-methoxy analog **1b** was investigated because it might lead to bicyclic products, *via* a cyanhydrin–lactone route, for example, in which R and OR′ in **5a** were in a lactone ring. This might give better control over the stereochemistry of the reduction of the double bond than could be achieved with **5a** or **5b**. Compound **1b**, *cis*-2-isoamyl-3-methyl-4-methoxy-2,3-dihydrobenzofuran, was therefore synthesized by methods similar to those described for **1a**. Chlorination of resorcinol monomethyl ether gave 3-methoxy-4,6-dichlorophenol (**8a**), which was converted to the keto ether **8b**; this was cyclized to 2-isoamyl-3-methyl-4-methoxy-5,7-dichlorobenzofuran, **9a**, and the chlorine atoms were removed by catalytic reduction in acetic acid–sodium acetate with 10% Pd–C to yield 90% of the chlorine-free benzofuran **9b**, along with 10% of the correspondiug *cis*-2,3-dihydro compound **1b**. Catalytic reduction of the benzofuran **9b** with platinum gave mainly hydrogenolysis of the methoxyl group, with the formation of perhydrobenzofurans (**7b**), along with starting material. It was finally found that catalytic reduction of **9b** with 30% Pd–C in absolute alcohol gave a 60% yield of the *cis*-2,3-dihydro compound **1b**, along with 30% of the perhydro compound(s) **7b**.



8a, $R = H$
b, $R = CH_3COCHCH_2CH_2CH(CH_3)_2$



9a, $R = Cl$
b, $R = H$

Birch reduction of the *cis*-2,3-dihydro-4-methoxy compound **1b** gave the tetrahydro product **3b** (or double bond isomer), which, on hydrolysis with oxalic acid and purification by chromatography on alumina,

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[5] "Tetrahydro" and "hexahydro" refer to the benzofuran nucleus as a whole; the starting material for the Birch reduction is the dihydrobenzofuran.

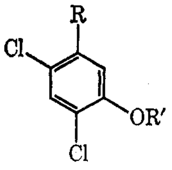
[6] Using the vpc attachment with an LKB 9000 mass spectrometer; spectra measured by Mr. C. T. Wetter and Mrs. Betty Fox.

[7] L. H. Brannigan, Ph.D. Thesis, Vanderbilt University, 1969.

gave a 79% yield of *cis*-2-isoamyl-3-methyl-4-keto-2,3,4,5,6,7-hexahydrobenzofuran (**4b**).

The *cis* configuration of the 4-methoxy-2,3-dihydro compound **1b** is assigned on the fact that it is prepared by catalytic reduction of the 2,3 double bond in **9b**. This is supported by the isomerization of **1b** to the corresponding *trans* compound **2b**, by the action of cold concentrated sulfuric acid.[8] Although the *trans* compound **2b** has a cracking pattern in the mass spectrometer almost identical with that of the *cis* compound **2a**, the 3-CH_3 is shifted in the nmr spectrum to 1.22 ppm, compared with 1.08 ppm for the 3-CH_3 in the *cis* compound **1a**. This is analogous to the relationships observed in the 3-CH_3 of the *cis–trans* pair **1a** and **2a**, where the configurations are established by several unequivocal methods.[2]

Another approach to introducing a functional group at position 4 involved the side-chain bromination of 3-methyl-4,6-dichlorophenyl acetate (**10a**); the benzyl bromide **10b** was converted to the methoxymethylphenol **10c** by sodium methoxide, and from the latter was prepared the keto ether **10d**. This could not be cyclized to the corresponding benzofuran.



10a, R = CH_3; R′ = Ac
b, R = CH_2Br; R′ = Ac
c, R = CH_2OCH_3; R′ = H
d, R = CH_2OCH_3; R′ = $CH_3OCCHCH_2CH_2CH(CH_3)_2$

Experimental Section[9]

***cis*-2-Isoamyl-3,4-dimethyl-2,3-dihydrobenzofuran (1a).**—Platinum oxide (Englehard Industries, 100 mg) was added to a solution of 7.6 g (0.035 mol) of 2-isoamyl-3,4-dimethylbenzofuran in 200 ml of absolute ethanol, and the mixture was hydrogenated at atmospheric pressure. After 8 hr the uptake of hydrogen (0.035 mol) ceased. Platinum metal was removed by filtration and the alcohol was removed by evaporation under reduced pressure. Distillation through a Vigreux column gave 7.0 g (93% yield) of a colorless liquid, bp 148–150° (10 mm). Vapor phase chromatography on a 20% Apiezon column showed that this product was about 98% pure. Co-injection with authentic *cis*-2-isoamyl-3,4-dimethyl-2,3-dihydrobenzofuran showed only one peak. The nmr and ir spectra were identical with those reported by Hayward.[2,10]

Birch Reduction of *cis*-Isoamyl-3,4-dimethyl-2,3-dihydrobenzofuran (1a).—A solution of 2.18 g (0.01 mol) of the 2,3-dihydrobenzofuran 1a in 23 ml of *t*-butyl alcohol and 100 ml of ethyl ether was added slowly to 50 ml of liquid ammonia. Lithium wire (1.13 g, 0.16 g-atom) was added over about 15 min to the solution in small pieces. The mixture was allowed to reflux with stirring for 2 hr; absolute methanol (20 ml) was added and the blue color disappeared. The ammonia was evaporated by gentle warming and 50 ml of ethyl ether was added, followed by 100 ml of ice water, added dropwise. The ether layer was separated and the aqueous layer was extracted with ether. The combined ether solutions yielded an oil whose nmr spectrum (2.0 g) showed continuous complex absorption from 0.85 to 2.0 ppm, isoamyl, allylic, and ring protons; a multiplet at 2.65 ppm, tertiary allylic proton; a multiplet at 3.87 ppm, proton adjacent to the ether linkage; and a multiplet at 5.55 ppm, vinyl proton. The low integration of olefinic protons indicated the presence of over-reduced product. The lack of absorption above 6 ppm indicated the absence of starting material.

Hydrolysis of the Crude Birch Reduction Product.—The light yellow oil from the above Birch reduction of *cis*-2-isoamyl-3,4-dimethyl-2,3-dihydrobenzofuran was dissolved in 10 ml of 3% oxalic acid in 9:1 dioxane–water. After stirring at room temperature for 20 hr, 100 ml of water was added. The mixture was extracted with ether which was washed with 5% sodium carbonate and with distilled water; the combined washings were extracted twice with ether. The combined ether solutions were dried and the solvent was evaporated, yielding a yellow oil which was chromatographed on 90 g of neutral Woelm alumina, activity II. Elution with 180 ml of petroleum ether (bp 30–60°) gave 0.98 g of a clear colorless liquid, whose ir spectrum showed no hydroxyl or carbonyl absorption; the nmr spectrum showed continuous complex absorption from 0.8 to 2.0 ppm and weak, complex absorptions centered at 2.2 and 3.9 ppm, with no absorption in the aromatic region. These spectra indicated that this material was a mixture of hexahydrobenzofurans such as 4a as reported by Hayward.[10] Elution with ether gave 0.340 g of a viscous slightly yellow oil. The ir spectrum showed a broad hydroxyl absorption at 3420 cm^{-1} and absorptions in the carbonyl region at 1710 and 1670 and a weak band at 1620 cm^{-1}; the 1670-cm^{-1} band was stronger than the 1710-cm^{-1} band. The second fraction was a mixture of the saturated and α,β-unsaturated keto alcohols. These mixtures are similar to those obtained by Hayward.[10]

Birch Reduction of *cis*-2-Isoamyl-3,4-dimethyl-2,3-dihydrobenzofuran (2a) Using a 3-g-atom Excess of Lithium.—A solution of 2.18 g (0.01 mol) of *cis*-2-isoamyl-3,4-dimethyl-2,3-dihydrobenzofuran in 25 ml of anhydrous ether and 6.5 ml of *t*-butyl alcohol was slowly added to 50 ml of liquid ammonia. Lithium (0.35 g, 0.05 g-atom) was added in small pieces over a period of about 20 min. The mixture was treated as above, and the nmr spectrum of the resulting oil (2.1 g) showed both olefinic and aromatic absorptions, indicating incomplete reduction.

Hydrolysis of the Birch Reduction Product in 3% Oxalic Acid in THF and Water.—The reduction product (2.1 g) from the above reaction was stirred in 10 ml of 3% oxalic acid in 9:1 THF:water for 2 hr at room temperature and diluted with 100 ml of water. It was worked up as above, and the resulting 2.0 g of oil was chromatographed on 90 g of neutral Woelm alumina, activity II. Elution with petroleum ether gave 0.5 g of a colorless oil, the nmr spectrum of which was identical with that of the 2,3-dihydrobenzofuran 1a. Low integration of protons in the aromatic region of the spectrum indicated the presence of over-reduced products. Elution with ether gave 1.5 g of a viscous, yellow oil, whose ir spectrum had hydroxyl absorption at 3420 cm^{-1} and carbonyl absorptions at 1710 and 1670 cm^{-1}. The nmr spectrum showed no vinyl proton absorption, indicating that very little β,γ-unsaturated ketone was present. The mixture was about 75% α,β-unsaturated ketone, based on the relative intensities of the ir bands at 1710 (saturated carbonyl) and 1670 cm^{-1} (α,β-unsaturated carbonyl). Attempts to obtain the unsaturated ketone pure, by chromatography on alumina, silica gel, and alumina–silver nitrate (6%) failed. The above mixture was used for the following experiments.

***erythro*-2-(1,5-Dimethyl-2-acetoxyhexyl)-3-methylcyclohex-2-enone (6b).**—The mixture of saturated and unsaturated keto alcohols 5a and 6a (1.2 g, 0.005 mol), was dissolved in 4 ml of pyridine and 2 ml of acetic anhydride. The mixture was allowed to stand at room temperature for 24 hr and worked up as usual. The brown viscous product (1.1 g) was chromatographed on neutral Woelm alumina, activity II; elution with petroleum ether gave 100 mg of colorless oil, the ir spectrum of which was identical with the dihydrobenzofuran 1a. Elution with ether gave 849 mg of a yellow oil, whose ir spectrum showed strong absorptions at 1742 (ester carbonyl), 1712 (saturated carbonyl), 1675 (α,β-unsaturated carbonyl), and 1244 cm^{-1} (ester C–O). This spectrum indicated that this material was a mixture of saturated and α,β-unsaturated ketoacetates in a ratio of about 1:3. These esters were not separable by column chromatography on alumina, silica gel, or alumina impregnated with 6% silver nitrate.

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(8) D. P. Brust, D. S. Tarbell, S. M. Hecht, E. C. Hayward, and L. D. Colebrook, *J. Org. Chem.*, **31**, 2192 (1966).

(9) Microanalyses were done by the Galbraith Laboratories, Knoxville, Tenn.; all melting points and boiling points are uncorrected. Ir spectra were taken on a Beckman IR-10 spectrophotometer in KBr disks, solution or as liquid films, as indicated for each compound. Nmr spectra were recorded on a Varian A-60 spectrometer in $CDCl_3$ or CCl_4; chemicals shifts are reported in parts per million, with $(CH_3)_4Si$ as internal standard. Varian-Aerograph Model 90-P, A90-P or F & M Models 720 or 700 were used for vpc.

(10) E. C. Hayward, Ph.D. Thesis, University of Rochester, 1967.

***erythro*-2-(1,5-Dimethyl-2-acetoxyhexyl)-3-methylcyclohexanone (6b) from Hydrogenation of the Mixture of Saturated and Unsaturated Acetates.**—The mixture of saturated and unsaturated ketoacetates obtained above (335 mg, 0.0014 mol, based on unsaturated keto ester) was dissolved in 15 ml of absolute methanol, and 75 mg of 30% palladium on carbon was added. The mixture was hydrogenated at atmospheric pressure. The uptake of hydrogen stopped after 14 hr, when 32.4 ml had been used. The ir spectrum of the crude product showed carbonyl bands at 1745 (ester) and 1710 cm^{-1} (carbonyl), with no absorption near 1670 cm^{-1}.

Vapor phase chromatography of the above mixture on a 6 ft × 0.25 in. 1% SE-30 column of the mass spectrometer (temperature program 3°/min starting at 110°) gave nine peaks. The first peak was small and was not identified. Minor peaks eluting at 130, 132, and 133° were identified by the cracking patterns as diastereoisomeric perhydrobenzofurans **7a**. A minor peak at 138° was the saturated ketoacetates **6b**. The last eluting peak, 166°, was minor and was not identified. The peaks identified as the desired saturated ketoacetates were present in an approximate ratio of 1:3:3, in order of their elution temperatures.

Hydrogenation of the Mixture of Saturated and Unsaturated Keto Alcohols Obtained from Birch Reduction of *cis*-2-Isoamyl-3,4-dimethyl-2,3-dihydrobenzofuran (1a). Acetylation of the Hydrogenation Mixture.—The keto alcohol mixture (1.13 g), in 15 ml of methanol with 100 mg of 30% palladium on carbon, was stirred at room temperature under hydrogen at 1 atm. After about 12 hr, hydrogen uptake ceased at 250 ml. The catalyst was removed by filtration and the solvent by reduced pressure evaporation. The resultant oil, about 1.0 g, was dissolved in 4 ml of pyridine and 2 ml of acetic anhydride was added. The mixture was allowed to stand at room temperature for 48 hr. The excess pyridine and acetic anhydride was removed by slow evaporation under reduced pressure. Vapor phase chromatography on the 6 ft × 0.25 in. 1% SE-30 column of the mass spectrometer (temperature program 3°/min starting at 110°) showed 17 peaks. Of these, 13 were identified on the basis of the mass spectra scans. They are, in order of their elution temperatures, 125, 126, 130, and 133°, diastereoisomers of the perhydrobenzofuran **7a**; 137 and 140°, saturated keto alcohols; 142, 143, and 156°, saturated ketoacetates **6b**; 160°, minor, and 162°, major, identified as the unsaturated ketoacetate **5b** and its double-bond isomer; 164°, minor, and 169°, massive, identified as unsaturated alcohols. The ratio of the saturated ketoacetate diastereoisomers, approximated by inspection, was 1:3:4 in order of eluting temperature. There were minor peaks eluting at 121, 154, 173, and 226°, which were not identified.

4,6-Dichloro-3-methoxyphenol (8a).—3-Methoxyphenol[11] (108 g) was chlorinated with 270 g of sulfuryl chloride at 0° over a 3-hr period; the reaction mixture was warmed on a steam bath for 30 min; and the product was distilled through an 8-in. Vigreux column. One fraction was collected [bp 82–85° (0.4 mm), 155 g, 80% yield], which crystallized completely on standing. Two recrystallizations from petroleum ether gave analytically pure 4,6-dichloro-3-methoxyphenol. The ir and nmr spectra were in complete agreement with the structure assigned.

Anal.. Calcd for $C_7H_6Cl_2O_2$: C, 43.55; H, 3.13. Found: C, 43.69; H, 2.95.

3-(4,6-Dichloro-3-methoxyphenoxy)-6-methyl-2-heptanone (8b).—This was prepared from the above phenol (100 g) and 3-bromo-6-methyl-2-heptanone[12] (113 g) in dry acetone with finely powdered potassium carbonate (70 g) and a few milligrams of potassium iodide. The product was 139 g (84% crude yield) of a cloudy yellow oil; a portion of this product (4.6 g) was chromatographed on 50 g of Woelm neutral alumina, activity I. Elution with 90 ml of petroleum ether gave 2.3 g of an oil; elution with a second 90-ml portion of petroleum ether gave 2.0 g of a clear yellow oil. The ir spectra of these two oils were identical. Vapor phase chromatography of the combined fractions on a 25% QF-1 column showed only one peak eluting at 10.3 min. An analytical sample was prepared by collection of this peak as a colorless quite viscous oil, followed by evaporative distillation (bath temperature 110°, pressure 0.025 mm). The ir spectrum (CCl_4) showed strong absorptions (cm^{-1}) at 1718, ketone; 1595, aromatic; 1450–1500, aliphatic; 1360, 1385, *gem*-dimethyl group; 1205, ether C–O; and 880, 1,2,4,5-tetrasubstituted aromatic ring. The nmr spectrum (CCl_4) showed a doublet at 0.9 ppm (6 H), *gem*-dimethyl protons; a complex envelope from 1.17 to 2.1 (5 H), chain protons; a singlet at 2.17 (3 H), methyl protons adjacent to carbonyl; a singlet at 3.78 (3 H), methoxyl protons; a triplet at 4.49 (1 H), tertiary proton adjacent to carbonyl and ether linkage; a singlet at 6.43 (1 H), aromatic proton; and a singlet at 7.32 (1 H), aromatic proton.

Anal. Calcd for $C_{15}H_{20}Cl_2O_3$: C, 56.43; H, 6.32. Found: C, 56.72; H, 6.27.

2-Isoamyl-3-methyl-4-methoxy-5,7-dichlorobenzofuran.—3-(4,6-Dichloro-3-methoxyphenoxy)-6-methyl-2-heptanone (122 g, 0.38 mol) was cooled in an ice bath, and similarly cooled concentrated sulfuric acid (150 ml) was added with rapid stirring during about 15 min. After the addition was complete, the dark red mixture was stirred at 0° for 15 min and poured over 400 g of ice. The dark oily precipitate which formed was extracted with ether; the combined extracts were washed with water, twice with 10% sodium carbonate, and again with water. The washings were back-extracted with ether. The combined ether solutions yielded 75 g of red oil, which was chromatographed on Woelm neutral alumina, activity I. Elution with 2 l. of petroleum ether provided 70 g (61% yield) of a colorless liquid. Vapor phase chromatography of this liquid on a 10 ft × 0.25 in. UCON Polar column showed one peak with a retention time of 14.5 min. This single peak was collected and the resulting clear colorless liquid was evaporatively distilled (bath temperature 90°, pressure 0.5 mm). The nmr spectrum had a doublet at 0.92 ppm (6 H), *gem*-dimethyl group protons; a multiplet at 1.58 (3 H), side-chain protons; a singlet at 2.22 (3 H), allylic methyl protons; a triplet at 2.67 (2 H), allylic side-chain protons; a singlet at 3.86 (3 H), methoxyl protons; and a singlet at 7.09 (1 H), aromatic proton.

Anal. Calcd for $C_{15}H_{18}Cl_2O_2$: C, 59.81; H, 6.02. Found: C, 59.69; H, 6.04.

2-Isoamyl-3-methyl-4-methoxybenzofuran (9b).—To a solution of 24 g (0.08 mol) of 2-isoamyl-3-methyl-4-methoxy-5,7-dichlorobenzofuran (**9a**) in 50 ml of absolute ethanol was added 13.1 g (0.16 mol) of anhydrous sodium acetate, 9.6 g (0.16 mol) of glacial acetic acid, and 0.5 g of 10% Pd-C (Matheson Coleman and Bell).

The mixture was shaken in a Parr apparatus under 50 psi of hydrogen; hydrogen uptake (0.16 mol) ceased after 20 hr. The catalyst and salts were removed by filtration through a Celite mat, the solvents by evaporation under reduced pressure, and the cloudy residual oil was taken up in ether; the ether solution was washed with water, 10% sodium carbonate, and again with water, and dried. The product, distilled through an 8-in. Vigreux column, yielded 18.0 g (96% yield) of a clear colorless liquid, bp 93–95° (0.3 mm). Vapor phase chromatography on a 25% FFAP column showed peaks at 16.0, 22.8, and 30 min. The peak at 22.8 min was about 90% of the mixture, and the peak at 16 min about 10%. The peak at 30 min was very small and was identified as starting material by co-injection with 2-isoamyl-3-methyl-4-methoxy-5,7-dichlorobenzofuran. The peak at 16.0 min was identified in later experiments as *cis*-2-isoamyl-3-methyl-4-methoxy-2,3-dihydrobenzofuran (**1b**). The peak at 22.8 min was collected and evaporatively distilled (bath temperature 80°, 0.05 mm). The nmr spectrum (CCl_4) showed a doublet at 0.92 ppm (6 H), *gem*-dimethyl protons; a complex multiplet at 1.55 (3 H), side-chain protons; a singlet at 2.26 (3 H), allylic methyl protons; a triplet at 2.58 (2 H), allylic side chain protons; a singlet at 3.70 (3 H), methoxyl protons; a multiplet at 6.37 (1 H), aromatic proton between two other protons; and a multiplet at 6.89 (2 H), aromatic protons adjacent to ether linkages.

Anal. Calcd for $C_{15}H_{20}O_2$: C, 77.55; H, 8.68. Found: C, 77.41; H, 8.72.

Hydrogenation of 2-Isoamyl-3-methyl-4-methoxybenzofuran (9b) with Platinum Catalyst. 2-Isoamyl-3-methylperhydrobenzofuran (7b).—To a solution of 11.6 g of 2-isoamyl-3-methyl-4-methoxybenzofuran (0.05 mol) in 50 ml of methanol was added 100 mg of platinum oxide (Engelhard Industries); the mixture was shaken under hydrogen at 50 psi. In less than 1 hr, 0.05 mol of hydrogen was taken up. The platinum metal was removed by filtration, the solvent was removed by reduced pressure evaporation; the colorless oil was distilled through a Vigreux column. Three fractions were collected. The first fraction (3.1 g), bp 59° (0.15 mm), showed no aromatic or allylic protons in the nmr spectrum, indicating that it was a perhydrobenzofuran. The two high-boiling fractions were shown by vapor phase

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(11) W. H. Perkin, J. N. Ray and R. Robinson, *J. Chem. Soc.*, 945 (1926).

(12) *Cf.* D. S. Tarbell, S. E. Cremer, *et al.*, *J. Amer. Chem. Soc.*, **83**, 3112 (1961).

chromatography to be identical with the starting material. Hydrogenation over platinum catalyst at atmospheric pressure gave similar results.

Vapor phase chromatography of the fraction boiling at 59° (0.15 mm) on a 25% QF-1 column showed one peak with a retention time of 5.1 min. This peak was collected and evaporatively distilled (bath temperature, 60°; 0.5 mm). The ir spectrum (liquid film) had bands at 1390 and 1370, *gem*-dimethyl doublet, and 1080 cm^{-1}, C–O stretching of ether. The nmr spectrum (CCl_4) had two partially superimposed doublets centered at 0.9 ppm (9 H, total), methyl protons; a complex multiplet from 1.0 to 2.1 (15 H), ring and chain protons; and a multiplet at 3.72 (2 H), protons adjacent to ether linkages.

Anal. Calcd for $C_{14}H_{26}O$: C, 79.94; H, 12.46. Found: C, 80.12; H, 12.41.

Hydrogenation of 2-Isoamyl-3-methyl-4-methoxybenzofuran (9b) with 10% Palladium-on-Carbon Catalyst.—Palladium on carbon 10% (0.5 g) was added to a solution of 11.6 g (0.05 mol) of 2-isoamyl-3-methyl-4-methoxybenzofuran in 50 ml of methanol. The mixture was shaken under hydrogen at 50 psi; after 24 hr no hydrogen had been taken up. The catalyst was removed, 0.5 g of fresh catalyst was added, and the mixture was again shaken under hydrogen at 50 psi; after 24 hr no hydrogen had been taken up. The catalyst was removed by filtration and the solvent evaporated under reduced pressure. The liquid residue was dissolved in 40 ml of methanol and 10 ml of glacial acetic acid was added along with 0.5 g of 10% palladium on carbon. The mixture was shaken under hydrogen at 50 psi. After 12 hr, 0.05 mol of hydrogen had been taken up. The catalyst was removed by filtration, most of the solvent by evaporation under reduced pressure, and the residue was dissolved in ether, washed with water, 10% sodium carbonate, and again with water. The combined washings, basic to litmus, were back-extracted with ether. The combined ether solutions were dried, filtered, and concentrated under reduced pressure. Vapor phase chromatography on a 25% FFAP column showed peaks at 5.2, 20, and 23 min. The peak at 5.2 min, about 30% of the mixture, was shown by co-injection to be due to the perhydrobenzofuran **7b**. The peaks at 20 and 23.5 min were shown by co-injection to be the 2,3-dihydrobenzofuran **1b** and the benzofuran **9b** in approximately the same ratio as the starting material.

Hydrogenation of 2-Isoamyl-3-methyl-4-methoxybenzofuran (9b) with 30% Pd–C. *cis*-2-Isoamyl-3-methyl-4-methoxy-2,3-dihydrobenzofuran (1b).—To a solution of 23.2 g (0.1 mol) of 2-isoamyl-3-methyl-4-methoxybenzofuran (**9b**) in 20 ml of absolute ethanol was added 2.5 g of 30% Pd–C (Engelhard Industries). The mixture was stirred under hydrogen at atmospheric pressure; after 5 hr, 500 ml of hydrogen (about 20% of the theoretical amount) had been taken up. A few microliters of the reaction mixture was injected onto a 5 ft × 0.25 in. 3% SE-30 column (column temperature, 172°; flow rate, 60 ml of He/min). Two peaks were observed with retention times of 5.5 and 6.8 min. These were identified by co-injection as the same two peaks in the starting material. The relative concentration of the peak at 5.5 min had risen from about 5 to 20%. The hydrogenation was continued. After 13 hr a total of 900 ml of hydrogen had been taken up. Vapor phase chromatography (conditions above) at this point showed a third peak at 2.8 min, about 2% of the total mixture. This new peak was identified as the perhydrobenzofuran **7b** by co-injection. The peak at 5.5 min had risen to about 40%. After the theoretical amount of hydrogen had been taken up, the peak at 2.8 min had risen to about 20% and the peak at 5.5 min to 60%. Hydrogenation was continued until the peak at 6.8 min had decreased to 7%. This required 48 hr and 3900 ml of hydrogen (0.134 mol); the 2.8-min peak had increased to 28% and the 5.5-min peak to 65%. The catalyst was removed by filtration through a Celite mat and the solid mixture was washed thoroughly several times with absolute ethanol. The filtrate and washings were combined and the solvent removed by evaporation under reduced pressure. The residue was 23 g of a colorless cloudy liquid. The liquid was distilled through an 8-in. Vigreux column. Two fractions were collected: 6.5 g of colorless liquid, bp 63° (0.15 mm), and 16.0 g of a slightly cloudy colorless liquid, bp 97–105° (0.15 mm). The first was shown by vapor phase chromatography to be of more than 98% purity, and to be identical with the perhydrobenzofuran **7b** previously obtained. Vapor phase chromatography of the high-boiling fraction on a 20% Ucon Polar column gave three peaks with retention times 6.1, 11.0, and 17.0 min in a ratio of 1:40:4, respectively. The peaks at 11.0 and 17.0 min were identified by co-injection as the two components in the mixture before hydrogenation. The peak at 11.0 min was collected and evaporatively distilled (bath temperature 70°, 1 mm). Reinjection of the collected material showed that it was about 98% pure *cis*-2,3-dihydrobenzofuran **1b**; the nmr spectrum showed two close doublets at 0.92 and 1.08 ppm (total 9 H), *gem*-dimethyl and homobenzylic methyl protons; a complex envelope from 1.2 to 1.9 (5 H), side-chain protons; a multiplet at 3.28 (1 H), benzylic proton; a singlet at 3.69 (3 H), methoxy protons; a multiplet at 4.36 (1 H), proton adjacent to the ether linkage; two close doublets at 6.18 and 6.32 (total 2 H), aromatic protons; and a triplet at 6.81 (1 H), aromatic proton.

Anal. Calcd for $C_{15}H_{22}O_2$: C, 76.88; H, 9.46. Found: C, 77.02; H, 9.53.

The high-boiling fraction (15.5 g) was redistilled on an 18-in. annular Teflon spinning-band column. Two fractions were collected: 14.0 g (60% yield) bp 122° (0.5 mm), and 1.3 g, bp 124° (0.5 mm). Vapor phase chromatography of the low-boiling fraction showed that it was more than 98% pure **1b**; co-injection with the above analytical sample showed that the fraction boiling at 122° (0.5 mm) was *cis*-2-isoamyl-3-methyl-4-methoxy-2,3-dihydrobenzofuran.

Attempts to reduce the benzofuran **9b** to the 2,3-dihydro compound **1b** by diimide failed.[13]

***trans*-2-Isoamyl-3-methyl-4-methoxy-2,3-dihydrobenzofuran (2b).**—To 2 g of *cis*-isoamyl-3-methyl-4-methoxy-2,3-dihydrobenzofuran was added 5 ml of ice-cold concentrated sulfuric acid; the mixture was kept in the refrigerator for 16 hr, after which it was poured over 50 g of ice. The product, after the usual procedures, was 0.54 g of a red liquid. Vapor phase chromatography on a FFAP column showed peaks at 5.2, 16.7, 19.8, and 23.5 min in a ratio of 1:60:40:1. The peaks at 5.2, 16.7, and 23.5 min were identified, by co-injection with the appropriate known compounds, as the perhydrobenzofuran **7b**, *cis*-2-isoamyl-3-methyl-4-methoxy-2,3-dihydrobenzofuran (**1b**), and 2-isoamyl-3-methyl-4-methoxybenzofuran (**9b**), respectively. The peak at 16.7 min was collected and evaporatively distilled (bath temperature 80°, 0.1 mm). The mass spectrum was identical with that of the *cis*-dihydrobenzofuran **1b**. The nmr spectrum of the collected peak was nearly identical with that of the *cis* compound, except that the absorption of the 3-methyl group protons was shifted to 1.22 ppm from 1.07 ppm for the *cis* compound.

***cis*-2-Isoamyl-3-methylketo-2,3,4,5,6,7-hexahydrobenzofuran (4b).**—A solution of 7.24 g (0.031 mol) of *cis*-2-isoamyl-3-methyl-4-methoxy-2,3-dihydrobenzofuran in 70 ml of anhydrous ethyl ether and 70 ml of *t*-butyl alcohol was added slowly to 150 ml of liquid ammonia. Lithium wire (0.75 g, 0.107 g-atom) was added with rapid stirring over a period of 20 min. After the mixture had refluxed for 30 min, a second portion of 0.75 g of lithium wire was added. The procedure for the reduction of **1a** was followed essentially, and 7.2 g of a slightly yellow mobile liquid was obtained. The nmr spectrum of this crude material showed no aromatic absorption, indicating complete reduction. A complex multiplet at 4.63 ppm and a singlet at 3.51 suggested the presence of the enol ethers (tetrahydrobenzofurans). The crude mixture in 75 ml of tetrahydrofuran was stirred with 25 ml of 12% aqueous oxalic acid at room temperature for 18 hr. The mixture was diluted with water, the tetrahydrofuran layer was separated, and the aqueous layer was extracted with ether. The combined tetrahydrofuran and ether solutions were washed with water, 10% sodium carbonate, and again with water. The basic washings were back-extracted with 50 ml of ether. The combined organic solutions were worked up as usual, and concentrated by evaporation under reduced pressure. The ir spectrum of the residual oil, 6.8 g, showed a hydroxyl band at 3440 cm^{-1} and a strong broad band from 1620 to 1680 cm^{-1}. The product was chromatographed on Woelm neutral alumina, activity I. Elution with petroleum ether produced 0.1 g of a colorless liquid with an ir spectrum identical with that of the starting material. Elution with ether gave 5.47 g of a light yellow oil, whose ir and nmr spectra showed that it was the deisired 4-keto compound **4b**. The ir spectrum had bands at 1640 and 1680 cm^{-1}, O—C=C—C=O; and 1195 and 1245, C—O. The nmr (CCl_4) had a multiplet centered at 4.51 ppm (1 H), proton adjacent to ether linkage; a multiplet centered at 3.09 (1 H),

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[13] E. J. Corey, W. L. Mock, and D. J. Pasto, *Tetrahedron Lett.*, 347 (1961); S. Hünig, H. R. Muller, and W. Thier, *ibid.*, 353 (1961); R. S. Dewey and E. E. van Tamelen, *J. Amer. Chem. Soc.*, **83**, 3729 (1961); C. E. Miller, *J. Chem. Educ.*, **42**, 254 (1965).

tertiary allylic proton; 2.2 (4 H), a multiplet, allylic protons and protons adjacent to a carbonyl bond; a complex envelope from 1.1 to 1.8 (7 H), ring and side-chain protons; and two superimposed doublets at 0.95 (9 H), three sets of methyl group protons. Vapor phase chromatography of this liquid on a 5 ft × 0.25 in. UCON Polar column showed only one peak with a retention time of 31 min. This peak was collected and evaporatively distilled (bath temperature 90°, 0.05 mm).

Anal. Calcd for $C_{14}H_{22}O_2$: C, 75.63; H, 9.97. Found: C, 75.52; H, 9.92.

The yield of *cis*-2-isoamyl-3-methyl-4-keto-2,3,4,5,6,7-hexahydrobenzofuran (**4b**, 5.47 g) was 79%.

4,6-Dichloro-3-bromomethylphenyl Acetate (10b).—N-Bromosuccinimide (17.8 g, 0.1 mol), which had been freshly recrystallized from water and dried in a vacuum desiccator over phosphorus pentoxide, was refluxed in a solution of 21.8 g (0.1 mol) of 4,6-dichloro-3-methylphenyl acetate[14] in 200 ml of carbon tetrachloride, with the addition of 200 mg of benzoyl peroxide. Refluxing was continued for 4 hr and the mixture was allowed to stand overnight. The succinimide was removed by filtration and washed several times with carbon tetrachloride. The solvent was evaporated under vacuum at 35° and the resulting yellow oil was taken up in 100 ml of petroleum ether. After standing in the freezer overnight, the product crystallized, giving 18.4 g (mp 38–46°) of yellow oily crystals. Concentration of the mother liquor gave an additional 6.0 g of product. Recrystallization, with decolorization with activated charcoal, from petroleum ether gave 22.0 g (mp 51–53°, 74% yield). An analytical sample (mp 52.2–53°) was prepared by four recrystallizations from petroleum ether. The ir and nmr spectra were in agreement with those for the structure.

Anal. Calcd for $C_9H_7BrCl_2O_2$: C, 36.27; H, 2.37. Found: C, 36.28; H, 2.52.

4,6-Dichloro-3-methoxymethylphenol (10c).—The bromomethyl compound **10b** (19.6 g) was treated dropwise at room temperature with a solution of 4.8 g of sodium in 75 ml of dry methanol and was stirred overnight. Water (50 ml) was added carefully, and the mixture was refluxed for 2 hr. Conventional work-up gave an oil, which was distilled through a 4-in. Vigreux column. The main fraction was 10.6 g (74% yield) of a colorless liquid, bp 113–116° (0.6 mm), which crystallized, mp 61–64°. An analytical sample was prepared by three recrystallizations from petroleum ether and sublimation (bath temperature 60°, 0.5 mm). The pure sample of **10c** had mp 68–69.5°. The ir spectrum ($HCCl_3$) had bands at 3400 cm^{-1}, hydroxyl; 1080, 1170, and 1200, ether and phenol C–O stretching. The nmr spectrum (CCl_4) showed singlets at 3.43 ppm (3 H), methoxy protons; 4.42 (2 H), benzylic methylene protons; 6.59 (1 H), broad, phenolic protons; 7.02 (1 H) and 7.19 (1 H), aromatic protons.

Anal. Calcd for $C_8H_8Cl_2O_2$: C, 46.40; H, 3.89. Found: C, 46.51; H, 3.79.

3-(4,6-Dichloro-3-methoxymethylphenyl)-6-methyl-2-heptanone (10d) was prepared in the usual way from 9.0 g of the phenol, 8.9 g of 3-bromo-6-methyl-2-heptanone, 2.0 g of potassium carbonate, and a few milligrams of potassium iodide in 25 ml of dry acetone. Vapor phase chromatography of the resulting liquid on a 25% QF-1 column showed peaks at 1.7 and 8.3 min. The second peak, **10d**, about 90% of the mixture, was collected and evaporatively distilled (bath temperature 90°, 0.5). The ir spectrum (liquid film) had bands at 1720 cm^{-1}, carbonyl stretching; 1250, 1195, 1168, 1105, and 1080, ether stretching bands; and a doublet at 1360 and 1380, *gem*-dimethyl group. The nmr spectrum (CCl_4) had a doublet at 0.92 ppm (6 H), *gem*-dimethyl group; a complex envelope from 1.1 to 1.9 (5 H), aliphatic methylene and methine protons; a singlet at 2.23 (3 H), methyl ketone protons; a singlet at 3.40 (3 H), methoxyl protons; a singlet at 4.37 superimposed upon a multiplet at 4.50 (3 H, total), benzylic ether and ketone ether protons; a singlet at 6.95 (1 H), aromatic proton; and a singlet at 7.32 (1 H), aromatic proton.

Anal. Calcd for $C_{16}H_{22}Cl_2O_3$: C, 57.66; H, 6.65. Found: C, 57.59; H, 6.51.

Attempted Cyclization of 3-(4,6-Dichloro-3-methoxymethylphenoxy)-6-methyl-2-heptanone (10d).—3-(4,6-Dichloro-3-methoxymethylphenoxy)-6-methyl-2-heptanone (2.0 g, 0.006 mol), was cooled in an ice bath to 0°. Ice-cold sulfuric acid (5 ml) was added and the mixture was stirred for 12 min. The dark red mass was mixed thoroughly with 50 g of ice. The brown oily precipitate was extracted into five 25-ml portions of ethyl ether. The combined ether extracts were washed with water, 10% sodium hydroxide, and again with water and dried. The nmr and ir spectra of the viscous liquid residue were identical with those of the starting material. The experiment was repeated, replacing the sulfuric acid with polyphosphoric acid, at 0° for 2 hr, and at room temperature for 18 hr. When these mixtures were worked up as above, only starting material could be detected by nmr or ir spectra.

Registry No.—**1a**, 24099-57-8; **1b**, 24099-58-9; **2b**, 24099-59-0; **4b**, 24099-60-3; **6b**, 24099-61-4; **7b**, 24099-62-5; **8a**, 18113-13-8; **8b**, 24099-64-7; **9a**, 24099-65-8; **9b**, 24099-66-9; **10b**, 24099-67-0; **10c**, 24099-68-1; **10d**, 24099-69-2.

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[14] S. E. Cremer and D. S. Tarbell, *J. Org. Chem.*, **26**, 3653 (1961).

Reaction of Hexaalkyl- and α,α'-Dichlorotetraalkyldistannoxanes with Cyclic Carbonates

SHIZUYOSHI SAKAI, YOJI FUJIMURA, AND YOSHIO ISHII

Department of Synthetic Chemistry, Faculty of Engineering, Nagoya University, Chikusaku, Nagoya, Japan

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Hexaalkyldistannoxanes react with equimolar amounts of ethylene or propylene carbonate at 80–180° to give bis(trialkyltin) alkylene glycolates and/or 2-dialkylstanna-1,3-dioxolanes. However, α,α'-dichlorotetraalkyldistannoxane gives rise to 2-dialkylstanna-1,3-dioxolane exclusively. Formation of the stannadioxolanes was confirmed through a new cyclization reaction of bis(tributyltin) ethylene glycolates, $R_3SnOC_2H_4OSnR_3$, and their cyclizing tendencies were as follows: $ClEt_2Sn, Me_3Sn > Et_3Sn > n\text{-}Bu_3Sn$. Reactions of hexaethyl- and hexabutyldistannoxanes with ethylene monothiolcarbonate at higher temperature afford bis(trialkyltin) monothiolethylene glycolates, together with small amounts of 2-dialkylstanna-1-oxa-3-thialanes.

Davies and coworkers have reported the reaction of hexabutyldistannoxane with ethylene carbonate to afford bis(tributyltin) ethylene glycolate in a good yield.[1] In the course of our study on the reaction of distannoxane with cyclic carbonate, we obtained a cyclic organotin alkoxide, instead of the ethylene glycolate, for instance, 2-diethylstanna-1,3-dioxolane from hexaethyldistannoxane and ethylene carbonate. We investigated the similar reactions of four kinds of the distannoxanes with ethylene or propylene carbonate and ethylene thiolcarbonate at various temperature, which provided a new type of cyclization reaction of sterically less hindered bis(trialkyltin)·alkylene glycolate

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[1] A. G. Davies, P. R. Palan, and S. C. Vasishtha, *Chem. Ind.* (London), 229 (1967).