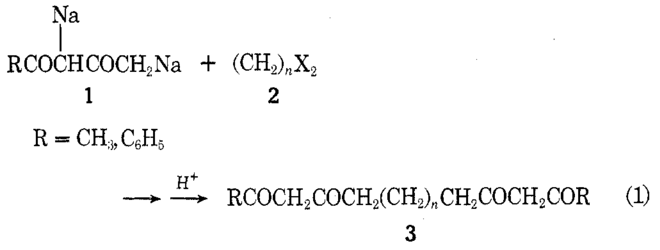
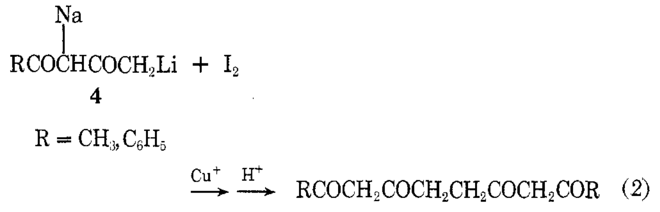
usually used for coupling in the absence of cuprous ions (eq 2).[2]



$$\underset{\mathbf{1}}{RCO\overset{Na}{C}HCOCH_2Na} + \underset{\mathbf{2}}{(CH_2)_nX_2} \quad R = CH_3, C_6H_5 \longrightarrow \xrightarrow{H^+} \underset{\mathbf{3}}{RCOCH_2COCH_2(CH_2)_nCH_2COCH_2COR} \quad (1)$$



$$\underset{\mathbf{4}}{RCO\overset{Na}{C}HCOCH_2Li} + I_2 \quad R = CH_3, C_6H_5 \xrightarrow{Cu^+} \xrightarrow{H^+} RCOCH_2COCH_2CH_2COCH_2COR \quad (2)$$

We now report that sodiolithio-2,4-pentanedione (**4**, R = CH_3) reacts with methylene and ethylene bromide (**2**, n = 1 and 2, respectively) to form the alkylation products **3**. These products were not obtained when the reaction was run under the same conditions in the absence of the copper catalyst. When dibromomethane was used (−63 to 0 °C, 3 h) as the substrate, 2,4,8,10-undecanetetrone was isolated in 8–10% yields. The low yield could be attributed to unreacted starting material (observed by gas chromatography) and intramolecular condensation of the alkylation product.[3] When diiodomethane was used as the substrate, a tar was formed from which the bis-β diketone **3** could not be isolated nor could starting material be detected by gas chromatography.

When 1,2-dibromoethane (**2**, n = 2) was used as substrate with **1** in the presence of cuprous ions 2,4,9,11-dodecanetetrone was isolated as a solid in 25–33% yield. The somewhat low yield of the bis-β diketone may be caused by incomplete crystallization of the low-melting product or intramolecular condensation side reactions[3] since ethylene bromide was shown to be absent from the crude reaction product. When 1,2-dichlorethane was used as the substrate, 2,4-pentanedione and 1,2-dichlorethane were recovered in 52 and 33% yields, respectively. This suggests that E_2 elimination may be the main reaction as in the reaction between disodio-2,4-pentanedione and ethylene chloride in liquid ammonia.[1] This difference in alkylation reactivity of bromo compounds vs. chloro compounds is consistent with previous observations of reactions of some haloacetals[4] and halocarboxylates[5] with dianions of β diketones.

That the alkylation products from these reactions are **3**, n = 1 and 2, respectively, is supported by analogy with homologues, ir and ^1H NMR spectra, and elemental analysis (see Experimental Section).

Experimental Section

Melting points were determined using capillary tubes in a Thomas-Hoover melting point apparatus. Infrared spectra were obtained with a Perkin-Elmer 257 grating infrared spectrophotometer using KBr pellets. The ^1H NMR spectra were obtained using a Varian Model A-60D spectrometer and samples dissolved in CCl_4 with Me_4Si as internal standard.

Condensation of Dibromomethane with 4. The sodiolithio-2,4-pentanedione (0.05 mol)–cuprous chloride (0.0076 mol) reagent was prepared in the THF as described previously.[2] To this mixture at −63 °C under an argon atmosphere was added a solution of 4.4 g (0.025 mol) of dibromomethane in 15 ml of THF over 15 min. After the mixture had stirred for 3 h, the reaction mixture was allowed to warm to 0 °C. It was quenched with ice and acidified with cold concentrated hydrochloric acid. The aqueous phase was extracted three times with 25 ml of ether. The ethereal solution was washed once with 30 ml of saturated sodium chloride solution and dried over anhydrous sodium sulfate.

Removal of solvent afforded about 8.0 g of a green, viscous liquid containing 2,4-pentanedione and dibromomethane as major components (VPC analysis). It was triturated in absolute ethanol and petroleum ether (bp 35–60 °C) and cooled in liquid nitrogen to afford 8–10% of 2,4,8,10-undecanetetrone as a light yellow solid, mp 59–60 °C. The solid was enolic to ferric chloride solution (red-brown color): ir (CCl_4) 2980, 2950, 1730, 1710 (m), 1680 cm^{-1}; ^1H NMR (CCl_4) τ 8.0 (s, 6 H) $O{=}CCH_3$, 7.4–7.85 (m, 6 H) $O{=}CCH_2CH_2CH_2C{=}O$, 4.55 (s, 2 H) $-CH{=}C$, and −4.50 (broad hump, 2 H) $-C{=}COH$. Anal. Calcd for $C_{11}H_{16}O_4$: C, 62.27; H, 7.55. Found: C, 62.18; H, 7.46.

The reaction was repeated using diiodomethane. A yellow, viscous liquid (4.8 g) was obtained. VPC analysis showed the absence of 2,4-pentanedione and diiodomethane. No **3**, n = 1, could be isolated from the liquid.

Condensation of 1,2-Dibromoethane with 4. To the sodiolithio-2,4-pentanedione–cuprous chloride reagent at −5 °C under a nitrogen atmosphere was added a solution of 4.7 g (0.025 mol) of 1,2-dibromomethane in 20 ml of dry THF over 15–20 min. The resulting yellowish-brown mixture was stirred for 8 h while the temperature slowly rose to 25 °C. The workup procedure described above afforded 4.0 g of a yellowish-green syrup. The liquid was dissolved in absolute ethanol and cooled in a freezer to obtain 1.4–1.8 g (25–33%) of 2,4,9,11-dodecanetetrone as a pale yellow solid, mp 48–52 °C. The compound gave a red-brown coloration with ferric chloride solutions. Recrystallization from absolute ethanol and vacuum drying gave an analytical sample: mp 52–53 °C; ir (CCl_4) 2960, 2930, 2860, 1715, 1680–1550 (broad), 1460, 1430, 1360, 1235, 1130, 1000 cm^{-1}; ^1H NMR (CCl_4) τ 8.3 (m, 4 H), 8.0 (s, 6 H), 7.7 (m, 4 H), 7.4 (s, ~1.5 H), 4.64 (s, ~2 H), −5.0 (hump, ~2 H).[6] Anal. Calcd for $C_{12}H_{18}O_4$: C, 63.70; H, 8.02. Found: C, 64.17; H, 8.17.

The reaction was repeated using 1,2-dichloroethane. This afforded 8.0 g of a liquid which showed starting materials by VPC. Fractional distillation gave 2.6 g (52%) of 2,4-pentanedione and 0.8 g (33%) of ethylene chloride and about 2.4 g of intractable pot residue.

Registry No.—**3** (R = CH_3; n = 1), 58816-10-7; **3** (R = CH_3; n = 2), 58816-11-8; **4** (R = CH_3), 56580-16-6; cuprous chloride, 7758-89-6; dibromomethane, 74-95-3; 2,4-pentanedione, 123-54-6; 1,2-dibromoethane, 106-93-4; 1,2-dichloroethane, 107-06-2; diiodomethane, 75-11-6.

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(6) NMR spectra of β diketones are complicated by extensive keto-enol tautomerism. It is observed that the absorptions may not be of integral intensity in this series of compounds because of this phenomenon.

A Facile Synthesis of (+)-Pinol from (−)-Carvone

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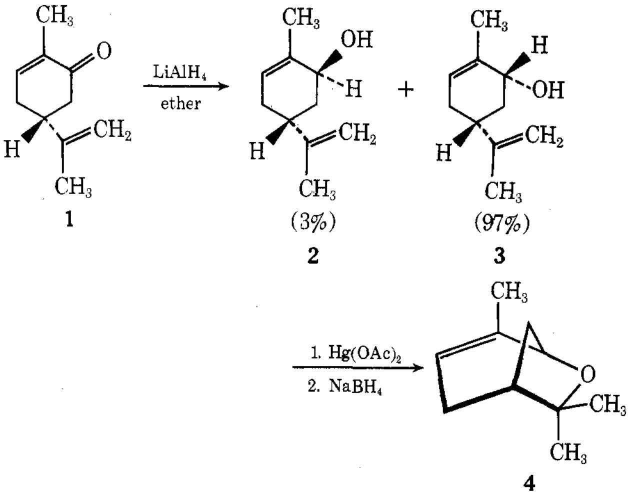
The use of chiral solvents in the determination of optical purity, particularly in the presence of lanthanide shift reagents, has received a great deal of recent attention.[1] In our studies of synthetic schemes leading to chiral solvents, we have developed a new and convenient route to the chiral bicyclic ether, (+)-pinol[2,3] (**4**), by the use of the oxymercuration–demercuration reaction. The route involves the stereospecific reduction of (−)-carvone with lithium aluminum hydride to give (−)-*cis*-carveol (**3**). This is followed by internal oxymercuration with mercuric acetate and reduction with sodium borohydride to give the bicyclic ether in 83% overall yield.[4]



Reduction of (−)-carvone (**1**) with $LiAlH_4$ in ether at room temperature yields a mixture of *trans*- and *cis*-carveols.[5] Lowering the reaction temperature to −78 °C provides a near-quantitative yield of the alcohol containing 97% of the isomer with the desired cis stereochemistry. The alcohol isolated from the reduction was of adequate purity to be used directly in the next step.

Halpern and Tinker[6] have observed that the second-order rate constant for the intramolecular oxymercuration of 1-penten-5-ol to form the cyclic product is more than 10 times greater than the corresponding oxymercuration of 1-butene. This result is explained by the neighboring group participation of the terminal hydroxy group. Treatment of (−)-*cis*-carveol with an equimolar amount of mercuric acetate in a tetrahydrofuran–water mixture provided, after 9 days, greater than 85% conversion to the ring-closed mercurial, **5**, as shown by gas chromatography. The observation that only the (−)-*cis*-carveol undergoes internal oxymercuration and the (−)-*trans*-carveol fails to react provides direct and conclusive proof for the stereochemistry of the carveols.[5b]

Reduction of the mercurial was readily accomplished with sodium borohydride in an aqueous solution containing 0.4 M NaOH. Attempts to reduce the mercurial under less basic conditions or through the use of weaker reducing agents ($NaBH_3CN$) resulted in low yields of **4** with the major fraction of the mercurial reverting to the (−)-*cis*-carveol. This result is presumably due to the acid-promoted deoxymercuration of **5** to form **3** and Hg^{2+} followed by reduction of the Hg^{2+} by borohydride. Deoxymercuration is generally facile in the presence of coordinating anions such as acetate ion.[7] The results further suggest that the rate of reduction of Hg^{2+} is more rapid than the rate of reduction of **5**. Hence, by slowing down the deoxymercuration reaction that forms Hg^{2+} the pathway leading to the reduction of the alkyl mercurial will favorably compete with the pathway leading to the reduction of Hg^{2+}.

Experimental Section

Gas chromatographic analyses were carried out on a Varian Series 1200 gas chromatograph fitted with a 10-ft 3% Carbowax 20M column and temperature programmed from 120 to 170 °C at 10 °C/min. Optical rotations were measured on a Perkin-Elmer 114 polarimeter using 5-ml cells. Refractive indices were determined with a Bausch and Lomb refractometer.

(−)-*cis*-Carveol (3). To 12.0 g (0.316 mol) of $LiAlH_4$ (Alpha Inorganics) in 700 ml of anhydrous diethyl ether cooled to −78 °C was added dropwise 46.6 g (0.310 mol) of (−)-carvone (Aldrich) in 75 ml of anhydrous diethyl ether over a 1-h period. Aliquots were removed, quenched with aqueous H_2SO_4, and the ether layer analyzed directly with gas chromatography. After an additional 30 min, the reduction was complete and the excess $LiAlH_4$ was quenched with a solution of wet ether. This mixture was then poured onto crushed ice; 200 ml of 10% H_2SO_4 was added, and the ether and aqueous layers were separated. The aqueous layer was extracted with two additional 100-ml portions of ether. All the ether layers were combined and dried over anhydrous sodium sulfate, and the solvent was removed in vacuo to yield 46.1 g (97.7%) of a clear liquid containing 97% (−)-*cis*-carveol and 3% (−)-*trans*-carveol. The (−)-carveol mixture obtained was used in the next step without further purification: bp 110 °C (13 mm); $[\alpha]^{25}\mathrm{D}$ −25.8° (neat); $n^{25}\mathrm{D}$ 1.4960 [lit.[5] bp 101 °C (10 mm); $[\alpha]^{25}\mathrm{D}$ −23.9° (neat); $n^{25}\mathrm{D}$ 1.4959]. Anal. Calcd for $C_{10}H_{16}O$: C, 78.89; H, 10.59. Found: C, 78.57; H, 10.60.

(+)-Pinol (4). To a solution of 15.25 g (0.100 mol) of (−)-carveol mixture in 100 ml of THF was added dropwise a solution consisting of 30.60 g (0.096 mol) of mercuric acetate in 50 ml of water. The progress of the reaction was monitored by gas chromatography. Reaction aliquots were removed periodically and quenched with base and reduced by the addition of 0.5 M $NaBH_4$ in 3 M NaOH; the aqueous phase was saturated with sodium chloride, and the THF phase analyzed directly with gas chromatography. The results indicated that more than 85% of the (−)-carveol mixture was converted to the oxymercurated product after 9 days.

The solution containing the oxymercurated product was cooled to 15 °C and made basic with the dropwise addition of 25 ml of 3 M NaOH. A cooled solution consisting of 5.7 g (0.15 mol) of sodium borohydride (Alpha Inorganics) and 100 ml of 3 M NaOH was then added dropwise to the basic solution of the mercurial. After a 3-h reaction period the aqueous phase was saturated with NaCl and 25 ml of ether was added to aid in the separation of phases. The organic phase was removed and dried over anhydrous sodium sulfate. The THF–ether in the organic phase was removed by distillation at atmospheric pressure. Two distillations of the crude product under reduced pressure provided **4** in greater than 99% purity: bp 65 °C (11 mm); $[\alpha]^{25}\mathrm{D}$ 81.1° (neat); $n^{25}\mathrm{D}$ 1.4670 [lit.[2] bp 64–65 °C (11 mm); $[\alpha]^{25}\mathrm{D}$ 87.5°; $n^{20}\mathrm{D}$ 1.4698]; NMR (neat) δ 4.98 (m, 1), 3.75 (d, 1, J = 3.5 Hz), 1.50–2.28 (m, 8), 1.19 (s, 3), 1.08 (s, 3). Anal. Calcd for $C_{10}H_{16}O$: C, 78.89; H, 10.59. Found: C, 78.57; H, 10.47.

Registry No.—**1**, 6485-40-1; **2**, 2102-58-1; **3**, 2102-59-2; **4**, 55822-06-5.

References and Notes

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Non-Saytzeff Alumina-Catalyzed Dehydration of 2-Ferrocenyl-3-methyl-2-butanol

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In the last 10 years a wide investigation on the heterogeneous dehydration of alcohols catalyzed by metal oxides gave some explanations on how the metal oxide works as a catalyst. The results are reviewed in the literature.[1–4]

As to orientation, alumina,[5,6] hydroxyapatite,[7] and thoria[8] have been found to be very selective with respect to elimination from secondary alcohols. Alumina and hydroxyapatite