22 g of concentrated product. A portion of the product (3.0 g) was retained for glpc analysis and the remainder was hydrogenated in 50 ml of anhydrous ethanol over 0.2 g of 5% palladium on charcoal using a Parr apparatus (initial pressure 43 psig). The solution of hydrogenated product was filtered and concentrated by distillation through a 12 in. helix-packed fractionating column (oil bath). The concentrated product was directly analyzed by glpc.

**Reduction of 1 and 6 with LTAH.**—Ketones **1** (4.22 g, 0.030 mol) and **6** (3.31 g, 0.030 mol) in 100 ml of tetrahydrofuran (distilled from $LiAlH_4$) were reduced by the dropwise inverse addition of LTAH (3.8 g, 0.015 mol) in 55 ml of tetrahydrofuran. Hydrolysis was effected in this case with water and 15% sodium hydroxide[12] after 2.5 hr of stirring. After concentration by distillation, a portion of the concentrated solution was directly analyzed by glpc while the remainder was hydrogenated over 0.3 g of 5% palladium on charcoal.

**Control Experiments.**—The fact that ketone ratios and ketone–alcohol ratios (of saturated compounds) did not vary significantly before and after hydrogenation lends confidence to the analytical procedure employed. In addition, a standard mixture of **1** and **10** was subjected to the hydrogenation and isolation procedures and was shown not to change in composition upon glpc analysis. Unsaturated ketones on hydrogenation also absorbed the exact amount of hydrogen (based on calibration of the apparatus) for conversion to the corresponding saturated alcohol.

**Registry No.**—**1,** 873-94-9; **2,** 78-59-1; **5,** 108-94-1; **6,** 16853-85-3; $LiAlH_4$, 17476-04-9.

**Acknowledgment.**—The author would like to thank Mr. P. Quezada for technical assistance.

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[12] See L. F. Fieser and M. Fieser, "Reagents for Organic Synthesis," Wiley, New York, N. Y., 1967, p 584.

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# The Addition of Lithium Dimethylcopper to Conjugated Cyclopropyl Enones

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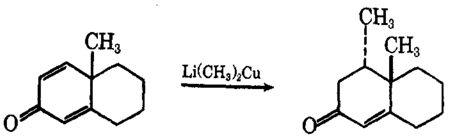
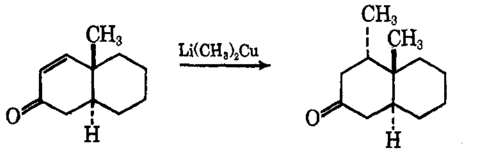
The addition of lithium dimethylcopper to 9,10-methano-1-octalin-3-one (**6**) affords a mixture of the expected 1,4 adducts (*ca.* 90% trans, 10% cis), a 1,6 adduct, 9-ethyl-4(10)-octalin-2-one (**8**), and a small amount of reduced cyclopropane cleavage product, 9-methyl-4(10)-octalin-2-one (**9**). Acid cleavage of the trans 1,4 adduct, *trans*-4-methyl-9,10-methanodecalin-2-one (**7a**), affords a 4:1 mixture of 4,9-dimethyl-*cis*-3-octalin-2-one (**19**) and *trans*-4,10-dimethyl-1(9)-octalin-2-one (**20a**), whereas the cis 1,4 adduct, *cis*-4-methyl-9,10-methanodecalin-2-one (**7b**), gives only *cis*-4,10-dimethyl-1(9)-octalin-2-one (**20b**) upon similar treatment. 5,10-Methano-1(9)-octalin-2-one (**16**), a cyclopropano enone isomeric with **6**, likewise affords 1,4- and 1,6-addition products upon treatment with lithium dimethylcopper.

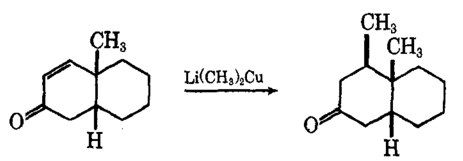
The conjugate addition of lithium dimethylcopper(I)[2] to $\Delta^1$-3-ones (eq 1–3) has been shown to proceed cleanly



(1)



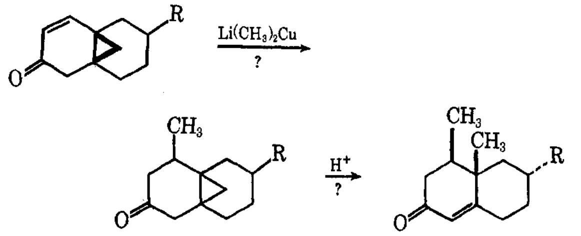
(2)



(3)

and stereoselectively. In the former two cases (eq 1 and 2) the methylation occurs trans to the angular methyl group to give *trans*-dimethyl products.[3] However, the cis-fused enone (eq 3) affords mainly the cis,cis product.[4] The latter arrangement of *vic*-methyl groups is of particular interest in connection with the valencane–eremophilane family of sesquiterpenes, a class of compounds based on the *cis,cis*-1,9-dimethyldecalin framework.[5]

In the course of synthetic studies related to the sesquiterpene grapefruit flavor constituent nootkatone,[6] we decided to examine the conjugate methylation–cyclopropane cleavage sequence shown in eq 4. Our initial work was carried out on a model system designed to test the overall feasibility and stereochemistry of the above sequence. Accordingly, the known cyclopropyl alcohol **1** (Scheme I) was reduced (Li, $NH_3$, EtOH) *via* the methanesulfonate derivative **2** to the tricyclic olefin **3**.[7] Epoxidation followed by base-induced elimination afforded the allylic alcohol(s) **5**, oxidation of which gave the desired enone **6**.



(4)

Addition of lithium dimethylcopper(I) to enone **6** in ether solution at 0° afforded principally the 1,4 adduct **7** (55%) along with enones **8** (39%) and **9** (6%). The production of the latter two cyclopropane cleavage products was of special interest since a simple cyclopropyl ketone, bicyclo[4.1.0]heptan-2-one,[8] and a con-

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[1] Predoctoral Fellow of the National Institutes of Health, Division of General Medical Sciences, Fellowship 5 FO1 GM 41100.

[2] H. O. House, W. L. Respess, and G. M. Whitesides, *J. Org. Chem.*, **31**, 3128 (1966).

[3] (a) T. M. Warne, Jr., "The Synthesis of (±)-Isonootkatone," Ph.D. Thesis, Northwestern University, Evanston, Ill., 1971, p 100; (b) R. M. Coates and J. E. Shaw, *Chem. Commun.*, 47 (1968); (c) R. L. Nale and L. N. Zalkow, *ibid.*, 1249 (1968).

[4] G. M. Cohen, unpublished results. *Cf.* J. A. Marshall and G. M. Cohen, *J. Org. Chem.*, **36**, 877 (1971).

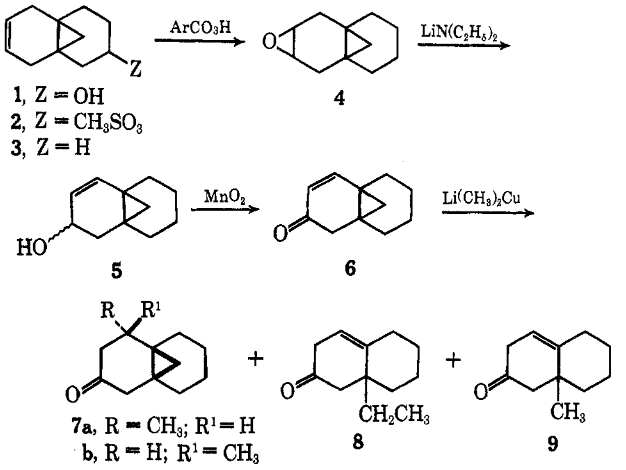
[5] *Cf.* J. A. Marshall and R. A. Ruden, *ibid.*, **36**, 594 (1971).

[6] W. D. Macleod, Jr., *Tetrahedron Lett.*, 4779 (1965).

[7] J. J. Sims, *J. Org. Chem.*, **32**, 1751 (1967).

[8] R. A. Ruden, "Stereoselective Total Synthesis of Racemic Nootkatone," Ph.D. Dissertation, Northwestern University, Evanston, Ill., 1971, p 66.

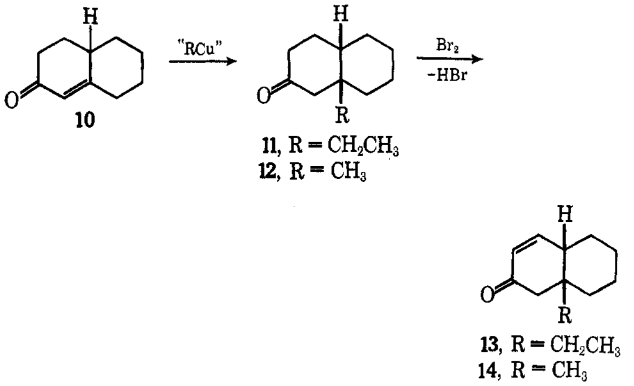
SCHEME I



jugated cyclopropyl cyclopentenone[9] failed to give cyclopropane cleavage products upon treatment with lithium dimethylcopper or phenylmagnesium bromide–cuprous iodide, respectively. In the present case, cyclopropane cleavage took place readily, even at −40°.

The structures of the cleavage products were ascertained through conversion with base to their conjugated isomers **13** and **14** which were synthesized independently as outlined in Scheme II.

SCHEME II



Hoping to find conditions more favorable to 1,4 addition, we conducted a brief study of temperature and solvent effects (Table I). The use of dioxane was suggested by our previous work on conjugate additions to a cyclohexadienone.[10] The present study indicated that in ether low temperature favors the cyclopropane cleavage reaction whereas in dioxane low temperature favors 1,4 addition. Under optimum conditions we obtained 72% of the 1,4 adduct, a 93:7 mixture of **7a** and **7b** (see below).

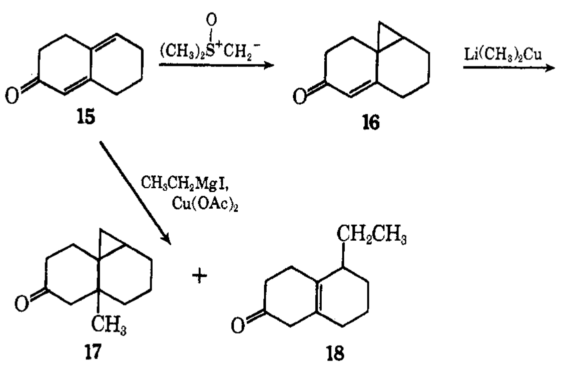
TABLE I

ADDITION OF $Li(CH_3)Cu$ TO CYCLOPROPYL ENONE 6

| Solvent | Temp, °C | 1,4 addition (**7**), % | 1,6 addition (**8**), % | Reduction (**9**), % |
|---|---|---|---|---|
| Ether | −40 | 40 | 55 | 5 |
| | 0 | 55 | 39 | 6 |
| | 15 | 60 | 34 | 6 |
| Dioxane | 15 | 72 | 24 | 4 |
| | 40 | 61 | 33 | 6 |

Since the addition of an organocopper reagent to the cyclopropane ring of a cyclopropyl ketone had not previously been reported, we were interested to see if enone **6** was an isolated case or if the reaction would occur with related cyclopropyl enones.[11] Accordingly the work outlined in Scheme III was undertaken. Cyclopropanation of the dienone **15**[12] afforded the cyclopropyl enone **16**.[13] Addition of ethereal lithium dimethylcopper at 0° yielded the 1,4 adduct **17** (43%) and the cyclopropane-cleaved 1,6 adduct **18** (49%). The latter product was independently synthesized through 1,6 addition of ethylmagnesium iodide to dienone **15**. The stereochemistry of the 1,4 adduct **17** has not yet been examined.

SCHEME III



In ether higher temperature once again favored the 1,4 addition reaction (Table II).

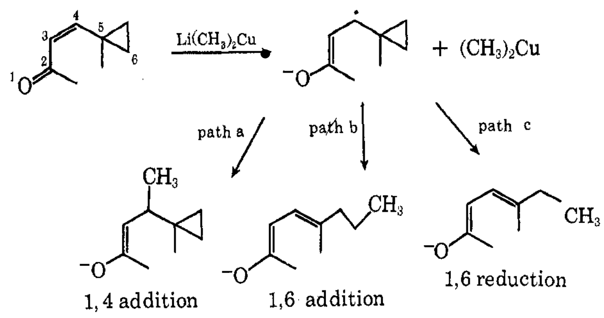
TABLE II

ADDITION OF $Li(CH_3)_2Cu$ TO CYCLOPROPYL ENONE 16

| Solvent | Temp, °C | 1,4 addition (**17**), % | 1,6 addition (**18**), % |
|---|---|---|---|
| Ether | −40 | 27 | 64 |
| | 0 | 43 | 49 |
| | 15 | 52 | 40 |

Scheme IV depicts a possible pathway for the observed addition reactions to cyclopropyl enones. Electron transfer from an organocopper species to a conjugated enone substrate leading to an intermediate radi-

SCHEME IV



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[9] H. E. Zimmerman and R. L. Morse, *J. Amer. Chem. Soc.*, **90**, 954 (1968).

[10] J. A. Marshall and S. F. Brady, *J. Org. Chem.*, **35**, 4068 (1970).

[11] While this manuscript was in preparation, a report of a related cyclopropane cleavage of a cyclopentenone appeared: C. Frejaville and R. Jullien, *Tetrahedron Lett.*, 2039 (1971).

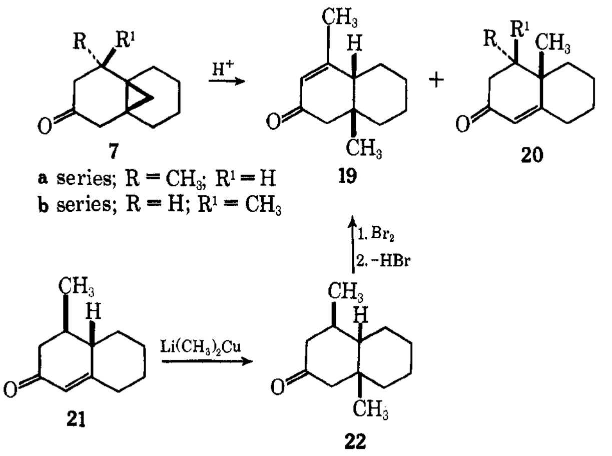
[12] N. N. Gaidamovich and I. U. Torgov, *Izv. Akad. Nauk SSSR*, 1903 (1961); *Chem. Abstr.*, **62**, 13197 (1962).

[13] E. J. Corey and M. Chaykovsky, *J. Amer. Chem. Soc.*, **87**, 1345 (1965).

cal anion has been suggested by House and Fischer.[14] In the present case, the resulting radical anion could react directly with the organocopper *via* methyl transfer as postulated by House to give the 1,4 adduct (path a) or cyclopropane participation could take place leading to either the 1,6 adduct *via* methyl transfer (path b) or the reduction product *via* hydrogen transfer (path c), possibly from the solvent. The latter reactions may proceed directly from the radical anion with concerted cyclopropane cleavage or conceivably a prior cleavage could take place to give a new radical anion which could then react *via* methyl transfer or H transfer as noted above.

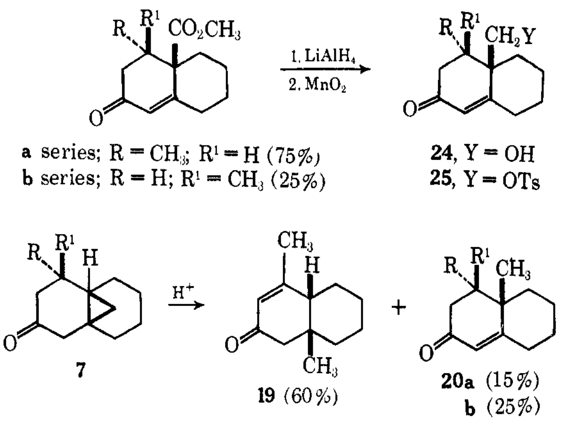
The stereochemistry of the 1,4 adduct **7** was ascertained through vpc analysis of the acid cleavage products, enones **20a** and **20b**, as shown in Scheme V. A sample of ketone **7** obtained from the addition of lithium dimethylcopper to enone **6** appeared homogeneous by nmr and vpc criteria. However, upon treatment with acetic acid–HCl a mixture of three enones, **19** (75%), **20a** (18%), and **20b** (7%), was secured in 97% yield. The structure of enone **19** was confirmed by direct comparison with a sample obtained *via* the sequence outlined in Scheme V. Enones **20a** and **20b** were identified by direct comparison with authentic samples.[3]

SCHEME V



The above findings indicate that at least 7% of the *cis*-methyl ketone **7b** must be formed in the 1,4 methylation of enone **6**. Since both **7a** and **7b** could give rise to enone **19** upon acid cleavage, and since they most likely would do so at differing rates, we could not utilize these results to deduce the relative amounts of methyl epimers obtained in the aforementioned 1,4 methylation. Attempts at direct analysis of this mixture were to no avail; so we decided to examine the acid cleavage of a known mixture of cyclopropyl ketones **7a** and **7b**. This mixture was prepared as shown in Scheme VI from a 3:1 mixture of keto esters **23a** and **23b**. Reduction with lithium aluminum hydride followed by $MnO_2$ oxidation afforded the keto alcohols **24a** and **24b** in 92% yield. The corresponding tosylate derivative **25** yielded the cyclopropyl ketones **7a** and **7b** in 98% yield upon treatment with zinc dust in aqueous acetic acid.[15] In view of the high yield of this step we assume that the ratio of ketones **7a** to **7b** is roughly the same (3:1) as that of the starting keto esters **23** and the intermediates **24** and **25** (analyzed *via* integration of $CH_3$ doublets in the nmr spectra).

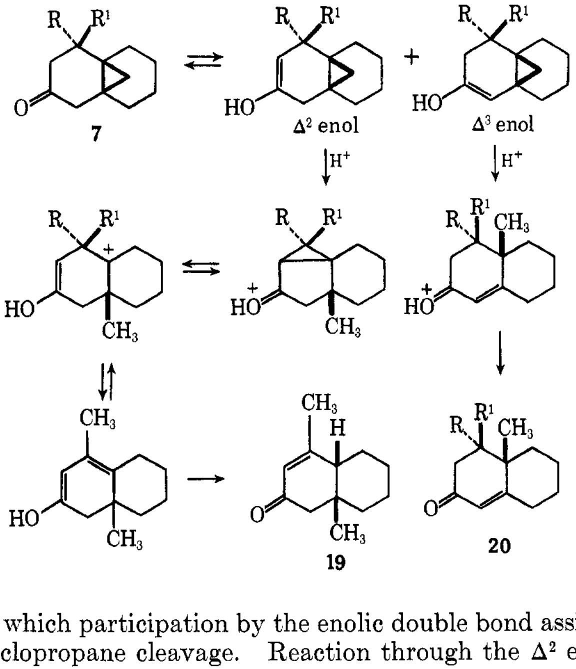
SCHEME VI



Cleavage of cyclopropyl ketones **7a** (75%) and **7b** (25%) with acetic acid–HCl afforded a 60:15:25 mixture of enones **19**, **20a**, and **20b** in 97% yield. Thus, ketone **7b** must cleave virtually unidirectionally to give enone **20b** under these conditions, whereas the epimeric ketone **7a** cleaves largely (4:1) in the opposite sense to give enone **19**.

The formation of enone **19** as the major cleavage product of ketone **7a** conforms to Sims's views on this reaction.[7] Accordingly, protonation of the cyclopropyl ketone conjugate acid will tend to give a dication intermediate with maximum charge separation. In the case of ketone **7b**, however, this direction of protonation is hindered by the *cis*-methyl grouping. An alternative explanation may be postulated (Scheme VII) in which participation by the enolic double bond assists cyclopropane cleavage. Reaction through the $\Delta^2$ enol (Scheme VII) may be less favorable in the **b** series owing to conformational changes which place the initially equatorial methyl grouping into the bowsprite position of a 1,4-cyclohexadiene-type boat conformation. The $\Delta^3$ enol may also give rise to a ketone-protonated cyclopropane intermediate isomeric with that derived from

SCHEME VII



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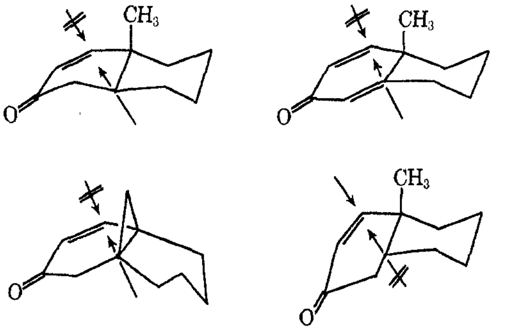
[14] H. O. House and W. F. Fischer, Jr., *J. Org. Chem.*, **33**, 949 (1968).

[15] S. Rakhit and M. Gut, *J. Amer. Chem. Soc.*, **86**, 1432 (1964).

the $\Delta^2$ enol. Formation of this intermediate (whose ultimate fate would be conversion to enone **19**) would appear geometrically unfavorable as judged by an examination of molecular models.

Thus, we have shown that the addition of lithium dimethylcopper to enone **6** gives largely (*ca* 90:10) the trans 1,4 adduct **7a**. This finding is somewhat surprising in view of the preferential formation of the cis 1,4 adduct from the cis-fused decalone analog of enone **6** (eq 3).[4] Evidently increased steric shielding of the top face of the double bond by the cyclopropane $CH_2$ plus the less concave geometry of enone **6** render trans addition more favorable than cis addition. The comparison of analogous systems is shown in Chart I.

CHART I



Finally, it should be noted that the acid cleavage of cyclopropyl decalones related to **7b** could be employed to generate compounds related to the valencane–eremophilane family of sesquiterpenes.[5]

## Experimental Section[16]

**9,10-Methano-2-octalin (3).**—To a cooled (0°), stirred solution of alcohol **1**[7] (340 mg) in 3 ml of dry pyridine was added 0.23 ml of methanesulfonyl chloride. After 1 hr, the ice bath was removed and the solution was stirred at room temperature for 3 hr. Isolation with ether afforded the mesylate **2** as a pale yellow oil: $\lambda_{max}^{film}$ 7.41, 8.52, and 10.09 $\mu$m. The crude mesylate was dissolved in 5 ml of ethanol and slowly added to a cooled (−78°) solution of $NH_3$ (80 ml) containing 1.2 g of lithium. The solution was stirred at −78° for 1 hr and at −33° for 0.5 hr. Cautious addition of 25 ml of 1:1 ethanol–pentane and evaporation of the ammonia followed by isolation with pentane and distillation [bath temperature 110° (10 mm)] afforded 190 mg (60%) of octalin **3** as a colorless oil: $\lambda_{max}^{film}$ 3.31, 6.05, 6.92, and 9.86 $\mu$m; $\delta_{TMS}^{CCl_4}$ 5.44 (vinyl H, broad) and 0.37 ppm (cyclopropyl $CH_2$, $\Delta\nu_{AB}$ = 26 Hz, $J_{AB}$ = 4 Hz). The analytical sample was obtained by preparative gas chromatography.

*Anal.* Calcd for $C_{11}H_{16}$: C, 89.12; H, 10.88. Found: C, 89.08; H, 10.94.

**9,10-Methano-1-octalin-3-one (6).**—A stirred solution containing 160 mg of alkene **3** in 5 ml of benzene was treated with 500 mg of *m*-chloroperoxybenzoic acid. After 12 hr at room temperature, isolation with benzene (a 10% KOH wash was used to remove acidic material) afforded 100 mg (56%) of the epoxide **4** as a colorless oil: $\lambda_{max}^{film}$ 6.92, 9.86, and 12.48 $\mu$m; $\delta_{TMS}^{CCl_4}$ 2.80 (triplet, $J$ = 3 Hz).

Lithium diethylamide was prepared by the dropwise addition of *n*-butyllithium (1.5 mmol) to a cooled ethereal solution (10 ml) of diethylamine (1.5 mmol).[17] After 10 min, 100 mg of epoxide in 3 ml of ether was aded, and the solution was heated at reflux for 24 hr. Isolation with ether afforded 67 mg (67%) of allylic alcohol **5**: $\lambda_{max}^{film}$ 3.07, 3.39, 6.11, and 9.57 $\mu$m; $\delta_{TMS}^{CCl_4}$ 5.78, 5.76, 5.60, 5.58, 5.25, 5.10 (vinyl H, AB part of ABX pattern), 3.96 (CHOH, broad t, $J$ = 8 Hz), and 0.52 ppm (cyclopropyl $CH_2$, $\Delta\nu_{AB}$ = 9.0 Hz, $J_{AB}$ = 4.2 Hz).

To a solution of 1.0 g of allylic alcohol **5** in 100 ml of chloroform was added 10.0 g of activated manganese dioxide.[18] After stirring at room temperature for 20 hr, the solution was filtered and the filtrate was concentrated at reduced pressure. Distillation at 110° (bath temperature) at 0.05 mm afforded 0.81 g (80%) of enone **6**: $\lambda_{max}^{film}$ 6.00, 6.96, 7.21, and 8.06 $\mu$m; $\delta_{TMS}^{CCl_4}$ 6.25 (vinyl H, $\Delta\nu_{AB}$ = 86 Hz, $J_{AB}$ = 10 Hz), 2.54 ($\alpha$-keto $CH_2$, $\Delta\nu_{AB}$ = 21.5 Hz, $J_{AB}$ = 18 Hz), and 0.80 ppm (cyclopropyl $CH_2$, $\Delta\nu_{AB}$ = 36 Hz, $J_{AB}$ = 4.0 Hz). This material was routinely purified for further use by preparative thick layer chromatography on silica gel using 1:1 ether–benzene as the solvent.

*Anal.* Calcd for $C_{11}H_{14}O$: C, 81.44; H, 8.70. Found: C, 81.20; H, 8.89.

**Addition of Lithium Dimethylcopper to 9,10-Methano-1-octalin-3-one (6). A. In Ether at 0°.**—A suspension of cuprous iodide (764 mg) in 25 ml of anhydrous ether was cooled to 0° with an ice bath and ethereal methyllithium (4.45 ml of 1.65 *M*) was added dropwide to the solution.[2] Enone **6** (180 mg) in 10 ml of ether was then added dropwise and the solution was stirred for 1 hr at 0°. The reaction mixture was poured into a rapidly stirred solution of saturated ammonium chloride. Isolation with ether (an ammonium hydroxide wash was used to remove suspended copper salts) and short path distillation afforded 180 mg (90%) of a colorless oil: bp 110° (bath temperature) at 0.1 mm; $\lambda_{max}^{film}$ 5.85 $\mu$m. The gas chromatogram showed peaks at 8.2 min (6.9%) and 11.6 min (92%).

This material was subjected to preparative gas chromatography. The first peak eluted was identified as enone **9** by comparison with an authentic sample. The second peak eluted was shown to be approximately a 60:40 mixture of ketones **7** and **8**.

In another run, the material obtained from the addition of $LiMe_2Cu$ to enone **6** was treated with $Na_2CO_3$ in methanol according to the general equilibration procedure given below. The gas chromatogram showed peaks at 7.6 min (0.8%), 8.8 min (6%), 10.8 min (60%), and 11.9 min (33%).

This material was subjected to preparative gas chromatography. The first peak eluted was cyclopropyl ketone **7**: $\lambda_{max}^{film}$ 5.85, 6.92, and 8.13 $\mu$m; $\delta_{TMS}^{CCl_4}$ 1.12 ($CH_3$ doublet, $J$ = 6.2 Hz) and 0.53 ppm (cyclopropyl H, $\Delta\nu_{AB}$ = 19 Hz, $J_{AB}$ = 6.0 Hz).

*Anal.* Calcd for $C_{12}H_{18}O$: C, 80.85; H, 10.18. Found: C, 80.89; H, 10.21.

The second peak to be eluted was identified as enone **13** by comparison with an authentic sample (see below).

Equilibration of the product mixture (31 mg) yielded 27 mg of ketones **9**, **14**, **7**, **8**, and **13**. From the percentages of these components it was determined that ketones **9**, **8**, and **7** were formed in a 5:55:40 ratio.

**B. In Dioxane.**—To a suspension of cuprous iodide (260 mg) in 4 ml of dioxane cooled to 15° was added 1.5 ml of 1.68 *M* ethereal methyllithium. After 0.5 hr, enone **6** (36 mg) in 6.0 ml of dioxane was added and the resulting solution was stirred at 15–20° for 6 hr. The reaction mixture was then poured into a rapidly stirred solution of ammonium chloride. Isolation with ether (an ammonium hydroxide wash was used to remove suspended copper salts) and short path distillation afforded 36 mg (90%) of a colorless oil. Equilibration of the addition products (23 mg) afforded 16 mg of a mixture whose composition indicated an initial composition of 4:24:72 for ketones **9**, **8**, and **7**.

**Product Analysis.**—Since the enone **8** and the cyclopropyl ketone **7** did not separate on the gas chromatogram, the product analysis was carried out on the conjugated enones **13** and **14** as follows. The mixture obtained from the addition of $LiMe_2Cu$ to enone **6** was dissolved in 10 ml of absolute methanol containing 20 mg of $Na_2CO_3$ and stirred for 8–10 hr at room temperature. Acetic acid was then added and the products were isolated with ether and distilled affording the equilibrated mixtures (yields 70–90%). The vapor phase chromatogram indicated that the

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[16] Reactions were conducted under a nitrogen atmosphere using the apparatus described by W. S. Johnson and W. P. Schneider ["Organic Syntheses," Collect. Vol. IV, Wiley, New York, N. Y., 1963, p 132]. Reaction products were isolated by addition of water and extraction with the specified solvent. The combined extracts were washed with saturated brine and dried over anhydrous magnesium sulfate. The solvent was removed from the filtered solutions on a rotary evaporator.

[17] B. Rickborn and R. P. Thummel, *J. Org. Chem.*, **34**, 3583 (1969).

[18] O. Mancera, G. Rosenkranz, and F. Sondheimer, *J. Chem. Soc.*, 2189 (1953).

per cent of conjugated enone in the equilibrium mixtures ranged from 85 to 90%, with 10–15% of the unconjugated isomers **8** and **9** remaining. Since the $\beta,\gamma$ unsaturated enone **8** did not separate from the cyclopropyl ketone **7**, a correction factor was used to determine the exact ratio of components. Assuming that the ratio of $\alpha,\beta/\beta,\gamma$ double bond isomers for enone **9** would be similar to that of enone **8** and knowing the former ratio **9**:**14** = 0.1, we could determine the percentage of enone **8** present in the mixture.

**Preparation of *trans*- and *cis*-1-Methyl-9,10-methano-1-octalin-3-one (3:1 7a/7b) from Keto Esters 23.**—To a solution of 0.83 g of a 3:1 mixture of keto esters **23a** and **23b**[19] in 100 ml of ether was added portionwise with stirring 0.50 g of lithium aluminum hydride. The solution was heated at reflux for 18 hr and treated with 0.5 ml of 15% NaOH and 1.5 ml of water. The mixture was filtered after several hours and the filtrate was concentrated under reduced pressure affording 0.79 g of diol: $\lambda_{max}^{film}$ 3.05 $\mu$m; $\delta_{TMS}^{CDCl_3}$ 5.51 (vinyl H), 1.00 ($CH_3$ doublet, $J$ = 6.2 Hz), and 0.88 ppm ($CH_3$ doublet, $J$ = 6.5 Hz).

The above diol in 100 ml of chloroform was stirred vigorously with 8.0 g of $MnO_2$[18] for 18 hr. The mixture was filtered and the filtrate was concentrated under reduced pressure affording 0.79 g of keto alcohol **24**: $\lambda_{max}^{film}$ 3.00 and 6.04 $\mu$m; $\delta_{TMS}^{CDCl_3}$ 5.83 (vinyl H, two peaks), 1.04 ($CH_3$ doublet, $J$ = 6.5 Hz), and 0.96 ppm ($CH_3$ doublet, $J$ = 7.0 Hz).

A solution of the above ketol in 5 ml of pyridine at 0° was stirred for 1 hr at 0° and 16 hr at room temperature with 1.6 g of *p*-toluenesulfonyl chloride. The product was isolated by extraction with ether affording 0.57 g of tosylate **25**: $\lambda_{max}^{film}$ 6.00, 7.38, 8.44, 8.52, and 10.40 $\mu$m.

The above tosylate in 100 ml of 1:1 aqueous acetic acid was stirred at reflux with 5.0 g of zinc dust.[15] The product was isolated *via* extraction with hexane and distilled affording 0.29 g (98% yield) of the cyclopropyl ketones **7a** and **7b** whose spectral properties closely matched those of the 93:7 mixture obtained *cia* conjugated methylation of enone **6** as described above.

***cis*-9-Ethyldecalin-2-one** (**11**).—A solution of ethylmagnesium iodide (prepared from 2.88 g of magnesium turnings and 16.8 g of ethyl iodide in 100 ml of ether) was cooled to −10° and a solution containing 5.0 g of 1(9)-octal-2-one (**10**) and 2.08 g of cupric acetate monohydrate in 150 ml of dry tetrahydrofuran was added over 0.5 hr with efficient stiring.[20] The dark mixture was allowed to warm to room temperature over 2 hr and was heated to reflux for 15 min. After excess aqueous ammonium chloride had been added to the mixture, the product was isolated with ether affording 4.2 g of a pale yellow oil: $\lambda_{max}^{film}$ 2.91 (OH) and 5.84 $\mu$m. The crude mtaerial was chromatographed on 300 ml of alumina and 3.20 g (50%) of ethyldecalone **11** was eluted with 10% ether–hexane: $\lambda_{max}^{film}$ 5.85, 6.87, and 8.19 $\mu$m; $\delta_{TMS}^{CCl_4}$ 1.40 ($CH_2$ quartet, $J$ = 7.0 Hz) and 0.80 ppm ($CH_3$ triplet, $J$ = 7.0 Hz).

*Anal.* Calcd for $C_{12}H_{20}O$: C, 79.94; H, 11.18. Found: C, 80.03; H, 11.38.

***cis*-9-Ethyl-3-octalin-2-one** (**13**).—To a cooled (0°), stirred solution of ethyldecalone **11** (1.0 g) in 50 ml of chloroform was added 0.96 g of bromine in 15 ml of chloroform over 5 min. After 0.5 hr at room temperature, isolation of the product with ether afforded 1.56 g of pale yellow bromo ketone, $\lambda_{max}^{film}$ 5.80 $\mu$m. The crude material was dissolved in 50 ml of dimethylacetamide and 1.50 g of calcium carbonate was added.[21] The mixture was then heated at reflux for 1 hr. Isolation with hexane and short path distillation [bp 100° (bath temperature) at 0.05 mm] afforded 920 mg (92%) of the unsaturated ketone **13**: $\lambda_{max}^{film}$ 5.97 $\mu$m; $\delta_{TMS}^{CCl_4}$ 6.18 (vinylic H's, ABX pattern, $\Delta\nu_{AB}$ = 47 Hz, $J_{AB}$ = 10 Hz, apparent $J_{AX}$ = 4.0 Hz, apparent $J_{BX}$ = 1.9 Hz), 2.16 ($CH_2CO$, AB pattern, $\Delta\nu_{AB}$ = 2.46 Hz, $J_{AB}$ = 15.0 Hz), and 0.81 ppm ($CH_3$ triplet, $J$ = 6.3 Hz). The analytical sample was obtained by preparative gas chromatography.

*Anal.* Calcd for $C_{12}H_{18}O$: C, 80.84; H, 10.18. Found: C, 80.60; H, 10.23.

***cis*-9-Methyl-3-octalin-2-one** (**14**).—To a cooled (0°), stirred solution of decalone **12** (2.0 g) in 100 ml of chloroform was added 2.08 g of bromine in 30 ml of chloroform. After 0.5 hr, isolation with ether afforded the pale yellow bromo ketone, $\lambda_{max}^{film}$ 5.80. The crude material was dissolved in 100 ml of dimethylacetamide and 1.50 g of calcium carbonate was added.[21] The mixture was heated at reflux for 1 hr. Isolation with hexane and short path distillation [bp 100° (bath temperature) at 0.05 mm] afforded 1.65 g (83%) of the unsaturated ketone **14**: $\lambda_{max}^{film}$ 5.96 $\mu$m; $\delta_{TMS}^{CCl_4}$ 6.20 (vinylic H's, ABX pattern, $\Delta\nu_{AB}$ = 33 Hz, $J_{AB}$ = 10 Hz, apparent $J_{AX}$ = 4 Hz, apparent $J_{BX}$ = 1.4 Hz), and 1.01 ppm ($CH_3$). The 2,4-dinitrophenylhydrazone derivative exhibited mp 140–143° (ethanol).

*Anal.* Calcd for $C_{17}H_{20}N_4O_4$: C, 59.29; H, 5.85; N, 16.27. Found: C, 59.39; H, 5.89; N, 16.39.

**5,10-Methano-(1)9-octalin-2-one** (**16**).—To a solution of dimethyloxosulfonium methylide (prepared from 7.35 g of trimethyloxosulfonium iodide and 1.27 g of 57% NaH dispersion)[13] in 30 ml of DMSO was added 3.17 g of dienone **15**[12] in 22 ml of DMSO. After 3 hr at room temperature, isolation with hexane and distillation afforded 1.17 g (30%) of ketone **16**: bp 90° (bath temperature) at 0.2 mm; $\lambda_{max}^{film}$ 6.00, 6.21, 8.01, 11.38, and 13.18 $\mu$m; $\delta_{TMS}^{CCl_4}$ 5.72 ppm (vinyl H, s). This material was purified for further use by preparative thick layer chromatography on silica gel using 1:1 ether–benzene as the solvent. The 2,4-dinitrophenylhydrazone exhibited mp 185–187° (ethanol).

*Anal.* Calcd for $C_{17}H_{18}N_4O_4$: C, 59.64; H, 5.30; N, 16.37. Found: C, 59.41; H, 5.30; N, 16.47.

**Addition of Lithium Dimethylcopper to Cyclopropyl Ketone 16.**—To a cooled (0°) stirred suspension of CuI (260 mg) in 8 ml of ether was added 1.8 ml of 1.5 *M* ethereal methyllithium.[2] To this colorless solution was added 133 mg of cyclopropyl ketone **16**. After 1 hr at 0°, the reaction mixture was poured into a rapidly stirred solution of ammonium chloride. Isolation with ether (an aqueous ammonia wash was used to remove suspended copper salts) and short path distillation [bp 110° (bath temperature) at 0.1 mm] afforded 130 mg (90%) of addition products, $\lambda_{max}^{film}$ 5.86 $\mu$m. The gas chromatogram showed peaks at 8.4 min (1.5%), 9.4 min (43%), 10.7 min (2.3%), 11.6 min (48%), and 12.8 min (4%).

The addition products were subjected to preparative gas chromatography. The first peak eluted was identified as ketone **17**: $\lambda_{max}^{film}$ 5.84 $\mu$m; $\delta_{TMS}^{CCl_4}$ 1.00 ($CH_3$) and 0.45–0.20 ppm (cyclopropyl CH, complex).

*Anal.* Calcd for $C_{12}H_{18}O$: C, 80.85; H, 10.18. Found: C, 80.69; H, 9.98.

The second peak eluted was identified as enone **18** by comparison with an authentic sample (see below).

**5-Ethyl-9-octalin-2-one** (**18**).—To a solution of ethylmagnesium iodide (prepared from 3.35 g of ethyl iodide and 575 mg of magnesium in 20 ml of ether) was added 1.0 g of dienone **15**[12] and 415 mg of cupric acetate monohydrate in 30 ml of THF.[20] After 2 hr, excess aqueous ammonium chloride was added and the product was isolated with ether affording 1.10 g (92%) of ketone **18**. The analytical sample was secured *via* preparative layer chromatography on silica gel using 30:70 ether–benzene as the solvent: $\lambda_{max}^{film}$ 5.85 and 6.91 $\mu$m; $\delta_{TMS}^{CCl_4}$ 2.60 ($CH_2$) and 0.84 ppm ($CH_3$ triplet, $J$ = 6.8 Hz).

*Anal.* Calcd for $C_{12}H_{18}O$: C, 80.85; H, 10.18. Found: C, 80.81; H, 10.31.

**Acid Cleavage of Cyclopropyl Ketone 7.**—To 4 ml of 1:3 mixture of concentrated HCl–acetic acid was added 92 mg of cyclopropyl ketone **7** (a 3:1 mixture of **7a** and **7b**). The solution was heated at reflux for 4 hr. Isolation with ether and short path distillation [bp 110° (bath temperature) at 0.05 mm] afforded 90 mg (97%) of a mixture of enones **19**, **20a**, and **20b**: vpc 8.0 min (4.0%), 13.3 min (59%), 18.0 min (13%), and 19.2 min (24%). The 13.3-min peak was isolated by preparative vapor phase chromatography and identified as **19** on the basis of its spectral data: $\lambda_{max}^{film}$ 5.98, 6.92, 7.29, and 8.02 $\mu$m; $\delta_{TMS}^{CCl_4}$ 5.60 (vinyl H, broad), 1.90 (vinyl $CH_3$, d, $J$ = 1 Hz), and 0.98 ppm ($CH_3$).

The last two peaks were identified by coinjection with authentic samples. The peak at 18.0 min was the trans isomer **20a**[15] and the peak at 19.2 min was the cis isomer **20b**.[16]

**4,9-Dimethyl-3-octalin-2-one** (**19**).—To a cooled (0°) solution of 900 mg of decalone **22** in 50 ml of chloroform was added 0.28 ml of bromine in 15 ml of chloroform. After 0.5 hr at 0°, the solution was allowed to warm to room temperature over 0.5 hr. Isolation with ether afforded the crude bromo ketone as a pale yellow oil, $\lambda_{max}^{film}$ 5.82 $\mu$m. This material was dissolved in 50 ml of dimethylacetamide, 1.50 g of calcium carbonate was added, and the solution was heated at reflux for 1 hr.[21] Isolation with hexane followed by short path distillation afforded 600 mg (66%) of enone **19**, bp 100° (bath temperature) at 0.1 mm. The spectral properties of this material exactly matched those of the major product of the acid-catalyzed rearrangement

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(19) Reference 3a, pp 94–98.

(20) A. J. Birch and M. Smith, *Proc. Chem. Soc.*, 356 (1962).

(21) G. Green and A. Long, *J. Chem. Soc.*, 2532 (1961).

of cyclopropyl ketone **7**. The analytical sample was obtained by thick layer chromatography on silical gel using 1:1 ether–benzene as the solvent.

*Anal.* Calcd for $C_{12}H_{18}O$: C, 80.85; H, 10.18. Found: C, 80.62; H, 10.18.

**4-Methyl-1(9)-octalin-2-one (21).**—To a solution of 30 g of the pyrrolidine enamine of cyclohexanone in 200 ml of benzene was added 17.0 g of *trans*-3-penten-2-one.[22] The mixture was then heated at reflux for 24 hr.[22] A buffer solution made up of 25 ml of acetic acid, 25 ml of water, and 12.5 g of sodium acetate was added and the solution was heated at reflux for 4 hr. Isolation with benzene and distillation gave 13.8 g of octalone **21**, bp 88–90° (0.6 mm). This material was obtained as a mixture of $\alpha,\beta$ and $\beta,\gamma$ double bond isomers. The pure conjugated isomer was obtained by cooling a hexane solution of the mixture in Dry Ice–acetone whereupon pure enone **21** crystallized and was obtained free of the $\beta,\gamma$ isomer: $\lambda_{max}^{film}$ 5.98 and 6.17 $\mu$m; $\delta_{TMS}^{CCl_4}$ 5.52 (vinyl H) and 1.06 ppm ($CH_3$, d, $J$ = 6.0 Hz).

*Anal.* Calcd for $C_{11}H_{16}O$: C, 80.44; H, 9.82. Found: C, 80.63; H, 9.84.

**4,9-Dimethyldecalin-3-one (22).**—To a cooled (0°), stirred suspension of cuprous iodide (4.90 g) in 100 ml of anhydrous ether was added 35 ml of 1.6 $M$ methyllithium.[2] To this clear solution was added 1.03 g of enone **21** in 15 ml of ether. After 1 hr, the mixture was poured into a saturated amonium chloride solution. Isolation with ether (an ammonium hydroxide wash was used to remove the suspended copper salts) and short path distillation afforded 1.04 g (90%) of ketone **22** as a colorless oil: bp 100° (bath temperature) at 0.2 mm; $\lambda_{max}^{film}$ 5.85 $\mu$m; $\delta_{TMS}^{CCl_4}$ 1.12 ($CH_3$) and 0.98 ppm ($CH_3$, d, $J$ = 6.0 Hz). The analytical sample was secured *via* a second distillation.

*Anal.* Calcd for $C_{12}H_{20}O$: C, 79.94; H, 11.18. Found: C, 80.15; H, 11.09.

**Registry No.**—**3,** 33021-03-3; **4,** 32970-11-9; **5,** 32970-12-0; **6,** 32970-13-1; **7a,** 32980-02-2; **7b,** 32980-03-3; **11,** 32980-04-4; **13,** 32980-05-5; **14,** 32980-06-6; **16,** 32970-14-2; **16** 2,4-DNP, 32970-15-3; **17,** 32970-16-4; **18,** 32970-17-5; **19,** 32980-07-7; **21,** 32980-08-8; **22,** 32980-09-9; **23a** diol derivative, 32980-10-2; **23b** diol derivative, 32971-05-4; **24a,** 32971-06-5; **24b,** 32971-07-6; **25a,** 32980-11-3; **25b,** 33015-67-7; lithium dimethylcopper, 32970-18-6.

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# A Mercury Salt Pathway for the Degradation of Carboxylic Acids to Alkyl Halides Using Halogen and Mercuric Oxide[1]

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The degradation of carboxylic acids to alkyl halides using the halogens and mercuric oxide involves the initial formation of the mercuric salt of the acid, followed by a normal Hunsdiecker reaction of the salt with halogen. The relative insensitivity of the technique to water by comparison with the Hunsdiecker reaction of a silver salt is a consequence of the solubility of the mercury salts in the reaction medium ($CCl_4$). The synthetic applicability of the method is thus comparable with that of the Hunsdiecker reaction, with the additional limitation that those acids which fail to form mercury salts under the reaction conditions or which give insoluble salts cannot successfully be degraded.

Some time ago, Cristol and Firth reported the degradation of carboxylic acids to alkyl bromides using bromine and mercuric oxide.[2] The technique had as an advantage over the analogous Hunsdiecker reaction of silver carboxylates the avoidance of having to prepare the pure dry silver salts, which is often difficult owing to their thermal instability. Furthermore, there was no need to maintain scrupulously anhydrous reaction conditions; indeed, water is one of the reaction products (eq 1)

$$2Br_2 + 2RCO_2H + HgO \longrightarrow 2RBr + H_2O + HgBr_2 + 2CO_2 \qquad (1)$$

Since this publication, scattered reports of the use of the reaction have appeared.[3-6] Davis and his coworkers showed[7] that $CO_2$ was evolved on treatment of a wide variety of acids with bromine and mercury oxide, and noted that although a very limited number of other metal oxides could replace mercury oxide in the reaction, the yields of $CO_2$ using these other oxides were consistently poor.

Concerning the mechanism of the reaction, Cristol and Firth proposed[2] that the function of the mercuric oxide was to oxidize bromine to a positive halogen intermediate, which then reacted with the carboxylic acid to yield an acyl hypobromite. Jennings and Ziebarth[8] have formulated this sequence as eq 2 and 3.

$$HgO + 2Br_2 \longrightarrow HgBr_2 + Br_2O \qquad (2)$$

$$Br_2O + RCO_2H \longrightarrow RCO_2Br + HOBr \qquad (3)$$

The proposed acyl hypobromite then decomposes to alkyl bromide by the decarboxylation sequence (eq 4–6) established for the Hunsdiecker reaction.[9-11]

$$RCO_2Br \longrightarrow RCO_2\cdot + Br\cdot \qquad (4)$$

$$RCO_2\cdot \longrightarrow R\cdot + CO_2 \qquad (5)$$

$$R\cdot + RCO_2Br \longrightarrow RBr + RCO_2\cdot \qquad (6)$$

In this proposed sequence the intermediacy of the alkyl radical R· has been established with some cer-

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