tosylates and reduction with lithium aluminum hydride in the usual manner gave a mixture of 2,5-dimethyltetrahydrofuran (cis and trans) and 2-methyltetrahydropyran (*ca.* 6:4 ratio by gc) identical by nmr and gc with a similarly proportioned authentic mixture.

Oxymercuration of 5-methoxycyclooctene (XXIII) (Brown's procedure[8]) gave a 70% yield of a mixture consisting of about 30% of ethers VI and VII and 70% of material of longer gc retention time, presumably a mixture of 4- and 5-methoxycyclooctanols.

Oxymercuration of 5-acetoxycyclooctene was carried out in usual fashion. The product (*ca.* 60%) contained a fair amount of unreacted unsaturated acetate, no bicyclic ethers VI or VII, but a considerable amount of material of very long gc retention time. This latter fraction was presumably a mixture of various cyclooctanediols and monoacetates thereof.

Stabilities of Oxides to Reaction Conditions.—Cyclooctadiene monoxide was found to be stable to glacial acetic acid at 25° for periods of up to 2 hr, and to 50% THF–water for even longer periods of time, as measured by gc analysis of sample mixtures. Saturated olefin oxides, such as cyclooctene oxide, styrene oxide, and propylene oxide, were unaffected by several minutes of exposure to 0.005 M mercuric acetate in 50% THF–water. Cyclooctene oxide could be recovered in 75% yield after 72 hr of exposure to these conditions.

Competition Experiments.—In aqueous THF, a solution of *ca.* 1 mmol of each of the competing olefins in 1 ml of THF was stirred at 25° while 1.0 ml of 0.1 M mercuric acetate in water was added. After a period of 0.5–3 min, 1 ml of 3 N sodium hydroxide followed by 1 ml of sodium borohydride solution was added, the aqueous layer was saturated with sodium hydroxide pellets, and the THF layer was analyzed by gc.

In acetic acid, a mixture of the two olefins (*ca.* 1 mmol each) was added to a stirred solution of 0.2 mmol of mercuric acetate in 1 ml of acetic acid at 25°. After 3 min of stirring, the flask was chilled and 3 N sodium hydroxide was added until basic. Reduction was then carried out with 0.5 M sodium borohydride in 3 N sodium hydroxide, the products were extracted with ether, and analysis was performed by gc.

Variation of reaction times between 0.5 and 3 min had no apparent effect on product composition. Each reported relative rate is the average of at least two experiments using different proportions of reactants. Reproducibility was at least of the order of 20%. It has been shown that relative rates measured under these conditions correlate excellently with measured absolute rates.[22c]

Registry No.—IV, 29359-88-4; IV (methoxy analog), 31598-89-7; V, 31598-90-0; V (methoxy analog), 31662-28-9; VIII, 31598-91-1; IX, 31603-51-7; IX bisphenylurethane, 31603-52-8; X, 29359-87-3; XI, 31598-76-2; XXVI, 28405-47-2; XXVI 2,4-DNPH, 31603-54-0.

Replacement of the Carbonyl Oxygen of Hydroxy Ketones by Methylene and 1,1-Ethano Groups by Reaction with the Simmons–Smith Reagent[1]

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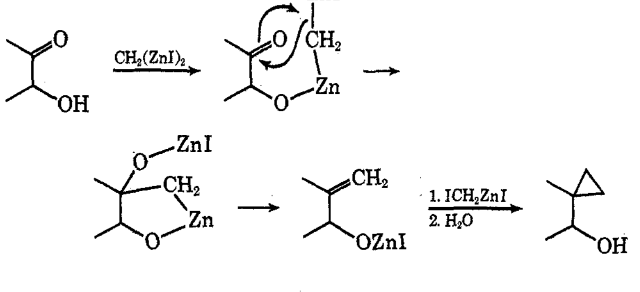
Received April 26, 1971

The reagent prepared from methylene iodide and zinc–copper couple replaces the carbonyl oxygen of ketones containing a neighboring hydroxyl group by the methylene and 1,1-ethano groups. Reaction conditions have been defined which allow the formation of either one of these products.

In a previous communication we reported[2] the unexpected formation of methylene and ethano derivatives **2** and **3** by reaction of 17β-acetoxy-11β-hydroxyestr-5(10)-en-3-one (**1**) with a reagent derived from methylene iodide and zinc–copper couple (Simmons–Smith reagent). Further work has shown that the reaction is not limited to hydroxy ketones; for example, 5α-androstan-3-one (**4**) was converted into a mixture of 3,3-methylene-5α-androstane (**5**), 3,3-ethano-5α-androstane (**6**), and other unidentified products. However, good yields were obtained only in the cases where assistance by hydroxyl is sterically allowed. No reaction was observed with α,β-unsaturated carbonyl groups, although the dienone **7** gave the derivatives **8a** and **8b** by by a normal cyclopropyl-forming reaction on the more nucleophilic, terminal double bond.

The reaction of α-hydroxy ketones with the Simmons–Smith reagent prepared in the usual manner led to mixtures of the methylene and ethano derivatives. For example, 17α-hydroxypregn-4-ene-3,20-dione (**9**) gave a mixture of **10** and **11**. Variation of the reaction conditions indicated that the relative yields of the two products were critically but reproducibly dependent on the procedure by which the reagent was prepared. A reagent formed *in situ* or by refluxing an ether solution of methylene iodide with zinc–copper couple for up to 1 hr reacted with the ketone **9** to give the ethano derivative **11** in high yield, whereas a reagent preformed by refluxing for 2–4 hr reacted to give the methylene derivative **10**, also in high yield. These results can be rationalized in terms of an inhomogeneous and time-variable composition for the reagent.

Olefination of aldehyde and ketone carbonyls by *gem*-dimetallic reagents of the type MCH_2M is quite general;[3] we therefore attribute the formation of ethano derivatives from hydroxy ketones to hydroxyl-assisted methylenation of the carbonyl by a species of the general structure $\cdots ZnCH_2Zn \cdots$, followed by a typical hydroxyl-assisted cyclopropyl formation. This mechanism was suggested[2] earlier for the conversion of **1** into



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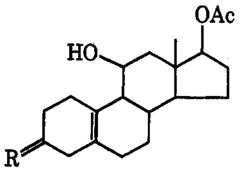
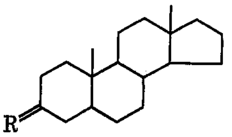
[1] Publication no. 385 from the Syntex Institute of Organic Chemistry. For publication no. 384, see L. Tökés, "Photochemical Cycloadducts," part VI, in press.

[2] P. Turnbull, K. Syhora, and J. H. Fried, *J. Amer. Chem. Soc.*, **88**, 4764 (1966).

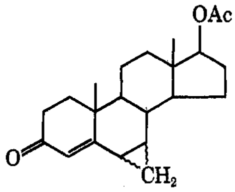
[3] F. Bertini, P. Grasselli, G. Zubiani, and G. Cainelli, *Tetrahedron*, **26**, 1281 (1970).



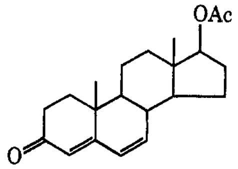
1, R = O
2, R = CH_2
3, R = $\begin{matrix}CH_2\\|\\CH_2\end{matrix}$



4, R = O
5, R = CH_2
6, R = $\begin{matrix}CH_2\\|\\CH_2\end{matrix}$



8a, 6β, 7β
b, 6α, 7α



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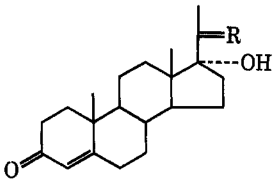
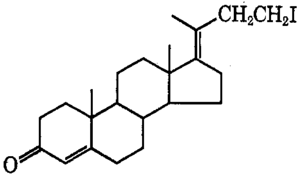


9, R = O
10, R = CH_2
11, R = $\begin{matrix}CH_2\\|\\CH_2\end{matrix}$



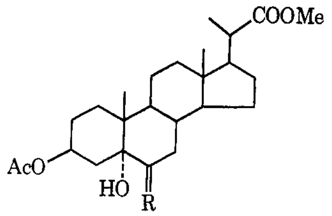
12

2 and **3**. The less reactive reagent preformed by longer refluxing periods leads only to the methylenation product and therefore contains only minor amounts of the cyclopropyl-forming reagent ICH_2ZnI. A further reaction observed was the cleavage of the cyclopropylcarbinol **11** to the iodoethyl derivative **12** by the Lewis acid by-product ZnI_2.

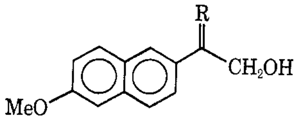
The generality of the methylenation and cyclopropyl-forming reactions was further supported by application to methyl 3β-acetoxy-5α-hydroxybisnorcholan-6-on-21-oate (**13**), forming the methylene derivative **14**, and by conversion of hydroxymethyl (6′-methoxy-2′-naphthyl) ketone (**15**) to the derivative **16**. The cyclopropyl derivative **17** was formed from ω-hydroxyacetophenone.

A more complex reaction was observed on treatment of the nonhydroxylic ketone **18** with the more reactive cyclopropyl-forming zinc–methylene iodide reagent. From the products of this reaction there was isolated 17β-acetoxy-2ξ-methyl-5,19ξ-cycloandrostane (**19**) and the 4 isomer **20**. Unstable intermediates which could be isolated from the reaction mixture are considered to be the cyclopropanols **21** and **22** formed by methylenation of enol intermediates. Chromatography of **21** and **22** caused ring opening, forming the observed methyl ketones. This result is reminiscent of the reaction of lithium enolates with methylene iodide and zinc, which has been used[4] as a means of α-methylation of ketones.

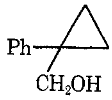
After most of this work was completed, a simplified preparation of the Simmons–Smith reagent, using a mixture of zinc and cuprous halide in place of zinc–copper couple, was described.[5] This new method is also



13, R = O
14, R = CH_2



15, R = O
16, R = $\begin{matrix}CH_2\\|\\CH_2\end{matrix}$



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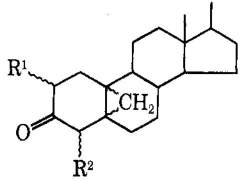
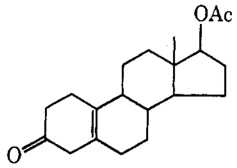


19, R^1 = Me; R^2 = H
20, R^1 = H; R^2 = Me



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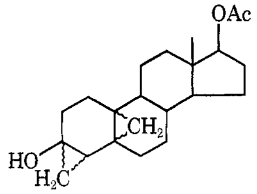

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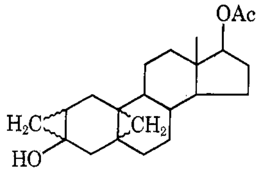

22

satisfactory for the preparation of methylene or ethano derivatives from hydroxy ketones.

Experimental Section[6]

General Procedure for the Reaction of Ketones with the Zinc–Methylene Iodide Reagent. A. Cyclopropyl-Forming Conditions.—A stirred mixture of zinc-copper couple[7] (3.2 g) and methylene iodide (2.5 ml) in ether (20 ml) was heated under reflux in a nitrogen atmosphere for 1 hr (shorter periods of reflux also gave satisfactory results). The ketone (1.3 mmol) was then added to the cooled mixture and stirring continued at about 25° for 24 hr. The mixture was then diluted with benzene, solids were removed by filtration, and the solution was washed successively with NH_4Cl and $NaHSO_3$ solutions. Products were isolated by column chromatography on silica gel or by tlc, followed by crystallization.

B. Methylene-Forming Conditions.—The above general procedure was used except that the reagent was heated for 4 hr before reaction with the ketone. Reflux periods in the range 2–4 hr were satisfactory.

20,20-Ethano-17α-hydroxypregn-4-en-3-one (11).—The general procedure A converted the ketone **9** (2 g) into **11**: yield 1.84 g (89%); mp 229–231°; $[\alpha]_D$ +82° ($CHCl_3$); uv max 240 nm (ε 17,500); nmr ($CDCl_3$) δ 0.4–0.8 (m, cyclopropyl). *Anal.* Calcd for $C_{23}H_{34}O_2$: C, 80.65; H, 10.01. Found: C, 80.45; H, 9.64. A minor, less polar product was identified as 20-(2′-iodoethyl)pregna-4,17(20)-dien-3-one (**12**): mp 159–161° dec; $[\alpha]_D$ +99° ($CHCl_3$); uv max (dioxane) 235 nm (ε 23,400); nmr ($CDCl_3$) ε 2.52 (t, CH_2I); mass spectrum *m/e* 452 (M^+).

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[4] H. W. Whitlock and L. E. Overman, *J. Org. Chem.*, **34**, 1962 (1969).

[5] R. J. Rawson and I. T. Harrison, *ibid.*, **35**, 2057 (1970).

[6] Melting points were determined on a Fisher-Johns hot stage apparatus. We wish to thank Drs. L. Throop, L. J. Tökés, and M. L. Maddox for the determination of physical data.

[7] E. LeGoff, *J. Org. Chem.*, **29**, 2048 (1964).

Anal. Calcd for $C_{23}H_{33}IO$: C, 61.04; H, 7.34; I, 28.05. Found: C, 60.95; H, 7.15; I, 27.73.

17α-Hydroxy-20-methylenepregn-4-en-3-one (10).—The ketone **9** (2 g) was converted by procedure B into **10**: yield 1.84 g (93%); mp 239–241°; $[\alpha]_D$ −113° ($CHCl_3$); uv max 240 nm (ε 16,700); nmr ($CDCl_3$) δ 4.92 (d, $C{=}CH_2$). *Anal.* Calcd for $C_{22}H_{32}O_2$: C, 80.44; H, 9.83. Found: C, 80.06; H, 9.85.

Methyl 3β-Acetoxy-5α-hydroxy-6-methylenebisnorcholan-21-oate (14).—The general method B converted the ketone **13** (2.0 g) into **14**: yield 1.9 g (96%) mp 103–105°; $[\alpha]_D$ −59° ($CHCl_3$); nmr ($CDCl_3$) δ 4.77 and 4.63 ($C{=}CH_2$). *Anal.* Calcd for $C_{26}H_{40}O_5$: C, 72.19; H, 9.32. Found: C, 72.10; H. 8.95.

1-Hydroxymethyl-1-(6′-methoxy-2′-naphthyl)cyclopropane (16).—The ketone **15** (2.5 g) was converted by the general method A into **16**: yield 2.0 g (76%); mp 79–80°; nmr ($CDCl_3$) δ 0.86 (m, cyclopropyl) and 3.66 (s, CH_2); mass spectrum *m/e* (rel intensity) 228 (47) and 197 (100).

1-Hydroxymethyl-1-phenylcyclopropane (17).—Method A converted ω-hydroxyacetophenone (0.4 g) into the known[8] **17**: yield 0.215 g (49%); nmr ($CDCl_3$) δ 0.78 (s, cyclopropyl), 2.06 (s, OH), 3.55 (s, CH_2), 7.1–7.3 (m, aromatic).

Reaction of Androstan-3-one (4) with the Zinc–Methylene Iodide Reagent.—The general procedure A, modified by the use of tetrahydrofuran as solvent, converted the ketone **4** into a mixture from which was isolated a low yield of the known[9] 3,3-ethano derivative **6**: mp 76–77°; $[\alpha]_D$ +6° ($CHCl_3$); nmr ($CDCl_3$) δ 0.19 (cyclopropyl). The methylene derivative **5** was also isolated: mp 89–90°; $[\alpha]_D$ −9° ($CHCl_3$); nmr ($CDCl_3$) δ 4.63 ($C{=}CH_2$). *Anal.* Calcd for $C_{20}H_{32}$: C, 88.16; H, 11.84. Found: C, 88.12; H, 11.49.

Reaction of 17β-Acetoxyandrosta-4,6-dien-3-one (7) with the Zinc–Methylene Iodide Reagents.—The process A, modified by the use of tetrahydrofuran as solvent, converted the ketone **7** (100 mg) into the known derivatives **8a**, yield 19 mg (18%), nmr ($CDCl_3$) δ 6.00 (s, 4 H), and the isomer **8b**, yield 12 mg (12%), nmr ($CDCl_3$) δ 5.94 (s, 4 H). Identification was confirmed by comparison of infrared spectra and gas chromatographic retention times with those of authentic samples.[10]

Reaction of 17β-Acetoxy-19-norandrost-5(10)-en-3-one (18) with the Zinc–Methylene Iodide Reagent.—The general procedure A converted the ketone **18** (0.5 g) into a mixture, ir (film) 3450 cm^{-1}. Column chromatography on silica gel or standing in methylene chloride solution converted the two major components into new compounds of different tlc polarity. The products isolated by column chromatography are considered to be the 2 (or 4) ξ-methyl ketone **19**, yield 110 mg (10%), nmr ($CDCl_3$) δ 0.8 (m, cyclopropyl), 1.15 (d, J = 7 Hz, CH_3), mass spectrum *m/e* 344 (M^+), and the 4 (or 2) ξ isomer **20**, 110 mg (10%), nmr ($CDCl_3$) δ 0.48 (m, cyclopropyl), 1.14 (d, J = 7 Hz, CH_3), mass spectrum *m/e* 344 (M^+).

Registry No.—**4,** 1224-95-9; **5,** 28113-74-8; **6,** 21152-61-4; **7,** 2352-19-4; **10,** 25596-88-7; **11,** 31729-63-2; **12,** 31790-94-0; **14,** 31729-64-3; **16,** 31729-65-4; **17,** 31729-66-5; **18,** 19906-32-2; **19,** 31729-68-7; **20,** 31729-69-8; zinc–methylene iodide, 31729-70-1.

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[9] N. S. Bhacca, M. E. Wolff, and W. Ho, *Tetrahedron Lett.*, 5427 (1968).

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Dechlorination of Benzotrichloride and Tolane Tetrachloride by Metals

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Received April 16, 1971

The reductions of benzotrichloride and tolane tetrachloride to *cis*- and *trans*-α,α′-dichlorostilbene by iron, copper, and zinc are often quantitatively irreproducible owing to their heterogeneity. Only zinc caused any complete dechlorination to diphenylacetylene, while only copper preferentially converted tolane tetrachloride to the trans isomer. An authentic pure sample of *cis*-α,α′-dichlorostilbene was obtained by preparative gas chromatography, and the literature melting point was shown to be incorrect. The ir and Raman spectra of the cis and trans isomers are compared.

During a study of the oxidizing ability of organic polyhalides, it became apparent that there are discrepancies in the literature regarding the dechlorination of benzotrichloride and of tolane tetrachloride. Consequently, we have used improved analytical techniques to determine the products of dechlorination of benzotrichloride and tolane tetrachloride by iron, copper, and zinc and have found that these heterogeneous reactions are often hard to reproduce.

Results

Reduction of Benzotrichloride by Iron and Copper.—Iron powder in boiling aqueous suspension is reported[1] to reduce benzotrichloride to *trans*-α,α′-dichlorostilbene, *via* the intermediacy of tolane tetrachloride.[2] We confirmed that reduction for 1 hr gave tolane tetrachloride; however, after 24 hr we obtained 72% *cis*-α,α′-dichlorostilbene and only 28% of the trans isomer. Reduction with active copper powder[3] in pyridine at 65° for 2 hr gave only tolane tetrachloride.[4] Thus, both methods are suitable for the convenient synthesis of tolane tetrachloride.

In contrast, neat dry benzotrichloride shaken with iron powder for 1 day at 20° gave no coupled products, although a dark red solution was formed.

Reduction of Tolane Tetrachloride by Iron.—Reduction of tolane tetrachloride with iron powder for 4 hr in boiling aqueous suspension is reported to yield 64% of *trans*-α,α′-dichlorostilbene.[2] However, even after 1 day, we obtained 68% unchanged tolane tetrachloride, 23% *cis*-α,α′-dichlorostilbene, and only 9% of the trans isomer. The cis/trans ratio, 2.6, is identical with that which we obtained on reduction of benzotrichloride with iron powder. This is therefore consistent with the intermediate formation of tolane tetrachloride in this latter reaction.

Reduction of Tolane Tetrachloride by Copper.—Freshly prepared active copper powder[3] suspended in dimethylformamide at 140° completely dechlorinated tolane tetrachloride to 28% *cis*- and 72% *trans*-α,α′-dichlorostilbene in only 30 min. Reduction in pyridine

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[2] Y. Ogata and H. Nakamura, *J. Org. Chem.*, **21**, 1170 (1956).

[3] A. H. Blatt, Ed., "Organic Syntheses," Collect. Vol. II, Wiley, New York, N. Y., 1953, p 446.

[4] Compare U. Hanhart, *Ber.*, **15**, 898 (1882).