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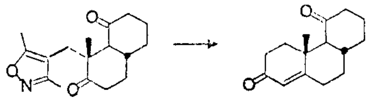
(2) Amendolla, C.; Rosenkranz, G.; Sondheimer, F. *J. Chem. Soc.* **1954,** 1226–1233. Anthousen, T.; McCabe, P. H.; McGrindle, R.; Murray, R. D. H. *Tetrahedron* **1969,** *25,* 2233–2239. Ireland, R. E.; Beslin, P.; Giger, R.; Hengartner, V.; Kirst, H. A.; Maag, H. *J. Org. Chem.* **1977,** *42,* 1267–1276. For an exception, see Barton, D. H. R.; Laws, G. F., *J. Chem. Soc.* **1954,** 52.

(3) Compounds **1a** and **1b** were obtained via epoxidation of the conjugated dienol ether from 10-methyl-$\Delta^{1,4}$-2-octalone; cf. Wege, P. M.; Clark, R. D.; Heathcock, C. H. *J. Org. Chem.* **1976,** *41,* 3144–3148, note 26.

(4) Assignment of stereochemistry is based on the known stereochemistry of alkylation of systems of this type; cf. Matthews, R. S.; Girgenti, S. J.; Folkers, E. A. *J. Chem. Soc., Chem. Commun.* **1970,** 708. The major (isomer **3b** had its methyl absorptions at δ 0.95 (s) and 1.32 (J = 8 Hz). The epimer **3c** had δ 1.12 (s) and 1.19 (J = 8 Hz). That **3b** is the kinetic isomer was shown by base equilibration to a 60:40 mixture of **3b** and **3c.**

(5) Assignment of stereochemistry was made on the assumption that the equatorial methyl would be the more shielded (higher field) by the carbonyl at "C_{11}". The chemical shift of the (axial) methyl group in **9a** was 1.33 ppm; the (equatorial) isomer **10a** had a shift of 1.22 ppm. The same shifts were observed for the isomers **9b** and **10b.** The ring fusion of diones **9a–d** results from kinetic protonation and is initially trans. Base-catalyzed isomerization leads to a 60:40 trans–cis mixture in each case. The stereochemistry assigned **9a–d** was confirmed, in any event, by the construction of known steroids (see accompanying communication): Stork, G.; Logusch, E. W. *J. Am. Chem. Soc.*, following paper in this issue.

(6) Dione **9d** could be converted into the tricyclic dione **14** (mp 101–103 °C)


9d 14

via the usual sequence of hydrogenation over W-2 Raney nickel, followed by base-catalyzed cyclization (see ref 7).

(7) Stork, G.; Danishefsky, S.; Ohashi, M. *J. Am. Chem. Soc.* **1967,** *89,* 5459–5460. Stork, G.; McMurry, J. E. *Ibid.* **1967,** *89,* 5464–5465.

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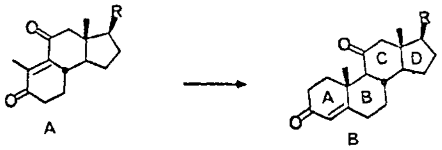
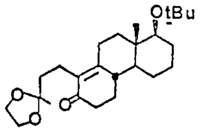
Reductive Alkylation of Enediones. 2. Synthesis of Corticosteroids

Sir:

With the spectacular exception of Johnson's polyene cyclization route to cortisone,[1] the construction of corticosteroids usually involves the introduction of the 11-oxygen function at a very late stage of their synthesis.[2] A particularly expeditious route within the classical DC → B → A approach would result, however, if it were possible to achieve the transformation A → B in two or three steps. The work on the reductive alkylation of enediones described in the accompanying communication[3] suggested that this might be possible. We now describe experiments which eventually led to a very simple construction of adrenosterone (B, R = carbonyl oxygen).


A B

The previously reported tricyclic enone **1,** which is conveniently prepared by annulation using the silylated enone methodology,[4] was converted into the homoallylic alcohol **2** by sodium borohydride reduction in refluxing methanol of the corresponding dienol acetate (prepared by refluxing **1** with potassium *tert*-butoxide in benzene, followed by quenching with acetic anhydride). Epoxidation of **2** with *m*-chloroperbenzoic acid, followed by Collins oxidation and exposure to methanolic sodium hydroxide, furnished the hydroxyenone **3a** (mp 88–91 °C) in 78% yield from **1.** Oxidation of **3a** with pyridinium chlorochromate furnished enedione **3b** (mp 109–111 °C) in 89% yield.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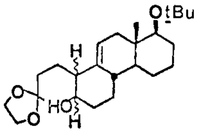
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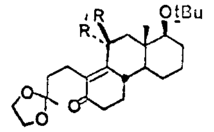
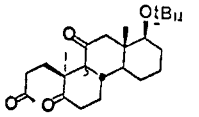

3a R= H, R'= OH
3b R,R'= O=

Treatment of **3b** with lithium in ammonia–tetrahydrofuran (2:1), followed by quenching with methyl iodide and hydrolysis with aqueous acetic acid, provided triketone **4** in ~70% yield. The equatorial configuration of the newly introduced methyl group at C-10 was strongly suggested by its chemical shift of 1.20 ppm. This inference was confirmed when cyclization of **4** in refluxing methanolic sodium hydroxide afforded enone **5** (mp 101–102 °C) and enone **6** (mp 119–121 °C) in a ratio of 3:1. The latter result is understandable, since cyclization to the 9β,10α-*D*-homoandrostane skeleton of **6** requires ring B to assume a twist-boat conformation.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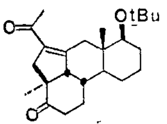
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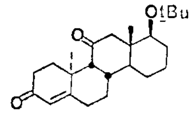
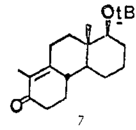

6

The stereochemical outcome of the reductive alkylation of the enedione **1,** which essentially parallels results in the simple bicyclic model series, thus required that the carbon atoms needed for ring A, rather than the methyl group, be introduced last. This was accomplished in the following manner. The tricyclic enone **7** (mp 91–91.5 °C) was prepared in 78% yield from 5-*tert*-butoxy-10-methyl-$\Delta^{1,9}$-2-octalone, in a manner similar to that described for enone **1.** Enone **7** was converted into dione **8,** mp 148.5–150.5 °C, in 74% yield, using the method described for **3.**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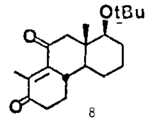
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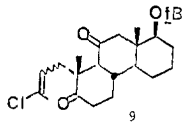
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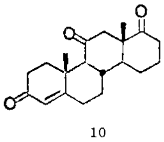
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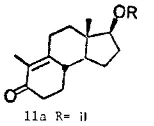
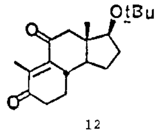
Reductive alkylation of **8** by aprotic Michael addition using silyl enones was unfortunately unsuccessful, possibly because of facile electron transfer from the intermediate dienediolate. Other annulating agents could, however, be used successfully: the modified Wichterle reagent,[5] 4-bromo-2-chloro-2-butene, thus afforded dione **9.** The latter was converted in 37% yield from **3** into (±)-*D*-homoadrenosterone (**10**), mp 199–201 °C,[6] via a sequence which involved refluxing formic-perchloric acid,[7] hydrolysis of the intermediate C-17a formate, and Jones oxidation.

The above sequence was applied with equal success to the series of compounds possessing a five-membered D ring, starting with the optically active enone **11a.**[8] The corresponding *tert*-butyl ether **11b,** mp 77.5–78.5 °C was converted in the usual manner in 71% overall yield into the enedione **12**


11a R= H
11b R= tBu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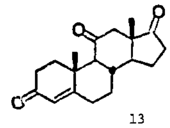
13

[mp 131–132.5 °C, $[\alpha]^{25}{}_D$ 29° (c 1.0, methanol)]. The latter on reductive alkylation with the Wichterle reagent and cycli-

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zation furnished adrenosterone **13**, identical in all respects with the natural material.

Acknowledgment. We thank the National Institutes of Health and the National Science Foundation for their support of this work.

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(3) Stork, G.; Logusch, E. W. *J. Am. Chem Soc.*, preceding paper in this issue.
(4) Stork, G.; Singh, J. *J. Am. Chem. Soc.* **1974**, *96*, 6181–6182.
(5) Wichterle, D.; Prochaska, J.; Hoffman, *J. Collect. Czech. Commun.* **1948**, *13*, 300–315.
(6) This substance was identical (NMR, IR) with an authentic optically active sample, kindly furnished by Sterling-Winthrop Corporation.
(7) Kobayashi, M.; Matsumoto, T. *Chem. Lett.* **1973**, 957–960.
(8) Roussel-UCLAF French Patent 1 350 675, 1964; *Chem. Abstr.* **1964**, *61*, P14555a.

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Flash Photolysis of Chromium Hexacarbonyl in Perfluorocarbon Solvents. Observation of a Highly Reactive Chromium Pentacarbonyl

Sir:

While the important role of coordinatively unsaturated coordination compounds in reactions catalyzed by organometallic compounds is widely accepted, direct observation of these intermediates in thermally induced reactions is usually difficult. It has, however, been amply demonstrated in recent years that complexes of this type can be generated by flash photolysis of metal carbonyls.[1] For example, in cyclohexane, chromium pentacarbonyl is formed by flash photolysis of $Cr(CO)_6$, and its reactivity with various nucleophiles has been studied.[1b] Detailed spectroscopic and structural information about metal carbonyl fragments has also been gained from photolytic decomposition of metal carbonyls in low-temperature matrices.[2] Perutz and Turner have observed that the position of maximum absorption of the visible band of the chromium pentacarbonyl species, formed from $Cr(CO)_6$, depends markedly on the matrix in which it is formed (e.g., Ne, 624; CF_4, 547; Ar, 533; Xe, 492; CH_4, 489 nm), and they have interpreted this blue shift in terms of an increasing interaction of electrons of the matrix material with the vacant coordination site on the metal.[2] One might conclude from these observations that $Cr(CO)_5$ in solution should be more weakly bonded, and therefore more reactive, in perfluorocarbon solvents than in hydrocarbon solvents. In this communication we report preliminary results from a study of the laser flash photolysis of $Cr(CO)_6$ in perfluoromethylcyclohexane, which confirm the above interpretation and reveal that in C_7F_{14} chromium pentacarbonyl is extremely reactive, combining with carbon monoxide, nitrogen, cyclohexane, and $Cr(CO)_6$ with rate constants approaching those of diffusion control.

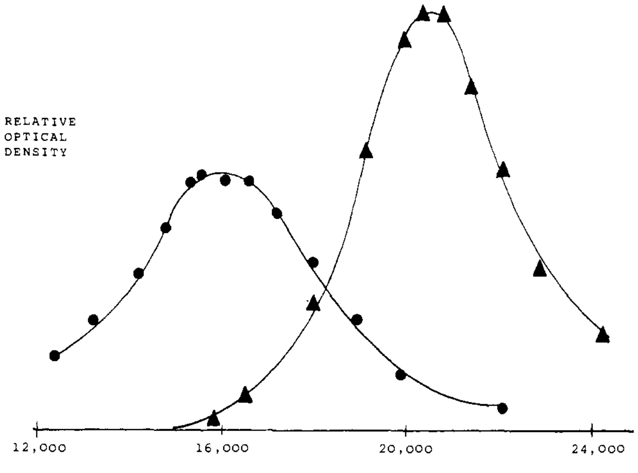

Figure 1. Transient absorption spectra recorded after laser flash photolysis of $Cr(CO)_6$ in perfluoromethylcyclohexane: (a) $Cr(CO)_5$ (●); recorded 10 ns after photolysis of 2.4×10^{-3} M $Cr(CO)_6$; (b) $Cr_2(CO)_{11}$ (▲), recorded 200 ns after photolysis of 1.2×10^{-2} M $Cr(CO)_6$.

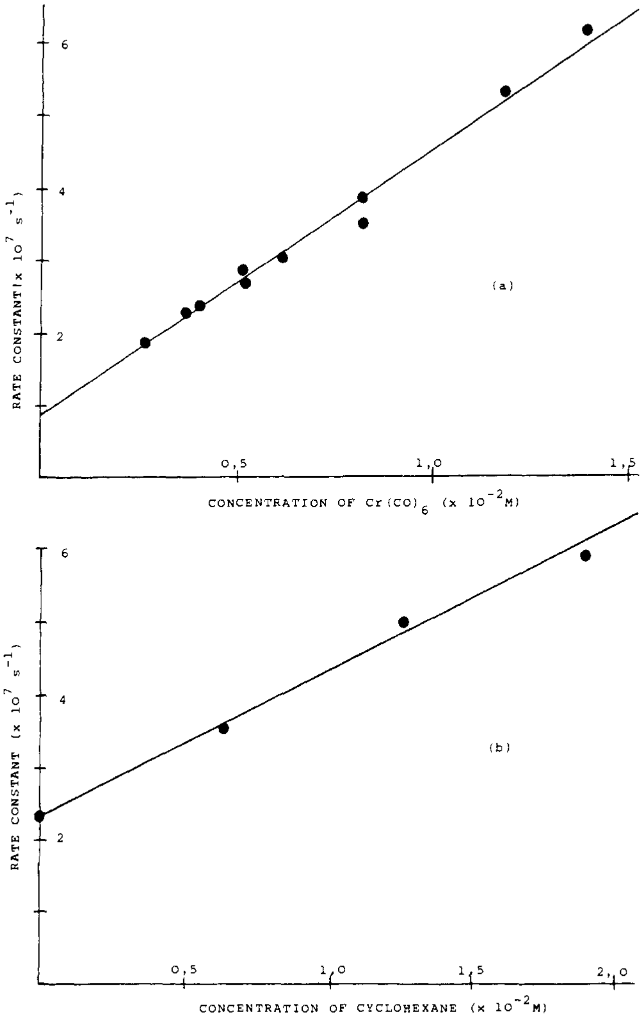

Figure 2. Dependence of the pseudo-first-order rate constant for decay (measured at λ 640 nm) of $Cr(CO)_5$ in perfluoromethylcyclohexane on (a) the concentration of $Cr(CO)_6$, (b) the concentration of cyclohexane; $[Cr(CO)_6] = 3.7 \times 10^{-3}$ M.

Excitation of $Cr(CO)_6$ (2.5×10^{-3} to 1.5×10^{-2} M) in argon-flushed perfluoromethylcyclohexane at room temperature using the third harmonic of a Quantel neodymium laser (353 nm; pulse duration 5 ns) produces a transient species absorbing in the visible, exhibiting a broad maximum at 620 ± 10 nm (Figure 1a). The rate of decay of this species depends upon the concentration of $Cr(CO)_6$ (Figure 2a). Concurrent with the disappearance of the 620-nm species is the appearance of a product possessing maximum absorption at ~485 nm (Figure 1b).[3] These observations may be explained most simply by the following reactions:

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