Reaction of C_{60} with Cyclopent-2-enone Acetals. A Convenient Access to Chiral C_{60} Derivatives

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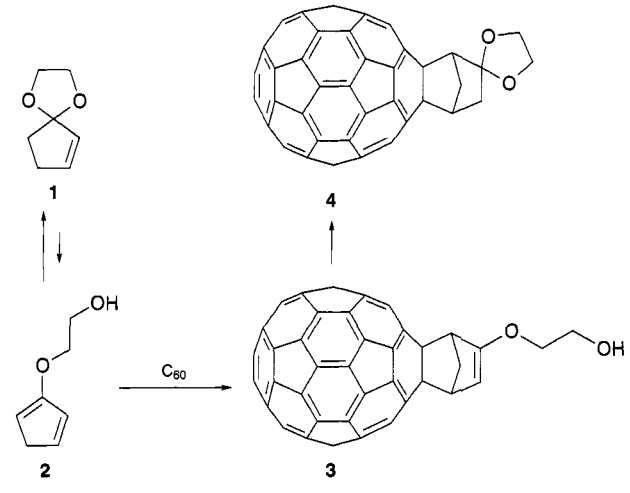
C_{60} reacts with cyclopent-2-enone ethylene acetal to give C_{60}-fused norbornan-2-one acetal; modification of the starting acetal with a chiral auxiliary leads to a mixture of diastereoisomeric adducts from which a pair of enantiomerically pure C_{60}-fused norbornan-2-ones are readily obtained.

Since the discovery of a method for the preparation of fullerenes in macroscopic quantities,[1] much attention has been focused on their chemical modification.[2] Although C_{60} reacts readily with a variety of 1,3-dienes in a [2 + 4] manner, the potential of this reaction for the derivatization of fullerenes has been restricted by the propensity of the adducts to undergo cycloreversion to the reaction components under heating and/or mass spectrometric conditions.[3] In this communication we report the reaction of cyclopent-2-enone acetal **1** with C_{60} *via* its ring-opened form **2**, where the primary [2 + 4] cycloadduct **3** is promptly converted to the acetal **4**, thereby effectively preventing the reversion of the adduct to the reactants (Scheme 1).[4]† The present method, moreover, provides a simple and efficient access to chiral C_{60} derivatives, (+)-**5** and (−)-**5**, and should be of substantial value, in the light of considerable current interest in the physical and biological properties of chiral fullerenes.[5–7]

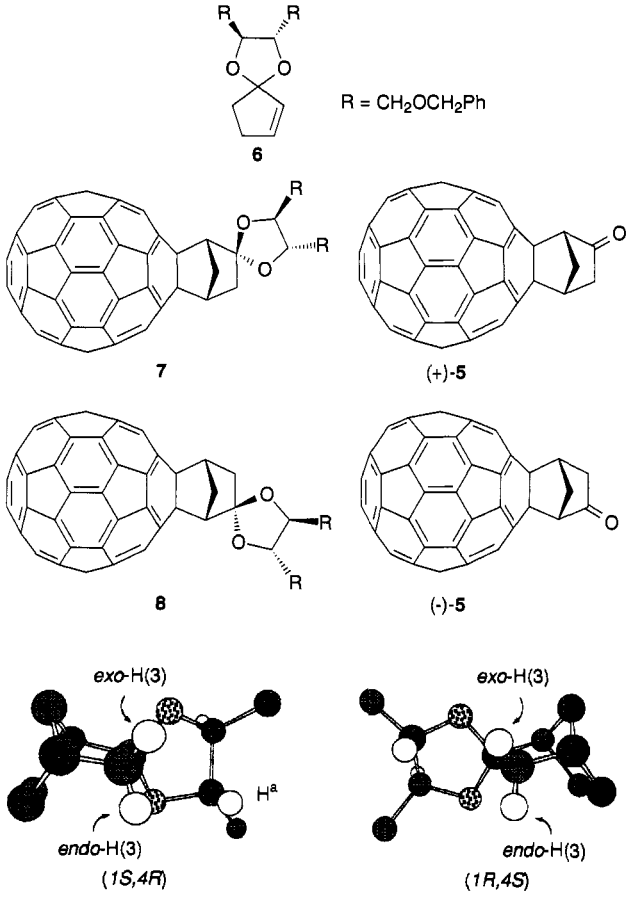
When a toluene solution of **1** (2 equiv.) and C_{60} was heated at 80 °C for 24 h in the presence of pyridinium toluene-*p*-sulfonate (PPTS, 5 mol%), **4** was obtained in 58% yield (66% based on unrecovered C_{60}) after chromatography on silica gel.† HPLC monitoring of the reaction revealed an intermediate presumed to be **3**, but its content remained negligible throughout the reaction. Compound **4** is thermally stable and no degradation was detected when purified **4** was heated in refluxing toluene for 24 h even in the presence of PPTS. The UV–VIS spectrum of **4** shows bands at 432 and 707 nm which are typical of 1,2-adducts across a 6,6-ring junction of C_{60},[8] supporting the reaction of C_{60} with **2** at the 6,6-ring junction as with other reactive dienes.[2,3] Hydrolysis of **4** (*p*-$MeC_6H_4SO_3H$–H_2O–toluene) afforded the corresponding ketone (±)-**5** in quantitative yield.‡

In anticipation of possible asymmetric induction in the reaction, we next investigated the reaction of C_{60} with the acetal **6**, bearing a chiral auxiliary[9] and derived from L-tartaric acid. Treatment of C_{60} with **6** in refluxing toluene for 30 h in the presence of PPTS produced two diastereoisomeric monoadducts **7** and **8** in nearly equal amounts (44% in total), indicating insignificant asymmetric induction in the process. These adducts were, however, readily separable by conventional chromatography owing to a large difference in their R_f values, 0.28 and 0.43 for **8** and **7**, respectively (silica gel, benzene). Hydrolysis of the isolated **7** and **8** afforded optically pure ketones (+)-**5** ($[\alpha]_D^{27}$ +450, *c* 0.006, toluene) and (−)-**5** ($[\alpha]_D^{27}$ −450, *c* 0.006, toluene), respectively, in nearly quantitative yields. The mirror image structures of these ketones are reflected in their mirror image CD curves.§

NOE values for **7** and **8** permitted the assignment of their absolute configurations. In the (1*R*,4*S*)-adduct,¶ the dioxolane methine proton H^a *anti* to the adjacent bridgehead proton is expected to be nearer to *endo*-H(3) than to *exo*-H(3), while the opposite is the case in the (1*S*,4*R*)-product (Scheme 2‖). Molecular mechanics calculations on model compounds, in which the fullerene moiety is omitted and the benzyloxymethyl groups are replaced by methyl groups, in fact reveal that H^a will be much nearer to *exo*-H(3) (2.70 Å) than to *endo*-H(3) (3.32 Å) in the (1*R*,4*S*)-isomer,** while the relative proximity of H^a to *exo*-H(3) and to *endo*-H(3) (3.18 Å and 2.78 Å, respectively) will be reversed in the (1*S*,4*R*)-isomer. Irradiation of H^a in **7** led to a weak, but distinct, NOE in *endo*-H(3) but not in *exo*-H(3),†† whereas similar irradiation of H^a in **8** resulted in a positive NOE for *exo*-H(3) but not *endo*-H(3). Accordingly, we



Scheme 1



Scheme 2

assigned a (1*R*,4*S*)-configuration for **7**, and hence for (+)-**5**, and a (1*S*,4*R*)-configuration for (−)-**5**.

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Footnotes

† After submission of this paper we learned that Takeshita *et al.*[10] made a similar finding.

‡ *Selected physical data for* **5**: ^{1}H NMR (400 MHz; CS_2–$CDCl_3$ 4:1) δ 2.82 (dt, *J* 11.7, 1.5 Hz, 1H), 3.05 (dd, *J* 18.6, 4.9 Hz, 1H), 3.52 (dd, *J* 18.6, 4.4 Hz, 1H), 3.78 (ddt, *J* 11.7, 4.4, 1.5 Hz, 1H), 4.15 (br s, 1H), 4.19 (dq, *J* 4.9, 1.5 Hz, 1H); ^{13}C NMR [100 MHz; CS_2–$CDCl_3$, 4:1, 0.03 mol dm^{-3} Cr(acac)$_3$] δ 35.08, 44.94, 48.34, 62.82, 70.56, 72.20, 136.10, 136.27, 136.94, 137.38, 139.43, 139.54, 139.83, 139.87, 141.15, 141.26, 141.35, 141.44, 141.51, 141.59, 141.66, 142.04, 142.15, 142.54, 143.85, 143.91, 144.13, 144.73, 144.77, 144.82, 144.92, 144.97, 145.08, 145.41, 145.46, 145.54, 145.67, 145.72, 145.83, 145.87, 146.78, 152.18, 152.45, 153.33, 153.53, 210.84; IR (CS_2) ν/cm^{-1}: 1760, 1186, 1162, 930, 728, 694, 528; UV–VIS ($CHCl_3$) λ_{max}/nm 312 (ε 36 000), 432 (3700), 697 (400); FD-MS *m/z* 802 (M^+, 92), 801 (100), 720 (9).

§ The characteristics of the CD of optically active **5** will be discussed elsewhere.

¶ Numbering for the norbornan-2-one moiety.

‖ Only relevant protons are shown and others are omitted for clarity.

** Note that the notation of absolute configuration for the model compound is opposite to that for the adduct of the corresponding configuration.

†† *endo*-H(3) was readily differentiated from *exo*-H(3) from the magnitude of their coupling with the methylene bridge proton *anti* to the acetal moiety and also with the vicinal bridgehead proton.

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