Preparation and Structures of Acetylene Adducts of 4,6-*O*-Isopropylidene- and 4-*O*-Acetyl-6-*O*-triphenylmethyl-1,5-anhydro-2-deoxy-D-*erythro*-hex-1-en-3-uloses[1)]

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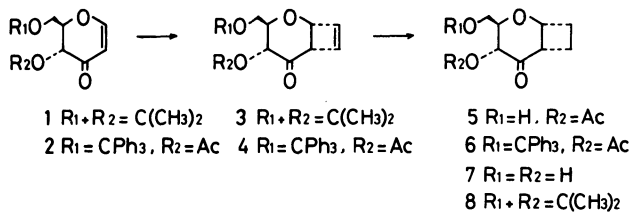
Synopsis. Cyclobutene adducts were formed stereoselectively in good yields by the irradiation of acetone solutions of 4,6-*O*-isopropylidene- and 4-*O*-acetyl-6-*O*-triphenylmethyl-1,5-anhydro-2-deoxy-D-*erythro*-hex-1-en-3-uloses, derived from D-glucal triacetate, in the presence of acetylene. The stereochemistry at the ring junction was achieved by a single-crystal X-ray analysis and a chemical correlation with the derived compounds.

Carbohydrate enones can be used to produce chiral compounds with four- and six-membered rings by the photochemical addition and Diels–Alder reaction of olefins, although in certain cases there are problems of regio- and stereochemical-selectivity in cycloadduct formation. In recent reports,[2)] Fraser-Reid et al. have demonstrated that annulated pyranosids obtained from carbohydrate α-enones can be converted into a variety of natural products and analogues. We have been concerned with the use of an enone system in pyranone compounds in order to prepare thermal and photochemical cycloadducts, e.g., the Diels–Alder adducts[3)] of methyl 2-oxo-2*H*-pyran-5-carboxylate with isoprene and the acetylene adducts[1)] of 7-methoxychromone, which are rearranged to cyclic skeletons and transformed into aromatic compounds.[1,4)] In the present investigation, conversions of carbohydrates into the chiral pyranone compounds and the use of their enone systems in cycloaddition reactions have been studied. This paper describes how photochemical reactions of 4,6-*O*-isopropylidene- and 4-*O*-acetyl-6-*O*-triphenylmethyl-1,5-anhydro-2-deoxy-D-*erythro*-hex-1-en-3-uloses (**1** and **2**), derived from readily available D-glucal triacetate,[5)] with acetylene gave stereoselectively the optically active cyclobutene adducts (**3** and **4**); the stereochemistry of the products was revealed by a single-crystal X-ray analysis and a chemical correlation.

Irradiation of **1** in an acetone solution saturated with a stream of acetylene by means of a 500-W high-pressure mercury lamp afforded [2+2]-cycloadduct (**3**) as a single compound in 81% yield. The single-crystal X-ray analysis confirmed the syn relationship of the cyclobutene ring to the proton at the C-5 position,[6)] indicating that acetylene approaches from the least hindered side of the molecule. Under similar conditions, enone **2** underwent a photochemical cycloaddition with acetylene to give the same type adduct (**4**) in 75% yield. The structural proof of **4** was based on a chemical correlation with **3**. That is, treatment of **4** with H_2 over Pd-C followed by deacetylation of the resulting cyclobutane acetate (**5**) afforded cyclobutane diol (**7**), which was identical in all respects with the product obtained from **3** (Scheme 1). Thus, the stereoselectivity of these cycloadditions seems to derive from the steric influence of the isopropylidene and triphenylmethyl substituents that blocks approach of acetylene from the β-face of the enone molecules.



Scheme 1.

As an application, we have examined the photochemical behavior of **3** and **4** having a bicyclic β,γ-unsaturated ketone system.[8)] When both **3** and **4** were irradiated in acetone and acetonitrile, the photoreduction products **8** and **6** were obtained in detectable amounts (27 and 20% yields), which were identical with the samples prepared by isopropylidenation of **7** and isolated from catalytic hydrogenation of **4**, respectively.

Experimental

Melting points are uncorrected. IR spectra were measured in $CHCl_3$ with a Hitachi 260-50 spectrophotometer. ^1H and ^{13}C NMR spectral data were obtained in $CDCl_3$ on a JEOL JNM-PMX 60 spectrometer and a JEOL JNM-FX 60 Fourier transform spectrometer, respectively. Chemical shifts are

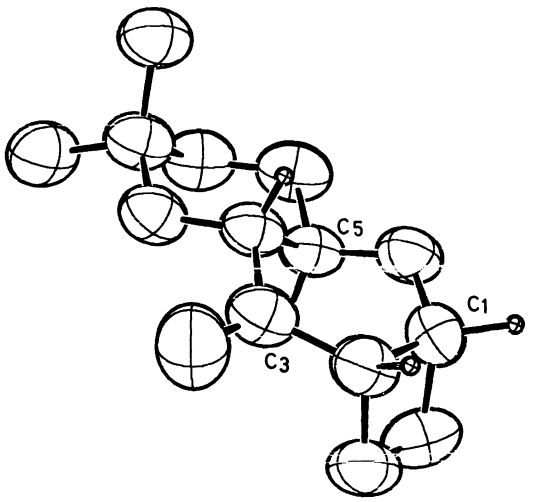


Fig. 1. ORTEP drawing of the molecular structure of **3**.[7)]

reported in δ values (ppm) downfield from an internal TMS reference. The mass spectra were measured with a JEOL JMS-D 300S spectrometer. Optical rotations were taken on a JASCO DIP-SL polarimeter. X-Ray diffraction data were obtained on an Enraf-Nonius CAD-4 automated four-circle diffractometer with a SDP program package. All irradiations were carried out with a 500-W high-pressure mercury lamp (Eikosha EHB-WI-500).

Photoaddition of Acetylene to 4,6-*O*-Isopropylidene- and 4-*O*-Acetyl-6-*O*-triphenylmethyl-1,5-anhydro-2-deoxy-D-*erythro*-hex-1-en-3-uloses (1 and 2). (a) To 1. A solution of **1** (120 mg) in dry acetone (250 ml) was irradiated through a Pyrex filter at room temperature for 30 min under a continuous introduction of acetylene. The removal of the solvent under reduced pressure and chromatography of the residue on silica gel using hexane–ethyl acetate (4:1) as eluent gave **3** (112 mg, 81% yield); mp 117—118.5 °C (hexane–ethyl acetate); $[\alpha]_D^{24}$ +103° (*c* 0.54 in EtOH); IR: 1725, 1390, 1380, and 1125 cm^{-1}; ^1H NMR δ=1.51 (6H, s, $-C(CH_3)_2$), 3.7—4.4 (5H, m), 5.14 (1H, d, *J*=2 Hz, $-OCHCH=$), and 6.2—6.4 (2H, m, $-CH=CH-$); ^{13}C NMR δ=18.6, 28.6, 55.9, 62.4, 63.2, 75.4, 77.6, 100.2, 137.0, 140.0, and 200.1; MS: *m/z* 210 (M^+); Found: C, 62.85; H, 6.92%. Calcd for $C_{11}H_{14}O_4$: C, 62.84; H, 6.71%.

(b) To 2. A solution of **2** (200 mg) in dry acetone (600 ml) was irradiated through a Pyrex filter at room temperature for 30 min under a continuous introduction of acetylene. After removing the solvent, the residue was subjected to column chromatography on silica gel using hexane–ethyl acetate (9:1) as eluent to afford **4** (158 mg, 75% yield); mp 157—158 °C (hexane–acetone); $[\alpha]_D^{24}$ +187° (*c* 0.53 in EtOH); IR: 1745, 1720, and 1600 cm^{-1}; ^1H NMR δ=1.78 (3H, s, OAc), 2.97 and 3.36 (each 1H, dd, *J*=3 and 10 Hz, $-CH_2OCPh_3$), 3.66 (1H, d, *J*=4 Hz, $-COCH-$), 4.10 (1H, dt, *J*=3 and 10 Hz, Ph_3COCH_2CH-), 5.05 (1H, d, *J*=4 Hz, $-OCHCH=$), 5.23 (1H, d, *J*=10 Hz, $-CHOAc$), 6.08 (2H, s, $-CH=CH-$), and 7.0—7.5 (15H, m, 3×Ph); ^{13}C NMR δ=20.3, 55.9, 62.1, 69.5, 74.9, 127.0, 127.1, 127.9, 128.8, 129.7, 137.0, 140.9, 143.6, 169.1, and 200.3; MS: *m/z* 454 (M^+); Found: C, 76.57; H, 5.91%. Calcd for $C_{29}H_{26}O_5$: C, 76.63; H, 5.77%.

Conversion of 3 and 4 to 7. (a) From 3. A mixture of **3** (100 mg) and 5% Pd-C (25 mg) in ethanol (15 ml) was stirred under a hydrogen atmosphere at room temperature for 90 min until it absorbed ca. 18 ml of H_2. The catalyst was removed by filtration and the solvent was evaporated to give an oil (100 mg); this was chromatographed on silica gel using benzene–ethyl acetate (1:1) as eluent to afford **7** (colorless oil, 80 mg). IR: 3600, 3500, and 1715 cm^{-1}; ^1H NMR δ=1.6—2.6 (4H, m, $-CH_2CH_2-$), 2.84 (2H, bs, 2×OH), 3.0—3.6 (1H, m, $-COCH-$), 3.72 (1H, dd, *J*=3 and 10 Hz, $-OCHCH_2OH$), 3.91 (2H, d, *J*=3 Hz, $-CH_2OH$), 4.37 (1H, d, *J*=10 Hz, $-CHOH$), and 4.90 (1H, dd, *J*=8 and 15 Hz, $-OCH-$); MS: *m/z* 173 ($[M+1]^+$).

Isopropylidene Derivative (8) of 7. *p*-Toluenesulfonic acid (43 mg) was added to a mixed solution of **7** (110 mg), 2,2-dimethoxypropane (10 ml) and dry *N,N*-dimethylformamide (0.5 ml), and then the mixture was stirred at room temperature for 50 min. A usual work-up and purification by silica-gel column chromatography (hexane–ethyl acetate, 9:1) gave **8** in 32% yield; mp 138—139 °C (hexane–ethyl acetate); IR: 1730, 1390, and 1380 cm^{-1}; ^1H NMR δ=1.54 (6H, s, $-C(CH_3)_2$), 1.7—2.7 (4H, m, $-CH_2CH_2-$), 3.0—3.5 (1H, m, $-COCH-$), 3.8—4.5 (2H, m, $-OCHCHO-$), 3.93 (2H, d, *J*=3 Hz, $-OCH_2-$), and 4.84 (1H, dd, *J*=8 and 15 Hz, $-OCH-$); MS: *m/z* 212 (M^+); Found: C, 62.24; H, 7.75%. Calcd for $C_{11}H_{16}O_4$: C, 62.25; H, 7.60%.

(b) From 4. A mixture of **4** (200 mg) and 5% Pd-C (120 mg) in ethyl acetate (20 ml) was stirred with H_2 at room temperature for 17 min. After ca. 20 ml of H_2 had been consumed, a similar work-up to that described above gave 210 mg of oily product, which was chromatographed on silica gel using hexane–ethyl acetate (98:2, 95:5, and 50:50) as developing agent to afford triphenylmethanol (75 mg), **6** (65 mg), and **5** (60 mg) in the order of elution. **5**: Colorless oil; IR: 3580, 3500, 1740, and 1720 cm^{-1}; ^1H NMR δ=1.5—2.7 (4H, m, $-CH_2CH_2-$), 2.21 (3H, s, OAc), 3.0—3.4 (2H, m, $-COCH-$ and OH), 3.80 (2H, d, *J*=2 Hz, $-CH_2OH$), 4.07 (1H, dt, *J*=2 and 10 Hz, $-CHCH_2OH$), 4.87 (1H, dd, *J*=7 and 15 Hz, $-OCH-$), and 5.23 (1H, d, *J*=10 Hz, $-CHOAc$). **6**: Mp 130—131 °C (ethanol); IR: 1740, 1730, 1600, 1490, and 1450 cm^{-1}; ^1H NMR δ=1.90 (3H, s, OAc), 1.5—3.3 (5H, m, $-CH_2CH_2-$ and $-COCH-$), 3.11 and 3.42 (each 1H, dd, *J*=3 and 10 Hz, $-CH_2OCPh_3$), 4.01 (1H, dt, *J*=3 and 10 Hz, Ph_3COCH_2CH-), 4.81 (1H, dd, *J*=8 and 14 Hz, $-OCH-$), and 5.34 (1H, d, *J*=10 Hz, $-CHOAc$). Alkaline hydrolysis of **5** (25 mg of **5**, 5 ml of methanol, 55 mg of Na_2CO_3, and stirring at room temperature for 25 h) gave **7** which was identical with the above material.

Irradiation of 3. A solution of **3** (203 mg) in anhydrous acetone (500 ml) was irradiated through a Pyrex filter at room temperature for 60 min. After removing the solvent, the residue was chromatographed on silica gel using hexane–ethyl acetate (7:3) as an eluent to afford **8** (55 mg, 27% yield); this was identical in all respects with the sample prepared by isopropylidenation of **7**.

Irradiation of 4. Irradiation of a solution of **4** (200 mg) in anhydrous acetonitrile (600 ml) through a Pyrex filter at room temperature for 30 min, followed by a silica-gel column chromatographic work-up of the residual oil using hexane–ethyl acetate (95:5) as an eluent afforded **6** (40 mg, 20% yield); this was identical with the compound previously obtained from the catalytic hydrogenation of **4**.

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References

1) This work is Part 3 of "Cycloadditions in Pyrones," Part 2: T. Matsui and M. Nakayama, *Bull. Chem. Soc. Jpn.*, **56**, 3531 (1983).

2) B. J. Fitzsimmons and B. Fraser-Reid, *Tetrahedron*, **40**, 1279 (1984) and references therein.

3) T. Matsui, T. Inoue, M. Nakayama, and J. D. White, *Bull. Chem. Soc. Jpn.*, **56**, 647 (1983); M. Nakayama, J. Kuramoto, T. Matsui, and J. D. White, *Bull. Chem. Soc. Jpn.*, **58**, 3051 (1985).

4) T. Imagawa, T. Nakagawa, M. Kawanisi, and K. Sisido, *Bull. Chem. Soc. Jpn.*, **52**, 1506 (1979).

5) C. D. Hurd and H. Jenkins, *Carbohydr. Res.*, **2**, 240 (1966); W. Roth and W. Pigman, "Methods in Carbohydr. Chem.," ed by R. L. Whistler, M. L. Wolfrom, and J. N. BeMiller, Academic Press, New York (1963), Vol. 2, pp. 405—408.

6) The final Fo and Fc data are deposited at the Office of the Editor of the Bulletin of the Chemical Society of Japan (Document No. 8716).

7) C. K. Johnson, ORTEP. Oak Ridge National Laboratory Report ORNL-3794 (1965).

8) For photorearrangement examples of β,γ-unsaturated carbonyl systems, an oxa-di-π-methane rearrangement of an acyclic β,γ-unsaturated ketone (W. G. Dauben, M. S. Kellogg, J. I. Seeman, and W. A. Spitzer, *J. Am. Chem. Soc.*, **92**, 1786 (1970)) and a construction of the bicyclobutane compound from 5-methoxy-2a,8a-dihydro-8*H*-benzo[*b*]cyclobuta[*e*]pyran-8-one (see Ref. 1).