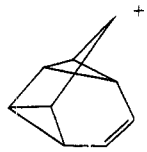
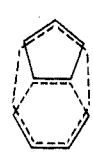
steric strain considerations than those involving more delocalized structures like X.



IX



X

Experimental Section

exo-Bicyclo[4.2.1]nona-2,4,7-trien-9-ol. A solution containing 10 g of ketone I,[4] 50 g of aluminum isopropoxide, freshly distilled (131–134°, 4–5 mm), 0.5 ml of acetone, and 500 ml of xylene, dried over sodium, was refluxed for 12 hr. To the cooled mass was added 100 ml of 10% aqueous NaOH and the mixture was extracted with ether. After the ethereal extract was washed with water and dried, the ether and xylene were removed by distillation at 1 atm. The remaining residue was chromatographed on 100 g of activity III alumina. The pentane fractions contained 6.17 g of *endo*-II-OH while the 50% ether–pentane fractions contained 1.66 g of *exo*-II-OH.

Analysis of the ethereal extract before distillation by VPC on a 2-m column containing 2.5% KOH–Carbowax 20M on Chromosorb W 80/100 mesh at 120° revealed a mixture of 80% *endo*-II-OH (4.5 min) and 20% *exo*-II-OH (11.0 min). Only 0.1% of another product was detected. This endo/exo ROH ratio of 4:1 did not change when the reaction mixture was heated for up to 4 days.[5]

Epimerization of *exo*-II-OH under the same conditions for 16 hr gave a 1:4 endo/exo ROH mixture.

The carbinol, *exo*-II-OH, was recrystallized from hexanes: mp 84–85°; ir (KBr) 3250, 3160, 3140, 2960, 2920, 1580 cm^{-1}; δ_{Me_4Si} (CS_2) 5.84 (m, 2.04, H_2), 5.69 (m, 2.04, H_3), 5.13 (d, J = 1.5 Hz, 2.04, H_7), 3.77 (s, 0.95, H_9), 2.78 (d, J = 7.2 Hz, 2.00, H_1), and ca. 2.8 (broad, 0.94, OH). The exo stereochemistry is indicated by the lack of coupling between H_1 and H_9.

Preparation of Ketone–$SnCl_4$ Complex. Sulfur dioxide (0.4 ml) was distilled into a NMR tube containing 34 mg of ketone I under nitrogen at −78°. Excess $SnCl_4$, 2–5 equiv, was added and the tube was stoppered. Spectral measurements were made at −40°.

After 0.5 hr, 1 ml of saturated Na_2CO_3 in methanol was added and the mixture was extracted with ether in the usual manner. The ketone I was recovered in 25% yield, and was >95% pure. Long reaction times produced ca. 10% of another ketonic product, not identified ($\nu_{C=O}$ 1720 cm^{-1}).

While the recovery from liquid SO_2 was poor (25%), the recovery from a nitromethane solution was good. The ketone was recovered in 93% yield along with 5% of an aromatic product.

Preparation of Sodium Alcoholates. To 1 mmol of the carbinol in 1 ml of anhydrous DME was added 2 equiv of pentane-washed sodium hydride with stirring. Color developed after a few minutes with the *endo*-II-OH. After NMR measurements were made at 0°, the solutions were diluted with DME and the uv–visible spectra were measured. *endo*-II-OH had λ_{max} 538 nm (ϵ 114) while *exo*-II-OH had no spectra. The solutions were quenched with wet ether and worked up in the usual way. The recovered yield of *endo*-II-OH was 91%.

Acknowledgment. The authors wish to express their gratitude to the Centro de Servicios de Computo de la Universidad Nacional Autonoma de Mexico for the use of the computer.

Registry No.—I, 34733-74-9; *endo*-II-OH, 34712-67-9; *exo*-II-OH, 55606-59-2; III, 55606-56-9; *endo*-IV, 55606-60-5; *exo*-IV, 55606-61-6; 9-bicyclo[4.2.1]nona-2,4,7-trienyl cation, 50613-69-9; aluminum isopropoxide, 555-31-7; $SnCl_4$, 7646-78-8; sodium hydride, 7646-69-7.

References and Notes

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Synthesis and Chemistry of 2,4-Dehydro-5-homoadamantanone[1]

Roger K. Murray, Jr.,* Kevin A. Babiak, and Thomas K. Morgan, Jr.[2]

Department of Chemistry, University of Delaware, Newark, Delaware 19711

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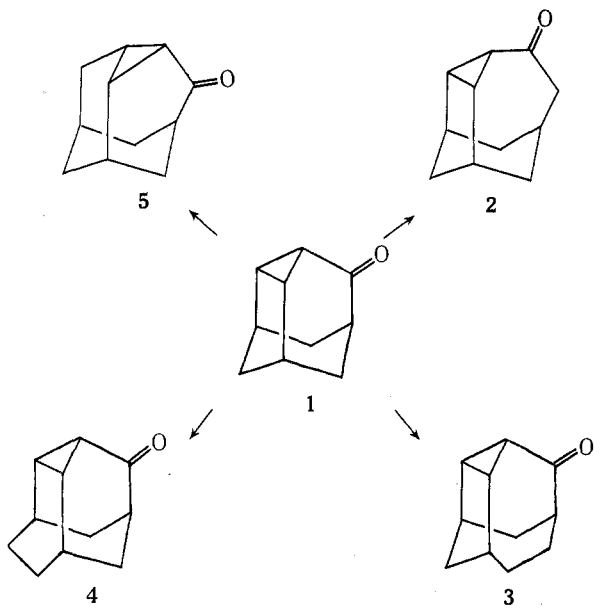
2,4-Dehydro-5-homoadamantanone (**5**) is readily prepared by a four-step reaction sequence from bicyclo[3.3.1]non-6-ene-3-carboxylic acid. Treatment of **5** with lithium in liquid ammonia proceeds by regiospecific cleavage of the C-3 to C-4 bond in **5** to give tricyclo[5.3.1.$0^{4,9}$]undecan-2-one (**27**). In contrast, perchloric acid catalyzed acetolysis of **5** leads to regiospecific cleavage of the C-2 to C-4 bond in **5** and formation of 2-*exo*-acetoxy-5-homoadamantanone. Sodium borohydride reduction of **5** occurs stereospecifically to afford 2,4-dehydro-5-*endo*-homoadamantanol (**9**). Acid-catalyzed isomerization of **9** provides 2-*exo*-homoadamant-4-enol exclusively which, in turn, gives homoadamant-4-en-2-one (**14**) upon Jones oxidation. Sodium borohydride reductions of enone **14** and ketone **27** both proceed by stereospecific attack at the exo face of the carbonyl carbon. The stereospecific synthesis of both 2-exo- and 2-endo-substituted homoadamantanes is presented. It is also shown that the stereochemistry of a 2-monosubstituted homoadamantane can be directly assigned from its characteristic ^1H NMR spectrum.

Homologation of 8,9-dehydro-2-adamantanone (**1**), without disruption of the conjugated cyclopropyl ketone moiety, allows for four "dehydrohomoadamantanones", **2–5** (Scheme I). As **1** has been shown to be a useful precursor for the synthesis of adamantyl,[3–6] protoadamantyl,[5–8] and isotwistyl[8,9] derivatives, cyclopropyl ketones **2–5** offer the potential for the synthesis of a variety of variously substituted polycyclic compounds. Recently, we have prepared

Scheme I

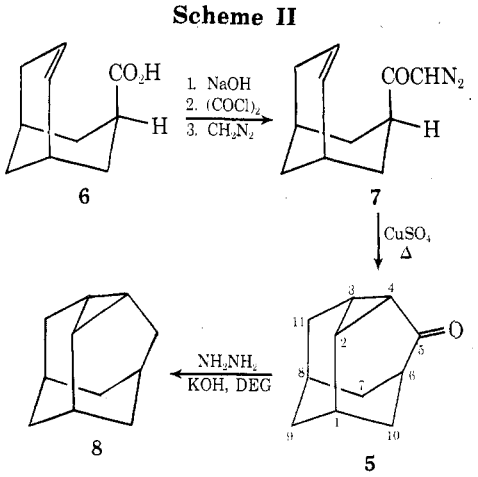


9,10-dehydro-2-homoadamantanone (**3**).[10] We now wish to report the synthesis of 2,4-dehydro-5-homoadamantanone (**5**) and some of the aspects of its chemistry.[11]

Results and Discussion

Cyclopropyl ketone **5** is readily obtained from bicyclo[3.3.1]non-6-ene-3-*endo*-carboxylic acid (**6**).[12] Sequential treatment of the sodium salt of **6** with oxalyl chloride and then diazomethane gives α-diazomethyl ketone **7** which, when decomposed in the presence of cupric sulfate in refluxing tetrahydrofuran, provides **5** (Scheme II). By this route, **5** was obtained in isolated yields of 50–70% from **6**. The skeletal framework of **5** was established by Wolff–Kishner reduction of **5** to give the known hydrocarbon 2,4-dehydrohomoadamantane (**8**).[13] The carbonyl absorption at 1688 cm^{-1} in **5** is indicative of a conjugated carbonyl.

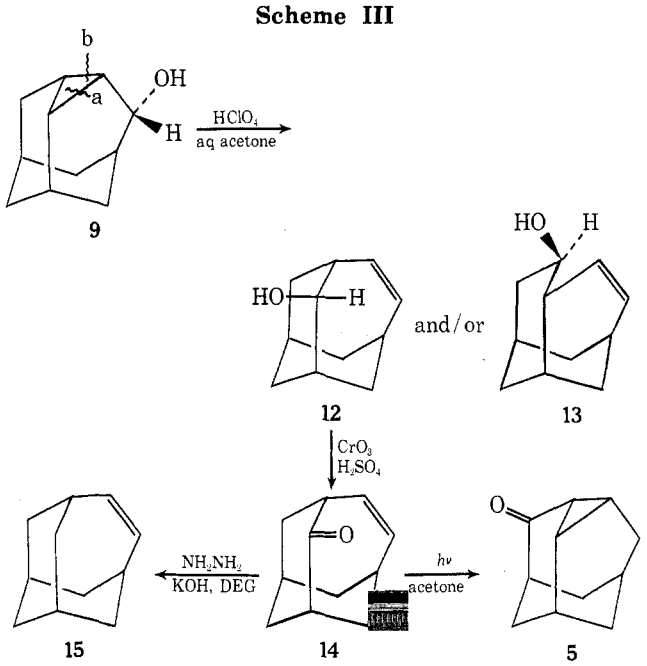
Scheme II

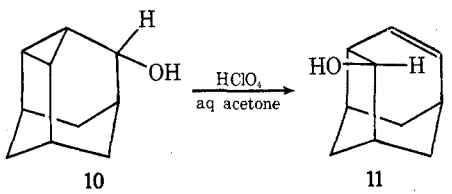


Sodium borohydride reduction of **5** affords a single alcohol to which we have assigned the structure of 2,4-dehydro-5-*endo*-homoadamantanol (**9**)[14] (Scheme III). An examination of molecular models shows that attack at the carbonyl carbon in **5** across the face of the seven-membered ring (i.e., endo attack) should be significantly impeded by the endo hydrogen at C-11. By contrast, there is no apparent steric hindrance to attack at the carbonyl carbon in **5** across the face of the six-membered ring (i.e., exo attack).

We have shown previously that treatment of 8,9-dehydro-2-adamantanol (**10**) with dilute perchloric acid in refluxing 80% aqueous acetone affords 2-*exo*-protoadamantenol (**11**).[5] An analogous cyclopropylcarbinyl–homoallyl

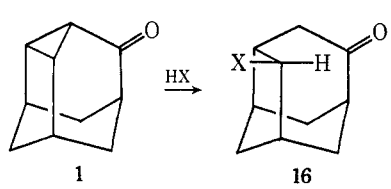
Scheme III





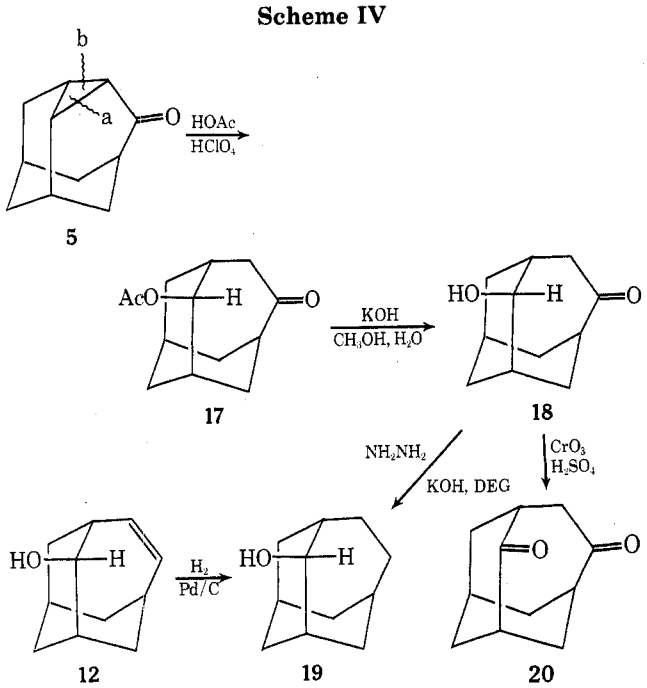
rearrangement in **9** might lead to 2-*exo*-homoadamant-4-enol (**12**) by cleavage of bond a in **9** and/or to 2-*exo*-tricyclo[5.3.1.$0^{4,9}$]undec-5-enol (**13**) by cleavage of bond b in **9**. Reaction of **9** with 0.005 *M* perchloric acid in refluxing aqueous acetone gives **12** exclusively. The skeletal framework of **12** follows from the conversion of **12** to the known hydrocarbon 4-homoadamantene (**15**).[13,15] Jones oxidation of **12** gives homoadamant-4-en-2-one (**14**) and Wolff–Kishner reduction of **14** provides **15**. Furthermore, irradiation of an acetone solution of **14** through a Pyrex filter regenerates ketone **5** by an oxadi-π-methane photorearrangement,[16] a reaction characteristic of β,γ-unsaturated ketones.

We have also shown that acid-catalyzed conjugate additions to **1** provide a general route to 2-exo-substituted 5-protoadamantanones (**16**).[8] Cyclopropyl ketone **5** under-



goes an analogous reaction. Perchloric acid catalyzed acetolysis of **5** affords 2-*exo*-acetoxy-5-homoadamantanone (**17**) in ca. 90% yield (Scheme IV). Thus, conjugate addition to **5** also proceeds by the preferential cleavage of bond a. The skeletal framework of **17** and the skeletal position and stereochemistry of the acetoxy substituent in **17** follow from the conversion of **17** to 2-*exo*-homoadamantanol (**19**). Hydrolysis of **17** gives 2-*exo*-hydroxy-5-homoadamantanone (**18**) and Wolff–Kishner reduction of **18** provides **19**. Catalytic hydrogenation of enol **12** affords an independent

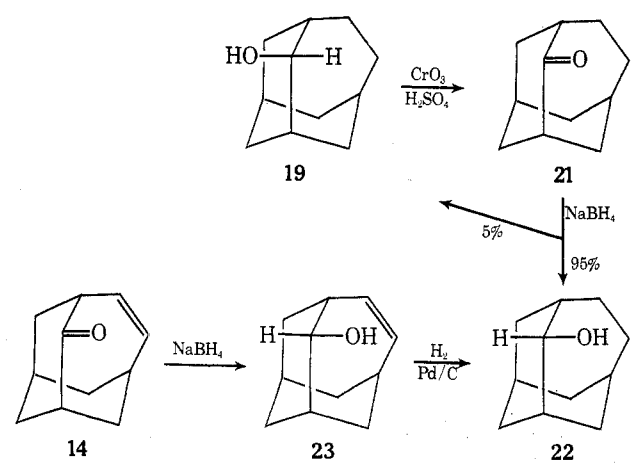
Scheme IV



route to **19**. It might also be noted that Jones oxidation of keto alcohol **18** gives 2,5-homoadamantanedione (**20**).

As expected, Jones oxidation of alcohol **19** gives 2-homoadamantanone (**21**) (Scheme V). Although 4-homoadamantanone (**26**) has been known for some time,[15,17] ketone **21** and 9-homoadamantanone, the other possible "homoadamantanones", have not been reported previously. Sodium borohydride reduction of **21** provides a 95:5 mixture of 2-*endo*-homoadamantanol (**22**) and **19**, respectively. An examination of molecular models shows that whereas there is no apparent steric hindrance to attack at the exo face of the carbonyl carbon in **21**, the endo hydrogen at C-5 in **21** appears to create some difficulty for attack at the endo face of the carbonyl carbon.

Scheme V

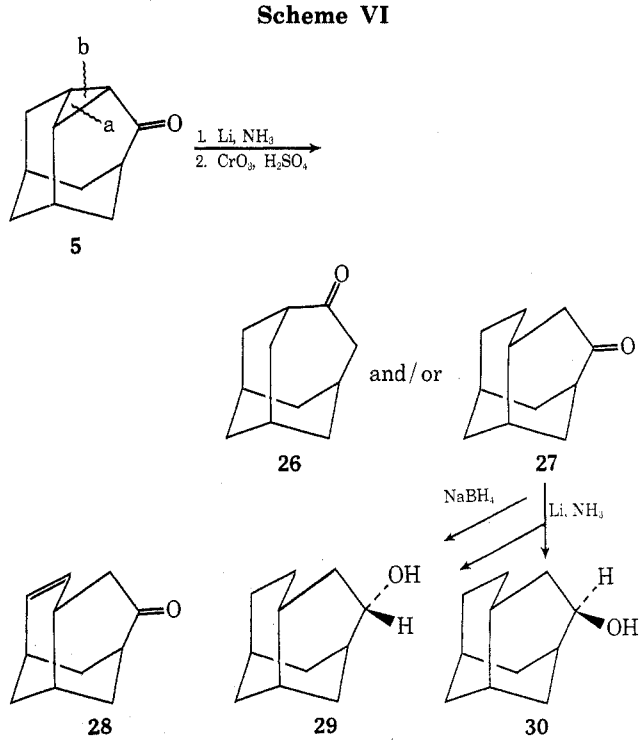


Alcohol **22** has also been independently synthesized. Sodium borohydride reduction of enone **14** gives 2-*endo*-homoadamant-4-enol (**23**) exclusively and catalytic hydrogenation of **23** provides **22**. An examination of molecular models shows that attack at the carbonyl carbon of **14** proceeds exclusively at its exo face because the orbitals of the π bond in **14** effectively prevent attack at the endo face. It is to be emphasized that the reactions summarized in Schemes III–V permit the stereospecific synthesis of both 2-exo- and 2-endo-substituted homoadamantanes.

The ^{1}H NMR spectra of the compounds generated in this study suggest that the stereochemistry of a 2-monosubstituted homoadamantane can be directly assigned from the characteristic splitting pattern of the C-2 hydrogen signal. Thus, whereas the ^{1}H NMR signals of the endo hydrogens at C-2 in **12** and **17–19** all appear as broad singlets, the ^{1}H NMR signals of the exo hydrogens at C-2 in **22** and **23** both appear as doublets of doublets. This is also the case for 2-*exo*-acetoxyhomoadamantane (**24**) and 2-*endo*-acetoxyhomoadamantane (**25**) (see Experimental Section).

Reductive cleavage of the cyclopropane ring in conjugated cyclopropyl ketones with lithium in liquid ammonia usually proceeds regiospecifically.[18] Such a reaction with cyclopropyl ketone **5** might lead to 4-homoadamantanone (**26**) by cleavage of bond a in **5** and/or to tricyclo[5.3.1.0^{4,9}]undecan-2-one (**27**) by cleavage of bond b in **5** (Scheme VI). Treatment of **5** with lithium in refluxing ammonia, followed by Jones oxidation of the reaction mixture, gives ketone **27** exclusively. As ketone **27** is identical with the ketone resulting from the catalytic hydrogenation of enone **28**,[19] the skeletal structure and the skeletal position of the carbonyl substituent in **27** are established. *Thus, it is possible to achieve selective regiospecific cleavage of the C-2 to C-4 bond* (i.e., **5** → **17**) *or the C-3 to C-4 bond* (i.e., **5** → **27**) *in 2,4-dehydro-5-homoadamantanone.*

Scheme VI



Sodium borohydride reduction of ketone **27** also proceeds stereospecifically to give 2-*endo*-tricyclo[5.3.1.0^{4,9}]-undecanol (**29**). An examination of molecular models clearly shows that attack at the endo face of the carbonyl carbon in **27** is prevented by the endo hydrogen at C-6. In contrast, reduction of **27** with lithium in liquid ammonia provides a ca. 1:1 mixture of **29** and 2-*exo*-tricyclo[5.3.1.0^{4,9}]undecanol (**30**). Jones oxidation of **29** or **30** regenerates **27**.

Aspects of the chemistry of 2-homoadamantanone and its derivatives are currently under active investigation.[21]

Experimental Section

All melting points were obtained in sealed capillary tubes using a Thomas-Hoover capillary melting point apparatus and are uncorrected. Infrared spectra were obtained on Perkin-Elmer 180 or

337 spectrophotometers and proton magnetic resonance spectra were recorded with Varian A-60A or Perkin-Elmer R-12B 60-MHz spectrometers. Apparent splittings are given in all cases. Unless noted otherwise, yields were obtained by integration of appropriate signals in the ^1H NMR spectrum of the product(s) vs. the signal of a predetermined amount of added standard (generally trichloroethylene) and are regarded as being accurate to ca. ±10%. Elemental analyses were performed by Micro-Analysis, Inc., Wilmington, Del.

2,4-Dehydro-5-homoadamantanone (5). A slurry of 4.61 g (27.7 mmol) of 3-*endo*-carboxybicyclo[3.3.1]non-6-ene (**6**)[12] in 50 ml of water was titrated to a phenolphthalein end point with 1 *N* sodium hydroxide. The solvent was evaporated at reduced pressure and the residue was heated at 70° (0.1 mm) for 12 hr. The resulting dry sodium salt of **6** was treated with 50 ml of anhydrous benzene and 4 ml of anhydrous pyridine, cooled to 0°, and stirred as 7 ml (82.6 mmol) of oxalyl chloride was added dropwise. After addition was complete, the reaction mixture was stirred at 0° for 15 min and at room temperature for 15 min. The mixture was then filtered and the residue was washed several times with benzene. Evaporation of the solvent and excess oxalyl chloride provided a residue of 3-*endo*-bicyclo[3.3.1]non-6-enoyl chloride. The crude acid chloride was dissolved in 100 ml of anhydrous ether, cooled to 0°, and a solution of ca. 4.5 g (107.1 mmol) of diazomethane in 400 ml of anhydrous ether was added rapidly with stirring. The reaction mixture was stirred at 0° for 1 hr and at room temperature for 19 hr. Evaporation of the solvent at reduced pressure gave 3-*endo*-bicyclo[3.3.1]non-6-enyl diazomethyl ketone (**7**) as a viscous oil.

The unpurified α-diazo ketone **7**, dissolved in 100 ml of tetrahydrofuran, and 4.5 g of cupric sulfate were stirred at reflux for 12 hr, then cooled and filtered. The solvent was evaporated at reduced pressure and the residue was dissolved in 30 ml of water and 50 ml of ether. The aqueous and ethereal layers were separated and the aqueous layer was extracted with ether (3 × 25 ml). The ether extracts were combined and dried over anhydrous magnesium sulfate, and the solvent was evaporated at reduced pressure. The residue was dissolved in a solution of 50 ml of methanol and 50 ml of water, 4.5 g of potassium hydroxide was added, and the mixture was refluxed for 4 hr. Evaporation at reduced pressure removed the methanol from the reaction mixture and the residue was extracted with ether (3 × 50 ml). The combined ether extracts were dried over anhydrous magnesium sulfate and the solvent was evaporated at reduced pressure. The residue was sublimed (100°, 0.1 mm), then column chromatographed on silica gel with benzene as eluent, and finally resublimed to give 2.29 g (51% yield) of pure **5**: mp 253–254°; δ_{Me_4Si} ($CDCl_3$) 2.7–1.1 (br m); ν (CCl_4) 3030, 2935, 2860, 1688, 1460, 1450, 1440, 1350, 1340, 1300, 1250, 1160, 1125, 1095, 1015, and 1000 cm^{-1}.

Anal. Calcd for $C_{11}H_{14}O$: C, 81.44; H, 8.70. Found: C, 81.29; H, 8.49.

2,4-Dehydrohomoadamantane (8). A solution of 209 mg (1.29 mmol) of **5**, 1.0 g of potassium hydroxide, and 1.0 g of 95% hydrazine in 8 ml of diethylene glycol was heated with stirring at 110° for 30 min, and then for 24 hr at 180°. During this time, a white solid appeared on the water-cooled condenser. The system was cooled and the material on the condenser was dissolved in cyclohexane. The pot residue was diluted with water (50 ml) and extracted with cyclohexane (3 × 30 ml). The cyclohexane extracts from condenser and pot were combined and dried over anhydrous magnesium sulfate. Evaporation of the solvent at reduced pressure provided a solid which GLC analysis (5 ft × 0.25 in. Carbowax column, 175°) showed contained a major component of short retention time and a minor component of much longer retention time (which was not investigated further). Isolation of the major product by GLC (above conditions) gave pure **8** which was identified by comparison of its ir spectrum with that of an authentic sample prepared by an alternative route.[13] GLC analysis of the product mixture showed that **8** was obtained from **5** in ca. 35% yield.

5-*endo*-2,4-Dehydrohomoadamantanol (9). A solution of 500 mg (3.09 mmol) of **5** in 5 ml of methanol was added dropwise to a stirred solution of 380 mg (10.0 mmol) of sodium borohydride in 10 ml of methanol at 0°. The reaction mixture was stirred for 45 min at 0° and then for 45 min at room temperature, at which point 10 ml of water was added. The resulting solution was saturated with sodium chloride and then extracted with ether (3 × 50 ml). The combined ether extracts were dried over anhydrous magnesium sulfate and the solvent was evaporated at reduced pressure. Analysis of the residue by ^1H NMR indicated that **9** was obtained in ca. 75% yield. GLC analysis (5 ft × 0.25 in. FFAP column, 170°) showed a single component to be present and purification of **9** by GLC (above conditions) gave a white solid: mp 269–272°; δ_{Me_4Si} ($CDCl_3$) 4.28 (apparent t, J = 5.5 Hz, 1 H, CHOH) and 2.6–0.6 (br m, 15 H); ν (CCl_4) 3675, 3450 (br), 3050, 2935, 2875, 1440, 1380, 1345, 1080, 1060 and 1040 cm^{-1}.

Anal. Calcd for $C_{11}H_{16}O$: C, 80.44; H, 9.82. Found: C, 80.66; H, 9.53.

2-*exo*-Homoadamant-4-enol (12). A solution of 128 mg (0.78 mmol) of **9** in 15 ml of 80% aqueous acetone which was 0.005 *M* in perchloric acid was stirred at reflux for 15 hr. The solution was then saturated with sodium chloride and extracted with ether (3 × 30 ml). The combined ether extracts were dried over anhydrous magnesium sulfate and the solvent was evaporated at reduced pressure. Analysis of the residue by ^1H NMR indicated that **12** was obtained in approximately quantitative yield. GLC analysis (10 ft × 0.25 in. FFAP column, 200°) showed a single component to be present and purification of **12** by GLC (above conditions) gave a white solid: mp 265–266°; δ_{Me_4Si} ($CDCl_3$) 6.24–5.58 (m, 2 H, CH=CH), 3.84 (br s, 1 H, CHOH), and 2.8–0.8 (br m, 13 H); ν (CCl_4) 3630, 3420 (br), 3025, 2920, 2845, 1440, 1060, and 1020 cm^{-1}.

Anal. Calcd for $C_{11}H_{16}O$: C, 80.44; H, 9.82. Found: C, 80.54; H, 9.76.

Homoadamant-4-en-2-one (14). To a stirred solution of 129 mg (0.78 mmol) of **12** in 15 ml of acetone at 0° was added 600 μl of a freshly prepared solution of Jones reagent (2.8 g of chromic anhydride, 4.5 ml of sulfuric acid, and 12 ml of water). The reaction mixture was stirred at 0° for 20 min, then 20 ml of water was added, and the mixture was stirred at room temperature for an additional 30 min. The resulting solution was saturated with sodium chloride and extracted with ether (3 × 40 ml). The combined ether extracts were washed with saturated aqueous sodium bicarbonate (3 × 50 ml) and dried over anhydrous magnesium sulfate. The solvent was evaporated at reduced pressure and the residue was column chromatographed on silica gel with benzene as eluent and then sublimed at 100° (0.5 mm) to afford 114 mg (89% yield) of **14** as a white solid: mp 252–253°; δ_{Me_4Si} ($CDCl_3$) 6.34–5.64 (m, 2 H, CH=CH) and 3.1–1.2 (br m, 12 H); ν (CCl_4) 3065, 2950, 2875, 1712, 1435, 1300, 1255, and 1100 cm^{-1}.

Anal. Calcd for $C_{11}H_{14}O$: C, 81.44; H, 8.70. Found: C, 81.31; H, 8.74.

Homoadamantene (15). By a procedure analogous to that employed for **5** → **8**, Wolff–Kishner reduction of **14** provided **15** as the only reaction product (GLC analysis) in ca. 40% yield. Olefin **15** was isolated by GLC (5 ft × 0.25 in. FFAP column, 130°) and was identified by comparison of its ir spectrum with that of an authentic sample prepared by an alternative route.[15]

Acetone-Sensitized Photoisomerization of 14. A solution of 55 mg of **14** in 3 ml of acetone was irradiated through a Pyrex filter with a Hanovia L 450-W high-pressure mercury lamp. Monitoring the photolysis by GLC (5 ft × 0.25 in. FFAP column, 200°) showed a gradual disappearance of **14** and the appearance of a single photoproduct of longer retention time. After irradiation for 2.5 hr, no starting material remained and only the photoisomer was present. The solvent was evaporated at reduced pressure and the residue was sublimed to give 26 mg (47% yield) of **5**.

2-*exo*-Acetoxy-5-homoadamantanone (17). A solution containing 1.01 g (6.23 mmol) of **5** and 300 μl of 70% perchloric acid in 30 ml of acetic acid was stirred for 14 hr at 100°, then diluted with water (100 ml) and neutralized with solid sodium bicarbonate. The resulting mixture was extracted with ether (4 × 50 ml) and the combined ether extracts were dried over anhydrous magnesium sulfate. Evaporation of the solvent at reduced pressure provided an oil which by ^1H NMR analysis contained a ca. 90% yield of **17**. GLC analysis (5 ft × 0.25 in. FFAP column, 190°) showed a single component to be present and isolation by GLC (above conditions) gave **17** as a clear oil: δ_{Me_4Si} ($CDCl_3$) 4.74 (br s, $W_{1/2}$ = 5.4 Hz, 1 H, $CHOCOCH_3$) and 2.9–1.2 (br m, 17 H, containing $CHOCOCH_3$ singlet at δ 2.07); ν (CCl_4) 2930, 2865, 1736, 1701, 1445, 1370, 1085, and 1025 cm^{-1}.

Anal. Calcd for $C_{13}H_{18}O_3$: C, 70.24; H, 8.16. Found: C, 70.14; H, 8.04.

2-*exo*-Hydroxy-5-homoadamantanone (18). A reaction mixture containing 1.095 g (4.93 mmol) of **17**, 1 g of potassium hydroxide, 25 ml of methanol, and 25 ml of water was refluxed for 4 hr. At this point the methanol was evaporated at reduced pressure and the residue was saturated with sodium chloride and extracted with ether (4 × 50 ml). The combined ether extracts were dried over anhydrous magnesium sulfate and the solvent was evaporated at reduced pressure. GLC analysis (5 ft × 0.25 in. Carbowax column, 220°) of the residue showed a major component of long retention

time and several very minor components of short retention time (which were not investigated further). Analysis of the residue by ^{1}H NMR indicated that **18** was obtained in ca. 85% yield. Purification by GLC (above conditions) gave **18** as a white solid: mp 310.5–312°; δ_{Me_4Si} ($CDCl_3$) 3.73 (br s, $W_{1/2}$ = 5 Hz, 1 H, CHOH) and 2.8–1.1 (br m, 15 H); ν (CCl_4) 3610, 3460, 2910, 2850, 1698, 1440, 1350, 1080, and 1030 cm^{-1}.

Anal. Calcd for $C_{11}H_{16}O_2$: C, 73.30; H, 8.95. Found: C, 73.33; H, 8.71.

2-*exo*-Homoadamantanol (19). A. A solution of 95 mg of **12** in 50 ml of ethanol was stirred with 400 mg of 5% palladium on charcoal under an atmosphere of hydrogen for 24 hr. The reaction mixture was then filtered to remove the catalyst. The catalyst was washed several times with methanol and the filtrate and washings were combined. Evaporation of the solvent at reduced pressure gave a solid residue which by ^{1}H NMR analysis contained a ca. 85% yield of **19**. Isolation of the product by GLC (5 ft × 0.25 in. Carbowax column, 190°) provided **19** as a white solid: mp 282.5–284°; δ_{Me_4Si} ($CDCl_3$) 3.62 (br s, $W_{1/2}$ = 5 Hz, 1 H, CHOH) and 2.5–1.0 (br m, 17 H); ν ($CHCl_3$) 3625, 3015, 2910, 1450, 1440, 1055, 1020, 980, and 945 cm^{-1}.

Anal. Calcd for $C_{11}H_{18}O$: C, 79.46; H, 10.91. Found: C, 79.32; H, 10.76.

B. By a procedure analogous to that employed for **5** → **8**, Wolff–Kishner reduction of **18** afforded **19** in an isolated yield of ca. 70%.

2,5-Homoadamantanedione (20). Oxidation of 77 mg of **18** with Jones reagent by the procedure described for **12** → **14** provided 62 mg of material which was purified by GLC (5 ft × 0.25 in. Carbowax column, 235°) to give **20** as a white solid: mp 306.5–307°; δ_{Me_4Si} ($CDCl_3$) 3.2–1.5 (br m); ν (CCl_4) 2920, 2850, 1702 (br), 1450, 1285, 1165, and 1045 cm^{-1}.

Anal. Calcd for $C_{11}H_{14}O_2$: C, 74.13; H, 7.92. Found: C, 74.21; H, 7.66.

2-Homoadamantanone (21). Oxidation of 258 mg of **19** with Jones reagent by the procedure described for **12** → **14** gave 224 mg (88% yield) of **21**. Isolation by GLC (5 ft × 0.25 in. Carbowax column, 190°) afforded **21** as a white solid: mp 278–279°; δ_{Me_4Si} ($CDCl_3$) 3.0–1.0 (br m); ν (CCl_4) 2915, 2860, 1700, 1440, 1220, 1115, 1070, 1000, and 960 cm^{-1}.

Anal. Calcd for $C_{11}H_{16}O$: C, 80.44; H, 9.82. Found: C, 80.50; H, 9.76.

2-*endo*-Homoadamant-4-enol (23). Sodium borohydride reduction of **14** by the procedure described for **5** → **9** provided **23**. Isolation by GLC (5 ft × 0.25 in. Carbowax column, 190°) gave **23** as a white solid: mp 291.5–292.5°; δ_{Me_4Si} ($CDCl_3$) 6.19 (dd, J = 10 and 8 Hz, 1 H, CH=CH at C-5), 5.67 (dd, J = 10.5 and 8 Hz, 1 H, CH=CH at C-4),[20] 3.73 (dd, J = 6 and 5 Hz, 1 H, CHOH), and 2.8–1.1 (br m, 13 H); ν ($CHCl_3$) 3580, 3450, 3020, 2915, 2860, 1460, 1450, 1400, 1390, 1090, 1050, and 1040 cm^{-1}.

Anal. Calcd for $C_{11}H_{16}O$: C, 80.44; H, 9.82. Found: C, 80.68; H, 9.53.

Oxidation of **23** with Jones reagent by the procedure described for **12** → **14** regenerated **14**.

2-*endo*-Homoadamantanol (22). Catalytic hydrogenation of **23** by the procedure described for **12** → **19** gave **22**. Isolation by GLC (5 ft × 0.25 in. Carbowax column, 190°) provided **22** as a white solid: mp 283.5–285.5°; δ_{Me_4Si} ($CDCl_3$) 3.85 (dd, J = 5.5 and 4 Hz, 1 H, CHOH) and 2.5–0.9 (br m, 17 H); ν ($CHCl_3$) 3625, 3450, 3010, 2915, 1445, 1060, and 1025 cm^{-1}.

Anal. Calcd for $C_{11}H_{18}O$: C, 79.46; H, 10.91. Found: C, 79.52; H, 10.78.

Jones oxidation of **22** by the procedure described for **12** → **14** gave **21**.

2-*exo*-Acetoxyhomoadamantane (24). To a solution of 262 mg (1.58 mmol) of **19** in 6 ml of acetic anhydride was added 0.5 g of sodium acetate. The mixture was stirred at 95° for 2 hr, then cooled and diluted with water (75 ml). The resulting mixture was neutralized with solid sodium bicarbonate and extracted with ether (3 × 30 ml). The combined ether extracts were dried over anhydrous magnesium sulfate and the solvent was evaporated at reduced pressure. Analysis of the residue by ^{1}H NMR indicated that **24** was obtained in ca. 90% yield. Isolation by GLC (5 ft × 0.25 in. Carbowax column, 220°) gave **24** as an oil: δ_{Me_4Si} ($CDCl_3$) 4.62 (br s, $W_{1/2}$ = 5 Hz, 1 H, $CHOCOCH_3$) and 2.4–1.0 (br m, 19 H, containing $CHOCOCH_3$ singlet at δ 2.00); ν (CCl_4) 2900, 2850, 1730, 1440, 1360, 1240, 1035, and 985 cm^{-1}.

Anal. Calcd for $C_{13}H_{20}O_2$: C, 74.96; H, 9.68. Found: C, 75.07; H, 9.77.

2-*endo*-Acetoxyhomoadamantane (25). Treatment of **22** according to the conditions employed for **19** → **24** provided **25** which was isolated by GLC (5 ft × 0.25 in. QF-1 column, 175°) as an oil: δ_{Me_4Si} ($CDCl_3$) 4.92 (dd, J = 6 and 4 Hz, 1 H, $CHOCOCH_3$) and 2.7–0.9 (br m, 19 H, containing $CHOCOCH_3$ singlet at δ 2.02); ν (CCl_4) 2910, 2850, 1730, 1445, 1360, 1240, 1040, and 1025 cm^{-1}.

Anal. Calcd for $C_{13}H_{20}O_2$: C, 74.96; H, 9.68. Found: C, 75.21; H, 9.72.

Tricyclo[5.3.1.0^{4,9}]undecan-2-one (27). To a mechanically stirred slurry of 3.15 g (0.45 mol) of lithium in ca. 250 ml of refluxing ammonia was added dropwise a solution of 1.75 g (10.8 mmol) of **5** in 15 ml of anhydrous ether. The reaction mixture was stirred at reflux for 4 hr and then 35 g of solid ammonium chloride was slowly added. The ammonia was allowed to evaporate, and the resulting residue was diluted with water (250 ml) and extracted with ether (4 × 200 ml). The combined ether extracts were washed successively with 5% hydrochloric acid (2 × 100 ml), 5% aqueous sodium bicarbonate (100 ml), and saturated sodium chloride, and then dried over anhydrous magnesium sulfate. The solvent was evaporated at reduced pressure and the residue was oxidized with Jones reagent by the procedure described for **12** → **14**. Column chromatography of the oxidation product on silica gel with benzene as eluent, followed by sublimation (90°, 0.3 mm), provided 880 mg (50% yield) of **27**. Final purification by GLC (5 ft × 0.25 in. QF-1 column, 175°) gave **27** as a white solid: mp 297–298°; δ_{Me_4Si} ($CDCl_3$) 3.0–0.5 (br m); ν (CCl_4) 2925, 2865, 1705, 1450, 1440, 1405, 1260, 1220, 1145, 1090, 1080, 1050, and 1030 cm^{-1}.

Anal. Calcd for $C_{11}H_{16}O$: C, 80.44; H, 9.82. Found: C, 80.29; H, 9.61.

2-*endo*-Tricyclo[5.3.1.0^{4,9}]undecanol (29). Sodium borohydride reduction of 81 mg of **27** by the procedure described for **5** → **9** afforded 93 mg of material which by ^{1}H NMR analysis contained a ca. 85% yield of **29**. Isolation by GLC (5 ft × 0.25 in. Carbowax column, 190°) gave **29** as a white solid: mp >300°; δ_{Me_4Si} ($CDCl_3$) 4.23 (apparent t, J = 8.6 Hz, 1 H, CHOH) and 2.5–0.6 (br m, 17 H); ν (CCl_4) 3630, 3335, 2910, 2855, 1460, 1445, 1100, and 1020 cm^{-1}.

Anal. Calcd for $C_{11}H_{18}O$: C, 79.46; H, 10.91. Found: C, 79.63; H, 10.85.

Jones oxidation of **29** by the procedure described for **12** → **14** gave **27**.

Lithium–Ammonia Reduction of 27. Reduction of 120 mg of **27** with lithium in liquid ammonia was carried out by the procedure described for **5** → **27**. GLC (5 ft × 0.25 in. Carbowax column, 190°) and ^{1}H NMR analysis of the crude reaction mixture suggested the presence of two alcohol products. The residue from the reaction was chromatographed on silica gel. Elution with 50:50 benzene–heptane provided 25 mg of **29** (shorter retention time by GLC). Further elution with 75:25 benzene–heptane afforded 25 mg of **2-*exo*-tricyclo[5.3.1.0^{4,9}]undecanol (30)** which was isolated by GLC (above conditions) as a white solid: mp 240–241°; δ_{Me_4Si} ($CDCl_3$) 4.08 (apparent t, J = 8.5 Hz, 1 H, CHOH); ν (CCl_4) 3625, 3350, 2915, 2875, 1465, 1450, 1040, and 985 cm^{-1}.

Anal. Calcd for $C_{11}H_{18}O$: C, 79.46; H, 10.91. Found: C, 79.34; H, 10.74.

Jones oxidation of **30** by the procedure described for **12** → **14** gave **27**.

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Registry No.—**5**, 55638-01-2; **6**, 21932-98-9; **8**, 55638-02-3; **9**, 55638-03-4; **12**, 55638-04-5; **14**, 55638-05-6; **15**, 24669-57-6; **17**, 55638-06-7; **18**, 55638-07-8; **19**, 55638-08-9; **20**, 55638-09-0; **21**, 55638-10-3; **22**, 55659-65-9; **23**, 55659-66-0; **24**, 55638-11-4; **25**, 55659-67-1; **27**, 55638-12-5; **29**, 55638-13-6; **30**, 55659-68-2.

References and Notes

(1) A preliminary report of this work was presented at the 9th Middle Atlantic Regional Meeting of the American Chemical Society, Wilkes-Barre, Pa., April 25, 1974.
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(20) This assignment follows from our earlier observation[6] that the upfield and downfield olefinic "triplets" in the ^{1}H NMR spectrum of 2-protoadamantenone may be assigned to the hydrogens at C-4 and C-5, respectively.
(21) Note Added in Proof. An independent synthesis of ketone **5** has recently been reported: D. P. G. Hamon and G. F. Taylor, *Tetrahedron Lett.*, 155 (1975).

Synthesis and Chemistry of 4-Amino-4,6-dideoxy Sugars. VI. Methyl 4-Amino-4,6-dideoxy-α-D-idopyranoside[1,2]

Calvin L. Stevens,* James P. Dickerson,[3] K. Grant Taylor, Peter Blumbergs, and P. Madhavan Pillai

Department of Chemistry, Wayne State University, Detroit, Michigan 48202

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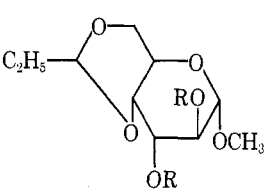
The synthesis of methyl 4-amino-4,6-dideoxy-α-D-idopyranoside (**11**) starting from methyl 4,6-*O*-benzylidene-α-D-altropyranoside (**1**) is presented. The structure of **11** was confirmed by mass spectral analysis and also by degradation of its *N*-acetate **12** to L-threoninol. Methyl 4-acetamido-2,3-di-*O*-acetyl-4,6-dideoxy-α-D-idopyranoside (**12**) is shown to exist in the *C1* conformation (**15**) in solution by NMR. The preparation of methyl 4,6-dideoxy-4-*N*,*N*-dimethylamino-α-D-idopyranoside is also discussed.

The synthesis of several 4-amino-4,6-dideoxy hexoses and their derivatives of potential biological activity were reported previously.[1,4] The preparation of the derivatives of all the eight members of this class of carbohydrates was undertaken in our laboratory with two major objectives in mind: (1) to establish the structures of those 4-amino-4,6-dideoxy hexoses such as glucose,[5] galactose,[6] and mannose,[7] which were isolated from natural sources and to provide samples for the identification of other members of these amino sugars and their derivatives which may subsequently be found to occur in nature and (2) to investigate their immunochemical and other biological properties. This paper describes the synthesis of the derivatives of 4-amino-4,6-dideoxy-D-idose.

Conversion of methyl 4,6-*O*-benzylidene-α-D-altropyranoside (**1**) to its dibenzyl ether, **2**, followed by mild acid hydrolysis provided methyl 2,3-di-*O*-benzyl-α-D-altropyranoside (**3**). Treatment of **3** with excess of methanesulfonyl chloride in pyridine gave the di-*O*-methylsulfonate **4**. Selective displacement of the primary methylsulfonyl group with iodide to give **5** and subsequent reduction with Raney nickel yielded the 6-deoxy derivative, **6**. Treatment of **6** with lithium azide in dimethylformamide at 150° provided the 4-azido sugar, **7**, with inversion of configuration at C-4. Reduction of **7** with lithium aluminum hydride gave methyl 4-amino-4,6-dideoxy-2,3-di-*O*-benzyl-α-D-idopyranoside (**8**), which was characterized as its *N*-acetate, **9**. Reductive debenzylation of **9** in the presence of 10% Pd/C as a catalyst under neutral conditions gave 70% of methyl 4-acetamido-4,6-dideoxy-α-D-idopyranoside (**10**). Hydrolysis of **10** with barium hydroxide provided methyl 4-amino-4,6-dideoxy-α-D-idopyranoside (**11**) in 84% yield. Hydrogenation of **8** in the presence of 10% Pd/C and hydrogen chloride as catalysts also yielded amino sugar **11**, which was further characterized by acetylation with acetic anhydride in pyridine to obtain the triacetate **12**.



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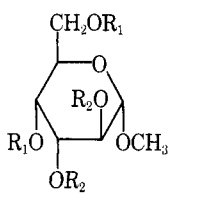
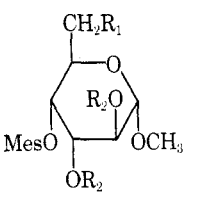
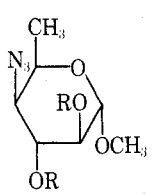
2, R = $CH_2C_6H_5$



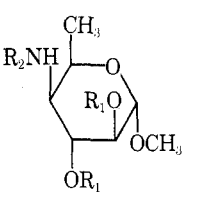
3, R_1 = H; R_2 = $CH_2C_6H_5$
4, R_1 = Mes; R_2 = $CH_2C_6H_5$



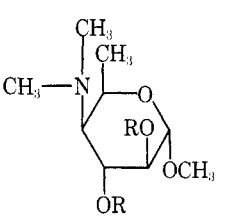
5, R_1 = I; R_2 = $CH_2C_6H_5$
6, R_1 = H; R_2 = $CH_2C_6H_5$



7, R = $CH_2C_6H_5$



8, R_1 = $CH_2C_6H_5$; R_2 = H
9, R_1 = $CH_2C_6H_5$; R_2 = Ac
10, R_1 = H; R_2 = Ac
11, R_1 = R_2 = H
12, R_1 = R_2 = Ac



13, R = $CH_2C_6H_5$
14, R = H

Since 4-*N*,*N*-dimethylamino-4,6-dideoxy-D-glucose oc-