Photochemistry of Dihydromayurone. Novel Solvent Participation in a Photoisomerization[1]

G. W. SHAFFER

Givaudan Corporation, Clifton, New Jersey 07014

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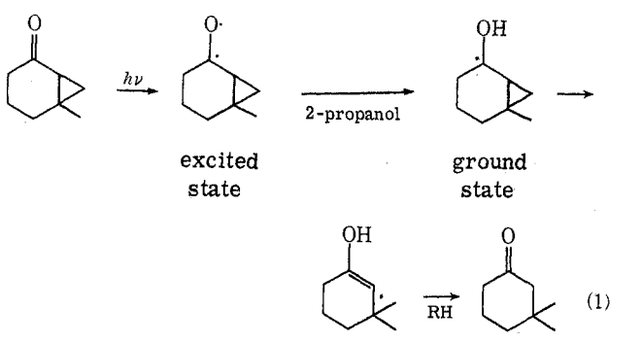
When irradiated in 2-propanol, both *cis*- and *trans*-dihydromayurone (**1** and **6**) react to give a mixture of isomerized (**2** and **3**) and reduced (**4** and **5**) products. The isomeric photoproducts (**2** and **3**) are unusual in that a reducing solvent is necessary for their formation although a net reduction has not occurred. An exchange of hydrogen atoms during isomerization was demonstrated by irradiation of dideuterio-*trans*-dihydromayurone (**8**) in 2-propanol to give monodeuterated hydrindanone **9** and irradiation of **1** in 2-propanol-d_1 to give monodeuterated hydrindanone **7**. Hydrindanone **2** is a secondary product derived from the photoisomerization of **3**. The difference between the photoreduction of **1** and that of simpler bicyclo[4.1.0]heptan-2-ones is attributed to the *gem*-dimethyl group, which sterically hinders hydrogen abstraction.

The photoreduction of conjugated cyclopropyl ketones in 2-propanol has been shown[2] to proceed with hydrogen abstraction by the n–π^* excited carbonyl oxygen atom, followed by a ground-state rearrangement of the α-hydroxycyclopropylcarbinyl radical. The products obtained from bicyclo[4.1.0]heptan-2-ones are cyclohexanones derived from the reductive opening of the cyclopropyl ring (eq 1). The alternate



(1)

products, cycloheptanones, are normally not observed owing to both the thermodynamic preference for opening to a six-membered ring as well as preference for opening of the outer cyclopropyl bond which is geometrically aligned for better overlap, as compared to the inside bond, with the adjacent carbonyl center.

The irradiation of either *cis*- or *trans*-dihydromayurone (**1** and **6**, respectively) in 2-propanol does not follow this simple reaction course, but rather gives a complex mixture of products (Scheme I).

The ketones were irradiated in 2-propanol with a Corex-filtered (>260 nm) 450-W Hanovia medium-pressure mercury lamp and the reaction progress was monitored by gas–liquid chromatography (glc). After removal of the solvent and oxidation of the total mixture to convert any alcohols to the corresponding ketones, the products were isolated by a combination of alumina and silica gel chromatography and recrystallization. The isolated yields are listed in Table I.

3a,7,7-Trimethyl-7a-vinylhexahydro-1-indanone (**2**) was identified on the basis of its spectral data. The nmr spectrum clearly shows a vinylic group at a quaternary center, three methyl singlets, and two hydrogens α to the carbonyl group (see Experimental Section). This ketone is isomeric with **1** (mol wt 206) and the ir carbonyl stretching frequency (1732 cm^{-1}) indicates a cyclopentanone moiety. The structure of **2** has not been proven by synthesis and the stereochemistry at C-7a is unknown.

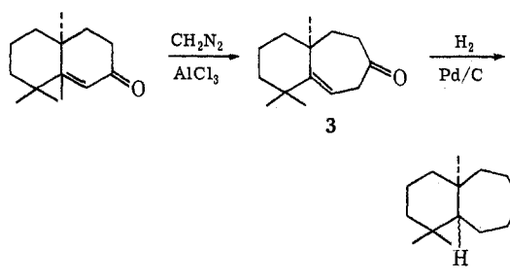
TABLE I

ISOLATED YIELDS FROM THE 2-PROPANOL IRRADIATIONS OF 1 AND 6

	Products, %						
Reactant	1	2	3	4	5	6	Non-monomeric material[a]
1	25	14	6	9	8	2	36
6	2	12.5	4	8.5	2	29	42

[a] Consists mainly of tertiary alcohols from dimerization and solvent addition.

7,11,11-Trimethylbicyclo[5.4.0]-1-undecen-4-one (**3**) was readily identified from spectral data and by comparison with an authentic sample prepared by diazomethane ring expansion of 8,8,10-trimethyl-1(9)-octal-2-one (eq 2).[3]



(2)

Further evidence for the structural assignment of **2** was obtained by isolation of **3** and reirradiation in 2-propanol. Ketone **2** was isolated in 23% yield and was identical with the sample of **2** obtained by direct irradiation of either **1** or **6**. The formation of α-vinyl ring-contracted ketones from the irradiation of cyclic β,γ-unsaturated ketones is well documented.[4]

7,11,11-Trimethylbicyclo[5.4.0]undecan-4-one (**4**) was isolated as a mixture of epimers from both the irradiations of **1** and **6** (80:20 ratio from **1**, 55:45 ratio from **6**). This was determined from the fact that **4** was partially resolved into two peaks on glc and the

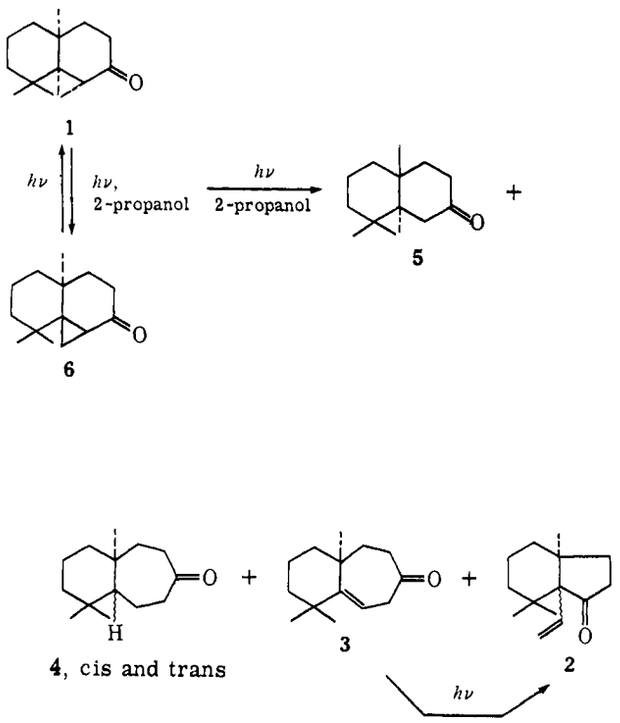
(1) The results of this research were first disclosed at the XXIII IUPAC Congress in Boston, July 1971, Abstracts, p 100.

(2) W. G. Dauben, L. Schutte, R. E. Wolf, and E. J. Deviny, *J. Org. Chem.*, **34**, 2512 (1969).

(3) C. Enzell, *Tetrahedron Lett.*, 185 (1962).

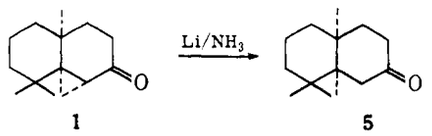
(4) L. A. Paquette and R. F. Eizember, *J. Amer. Chem. Soc.*, **89**, 6205 (1967); R. G. Carlson and J. H. Bateman, *Tetrahedron Lett.*, 4151 (1967); L. A. Paquette, R. F. Eizember, and O. Cox, *J. Amer. Chem. Soc.*, **90**, 5153 (1968); L. A. Paquette and G. V. Meehan, *J. Org. Chem.*, **34**, 450 (1969).

SCHEME I



nmr spectrum showed six methyl singlets whose relative intensities varied depending on whether **4** was isolated from the irradiation of **1** or **6**. Catalytic reduction of **3** gave one epimer of **4** (eq 2) which was identical with the major epimer of **4** isolated from the irradiation of **1**. The ring fusion stereochemistry of this epimer has not been determined.

cis-8,8,9,10-Tetramethyl-2-decalone (**5**), the expected product from the irradiation of **1** based on the work of Dauben,[2] was identified by comparison with **5** obtained as the sole product from lithium–ammonia reduction of **1** (eq 3).



(3)

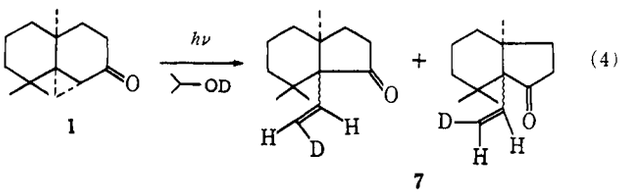
The interconversion of **1** and **6** was demonstrated only by glc retention times. The irradiation of either **1** or **6** gave a low yield (2%) of the epimer and isolation was not possible.

The interconversion of **1** and **6**, as well as formation of isomeric photoproducts **2** and **3**, suggested that for these products a hydrogen-donating solvent would not be necessary since a net photoreduction had not occurred. However, **1** was quite stable to irradiation in 2-methyl-2-propanol. Although small amounts of the same products were detected, the rate of reaction was very much slower than the rate in 2-propanol and probably the small amount of reaction that was observed was initiated by inefficient hydrogen abstraction from 2-methyl-2-propanol.

In the case of **6**, prolonged irradiation in 2-methyl-2-propanol afforded 10% **1** but none of the products **2**–**5**.

The absence of rapid formation of isomeric ketones **2** and **3** without the presence of a hydrogen-donating solvent demonstrated that a unique hydrogen abstraction–loss process must be involved to result in nonreduced products.

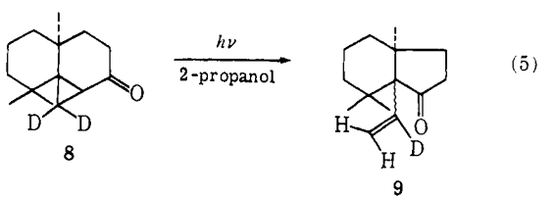
Confirmation of this hypothesis was obtained by two deuteration experiments. The hydrindanone product isolated from the irradiation of **1** in 2-propanol-d_1 contains one deuterium (mol wt 207) and the nmr spectrum shows conclusively that the deuterium is located at the terminal position of the double bond (eq 4). The nmr



(4)

spectrum of **7** is identical with that of **2** except for the vinylic region. Ketone **7** has one vinylic hydrogen at δ 5.65–6.13 (m), one-half of a terminal vinylic hydrogen at 5.21 (d, J = 11 Hz, cis coupling), and one-half of a terminal vinylic hydrogen at 4.90 (d, J = 18 Hz, trans coupling). This differs from the spectrum of **2** in that the vinylic hydrogen of **2** appears as a clean doublet of doublets at δ 5.91 (J = 11 Hz, J' = 17.5 Hz) instead of the multiplet obtained from **7** due to additional deuterium coupling, and the terminal methylene hydrogens of **2** appear as eight peaks (J_{cis} = 11 Hz, J_{trans} = 17.5 Hz, J_{gem} = 2 Hz) instead of the four peaks obtained from **7** due to the elimination of observable geminal coupling. The integration of the nmr spectrum of **7** allows the conclusion that the deuterium is equally substituted at both positions of the terminal methylene group.

The hydrindanone product isolated from the irradiation of *trans*-dideuteriodihydromayurone (**8**) (mol wt 208) also contains one deuterium (mol wt 207) and its location exclusively at the α position of the double bond (eq 5) can be unambiguously determined from



(5)

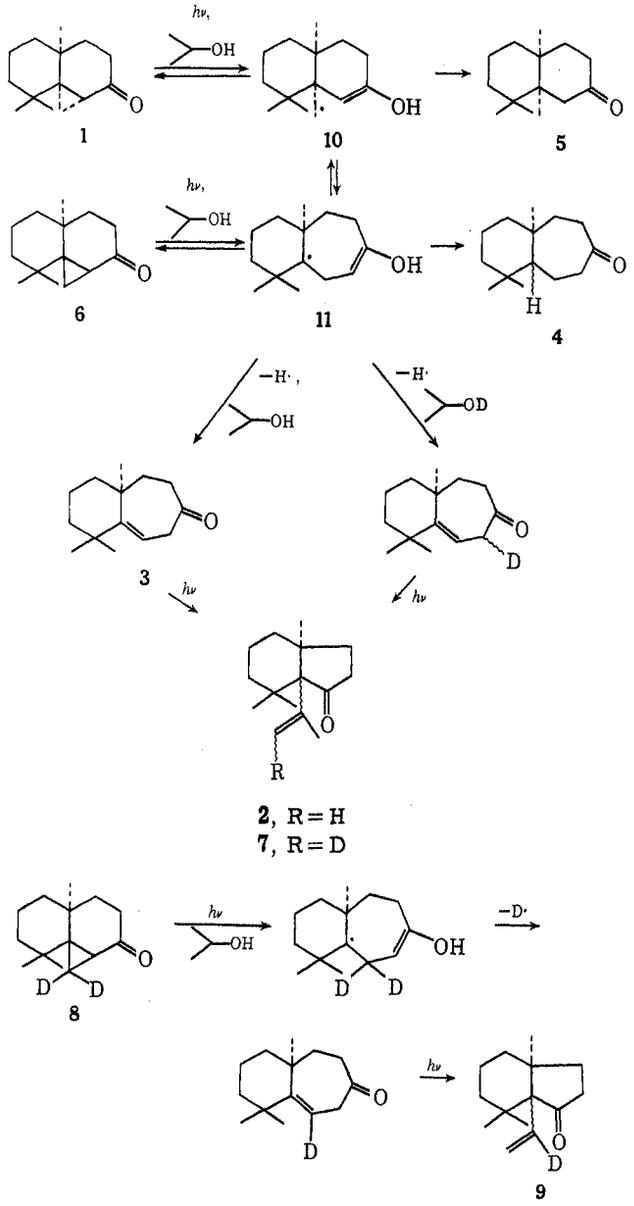
the nmr spectrum. Again, except for the vinylic region, the nmr spectrum of **9** is identical with that of **2**. Both the vinylic hydrogen absorption of **2** at δ 5.91 and the large vicinal coupling constants of the terminal methylene hydrogens of **2** are completely absent from the spectrum of **9**. The two terminal methylene hydrogens of **9** appear as two narrow multiplets (6–8-Hz width) at δ 5.26 and 4.94.

By glc, the irradiations of **8** in 2-propanol and **1** in 2-propanol-d_1 closely paralleled the original irradiations of **1** and **6**, although the products other than **7** and **9** were not isolated.

These experiments not only show an exchange of hydrogen during the isomerization of **1** or **6** to **2**, but the location of deuterium in **7** and **9** allows a reasonable

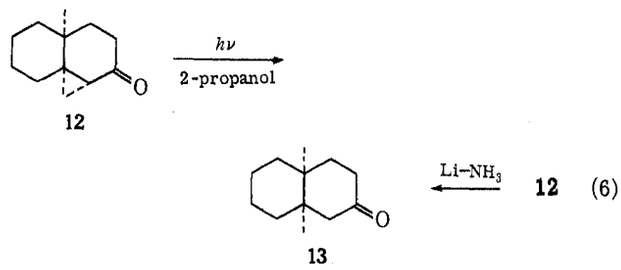
mechanism[5] to be proposed for the formation of **2** and **3** (Scheme II). The other products can also arise from the same radicals **10** and **11**.

SCHEME II



In the presence of a hydrogen-donating solvent *cis*-dihydromayurone opens the geometrically aligned cyclopropyl bond to give radical **10** which can abstract a second hydrogen to give **5**. However, the *gem*-dimethyl group sterically hinders **10** from hydrogen abstraction and allows the ground-state radical sufficient time to rearrange to tertiary radical **11**. In an inert solvent the same cyclopropyl bond probably opens but the excited-state diradical does not have the lifetime of ground-state radical **10** and therefore recloses to **1** rather than undergoes rearrangement.

The results from the reduction of *cis*-1,9-methano-10-methyl-2-decalone (**12**) are in support of this explanation involving the hindrance of radical **10** as the cause of these unusual products from the irradiation of dihydromayurone. Both photoreduction and lithium–ammonia reduction of **12** give only the expected *cis*-decalone (**13**) (eq 6). Without the *gem*-dimethyl

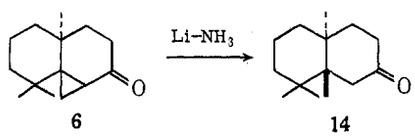


(6)

group of **1**, **12** reacts in the same manner as the simpler bicyclo[4.1.0]heptan-2-ones.

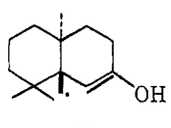
The formation of **2** and **3** from dihydromayurone represents the first example of a photoisomerization which occurs only under reducing conditions.

One aspect of the photochemistry of the dihydromayurones remains without a satisfactory explanation. *trans*-8,8,9,10-Tetramethyl-2-decalone (**14**), formed as the sole product from lithium–ammonia reduction of **6** (eq 7), was not present in the photomixture from **1** and,



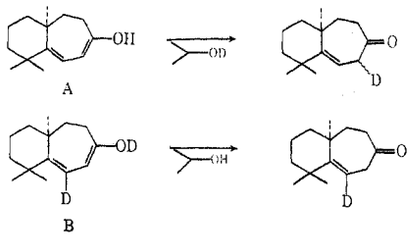
(7)

if formed at all in the irradiation of **6**, was present in only trace amounts. Inspection of molecular models shows little difference in steric hindrance toward hydrogen abstraction between radicals **10** and **15**; therefore, if radical **15** were formed in the sequence of photoreduction, then ketone **14** should have been present at least to the extent of a few per cent.



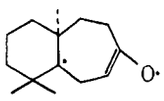
This implies that **6**, unlike its cis isomer **1**, directly opens to tertiary radical **11** although molecular models show that in both isomers the outside cyclopropyl bond should be the favored one for reductive cleavage. The irradiations in 2-methyl-2-propanol also support this conclusion. A substantial amount (10%) of ketone **6** photoisomerizes to **1** in 2-methyl-2-propanol; however, the reversibility of this reaction is not observed. This is consistent with the direct formation of tertiary

(5) A referee noted that the deuterium-labeling studies are also compatible with an alternate mechanism in which **1** or **8** undergo an internal rearrangement to enol A or B, respectively, followed by ketonization. The author



feels that the failure of rearrangement in 2-methyl-2-propanol argues decisively against this alternate mechanism; the referee further noted that differences in solvent acidities and dielectric constants make various solvent effects possible.

diradical **16** from the irradiation of **6**, followed by reclosure to either the cis or trans isomer.



16

Presently, we are studying a series of analogous cyclopropyl ketones without the *gem*-dimethyl group of the dihydromayurones (*e.g.*, **12** and its trans isomer) to elucidate the reasons for this differing behavior between cis and trans isomers.

Experimental Section

Preparative irradiations were carried out with a 450-W medium-pressure Hanovia mercury lamp in a quartz, water-cooled, immersion probe. The filter was a glass cylinder of Corex (>255 nm) insertable between the lamp and the probe. Solutions were outgassed with argon before and during the irradiations.

Infrared spectra were taken as neat samples (except where noted) on a Perkin-Elmer 457 and absorptions are reported as inverse centimeters, uv spectra were taken on a Beckman Acta III, nmr spectra were taken on a Varian A-60A as chloroform-d_1 solutions and are reported as δ units relative to TMS, and molecular weights were determined from mass spectra obtained with a Perkin-Elmer 270. Gas–liquid chromatography was done on a 10% Carbowax 20M (12 ft × 1/8 in.) column. Melting points are uncorrected.

Irradiation of *cis*-Dihydromayurone (1).—A solution of 4.00 g of **1**[6] in 150 ml of 2-propanol (0.13 *M*) was irradiated for 3.75 hr. Glc showed six ketonic components with the following relative retention times: A, 0.33; B, 0.66; C, 0.73; D, 0.82; 1, 1.0; E, 1.1. The solvent was removed under reduced pressure, the residual oil (4.60 g) was oxidized at 0° with excess Jones reagent,[7] and the resulting mixture (4.02 g) was chromatographed on 300 g of alumina (neutral III, 2.5 × 60 cm column).

Compound A was eluted with hexane–benzene (10:1) and was identified as 3a,7,7-trimethyl-7a-vinylhexahydro-1-indanone (**2**): 0.552 g (14% yield); mol wt 206; λ_{max}^{MeOH} 301 nm (ϵ 40); ir (CCl_4) 1732 (s), 1620 (w), 1002 (m), 992 (w), 928 (s); nmr 5.91 (1 H, d of d, J = 11 Hz, J' = 17.5 Hz, vinylic H), 5.22 (1 H, d of d, J = 11 Hz, J' = 2 Hz, terminal methylene H), 4.90 (1 H, d of d, J = 17.5 Hz, J' = 2 Hz, terminal methylene H), 2.2 (2 H, m, α H), 1.18 , 1.15, 0.9 (9 H, 3 s, methyl H). The ketone was sublimed at 1 mm and recrystallized from aqueous ethanol, mp 196–199° (sealed capillary).

Anal. Calcd for $C_{14}H_{22}O$: C, 81.50; H, 10.75. Found: C, 81.45; H, 10.63.

Compounds C and D were eluted together with hexane–benzene (1:1). The early factions were enriched in C and identification was made on 80–90% pure material. Compound C gave two partially resolved peaks on glc and was identified as *cis*- and *trans*-7,11,11-trimethylbicyclo[5.4.0]undecan-4-one (**4**): 0.357 g, 9%; mol wt 208; ir 1704; nmr 1.05, 1.02, 0.98 (3 s, methyl H, major epimer), 0.95, 0.90, 0.82 (3 s, methyl H, minor epimer). The ratio of epimers was 4:1. The major epimer in this sample was identical (ir and nmr spectra, glc) with synthetic **4** obtained by low-pressure hydrogenation of 7,11,11-trimethylbicyclo[5.4.0]-1-undecen-4-one (**3**) prepared according to the procedure of Enzell.[3] Synthetic **4** consisted of only one epimer (nmr singlets at 1.05, 1.02, 0.98).

Compound D (0.299 g, 8%) was isolated pure (mp 149–150°) by two recrystallizations from hexane of fractions containing *ca.* equal amounts of C and D. Crystalline D was identified as *cis*-8,8,9,10-tetramethyl-2-decalone (**5**) by comparison (ir and nmr spectra, glc, mmp 148.0–150.5°) with **5** obtained by lithium–ammonia reduction of **1**.

Starting material **1** (1.0 g, 25%) and E were eluted together with benzene and benzene–ether (50:1). Compound E (0.08 g, 2%) was identified as *trans*-dihydromayurone (**6**) on the basis of an identical glc retention time with that of synthetic material.

(6) S. Nagahama, H. Kobayashi, and S. Akiyoshi, *Bull. Chem. Soc. Jap.*, **35**, 140 (1962); T. Nozoe, *et al.*, *Chem. Pharm. Bull.*, **8**, 936 (1960).

(7) A. Bowers, T. G. Halsall, E. R. H. Jones, and A. J. Lemin, *J. Chem. Soc.*, 2548 (1953).

Compound B was not very stable on alumina but was isolated (>90% pure, 0.24 g, 6%) from a silica gel chromatogram by elution with benzene–ether (100:1 and 50:1) and was identified as 7,11,11-trimethylbicyclo[5.4.0]-1-undecen-4-one (**3**): mol wt 206; ir 1708; nmr 5.52 (1 H, broadened t, J = 6 Hz, vinyl H), 3.20 (2 H, d, J = 6 Hz, one peak further split into d, J' = 2 Hz, allylic H), 2.38–2.66 (2 H, m, H α to carbonyl), 1.10, 1.14, 1.19 (9 H, 3 s, methyl H). This sample was identical (ir and nmr spectra, glc) with synthetic **3**.[3]

The remaining 36% included trace ketonic products but was mainly very polar material including a large amount of tertiary alcohols (dimers and 2-propanol addition products) whose structures were not investigated.

Extended irradiation of **1** in 2-methyl-2-propanol (0.590 g of **1**, 150 ml of 2-methyl-2-propanol, 0.02 *M*, 15 hr) and chromatography as above gave 3% **2** (ir and nmr spectra, glc), 3% **5** (glc), trace amounts of **3** and **4** (glc), 78% **1**, and 16% nonmonomeric alcoholic material. The presence of **6** could not be detected in the irradiation mixture.

Isolation of **3** and reirradiation in 2-propanol (0.13 g, 5 ml of 2-propanol, 0.13 *M*, 8-RUL 3000-Å Rayonet lamps, 10 hr) gave **2** in 23% yield after isolation by alumina chromatography. The sample was identical (glc retention time, nmr spectrum) with **2** isolated from the direct irradiation of **1**.

Isolation of **2** and reirradiation in 2-propanol (0.81 g, 150 ml of 2-propanol, 0.026 *M*, 3 hr) rapidly gave a product whose glc retention time was identical with that of **3**. This glc peak remained at constant percentage (5–10%) throughout the irradiation as the glc peak for **2** decreased very slowly.

Irradiation of *trans*-Dihydromayurone (6).—A solution of 1.08 g of **6**[8] in 150 ml of 2-propanol (0.035 *M*) was irradiated for 3 hr. The reaction was worked up and the products were isolated as described above. The products (yields) follow: **2**, 12.5%; **3**, 4%; **4**, 8.5% (55–45% mixture of epimers); **5**, 2%; **1**, 2%; **6**, 29%. The remaining 42% was nonoxidizable alcoholic material and was not investigated. The identification of **1**, **3**, and **5** was made solely on the basis of identical glc retention times with those of authentic samples. In addition to **1**–**6**, the irradiation mixture contained a trace component with an identical glc retention time with that of synthetic *trans*-8,8,9,10-tetramethyl-2-decalone (**14**).

Extended irradiation of *trans*-dihydromayurone (**6**) in 2-methyl-2-propanol (0.046 *M*) for 9 hr gave none of the products **2**–**5**, 10% **1** (identified only by glc retention time), 84% unreacted **6**, and ~6% nonmonomeric material (percentages determined by equal volume glc injections).

Irradiation of *cis*-1,9-Methano-10-methyl-2-decalone (12).—A solution of 1.96 g of **12** (95% cis, 5% trans), prepared by Jones oxidation[7] of *cis*-1,9-methano-10-methyl-2-decalol,[9] in 150 ml of 2-propanol (0.073 *M*) was irradiated for 1.5 hr. The reaction was worked up as described above and the products were isolated by chromatography of the crude mixture (1.82 g) on 250 g of alumina (neutral III, 2.5 × 44 cm column).

Benzene eluted 0.582 g (32%) of crystalline material identified after recrystallization from hexane (mp 128–131°) as *cis*-9,10-dimethyl-2-decalone (**13**, mol wt 180) by comparison (ir and nmr spectra, glc, mmp 127.5–132.0°) with **13** obtained by lithium–ammonia reduction of **12**. Further elution with benzene gave recovered **12**, 0.640 g (35%).

By glc, there were several other ketonic photoproducts but all were present in very low yield and could not be isolated pure. Most of the remaining 33% was a mixture of tertiary alcohols including one crystalline alcohol (0.198 g) eluted with ether–methanol (100:1): mol wt 238; mp 125–130° recrystallized from hexane; ir 3360; nmr 1.40, 1.26, 0.93 (3 s, methyl H). This alcohol was tentatively identified as 1,9-methano-2-(1-hydroxy-1-methylethyl)-10-methyl-2-decalol.

Irradiation of *trans*-Dideuteriodihydromayurone (8).—A solution of 0.385 g of **8**[8] in 150 ml of 2-propanol (0.012 *M*) was irradiated for 1 hr. The hydrindanone product was isolated by alumina chromatography and identified as 3a,7,7-trimethyl-7a-(1-deuteriovinyl)-hexahydro-1-indanone (**9**): 0.057 g (15%

(8) *trans*-Dihydromayurone (**6**) was prepared from 8,8,10-trimethyl-$\Delta^{1,9}$-octalin by the following sequence: allylic bromination with *N*-bromosuccinimide, followed by hydrolysis with aqueous acetone, followed by the Simmons–Smith reaction and Jones oxidation (W. G. Dauben and E. I. Aoyagi, private communication). *trans*-Dideuteriodihydromayurone (**8**) was prepared by the same sequence using dideuteriomethylene iodide in the Simmons–Smith reaction.

(9) W. G. Dauben, P. Lang, and G. H. Berezin, *J. Org. Chem.*, **31**, 3869 (1966).

yield); mol wt 207; ir (CCl_4) 1734 (s), 928 (m); nmr 5.26 and 4.94 (2 H, 2 m, terminal vinylic H), 2.2 (2 H, m, α H), 1.19, 1.15, 0.92 (9 H, 3 s, methyl H). Except for the vinylic region (4.6–6.2), the nmr spectrum of **11** was identical with that of **2**.

The other photoproducts from **8** were not isolated but according to glc the irradiation of **8** closely paralleled the irradiations of **1** and **6**.

Irradiation of *cis*-Dihydromayurone (1) in 2-Propanol-d_1.—A solution of 0.200 g of **1** in 10 ml of 2-propanol-d_1 (Stohler Isotopes, deuteration on oxygen) (0.097 M) was irradiated for 11 hr using 8-RUL 3000-Å Rayonet lamps. The hydrindanone product was isolated by alumina chromatography and identified as 3a,7,7-trimethyl-7a-(2-deuteriovinyl)-hexahydro-1-indanone (**7**): 0.015 g (8% yield); mol wt 207; nmr 5.65–6.13 (1 H, m, vinylic H), 5.21 (0.5 H, d, J = 11 Hz, terminal vinylic H), 4.90 (0.5 H, d, J = 18 Hz, terminal vinylic H), 2.2 (2 H, m, α H), 1.18, 1.15, 0.92 (9 H, 3 s, methyl H). Except for the vinylic region (4.6–6.2), the nmr spectrum of **7** was identical with that of **2**.

The other photoproducts were not isolated, but, according to glc, the irradiation closely paralleled the undeuterated 2-propanol irradiation. By mass spectroscopy, no deuterium incorporation could be detected in recovered **1**.

***cis*-8,8,9,10-Tetramethyl-2-decalone (5).**—From lithium–ammonia reduction[10] of **1** there was obtained **5**: mp 150–151° recrystallized from hexane; mol wt 208; ir 1702; nmr 1.10, 1.05, 0.88, 0.81 (4 s, methyl H).

Anal. Calcd for $C_{14}H_{24}O$: C, 80.71; H, 11.61. Found: C, 80.60; H, 11.47.

***trans*-8,8,9,10-Tetramethyl-2-decalone (14).**—From lithium–ammonia reduction[10] of **6** there was obtained **14**: mol wt 208; ir 1705; nmr 1.37, 1.07, 0.81 (3 s, methyl H), 0.92 (d, J = 1 Hz, methyl H).

Anal. Calcd for $C_{14}H_{24}O$: C, 80.71; H, 11.61. Found: C, 80.67; H, 11.79.

***cis*-9,10-Dimethyl-2-decalone (13).**—From lithium–ammonia reduction[10] of **12** there was obtained **13**, isolated by benzene elution from an alumina (neutral III) chromatogram: mp 132–134° recrystallized from hexane (lit.[11] mp 108–118°); mol wt 180; ir 1705; nmr 1.04, 0.90 (2 s, methyl H) (lit.[11] nmr 1.05, 0.90).

Registry No.—**1**, 7129-16-0; **2**, 35342-07-5; **3**, 35342-08-6; ***cis*-4**, 35342-09-7; ***trans*-4**, 35342-10-0; **5**, 35342-11-1; **6**, 31090-36-5; **8**, 35342-13-3; **9**, 35342-14-4; **12**, 35340-22-8; **13**, 5523-99-9; **14**, 35340-24-0; 1,9-methano-2-(1-hydroxy-1-methylethyl)-10-methyl-2-decalol, 35340-25-1.

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(10) W. G. Dauben and E. J. Deviny, *J. Org. Chem.*, **31**, 3794 (1966).

(11) J. A. Marshall, W. I. Fanta, and H. Roebke, *ibid.*, **31**, 1016 (1966).

Sterically Controlled Syntheses of Optically Active Organic Compounds. XV. Syntheses of Optically Active Aspartic Acid through β-Lactam[1]

TADASHI OKAWARA AND KAORU HARADA*

Institute for Molecular and Cellular Evolution and Department of Chemistry, University of Miami, Coral Gables, Florida 33134

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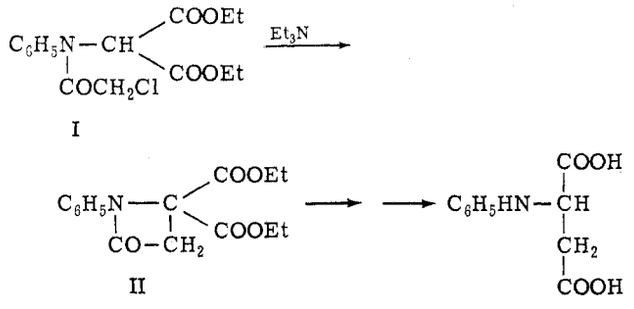
Optically active *N*-alkyl-*N*-chloroacetamidoacetonitriles were prepared and were converted to their corresponding β-lactams by treatment with sodium hydride. The β-lactams were hydrolyzed and hydrogenolyzed to form optically active aspartic acid. When (*R*)-α-alkylbenzylamines were used, (*S*)-aspartic acid was the result. The yield of aspartic acid from aminoacetonitriles ranged from 36 to 96%. The optical purity of aspartic acid ranged from 21 to 67%. A temperature effect on the sterically controlled reaction was examined. The effect of temperature on the optical purity and yield was found to be small. To examine whether the sterically controlled reaction is due to an asymmetric induction or to a first-order asymmetric transformation, equilibration reactions were carried out using three solvents (dioxane, benzene, acetonitrile). The results indicate that the formation of optically active aspartic acid is largely due to an asymmetric induction.

The cyclization of diethyl *N*-phenyl-*N*-chloroacetamidomalonate (I) to β-lactam (II) has been reported by Sheehan and Bose.[2] Hydrolysis and decarboxylation of the β-lactam yielded *N*-phenylaspartic acid (III).



I

II

III

This reaction is similar to that of cyclization of diethyl ω-bromopropylmalonate in the presence of sodium ethoxide.[3] Several similar β-lactam formations have been recorded.[4–6] Recently, Martin, *et al.*,[7] reported the synthesis of *N*,2-diphenylaspartic acid in a similar way from β-lactam that was formed by cyclization of *N*-chloroacetyl-*N*,2-diphenylglycine ethyl ester. The preparation of β-lactams is summarized in a review by Sheehan and Corey.[8]

In the present study, the β-lactams were prepared from *N*-alkyl-*N*-chloroacetamidoacetonitriles by the cyclization reaction. Hydrolysis and subsequent hydrogenolysis of the β-lactams yielded aspartic acid. When the *N*-alkyl groups were chiral, optically active aspartic acid was obtained. The reaction scheme of this study is shown in Scheme I.

The optically active moieties used were (a) racemic α-

(1) Contribution no. 198 of the Institute for Molecular and Cellular Evolution, University of Miami. Part XIV: K. Harada and K. Matsumoto, *Bull. Chem. Soc. Jap.*, **44**, 1068 (1971).

(2) J. C. Sheehan and A. K. Bose, *J. Amer. Chem. Soc.*, **72**, 5158(1950).

(3) H. M. Walborsky, *ibid.*, **71**, 2941 (1949).

(4) J. C. Sheehan and A. K. Bose, *ibid.*, **73**, 1261 (1951).

(5) A. K. Bose, B. N. Ghosh-Mazumdar, and B. G. Chatterjee, *ibid.*, **82**, 2382 (1960).

(6) B. G. Chatterjee, V. V. Rao, and B. N. Ghosh-Mazumdar, *J. Org. Chem.*, **30**, 4101 (1965).

(7) T. A. Martin, W. T. Comer, C. M. Combs, and J. R. Corrigan, *ibid.*, **35**, 3814 (1970).

(8) J. C. Sheehan and E. J. Corey, *Org. React.*, **9**, 388 (1957).