and 8.0 in the denitration reaction.

Experimental Section

Melting points are uncorrected. UV spectra were recorded on a Cary Model 219 instrument. ^1H NMR spectra were obtained with a JEOL C60-HL apparatus. Low-resolution mass spectra were obtained with an AEI MS 12 spectrometer, high-resolution mass spectra with a Kratos MS 80 spectrometer.

2-Bromo-1-methyl-5-nitropyrrole (1a). A solution of bromine (420 mg, 2.63 mmol) in 5 mL of AcOH was rapidly added at room temperature to a solution of 340 mg of 1-methyl-2-nitropyrrole (2.70 mmol) in 5 mL of AcOH. After 1 h the reaction mixture was poured into water and kept overnight in a refrigerator. The petroleum ether extract (10 × 80 mL) was washed with a $NaHCO_3$ solution and water and dried (Na_2SO_4). After removal of the solvent the residue was subjected to column chromatography on silica gel. The first eluent was benzene, which was progressively enriched with CH_2Cl_2 up to a 1:1 ratio (vol). Four fractions were collected. The first and fourth were not further examined because their ^1H NMR spectra were not consistent with the presence of any simple bromination product. The second fraction (125 mg) showed (TLC) the presence of two compounds. Its ^1H NMR spectrum in CCl_4 was consistent with the presence of two monobromo derivatives of the starting compound. The third fraction (80 mg) was 3,4-dibromo-1-methylmaleimide, identified through its mp (119–120 °C, lit.[14] mp 121 °C) and MS spectrum (*m/e* 267, 269, 271 (M^+)). The second fraction was again subjected to column chromatography (silica gel, CCl_4). Two subfractions were obtained. The first (20 mg) was identified as 2-bromo-1-methyl-5-nitropyrrole (**1a**): mp (petroleum ether, 40–70 °C) 93.5–94.5 °C; ^1H NMR (CCl_4) δ 4.02 (s, 3 H, N-Me), 6.25 (d, 1 H, J = 4.5 Hz, H-3), 7.10 (d, 1 H, J = 4.5 Hz, H-4); UV (MeOH) λ_{max} 343 nm (ϵ 1.3 × 10^4); mass spectrum, calcd for $C_5H_5N_2O_2Br$ (M^+) *m/e* 203.9534, 205.9514, .9514, found 203.9520, 205.9503; yield 3.7%. The second subfraction (70 mg) was identified as the isomeric 3-bromo-1-methyl-5-nitropyrrole: mp 62–63 °C; ^1H NMR ($CDCl_3$) δ 3.99 (s, 3 H, N-Me), 6.80 (d, 1 H, J = 2.25 Hz, H-β), 7.17 (d, 1 H, J = 2.25 Hz, H-α); mass spectrum, *m/e* 205, 207 (M^+); yield 12.6%.

The structure assignments for these isomers were based upon their J values, by taking into account the fact that in the presence of nitro groups the J values are generally higher than those in other pyrrole derivatives.[15]

2-Chloro-1-methyl-5-nitropyrrole (1b). A solution of SO_2Cl_2 (850 mg, 6 mmol) in 2 mL of Et_2O was slowly added to a solution of 1-methylpyrrole (500 mg, 6 mmol) in 2 mL of Et_2O at 0 °C. The reaction mixture was kept at 10 °C for 1 h. A 10% K_2CO_3 solution (7 mL) was added, and the ether layer was separated and washed with water, and dried (Na_2SO_4). The solvent was cautiously removed at room temperature at nearly 300 mmHg, and the crude residue containing presumably 2-chloro-1-methylpyrrole was dissolved in 30 mL of Ac_2O for nitration. A nitrating mixture, made up from 100% HNO_3 (290 mg, 4.6 mmol) and Ac_2O (10 mL), was slowly added (1 h) under stirring to the Ac_2O solution of the chloro derivative at −10 °C. After 15 min the reaction mixture was poured on ice. The resulting black solution was repeatedly extracted with Et_2O, and the ether extracts were washed with $NaHCO_3$ and water, dried, and concentrated. The residue was subjected to column chromatography (silica gel, benzene–1:1 benzene/ethyl acetate). Seven fractions were collected. The first one (50 mg) was identified through its ^1H NMR spectrum as 2,5-dichloro-1-methylpyrrole.[8] The second fraction (50 mg) was identified as 2-chloro-1-methyl-5-nitropyrrole (**1b**): mp (petroleum ether, 40–70 °C) 72–72.5 °C; ^1H NMR (CCl_4) δ 4.00 (s, 3 H, N-Me), 6.15 (d, 1 H, J = 4.5 Hz, H-3), 7.11 (d, 1 H, J = 4.5 Hz, H-4); UV (MeOH) λ_{max} 340 nm (ϵ 1.2 × 10^4); mass spectrum, calcd for $C_5H_5N_2O_2Cl$ (M^+) *m/e* 160.0040, found 160.0035; yield 5%. The third fraction (40 mg) had a ^1H NMR spectrum consistent with the presence of **1b** and 1-methyl-2-nitropyrrole. The other fractions were not further examined.

Substitution Products. 2-Halogeno-1-methyl-5-nitropyrroles **1a,b** were kept with the equivalent amount of sodium methoxide in methanol at 40 °C for 4–5 days. 2-Methoxy-1-methyl-5-nitropyrrole[3] was obtained in good yields from both substrates. However, the yields were not quantitative because under the reaction conditions the methoxy derivative decomposes slowly. A similar behavior can be observed during the substitution of 2-bromo-5-nitrofuran with piperidine or benzenethiolate ion.[16] It must be observed that during the methoxy denitration of **1c** the decomposition reaction of the product does not interfere with the kinetic experiments because the denitration reaction occurs more rapidly than the dehalogenation reactions of **1a** or **1b**.

Kinetic Measurements. The kinetics were followed spectrophotometrically in the thermostated compartment of a Cary 219 instrument, under pseudo-first-order conditions in the presence of an excess of sodium methoxide. Kinetic experiments were carried out at the absorbance maximum of the product (375 nm). Rate constants were corrected for the thermal dilatation of methanol. The substrate concentrations were in the range 3–5 × 10^{-5} M, the MeO^- ion concentration in the range 0.03–0.25 M. The reactions were second order, first order in both substrate and nucleophile. Because of the instability of the reaction product under the reaction conditions, absorbance values at infinite time were calculated by Mangelsdorf's method.[17] The rate constants at 25 °C and the activation parameters were calculated with Eyring's equation.

Acknowledgment. We thank Prof. G. Illuminati for helpful discussions.

Registry No. **1a**, 91606-34-7; **1b**, 91606-35-8.

(14) de Varda, G. *Chem. Ber.* **1888**, *21*, 2871.
(15) Devincenzis, G.; Mencarelli, P.; Stegel, F. *J. Org. Chem.* **1983**, *48*, 162.
(16) Spinelli, D.; Guanti, G.; Dell'Erba, C. *Boll. Sci. Fac. Chim. Ind. Bologna* **1967**, *25*, 71.
(17) Margerison, D. In "Comprehensive Chemical Kinetics"; Bamford, C. H., Tipper, C. F., Eds.; Elsevier: Amsterdam, 1969; Vol. 1, p 390.

Intramolecular Photochemistry of a Vinylogous Amide and Some Transformations of the Photoproduct

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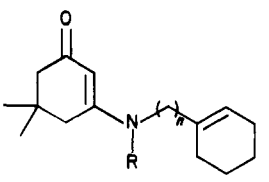
In connection with our interest in the intramolecular photochemistry of vinylogous imides we decided to investigate the similar reaction of a secondary vinylogous amide. Previously we had found that irradiation of vinylogous imide **1a** produced the expected photocyclo-



1a, R = Ac; *n* = 1
1b, R = Ac; *n* = 2
1c, R = Ac, *n* = 3
1d, R = H; *n* = 2

addition product[1] while irradiation of vinylogous imides **1b** and **1c** provided major photoproducts formally arising via an ene-type reaction.[2] We now report on the photochemistry of the nonacetylated vinylogous amide **1d** and

(1) Schell, F. M.; Cook, P. M.; Hawkinson, S. W.; Cassady, R. E.; Thiessen, W. E. *J. Org. Chem.* **1979**, *44*, 1380.
(2) Schell, F. M.; Cook, P. M. *J. Org. Chem.* **1978**, *43*, 4420.

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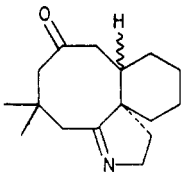
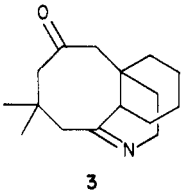
some transformations which helped to define the structure of the product.

In contrast to the *N*-acyl derivatives **1a–c**, the vinylogous amide **1d** is relatively insoluble in cyclohexane and use of *tert*-butyl alcohol as cosolvent or solvent is required for dissolving reasonable quantities. Irradiation of **1d**[2] in *tert*-butyl alcohol led to a single material which was immediately recognized as an imino ketone by its infrared absorptions at 5.92 and 6.17 μm and its carbon NMR resonances at δ 211.2 and 178.8. Thus, cycloaddition had occurred to provide a cyclobutane which unraveled via a retro-mannich reaction[3] to provide either **2** or **3** rather than



2a, α-H
2b, β-H



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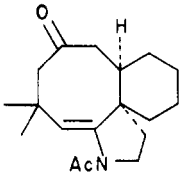
the photoene product observed in the *N*-acyl derivative **1b**.[6] Cyclobutane formation has been observed in related tertiary vinylogous amide reactions[7] as well as in related vinylogous ester cases.[5] We were unable to observe the presumed cyclobutane intermediate in the reaction of **1d**. Apparently the retro-Mannich process is facile in hydroxylic media since it relieves the stain inherent in the cyclobutane derived from the secondary vinylogous amide. Based on ample literature precedent[8], it was expected that the photoaddition would lead to **2** rather than **3**. Nevertheless, we felt compelled to document this point and to define the stereochemistry of the product.

Inspection of the carbon NMR spectra of the photoproduct revealed an aliphatic quaternary resonance at δ 56.1 which is in accord with the expected structure **2**. To confirm the location of this center, selective reduction of the imine with sodium cyanoborohydride was attempted.[9] Surprisingly, prolonged treatment with this reagent at pH 4 failed to give any reduced material. While not providing the chemical shift changes we had hoped for, this negative result does speak for a particularly hindered imine such as **2**. Also in accord with structure **2** is its conversion to a single enamide **4** on treatment with acetyl chloride and pyridine.

Structure **2** was established by deuterium exchange experiments. Thus, treatment of the photoproduct with deuterium oxide under basic conditions led to recovery of an imino ketone whose carbon NMR spectrum was missing only methylene resonances at δ 56.1, 52.2, and 39.9 present in the spectrum of the original material. It is interesting to note that **2** showed no tendency to exist as an amino diketone or to form the alternative Schiff base. Further confirmation that only three carbons could exchange was obtained by treatment of **2** with benzoyl chloride under Schötten–Baumann conditions to provide diketo amide **5**. Exposure of this substance to sodium methoxide in methanol-*d* led to exchange of only three methylene resonances.



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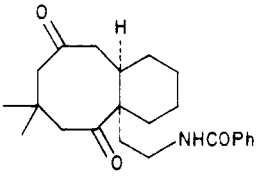
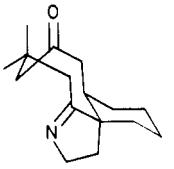


5

It seems quite reasonable that the ring fusion of the six- and eight-membered rings in **2** is cis (i.e., **2a**), and this is readily confirmed by a simple analysis of the carbon NMR data. The deuterium exchange experiments identify the methylenes in the eight-membered ring, and the resonance at δ 54.4 is clearly due to the imino methylene. The five remaining methylene resonances at δ 35.7, 31.8, 27.9, 22.0, and 19.5 are readily classified in two groups. The three low-field absorptions must be due to the three methylenes next to substituted centers while the high-field pair must belong to the remaining two methylenes. If it is assumed that the cyclohexane ring is in a chair conformation, then the high-field shift of the latter two absorptions requires two axial substituents.[10] This is only possible if the six- and eight-membered rings are cis-fused. Thus, the NMR analysis not only defines the stereochemistry of **2a** but provides conformational information as well.

It is at first surprising to find evidence for diaxial substitution in the conformationally mobile six-membered ring. However, inspection of molecular models reveals that in diequatorial conformations the imino methylene is required to occupy an axial position. With two axial substituents the imino ketone **2a** can adopt a conformation such as **6** in which the eight-membered-ring transannular



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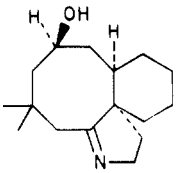

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interactions are minimized, the *gem*-dimethyls are isolated from serious interaction, and the imine and ketone dipoles are opposed. This conformation is in accord with further transformations.

When **2a** proved resistent to selective reduction of the imine with sodium cyanoborohydride (vide supra) other reducing conditions were employed. Exposure to an excess of lithium aluminum hydride provided a single crystalline product. Inspection of its infrared and carbon NMR spectra showed that only the ketone had been reduced. Even in refluxing tetrahydrofuran no further reduction occurred. While this may be simply a consequence of the

(3) This constitutes the nitrogen equivalent of an intramolecular de Mayo reaction.[4] The intramolecular de Mayo reaction has recently been exploited in synthesis.[5]

(4) deMayo, P. *Acc. Chem. Res.* **1971**, *4*, 41.

(5) Oppolzer, W. *Acc. Chem. Res.* **1982**, *15*, 135 and references therein.

(6) Similar results have been obtained in related systems derived from 1,3-cyclohexanedione: Kraus, W.; Vogler, B., unpublished observations.

(7) Tamura, Y.; Ishibashi, H.; Hirai, M.; Kita, Y.; Ikeda, M. *J. Org. Chem.* **1975**, *40*, 2702.

(8) The regiochemistry of photocyclization of 1,5-, 1,6-, and 1,7-dienes is well established: Agosta, W. C.; Wolff, S. *J. Org. Chem.* **1980**, *45*, 3139. Scheffer, J. R.; Boire, B. A. *J. Am. Chem. Soc.* **1971**, *93*, 5490. Scheffer, J. R.; Wostradowski, R. A. *J. Org. Chem.* **1972**, *37*, 4317.

(9) Borch, R. F.; Bernstein, M. D.; Durst, H. D. *J. Am. Chem. Soc.* **1971**, *93*, 2897.

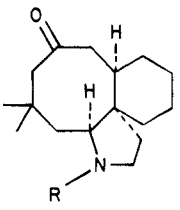
(10) Appropriate 1,1,2-trisubstituted cyclohexane models with diequatorial substitution are available. Cholestane[11] represents a rigid system whose C-1,2,3,4 shifts are at δ 39.2, 22.6, 27.3, and 29.6, while the mobile 1,1,2-trimethylcyclohexane[12] has resonances at δ 31.9, 27.4, 23.4 and 41.8 for C-3,4,5,6, respectively. The absence of high-field methylenes in this latter substance, which is assumed by Dalling and Grant to have a high concentration of skew-boat conformers, strengthens our assumption of a chair form in the six-membered ring of **2**. Furthermore, Dalling and Grant calculate two high-field resonances in the chair conformer with diaxial substituents as expected for two γ-effects.

(11) Reich, H. J.; Jautelat, M.; Messe, M. T.; Weigert, F. J.; Roberts, J. D. *J. Am. Chem. Soc.* **1969**, *91*, 7445.

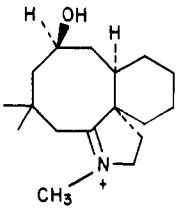
(12) Dalling, D. K.; Grant, D. M. *J. Am. Chem. Soc.* **1967**, *89*, 6612.

steric hinderance at the neopentyl imine carbon, electronic protection via base-induced formation of the imine enolate cannot be ruled out. The production of a single imino alcohol is easily rationalized in terms of structure **2a**. The top face of the ketone carbonyl in diaxial conformations such as **6** is heavily shielded and reduction can only occur to provide **7**.

The structure of **7** was serendipitously confirmed during characterization. Attempted conversion of **7** to an ester enamide with acetyl chloride and pyridine led instead to a keto amide which must have structure **8**. Clearly this



8, R = Ac
10, R = CH_3



9

is the result of imine activation during acylation followed by transannular hydride donation from the alcohol carbon. Since intramolecular hydride transfer can only occur on the bottom face of the imine, the stereochemistry must be as shown, and the stereochemistry of the alcohol **7** is likewise required.[13] Finally, it might be noted that **7** could be converted to immonium salt **9** and subsequently treated with dilute aqueous base to provide **10**.

Experimental Section

Melting points were measured on a Mel-Temp apparatus and are uncorrected. Infrared spectra were recorded on a Beckman IR-5A spectrophotometer. Unless otherwise noted, ^1H and ^{13}C NMR spectra were obtained on deuteriochloroform solutions. Proton spectra were recorded on Varian T60A and HA-100 spectrometers, and chemical shifts are reported in parts per million downfield from internal Me_4Si. Carbon spectra were recorded on a Nicolet TT-14 spectrometer, and chemical shifts, reported in parts per million downfield from Me_4Si, were determined by using the solvent signal as an internal standard.

Photochemical reactions were carried out by using a Pyrex immersion well and a Hanovia 450-W medium-pressure lamp. All experiments requiring anhydrous conditions were conducted under a positive pressure of dry nitrogen in glassware that had been flamed in a dry nitrogen stream. Tetrahydrofuran was distilled from lithium aluminum hydride immediately prior to use. Combustion analyses were carried out by Galbraith Laboratories, Knoxville, TN.

Photocyclization of Vinylogous Amide 1d. A solution of 4.9 g (19.8 mmol) of vinylogous amide **1d**[2] in 800 mL of *tert*-butyl alcohol was degassed for 0.75 h with oxygen-free nitrogen and irradiated through Pyrex for 8 h. The solvent was then evaporated and the residue was chromatographed on alumina with ligroin:benzene (5:1) to yield 2.8 g (57%) of a white solid that slowly crystallized. Sublimation provided material melting at 73.5–74.5 °C: IR ($CHCl_3$) C=O 5.92 (s), C=N 6.17 μm (m); ^1H NMR ($CDCl_3$) δ 1.02 (s, 3 H, CH_3), 1.14 (s, 3 H, CH_3), 1.34–1.64 (complex multiplet, 16 H), 3.14 (dd, 1 H, J = 12.0, 18.0 Hz), 3.47 (t, 2 H, J = 7.0 Hz, CH_2N); ^{13}C NMR CH_3 carbons at δ 30.2, 28.1, CH_2 carbons at 56.1, 52.2, 45.4, 39.9, 35.7, 31.8, 27.9, 22.0, 19.5, CH carbon at 37.6, C carbons at 211.3, 178.8, 56.1, 34.3.

Anal. Calcd for $C_{16}H_{25}NO$: C, 77.68; H, 10.19; N, 5.66. Found: C, 77.61; H, 10.32; N, 5.59.

Deuteration of Imino Ketone 2a. To a solution containing sodium deuteroxide from 0.05 g of sodium and 5 mL of deuterium oxide were added 10 mL of dry tetrahydrofuran and 215 mg of imino ketone **2a**. The reaction mixture was stirred for 48 h at room temperature and extracted with methylene chloride. The organic phase was dried over anhydrous potassium carbonate and filtered, and the solvent was removed to provide 192 mg of crystalline material. The ^1H NMR spectrum indicated the loss of the doublet of doublets centered at 3.14 ppm in the spectrum of **2a** as well as other resonances in the region 1.34–1.64 ppm. Resonances at δ 56.1, 52.2, and 39.9 were absent in the ^{13}C NMR spectrum.

Diketo Benzamide 5. A solution of 195 mg (0.79 mmol) of imino ketone **2a**, 5 mL of 10% aqueous potassium hydroxide, 2 mL of benzoyl chloride, and 10 mL of tetrahydrofuran was stirred at room temperature for 3 h. Methylene chloride (10 mL) was then added, the layers were separated, and the aqueous layer was washed with an additional 10 mL of methylene chloride. The organic fractions were combined and washed twice with saturated sodium chloride solution. After drying over anhydrous potassium carbonate, the solution was filtered and the solvent was evaporated to give a white foam. This was chromatographed on alumina with benzene to give 244 mg (84% yield) of a white solid. Sublimation provided a sample melting at 168–169 °C: IR ($CHCl_3$) NH 2.98 (m), C=O, 5.89 (s), amide C=O 6.08 μm (s); ^1H NMR ($CDCl_3$) δ 1.00 (s, 3 H, CH_3), 1.12 (s, 3 H, CH_3), 1.14–3.50 (complex multiplet, 19 H), 6.84 (bs, 1 H, NH), 7.20–7.82 (m, 5 H, aromatic CH); ^{13}C NMR CH_3 carbons at δ 26.4 and 32.4, CH_2 carbons at 52.0, 47.7, 46.3, 35.4, 32.0, 28.1, 21.3, 19.9, 19.3, CH carbons at 130.9, 127.9 (2C), 126.5 (2C), 36.5; C carbons at 213.6, 210.5, 167.3, 133.8, 53.0, 34.6.

Anal. Calcd for $C_{23}H_{31}NO_3$: C, 74.76; H, 8.46; N, 3.79. Found: C, 74.72; H, 8.54; N, 3.75.

Deuteration of 5. To a solution prepared from 10 mL of methanol-*d* and 0.4 g of sodium was added 268 mg of amido ketone **5**. The resulting mixture was stirred at room temperature for 14 h. Deuterium oxide (5 mL) was then added and the solution was extracted with methylene chloride. The organic washings were dried over anhydrous potassium carbonate and filtered, and the solvent was removed to provide 268 mg of deuterated material. The ^{13}C NMR spectrum indicated the loss of methylene resonances at δ 52.0, 47.7, and 46.3 present in the spectrum of **5**.

Acetylation of 2a. To a stirred solution of 1.05 g (4.25 mmol) of imino ketone **2a** in 5 mL of dry pyridine and 25 mL of dry tetrahydrofuran under a nitrogen atmosphere was added 3 mL of acetyl chloride in 10 mL of dry tetrahydrofuran. The mixture was stirred at room temperature for 1 h, 10 mL of hydrochloric acid was added, and the solution was extracted 3 times with methylene chloride. The organic fractions were combined, washed twice with 10 mL of 10% hydrochloric acid, and dried over anhydrous potassium carbonate. After filtration and removal of the solvent, the solid residue was recrystallized from ether:ligroin (2:1) to yield 1.01 g (82% yield) of **4** as colorless crystals. Another recrystallization provided material melting at 116–117.5 °C: IR ($CHCl_3$) C=O 5.88 (s), amide C=O 6.10 μm (s); ^1H NMR ($CDCl_3$) δ 1.26 (s, 6 H, 2 CH_3), 1.40–2.11 (complex multiplet, 9 H), 2.13 (s, 3 H, CH_3CO), 2.15–3.20 (complex multiplet, 6 H), 3.49 (dd, 2 H, J = 5.0 Hz, 10.0 Hz, CH_2N), 5.30 (bs, 1 H, =CH); ^{13}C NMR CH_3 carbons at δ 34.3, 29.5, 22.2, CH_2 carbons at 51.3, 47.4, 41.8, 33.3, 28.1, 27.2, 10.8, 18.8, CH carbons at 127.9, 37.1, C carbons at 211.4, 169.2, 142.2, 48.1, 34.6.

Anal. Calcd for $C_{18}H_{27}NO_2$: C, 74.70; H, 9.40; N, 4.84. Found: C, 74.78; H, 9.11; N, 4.70.

Lithium Aluminum Hydride Reduction of 2a. A solution of 1.0 g (4.1 mmol) of imino ketone **2a** in 10 mL of dry tetrahydrofuran was added dropwise to a stirred solution of 0.25 g (7.4 mmol) of lithium aluminum hydride in 25 mL of dry tetrahydrofuran under an inert atmosphere at room temperature. The resulting mixture was stirred for 1 h and the excess reducing agent was decomposed with water. The solution was filtered and the filtercake was washed well with tetrahydrofuran. The filtrate and washings were dried over anhydrous potassium carbonate and filtered, and the solvent was evaporated to yield a white crystalline material. Recrystallization from ether provided 822 mg (81% yield) of crystalline **7** melting at 144–145 °C: IR ($CHCl_3$) OH 3.04 (s), C=N 6.15 μm (s); ^1H NMR ($CDCl_3$) δ 1.01 (s, 3 H, CH_3), 1.20

(13) Although intramolecular hydride transfer is well documented in cyclooctyl derivatives,[14] the obvious deuterium experiments were carried out. Thus, reduction of **2a** with lithium aluminum deuteride followed by acetylation produced deuterio derivatives of **7** and **8** whose carbon NMR spectra were missing resonances at δ 73.0 and 62.9, respectively.

(14) Prelog, V.; Traynham, J. G. In de Mayo, P. "Molecular Rearrangements"; Interscience Publishers: New York, 1963; Part 1, pp 593–613.

(s, 3 H, CH_3), 1.28–2.80 (complex multiplet, 17 H), 3.71 (m, 4 H, NCH_2, CHOH); ^{13}C NMR CH_3 carbons at δ 32.3, 31.6, CH_2 carbons at 56.7, 43.2, 41.4, 37.3, 35.8, 33.2, 29.4, 22.7, 20.3, CH carbons at 73.0, 38.4; C carbons at 180.9, 56.5, 34.3.

Anal. Calcd for $C_{16}H_{27}NO$: C, 77.06; H, 10.91; N, 5.62. Found: C, 77.24; H, 11.04; N, 5.52.

Acetylation of 7. To a stirred solution of 78 mg (0.31 mmol) of imino alcohol **7**, 10 mL of dry tetrahydrofuran and 2 mL of pyridine under an inert atmosphere was added 1 mL of acetyl chloride in 5 mL of dry tetrahydrofuran. The resulting mixture was stirred for 5 h and quenched with 10 mL of water. The resulting solution was extracted twice with 10-mL portions of methylene chloride and the organic fractions were combined and washed twice with 10-mL portions of 10% aqueous hydrochloric acid. The organic layer was dried over anhydrous potassium carbonate, filtered, and evaporated to give a solid residue. Recrystallization from ether:ligroin (1:1) provided 76 mg (85% yield) of colorless crystals melting at 172–174 °C: IR ($CHCl_3$) C=O 5.91 (s), amide C=O 6.04 μm (s); ^1H NMR ($CDCl_3$) δ 1.00 (s, 3 H, CH_3), 1.30 (s, 3 H, CH_3), 1.35–2.65 (complex multiplet, 20 H), 1.95 (s, CH_3CO), 3.33 (m, 3 H, CH_2NCH); ^{13}C NMR CH_3 carbons at δ 34.4, 24.3 (2C), CH_2 carbons at 58.3, 45.9 (2C), 36.9, 34.9, 23.2, 21.7, 20.2, CH carbons at 62.9, 43.7, C carbons at 214.3, 169.3, 46.9, 36.3.

Anal. Calcd for $C_{18}H_{29}NO_2$: C, 74.18; H, 10.03; N, 4.81. Found: C, 74.13; H, 10.03; N, 4.81.

Lithium Aluminum Deuteride Reduction of Imino Ketone 2a and Subsequent Acetylation. A solution containing 520 mg (2.10 mmol) imino ketone **2a** in 10 mL of dry tetrahydrofuran was added to a stirred mixture of 0.2 g of lithium aluminum deuteride in 50 mL of dry tetrahydrofuran under an inert atmosphere. The reaction mixture was stirred for 2 h at room temperature and excess reducing agent was destroyed with water. The precipitate was filtered and washed well with tetrahydrofuran. The filtrate was dried over anhydrous potassium carbonate and filtered, and the solvent was removed. Recrystallization of the residue from ether provided 411 mg (79% yield) of white crystals: ^1H NMR ($CDCl_3$) δ 1.01 (s, 3 H, CH_3), 1.20 (s, 3 H, CH_3), 1.28–2.80 (complex multiplet, 17 H), 3.71 (t, 2 H, J = 8.0 Hz, CH_2N), 4.05 (bs, 1 H, OH). All ^{13}C NMR resonances of **7** are present except a methine resonance at 73.0 ppm.

Acetyl chloride (2 mL in 5 mL of dry tetrahydrofuran) was added to a stirred solution of 275 mg (1.10 mmol) of the deuterio imino alcohol above in 5 mL of pyridine and 10 mL of tetrahydrofuran. The reaction mixture was stirred for 0.5 h and water was added. The mixture was then extracted 3 times with methylene chloride and the organic extracts were combined and washed twice with 10-mL portions of 10% hydrochloric acid. The organic layer was dried over anhydrous potassium carbonate and filtered, and the solvent was removed. After chromatography on alumina, 244 mg (76% yield) of pure material was obtained: ^1H NMR ($CDCl_3$) δ 1.00 (s, 3 H, CH_3), 1.30 (s, 3 H, CH_3), 1.35–2.65 (complex multiplet, 20 H), 1.95 (s, CH_3CO), 3.35 (dd, 2 H, J = 3.0, 12.0 Hz, CH_2N). All ^{13}C NMR resonances of **8** are present except a methine resonance at 62.9 ppm.

Methylation of 7. Alcohol **7** (195 mg, 0.78 mmol) was dissolved in 25 mL of dry benzene containing 1 mL of methyl iodide, and the solution was stirred for 16 h. Precipitation of the *N*-methyl immonium salt occurred during this time. Filtration and drying in vacuo provided 297 mg (97% yield) of **9** (which melted at 282–284 °C dec) after recrystallization for ethanol:ligron (5:1).

Anal. Calcd for $C_{17}H_{30}NOI$: C, 52.13; H, 7.73; N, 3.58. Found: C, 52.30; H, 7.81; N, 3.40.

The immonium salt **9** (386 mg, 0.97 mmol) was dissolved in 25 mL of 10% potassium hydroxide solution. After being stirred for 0.5 h, the solution was extracted twice with methylene chloride and the combined organic solutions were dried over potassium carbonate. The solvent was removed to give a white solid that was recrystallized from ether:ligroin (1:1) to provide 237 mg (91% yield) of **10** as colorless crystals melting at 280–282 °C dec: IR ($CHCl_3$) C=O 5.92 μm (s); ^1H NMR ($CDCl_3$) δ 1.11 (s, 6 H, $3CH_3$), 1.14–2.40 (complex multiplet, 16 H), 2.24 (s, 3 H, NCH_3), 2.58 (d, 1 H), 2.82–3.61 (m, 3 H, $CHNCH_2$).

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Registry No. **1d**, 67505-54-8; **2a**, 91631-77-5; **2a**-d_2, 91631-78-6; **4**, 91631-79-7; **5**, 91631-80-0; **7**, 91631-81-1; **7**-d_2, 91631-82-2; **8**, 91631-83-3; **8**-*d*, 91631-84-4; **9**, 91631-85-5; **10**, 91631-86-6.

Synthesis of Enantiomerically Pure Alkyl and Aryl Methyl Sulfoxides from Cholesteryl Methanesulfinates[1a]

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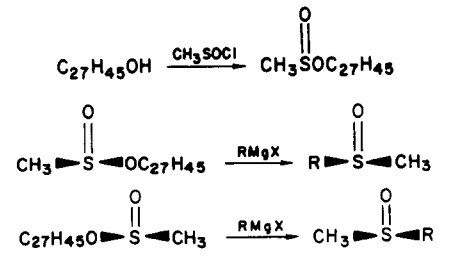
Optically active sulfoxides, chiral by virtue of asymmetry at sulfur, play a central role in organic sulfur stereochemistry especially in studies of nucleophilic substitution at sulfur.[2] Recently chiral sulfoxides have assumed importance in asymmetric synthesis.[3-5]

Simple alkyl aryl and diaryl sulfoxides are usually accessible in high enantiomeric purity, often 100%, but dialkyl sulfoxides are not. Johnson and co-workers synthesized several dialkyl sulfoxides from alkyl aryl sulfoxides by treating the latter with alkyllithiums, a reaction which interchanges the *S*-aryl and alkyllithium groups.[6] Recently, Kjaer and Malver described synthetic routes to alkyl methyl sulfoxides of high enantiomeric purity via hydrodeamination of enantiomerically homogeneous ω-aminoalkyl sulfoxides.[7] We report an alternative synthesis of methyl sulfoxides.

Alkyl aryl and diarly sulfoxides are usually prepared by treating epimerically pure crystalline menthyl arenesulfinates with the appropriate alkyl or aryl Grignard reagent.[2] For synthesis of dialkyl sulfoxides, the required alkanesulfinates have not been available epimerically pure at sulfur; e.g., the menthyl methanesulfinates are oils and attempts to separate them have not succeeded. We found, however, that substitution of cholesterol for menthol leads to crystalline cholesteryl methanesulfinates which can be separated by crystallization and which, upon treatment with alkyl or aryl Grignard reagents, yield alkyl or aryl methyl sulfoxides of high enantiomeric purity.



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