agreement and because the choice of coordination sites is so clear-cut for rigid bifunctional molecules, whose solution geometry must be nearly identical with their crystal geometry, we are convinced that assessment of solution geometry for conformationally flexible molecules by the analysis of LIS data is a fairly sensitive and, when applied with due caution, an appropriate procedure.

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Registry No.—1, 56587-28-1.

Supplementary Material Available. Table III, torsion angles excluding atoms C(8), C(9), O(1), O(2), O(3); Table IV, equations of planes and dihedral angles; Table V, crystal data for $C_{13}H_{14}O_3$; and Table VI, positional and thermal parameters and standard deviations for the structure of 1 (3 pages). Ordering information is given on any current masthead page.

References and Notes

(1) The *Chemical Abstracts* nomenclature for compound 1 is [3′aβ,4′α,-7′α,7′aβ]-3′a,4′,7′,7′a-tetrahydrospiro[cyclopentane-1,8′-[4,7]methanoisobenzofuran]-1′,3′-dione.
(2) Eloise Gerry Fellow, 1975–1976.
(3) R. E. R. Craig, A. C. Craig, and G. D. Smith, *Tetrahedron Lett.*, 1189 (1975).
(4) R. E. R. Craig, A. C. Craig, R. D. Larsen, and C. N. Caughlan, *J. Org. Chem.*, **41**, 2129 (1976).
(5) R. M. Larter, R. E. R. Craig, A. C. Craig, and B. P. Mundy, *J. Org. Chem.*, **42**, 1259 (1977).
(6) (a) R. Destro, G. Filippini, C. M. Gramaccioli, and M. Simonetta, *Acta Crystallogr., Sect. B*, **25**, 2465 (1969); (b) G. Filippini, C. M. Gramaccioli, C. Rovere, and M. Simonetta, *ibid.*, **28**, 2869 (1972).
(7) C. F. Wilcox, Jr., and R. R. Craig, *J. Am. Chem. Soc.*, **83**, 3866 (1961).
(8) Computer programs used were by F. R. Ahmed and co-workers (NRC-2, Data Reduction; NRC-8, Fourier for Distorted and Undistorted Nets; and NRC-12, Scan of Interatomic Distances and Angles; National Research Council, Ottawa, Ontario, Canada), Busing and Levy (ORFLS), Carrol K. Johnson (ORTEP), and Germaine, Main, and Woolfson (MULTAN, 1972 version). These programs were locally modified for use with the XDS Sigma 7 computer. Other programs were written locally by G. D. Smith, C. N. Caughlan, and R. D. Larsen.
(9) J. DeMeulemaer and J. Tompa, *Acta Crystallogr.*, **19**, 1014 (1965).
(10) G. H. Stout and L. H. Jensen, "X-Ray Structure Determination", Macmillan, New York, N.Y., 1968, p 457.
(11) D. T. Cromer and J. B. Mann, *Acta Crystallogr., Sect. A*, **24**, 321 (1968).
(12) R. F. Stewart, E. R. Davidson, and W. T. Simpson, *J. Chem. Phys.*, **42**, 3175 (1965).
(13) S. C. Abrahams and E. T. Keve, *Acta Crystallogr., Sect. A*, **27**, 157 (1971).
(14) R. E. Davis and M. R. Wilcott, "Nuclear Magnetic Resonance Shift Reagents", R. A. Sievers, Ed., Academic Press, New York, N.Y., 1973, pp 143–157. We thank the authors for making PDIGM available.
(15) The PDIGM program, using lanthanide positions selected by the user, calculates shift factors for all protons and assesses their agreement with experimental shifts. The ease of selection of lanthanide coordinates and the rapidity with which one can obtain the position best fit make the program useful.

Total Synthesis of (±)-Discretamine and (±)-Stepholidine

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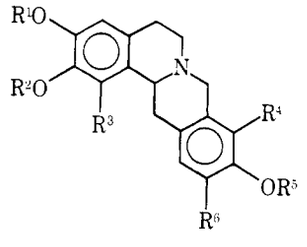
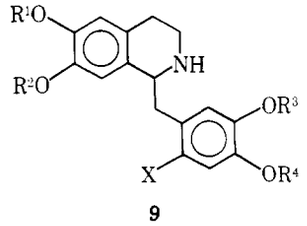
Discretamine, a tetrahydroprotoberberine alkaloid, was isolated in 1959 by Schmutz[1b] from *Xylopia discreta*. Elemental analysis gave the empirical formula $C_{19}H_{21}NO_4$ indicating the presence of two hydroxyl and two methoxyl groups in the cyclic moiety. Methylation with diazomethane gave (−)-tetrahydropalmatine (1), establishing absolute configuration and a 2,3,9,10-tetraoxygenated substitution pattern. Recently, structure **2** was proposed for discretamine based on mass spectroscopic evidence.[2]

Another diphenolic tetrahydroprotoberberine alkaloid, stepholidine, was isolated from *Stephania glabra* in 1968 and assigned structure **3** based on degradative evidence.[3] In 1975 stepholidine was discovered in opium[4] which also contains a third isomer, namely, scoulerine (**4**).[5] Neither discretamine nor stepholidine has been previously synthesized. The purpose of the investigation reported in the present communication was to confirm the structures of discretamine and stepholidine by synthesis, and to prepare these alkaloids in sufficient quantities for later use as cold carriers in biosynthetic studies.

Many approaches have been described for synthesis of protoberberines.[6,7] The oldest method which is still widely used is based on intramolecular Mannich condensation of an appropriately substituted 1-benzyltetrahydroisoquinoline with formaldehyde.[8,9] If the benzyltetrahydroisoquinoline carries a 3-hydroxy substituent in the benzyl moiety, cyclization occurs ortho and para to the phenolic hydroxyl group to afford a mixture of a tetrahydroprotoberberine and a tetrahydropseudoberberine, their relative proportion depending on steric factors and on reaction conditions such as pH and temperature. Applying this method to norreticuline (**9a**) at pH 6.3 and room temperature, Battersby et al.[10] obtained a mixture of scoulerine (**4**) and coreximine (**5**) in a ratio of approximately 2:1. When norreticuline was heated with formaldehyde in ethanol or in formic acid, Kametani et al.[11,12] and Tomita et al.[13] could isolate only coreximine. However, by blocking the para position with bromine (as in **9b**) ortho cyclization proceeded cleanly and debromination gave the 9,10-substituted tetrahydroprotoberberine.[14,15] With methoxy or benzyloxy groups in 3 and 4 positions of the benzyl moiety, only 10,11-substituted products could be obtained.[9,12,13,16,17]



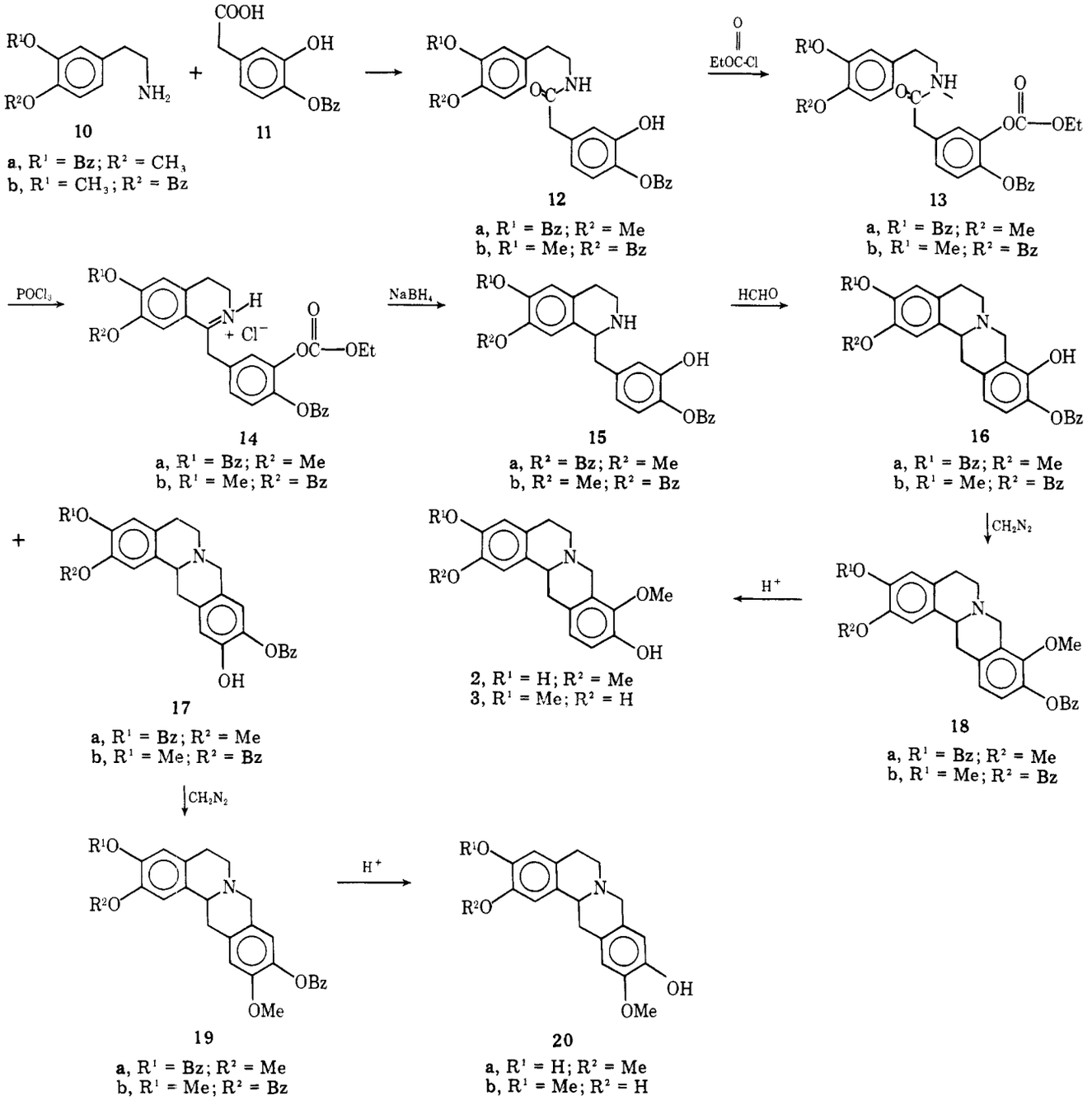
1, $R^1 = R^2 = R^5 = Me$; $R^3 = R^6 = H$; $R^4 = OMe$
2, $R^1 = R^3 = R^5 = R^6 = H$; $R^2 = Me$; $R^4 = OMe$
3, $R^1 = Me$; $R^2 = R^3 = R^5 = R^6 = H$; $R^4 = OMe$
4, $R^1 = R^5 = Me$; $R^2 = R^3 = R^6 = H$; $R^4 = OH$
5, $R^1 = R^5 = Me$; $R^2 = R^3 = R^4 = H$; $R^6 = OH$
6, $R^1 = R^2 = Me$; $R^3 = R^5 = R^6 = H$; $R^4 = OMe$
7, $R^1 = R^2 = Me$; $R^3 = OH$; $R^4 = OMe$; $R^5 = R^6 = H$
8, $R^1 = R^2 = R^5 = Me$; $R^3 = R^4 = H$; $R^6 = OMe$



9

a, $R^1 = R^4 = Me$; $R^2 = R^3 = X = H$
b, $R^1 = R^4 = Me$; $R^2 = R^3 = H$; $X = Br$

Scheme I



Kikemanine (**6**) and capaurimine (**7**), which are 10-hydroxy-9-methoxy substituted protoberberines, were also synthesized by the Mannich reaction.[18,19] This method, which is illustrated in Scheme I, was chosen for the synthesis of discretamine and stepholidine, particularly because the tetrahydropseudoberberines (**17a** and **17b**), which could be expected as by-products, would be needed for structural studies in progress. According to a recent report, the L isomer of **20b** has been isolated from *Corydalis govaniana*.[20] Fusion of 3-benzyloxy-4-methoxyphenethylamine[21] (**10a**) with 4-benzyloxy-3-hydroxyphenylacetic acid (**11**), obtained from 4-benzyloxy-3-tosyloxybenzyl cyanide,[22] gave the amide (**12a**) which was converted by ethoxycarbonylation to the nonphenolic amide (**13a**). Bischler–Napieralski cyclization with phosphorus oxychloride in dry toluene to **14a** was followed by reduction with sodium borohydride and hydrolysis of the ester group to **15a**. Intramolecular Mannich reaction of the 1-benzyltetrahydroisoquinoline (**15a**) with formaldehyde at pH 6.3 and room temperature resulted in a mixture of the protoberberines **16a** and **17a** which was separated by column chromatography on silica gel. 3,10-Benzyloxy-9-hydroxy-2-methoxytetrahydroprotoberberine (**16a**) was methylated with diazomethane to the nonphenolic base **18a** [(±)-*O,O*-dibenzyldiscretamine]. Debenzylation of **18a** with ethanolic hydrochloric acid gave the diphenolic base **2**. Elemental analysis showed a $C_{19}H_{21}NO_4$ composition. The mass spectrum was identical with that of natural discretamine[2] and showed the presence of a 9-methoxy group.[23] Methylation of **2** with diazomethane gave (±)-tetrahydropalmatine (**1**) which was spectroscopically identical with an authentic sample of (−)-tetrahydropalmatine.[24]

(±)-Stepholidine was synthesized from 4-benzyloxy-3-methoxyphenethylamine (**10b**) and 4-benzyloxy-3-hydroxyphenylacetic acid (**11**) by the same method outlined for (±) discretamine. The synthetic product (**3**) was spectroscopically identical with natural stepholidine.[3,4,23] Methylation with

Table I. Melting Points and Spectroscopic Data

Registry no.	Compd	Mp, °C	NMR ($CDCl_3$), ppm	MS (EI), *m/e* (rel intensity)	MS (CI)	Accurate mass $(M + 1)^+$
42522-12-3	**12a**	128–131	3.40 (s, $COCH_2Ar$) 3.84 (s, OMe) 5.07 (s, OCH_2Ph) 5.09 (s, OCH_2Ph)		498	
62744-12-1	**12b**	122–125	3.42 (s, $COCH_2Ar$) 3.83 (s, OMe) 5.09 (s, OCH_2Ph) 5.11 (s, OCH_2Ph)		498	
42522-13-4	**13a**	81–83	1.31 (t, J = 7.0 Hz, OCH_2CH_3) 3.41 (s, $COCH_2Ar$) 3.84 (s, OMe) 4.26 (q, J = 7.0 Hz, OCH_2CH_3) 5.09 (s, 2 OCH_2Ph)		570	
62744-13-2	**13b**	68–71	1.30 (t, J = 7.0 Hz, OCH_2CH_3) 3.41 (s, $COCH_2Ar$) 3.83 (s, OMe) 4.26 (q, J = 7.0 Hz, OCH_2CH_3) 5.10 (s, 2 OCH_2Ph)		570	
	14a	Oil (not purified)				
62744-14-3	**14b**	188–190				
42522-14-5	**15a**	134–136	3.79 (s, OMe) 5.07 (s, 2 OCH_2Ph)		482	482.2345 ± 0.002
62744-15-4	**15b**	159–161	3.83 (s, OMe) 5.05 (s, 2 OCH_2Ph)		482	482.2338 ± 0.002
50796-02-6	**16a**	109–112 dec	3.89 (s, OMe) 5.10 (s, OCH_2Ph) 5.13 (s, OCH_2Ph) 6.66 (1 H, s, ArH) 6.69 (1 H, s, ArH) 6.77 (2 H, s, ArH)	493 (12.1) (M^+) 403 (34.6) 402 (100) 311 (9.1) 268 (16.3) 176 (26.2) 135 (25.0) 91 (90.3)		
62744-16-5	**16b**	85–88 dec	3.87 (s, OMe) 5.09 (s, OCH_2Ph) 5.13 (s, OCH_2Ph) 6.64 (2 H, s, ArH) 6.75 (2 H, s, ArH)	493 (12.5) (M^+) 403 (32.1) 402 (100) 311 (4.6) 268 (21.7) 176 (12.9) 135 (28.9) 91 (63.4)		
50796-03-7	**17a**	87–90	3.89 (s, OMe) 5.09 (s, OCH_2Ph) 5.13 (s, OCH_2Ph) 6.65 (2 H, s, ArH) 6.76 (2 H, s, ArH)	493 (15.5) (M^+) 402 (100) 268 (15.7) 176 (24.2) 135 (22.6) 91 (83.7)		494.2315 ± 0.002
62744-17-6	**17b**	78–80	3.88 (s, OMe) 5.09 (s, OCH_2Ph) 5.14 (s, OCH_2Ph) 6.64 (2 H, s, ArH) 6.75 (2 H, s, ArH)	493 (13.5) (M^+) 402 (100) 268 (23.9) 176 (13.4) 135 (28.9) 91 (85.3)		494.2315 ± 0.002
62744-18-7	**18a**	139–141	3.89 (s, OMe) 3.90 (s, OMe) 5.10 (s, OCH_2Ph) 5.13 (s, OCH_2Ph) 6.64 (1 H, s, ArH) 6.74 (1 H, s, ArH) 6.83 (2 H, s, ArH)	507 (28.4) (M^+) 417 (32.5) 416 (100) 414 (5.1) 178 (10.0) 176 (11.6) 150 (12.5) 149 (60.5) 121 (17.5) 91 (66.1)		
62744-18-7	**18b**	100–102	3.87 (s, OMe) 3.89 (s, OMe) 5.10 (s, OCH_2Ph) 5.13 (s, OCH_2Ph) 6.64 (1 H, s, ArH) 6.74 (1 H, S, ArH) 6.80 (2 H, s, ArH)	507 (21.3) (M^+) 416 (100) 414 (10.2) 150 (9.9) 149 (77.3) 121 (15.0) 91 (63.9)		

Table I (*Continued*)

Registry no.	Compd	Mp, °C	NMR ($CDCl_3$), ppm	MS (EI), *m/e* (rel intensity)	MS (CI)	Accurate mass $(M + 1)^+$
55934-50-4	**2**	208–212 dec	3.82 (s, OMe) 3.90 (s, OMe) 6.68 (1 H, s, ArH) 6.70 (1 H, s, ArH) 6.82 (2 H, s, ArH)	327 (62.6) (M^+) 326 (34.9) 296 (9.1) 178 (100) 176 (27.1) 150 (35.3) 149 (17.8) 135 (29.9)		
16562-14-4	**3**	136–140 dec	3.82 (s, OMe) 3.88 (s, OMe) 6.60 (1 H, s, ArH) 6.82 (3 H, s, ArH)	327 (59.4) (M^+) 326 (39.1) 296 (10.2) 178 (100) 176 (23.3) 150 (25.9) 149 (23.6) 135 (22.5)		
55934-51-5	**19a**	134–136	3.86 (s, OMe) 3.89 (s, OMe) 5.12 (s, 2 OCH_2Ph) 6.60 (1 H, s, ArH) 6.65 (1 H, s, ArH) 6.69 (1 H, s, ArH) 6.77 (1 H, s, ArH)	507 (20.4) 417 (19.4) 416 (54.7) 241 (10.2) 240 (13.7) 150 (15.9) 91 (100)		508.2472 ± 0.002
60342-44-1	**19b**	130–132	3.87 (s, 2 OMe) 5.11 (s, OCH_2Ph) 5.13 (s, OCH_2Ph) 6.58 (1 H, s, ArH) 6.64 (2 H, s, ArH) 6.76 (1 H, s, ArH)	507 (20.3) (M^+) 417 (24.5) 416 (77.6) 241 (12.9) 240 (15.4) 150 (12.4) 91 (100)		508.2500 ± 0.002
62744-19-8	**20a**	218–220	3.87 (s, OMe) 3.90 (s, OMe) 6.64 (2 H, s, ArH) 6.68 (1 H, s, ArH) 6.71 (1 H, s, ArH)	327 (65.4) (M^+) 326 (27.6) 178 (100) 176 (35.7) 151 (33.7) 150 (93.8) 135 (15.3)		
60383-78-0	**20b**	222–225	3.87 (s, OMe) 3.88 (s, OMe) 6.60 (1 H, s, ArH) 6.63 (2 H, s, ArH) 6.82 (1 H, s, ArH)	327 (55.7) (M^+) 326 (24.9) 178 (100) 176 (25.6) 151 (31.1) 150 (87.5) 135 (14.4)		

diazomethane gave (±)-tetrahydropalmatine, identical with authentic material. Thus, the structures proposed for discretamine and stepholidine were confirmed.

The products of para cyclization (**17a, 17b**) were methylated with diazomethane to **19a** and **19b,** respectively, and debenzylated to afford 3,10-dihydroxy-2,11-dimethoxytetrahydropseudoberberine (**20a**) and 2,10-dihydroxy-3,11-dimethoxytetrahydropseudoberberine (**20b**). When the hydrochlorides of **15a** and **15b** were reacted with formaldehyde under reflux without pH adjustment the products of para cyclization were the only products which could be isolated. Methylation of **20a** and **20b** with diazomethane gave (±)-xylopinine (**8**) [= (±)-norcoralydine], spectroscopically identical with (−)-xylopinine.[25] Compounds **20a** and **20b** were synthesized earlier by Tomita et al.[26] and by Kametani et al.[16] using a different approach.

Experimental Section

General. Melting points were determined with a Thomas-Hoover apparatus and are uncorrected. Infrared (IR) spectra were obtained in potassium bromide on a Perkin-Elmer 337 spectrometer. ^1H NMR spectra were obtained in deuteriochloroform with tetramethylsilane as an internal reference at a field strength of 100 MHz on a Varian XL-100 spectrometer equipped with a Nicolet Technology Corp. Fourier transform accessory. Electron impact (EI) mass spectra were taken on a AEI MS-12 mass spectrometer interfaced to a PDP 8/I computer using the DS-30 software. High-resolution and chemical ionization (CI) mass spectra were taken on an AEI MS-9 spectrometer with a specially modified source for chemical ionization using isobutane as the reagent gas. The analytical samples were vacuum dried (0.1 mmHg) at 56.5 °C (boiling acetone). Elemental analyses were carried out at the Department of Chemistry, National Taiwan University, and the Microanalytical Department, University of California at Berkeley. The syntheses were carried out as described by Kametani et al.[18] for the synthesis of (±)-kikemanine. The results of the combustion analyses for carbon, hydrogen, and nitrogen were within 0.4% of the calculated values. The melting points, NMR, and MS data are recorded in Table I.

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References and Notes

(1) (a) Address correspondence to this author at the University of California. (b) J. Schmutz, *Helv. Chim. Acta*, **42**, 335 (1959).
(2) W. J. Richter and E. Brochmann-Hanssen, *Helv. Chim. Acta*, **58**, 209 (1975).
(3) M. P. Cava, K. Nomura, S. K. Talapatra, M. J. Mitchell, R. H. Schlessinger, K. T. Buck, J. L. Beal, B. Douglas, R. F. Raffauf, and J. A. Weisbach, *J. Org. Chem.*, **33**, 2785 (1968).
(4) E. Brochmann-Hanssen and W. J. Richter, *J. Pharm. Sci.*, **64**, 1040 (1975).
(5) E. Brochmann-Hanssen and B. Nielsen, *Tetrahedron Lett.*, 2261 (1966).
(6) M. Shamma, "The Isoquinoline Alkaloids, Chemistry and Pharmacology", Academic Press, New York, N.Y., 1972, p 271.
(7) I. Ninomiya and T. Naito, *J. Chem. Soc., Chem. Commun.*, 137 (1973).
(8) A. Pictet and A. Gams, *Chem. Ber.*, **44**, 2480 (1911).
(9) R. D. Haworth, W. J. Perkin, Jr., and J. Rankin, *J. Chem. Soc.*, **125**, 1686 (1924).
(10) A. R. Battersby, R. Southgate, J. Staunton, and M. Hirst, *J. Chem. Soc. C*, 1052 (1966).
(11) T. Kametani, K. Fukumoto, T. Terui, K. Yamaki, and E. Taguchi, *J. Chem. Soc. C*, 112 (1968).
(12) T. Kametani and M. Ihara, *J. Pharm. Soc. Jpn.*, **87**, 174 (1967).
(13) M. Tomita and J. Kunimoto, *J. Pharm. Soc. Jpn.*, **80**, 1238 (1960).
(14) T. Kametani and M. Ihara, *J. Chem. Soc. C*, 530 (1967).
(15) T. Kametani, I. Noguchi, K. Saito, and S. Kaneda, *J. Chem. Soc. C*, 2036 (1969).
(16) T. Kametani and M. Satoh, *J. Pharm. Soc. Jpn.*, **87**, 179 (1967).
(17) H. Iida, H. C. Hsu, H. Miyano, and T. Kikuchi, *J. Pharm. Soc. Jpn.*, **91**, 795 (1971).
(18) T. Kametani, T. Honda, and M. Ihara, *J. Chem. Soc. C*, 3318 (1971).
(19) T. Kametani, T. Honda, and M. Ihara, *J. Chem. Soc. C*, 2396 (1971).
(20) K. Mehra, H. S. Garg, D. S. Bhakuni and N. M. Khanna, *Indian J. Chem., Sect. B*, **14**, 216 (1976); *Chem. Abstr.*, **85**, 108856c (1976).
(21) A. R. Battersby, D. J. LeCount, S. Garratt, and R. I. Thrift, *Tetrahedron*, **14**, 46 (1961).
(22) B. Hegedus, *Helv. Chim. Acta*, **46**, 2604 (1963).
(23) W. J. Richter and E. Brochmann-Hanssen, *Helv. Chim. Acta*, **58**, 203 (1975).
(24) Pierce Chemical Co.
(25) Prepared by methylation of (−)-coreximine with diazomethane.
(26) M. Tomita and J. Kunimoto, *J. Pharm. Soc. Jpn.*, **80**, 1245 (1960).

A Convenient Synthesis of Allylic Hydroperoxides

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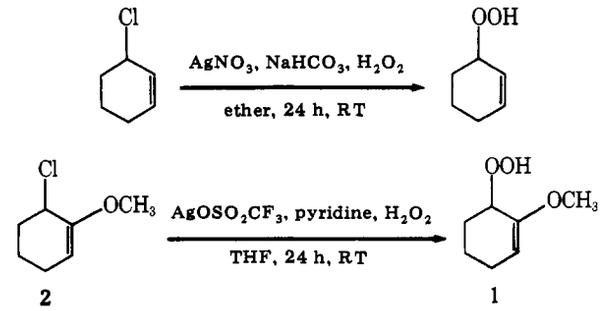
Because of our recent investigation of the singlet oxygen "ene" reaction of 1-methoxycyclohexene,[2] we were interested in preparing the enol ether allylic hydroperoxide, 3-hydroperoxy-2-methoxycyclohexene (**1**). Allylic hydroperoxides have been synthesized by various methods:[3] (a) from the free-radical autoxidation of olefins, initiated thermally or photolytically; (b) from the autoxidation of organometallic compounds, particularly Grignard reagents; (c) from the reaction of olefins with singlet oxygen; (d) from the solvolysis of alkenyl sulfates (prepared in situ from equimolar quantities of alcohol and sulfuric acid) in hydrogen peroxide; (e) from the solvolysis of allylic mesylates and other sulfonate esters in basic hydrogen peroxide; and (f) from the nucleophilic displacement of allyl halides with basic hydrogen peroxide.

Methods a and c are often problematic since they yield a multiplicity of products. Isolation and purification is a serious problem with hydroperoxides in general and alkenyl hydroperoxides in particular.[2b] Because hydroperoxide **1**, in addition to being allylic, is at the same time an enol ether, methods involving acidic hydrogen peroxide or acidic workups are to be avoided (method d).[4] Nor could a Grignard path (method b) be used since enol ethers react with Grignard reagents at the double bond site.[4]

We would like to report a convenient synthesis of allylic hydroperoxides via the silver ion assisted reaction of the corresponding allylic halide and hydrogen peroxide. In particular, an ether solution of 3-chlorocyclohexene,[5] silver nitrate,[6] $NaHCO_3$ (in a 1:1:2 molar ratio), and a tenfold excess of 98% H_2O_2 was stirred for 24 h at room temperature in the dark under argon.[7] Filtration and evaporation of the solvent under reduced pressure gave an almost quantitative yield of 3-hydroperoxycyclohexene.



Similarly, a THF solution of 3-chloro-2-methoxycyclohexene (**2**) was stirred for 1 day in the dark under argon[7] with 1 equiv of pyridine,[8] 2 equiv of silver triflate, and 15 equiv of 98% H_2O_2. Filtration and evaporation of the solvent and pyridine under high vacuum gave the desired hydroperoxide in an 80% yield.

At this juncture we would like to note that when **2** was allowed to react with H_2O_2 in the presence of silver nitrate, the yet unknown[9] 2-methoxy-2-cyclohexen-1-yl nitrate (**3**) was obtained, in approximately 50% yield, in addition to the allylic hydroperoxide **1**. The unstable nitrate was isolated by high vacuum distillation and identified by its spectral data (see Experimental Section).

The starting allylic chloride **2**[11] could not by synthesized from 1-methoxycyclohexene and *N*-chloro amides since enol ethers react via a polar, not free-radical, mechanism with these chlorinating agents.[4] Nor could it be prepared conveniently by the action of Ph_3P–CCl_4 on 3-hydroxy-2-methoxycyclohexene (**4**).[13] In contrast to 3-hydroxycyclohexene, which in the presence of Ph_3P–CCl_4 proceeded smoothly and quantitatively to the corresponding chloride, **4** yielded only 25% **2**. Surprisingly, the major product was 2-methoxycyclohexanone (**5**), which was readily synthesized by reducing 2-methoxy-2-cyclohexen-1-one (**6**) with hydrogen and palladium.

Chloride **2** was successfully prepared as follows. Epoxidation of commercially available (Aldrich Chemical Co.) 2-cyclohexen-1-one (**8**) with either alkaline hydrogen peroxide[14] or *tert*-butyl hydroperoxide[15] affords 2,3-epoxycyclohexanone (**7**). The latter method is the procedure of choice since it gives the desired product in approximately 80% yield while the former gives it in 30% yield. Treatment of the epoxide with methoxide in methanol followed by neutralization and distillation gives 26–34% yield of ketone **6**.[16] Reduction of **6** with diisobutylaluminum hydride (DIBAL),[17] neutralization with methanol, and distillation give alcohol **4** in 88% yield.[18] The corresponding mesylate **9** was conveniently prepared in situ according to the procedure of Crossland and Servis.[19] Displacement of the mesylate group with chloride ion, workup, and distillation gave the desired product in 75% yield.[20,21]

Both 3-hydroperoxycyclohexene and its 2-methoxy analogue (**1**) are readily reduced by triphenylphosphine to yield the corresponding alcohols. Thermolysis of these two hydroperoxides in the VPC injection port produced both the corresponding alcohol and ketone. The mechanism of such a thermal cleavage is discussed by Walsh[22] and Frank.[23,24]

Throughout this work most spectra were recorded using deuteriochloroform as solvent. In many cases, it was convenient to follow the progress of the reaction by NMR particularly by studying the growth and disappearance of methoxy group absorptions which show up as sharp singlets. As can be seen from Table I, however, the methoxy absorptions in $CDCl_3$