time showed no curvature over 4 half-lives. Rate constants were determined by least-squares analysis. Correlation coefficients were greater than 0.999 for all runs. At a given temperature setting, the rate constants were reproducible (see Table I). The error in measurement (±0.3 °C) of the reaction mixture temperature was greater than the thermal stability (±0.1 °C) of the system. Therefore, experiments with 1 and 2 were always carried out without altering the temperature bath settings for each set of runs. Runs with $5.0 \times 10^{-4}$ M DPA or no added fluorescer yielded results identical with those with DBA (concentration = $5.0 \times 10^{-4}$ M or less).

**Yields of Excited States.** The apparatus was calibrated by taking the yield of triplet acetone from **2**, determined by the DBA method, as 0.30 at 60 °C. All experiments were carried out at 60 °C with a constant concentration (initial) of dioxetane. The concentrations of DBA or DPA were varied. The method of calculation of singlet and triplet carbonyl yields by the DBA/DPA method has been discussed in detail.[2] Acetone-$d_6$ was assumed to have identical properties with those of acetone.

**Acknowledgment** is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial support of this research and to NIH (RR 09210). Mass spectra were taken at the Georgia Institute of Technology on an instrument supported in part by the NSF.

**Registry No.** 1, 88635-83-0; 2, 35856-82-7; AgOAc, 563-63-3; $D_2$, 7782-39-0; $Na_2EDTA$, 139-33-3; β-bromotetra(methyl-$d_3$)-ethane hydroperoxide, 90531-19-4; 9,10-dibromoanthracene, 523-27-3; 9,10-diphenylanthracene, 1499-10-1.

## Lead Tetraacetate Oxidation of Oxyprotoberberines. A Convenient Synthesis of 13-Oxygenated Berbines and Oxyprotoberberines

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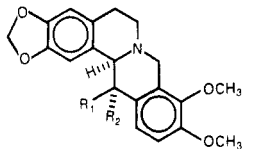
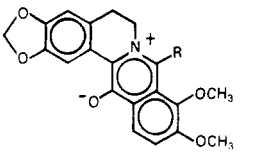
Ophiocarpine (1) is a member of a small subgroup of berbine alkaloids characterized by a hydroxyl group in ring C.[1] Stereochemically, the 13,13a hydrogens in the naturally occurring alkaloids possess a cis relationship. The relationship of **1** to the catecholamines (e.g., epinephrine)



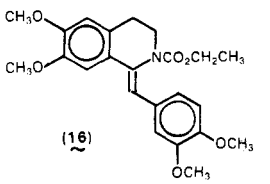
(1) $R_1$ = OH, $R_2$ = H

(2) $R_1$ = H, $R_2$ = OH



(3) R = H

(4) R = OMe

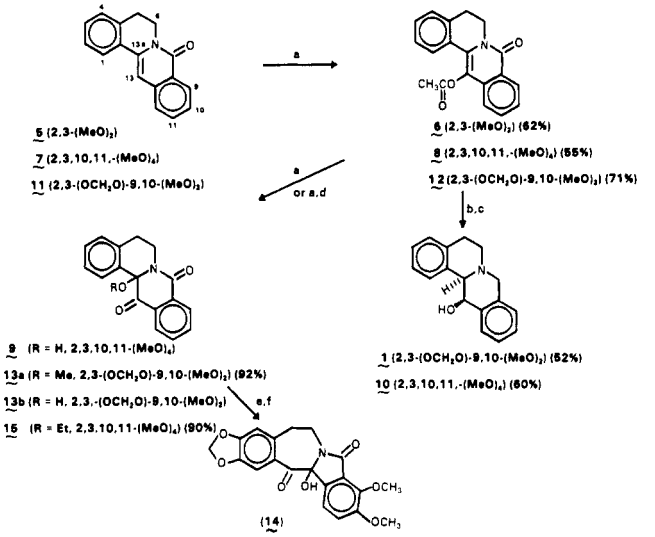


(16)

and its intermediacy in the biosynthesis of the phthalide–isoquinoline and rhoeadine alkaloids[2] has resulted in a variety of synthetic approaches to these compounds. The initial synthesis proceeded from the naturally occurring phthalide–isoquinoline alkaloid, hydrastine, to generate the correct stereochemistry.[3] These syntheses were, in a sense, a reverse biomimetic synthesis. Subsequent approaches, starting from a benzylisoquinoline, have yielded the epimeric epiophiocarpine (**2**), which is not naturally occurring, as the predominant or exclusive product.[4] A solution to the stereoselective reduction of protoberberine derivatives was found when it was observed that borohydride reduction of berberinephenol betaine (**3**),[5] or its 8-methoxy derivative,[6] gave predominantly ophiocarpine (**1**). Presumably, the amine, resulting from the initial reduction, controls the subsequent reduction of the 13-ketone or its enolate to form **1** in preference to **2**. Both **3** and **4** were ultimately derived from the commercially available protoberberine alkaloid berberine chloride.

Since the generality and synthetic limitations for the preparation of compounds **3** and **4** are not known, we decided to approach the synthesis of 13-hydroxyberbines, possessing the correct natural stereochemistry, by using a class of compounds which were readily accessible by a variety of synthetic methods. Additionally oxygen had to be introduced at what ultimately becomes the C13 hydroxyl group and the amino function had to be generated first to control the stereochemistry of the C13 alcohol. To meet these requirements, we selected the oxyprotoberberines because they are synthetically readily available[7]

Scheme I[a]




[a] Reagents: (a) lead tetraacetate, (b) lithium aluminum hydride, (c) sodium borohydride, (d) alcohol, *p*-toluenesulfonic acid, (e) HCl, (f) aqueous ammonia.

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(2) (a) Battersby, A. R.; Hirst, M.; McCaldin, D. J.; Southgate, R.; Staunton, J. *J. Chem. Soc. C* **1968**, 2163. (b) Runsch, H. *Eur. J. Biochem.* **1973**, *28*, 123. (c) Jeffs, P. W.; Scharver, J. D. *J. Org. Chem.* **1975**, *40*, 644.

(3) (a) Govindachari, T. R.; Rajadurai, S. *J. Chem. Soc.* **1957**, 557. (b) Takemoto, T.; Kondo, M. *J. Pharm. Soc. Jpn.* **1962**, *82*, 1413. (c) Ohta, M.; Tani, H.; Morozumi, S. *Chem. Pharm. Bull. Jpn.* **1964**, *12*, 1072.

(4) (a) Elliott, I. W., Jr. *J. Heterocycl. Chem.* **1967**, *4*, 639. (b) Kametani, T.; Matsumoto, H.; Satoh, Y.; Nemoto, H.; Fukumoto, K. *J. Chem. Soc., Perkin Trans. 1* **1977**, 376.

(5) Kondo, Y.; Imai, J.; Inoue, H. *J. Chem. Soc., Perkin Trans. 1* **1980**, 911.

(6) Moniot, J. L.; Shamma, M. *J. Org. Chem.* **1979**, *44*, 4337. See also: Hanaoka, M.; Mukai, C.; Arata, Y. *Chem. Pharm. Bull. Jpn.* **1983**, *31*, 947.

(7) Oxyprotoberberines have been prepared by (a) Bischler–Napieralski cyclization (Haworth, R. D.; Perkin, W. H., Jr.; Pink, H. S. *J. Chem. Soc.* **1925**, 1709), (b) Pomeranz–Fritsch cyclizations (Brown, D. W.; Dyke, S. F.; Sainsbury, M.; Hardy, G. *J. Chem. Soc. C* **1971**, 3219), (c) base-catalyzed disproportionation of protoberberine pseudobases (Perkin, W. J., Jr. *J. Chem. Soc.* **1918**, 722), (d) photocyclization of benzylideneisoquinoline enamides (Yang, N. C.; Shani, A.; Lenz, G. R. *J. Am. Chem. Soc.* **1966**, *88*, 5369), (e) dehydrogenation of 8-oxoberbines (Lenz, G. R. *J. Org. Chem.* **1974**, *39*, 2846), (f) oxidative photocyclization of enamides (Lenz, G. R. *Ibid.* **1974**, *39*, 2839), (g) photorearrangement of spirobenzylisoquinoline ketones (Greenslade, D.; Ramage, R. *Tetrahedron* **1977**, *33*, 927), and (h) polyphosphoric acid cyclization of enamides (see Experimental Section).

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and possess the complete correct molecular framework of the berbine alkaloids. Prior to this work, the only 13-oxygenated oxyprotoberberine known was **12**, which was prepared in a circuitous manner from berberine.[6] Since enamides are readily acetoxylated with lead tetraacetate,[8] the pyridone C ring should react analogously to yield 13-acetoxyoxyprotoberberines.[9] Reduction of the resultant 13-acetoxyoxyprotoberberines with lithium aluminum hydride (LAH) would then reduce the lactam group to the amine while protecting the enolate at C13 from further reduction,[10] thus fulfilling the last requirement listed above. Subsequent reduction with borohydride would then yield the correct stereochemistry.

In practice, the substituted oxyprotoberberines **5**, **7**, and **11** were oxidized with lead tetraacetate to give the 13-acetoxyoxyprotoberberines **6**, **8**, and **12** in good overall yields (Scheme I). Either overoxidation of the oxyprotoberberines or subsequent oxidation of the 13-acetoxylated derivatives led to the 8,13-dioxo-13a-hydroxy compound **9** or the subsequent ethers **13a** and **15** in excellent yields. Reduction of the acetoxyoxyprotoberberines **8** and **12** was accomplished in two steps by using LAH and borohydride, without isolation of intermediates, to yield 13$\beta$-hydroxyxylopinine (**10**) and ophiocarpine (**1**). Conversion of ether **13a** to the 13a-alcohol **13b** with acid, followed by treatment with aqueous ammonia according to Shamma's procedure,[11] led to the novel highly oxidized indenobenzazepine alkaloid **14** chilenine[11] as an added bonus of the synthetic sequence.

Controlling the level of oxidation of oxyprotoberberines with lead tetraacetate can lead to 13-acetoxyoxyprotoberberines, which can be reduced to the naturally occurring 13-hydroxyberbines, or to 13a-hydroxy-8,13-dioxoberbines, one of which was rearranged to the indenobenzazepine alkaloid chilenine.

## Experimental Section

**General Methods.** Melting points were run on a Thomas-Hoover Unimelt capillary apparatus and are uncorrected. IR spectra were recorded in KBr on a Beckman IR-12 and UV spectra were run in methanol on a Beckman DK-2A spectrophotometer unless otherwise indicated. NMR spectra were recorded on Varian T-60, A-60, FT-80 spectrometers and were run in deuteriochloroform with tetramethylsilane as an internal standard. Mass spectra were determined on an AEI MS-30. Microanalyses were determined by the Searle Laboratories Microanalytical Service under the direction of Mr. Emanuel Zielinski.

**2,3,10,11-Tetramethoxyoxyprotoberberine (7).** Polyphosphoric acid (approximately 250 mL) was stirred and heated to 100 °C. Enamide **16**[7d] (16 g, 38.7 mmol) was added as a finely divided powder. After 1 h, the solution was poured onto ice and stirred until the PPA dissolved. After dilution with water, the suspension was extracted several times with chloroform. The combined extracts were dried over sodium sulfate and the solvent removed. The crystalline residue was dissolved in 350 mL of methylene chloride, treated with decolorizing carbon, filtered, and reduced to a small volume. The hot solution was diluted with ethanol and heated until all the methylene chloride had distilled. After cooling, the product was collected and washed with a small amount of cold methanol to yield 9.2 g (25.1 mmol, 65%) of **7**, mp 187–188 °C (lit. mp 190 °C,[12] 198–199 °C[13]).

**Lead Tetraacetate Oxidation of the Oxyprotoberberine 11.** The oxyprotoberberine **11**[7c] (1.0 g, 2.85 mmol), was dissolved in 100 mL of methylene chloride, and 1.25 equiv (3.56 mmol, 1.6 g) of lead tetraacetate, which had been dried over refluxing acetone in vacuo, was added. After 2 h of magnetic stirring, the excess lead tetraacetate was quenched with glycerine. The reaction mixture was washed with water and dried with sodium sulfate. After removal of the solvent, the residue was crystallized from methanol to yield 13-acetoxy-9,10-dimethoxy-2,3-(methylenedioxy)oxyprotoberberine (**12**): 0.82 g, 2.01 mmol (71%); mp 236–237 °C (lit.[6] mp 237–238 °C); NMR $\delta$ 7.43 (s, 1 H), 7.34 (d, $J$ = 9 Hz, 1 H), 7.16 (d, $J$ = 9 Hz, 1 H), 6.64 (s, 1 H), 5.97 (s, 2 H), 5.15 (m, 1 H), 3.99 (s, 3 H), 3.93 (s, 3 H), 2.7–3.5 (m, 3 H), 2.35 (s, 3 H); UV 227 nm ($\epsilon$ 45 400), 280 (min, 5100), 312 (sh, 13 000), 331 (sh, 24 000), 341 (26 600), 369 (sh, 14 400), 386 (sh, 9300).

Our NMR assignments differ from those of ref 6. The reason appears to be that 13-oxygenated oxyprotoberberines can exist as two enantiomeric rotamers. At room temperature, the six protons are nonequivalent but close to coalescence and, in some cases, are not observable except by integration. At, or below, room temperature, one C6-hydrogen appears around $\delta$ 5.1 and the other around $\delta$ 3.6.[14]

**13-Acetoxy-2,3-dimethoxyoxyprotoberberine (6).** The oxyprotoberberine **5**[7f] (1.00 g, 3.25 mmol) was dissolved in 100 mL of dry benzene and reacted with dry lead tetraacetate as detailed for the preparation of **12** to yield 13-acetoxy-2,3-dimethoxyoxyprotoberberine (**6**): 0.73 g, 2.0 mmol (62%); mp 208–212 °C (methanol); IR 1765 cm$^{-1}$, 1665, 1625, 1610; UV 227 nm ($\epsilon$ 32 000), 257 (sh, 13 500), 281 (min, 5500), 332 (25 000), 350 (sh, 19 500), 366 (sh, 11 500); NMR $\delta$ 8.35 (m, 1 H), 7.50 (s, 1 H), 2.29 (s, 3 H), 2.4–3.6 (m, 3 H).

Anal. Calcd for $C_{21}H_{19}NO_5 \cdot H_2O$: C, 65.78; H, 5.52; N, 3.65. Found: C, 65.69; H, 5.46; N, 3.68.

**13-Acetoxy-2,3,10,11-tetramethoxyoxyprotoberberine (8).** A solution of 11.0 g (29.9 mmol) of oxyprotoberberine **7** in 1.1 L of methylene chloride was treated with 15 g of dry lead tetraacetate. After 4 h of stirring, an additional 1.3 g of lead tetraacetate was added. The progress of the reaction was monitored by NMR after quenching an aliquot with glycerine. After 3 days, the reaction was quenched with 10 mL of glycerine and then washed with water. After separation, the organic layer was washed with dilute sodium bicarbonate solution and then dried with sodium sulfate. The methylene chloride solution was concentrated to a small volume and diluted with methanol. The remaining methylene chloride was boiled off and, after cooling, 6.8 g (16 mmol, 55%) of **8** were collected: mp 229.5–232 °C; IR 1775 cm$^{-1}$, 1650, 1597; UV 231.5 nm ($\epsilon$ 34 500), 246 (min, 22 000), 263 (28 000), 288 (min, 5500), 333 (24 500), 345 (23 750), 364 (sh, 13 750); NMR $\delta$ 7.82 (s, 1 H), 7.55 (s, 1 H), 6.77 (s, 1 H), 6.74 (s, 1 H), 4.01 (s, 3 H), 3.98 (s, 3 H), 3.92 (s, 6 H), 2.7–3.7 (m, 3 H). The remaining C6 hydrogen appears between $\delta$ 4.2 and 5.0 by integration:[14] MS, $m/e$ (relative intensity) 425 (parent, 25), 383 ($C_2H_2O$, 90), 382 ($C_2H_3O$, 64), 44 (100).

Anal. Calcd for $C_{23}H_{23}NO_7$: C, 64.93; H, 5.45; N, 3.29. Found: C, 64.76; H, 5.42; N, 3.25.

**Lead Tetraacetate Oxidation of 13-Acetoxy-2,3,10,11-tetramethoxyoxyprotoberbine (8). Method A.** To a stirred solution of 1.00 g (2.35 mmol) of **8** in 100 mL of chloroform was added 2.0 g of lead tetraacetate. The solution turned a dark red. After 18 h, it was quenched with glycerine and then washed 3 times with water and dried with sodium sulfate and the solvent evaporated. The residue was flash chromatographed by using 5:95 ethyl acetate:methylene chloride.[15] The first product eluted was 8,13-dioxo-13a-ethoxy-2,3,10,11-tetramethoxyberbine (**15**): 400 mg, 0.94 mmol (40%); mp 130–132 °C dec; IR 1710 sh cm$^{-1}$, 1655, 1590; UV 254 nm ($\epsilon$ 45 300), 311 (7200), 329 (7200); NMR $\delta$ 7.68 (s, 1 H), 7.47 (s, 1 H), 7.30 (s, 1 H), 6.58 (s, 1 H), 4.88 (m, 1 H), 4.03 (s, 3 H), 4.00 (s, 3 H), 3.89 (s, 3 H), 3.83 (s, 3 H), 3.43 (q, 2 H), 2.0–4.0 (m, 3 H), 1.19 (t, 3 H).

Anal. Calcd for $C_{23}H_{25}NO_7$: C, 64.63; H, 5.89; N, 3.28. Found: C, 64.59; H, 5.86; N, 3.23.

(8) Boar, R. B.; McGhie, T. F.; Robinson, M.; Barton, D. H. R. *J. Chem. Soc., Perkin Trans. 1* **1975**, 1237, 1242.

(9) The oxidation of oxyprotoberberines **7** and **11** with pyridinium chlorochromate leads directly to 8,13-dioxo-13a-hydroxyberbines **9** and **13** in reasonable yields (Manikumar, G.; Shamma, M. *Heterocycles* **1980**, *14*, 827).

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The second compound eluted was 8,13-dioxo-13a-hydroxy-2,3,10,11-tetramethoxyberbine (**9**): 430 mg, 1.08 mmol (46%); mp 150 °C dec (lit.[9] mp 160–161 °C); UV 251 nm ($\epsilon$ 25000); NMR $\delta$ 7.63 (s, 1 H), 7.42 (s, 1 H), 7.04 (s, 1 H), 6.58 (s, 1 H), 4.84 (m, 1 H, C-6), 4.02 (s, 3 H), 3.99 (s, 3 H), 3.86 (s, 3 H), 3.84 (s, 3 H), 2.4–3.7 (m, 3 H); MS, *m/e* 399 (relative intensity) (parent, 10.4), 383 (–16, 20), 368 (–31, 12).

Anal. Calcd for $C_{21}H_{21}NO_7$: C, 63.15; H, 5.30; N, 3.51. Found: C, 62.91; H, 5.25; N, 3.42.

**Method B.** Compound **8** (770 mg, 1.81 mmol) and 3.0 g of lead tetraacetate were stirred in 100 mL of chloroform at room temperature for 18 h. After being quenched with glycerine, the solution was washed 3 times with water and dried with sodium sulfate. The solution was diluted with 30 mL of absolute ethanol, and a few crystals of *p*-toluenesulfonic acid monohydrate were added. After 18 h, TLC (1:1 ethyl acetate:toluene) indicated complete conversion to the ethyl ether **15**. After being quenched with 1 mL of triethylamine, the solution, after addition of 50 mL of chloroform, was washed 3 times with water, dried with sodium sulfate, and evaporated. The residue was crystallized from ether:petroleum ether to yield 690 mg (1.62 mmol, 90%) of **15**.

**Lead Tetraacetate Oxidation of 13-Acetoxy-2,3-(methylenedioxy)-9,10-dimethoxyoxyprotoberberine (12).** Compound **12** (800 mg, 1.95 mmol) was oxidized according to method B above. Methanol was used, however, in place of ethanol. The residue, after workup, was flash chromatographed by using 5:95 ethyl acetate:methylene chloride to yield 709 mg (1.79 mmol, 92%) of 8,13-dioxo-2,3-(methylenedioxy)-9,10,13a-trimethoxyberbine (**13**): mp 129–130.5 °C dec (lit.[9] mp 125–126 °C).

**13$\beta$-Hydroxy-2,3,10,11-tetramethoxyberbine (13$\beta$-Hydroxyxylopinine) (10).** To a solution of 1.4 g of lithium aluminum hydride in 100 mL of tetrahydrofuran under argon was added 1.40 g (3.29 mmol) of acetoxylated oxyprotoberberine **8**. After stirring for 23 h at room temperature, excess hydride was quenched with a saturated solution of Rochelle salt. After separation of the layers, the Rochelle salt solution was further extracted with methylene chloride. The combined extracts were dried with sodium sulfate and the methylene chloride and a portion of the THF evaporated under reduced pressure. The remaining solution was diluted with 200 mL of methanol, 3 g of sodium borohydride were added, and the resultant mixture was stirred overnight. The majority of the solvent was removed, then diluted with water, and extracted with chloroform. After being dried with sodium sulfate, the solvent was evaporated and the residue flash chromatographed by using 4:96 methanol:methylene chloride to yield 730 mg (1.97 mmol, 60%) of 13$\beta$-hydroxyxylopinine (**10**): mp 202–205 °C (acetone–water) (lit.[16] 197–198 °C); IR 3460 cm$^{-1}$, 1517; NMR $\delta$ 6.92 (s, 1 H), 6.75 (s, 1 H), 6.58 (s, 1 H), 6.55 (s, 1 H), 4.75 (br s ($w_{1/2}$ = 3 Hz), 1 H, 13$\alpha$-H), 3.88 (s, 6 H), 3.86 (s, 6 H), 2.4–3.8 (m, 7 H).[2c,17]

Anal. Calcd for $C_{21}H_{25}NO_5$: C, 67.91; H, 6.78; N, 3.77. Found: C, 67.48; H, 6.78; N, 3.96.

**(±)-Ophiocarpine (1).** The 13-acetoxylated oxyprotoberberine **12** (521 mg, 1.27 mmol) was reduced sequentially as illustrated for compound **8** to yield 223 mg (0.63 mmol 52%) of ophiocarpine (**1**), mp 249–251 °C (methanol) (lit.[3,4b] mp 254–256 °C), and whose NMR spectrum agreed with published spectra (C-13$\alpha$ $\delta$ 4.71 (br s, $w_{1/2}$ = 3 Hz)).[3c,4b]

**(±)-Chilenine (14).** A deep red-violet solution of compound **13a** (119 mg) in 18 mL of concentrated hydrochloric acid was poured into 1.2 L of water and extracted with three portions of chloroform. The combined extracts were dried with magnesium sulfate, filtered, and concentrated to yield 103 mg (88%) of a chromatographically homogeneous, but dark red, 13a-hydroxy derivative of **13b**: NMR $\delta$ 7.81, 7.14 (AB q, $J$ = 9 Hz, 2 H), 6.90 (s, 1 H, C1), 6.58 (s, 1 H, C4), 5.91 (s, 2 H), 4.71–5.01 (m, 1 H), 3.95 (s, 3 H), 3.94 (s, 3 H), 2.46–3.13 (m, 3 H).

A solution of 98 mg of **13b** in 64 mL of chloroform was vigorously shaken with 64 mL of 10% aqueous ammonia for 0.5 h. The organic layer was separated, dried with magnesium sulfate, filtered, and evaporated. Radial preparative thick layer chromatography (Chromatotron) on silica (1:4 ethyl acetate:methylene chloride) afforded 65 mg (66%) of chilenine (**14**) as a foam. Two recrystallizations from methanol gave an analytical sample: mp 114.5–116 °C (lit.[18] 155 °C); IR (chloroform) 1710, 1685, 1610 cm$^{-1}$; NMR $\delta$ 7.03, 7.30 (AB q, $J$ = 8 Hz, 2 H), 6.68 (s, 1 H), 6.63 (s, 1 H), 5.91 (s, 2 H), 4.05 (br s, 1 H), 3.98 (s, 3 H), 3.85 (s, 3 H), 2.78–4.38 (br m, 4 H); MS, *m/e* (relative intensity) 383 (parent, 11), 367 (39), 352 (13), 338 (44), 308 (16), 220 (45), 176 (79), 148 (100).

Anal. Calcd for $C_{20}H_{17}NO_7$: C, 62.66; H, 4.47; N, 3.65. Found: C, 62.40; H, 4.28; N, 3.61.

**Registry No.** (±)-**1**, 18090-55-6; **5**, 32255-47-3; **6**, 90553-68-7; **7**, 10211-78-6; **8**, 90553-69-8; (±)-**9**, 75091-35-9; (±)-**10**, 59373-39-6; **11**, 549-21-3; **12**, 66054-87-3; (±)-**13a**, 71733-96-5; (±)-**13b**, 71766-69-3; (±)-**14**, 71700-15-7; (±)-**15**, 90553-70-1; **16**, 90553-67-6; lead tetraacetate, 546-67-8.

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## Oxidation of $\beta$-Diketones with (Diacetoxyiodo)benzene

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In an earlier paper[1] we reported that the ethyl esters of aroylpyruvic acids undergo an oxidative cleavage reaction with (diacetoxyiodo)benzene (PIDA) in acetic acid–water. These investigations were continued in order to determine the pathway of the oxidative cleavage of the $\beta$-dicarbonyl compounds. We now report on the oxidation of some $\beta$-diketones with PIDA. This reaction has been investigated by Neiland[2] and Mizukami[3] who employed anhydrous conditions. The end products were the corresponding $\alpha$-acetoxy derivatives.

In this paper we describe the oxidations of dibenzoylmethane, benzoylacetone, 4,4,4-trifluoro-1-phenyl-1,3-butanedione, 1,3-indandione, 2-phenyl-1,3-indandione, methyldibenzoylmethane, and, as a support for the suggested pathway of oxidative cleavage, the oxidations of acetoxydibenzoylmethane, acetoxy-4,4,4-trifluoro-1-phenyl-1,3-butanedione, 2-acetoxy-2-phenyl-1,3-indandione, dibenzoylmethanol, 1,3-diphenylpropanetrione, dibenzoyl, phenylglyoxaldehyde, phenylglyoxalic acid, and ninhydrin.

### Results and Discussion

The oxidations were conducted for various molar ratios of substrate–PIDA in acetic acid containing water. The reactions proceed at room temperature and, in some cases, are even exothermic. However, in order to increase the rate of reaction, the temperature was maintained at 80–100 °C. Under these conditions, the oxidations of $\beta$-diketones with an unsubstituted methylene group at substrate–PIDA molar ratios of 1:1, 1:2, and 1:3, proceeded with $CO_2$ evolution and gave the corresponding $\alpha$-acetoxy derivatives and carboxylic acids. When the amount of PIDA was increased, the yields of the $\alpha$-acetoxy derivatives decreased and the yields of the carboxylic acids increased. At a molar

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