Diels–Alder Reaction of Pyrrole with Dimethyl Acetylenedicarboxylate

Chang Kiu Lee* and Chi Sun Hahn

Department of Chemistry, Yonsei University, Seoul, Korea

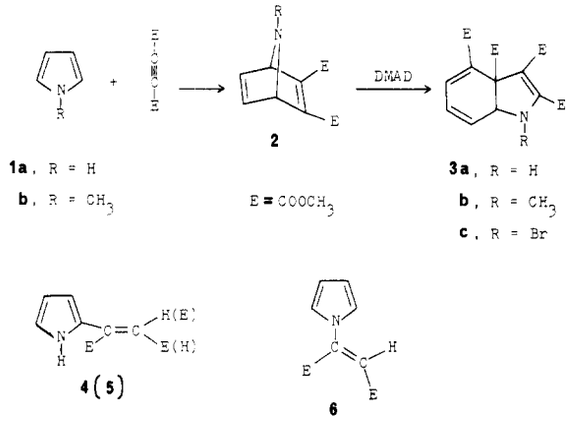
Wayland E. Noland

Department of Chemistry, University of Minnesota, Minneapolis, Minnesota 55455

Received November 15, 1977

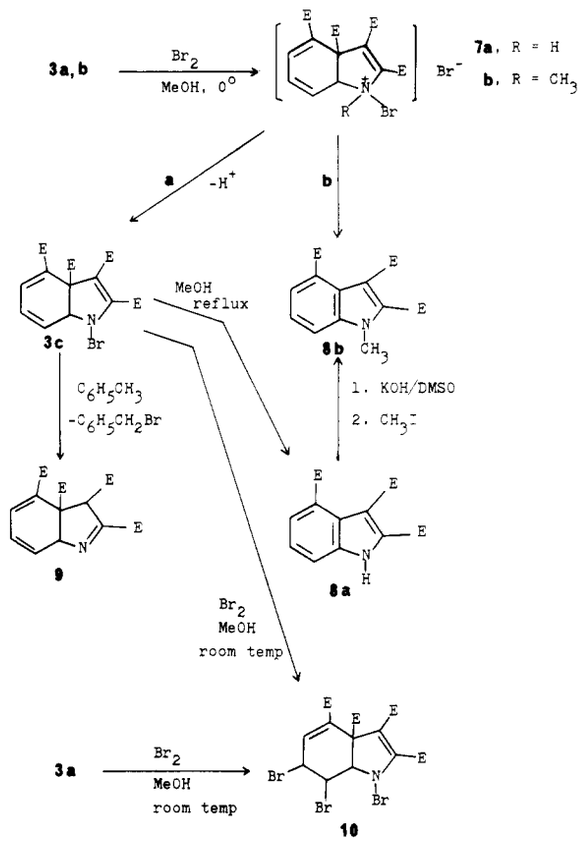
Pyrrole and dimethyl acetylenedicarboxylate gave the 1:2 adduct tetramethyl 3a,7a-dihydroindole-2,3,3a,4-tetracarboxylate, which has a structure similar to the known 1:2 adduct obtained from 1-methylpyrrole. The significant differences in the chemistry between the two adducts are described.

The reaction of pyrroles with common dienophiles seems to follow two different pathways, that is, [4 + 2] cycloaddition or a Michael-type addition at the α position of pyrroles.[1] Pyrroles which have aryl or electron-withdrawing substituents on the nitrogen gave 1:1 adducts of type **2** with dimethyl acetylenedicarboxylate (DMAD). With an *N*-alkyl group, the 1:1 adduct of type **2** reacted further with DMAD to give a 1:2



adduct of type **3**.[2] On the other hand, pyrrole (**1a**) itself was reported to give a Michael-type 1:1 adduct **5**, though the structure was not throughly established.[3] The purpose of this paper is to report that pyrrole (**1a**) also gave the 1:2 adduct **3a** when refluxed with DMAD in ether for 4 days and that the chemistry of the compound **3a** was found to be quite different from that of the *N*-methyl analogue **3b**.

Scheme I



Results and Discussion

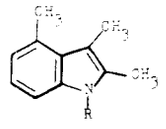
Although the adduct **3a** began to form after 2 days, the yield increased to 6% in 4 days and could be improved to 10% by removing the product and refluxing for a longer period of time (7 days). The yield of **3b** was more than 80% under identical conditions. Compound **3b** formed in 70% yield after 2 days at room temperature without solvent, but **3a** could not be obtained by stirring a solution of **1a** and DMAD at room temperature for 4 days. Instead, Michael-type adducts **4** and **5** together with adduct **6**, in which the Michael-type addition took place on the nitrogen, were isolated under these conditions.

The adducts **3a** and **3b** behaved quite differently. Compound **3b** gave the oxidized product **8b** (see Scheme I) upon treatment with bromine in methanol,[2] but the 1-bromo derivative **3c** resulted when bromine was added to a suspension of **3a** in methanol at 0 °C. When the reaction of **3a** with bromine was done at room temperature, the tribromo compound **10** was formed. The same compound could also be obtained from **3c** under identical conditions. The initial reaction of bromine with **3** seems to involve the formation of an N–Br bond (cf. compound **7**). Loss of HBr from **7b** and subsequent loss of a 3a-methoxycarbonyl group would give the fully aromatized indole derivative **8b**. In order to form **3c** from **7b**, a methyl carbonium ion would have to be eliminated, but this is very unlikely. On the other hand, the proton on the nitrogen in **7a** could be lost readily to give **3c**, and in fact, this process took place. Compound **3c** could be isolated almost quantitatively and recrystallized from methanol, but it gave trimethyl indole-2,3,4-tricarboxylate (**8a**) upon refluxing for 24 h in methanol. When **3c** was refluxed in toluene for 24 h, an imine derivative **9** was obtained in 47% yield. Since benzyl bromide was isolated from the reaction, we believe that the formation of **9** involves a radical process similar to the reaction of *N*-bromosuccinimide.[4] The imine was quite stable and did not tautomerize to the enamine form **3a** when refluxed in an AcOH–MeOH solution or in an AcOH–xylene solution.

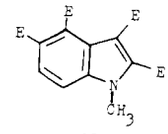
In addition to similarities in spectra, the conversion of **8a** to **8b** (KOH/Me_2SO and CH_3I) provides the definite evidence that pyrrole, like 1-substituted pyrroles, undergoes initial Diels–Alder addition. However, the report that pyrrole (**1a**) gave a Michael-type 1:1 adduct with DMAD[3] and our result that a similar type of 1:2 adduct **3a** formed from the reaction

0022-3263/78/1943-3727$01.00/0

raised a suspicion of the structures of them. Although the NMR spectra and chemical degradation products are well consistent with Acheson's structure **3b**, it seemed to need an unambiguous proof. Thus, **8b** was reduced to 1,2,3,4-tetramethylindole (**11b**), which in turn was prepared by the methylation of 2,3,4-trimethylindole (**11a**).[5]



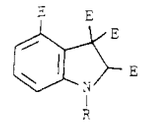
11a, R = H
b, R = CH_3



12

Compound **3a** could be converted to **8a** by sodium methoxide in methanol at room temperature. Quite to the contrary, **3b** did not react under identical conditions, but it gave **12** when the solution was refluxed for 24 h. It is interesting that both aromatization and rearrangement of a 3a-ester group to the 5 position took place. The mechanisms of both reactions are currently under investigation in our laboratory.

Compound **3b** was reported to isomerize to the indoline derivative **13b** in 4% yield upon heating at 180 °C for 6 h in the



13a, R = H
b, R = CH_3

presence of 5% palladium–charcoal.[6] The isomerization could be carried out as efficiently as 74% by refluxing **3b** in xylene for 24 h. On the other hand, **3a** did not give a similar reaction under these conditions. However, when **3a** was refluxed in pyridine for 20 min, the rearrangement took place and **13a** was isolated in 24%.

Experimental Section

Melting points were determined on a Thomas-Hoover capillary melting point apparatus and are uncorrected. IR spectra were recorded on a Beckman IR-18A or a Perkin-Elmer Model 257 spectrophotometer. UV and visible spectra were recorded on a Cary Model 11 or a Shimadzu double-beam spectrophotometer. NMR spectra were recorded on a Varian T-60 spectrometer in $CDCl_3$ containing Me_4Si as an internal reference. Mass spectra were obtained using an Associated Electrical Industries, Scientific Apparatus, Inc., AEI MS-30 double-beam, double focusing mass spectrometer with an AEI DS-30 data system at 70 eV and 200 °C. Elemental analyses were performed by M-H-W Laboratories, Garden City, Mich. Thin-layer chromatography was conducted on 20 × 20 cm × 1 mm silica gel PF-254 TLC plates. Compounds were isolated from the silica gel by extraction in a Soxhlet apparatus with chloroform.

Starting Materials. Commercial pyrroles (**1a** and **1b**) and DMAD were distilled before use. Compounds **3b, 8b, 11a,** and **12** were prepared by following literature methods.[2,5,6]

Tetramethyl 3a,7a-Dihydroindole-2,3,3a,4-tetracarboxylate (3a). A solution of pyrrole (3.35 g, 50.0 mmol) and DMAD (14.21 g, 100.0 mmol) in ether (60 mL) was refluxed for 96 h, during which time some white precipitate formed. The precipitate was collected, washed with ether, and then recrystallized from methanol, giving **3a** as colorless prisms (1.16 g, 6%): mp 162–165 °C; IR (KBr) 1745, 1715, and 1693 (C=O), 1602 (C=C), 1337, 1225, and 1130 (C–O) cm^{-1}; NMR ($CDCl_3$) δ 3.66 (s, 3 H), 3.77 (s, 3 H), 3.80 (s, 3 H), and 3.85 (s, 3 H, all $COOCH_3$), 4.73 (d, 1 H, N–H, $J_{1,7a}$ = 1.2 Hz), 5.18 (dd, 1 H, 7a-H, $J_{7a,7}$ = 5.4 Hz, $J_{7a,1}$ = 1.2 Hz), 6.24 (dd, 1 H, 6-H, $J_{6,5}$ = 6.0 Hz, $J_{6,7}$ = 9.5 Hz), 6.51 (dd, 1 H, 7-H, $J_{7,6}$ = 9.5 Hz, $J_{7,7a}$ = 5.4 Hz), 7.20 (d, 1 H, 5-H, $J_{5,6}$ = 6.0 Hz); UV (MeOH) nm (log *A*) 272 (4.10), 300 infl (3.76); MS *m/e* (%) 351 (1.5, M^+), 260 (100), 228 (44), 216 (21).

Anal. Calcd for $C_{16}H_{17}NO_8$: C, 54.70; H, 4.88; N, 3.99. Found: C, 54.86; H, 4.91; N, 3.99.

Tetramethyl 1-Bromo-3a,7a-dihydroindole-2,3,3a,4-tetracarboxylate (3c). Bromine (0.83 g, 5.20 mmol) was added to a suspension of **3a** (1.83 g, 5.20 mmol) in methanol (35 mL) at 0 °C. The mixture became a clear solution, and a white precipitate formed within 1 min. The mixture was stirred at 0 °C for 48 h. The solid was collected, washed with cold methanol, and then recrystallized from methanol, giving **3c** as colorless prisms (1.68 g, 75%): mp 106–107 °C; IR (KBr) 1740 and 1718 (C=O), 1275, 1195, and 1134 (C–O) cm^{-1}; NMR ($CDCl_3$) δ 3.72 (s, 3 H), 3.80 (s, 3 H), 3.83 (s, 3 H), and 3.95 (s, 3 H, all $COOCH_3$), 5.60 (m, 1 H, 7a-H), 6.15 (m, 2 H, 6- and 7-H), 7.22 (m, 1 H, 5-H); UV (MeOH) nm (log *A*) 287 (3.75); MS *m/e* (%) 349 (16), 318 (24), 260 (90), 228 (60), 44 (100).

Anal. Calcd for $C_{16}H_{16}BrNO_8$: C, 44.67; H, 3.75; Br, 18.57; N, 3.25. Found: C, 44.62; H, 4.00; Br, 18.31; N, 3.12.

Dimethyl (*Z*)- and (*E*)-Pyrrol-2-ylbutenedioate (4 and 5) and Dimethyl (*E*)-Pyrrol-1-ylbutenedioate (6). A solution of pyrrole (0.67 g, 10.0 mmol) and DMAD (1.42 g, 10.0 mmol) was stirred under nitrogen for 90 h. The brown solution was chromatographed on a column (2.5 × 60 cm) of silica gel, eluting with the following: (1) petroleum ether (bp 60–70 °C), 0.5 L; (2) petroleum ether, 1.00 L; (3) petroleum ether–benzene (2:1), 1.00 L; (4) petroleum ether–benzene (1:1) 0.40 L; (5) petroleum ether–benzene (1:2), 0.75 L; (6) benzene, 0.50 L; (7) benzene–chloroform (2:1), 0.50 L; (8) benzene–chloroform (1:1), 1.25 L; and (9) chloroform, 0.75 L. Fraction 1 gave no organic material. Fraction 2 gave **4** as a yellow oil (0.87 g, 42%): IR (neat) 3260 (N–H), 1735 and 1690 (C=O), 1582 (C=C), 1291, 1234, 1212, 1100, and 1042 (C–O), 755 cm^{-1}; NMR ($CDCl_3$) δ 3.73 (s, 3 H) and 3.83 (s, 3 H, both $COOCH_3$), 5.92 (s, 1 H, vinyl H), 6.27 (m, 1 H, 4-H), 6.72 (m, 1 H, 3-H), 6.98 (m, 1 H, 5-H), 12.61 (broad s, 1 H, N–H); UV (MeOH) nm (log *A*) 346 (4.17); MS *m/e* (%) 210 (11, $M^+ + 1$), 209 (100, M^+), 178 (18, $M^+ - CH_3O$), 177 (44, $M^+ - CH_3OH$), 151 (12), 150 (47, $M^+ - CH_3OCO$), 119 (10), 118 (57), 91 (65).

Anal. Calcd for $C_{10}H_{11}NO_4$: C, 57.41; H, 5.30; N, 6.69. Found: C, 57.40; H, 5.28; N, 6.49.

Fraction 3 gave **6** as a yellow oil (0.12 g, 6%): IR (neat) 1747 and 1715 (C=O), 1630 (C=C), 1238, 1197, 1169, 1116, and 1055 (C–O) cm^{-1}; NMR ($CDCl_3$) δ 3.73 (s, 3 H) and 3.97 (s, 3 H, both $COOCH_3$), 5.88 (s, 1 H, vinyl H), 6.28 (dd, 2 H, 3- and 4-H, J = 2.5 Hz), 6.83 (dd, 2 H, 2- and 5-H, J = 2.5 Hz); UV (MeOH) nm (log *A*) 283 (4.17), 328 infl (3.17); MS *m/e* (%) 210 (11, $M^+ + 1$), 209 (100, M^+), 178 (19, $M^+ - CH_3O$), 151 (17), 150 (30, $M^+ - CH_3OCO$), 149 (13), 94 (12).

Anal. Calcd for $C_{10}H_{11}NO_4$: C, 57.41; H, 5.30; N, 6.69. Found: C, 57.24; H, 5.48; N, 6.47.

Fractions 4–6 gave a trace amount of a mixture of **5** and **6.** Fractions 7–9 gave **5** as a deep yellow oil (0.53 g, 25%): IR (neat) 3350 (N–H), 1740 and 1712 (C=O), 1602 (C=C), 1234, 1200, an 1170 (C–O), 732 cm^{-1}; NMR ($CDCl_3$) δ 3.68 (s, 3 H) and 3.90 (s, 3 H, both $COOCH_3$), 5.97 (s, 1 H, vinyl H), 6.17 (m, 1 H, 4-H), 6.42 (m, 1 H, 3-H), 6.82 (m, 1 H, 5-H), 9.03 (broad s, 1 H, N–H); UV (MeOH) nm (log *A*) 335 (4.06); MS *m/e* (%) 210 (12, $M^+ + 1$), 209 (100, M^+), 178 (24, $M^+ - CH_3O$), 177 (45, $M^+ - CH_3OH$), 151 (12), 150 ($M^+ - CH_3OCO$), 119 (12), 118 (55), 91 (68).

Anal. Calcd for $C_{10}H_{11}NO_4$: C, 57.41; H, 5.30; N, 6.69. Found: C, 57.41; H, 5.24; N, 6.49.

Trimethyl Indole-2,3,4-tricarboxylate (8a). A. From 3a. A solution of sodium methoxide (0.16 g, 3.00 mmol) in methanol (15 mL) was added to a solution of **3a** (1.03 g, 2.90 mmol) in methanol (40 mL). As soon as a drop of sodium methoxide solution was added, the solution of the ester developed a deep blue color which persisted during the addition (10 min), and then the solution turned dark brown. The solution was stirred at room temperature for 1.5 h, and the methanol was distilled off under aspirator pressure without applying heat, leaving a black gummy material. This was dissolved in chloroform (60 mL), and the solution was washed with an acetic acid–water (1:40 v/v) solution (20 mL) and then with a saturated sodium chloride solution (20 mL). The chloroform solution was dried over sodium sulfate and evaporated to dryness, leaving a brown oil. The oil was chromatographed on a preparative silica gel TLC plate, eluting with benzene to give two bands: (1) R_f 0.12–0.23; (2) R_f 0.06–0.12. Each band was extracted with chloroform using a Soxhlet extractor. Fraction 1 gave a trace of yellow oil which could not be characterized. Fraction 2 gave **8a** as colorless prisms (0.32 g, 38%), mp 160–162 °C, having IR (KBr) and NMR ($CDCl_3$) spectra identical with those of the compound obtained below.

B. From 3c. A solution of **3c** (0.20 g, 0.48 mmol) in methanol (10 mL) was refluxed for 24 h. The solution was evaporated to dryness to give a pale yellow gummy material which was triturated with petroleum ether and then recrystallized from methanol, giving colorless prisms (0.08 g, 61%): mp 162.5–164 °C; IR (KBr) 3310 (N–H), 1733, 1720, and 1682 (C=O), 1286, 1250, 1203, 1195, 1173, and 1145 (C–O), 746 cm^{-1}; NMR ($CDCl_3$) δ 3.93 (s, 6 H) and 4.02 (s, 3 H, both $COOCH_3$), 7.33 (dd, 1 H, 6-H, $J_{6,7}$ = 8.5 Hz, $J_{6,5}$ = 7.0 Hz), 7.63 (dd, 1 H, 7-H, $J_{7,5}$ = 1.5 Hz, $J_{7,6}$ = 8.5 Hz), 7.87 (dd, 1 H, 5-H, $J_{5,7}$ = 1.5

Hz, $J_{5,6}$ = 7.0 Hz), 9.53 (broad s, 1 H, N–H); UV (MeOH) nm (log A) 224 (4.42), 245 infl (3.86), 252 infl (3.76), 314 (4.25); MS m/e (%) 291 (42, M^+), 260 (49, $M^+ - CH_3O$), 259 (34, $M^+ - CH_3OH$), 229 (11), 228 (64), 201 (31).

Anal. Calcd for $C_{14}H_{13}NO_6$: C, 57.73; H, 4.50; N, 4.81. Found: C, 57.64; H, 4.58; N, 4.81.

Trimethyl 1-Methylindole-2,3,4-tricarboxylate (8b). A mixture of freshly crushed potassium hydroxide (0.10 g, 1.75 mmol) and Me_2SO (10 mL) was stirred for 10 min. Compound **8a** (0.15 g, 0.52 mmol) was added, and the mixture was stirred for 1 h. Methyl iodide (0.80 g, 5.63 mmol) was added and the stirring continued for an additional 2 h, giving a yellow solution. Water (20 mL) was added, and the solution was extracted with chloroform (2 × 20 mL). The chloroform extract was dried over sodium sulfate. The dried extract was evaporated to about 5 mL, and the solution was kept in a refrigerator overnight, during which time some white solid formed. The solid was collected and recrystallized from methanol to give **8b** as white prisms (0.13 g, 80%), mp and mmp 122–123 °C (lit.[2] 124 °C), having IR (KBr) and NMR ($CDCl_3$) spectra identical with those of an authentic sample.

Tetramethyl 3a,7a-Dihydro-3*H*-indole-2,3,3a,4-tetracarboxylate (9). A mixture of **3c** (0.51 g, 1.18 mmol) and toluene (10 mL) was refluxed for 24 h. The resulting solution was reduced to dryness in vacuo at room temperature. The residual yellow gummy oil was suspended in ether (5 mL) for 10 min. The ethereal layer was decanted, and the undissolved gummy material was dissolved in hot methanol (2 mL). Upon cooling, crystals formed which were recrystallized from methanol to give **9** as colorless crystals (0.20 g, 47%): mp 129–129.5 °C; IR (KBr) 1735, 1724, and 1708 (C=O), 1287, 1233, 1198, and 1118 (C–O) cm^{-1}; NMR ($CDCl_3$) δ 3.57 (s, 3 H), 3.73 (s, 3 H), 3.78 (s, 3 H), and 3.92 (s, 3 H, all $COOCH_3$), 5.03 (s, 1 H, 3-H), 5.50 (m, 1 H, 7a-H), 6.12 (m, 2 H, 6- and 7-H), 7.13 (m, 1 H, 5-H); UV (MeOH) nm (log A) 293 (3.77), 333 diffuse infl (3.13); MS m/e (%) 351 (0.1, M^+), 320 (5), 261 (14), 260 (100), 228 (65).

Anal. Calcd for $C_{16}H_{17}NO_8$: C, 54.70; H, 4.88; N, 3.99. Found: C, 54.54; H, 5.08; N, 3.87.

The ethereal layer was evaporated to dryness, leaving a yellow viscous oil. The IR (neat) and NMR ($CDCl_3$) spectra of the oil showed it to be a mixture of benzyl bromide and the ester **9**. The oil was chromatographed by preparative TLC in benzene, and the resulting bands were extracted with chloroform: (1) R_f 0.38; (2) R_f 0.09. Fraction 1 was benzyl bromide (0.01 g, 20%), having IR (neat)[8] and NMR ($CDCl_3$)[9] spectra identical with those reported in the literature. Fraction 2 was the ester **9** (total 0.29 g, 70%).

Tetramethyl 1,6,7-Tribromo-3a,6,7,7a-tetrahydroindole-2,3,3a,4-tetracarboxylate (10). A. From 3a. Bromine (0.50 g, 3.10 mmol) was added to a suspension of **3a** (0.50 g, 1.40 mmol) in methanol (20 mL) at room temperature. The mixture became a clear solution, and a white precipitate formed within 1 min. The mixture was stirred for 3 h, and then the solid was collected, washed with methanol, and recrystallized from methanol to give **10** as white leaflets (0.71 g, 86%): mp 172–175 °C; IR (KBr) 1739 and 1725 (C=O), 1320, 1244, 1197, and 1134 (C–O) cm^{-1}; NMR ($CDCl_3$) δ 3.73 (s, 3 H), 3.80 (s, 3 H), 3.88 (s, 3 H), and 3.93 (s, 3 H, all $COOCH_3$), 4.38 (dd, 1 H, 7-H, $J_{7,6}$ = 3.5 Hz, $J_{7,7a}$ = 12 Hz), 4.90 (dd, 1 H, 6-H, $J_{6,7}$ = 3.5 Hz, $J_{6,5}$ = 7 Hz), 5.47 (d, 1 H, 7a-H, $J_{7a,7}$ = 12 Hz), 7.20 (d, 1 H, 5-H, $J_{5,6}$ = 7 Hz); UV (MeOH) nm (log A) 220 (4.04; rising end absorption); MS m/e (%) 512 (1.2), 510 (2.0), and 508 (1.0, all M^+ – Br), 480 (1.7), 478 (2.8), and 476 [1.4, all $M^+ - (HBr, CH_3O)$], 429 (1.3) and 427 (1.1, $M^+ - 2HBr$), 350 (11), 340 (11), 338 (11), 260 (100), 228 (57).

Anal. Calcd for $C_{16}H_{16}Br_3NO_8$: C, 32.57; H, 2.73; Br, 40.63; N, 2.37. Found: C, 32.45; H, 2.87; Br, 40.34; N, 2.21.

B. From 3c. Bromine (2 drops) was added to a suspension of **3c** (90 mg, 0.21 mmol) in methanol (2 mL) at room temperature. The mixture became a clear solution, but a precipitate did not form immediately. The solution was stirred at room temperature for 12 h. A white precipitate formed upon scratching the flask, and this was recrystallized from methanol to give **10** as white leaflets (56 mg, 45%), mp and mmp 173–175 °C, having an IR spectrum (KBr) identical with that of the sample prepared by the bromination of **3a**.

1,2,3,4-Tetramethylindole (11b). A mixture of lithium aluminum hydride (6.03 g, 160 mmol) and anhydrous ether (200 mL) was refluxed for 2 h under nitrogen and cooled to room temperature. A solution of **8b** (4.77 g, 15.6 mmol) in tetrahydrofuran (100 mL) was added slowly to the mixture so that the mixture boiled gently for 2 h. The mixture was refluxed for 5 days and cooled to 0 °C in an ice bath. A precooled solution of aluminum chloride (12.5 g, 93.7 mmol) in anhydrous ether (100 mL) was added slowly over 1 h. Then the mixture was refluxed for 2 days. After cooling in an ice bath, water (5 mL) and a 15% sodium hydroxide solution (15 mL) were added carefully. The mixture was filtered through a sintered glass funnel, and the solid was washed with ether (100 mL). The filtrate and ethereal wash were combined and dried over sodium sulfate overnight. The dried solution was evaporated, and the resulting brown oil was chromatographed on preparative TLC plates eluting with benzene. The band at R_f 0.76 was extracted with chloroform using a Soxhlet extractor. The extract gave a white powder which was recrystallized from methanol–water (7:3 v/v) to give white prisms (0.24 g, 11%): mp 77–79 °C; IR (KBr) 2920 (CH_3), 1618 and 1580 (C=C), 1470 (CH_3), 750 (=CH) cm^{-1}; NMR ($CDCl_3$) δ 2.20 (s, 3 H, 3-CH_3), 2.40 (s, 3 H, 2-CH_3), 2.67 (s, 3 H, 4-CH_3), 3.43 (s, 3 H, N–CH_3), 6.67–7.03 (m, 3 H, 5-, 6-, and 7-H); UV (MeOH) nm (log A) 232 (4.51), 282 infl (3.79), 289 (3.82), 297 infl (3.77); MS m/e (%) 174 (12, $M^+ + 1$), 173 (94, M^+), 172 (100, $M^+ - H$), 158 (55, $M^+ - CH_3$), 157 (10), 115 (14), 86 (15).

Anal. Calcd for $C_{12}H_{15}N$: C, 83.19; H, 8.73; N, 8.08. Found: C, 83.09; H, 8.70; N, 8.13.

Compound **11b** could be obtained from **11a**[5] in 70% yield by following the similar procedure for methylation of **8a**.

Tetramethyl 1-Methylindole-2,3,4,5-tetracarboxylate (12). A solution of **3b** (1.04 g, 2.68 mmol) and sodium methoxide (0.17 g, 3.00 mmol) in methanol (55 mL) was refluxed for 24 h. The methanol was evaporated to reduce the volume of the solution to about 20 mL, and the solution was kept in a refrigerator overnight, causing a white precipitate to form. The precipitate was collected and crystallized from methanol, giving **12** as white needles (0.15 g, 14%), mp 197–198 °C (lit.[6] mp 200 °C). The structure was determined by comparison of the NMR ($CDCl_3$) and UV (MeOH) spectra with the corresponding spectra in the literature.[7]

Tetramethyl Indoline-2,3,3,4-tetracarboxylate (13a). A solution of **3a** (0.36 g, 1.00 mmol) in pyridine (25 mL) was refluxed for 20 min. The pyridine was distilled off under aspirator pressure, and the residual brown oil was dissolved in methanol, decolorized with charcoal, and kept in a refrigerator overnight, giving pale yellow prisms. The prisms were collected and recrystallized from methanol to give **13a** as pale yellow prisms (87 mg, 24%): mp 120 °C; IR (KBr) 3420 (N–H), 1722 and 1680 (C=O), 1301, 1277, 1262, 1195, and 1016 (C–O) cm^{-1}; NMR ($CDCl_3$) δ 3.62 (s, 3 H), 3.70 (s, 3 H), 3.83 (s, 3 H), and 3.88 (s, 3 H, all $COOCH_3$), 5:52 (s, 1 H, 2-H), 6.70–7.50 (m, 3 H, 5-, 6-, and 7-H), 10.00 (broad s, 1 H, N–H); UV (MeOH) nm (log A) 220 (4.23), 321 (4.20); MS m/e (%) 351 (21, M^+), 319 (23), 292 (27, $M^+ - CH_3OCO$), 260 (74), 228 (100).

Anal. Calcd for $C_{16}H_{17}NO_8$: C, 54.70; H, 4.88; N, 3.99. Found: C, 54.57; H, 4.76; N, 3.80.

Acknowledgment. C.K.L. wishes to thank the University of Minnesota for a Teaching Assistantship in 1972–1976. We wish to thank Mr. Thomas Robison for helpful suggestions in preparing the manuscript.

Registry No.—**1a,** 109-97-7; **2** (R = H; E = $COOCH_3$), 66653-21-2; **3a,** 66653-22-3; **3b,** 1444-11-7; **3c,** 66653-23-4; **4,** 66653-24-5; **5,** 66653-25-6; **6,** 66653-26-7; **8a,** 66653-27-8; **8b,** 969-47-1; **9,** 66653-28-9; **10,** 66653-29-0; **11a,** 10299-63-5; **11b,** 66653-30-3; **12,** 1244-74-2; **13a,** 66653-31-4; DMAD, 762-42-5; benzyl bromide, 100-39-0.

References and Notes

(1) For a review, see R. A. Jones and G. P. Bean, "The Chemistry of Pyrroles", Academic Press, New York, N.Y., 1977, pp 146 and 256.
(2) R. M. Acheson and J. M. Vernon, *J. Chem. Soc.*, 1148 (1962).
(3) R. M. Acheson and J. M. Vernon, *J. Chem. Soc.*, 1008 (1963).
(4) J. K. Kochi, *Free Radicals 1973,* **1,** 572 (1973).
(5) W. E. Noland and F. J. Baude, *J. Org. Chem.*, **31,** 3321 (1966).
(6) R. M. Acheson and J. M. Vernon, *J. Chem. Soc.*, 1907 (1963).
(7) R. M. Acheson, *J. Chem. Soc.*, 2630 (1965).
(8) C. J. Pouchert, "The Aldrich Library of Infrared Spectra", 2nd ed, Aldrich Chemical Co., Inc., 1975, No. 525A.
(9) C. J. Pouchert and J. R. Campbell, "The Aldrich Library of NMR Spectra", Aldrich Chemical Co., 1975, No. 4, 38C.