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Photocyclization of N-Chloroacetyl-2,5-dimethoxyphenethylamine. Synthesis of Pyrroloindoles*

Yohmei Okuno,[1] Masatoshi Kawamori,[1a] Ken-ichi Hirao, and Osamu Yonemitsu[1]

Faculty of Pharmaceutical Sciences, Hokkaido University[1]

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On irradiation in an aqueous solution, N-chloroacetyl-2,5-dimethoxyphenethylamine (**1**) gave 6,9-dimethoxy-1,2,4,5-tetrahydro-3H-3-benzazepin-2-one (**2**), 7-hydroxy-1,2,4,5-tetrahydro-3H-3-benzazepin-2-one (**4**), 4-methoxy-1-azatricyclo[6,2,1,$0^{4,11}$]undeca-5-ene-2,7-dione (**7**) and 11-methoxy-1-azatricyclo[6,2,1,$0^{4,11}$]undeca-7-ene-2,6-dione (**8**). The structure of **2**, **4** and **8** were determined by their spectral data. Compound **7** has also nicely assignable spectra except the ultraviolet spectrum in which no π–π^* band of the enone group appears above 200 nm. However, the structure of **7** has been confirmed through the conversion to pyrroloindole derivatives (**11**, **13**, **14**) and the deuterium exchange reaction. Compound **8** also gave other pyrroloindole derivatives (**16**, **17**). The mechanism of these rather unusual photocyclizations were finally discussed.

In photochemistry much more frequently than in ground state chemistry, a delicate change in structure is responsible for a variation in reaction pathway to afford completely different photo-products. This has been applied to the photochemical synthesis of many novel heterocycles from N-chloroacetylphenethylamines through various cyclizations owing to the variation of number and/or position of electron-donating substituents such as hydroxy and/or methoxy on the benzene ring.[2]

On the basis of studies on fluorescence quenching,[3] solvent effect,[4] calculation of odd electron density[4a,5] and flash photolysis,[6] a common feature of initial stages in the photocyclization in aqueous solvents has been proposed as follows:[4,6] Intramolecular electron transfer from the excited singlet state of an aromatic chromophore to the chloroacetyl moiety probably via an exciplex leads to the cleavage of the C–Cl bond, and the resultant methylene radical couples readily with the aromatic radical cation or with the phenoxy radical to result in the formation of cyclization products. The reactivities of the positions on the aromatic ring correspond with the odd electron densities of the aromatic radical cation or the phenoxy radical.

If this is the correct mechanism, in the case of N-chloroacetyl-2,5-dimethoxyphenethylamine (**1**) all positions of the benzene ring may be reactive because of their high odd electron

* Dedicated to the memory of Prof. Eiji Ochiai.

1) Location: *Kita-12, Nishi-6, Kita-ku, Sapporo*; *a*) Present address: *Organic Chemistry Research Laboratory, Tanabe Seiyaku, Toda, Saitama.*

2) T. Iwakuma, H. Nakai, O. Yonemitsu, and B. Witkop, *J. Am. Chem. Soc.*, **96**, 2564 (1974); T. Iwakuma, K. Hirao, and O. Yonemitsu, *ibid.*, **96**, 2570 (1974), and references cited therein.

3) M.T. McCall, G.S. Hammond, O. Yonemitsu, and B. Witkop, *J. Am. Chem. Soc.*, **92**, 6991 (1970).

4) *a*) O. Yonemitsu, H. Nakai, Y. Okuno, S. Naruto, K. Hemmi, and B. Witkop, *Photochem. Photobiol.*, **15**, 509 (1972); *b*) Y. Okuno and O. Yonemitsu, *Tetrahedron Letters*, 1974, 1169; *c*) *Idem*, *Chem. Pharm. Bull.* (Tokyo), **23**, 1039 (1975).

5) S. Naruto and O. Yonemitsu, *Tetrahedron Letters*, 1971, 2297; *Idem*, *Chem. Pharm. Bull.* (Tokyo), **20**, 2163 (1972).

6) S. Naruto, O. Yonemitsu, N. Kanamaru, and K. Kimura, *J. Am. Chem. Soc.*, **93**, 4053 (1971); S. Naruto and O. Yonemitsu, *Chem. Pharm. Bull.* (Tokyo), **21**, 629 (1973).

densities.[7] Although the cyclization at position 6 may give a usual photo-product, a benzazepinone derivative, the reactions at other positions are expected to give unusual products. We report here on the photochemistry of N-chloroacetyl-2,5-dimethoxyphenethylamine (**1**).[10]

Results and Discussion

When a 10 mM solution of **1** in 20% aqueous ethanol was irradiated with a 100 W high pressure mercury lamp for 1.5 hr, two benzazepinones **2** and **4** and two tricyclic enones **7** and **8** with pyrroloindole skeleton by direct recrystallization of the evaporated reaction mixture and by column chromatography on silica-gel, though in poor yields (**2**, 8.3%; **4**, 1.5%; **7**, 12.4%, **8**, 3%).

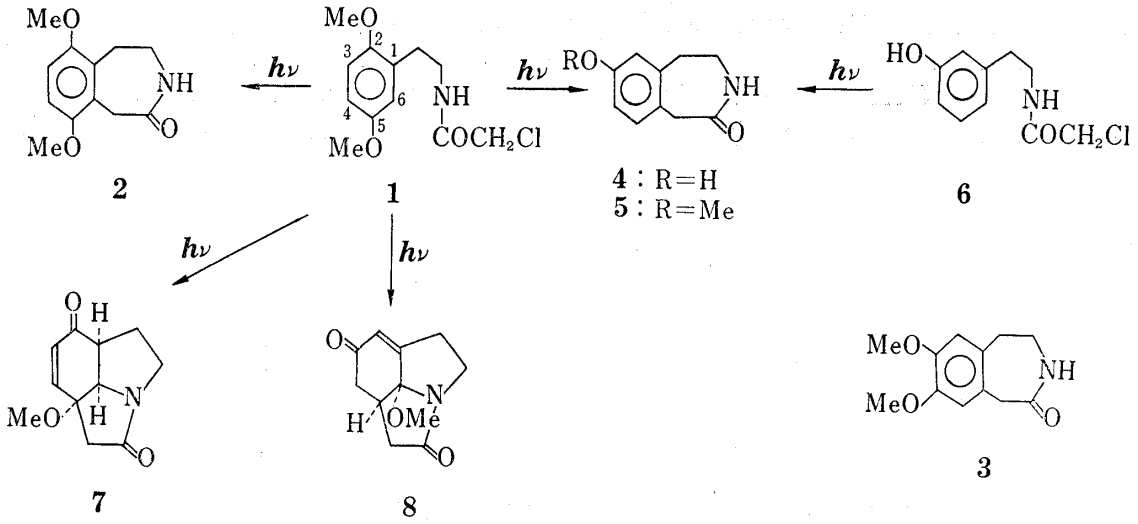


Chart 1

Benzazepinones

The structure of a benzazepinone **2** was established as 6,9-dimethoxy-1,2,4,5-tetrahydro-3H-3-benzazepin-2-one by spectral data in analogy with the 6,7-dimethoxy compound **3**.[11] The mass spectrum [*m/e* 221 (M^+)] and elemental analysis indicate that **2** forms with the loss of the elements of hydrogen chloride. The ultraviolet (UV) spectrum (λ_{max}^{EtOH} at 292 nm) is indicative of an intact dimethoxybenzene chromophore. The infrared (IR) spectrum (amide I at 1670 cm^{-1}, no amide II) shows that **2** is a lactam with six or more, but less than nine membered ring.[12] In the ^1H nuclear magnetic resonance (NMR) spectrum two aromatic protons appear as a sharp singlet at 6.68 ppm.

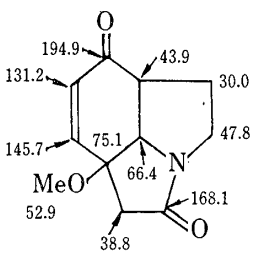
Another benzazepinone **4** with the composition $C_{10}H_{11}O_2N$ is 7-hydroxy-1,2,4,5-tetrahydro-3H-3-benzazepin-2-one, which has been prepared photochemically from N-chloroacetyl-m-tyramine (**6**).[13] Methylation of **4** with diazomethane gave another known product **5**.[13] A probable mechanism for the formation of **4** will be discussed later.

7) Electron spin densities in the cation radical of 1,4-dimethoxybenzene calculated by SCF-CI-MO method[8] are as follows: electron spin density (position); 0.2506 (1, 4), 0.0624 (2, 3, 5, 6).[9]
8) H.C. Longuet-Higgins and J.A. Pople, *Proc. Phys. Soc.* **A68**, 591 (1955).
9) S. Naruto and O. Yonemitsu, unpublished results.
10) The preliminary communication of this paper appeared in Y. Okuno, M. Kawamori, and O. Yonemitsu, *Tetrahedron Letters*, **1973**, 3009.
11) O. Yonemitsu, Y. Okuno, Y. Kanaoka, and B. Witkop, *J. Am. Chem. Soc.*, **92**, 5686 (1970).
12) R. Huisgen, H. Brade, H. Walz, and I. Glogger, *Chem. Ber.*, **90**, 1437 (1957).
13) O. Yonemitsu, T. Tokuyama, M. Chaykovsky, and B. Witkop, *J. Am. Chem. Soc.*, **90**, 776 (1968); Y. Okuno, K. Hemmi, and O. Yonemitsu, *Chem. Pharm. Bull.* (Tokyo), **20**, 1164 (1972).

Pyrroloindoles

Two tricyclic enones, **7** and **8**, were isolated by column chromatography on silicagel. Compound **7** was recrystallized from ethyl acetate to form colorless prisms, whose composition was determined by mass spectrometry and by elemental analysis as $C_{11}H_{13}O_3N$. It differs from the starting material by loss of hydrogen chloride and a methylene group. In the IR spectrum two carbonyl groups of enone and lactam happen to be in the same position at 1685 cm^{-1}. The n-π^* band in the UV spectrum is observed in ethanol at 333 nm (ε 43) or in methylene chloride at 340 nm (ε 36), however the π—π^* band of the enone appears surprisingly not at the usual position (calculated value 227 nm),[14] but at 198 nm probably superposed on that of the lactam. This shows doubt on the structure of **7**, which is nevertheless confirmed by NMR spectra and the following unambiguous chemical evidence.

In the ^{1}H-NMR spectrum two vinyl protons appear at δ 6.28 and 6.53 ppm (J=10 Hz), and the proton of the latter signal has a long-range coupling (J=1.7 Hz) across W-path with the bridge-head methine proton adjacent to the nitrogen atom appeared at 4.35 ppm. The signals in the ^{13}C-NMR spectra in wide band and off-resonance ^{1}H-decoupled experiments are nicely assigned as shown in Fig. 1 (values in ppm downfield from tetramethylsilane).



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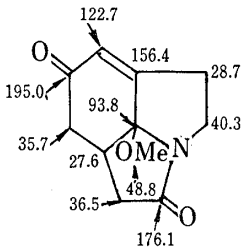

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Fig. 1. Chemical Shifts in the ^{13}C-NMR Spectra of **7** and **8**

The treatment of **7** with 1 N hydrogen chloride in anhydrous methanol at room temperature gave partially a methanol addition product **9** [*m/e* 239 (M^+)], which has ^{1}H-NMR signals of two methoxy groups at 3.32 and 3.37 ppm and of no vinyl group. The reduction of **7** with sodium borohydride in methanol at 0° gave an allyl alcohol **10** though in 22% yield. Compound **10** reverted easily to **7** by the treatment with manganese dioxide. Upon heating with alumina in toluene,[11] **10** aromatized with the loss of water and methanol to 2-oxo-1,2,4,5-tetrahydropyrrolo[3,2,1-hi]indole (**11**) [*m/e* 159 (M^+)], which is identical with the authentic sample synthesized from N-chloroacetylindoline (**12**) by Friedel-Crafts reaction.[5] On treatment with sodium methoxide at room temperature, the enone **7** converted with the loss of methanol to a phenolic compound **13** [*m/e* 175 (M^+)], which was treated with diazomethane overnight to yield a methoxy compound **14** with a pyrroloindole skeleton. The mass and ^{1}H-NMR spectra are almost superimposable on those of the known isomer **15**,[11] though **14** and **15** differ from one another in their melting point and IR and UV spectra. It is known that α-proton in enone is easily subject to a base catalyzed deuterium exchange reaction,[15] which offers further evidence for the presence of an enone group in **7**. When **7** was treated for a short time (6 min) with equimolar amount of sodium methoxide in methanol-d_4, a deuterium exchanged product **7a** was detected in the ^{1}H-NMR spectrum, in which an unchanged vinyl proton appears at 6.35 ppm as a broad singlet. When the above reaction mixture was allowed to stand at room temperature overnight, a monodeuterophenol **13a** with an aromatic proton at 6.81 ppm as a singlet was isolated.

14) H.H. Jaffe and M. Orchin, "Theory and Application of Ultraviolet Spectroscopy," Wiley, New York, N. Y., 1962, p. 215.
15) M.F. Rockett, T.M. Harris, and C.R. Hauser, *J. Am. Chem. Soc.*, **85**, 3491 (1963); M.F. Zinn, T.M. Harris, D.R. Hill, and C.R. Hauser, *ibid.*, **85**, 71 (1963).

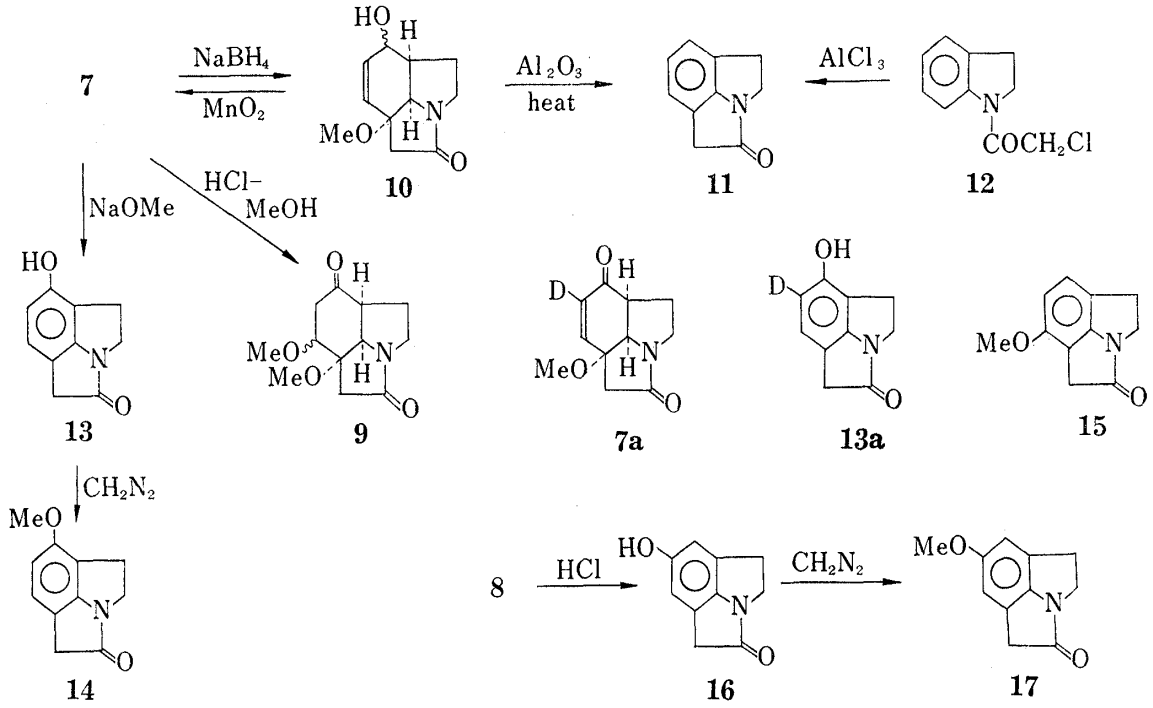

Chart 2

Another tricyclic enone **8** also has the composition $C_{11}H_{13}O_3N$ isomeric with **7**. In the IR and ^{1}H-NMR spectra **8** has distinct signals of the following groups; five-membered lactam without NH (1705 cm^{-1}), enone (1670 cm^{-1}), one methoxy (3.33 ppm) and one vinyl proton (5.85 ppm, singlet). The π—π^* and n-π^* bands in the UV spectrum appear at 240 nm (Calcd. 244 nm)[14] and 324 nm, respectively. On treatment with concentrated hydrochloric acid **8** aromatized to yield a phenolic compound **16** [*m/e* 175 (M$^+$)], which was treated with diazomethane to give a methoxy compound **17** [*m/e* 189 (M$^+$)] isomeric with **14** and **15**. The mass and ^{1}H-NMR spectra are quite similar to those of **14** and **15**. Only a clear difference is a signal of aromatic protons appeared as a singlet at 6.64 ppm.

In the enone **7**, inspection of molecular models indicates that the carbonyl group and the double bond in the enone system are not coplanar because of the fused tricyclic system. The nonplanarity may be responsible for the quite large blue shift (*ca.* 30 nm) in the π—π^* band of the enone, which still requires further clarification. This unusual evidence in UV spectroscopy of enone may be without precedents.[16]

Mechanism

There are many examples of the formation of benzazepinones from N-chloroacetylphenethylamines with the loss of hydrogen chloride.[2] The formation of **2** offers only an additional example, while **4** may form by a somewhat complicated mechanism as Chart 3 shows. The process from **1** to **4** requires at least two photons. The high reactivity of the position substituted by a methoxy group has been demonstrated in the photocyclization of N-chloroacetyl derivatives of *ar*-methoxyphenethylamines.[4a,11,18] The last step, the formation of the phenol

16) It is known that inefficient overlap of two π-systems in $\alpha\beta$-enone causes a significant decrease in absorbance (ε) rather than shift of λ_{max}.[17] However, examining carefully UV spectra of **7** and **8** in various solvents we cannot but consider that this is not true in the case of **7**.

17) E.A. Braude and C.J. Timmons, *J. Chem. Soc.*, **1955**, 3766; G.L. Buchanan, A.F. Cameron, and G. Jamieson, *Chem. Commun.*, **1969**, 1145.

18) O. Yonemitsu, H. Nakai, Y. Kanaoka, I.L. Karle, and B. Witkop, *J. Am. Chem. Soc.*, **92**, 5691 (1970); H. Nakai, K. Hemmi, T. Iwakuma, and O. Yonemitsu, *Chem. Pharm. Bull.* (Tokyo), **20**, 998 (1972).

4 from a cyclohexa-2,5-dienone **19** with the loss of a methoxy group is also rather unusual, though there are a few precedents.[19]

The tricyclic enones **7** and **8** may arise *via* cationic intermediates **20** and **21**, respectively, both of which cannot aromatize because of large steric hindrance and strain, but recyclize to less-strained tricyclic compounds **22** and **23** through a facile transannular addition of lone-pair electrons on the nitrogen atom. Finally **22** and **23** are hydrolyzed to **7** and **8** by hydrochloric acid generated as the reactions proceed.

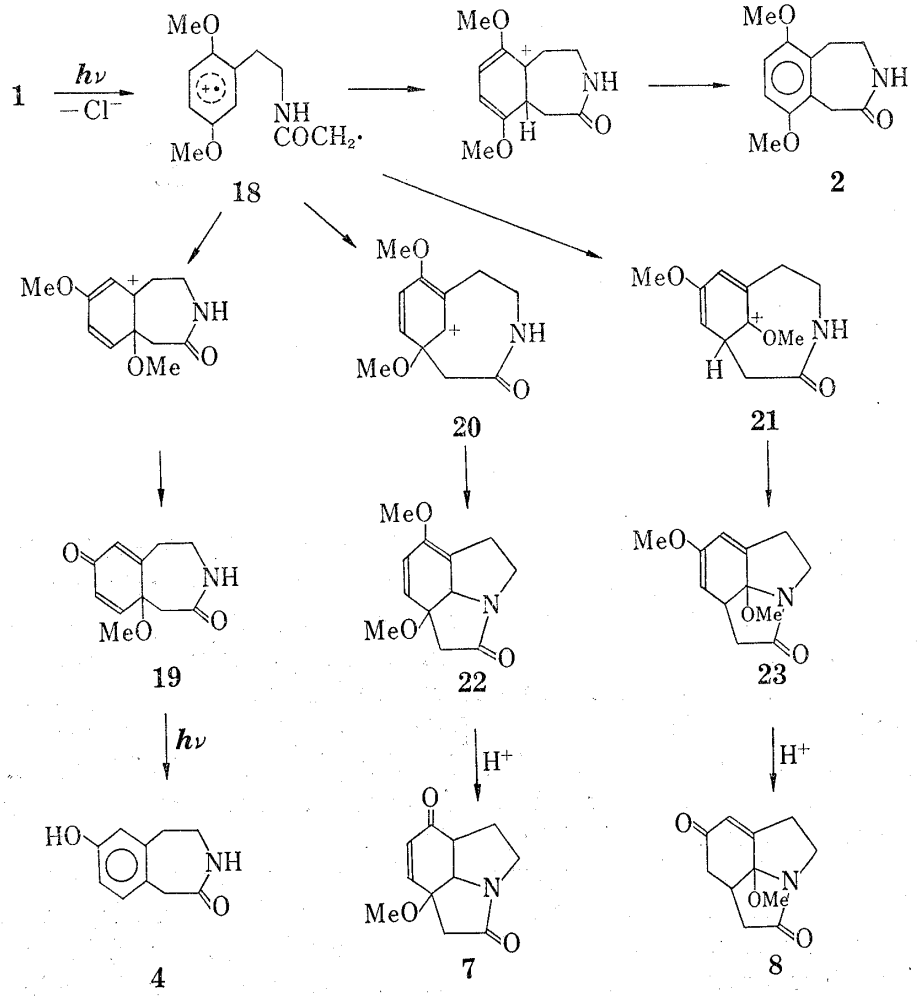

Chart 3

Experimental

Photocyclization of N-Chloroacetyl-2,5-dimethoxyphenethylamine (1) in Aqueous Ethanol——A solution of 1.03 g (4 mmole) of N-chloroacetyl-2,5-dimethoxyphenethylamine (**1**) in 400 ml of 10% aqueous EtOH was irradiated for 1.5 hr with a 100 W high pressure mercury lamp (Osawa) under nitrogen. Excess $AgCO_3$ (600 mg) was added to the solution and the precipitated salts were then removed by filtration over Celite. Three batches totaling a volume of 1.2 liter were combined, concentrated *in vacuo* to *ca.* 250 ml at 40° and extracted with EtOAc several times. The combined extracts (*ca.* 1 liter) was dried over anhydrous Na_2SO_4, and evaporated to dryness under reduced pressure at 45°. To the residual yellow solid, weighing 1.552 g, was added 25 ml of CH_2Cl_2, and then 47 mg (2.2%) of CH_2Cl_2-insoluble crystals, 7-hydroxy-1,2,4,5-tetrahydro-3H-3-benzazepin-2-one (**4**), was collected by filtration. This was recrystallized from MeOH to give 32 mg (1.5%) of colorless needles, mp 254—256°. UV λ_{max}^{EtOH} nm (ε): 281 (2200), 286 (sh. 2060); $\lambda_{max}^{EtOH\text{-}NaOH}$ nm (ε): 300 (3400). IR ν_{max}^{Nujol} cm^{-1}: 3200, 1650. Mass Spectrum *m/e*: 177 (M^+), 148. ^{1}H-NMR $\delta^{DMSO\text{-}d_6\text{-}D_2O}$: 2.93 (t, 2H, J=6 Hz), 3.47 (t, 2H, J=6 Hz), 3.63 (s, 2H), 6.5—7.1 (2H).

19) T. Matsuura, *Bull. Chem. Soc. Japan*, 37, 564 (1964); R. Warszawski, K. Schaffner, and O. Jager, *Helv. Chim. Acta*, 43, 500 (1960).

The above CH_2Cl_2-soluble fraction was concentrated and chromatographed on a column of silica-gel (2×36 cm). Elution with EtOAc–benzene (1: 1) afforded 104 mg (3.4%) of the recovered starting material (1) and other three fractions.

The first fraction was 11-methoxy-1-azatricyclo[6,2,1,$0^{4,11}$]undeca-7-ene-2,6-dione (**8**), which was recrystallized from EtOAc to give 74 mg (3.0%) of colorless leaflets, mp 125—126°. *Anal.* Calcd. for $C_{11}H_{13}O_3N$: C, 63.75; H, 6.32; N, 6.76. Found: C, 63.85; H, 6.29; N, 6.60. UV λ_{max}^{MeOH} nm (ε): 241 (sh. 6200), 324 (39); $\lambda_{max}^{cyclohexane}$ nm (ε): 240.5 (5100). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1710, 1685, 1672; ν_{max}^{Nujol} cm^{-1}: 1705, 1670. Mass Spectrum *m/e* 207 (M^+), 192, 176. ^{1}H-NMR $\delta^{acetone\text{-}d_6}$: 1.7—2.2 (2H), 2.4—3.3 (6H), 3.34 (s, 3H), 3.8 (m, 1H), 5.86 (s, 1H); $\delta^{methanol\text{-}d_4}$: 1.89 (d, 1H. J=8 Hz), 2.18 (d, 1H, J=8 Hz), 2.4—3.3 (m, 6H), 3.32 (s, 3H), 3.8 (m, 1H), 5.9 (s, 1H). ^{13}C-NMR $\delta^{DMSO\text{-}d_6}$: 27.6 (CH), 28.7 (CH_2), 35.7 (CH_2), 36.5 (CH_2), 40.3 (CH_2), 48.8 (CH_3), 93.8 (C), 122.7 (CH), 156.4 (C), 176.1 (C), 195.0 (C).

The next fraction was 340 mg (13.7%) of 4-methoxy-1-azatricyclo[6,2,1,$0^{4,11}$]undeca-5-ene-2,7-dione (**7**), which was recrystallized from EtOAc to give 309 mg (12.4%) of colorless prisms, mp 112—113°. *Anal.* Calcd. for $C_{11}H_{13}O_3N$: C, 63.75; H, 6.32; N, 6.76. Found: C, 63.76; H, 6.33; N, 6.74. UV λ_{max}^{EtOH} nm (ε): 333 (43); $\lambda_{max}^{CH_2Cl_2}$ nm (ε): 340 (36); $\lambda_{max}^{H_2O}$ nm (ε): 198 (14000); in EtOH, THF, cyclohexane and CH_2Cl_2: end absorption. IR ν_{max}^{Nujol} cm^{-1}: 1680; $\nu_{max}^{CHCl_3}$ cm^{-1}: 1685. Mass Spectrum *m/e*: 207 (M^+), 192, 179, 164. ^{1}H-NMR δ^{CDCl_3}: 2.2—3.3 (m, 7H), 3.32 (s, 3H), 4.35 (d.d, 1H, J=6, 1.7 Hz), 6.28 (d, 1H, J=10 Hz), 6.53 (d.d, 1H, J=10, 1.7 Hz). ^{13}C-NMR δ^{CDCl_3}: 30.0 (CH_2), 38.8 (CH_2), 43.9 (CH), 47.8 (CH_2), 52.9 (CH_3), 66.4 (CH), 75.1 (C), 131.2 (CH), 145.7 (CH), 168.1 (C), 194.9 (C). Molecular weight determined by vapor pressure osmometry: 199.6±10.

The third fraction was purified by recrystallization from EtOAc to give 220 mg (8.3%) of 6,9-dimethoxy-1,2,4,5-tetrahydro-3H-3-benzazepin-2-one (**2**) as colorless needles, mp 219—221°. *Anal.* Calcd. for $C_{12}H_{15}O_3N$: C, 65.14; H, 6.83; N, 6.33. Found: C, 65.11; H, 6.92; N, 6.40. UV λ_{max}^{EtOH} nm (ε): 292 (3700), 296 (sh. 3500). IR ν_{max}^{Nujol} cm^{-1}: 3240, 3080, 1670. Mass Spectrum *m/e*: 221 (M^+), 206, 192, 177, 164. ^{1}H-NMR δ^{CDCl_3}: 2.98 (t, 2H, J=7 Hz), 3.50 (t, 2H, J=7 Hz), 3.74 (s, 6H), 3.93 (s, 2H), 6.68 (s, 2H), 6.65 (broad s, 1H).

4,5-Dimethoxy-1-azatricyclo[6,2,1,$0^{4,11}$]undeca-2,7-dione (**9**)——Fifty five mg of **7** was dissolved in an anhydrous 1 N HCl–MeOH solution and allowed to stand at room temperature for 32 hr. After evaporation of the solvent, the residue was chromatographed on a silica-gel column (1×19 cm) to give 31 mg of the recovered starting material (**7**) and 13 mg of **9**, mp 173—175° (colorless needles from EtOAc–*n*-hexane). IR ν^{CHCl_3} cm^{-1}: 1690. Mass Spectrum *m/e* 239 (M^+), 224. 208. ^{1}H-NMR δ^{CDCl_3} : 2.3 (t, 2H, J=6 Hz), 2.65—3.2 (6H), 3.30 (s, 3H), 3.37 (s, 3H), 3.5—3.9 (m, 2H), 4.27 (d, 1H, J=8 Hz).

7-Hydroxy-4-methoxy-1-azatricyclo[6,2,1,$0^{4,11}$]undeca-5-en-2-one (**10**)——Compound **7** (260 mg) was dissolved in 10 ml of MeOH and 20 mg of $NaBH_4$ was gradually added with stirring at 0°. After 3 hr, the excess reagent was decomposed by the addition of 1 N HCl, and then the excess acid was neutralized with $NaHCO_3$. The neutral solution was evaporated to dryness *in vacuo* and extracted with EtOH–EtOAc (1: 1). Evaporation of the solvent gave 274 mg of colorless oil which was subjected to preparative thin-layer chromatographies (TLC) of silica-gel and of alumina to yield 57 mg of **10** as a colorless oil. IR ν^{neat} cm^{-1}: 3400, 1680. Mass Spectrum *m/e*: 209 (M^+), 194, 178, 126. ^{1}H-NMR δ^{CDCl_3}: 1.9—2.7 (4H,) 2.8—3.3 (3H), 3.21 (s, 3H), 3.62 (m, 1H), 3.72 (s, 1H), 4.03 (q, 1H, J=4.5, 2.5 Hz), 5.59 (d, 1H, J=10 Hz), 6.05 (q, 1H, 10, 2.5 Hz).

Conversion of 10 to 7——To a stirred solution of 28 mg of **10** in 2 ml of CH_2Cl_2 was added 100 mg of MnO_2 at room temperature. After 3 hr, the reaction mixture was filtered to remove the MnO_2, and the filtrate was evaporated *in vacuo* to leave a solid, which was purified on a preparative TLC of silica-gel to give 12 mg of colorless prisms of **7**. This was identical with the above sample **7** by mass spectrum, TLC and mixed melting point.

2-Oxo-1,2,4,5-tetrahydropyrrolo[3,2,1-hi]indole (**11**)——To a solution of 28 mg of **10** in 5 ml of toluene was added 600 mg of alumina. The mixture was heated under reflux for 3 hr, and then filtered to remove the alumina. The filtrate was evaporated *in vacuo* to leave an oil, which was chromatographed on a silica-gel preparative TLC developing with EtOH–EtOAc (1: 10) to give 2 mg of **11**, mp 129—131°. UV λ_{max}^{EtOH} nm (ε): 254 (9700), 293 (2100). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1705, 1665. Mass Spectrum *m/e*: 159 (M^+), 130. ^{1}H-NMR δ^{CCl_4}:3.55 (t, 2H, J=7 Hz), 3.63 (s, 2H), 4.02 (t, 2H, J=7 Hz), 6.5—7.4 (3H).

6-Hydroxy-2-oxo-1,2,4,5-tetrahydropyrrolo[3,2,1-hi]indole (**13**)——Compound **7** (67 mg) and NaOMe (34 mg) were dissolved in 12 ml of MeOH and the solution was stirred for 2 hr at room temperature. Evaporation of the solvent left a brown residue, to which H_2O was added, and the mixture was neutralized with dilute HCl and extracted with EtOAc several times. The combined extracts were dried over anhydrous Na_2SO_4 and concentrated *in vacuo* to leave 30 mg of a solid, which was recrystallized from EtOAc to give 15 mg of **13**, mp 220—225°. UV λ_{max}^{EtOH} nm (ε): 221 (29200), 261 (5000), 290 (sh. 2600). IR ν_{max}^{Nujol} cm^{-1}: 3300, 1705, 1660, 1640. Mass Spectrum *m/e*: 175 (M^+), 147, 146, 130. ^{1}H-NMR $\delta^{DMSO\text{-}d_6\text{-}D_2O}$: 3.40 (t, 2H, J=8 Hz), 3.59 (s, 2H), 3.91 (t, 2H, J=8 Hz), 6.28 (d, 1H, J=8 Hz), 6.78 (d, 1H, J=8 Hz).

6-Methoxy-2-oxo-1,2,4,5-tetrahydropyrrolo[3,2,1-hi]indole (**14**)——To a stirred solution of 10 mg of **13** in MeOH was added excess diazomethane in ether, and the solution was allowed to stand at room temperature overnight. Evaporation of the solvent *in vacuo* left a solid, which was recrystallized from benzene–

n-hexane to yield 5 mg of **14**, mp 129—131°. UV λ_{max}^{EtOH} nm (ε): 222 (19600), 258 (7100), 287 (sh. 1850). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1710, 1670. Mass Spectrum *m/e*: 189 (M$^+$), 161, 146, 130. ^{1}H-NMR δ^{CDCl_3}: 3.52 (t, 2H, J=7 Hz), 3.67 (s, 2H), 3.82 (s, 3H), 4.00 (t, 2H, J=7 Hz), 6.36 (d, 1H, J=8 Hz), 6.87 (d, 1H, J=8 Hz).

7-Hydroxy-2-oxo-1,2,4,5-tetrahydropyrrolo[3,2,1-hi]indole (16)——To 30 mg of **8** was added 5 ml of EtOH and *ca.* 0.1 ml of concentrated HCl. After the starting material was disappeared, the solvent was evaporated *in vacuo* to leave a solid, which was washed with benzene and recrystallized from EtOH to give 15 mg of **16**, mp 229—230° (decomp). UV λ_{max}^{EtOH} nm (ε): 261 (9500), 322 (2700); $\lambda_{max}^{EtOH\text{-}NaOH}$ nm (ε): 280 (11000), 342 (4400). IR ν_{max}^{Nujol} cm^{-1}: 3200, 1680, 1650. Mass Spectrum *m/e*: 175 (M$^+$), 146, 130. ^{1}H-NMR $\delta^{DMSO\text{-}d_6}$: 3.42 (t, 2H, J=7 Hz), 3.67 (s, 2H), 3.91 (t, 2H, J=7 Hz), 6.53 (s, 2H).

7-Methoxy-2-oxo-1,2,4,5-tetrahydropyrrolo[3,2,1-hi]indole (17)——Methylation of **16** was carried out as described above to yield **17**, mp 107—108°. UV λ_{max}^{EtOH} nm (ε): 259 (9900), 318 (2300). IR ν_{max}^{Nujol} cm^{-1}: 1695, 1660. Mass Spectrum *m/e*: 189 (M$^+$), 161, 146, 130. ^{1}H-NMR δ^{CDCl_3}: 3.50 (t, 2H, J=7 Hz), 3.73 (s, 5H), 4.01 (t, 2H, J=7 Hz), 6.64 (s, 2H).

Deuterium Exchange Reaction of 7——Compound **7** (20.7 mg) was dissolved in CD_3OD in a NMR sample tube, and 5.4 mg of NaOMe in CD_3OD was added. After 6 min, the original qualtet in the NMR of **7** was disappeared and a new singlet at 6.35 ppm was observed (**7a**).

The solution was allowed to stand at room temperature overnight, and then evaporated *in vacuo*. To the residue *ca.* 3 ml of H_2O was added, and the mixture was acidified with 10% HCl and extracted with EtOAc several times. The combined extracts were dried over Na_2SO_4, and evaporated *in vacuo* to leave to 10 mg of pale yellow solid of **13a**. Mass Spectrum *m/e*: 176 (M$^+$), 148, 131. ^{1}H-NMR $\delta^{DMSO\text{-}d_6}$: 3.41 (2H), 3.62 (s, 2H), 3.85 (2H), 6.81 (s, 1H).