Anal. Calcd for $C_{19}H_{21}NO_2$: C, 77.26; H, 7.17; N, 4.74. Found: C, 77.43; H, 7.14; N, 4.68.

1,2,3,4-Tetrahydroanthracen-1,4-imine Hydrochloride. A solution of **14** (1.94 g, 6.62 mmol) in 75 mL of nitromethane was cooled to 5 °C in an ice bath and dry hydrogen chloride was bubbled into this stirred solution for 2 h. Addition of 100 mL of ether to the cold nitromethane solution precipitated 1.25 g (85%) of the hydrochloride as fine white crystals, mp 275–277 °C. Sublimation [165 °C (0.05 mm)] gave an analytical sample, mp 276–277 °C.

Anal. Calcd for $C_{14}H_{14}ClN$: C, 72.56; H, 6.09; Cl, 15.30; N, 6.04. Found: C, 72.52; H, 6.61; Cl, 15.12; N, 6.14.

1,2,3,4-Tetrahydroanthracen-1,4-imine (9). Addition of the hydrochloride of **9** (1.25 g, 5.41 mmol) to an excess of 10% aqueous potassium hydroxide followed by extraction with two 50-mL portions of ether gave, after drying over anhydrous magnesium sulfate and concentration of the solution, a white solid (1.02 g, 96%), mp 105–108 °C. Sublimation of this material [65 °C (0.02 mm)] gave white crystals: mp 108–109 °C; UV (95% ethanol) 319 (log ϵ 3.76), 3.06 (3.75), 284 (4.55), 274 (4.74), and 265 nm (4.71); IR (KBr) 3285, 3054, 3004, 2980, 2960, 2944, 2905, 2860, 1607, 1498, 1339, 1279, 1035, 906, 871, 848, 809, 745, 565, and 475 cm^{-1}; NMR (CCl_4) δ 7.50 (m, 6 H, naphthyl), 4.45 (m, 2 H, bridgehead), 2.30 (s, 1 H, NH, exchanges with D_2O), 1.90 (m, 2 H, C-2, C-3 exo protons), and 1.25 (m, 2 H, C-2, C-3 endo protons); mass spectrum *m/e* (rel intensity) 195 (5), 167 (100), 140 (13), 139 (14), 83.5 (18).

Anal. Calcd for $C_{14}H_{13}N$: C, 86.11, H, 6.71; N, 7.17. Found: C, 85.89; H, 6.81; N, 7.01.

Benz[*f*]isoindole (5). Compound **9** (200 mg, 1.03 mmol) was subjected to flash vacuum thermolysis in a quartz reactor tube at 600 °C (0.05 mm). The thermolysis required 10 min. The product was deposited as a cream-colored solid in essentially quantitative yield on a cold finger cooled by liquid nitrogen. The coproduct ethylene was removed by low temperature volatilization, effected by replacement of the liquid nitrogen coolant with dry ice–acetone while maintaining the low pressure. The olefin was characterized as its dibromide in the usual way.[5] The product, benz[*f*]isoindole, exhibited the following spectral data: UV (95% ethanol) 340, 324, 298, 288, 278, and 245 nm; UV (hexane) 337, 328, 322, 314, 298, 285, 275, and 265 nm; mass spectrum *m/e* (rel intensity) 167 (57), 166 (100), 153 (30), 140 (82), 139 (67), and 83.5 (60); NMR ($CDCl_3$, −40 °C) δ 8.70 (m, 1 H, C-3 proton) 8.10 (s, br, C-4, C-9 protons) 7.90 (m, C-5, C-8 protons) 7.50 (m, C-6, C-7 protons), and 4.95 (d, 2 H, C-1 protons).

***N*-Phenylmaleimide Adduct (8) of Benz[*f*]isoindole.** A 201-mg sample (1.03 mmol) of **9** was converted to **5** by the method described above. A solution of 200 mg (1.16 mmol) of *N*-phenylmaleimide in chloroform was added to the product on the cold finger, which was maintained at the temperature of liquid nitrogen. The reaction mixture was warmed sufficiently to permit its transfer to a flask and the mixture was kept at −10 °C for 48 h. The solvent was removed in vacuo and the resulting brown solid was chromatographed on silica gel, first with dichloromethane and then with chloroform as eluents. The product fraction yielded a tan solid (0.165 g, 47.2%), mp 220–238 °C dec. Recrystallization from absolute ethanol after treatment with activated charcoal gave 98 mg (28%) of colorless plates, mp 242–244 °C dec (lit.[4] mp 241.4–242 °C dec). A second recrystallization from hexane–benzene (1:1) provided an analytical sample: mp 243–244 °C dec; UV (95% ethanol) 325 (log ϵ 3.08), 310 (2.97), 286 (3.57), 275 (3.80), and 265 (3.87) nm; NMR (Me_2SO-d_6) δ 8.0–7.2 (m, 11 H, aromatic), 4.9 (s, 2 H, bridgehead), 3.9 (s, br, 1 H, NH, exchanges with D_2O), and 3.2 (s, 2 H, α to imide carbonyl).

Anal. Calcd for $C_{22}H_{16}N_2O_2$: C, 77.63; H, 4.74; N, 8.23. Found: C, 77.42; H, 4.86; N, 8.09.

Registry No.—**5**, 268-49-5; **8**, 18009-78-4; **9**, 57833-62-2; **9** HCl, 67598-14-5; **11**, 67598-15-6; **12**, 57833-63-3; **13**, 67598-16-7; **14**, 67598-17-8; 2-naphthalenediazonium 3-carboxylate, 30013-85-5; 1-(phenylmethyl)pyrrole, 2051-97-0; 1,2,3,4-tetrahydroanthracene, 2141-42-6; *tert*-butyl pyrrole-1-carboxylate, 5176-27-2; *N*-phenylmaleimide, 941-69-5.

References and Notes

(1) L. J. Kricka and J. M. Vernon, *Adv. Heterocycl. Chem.*, **16**, 87 (1974).
(2) R. Kreher and K. J. Herd, *Angew. Chem., Int. Ed. Engl.*, **17**, 68 (1978).
(3) (a) E. Chacko, J. Bornstein, and D. J. Sardella, *J. Am. Chem. Soc.*, **99**, 8248 (1977); (b) J. Bornstein, D. A. McGowan, A. L. DiSalvo, J. E. Shields, and J. Kopecky, *Chem. Commun.*, 1503 (1971); (c) J. E. Shields and J. Bornstein, *J. Am. Chem. Soc.*, **91**, 5192 (1969).
(4) J. E. Shields and J. Bornstein, *Chem. Ind. (London)*, 1404 (1967).
(5) J. Bornstein, D. E. Remy, and J. E. Shields, *J. Chem. Soc., Chem. Commun.*, 1149 (1972).
(6) J. Bornstein, D. E. Remy, and J. E. Shields, *Tetrahedron Lett.*, **48**, 4247 (1974).
(7) C. W. Rees and R. C. Storr, *J. Chem. Soc. C*, 765 (1969).
(8) W. Rettig and J. Wirz, *Helv. Chim. Acta*, **59**, 1054 (1976).
(9) J. G. Grasselli and W. M. Ritchey, Ed., "Atlas of Spectral Data and Physical Constants for Organic Compounds", 2nd ed, Vol. III, CRC Press, Inc., Cleveland, Ohio, 1975, pp 649.
(10) J. Kopecký, J. E. Shields, and J. Bornstein, *Tetrahedron Lett.*, 3669 (1967).
(11) J. G. Smith and R. T. Wikman, *J. Org. Chem.*, **39**, 3648 (1974); *Tetrahedron*, **30**, 2603 (1974).
(12) E. Chacko, D. J. Sardella, and J. Bornstein, *Tetrahedron Lett.*, 2507 (1976).
(13) R. Bonnett, R. F. C. Brown, and R. G. Smith, *J. Chem. Soc., Perkin Trans. 1*, 1432 (1973).
(14) C. Merritt, Jr., C. DiPietro, C. W. Hand, J. H. Cornell, and D. E. Remy, *J. Chromatogr.*, **112**, 301 (1975).
(15) C. F. Wilcox, Jr., and S. S. Talwar, *J. Chem. Soc. C*, 2162 (1970).
(16) G. Schroeter, *Ber. Dtsch. Chem. Ges.*, **57**, 2003 (1924).

Reactions of Acylaminoquinone Tosylhydrazones. 4.[1] A New Synthesis of Pyrrolo[1,2-*a*]indoloquinone and Related Compounds via Benzoxazoline by Thermolysis and Photolysis

Mitsuo Akiba,* Yoshiyuki Kosugi, and Toyozo Takada

Tokyo College of Pharmacy, 1432-1 Horinouchi, Hachioji, Tokyo, 192-03, Japan

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In our synthetic studies on mitomycin antibiotics, recently we reported that the thermolysis of acetylaminoquinone tosylhydrazones (**1**) gave the pyrrolo[1,2-*a*]indoloquinones and related compounds (**8**) in a one-step synthesis. These results suggested tentatively the existence of carbenes as the reaction intermediates. In this paper, however, we wish to describe the isolation of the unstable benzoxazoline intermediates (**5**) by the carefully controlled thermolysis and photolysis of **1** in good yields. Compounds **5** then turned into **8** via the dihydro compounds **7**. We also examined the solvent effects in the thermolysis and photolysis of **1**. This stepwise procedure via the benzoxazoline appears to be distinctly more versatile than the original procedure, which also afforded indazoloquinones and indazoles as the minor products, for the synthesis of pyrrolo[1,2-*a*]indoloquinones and related compounds.

During our course of synthetic studies on mitomycin antibiotics,[2] we have reported[3] that the thermolysis of acetylmono-**1a** and diaminoquinone tosylhydrazones **1d** gave the pyrrolo[1,2-*a*]indoloquinones **8a** and **8d**, respectively, both of which involve the parent skeleton of the mitomycins. Analogous products **8b,c,e,f** have also been obtained from the corresponding tosylhydrazones **1b,c,e,f** by the improved one-flask operation. These results suggested tentatively the

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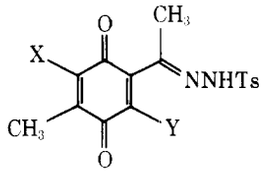
Table I. Influence of Solvent on Thermolysis of Acetylaminoquinone Tosylhydrazones (1a–c)

compd	registry no.	solvent	reaction time, min	products, % 5	8	9
1a	54698-02-1	benzene	60[a]	78		
		toluene	60	76	10	
		DMF	30		78[d]	
1b	54698-03-2	benzene	120			
		toluene	60[b]	12	17	26[g]
		DMF	30		37[e]	
1c	54698-04-3	benzene	120			
		toluene	120[c]	23	19	27[h]
		DMF	30		60[f]	

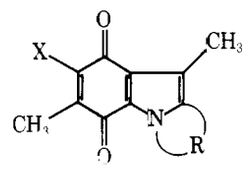
[a] Registry no. 64269-20-10. [b] Registry no. 67542-34-1. [c] Registry no. 67542-35-2. [d] Registry no. 54698-20-3. [e] Registry no. 54698-21-4. [f] Registry no. 67542-36-3. [g] Registry no. 67576-99-2. [h] Registry no. 67542-37-4.

existence of carbenes as the reaction intermediates.

In this paper, however, we wish to describe the isolation of the unstable benzoxazoline intermediates **5** upon the carefully controlled thermolysis and photolysis of **1**.



1a, X = H; Y = pyrrolidino
b, X = H; Y = piperidino
c, X = H; Y = morpholino
d, X = Y = pyrrolidino
e, X = Y = piperidino
f, X = Y = morpholino

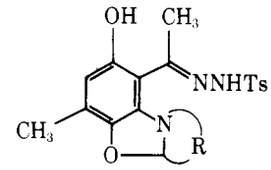


8a, X = H; R = $(CH_2)_3$
b, X = H; R = $(CH_2)_4$
c, X = H; R = $(CH_2)_2OCH_2$
d, X = OH; R = $(CH_2)_3$
e, X = OH; R = $(CH_2)_4$
f, X = OH; R = $(CH_2)_2OCH_2$

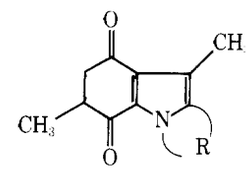
Refluxing the pyrrolidinoquinone **1a** in benzene gave a new compound in 78% yield. The same product was also obtained in 82% yield by the photolysis in benzene using a high-pressure mercury lamp through Pyrex glass. The product, a yellow crystalline material, decomposed on heating in chlorobenzene or dimethylformamide to form the final product **8a**. This fact compelled us to consider that this material might be an intermediate of the overall synthesis. The structure of this compound was characterized by the appearance of a deshielded methine proton in its NMR spectrum and the disappearance of quinone carbonyl band in its IR spectrum, being assigned as an oxazoline derivative **5a**.

The mass spectrum of **5a** did not show a molecular ion at *m/e* 401 but had strong peaks at *m/e* 217 and 215 which agreed with the molecular weight of the compounds **7a** and **8a**, respectively. This fragmentation pattern suggested that the thermal decomposition of **5a** might proceed similarly during the indoloquinone synthesis. In fact, upon heating **5a** in chlorobenzene, **7a** (19%) and **8a** (23%) were obtained as the major products, and small amounts of ditolyl disulfide and ditolyl thiosulfonate were also isolated as the other fragments of the thermolysis. The structure of **7a**, in which the keto form[4] appears to be favored, was confirmed by the spectral data and the following chemical method.

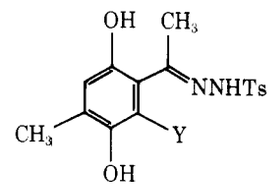
When refluxed in dimethylformamide, **7a** was converted into **8a** in a quantitative yield; on reduction with sodium hydrosulfite in water–chloroform, **8a** reversed to **7a**.



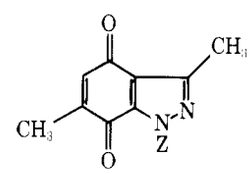
5a, R = $(CH_2)_3$
b, R = $(CH_2)_4$
c, R = $(CH_2)_2OCH_2$



7a–c



9a, Y = pyrrolidino
b, Y = piperidino
c, Y = morpholino



10, Z = Ts
11, Z = H

We have also examined the thermolysis and photolysis of **1a–c** in various solvents. The results are summarized in Tables I and II. When the piperidino **1b** and the morpholinoquinone **1c** were refluxed in benzene the oxazolines **5b,c** were not obtained, but in toluene, **1a–c** gave **5a–c**, **8a–c**, and the hydroquinones **9b,c**. When dimethylformamide was used as the solvent, **8a–c** were obtained selectively in all cases.

On the other hand, the photolysis of **1** was studied in benzene, chloroform, and ethanol. The irradiation of **1a** in ethanol or other solvents afforded **5a** in 70% yield, along with a trace of **8a**. In the case of the photolysis of **1b,c**, we obtained **9b,c**, *N*-tosylindazoloquinone **10**,[3] indazoloquinone **11**, and indoloquinone **8b,c** together with the oxazoline **5**. Compound **11** was also obtained by the irradiation of **10** in chloroform.

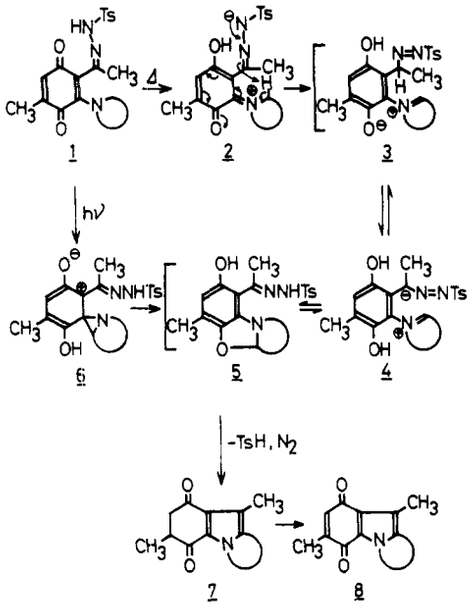
The differentiation of the reactivity of five- and six-membered aminoquinones was detected from the experimental results shown in Tables I and II. It was seen that the formation of the oxazoline was most efficient with five-

Table II. Influence of Solvent on Photolysis of Acetylaminoquinone Tosylhydrazones (1a–c)

compd	solvent	reaction time, min	products, % 5	8	9	10	11
1a	benzene	25	82				
	ethanol	30	70	trace			
1b	chloroform	60		trace	15	4[a]	28[b]
	ethanol	60	trace	11	18		
1c	chloroform	30	23		trace	trace	28
	ethanol	45	47	14	28		

[a] Registry no. 54698-23-6. [b] Registry no. 15966-74-2.

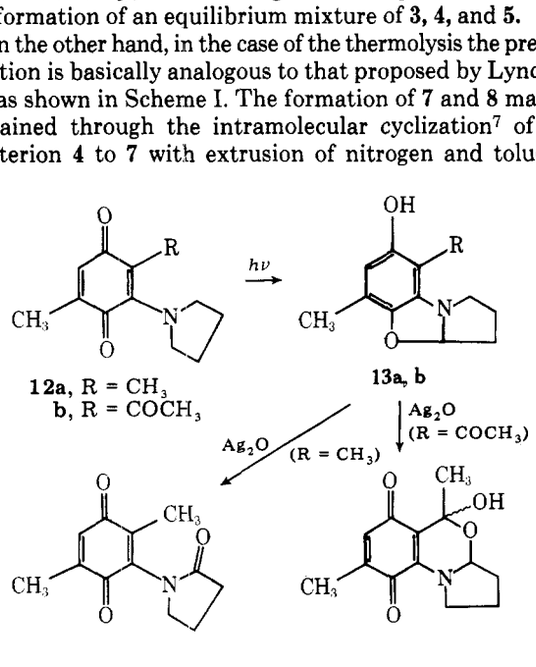
Scheme I



membered pyrrolidinoquinone. This seems due to the stability of the oxazoline intermediate and the fact that only **1a** of the aminoquinones does not undergo conversion to the indazoloquinones **10** or **11** nor the reduced products **9b,c** in the reaction course of the thermolysis and photolysis. The cause has not been clarified. However, we found, from the results of the solvent effects, that the thermal reaction using DMF as the solvent appeared to be more versatile than the photochemical reaction for the synthesis of indoloquinones. The formation of **10** may be rationally explained by considering the photointramolecular nucleophilic substitution of **1** followed by elimination of amines, as reported previously in the case of the thermolysis.[3] The reduced products **9b,c** may result from a reaction involving abstraction of hydrogen from the solvents. The structures **9b,c** were also confirmed by reduction of **1b,c** with sodium hydrosulfite.

From these experiments, the following mechanism seems to be reasonable for the formation of **8** from **1**. The reaction probably proceeds through a spiroaziridine intermediate **6** formed by γ-hydrogen abstraction[5] on the photoexcited structure of **1** (presumably the hydrogen of NCH_2 is favored over that of CH_3), which undergoes rearrangement leading to the formation of an equilibrium mixture of **3, 4,** and **5.**

On the other hand, in the case of the thermolysis the present reaction is basically analogous to that proposed by Lynch et al.[6] as shown in Scheme I. The formation of **7** and **8** may be explained through the intramolecular cyclization[7] of the zwitterion **4** to **7** with extrusion of nitrogen and toluenesulfinic acid. Further, **7** undergoes dehydrogenation to form **8.** This stepwise procedure via the benzoxazoline appears to be distinctly more versatile than the original procedure[2] for the synthesis of pyrrolo[1,2-*a*]indoloquinones and related compounds without any formation of indazoloquinones.



While the present work was in progress, the results of an independent investigation of the photolysis of the acetylaminoquinones **12a,b** were reported by Frank et al.[8] They solved the problem of the introduction of an oxa substituent at the carbon of the pyrrolidine ring, but failed in the construction of carbon–carbon bond.

In connection with our studies on the mitomycins, further investigation on photolysis and thermolysis of substituted aminoquinones having an aziridino group on the pyrrolidine ring is being carried out and will be reported elsewhere.

Experimental Section

IR, UV, and mass spectra were recorded on a Hitachi Model 215 spectrometer, a Hitachi Model 200-10 spectrometer, and a Hitachi Model RMU-7L spectrometer, respectively. NMR spectra were measured by a JEOL PS-100 spectrometer. Melting points were determined on a Yanagimoto micro-hot-stage apparatus.

Acetylaminoquinone tosylhydrazones (**1a–c**) were prepared by the method described in the previous report.

Irradiations were carried out using a 100 W high-pressure mercury arc lamp through Pyrex filter.

Thermolysis of 2-Acetyl-5-methyl-3-pyrrolidino-1,4-benzoquinone Tosylhydrazone (1a). A solution of **1a** (300 mg) in C_6H_6 (100 mL) was refluxed for 1 h. After cooling, the solvent was evaporated to dryness and the residue was recrystallized from 1:1 C_6H_6–hexane to give 257 mg (78%) of **5a** as yellow needles: mp 192 °C dec; IR ν (KBr) 3430 (OH), 3100 (NH), 1640 (C=N), 1600, 1410, 1170 cm^{-1} (SO_2); NMR ($CDCl_3$) δ 10.36 (1 H, s, OH), 9.40 (1 H, br, NH), 7.70 (2 H, d, J = 8 Hz, Ar-H), 7.30 (2 H, d, J = 8 Hz, Ar-H), 6.12 (1 H, s, Ar-H), 5.70 (1 H, t, J = 3 Hz, oxazoline H), 3.2–1.6 (6 H, m, $3CH_2$), 2.46 (3 H, s, CH_3), 2.38 (3 H, s, CH_3), 2.04 (3 H, s, CH_3); UV λ_{max} (EtOH) (ϵ) 238 (19 800), 337 (11 000), 413 (2570).

Anal. Calcd for $C_{20}H_{23}N_3O_4S \cdot C_6H_6$: C, 62.73; H, 5.91; N, 9.55. Found: C, 62.60; H, 5.89; N, 9.42.

An NMR spectrum and a chemical analysis of the crystals suggested 0.5 mol of benzene solvate/mol of **5a.**

Photolysis of 1a in C_6H_6. A solution of **1a** (30 mg) was irradiated for 25 min. After evaporation, the residue was chromatographed on silica gel with 4:1 $CHCl_3$–AcOEt as solvent. Concentration of the main yellow band eluate gave 24.5 mg (82%) of **5a** as a crude solid. Recrystallization from 1:1 C_6H_6–hexane afforded yellow needles which were identical with the compound produced by thermolysis of **1a.**

Thermolysis of 5a in C_6H_5Cl. A solution of **5a** (200 mg) in C_6H_5Cl (50 mL) was refluxed for 1 h. After cooling, the solution was concentrated under reduced pressure and chromatographed on silica gel with 5:1 C_6H_6–$CHCl_3$ as solvent to give two decomposition products: (1) 2,3,6,7-Tetrahydro-6,9-dimethyl-1*H*-pyrrolo[1,2-*a*]indole-5,8-dione (**7a**), 19.5 mg (19%). Recrystallization from 30% aqueous EtOH gave pale yellow needles; mp 130–131 °C; IR ν_{max} (KBr) 2960 (CH), 1660 (C=O), 1470, 1210, 1120, 1020 cm^{-1}; NMR ($CDCl_3$) δ 4.34 (2 H, t, J = 6 Hz, N-CH_2), 3.2–2.6 (7 H, m, CH_2 and CH), 2.30 (3 H, s, CH_3), 1.32 (3 H, d, J = 6 Hz, CH_3); UV λ_{max} (EtOH) (ϵ) 222 (11 700), 236 (12 100), 282 (8030), 333 nm (10 700); mass spectrum 217 (M^+). Anal. Calcd for $C_{13}H_{15}NO_2$: C, 71.86; H, 6.96; N, 6.45. Found: C, 71.82; H, 6.88; N, 6.45. (2) Orange needles, 24.7 mg (23%). This compound was identical with the pyrrolo[1,2-*a*]indoloquinone (**8a**).

Solvent Effects in the Thermolysis and Photolysis of Acetylaminoquinone Tosylhydrazones (1a–c). **1a–c** were decomposed under the reaction conditions described in Tables I and II. The products were separated on preparative TLC using 4:1 $CHCl_3$–AcOEt and the yields of the products were shown in Tables I and II. The properties of the benzoxazolines (**5b,c**) obtained in these reactions were as follows:

9-Acetyl-2,3,4,4a-tetrahydro-6-methyl-1*H*-pyrido[2,1-*b*]benzoxazol-8-ol tosylhydrazone (**5b**): pale yellow crystals; mp 146–147 °C dec; IR ν_{max} (KBr) 3300 (OH, NH), 2945, 1620 (C=N), 1590, 1460, 1235, 1130, 1080, 890 cm^{-1}; NMR (acetone-d_6) δ 9.80 (1 H, s, OH), 9.60 (1 H, br, NH), 7.86 (2 H, d, J = 8 Hz, Ar-H), 7.44 (2 H, d, J = 8 Hz, Ar-H), 6.24 (1 H, s, Ar-H), 5.00 (1 H, t, J = 4 Hz, oxazoline H), 2.60 (2 H, t, J = 5 Hz, N-CH_2), 2.42 (6 H, s, $2CH_3$), 2.08 (3 H, s, CH_3).

6-Acetyl-1,3,4,10a-tetrahydro-9-methyl[1,4]oxazino[3,4-*b*]benzoxazol-7-ol tosylhydrazone (**5c**): pale yellow crystals; mp 130–132 °C dec; IR ν_{max} (KBr) 3400 (OH), 3130 (NH), 1640 (C=N), 1160 cm^{-1}

(SO_2); NMR ($CDCl_3$) δ 10.5 (1 H, br, NH and OH), 7.88 (2 H, d, J = 8 Hz, Ar-H), 7.35 (2 H, d, J = 8 Hz, Ar-H), 6.48 (1 H, s, Ar-H), 4.84 (1 H, d, J = 2 Hz, J = 1 Hz, N-CH-O), 4.5–3.3 (6 H, m, CH_2), 2.52 (3 H, s, CH_3), 2.43 (3 H, s, CH_3), 2.21 (3 H, s, CH_3); UV λ_{max} (EtOH) (ϵ) 227 (16 100), 316 (10 100), 400 nm (4490).

Reduction of 1a with Sodium Hydrosulfite. To a solution of **1a** (100 mg) in $CHCl_3$ (20 mL) was added a solution of sodium hydrosulfite (350 mg) in H_2O with stirring. After 30 min, the red–purple mixture became colorless. The chloroform layer was dried over anhydrous Na_2SO_4 and evaporated to dryness. Recrystallization of the residual solid from C_6H_6 gave 62 mg (57%) of 3,6-dihydroxy-4-methyl-2-pyrrolidinoacetophenone tosylhydrazone (**9a**) as colorless crystals: mp 125–126 °C; IR ν_{max} (KBr) 3440 (OH), 3180 (NH), 2960 (CH), 1625 (C=N), 1600, 1160 (SO_2), 675 cm^{-1}; NMR (acetone-d_6) δ 9.0 (1 H, br, NH), 7.66 (2 H, d, J = 8 Hz, Ar-H), 7.24 (2 H, d, J = 8 Hz, Ar-H), 6.37 (1 H, s, Ar-H), 2.92 (6 H, m, 2OH, 2 CH_2), 2.34 (3 H, s, CH_3), 2.17 (3 H, s, CH_3), 2.09 (3 H, s, CH_3), 1.72 (4 H, m, 2 CH_2); UV λ_{max} (ϵ) 309 nm (5200). Anal. Calcd for $C_{20}H_{25}O_4N_3S \cdot C_6H_6$: C, 62.42; H, 6.38; N, 9.50. Found: C, 62.34; H, 6.41; N, 9.46.

From TLC analysis, this compound (**9a**) was not produced by thermolysis and photolysis of **1a**.

Reduction of 1b with Sodium Hydrosulfite. This reaction was carried out in the same procedure as described above. Recrystallization of the crude product gave 49 mg (49%) of 3,6-dihydroxy-4-methyl-2-piperidinoacetophenone tosylhydrazone (**9b**) as colorless crystals: mp 168 °C; IR ν_{max} (KBr) 3480 (OH), 3225 (NH), 2940 (CH), 1625 (C=N), 1600, 1165 (SO_2), 1090, 750, 715 cm^{-1}; NMR (acetone-d_6) δ 9.18 (1 H, br, NH), 7.70 (2 H, d, J = 8 Hz, Ar-H), 7.34 (2 H, br, 2OH), 7.24 (2 H, d, J = 8 Hz, Ar-H), 6.36 (1 H, s, Ar-H), 2.62 (4 H, br, $2CH_2$), 2.36 (3 H, s, CH_3), 2.18 (3 H, s, CH_3), 2.08 (3 H, s, CH_3), 1.46 (6 H, m, $3CH_2$).

Reduction of 1c with Sodium Hydrosulfite. This reaction was carried out in the same procedure as described above. Recrystallization of the crude product from C_6H_6 gave 55 mg (55%) of 3,6-dihydroxy-4-methyl-2-morpholinoacetophenone tosylhydrazone (**9c**) as colorless crystals: mp 205 °C dec; IR ν_{max} (KBr) 3450 (OH), 3250 (NH), 1620 (C=N), 1600, 1415, 1160 (SO_2), 1100, 870, 715 cm^{-1}; NMR (acetone-d_6) δ 9.4 (1 H, br, NH), 7.84 (2 H, d, J = 8 Hz, Ar-H), 7.40 (2 H, d, J = 8 Hz, Ar-H), 6.54 (1 H, s, Ar-H), 3.56 (4 H, t, J = 4 Hz, $2CH_2$), 2.88 (2 H, br, 2 OH), 2.73 (4 H, t, J = 4 Hz, $2CH_2$), 2.41 (3 H, s, CH_3), 2.25 (3 H, s, CH_3), 2.15 (3 H, s, CH_3).

As shown in Tables I and II, **9b** and **9c** were also obtained by thermolysis and photolysis of **1b** and **1c**, respectively.

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References and Notes

(1) Preliminary communication, M. Akiba, Y. Kosugi, and T. Takada, *Heterocycles*, **6**, 1125 (1977).
(2) More recently, the first total synthesis of the mitomycins has been reported in a brilliant synthetic route by F. Nakatsubo, A. J. Cocuzza, D. E. Keeley, and Y. Kishi, *J. Am. Chem. Soc.*, **99**, 4835 (1977); F. Nakatsubo, T. Fukuyama, A. J. Cocuzza, and Y. Kishi, *ibid.*, **99**, 8115 (1977); T. Fukuyama, F. Nakatsubo, A. J. Cocuzza, and Y. Kishi, *Tetrahedron Lett.*, 4295 (1977).
(3) T. Takada, Y. Kosugi, and M. Akiba, *Chem. Pharm. Bull.*, **25**, 259 (1977); **25**, 543 (1977).
(4) J. G. Berger, *Tetrahedron Lett.*, 393 (1972).
(5) S. Farid, *Chem. Commun.*, 73 (1971); C. M. Orlando, Jr., H. Mark, A. K. Bose, and M. S. Manhas, *J. Org. Chem.*, **33**, 2512 (1968); C. M. Orlando, Jr., H. Mark, A. K. Bose, and M. S. Manhas, *J. Am. Chem. Soc.*, **89**, 6527 (1967); D. W. Cameron and R. G. F. Giles, *J. Chem. Soc., C.*, 1461 (1968); J. M. Bruce, D. Creed, and K. Dawes, *J. Chem. Soc., C.*, 3749 (1971); R. G. F. Giles, *Tetrahedron Lett.*, 2253 (1972).
(6) J. Lynch and O. Meth-Cohn, *Tetrahedron Lett.*, 161 (1970).
(7) We have reported that the photolysis of the 2-amino-substituted 1,4-naphthoquinones having an active methylene group at the 3 position pointed to the formation of a zwitterion intermediate analogous to **4** followed by its intramolecular nucleophilic attack to give a number of heterocyclic quinones. M. Akiba, Y. Kosugi, M. Okuyama, and T. Takada, *J. Org. Chem.*, **43**, 181 (1978).
(8) K. J. Falci, R. W. Franck, and G. P. Smith, *J. Org. Chem.*, **42**, 3319 (1977).

Nuclear Magnetic Resonance Determination of Absolute Configuration and Enantiomeric Compositions of Chiral Oxaziridines Using Chiral Solvating Agents

William H. Pirkle* and Peter L. Rinaldi

The Roger Adams Laboratory, School of Chemical Sciences, University of Illinois, Urbana, Illinois 61801

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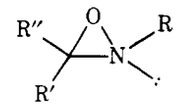
Simultaneous determinations of enantiomeric composition and absolute configuration of chiral oxaziridines (1) are possible by a convenient NMR–chiral solvating agent method. Addition of chiral fluoro alcohols such as 2,2,2-trifluoro-1-(9-anthryl)ethanol (**2a**) to 1 causes the enantiomers of 1 to have nonidentical NMR spectra. This spectral nonequivalence arises as a consequence of the formation of short-lived chelate-like diastereomeric solvates in which the stereochemical disposition of the oxaziridine substituents (with respect to the anthryl group of **2a**) causes the observed anisochronicity of the enantiotopic groups. Evidence is presented that the primary solvation interaction is hydroxyl hydrogen bonding at the ring nitrogen. Weaker carbinyl hydrogen bonding to the ring oxygen or, if present, to aryl ring substituents cis to the nitrogen lone pair of electrons completes the chelation. Coupled with knowledge of the absolute configuration of **2a**, the solvation models allow assignment of absolute configuration to a variety of oxaziridines from the observed "senses of nonequivalence". Enantiomeric compositions are determined by measuring relative intensities of the enantiotopic groups anisochronous resonances.

Oxaziridines (1) have recently received considerable attention as a consequence of the high barrier to inversion and asymmetry at the nitrogen center.[1] Since there are no known



1a, R′ = CH_3; R″ = H; R = *t*-Bu

stereoselective reactions of 1 so as to allow conversion to compounds of established stereochemistry, the first assignments of absolute configuration for oxaziridines were reported only recently on the basis of X-ray structure analysis.[2,3] Subsequently, a claim of configurational correlation with the sign of molecular rotation was made.[4]

We noted earlier that enantiomeric purity of oxaziridines can generally be determined by NMR, using chiral solvating

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