The Chemistry of 5,6,7,12-Tetrahydro-5,7-dioxo-*N*-phenyldibenz[*b*,*g*]azocine: A New Entry in the Dibenz[*b*,*g*]azocine Class

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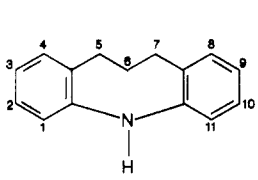
5,6,7,12-Tetrahydro-5,7-dioxo-*N*-phenyldibenz[*b*,*g*]azocine was isolated as a byproduct of the methylation of the sterically hindered 2,2′-dicarbomethoxytriphenylamine. The isolation, chemical and physical characterization and single-crystal X-ray structure of the title compound are described. The structure and properties for several derivatives are also reported.

The class of compounds known as dibenz[*b*,*g*]azocines has received little attention in the literature. To our knowledge, the only compound known in this class is due to Jacob and Fouche,[1-3] who synthesized 5,6,7,12-tetrahydrodibenz[*b*,*g*]azocine (**1**) via an intramolecular cyclocondensation reaction of 1,3-bis(2-aminophenyl)propane. Later, Kawashima et al. prepared the same compound by the reductive ring expansion of dibenz[*b*,*f*]cycloprop[*d*]-azepine.[4] We wish to report here the synthesis, characterization, and certain chemistry of several unusually strained derivatives of dibenz[*b*,*g*]azocine in which two sp^2-hybridized carbonyls are incorporated at C-5 and C-7 as depicted in **2**.



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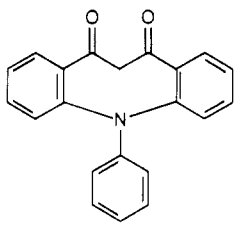

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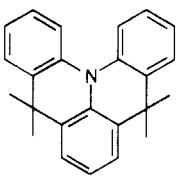

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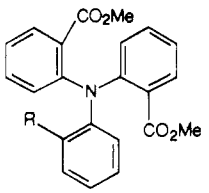
Results and Discussion

I. 5,6,7,12-Tetrahydro-5,7-dioxo-*N*-phenyldibenz-[*b*,*g*]azocine. (2). Isolation and Spectral Characterization. Our interest in the dibenz[*b*,*g*]azocine class of compounds resulted from attempts to improve the synthesis of the tetramethylquinacridine **3**[5] by methyl Grignard addition of the diester **4** followed by cyclodehydration of the resulting diol **6**. Thus, treatment of



4, R = H
5, R = CO_2Me

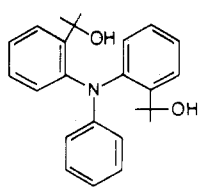


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Table I. Summary of Twist and Valence Angles and Opposite Bond Lengths for 2

twist angles between planes, deg			bond lengths, Å		opposite valence angles, deg	
BP[7]	A	65.6 (1)	N–C1	1.435	C15–N–C16	121.9
BP	B	83.1 (1)	N–C15	1.435	C1–N–C16	122.0
BP	C	11.1 (4)	N–C16	1.404	C1–N–C15	114.0

the diester **4** with 5 equiv of methylmagnesium bromide in THF gave the desired diol (**6**) in 69% yield.[6] The only other product isolable from the methyl Grignard reaction was found to have a molecular ion m/e = 313 by FDMS, which corresponded to a molecular formula of $C_{21}H_{15}NO_2$. However, the 270-MHz ^1H NMR spectrum showed only 13 aromatic protons. Furthermore, no hydroxyl groups were present by FTIR; the carbonyl singlet of the starting diester shifted from 1725 cm^{-1} to a doublet at 1665 and 1680 cm^{-1}.

The first essential clue necessary to solve the apparent contradiction between 270-MHz ^1H NMR data and the molecular formula came from NMR studies at 90 MHz. At room temperature, the NMR spectrum showed two broad bands at δ 3.7 and 4.7. At −40 °C, each band was refined to yield a doublet with a coupling constant of J = 15.5 Hz. Neither doublet was eliminated by D_2O exchange. The second clue was from the coupled ^{13}C NMR at 100 °C, which showed a triplet at δ 58.5 (J = 132 Hz), indicating the presence of a methylene carbon. Furthermore, only one carbonyl resonance was seen at δ 192.6, suggesting that the two carbonyl carbons must be identical. This combination of data led us to propose the structure **2**.

Single Crystal X-ray Crystallographic Analysis. To confirm the assignment, a single-crystal X-ray structure was obtained. Figure 1 in the supplementary material shows a plot of structure **2** with selected bond distances and angles. The eight-membered ring is in the boat configuration, which makes the molecule unsymmetrical. The nitrogen, while pyramidal, is flattened, being only 0.12 Å out of the basal plane.[7] By comparison, tri-*p*-tolylamine is 0.035 Å[8] out of the basal plane, and the nitrogen of tribenzylamine is approximately 0.5 Å out of its basal plane.[9] The comparatively short N–C bond length in the *N*-phenyl linkage suggests that π bonding is greatest between the lone pair of nitrogen and this unsubstituted aryl ring.[10] The small twist angle between the basal plane and

(1) Fouche, J. C. L. *Ind. Chim. Belg.* **1967**, 226; *Chem. Abstr.* **1969**, *70*, 68105p.
(2) Jacob, R. M.; Fouche, J. C. L. Br. Pat. 926 335, **1963**; *Chem. Abstr.* **1964**, *61*, P1843g.
(3) Fouche, J. C. L. Br. Pat. 983 859, **1965**.
(4) Kawashima, K.; Saraie, T.; Kawano, Y.; Ishiguro, T. *Chem. Pharm. Bull.* **1978**, 942.
(5) Hellwinkel, D.; Melan, M. *Chem. Ber.* **1971**, 1001.
(6) Fox, J. L.; Chen, C. H.; Stenberg, J. F. *OPPI* **1985**, 169.
(7) The basal plane is defined by the three N-bonded carbon atoms. Planes A, B, and C are defined in Figures 1 and 2 (supplementary material).
(8) Reynolds, S. L.; Scaringe, R. P. *Cryst. Struct. Commun.* **1982**, 1129.
(9) Iwasaki, F.; Iwasaki, H. *Acta Crystallogr., Sect. B B28*, 3370.
(10) The standard N–C single bond length is 1.45 Å: Burke-Laing, M.; Laing, M. *Acta Crystallogr., Sect. B* **1976**, *32*, 3216.

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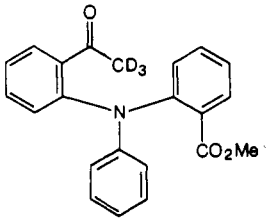
the plane of the aryl ring supports this conclusion.[9] These data are summarized in Table I.

Chemical Properties. The chemical properties of **2** are significantly influenced by the twisted boat conformation of the eight-membered ring. Presumably the reason the methylene protons cannot be exchanged with D_2O is that the process would require enolization and thus destabilization of the energetically favored boat conformation. Further, enolization would produce seven sp^2 centers in an eight-membered ring, forcing the ring into an almost planar and extremely strained configuration. Thus, when **2** was added to a refluxing solution of CH_3ONa/CH_3OD, only the trideuteriated reverse Claisen product (**7**) was observed; none of the starting diketone or the mono- or dideuteriated diketone was detected.[11] The diketone **2**



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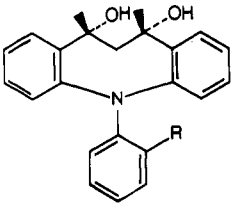
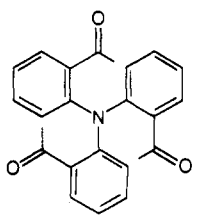


8, R = H
9, R = CO_2Me

does not react with BF_3 owing to the lack of enolization, but it readily forms a ditosylhydrazone derivative under standard conditions. When the purified diketone is treated with 2.15 equiv of methylmagnesium bromide, the diol **8** is formed in 72% recrystallized yield. Unlike its precursor **2**, the methylene protons are sharp doublets at room temperature. As expected, the chemical shifts of the methylene protons move upfield from δ 3.7 and 4.7 in the diketone to δ 2.4 and 3.5 in the diol.

The stereochemical assignment of the quarternary carbons in the diol was predicted on the observance of only one methyl resonance and one OH resonance in the ^1H NMR δ 1.5 and 3.2, respectively ($CDCl_3$). Only the *meso* stereochemical configuration would produce time-averaged equivalent methyl and hydroxyl groups. The *dl* isomer, on the other hand, should be asymmetrical, and nonequivalencies would be expected in the NMR signals.

II. 5,6,7,12-Tetrahydro-*N*-(2-carbomethoxyphenyl)-(*R*,*S*)-5,7-dihydroxy-5,7-dimethyldibenz[*b*,*g*]azocine (9). Isolation. In a reaction analogous to the methyl Grignard addition of **4**, tricarbomethoxytriphenylamine **5** yielded the diol **9** as the major product. Thus, when 8 equiv of methylmagnesium bromide was added dropwise to a THF solution of **5** at 40 °C, three products were isolated: the diol **9** (65%), the triketone **10** (4%), and the diketo alcohol **11** (9%). None of the desired triol was observed.



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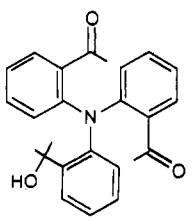

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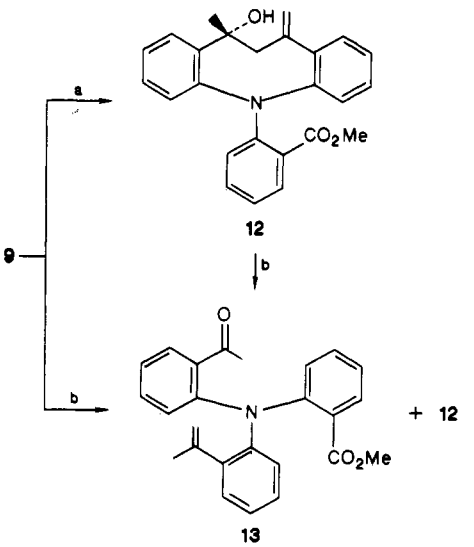
Single-Crystal X-ray Crystallographic Analysis. The X-ray structure of **9** in Figure 2 in the supplementary material demonstrates the meso configuration of the 5,7-diol. By comparison, the nitrogen atom in the diol is 0.21 Å out of the basal plane and is therefore more pyramidalized than the diketone **2**, which is only 0.12 Å out of the basal plane.

(11) By field desorption mass spectroscopy.

Table II. Summary of Twist and Valence Angles and Opposite Bond Lengths for 9

	twist angles between planes, deg		bond lengths, Å		opposite valence angles, deg	
BP[7]	A	85.1 (6)	N-C1	1.43	C15-N-C16	124
BP	B	64.0 (6)	N-C15	1.42	C1-N-C16	118
BP	C	14 (2)	N-C16	1.40	C1-N-C15	112

Scheme I[a]



[a] Reaction conditions: (a) $COCl_2/CH_2Cl_2$/room temperature; (b) neutral $Al_2O_3/Cl_2CHCHCl_2$/100 °C/1 h.

Table II summarizes the twist and valence angles of **9**. As demonstrated in the case of the diketone, the major contributor to the π stabilization of the nitrogen lone pair is ring C. The large twist angles for rings A and B suggest that lone pair stabilization is much less important than strain relief in the eight-membered ring.

Table III summarizes the comparative ^1H and ^{13}C NMR data for diols **8** and **9**. In both diols, the methylene protons are nonequivalent; even elevated temperatures fail to generate one signal. The methyl and hydroxyl groups in **8** are equivalent at 30 °C while the same groups are nonequivalent at the same temperature in the diol **9**. Only at elevated temperatures (100 °C) do the ^1H and ^{13}C signals coalesce. Since the only difference between the diols is the 2'-carbomethoxy of **9**, restricted free rotation of this moiety must cause nonequivalence of the methyl and hydroxyl NMR signals at 30 °C.

Chemical Properties. As previously discussed, the methylene protons in the diketone **2** are nonexchangeable because it is energetically prohibitive to form the endocyclic enol. For the same reason, dehydration of the diol **9** would be expected to form exocyclic rather than endocyclic ene products upon dehydration. Thus, when **9** was heated in 1,1,2,2-tetrachloroethane with neutral alumina at 100 °C for 3 h,[12] the exocyclic ene **12** and the cleavage product **13** were observed.

Treatment of **9** with phosgene under nonbasic conditions yielded not the expected cyclic carbonate but rather the

(12) Chen, C. H.; Reynolds, G. A.; Zumbulyadis, N.; Van Allan, J. A. *J. Heterocycl. Chem.* **1978**, 289.
(13) Programs were from: Structure Determination Package SDP-PLUS, VI.1; Enraf-Nonius Corp., Delft, Holland, 1983.

Table III. Comparison of Selected ^1H and ^{13}C NMR Data for Diols 8 and 9 in Me_2SO

	^1H NMR, δ (°C)			^{13}C NMR, δ (°C)		
	8 (30)	9 (100)	9 (30)	8 (30)	9 (100)	9 (30)
CH_2A	3.30	4.08	4.06	51.61	51.72	51.23
CH_2B	2.22	2.26	2.22	51.41	51.72	51.23
Me_1	1.35	1.48	1.67	36.02	35.40	36.72
Me_2	1.35	1.48	1.18	36.02	35.40	33.80
R_3COH_1	5.90	5.07	5.25	74.77	73.90	74.22
R_3COH_2	5.90	5.07	5.56	74.77	73.90	73.33
CO_2Me		2.92	3.12		51.10	51.23

dehydration product **12** in 77% yield. Treatment of the latter with neutral alumina in tetrachloroethane yielded the cleavage product **13** in 75% yield. These results are summarized in Scheme I.

Experimental Section

^1H NMR spectra were recorded on Varian EM-390 and Bruker WH 270-MHz spectrometers, with Me_4Si as internal standard. ^{13}C NMR spectra were recorded on a Bruker spectrometer at 67.89 MHz, with Me_4Si as internal standard; the multiplicity was determined by the off-resonance proton decoupling. Mass spectra were obtained on an AEI MS-30 mass spectrometer. Field-desorption mass spectra were recorded on a Varian MAT-731 spectrometer. Microanalyses were done by the Analytical Sciences Division, Kodak Research Laboratories. Melting points (uncorrected) were obtained on a Thomas-Hoover capillary melting-point apparatus. UV spectra were recorded on a Cary 17 spectrophotometer. Infrared spectra were recorded on Perkin-Elmer 137 and Beckman IR 4250 spectrophotometers.

5,6,7,12-Tetrahydro-5,7-dioxo-*N*-phenyldibenz[*b*,*g*]azocine (2). In a large run[6] using 75.11 g (0.028 M) of **4** and 358 mL (5 equiv) of methylmagnesium bromide in ether (2.9 M) in 800 mL of THF was isolated 48 g of **6**. The hexane mother liquors from the trituration of **6** were found to contain, by thin-layer chromatography (2:1 hexane/EtOAc), a mixture of **2** and **6**. Flash chromatography using 3:2 dichloromethane/cyclohexane eluted the diketone **2**. Recrystallization of **2** from ethanol yielded 16 g (25%) of **2** as pale yellow needles: mp 179–180 °C; field desorption mass spectrum, *m/e* 313 (M^+ for $C_{21}H_{15}NO_2$); FTIR (KBr) (carbonyl doublet) 1665 and 1680 cm^{-1}; ^1H NMR (90 MHz, $CDCl_3$, −40 °C) δ 3.7 (d, 1 H, CH_2, J = 15.5 Hz), 4.7 (d, 1 H, CH_2, J = 15.5 Hz), 6.6 (d, 2 H, Ar H), 6.85 (t, 1 H, Ar H), 7.15 (t, 2 H, Ar H), 7.4 (t, 2 H, Ar H), 7.5 (d, 2 H, Ar H), 7.65 (t, 2 H, Ar H), 7.9 (d, 2 H, Ar H); ^{13}C NMR (67.87 MHz, $C_2D_2Cl_4$, 100 °C, coupled) δ 58.5 (t, CH_2, J = 132.0 Hz), 195.6 (s, C=O). Anal. Calcd for $C_{21}H_{15}NO_2$: C, 80.5; H, 4.8; N, 4.5. Found: C, 80.4; H, 4.7; N, 4.4.

Ditosylhydrazone Derivative of 1. The ditosylhydrazone was prepared from **2** and 2 equiv of tosyl hydrazide by using standard procedures.[14] Recrystallization from ethanol produced colorless plates in 57% yield; field desorption mass spectrum, *m/e* 649 (M^+); mp 180–181 °C. Anal. Calcd for $C_{35}H_{31}N_5O_4S_2$: C, 64.7; H, 4.8; N, 10.8. Found: C, 64.9; H, 4.9; N, 10.6.

5,6,7,12-Tetrahydro-(*R*,*S*)-5,7-dihydroxy-5,7-dimethyl-*N*-phenyldibenz[*b*,*g*]azocine (8). To a 50-mL, three-necked, round-bottomed flask were added 20 mL of distilled THF and 260 mg (0.83 mmol) of the diketone **2**. The solution was cooled to −10 °C in an ice/acetone bath, and 0.7 mL of 3.1 M methylmagnesium bromide (2.15 equiv) in Et_2O was added dropwise. The solution was allowed to warm to room temperature overnight and was then quenched by slow addition of 2.5 mL of 1 N ammonium chloride solution. The phases were separated, and the aqueous phase was washed twice with 15 mL of Et_2O. The combined organic phases were washed with 10 mL of saturated sodium chloride solution. After the solution was dried (Na_2SO_4), the solvent was removed by rotary evaporation and the residue purified by flash chromatography (6:1 CH_2Cl_2/EtOAc; SiO_2, 1 × 12 in.) to yield, after recrystallization from hexane/toluene (7:2), 20 mg (72%) of **8** as pale yellow crystals; field desorption mass spectrum, *m/e* 345 (M^+); mp 176–178 °C; ^1H NMR ($CDCl_3$) δ 1.48 (s, 6 H), 2.40 (d, J = 15 Hz, 1 H), 3.20 (s, 2 H, OH), 3.56 (d, J = 15 Hz, 1 H), 6.51 (d, J = 8 Hz, 2 H), 6.76 (t, J = 8 Hz, 1 H), 7.15 (t, J = 8 Hz, 2 H), 7.30 (m, 6 H), 7.80 (dd, J = 6 and 3 Hz, 2 H). Anal. Calcd for $C_{23}H_{23}NO_2$: C, 80.0; H, 6.7; N, 4.1. Found: C, 79.9; H, 6.8; N, 4.0.

2-Carbomethoxy-2′-(trideuterioacetyl)triphenylamine (7). To a 15-mL flask under nitrogen were added 5 mL of methanol-d_1 and a small piece of sodium metal. After gas evolution ceased, 313 mg (1 mmol) of the diketone **2** in 3 mL of THF was added, and the resulting solution was refluxed for 48 h. After the mixture was allowed to cool to room temperature, three drops of 38% DCl in D_2O were added followed by rotary evaporation of the solvent. The residue was triturated with 30 mL hexane/toluene (2:1), the solvent decanted and rotary evaporated, and the resulting solid recrystallized from 10 mL of cyclohexane/hexane (1:1) to yield 245 mg (70%) of **7** as colorless plates; field desorption mass spectrum, *m/e* 348 (M^+ for $C_{32}H_{16}D_3NO_3$), 346, 347 (<3%); mp 149–151 °C; ^1H NMR ($CDCl_3$) δ 3.35 (s, 3), 6.8 (d, J = 8 Hz, 2), 6.9 (t, J = 8 Hz, 1), 7.06–7.2 (m, 6), 7.32–7.45 (m, 3), 7.6 (dd, J = 8 and 2 Hz, 1).

Reaction of 2,2′,2″-Nitrilotribenzoic Acid Trimethyl Ester (5) with Methylmagnesium Bromide. To a 250-mL, three-necked, round-bottomed flask equipped with reflux condenser, nitrogen inlet, temperature probe, 50-mL dropping funnel, and a stirring bar were added 150 mL THF and 5.05 g (12 mmol) of 2,2′,2″-nitrilotribenzoic acid trimethyl ester (**5**). The solution was warmed to 40 °C, and to it was added dropwise over 30 min 35.6 mL (96 mmol) of 2.7 M methylmagnesium bromide in Et_2O. After the addition was complete, the reaction mixture was heated at 50 °C for 6 h. The solution was cooled to 0 °C in an ice–water bath, and 50 mL of 2 N ammonium chloride solution was added over 30 min. The mixture was diluted with 100 mL of diethyl ether and 50 mL of water. The aqueous phase was extracted with three 50-mL portions of ether. The combined extracts were washed with 50 mL of saturated sodium chloride and dried ($MgSO_4$). The solvent was removed on a rotary evaporator and the remaining oil purified by flash chromatography (SiO_2, 1.5 × 18 in.) to yield three products.

1: **2,2′,2″-Triacetyltriphenylamine (10).** The first product was eluted with 19:1 CH_2Cl_2/EtOAc and recrystallized from 2:1 hexane/toluene to yield 180 mg (4%) of **10** as white needles; field desorption mass spectrum, *m/e* 371 (M^+); mp 165–168 °C; ^1H NMR ($CDCl_3$) δ 2.20 (s, 9 H), 7.02 (d, J = 8 Hz, 3 H), 7.11 (t, J = 8 Hz, 3 H), 7.35 (m, 6 H). Anal. Calcd for $C_{24}H_{21}NO_3$: C, 77.6; H, 5.7; N, 3.8. Found: C, 77.7; H, 5.7; N, 3.6.

2: **5,6,7,12-Tetrahydro-*N*-(2-carbomethoxyphenyl)-(*R*,*S*)-5,7-dihydroxy-5,7-dimethyldibenz[*b*,*g*]azocine (9).** The second component of the reaction mixture was also eluted with 19:1 CH_2Cl_2/EtOAc and recrystallized from 3:2 hexane/toluene to yield 3.13 g (64.7%) of **9** as white needles; field desorption mass spectrum, *m/e* 403 (M^+); mp 182–184 °C; ^1H NMR (Me_2SO-d_6) δ 1.17 (br s, 3 H), 1.66 (br s, 3 H), 2.23 (d, J = 15 Hz, 1 H), 3.09 (s, 3 H), 4.05 (d, J = 15 Hz 1 H), 5.25 (s, 1 H, OH), 5.54 (s, 1 H, OH), 6.42 (d, J = 8 Hz, 1 H), 6.80 (t, J = 8 Hz, 1 H), 7.0–7.3 (m, 8 H), 7.52 (br s, 1 H), 7.87 (br s, 1 H); FTIR (KBr) 3430, 1720, 1595, 1570, 1485, 1440, 1320, 1305, 1230, 1090, 755 cm^{-1}. Anal. Calcd for $C_{25}H_{25}NO_4$: C, 74.4; H, 6.2; N, 3.5. Found: C, 74.4; H, 6.1; N, 3.6.

3: **2,2′-Diacetyl-2″-(1-hydroxy-1-methylethyl)triphenylamine (11).** The last product was eluted with 4:1 CH_2Cl_2/EtOAc and was recrystallized from 2:1 hexane/toluene to yield 420 mg (9%) of **11**; field desorption mass spectrum, *m/e* 387 (M^+); mp 141–143 °C; ^1H NMR (Me_2SO-d_6, 100 °C) δ 1.28 (br s, 6 H), 2.06 (s, 3 H), 2.10 (s, 3 H), 5.22 (s, 1 H, OH), 6.56 (d, J = 8 Hz, 1 H), 6.9–7.5 (m, 11 H); FTIR (KBr) 3475, 2970, 1680, 1595, 1570, 1480,

(14) Fox, J. L.; Chen, C. H.; Luss, H. R. *J. Org. Chem.* **1986**, *51*, 3551.

1440, 1350, 1295, 1230, 760. Anal. Calcd for $C_{25}H_{25}NO_3$: C, 77.5; H, 6.5; N, 3.6 Found: C, 77.3; H, 6.6; N, 3.5.

5,6,7,12-Tetrahydro-*N*-(2-carbomethoxyphenyl)-5-hydroxy-5-methyl-7-methylenedibenz[*b*,*g*]azocine (12). To a 10-mL, round-bottomed flask under nitrogen were added 101 mg (0.25 mmol) of **9** and 3 mL of distilled CH_2Cl_2 (CaH_2). The solution was cooled to 0 °C and 250 μL (0.27 mmol) of 12.5% phosgene in toluene was added. The solution was allowed to warm to room temperature overnight. The solvent was removed by rotary evaporation and the residue purified by preparative thin-layer chromatography (5:1 cyclohexane/EtOAc; SiO_2, 0.5 mm × 20 cm × 20 cm) to yield, after recrystallization from 10:1 hexane/benzene, 83 mg (77%) of **12**; field desorption mass spectrum, *m/e* 385 (M^+); mp 147–148 °C; ^1H NMR ($CDCl_3$) δ 1.37 (s, 3 H), 2.39 (s, 1 H, OH), 2.74 (d, *J* = 13.5 Hz, 1 H), 3.21 (s, 3 H), 4.48 (dd, *J* = 13.5 and 1 Hz, 1 H), 5.06 (s, 1 H), 5.31 (s, 1 H), 6.37 (d, *J* = 7 Hz, 1 H), 6.85 (t, *J* = 7 Hz, 1 H), 7.0–7.5 (m, 9 H), 7.92 (dd, *J* = 8 and 2 Hz, 1 H); FTIR (KBr) 3420, 1725, 1615, 1595, 1570, 1480, 1440, 1320, 1230, 1080, 745 cm^{-1}. Anal. Calcd for $C_{25}H_{23}NO_3$: C, 77.9; H, 6.0; N, 3.6. Found: C, 77.7; H, 6.4; N, 3.5.

2-Acetyl-2′-carbomethoxy-2″-isopropenyltriphenylamine (13). (a) Preparation from 9. To a 25-mL flask equipped with a reflux condenser were added 120 mg (0.30 mmol) of **9**, 450 mg neutral alumina (activity grade Super I), and 10 mL of dry chloroform (4A sieves). The suspension was refluxed for 6 h and allowed to cool, and the alumina was removed by filtration through Celite. The solvent was removed by rotary evaporation and the residue purified by separation on a 1-mm Chromatotron plate (5:1:1 cyclohexane/CH_2Cl_2/EtOAc; SiO_2) to yield as the first fraction 80 mg (70%) of **13** as a yellow oil; field desorption mass spectrum, *m/e* 385 (M^+); ^1H NMR ($CDCl_3$) δ 1.82 (d, *J* = 5 Hz, 3 H), 2.18 (d, *J* = 23 Hz, 3 H), 3.30 (s, 3 H), 4.76 (dd, *J* = 12 and 2 Hz, 1 H), 4.82 (dd, *J* = 8 and 2 Hz, 1 H), 6.7–7.4 (m, 12 H); FTIR (KBr) 1720, 1690, 1635, 1595, 1485, 1445, 1320, 1295, 1240, 1095 cm^{-1}. Anal. Calcd for $C_{25}H_{23}NO_3$: C, 77.9; H, 6.0; N, 3.6. Found: C, 80.1; H, 6.0; N, 3.4.

The second fraction was eluted with the same solvent to yield 24 mg (21%) of **12**.

(b) Preparation from 12. To a 10-mL, round-bottomed flask equipped with a reflux condenser were added 116 mg (0.30 mmol) of **12**, 450 mg neutral alumina (activity grade Super I), and 10 mL dry chloroform (4A sieves). The suspension was refluxed for 6 h, allowed to cool and the alumina removed by filtration through Celite. The solvent was removed by rotary evaporation and the residue purified by separation on a 1-mm Chromatotron plate (5:1:1 cyclohexane/CH_2Cl_2/EtOAc; SiO_2) to yield 89 mg (75%) of **13** as a yellow oil.

Crystal Structure Determination of 2. A long, yellow needle crystal, grown from ethanol, was cut to size, mounted on a glass rod, and used for data collection on an Enraf-Nonius CAD4 diffractometer.[13] Pertinent crystallographic data are summarized in the supplementary material. The structure was solved by direct methods (MULTAN 11/82) and refined by the full-matrix least-squares method. Anisotropic thermal parameters for non-hydrogen atoms and isotropic thermal parameters for hydrogens were applied in the final cycles of refinement. An extinction correction (*g*), calculated in the form $= |F_c|(1 + gI_c)^{-1}$, was applied.

Crystal Structure Determination of 9. A clear, six-sided needle grown from 3:2 hexane/tolene was cut to size and mounted as above. See supplementary material for crystal data. This structure was also solved by direct methods, but the refinement was complicated by the presence of a disordered hexane solvent molecule. The molecules of **9** are joined around the sixfold axis by intermolecular hydrogen bonds (03····04, *d* = 2.91 (1) Å) forming a helix. The direction of the helix is dependent on the choice of space group. Efforts to distinguish between $P6_1$ and $P6_5$ via the anomalous scattering effect were unsuccessful so the structure was refined in $P6_1$. The cavity in the center of the helix (the 6_1 axis) accommodates a necessarily disordered hexane molecule (one/unit cell) whose presence was confirmed by ^1H NMR. This disorder could not easily be modeled and was excluded from the calculations. Only the phenyl and methylene hydrogens were visible in a difference electron density map or were unambiguously calculable so only these hydrogens were included in the refinement at calculated positions and riding on the parent carbon. All non-hydrogen atoms were refined with anisotropic thermal parameters. The largest peaks in the final difference electron density map (+0.75 e/Å^3 max) were in the cavity discussed above. Elsewhere, residual density was ±0.33 e/Å^3.

Registry No. **2**, 99233-89-3; **2** (ditosylhydrazone), 108561-05-3; **4**, 49785-64-0; **5**, 34069-90-4; **6**, 52066-61-2; **7**, 108561-07-5; **8**, 108561-06-4; **9**, 108561-08-6; **10**, 104014-57-5; **11**, 104014-59-7; **12**, 108561-09-7; **13**, 108561-10-0; MeMgBr, 75-16-1; phosgene, 75-44-5.

Supplementary Material Available: Tables of crystal data, positional and thermal parameters, bond distances and angles, and crystallographic Figure 1 for compound **2** and Figure 2 for compound **9** (16 pages). Ordering information is given on any current masthead page.

Nickel-Catalyzed Transformations of 2,1-Benzisoxazoles with Organozinc Reagents

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A novel transformation of 2,1-benzisoxazoles (anthranils) involving nitrogen–oxygen bond rupture with concomitant nitrogen–carbon bond formation by reaction with aryl-, methyl-, or 2-thienylzinc chlorides in the presence of nickel catalyst is described. The products of the reaction are *o*-(substituted-amino)benzaldehydes and benzophenones, precursors of a series of heterocyclic derivatives, including acridines, quinolones, and the novel 7-chloro-1,3-dihydro-1,5-diphenyl-2*H*-1,4-benzodiazepin-2-one (**21**).

In studying the potential agricultural utility of 2-(*o*-carboxyphenyl)benzothiazoles,[1] benzimidazoles,[2] and benzoxazoles,[2] we extended our work to the related 2,1-benzisoxazole (anthranil) ring system and specifically required the synthesis of 3-(*o*-carboxyphenyl)-5-phenylanthranil (**3**). Since the yield of **3** from a classical anthranil synthetic procedure was low, we investigated the introduction of the 5-phenyl group via a metal-catalyzed cross-coupling reaction, an efficient method useful for the synthesis of carbo-substituted heteroaromatic ring sys-

(1) Baum, J. S.; Chen, T. M. U.S. Pat. 4556411, 1985; *Chem. Abstr.* **1986**, *104*, 143970t.
(2) Baum, J. S.; Chen, T. M., U.S. Patent pending.

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