Sulfur Dioxide Extrusion from Substituted 1,3-Dihydro-1,3-diphenylthieno[3,4-b]quinoxaline 2,2-Dioxides. Substituted 6-Phenylbenzo[b]phenazines[1,2]

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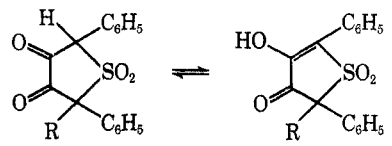
The extrusion of SO_2 from cis–trans mixtures of 5,8-dimethyl- (**4**), 5-methyl- (**5**), 5-methoxy- (**6**), 5-nitro- (**7**), 5-amino- (**8**), 1,3,5,8-tetramethyl- (**9**), and 1,5- (**10a**) and 1,8-dimethyl-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]-quinoxaline 2,2-dioxide (**10b**) by oxidative (alkaline hydrogen peroxide, oxygen, and peracetic acid) and reductive methods (Raney nickel and sodium borohydride) is reported. Thus, alkaline hydrogen peroxide oxidation of **4**, **5**, and **6** afforded, respectively, 2-benzoyl-3-benzyl-5,8-dimethylquinoxaline (**13**) and separable mixtures of 2-benzoyl-3-benzyl- (**14**) and 3-benzoyl-2-benzyl-5-methylquinoxaline (**15**) and 2-benzoyl-3-benzyl- (**16**) and 3-benzoyl-2-benzyl-5-methoxyquinoxaline (**17**). Similar oxidation of **8** and **10a–b**, respectively, gave mixtures of 2-benzoyl-3-benzyl- (**18**) and 3-benzoyl-2-benzyl-5-aminoquinoxaline (**19**), and 2-benzoyl-3-(α-methylbenzyl)- (**20**) and 3-benzoyl-2-(α-methylbenzyl)-5-methylquinoxaline (**21**). Diketones 5,8-dimethyl- (**26**), 5-methyl- (**27**), and 5-methoxy-2,3-dibenzoylquinoxalines (**28**) were obtained by direct oxygenation of **4**, **5**, and **6**, respectively, in KO-*tert*-Bu, *tert*-BuOH. Preformed peracetic acid oxidation of **4** and **5** afforded **13** and **14**, respectively. Oxidation of **5** with hydrogen peroxide in acetic acid gave 2-benzoyl-3-benzyl-5-methylquinoxaline 1-oxide (**24**), also obtainable by the further peracid oxidation of **14**. Raney nickel desulfurization of **4**, **5**, **6**, **8**, and **9** afforded 2,3-dibenzyl-5,8-dimethyl- (**31**), 2,3-dibenzyl-5-methyl- (**32**), 2,3-dibenzyl-5-methoxy- (**33**), 5-amino-2,3-dibenzyl- (**34**), and 5,8-dimethyl-2,3-di(α-methylbenzyl)quinoxaline (**35**). Sodium borohydride–methanol reduction was successful only with **4** and **5** affording, respectively, **31** and **32**. Cyclodehydration of **13**, **14**, **15**, and 2-benzoyl-3-(α-methylbenzyl)-5,8-dimethylquinoxaline (**22**) with concentrated sulfuric acid gave 1,4-dimethyl-6-phenyl- (**38**), 1-methyl-6-phenyl- (**39**), 1-methyl-11-phenyl- (**40**), and 1,4,11-trimethyl-6-phenylbenzo[*b*]phenazine (**45**), respectively. Similar cyclodehydration of the **16–17** mixture afforded the separable isomers 1-methoxy-6-phenyl- (**41**) and 1-methoxy-11-phenylbenzo[*b*]phenazine (**42**). $AlCl_3$ cleavage of **41** and **42** produced, respectively, 1-hydroxy-6-phenyl- (**43**) and 1-hydroxy-11-phenylbenzo-[*b*]phenazine (**44**). The results provide support for previously proposed mechanisms of SO_2 extrusion and cyclodehydration.

We recently reported on various oxidative and reductive methods of SO_2 extrusion from cis–trans mixtures of each of 1,3-diphenyl- (**1**), 1-methyl-1,3-diphenyl- (**2**), and 1,3-dimethyl-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-dioxide (**3**).[4] Thus, alkaline hydrogen peroxide oxidation of **1** and **2** afforded 2-benzoyl-3-benzyl- (**11**) and 2-benzoyl-3-(α-methylbenzyl)quinoxaline (**12**), respectively. Selenium dioxide/chromic acid oxidation of **11** converted it to 2,3-dibenzoylquinoxaline (**25**). Peroxy acid oxidation of **1** led to 2-benzoyl-3-benzylquinoxaline 1-oxide (**23**) *via* its isolable precursor **11**, while **2** afforded **12**. The site of the *N*-oxide function in **23** was based on an analysis of its nmr spectrum and by cyclodehydration with concentrated sulfuric acid to 6-phenylbenzo[*b*]phenazine 12-oxide (**46**). The C-1 and C-11 protons, peri to the *N*-oxide function, are deshielded[5] [relative to the remaining benzo[*b*]phenazine (δ 8.25–7.30) and phenyl protons (δ 7.60)] and appear at δ 8.66 and 9.35, respectively.[4] Similar aromatic cyclodehydration of **11** and **12** afforded 6-phenyl- (**36**) and 11-methyl-6-phenylbenzo[*b*]phenazine (**37**). The parent phenazine (**36**) and its *N*-oxide (**46**) were interconverted *via* oxidative and reductive techniques. Sulfur dioxide extrusion from **1** and **2** under reductive conditions was achieved with sodium borohydride in methanol to give 2,3-dibenzyl- (**29**) and 2-benzyl-3-(α-methylbenzyl)quinoxaline (**30**), respectively.

In this paper we conclude our study of this sulfone system with a report on the preparation of cis–trans mixtures of two (**4**, **9**) symmetrically and five (**5–8**, **10**) unsymmetrically substituted 1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-dioxides and their response to similar oxidative and reductive methods of SO_2 extrusion.

Syntheses and Structure.—Inseparable cis and trans mixtures of 5,8-dimethyl- (**4**, 41%), 5-methyl- (**5**, 87%), 5-methoxy- (**6**, 97%), 5-nitro- (**7**, 64%), and 5-amino-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-dioxide (**8**, 98%) were prepared by the condensation of the appropriate 3-substituted *o*-phenylenediamines and 2,5-diphenyl-3-keto-4-hydroxy-2,3-dihydrothiophene 1,1-dioxide (A).[6] Treatment of sulfone **4** with



A, R = H
B, R = CH_3

potassium *tert*-butoxide and excess methyl iodide afforded 1,3,5,8-tetramethyl-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-dioxide (**9**, 80%) also as a cis–trans mixture.

In our previous work, an nmr analysis of **3** clearly established it as a cis–trans mixture,[7] which by analogy

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(2) Presented before the Organic Division at the 153rd National Meeting of the American Chemical Society, Miami Beach, Fla., April 9–14, 1967; Abstract of Papers, O–100. From the Ph.D. Theses of T. E. Brady and R. E. Misner, Fordham University, 1968.

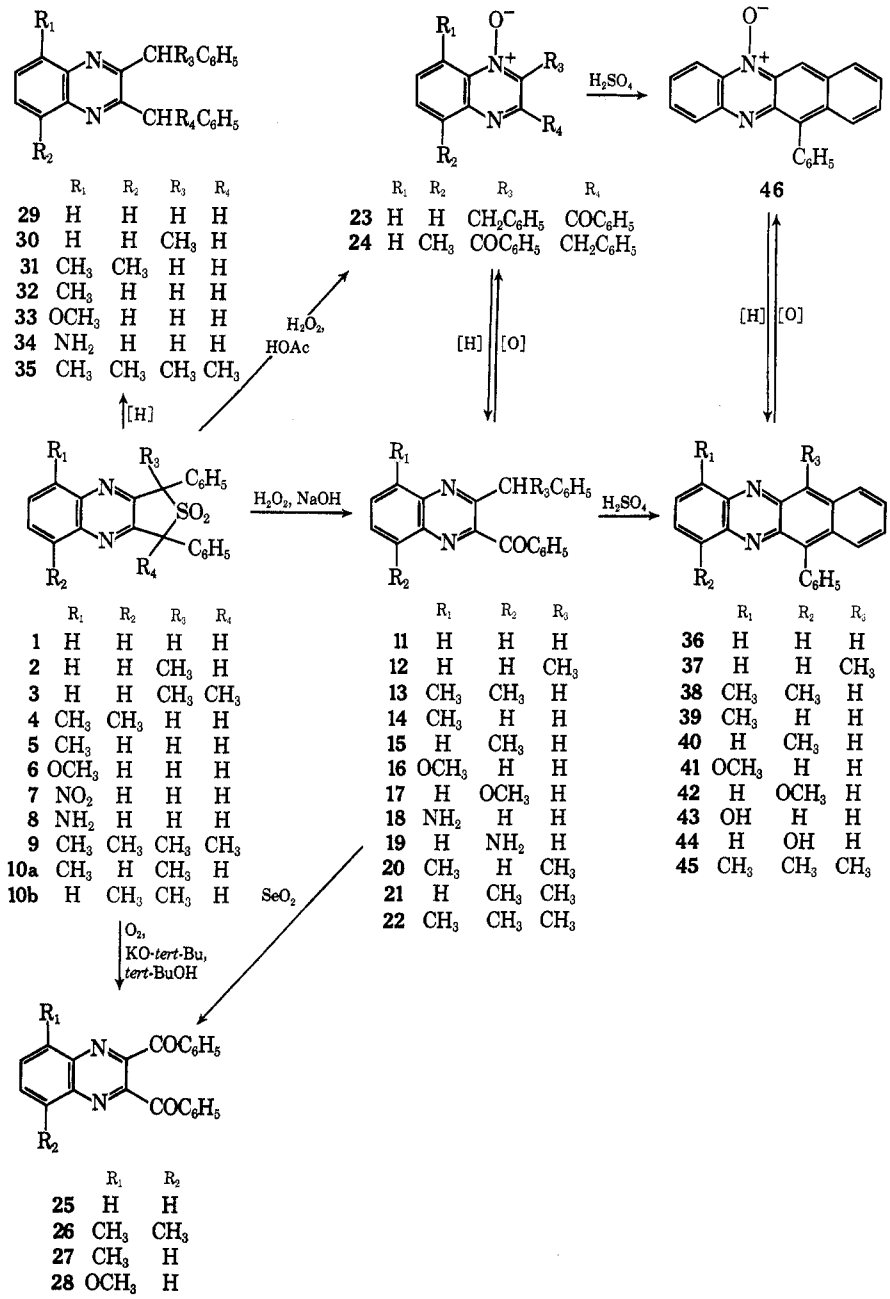
(3) Graduate Research Assistant, 1965–1968, on grants[1] supported by the NIH and WRAIR.

(4) E. J. Moriconi, R. E. Misner, and T. E. Brady, *J. Org. Chem.*, **34**, 1651 (1969).

(5) Y. Morita, *Chem. Pharm. Bull.*, **14**, 419 (1966).

(6) C. G. Overberger, S. P. Lighthelm, and E. A. Swire, *J. Amer. Chem. Soc.*, **72**, 2957 (1950).

(7) In the trans isomer the protons of each methyl group are in the shielding region of a phenyl substituent, while in the cis isomer each phenyl group shields the other.



was extended to the less soluble sulfones **1** and **2**. This general insolubility and high melting point with decomposition also characterized the sulfones **4–10** described herein. Although vigorous efforts were made to separate each cis–trans mixture, success was partially achieved only with the separation of the trans isomer (mp 238–240°) of **9** from the mixture (mp 208–213°). The nmr of the latter was analogous to the cis–trans mixture of **3**: two phenyl proton singlets at δ 7.28 (trans) and 7.00 (cis), and two α-methyl singlets at 2.19 (cis) and 2.06 (trans). Further, since the 5,8-methyl substituents in the cis isomer of **9** reside more in the deshielding plane of the 1,3-phenyl groups,[8] these protons appear at δ 2.78 in the nmr while the less deshielded protons of the same methyls in the trans isomer appear at δ 2.71.[8b] Although the ir and uv spectra of the mixture were almost identical with that of the pure trans isomer, the nmr of the latter displayed only a six-proton singlet at δ 2.71 for the 5,8-dimethyl substituents. Both *cis–trans* sulfone mixtures, **4** and **5**, showed the two anticipated signals ascribed to methyl protons on the quinoxaline ring,[8] while the nonequivalent benzylic protons appear in both as a singlet at δ 5.83.[9]

Finally, condensation of 2,3-diaminotoluene with 4-hydroxy-3-keto-2,5-diphenyl-2-methyl-2,3-dihydrothiophene 1,1-dioxide (B)[10] afforded 1,5- (**10a**) and 1,8-dimethyl-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-dioxide (**10b**) as inseparable cis–trans mixtures (four isomers) in 15% yield.

Oxidative Extrusion of SO_2.—Alkaline hydrogen peroxide oxidation of sulfone **4** afforded 2-benzoyl-3-benzyl-5,8-dimethylquinoxaline (**13**, 51%) which was

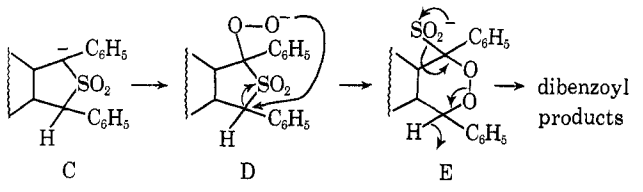
(8) (a) Dreiding models show that the phenyl groups in the cis isomer are rotationally restricted and this effect seems to be transmitted to the 5,8-quinoxaline methyls.[8b] (b) These long-range shielding effects have been observed in stilbenes [L. M. Jackman, "Applications of NMR Spectroscopy" Pergamon Press, New York, N.Y., 1959, p 126], 1,2-diphenylcyclopentanes [D. Y. Curtin, H. Gruen, and B. A. Shoulders, *Chem. Ind. (London)*, 1205 (1958)], and 1,3-diphenylisoindoles [L. A. Carpino, *J. Amer. Chem. Soc.*, **84**, 2196 (1962).

(9) Deshielded by three electronegative groups: SO_2, C_6H_5, and the quinoxaline ring.

(10) C. G. Overberger and J. M. Hoyt, *ibid.*, **73**, 3957 (1951).

further oxidized with selenium dioxide to the 2,3-dibenzoyl derivative (**26**, 68%). We have suggested that the extrusion of SO_2 from these sulfones commences with nucleophilic attack by the perhydroxyl anion on the α carbon of the sulfone.[4] The intermediacy of such an anion dictates an indiscriminate attack on both α carbons. Although symmetrical sulfones **1** and **4** expectedly afford single oxidation products, **11** and **13**, respectively, unsymmetrically substituted sulfones should yield two ketonic products in each case. This has now been realized with **5–8** and **10**. Thus, **5** led to a separable mixture (57%) of 2-benzoyl-3-benzyl- (**14**) and 3-benzoyl-2-benzyl-5-methylquinoxaline (**15**) (55:45 ratio, respectively), while **6** afforded a similar yield of 2-benzoyl-3-benzyl- (**16**) and 3-benzoyl-2-benzyl-5-methoxyquinoxaline (**17**). Decisive evidence for the isomeric nature of **14–15** and **16–17** was obtained from their nmr spectra, by aromatic cyclodehydration studies (*vide infra*), and by selenium dioxide oxidation of each mixture to single diketonic products, 2,3-dibenzoyl-5-methyl- (**27**) and 2,3-dibenzoyl-5-methoxyquinoxaline (**28**) in 86 and 87% yields, respectively. Similarly, alkaline hydrogen peroxide oxidation of **8** and **10a–b** afforded, respectively, 24% of 2-benzoyl-3-benzyl- (**18**) and 3-benzoyl-2-benzyl-5-aminoquinoxaline (**19**) and 35% (74:26 ratio) of 2-benzoyl-3-(α-methylbenzyl)- (**20**) and 3-benzoyl-2-(α-methylbenzyl)-5-methylquinoxaline (**21**). Ketone **20** was independently prepared by the alkylation of the anion of **14** with methyl iodide in DMSO. Similar treatment of **13** with sodium hydride and excess methyl iodide led to 2-benzoyl-3-(α-methylbenzyl)-5,8-dimethylquinoxaline (**22**, 52%).

Diketones **26** (33%), **27** (33%), and **28** (44%) were also prepared by direct oxygenation of sulfones **4**, **5**, and **6**, respectively, in solutions of KO-*tert*-Bu, *tert*-BuOH. In the former two cases, diketone precursors **13** (6%) and **14–15** (5%) could also be isolated. This reaction appears to be a precedented singlet oxygen oxidation of the generated carbanion C leading, *via* the hydroperoxide anion D, to peroxide E and ultimately to dibenzoyl products.[11] Hydride transfer (from E) to D could



C D E

initiate the ultimate formation of the benzoylbenzylquinoxaline by-products.

Oxidation of **5** with hydrogen peroxide in acetic acid also resulted in the extrusion of SO_2 to give the mono-*N*-oxide of **14**, 2-benzoyl-3-benzyl-5-methylquinoxaline 1-oxide (**24**, 33%). The consequences of a proton (C-8) peri to the anisotropic *N*-oxide linkage was again demonstrated by its appearance in the nmr at δ 8.33.[4,5] Treatment of **5** with preformed peracetic acid afforded the single product **14** which could be oxidized further to **24** (48%) with hydrogen peroxide in acetic acid and longer reaction times. Reduction of the latter with sodium hydrosulfite led to **14** (53%). Since indiscriminate attack by the peroxy molecule on both α carbons would have afforded both **14** and **15** as SO_2 extrusion products, the result supports our original mechanistic suggestion that the oxidation commences with coordination of the peroxy acid molecule to the less sterically hindered (*anti*)-quinoxaline nitrogen.[4]

Peracetic acid oxidation of **4** afforded **13** (28%),[12] while similar treatment of **6** and **7**[13] led to a complex mixture of products.[14] Sulfone **9** was unreactive to both alkaline hydrogen peroxide and peracetic acid oxidations.

Reductive Extrusion of SO_2.—The sodium borohydride–methanol reduction technique was successful only with sulfones **4** and **5**, affording the 2,3-dibenzyl-5,8-dimethyl- (**31**, 35%) and 2,3-dibenzyl-5-methylquinoxaline (**32**, 87%), respectively. Raney nickel desulfurization, however, worked with sulfones **4**, **5**, **6**, **8**, and **9**,[15] to give, respectively, **31** (59%), **32** (43%), 2,3-dibenzyl-5-methoxy- (**33**, 35%), 5-amino-2,3-dibenzyl- (**34**, 48%), and 5,8-dimethyl-2,3-di(α-methylbenzyl)quinoxaline (**35**, 47%), the last as a meso–*dl* mixture obtained from both the trans isomer and the cis–trans mixture of **9**.

6-Phenylbenzo[*b*]phenazines.—Cyclodehydration of **13** with concentrated sulfuric acid afforded 1,4-dimethyl-6-phenylbenzo[*b*]phenazine (**38**, 75%) whose nmr displayed a deshielded peri proton (R_3) at δ 8.85 and methyl protons at δ 2.90 and 2.57. The C-4 methyl protons are located in the diamagnetic shielding zone[16] of the virtually nonconjugated C-6 phenyl substituent[4] and appear 0.33 ppm upfield relative to the C-1 methyl protons.[17] Conclusive evidence for the low field assignment to the C-11 proton in **38** was obtained in the nmr spectrum of 1,4,11-trimethyl-6-phenylbenzo[*b*]phenazine (**45**) similarly prepared from **22** (60%). In **45**, the C-11 proton has been replaced by a methyl group and the effects that normally move the peri proton out of the aromatic envelope also deshield the C-11 methyl protons which now appear at δ 3.43. The 1- and 4-CH_3 protons appear at δ 2.86 and 2.50, respectively.

Cyclodehydration of **14** and **15** afforded 1-methyl-6-phenyl- (**39**, 54%) and 1-methyl-11-phenylbenzo[*b*]-

(11) R. Stewart, "Oxidation Mechanisms," W. A. Benjamin, New York, N.Y., 1964, p 122.

(12) The absence of any *N*-oxide products seems relevant here. The formation of quinoxaline mono- and di-*N*-oxides is markedly dependent on the degree and type of substitution on both carbocyclic and heterocyclic rings. 5-Substituted quinoxalines afford mono-*N*-oxides primarily and are resistant to further N oxidation: J. K. Landquist and G. J. Stacey, *J. Chem. Soc.*, 2822 (1953). Further, 5,8-dichloroquinoxaline has been prepared but its peroxy acid oxidation has not been observed: J. K. Landquist, *ibid.*, 2816 (1953). We have prepared, however, 5,8-dimethylquinoxaline and have converted it to the mono-*N*-oxide (12%) with peracetic acid under forcing conditions (see Experimental Section).

(13) Peracetic acid oxidation of **8** was not attempted since aromatic amino groups are known to be oxidized to nitro groups under such reaction conditions: W. D. Emmons, *J. Amer. Chem. Soc.*, **76**, 3470 (1954); **79**, 5528 (1957).

(14) A 10% yield of **28** could be isolated from the peracetic acid oxidation of **6**.

(15) The desulfurization of **7** over Raney Ni was unsuccessful since such nitro derivatives are known to effectively inhibit the catalytic process: H. Hauptmann, B. Wladislaw, L. Nazario, and W. Walter, *Justus Liebigs Ann. Chem.*, **576**, 45 (1952).

(16) T. H. Regan and J. B. Miller, *J. Org. Chem.*, **31**, 3053 (1966).

(17) The magnitude of the field about a benzene ring is such that appreciable effects may be observed for protons as far removed as 5–6 Å from the ring center.[8b] Dreiding models indicate the C-4 methyl protons are *ca.* 4 Å from the center of the C-6 phenyl ring. The reported shielding effect of a phenyl ring to an adjacent peri position ranges from 0.6 to 0.9 ppm.[18] There are no reported instances of a shielding effect over three fused rings, but its probability has been acknowledged.[8b]

(18) (a) T. H. Regan and J. B. Miller, *ibid.*, **32**, 593 (1967); (b) J. B. Miller, *ibid.*, **31**, 4082 (1966).

phenazine (**40**, 87%), respectively.[19a] The specific products formed verify the isomeric nature of **14** and **15** (fixing the position of the 2,3 substituents on the quinoxaline ring) and support a simple aromatic cyclodehydration mechanism for these conversions.[19b] Similarly, cyclodehydration of the **16–17** mixture afforded the separable isomers, 1-methoxy-6-phenyl- (**41**, 57%) and 1-methoxy-11-phenylbenzo[*b*]phenazine (**42**, 43%). Aluminum chloride cleavage of **41** and **42** produced 1-hydroxy-6-phenyl- (**43**, 53%) and 1-hydroxy-11-phenylbenzo[*b*]phenazine (**44**, 78%), respectively. The nmr of **41–44** all display deshielded peri protons, respectively, at δ 9.10 (C-11), 8.99 (C-6), 8.93 (C-11), and 8.91 (C-6). None of the new compounds reported herein showed any antimalarial activity in the primary mosquito and rodent screens.

Experimental Section[20]

cis- **and** *trans-***5,8-Dimethyl-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-Dioxide (4).**—A mixture of 2,3- and 2,5-dinitro-*p*-xylene[21] (15 g, 0.099 mol) in ethyl acetate was hydrogenated for 2 hr over 10% Pd/C in a Parr shaker. The solution was filtered and evaporated *in vacuo*. The residue (11.0 g, 82%) was used without further purification (*ca.* 65% of the 2,3 isomer.[21] The diamine mixture (7.15 g, 0.0053 mol) was refluxed with 14.3 g (0.0053 mol) of A[6] in 75 ml of absolute ethanol for 4 hr, after which it was cooled and filtered. The yellow filter cake was washed with ethyl ether to give 8.45 g (41%) of crude **4**. One recrystallization (Darco) from nitromethane gave pure **4** as a yellow powder: mp 239–240° dec; ir 7.53, 7.58, 8.53, 8.69, and 8.80 μ (SO_2); uv max (CH_3CN) 221 mμ (ϵ 28,200), 254 (41,400), and 327 (6100); nmr ($CDCl_3$) δ 7.54–7.23 (m, 24, aromatic), 5.83 (s, 4, CH), and 2.66 (s, 3, CH_3) and 2.61 (s, 3, CH_3).

Anal. Calcd for $C_{24}H_{20}N_2O_2S$: C, 71.97; H, 5.03; N, 6.99. Found: C, 72.01; H, 5.20; N, 7.00.

cis- **and** *trans-***5-Methyl-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-Dioxide (5).**—A solution of 12.5 g (0.042 mol) of A[6] in 70 ml of absolute ethanol and 5.0 g (0.042 mol) of 2,3-diaminotoluene in 30 ml of the same solvent was refluxed for 2 hr, cooled to room temperature, and filtered. The residue (14.0 g, 87%) was washed with ethyl ether and recrystallized (Darco) once from nitromethane to give **5** as a hard yellow powder: mp 230–230.5° dec; ir 7.54, 8.60, 8.78, and 8.86 μ (SO_2); uv max 220 mμ (ϵ 27,500), 244 (31,200), 304 (5800), and 320 (6900); nmr ($CDCl_3$) δ 8.0–7.2 (m, 14, aromatic), 5.83 (s, 4, CH), 2.71 (s, 3, CH_3), and 2.66 (s, 3, CH_3).

Anal. Calcd for $C_{23}H_{18}N_2O_2S$: C, 71.48; H, 4.69; N, 7.25. Found: C, 71.34; H, 4.88; N, 7.45.

cis- **and** *trans-***5-Methoxy-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-Dioxide (6).**—2,3-Dinitroanisole[22] (3.0 g, 0.015 mol) in ethyl acetate was hydrogenated over 10% Pd/C in a Paar apparatus. The mixture was filtered and the solvent was removed *in vacuo;* the residual oil was dissolved in 60 ml of absolute ethanol; and, after addition of 3.3 g (0.011 mol) of A,[6a] the solution was refluxed for 2 hr. The mixture was cooled to room temperature and filtered, and the residue was washed with ethyl ether to yield 4.3 g (97%) of crude **6**. One recrystallization (Darco) from nitromethane–ether afforded **6** as a yellow powder: mp 251.5–252° dec; ir 7.54, 8.57, and 8.80 μ (SO_2), 7.90 and 8.90 (OCH_3); uv max (CH_3CN) 221 mμ (ϵ 21,200), 261 (28,000), and 322 (3600).

Anal. Calcd for $C_{23}H_{18}N_2O_3S$: C, 68.64; H, 4.51; N, 6.96. Found: C, 68.51; H, 4.66; N, 7.13.

cis- **and** *trans-***5-nitro-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-dioxide (7)** (2.64 g, 64%) was prepared in a similar manner by refluxing (4 hr) 1.53 g (0.01 mol) of 3-nitro-*o*-phenylenediamine and A[6] (3.0 g, 0.01 mol) in 50 ml of glacial acetic acid. It was obtained as an orange powder: mp 280–281° dec (from nitromethane, Darco); ir 7.68 and 8.91 μ (SO_2), 6.52 and 7.44 (NO_2); uv max (CH_3CN) 218 mμ (ϵ 25,000), 282 (23,300), and 355 (960).

Anal. Calcd for $C_{22}H_{15}N_3O_4S$: C, 63.30; H, 3.62; N, 10.06. Found: C, 63.24; H, 3.71; N, 10.04.

cis- **and** *trans-***5-Amino-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-Dioxide (8).**—A mixture of 4.2 g (0.027 mol) of 3-nitro-*o*-phenylenediamine and 10% Pd/C in ethyl acetate was hydrogenated on a Parr apparatus until hydrogen uptake ceased. The catalyst was filtered and the solvent was removed *in vacuo*. The crude triamine in 100 ml of absolute ethanol and 6.6 g (0.022 mol, assuming 80% hydrogenation) of A[6] were then refluxed for 4 hr. The solution was cooled to room temperature, filtered, and washed with several volumes of ethyl ether to give 7.2 g (98%) of crude **8**. One recrystallization (Darco) from nitromethane afforded pure **8** as yellow needles: mp 265–266° dec; ir 2.90 and 2.98 μ (NH_2), 7.59 and 8.88 (SO_2); uv max 219 mμ (ϵ 27,000) and 282 (26,200).

Anal. Calcd for $C_{22}H_{17}N_3O_2S$: C, 68.24; H, 4.92; N, 10.79. Found: C, 68.08; H, 4.68; N, 10.71.

cis- **and** *trans-***1,3,5,8-Tetramethyl-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-Dioxide (9).**—A suspension of 2.0 g (0.005 mol) of **4** and 1.12 g (0.01 mol) of potassium *tert*-butoxide in 50 ml of anhydrous *tert*-BuOH was refluxed for 1 hr under N_2. After cooling to room temperature and the addition of 3.0 g (0.024 mol) of CH_3I, the mixture was again refluxed for 3 hr. The solution was then poured into H_2O and extracted several times with Et_2O. The combined ether extracts were washed with 10% HCl solution and the organic phase was dried (Na_2SO_4) and filtered. After removal of the Et_2O solvent *in vacuo*, the residue was deposited on a 2.5 × 25 cm Florisil column. Successive elution with 1:1 CH_2Cl_2–CCl_4 and CH_2Cl_2 afforded ultimately 1.7 g (80%) of a sulfone mixture. This solid was treated with 95% EtOH leaving 0.40 g of insoluble material.

The ethanol solution was charcoaled (Darco), filtered, and, upon addition of water, precipitated the cis–trans mixture of **9** as white needles: mp 208–213°; nmr ($CDCl_3$) δ 7.55 (s, 4, C-6,7 protons), 7.28 (s, 10, C_6H_5), 7.00 (s, 10, aromatic), 2.81 (s, 6, C-5,8 CH_3), 2.71 (s, 6, C-5,8 CH_3), 2.19 (s, 6, C-1,3 CH_3), and 2.06 (s, 6, C-1,3 CH_3).

Anal. Calcd for $C_{26}H_{24}N_2O_2S$: C, 72.87; H, 5.64; N, 6.54. Found: C, 72.61; H, 5.64; N, 6.73.

The ethanol insoluble material was recrystallized from CH_2Cl_2–hexane (Darco) to give the *trans*-**9** isomer: mp 238–240°; nmr ($CDCl_3$) δ 7.58 (s, 2, C-6,7 protons), 7.31 (s, 10, C_6H_5), 2.71 (s, 6, C-5,8 CH_3), and 2.09 (s, 6, C-1,3 CH_3).

Anal. Found: C, 72.65; H, 5.90; N, 6.56.

The ir for the cis–trans mixture and the trans isomer of **9** are similar while the uv are identical: ir 7.60 and 8.70 μ (SO_2); uv max 216 mμ (ϵ 37,700), 253 (71,900), and 327 (11,400).

cis- **and** *trans-***1,5-Dimethyl- (10a) and** *cis-* **and** *trans-***1,8-Dimethyl-1,3-diphenyl-1,3-dihydrothieno[3,4-*b*]quinoxaline 2,2-Dioxide (10b).**—A solution of 2,3-diaminotoluene (1.22 g, 0.01 mol) and B[10] (3.14 g, 0.01 mol) in 25 ml of glacial acetic acid was refluxed for 6 hr. The solution was cooled and poured into H_2O, and the whole mixture was extracted with Et_2O. The combined ether extracts were washed successively with H_2O and dilute $NaHCO_3$ solution, dried ($MgSO_4$), and filtered. Concentration of the filtrate accompanied by the addition of hexane afforded 0.60 g (15%) of crude **10a–b**. Recrystallization (Darco) from Et_2O gave **10a–b** as small yellow clumps: mp 203–205°; ir 7.60, 8.72, and 8.91 μ (SO_2); uv max 220 mμ (ϵ 23,600), 247 (36,800), and 327 (6800); nmr ($CDCl_3$) δ 8.05–7.15 (m, 26, aromatic), 5.60 (s, 2, CH), 2.83 (s, 3, C-5/8 CH_3), 2.68 (s, 3, C-8/5 CH_3), 2.38 (s, 3, C-1 CH_3), and 2.31 (s, 3, C-1 CH_3).

Anal. Calcd for $C_{24}H_{20}N_2O_2S$: C, 71.98; H, 5.03; N, 6.99. Found: C, 71.76; H, 5.26; N, 6.87.

Alkaline Hydrogen Peroxide Oxidation.—The general procedure used was as follows. To 1.0 g of the sulfone suspended in 20 ml of 95% EtOH was added 5 ml of 30% H_2O_2. The mixture was warmed (steam bath) and 5 ml of 10% NaOH was added slowly. The reaction mixture was then heated until the vigorous reaction subsided. The cooled mixture was then diluted with

(19) (a) Cyclodehydration of the **14–15** mixture led to a separable mixture of **39** (32%) and **40** (39%). (b) C. K. Bradsher, *Chem. Rev.*, **38**, 447 (1946).

(20) (a) Melting points were taken on a Koffler hot-stage apparatus and are corrected; (b) the infrared spectra were obtained on a Perkin-Elmer Model 337 grating spectrophotometer using KBr wafers unless otherwise stated; (c) the ultraviolet spectra were recorded in 95% ethanol solution, unless otherwise stated, on a Cary Model 15 dual-beam recording spectrophotometer; (d) unless otherwise stated, the nmr spectra were obtained on a Varian A-60 spectrometer using dilute solutions (*ca.* 100 mg/ml) and chemical shifts are reported in ppm downfield from tetramethylsilane.

(21) K. A. Kobe and T. B. Hudson, *Ind. Eng. Chem.*, **42**, 356 (1953).

(22) D. L. Vivian, G. Y. Greenburg, and S. L. Hartwell, *J. Org. Chem.*, **16**, 1 (1951).

H_2O and extracted with several equal volumes of 30–60° petroleum ether. The organic layer was dried (Na_2SO_4), filtered, concentrated on a steam bath, and cooled to give product. Any variations in product isolation procedures are noted.

Sulfone **4** (0.0025 mol) gave 0.45 g (51%) of **2-benzoyl-3-benzyl-5,8-dimethylquinoxaline** (**13**) as white needles, mp 111–112° (from 95% EtOH, Darco). The product was obtained directly after the addition of H_2O and no petroleum ether extraction was required: ir 5.99 μ (C=O); uv max 251 mu (ε 31,300), 259 (33,500), and 323 (7100); nmr ($CDCl_3$) δ 7.89–6.96 (m, 12, aromatic), 4.55 (s, 2, CH_2), 2.77 (s, 3, C-5 CH_3), and 2.58 (s, 3, C-8 CH_3).

Anal. Calcd for $C_{24}H_{20}N_2O$: C, 81.79; H, 5.72; N, 7.95. Found: C, 81.91; H, 5.84; N, 8.23.

Sulfone **5** (0.0026 mol) gave 0.55 g (57%) of a mixture of **2-benzoyl-3-benzyl-** (**14**) and **3-benzoyl-2-benzyl-5-methylquinoxaline** (**15**) as white needles: mp 94–99° (from 30–60° petroleum ether, Darco); ir 6.00 μ (C=O); uv max 245 mμ (ε 38,500), 253 (41,200), and 322 (11,500); nmr ($CDCl_3$) δ 7.90–7.00 (m, 26, aromatic), 4.52 and 4.50 (superimposed singlets, 4, CH_2), 2.81 (s, 3, CH_3), and 2.62 (s, 3, CH_3).

Anal. Calcd for $C_{23}H_{18}N_2O$: C, 81.63; H, 5.36; N, 8.28. Found: C, 81.81; H, 5.36; N, 8.36.

Careful fractional crystallization from 30–60° petroleum ether separated the two components of the mixture. Component **14** was obtained as white needles: mp 121–123°; ir 6.00 μ (C=O); uv max 249 mμ (ε 31,800), 254 (33,500), and 322 (8100); nmr ($CDCl_3$) δ 7.8–7.0 (m, 13, aromatic), 4.50 (s, 2, CH_2), and 2.82 (s, 3, CH_3).

Anal. Found: C, 81.83; H, 5.45; N, 8.44.

Component **15** was obtained as light yellow needles: mp 103–105°; ir 6.02 μ (C=O); uv max 244 mμ (ε 41,000), 254 (46,700), and 319 (12,850); nmr ($CDCl_3$) δ 7.95–6.95 (m, 13, aromatic), 4.54 (s, 2, CH_2), and 2.62 (s, 3, CH_3).

Anal. Found: C, 81.74; H, 5.51; N, 8.40.

Sulfone **6** (2.0 g, 0.0048 mol) gave 1.0 g (57%) of a mixture of **2-benzoyl-3-benzyl-** (**16**) and **3-benzoyl-2-benzyl-5-methoxyquinoxaline** (**17**), using Et_2O as the extractant: white needles, mp 124–127° (from CH_3OH, Darco); ir 6.01 μ (C=O); uv max 262 mμ (ε 30,100) and 323 (3100); nmr ($CDCl_3$) δ 7.80–7.10 (m, 26, aromatic), 4.68 (s, 2, CH_2), 4.54 (s, 2, CH_2), 4.16 (s, 3, CH_3), and 3.99 (s, 3, CH_3).

Anal. Calcd for $C_{23}H_{18}N_2O_2$: C, 77.95; H, 5.12; N, 7.90. Found: C, 78.22; H, 5.19; N, 7.95.

Sulfone **8** (0.0026 mol) gave 0.21 g (24%) of a mixture of **2-benzoyl-3-benzyl-** (**18**) and **3-benzoyl-2-benzyl-5-aminoquinoxaline** (**19**), using Et_2O as the extractant. The analytical sample was prepared by chromatography over Florisil, using 1:1 Et_2O–hexane as eluent. One recrystallization of the chromatographed material from aqueous EtOH gave the **18–19** mixture as yellow needles: mp 93.5–94.5°; ir 2.91 and 2.97 μ (NH_2), 5.98 (C=O); uv max 240 mμ (ε 21,700) and 281 (37,300); nmr ($CDCl_3$) δ 7.90–6.80 (m, 26, aromatic), 4.86–4.50 (m, 4, NH_2), 4.55 (s, 2, CH_2), and 4.46 (s, 2, CH_2).

Anal. Calcd for $C_{22}H_{17}N_3O$: C, 77.86; H, 5.05; N, 12.38. Found: C, 77.78; H, 5.06; N, 12.22.

Sulfone mixture **10a–b** (0.85 g, 0.021 mol) gave 0.26 g (35%) of a mixture of **2-benzoyl-3-(α-methylbenzyl)-** (**20**) and **3-benzoyl-2-(α-methylbenzyl)-5-methylquinoxaline** (**21**), using Et_2O as the extractant: white needles; mp 102–104° (from CH_3OH, Darco); ir 6.00 μ (C=O); uv max 252 mμ (ε 30,100) and 322 (7100); nmr ($CDCl_3$) δ 7.97–7.00 (m, 26, aromatic), 4.89 (q, 2, J = 7 Hz, CH), 2.91 (s, 3, CH_3), 2.65 (s, 3, CH_3), and 1.86 (d, 6, J = 7 Hz, α-CH_3).

Anal. Calcd for $C_{24}H_{20}N_2O$: C, 81.79; H, 5.72; N, 7.95. Found: C, 81.91; H, 5.69; N, 7.81.

2-Benzoyl-3-(α-methylbenzyl)-5-methylquinoxaline (**20**).—To a solution of 0.34 g (0.008 mol) of NaH (57% mineral oil dispersion) in 10 ml of dry DMSO was added, with cooling and under N_2, 1.2 g (0.0036 mol) of **14** in 20 ml of dry DMSO. After stirring at room temperature for 15 min, 1.8 g (0.014 mol) of CH_3I was added and whole mixture was stirred for an additional 16 hr. The solution was poured into H_2O, extracted with several volumes of pentane, dried (Na_2SO_4), and filtered. After reduction of the filtrate volume on a steam bath, cooling gave 0.60 g (46%) of **20**. An analytical sample was prepared by chromatography (twice) over Florisil (2.5 × 25 cm column, 1:1 CH_2Cl_2–CCl_4 eluent) followed by recrystallization (Darco) from CH_3OH: white needles; mp 110–112°; ir 5.99 μ (C=O); uv max 252 mμ (ε 35,400) and 323 (8800); nmr ($CDCl_3$) δ 7.97–6.93 (m, 13, aromatic), 4.83 (q, 1, J = 7 Hz, CH), 2.88 (s, 3, C-5 CH_3), and 1.85 (d, 3, J = 7 Hz, α-CH_3).

Anal. Calcd for $C_{24}H_{20}N_2O$: C, 81.79; H, 5.72; N, 7.95. Found: C, 81.94; H, 6.01; N, 7.92.

2-Benzoyl-3-(α-methylbenzyl)-5,8-dimethylquinoxaline (**22**).—Similar treatment of 0.34 g (0.008 mol) of NaH in 10 ml of DMSO, 1.3 g (0.0037 mol) of **13**, and 1.8 g (0.014 mol) of CH_3I to the point of addition of the reaction mixture to water, precipitated crude **22**. It was filtered, air-dried, and chromatographed (2.5 × 25 cm column packed with Woelm alumina (neutral activity I) using increasing amounts of $CHCl_3$ in CH_2Cl_2 as eluent. Evaporation of the solvent led to 0.70 g (52%) of **22** as white needles: mp 129–130° (from CH_3OH, Darco); ir 6.00 μ (C=O); uv max 257 mμ (ε 34,100) and 325 (7200); nmr ($CDCl_3$) δ 7.90–7.00 (m, 12, aromatic), 4.91 (q, 1, J = 7 Hz, CH_3, 2.86 (s, 3, C-5 CH_3), 2.61 (s, 3, C-8 CH_3), and 1.86 (d, 3, J = 7 Hz, α-CH_3).

Anal. Calcd for $C_{25}H_{20}N_2O$: C, 81.94; H, 6.05; N, 7.64. Found: C, 82.25; H, 6.28; N, 7.46.

Selenium Dioxide Oxidation.—The general procedure used was as follows. The product mixture was dissolved in 10–15 ml of glacial acetic acid to which was added freshly sublimed SeO_2. The mixture was refluxed 6 hr, after which the precipitated selenium was filtered from the hot solution. Chilling of the filtrate sufficed to precipitate **26**; a few drops of H_2O caused crystallization of diketone **27** while sufficient H_2O was added to the reaction mixture to precipitate **28**.

Thus 0.50 g (0.0014 mol) of **13** and 0.17 g (0.0016 mol) of SeO_2 gave 0.40 g (68%) of **2,3-dibenzoyl-5,8-dimethylquinoxaline** (**26**) as pale green plates: mp 183–184° (from acetic acid, Darco); ir 6.00 and 6.02 μ (C=O); uv max 276 mμ (ε 51,900) and 322 (5650) nmr ($CDCl_3$) δ 8.30–8.10 (m, 2, C-6,7 protons), 7.80–7.39 (m, 10, C_6H_5), and 2.75 (s, 6, CH_3).

Anal. Calcd for $C_{24}H_{18}N_2O_2$: C, 78.67; H, 4.95; N, 7.64. Found: C, 78.86; H, 4.72; N, 7.78.

Similarly, 0.50 g (0.0015 mol) of the **14–15** mixture or **14** alone with 0.16 g (0.0015 mol) of SeO_2 afforded 0.45 g (86%) of **2,3-dibenzoyl-5-methylquinoxaline** (**27**) as pale green needles: mp 168–169° (from CH_3OH, Darco); ir 5.98 and 6.08 μ (C=O); uv max 267 mμ (ε 48,600) and 320 (6700); nmr ($CDCl_3$) δ 8.27–7.46 (m, 13, aromatic) and 2.78 (s, 3, CH_3).

Anal. Calcd for $C_{23}H_{16}N_2O_2$: C, 78.39; H, 4.57; N, 7.95. Found: C, 78.16; H, 4.57; N, 7.78.

Finally, 0.50 g (0.0014 mol) of the **16–17** mixture and 0.17 g (0.0015 mol) of SeO_2 gave 0.45 g (87%) of **2,3-dibenzoyl-5-methoxyquinoxaline** (**28**) as pale yellow plates: mp 168–169°; ir 6.00 and 6.06 μ (C=O); uv max 248 mμ (ε 22,800) and 280 (37,100); nmr ($CDCl_3$) δ 8.25–8.00 (m, 3, C-6,7,8 protons), 7.80–7.10 (m, 10, C_6H_5), and 4.01 (s, 3, OCH_3).

Anal. Calcd for $C_{23}H_{16}N_2O_3$: C, 74.99; H, 4.38; N, 7.60. Found: C, 74.83; H, 4.49; N, 7.59.

Oxygen Oxidation.—The general procedure used was as follows. The sulfone was suspended in 50 ml of dry *tert*-BuOH to which was added 0.5 g (0.0045 mol) of solid KO-*tert*-Bu at once. The temperature was brought to 50–55° and a stream of O_2 was bubbled into the mixture for 3 hr. The mixture was poured into H_2O and extracted with Et_2O; the combined ether extracts were washed with 10% HCl, dried (Na_2SO_4), and filtered, and the filtrate was evaporated to dryness *in vacuo*. The oily residue was chromatographed over a 2.5 × 25 cm silica gel column.

Thus, 1.0 g (0.0025 mol) of **4** gave 0.05 g (6%) of **13** and 0.30 g (33%) of **26**, using CH_2Cl_2 and $CHCl_3$ as eluents. Similarly 1.0 g (0.0026 mol) of **5** afforded 0.04 g (5%) of **14–15** and 0.30 g (33%) of **27** using 1:1 CH_2Cl_2–CCl_4 as eluent. Finally, 1.0 g (0.0024 mol) of **6** gave 0.40 g (44%) of **28**, using $CHCl_3$ as eluent.

Peracetic Acid Oxidation of 5.—A mixture of 1.0 g (0.0026 mol) of **5** in 20 ml of glacial HOAc and 10 ml of 30% H_2O_2 was stirred at 50–60° for 16 hr. The solution was added to H_2O and the whole mixture was extracted with Et_2O. The combined ether extracts were washed successively with H_2O and dilute $NaHCO_3$, dried (Na_2SO_4), filtered, and evaporated *in vacuo*. The thick residue was recrystallized twice from 95% EtOH (Darco) to give 0.30 g (33%) of **2-benzoyl-3-benzyl-5-methylquinoxaline 1-oxide** (**24**) as pale yellow cubes: mp 169–171°; ir 6.00 μ (C=O); uv max 252 mμ (ε 44,200), 312 (10,250), and 322 (10,950); nmr ($CDCl_3$) δ 8.33 (m, 1, C-8 proton), 7.71–6.97 (m, 12, aromatic), 4.23 (s, 2, CH_2), and 2.82 (s, 3, CH_3).

Anal. Calcd for $C_{23}H_{18}N_2O_2$: C, 77.95; H, 5.12; N, 7.90. Found: C, 77.72; H, 5.17; N, 7.67.

Alternatively, a suspension of **5** (1.0 g, 0.0026 mol) in 25 ml of $CHCl_3$ and 5 ml (0.026 mol) of 40% CH_3CO_3H was refluxed for

16 hr. After cooling to room temperature, the solution was diluted with $CHCl_3$, washed several times with H_2O, dried (Na_2SO_4), and filtered. After evaporation of the filtrate *in vacuo*, the residue was successively recrystallized from 95% EtOH and 30–60° petroleum ether (Darco) to give 0.60 g (65%) of **14**.

Further oxidation of 0.80 g (0.0024 mol) of **14** in 25 ml of glacial HOAc with 10 ml of 30% H_2O_2 (50 hr at 50–60°) ultimately afforded 48% of **24**.

Reduction of **24** (0.40 g, 0.0011 mol) dissolved in 25 ml of 80% EtOH with 0.21 g (0.0012 mol) of sodium hydrosulfite ultimately gave 53% of **14**.

Peracetic Acid Oxidation of 4.—Similar oxidation of **4** (1.0 g, 0.0025 mol) suspended in 25 ml of $CHCl_3$ with 5 ml of 40% CH_3CO_3H (0.026 mol) ultimately gave 0.25 g of **13** (28%); 0.57 g of unreacted **4** was also recovered.

Sodium Borohydride Reduction.—Excess $NaBH_4$ was added in small portions to a suspension of 1.0 g (0.0025 mol) of **4** in 50 ml of CH_3OH, until the vigorous reaction ceased. The solution was cooled and diluted with H_2O and 30–60° petroleum ether, and the two-phase system was filtered to remove unreacted **4** (0.70 g). The organic phase was separated and the aqueous layer was extracted with several volumes of petroleum ether. The combined petroleum ether extracts were dried (Na_2SO_4) and filtered, and the volume of the filtrate was reduced to initiate crystallization. Filtration of the resulting solid gave 0.29 g (35%) of crude **2,3-dibenzyl-5,8-dimethylquinoxaline** (**31**). One crystallization (Darco) from 30–60° petroleum ether afforded pure **31** as white needles: mp 131–132°; uv max 250 mμ (ε 74,300), 264 (15,500), 271 (8800), 315 (13,500), and 323 (14,850); nmr ($CDCl_3$) δ 7.43 (s, 2, C-6,7 protons), 7.25 (s, 10, C_6H_5), 4.30 (s, 4, CH_2), and 2.75 (s, 6, CH_3).

Anal. Calcd for $C_{24}H_{22}N_2$: C, 85.17; H, 6.55; N, 8.28. Found: C, 85.02; H, 6.53; N, 8.45.

Similar treatment of 1.0 g (0.0026 mol) of **5** (warmed on a steam bath) with excess $NaBH_4$ (using pentane as the extractant) led ultimately to 0.70 g (87%) of **32** as small white needles: mp 73–74° (from 30–60° petroleum ether, Darco); uv max 243 mμ (ε 54,400), 264 (6300), 271 (4500), 312 (9400), and 322 (11,650); nmr ($CDCl_3$) δ 7.78 (m, 3, C-6,7,8 protons), 7.25 (s, 10, C_6H_5), 4.29 (s, 4, CH_2), and 2.78 (s, 3, CH_3).

Anal. Calcd for $C_{23}H_{20}N_2$: C, 85.15; H, 6.21; N, 8.63. Found: C, 85.29; H, 6.27; N, 8.44.

Raney Nickel Desulfurization. 2,3-Dibenzyl-5,8-dimethylquinoxaline (**31**).—A suspension of 1.0 g (0.0025 mol) of **4** in 50 ml of 95% EtOH and 10 g of W-7 Raney nickel catalyst was refluxed 6 hr and filtered while hot. The filtrate was cooled (−30°) to yield 0.50 g (59%) of **31**.

2,3-Dibenzyl-5-methylquinoxaline (**32**).—Similar treatment of **5** (1.0 g 0.0026 mol) afforded **32** (0.35 g, 43%).

2,3-Dibenzyl-5-methoxyquinoxaline (**33**).—One gram (0.0025 mol) of **6** was reduced in the same manner as **4** and **5**. After filtration, the solvent was removed *in vacuo*, and the residual oil was deposited on a 2.5 × 25 cm silica gel column. Elution with 3:1 Et_2O–hexane ultimately gave 0.30 g (35%) of **33** as white needles: mp 83–84° (from 30–60° petroleum ether, Darco); uv max 257 mμ (ε 32,900) and 323 (4100); nmr ($CDCl_3$) δ 7.75–7.00 (m, 13, aromatic), 4.40 (s, 2, CH_2), 4.28 (s, 2, CH_2), and 4.06 (s, 3, OCH_3).

Anal. Calcd for $C_{23}H_{20}N_2O$: C, 81.15; H, 5.92; N, 8.23. Found: C, 81.18; H, 6.01; N, 8.25.

5-Amino-2,3-dibenzylquinoxaline (**34**).—Reduction of 1.0 g (0.0026 mol) of **8** ultimately gave 0.40 g (48%) of **34** as yellow needles: mp 96–98° (from 30–60° petroleum ether, Darco); ir 2.99 and 3.11 μ (NH_2); uv max 241 mμ (ε 9750), 278 (36,000), and 326 (2400); nmr ($CDCl_3$) δ 7.57–7.13 (m, 13, aromatic), *ca.* 4.93–4.71 (broad mound, 2, NH_2), 4.21 (s, 2, CH_2), and 4.18 (s, 2, CH_2).

Anal. Calcd for $C_{22}H_{19}N_3$: C, 81.20; H, 5.88; N, 12.91. Found: C, 81.34; H, 6.18; N, 12.69.

5,8-Dimethyl-2,3-di(α-methylbenzyl)quinoxaline (**35**).—Reduction of 1.0 g (0.0023 mol) of **9** ultimately gave 0.40 g (47%) of **35** as a meso-*dl* mixture: white needles, mp 110–112° (from 95% EtOH, Darco); uv max 249 mμ (ε 42,700), 270 (4750), 312 (6600) and 323 (7300); nmr ($CDCl_3$) δ 7.37–7.01 (m, 24, aromatic), 4.82–4.29 (q, 4, J = 7 Hz, CH), 2.80 (s, 6, *meso* C-5,8 CH_3), 2.73 (s, 6, *dl* C-5,8 CH_3), 1.78 (d, 6, J = 7 Hz, *meso* α-CH_3), and 1.58 (d, 6, *dl* α-CH_3).

Anal. Calcd for $C_{26}H_{26}N_2$: C, 85.21; H, 7.15; N, 7.64. Found: C, 85.19; H, 7.41; N, 7.40.

6-Phenylbenzo[*b*]phenazines.—The general procedure used was as follows. A mixture of the quinoxaline and 10 ml of concentrated H_2SO_4 was warmed on a steam bath for 30 min. The mixture was then poured onto ice and extracted several times with CH_2Cl_2. The combined extracts were dried (Na_2SO_4) and filtered and the solvent was removed *in vacuo*. The residue was deposited on a 2.5 × 25 cm Woelm alumina column (neutral activity I) and eluted. Evaporation of the eluent left crude product which was recrystallized.

1,4-Dimethyl-6-phenylbenzo[*b*]phenazine (**38**, 0.57 g, 75%) was obtained from **13** (0.80 g, 0.0023 mol) using 30% CH_2Cl_2–CCl_4 as eluent: mp 168–169°, bright red needles (from CH_2Cl_2, Darco); uv max (CH_3OH) 216 mμ (ε 30,800), 242 (19,100), 250 (22,500), and 285 (146,000); nmr ($CDCl_3$) δ 8.85 (s, 1, C-11 proton), 8.11–7.33 (m, 11, aromatic), 2.90 (s, 3, C-1 CH_3), and 2.57 (s, 3, C-4 CH_3).

Anal. Calcd for $C_{24}H_{18}N_2$: C, 86.19; H, 5.42; N, 8.38. Found: C, 85.99; H, 5.29; N, 8.62.

1-Methyl-6-phenylbenzo[*b*]phenazine (**39**, 0.30 g, 54%) was obtained from **14** (0.60 g, 0.0018 mol) using 30% CH_2Cl_2–CCl_4 as eluent: mp 217–218°, red needles (from CH_2Cl_2, Darco); uv max (CH_3OH) 215 mμ (ε 20,800), 254 (24,000), and 284 (101,000); nmr ($CDCl_3$) δ 8.80 (s, 1, C-11 proton), 8.07–7.20 (m, 12, aromatic), and 2.86 (s, 3, CH_3).

Anal. Calcd for $C_{23}H_{16}N_2$: C, 86.22; H, 5.03; N, 8.74. Found: C, 86.08, H, 5.26; N, 8.66.

1-Methyl-11-phenylbenzo[*b*]phenazine (**40**) was obtained from a crude **14–15** mixture (1.0 g, 0.029 mol) using 30% CH_2Cl_2–CCl_4 as eluent. The first 600 ml of eluent gave 0.30 g (32%) of **39**. Further elution afforded ultimately 0.37 g (39%) of **40**: mp 217.5–218°, dark red cubes (from CH_2Cl_2, Darco); uv max (CH_3OH) 215 mμ (ε 22,400), 255 (34,300), and 285 (134,000); nmr ($CDCl_3$) δ 8.77 (s, 1, C-6 proton), 8.20–7.20 (m, 12, aromatic) and 2.60 (s, 3, CH_3).

Anal. Calcd for $C_{23}H_{16}N_2$: C, 86.22; H, 5.03; N, 8.74. Found: C, 86.23; H, 5.16; N, 8.75.

1-Methoxy-6-phenyl- (**41**, 57%) **and 1-methoxy-11-phenylbenzo[*b*]phenazine** (**42**, 43%) were obtained by cyclodehydration of 0.50 g (0.0014 mol) of **16–17** mixture. Elution with $CHCl_3$ ultimately gave 0.27 g of **41**: mp 248–249°, red needles (from CH_2Cl_2, Darco); uv max (CH_3OH) 218 mμ (ε 26,800), 248 (16,800), and 287 (147,000); nmr ($CDCl_3$) δ 9.10 (s, 1, C-11 proton), 7.80–7.20 (m, 12, aromatic), and 4.18 (s, 3, OCH_3).

Further elution with 30% Et_2O–CCl_4 ultimately afforded 0.20 g of **42**: mp 229–230°, red plates (from CH_2Cl_2, Darco); uv max (CH_3OH) 218 mμ (ε 24,100), 248 (15,400), and 287 (136,500); nmr ($CDCl_3$) δ 8.89 (s, 1, C-6 proton), 8.00–7.20 (m, 12, aromatic), and 3.93 (s, 3, OCH_3).

Anal. Calcd for $C_{23}H_{16}N_2O$: C, 82.12; H, 4.79; N, 8.33. Found for **41**: C, 82.28; H, 4.79; N, 8.45. Found for **42**: C, 82.02; H, 4.81; N, 8.37.

1,4,11-Trimethyl-6-phenylbenzo[*b*]phenazine (**45**, 0.40 g, 60%) was obtained from **22** (0.70 g, 0.0019 mol) using CCl_4 as eluent: mp 201–202°, red needles (from CH_2Cl_2, Darco); uv max (CH_3OH) 217 mμ (ε 28,700), 261 (26,050), and 291 (141,500); nmr ($CDCl_3$) δ 8.36–7.18 (m, 11, aromatic), 3.43 (s, 3, C-11 CH_3), 2.86 (s, 3, C-1 CH_3), and 2.50 (s, 3, C-4 CH_3).

Anal. Calcd for $C_{25}H_{20}N_2$: C, 86.18; H, 5.78; N, 8.03. Found: C, 86.28; H, 6.14; N, 7.99.

1-Hydroxy-6-phenylbenzo[*b*]phenazine (**43**).—A mixture of 0.40 g (0.0012 mol) of **41** in 30 ml of dry C_6H_6 and 0.40 g (0.003 mol) of $AlCl_3$ was refluxed 12 hr under anhydrous conditions. The reaction mixture was cooled and poured onto ice, and the whole mixture was extracted with CH_2Cl_2. The combined extracts were dried (Na_2SO_4) and filtered, and the solvent removed *in vacuo*. The residue was placed on a 2.5 × 25 cm Woelm alumina column (neutral activity III) and successively eluted with CH_2Cl_2 (to wash out minor components) and 30% Et_2O–$CHCl_3$. From the latter was ultimately obtained 0.20 g (53%) of **43** as a red powder: mp 247–248° (from CH_2Cl_2, Darco); ir 2.96 μ (OH); uv max (CH_3OH) 220 mμ (ε 8400) and 289 (84,300); nmr ($CDCl_3$, 100 Mc) δ 8.91 (s, C-11 proton) and 8.29–7.05 (m, 13, OH and aromatic).

Anal. Calcd for $C_{22}H_{14}N_2O$: C, 81.97; H, 4.38; N, 8.69. Found: C, 82.10; H, 4.38; N, 8.76.

1-Hydroxy-11-phenylbenzo[*b*]phenazine (**44**) (9.39 g, 78%) was obtained by similar treatment of **42** (0.40 g, 0.0012 mol) using CCl_4 instead as the final eluent: mp 250–251°; ir 2.96 and 2.98 μ (OH); uv max (CH_3OH) 220 mμ (ε 16,800) and 289 (150,000);

nmr ($CDCl_3$, 100 Mc) δ 8.93 (s, 1, C-6 proton) and 8.20–7.00 (m, 13, OH and aromatic).

Anal. Calcd for $C_{22}H_{14}N_2O$: C, 81.97; H, 4.38; N, 8.69. Found: C, 81.99; H, 4.64; N, 8.50.

2,5-Dimethylquinoxaline.—A mixture of 2,3-dinitro- and 2,5-dinitro-*p*-xylene (5.0 g, 0.026 mol) was hydrogenated in EtOAc over 10% Pd/C at 3 atm. The mixture was filtered, and the crude oil (0.018 mol containing 68% of the desired 2,3-diamino isomer), obtained by evaporation of the solvent, was heated for 2 hr at 60° with 4.65 g (0.018 mol) of the $NaHSO_3$ adduct of glyoxal (10% excess of the adduct was added after 1 hr). The solution was made strongly alkaline with aqueous KOH and extracted with Et_2O. The combined ether extracts were dried (Na_2SO_4), filtered, and evaporated to dryness *in vacuo*. The residue was deposited on a 2.5 × 25 cm silica gel column and elution with 1:1 CH_2Cl_2–CCl_4 ultimately afforded **2,5-dimethylquinoxaline** (0.30 g, 11%) as white needles: mp 71–72° (from 30–60° petroleum ether, Darco); uv max 245 mμ (ε 39,000) and 318 (5400); nmr ($CDCl_3$) δ 8.78 (s, 2, C-2,3 protons), 7.41 (s, 2, C-6,7 protons), and 2.70 (s, 6, CH_3).

Anal. Calcd for $C_{10}H_{10}N_2$: C, 75.92; H, 6.37; N, 17.71. Found: C, 75.70; H, 6.38; N, 17.92.

5,8-Dimethylquinoxaline 1-Oxide.—A mixture of 5,8-dimethylquinoxaline (1.0 g, 0.0063 mol) in 25 ml of $CHCl_3$ and 5 ml of 40% peracetic acid was refluxed for 16 hr. After cooling to room temperature, the solution was diluted with $CHCl_3$ and washed four times with H_2O. The $CHCl_3$ layer was dried (Na_2SO_4) and filtered, and the solvent was evaporated *in vacuo*. Deposition of the residue on a 2.5 × 25 cm silica gel column and elution with 1:1 CH_2Cl_2–CCl_4 ultimately gave 0.80 g of recovered starting material. Further elution with $CHCl_3$ yielded 0.15 g (12%) of **5,8-dimethylquinoxaline 1-oxide** as yellow needles: mp 109.5–110° (from 30–60° petroleum ether, Darco); uv max 252 mμ (ε 36,100), 292 (3850), 337 (4600), and 349 (5000); nmr ($CDCl_3$) δ 8.48–8.10 (AB pattern, 2, C-2,3 protons), 7.44–7.10 (AB pattern, 2, C-6,7 protons), 2.96 (s, 3, C-8 CH_3), and 2.60 (s, 3, C-5 CH_3).

Anal. Calcd for $C_{10}H_{10}N_2O$: C, 68.95; H, 5.79; N, 16.08. Found: C, 69.17; H, 5.94; N, 16.04.

Reduction of the *N*-**oxide** (0.10 g, 0.00052 mol) with 0.10 g (0.00058 mol) of sodium hydrosulfite in 20 ml of 80% EtOH gave **5,8-dimethylquinoxaline** (40%).

Registry No.—**4** *cis*, 26940-78-3; **4** *trans*, 26940-79-4; **5** *cis*, 26940-80-7; **5** *trans*, 26940-81-8; **6** *cis*, 26940-82-9; **6** *trans*, 26940-83-0; **7** *cis*, 26940-84-1; **7** *trans*, 26940-85-2; **8** *cis*, 26940-86-3; **8** *trans*, 26940-87-4; **9** *cis*, 26940-88-5; **9** *trans*, 26940-89-6; **10a** *cis*, 26940-90-9; **10a** *trans*, 26992-53-0; **10b** *cis*, 26940-91-0; **10b** *trans*, 26940-92-1; **13**, 26940-93-2; **14**, 26940-94-3; **15**, 26940-95-4; **16**, 26940-96-5; **17**, 26940-97-6; **18**, 26940-98-7; **19**, 26940-99-8; **20**, 26941-00-4; **21**, 26941-01-5; **22**, 26941-02-6; **24**, 26941-03-7; **26**, 26941-04-8; **27**, 26941-05-9; **28**, 26941-06-0; **31**, 26941-07-1; **32**, 26941-08-2; **33**, 26941-09-3; **34**, 26941-10-6; **35**, 26941-11-7; **38**, 26941-12-8; **39**, 26941-13-9; **40**, 26941-14-0; **41**, 26941-15-1; **42**, 26941-16-2; **43**, 26941-17-3; **44**, 26941-18-4; **45**, 26941-19-5; 2,5-dimethylquinoxaline, 26941-20-8; 5,8-dimethylquinoxaline, 26941-21-9.

Notes

A Study of the Bromination of the Syn and Anti Photodimers of 1,4-Naphthoquinone. The Chemistry of the Brominated Derivatives

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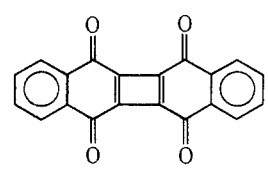
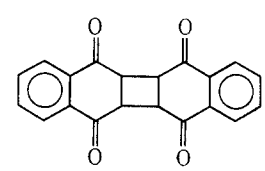
Various efforts to synthesize cyclobutadiene or derivatives thereof are cited in the literature.[1] These efforts were, however, unsuccessful, supporting calculations[2] which show zero aromatic nature for cyclobutadiene. In some cases[3,4] the presence of nonisolable cyclobutadiene derivatives has been claimed. The symmetrically substituted diphthaloylcyclobutadiene **1** should exhibit an enhanced stability compared to cyclobutadiene owing to the electronegative carbonyl groups adjacent to the four-membered ring. In order to attempt the synthesis of **1**, we first considered it necessary to investigate the bromination and chemistry of the syn (**2a**) and anti (**2b**) dimers[5,6] of 1,4-naphthoquinone.



1



2a, syn
b, anti

It has been shown that both **2a** and **2b** enolize in acidic media to establish an equilibrium between **2b** and **3**.[7] Both **3** and its fully enolized derivative **4**[8] exhibit typical olefinic reactions, *e.g.*, bromination[7] to **5** and **6**, respectively.

The bromination of **2** leads to various products, depending on the reaction conditions. If the reaction is carried out with 4 equiv of bromine in acetic acid

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