Anal. Calcd for $C_{20}H_{20}N_2O_3S$: C, 65.20; H, 5.47; N, 7.60. Found: C, 65.48; H, 5.51; N, 7.64.

1-(*o*-Benzyloxyphenyl)-1-ethyloxalyl-2-(*p*-toluenesulfonyl)hydrazine (19).—1-*o*-Benzyloxyphenyl)-2-(*p*-toluenesulfonyl)hydrazine (**18**, 3.6 g, 0.015 mol) and ethyl oxalyl chloride (1.5 g, 0.011 mol) were stirred and heated to 50° in anhydrous C_6H_6 containing $NaHCO_3$ (0.84 g, 0.01 mol) for 2 hr. The reaction mixture was combined with 50 ml of C_6H_6 and washed four times with 70 ml of H_2O and once with 50 ml of saturated NaCl solution. The C_6H_6 solution was dried (Na_2SO_4) and the solvent was removed to give a dark oil, which crystallized slowly from 10 ml of Et_2O. Recrystallization (Me_2CO–Et_2O) gave 2.0 g (44%) of **19** as white crystals, mp 113–114.5°; spectral data are consistent with the assigned structure.

Anal. Calcd for $C_{24}H_{24}N_2SO_6$: C, 61.52; H, 5.16; N, 5.98. Found: C, 61.17; H, 5.30; N, 5.61.

4-(*p*-Toluenesulfonamido)-1,4-benzoxazine-2,3-dione (20).—1-(*o*-Benzyloxyphenyl)-1-ethyloxalyl-2-(*p*-toluenesulfonylhydrazine (**19**, 0.46 g, 0.001 mol) was hydrogenated at 25° under 1-atm pressure with 100 mg of 5% Pd/C as the catalyst and 40 ml of EtOAc as the solvent. The uptake of H_2 slowed appreciably after 0.001 mol had been consumed. The catalyst was removed by filtration and the solvent was removed *in vacuo* to give a solid which was recrystallized (C_6H_6) to give 0.20 g (63%) of an amorphous white solid, Recrystallization (Me_2CO–Et_2O) gave the same white solid, mp 200–202°; spectral data are consistent with the assigned structure.

Anal. Calcd for $C_{15}H_{12}N_2O_5S$: C, 54.21; H, 3.64; N, 8.43. Found: C, 54.11; H, 3.49; N, 8.75.

Registry No.—**4**, 34288-06-7; **5a**, 34288-07-8; **5b**, 34288-08-9; **8a**, 34288-09-0; **8b**, 34288-10-3; **10**, 34288-11-4; **11**, 34288-12-5; **12**, 34288-13-6; **13**, 34288-14-7; **17**, 34288-15-8; **18**, 34288-16-9; **19**, 34288-17-0; **20**, 34288-18-1; *o*-benzyloxyacetanilide, 34288-19-2.

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Heteroaromatic Fused-Ring Mesoionic Compounds. Sydno[3,4-*a*]quinoxalines[1]

Robert A. Coburn* and John P. O'Donnell

Department of Medicinal Chemistry, School of Pharmacy, State University of New York at Buffalo, Buffalo, New York 14214

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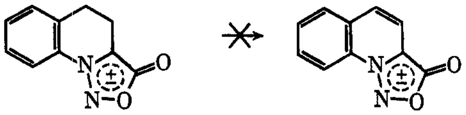
A number of derivatives of sydno[3,4-*a*]quinoxalines have been synthesized from 3-(*o*-nitrophenyl)sydnone. Incorporation of the five-membered mesoionic sydnone ring into a conjugated fused-ring heteroaromatic system produces compounds of enhanced stability toward thermal and aqueous acid-catalyzed decomposition. Susceptibility toward base-catalyzed reaction is increased. SCF molecular orbital treatments were found to be useful in predicting electronic absorption spectra, relative stability of tautomers, and the probable site of O alkylation.

Sydnones have been the most extensively studied member of mesoionic heterocyclic systems.[2] Classified as nonbenzenoid aromatic compounds, sydnones possess an unusual electronic structure characterized by an interplay of charge separation and electron delocalization. A large number of sydnone derivatives have been reported to date, many of which have been found to possess one or more of a wide variety of biological activities.[3] Despite this activity in sydnone chemistry, no conjugated heteroaromatic fused-ring sydnones have been reported.[4] Hammick and Voaden[5] have reported unsuccessful attempts to prepare sydno[3,4-*a*]quinoline (2) from 4,5-dihydrosydno[3,4-*a*]quinoline (1).



1 **2**

We wish to report the syntheses of a number of quinoxaline ring-fused sydnones. The effect upon the molecular properties of sydnones produced by this ring fusion were examined by quantum chemical and spectroscopic methods.

Results and Discussion

Despite the failures to prepare **2** and the absence of reported examples of heteroaromatic fused-ring sydnone derivatives, there is no apparent rationale to suggest a destabilizing influence effected by such a ring fusion. Stabilization achieved by such extended conjugation might be of practical significance, since many of the simple sydnones with potentially useful biological activities lack thermal stability and frequently darken upon exposure to light and air.[6]

The initial objective of this investigation was sydno[3,4-*a*]quinoxalin-4-one (**3**), chosen in part because of the electron-withdrawing effect upon the sydnone 4 position as depicted in the valence-bond representation **3b**. Electron-withdrawing substituents at C-4 in sydnones have been observed to enhance their stability, especially toward acid-catalyzed ring-opening hydrolysis.[7]

In order to estimate the perturbation of the sydnone π-electron system effected by this ring fusion, we have compared the results of semiempirical Pople–Parr–Pariser SCF-MO treatments of the π systems of *N*-phenylsydnone and **3**. For sydnones, the results of this type of treatment compare favorably with those obtained from CNDO/2 calculations.[8] The results of

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[1] Taken in part from the M.S. Thesis of J. P. O'Donnell, SUNY/B, Sept 1971. Presented at the 3rd Northeast Regional Meeting of the American Chemical Society, Buffalo, N. Y., Oct 13, 1971.

[2] W. Baker and W. D. Ollis, *Quart. Rev., Chem. Soc.*, **11**, 15 (1959); F. H. C. Stewart, *Chem. Rev.*, **64**, 129 (1964).

[3] L. B. Kier and E. B. Roche, *J. Pharm. Sci.*, **56**, 149 (1967); E. Ackermann, *Pharmazie*, **22**, 537 (1967).

[4] M. Ohta and H. Kato in "Nonbenzenoid Aromatics," Vol. I, J. P. Snyder, Ed., Academic Press, New York, N. Y., 1969.

[5] D. L. Hammick and D. J. Voaden, *J. Chem. Soc.*, 3303 (1961).

[6] *N*-Methylsydnone darkens upon distillation at reduced pressure even in a short-path Kugelrohr distillation apparatus.

[7] F. H. C. Stewart, unpublished results cited in ref 2.

[8] F. P. Billingsley and J. E. Bloor, *Theor. Chim. Acta*, **11**, 325 (1968).

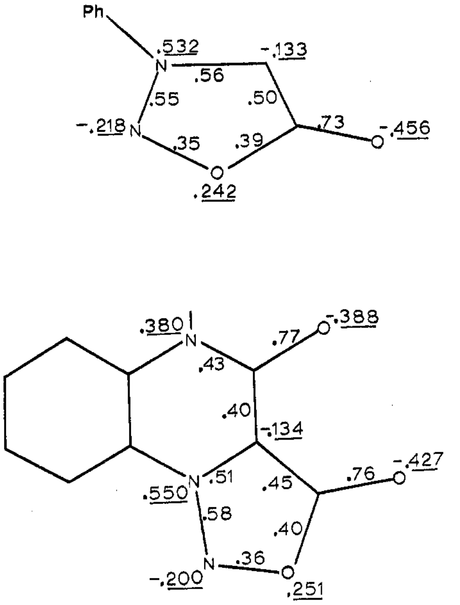
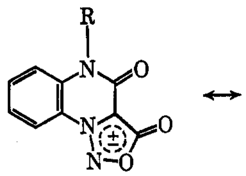
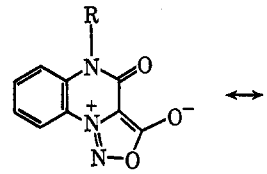
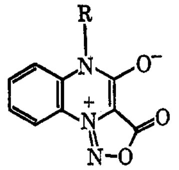


Figure 1.—VESCF π-MO calculated bond orders and charge densities for 3-phenylsydnone and sydno[3,4-*a*]quinoxalin-4-one.


3


3a


3b

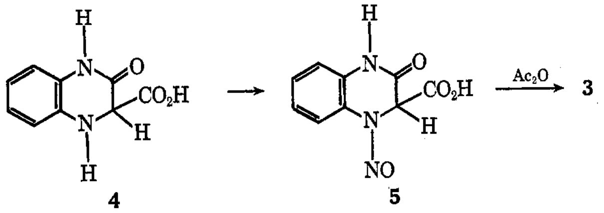
variable-electronegativity SCF calculations[9] are shown in Figure 1.

The electron deficiency of the sydnone N_3 atom increases in the fused system. The π-electron density of the exocyclic sydnone-ring oxygen decreases while the bond order for this oxygen–carbon bond increases. The near equality of bond orders for the two carbon exocyclic oxygen bonds implies nearly equal contribution of resonance structures **3a** and **3b**.

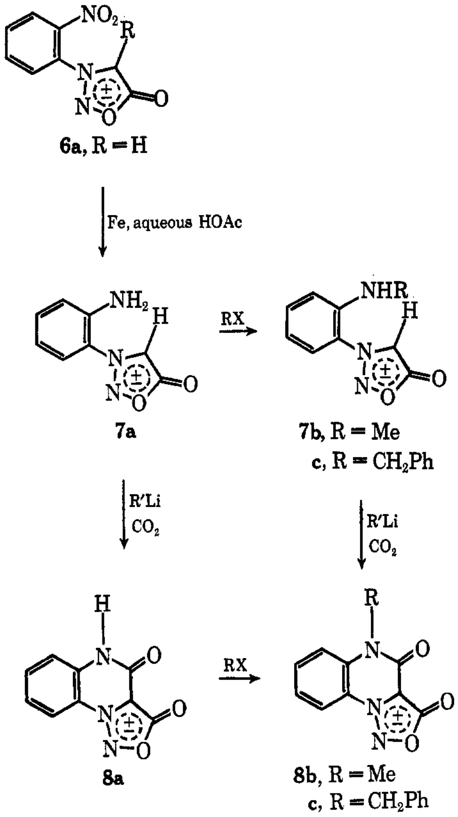
Two general synthetic routes leading to sydno[3,4-*a*]quinoxalines were investigated. The first route, depicted in Scheme I, involves construction of the sydnone ring *via* a quinoxaline derivative. Such a route is attractive owing to the limited number of steps and the avoidance of synthetic manipulation of mesoionic intermediates.

Quinoxalone **4** is available by catalytic hydrogenation of quinoxalin-2-one-3-carboxylic acid,[10] which in turn may be prepared from *o*-phenylenediamine and either mesoxalic acid or alloxan.[11] In spite of the apparent simplicity of this route, the difficulty encountered in the preparation of **5** by the nitrosation of **4** led to the adoption of the second route shown in Scheme II.

SCHEME I



SCHEME II



3-(2'-Nitrophenyl)sydnone (**6a**) was prepared according to the procedure of Eade and Earl[12] by the cyclodehydration of *N*-nitroso-*N*-(2'-nitrophenyl)glycine. Metalation of **6a** using a variety of organolithium reagents (methyllithium, *n*-butyllithium, and *tert*-butyllithium) in various solvents (ether, THF, triethylamine, tetramethylethylenediamine) was investigated by quenching the reaction mixtures with D_2O and observing the intensity of the C-4 proton signal in the pmr spectrum of recovered sydnone. This procedure showed no evidence of metalation having occurred with **6a**, despite the general utility of this method in preparing 4-carboxyl derivatives of other sydnones.[13] Sydnone **6a** was brominated in aqueous ethanol, giving the 4-bromo derivative **6b** (R = Br). Metalation of **6b** was attempted under similar conditions followed by quenching with H_2O. No signal

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(9) The method employed was similar to that used in previous treatments of mesoionic structures by K. Sundaram and W. P. Purcell, *Int. J. Quantum Chem.*, **2**, 145 (1968). A limited configuration interaction employing a triangularly generated matrix of 21 configurations was used to estimate singlet electronic transitions. Geometries were approximated from X-ray crystallographic data by H. Barnighausen, F. Jellinek, J. Munnik and A. Vos, *Acta Crystallogr.*, **16**, 471 (163).

(10) E. C. Taylor and M. J. Thompson, *J. Org. Chem.*, **26**, 3511 (1961).

(11) O. Kuhling, *Ber.*, **24**, 2363 (1891).

(12) R. A. Eade and J. C. Earl, *J. Chem. Soc.*, 591 (1946).

(13) C. V. Greco, M. Pesce, and J. M. Franco, *J. Heterocycl. Chem.*, **3**, 391 (1966); S. A. Zotova and V. G. Yashunskii, *Zh. Org. Khim.*, **1**, 2281 (1965).

corresponding to the C-4 proton of **6a** was observed in the crude product mixture.

Sydnone **6a** was reduced with iron in aqueous acetic acid to 3-(2′-aminophenyl)sydnone (**7a**). Use of an excess of methyllithium in either triethylamine or ether effected the desired metalation of the 4 position as judged by the amount of deuterium incorporation (*ca.* 95%) following D_2O quenching of the reaction mixture. Addition of this metalated intermediate to a Dry Ice–ether slurry gave, after evaporation of solvent, a water-soluble lithium salt. Acidification of an aqueous solution of this salt produced effervesence at pH 6 as the *N*-carboxylic acid group decarboxylated. At pH 1, **8a** precipitated following the apparent cyclodehydration of 3-(2′-aminophenyl)sydnone-4-carboxylic acid. The structural assignment of **8a** was supported by the disappearance of spectral evidence for the C-4 hydrogen of the sydnone ring (ν_{CH} 3190 cm^{-1}, δ 7.75) and the appearance of a strong absorption at 1675 cm^{-1} assigned to the quinoxalone lactam carbonyl; in addition the pmr multiplet of the aromatic protons undergoes a shift to lower field, as would be expected when the electron-releasing effect of the amino group is moderated. The remaining pmr signal appears at very low field, characteristic of a enolic or α-pyridone-like hydrogen.

The product **8a** can conceivably exist in any of three different tautomeric states, shown in Figure 2. The VESCF–MO treatment of the π systems of these tautomers would indicate that I is the most stable based upon π-electron delocalization energies. Also indicated are the three longest wavelength $\pi \rightarrow \pi^*$ singlet transitions. Since the predicted transitions differ substantially in their values and patterns, it was believed that they would be of assistance in structure assignment. The observed electronic absorptions of the product **8a** agree very closely with that predicted for the quinoxalone lactam tautomer (I). Supporting evidence for this assignment also comes from the spectral data for the N-alkylated derivatives of **8a**.

Alkylation of the sodium salt of **8a** in THF with alkyl halides or dimethyl sulfate was found to occur exclusively on nitrogen.[14] The structure of the alkylated product was indicated by the similarity of ir and uv spectra of **8a** with its methyl and benzyl derivatives, **8b** and **8c**. Confirmation of the site of alkylation was obtained by synthesis of **8b** and **8c** by metalation and carbonation of the corresponding 3-(2-alkylaminophenyl)sydnones, **7b** and **7c**.

O methylation was achieved by treatment of **8a** with an excess ethereal solution of diazomethane. Although N methylation usually predominates in the diazomethane methylation of quinoxalin-2-ones,[15] no corresponding product (**8b**) could be detected. The possibility exists of alkylation occurring at either of the two exocyclic oxygen atoms to give **9** or **10**.

The methyl derivative obtained from the reaction of **8a** and diazomethane was easily distinguished from **8b** *via* physical (melting point, tlc, and solubility in benzene) and spectral properties. It exhibited very strong absorption in the high-frequency region of carbonyl absorption (1800–1785 cm^{-1}) but lacked the 1675-cm^{-1} band observed for **8a**. This is consistent for structure **9**, since a high frequency, very intense carbonyl absorption is characteristic of sydnones.[16] From spectral data reported for quinoxalin-2-ones and several six-membered ring mesoionic systems, the anticipated carbonyl absorption of **10** would be likely to occur below 1700 cm^{-1}.[17]

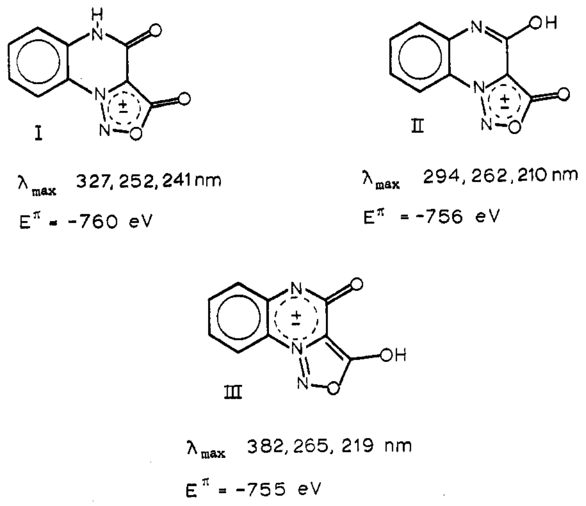
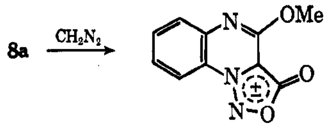
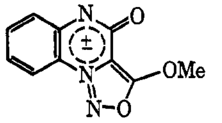


Figure 2.—VESCF π-MO calculated $\pi \rightarrow \pi^*$ singlet transitions and delocalization energies of the tautomers of sydno[3,4-*a*]-quinoxalin-4-one.



9



10

The prominent parent molecular ion of **9** exhibits a very facile loss of NO followed by CO in a fashion identical with other sydnones[18] and sydno[3,4-*a*]-quinoxalines reported here (*vide infra*). Although the longest wavelength ultraviolet absorption of the product (376 nm) is close to that predicted for **10**, this band undergoes a 10-nm hypsochromic shift in water which suggests an n → π^* transition.

It is conceivable that O alkylation could occur at the sydnone exocyclic oxygen atom under kinetically controlled conditions. Potts has reported the O alkylation of 3-phenylsydnone with Meerwein's reagent.[19] However, INDO calculated total ($\sigma + \pi$) electron densities (Figure 3) indicate that the quinoxalone oxygen is substantially more electron rich and presumably more nucleophilic in spite of the reverse ordering based upon π-electron considerations alone (Figure 1). We have

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(14) In DMF alkylation of the sodium salt of **8a** was found to produce both N- and O-alkylated derivatives.

(15) G. W. H. Cheeseman, *J. Chem. Soc.*, 1804 (1955).

(16) B. E. Zaitsev and Yu. N. Sheinker, *Izv. Akad. Nauk SSSR, Otd. Khim. Nauk*, 407 (1962).

(17) G. W. H. Cheeseman, A. R. Katritzky, and S. ØKsne, *J. Chem. Soc.*, 3983 (1963); J. Honzl and M. Sorm, *Tetrahedron Lett.*, 333 (1969); L. Paoloni, M. L. Tosato, and M. Cignitti, *Theor. Chim. Acta*, **14**, 221 (1969).

(18) J. H. Bowie, R. A. Eade, and J. C. Earl, *Aust. J. Chem.*, **21**, 1665 (1968); R. S. Goudie, P. N. Preston, and M. H. Palmer, *Org. Mass Spectrom.*, **2**, 953 (1969); R. C. Dougherty, R. L. Foltz, and L. B. Kier, *Tetrahedron*, **26**, 1989 (1970).

(19) K. T. Potts, E. Houghton, and S. Husain, *Chem. Commun.*, 1025 (1970).

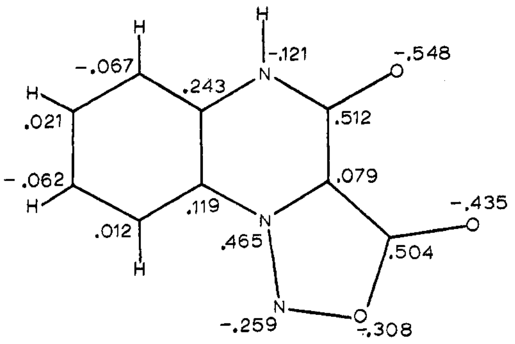
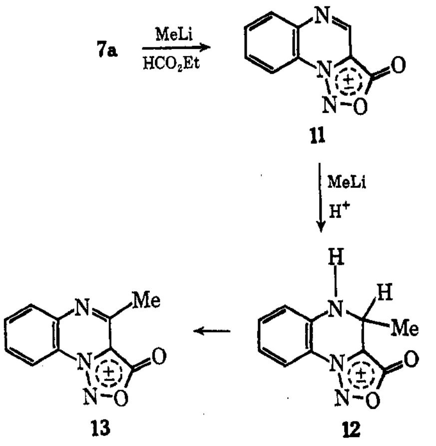


Figure 3.—INDO all-valence electron SCF net ($\sigma + \pi$) atom charges calculated for sydno[3,4-*a*]quinoxalin-4-one.

been unsuccessful in attempts to achieve O alkylation of the sydnone exocyclic oxygen *via* Meerwein's reagent. It is interesting to note that the INDO-calculated π-charge density of N-10 indicates the loss of 0.9 e, making this position extremely electron deficient.

If the metalated intermediate in Scheme II is treated with ethyl formate or ethyl orthoformate instead of CO_2, the parent sydno[3,4-*a*]quinoxaline (**11**) can be obtained. The use of an excess of methyllithium results in the formation of the 4,5-dihydro-4-methyl derivative **12**, which is easily air oxidized to 4-methylsydno[3,4-*a*]quinoxaline (**13**). The reactivity of the 4,5 bond toward nucleophilic addition provides a facile route for the preparation of 4-alkyl- or 4-aryl-substituted derivatives.



Sydnones are hydrolyzed in aqueous HCl to give substituted hydrazines, carboxylic acids, and carbon dioxide. For alkyl sydnones this reaction is facile and has been recommended for use in the preparation of difficulty accessible hydrazines.[4] Aryl sydnones are more resistant, requiring >0.1 *N* HCl and elevated temperatures ($k \sim$ *ca.* 10^{-6} sec^{-1}, 1 *N* HCl, 50°).[20] All of the sydno[3,4-*a*]quinoxalines exhibited great stability toward acid-catalyzed ring openings. For instance, **8a** was unchanged after 5 days at 80° in 0.8 *N* HCl as judged by spectrophotometric analysis and by recovery of unchanged starting material ($k \sim$ $<10^{-7}$ sec^{-1}).

Garrett[21] has studied the rate of base-catalyzed ring opening of a number of alkyl- and aryl-substituted sydnones. Although sydnones are known to undergo ring opening in alkali to give *N*-nitroso carboxylate salts, as in previous studies we were unable to characterize these unstable products from the dilute solutions employed in kinetic studies. The product solutions, however, did give positive Liebermann tests for the *N*-nitroso group, in contrast to negative results obtained from the starting materials. Table I gives the comparative results of the rate of disappearance of a representative selection of sydno[3,4-*a*]quinoxalines in aqueous alkali together with 3-phenyl-4-acetylsydnone (**14**). The rate of reaction of **8a** is comparable to that of previously reported simple sydnone derivatives.[21] The slower rate of reaction of **8a,** in comparison to the other listed compounds, is due to its conversion to an anion in base (p$K_a \sim 8.8$, determined spectrophotometrically). An electron-withdrawing substituent at the sydnone 4 position substantially increases the rate of ring opening, possibly by increasing the ease of nucleophilic attack at the sydnone pseudocarbonyl.[22]

TABLE I

RELATIVE RATES OF REACTIVITY OF SYDNONES IN 0.10 *N* KOH AT 39°

Compd	Relative rate[a]
8a	1
8b	22
14	29
9	153
13	283

[a] $k_{obsd} = 3.0 \times 10^{-5}$ sec^{-1} for **10a.**

The sydno[3,4-*a*]quinoxalines, in general, exhibited appreciably greater thermal stability. Compounds **11** and **13** are easily purified by sublimation (175–225°) while **8a** exhibits no sign of decomposition below its melting point, 307–308°. The normal sydnone pseudocarbonyl stretching vibration occurs at *ca.* 1740 cm^{-1}, while that for the sydno[3,4-*a*]quinoxalines occurs near 1790 cm^{-1}. The position of this intense absorption is sensitive to phase and concentration effects but nevertheless suggests an increase in the carbon–exocyclic oxygen bond order.

In conclusion, the sydno[3,4-*a*]quinoxalines have been found to exhibit increased thermal stability and resistance to acid-catalyzed ring opening. The properties of these fused-ring structures can be rationalized in terms of existing knowledge of the properties of the two-component ring systems. In this way they differ from the type of bicyclic mesoionic structures represented by the mesoionic purinone analogs[23] in which charge separation is formally required to involve both ring systems.

Experimental Section

Pmr spectra were obtained on a Varian T-60 spectrometer; chemical shifts are reported relative to TMS as an internal standard. Ultraviolet spectra were recorded on a Beckman Model DB spectrophotometer. Infrared spectra were obtained on a Perkin-Elmer Model 237 spectrophotometer. Microanalyses were performed by Galbraith Laboratories, Knoxville, Tenn. All melting points were determined with a Mel-Temp

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[20] S. Aziz, A. F. Cockerill, and J. G. Tillett, *Tetrahedron Lett.*, 5479 (1968).

[21] The mechanism of this reaction has not been resolved. Garrett[22] suggests hydroxide ion attack at the divalent nitrogen while attack of the pseudocarbonyl group is favored by E. B. Roche and L. B. Kier, *Tetrahedron*, **24**, 1673 (1968).

[22] E. R. Garrett and P. J. Mehta, *J. Pharm. Sci.*, **56**, 1468 (1967); E. R. Garrett, *ibid.*, **53**, 42 (1964).

[23] R. A. Coburn, *J. Heterocycl. Chem.*, **8**, 881 (1971).

melting point apparatus and are uncorrected. Mass spectra were obtained by using a Hitachi Perkin-Elmer RMC-6 single focusing mass spectrometer.

3-(2'-Nitrophenyl)-4-bromosydnone (6b).—Sodium bicarbonate (2.0 g, 24 mmol) in water (25 ml) was added to a suspension of **6a** (0.7 g, 3.3 mmol) in ethanol (35 ml) at room temperature. Bromine (2.5 g, 15 mmol) in ethanol (25 ml) was added dropwise until the resultant cloudy solution became clear. The reaction was stirred for 20 min, followed by the addition of water (30 ml). The solvent was evaporated *in vacuo* at 50° and the resulting residue was washed with water and dried. Recrystallization from benzene–petroleum ether (bp 30–60°) gave 0.74 g of **8b** as light yellow crystals: mp 114–116° dec; ir (KBr) 1780 cm^{-1} (C=O); uv max (EtOH) 310 nm (ϵ 5577), 251 (15, 964); nmr (DMSO-d_6) δ 8.1 (m). This compound rapidly decomposed upon warming and darkened upon exposure to light and air. Satisfactory microanalysis was not obtained.

3-(2'-Aminophenyl)sydnone (7a).—A mixture of **6a** (1.0 g, 4.9 mmol) and 3.0 g of powdered iron was added to 60 ml of 2% acetic acid at 90°. The mixture was refluxed for 12 min and then chilled. Sodium bicarbonate (1.7 g, 0.023 mol) was added in small portions with stirring followed by filtration. The solid was washed with ice water (3 × 25 ml), air dried, and extracted with boiling tetrahydrofuran (4 × 20 ml). The combined extracts were evaporated *in vacuo* and the residue was recrystallized from THF–petroleum ether to yield 0.7 g (81%) of **7a** as light-yellow crystals: mp 136–137°; ir (KBr) 1750 cm^{-1} (C=O), 3400, 3500 cm^{-1} (-NH$_2$); uv max (EtOH) 302 nm (ϵ 6720), 233 (15, 960); nmr (CDCl$_3$) δ 4.54 (s, 2, -NH$_2$), 6.63 (s, 1, sydnone H), 7.18 (multiplet, 4, phenyl).

Anal. Calcd for $C_8H_7N_3O_2$: C, 54.23; H, 3.98; N, 23.72. Found: C, 53.97; H, 3.80; N, 23.59.

3-(2'-Methylaminophenyl)sydnone (7b).—To **7a** (1 g, 6 mmol) in anhydrous ethyl ether (100 ml) was added NaH (0.4 g, 57% in oil). After stirring for 10 min, methyl iodide (3 ml) was added and stirring was contined for 48 hr. The mixture was filtered and the residue was washed with ether (2 × 250 ml). The combined ether filtrate was evaporated *in vacuo*, giving 0.8 g of residue. This residue was taken up in methylene chloride–ethyl acetate (95:5) and placed on a silica gel (Woelm) column. Elution with the same solvent system gave 360 mg (32%) of **7b** as green crystals, recrystallized from benzene–hexane: mp 116–118°; ir (KBr) 3400 (NH), 3180 (sydnone CH), 1730 cm^{-1} (C=O); uv max (EtOH) 303 nm (ϵ 7350), 244 (16,200); nmr (CDCl$_3$) δ 3.1 (d, 3, J = 2.5 Hz, CH$_3$N), 5.0 (broad, 1, NH), 6.55 (s, 1, sydnone H), 7.1 (m, 4, aryl).

Anal. Calcd for $C_9H_9N_3O_2$: C, 56.54; H, 4.74; N, 21.98. Found: C, 56.77; H, 4.76; N, 21.90.

3-(2'-Benzylaminophenyl)sydnone (7c).—A procedure identical with that used in the preparation of **7b** was employed using benzyl bromide (1.5 g), NaH (0.4 g, 57% in oil), and **7a** (1 g, 6 mmol). **7c** (641 mg, 40%) was obtained following elution column chromatography (silica gel) of the crude product mixture using methylene chloride–ethyl acetate (95:5). Recrystallization from benzene–hexane gave white crystals: mp 114–115°; ir (KBr) 3250 (NH), 3150 (sydnone CH), 1730 cm^{-1} (C=O); uv max (EtOH) 304 nm (ϵ 7480), 246 (16,400); nmr (CDCl$_3$) δ 4.4 (d, 2, J = 2.5 Hz, PhCH$_2$–), 5.4, (broad, 1, NH) 6.6 (s, 1, sydnone H), 6.7 (m, 4, aryl), 7.3 (s, 5, phenyl).

Anal. Calcd for $C_{15}H_{13}N_3O_2$: C, 67.41; H, 4.90; N, 15.71. Found: 67.69; H, 4.80; N, 15.55.

Sydno[3,4-*a*]quinoxalin-4-one (8a).—A solution of methyllithium (2.5 ml, 2.1 *M* in ether) was added dropwise to a suspension of **7a** (0.33 g, 1.86 mmol) in 3 ml of ether at −20° under a nitrogen atmosphere. After stirring for 1 hr the mixture was added to a Dry Ice–ether slurry. The reaction mixture was evaporated to dryness at room temperature and 20 ml of water was added. The pH of the solution was adjusted to 6 with concentrated HCl. The resulting precipitate was collected, giving 0.18 g, of starting material **7a**. The filtrate was acidified to pH 1 and the resulting precipitate was collected and washed with water. The product (0.12 g, 64% conversion) was recrystallized from THF–petroleum ether for analysis: mp 307–308°; ir (KBr) 3250 (NH), 1800 (sydnone C=O), 1675 cm^{-1} (lactam C=O); uv max (EtOH) 332 nm (ϵ 5640), 256 (15,600), 232 (22, 800); nmr (DMSO-d_6) δ 7.7 (m, 4, aryl), 11.7 (s, 1, NH).

Anal. Calcd for $C_9H_5N_3O_3$: C, 53.21; H, 2.48; N, 20.68. Found: C, 53.08; H, 2.41; N, 20.53.

5-Methylsydno[3,4-*a*]quinoxalin-4-one (8b). A. Preparation from 9b.—A solution of methyllithium (3.0 ml, 2.1 *M* in ether) was slowly added to **7b** (0.5 g, 2.6 mmol) in 10 ml of ether at −20° under a nitrogen atmosphere. After stirring for 1 hr the mixture was added to a Dry Ice–ether slurry. Acidification of the aqueous solution of the residue, obtained by evaporation of the ether slurry, resulted in a precipitate which was collected and washed with water. Recrystallization from benzene–hexane yielded 0.3 g (54%) of **8b**: mp 235–238° (sublimes); ir (KBr) 1790 (sydnone C=O), 1670 cm^{-1} (lactam C=O); uv max (EtOH) 342 nm (ϵ 5340), 262 (16,500), 235 (23,500); nmr (DMSO-d_6) δ 3.9 (s, 3, CH$_3$), 7.8 (m, 4, aryl).

Anal. Calcd for $C_{10}H_7N_3O_3$: C, 55.30; H, 3.25; N, 19.35. Found: C, 55.18; H, 3.25; N, 19.15.

B. By Alkylation of 8a.—To a solution of **8a** (0.3 g, 1.4 mmol) in anhydrous ether (200 ml) was added NaH (5 g, 57% in oil). After stirring for 10 min, dimethyl sulfate (0.3 ml. 2,4 mmol) was added to the reaction mixture and stirring was continued for 48 hr. The mixture was filtered and the residue was washed with THF (4 × 100 ml). The filtrate and washings were combined and the solvent was evaporated *in vacuo*. The residue was sublimed at 190° (1 mm), giving 50 mg of **8b**, mp 235–236°. This material was identical with that prepared by method A, as judged by comparison of ir and nmr spectra and by mixture melting point. Tlc (silica gel) examination of the crude product mixture showed only two spots, corresponding to starting material and isolated product. The solvent system employed, chloroform–tetrahydrofuran (95:5), was found to clearly separate **8b** and **9** (*vide infra*).

5-Benzylsydno[3,4-*a*]quinoxalin-4-one (8c). A. Preparation from 7c.—A procedure identical with that used in the preparation of **8a** and **8b** was employed to give **8c** (63%) after recrystallization from benzene–hexane: mp 213–214°; ir (KBr) 1785, 1675 cm^{-1} (C=O); uv max (EtOH) 338 nm (ϵ 6530), 262 (18,500), 235 (27,400); nmr (CDCl$_3$) δ 5.4 (s, 2, PhCH$_2$), 7.35 (m, 9, aryl).

Anal. Calcd for $C_{16}H_{11}N_3O_3$: C, 65.53; H, 3.78; N, 14.33. Found: C, 65.33; H, 3.83; N, 14.43.

B. By Alkylation of 8a.—A procedure identical with that employed in the methylation of **8a** was used with benzyl bromide as the alkylating agent. The product obtained (43%) exhibited identical ir and nmr spectra with those of **8c** prepared above. A mixture melting point exhibited no depression.

4-Methoxysydno[3,4-*a*]quinoxaline (9).—To a solution of **8a** (0.2 g, 0.98 mmol) in 15 ml of dimethylformamide–tetrahydrofuran (1:2) was added a distilled ethereal solution (50 ml, *ca.* 0.1 *M*) of diazomethane prepared from EXR-101. After standing overnight, the solvent was removed *in vacuo*. Tlc of the resulting residue revealed only two spots corresponding to starting material and product. The product spot exhibited a greater R_f than that of **8b**. The residue was taken up in benzene and the solution was filtered to remove insoluble starting material. Addition of hexane and cooling gave **9** as light yellow crystals (0.2 g, 92%): mp 183–185°; ir (CHCl$_3$) 1800–1785 cm^{-1} (doublet, C=O); uv max (THF) 376 nm (ϵ 4590), 355 (5270), 338 (4160), 322 (4500), 280 (13,300); uv max (H$_2$O) 364 nm (ϵ 4100), 345 (5100), 285 (14,000); nmr (CDCl$_3$) δ 4.18 (s, 3, OCH$_3$), 7.2–7.8 (m, 3, aryl), 8.2 (d, 1, aryl); mass spectrum (70 eV) m/e (rel intensity) 217 (28), 188 (27), 187 (95), 160 (16), 159 (50) 144 (50) 131 (30), 129 (100), 116 (37), 90 (63), 89 (38), 76 (24), 75 (25), 64 (30), 63 (27), 62 (26), 51 (28), 50 (37), 44 (21).

Anal. Calcd for $C_{10}H_7N_3O_3$: C, 55.30; H, 3.25; N, 19.35. Found: C, 55.22; H, 3.17; N, 19.11.

Sydno[3,4-*a*]quinoxaline (11).—A solution of methyllithium (15 ml, 2.1 *M* in ether) was slowly added to **7a** (2.5 g, 14 mmol) in 15 ml of anhydrous ether at −25° under a dry nitrogen atmosphere. After stirring for 1 hr, dry ethyl formate (1.04 g, 14 mmol) in anhydrous ether (15 ml) was slowly added. Following an additional 1 hr of stirring the reaction mixture was washed with aqueous ammonium chloride solution and the solvent was removed *in vacuo*. The residue was placed on a column of silica gel (Woelm, 100 g) and eluted with chloroform–hexane (95:5). There was obtained 1.1 g (42%) of **11** as white crystals purified by sublimation: mp 225–226° (sealed tube); ir (CHCl$_3$) 1790–1775 (vs doublet, C=O), 1585 cm^{-1} (s); uv max (EtOH) 369 nm (ϵ 7380), 352 (9480), 340 sh (7530), 290 (7550), 281 (7830), 250 sh (19,000), 241 (28,700); nmr (CDCl$_3$) δ 7.7–8.3 (m, 4, aryl), 8.9 (s, 1, C$_4$ H); mass spectrum (70 eV) m/e (rel intensity) 187 (15), 157 (44), 130 (15), 129 (100), 103 (7), 104 (73), 76 (19), 75 (26), 64.5 (10), 63 (10), 51 (26), 50 (25).

Anal. Calcd for $C_9H_5N_3O_2$: C, 57.72; H, 2.69; N, 22.46. Found: C, 57.52; H, 2.47; N, 22.18.

4,5-Dihydro-4-methylsydno[3,4-*a*]quinoxaline (12) and 4-Methylsydno[3,4-*a*]quinoxaline (13).—A solution of methyllithium (5 ml, 2.1 *M* in ether) was slowly added to a suspension of **7a** (0.3 g, 1.7 mmol) and anhydrous ether (5 ml) at −20° under a dry nitrogen atmosphere. The mixture was stirred for 1 hr and added to a solution of ethyl formate (0.5 g, 6.7 mmol) in ether (20 ml). After stirring for 1 hr, the mixture was extracted with aqueous ammonium chloride solution. The ether solution was dried ($MgSO_4$) and the solvent was evaporated *in vacuo*. The residue was taken up in methylene chloride and placed on a 15-g column of silica gel (Woelm). Elution with methylene chloride–ethyl acetate (95:5) yielded 26 mg of **13**, recrystallized from benzene–hexane: mp 160–162° (sublimes); ir (KBr) 1800 cm^{-1} (C═O); uv max (H_2O) 346 nm (ϵ 7320); nmr ($CDCl_3$) δ 2.9 (s, 3, CH_3), 7.8 (m, 4, aryl); mass spectrum (70 ev) *m/e* (rel intensity) 201 (16), 173 (9), 171 (25), 145 (23), 144 (56), 143 (100), 132 (11), 117 (42), 103 (10), 102 (44), 81 (10), 78 (22), 77 (21), 76 (34), 75 (21), 69 (20), 50 (25).

Anal. Calcd for $C_{10}H_7N_3O_2$: C, 59.70; H, 3.51; N, 20.89. Found: C, 59.20; H, 3.33; N, 20.44.

Further elution gave 20 mg of **12** which was recrystallized from benzene: mp 166–167°; ir (KBr) 1735 cm^{-1} (C═O); uv max (EtOH) 325 nm (ϵ 4580), 242 (25,700); nmr ($CDCl_3$) δ 1.54 (d, 3, CH_3), 4.5 (broad, 1, NH), 4.75 (q, 1, C_4 H), 6.6–7.9 (m, 4, aryl). This compound when exposed to air was slowly transformed to a substance identical in melting point and ir and nmr spectra with **13**. In solution this transformation was facile and **12** could be converted to **13** by shaking a solution of **12** in chloroform in a separatory funnel. The mass spectrum of **12** was identical with that of **13** when introduced *via* the glass inlet system.

Kinetic Procedures.—For alkaline hydrolsyes, a few drops of a master solution of the compound in ethanol were added to a cuvette containing aqueous KOH which had been brought to 39 ± 0.1° in the sample holder of a Gilford Model 2400 uv spectrophotometer by means of a circulating constant-temperature bath. Readings of optical density of the longest wavelength maximum were recorded until no perceptible change could be detected. Base concentrations ranged from 0.02 to 0.8 *N* with a minimum of three different values being used for each compound. Concentrations of sydnone were *ca.* 10^{-4} *M*. The apparent first-order rate constants were calculated by the method of least squares. For acid hydrolyses, 20 ml of a 10^{-3} *M* master solution of sydnone was added to 80 ml of 1.0 *M* hydrochloric acid solution maintained at 80°. Aliquots, which were quickly cooled, were taken over a period of 7 days to observe the decrease in optical density of the longest wavelength ultraviolet maximum.

Semiempirical SCF–MO Calculations.—The semiempirical self-consistent field π molecular orbital calculations were performed using QCPE program 167 which was modified to include the variable electronegativity procedure[9] and a Givens method of obtaining eigenvalues and eigenvectors. Repulsion integrals were obtained by the Mataga method and penetration integrals were neglected. Resonance integrals were evaluated by $B_{ij}^{SCF} = KS_{ij}(I_i + I_j)$ where S_{ij} is the overlap integral between atoms i and j and *I* is the ionization potential. The value of *K* was adjusted to reproduce the spectrum of 3-phenylsydnone (including CI) and was given the value 0.65.

The semiempirical all valence electron calculation was performed using the CNINDO program of Dobosh (QCPE 142). Only a limited number of geometries were investigated.

Registry No.—**6b** (R = Br), 14715-65-2; **7a**, 34315-02-3; **7b**, 34315-04-3; **7c**, 34315-05-4; **8a**, 11094-23-8; **8b**, 11094-25-0; **8c**, 11094-28-3; **9**, 11094-26-1; **11**, 11094-22-7; **12**, 11094-27-2; **13**, 11094-24-9.

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Thiophene Analogs of Anthraquinone

D. W. H. MACDOWELL* AND JAMES C. WISOWATY[1]

Department of Chemistry, West Virginia University, Morgantown, West Virginia 26506

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Six possible isomers resulting from the replacement of one or both benzene rings in 9,10-anthraquinone with thiophene rings have been synthesized: 4,9-dihydronaphtho[2,3-*b*]thiophene-4,9-dione (**1**), 4,9-dihydronaphtho-[2,3-*c*]thiophene-4,9-dione (**2**), 4,8-dihydrobenzo[1,2-*b*:5,4-*b'*]dithiophene-4,8-dione (**3**), 4,8-dihydrobenzo[1,2-*b*:4,5-*b'*]dithiophene-4,8-dione (**4**), 4,8-dihydrobenzo[1,2-*b*:4,5-*c'*]dithiophene-4,8-dione (**5**), and 4,8-dihydrobenzo[1,2-*c*:4,5-*c'*]dithiophene-4,8-dione (**6**). Compound **6** was prepared by dechlorination of 1,3-dichloro-4,8-dihydrobenzo[1,2-*c*:4,5-*c'*]dithiophene-4,8-dione (**15**). The compounds **1**, **2**, **3**, **4**, **5**, and **15** were subjected to reduction by means of an equimolar mixture of aluminum chloride–lithium aluminum hydride. Compounds **3** and **4** show only reduction to the hydroquinone stage. Compounds **2** and **15** provide good yields of the corresponding dihydroaromatic systems, while **1** and **5** afford only moderate yields of the dihydroaromatic systems. These results are explained in terms of the position of keto–enol tautomerism in the corresponding anthrone–anthrol systems and the stability of the parent aromatic systems.

Two previous papers[2] report the synthesis of a series of thiophene analogs of anthrone which possess significantly different enolizabilities. It was found that substitution of a *b*-fused thiophene ring for one of the benzene portions of anthrone leads to an increase in the stability of the enol form, while a similar substitution of a *c*-fused thiophene ring promotes a decrease in the stability of the enol tautomer.

Replacement of one or both of the benzene rings in 9,10-anthraquinone by a thiophene ring gives rise to two isomeric naphthothiophenediones **1** and **2** and four isomeric benzodithiophenediones **3**–**6**. Of these, **1** has been known for some time,[3] while a brief, recent report[4] refers to a synthesis of **4**.

Synthesis of the Six Diones.—The known quinone 4,9-dihydronaphtho[2,3-*b*]thiophene-4,9-dione (**1**) was prepared in 75% yield by the cyclization of *o*-(2-thenoyl)benzoic acid under the influence of aluminum chloride in nitrobenzene following the method of Weinmayr.[3c] A direct pathway to 4,9-dihydronaptho-[2,3-*c*]thiophene-4,9-dione (**2**) can be envisioned as

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[1] NDEA Fellow, 1967–1970.

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