2 *N* hydrochloric acid. On recrystallization from ethanol it formed colorless crystals, mp 149° dec.

Anal. Calcd for $C_{16}H_{15}N_3O_3$: C, 64.64; H, 5.09; N, 14.13. Found: C, 64.68; H, 5.14; N, 14.07.

When the lower melting isomer of **22a** was subjected to similar treatment, **23a** was obtained in quantitative yield.

***t*-Butyl 2-(3-Cyano-1-methyloxindolyl)cyanoacetate (23b).**—This was obtained in quantitative yield by the procedure used for the preparation of **23a**. It formed colorless crystals, mp 111°, from methanol.

Anal. Calcd for $C_{17}H_{17}N_3O_3$: C, 65.58; H, 5.50; N, 13.50. Found: C, 65.28; H, 5.52; N, 13.31.

3-Cyano-3-cyanomethyloxindole (25a).—When **23a** (8.91 g, 0.030 mole) was slowly heated to 149° (1–2 mm), pyrolysis commenced with foaming. After the initial reaction had subsided, the temperature was raised to 160° and held until foaming had substantially ceased. On cooling the residual oil crystallized on trituration with 50 ml of ether. Recrystallization from ethyl acetate gave 5.7 g (96%) of colorless crystals, mp 176°.

Anal. Calcd for $C_{11}H_7N_3O$: C, 67.00; H, 3.58; N, 21.31. Found: C, 67.16; H, 3.67; N, 21.42.

3-Cyano-3-cyanomethyl-1-methyloxindole (25b).—Similar pyrolysis of **23b** at 130–140° gave a 95% yield of **25b**, mp 127–128°, from methanol.

Anal. Calcd for $C_{12}H_9N_3O$: C, 68.23; H, 4.30; N, 19.90. Found: C, 68.46; H, 4.39; N, 19.78.

1-Methylisatin and 1-Methylisatin Dimethyl Ketal.—In employing the procedure of Harley-Mason and Inglesby[11] for the preparation of 1-methylisatin, we have found that, after a single methylation of isatin with dimethyl sulfate, a considerable amount of unreacted isatin remains in the product. Their procedure has therefore been modified.

To a suspension of 14.7 g (0.1 mole) of isatin in 200 ml of anhydrous methanol, 100 ml of 10% methanolic potassium hydroxide solution was added in portions with shaking. To the purple solution 15 ml of freshly distilled dimethyl sulfate was added and, after 30 min, the solution was filtered from potassium methyl sulfate which separated. After removal of about 270 ml of solvent under reduced pressure, the residue was poured into 45 ml of warm water. On cooling 14.8 g of crude product, mp 115°, crystallized. This was extracted twice with 100 ml of petroleum ether. The insoluble part (13 g, 82%) on recrystallization from ethanol gave pure 1-methylisatin, mp 134° (lit. mp 134–136°).

Removal of the solvent from the petroleum ether extracts left 0.93 g (4.5%) of crude 1-methylisatin dimethyl ketal, which after recrystallization from *n*-hexane (charcoal), gave the pure ketal, mp 81–82°.

Anal. Calcd for $C_{11}H_{13}NO_3$: C, 63.76; H, 6.32; N, 6.76. Found: C, 63.92; H, 6.31; N, 6.76.

On hydrolysis with hydrochloric acid, pure 1-methylisatin was obtained from the ketal in quantitative yield.

Registry No.—Sodium salt of **2**, 14179-69-2; **3**, 14179-70-5; **4**, 14179-71-6; **6**, 14179-72-7; **7**, 1940-01-8; **8**, 14179-74-9; **9**, 14179-75-0; **10**, 14179-76-1; immonium salt ($C_{12}H_{14}BrClN_2O$), 14179-77-2; **11**, 14179-78-3; **12**, 3335-86-2; **13**, 3265-16-5; **14**, 14179-81-8; **16**, 3265-25-6; **18a**, 14271-44-4; **18b**, 14179-83-0; **19a**, 14179-84-1; **19b**, 14271-45-5; **20**, 14264-75-6; **22a**, 14179-85-2; **22b**, 14179-86-3; **23a**, 14179-87-4; **23b**, 14179-88-5; **24**, 14179-89-6; **25a**, 14179-90-8; **25b**, 14179-91-0; 1-methylisatin, 2058-74-4; 1-methylisatin dimethyl ketal, 14271-46-6.

The Borohydride Reduction of Thioxanthone Sulfoxide. A Base-Induced Dehydration of Thioxanthenol Sulfoxide

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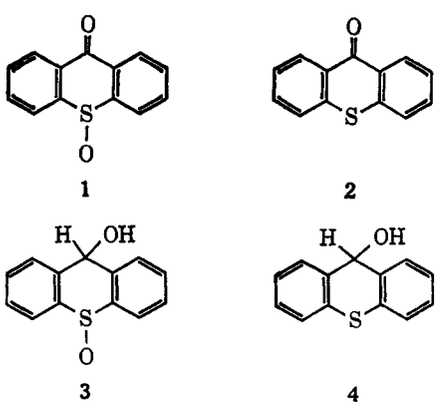
Received June 1, 1967

Reduction of thioxanthone sulfoxide with excess sodium borohydride affords mainly *cis*-thioxanthenol sulfoxide. Reduction in an alkaline medium affords thioxanthenol. This latter process is shown to proceed *via* the base-induced dehydration of thioxanthenol sulfoxide to thioxanthone. A comparison of the ultraviolet spectra of the isomeric thianthrene disulfoxides and the isomeric thioxanthenol sulfoxides indicates that the intense short-wavelength transitions present in these spectra are probably best considered to be perturbed aromatic transitions.

Thioxanthone sulfoxide (**1**) may be prepared by the dinitrogen tetroxide oxidation of thioxanthone[2] (**2**). As part of our investigation of this heterocyclic system we attempted to prepare the corresponding alcohols, *cis*- and *trans*-thioxanthenol sulfoxide (**3**α and **3**β), by the sodium borohydride reduction of **1**.[3] The reduction of **1** (in 95% ethanol) afforded *cis*-thioxanthenol sulfoxide (**3**α) as the major product even in the presence of a large excess of borohydride. However, if the same reduction is performed in the presence of trace quantities of base, the product that is obtained is thioxanthenol (**4**). Thus, the *net* reaction in an alkaline medium involves reduction of the sulfoxide group as well as of the carbonyl group.

Results and Discussion

There are two conceptually different pathways that could account for the conversion of thioxanthone sulfoxide (**1**) to thioxanthenol (**4**). The essential difference between these pathways resides in the actual sequence of reductions. In one of these the sulfoxide



(1) To whom inquiries should be directed. This investigation was supported by Public Health Service Research Grant No. CA-10139 from the National Cancer Institute. Presented, in part, at the 153rd National Meeting of the American Chemical Society, Miami Beach, Fla., April 1967, Abstracts, p O 105.

(2) A. L. Ternay, Jr., Ph.D. Dissertation, New York University, 1963 (*Dissertation Abstr.*, **24**, 3995 (1964)).

(3) The assignment of configuration has been made by X-ray analysis: A. L. Ternay, Jr., D. Chasar, and M. Sax, *J. Org. Chem.*, **32**, 2465 (1967).

group is reduced prior to reduction of the carbonyl group while the opposite sequence is operative in the alternate pathway.

In order to identify the intermediate (*i.e.*, **2** or **3**) that is involved in the reduction of **1** to **4**, the reaction was carried out with only 1 equiv of reductant. When **1** is reduced with 1 equiv of borohydride, in the absence of base, the major product was found to be *cis*-thioxanthenol sulfoxide (**3**α). (One might anticipate this outcome since **3**α was the product of neutral reduction employing a large excess of borohydride.) However, if the reduction is carried out in the presence of sodium hydroxide, then thioxanthone (**2**) is the major (>90%) reaction product.

Inspection of the molecular formulas of **2** and **3** suggests that the isomeric thioxanthenol sulfoxides can be viewed as the isomeric "hydrates" of thioxanthone. The results presented above suggest that the sequence leading from **1** to **4** involves a base-induced dehydration reaction, shown below.

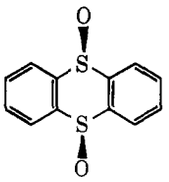
$$1 \xrightarrow{BH_4^-} 3 \xrightarrow[-H_2O]{OH^-} 2 \xrightarrow{BH_4^-} 4$$

It is possible to demonstrate that this dehydration does, indeed, occur.[4] Thus, either **3**α or **3**β is converted, essentially quantitatively, to **2** in the presence of base. Moreover, the choice of base is not restricted to sodium hydroxide; **3**α and **3**β are also converted to **2** by amines, *e.g.*, morpholine.

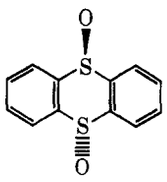
Thus, what superficially appears to be a unique[5] borohydride reduction of the sulfoxide groups is, in reality, a sequence of two normal reductions linked by a novel dehydration reaction.

The dehydration reaction of either isomer of **3** by sodium hydroxide is accompanied by the formaton of a blue-violet color. Moreover, this color disappears when oxygen is bubbled through the system. The main products which are isolated from this oxygenated mixture are **1** and **2**.[6] While the mechanistic details of this reaction are under investigation, the production of this blue-violet color, the observation of a transient epr signal,[6] and the isolation of **1** are consistent with radical anion formation under these conditions. This, of course, does not demand that a radical anion be directly involved in the dehydration of **3**. The mechanism of dehydration is presumed to involve a tautomer of **3**.

The spectral properties that have been thus far determined for *cis*- and *trans*-thioxanthenol sulfoxide are consistent with structures **3**α and **3**β and *not* with any tautomeric structures. That **3**α and **3**β do not rapidly isomerize in solution to some common species is evidenced by the dissimilarity of the ultraviolet spectra (95% ethanol) of **3**α and **3**β. Indeed, the observed spectra bear a striking resemblance to the ultraviolet spectra of the stereoisomeric thianthrene disulfoxides (**5**).[7] Secondly, the infrared spectra of **3**α and **3**β differ in solution as well as in the solid state. The patterns that were found[3] to be characteristic of the



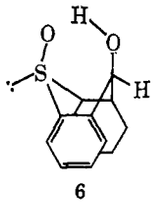
5α



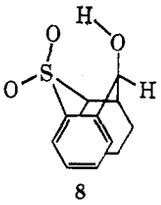
5β

solid state are also present in solution (see Experimental Section).

These spectra can provide information about the conformational distribution within a particular stereoisomer. Recently, Castrillón and Szmant[8] have speculated that "the axial orientation is also preferred in the sulfoxide of thiaxanthydrol because of the formation of an intramolecular hydrogen bond." Unfortunately, no experimental evidence was provided to substantiate this claim beyond the solid-state (KBr) spectrum of a stereoisomer of thioxanthenol sulfoxide (**3**) whose configuration had not been assigned. Because of the difficulties associated with investigating intramolecular hydrogen bonding *via* infrared studies of the solid phase, we have examined the solution spectrum of **3**α. In carbon tetrachloride ($10^{-4}M$), **3**α exhibits a weak, broad absorption (*ca.* 3380 cm^{-1}) which we have tentatively assigned to an intramolecular hydrogen bond (**6**). However, the presence of several other absorptions in the O–H stretching region suggests that **6** is not the sole conformer that is present in a solution of **3**α (in carbon tetrachloride).[9]



6



8

A related situation has been observed with thioxanthenol sulfone (**7**). The observation of a moderate, broad absorption at 3510 cm^{-1} suggests the presence of conformer **8**.[9] However, other absorptions are also present in the O–H stretching region, suggesting the occurrence of conformations in addition to **8**. A complete conformational analysis of **3**α, **3**β, and related compounds will be the subject of a future discussion.

We have already alluded to the similarity between the ultraviolet spectra of the isomeric thioxanthenol sulfoxides and the corresponding thianthrene disulfoxides. These spectra, when considered along with the other data that are collected in Table I, shed some light upon the nature of the intense short-wavelength transitions in these sulfoxides. The spectrum of *cis*-thioxanthenol sulfoxide (**3**α) is similar to that of *cis*-thianthrene disulfoxide (**5**α), while the spectrum of *trans*-thioxanthenol sulfoxide (**3**β) is similar to that of *trans*-thianthrene disulfoxide (**5**β).[3] Thus, substitution of a carbinol moiety for the sulfoxide moiety does not result in a gross change in the ultraviolet spectra of **5**α and **5**β. It appears, therefore, that sulfoxide–sulfoxide interactions are not primarily responsible for the differences in the ultraviolet spectra of the stereoisomeric thianthrene disulfoxides. Similarly, sulfinyl–hydroxyl interactions

(4) Thioxanthenol sulfoxides have been observed by us to dehydrate to **2** in the presence of acid. This reaction is presumed to involve protonation of the sulfoxide group followed by dehydration (unpublished results).

(5) A borohydride reduction of the sulfoxide group does not appear to have been reported.

(6) D. W. Chasar and H. Grossman, unpublished results.

(7) K. Mislow, P. Schneider, and A. L. Ternay, Jr., *J. Am. Chem. Soc.*, **86**, 2957 (1964).

(8) J. P. A. Castrillón and H. H. Szmant, *J. Org. Chem.*, **32**, 976 (1967).

(9) We are deeply indebted to Miss Lynn Wolfram for these determinations. The appropriate data are included in the Experimental Section.

TABLE I

ULTRAVIOLET SPECTRA OF SULFOXIDES. SHORT-WAVELENGTH REGION[a]

Compound	λ_{max}	ϵ ($\times 10^{-3}$)
cis-Thioxanthenol sulfoxide (3α)[b]	204	42
trans-Thioxanthenol sulfoxide (3β)[b]	214	42
cis-2-Chlorothioxanthenol sulfoxide[b]	205	44
trans-2-Chlorothioxanthenol sulfoxide[b]	215	39
Thioxanthene sulfoxide (9)	203	46
cis-Thianthrene disulfoxide (5α)[c]	212	52
trans-Thianthrene disulfoxide (5β)[c]	221	55
Thioxanthene sulfone	202	47

[a] Spectra in 95% ethanol. [b] See ref 3. [c] See ref 7.

(*e.g.*, hydrogen bonding) are probably not responsible for the gross differences in the ultraviolet spectra of 3α and 3β.

It has been suggested[8] that the transitions at 212 and 221 mμ for 5α and 5β, respectively, are "...electronic transitions of the non-bonding electrons of the sulfoxide oxygen..."[10] The similarity in the ultraviolet spectra that are presented in Table I, and particularly the relative constancy of the intensity of the short wavelength transitions, suggest that these transitions are probably more properly considered to be perturbed aromatic transitions. It is particularly interesting that thioxanthene sulfone possesses a short wavelength transition that is almost identical with that of thioxanthene sulfoxide.

An alternative explanation for the differences in the ultraviolet spectra of the isomeric thianthrene disulfoxides (and the isomeric thioxanthenol sulfoxides) rests in considering the S–O and S–O (*or* S–O and C–O) dipoles as being largely responsible for the observed spectral differences, the spectra reflecting, in part, the different orientations of these groups relative to the aryl planes.[11] As in the case of the isomeric thianthrene disulfoxides,[7] it follows that 3α and 3β are "distinct chromophoric entities." *On this basis*, it is tempting to speculate that the conformational distribution (in 95% ethanol) of *cis*-thioxanthenol sulfoxide (3α) is similar to that of *cis*-thianthrene disulfoxide (5α).

Experimental Section[12]

Thioxanthone Sulfoxide (1).—Thioxanthone was oxidized with dinitrogen tetroxide according to the procedure of Addison and Sheldon.[13] The only modification from the standard procedure (reaction temperature, 0°; solvent, chloroform) was an increase in the reaction time to 4 days. The crude reaction product was free of the corresponding sulfone as determined by thin layer chromatography. Recrystallization of the crude reaction product from benzene afforded 1, mp 199–201° (lit.[2,8] mp 199–201°, 200–201°, respectively). Average yields of 1 are 60–70%. Spectral properties of the reaction product are identical with the literature values.[2,8]

***cis*-Thioxanthenol Sulfoxide (3α).**—*cis*-Thioxanthenol sulfoxide (3α) was prepared as described previously.[3] Thus, the oxidation of thioxanthenol (4) with 30% hydrogen peroxide in acetone afforded *cis*-thioxanthenol sulfoxide (3α) in 32% yield, mp 218–218.5° (lit.[3] mp 218–218.5°).

The infrared (Nujol) and ultraviolet spectra of 3α have already been reported.[3] The infrared spectrum in solution ($CHCl_3$, 5×10^{-3} *M*) exhibits strong absorptions at 1094 and 1028 cm^{-1} in the S–O region and at 3380, 3580, and 3630 cm^{-1} in the O–H region.

***trans*-Thioxanthenol sulfoxide (3β)** was prepared as described previously.[3] Thus, oxidation of 4 with *m*-chloroperbenzoic acid in acetone afforded a mixture of 3α and 3β. Recrystallization of the crude product, preceeded by extraction with benzene, afforded 3β in 20% yield, mp 205–206° (lit.[3] mp 205–206°).

The infrared (Nujol) and ultraviolet spectra of 3β have already been reported.[3] The infrared spectrum in solution ($CHCl_3$, 5×10^{-2} *M*) is more complex than is that of 3α, exhibiting absorptions of moderate to strong intensity at 1079, 1029, and 1005 cm^{-1}. The latter absorption is quite broad.

Thioxanthenol Sulfone (7).—Thioxanthone sulfone[14] (1.0 g, 4.1 mmoles) was suspended in 50 ml of 95% ethanol and treated with 0.5 g (13 mmoles) of sodium borohydride. After stirring for 2 hr, water (5 ml) was added and the reaction mixture was warmed on a steam bath for 5 min. The reaction mixture was then poured onto ice and the resulting solid filtered off to afford 1.0 g (100% yield) of crude 7, mp 183–185°. This solid was dissolved in chloroform and the resulting solution was dried (magnesium sulfate). The solvent was evaporated to afford 0.9 g (90%) of 7, mp 184–186° (lit.[15] mp 184–185°). The product was homogeneous by thin layer chromatography. The infrared spectrum of 7 (Nujol) exhibits intense absorptions at 3520, and at 1300 and 1050 cm^{-1}. In carbon tetrachloride (1.3×10^{-3} *M*, 10 mm path length), the spectrum exhibits a broad absorption at *ca.* 3510 cm^{-1} (m) and two sharp bands at 3590 (m) and 3610 cm^{-1} (s).[16]

Thioxanthene Sulfoxide (9).[17]—*m*-Chloroperbenzoic acid[18] (0.97 g) dissolved in 75 ml of methylene chloride was added with stirring to a solution of thioxanthene (1.00 g, 5.0 mmoles) in methylene chloride (50 ml). The reaction mixture was maintained at 0° for 17 hr and then at 25° for 3 hr. The resulting solution was washed with four 100-ml portions of saturated sodium bicarbonate and dried (magnesium sulfate). The solvent was removed under reduced pressure to afford 1.18 g of crude product. Recrystallization (*n*-hexane) afforded 0.49 g (2.3 mmoles, 46% yield) of thioxanthene sulfoxide, mp 116–117° (lit.[19] mp 109°). This material was homogeneous on thin layer chromatography.

Anal. Calcd for $C_{13}H_{10}OS$: C, 72.86; H, 4.70; S, 14.96. Found: C, 72.60; H, 4.72; S, 15.20.

Thioxanthene sulfone was prepared according to the method of Hilditch and Smiles.[19] The desired product, mp 170–171° (lit.[19] mp 170°), was obtained in 48% yield. This material was homogeneous on thin layer chromatography. The infrared spectrum (Nujol) of this material exhibited intense absorptions at 1298, 1171, and 1162 cm^{-1}.

Reduction of Thioxanthone Sulfoxide (1) with Lithium Aluminum Hydride.—Lithium aluminum hydride (0.307 g, 8.07 mmoles) was added to a suspension of 1 (0.301 g, 1.32 mmoles) in 50 ml of anhydrous ether and the reaction mixture was stirred for 2 hr. Water (*ca.* 2 ml) was added and the resulting suspension was filtered. The filtrate was dried (magnesium sulfate) and the solvent removed (N_2) to afford 0.232 g (1.08 mmoles, 82% yield) of a white, crystalline solid, mp 97–104°. The infrared spectrum (Nujol) was identical with that of authentic thioxanthenol, mp 102–105°.

(10) Castrillón and Szmant also have suggested that a "... transannular interaction involving the p orbital of oxygen..." may account for the apparent dependency of transition energy upon conformation that is observed in this series. It is difficult to envision an appropriate "transannular" interaction that could be applicable to the isomeric thioxanthenol sulfoxides. Solvent effects that have been observed[8] perhaps may be due to changes in the sulfoxide dipole and in the concomitant effect upon the aryl transition. (Moreover, there is no *a priori* reason to anticipate that the conformational distribution of a particular sulfoxide will remain the same upon changing the solvent from, for example, cyclohexane to trifluoroethanol.)

(11) We gladly acknowledge valuable discussions with Professor E. W. Abrahamson of this department.

(12) Melting points were obtained in a Mel-Temp apparatus and are corrected. Infrared spectra were recorded on either a Beckman Model IR-8 or a Perkin-Elmer Model 521. Ultraviolet spectra (320–200 mμ) were recorded on a Cary Model 15. Microanalyses were performed by the Galbraith Laboratories, Knoxville, Tenn. Thin layer chromatographies were performed employing glass plates coated with silica containing a fluorescent indicator. Development was achieved with ethyl acetate, benzene, or chloroform. Both ultraviolet light and iodine vapor were used for visualization.

(13) C. C. Addison and J. C. Sheldon, *J. Chem. Soc.*, 2705 (1956). See ref 2.

(14) M. Gomberg and E. C. Britton, *J. Am. Chem. Soc.*, **43**, 1945 (1921).

(15) E. A. Fehnel, *ibid.*, **71**, 1063 (1949).

(16) These latter absorptions may reflect π-bonded and free-hydroxyl absorption.

(17) Prepared by L. Ens in this laboratory. The solution spectra of this material (unpublished results) are consistent with this compound existing as the sulfoxide (as opposed to a tautomer) in solution.

(18) F. M. C. Corp., 85% min assay.

(19) T. P. Hilditch and S. Smiles, *J. Chem. Soc.*, **99**, 145 (1911).

Reduction of Thioxanthone Sulfoxide (1) with Sodium Borohydride.—Thioxanthone sulfoxide (0.100 g, 0.438 mmole) was allowed to react with 0.150 g (3.97 mmoles) of sodium borohydride in 15 ml of 95% ethanol. After stirring for 2 hr, the reaction mixture was worked up in the normal manner to afford 0.0763 g of a white solid, mp 203–217°. Thin layer chromatography of this solid indicated that it is mainly *cis*-thioxanthenol sulfoxide (**3α**) (lit.[3] mp 218–218.5°), contaminated with trace amounts of thioxanthone and thioxanthenol. The infrared spectrum (Nujol) of the crude reaction product was quite similar to the spectrum of **3α**.[20]

Reduction of Thioxanthone Sulfoxide (1) with Sodium Borohydride in the Presence of Base. A. Excess Sodium Borohydride.—Sodium borohydride (0.805 g, 21.3 mmoles) was added to a solution of **1** (0.305 g, 1.34 mmoles) and sodium hydroxide (0.0507 g, 1.27 mmoles) in 50 ml of 95% ethanol. The reaction mixture was stirred for 2 hr, diluted with 5 ml of water, and then warmed on a steam bath for several minutes. The resulting solution was diluted with 300 ml of ice–water, allowed to stand for 1 hr, and the resulting solid removed by filtration. The solid was dried (*in vacuo*, calcium chloride) to afford 0.226 g (1.06 mmoles, 79% yield) of thioxanthenol (**4**), mp 104–105° (lit.[21] mp 104–105°). The infrared spectrum of this material was identical with that of authentic thioxanthenol.

B. An Equivalent of Sodium Borohydride.—Sodium borohydride (0.0152 g, 0.4 mmole) was added to a solution of thioxanthone sulfoxide (0.3003 g, 1.32 mmoles) and sodium hydroxide (0.0489 g, 1.22 mmoles) in 50 ml of 95% ethanol.[22] After stirring for 2 hr, the reaction mixture was diluted with 5 ml of water, heated on a steam bath (5 min), and then diluted with ice–water (300 ml). After standing for 1 hr, the resulting solid was removed by filtration and dried (*in vacuo*, calcium chloride). Thus, there was obtained 0.273 g (1.29 mmoles, 98% yield) of thioxanthone (**2**), mp 214–216° (lit.[23] mp 209°). Thin layer chromatography showed the material to be homogeneous and its infrared spectrum (Nujol) was identical with that of authentic thioxanthone.

Reaction of Thioxanthenol Sulfoxide (3) with Base. A. Sodium hydroxide (0.0543 g, 1.36 mmoles) was added to a solution of thioxanthenol sulfoxide (**3**)[24] (0.309 g, 1.34 mmoles) in 50 ml of 95% ethanol.[22] After stirring for 2 hr, the reaction mixture was diluted with water (5 ml), heated on a steam bath (5 min), and then diluted with ice–water (300 ml). After standing for 1 hr, the resulting solid was removed by filtration and dried (*in vacuo*, calcium chloride) to afford 0.279 g (1.32 mmoles, 97% yield) of **2**, mp 214–215° (lit.[23] mp 209°). The infrared spectrum (Nujol) of this material was identical with that of authentic **2**. Thin layer chromatography indicated the presence of **2** contaminated with trace quantities (<5%) of **1**.

B. Morpholine.—In separate experiments, **3α** (0.0070 g, 0.030 mmole) and **3β** (0.0069 g, 0.030 mmole) were each dissolved in 0.5 ml of morpholine. These solutions were examined by thin layer chromatography after standing for 10 hr at room temperature. Each solution suffered extensive conversion to thioxanthone, reaction being greater for **3β** than for **3α**. No other products could be detected by tlc. The reaction mixture did not develop a color under these conditions.

(20) All of the bands that do not appear in the spectrum of authentic **3α** may be found in the spectra of **2** and **4**.

(21) H. F. Oehlschlaeger and I. R. MacGregor, *J. Am. Chem. Soc.*, **73**, 5332 (1950).

(22) The solvent was degassed under vacuum and the reaction was carried out in an inert (N_2) atmosphere.

(23) E. G. Davis and S. Smiles, *Trans. Chem. Soc.*, **97**, 1290 (1910).

(24) A mixture was prepared from 0.1426 g of **3β** and 0.1664 g of **3α**.

Condensation of a 1,3,5-Triketone with Primary Amines to Form Diketoenamines or Diketoimines. Cyclization to Form N-Aryl-4-pyridones[1]

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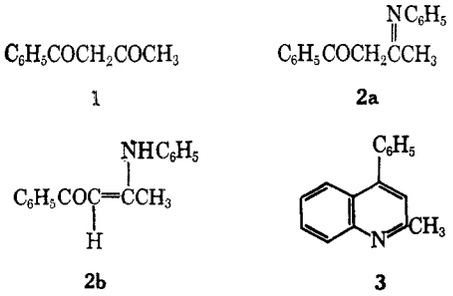
Received June 8, 1967

A 1,3,5-triketone was condensed with aniline and certain other primary amines in refluxing ethanol to form diketoenamines or the tautomeric diketoimines. The condensation involved the carbonyl group adjacent to the methyl group of the triketone. The diketoenamines obtained from the arylamines were cyclized by means of hot polyphosphoric acid to form N-aryl-2-methyl-6-phenyl-4-pyridones. The diketoenamine produced from *n*-butylamine failed to afford satisfactorily the N-alkyl-4-pyridone; instead the 4-pyrone was obtained. Mechanisms are suggested for these two courses of cyclizations.

The well-known condensation of a ketone with a primary amine to form an imine was long ago applied to benzoylacetone (**1**); either of the two carbonyl groups of this β-diketone might react with the amine. Actually, the carbonyl adjacent to the methyl group was shown to condense with aniline to give the ketoimine **2a**[2] or, more likely, the tautomeric ketoenamine **2b**.[3]



1

2a

2b

3

The ketoenamine was subsequently cyclized by means of sulfuric acid to afford quinoline **3** (see Experimental Section).[4]

In the present investigation, this type of carbon–nitrogen condensation was applied to triketone **4**, and the products were subjected to acid-catalyzed cyclization. Such a study promised to be of interest since not only might any of the three carbonyl groups of triketone **4** react with the amine, but the product from an aromatic amine might conceivably undergo two types of acid-catalyzed cyclizations. One of these cyclizations would be like that observed with **2a** (or **2b**) to afford a quinoline, and the other like that observed with triketone **4** and ethanolic ammonia which yields pyridone **5**.[5] In the latter cyclization, a diketoenamine was presumably an intermediate, but it was not isolated.[5]

(1) This investigation was supported by U. S. Public Health Service Research Grant No. U. S. PHS CA 04455-08 and by the National Science Foundation Research Grant No. NSF GP 6486.

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