Several mechanisms can be envisaged to account for this transformation. Protonation of **3** followed by loss of methanol could lead to the carbonium ion **5**. Such a cation should be stabilized by the heterocyclic oxygen as well as the aromatic ring. An attack on the methylene group by water could cleave the carbon–carbon bond and lead to **6**, a hemiacetal of formaldehyde, which would then hydrolyze to flavonol **1**. Alternately, water could open the oxirane ring to the diol **7** which might then undergo fragmentation to flavonol **1**. A third possibility would be a rearrangement of **3** to a dioxole **8** followed by hydrolysis.

Experimental Section

Spectra.—Except for the data reported in Table I, all ir spectra were taken as Nujol mulls on a Perkin-Elmer Infracord, Model 137 (NaCl prism).[10] All nmr spectra were obtained in $CDCl_3$ using a Varian A-60A spectrometer.[10]

All melting points are uncorrected. Analyses were carried out by Schwarzkopf Microanalytical Laboratory.

Diazomethane.—This was prepared from *N,N'*-dimethyl-*N,N'*-dinitrosoterephthalamide (**8**) according to the procedure of Moore and Reed.[11] When running 1-g batches of the flavandione hemiketals **2a–d**, we used 7.2 g of the 70% suspension of **8** in mineral oil, adding this to 120 ml of ether, 18 ml of 2-(2'-ethoxyethoxy)ethanol, and 24 ml of 30% aqueous NaOH. This should produce about a tenfold excess of CH_2N_2. In practice the CH_2N_2–ether was distilled directly into a flask containing **2a–d** suspended in a little ether.

Flavonols (1a–d).—The flavonols **1a** and **1b** were prepared directly from *o*-hydroxyacetophenone and the corresponding benzaldehydes according to the procedure of Smith, Neuman and Webb.[12] This procedure is erratic for flavonols with methoxyls in the *o*-hydroxyacetophenone. However, alkaline hydrogen peroxide converts the corresponding 2'-hydroxychalcones into flavonols in yields of 40–50% using essentially the procedure of Algar and Flynn.[13] **1c** and **1d** were made this way.

2-Methoxy-3,4-flavandione Methyl 3-Hemiketals (2a–d).[10]—These were prepared as reported previously.[4] For nmr data, see Table II.

2-Methoxy-3,3-oxymethyleneflavanone (3a).—A 1.0-g sample of **2a** was treated with diazomethane at room temperature over night. The reaction was followed qualitatively by tlc on SiO_2 ($CHCl_3$), **2a** being much less mobile than the epoxide **3a**. Upon standing overnight **2a** had substantially disappeaerd. A trace of a second product was detected but not isolated. Evaporation of the filtered ether solution yielded a mixture of oil and solid. Crystallization from 15 ml of methanol afforded 0.58 g (62%) of **3a**, mp 133–134°.

Anal. Calcd for $C_{17}H_{14}O_4$: C, 72.33; H, 5.00; OCH_3, 10.99. Found: C, 72.62; H, 5.19; OCH_3, 10.71.

2,4'-Dimethoxy-3,3-oxymethyleneflavanone (3b).—A 1-g sample, treated twice with diazomethane, yielded a tough residue upon evaporation of the solvent. This was crystallized from 20 ml of methanol to give 0.61 g (64%) of rodlike crystals, mp 138–139°.

Anal. Calcd for $C_{18}H_{16}O_5$: C, 69.22; H, 5.16; OCH_3, 19.88. Found: C, 69.00; H, 5.16; OCH_3, 20.90.

2,7-Dimethoxy-3,3-oxymethyleneflavanone (3c).—A 1-g sample, treated twice with diazomethane, yielded a solid upon evaporation of the solvent. When recrystallized from 15 ml of MeOH, it afforded a 47% yield of white crystals melting at 135–137°. The analytical sample melted at 139–140° (MeOH).

Anal. Calcd for $C_{18}H_{16}O_5$: C, 69.22; H, 5.16; OCH_3, 19.87. Found: C, 69.13; H, 5.26; OCH_3, 19.34.

2,4',7-Trimethoxy-3,3-oxymethyleneflavanone (3d).—A 1-g sample of **2d** was treated with two portions of diazomethane, tlc indicating incomplete reaction after the first one. Both the starting hemiketal **2d** and the product **3d** have limited solubility in ether. At the end of the second treatment, there was 400 mg of a solid which was **3d** mixed with some polymer. Evaporation of the filtrate from this yielded an oil–solid mixture. This mixture yielded 180 mg (21%) of crystalline **3d**, mp 185–187° from 40 ml of MeOH. The analytical sample melted at 187.5–189°.

Anal. Calcd for $C_{19}H_{18}O_6$: C, 66.69; H, 5.30; OCH_3, 27.20. Found: C, 66.67; H, 5.38; OCH_3, 27.45.

3-Hydroxy-3-iodomethyl-2-methoxyflavanone (4).—A 500-mg sample of **3a** was rapidly converted to **4** in a hot mixture of 15 ml of acetic acid and 750 mg of KI. Tlc (SiO_2, $CHCl_3$) showed that reaction was complete in 10 min. The hot, brown solution was poured into 200 ml of water containing 1 g of sodium bisulfite. A formless solid separated. After drying, it was crystallized from 15 ml of petroleum ether (bp 60–110°), fine crystals separating. The yield of **4** was 450 mg (63%), mp 124–125°, nmr, see discussion. When treated with sodium methoxide in methanol, **4** was converted to the epoxide **3** in high yield.

Anal. Calcd for $C_{17}H_{15}O_4I$: C, 49.80; H, 3.79; I, 30.94. Found: C, 50.00, 50.87; H, 3.28, 3.67; I, 29.39, 30.3.

Conversion of Epoxide to Flavonol. With Boron Trifluoride Etherate.—**2a** (150 mg) was heated at 65° for 1 hr with a mixture of 20 ml of benzene and 2 ml of $BF_3 \cdot Et_2O$. The addition of 60 ml of ether afforded a copious precipitate of flavonol, 70 mg (47%), mp 168–170° (from MeOH).

With Sulfuric Acid.—**2a** (200 mg) was stirred with 40 ml of 50% H_2SO_4 for 1 hr at 100–120°. The resulting yellow solution was filtered through charcoal and diluted with 20 ml of water. After standing, the flavonol (**1a**) was collected by filtration, 120 mg (71%), mp 169°, ir identical with that of an authentic sample.

Registry No.—**1a**, 577-85-5; **2a**, 1603-46-9; **2b**, 1808-05-5; **2c**, 2047-54-3; **2d**, 1808-02-2; **3a**, 34917-93-6; **3b**, 34887-89-3; **3c**, 34887-90-6; **3d**, 34887-91-7; **4**, 34887-92-8; diazomethane, 334-88-3.

(10) The ir and nmr spectra of hemiketal **2a**, epoxide **3a**, and iodohydrin **4** will appear following these pages in the microfilm edition of this volume of the journal. Single copies may be obtained from the Business Operations Office, Books and Journals Division, American Chemical Society, 1155 Sixteenth St., N.W., Washington, D. C. 20036, by referring to code number JOC-72-2774. Remit check or money order for $3.00 for photocopy or $2.00 for microfiche.

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2-Thiocyanobenzimidazoles. The Synthesis of 13*H*-[1,3,5]Thiadiazino[3,2-*a*:5,6-*a'*]-bisbenzimidazole-13-thiones

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We recently reported[1] that 2-thiocyanomethylbenzimidazoles (**1**) cyclized readily to yield 1-imino-1*H*,3*H*-thiazolo[3,4-*a*]benzimidazoles (**2**). These results encouraged us to investigate the utility of 2-thiocyanobenzimidazole (**3**) for the synthesis of novel fused benzimidazole ring systems. Thus, it was hoped that the reaction of **3** with carbon disulfide in basic medium would furnish[2] A. However, the yellow crystalline product isolated in 86% yield from the reaction mixture (reaction time 5 min) showed no exchangeable proton (D_2O) in the nmr but exhibited only aromatic protons, with a one-proton multiplet significantly downfield from the remaining three protons. We have observed similar chemical shifts for 3,4-dihydropyrimido-

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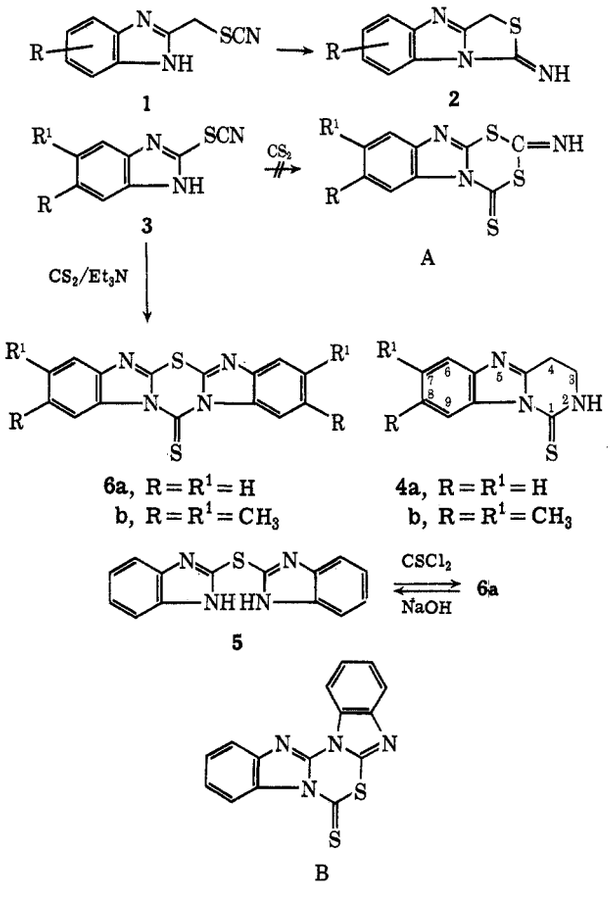
[3,4-*a*]benzimidazole-1(2*H*)-thiones (**4**) the most downfield signal, namely 9-H, being due to the deshielding effect of the thione function. The ir of the product was devoid of NH absorption but showed a band at 1500 cm^{-1} compatible with a S=CN< moiety. Its mass spectrum showed a molecular ion of M^+ 308 consistent with the formula $C_{15}H_8N_4S_2$, suggestive of two benzimidazole rings linked by CS_2 (structure **6a** or B). Whereas oxidative degradation of the reaction product resulted in ill-defined products and acid hydrolysis led to the recovery of starting material, mild base hydrolysis furnished a white solid which was subsequently identified as dibenzimidazol-2-yl sulfide[3] **5**, obtained by the alkylation of 2-mercaptobenzimidazole with 2-chlorobenzimidazole. Based on the above facts, we have assigned the pentacylic structure **6a** to the product. This was confirmed by synthesizing **6a** from **5** by the interaction of the sodium salt of **5** with thiophosgene.

We have extended this facile one-step synthesis of the pentacyclic system to the preparation of the tetramethyl analog **6b**.

Presently, we are investigating the scope of this interesting cyclization.



Experimental Section

Melting points were determined on a Thomas-Hoover "Uni-Melt" apparatus and are uncorrected. Ir spectra were determined in Nujol. Nmr spectra were obtained on a Varian A-60 instrument. Signals are described as singlet (s) or multiplet (m).

13*H*-[1,3,5]Thiadiazino[3,2-*a*:5,6-*a*']bisbenzimidazole-13-thione (6a).—To a solution of 5 g of 2-thiocyanobenzimidazole in 20 ml of dimethyl sulfoxide, there was added at once 5 ml of carbon disulfide and 5 ml of triethylamine. A yellow solid, deposited after 1 min, was filtered off after 1 hr of standing. The solid was washed with ethanol to yield 3.6 g of **6a**. Two crystallizations from benzene–ethyl ether furnished the pure product: mp 184–185°; nmr ($CDCl_3$) δ 7.26–7.84 (m, 6 H, ArH), 8.93–9.09 (m, 2 H, 1-H, 11-H); mass spectrum *m/e* 308.0187 (M^+). *Anal.* Calcd for $C_{15}H_8N_4S_2$: C, 58.42; H, 2.62; N, 18.17; S, 20.80. Found: C, 58.42; H, 2.75; N, 18.50; S, 21.03.

2,3,9,10-Tetramethyl-13*H*-[1,3,5]thiadiazino[3,2-*a*:5,6-*a*']bisbenzimidazole-13-thione (6b).—To a solution of 1.9 g of 2-thiocyano-5,6-dimethylbenzimidazole in 10 ml of dimethyl sulfoxide was added 2 ml of carbon disulfide and 2 ml of triethylamine. The mixture was allowed to stand at room temperature overnight. The yellow crystals were filtered off, washed with methanol, and crystallized from benzene to yield 0.8 g of **6b**. Recrystallization from benzene yielded the pure product, mp 338–340°, mass spectrum *m/e* 364.0856 (M^+). *Anal.* Calcd for $C_{19}H_{16}N_4S_2$: C, 62.61; H, 4.43; N, 15.37. Found: C, 62.74; H, 4.66; N, 15.46.

3,4-Dihydropyrimido[3,4-*a*]benzimidazole-1(2*H*)-thione (4a).—A mixture of 4.6 g of 2-(β-aminoethyl)benzimidazole, 30 ml of dimethyl sulfoxide, 4.6 ml of triethylamine, and 4.6 ml of carbon disulfide was stirred at room temperature for 14 hr. The product that separated upon diluting the reaction mixture with water was crystallized from acetone to yield **4a**: mp 212–213° (lit.[4] mp 216°); nmr (dimethyl sulfoxide-d_6) δ 3.13–3.83 (m, 4 H, $-CH_2-CH_2-$), 7.23–7.92 (m, 3 H, ArH), 8.82–9.02 (m, 1 H, 9-H).

7,8-Dimethyl-3,4-dihydropyrimido[3,4-*a*]benzimidazole-1(2*H*)-thione (4b).—A suspension of 6 g of 2-(β-aminoethyl)-5,6-dimethylbenzimidazole dihydrochloride, 6 ml of triethylamine, 6 ml of carbon disulfide, and 40 ml of dimethyl sulfoxide was stirred at room temperature overnight. Water was added and the crude product was filtered off. Crystallization from diglyme gave 3.5 g of pure **4b**: mp 232°, nmr (dimethyl sulfoxide-d_6) δ 2.34 (s, 6 H, CH_3), 2.98–3.78 (m, 4 H, $-CH_2CH_2-$), 7.38 (s, 1 H, 6-H), 8.57 (s, 1 H, 9-H), 10–10.53 (s, 1 H, NH). *Anal.* Calcd for $C_{12}H_{13}N_3S$: C, 62.30; H, 5.66; N, 18.17. Found: C, 61.95; H, 5.94; N, 18.45.

Hydrolysis of 13*H*-[1,3,5]Thiadiazino[3,2-*a*:5,6-*a*']bisbenzimidazole-13-thione (6a).—A mixture of 0.4 g of **6a**, 8 ml of methanol and 2 ml of 10% NaOH was heated on the steam bath for 1 min. By this time, the compound has dissolved and had lost its yellow color. The cooled mixture was filtered and the filtrate was adjusted to pH 7 with 10% HCl. The precipitate was filtered off and dried to yield 0.35 g of crude sulfide **5**. Crystallization from ethanol yielded the pure product, mp 273–275°, the ir of which was identical with that of an authentic sample prepared by the method of Harrison and Ralph.[3]

Synthesis of 6a.—To a suspension of 0.15 g of the sulfide **5** in 20 ml of glyme, there was added 0.03 g of sodium hydride. After 2 hr of stirring at room temperature 0.05 ml of thiophosgene was added to the suspension and the stirring was continued for 2 hr. The mixture was evaporated and the product was extracted with benzene. Two crystallizations from benzene–ethyl ether furnished 0.05 g of **6a**, mp 180–182°, the ir of which was identical with that of the product obtained by the reaction of 2-thiocyanobenzimidazole with carbon disulfide.

Registry No.—**4b**, 34858-78-1; **5**, 2469-66-1; **6a**, 34858-80-5; **6b**, 34858-81-6.

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Quaternary Ammonium Salts and Betaines of Thionocarbamic Esters

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An earlier paper[1] described tertiary aminoalkyl esters of thionocarbamic acids (**1**) and their isomerism due to

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