The Preparation and Properties of Isomeric Diamino-*v*-triazolopyridines. 1- and 3-Deaza-2,6-diamino-8-azapurines[1]

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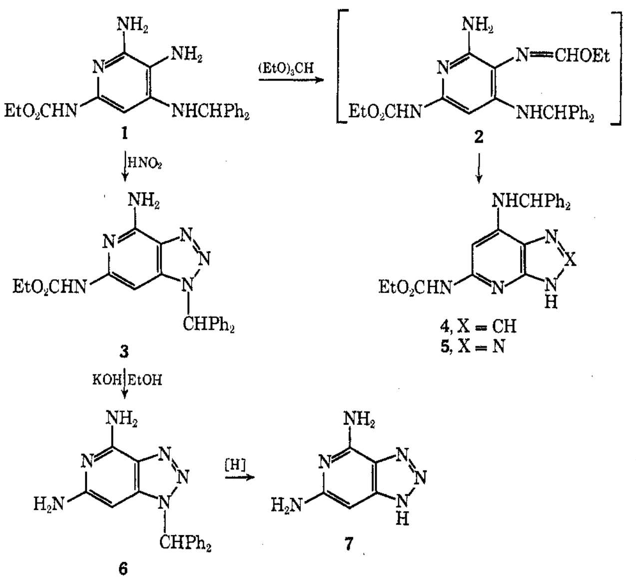
The nitrosation of ethyl 5,6-diamino-4-[(diphenylmethyl)amino]pyridine-2-carbamate (1) resulted in ring closure between the 5-amino- and 4-(diphenylmethyl)amino groups to give ethyl 4-amino-1-[(diphenylmethyl)-amino]-1*H*-*v*-triazolo[4,5-c]pyridine-6-carbamate (3). Removal of the blocking groups of 3 gave 4,6-diamino-1*H*-*v*-triazolo[4,5-*c*]pyridine (7). The isomeric 5,7-diamino-3*H*-*v*-triazolo[4,5-*b*]pyridine (14) was prepared from 5-amino-7-chloro-3*H*-*v*-triazolo[4,5-*b*]pyridine (10) by reduction of the corresponding 7-azido derivative 12. Two other routes for the preparation of 14 are discussed. The Dimroth rearrangement between 7 and 14 was investigated.

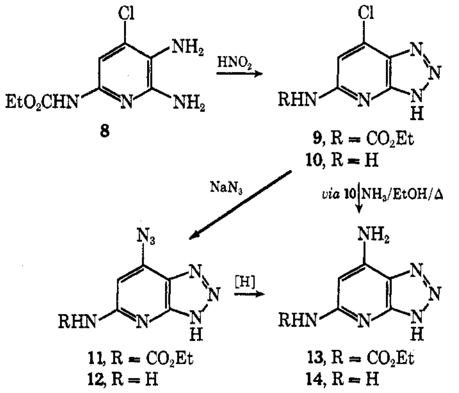
The isomeric 4,6-diamino-1*H*-*v*-triazolo[4,5-*c*]pyridine (8-aza-3-deaza-2,6-diaminopurine) (7) and 5,7-diamino-3*H*-*v*-triazolo[4,5-*b*]pyridine (8-aza-1-deaza-2,6-diaminopurine) (14) compounds are of theoretical and biological interest as purine ring analogs. Although the nitrosation of the known 2,3,4,6-tetraaminopyridine[2] might provide either one or both of 7 and 14, this method might lead to ambiguous structural assignments. The present paper describes the effect of the (diphenylmethyl)amino group on the mode of cyclization in tetraaminopyridines, the nucleophilic displacement of the chloro group in the 5-amino-7-chlorotriazolopyridine 10, and the Dimroth rearrangement between 7 and 14.[3]

Treatment of 1 with ethyl orthoformate was shown to result in cyclization between the 5,6-diamino groups to give ethyl 7-[(diphenylmethyl)amino]-3*H*-imidazo[4,5-*b*]pyridine-5-carbamate (4).[4] This mode of cyclization was attributed to steric interaction between the 4-[(diphenylmethyl)amino] and 5-[(ethoxymethylene)amino] groups of the presumed intermediate 2. In contrast, nitrosation of 1 gave a homogeneous product (tlc), which was assigned structure 3 rather than 5. Initially the assignment of structure was based on the greater nucleophilicity of the (diphenylmethyl)amino group over that of the 6-amino group in the presumed 5-diazopyridine intermediate (see 21 and 22), and this surmise was confirmed by the results described below.



Cleavage of the urethane group of 3 was effected with refluxing ethanolic KOH to give 6. Support for this structure (6) was provided by its pmr spectrum, which showed the CH of the Ph$_2$CHN group as a singlet. This CH in the isomeric compound obtained from 5 might appear as a doublet as a result of spin-spin coupling between the CH and NH of the Ph$_2$CHNH group. This type of splitting is observed in the spectrum of the related imidazopyridine 4.[4] Removal of the diphenylmethyl blocking group of 6 to give 7 was more difficult. Treatment of 6 with concentrated HCl[4] at room temperature gave mainly recovered 6 and unidentified decomposition products, but none of 7. Similarly, hydrogenation of 6 in the presence of Raney nickel gave none of 7. In contrast, hydrogenation of 6 in the presence of palladium at 60° resulted in overreduction (1.8 molar equiv of H_2), but the resulting mixture gave a 45% yield of 7. Additional proof for the structure of 7 (and 3) was provided by the synthesis of the isomeric compound 14.

Nitrosation of 8[4] gave a good yield of 9. Treatment of 9 with sodium azide resulted in azidodechlorination to give 11, which was readily hydrogenated in the presence of palladium to give 13. The azide reaction demonstrated that the reactivity of the chloro group in the triazolopyridine 9 was greater than that of the chloro group in the corresponding imidazopyridine series.[4] Simultaneously, a similar sequence of reactions was used to prepare the 5,7-diamino compound 14.



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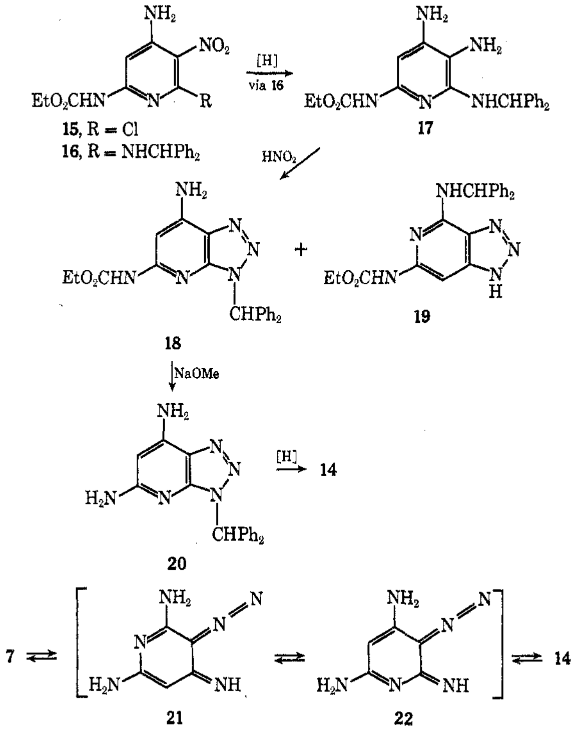
[1] This investigation was supported by Contract NIH-71-2021 from the Division of Cancer Treatment, National Cancer Institute, National Institutes of Health.

[2] R. D. Elliott, C. Temple, Jr., and J. A. Montgomery, *J. Org. Chem.*, **33**, 2393 (1968).

[3] C. Temple, Jr., B. H. Smith, Jr., and J. A. Montgomery, *ibid.*, **37**, 3601 (1972); *Chem. Commun.*, 52 (1972).

[4] C. Temple, Jr., B. H. Smith, Jr., and J. A. Montgomery, *J. Org. Chem.*, in press.

Treatment of **9** with NaOMe in refluxing ethanol for 26 hr gave **10**, which was treated with sodium azide to give **12**. Unexpectedly, hydrogenation of **12** with either Raney nickel or palladium resulted in only partial conversion to **14**. Apparently the formation of **14** poisoned the catalysts. However, treatment of **12** with sodium hydrosulfite gave a pure sample of the desired product **14**. Also, treatment of **10** with 12% ethanolic ammonia in the presence of NH_4Cl in a bomb at 150° for 19 hr resulted in a 16% yield of **14** contaminated with a trace amount of **10** (tlc). In another approach, reaction of **15**[5] with diphenylmethylamine gave **16**, which was hydrogenated in the presence of Raney nickel to give **17**. Nitrosation of **17** gave a mixture from which pure **18** was separated. This reaction gave another product that was homogeneous (tlc) and analyzed correctly for **19**. However, this sample was insoluble in dilute NaOH, and on storage was converted to a mixture containing **18** (tlc). These results suggested that the sample initially isolated was an unstable polymeric material rather than **19**. Cleavage of the urethane group of **18** was effected with $NaOCH_3$ in PrOH to give **20**. Hydrogenation of the latter in the presence of a palladium catalyst was difficult and gave only partial conversion to **14**.



The results of previous studies suggested that rearrangement of **7** to **14** might occur readily.[3] Although the chemical shifts of the ring CH's of **7** and **14** are quite similar in deuterated DMSO, the signals from these protons are readily distinguished in the spectrum of the mixture, so that pmr spectroscopy could be used to monitor the rearrangement. Treatment of **7** with 12% ethanolic ammonia in a bomb at 150° gave about a 50% conversion to **14** in 17 hr and about an 85% conversion in 120 hr (7 half-lives). Presumably, this conversion involves the diazopyridine intermediates **21** and **22**. These results show that the thermodynamic stability of **14** is greater than that of **7** in the presence of ammonia, which was confirmed by treatment of **14** with ethanolic ammonia. No rearrangement of **14** to **7** either at 150° or 175° was detected by tlc.

Experimental Section[6]

Ethyl 4-Amino-1-(diphenylmethyl)-1*H*-*v*-triazolo[4,5-*c*]pyridine-6-carbamate (3).—Solid sodium nitrite (1.5 g) was added to a solution of **1** (7.9 g)[4] in DMF (100 ml) containing 1 *N* HCl (21 ml) at 5°. After the addition was complete the reaction mixture was stirred at room temperature for 5 hr and diluted with H_2O (1000 ml). The resulting suspension was adjusted to pH 8 (paper) with $NaHCO_3$, and the crude product was collected by filtration and washed with H_2O, yield 7.0 g (86%). The analytical sample, recrystallized from EtOH, decomposed from about 120°.

Anal. Calcd for $C_{21}H_{20}N_6O_2$: C, 64.93; H, 5.19; N, 21.64. Found: C, 64.66; H, 5.24; N, 21.37.

4,6-Diamino-1-(diphenylmethyl)-1*H*-*v*-triazolo[4,5-*c*]pyridine (6).—A mixture of **3** (1.0 g) and KOH (1.4 g) in EtOH (50 ml) was refluxed for 10 hr, cooled, and filtered. The resulting residue was suspended in H_2O (20 ml), and the mixture was acidified to pH 5 (paper) with HOAc. The solid was collected by filtration, washed with H_2O, and dried *in vacuo* over P_2O_5 at 78°, yield 0.31 g (38%), mp 245–246°.

Anal. Calcd for $C_{18}H_{16}N_6$: C, 68.33; H, 5.10; N, 26.57. Found: C, 68.11; H, 5.07; N, 26.40.

The reaction filtrate from above was worked up in a similar manner to give an additional 0.37 g of crude **6**. The total yield was 0.68 g (83%).

4,6-Diamino-1*H*-*v*-triazolo[4,5-c]pyridine (7).—A suspension of **6** (2.0 g) in a mixture of EtOH (200 ml) and DMF (2 ml) was hydrogenated in the presence of 5% palladium on charcoal (2 g) at atmospheric pressure and room temperature. The uptake of hydrogen was very slow. After 2 hr additional 5% palladium (2 g) was added, and the mixture was hydrogenated at 60° for 72 hr. The uptake ceased after about 1.8 molar proportions of H_2 was absorbed. The catalyst was removed by filtration (Celite), and the filtrate was evaporated to dryness *in vacuo*. The resulting residue was washed with Et_2O and recrystallized from H_2O (dried 78°), yield 0.43 g (45%), mp 228–229° dec.

Anal. Calcd for $C_5H_6N_6$: C, 40.00; H, 4.03; N, 55.97. Found: C, 39.88; H, 3.99; N, 55.77.

Ethyl 7-Chloro-3*H*-*v*-triazolo[4,5-*b*]pyridine-5-carbamate (9).—Solid sodium nitrite (3.3 g) was added slowly with stirring to a suspension of **8** (10 g)[4] in 5% aqueous HOAc (200 ml), which was cooled in an ice bath. After the addition was complete the reaction mixture was stirred at room temperature for 20 hr. The solid was collected by filtration and reprecipitated from hot EtOH (Norit) by the addition of H_2O, yield 9.0 g (86%), mp 211° dec.

Anal. Calcd for $C_8H_8ClN_5O_2$: C, 39.77; H, 3.34; Cl, 14.67; N, 28.98. Found: C, 39.62; H, 3.62; Cl, 14.50; N, 28.65.

5-Amino-7-chloro-3*H*-*v*-triazolo[4,5-*b*]pyridine (10).—A mixture of **9** (5.0 g) and MeONa (5.6 g) in EtOH (250 ml) was refluxed for 26 hr. The reaction mixture was evaporated to dryness, and the residue was dissolved in 1 *N* HCl (155 ml). The resulting solution was adjusted first to pH 8 (paper) with dilute NH_4OH and then to pH 5 with dilute HCl. After chilling, the product was collected by filtration and dried *in vacuo* over P_2O_5 at 78°, yield 3.0 g (86%), mp >350°.

Anal. Calcd for $C_5H_4ClN_5$: C, 35.41; H, 2.38; Cl, 20.91; N, 41.30. Found: C, 35.20; H, 2.49; Cl, 20.93; N, 41.16.

Ethyl 7-Azido-3*H*-*v*-triazolo[4,5-*b*]pyridine-5-carbamate (11).—A solution of **9** (1.0 g) in a mixture of 1:1 EtOH–H_2O (50 ml) containing sodium azide (6.0 g) was refluxed for 48 hr. The reaction mixture was evaporated to dryness, the residue was dissolved in H_2O, and the resulting solution was acidified to pH 5 (paper) with HOAc. The solid that deposited was collected by filtration, recrystallized from aqueous EtOH, and dried *in vacuo* over P_2O_5 at 56°, yield 0.62 g (60%). This sample decomposed from $\sim$160°.

Anal. Calcd for $C_8H_8N_8O_2$: C, 38.71; H, 3.25; N, 45.15. Found: C, 38.96; H, 3.50; N, 45.22.

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[5] R. D. Elliott, C. Temple, Jr., J. L. Frye, and J. A. Montgomery, *J. Org. Chem.*, **36**, 2818 (1971).

[6] Melting points, unless otherwise noted, were determined on a Mel-Temp apparatus, and thin layer chromatograms (silica gel H) were developed with mixtures of $CHCl_3$ and MeOH.

TABLE I

SPECTRAL PROPERTIES OF SOME *v*-TRIAZOLOPYRIDINES

Compd	Uv absorption[a] spectra at pH 7, λ_{max}, nm ($\epsilon \times 10^{-3}$)	Ir absorption[b] spectra in KBr, selected bands, cm^{-1}	Pmr spectral assignments,[c] chemical shifts, δ (rel area)
3	233 (28.3), 290 (11.4), 303 sh (10.8)	1730, 1630, 1605	1.21 t (3, CH_3), 4.10 q (2, CH_2), 7.01,[d] 7.10, 7.37 m [14, NH_2, CH (C_6H_5, CH)], 9.43 (1, NH)[d]
6	228 sh (24.9), 285 (6.33), 322 (7.12)	1645, 1600, 1590	5.42,[e] 5.55[d] (3, 7 H, NH_2), 6.73 (2, NH_2),[d] 7.21, 7.37 (11, HCPh, C_6H_5)
7	225 (27.1), 275 (4.75), 314 (5.37)	1660, 1620, 1595	5.43 br, 5.68 (3, NH_2, 7 H), 6.60 br (2, NH_2), ~14 br (1, NH)
9	222 (22.9), 302 (14.9)	1750, 1725, 1595	
10	265 sh (5.10), 293 (7.41)[f]	1615, 1535	6.72 (6 H), 6.85 (NH_2), ~14 br (NH)
11	222 (21.5), 300 (17.5)	2115, 1700, 1615	
12	284 (12.6), 307 sh (9.55)[f]	2120, 1625, 1580	1.08, 3.48 (CH_3CH_2OH), 6.17 (1, 6 H), 6.64 (2, NH_2),[d] ~12 (1, NH)[d]
13	281 (16.9), 302 (22.2)[g]	1715, 1700, 1645	
14	280 sh (15.6), 293 (18.2)[f]	1640, 1600, 1535	5.71 (1, 6 H), 7.43 br (2, NH_2), ~9.6 br (4, NH_2, NH, NH^+)
17	222 (34.8), 296 (8.10)	1725, 1660, 1610	
18	232 (22.7), 283 (16.4), 297 sh (14.1)	1720, 1650, 1630	1.23 t (CH_3), 4.13 q (2, CH_2), 7.17, 7.24,[h] 7.35 [14, CH (CH, NH_2), C_6H_5], 9.81 (1, NH)
20	292 (16.0)	1625, 1600, 1515	3.33 br (4, $NH_2 + H_2O$), 5.61 (1, 6 H), 6.32 br (2, NH_2), 7.07 (1, HCPh), 7.32 (10, C_6H_5)

[a] Cary Model 17 spectrophotometer. Unless otherwise noted, solvent contains 10% MeOH and 90% pH 7 phosphate buffer. [b] Perkin-Elmer Model 521 and 621 spectrophotometers. [c] Pmr spectra of samples were determined in DMSO-d_6 solutions (5–10% w/v) with Varian A-60A and XL-100-15 spectrometers with TMS as an internal reference; peak positions quoted in the case of multiples are measured from the approximate center, and the relative peak areas are given to the nearest whole number. [d] Undergoes deuterium exchange on addition of D_2O. [e] Undergoes deuterium exchange in the presence of D_2O within 96 hr. [f] Solvent contains 0.8% DMSO, 9.2% MeOH, and 90% pH 7 phosphate buffer. [g] Determined in 0.1 *N* HCl as solvent. [h] Undergoes partial deuterium exchange on addition of D_2O.

5-Amino-7-azido-3*H*-*v*-triazolo[4,5-*b*]pyridine (12).—A mixture of **10** (0.50 g) and sodium azide (4.3 g) in 1:1 PrOH–H_2O (30 ml) was refluxed for 68 hr. The reaction mixture was evaporated to dryness, and the residue was treated with H_2O (35 ml). After filtration the filtrate was acidified with HOAc to pH 5 (paper) to deposit the product, yield 0.32 g (62%). A sample (0.13 g) of this material was recrystallized from EtOH, yield 0.10 g (77% recovery), mp 245° dec. The presence of EtOH in the sample was confirmed by the pmr spectrum (Table I).

Anal. Calcd for $C_5H_4N_8\cdot{}^1/_4C_2H_6O$: C, 35.20; H, 2.96; N, 59.71. Found: C, 35.32; H, 2.72; N, 59.74.

Ethyl 7-Amino-3*H*-*v*-triazolo[4,5-*b*]pyridine-5-carbamate (13).—A suspension of **11** (0.50 g) in EtOH (125 ml) was hydrogenated in the presence of 5% palladium on charcoal at atmospheric pressure and room temperature for 4 hr. After the reaction mixture was warmed, the catalyst was removed by filtration (Celite) and washed with EtOH. The combined filtrate and wash was evaporated to dryness *in vacuo;* the resulting solid was recrystallized from 30% aqueous EtOH and dried *in vacuo* over P_2O_5 at 100° for 18 hr, yield 0.34 g (74%), mp >300°.

Anal. Calcd for $C_8H_{10}N_6O_2\cdot{}^1/_3H_2O$: C, 42.11; H, 4.71; N, 36.84. Found: C, 42.06; H, 4.53; N, 36.51.

A sample of this product was dried *in vacuo* over P_2O_5 at 110°.

Anal. Calcd for $C_8H_{10}N_6O_2$: C, 43.24; H, 4.54; N, 37.82. Found: C, 42.80; H, 4.68; N, 37.75.

5,7-Diamino-3*H*-*v*-triazolo[4,5-*b*]pyridine (14).—A mixture of **12** (0.18 g) in MeOH (45 ml) and H_2O (20 ml) containing sodium hydrosulfite (1.0 g) was refluxed for 4.5 hr, acidified to pH 1 (paper) with dilute H_2SO_4, and filtered. The filtrate was adjusted to about pH 5 with dilute NaOH and chilled to deposit the hemisulfate salt. The product was collected by filtration, washed with water and hot PrOH, and dried *in vacuo* over P_2O_5 at 78°, yield 0.10 g (49%), mp 305° dec.

Anal. Calcd for $C_5H_6N_6\cdot{}^1/_2H_2SO_4$: C, 30.15; H, 3.55; N, 42.19. Found: C, 30.25; H, 3.46; N, 41.96.

B.—A solution of **20** (100 mg) in 5% ethanolic DMAC (10 ml) was hydrogenated in the presence of 5% palladium on charcoal for 6 hr at atmospheric pressure and room temperature. After filtration the catalyst was washed with hot DMAC, the combined filtrate and wash were evaporated to dryness, and the resulting residue was washed with hexane to remove Ph_2CH_2, yield 59 mg. Tlc indicated that this product was a mixture of **14** and **20**. A portion of this sample (30 mg) was washed with Et_2O to give **14** (7 mg). The uv spectrum of the latter was identical with that described above.

C.—A mixture of **7** (50 mg) in 12% ethanolic ammonia was heated in a bomb at 150° for 17 hr and evaporated to dryness *in vacuo*, yield 50 mg (100%). Tlc indicated that the product was a mixture of **7** and **14**, and the pmr spectrum in deuterated DMSO showed that the ratio of **7**:**14** was 1:1. In a similar experiment at 150° for 120 hr (7 half-lives), the ratio of **7**:**14** was 3:17.

Ethyl 4-Amino-6-[(diphenylmethyl)amino]-5-nitro-2-pyridinecarbamate (16).—A mixture of **15** (4.00 g),[5] diphenylmethylamine (4.00 g), and Et_3N (3.12 g) in MeOH (60 ml) was heated at 75° for 36 hr. The resulting solution was cooled to deposit a yellow solid, which was collected by filtration. The product was washed with H_2O and MeOH and dried *in vacuo* over P_2O_5 at 78°, yield 4.55 g (73%), mp 159–160°.

Anal. Calcd for $C_{21}H_{21}N_5O_4$: C, 61.90; H, 5.20; N, 17.19. Found: C, 61.67; H, 5.14; N, 16.94.

An additional 0.9 g of crude product was obtained from the reaction filtrate. The total yield was 5.45 g (87%).

Ethyl 4,5-Diamino-6-[(diphenylmethyl)amino]-2-pyridinecarbamate (17).—A suspension of **16** (2.00 g) in EtOH (280 ml) was hydrogenated in the presence of Raney nickel (2.0 g wet, washed with H_2O and EtOH) at room temperature and atmospheric pressure. The resulting reaction mixture was filtered (Celite) into a flask containing concentrated HCl (1.0 ml). The dark filtrate was treated with Norit (0.5 g) and evaporated to dryness *in vacuo;* the pale pink solid was dried *in vacuo* over P_2O_5 at 78°, yield 1.45 g (66%). This material does not melt, but undergoes decomposition from 210°.

Anal. Calcd for $C_{21}H_{23}N_5O_2\cdot 2HCl$: C, 56.00; H, 5.60; Cl, 15.74; N, 15.55. Found: C, 55.84; H, 5.49; Cl, 15.55; N, 15.40.

Ethyl 7-Amino-3-(diphenylmethyl)-3*H*-*v*-triazolo[4,5-*b*]pyridine-2-carbamate (18).—Solid sodium nitrite (1.1 g) was added with stirring to a solution of **17**·2HCl (6.4 g) in DMF (80 ml), which was precooled in an ice bath to 5°. After 30 min the ice bath was removed, and the solution was stirred at room temperature for 5 hr. After filtration the reaction mixture was poured into ice water (1500 ml), and the resulting solution was neutralized with $NaHCO_3$. The precipitate was collected by filtration, dried *in vacuo* over P_2O_5, and extracted with boiling petroleum ether (3000 ml) (bp 80–110°). The product that crystallized from the cooled extract was collected by filtration, and the filtrate was used to again extract the insoluble material from the first extract. This procedure was repeated four times. The recrystallized crops were combined and dried *in vacuo* over P_2O_5, yield 2.6 g (47%). The pmr spectrum and tlc data indicated that this material was homogeneous; however, the melting point was indefinite. This sample solidified after melting at 208° on the Kofler Heizbank apparatus and melted at >350° on the Mel-Temp apparatus. In another experiment the homogeneous material (tlc) melted in these apparatus at 132 and 145–147°, respectively.

Anal. Calcd for $C_{21}H_{20}N_6O_2$: C, 64.93; H, 5.19; N, 21.64. Found: C, 65.14; H, 5.33; N, 21.50.

The petroleum ether insoluble material was homogeneous on tlc and analyzed correctly for ethyl 4-[(diphenylmethyl)amino]-1*H*-*v*-triazolo[4,5-c]pyridine-6-carbamate (**19**), yield 1.5 g (27%), mp ~315° dec. The insolubility of this product in deuterated DMSO precluded the determination of its pmr spectrum. However, after 3 years tlc indicated that this product was a mixture containing **18**, suggesting that the original material was an unstable polymeric product and not **19**.

Anal. Calcd for $C_{21}H_{20}N_6O_2$: C, 64.93; H, 5.19; N, 21.64. Found: C, 64.76; H, 4.99; N, 21.84.

5,7-Diamino-3-(diphenylmethyl)-3*H*-*v*-triazolo[4,5-*b*]pyridine (20).—A mixture of **18** (0.50 g) and $NaOCH_3$ (0.35 g) in PrOH (20 ml) was refluxed for 20 hr and evaporated to dryness *in vacuo*. The residue was heated in 0.1 *N* HCl at 50° for 15 min, cooled, and adjusted to pH 8 (paper) with dilute NaOH. The precipitate was collected by filtration, recrystallized from C_6H_6, and dried *in vacuo* over P_2O_5 at 56°, yield 0.28 g (69%), mp 115° (Kofler Heizbank).

Anal. Calcd for $C_{18}H_6N_6$: C, 68.34; H, 5.10; N, 26.57. Found: C, 68.38; H, 5.16; N, 26.37.

Registry No.—**1**, 38359-68-1; **3**, 38359-69-2; **6**, 38359-70-5; **7**, 38359-71-6; **8**, 37437-06-2; **9**, 38359-73-8; **10**, 38359-74-9; **11**, 38359-75-0; **12**, 38359-76-1; **13**, 38359-77-2; **14**, 38359-78-3; **15**, 6502-04-1; **16**, 38359-79-4; **17** 2HCl, 38359-80-7; **18**, 38359-81-8; **20**, 38359-82-9.

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Synthesis and Properties of Pyrido- and Azapyridocyanines

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A summary of the synthesis of 2,2′-, 2,4′-, and 4,4′-pyrido- and -azapyridocyanines, including the *N*,*N*′-(1,ω-alkylene)-2,2′-cyanines is given. Several new dyes of those classes are described, and it is shown that some previous results reported in the literature must be corrected.

Pyridocyanines have been proposed recently for coupling to the conjugated backbone in a proposed model for superconducting polymers.[2] This renewed interest in this dye class promoted us to report on a comprehensive study of the syntheses of pyridocyanines and the related class of azapyridocyanines, which were prepared for an investigation of their stereoisomerism and molecular spectra.[3,4]

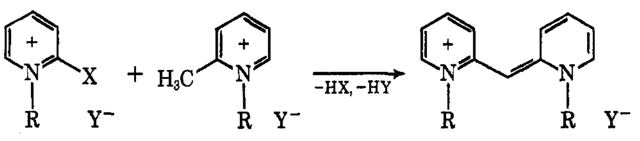
Although the syntheses of these dyes often *appear* to be straightforward, it became apparent during this work that syntheses and structures of several previously reported dyes needed revision. In addition, syntheses and properties of many new dyes of these classes will be reported. An earlier compilation of the syntheses and properties of cyanine dyes has been given by Hamer.[5]

Discussion

A. Pyridocyanines.—To synthesize pyridocyanines one can either quaternize the corresponding dipyridylmethanes or use condensation procedures. The first procedure is often useful for structure determination and the latter one is advantageous for the synthesis of large quantities of the dyes, because the starting materials can be obtained with less effort.

1. 2,2′-Pyridocyanines. a. *N*,*N*′-Dialkyl-2,2′-pyridocyanines (I).—The principle of synthesis of pyridocyanine dyes is well demonstrated by the various syntheses of the *N*,*N*′-dialkyl-2,2′-pyridocyanines (I).

Most commonly these dyes are synthesized by condensation from *N*-alkyl-2-X-pyridinium (1) [X = -I,[6] -Cl,[7,8] -SR[9] (R = CH_3, C_2H_5)] and *N*-alkyl-2-methylpyridinium salts (2) in the presence of suitable organic bases, *e.g.*, triethylamine.



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An alternative synthesis is from di(2-pyridyl)methane[10] (3) and alkyl iodide, which may proceed *via* two different routes.[11-13] With methyl iodide the reaction proceeds *via* the intermediate **6**,

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