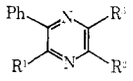
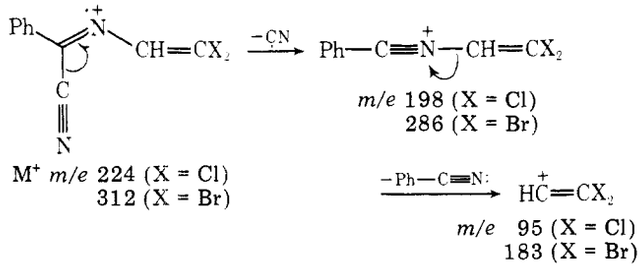
Table I. Preparation and NMR Spectral Data of Dihalopyrazines



	R¹	R²	R³	Registry no.	Type of starting material	Yield, %	Mp, °C (lit. mp, °C)	NMR (ring proton), δ
1	H	Cl	Cl	32493-80-4			(106-107)[1]	8.67
2	H	Br	Br	64163-08-02	Dihydroxy[1]	85[f]	115[a]	8.81
	Cl	H	Cl	64163-09-3	Bromohydroxy[3]	96[g]	58-59[d] (59-60)[3]	8.31
	Br	H	Br	64163-10-6	Bromohydroxy[3]	89[g]	83-84[b] (71-72)[3]	8.39
	Cl	Cl	H	64163-11-7	Chlorohydroxy	93	57-58[e,h]	8.54
	Br	Br	H	64163-12-8	Dichloro	84[g]	66-67[c]	8.65

[a] Anal. Calcd for $C_{10}H_6N_2Br_2$: C, 38.25; H, 1.93; N, 8.92; Br, 50.90. Found: C, 38.45; H, 2.08; N, 9.01; Br, 50.92. [b] Found: C, 38.33; H, 1.87; N, 8.95; Br, 51.09. [c] Found: C, 38.38; H, 1.94; N, 8.95; Br, 50.48. [d] Anal. Calcd for $C_{10}H_6N_2Cl_2$: C, 53.36; H, 2.69; N, 12.45; Cl, 31.15. Found: C, 53.30; H, 2.27; N, 12.34; Cl, 31.34. [e] Found: C, 53.58; H, 2.59; N, 12.44; Cl, 31.56. [f] Recrystallized from *n*-hexane. [g] Recrystallized from ethanol. [h] Bp 122-123 °C (0.1 mm).



3-bromo-4-methylphenylhydrazine reacts with chloral to form the hydrazone,[6] whereas hydrazine gives the adduct *N*-(1-hydroxy-2,2,2-trichloroethyl)hydrazine.[7] This halohydrazone was dehydrochlorinated to form 3-bromo-4-methylbenzeneazo-β,β-dichloroethylene,[6] supporting the transformation of Schiff base **5** to **3** or **4**.

Experimental Section

Melting points were determined in a capillary and are corrected. IR spectra (KBr) were recorded on a Hitachi Model EPI-G3 spectrometer. NMR spectra ($CDCl_3$) were recorded on a JEOL Model JNM-MH-100 instrument with tetramethylsilane as an internal standard. Mass spectra were measured on a Hitachi Model RMU-6L instrument at 70 eV.

General Procedure for Preparation of Dihalopyrazines. These results are summarized in Table I.

A mixture of the starting material indicated in Table I (0.01 mol) and phosphoryl chloride or phosphorus tribromide (20 mL) in a sealed tube was heated at 180–200 °C for 5–40 h and then poured into ice water. The precipitate which formed was collected by filtration, and the mother liquor was extracted with ether. The extract was combined with the precipitate, and undissolved matter was removed by filtration. The filtrate was washed with water, dried over magnesium sulfate, evaporated, and recrystallized to afford dihalopyrazine.

Preparation of 2-hydroxy-6-chloro-5-phenylpyrazine is as follows. A mixture of 1-hydroxy-2-keto-5-phenyl-1,2-dihydropyrazine[8] (7.21 g, 0.038 mol) in 30 mL of phosphoryl chloride was refluxed with stirring for 30 min and then poured into ice water. The precipitate which formed was collected by filtration, sublimed at 180–185 °C (0.01 mm), and recrystallized from ethanol to give colorless prisms (4.57 g, 58%): mp 235–236 °C; IR 3050–2550 (br), 1656, 1590, 846 cm^{-1}; NMR δ 12.5 (br s, 1), 8.20 (s, 1), 7.75–7.6 (m, 2), 7.55–7.4 (m, 3).

Anal. Calcd for $C_{10}H_7N_2OCl$: C, 58.13; H, 3.41; N, 13.56; Cl, 17.16. Found: C, 57.92; H, 3.51; N, 13.40; Cl, 17.00.

***N*-(2,2-Dichloroethenyl)-1-imino-1-phenylacetonitrile (3)** was prepared according to the procedure of Minovici and Bente:[2] mp 102 °C from ethanol (lit.[2] mp 102 °C); IR 2210, 1596, 1572, 1448, 1302, 1279, 952, 855 cm^{-1}; NMR δ 7.78 (s, 1), 8.2–8.0 (m, 2), 7.7–7.3 (m, 3); mass spectrum *m/e* 224 (M^+, 64), 228 (8), 226 (42), 200 (6), 198 (9), 191 (36), 189 (100), 183 (9), 182 (7), 164 (7), 162 (20), 154 (7), 153 (31), 129 (10), 115 (19), 114 (11), 113 (14), 112 (14), 111 (10), 104 (21), 103 (20), 102 (10), 99 (10), 97 (13), 95 (14), 88 (14), 85 (28), 83 (16), 81 (18), 77 (24).

Anal. Calcd for $C_{10}H_6N_2Cl_2$: C, 53.36; H, 2.69; N, 12.45; Cl, 31.51. Found: C, 53.44; H, 2.66; N, 12.54; Cl, 31.49.

***N*-(2,2-Dibromoethenyl)-1-imino-1-phenylacetonitrile (4)** was similarly prepared: mp 120 °C from ethanol (lit.[2] mp 120 °C); IR 2205, 1592, 1566, 1442, 1294, 1272, 879, 852 cm^{-1}; NMR δ 8.11 (s, 1), 8.3–8.1 (m, 2), 7.7–7.3 (m, 3); mass spectrum *m/e* 312 (M^+, 44), 314 (88), 316 (44), 290 (2), 288 (4), 286 (2), 235 (38), 233 (38), 208 (8), 206 (9), 187 (5), 185 (10), 183 (5), 155 (13), 154 (100), 152 (35), 127 (20), 115 (14), 114 (12), 104 (31), 103 (21), 102 (24), 88 (16), 77 (24).

Anal. Calcd for $C_{10}H_6N_2Br_2$: C, 38.25; H, 1.93; N, 8.92; Br, 50.90. Found: C, 38.33; H, 2.05; N, 8.84; Br, 50.85.

Acknowledgment. The authors wish to thank Dr. T. Nakagawa for his helpful suggestions.

Registry No.—**3**, 64201-59-8; **4**, 64201-60-1; α-amino-α-phenylacetonitrile, 16750-42-8; chloral, 75-87-6; bromal, 115-17-3; phosphorus tribromide, 7789-60-8; 1-hydroxy-2-keto-5-phenyl-1,2,-dihydropyrazine, 64163-13-9; 2-hydroxy-6-chloro-5-phenylpyrazine, 64163-14-0; phosphoryl chloride, 10025-87-3; 2,3-dihydroxy-5-phenylpyrazine, 32493-63-3; 2-bromo-3-phenyl-5-hydroxypyrazine, 64163-15-1; 2-chloro-3-phenyl-5-hydroxypyrazine, 64163-16-2; 2,5-dichloro-3-phenylpyrazine, 64163-09-3.

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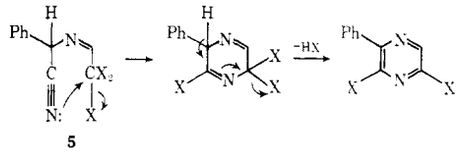

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Studies on Pyrazines. 3.[1] A Facile Synthetic Method for 2,3-Diaminopyrazines

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Methods for the preparation of 2,3-diaminopyrazines **1** have hitherto involved amination of 2,3-dihalopyrazines or 2-amino-3-halopyrazines, whose synthesis requires several steps.[2-5] We have found a more direct synthetic method for

0022-3263/78/1943-0341$01.00/0

Table I. Preparation of Furazanopyrazines 5d–f

Compd	Registry no.	Method	Yield, %	Mp,[c] °C
5d[a]	64163-29-7	A	92	145–146
e[b]	64163-30-0	A	79	110–111
f	24294-88-0	B	98	195–196 (lit.[d] 195–196)

[a] Anal. Calcd for $C_{10}H_6N_4O$: C, 60.60; H, 3.05; N, 28.27. Found: C, 60.70; H, 3.33; N, 28.32. [b] Anal. Calcd for $C_{11}H_8N_4O$: C, 62.25; H, 3.80; N, 26.40. Found: C, 62.47; H, 3.79; N, 26.56. [c] Recrystallized from ethanol. [d] A. Gasco, G. Rua, E. Menziani, G. M. Nano, and G. Tappi, *J. Heterocycl. Chem.*, **6**, 769 (1969).

Table II. Preparation of Triazolopyrazines 6a–f

Compd	Registry no.	Method	Yield, %	Mp, °C
6a[a]	64163-31-1	C	89	179–180[f]
b[b]	64163-32-2	C	91	140–142[f]
c[c]	64163-33-3	A	88	208–209[g]
d[d]	64163-34-4	A	92	184–185[g]
e[e]	64163-35-5	A	86	153[g]
f	64163-36-6	A	90	224[h] (lit.[11] 217)

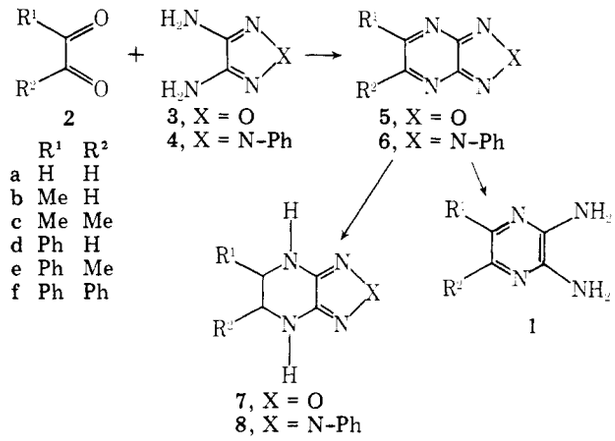
[a] Anal. Calcd for $C_{10}H_7N_5$: C, 60.90; H, 3.58; N, 35.52. Found: C, 61.18; H, 3.64; N, 35.79. [b] Anal. Calcd for $C_{11}H_9N_5$: C, 62.55; H, 4.30; N, 33.16. Found: C, 62.48; H, 4.20; N, 32.90. [c] Anal. Calcd for $C_{12}H_{11}N_5$: C, 63.98; H, 4.92; N, 31.09. Found: C, 63.69; H, 5.08; N, 30.81. [d] Anal. Calcd for $C_{16}H_{11}N_5$: C, 70.31; H, 4.06; N, 25.63. Found: C, 70.43; H, 3.90; N, 25.77. [e] Anal. Calcd for $C_{17}H_{13}N_5$: C, 71.06; H, 4.56; N, 24.38. Found: C, 71.18; H, 4.36; N, 24.23. [f] Recrystallized from methanol. [g] Recrystallized from ethanol. [h] Recrystallized from acetic acid.

Table III. Preparation of 2,3-Diaminopyrazines 1d–f

Compd	Registry no.	Yield, %	Mp,[a] °C	Lit. mp, °C
1d	32493-83-7	97	172–173[b]	172[1]
e	32493-84-8	67	169–170[b]	167–168[1]
f[c]	64163-37-7	65	282–283	275–285[5]

[a] Recrystallized from benzene. [b] This compound was also identified with an authentic sample[1] by IR spectrum. [c] Anal. Calcd for $C_{16}H_{14}N_4$: C, 73.26; H, 5.38; N, 21.36. Found: C, 73.30; H, 5.25; N, 21.12.

diaminopyrazines **1d–f** in the catalytic hydrogenation of furazanopyrazines **5d–f**, readily obtained by condensation of 3,4-diaminofurazan **3** with the corresponding 1,2-dicarbonyl compounds **2d–f**, with palladium on carbon.[6] Condensations of **3** with **2a–c** to give **5a–c** were unsuccessful under various



conditions so far examined and resulted in the recovery of **3** on using acidic solvent as a condensing agent or in the formation of a small amount of unidentified byproducts in basic solvent.

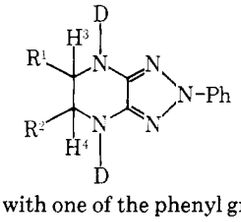
With palladium on carbon, platinum black, or Raney nickel, triazolopyrazines **6a–f**, easily prepared by the condensation of 4,5-diaminotriazole **4** with the corresponding **2a–f**, were converted to triazolopiperazines **8a–f** in excellent yields instead of diaminopyrazine **1**. The structure of **8** was confirmed by elemental and NMR spectral analyses. Coupling constants of the protons in **8** (in Me_2SO-d_6 and D_2O) are approximately consistent with those (in aqueous solution) of *trans*-2,5-dimethylpiperazine,[7] which exists in the chair conformation and whose coupling constants[8] $J_{3,4}$, $J_{2,3}$, $J_{2,4}$, and J_{Me,H^3} are 2.9, 10.8, 12.5, and 6.4 Hz, respectively. A slight difference of the coupling constants between **8** and dimethylpiperazine, particularly $J_{2,3}$, may be caused by a distorted chair conformation of the piperazine ring of **8** fused with the triazolopiperazine ring.

Triazolopiperazines **8** were also prepared by the reduction

Table IV. Preparation and NMR Spectral Data of Triazolopiperazines 8a–f

				NMR[k] (Me_2SO-d_6 + D_2O)							
				Chemical shift, δ				Coupling constant, Hz			
Compd	Registry no.	Yield,[g] %	Mp, °C	R^1	R^2	H^3	H^4	$J_{3,4}$	$J_{2,3}$	$J_{2,4}$	$J_{Me,H_3\ (H_4)}$
8a[a]	64163-38-8	96	190–191[h]		3.27			0	0	0	
b[b]	64163-39-9	97	145–146[h]	1.15	2.87	3.42	3.27	3.0	8.4	11.4	6.2
c[c]	64163-40-2	98	125–126[i]	1.07		3.44		0			6.8
d[d]	64163-41-3	84	155–156[i]	*l*	3.19	4.50	3.42	3.5	7.8	12.0	
e[e]	64163-42-4	95	66–67[h]	*l*	0.87	4.53	*m*	3.0			7.0
f[f]	64163-43-5	98	236[j]	*l*	*l*	4.77		0			

[a] Anal. Calcd for $C_{10}H_{11}N_5$: C, 59.68; H, 5.51; N, 34.81. Found: C, 59.84; H, 5.29; N, 34.78. [b] Anal. Calcd for $C_{11}H_{13}N_5$: C, 61.37; H, 6.09; N, 32.54. Found: C, 61.47; H, 5.95; N, 32.53. [c] Anal. Calcd for $C_{12}H_{15}N_5$: C, 62.87; H, 6.62; N, 30.55. Found: C, 62.87; H, 6.66; N, 30.66. [d] Anal. Calcd for $C_{16}H_{15}N_5$: C, 69.29; H, 5.45; N, 25.26. Found: C, 69.59; H, 5.53; N, 24.92. [e] Anal. Calcd for $C_{17}H_{17}N_5$: C, 70.08; H, 5.88; N, 24.04. Found: C, 69.73; H, 6.02; N, 23.85. [f] Anal. Calcd for $C_{22}H_{19}N_5$: C, 74.76; H, 5.42; N, 19.82. Found: C, 74.82; H, 5.36; N, 19.83. [g] These yields result from hydrogenation of **6** with 10% palladium on carbon. [h] Recrystallized from *n*-hexane. [i] Recrystallized from cyclohexane. [j] Recrystallized from benzene/petroleum ether. [k] Structure.

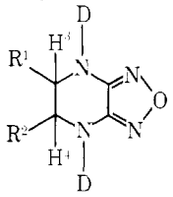


[l] This peak can not be determined because of overlap with one of the phenyl groups situated in the triazolo ring. [m] This peak can not be determined because of overlap with one of water.

Table V. Preparation and NMR Spectral Data of Furazanopyrazines 7d-f

Compd	Registry no.	Yield,[d] %	Mp, °C	NMR[g] (Me_2SO-d_6 + D_2O) Chemical shift, δ R^1	R^2	H^3	H^4	Coupling constant, Hz $J_{3,4}$	$J_{2,3}$	$J_{2,4}$	J_{Me,H^4}
7d[a]	64163-44-6	84	189-190[e]	7.37	3.16	4.53	3.40	3.5	8.0	12.0	
e[b]	64163-45-7	87	203[f]	7.2-7.4	0.84	4.52	*h*	3.5			6.5
f[c]	64163-46-8	84	234-235[e]	7.0-7.2		4.80		0			

[a] Anal. Calcd for $C_{10}H_{10}N_4O$: C, 59.39; H, 4.98; N, 27.71. Found: C, 59.33; H, 5.22; N, 27.38. [b] Anal. Calcd for $C_{11}H_{12}N_4O$: C, 61.09; H, 5.59; N, 25.90. Found: C, 61.02; H, 5.52; N, 25.70. [c] Anal. Calcd for $C_{16}H_{14}N_4O$: C, 69.05; H, 5.07; N, 20.13. Found: C, 68.91; H, 4.83; N, 20.13. [d] These result from the reduction of 5 with sodium borohydride. [e] Recrystallized from benzene. [f] Recrystallized from benzene/petroleum ether. [g] Structure



[h] This peak can not be determined because of overlap with one of water.

of **6** with sodium borohydride, but compounds **6** were inert to lithium aluminum hydride. On the other hand, furazanopyrazines **5** were reduced with lithium aluminum hydride, as well as sodium borohydride, to yield furazanopiperazines **7**. The NMR spectra of **7** give the same results as those of **8**.

Recently, syntheses of 3,4-diamino-1,2,5-thiadiazole and 1,2,5-thiadiazolo[3,4-*b*]pyrazines were reported,[9] and the latter would be expected to give diaminopyrazines **1** under reductive conditions.

Experimental Section

All melting points were determined in a capillary and are corrected. NMR spectra were measured on a JEOL Model JNM-MH-100 instrument with tetramethylsilane as an internal standard.

Condensation of 3,4-Diaminofurazan (3)[10] or 4,5-Diamino-2-phenyl-1,2,3-triazole (4)[11] with 1,2-Dicarbonyl Compounds 2. The results are summarized in Tables I and II, respectively.

Method A. A solution of **3** or **4** (0.01 mol) and **2** (0.011 mol) in 20 mL of acetic acid/ethanol (1:3 v/v) was refluxed for 2 h. After cooling to room temperature, the precipitate which formed was collected by filtration and recrystallized to afford **5** or **6**, respectively.

Method B. A mixture of **3** (0.01 mol), **2f** (0.01 mol), and boron trifluoride etherate (1 mL) was heated at 120–130 °C for 10 min. The precipitate that formed after cooling to room temperature was collected by filtration, washed with water, and recrystallized from ethanol to provide **5f**.

Method C. A warm (~80 °C) solution of **2** (bisulfite salt, 0.011 mol) in 20 mL of water was added to a stirred solution (at 80 °C) of **4** in 50 mL of water. The resulting solution was maintained at 80 °C for 1 h. Sodium carbonate (0.011 mol) was added to the cooled solution, and the precipitates were collected by filtration. The filtrate was extracted with three 10-mL portions of ether, and the extracts were washed with water, dried over magnesium sulfate, and evaporated. The combined products were recrystallized to give **6**.

Hydrogenation of 5 or 6 in the Presence of Palladium Catalyst. A solution of **5** or **6** (0.01 mol) in 30–200 mL of ethyl acetate, except for **6c** where tetrahydrofuran was used, was hydrogenated in the presence of 10% palladium on carbon (~2g) under atmospheric pressure until the uptake of hydrogen ceased (~20 h) and then was filtered. The filtrate was evaporated to dryness under reduced pressure, and the residue was recrystallized to give **1** or **8**, respectively. These results are summarized in Tables III and IV, respectively.

Reduction of 5 or 6 with Sodium Borohydride. A mixture of **5** or **6** (3 mmol) and sodium borohydride (6 mmol) in 50 mL of ethanol was refluxed for 1 h. A small amount of acetic acid was added to the cooled mixture to decompose excess sodium borohydride, and the mixture was then evaporated to dryness under reduced pressure. The residual solid was triturated with diluted aqueous sodium hydroxide, filtered, and recrystallized to provide **7** or **8**, respectively. The results of **7** are summarized in Table V.

Reduction of 5 with Lithium Aluminum Hydride. A solution of lithium aluminum hydride (6 mmol) in 20 mL of dry tetrahydrofuran was added dropwise to a solution of **5** (3 mmol) in 10 mL of the same solvent, and the mixture was refluxed for 2 h. Excess lithium aluminum hydride was decomposed by the addition of water and diluted aqueous sodium hydroxide. The resulting solution was evaporated to dryness under reduced pressure, and the residue was extracted with hot chloroform. The solution was evaporated, and the residue was recrystallized to afford **7**.

The procedure for reaction of **6** with lithium aluminum hydride is as follows. A mixture of **6** (3 mmol) and lithium aluminum hydride (15 mmol) in 100 mL of dry dioxane was refluxed for 5 h under nitrogen atmosphere and then treated in the predescribed manner to recover a 95–97% yield of **6**.

Acknowledgment. The authors are grateful to Dr. T. Nakagawa for his helpful suggestions.

Registry No.—**2a,** 107-22-2; **2b,** 78-98-8; **2c,** 431-03-8; **2d,** 1074-12-0; **2e,** 579-07-7; **2f,** 134-81-6; **3,** 17220-38-1; **4,** 53543-28-5; **2a** bisulfite salt, 18381-20-9; **2b** bisulfite salt, 64163-47-9.

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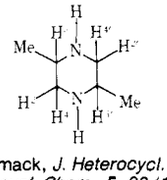

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Photochemical Rearrangements of Cross-Conjugated Cyclohexadienones Related to Epimaalienone[1]

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Recently, we reported that the tricyclic cross-conjugated cyclohexadienone **1a,** derived from epimaalienone, was pho-

