

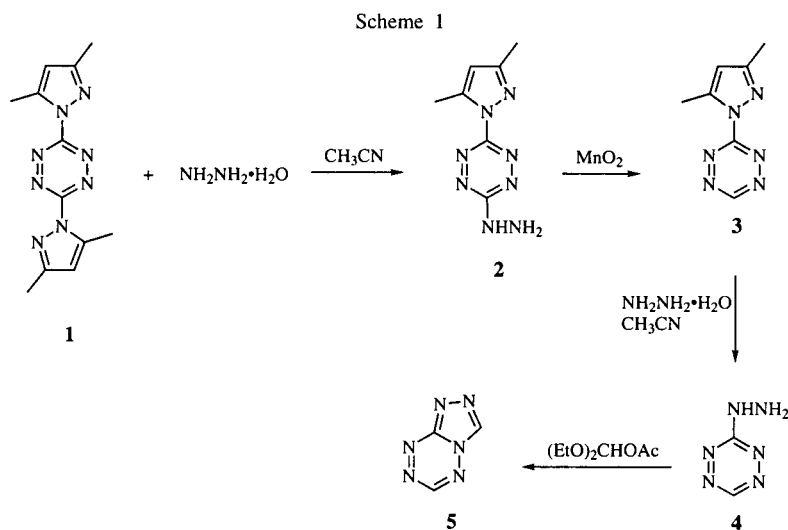
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The synthesis of the previously unknown parent ring system was developed. Treatment of 3-hydrazino-1,2,4,5-tetrazine (4) with diethoxymethyl acetate gave the parent ring system. Similar treatment of 3-(3,5-dimethylpyrazol-1-yl)-6-hydrazino-1,2,4,5-tetrazine (2) with one carbon cyclizing reagents gave 3,6-disubstituted derivatives of the 1,2,4-triazolo-1,2,4,5-tetrazine ring system.

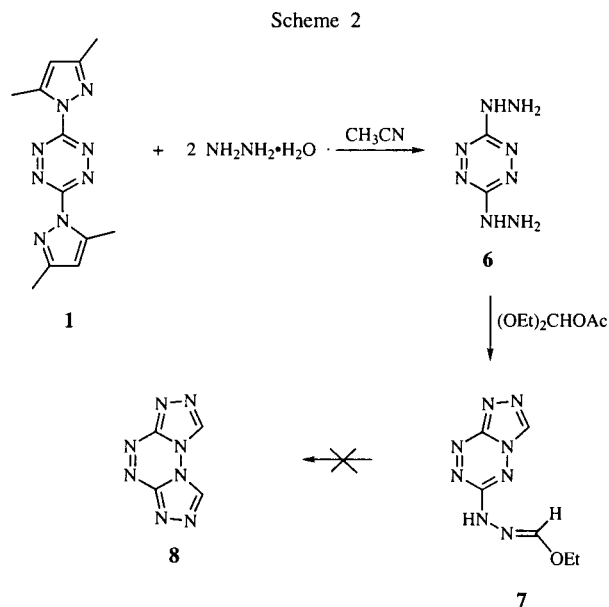
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The first synthesis of the bi-heterocyclic ring system 1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine was reported in 1968 by Ershov [1]. The compound reported was substituted with a phenyl group at the 6 position and its synthesis involved fusing a triazole ring to a tetrazine using the one carbon cyclizing reagent triethyl orthoformate and 3-hydrazino-6-phenyl-1,2,4,5-tetrazine.

In this study, 3-hydrazino-1,2,4,5-tetrazine (4) was synthesized in order to study its reaction with diethoxymethyl acetate [2]. The synthesis of 4 involved a 3 step procedure starting with the readily available 3,6-bis(3,5-dimethylpyrazol-1-yl)-1,2,4,5-tetrazine (1) [3] (Scheme 1). Treatment of 1 with one equivalent of hydrazine hydrate gave 3-(3,5-dimethylpyrazol-1-yl)-6-hydrazino-1,2,4,5-tetrazine (2) in 93% yield. This product was then oxidized with activated manganese dioxide [4] to give 3-(3,5-dimethylpyrazol-1-yl)-1,2,4,5-tetrazine (3). Subsequent treatment of 3 with hydrazine hydrate afforded the desired 3-hydrazino-1,2,4,5-tetrazine. By heating this hydrazino compound with diethoxymethyl acetate, a much more reactive single carbon cyclizing reagent, we obtained the 1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine parent ring system 5.

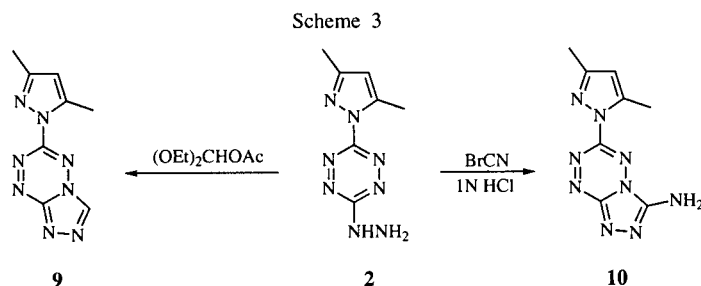
A hypsochromic shift in the visible spectrum from red to yellow was reported by Ershov in going from the



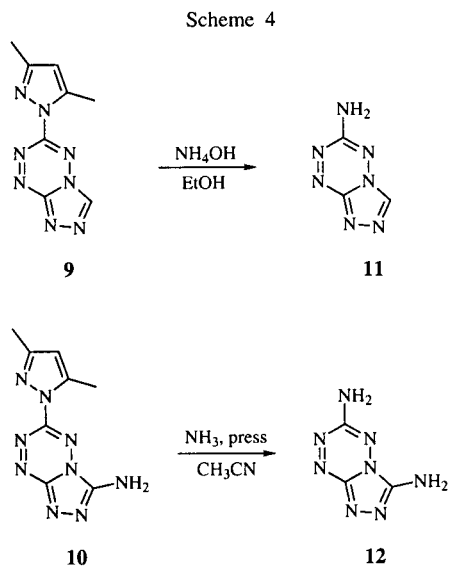
3-hydrazino-6-phenyl-1,2,4,5-tetrazine to the fused *s*-triazolo-*s*-tetrazine ring system. We also observed this shift visually as the deep red brown 3-hydrazino-1,2,4,5-tetrazine converted to the yellow parent ring.

The same cyclization procedure was performed on 3,6-dihydrazino-1,2,4,5-tetrazine (**6**) [5,6], which was obtained from **1** by treatment with 2 equivalents of hydrazine hydrate. We had hoped to produce the unknown tri-heterocyclic ring system **8**, however the reaction proceeded only to intermediate **7** (Scheme 2).

To obtain substitution at the 3 and 6 positions of the new parent ring system we used (**2**) as a starting material. Treatment of **2** with diethoxymethyl acetate gave the new compound 6-(3,5-dimethylpyrazol-1-yl)-1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine (**9**). Similarly treatment of **2** with cyanogen bromide [7] gave the 3,6-disubstituted derivative 3-amino-6-(3,5-dimethylpyrazol-1-yl)-1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine (**10**) (Scheme 3).



Compound **9** exhibited a hypsochromic shift similar to the parent as it was yellow-green in color. Compound **10** however was a deep purple color, which was due to the amino group present at the 3-position.



Both **9** and **10** contain the 3,5-dimethylpyrazol-1-yl moiety at the 6 positions which has been shown to act as a leaving group for tetrazines in previous studies from this laboratory [3]. We used ammonia to displace the 3,5-dimethylpyrazole group of both **9** and **10** to give 6-amino-1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine (**11**) and 3,6-diamino-1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine (**12**) respectively (Scheme 4).

These compounds may serve as useful intermediates in diazotization and oxidation reactions, and may lead to novel high-nitrogen energetic materials. Compound **3** may also lead to interesting 3-substituted-1,2,4,5-tetrazines by nucleophilic displacements.

## EXPERIMENTAL

Hydrazine hydrate was purchased from Fisher Chemical Company. Activated manganese dioxide was purchased from Acros Chemical Company. Diethoxymethyl acetate was purchased from Aldrich Chemical Company. All nmr spectra were obtained on a JEOL GSX-270 spectrometer. Chemical shifts are reported relative to internal tetramethylsilane = 0 for <sup>1</sup>H and <sup>13</sup>C nmr spectra. Microanalyses were performed at Los Alamos National Laboratory by W. F. King. All melting points were determined at a 2° per minute with a Mettler FP1 apparatus and are corrected. The ir spectra were obtained on a Bio-Rad FTS-40 FTIR spectrometer.

3-(3,5-Dimethylpyrazol-1-yl)-6-hydrazino-1,2,4,5-tetrazine (**2**).

To a slurry of **1** (13.5 g, 0.05 mole) in acetonitrile (150 ml) was added hydrazine hydrate (2.5 g, 0.05 mole) dropwise at ambient temperature. A red precipitate formed immediately. The slurry was allowed to stir for 30 minutes, filtered, washed with toluene and air dried to give 8.3 g of pure material. The mother liquor was concentrated under reduced pressure and the residue treated with toluene, filtered and air dried to give an additional 1.3 g of pure material for a combined yield of 93% of a red solid mp 135-136° dec; <sup>1</sup>H nmr (deuteriomethyl sulfoxide): δ 2.21 (s, 3H), 2.37 (s, 3H), 4.60 (s, 2H), 6.17 (s, 1H), 9.75 (s, 1H); <sup>13</sup>C nmr (deuteriomethyl sulfoxide): δ 12.0, 13.2, 108.3, 141.2, 149.9, 156.95, 162.9; ir (potassium bromide): 3336, 3282, 3225, 3186, 3008, 2929, 1652, 1568, 1481, 1417, 1386, 1370, 1302, 1165, 1153, 1133, 1074, 1040, 1022, 1022 cm<sup>-1</sup>.

Anal. Calcd. for C<sub>7</sub>H<sub>10</sub>N<sub>8</sub>: C, 40.77; H, 4.89; N, 54.34. Found: C, 40.65; H, 5.12; N, 54.71.

3-(3,5-Dimethylpyrazol-1-yl)-1,2,4,5-tetrazine (**3**).

Activated manganese dioxide (5.2 g, 0.06 mole) was suspended in tetrahydrofuran (50 ml). The mixture was stirred and **2** (2.06 g, 0.01 mole) was added portion wise at 0° over 10 minutes. The mixture was allowed to stir 30 minutes at 0°, and then filtered through a bed of Celite and concentrated under reduced pressure. The residue was dissolved in methylene chloride and filtered through a mat of silica gel and concentrated to give 1.2 g (68%) of **3** as a brilliant red-purple solid, mp 106-107°; <sup>1</sup>H nmr (deuteriochloroform): δ 2.38 (s, 3H), 2.73 (s, 3H), 6.19 (s, 1H), 10.17 (s, 1H); <sup>13</sup>C nmr (deuteriochloroform): δ 13.5, 14.7,

112.7, 144.6, 155.5, 157.3, 161.9; ir (potassium bromide): 3106, 3066, 2982, 2926, 1579, 1489, 1457, 1438, 1407, 1389, 1367, 1157, 1141, 1098, 1033  $\text{cm}^{-1}$ .

*Anal.* Calcd. for  $\text{C}_7\text{H}_8\text{N}_6$ : C, 47.73; H, 4.58; N, 47.70. Found: C, 47.40; H, 4.60; N, 47.50.

### 3-Hydrazino-1,2,4,5-tetrazine (4).

To a solution of **3** (1.76 g, 0.01 mole) in methanol (20 ml) is added hydrazine hydrate (0.5 g, 0.01 mole). The solution is stirred for 30 minutes at room temperature and then concentrated under reduced pressure. The residue is treated with ether and the solid is filtered, washed with ether and air dried to give 0.86 g (77%) of a red brown solid, mp  $88.3^\circ$  dec;  $^1\text{H}$  nmr (deuteriomethyl sulfoxide):  $\delta$  4.59 (s, 2H), 9.55 (s, 1H), 9.74 (s, 1H);  $^{13}\text{C}$  nmr (deuteriomethyl sulfoxide):  $\delta$  153.5, 165.0; ir (potassium bromide): 3325, 3231, 3083, 1630, 1562, 1512, 1469, 1353, 1198, 1155, 1110, 1049  $\text{cm}^{-1}$ .

*Anal.* Calcd. for  $\text{C}_2\text{H}_4\text{N}_6$ : C, 21.43; H, 3.60; N, 74.97. Found: C, 21.38; H, 3.59; N, 75.15.

### 1,2,4-Triazolo[4,3-*b*][1,2,4,5]tetrazine (5).

A mixture of **4** (0.112 g, 0.001 mole) and diethoxymethyl acetate (0.6 g, 0.003 mole) was heated at reflux for 5 minutes. The solution was allowed to cool to ambient temperature and a solid precipitate formed. The solid was filtered, washed with toluene and air dried to give 75 mg (61%) of a yellow brown solid. This material was purified by dissolving the product in acetonitrile, filtering through a mat of silica gel and evaporating the solvent to yield a yellow solid. An analytical sample was recrystallized from benzene, mp  $210^\circ$  dec;  $^1\text{H}$  nmr (deuteriomethyl sulfoxide):  $\delta$  9.99 (s, 1H), 10.04 (s, 1H);  $^{13}\text{C}$  nmr (deuteriomethyl sulfoxide):  $\delta$  137.9, 147.8, 151.5; ir (potassium bromide): 3125, 3101, 3052, 1537, 1477, 1360, 1282, 1208, 1154, 1042  $\text{cm}^{-1}$ .

*Anal.* Calcd. for  $\text{C}_3\text{H}_2\text{N}_6$ : C, 29.51; H, 1.65; N, 68.84. Found: C, 29.55; H, 1.38; N, 67.61.

### 3,6-Dihydrazino-1,2,4,5-tetrazine (6).

To a slurry of **1** (13.5 g, 0.05 mole) in acetonitrile (150 ml) was added hydrazine hydrate (5.5 g, 0.11 mole) dropwise at ambient temperature. After the addition was complete, the mixture was refluxed for 20 minutes. The mixture was then cooled to room temperature, filtered and washed with acetonitrile to provide **6** in quantitative yield, identical in all respects to that previously reported [5,6].

### 6-Ethoxymethylenehydrazino-1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine (7).

A mixture of **6** (0.142 g, 0.001 mole) and diethoxymethyl acetate (0.6 g, 0.003 mole) was heated at reflux for 5 minutes. The solution was allowed to cool to ambient temperature and a solid precipitate formed. The solid was filtered, washed with toluene and air dried to give 145 mg (69%) of a red-brown solid. Recrystallization from chloroform/hexanes provided an analytical sample, mp  $206^\circ$  dec;  $^1\text{H}$  nmr (deuteriochloroform):  $\delta$  1.47 (triplet, 3H), 4.30 (quartet, 2H), 6.90 (s, 1H), 9.31 (bs, 1H);  $^{13}\text{C}$  nmr (deuteriomethyl sulfoxide):  $\delta$  15.1, 67.6, 137.2, 148.0, 150.7, 155.0; ir (potassium bromide): 3154, 3030, 2992, 2955, 2890, 1655, 1585, 1528, 1393, 1343, 1320, 1186, 1105, 1039, 1004  $\text{cm}^{-1}$ .

*Anal.* Calcd. for  $\text{C}_6\text{H}_8\text{N}_8\text{O}$ : C, 34.56; H, 3.87; N, 53.82. Found: C, 34.24; H, 3.52; N, 53.85.

### 6-(3,5 Dimethylpyrazol-1-yl)-1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine (9).

A mixture of **2** (2.06 g, 0.01 mole) and diethoxymethyl acetate (6.0 g, 0.03 mole) was heated at reflux for 5 minutes. A precipitate formed during this time and the mixture was allowed to cool to room temperature, filtered and washed with toluene to provide 2.0 g (93%) as a yellow-green solid, mp  $246\text{--}247^\circ$  dec;  $^1\text{H}$  nmr (deuteriomethyl sulfoxide):  $\delta$  2.37 (s, 3H), 2.76 (s, 3H), 6.22 (s, 1H), 9.18 (s, 1H);  $^{13}\text{C}$  nmr (deuteriomethyl sulfoxide):  $\delta$  13.5, 14.7, 112.9, 136.8, 145.3, 150.3, 151.4, 156.0; ir (potassium bromide): 3083, 1585, 1525, 1471, 1360, 1282, 1229, 1144, 1108, 1072, 1072, 1012  $\text{cm}^{-1}$ .

*Anal.* Calcd. for  $\text{C}_8\text{H}_8\text{N}_8$ : C, 44.44; H, 3.73; N, 51.83. Found: C, 44.30; H, 3.72; N, 51.62.

### 3-Amino-6-(3,5-dimethylpyrazol-1-yl)-1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine (10).

To 1N hydrochloric acid (30 ml) was added **2** (2.06 g, 0.01 mole). Cyanogen bromide (1.06 g, 0.01 mole) was then added and the solution was stirred 24 hours. The purple precipitate was filtered, washed with water and air dried to yield 1.5 g (65%) of **10**. An analytical sample was obtained by recrystallization from water/acetonitrile to give a monohydrate, mp  $151\text{--}152^\circ$ ;  $^1\text{H}$  nmr (deuteriomethyl sulfoxide):  $\delta$  2.25 (s, 3H), 2.60 (s, 3H), 6.28 (s, 1H), 7.60 (s, 2H);  $^{13}\text{C}$  nmr (deuteriomethyl sulfoxide):  $\delta$  13.0, 13.1, 110.4, 143.7, 149.2, 149.7, 150.0, 152.1; ir (potassium bromide): 3467, 3313, 3269, 3143, 1674, 1581, 1538, 1461, 1437, 1399, 1353, 1294, 1203, 1148, 1115, 1072, 1032, 1020  $\text{cm}^{-1}$ .

*Anal.* Calcd. for  $\text{C}_8\text{H}_9\text{N}_9\cdot\text{H}_2\text{O}$ : C, 38.55; H, 4.45; N, 50.58. Found: C, 38.91; H, 4.43; N, 50.77.

### 6-Amino-1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine (11).

To 40 ml absolute ethanol was added **9** (2.16 g, 0.01 mole) and 30% ammonium hydroxide (3.0 g). This mixture was heated at reflux for 2 hours. The reaction was cooled below  $10^\circ$  to precipitate the product. The solid was filtered, washed with ether and air dried to give **11** as a yellow solid (1.06 g, 77%). An analytical sample was obtained by recrystallization from water to provide a monohydrate, mp  $217\text{--}218^\circ$ ;  $^1\text{H}$  nmr (deuteriomethyl sulfoxide):  $\delta$  8.04 (s, 2H), 9.33 (s, 1H);  $^{13}\text{C}$  nmr (deuteriomethyl sulfoxide):  $\delta$  136.8, 150.1, 157.6; ir (potassium bromide): 3327, 3101, 1652, 1558, 1360, 1301, 1153, 1048  $\text{cm}^{-1}$ .

*Anal.* Calcd. for  $\text{C}_3\text{H}_3\text{N}_7\cdot\text{H}_2\text{O}$ : C, 23.23; H, 3.25; N, 63.21. Found: C, 23.16; H, 3.25; N, 63.85.

### 3,6-Diamino-1,2,4-triazolo[4,3-*b*][1,2,4,5]tetrazine (12).

A 100 ml capacity pressure reactor equipped with a magnetic stirrer was charged with **10** (2.31 g, 0.01 mole) and acetonitrile (40 ml). Ammonia (1.5 g, 0.088 mole) was introduced into the closed vessel. The reactor was heated on a steam cone for 3 hours. It was then cooled to room temperature and the slurry was concentrated to dryness, treated with toluene, filtered and dried to give 1.5 g of **12** (99%) as a dark brown solid. An analytical sample was prepared by recrystallization from water, mp  $332\text{--}333^\circ$  dec;  $^1\text{H}$  nmr (deuteriomethyl sulfoxide):  $\delta$  6.80 (s, 2H), 7.60 (s, 2H);  $^{13}\text{C}$  nmr (deuteriomethyl sulfoxide):  $\delta$  148.8, 149.9, 155.7; ir (potassium bromide): 3423, 3293, 3112, 1656, 1607, 1547, 1461, 1401, 1366, 1318, 1261, 1166, 1046  $\text{cm}^{-1}$ .

*Anal.* Calcd. for  $\text{C}_3\text{H}_4\text{N}_8$ : C, 23.69; H, 2.65; N, 73.66. Found: C, 24.02; H, 2.74; N, 73.35.

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