Heterocycles. CXVIII. A Novel Method of Annelation of the 1,2,4-Triazole Ring of the N_2–C_3 Bond to Azines[1]

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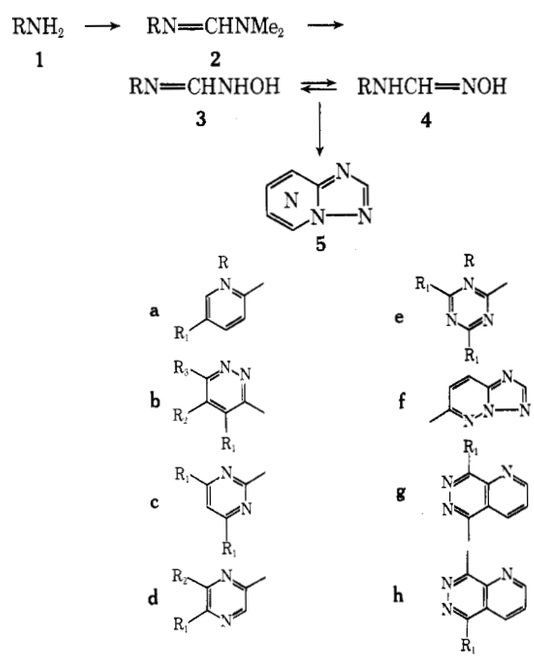
Several examples of formation of triazoloazines by a novel synthetic procedure are described. 2-Aminoazines were transformed into the corresponding *N,N*-dimethylaminomethyleneamino derivatives, which reacted with hydroxylamine to afford the hydroxyiminomethyleneamino compounds. In the presence of polyphosphoric acid, these were cyclized to give triazoloazines. Several other transformations involving these ring systems are described.

In a short communication we have described a new route to *s*-triazoloazines in which the triazole ring is fused to the azine ring through the N_2–C_3 bond.[2] We wish now to report the details of this general synthetic method and its extension to several heterocyclic systems.

2-Aminoazines react readily with *N,N*-dimethylaminoformamide dimethyl acetal to give the corresponding *N,N*-dimethylaminomethylene derivatives (**2**) (Table I). These reacted further with hydroxylamine with displacement of the dimethylamino group to give the corresponding hydroxyiminomethyleneamino derivatives (**3** *vs.* **4**)



(Table II). Besides hydroxylamine, *O*-methylhydroxylamine reacted similarly, whereas no reaction occurred with *N,O*-dimethylhydroxylamine. There are some reports concerning the hydroxyiminomethyleneamino compounds and their structure, *i.e.*, the possibility to exist either in the hydroxylamino or hydroxyimino form.[3,4] In the heterocyclic series such compounds result from the action of hydroxylamine on quinazoline, with cleavage of the pyrimidine ring,[5] and similar transformations were recorded in the case of 4-hydroxy-6-methylpteridine.[6] Nmr studies on our ^{15}N compounds revealed that these compounds are best represented as formamidoximes (**4**).[7] It was also shown that they exist in the anti (*Z*) form. This is certainly due to hydrogen bonding, since for the majority of aliphatic,[8] aromatic,[9] or six-membered heterocyclic[10] aldoximes the *E* configuration is thermodinamically more stable. They react with phenyl isocyanate to give the corresponding *O*-acylamino derivatives which are unstable.

With acetic anhydride or isopropenyl acetate dehydration took place and the oxime **4a** (R_1 = H) was transformed into the known[11] 2-cyanoaminopyridine. However, treatment with polyphosphoric acid afforded in good yield the corresponding *s*-triazoloazines (**5**) (Table III). In this manner, at position 2 unsubstituted representatives of *s*-triazolo[1,5-*a*]pyridine (**6**), *s*-triazolo[1,5-*b*]pyridazine (**7**),[12] *s*-triazolo[1,5-*a*]pyrimidine (**8**), *s*-triazolo[1,5-*a*]pyra-

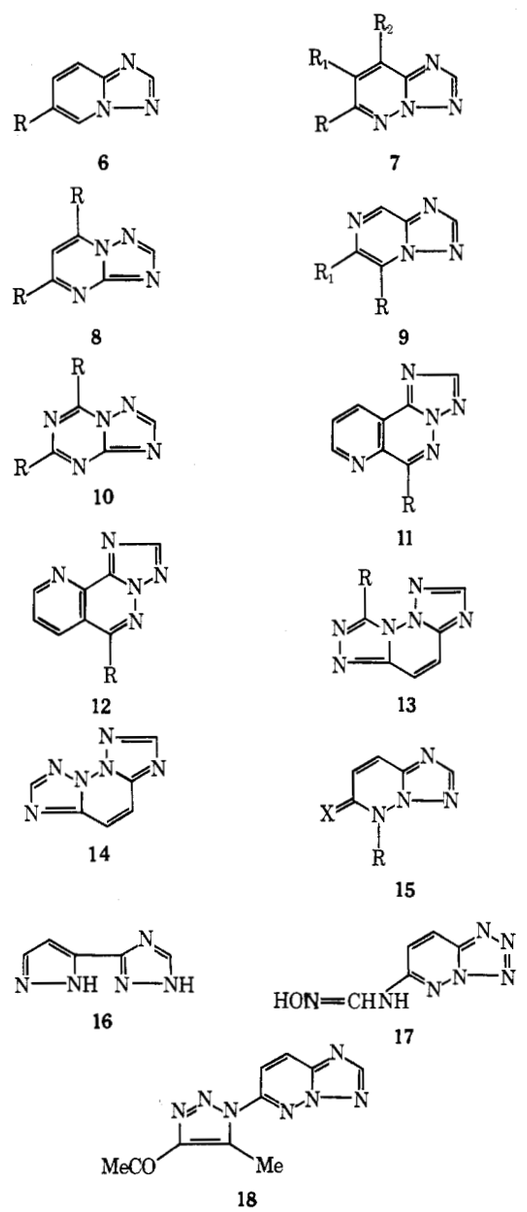


Table I
Dimethylaminomethyleneamino Heterocycles[a]

RN=CHNMe$_2$

Registry no.	Compd	Mp, °C	Crystallized from	Yield, %	Mass spectrum M$^+$	Nmr spectrum, τ
51519-06-3	**2a**, R_1 = NO_2	159–160	Ethanol	98	194	DMSO-d_6: 3.24 (d, H_3), 1.86 (dd H_4), 1.13 (d, H_6), 1.42 (s, CH) 6.86 and 6.96 (s, NMe_2); $J_{3,4}$ = 9.0, $J_{4,6}$ = 3.0 Hz
51519-07-4	**2b**, R_1 = H; R_2 = Me; R_3 = Cl	87	*n*-Hexane	82	198	$CDCl_3$: 1.41 (s, N=CH), 2.99 (q, H_6), 6.90 and 6.92 (s, NMe_2), 7.71 (d, 5-Me); $J_{4,5\text{-Me}}$ = 0.7 Hz
51519-08-5	**2b**, R_1 = R_2 = Me; R_3 = Cl	90	*n*-Hexane	82	212	$CDCl_3$: 1.64 (s, CH), 6.92 (s, NMe_2), 7.71 (s, 4-, 5-Me)
6578-34-3	**2c**, R_1 = H	104–106	Chloroform and petroleum ether	93	150	DMSO-d_6: 1.57 (d, H_4 and H_6), 3.15 (t, H_5), 1.45 (s, CH), 6.89 and 6.98 (s, NMe_2); $J_{4,5}$ = $J_{5,6}$ = 5.0 Hz
51567-39-6	**2c**, R_1 = Me		Distilled at 120–130° (2 mm)	90		$CDCl_3$: 3.43 (s, H_5), 1.41 (s, CH), 7.63 (s, 4-, 6-Me), 6.87 and 6.91 (s, NMe_2)
51519-09-6	**2d**, R_1 = R_2 = H		Distilled at 130–140° (5 mm)	92	150	$CDCl_3$: 2.00 (s, H_3), 1.80 and 1.99 (d, H_5 and H_6), 1.64 (s, CH), 6.92 (s, NMe_2); $J_{5,6}$ = 1.0 Hz
51519-10-9	**2d**, R_1 = Cl; R_2 = H	97–99	Ethyl acetate and petroleum ether	89	184 and 186	DMSO-d_6: 1.72 and 2.03 (d, H_3 and H_5), 1.49 (s, CH), 6.89 and 6.98 (s, NMe_2); $J_{3,6}$ = 1.5 Hz
51519-11-0	**2d**, R_1 = H; R_2 = Cl	60–62	Chloroform and *n*-hexane	87	184 and 186	$CDCl_3$: 1.89 and 1.97 (s, H_3 and H_5), 1.55 (s, CH), 6.86 and 6.89 (s, NMe_2)
51519-12-1	**2e**, R_1 = morpholino	203–205	Chloroform and *n*-hexane	93	321	$CDCl_3$: 1.21 (s, CH), 6.88 (s, NMe_2), 6.23 (broad s, 4- and 6-morpholino group)
51519-13-2	**2g**, R_1 = Cl	172–173	Ethyl acetate	97	235 and 237	DMSO-d_6: 0.63 (dd, H_2), 1.95 (dd, H_3), 1.15 (dd, H_4), 1.18 (s, CH), 6.68 and 6.75 (s, NMe_2); $J_{2,3}$ = 4.5, $J_{3,4}$ = 8.0, $J_{2,4}$ = 1.5 Hz
51519-14-3	**2h**, R_1 = Cl	152–154	Chloroform and *n*-hexane	98	235 and 237	DMSO-d_6: 0.62 (dd, H_2), 1.94 (dd, H_3), 1.43 (dd, H_4), 1.40 (s, CH), 6.74 and 6.79 (s, NMe_2)

[a] Satisfactory analytical data were obtained for all compounds listed.

Table II
Hydroxyiminomethyleneamino Heterocycles[a]

RNHCH=NOH

Registry no.	Compd	Mp, °C	Crystallized from	Yield %	Mass spectrum M$^-$	Nmr spectrum, τ
21881-75-4	**4a**, R_1 = NO_2	218	Ethanol	90	182	DMF-d_7: 2.75 (d, H_3), 1.68 (dd, H_4), 1.06 (d, H_6), 2.15 (deg. d, CH), −0.13 (broad, NH), −0.50 (broad, OH); $J_{3,4}$ = 9.5, $J_{4,6}$ = 3.0, J_{CHNH} = 8.0 Hz
51519-15-4	**4b**, R_1 = R_2 = H; R_3 = Cl	190–194	Methanol and diethyl ether	88	172	DMSO-d_6: 2.40 and 2.65 (d, H_4, H_5), 2.17 (d, CH), 0.27 (d, CHN**H**), −0.38 (s, OH); $J_{4,5}$ = 9.0, J_{CHNH} = 10.5 Hz
51519-16-5	**4b**, R_1 = H; R_2 = Me; R_3 = Cl	200–203	Methanol	97	186	DMSO-d_6: 2.72 (s, H_5), 7.74 (s, 4-Me), 2.19 (d, CH), 0.47 (d, NH), −0.25 (s, OH); J_{NHCH} = 9.2 Hz
51519-17-6	**4b**, R_1 = R_2 = Me; R_3 = Cl	190	Methanol	87	200	DMSO-d_6: 2.11 (s, CH), 7.69 and 7.76 (s, 4- and 5-Me), −0.41 (broad, NH and OH).
51519-18-7	**4c**, R_1 = H	198–200	Ethanol	88	138	DMSO-d_6: 1.45 (d, H_4 and H_6), 3.00 (t, H_5), 2.17 (s, CH), 0.95 (broad, NH), −0.40 (broad, OH); $J_{4,5}$ = $J_{5,6}$ = 5.0 Hz
51519-19-8	**4c**, R_1 = Me	269–270	Methanol	90	166	DMSO-d_6 (124°): 3.39 (s, H_5), 2.34 (s, CH), 7.73 (s, 4- and 6-Me)
51519-20-1	**4d**, R_1 = R_2 = H	202–204	Ethanol	91	138	DMSO-d_6: 1.53 (d, H_3), 1.85 (q, H_6), 1.95 (d, H_5), 2.20 (d, CH), 0.30 (d, NH), −0.25 (broad s, OH); $J_{5,6}$ = 3.0, $J_{3,6}$ = 1.0, J_{NHCH} = 9.0 Hz

Table II
(Continued)

Registry no.	Compd	Mp, °C	Crystallized from	Yield %	Mass spectrum M+	Nmr spectrum, τ
51519-21-2	**4d**, R_1 = Cl; R_2 = H	217–218	Methanol	80	172 and 174	DMSO-d_6: 1.70 (s, H_3 and H_6), 2.25 (broad, CH), 0.05 (broad, NH), −0.40 (broad, OH)
51519-22-3	**4d**, R_1 = H; R_2 = Cl	214–216	Ethanol	76	172 and 174	DMSO-d_6: 1.61 and 1.92 (s, H_3 and H_5), 2,38 (deg. d, CH), 0.05 (broad, NH), −0.50 (broad, OH); J_{NHCH} = 2.0 Hz
51519-23-4	**4e**, R_1 = morpholino	238–242	Ethanol	71	309	DMSO-d_6: 2.36 (d, CH), 6.40 (broad s, 4-, 6-morpholino), 1.86 (d, NH), −0.25 (s, OH); J_{NHCH} = 10.5 Hz
51519-24-5	**4f**[b]	245–248	Water	81	178	DMSO-d_6: 1.47 (s, H_2), 1.60 (d, H_8), 2.27 (d, H_7), 2.10 (d, CH), −0.78 (broad, OH), −0.11 (broad, NH); $J_{7,8}$ = 8.6, J_{CHNH} = 9.0 Hz
51519-25-6	**4g**, R_1 = Cl	188–189	Methanol	65	223 and 225	DMSO-d_6: 0.85 (dd, H_2), 2.08 (dd, H_3), 1.05 (dd, H_4), 2.02 (s, CH), 0.15 (broad, NH), −0.40 (broad, OH); $J_{2,3}$ = 4.5, $J_{3,4}$ = 8.0, $J_{2,4}$ = 1.5 Hz
51519-26-7	**4h**, R_1 = Cl	188–190	Methanol and *n*-hexane	79	223 and 225	DMSO-d_6: 1.57 (dd, H_4), 1.99 (dd, H_3), 0.85 (dd, H_2), 1.98 (s, CH), −0.79 (s, OH), 0.85 (broad, NH); $J_{2,3}$ = 4.5, $J_{2,4}$ = 1.5, $J_{3,4}$ = 8.0 Hz

[a] Satisfactory analytical data were obtained for all compounds listed. [b] Obtained after 4 hr under reflux.

Table III
***s*-Triazoloazines**[a]

Registry no.	Compd	Mp, °C	Crystallized from	Yield, %	Mass spectrum, M+	Nmr spectrum, τ
31040-14-9	**6**, R = NO_2	204–208[b]	Ethanol	61	164	*c*
42399-79-1	**7**, R = Cl; R_1 = R_2 = H	135–138	Ethanol	67	154	*c*
51519-27-8	**7**, R = Cl; R_1 = Me; R_2 = H	138–142	Water	78	168	$CDCl_3$: 1.66 (s, H_2), 2.11 (q, H_8), 7.47 (d, 7-Me); $J_{8,7\text{-Me}}$ = 1.2 Hz
51519-28-9	**7**, R = Cl; R_1 = R_2 = Me	108–110	Water	88	182	$CDCl_3$: 1.70 (s, H_2), 7.30 and 7.52 (s, 7- and 8-Me)
275-02-5	**8**, R = H	140–141[d]		82	120	*c*
7681-99-4	**8**, R = Me	135–137[e]	Ethanol	81	148	$CDCl_3$: 1.41 (s, H_2), 2.99 (s, H_6), 7.13 and 7.28 (s, 5- and 7-Me)
399-66-6	**9**, R = R_1 = H	127	Ethanol	70	120	*c*
42399-82-6	**9**, R = Cl; R_1 = H	108–110	Ethanol	61	154 and 156	*c*
51519-29-0	**9**, R = H; R_1 = Cl	140–141	Ethanol	76	154 and 156	DMSO-d_6: 1.30 (s, H_2), 0.75 (d, H_5) 0.55 (d, H_8); $J_{5,8}$ = 1.5 Hz
42399-84-8	**10**, R = morpholino	218–222	Ethanol	70	291	*c*
51519-30-3	**11**, R = Cl	218–220	Ethanol	71	205 and 207	$CDCl_3$: 1.64 (s, H_2), 0.81 (dd, H_8), 2.12 (dd, H_9), 1.14 (dd, H_{10}); $J_{8,9}$ = 4.5, $J_{9,10}$ = 8.0, $J_{8,10}$ = 1.5 Hz
51519-31-4	**12**, R = Cl	224–226	Ethanol	54	205 and 207	DMSO-d_6: 1.38 (s, H_2), 1.33 (dd, H_7), 2.03 (dd, H_8), 0.73 (dd, H_9); $J_{7,8}$ = 8.0, $J_{7,9}$ = 1.5, $J_{8,9}$ = 4.5 Hz
51519-32-5	**14**	208–212	Chloroform and *n*-hexane	67	160	DMSO-d_6: 1.36 (s, H_2, H_7), 1.38 (s, H_4, H_5)

[a] Satisfactory analytical data were obtained for all compounds listed. [b] Lit.[27] mp 207°. [c] See ref 2. [d] Lit.[28] mp 140–142°. [e] Lit.[29] mp 136–137°.

zine (**9**), *s*-triazolo[1,5-*a*]-1,3,5-triazine (**10**), pyrido[3,2-*d*]-*s*-triazolo[1,5-*b*]pyridazine (**11**), and the isomeric pyrido[2,3-*d*]-*s*-triazolo[1,5-*b*]pyridazine (**12**), *s*-triazolo[4,3-*b*]-*s*-triazolo[5′,1′-*f*]pyridazine (**13**) and bis-*s*-triazolo[1,5-*b*:5′,1′-*f*]pyridazine (**14**) have been prepared. The last four are new heterocyclic systems.

s-Triazolo[1,5-*a*]pyridines (**6**) have previously been prepared by oxidative cyclization of 2-pyridylamidines.[13] Most of the methyl-substituted 2-hydroxyiminomethyleneaminopyridines (**4d**) did not cyclize in the presence of polyphosphoric acid. The corresponding oxime derived from 2-aminopyridine was transformed under the same experimental conditions into *N*-pyridyl-2-urea,[14] indicating that Beckmann rearrangement took place. In an attempt to cylize the oxime **4a** (R_1 = H) with lead tetraacetate, 2-cyanoaminopyridine was isolated, whereas the same reaction on 2-methoxyiminomethyleneaminopyridine afforded methyl *N*-(pyridyl-2)-carbamate.[15] A successful

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Experimental Section

General. - Melting points were determined on a Kofler micro hot stage. JEOL JNM C60-HL spectrometer was used to obtain the nmr spectra (TMS as internal standard). Mass spectra were taken on a Hitachi Perkin-Elmer RMU-6L instrument using direct sample insertion. The following starting compounds were prepared according to the literature: 2-amino-6-chloropyrazine[23] 2-amino-5-chloropyrazine[24,25] N,N-dimethyl-N'-(pyridazinyl-3)formamidine and its 6-chloro analog[26] and 6-dimethylamino-methyleneaminotetrazolo(1,5-b)pyridazine[18]. Throughout this paper polyphosphoric acid Fluka, containing 83 % P_2O_5, was used.

6-Dimethylaminomethyleneamino-s-triazolo(1,5-b)pyridazine (2 f). - A mixture of 6-amino-s-triazolo(1,5-b)pyridazine (2.25 g), N,N-dimethylformamide dimethylacetal (2.25 g) and toluene (6 ml) were heated under reflux for 2 hr. The solvent was evaporated to dryness and the residue was crystallized from chloroform and n-hexane, 1:1; mp 143° (yield 93 %); mass spectrum M^+ 190; nmr ($CDCl_3$) δ 1.52 (s, CH=N), 1.70 (s, H_2), 2.11 (d, H_8), 2.85 (d, H_9), 6.85 and 6.88 (s, NMe_2).

Anal. Calcd for $C_8H_{10}N_6$: C, 50.51; H, 5.30; N, 44.19. Found: C, 50.28; H, 5.12; N, 43.60.

In a similar way were prepared compounds which are listed in Table I.

3-Hydroxyiminomethyleneaminopyridazine (4b, $R_1 = R_2 = R_3 = H$). - N,N-Dimethyl-N'-(pyridazinyl-3)formamidine[18] (0.15 g) was treated with a methanolic solution of hydroxylamine (prepared from 80 mg of hydroxylamine hydrochloride and methanolic sodium methylate, prepared from 25 mg of sodium and 5 ml of methanol). After standing at room temperature for 5 hr the solvent was evaporated to dryness, some water was added and the residue was filtered off (yield 43 %). For analysis the product was crystallized from methanol and diethyl ether, mp 194–195°; mass spectrum M^+ 138; nmr (DMSO-d_6) δ 1.30 (m, H_8), 2.60 (m, H_4, H_5), 1.90 (d, CH), 0.25 (d, NH), -0.45 (s, OH), $J_{5,6} = 4.2$, $J_{4,6} = 2.0$, $J_{4,5} = 9.0$ and $J_{NHCH} = 10.5$ Hz.

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Anal. Calcd for $C_5H_6N_4O$: C, 43.47; H, 4.38; N, 40.56. Found: C, 43.73; H, 4.69; N, 40.45.

In an analogous way compounds, listed in Table II, were prepared.

6-Hydroxyiminomethyleneamino tetrazolo(1,5-b)pyridazine (17). - 6-Dimethylaminomethyleneaminotetrazolo(1,5-b)pyridazine[18] (5.0 g) was treated with a methanolic solution of hydroxylamine (prepared from 3.8 g of hydroxylamine hydrochloride and a solution of sodium methoxide, obtained from 1.26 g sodium and 100 ml methanol). The mixture was left to stand at room temperature overnight and then heated under reflux for 8 hr, treated again with the same quantity of methanolic hydroxylamine and left to stand at room temperature overnight. After heating for 3 hr under reflux the solvent was evaporated to dryness, some water was added and the product was filtered off (1.95 g, 42%), mp 202–203° (twice from ethanol); mass spectrum M^+ 179; nmr (DMSO-d_6) δ 2.32 (d, H_9), 1.45 (d, H_8), 2.20 (s, CHNH), -0.6 (broad, CHNH), $J_{7,8} = 9.5$ Hz.

Anal. Calcd for $C_5H_5N_7O$: C, 33.53; H = 2.81. Found: C, 33.62; H, 3.28.

If the above compound (17) is heated at 230–240° for 10–15 min 6-aminotetrazolo(1,5-b)pyridazine is formed. Similarly, upon heating with acetic anhydride for 20 min 6-acetaminotetrazolo(1,5-b)-pyridazine is formed, which is in turn prepared from the 6-amino derivative in the same manner, mp 228–232° (from methanol and diethylether); mass spectrum M^+ 178; nmr (CD_3OD) δ 1.50 (d, H_9), 1.30 (d, H_8), 7.71 (s, CH_3), $J_{7,8} = 9.5$ Hz.

Anal. Calcd for $C_6H_6N_6O$: C, 40.45; H, 3.39; N, 47.18. Found: C, 40.78; H, 3.85; N, 47.31.

s-Triazolo(1,5-b)pyridazine (7, $R = R_1 = R_2 = H$). - Compound 4b ($R_1 = R_2 = R_3 = H$) (1.8 g) was thoroughly mixed with polyphosphoric acid (54 g) and the mixture was heated at 70–80° for 2 hr. The cold reaction mixture was treated with water (100 ml) and neutralized with solid $NaHCO_3$. Thereafter it was repeatedly extracted with chloroform, the extracts were dried over Na_2SO_4 and upon evaporation of the solvent the product (0.8 g) was sublimed at 145° and then crystallized from chloroform and n-hexane, mp 138–142° (yield 51%); mass spectrum M^+ 120; nmr (see ref. 2).

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Anal. Calcd for $C_5H_4N_4$: C, 49.99; H, 3.36; N, 46.65. Found: C, 49.99; H, 3.59; N, 46.66.

All other cyclic products, obtained in a likewise manner, are listed in Table III.

6-Amino-s-triazolo(1,5-b)pyridazine (7, R = NH_2, $R_1 = R_2 = H$). - A mixture of the 6-chloro compound (7, R = Cl, $R_1 = R_2 = H$) (0.5 g) and liquid ammonia (10 ml) was placed in an autoclave and heated at 130° for 2 hr. The reaction mixture was mixed with water and the product filtered off. It was crystallized from a minimum amount of water (yield 68%), mp 254–256°; mass spectrum M^+ 135; nmr (DMSO-d_6) δ 1.87 (s, H_2), 2.10 (d, H_8), 3.10 (d, H_9), 3.36 (s, NH_2), $J_{7,8} = 9.2$ Hz.

Anal. Calcd for $C_5H_5N_5$: C, 44.44; H, 3.73; N, 51.83. Found: C, 44.60; H, 4.08; N, 52.04.

6-Hydrazino-s-triazolo(1,5-b)pyridazine (7, R = $NHNH_2$, $R_1 = R_2 = H$). - A mixture of the chloro compound (7, R = Cl, $R_1 = R_2 = H$) (1.0 g), ethanol (25 ml) and hydrazine hydrate (2 ml of 80%) was heated under reflux for 1.5 hr. Upon cooling, the product was filtered off and thoroughly washed with ethanol. The product was crystallized from N,N-dimethylformamide and ethanol (0.4 g, 41%), mp 258–261°; mass spectrum M^+ 150; nmr (DMSO-d_6) δ 1.86 (s, H_2), 3.07 (d, H_7), 2.16 (d, H_8), 1.8 (broad, $NHNH_2$), 5.7 (broad, $NHNH_2$), $J_{7,8} = 9.5$ Hz.

Anal. Calcd for $C_5H_6N_6$: C, 39.99; H, 4.03; N, 55.98. Found: C, 40.08; H, 4.24; N, 56.02.

The compound formed an isopropylidene derivative, mp 219°, prepared in the usual manner. Mass spectrum M^+ 190. Similarly, the benzylidene derivative, mp 269–272° (from N,N-dimethylformamide and ethanol, 1:1) was prepared; mass

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spectrum M^+ 238; the ethylidene derivative had m.p. 223–225° (sublimed at 170–175°/5 mm), mass spectrum M^+ 176.

6-Azido-s-triazolo(1,5-b)pyridazine (7, R = N_3, $R_1 = R_2 = H$). - A. - Compound 17 (0.17 g) was suspended in polyphosphoric acid (6 g) and the mixture was heated at 70–80° for 2 hr. Upon addition of water, neutralization with $NaHCO_3$, extraction with chloroform and evaporation of the solvent the product (0.1 g) was crystallized from methanol, mp 158–162°.

B. - The hydrazino derivative (7, R = NHNR, $R_1 = R_2 = H$) (1.5 g) was dissolved in hydrochloric acid (20 ml of 10%), and to the cold (0°) solution a solution of sodium nitrite was added dropwise (iodide-starch paper). Upon neutralization with $NaHCO_3$ the solution was extracted with chloroform and the residue, obtained after evaporation of the solvent, was crystallized from methanol (1.35 g), mp 158–162°; mass spectrum M^+ 161; nmr (see ref. 2).

Anal. Calcd for $C_5H_3N_7$: C, 37.27; H, 1.86; N, 60.86. Found: C, 37.30; H, 1.97; N, 61.20.

6-Diethylaminomethyleneamino-s-triazolo(1,5-b)pyridazine (7, R = Et_2NCH = N, $R_1 = R_2 = H$). - A mixture of the above azido compound (0.5 g) and diethylamine (120 ml) was heated under reflux for 3 hr. Upon evaporation to dryness the residue was dissolved in chloroform and purified by tlc (Fertigplatten, Al_2O_3 T - 1,5 mm, Merck, chloroform and methanol, 50 : 1, as solvent). The product with $R_f = 0.3$ was eluted and identified as 6-amino-s-triazolo(1,5-b)-pyridazine (25 mg). The other product (7, R = Et_2NCH = N-, $R_1 = R_2 = H$) with $R_f = 0.9$ (0.45 g, 67%) was after elution and evaporation of the solvent dissolved in chloroform and filtered. The filtrate was evaporated to dryness and n-hexane was added. Upon standing on ice the pure product separated, mp 66°; mass spectrum M^+ 218; nmr (DMSO-d_6) δ 1.58 (s, H_2), 2.75 (d, H_7), 1.83 (d, H_8), 1.58 (s, CH), 6.50 and 6.55 (s, CH_2CH_3), 8.76 and 8.78 (t, CH_2CH_3), $J_{7,8} = 9.4$ and $J_{Et} = 7.2$ Hz.

Anal. Calcd for $C_{10}H_{14}N_6$: C, 55.03; H, 6.47. Found: C, 54.95; H, 6.27.

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s-Triazolo(1,5-b)pyridazin-6(5H)one (15, R = H, X = O). - A mixture of the chloro compound (7, R = Cl, $R_1 = R_2 = H$) (0.3 g) and aqueous potassium hydroxide (prepared from 0.35 KOH and 10 ml of water) was heated under reflux for 1 hr. Upon cooling and neutralization with hydrochloric acid (1:1), the separated product was filtered off and for analysis sublimed at 250–256°/5 mm (yield 63%), mp 156–157°; mass spectrum M^+ 136; nmr (DMSO-d_6) δ 1.72 (s, H_2), 1.88 (d, H_3), 2.93 (d, H_8), $J_{7,8} = 9.8$ Hz.

Anal. Calcd for $C_5H_4N_4O$: C, 44.12; H, 2.96; N, 41.17. Found: C, 44.32; H, 3.18; N, 40.98.

6-Methoxy-s-triazolo(1,5-b)pyridazine (7, R = OMe, $R_1 = R_2 = H$). - A mixture of the chloro compound (7, R = Cl, $R_1 = R_2 = H$) (0.2 g) and methanolic sodium methoxide (prepared from 50 mg sodium and 10 ml methanol) was heated under reflux for 15 min. Upon evaporation to dryness the crude product was sublimed at 150–155°/5 mm and then crystallized from water (yield 92%), mp 178–180°; mass spectrum M^+ 150; nmr ($CDCl_3$) δ 1.79 (s, H_2), 2.13 (d, H_8), 3.07 (d, H_7), 5.94 (s, OCH_3), $J_{7,8} = 9.8$ Hz.

Anal. Calcd for $C_6H_6N_4O$: C, 48.00; H, 4.03. Found: C, 47.92; H, 4.08.

Methylation of s-triazolo(1,5-b)pyridazin-6(5H)one. - A solution of compound 15 (R = H, X = O) (0.5 g) in ethanol (5 ml) and aqueous potassium hydroxide (0.3 g KOH in 5 ml of water) was treated with methyl iodide (1.2 g) and heated under reflux for 1 hr. The solvent was evaporated in vacuo and the residue dissolved in methanol and separated by tlc (Merck DC-Fertigplatten Al_2O_3 F-254, Typ T, 1.5 mm, n-hexane and chloroform, 1:1 as solvent). Elution with methanol of the compound with $R_f = 0.64$ afforded 16 mg of 6-methoxy-s-triazolo(1,5-b)pyridazine (7, R = OMe, $R_1 = R_2 = H$) and the compound with $R_f = 0.5$ was identified as 5-methyl-s-triazolo(1,5-b)pyridazin6(5H)one (15, R = Me, X = O) (28 mg), mp 143–144° (from methanol); mass spectrum M^+ 150; nmr ($CDCl_3$) δ 2.02 (s, H_2), 2.36 (d, H_8), 3.19 (s, H_7), 6.07 (s, CH_3), $J_{7,8} = 9.8$ Hz.

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s-Triazolo(1,5-b)pyridazine-6(5H)thione (15, R = H, X = S). - A mixture of the 6-chloro compound (7, R = Cl, $R_1 = R_2 = H$) (0.6 g) and an ethanolic solution of potassium hydrosulfide (2C ml of 2 N) was heated under reflux for 1 hr. Upon cooling the product was filtered off and the salt was dissolved in warm water (20 ml), charcoaled and filtered. The filtrate was acidified with hydrochloric acid (1:1) and the separated product was collected (yield 56%), mp 157–160°; mass spectrum M^+ 152; nmr (DMSO-d_6) δ 1.46 (s, H_2), 1.67 (d, H_8), 2.19 (d, H_7), $J_{7,8} = 9.2$ Hz.

Anal. Calcd for $C_5H_4N_4S$: C, 39.47; H, 2.65; N, 36.83; S, 21.05. Found: C, 39.47; H, 2.93; N, 36.91; S, 20.99.

The potassium salt upon methylation with methyl iodide afforded the 6-methylthio compound (7, R = SMe, $R_1 = R_2 = H$), mp 128–130° (from ethanol and n-hexane, 1:1); mass spectrum M^+ 166; nmr (DMSO-d_6) δ 1.41 (s, H_2), 1.70 (d, H_8), 2.38 (d, H_7), 7.35 (s, SCH_3), $J_{7,8} = 9.5$ Hz.

Anal. Calcd for $C_6H_6N_4S$: C, 43.35; H, 3.64; N, 33.71; S, 19.30. Found: C, 42.94; H, 3.87; N, 33.98; S, 19.20.

6,7,8-Trichloro-s-triazolo(1,5-b)pyridazine (7, $R = R_1 = R_2 = Cl$). - A mixture of compound 7 (R = Cl, $R_1 = R_2 = H$) (C.5 g) and phosphorous pentachloride (3.4 g) was heated in a sealed tube at 260–265° for 6 hr. The reaction mixture was mixed with iced water and extracted with chloroform. Upon evaporation of the solvent the product was purified by tlc (Merck DC-Fertigplatten Al_2O_3 Typ E, 0.25 mm, chloroform and n-hexane, 1:1, as solvent). The product with $R_f = 0.8$ was eluted and sublimed at 110–115°/5 mm, mp 113° (yield 87%); mass spectrum M^+ 222; nmr ($CDCl_3$) δ 1.56 (s, H_2).

Anal. Calcd for $C_5HCl_3N_4$: C, 26.98; H, 0.45; N, 25.07. Found: C, 27.15; H, 0.62; N, 25.12.

7-Chloro-6,8-dimethoxy-s-triazolo(1,5-b)pyridazine (7, $R = R_2$ = OMe, R_1 = Cl). - The above trichloro compound (7, $R = R_1 = R_2$ = Cl) (0.447 g) was heated with methanolic sodium methylate (prepared from 0.092 g sodium and 10 ml

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of methanol) under reflux for 1 hr. The solvent was evaporated to dryness, water (10 ml) was added and after 1 hr the residue was filtered off and crystallized from water (yield 65%), mp 150°; mass spectrum M^+ 214; nmr ($CDCl_3$) δ 1.77 (s, H_2), 5.32 and 5.86 (s, 6-and 8-OMe).

Anal. Calcd for $C_7H_7ClN_4O_2$: C, 39.18; H, 3.29; N, 26.11. Found: C, 39.27; H, 3.63; N, 26.39.

6,8-Dimethoxy-s-triazolo(1,5-b)pyridazine (7, $R = R_2$ = OMe, R_1 = H). - A mixture of the above compound (7, $R = R_2$ = OMe, R_1 = Cl) (0.185 g), methanol (31 ml), conc. ammonia (3 ml) and palladized carbon (0.25 g of 5%) was stirred in an atmosphere of hydrogen until the required amount was consumed. Upon filtration, evaporation of the solvent to dryness the residue was repeatedly extracted with chloroform and the solvent evaporated to dryness. The product was sublimed at 130°/5 mm (yield 72%), mp 189°; mass spectrum M^+ 180; nmr (DMSO-d_6) δ 1.66 (s, H_2), 3.31 (s, H_7), 5.94 and 6.02 (s, 6- and 8-OMe).

Anal. Calcd for $C_7H_8N_4O_2$: N, 31.10. Found: N, 31.29.

In a similar manner were prepared:

7-Methyl-s-triazolo(1,5-b)pyridazine (7, $R = R_2$ = H, R_1 = Me) from its 6-chloro analog (7, R = Cl, R_1 = Me, R_2 = H) in 52 % yield, mp 127–130° (sublimed at 105°/5 mm); mass spectrum M^+ 134; nmr ($CDCl_3$) δ 1.73 and 1.77 (s, H_2 and H_8), 2.25 (m, H_8), 7.50 (d, 7-CH_3), $J_{7CH_3,8H} = 1.0$ Hz.

7,8-Dimethyl-s-triazolo(1,5-b)pyridazine (7, $R = R_1 = H$, R_2 = Me) was obtained from the 6-chloro analog (7, R = Cl, $R_1 = R_2$ = Me) in 80% yield, mp 137° (sublimed at 120–125°/5 mm); mass spectrum M^+ 148; nmr ($CDCl_3$) δ 1.73 and 1.80 (s, H_2 and H_6), 7.43 and 7.61 (s, 7- and 8-Me).

Anal. Calcd for $C_7H_8N_4$: C, 56.74; H, 5.44; N, 37.82. Found: C, 56.22; H, 5.51; N, 38.14.

6,7-Dichloro-8-dimethylamino-s-triazolo(1,5-b)pyridazine (7, $R = R_1$ = Cl, R_2 = NMe_2). - A mixture of the trichloro compound (7, $R = R_1 = R_2$ = Cl) (0.5 g) and aqueous dimethylamine (5 ml of 25%) was heated under reflux for 1 hr. The

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mixture was evaporated to dryness and the residue sublimed at 128–133°/5 mm and crystallized from methanol, mp 140° (yield 67%); mass spectrum M^+ 232; nmr ($CDCl_3$) δ 1.71 (s, H_2), 6.48 (s, NMe_2).

8-Dimethylamino-s-triazolo(1,5-b)pyridazine (7, $R = R_1 = H$, R_2 = NMe_2). - The above compound (7, $R = R_1$ = Cl, R_2 = NMe_2) (0.3 g), methanol (20 ml), conc. ammonia (3 ml) and palladized charcoal (0.12 g of 5%) were stirred at room temperature in an atmosphere of hydrogen. After the necessary amount of hydrogen has been consumed, the reaction mixture was filtered, evaporated to dryness, the residue extracted with chloroform and the solvent evaporated. The product was sublimed at 120–125°/5 mm (71% yield), mp 140°; mass spectrum M^+ 163; nmr ($CDCl_3$) δ 1.79 (s, H_2), 2.01 (d, H_6), 4.01 (d, H_7), 6.58 (s, NMe_2), $J_{6,7} = 6.0$ Hz.

Anal. Calcd for $C_7H_9N_5$: N, 42.92. Found: N, 43.24.

5,6,7,8-Tetrahydro-s-triazolo(1,5-b)pyridazine. - The procedure was the same as described above. The product was obtained in 73% yield and was sublimed at 90–95°/5 mm, mp 80°; mass spectrum M^+ 124; nmr ($CDCl_3$) δ 2.41 (s, H_2), 6.60 (m, H_5), 7.98 (m, H_6), 7.05 (m, H_8).

Anal. Calcd for $C_5H_8N_4$: C, 48.37; H, 6.50; N, 45.13. Found: C, 48.19; H, 6.37; N, 45.50.

8-Methyl-s-triazolo(4,3-b)-s-triazolo(5',1'-f)pyridazine (13, R = Me). - A mixture of 6-ethylidenehydrazino-s-triazolo(1,5-b)pyridazine (7, R = CH_3CH = NNH, $R_1 = R_2 = H$) (0.6) and dry methylene chloride (160 ml) was treated with lead tetraacetate (1.8 g) and left at room temperature for 2.5 hr. Upon filtration the filtrate was evaporated to dryness and the residue dissolved in chloroform. Charcoal was added and the mixture heated to boil and filtered into n-hexane. The separated product was collected and sublimed at 200°/5 mm, mp 222–223° (0.3 g, 51%); mass spectrum M^+ 174; nmr ($CDCl_3$) δ 1.77 (s, H_2), 2.19 and 2.48 (d, H_4, H_5), 6.81 (s, CH_3), $J_{9,10} = 10.5$ Hz.

Anal. Calcd for $C_7H_6N_6$: C, 48.27; H, 3.47. Found: C, 48.77; H, 3.60.

8-Phenyl-s-triazolo(4,3-b)-s-triazolo(5',1'-f)pyridazine (13, R = Ph). - To a mixture of the benzylidene compound (7, R = PhCH = NNH, $R_1 = R_2 = H$)

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(0.4 g) and glacial acetic acid (24 ml) bromine (0.8 ml) was added dropwise and the mixture heated under reflux for 10 min. Upon cooling to 0°, the separated product was filtered off and washed with glacial acetic acid (10 ml). The residue was suspended in water (25 ml) and filtered after 30 min. The product was crystallized from ethanol, mp 206–211° (yield 27%); mass spectrum M^+ 236; nmr (DMSO-d_6) δ 1.58 (s, H_2), 1.81 and 2.12 (d, H_4, H_5), 2.13 and 2.43 (m, Ph), $J_{4,5} = 10.0$ Hz.

3-(Pyrazolyl-3')-s-triazole(16). - A mixture of s-triazolo(1,5-b)-pyridazine (2.0 g) and hydrazine hydrate (25 ml of 98 %) were heated under reflux for 23 days. The product was crystallized from ethanol, mp 278–28°° (yield 58%); mass spectrum M^+ 135; nmr (DMSO-d_6) δ 1.78 (s, H_2), 1.81 (d, $H_{3'}$), 3.10 (d, $H_{4'}$), 3.55 (broad, NH), $J_{3',4'} = 2.6$ Hz.

Anal. Calcd for $C_5H_5N_5$: N, 51.83. Found: N, 52.09.

4-Acetyl-5-methyl-1-/-s-triazolo(1,5-b)pyridazinyl-6'/-1H-1,2,3-triazole (18). - The 6-azido compound (7, R = N_3, $R_1 = R_2 = H$) (0.25 g), acetylacetone (0.5 ml), ethanol (6 ml) and triethylamine (0.3 ml) were heated under reflux for 5 min. The separated product was filtered off and crystallized from ethanol (yield 67%), mp 163–164°; mass spectrum M^+ 245; nmr ($CDCl_3$) δ 1.49 (s, H_2), 1.65 (d, H_8), 1.71 (s, H_7), 6.96 (s, 4-CH_3CO), 7.25 (s, 5-CH_3), $J_{7,8} = 9.0$ Hz.

Anal. Calcd for $C_{10}H_9N_7O$: N, 40.31. Found: N, 40.60.

Photochemical cyclization. - Compound 4a ($R_1 = H$) (0.1 g) was dissolved in methanol (17 ml) and the solution irradiated in a Rayonet photochemical reactor with 2537-Å lamps for 10 days. The solvent was evaporated to 2-3 ml and diluted with chloroform. A Varian Model 1800 temperature-programming vapor phase chromatograph was employed for separation (stainless steel 195 cm column packed with 10% OV 1 on 60/80 mesh Chromosorb A; temperature 160°/4 min, then 260°). Three fractions were identified as 2-aminopyridine (mass spectrum M^+ 94), s-triazolo(1,5-a)pyridine (mass spectrum M^+ 199; identical with an authentic Specimen[27]; yield 5 mg) and 2-formylaminopyridine (mass spectrum M^+ 122; identical with an authentic specimen). Tlc of the reaction product revealed that about half of the starting material remained unchanged.

synthesis of the parent compound (6, R = H) was achieved by irradiation (λ 254 nm, 10 hr) of a methanolic solution of 4a (R_1 = H). As by-products 2-aminopyridine and 2-formylaminopyridine were formed and separated by glc.

In the pyridazine series no difficulties were encountered. Although we have recently described[16] a synthesis of *s*-triazolo[1,5-*b*]pyridazines (7), 2-unsubstituted derivatives could not be obtained by this method. The cyclization of the corresponding oximes could be extended to build two tricyclic systems (13 and 14). Several reactions have been investigated on the bicyclic system and nucleophilic substitutions proceeded as anticipated. The chlorine atom of 6-chloro-*s*-triazolo[1,5-*b*]pyridazine is replaceable and the corresponding 6-amino (7, R = NH_2; R_1 = R_2 = H), 6-hydrazino (7, R = $NHNH_2$; R_1 = R_2 = H), 6-oxo (15, X = O; R = H), 6-thiono (15, R = H; X = S) or 6-methoxy (7, R = OMe; R_1 = R_2 = H) compounds were thus prepared. The 6-azido compound (7, R = N_3; R_1 = R_2 = H) could be prepared either from the corresponding 6-hydrazino compound by nitrosation or from the substituted tetrazolo[1,5-*b*]pyridazine (17) by simultaneous formation of the triazole ring and tetrazolo–azido isomerization, as previously applied to related systems.[17] The azido compound reacted with diethylamine to give 6-diethylaminomethyleneamino compound (7, R = $Et_2NCH{=}N$–; R_1 = R_2 = H). This is another example of this unusual reaction which we have discovered recently.[18] Moreover, the azido compound reacted with acetylacetone to give the cycloaddition product (18) in accordance with our observations on related systems.[19] Methylation of the 6-oxo compound (15, R = H; X = O) afforded a mixture of the 6-methoxy (7, R = OMe; R_1 = R_2 = H) and *N*-methyl derivative (15, R = Me; X = O). Chlorination of 6-chloro-*s*-triazolo[1,5-*b*]pyridazine with phosphorus pentachloride afforded the trichloro compound (7, R = R_1 = R_2 = Cl), position 2 of the bicyclic system remaining unaffected. The chlorine atoms at position 6 and 8 of the trichloro compound reacted readily with sodium methoxide, but the most reactive is that at position 8 as evidenced from the reaction with dimethylamine which gave the monosubstitution product (7, R = R_1 = Cl; R_2 = NMe_2). Hydrogenolysis over palladium afforded the dehalogenated products, except in the case of 6-chloro-*s*-triazolo[1,5-*b*]pyridazine, which was transformed into 5,6,7,8-tetrahydro-*s*-triazolo[1,5-*b*]pyridazine with simultaneous dehalogenation and reduction of the pyridazine part. On the other hand, hydrazinolysis of the parent compound cleaved the six-membered ring and recyclization afforded the pyrazolyltriazole (16). Similar transformations we have observed with some of the related heterocyclic system.[20,21]

The *s*-triazolo[1,5-*a*]pyrazine system (9) has been reported only once,[22] and the synthetic approach described provides only 2-substituted compounds. 2-Unsubstituted *s*-triazolo[1,5-*a*]pyrazines are now readily available by this new method from the appropriate 2-aminopyrazines. Many reactions involving this system will be dealt with in another report.

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Registry No.—2f, 51519-33-6; **4b** (R_1 = R_2 = R_3 = H), 51519-34-7; 7 (R = R_1 = R_2 = H), 40369-38-8; 7 (R = NH_2; R_1 = R_2 = H), 51519-35-8; 7 (R = $NHNH_2$; R_1 = R_2 = H), 51519-36-9; 7 (R = $NHN{=}CMe_2$; R_1 = R_2 = H), 51519-37-0; 7 (R = NHN=CPh; R_1 = R_2 = H), 51519-38-1; 7 (R = NHN=CHMe; R_1 = R_2 = H), 51519-39-2; 7 (R = N_3; R_1 = R_2 = H), 42399-80-4; 7 (R = $Et_2NCH{=}N$; R_1 = R_2 = H), 51519-40-5; 7 (R = OMe; R_1 = R_2 = H), 51519-41-6; 7 (R = SMe; R_1 = R_2 = H), 51519-42-7; 7 (R = R_1 = R_2 = Cl), 51519-43-8; 7 (R = R_2 = OMe; R_1 = Cl), 51519-44-9; 7 (R = R_2 = OMe; R_1 = H), 51519-45-0; 7 (R = R_2 = H; R_1 = Me), 51519-46-1; 7 (R = H; R_1 = R_2 = Me), 51519-47-2; 7 (R = R_1 = Cl; R_2 = NMe_2), 51519-48-3; 7 (R = R_1 = H; R_2 = NMe_2), 51519-49-4; 13 (R = Me), 51519-50-7; 13 (R = Ph), 51519-51-8; 15 (R = H; X = O), 51519-52-9; 15 (R = Me, X = O), 51519-53-0; 15 (R = H, X = S), 51519-54-1; 16, 51519-55-2; 17, 42489-25-8; 18, 51519-56-3; 6-amino-*s*-triazolo[1,5-*b*]pyridazine, 51519-35-8; *N,N*-dimethylformamide dimethyl acetal, 4637-24-5; *N,N*-dimethyl-7′-(pridazinyl-3)formamidine, 35053-54-4; 6-acetamidotetrazolo-[1,5-*b*]pyridazine, 51519-57-4; 5,6,7,8-tetrahydro-*s*-triazolo[1,5-*b*]-pyridazine, 51519-58-5.

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References and Notes

(1) Pyridazines, Part LXVI.
(2) S. Polanc, B. Verček, B. Stanovnik, and M. Tišler, *Tetrahedron Lett.*, 1677 (1973).
(3) N. E. Alexandrou and D. N. Nicolaides, *Org. Magn. Resonance*, **4**, 229 (1972).
(4) N. E. Alexandrou and D. N. Nicolaides, *Org. Magn. Resonance*, **4**, 591 (1972).
(5) K. Adachi, *Chem. Pharm. Bull.*, **7**, 479 (1959).
(6) J. Clark and G. Neath, *J. Chem. Soc. C*, 919 (1968).
(7) S. Polanc, B. Verček, B. Stanovnik, and M. Tišler, *J. Heterocycl. Chem.*, **11**, 103 (1974).
(8) G. J. Karabatsos and R. A. Taller, *Tetrahedron*, **24**, 3347 (1968).
(9) G. Westmark, *Svensk. Kem. Tidskr.*, **79**, 249 (1967).
(10) E. J. Poziomek and L. G. Vaughan, *J. Pharm. Sci.*, **54**, 811 (1965).
(11) R. Charonnat and F. Le Perdriel, *Ann. Pharm. Fr.*, **26**, 469 (1968); *Chem. Abstr.*, **70**, 37615 (1969).
(12) A referee suggested this naming instead of *s*-triazolo[2,3-*b*]pyridazine as used previously.[2]
(13) J. D. Bower and G. R. Ramage, *J. Chem. Soc.*, 4506 (1957).
(14) M. P. Gerchuk and S. Z. Taits, *Zh. Obshch. Khim.*, **20**, 910 (1950); *Chem. Abstr.*, **44**, 9443 (1950).
(15) R. L. Shriner and R. G. Child, *J. Amer. Chem. Soc.*, **74**, 549 (1952).
(16) M. Zupan, B. Stanovnik, and M. Tišler, *Tetrahedron Lett.*, 4179 (1972).
(17) For review see M. Tisler, *Synthesis*, 123 (1973).
(18) S. Polanc, B. Stanovnik, and M. Tišler *J. Heterocycl. Chem.*, **10**, 565 (1973).
(19) A. Gorup, M. Kovačič, B. Kranjc-Škraba, B. Mihelčič, S. Simonič, B. Stanovnik, and M. Tišler, *Tetrahedron*, in press.
(20) A. Bezeg, B. Stanovnik, B. Šket, and M. Tišler, *J. Heterocycl. Chem.*, **9**, 1171 (1972).
(21) A. Pollak, S. Polanc, B. Stanovnik, and M. Tišler, *Monatsh. Chem.*, **103**, 1591 (1972).
(22) T. Okamoto, Y. Torigoe, M. Sato, and Y. Isogai, *Chem. Pharm. Bull.*, **16**, 1154 (1968).
(23) L. Bernardi, G. Palamidessi, A. Leone, and G. Larini, *Gazz. Chim. Ital.*, **91**, 1431 (1961).
(24) J. B. Bicking, J. W. Mason, O. W. Woltersdorf, J. H. Jones, S. F. Kwong, C. M. Robb, and E. J. Cragoe, *J. Med. Chem.*, **8**, 638 (1965).
(25) G. Palamidessi and L. Bernardi, *J. Org. Chem.*, **29**, 2491 (1964).
(26) M. Zupan, B. Stanovnik, and M. Tišler, *J. Org. Chem.*, **37**, 2960 (1972).
(27) K. T. Potts and C. R. Surapaneni, *J. Heterocycl. Chem.*, **7**, 1019 (1970).
(28) C. F. H. Allen, H. R. Beilfuss, D. M. Burness, G. A. Reynolds, J. F. Tinker, and J. A. Van Allan, *J. Org. Chem.*, **24**, 796 (1959).
(29) J. A. Bee and F. L. Rose, *J. Chem. Soc.*, 2031 (1966).