Ring Transformations of 5-Chloro-1,2,3-thiadiazole-4-carbaldehyde with Amines, Hydrazines and Hydroxylamine

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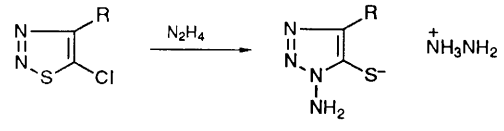
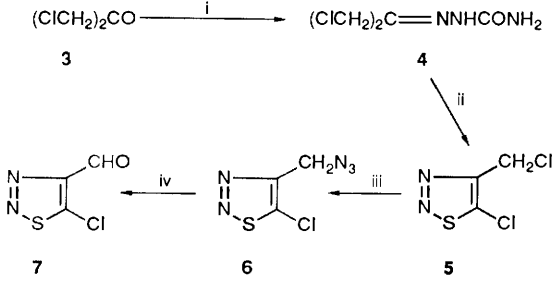
5-Chloro-1,2,3-thiadiazole-4-carbaldehyde, prepared in four steps from 1,3-dichloroacetone, reacts with alkyl- and aryl-amines in alcohol solution to give 1,2,3-triazole-4-thiocarboxamides **9a–f**. Similarly, hydrazine and *N*-aminomorpholine furnish the 1,2,3-triazole-4-thiohydrazides **9g** and **9h**, whereas phenylhydrazine and hydroxylamine yield unrearranged products **8i** and **8j**. These, however, are transformed into 1,2,3-triazole-4-carboxylic acids **14i** and **14j** upon storage in dimethyl sulphoxide solution. The mechanism of the rearrangement is discussed.

1,2,3-Thiadiazoles are known to undergo thermal rearrangements *via* α-diazo thioketones as elusive intermediates.[1] We recently reported that 5-chloro-1,2,3-thiadiazoles **1**, bearing a hydrogen, phenyl, or ester function at the 4-position, react with hydrazine to give the Dimroth rearrangement products **2** or their derivatives.[2] In continuation of this research, we have now investigated the title reactions which furnish triazoles resulting from a different mode of cyclization of the intermediate diazo compounds.



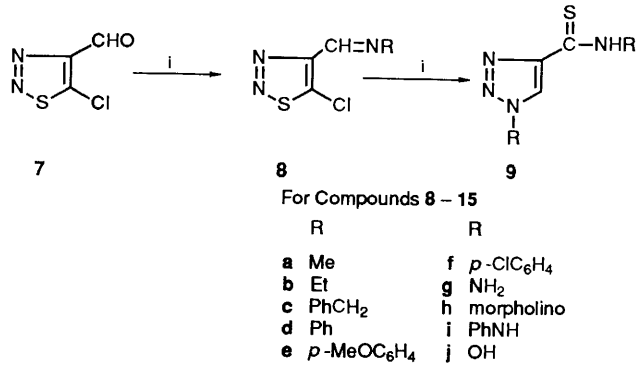
1 R = H, Ph, CO_2Et **2**

5-Chloro-1,2,3-thiadiazole-4-carbaldehyde **7** was prepared by the sequence outlined in Scheme 1. The method of Hurd and Mori[3] provided the thiadiazole **5**, whose further conversion into the aldehyde **7** *via* the azide **6** was straightforward and has been utilized already in a number of other syntheses.[4] The aldehyde **7**, obtained as a dark brown oil in 33% overall yield, can be purified chromatographically, and was crystallized from dichloromethane–hexane at −20 °C, but it darkens again upon storage at room temperature. Hence, it was found advantageous to use it without purification in the following reactions.



Scheme 1 *Reagents:* i, $H_2NNHCONH_2$; ii, $SOCl_2$; iii, NaN_3; iv, H_2SO_4

Treatment of the aldehyde **7** with a series of amines in methanol at room temperature yielded the triazole-4-thiocarboxamides **9a–f** as the sole reaction products. They gave a positive Feigl test for the C=S function[5] and were characterized by spectral analysis. In particular, the ^{13}C NMR spectra exhibited typical signals at δ_C 126–129 (C-5, $^1J_{CH}$ 199–203 Hz), 147–149 (C-4, $^2J_{CH}$ 8–8.5 Hz, $^3J_{CH}$ 3.5–4 Hz) and 182–184 (C=S).



7 **8** **9**

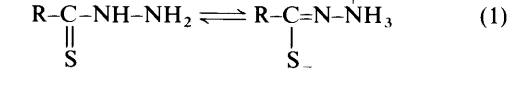
For Compounds **8** – **15**

	R		R
a	Me	**f**	*p*-ClC_6H_4
b	Et	**g**	NH_2
c	$PhCH_2$	**h**	morpholino
d	Ph	**i**	PhNH
e	*p*-$MeOC_6H_4$	**j**	OH

Reagent: i, RNH_2

An independent synthesis of compound **9d** by sulphurization of *N*,1-diphenyl-1,2,3-triazole-4-carboxamide with phosphorus pentasulphide confirmed the structure assignment.

Hydrazine and *N*-aminomorpholine also furnished rearranged products (compounds **9g** and **9h**) according to ^{13}C NMR analysis. A point of much concern, however, was the higher field signal for C=S in the thiohydrazide **9g** (δ_C 169.3) compared with that in the thioamides **9a–f** (δ_C 182–184) and the morpholine **9h** (δ_C 179.6). A similar upfield shift in going from thiobenzamides (δ_C ~200)[6] to thiobenzohydrazide (PhC-SNHNH$_2$, δ_C 182.8) has also been noted. This may be explained by the existence of two tautomeric thiohydrazide forms in dimethyl sulphoxide solution[7] [equation (1)]. If this is the case, addition of deuterium chloride to the NMR tube containing the thiohydrazide **9g** should cause a downfield shift for the CS resonance, which is indeed observed (δ_C 169 ⟶ 177).

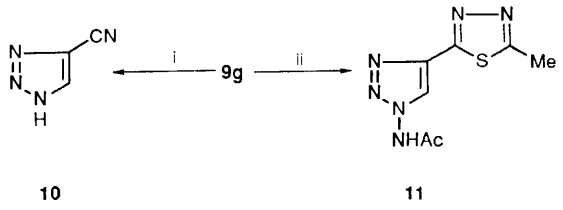


(1)

Compound **9h**, on the other hand, exhibits a normal C=S signal in $CDCl_3$ or [$^2H_6$]DMSO solution (δ_C 179.6) and does not exist in the zwitterionic form. This is also revealed by the multiplicity of the C-4 resonance in the coupled ^{13}C NMR spectrum (δ_C 145.3, dd, $^2J_{CH}$ 8 Hz, $^3J_{CH}$ 2 Hz). Coupling of C-4 with NH is absent in compound **9g**.

The structure of compound **9g** was further ascertained by a positive Feigl test,[5] and by its conversion into the corresponding nitrile **10** and 1,3,4-thiadiazole **11** through well established reactions.[8] Finally, an X-ray crystal-structure analysis of compound **9g** was carried out, and confirmed our structure assignment.[9]

Phenylhydrazine and hydroxylamine reacted with the alde-

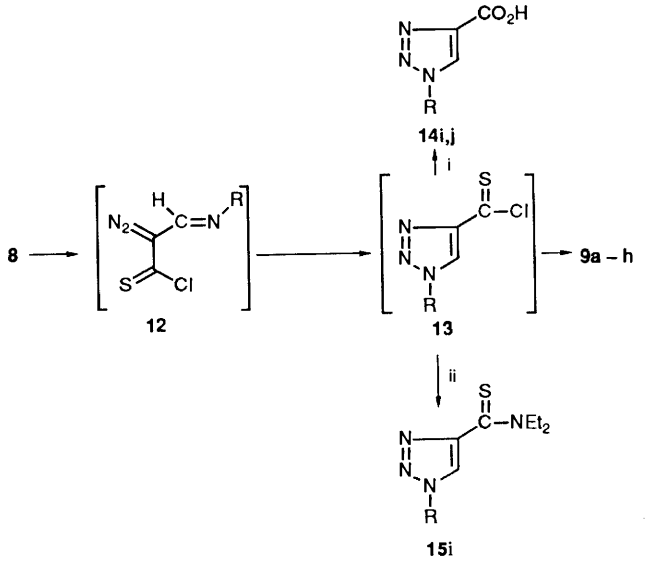


10 11

Reagents: i, 'HNO_2'; ii, Ac_2O

hyde **7** to give the unrearranged products (**8i** and **8j**), which precipitated from their respective methanolic solution. The phenylhydrazone **8i** was found to exist in two stereochemical configurations in $CDCl_3$ solution, with a large predominance of the *Z*-form due to hydrogen bonding with the thiadiazole N-3 atom. The two isomers were easily distinguished by the $^1J_{CH=N}$ coupling constants: 188 Hz for the *Z*-isomer and 164 Hz for the *E*-isomer.[10]

When the NMR spectrum of compound **8i** was recorded in [$^2H_6$]DMSO solution, only the *E*-isomer was observed and the product gradually disappeared and was transformed into the acid **14i**. The oxime **8j** showed similar behaviour in DMSO solution, yielding **14j**.



Scheme 2 *Reagents:* i, water; ii, Et_2NH

Some comments about the mechanistic details are in order (Scheme 2). It is evident that aldehyde **7** is transformed first into compounds **8**, since hydrazone **8i** and oxime **8j** have been isolated. Ring opening of compounds **8** would give the diazo intermediate **12**, which would then cyclize to the thiocarboxylic chloride **13**. A prerequisite for compounds **8** to undergo rearrangement is the *cis*-relationship between the triazole (or diazo) group and the imino-nitrogen lone pair.[1,11] This is supported by our observation that the isomerization of hydrazone **8i** is promoted in DMSO (*E*-form) and not in $CDCl_3$ (mainly *Z*-form). The reactive thioacyl chloride **13** is trapped by the excess of amine, for products **9a–h**, or hydrolysed by water, for products **14i,j**. We have checked this pathway by conducting the decomposition of compound **8i** in DMSO in the presence of 2 mol equiv. of diethylamine, when thioamide **15i** was obtained. Finally, we have assumed that the chlorine atom is substituted after rearrangement, *i.e.* **13**, and not before rearrangement, *i.e.*, **8**. This was demonstrated by the reaction of aldehyde **7** with 1 mol equiv. of benzylamine, which yielded compound **9c**, benzylamine hydrochloride, and unchanged aldehyde **7**. No trace of imine **8c** was found in the reaction mixture, suggesting its fast rearrangement to thioamide **9c**.

IR Spectra were recorded on a Perkin-Elmer spectrophotometer, ^1H and ^{13}C NMR spectra on a Bruker WM-250 spectrometer operating at 250 MHz (^1H) and 62.9 MHz (^{13}C), and mass spectra on a Kratos MS50 TC instrument.

Experimental

1,3-*Dichloroacetone Semicarbazone* **4**.—To a stirred solution of semicarbazide hydrochloride (22.3 g, 0.2 mol) and sodium acetate (16.4 g, 0.2 mol) in water (200 cm^3) was added an ethanolic solution (200 cm^3) of 1,3-dichloroacetone **3** (25.4 g, 0.2 mol). The mixture was allowed to settle and the *title semicarbazone* **4** precipitated from the reaction mixture and was collected (22.6 g). The filtrate was concentrated and gave a second crop of product (10.7 g; total yield 88%), m.p. 123 °C; ν_{max}(KBr)/cm^{-1} 3460s (NH), 3320 and 3240m (NH_2) and 1700s (CO); δ_H([$^2H_6$]DMSO) 4.4 and 4.5 (4 H, 2 s, 2 × CH_2), 6.55 (2 H, br s, NH_2) and 10.0 (1 H, s, NH) (Found: C, 26.3; H, 3.7. $C_4H_7Cl_2N_3O$ requires C, 26.11; H, 3.83%).

5-*Chloro*-4-*chloromethyl*-1,2,3-*thiadiazole* **5**.—A solution of compound **4** (32.3 g, 0.176 mol) in thionyl chloride (100 cm^3) was stirred and heated overnight at 65 °C. The excess of thionyl chloride was distilled off and the residue was dissolved in dichloromethane. After filtration and evaporation of the solvent, the resulting oil (18.3 g, 62%) was further purified by flash chromatography on silica gel with dichloromethane as eluent.

In an alternative procedure, the reaction mixture was treated with water and extracted with chloroform. After drying and removal of the solvent, the oil was crystallized from light petroleum to give *compoumd* **5** (69%), m.p. 34 °C; δ_H($CDCl_3$) 5.0 (2 H, s, CH_2); δ_C($CDCl_3$) 34.6 (CH_2), 145.0 (C-5) and 156.1 (C-4) (Found: C, 21.1; H, 1.1. $C_3H_2Cl_2N_2S$ requires C, 21.32; H, 1.19%).

4-*Azidomethyl*-5-*chloro*-1,2,3-*thiadiazole* **6**.—Compound **5** (18.3 g, 0.108 mol) was treated overnight with sodium azide (14 g, 0.215 mol) and sodium iodide (100 mg) in acetone (200 cm^3). After removal of the solvent, the residue was dissolved in diethyl ether (200 cm^3) and washed successively with saturated aq. sodium thiosulphate (100 cm^3) and then twice with water (100 cm^3). The extracts were dried ($MgSO_4$), evaporated, and subjected to flash chromatography on silica gel with dichloromethane as eluent to give compound **6** (15.5 g, 79%).

In an alternative procedure, compound **5** (7.4 g, 44 mmol) and sodium azide (10 g, 154 mmol) were treated overnight in dichloromethane–water (100:40 cm^3) containing tetrabutylammonium bromide (1.4 g, 4.3 mmol) as transfer reagent. The organic layer was separated and the aq. layer was extracted twice with dichloromethane (50 cm^3). The combined organic layers were dried, evaporated, and chromatographed to give *compound* **6** as a pale yellow oil (5.21 g, 68%), ν_{max}(neat)/cm^{-1} 2100s (N_3); δ_H($CDCl_3$) 4.8 (s, CH_2); δ_C($CDCl_3$) 44.7 (CH_2), 144.5 (C-5) and 154.8 (C-4) (Found: C, 20.7; H, 1.15. $C_3H_2ClN_5S$ requires C, 20.52; H, 1.15%).

5-*Chloro*-1,2,3-*thiadiazole*-5-*carbaldehyde* **7**.—Compound **6** (5 g, 28.5 mmol) was added dropwise to conc. sulphuric acid (20 cm^3) and cooled at −10 to −15 °C. After being stirred at room temperature for 10 days, the mixture was poured into ice–water (100 cm^3) and extracted with chloroform. The extracts were dried and evaporated to give a dark brown oil (2.9 g, 68%) of satisfactory quality (NMR, TLC) for further use. *Note:* When the oil was further purified by column chromatography on silica gel with dichloromethane–light petroleum (1 : 1) as eluent, an oil was obtained which darkened on storage. Upon cooling in dichloromethane–hexane at −20 °C, crystals were obtained, m.p. 34 °C, which sublimed *in vacuo*.

Spectral data of *compound* **7**: ν_{max}(neat)/cm^{-1} 2860m and 1710s

(CO); $\delta_H(CDCl_3)$ 10.5 (s, CHO); $\delta_C(CDCl_3)$ 152.3 (C-5), 154.2 (C-4) and 181.7 (CO); *m/z* 148 ($M^{\bullet+}$ for ^{35}Cl, 1%), 120 ($M^{\bullet+}$ – CO, 18), 92 ($M^{\bullet+}$ – CO – N_2, 56) and 57 (92 – Cl, 100). *Note:* since compound **7** deteriorates on storage, no microanalysis was performed (Found: $M^{\bullet+}$, 147.9451. C_3HClN_2OS requires M, 147.9498).

N,1-*Dimethyl*-1,2,3-*triazole*-4-*thiocarboxamide* **9a**.—To a solution of aldehyde **7** (0.5 g, 3.4 mmol) in methanol (10 cm^3) was added aq. methylamine (40%; 1.32 cm^3, 17 mmol), and the whole mixture was stirred at room temperature for 30 min. The precipitate was filtered off, washed successively with methanol and water, and dried to give *compound* **9a** (0.46 g, 87%), m.p. 210 °C (from EtOH); ν_{max}(KBr)/cm^{-1} 3270s (NH) and 3120m; $\delta_H([^2H_6]DMSO)$ 3.2 (3 H, d, NH*Me*), 4.1 (3 H, s, ring Me), 8.6 (1 H, s, triazole H) and 10.5 (1 H, br, NH); $\delta_C([^2H_6]DMSO)$ 31.7 (NHMe), 36.4 (ring Me), 128.9 (C-5, $^1J_{CH}$ 201), 147.7 (C-4, $^2J_{CH}$ 8, $^3J_{CH}$ 3.5) and 184.3 (CS); *m/z* 156 ($M^{\bullet+}$, 100%) (Found: C, 38.5; H, 5.05. $C_5H_8N_4S$ requires C, 38.45; H, 5.16%).

N,1-*Diethyl*-1,2,3-*triazole*-4-*thiocarboxamide* **9b**.—To a solution of compound **7** (0.5 g, 3.4 mmol) in methanol (10 cm^3) was added aq. ethylamine (70%; 1.09 cm^3, 17 mmol), and the whole mixture was stirred overnight at room temperature. The reaction mixture was poured into water and the precipitate was collected (70 mg). The filtrate was extracted with chloroform and washed with water to remove residual ethylamine. After drying and evaporation of the solvent, *compound* **9b** was obtained (overall 0.32 g, 50%), m.p. 97 °C (from Et_2O); ν_{max}(KBr)/cm^{-1} 3280s (NH) and 3120m; $\delta_H(CDCl_3)$ 1.4 and 1.6 (6 H, 2 t, 2 × Me), 3.9 and 4.45 (4 H, 2 q, 2 × CH_2), 8.25 (1 H, s, triazole H) and 8.95 (1 H, br, NH); $\delta_C(CDCl_3)$ 13.3 and 39.8 (NHEt), 15.2 and 45.7 (ring Et), 126.8 (C-5), 148.3 (C-4) and 184.3 (CS); *m/z* 184 ($M^{\bullet+}$, 100%) (Found: C, 45.8; H, 6.5. $C_7H_{12}N_4S$ requires C, 45.63; H, 6.56%).

N,1-*Dibenzyl*-1,2,3-*triazole*-4-*thiocarboxamide* **9c**.—A solution of aldehyde **7** (0.5 g, 3.4 mmol) and benzylamine (1.8 g, 17 mmol) in methanol (10 cm^3) was stirred at room temperature for 30 min. The precipitate was filtered off, washed successively with methanol and water, and dried to give compound **9c** (0.93 g, 89%), m.p. 168 °C (from EtOH); ν_{max}(KBr)/cm^{-1} 3260s (NH); $\delta_H(CDCl_3)$ 5.0 (2 H, d, CH_2), 5.55 (2 H, s, CH_2), 7.2–7.4 (10 H, m, 2 × Ph), 8.2 (1 H, s, triazole H) and 9.15 (1 H, br, NH); $\delta_C(CDCl_3)$ 48.9 ($NHCH_2$), 54.6 (ring CH_2), 127.5 (C-5, $^1J_{CH}$ 199), 127.5, 128.0, 128.2, 128.8, 129.1, 129.2, 136.0 and 136.6 (Ph C-atoms), 148.4 (C-4, $^2J_{CH}$ 8.5, $^3J_{CH}$ 3.5) and 184.3 (CS); *m/z* 308 ($M^{\bullet+}$, 36%) and 91 ($C_7H_7^+$, 100) (Found: C, 66.1; H, 5.1. $C_{17}H_{16}N_4S$ requires C, 66.21; H, 5.23%).

Note: When aldehyde **7** (300 mg, 2 mmol) was allowed to react overnight with 1 mol equiv. of benzylamine (214 mg) in ethanol (15 cm^3), compound **9c** was precipitated (193 mg, 31%). After removal of methanol, the residue was treated with dichloromethane, leaving a precipitate of benzylamine hydrochloride (85 mg, 29%). From the dichloromethane solution the aldehyde **7** was recovered as an oil (170 mg, 57%).

N,1-*Diphenyl*-1,2,3-*triazole*-4-*thiocarboxamide* **9d**.—A solution of aldehyde **7** (0.5 g, 3.4 mmol) and aniline (1.58 g, 17 mmol) in methanol (10 cm^3) was stirred at room temperature for 30 min. The precipitate was filtered off, washed successively with methanol and water, and dried to give *compound* **9d** (885 mg, 93%), m.p. 142 °C (from EtOH); ν_{max}(KBr)/cm^{-1} 3330s (NH); δ_H(250 MHz; $CDCl_3$) 7.2–8.0 (10 H, 4 m, 2 × Ph), 8.7 (1 H, s, triazole H) and 10.65 (1 H, br, NH); $\delta_C(CDCl_3)$ 120.6, 129.5, 129.9 and 136.4 (ring Ph C_o, C_p, C_m and C_i), 123.1, 126.8, 128.9 and 138.0 (NHPh C_o, C_p, C_m and C_i), 125.9 (C-5, $^1J_{CH}$ 200), 149.7 (C-4, $^2J_{CH}$ 8. $^3J_{CH}$ 4) and 181.9 (CS); *m/z* 280 ($M^{\bullet+}$, 66%) and 149 (100) (Found: C, 64.2; H, 4.3. $C_{15}H_{12}N_4S$ requires C, 64.27; H, 4.31%).

N,1-*Bis*(p-*methoxyphenyl*)-1,2,3-*triazole*-4-*thiocarboxamide* **9e**.—A solution of compound **7** (0.5 g, 3.4 mmol) and *p*-anisidine (2.09 g, 17 mmol) in methanol (10 cm^3) was stirred at room temperature for 1 h. The precipitated *product* **9e** was filtered off (885 mg, 77%), m.p. 171 °C (from EtOH); ν_{max}(KBr)/cm^{-1} 3320 (NH); δ_H(250 MHz; $CDCl_3$) 3.8 and 3.9 (6 H, 2 s, 2 × OMe), 6.95 and 7.05 (4 H, 2 d, *ortho* anisyl H), 7.70 and 7.85 (4 H, 2 d, *meta* anisyl H), 8.60 (1 H, s, triazole H) and 10.55 (1 H, br, NH); $\delta_C(CDCl_3)$ 55.5 and 55.7 (OMe), 114.1 and 115.0 (anisyl C_o), 122.3, 129.9 and 160.4 (ring anisyl C_m, C_p and C_i), 124.9, 131.2 and 158.2 (anisyl C_m, C_p and C_i), 125.9 (C-5, $^1J_{CH}$ 200), 149.5 (C-4, $^2J_{CH}$ 8, $^3J_{CH}$ 4) and 181.8 (CS); *m/z* 340 ($M^{\bullet+}$, 61%) and 179 (100) (Found: C, 59.9; H, 4.7. $C_{17}H_{16}N_4O_2S$ requires C, 59.98; H, 4.74%).

N,1-*Bis*(p-*chlorophenyl*)-1,2,3-*triazole*-4-*thiocarboxamide* **9f**.—A solution of compound **7** (0.5 g, 3.4 mmol) and *p*-chloroaniline (2.17 g, 17 mmol) in methanol (10 cm^3) was stirred at room temperature for 30 min. The precipitate was filtered off, washed successively with methanol and water, and dried to give *compound* **9f** (1.11 g, 93%), m.p. 210 °C (from EtOH); ν_{max}(KBr)/cm^{-1} 3230 (NH); δ_H(250 MHz; $[^2H_6]$DMSO) 7.5, 7.7, 7.9 and 8.1 (8 H, 4 d, ArH), 9.4 (1 H, s, triazole H) and 12.15 (1 H, s, NH); $\delta_C([^2H_6]DMSO)$ 122.3 and 126.4 (aryl C *meta* to Cl), 127.3 (C-5, $^1J_{CH}$ 203), 128.3 and 129.8 (aryl C *ortho* to Cl), 130.3 and 133.6 (ClC), 134.9 and 137.7 (aryl CN), 149.5 (C-4, $^2J_{CH}$ 8, $^3J_{CH}$ 4) and 183.2 (CS) (Found: C, 51.5; H, 2.9. $C_{15}H_{10}Cl_2N_4S$ requires C, 51.59; H, 2.89%).

1-*Amino*1,2,3-*triazole*-4-*thiocarbohydrazide* **9g**.—A solution of aldehyde **7** (0.5 g, 3.4 mmol) and hydrazine hydrate (0.85 g, 17 mmol) in ethanol (10 cm^3) was stirred at room temperature for 1 h. The precipitated *product* **9g** was filtered off and dried (349 mg, 65%), m.p. 180 °C (decomp.); ν_{max}(KBr)/cm^{-1} 2900–3340 br; $\delta_H([^2H_6]DMSO)$ 6.5 (2 H, br, NH_2), 7.15 (2 H, br s, NH_2), 8.1 (1 H, s, triazole H) and ~12 (1 H, br, NH); $\delta_C([^2H_6]DMSO)$ 125.5 (C-5, $^1J_{CH}$ 202), 144.8 (C-4, $^2J_{CH}$ 8.7) and 169.3 (CS); *m/z* 158 ($M^{\bullet+}$, 100%) (Found: C, 23.0; H, 3.7. $C_3H_6N_6S$ requires C, 22.78; H, 3.82%).

N,1-*Dimorpholino*-1,2,3-*triazole*-4-*thiocarboxamide* **9h**.—A solution of compound **7** (0.5 g, 3.4 mmol) and *N*-aminomorpholine (1.72 g, 16.8 mmol) in ethanol (20 cm^3) was stirred at room temperature for 4 h. The precipitated *product* **9h** was filtered off, washed with ethanol, and crystallized from methanol (753 mg, 75%), m.p. 192 °C; ν_{max}(KBr)/cm^{-1} 3240 (NH); $\delta_H(CDCl_3)$ 3.1 and 3.4 (8 H, 2 t, 4 × NCH_2), 3.9 (8 H, t, 4 × OCH_2), 8.3 (1 H, s, triazole H) and 9.5 (1 H, s, NH); $\delta_C(CDCl_3)$ 54.4 and 56.3 (NCH_2), 66.0 and 66.4 (OCH_2), 126.1 (C-5, $^1J_{CH}$ 203), 145.3 (C-4, $^2J_{CH}$ 8, $^3J_{CH}$ 2) and 179.6 (CS); *m/z* 298 ($M^{\bullet+}$, 36%) and 86 (100) (Found: C, 44.4; H, 6.0. $C_{11}H_{18}N_6O_2S$ requires C, 44.28; H, 6.08%).

5-*Chloro*-1,2,3-*thiadiazole*-4-*carbaldehyde* N-*Phenylhydrazone* **8i**.—A solution of compound **7** (0.5 g, 3.4 mmol) and phenylhydrazine (1.84 g, 17 mmol) in methanol (10 cm^3) was stirred at 30 °C for 1 h. The precipitated *product* **8i** was filtered off, washed successively with methanol and water, and dried (488 mg, 60%) (*Note:* a 70% yield was obtained when 1 or 2 mol equiv. of phenylhydrazine were used), m.p. 140 °C (from EtOH); ν_{max}(KBr)/cm^{-1} 3310 (NH); $\delta_H(CDCl_3)$ 6.9–7.4 (5 H, 2 m, ArH), 8.1 and 11.5 (1 H, br, NH of *Z* and *E* isomers) and 8.2 (1 H, s, CH=N); δ_H(250 MHz; $[^2H_6]$DMSO) 6.8, 7.15, and 7.3 (5 H, t, d and t, Ph), 8.3 (1 H, s, CH=N) and 11.0 (1 H, s, NH); $\delta_C(CDCl_3)$ *Z*-isomer: 113.6, 121.5, 129.4 and 144.0 (Ph C_o, C_p, C_m

and C_i), 116.4 (CH=N, $^1J_{CH}$ 188, $^3J_{CH}$ 4), 142.6 (C-5, $^3J_{CH}$ < 1) and 153.5 (C-4, $^2J_{CH}$ 12); *E*-isomer: 113.2, 121.4 and 129.4 (Ph C_o, C_p and C_m), 126.2 (CH=N, $^1J_{CH}$ 164); δ_C([$^2H_6$]DMSO) *E*-isomer: 112.3, 119.9, 129.2 and 144.3 (Ph C_o, C_p, C_m and C_i), 125.5 (CH=N, $^1J_{CH}$ 167.1), 138.9 (C-5, $^3J_{CH}$ 4.4) and 154.4 (C-4, $^2J_{CH}$ 8.8); *m/z* 238 ($M^{\bullet+}$, 38%) and 77 (100) (Found: C, 45.4; H, 2.9. $C_9H_7ClN_4S$ requires C, 45.29; H, 2.96%).

5-*Chloro*-4-*hydroxyiminomethyl*-1,2,3-*thiadiazole* **8j**.—To aq. hydroxylamine hydrochloride (1.173 g, 17 mmol in 5 cm^3) treated with sodium hydrogencarbonate (to pH 4) was added a methanolic solution of aldehyde **7** (0.5 g, 3.4 mmol in 10 cm^3) and the whole mixture was stirred at room temperature for 1 h. The precipitated product **8j** was filtered off, washed successively with methanol and water, and dried (0.39 g, 70%), m.p. 145 °C (from EtOH); ν_{max}(KBr)/cm^{-1} 3200br (NH); δ_H([$^2H_6$]DMSO) 8.5 (1 H, s, CH=N) and 12.2 (1 H, br, OH); δ_C([$^2H_6$]DMSO) 139.0 (CH=N, $^1J_{CH}$ 171), 142.9 (C-5, $^3J_{CH}$ 3.2) and 152.1 (C-4, $^2J_{CH}$ 7.6); *m/z* 162.9 ($M^{\bullet+}$, 13%), 134.9 ($M^{\bullet+}$ − N_2, 77), 117.9 ($M^{\bullet+}$ − N_2 − OH, 13), 107.9 (46), 90.9 (71), 78.9 (34) and 45 (HCS^+, 100) (Found: C, 22.2; H, 1.15. $C_3H_2ClN_3OS$ requires C, 22.03; H, 1.23%).

1,2,3-*Triazole*-4(5)-*carbonitrile* **10**.—To a stirred, ice-cooled suspension of compound **9g** (158 mg, 1 mmol) in aq. hydrochloric acid (1 mol dm^{-3}, 10 cm^3) was added dropwise aq. sodium nitrite (130 mg, 2 mmol in 5 cm^3). After being stirred overnight at room temperature, the reaction mixture was extracted three times with ethyl acetate (20 cm^3) and the combined extracts were dried ($MgSO_4$) and evaporated. The residue was heated in chloroform (20 cm^3), then filtered, and the filtrate was cooled to give nitrile **10** (60 mg, 64%), m.p. 110 °C (lit.,[12] 110–112 °C).

2-(1-*Acetamido*-1,2,3-*triazole*-4-*yl*)-5-*methyl*-1,3,4-*thiadiazole* **11**.—A suspension of compound **9g** (200 mg, 1.26 mmol) in acetic anhydride (5 cm^3) was stirred overnight at room temperature. The precipitated product **11** was filtered off, washed with diethyl ether, and dried (180 mg, 63%), m.p. 236 °C (from EtOAc); ν_{max}(KBr)/cm^{-1} 3130 (NH) and 1715 (CO); δ_H([$^2H_6$]DMSO) 2.15 (3 H, s, Ac), 2.80 (3 H, s, ring Me), 9.05 (1 H, s, triazole H) and 12.85 (1 H, br, NH); δ_C([$^2H_6$]DMSO) 15.2 and 20.6 (Me), 125.2 (triazole C-5, $^1J_{CH}$ 205), 137.8 (triazole C-4), 159.5 (thiadiazole C-2), 165.1 (thiadiazole C-5) and 168.7 (CO); *m/z* 224 ($M^{\bullet+}$, 1%), 196 ($M^{\bullet+}$ − N_2, 8), 154 ($M^{\bullet+}$ − N_2 − CH_2CO, 6), 125 (73), 100 (9), 59 (31) and 43 (CH_3CO^+, 100) (Found: C, 37.7; H, 3.6. $C_7H_8N_6OS$ requires C, 37.49; H, 3.60%).

1-*Anilino*-1,2,3-*triazole*-4-*carboxylic Acid* **14i**.—A solution of compound **8i** (0.477 g, 2 mmol) in DMSO (3 cm^3) was stirred at room temperature for 2 days. After addition of water (20 cm^3) and filtration, the filtrate was cooled (0 °C) to give compound **14i**, which was recrystallized from acetone (294 mg, 72%), m.p. 188 °C (decomp.) (*Note:* this compound deteriorates upon storage); ν_{max}(KBr)/cm^{-1} 1690 (CO); δ_H([$^2H_6$]DMSO) 6.5, 7.0, and 7.25 (5 H, d, t and t, Ph), 9.0 (1 H, s, triazole H) and 10.55 (1 H, br, CO_2H); δ_C([$^2H_6$]DMSO) 113.2, 121.6, 129.3, and 146.6 (Ph C_o, C_p, C_m and C_i), 130.4 (C-5, $^1J_{CH}$ 203), 138.7 (C-4, $^2J_{CH}$ 9.5) and 161.3 (CO); *m/z* 204 ($M^{\bullet+}$, 12%), 175 ($M^{\bullet+}$ − N_2 − H, 13), 131 (175 − CO_2, 12) and 71 (100).

This compound was converted into the *methyl ester* (57%) by treatment with diazomethane in diethyl ether, m.p. 158 °C (Found: C, 54.9; H, 4.6. $C_{10}H_{10}N_4O_2$ requires C, 55.05; H, 4.59%).

1-*Hydroxy*-1,2,3-*triazole*-4-*carboxylic Acid* **14j**.—A solution of oxime **8j** (164 mg, 1 mmol) in DMSO (2 cm^3), containing a few drops of water, was stirred overnight at room temperature. After removal of the solvent under reduced pressure, the residue was crystallized from acetone–diethyl ether at −20 °C to give compound **14j** (62 mg, 48%), m.p. 93 °C; ν_{max}(KBr)/cm^{-1} 3400br, 3165 (C–H) and 1705 (CO); δ_H([$^2H_6$]DMSO) 8.6 (1 H, s, triazole H) and 13.8 (2 H, s, OH and CO_2H); δ_C([$^2H_6$]DMSO) 122.9 (C-5, $^1J_{CH}$ 204.4), 138.0 (C-4, $^2J_{CH}$ 8.9) and 161.8 (CO); *m/z* 129 ($M^{\bullet+}$, 2%) and 84 (100).

This compound was converted into methyl 1-methoxy-1,2,3-triazole-4-carboxylate (62%) by treatment with diazomethane in acetone–diethyl ether, m.p. 81 °C (Found: C, 38.4; H, 4.4. $C_5H_7N_3O_3$ requires C, 38.22; H, 4.46%).

1-*Anilino*-N,N-*diethyl*-1,2,3-*triazole*-4-*thiocarboxamide* **15i**.—A solution of compound **8i** (0.38 g, 1.6 mmol) and diethylamine (0.23 g, 3.2 mmol) in DMSO (10 cm^3) was stirred overnight at room temperature. The reaction mixture was poured into ice–water (100 cm^3) and the precipitate was filtered off and crystallized from methanol to give the *thiocarboxamide* **15i** (310 mg, 70%), m.p. 158 °C; ν_{max}(KBr/cm^{-1} 3280s (NH); δ_H(250 MHz; $CDCl_3$) 1.4 (6 H, t, 2 × Me), 4.0 and 4.1 (4 H, 2 q, 2 × CH_2), 6.6, 7.0, and 7.25 (5 H, d, t and t, Ph), 7.8 (1 H, s, NH) and 8.3 (1 H, s, triazole H); δ_C($CDCl_3$) 11.0 and 14.1 (Me), 48.4 and 48.8 (CH_2), 114.6, 123.3, 129.4, and 145.3 (Ph C_o,C_p, C_m and C_i), 130.6 (C-5, $^1J_{CH}$ 203), 148.8 (C-4, $^2J_{CH}$ 8) and 184.6 (CS) (Found: C, 56.7; H, 6.1. $C_{13}H_{17}N_5S$ requires C, 56.73; H, 6.18%).

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