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A Facile One-Pot Synthesis of 1-Substituted Tetrazole-5-thiones and 1-Substituted 5-Alkyl(aryl)sulfanyltetrazoles from Organic Isothiocyanates

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Treatments of organic isothiocyanates (R-NCS) with NaN_3 in the presence of pyridine in water at room temperature gave corresponding various organic tetrazole-thiones, [S=CN_4(R)] (R = alkyl or aryl). Isolated products are obtained as white or yellow solids in good yields (76-97%). The molecular structure by X-ray diffraction study for one of products shows the proposed formation. In addition, one-pot synthesis of 1-substituted 5-alkyl(or aryl)sulfanyltetrazoles has been demonstrated. Addition of alkyl or aryl halides into the mixture of organic isothiocyanates, NaN_3, and pyridine in water at room temperature exclusively formed 1-substituted 5-alkyl(or aryl)sulfanyltetrazoles (S-derivatives) in high yields.

Key Words : 1-Substituted tetrazole-5-thione, 1-Substituted 5-alkyl(aryl)sulfanyltetrazoles, Isothiocyanate

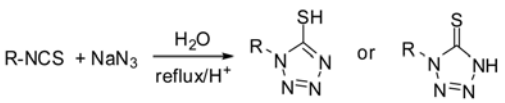
Introduction

Although various tetrazole derivatives have long been studied, synthetic methodologies and physical or chemical properties of 1-substituted tetrazole-5-thiones, one class of tetrazole derivatives, have been relatively less explored.[1] Research Interestsin such derivatives have considerably increased since mid 1980s.[2] The synthetic route to these derivatives was first reported by Lieber *et al.* in 1957 as shown in Scheme 1.[3,4] However their synthetic method gives low yields and requires vigorous reaction conditions. Futhermore, certain organic isothiocyanates such as *n*-butyl and *n*-heptyl could not form tetrazole-thione products according to the Scheme 1.

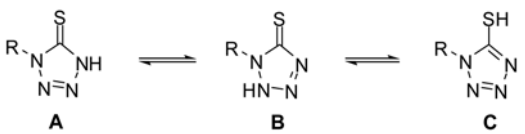
Organic tetrazole-thiol or -thione can exist in three tautomeric forms in Scheme 2. Earlier works by Lieber[3,4] and Altland[5] groups proposed the presence of such tautomers.

However, the accurate structure of 1-substituted tetrazole-5-thiones (**A**, **B**) or 1-substituted tetrazole-5-thiol (**C**) is still unclear, because the current spectral data cannot clearly confirm it. One research group suggested that, 4*H*-tautomer thione form (**A**) exists dominantly both in solution and in solid state[6] and is thermodynamically more stable according to the quantum-chemical calculations.[7] On the other hand, commercially available 1-substituted tetrazole-5-thiols (**C**) are currently believed as a genuine one among the three possible tautomers.[8] We also found many cases this incorrect tautomer in recent papers.[9]

In this work, the structure of the 4*H*-tautomer thione form (**A**) was structurally characterized by X-ray diffraction. We also found a facile synthetic route to 1-substituted 5-alkyl (aryl)sulfanyltetrazoles (Scheme 3), which were used as a highly efficient olefination reagents[10] during the reactions of tetrazole-thiones. We herein report the synthesis of 1-substituted tetrazole-5-thiones and 1-substituted 5-alkyl(aryl) sulfanyltetrazoles and the structure of 1-phenethyl tetrazole-5-thione.



Scheme 1



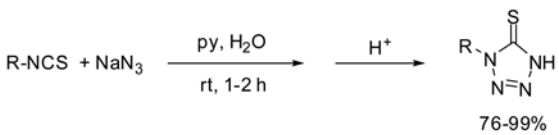
Scheme 2. Three tautomeric forms of tetrazole-thion or thiol.

Results and Discussion

We found that the reaction of an organic isothiocyanate and sodium azide in water was accelerated enormously and completed within 2 h when pyridine was added (Scheme 3).

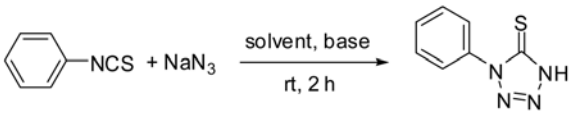
To find out optimum conditions for preparation of the tetrazole-thiones, we treated phenyl isothiocyanate as a representative substrate with various bases and solvents at room temperature. The reaction was finished within 2 h. As shown in Table 1, the best experimental variables appear to be water as a solvent and pyridine as a base at room temperature.

While such experimental variables were fixed, various



Scheme 3

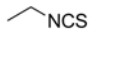
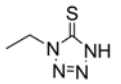
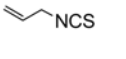
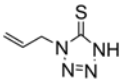
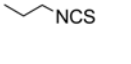
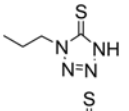
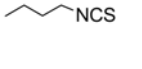
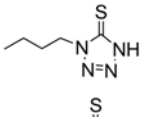
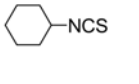
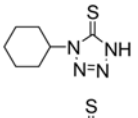
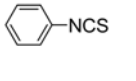
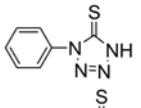
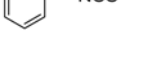
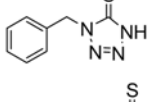
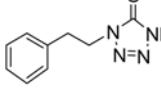
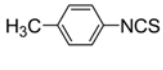
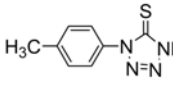
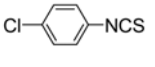
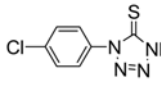
Table 1. Effect of solvent and base in the reaction of phenyl isothiocyanate and sodium azide at rt[a]



Entry	Solvent	Base	Yield (%)[c]
1	THF	NaOH	32
2	THF/H_2O[b]	NaOH	45
3	THF/H_2O[b]	Na_2CO_3	54
4	THF/H_2O[b]	TEA	48
5	THF/H_2O[b]	py	80
6	H_2O	py	83

[a]Phenyl isothiocyanate (1 mmoL) was reacted with sodium azide (1.2 mmoL) and base (3 mmoL) in solvent (3 mL) for 2 h at rt. [b]Volume ratio, 1:1. [c]Isolated yields.

Table 2. Synthesis of 1-substituted tetrazole-5-thiones from organic isothiocyanates in water[a]

Entry	Reactant	Product		Yield (%)[b]	mp (°C)	mp (°C)[ref]
1			**1a**	72	50	50[4]
2			**1b**	85	69	69[4]
3			**1c**	86	78	77-78[11]
4			**1d**	99	60	60[12]
5			**1e**	97	102	101-103[13]
6			**1f**	83	150	150[14]
7			**1g**	85	142	144[4]
8			**1h**	84	145	
9			**1i**	81	149	150[4]
10			**1j**	76	157	156-157[12]

[a]Organic isothiocyanate (1 mmoL) was reacted with sodium azide (1.2 mmoL) and pyridine (3 mmoL) in water (3 mL) at rt for 2 h. [b]Isolate yield.

alkyl and aryl isothiocyanates were treated with sodium azide in the presence of 3 equiv of pyridine in water at room temperature (Table 2). All of the organic isothiocyanates proceeded smoothly to give tetrazole-thiones under mild conditions. The products were obtained as white or yellow solids, which could be purified by recrystallization from ethyl acetate and hexane. All organic isothiocyanates gave corresponding tetrazole-thiones in good yields (76-97%) and the reactions were completed within 2 h. Interestingly, cyclohexyl isothiocyanate gave the highest yield (97%) (entry 5). Isolated products were characterized by spectroscopic (IR and NMR) and elemental analyses. The NH hydrogen in all the products appears as a broad signal at 12.1-15.0 ppm in ^{1}H-NMR. Their down-field chemical shift may probably be ascribed to hydrogen bonding (see below). In ^{13}C NMR spectra of the products, the carbon atom of the tetrazole ring [S=***C***N_4(R)] appears at 161.8-167.1 ppm. The above experimental results indicate that various tetrazole-thiones can be synthesized efficiently in water media.

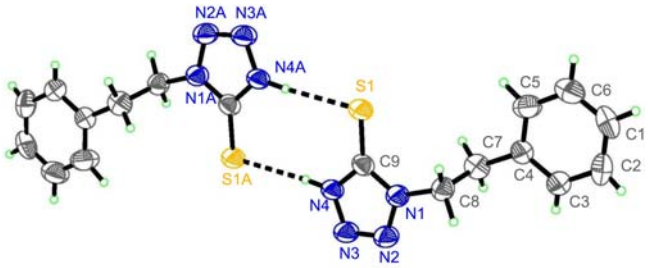
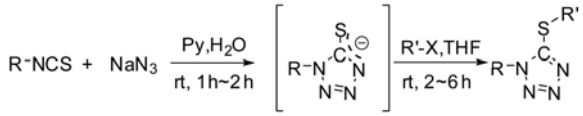


Figure 1. ORTEP drawing of **1h**. Selected bond lengths (Å) and bond angles (°): S1–C9 1.669(3), N1–C9 1.345(3), N1–N2 1.362(3), N2–N3 1.281(3), N3–N4 1.337(3), N4–C9 1.343(3), N4–HN4 0.88(2), S2–C18 1.661(3), N5–C18 1.352(3), N5–N6 1.362(3), N6–N7 1.267(3), N7–N8 1.334(3), N8–C18 1.340(3), N8–HN8 0.81(2); C9–N1–N2 111.0(2), N2–N3–N4 107.1(2), N3–N4–C9 112.6(2), C18–N5–N6 111.0(2), N6–N7–N8 107.4(2), N7–N8–C18 113.0(3).

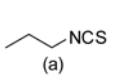
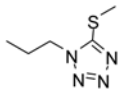
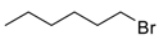
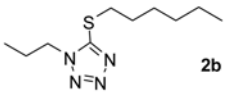
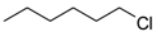
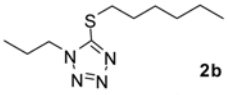
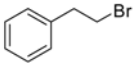
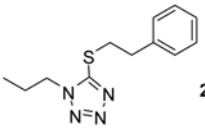
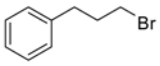
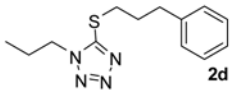
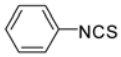
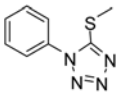
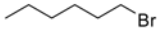
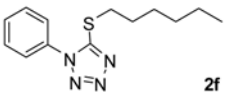
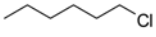
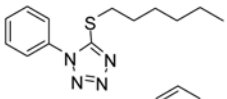
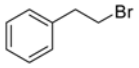
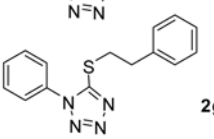
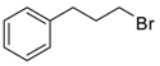
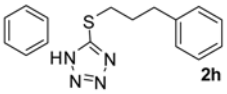
ORTEP drawings of 1 h (Fig. 1) clearly confirm the formation of tetrazole-thione compounds (**A**-type). The crystal and refinements data for complex 1 h are summarized in Table 4. Compound 1 h consists of two crystallographically independent molecules, which are chemically indistinguishable. As shown in Figure 1, these two molecules are connected by the hydrogen bonds of the N–H···S type. Each sulfur atom does not have the attached hydrogen atom, and one nitrogen atom (N1 or N5) adjacent to the C–S group in each molecule is protonated. The C–S bond lengths (1.669(2) and 1.668(2)) are intermediate between the typical carbon-sulfur single bond (1.80 Å) and double bond (1.56 Å) lengths. These C–S bond lengths indicate the strong delocalization of the bonds in the tetrazole-thione system.

Finally, we examined one-pot synthesis of 1-substituted 5-alkyl(aryl)sulfanyltetrazoles using various alkyl and aryl halides (Scheme 4). Alkyl and aryl halides in THF were



Scheme 4. One-pot synthesis of 1-substituted 5-alkyl(aryl)sulfanyl-tetrazoles.

Table 3. A one-pot synthesis of 1-substituted-alkyl(aryl)sulfanyl tetrazoles from organic isothiocyanates[a]

Entry	R-NCS	R'-X	Product	Yield (%)[b]
1	 (a)	CH_3I	 **2a**	90
2	(a)		 **2b**	91
3	(a)		 **2b**	90
4	(a)		 **2c**	92
5	(a)		 **2d**	95
6	 (b)	CH_3I	 **2e**	94
7	(b)		 **2f**	88
8	(b)			90
9	(b)		 **2g**	95
10	(b)		 **2h**	98

[a]Organic isothocyanate (1 mmoL) was reacted with sodium azide (1.2 mmoL) and pyridine (3 mmoL) in water (3 mL) at rt. After the solution was stirred for 2 h, alkyl halide (1.5 equiv) in THF (3 mL) was added and stirred the mixture at rt for 2-6 h. [b]Isolate yield.

added to a mixture of organic isothiocyanate, sodium azide, and pyridine in water at room temperature. As shown in Table 3, the reaction of alkyl and aryl bromides gave exclusively S-derivatives in high yields (88-98%) within 2 h. Earlier works on the alkylation of 1-substituted tetrazole-5-thiones with alkyl halides exhibited a high regioselectivity at sulfur atom but those reactions showed poor yields and requires a few steps.[11] On the contrary, our synthetic method gave high yields of 1-substituted 5-alkyl(aryl)sulfanyl-tetrazoles with high regioselectivity by the one-pot reaction from organic isothiocyanates.

In summary, we have synthesized1-substituted tetrazole-5-thione and 1-substituted 5-alkyl(aryl)sulfanyltetrazoles from organic isothiocyanate by a facile one-pot reaction under mild conditions. In addition, the structure of 1-substituted tetrazole-5-thione was determined by X-ray crystallography.

Table 4. X-ray data collection and structure refinement for complex **1**

empirical formula	$C_9H_{10}N_4S$
formula weight	206.27
temperature, K	296(2)
crystal system	orthorhombic
space group	*Pccn*
a, Å	24.0607(6)
b, Å	12.0026(3)
c, Å	14.6889(4)
V, Å^3	4242.0(2)
Z	16
d_{cal}, g cm^{-3}	1.292
μ, mm^{-1}	0.272
F(000)	1728
T_{max}	0.9681
T_{min}	0.9038
θ range (º)	1.69-28.38
No. of reflns measured	68778
No. of reflns unique	5272
No. of reflns with $I > 2\sigma(I)$	2144
No. of params refined	333
Max., in $\Delta\rho$ (e Å^{-3})	0.193
Min., in $\Delta\rho$ (e Å^{-3})	–0.143
GOF on F^2	0.988
R^a	0.0510
$wR2^b$	0.1017

[a]$R = \Sigma[|F_o| - |F_c|]/\Sigma|F_o|$. [b]$wR2 = \Sigma[w(F_o^2 - F_c^2)^2]/\Sigma[w(F_o^2)^2]^{1/2}$

Experimental

General. All the solvents and reagents were purchased from Aldrich, Fluka and Merck chemical companies. Melting points were measured using an Electrothermal melting point apparatus and are uncorrected. The ^{1}H and ^{13}C NMR spectra were recorded on a Jeol Lambda-300 MHz spectrometer or ECA 600 MHz spectrometer. X-ray data were collected with Bruker Smart APEX2 diffractometer equipped with a Mo X-ray tube. The elemental analyses (C, H, N, S) were performed using a CE instruments EA1110. Infrared spectra were recorded on a Perkin Elmer BX spectrophotometer in a KBr pellet. GC and Mass data were recorded on the Agilent 6890N, Agilent GC-Ms 5973i MSD.

General Procedure for the Synthesis of 1-Substituted tetrazole-5-thiones. A representative procedure for Table 2: a mixture of phenyl isothiocyanate (135 mg, 1 mmoL) and sodium azide (78 mg, 1.2 mmoL) and pyridine (237 mg, 3 mmoL) in water (3 mL) was stirred for a period of 2 h at room temperature. The resulting mixture was washed with ethyl acetate (10 mL) and aqueous layer was acidified withn concentrated hydrochroric acid to pH 1. The acidified solution was extracted with ethyl acetate (10 mL). The ethyl acetate extract was washed with water and dried over

anhydrous $MgSO_4$ and the solvent was removed under vacuum to yield 147 mg (83%) of 1-phenyl-1*H*-tetrazole-5(4*H*)-thione (**1f**) as a white solid. This solid was recrystallized from ethyl acetate and *n*-hexane and characterized by spectral and physical data.

General Procedure for the Synthesis of 1-Substituted alkyl(aryl)sulfanyltetrazoles. A representative procedure for Table 3: a mixture of phenyl isothiocyanate (135 mg, 1 mmoL) and sodium azide (78 mg, 1.2 mmoL) and pyridine (237 mg, 3 mmoL) in water (3 mL) was stirred for 2 h at room temperature, and a THF (3 mL) solution of 1-(2-bromoethyl)benzene (277 mg, 1.5 mmoL) was added to the mixture. The reaction mixture stirred for 6 h. The resultant mixture was extracted with ethyl acetate (10 mL) and dried over anhydrous $MgSO_4$ and the solvent was removed under vacuum to produce 235 mg (95%) of 5-(3-phenethylthio)-1-phenyl-1*H*-tetrazole (**2h**) as a brown liquid.

1-Ethyl-1*H*-tetrazole-5(4*H*)-thione (1a): White crystal; mp 50 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 14.49 (s, 1H, NH), 4.37 (q, J = 7.3 Hz, 2H), 1.55 (t, J = 7.3 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.30, 42.80, 13.26; FT-IR (KBr, cm^{-1}): 3056, 2929, 2819, 2761, 1517, 1350, 1049, 810; Anal. Calcd for ($C_3H_6N_4S$) C, 27.68; H, 4.65; N, 43.04; found C, 27.68; H, 4.65; N, 43.03.

1-Allyl-1*H*-tetrazole-5(4*H*)-thione (1b): Pale yellow crystal; mp 69 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 14.15 (s, 1H, NH), 6.07-5.94 (m, 1H), 5.42-5.36 (m, 2H), 4.90 (dt, J = 5.9 Hz,J = 2.6 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 161.81, 128.34, 117.98, 45.82; FT-IR (KBr, cm^{-1}): 3492, 3070, 2941, 2801, 2560, 2361, 1506, 1354, 1057, 945, 771; Anal. Calcd for ($C_4H_6N_4S$) C, 33.79; H, 4.25; N, 39.40; found C, 33.78; H, 4.25; N, 39.39.

1-Propyl-1*H*-tetrazole-5(4*H*)-thione (1c): White powder; mp 69 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 13.66 (s, 1H, NH), 4.26 (t, J = 7.3 Hz, 2H), 2.04-1.92 (m, 2H), 1.01 (t, J = 7.3 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.89, 48.96, 21.44, 10.90; FT-IR (KBr, cm^{-1}): 3062, 2936, 2884, 2787, 1512, 1354, 1051, 788; Anal. Calcd for ($C_4H_8N_4S$) C, 33.32; H, 5.59; N, 38.85; found C, 33.32; H, 5.60; N, 38.85.

1-Butyl-1*H*-tetrazole-5(4*H*)-thione (1d): White crystal; mp 60 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 14.79 (s, 1H, NH), 4.32 (t, J = 7.3 Hz, 2H), 1.93 (m, 2H), 1.42 (sext, J = 7.3 Hz, 2H), 0.99 (t, J = 7.3 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.43, 47.15, 29.81, 19.59, 13.41; FT-IR (KBr, cm^{-1}): 3051, 2983, 2912, 2764, 1508, 1353, 1042, 712; Anal. Calcd for ($C_5H_{10}N_4S$) C, 37.95; H, 6.37; N, 35.41; found C, 38.10; H, 6.35; N, 35.28.

1-Cyclohexyl-1*H*-tetrazole-5(4*H*)-thione (1e): White powder; mp 130 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 13.30 (s, 1H, NH), 4.67-4.56 (m, 1H), 2.09 (m, 2H), 1.96-1.75 (m, 5H), 1.56-1.23 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 162.99, 57.31, 31.23, 25.09, 24.92; FT-IR (KBr, cm^{-1}): 3064, 2947, 2856, 2771, 1509, 1360, 1048, 788; Anal. Calcd for ($C_7H_{12}N_4S$) 45.63; H, 6.56; N, 30.41; found C, 45.63; H, 6.56; N, 30.41.

1-Phenyl-1*H*-tetrazole-5(4*H*)-thione (1f): White powder; mp 150 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 10.16 (s, 1H, NH), 7.96-7.93 (m, 2H, Ar-H), 7.59-7.55 (m, 3H, Ar-H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.41, 129.95, 129.40, 123.81; FT-IR (KBr, cm^{-1}): 3041, 2889, 2759, 1510, 1492, 1353, 1052, 754; Anal. Calcd for ($C_7H_6N_4S$) C, 47.18; H, 3.39; N, 31.44; found C, 47.18; H, 3.40; N, 31.42.

1-Benzyl-1*H*-tetrazole-5(4*H*)-thione (1g): White powder; mp 142 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 13.77 (s, 1H, NH), 7.49-7.46 (m, 2H, Ar-H), 7.38-7.35 (m, 3H, Ar-H), 5.46 (s, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) d 163.92, 133.09, 128.98, 128.79, 50.67; FT-IR (KBr, cm^{-1}): 3051, 2911, 2795, 1608, 1499, 1360, 1056, 745; Anal. Calcd for ($C_8H_8N_4S$) C, 49.98; H, 4.19; N, 29.14; found C, 49.99; H, 4.20; N, 29.11.

1-Phenethyl-1*H*-tetrazole-5(4*H*)-thione (1h): White powder; mp 145 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 12.15 (s, 1H, NH), 7.35-7.22 (m, 5H, Ar-H), 4.53 (t, J = 7.6 Hz, 2H), 3.24 (t, J = 7.7 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.62, 136.23, 128.84, 128.75, 127.26, 48.58, 33.81; FT-IR (KBr, cm^{-1}): 3060, 2931, 2830, 2784, 1514, 1352, 1060, 735; Anal. Calcd for ($C_9H_{10}N_4S$) C, 52.41; H, 4.89; N, 27.16; found C, 52.79; H, 5.20; N, 27.36.

1-*p*-Tolyl-1*H*-tetrazole-5(4*H*)-thione (1i): White powder, mp 150 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 13.86 (s, 1H, NH), 7.80-7.77 (m, 2H, Ar-H), 7.38-7.35 (m, 3H, Ar-H), 2.44 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.81, 129.84, 129.71, 123.77, 21.27; FT-IR (KBr, cm^{-1}): 3023, 2894, 2912, 2764, 1588, 1521, 1301, 1070, 745; Anal. Calcd for ($C_8H_8N_4S$) C, 49.98; H, 4.19; N, 29.14; found C, 50.01; H, 4.18; N, 29.15.

1-(4-Chlorophenyl)-1*H*-tetrazole-5(4*H*)-thione (1j): White powder; mp 157 °C; ^{1}H NMR (300 MHz, DMSO-d_6) δ 14.71 (s, 1H, NH), 7.98-7.95 (m, 2H, Ar-H), 7.70-7.67 (m, 2H, Ar-H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.88, 133.94, 132.79, 129.22, 126.03; FT-IR (KBr, cm^{-1}): 3044, 2928, 2895, 2759, 1494, 828; Anal. Calcd for ($C_7H_5ClN_4S$) C, 39.54; H, 2.37; N, 26.35; found C, 39.55; H, 2.35; N, 26.36.

5-Methylthio-1-propyl-1*H*-tetrazole (2a): Pale yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.20 (t, J = 7.3 Hz, 2H), 2.67 (s, 3H), 1.97 (sext, J = 7.3 Hz, 2H), 0.91 (t, J = 7.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 154.11, 48.80, 34.26, 32.98, 31.23; FT-IR (KBr, cm^{-1}): 3042, 3035, 2921, 2250, 1499, 1301; Anal. Calcd for ($C_5H_{10}N_4S$) C, 37.95; H, 6.37; N, 35.41; found C, 37.97; H, 6.41; N, 35.61.

5-Hexylthio-1-propyl-1*H*-tetrazole (2b): Yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.97 (t, J = 7.0 Hz, 2H), 3.16 (t, J = 7.3 Hz, 2H), 1.73 (sext, J = 7.0 Hz, 2H), 1.58 (quin, J = 7.4 Hz, 2H), 1.42 (quin, J = 7.0 Hz, 2H), 1.21-1.33 (m, 4H), 0.78-0.72 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 153.89, 48.80, 34.26, 32.98, 30.78, 31.27, 22.41, 21.70, 13.46, 10.90; FT-IR (KBr, cm^{-1}): 2966, 2937, 2870, 2250, 1461, 1392; Anal. Calcd for ($C_{10}H_{20}N_4S$) C, 52.60; H, 8.83; N, 24.53; found C, 53.88; H, 8.80; N, 24.71.

5-Phenethylthio-1-propyl-1*H*-tetrazole (2c): Yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.20-7.35 (m, 5H, Ar-H), 4.15 (t, J = 7.3 Hz, 2H), 3.60 (t, J = 7.3 Hz, 2H), 3.15 (t, J = 7.7 Hz, 2H), 1.91 (sext, J = 7.3 Hz, 2H), 0.95 (t, J = 7.3 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 155.63, 128.67, 128.61, 126.90,

126.83, 48.83, 34.40, 32.92, 22.43, 10.91; FT-IR (KBr, cm^{-1}): 3084, 2981, 2900, 2258, 1432, 1391; Anal. Calcd for ($C_{12}H_{16}N_4S$) C, 58.04; H, 6.49; N, 22.56; found C, 58.36; H, 6.83; N, 22.83.

5-(3-Phenylpropylthio)-1-propyl-1*H*-tetrazole (2d): Yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.18-7.32 (m, 5H, Ar-H), 4.18 (t, J = 6.9 Hz, 2H), 3.38 (t, J = 7.3 Hz, 2H), 2.78 (t, J = 7.4 Hz, 2H), 2.15 (quin, J = 7.7 Hz, 2H), 1.93 (sext, J = 7.4 Hz, 2H), 0.96 (t, J = 7.3 Hz, 3H); ^{13}C NMR (75 MHz, CD Cl_3) δ 154.51, 128.52, 128.47, 128.42, 126.20, 126.14, 48.85, 34.46, 32.53, 30.78, 22.45, 10.93; FT-IR (KBr, cm^{-1}): 3019, 2977, 2920, 2250, 1450, 1388; Anal. Calcd for ($C_{13}H_{18}N_4S$) C, 59.51; H, 6.91; N, 21.35; found C, 59.76; H, 7.05; N, 21.58.

5-Methylthio-1-phenyl-1*H*-tetrazole (2e): Pale yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.19-7.53 (m, 5H, Ar-H), 2.74 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 155.16, 130.05, 129.15, 123.84, 31.05; FT-IR (KBr, cm^{-1}): 3055, 3018, 2929, 2245, 1501, 1317; Anal. Calcd for ($C_8H_8N_4S$) C, 49.98; H, 4.19; N, 29.14; found: C, 50.24; H, 4.57; N, 29.33.

5-Hexylthio-1-phenyl-1*H*-tetrazole (2f): Yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.46-7.53 (m, 5H, Ar-H), 3.33 (t, J = 4.0 Hz, 2H), 1.75 (quin, J = 7.7 Hz, 2H), 1.36 (quin, J = 7.3 Hz, 2H), 1.18-1.26 (m, 4H), 0.82 (t, J = 4.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 154.03, 138.05, 134.27, 130.48, 48.78, 32.27, 22.14, 21.70, 13.50, 10.90; FT-IR (KBr, cm^{-1}): 2959, 2937, 2856, 2250, 1500, 1388; Anal. Calcd for ($C_{13}H_{18}N_4S$) C, 59.51; H, 6.91; N, 21.35; found C, 59.80; H, 7.38; N, 21.44.

5-Phenethylthio-1-phenyl-1*H*-tetrazole (2g): Yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.56 (s, 5H, Ar-H), 7.20-7.34 (m, 5H, Ar-H), 3.64 (t, J = 7.7 Hz, 2H), 3.15 (t, J = 7.3 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 154.15, 138.95, 133.64, 130.08, 129.76, 128.65, 128.62, 128.58, 126.89, 126.82, 123.80, 35.39, 34.44; FT-IR (KBr, cm^{-1}): 3032, 3020, 2907, 2250, 1499, 1387; Anal. Calcd for ($C_{15}H_{14}N_4S$) C, 63.80; H, 5.00; N, 19.84; found C, 64.09; H, 5.39; N, 20.20.

5-(3-Phenylpropylthio)-1-phenyl-1*H*-tetrazole (2h): Yellow oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.50-7.52 (m, 5H, Ar-H), 7.10-7.24 (m, 5H, Ar-H), 3.33 (t, J = 7.3 Hz, 2H), 2.71 (t, J = 7.3 Hz, 2H), 2.10 (quin, J = 7.7 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 154.95, 140.50, 130.09, 129.77, 128.71, 128.50, 128.47, 128.41, 126.19, 126.12, 123.83, 34.49, 32.56, 30.55; FT-IR (KBr, cm^{-1}): 3025, 2937, 2856, 2243, 1499, 1388; Anal. Calcd for ($C_{16}H_{16}N_4S$) C, 64.84; H, 5.44; N, 18.90; found C, 65.15; H, 5.73; N, 19.27.

X-ray Structure Determination. All X-ray data were collected with a Bruker Smart APEX2 diffractometer equipped with a Mo X-ray tube. Collected data were corrected for absorption with SADABS based upon the Laue symmetry by using equivalent reflections.[15] All calculations were carried out with the SHELXTL programs.[16] All structures were solved by direct methods. All non-hydrogen atoms were refined anisotropically, and all hydrogen atoms were generated in ideal positions and refined in a riding model.

CCDC 784735 contains the supplementary crystallographic data for this paper**.** Copies of this information may be obtained free of charge from: The director, CCDC, 12 Union Road, Cambridge, CB21EZ, UK (Fax: +44-1223-336-033; email: deposit@ccdc.cam.ac.uk or www: http://www.ccdc.cam.ac.uk).

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