A simple, one-pot and phosphine-free procedure for thiocyanation of alcohols using *N*-(*p*-toluenesulfonyl) imidazole (TsIm)

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An efficient, one-pot, phosphine-free thiocyanation of alcohols has been achieved utilising potassium thiocyanate and *N*-(*p*-toluenesulfonyl) imidazole (TsIm) as a coupling agent in the presence of triethylamine in anhydrous DMF at 70 °C. This method converts primary alcohols into the corresponding thiocyanates, without isomerisation to isothiocyanates, in good to excellent yields. A total of 17 thiocyananates were prepared, five of which are novel. Using one equivalent of KSCN, the method shows good selectivity in the thiocyanation of a primary alcohol in the presence of a secondary alcohol.

Keywords: alcohols, phosphine-free thiocyanation, potassium thiocyanate, *N*-(*p*-toluenesulfonyl) imidazole (TsIm)

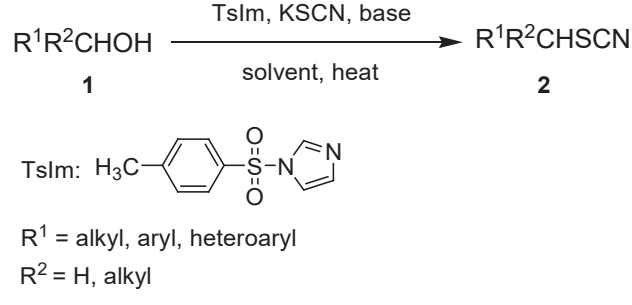
Alkyl thiocyanates are valuable compounds, particularly in the field of heterocyclic chemistry.[1] They are versatile synthetic precursors for the preparation of sulfur-containing organic compounds such as cyano-thiolated compounds[2] and sulphides.[3] Moreover, thiocyanate is an attractive functionality for safe and non-toxic incorporation of latent nitriles into molecular scaffolds *via* a subsequent desulfuration process.[4] In addition, they have been extensively used as insecticides,[5] biocidal[6] and antiasthmatic[7] agents and as vulcanisation accelerators.[8] To prepare alkyl thiocyanates, most traditional procedures involve the conversion of alkyl halides or sulfonate esters to alkyl thiocyanates with metal thiocyanates or diverse sources of thiocyanates including $M(SCN)_n$ (M = Na, K, n = 1; Zn, n = 2),[9] NH_4SCN,[10] Me_3SiNCS,[11] $Me_3SiNCS/TiCl_4$,[12] Me_3SiNCS/Bu_4NF,[13] [bmim]SCN,[14] 2-hydroxy-*N*,*N*,*N*-tributylethanammonium thiocyanate,[15] cross-linked poly(*N*-methyl-4-vinylpyridinium) thiocyanate [P4-Me]SCN[16] and $KSCN/SiO_2$.[17] Thiocyanates can also be produced from silyl ethers[18] and amines.[19]

Despite the usefulness of alkyl halides in reaction with diverse sources of thiocyanate listed above, the high risk of toxicity has limited the applicability of their use in large-scale synthesis because they are well known today as harmful carbon-electrophiles with known carcinogenic properties. Therefore, employing a carbon electrophile with a lower toxicity and environmental cost is essential. To overcome this problem, the direct thiocyanation of alcohols would be a highly advantageous strategy, since alcohols are versatile reagents having less toxicity, are easily handled and are widely available with respect to the corresponding alkyl halides. However, alcohols are known to be inert towards nucleophilic substitution reactions. In this regard, the use of an appropriate reagent for the *in situ* conversion of the hydroxyl moiety into a reactive leaving group is essential. In general, the Mitsunobu reaction and related approaches are the most common procedures for thiocyanation of alcohols using reagents such as PPh_3/DEAD/NH_4SCN[20] and PPh_3/DDQ/n-Bu_4NSCN.[21] Nevertheless, the thiocyanation of alcohols using Mitsunobu conditions suffers from some disadvantages, including (i) the use of expensive diethyl azodicarboxylate (DEAD), (ii) the explosive nature of DEAD and (iii) the high toxicity of DDQ. These drawbacks have considerably restricted the applicability of Mitsunobu conditions in the large-scale synthesis of alkyl thiocyanates. In addition, the phosphine-based reagents $Ph_3P(SCN)_2$[22] and $Ph_3P(Br)_2/NH_4SCN$[23] have been used for the activation of the hydroxyl group of alcohols. Again, the use of Ph_3P in these reagents has certain drawbacks. The presence of unreacted Ph_3P and the *in situ* generation of $Ph_3P{=}O$ as a side product yield a complex mixture of starting materials and products which results in tedious work-ups and cumbersome separation processes. In recent years a few phosphine-free approaches have been developed for thiocyanation of alcohols, including 2-chloro-1-methylpyridinium iodide/NH_4SCN,[24] trichloroisocyanuric acid/NH_4SCN,[25] [P4-VP]Pr-SCN/cyanuric chloride/DMF,[26] *N*-thiocyanatosuccinimide/NH_4SCN,[27] $[PCl_{3-n}(SiO_2)_n]/I_2/NH_4SCN$[28] and Selectfluor TM F-TEDA-BF4/NH_4SCN.[29] However, many of these reported methods have various drawbacks, including the formation of the corresponding isothiocyanates as by-products, the involvement of strong oxidising agents, toxicity of reagent, prolonged reaction times, expensive reagents, environmental incompatibility, poor availability and uncommon reagents. Thus, there is still a need to establish an alternative approach for a mild, selective and efficient phosphine-free procedure for thiocyanation of alcohols.

Over the past decade, we have developed the utilisation of *N*-(*p*-toluenesulfonyl) imidazole (TsIm) as a cheap, non-toxic and stable coupling agent to access diverse carbon-nucleophile bonds through a one-pot process using alcohols and nucleophiles.[30–36] Here we would like to report the one-pot synthesis of alkyl thiocyanates *via* thiocyanation of alcohols using TsIm, KSCN and a base.

Results and discussion

Our proposed route for the thiocyanation is outlined in Scheme 1. To optimise the reaction conditions, we examined the reaction of 2-phenylethanol (**1a**; $R^1 = C_6H_4CH_2$, R^2 = H) with KSCN using TsIm as a model reaction (Scheme 1). Since DMF is well known as a solvent in S_N2-type reactions, we initiated our tests for the optimum temperature using anhydrous DMF, and the results are shown in Table 1 (entries 1–7). At ambient temperature a low yield (25%) of 1-(2-thiocyanatoethyl)benzene (**2a**; $R^1 = C_6H_4CH_2$,



Scheme 1

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Table 1 Effects of various reaction parameters (temperature, solvent, base) on the yields of (2-thiocyanatoethyl)benzene (**2a**; R^1 = $C_6H_4CH_2$, R^2 = H) prepared by treatment of 2-phenylethanol (**1a**; R^1 = $C_6H_4CH_2$, R^2 = H) with KSCN and a base in the presence of TsIm (Scheme 1) and other coupling agents **3**–**11** (Fig. 1)[a]

Entry	Solvent	Base	Reagent	Temperature/°C	Time/h	Yield[b]/%
1	DMF	Et_3N	TsIm	r.t.	24	25
2	DMF	Et_3N	TsIm	50	15	41
3	DMF	Et_3N	TsIm	70	8	92
4	DMF	Et_3N	TsIm	90	6	65
5	DMF	Et_3N	TsIm	110	5	52
6	DMF	Et_3N	TsIm	130	4	50
7	DMF	Et_3N	TsIm	reflux	4	43
8	MeCN	Et_3N	TsIm	70	12	72
9	HMPA	Et_3N	TsIm	70	15	39
10	DMSO	Et_3N	TsIm	70	8	78
11	NMP	Et_3N	TsIm	70	8	75
12	Toluene	Et_3N	TsIm	70	18	21
13	bmim[Br]	Et_3N	TsIm	70	12	60
14	PEG 200	Et_3N	TsIm	70	24	NR[c]
15	H_2O	Et_3N	TsIm	70	24	NR[c]
16	DMF	–	TsIm	70	24	NR[c]
17	DMF	NaH	TsIm	70	13	32
18	DMF	DBU	TsIm	70	8	90
19	DMF	DMAP	TsIm	70	8	85
20	DMF	DABCO	TsIm	70	8	86
21	DMF	MgO	TsIm	70	24	NR[c]
22	DMF	K_2CO_3	TsIm	70	10	56
23	DMF	Cs_2CO_3	TsIm	70	8	58
24	DMF	Basic Al_2O_3	TsIm	70	24	NR[c]
25	DMF	Et_3N	**3**	70	9	79
26	DMF	Et_3N	**4**	70	9	84
27	DMF	Et_3N	**5**	70	11	68
28	DMF	Et_3N	**6**	70	10	88
29	DMF	Et_3N	**7**	70	13	61
30	DMF	Et_3N	**8**	70	24	NR[c]
31	DMF	Et_3N	**9**	70	16	54
32	DMF	Et_3N	**10**	70	20	19
33	DMF	Et_3N	**11**	70	18	25

[a]Reaction conditions: a mixture of 2-phenylethanol (**1a**; R^1 = $C_6H_4CH_2$, R^2 = H), KSCN and a base in the presence of TsIm or some of its analogues **3**–**11** (Fig. 1) in a dry solvent (10 mL) was heated at various temperatures for various times (Scheme 1).

[b]Isolated yield.

[c]No reaction.

R^2 = H) was obtained after prolonging the reaction for a day (entry 1). Thus, we gradually increased the temperature, and the maximum yield of **2a** was obtained when the reaction was kept at 70 °C for 8 h (entry 3). Increasing the temperature above 70 °C (entries 4–7) decreased the reaction yield, presumably due to isomerisation of thiocyanate to the corresponding isothiocyanate. Utilising anhydrous DMF at 70 °C gave the best result, and this temperature was employed for all the ensuing investigations.

Next, we focused our attention on the choice of an appropriate solvent. The use of MeCN, DMSO, NMP and bmim[Br] as a room temperature ionic liquid led to acceptable yields of **2a** (Table 1, entries 8, 10, 11, 13), whereas HMPA and toluene (entries 9, 12) gave poor yields of the desired product. Protic solvents like water or polyethylene glycol (PEG) failed to give any product even if reaction was prolonged for 24 h (entries 14, 15).

Then we explored the influence of different organic and inorganic bases on the model reaction (Table 1, entries 3, 17–24). Since alcohols are weak nucleophiles, the use of a strong base for enhancing their nucleophilicity towards TsIm is crucial. As Table 1 indicates, in the absence of the base, no reaction occurred (entry 16). The best result was observed when triethylamine (TEA) was used (entry 3). Other bases, including DBU, DMAP and DABCO, also gave **2a** in excellent yield (entries 18–20). However, since they are expensive compared to TEA, they were rejected. The use of carbonates produced moderate yields of **2a** (entries 22, 23), whereas MgO and/or basic alumina failed to produce **2a** after extension of the reaction time to a day (entries 21, 24).

In complementary experiments for optimisation, we also investigated the coupling power of analogues of TsIm, the structures of which (**3**–**11**) are shown in Fig. 1.[36] As can be seen in Table 1, the highest yield of **2a** in the shortest reaction time was obtained when TsIm itself was employed (entry 3). The use of coupling reagents **3**–**7** also afforded good yields (61–88%) of **2a** but in longer reaction times (entries 25–29). Employing reagents **9**–**11** resulted in only low to moderate yields of **2a** (entries 31–33). The *N*-tosyl imide, *N*-tosylphthalimide was inactive even if the reaction time was prolonged to 24 h (entry 30).

With the optimal reaction conditions in hand, we then screened the versatility and the scope of the method for the conversion of other primary and secondary alcohols containing different functionalities to their corresponding alkyl thiocyanates, and the results are shown in Table 2. As can be seen, the alcohols

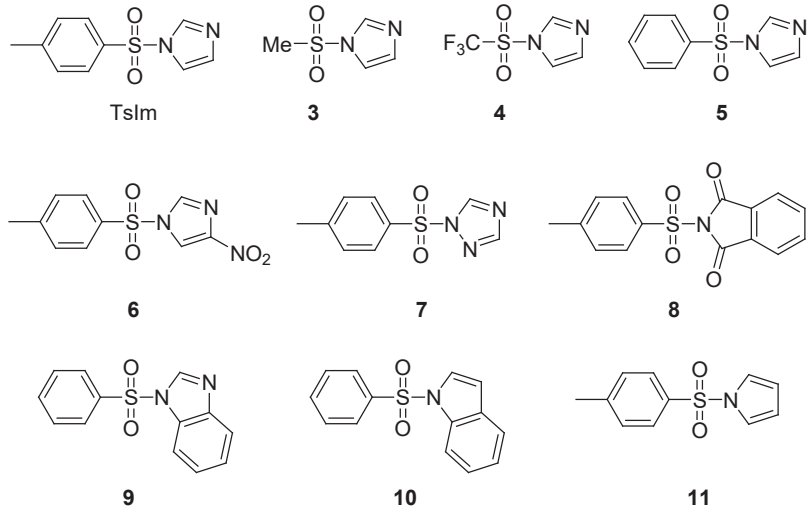
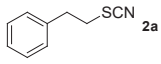
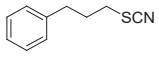
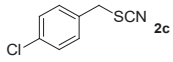
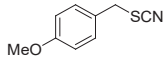
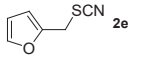
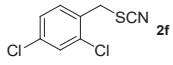
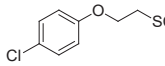
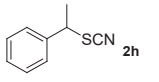
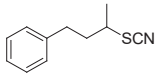
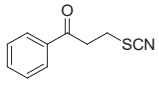
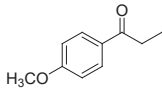
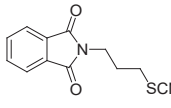
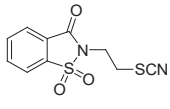
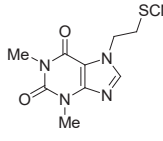
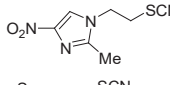
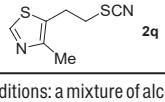


Fig. 1 Structures of analogues of TsIm tested as coupling reagents.

Table 2 Yields and duration of reaction for the preparation of alkyl thiocyanate **2a–q** from alcohols **1a–q** using TsIm, KSCN and TEA in anhydrous DMF (Scheme 1).

Entry[ref.]	Product[a]	Time/h	Yield[b]/%
1[22]	 **2a**	8	92
2[10]	 **2b**	10	94
3[22]	 **2c**	9	86
4[22]	 **2d**	8	90
5[22]	 **2e**	9	75
6[10]	 **2f**	6	81
7	 **2g**	7	89
8[26]	 **2h**	12	40
9[38]	 **2i**	12	30
10[37]	 **2j**	8	68
11[37]	 **2k**	6	73
12[10]	**2l**	6	93
13[39]	 **2m**	10	81
14	 **2n**	7	78
15	 **2o**	7	95
16	 **2p**	11	91
17	 **2q**	8	88

[a]Reaction conditions: a mixture of alcohol **1** (0.01 mol), TEA (0.015 mol), KSCN (0.015 mol) and TsIm (0.012 mol) in anhydrous DMF (10 mL) was heated at 70 °C for 6–12 h.
[b]Isolated yield.

evaluated encompassed benzylic (entries 3, 4, 6), furfuryl (entry 5), simple aliphatic (entry 12) as well as other primary alcohols bearing various functionalities such as aryl (entries 1, 2), aryloxy (entry 7), ketone (entries 10, 11) and heteroaliphatic groups (entries 13–17). All were readily converted to the corresponding alkyl thiocyanates in good to excellent yields. However, the secondary alcohols (entries 8 and 9) gave poor yields if the thiocyanation products and tertiary alcohols such as *t*-butyl alcohol were inert to thiocyanation (not shown in Table 2).

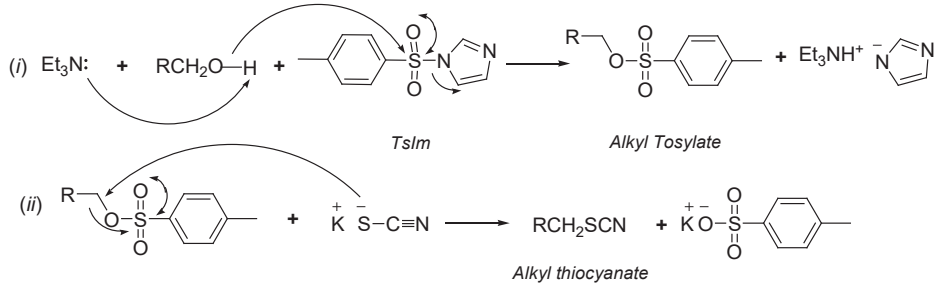
To investigate the selectivity of this method for alcohol type, we performed a competitive reaction between a mixture consisting of an equimolar ratio of a primary and a secondary alcohol under the optimised conditions. Thus when a mixture of two isomeric alcohols, 2-phenylethanol (**1a**, 1 equiv.) and 1-phenylethanol (**1h**,1 equiv.) was allowed to react with KSCN (1 equiv.) in the presence of TsIm (1 equiv.) a good selectivity (approx. 13:1) for primary alcohol was observed in which **2a** was obtained in 93% yield and **2h** in 8% yield.

A plausible mechanism for one-pot thiocyanation of alcohols *via* KSCN, TEA and TsIm as a coupling agent in anhydrous DMF is shown in Scheme 2. In this mechanism, TEA as a homogeneous base first scavenges a proton from the alcohol, and then the activated alcohol (alkoxide ion) attacks TsIm to give the corresponding alkyl tosylate. To confirm this, the presence of alkyl tosylate was readily observed during the early stages of the reaction process and the *in situ* generation of alkyl tosylate was confirmed by comparing with authentic samples using GC analysis. Afterwards, the thiocyanate anion attacks the electrophilic carbon at the *in situ* generated alkyl tosylate to afford the corresponding alkyl thiocyanate.

In conclusion, we have developed a one-pot, phosphine-free thiocyanation of alcohols using TsIm as a highly efficient and useful coupling reagent in the presence of KSCN/Et_3N in anhydrous DMF at 70 °C. This has provided rapid, simple and high-yield access to alkyl thiocyanates from alcohols. This method showed good selectivity towards primary alcohols in comparison with secondary alcohols, whereas tertiary alcohols were inert.

Experimental

All chemical reagents were purchased from either Fluka or Merck. TsIm was freshly prepared by an established procedure.[30] Solvents were purified by standard procedures and stored over 3 Å molecular sieves. Reactions were followed by TLC using SILG/UV 254 silica-gel plates. Column chromatography was performed on silica gel 60 (0.063–0.200 mm, 70–230 mesh; ASTM). IR spectra were obtained using a Shimadzu FTIR-8300 spectrophotometer. ^1H and ^{13}C NMR spectra were recorded on a Bruker Avance-DPX-250 spectrometer operating in $CDCl_3$ at 250/62.5 MHz, respectively. Chemical shifts are given in δ relative to tetramethylsilane (TMS) as internal standard, and coupling constants *J* are given in Hz. Abbreviations used are: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad. GC/MS was performed on a Shimadzu GC/MS-QP 1000-EX



Scheme 2

apparatus (*m/z*; rel.%). Elemental analyses were performed on a PerkinElmer 240-B micro-analyser.

Thiocyanation of alcohol using TsIm; general procedure

In a round-bottom flask (50 mL) equipped with a condenser, a mixture of an appropriate alcohol (0.01 mol), TsIm (0.012 mol), KSCN (0.015 mol) and Et_3N (0.015 mol) in anhydrous DMF (10 mL) was heated at 70 °C for the times indicated in Table 2. In most cases, darkening of the reaction media occurred, and heating was continued until TLC monitoring indicated no further improvement in the conversion (Table 2). After completion of the reaction, the mixture was diluted in water (100 mL), $CHCl_3$ (100 mL) was added and the organic phase was washed with water (4 × 100 mL). The organic layer was evaporated *in vacuo* to obtain the crude product which was purified by short column chromatography on silica gel eluted with *n*-hexane:EtOAc.

(2-Thiocyanatoethyl)benzene (**2a**): Colourless oil (92%); IR (ν_{max} cm^{-1}): 3100, 2981, 2175, 1468; ^1H NMR ($CDCl_3$) δ 2.74 (d, *J* = 7.2 Hz, 2H, PhC$\underline{H}_2$), 3.19 (d, *J* = 7.2 Hz, 2H, CH_2SCN), 7.12–7.37 (m, 5H, aryl); ^{13}C NMR ($CDCl_3$) δ 37.2, 40.4, 112.8, 127.1, 128.5, 129.8, 141.0; MS (EI) *m/z* (%): 163 (10.1) (M^+); Anal. calcd for C_9H_9NS: C, 66.22; H, 5.56; N, 8.58; found: C, 66.29; H, 5.68; N, 8.71%.

(3-Thiocyanatopropyl)benzene (**2b**): Colourless oil (94%); IR (ν_{max} cm^{-1}): 3081, 2963, 2170, 1487; ^1H NMR ($CDCl_3$) δ 2.24–2.29 (m, 2H, $PhCH_2C\underline{H}_2$), 2.61 (t, *J* = 7.4 Hz, 2H, PhC$\underline{H}_2$), 2.96 (t, *J* = 7.4 Hz, 2H, CH_2SCN), 7.20–7.29 (m, 5H, aryl); ^{13}C NMR ($CDCl_3$) δ 31.9, 34.1, 35.0, 112.8, 127.2, 128.8, 129.5, 141.3; MS (EI) *m/z* (%): 177 (13.7) (M^+); Anal. calcd for $C_{10}H_{11}NS$: C, 67.76; H, 6.25; N, 7.90; found: C, 67.70; H, 6.38; N, 7.97%.

1-Chloro-4-(thiocyanatomethyl)benzene (**2c**): Colourless oil (86%); IR (ν_{max} cm^{-1}): 3050, 2948, 2165, 1437, 1076; ^1H NMR ($CDCl_3$) δ 4.47 (s, 2H, CH_2), 6.89 (d, *J* = 8.2 Hz, 2H, aryl), 7.20 (d, *J* = 8.2 Hz, 2H, aryl); ^{13}C NMR ($CDCl_3$) δ 38.6, 112.7, 128.8, 130.1, 133.4, 140.3; MS (EI) *m/z* (%): 182 (15.7) (M^+); Anal. calcd for C_8H_6ClNS: C, 52.32; H, 3.29; N, 7.63; found: C, 52.41; H, 3.37; N, 7.70%.

1-Methoxy-4-(thiocyanatomethyl)benzene (**2d**): Colourless oil (90%); IR (ν_{max} cm^{-1}): 3100, 2975, 2173, 1468, 1159; ^1H NMR ($CDCl_3$) δ 3.58 (s, 3H, OCH_3), 4.09 (s, 2H, CH_2), 6.85 (d, *J* = 8.0 Hz, 2H, aryl), 7.31 (d, *J* = 8.0 Hz, 2H, aryl); ^{13}C NMR ($CDCl_3$) δ 37.8, 54.1, 112.9, 115.6, 129.6, 133.0, 158.4; MS (EI) *m/z* (%): 179 (17.2) (M^+); Anal. calcd for C_9H_9NOS: C, 60.31; H, 5.06; N, 7.81; found: C, 60.38; H, 5.15; N, 7.95%.

2-(Thiocyanatomethyl)furan (**2e**): Colourless oil (75%); IR (ν_{max} cm^{-1}): 3028, 2985, 2168, 1453; ^1H NMR ($CDCl_3$) δ 4.26 (s, 2H, CH_2), 6.30–6.35 (m, 2H, aryl), 7.38–7.41 (m, 1H, aryl); ^{13}C NMR ($CDCl_3$) δ 35.9, 107.5, 111.2, 113.2, 143.8, 152.3; MS (EI) *m/z* (%): 139 (9.8) (M^+); Anal. calcd for C_6H_5NOS: C, 51.78; H, 3.62; N, 10.06; found: C, 51.70; H, 3.71; N, 10.18%.

2,4-Dichloro-1-(thiocyanatomethyl)benzene (**2f**): Colourless oil (81%); IR (ν_{max} cm^{-1}): 3076, 2953, 2160, 1472, 1094; ^1H NMR ($CDCl_3$) δ 4.20 (s, 2H, CH_2), 6.91 (d, *J* = 8.1 Hz, 1H, aryl), 7.05 (d, *J* = 8.1 Hz, 1H, aryl), 7.21 (s, 1H, aryl); ^{13}C NMR ($CDCl_3$) δ 35.9, 112.0, 128.6, 130.4, 131.8, 132.5, 136.1, 138.0; MS (EI) *m/z* (%): 218 (22.3) (M^+); Anal. calcd for $C_8H_5Cl_2NS$: C, 44.06; H, 2.31; N, 6.42; found: C, 44.13; H, 2.39; N, 6.50%.

1-Chloro-4-(2-thiocyanatoethoxy)benzene (**2g**): White foam (89%); IR (ν_{max} cm^{-1}): 3100, 2986, 2174, 1435, 1237, 1083; ^1H NMR ($CDCl_3$) δ 3.41 (t, *J* = 7.3 Hz, 2H, CH_2SCN), 4.30 (t, *J* = 7.3 Hz, 2H, OCH_2), 6.83 (d, *J* = 8.4 Hz, 2H, aryl),7.25 (d, *J* = 8.4 Hz, 2H, aryl); ^{13}C NMR ($CDCl_3$) δ 32.8, 71.9, 113.4, 116.8, 126.1, 129.0, 154.7; MS (EI) *m/z* (%): 215 (19.4) (M^+); Anal. calcd for C_9H_8ClNOS: C, 50.59; H, 3.77; N, 6.55; found: C, 50.68; H, 3.84; N, 6.46%.

(1-Thiocyanatoethyl)benzene (**2h**): Colourless oil (40%); IR (ν_{max} cm^{-1}): 3045, 2978, 2158, 1490; ^1H NMR ($CDCl_3$) δ 1.84 (d, *J* = 6.8 Hz, 3H, CH_3), 4.47 (q, *J* = 6.8 Hz, 1H, PhC$\underline{H}$), 7.12–7.19 (m, 5H, aryl); ^{13}C NMR ($CDCl_3$) δ 21.0, 43.5, 112.8, 127.9, 128.4, 129.1, 142.0; MS (EI) *m/z* (%): 163 (8.7) (M^+); Anal. calcd for C_9H_9NS: C, 66.22; H, 5.56; N, 8.58; found: C, 66.31; H, 5.50; N, 8.67%.

(3-Thiocyanatobutyl)benzene (**2i**): Colourless oil (30%); IR (ν_{max} cm^{-1}): 3025, 2958, 2165, 1435; ^1H NMR ($CDCl_3$) δ 1.62 (d, *J* = 7.2 Hz, 3H, CHC$\underline{H}_3$), 1.90–1.97 (m, 2H, $PhCH_2C\underline{H}_2$), 2.73 (t, *J* = 7.3 Hz, 2H, PhC$\underline{H}_2$), 3.19–3.24 (m, 1H, CHSCN), 7.19–7.28 (m, 5H, aryl); ^{13}C NMR ($CDCl_3$) δ 23.0, 34.1, 39.2, 45.7, 112.4, 127.1, 129.0, 129.8, 141.6; MS (EI) *m/z* (%): 191 (16.7) (M^+); Anal. calcd for $C_{11}H_{13}NS$: C, 69.07; H, 6.85; N, 7.32; found: C, 69.16; H, 6.92; N, 7.38%.

1-Phenyl-3-thiocyanatopropan-1-one (**2j**): Yellow oil (68%); IR (ν_{max} cm^{-1}): 3100, 2939, 2168, 1710, 1466; ^1H NMR ($CDCl_3$) δ 3.35 (t, *J* = 6.9 Hz, 2H, $C\underline{H}_2CH_2SCN$), 3.76 (t, *J* = 6.9 Hz, 2H, CH_2SCN), 7.32–7.37 (m, 3H, aryl), 7.75–7.81 (m, 2H, aryl); ^{13}C NMR ($CDCl_3$) δ 27.2, 40.7, 112.6, 128.9, 129.4, 134.0, 137.1, 189.7; MS (EI) *m/z* (%): 191 (14.9) (M^+); Anal. calcd for $C_{10}H_9NOS$: C, 62.80; H, 4.74; N, 7.32; found: C, 62.95; H, 4.83; N, 7.39%.

1-(4-Methoxyphenyl)-3-thiocyanatopropan-1-one (**2k**): Yellow oil (73%); IR (ν_{max} cm^{-1}): 3065, 2949, 2165, 1712, 1457, 1180; ^1H NMR ($CDCl_3$) δ 3.26 (t, *J* = 7.1 Hz, 2H, $C\underline{H}_2CH_2SCN$), 3.51 (t, *J* = 7.1 Hz, 2H, CH_2SCN), 3.96 (s, 3H, OCH_3), 6.92 (d, *J* = 8.5 Hz, 2H, aryl), 7.85 (d, *J* = 8.5 Hz, 2H, aryl); ^{13}C NMR ($CDCl_3$) δ 29.6, 42.0, 56.1, 112.0, 115.8, 129.7, 131.1, 162.9, 188.6; MS (EI) *m/z* (%): 221 (18.1) (M^+); Anal. calcd for $C_{11}H_{11}NO_2S$: C, 59.71; H, 5.01; N, 6.33; found: C, 59.84; H, 5.16; N, 6.41%.

1-Thiocyanatooctane (**2l**): Colourless oil (93%); IR (ν_{max} cm^{-1}): 2986, 2861, 2158; ^1H NMR ($CDCl_3$) δ 0.98 (t, *J* = 7.1 Hz, 3H, CH_3), 1.30–1.45 (m, 10H, $5CH_2$), 1.86–1.90 (m, 2H, CH_2), 2.89 (t, *J* = 7.1 Hz, 2H, CH_2SCN); ^{13}C NMR ($CDCl_3$) δ 16.7, 25.1, 31.5, 31.9, 32.4, 33.0, 33.9, 34.6, 113.7; MS (EI) *m/z* (%): 171 (11.8) (M^+); Anal. calcd for $C_9H_{17}NS$: C, 63.10; H, 10.00; N, 8.18; found: C, 63.18; H, 10.09; N, 8.06%.

2-(3-Thiocyanatopropyl)isoindoline-1,3-dione (**2m**): Creamy foam (81%); IR (ν_{max} cm^{-1}): 3100, 2981, 2167, 1690, 1483; ^1H NMR ($CDCl_3$) δ 2.01–2.08 (m, 2H, $NCH_2C\underline{H}_2$), 2.87 (t, *J* = 7.0 Hz, 2H, CH_2SCN), 3.94 (t, *J* = 7.0 Hz, 2H, NCH_2), 7.25–7.32 (m, 2H, aryl), 7.89–7.95 (m, 2H, aryl); ^{13}C NMR ($CDCl_3$) δ 27.6, 30.1, 36.0, 112.1, 124.5, 132.6, 135.2, 169.7; MS (EI) *m/z* (%): 246 (15.6) (M^+); Anal. calcd for $C_{12}H_{10}N_2O_2S$: C, 58.52; H, 4.09; N, 11.37; found: C, 58.65; H, 4.17; N, 11.41%.

1,1-Dioxo-2-(2-thiocyanato-ethyl)-1,2-dihydro-1l6-benzo[d] isothiazol-3-one (**2n**): White foam (78%); IR (ν_{max} cm^{-1}): 3049, 2935, 2170, 1615, 1482, 1240; ^1H NMR ($CDCl_3$) δ 3.47 (t, *J* = 7.2 Hz, 2H, CH_2SCN), 3.69 (t, *J* = 7.2 Hz, 2H, NCH_2), 7.01–7.12 (m, 4H, aryl); ^{13}C NMR ($CDCl_3$) δ 30.4, 43.0, 111.6, 127.5, 128.0, 128.9, 132.6, 133.1, 141.3, 169.4; MS (EI) *m/z* (%): 268 (21.3) (M^+); Anal. calcd for $C_{10}H_8N_2O_3S_2$: C, 44.76; H, 3.01; N, 10.44; found: C, 44.85; H, 3.14; N, 10.57%.

1,3-Dimethyl-7-(2-thiocyanatoethyl)-1H-purine-2,6(3H,7H)-dione (**2o**): White foam (95%); IR (ν_{max} cm^{-1}): 3100, 2968, 2170, 1714, 1702, 1657, 1475; ^1H NMR ($CDCl_3$) δ 3.25 (s, 3H, N(3)–CH_3), 3.40 (s, 3H, N(1)–CH_3), 3.78 (t, 2H, *J* = 7.5 Hz, CH_2SCN), 4.06 (t, 2H, *J* = 7.5 Hz, NCH_2), 7.91 (s, 1H, C(8)–H, theophylline); ^{13}C NMR ($CDCl_3$) δ 28.5, 32.0, 33.8, 46.1, 106.3, 112.0, 146.7, 151.2, 152.4, 155.8; MS (EI) *m/z* (%): 265 (9.8) (M^+); Anal. calcd for $C_{10}H_{11}N_5O_2S$: C, 45.27; H, 4.18; N, 26.40; found: C, 45.39; H, 4.27; N, 26.49%.

2-Methyl-4-nitro-1-(2-thiocyanatoethyl)-1H-imidazole (**2p**): Pale-yellow foam (91%); IR (ν_{max} cm^{-1}): 3074, 2967, 2170, 1680, 1553, 1447, 1351; ^1H NMR ($CDCl_3$) δ 2.28 (s, 3H, CH_3), 3.39 (t, 2H, *J* = 6.9 Hz, CH_2SCN), 4.41 (t, 2H, *J* = 6.9 Hz, NCH_2), 7.83 (s, 1H, C(5)–H, imidazole); ^{13}C NMR ($CDCl_3$) δ 14.6, 34.7, 46.0, 112.9, 132.5, 139.0, 153.7; MS (EI) *m/z* (%): 212 (18.3) (M^+); Anal. calcd for $C_7H_8N_4O_2S$: C, 39.62; H, 3.80; N, 26.40; found: C, 39.71; H, 3.94; N, 26.48%.

4-Methyl-5-(2-thiocyanatoethyl)thiazole (**2q**): Pale-yellow oil (88%); IR (ν_{max} cm^{-1}): 3100, 2953, 2165, 1645, 1458; ^1H NMR ($CDCl_3$) δ 2.51 (s, 3H, CH_3), 2.97 (t, 2H, *J* = 7.3 Hz, $C\underline{H}_2CH_2SCN$), 3.55 (t, 2H, *J* = 7.3 Hz, CH_2SCN), 8.29 (s, 1H, C(2)–H, thiazole); ^{13}C NMR ($CDCl_3$) δ 12.8, 27.4, 36.8, 112.6, 129.7, 150.1, 153.0; MS (EI) *m/z* (%): 184 (12.7) (M^+); Anal. calcd for $C_7H_8N_2S_2$: C, 45.62; H, 4.38; N, 15.20; found: C, 45.56; H, 4.45; N, 15.31%.

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