SYNTHESIS OF ALKYLTHIO- AND ARYLTHIOHETEROARENES BY REGIOSELECTIVE GRIGNARD REACTION OF THIOCYANATO-HETEROARENES

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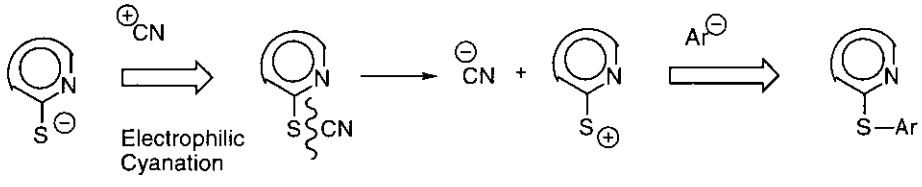
Abstract — Treatment of thiocyanatoheteroarenes (**1**) with Grignard reagents (**2**) afforded alkylthio- or arylthioheteroarenes (**3-6**) in good yields. Grignard reagents regioselectively attacked the sulfur atom of the thiocyanato group owing to the metal-chelating effect of this group in combination with the hetero ring-nitrogen. 2-Thiocyanatopyridine (**1a**), 2-thiocyanatopyrimidine (**1b**), 2-thiocyanatobenzothiazole (**1c**), and 4-thiocyanatoquinazoline (**1d**) were converted into a variety of sulfides. Sulfides consisting of two heteroarenes linked by a sulfur atom were readily obtained by this method.

Alkyl heteroaryl sulfides (alkylthioheteroarenes) are generally synthesized by alkylation of heteroarenethiols under basic conditions.[1] However, this approach fails with aryl heteroaryl sulfides (arylthioheteroarenes), which are instead usually synthesized from haloheteroarenes and arenethiols. If a simple method was available to obtain aryl heteroaryl sulfides from heteroarenethiols, it would be useful for organic synthesis.[2] It has been reported from our laboratory that 2-thiocyanatoquinoxaline reacted with phenylmagnesium bromide to give 2-phenylthioquinoxaline.[3] The formation of 2-phenylthioquinoxaline was suggested to occur *via* the formation of the quinoxalinylthio cation (-S^+). In contrast, the alkylation of heteroarenethiols proceeds

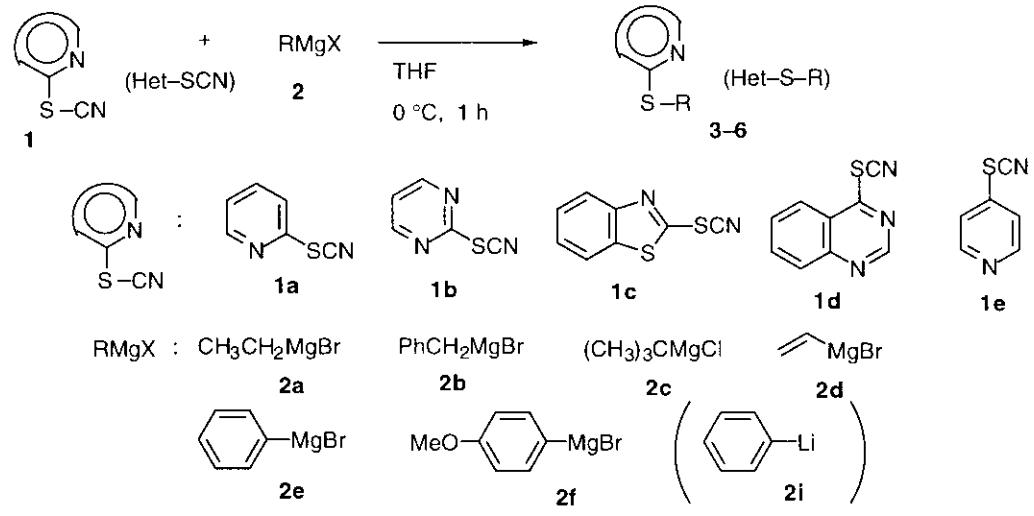
Scheme 1



through the formation of the heteroarenethiolate anion (-S^-). We recently reported that thiocyanatoheteroarenes such as 2-thiocyanatopyridine (**1a**) and 2-thiocyanatopyrimidine (**1b**) could be synthesized by electrophilic cyanation from heteroarenethiols.[4] Therefore we hoped to achieve the synthesis of arylthioheteroarenes from heteroarenethiols as shown in Scheme 1. This is considered as an umpolung reaction.

To provide heteroarylthio cation, a diheteroaryl disulfide such as di(2-pyridyl) disulfide or di(2-benzothiazolyl) disulfide is often used because of the nonequivalent cleavage of the S–S moiety, giving heteroarylthio anion and cation.[5] However, this method is not efficient. Alkylsulfenyl chloride is also used for the same purpose,[6] but its synthesis is not easy. Thiocyanatoheteroarenes also provide heteroarylthio cation, but preferential cleavage of the C–S bond of the thiocyanato group is difficult. In this paper we wish to report a synthetic

Scheme 2



Entry	HetSCN	RMgX	Het–S–R 3–6	Yield (%)
1	**1a**	**2a**	**3a**	74
2	**1a**	**2b**	**3b**	94
3	**1a**	**2c**	**3c**	83
4	**1a**	**2d**	**3d**	94
5	**1a**	**2e**	**3e**	84
6	**1a**	**2f**	**3f**	83
7	**1b**	**2a**	**4a**	80
8	**1b**	**2b**	**4b**	87
9	**1b**	**2c**	**4c**	84
10	**1b**	**2d**	**4d**	97
11	**1b**	**2e**	**4e**	84

Entry	HetSCN	RMgX	Het–S–R 3–6	Yield (%)
12	**1b**	**2f**	**4f**	76
13	**1c**	**2a**	**5a**	94
14	**1c**	**2b**	**5b**	77
15	**1c**	**2c**	**5c**	75
16	**1c**	**2d**	**5d**	87
17	**1c**	**2e**	**5e**	85
18	**1c**	**2f**	**5f**	89
19	**1d**	**2a**	**6a**	91
20	**1d**	**2b**	**6b**	66
21	**1d**	**2d**	**6d**	91
22	**1d**	**2e**	**6e**	85

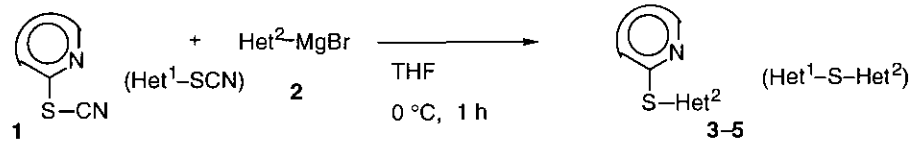
method for arylthio- and alkylthioheteroarenes by utilizing the reaction of thiocyanatoheteroarenes with Grignard reagents. The metal-chelating effect of the ring-nitrogen and the thiocyanato group results in the regioselective cleavage of the C–S bond.

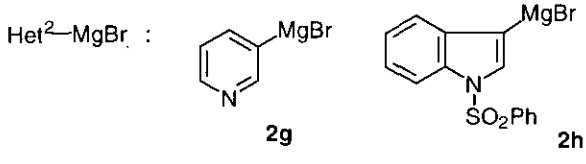
The reaction of 2-thiocyanatopyridine (**1a**) with phenylmagnesium bromide (**2e**) afforded 2-phenylthiopyridine (**3e**) in 83% yield. Similarly, 4-methoxyphenylmagnesium bromide (**2f**) yielded 2-(4-methoxyphenyl)thiopyridine (**3f**). Further, alkylmagnesium halides such as ethylmagnesium bromide (**2a**), benzylmagnesium bromide (**2b**), and vinylmagnesium bromide (**2d**) regioselectively attack the sulfur atom of the thiocyanato group to give the corresponding sulfides (**3a**, **3b**, **3d**) in good yields. Grignard reagents were also treated with other thiocyanatoheteroarenes such as 2-thiocyanatopyrimidine (**1b**), 2-thiocyanatobenzothiazole (**1c**) and 4-thiocyanatoquinazoline (**1d**), and in the all cases, the corresponding sulfides (**4**, **5**, **6**) were obtained in good yields.

When a bulky Grignard reagent was used, the reaction proceeded to afford the expected sulfides. Namely, *tert*-butylmagnesium chloride (**2c**) reacted with 2-thiocyanatopyridine (**1a**), 2-thiocyanatopyrimidine (**1b**) and 2-thiocyanatobenzothiazole (**1c**) to give the corresponding *tert*-butylthioheteroarenes (**3c**, **4c**, **5c**) in good yields.

To extend the scope of this reaction, heteroarylmagnesium halide was used. When 3-pyridylmagnesium bromide (**2g**)[7] was treated with 2-thiocyanatopyridine (**1a**), the expected 2-(3-pyridylthio)pyridine (**3g**) was

Scheme 3



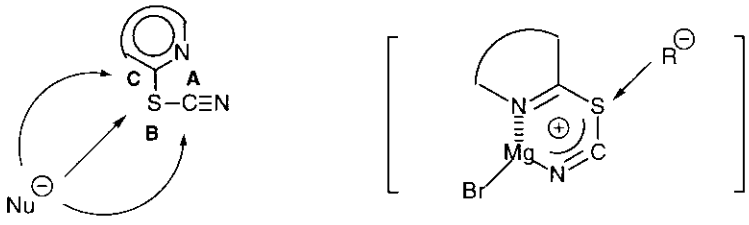


Entry	Het^1SCN	Het^2MgBr	$Het^1–S–Het^2$ 3–5	Yield (%)
1	**1a**	**2g**	**3g**	67
2	**1a**	**2h**	**3h**	52
3	**1b**	**2g**	**4g**	76
4	**1b**	**2h**	**4h**	79
5	**1c**	**2g**	**5g**	79
6	**1c**	**2h**	**5h**	90

obtained in 67% yield. Similar treatment of 2-thiocyanatopyrimidine (**1b**) and 2-thiocyanatobenzothiazole(**1c**) with 3-pyridylmagnesium bromide (**2g**) furnished the corresponding sulfides, 2-(3-pyridylthio)pyrimidine (**4g**) and 2-(3-pyridylthio)benzothiazole (**5g**), in 76% and 79% yields, respectively. 1-Phenylsulfonylindol-3-ylmagnesium bromide (**2h**)[8] also reacted with the thiocyanatoheteroarenes (**1a**, **1b**, **1c**), resulting in the formation of 2-(1-phenylsulfonylindol-3-ylthio)pyridine (**4h**), 2-(1-phenylsulfonylindol-3-ylthio)pyrimidine (**5h**), and 2-(1-phenylsulfonylindol-3-ylthio)benzothiazole (**6h**) in moderate to good yields.

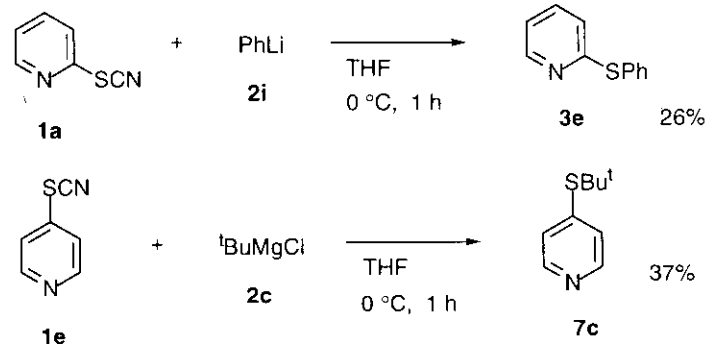
A useful method of synthesizing alkylthio- and arylthioheteroarenes, especially arylthioheteroarenes, from thiocyanatoheteroarene was thus developed by the use of cyanide-induced heteroarylthio cation formation. Compounds having two heteroarenes linked by a sulfur atom were easily obtained by this method.

Scheme 4



Thiocyanatoheteroarenes are considered to have three electron-deficient positions (**A**, **B**, and **C**) as shown in Scheme 4. However, Grignard reagents attack only the sulfur atom in this reaction. We considered that this regioselectivity is caused by the metal-chelating effect of the ring-nitrogen and the thiocyanato group. As shown in Scheme 4, the carbanion attacks the sulfur atom of the six-membered chelated intermediate. In this reaction, the presence of the ring-nitrogen at the α-position of the thiocyanato group and the affinity for the metal are important for the formation of a stable chelated intermediate, because the regioselectivity was low

Scheme 5



when 4-thiocyanatopyridine (**1e**) was treated with *tert*-butylmagnesium chloride (**2c**) or when 2-thiocyanatopyridine was treated with phenyllithium (**2i**). Namely, the reaction of 4-thiocyanatopyridine (**1e**) with *tert*-butylmagnesium chloride (**2c**) resulted in the formation of 4-*tert*-butylthiopyridine (**7c**) in only 37% yield. Phenyllithium (**2i**) reacted with 2-thiocyanatopyridine (**1a**) to give 2-phenylthiopyridine (**3e**), but again in low yield (26%). In these reactions, complex mixture was given together. It is known that magnesium is "softer" than lithium. To form a stable chelated intermediate, a "soft" metal and ring-nitrogen at the α-position of the thiocyanato group are appeared to be required.

In summary, we have found a facile preparative method for sulfides from thiocyanatoheteroarenes by the use of Grignard reagent. Arylthioheteroarenes and (heteroarylthio)heteroarenes are readily obtained by this reaction. By means of sequential electrophilic cyanation and Grignard reaction, arylthioheteroarenes can also be synthesized from heteroarenethiols.

EXPERIMENTAL

All melting points were measured without correction. IR spectra were recorded on a JASCO A-102 diffraction grating IR spectrophotometer. ^{1}H-NMR spectra were measured at 60 MHz on a JEOL PMX60SI NMR spectrometer and at 270 MHz on a JEOL JNM-GSX270 FT-NMR spectrometer. Chemical shifts are quoted in parts per million (ppm) with tetramethylsilane as an internal standard, and coupling constants (*J*) are given in Hz.

Reaction of Thiocyanatoheteroarene (1) with Grignard Reagent (2). General Procedure Exemplified by Synthesis of 2-Ethylthiopyridine (3a)

A solution of ethylmagnesium bromide (3.7 mL, 0.9 M solution in THF) was slowly added to a solution of 2-thiocyanatopyridine (**1a**, 3.0 mmol/3.0 mL of THF) under ice-H_2O cooling. The reaction mixture was stirred at 0 °C for 1 h, then the mixture was poured into NH_4Cl-NH_3 solution (2.0 g of NH_4Cl in 20 mL of H_2O and 5.0 mL of 30% NH_3), and the whole was extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with hexane and CH_2Cl_2. The fraction eluted with hexane-CH_2Cl_2(1:2) gave 2-ethylthiopyridine (**3a**). Alkylthio- and arylthioheteroarenes (**3**-**6**) were similarly obtained and purified by column chromatography on SiO_2 with hexane and CH_2Cl_2.

***2-Ethylthiopyridine* (3a)**

Yellow oil. MS (*m/z*): 139 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.42 (1H, d, *J* = 4.9 Hz, C^6-H), 7.49-6.93 (3H, m, aromatic H), 3.17 (2H, q, *J* = 7.3 Hz, CH_2), 1.33 (3H, t, *J* = 7.3 Hz, Me). Picrate:yellow needles (hexane-

AcOEt), mp 112 °C (lit.,[9] 113-114 °C).

2-Benzylthiopyridine (3b)

Yellow oil. ^{1}H-NMR ($CDCl_3$) δ: 8.45 (1H, d, J = 4.0 Hz, C^6-H), 7.63-6.80 (8H, m, aromatic H), 4.43 (2H, s, CH_2). Picrate: Yellow needles (hexane-AcOEt), mp 154-155 °C (lit.,[9] 155 °C).

2-*tert*-Butylthiopyridine (3c)

Yellow oil. MS (*m/z*): 167 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.51 (1H, d, J = 5.0 Hz, C^6-H), 7.54-7.05 (3H, m, aromatic H), 1.51 (9H, s, Me x 3).

2-Vinylthiopyridine (3d)

Yellow oil. MS (*m/z*): 136 ($M-1^+$). ^{1}H-NMR ($CDCl_3$) δ: 8.47 (1H, d, J = 4.1 Hz, C^6-H), 7.56-7.01 (3H, m, aromatic H), 7.12 (1H, dd, J = 17.0, 9.7 Hz, vinyl), 5.59 (1H, d, J = 17.0 Hz, vinyl), 5.52 (1H, d, J = 9.7 Hz, vinyl).

2-Phenylthiopyridine (3e)

Colorless oil. MS (*m/z*): 187 (M^+), 186 ($M-1^+$). ^{1}H-NMR ($CDCl_3$) δ: 8.40 (1H, d, J = 4.0 Hz, C^6-H), 7.73-6.73 (8H, m, aromatic H). Picrate: colorless needles (hexane-AcOEt), mp 139-140 °C (lit.,[10] 142-143 °C).

2-(4-Methylphenylthio)pyridine (3f)

Colorless scales (hexane-acetone), mp 51 °C. *Anal.* Calcd for $C_{12}H_{11}NOS$: C, 66.33; H, 5.10; N, 6.45. Found: C, 66.46; H, 5.27; N, 6.39. MS (*m/z*): 217 (M^+), 216 ($M-1^+$). ^{1}H-NMR ($CDCl_3$) δ: 8.35 (1H, d, J = 4.0 Hz, C^6-H), 7.67-6.65 (7H, m, aromatic H), 3.83 (3H, s, OMe).

2-Ethylthiopyrimidine (4a)

Yellow oil. (lit.,[11] $bp_{0.1}$ 62 °C). MS (*m/z*): 140 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.51 (2H, d, J = 5.1 Hz, C^4- and C^6-H), 6.95 (1H, t, J = 5.1 Hz, C^5-H), 3.16 (2H, q, J = 7.3 Hz, CH_2), 1.40 (3H, t, J = 7.3 Hz, Me).

2-Benzylthiopyrimidine (4b)

Colorless plates (MeOH), mp 56-57.5 °C (lit.,[11] 56 °C). MS (*m/z*): 202 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.43 (2H, d, J = 4.0 Hz, C^4- and C^6-H), 7.53-7.05 (5H, m, aromatic H), 6.88 (1H, t, J = 4.0 Hz, C^5-H), 4.38 (2H, s, CH_2). Picrate: Yellow plates (hexane-AcOEt), mp 145-146 °C. *Anal.* Calcd for $C_{17}H_{13}N_5O_7S$: C, 47.33; H, 3.04; N, 16.24. Found: C, 47.17; H, 2.88; N, 15.94.

2-*tert*-Butylthiopyrimidine (4c)

Colorless oil. MS (*m/z*): 168 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.50 (2H, d, J = 5.0 Hz, C^4- and C^6-H), 6.92 (1H, t, J = 5.0 Hz, C^5-H), 1.62 (9H, s, Me x 3).

2-Vinylthiopyrimidine (4d)

Yellow oil. MS (*m/z*): 137 ($M-1^+$). ^{1}H-NMR ($CDCl_3$) δ: 8.55 (2H, d, J = 4.9 Hz, C^4- and C^6-H), 7.26 (1H, dd, J = 17.4, 10.3 Hz, vinyl)), 7.02 (1H, t, J = 4.9 Hz, C^5-H), 560 (1H, d, J = 17.4 Hz, vinyl), 5.53 (1H, d, J = 10.3 Hz, vinyl).

2-Phenylthiopyrimidine (4e)

Colorless needles (petroleum benzine), mp 46 °C (lit.,[12] 45 °C). MS (*m/z*):188 (M^+), 187 ($M\text{-}1^+$). ^{1}H-NMR ($CDCl_3$) δ: 8.43 (2H, d, *J* = 5.0 Hz, C^4- and C^6-H), 7.73-7.17 (5H, m, aromatic H), 6.90 (1H, t, *J* = 5.0 Hz, C^5-H). Picrate: yellow needles (hexane-AcOEt), mp 106-108 °C.

2-(4-Methylphenylthio)pyrimidine (4f)

Colorless needles (hexane-MeOH), mp 75-76 °C. *Anal.* Calcd for $C_{11}H_{10}N_2OS$: C, 60.53; H, 5.10; N, 12.83. Found: C, 60.63; H, 4.67; N, 12.77. MS (*m/z*): 218 (M^+), 217 ($M\text{-}1^+$). ^{1}H-NMR ($CDCl_3$) δ: 8.41 (2H, d, *J* = 5.0 Hz, C^4- and C^6-H), 7.51 (2H, d, *J* = 9.0 Hz, aromatic H), 7.07-6.77 (3H, m, aromatic H), 3.80 (3H, s, OMe).

2-Ethylthiobenzothiazole (5a)

Yellow oil. (lit.,[13] mp 28 °C, bp_3 128 °C). MS (*m/z*): 195 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 7.88-7.23 (4H, m, aromatic H), 3.34 (2H, q, *J* = 7.3 Hz, CH_2), 1.47 (3H, t, *J* = 7.3 Hz, Me).

2-Benzylthiobenzothiazole (5b)

Colorless plates (petroleum benzine), mp 39-40 °C (lit.,[14] 40-41 °C). MS (*m/z*): 257 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.03-7.03 (9H, m, aromatic H), 4.56 (2H, s, CH_2). Picrate: Yellow plates (hexane-AcOEt), mp 112 °C.

2-*tert*-Butylthiobenzothiazole (5c)

Yellow oil. MS (*m/z*): 223 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 7.98-7.29 (4H, m, aromatic H), 1.59 (9H, s, Me x 3).

2-(Vinylthio)benzothiazole (5d)

Yellow oil. MS (*m/z*): 192 ($M\text{-}1^+$). ^{1}H-NMR ($CDCl_3$) δ: 7.92-7.26 (4H, m, aromatic H), 7.02 (1H, dd, *J* = 16.7, 9.7 Hz, vinyl), 5.73 (1H, d, *J* = 16.7 Hz, vinyl), 5.67 (1H, d, *J* = 9.7 Hz, vinyl).

2-Phenylthiobenzothiazole (5e)

Colorless oil (lit.,[15] bp_3 186-189 °C). MS (*m/z*): 243 (M^+), 242 ($M\text{-}1^+$). ^{1}H-NMR ($CDCl_3$) δ: 7.96-7.03 (9H, m, aromatic H).

2-(4-Methylphenylthio)benzothiazole (5f)

Colorless needles (hexane-MeOH), mp 61-62 °C. *Anal.* Calcd for $C_{14}H_{11}NOS_2$: C, 61.51; H, 4.06; N, 5.12. Found: C, 61.54; H, 4.13; N, 5.04. MS (*m/z*): 273 (M^+), 272 ($M\text{-}1^+$). ^{1}H-NMR ($CDCl_3$) δ: 7.95-6.83 (8H, m, aromatic H), 3.85 (3H, s, OMe).

4-Ethylthioquinazoline (6a)

Yellow oil. MS (*m/z*): 190 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.98 (1H, s, C^2-H), 8.09-7.54 (4H, m, aromatic H), 3.38 (2H, q, *J* = 7.3 Hz, CH_2), 1.46 (3H, t, *J* = 7.3 Hz, Me). Picrate: Yellow needles (MeOH), mp 181-182 °C (lit.,[16] 179-181 °C).

4-Benzylthioquinazoline (6b)

Colorless needles (hexane-acetone), mp 105-106 °C (lit.,[17] 103-104 °C). MS (*m/z*): 252 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.90 (1H, s, C^2-H), 8.10-7.10 (9H, m, aromatic H), 4.60 (2H, s, CH_2).

4-Vinylthioquinazoline (6d)

Yellow oil. MS (*m/z*): 187 ($M\text{-}1^+$). ^{1}H-NMR ($CDCl_3$) δ: 9.01 (1H, s, C^2-H), 8.03-7.57 (4H, m, aromatic H),

7.50 (1H, dd, J = 17.3, 10.0 Hz, vinyl), 5.75 (1H, d, J = 17.3 Hz, vinyl), 5.69 (1H, d, J = 10.0 Hz, vinyl).

4-Phenylthioquinazoline (6e)

Yellow needles (hexane-acetone), mp 116-117 °C. *Anal.* Calcd for $C_{14}H_{10}N_2S$: C, 70.56; H, 4.23; N, 11.76. Found: C, 70.49; H, 4.27; N, 11.71. MS (*m/z*): 238 (M^+), 237 (M-1$^+$). ^{1}H-NMR ($CDCl_3$) δ: 8.80 (1H, s, C^2-H), 8.30-7.20 (9H, m, aromatic H).

4-(4-Methylphenylthio)quinazoline (6f)

Colorless needles (hexane-AcOEt), mp 129 °C. *Anal.* Calcd for $C_{15}H_{12}N_2OS$: C, 67.14; H, 4.51; N, 10.44. Found: C, 67.15; H, 4.54; N, 10.46. MS (*m/z*): 268 (M^+), 267 (M-1$^+$). ^{1}H-NMR ($CDCl_3$) δ: 8.75 (1H, s, C^2-H), 8.27-6.80 (8H, m, aromatic H), 3.82 (3H, s, OMe).

Reaction of Thiocyanatoheteroarene (1) with Heteroarylmagnesium Bromide (2). General Procedure Exemplified by Synthesis of 2-(3-pyridylthio)pyridine (3g)

A solution of 3-pyridylmagnesium bromide (8.7 mL, 0.38 M solution in THF: prepared from 3-bromopyridine) was slowly added to a solution of 2-thiocyanatopyridine (**1a**, 3.0 mmol/3.0 mL of THF) under ice-H_2O cooling. The reaction mixture was stirred at 0 °C for 1 h, then the mixture was poured into NH_4Cl-NH_3 solution (2.0 g of NH_4Cl in 20 mL of H_2O and 5.0 mL of 30% NH_3), and the whole was extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with hexane and CH_2Cl_2. The fraction eluted with hexane-CH_2Cl_2(1:2) gave 2-(3-pyridylthio)pyridine (**3g**).

Diheteroaryl sulfides (**3-5**) were similarly obtained and purified by column chromatography on SiO_2 with hexane and CH_2Cl_2.

2-(3-Pyridylthio)pyridine (3g)

Colorless oil. MS (*m/z*): 187 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.77 (1H, s, 3-pyridyl, C^2-H), 8.63-7.00 (7H, m, aromatic H). Picrate (di): Yellow needles (hexane-acetone), mp 174-174.5 °C. *Anal.* Calcd for $C_{22}H_{14}N_8O_{12}S$: C, 46.05; H, 2.66; N, 16.78. Found: C, 45.90; H, 2.44; N, 16.83.

2-(1-Phenylsulfonylindol-3-ylthio)pyridine (3h)

Colorless plates (hexane-acetone), mp 108-110 °C. *Anal.* Calcd for $C_{19}H_{14}N_2O_2S_2$: C, 62.78; H, 3.85; N, 7.64. Found: C,62.48; H, 4.10; N, 7.63. MS (*m/z*): 366 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.41-6.67 (14H, m, aromatic H).

2-(3-Pyridylthio)pyrimidine (4g)

Colorless plates (hexane-acetone), mp 116-118 °C. *Anal.* Calcd for $C_9H_7N_3S$: C, 57.12; H, 3.73; N, 22.21. Found: C, 56.85; H, 3.64; N, 22.00. MS (*m/z*): 189 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.80 (1H, d, J = 1.7 Hz, 3-pyridyl C^2-H), 8.65 (1H, dd, J = 4.6, 1.7 Hz, 3-pyridyl C^4-H), 8.49 (2H, d, J = 5.0 Hz, C^4- and C^6-H),7.95 (1H, m, 3-pyridyl C^6-H), 7.39 (1H, dd, J = 7.9, 4.6 Hz, 3-pyridyl C^5-H), 7.02 (1H, t, J = 5.0 Hz, C^5-H).

2-(1-Phenylsulfonylindol-3-ylthio)pyrimidine (4h)

Colorless plates (hexane-acetone), mp 150-151 °C. *Anal.* Calcd for $C_{18}H_{13}N_3O_2S_2$: C, 58.88; H, 3.57; N, 11.44. Found: C, 58.91; H, 3.52; N, 11.33. MS (*m/z*): 367 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.43-6.95 (13H, m, aromatic H).

2-(3-Pyridylthio)benzothiazole (5g)

Colorless plates (hexane-acetone), mp 82-84 °C. *Anal.* Calcd for $C_{12}H_8N_2S_2$: C, 58.99; H, 3.30; N, 11.47. Found: C, 58.89; H, 3.16; N, 11.34. MS (*m/z*): 243 ($M-1^+$). ^{1}H-NMR ($CDCl_3$) δ: 8.92-7.27 (8H, m, aromatic H).

2-(1-Phenylsulfonylindol-3-ylthio)benzothiazole (5h)

Colorless plates (hexane-acetone), mp 136-138 °C. *Anal.* Calcd for $C_{21}H_{14}N_2O_2S_2$: C, 59.70; H, 3.34; N, 6.63. Found: C, 59.55; H, 3.24; N, 6.52. MS (*m/z*): 422 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.09-7.21 (14H, m, aromatic H).

Reaction of 2-Thiocyanatopyridine (1a) with Phenyllithium (2i).

A solution of a phenyllithium (3.3 mL, 1.0 M solution in hexane) was slowly added to a solution of 2-thiocyanatopyridine (**1a**, 3.0 mmol/3.0 mL of THF) under ice-H_2O cooling. The reaction mixture was stirred at 0 °C for 1 h, poured into NH_4Cl-NH_3 solution (2.0 g of NH_4Cl in 20 mL of H_2O and 5.0 mL of 30% NH_3), and extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with hexane and CH_2Cl_2. The fraction eluted with hexane-CH_2Cl_2(1:1) gave 2-(phenylthio)pyridine (**3e**) in 28 % (155 mg) yield.

Reaction of 4-Thiocyanatopyridine (1e) with *tert*-Butylmagnesium chloride (2c).

A solution of a *tert*-butylmagnesium chloride (**2c**, 8.7 mL, 0.38 M solution in THF) was slowly added to a solution of 4-thiocyanatopyridine (**1e**, 3.0 mmol/3.0 mL of THF) under ice-H_2O cooling. The reaction mixture was stirred at 0 °C for 1 h, poured into NH_4Cl-NH_3 solution (2.0 g of NH_4Cl in 20 mL of H_2O and 5.0 mL of 30% NH_3), and extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with hexane and AcOEt. The fraction eluted with hexane-AcOEt(1:2) gave 4-*tert*-butylthiopyridine (**7c**) in 37 % (187 mg) yield.

4-(*tert*-Butylthio)pyridine (**7c**): Yellow oil. MS (*m/z*): 167 (M^+). ^{1}H-NMR ($CDCl_3$) δ: 8.53 (2H, d, J = 4.6 Hz, C^2- and C^6-H), 7.39 (2H, d, J = 4.6 Hz, C^3- and C^5-H), 1.38 (9H, s, Me x 3). Picrate: Yellow needles (hexane-acetone), mp 151-153 °C. *Anal.* Calcd for $C_{15}H_{16}N_4O_7S$: C, 45.45; H, 4.07; N, 14.14. Found: C, 45.61; H, 4.20; N, 13.96.

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