Supporting Information

K$_2$S$_2$O$_8$-Promoted Direct Thiocyanation of Pyrazolin-5-ones with Ammonium Thiocyanate at Room Temperature

Xiaokang Mao,$^{a,b}$ Jiabin Ni,$^{b,c}$ Bin Xu*$^{a,d}$ and Chunyong Ding$^{*,b,c}$

$^a$Department of Chemistry, Innovative Drug Research Center, School of Materials Science and Engineering, Shanghai University, Shanghai 200444, People’s Republic of China.
$^b$CAS Key Laboratory of Receptor Research, and the State Key Laboratory of Drug Research, Shanghai Institute of Materia Medica (SIMM), Chinese Academy of Sciences, Shanghai 201203, China.
$^c$University of Chinese Academy of Sciences, Beijing 100049, China.
$^d$State Key Laboratory of Organometallic Chemistry, Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences, Shanghai 200032, People’s Republic of China.

*E-mail: chding@simm.ac.cn; xubin@shu.edu.cn

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1. General information

All reactions were performed in flame-dried glassware. Liquids and solutions were transferred with syringes. All solvents and chemical reagents were obtained from commercial sources and used without further purification. $^1$H and $^{13}$C NMR spectra were recorded with tetramethylsilane as an internal in CD$_3$OD or in CDCl$_3$. Mass analyses and HRMS were obtained by ESI on a TOF mass analyzer. Column chromatography on silica gel (200–300 mesh) was used for the routine purification of the reaction products. The column output was monitored by TLC on silica gel (100–200 mesh) precoated on glass plates (15 × 50 mm), and spots were visualized by UV light at 254 nm. Commercially available chemicals were obtained from Acros Organics, Alfa Aesar, Adamas-beta, and J&K. Starting materials (pyrazolones) were prepared according to the literature procedures.1, 2

2. General procedures for synthesis of C-4 thiocyanated pyrazoles 3

\[
\begin{align*}
\text{R}_1 \text{N} &+ \text{NH}_4\text{SCN} \\
\text{K}_2\text{S}_2\text{O}_8 \text{ (2 equiv)} &\text{MeCN, rt, overnight} \\
\text{R}_2 \text{N} &+ \text{NH}_4\text{SCN} \\
\end{align*}
\]

Acetonitrile (2 mL) was added to a mixture of pyrazolone 1 (0.2 mmol), ammonium thiocyanate 2 (0.6 mmol), and K$_2$S$_2$O$_8$ (0.4 mmol) in a 10 mL round-bottomed flask at room temperature. The reaction vessel was allowed to stir at room temperature overnight. After completion of the reaction, the resulting mixture was concentrated under vacuum and the residue was purified by silica gel column by using dichloromethane and methanol as a mixed eluent to provide the desired products 3a-u.

**Gram-scale synthesis of 3a:** Acetonitrile (30 mL) was added to a mixture of pyrazolone 1a (10 mmol, 1.74 g), ammonium thiocyanate 2 (30 mmol, 2.28 g),
K$_2$S$_2$O$_8$ (20 mmol, 5.4 g) in a 100 mL round-bottomed flask at room temperature. The reaction vessel was allowed to stir at room temperature overnight. After completion of the reaction, the resulting mixture was concentrated under vacuum and the resulting residue was purified by silica gel column using a mixture of dichloromethane and methanol as eluent to provide the desired product 3a (1.97 g, 85%).

3. Radical trapping experiments

![Chemical structure diagram]

Acetonitrile (2 mL) was added to a mixture of pyrazolone 1a (0.2 mmol), ammonium thiocyanate 2 (0.6 mmol), K$_2$S$_2$O$_8$ (0.4 mmol), TEMPO (62.5 mg, 2.0 equiv) or BQ (43.2 mg, 2.0 equiv) in a 10 mL round-bottomed flask at room temperature. The reaction vessel was allowed to stir at room temperature overnight. After completion of the reaction, the resulting mixture was concentrated under vacuum and the resulting residue was purified by silica gel column using a mixture of dichloromethane and methanol as eluent to provide the desired product 3a.
4. Characterization data of products 3a-3u

Methyl-1-phenyl-4-thiocyanato-1H-pyrazol-5-ol (3a). Compound 3a was obtained in 89% yield according to the general procedure. Yellow solid. $^1$H NMR (500 MHz, Chloroform-$d$) $\delta$ 10.54 (s, 1H), 7.35 (d, $J$ = 7.6 Hz, 2H), 7.24 (dd, $J$ = 12.6, 5.4 Hz, 2H), 7.20 (d, $J$ = 7.1 Hz, 1H), 2.29 (s, 3H). $^{13}$C NMR (126 MHz, Chloroform-$d$) $\delta$ 160.65, 151.38, 134.99, 129.11 (2C), 127.44, 122.07 (2C), 110.76, 82.20, 11.55. HRMS (ESI) calcd for C$_{11}$H$_8$N$_3$OS (M-H)- 230.0394, found 230.0388.

(4-Fluorophenyl)-3-methyl-4-thiocyanato-1H-pyrazol-5-ol (3b). Compound 3b was obtained in 82% yield according to the general procedure. Yellow solid. $^1$H NMR (500 MHz, Chloroform-$d$) $\delta$ 10.77 (s, 1H), 7.36 (dd, $J$ = 8.8, 4.6 Hz, 2H), 6.97 (t, $J$ = 8.4 Hz, 2H), 2.37 (s, 3H). $^{13}$C NMR (126 MHz, Chloroform-$d$) $\delta$ 162.25, 160.41 (d, $J_{CF}$ = 34.0 Hz), 151.58, 131.28 (d, $J_{CF}$ = 3.8 Hz), 124.26 (d, $J_{CF}$ = 8.8 Hz), 116.00 (d, $J_{CF}$ = 23.9 Hz), 110.88, 81.80, 11.70; $^{19}$F NMR (471 MHz, Methanol-$d_4$) $\delta$ -116.53 (s, 1F). HRMS (ESI) calcd for C$_{11}$H$_8$FN$_3$OS (M-H) 248.0299, found 248.0295.
1-(4-Chlorophenyl)-3-methyl-4-thiocyanato-1\textit{H}-pyrazol-5-ol (3c). Compound 3c was obtained in 77\% yield according to the general procedure. Yellow solid. $^1\text{H}$ NMR (500 MHz, Methanol-$d_4$) $\delta$ 7.64 (d, $J = 8.4$ Hz, 2H), 7.43 (d, $J = 8.4$ Hz, 2H), 2.34 (s, 3H). $^{13}\text{C}$ NMR (126 MHz, Methanol-$d_4$) $\delta$ 158.59, 151.42, 135.42, 131.29, 128.32 (2C), 122.38 (2C), 110.69, 79.10, 10.44. HRMS (ESI) calcd for C$_{11}$H$_7$ClN$_3$OS (M-H)$^-$ 264.0004, found 263.9998.

1-(4-Bromophenyl)-3-methyl-4-thiocyanato-1\textit{H}-pyrazol-5-ol (3d). Compound 3d was obtained in 94\% yield according to the general procedure. Yellow solid. $^1\text{H}$ NMR (500 MHz, Chloroform-$d$) $\delta$ 10.85 (s, 1H), 7.35 (d, $J = 8.4$ Hz, 2H), 7.27 (d, $J = 9.8$ Hz, 2H), 2.36 (s, 3H). $^{13}\text{C}$ NMR (126 MHz, Chloroform-$d$) $\delta$ 160.62, 152.17, 134.28, 132.18 (2C), 123.19 (2C), 120.70, 110.88, 82.14, 11.87. HRMS (ESI) calcd for C$_{11}$H$_7$BrN$_3$OS (M-H)$^-$ 307.9499, found 307.9495.

1-(4-(Tert-butyl)phenyl)-3-methyl-4-thiocyanato-1\textit{H}-pyrazol-5-ol (3e). Compound 3e was obtained in 71\% yield according to the general procedure. Yellow solid. $^1\text{H}$
NMR (400 MHz, Chloroform-d) δ 11.44 (s, 1H), 7.31 (d, J = 8.7 Hz, 2H), 7.27 (d, J = 9.9 Hz, 2H), 2.28 (s, 3H), 1.26 (s, 9H, -tBu). 
$^{13}$C NMR (126 MHz, Chloroform-d) δ 160.20, 150.35, 150.20, 131.92, 125.60 (2C), 121.33 (2C), 110.34, 34.19, 30.83, 10.97. HRMS (ESI) calcd for C$_{15}$H$_{16}$N$_{3}$OS (M-H)$^-$ 286.1020, found 286.1013.

1-(4-Methoxyphenyl)-3-methyl-4-thiocyanato-1H-pyrazol-5-ol (3f). Compound 3f was obtained in 78% yield according to the general procedure. Yellow solid. 
$^1$H NMR (400 MHz, Chloroform-d) δ 9.27 (s, 1H), 7.19 (d, J = 8.9 Hz, 2H), 6.74 (d, J = 9.0 Hz, 2H), 3.75 (s, 3H), 2.27 (s, 3H). 
$^{13}$C NMR (126 MHz, Chloroform-d) δ 160.43, 158.89, 150.50, 127.78, 124.42 (2C), 114.25 (2C), 110.93, 81.77, 55.52, 11.46. HRMS (ESI) calcd for C$_{12}$H$_{10}$N$_{3}$O$_{2}$S (M-H)$^-$ 260.0499, found 260.0497.

3-Methyl-4-thiocyanato-1-(4-(trifluoromethyl)phenyl)-1H-pyrazol-5-ol (3g). Compound 3g was obtained in 77% yield according to the general procedure. Yellow solid. 
$^1$H NMR (500 MHz, Methanol-d$_4$) δ 8.00 (d, J = 8.5 Hz, 2H), 7.71 (d, J = 8.5 Hz, 2H), 2.33 (s, 3H). 
$^{13}$C NMR (126 MHz, Methanol-d$_4$) δ 163.14, 153.88, 142.88, 127.79 (q, $J_{CF}$= 32.8 Hz), 126.95 (q, $J_{CF}$= 3.8 Hz, 2C), 124.53, 121.51 (2C), 113.39, 78.32, 12.70; 
$^{19}$F NMR (471 MHz, Methanol-d$_4$) δ -63.88 (s, 3F). HRMS (ESI) calcd for C$_{12}$H$_{7}$F$_{3}$N$_{3}$OS (M-H)$^-$ 298.0267, found 298.0262.
Ethyl 4-(5-hydroxy-3-methyl-4-thiocyanato-1H-pyrazol-1-yl)benzoate (3h).

Compound 3h was obtained in 78% yield according to the general procedure. Yellow solid. \( ^1\)H NMR (600 MHz, Methanol-\( d_4 \)) \( \delta \) 8.06 (d, \( J = 8.7 \) Hz, 2H), 7.87 (d, \( J = 8.8 \) Hz, 2H), 4.36 (q, \( J = 7.1 \) Hz, 2H), 2.35 (s, 3H), 1.39 (t, \( J = 7.1 \) Hz, 3H). \( ^{13}\)C NMR (151 MHz, Methanol-\( d_4 \)) \( \delta \) 165.59, 159.97, 152.19, 141.19, 129.63 (2C), 126.73, 119.43 (2C), 111.00, 78.34, 60.41, 12.81, 10.69. HRMS (ESI) calcd for C\(_{14}\)H\(_{14}\)N\(_3\)O\(_3\)S (M+H\(^+\)) 304.0750, found 304.0748.

3-Methyl-4-thiocyanato-1-(m-tolyl)-1H-pyrazol-5-ol (3i). Compound 3i was obtained in 81% yield according to the general procedure. Yellow solid. \( ^1\)H NMR (600 MHz, Methanol-\( d_4 \)) \( \delta \) 7.44 (d, \( J = 1.9 \) Hz, 1H), 7.42 – 7.38 (m, 1H), 7.33 (t, \( J = 7.8 \) Hz, 1H), 7.15 (d, \( J = 7.6 \) Hz, 1H), 2.38 (s, 3H), 2.36 (s, 3H). \( ^{13}\)C NMR (151 MHz, Methanol-\( d_4 \)) \( \delta \) 158.82, 150.84, 138.64, 136.33, 128.21, 127.01, 122.05, 118.63, 110.73, 79.35, 19.65, 10.24. HRMS (ESI) calcd for C\(_{12}\)H\(_{12}\)N\(_3\)OS (M+H\(^+\)) 246.0696, found 246.0699.

1-(3-Fluorophenyl)-3-methyl-4-thiocyanato-1H-pyrazol-5-ol (3j). Compound 3j was obtained in 82% yield according to the general procedure. Yellow solid. \( ^1\)H NMR
(500 MHz, Methanol-$d_4$) δ 7.53 (d, $J = 8.8$ Hz, 2H), 7.49 – 7.44 (m, 1H), 7.04 (td, $J = 8.1$, 2.0 Hz, 1H), 2.37 (s, 3H). $^{13}$C NMR (126 MHz, Methanol-$d_4$) δ 163.27, 161.33, 158.86, 151.68, 138.23 (d, $J_{CF}$ = 11.3 Hz), 129.81 (d, $J_{CF}$ = 10.1 Hz), 116.03 (d, $J_{CF}$ = 3.8 Hz), 112.25 (d, $J_{CF}$ = 21.4 Hz), 110.67, 107.75 (d, $J_{CF}$ = 26.5 Hz), 79.22, 10.42; $^{19}$F NMR (471 MHz, Methanol-$d_4$) δ -113.88 (s, 1F). HRMS (ESI) calcd for C$_{11}$H$_7$FN$_3$OS (M-H)$^-$ 248.0299, found 248.0293.

**1-(3-Chlorophenyl)-3-methyl-4-thiocyanato-1H-pyrazol-5-ol (3k).** Compound 3k was obtained in 79% yield according to the general procedure. Yellow solid. $^1$H NMR (500 MHz, Chloroform-$d$) δ 10.74 (s, 1H), 7.33 (dd, $J = 8.8$, 4.6 Hz, 2H), 6.94 (t, $J = 8.4$ Hz, 2H), 2.34 (s, 3H). $^{13}$C NMR (126 MHz, Chloroform-$d$) δ 162.25, 160.54, 151.58, 131.29, 124.29, 124.22, 116.10, 115.91, 110.88, 81.80, 11.70. HRMS (ESI) calcd for C$_{11}$H$_7$ClN$_3$OS (M-H)$^-$ 264.0004, found 263.9997.

**1-(3-Bromophenyl)-3-methyl-4-thiocyanato-1H-pyrazol-5-ol (3l).** Compound 3l was obtained in 82% yield according to the general procedure. Yellow solid. $^1$H NMR (500 MHz, Methanol-$d_4$) δ 7.91 (t, $J = 2.0$ Hz, 1H), 7.68 (ddd, $J = 8.1$, 2.1, 1.0 Hz, 1H), 7.45 – 7.42 (m, 1H), 7.35 (t, $J = 8.1$ Hz, 1H), 2.37 (s, 3H). $^{13}$C NMR (126 MHz, Methanol-$d_4$) δ 159.31, 152.21, 138.44, 130.28, 129.00, 123.84, 122.01, 119.59, 111.12, 79.69, 10.93. HRMS (ESI) calcd for C$_{11}$H$_7$BrN$_3$OS (M-H)$^-$ 307.9499, found 307.9492.
3-Methyl-4-thiocyanato-1-(o-tolyl)-1H-pyrazol-5-ol (3m). Compound 3m was obtained in 84% yield according to the general procedure. Yellow solid. $^1$H NMR (500 MHz, Chloroform-$d$) δ 10.73 (s, 1H), 7.26 (s, 1H), 7.16 (d, $J = 7.2$ Hz, 1H), 7.09 (td, $J = 7.6$, 1.5 Hz, 1H), 6.92 – 6.87 (m, 1H), 2.14 (s, 3H), 1.90 (s, 3H). $^{13}$C NMR (126 MHz, Chloroform-$d$) δ 161.03, 150.67, 136.32, 133.36, 131.14, 129.81, 127.60, 126.67, 111.05, 80.63, 17.64, 11.32. HRMS (ESI) calcd for C$_{12}$H$_{10}$N$_3$OS (M-H)$^- $ 244.0550, found 244.0545.

1-(2-Fluorophenyl)-3-methyl-4-thiocyanato-1H-pyrazol-5-ol (3n). Compound 3n was obtained in 82% yield according to the general procedure. Yellow solid. $^1$H NMR (500 MHz, Methanol-$d_4$) δ 7.49 – 7.44 (m, 2H), 7.29 (t, $J = 8.5$ Hz, 2H), 2.33 (s, 3H). $^{13}$C NMR (126 MHz, Methanol-$d_4$) δ 160.11, 157.75, 155.74, 151.42, 130.07 (d, $J_{CF} = 7.6$ Hz), 128.17, 124.04 (d, $J_{CF} = 3.8$ Hz), 115.84 (d, $J_{CF} = 18.9$ Hz), 111.03, 77.32, 10.44; $^{19}$F NMR (471 MHz, Methanol-$d_4$) δ -122.56 (s, 1F). HRMS (ESI) calcd for C$_{11}$H$_7$FN$_3$OS (M-H)$^- $ 248.0299, found 248.0293.
1-(3,4-Dimethylphenyl)-3-methyl-4-thiocyanato-1\textit{H}-pyrazol-5-ol (3o). Compound 3o was obtained in 83% yield according to the general procedure. Yellow solid. $^1$H NMR (500 MHz, Chloroform-$d$) $\delta$ 10.98 (s, 1H), 7.11 – 7.07 (m, 1H), 7.06 – 6.99 (m, 1H), 6.95 (d, $J$ = 8.1 Hz, 1H), 2.29 (s, 3H), 2.17 (s, 3H), 2.09 (s, 3H). $^{13}$C NMR (126 MHz, Chloroform-$d$) $\delta$ 160.52, 150.60, 137.56, 136.28, 132.63, 130.01, 123.39, 119.74, 110.80, 81.95, 19.74, 19.37, 11.42. HRMS (ESI) calcd for C$_{13}$H$_{14}$N$_3$OS (M+H)$^+$ 260.0852, found 260.0856.

![](image)

1-(3-Chloro-4-methylphenyl)-3-methyl-4-thiocyanato-1\textit{H}-pyrazol-5-ol (3p). Compound 3p was obtained in 95% yield according to the general procedure. Yellow solid. $^1$H NMR (500 MHz, Chloroform-$d$) $\delta$ 7.43 (d, $J$ = 2.2 Hz, 1H), 7.22 – 7.17 (m, 1H), 7.08 (d, $J$ = 8.4 Hz, 1H), 2.37 (s, 3H), 2.30 (s, 3H). $^{13}$C NMR (126 MHz, Chloroform-$d$) $\delta$ 160.53, 151.81, 135.07, 134.50, 134.04, 131.10, 122.15, 119.78, 111.03, 81.70, 19.65, 11.80. HRMS (ESI) calcd for C$_{12}$H$_{11}$ClN$_3$OS (M+H)$^+$ 280.0306, found 280.0332.

![](image)

1-(3,5-Dimethylphenyl)-3-methyl-4-thiocyanato-1\textit{H}-pyrazol-5-ol (3q). Compound 3q was obtained in 87% yield according to the general procedure. Yellow solid. $^1$H NMR (500 MHz, Chloroform-$d$) $\delta$ 6.94 (s, 2H), 6.81 (s, 1H), 2.32 (s, 3H), 2.15 (s, 6H, -2CH$_3$). $^{13}$C NMR (126 MHz, Chloroform-$d$) $\delta$ 160.46, 150.83, 138.92 (2C), 134.81,
129.17, 119.89 (2C), 110.70, 82.03, 21.17, 11.44. HRMS (ESI) calcd for C_{13}H_{14}N_{3}OS (M+H)^+ 260.0852, found 260.0857.

3-Methyl-1-(naphthalen-2-yl)-4-thiocyanato-1H-pyrazol-5-ol (3r). Compound 3r was obtained in 87% yield according to the general procedure. Yellow solid. \(^1\)H NMR (500 MHz, Methanol-\(d_4\)) \(\delta\) 8.09 (d, \(J = 2.1\) Hz, 1H), 7.96 (d, \(J = 8.8\) Hz, 1H), 7.93 – 7.89 (m, 2H), 7.80 (dd, \(J = 8.8, 2.2\) Hz, 1H), 7.53 (ddd, \(J = 7.5, 5.6, 1.8\) Hz, 2H), 2.41 (s, 3H). \(^{13}\)C NMR (126 MHz, Methanol-\(d_4\)) \(\delta\) 148.47, 140.95, 123.56, 122.59, 121.27, 118.00, 116.97, 116.69, 115.89, 115.36, 109.67, 108.92, 100.36, 69.42, 8.64. HRMS (ESI) calcd for C_{15}H_{12}N_{3}OS (M+H)^+ 282.0696, found 282.0699.

Ethyl-1-phenyl-4-thiocyanato-1H-pyrazol-5-ol (3s). Compound 3s was obtained in 94% yield according to the general procedure. Yellow solid. \(^1\)H NMR (400 MHz, Chloroform-\(d\)) \(\delta\) 10.39 (s, 1H), 7.31 (d, \(J = 7.5\) Hz, 2H), 7.20 (d, \(J = 8.0\) Hz, 3H), 2.67 (q, \(J = 7.6\) Hz, 2H), 1.25 (t, \(J = 7.6\) Hz, 3H). \(^{13}\)C NMR (126 MHz, Chloroform-\(d\)) \(\delta\) 160.71, 156.45, 134.97, 129.02 (2C), 127.37, 122.15 (2C), 111.01, 81.30, 19.83, 12.52. HRMS (ESI) calcd for C_{12}H_{10}N_{3}OS (M-H)^− 244.0550, found 244.0547.
1,3-Diphenyl-4-thiocyanato-1H-pyrazol-5-ol (3t). Compound 3t was obtained in 93% yield according to the general procedure. Yellow solid. \(^1\)H NMR (400 MHz, Chloroform-\(d\)) \(\delta\) 9.53 (s, 1H), 7.65 – 7.57 (m, 2H), 7.45 – 7.36 (m, 3H), 7.30 (d, \(J = 7.6\) Hz, 2H), 7.20 (dt, \(J = 14.3, 7.1\) Hz, 3H). \(^{13}\)C NMR (126 MHz, Chloroform-\(d\)) \(\delta\) 159.27, 152.29, 135.65, 130.46, 129.00, 128.82, 128.44, 128.31, 127.52, 122.33, 111.62, 80.48. HRMS (ESI) calcd for C\(_{16}\)H\(_{10}\)N\(_3\)OS (M-H) 292.0550, found 292.0544.

Isopropyl-4-thiocyanato-1-(m-tolyl)-1H-pyrazol-5-ol (3u). Compound 3u was obtained in 89% yield according to the general procedure. Yellow solid. \(^1\)H NMR (500 MHz, Methanol-\(d_4\)) \(\delta\) 7.64 (d, \(J = 8.0\) Hz, 2H), 7.48 (t, \(J = 7.8\) Hz, 2H), 7.37 – 7.32 (m, 1H), 3.25 (p, \(J = 7.0\) Hz, 1H), 1.40 (d, \(J = 7.2\) Hz, 6H). \(^{13}\)C NMR (126 MHz, Methanol-\(d_4\)) \(\delta\) 159.38, 158.40, 136.51, 128.29, 126.45, 122.08, 111.06, 77.73, 26.84, 19.61. HRMS (ESI) calcd for C\(_{13}\)H\(_{14}\)N\(_3\)OS (M+H)\(^+\) 260.0852, found 260.0853.

5. Reference

6. Copies of NMR spectra for compounds 3a–3u
$^{19}$F NMR spectrum of 3b:
$^{19}$F NMR spectrum of 3g:
$^{19}$F NMR spectrum of 3j:
19F NMR spectrum of 3n: