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SYNTHESIS OF *N,N*-DIALKYL-5(or 10)-OXOBENZO[*b*][1,8 or 1,7(or 1,6)]NAPHTHYRIDINE-10(5*H*)(or 5(10*H*))-CARBOTHIOAMIDES BASED ON THE REACTION OF THE RESPECTIVE (CHLOROPYRIDINYL)(2-ISOTHIOCYANATOPHENYL)METHANONES WITH SECONDARY AMINES

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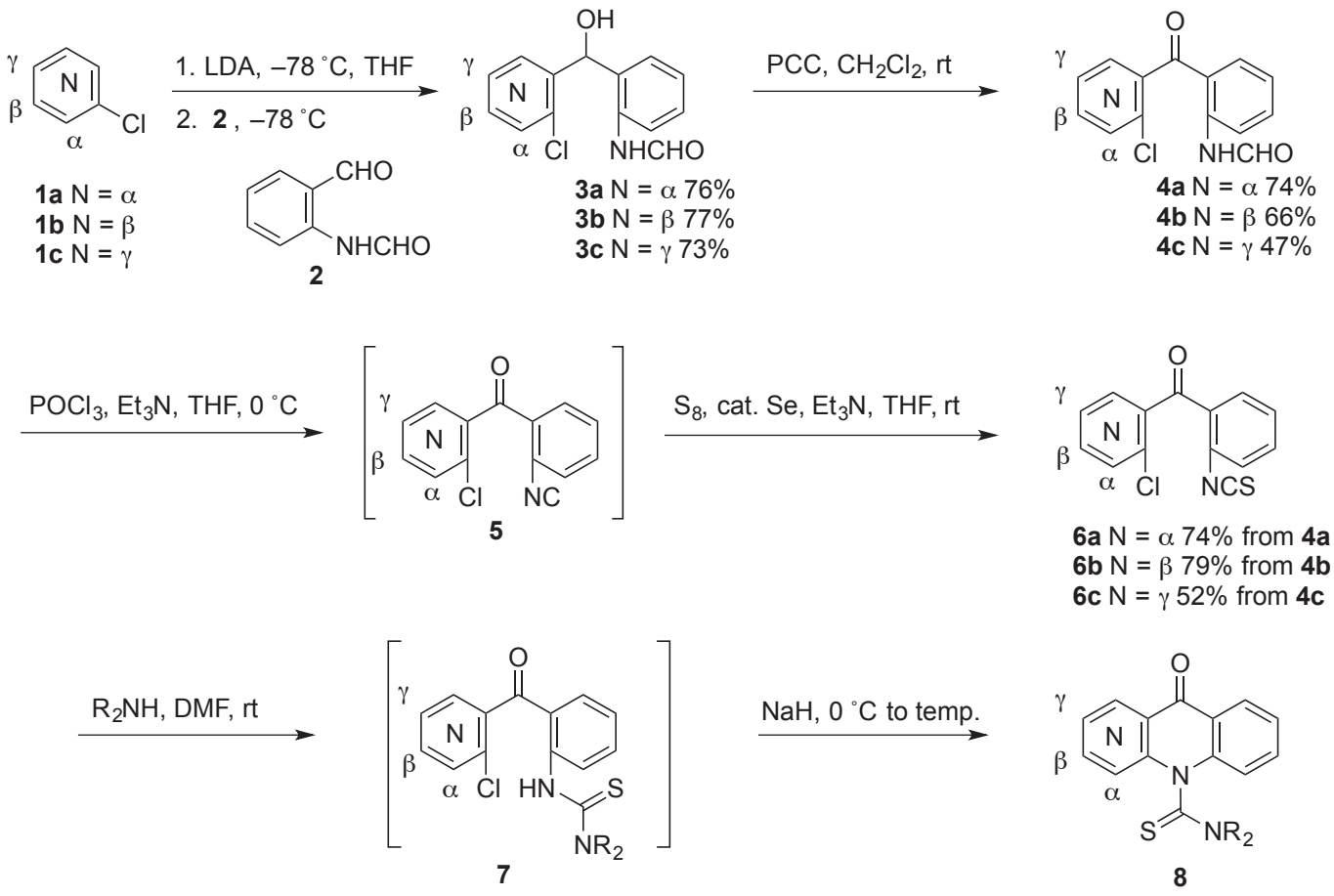
Abstract – The addition of secondary amines to (2-chloropyridin-3-yl)(2-isothiocyanatophenyl)methanone, derived from 2-chloropyridine and *N*-(2-formylphenyl)formamide, followed by treatment of the resulting thiourea intermediates with sodium hydride has proven to provide a method for the synthesis of *N,N*-dialkyl-5-oxobenzo[*b*][1,8]naphthyridine-10(5*H*)-carbothioamides. Similarly, *N,N*-dialkyl-5-oxobenzo[*b*][1,7]naphthyridine-10(5*H*)-carbothioamides and *N,N*-dialkyl-10-oxobenzo[*b*][1,6]naphthyridine-5(10*H*)-carbothioamides can be prepared from the respective (chloropyridinyl)(2-isothiocyanatophenyl)methanones.

Previous work from our laboratory has established that the addition of secondary amines to (2-halophenyl)(2-isothiocyanatophenyl)methanones, followed by treatment of the resulting thiourea intermediates with sodium hydride, leads to a general approach to the synthesis of *N,N*-disubstituted 9-oxo-10*H*-acridine-10-carbothioamides.[1] We envisaged that a similar sequence using (chloropyridinyl)(2-isothiocyanatophenyl)methanones could provide access to aza-analogues of these derivatives. In this paper, we wish to describe the results of an extensive study of this methodology, which offer the first entry to *N,N*-dialkyl-5(or 10)-oxobenzo[*b*][1,8 or 1,7(or 1,6)]naphthyridine-10(5*H*)(or 5(10*H*))-carbothioamides. Several methods for the synthesis of benzo[*b*]naphthyridinone derivatives have been reported,[2] because they are interesting from a biological point of view.[3] However, there have

been so far no reports on methods for the synthesis of these oxobenzo[*b*]naphthyridinecarbothioamide derivatives, which are of potential biological interest as well.

The synthesis of *N,N*-disubstituted oxobenzo[*b*]naphthyridinecarbothioamides (**8**) from chloropyridines (**1**) was conducted according to the sequence illustrated in Scheme 1. Thus, the reaction of lithiated chloropyridines[4] with *N*-(2-formylphenyl)formamide, followed by the PCC oxidation of the resulting alcohols (**3**) led to the formation of *N*-{[2-(chloropyridinyl)carbonyl]phenyl}formamides (**4**). These formamides (**4**) were dehydrated with phosphorous oxychloride in the presence of triethylamine to afford the corresponding isocyanides (**5**), which, without any purification, were subjected to the treatment with sulfur in the presence of a catalytic amount of selenium under the Fujiwara's conditions[5] to afford (chloropyridinyl)(2-isothiocyanatophenyl)methanones (**6**) in satisfactory yields from **4**. It should be noted that compounds (**4c**) and (**6c**), derived from 4-chloropyridine, were rather unstable. So, it must be used immediately after purification in the next steps.



Scheme 1

First, *N,N*-dialkyl-5-oxobenzo[*b*][1,8]naphthyridine-10(5*H*)-carbothioamides (**8a-c**) were prepared in one-pot from (2-chloropyridin-3-yl)(2-isothiocyanatophenyl)methanone (**6a**). Thus, **6a** was allowed to

react with secondary amines in DMF at room temperature to resulted in the immediate formation of the corresponding thiourea derivatives (**7**) (N = α position), which on treatment with sodium hydride at the same temperature underwent smooth ring closure to give the desired products in good yields (Table 1, Entries 1–3).

Table 1. Preparation of oxobenzo[*b*]naphthyridinecarbothioamides (**8**)

Entry	**6**	R_2NH	Temp	**8**	Yield/%[a]
1	**6a** (N = α)	Et_2NH	rt	**8a**	78
2	**6a**	pyrrolidine	rt	**8b**	83
3	**6a**	piperidine	rt	**8c**	85
4	**6b** (N = β)	Et_2NH	80 ˚C	**8d**	65
5	**6b**	pyrrolidine	80 ˚C	**8e**	62
6	**6b**	morpholine	100 ˚C	**8f**	58
7	**6c** (N = γ)	Et_2NH	rt	**8g**	49
8	**6c**	pyrrolidine	rt	**8h**	35
9	**6c**	morpholine	rt	**8i**	44

[a] Yields of isolated products.

Next, *N*,*N*-dialkyl-5-oxobenzo[*b*][1,7]naphthyridine-10(5*H*)-carbothioamides (**8d-f**) could similarly be synthesized from (3-chloropyridin-4-yl)(2-isothiocyanatophenyl)methanone (**6b**). The addition of secondary amines to **6b** also completed immediately. However, the cyclization of the resulting thiourea intermediates (**7**) (N = β-position) with sodium hydride was very reluctant at room temperature and the higher temperatures (80 to 100 ˚C) were needed for satisfactory progress. Therefore, the yields of the desired products were somewhat lower than those of **8a-c** (Entries 4–6).

Subsequently, the successive treatment of (4-chloropyridin-3-yl)(2-isothiocyanatophenyl)methanone (**6c**) with secondary amines and sodium hydride was carried out to obtain the corresponding *N*,*N*-dialkyl-10-oxobenzo[*b*][1,6]naphthyridine-5(10*H*)-carbothioamides (**8g-i**). When **6c** was treated with secondary amines under the same conditions, a few spots, resulted from other than the expected thiourea derivative, were observed by TLC analyses in each case. After addition of sodium hydride, the intermediates were consumed smoothly at room temperature. However, these reactions resulted in the formation of rather complicated mixtures of products, from which only low-to-moderate yields of the desired products could be isolated (Entries 7–9). This may presumably be due to the instability of **6c** as stated above.

In conclusion, the method described here enables us to synthesize three types of oxobenzo[*b*] naphthyridinecarbothioamides from the respective chloropyridines by essentially same operations. As these derivatives are hard to prepare by previous methods and of potentially biological interest, the present method may be of value in organic synthesis.

EXPERIMENTAL

All melting points were obtained on a Laboratory Devices MEL-TEMP II melting apparatus and are uncorrected. IR spectra were recorded with a Perkin–Elmer Spectrum65 FTIR spectrophotometer. ^{1}H NMR spectra were recorded in $CDCl_3$ using TMS as an internal reference with a JEOL ECP500 FT NMR spectrometer operating at 500 MHz or a JEOL LA400FT NMR spectrometer operating at 400 MHz. ^{13}C NMR spectra were recorded in $CDCl_3$ using TMS as an internal reference with a JEOL ECP500 FT NMR spectrometer operating at 125 MHz. High-resolution MS spectra (DART, positive) were measured by a Thermo Scientific Exactive spectrometer. TLC was carried out on Merck Kieselgel 60 PF_{254}. Column chromatography was performed using WAKO GEL C-200E. All of the organic solvents used in this study were dried over appropriate drying agents and distilled prior to use.

Starting Materials. *n*-BuLi was supplied by Asia Lithium Corporation. All other chemicals used in this study were commercially available.

***N*-[2-(Hydroxymethyl)phenyl]formamide.** A solution of (2-aminophenyl)methanol (11 g, 86 mmol) in HCO_2Et (70 mL) was heated at reflux temperature for 45 h. After evaporation of excess HCO_2Et, the residue was purified by column chromatography on silica gel (AcOEt/hexane 1:2) to give the desired product (9.7 g, 75%); a white solid; mp 76–79 °C (hexane/CH_2Cl_2) (lit.,[6] 79–80 °C). Spectral (IR and ^{1}H NMR) data for this compound were identical to those reported previously.[6]

***N*-(2-Formylphenyl)formamide (2).** A mixture of the above alcohol (0.91 g, 6.0 mmol) and PCC (2.6 g, 12 mmol) in CH_2Cl_2 (65 mL) containing Celite 545 (12 g) was stirred at rt for 30 min. The mixture was filtered under reduced pressure, and the filtrate was concentrated by evaporation and subjected to purification by column chromatography on silica gel (THF/hexane 1:4) to give **2** (0.65 g, 73%); a white solid; mp 75–76 °C (hexane–CH_2Cl_2) (lit.,[7] 75–77 °C). Spectral (IR and ^{1}H NMR) data for this compound were identical to those reported previously.[7]

Typical Procedure for the Preparation of *N*-{[2-(Chloropyridinyl)hydroxymethyl]-phenyl}formamides (3). *N*-{[2-(2-Chloropyridin-3- yl)hydroxymethyl]phenyl}formamide (3a). To a stirred solution of LDA (5.0 mmol), generated by the standard conditions from *n*-BuLi and *i*-Pr_2NH, in THF (5 mL) at –78 °C was added a solution of 2-chloropyridine (0.23 g, 2.0 mmol) dropwise.[4] After 1.5 h, a solution of **2** (0.15 g, 1.0 mmol) in THF (2 mL) was added and stirring was continue at the same temperature for an additional 15 min before saturated aqueous NH_4Cl (10 mL) was added. The mixture was warned to rt and extracted with AcOEt (3 × 10 mL). The combined extracts were washed with brine (15 mL), dried (Na_2SO_4), and concentrated by evaporation. The residue was purified by column chromatography on silica gel to give **3a** (0.20 g, 76%); an orange oil; R_f 0.30 (AcOEt/hexane 1:4); IR (neat) 3320, 1677 cm^{-1}; ^{1}H NMR (400 MHz) δ 2.23 and 2.73 (2s, combined 1H), 6.14 and 6.23 (combined 1H), 6.70–9.41 (m, 9H); ^{13}C NMR δ 69.38, 69.67, 121.26, 122.83, 124.39, 125.83, 126.03,

128.25, 128.79, 128.85, 129.35, 132.04, 132.51, 134.79, 135.61, 136.33, 136.40, 137.47, 137.53, 148.33, 148.33, 148.47, 149.16, 149.38, 160.56, 163.24. Anal. Calcd for $C_{13}H_{11}ClN_2O_2$: C, 59.44; H, 4.22; N, 10.66. Found: C, 59.39; H, 4.29; N, 10.37.

***N*-{[2-(3-Chloropyridin-4-yl)hydroxymethyl]phenyl}formamide (3b):** a yellow oil; R_f 0.36 (AcOEt/hexane 1:2); IR (neat) 3300, 1682 cm^{-1}; ^1H NMR (400 MHz) δ 3.81 and 4.19 (2d, J = 4.6 Hz each, combined 1H), 6.11 and 6.22 (2d, J = 4.6 Hz each, combined 1H), 6.92–8.79 (m, 9H). Anal. Calcd for $C_{13}H_{11}ClN_2O_2$: C, 59.44; H, 4.22; N, 10.66. Found: C, 59.30; H, 4.38; N, 10.64.

***N*-{[2-(4-Chloropyridin-3-yl)hydroxymethyl]phenyl}formamide (3c):** a yellow oil; R_f 0.23 (AcOEt/hexane 1:2); IR (neat) 3306, 1679 cm^{-1}; ^1H NMR (400 MHz) δ 3.9–4.5 (br, 1H), 6.22 and 6.30 (2s, combined 1H), 6.90–8.83 (m, 9H). Anal. Calcd for $C_{13}H_{11}ClN_2O_2$: C, 59.44; H, 4.22; N, 10.66. Found: C, 59.25; H, 4.20; N, 10.68.

Typical Procedure for the Preparation of *N*-{[2-(Chloropyridinyl)carbonyl]phenyl}formamides (4).

***N*-{[2-(2-Chloropyridin-3-yl)carbonyl]phenyl}formamide (4a).** Compound (**3a**) (0.15 g, 0.56 mmol) was oxidized with PCC (0.24 g, 1.1 mmol) in CH_2Cl_2 (6 mL) containing Celite 545 (1.1 g) as described for the preparation of **2** to give **4a** (86 mg, 59%); a white solid; mp 149–151 ˚C (hexane/CH_2Cl_2); IR (KBr) 3277, 1695, 1638 cm^{-1}; ^1H NMR (500 MHz) δ 7.10–11.36 (m, 9H); ^{13}C NMR δ 120.94, 121.61, 122.24, 123.10. 134.16, 134.85, 136.35, 137.34. 140.78. 147.19, 150.91, 159.86, 196.86. Anal. Calcd for $C_{13}H_9ClN_2O_2$: C, 59.90; H, 3.48; N, 10.75. Found: C, 59.70; H, 3.52; N, 10.43.

***N*-{[2-(3-Chloropyridin-4-yl)carbonyl]phenyl}formamide (4b):** a white solid; mp 146–147 ˚C (hexane/CH_2Cl_2); IR (KBr) 3288, 1694, 1644 cm^{-1}; ^1H NMR (500 MHz) δ 7.09–11.31 (m, 9H). Anal. Calcd for $C_{13}H_9ClN_2O_2$: C, 59.90; H, 3.48; N, 10.75. Found: C, 59.61; H, 3.53; N, 10.70.

***N*-{[2-(4-Chloropyridin-2-yl)carbonyl]phenyl}formamide (4c):** a white solid; mp 109–110 ˚C (hexane/CH_2Cl_2); IR (KBr) 3287, 1702, 1644, 1604 cm^{-1}; ^1H NMR (500 MHz) δ 7.10–11.32 (m, 9H). HR MS. Calcd for $C_{13}H_{10}ClN_2O_2$ (M+H): 261.0431. Found: *m/z* 261.0427.

Typical Procedure for the Preparation of (Chloropyridinyl)(2-isothiocyanatophenyl)methanones (6).

(2-Chloropyridin-3-yl)(2-isothiocyanatophenyl)methanone (6a). To a stirred solution of **4a** (86 mg, 0.33 mmol) in THF (2 mL) containing Et_3N (0.23 g, 2.3 mmol) at 0 ˚C was added $POCl_3$ (76 mg, 0.50 mmol) dropwise.[8] After 15 min, saturated aqueous $NaHCO_3$ (10 mL) was added and the mixture was extracted with AcOEt (3 × 10 mL). The combined extracts were washed with brine (15 mL), dried (Na_2SO_4), and concentrated by evaporation. The residual crude isocyanide (**5a**) was dissolved in THF (2 mL), and Et_3N (0.11 mL), S_8 (11 mg, 0.33 mmol), and Se (2.6 mg, 0.033 mmol) were added.[5] The mixture was stirred overnight at rt and the precipitate was filtered off. The filtrate was concentrated by evaporation and the residue was purified by column chromatography on silica gel to give **6a** (67 mg, 74%); a brown oil; R_f 0.33 (AcOEt/hexane 1:2); IR (neat) 2106, 1674 cm^{-1}; ^1H NMR (400 MHz) δ

7.36–7.40 (m, 2H), 7.44 (dd, *J* = 7.8, 4.9 Hz, 1H), 7.59 (t, *J* = 7.8 Hz, 1H), 7.66 (dd, *J* = 7.8, 2.0 Hz, 1H), 7.88 (dd, *J* = 7.8, 2.0 Hz, 1H), 8.56 (dd, *J* = 4.9, 2.0 Hz, 1H). Anal. Calcd for $C_{13}H_7ClN_2OS$: C, 56.83; H, 2.57; N, 10.20. Found: C, 56.75; H, 2.64; N, 10.05.

(3-Chloropyridin-4-yl)(2-isothiocyanatophenyl)methanone (6b): a brown oil; R_f 0.44 (AcOEt/hexane 1:2); IR (neat) 2106, 1678 cm^{-1}; ^1H NMR (400 MHz) δ 7.35 (d, *J* = 4.6 Hz, 1H), 7.37–7.41 (m, 2H), 7.61 (td, *J* = 7.4, 1.1 Hz, 1H), 7.67 (dd, *J* = 7.4, 1.1 Hz, 1H), 8.68 (d, *J* =4.6 Hz, 1H), 8.74 (s. 1H). Anal. Calcd for $C_{13}H_7ClN_2OS$: C, 56.83; H, 2.57; N, 10.20. Found: C, 56.70; H, 2.43; N, 10.10.

(4-Chloropyridin-3-yl)(2-isothiocyanatophenyl)methanone (6c): a brown oil; R_f 0.26 (AcOEt/hexane 1:2); IR (neat) 2104, 1670 cm^{-1}; ^1H NMR (400 MHz) δ 7.35–7.40 (m, 2H), 7.45 (d, *J* = 5.9 Hz, 1H), 7.59 (td, *J* = 7.8, 2.0 Hz, 1H), 7.65 (d, *J* = 7.8 Hz, 1H), 8.64 (d, *J* = 5.9 Hz, 1H), 8.69 (s, 1H). HR MS. Calcd for $C_{13}H_8ClN_2OS$ (M+H): 275.0046. Found: *m/z* 275.0419.

Typical Procedure for the Preparation of *N,N*-Disubstituted Oxobenzonaphthyridine-carbothioamides (8). *N,N*-Diethyl-5-oxobenzo[*b*][1,8]naphthyridine-10(5*H*)- carbothioamide (8a). To a stirred solution of **6a** (62 mg, 0.22 mmol) in DMF (2 mL) was added Et_2NH (16 mg, 0.22 mmol) dropwise. After 15 min, the mixture was cooled to 0 ˚C and NaH (60% in mineral oil; 9.0 mg, 0.22 mmol) was added. The mixture was warmed to rt and stirring was continued for 1 h before water (10 mL) was added. The resulting mixture was extracted with AcOEt (3 × 10 mL), and the combined extracts were washed with brine (15 mL) and dried (Na_2SO_4). After evaporation of the solvent, the residual solid was recrystallized from hexane/Et_2O to give **8a** (0.47 g, 68%): a pale-yellow solid; mp 190–191 ˚C; IR (KBr) 1650, 1606, 1263 cm^{-1}; ^1H NMR (500 MHz) δ 1.04 (t, *J* = 7.4 Hz, 3H), 1.61 (t, *J* = 7.4 Hz, 3H), 3.33–3.38 (m, 2H), 4.15–4.22 (m, 1H), 4.33–4.40 (m, 1H), 7.31 (dd, *J* = 8.0, 4.6 Hz, 1H, 7-H), 7.38 (dd, *J* = 8.0, 7.4 Hz, 1H, 3-H), 7.49 (d, *J* = 8.6 Hz, 1H, 1-H), 7.74 (ddd, *J* = 8.6, 7.4, 1.1 Hz, 1H, 2-H), 8.50 (dd, *J* = 8.0, 1.7 Hz, 1H, 6-H), 8.75–8.78 (m, 2H, 4- and 8-H); ^{13}C NMR δ 10.50, 13.08, 47.16, 47.79, 116.62, 116.80, 118.77, 122.28, 123.09, 127.47, 134.45, 136.67, 139.49, 149.39, 153.98, 178.28, 180.35. HR MS. Calcd for $C_{17}H_{18}N_3OS$ (M+H): 312.1170. Found: *m/z* 312.1148. Anal. Calcd for $C_{17}H_{17}N_3OS$: C, 65.57; H, 5.50; N, 13.49. Found: C, 65.70; H, 5.57; N, 13.40.

10-(Pyrrolidin-1-ylcarbonothioyl)benzo[*b*][1,8]naphthyridin-5(10*H*)-one (8b): a yellow solid; mp 182–184 ˚C (hexane/Et_2O); IR (KBr) 1645, 1607, 1265 cm^{-1}; ^1H NMR (500 MHz) δ 1.94–2.05 (m, 2H), 2.16–2.21 (m, 2H), 3.29–3.32 (m, 2H), 4.08–4.14 (m, 1H), 4.23–4.29 (m, 1H), 7.32 (dd, *J* = 7.4, 4.6 Hz, 1H), 7.39 (dd, *J* = 8.0, 6.9 Hz, 1H), 7.49 (d, *J* = 8.0 Hz, 1H), 7.75 (ddd, *J* = 8.6, 6.9, 1.1 Hz, 1H), 8.51 (dd, *J* = 8.0, 1.1 Hz, 1H), 8.76–8.79 (m, 2H); ^{13}C NMR δ 24.82, 25.84, 51.41, 53.74, 116.21, 116.78, 118.65, 122.24, 123.09, 127.56, 134.65, 136.83, 138.61, 148.79, 154.14, 177.56, 178.22. HR MS. Calcd for $C_{17}H_{16}N_3OS$ (M+H): 310.1014. Found: *m/z* 310.1000. Anal. Calcd for $C_{17}H_{15}N_3OS$: C, 66.00; H, 4.89; N, 13.58. Found: C, 65.90; H, 4.98; N, 13.28.

10-(Piperidin-1-ylcarbonothioyl)benzo[*b*][1,8]naphthyridin-5(10*H*)-one (8c): a yellow solid; mp 175–177 °C (hexane/CH_2Cl_2); IR (KBr) 1648, 1606, 1263 cm^{-1}; ^1H NMR (500 MHz) δ 1.39–1.45 (m, 1H), 1.58–1.65 (m, 1H), 1.67–1.79 (m, 2H), 1.88–1.96 (m, 1H), 2.03–2.09 (m, 1H), 3.31–3.36 (m, 1H), 3.43–3.47 (m, 1H), 4.33–4.38 (m, 1H), 4.69–4.74 (m, 1H), 7.32 (dd, *J* = 7.4, 4.6 Hz, 1H), 7.39 (d, *J* = 8.0, 7.4 Hz, 1H), 7.54 (d, *J* = 8.6 Hz, 1H), 7.75 (ddd, *J* = 8.6, 7.4, 1.1 Hz, 1H), 8.50 (dd, *J* = 8.0, 1.1 Hz, 1H), 8.76–8.79 (m, 2H); ^{13}C NMR δ 23.76, 25.29, 26.25, 51.11, 51.81, 116.62, 116.67, 118.73, 122.20, 123.08, 127.43, 134.52, 136.71, 139.04, 149.10, 154.05, 178.19, 179.26. HR MS. Calcd for $C_{18}H_{18}N_3OS$ (M+H): 324.1170. Found: *m/z* 324.1167. Anal. Calcd for $C_{18}H_{17}N_3OS$: C, 66.85; H, 5.30; N, 12.99. Found: C, 66.77; H, 5.19; N, 12.72.

***N*,*N*-Diethyl-5-oxobenzo[*b*][1,7]naphthyridine-10(5*H*)-carbothioamide (8d):** a yellow solid; mp 137–139 °C (hexane/CH_2Cl_2); IR (KBr) 1650, 1605, 1263 cm^{-1}; ^1H NMR (400 MHz) δ 1.02 (t, *J* = 7.8 Hz, 3H), 1.63 (t, *J* = 6.9 Hz, 3H), 3.33 (q, *J* = 6.9 Hz, 2H), 4.20–4.31 (m, 2H), 7.38–7.44 (m, 2H, 1- and 3-H), 7.76 (dd, *J* = 8.8, 6.9 Hz, 1H, 2-H), 8.26 (d, *J* = 4.9 Hz, 1H, 6-H), 8.51 (dd, *J* = 8.8, 2.0 Hz, 1H, 4-H), 8.59 (d, *J* = 4.9 Hz, 1H, 7-H), 8.95 (s, 1H, 9-H); ^{13}C NMR δ 10.43, 13.59, 47.30, 47.99, 115.94, 118.69, 122.13, 123.31, 125.53, 127.62, 133.96, 134.93, 139.04, 139.98, 142.30, 177.20, 178.62. HR MS. Calcd for $C_{17}H_{18}N_3OS$ (M+H): 312.1170. Found: *m/z* 312.1153. Anal. Calcd for $C_{17}H_{17}N_3OS$: C, 65.57; H, 5.50; N, 13.49. Found: C, 65.41; H, 5.48; N, 13.20.

10-(Pyrrolidin-1-ylcarbonothioyl)benzo[*b*][1,7]naphthyridin-5(10*H*)-one (8e): a yellow solid; mp 185–186 °C (hexane/CH_2Cl_2); IR (KBr) 1647, 1607, 1265 cm^{-1}; ^1H NMR (400 MHz) δ 1.98–2.03 (m, 2H), 2.17–2.23 (m, 2H), 3.26 (t, *J* = 6.9 Hz, 2H), 4.16 (t, *J* = 6.9 Hz, 2H), 7.39–7.42 (m, 2H), 7.78 (ddd, *J* = 8.6, 6.9, 1.7 Hz, 1H), 8.27 (d, *J* = 5.2 Hz, 1H), 8.52 (dd, *J* = 8.6, 1.7 Hz, 1H), 8.60 (d, *J* = 5.2 Hz, 1H), 8.94 (s, 1H); ^{13}C NMR δ 24.77, 25.91, 51.39, 53.97, 115.44, 118.87, 122.16, 123.27, 125.60, 127.80, 133.17, 135.19, 138.23, 139.63, 142.33, 175.84, 177.18. HR MS. Calcd for $C_{17}H_{16}N_3OS$ (M+H): 310.1014. Found: *m/z* 310.1006. Anal. Calcd for $C_{17}H_{15}N_3OS$: C, 66.00; H, 4.89; N, 13.58. Found: C, 65.94; H, 4.97; N, 13.54.

10-(Morpholin-4-ylcarbonothioyl)benzo[*b*][1,7]naphthyridin-5(10*H*)-one (8f): a yellow solid; mp 233–235 °C (hexane/CH_2Cl_2); IR (KBr) 1652, 1605, 1273 cm^{-1}; ^1H NMR (400 MHz) δ 3.38–3.41 (m, 2H), 3.56 (t, *J* = 4.9 Hz, 2H), 4.04 (t, *J* = 4.9 Hz, 2H), 4.50–4.63 (m, 2H), 7.41–7.44 (m, 2H), 7.80 (ddd, *J* = 8.7, 6.9, 2.0 Hz, 1H), 8.27 (d, *J* = 4.9 Hz, 1H), 8.52 (dd, *J* = 8.7, 2.0 Hz, 1H), 8.61 (d, *J* = 4.9 Hz, 1H), 8.97 (s, 1H); ^{13}C NMRδ 50.11, 50.50, 66.05, 66.32, 115.58, 118.88, 122.52, 123.52, 125.60, 127.86, 133.61, 135.21, 138.65, 139.65, 142.58, 176.99, 178.51. HR MS. Calcd for $C_{17}H_{16}N_3O_2S$ (M+H): 326.0963. Found: *m/z* 326.0949. Anal. Calcd for $C_{17}H_{15}N_3O_2S$: C, 62.75; H, 4.65; N, 12.91. Found: C, 62.71; H, 4.66; N, 12.70.

***N*,*N*-Diethyl-10-oxobenzo[*b*][1,6]naphthyridine-5(10*H*)-carbothioamide (8g):** a pale-yellow solid; mp 212–214 °C (hexane/CH_2Cl_2); IR (KBr) 1655, 1609, 1258 cm^{-1}; ^1H NMR (500 MHz) δ 1.01 (t, *J* = 7.4 Hz, 3H), 1.61 (t, *J* = 7.4 Hz, 3H), 3.25–3.34 (m, 2H), 4.19–4.27 (m, 2H), 7.22 (d, *J* = 5.7 Hz, 1H, 4-H), 7.39 (d, *J* = 8.0 Hz, 1H, 6-H), 7.42 (ddd, *J* = 8.0, 7.4, 1.1 Hz, 1H, 8-H), 7.75 (ddd, *J* = 8.0, 7.4, 1.7 Hz, 1H, 7-H), 8.53 (dd, *J* = 8.0, 1.7 Hz, 1H, 9-H), 8.69 (d, *J* = 5.7 Hz, 1H, 3-H), 9.63 (s, 1H, 1-H); ^{13}C NMR δ 10.38, 13.42, 47.28, 47.95, 109.64, 116.03, 116.59, 123.57, 123.80, 127.53, 134.71, 139.10, 143.55, 151.17, 152.11, 177.32, 178.35. HR MS. Calcd for $C_{17}H_{18}N_3OS$ (M+H): 312.1170. Found: *m*/*z* 312.1164. Anal. Calcd for $C_{17}H_{17}N_3OS$: C, 65.57; H, 5.50; N, 13.49. Found: C, 65.51; H, 5.56; N, 13.40.

5-(Pyrrolidin-1-ylcarbonothioyl)benzo[*b*][1,6]naphthyridin-10(5*H*)-one (8h): a white solid; mp 177–178 °C (hexane/CH_2Cl_2); IR (KBr) 1652, 1607, 1262 cm^{-1}; ^1H NMR (500 MHz) δ 1.97–2.02 (m, 2H), 2.16–2.22 (m, 2H), 3.20–3.23 (m, 2H), 4.13 (t, *J* = 6.9 Hz, 2H), 7.20 (d, *J* = 5.7 Hz, 1H), 7.37 (d, *J* = 8.6 Hz, 1H), 7.42 (t, *J* = 7.4 Hz, 1H), 7.75 (ddd, *J* = 8.6, 7.4, 1.1 Hz, 1H), 8.53 (dd, *J* = 7.4, 1.1 Hz, 1H), 8.70 (d, *J* = 5.7 Hz, 1H), 9.63 (s, 1H); ^{13}C NMR δ 24.74, 25.89, 51.34, 53.95, 109.21, 115.58, 116.66, 123.64, 123.76, 127.73, 134.95, 138.30, 142.80, 151.26, 152.33, 175.66, 177.29. HR MS. Calcd for $C_{17}H_{16}N_3OS$ (M+H): 310.1014. Found: *m*/*z* 310.0998. Anal. Calcd for $C_{17}H_{15}N_3OS$: C, 66.00; H, 4.89; N, 13.58. Found: C, 65.83; H, 5.07; N, 13.46.

5-(Morpholin-4-ylcarbonothioyl)benzo[*b*][1,6]naphthyridin-10(5*H*)-one (8i): a white solid; mp 231–232 °C (hexane/CH_2Cl_2); IR (KBr) 1652, 1274 cm^{-1}; ^1H NMR (500 MHz) δ 3.35 (t, *J* = 4.9 Hz, 2H), 3.54 (t, *J* = 4.9 Hz, 2H), 4.02 (t, *J* = 4.9 Hz, 2H), 4.54 (t, *J* = 4.9 Hz, 2H), 7.22 (d, *J* = 5.7 Hz, 1H), 7.39 (d, *J* = 8.6 Hz, 1H), 7.44 (dd, *J* = 8.0, 7.4 Hz, 1H), 7.78 (ddd, *J* = 8.6, 7.4, 1.1 Hz, 1H), 8.54 (dd, *J* = 8.0, 1.1 Hz, 1H), 8.72 (d, *J* = 5.7 Hz, 1H), 9.63 (s, 1H); ^{13}C NMR δ 50.07, 50.44, 66.00, 66.26, 109.30, 115.74, 116.56, 123.54, 123.98, 127.74, 134.94, 138.72, 143.19, 151.29, 152.41, 177.06, 178.27. HR MS. Calcd for $C_{17}H_{16}N_3O_2S$ (M+H): 326.0963. Found: *m*/*z* 326.0956. Anal. Calcd for $C_{17}H_{15}N_3O_2S$: C, 62.75; H, 4.65; N, 12.91. Found: C, 62.50; H, 4.63; N, 12.76.

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