# Efficient synthesis of novel 5-phenylsulfonyl-substituted 4,5-dihydro-1*H*-pyrazolo[3,4-*b*]pyridines

**Ling Fan*, Chengcheng Ruan, Binghuang Guo, Xiwu Tang and Peng Xia**

*Hubei Collaborative Innovation Center for Rare Metal Chemistry, Hubei Key Laboratory of Pollutant Analysis and Reuse Technology, Hubei Normal University, Huangshi 435002, P.R. China*

An efficient method for the synthesis of novel 5-phenylsulfonyl substituted 4,5-dihydro-1*H*-pyrazolo[3,4-*b*]pyridines from 5-aminopyrazoles, aldehydes and β-ketosulfones in refluxing acetic acid is described. The X-ray crystallographic structure of the product was determined.

**Keywords:** phenylsulfonyl group, 4,5-dihydro-1*H*-pyrazolo[3,4-*b*]pyridines, β-ketosulfones, Hantzsch-type reaction

Recently, the Hantzsch-type three-component reaction of an aldehyde, an active methylene compound and aminopyrazole has been extensively investigated, often affording the substituted 4,7-dihydro-1*H*-pyrazolo[3,4-*b*]pyridine.[1,2] The phenylsulfonyl moiety is usually incorporated as an active unit in many nitrogen-containing pharmaceutical heterocyclic molecules[3] and commercial drugs, such as rofecoxib,[4] parecoxib[5] and etoricoxib.[6] Moreover, β-ketosulfone can be used as an important synthon for introducing the sulfonyl moiety into a molecule.[7] However, unlike other β-dicarbonyl compounds and their analogues, β-ketosulfone has rarely been exploited as an active methylene compound in the Hantzsch-type multicomponent reaction.[8] Recently, Saleh and co-workers found that sonicating a mixture of 5-aminopyrazole, aromatic aldehyde and β-ketosulfone at room temperature in the presence of a catalytic amount of *p*-toluenesulfonic acid yielded the 5-position unsubstituted pyrazolo[3,4-*b*]pyridines in excellent yields involving the desulfonylation pathway.[9] As a continuation of our work on the synthesis of functionalised pyrazolo[3,4-*b*]pyridine,[10] we herein report an efficient synthesis of novel 5-phenylsulfonyl-substituted 4,5-dihydro-pyrazolo[3,4-*b*]pyridines from 5-aminopyrazole, aldehyde and β-ketosulfone in refluxing acetic acid.

When a mixture of benzaldehyde (**1a**), 3-methyl-1-phenyl-1*H*-pyrazol-5-amine (**2a**) and 1-phenyl-2-(phenylsulfonyl) ethanone (**3a**) was heated in refluxing acetic acid for 8 h, (4*RS*,5*SR*)-3-methyl-1,4,6-triphenyl-5-(phenylsulfonyl)-4,5-dihydro-1*H*-pyrazolo[3,4-*b*]pyridine (**4a**) was obtained in 67% yield, which was confirmed by means of $^{1}$H NMR, $^{13}$C NMR, IR, MS and X-ray single-crystal diffraction analysis (Fig. 1). It is well known that the Hantzsch-type multicomponent reaction often affords the usual 4,7-dihydro-1*H*-pyrazolo[3,4-*b*] pyridine or its aromatisation product pyrazolo[3,4-*b*]pyridine. However, it should be noted that the novel 5-phenylsulfonyl-substituted 4,5-dihydro-1*H*-pyrazolo[3,4-*b*]pyridine was the main product in this reaction, probably due to the effect of the electron-withdrawing sulfonyl group. In addition, 3,5-dimethyl-1,4,7-triphenyl-1,7-dihydrodipyrazolo[3,4-*b*:4',3'-*e*]pyridine (**4a'**) was isolated in 12% yield. Decreasing the reaction temperature resulted in a lower yield of **4a**.

In order to explore the generality of the reaction, the substrate scope was further examined, as shown in Scheme 1. The reactions of electron-donating (–Me, –OMe, –N(CH$_3$)$_2$) and electron-withdrawing (–NO$_2$, –Cl, –Br) substituted benzaldehydes with **2a** and **3a** afforded the corresponding products **4b**–**h** in 52–73% yields. The substrates for furan-2-carbaldehyde and thiophene-2-carbaldehyde were also suitable for the reaction, delivering the corresponding products **4i** and **4j** in 50% and 56% yields, respectively. However, aliphatic butanal gave only the product **4k** in 30% yield. In addition, replacement of **2a** with 1,3-diphenyl-1*H*-pyrazol-5-amine (**2b**) also resulted in **4l** in good yield. Moreover, when 1-(phenylsulfonyl)propan-2-one (**3b**) was employed to react with **1a** and **2a**, it was found that **4m** and **4m'** were obtained in 51% and 20% yields, respectively (Scheme 2).

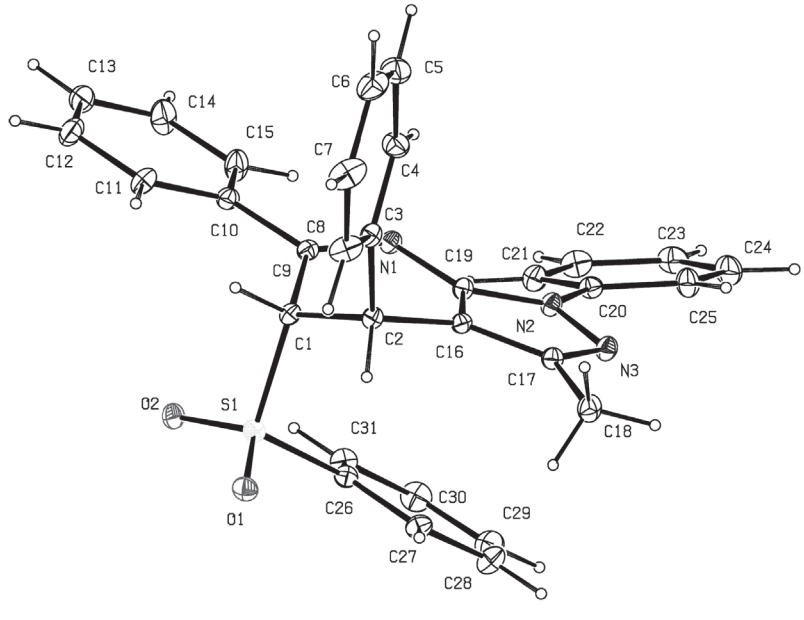
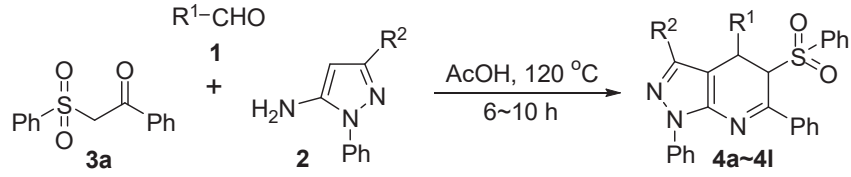


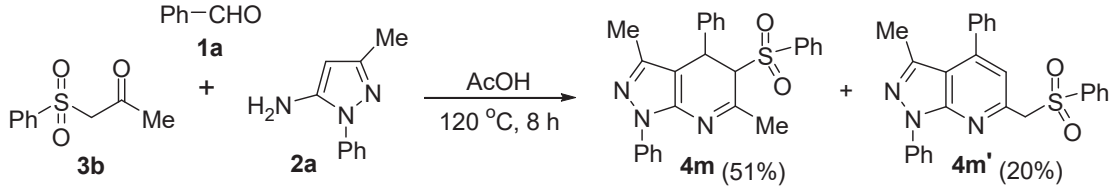

**Fig. 1** X-ray structure of compound **4a** with 30% probability.

* Correspondent. E-mail: fanlinghbnu@163.com




**4a** ($R^1$=Ph, $R^2$=Me, 67%)
**4b** ($R^1$=4-Me$C_6H_4$, $R^2$=Me, 52%)
**4c** ($R^1$=4-MeO$C_6H_4$, $R^2$=Me, 73%)
**4d** ($R^1$=2-MeO$C_6H_4$, $R^2$=Me, 61%)
**4e** ($R^1$=4-N$Me_2C_6H_4$, $R^2$=Me, 68%)
**4f** ($R^1$=2-$NO_2C_6H_4$, $R^2$=Me, 56%)
**4g** ($R^1$=4-$ClC_6H_4$, $R^2$=Me, 57%)
**4h** ($R^1$=4-$BrC_6H_4$, $R^2$=Me, 52%)
**4i** ($R^1$=2-furyl, $R^2$=Me, 50%)
**4j** ($R^1$=2 thienyl, $R^2$=Me, 56%)
**4k** ($R^1$=*n*-$C_3H_7$, $R^2$=Me, 30%)
**4l** ($R^1$=Ph, $R^2$=Ph, 55%)

**Scheme 1** Scope of the substrates.




**Scheme 2**

In summary, we have developed an efficient method for the synthesis of novel 4,5-dihydro-1*H*-pyrazolo[3,4-*b*]pyridines, instead of the commonly reported 4,7-dihydro-1*H*-pyrazolo[3,4-*b*] pyridines, from 5-aminopyrazoles, aldehydes and β-ketosulfones in refluxing acetic acid. The phenylsulfonyl group was successfully introduced into the nitrogen-containing heterocyclic molecules. All these newly synthesised compounds were characterised by means of $^1$H NMR, $^{13}$C NMR, IR and MS. The structure of **4a** was further confirmed by X-ray single-crystal diffraction analysis.

## Experimental

All reactants were commercially available and used without further purification. Melting points were determined using an X-4 Melting-point Apparatus (KWF Sci-Tech Development Company Limited, Beijing, China) and are uncorrected. $^1$H and $^{13}$C NMR were recorded in $CDCl_3$ using Bruker AV 300 MHz spectrometers at 300 and 75 MHz, respectively. Chemical shifts are reported relative to TMS (internal standard). IR spectra were recorded in KBr on a Nicolet 5700 FTIR spectrometer. Mass spectra were recorded on an Ultraflex TOF/TOF (MALDI) or a LCQ Advantage MAX (ESI). The CHN microanalyses were carried out with a PerkinElmer 2400 Elemental Analyzer. Flash column chromatography was performed on 200–300 mesh silica gel.

*Synthesis of* **4***; general procedure*

A mixture of aldehydes (**1**, 0.5 mmol), 5-aminopyrazoles (**2**, 0.5 mmol) and β-ketosulfones (**3**, 0.5 mmol) was heated in acetic acid (5 mL) below 120 °C. After the reaction was completed (6~10 h, monitored by TLC), the mixture was slowly cooled to room temperature and purified by column chromatography using petroleum ether–ethyl acetate as the eluent to deliver the desired products **4**.

*(4RS,5SR)-3-Methyl-1,4,6-triphenyl-5-(phenylsulfonyl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4a**): Yellow solid; 169 mg, yield 67%; m.p. 212–214 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.93 (d, *J* = 7.0 Hz, 2H), 7.54–7.39 (m, 9H), 7.30–7.18 (m, 7H), 7.09–7.06 (m, 2H), 5.18 (s, 1H), 4.99 (s, 1H), 2.18 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 156.9, 145.2, 139.3, 138.4, 137.0, 136.4, 134.2, 131.7, 129.3, 129.0, 128.7, 128.6, 128.2, 128.0, 127.8, 126.8, 126.2, 121.8, 104.3, 69.0, 37.1, 12.0; FTIR (KBr) (ν cm$^{-1}$): 3438, 2924, 1494, 1318, 1184, 1125, 1077, 757, 681; ESI-MS: *m/z* 504.02 [M + H]$^+$. Anal. calcd for $C_{31}H_{25}N_3O_2S$: C, 73.93; H, 5.00; N, 8.34; found: C, 74.05; H, 5.01; N, 8.32.

*3,5-Dimethyl-1,4,7-triphenyl-1,7-dihydrodipyrazolo[3,4-b:4',3'-e] pyridine* (**4a'**):[11] Yellow solid; 25 mg, yield 12%; $^1$H NMR ($CDCl_3$, 300 MHz) δ 8.42 (d, *J* = 8.6 Hz, 4H), 7.59–7.46 (m, 9H), 7.31–7.26 (m, 2H), 2.10 (s, 6H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 150.5, 144.5, 141.5, 139.7, 134.3, 129.03, 128.95, 128.8, 128.1, 125.1, 120.3, 113.5, 14.8; Anal. calcd for $C_{27}H_{21}N_5$: C, 78.05; H, 5.09; N, 16.86; found: C, 78.19; H, 5.10; N, 16.83.

*(4RS,5SR)-3-Methyl-1,6-diphenyl-5-(phenylsulfonyl)-4-p-tolyl-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4b**): Yellow solid; 134 mg, yield 52%; m.p. 187–189 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.94 (d, *J* = 8.3 Hz, 2H), 7.55–7.38 (m, 9H), 7.31–7.17 (m, 4H), 7.03 (d, *J* = 8.0 Hz, 2H), 6.95 (d, *J* = 8.0 Hz, 2H), 5.14 (s, 1H), 4.98 (s, 1H), 2.25 (s, 3H), 2.18 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 156.9, 145.2, 145.0, 138.4, 137.5, 137.0, 136.5, 136.2, 134.2, 131.6, 129.9, 129.0, 128.65, 128.56, 128.2, 127.9, 126.7, 126.1, 121.8, 104.5, 69.1, 36.7, 21.0, 12.0; FTIR (KBr) (ν cm$^{-1}$): 3440, 2923, 1499, 1310, 1181, 1121, 1076, 768, 683; HRMS *m/z* (MALDI) calcd for $C_{32}H_{28}N_3O_2S$ [M + H]$^+$ 518.1897; found: 518.1907.

*(4RS,5SR)-4-(4-Methoxyphenyl)-3-methyl-1,6-diphenyl-5-(phenylsulfonyl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4c**): Yellow solid; 194 mg, yield 73%; m.p. 150–151 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.93 (d, *J* = 7.9 Hz, 2H), 7.54 (d, *J* = 8.8 Hz, 2H), 7.50–7.38 (m, 7H), 7.31–7.17 (m, 4H), 7.00–6.95 (m, 2H), 6.77–6.74 (m, 2H), 5.13 (s, 1H), 4.96 (s, 1H), 3.72 (s, 3H), 2.17 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 159.1, 156.9, 145.2, 145.1, 138.5, 137.1, 136.6, 134.2, 131.6, 131.3, 129.0, 128.7, 128.6, 128.3, 127.98, 127.96, 126.1, 121.8, 114.6, 104.7, 69.4, 55.2, 36.4, 12.0; FTIR (KBr) (ν cm$^{-1}$): 3437, 2932, 1504, 1315, 1247, 1181, 1123, 1078, 752, 682; HRMS *m/z* (MALDI) calcd for $C_{32}H_{28}N_3O_3S$ [M + H]$^+$ 534.1846; found: 534.1847.

*(4RS,5SR)-4-(2-Methoxyphenyl)-3-methyl-1,6-diphenyl-5-(phenylsulfonyl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4d**): Yellow solid; 163 mg, yield 61%; m.p. 117–119 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.92 (d, *J* = 8.2 Hz, 2H), 7.56 (d, *J* = 7.6 Hz, 2H), 7.50–7.38 (m, 7H), 7.32–7.15 (m, 5H), 6.91 (d, *J* = 8.1 Hz, 1H), 6.71 (t, *J* = 7.5 Hz, 1H), 6.59 (d, *J* = 7.5 Hz, 1H), 5.52 (s, 1H), 5.15 (s, 1H), 3.95 (s, 3H), 2.17 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 157.8, 156.3, 145.9, 145.4, 138.5, 137.2, 137.1, 134.0, 131.4, 129.00, 128.96, 128.6, 128.5, 128.2, 127.9, 126.2, 126.0, 121.8, 120.8, 110.7, 103.5, 66.6, 55.5, 31.5, 12.1; FTIR (KBr) (ν cm$^{-1}$): 3437, 2932, 1504, 1315, 1247, 1181, 1123, 1078, 752, 682; HRMS *m/z* (MALDI) calcd for $C_{32}H_{28}N_3O_3S$ [M + H]$^+$ 534.1846; found: 534.1836.

*(4RS,5SR)-N,N-Dimethyl-4-[3-methyl-1,6-diphenyl-5-(phenylsulfonyl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridin-4-yl]aniline* (**4e**): Yellow solid; 186 mg, yield 68%; m.p. 132–134 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.95 (d, *J* = 8.3 Hz, 2H), 7.65–7.38 (m, 11H), 7.28–7.17 (m, 2H), 6.91 (d, *J* = 8.8 Hz, 2H), 6.56 (d, *J* = 8.7 Hz, 2H), 5.09 (s, 1H), 4.98 (s, 1H), 2.87 (s, 6H), 2.18 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 156.9, 149.8, 145.2,

145.0, 138.5, 137.2, 136.6, 134.1, 131.5, 129.0, 128.63, 128.56, 128.3, 127.9, 127.6, 126.0, 121.8, 113.0, 105.1, 69.3, 40.5, 36.4, 12.0; FTIR (KBr) (ν $cm^{-1}$): 3429, 2918, 2302, 1618, 1510, 1126, 1074, 761, 686; HRMS *m/z* (MALDI) calcd for $C_{33}H_{31}N_4O_2S$ $[M+H]^+$ 547.2162; found: 547.2157.

*(4RS,5SR)-3-Methyl-4-(2-nitrophenyl)-1,6-diphenyl-5-(phenylsulfonyl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4f**): Yellow solid; 153 mg, yield 56%; m.p. 230–232 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.95 (d, *J* = 7.9 Hz, 1H), 7.86 (d, *J* = 7.4 Hz, 2H), 7.63 (d, *J* = 7.8 Hz, 2H), 7.51–7.20 (m, 13H), 6.78 (d, *J* = 7.3 Hz, 1H), 5.73 (s, 1H), 5.25 (s, 1H), 2.14 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 157.8, 148.3, 146.7, 145.2, 138.4, 137.4, 136.7, 134.1, 133.7, 132.5, 131.9, 130.3, 129.1, 129.0, 128.8, 128.7, 128.2, 126.5, 125.2, 122.0, 103.3, 67.6, 31.9, 12.0; FTIR (KBr) (ν $cm^{-1}$): 3423, 1509, 1338, 1182, 1127, 1079, 751, 689, 531; HRMS *m/z* (MALDI) calcd for $C_{31}H_{25}N_4O_4S$ $[M+H]^+$ 549.1591; found: 549.1590.

*(4RS,5SR)-4-(4-Chlorophenyl)-3-methyl-1,6-diphenyl-5-(phenylsulfonyl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4g**): Yellow solid; 154 mg, yield 57%; m.p. 213–215 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.93 (d, *J* = 8.4 Hz, 2H), 7.54–7.39 (m, 9H), 7.32–7.18 (m, 6H), 7.01 (d, *J* = 8.4 Hz, 2H), 5.16 (s, 1H), 4.92 (s, 1H), 2.17 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 156.8, 145.1, 138.4, 137.7, 136.8, 136.3, 134.3, 133.8, 131.8, 129.5, 129.0, 128.8, 128.6, 128.3, 128.2, 128.0, 126.3, 121.8, 103.8, 68.9, 36.6, 12.0; FTIR (KBr) (ν $cm^{-1}$): 3443, 2922, 2335, 1494, 1183, 1123, 1080, 757, 680; HRMS *m/z* (MALDI) calcd for $C_{31}H_{25}ClN_3O_2S$ $[M+H]^+$ 538.1351; found: 538.1359.

*(4RS,5SR)-4-(4-Bromophenyl)-3-methyl-1,6-diphenyl-5-(phenylsulfonyl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4h**): Yellow solid; 151 mg, yield 52%; m.p. 204–206 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.93 (d, *J* = 7.0 Hz, 2H), 7.54–7.35 (m, 11H), 7.32–7.17 (m, 4H), 6.95 (d, *J* = 8.4 Hz, 2H), 5.14 (s, 1H), 4.92 (s, 1H), 2.17 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 156.8, 145.1, 138.3, 138.2, 136.8, 136.3, 134.3, 132.4, 131.8, 129.0, 128.8, 128.6, 128.2, 128.0, 126.3, 121.9, 121.8, 103.7, 68.8, 36.6, 12.0; FTIR (KBr) (ν $cm^{-1}$): 3397, 1493, 1316, 1185, 1126, 1076, 825, 758, 684; HRMS *m/z* (MALDI) calcd for $C_{31}H_{25}BrN_3O_2S$ $[M+H]^+$ 582.0845; found: 582.0847.

*(4RS,5SR)-4-(Furan-2-yl)-3-methyl-1,6-diphenyl-5-(phenylsulfonyl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4i**): Yellow solid; 123 mg, yield 50%; m.p. 149–150 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.96 (d, *J* = 8.0 Hz, 2H), 7.44–7.28 (m, 11H), 7.22–7.08 (m, 6H), 6.10–6.08 (m, 1H), 5.75–5.74 (m, 1H), 5.19 (s, 2H), 2.25 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 157.1, 151.4, 145.2, 144.9, 142.8, 138.3, 136.8, 136.5, 134.2, 131.8, 129.0, 128.8, 128.5, 128.3, 128.0, 126.2, 121.9, 110.4, 106.8, 101.9, 65.0, 31.6, 12.0; FTIR (KBr) (ν $cm^{-1}$): 3438, 2924, 1502, 1439, 1307, 1127, 1076, 740, 683; HRMS *m/z* (MALDI) calcd for $C_{29}H_{24}N_3O_3S$ $[M+H]^+$ 494.1533; found: 494.1529.

*(4RS,5SR)-3-Methyl-1,6-diphenyl-5-(phenylsulfonyl)-4-(thiophen-2-yl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4j**): Yellow solid; 143 mg, yield 56%; m.p. 213–215 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 8.01 (d, *J* = 6.8 Hz, 2H), 7.51–7.37 (m, 9H), 7.30–7.16 (m, 4H), 7.10 (d, *J* = 5.0 Hz, 1H), 6.85–6.82 (m, 1H), 6.77–6.76 (m, 1H), 5.45 (s, 1H), 5.14 (s, 1H), 2.29 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 157.0, 145.0, 144.5, 142.8, 138.4, 136.9, 136.4, 134.3, 131.8, 129.0, 128.8, 128.5, 128.3, 128.0, 127.3, 126.2, 125.1, 124.5, 121.9, 104.7, 68.9, 32.8, 12.0; FTIR (KBr) (ν $cm^{-1}$): 3438, 3059, 2922, 1497, 1444, 1305, 1179, 1122, 1075, 757, 691, 526; HRMS *m/z* (MALDI) calcd for $C_{29}H_{24}N_3O_2S_2$ $[M+H]^+$ 510.1304; found: 510.1305.

*(4RS,5SR)-3-Methyl-1,6-diphenyl-5-(phenylsulfonyl)-4-propyl-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4k**): Yellow oil; 70 mg, yield 30%; $^1$H NMR ($CDCl_3$, 300 MHz) δ 8.05 (d, *J* = 7.4 Hz, 2H), 7.48–7.39 (m, 5H), 7.33–7.28 (m, 4H), 7.19–7.14 (m, 2H), 7.10–7.05 (m, 2H), 4.72 (s, 1H), 3.83–3.78 (m, 1H), 2.23 (s, 3H), 1.32–1.28 (m, 4H), 0.84–0.82 (m, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 157.1, 144.8, 144.4, 138.4, 137.1, 136.8, 134.0, 131.7, 128.8, 128.5, 128.3, 127.8, 126.0, 121.8, 105.6, 66.4, 36.9, 31.8, 19.6, 13.9, 12.3; FTIR (KBr) (ν $cm^{-1}$): 3442, 2925, 1632, 1500, 1438, 1310, 1126, 1077, 757, 682; HRMS *m/z* (MALDI) calcd for $C_{28}H_{28}N_3O_2S$ $[M+H]^+$ 470.1897; found: 470.1899.

*(4RS,5SR)-1,3,4,6-Tetraphenyl-5-(phenylsulfonyl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4l**): Yellow solid; 155 mg, yield 55%; m.p. 239–241 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.90–7.80 (m, 3H), 7.62–7.53 (m, 5H), 7.39–7.29 (m, 13H), 7.19–7.09 (m, 4H), 5.37 (s, 1H), 4.95 (s, 1H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 157.5, 147.3, 146.2, 139.0, 138.5, 137.0, 136.3, 134.2, 132.4, 131.8, 130.3, 129.8, 129.5, 129.1, 128.8, 128.7, 128.6, 128.3, 128.0, 127.1, 126.7, 126.6, 122.2, 102.8, 69.4, 38.1; FTIR (KBr) (ν $cm^{-1}$): 3440, 3059, 2927, 1493, 1447, 1310, 1183, 1128, 1076, 756, 686, 535; HRMS *m/z* (MALDI) calcd for $C_{36}H_{28}N_3O_2S$ $[M+H]^+$ 566.1897; found: 566.1901.

*(4RS,5SR)-3,6-Dimethyl-1,4-diphenyl-5-(phenylsulfonyl)-4,5-dihydro-1H-pyrazolo[3,4-b]pyridine* (**4m**): Yellow solid; 112 mg, yield 51%; m.p. 155–157 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 7.64 (d, *J* = 8.4 Hz, 2H), 7.45–7.33 (m, 5H), 7.31–7.24 (m, 6H), 7.01 (d, *J* = 7.8 Hz, 2H), 4.88 (s, 1H), 4.10 (s, 1H), 2.49 (s, 3H), 2.06 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 161.4, 145.0, 144.2, 139.7, 138.3, 136.4, 134.3, 129.3, 128.8, 128.6, 128.1, 127.8, 126.8, 126.2, 121.9, 103.3, 73.3, 36.7, 28.4, 11.8; FTIR (KBr) (ν $cm^{-1}$): 3435, 3057, 2925, 1593, 1498, 1438, 1308, 1122, 1076, 759, 689; HRMS *m/z* (MALDI) calcd for $C_{26}H_{24}N_3O_2S$ $[M+H]^+$ 442.1584; found: 442.1587.

*3-Methyl-1,4-diphenyl-6-(phenylsulfonylmethyl)-1H-pyrazolo[3,4-b]pyridine* (**4m'**): White solid; 44 mg, yield 20%; m.p. 236–238 °C; $^1$H NMR ($CDCl_3$, 300 MHz) δ 8.35 (d, *J* = 7.7 Hz, 2H), 7.94 (d, *J* = 7.9 Hz, 2H), 7.75 (d, *J* = 7.2 Hz, 2H), 7.69–7.64 (m, 1H), 7.56–7.46 (m, 7H), 7.33–7.28 (m, 1H), 7.21 (s, 1H), 4.78 (s, 2H), 2.70 (s, 3H); $^{13}$C NMR ($CDCl_3$, 75 MHz) δ 156.4, 151.5, 141.6, 139.4, 138.3, 137.7, 134.3, 132.1, 129.7, 129.3, 129.0, 128.8, 128.7, 127.4, 125.6, 121.0, 117.4, 114.9, 59.3, 15.1; FTIR (KBr) (ν $cm^{-1}$): 3436, 2923, 1592, 1497, 1413, 1141, 1083, 752, 686; HRMS *m/z* (MALDI) calcd for $C_{26}H_{22}N_3O_2S$ $[M+H]^+$ 440.1427; found: 440.1429.

## Single crystal X-ray crystallography

The X-ray data were collected on a Bruker SMART APEX CCD area-detector diffractometer using graphite monochromated Mo Ka radiation (λ = 0.71073 Å) at 296(2) K. The structures were solved by direct methods with the SHELXS-97 program and refinements on $F^2$ were performed with the SHELXL-97 program using full-matrix least-squares techniques. CCDC 1483380 contains the supplementary data for this paper. The data can be obtained free of charge from the Cambridge Crystallographic Data Centre *via* www.ccdc.cam.ac.uk/data_request/cif.

*Crystal data for compound* (**4a**). $C_{31}H_{25}N_3O_2S$, M = 503.60, crystal system: monoclinic, space group P2(1)/c, lattice parameters: *a* = 9.624(4) Å, *b* = 18.149(8) Å, *c* = 14.421(7) Å, α = 90°, β = 96.387(9)°, γ = 90°, *V* = 2503.2(19) $Å^3$, *Z* = 4, $D_c$ = 1.336 g·$cm^{-3}$, F000 = 1056, final *R* indices [*I* > 2sigma(*I*)]: $R_1$ = 0.0500, $wR_2$ = 0.1316.

## Acknowledgment

We gratefully acknowledge the support from the Educational Commission of Hubei Province (No. B2015132).

## Electronic Supplementary Information

The $^1$H NMR and $^{13}$C NMR spectra of compounds **4** are available through:
stl.publisher.ingentaconnect.com/content/stl/jcr/supp-data

*Received 3 June 2016; accepted 27 July 2016*
*Paper 1604127 doi: 10.3184/174751916X14737765008687*
*Published online: 23 September 2016*

## References

1 J.P. Wan and Y. Liu, *RSC Adv.*, 2012, **2**, 9763.
2 D.K. Dodiya, A.R. Trivedi, V.B. Kataria and V.H. Shah, *Curr. Org. Chem.*, 2012, **16**, 400.
3 M.E. Salem, A.A. Ahmed, M.R. Shaaban, M.F. Shibl and A.M. Farag, *Spectrochim. Acta Part A: Mol. Biomol. Spectrosc.*, 2015, **148**, 175.
4 M.J. Langman, D.M. Jensen, D.J. Watson, S.E. Harper, P.L. Zhao, H. Quan, J.A. Bolognese and T.J. Simon, *J. Am. Med. Assoc.*, 1999, **282**, 1929.
5 D.J. Cochrane, B. Jarvis and G.M. Keating, *Drugs*, 2002, **62**, 2637.
6 A. Dallob, C.J. Hawkey, H. Greenberg, N. Wight, P. De Schepper, S. Waldman, P. Wong, L. DeTora, B. Gertz, N. Agrawal, J. Wagner and K.J. Gottesdiener, *Clin. Pharmacol.*, 2003, **43**, 573.
7 J. Peña, R.F. Moro, I.S. Marcos and D. Díez, *Curr. Org. Chem.*, 2014, **18**, 2972.
8 C.S. Yao, K. Lu, B. Song, B. Liu, T.J. Li and C.X. Yu, *J. Heterocycl. Chem.*, 2014, **51**, 1807.
9 T.S. Saleh, T.M.A. Eldebss and H.M. Albishri, *Ultrason. Sonochem.*, 2012, **19**, 49.
10 L. Fan, C.C. Yao and M.M. Shu, *Heterocycl. Commun.*, 2016, **22**, 63.
11 E. Kolehmainen, K. Laihia, D. Rasala and A. Puchala, *Magn. Reson. Chem.*, 1996, **34**, 570.