Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry

Supporting Information

Masuda borylation-Suzuki coupling (MBSC) sequence of vinylhalides and its application in a one-pot synthesis of 3,4-biarylpyrazoles

Boris O. A. Tasch, Lisa Bensch, Dragutin Antovic, Thomas J. J. Müller*

Institut für Organische Chemie und Makromolekulare Chemie, Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, D-40225 Düsseldorf, Germany

Fax: (+)49 (0)211 81 14324

E-Mail: ThomasJJ.Mueller@uni-duesseldorf.de

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1 General Considerations

All cross-coupling reactions were carried out in oven-dried Schlenk glassware using septa and syringes under nitrogen or argon atmosphere. 1,4-Dioxane was dried using an *MBraun* system MB-SPS-800.

Triethylamine was refluxed under argon over ketyl sodium, distilled and stored in a Schlenk flask with potassium hydroxide pellets under argon atmosphere. Dry methanol was purchased from *Sigma-Aldrich Chemie GmbH*. 4,4,5,5-Tetramethyl-1,3,2-dioxaborolane (pinacolyl borane) was purchased from *Sigma-Aldrich Chemie GmbH* and used as received.

Tetrakis(triphenylphosphane)palladium(0) and cesium carbonate were purchased from *Sigma-Aldrich Chemie GmbH*. Commercial grade reagents were used as supplied without further purification and were purchased from *Sigma-Aldrich Chemie GmbH*, *Acros Organics N. V.*, *ABCR GmbH & Co. KG*, *Alfa Aesar GmbH & Co. KG* and *Merck KGaA*.

The purification of products was performed on silica gel 60 (0.015-0.040 mm) from *Merck KGaA* using flash technique and under pressure of 2 bar. The crude mixtures were adsorbed on Celite® 545 (0.02-0.10 mm) from *Merck KGaA* before chromatographic purification. The reaction progress was monitored qualitatively using TLC Silica gel 60 F254 5 x 7.5 cm aluminium sheets obtained by *Merck KGaA*. The spots were detected with UV light at 254 nm and using aqueous potassium permanganate solution.

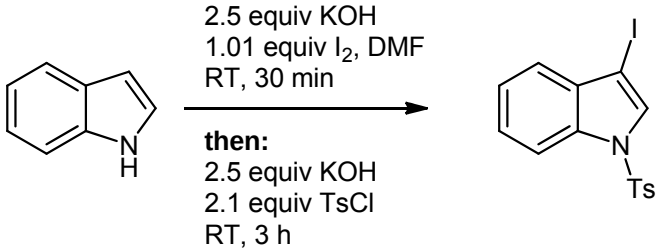
^{1}H, ^{13}C, and 135-DEPT NMR spectra were recorded on *Bruker* Avance III - 600, Avance DRX 500 und Avance III - 300 spectrometers. $CDCl_3$ and DMSO-d_6 were used as deuterated solvents. TMS was used as reference (δ = 0.0) or the resonances of the solvents were locked as internal standards ($CDCl_3$: ^{1}H δ = 7.26, ^{13}C δ = 77.0; DMSO-d_6: ^{1}H δ = 2.50, ^{13}C δ = 39.4). The multiplicities of the signals were abbreviated as follows: s: singlet; d: doublet; t: triplet; dd: doublet of doublets; ddd: doublet of doublets of doublets; dt: doublet of triplets; td: triplet of doublets; tt: triplet of triplets; q: quartet; quint: quintet; sext: sextet; m: multiplet and br: broad signal. The type of carbon atoms was determined on the basis of 135-DEPT NMR spectra. Mass spektra were measured on *Varian* MAT 311 A, *Finnigan* MAT 8200, *Finnigan* TSQ 7000 and on *Shimadzu* GC 2010 with GCMS-QP20105. Method of ionization was EI (Electron Impact). HRMS-spectra were obtained on *Bruker* MaXis 4G. Method of ionization was ESI (Elektron Spray Ionization). IR spectra were obtained on *Bruker* Vector 22 FT-IR (solids were measured as KBr pellets and oils as films on KBr plates) and *Shimadzu* IR-Affinity-1 (compounds were measured directly). The intensity of signals is abbreviated as follows: s (strong), m (medium) and w (weak). The melting points (uncorrected) were measured on *Reichert-Jung* Thermovar. Combustion analyses were carried out on *Perkin*

1 General Considerations

Elmer Series II Analyser 2400 in the microanalytical laboratory of Institut für Pharmazeutische und Medizinische Chemie der Heinrich-Heine-Universität Düsseldorf.

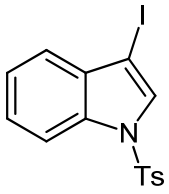
2 Synthesis of Starting Materials

2.1 Synthesis of 3-Iodo-1-tosyl-1*H*-indole (2g)[1]



A solution of iodine (28.0 g, 111 mmol, 1.01 equiv) in 193 mL DMF was dropped to the solution of 1*H*-indole (13.0 g, 110 mmol) and potassium hydroxide (18.2 g, 275 mmol, 2.50 equiv) in 193 mL DMF at room temperature and the solution was stirred for 30 min. Potassium hydroxide (18.2 g, 275 mmol, 2.50 equiv) was then again added, followed by tosyl chloride (44.5 g, 231 mmol, 2.10 equiv) and the mixture was stirred for 3 h at room temperature. The reaction mixture was then poored on 400 mL of water, the resulting precipitate filtrated and washed with 150 mL water and 100 mL *n*-hexane and dried in vacuo to obtain 23.0 g (57.9 mmol, 53 % yield) of **2g** as a colorless solid.

The procedure is described by: Mitsudo *et al.*[1]

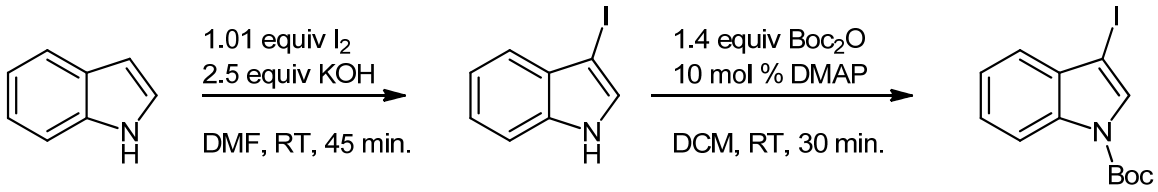


$C_{15}H_{12}INO_2S$

397.23

Mp 129-131 °C. ^{1}H NMR (DMSO-d_6, 300 MHz): δ 2.30 (s, 3 H), 7.31-7.47 (m, 5 H), 7.87-7.97 (m, 3 H), 8.06 (s, 1 H). ^{13}C NMR (DMSO-d_6, 75 MHz): δ 21.0 (CH_3), 68.5 (C_{quat}), 113.2 (CH), 121.7 (CH), 124.2 (CH), 125.9 (CH), 126.9 (CH), 130.2 (CH), 130.4 (CH), 132.2 (C_{quat}), 133.7 (C_{quat}), 133.8 (C_{quat}), 145.8 (C_{quat}). EI + MS (*m*/*z* (%)): 399 (6), 398 (16), 397 (M^+, 97), 244 (2), 243 (31), 242 ((M-$C_7H_7O_2S$)$^+$, 100), 155 (3), 155 ($C_7H_7O_2S^+$, 40), 116 (13), 115 ((M-$C_7H_7O_2S$-I)$^+$, 34), 90 (46). IR (KBr): $\tilde{\nu}$ 3152 (w), 3121 (w), 3030 (w), 2918 (w), 2857 (w), 1921 (w), 1593 (w), 1439 (m), 1400 (w), 1369 (s), 1267 (m), 1188 (m), 1171 (s), 1153 (m), 1126 (s), 1109 (m), 1086 (s), 1022 (s), 1013 (s), 972 (w), 924 (m), 814 (m), 798 (m), 744 (s), 702 (s), 687 (s), 654 (s) cm^{-1}. Anal. calcd. for $C_{15}H_{12}INO_2S$ (397.2): C 45.35, H 3.04, N 3.53. Found: C 45.48, H 3.02, N 3.53.

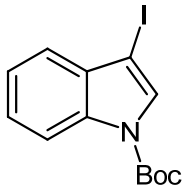
2.2 Synthesis of *N*-Boc-3-iodo indole (2i)[2]



A solution of iodine (44.1 g, 173 mmol, 1.01 equiv) in 150 mL DMF was dropped to the solution of 1*H*-indole (20.0 g, 171 mmol, 1.00 equiv) and potassium hydroxide (28.2 g, 428 mmol, 2.50 equiv) in 150 mL DMF at room temperature and the mixture was stirred for 45 min. The reaction mixture was then poored on 2 L of ice water containing 0.5 % ammonia and 0.1 % sodium disulfite. The mixture was placed in a refrigerator to ensure the complete precipitation. The precipitate was filtered, washed with 400 mL ice water and dried in vacuo to obtain 32.8 g (135 mmol, 79 % yield) of a yellow solid. It was used without further purification for the next step.

The obtained solid was suspended in 175 mL dichloromethane. 4-Dimethylaminopyridine (1.68 g, 13.5 mmol, 10 mol %) and di-*tert*-butyl dicarbonate (45.6 g, 203 mmol, 1.50 equiv), dissolved in 175 mL dichloromethane, were added and the mixture was stirred for 30 min at room temperature, washed with 175 mL 0.1 *N* HCl and the aqueous phase was extracted with dichloromethane (3 x 100 mL, monitored by TLC). The combined organic layers were dried with sodium sulfate. The solvents were removed under reduced pressure. The residue was adsorbed onto Celite® and purified chromatographically on silica gel with n-hexane/ethyl acetate (He/EtOAc = 50:1), (R_f (He/EtOAc = 50:1): 0.38) to give 26.3 g (108 mmol, 80 % yield, 63 % total yield over two steps) of *N*-Boc-3-iodo indole (**2i**) as a pale brown oil.

The procedure is described by: Witulski *et al.*[2]



$C_{13}H_{14}INO_2$

343.16

^{1}H NMR ($CDCl_3$, 500 MHz): δ 1.66 (s, 9 H), 7.28-7.32 (m, 1 H), 7.33-7.36 (m, 1 H), 7.36-7.40 (m, 1 H), 7.72 (s, 1 H), 8.12 (d, J = 7.3 Hz, 1 H). ^{13}C NMR ($CDCl_3$, 125 MHz): δ 28.1 (CH_3), 65.4 (C_{quat}), 84.2 (C_{quat}), 115.0 (CH), 121.4 (CH), 123.3 (CH), 125.3 (CH), 130.0 (CH), 132.0 (C_{quat}), 134.8 (C_{quat}), 148.6 (C_{quat}). EI + MS (m/z (%)): 343 (M^+, 14), 287 ($(M-C_4H_9+H)^+$, 59), 270 ($(M-C_4H_9O+H)^+$, 6), 243 ($(M-C_5H_9O_2+H)^+$, 79), 116 ($C_8H_6N^+$, 30), 115 ($C_8H_5N^+$, 22), 88 (10), 57 ($C_4H_9^+$, 100), 41 (13). IR (film): $\tilde{\nu}$ 3151 (w), 3052 (w), 2979 (m), 2932 (w), 1747 (s), 1731 (s), 1606 (w), 1528 (w), 1476 (m), 1449 (s), 1375 (s), 1358 (s), 1336 (m), 1311 (m), 1249 (m), 1211 (m), 1148 (m), 1112 (m), 1054 (m), 1016 (w), 938 (w), 854 (w), 800 (w), 769 (m), 745 (m), 672 (w), 589 (w) cm^{-1}. Anal. calcd. for $C_{13}H_{14}INO_2$ (343.2): C 45.50, H 4.11, N 4.08. Found.: C 45.24, H 4.30, N 3.89.

For literature data see: Kelly *et al.*[3]

3 Coupling of Vinylhalides

3.1 Synthesis of the *α*-substituted Styrenes 3

$PdCl_2$ (3.5 mg, 0.02 mmol, 2 mol%) and cataCXium® AHI (19 mg, 0.04 mmol, 4 mol%) were placed under argon atmosphere in a dry screw-cap vessel with septum. *α*-Bromostyrene (**1a**) (203 mg, 1.00 mmol, 1.0 equiv) was added toghether with 2 mL of dry 1,4-dioxane. The mixture was degassed with nitrogen (5 min). Dry triethylamine (0.5 mL) and 4,4,5,5-tetramethyl-1,3,2-dioxaborolane (0.22 mL, 1.50 mmol, 1.5 equiv) were successively added to the mixture, which was stirred at 80 °C (preheated oil bath) for 4 h (monitored by TLC). Then, after cooling to room temperature (water bath), methanol (2 mL), Cs_2CO_3 (815 mg, 2.50 mmol, 2.5 equiv) and the coupling partner **2** (1.00 mmol, 1.0 equiv) were successively added. The mixture was stirred at 100 °C for 20 h (preheated oil bath). Then, after cooling to room temperature, the solvents were removed under reduced pressure, the residue was absorbed onto Celite® and purified chromatographically on silica gel. Additionally, due to the sensitivity towards air and light, several compounds were washed trough a plug of silica with THF before analysis was performed.

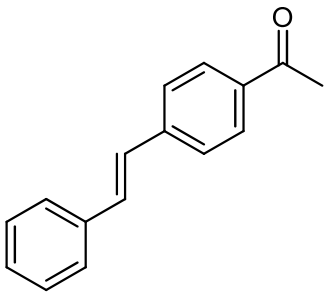
The experimental details are given in **Table 1**.

Table 1: Synthesis of the *α*-substituted styrenes **3**.

Entry	Coupling partner in the *Suzuki*-step	Vinylhalide **3** (isolated yield)	Chromatographic purification (eluent) R_f (eluent)
1	1-(4-Iodophenyl)ethanone (**2a**) (*Alfa Aesar*) 251 mg (1.00 mmol)	(**4**) colorless solid 78 mg (0.35 mmol, 35 %)	He/EtOAc = 20/1 R_f (He/EtOAc = 20/1): 0.12
2	1-(4-Iodophenyl)ethanone (**2a**) (*Alfa Aesar*) 251 mg (1.00 mmol)	(**3a**) colorless oil 184 mg (0.83 mmol, 83 %)	He/EtOAc = 20/1 R_f (He/EtOAc = 10/1): 0.33
3	(1-Bromovinyl)benzene (**1a**) (*Aldrich*) 203 mg (1.00 mmol)	(**3b**) yellow oil 154 mg (0.75 mmol, 75 %)	He = 1 R_f (He = 1): 0.20
4	2-Bromothiazole (**2b**) (*Aldrich*) 0.09 mL (1.00 mmol)	(**3c**) yellow oil 117 mg (0.62 mmol, 62 %)	He/EtOAc = 70/1 R_f (He/EtOAc = 50/1): 0.20
5	2-Iodothiophene (**2c**) (*Aldrich*) 163 mg (1.00 mmol)	(**3d**) colorless oil 140 mg (0.75 mmol, 75 %)	He = 1 R_f (He): 0.48
6	2,5-Diiodothiophene (**2d**) (*Aldrich*) 342 mg (1.00 mmol)	(**3e**) colorless oil 101 mg (0.35 mmol, 35 %)[1]	He = 1 R_f (He): 0.25

[1] Reaction was performed with $PdCl_2$ (0.007 mg, 0.04 mmol, 2.0 mol%), cataCXium® AHI (0.038 mg, 0.08 mmol, 4.0 mol%), *α*-bromostyrene (**1a**) (406 mg, 2.00 mmol, 1.0 equiv), 4 mL dioxane, 1.0 mL TEA, HBpin (0.44 mL, 3.00 mmol, 1.5 equiv), 4 mL MeOH, Cs_2CO_3 (1.63 g, 5.00 mmol, 2.5 equiv).

3.1.1 (*E*)-1-(4-Styrylphenyl)ethanone (4)

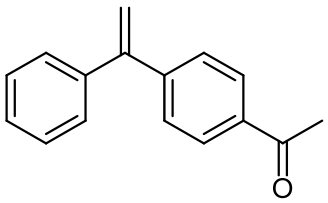


$C_{16}H_{14}O$

222.28

According to the general procedure 78 mg (0.35 mmol, 35 % total yield) were obtained as a colorless solid. Eluent for column chromatography was *n*-hexane/ethyl acetate 20/1. Mp 139-140 °C. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 2.53 (s, 3 H), 7.05 (d, J = 16.3 Hz, 1 H), 7.16 (d, J = 16.3 Hz, 1 H), 7.19-7.25 (m, 1 H), 7.27-7.34 (m, 2 H), 7.43-7.53 (m, 4 H), 7.84-7.80 (m, 2 H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 26.7 (CH_3), 126.6 (CH), 126.9 (CH), 127.6 (CH), 128.5 (CH), 128.9 (CH), 129.1 (CH), 131.6 (CH), 136.1 (C_{quat}), 136.8 (C_{quat}), 142.1 (C_{quat}), 197.6 (C_{quat}). EI + MS (*m/z* (%)): 224 (6), 223 (13), 222 (M^+, 69), 209 (10), 208 (16), 207 ($(M\text{-}CH_3)^+$, 100), 179 ($(M\text{-}C_2H_3O)^+$, 19), 178 (58), 177 (8), 176 (10), 152 (11), 77 ($(C_6H_5)^+$, 5). IR (KBr): $\tilde{\nu}$ 1724 (w), 1676 (s), 1593 (m), 1558 (w), 1491 (w), 1448 (w), 1410 (m), 1356 (m), 1261 (s), 1219 (w), 1178 (m), 1113 (w), 1074 (w), 999 (w), 964 (s), 955 (s), 914 (w), 868 (m), 820 (s), 754 (s), 712 (m), 688 (s), 609 (m) cm^{-1}. Anal. calcd. for $C_{16}H_{14}O$ (222.3): C 86.45, H 6.35. Found: C 86.33, H 6.61.

3.1.2 1-(4-(1-Phenylvinyl)phenyl)ethanone (3a)

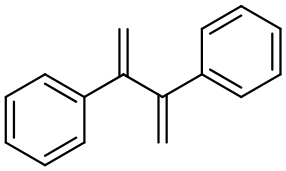


$C_{16}H_{14}O$

222.28

According to the general procedure 184 mg (0.83 mmol, 83 % total yield) were obtained as a colorless oil. Eluent for column chromatography was *n*-hexane/ethyl acetate 20/1. ^{1}H NMR (DMSO-d_6, 300 MHz): *δ* 2.54 (s, 3 H), 5.47 (d, *J* = 1.0 Hz, 1 H), 5.48 (d, *J* = 1.0 Hz, 1 H), 7.17-7.28 (m, 5 H), 7.33-7.38 (m, 2 H), 7.82-7.87 (m, 2 H). ^{13}C NMR (DMSO-d_6, 75 MHz): *δ* 26.8 (CH_3), 116.1 (CH_2), 128.2 (CH), 128.3 (CH), 128.5 (CH), 128.6 (CH), 136.5 (C_{quat}), 136.9 (CH), 140.9 (C_{quat}), 146.4 (C_{quat}), 149.3 (C_{quat}), 197.8 (C_{quat}). EI + MS (*m/z* (%)): 223 (10), 222 (M^+, 60), 208 ($(M-CH_2)^+$, 17), 207 (100), 179 ($(M-C_2H_3O)^+$, 12), 178 (55), 105 (12), 77 (10). IR (KBr): $\tilde{\nu}$ 3080 (w), 2922 (w), 1811 (w), 1724 (w), 1680 (s), 1603 (m), 1558 (w), 1493 (w), 1445 (w), 1425 (w), 1402 (m), 1356 (m), 1327 (w), 1306 (w), 1265 (s), 1182 (w), 1149 (w), 1117 (w), 1065 (w), 1026 (w), 1015 (w), 957 (m), 905 (m), 849 (s), 835 (s), 777 (s), 750 (w), 702 (s), 663 (s), 644 (m), 625 (m) cm^{-1}. Anal. calcd. for $C_{16}H_{14}O$ (222.3): C 86.45, H 6.35. Found: C 86.16, H 6.44.

3.1.3 Buta-1,3-diene-2,3-diyldibenzene (3b)

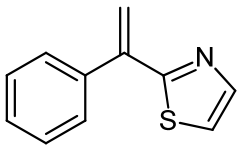


$C_{16}H_{14}$

206.28

According to the general procedure 154 mg (0.75 mmol, 75 % total yield) were obtained as a colorless oil that started to crystallize after a few days. Eluent for column chromatography was *n*-hexane. ^{1}H NMR (DMSO-d_6, 300 MHz): δ 5.26 (d, J = 1.7 Hz, 2 H), 5.49 (d, J = 1.7 Hz, 2 H), 7.12-7.25 (m, 6 H), 7.31-7.37 (m, 4 H). ^{13}C NMR (DMSO-d_6, 75 MHz): δ 116.6 (CH_2), 127.7 (CH), 128.4 (CH), 140.4 (C_{quat}), 150.0 (C_{quat}). EI + MS (*m/z* (%)): 206 (M^+, 26), 205 (32), 204 (100), 203 (97), 202 (58), 201 (10), 200 (11), 100 (32), 91 (15), 89 (10). IR: $\tilde{\nu}$ 3092 (w), 3053 (w), 3030 (w), 2955 (w), 2926 (w), 2855 (w), 1888 (w), 1807 (w), 1726 (w), 1684 (w), 1574 (w), 1493 (m), 1443 (m), 1393 (w), 1362 (w), 1302 (w), 1286 (w), 1254 (w), 1229 (w), 1186 (w), 1070 (w), 1028 (m), 920 (m), 903 (s), 795 (w), 773 (s), 756 (m), 704 (s), 689 (s), 675 (s), 631 (w), 617 (w) cm^{-1}. Anal. calcd. for $C_{16}H_{14}$ (206.3): C 93.16, H 6.84. Found: C 92.88, H 6.77.

3.1.4 2-(1-Phenylvinyl)thiazole (3c)

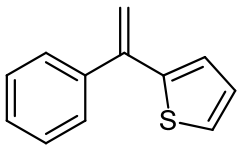


$C_{11}H_9NS$

187.26

According to the general procedure 117 mg (0.62 mmol, 62 % total yield) were obtained as a yellow oil that is sensitive towards air and light. Eluent for column chromatography was *n*-hexane/ethyl acetate 70/1. ^{1}H-NMR (DMSO-d_6, 300 MHz): δ 5.63 (s, 1 H), 6.07 (d, J = 0.4 Hz, 1 H), 7.50-7.40 (m, 5 H), 7.77 (d, J = 3.3 Hz, 1 H), 7.90 (d, J = 3.3 Hz, 1 H). ^{13}C-NMR (DMSO-d_6, 75 MHz): δ 118.5 (CH_2), 121.0 (CH), 128.1 (CH), 128.3 (CH), 128.5 (CH), 138.8 (C_{quat}), 142.2 (C_{quat}), 143.5 (CH), 167.4 (C_{quat}). MS + EI (*m/z* (%)): 188 (8), 187 (M^+, 35), 186 (100). IR: $\tilde{\nu}$ 3109 (w), 3078 (w), 3055 (w), 3026 (w), 2930 (w), 2841 (w), 2359 (w), 1950 (w), 1643 (w), 1587 (m), 1556 (m), 1493 (m), 1447 (m), 1385 (w), 1356 (w), 1321 (w), 1286 (m), 1267 (w), 1238 (m), 1184 (s), 1165 (w), 1144 (w), 1105 (m), 1070 (m), 1057 (m), 1026 (m), 1011 (w), 993 (w), 966 (w), 910 (m), 862 (m), 851 (m), 835 (w), 798 (w), 775 (m), 756 (s), 712 (s), 696 (s), 683 (s), 667 (s), 652 (s), 619 (m) cm^{-1}. Anal. calcd. for $C_{11}H_9NS$ (187.3): C 70.55, H 4.84, N 7.48. Found: C 70.30, H 5.02, N 7.28.

3.1.5 2-(1-Phenylvinyl)thiophene (3d)



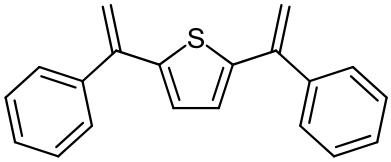
$C_{12}H_{10}S$

186.27

According to the general procedure 140 mg (0.75 mmol, 75 % total yield) were obtained as a colorless oil that is sensitive towards air and light. Eluent for column chromatography was *n*-hexane. ^{1}H NMR (DMSO-d_6, 300 MHz): δ 5.27 (s, 1 H), 5.58 (s, 1 H), 6.97 (dd, J = 3.6 Hz, J = 1.2 Hz, 1 H), 7.06 (dd, J = 5.1 Hz, J = 3.6 Hz, 1 H), 7.41 (brs, 5 H), 7.53 (dd, J = 5.1 Hz, J = 1.1 Hz, 1 H). ^{13}C NMR (DMSO-d_6, 75 MHz): δ 113.8 (CH_2), 126.1 (CH), 126.4 (CH), 127.7 (CH), 127.8 (CH), 128.3 (CH), 128.4 (CH), 140.3 (C_{quat}), 142.6 (C_{quat}), 143.7 (C_{quat}). GCMS (EI) (*m/z* (%)): 188 (5), 187 (16), 186 (M^+, 100), 185 (64), 184 (35), 171 (54), 153 (13), 152 (29), 141 (20), 139 (10), 115 (22), 92 (10), 77 (23), 76 (10), 75 (10), 69 (12), 65 (18), 63 (21), 58 (11), 51 (37), 50 (18). Anal. calcd. for $C_{12}H_{10}S$ (186.3): C 77.37, H 5.41. Found: C 77.22, H 5.32.

Due to the sensitivity of the compound an IR-spectrum could not obtained.

3.1.6 2,5-Bis(1-phenylvinyl)thiophene (3e)



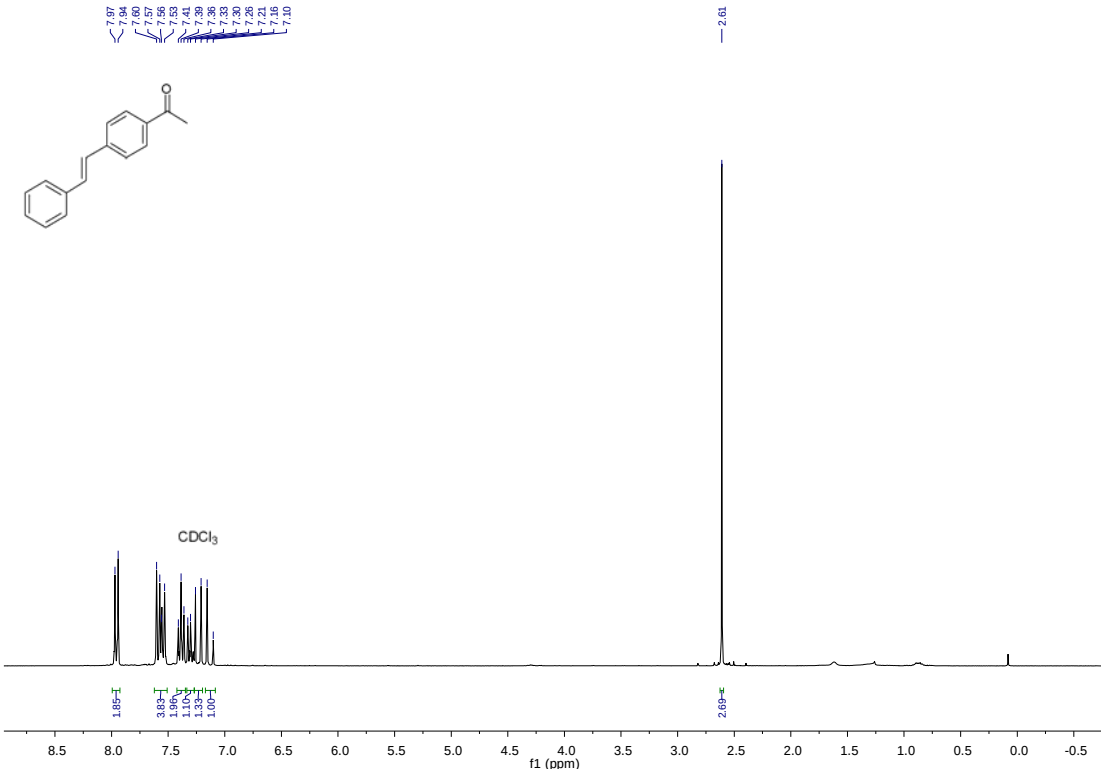
$C_{20}H_{16}S$

288.41

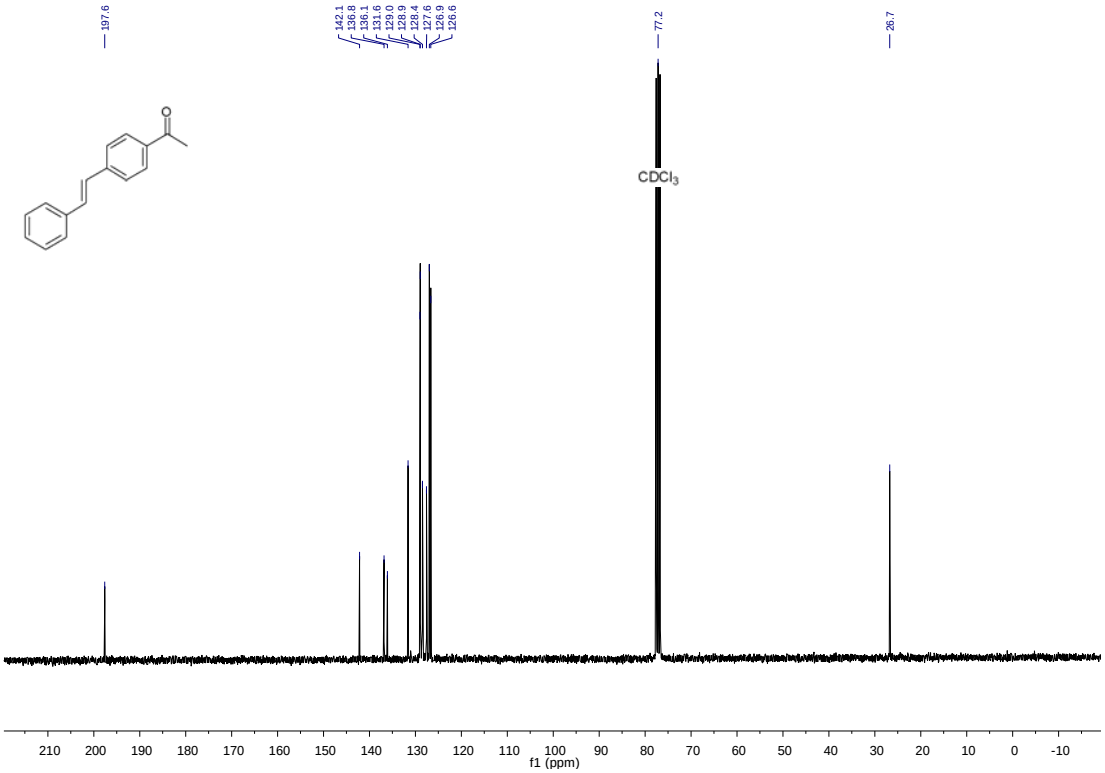
According to the general procedure 101 mg (0.35 mmol, 35 % total yield) were obtained as a colorless oil that is sensitive towards air and light. Eluent for column chromatography was *n*-hexane. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 5.16 (s, 2 H), 5.51 (s, 2 H), 6.69 (s, 2 H), 7.26-7.32 (m, 6 H), 7.35-7.40 (m, 4 H). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 113.9 (CH_2), 126.9 (CH), 128.2 (CH), 128.3 (CH), 128.5 (CH), 140.9 (C_{quat}), 143.6 (C_{quat}), 144.3 (C_{quat}). GCMS (EI) (*m/z* (%)): 290 (7), 289 (22), 288 (M^+, 100), 287 (15), 273 (16), 272 (9), 271 (13), 185 ($(M-C_8H_7)^+$, 18), 152 (16), 139 (10), 128 (11), 115 (26), 103 ($(C_8H_7)^+$, 64), 102 (13), 89 (11), 78 (14), 77 ($(C_6H_5)^+$, 60), 63 (15), 51 (36). IR: $\tilde{\nu}$ 3055 (w), 3024 (w), 2953 (w), 2928 (w), 2361 (w), 2332 (w), 1730 (w), 1636 (w), 1597 (m), 1491 (m), 1443 (m), 1317 (w), 1288 (m), 1258 (w), 1221 (w), 1178 (w), 1157 (w), 1138 (w), 1072 (m), 1026 (m), 1001 (m), 966 (w), 887 (m), 866 (w), 845 (w), 808 (m), 771 (s), 760 (s), 696 (s), 669 (m), 635 (m), 615 (m) cm^{-1}. Anal. calcd. for $C_{20}H_{16}S$ (288.4): C 83.29, H 5.59. Found: C 83.30, H 5.36.

3.2 ^{1}H NMR and ^{13}C NMR Spectra of the *α*-substituted Styrenes 3

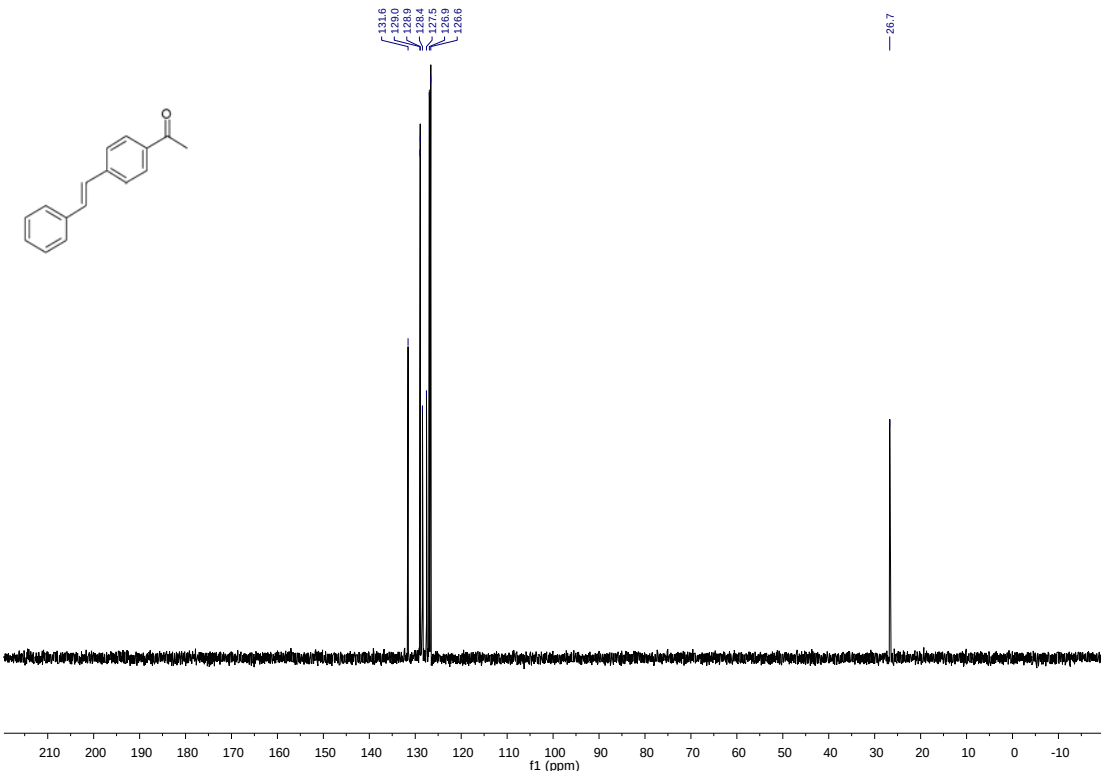
3.2.1 (*E*)-1-(4-Styrylphenyl)ethanone (4)



^{1}H NMR of **4** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (*δ* in ppm).

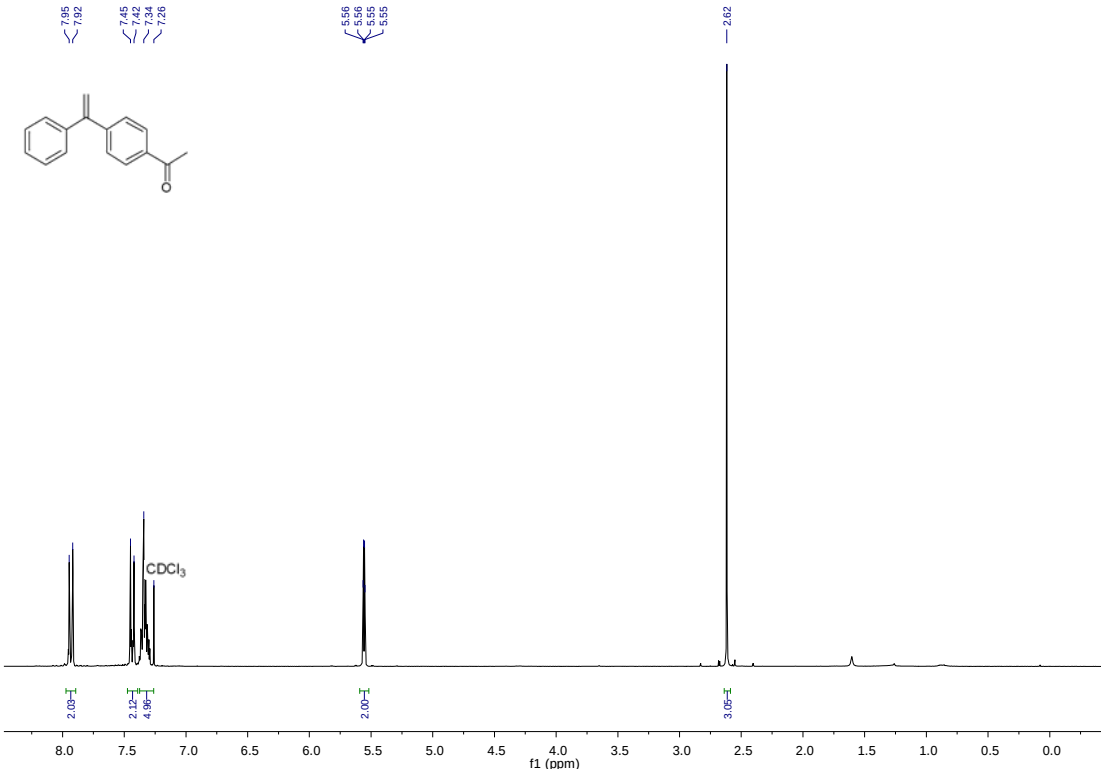


^{13}C NMR of **4** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (*δ* in ppm).

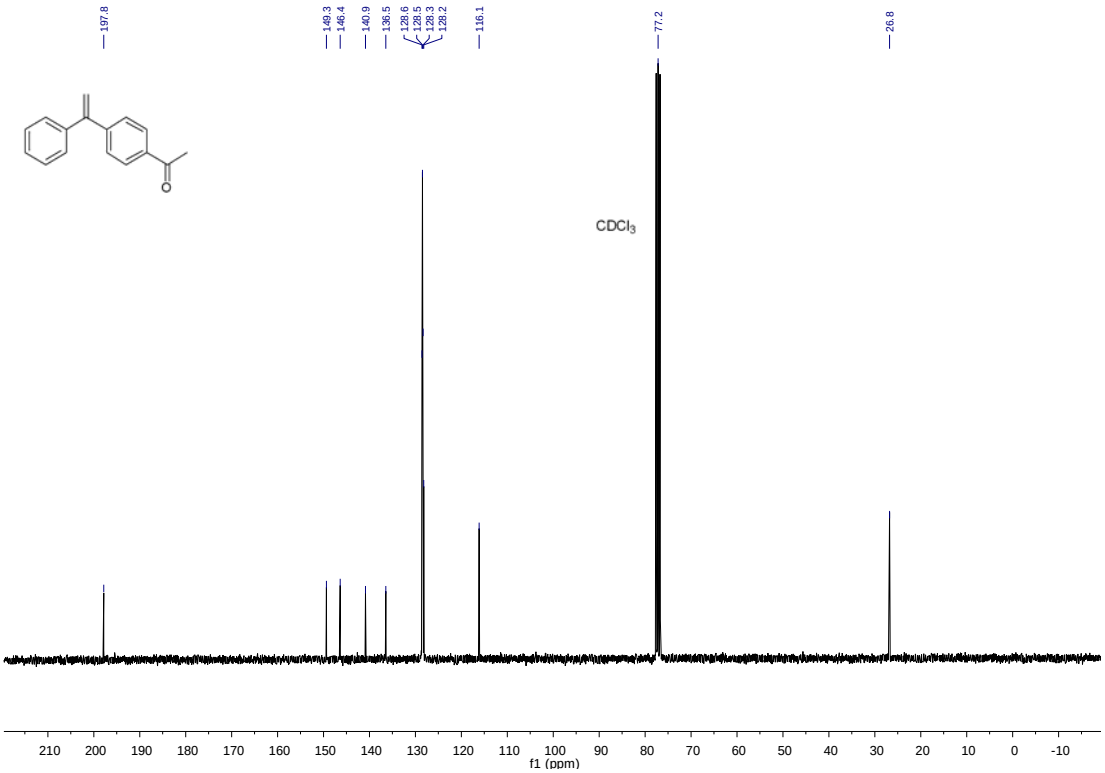


^{13}C 135-DEPT NMR of **4** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

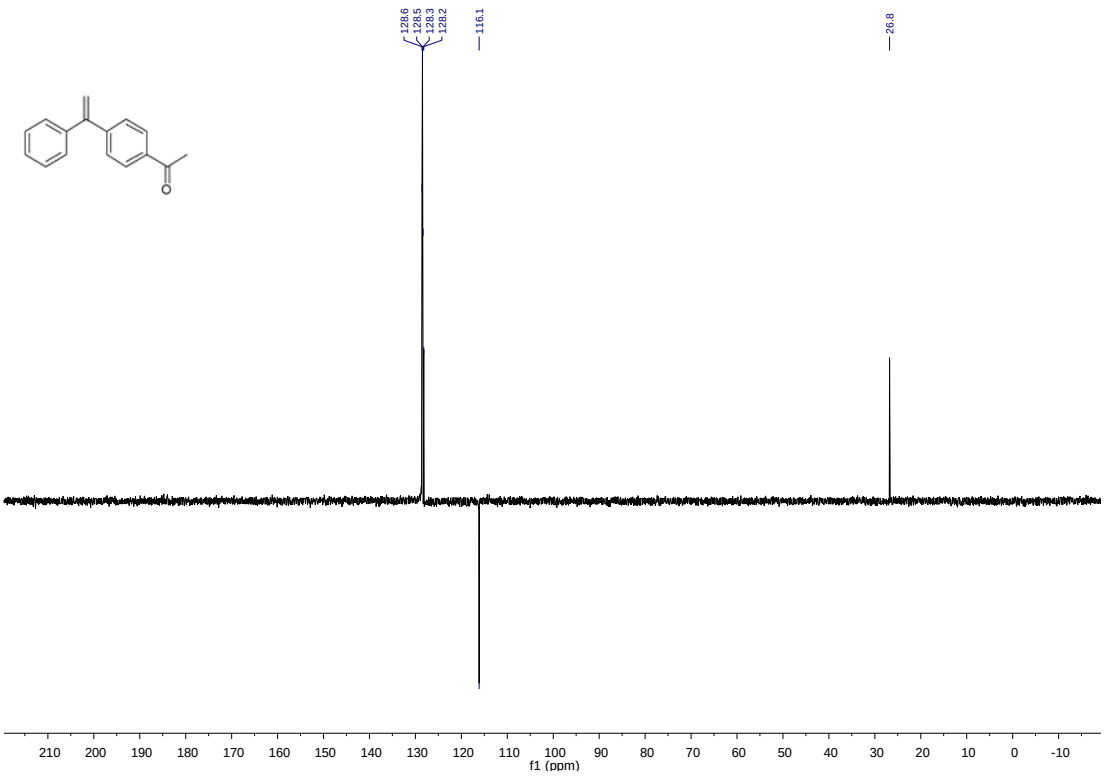
3.2.2 1-(4-(1-Phenylvinyl)phenyl)ethanone (3a)



^{1}H NMR of **3a** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

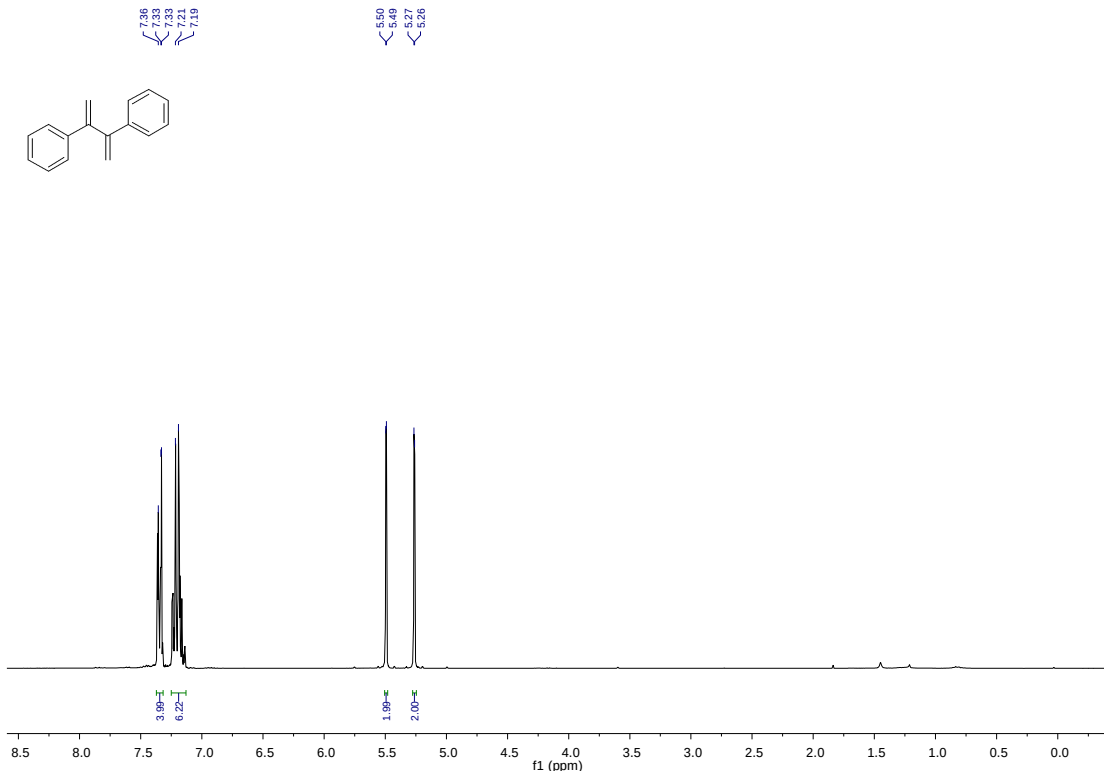


^{13}C NMR of **3a** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

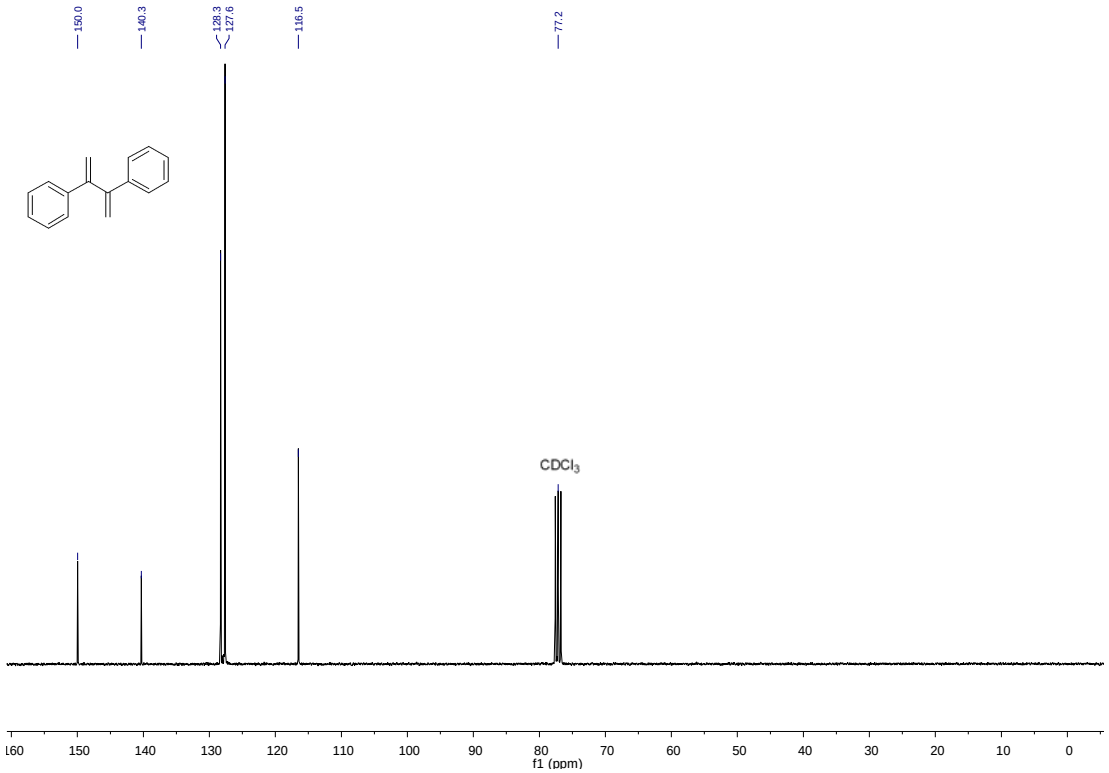


^{13}C 135-DEPT NMR of **3a** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

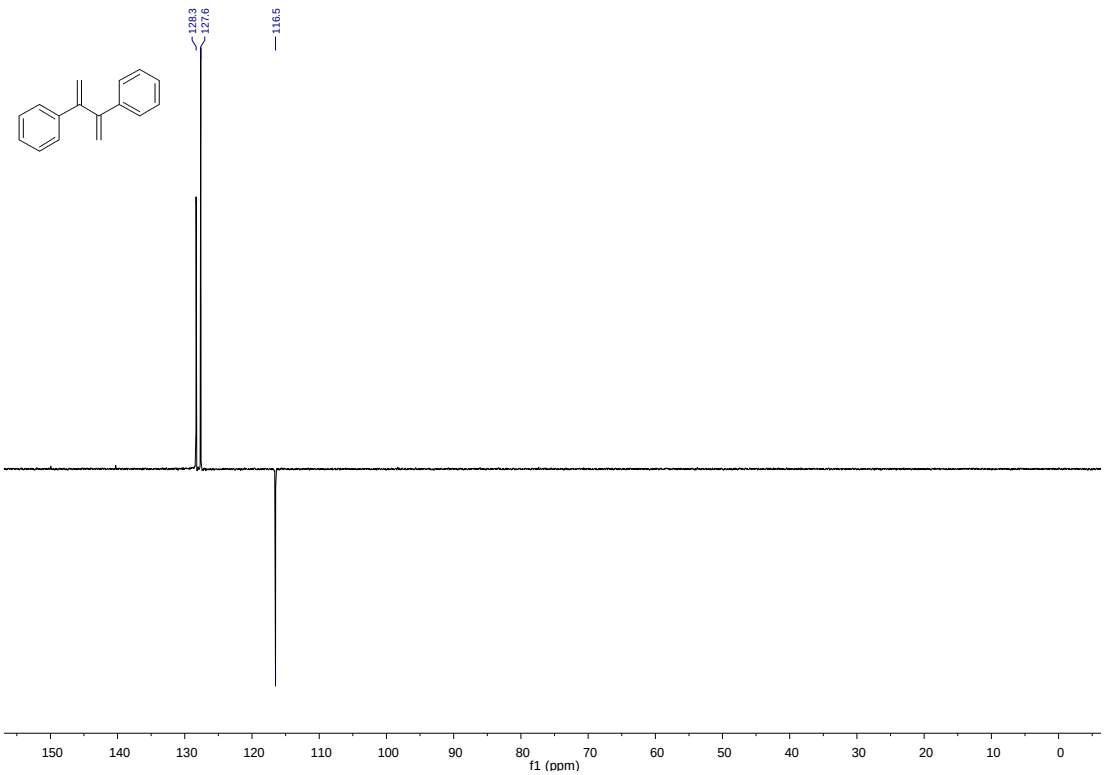
3.2.3 2,3-Diphenylbuta-1,3-diene (3b)



^{1}H NMR of **3b** (30 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

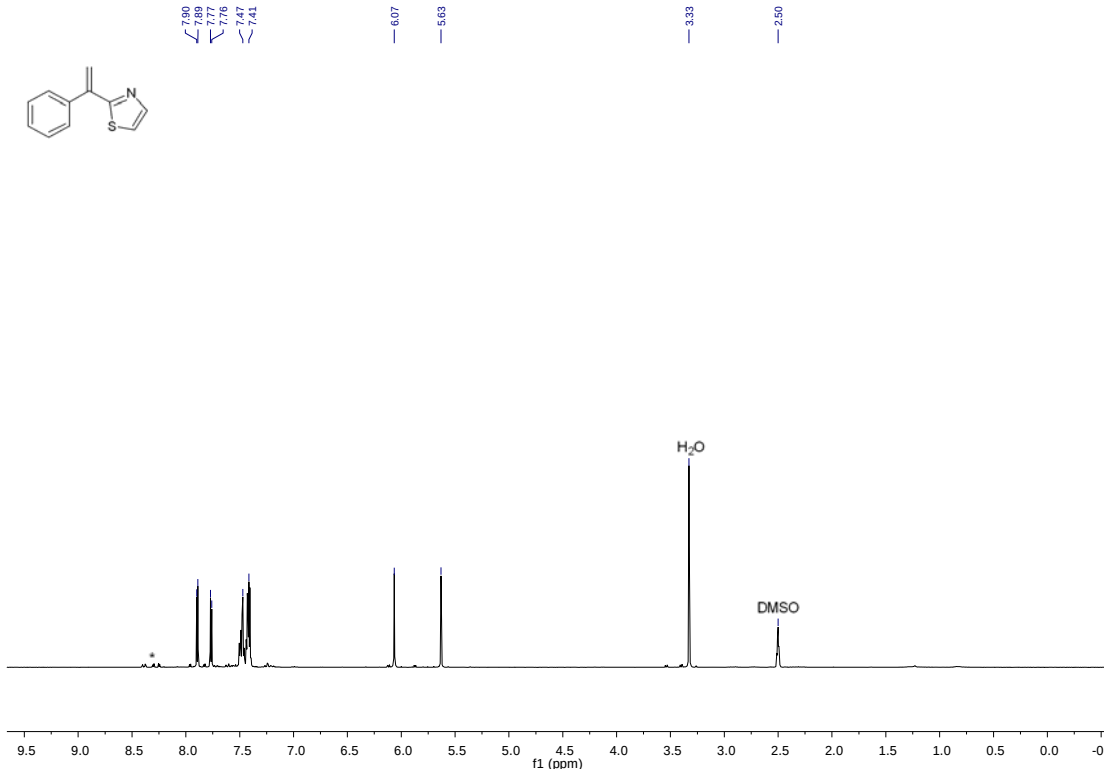


^{13}C NMR of **3b** (30 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

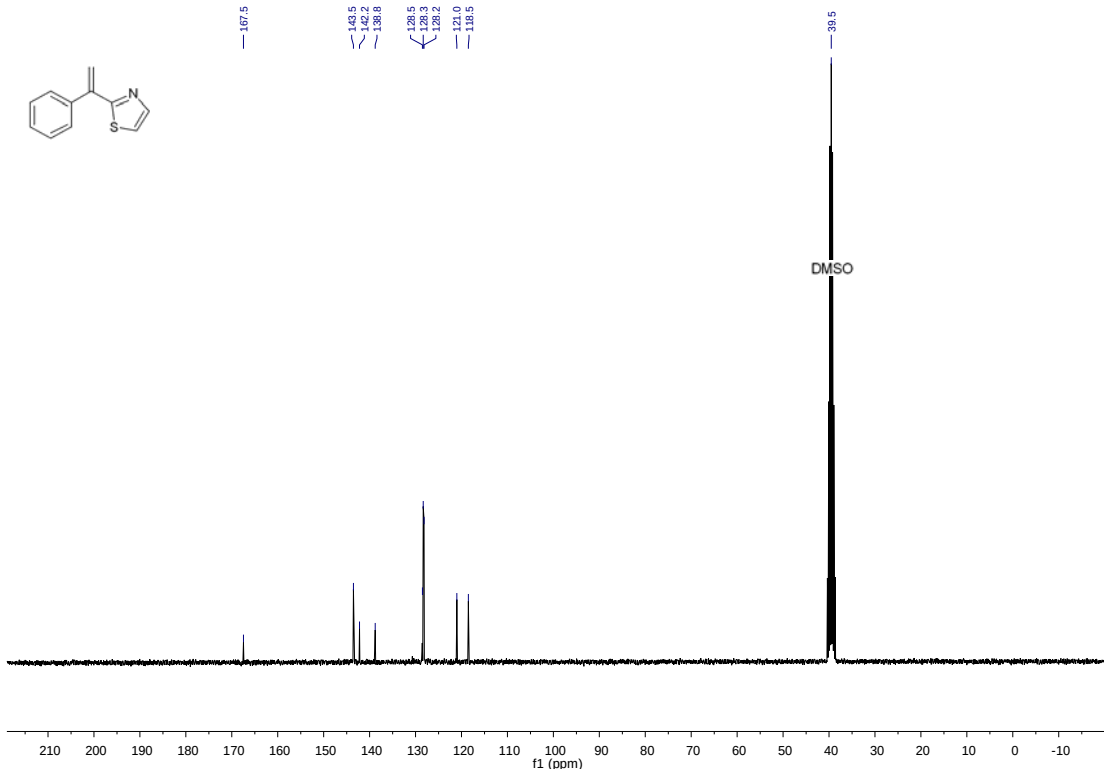


^{13}C 135-DEPT NMR of **3b** (30 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

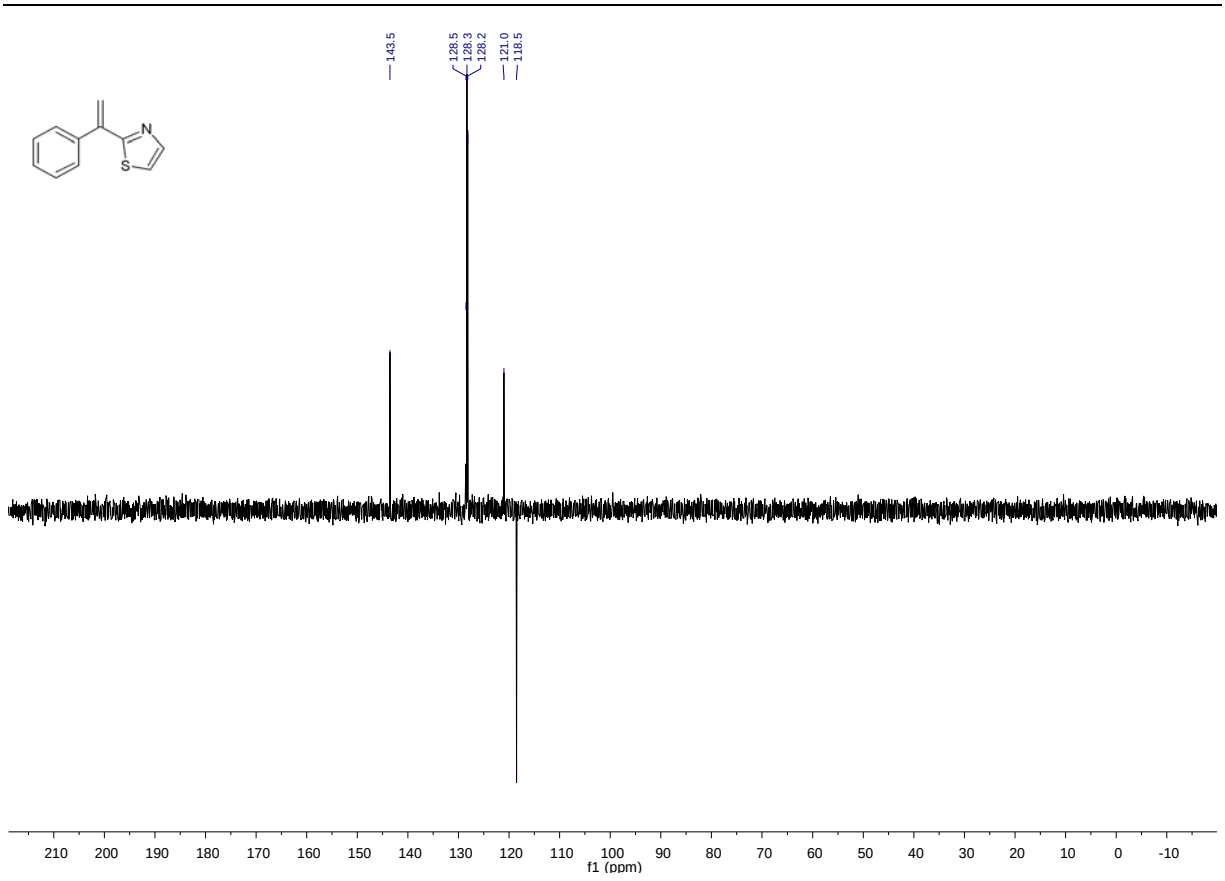
3.2.4 2-(1-Phenylvinyl)thiazole (3c)



^{1}H NMR of **3c** (15 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm). (* Impurities in NMR-sample.)

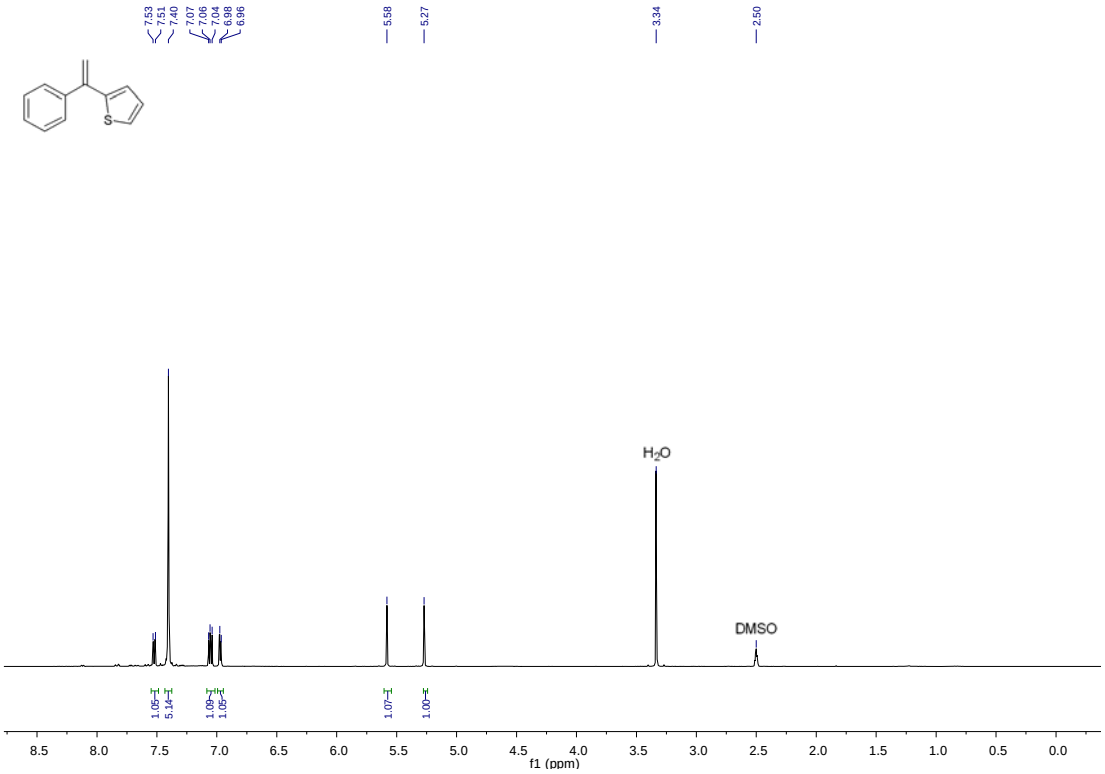


^{13}C NMR of **3c** (15 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

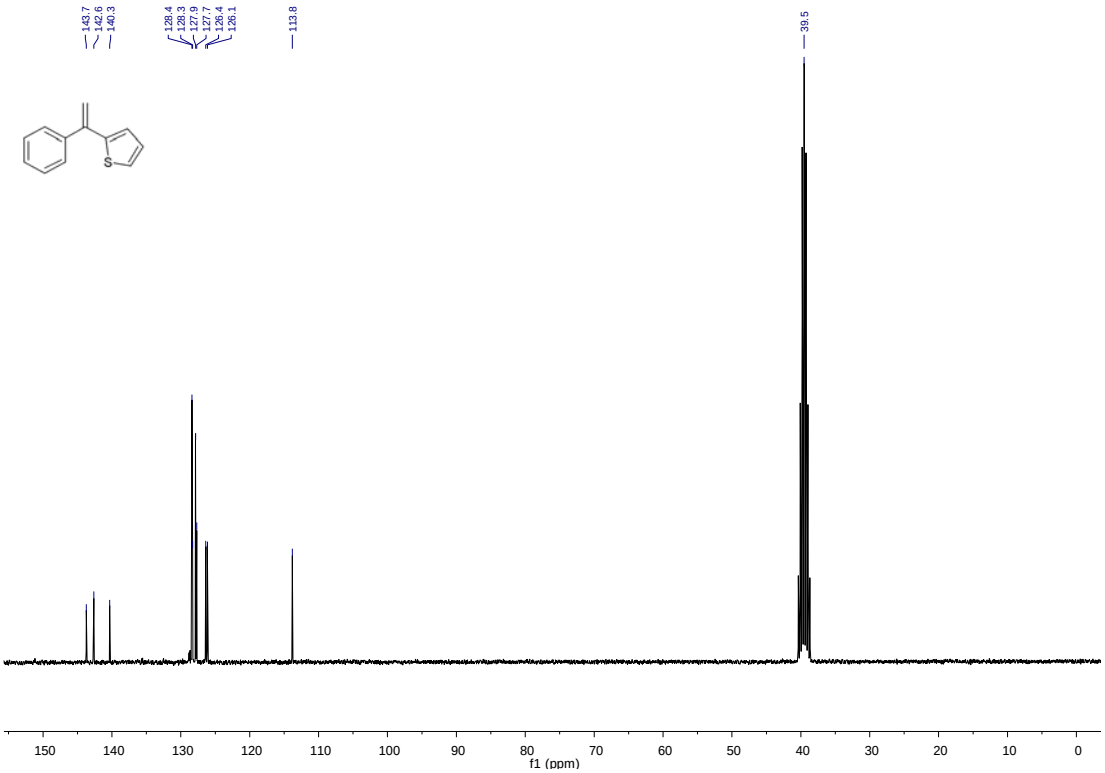


^{13}C 135-DEPT NMR of **3c** (15 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

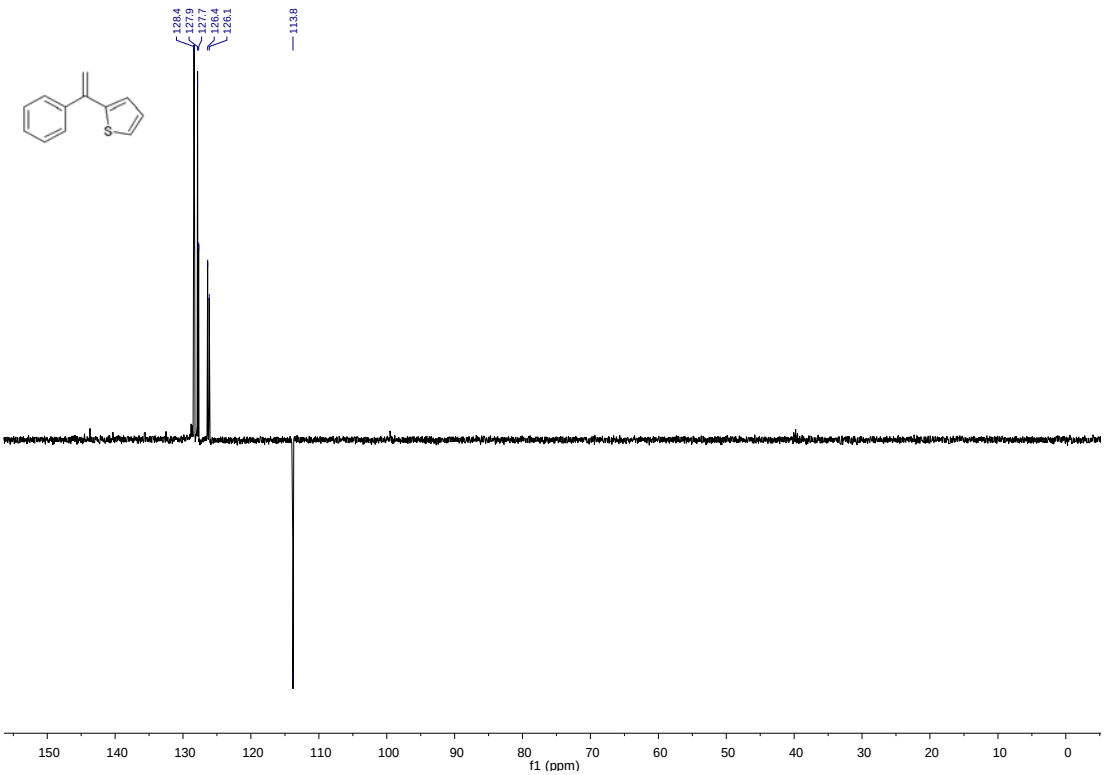
3.2.5 2-(1-Phenylvinyl)thiophene (3d)



^{1}H NMR of **3d** (25 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

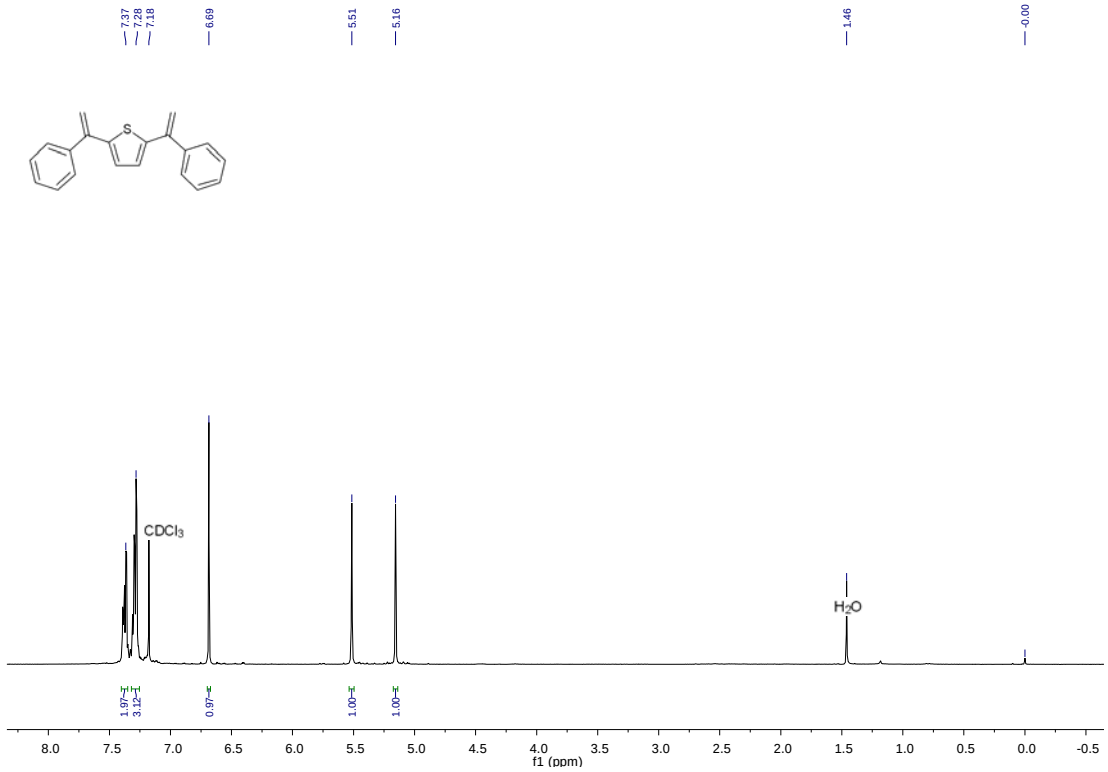


^{13}C NMR of **3d** (25 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

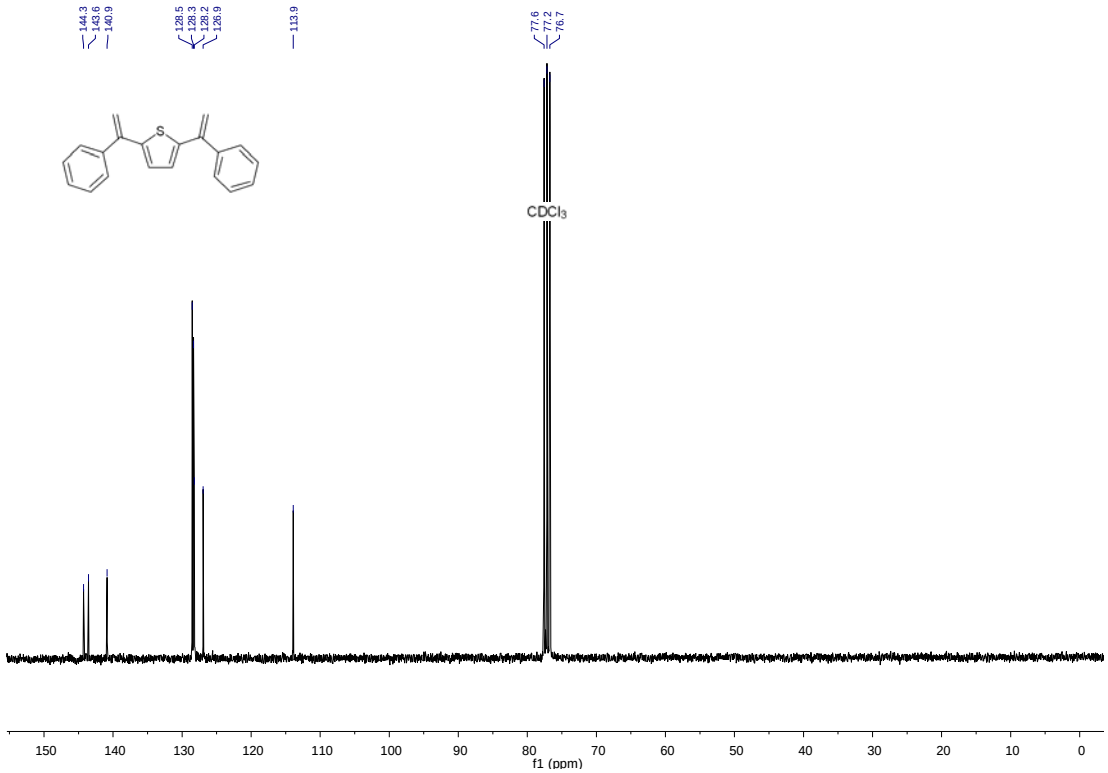


^{13}C 135-DEPT NMR of **3d** (25 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

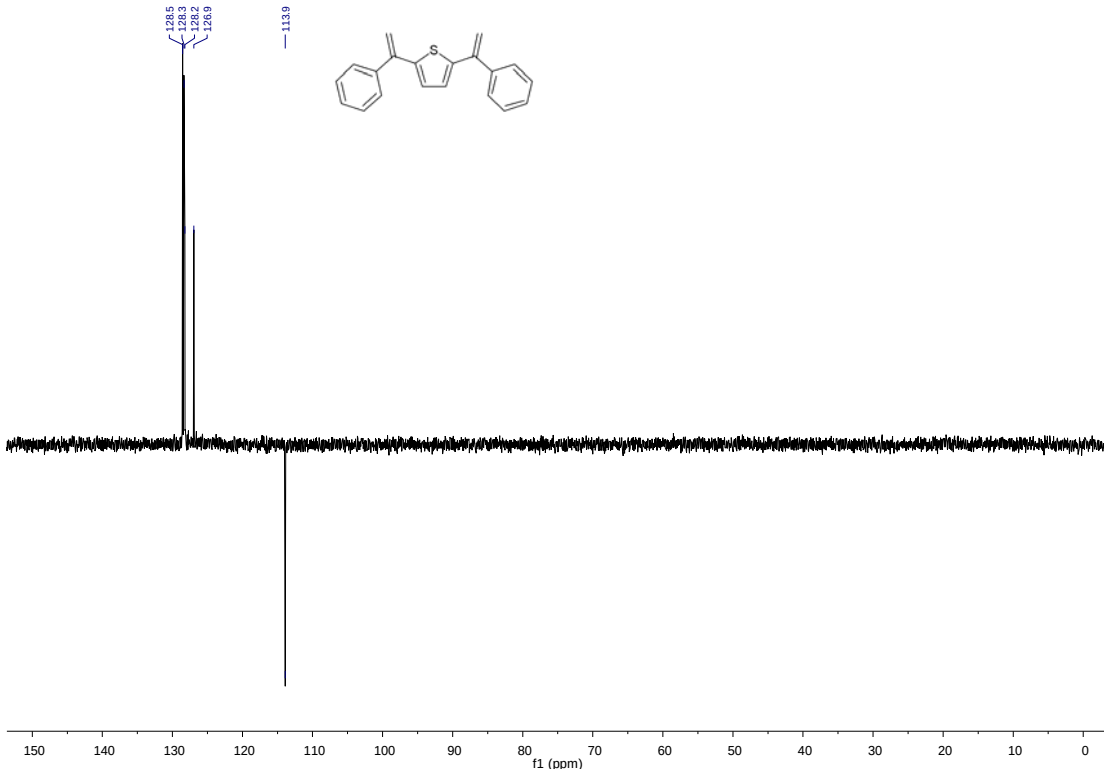
3.2.6 2,5-Bis(1-phenylvinyl)thiophene (3e)



^{1}H NMR of **3e** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).



^{13}C NMR of **3e** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).



^{13}C 135-DEPT NMR of **3e** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

3.3 Synthesis of the substituted Cinnamaldehydes 5

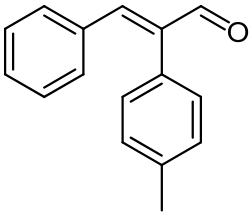
$PdCl_2$ (3.5 mg, 0.02 mmol, 2 mol%) and cataCXium® AHI (19 mg, 0.04 mmol, 4 mol%) were placed under argon atmosphere in a dry screw-cap vessel with septum. The substrate for the borylation (1.00 mmol, 1.0 equiv) was added followed by 2 mL of dry 1,4-dioxane. Dry triethylamine (0.5 mL) and 4,4,5,5-tetramethyl-1,3,2-dioxaborolane (0.22 mL, 1.50 mmol, 1.5 equiv) were successively added to the mixture, which was stirred at 100 °C (preheated oil bath) for 4 h (monitored by TLC). Then, after cooling to room temperature (water bath), destilled water (2 mL), Cs_2CO_3 (815 mg, 2.50 mmol, 2.5 equiv), and *α*-bromocinnamaldehyde (**1b**) (215 mg, 1.00 mmol, 1.0 equiv) were successively added. The mixture was stirred at 100 °C for 20 h (preheated oil bath). Then, after cooling to room temperature, 30 mL 0.1 *N* HCl were added to the mixture and the aqueous phase was extracted with dichloromethane (3 x 35 mL, monitored by TLC). The combined organic layers were dried with sodium sulfate. The solvents were removed under reduced pressure. The residue was adsorbed onto Celite® and purified chromatographically on silica.

The experimental details are given in **Table 2**.

Table 2: Synthesis of the substituted Cinnamaldehydes **5**

Entry	Substrate *Masuda* borylation	Substituted cinnamaldehyde **5** (isolated yield)	Chromatographic purification (eluent) R_f (eluent)
1	220 mg (1.00 mmol) 4-Iodotoluene (**2e**) (*Aldrich*)	(**5a**) pale yellow solid 178 mg (0.80 mmol, 80 %)	He/EtOAc = 50/1 R_f (He/EtOAc = 50:1): 0.10
2	242 mg (1.00 mmol) 2-Bromo-6-methoxynaphthaline (**2f**) (*Alfa Aesar*)	(**5b**) pale yellow solid 187 mg (0.65 mmol, 65 %)	He/EtOAc = 10/1 R_f (He/EtOAc = 10:1): 0.19
3	203 mg (1.00 mmol) (1-Bromovinyl)benzene(**1a**) (*Aldrich*)	(**5c**) pale yellow solid 130 mg (0.56 mmol, 56 %)	He/EtOAc = 50/1 R_f (He/EtOAc = 50:1): 0.04
4	397 mg (1.00 mmol) 3-Iodo-1-tosyl-1*H*-indole (**2g**)	(**5d**) yellow solid 330 mg (0.82 mmol, 82 %)	He/EtOAc = 10/1 R_f (He/EtOAc = 10:1): 0.08

3.3.1 (*E*)-3-Phenyl-2-(*p*-tolyl)acrylaldehyde (5a)

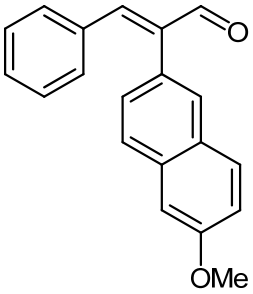


$C_{16}H_{14}O$

222.28

According to the general procedure 178 mg (0.80 mmol, 80 % total yield) were obtained as a pale yellow solid. Eluent for column chromatography was *n*-hexane/ethyl acetate 50/1. Mp 73-74 °C. ^{1}H-NMR ($CDCl_3$, 300 MHz): δ 2.39 (s, 3 H), 7.05-7.11 (m, 2 H), 7.17-7.32 (m, 7 H), 7.35 (s, 1 H), 9.76 (s, 1 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): δ 21.6 (CH_3), 128.7 (CH), 129.4 (CH), 129.8 (CH), 130.3 (CH), 130.4 (C_{quat}), 130.9 (CH), 134.4 (C_{quat}), 138.3 (C_{quat}), 142.0 (C_{quat}), 150.1 (CH), 194.4 (CH). EI + MS (*m/z* (%)): 223 (16), 222 (M^+, 94), 221 (43), 207 ($(M\text{-}CH_3)^+$, 10), 193 ($(M\text{-}CHO)^+$, 29), 191 (15), 189 (17), 180 (13), 179 (88), 178 ($(M\text{-}CH_3\text{-}CHO)^+$, 100), 177 (12), 176 (16), 165 (25), 152 (27), 151 (10), 131 ($(M\text{-}C_7H_7)^+$, 4), 130 (19), 116 (39), 115 (96), 102 (27), 92 (30), 91 ($C_7H_7^+$, 39), 89 (33), 78 (16), 77 ($C_6H_5^+$, 27), 76 (20), 75 (13), 65 (36), 63 (34), 52 (10), 51 (49), 50 (16). IR: $\tilde{\nu}$ 3298 (w), 3275 (w), 3028 (w), 2953 (w), 2924 (w), 2843 (w), 2727 (w), 1722 (w), 1661 (s), 1626 (w), 1607 (w), 1593 (w), 1574 (w), 1531 (w), 1512 (s), 1447 (m), 1414 (w), 1373 (w), 1341 (w), 1317 (w), 1302 (m), 1287 (w), 1223 (m), 1194 (w), 1175 (m), 1142 (w), 1107 (w), 1090 (m), 1067 (s), 1026 (w), 976 (w), 930 (w), 889 (w), 856 (w), 841 (w), 829 (w), 808 (w), 766 (m), 745 (s), 716 (w), 694 (s), 667 (s) cm^{-1}. Anal. calcd. for $C_{16}H_{14}O$ (222.3): C 86.45, H 6.35. Found: C 86.30, H 6.49.

3.3.2 (*E*)-2-(6-Methoxynaphthalin-2-yl)-3-phenylacrylaldehyde (5b)

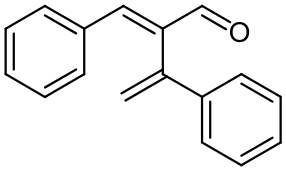


$C_{20}H_{16}O$

288.34

According to the general procedure 187 mg (0.65 mmol, 65 % total yield) were obtained as a pale yellow solid. Eluent for column chromatography was *n*-hexane/ethyl acetate 10/1. Mp 107-108 °C. ^{1}H-NMR (DMSO-d_6, 300 MHz): δ 3.90 (s, 3 H), 7.18 (dt, J = 8.3 Hz, J = 2.2 Hz, 2 H), 7.23-7.35 (m, 5 H), 7.37 (d, J = 2.5 Hz, 1 H), 7.65 (s, 1 H), 7.76 (s, 1 H), 7.83 (t, J = 8.9 Hz, 2 H), 9.82 (s, 1 H). ^{13}C-NMR (DMSO-d_6, 75 MHz): δ 55.3 (CH_3), 105.9 (CH), 118.9 (CH), 127.1 (CH), 127.5 (CH), 128.1 (CH), 128.47 (C_{quat}), 128.49 (C_{quat}), 128.6 (CH), 129.5 (CH), 130.3 (CH), 130.4 (CH), 133.8 (C_{quat}), 134.1 (C_{quat}), 141.4 (C_{quat}), 150.3 (CH), 157.7 (C_{quat}), 194.5 (CH). EI + MS (*m/z* (%)): 289 (22), 288 (M^+, 100), 287 (8), 260 (11), 259 ($(M\text{-}CHO)^+$, 30), 245 (10), 244 (12), 228 (11), 226 (10), 216 (12), 215 (39), 202 (10), 182 ($(M\text{-}C_6H_5\text{-}CHO)^+$, 6), 158 (24). IR: $\tilde{\nu}$ 2835 (w), 2820 (w), 1667 (s), 1628 (w), 1616 (w), 1597 (m), 1489 (m), 1464 (w), 1452 (w), 1418 (w), 1406 (w), 1391 (w), 1327 (w), 1294 (w), 1263 (m), 1227 (s), 1213 (w), 1184 (m), 1163 (m), 1125 (m), 1086 (w), 1069 (s), 1032 (s), 1005 (w), 974 (w), 935 (m), 924 (w), 901 (m), 858 (s), 845 (w), 808 (s), 762 (s), 737 (s), 696 (s), 664 (w), 611 (w) cm^{-1}. Anal. calcd. for $C_{20}H_{16}O_2$ (288.3): C 83.31, H 5.59. Found: C 83.45, H 5.57.

3.3.3 (*E*)-2-Benzyliden-3-phenylbut-3-enal (5c)

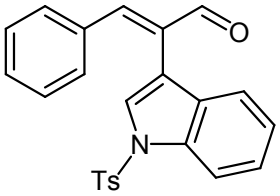


$C_{17}H_{14}O$

234.29

According to the general procedure 130 mg (0.56 mmol, 56 % total yield) were obtained as a pale yellow solid. Eluent for column chromatography was *n*-hexane/ethyl acetate 50/1. Mp 89-91 °C. ^{1}H-NMR (DMSO-d_6, 300 MHz): δ 5.15 (s, 1 H), 6.03 (s, 1 H), 7.27-7.37 (m, 6 H), 7.40-7.44 (m, 2 H), 7.65 (dd, J = 6.6 Hz, J = 3.2 Hz, 2 H), 7.76 (s, 1 H), 9.71 (s, 1 H). ^{13}C-NMR (DMSO-d_6, 75 MHz): δ 116.4 (CH_2), 125.5 (CH), 128.2 (CH), 128.7 (CH), 128.8 (CH), 130.5 (CH), 130.6 (CH), 133.8 (C_{quat}), 137.1 (C_{quat}), 141.1 (C_{quat}), 141.6 (C_{quat}), 150.5 (CH), 194.2 (CH). EI + MS (*m/z* (%)): 235 (4), 234 (M^+, 22), 206 (30), 205 ((M-CHO)$^+$, 83), 204 (18), 203 (29), 202 (20), 191 (30), 190 (19), 189 (16), 178 (10), 165 (17), 129 (22), 128 ((M-C_6H_5-CHO)$^+$, 60), 127 (30), 126 (12), 115 (18), 103 (15), 102 (33), 101 (15), 91 ($C_7H_7^+$, 45), 89 (20), 78 (75), 77 ($C_6H_5^+$, 100), 76 (28), 75 (17), 74 (13), 65 (18), 63 (32), 52 (28), 51 ($C_4H_3^+$, 99), 50 (31). IR: $\tilde{\nu}$ 3082 (w), 3057 (w), 3028 (w), 2930 (w), 2818 (w), 2710 (w), 1753 (w), 1728 (w), 1680 (s), 1626 (m), 1597 (m), 1572 (w), 1493 (m), 1445 (m), 1418 (w), 1371 (w), 1325 (w), 1308 (w), 1290 (w), 1256 (w), 1213 (w), 1182 (w), 1146 (s), 1096 (m), 1074 (m), 1049 (w), 1028 (m), 1001 (w), 970 (w), 930 (w), 908 (m), 864 (w), 837 (w), 793 (s), 756 (s), 691 (s), 638 (m), 611 (m) cm^{-1}. Anal. calcd. for $C_{17}H_{14}O$ (234.3): C 87.15, H 6.02. Found: C 87.32, H 6.27.

3.3.4 (*E*)-2-(6-Methoxynaphthalin-2-yl)-3-phenylacrylaldehyde (5d)



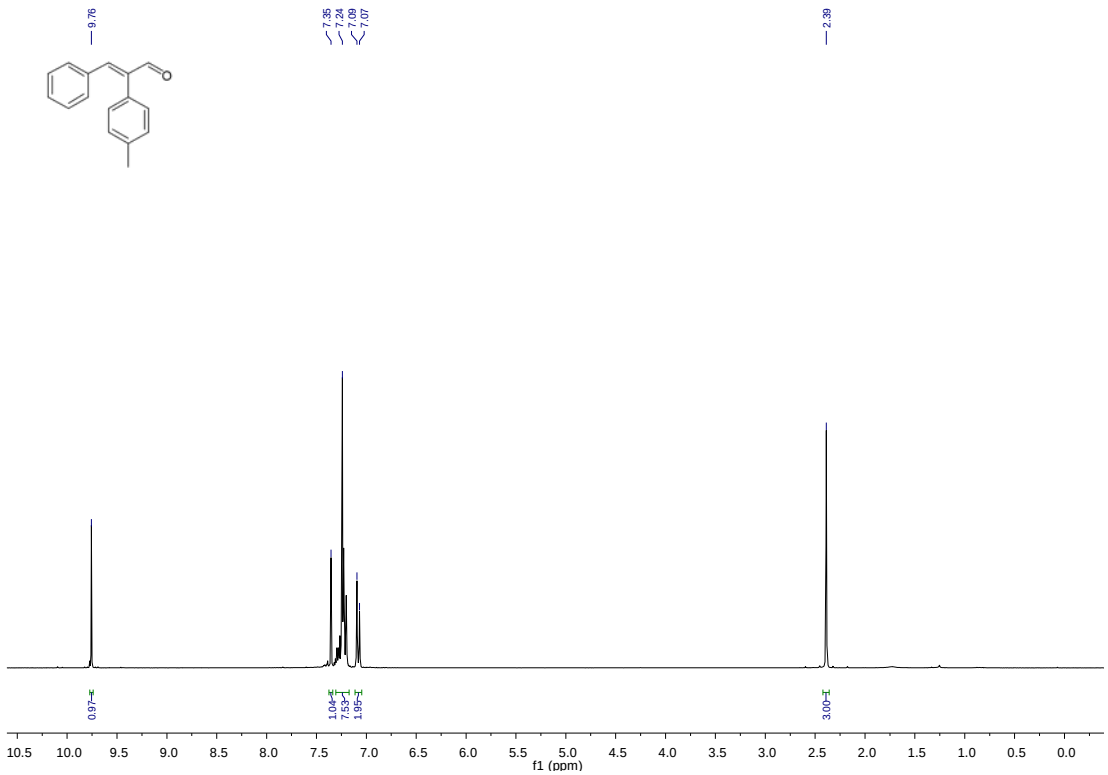
$C_{24}H_{19}NO_3S$

401.48

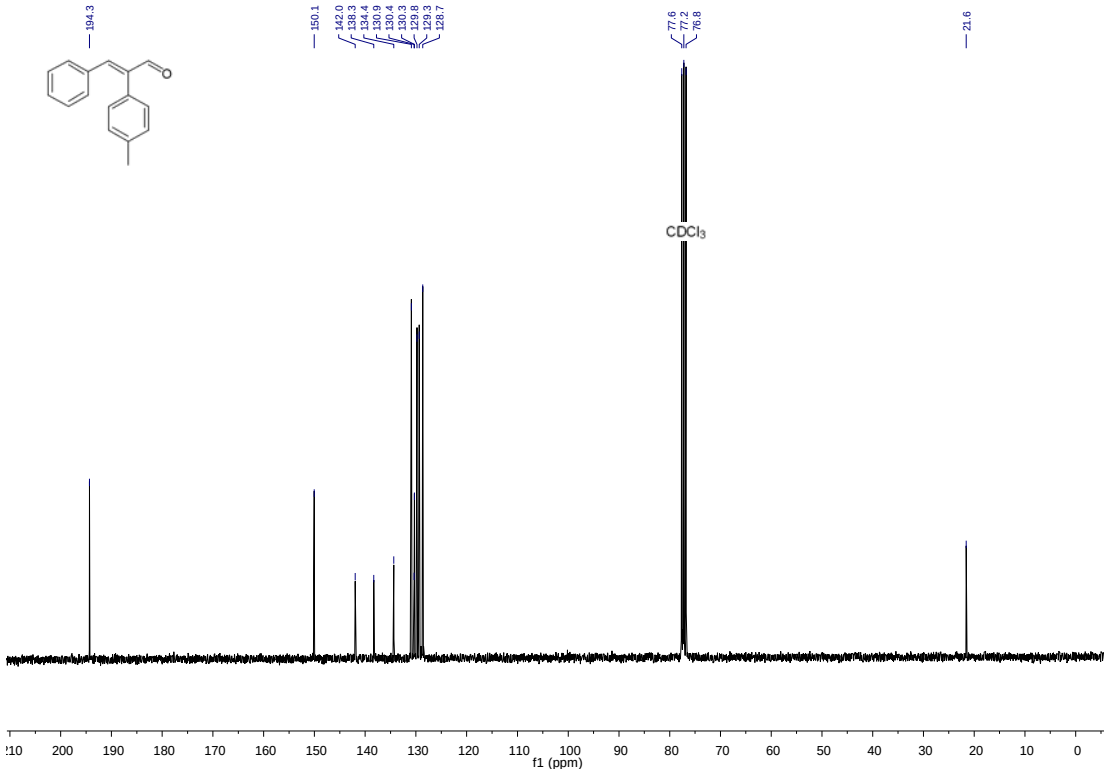
According to the general procedure 330 mg (0.82 mmol, 82 % total yield) were obtained as a yellow solid. Eluent for column chromatography was *n*-hexane/ethyl acetate 10/1. Mp 43-46 °C. ^{1}H-NMR (DMSO-d_6, 300 MHz): δ 2.36 (s, 3 H), 6.90 (d, J = 7.7 Hz, 1 H), 7.05-7.15 (m, 3 H), 7.16-7.20 (m, 2 H), 7.26-7.35 (m, 2 H), 7.42 (d, J = 8.0 Hz, 2 H), 7.79 (s, 1 H), 7.87 (d, J = 8.4 Hz, 2 H), 7.93 (s, 1 H), 7.97 (d, J = 8.3 Hz, 1 H), 9.81 (s, 1 H). ^{13}C-NMR (DMSO-d_6, 75 MHz): δ 21.0 (CH_3), 113.5 (CH), 114.9 (C_{quat}), 120.5 (CH), 123.5 (CH), 125.1 (CH), 126.5 (CH), 126.7 (CH), 128.5 (CH), 128.7 (C_{quat}), 130.1 (CH), 130.3 (CH), 130.5 (CH), 132.0 (C_{quat}), 134.0 (C_{quat}), 134.1 (C_{quat}), 134.5 (C_{quat}), 145.6 (C_{quat}), 151.8 (CH), 193.6 (CH). EI + MS (*m/z* (%)): 403 (5), 402 (15), 401 (M^+, 53), 247 (7), 246 ((M-Ts)$^+$, 20), 219 (16), 218 (100), 217 ((M-Ts-CHO)$^+$, 99), 216 (28), 189 (24), 155 (Ts^+, 5), 140 (10), 115 ($C_8H_5N^+$, 4), 91 ($C_7H_7^+$, 23), 57 (10), 43 (13). IR: $\tilde{\nu}$ 2953 (w), 2924 (w), 2849 (w), 2718 (w), 1682 (s), 1634 (w), 1597 (w), 1543 (w), 1447 (m), 1398 (w), 1368 (s), 1294 (w), 1267 (w), 1173 (s), 1128 (s), 1109 (m), 1090 (s), 1040 (m), 1016 (w), 1001 (w), 953 (m), 930 (w), 897 (w), 812 (w), 777 (w), 746 (s), 735 (w), 718 (w), 691 (s), 664 (s), 637 (w) cm^{-1}. Anal. calcd. for $C_{24}H_{19}O_3S$ (401.5): C 71.80, H 4.77, N 3.49. Found: C 72.10, H 5.06, N 3.33.

3.4 ^{1}H NMR and ^{13}C NMR Spectra of the Cinnamaldehydes 5

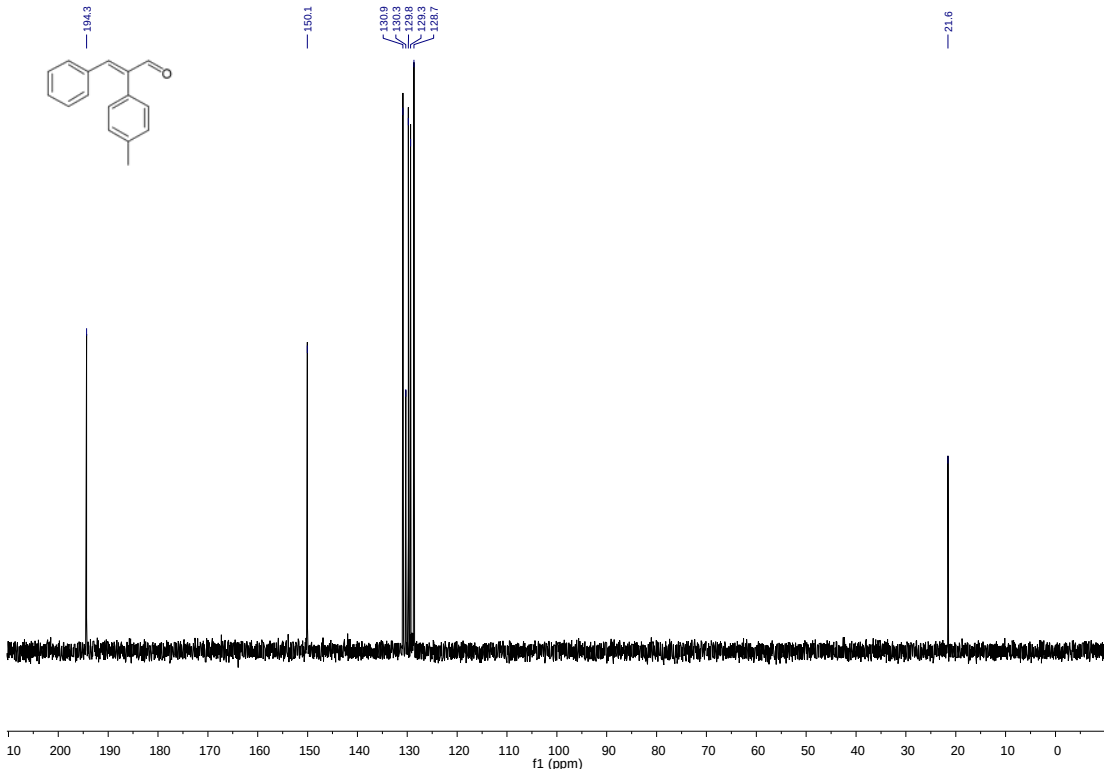
3.4.1 (*E*)-3-Phenyl-2-(*p*-tolyl)acrylaldehyde (5a)



^{1}H NMR of **5a** (25 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

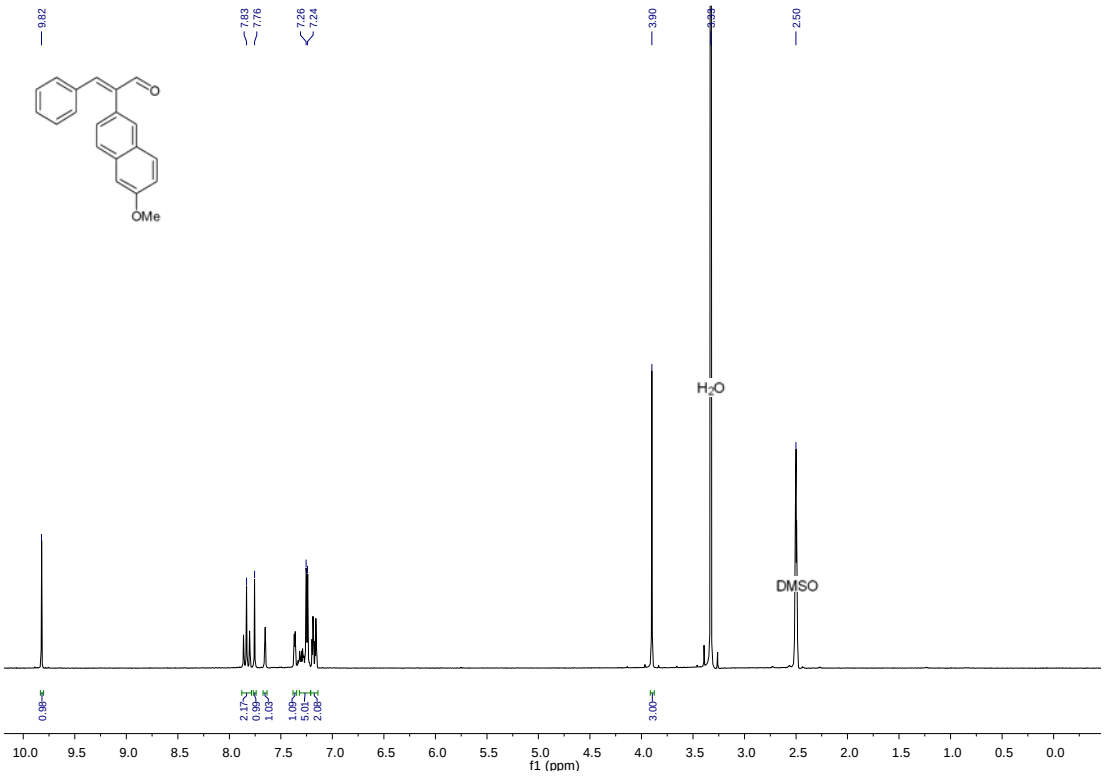


^{13}C NMR of **5a** (25 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

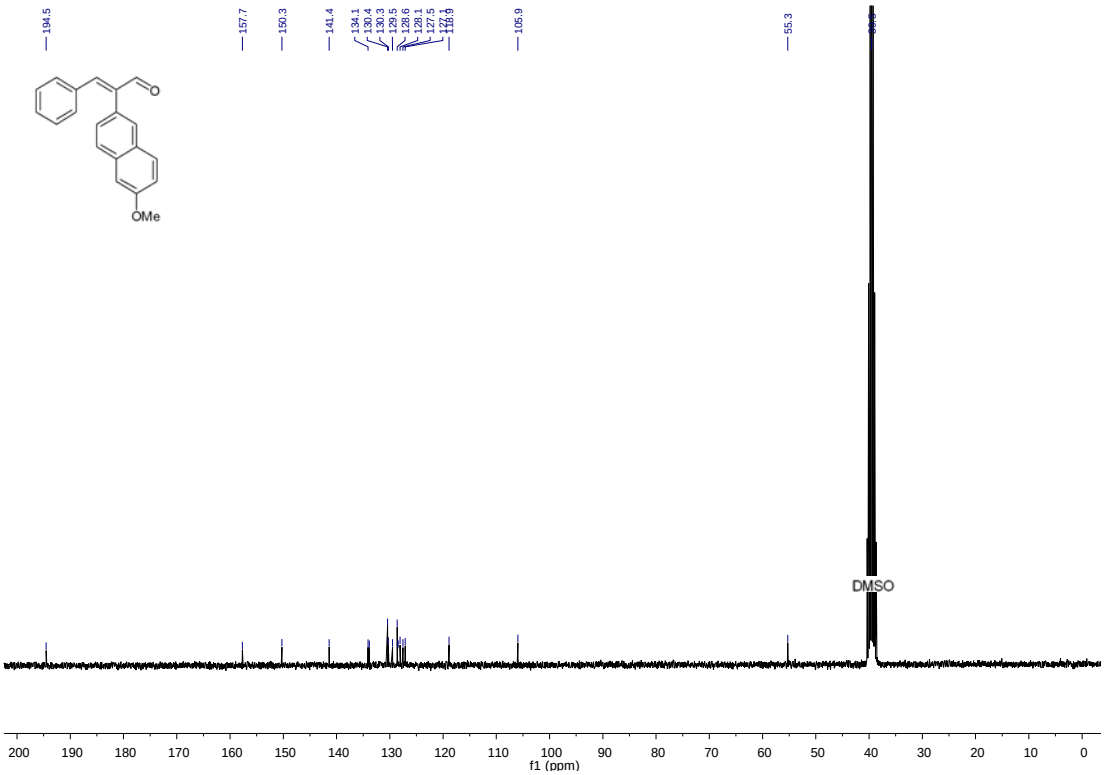


^{13}C 135-DEPT NMR of **5a** (25 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

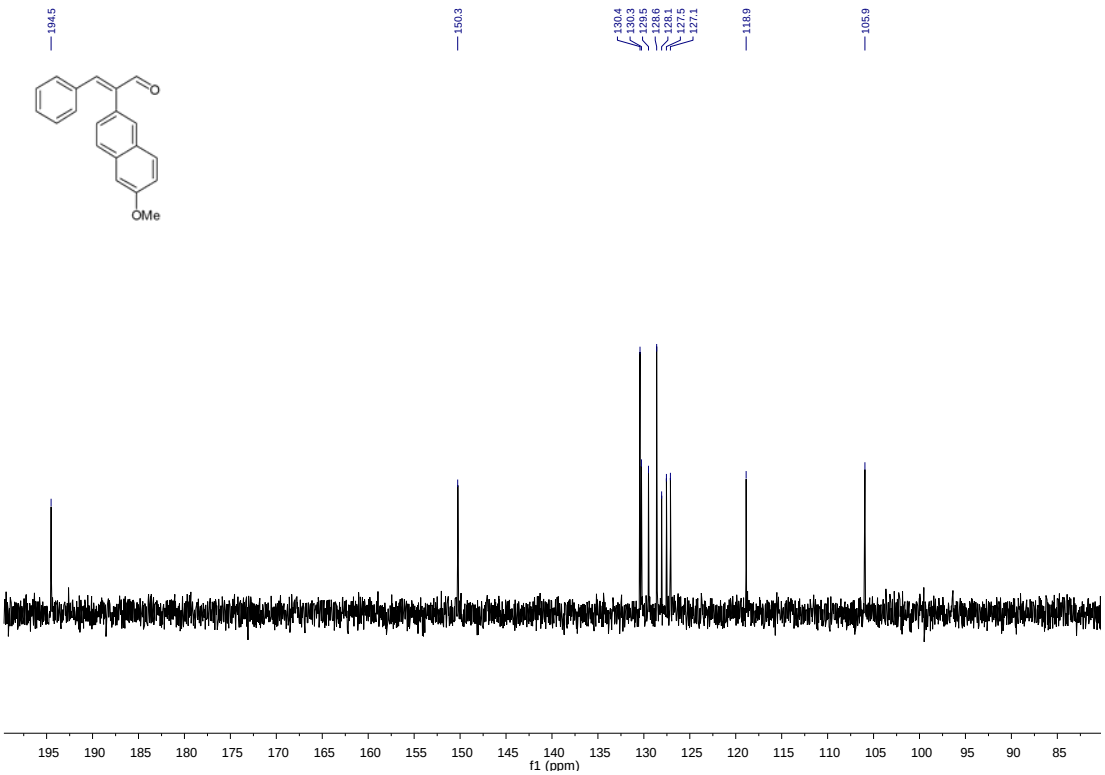
3.4.2 (*E*)-2-(6-Methoxynaphthalin-2-yl)-3-phenylacrylaldehyde (5b)



^{1}H NMR of **5b** (12 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

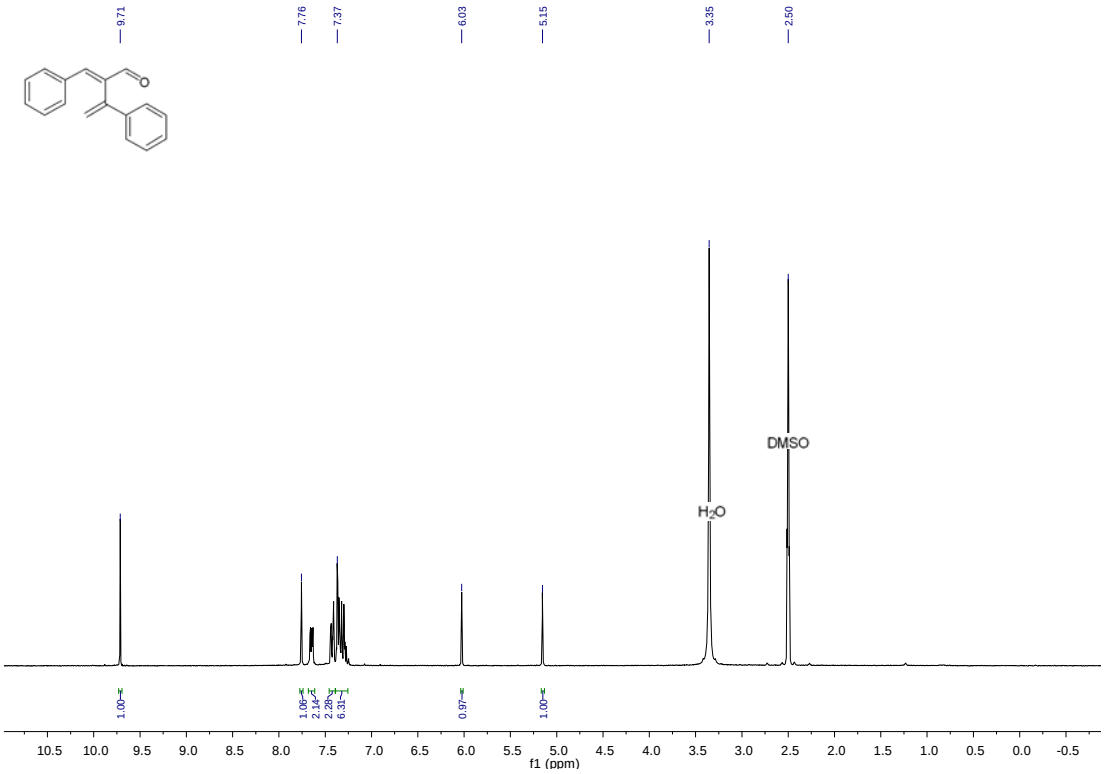


^{13}C NMR of **5b** (12 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

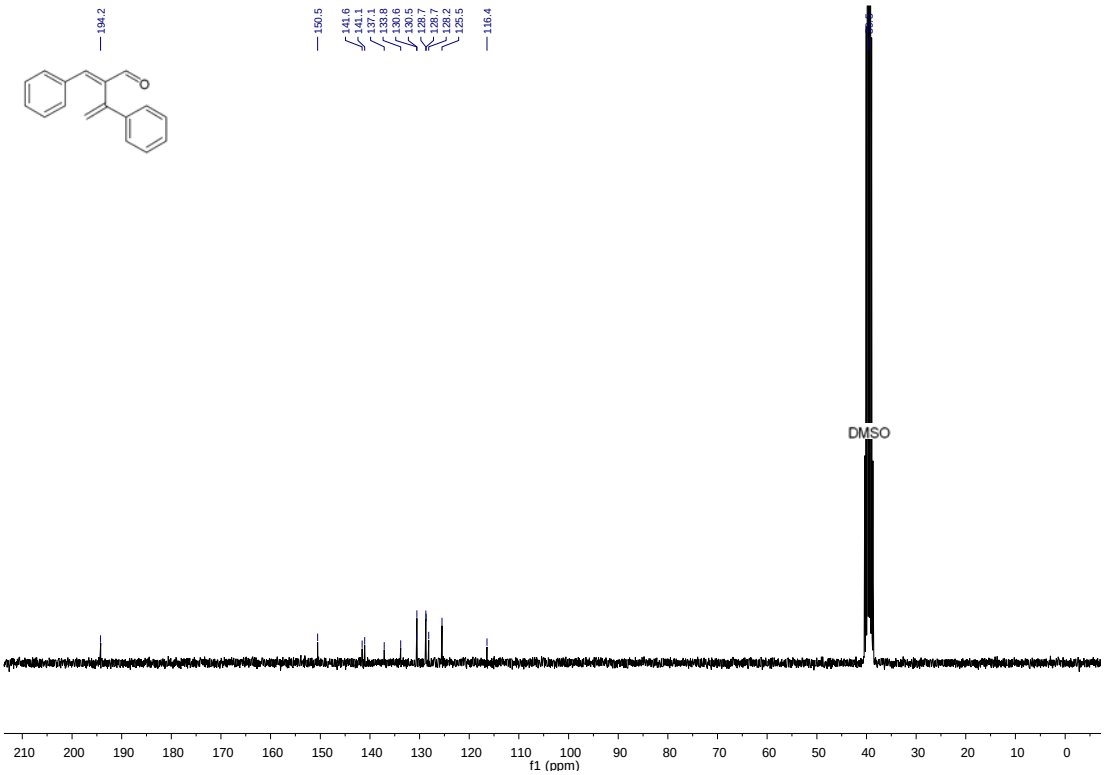


^{13}C 135-DEPT NMR of **5b** (12 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

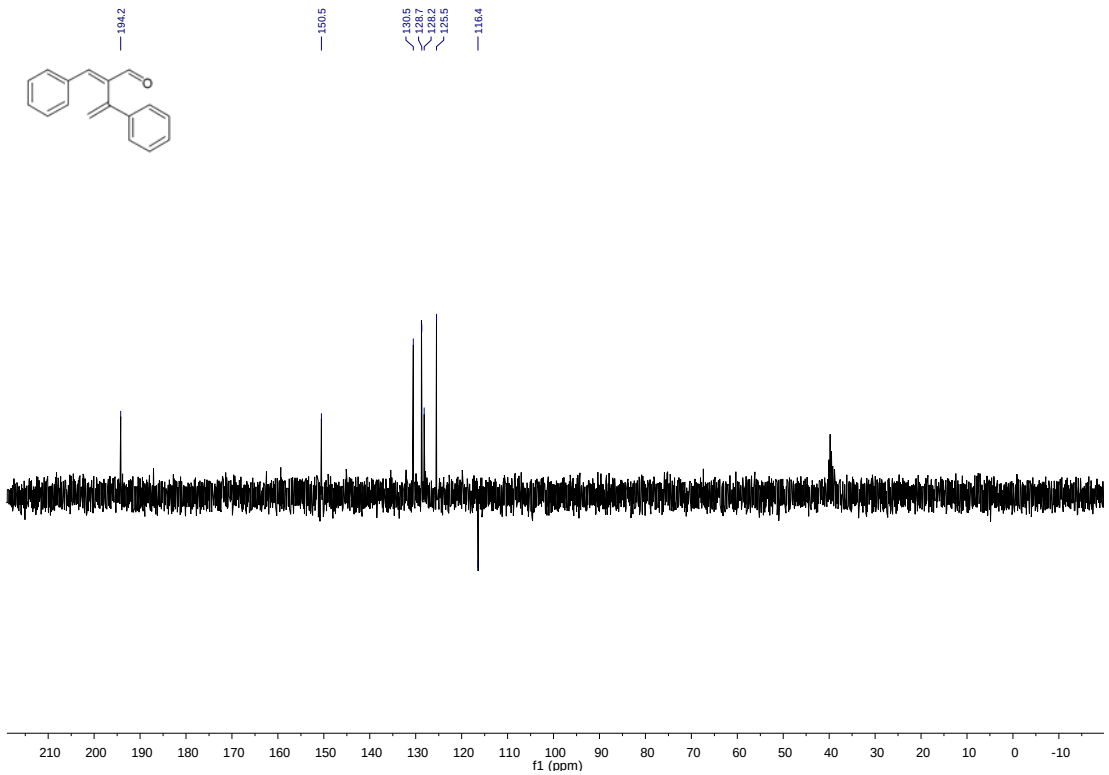
3.4.3 (*E*)-2-Benzyliden-3-phenylbut-3-enal (5c)



^{1}H NMR of **5c** (15 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

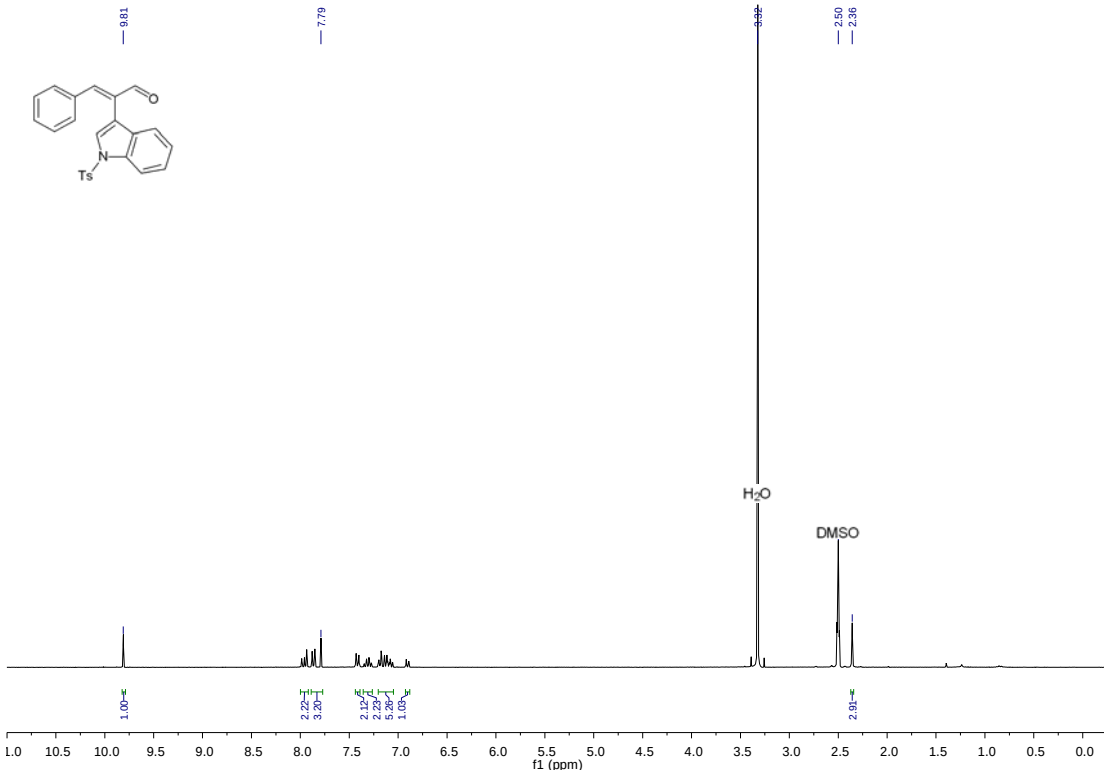


^{13}C NMR of **5c** (15 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

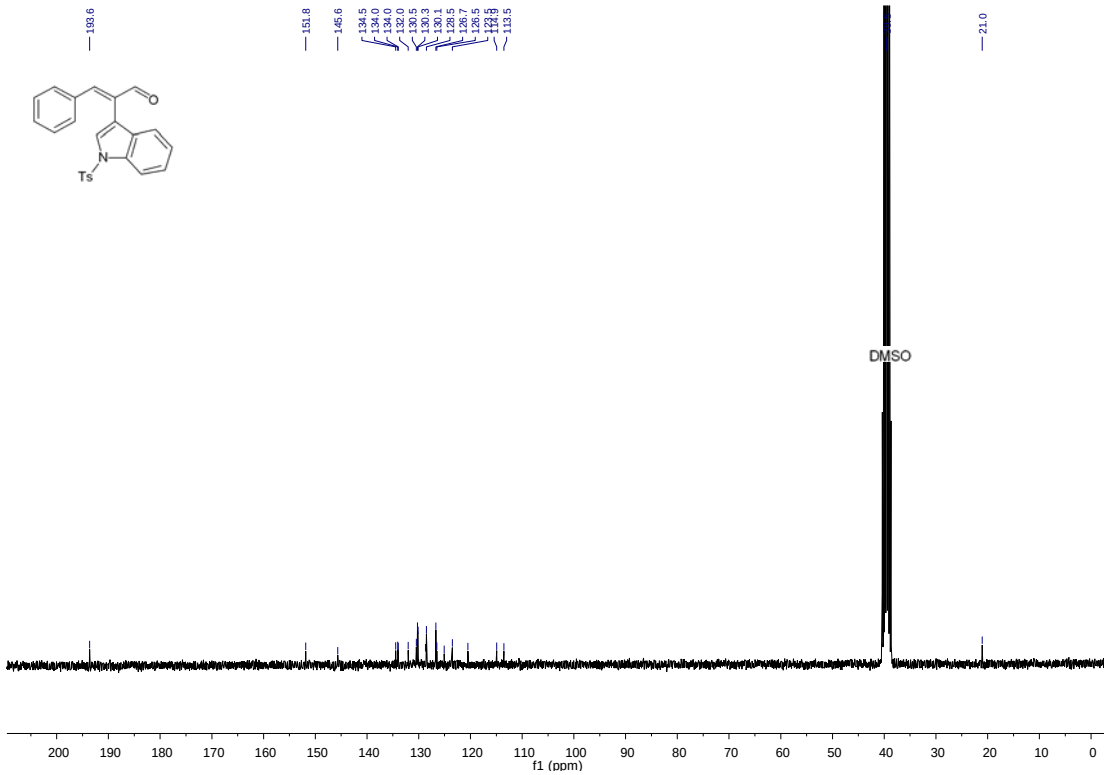


^{13}C 135-DEPT NMR of **5c** (15 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

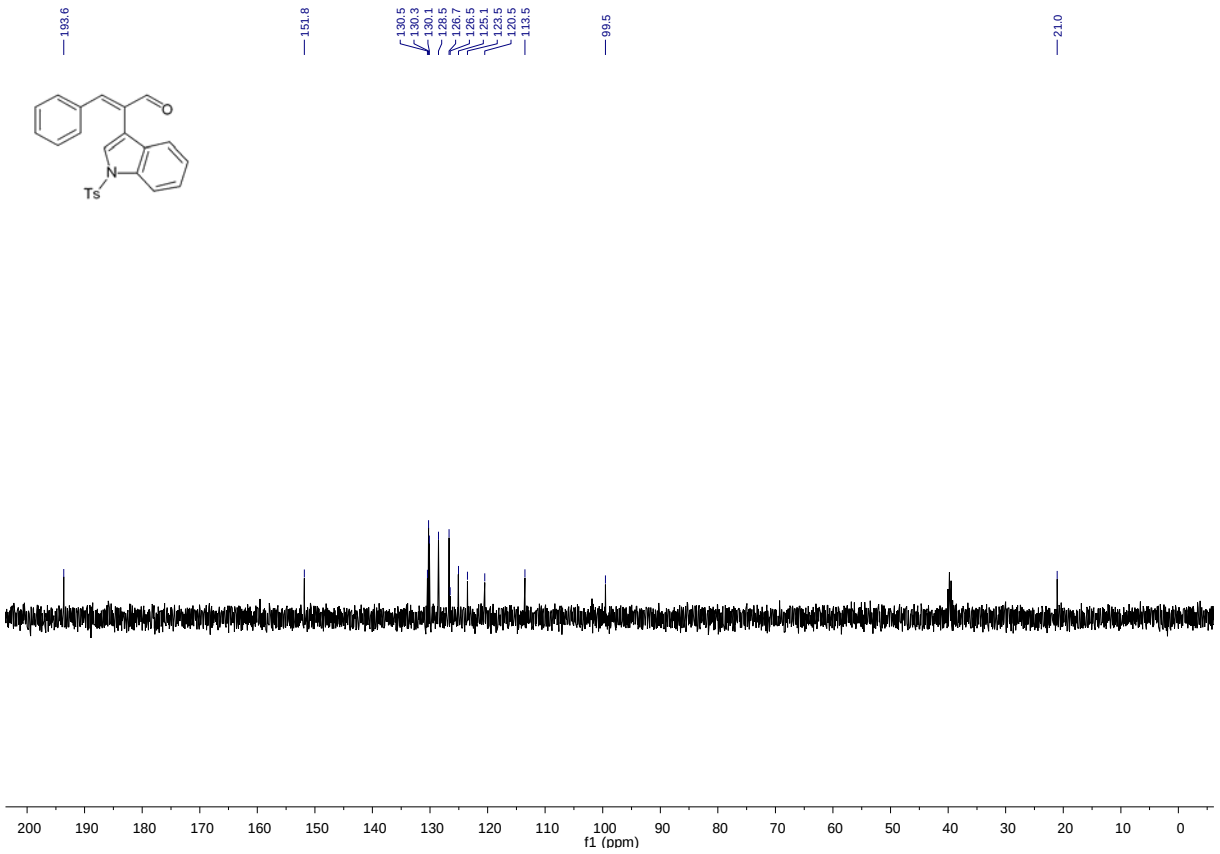
3.4.4 (*E*)-2-(6-Methoxynaphthalin-2-yl)-3-phenylacrylaldehyde (5d)



^{1}H NMR of **5d** (10 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).



^{13}C NMR of **5d** (10 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).



^{13}C 135-DEPT NMR of **5d** (10 mg) in 0.6 mL DMSO-d_6 at 298 K (δ in ppm).

3.5 Synthesis of the Pyrazoles 7

$PdCl_2$ (3.5 mg, 0.02 mmol, 2 mol%) and cataCXium® AHI (19 mg, 0.04 mmol, 4 mol%) were placed under argon atmosphere in a dry screw-cap vessel with septum. The substrate for the borylation (1.00 mmol, 1.0 equiv) was added followed by 2 mL of dry 1,4-dioxane. Dry triethylamine (0.5 mL) and 4,4,5,5-tetramethyl-1,3,2-dioxaborolane (0.22 mL, 1.50 mmol, 1.5 equiv) were successively added to the mixture, which was stirred at 100 °C (preheated oil bath) for 4 h (monitored by TLC). Then, after cooling to room temperature (water bath), destilled water (2 mL), Cs_2CO_3 (815 mg, 2.50 mmol, 2.5 equiv) and *α*-bromocinnamaldehyde (**1b**) (215 mg, 1.00 mmol, 1.0 equiv) were successively added. The mixture was stirred at 100 °C for 20 h (preheated oil bath). Then, after cooling to room temperature, sodium hydroxide (60 mg, 1.50 mmol, 1.5 equiv), $(n\text{-Bu})_4NBr$ (493 mg, 1.20 mmol, 1.2 equiv) and tosylhydrazide (**6**) (230 mg, 1.20 mmol, 1.2 equiv) were added. The reaction mixture was stirred at 80 °C (preheated oil bath) for 20 h. Then, after cooling to room temperature, 30 mL 0.1 *N* HCl were added to the mixture and the aqueous phase was extracted with dichloromethane (3 x 35 mL, monitored by TLC). The combined organic layers were dried with sodium sulfate. The solvents were removed under reduced pressure. The residue was adsorbed onto Celite® and purified chromatographically on silica.

After drying in vacuo, the compounds tend to contain solvent residue that can sometimes be seen in the NMR spectra. Therefore, instead of elemental analysis, HRMS spectra were obtained. Especially, the examples **7e** and **7f** both containing an indole were found to be challenging to isolate.

The experimental details are given in **Table 3**.

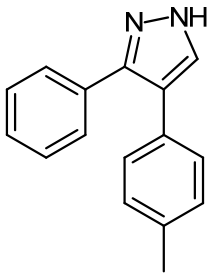
Table 3: Synthesis of the Pyrazoles **7**

Entry	Substrate *Masuda* borylation	Pyrazole (**7**) (isolated yield)	Chromatographic purification (eluent) R_f (eluent)
2	220 mg (1.00 mmol) 4-Iodotoluene (**2e**) (*Aldrich*)	(**7a**) pale yellow solid 192 mg (0.82 mmol, 82 %)	He/EtOAc = 5/1 → 3/1 R_f (He/EtOAc = 5:1): 0.04
3	241 mg (1.00 mmol) 1-Chloro-4-iodobenzene (**2h**) (*Acros*)	(**7b**) yellow oil 165 mg (0.65 mmol, 65 %)	He/EtOAc = 2/1 R_f (He/EtOAc = 2:1): 0.20
4	251 mg (1.00 mmol) 1-(4-Iodophenyl)ethanone (**2a**) (*Alfa Aesar*)	(**7c**) yellow oil 123 mg (0.47 mmol, 47 %)	He/EtOAc = 2/1 R_f (He/EtOAc = 2:1): 0.10
5	242 mg (1.00 mmol) 2-Bromo-6-methoxynaphthaline (**2f**) (*Alfa Aesar*)	(**7d**) pale yellow solid 193 mg (0.64 mmol, 64 %)	DCM/MeOH/NH_3 = 100/1/1 R_f (DCM/MeOH/NH_3 = 100/1/1): 0.04
6	397 mg (1.00 mmol) 3-Iodo-1-tosyl-1*H*-indole (**2g**)	(**7e**) yellow oil 277 mg (0.67 mmol, 67 %)[1]	He/EtOAc = 3/1 → 2/1 R_f (He/EtOAc = 1:1): 0.33
7	343 mg (1.00 mmol) *tert*-Butyl 3-iodo-1*H*-indol-1-carboxylate (**2i**)	(**7f**) yellow oil 150 mg (0.58 mmol, 58 %)	He/EtOAc = 2/1 R_f (He/EtOAc = 2:1): 0.08
8	337 mg (1.00 mmol) 1,4-Diiodobenene (**2j**) (*Alfa Aesar*)	(**7g**) colorless solid 184 mg (0.51 mmol, 51 %)[2]	DCM/MeOH/NH_3 = 100/1/1 R_f (DCM/MeOH/NH_3 = 100/1/1): 0.30

[1] Cyclocondensation step was performed with NaOH (140 mg, 3.50 mmol).

[2] Reaction was performed with $PdCl_2$ (0.007 mg, 0.04 mmol), cataCXium® AHI (0.038 mg, 0.08 mmol), 4 ml dioxane, 1.0 mL NEt_3, HBpin (0.44 mL, 3.00 mmol), 4 mL H_2O, Cs_2CO_3 (1.63 g, 5.00 mmol), cinnamaldehyde (**1b**) (430 mg, 2.00 mmol), NaOH (97 mg, 2.40 mmol), (nBu)$_4$NBr (789 mg, 2.40 mmol), tosylhydrazide (**6**) (461 mg, 2.40 mmol).

3.5.1 3-Phenyl-4-(*p*-tolyl)-1*H*-pyrazole (7a)



$C_{16}H_{14}N_2$

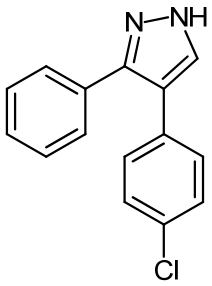
234.30

According to the general procedure 192 mg (0.82 mmol, 82 % total yield) were obtained as a pale yellow solid. Eluent for column chromatography was a *n*-hexane/ethyl acetate-gradient 5/1→3/1. Mp 115-117 °C. ^{1}H-NMR ($CDCl_3$, 600 MHz): δ 2.35 (s, 3 H), 5.29 (s, 1 H), 7.11 (d, J = 7.9 Hz, 2 H), 7.19 (d, J = 8.1 Hz, 2 H), 7.31-7.34 (m, 3 H), 7.44-7.47 (m, 2 H), 7.64 (s, 1 H). ^{13}C-NMR ($CDCl_3$, 151 MHz): δ 25.0 (CH_3), 125.9 (C_{quat}), 126.5 (C_{quat}), 128.27 (CH), 128.30 (CH), 128.4 (CH), 128.7 (CH), 129.4 (CH), 130.2 (C_{quat}), 131.5 (C_{quat}), 136.4 (CH).[1] ^{13}C-NMR (DMSO-d_6, 75 MHz): δ 20.7 (CH_3), 118.7 (C_{quat}), 127.7 (CH), 127.8 (CH), 127.9 (CH), 128.5 (CH), 129.1 (CH), 130.5 (C_{quat}), 135.4 (C_{quat}).[2] GCMS (EI) (*m/z* (%)): 235 (17), 234 (M^+, 100), 233 (39), 219 ($(M-CH_3)^+$, 34), 205 ($(M-HN_2)^+$, 6), 165 (15), 130 (14), 116 ($(M-C_7H_7-HN_2)^+$, 25), 115 (19), 104 (14), 103 (30), 102 (19), 91 ($C_7H_7^+$, 8), 89 (19), 78 (20), 77 ($C_6H_5^+$, 70), 76 (28), 75 (15), 74 (10), 65 (17), 63 (31), 52 (19), 51 (68), 50 (25). IR: $\tilde{\nu}$ 2835 (w), 1443 (m), 1339 (w), 1277 (w), 1242 (w), 1188 (w), 1175 (w), 1115 (m), 1107 (m), 1070 (w), 1030 (w), 970 (w), 953 (s), 912 (w), 870 (w), 812 (s), 766 (s), 696 (s), 683 (m), 644 (w) cm^{-1}. ESI/HRMS *m/z* calcd. for $C_{16}H_{14}N_2$: 235.12297. Found: 235.12250.

[1] One signal is missing in the ^{13}C-NMR-spectrum due to the tautomerism (1 C_{quat})

[2] Three signals are missing in the ^{13}C-NMR-spectrum due to the tautomerism (2 C_{quat} and 1 CH).

3.5.2 4-(4-Chlorophenyl)-3-phenyl-1*H*-pyrazole (7b)

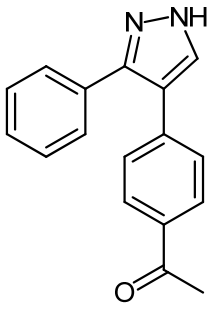


$C_{15}H_{11}ClN_2$

254.71

According to the general procedure 165 mg (0.65 mmol, 65 % total yield) were obtained as a yellow oil that started to crystallize after a few days. Eluent for column chromatography was *n*-hexane/ethyl acetate 2/1. ^{1}H-NMR ($CDCl_3$, 600 MHz): δ 7.17-7.37 (m, 7 H), 7.40-7.48 (m, 2 H), 7.61-7.65 (m, 1 H) 11-12 (brs, 1H). ^{13}C-NMR ($CDCl_3$, 151 MHz): δ 118.8 (C_{quat}), 126.4 (CH), 126.6 (CH), 128.4 (CH), 128.9 (CH), 129.7 (CH), 131.2 (C_{quat}) 131.7 (C_{quat}), 132.6 (C_{quat}), 133.2 (C_{quat}). IR: $\tilde{\nu}$ 3142 (w), 2936 (w), 1736 (w), 1720 (w), 1603 (w), 1518 (w), 1483 (w), 1443 (w), 1425 (w), 1398 (w), 1344 (w), 1329 (w), 1298 (w), 1234 (w), 1157 (w), 1113 (w), 1094 (m), 1072 (w), 1016 (w), 966 (w), 953 (m), 920 (w), 881 (w), 852 (w), 824 (s), 766 (m), 760 (m), 737 (w), 692 (s), 673 (w), 635 (w), 613 (w) cm^{-1}. ESI/HRMS *m/z* calcd. for $C_{15}H_{12}{}^{35}ClN_2$: 255.06835. Found: 255.06841.

3.5.3 1-(4-(3-Phenyl-1*H*-pyrazol-4-yl)phenyl)ethanon (7c)

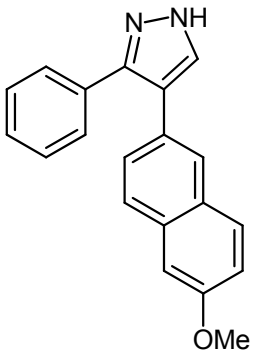


$C_{17}H_{14}N_2O$

262.31

According to the general procedure 123 mg (0.47 mmol, 47 % total yield) were obtained as a yellow oil that started to crystallize after a few days. Eluent for column chromatography was *n*-hexane/ethyl acetate 2/1. ^{1}H-NMR ($CDCl_3$, 600 MHz): δ 2.59 (s, 3 H), 7.30-7.48 (m, 7 H), 7.70-7.74 (m, 1 H), 7.88 (d, J = 8.3 Hz, 2 H), 11-12 (brs, 1 H). ^{13}C-NMR ($CDCl_3$, 151 MHz): δ 26.7 (CH_3), 119.0 (C_{quat}), 128.2 (CH), 128.5 (CH), 128.8 (CH), 128.85 (CH), 128.94 (CH), 129.4 (CH), 131.0 (C_{quat}), 135.3 (C_{quat}), 138.3 (C_{quat}), 144.1 (C_{quat}), 197.9 (C_{quat}). IR: $\tilde{\nu}$ 3173 (w), 2955 (w), 2928 (w), 2872 (w), 2857 (w), 1722 (w), 1678 (m), 1605 (s), 1556 (w), 1522 (w), 1481 (w), 1464 (w), 1445 (w), 1427 (w), 1404 (w), 1356 (m), 1267 (s), 1184 (w), 1155 (w), 1121 (m), 1072 (m), 1040 (w), 1016 (w), 951 (m), 918 (w), 883 (w), 841 (m), 827 (m), 770 (m), 739 (m), 696 (s), 652 (w), 636 (w), 613 (m) cm^{-1}. ESI/HRMS *m/z* calcd. for $C_{17}H_{15}N_2O$: 263.11789. Found: 263.11826.

3.5.4 4-(6-Methoxynaphthalen-2-yl)-3-phenyl-1*H*-pyrazole (7d)



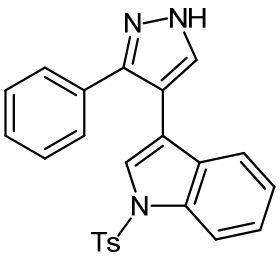
$C_{20}H_{16}N_2O$

300.35

According to the general procedure 193 mg (0.64 mmol, 64 % total yield) were obtained as a pale yellow solid. Eluent for column chromatography was dichlormethane/methanol/aqueous ammonia 100/1/1. Mp 155-159 °C. ^{1}H-NMR ($CDCl_3$, 600 MHz): δ 3.91 (s, 3 H), 7.08-7.16 (m, 2 H), 7.28-7.38 (m, 4 H), 7.45-7.54 (m, 2 H), 7.64 (t, J = 7.7 Hz, 2 H), 7.72 (s, 1 H), 7.73 (s, 1 H), 10.74-12.77 (brs, 1 H). ^{13}C-NMR ($CDCl_3$, 151 MHz): δ 55.5 (CH_3), 67.2 (C_{quat}), 105.8 (CH), 119.1 (CH), 120.1 (C_{quat}), 126.7 (CH), 127.0 (CH), 127.8 (CH), 128.3 (CH), 128.4 (CH), 128.5 (C_{quat}), 128.8 (CH), 129.2 (C_{quat}), 129.5 (CH), 131.4 (C_{quat}), 133.4 (C_{quat}), 157.7 (C_{quat}).[1] GCMS (EI) (*m/z* (%)): 301 (8), 300 (M^+, 33), 258 ($(M-HN_2)^+$, 3), 171 (42), 155 (30), 144 (100), 143 ($C_9H_7N_2^+$, 13), 139 (11), 115 (14), 108 (11), 107 (17), 101 (18), 92 (12), 91 ($C_7H_7^+$, 64), 89 (11), 86 (18), 84 (24), 77 ($C_6H_5^+$, 13), 65 (16), 51 (14), 49 (23), 43 (13). IR: $\tilde{\nu}$ 3102 (w), 3055 (w), 3026 (w), 3001 (w), 2955 (w), 2934 (w), 2918 (w), 2843 (w), 1611 (s), 1499 (w), 1479 (m), 1456 (w), 1439 (m), 1391 (m), 1261 (m), 1242 (m), 1209 (m), 1163 (s), 1123 (s), 1076 (w), 1028 (s), 955 (s), 943 (m), 899 (s), 854 (s), 835 (m), 812 (s), 768 (s), 696 (s), 685 (s), 667 (s), 654 (m), 623 (w) cm^{-1}. ESI/HRMS *m/z* calcd. for $C_{20}H_{16}N_2O$: 301.13354. Found: 301.13384.

[1]One signal is missing in the ^{13}C-NMR-spectrum due to the tautomerism (1 CH).

3.5.5 3-(3-Phenyl-1*H*-pyrazol-4-yl)-1-tosyl-1*H*-indole (7e)

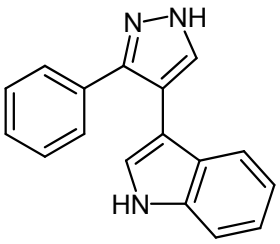


$C_{24}H_{19}N_3O_2S$

413.49

According to the general procedure 277 mg (0.67 mmol, 67 % total yield) were obtained as a yellow oil that started to crystallize after a few days. Eluent for column chromatography was a *n*-hexane/ethyl acetate-gradient 3/1→2/1. ^{1}H-NMR ($CDCl_3$, 600 MHz): δ 2.37 (s, 3 H), 5.29 (s, 1 H), 7.14-7.17 (m, 1 H), 7.21-7.28 (m, 4 H), 7.30-7.34 (m, 3 H), 7.39-7.42 (m, 3 H), 7.71-7.75 (m, 3 H), 8.01-8.04 (m, 1 H). ^{13}C-NMR ($CDCl_3$, 151 MHz): δ 21.7 (CH_3), 110.3 (CH), 113.9 (CH), 115.2 (C_{quat}), 120.7 (CH), 123.5 (CH), 124.0 (CH), 125.0 (CH), 127.0 (CH), 127.8 (CH), 128.6 (CH), 128.8 (CH), 130.0 (CH), 130.4 (C_{quat}), 131.1 (C_{quat}), 135.27 (C_{quat}), 135.30 (C_{quat}), 135.8 (C_{quat}), 145.1 (C_{quat}), 171.5 (C_{quat}). EI + MS (*m/z* (%)): 415 (4), 414 (14), 413 (M^+, 50), 259 (21), 258 ((M-Ts)$^+$, 100), 257 (26), 242 (15), 231 ((M-Ts-HN_2)$^+$, 16), 204 (10), 155 (Ts^+, 3), 91 ($C_7H_7^+$, 8). IR: $\tilde{\nu}$ 3130 (w), 3100 (w), 3028 (w), 2957 (w), 2924 (w), 2857 (w), 2357 (w), 1732 (w), 1597 (w), 1495 (w), 1445 (m), 1368 (m), 1306 (w), 1261 (m), 1173 (s), 1126 (s), 1109 (m), 1090 (s), 1043 (w), 1026 (m), 1018 (m), 989 (m), 953 (m), 908 (w), 854 (w), 812 (m), 762 (m), 745 (s), 704 (s), 696 (s), 683 (s), 660 (s), 633 (m) cm^{-1}. ESI/HRMS *m/z* calcd. for $C_{24}H_{19}N_3O_2S$: 414.12707. Found: 414.12723.

3.5.6 3-(3-Phenyl-1*H*-pyrazol-4-yl)-1*H*-indole (7f)



$C_{17}H_{13}N_3$

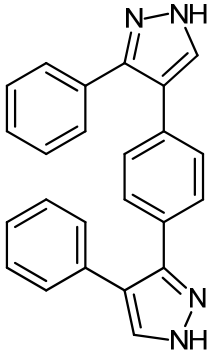
259.31

According to the general procedure 150 mg (0.58 mmol, 58 % total yield) were obtained as a yellow oil. Eluent for column chromatography was *n*-hexane/ethyl acetate 2/1. ^{1}H-NMR ($CDCl_3$, 600 MHz): δ 7.03-7.09 (m, 2 H), 7.18-7.22 (m, 1 H), 7.24-7.28 (m, 3 H), 7.38 (d, J = 8.1 Hz, 1 H), 7.45 (d, J = 8.0 Hz, 1 H), 7.50-7.56 (m, 2 H), 7.76 (s, 1 H), 8.27 (s, 1 H).[1] ^{13}C-NMR ($CDCl_3$, 151 MHz): δ 108.5 (C_{quat}), 111.3 (CH), 112.5 (C_{quat}), 120.0 (CH), 120.1 (CH), 122.3 (CH), 122.7 (C_{quat}), 127.1 (C_{quat}), 127.8 (CH), 128.1 (CH), 128.6 (CH), 136.2 (C_{quat}).[2] IR: $\tilde{\nu}$ 3406 (w), 3188 (w), 3057 (w), 2961 (w), 2872 (w), 1888 (w), 1728 (w), 1713 (w), 1688 (w), 1622 (w), 1605 (w), 1574 (w), 1489 (w), 1456 (m), 1447 (m), 1418 (w), 1371 (w), 1360 (w), 1335 (w), 1300 (w), 1259 (w), 1240 (m), 1177 (w), 1153 (m), 1097 (m), 1070 (m), 1045 (m), 1011 (m), 951 (m), 928 (m), 864 (w), 847 (w), 806 (m), 766 (m), 741 (s), 719 (m), 696 (s), 635 (m), 621 (m) cm^{-1}. ESI/HRMS *m/z* calcd. for $C_{17}H_{14}N_3$: 260.11833. Found: 260.11822.

[1] The signal of one proton is missing. This is most probably the signal of the indol-NH.

[2] Three signals are missing in the ^{13}C-NMR-spectrum due to the tautomerism (2 CH and 1 C_{quat}).

3.5.7 3-Phenyl-4-(4-(4-phenyl-1*H*-pyrazol-3-yl)phenyl)-1*H*-pyrazole (7g)



$C_{24}H_{18}N_4$

362.43

According to the general procedure 184 mg (0.51 mmol, 51 % total yield) were obtained as a colorless solid. The workup procedure was adapted as follows:

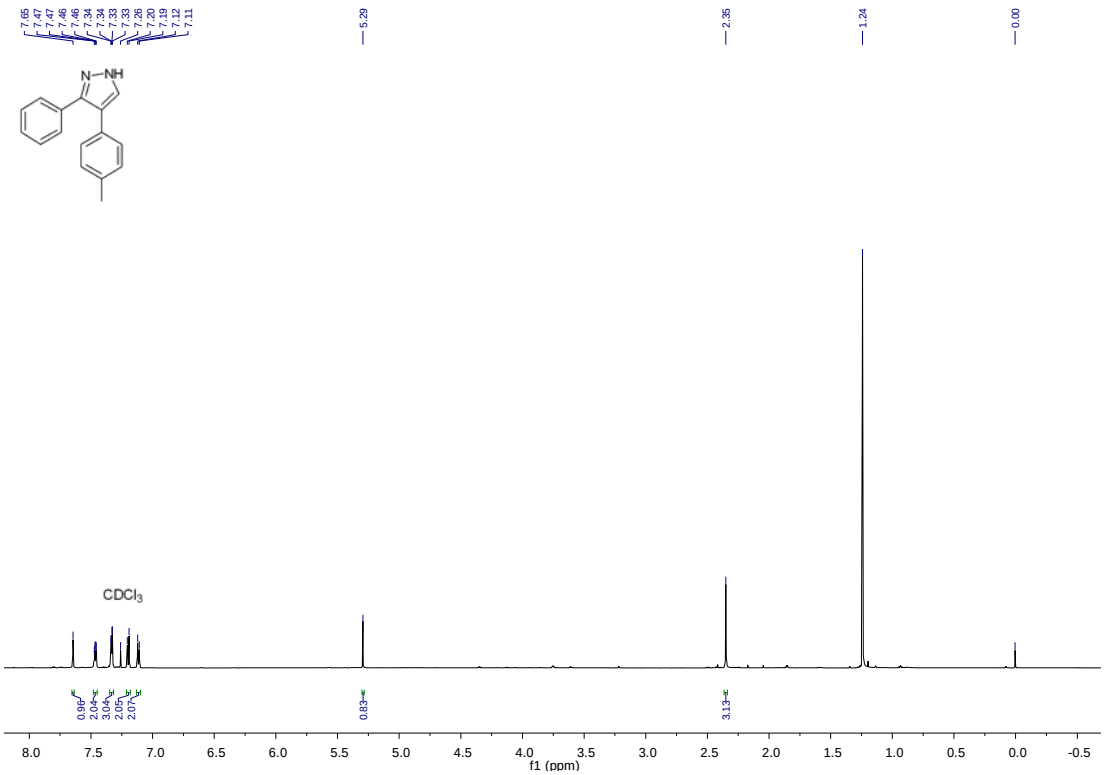
After the reaction, the mixture was allowed to cool down to room temperature. 30 mL 0.1 *N* HCl were added to the mixture and a colorless precipitate was found. It was filtrated from the mixture, washed with 30 mL 0.1 *N* HCl, solved in THF, adsorbed to Celite® and purified chromatographically on silica.

Eluent for column chromatography was dichlormethane/methanol/aqueous ammonia 100/1/1. Mp > 316 °C. IR: $\tilde{\nu}$ 3140 (w), 3061 (w), 2978 (m), 2869 (w), 1555 (w), 1518 (w), 1495 (w), 1481 (w), 1445 (w), 1427 (w), 1396 (w), 1344 (w), 1298 (w), 1277 (w), 1238 (w), 1173 (w), 1119 (w), 1090 (w), 968 (m), 955 (m), 914 (w), 895 (w), 829 (m), 766 (m), 690 (s) cm^{-1}. ESI/HRMS *m/z* ber. für $C_{24}H_{19}N_4$: 363.16015 Gef.: 363.16042.

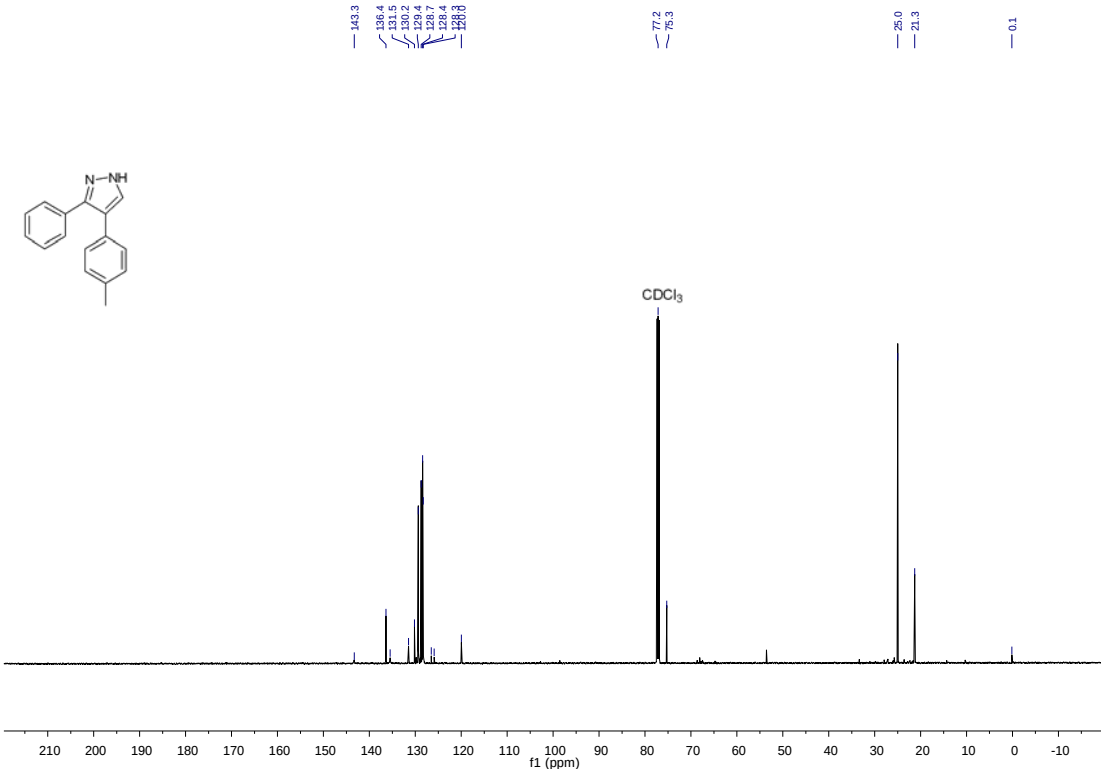
After drying in vacuo the compound was found to be insoluable in common NMR-solvents.

3.6 ^{1}H NMR and ^{13}C NMR Spectra of the Pyrazoles 7

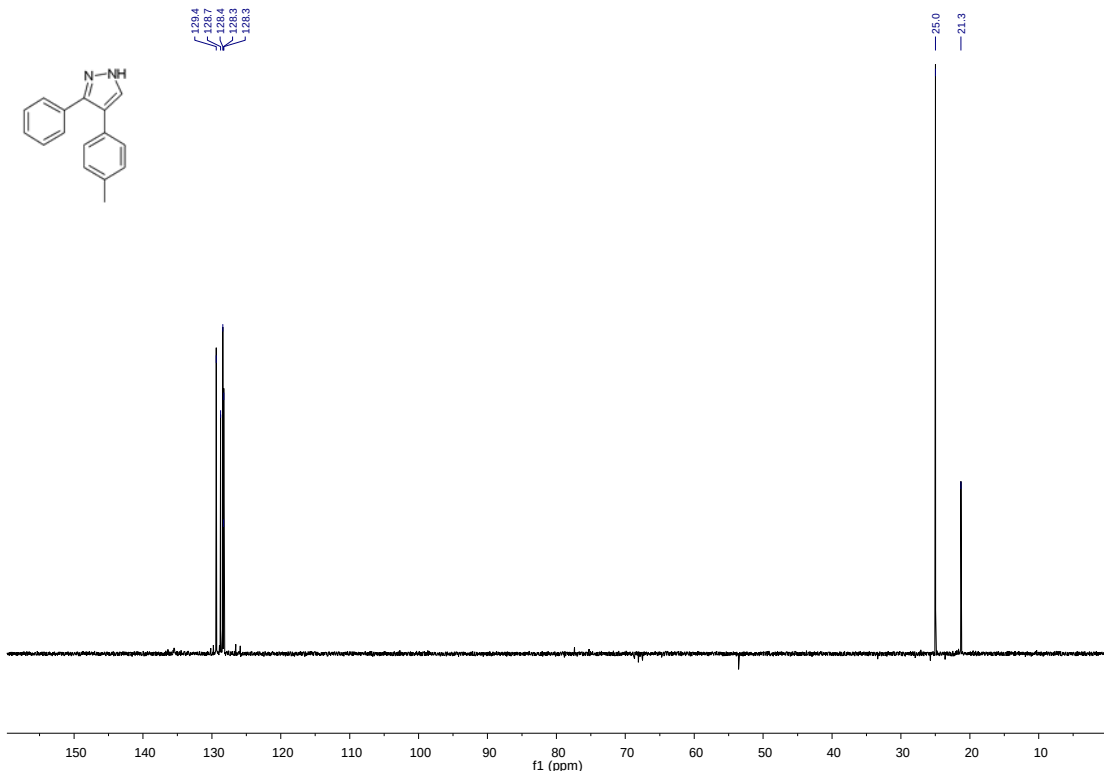
3.6.1 3-Phenyl-4-(*p*-tolyl)-1*H*-pyrazole (7a)



^{1}H NMR of **7a** (20 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

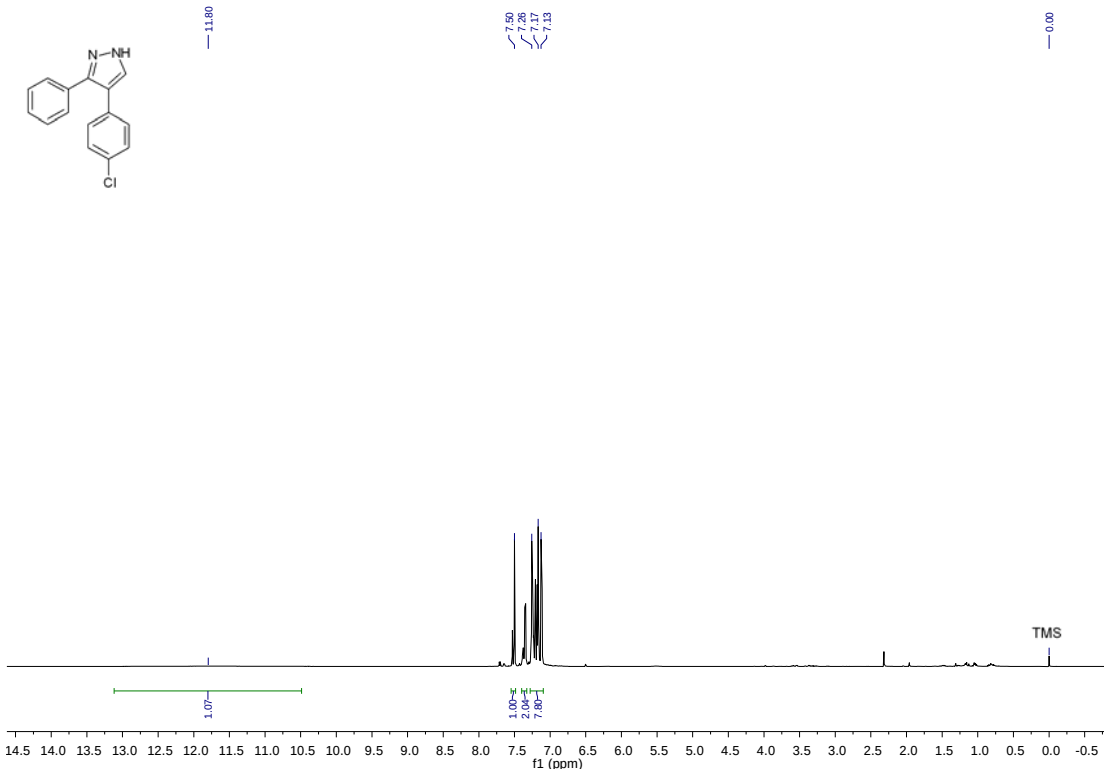


^{13}C NMR of **7a** (20 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

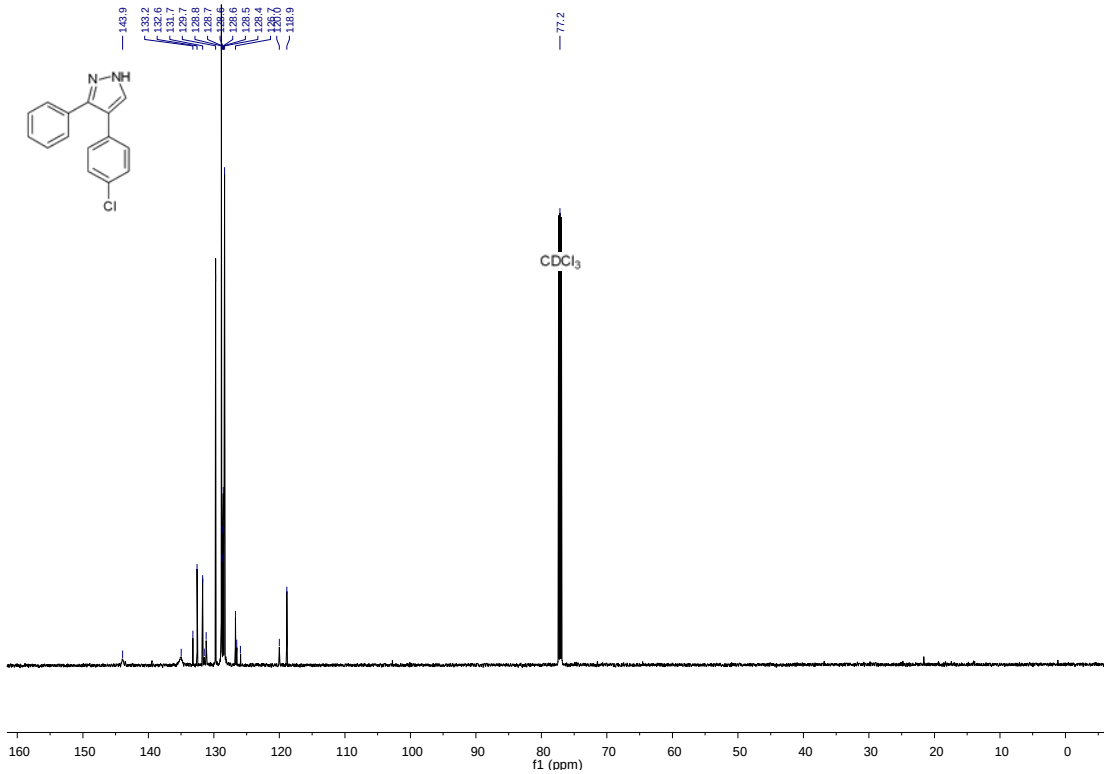


^{13}C 135-DEPT NMR of **7a** (25 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

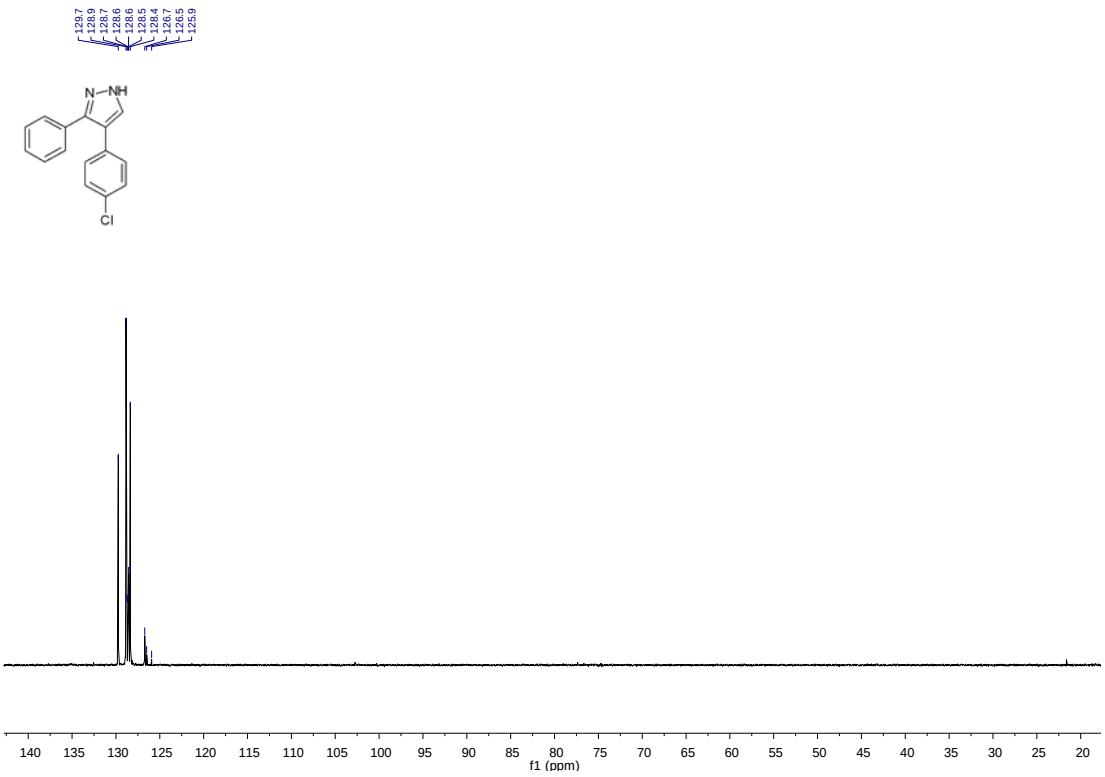
3.6.2 4-(4-Chlorophenyl)-3-phenyl-1*H*-pyrazole (7b)



^{1}H NMR of **7b** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

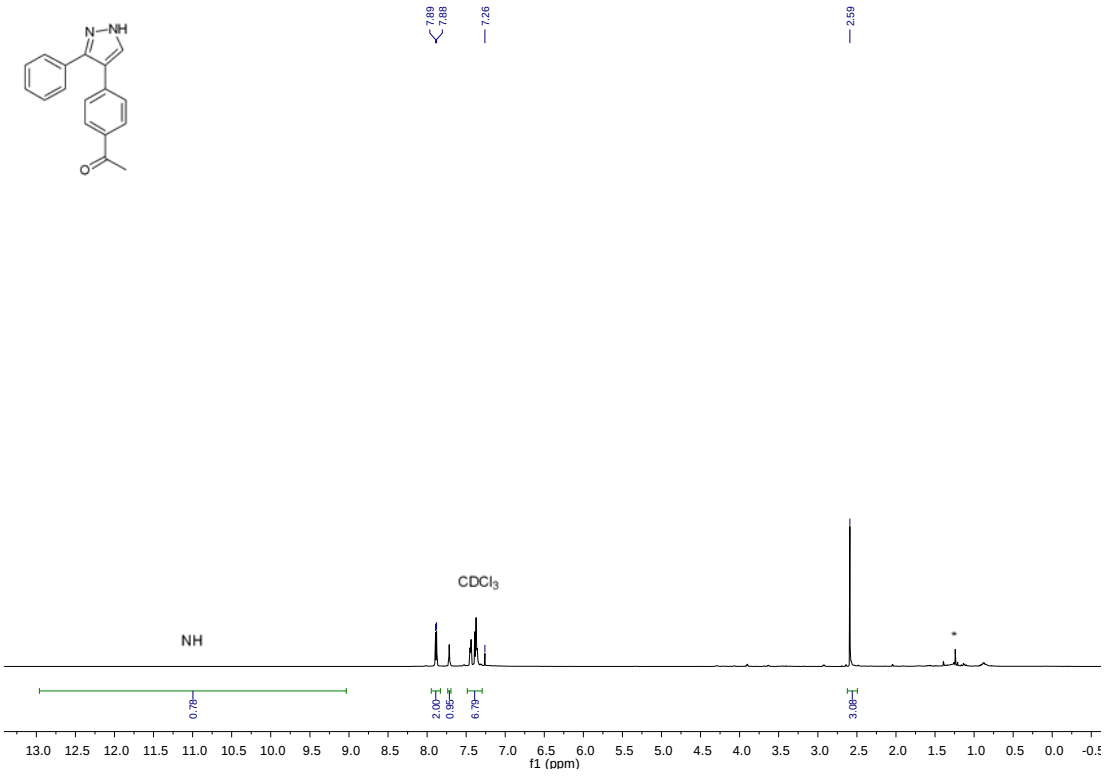


^{13}C NMR of **7b** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

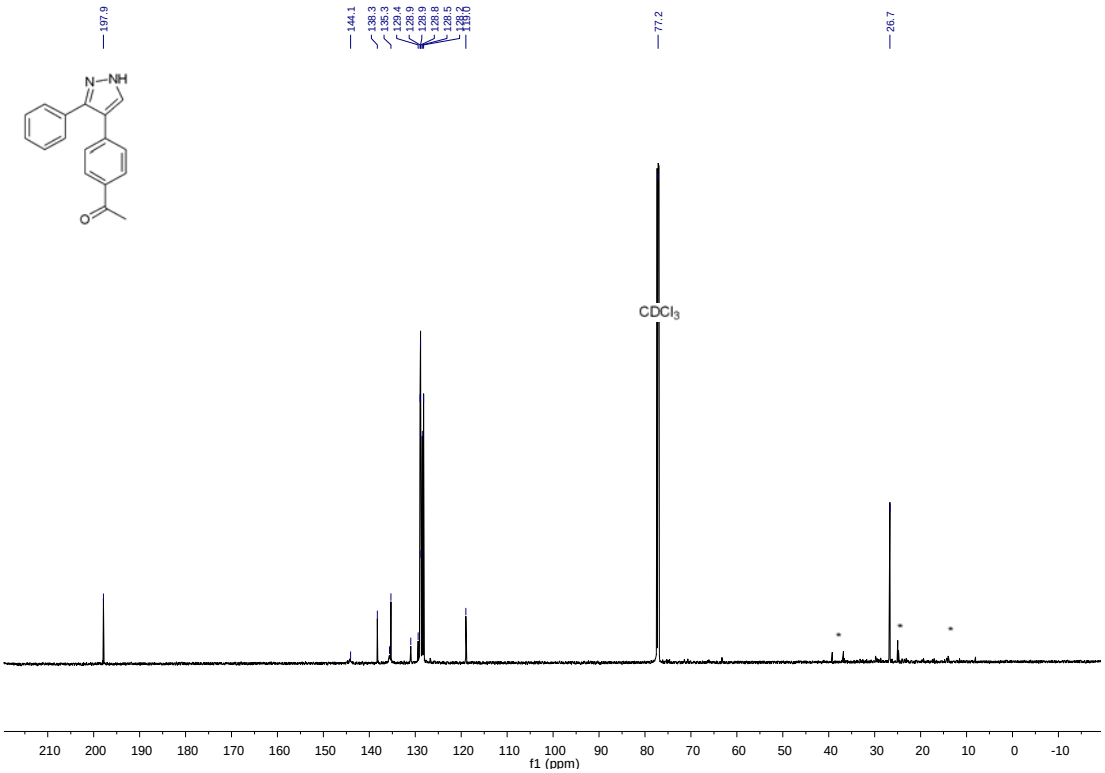


^{13}C 135-DEPT NMR of **7b** (15 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

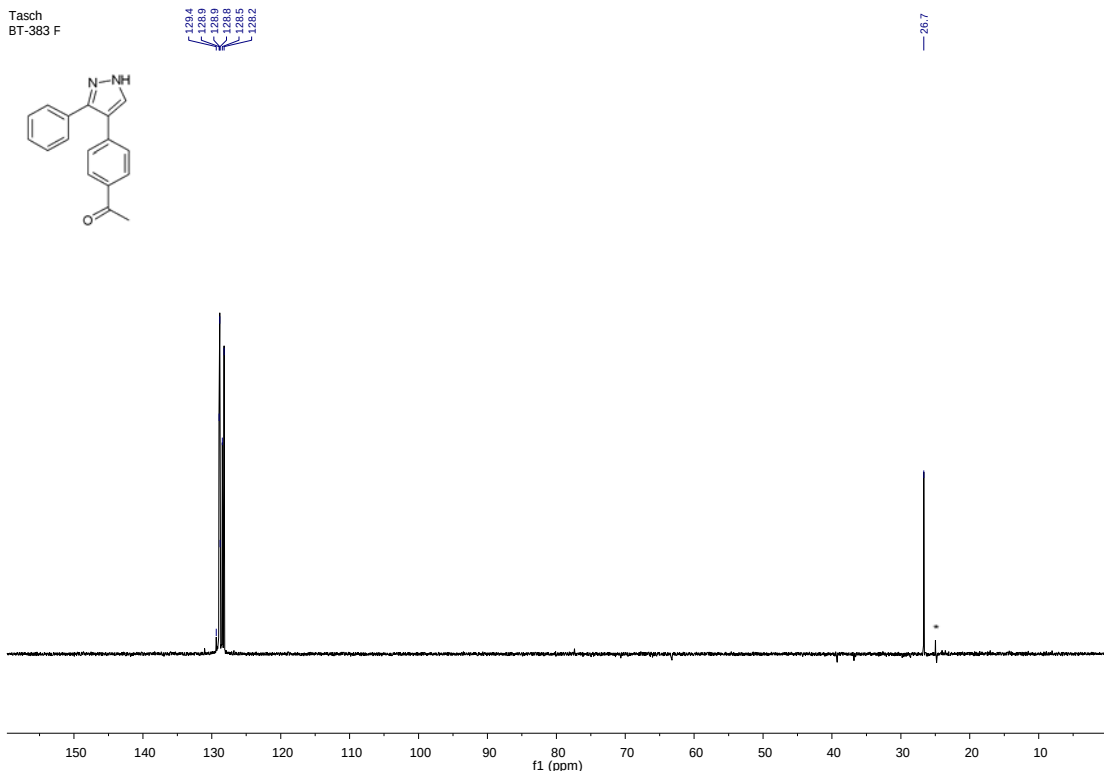
3.6.3 1-(4-(3-Phenyl-1*H*-pyrazol-4-yl)phenyl)ethanon (7c)



^{1}H NMR of **7c** (10 mg) in 0.4 mL $CDCl_3$ at 298 K (δ in ppm). (* Solvent residue)

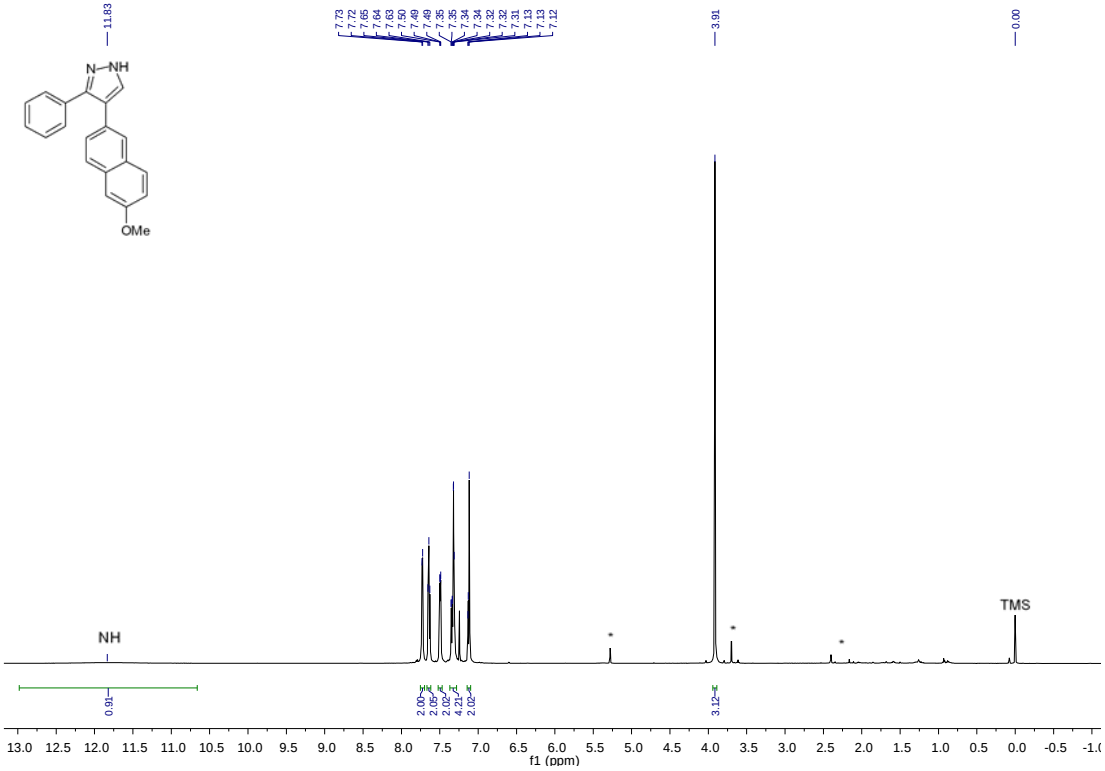


^{13}C NMR of **7c** (10 mg) in 0.4 mL $CDCl_3$ at 298 K (δ in ppm). (* Solvent residue)

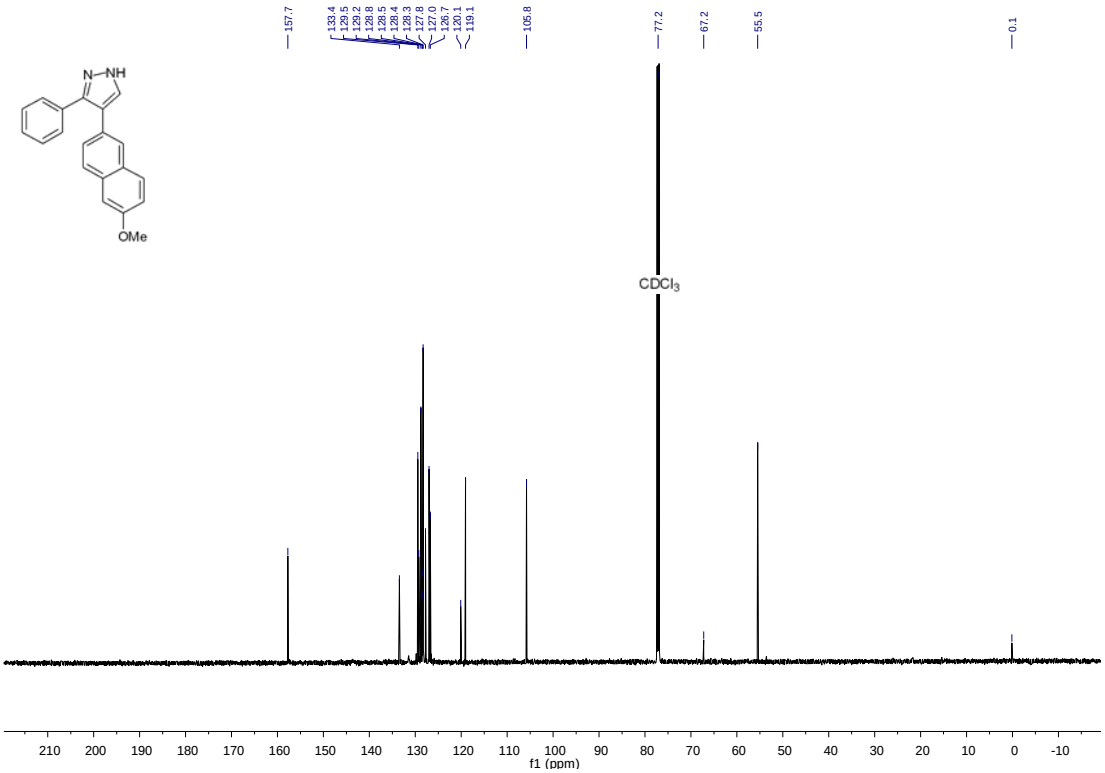


^{13}C 135-DEPT NMR of **7c** (10 mg) in 0.4 mL $CDCl_3$ at 298 K (δ in ppm). (* Solvent residue)

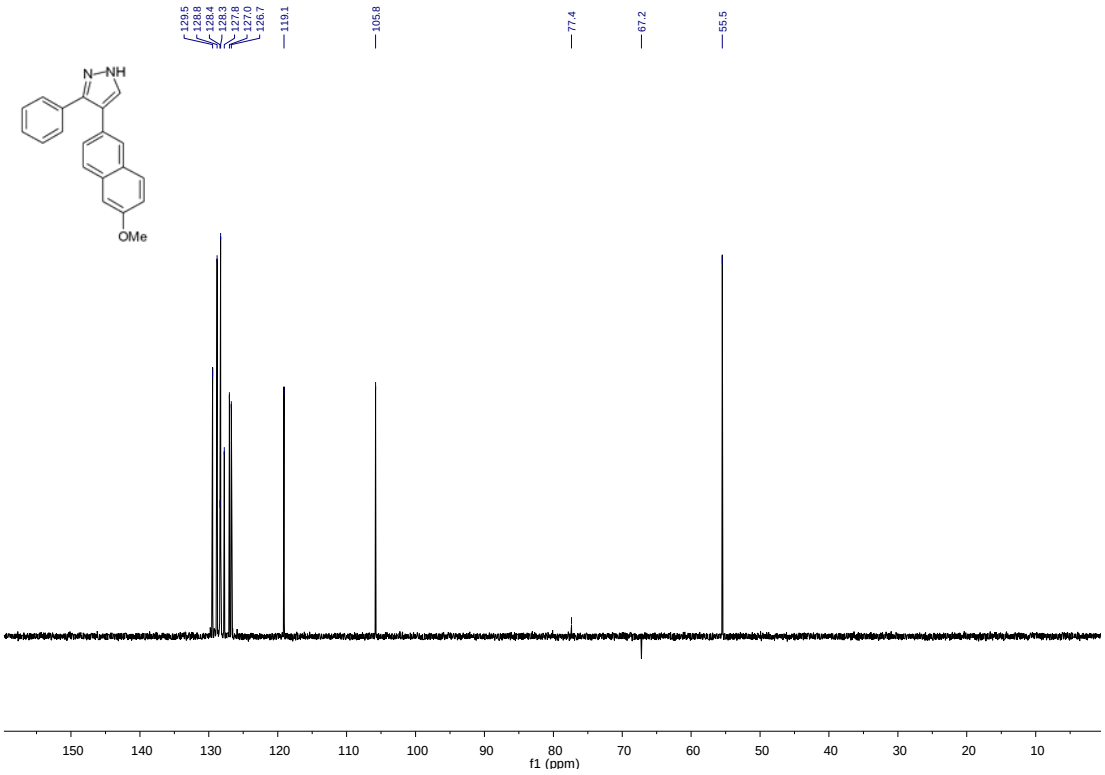
3.6.4 4-(6-Methoxynaphthalen-2-yl)-3-phenyl-1*H*-pyrazole (7d)



^{1}H NMR of **7d** (20 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm). (* Solvent residue)

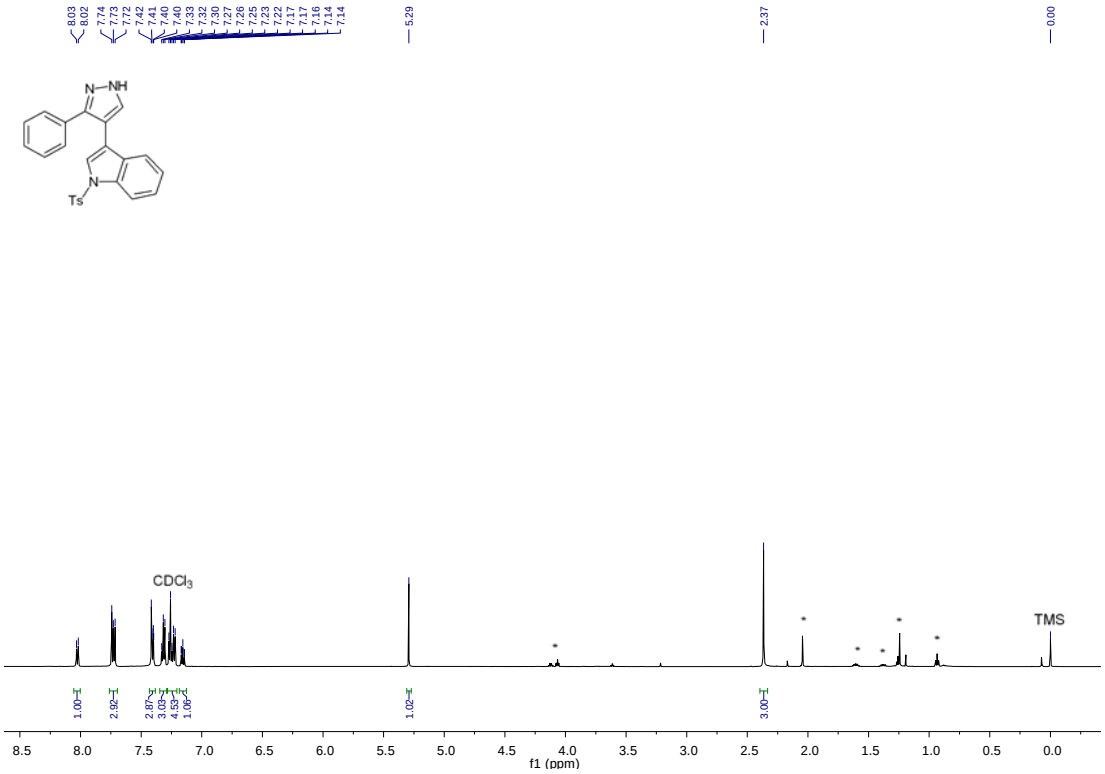


^{13}C NMR of **7d** (20 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

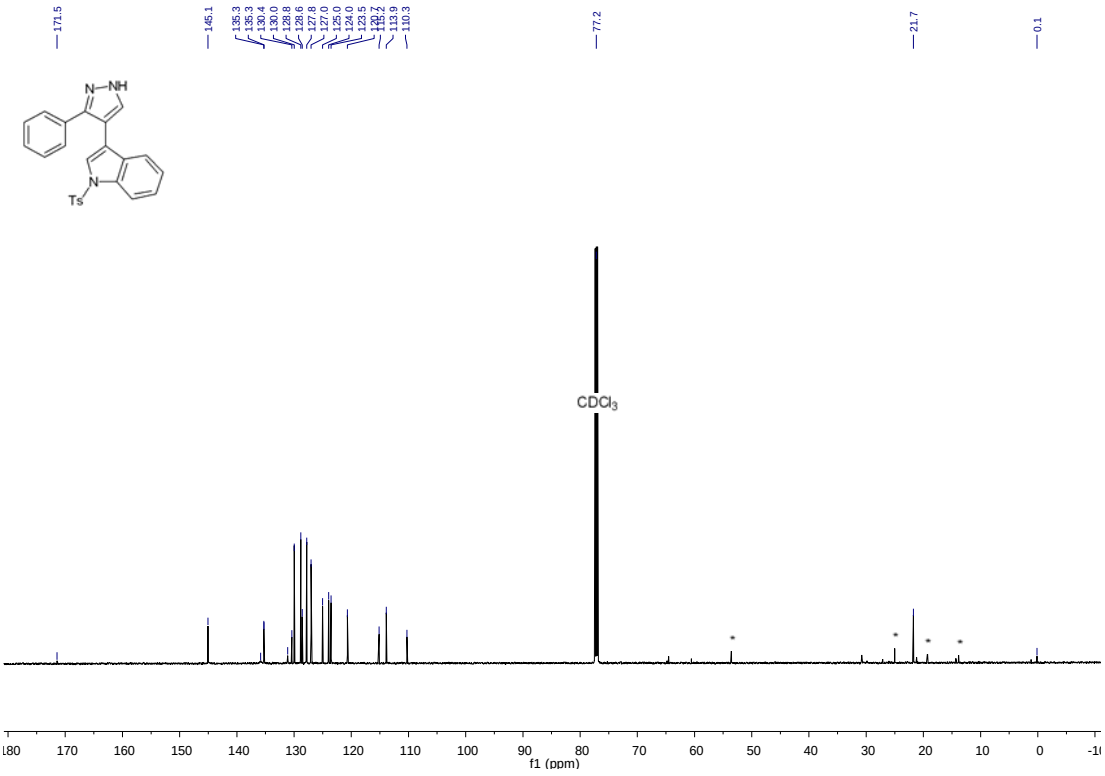


^{13}C 135-DEPT NMR of **7d** (20 mg) in 0.6 mL $CDCl_3$ at 298 K (δ in ppm).

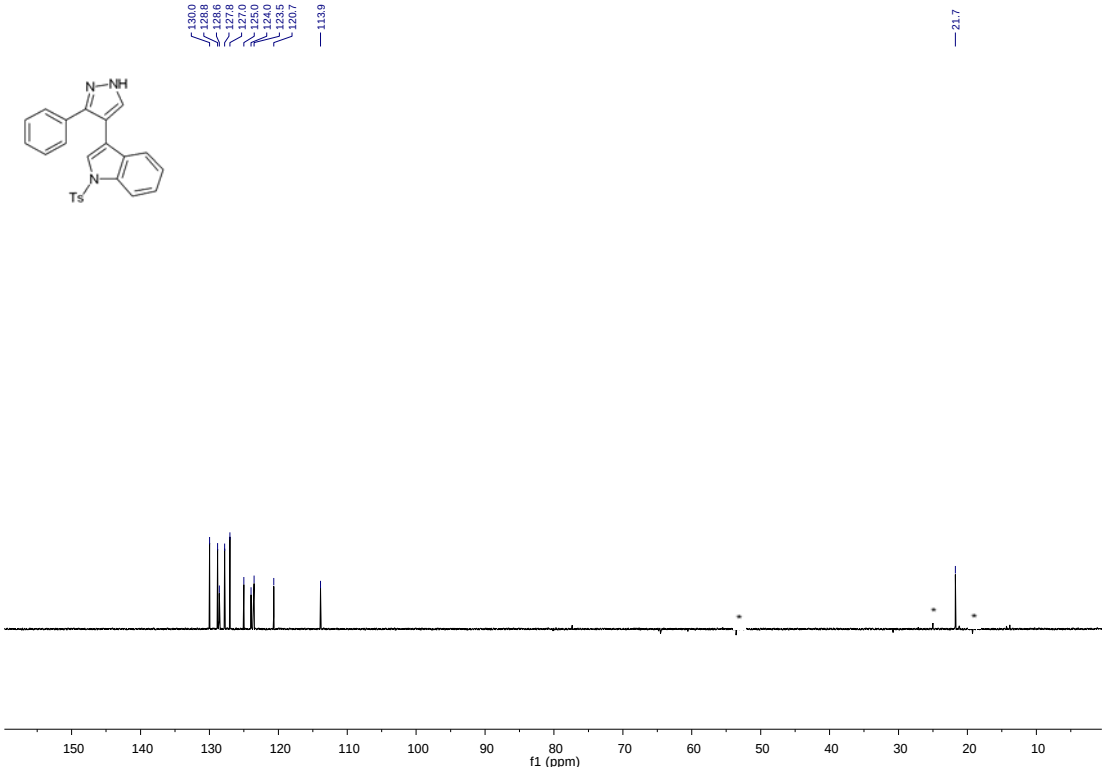
3.6.5 3-(3-Phenyl-1*H*-pyrazol-4-yl)-1-tosyl-1*H*-indole (7e)



^{1}H NMR of **7e** (10 mg) in 0.4 mL $CDCl_3$ at 298 K (δ in ppm). (* Solvent residue)

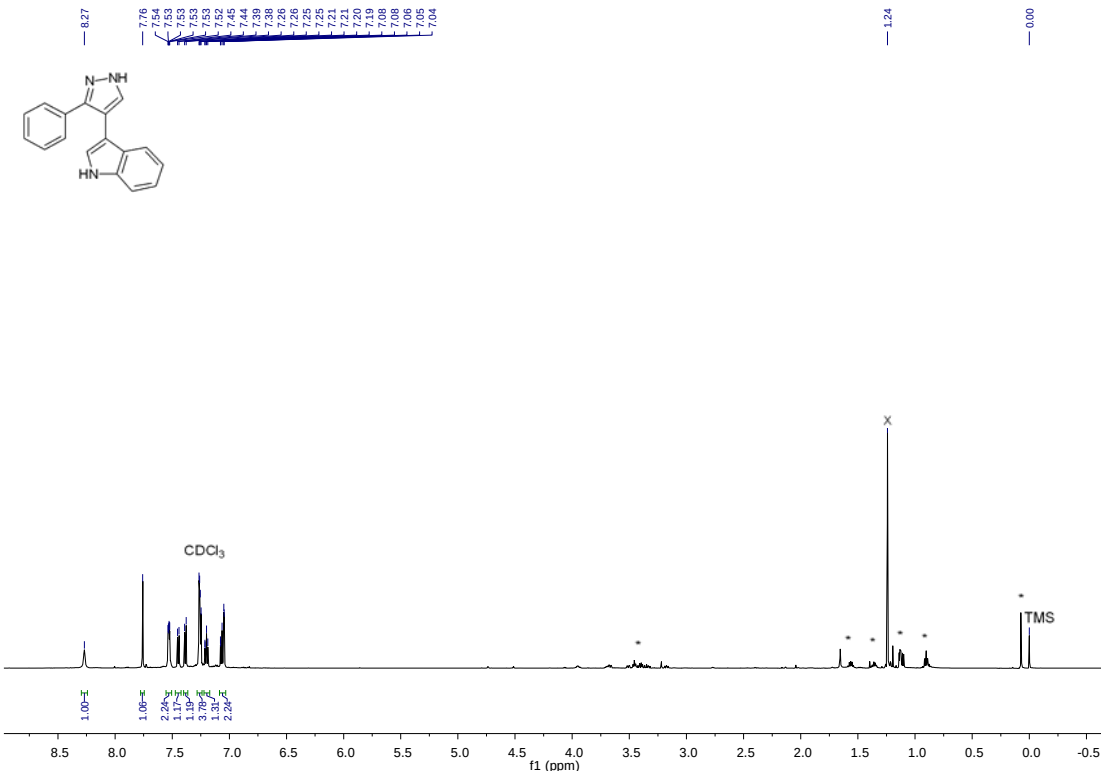


^{13}C NMR of **7e** (10 mg) in 0.4 mL $CDCl_3$ at 298 K (δ in ppm). (* Solvent residue)

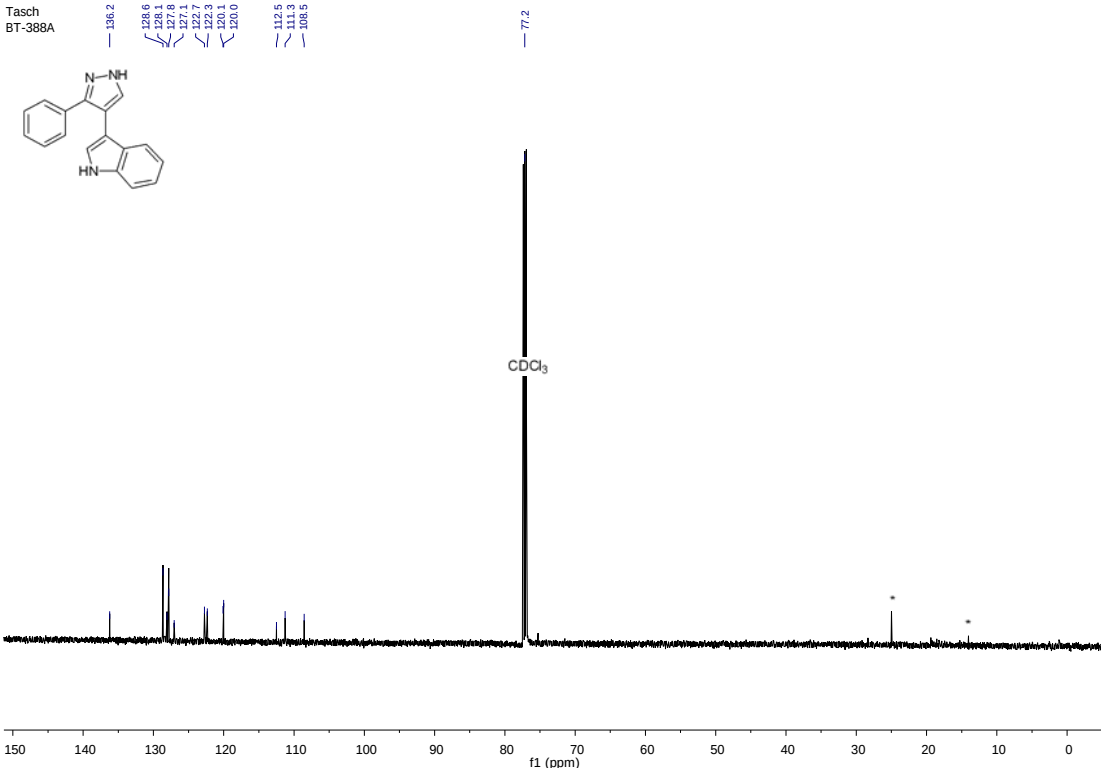


^{13}C 135-DEPT NMR of **7e** (10 mg) in 0.4 mL $CDCl_3$ at 298 K (δ in ppm). (* Solvent residue)

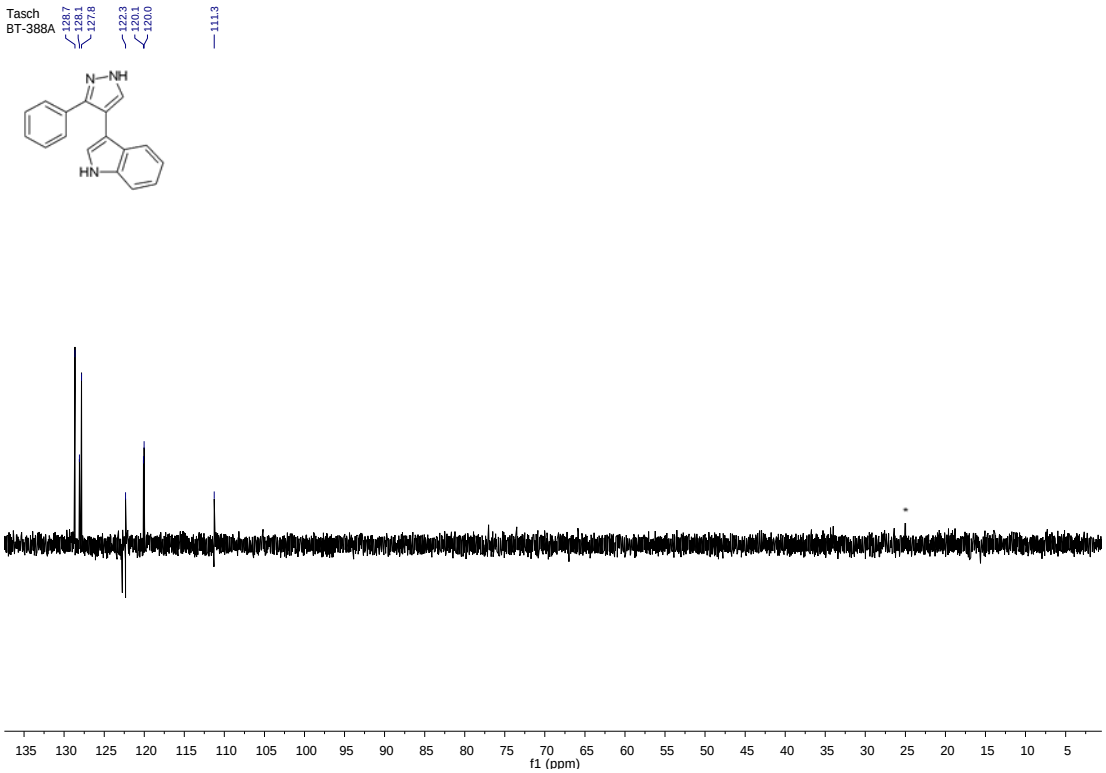
3.6.6 3-(3-Phenyl-1*H*-pyrazol-4-yl)-1*H*-indole (7f)



^{1}H NMR of **7f** (15 mg) in 0.5 mL $CDCl_3$ at 298 K (δ in ppm). (* Solvent residue, ^{x} impurity in NMR-solvent)



^{13}C NMR of **7f** (15 mg) in 0.5 mL $CDCl_3$ at 298 K (δ in ppm). (* Solvent residue)



^{13}C 135-DEPT NMR of **7f** (15 mg) in 0.5 mL $CDCl_3$ at 298 K (δ in ppm). (* Solvent residue)

4 Literature

1 K. Mitsudo, P. Thansandote, T. Wilhelm, B. Mariampillai, M. Lautens, *Org. Lett*. **2006**, *8*, 3939-3942.

2 B. Witulski, N. Buschmann, U. Bergsträßer, *Tetrahedron* **2000**, *56*, 8473-8480.

3 T. A. Kelly, D. W. McNeil, J. M. Rose, E. David, C.-K. Shih, P. M. Grob, *J. Med. Chem.* **1997**, *40*, 2430-2433.