Co(III)-catalyzed three-component assembling of *N*-(2-pyrimidyl) indoles with dienes and formaldehyde

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Electronic supporting Information (ESI)

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Experimental Section

General Information. All reactions were carried out under the N_2 atmosphere in flame-dried glassware. Syringes which were used to transfer anhydrous solvents or reagents were purged with nitrogen prior to use (three times). Dry solvents were used for the reaction. Column chromatographical purifications were performed using SiO_2 (100-200 mesh ASTM) from Avra Pvt. Ltd., India. Abbreviations for signal coupling are as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet. Indoles,[2-3] $[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$, were prepared according to literature procedures. Commercially available dienes, metal salts, para formaldehyde and other chemicals were purchased from Sigma-Aldrich and Spectrochem. Pvt. Ltd., India. These chemicals were used without further purification.

General procedure for the sequential three component C-H functionalization to provide 4 and 6.

Indole **1** (50 mg) (1 equiv), HCHO (3 equiv), $[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$ (10 mol %) and PhCOOH (50 mol %) were taken in a 15-mL pressure tube. Dry trifluoro ethanol (TFE) (2.0 mL) was added to the reaction mixture under N_2 medium. Then, dienes **2 or 5,** (2.0 equiv) was added followed by the addition of dry TFE (2.0 mL) and the reaction mixture was stirred under an N_2 atmosphere for five minutes. Then, a screw cap was used to cover the tube and the reaction mixture was allowed to stir at 60 °C for 24 h. Then, the reaction mixture was diluted with CH_2Cl_2, filtered through celite, and the filtrate was concentrated. The crude residue was purified by column chromatography silica-gel 120-200 mesh, EtOAc:Hexane gave the desired products **4** and **6**.

Procedure for the alkenylation followed by hydroxymethyl arylation of Indole pyrimidine (1a) with isoprene (2) and Formaldehyde (3) by a Cobalt catalysis (1 mmol scale).

Indole **1a** (195 mg, 1 mmol), HCHO (3 equiv), $[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$ (10 mol %, 0.1 mmol, 78.8 mg) and PhCOOH (50 mol %, 0.5 mmol, 62 mg) were taken in a 15-mL pressure tube. Trifluoro ethanol (TFE) (5.0 mL) was added to the reaction mixture. Then, diene **2** (2.0 equiv, 2 mmol) was added followed by the addition of dry TFE (5.0 mL) and the reaction mixture was stirred under N_2 atmosphere for five minutes. Then, a screw cap was used to cover the tube and the reaction mixture was allowed to stir at 60 °C for 24 h. Then, the reaction mixture was diluted with CH_2Cl_2, filtered through celite, and the filtrate was

concentrated. The crude residue was purified by column chromatography silica-gel 120-200 mesh, EtOAc:Hexane gave desired products **4a**. 154 mg in 52% yield as pale-yellow liquid.

Preparation of Starting Materials 1 and 2.

Substituted indoles **1a−x** were prepared by the known reported procedurse. [2-3] Remaining dienes are purchased from Sigma-Aldrich and Spectrochem. Pvt. Ltd., India.

Preparation of $[Cp^*Co(MeCN)_3][SbF_6]_2$:

In an N_2-filled glove box, to a suspension of $[Cp^*Co(CO)I_2]$[1] (4.76 g, 10.0 mmol) in dried MeCN (25 mL) in a 250 mL single necked round bottom flask, a solution of $AgSbF_6$ (6.53 g, 19.0 mmol) in dried MeCN (25 mL) was added in 5 mL portions over 5 mins, causing AgI to precipitate immediately. The reaction flask was sealed with a rubber septum, removed from the glove box, and the reaction mixture was stirred with a N_2 inlet at 23 °C in a water bath for 3 h. Then the solid was filtered through celite in air to remove AgI and washed with MeCN (3 × 50 mL, 200 mL total volume). The product complex was then precipitated via the rapid addition of Et_2O (800 mL) and a purple solid precipitated immediately. The purple solid was collected by filtration under vacuum using a medium fritted funnel in air, washed with CH_2Cl_2 (3 × 50 mL) and Et_2O (2 × 50 mL), collected and dried under reduced pressure to furnish the product as a purple solid (5.97 g, 7.57 mmol, 80%). The analytical data for this compound are consistent with previously reported data.

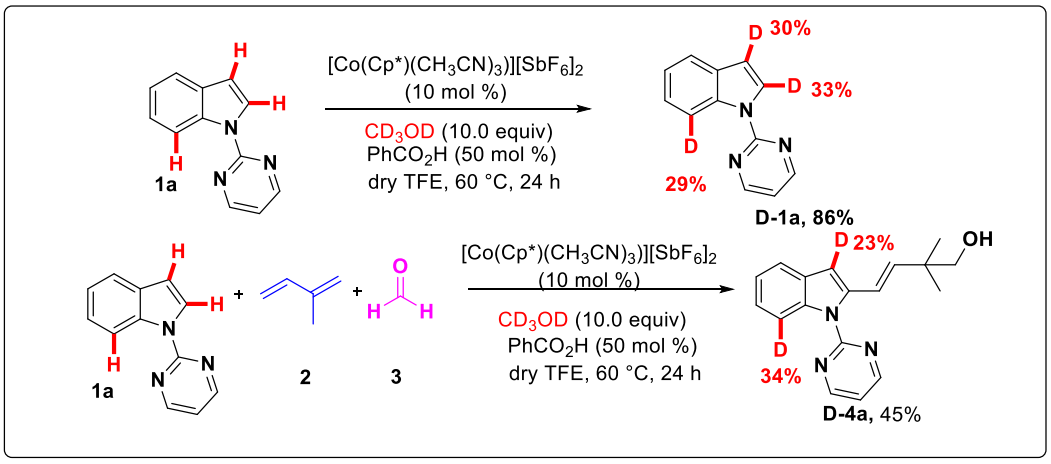
Mechanistic Investigation

Deuterium Labelling Studies for D-1a.

A 15 mL pressure tube with a septum containing Indole **1a** (75 mg), $[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$ (10 mol %), and PhCOOH (50 mol%), dry TFE (3.0 mL) were added to the reaction. Then, CD_3OD (10.0 equiv) was added and the reaction mixture was stirred under N_2 atmosphere for five minutes. Then, a screw cap was used to cover the tube and the reaction mixture was allowed to stir at 60 °C for 24h. Then, the reaction mixture was diluted with CH_2Cl_2, filtered through Celite, and the filtrate was concentrated. The crude residue was purified by column chromatography silica-gel 120-200 mesh, EtOAc:Hexane gave product **D-1a**. In the reaction, product **D-1a** was observed in 86% yield with 33, 30 and 29 % of deuterium incorporation at C2, C3, C7 carbons of indoles respectively.

Preparation of Compounds D-4a.

Indole **1a** (75 mg) (1.0 equiv), HCHO (3 equiv), $[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$ (10 mol %), and PhCOOH (50 mol %), dry TFE (2.0 mL) were taken in a 15-mL pressure tube. CD_3OD (10.0 equiv) were added to the reaction mixture. Then, diene **2b** (3.0 equiv) was added followed by the addition of dry TFE (1.0 mL) and the reaction mixture was stirred under N_2 atmosphere for five minutes. Then, a screw cap was used to cover the tube and the reaction mixture was allowed to stir at 60 °C for 24 h. Then, the reaction mixture was diluted with CH_2Cl_2, filtered through Celite, and the filtrate was concentrated. The crude residue was purified by column chromatography silica-gel 120-200 mesh, EtOAc:Hexane gave product **D-4a** in 45%. In the reaction, 23% and 34% of deuterium incorporation was observed at C3 and C7 positions of functionalised indoles. This result also clearly reveals that the C-H bond activation as a key intermediate in the reaction as well as it is the reversible process.



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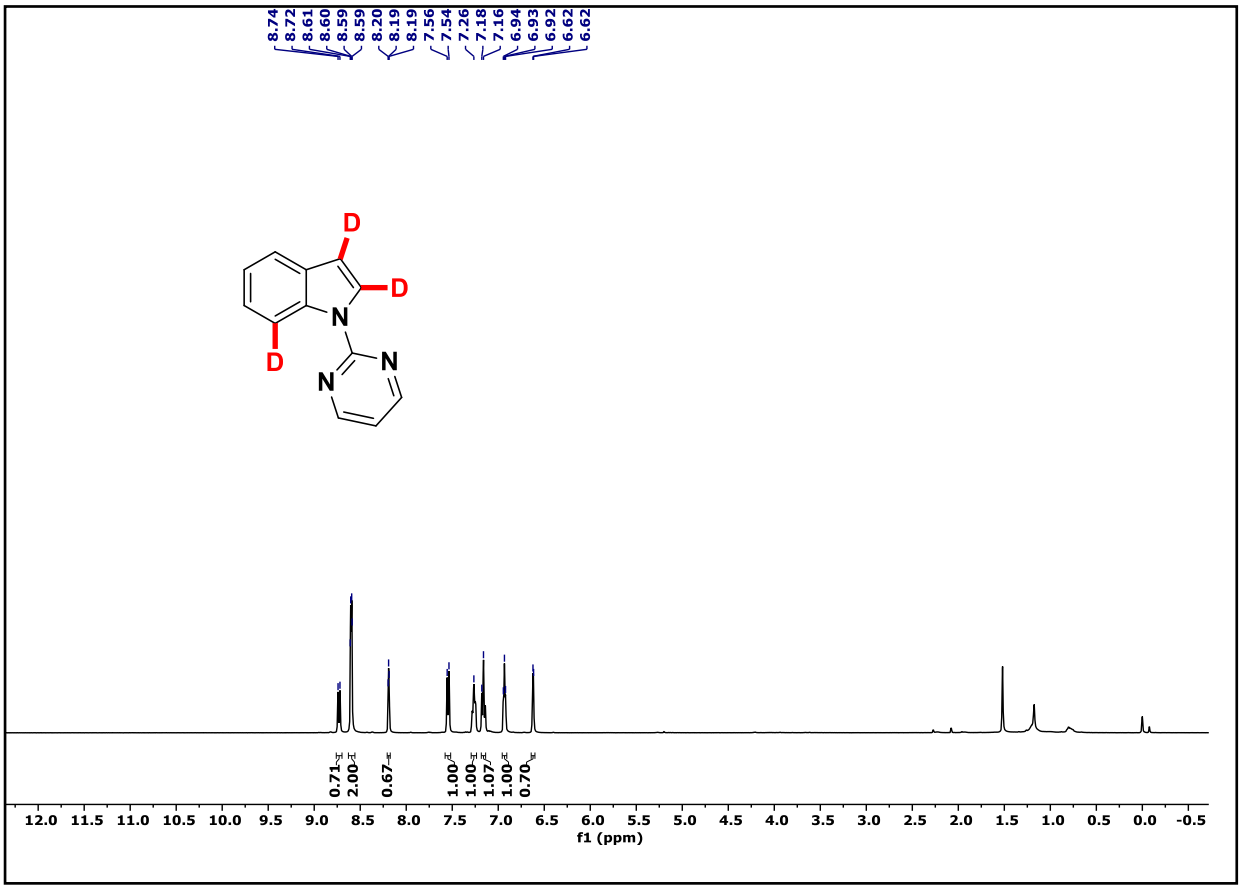
^{1}H Spectra of Compound **D-1a.**



^{1}H Spectra of Compound **D-4a.**

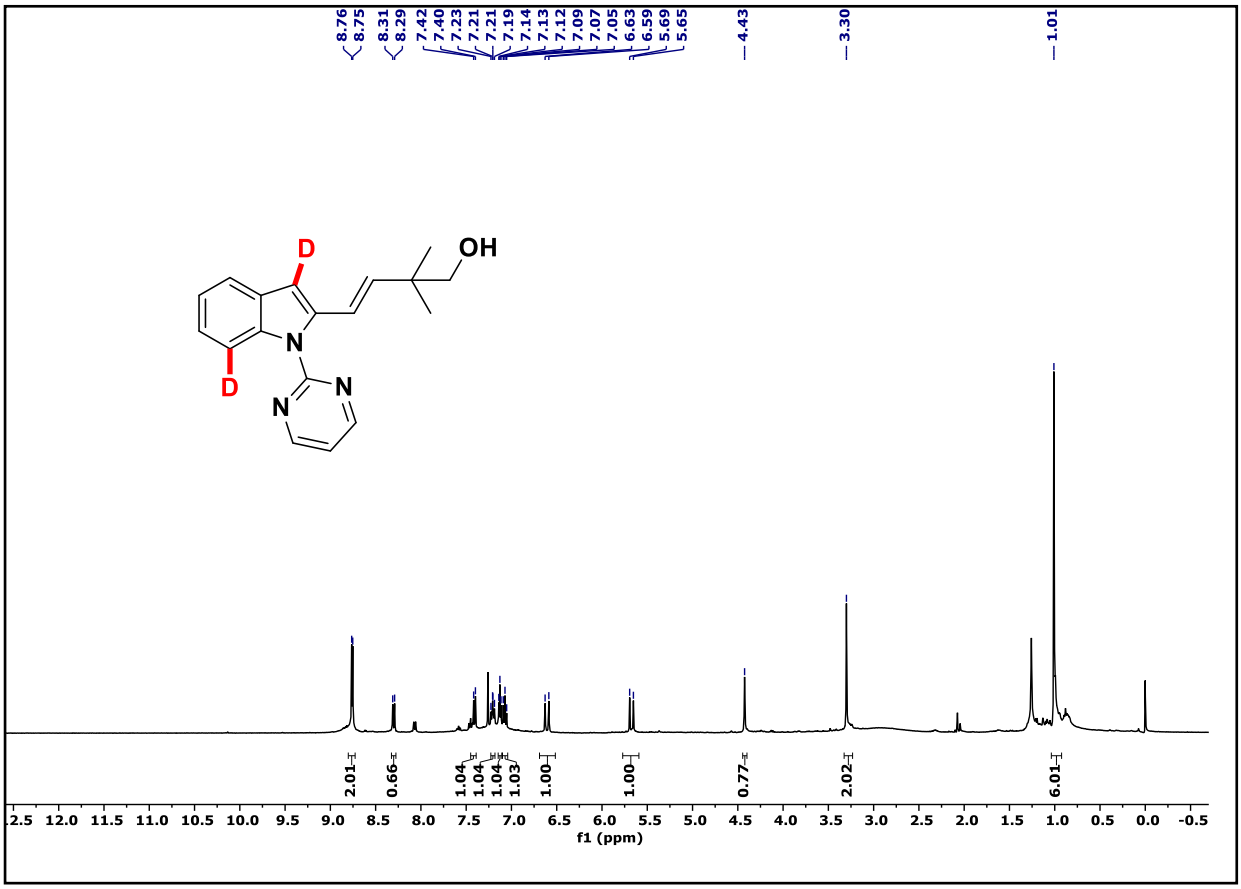


Table S1. Optimization table[a]

S. No	Solvent	Catalyst (10 mol %)/Additive (20 mol %)	Acid	temperature	Yield (%)[b]
1	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	AcOH	60 ˚C	25
2	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ AgBF4	AcOH	60 ˚C	20
3	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ AgOTf	AcOH	60 ˚C	trace
4	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $Ag(NTf)_2$	AcOH	60 ˚C	trace
5	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	Piv-OH	60 ˚C	trace
6	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	HCO_2H	60 ˚C	40
7	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	Adm-COOH	60 ˚C	20
8	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	Mes-COOH	60 ˚C	trace
9	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH	60 ˚C	45
10	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	AgOAc	60 ˚C	trace
11	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	$AgCO_3$	60 ˚C	NR
12	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	AgO_2	60 ˚C	NR
13	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	NaOAc	60 ˚C	31
14	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	CsOAc	60 ˚C	33
15	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	LiOAc	60 ˚C	20
16	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	$Cu(OAc)_2 \cdot H_2O$	60 ˚C	NR
17	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH (20 mol %)	60 ˚C	38
18	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH (50 mol %)	60 ˚C	45
19	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH(1equiv)	60 ˚C	30
20	1,4-Dioxane	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH(1.5equiv)	60 ˚C	25
21	DCE	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH (50 mol %)	60 ˚C	42
22	THF	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH (50 mol %)	60 ˚C	40
23	MeOH	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH (50 mol %)	60 ˚C	NR
24	Toluene	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH (50 mol %)	60 ˚C	29
25	TFE	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH (50 mol %)	60 ˚C	52
26	IsoAmyl alcohol	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH (50 mol %)	60 ˚C	50
27	CH_3CN	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH (50 mol %)	60 ˚C	NR

28	DME	$[Co(Cp^*)COI_2]$/ $AgSbF_6$	PhCOOH (50 mol %)	60 ˚C	NR
29	**TFE**	**$[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$**	**PhCOOH (50 mol%)**	**60 ˚C**	**55**
30	TFE	$[RhCl_2Cp^*]_2$	PhCOOH (50 mol %)	60 ˚C	NR
31	TFE	$[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$	PhCOOH (50 mol %)	100 ˚C	30
32	TFE	$[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$	PhCOOH (50 mol %)	80 ˚C	40
33	TFE	$[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$	PhCOOH (50 mol %)	60 ˚C[c]	30
34	TFE	$[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$	PhCOOH (50 mol %)	60 ˚C[d]	40

[a] All reactions were carried out using substituted chalcone **1a** (50 mg), alkene **2a** (3.0 equiv), $[Co(Cp^*)(CH_3CN)_3)][SbF_6]_2$ (10 mol %), Acid (50 mol %) in dry TFE under N_2 at 60 ˚C for 24 h. [b] Isolated yield. [c] (16 h) of reaction time. [d] (48 h) of reaction time.

Detail Optimisation Studies:

At first, various silver salts were tested, and the reaction was concluded to progress best with $AgSbF_6$. In a screening of various acids, when the acid was changed to benzoic acid, a higher yield of 40% was observed. Note that the reaction did not proceed in the absence of acids or with bases such as NaOAc, LiOAc and other carbonate or phosphate bases. Later, the transformation was analysed with various relative amounts of acid additive, and use of 50–60 mol% of acid resulted in the maximum yield. Furthermore, various solvents such as MeOH, toluene, TFE, THF, DCE, CH_3CN, iso-amyl alcohol and DME were tested. When TFE was used, the yield of desired product was 50%; other solvents were less effective or ineffective for this transformation (note yields of 40–45% when testing iso-amyl alcohol, THF and DCE). The use of $[CoCp^*(CH_3CN)_3][SbF_6]_2$ rather than $[RhCl_2Cp^*]_2$ and $[CoCp^*COI_2]$ catalysts was determined to be crucial for this transformation and showed a significantly higher yield of 55%. Furthermore, this transformation was repeated at various temperatures such as 120°C, 100 °C, 80 °C, 60 °C, and room temperature. The product 4a was observed with a yield of 55% in the case of 60 °C. Finally, with varying the reaction time from 16 h to 48 h, it was observed that 24 h provided the desired product 4a with the highest yield, of 55%

Reference:

1. B.Sun, T. Yoshino, S. Matsunaga, M. Kanai, *Adv. Synth. Catal.*, 2014, **356**, 1491.
2. L. Ackermann, A. V. Lygin, *Org. Lett.*, 2011, **13**, 3332.
3. J. A. Leitch, C. L. McMullin, M. F. Mahon, Y. Bhonoah, C. G. Frost, *ACS Catal.*, 2017, **7**, 2616.

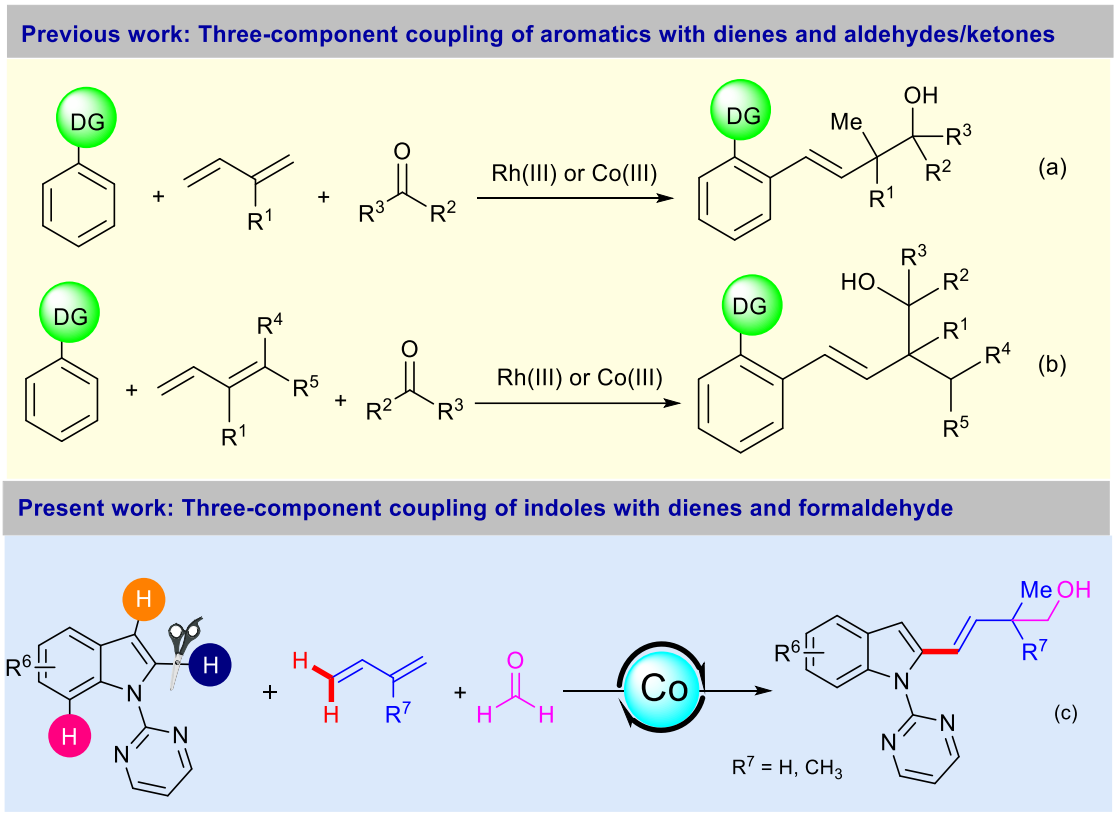


Figure S1. Co(III)-catalysed three-component addition for the synthesis of homoallylic alcohols.

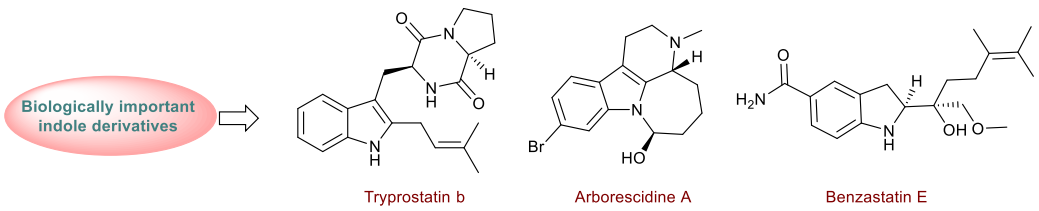


Figure S2. Some biologically important indole derivatives.

It is noted that this protocol remains unsuccessful for the dienes mentioned below and for aldehydes such as acetaldehyde, benzaldehyde, and ethyl glyoxalate. We have conducted an optimisation study for the dienes by varying with different substrates and solvents, but concluded with no desired products.

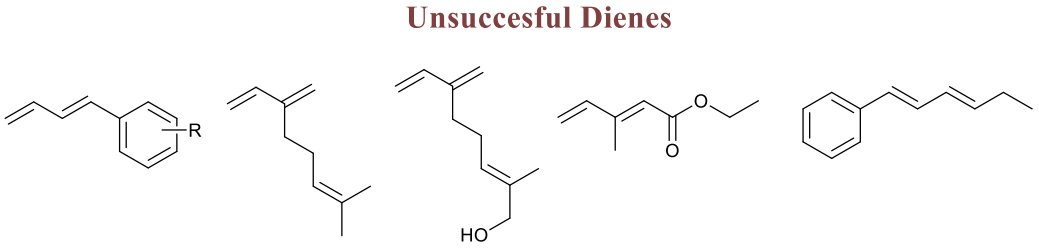
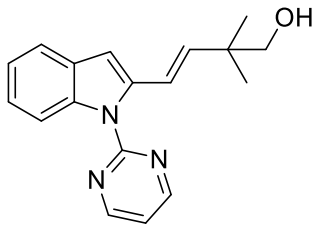


Figure S3. Unsuccessful dienes.

Spectral Data of all Compounds:

(*E*)-2,2-Dimethyl-4-(1-(pyrimidin-2-yl)-1H-indol-2-yl) but-3-en-1-ol (4a).



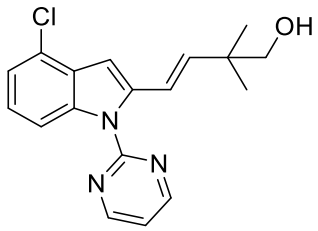
Brown liquid; eluent (hexane, 80% ethyl acetate). The reaction scale is 50 mg, 42 mg of product was isolated and yield is 55%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.76 (dt, *J* = 4.3, 1.7 Hz, 2H), 8.30 (d, *J* = 8.3 Hz, 1H), 7.41 (d, *J* = 7.9 Hz, 1H), 7.21 (t, *J* = 8.1 Hz, 1H), 7.12 (t, *J* = 2.2 Hz, 1H), 7.07 (s, 1H), 6.61 (dd, *J* = 16.5, 2.2 Hz, 1H), 5.68 (dd, *J* = 16.6, 2.2 Hz, 1H), 4.43 (s, 1H), 3.31 (s, 2H), 1.02 (s, 6H).

^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.11, 158.07, 141.2, 136.4, 133.9, 130.2, 123.6, 123.3, 123.2, 122.0, 121.8, 119.5, 116.9, 116.8, 113.8, 71.2, 39.3, 23.8.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{18}H_{20}N_3O$ 294.1606; Found 294.1593.

(*E*)-4-(4-Chloro-1-(pyrimidin-2-yl)-1H-indol-2-yl)-2,2-dimethylbut-3-en-1-ol. (4b).



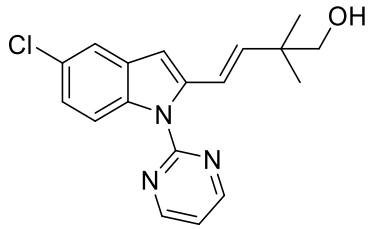
Brown liquid; eluent (hexane, 75% ethyl acetate). The reaction scale is 50 mg, 44 mg of product was isolated and yield is 60%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.78 (t, *J* = 3.8 Hz, 2H), 7.97 (d, *J* = 8.1 Hz, 1H), 7.20 (dd, *J* = 7.9, 2.9 Hz, 2H), 7.14 (d, *J* = 2.4 Hz, 1H), 6.07 (d, *J* = 16.4 Hz, 1H), 5.30 (dd, *J* = 16.4, 2.7 Hz, 1H), 5.08 (s, 1H), 3.00 (s, 2H), 2.05 (t, *J* = 3.6 Hz, 1H), 0.63 (s, 3H), 0.48 (s, 3H).

^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.4, 158.3, 157.7, 142.9, 138.0, 135.9, 126.7, 126.6, 123.7, 123.3, 119.4, 117.8, 117.1, 111.2, 71.3, 39.1, 23.1, 22.7.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{18}H_{19}ClN_3O$ 328.1217; Found 328.1204.

(*E*)-4-(5-Chloro-1-(pyrimidin-2-yl)-1H-indol-2-yl)-2,2-dimethylbut-3-en-1-ol (4c).

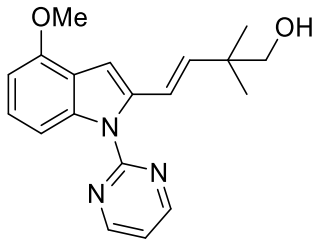


Yellow liquid; eluent (hexane, 78% ethyl acetate). The reaction scale is 50 mg, 33 mg of product was isolated and yield is 44%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.76 (d, *J* = 4.9 Hz, 2H), 8.25 (d, *J* = 8.9 Hz, 1H), 7.42 (d, *J* = 2.1 Hz, 1H), 7.17 – 7.13 (m, 2H), 6.64 (d, *J* = 16.5 Hz, 1H), 5.76 (d, *J* = 16.5 Hz, 1H), 4.33 (s, 1H), 3.35 (s, 2H), 2.07 (s, 1H), 1.06 (s, 6H).
^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.2, 157.8, 150.4, 142.1, 135.3, 134.7, 131.3, 127.5, 123.8, 121.8, 118.9, 117.2, 115.8, 115.3, 71.2, 39.5, 23.7.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{23}H_{26}O_2Na$ 328.1217; Found 328.1201.

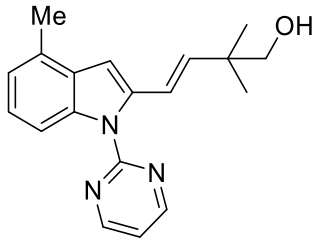
(*E*)-4-(4-Methoxy-1-(pyrimidin-2-yl)-1H-indol-2-yl)-2,2-dimethylbut-3-en-1-ol (4d).



Brown liquid; eluent (hexane, 85% ethyl acetate). The reaction scale is 50 mg, 36 mg of product was isolated and yield is 50%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.74 (d, *J* = 4.8 Hz, 2H), 7.70 (d, *J* = 8.4 Hz, 1H), 7.17 – 7.08 (m, 2H), 6.63 (d, *J* = 7.9 Hz, 1H), 6.19 (d, *J* = 16.5 Hz, 1H), 5.19 (d, *J* = 16.5 Hz, 1H), 4.97 (s, 1H), 3.82 (s, 3H), 2.96 (d, *J* = 3.0 Hz, 2H), 2.54 (s, 1H), 1.25 (s, 6H).
^{13}C{1H} NMR (126 MHz, $CDCl_3$): δ 158.3, 158.2, 158.2, 155.0, 140.4, 138.2, 132.6, 124.0, 120.3, 120.0, 119.1, 117.2, 105.8, 102.8, 71.1, 55.3, 38.9, 29.7.
HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{19}H_{22}N_3O_2$ 324.1712; Found 324.1690.

(*E*)-2,2-Dimethyl-4-(4-methyl-1-(pyrimidin-2-yl)-1H-indol-2-yl)but-3-en-1-ol (4e).

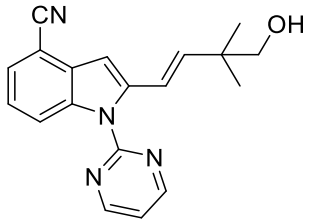


Brown liquid; eluent (hexane, 75% ethyl acetate). The reaction scale is 50 mg, 35 mg of product was isolated and yield is 47%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.76 (d, *J* = 4.9 Hz, 2H), 7.91 (d, *J* = 8.3 Hz, 1H), 7.16 – 7.11 (m, 2H), 6.97 (d, *J* = 7.2 Hz, 1H), 6.07 (d, *J* = 16.4 Hz, 1H), 5.26 (d, *J* = 16.4 Hz, 1H), 4.80 (s, 1H), 3.00 (d, *J* = 13.1 Hz, 2H), 2.75 (s, 3H), 0.64 (s, 3H), 0.49 (s, 3H).
^{13}C{1H} NMR (126 MHz, $CDCl_3$): δ 157.2, 157.1, 141.0, 136.3, 133.7, 130.1, 127.5, 123.1, 122.5, 118.7, 117.1, 116.3, 109.3, 70.4, 38.1, 22.4, 21.8, 19.9.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{19}H_{22}N_3O$ 308.1763; Found 308.1739.

(*E*)-2-(4-Hydroxy-3,3-dimethylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indole-4-carbonitrie (4f).

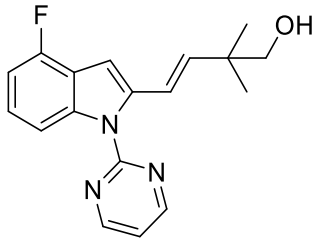


Brown liquid; eluent (hexane, 65% ethyl acetate). The reaction scale is 50 mg, 40 mg of product was isolated and yield is 55%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.86 – 8.81 (m, 2H), 8.52 (d, *J* = 8.5 Hz, 1H), 7.52 (d, *J* = 7.6 Hz, 1H), 7.26 (t, *J* = 5.5 Hz, 2H), 6.96 (s, 1H), 6.85 (d, *J* = 16.2 Hz, 1H), 6.25 (d, *J* = 16.2 Hz, 1H), 3.46 (s, 2H), 2.05 (s, 1H), 1.16 (s, 6H).
^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.4, 157.3, 141.7, 141.0, 136.5, 131.1, 128.4, 126.9, 122.8, 121.5, 118.8, 118.4, 118.0, 102.8, 102.3, 71.2, 39.3, 23.7.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{19}H_{19}N_4O$ 319.1559; Found 319.1562.

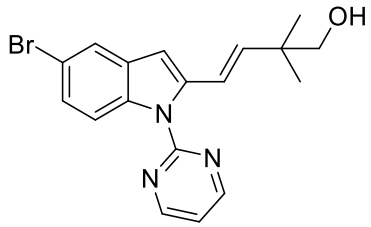
(*E*)-4-(4-Fluoro-1-(pyrimidin-2-yl)-1H-indol-2-yl)-2,2-dimethylbut-3-en-1-ol (4g).



Brown liquid; eluent (hexane, 62% ethyl acetate). The reaction scale is 50 mg, 37 mg of product was isolated and yield is 50%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.76 (d, *J* = 4.8 Hz, 2H), 7.93 (d, *J* = 8.3 Hz, 1H), 7.15 (d, *J* = 5.1 Hz, 2H), 6.85 (dd, *J* = 10.9, 8.0 Hz, 1H), 6.23 (d, *J* = 16.5 Hz, 1H), 5.36 (d, *J* = 16.5 Hz, 1H), 4.72 (s, 1H), 3.07 (s, 2H), 0.68 (s, 6H).
^{13}C{1H} NMR (126 MHz, $CDCl_3$): δ 158.2, 158.0 (d, *J* = 6.5 Hz), 156.1, 142.1, 138.8 (d, *J* = 10.3 Hz), 134.4, 123.8 (d, *J* = 7.8 Hz), 120.2, 118.9, 118.8, 117.5, 115.6 (d, *J* = 4.4 Hz), 109.2 (d, *J* = 3.5 Hz), 107.7 (d, *J* = 19.7 Hz), 71.2, 39.1, 23.2.
HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{18}H_{19}FN_3O$ 312.1512; Found 312.1513.

(*E*)-4-(5-Bromo-1-(pyrimidin-2-yl)-1H-indol-2-yl)-2,2-dimethylbut-3-en-1-ol (4h).



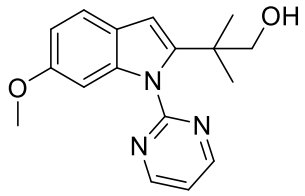
Orange yellow liquid; eluent (hexane,67% ethyl acetate). The reaction scale is 50 mg, 35 mg of product was isolated and yield is 52%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.75 (d, *J* = 4.8 Hz, 2H), 8.19 (d, *J* = 8.8 Hz, 1H), 7.58 (d, *J* = 2.0 Hz, 1H), 7.29 – 7.24 (m, 2H), 7.15 (t, *J* = 4.8 Hz, 1H), 6.64 (d, *J* = 16.5 Hz, 1H), 5.76 (d, *J* = 16.5 Hz, 1H), 4.32 (s, 1H), 3.34 (s, 2H), 2.07 (s, 1H), 1.06 (s, 6H).

^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.2, 158.1, 157.7, 142.1, 135.1, 135.0, 131.8, 126.4, 122.0, 121.7, 117.2, 115.8, 115.7, 115.2, 71.3, 39.5, 23.8, 20.5.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{18}H_{19}BrN_3O$ 372.0711; Found 372.0611.

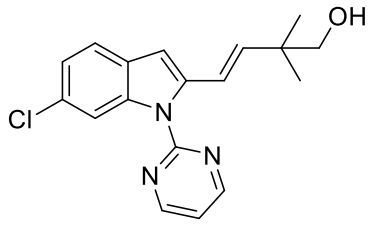
2-(6-Methoxy-1-(pyrimidin-2-yl)-1H-indol-2-yl)-2-methylpropan-1-ol (4i)



Yellow liquid; eluent (hexane, 76% ethyl acetate). The reaction scale is 30 mg, 55 mg of product was isolated and yield is 45%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.75 (dd, *J* = 4.9, 1.5 Hz, 2H), 7.93 (d, *J* = 2.1 Hz, 1H), 7.23 (m, 1H), 7.13 – 7.09 (m, 1H), 6.71 (dt, *J* = 8.7, 2.0 Hz, 1H), 6.60 (dd, *J* = 16.5, 1.4 Hz, 1H), 5.63 (dd, *J* = 16.4, 1.5 Hz, 1H), 4.35 (s, 1H), 3.82 (d, *J* = 1.5 Hz, 3H), 3.31 (s, 2H), 2.06 (s, 1H), 1.03 (s, 6H).
^{13}C{1H} NMR (126 MHz, $CDCl_3$): δ 158.2, 158.1, 157.4, 140.1, 137.4, 132.9, 124.5, 122.0, 120.0, 117.0, 116.7, 110.6, 98.9, 71.2, 55.7, 39.3, 23.9.
HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{24}O_4Na$ 387.1572; Found 387.1543.

(*E*)-4-(6-Chloro-1-(pyrimidin-2-yl)-1H-indol-2-yl)-2,2-dimethylbut-3-en-1-ol (4j)

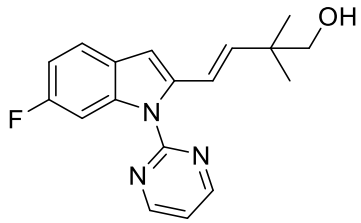


Yellow liquid; eluent (hexane, 75% ethyl acetate). The reaction scale is 50 mg, 40 mg of product was isolated and yield is 55%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.78 (d, *J* = 4.8 Hz, 2H), 8.37 (d, *J* = 1.9 Hz, 1H), 7.23 (d, *J* = 8.4 Hz, 1H), 7.17 (t, *J* = 4.9 Hz, 1H), 7.03 (dd, *J* = 8.4, 2.0 Hz, 1H), 6.60 (d, *J* = 16.5 Hz, 1H), 5.70 (d, *J* = 16.5 Hz, 1H), 4.36 (s, 1H), 3.33 (s, 2H), 1.04 (s, 6H).

^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.3, 157.8, 141.8, 139.1, 136.7, 134.7, 129.6, 128.6, 122.6, 121.6, 120.1, 117.3, 116.2, 114.2, 71.2, 39.4, 23.9.
HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{18}H_{19}ClN_3O$ 328.1217; Found 328.1215.

(*E*)-4-(6-Fluoro-1-(pyrimidin-2-yl)-1H-indol-2-yl)-2,2-dimethylbut-3-en-1-ol (4k)



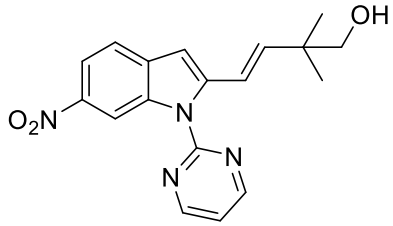
Yellow liquid; eluent (hexane, 70% ethyl acetate). The reaction scale is 50 mg, 46 mg of product was isolated and yield is 62%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.76 (d, *J* = 4.8 Hz, 2H), 8.11 (dd, *J* = 11.0, 2.4 Hz, 1H), 7.26 – 7.22 (m, 1H), 7.15 (t, *J* = 4.8 Hz, 1H), 6.82 (td, *J* = 8.9, 2.4 Hz, 1H), 6.62 (d, *J* = 16.5 Hz, 1H), 5.68 (d, *J* = 16.5 Hz, 1H), 4.36 (s, 1H), 3.33 (s, 2H), 1.04 (s, 6H).

^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.2, 157.9, 141.2, 136.5, 126.5, 121.9, 120.1, 119.9, 117.1, 116.4, 110.4, 110.2, 101.5, 101.3, 71.2, 39.4, 23.9.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{18}H_{19}FN_3O$ 312.1512; Found 312.1531.

(*E*)-2,2-Dimethyl-4-(6-nitro-1-(pyrimidin-2-yl)-1H-indol-2-yl)but-3-en-1-ol (4l).

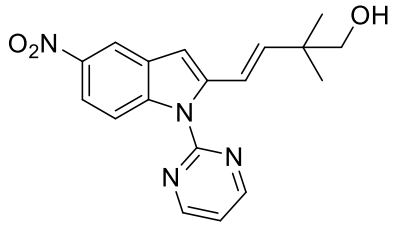


Black liquid; eluent (hexane, 78% ethyl acetate). The reaction scale is 50 mg, 51 mg of product was isolated and yield is 71%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 9.27 – 9.18 (m, 1H), 8.86 (d, *J* = 4.8 Hz, 2H), 8.10 – 8.07 (m, 1H), 7.59 – 7.56 (m, 1H), 7.46 (d, *J* = 7.6 Hz, 1H), 7.29 (d, *J* = 4.8 Hz, 1H), 6.84 (d, *J* = 18.2 Hz, 1H), 6.23 (d, *J* = 16.1 Hz, 1H), 3.46 (s, 2H), 1.16 (s, 6H).
^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.5, 144.3, 141.3, 135.5, 134.2, 133.5, 130.1, 128.4, 121.6, 119.7, 118.2, 117.8, 111.3, 104.6, 71.3, 39.4, 23.8.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{18}H_{19}N_4O_3$ 339.1457; Found 339.1464.

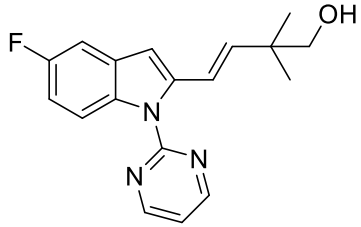
(*E*)-2,2-Dimethyl-4-(5-nitro-1-(pyrimidin-2-yl)-1H-indol-2-yl)but-3-en-1-ol (4n).



Yellow liquid; eluent (hexane, 70% ethyl acetate). The reaction scale is 50 mg, 37 mg of product was isolated and yield is 52%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.84 (d, *J* = 4.9 Hz, 2H), 8.44 (d, *J* = 2.3 Hz, 1H), 8.33 (d, *J* = 9.2 Hz, 1H), 8.09 (dd, *J* = 9.2, 2.3 Hz, 1H), 7.30 – 7.26 (m, 1H), 6.84 (s, 1H), 6.80 (d, *J* = 16.2 Hz, 1H), 6.18 (d, *J* = 16.2 Hz, 1H), 3.45 (s, 2H), 1.15 (s, 6H).
^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.5, 157.3, 143.3, 142.1, 140.7, 130.5, 128.9, 128.1, 121.5, 118.4, 118.3, 116.5, 114.2, 105.3, 71.3, 39.3, 23.8.
HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{18}H_{19}N_4O_3$ 339.1457; Found 339.1468.

(*E*)-4-(5-Fluoro-1-(pyrimidin-2-yl)-1H-indol-2-yl)-2,2-dimethylbut-3-en-1-ol (4o).



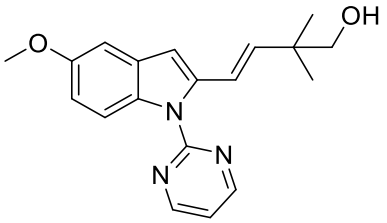
Yellow liquid; eluent (hexane, 68% ethyl acetate). The reaction scale is 50 mg, 51 mg of product was isolated and yield is 69%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.75 (d, *J* = 4.8 Hz, 2H), 8.28 (dd, *J* = 9.1, 4.7 Hz, 1H), 7.14 (t, *J* = 4.8 Hz, 1H), 7.01 (dd, *J* = 9.3, 2.6 Hz, 1H), 6.92 (td, *J* = 9.0, 2.6 Hz, 1H), 6.65 (d, *J* = 16.5 Hz, 1H), 5.74 (d, *J* = 16.5 Hz, 1H), 4.33 (s, 1H), 3.34 (s, 2H), 2.05 (s, 1H), 1.06 (s, 6H).

^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 155.1, 154.8, 138.9, 132.5, 130.4 – 129.4 (m), 127.9 (d, *J* = 9.4 Hz), 118.8, 114.0, 113.1 (d, *J* = 4.2 Hz), 112.1 (d, *J* = 9.0 Hz), 108.5, 108.2, 101.8, 101.5, 68.2, 36.4, 20.8.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{18}H_{19}FN_3O$ 312.1512; Found 312.1511.

(*E*)-4-(5-Methoxy-1-(pyrimidin-2-yl)-1H-indol-2-yl)-2,2-dimethylbut-3-en-1-ol (4p).

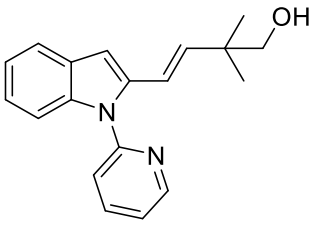


Brown liquid; eluent (hexane, 67% ethyl acetate). The reaction scale is 50 mg, 37 mg of product was isolated and yield is 51%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.71 (d, *J* = 4.9 Hz, 2H), 8.26 (d, *J* = 9.0 Hz, 1H), 7.07 (s, 1H), 6.90 – 6.86 (m, 1H), 6.82 (dd, *J* = 9.1, 2.6 Hz, 1H), 6.68 (d, *J* = 16.5 Hz, 1H), 5.72 (d, *J* = 16.5 Hz, 1H), 4.36 (s, 1H), 3.63 (s, 3H), 3.33 (s, 2H), 1.06 (s, 6H).
^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.1, 155.4, 141.0, 134.6, 133.5, 131.0, 130.1, 128.4, 122.2, 116.8, 116.6, 115.1, 112.7, 101.8, 71.2, 55.4, 39.4, 24.0.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{19}H_{22}N_3O_2$ 324.1712; Found 324.1708.

(*E*)-2-(4-Hydroxy-3,3-dimethylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indole-3-carbonitrile (4q).



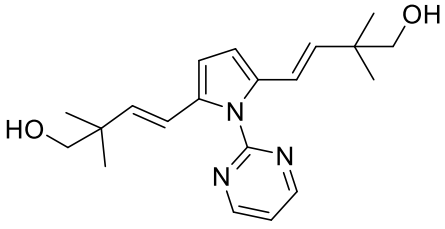
Pale yellow liquid; eluent (hexane, 78% ethyl acetate). The reaction scale is 50 mg, 39 mg of product was isolated and yield is 52%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.57 – 8.48 (m, 1H), 7.76 (tt, *J* = 7.8, 1.6 Hz, 1H), 7.48 (d, *J* = 7.8 Hz, 1H), 7.34 (d, *J* = 8.2 Hz, 1H), 7.30 – 7.25 (m, 1H), 7.22 – 7.18 (m, 1H), 7.11 – 7.02 (m, 2H), 6.06 (d, *J* = 16.6 Hz, 1H), 5.33 (d, *J* = 16.6 Hz, 1H), 4.39 (s, 1H), 3.01 (s, 2H), 0.66 (s, 6H).

^{13}C{1H} NMR (126 MHz, $CDCl_3$): δ 151.0, 148.1, 141.8, 137.2, 133.3, 129.0, 128.4, 121.9, 121.1, 120.8, 119.9, 118.2, 116.9, 113.6, 109.3, 70.1, 38.2, 22.5.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{19}H_{21}N_2O$ 293.1654; Found 293.1649.

(*E*)-2,2-Dimethyl-4-(1-(pyrimidin-2-yl)-1H-pyrrol-2-yl)but-3-en-1-ol (4r).



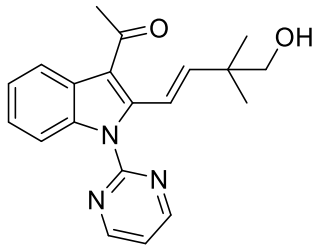
Brown liquid; eluent (hexane, 72% ethyl acetate). The reaction scale is 50 mg, 25 mg of product was isolated and yield is 30%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.81 (dd, *J* = 4.9, 1.6 Hz, 2H), 7.27 (d, *J* = 1.6 Hz, 1H), 6.40 – 6.34 (m, 4H), 5.84 (d, *J* = 1.4 Hz, 1H), 5.81 (d, *J* = 1.3 Hz, 1H), 3.32 (d, *J* = 1.9 Hz, 4H), 2.05 (d, *J* = 2.6 Hz, 2H), 1.02 (s, 6H), 1.02 (s, 6H).

^{13}C{1H} NMR (126 MHz, $CDCl_3$): δ 158.4, 158.4, 158.3, 157.3, 135.7, 133.5, 120.2, 120.2, 118.8, 108.5, 71.4, 38.9, 23.8.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{20}H_{28}N_3O_2$ 342.2182; Found 342.2244.

(*E*)-1-(2-(4-Hydroxy-3,3-dimethylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indol-3-yl)ethan-1-one (4u)

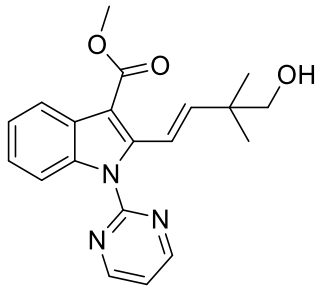


Yellow liquid; eluent (hexane, 35% ethyl acetate). The reaction scale is 50 mg, 53 mg of product was isolated and yield is 75%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.84 (d, *J* = 4.8 Hz, 2H), 8.19 (dd, *J* = 7.7, 1.7 Hz, 1H), 8.02 – 7.93 (m, 1H), 7.35 – 7.27 (m, 3H), 6.91 (d, *J* = 16.5 Hz, 1H), 5.66 (d, *J* = 16.5 Hz, 1H), 3.32 (s, 2H), 2.61 (s, 3H), 2.06 (s, 1H), 1.06 (s, 6H).
^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 196.3, 158.5, 157.4, 146.6, 142.7, 136.3, 130.0, 128.3, 127.1, 124.3, 123.6, 121.6, 121.0, 118.8, 112.9, 70.9, 39.6, 31.5, 23.2.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{20}H_{22}N_3O_2$ 336.1712; Found 336.1718.

Methyl(*E*)-2-(4-hydroxy-3,3-dimethylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indole-3-carboxylate (4v).

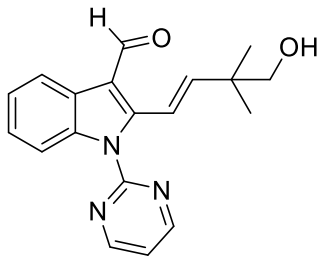


Brown liquid; eluent (hexane, 35 ethyl acetate). The reaction scale is 50 mg, 49 mg of product was isolated and yield is 70%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.86 (d, *J* = 4.8 Hz, 2H), 8.21 – 8.12 (m, 1H), 7.91 (dd, *J* = 7.0, 2.3 Hz, 1H), 7.38 – 7.27 (m, 3H), 6.98 (d, *J* = 16.6 Hz, 1H), 5.59 (d, *J* = 16.6 Hz, 1H), 4.76 (s, 1H), 3.96 (s, 3H), 3.29 (s, 2H), 1.05 (s, 6H).
^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 165.9, 158.5, 157.5, 145.7, 143.9, 136.5, 130.0, 128.3, 127.1, 124.1, 123.2, 121.9, 119.5, 118.9, 112.5, 70.9, 51.2, 39.6, 23.2.

HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{20}H_{21}N_3O_3Na$ 374.1481; Found 374.1487.

(*E*)-2-(4-Hydroxy-3,3-dimethylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indole-3-carbaldehyde (4w).

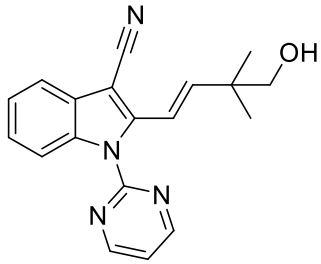


Yellow Solid; eluent (hexane, 36% ethyl acetate). The reaction scale is 50 mg, 54 mg of product was isolated and yield is 74%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 10.05 (d, *J* = 2.9 Hz, 1H), 8.78 (t, *J* = 3.9 Hz, 2H), 8.36 (dt, *J* = 7.0, 3.3 Hz, 1H), 8.20 (q, *J* = 3.9 Hz, 1H), 7.29 (dt, *J* = 7.5, 3.3 Hz, 2H), 7.23 (q, *J* = 4.4 Hz, 1H), 6.71 (dd, *J* = 16.2, 2.9 Hz, 1H), 6.03 (dd, *J* = 15.4, 2.4 Hz, 1H), 3.40 (s, 2H), 1.12 (s, 6H).
^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 187.7, 158.5, 157.1, 148.8, 136.0, 130.1, 128.4, 126.3, 125.2, 124.3, 121.8, 119.3, 118.7, 117.8, 114.0, 71.2, 40.1, 23.7.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{19}H_{20}O_2N_3$ 322.1556; Found 322.1559.

(*E*)-2-(4-Hydroxy-3,3-dimethylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indole-3-carbonitrile (4x).



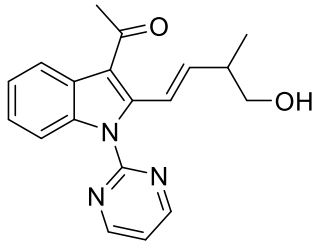
Yellow liquid; eluent (hexane, 30% ethyl acetate). The reaction scale is 50 mg, 47 mg of product was isolated and yield is 65%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.77 (s, 2H), 8.15 (q, *J* = 3.7, 3.3 Hz, 1H), 7.63 (q, *J* = 3.6 Hz, 1H), 7.26 (dt, *J* = 9.1, 4.0 Hz, 3H), 6.73 – 6.61 (m, 1H), 6.56 – 6.44 (m, 1H), 3.41 (s, 2H), 2.25 (s, 1H), 1.10 (s, 6H).

^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.5, 156.9, 145.6, 135.5, 133.4, 130.1, 128.4, 127.8, 125.2, 123.9, 119.2, 119.1, 118.8, 116.3, 114.6, 71.3, 39.9, 23.4.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{19}H_{19}N4O$ 319.1559; Found 319.1566.

(*E*)-1-(2-(4-Hydroxy-3-methylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indol-3-yl)ethan-1-one (6u).

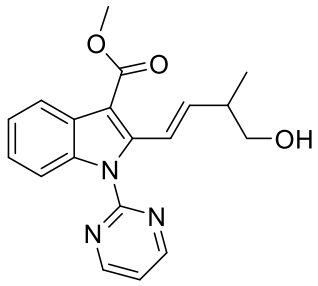


Yellow liquid; eluent (hexane, 44% ethyl acetate). The reaction scale is 50 mg, 37 mg of product was isolated and yield is 55%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.85 (d, *J* = 4.8 Hz, 2H), 8.23 – 8.14 (m, 1H), 8.01 – 7.94 (m, 1H), 7.33 – 7.28 (m, 3H), 7.00 (d, *J* = 16.1 Hz, 1H), 5.60 (dd, *J* = 16.2, 8.2 Hz, 1H), 3.55 (dd, *J* = 10.7, 4.9 Hz, 1H), 3.34 (dd, *J* = 10.8, 8.3 Hz, 1H), 2.63 (s, 4H), 1.01 (d, *J* = 6.8 Hz, 3H).
^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 196.4, 158.6, 158.4, 157.5, 142.6, 142.2, 136.3, 128.3, 127.1, 124.3, 123.6, 122.8, 121.6, 118.8, 112.9, 66.7, 40.5, 31.5, 15.4.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{19}H_{20}N_3O_2$ 322.1556; Found 322.1548.

Methyl (*E*)-2-(4-hydroxy-3-methylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indole-3-carboxylate (6v).



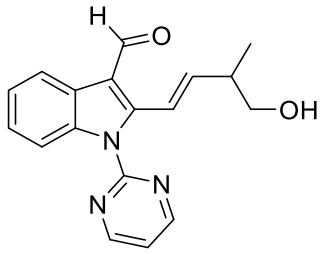
Yellow liquid; eluent (hexane, 35% ethyl acetate). The reaction scale is 50 mg, 48 mg of product was isolated and yield is 72%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.87 (d, *J* = 4.8 Hz, 2H), 8.17 (dd, *J* = 7.5, 1.8 Hz, 1H), 7.93 – 7.87 (m, 1H), 7.31 (dq, *J* = 5.5, 2.6 Hz, 3H), 7.05 (dd, *J* = 16.3, 1.1 Hz, 1H), 5.53 (dd, *J* = 16.3, 8.3 Hz, 1H), 3.96 (s, 3H), 3.55 (dd, *J* = 10.8, 4.6 Hz, 1H), 3.28 (dd, *J* = 10.8, 8.3 Hz, 1H), 2.59 – 2.52 (m, 1H), 0.99 (d, *J* = 6.8 Hz, 3H).

^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 165.9, 158.6, 158.4, 157.6, 143.3, 141.7, 136.5, 127.1, 124.2, 123.3, 121.9, 121.3, 118.9, 112.5, 108.7, 66.6, 51.3, 40.6, 15.5.

HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{19}H_{19}N_3NaO_3$ 360.1324; Found 360.1331.

(*E*)-2-(4-Hydroxy-3-methylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indole-3-carbaldehyde (6w).



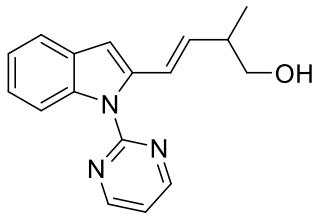
Yellow liquid; eluent (hexane, 42% ethyl acetate). The reaction scale is 50 mg, 56 mg of product was isolated and yield is 81%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 10.12 (d, *J* = 1.6 Hz, 1H), 8.82 (dd, *J* = 4.9, 1.4 Hz, 2H), 8.41 (dd, *J* = 6.2, 3.2 Hz, 1H), 8.22 (dd, *J* = 6.1, 3.4 Hz, 1H), 7.34 (dd, *J* = 6.2, 3.2 Hz, 2H), 7.28 (dd, *J* = 5.6, 4.2 Hz, 1H), 6.84 (d, *J* = 15.8 Hz, 1H), 6.01 (dd, *J* = 15.8, 8.1 Hz, 1H), 3.67 (dd, *J* = 10.4, 4.6 Hz, 1H), 3.50 (dd, *J* = 10.7, 8.3 Hz, 1H), 2.72 – 2.66 (m, 1H), 1.14 (d, *J* = 6.8 Hz, 3H).

^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 187.4, 158.5, 158.4, 157.1, 148.4, 144.5, 135.9, 126.2, 125.1, 124.2, 121.7, 121.0, 118.6, 118.0, 113.9, 67.0, 40.6, 15.8.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{18}H_{18}O_2N3$ 308.1399; Found 308.1406.

(*E*)-2-Methyl-4-(1-(pyrimidin-2-yl)-1H-indol-2-yl)but-3-en-1-ol (6a).

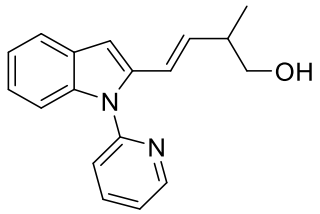


Brown liquid; eluent (hexane, 68% ethyl acetate). The reaction scale is 50 mg, 43 mg of product was isolated and yield is 60%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.81 – 8.75 (m, 2H), 8.30 (dd, *J* = 8.4, 4.8 Hz, 1H), 7.40 (d, *J* = 7.9 Hz, 1H), 7.20 (ddt, *J* = 8.5, 7.1, 1.5 Hz, 1H), 7.13 (td, *J* = 4.8, 1.4 Hz, 1H), 7.08 – 7.03 (m, 1H), 6.71 (dd, *J* = 18.4, 16.1 Hz, 1H), 5.64 (ddd, *J* = 16.2, 8.2, 2.2 Hz, 1H), 4.45 (s, 1H), 3.61 – 3.54 (m, 1H), 3.32 (dd, *J* = 10.7, 8.7 Hz, 1H), 2.55 – 2.50 (m, 1H), 2.05 (s, 1H), 0.99 (d, *J* = 6.4 Hz, 3H).
^{13}C{1H} NMR (126 MHz, $CDCl_3$): δ 158.2, 158.1, 137.1, 136.4, 133.7, 130.2, 123.9, 123.7, 122.1, 119.6, 119.6, 116.9, 113.8, 113.7, 67.1, 40.5, 15.9.

HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{17}H_{18}ON_3$ 280.1450; Found 280.1431.

(*E*)-2-Methyl-4-(1-(pyridin-2-yl)-1H-indol-2-yl)but-3-en-1-ol (6q).

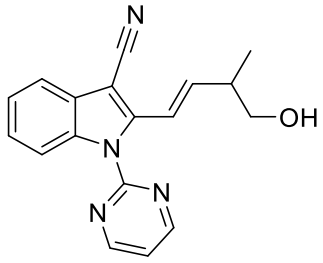


Pale yellow liquid; eluent (hexane, 68% ethyl acetate). The reaction scale is 50 mg, 34 mg of product was isolated and yield is 48%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.60 (dt, *J* = 4.6, 2.2 Hz, 1H), 7.85 (tdd, *J* = 7.8, 3.8, 2.0 Hz, 1H), 7.55 (dd, *J* = 11.1, 7.9 Hz, 1H), 7.42 (dd, *J* = 8.2, 6.4 Hz, 1H), 7.37 (t, *J* = 7.3 Hz, 1H), 7.29 (td, *J* = 5.1, 2.4 Hz, 1H), 7.16 (ddd, *J* = 8.5, 5.7, 1.3 Hz, 1H), 7.11 (t, *J* = 7.8 Hz, 1H), 6.36 – 6.10 (m, 1H), 5.38 (ddd, *J* = 24.6, 16.2, 8.0 Hz, 1H), 4.56 – 4.40 (m, 1H), 3.38 (dt, *J* = 11.0, 4.1 Hz, 1H), 3.13 (ddd, *J* = 11.0, 8.4, 7.0 Hz, 1H), 2.25 (d, *J* = 8.1 Hz, 1H), 0.76 (dd, *J* = 17.7, 6.8 Hz, 3H).
^{13}C{1H} NMR (126 MHz, $CDCl_3$): δ 151.8, 149.2, 138.9, 138.5, 138.3, 134.0, 129.4, 123.0, 122.1, 121.9, 120.9, 120.0, 119.4, 114.6, 110.3, 66.8, 40.8, 16.2.

HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{18}H_{19}ON_2$ 279.1497; Found 279.1496.

(*E*)-2-(4-Hydroxy-3-methylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indole-3-carbonitrile (6x).



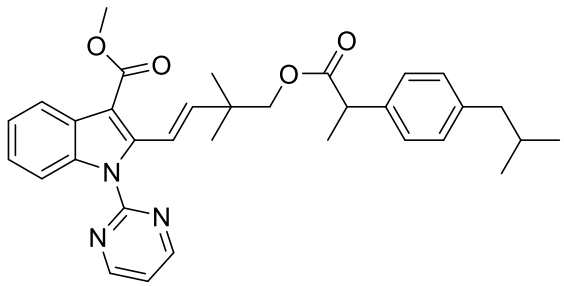
Brown liquid; eluent (hexane, 54% ethyl acetate). The reaction scale is 50 mg, 35 mg of product was isolated and yield is 50%.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.79 (t, *J* = 5.4 Hz, 2H), 8.15 – 8.06 (m, 1H), 7.63 (d, *J* = 4.3 Hz, 1H), 7.25 (d, *J* = 5.1 Hz, 3H), 6.72 (s, 1H), 6.50 (dd, *J* = 16.1, 7.8 Hz, 1H), 3.59 (d, *J* = 6.5 Hz, 1H), 3.52 – 3.45 (m, 1H), 2.61 – 2.55 (m, 1H), 1.09 (d, *J* = 6.9 Hz, 3H).

^{13}C{1H} NMR (101 MHz, $CDCl_3$): δ 158.6, 143.0, 141.5, 135.4, 127.8, 125.2, 125.0, 123.8, 123.7, 120.7, 119.1, 118.9, 118.6, 114.4, 114.2, 67.0, 40.5, 15.6.

HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{29}H_{38}O_5Na$ 489.2617; Found 489.2620.

Methyl(*E*)-2-(4-((2-(4-isobutylphenyl)propanoyl)oxy)-3,3-dimethylbut-1-en-1-yl)-1-(pyrimidin-2-yl)-1H-indole-3-carboxylate (8).

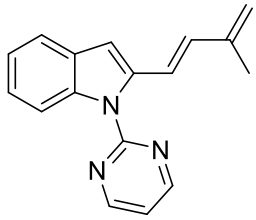


Pale yellow Solid; eluent (hexane, 25% ethyl acetate). The reaction scale is 50 mg, 69 mg of product was isolated and yield is 89%.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.81 (d, *J* = 4.9 Hz, 2H), 8.23 – 8.15 (m, 1H), 7.77 – 7.65 (m, 1H), 7.32 – 7.24 (m, 3H), 7.18 – 7.13 (m, 3H), 7.03 – 7.00 (m, 2H), 5.31 (d, *J* = 16.7 Hz, 1H), 3.94 (s, 3H), 3.68 (d, *J* = 7.6 Hz, 1H), 2.37 (d, *J* = 7.2 Hz, 2H), 1.77 (t, *J* = 6.7 Hz, 1H), 1.46 (d, *J* = 7.2 Hz, 3H), 0.92 (d, *J* = 4.3 Hz, 6H), 0.84 (d, *J* = 6.6 Hz, 6H).
^{13}C{1H} NMR (126 MHz, $CDCl_3$): δ 174.4, 158.6, 144.2, 140.5, 137.5, 129.2, 127.2, 127.0, 124.0, 123.1, 121.8, 119.1, 118.4, 111.7, 71.5, 51.0, 45.1, 44.9, 37.5, 33.9, 30.0, 23.4, 22.2, 18.0.

HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{33}H_{37}N_3O_4Na$ 562.2682; Found 562.2693.

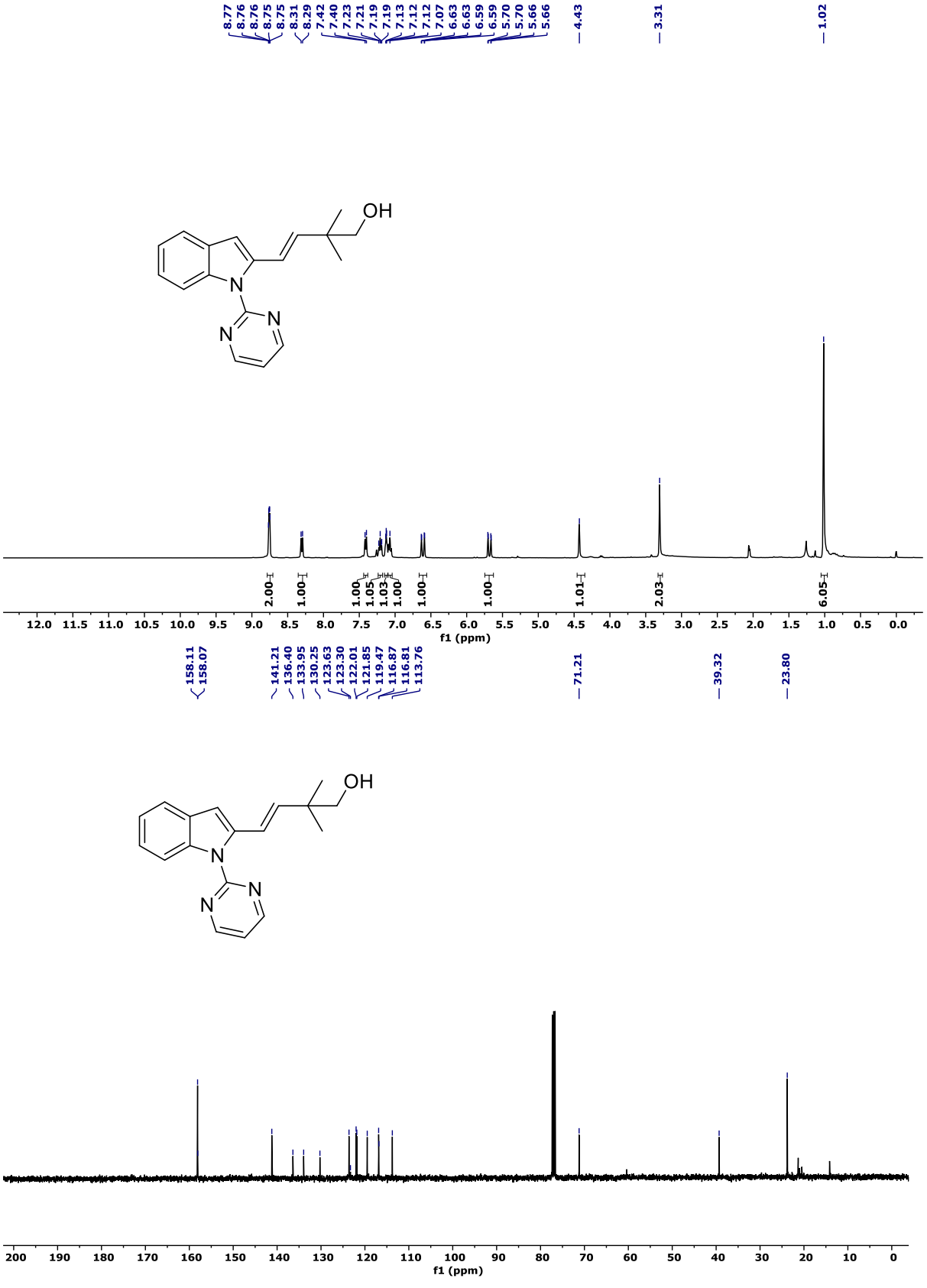
(E)-2-(3-methylbuta-1,3-dien-1-yl)-1-(pyrimidin-2-yl)-1H-indole. (9)



White Solid; eluent (hexane, 0% ethyl acetate). The reaction scale is 100 mg, 11 mg of product was isolated and yield is 8%.

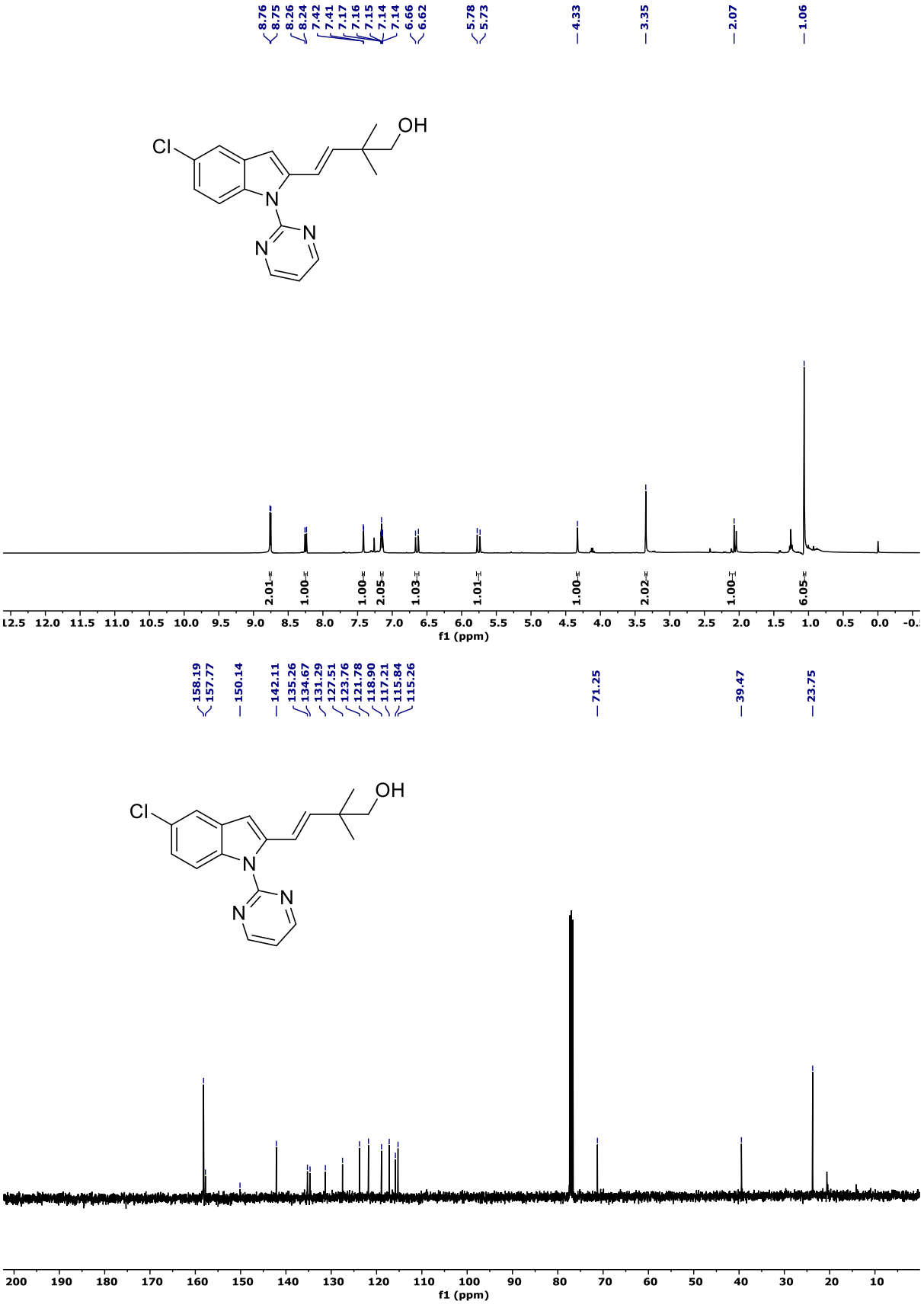
^{1}H NMR (500 MHz, $CDCl_3$): δ 8.83 (d, *J* = 4.8 Hz, 2H), 8.25 (d, *J* = 8.2 Hz, 1H), 7.57 (d, *J* = 7.6 Hz, 1H), 7.21 (s, 1H), 7.20 – 7.17 (m, 2H), 7.12 (d, *J* = 16.0 Hz, 1H), 6.95 – 6.86 (m, 2H), 5.10 (d, *J* = 27.3 Hz, 2H), 1.95 (s, 3H).

^{1}H and ^{13}C NMR Spectra of Compound **4a.** ($CDCl_3$ solvent was used, 400 NMR MHz)

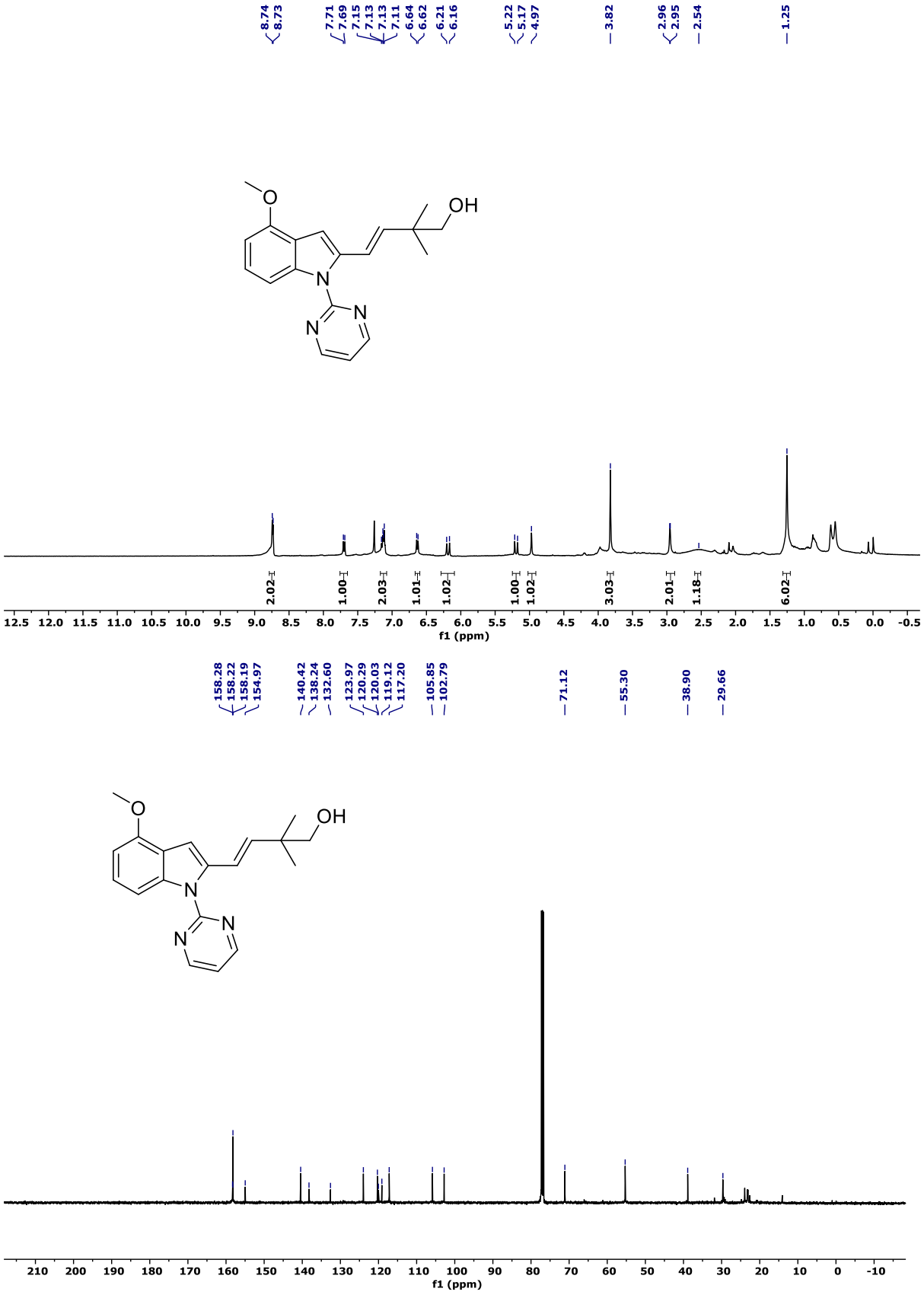


^{1}H and ^{13}C NMR Spectra of Compound **4b.** ($CDCl_3$ solvent was used, 400 NMR MHz)

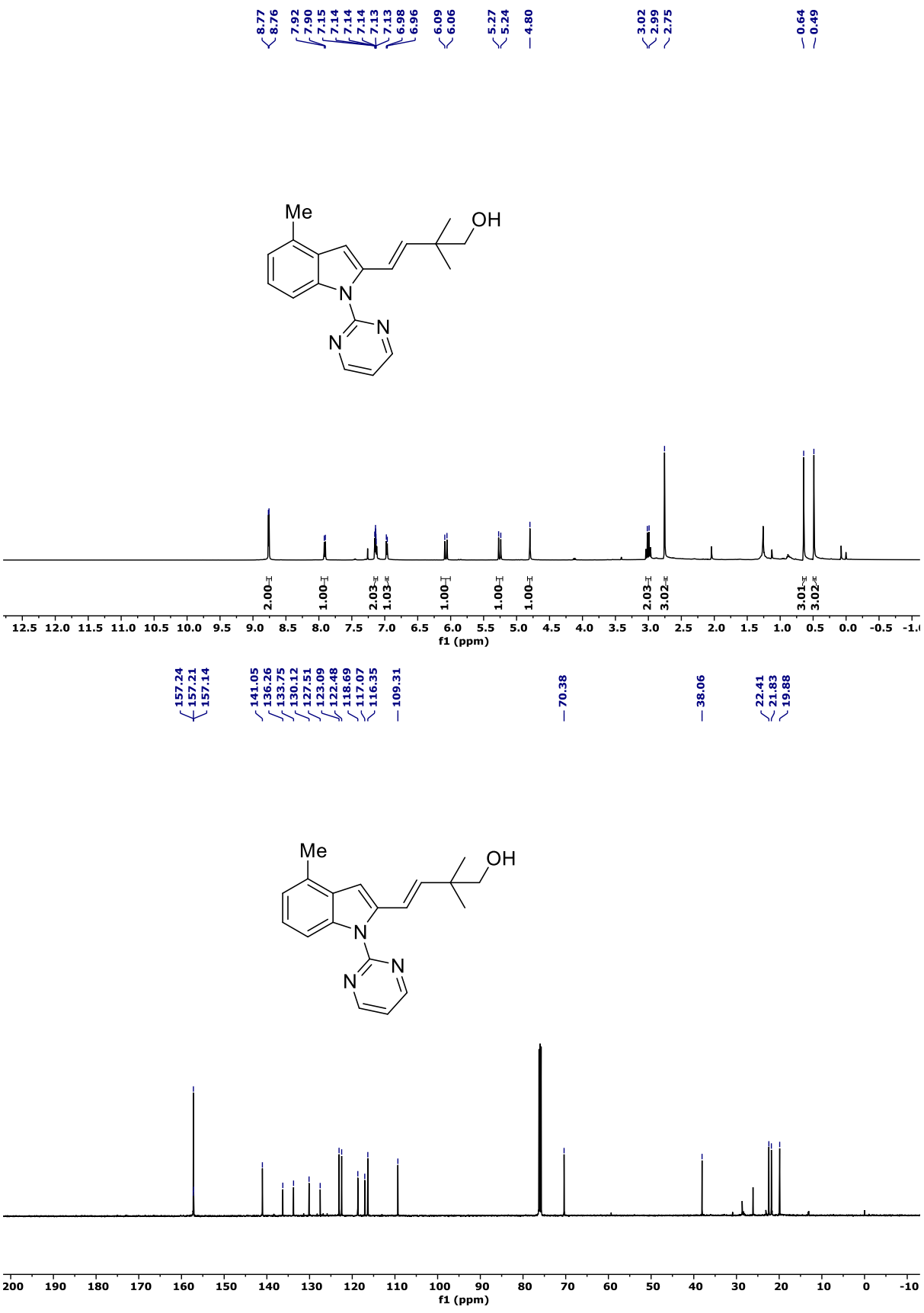
^{1}H and ^{13}C NMR Spectra of Compound **4C.** ($CDCl_3$ solvent was used, 400 NMR MHz)



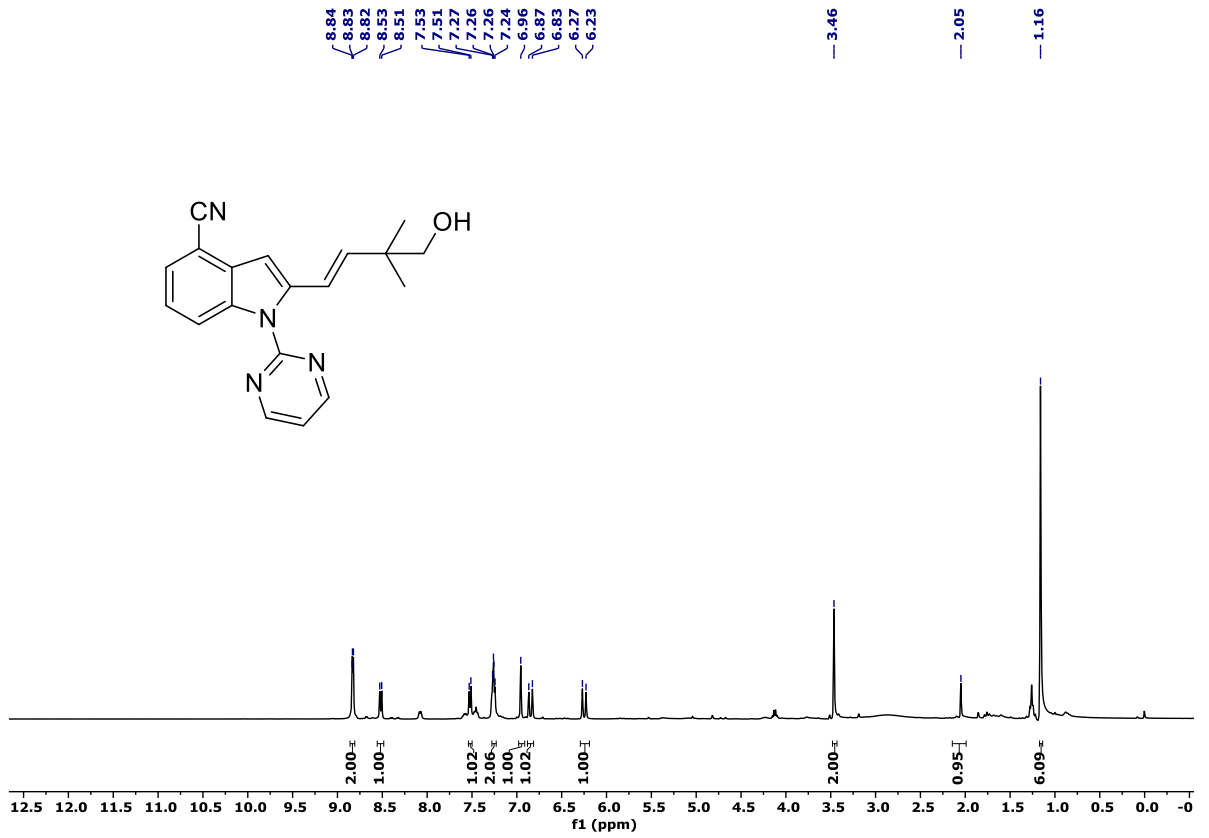
^{1}H and ^{13}C NMR Spectra of Compound **4d.** ($CDCl_3$ solvent was used, 400 NMR MHz)

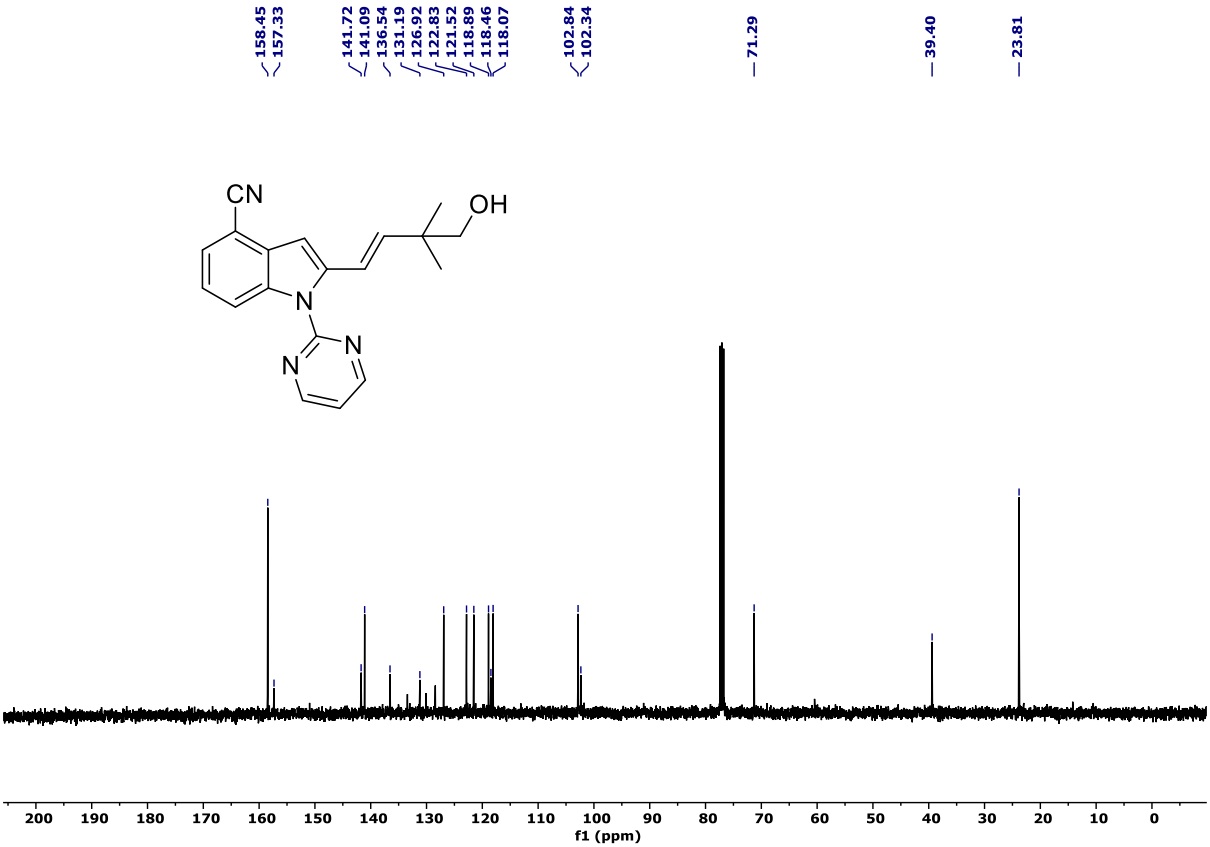


^{1}H and ^{13}C NMR Spectra of Compound **4e.** ($CDCl_3$ solvent was used, 500 NMR MHz)

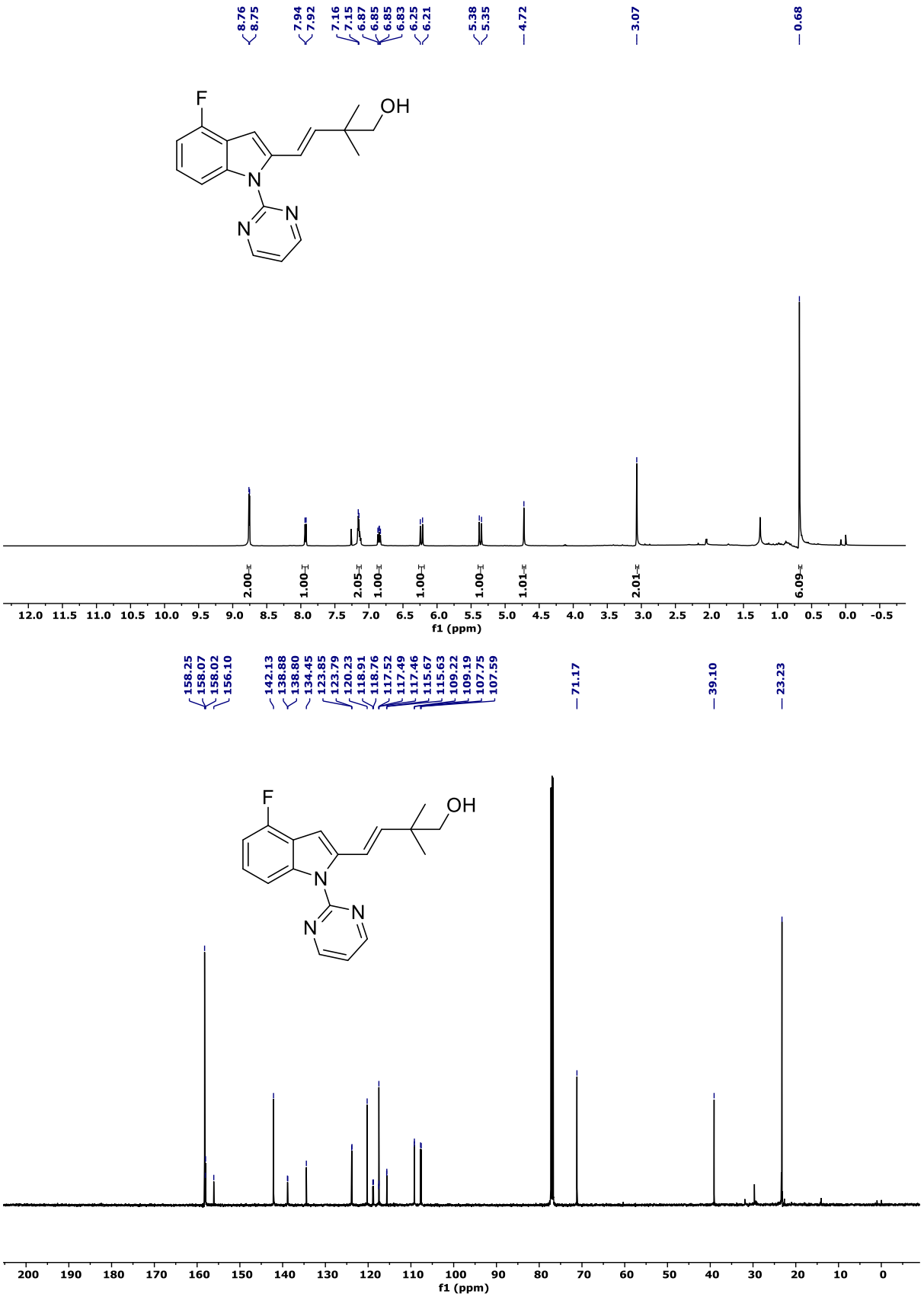


^{1}H and ^{13}C NMR Spectra of Compound **4f.** ($CDCl_3$ solvent was used, 400 NMR MHz)

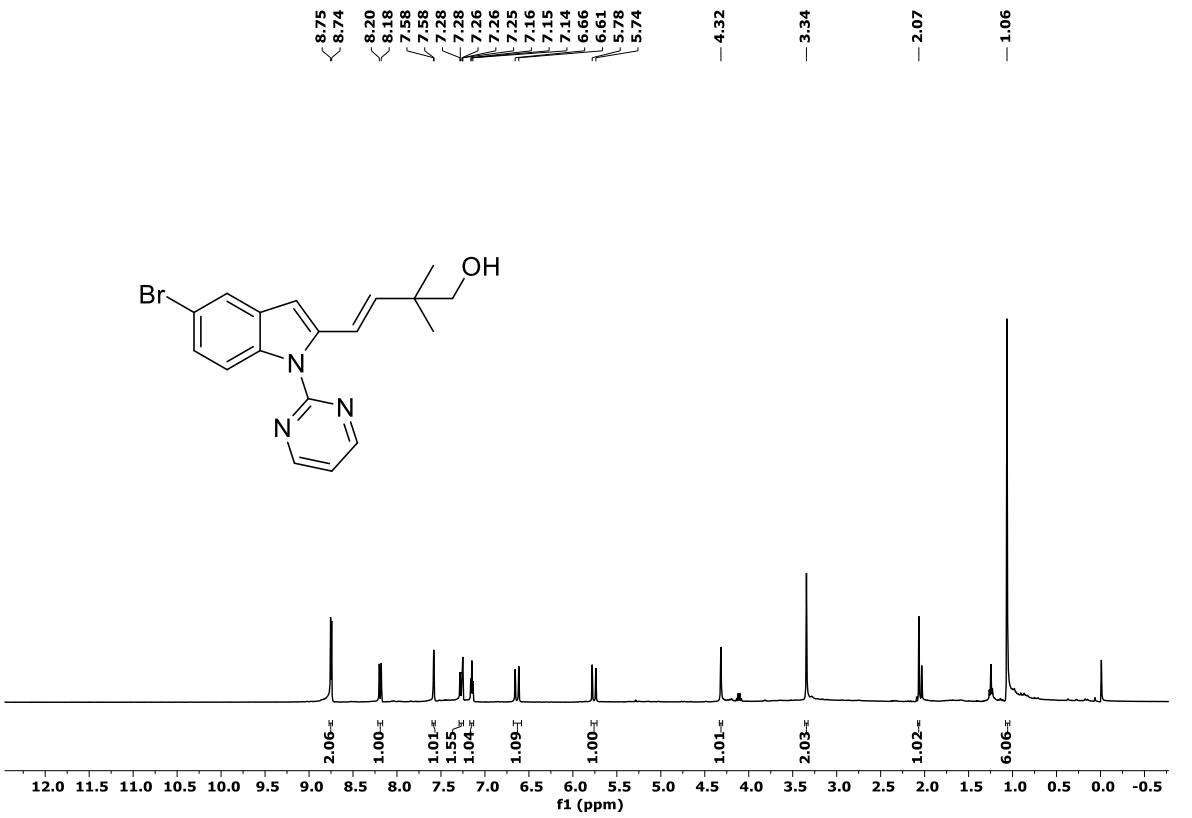


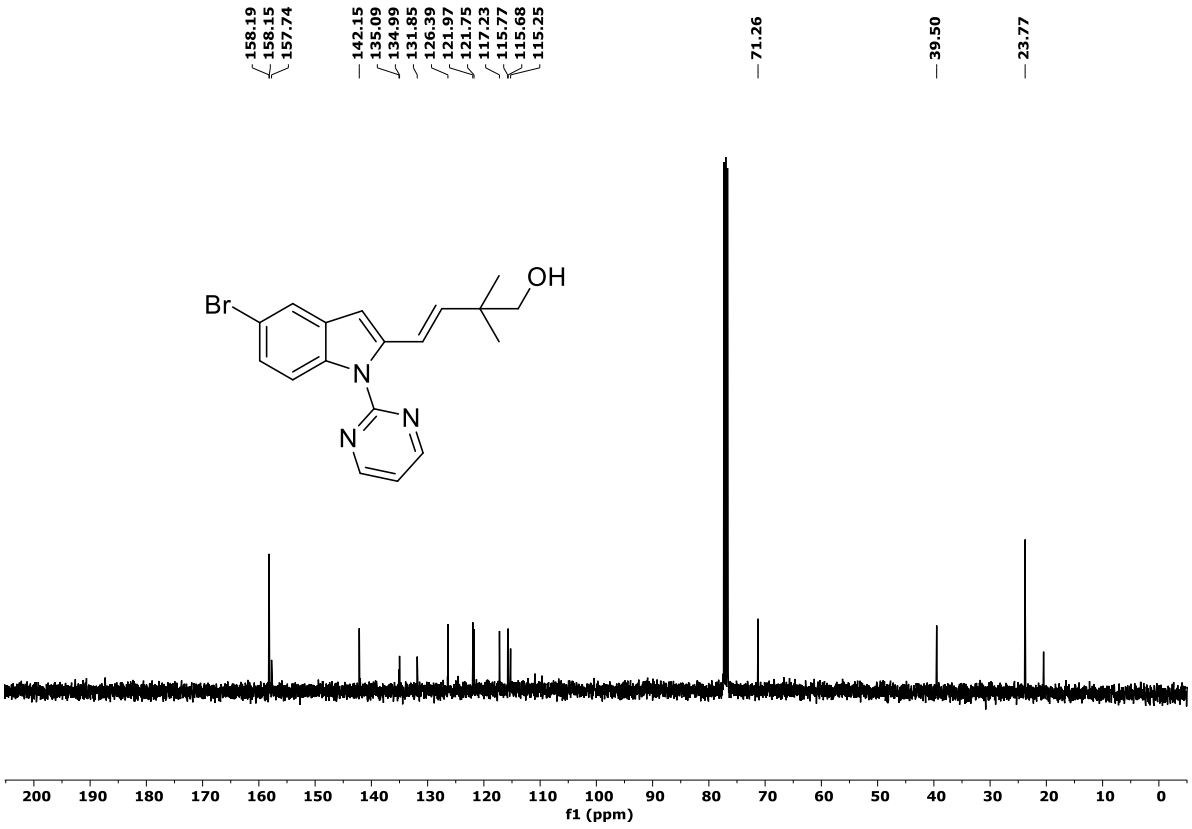


^{1}H and ^{13}C NMR Spectra of Compound **4g.** ($CDCl_3$ solvent was used, 500 NMR MHz)

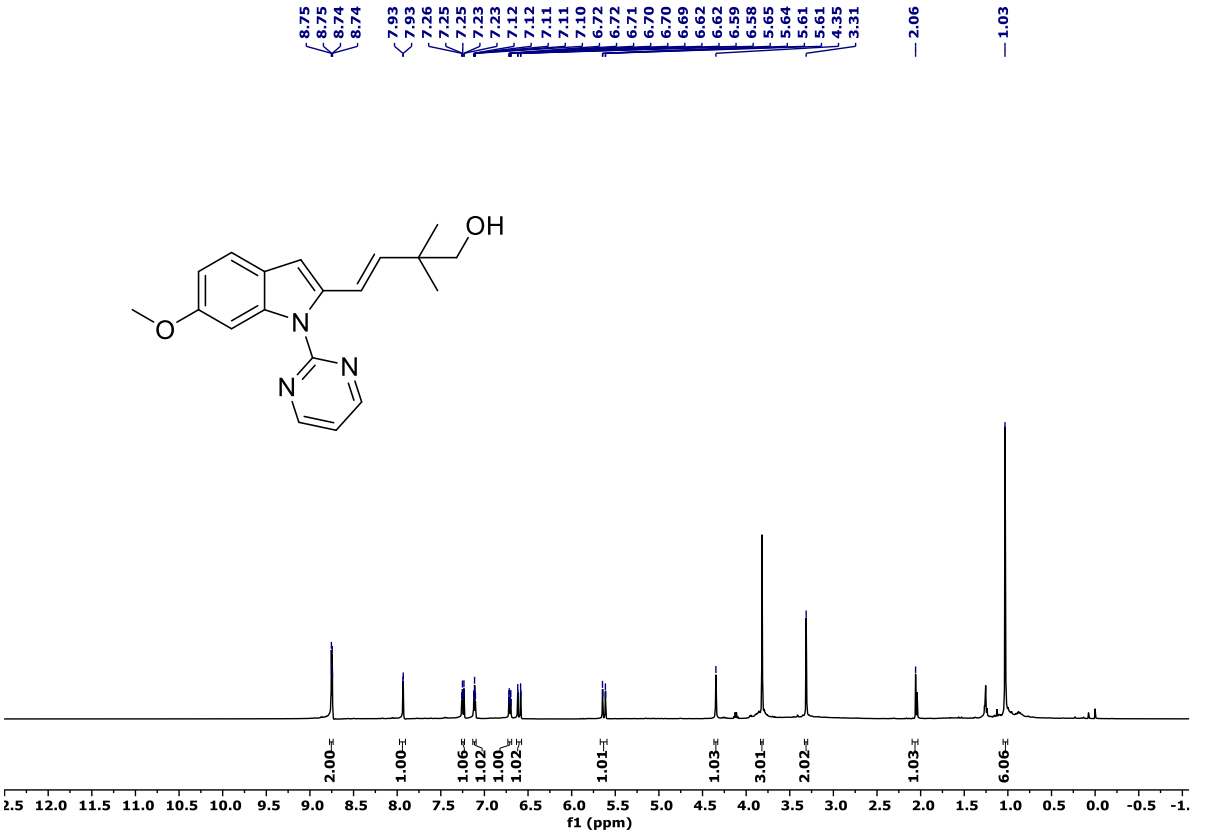


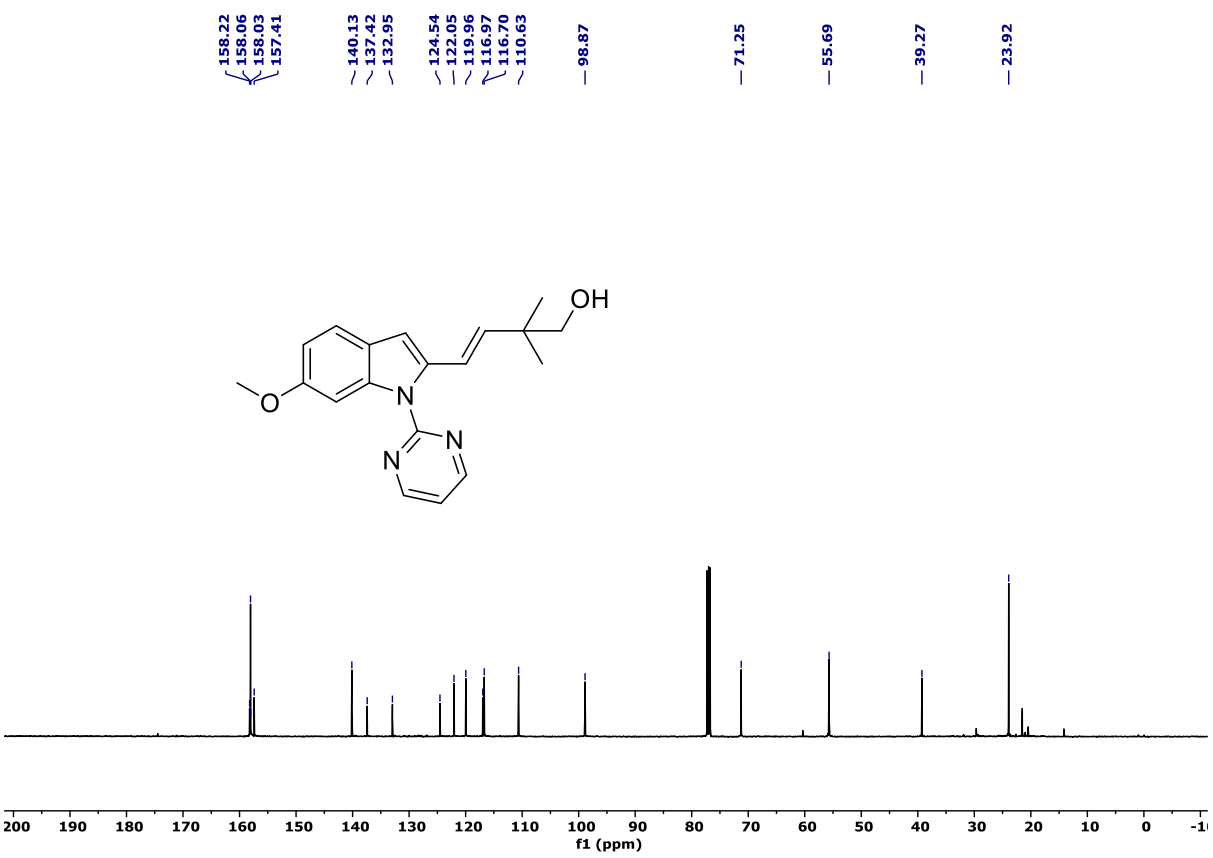
^{1}H and ^{13}C NMR Spectra of Compound **4h.** ($CDCl_3$ solvent was used, 400 NMR MHz)



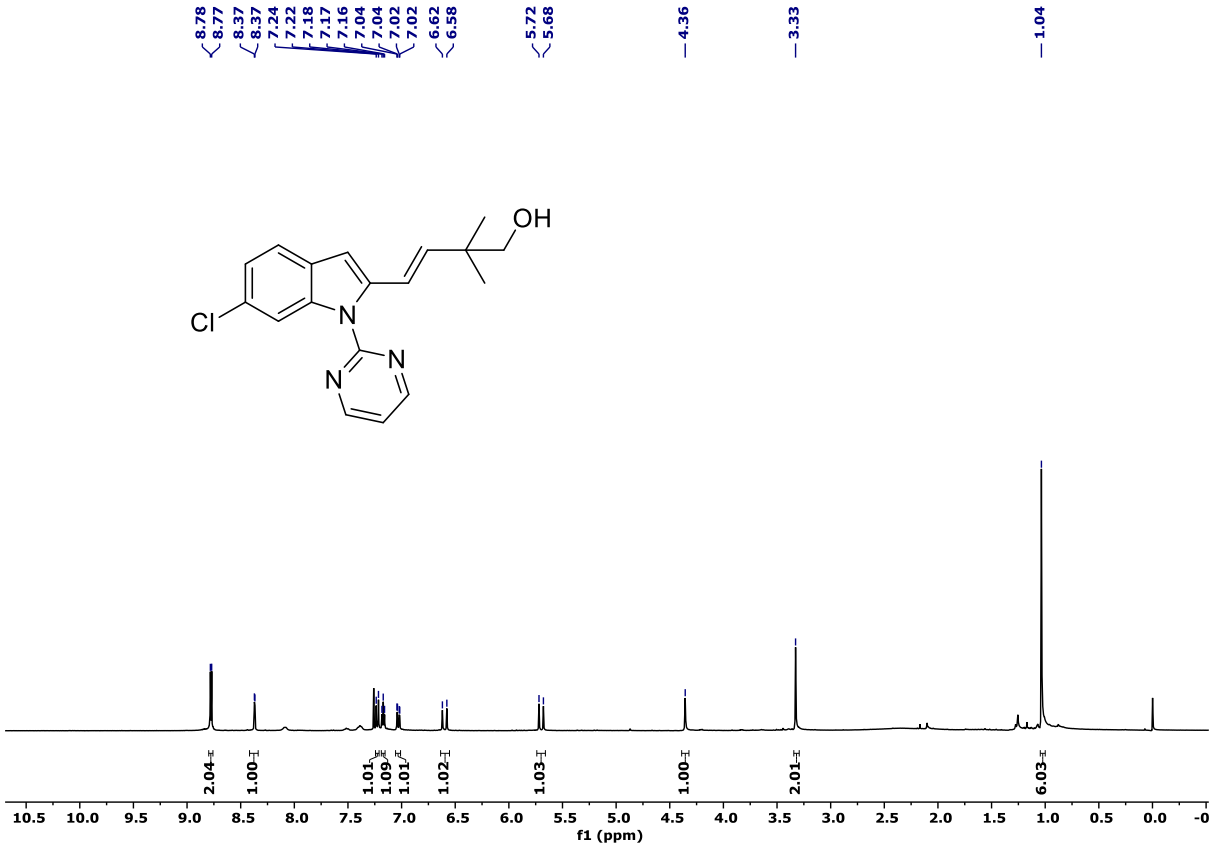


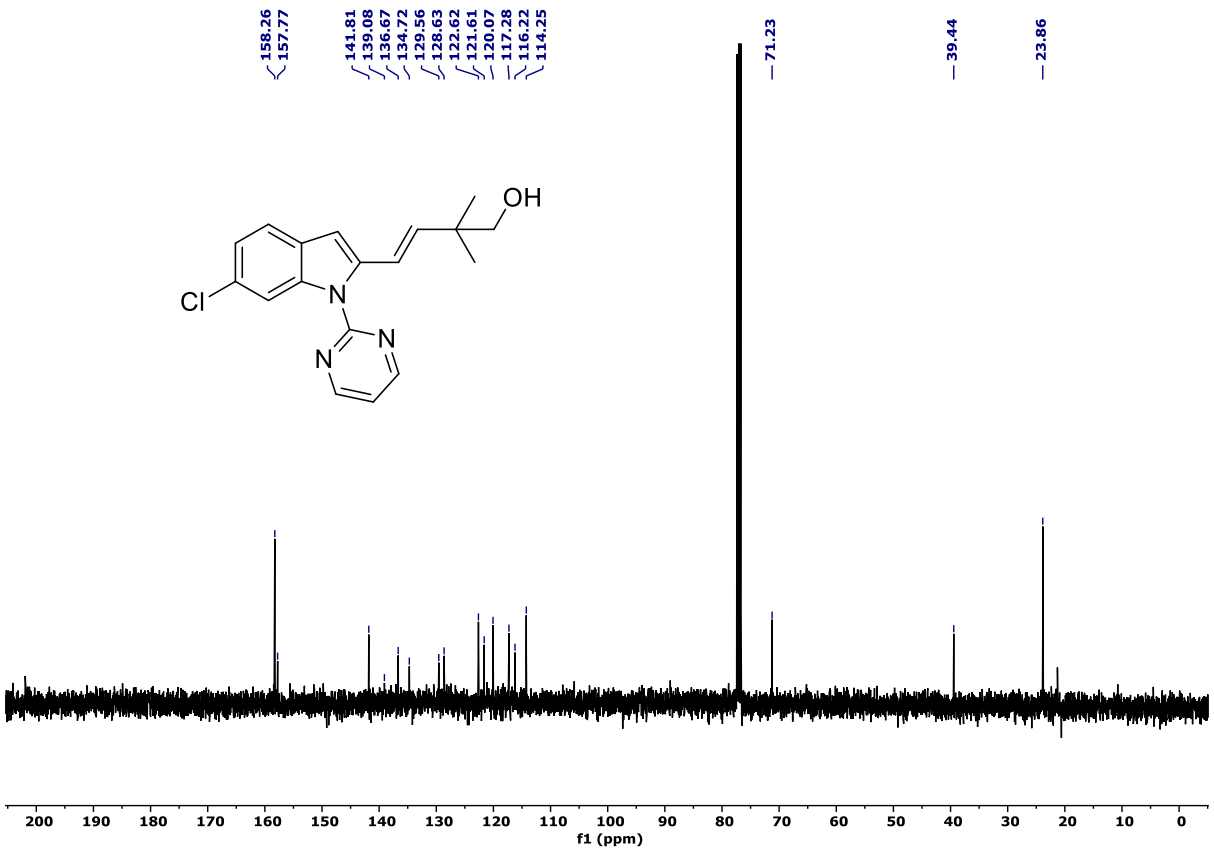
^{1}H and ^{13}C NMR Spectra of Compound **4i.** ($CDCl_3$ solvent was used, 500 NMR MHz



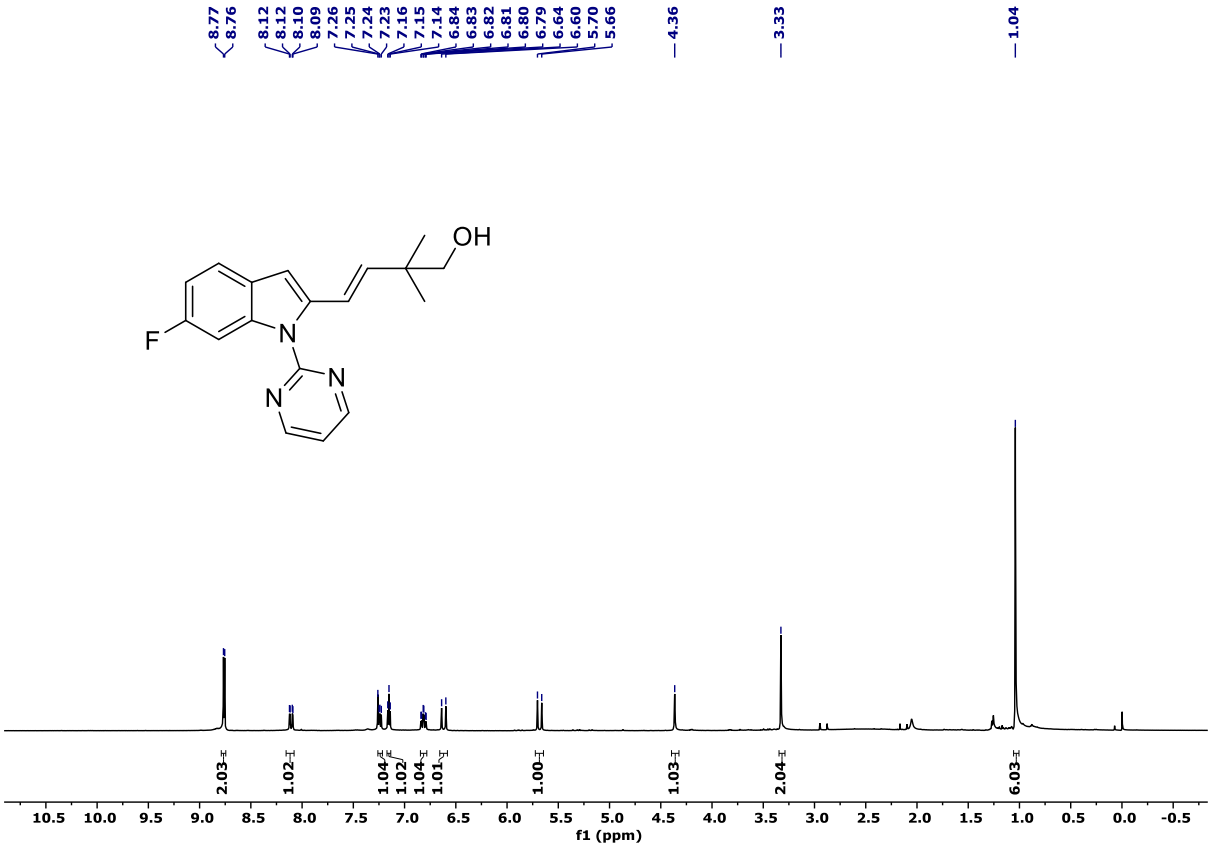


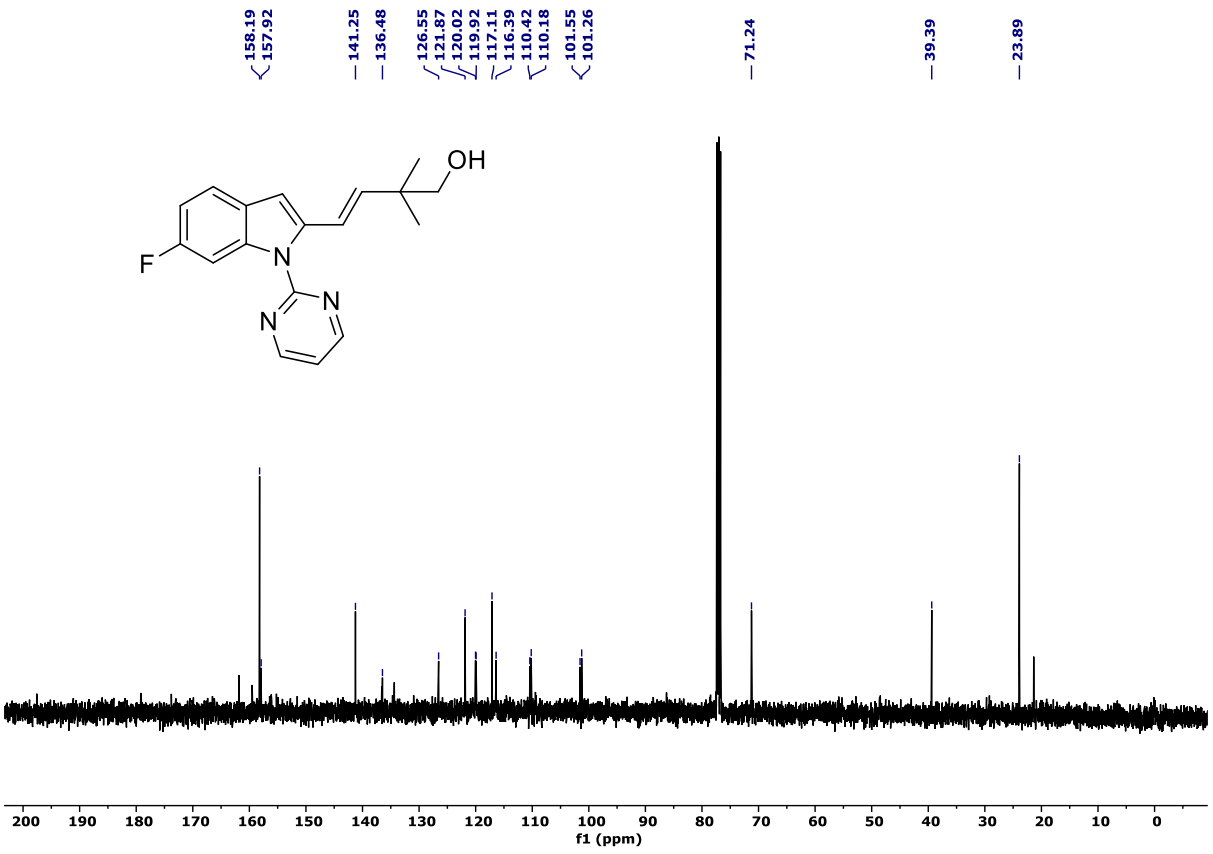
^{1}H and ^{13}C NMR Spectra of Compound **4j.** ($CDCl_3$ solvent was used, 400 NMR MHz)



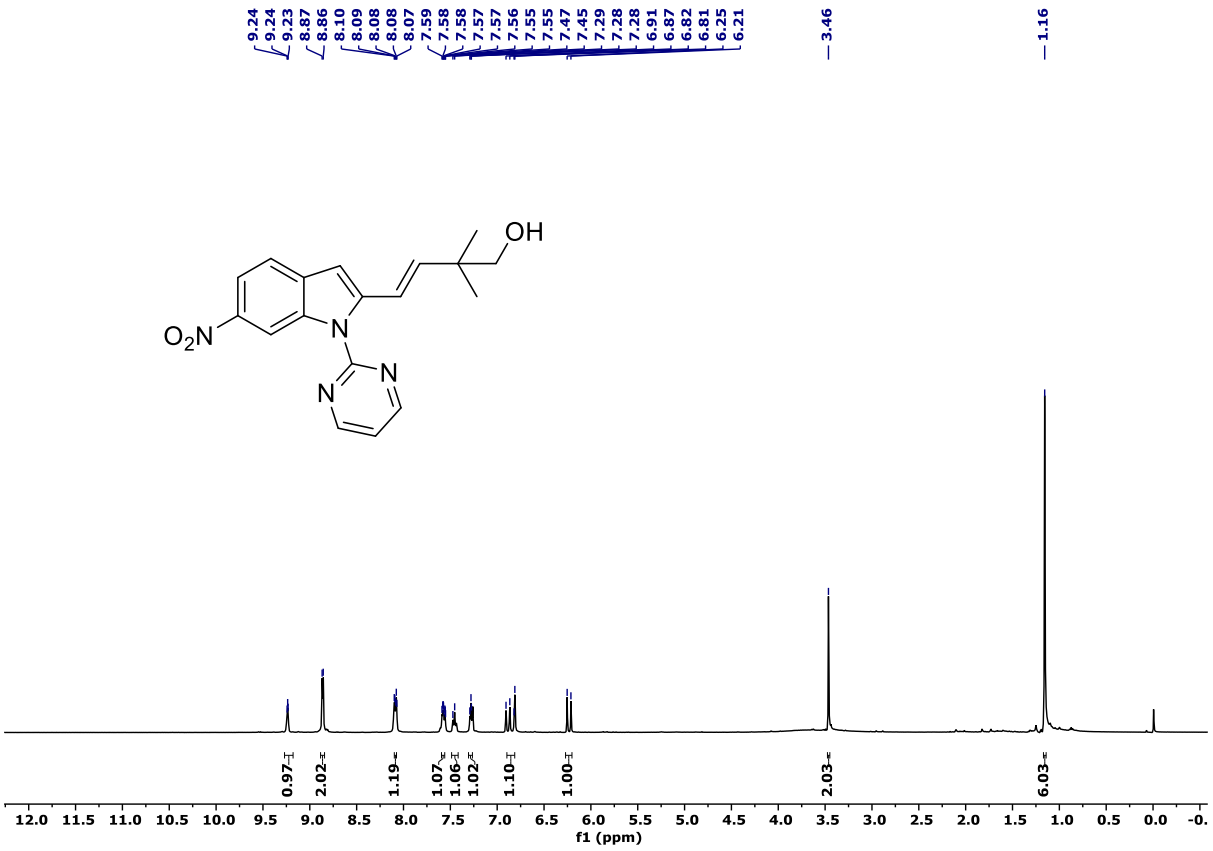


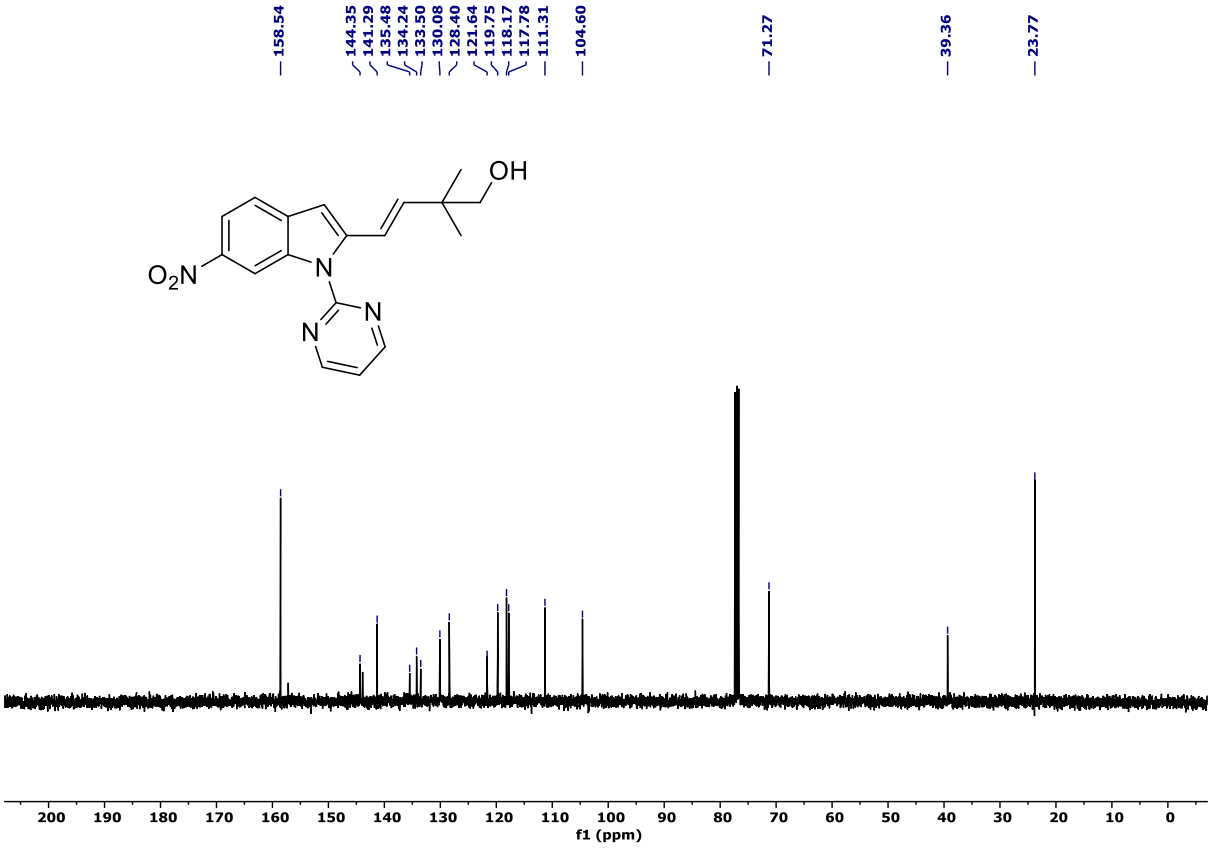
^{1}H and ^{13}C NMR Spectra of Compound **4k.** ($CDCl_3$ solvent was used, 400 NMR MHz)



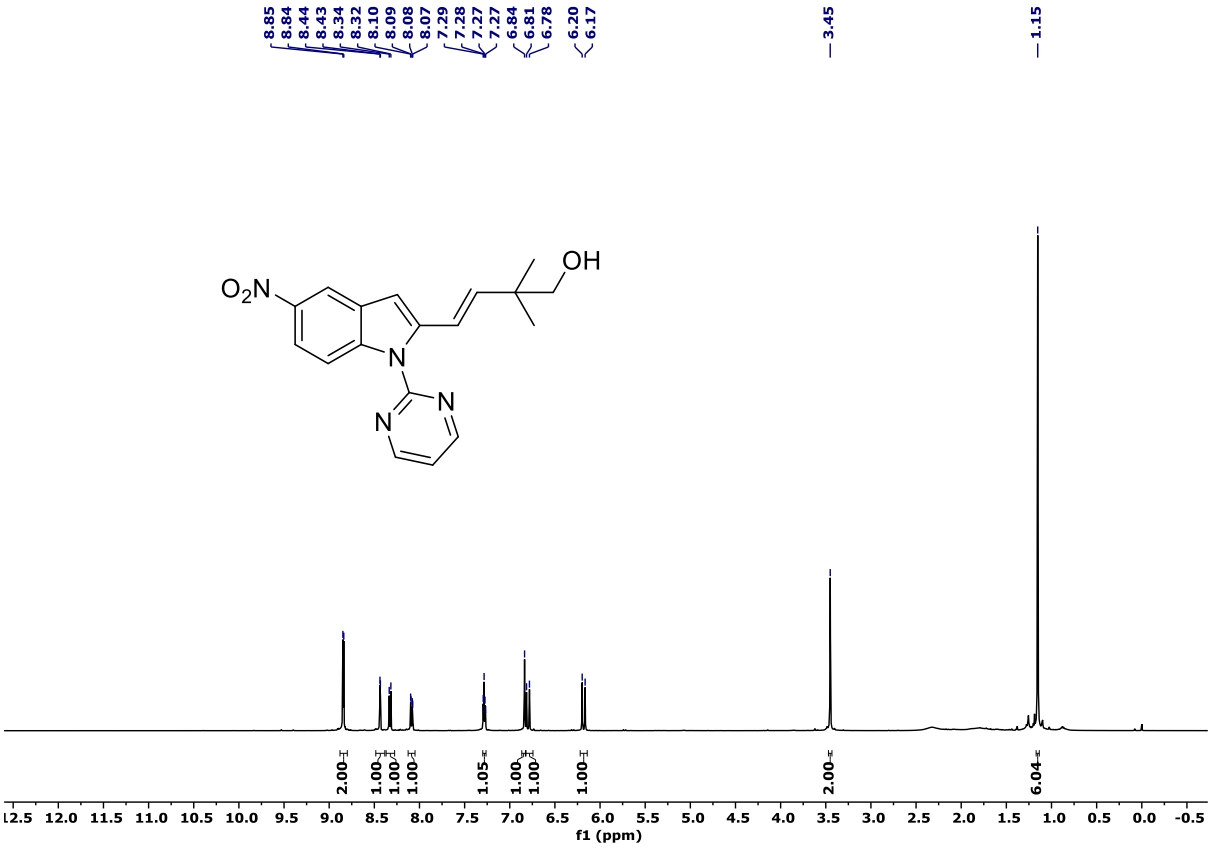


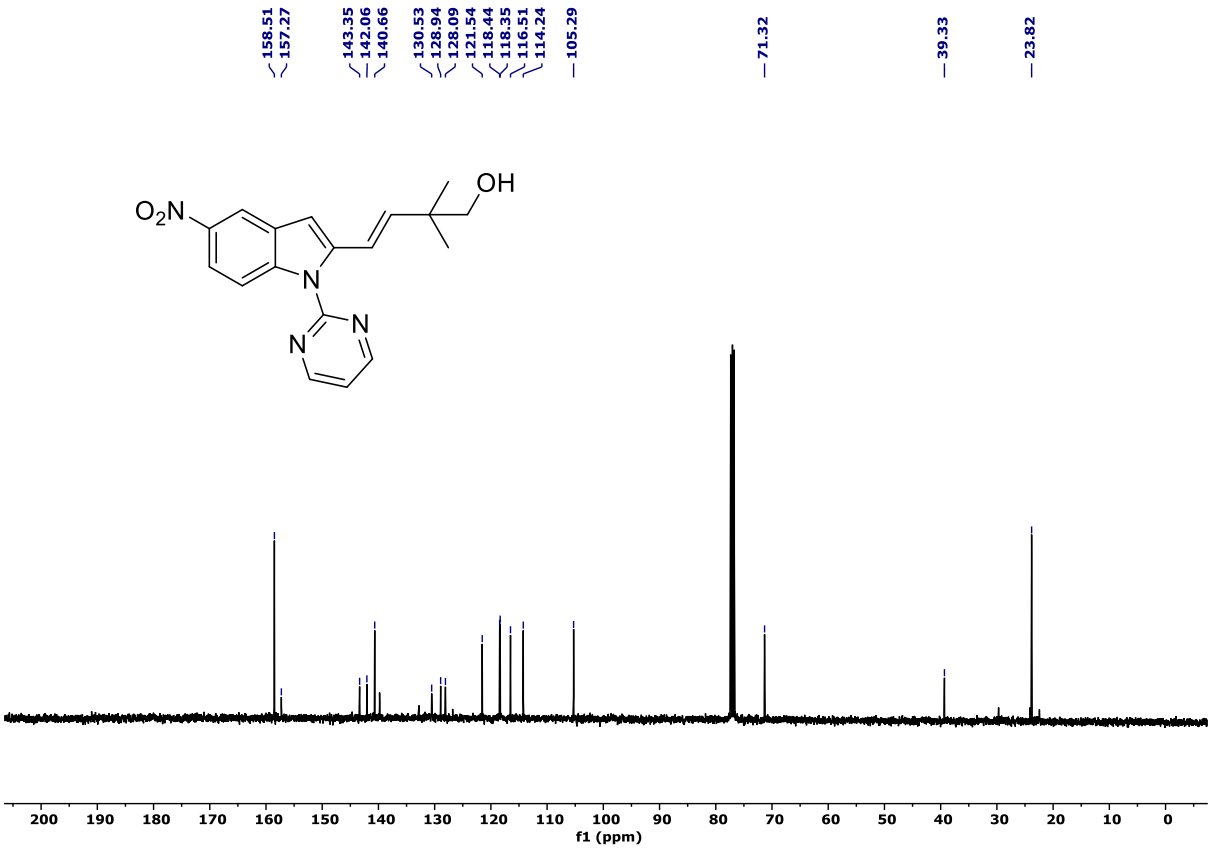
^{1}H and ^{13}C NMR Spectra of Compound **4l.** ($CDCl_3$ solvent was used, 400 NMR MHz)



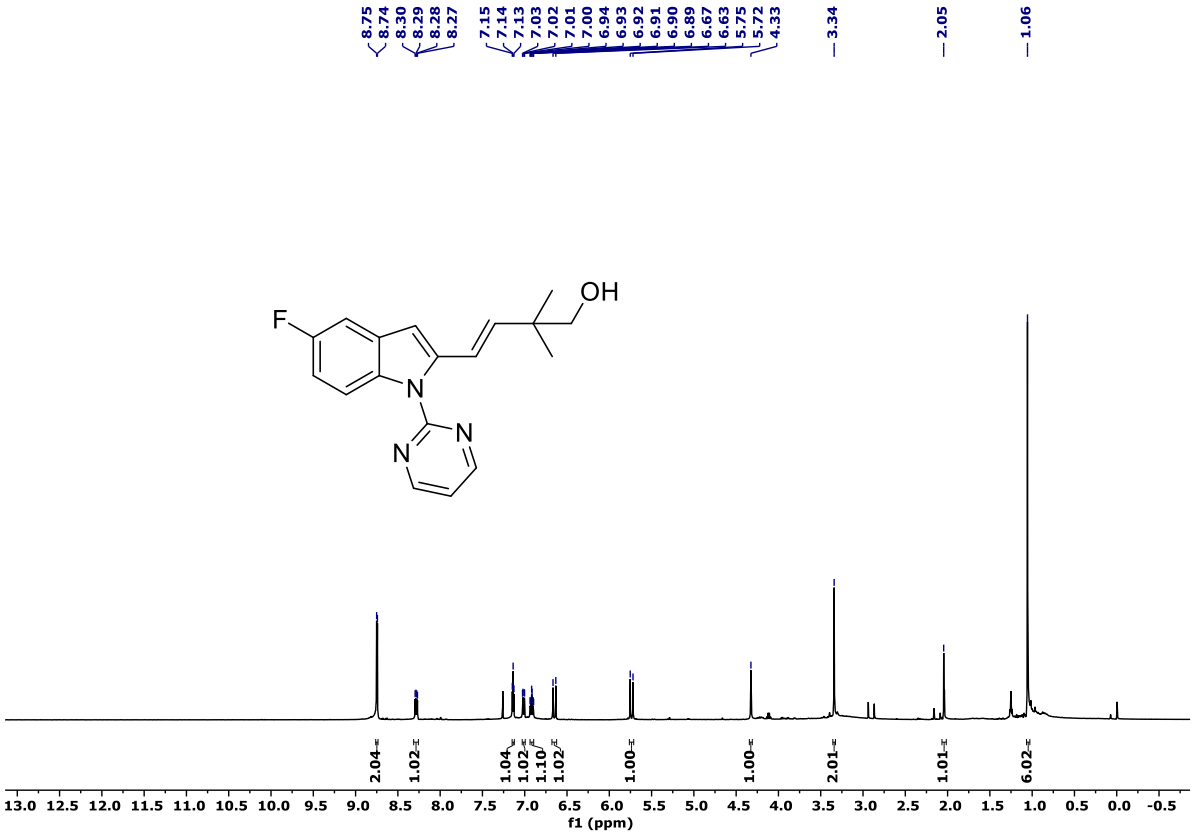


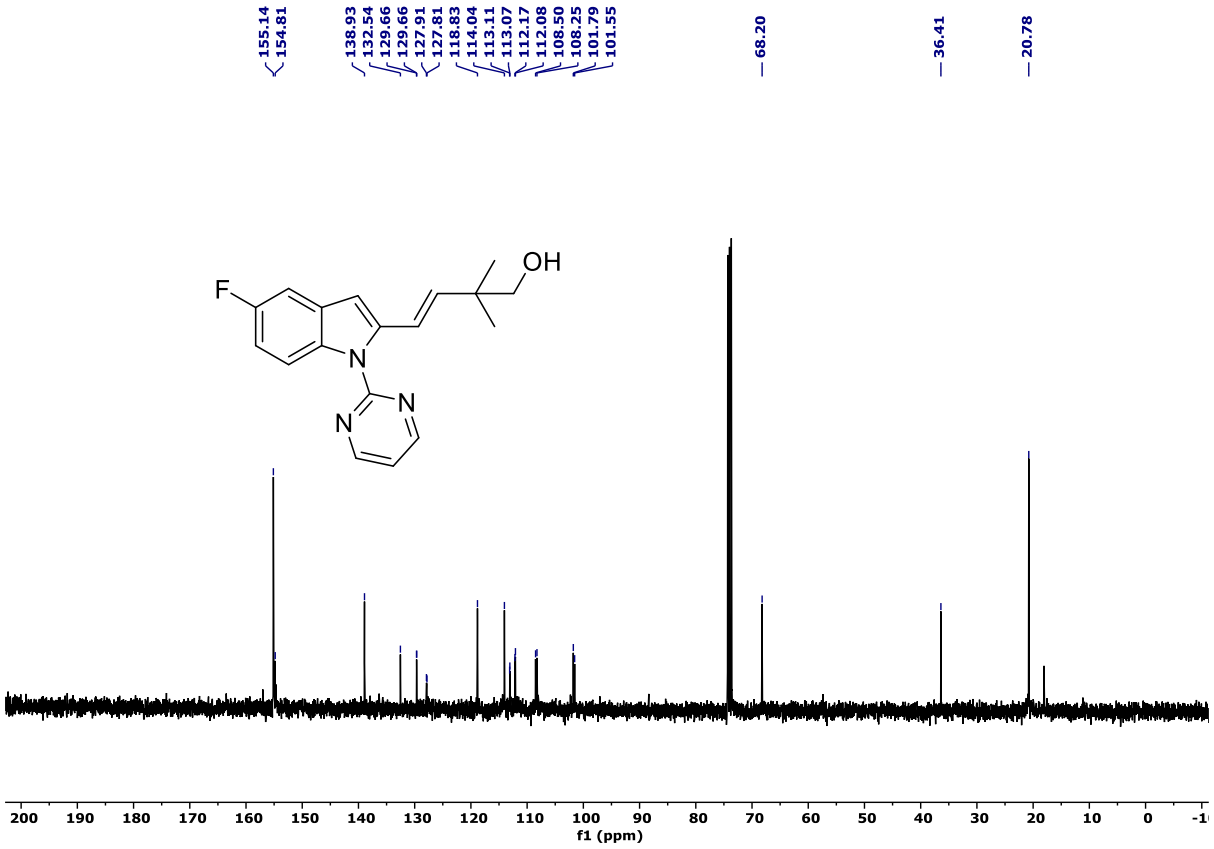
^{1}H and ^{13}C NMR Spectra of Compound **4n.** ($CDCl_3$ solvent was used, 400 NMR MHz)



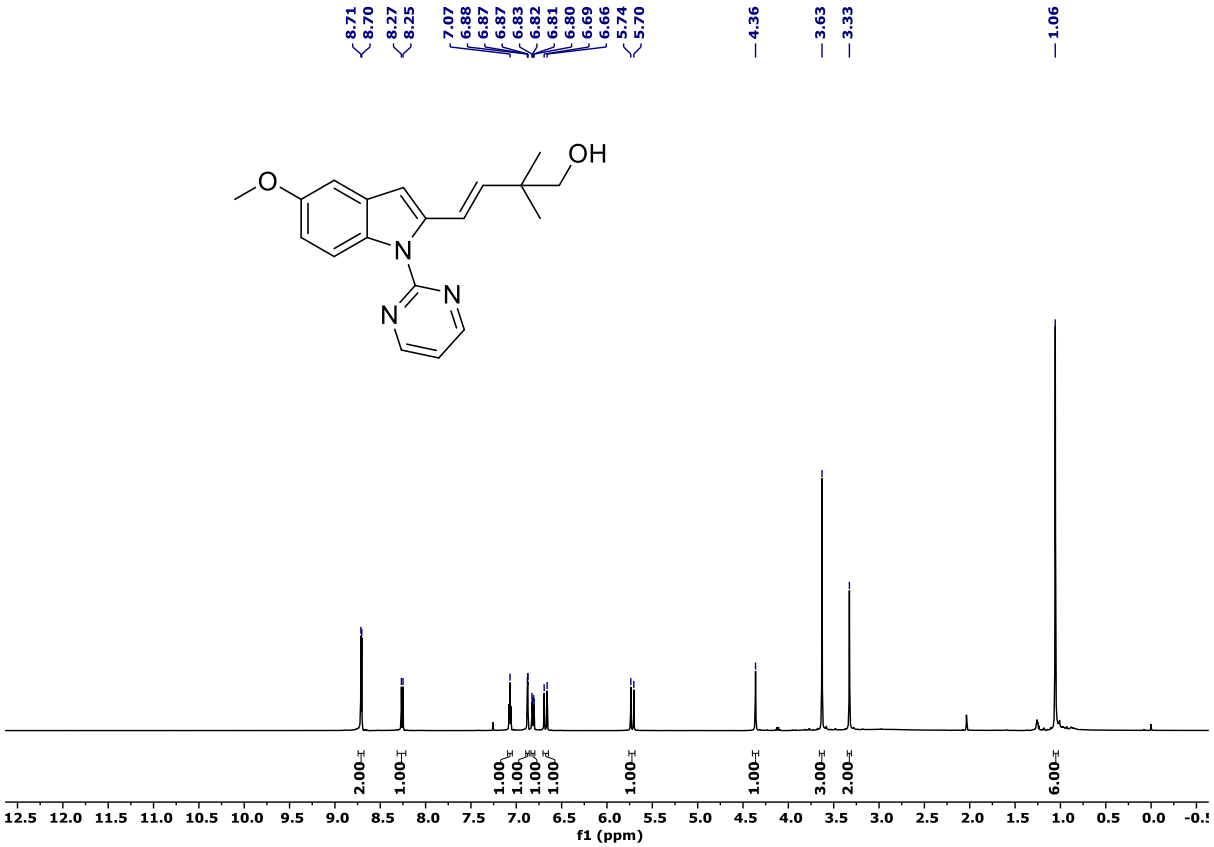


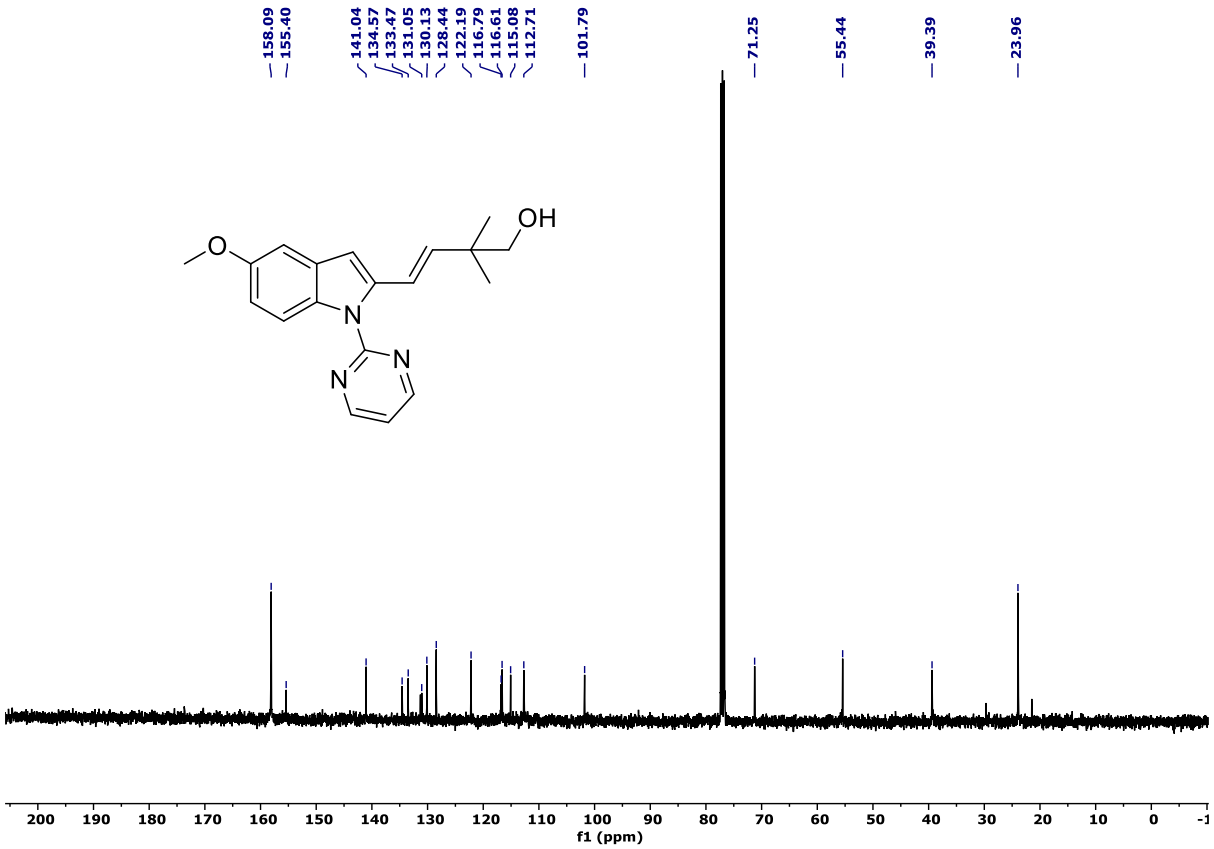
^{1}H and ^{13}C NMR Spectra of Compound **4o.** ($CDCl_3$ solvent was used, 500 NMR MHz)



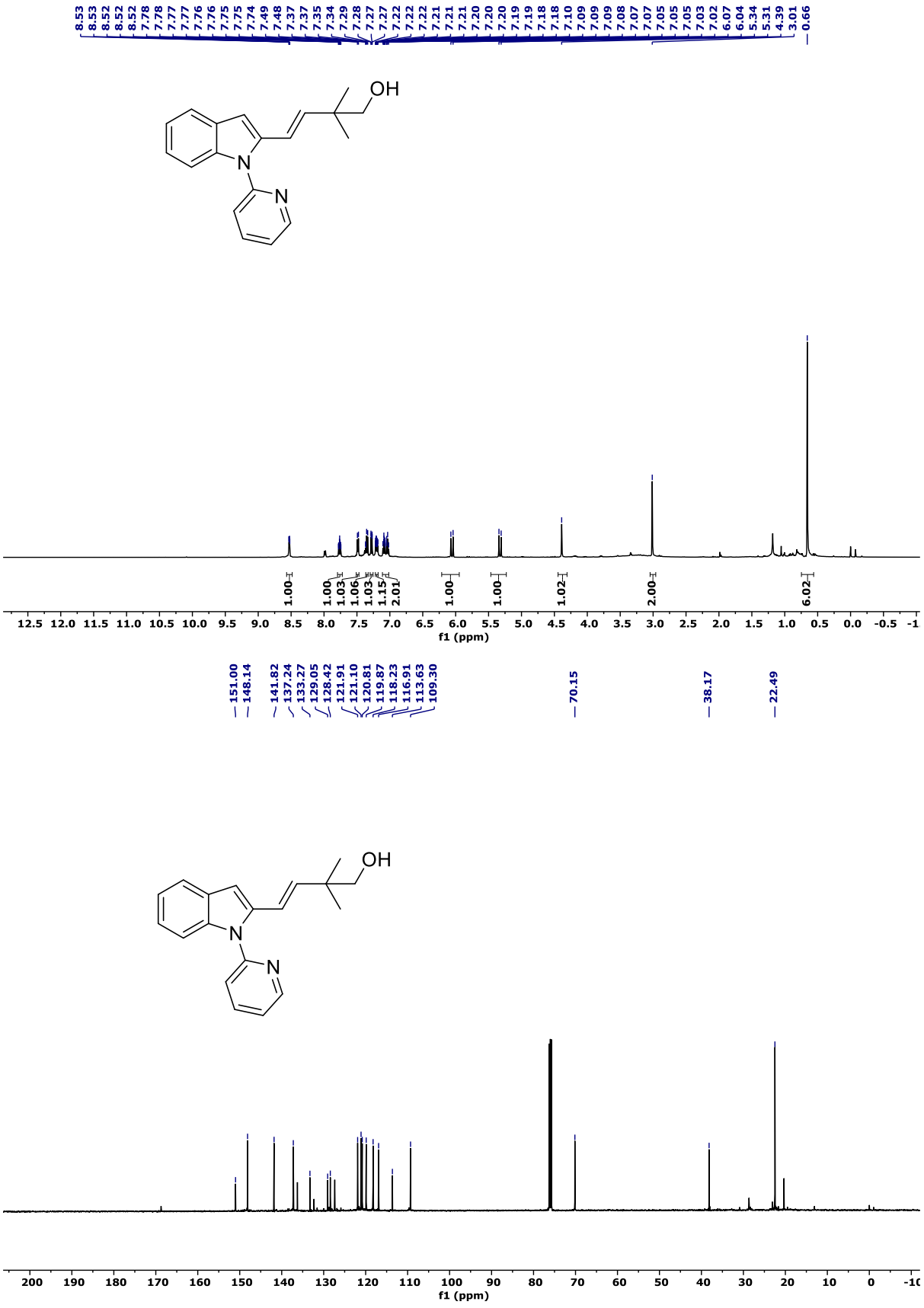


^{1}H and ^{13}C NMR Spectra of Compound **4p.** ($CDCl_3$ solvent was used, 400 NMR MHz)

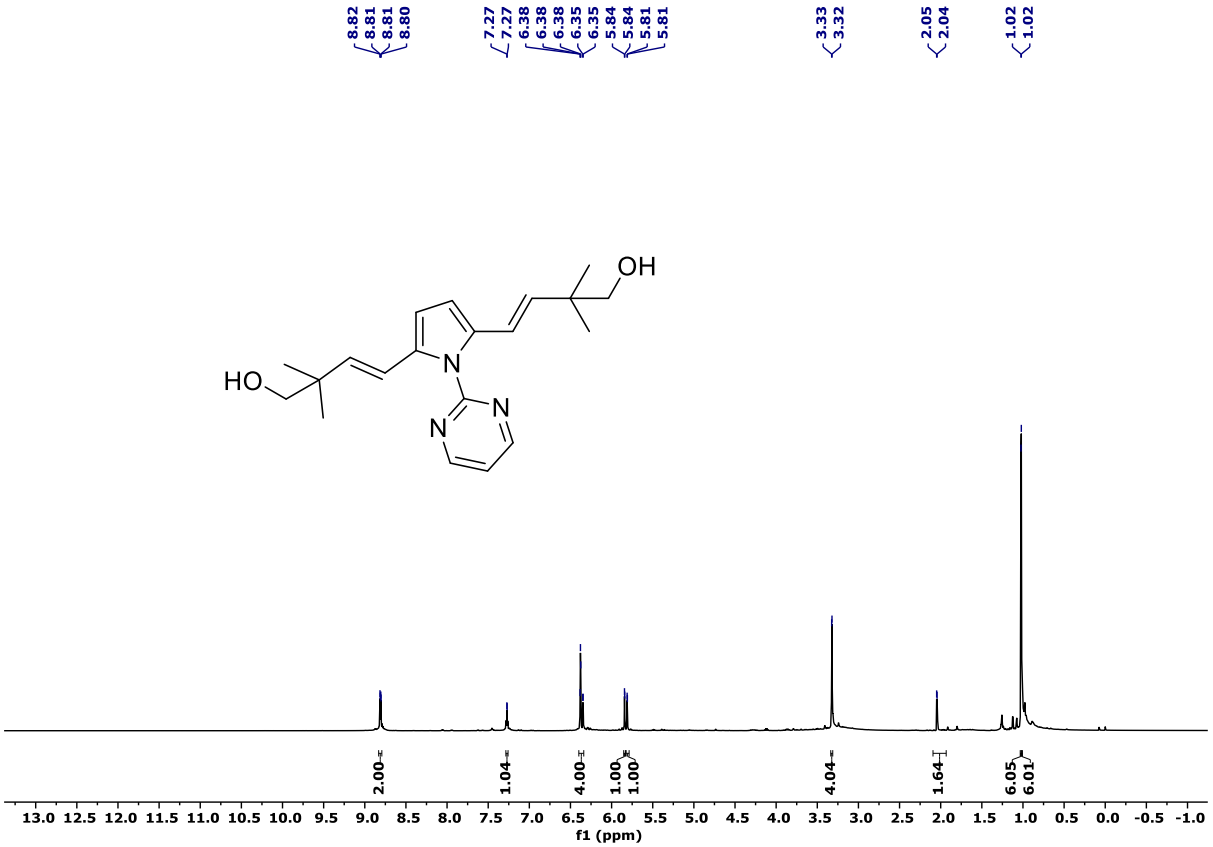


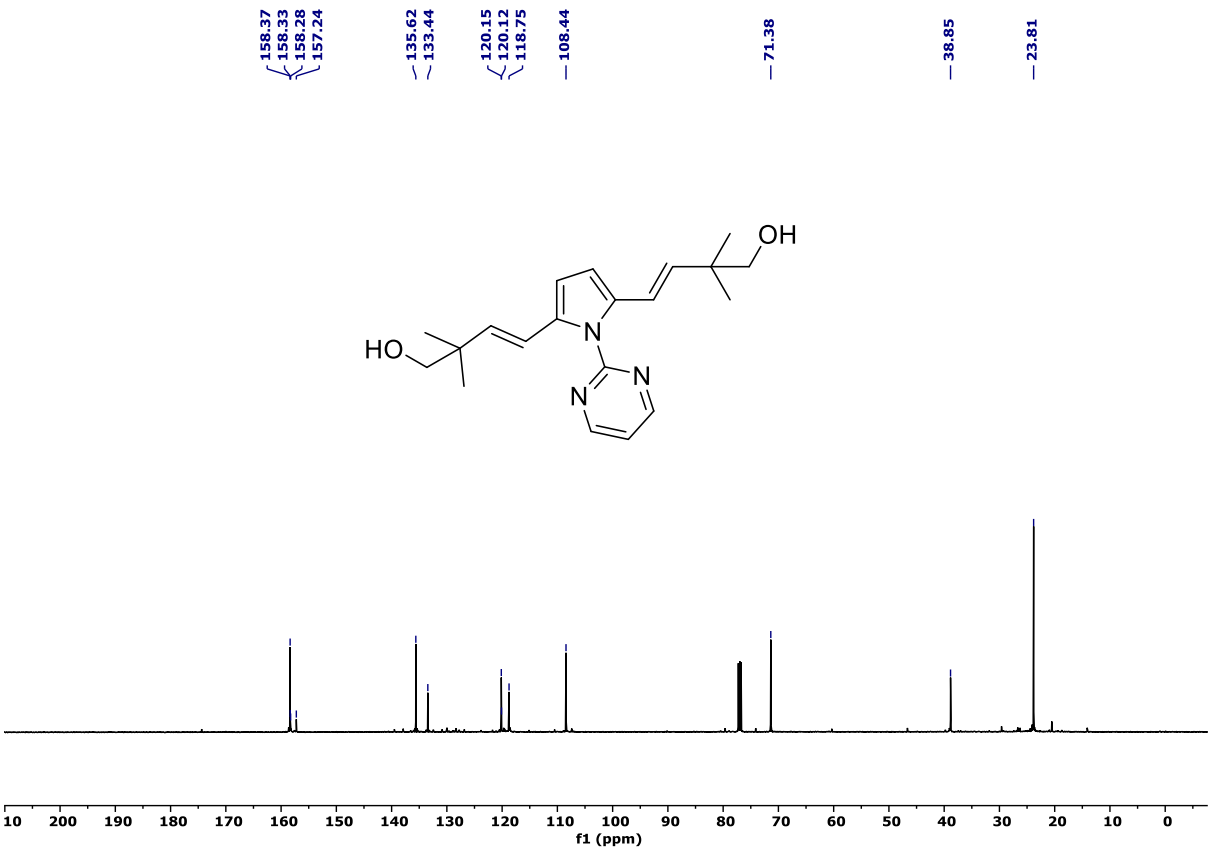


^{1}H and ^{13}C NMR Spectra of Compound **4q.** ($CDCl_3$ solvent was used, 500 NMR MHz)

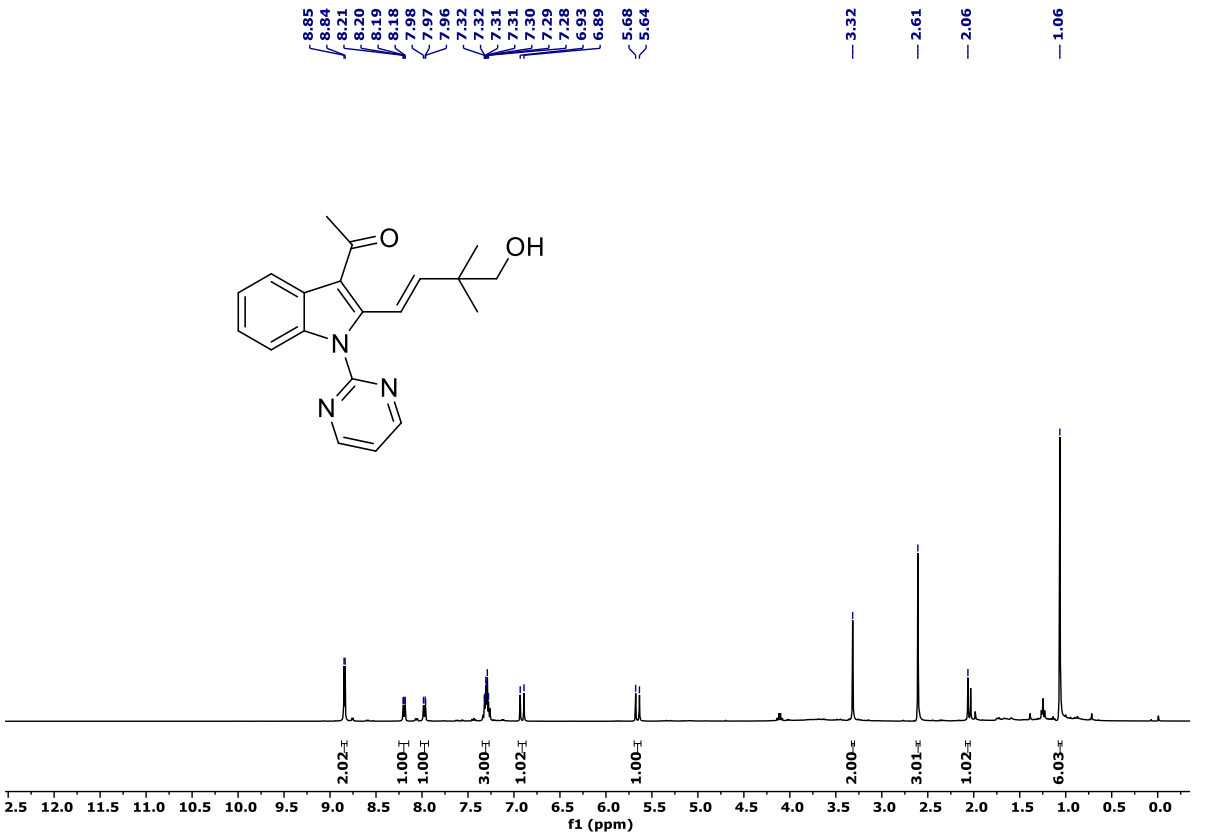


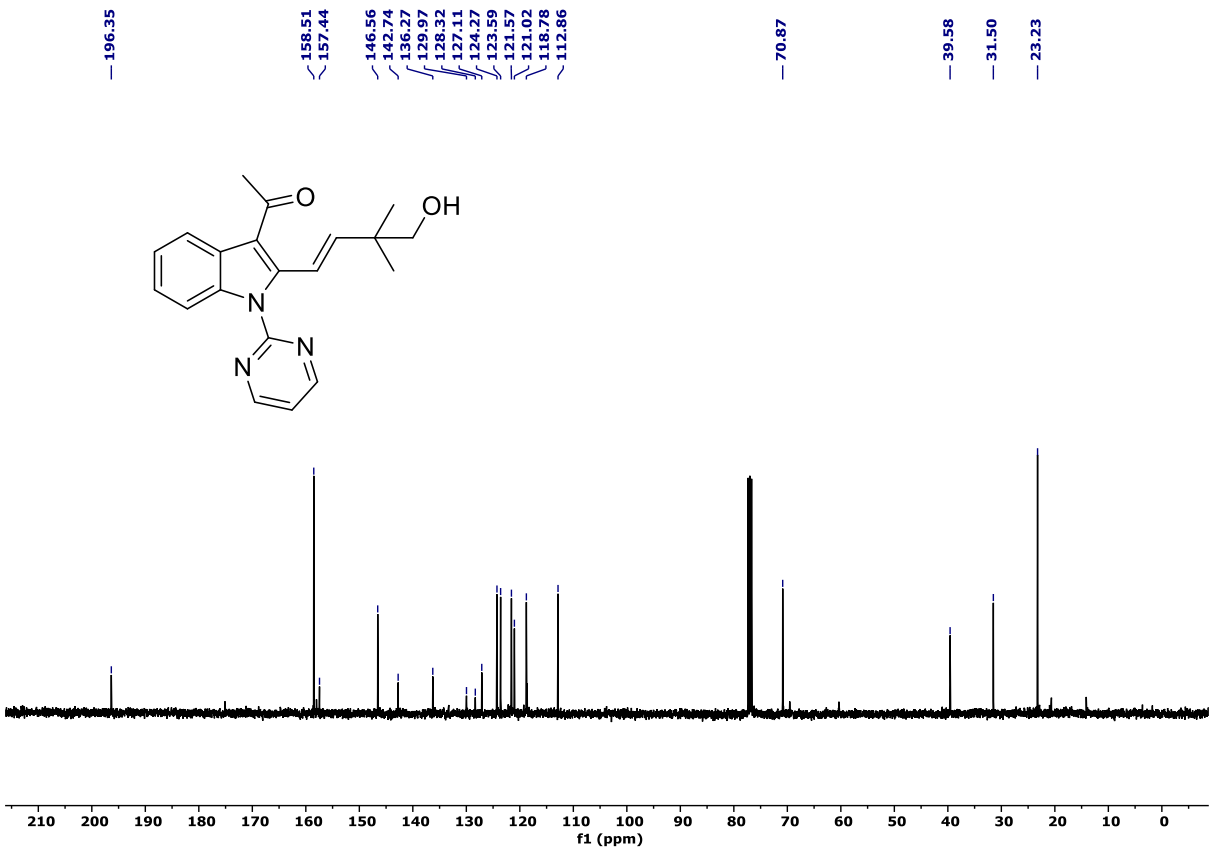
^{1}H and ^{13}C NMR Spectra of Compound **4r.** ($CDCl_3$ solvent was used, 500 NMR MHz)



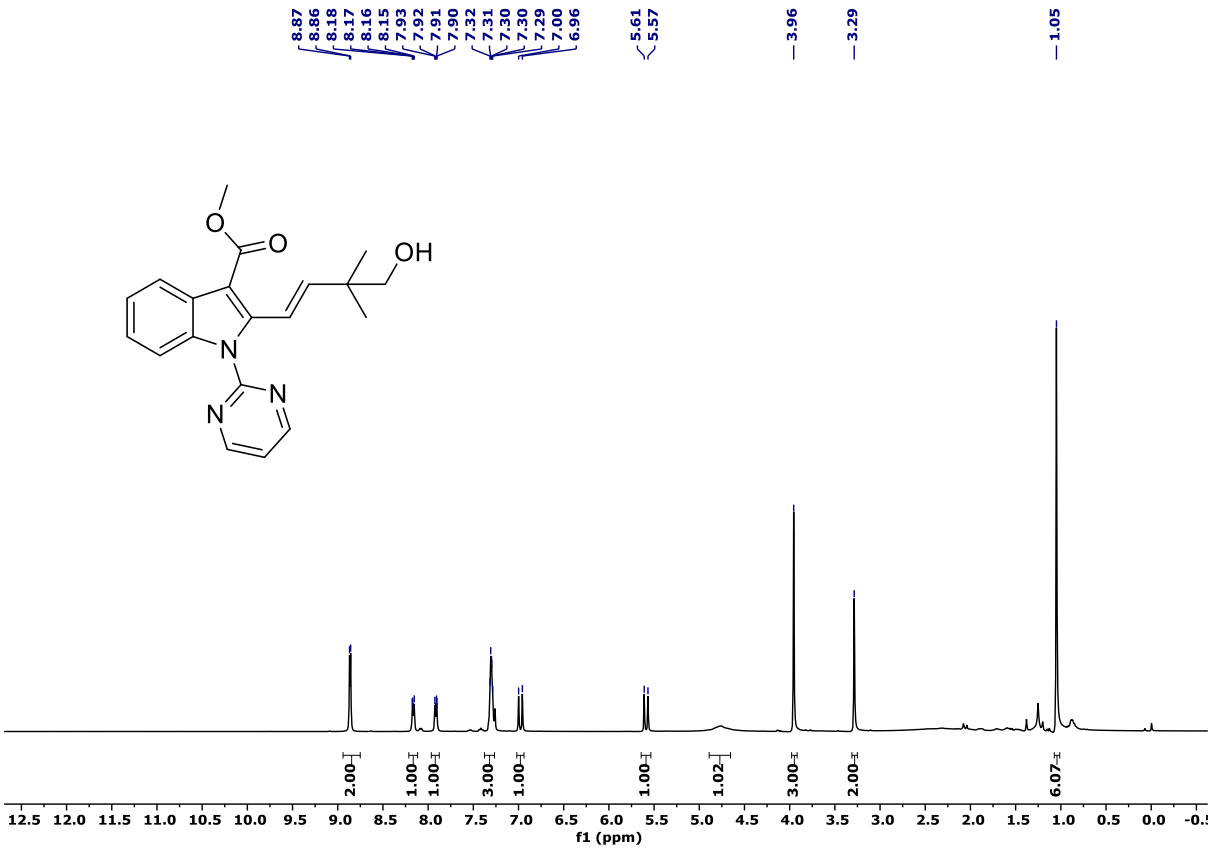


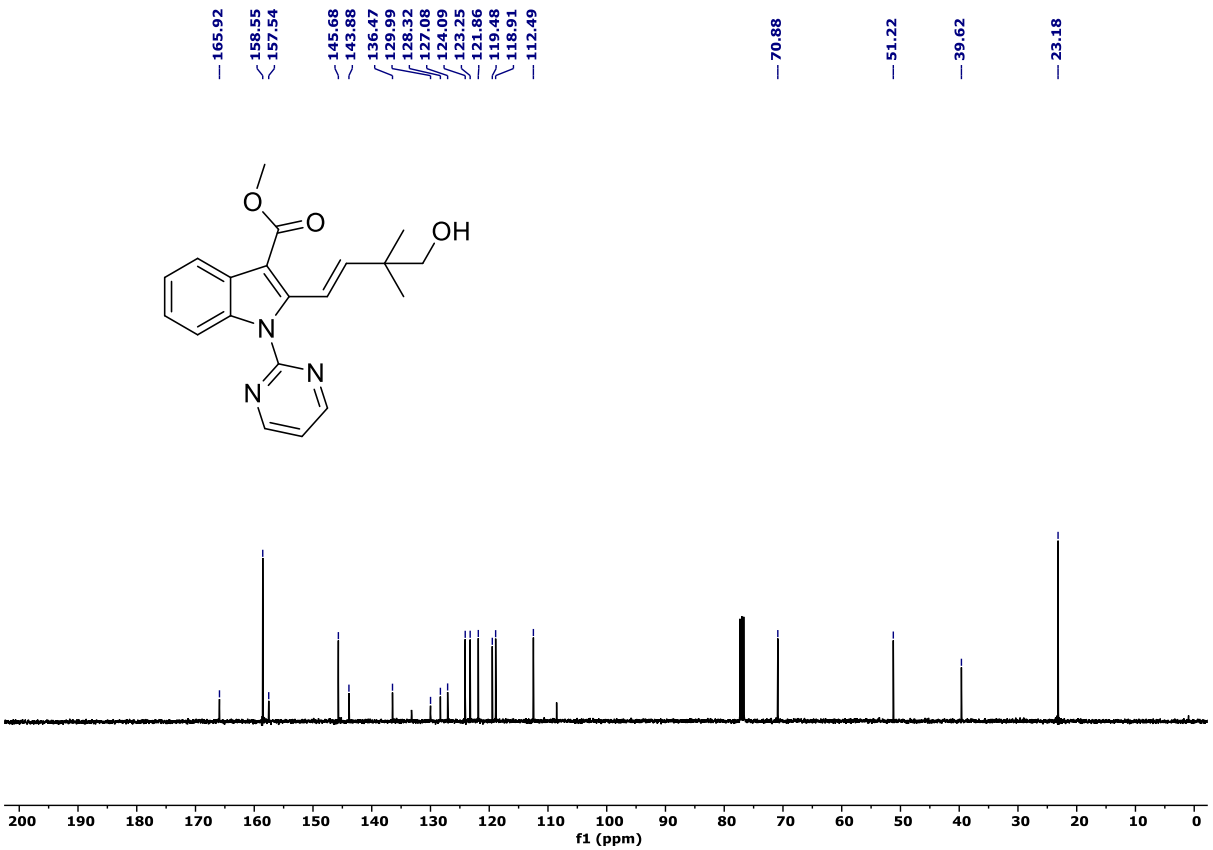
^{1}H and ^{13}C NMR Spectra of Compound **4u.** ($CDCl_3$ solvent was used, 400 NMR MHz)



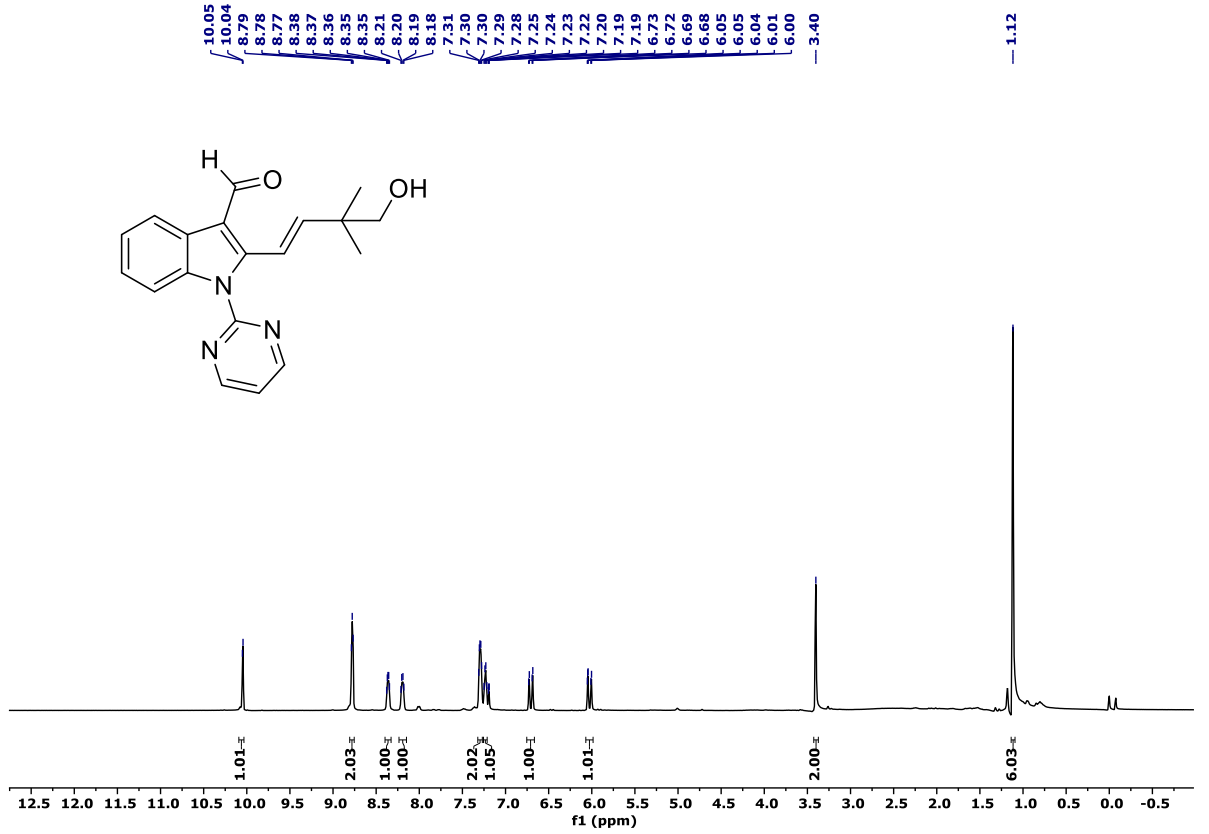


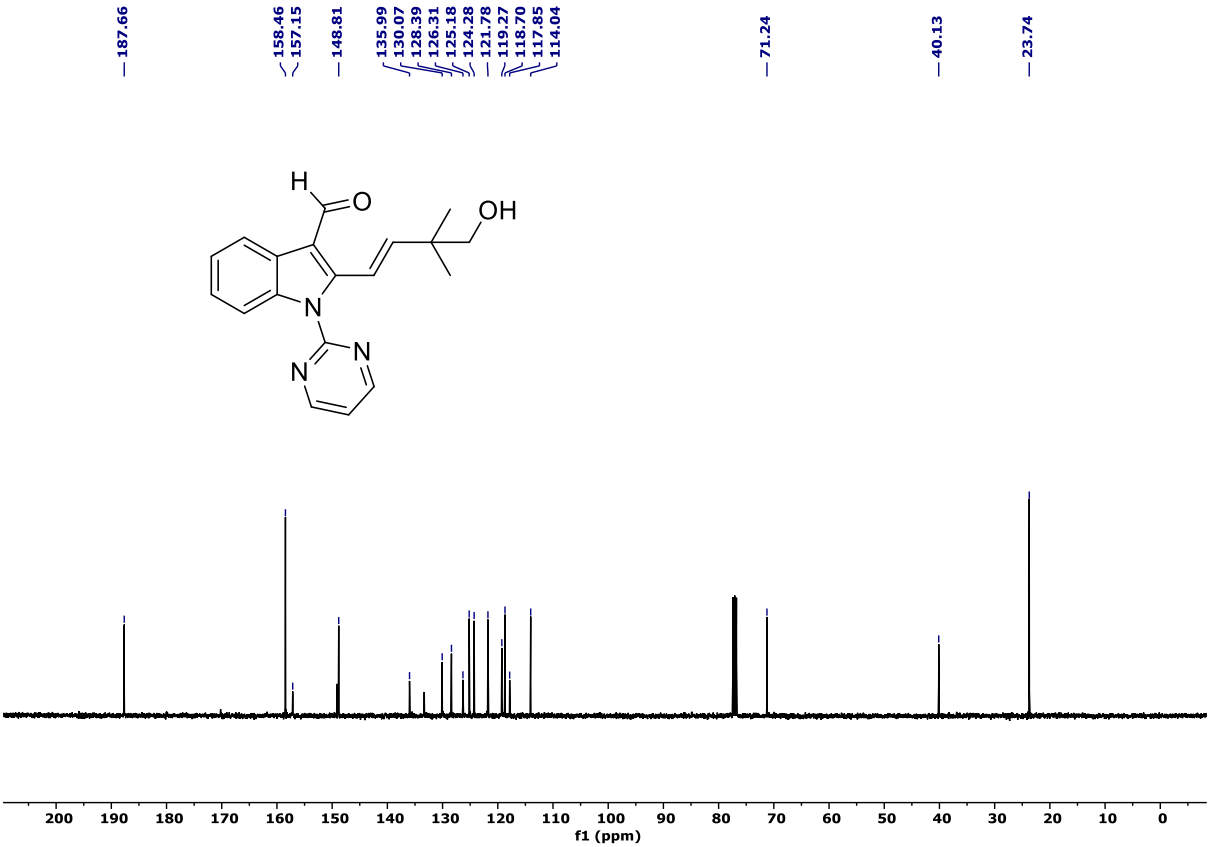
^{1}H and ^{13}C NMR Spectra of Compound **4v.** ($CDCl_3$ solvent was used, 400 NMR MHz)



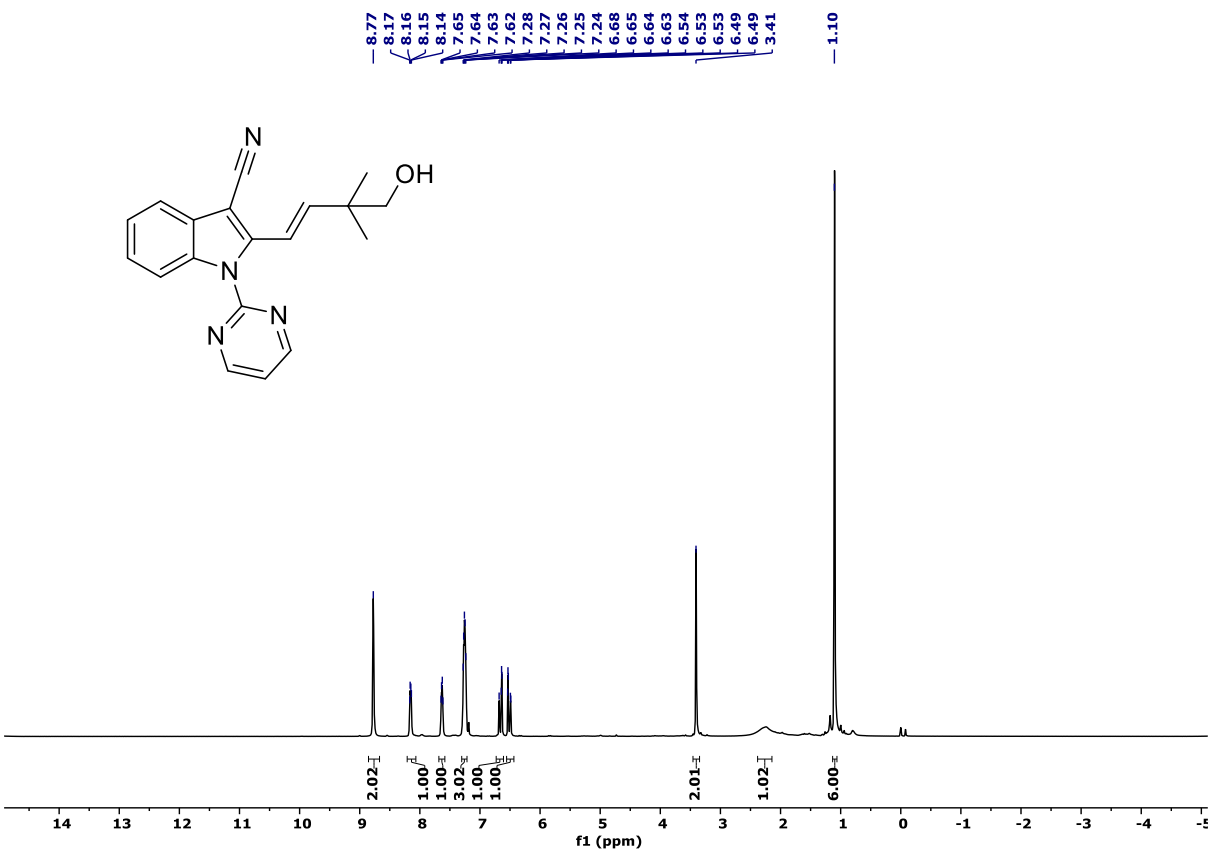


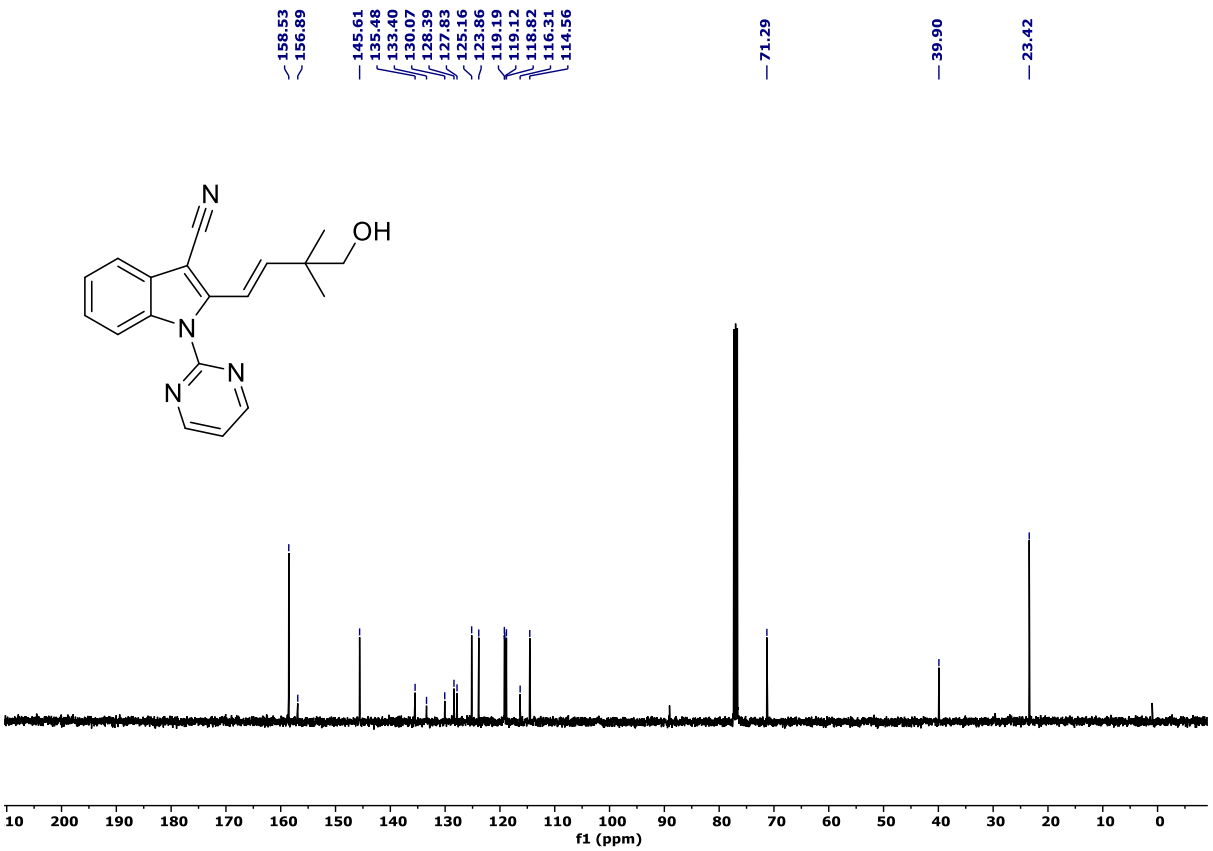
^{1}H and ^{13}C NMR Spectra of Compound **4w.** ($CDCl_3$ solvent was used, 400 NMR MHz)



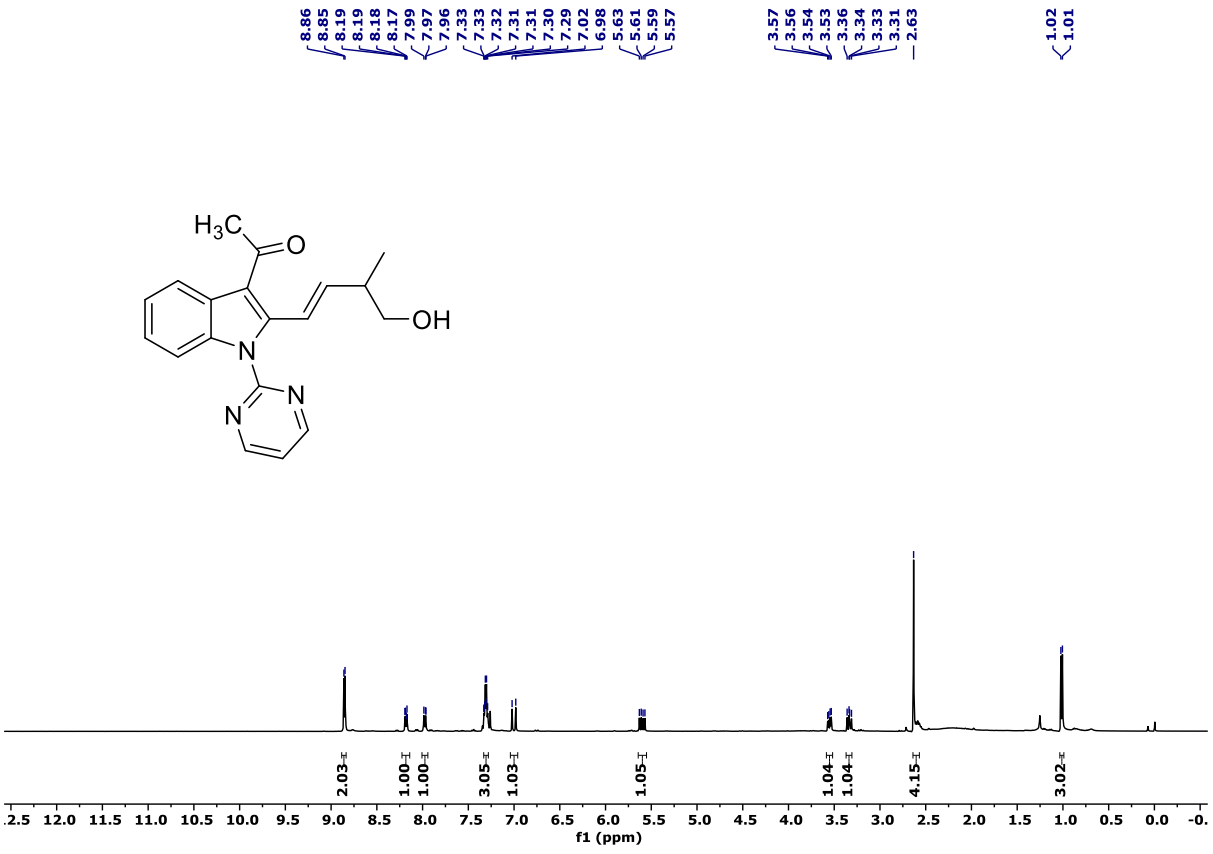


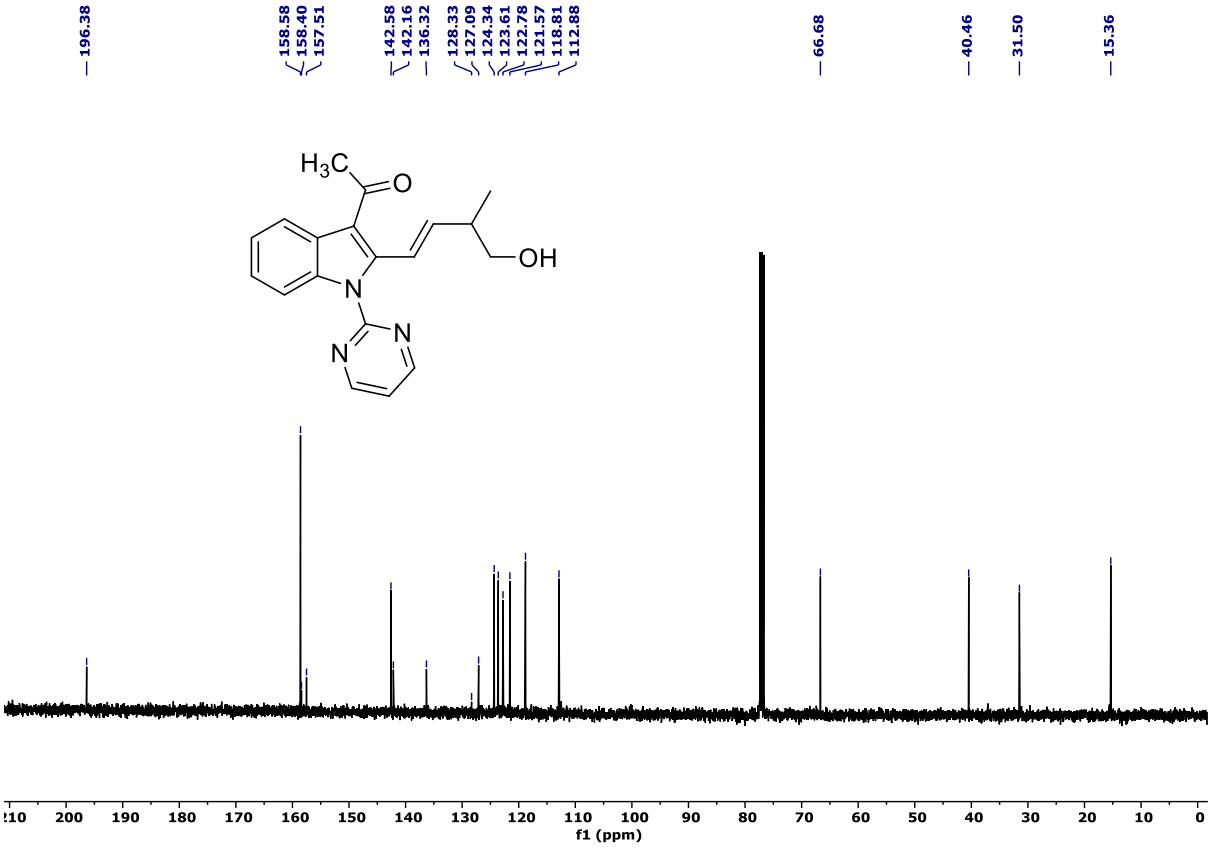
^{1}H and ^{13}C NMR Spectra of Compound **4x.** ($CDCl_3$ solvent was used, 400 NMR MHz)



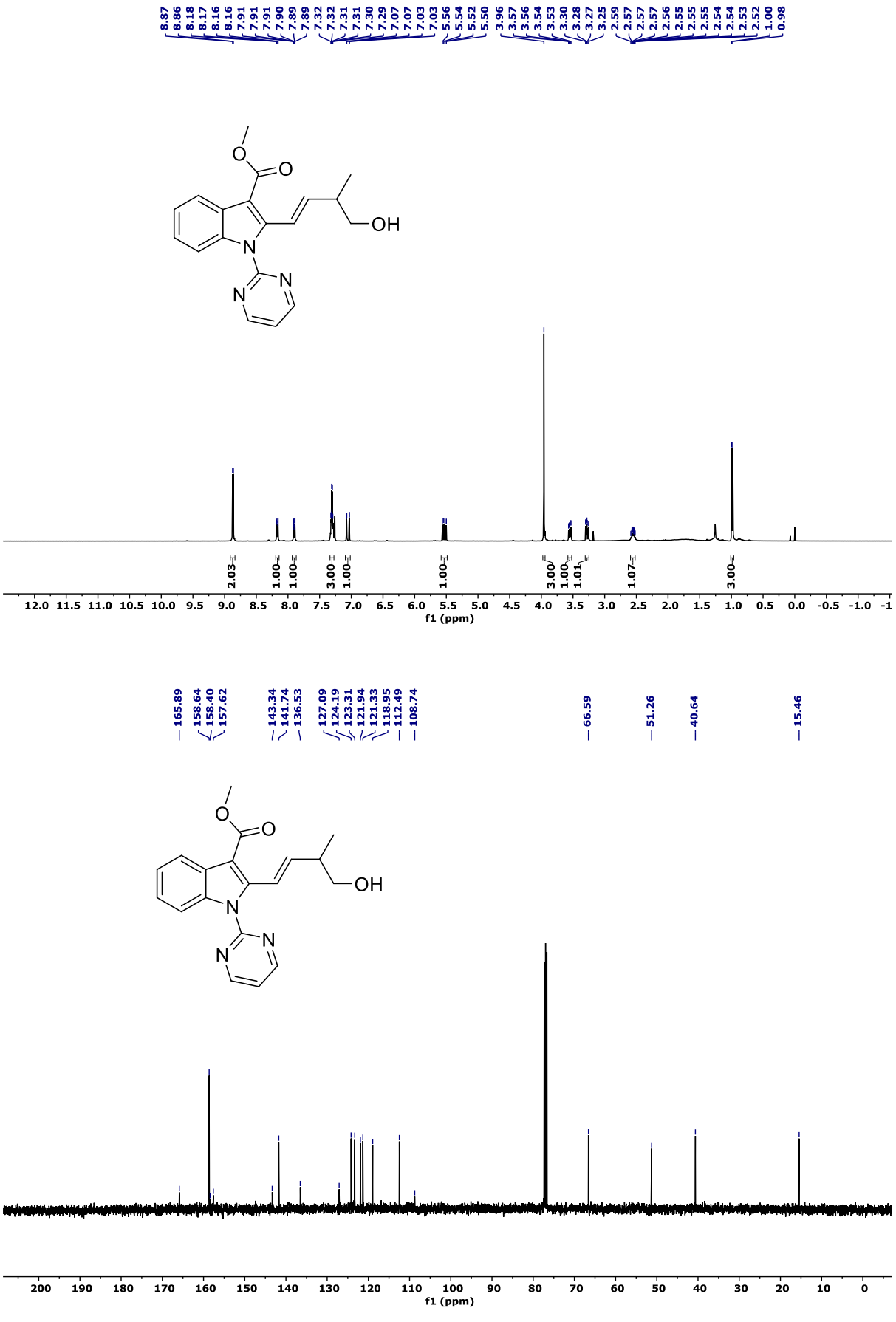


^{1}H and ^{13}C NMR Spectra of Compound **6u.** ($CDCl_3$ solvent was used, 400 NMR MHz)

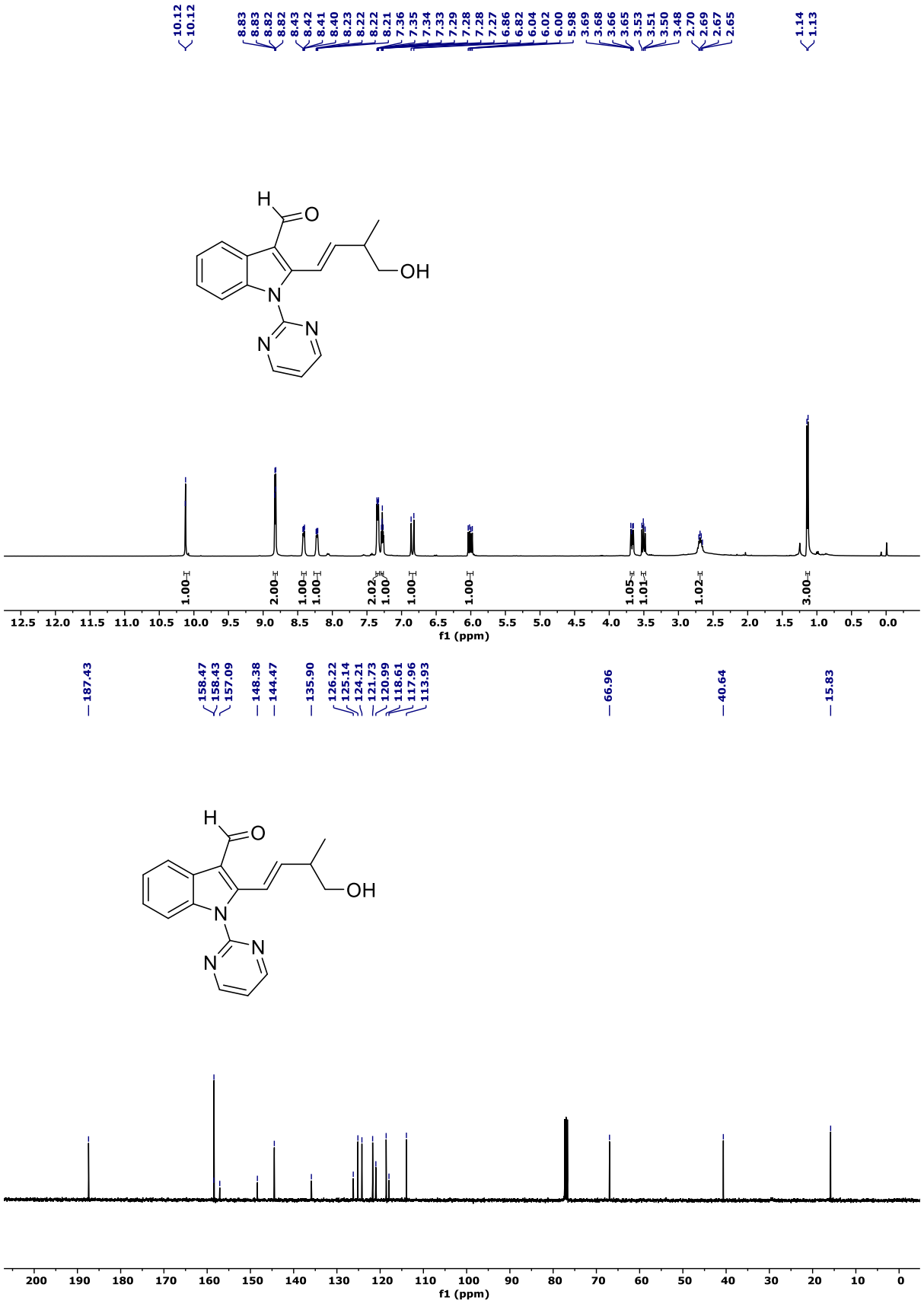




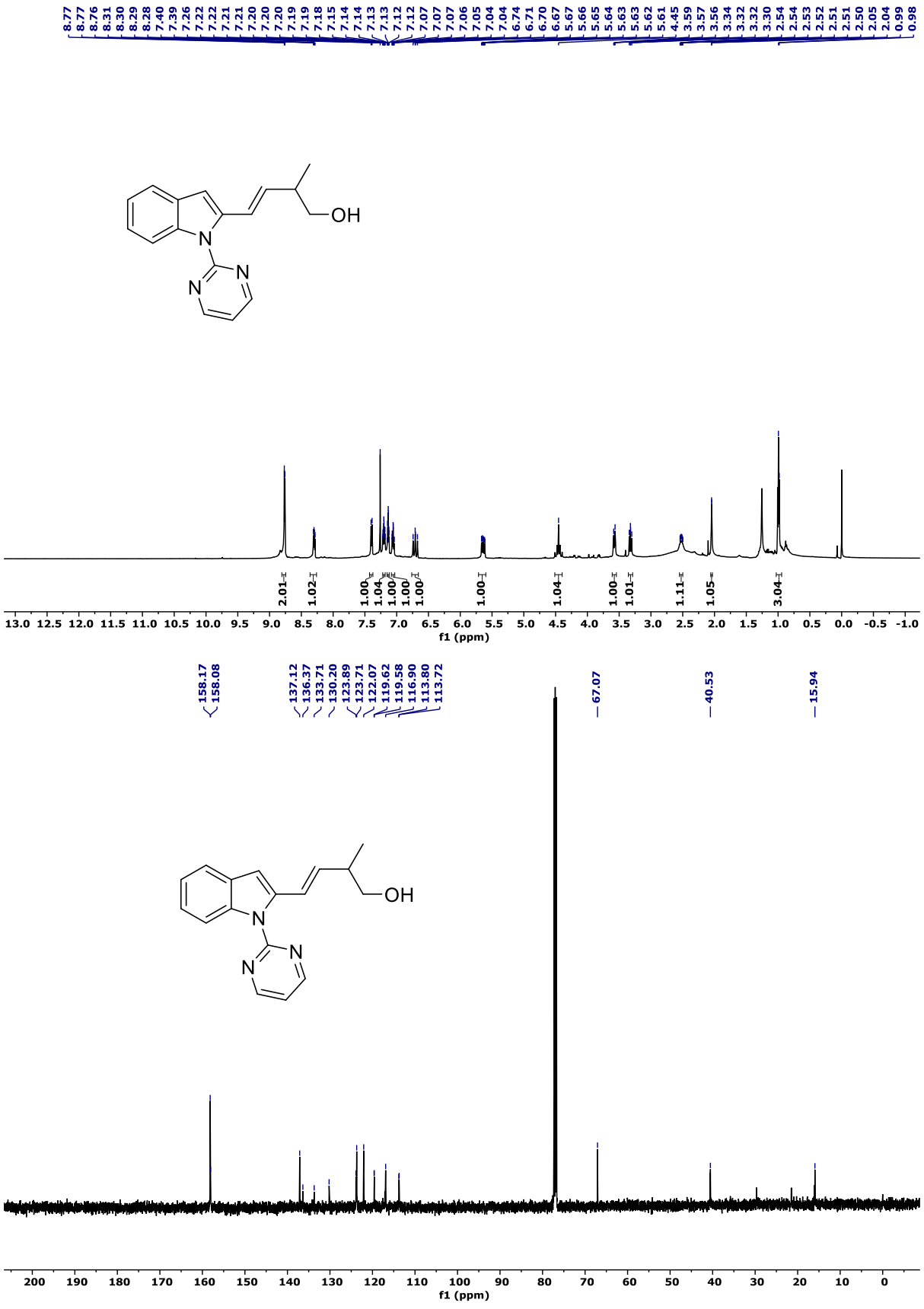
^{1}H and ^{13}C NMR Spectra of Compound **6v.** ($CDCl_3$ solvent was used, 400 NMR MHz)



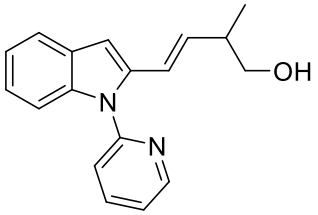
^{1}H and ^{13}C NMR Spectra of Compound **6w.** ($CDCl_3$ solvent was used, 400 NMR MHz)

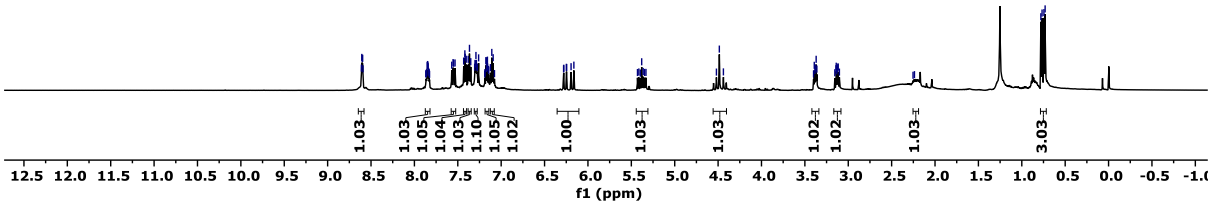


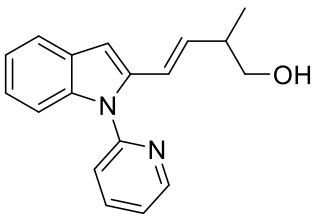
^{1}H and ^{13}C NMR Spectra of Compound **6a.** ($CDCl_3$ solvent was used, 500 NMR MHz)

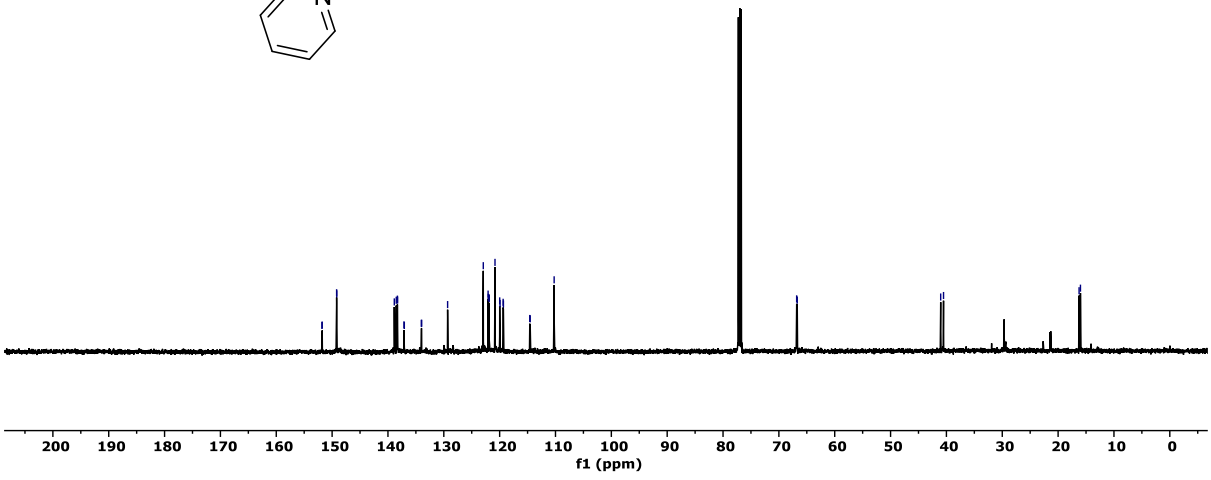


^{1}H and ^{13}C NMR Spectra of Compound **6q.** ($CDCl_3$ solvent was used, 500 NMR MHz)

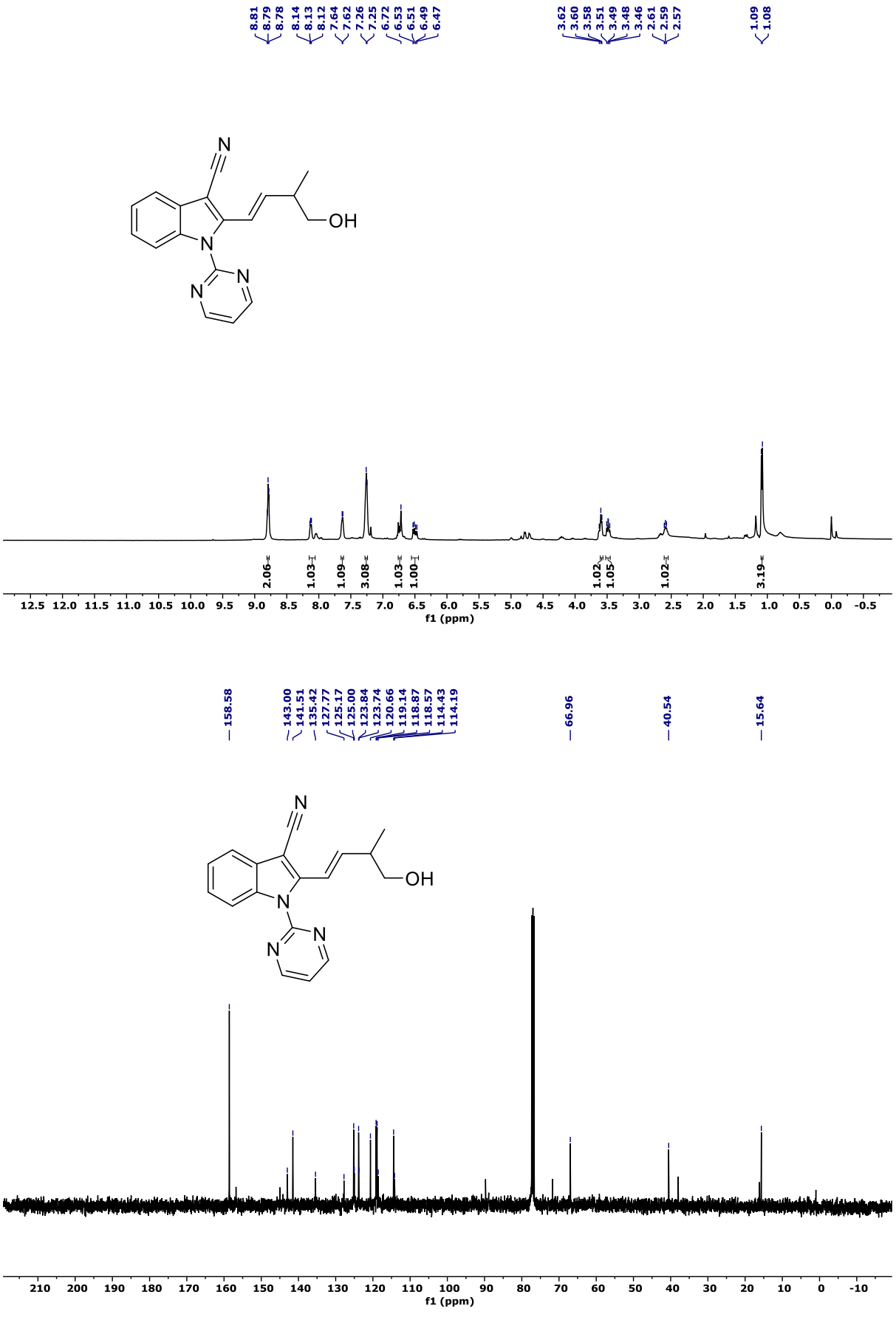




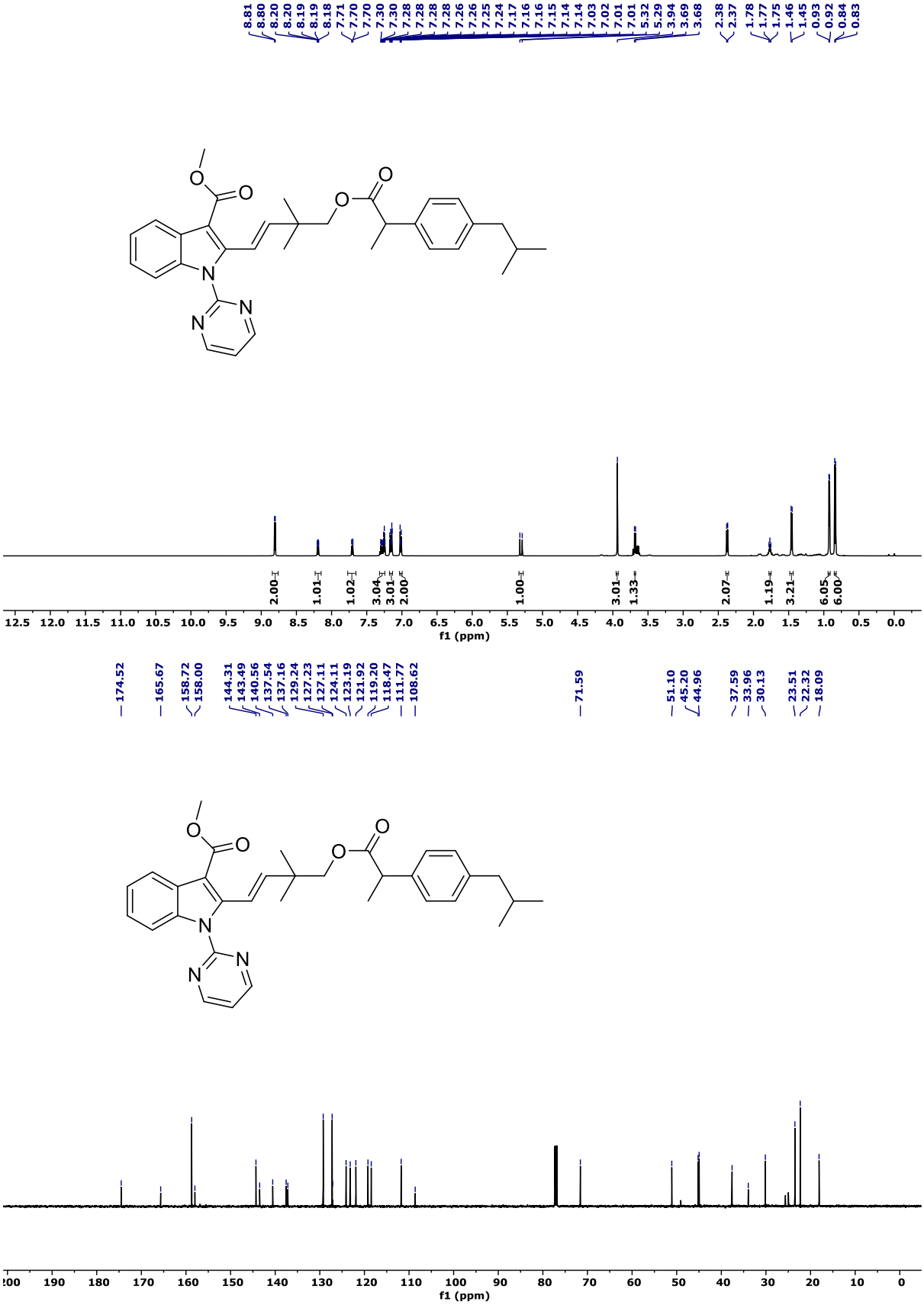




^{1}H and ^{13}C NMR Spectra of Compound **6x.** ($CDCl_3$ solvent was used, 500 NMR MHz



^{1}H and ^{13}C NMR Spectra of Compound **8.** ($CDCl_3$ solvent was used, 500 NMR MHz)



^{1}H Spectra of Compound **9.** ($CDCl_3$ solvent was used, 500 NMR MHz)