Supporting Information

for

# Remote C-6 Selective Ruthenium-Catalyzed C-H Alkylation of Indole Derivatives *via* σ-Activation

Jamie A. Leitch,[†] Claire L. McMullin,[†] Mary F. Mahon,[†] Yunas Bhonoah,[‡] and Christopher G. Frost.*[†]

Corresponding Author Email: c.g.frost@bath.ac.uk

[†]Department of Chemistry, University of Bath, Claverton Down, Bath, Somerset, BA2 7AY, United Kingdom

[‡]Syngenta, Jealott's Hill International Research Centre, Bracknell, Berkshire, RG42 6EY, United Kingdom

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# 1. General

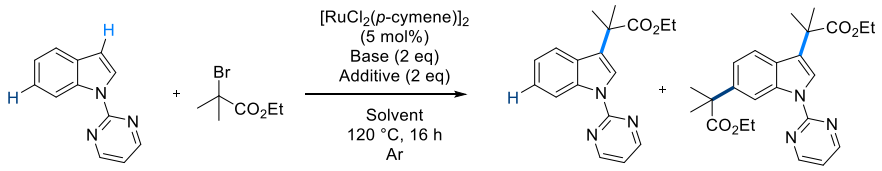
Proton, carbon and fluorine NMR spectra were recorded on Bruker 300 MHz, or Agilent Technologies 500 MHz, spectrometer ($^{1}$H NMR at 500 MHz, or 300 MHz, $^{13}$C NMR at 126 MHz, or 75 MHz, and $^{19}$F NMR at 470 MHz. Chemical shifts for protons are reported in parts per million downfield from $Si(CH_3)_4$ and are referenced to residual protium in the deuterated solvent ($CHCl_3$ at 7.26 ppm, or $CH_3OH$ at 3.31 & 4.87 depending on solvent used). Chemical shifts for fluorines are reported in parts per million downfield from $CFCl_3$. NMR data are presented in the following format: chemical shift (number of equivalent nuclei by integration, multiplicity [app = apparent, br = broad, d = doublet, t = triplet, q = quartet, dd = doublet of doublets), dt = doublet of triplets), dq = doublet of quartets), ddd = doublet of doublet of doublets), m = multiplet], coupling constant [in Hz], assignment). Electrospray ionisation ultrahigh resolution time-of-flight mass spectrometry (ESI–UHR–TOF–MS) was performed on a Bruker maXis mass spectrometer. Electrospray ionisation high resolution time-of-flight mass spectrometry (ESI–HR–TOF–MS) was performed on a Bruker micrOTOF spectrometer. Infrared (IR) spectra were recorded on a Perkin–Elmer 1600 FT (Fourier transform), IR spectrophotometer, with absorbencies quoted as wavelength (v [in cm−1]). Melting points were obtained on a Bibby Sterilin SMP10 melting point machine and are uncorrected.

Analytical thin-layer chromatography (TLC) was performed on aluminium-backed plates coated with Alugram® SIL G/UV254 purchased from Macherey–Nagel and visualised with UV light (254 or 365 nm), and/or KMnO4, 2,4-DNPH or $I_2$/Silica staining. Silica gel column chromatography was performed using 60 Å, 200–400 mesh particle size silica gel purchased from Sigma–Aldrich. Samples were loaded as saturated solutions in an appropriate solvent system.

All reactions were performed using reagents obtained from Sigma-Aldrich, Acros Organics, Alfa Aesar, Fluorochem chemicals without further purification unless stated. $[RuCl_2(p\text{-cymene})]_2$ was purchased from STREM chemicals or Acros Organics. All water used was purified through a Merck Millipore reverse osmosis purification system prior to use. Anhydrous solvents were dried and degassed by passing through anhydrous alumina columns using an Innovative Technology Inc. PS–400–7 solvent purification system (SPS) and stored under an atmosphere of $N_2$ prior to use.

Reactions were performed in oven-dried glassware and under a blanket of $N_2$ if not stated. Temperatures quoted are external. Solvents were removed under reduced pressure using Bü chi-Rotorvapor apparatus.

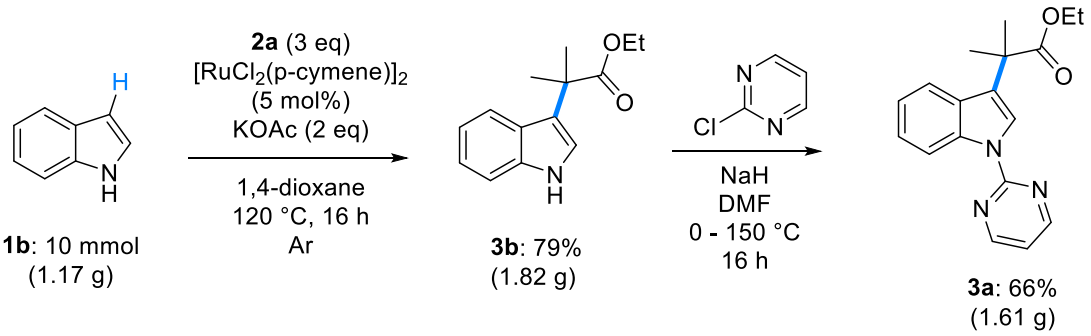
## 2. Optimization



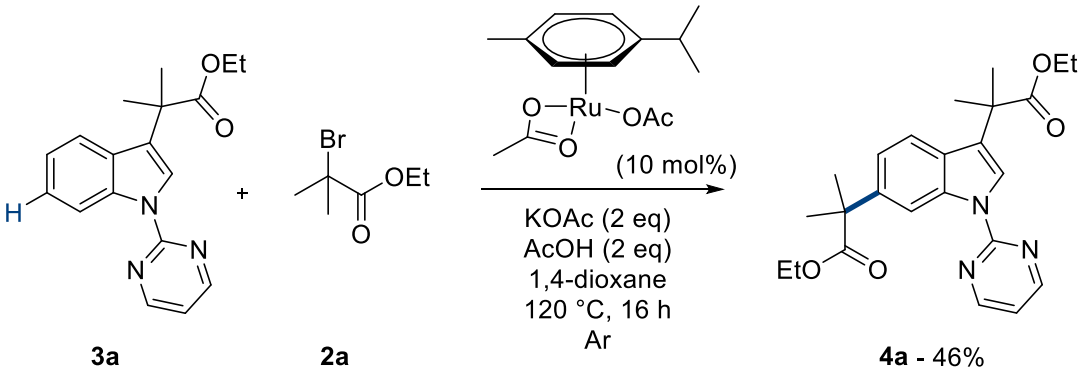

| Entry | Base | Additive | Solvent | Temp | Time | CP (eq) | Base (eq) | Add. (eq) | Mono (%) | Di (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | KOAc | - | 1,4-dioxane | 120 | 16 | 3 | 2 | 2 | 21 | 8 |
| **2** | KOAc | AcOH | 1,4-dioxane | 120 | 16 | 3 | 2 | 2 | 49 | 47 |
| **3** | - | AcOH | 1,4-dioxane | 120 | 16 | 3 | 2 | 2 | 26 | 0 |
| **4** | KOAc | AcOH | 2-MeTHF | 120 | 16 | 3 | 2 | 2 | 62 | 32 |
| **5** | KOAc | AcOH | DME | 120 | 16 | 3 | 2 | 2 | 48 | 45 |
| **6** | **KOAc** | **AcOH** | **AcOH** | **120** | **16** | **3** | **2** | **2** | **91** | **5** |
| **7** | **KOAc** | **AcOH** | **THF** | **120** | **16** | **3** | **2** | **2** | **39** | **57** |
| **8** | KOAc | AcOH | TBME | 120 | 16 | 3 | 2 | 2 | 83 | 14 |
| **9** | KOAc | AcOH | DCE | 120 | 16 | 3 | 2 | 2 | 65 | 33 |
| **10** | KOAc | AcOH | *t*-AmOH | 120 | 16 | 3 | 2 | 2 | 12 | 6 |
| **11** | KOAc | AcOH | PhMe | 120 | 16 | 3 | 2 | 2 | 59 | 37 |
| **12** | KOAc | AcOH | NMP | 120 | 16 | 3 | 2 | 2 | 0 | 0 |
| **13** | NaOAc | AcOH | THF | 120 | 16 | 3 | 2 | 2 | 35 | 9 |
| **14** | $NBu_4OAc$ | AcOH | THF | 120 | 16 | 3 | 2 | 2 | 0 | 0 |
| **15** | $K_2CO_3$ | AcOH | THF | 120 | 16 | 3 | 2 | 2 | 6 | 3 |
| **16** | $K_2CO_3$* | AcOH | THF | 120 | 16 | 3 | 2 | 2 | 46 | 43 |
| **17** | $Na_2CO_3$ | AcOH | THF | 120 | 16 | 3 | 2 | 2 | 0 | 0 |
| **18** | KOPiv | AcOH | THF | 120 | 16 | 3 | 2 | 2 | 17 | 9 |
| **19** | KOAc | PivOH | THF | 120 | 16 | 3 | 2 | 2 | 65 | 32 |
| **20** | KOAc | $AdCO_2H$ | THF | 120 | 16 | 3 | 2 | 2 | 8 | 10 |
| **21** | KOAc | $MesCO_2H$ | THF | 120 | 16 | 3 | 2 | 2 | 50 | 30 |
| **22** | KOAc | Piv-Val-OH | THF | 120 | 16 | 3 | 2 | 2 | 62 | 14 |
| **23** | KOAc | TFA | THF | 120 | 16 | 3 | 2 | 2 | 31 | 3 |
| **24** | KOAc | KOAc | THF | 120 | 16 | 3 | 2 | 2 | 55 | 40 |
| **25** | KOAc | AcOH | THF | 120 | 16 | 1 | 2 | 2 | 70 | 30 |
| **27** | KOAc | AcOH | THF | 120 | 16 | 5 | 2 | 2 | 36 | 26 |
| **28** | KOAc | AcOH | THF | 120 | 16 | 10 | 2 | 2 | 37 | 28 |
| **29** | KOAc | AcOH | THF | 100 | 16 | 3 | 2 | 2 | 55 | 43 |
| **30** | KOAc | AcOH | THF | 120 | 16 | 3 | 2 | 1 | 27 | 14 |
| **31** | KOAc | AcOH | THF | 120 | 16 | 3 | 2 | 3 | 56 | 46 |
| **32** | KOAc | AcOH | THF | 120 | 16 | 3 | 2 | 10 | 69 | 31 |
| **33** | KOAc | AcOH | THF | 120 | 16 | 3 | 1 | 2 | 71 | 17 |
| **34** | KOAc | AcOH | THF | 120 | 16 | 3 | 3 | 2 | 26 | 74 |
| **35**** | KOAc | AcOH | THF | 120 | Time | 3 | 2 | 2 | 0 | 0 |

Standard Conditions: Indole (0.25 mmol), ethyl α--bromoisobutyrate (0.75 mmol), $[RuCl_2(p\text{-cymene})]_2$ (5 mol%), Base (2 eq), Additive (2 eq), Solvent (1 mL), 120 °C, 16 h under Argon. * = KOAc (30 mol%) added. ** = $[RuCl_2(p\text{-cymene})]_2$ (0 mol%).

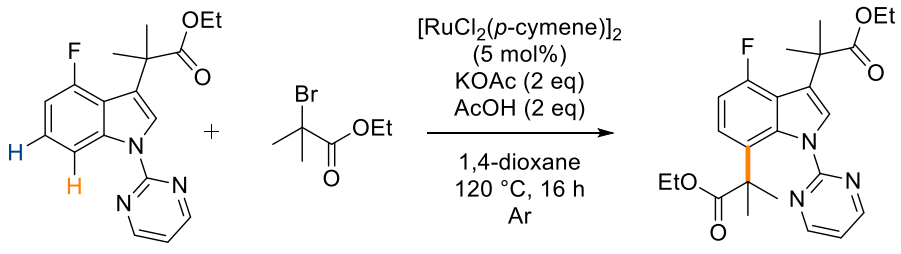
**Scheme S1**: Gram-scale synthesis of **3a** for reaction probing




**Scheme S2**: Remote C-6 alkylation using [Ru(OAc)$_2$(*p*-cymene)] monomer as catalyst



**Scheme S3**: Ruthenium Catalyzed C-H Alkylation of C4 Substituted Derivatives




**S3a** **S4a**: 14%
**C7 Observed**

C7 selectivity was exclusively observed in the C4-F derivative in low yields. This shows that the electronic nature of the fluorine strongly influences the selectivity of the product. This was investigated using the computational methods used previously (Figure S1) and this showed that this functionalization is likely to take place on an organic non-cyclometalated substrate. This C7 functionalization could then impact on potential C2 cyclometalation and C6 functionalisation.

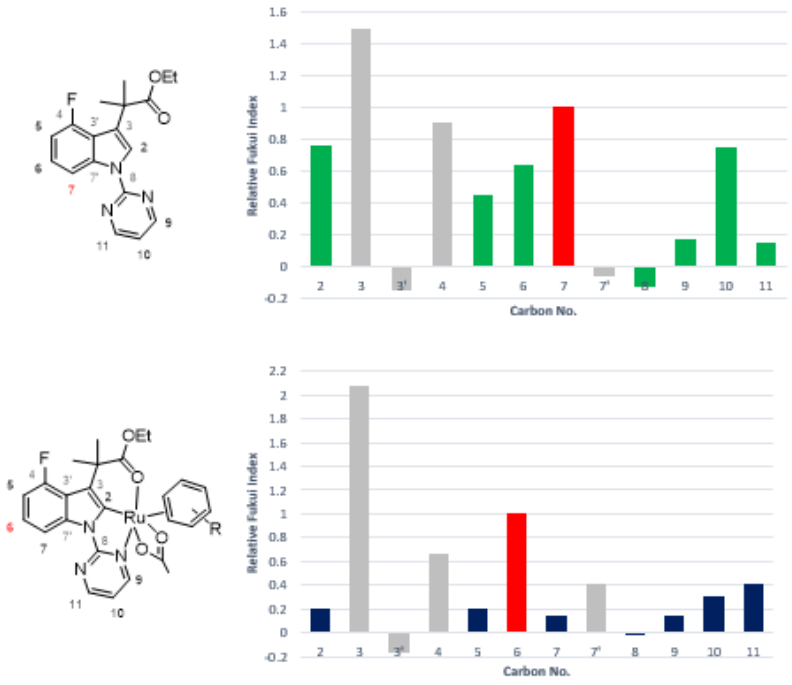
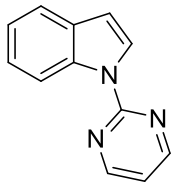



Figure S1: Relative nucleophilicity Fukui indices for organic and inorganic computed structures. Calculations were performed at the BP86/6-31G**&SDD(Ru) level of theory. Fukui indices were calculated with NBO total atomic charges from the optimized neutral structure. Most reactive vacant C-H position is highlighted in red.

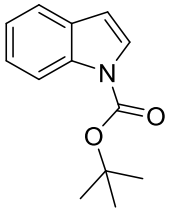
3. Synthesis of Starting Materials

Synthesis of 1-(pyrimidin-2-yl)-1*H*-indole (**1a**)



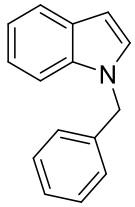
To a solution of indole (2.34 g, 20 mmol) in DMF (50 mL) was added sodium hydride (60% wt. in mineral oil, 1.2 g, 30 mmol) portion-wise. The reaction mixture was allowed to stir at room temperature for 1 hour. To the solution was added 2-chloropyrimidine (3.43 g, 30 mmol) and the reaction mixture was heated to 150 °C overnight. The reaction mixture was allowed to return to room temperature before being poured into brine (300 mL) and EtOAc (300 mL). The organic layer was separated and the aqueous layer was re-extracted with EtOAc (2 x 300 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude mixture was purified *via* silica gel column chromatography (EtOAc/Petroleum Ether 40-60 °C) to give a white solid, 99% (3.88 g). **$^1$H NMR** (300 MHz, $CDCl_3$ δ 8.82 (1H, dq, *J* = 8.4, 0.9 Hz), 8.71 (2H, d, *J* = 4.8 Hz), 8.28 (1H, d, *J* = 3.7 Hz), 7.69–7.58 (1H, m), 7.35 (1H, ddd, *J* = 8.5, 7.1, 1.4 Hz), 7.28–7.19 (1H, m), 7.06 (1H, t, *J* = 4.8 Hz), 6.71 (1H, dd, *J* = 3.7, 0.8 Hz). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 158.3, 154.9, 147.6, 131.4, 125.9, 123.8, 122.2, 121.0, 116.4, 116.2, 107.1. Data is in line with literature precedent.[1]

Synthesis of *tert*-butyl 1*H*-indole-1-carboxylate (**S1a**)



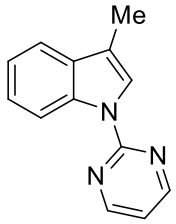
To a solution of 1*H*-indole (2.34 g, 20 mmol) and *N,N*-dimethylaminopyridine (0.244 g, 2 mmol) in $CH_2Cl_2$ (40 mL) was added di-*tert*-butyl dicarbonate (4.8 g, 22 mmol). The reaction was allowed to stir at room temperature overnight. Brine (100 mL) and $CH_2Cl_2$ (60 mL) were added to the reaction mixture and the organic layer extracted. The aqueous layer was re-extracted with $CH_2Cl_2$ (2 x 100 mL). The combined organic phases were dried over $MgSO_4$ and concentrated *in vacuo* to give a yellow oil, 90% (3.89 g). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.21 (1H, d, *J* = 8.3 Hz), 7.64 (1H, d, *J* = 3.8 Hz), 7.60 (1H, ddd, *J* = 7.8, 1.3, 0.8 Hz), 7.36 (1H, ddd, *J* = 8.3, 7.2, 1.3 Hz), 7.30–7.22 (1H, m), 6.61 (1H, dd, *J* = 3.7, 0.8 Hz), 1.72 (9H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 149.9, 135.3, 130.7, 126.0, 124.3, 122.7, 121.0, 115.3, 107.4, 83.7, 28.3. Data is in line with literature precedent.[2]

Synthesis of 1-benzyl-1*H*-indole (**S1b**)



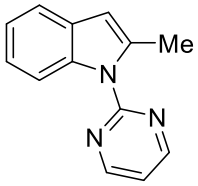
To a solution of 1*H*-indole (2.34 g, 20 mmol) in DMF (20 mL) was added sodium hydride (60% wt. in mineral oil, 2.85 g, 24 mmol). The reaction mixture was left to stir at room temperature for 1 hour. To the resulting slurry was added benzyl bromide (3.6 mL, 30 mmol) at 0 °C. The reaction mixture was allowed to stir at room temperature overnight. The resulting mixture was quenched with water (200 mL) and EtOAc (200 mL) was added. The organic layer was extracted and the aqueous layer was re-extracted with EtOAc (2 x 200 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo* to a yellow oil 95%, (3.93 g). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.84 (1H, ddd, *J* = 7.7, 1.4, 0.8 Hz), 7.58–7.48 (1H, m), 7.46–7.38 (4H, m), 7.38–7.26 (2H, m), 7.27–7.19 (3H, m), 5.39 (2H, d, *J* = 0.7 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 137.6, 128.8, 128.8, 128.5, 128.3, 127.8, 127.7, 127.6, 126.8, 121.8, 121.1, 119.6, 109.8, 101.8, 50.1. Data is in line with literature precedent.[2]

Synthesis of 3-methyl-1-(pyrimidin-2-yl)-1*H*-indole (**1c**)



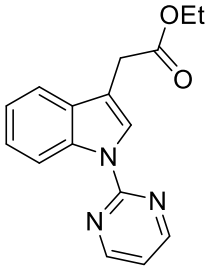

To a solution of 3-methylindole (2.62 g, 20 mmol) in DMF (20 mL) was added sodium hydride (60% wt. in mineral oil, 1.2 g, 30 mmol) portion-wise. The reaction mixture was allowed to stir at room temperature for 1 hour. To the solution was added 2-chloropyrimidine (3.43 g, 30 mmol) and the reaction mixture was heated to 150 °C overnight. The reaction mixture was allowed to return to room temperature before being poured into brine (300 mL) and EtOAc (300 mL). The organic layer was separated and the aqueous layer was re-extracted with EtOAc (2 x 300 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude mixture was purified *via* silica gel column chromatography (EtOAc/Petroleum Ether 40-60 °C) to give a white solid, 24% (1.01 g). **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 8.78 (1H, dd, *J* = 8.5, 3.1 Hz), 8.66 (2H, t, *J* = 4.3 Hz), 8.04 (1H, dt, *J* = 2.7, 1.4 Hz), 7.57 (1H, dd, *J* = 8.0, 3.0 Hz), 7.36 (1H, tdd, *J* = 8.4, 3.9, 1.5 Hz), 7.27 (1H, dt, *J* = 8.4, 3.4 Hz), 6.98 (1H, q, *J* = 4.6 Hz), 2.39–2.35 (3H, m). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 158.2, 135.8, 132.2, 123.8, 123.0, 121.9, 118.9, 116.3, 116.2, 115.7, 9.9. Data is in line with literature precedent.[3]

Synthesis of 2-methyl1-(pyridin-2-yl)-1*H*-indole (**1d**)



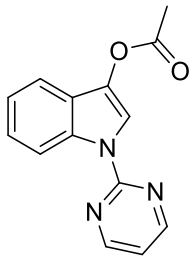

To a solution of 2-methylindole (0.65 g, 5 mmol) in DMF (5 mL) was added sodium hydride (60% wt. in mineral oil, 0.3 g, 7.5 mmol) portion-wise. The reaction mixture was allowed to stir at room temperature for 1 hour. To the solution was added 2-chloropyrimidine (0.84 g, 7.5 mmol) and the reaction mixture was heated to 150 °C overnight. The reaction mixture was allowed to return to room temperature before being poured into brine (75 mL) and EtOAc (75 mL). The organic layer was separated and the aqueous layer was re-extracted with EtOAc (2 x 75 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude mixture was purified *via* silica gel column chromatography ($CH_2Cl_2$/Petroleum Ether 40-60 °C) to give a white solid, 5% (0.052 g). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.77 (2H, d, *J* = 4.9 Hz), 8.32 (1H, d, *J* = 8.1 Hz), 7.54 (1H, d, *J* = 7.5 Hz), 7.23 (2H, dt, *J* = 19.7, 6.9 Hz), 7.10 (1H, t, *J* = 4.8 Hz), 6.46 (1H, s), 1H), 2.74 (3H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 158.1, 137.9, 136.9, 129.5, 122.4, 121.9, 119.6, 117.0, 114.1, 106.8, 16.7. Data is in line with literature precedent.[4]

Synthesis of ethyl 2-(1-(pyrimidin-2-yl)-1*H*-indol-3-yl)acetate (**3e**)



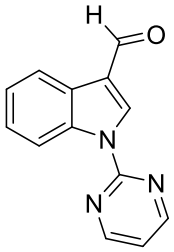

To a solution of indole-3-acetic acid (1.6 g, 9.1 mmol) in EtOH (40 mL) was added $H_2SO_4$ (2 mL). The reaction mixture was refluxed overnight. The reaction mixture was allowed to return to room temperature and was diluted in $H_2O$ (100 mL) and EtOAc (100 mL). The organic layer was extracted, and the aqueous layer was re-extracted with EtOAc (100 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The resulting residue was purified *via* silica gel column chromatography (EtOAc:Petroleum Ether 40-60 °C, 1:10 v:v) to afford a yellow oil. This yellow oil was diluted in DMF (7 mL) and sodium hydride (60% wt. in mineral oil, 0.39 g, 9.75 mmol) was added portionwise at 0 °C. The resulting slurry was allowed to stir for 1 hour. Following this 2-chloropyrimidine (1.12 g, 9.75 mmol) was added and the reaction was allowed to stir at room temperature overnight. The reaction mixture was concentrated *in vacuo*. The resulting residue was diluted in EtOAc (200 mL) and brine (200 mL). The organic layer was extracted and the aqueous layer was re-extracted with EtOAc (2 x 200 mL). The combined organic phases were filtered through a pad of cotton wool before being dried over $MgSO_4$ and concentrated *in vacuo*. The resulting residue was purified *via* silica gel column chromatography (EtOAc:Petroleum Ether 40-60 °C, 1:20 v:v) to afford a yellow oil, 14% from free acid (0.388 g). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.80 (1H, dt, *J* = 8.4, 0.9 Hz), 8.68 (2H, d, *J* = 4.8 Hz), 8.26 (1H, t, *J* = 1.1 Hz), 7.61 (1H, ddd, *J* = 7.8, 1.3, 0.7 Hz), 7.36 (1H, ddd, *J* = 8.4, 7.1, 1.3 Hz), 7.30–7.25 (1H, m), 7.02 (1H, t, *J* = 4.8 Hz), 4.19 (2H, q, *J* = 7.1 Hz), 3.80 (2H, d, *J* = 1.1 Hz), 1.27 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 171.4, 158.1, 135.7, 130.9, 124.6, 124.0, 122.1, 119.7, 119.0, 116.5, 116.1, 113.0, 111.3, 61.0, 31.6, 31.5, 14.3, 14.3. Data is in line with literature precedent.[5]

Synthesis of 1-(pyrimidin-2-yl)-1*H*-indol-3-yl acetate (**3f**)



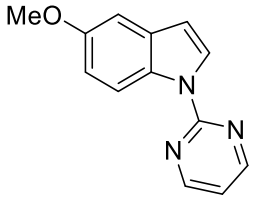
To an oven dried Schlenk flask was added 1-(pyrimidin-2-yl)-1*H*-indole (0.98 g, 5 mmol) and $PhI(OAc)_2$ (1.77 g, 5.5 mmol). The flask was evacuated and refilled with argon three times. Degassed acetic acid (3.5 mL) and acetic anhydride (1.5 mL) were added *via* septum. The reaction mixture was then heated to 60 °C and left to stir overnight. The mixture was allowed to return to room temperature and was quenched with water (25 mL) and subsequently saturated $NaHCO_3$ solution (75 mL). EtOAc (100 mL) was added and the organic layer was extracted. The aqueous layer was extracted with EtOAc (2 x 100 mL) and the combined organic phases were dried over $MgSO_4$ and concentrated *in vacuo*. The crude residue was purified *via* silica gel column chromatography (EtOAc/Petroleum Spirit 40-60 °C) to give a white solid, 61% (0.77 g). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.82 (1H, dt, *J* = 8.5, 0.8 Hz), 8.68 (2H, d, *J* = 4.7 Hz), 8.43 (1H, s), 7.56 (1H, ddd, *J* = 7.9, 1.3, 0.7 Hz), 7.38 (1H, ddd, *J* = 8.5, 7.1, 1.3 Hz), 7.30–7.21 (1H, m), 7.02 (1H, t, *J* = 4.8 Hz), 2.40 (3H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 168.2, 158.2, 157.9, 133.7, 133.0, 124.7, 124.2, 122.3, 117.6, 116.6, 116.2, 114.7, 21.2. Data is in line with literature precedent.[6]

Synthesis of 1-(pyrimidin-2-yl)-1*H*-indole-3-carbaldehyde (**3g**)



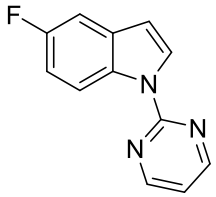
To a solution of indole-3-carboxaldehyde (0.725 g, 5 mmol) in DMF (10 mL) was added sodium hydride (60% wt. in mineral oil, 0.3 g, 7.5 mmol) portion-wise. The reaction mixture was allowed to stir at room temperature for 1 hour. To the solution was added 2-chloropyrimidine (0.863 g, 7.5 mmol) and the reaction mixture was heated to 150 °C overnight. The reaction mixture was allowed to return to room temperature before being poured into aqueous LiCl solution (5%, 100 mL) and EtOAc (100 mL). The organic layer was separated and the aqueous layer was re-extracted with EtOAc (2 x 100 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude mixture was purified *via* silica gel column chromatography (EtOAc/Petroleum Ether 40-60 °C) and then recrystallized from EtOH to give a white fluffy solid, 22% (0.239 g). **mp** (from $CHCl_3$): 159-164 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 3138.5, 1673.5, 1569.5, 1547.9. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 10.15 (1H, s), 8.91 (1H, s), 8.79 (1H, dt, *J* = 8.4, 1.0 Hz), 8.76 (2H, d, *J* = 4.8 Hz), 8.34 (1H, ddd, *J* = 7.7, 1.5, 0.8 Hz), 7.43 (1H, ddd, *J* = 8.5, 7.2, 1.5 Hz), 7.41–7.35 (1H, m), 7.20 (1H, t, *J* = 4.8 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 186.0, 158.5, 157.1, 136.9, 136.5, 127.0, 125.7, 124.4, 122.1, 121.4, 118.0, 116.5. **HRMS** (ESI): m/z calculated for $C_{13}H_9N_3O_1$ requires 224.0824 for $[M+H]^+$, found 224.0809.

Synthesis of 5-methoxy-1-(pyrimidinyl-2-yl)-1*H*-indole (**1n**)



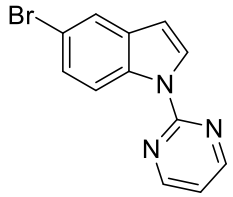

To a solution of 5-methoxyindole (0.735 g, 5 mmol) in DMF (10 mL) was added sodium hydride (60% wt. in mineral oil, 0.3 g, 7.5 mmol) portion-wise. The reaction mixture was allowed to stir at room temperature for 1 hour. To the solution was added 2-chloropyrimidine (0.863 g, 7.5 mmol) and the reaction mixture was heated to 150 °C over the weekend. The reaction mixture was allowed to return to room temperature before being poured into brine (100 mL) and EtOAc (100 mL). The organic layer was separated and the aqueous layer was re-extracted with EtOAc (2 x 100 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude mixture was purified *via* silica gel column chromatography (EtOAc/Petroleum Ether 40-60 °C) to give a powdery white solid, 60% (0.670 g). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.73–8.68 (1H, m), 8.67 (2H, d, *J* = 4.8 Hz), 8.25 (1H, d, *J* = 3.6 Hz), 7.10 (1H, dd, *J* = 2.6, 0.5 Hz), 7.00 (1H, t, *J* = 4.8 Hz), 6.97 (1H, ddd, *J* = 9.1, 2.6, 0.5 Hz), 6.63 (1H, dd, *J* = 3.7, 0.8 Hz), 3.89 (3H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 158.2, 157.8, 155.6, 132.2, 130.4, 126.5, 117.2, 116.0, 112.7, 106.9, 103.3, 55.8. Data is in line with literature precedent.[5]

Synthesis of 5-fluoro-1-(pyrimidin-2-yl)-1*H*-indole (**1o**)



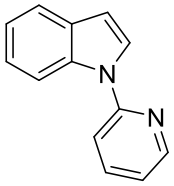
To a solution of 5-fluoroindole (0.675 g, 5 mmol) in DMF (10 mL) was added sodium hydride (60% wt. in mineral oil, 0.3 g, 7.5 mmol) portion-wise. The reaction mixture was allowed to stir at room temperature for 1 hour. To the solution was added 2-chloropyrimidine (0.863 g, 7.5 mmol) and the reaction mixture was heated to 150 °C over the weekend. The reaction mixture was allowed to return to room temperature before being poured into brine (100 mL) and EtOAc (100 mL). The organic layer was separated and the aqueous layer was re-extracted with EtOAc (2 x 100 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude mixture was purified *via* silica gel column chromatography (EtOAc/Petroleum Ether 40-60 °C) to give a powdery white solid, 85% (0.897 g). **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 8.76 (1H, ddt, *J* = 9.1, 4.8, 0.6 Hz), 8.69 (2H, d, *J* = 4.8 Hz), 8.31 (1H, dd, *J* = 3.7, 0.5 Hz), 7.32–7.20 (1H, m), 7.10–7.02 (2H, m), Pm*H* & In*H*), 6.65 (1H, dd, *J* = 3.7, 0.8 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 159.1 (d, *J* = 237.8 Hz), 158.3, 132.2 (d, *J* = 10.0 Hz), 127.5, 117.4 (d, *J* = 8.6 Hz), 116.4, 111.5 (d, *J* = 25.0 Hz), 106.7 (d, *J* = 3.9 Hz), 106.2 (d, *J* = 23.4 Hz). **$^{19}$F NMR** (470 MHz, $CDCl_3$) δ -122.0 (td, *J* = 9.1, 4.9 Hz). Data is in line with literature precedent.[7]

Synthesis of 5-bromo-1-(pyrimidin-2-yl)-1*H*-indole (**1p**)



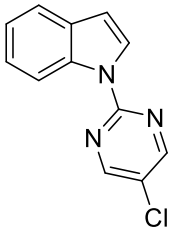

To a solution of 5-bromoindole (0.980 g, 5 mmol) in DMF (10 mL) was added sodium hydride (60% wt. in mineral oil, 0.3 g, 7.5 mmol) portion-wise. The reaction mixture was allowed to stir at room temperature for 1 hour. To the solution was added 2-chloropyrimidine (0.863 g, 7.5 mmol) and the reaction mixture was heated to 150 °C overnight. The reaction mixture was allowed to return to room temperature before being poured into aqueous LiCl solution (5%, 100 mL) and EtOAc (100 mL). The organic layer was separated and the aqueous layer was re-extracted with EtOAc (2 x 100 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude mixture was purified *via* silica gel column chromatography (EtOAc/Petroleum Ether 40-60 °C) to give a powdery white solid, 86% (1.18 g). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.73–8.66 (3H, m), 8.28 (1H, dd, *J* = 3.7, 0.4 Hz), 7.74 (1H, dd, *J* = 2.1, 0.5 Hz), 7.41 (1H, ddd, *J* = 8.8, 2.0, 0.4 Hz), 7.07 (1H, t, *J* = 4.8 Hz), 6.63 (1H, dd, *J* = 3.7, 0.8 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 158.3, 157.6, 134.2, 133.2, 127.1, 126.5, 123.5, 117.9, 116.6, 115.6, 110.2, 106.2. Data is in line with literature precedent.[2]

Synthesis of 1-(pyridine-2-yl)-1*H*-indole (**1h**)



To a solution of indole (1.17 g, 10 mmol) in DMF (15 mL) was added sodium hydride (60% wt. in mineral oil, 0.6 g, 15 mmol) portion-wise. The reaction mixture was allowed to stir at room temperature for 1 hour. To the solution was added 2-bromopyridine (1.14 mL, 1.90 g, 12 mmol) and the reaction mixture was heated to 150 °C overnight. The reaction mixture was allowed to return to room temperature before being poured into brine (100 mL) and EtOAc (100 mL). The organic layer was separated and the aqueous layer was re-extracted with EtOAc (2 x 100 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude mixture was purified *via* silica gel column chromatography (EtOAc/Petroleum Ether 40-60 °C) to give a light brown oil, 56% (1.08 g). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.64–8.48 (1H, m), 8.22 (1H, dd, *J* = 8.4, 0.9 Hz), 7.82 (1H, ddd, *J* = 8.2, 7.4, 2.0 Hz), 7.74 (1H, d, *J* = 3.4 Hz), 7.68 (1H, ddd, *J* = 7.8, 1.3, 0.8 Hz), 7.50 (1H, dt, *J* = 8.2, 0.9 Hz), 7.31 (1H, dd, *J* = 8.4, 7.1, 1.3 Hz), 7.22 (1H, ddd, *J* = 8.1, 7.1, 1.0 Hz), 7.17 (1H, ddd, *J* = 7.4, 4.9, 0.9 Hz), 6.73 (1H, dd, *J* = 3.5, 0.8 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 152.6, 149.1, 138.5, 135.2, 130.6, 126.1, 123.2, 121.4, 121.2, 120.2, 114.7, 113.1, 105.7, 105.6.[8]

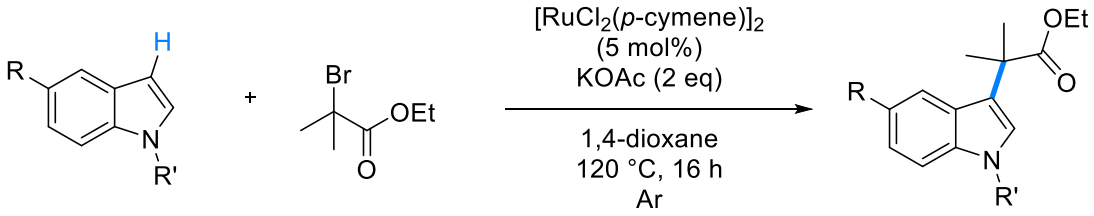
Synthesis of 1-(5-chloropyrimidin-2-yl)-1*H*-indole (**1i**)



To a solution of indole (0.585 g, 5 mmol) in DMF (5 mL) was added sodium hydride (60% wt. in mineral oil, 0.3 g, 7.5 mmol) portion-wise. The reaction mixture was allowed to stir at room temperature for 1 hour. To the solution was added 2,5-dichloropyrimidine (1.39 g, 7.5 mmol) and the reaction mixture was heated to 150 °C overnight. The reaction mixture was allowed to return to room temperature before being poured into brine (100 mL) and EtOAc (100 mL). The organic layer was separated and the aqueous layer was re-extracted with EtOAc (2 x 100 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude mixture was purified *via* silica gel column chromatography (EtOAc/Petroleum Ether 40-60 °C) to give a powdery white solid, 36% (0.416 g). **mp** (from $CHCl_3$) = 115-117 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 3051.4, 727.5 (C-Cl). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.71 (1H, dt, *J* = 8.4, 0.9 Hz), 8.62 (2H, d, *J* = 1.0 Hz), 8.19 (1H, dd, *J* = 3.7, 1.0 Hz), 7.62 (1H, ddd, *J* = 7.8, 1.3, 0.8 Hz), 7.35 (1H, ddd, *J* = 8.5, 7.3, 1.3 Hz), 7.30–7.18 (1H, m), 6.71 (1H, dd, *J* = 3.7, 0.8 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 156.4, 155.7, 135.2, 131.3, 125.8, 125.0, 123.8, 122.4, 120.9, 116.1, 107.5. **HRMS** (ESI): m/z calculated for $C_{12}H_9N_3Cl_1$ requires 230.0485 for $[M+H]^+$, found 230.0480.

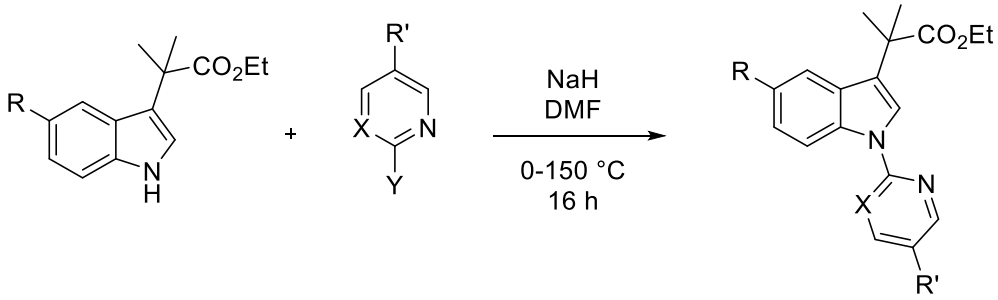
## 3. Synthesis of C-3 Functionalized Materials

General Procedure **A** for the radical C-3 alkylation of indoles



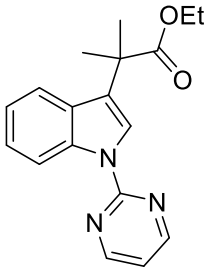

To an oven dried flask was charged relevant indole (2 mmol), ethyl α-bromo isobutyrate (0.95 L, 6 mmol), $[RuCl_2(p\text{-cymene})]_2$ (0.061 g, 0.1 mmol), potassium acetate (0.392 g, 4 mmol), and 1,4-dioxane (8 mL). The vessel was evacuated and refilled with argon three times. The reaction mixture was heated to 120 °C and left to stir for 16 h. The reaction mixture was allowed to return to room temperature and diluted with EtOAc (80 mL) and sat. $NaHCO_3$ solution (80 mL). The organic layer was extracted and the aqueous layer was re-extracted with EtOAc (2 x 20 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude residue was purified *via* silica gel column chromatography using EtOAc/Petroleum Ether 40-60 °C (1:20-1:10, *v:v*) to give pure C-3 functionalized product.

General Procedure **B** for the pyrimidination/pyridination C-3 alkylated indoles



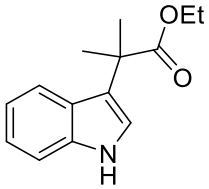

To a solution of C-3 alkylated indole (1 eq) in DMF (0.5-1 M), was added sodium hydride (60% wt. in mineral oil, 1.5 eq) portion-wise. The reaction mixture was allowed to stir at room temperature for 1 hour. To the solution was added 2-chloropyrimidine/2,5-dichloropyrimidine/2-bromopyridine (1.5 eq) and the reaction mixture was heated to 150 °C overnight. The reaction mixture was allowed to return to room temperature before being poured into aqueous LiCl solution (5%, 100 mL) and EtOAc (100 mL). The organic layer was separated and the aqueous layer was re-extracted with EtOAc (2 x 100 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude mixture was purified *via* silica gel column chromatography (EtOAc/Petroleum Ether 40-60 °C, 10-20:90-80 *v:v*) to give *N*-substituted products.

Synthesis of ethyl 2-methyl-2-(1-(pyrimidin-2-yl)-1*H*-indol-3-yl)propanoate (**3a**)



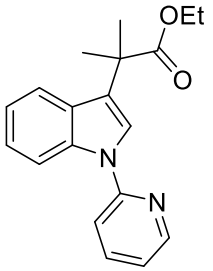

The above compound was synthesized using General Procedure **B** using ethyl 2-(1*H*-indol-3-yl)-2-methylpropanoate (1.16 g, 5 mmol), sodium hydride (60% wt. dispersion in mineral oil, 0.3 g, 7.5 mmol), 2-chloropyrimidine (0.863 g, 7.5 mmol) and DMF (5 mL) Silica gel chromatography gave a white solid, 89% (0.412 g). **mp** (from $CHCl_3$): 113-117 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2981.1, 1725.6, 1579.3, 1562.7. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.82 (1H, dt, *J* = 8.4, 0.9 Hz), 8.69 (2H, d, *J* = 4.8 Hz), 8.17 (1H, s), 7.60 (1H, ddd, *J* = 7.9, 1.3, 0.7 Hz), 7.33 (1H, ddd, *J* = 8.4, 7.1, 1.3 Hz), 7.21 (1H, ddd, *J* = 8.1, 7.1, 1.1 Hz), 7.02 (1H, t, *J* = 4.8 Hz), 4.13 (2H, q, *J* = 7.1 Hz), 1.73 (6H, s), 1.13 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 176.8, 158.2, 157.8, 136.3, 129.5, 123.8, 122.1, 122.0, 120.3, 116.6, 116.0, 61.1, 42.2, 26.1, 14.3. **HRMS** (ESI): m/z calculated for $C_{18}H_{19}N_3O_2$ requires 310.1556 for $[M+H]^+$, found 310.1554.

Synthesis of ethyl 2-(1*H*-indol-3-yl)-2-methylpropanoate (**3b**)



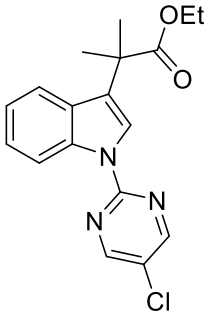

The above compound was synthesized using General Procedure **A** using 1*H*-indole (**1c**), 0.234 g). Silica gel chromatography gave a white solid, 89% (0.412 g). **mp** (from $CHCl_3$): 106-110 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 3409.7, 2979.5, 1709.6. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.02 (1H, s), N*H*), 7.68 (1H, dq, *J* = 8.0, 0.9 Hz), 7.34 (1H, dt, *J* = 8.2, 1.0 Hz), 7.18 (1H, ddd, *J* = 8.2, 7.0, 1.1 Hz), 7.09 (1H, ddd, *J* = 8.1, 7.1, 1.1 Hz), 7.04 (1H, d, *J* = 2.5 Hz), 4.13 (2H, q, *J* = 7.1 Hz), 1.70 (6H, s), 1.16 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.2, 137.0, 125.8, 122.0, 121.1, 120.6, 120.6, 119.5, 111.4, 60.9, 42.2, 26.3, 14.3. **HRMS** (ESI): m/z calculated for $C_{14}H_{17}N_1O_2$ requires 232.1338 for $[M+H]^+$, found 232.1317.

Synthesis of 2-methyl-2-(1-(pyridin-2-yl)-1*H*-indol-3-yl)propanoate (**3h**)



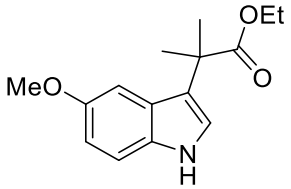

The above compound was synthesized using General Procedure **B** using ethyl 2-(1*H*-indol-3-yl)-2-methylpropanoate (0.231 g, 1 mmol), sodium hydride (60% wt. dispersion in mineral oil, 0.06 g, 1.5 mmol), 2-bromopyridine (0.143 mL, 1.5 mmol, 0.237 g) and DMF (2 mL) Silica gel chromatography gave an amorphous oil, 19% (0.060 g). **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.0, 1723.0, 1591.1. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 8.56 (1H, ddd, *J* = 4.9, 1.9, 0.9 Hz), 8.13 (1H, dt, *J* = 8.3, 0.9 Hz), 7.81 (1H, ddd, *J* = 8.2, 7.4, 1.9 Hz), 7.71–7.63 (2H, m), 7.52 (1H, dt, *J* = 8.3, 0.9 Hz), 7.33–7.24 (1H, m), 7.21–7.13 (2H, m), 4.13 (2H, q, *J* = 7.1 Hz), 1.74 (6H, s), 1.15 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 176.9, 152.4, 149.1, 138.4, 135.9, 128.5, 123.7, 123.2, 122.6, 121.0, 120.7, 120.1, 114.8, 112.9, 61.0, 42.2, 26.2, 14.3. **HRMS** (ESI): m/z calculated for $C_{19}H_{20}N_2O_2$ requires 309.1603 for $[M+H]^+$, found 309.1610.

Synthesis of ethyl 2-methyl-2-(1-(5-chloropyrimidin-2-yl)-1*H*-indol-3-yl)propanoate (**3i**)



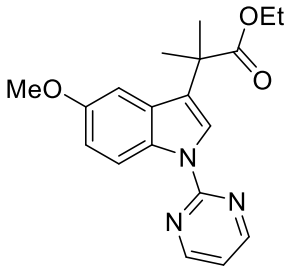

The above compound was synthesized using General Procedure **B** using ethyl 2-(1*H*-indol-3-yl)-2-methylpropanoate (0.231 g, 1 mmol), sodium hydride (60% wt. dispersion in mineral oil, 0.06 g, 1.5 mmol), 2,5-dichloropyrimidine (0.22 g, 1.5 mmol) and DMF (5 mL) Silica gel chromatography gave a white solid, 66% (0.225 g). **mp** (from $CHCl_3$): 120-124 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.3, 1725.00, 1573.4, 1543.1. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.72 (1H, dt, *J* = 8.5, 0.9 Hz), 8.61 (2H, s), 8.09 (1H, s), 7.60 (1H, ddd, *J* = 8.0, 1.2, 0.7 Hz), 7.33 (1H, ddd, *J* = 8.4, 7.1, 1.3 Hz), 7.22 (1H, ddd, *J* = 8.1, 7.2, 1.1 Hz), 4.14 (2H, q, *J* = 7.1 Hz), 1.73 (6H, s), 1.14 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 176.7, 156.5, 155.7, 136.2, 129.6, 125.6, 124.9, 124.0, 122.3, 122.1, 120.4, 116.4, 61.1, 42.2, 26.1, 14.3. **HRMS** (ESI): m/z calculated for $C_{18}H_{18}Cl_1N_3O_2$ requires 344.1166 for $[M+H]^+$, found 344.1159.

Synthesis of ethyl 2-(5-methoxy-1*H*-indol-3-yl)-2-methylpropanoate (**S3b**)



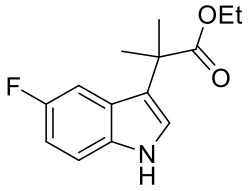

The above compound was synthesized using General Procedure **A** using 5-methoxyindole, 0.294 g). Silica gel chromatography gave a white solid, 69% (0.362 g). **mp** (from $CHCl_3$): 121-126 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 3412.9, 2981.9, 1715.8, 1624.8, 1582.5. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.99 (1H, s), 7.21 (1H, dd, *J* = 8.8, 0.6 Hz), 7.13 (1H, dd, *J* = 2.5, 0.7 Hz), 7.01 (1H, dd, *J* = 2.7, 0.4 Hz), 6.85 (1H, ddd, *J* = 8.8, 2.5, 0.5 Hz), 4.13 (2H, q, *J* = 7.1 Hz), 3.84 (3H, s), 1.68 (6H, s), 1.17 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.2, 153.8, 132.1, 126.1, 121.4, 120.6, 112.2, 112.1, 102.5, 60.9, 56.0, 42.1, 26.1, 14.3. **HMRS** (ESI): m/z calculated for $C_{15}H_{19}N_1O_3$ requires 284.1263 for $[M+Na]^+$, found 284.1284.

Synthesis of ethyl 2-(5-methoxy-1-(pyrimidin-2-yl)-1*H*-indol-3-yl)-2-methylpropanoate (**3n**)



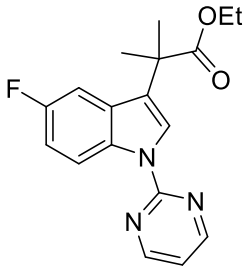

The above compound was synthesized using General Procedure **B** using ethyl 2-(5-methoxy-1*H*-indol-3-yl)-2-methylpropanoate (0.342 g, 1.3 mmol), sodium hydride (60% wt. dispersion in mineral oil, 0.078 g, 1.95 mmol) and 2-chloropyrimidine (0.224 g, 1.95 mmol). Silica gel column chromatography gave a white solid, 82% (0.361 g). **mp** (from $CHCl_3$): 71-75 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2981.2, 1725.5, 1578.8, 1561.6. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.71 (1H, d, *J* = 9.0 Hz), 8.65 (2H, d, *J* = 4.8 Hz), 8.14 (1H, s), 7.06 (1H, d, *J* = 2.5 Hz), 6.99 (1H, t, *J* = 4.8 Hz), 6.95 (1H, dd, *J* = 9.1, 2.6 Hz), 4.14 (2H, q, *J* = 7.1 Hz), 3.86 (3H, s), 1.72 (6H, s), 1.15 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 176.8, 158.1, 157.7, 155.3, 131.2, 130.3, 124.8, 122.6, 117.35, 115.8, 112.5, 103.0, 61.1, 55.8, 42.1, 26.0, 14.3. **HRMS** (ESI): m/z calculated for $C_{19}H_{21}N_3O_3$ requires 340.1661 for $[M+H]^+$, found 340.1670.

Synthesis of ethyl 2-(5-fluoro-1*H*-indol-3-yl)-2-methylpropanoate (**S3c**)



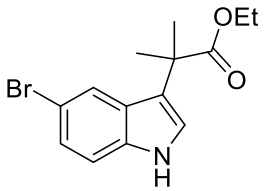

The above compound was synthesized using General Procedure **A** using 5-fluoroindole, 0.270 g). Silica gel chromatography gave an off-white solid, 74% (0.366 g). **mp** (from $CHCl_3$): 97-102 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 3370.7, 2980.0, 1705.3, 1630.2, 1580.5. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.08 (1H, s), 7.34 (1H, ddt, *J* = 10.3, 2.6, 0.6 Hz), 7.23 (1H, ddd, *J* = 8.8, 4.5, 0.5 Hz), 7.07 (1H, d, *J* = 2.5 Hz), 6.92 (1H, td, *J* = 9.0, 2.5 Hz), 4.14 (2H, q, *J* = 7.1 Hz), 1.67 (6H, s), 1.18 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 176.9, 157.6 (d, *J* = 234.1 Hz), 133.5, 126.1 (d, *J* = 10.0 Hz), 122.5, 121.1 (d, *J* = 4.9 Hz), 111.9 (d, *J* = 9.8 Hz), 110.5 (d, *J* = 26.3 Hz), 105.6 (d, *J* = 24.0 Hz), 61.0, 42.1, 26.1, 14.3. **$^{19}$F NMR** (470 MHz, $CDCl_3$) δ -124.5 (td, *J* = 9.8, 4.6 Hz). **HRMS** (ESI): m/z calculated for $C_{14}H_{16}N_1O_2F_1$ requires 250.1243 for $[M+H]^+$, found 250.1243.

Synthesis of ethyl 2-(5-fluoro-1-(pyrimidin-2-yl)-1*H*-indol-3-yl)-2-methylpropanoate (**3o**)



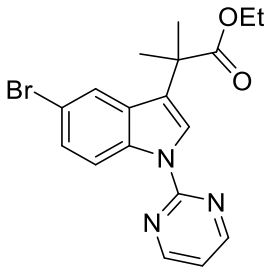

The above compound was synthesized using General Procedure **B** using ethyl 2-(5-fluoro-1*H*-indol-3-yl)-2-methylpropanoate (0.349 g, 1.4 mmol), sodium hydride (60% wt. dispersion in mineral oil, 0.084 g, 2.1 mmol) and 2-chloropyrimidine (0.242 g, 2.1 mmol). Silica gel column chromatography gave a white solid, 66% (0.302 g). **mp** (from $CHCl_3$): 110-114 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.2, 1727.2, 1580.0, 1564.4. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.84–8.74 (1H, m), 8.67 (2H, d, *J* = 4.8 Hz), 8.21 (1H, s), 7.31–7.22 (1H, m), 7.10–6.97 (2H, m), 4.14 (2H, q, *J* = 7.1 Hz), 1.71 (6H, s), 1.16 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 176.5, 158.8 (d, *J* = 238.0 Hz), 158.2, 157.6, 132.7, 130.3 (d, *J* = 9.6 Hz), 124.7 (d, *J* = 4.2 Hz), 123.6, 117.5 (d, *J* = 9.0 Hz), 116.2, 111.5 (d, *J* = 24.8 Hz), 105.9 (d, *J* = 24.2 Hz), 61.2, 42.1, 26.0, 14.3. **$^{19}$F NMR** (470 MHz, $CDCl_3$) δ -121.4 (td, *J* = 9.6, 5.1 Hz). **HRMS** (ESI): m/z calculated for $C_{18}H_{18}N_3O_2F_1$ requires 328.1461 for $[M+H]^+$, found 328.1453.

Synthesis of ethyl 2-(5-bromo-1*H*-indol-3-yl)-2-methylpropanoate (**S3d**)



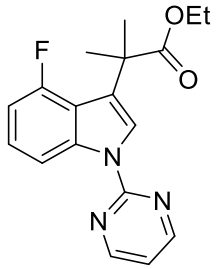

The above compound was synthesized using General Procedure **A** using 5-bromoindole, (0.392 g). Silica gel chromatography gave a light brown solid, 79% (0.490 g). **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 3352.4, 2979.1, 1703.4. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.15 (1H, s), 7.82 (1H, dd, *J* = 1.9, 0.6 Hz), 7.24 (1H, dd, *J* = 8.6, 1.9 Hz), 7.19–7.15 (1H, m), 4.20–4.09 (2H, m), 1.67 (6H, s), 1.20 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 176.9, 135.6, 127.5, 124.9, 123.1, 122.0, 120.6, 112.8, 112.8, 61.1, 42.1, 26.3, 14.3. **HRMS** (ESI): m/z calculated for $C_{14}H_{16}N_1O_2Br_1$ requires 310.0443 for $[M+H]^+$, found 310.0430.

Synthesis of ethyl 2-(5-bromo-1-(pyrimidin-2-yl)-1*H*-indol-3-yl)-2-methylpropanoate (**3p**)




The above compound was synthesized using General Procedure **B** using ethyl 2-(5-bromo-1*H*-indol-3-yl)-2-methylpropanoate (0.440 g, 1.4 mmol), sodium hydride (60% wt. dispersion in mineral oil, 0.084 g, 2.1 mmol) and 2-chloropyrimidine (0.242 g, 2.1 mmol). Silica gel column chromatography gave a white solid, 43% (0.215 g). **mp** (from $CHCl_3$): 113-118 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2981.2, 1723.9, 1575.5, 1563.5. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.70 (1H, dd, *J* = 8.9, 0.5 Hz), 8.68 (2H, d, *J* = 4.8 Hz), 8.17 (1H, s), 7.74 (1H, dd, *J* = 2.0, 0.5 Hz), 7.40 (1H, dd, *J* = 8.9, 2.0 Hz), 7.04 (1H, t, *J* = 4.8 Hz), 4.16 (2H, q, *J* = 7.1 Hz), 1.71 (6H, s), 1.18 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 176.4, 158.2, 157.5, 135.0, 131.2, 126.6, 124.3, 123.3, 123.0, 118.1, 116.4, 115.4, 61.2, 42.1, 26.1, 14.3. **HMRS** (ESI): m/z calculated for $C_{18}H_{18}N_3O_2Br_1$ requires 388.0661 for $[M+H]^+$, found 388.0660.

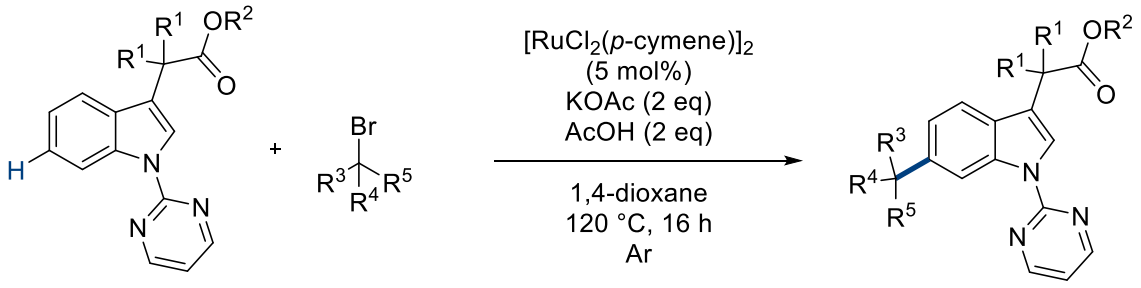
Synthesis of ethyl 2-(4-fluoro-1-(pyrimidin-2-yl)-1*H*-indol-3-yl)-2-methylpropanoate (**S3a**)




The above compound was synthesized using General Procedure **A** using 4-fluoroindole (0.405 g, 3 mmol) and other reagents scaled respectively. Silica gel chromatography gave a white solid which was immediately submitted to General Procedure **B** without analysis. This procedure was followed using sodium hydride (60% wt. dispersion in mineral oil, 0.072 g, 1.8 mmol), 2-chloropyrimidine (0.344 g, 3 mmol) and DMF (5 mL). Silica gel column chromatography gave a white solid, 40% over two steps (0.360 g). **mp** (from $CHCl_3$): 119-121 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2979.9, 2923.8, 1727.0, 1578.6, 1563.2, 1445.3. **$^1$H NMR** (300 MHz, $CDCl_3$) δ 8.69 (2H, d, *J* = 4.8 Hz, Pm*H*), 8.64 (1H, d, *J* = 8.4 Hz, In*H*), 8.13 (1H, s, In*H*), 7.33–7.15 (1H, m, In*H*), 7.05 (1H, t, *J* = 4.8 Hz, Pm*H*), 6.89 (1H, ddd, *J* = 11.0, 8.0, 0.8 Hz, In*H*), 4.16 (2H, q, *J* = 7.1 Hz, $CO_2CH_2CH_3$), 1.72 (6H, s, $C(CH_3)_2$), 1.16 (2H, t, *J* = 7.1 Hz, $CO_2CH_2CH_3$). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 177.1 ($CO_2R$), 158.2 (Ar*C*), 157.6 (d, *J* = 5.8 Hz, Ar*C*), 154.3 (Ar*C*), 138.5 (d, *J* = 10.5 Hz, Ar*C*), 124.6 (d, *J* = 8.0 Hz, Ar*C*), 124.2 (d, *J* = 3.5 Hz, Ar*C*), 122.2 (Ar*C*), 118.2 (d, *J* = 19.9 Hz, Ar*C*), 116.4 (Ar*C*), 112.6 (d, *J* = 3.6 Hz, Ar*C*), 107.9 (d, *J* = 20.6 Hz, Ar*C*), 61.0 ($CO_2CH_2CH_3$), 42.5 ($C(CH_3)_2$), 26.9 ($C(CH_3)_2$), 26.9 ($C(CH_3)_2$), 14.2 ($CO_2CH_2CH_3$). **$^{19}$F NMR** (470 MHz, $CDCl_3$) δ -123.66 (dd, *J* = 10.9, 5.2 Hz). **HRMS** (ESI): m/z calculated for $C_{24}H_{28}N_3O_4$ requires 442.2142 for $[M+H]^+$, found 442.2162.

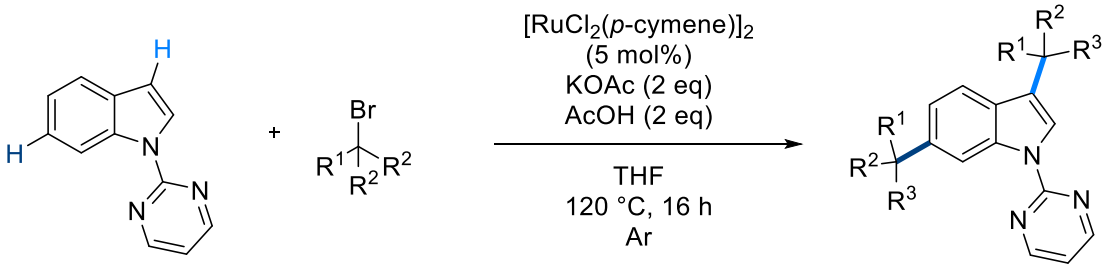
## 4. Synthesis of C-6 Functionalized Materials

General Procedure **C** for the C-3 Stabilised C-6 C-H Radical Alkylation of Indole Derivatives



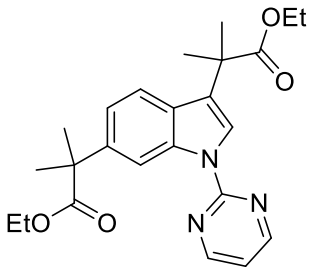

To an oven dried carousel tube was charged relevant C-3 functionalized material (0.25 mmol), α-bromo ester (0.75 mmol), $[RuCl_2(p\text{-cymene})]_2$ (0.0077 g), potassium acetate (0.049 g, 0.5 mmol), acetic acid (0.029 mL, 0.5 mmol, 0.030 g) and 1,4-dioxane (1 mL). The vessel was evacuated and refilled with argon three times. The reaction mixture was heated to 120 °C and left to stir for 16 h. The reaction mixture was allowed to return to room temperature and diluted with EtOAc (20 mL) and sat. $NaHCO_3$ solution (20 mL). The organic layer was extracted and the aqueous layer was re-extracted with EtOAc (2 x 20 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude residue was purified *via* silica gel column chromatography using EtOAc/Petroleum Ether 40-60 °C (1:20-1:10, *v:v*) to give pure C-6 functionalized product.

General Procedure **D** for the One-Pot Sequential C-3/C-6 Alkylation of Indole Derivatives



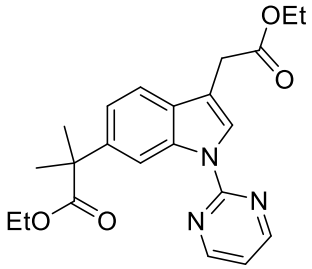

To an oven dried carousel tube was charged relevant indole derivative (0.25 mmol), α-bromo ester (0.75 mmol), $[RuCl_2(p\text{-cymene})]_2$ (0.0077 g), potassium acetate (0.049 g, 0.5 mmol), acetic acid (0.029 mL, 0.5 mmol, 0.030 g) and THF (1 mL). The vessel was evacuated and refilled with argon three times. The reaction mixture was heated to 120 °C and left to stir for 16 h. The reaction mixture was allowed to return to room temperature and diluted with EtOAc (20 mL) and sat. $NaHCO_3$ solution (20 mL). The organic layer was extracted and the aqueous layer was re-extracted with EtOAc (2 x 20 mL). The combined organic layers were dried over $MgSO_4$ and concentrated *in vacuo*. The crude residue was purified *via* silica gel column chromatography using EtOAc/Petroleum Ether 40-60 °C (1:20-1:10, *v:v*) to give a mixture of C-3 functionalized and C-3/C-6 di-functionalized products.

Synthesis of **4a**



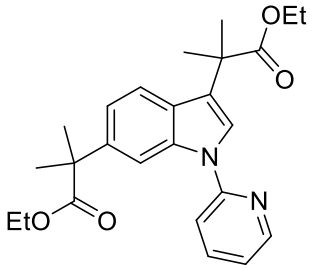

The above compound was synthesized using General Procedure **C** using **3a** (0.077 g) and ethyl α-bromoisobutyrate (0.12 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave a white solid, 80% (0.085 g). **mp** (from $CHCl_3$): 94-99 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2978.7, 1725.1, 1578.1, 1562.8. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.88 (1H, dd, *J* = 1.8, 0.6 Hz), 8.68 (2H, d, *J* = 4.8 Hz), 8.14 (1H, s), 7.54 (1H, dd, *J* = 8.4, 0.6 Hz), 7.19 (1H, dd, *J* = 8.4, 1.8 Hz), 7.01 (1H, t, *J* = 4.8 Hz), 4.14 (4H, m), 1.71 (6H, s), 1.67 (6H, s), 1.20 (3H, t, *J* = 7.1 Hz), 1.15 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.4, 176.7, 158.2, 157.8, 140.9, 136.5, 128.1, 124.8, 122.4, 120.0, 116.0, 113.7, 61.0, 60.9, 47.0, 42.2, 27.2, 26.1, 14.2, 14.2. **HRMS** (ESI): m/z calculated for $C_{24}H_{29}N_3O_4$ requires 424.2236 for $[M+H]^+$, found 424.2254.

Synthesis of **4g**



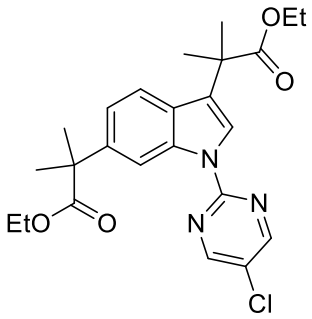

The above compound was synthesized using General Procedure **C** using **3a** (0.070 g) and ethyl α-bromoisobutyrate (0.12 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave an off white amorphous solid, 40% (0.040 g). **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2979.5, 1727.6, 1577.8, 1567.6. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 8.87 (1H, d, *J* = 1.8 Hz), 8.68 (2H, d, *J* = 4.8 Hz), 8.28 (1H, s), 7.54 (1H, d, *J* = 8.4 Hz), 7.28–7.22 (2H, m), 7.03 (1H, t, *J* = 4.8 Hz), 4.45 (1H, d, *J* = 1.4 Hz), 4.24–4.09 (4H, m), 1.68 (6H, s), 1.17-1.13 (3H, m), 0.95–0.85 (3H, m).**$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.28, 172.70, 158.23, 141.04, 135.50, 130.14, 126.37, 120.33, 119.20, 116.30, 113.76, 113.55, 60.95, 60.89, 48.87, 45.64, 27.22, 14.26, 14.21. **HRMS** (ESI): m/z calculated for $C_{22}H_{25}N_3O_4$ requires 418.1745 for $[M+Na]^+$, found 418.1775.

Synthesis of **4h**



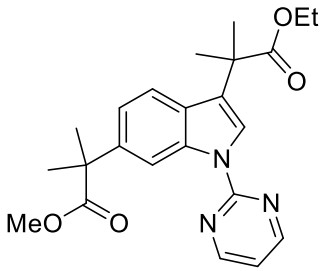

The above compound was synthesized using General Procedure **C** and using 1-(pyridinyl-1-yl)-1*H*-indole (0.049 g) and ethyl α-bromoisobutyrate (0.12 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave an amorphous solid, 55% (0.058 g). **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2979.7, 1723.2, 1589.8, 1555.1. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 8.56 (1H, ddd, *J* = 4.9, 2.0, 0.9 Hz), 8.14 (1H, dd, *J* = 1.7, 0.7 Hz), 7.82 (1H, ddd, *J* = 8.2, 7.4, 2.0 Hz), 7.60 (2H, d, *J* = 8.9 Hz), 7.48 (1H, dt, *J* = 8.2, 0.9 Hz), 7.22–7.12 (2H, m), 4.17–4.08 (4H, m), 1.71 (6H, s), 1.64 (6H, s), 1.22–1.14 (6H, m). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.2, 176.8, 152.4, 149.2, 140.2, 138.5, 136.0, 127.1, 123.4, 122.9, 120.5, 120.1, 119.3, 114.9, 109.8, 61.0, 60.9, 46.8, 42.2, 27.1, 26.2, 14.3, 14.2. **HRMS** (ESI): m/z calculated for $C_{25}H_{30}N_2O_4$ requires 445.2103 for $[M+Na]^+$, found 445.2112.

Synthesis of **4i**



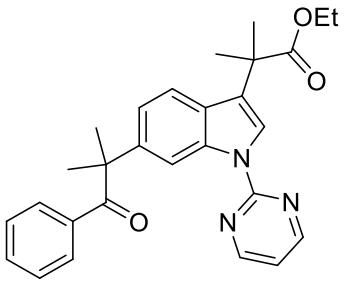

The above compound was synthesized using General Procedure **C** using 1-(5-chloropyrimidin-2yl)-1*H*-indole (0.057 g, 0.25 mmol) and ethyl α-bromoisobutyrate (0.12 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave a white solid, 40% (0.046 g). **mp** (from $CHCl_3$): 129-133 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.0, 1725.6, 1573.3. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.77 (1H, dd, *J* = 1.9, 0.6 Hz), 8.62 (2H, s), 8.06 (1H, s), 7.53 (1H, dd, *J* = 8.4, 0.6 Hz), 7.21 (1H, dd, *J* = 8.4, 1.8 Hz), 4.18-4.10 (4H, m), 1.71 (6H, s), 1.66 (6H, s), 1.20 (3H, t, *J* = 7.1 Hz), 1.15 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.2, 176.6, 156.5, 155.7, 141.1, 136.3, 128.16, 125.4, 124.9, 122.4, 120.4, 120.2, 113.6, 61.1, 60.9, 47.0, 42.2, 27.1, 26.0, 14.2. **HRMS** (ESI): m/z calculated for $C_{24}H_{28}Cl_1N_3O_4$ requires 458.1847 for $[M+H]^+$, found 458.1855.

Synthesis of **4j**



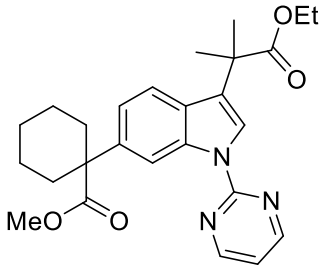

The above compound was synthesized using General Procedure **C** using **3a** (0.077 g) and ethyl α-bromoisobutyrate (0.12 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave a white solid, 65% (0.066 g). **mp** (from $CHCl_3$): 81-85 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2977.6, 1727.5, 1578.0, 1562.7. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.88 (1H, dd, *J* = 1.9, 0.6 Hz), 8.68 (2H, d, *J* = 4.8 Hz), 8.14 (1H, s), 7.54 (1H, dd, *J* = 8.4, 0.6 Hz), 7.18 (1H, dd, *J* = 8.4, 1.9 Hz), 7.01 (1H, t, *J* = 4.8 Hz), 4.12 (2H, q, *J* = 7.1 Hz), 3.67 (3H, s), 1.71 (6H, s), 1.68 (6H, s), 1.15 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.9, 176.7, 158.2, 157.8, 140.6, 136.5, 128.2, 124.8, 122.4, 120.1, 120.1, 116.0, 113.6, 61.0, 52.3, 47.0, 42.2, 27.1, 26.1, 14.2. **HRMS** (ESI): m/z calculated for $C_{23}H_{27}N_3O_4$ requires 432.1902 for $[M+Na]^+$, found 432.1947.

Synthesis of **4k**



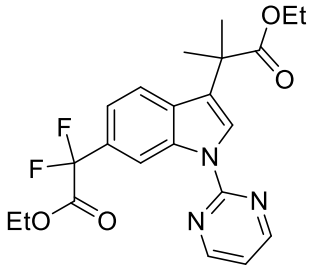

The above compound was synthesized using General Procedure **C** using **3a** (0.077 g) and 2-bromo isobutyrophenone (0.15 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave an amorphous solid, 26% (0.030 g). **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.8, 1727.3, 1676.5, 1577.8, 1565.8. **$^{1}$H NMR** (500 MHz, $CD_3OD$) δ 8.94 (1H, dd, *J* = 1.8, 0.6 Hz), 8.72 (2H, d, *J* = 4.8 Hz), 8.20 (1H, s), 7.52 (1H, dd, *J* = 8.4, 0.6 Hz), 7.50–7.47 (2H, m), 7.36–7.28 (1H, m), 7.20–7.16 (2H, m), 7.14 (1H, t, *J* = 4.8 Hz), 7.11 (1H, dd, *J* = 8.3, 1.8 Hz), 4.10 (2H, q, *J* = 7.1 Hz), 1.69 (6H, s), 1.66 (6H, s), 1.08 (3H, t, *J* = 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CD_3OD$) δ 178.2, 159.62, 158.8, 142.2, 138.1, 137.9, 132.8, 130.7, 129.4, 129.0, 125.7, 123.7, 121.5, 121.1, 117.7, 114.7, 62.1, 52.8, 43.2, 28.7, 26.3, 14.4. **HRMS** (ESI): m/z calculated for $C_{28}H_{29}N_3O_3$ requires 456.2287 for $[M+H]^+$, found 456.2307.

Synthesis of **4l**



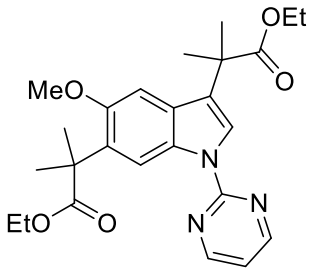

The above compound was synthesized using General Procedure **C** using **3a** (0.077 g) and methyl 1-bromo-1-cyclohexanecarboxylate (0.12 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave an amorphous solid, 14% (0.016 g). **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2924.8, 2854.9, 1726.0, 1578.0, 1562.6, 1438.7. **$^{1}$H NMR** (300 MHz, $CDCl_3$) δ 8.93 (1H, dd, *J* = 1.8, 0.6 Hz, In*H*), 8.70 (2H, d, *J* = 4.8 Hz, Pm*H*), 8.13 (1H, s, In*H*), 7.52 (1H, dd, *J* = 8.5, 0.6 Hz, In*H*), 7.37–7.13 (1H, m, In*H*), 7.03 (1H, t, *J* = 4.8 Hz, Pm*H*), 4.12 (2H, q, *J* = 7.1 Hz, $CO_2C\mathit{H}_2CH_3$), 3.65 (3H, s, $CO_2C\mathit{H}_3$).2.61 (2H, d, J = 13.0 Hz, Cy*H*), 1.96–1.55 (10H, m, Cy*H* & $C(C\mathit{H}_3)_2$), 1.55–1.47 (2H, m, Cy*H*), 1.37–1.28 (2H, m, Cy*H*), 1.15 (3H, t, J = 7.1 Hz, $CO_2CH_2C\mathit{H}_3$), 0.94–0.79 (2H, m, Cy*H*). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 176.8 ($\mathit{C}O_2R$), 176.3 ($\mathit{C}O_2R$), 158.2 (Ar*C*), 157.8 (Ar*C*), 139.9 (Ar*C*), 136.6 (Ar*C*), 128.2 (Ar*C*), 124.7 (Ar*C*), 122.4 (Ar*C*), 120.10 (Ar*C*), 116.0 (Ar*C*), 114.0 (Ar*C*), 67.9 ($CO_2\mathit{C}H_2R$), 66.2 ($CO_2\mathit{C}H_2R$), 61.1 ($\mathit{C}(CH_3)_2$), 52.1 (*C*(Cy)), 51.4 (Alk*C*H), 42.2 (Alk*C*H), 35.4 (Alk*C*H), 29.8 (Alk*C*H), 26.1 (Alk*C*H), 24.0 (Alk*C*H), 14.3 (Alk*C*H). **HRMS** (ESI): m/z calculated for $C_{27}H_{33}N_3O_4$ requires 472.2215 for $[M+Na]^+$, found 472.2216.

Synthesis of **4m**

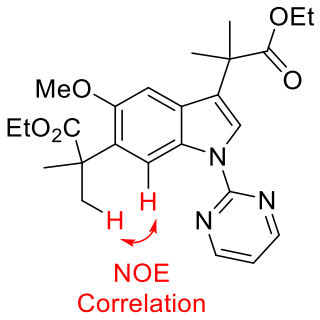


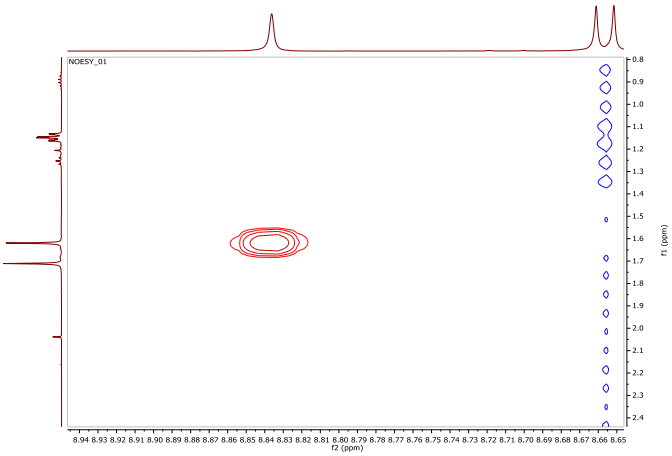

The above compound was synthesized using General Procedure **C** using **3a** (0.077 g) ethyl bromodifluoroacetate (0.096 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave an amorphous solid, 16% (0.017 g). **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2983.7, 2922.8, 1764.4, 1727.4, 1578.2, 1566.7, 1452.9. **$^{1}$H NMR** (300 MHz, $CDCl_3$) δ 9.15 (1H, dd, *J* = 1.7, 0.8 Hz, *In*H), 8.73 (2H, d, *J* = 4.8 Hz, Pm*H*), 8.28 (1H, s, In*H*), 7.66 (1H, dd, *J* = 8.4, 0.8 Hz, In*H*), 7.44 (1H, dd, *J* = 8.4, 1.7 Hz, In*H*), 7.09 (1H, t, *J* = 4.8 Hz, Pm*H*), 4.32 (2H, q, *J* = 7.1 Hz, $CO_2CH_2CH_3$), 4.12 (2H, q, *J* = 7.1 Hz, $CO_2CH_2CH_3$), 1.72 (6H, s, $C(CH_3)_2$), 1.32 (3H, t, *J* = 7.2 Hz, $CO_2CH_2CH_3$), 1.14 (3H, t, *J* = 7.1 Hz, $CO_2CH_2CH_3$). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 176.6 ($CO_2$R), 158.3 ($CO_2$R), 157.5 (Ar*C*), 135.6 (Ar*C*), 124.7 (Ar*C*), 124.2 (Ar*C*), 120.5 (Ar*C*), 119.0 (Ar*C*), 116.6 (Ar*C*), 114.3 (Ar*C*), 63.2 ($CO_2CH_2CH_3$), 61.2 ($CO_2CH_2CH_3$), 42.1 ($C(CH_3)_2$), 28.0 (d, *J* = 285.6 Hz, $CF_2$), 14.3 ($CO_2CH_2CH_3$), 14.1 ($CO_2CH_2CH_3$). **$^{19}$F NMR** (470 MHz, $CDCl_3$) δ -101.51. **HRMS** (ESI): m/z calculated for $C_{22}H_{23}N_3O_4F_2$ requires 432.1758 for $[M+H]^+$, found 432.1735.

Synthesis of **4p**

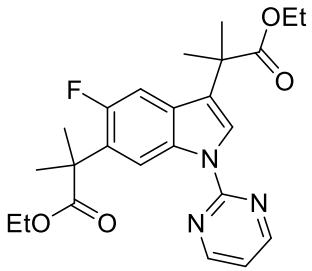



The above compound was synthesized using General Procedure **C**, using ethyl 2-(5-methoxy-1-(pyrimidin-2-yl)-1*H*-indol-3-yl)-2-methylpropanoate (0.085 g, 0.25 mmol), and ethyl α-bromoisobutyrate (0.12 mL, 0.75 mmol). Silica gel column chromatography gave a white solid, 92% (0.104 g). **mp** (from $CHCl_3$): 122-128 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.9, 1726.2, 1578.5, 1562.7. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.84 (1H, s), 8.66 (2H, d, *J* = 4.7 Hz), 8.11 (1H, s), 7.01 (1H, s), 6.98 (1H, t, *J* = 4.8 Hz), 4.12 (4H, app qd, *J* = 7.1, 2.4 Hz), 3.80 (3H, s), 1.71 (6H, s), 1.62 (6H, s), 1.15 (6H, app td, *J* = 7.1, 1.8 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 178.4, 176.8, 158.1, 157.7, 152.9, 131.4, 130.9, 128.6, 124.5, 122.1, 115.8, 113.9, 101.4, 61.0, 60.4, 55.4, 44.9, 42.1, 26.2, 26.0, 14.3, 14.3. **HRMS** (ESI): m/z calculated for $C_{25}H_{31}N_3O_5$ requires 454.2342 for $[M+H]^+$, found 454.2371.

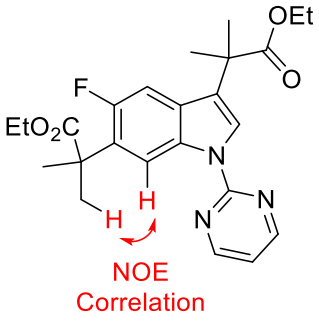


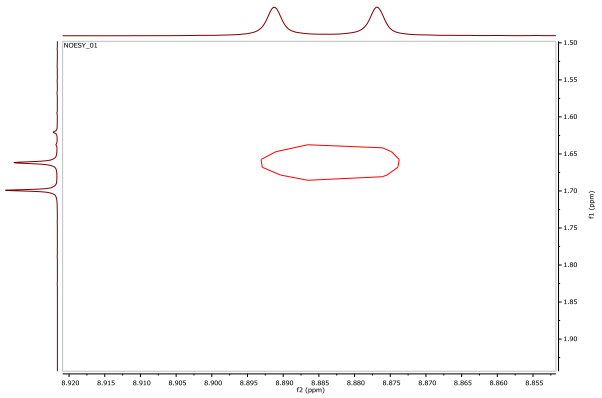



Synthesis of **4q**

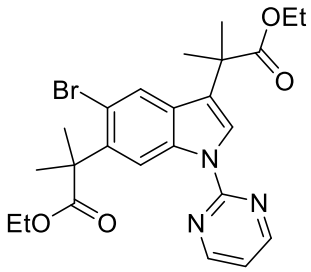



The above compound was synthesized using General Procedure **C**, using ethyl 2-(5-fluoro-1-(pyrimidin-2-yl)-1*H*-indol-3-yl)-2-methylpropanoate (0.082 g, 0.25 mmol), and ethyl α-bromoisobutyrate (0.12 mL, 0.75 mmol). Silica gel column chromatography gave a white solid, 87% (0.096 g). **mp** (from $CHCl_3$): 117-121 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2981.0, 1729.3, 1579.0, 1565.0. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.88 (1H, d, *J* = 7.2 Hz), 8.68 (2H, d, *J* = 4.8 Hz), 8.18 (1H, s), 7.25 (1H, d, *J* = 12.0 Hz), 7.04 (1H, t, *J* = 4.8 Hz), 4.15 (4H, app dq, *J* = 15.5, 7.1 Hz), 1.70 (6H, s), 1.66 (6H, s), 1.17 (6H, app dt, *J* = 8.6, 7.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.3, 176.4, 158.2, 157.9, 156.8 (d, *J* = 207.0 Hz), 132.7, 129.1 (d, *J* = 16.2 Hz), 128.8 (d, *J* = 10.1 Hz), 124.5 (d, *J* = 3.9 Hz), 123.4, 116.2, 114.3 (d, *J* = 5.1 Hz), 106.2 (d, *J* = 25.8 Hz), 61.0 (d, *J* = 25.7 Hz), 44.7, 42.2, 26.3, 26.0, 14.23, 14.19. **$^{19}$F NMR** (470 MHz, $CDCl_3$) δ -121.0 (dd, *J* = 12.0, 7.2 Hz). **HRMS** (ESI): m/z calculated for $C_{24}H_{28}N_3O_4F_1$ requires 442.2142 for $[M+H]^+$, found 442.2173.

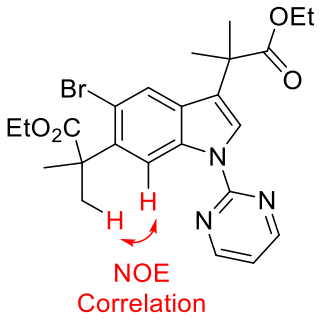


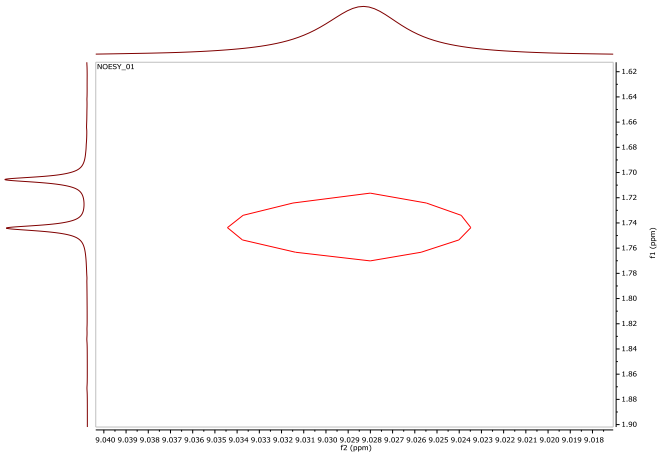



Synthesis of **4r**

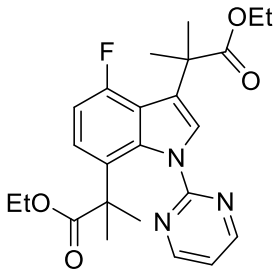



The above compound was synthesized using General Procedure **C**, using ethyl 2-(5-bromo-1-(pyrimidin-2-yl)-1*H*-indol-3-yl)-2-methylpropanoate (0.097 g, 0.25 mmol), and ethyl α-bromoisobutyrate (0.12 mL, 0.75 mmol). Silica gel column chromatography gave a white solid, 55% (0.069 g). **mp** (from $CHCl_3$): 130-134 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2989.2, 1723.3, 1576.4, 1563.4, 1461.9, 1435.5. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 9.03 (1H, s), 8.67 (2H, d, *J* = 4.8 Hz), 8.16 (1H, s), 7.82 (1H, s), 7.02 (1H, t, *J* = 4.8 Hz), 4.16 (4H, dq, *J* = 11.0, 7.1 Hz), 1.74 (6H, s), 1.71 (6H, s), 1.19 (6H, td, *J* = 7.1, 4.1 Hz). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.5, 176.3, 158.2, 157.5, 138.9, 135.5, 129.5, 125.5, 123.9, 123.4, 117.0, 116.3, 115.5, 61.2, 61.2, 48.5, 42.1, 27.1, 26.1, 14.2, 14.1. **HRMS** (ESI): m/z calculated for $C_{14}H_{28}N_3O_4Br_1$ requires 524.1160 for $[M+Na]^+$, found 524.1184.



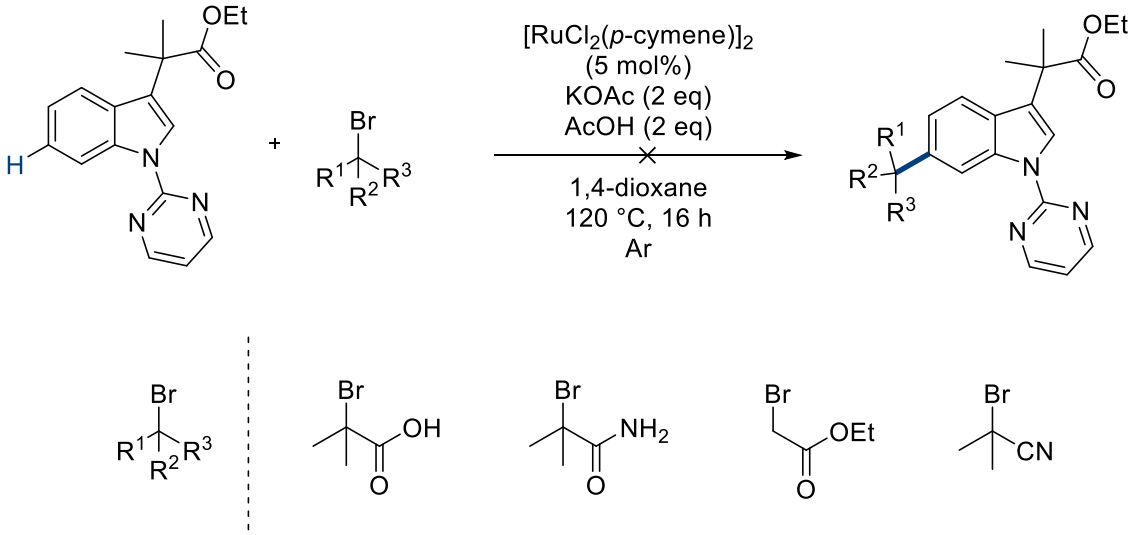



Synthesis of **S4a**



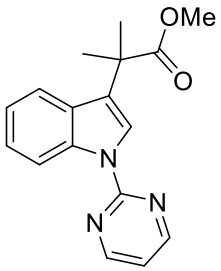

The above compound was synthesized using General Procedure **C**, using ethyl 2-(4-fluoro-1-(pyrimidin-2-yl)-1*H*-indol-3-yl)-2-methylpropanoate (0.082 g, 0.25 mmol), and ethyl α-bromoisobutyrate (0.12 mL, 0.75 mmol). Silica gel column chromatography gave an amorphous solid, 14% (0.015 g). **$^{1}$H NMR** (300 MHz, Chloroform-*d*) δ 8.76 – 8.60 (m, 3H), 8.10 (d, *J* = 0.6 Hz, 1H), 7.06 (t, *J* = 4.8 Hz, 1H), 6.90 (dd, *J* = 12.6, 1.5 Hz, 1H), 4.21 – 4.10 (m, 4H), 1.69 (s, 6H), 1.65 (s, 6H), 1.22 (d, *J* = 7.1 Hz, 2H), 1.22 – 1.11 (m, 4H). **$^{13}$C NMR** (75 MHz, $CDCl_3$) δ 177.0 (*C*$O_2$R), 176.9 (*C*$O_2$R), 158.2 (Ar*C*), 157.4 (d, *J* = 41.5 Hz, Ar*C*), 153.9 (Ar*C*), 142.4 (d, *J* = 7.0 Hz, Ar*C*), 138.4 (d, *J* = 11.0 Hz, Ar*C*), 124.0 (d, *J* = 3.4 Hz, Ar*C*), 122.4 (Ar*C*), 116.8 (d, *J* = 20.5 Hz, Ar*C*), 116.4 (Ar*C*), 109.9 (d, *J* = 3.5 Hz, Ar*C*), 106.2 (d, *J* = 21.6 Hz, Ar*C*), 61.02 ($CO_2CH_2CH_3$) 61.00 ($CO_2CH_2CH_3$), 46.9 (d, *J* = 1.6 Hz, ($C(CH_3)_2$), 42.5 ($C(CH_3)_2$), 29.9 ($C(CH_3)_2$), 27.0 ($C(CH_3)_2$), 26.8 ($CO_2CH_2CH_3$), 14.2 ($CO_2CH_2CH_3$). **HRMS** (ESI): m/z calculated for $C_{24}H_{28}N_3O_4F_1$ requires 442.2142 for $[M+H]^+$, found 442.2162.

**Unsuccessful Coupling Partners**

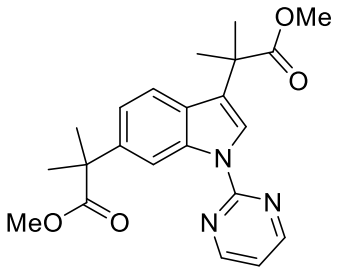


Synthesis of **3s** and **4s**

The above compounds were synthesized using General Procedure **D** using methyl α-bromoisobutyrate (0.10 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave two separable products **3s** (57%, 0.042 g) and **4s** (41%, 0.040 g).



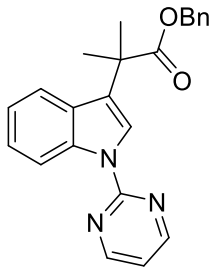

**3s. mp** (from $CHCl_3$): 110-114 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.4, 1727.2, 1578.8, 1562.5. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.84 (1H, d, *J* = 8.4 Hz), 8.67 (2H, d, *J* = 4.8 Hz), 8.19 (1H, s), 7.58 (1H, d, *J* = 7.9 Hz), 7.34 (1H, ddd, *J* = 8.4, 7.1, 1.3 Hz), 7.23 (1H, ddd, *J* = 8.1, 7.1, 1.1 Hz), 7.00 (1H, t, *J* = 4.8 Hz), 3.66 (3H, s), 1.75 (6H, s).**$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.4, 158.1, 158.1, 157.8, 136.3, 129.4, 124.9, 123.8, 122.10, 122.05, 120.0, 116.6, 116.0, 52.4, 42.1, 26.1. **HRMS** (ESI): m/z calculated for $C_{17}H_{17}N_3O_2$ requires 296.1399 for $[M+H]^+$, found 296.1383.



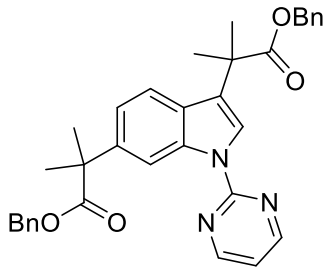

**4s. mp** (from $CHCl_3$): 108-112 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.9, 1726.2, 1578.0, 1562.6 **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.89 (1H, dd, *J* = 1.8, 0.6 Hz), 8.68 (2H, d, *J* = 4.8 Hz), 8.15 (1H, s), 7.52 (1H, dd, *J* = 8.4, 0.6 Hz), 7.19 (1H, dd, *J* = 8.4, 1.8 Hz), 7.01 (1H, t, *J* = 4.8 Hz), 3.67 (3H, s), 3.65 (3H, s), 1.72 (6H, s), 1.69 (6H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.9, 177.3, 158.2, 157.8, 140.6, 136.5, 128.1, 124.6, 122.4, 120.2, 119.9, 116.0, 113.7, 52.4, 52.3, 47.0, 42.1, 27.1, 26.1. **HRMS** (ESI): m/z calculated for $C_{22}H_{25}N_3O_4$ requires 418.1800 for $[M+Na]^+$, found 418.1816.

Synthesis of **3t** and **4t**

The above compounds were synthesized using General Procedure **D** using benzyl α-bromoisobutyrate (0.13 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave two amorphous solids), **3t** (55%, 0.051 g) and **4t** (31%, 0.048 g).



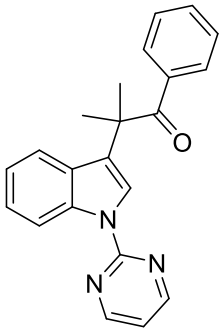

**3t. FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.9, 1726.2, 1578.7, 1562.0. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 8.83 (1H, dt, *J* = 8.4, 0.9 Hz), 8.67 (2H, d, *J* = 4.8 Hz), 8.18 (1H, s), 7.54 (1H, dt, *J* = 8.0, 0.9 Hz), 7.33 (1H, ddd, *J* = 8.4, 7.1, 1.2 Hz), 7.30–7.21 (2H, m), 7.21–7.11 (3H, m), 7.00 (1H, t, *J* = 4.8 Hz), 5.12 (2H, s), 1.77 (6H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 176.6, 158.2, 157.8, 136.3, 136.2, 129.4, 128.5, 128.0, 127.98, 127.97, 124.8, 123.8, 122.1, 122.0, 120.3, 116.5, 116.0, 66.7, 42.3, 26.1. **HRMS** (ESI): m/z calculated for $C_{23}H_{21}N_3O_2$ requires 372.1712 for $[M+H]^+$, found 372.1727.



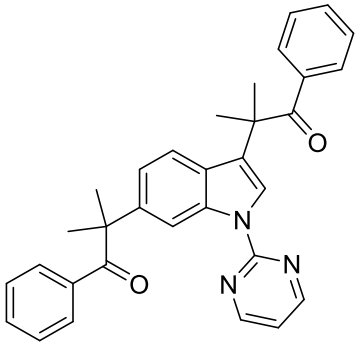

**4t. FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2978.1, 1725.8, 1577.5, 1562.4. **$^{1}$H NMR** (500 MHz, $CDCl_3$) δ 8.91 (1H, d, *J* = 1.7 Hz), 8.65 (2H, d, *J* = 4.8 Hz), 8.17 (1H, s), 7.44 (1H, d, *J* = 8.4 Hz), 7.30–7.19 (7H, m), 7.18–7.10 (3H, m), 7.00 (1H, t, *J* = 4.8 Hz), 5.15 (2H, s), 5.12 (2H, s), 1.75 (6H, s), 1.73 (6H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.0, 176.5, 158.1, 157.8, 140.5, 136.5, 136.4, 136.2, 128.4, 128.1, 128.0, 128.0, 127.9, 127.8, 127.7, 124.5, 122.5, 120.2, 120.0, 116.0, 113.8, 66.7, 66.5, 47.1, 42.3, 27.1, 26.0. **HRMS** (ESI): m/z calculated for $C_{34}H_{33}N_3O_4$ requires 548.2549 for $[M+H]^+$, found 548.2539.

Synthesis of **3u** and **4u**

The above compounds were synthesized using General Procedure **D** using 2-bromoisobutyrophenone (0.15 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave two off white solids), **3u** (38%, 0.032 g) and **4u** (12%, 0.015 g).



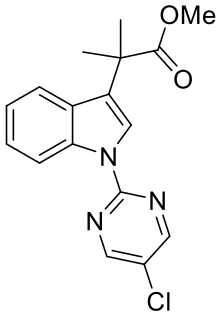

**3u. mp** (from $CHCl_3$): 120-128 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.8, 1673.4, 1577.9, 1562.5. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.82 (1H, dt, *J* = 8.4, 0.9 Hz), 8.74 (2H, d, *J* = 4.8 Hz), 8.34 (1H, s), 7.79–7.71 (2H, m), 7.45 (1H, ddd, *J* = 8.0, 1.2, 0.7 Hz), 7.35–7.26 (2H, m), 7.21–7.15 (2H, m), 7.14–7.07 (2H, m), 1.78 (6H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 204.5, 158.3, 137.3, 136.4, 131.9, 129.5, 129.1, 128.1, 125.8, 124.2, 122.4, 121.4, 120.4, 116.5, 116.3, 47.3, 27.3. **HRMS** (ESI): m/z calculated for $C_{22}H_{19}N_3O$ requires 364.1426 for $[M+Na]^+$, found 364.1417.



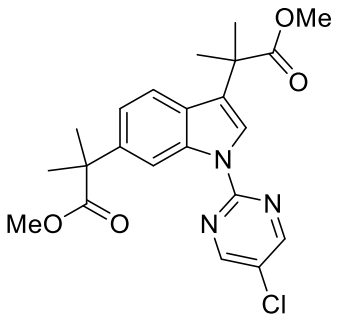

**4u. mp** (from $CHCl_3$): 106-110 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2980.7, 1674.4, 1577.1, 1562.8. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.86 (1H, dd, *J* = 1.8, 0.6 Hz), 8.72 (2H, d, *J* = 4.8 Hz), 8.33 (1H, s), 7.72 (2H, dd, *J* = 8.5, 1.2 Hz), 7.46–7.37 (3H, m), 7.35–7.31 (1H, m), 7.31–7.24 (2H, m), 7.21–7.16 (2H, m), 7.13–7.08 (2H, m), 7.08–7.05 (2H, m), 1.77 (6H, s), 1.65 (6H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 204.6, 204.2, 158.4, 157.8, 141.4, 137.4, 137.0, 136.7, 131.8, 131.5, 129.8, 129.0, 128.3, 128.1, 127.9, 125.5, 121.9, 120.7, 120.5, 116.3, 113.8, 51.9, 47.3, 28.3, 27.2. **HRMS** (ESI): m/z calculated for $C_{32}H_{29}N_3O_2$ requires 488.2338 for $[M+H]^+$, found 488.2360.

Synthesis of **3v** and **4v**

The above compounds were synthesized using General Procedure **A** using 1-(5-chloropyrimidin-2yl)-1*H*-indole (0.057 g, 0.25 mmol) and methyl α-bromoisobutyrate (0.10 mL, 0.75 mmol) as coupling partner. Silica gel chromatography gave two white solids), **3t** (39%, 0.032 g) and **4t** (30%, 0.032 g).



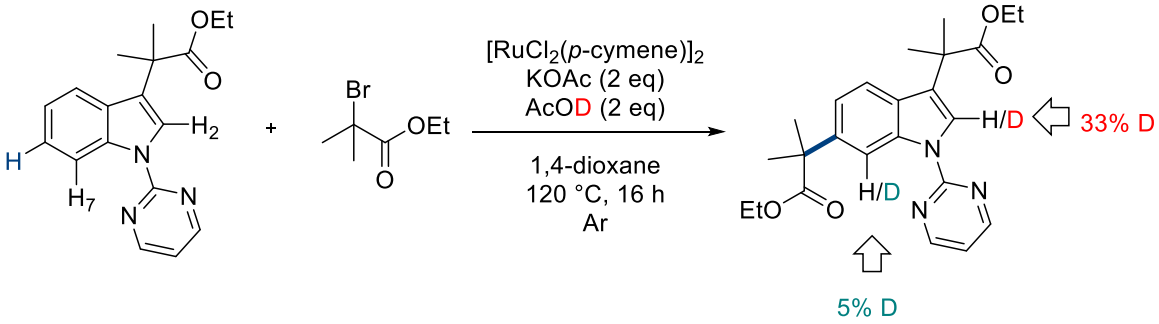

**3v. mp** (from $CHCl_3$): 151-153 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2981.5, 1729.4, 1573.5, 1544.3. **$^1$H NMR** (500 MHz, Chloroform-*d*) δ 8.72 (1H, dd, *J* = 8.4, 0.9 Hz), 8.60 (2H, d, *J* = 0.7 Hz), 8.10 (1H, d, *J* = 0.8 Hz), 7.57 (1H, dd, *J* = 7.9, 1.1 Hz), 7.34 (1H, dd, *J* = 8.3, 7.2 Hz), 7.26–7.19 (1H, m), 3.66 (3H, s), 1.74 (6H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.2, 156.4, 155.7, 136.2, 129.5, 125.5, 124.9, 124.1, 122.4, 122.1, 120.2, 116.5, 52.4, 42.1, 26.1. **HRMS** (ESI): m/z calculated for $C_{17}H_{16}Cl_1N_3O_2$ requires 352.0829 for $[M+Na]^+$, found 352.81800.



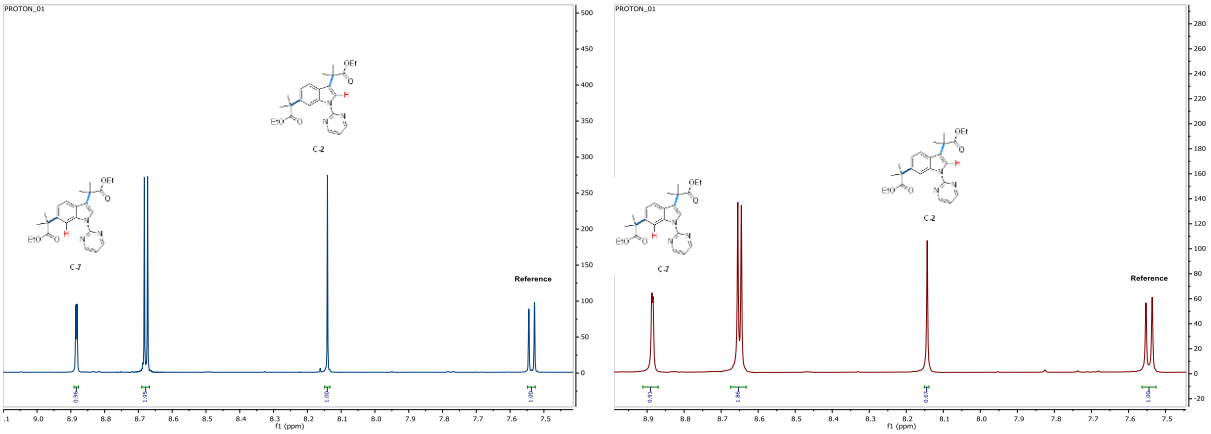

**4v. mp** (from $CHCl_3$): 142-148 °C. **FT-IR** (thin film): $\nu_{max}$ ($cm^{-1}$) = 2979.6, 1728.3, 1573.5, 1545.1. **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.78 (1H, dd, *J* = 1.8, 0.6 Hz), 8.63 (2H, s), 8.07 (1H, s), 7.51 (1H, dd, *J* = 8.4, 0.6 Hz), 7.20 (1H, dd, *J* = 8.4, 1.8 Hz), 3.67 (3H, s), 3.65 (3H, s), 1.71 (6H, s), 1.68 (6H, s). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 177.8, 177.1, 156.5, 155.7, 140.9, 136.4, 128.2, 125.2, 125.0, 122.5, 120.5, 120.1, 113.6, 52.5, 52.3, 47.0, 42.1, 27.1, 26.1. **HRMS** (ESI): m/z calculated for $C_{22}H_{24}Cl_1N_3O_4$ requires 452.1500 for $[M+Na]^+$, found 452.1374.

## 5. Deuterium Experiments

**Deuterium incorporation experiment on C-3 substituted indole**




**3a** **2a** **4a**: 74%

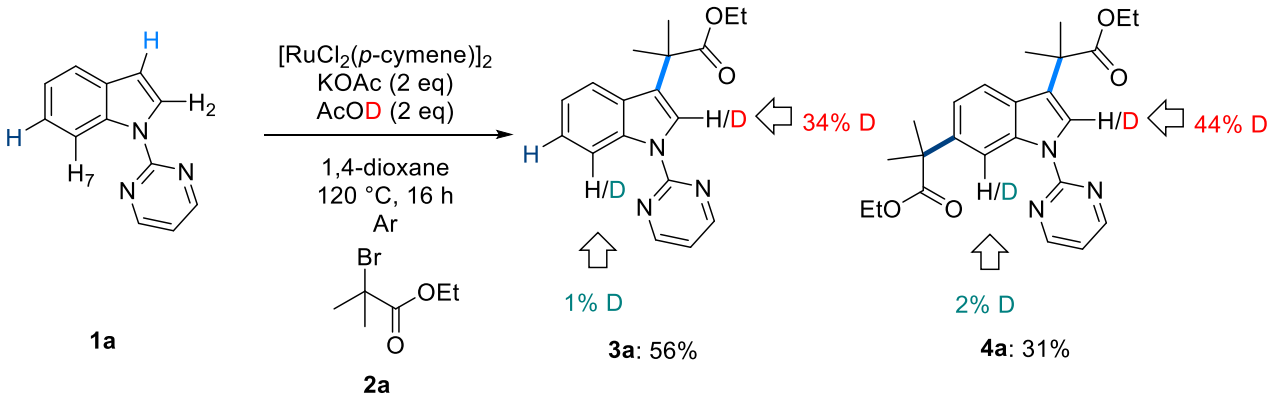



| Regular Spectra | Deuterium Incorpoation Spectra |
|---|---|
| C-2: 1.00 | C-2: 0.67 |
| C-7: 0.96 | C-7: 0.91 |

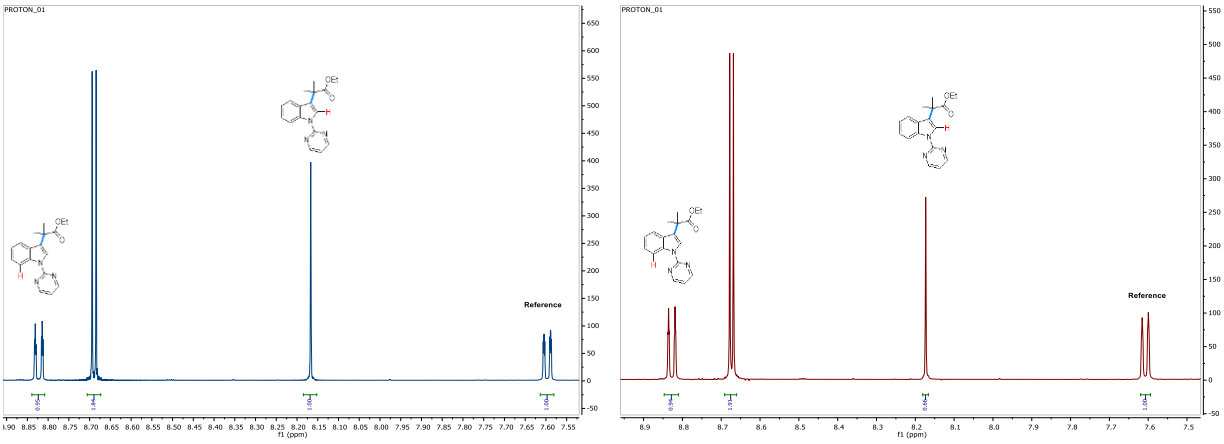
Deuterium incorporation at C-2 = **33%**

Deuterium incorporation at C-7 = **5%**

**Deuterium incorporation experiment on one-pot C-3/C-6 alkylation**




**3a** - Mono

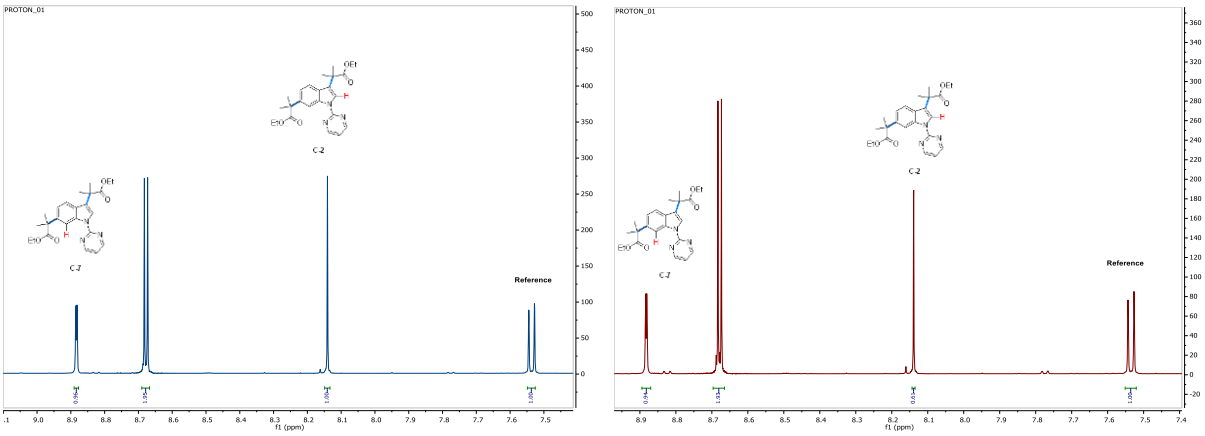



| Regular Spectra | Deuterium Incorporation Spectra |
|---|---|
| C-2: 1.00 | C-2: 0.66 |
| C-7: 0.95 | C-7: 0.94 |

Deuterium incorporation at C-2 = **34%**

Deuterium incorporation at C-7 = **1%**

**4a** - Di



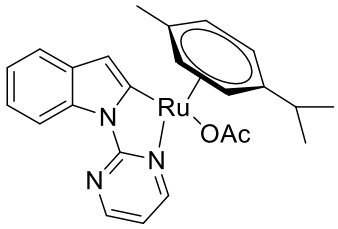

| Regular Spectra | Deuterium Incorporation Spectra |
|---|---|
| C-2: 1.00 | C-2: 0.61 |
| C-7: 0.96 | C-7: 0.94 |

Deuterium incorporation at C-2 = **39%**

Deuterium incorporation at C-7 = **2%**

## 6. Organometallic Work

Synthesis of **1a**-[Ru]-OAc




To an oven dried Schlenk flask was added $[RuCl_2(p\text{-cymene})]_2$ (0.239 g, 0.39 mmol), **1a** (0.150 g, 0.77 mmol) and potassium acetate (0.153 g, 1.56 mmol). The flask was evacuated and refilled with argon three times. Anhydrous methanol (5 mL) was then added *via* septum and the reaction mixture was stirred at 40 °C for 24 h. The mixture was filtered under a blanket of $N_2$, eluting with anhydrous methanol. The filtrate was then kept in the freezer for 7 days. The deep red crystals that formed in the filtrate were collected *via* vacuum filtration, giving **1a**-[Ru]-OAc, 32% (0.120 g). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 9.10 (1H, dd, *J* = 5.6, 2.3 Hz), 8.61 (1H, dd, *J* = 4.6, 2.3 Hz), 8.37 (1H, dq, *J* = 8.0, 0.9 Hz), 7.40 (1H, ddd, *J* = 7.7, 1.2, 0.7 Hz), 7.19–7.09 (1H, m), 7.03 (1H, ddd, *J* = 8.3, 7.2, 1.2 Hz), 6.89–6.81 (2H, m), 5.72 (1H, dd, *J* = 6.0, 1.2 Hz), 5.54 (1H, dd, *J* = 6.0, 1.2 Hz), 5.28 (1H, dd, *J* = 6.0, 1.2 Hz), 5.12 (1H, dd, *J* = 6.0, 1.2 Hz), 3.47 (3H, s), Ac*H*), 2.62 (1H, hept, *J* = 6.9 Hz), C*H*$(CH_3)_2$), 2.07 (3H, s), ArC*H*$_3$), 1.11 (3H, d, *J* = 7.0 Hz), CH(C*H*$_3)_2$), 0.97 (3H, d, *J* = 6.9 Hz), CH(C*H*$_3)_2$). **$^{13}$C NMR** (126 MHz, $CDCl_3$) δ 165.59 (*C*=O), 162.47, 158.97, 136.45, 135.09, 122.55, 120.29, 117.67, 113.71, 113.65, 113.32, 103.17, 101.27, 89.67, 88.80, 83.29, 82.77, 50.84 (Ac*C*$H_3$), 30.67 (*C*H$(CH_3)_2$), 22.74 (Ar*C*$H_3$), 21.73 (CH(*C*$H_3)_2$), 18.75 (CH(*C*$H_3)_2$). Data is in line with literature precedent.[9]

## 7. Computational Data

Computational Details / Methodology

DFT calculations were run with Gaussian 09 (Revision D.01).[10] Ru centers were described with the Stuttgart RECPs and associated basis sets,[11] and 6-31G** basis sets were used for all other atoms.[12] Initial BP86[13] optimizations were performed using the 'grid = ultrafine' option, with all stationary points being fully characterized via analytical frequency calculations as minima (all positive eigenvalues). All energies were recomputed with a larger basis set featuring cc-pVTZ on Ru and 6-311++G** on all other atoms. Corrections for the effect of 1,4-dioxane (ε = 2.2099) solvent were run using the polarizable continuum model and BS1.[14] Single-point dispersion corrections to the BP86 results employed Grimme's D3 parameter set with Becke-Johnson damping as implemented in Gaussian.[15] Natural Bond Orbital (NBO) analysis calculations were also computed with Gaussian 09.

Breakdown of Energy Contributions

The following tables detail the evolution of the relative energies as the successive corrections to the initial SCF energy are included. Terms used are:

| | |
|---|---|
| $\mathbf{\Delta E_{BS1}}$ | SCF energy computed with the BP86 functional with BS1 |
| $\mathbf{\Delta H_{BS1}}$ | Enthalpy at 0 K with BS1 |
| $\mathbf{\Delta G_{BS1}}$ | Free energy at 298.15 K and 1 atm with BS1 |
| $\mathbf{\Delta G_{BS1/diox}}$ | Free energy corrected for 1,4-dioxane solvent with BS1 |
| $\mathbf{\Delta G_{BS1/diox+D3}}$ | Free energy corrected for 1,4-dioxane and dispersion effects with BS1 |
| $\mathbf{\Delta G_{diox}}$ | Free energy corrected for basis set (BS2), dispersion effects and 1,4-dioxane solvent |

In each case the final data used in the main article is highlighted in bold.

Energy Tables

**Table S1** – Computed relative energies (kcal/mol) for the different isomers of the organic substrates and ruthenium complexes. Data in bold are those used in the main text. Energies are quoted relative to the lowest isomer for each species at 0.0 kcal/mol.

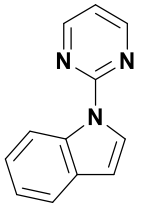
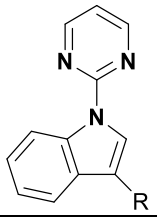
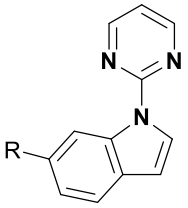
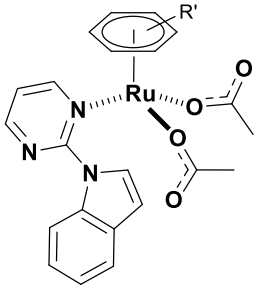
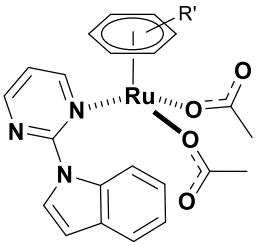
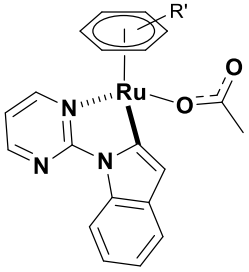
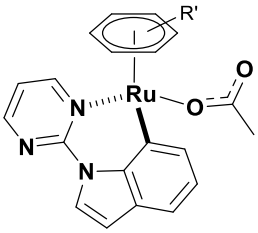
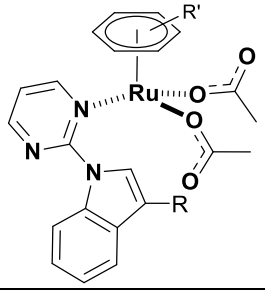
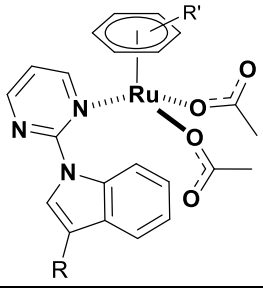
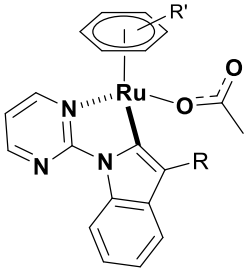
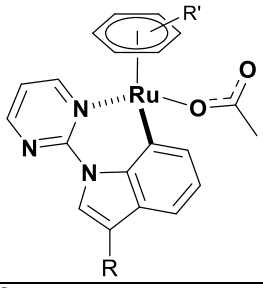
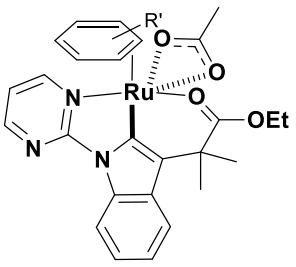
| | $\Delta E_{BS1}$ | $\Delta H_{BS1}$ | $\Delta G_{BS1}$ | $\Delta G_{BS1/diox}$ | $\Delta G_{BS1/diox+D3}$ | $\Delta E_{BS2}$ | $\Delta G_{diox}$ |
|---|---|---|---|---|---|---|---|
| **3a** | 0.7 | 0.6 | 0.8 | 0.7 | 0.2 | 0.9 | **0.4** |
| **3a'** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0** |
| **$^{1a}$A-C2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0** |
| **$^{1a}$A-C7** | 4.0 | 4.2 | 4.6 | 4.8 | 2.7 | 3.8 | **2.6** |
| **$^{1a}$B-C2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0** |
| **$^{1a}$B-C7** | 9.3 | 9.2 | 9.6 | 10.1 | 6.3 | 9.3 | **6.3** |
| **$^{3a}$A-C2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0** |
| **$^{3a}$A-C7** | 7.2 | 7.4 | 7.4 | 6.9 | 6.6 | 7.0 | **6.3** |
| **$^{3a}$B-C2** | 6.0 | 6.3 | 6.1 | 5.7 | 7.7 | 1.7 | **3.4** |
| **$^{3a}$B-C7** | 11.1 | 10.9 | 9.8 | 8.7 | 14.5 | 5.8 | **9.1** |
| **$^{3a}$B-C2*** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **0.0** |

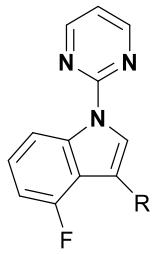
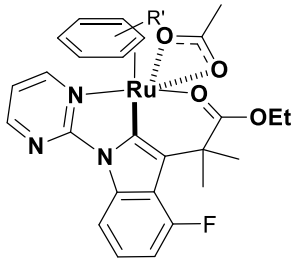
Complexes labelled "**A**" are bis-acetate with no cyclometalation of the substrate / no C-H activation

Complexes labelled "**B**" are mono-acetate post C-H activation complexes, with the substrate still cyclometalated.

The use of subscript **1a**, **3a** and **3a'** preceding the complex label refers to where / if there is any ester (R) substituent on the coordinated substrate.

Finally the **C2** / **C7** part of the label references the direction of the indole, and whether the C2 or C7 carbon is "inwards" and orientated to the coordinated acetate(s) of the complex.

| | | |
|---|---|---|
|  |  |  |
| **1a** | **3a** | **3a'** |
|  |  | |
| **$^{1a}$A-C2** | **$^{1a}$A-C7** | |
|  |  | |
| **$^{1a}$B-C2** | **$^{1a}$B-C7** | |
|  |  | |
| **$^{3a}$A-C2** | **$^{3a}$A-C7** | |
|  |  |  |
| **$^{3a}$B-C2** | **$^{3a}$B-C7** | **$^{3a}$B-C2*** |

| | | |
|---|---|---|
|  |  | |
| **S3a** | **$^{S3a}$B-C2*** | |

Relative Fukui Index

Relative nucleophilicity Fukui numbers were calculated by optimising the neutral molecule, and then performing NBO computations (nbo=npa, natural population analysis) on the neutral and cationic radical. For each atomic nucleophilicty Fukui number ($f_A^-$) the NBO charge of the cationic calculation ($P_A(N-1)$) is subtracted from the neutral NBO charge value ($P_A(N)$) (see Eq. 1), before the values are scaled relative to the largest positive value of the molecule, which is normalised and equal to 1.00[1]. This determines the nucleophilicty of atom *A* in molecule *M* (of *N* electrons), where *P* stands for the population of atom *A* in molecule *M*.

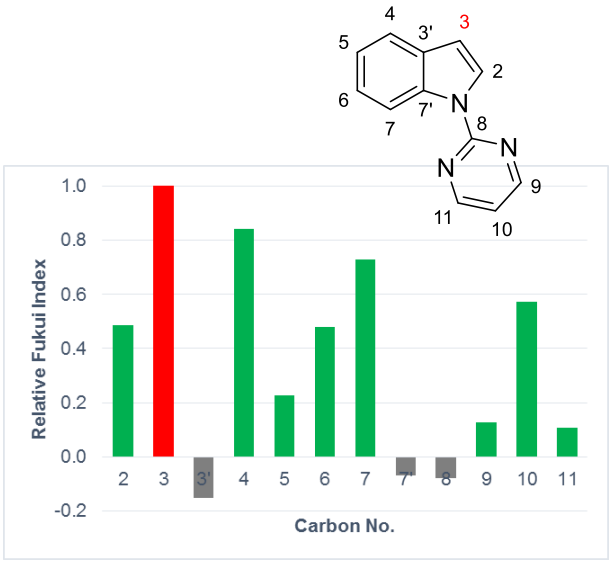
$$f_A^- = P_A(N) - P_A(N-1) \qquad \text{(Eq. 1)}$$

N.B. *N* is the number of electrons of the original molecule / ion. The equilibrium geometry of the original molecule is used for the cationic radical calculation. We also note that using the total atomic charge values gives positive Fukui values, whilst using the local atomic charge values gives the inverse of the Fukui value, i.e. $-f_A^-$.

[1] If C3 has already been alkylated then the next largest Fukui value is chosen to be the "relative" atom.

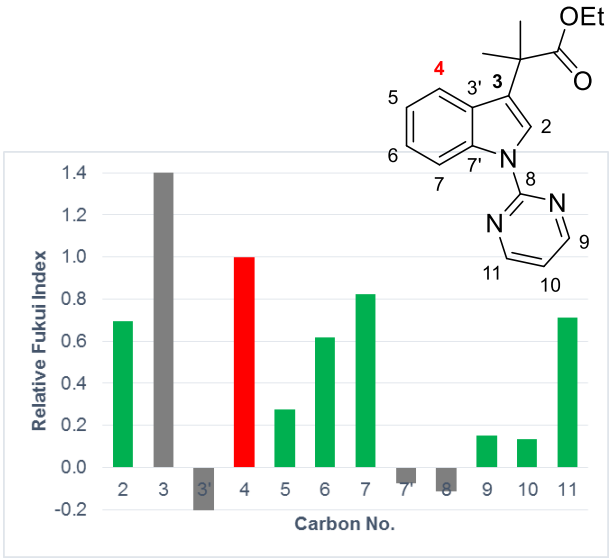
**1a**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 6.0408 | 5.9737 | 0.0671 | 0.4870 |
| **C3** | **6.2887** | **6.1510** | **0.1377** | **1.0000** |
| C3' | 6.0887 | 6.1097 | -0.0210 | -0.1523 |
| C4 | 6.2313 | 6.1152 | 0.1161 | 0.8432 |
| C5 | 6.2562 | 6.2248 | 0.0314 | 0.2279 |
| C6 | 6.2513 | 6.1850 | 0.0663 | 0.4813 |
| C7 | 6.2566 | 6.1561 | 0.1006 | 0.7302 |
| C7' | 5.8451 | 5.8544 | -0.0093 | -0.0675 |
| C8 | 5.4051 | 5.4159 | -0.0108 | -0.0783 |
| C9 | 5.9542 | 5.9369 | 0.0174 | 0.1261 |
| C10 | 6.3476 | 6.2689 | 0.0787 | 0.5714 |
| C11 | 5.9540 | 5.9394 | 0.0146 | 0.1059 |



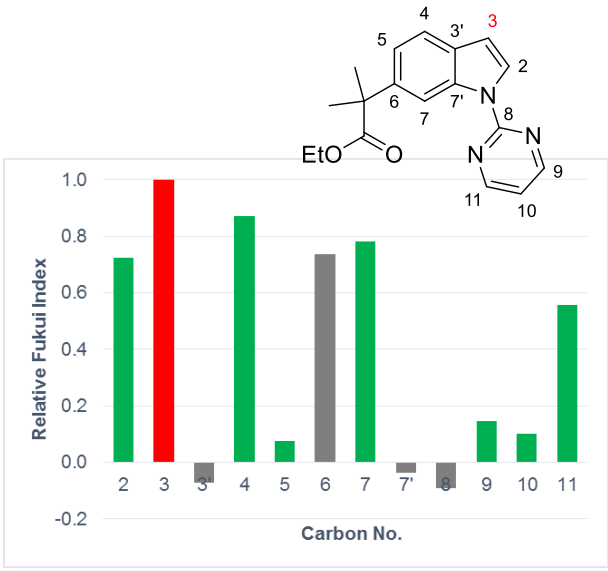

**3a**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 6.0270 | 5.9603 | 0.0667 | 0.6950 |
| C3 | 5.9346 | 6.0708 | 0.1363 | 1.4206 |
| C3' | 6.0933 | 6.0739 | -0.0194 | -0.2024 |
| **C4** | **6.1409** | **6.2368** | **0.0959** | **1.0000** |
| C5 | 6.2269 | 6.2534 | 0.0265 | 0.2765 |
| C6 | 6.1905 | 6.2499 | 0.0594 | 0.6197 |
| C7 | 6.1765 | 6.2552 | 0.0787 | 0.8210 |
| C7' | 5.8455 | 5.8385 | -0.0070 | -0.0734 |
| C8 | 5.4160 | 5.4051 | -0.0109 | -0.1132 |
| C9 | 5.9394 | 5.9541 | 0.0147 | 0.1531 |
| C10 | 5.9409 | 5.9538 | 0.0129 | 0.1345 |
| C11 | 6.2800 | 6.3481 | 0.0681 | 0.7098 |



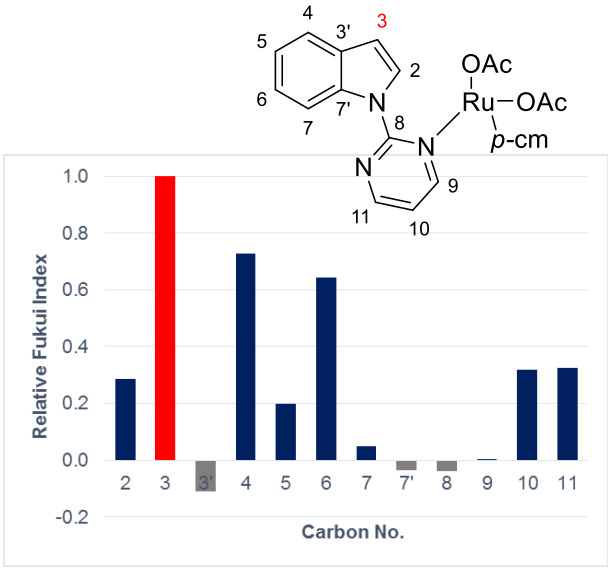
**3a'**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 6.0392 | 5.9620 | 0.0771 | 0.7247 |
| **C3** | **6.2900** | **6.1835** | **0.1065** | **1.0000** |
| C3' | 6.0892 | 6.0968 | -0.0075 | -0.0705 |
| C4 | 6.2225 | 6.1298 | 0.0927 | 0.8707 |
| C5 | 6.2502 | 6.2422 | 0.0080 | 0.0750 |
| C6 | 6.0294 | 5.9509 | 0.0785 | 0.7378 |
| C7 | 6.2537 | 6.1703 | 0.0834 | 0.7833 |
| C7' | 5.8357 | 5.8396 | -0.0039 | -0.0367 |
| C8 | 5.4060 | 5.4157 | -0.0097 | -0.0913 |
| C9 | 5.9551 | 5.9394 | 0.0156 | 0.1466 |
| C10 | 5.9523 | 5.9416 | 0.0107 | 0.1007 |
| C11 | 6.3473 | 6.2880 | 0.0593 | 0.5569 |



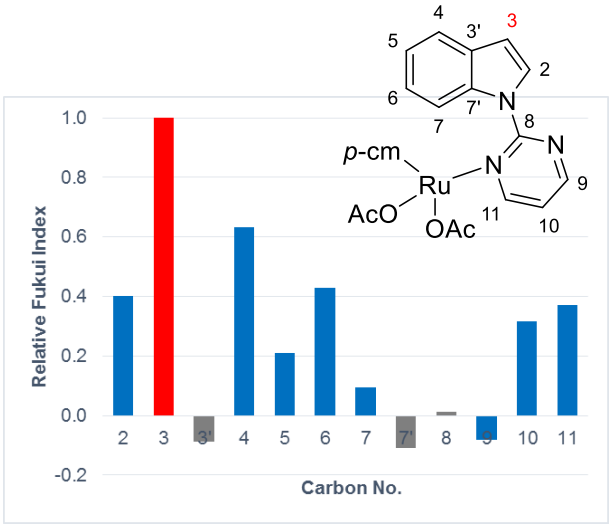

**[1a]A-C2**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 6.0232 | 6.0045 | 0.0187 | 0.2856 |
| **C3** | **6.3105** | **6.2450** | **0.0655** | **1.0000** |
| C3' | 6.0918 | 6.0990 | -0.0072 | -0.1106 |
| C4 | 6.2301 | 6.1825 | 0.0476 | 0.7276 |
| C5 | 6.2572 | 6.2442 | 0.0130 | 0.1981 |
| C6 | 6.2515 | 6.2094 | 0.0421 | 0.6429 |
| C7 | 5.2127 | 5.2096 | 0.0031 | 0.0478 |
| C7' | 5.8500 | 5.8522 | -0.0022 | -0.0341 |
| C8 | 5.3748 | 5.3772 | -0.0024 | -0.0370 |
| C9 | 5.9137 | 5.9135 | 0.0002 | 0.0032 |
| C10 | 6.3238 | 6.3028 | 0.0210 | 0.3201 |
| C11 | 5.9600 | 5.9388 | 0.0212 | 0.3239 |



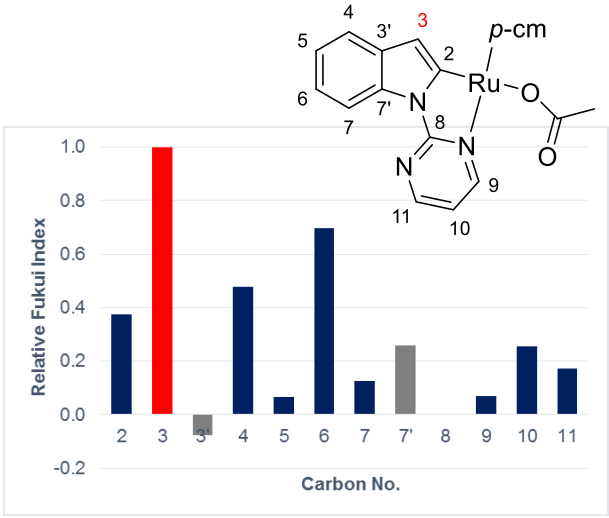
**$^{1a}$A-C7**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 6.0529 | 6.0280 | 0.0248 | 0.4025 |
| **C3** | **6.2981** | **6.2364** | **0.0617** | **1.0000** |
| C3' | 6.0988 | 6.1042 | -0.0054 | -0.0875 |
| C4 | 6.2353 | 6.1963 | 0.0390 | 0.6320 |
| C5 | 6.2615 | 6.2484 | 0.0131 | 0.2115 |
| C6 | 6.2522 | 6.2257 | 0.0265 | 0.4291 |
| C7 | 5.2045 | 5.1986 | 0.0059 | 0.0959 |
| C7' | 5.8497 | 5.8564 | -0.0067 | -0.1082 |
| C8 | 5.3792 | 5.3784 | 0.0008 | 0.0131 |
| C9 | 5.8919 | 5.8969 | -0.0050 | -0.0802 |
| C10 | 6.3198 | 6.3002 | 0.0196 | 0.3179 |
| C11 | 5.9513 | 5.9284 | 0.0228 | 0.3699 |



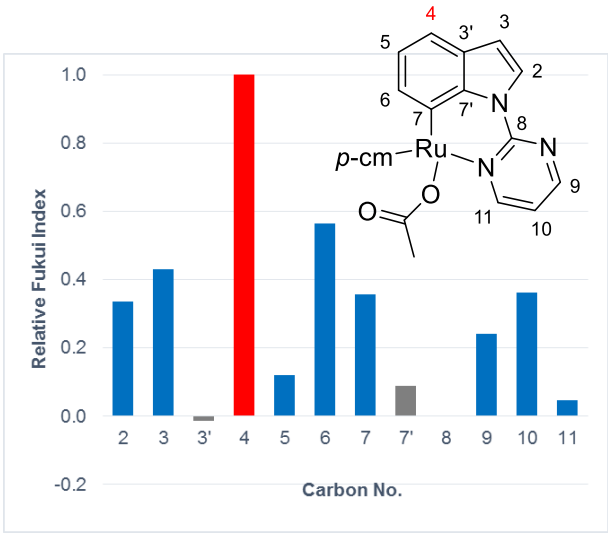

**$^{1a}$B-C2**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 5.8401 | 5.7969 | 0.0432 | 0.3738 |
| **C3** | **6.3242** | **6.2085** | **0.1157** | **1.0000** |
| C3' | 6.0740 | 6.0827 | -0.0088 | -0.0757 |
| C4 | 6.2377 | 6.1823 | 0.0553 | 0.4783 |
| C5 | 6.2542 | 6.2466 | 0.0076 | 0.0658 |
| C6 | 6.2601 | 6.1794 | 0.0807 | 0.6976 |
| C7 | 6.2586 | 6.2442 | 0.0144 | 0.1246 |
| C7' | 5.8529 | 5.8232 | 0.0297 | 0.2571 |
| C8 | 5.3621 | 5.3616 | 0.0005 | 0.0041 |
| C9 | 5.9340 | 5.9261 | 0.0079 | 0.0684 |
| C10 | 6.3491 | 6.3194 | 0.0297 | 0.2567 |
| C11 | 5.9536 | 5.9338 | 0.0198 | 0.1708 |



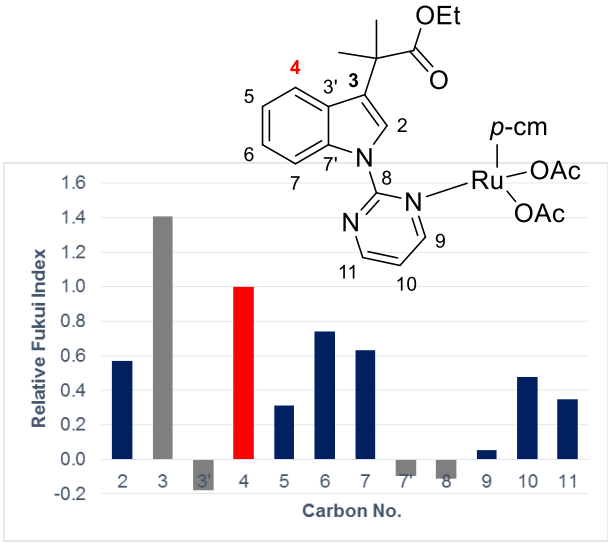
**[1a]B-C7**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 6.0551 | 6.0243 | 0.0308 | 0.3345 |
| C3 | 6.2744 | 6.2348 | 0.0396 | 0.4302 |
| C3' | 6.0918 | 6.0930 | -0.0012 | -0.0126 |
| **C4** | **6.2490** | **6.1569** | **0.0921** | **1.0000** |
| C5 | 6.2479 | 6.2368 | 0.0111 | 0.1205 |
| C6 | 6.2716 | 6.2196 | 0.0521 | 0.5655 |
| C7 | 6.0455 | 6.0127 | 0.0328 | 0.3559 |
| C7' | 5.8679 | 5.8598 | 0.0081 | 0.0883 |
| C8 | 5.3699 | 5.3699 | 0.0000 | 0.0003 |
| C9 | 5.9543 | 5.9321 | 0.0221 | 0.2404 |
| C10 | 6.3449 | 6.3116 | 0.0334 | 0.3623 |
| C11 | 5.9352 | 5.9308 | 0.0044 | 0.0476 |



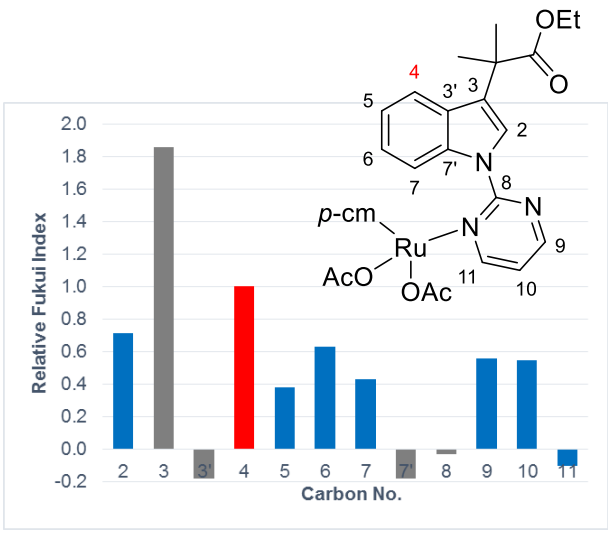

**[3a]A-C2**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 6.0436 | 6.0166 | 0.0271 | 0.5699 |
| C3 | 6.0772 | 6.0105 | 0.0667 | 1.4046 |
| C3' | 6.0784 | 6.0870 | -0.0086 | -0.1805 |
| **C4** | **6.2370** | **6.1895** | **0.0475** | **1.0000** |
| C5 | 6.2525 | 6.2378 | 0.0147 | 0.3107 |
| C6 | 6.2494 | 6.2144 | 0.0351 | 0.7382 |
| C7 | 6.2615 | 6.2314 | 0.0301 | 0.6335 |
| C7' | 5.8450 | 5.8498 | -0.0047 | -0.0998 |
| C8 | 5.3638 | 5.3692 | -0.0054 | -0.1146 |
| C9 | 5.9179 | 5.9154 | 0.0025 | 0.0518 |
| C10 | 6.3323 | 6.3098 | 0.0225 | 0.4741 |
| C11 | 5.9528 | 5.9363 | 0.0165 | 0.3484 |



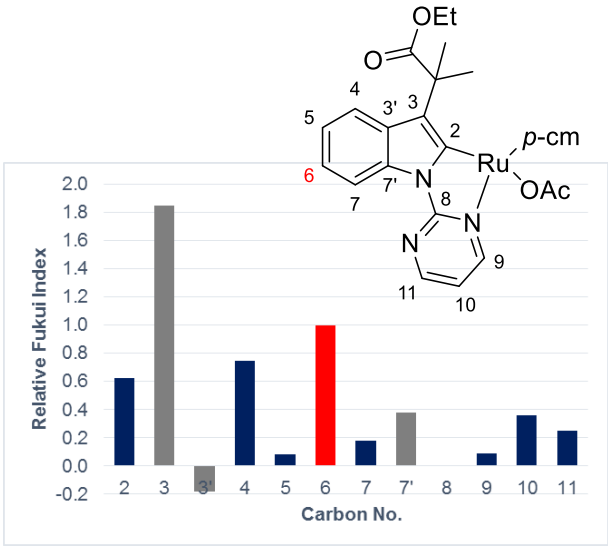
**$^{3a}$A-C7**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 6.0398 | 6.0137 | 0.0261 | 0.7105 |
| C3 | 6.0774 | 6.0092 | 0.0682 | 1.8569 |
| C3' | 6.0848 | 6.0914 | -0.0066 | -0.1807 |
| **C4** | **6.2408** | **6.2041** | **0.0367** | **1.0000** |
| C5 | 6.2600 | 6.2460 | 0.0141 | 0.3823 |
| C6 | 6.2505 | 6.2274 | 0.0231 | 0.6275 |
| C7 | 6.2534 | 6.2376 | 0.0158 | 0.4299 |
| C7' | 5.8434 | 5.8500 | -0.0067 | -0.1812 |
| C8 | 5.3790 | 5.3801 | -0.0011 | -0.0299 |
| C9 | 5.9505 | 5.9301 | 0.0204 | 0.5562 |
| C10 | 6.3207 | 6.3007 | 0.0200 | 0.5442 |
| C11 | 5.8925 | 5.8963 | -0.0038 | -0.1029 |



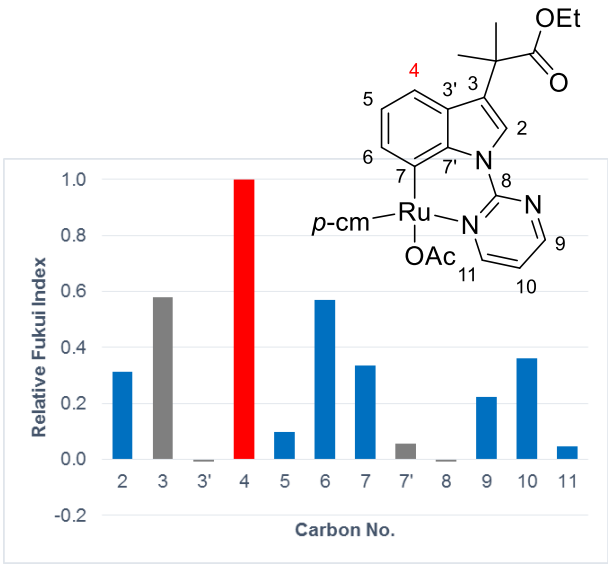

**$^{3a}$B-C2**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 5.8327 | 5.7862 | 0.0465 | 0.6230 |
| C3 | 6.1163 | 5.9784 | 0.1379 | 1.8473 |
| C3' | 6.0613 | 6.0749 | -0.0136 | -0.1827 |
| C4 | 6.2479 | 6.1921 | 0.0558 | 0.7476 |
| C5 | 6.2536 | 6.2474 | 0.0062 | 0.0836 |
| **C6** | **6.2593** | **6.1847** | **0.0746** | **1.0000** |
| C7 | 6.2598 | 6.2462 | 0.0136 | 0.1818 |
| C7' | 5.8496 | 5.8214 | 0.0282 | 0.3778 |
| C8 | 5.3679 | 5.3677 | 0.0002 | 0.0024 |
| C9 | 5.9401 | 5.9332 | 0.0069 | 0.0919 |
| C10 | 6.3487 | 6.3218 | 0.0268 | 0.3596 |
| C11 | 5.9572 | 5.9387 | 0.0186 | 0.2485 |



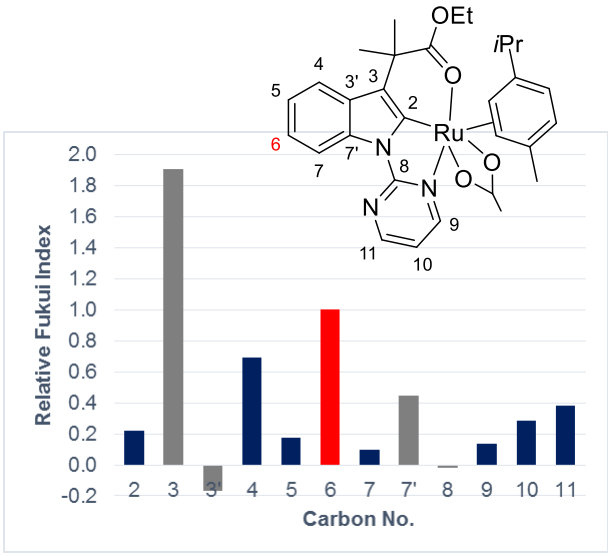
**$^{3a}$B-C7**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 6.0407 | 6.0118 | 0.0290 | 0.3143 |
| C3 | 6.0569 | 6.0035 | 0.0534 | 0.5801 |
| C3' | 6.0773 | 6.0779 | -0.0006 | -0.0071 |
| **C4** | **6.2559** | **6.1638** | **0.0921** | **1.0000** |
| C5 | 6.2448 | 6.2359 | 0.0089 | 0.0966 |
| C6 | 6.2701 | 6.2176 | 0.0525 | 0.5700 |
| C7 | 6.0444 | 6.0135 | 0.0309 | 0.3353 |
| C7' | 5.8622 | 5.8569 | 0.0053 | 0.0577 |
| C8 | 5.3701 | 5.3707 | -0.0006 | -0.0065 |
| C9 | 5.9539 | 5.9333 | 0.0206 | 0.2233 |
| C10 | 6.3455 | 6.3124 | 0.0332 | 0.3599 |
| C11 | 5.9354 | 5.9310 | 0.0044 | 0.0482 |



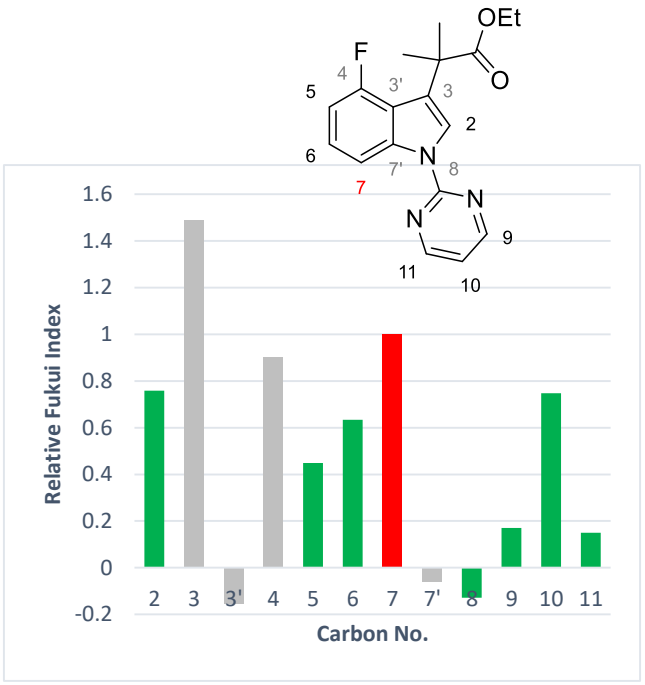

**$^{3a}$B-C2***

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative Fukui Index |
|---|---|---|---|---|
| C2 | 5.8054 | 5.7914 | 0.0140 | 0.2214 |
| C3 | 6.1597 | 6.0391 | 0.1207 | 1.9083 |
| C3' | 6.0599 | 6.0708 | -0.0108 | -0.1711 |
| C4 | 6.2593 | 6.2157 | 0.0437 | 0.6905 |
| C5 | 6.2528 | 6.2416 | 0.0111 | 0.1760 |
| **C6** | **6.2649** | **6.2016** | **0.0632** | **1.0000** |
| C7 | 6.2589 | 6.2529 | 0.0060 | 0.0952 |
| C7' | 5.8476 | 5.8193 | 0.0283 | 0.4477 |
| C8 | 5.3731 | 5.3742 | -0.0010 | -0.0163 |
| C9 | 5.9485 | 5.9399 | 0.0086 | 0.1355 |
| C10 | 6.3431 | 6.3250 | 0.0181 | 0.2863 |
| C11 | 5.9753 | 5.9512 | 0.0240 | 0.3802 |



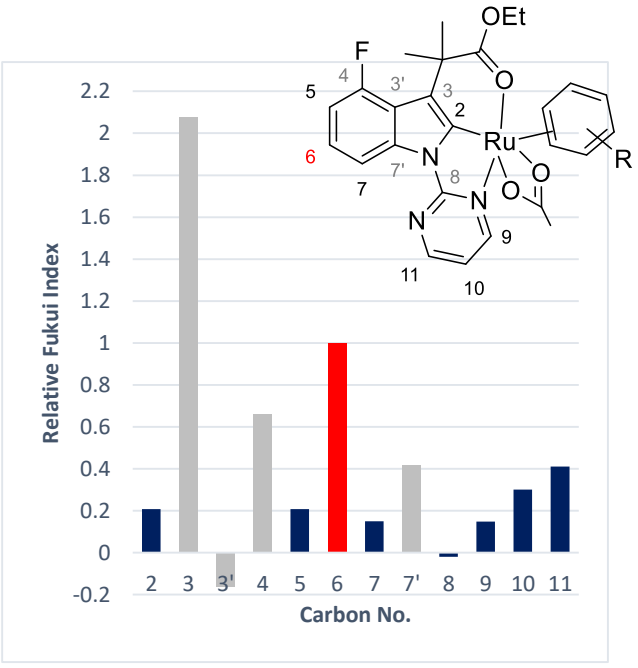
**S3a**

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative $f_A^-$ |
|---|---|---|---|---|
| C2 | 6.02567 | 5.96148 | 0.064 | 0.76 |
| C3 | 6.06719 | 5.94122 | 0.126 | 1.48 |
| C3' | 6.14059 | 6.15356 | -0.013 | -0.15 |
| C4 | 5.58118 | 5.50489 | 0.076 | 0.90 |
| C5 | 6.32625 | 6.28826 | 0.038 | 0.45 |
| C6 | 6.2412 | 6.18759 | 0.054 | 0.63 |
| **C7** | **6.27152** | **6.18694** | **0.085** | **1.00** |
| C7' | 5.82737 | 5.83237 | -0.005 | -0.06 |
| C8 | 5.40496 | 5.41587 | -0.011 | -0.13 |
| C9 | 5.95276 | 5.93835 | 0.014 | 0.17 |
| C10 | 6.3458 | 6.28262 | 0.063 | 0.74 |
| C11 | 5.95374 | 5.94103 | 0.013 | 0.15 |




**[S3a]B-C2***

| Atom | Neutral Total Charge | Cationic Total Charge | $f_A^-$ | Relative $f_A^-$ |
|---|---|---|---|---|
| C2 | 5.80685 | 5.79453 | 0.012 | 0.21 |
| C3 | 6.15508 | 6.03195 | 0.123 | 2.09 |
| C3' | 6.12663 | 6.13629 | -0.010 | -0.16 |
| C4 | 5.60015 | 5.56099 | 0.039 | 0.66 |
| C5 | 6.32599 | 6.31367 | 0.012 | 0.21 |
| **C6** | **6.25529** | **6.19607** | **0.059** | **1.00** |
| C7 | 6.27448 | 6.26565 | 0.009 | 0.15 |
| C7' | 5.8372 | 5.81257 | 0.025 | 0.42 |
| C8 | 5.37298 | 5.37419 | -0.001 | -0.02 |
| C9 | 5.9487 | 5.93998 | 0.009 | 0.15 |
| C10 | 6.34087 | 6.32309 | 0.018 | 0.30 |
| C11 | 5.9756 | 5.95126 | 0.024 | 0.41 |



**Cartesian Coordinates and Computed Energies (in Hartrees)**

**Organic Substrates**

**1a**

SCF (BP86) Energy = -626.959242130
Enthalpy 0K = -626.777477
Enthalpy 298K = -626.765736
Free Energy 298K = -626.814618
Lowest Frequency = 52.6744 $cm^{-1}$
Second Frequency = 69.0812 $cm^{-1}$

| | | | |
|---|---|---|---|
| C | -2.69171 | -1.89670 | 0.00003 |
| C | -1.35286 | -1.47764 | -0.00011 |
| C | -1.10818 | -0.09417 | -0.00010 |
| C | -2.17607 | 0.85849 | 0.00005 |
| C | -3.51064 | 0.40622 | 0.00018 |
| C | -3.75881 | -0.97114 | 0.00017 |
| H | -2.90962 | -2.96976 | 0.00001 |
| H | -0.52474 | -2.18589 | -0.00024 |
| H | -4.33638 | 1.12557 | 0.00029 |
| H | -4.79086 | -1.33708 | 0.00028 |
| N | 0.09907 | 0.64478 | -0.00027 |
| C | -0.22074 | 2.01773 | -0.00010 |
| H | 0.59203 | 2.73809 | -0.00014 |
| C | -1.58097 | 2.17590 | 0.00006 |
| H | -2.10864 | 3.12903 | 0.00015 |
| C | 1.41668 | 0.17203 | -0.00043 |
| N | 2.38113 | 1.12515 | -0.00003 |
| N | 1.59977 | -1.16754 | -0.00029 |
| C | 3.64428 | 0.67253 | 0.00032 |
| C | 2.88063 | -1.57777 | 0.00006 |
| C | 3.96747 | -0.69345 | 0.00031 |
| H | 4.42863 | 1.44101 | 0.00050 |
| H | 3.03359 | -2.66494 | 0.00005 |
| H | 5.00175 | -1.04489 | 0.00051 |

**3a**

SCF (BP86) Energy = -1012.08941768
Enthalpy 0K = -1011.756896
Enthalpy 298K = -1011.734559
Free Energy 298K = -1011.808544
Lowest Frequency = 20.0131 $cm^{-1}$
Second Frequency = 29.8197 $cm^{-1}$
SCF (1,4-dioxane) Energy = -1012.09344044
SCF (BP86-D3BJ) Energy = -1012.17419610
SCF (BS2) Energy = -1012.34767513

| | | | |
|---|---|---|---|
| C | -2.45512 | 3.50713 | -0.50896 |
| C | -2.62070 | 2.12652 | -0.33076 |
| C | -1.46630 | 1.35471 | -0.11922 |
| C | -0.15758 | 1.93416 | -0.08281 |
| C | -0.02961 | 3.32805 | -0.26598 |
| C | -1.17640 | 4.10258 | -0.47755 |
| H | -3.33923 | 4.13119 | -0.67517 |
| H | -3.60171 | 1.65271 | -0.35175 |
| H | 0.95342 | 3.80728 | -0.24449 |
| H | -1.07848 | 5.18381 | -0.61988 |
| N | -1.30815 | -0.03406 | 0.08719 |
| C | 0.06335 | -0.30165 | 0.24444 |
| H | 0.37000 | -1.33080 | 0.40112 |
| C | 0.79814 | 0.85471 | 0.15000 |
| C | -2.28546 | -1.03450 | 0.13661 |
| N | -1.82490 | -2.29363 | 0.34162 |
| N | -3.57482 | -0.65864 | -0.02109 |
| C | -2.76146 | -3.25294 | 0.39369 |
| C | -4.48013 | -1.65131 | 0.03685 |
| C | -4.13288 | -2.99260 | 0.24633 |
| H | -2.39291 | -4.27377 | 0.56080 |
| H | -5.52797 | -1.34960 | -0.09099 |
| H | -4.88229 | -3.78608 | 0.29169 |
| C | 2.31235 | 0.98753 | 0.29632 |
| C | 2.65705 | 1.90049 | 1.49919 |
| H | 3.74953 | 2.00427 | 1.60203 |
| H | 2.21917 | 2.90122 | 1.36375 |
| H | 2.26907 | 1.47211 | 2.43526 |
| C | 2.93719 | 1.55152 | -1.01258 |
| H | 2.53422 | 2.55240 | -1.23297 |
| H | 4.03268 | 1.64033 | -0.90963 |
| H | 2.71679 | 0.89321 | -1.86560 |
| C | 2.94186 | -0.39832 | 0.57774 |
| O | 3.48019 | -0.73071 | 1.62510 |
| O | 2.85161 | -1.22386 | -0.50640 |
| C | 3.45054 | -2.54125 | -0.32819 |
| H | 2.96178 | -3.04143 | 0.52611 |
| H | 4.51512 | -2.41268 | -0.06588 |
| C | 3.26297 | -3.30573 | -1.62987 |
| H | 3.70448 | -4.31227 | -1.53839 |
| H | 2.19393 | -3.41785 | -1.87287 |
| H | 3.75639 | -2.78762 | -2.46819 |

**3a'**

SCF (BP86) Energy = -1012.09047729
Enthalpy 0K = -1011.757862
Enthalpy 298K = -1011.735711
Free Energy 298K = -1011.809737
Lowest Frequency = 15.6272 $cm^{-1}$
Second Frequency = 21.8658 $cm^{-1}$
SCF (1,4-dioxane) Energy = -1012.09444129
SCF (BP86-D3BJ) Energy = -1012.17434582
SCF (BS2) Energy = -1012.34917083

| | | | |
|---|---|---|---|
| C | -1.35866 | 1.09422 | -0.58130 |
| C | -0.09274 | 0.48116 | -0.46880 |
| C | 0.96634 | 1.22609 | 0.06783 |
| C | 0.79724 | 2.57954 | 0.49854 |
| C | -0.47173 | 3.17519 | 0.38226 |
| C | -1.53239 | 2.43210 | -0.15005 |
| H | 0.06810 | -0.55226 | -0.77932 |
| H | -0.62965 | 4.20912 | 0.70700 |
| H | -2.51442 | 2.90533 | -0.23056 |

| | | | |
|---|---|---|---|
| N | 2.32109 | 0.88902 | 0.30271 |
| C | 2.96594 | 2.01016 | 0.86307 |
| H | 4.02094 | 1.93013 | 1.10875 |
| C | 2.07413 | 3.04182 | 0.99249 |
| H | 2.29936 | 4.02812 | 1.39664 |
| C | 2.98027 | -0.32021 | 0.04864 |
| N | 4.29439 | -0.35357 | 0.37980 |
| N | 2.25356 | -1.32184 | -0.49348 |
| C | 4.92293 | -1.51425 | 0.13608 |
| C | 2.92057 | -2.46713 | -0.72091 |
| C | 4.28031 | -2.62997 | -0.42289 |
| H | 5.98781 | -1.54725 | 0.40201 |
| H | 2.33141 | -3.28239 | -1.16035 |
| H | 4.80789 | -3.56728 | -0.61389 |
| C | -2.51236 | 0.27580 | -1.21029 |
| C | -3.87930 | 0.99356 | -1.12914 |
| H | -4.66936 | 0.34514 | -1.54387 |
| H | -4.15145 | 1.24226 | -0.09252 |
| H | -3.86360 | 1.91998 | -1.72782 |
| C | -2.18385 | -0.03170 | -2.69141 |
| H | -2.07679 | 0.91315 | -3.24954 |
| H | -1.24904 | -0.60329 | -2.78393 |
| H | -2.98979 | -0.62655 | -3.15375 |
| C | -2.58918 | -1.06270 | -0.43984 |
| O | -2.17730 | -2.14156 | -0.84965 |
| O | -3.15666 | -0.89834 | 0.78906 |
| C | -3.21098 | -2.10112 | 1.60833 |
| H | -3.77998 | -2.87648 | 1.06598 |
| H | -2.18381 | -2.48253 | 1.74394 |
| C | -3.86443 | -1.72219 | 2.92888 |
| H | -3.92268 | -2.60686 | 3.58496 |
| H | -3.28219 | -0.94400 | 3.44839 |
| H | -4.88704 | -1.34252 | 2.77053 |

**Ruthenium Complexes**

**$^{1a}$A-C2**

SCF (BP86) Energy = -1568.52019475
Enthalpy 0K = -1568.029080
Enthalpy 298K = -1567.992958
Free Energy 298K = -1568.098246
Lowest Frequency = 10.0070 $cm^{-1}$
Second Frequency = 27.0840 $cm^{-1}$
SCF (1,4-dioxane) Energy = -1568.52709297
SCF (BP86-D3BJ) Energy = -1568.67907801
SCF (BS2) Energy = -1568.61523144

| | | | |
|---|---|---|---|
| C | -1.84266 | 0.39264 | 1.71035 |
| C | -2.76877 | 1.39655 | 1.85813 |
| C | -3.86026 | 1.12929 | 0.94818 |
| N | -0.27021 | -1.69277 | 0.26026 |
| C | 0.32008 | -2.91829 | 0.21143 |
| Ru | 0.97977 | 0.01260 | -0.37417 |
| O | 2.54625 | -1.32378 | 0.01391 |
| C | 1.73733 | 0.39097 | -2.39014 |
| C | 0.40937 | -0.10353 | -2.55437 |
| C | -0.61899 | 0.55554 | -1.78747 |
| C | 2.02961 | 1.54150 | -1.57099 |
| H | -2.69641 | 2.22203 | 2.56549 |
| C | 0.10058 | -1.29422 | -3.42865 |
| H | 1.41409 | -2.88293 | 0.18939 |
| H | -0.20163 | -0.96335 | -4.43941 |
| H | 0.98170 | -1.94661 | -3.53840 |
| H | -0.72728 | -1.89382 | -3.01559 |
| H | -0.91490 | 0.16848 | 2.23283 |
| O | 0.78965 | -1.15042 | 2.80426 |
| C | 1.46438 | -0.12125 | 2.63727 |
| C | 2.36010 | 0.43528 | 3.74939 |
| H | 2.26504 | 1.53010 | 3.82542 |
| H | 2.10518 | -0.03652 | 4.70908 |
| H | 3.41406 | 0.21353 | 3.50879 |
| O | 1.50144 | 0.62800 | 1.54825 |
| C | 3.81234 | -1.14933 | -0.33565 |
| C | 4.71999 | -2.23271 | 0.25960 |
| H | 5.70676 | -2.19994 | -0.22345 |
| H | 4.84293 | -2.05323 | 1.34119 |
| H | 4.27565 | -3.23466 | 0.14456 |
| O | 4.27404 | -0.23633 | -1.03589 |
| C | -3.55875 | -0.09594 | 0.27454 |
| N | -2.41609 | -2.79251 | 0.25958 |
| C | -1.63442 | -1.70906 | 0.40407 |
| C | -5.59276 | 0.04930 | -0.98534 |
| H | -6.28411 | -0.36134 | -1.72816 |
| C | -5.91294 | 1.26084 | -0.33004 |
| H | -6.84634 | 1.77590 | -0.57947 |
| C | -5.05792 | 1.80609 | 0.63437 |
| H | -5.31036 | 2.74425 | 1.13967 |
| C | -4.41250 | -0.64931 | -0.69291 |
| H | -4.18239 | -1.60508 | -1.16824 |
| N | -2.29616 | -0.52021 | 0.74213 |
| C | -1.80938 | -3.97751 | 0.09294 |
| H | -2.46627 | -4.84241 | -0.06128 |
| C | -0.41499 | -4.10176 | 0.14571 |
| H | 0.08870 | -5.06982 | 0.09454 |
| C | -0.35505 | 1.69609 | -0.96968 |
| C | 0.98800 | 2.20597 | -0.85444 |
| H | 2.58197 | -0.14954 | -2.82473 |
| H | 3.07684 | 1.79757 | -1.41319 |
| H | -1.16052 | 2.12974 | -0.37115 |
| H | -1.63311 | 0.14180 | -1.79604 |
| C | 1.24825 | 3.38972 | 0.06724 |
| H | 0.63492 | 3.21311 | 0.97115 |
| C | 0.73925 | 4.68136 | -0.62012 |
| H | 0.85595 | 5.54248 | 0.05966 |
| H | 1.31802 | 4.89230 | -1.53649 |
| H | -0.32537 | 4.60927 | -0.89992 |
| C | 2.71324 | 3.53254 | 0.51134 |
| H | 3.06985 | 2.60352 | 0.98208 |
| H | 3.37499 | 3.78333 | -0.33662 |
| H | 2.79952 | 4.35157 | 1.24533 |

**$^{1a}$A-C7**

SCF (BP86) Energy = -1568.51385820
Enthalpy 0K = -1568.022457

Enthalpy 298K = -1567.986382
Free Energy 298K = -1568.091024
Lowest Frequency = 13.1924 $cm^{-1}$
Second Frequency = 27.9311 $cm^{-1}$
SCF (1,4-dioxane) Energy =
-1568.52038273
SCF (BP86-D3BJ) Energy =
-1568.67603733
SCF (BS2) Energy = -1568.60911254

| | | | |
|---|---|---|---|
| C | -3.74402 | -1.03411 | -1.21502 |
| C | -4.47626 | 0.12864 | -1.23009 |
| C | -3.96861 | 0.97534 | -0.17488 |
| N | -0.54134 | -1.74932 | 0.32091 |
| C | 0.13675 | -2.80322 | 0.86103 |
| Ru | 0.78903 | -0.04155 | -0.39049 |
| O | 2.31446 | -1.29404 | 0.31820 |
| C | 1.67429 | 0.04543 | -2.39781 |
| C | 0.30835 | -0.30238 | -2.58652 |
| C | -0.67677 | 0.54611 | -1.95731 |
| C | 2.05695 | 1.22481 | -1.65607 |
| H | -5.30007 | 0.35077 | -1.90753 |
| C | -0.09917 | -1.52834 | -3.36678 |
| H | 1.16197 | -2.57598 | 1.15733 |
| H | -0.32536 | -1.25884 | -4.41497 |
| H | 0.70739 | -2.27865 | -3.37780 |
| H | -1.00415 | -1.99448 | -2.94380 |
| H | -3.81937 | -1.93844 | -1.81403 |
| O | 0.38162 | -0.89858 | 2.90523 |
| C | 0.98287 | 0.16422 | 2.67127 |
| C | 1.70826 | 0.92410 | 3.78897 |
| H | 1.55916 | 2.01137 | 3.69603 |
| H | 1.35738 | 0.57330 | 4.77021 |
| H | 2.79240 | 0.73216 | 3.70967 |
| O | 1.08024 | 0.77993 | 1.50927 |
| C | 3.58086 | -1.33306 | -0.06387 |
| C | 4.39875 | -2.30993 | 0.79106 |
| H | 5.40975 | -2.41531 | 0.37332 |
| H | 4.46772 | -1.93209 | 1.82498 |
| H | 3.90846 | -3.29645 | 0.83707 |
| O | 4.10957 | -0.68165 | -0.97755 |
| C | -2.89622 | 0.27041 | 0.45586 |
| N | -2.42609 | -3.22555 | 0.00105 |
| C | -1.85713 | -2.00589 | 0.04752 |
| C | -2.64251 | 2.00606 | 2.07665 |
| H | -2.15392 | 2.41426 | 2.96699 |
| C | -3.66863 | 2.74873 | 1.44315 |
| H | -3.95247 | 3.72575 | 1.84804 |
| C | -4.34288 | 2.24123 | 0.32717 |
| H | -5.16013 | 2.80191 | -0.13850 |
| C | -2.23933 | 0.75186 | 1.59798 |
| H | -1.45722 | 0.16877 | 2.09272 |
| N | -2.74577 | -0.95161 | -0.22813 |
| C | -1.68535 | -4.26755 | 0.40420 |
| H | -2.14867 | -5.25816 | 0.31616 |
| C | -0.40491 | -4.08643 | 0.94029 |
| H | 0.17531 | -4.90970 | 1.36303 |
| C | -0.31571 | 1.70465 | -1.21383 |
| C | 1.07276 | 2.07015 | -1.06343 |
| H | 2.47026 | -0.62120 | -2.73737 |
| H | 3.11925 | 1.37435 | -1.46414 |
| H | -1.09190 | 2.27864 | -0.70057 |
| H | -1.73186 | 0.26937 | -2.02469 |
| C | 1.42493 | 3.29169 | -0.22728 |
| H | 0.76853 | 3.24822 | 0.66222 |
| C | 1.07614 | 4.56860 | -1.03192 |
| H | 1.25556 | 5.46523 | -0.41459 |
| H | 1.70502 | 4.64802 | -1.93612 |
| H | 0.02015 | 4.58096 | -1.35063 |
| C | 2.88108 | 3.32224 | 0.26393 |
| H | 3.12290 | 2.40957 | 0.83018 |
| H | 3.59458 | 3.42410 | -0.57303 |
| H | 3.03037 | 4.19056 | 0.92772 |

**$^{1a}$B-C2**

SCF (BP86) Energy = -1339.43971590
Enthalpy 0K = -1339.009562
Enthalpy 298K = -1338.979728
Free Energy 298K = -1339.068792
Lowest Frequency = 24.0588 $cm^{-1}$
Second Frequency = 29.3467 $cm^{-1}$
SCF (1,4-dioxane) Energy =
-1339.44656612
SCF (BP86-D3BJ) Energy =
-1339.57691145
SCF (BS2) Energy = -1339.46136352

| | | | |
|---|---|---|---|
| Ru | -1.08759 | -0.16104 | 0.01029 |
| O | -0.55204 | -2.18262 | -0.14849 |
| C | -0.59045 | -2.84659 | -1.29171 |
| C | 0.06554 | -4.22692 | -1.17323 |
| C | -3.32457 | -0.00989 | 0.66068 |
| C | -2.56334 | 1.18594 | 0.91658 |
| C | -1.90744 | 1.93391 | -0.12073 |
| C | -3.28197 | -0.59781 | -0.62852 |
| O | -1.06816 | -2.45313 | -2.36868 |
| H | 1.14960 | -4.11921 | -1.35150 |
| H | -0.06816 | -4.65502 | -0.16790 |
| H | -0.34477 | -4.90303 | -1.93767 |
| C | -1.30946 | 3.30271 | 0.18802 |
| H | -0.87348 | 3.23531 | 1.20477 |
| C | 3.09141 | 0.21515 | -0.15865 |
| C | 2.89894 | 0.43862 | -1.55722 |
| C | 4.03011 | 0.65497 | -2.36832 |
| C | 5.46467 | 0.42142 | -0.39475 |
| C | 5.30342 | 0.64375 | -1.77874 |
| H | 3.91478 | 0.82562 | -3.44399 |
| H | 6.46961 | 0.41664 | 0.03964 |
| H | 6.18794 | 0.80907 | -2.40327 |
| C | -1.87744 | 1.31179 | -1.41824 |
| C | -2.52749 | 0.06661 | -1.67098 |
| H | -2.39316 | -0.43696 | -2.62896 |
| H | -1.28631 | 1.76666 | -2.21789 |
| H | -2.51119 | 1.57066 | 1.94277 |
| H | -3.85196 | -0.51410 | 1.47602 |
| C | -2.43943 | 4.36118 | 0.23139 |

H  -2.03301  5.34894  0.50939
H  -2.92011  4.45891 -0.75807
H  -3.22224  4.09513  0.96190
C  -0.19262  3.73523 -0.77826
H   0.59028  2.96481 -0.86674
H  -0.59154  3.93929 -1.78826
H   0.27278  4.66904 -0.42061
C  -3.97265 -1.90485 -0.92428
H  -4.17351 -2.47437 -0.00316
H  -4.93867 -1.70968 -1.42570
H  -3.35077 -2.51182 -1.59998
C   1.39438 -0.28295  1.64694
N   2.27938 -0.44759  2.64872
N   0.02172 -0.40632  1.76630
C   1.77123 -0.78259  3.84571
C  -0.45022 -0.77020  2.97728
C   0.39776 -0.96771  4.07158
H   2.49986 -0.91408  4.65540
H  -1.53360 -0.90272  3.04294
H   0.00220 -1.25861  5.04669
N   1.79913  0.03337  0.38288
C   0.80035  0.14571 -0.64082
C   1.47230  0.38754 -1.82199
H   1.00388  0.48479 -2.80109
C   4.35566  0.20261  0.44180
H   4.46338  0.02453  1.51306

**$^{1a}$B-C7**

SCF (BP86) Energy = -1339.42493954
Enthalpy 0K = -1338.994874
Enthalpy 298K = -1338.965122
Free Energy 298K = -1339.053525
Lowest Frequency = 24.3551 $cm^{-1}$
Second Frequency = 32.9007 $cm^{-1}$
SCF (1,4-dioxane) Energy =
-1339.43099452
SCF (BP86-D3BJ) Energy =
-1339.56818785
SCF (BS2) Energy = -1339.44658019

Ru -0.81599  0.09005  0.12574
O  -1.42854 -1.75853 -0.63762
C  -2.15480 -1.88709 -1.73277
C  -2.28423 -3.34937 -2.17284
C  -2.35108  0.82256  1.74810
C  -1.05657  1.44351  1.84690
C  -0.47386  2.21915  0.78650
C  -3.00579  0.78085  0.49148
O  -2.68120 -0.97115 -2.38977
H  -1.40805 -3.61043 -2.79154
H  -2.29971 -4.03403 -1.31069
H  -3.19003 -3.47894 -2.78325
C   0.77994  3.04965  1.04402
H   1.44178  2.43604  1.68715
C   1.98305 -0.29505 -0.95344
C   3.09749 -0.16521 -1.83509
C   0.65443  0.00225 -1.29228
C   2.86661  0.22041 -3.17022
C   0.46579  0.34745 -2.65213
C   1.54154  0.44711 -3.56640
H   3.69674  0.32600 -3.87610
H  -0.55336  0.52725 -3.01032
H   1.32825  0.72106 -4.60602
C  -1.17609  2.18314 -0.46970
C  -2.39507  1.46364 -0.63162
H  -2.84147  1.35720 -1.62167
H  -0.72367  2.64810 -1.35017
H  -0.50202  1.35690  2.78986
H  -2.77392  0.29181  2.60684
C   0.40038  4.32312  1.84009
H   1.30279  4.90946  2.08532
H  -0.27156  4.96772  1.24612
H  -0.11530  4.07806  2.78416
C   1.56463  3.41982 -0.22701
H   1.82098  2.53098 -0.82463
H   0.99024  4.11486 -0.86538
H   2.50122  3.93334  0.04838
C  -4.30858  0.04637  0.29895
H  -4.48062 -0.69200  1.09832
H  -5.14847  0.76543  0.31055
H  -4.30867 -0.46440 -0.67640
C   1.76668 -1.27166  1.33427
N   2.47386 -1.86455  2.32312
N   0.39645 -1.20313  1.28714
C   1.78666 -2.54085  3.25145
C  -0.26468 -1.97342  2.19249
C   0.39033 -2.67947  3.20176
H   2.38007 -2.99808  4.05329
H  -1.35058 -1.98573  2.07694
H  -0.16596 -3.28429  3.92058
N   2.49690 -0.72632  0.29815
C   3.90275 -0.83286  0.19528
H   4.46783 -1.17783  1.05600
C   4.28711 -0.49444 -1.07466
H   5.31461 -0.48260 -1.43851

**$^{3a}$A-C2**

SCF (BP86) Energy = -1953.65691484
Enthalpy 0K = -1953.014461
Enthalpy 298K = -1952.967930
Free Energy 298K = -1953.096613
Lowest Frequency = 11.6754 $cm^{-1}$
Second Frequency = 16.9763 $cm^{-1}$
SCF (1,4-dioxane) Energy =
-1953.66404381
SCF (BP86-D3BJ) Energy =
-1953.85793198
SCF (BS2) Energy = -1953.85431845

Ru -1.79312 -0.10478 -0.33911
O  -3.51793  1.08245 -0.43525
C  -4.69122  0.69294 -0.91080
C  -5.78287  1.74175 -0.66312
C   0.07219 -0.43138 -1.48535
C  -0.12468 -1.57502 -0.65366
C  -1.37826 -2.27524 -0.67527

| | | | |
|---|---|---|---|
| C | -0.92328 | 0.03229 | -2.41541 |
| O | -4.95022 | -0.37855 | -1.47847 |
| H | -6.16495 | 1.62670 | 0.36639 |
| H | -5.38970 | 2.76533 | -0.76381 |
| H | -6.61711 | 1.58200 | -1.36140 |
| C | -1.58440 | -3.46653 | 0.25219 |
| H | -1.06286 | -3.21580 | 1.19446 |
| C | 2.32956 | 2.36834 | -0.28249 |
| C | 3.40916 | 1.47422 | -0.01638 |
| C | 4.66458 | 1.72047 | -0.61566 |
| C | 3.72778 | 3.71329 | -1.68888 |
| C | 4.81040 | 2.83797 | -1.44621 |
| H | 5.50376 | 1.03988 | -0.44384 |
| H | 3.87141 | 4.58506 | -2.33528 |
| H | 5.77957 | 3.03829 | -1.91449 |
| C | -2.39695 | -1.81570 | -1.57359 |
| C | -2.16461 | -0.67392 | -2.41547 |
| H | -3.01226 | -0.29030 | -2.98907 |
| H | -3.40640 | -2.22510 | -1.54252 |
| H | 0.65515 | -1.86260 | 0.05294 |
| H | 1.00697 | 0.12768 | -1.39205 |
| C | -0.89034 | -4.70448 | -0.36832 |
| H | -0.97355 | -5.56711 | 0.31455 |
| H | -1.36410 | -4.98268 | -1.32630 |
| H | 0.18055 | -4.52104 | -0.55823 |
| C | -3.05943 | -3.76548 | 0.57496 |
| H | -3.57252 | -2.87006 | 0.95995 |
| H | -3.60649 | -4.12674 | -0.31382 |
| H | -3.11865 | -4.56078 | 1.33726 |
| C | -0.68220 | 1.22714 | -3.30531 |
| H | 0.05380 | 1.91575 | -2.85949 |
| H | -0.28368 | 0.90463 | -4.28514 |
| H | -1.61634 | 1.78204 | -3.48852 |
| C | -0.02741 | 2.49845 | 0.57362 |
| N | 0.01100 | 3.83794 | 0.66025 |
| N | -1.15682 | 1.73627 | 0.72377 |
| C | -1.07698 | 4.45402 | 1.14874 |
| C | -2.18316 | 2.36126 | 1.37123 |
| C | -2.16592 | 3.72976 | 1.65012 |
| H | -1.04814 | 5.55042 | 1.16631 |
| H | -3.03165 | 1.72036 | 1.60818 |
| H | -3.00269 | 4.20829 | 2.16325 |
| N | 1.19426 | 1.85136 | 0.37972 |
| C | 1.56919 | 0.67894 | 1.07529 |
| H | 0.81259 | 0.13791 | 1.65424 |
| C | 2.90754 | 0.42933 | 0.86932 |
| C | 2.46976 | 3.49283 | -1.11110 |
| H | 1.63813 | 4.18143 | -1.27122 |
| C | -1.88264 | -0.90335 | 2.56367 |
| C | -2.72051 | -1.21287 | 3.80854 |
| H | -2.09322 | -1.14262 | 4.70890 |
| H | -3.58685 | -0.53853 | 3.88898 |
| H | -3.10964 | -2.24328 | 3.73433 |
| O | -0.64362 | -1.03593 | 2.57830 |
| O | -2.62318 | -0.53393 | 1.53744 |
| C | 3.74272 | -0.66225 | 1.52654 |
| C | 4.79908 | -0.02164 | 2.46124 |
| H | 4.28519 | 0.51310 | 3.27656 |
| H | 5.44914 | -0.79800 | 2.89611 |
| H | 5.43986 | 0.69402 | 1.92580 |
| C | 2.86873 | -1.64154 | 2.34856 |
| H | 3.50412 | -2.41220 | 2.81666 |
| H | 2.33943 | -1.10082 | 3.14918 |
| H | 2.11481 | -2.14632 | 1.72754 |
| C | 4.48301 | -1.45470 | 0.42154 |
| O | 5.69797 | -1.49266 | 0.26891 |
| O | 3.61131 | -2.12535 | -0.38641 |
| C | 4.23964 | -2.88241 | -1.46405 |
| H | 4.99470 | -3.55857 | -1.02785 |
| H | 4.77326 | -2.17533 | -2.12303 |
| C | 3.14392 | -3.63766 | -2.19960 |
| H | 3.58280 | -4.21121 | -3.03320 |
| H | 2.63227 | -4.34689 | -1.52856 |
| H | 2.39228 | -2.94674 | -2.61454 |

**$^{3a}$A-C7**

SCF (BP86) Energy = -1953.64537803
Enthalpy 0K = -1953.002636
Enthalpy 298K = -1952.956240
Free Energy 298K = -1953.084885
Lowest Frequency = 13.4252 $cm^{-1}$
Second Frequency = 17.0411 $cm^{-1}$
SCF (1,4-dioxane) Energy = -1953.65329427
SCF (BP86-D3BJ) Energy = -1953.84684443
SCF (BS2) Energy = -1953.84322045

| | | | |
|---|---|---|---|
| Ru | 2.06436 | 0.16721 | -0.37584 |
| O | 3.96490 | -0.57882 | 0.16155 |
| C | 4.55952 | -1.57950 | -0.46556 |
| C | 6.00426 | -1.77554 | 0.00939 |
| C | 0.33714 | 0.23153 | -1.77022 |
| C | 0.56155 | 1.54840 | -1.27478 |
| C | 1.86846 | 2.15051 | -1.38113 |
| C | 1.37252 | -0.54166 | -2.41128 |
| O | 4.05720 | -2.31589 | -1.33304 |
| H | 6.60741 | -0.88887 | -0.24946 |
| H | 6.04059 | -1.87753 | 1.10660 |
| H | 6.43870 | -2.66668 | -0.46504 |
| C | 2.09204 | 3.53528 | -0.79097 |
| H | 1.57392 | 3.53123 | 0.18630 |
| C | -1.46648 | -0.00483 | 0.96421 |
| C | -2.73955 | 0.36522 | 0.42996 |
| C | -3.29481 | 1.60823 | 0.81249 |
| C | -1.34785 | 2.00583 | 2.24897 |
| C | -2.58833 | 2.41922 | 1.70830 |
| H | -4.27848 | 1.90925 | 0.44236 |
| H | -0.83242 | 2.64624 | 2.97172 |
| H | -3.01463 | 3.38022 | 2.01517 |
| C | 2.91258 | 1.38601 | -1.98611 |
| C | 2.66532 | 0.05280 | -2.48078 |
| H | 3.50254 | -0.55566 | -2.83031 |
| H | 3.93566 | 1.76732 | -1.98475 |
| H | -0.23824 | 2.06913 | -0.74133 |
| H | -0.64803 | -0.22178 | -1.63353 |

```
C   1.41509  4.58885 -1.70236
H   1.50344  5.59168 -1.25106
H   1.89792  4.62017 -2.69504
H   0.34325  4.37691 -1.85313
C   3.56762  3.88222 -0.53560
H   4.04051  3.12235  0.10607
H   4.13812  3.96953 -1.47805
H   3.63657  4.85723 -0.02451
C   1.13272 -1.94262 -2.91469
H   0.26495 -2.40296 -2.41475
H   0.92655 -1.93437 -4.00083
H   2.02464 -2.56006 -2.72422
C  -0.04501 -2.08664  0.74718
N  -0.33986 -3.38105  0.96283
N   1.20733 -1.53770  0.79496
C   0.64329 -4.16964  1.41967
C   2.14016 -2.32010  1.41046
C   1.89629 -3.64688  1.76186
H   0.40036 -5.23256  1.53909
H   3.10385 -1.84004  1.56746
H   2.67541 -4.25019  2.23226
N  -1.15826 -1.28072  0.45706
C  -2.24086 -1.72202 -0.31874
H  -2.20434 -2.72116 -0.74421
C  -3.20654 -0.74089 -0.39785
C  -0.76638  0.78228  1.89053
H   0.18345  0.44841  2.31845
C   2.66535  0.96633  2.54740
C   3.41116  2.02012  3.37524
H   3.24697  1.84026  4.44757
H   4.49169  1.93928  3.16411
H   3.09615  3.04036  3.10572
O   2.29306 -0.10322  3.06135
O   2.48651  1.34869  1.29926
C  -4.50280 -0.82590 -1.19955
C  -4.61262 -2.18465 -1.93058
H  -5.54034 -2.22265 -2.52528
H  -3.76180 -2.31752 -2.61946
H  -4.63707 -3.01582 -1.21003
C  -4.57071  0.32252 -2.23711
H  -3.75896  0.19332 -2.97297
H  -5.53247  0.30545 -2.77629
H  -4.45704  1.31260 -1.77321
C  -5.67412 -0.77998 -0.18004
O  -6.03266 -1.73200  0.49832
O  -6.26408  0.44930 -0.11442
C  -7.35152  0.55256  0.85550
H  -6.94216  0.35948  1.86208
H  -8.08784 -0.24063  0.64126
C  -7.94722  1.94615  0.72963
H  -7.19817  2.72327  0.95308
H  -8.33712  2.12096 -0.28632
H  -8.78081  2.05924  1.44281
```

**$^{3a}$B-C2**

```
Ru_indole_C3sub_alt_OAc_b
SCF (BP86) Energy = -1724.56378002
Enthalpy 0K = -1723.982148
Enthalpy 298K = -1723.941966
Free Energy 298K = -1724.053890
Lowest Frequency = 15.9073 cm-1
Second Frequency = 26.3722 cm-1
SCF (1,4-dioxane) Energy =
      -1724.56985957
SCF (BP86-D3BJ) Energy =
      -1724.74995668
SCF (BS2) Energy = -1724.68731711

Ru -1.23944  0.72157  0.04010
O  -1.35390  1.21069 -2.00391
C  -2.53155  1.45093 -2.54369
C  -2.44268  1.72865 -4.04833
C  -2.56646  2.45944  0.75213
C  -2.86797  1.30933  1.50776
C  -1.83467  0.55705  2.19689
C  -1.19860  2.93067  0.65016
O  -3.63561  1.44335 -1.96149
H  -1.49660  2.22414 -4.31399
H  -2.48232  0.76886 -4.59259
H  -3.30052  2.33902 -4.36722
C  -2.23115 -0.66336  3.02174
H  -2.97660 -1.22392  2.42241
C   1.17059 -2.66995 -0.40415
C   2.28363 -1.79447 -0.56159
C   3.57519 -2.36725 -0.53017
C   2.58645 -4.59861 -0.29566
C   3.71242 -3.75780 -0.39995
H   4.46462 -1.73402 -0.56843
H   2.71948 -5.68130 -0.20262
H   4.71650 -4.19503 -0.37369
C  -0.49586  1.03717  2.10020
C  -0.18109  2.22919  1.35184
H   0.86961  2.52719  1.27181
H   0.32331  0.47939  2.55925
H  -3.89517  0.92831  1.51294
H  -3.34889  2.93532  0.15735
C  -2.93278 -0.19789  4.32140
H  -3.29155 -1.06735  4.89828
H  -2.23231  0.36909  4.95934
H  -3.79881  0.45205  4.11078
C  -1.06564 -1.61552  3.34250
H  -0.52072 -1.92296  2.43505
H  -0.34281 -1.14883  4.03484
H  -1.44788 -2.52431  3.83642
C  -0.89747  4.14481 -0.19443
H  -1.26313  4.00164 -1.22489
H  -1.40749  5.03068  0.22478
H   0.18139  4.35545 -0.23334
C  -1.28905 -2.17463 -0.46000
N  -1.69160 -3.45281 -0.57898
N  -2.12601 -1.07858 -0.44700
C  -3.01008 -3.64696 -0.76022
C  -3.44035 -1.29660 -0.68406
C  -3.93516 -2.59567 -0.84885
H  -3.33034 -4.69259 -0.84935
H  -4.04584 -0.38988 -0.77852
```

| | | | |
|---|---|---|---|
| H | -4.99625 | -2.76991 | -1.03844 |
| N | 0.03324 | -1.84056 | -0.35222 |
| C | 0.39484 | -0.44470 | -0.44154 |
| C | 1.77207 | -0.41914 | -0.66886 |
| C | 1.28915 | -4.06070 | -0.28832 |
| H | 0.40120 | -4.68745 | -0.19423 |
| C | 2.64000 | 0.77746 | -1.09382 |
| C | 3.45834 | 1.21650 | 0.14175 |
| O | 4.71680 | 0.68910 | 0.15043 |
| C | 5.53648 | 1.00466 | 1.31699 |
| H | 6.22093 | 0.14625 | 1.40695 |
| H | 4.88298 | 1.05393 | 2.20268 |
| O | 3.03606 | 1.93463 | 1.04685 |
| C | 1.79773 | 1.98283 | -1.56396 |
| H | 2.46493 | 2.78171 | -1.93289 |
| H | 1.12001 | 1.67072 | -2.37265 |
| H | 1.18065 | 2.38837 | -0.75851 |
| C | 3.54463 | 0.38992 | -2.29554 |
| H | 2.89803 | 0.13808 | -3.15246 |
| H | 4.17845 | 1.24637 | -2.58218 |
| H | 4.19934 | -0.46769 | -2.10261 |
| C | 6.29426 | 2.31309 | 1.11583 |
| H | 5.59178 | 3.15818 | 1.04643 |
| H | 6.96693 | 2.49283 | 1.97210 |
| H | 6.90489 | 2.27917 | 0.19881 |

**$^{3a}$B-C7**

SCF (BP86) Energy = -1724.55562335
Enthalpy 0K = -1723.974903
Enthalpy 298K = -1723.934477
Free Energy 298K = -1724.048026
Lowest Frequency = 15.9514 $cm^{-1}$
Second Frequency = 17.5294 $cm^{-1}$
SCF (1,4-dioxane) Energy = -1724.56291408
SCF (BP86-D3BJ) Energy = -1724.73576488
SCF (BS2) Energy = -1724.68082536

| | | | |
|---|---|---|---|
| Ru | 2.17831 | 0.17401 | -0.01039 |
| O | 2.71175 | -1.31793 | -1.37566 |
| C | 3.41879 | -2.38361 | -1.04697 |
| C | 3.49002 | -3.40482 | -2.18733 |
| C | 3.76381 | 1.90605 | -0.09651 |
| C | 2.49685 | 2.30292 | 0.45781 |
| C | 1.92965 | 1.70028 | 1.63301 |
| C | 4.39797 | 0.73558 | 0.39169 |
| O | 3.96930 | -2.60404 | 0.04673 |
| H | 2.59442 | -4.04857 | -2.14141 |
| H | 3.49740 | -2.91409 | -3.17296 |
| H | 4.37985 | -4.04011 | -2.06733 |
| C | 0.71558 | 2.33096 | 2.30808 |
| H | 0.04147 | 2.67208 | 1.49732 |
| C | -0.64667 | -0.89267 | 0.20772 |
| C | -1.76565 | -1.60156 | 0.73975 |
| C | 0.69292 | -1.10838 | 0.56670 |
| C | -1.51461 | -2.65456 | 1.64523 |
| C | 0.89313 | -2.19792 | 1.44656 |
| C | -0.18301 | -2.95332 | 1.96511 |
| H | -2.33027 | -3.23730 | 2.08247 |
| H | 1.91763 | -2.47227 | 1.71891 |
| H | 0.03181 | -3.78574 | 2.64494 |
| C | 2.61051 | 0.53080 | 2.12331 |
| C | 3.79845 | 0.03708 | 1.51068 |
| H | 4.22652 | -0.91384 | 1.83199 |
| H | 2.16373 | -0.04788 | 2.93674 |
| H | 1.95325 | 3.13231 | -0.01211 |
| H | 4.17788 | 2.43715 | -0.95924 |
| C | 1.16156 | 3.58164 | 3.10577 |
| H | 0.28876 | 4.08503 | 3.55647 |
| H | 1.84837 | 3.29779 | 3.92278 |
| H | 1.68423 | 4.31168 | 2.46461 |
| C | -0.07692 | 1.36757 | 3.20913 |
| H | -0.37747 | 0.45592 | 2.66922 |
| H | 0.51201 | 1.06959 | 4.09504 |
| H | -0.98809 | 1.86657 | 3.57988 |
| C | 5.66839 | 0.20621 | -0.22439 |
| H | 5.82337 | 0.60323 | -1.24030 |
| H | 6.53526 | 0.50244 | 0.39478 |
| H | 5.63472 | -0.89356 | -0.26302 |
| C | -0.44692 | 0.75384 | -1.65890 |
| N | -1.17103 | 1.41745 | -2.58928 |
| N | 0.92426 | 0.69752 | -1.63275 |
| C | -0.50757 | 1.94097 | -3.62705 |
| C | 1.55696 | 1.16071 | -2.74378 |
| C | 0.87891 | 1.78848 | -3.78903 |
| H | -1.11321 | 2.48910 | -4.35978 |
| H | 2.63939 | 1.01537 | -2.74815 |
| H | 1.41189 | 2.15791 | -4.66731 |
| N | -1.16052 | 0.07374 | -0.69398 |
| C | -2.56745 | -0.01754 | -0.69268 |
| H | -3.13268 | 0.64334 | -1.34179 |
| C | -2.97552 | -1.00987 | 0.16383 |
| C | -4.41484 | -1.44328 | 0.43115 |
| C | -4.75828 | -1.28040 | 1.93998 |
| H | -5.79881 | -1.59374 | 2.13398 |
| H | -4.09291 | -1.90570 | 2.55532 |
| H | -4.64266 | -0.23340 | 2.25644 |
| C | -4.61769 | -2.91259 | -0.01545 |
| H | -3.92489 | -3.57792 | 0.52181 |
| H | -5.65109 | -3.23694 | 0.18928 |
| H | -4.43800 | -3.01788 | -1.09565 |
| C | -5.39413 | -0.57151 | -0.39057 |
| O | -6.08208 | -0.96592 | -1.32242 |
| O | -5.42627 | 0.71727 | 0.06253 |
| C | -6.35098 | 1.59381 | -0.64532 |
| H | -7.36534 | 1.16276 | -0.58277 |
| H | -6.07228 | 1.61765 | -1.71345 |
| C | -6.26477 | 2.96654 | 0.00463 |
| H | -6.95285 | 3.66367 | -0.50226 |
| H | -6.54490 | 2.91873 | 1.06950 |
| H | -5.24390 | 3.37569 | -0.06697 |

**$^{3a}$B-C2***

SCF (BP86) Energy = -1724.57336183
Enthalpy 0K = -1723.992200

Enthalpy 298K = -1723.952181
Free Energy 298K = -1724.063609
Lowest Frequency = 23.3895 $cm^{-1}$
Second Frequency = 24.7214 $cm^{-1}$
SCF (1,4-dioxane) Energy =
-1724.57885031
SCF (BP86-D3BJ) Energy =
-1724.76274897
SCF (BS2) Energy = -1724.69001003

| | | | |
|---|---|---|---|
| Ru | -0.96540 | 0.58093 | 0.24150 |
| O | -1.66773 | 0.12593 | 2.19307 |
| C | -2.62025 | 1.00724 | 2.18083 |
| C | -3.49007 | 1.16170 | 3.41026 |
| C | 0.05262 | 3.55033 | -1.86315 |
| C | 1.19599 | 2.72384 | -2.09617 |
| C | 1.09068 | 1.34296 | -2.16959 |
| C | -1.21617 | 3.01573 | -1.70188 |
| O | -2.78261 | 1.73696 | 1.14743 |
| H | -3.52032 | 0.22502 | 3.98646 |
| H | -3.06964 | 1.94932 | 4.05979 |
| H | -4.50630 | 1.46850 | 3.12029 |
| C | 2.24693 | 0.43231 | -2.57577 |
| H | 2.14237 | -0.49948 | -1.98649 |
| C | 2.65616 | -1.15530 | 1.02621 |
| C | 2.01191 | -2.37145 | 0.60716 |
| C | 2.76502 | -3.56415 | 0.68077 |
| C | 4.68576 | -2.31567 | 1.55736 |
| C | 4.08792 | -3.52496 | 1.15152 |
| H | 2.33138 | -4.52261 | 0.37721 |
| H | 5.71808 | -2.31297 | 1.92146 |
| H | 4.66370 | -4.45539 | 1.20402 |
| C | -0.20860 | 0.74167 | -1.94216 |
| C | -1.35895 | 1.57567 | -1.71825 |
| H | -2.36343 | 1.16828 | -1.89817 |
| H | -0.34898 | -0.28678 | -2.29465 |
| H | 2.16505 | 3.20720 | -2.25729 |
| H | 0.18154 | 4.63970 | -1.84770 |
| C | 3.64163 | 1.01483 | -2.28519 |
| H | 4.41952 | 0.26755 | -2.51590 |
| H | 3.84936 | 1.90427 | -2.90708 |
| H | 3.75053 | 1.30137 | -1.22618 |
| C | 2.12278 | 0.05032 | -4.07275 |
| H | 1.14243 | -0.40226 | -4.30039 |
| H | 2.23454 | 0.94497 | -4.71060 |
| H | 2.90592 | -0.67430 | -4.35703 |
| C | -2.44512 | 3.87275 | -1.51967 |
| H | -2.93486 | 3.64879 | -0.55492 |
| H | -2.20042 | 4.94725 | -1.55437 |
| H | -3.19334 | 3.67049 | -2.30913 |
| C | 1.68155 | 1.19789 | 1.22720 |
| N | 2.75792 | 1.79481 | 1.75212 |
| N | 0.43860 | 1.80289 | 1.01144 |
| C | 2.61387 | 3.08430 | 2.12263 |
| C | 0.33279 | 3.09599 | 1.40273 |
| C | 1.40924 | 3.78368 | 1.97662 |
| H | 3.50237 | 3.56176 | 2.55284 |
| H | -0.64801 | 3.55019 | 1.24304 |
| H | 1.30326 | 4.82517 | 2.28870 |
| N | 1.70730 | -0.12699 | 0.85466 |
| C | 0.49919 | -0.67117 | 0.34229 |
| C | 0.65077 | -2.03478 | 0.18689 |
| C | 3.97053 | -1.10609 | 1.49964 |
| H | 4.40687 | -0.15509 | 1.81161 |
| C | -0.44754 | -2.98495 | -0.26294 |
| C | -1.79343 | -2.28028 | -0.57714 |
| O | -2.69380 | -3.17531 | -1.03376 |
| C | -4.04190 | -2.69425 | -1.34492 |
| H | -4.40463 | -3.41505 | -2.09411 |
| H | -3.96547 | -1.69448 | -1.80018 |
| O | -2.13516 | -1.08282 | -0.46211 |
| C | -0.75523 | -4.00776 | 0.87924 |
| H | -1.50567 | -4.74867 | 0.56084 |
| H | 0.17158 | -4.53501 | 1.15318 |
| H | -1.11865 | -3.48316 | 1.77779 |
| C | -0.01277 | -3.75266 | -1.54988 |
| H | 0.94487 | -4.26244 | -1.36309 |
| H | -0.76250 | -4.50300 | -1.84531 |
| H | 0.14337 | -3.05394 | -2.38869 |
| C | -4.92308 | -2.67960 | -0.10114 |
| H | -4.55092 | -1.95098 | 0.63518 |
| H | -5.95001 | -2.39065 | -0.38267 |
| H | -4.96179 | -3.67650 | 0.36680 |

**S3a**
SCF (BP86) Energy = -1111.32363304
Enthalpy 0K = -1110.998319
Enthalpy 298K = -1110.975455
Free Energy 298K = -1111.050639
Lowest Frequency = 11.6412 $cm^{-1}$
Second Frequency = 35.1951 $cm^{-1}$

| | | | |
|---|---|---|---|
| C | -1.68286 | 1.11627 | -0.05807 |
| C | -0.37261 | 1.70043 | -0.00344 |
| C | -0.31720 | 3.10748 | -0.04421 |
| C | -2.72760 | 3.27188 | -0.20960 |
| C | -1.46347 | 3.89253 | -0.14791 |
| H | -3.62439 | 3.89362 | -0.29080 |
| H | -1.35650 | 4.98007 | -0.17511 |
| C | -2.47305 | -1.29487 | 0.01039 |
| N | -3.76940 | -0.92392 | -0.07891 |
| N | -1.99268 | -2.55917 | 0.09310 |
| C | -4.66214 | -1.93021 | -0.08059 |
| C | -2.91574 | -3.53275 | 0.09008 |
| C | -4.29378 | -3.27917 | 0.00439 |
| H | -5.71635 | -1.63274 | -0.15323 |
| H | -2.53020 | -4.55849 | 0.15882 |
| H | -5.03273 | -4.08369 | 0.00312 |
| N | -1.50427 | -0.28111 | 0.01915 |
| C | -0.12959 | -0.54853 | 0.11945 |
| C | 0.60050 | 0.61523 | 0.10278 |
| C | -2.85907 | 1.87872 | -0.16326 |
| H | -3.82879 | 1.38502 | -0.20218 |
| C | 2.12689 | 0.71197 | 0.15836 |
| C | 2.69067 | -0.72559 | 0.28290 |
| O | 3.39238 | -1.11048 | -0.82117 |

| | | | |
|---|---|---|---|
| C | 3.97137 | -2.44951 | -0.76567 |
| H | 4.02944 | -2.76192 | -1.82048 |
| H | 3.27938 | -3.10954 | -0.21794 |
| O | 2.53357 | -1.44120 | 1.26589 |
| C | 2.57204 | 1.45959 | 1.44779 |
| H | 3.67283 | 1.53706 | 1.48490 |
| H | 2.15468 | 2.47661 | 1.45482 |
| H | 2.22991 | 0.91328 | 2.33943 |
| C | 2.66986 | 1.43082 | -1.10178 |
| H | 2.28854 | 2.46088 | -1.13393 |
| H | 3.77125 | 1.46713 | -1.07951 |
| H | 2.36389 | 0.90863 | -2.02098 |
| C | 5.34649 | -2.42574 | -0.10577 |
| H | 5.26095 | -2.12802 | 0.95086 |
| H | 5.79848 | -3.43174 | -0.14474 |
| H | 6.02134 | -1.72413 | -0.62275 |
| F | 0.88890 | 3.75112 | 0.02692 |
| H | 0.19070 | -1.58047 | 0.22114 |

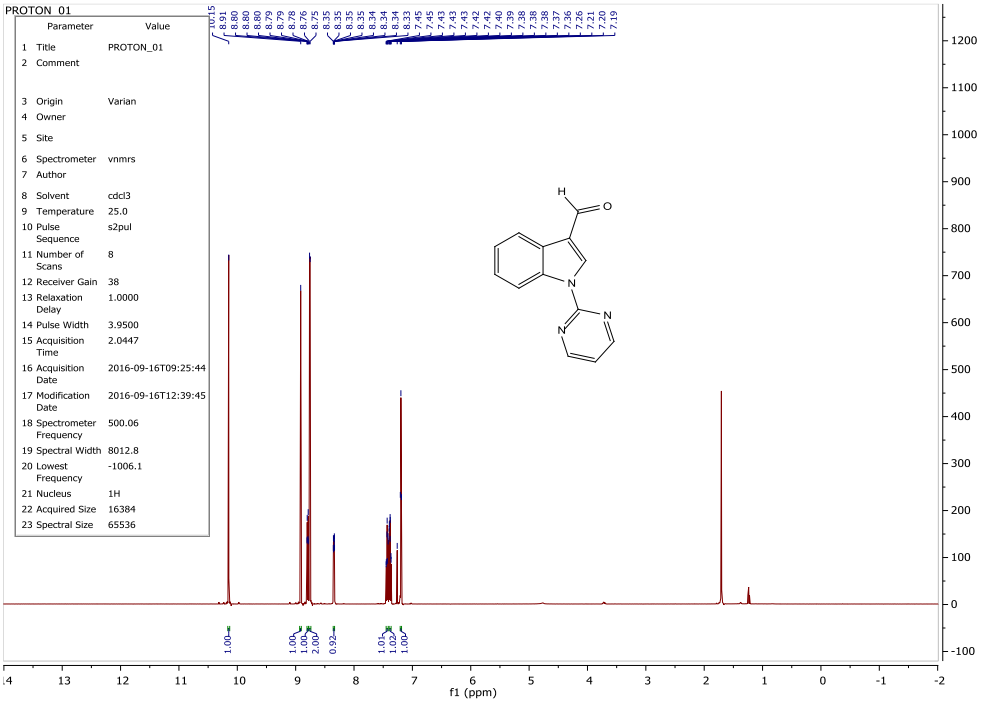
**$^{S3a}$B-C2***

SCF (BP86) Energy = -1823.80944051
Enthalpy 0K = -1823.235863
Enthalpy 298K = -1823.195113
Free Energy 298K = -1823.307863
Lowest Frequency = 22.8255 $cm^{-1}$
Second Frequency = 24.3554 $cm^{-1}$

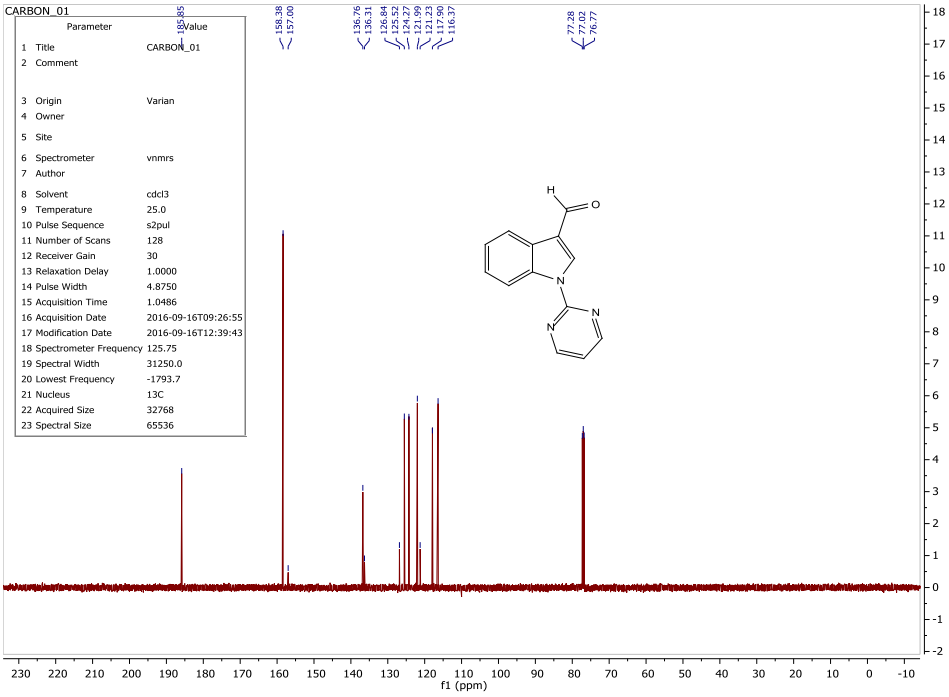
| | | | |
|---|---|---|---|
| Ru | -1.20912 | 0.25336 | -0.24666 |
| O | -1.35729 | 1.08235 | -2.19500 |
| C | -2.65291 | 1.15683 | -2.18810 |
| C | -3.36273 | 1.68358 | -3.41685 |
| C | -2.64604 | -2.55616 | 1.83392 |
| C | -1.25858 | -2.79897 | 2.07966 |
| C | -0.34425 | -1.75974 | 2.16775 |
| C | -3.14736 | -1.27361 | 1.67354 |
| O | -3.29464 | 0.76070 | -1.15920 |
| H | -2.70682 | 2.35883 | -3.98610 |
| H | -3.63579 | 0.83848 | -4.07278 |
| H | -4.28981 | 2.20079 | -3.12717 |
| C | 1.10968 | -1.95324 | 2.59164 |
| H | 1.71087 | -1.22387 | 2.01448 |
| C | 2.55974 | -1.14978 | -1.00048 |
| C | 2.98262 | 0.15827 | -0.56924 |
| C | 4.36926 | 0.38810 | -0.64376 |
| C | 4.79771 | -1.83750 | -1.51592 |
| C | 5.26916 | -0.57605 | -1.10265 |
| H | 5.50967 | -2.58654 | -1.87502 |
| H | 6.33328 | -0.32607 | -1.13217 |
| C | -0.81841 | -0.40898 | 1.94088 |
| C | -2.21593 | -0.16665 | 1.70331 |
| H | -2.62657 | 0.83675 | 1.88124 |
| H | -0.18385 | 0.40873 | 2.30163 |
| H | -0.93004 | -3.83096 | 2.24023 |
| H | -3.33598 | -3.40874 | 1.80851 |
| C | 1.67122 | -3.35655 | 2.30102 |
| H | 2.74593 | -3.39250 | 2.54693 |
| H | 1.17138 | -4.12986 | 2.91178 |
| H | 1.55721 | -3.62928 | 1.23885 |
| C | 1.27642 | -1.60542 | 4.09283 |
| H | 0.91243 | -0.58900 | 4.32085 |
| H | 0.70595 | -2.31374 | 4.71936 |
| H | 2.33810 | -1.66093 | 4.39091 |
| C | -4.61730 | -0.99106 | 1.47998 |
| H | -4.79069 | -0.47770 | 0.51713 |
| H | -5.21588 | -1.91667 | 1.50350 |
| H | -5.00184 | -0.31943 | 2.27053 |
| C | 0.19349 | -2.07470 | -1.22694 |
| N | 0.51825 | -3.26084 | -1.75200 |
| N | -1.10596 | -1.60157 | -1.02202 |
| C | -0.50473 | -4.05315 | -2.13607 |
| C | -2.10546 | -2.42275 | -1.42783 |
| C | -1.84577 | -3.67255 | -2.00332 |
| H | -0.22568 | -5.02239 | -2.56610 |
| H | -3.11539 | -2.03378 | -1.27866 |
| H | -2.66515 | -4.31854 | -2.32685 |
| N | 1.16151 | -1.17142 | -0.84271 |
| C | 0.71129 | 0.07347 | -0.32958 |
| C | 1.79620 | 0.91239 | -0.15702 |
| C | 3.42783 | -2.14238 | -1.47006 |
| H | 3.03310 | -3.10895 | -1.78658 |
| C | 1.70547 | 2.35972 | 0.30965 |
| C | 0.25435 | 2.83127 | 0.59337 |
| O | 0.25810 | 4.10120 | 1.04696 |
| C | -1.03148 | 4.73202 | 1.33596 |
| H | -0.77995 | 5.49555 | 2.08841 |
| H | -1.70266 | 3.98107 | 1.78116 |
| O | -0.84243 | 2.24301 | 0.46397 |
| C | 2.25905 | 3.31078 | -0.80139 |
| H | 2.21780 | 4.36272 | -0.47757 |
| H | 3.30603 | 3.04289 | -1.00219 |
| H | 1.68179 | 3.19399 | -1.73310 |
| C | 2.52155 | 2.56618 | 1.62450 |
| H | 3.56538 | 2.27685 | 1.43826 |
| H | 2.49609 | 3.61806 | 1.94908 |
| H | 2.12537 | 1.93263 | 2.43589 |
| C | -1.63549 | 5.35255 | 0.08138 |
| H | -1.88686 | 4.57726 | -0.65840 |
| H | -2.56255 | 5.88850 | 0.34723 |
| H | -0.93946 | 6.07403 | -0.37606 |
| F | 4.88307 | 1.60411 | -0.25688 |

# 8. NMR Spectra

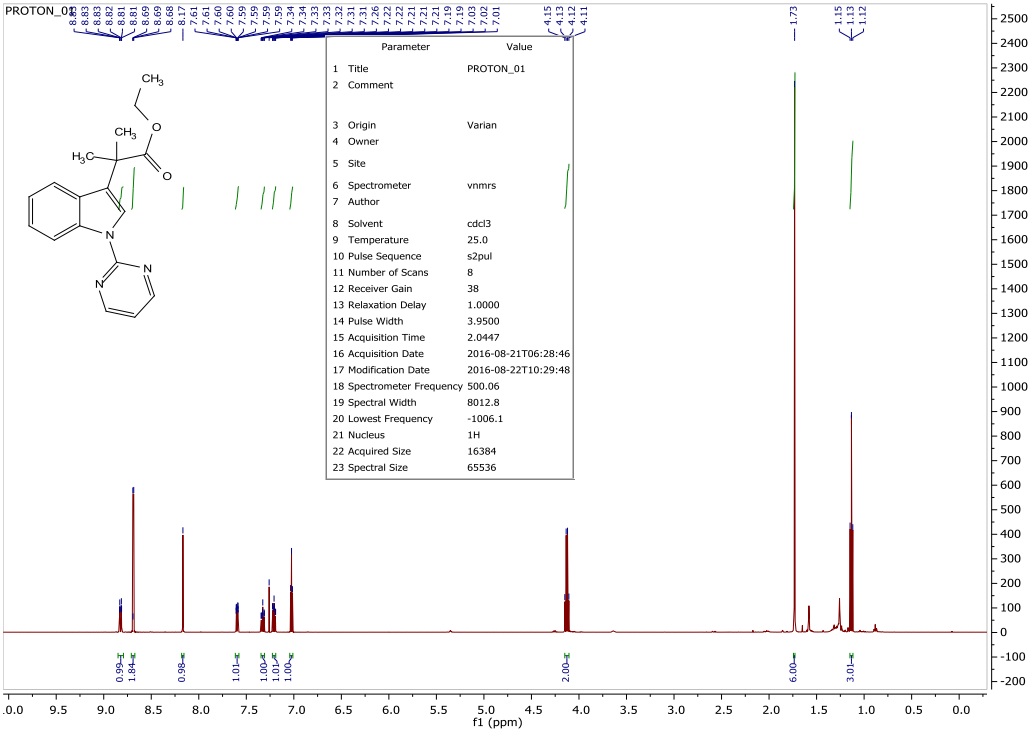
## **3i** – $^{1}$H NMR (500 MHz, $CDCl_3$)



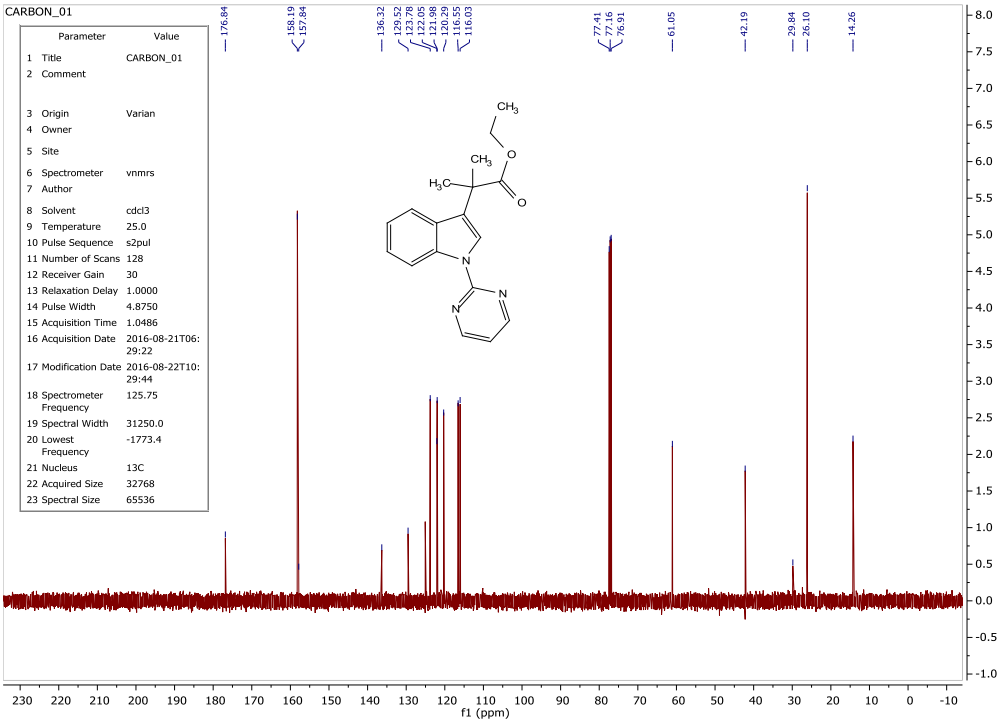

## **3i** – $^{13}$C NMR (126 MHz, $CDCl_3$)



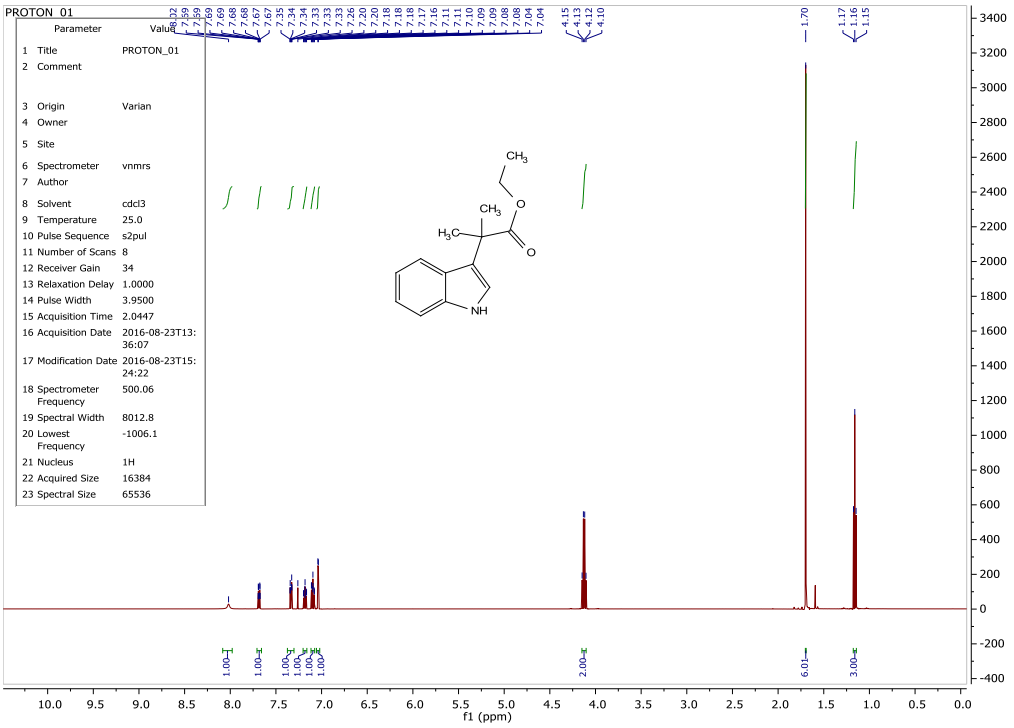
## **3a** – $^{1}$H NMR (500 MHz, $CDCl_3$)



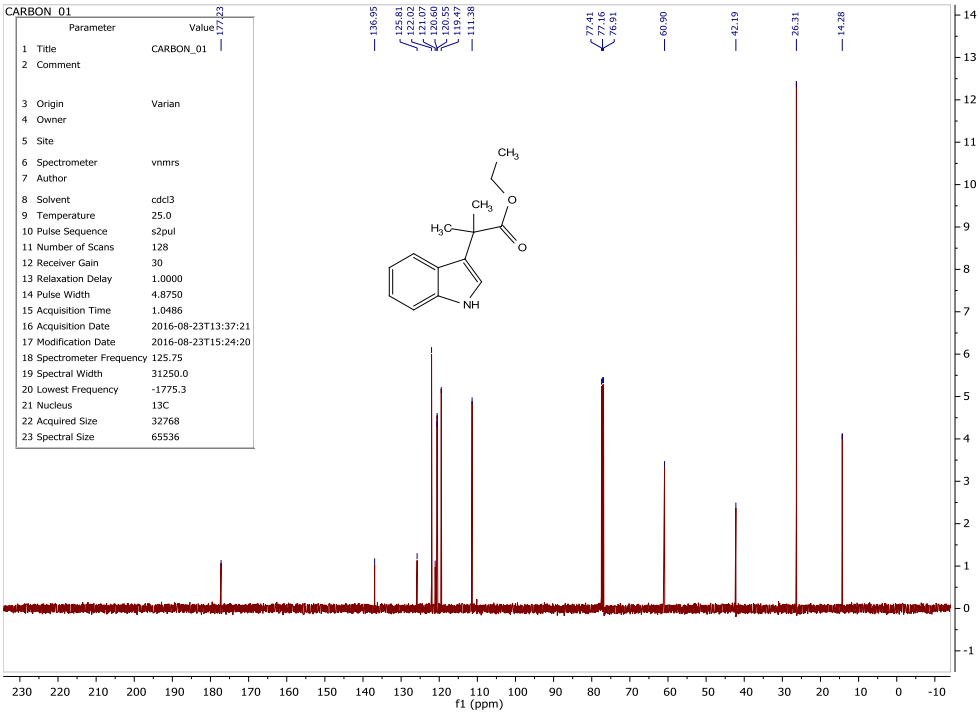

## **3a** – $^{13}$C NMR (126 MHz, $CDCl_3$)



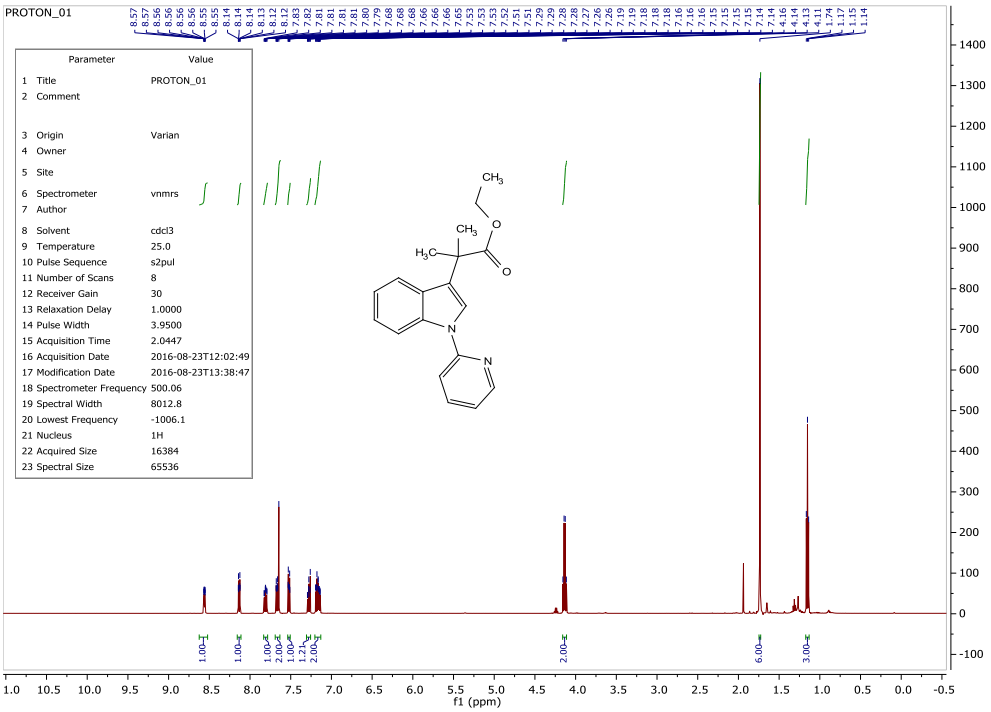
## **3b** – $^{1}$H NMR (500 MHz, $CDCl_3$)



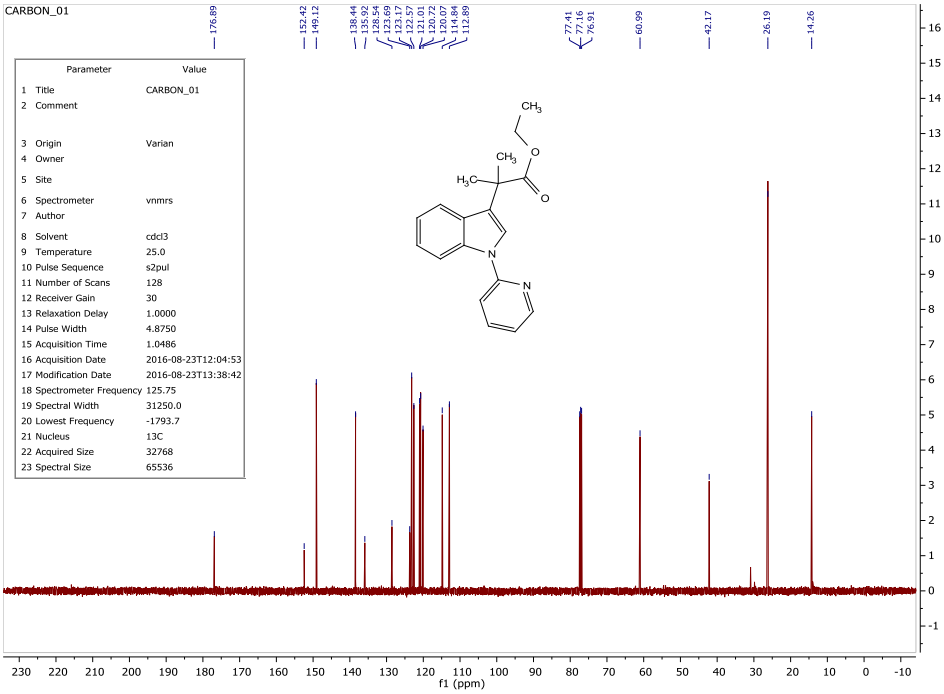

## **3b** – $^{13}$C NMR (126 MHz, $CDCl_3$)



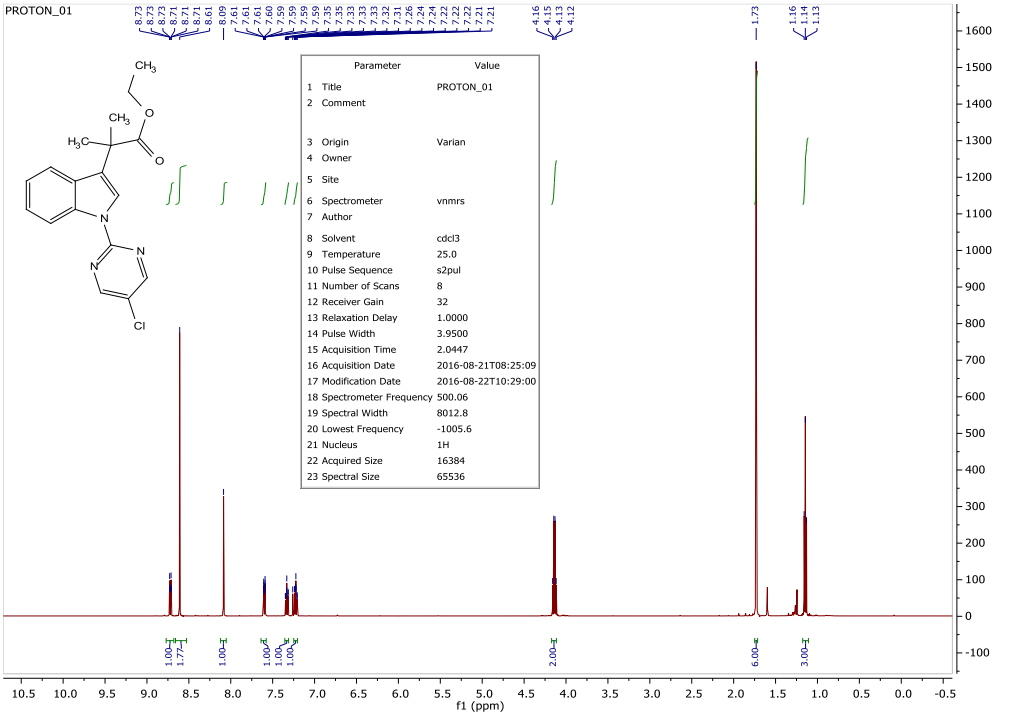
## **3j** – $^{1}$H NMR (500 MHz, $CDCl_3$)



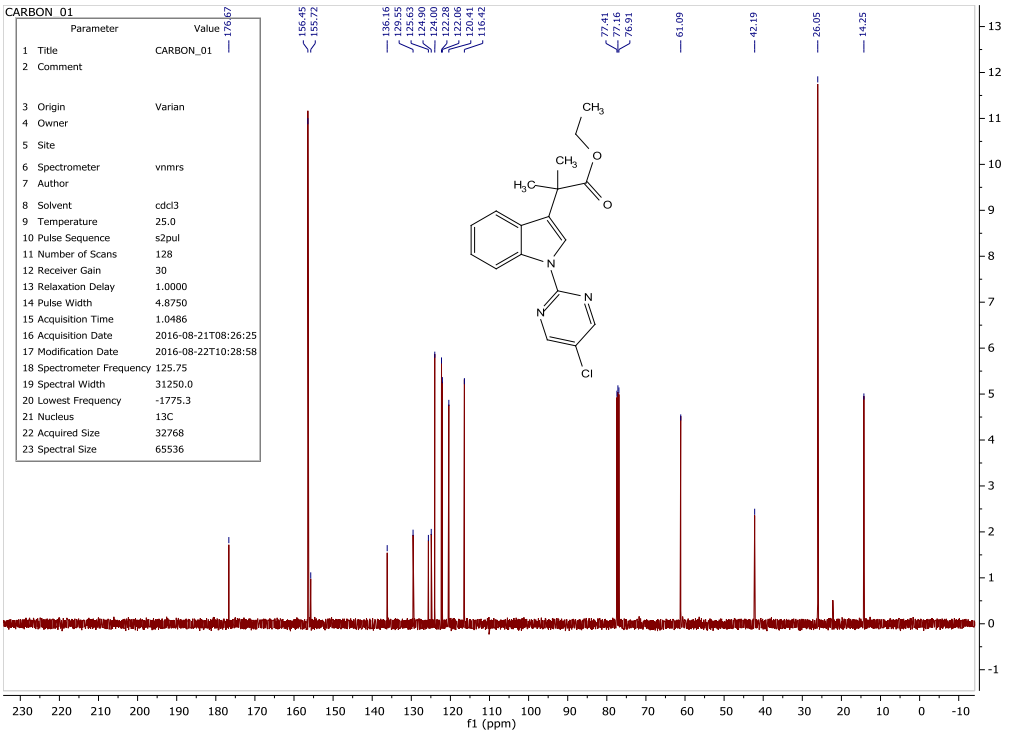

## **3j** – $^{13}$C NMR (126 MHz, $CDCl_3$)



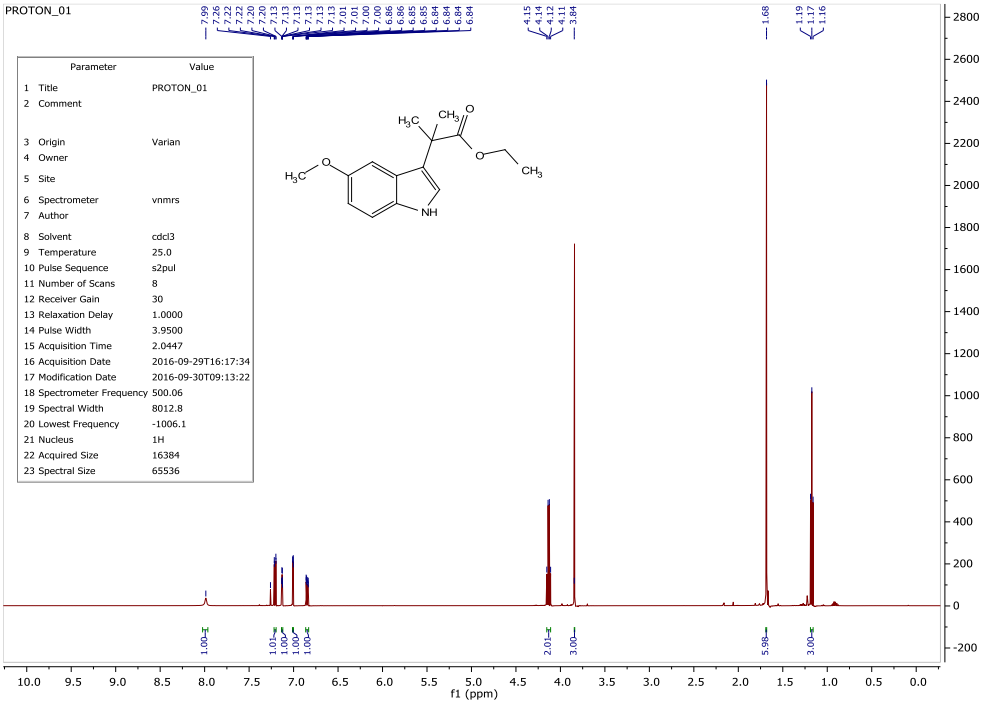
## **3k** – $^{1}$H NMR (500 MHz, $CDCl_3$)



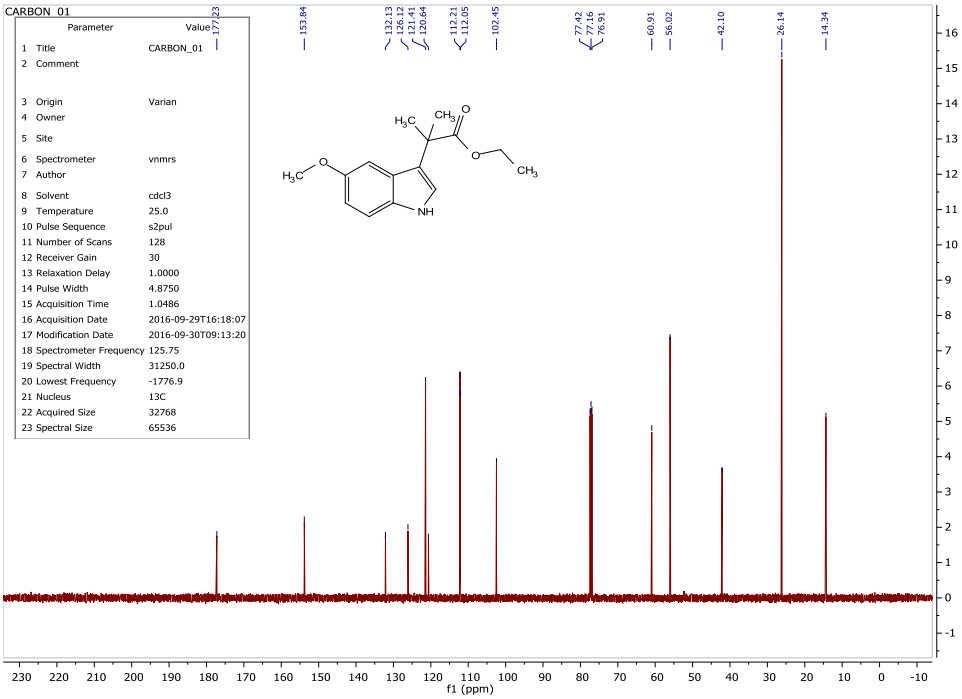

## **3k** – $^{13}$C NMR (126 MHz, $CDCl_3$)



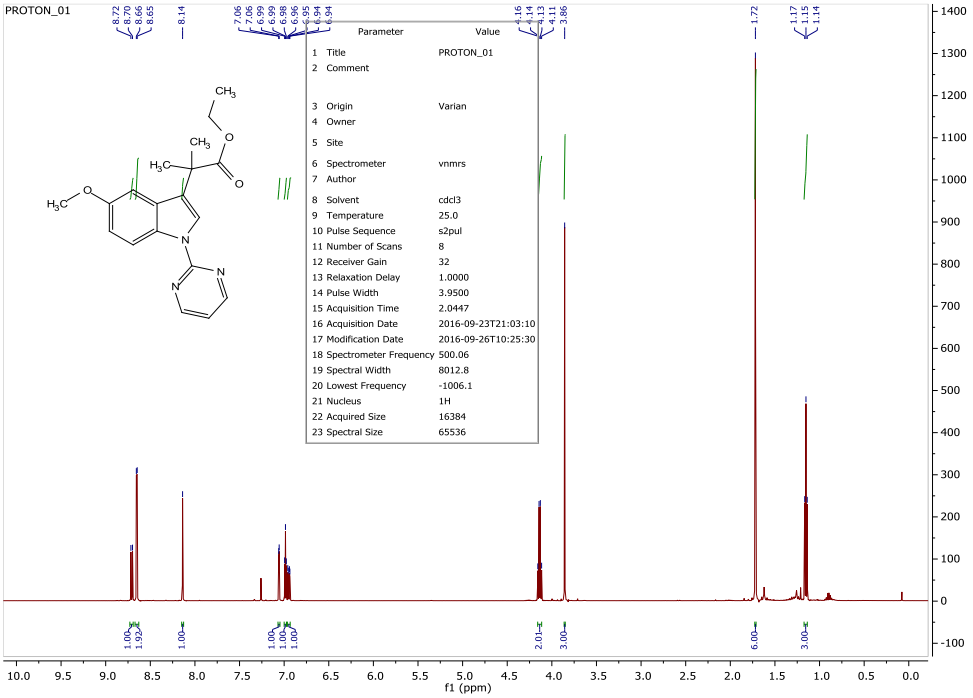
**S3b** – $^{1}$H NMR (500 MHz, $CDCl_3$)



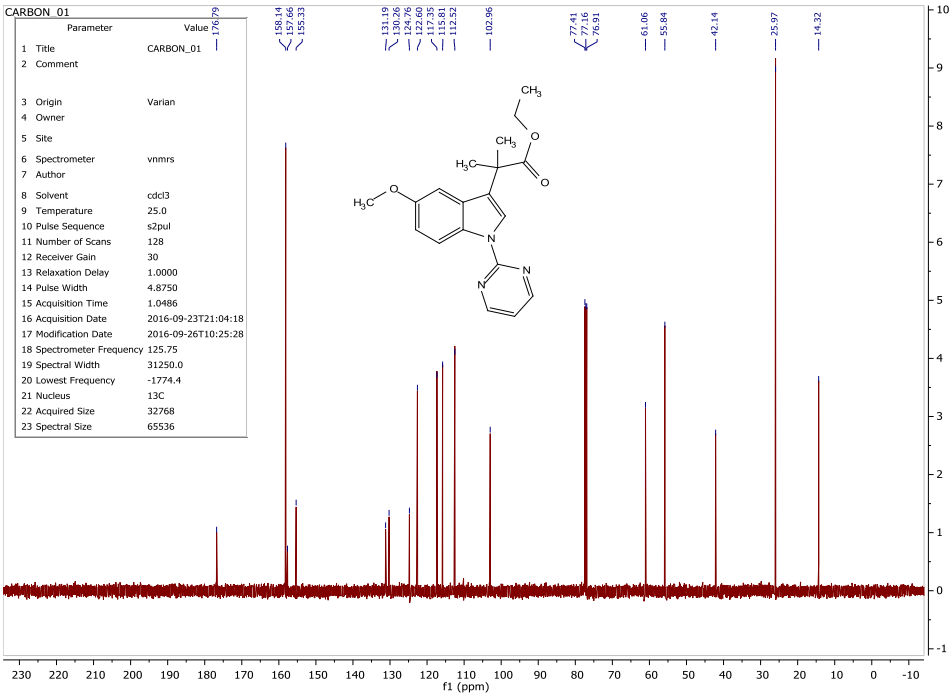

**S3b** – $^{13}$C NMR (126 MHz, $CDCl_3$)



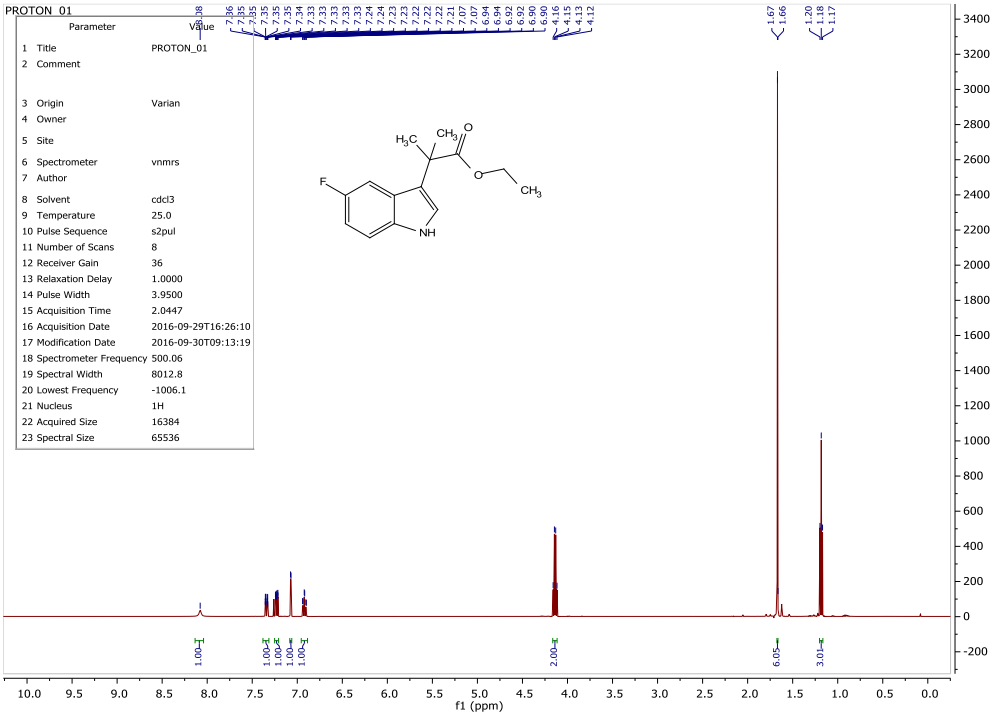
## **3p** – $^{1}$H NMR (500 MHz, $CDCl_3$)



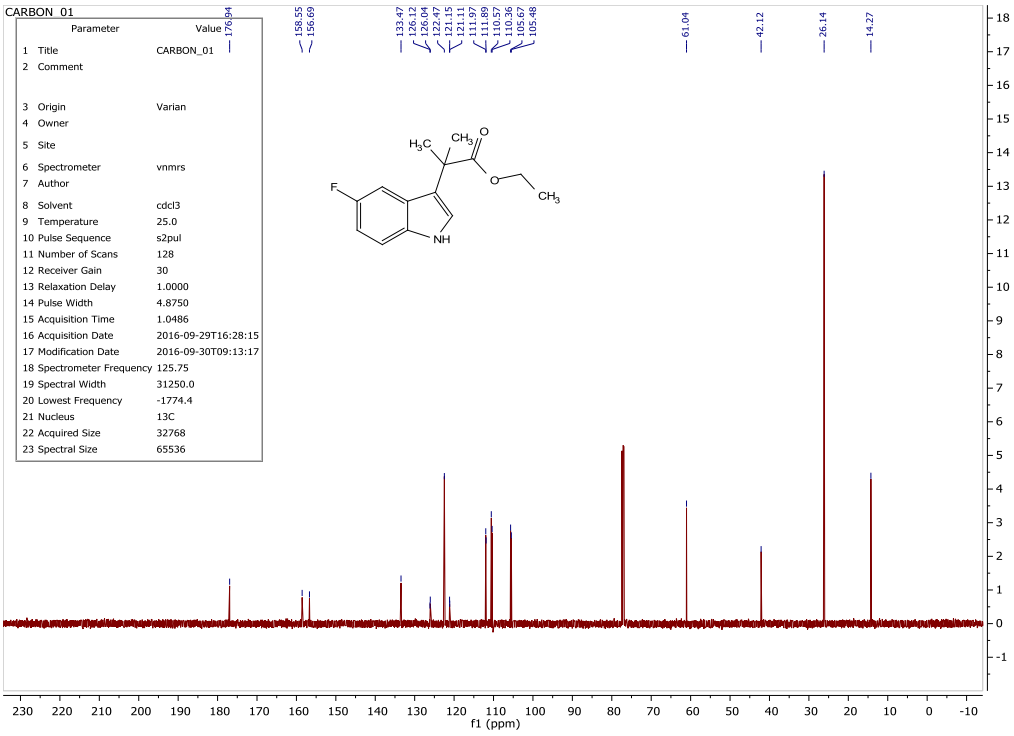

## **3p** – $^{13}$C NMR (126 MHz, $CDCl_3$)



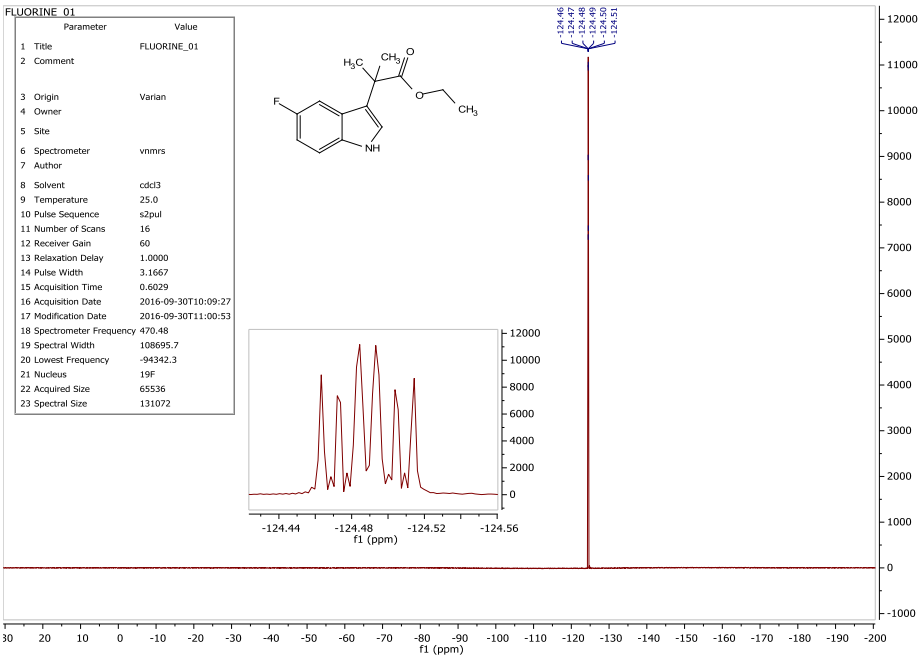
## **S3c** – $^{1}$H NMR (500 MHz, $CDCl_3$)



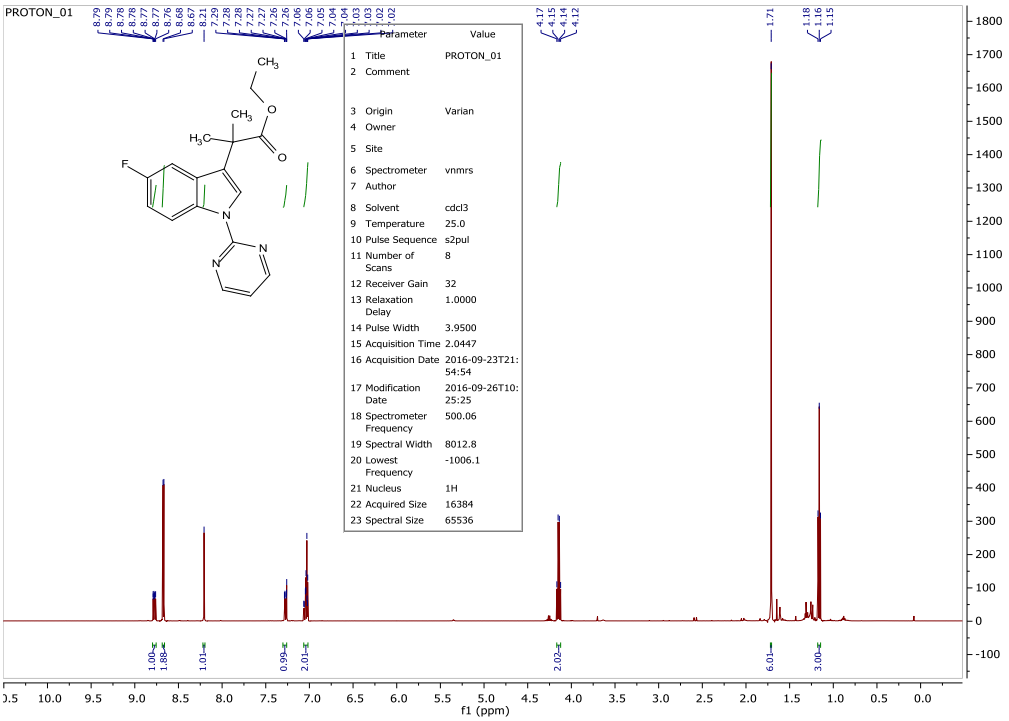

## **S3c** – $^{13}$C NMR (126 MHz, $CDCl_3$)



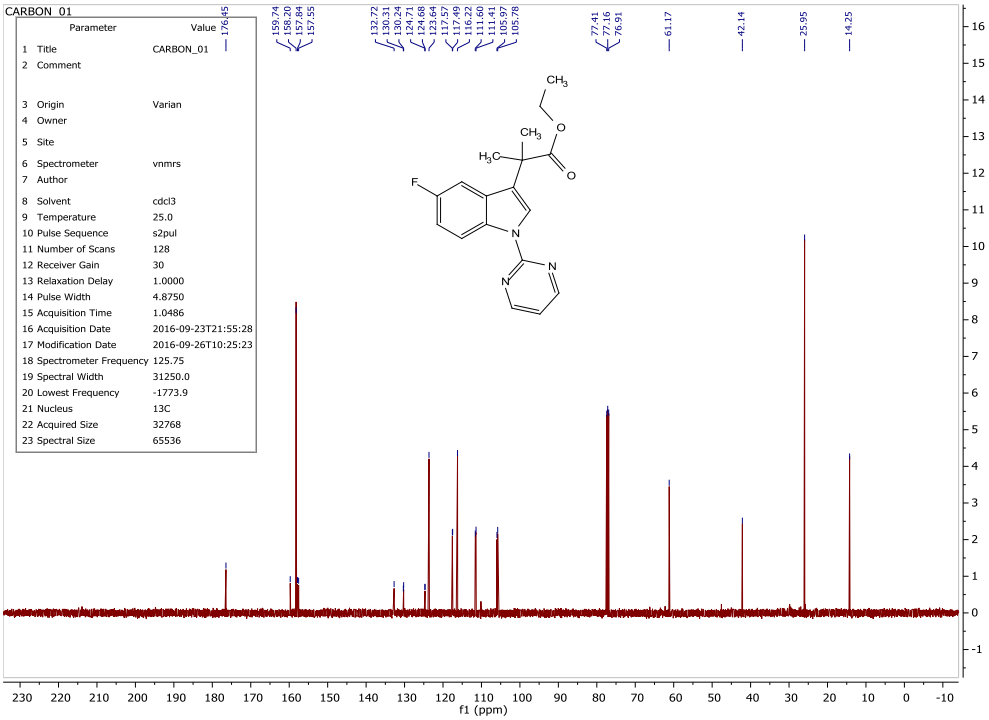
**S3c** – $^{19}F$ NMR (470 MHz, $CDCl_3$)



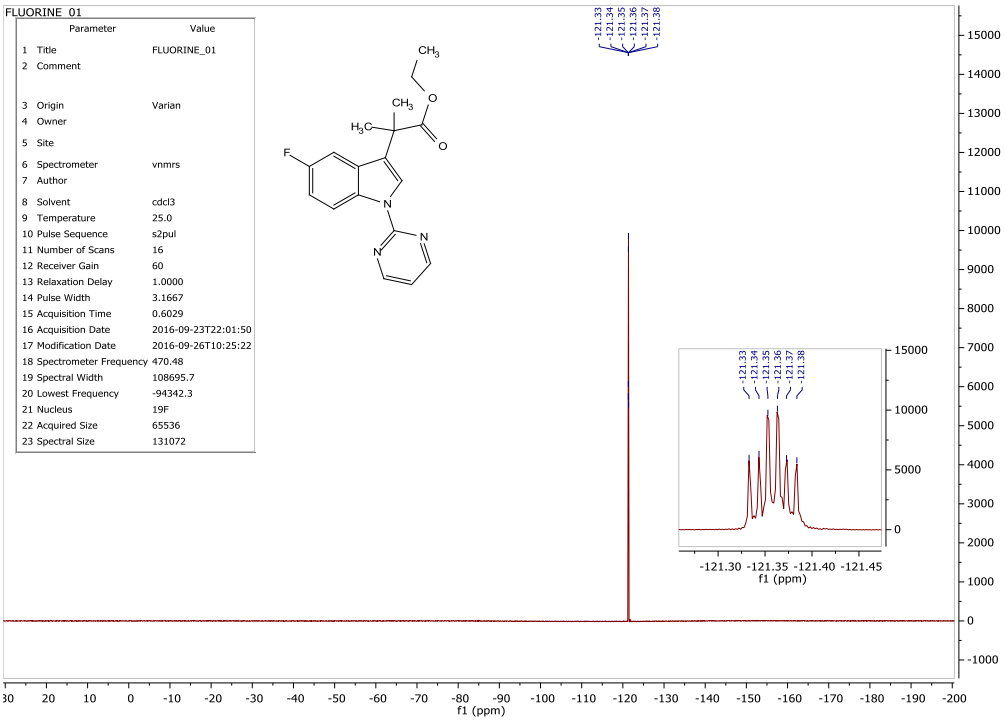
## **3q** – $^{1}$H NMR (500 MHz, $CDCl_3$)



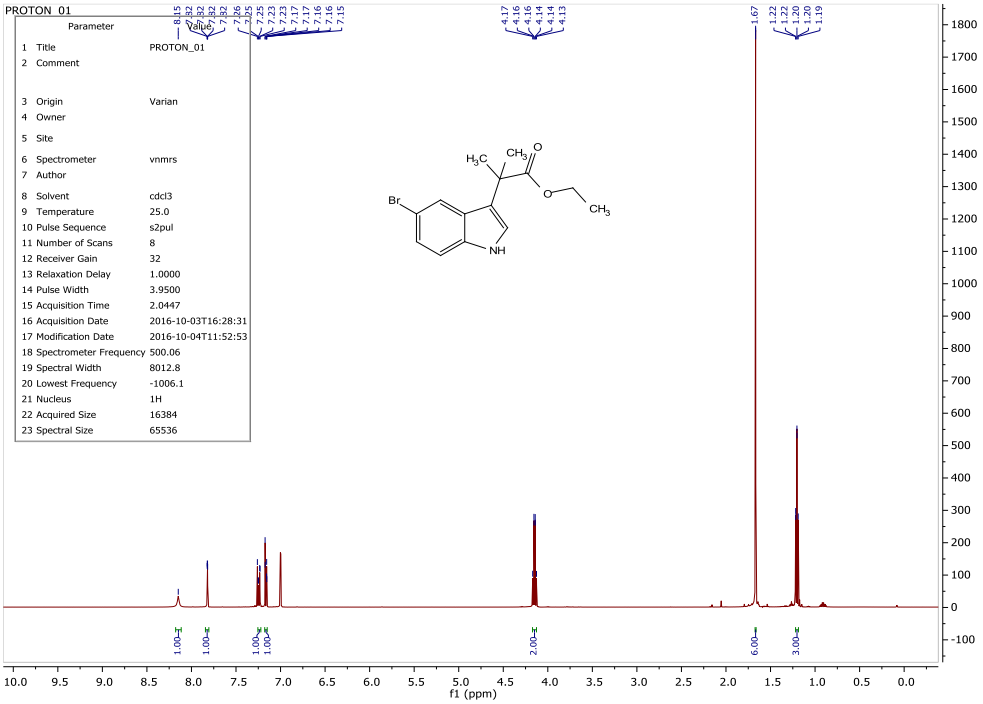

## **3q** – $^{13}$C NMR (126 MHz, $CDCl_3$)



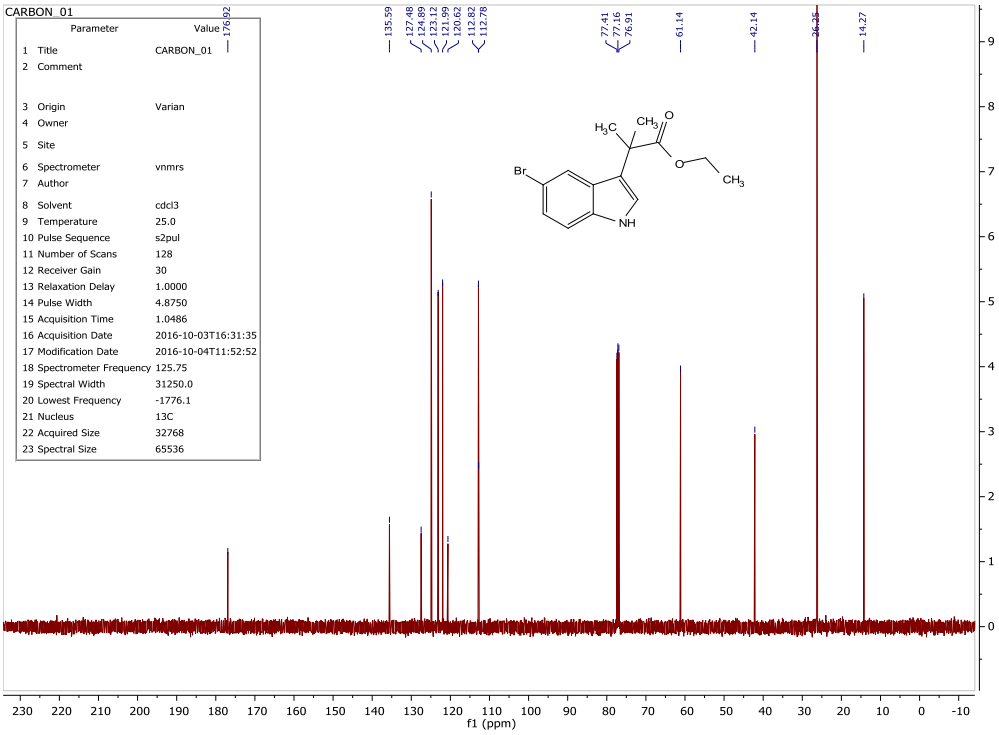
**3q** – $^{19}F$ NMR (470 MHz, $CDCl_3$)



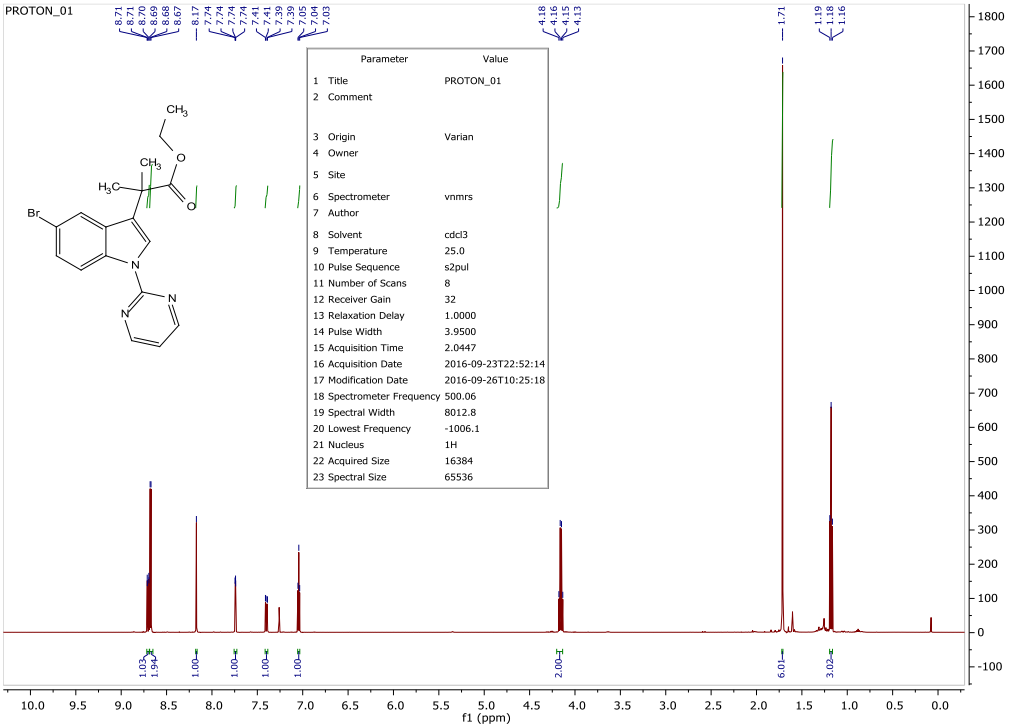
## **S3d** – $^{1}$H NMR (500 MHz, $CDCl_3$)



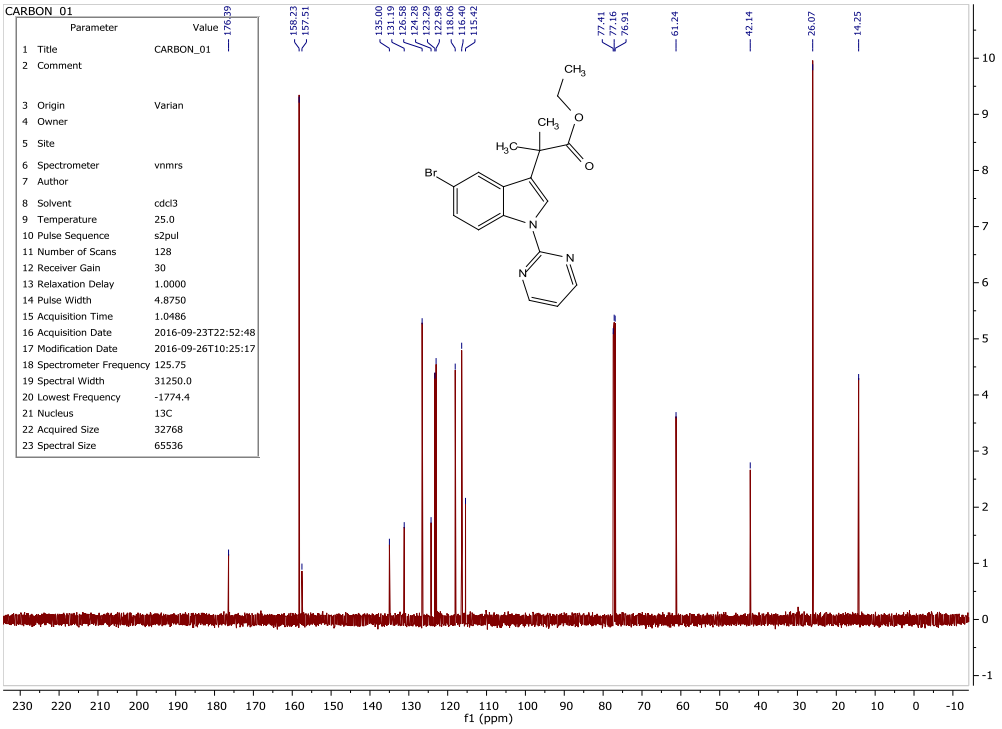

## **S3d** – $^{13}$C NMR (126 MHz, $CDCl_3$)



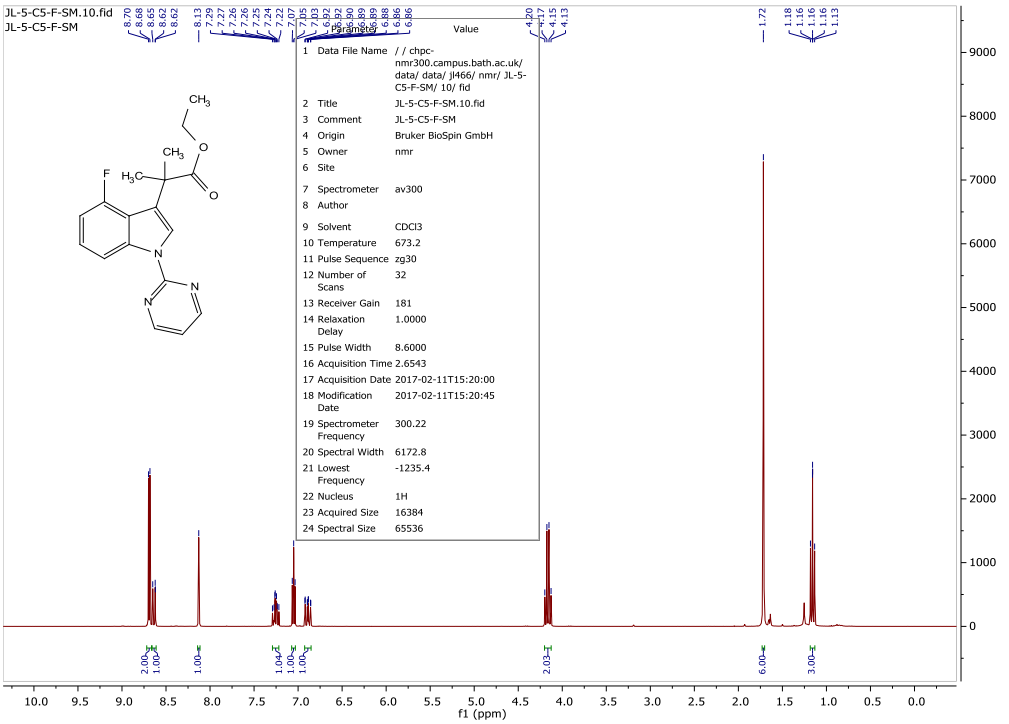
## **3r** – $^{1}$H NMR (500 MHz, $CDCl_3$)



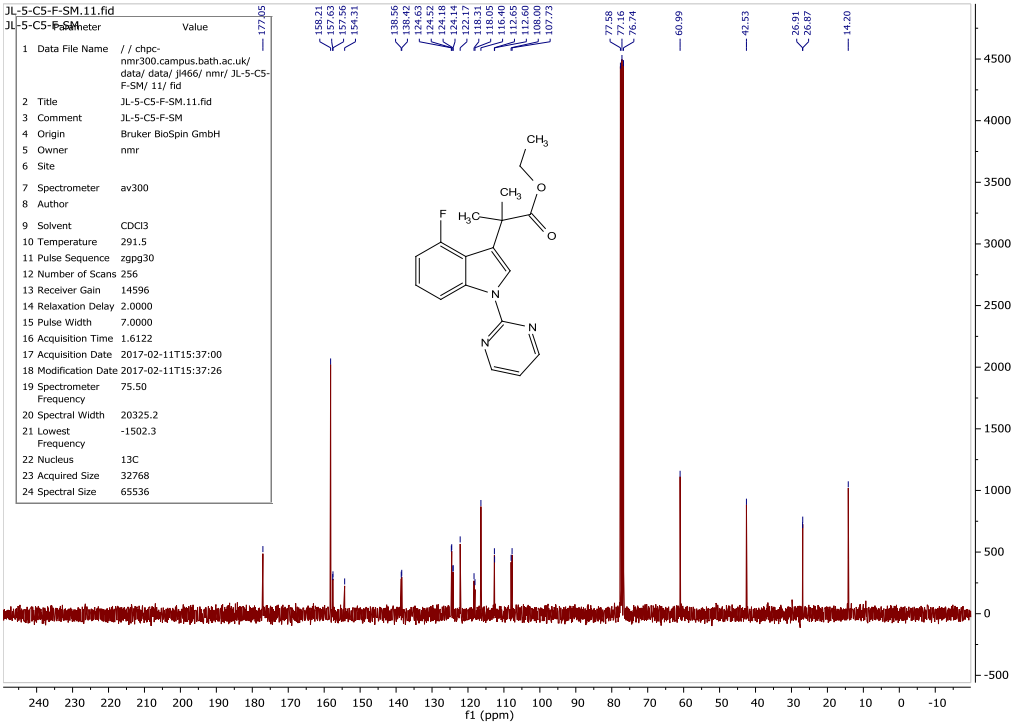

## **3r** – $^{13}$C NMR (126 MHz, $CDCl_3$)



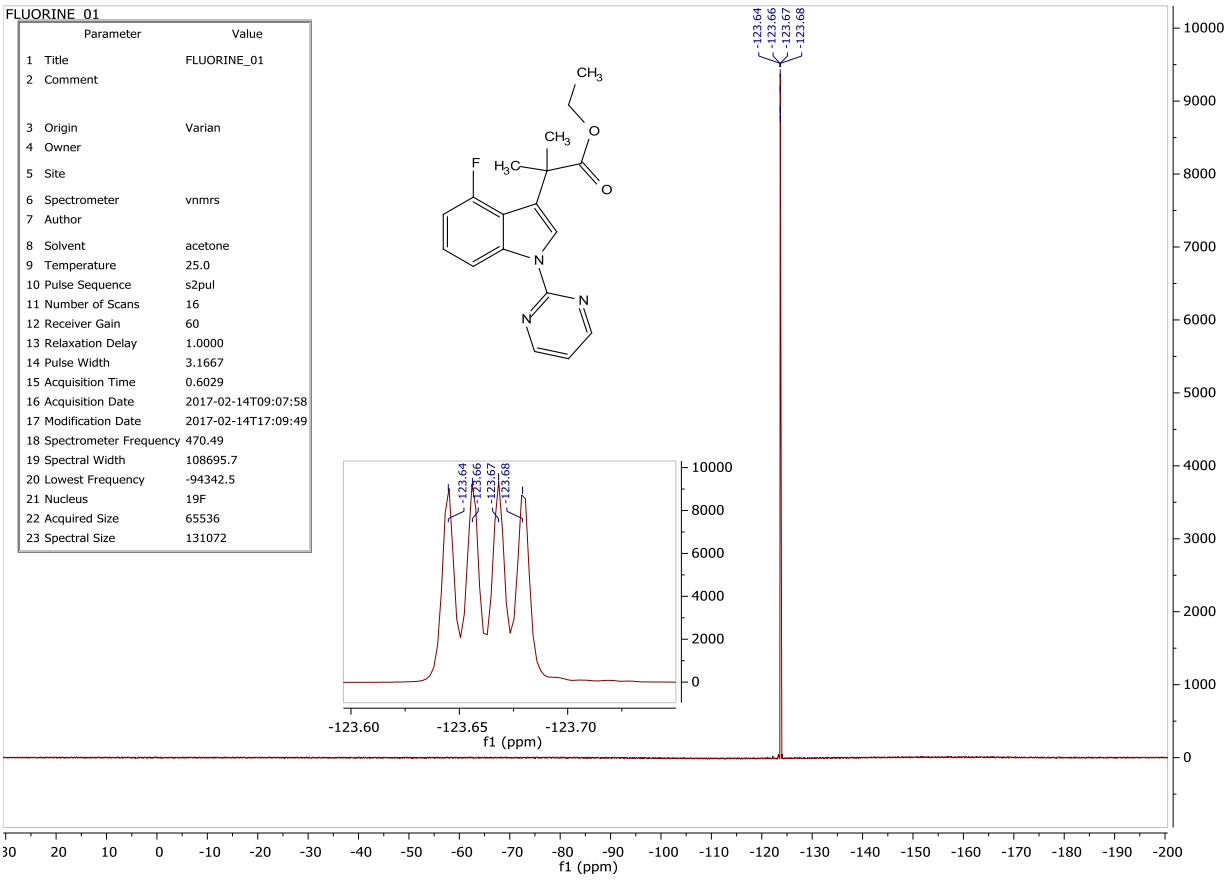
## **S3a** – $^{1}$H NMR (300 MHz, $CDCl_3$)



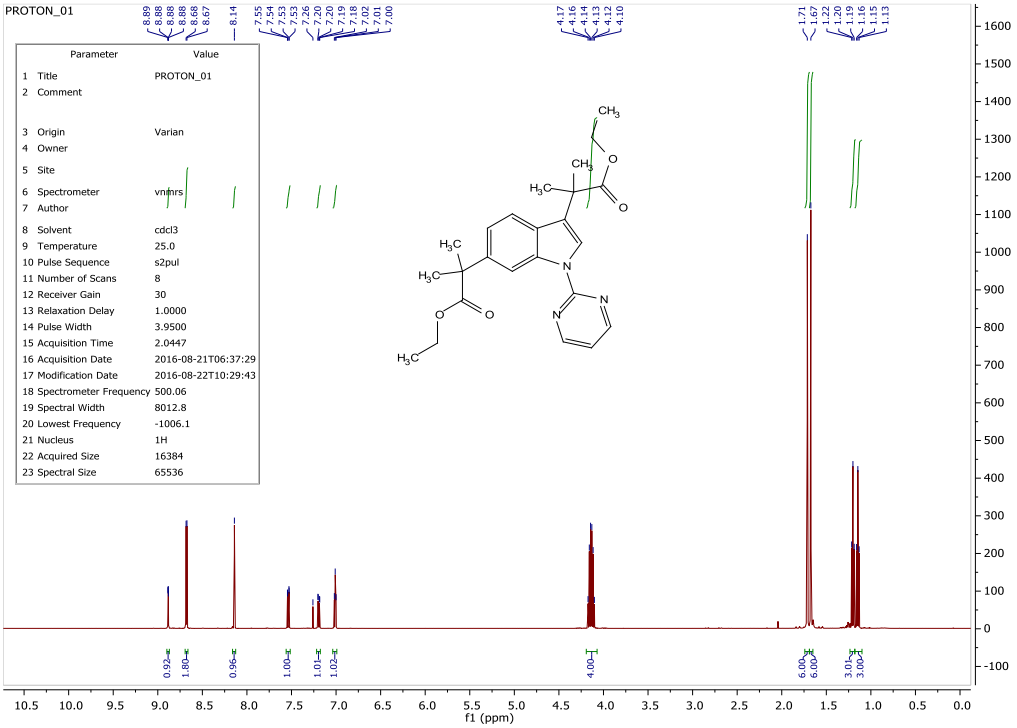

## **S3a** – $^{13}$C NMR (75 MHz, $CDCl_3$)



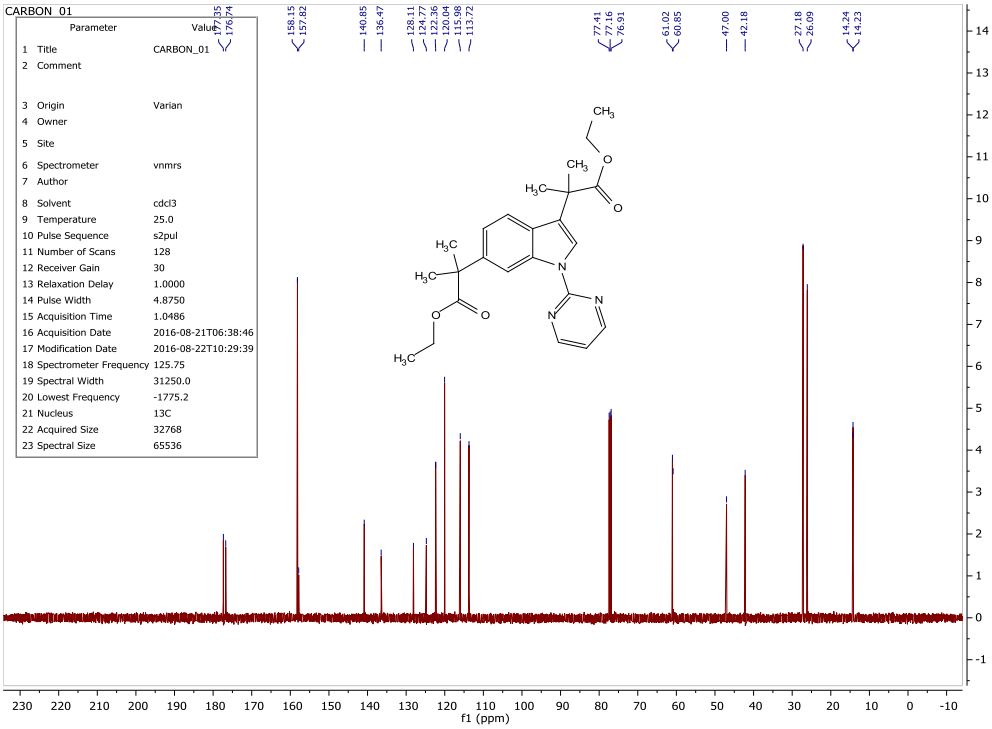
**S3a** – $^{19}F$ NMR (470 MHz, $CDCl_3$)



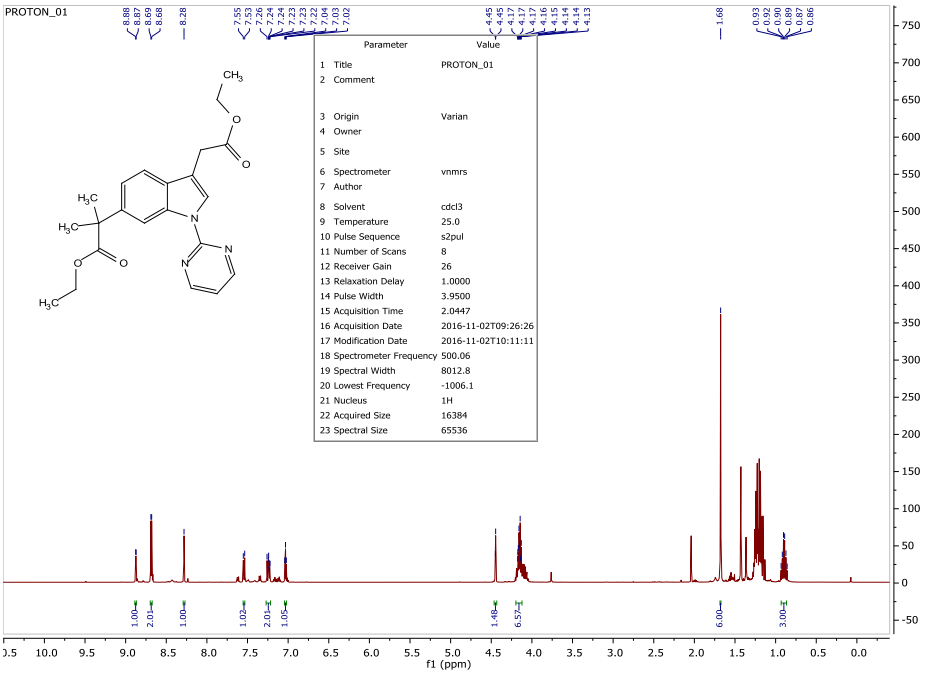
## **4a** – $^{1}$H NMR (500 MHz, $CDCl_3$)



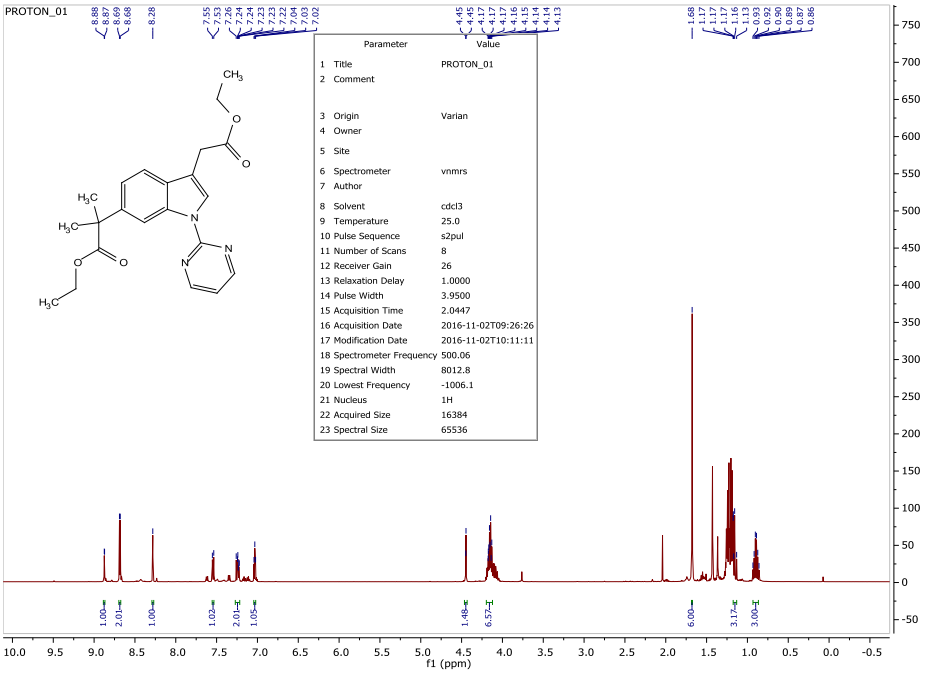

## **4a** – $^{13}$C NMR (126 MHz, $CDCl_3$)



## **4e** – $^{1}$H NMR (500 MHz, $CDCl_3$)*

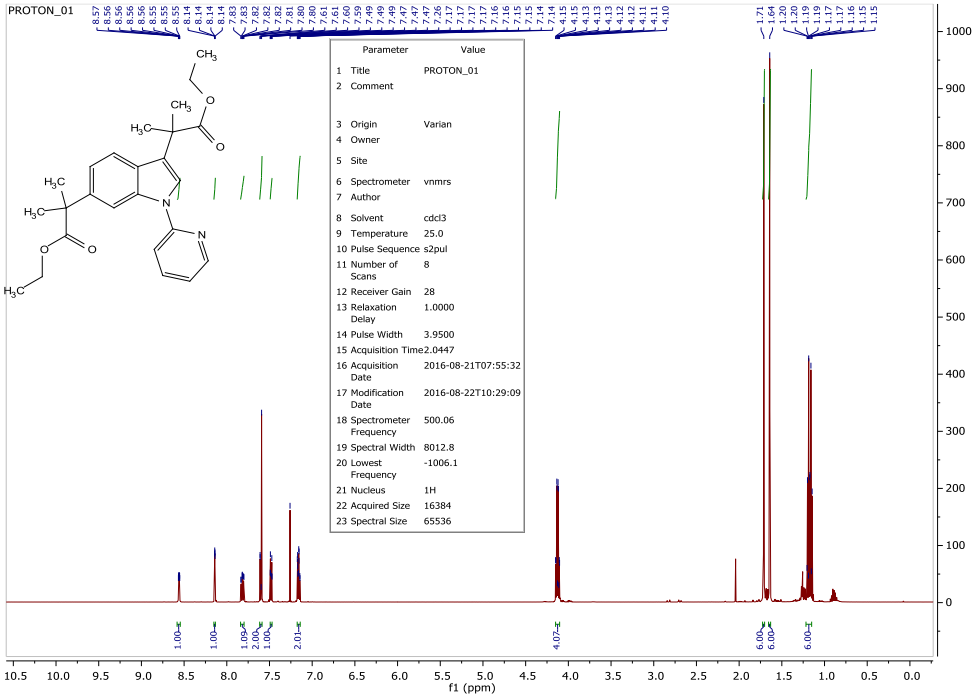



## **4e** – $^{13}$C NMR (126 MHz, $CDCl_3$)*

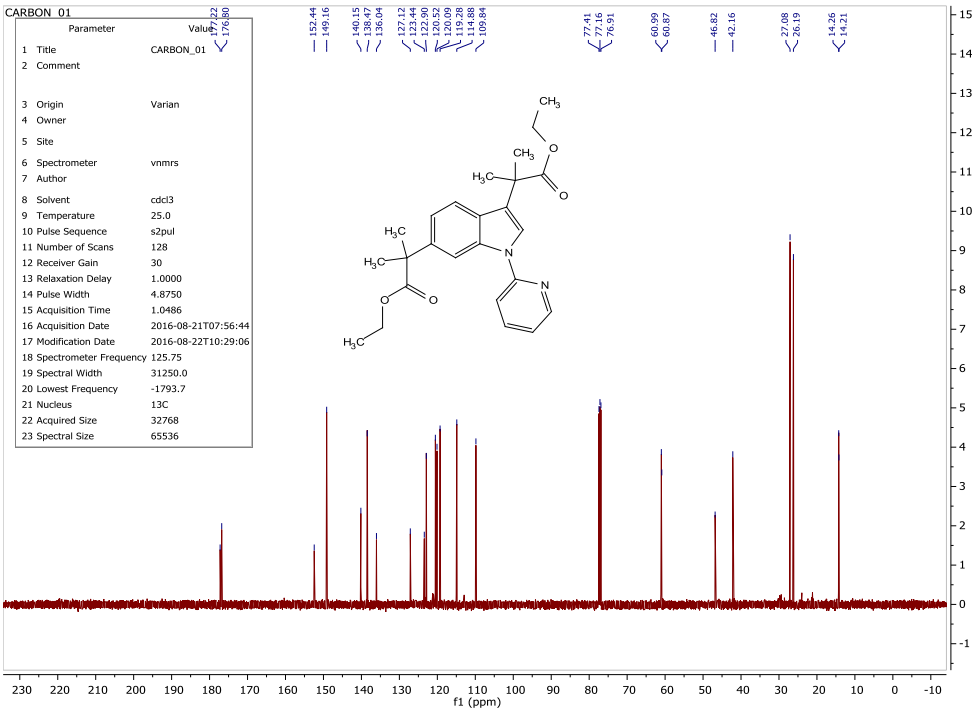



* Inseparable polymeric product observed. Lower integral of benzylic proton (1.45 H vs 2H) coupled with presence of more ethyl peaks (@ 4.17 and 1.22) and sporadic ($CH_3$) singlets suggest a polymeric impurity, most likely caused by potential stable radical formed at benzylic position.

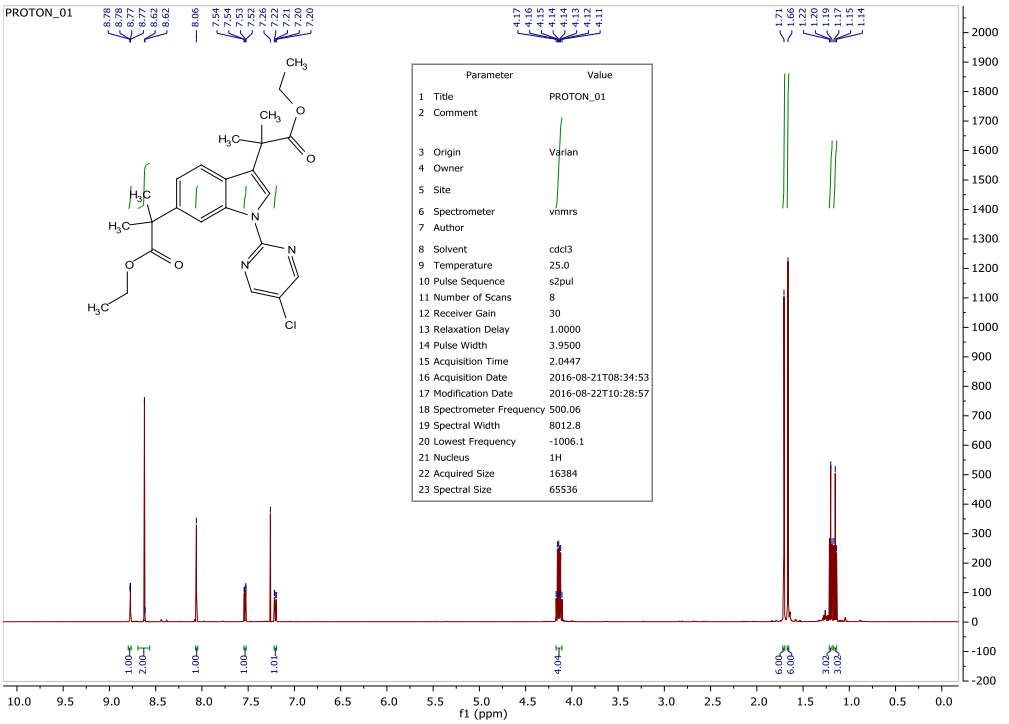
## **4h** – $^{1}$H NMR (500 MHz, $CDCl_3$)



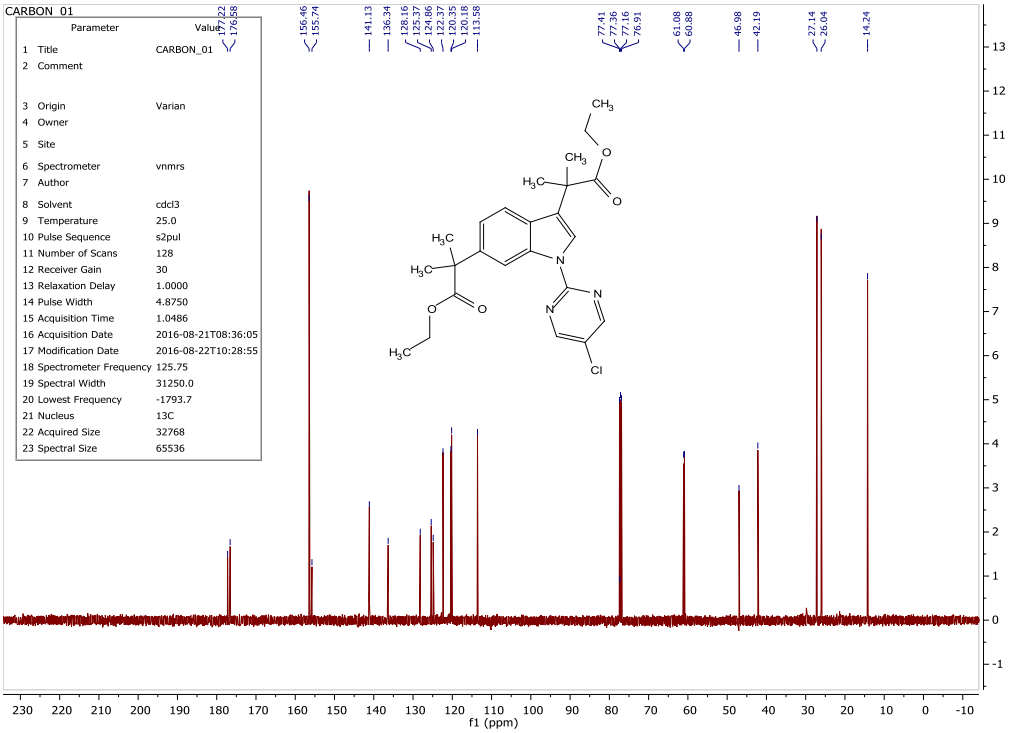

## **4h** – $^{13}$C NMR (126 MHz, $CDCl_3$)



## **4i** – $^{1}$H NMR (500 MHz, $CDCl_3$)




## **4i** – $^{13}$C NMR (126 MHz, $CDCl_3$)



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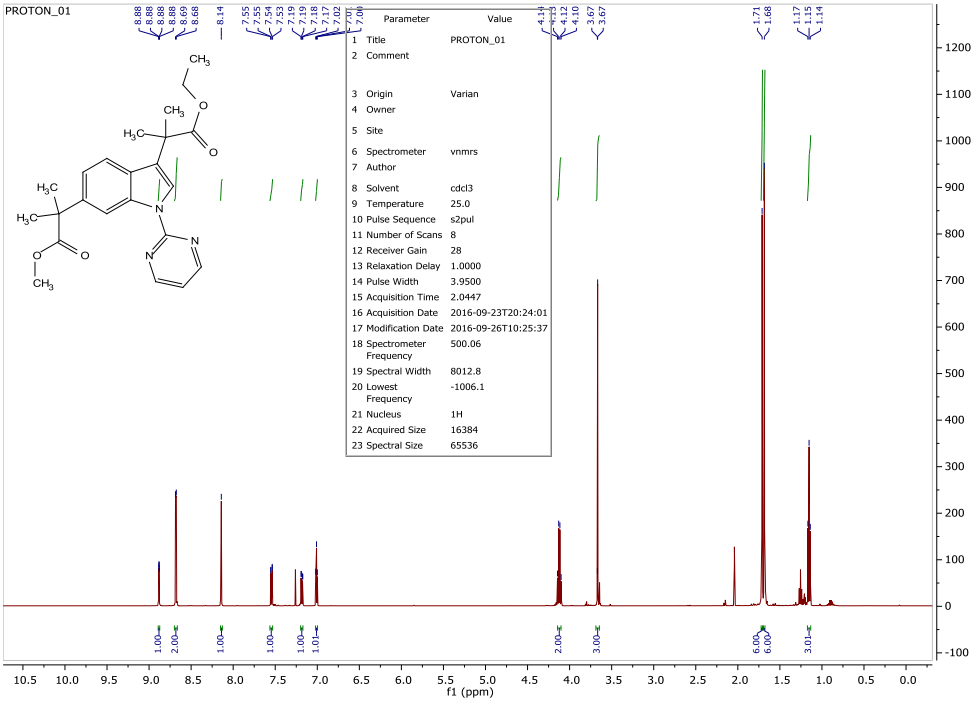
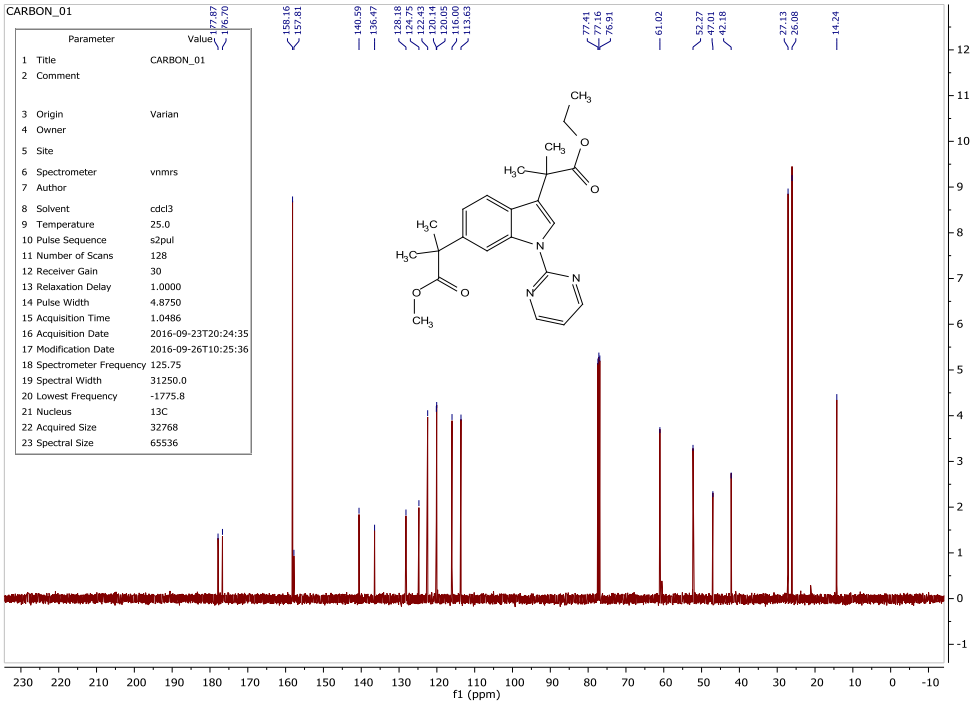
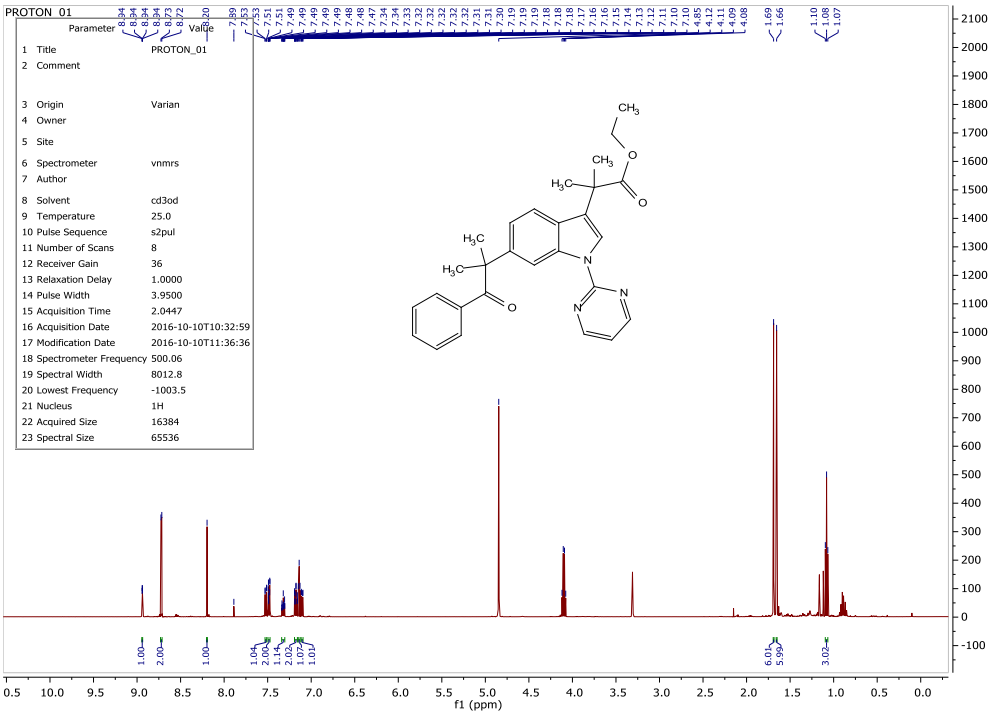


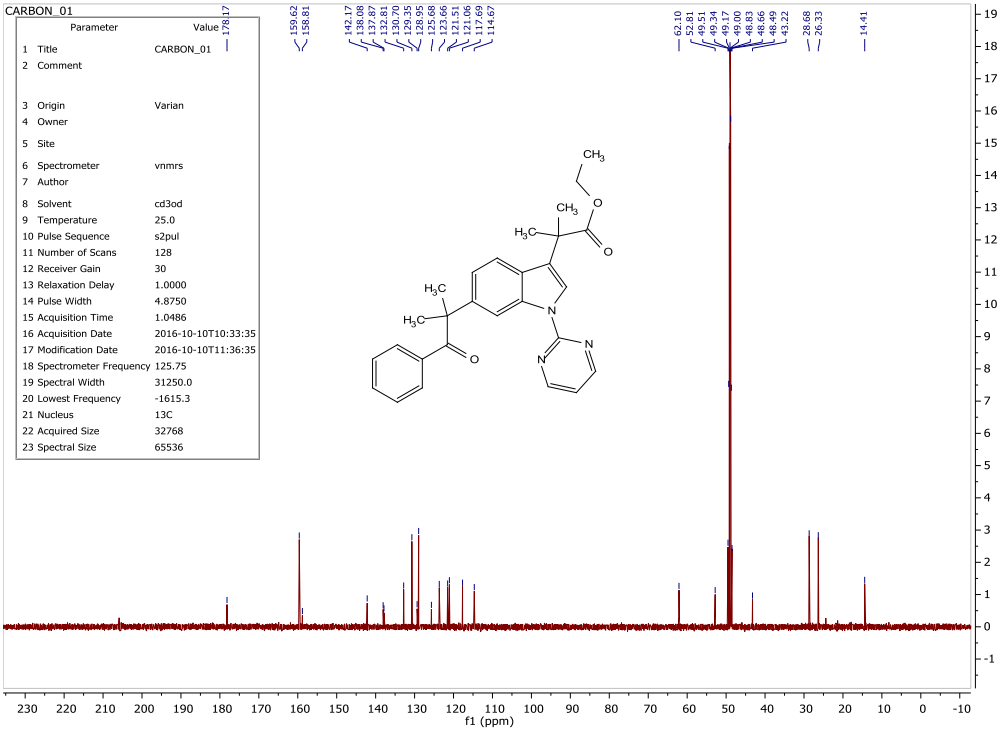

**4j** – $^{13}$C NMR (126 MHz, $CDCl_3$)



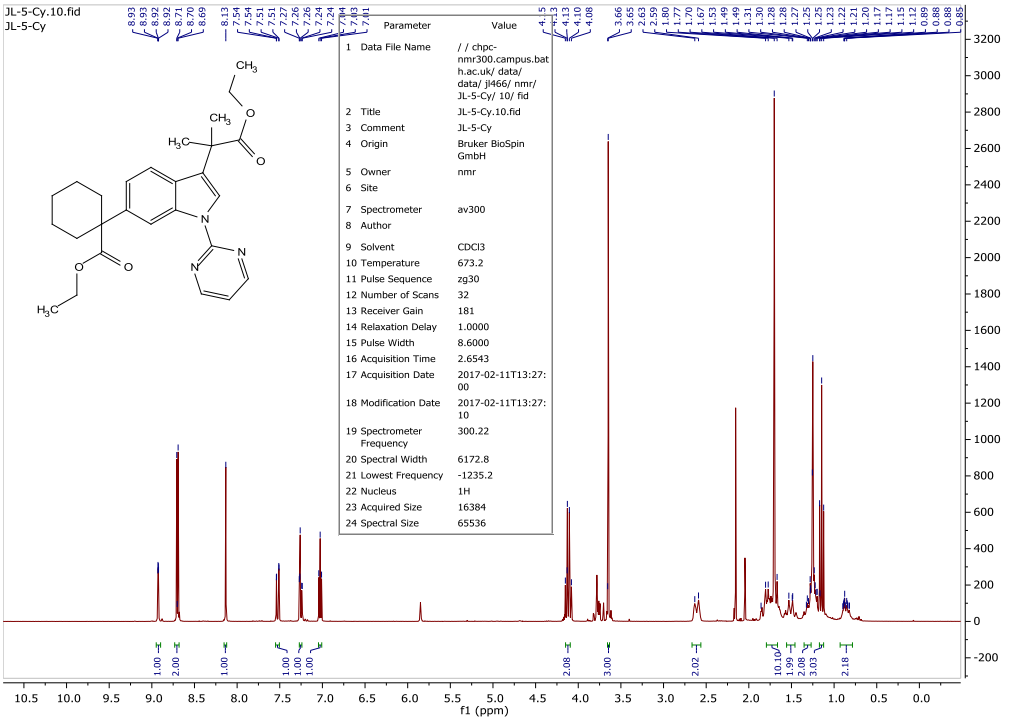
## **4k** – $^{1}$H NMR (500 MHz, $CD_3OD$)




## **4k** – $^{13}$C NMR (126 MHz, $CD_3OD$)



## **4l** – $^{1}$H NMR (300 MHz, $CDCl_3$)

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| 3 | Comment | JL-5-Cy |
| 4 | Origin | Bruker BioSpin GmbH |
| 5 | Owner | nmr |
| 6 | Site | |
| 7 | Spectrometer | av300 |
| 8 | Author | |
| 9 | Solvent | CDCl3 |
| 10 | Temperature | 673.2 |
| 11 | Pulse Sequence | zg30 |
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| 13 | Receiver Gain | 181 |
| 14 | Relaxation Delay | 1.0000 |
| 15 | Pulse Width | 8.6000 |
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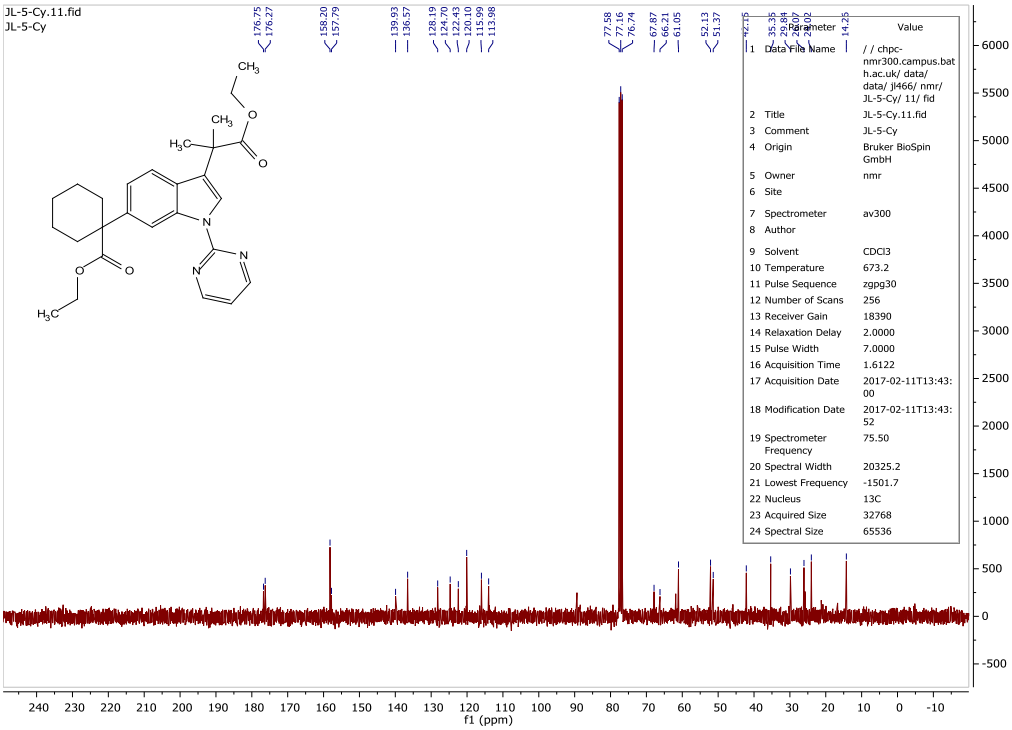
| 20 | Spectral Width | 6172.8 |
| 21 | Lowest Frequency | -1235.2 |
| 22 | Nucleus | 1H |
| 23 | Acquired Size | 16384 |
| 24 | Spectral Size | 65536 |

## **4l** – $^{13}$C NMR (75 MHz, $CDCl_3$)

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| 8 | Author | |
| 9 | Solvent | CDCl3 |
| 10 | Temperature | 673.2 |
| 11 | Pulse Sequence | zgpg30 |
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| 13 | Receiver Gain | 18390 |
| 14 | Relaxation Delay | 2.0000 |
| 15 | Pulse Width | 7.0000 |
| 16 | Acquisition Time | 1.6122 |
| 17 | Acquisition Date | 2017-02-11T13:43:00 |
| 18 | Modification Date | 2017-02-11T13:43:52 |
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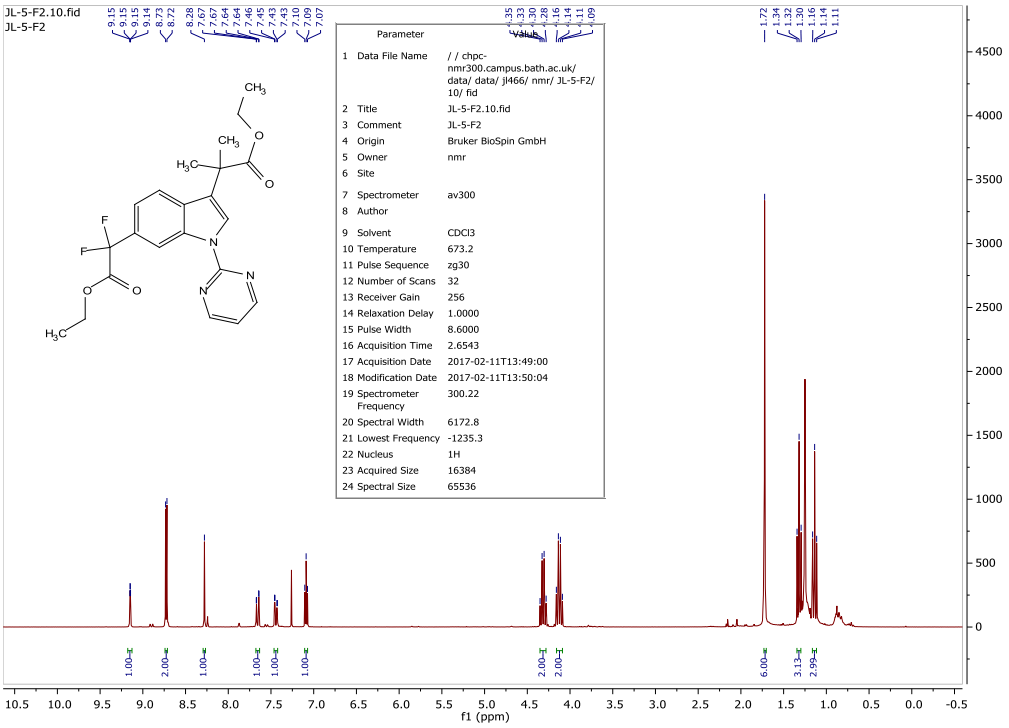
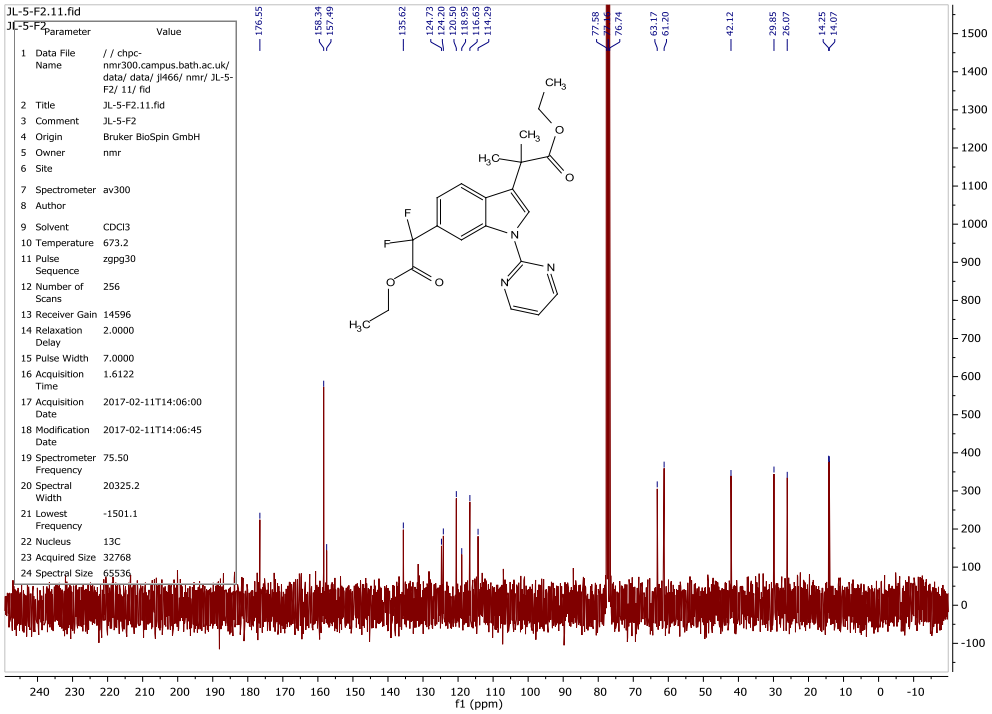
| 20 | Spectral Width | 20325.2 |
| 21 | Lowest Frequency | -1501.7 |
| 22 | Nucleus | 13C |
| 23 | Acquired Size | 32768 |
| 24 | Spectral Size | 65536 |

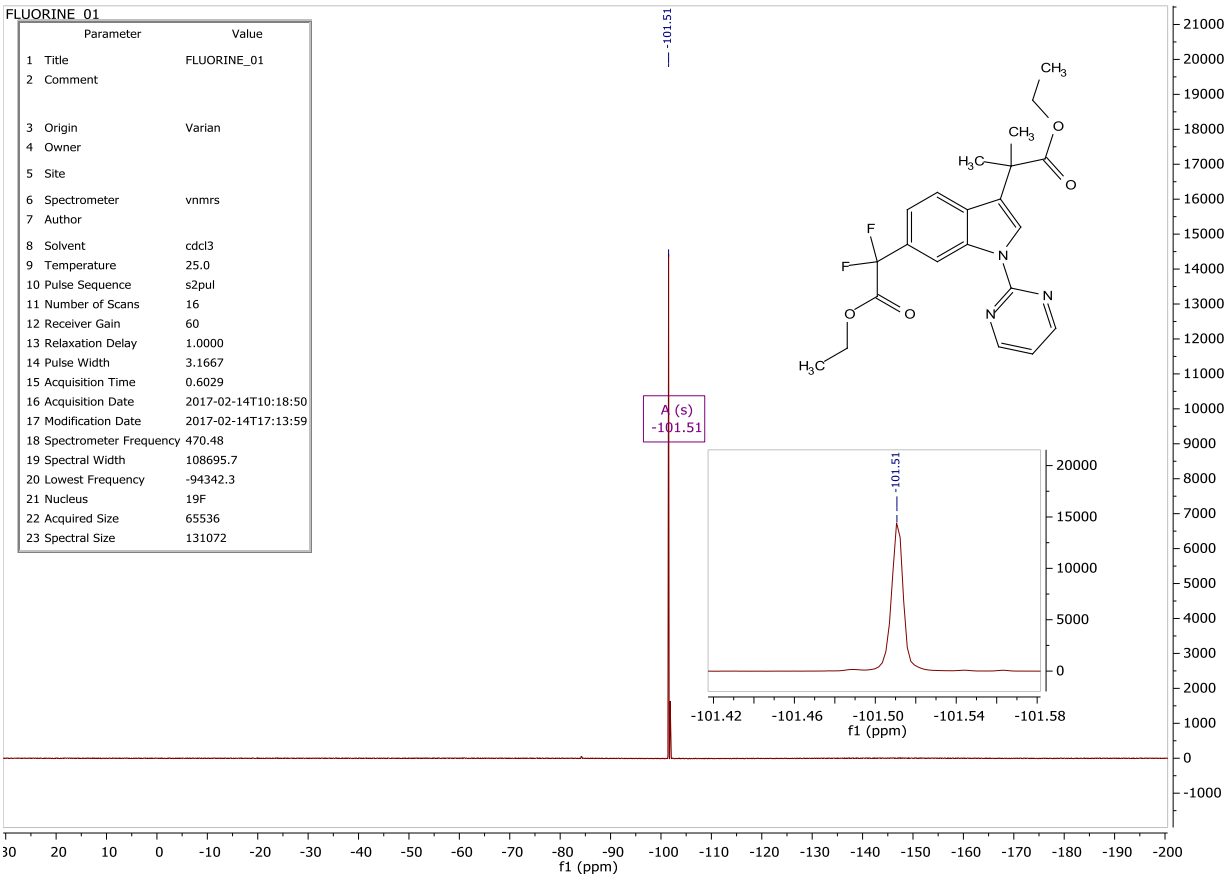
## **4m** – $^{1}$H NMR (300 MHz, $CDCl_3$)



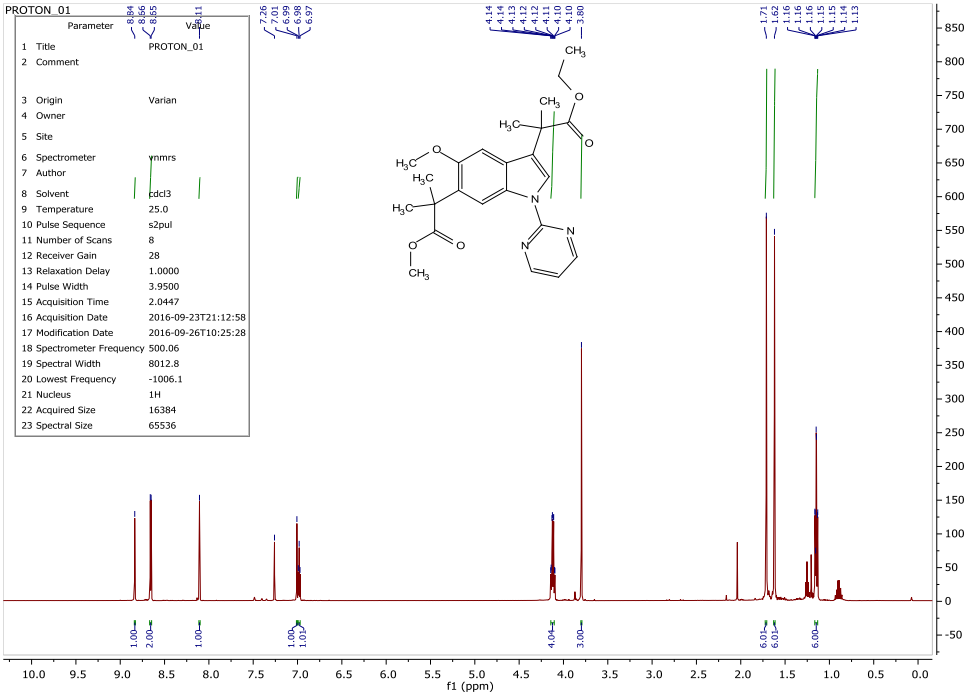

## **4m** – $^{13}$C NMR (75 MHz, $CDCl_3$)



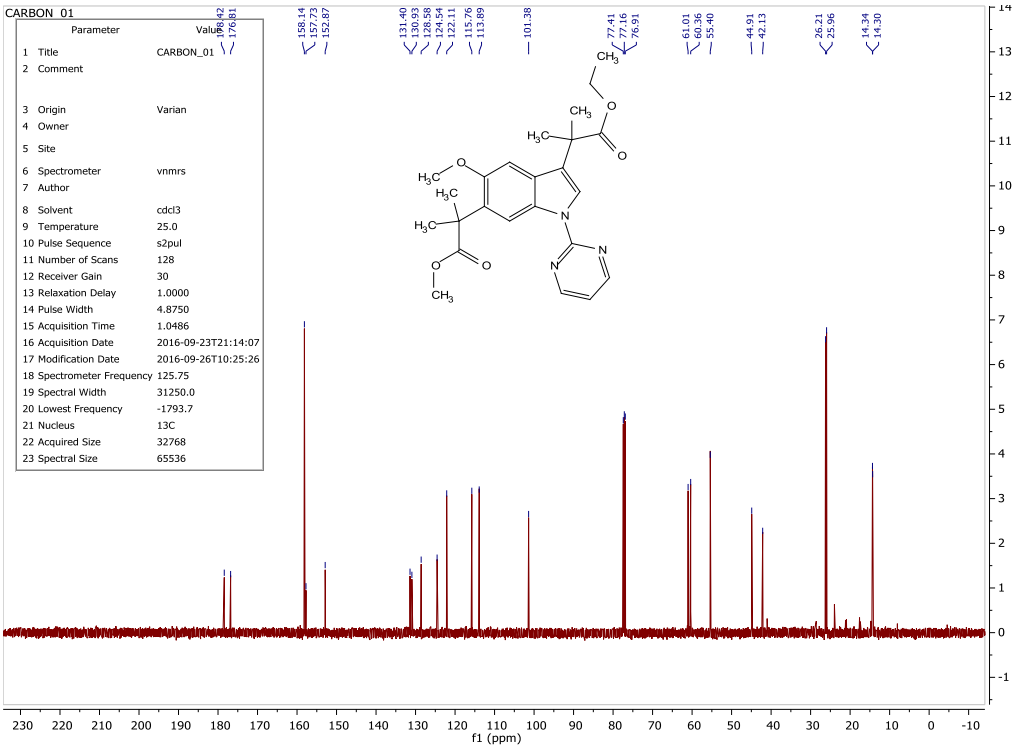
**4m** – $^{19}F$ NMR (470 MHz, $CDCl_3$)



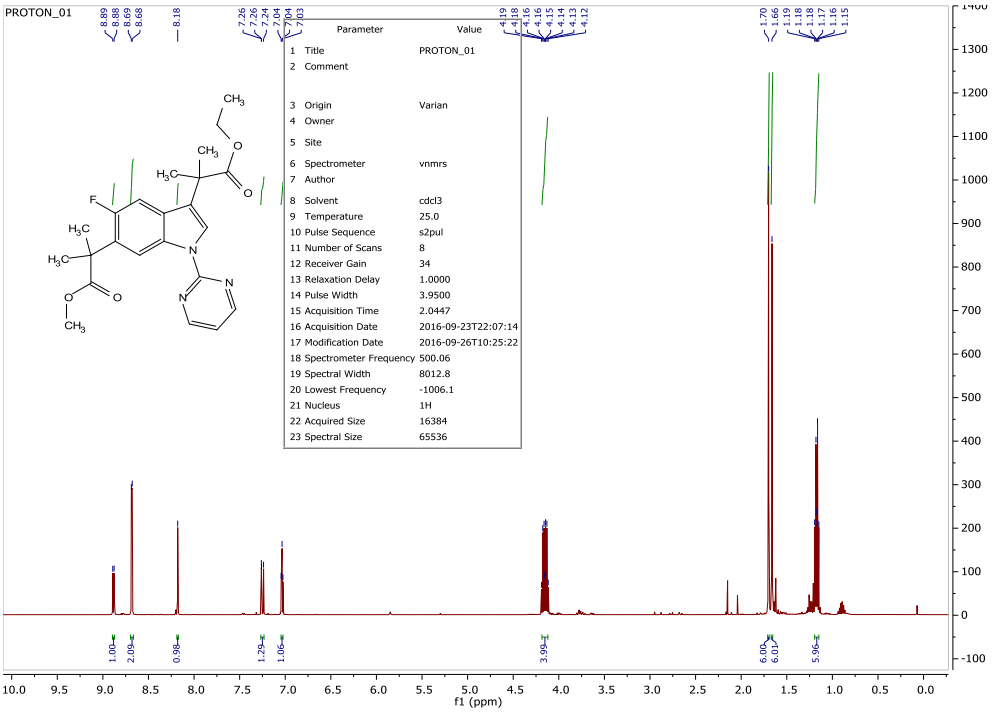
## **4p** – $^{1}$H NMR (500 MHz, $CDCl_3$)



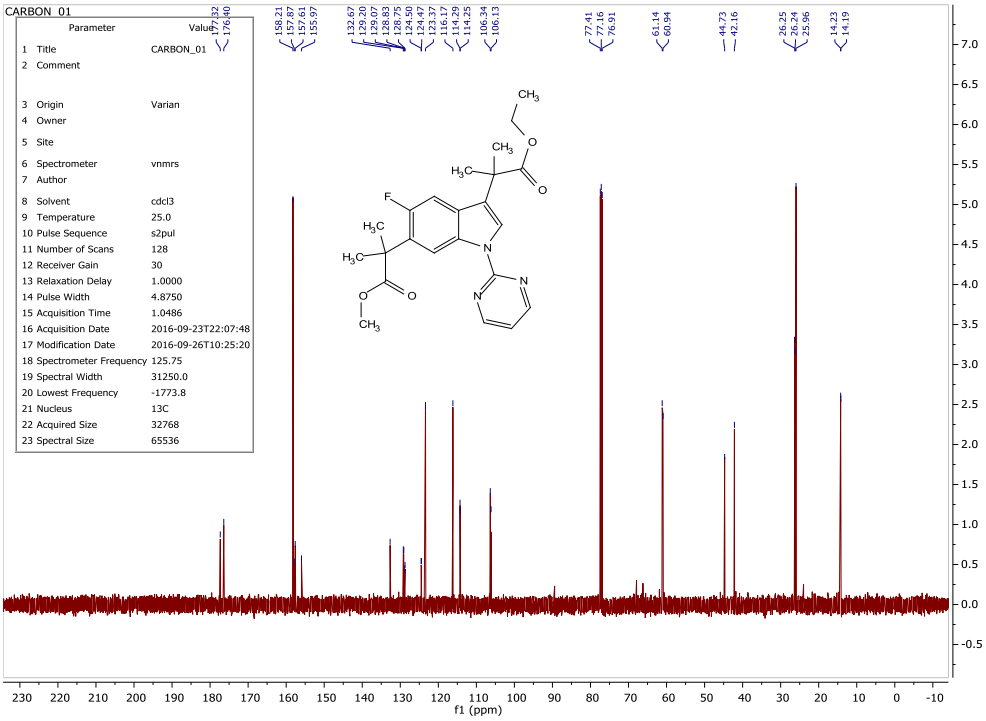

## **4p** – $^{13}$C NMR (126 MHz, $CDCl_3$)



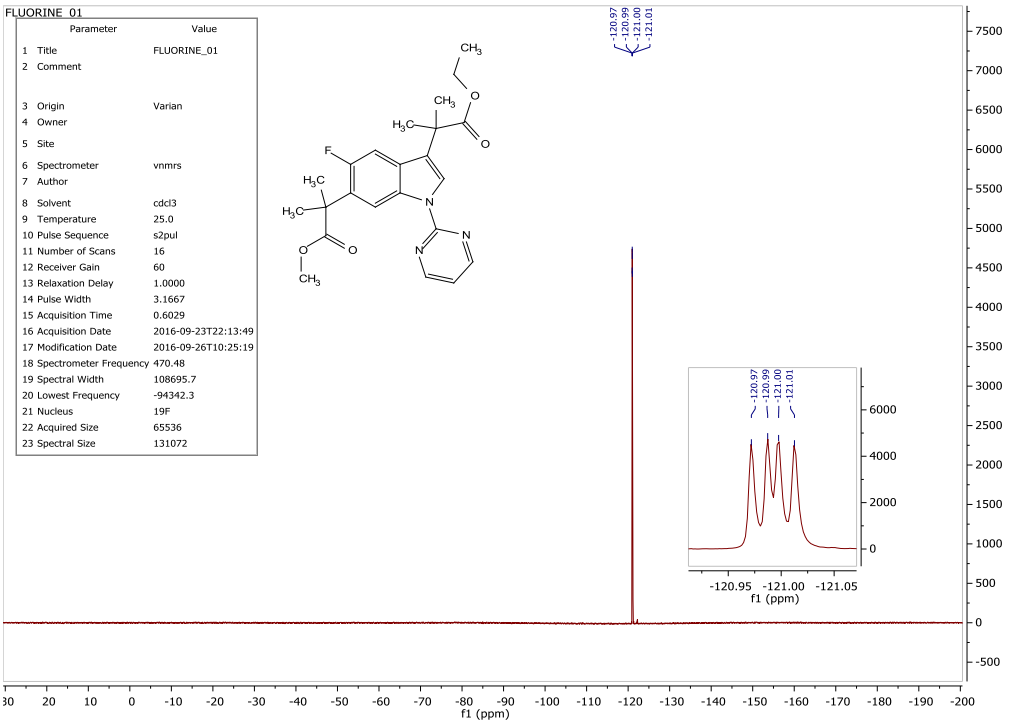
## **4q** – $^{1}$H NMR (500 MHz, $CDCl_3$)



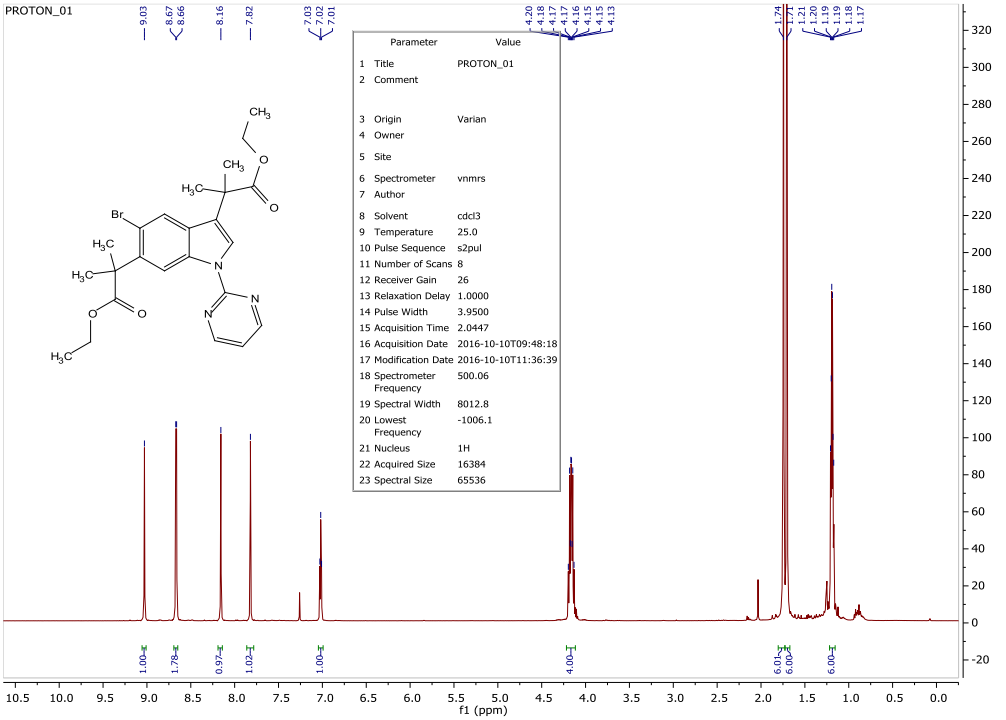

## **4q** – $^{13}$C NMR (126 MHz, $CDCl_3$)



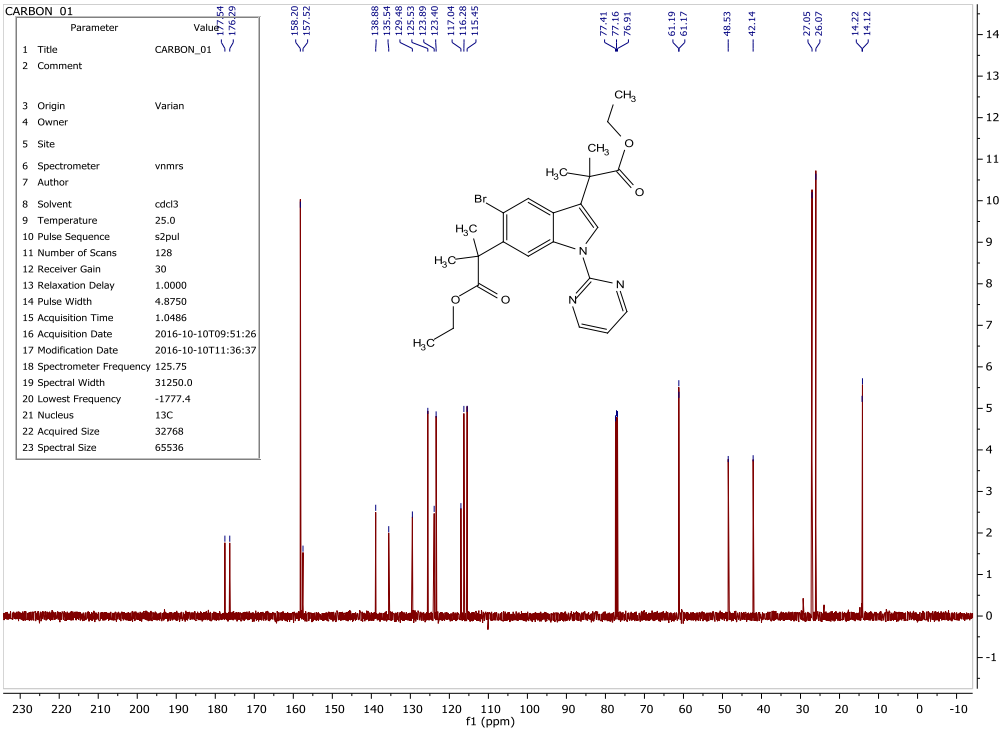
**4q** – $^{19}F$ NMR (470 MHz, $CDCl_3$)



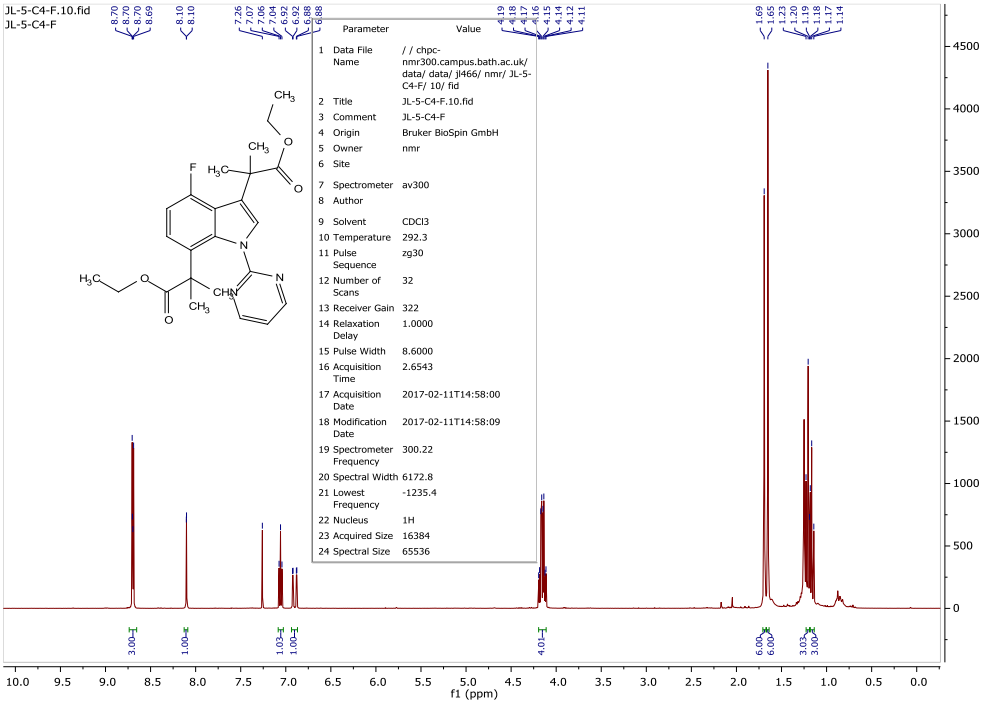
## **4r** – $^{1}$H NMR (500 MHz, $CDCl_3$)




## **4r** – $^{13}$C NMR (126 MHz, $CDCl_3$)



## **S4a** – $^{1}$H NMR (300 MHz, $CDCl_3$)

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| 3 Comment | JL-5-C4-F |
| 4 Origin | Bruker BioSpin GmbH |
| 5 Owner | nmr |
| 6 Site | |
| 7 Spectrometer | av300 |
| 8 Author | |
| 9 Solvent | CDCl3 |
| 10 Temperature | 292.3 |
| 11 Pulse Sequence | zg30 |
| 12 Number of Scans | 32 |
| 13 Receiver Gain | 322 |
| 14 Relaxation Delay | 1.0000 |
| 15 Pulse Width | 8.6000 |
| 16 Acquisition Time | 2.6543 |
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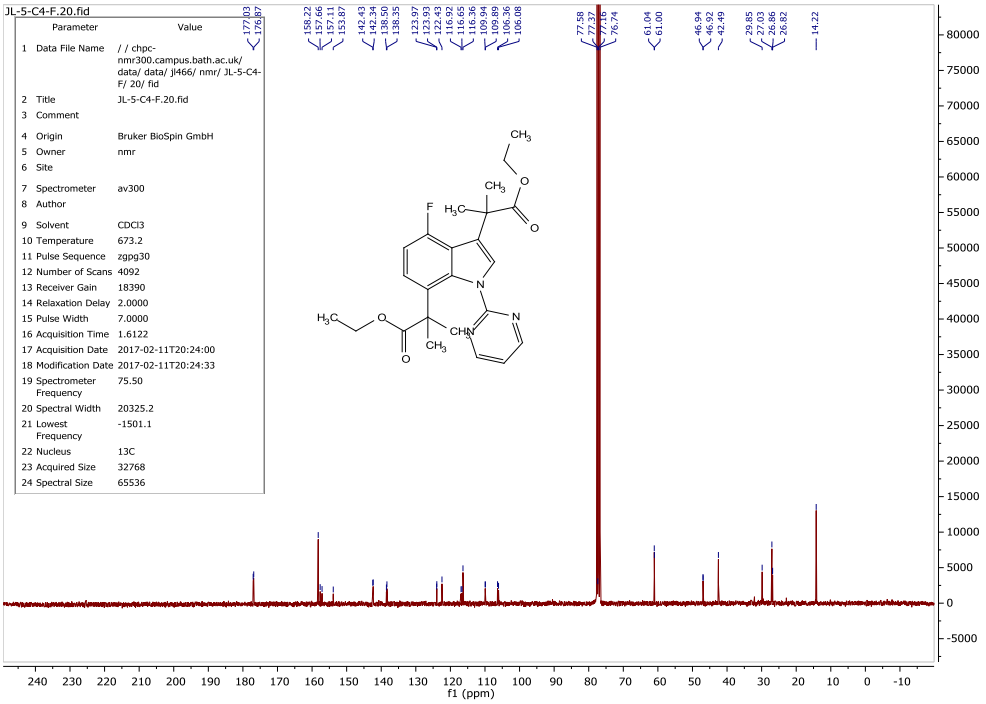
| 19 Spectrometer Frequency | 300.22 |
| 20 Spectral Width | 6172.8 |
| 21 Lowest Frequency | -1235.4 |
| 22 Nucleus | 1H |
| 23 Acquired Size | 16384 |
| 24 Spectral Size | 65536 |

## **S4a** – $^{13}$C NMR (75 MHz, $CDCl_3$)

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| 3 Comment | |
| 4 Origin | Bruker BioSpin GmbH |
| 5 Owner | nmr |
| 6 Site | |
| 7 Spectrometer | av300 |
| 8 Author | |
| 9 Solvent | CDCl3 |
| 10 Temperature | 673.2 |
| 11 Pulse Sequence | zgpg30 |
| 12 Number of Scans | 4092 |
| 13 Receiver Gain | 18390 |
| 14 Relaxation Delay | 2.0000 |
| 15 Pulse Width | 7.0000 |
| 16 Acquisition Time | 1.6122 |
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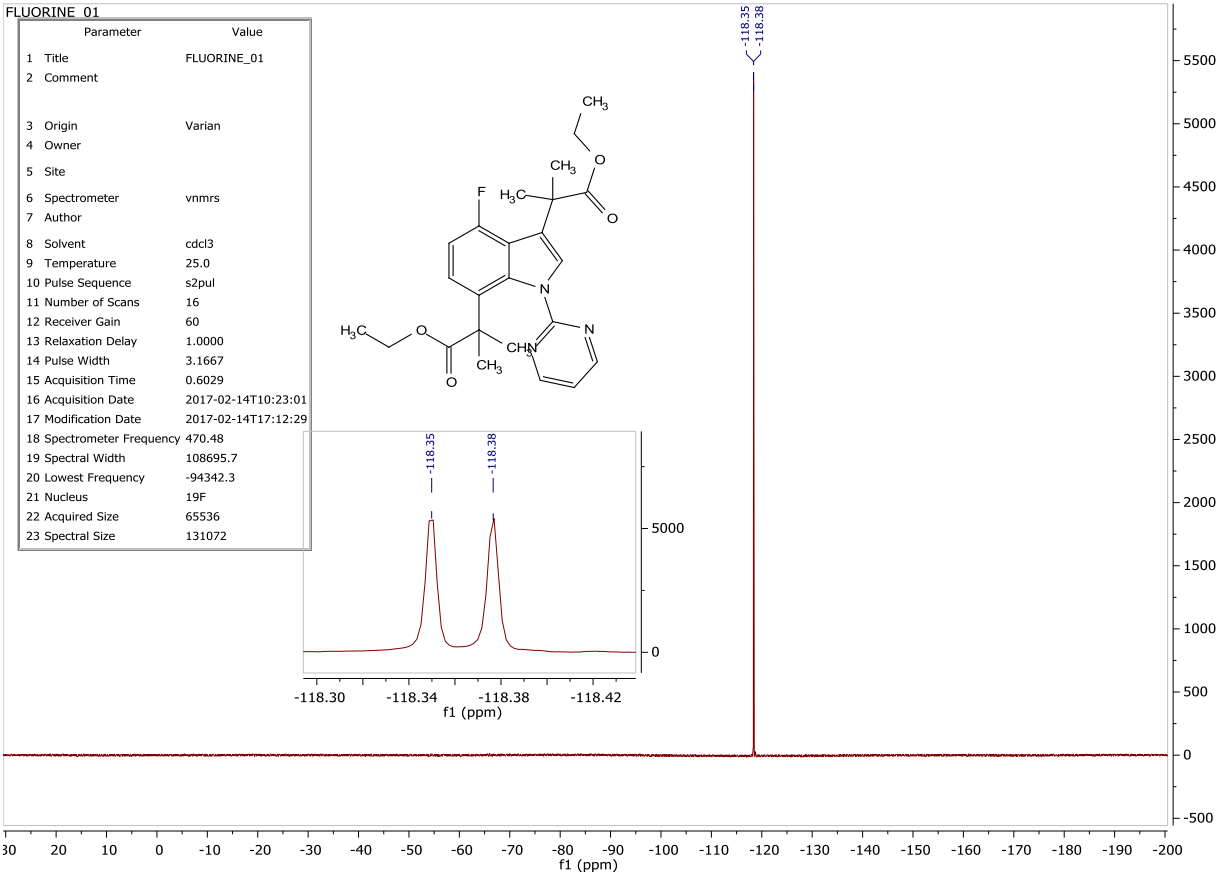
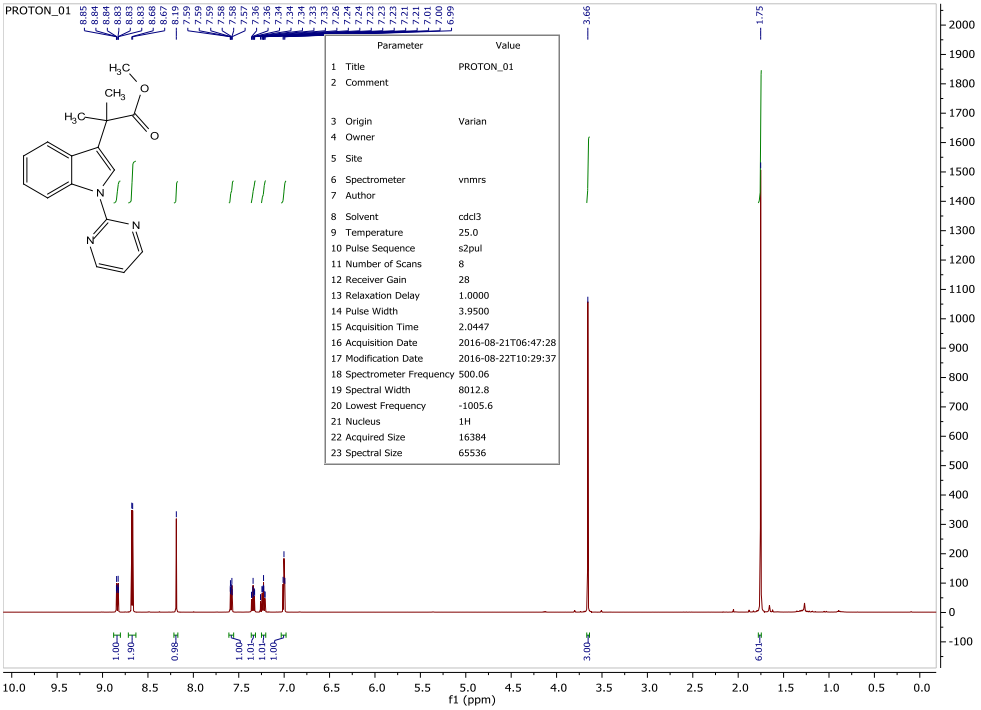
| 19 Spectrometer Frequency | 75.50 |
| 20 Spectral Width | 20325.2 |
| 21 Lowest Frequency | -1501.1 |
| 22 Nucleus | 13C |
| 23 Acquired Size | 32768 |
| 24 Spectral Size | 65536 |

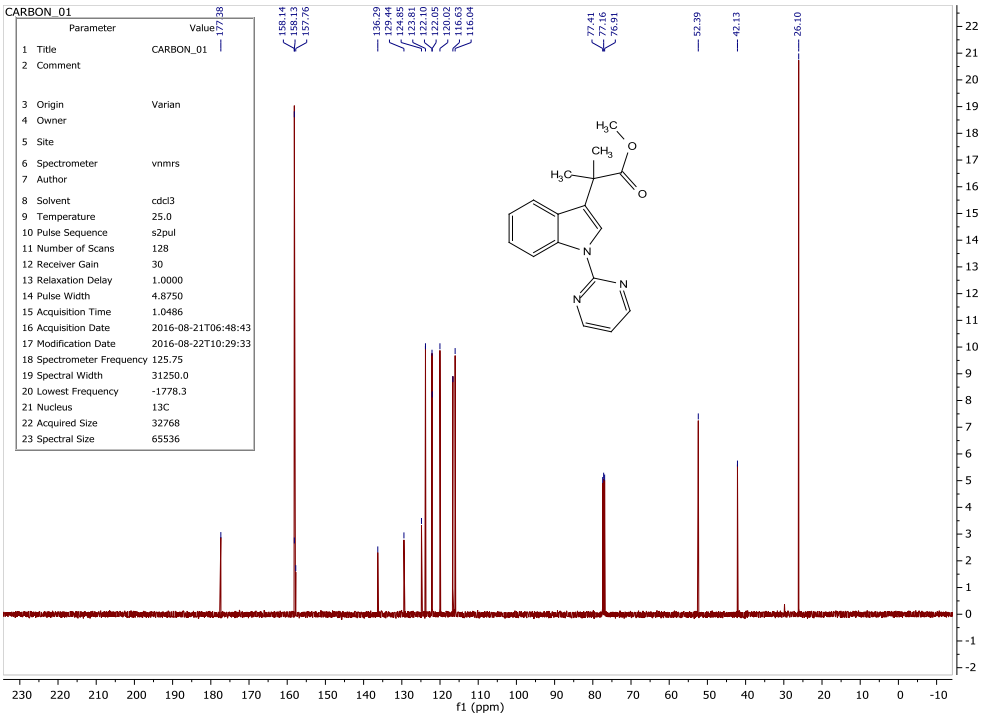
**S4a** – $^{19}F$ NMR (470 MHz, $CDCl_3$)



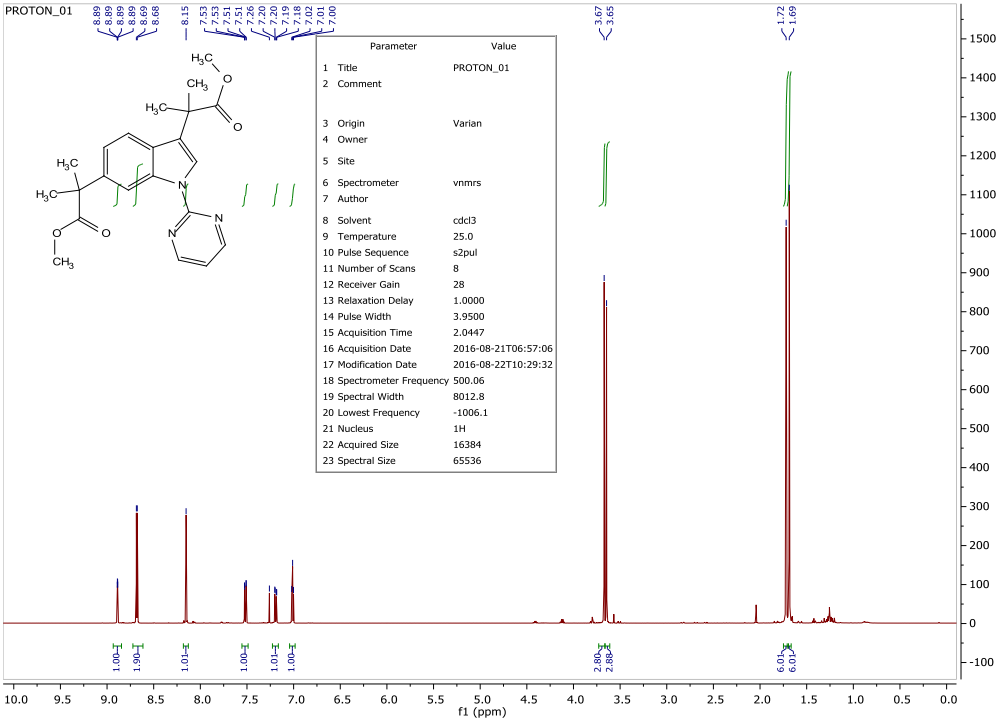
## **3s** – $^{1}$H NMR (500 MHz, $CDCl_3$)



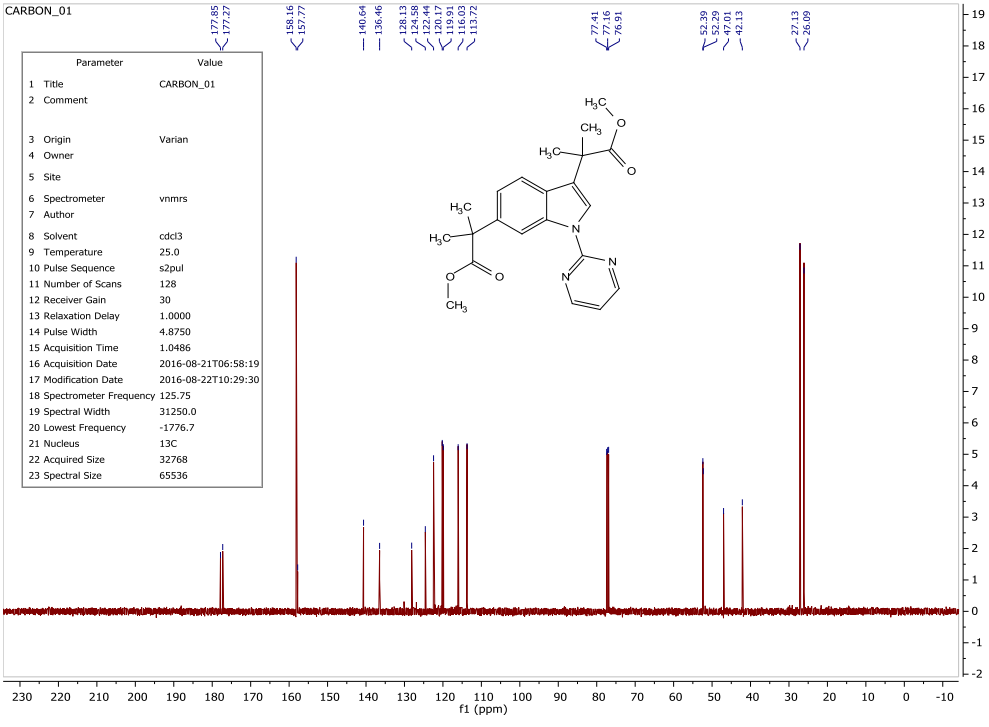

## **3s** – $^{13}$C NMR (126 MHz, $CDCl_3$)



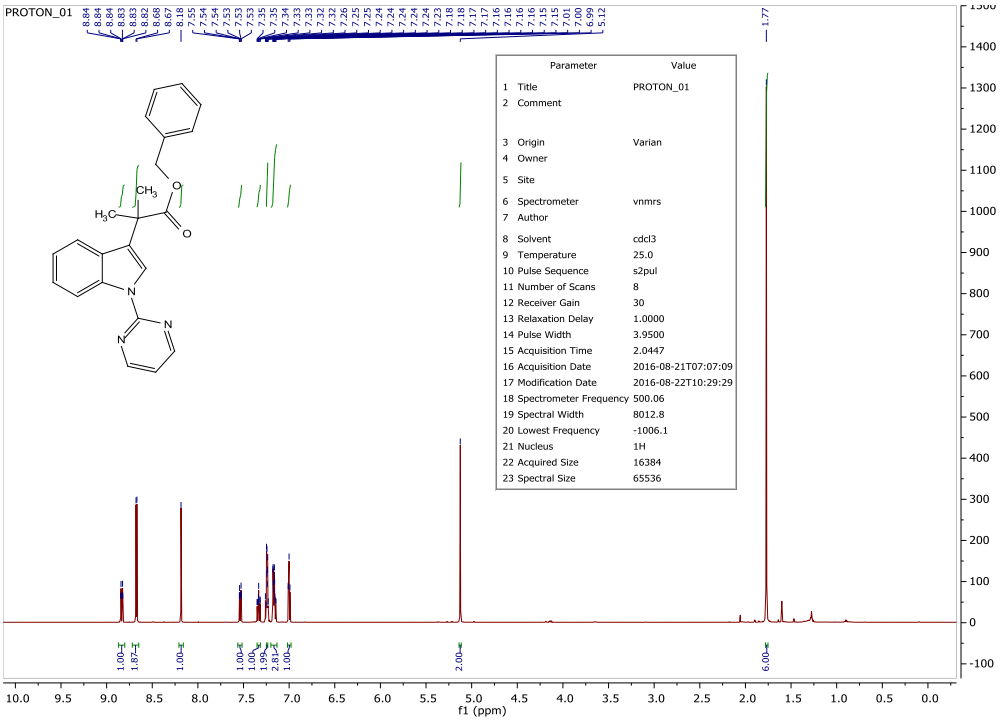
## **4s** – $^{1}$H NMR (500 MHz, $CDCl_3$)



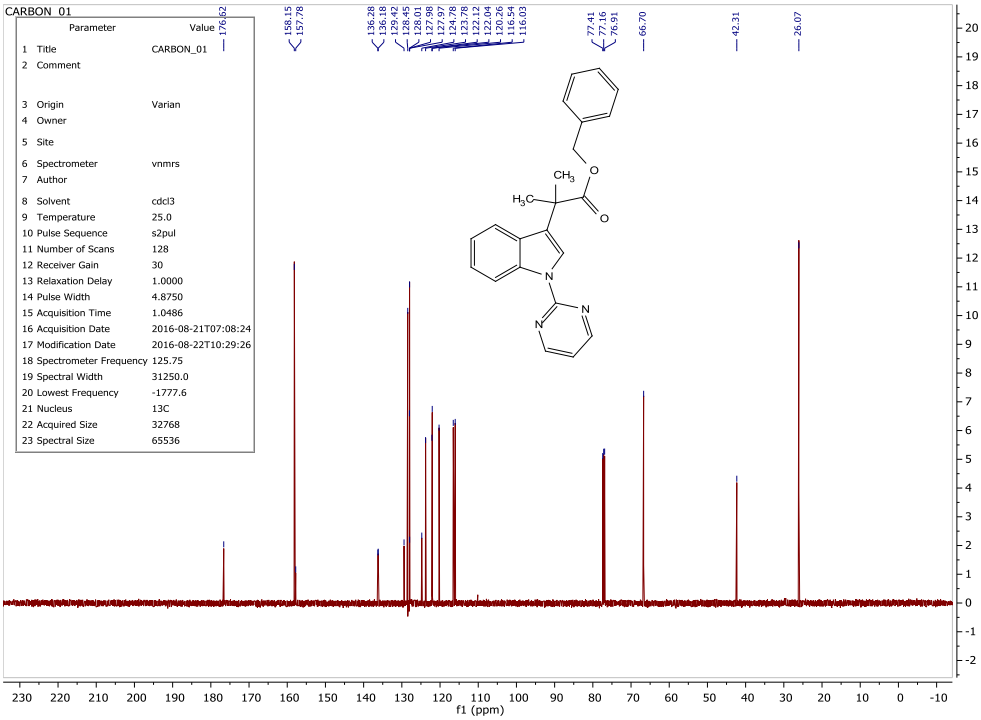

## **4s** – $^{13}$C NMR (126 MHz, $CDCl_3$)



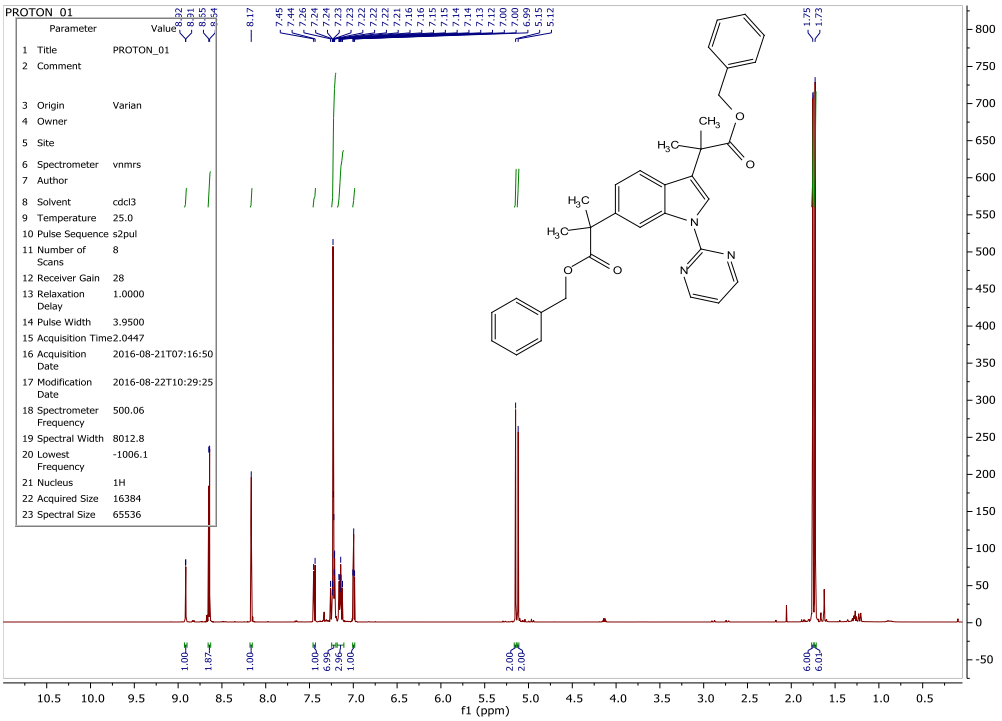
## **3t** – $^{1}$H NMR (500 MHz, $CDCl_3$)



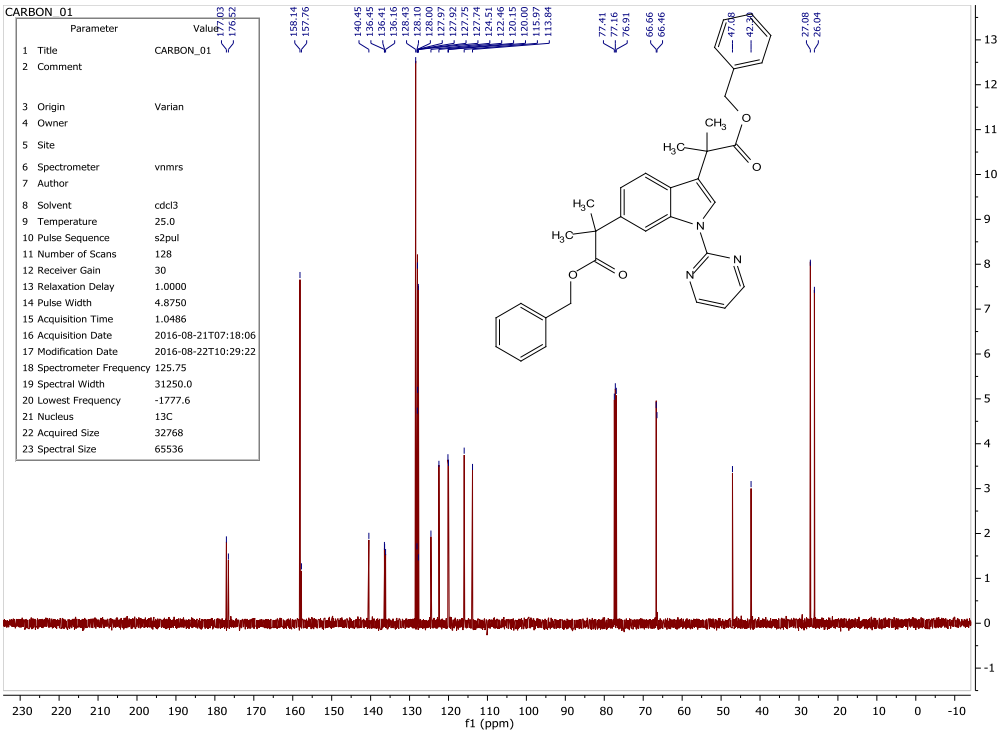

## **3t** – $^{13}$C NMR (126 MHz, $CDCl_3$)



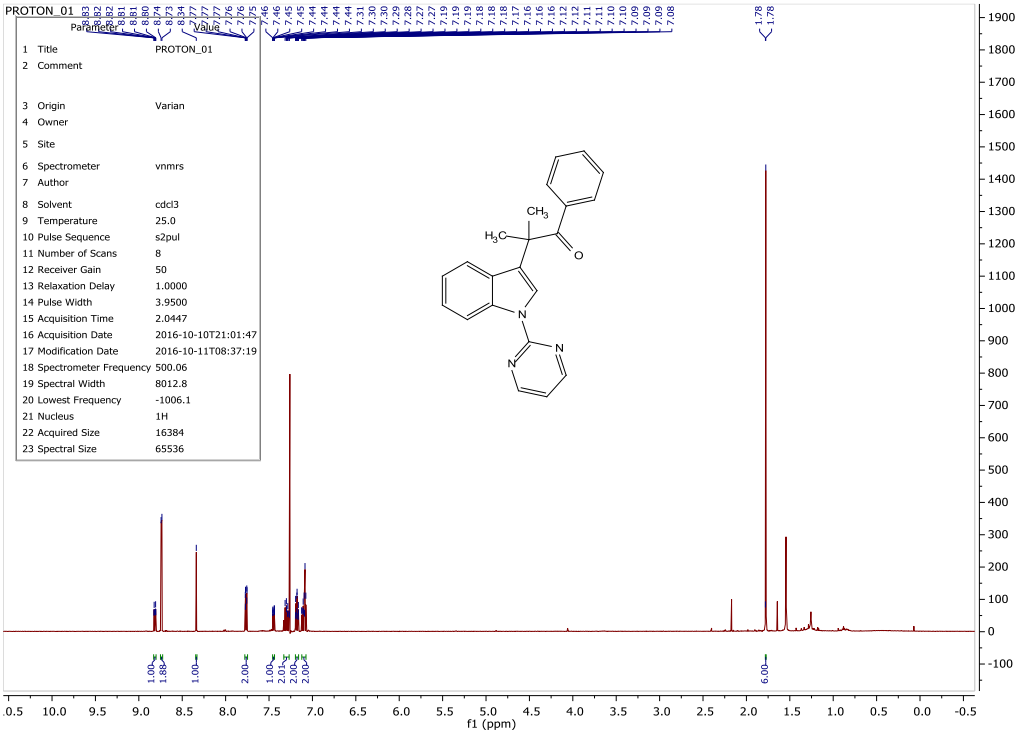
## **4t** – $^{1}$H NMR (500 MHz, $CDCl_3$)



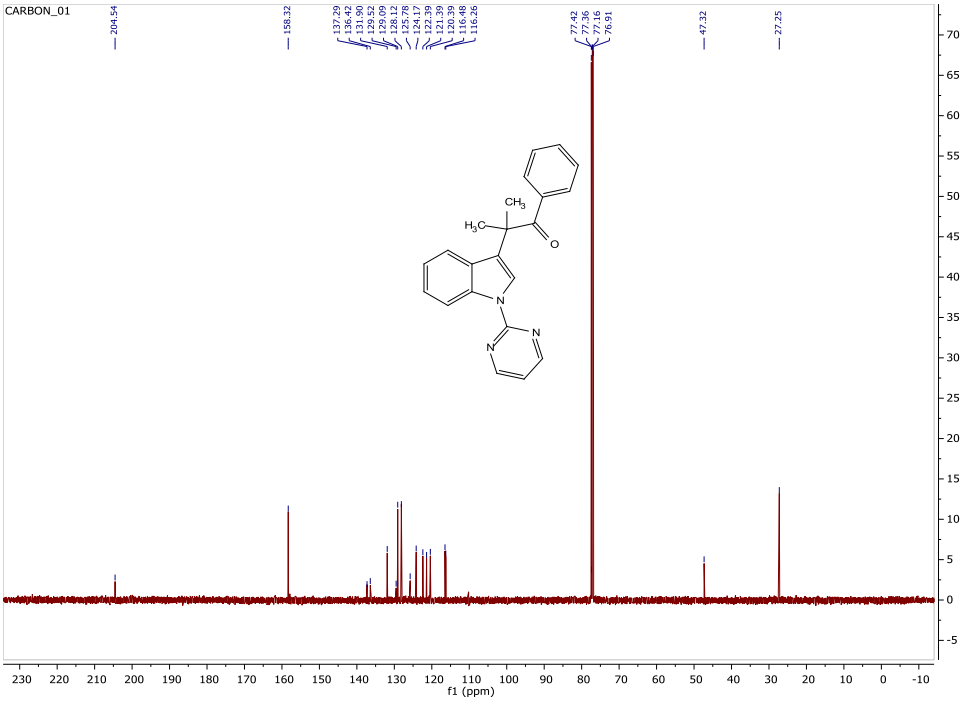

## **4t** – $^{13}$C NMR (126 MHz, $CDCl_3$)



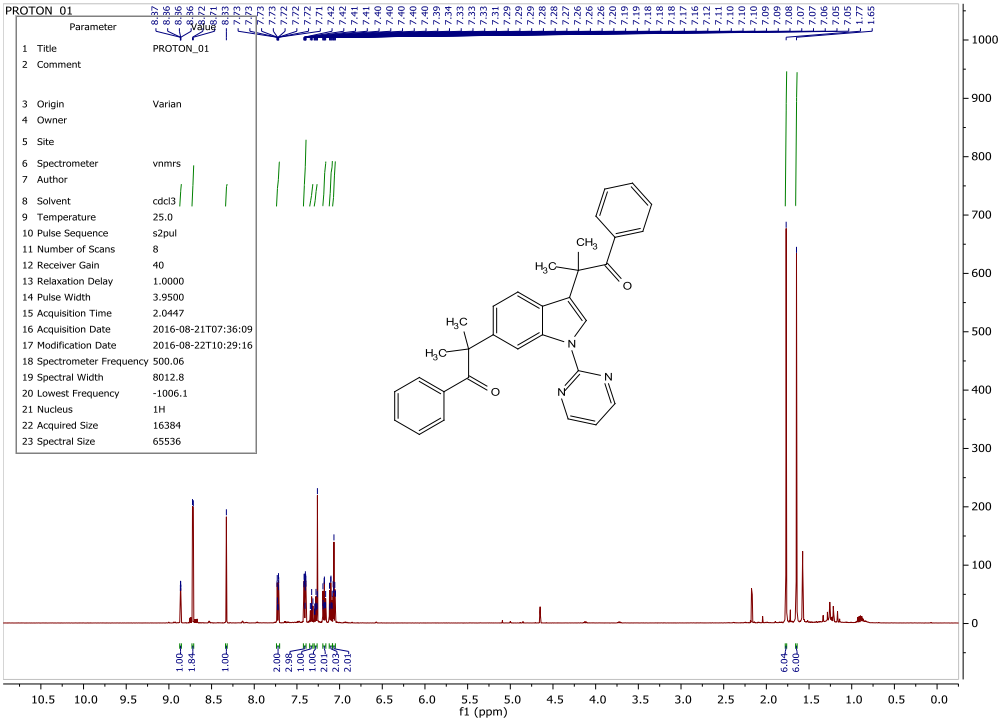
## **3u** – $^{1}$H NMR (500 MHz, $CDCl_3$)



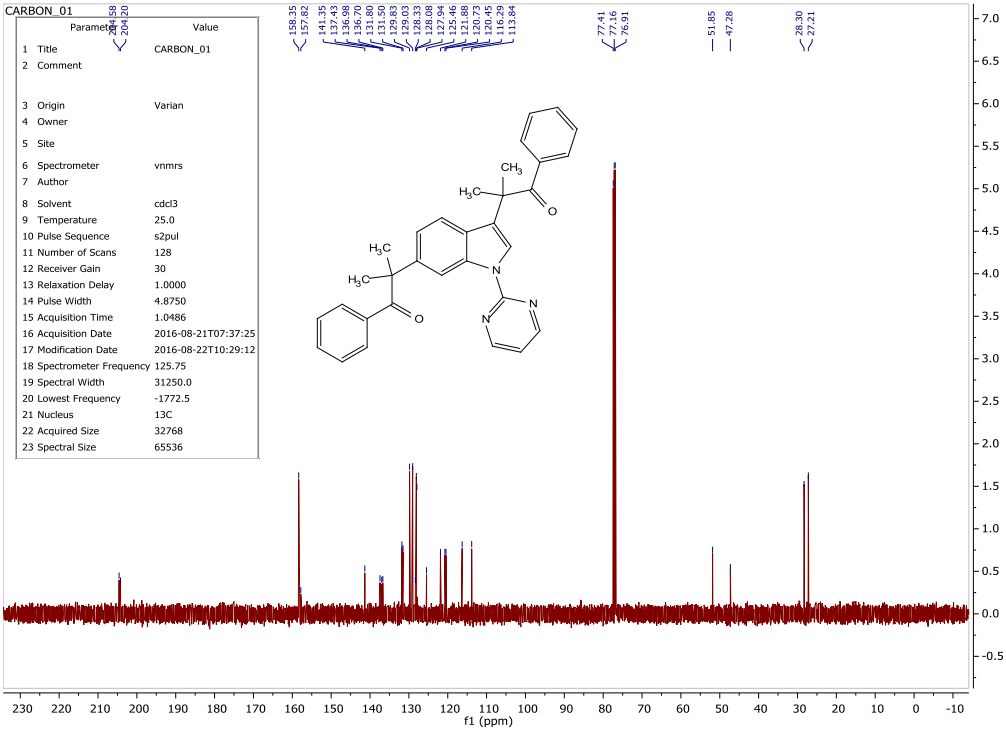

## **3u** – $^{13}$C NMR (126 MHz, $CDCl_3$)



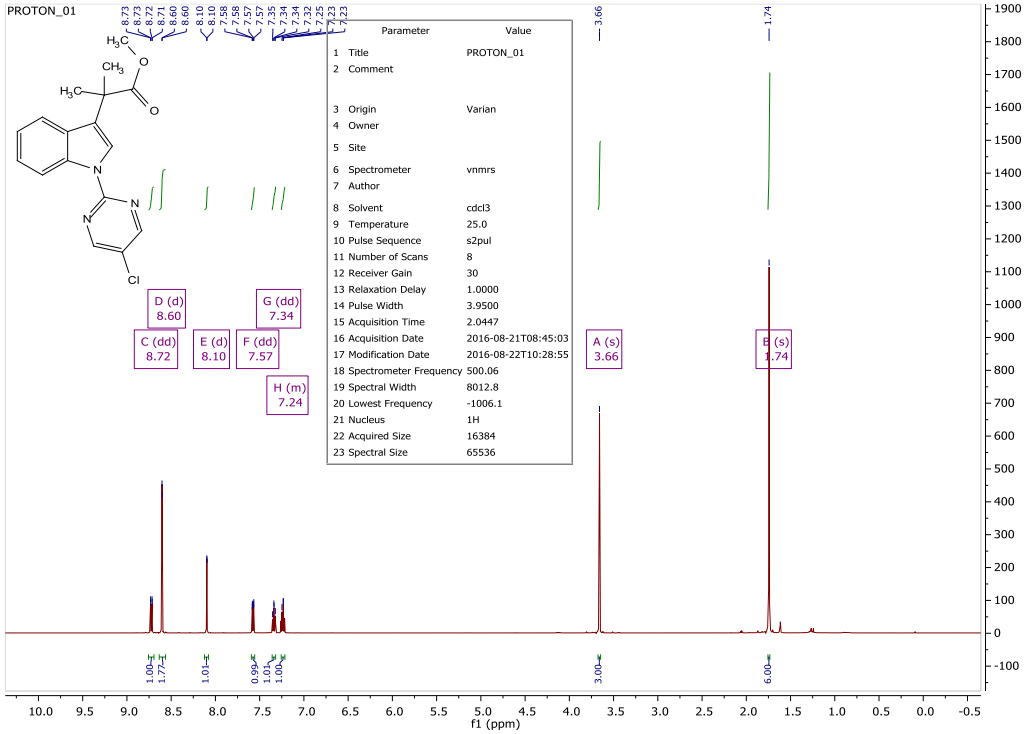
## **4u** – $^{1}$H NMR (500 MHz, $CDCl_3$)



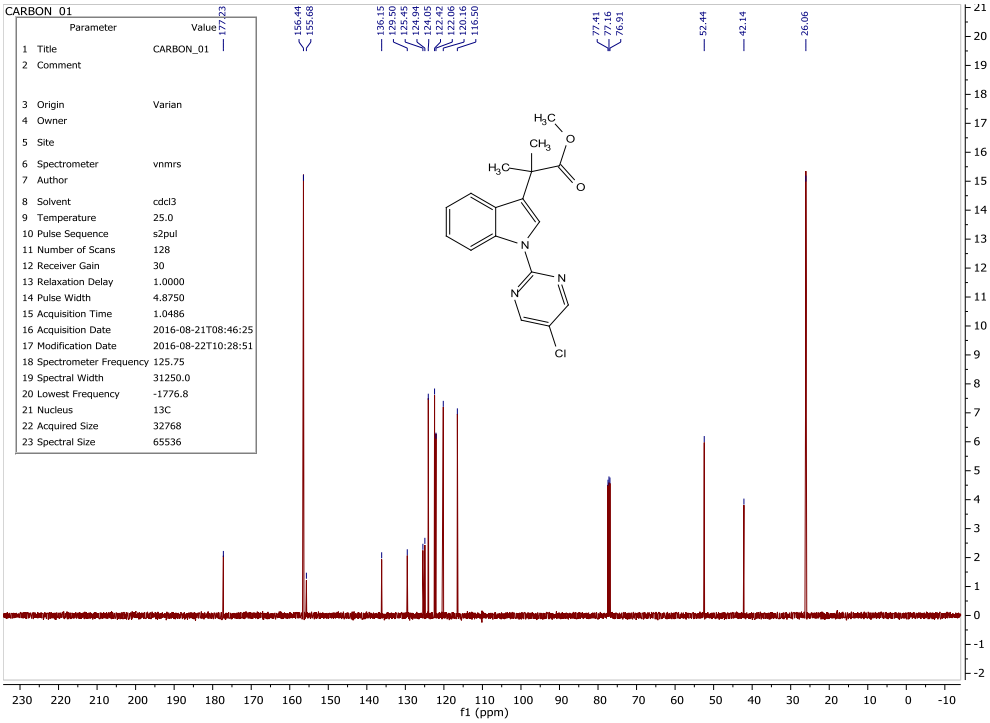

## **4u** – $^{13}$C NMR (126 MHz, $CDCl_3$)



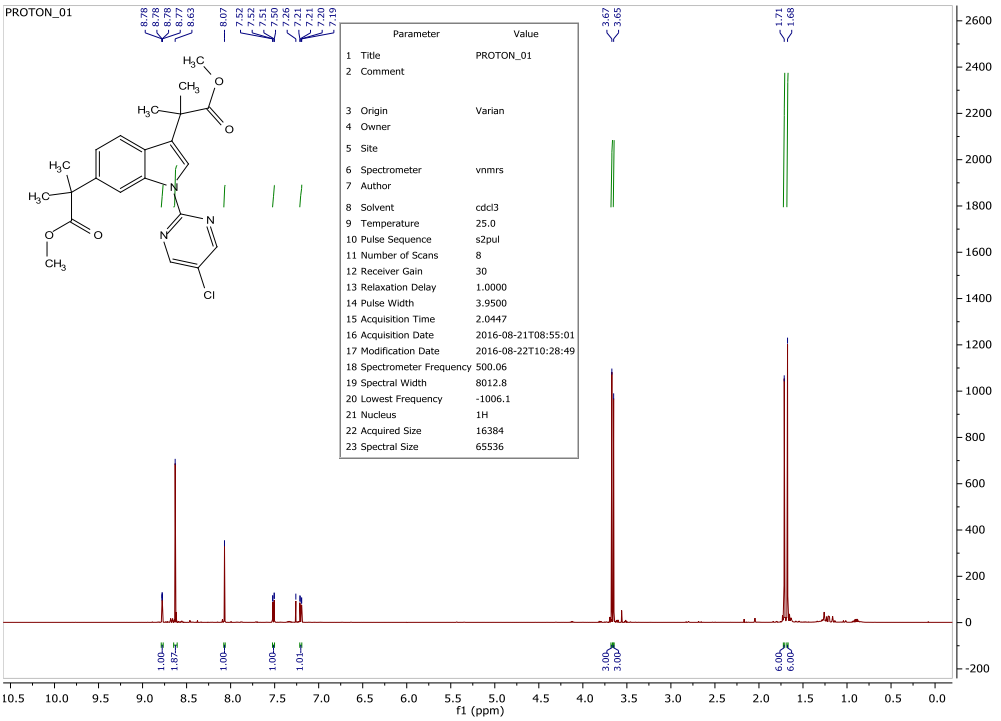
## **3v** – $^{1}$H NMR (500 MHz, $CDCl_3$)



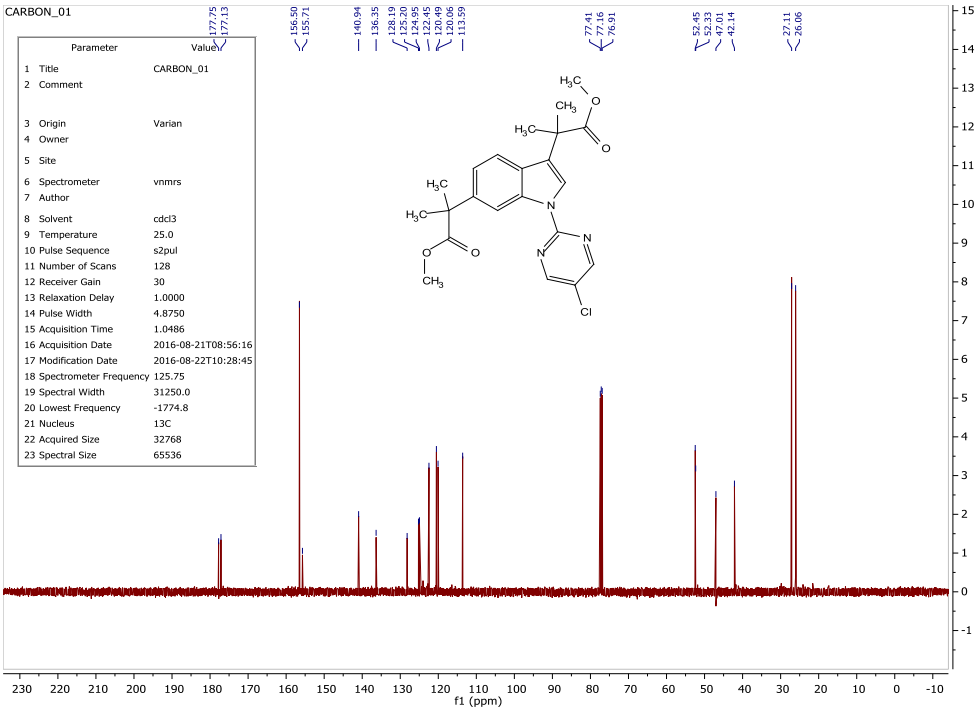

## **3v** – $^{13}$C NMMR (126 MHz, $CDCl_3$)



## **4v** – $^{1}$H NMR (500 MHz, $CDCl_3$)




## **4v** – $^{13}$C NMR (126 MHz, $CDCl_3$)



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