

## [Supporting Information]

### **Fully $\pi$ -conjugated, diyne-linked covalent organic framework formed via alkyne-alkyne cross-coupling reaction**

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#### **Table of Content**

**Section 1.** Material and Characterization

**Section 2.** Synthesis and Photocatalysis

**Section 3.** XPS Spectra of COF-JLU10

**Section 4.** Pore Size Distributions

**Section 5.** Thermogravimetric Analysis

**Section 6.** IR Spectra

**Section 7.** Characterization of COF-JLU10 After 5 Cycles

**Section 8.** Cyclic Voltammetry of aryldiazonium ion

**Section 9.** ESR Spectra

**Section 10.** Catalytic Data

**Section 11.** Characterization Data of Catalytic Products

**Section 12.** NMR Spectra of Catalytic Products

## Section 1. Material and Characterization

**Materials.** Trimethylsilylacetylene were obtained from Chembee Chemical Reagent. n-Butyllithium solution in hexanes (1.6 M), dichlorodicyanobenzoquinone (DDQ), tetrabutylammoniumfluoride (TBAF), Bis(triphenylphosphine)palladium (II) Dichloride ( $\text{Pd}(\text{PPh}_3)_2\text{Cl}_2$ ), pyrrole were obtained from Energy Chemical. The Copper iodide, Borontrifluoride etherate were obtained from Sinopharm Chemical Reagent. (Triisopropylsilyl)acetylene was obtained from Bide Pharmatech Ltd. Aniline and its derivatives were obtained from Energy Chemical. Other organic solvents for reactions were distilled over appropriate drying reagents under nitrogen. Deuterated solvents for NMR measurement were obtained from Aladdin.

**Instrumentations.** The Brunauer-Emmett-Teller (BET) method was utilized to calculate the specific surface areas and pore volume on a JW-BK 132F analyzer at 77 K, the polymer was dried in vacuum at 80°C for more than 6 hours before measurement. The Nuclear Magnetic Resonance (NMR) spectroscopy were measured by an Avance III-400 NMR spectrometer, and the chemical shift ( $\delta$ , ppm) is measured with the residual protons of the solvent as the standard. The thermogravimetric analysis (TGA) spectrum was recorded from 20 to 800 °C on a TA Q500 thermogravimeter at a rate of 10 °C min<sup>-1</sup> under nitrogen. The UV-vis absorption spectrum was recorded from 200–1500 nm on a Shimadzu Corporation U-4100 Spectrophotometer. The Fourier Transform Infrared (FT-IR) spectroscopy were recorded on an Avatar FT-IR 360 spectrometer by using KBr pellets within the wavenumber range 400 to 4000 cm<sup>-1</sup>. The powder X-ray diffraction (PXRD) data were carried out on a PANalytical BV Empyrean diffractometer, the powder was deposited on glass substrate with  $2\theta$  range of 1.5° to 40° at 298 K. The solid-state <sup>13</sup>C CP/MAS NMR spectra was recorded on a Bruker AVANCE III 400 WB spectrometer with a CP contact time of 2 ms and a MAS rate of 5 kHz. The field emission scanning electron microscopy (FE-SEM) was carried out on a SU8020 model HITACHI microscope. The Pd metal loading of obtained polymers was determined by Perkin-

Elmer ICP-OES optima 3300DV spectroscopy. X-ray photoelectron spectroscopy (XPS) was performed using an ESCALAB 250 spectrometer. The photocatalytic process is carried out under the irradiation of 30 W blue LED lamp (460 nm,  $36.2 \pm 0.1 \text{ Mw cm}^{-2}$ , distance app. 3 cm;  $28.1 \pm 0.1 \text{ mW cm}^{-2}$ , distance app. 5 cm). The electron paramagnetic resonance (EPR) spectra were measured by a JEOL JES-FA200 EPR spectrometer. The data of 5,5-dimethyl-1-pyrroline-N-oxide (DMPO) with the concentration of 0.1 M were collected on the measurement parameters, scanning frequency: 9225 MHz; scanning power, 0.998 mW; central field, 329.4 mT; scanning width, 100 G; scanning temperature: 25 °C.

**Electrochemical measurements.** The photocurrent of the polymer was performed on a VersaSTAT 3 electrochemical workstation under irradiation of 300 W Xe lamp. ITO electrode, platinum wire electrode and saturated calomel electrode are used as working electrode, assistant electrode and reference electrode respectively. The working electrode was prepared from the polymer and 5 wt% Nafion, the experiment was carried out in 0.1 M  $\text{Na}_2\text{SO}_4$  aqueous solution. The MottSchottky analysis was performed on a CHI760E electrochemical workstation at room temperature. Glassy carbon electrode, platinum wire electrode and saturated calomel electrode are used as working electrode, assistant electrode and reference electrode respectively. The Mott-Schottky measurement was carried out in 0.1 M  $\text{Na}_2\text{SO}_4$  aqueous solution at frequency of 2000, 2500 and 3000 Hz.

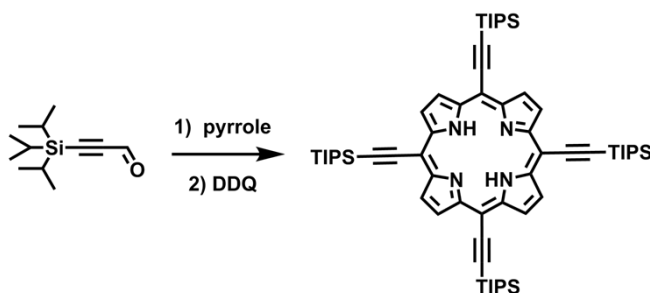
## Section 2. Synthesis and Photocatalysis

### Synthesis of 3-(Triisopropylsilyl)propiolaldehyde.



The n-Butyllithium solution (7.58 mL, 1.6 M in hexane) was slowly dropped into the solution of (Triisopropylsilyl)acetylene (2.0 mL, 8.66 mmol) in diethyl ether (5 mL) at  $-78\text{ }^{\circ}\text{C}$  under a nitrogen atmosphere. Then it was allowed to warm slowly to room temperature and stirred for 2 hours. Then DMF (1.29 mL, 16.72 mmol) was added to the mixture at  $-78\text{ }^{\circ}\text{C}$ . After completion, the solution was allowed to warm up to room temperature and slowly stirred for 2 h. A 20 ml of 1M hydrochloric acid was added to the reaction system and stirred vigorously for 2 hours. It then was extracted by  $\text{Et}_2\text{O}$  (20 mL  $\times$  3) and the organic layer was dried over  $\text{Na}_2\text{SO}_4$  and concentrated with a rotary evaporator. The crude product was isolated by column chromatography as a colorless oil (1.7 g, 93% yield).  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  9.19 (s, 1H), 1.12–1.06 (m, 21H) ppm.

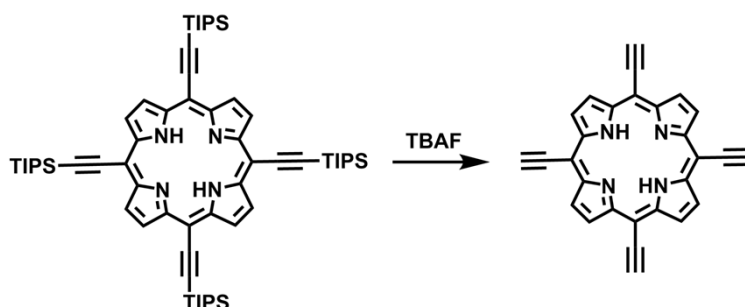
### Synthesis of 5,10,15,20-Tetrakis(triisopropylsilylethynyl)-porphyrin.



Boron trifluoride etherate (0.16 mL) was added to a stirred solution of 3-(Triisopropylsilyl)propiolaldehyde (2 mL, 8.08 mmol) and pyrrole (0.56 mL, 8.08 mmol) in  $\text{CH}_2\text{Cl}_2$  (500 mL) at  $-78\text{ }^{\circ}\text{C}$  under an  $\text{N}_2$  atmosphere. It then was allowed to warm slowly to room temperature. Stirring was continued for an additional 5 h and DDQ (1.37 g, 6.04 mmol) was added 2 h later, the solvent was removed under vacuum and the residue was purified by column chromatography yielding a purple powder (283 mg, 13.6% yield).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz):  $\delta$  9.59 (s, 8H), 1.43–1.46

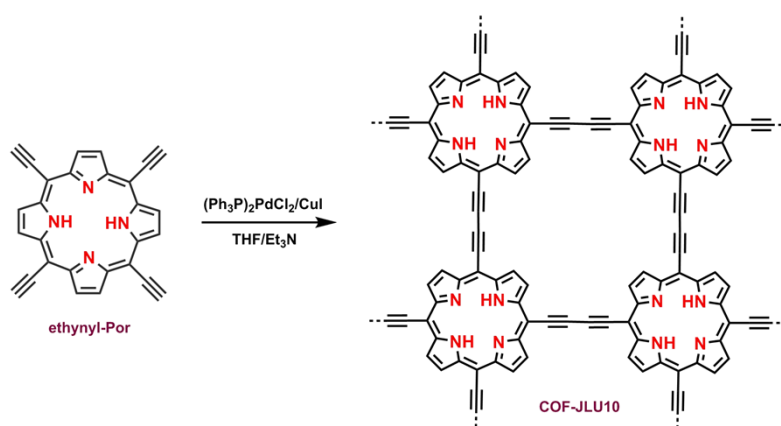
(m, 84H), -1.71 (s, 2H) ppm.

### Synthesis of 5,10,15,20-Tetraethynyl-porphyrin.



506.8 mg of tetrabutylammonium fluoride (TBAF, 1.94 mmol) was dissolved in 5 mL THF. The solution was added to a mixture of 5,10,15,20-Tetrakis-(triisopropylsilyl)ethynyl-porphyrin (250 mg, 0.24 mmol) in anhydrous THF (20 mL) and DCM (5 mL) under a N<sub>2</sub> atmosphere. It was stirred at room temperature for 3 h. Then the solution was evaporated under reduced pressure to remove the solvent. Then 10 mL MeOH was added and the precipitate was separated by filtration. The crude product was washed with MeOH (10 mL × 3), deionized water (10 mL × 3), and acetone (10 mL × 3) sequentially, resulting in a near black solid (87.6 mg, 88.9%).

### Synthesis of COF-JLU10.



5,10,15,20-Tetraethynyl-porphyrin (20 mg, 0.049 mmol), Pd(PPh<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub> (1.38 mg) and copper(I) iodide (0.37 mg) were dissolved in THF (0.5 mL) and Et<sub>3</sub>N (0.5 mL). The mixture was degassed using the freeze-pump-thaw cycle. The reaction system is heated at 40°C, and then heated at 40°C, 50°C, 60°C, 70°C and 80°C for 24 h. Then, a black powder was collected by centrifugation, washed with aqueous HCl solution

(2M), water, acetone, chloroform, tetrahydrofuran, and methanol. The desired polymer was collected and then dried in vacuum oven at 100 °C in vacuum oven to give a black powder (yield: 99%). The Pd metal loading of COF-JLU10 was determined by ICP to be 0.6wt%.

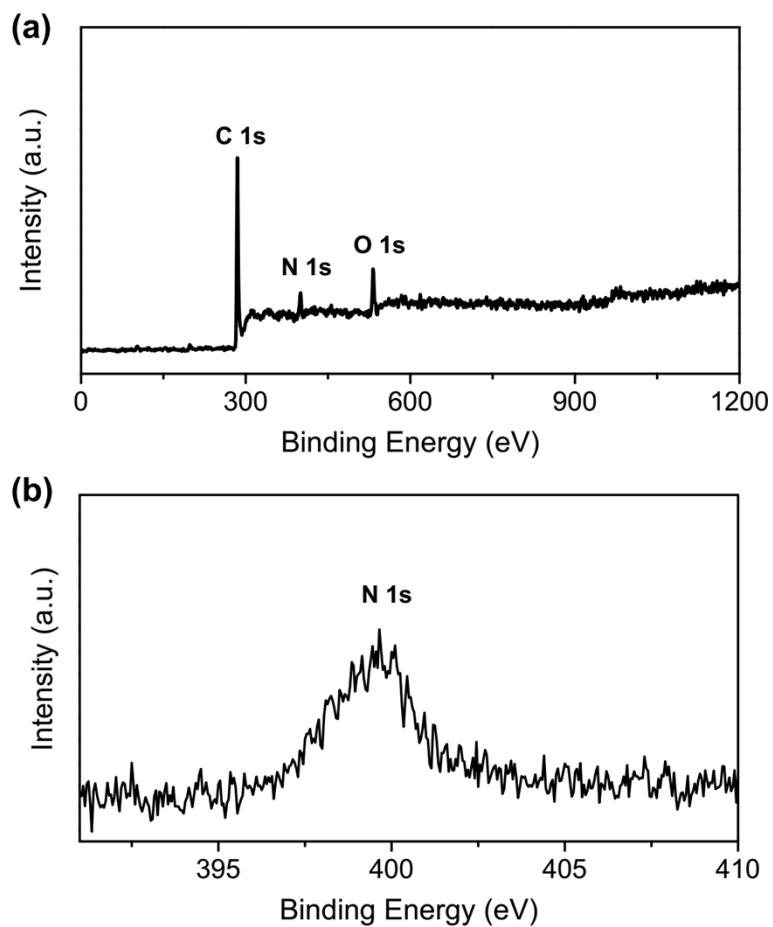
#### **Typical procedure for the borylation of arylamines.**

B<sub>2</sub>pin<sub>2</sub> (0.3 mmol, 76.2 mg), COF-JLU10 (3 mg), aryl amines (0.3 mmol) (if solid) were weighed in a 5.0 mL glass microwave tube. MeCN (2 mL), aryl amines (0.3 mmol) (if liquid) and <sup>t</sup>BuONO (0.66 mmol, 68.06 mg) were then added in succession under N<sub>2</sub> atmosphere. The resulting reaction solution was allowed to stir at room temperature under 30W blue LEDs. The progress of the reaction was monitored by TLC. After the reaction was completed, the mixture was filtered and washed with ethyl acetate, the filtrate was concentrated in vacuum. The concentrate was purified by column chromatography using petroleum ether/ ethyl acetate to obtain the corresponding products.

#### **Recycle experiment.**

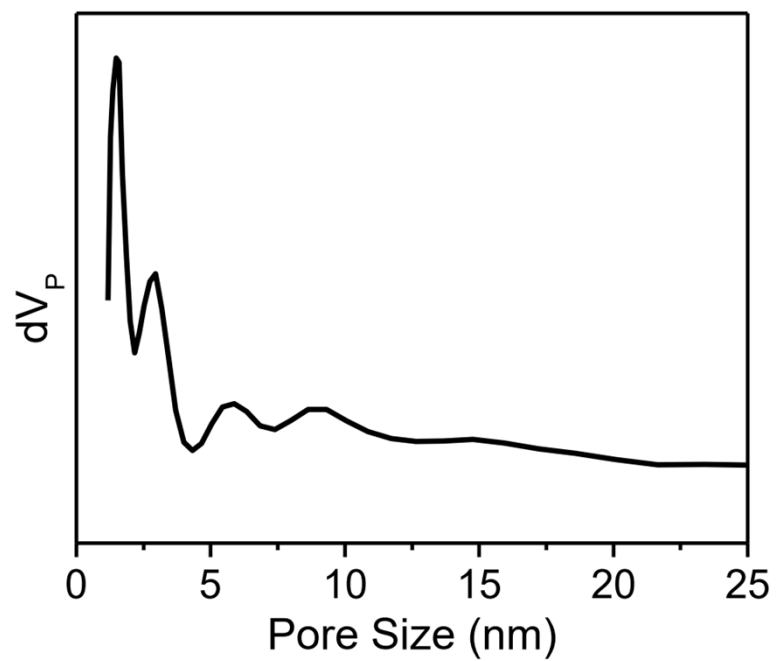
After the first run reaction was finished, the photocatalyst COF-JLU10 was recovered by centrifugation, and then washed thoroughly with THF and ethyl acetate to remove any residual products or unreacted substrates. The recovered COF-JLU10 was dried under vacuum at 80 °C overnight. The used photocatalyst COF-JLU10 was repeated use in next cycle under identical conditions.

### **Section 3. XPS Spectra**



**Figure S1.** XPS survey spectra of COF-JLU10 (a); The high-resolution N 1s XPS signal of COF-JLU10 (b).

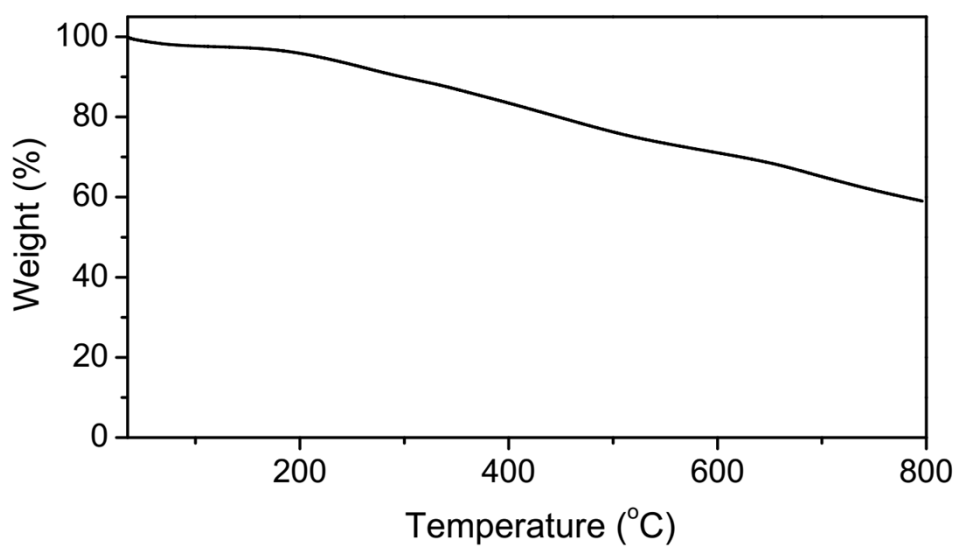
#### Section 4. Pore Size Distributions



**Figure S2.** Pore size distributions of COF-JLU10

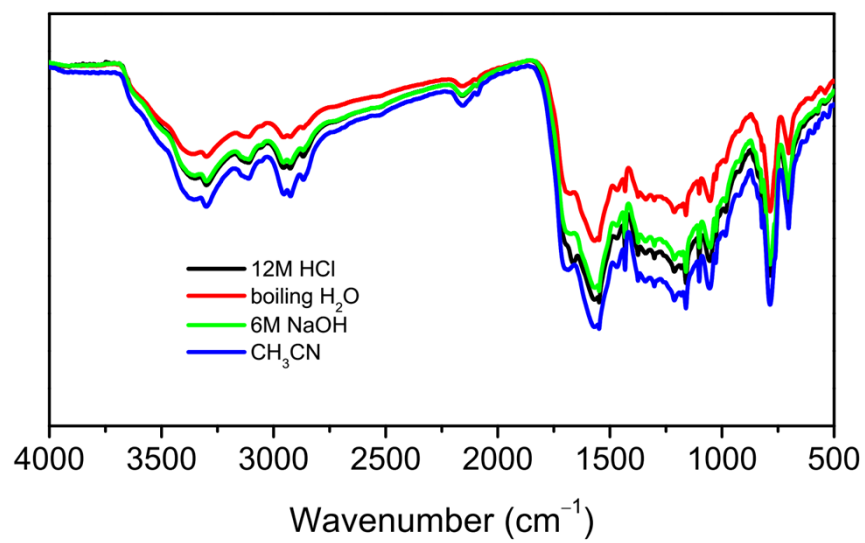
## Section 5. Thermogravimetric Analysis





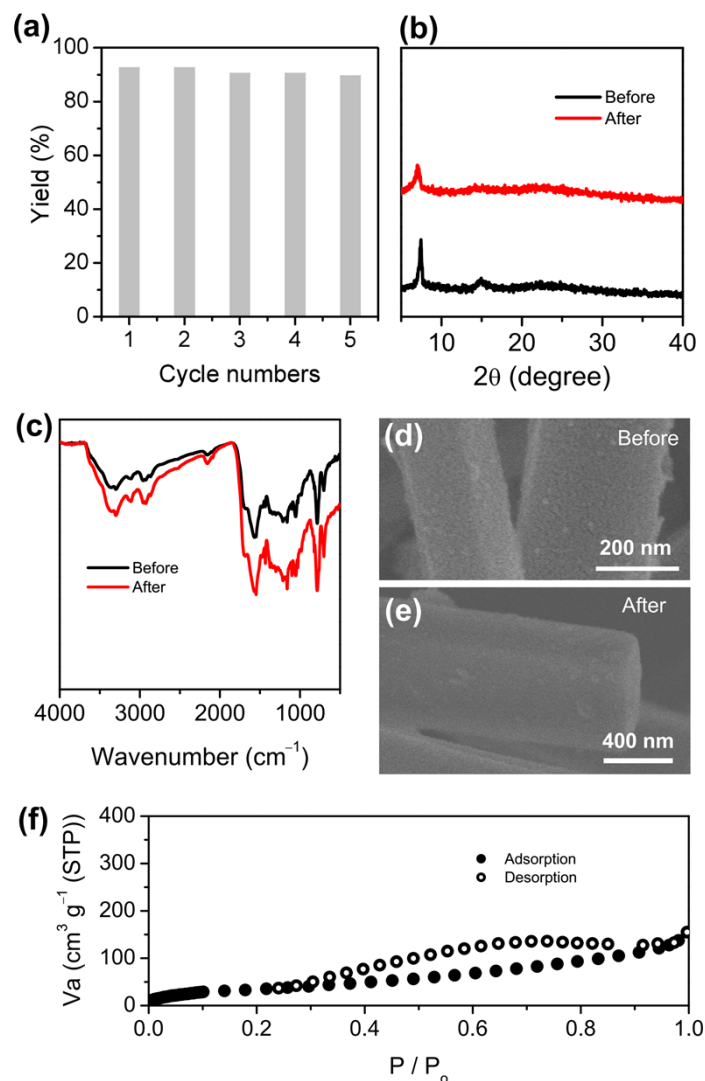
**Figure S3.** TGA curve of COF-JLU10.

## Section 6. IR Spectra



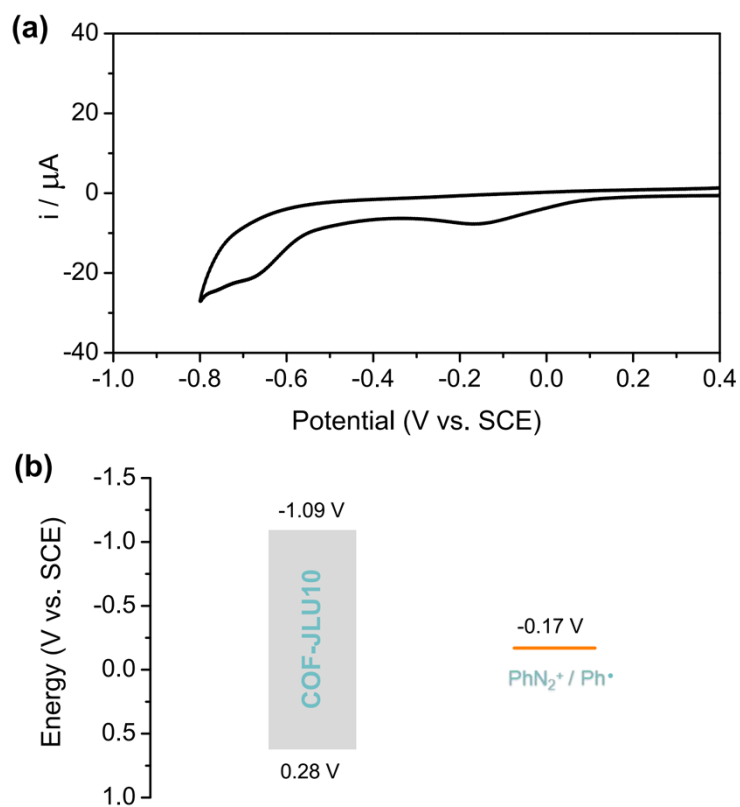
**Figure S4.** IR spectra of COF-JLU10 after treatment in different solvents.

## Section 7. Characterization of COF-JLU10 After 5 Cycles



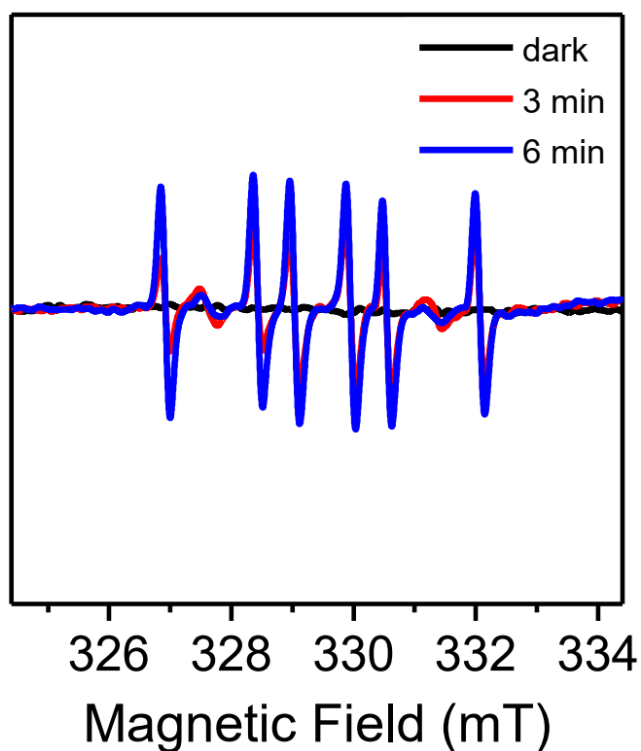
**Figure S5.** Reusability of COF-JLU10 in the borylation of aryl amines (a); Powder XRD spectra of photocatalyst COF-JLU10 before and after five cycles (b); FT-IR spectra of photocatalyst COF-JLU10 before and after five cycles (c); FE-SEM images of photocatalyst COF-JLU10 before (d) and after (e) five cycles. (f) N<sub>2</sub> sorption isotherm of COF-JLU10 after five cycles at 77 k ( $S_{\text{BET}} = 127 \text{ m}^2 \text{ g}^{-1}$ ).

## Section 8. Cyclic Voltammetry and Energy Band



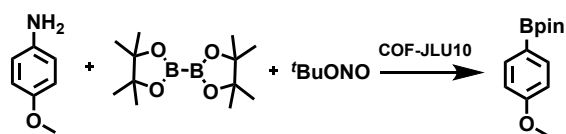
**Figure S6.** Cyclic voltammetry of 4-methoxyaryldiazonium ion ( $C = 9 \text{ mM}$  in ACN +  $0.1 \text{ M NBU}_4\text{BF}_4$ ) (a); Schematic diagram of the energy band structure of COF-JLU10 and  $\text{PhN}_2^+/\text{Ph}\cdot$  (b).

## Section 9. ESR Spectra



**Figure S7.** ESR profiles of DMPO-phenyl radical adduct in  $\text{CH}_3\text{CN}$  under light irradiation and dark conditions. DMPO-phenyl radical adduct detected by ESR from a reaction mixture containing  $\text{B}_2\text{pin}_2$  (0.2 M), COF-JLU10 (10 mg/L), 4-methoxybenzeneamine (0.1 M),  $^t\text{BuONO}$  (0.2 M) and 0.1 M DMPO.

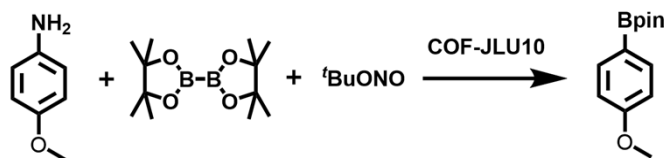
## Section 10. Catalytic Data

**Table S1.** Photocatalytic the borylation of arylamines by COF-JLU10<sup>a</sup>

Entry	Catalyst	Solvent	Time (h)	Yield (%) <sup>b</sup>
1	COF-JLU10	DMF	2	45
2	COF-JLU10	Dioxane	2	18
3	COF-JLU10	THF	2	22
4	COF-JLU10	Toluene	2	~
5	COF-JLU10	CH <sub>3</sub> CN	2	90
6	ethynyl-Por	CH <sub>3</sub> CN	2	49
7	~	CH <sub>3</sub> CN	2	8
8 <sup>c</sup>	COF-JLU10	CH <sub>3</sub> CN	2	~
9 <sup>d</sup>	COF-JLU10	CH <sub>3</sub> CN	2	~
10 <sup>e</sup>	COF-JLU10	CH <sub>3</sub> CN	2	57
11 <sup>f</sup>	COF-JLU10	CH <sub>3</sub> CN	2	43
12 <sup>g</sup>	COF-JLU10	CH <sub>3</sub> CN	2	91
13 <sup>h</sup>	COF-JLU10	CH <sub>3</sub> CN	2	trace
14 <sup>i</sup>	Pd(PPh <sub>3</sub> ) <sub>2</sub> Cl <sub>2</sub>	CH <sub>3</sub> CN	2	11

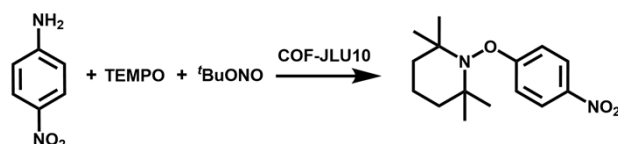
<sup>a</sup>Reaction conditions: photocatalyst (3.0 mg), 4-methoxyaniline (0.3 mmol), B<sub>2</sub>Pin<sub>2</sub> (0.3 mmol), solvent (2 mL), N<sub>2</sub> atmosphere (1.0 atm), 460 nm blue LED lamp with 30 W, 25 °C, 2 h. <sup>b</sup>Isolated yield. <sup>c</sup>Dark. <sup>d</sup>In absence of <sup>t</sup>BuONO. <sup>e</sup>520 nm green LED lamp with 30 W. <sup>f</sup>White LED lamp with 8 W. <sup>g</sup>B<sub>2</sub>Pin<sub>2</sub> (0.36 mmol). <sup>h</sup>2,6-dimethylaniline instead of 4-methoxyaniline. <sup>i</sup>0.12 mg Pd(PPh<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub> as catalyst.

**Scheme S1.** Large-scale photocatalytic reaction using COF-JLU10 as a heterogeneous photocatalyst.

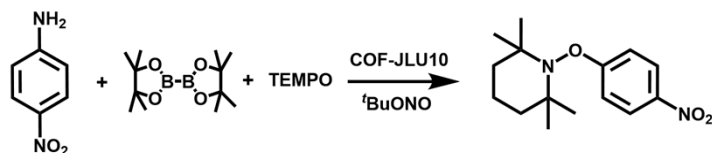


B<sub>2</sub>pin<sub>2</sub> (7 mmol, 0.86 g), COF-JLU10 (30 mg), aryl amines (7 mmol) were weighed in a 50 mL glass microwave tube. MeCN (25 mL) and <sup>t</sup>BuONO (15.4 mmol, 1.59 g) were then added in succession under N<sub>2</sub> atmosphere. The resulting reaction solution was allowed to stir at room temperature under 30W blue LEDs for 10 h. After the reaction was completed, the mixture was filtered and washed with ethyl acetate, the filtrate was concentrated in vacuum. The concentrate was purified by column chromatography using petroleum ether/ ethyl acetate to obtain 2-(4-methoxyphenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane 1.44 g (yield: 88%).

**Scheme S2.** Mechanism study experiments.



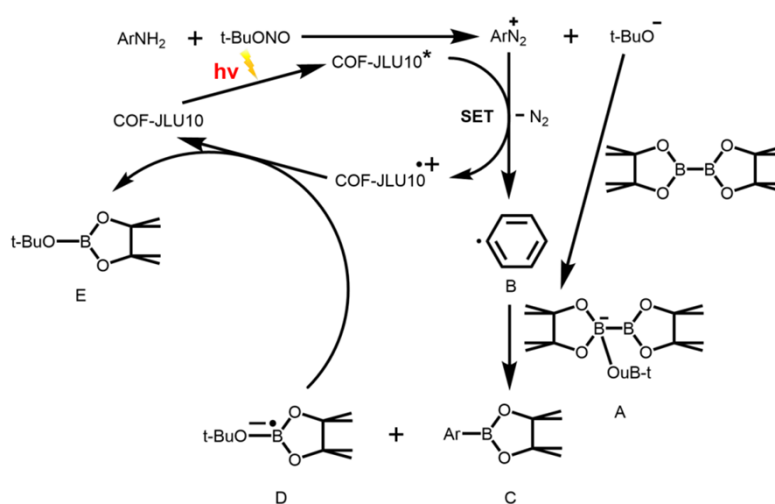
COF-JLU10 (3 mg), 4-Nitrophenylamine (0.3 mmol), and TEMPO (0.6 mmol) were weighed in a 5.0 mL glass microwave tube. MeCN (2 mL), and <sup>t</sup>BuONO (0.66 mmol, 68.06 mg) were then added in succession under N<sub>2</sub> atmosphere. The resulting reaction solution was allowed to stir at room temperature under 30W blue LEDs for 2 h. After the reaction was completed, the mixture was filtered and washed with ethyl acetate, the filtrate was concentrated in vacuum. The concentrate was purified by column chromatography using petroleum ether/ethyl acetate to obtain 2,2,6,6-Tetramethyl-1-(4-nitrophenoxy)piperidine (yield: 70%).



B<sub>2</sub>pin<sub>2</sub> (0.3 mmol, 76.2 mg), COF-JLU10 (3 mg), 4-Nitrophenylamine (0.3 mmol) and TEMPO (0.6 mmol) were weighed in a 5.0 mL glass microwave tube. MeCN (2 mL), and <sup>t</sup>BuONO (0.66 mmol, 68.06 mg) were then added in succession under N<sub>2</sub> atmosphere. The resulting reaction solution was allowed to stir at room temperature

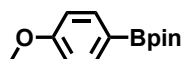
under 30W blue LEDs for 2 hours. After the reaction was completed, the mixture was filtered and washed with ethyl acetate, the filtrate was concentrated in vacuum. The concentrate was purified by column chromatography using petroleum ether/ ethyl acetate to obtain 2,2,6,6-Tetramethyl-1-(4-nitrophenoxy)piperidine (yield: 50%). Boric acid esters were not obtained in the reaction.

**Scheme S3.** Proposed reaction mechanism.

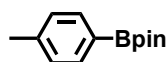


## Section 11. Characterization Data of Catalytic Products

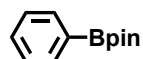




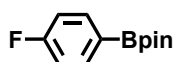
**2-(4-methoxyphenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (3a):**  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  1.33 (s, 12H), 3.83 (s, 3H), 6.90 (d,  $J = 8.1$  Hz, 2H), 7.75 (d,  $J = 8.1$  Hz, 2H) ppm;  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  25.0, 55.2, 83.6, 113.4, 136.6, 162.2 ppm.



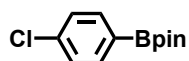
**4,4,5,5-Tetramethyl-2-p-tolyl-1,3,2-dioxaborolane (3b):**  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  1.36 (s, 12H), 2.39 (s, 3H), 7.21 (d,  $J = 7.5$  Hz, 2H), 7.74 (d,  $J = 7.6$  Hz, 2H) ppm;  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  21.8, 25.0, 83.7, 128.6, 134.9, 141.5 ppm.



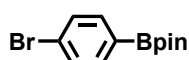
**4,4,5,5-Tetramethyl-2-phenyl-1,3,2-dioxaborolane (3c):**  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  1.36 (s, 12H), 7.38 (t,  $J = 7.3$  Hz, 2H), 7.47 (t,  $J = 7.4$  Hz, 1H), 7.83 (d,  $J = 7.0$  Hz, 2H) ppm;  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  25.0, 83.9, 127.8, 131.4, 134.9 ppm.



**2-(4-Fluorophenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (3d):**  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  1.34 (s, 12H), 7.05 (t,  $J = 8.8$  Hz, 2H), 7.81 (t,  $J = 7.3$  Hz, 2H) ppm;  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  25.0, 84.0, 114.9, 137.2, 164.0, 166.5 ppm.



**2-(4-Chlorophenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (3e):**  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  1.34 (s, 12H), 7.35 (d,  $J = 8.2$  Hz, 2H), 7.74 (d,  $J = 8.1$  Hz, 2H) ppm;  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  25.0, 84.1, 128.1, 136.2, 137.6 ppm.

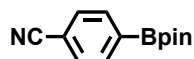


**3-(4-Bromophenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (3f):**  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  1.34 (s, 12H), 7.51 (d,  $J = 8.1$  Hz, 2H), 7.67 (d,  $J = 8.1$  Hz, 2H) ppm;  $^{13}\text{C}$

NMR (100 MHz, CDCl<sub>3</sub>) δ 25.0, 84.1, 126.3, 131.1, 136.4 ppm.



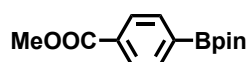
**4,4,5,5-Tetramethyl-2-(4-nitrophenyl)-1,3,2-dioxaborolane (3g):** <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 1.35 (s, 12H), 7.94 (d, J = 5.3 Hz, 2H), 8.15 (d, J = 8.5 Hz, 2H) ppm; <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 24.9, 84.6, 122.4, 135.6, 159.7 ppm.



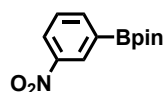
**4-(4,4,5,5-Tetramethyl-1,3,2-dioxaborolan-2-yl)benzonitrile (3h):** <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 1.34 (s, 12 H), 7.62 (d, J = 8.1 Hz, 2H), 7.87 (d, J = 8.0 Hz, 2H) ppm; <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 24.9, 84.6, 114.6, 118.9, 131.2, 135.2 ppm.



**2-(4-(Trifluoromethyl)phenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (3i):** <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 1.36 (s, 12H), 7.62 (d, J = 7.8 Hz, 2H), 7.92 (d, J = 7.8 Hz, 2H) ppm; <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 25.0, 84.4, 120.2, 122.9, 124.4, 124.5, 125.6, 128.4, 132.5, 133.1, 133.4, 135.2 ppm.

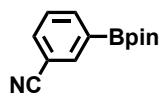


**Methyl 4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)benzoate (3j):** <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 1.36 (s, 12H), 3.92 (s, 3H), 7.86 (d, J = 8.0 Hz, 2H), 8.01 (d, J = 7. Hz, 2H) ppm; <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 25.0, 52.2, 84.3, 128.7, 132.4, 134.8, 167.2 ppm.

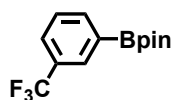


**4,4,5,5-Tetramethyl-2-(3-nitrophenyl)-1,3,2-dioxaborolane (3k):** <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 1.36 (s, 12H), 7.53 (t, J = 7.8 Hz, 1H), 8.09 (d, J = 7.3 Hz, 1H), 8.28 (d, J = 8.0

Hz, 1H), 8.63 (s, 1H) ppm;  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  25.0, 84.7, 126.0, 128.9, 129.5, 140.8, 147.9 ppm.

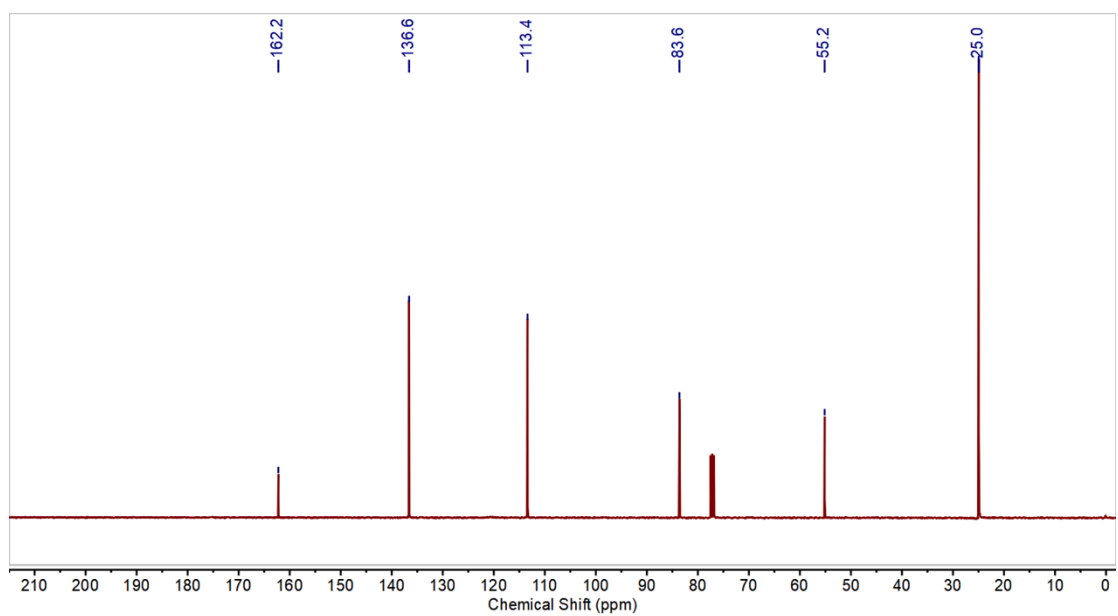
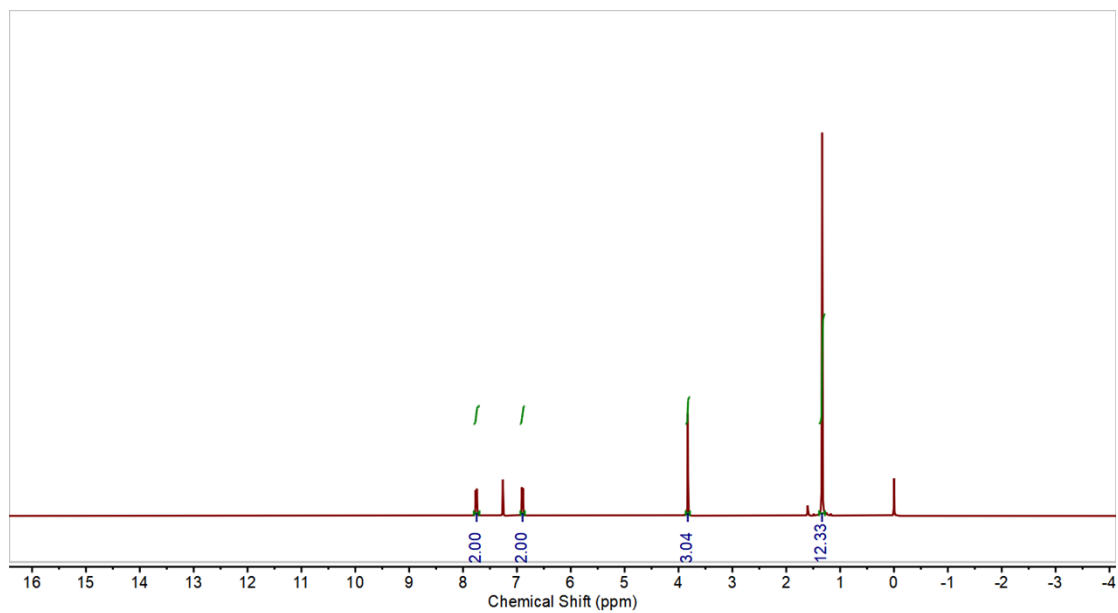


**3-(4,4,5,5-Tetramethyl-1,3,2-dioxaborolan-2-yl)benzonitrile (3l):**  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  1.35 (s, 12H), 7.45 (t,  $J = 7.6$  Hz, 1H), 7.69 (d,  $J = 7.8$  Hz, 1H), 7.98 (d,  $J = 7.5$  Hz, 1H), 8.06 (s, 1H) ppm;  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  24.9, 84.5, 112.1, 118.9, 128.5, 134.4, 138.4, 138.8 ppm.

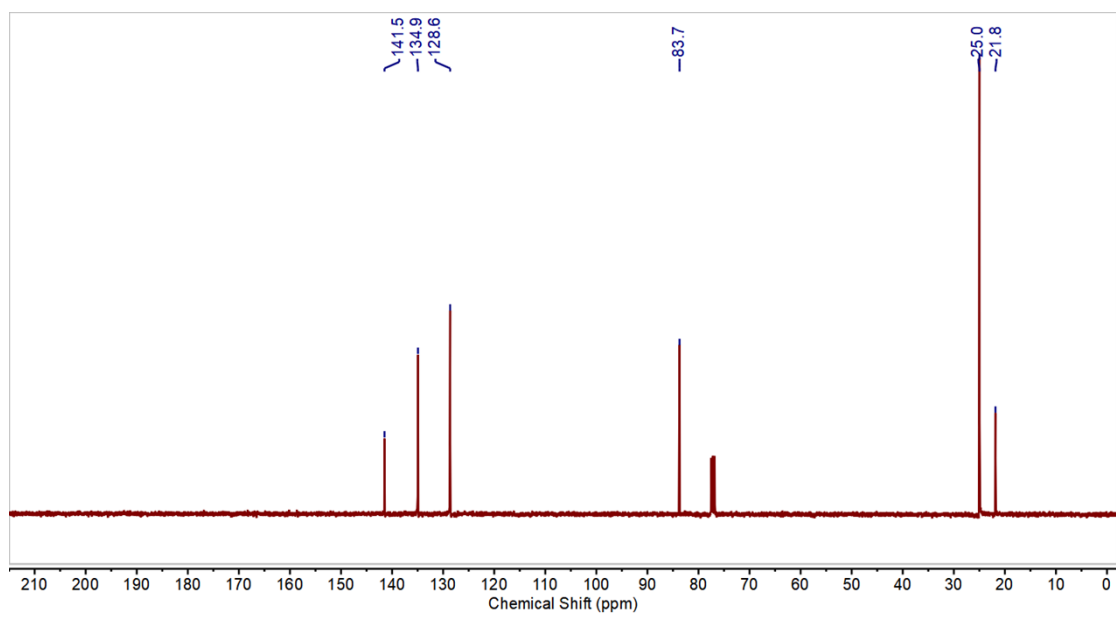
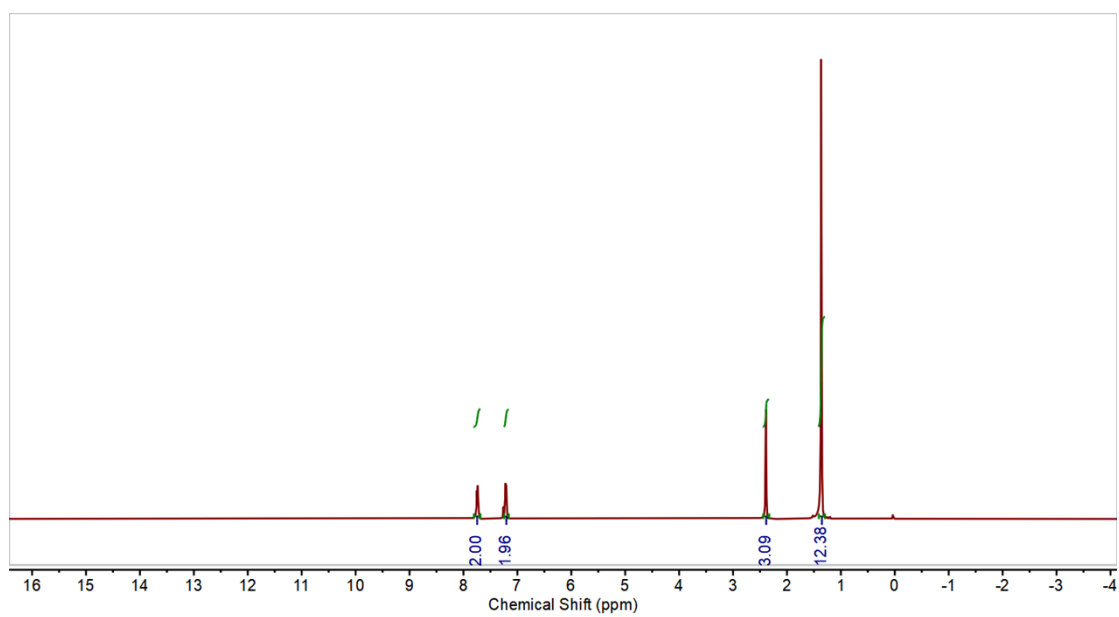


**4,4,5,5-Tetramethyl-2-(3-(trifluoromethyl)phenyl)-1,3,2 dioxaborolane (3m):**  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  1.36 (s, 12H) , 7.48 (t,  $J = 7.6$  Hz, 1H) , 7.70 (d,  $J = 7.5$  Hz, 1H) , 7.98 (d,  $J = 7.4$  Hz, 1H), 8.08 (s, 1H) ppm;  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  25.0, 84.4, 123.1, 125.8, 127.9, 128.0, 128.2, 130.0, 130.3, 131.4, 131.5, 138.2 ppm.

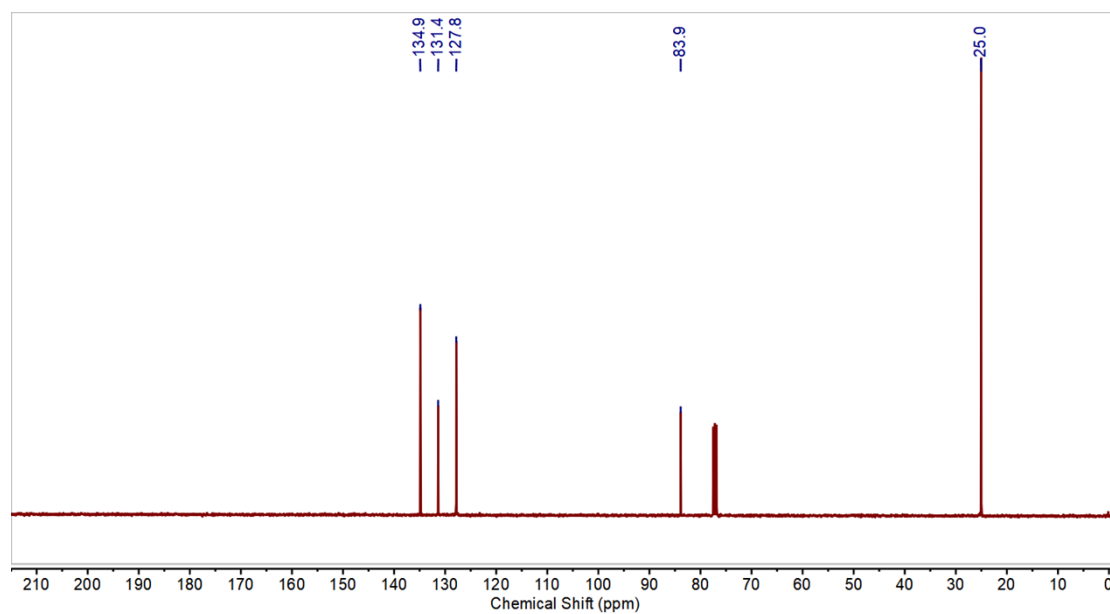
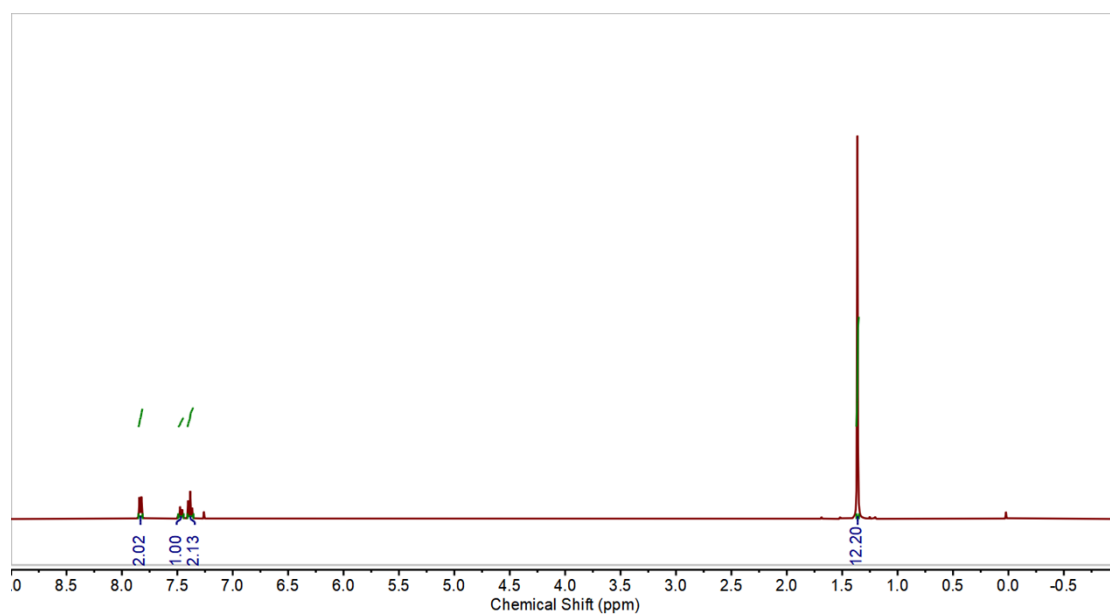
## Section 12. NMR Spectra of Catalytic Products



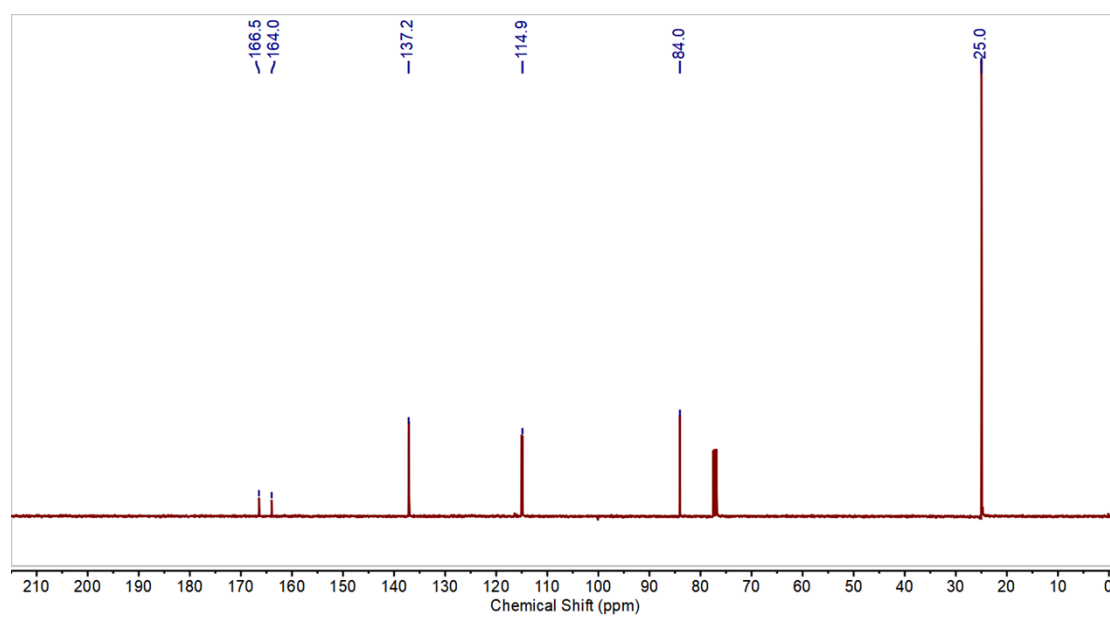
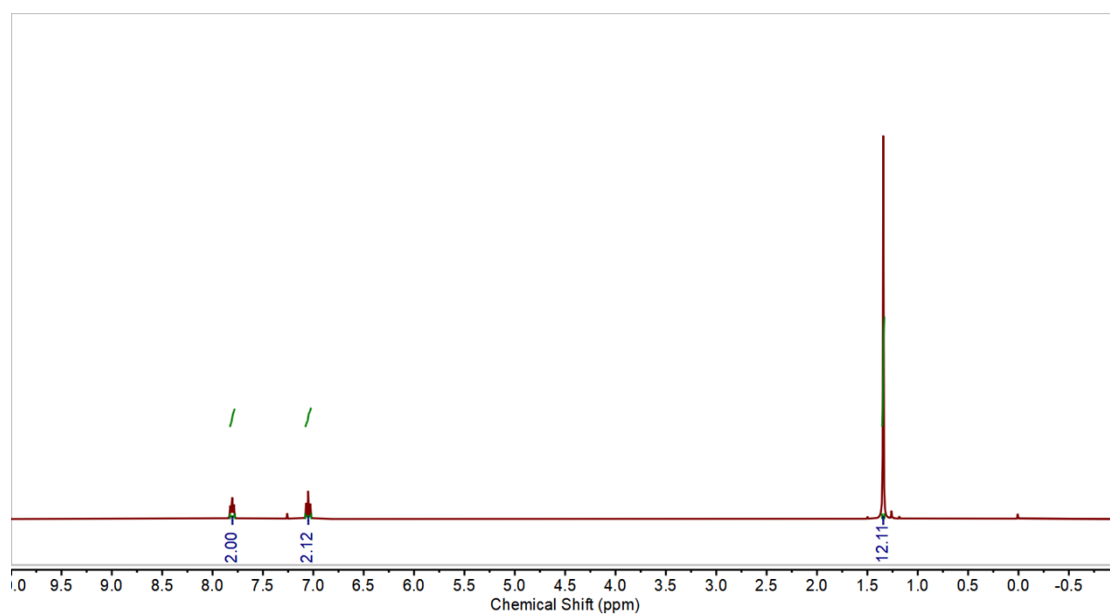
The  $^1\text{H-NMR}$  and  $^{13}\text{C-NMR}$  spectrum of 3a



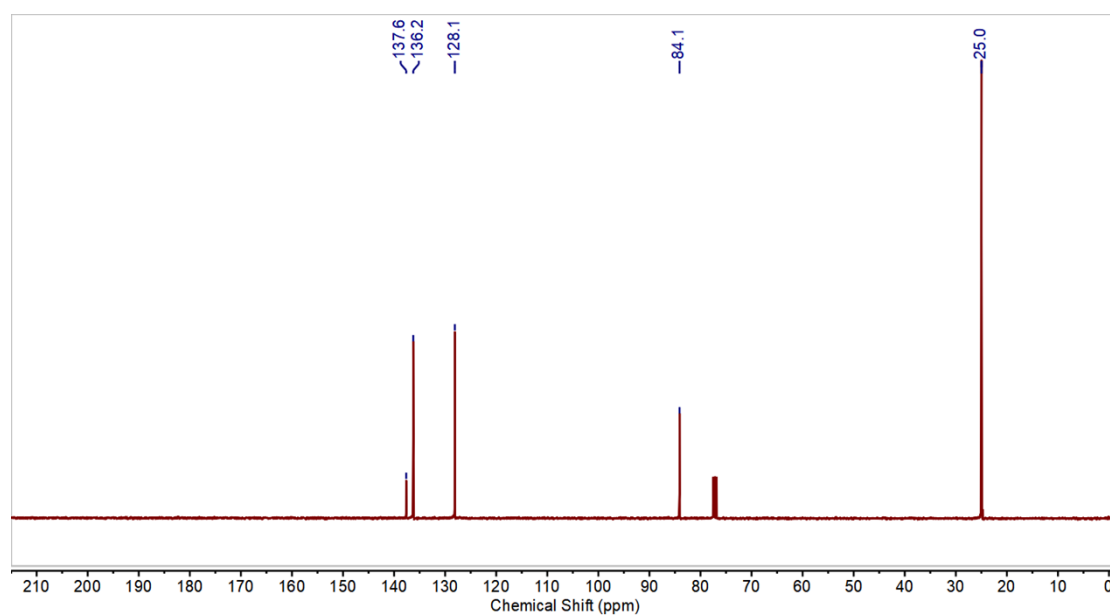
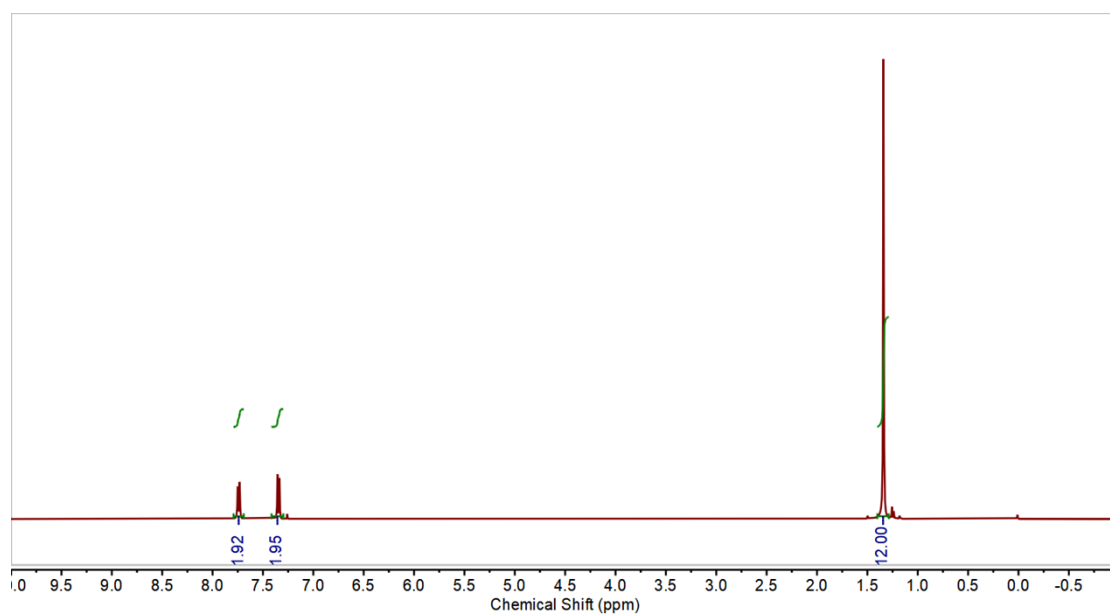
The  $^1\text{H}$ -NMR and  $^{13}\text{C}$ -NMR spectrum of 3b



The  $^1\text{H-NMR}$  and  $^{13}\text{C-NMR}$  spectrum of 3c

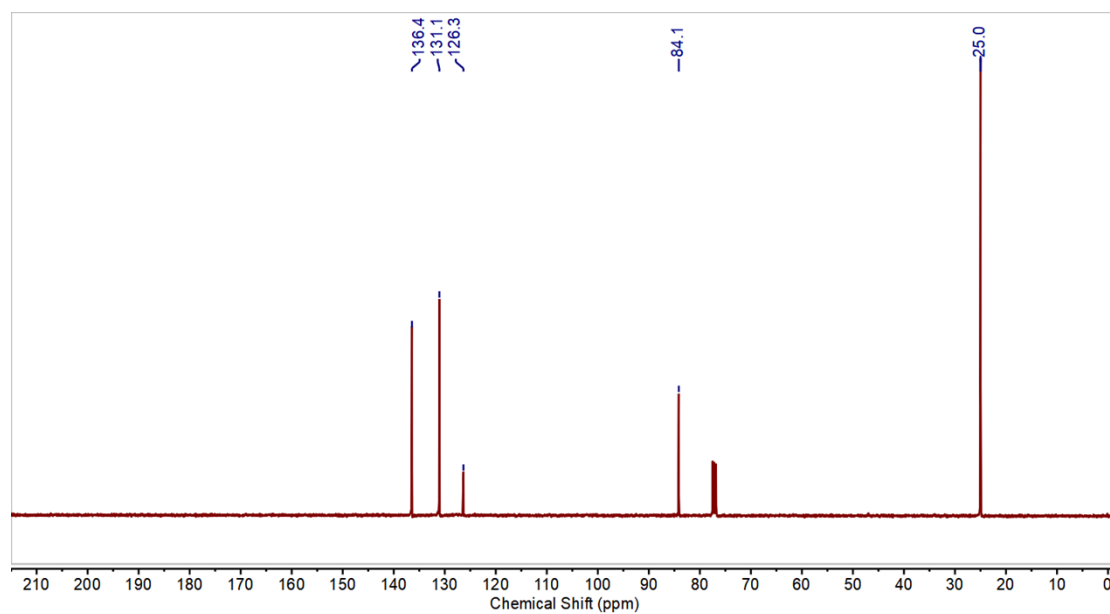
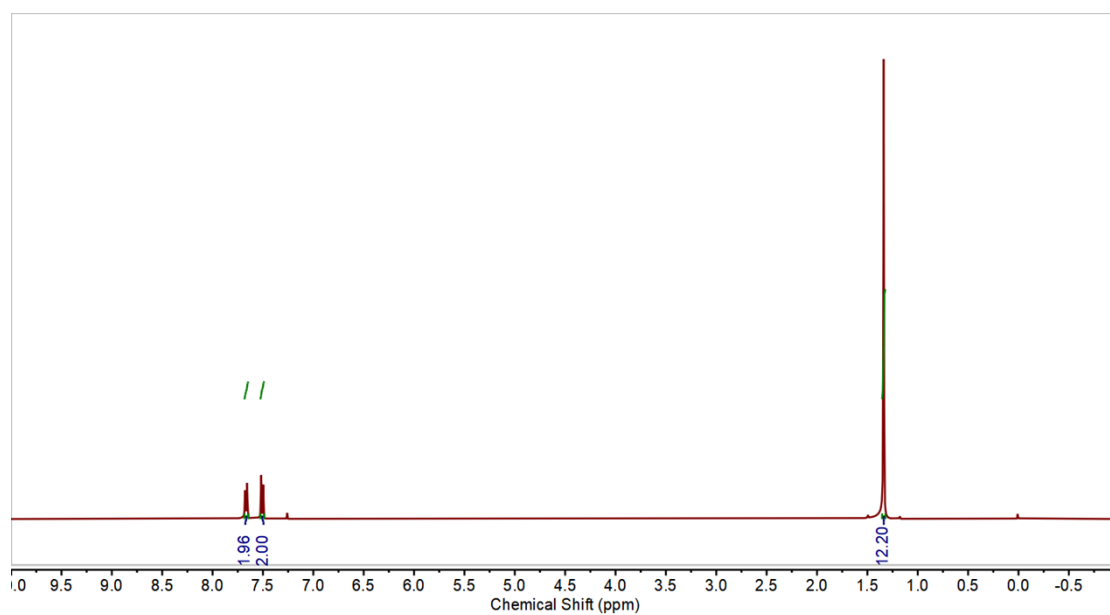


The  $^1\text{H-NMR}$  and  $^{13}\text{C-NMR}$  spectrum of 3d

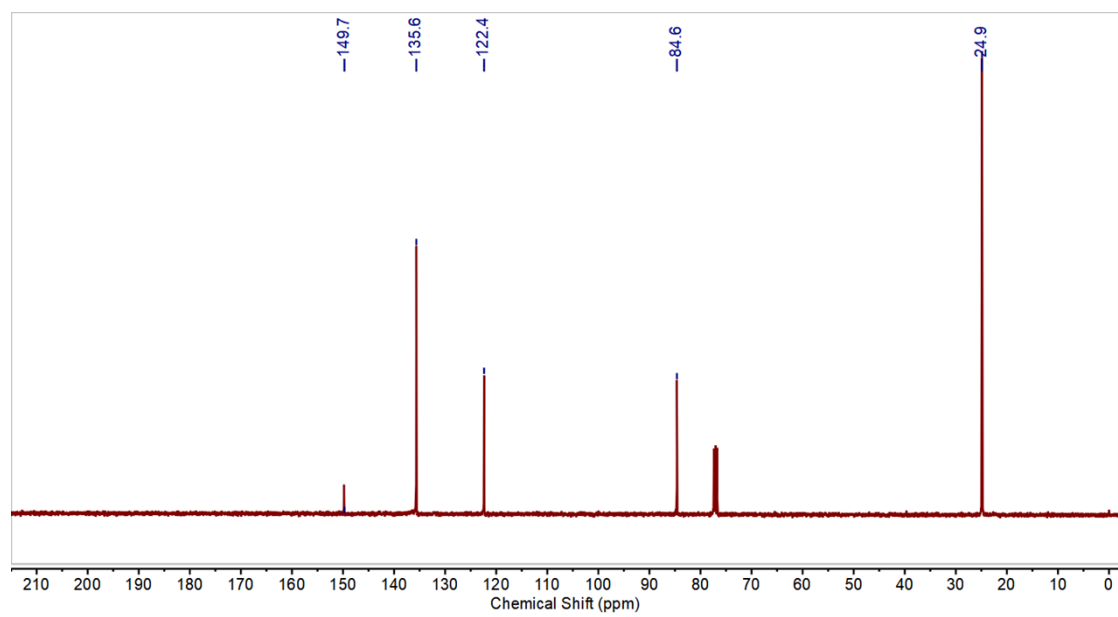
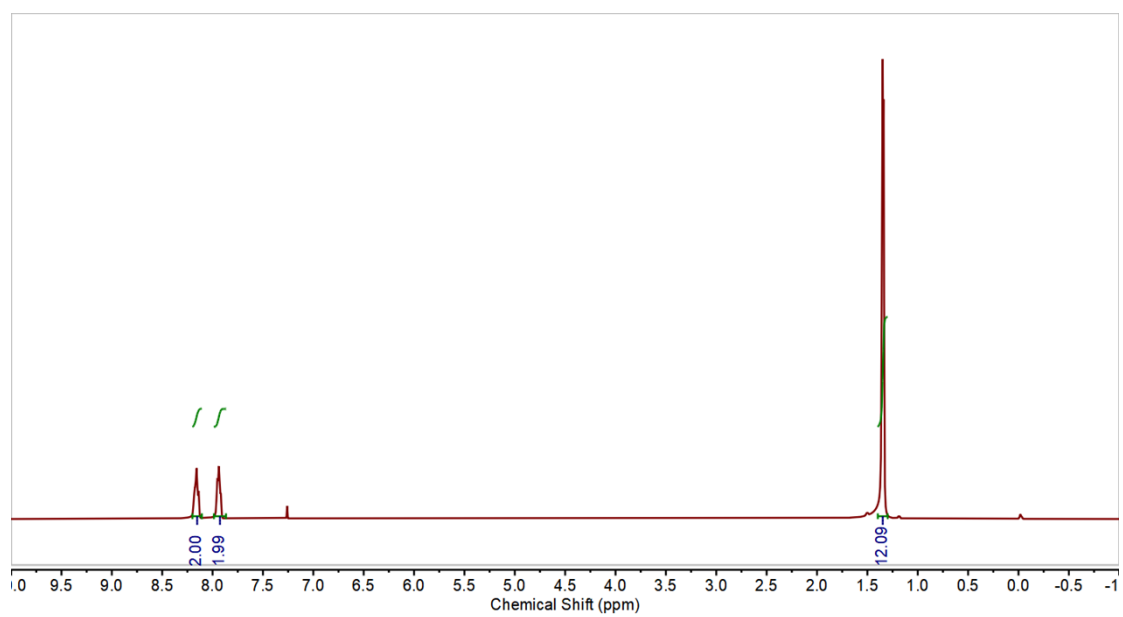


The  $^1\text{H-NMR}$  and  $^{13}\text{C-NMR}$  spectrum of 3e

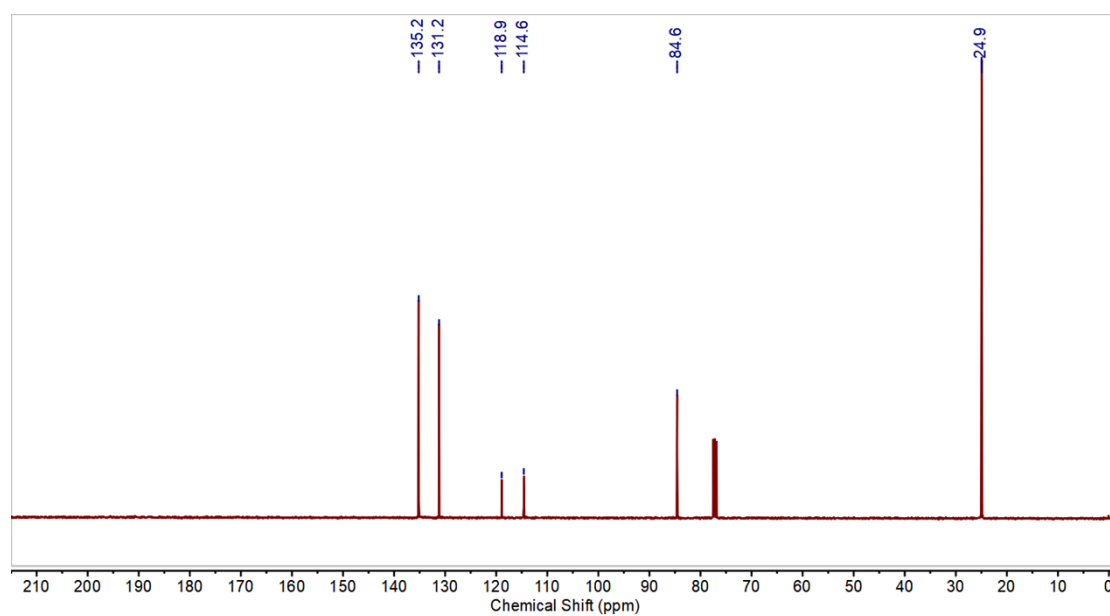
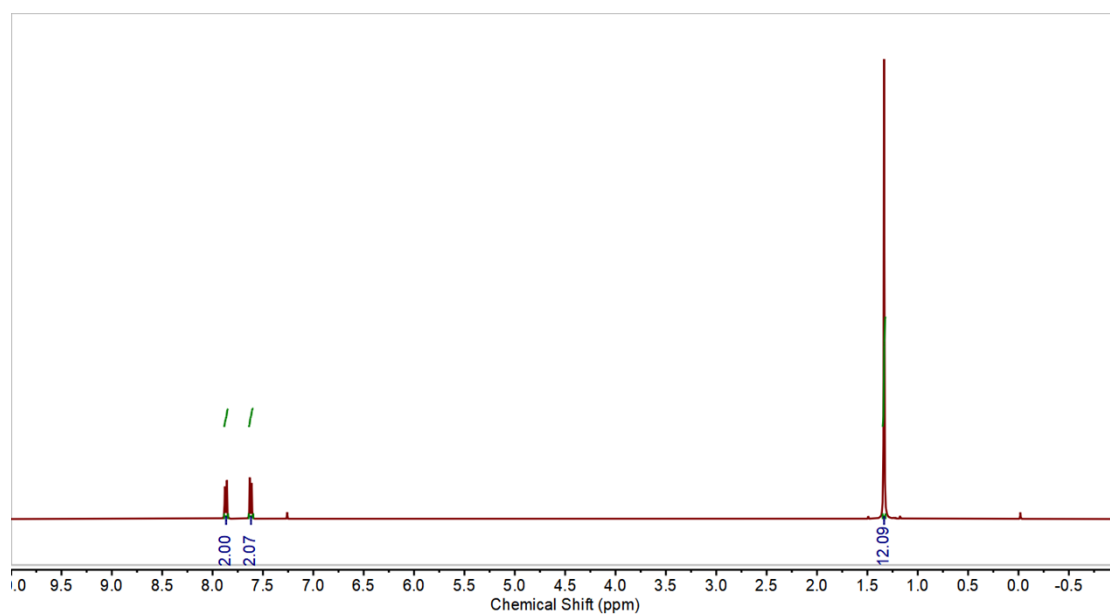




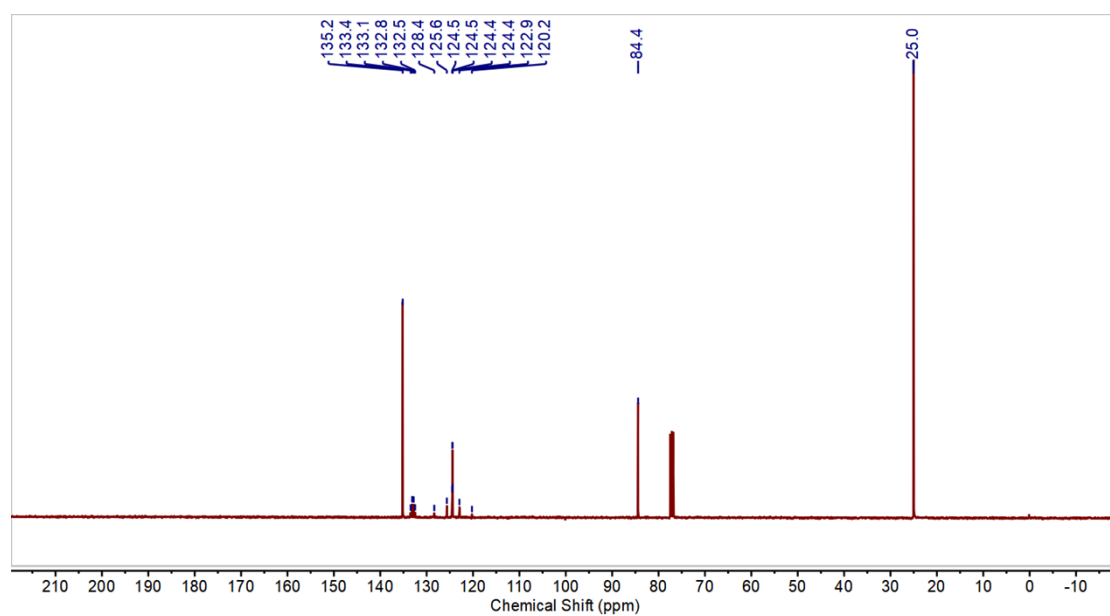
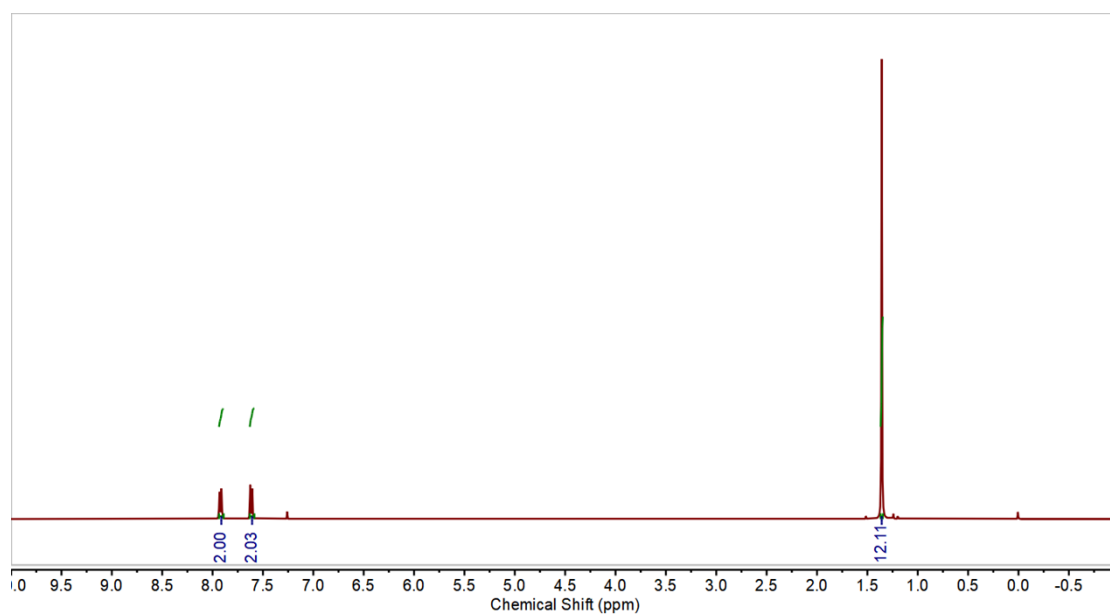
The  $^1\text{H-NMR}$  and  $^{13}\text{C-NMR}$  spectrum of 3f



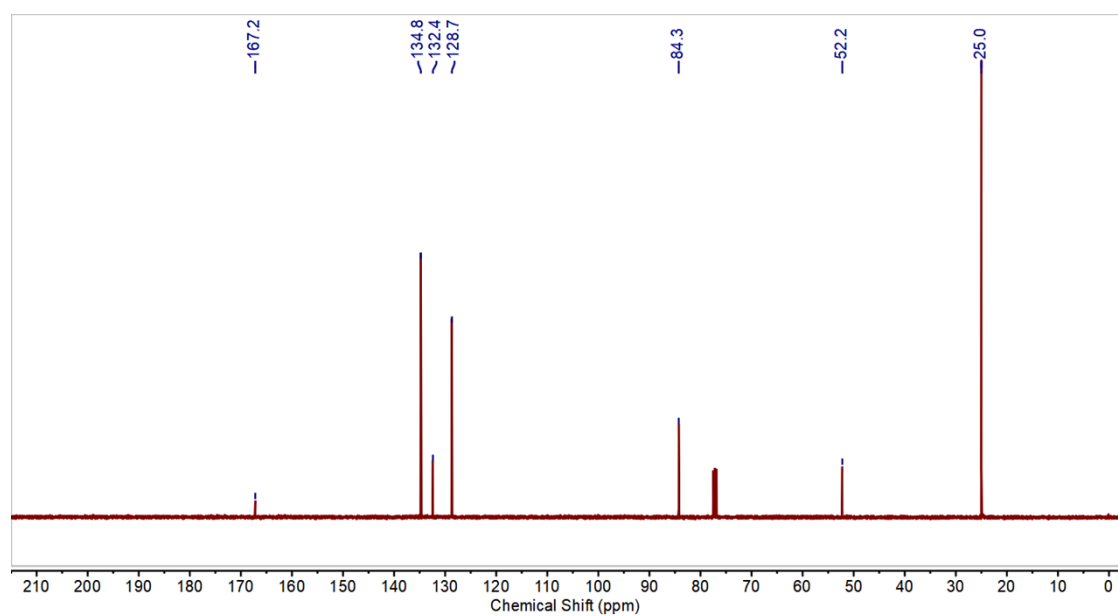
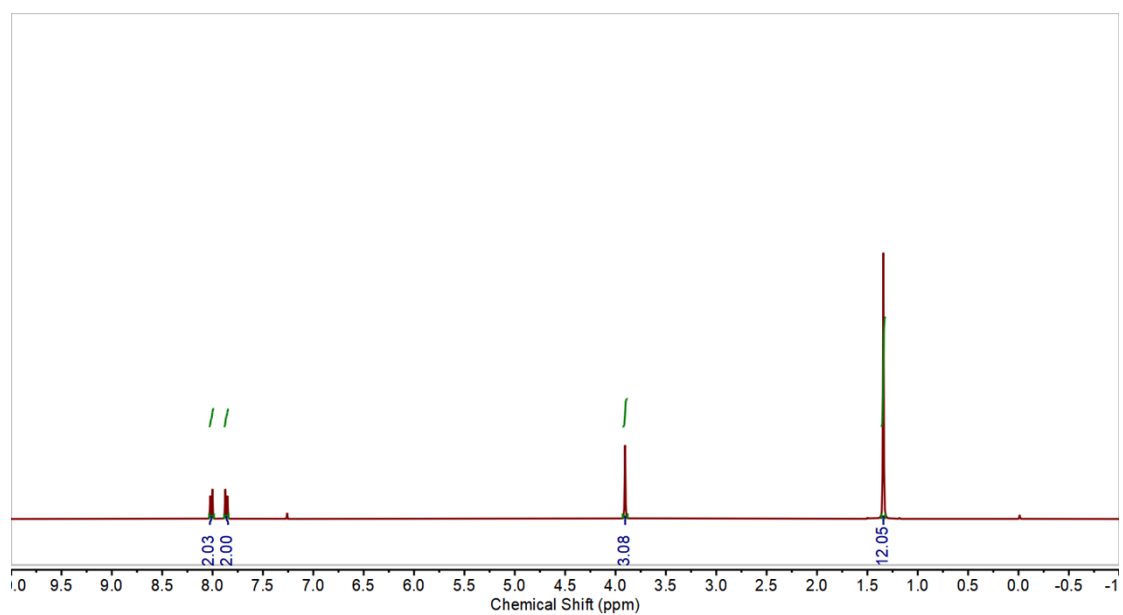
The  $^1\text{H-NMR}$  and  $^{13}\text{C-NMR}$  spectrum of 3g



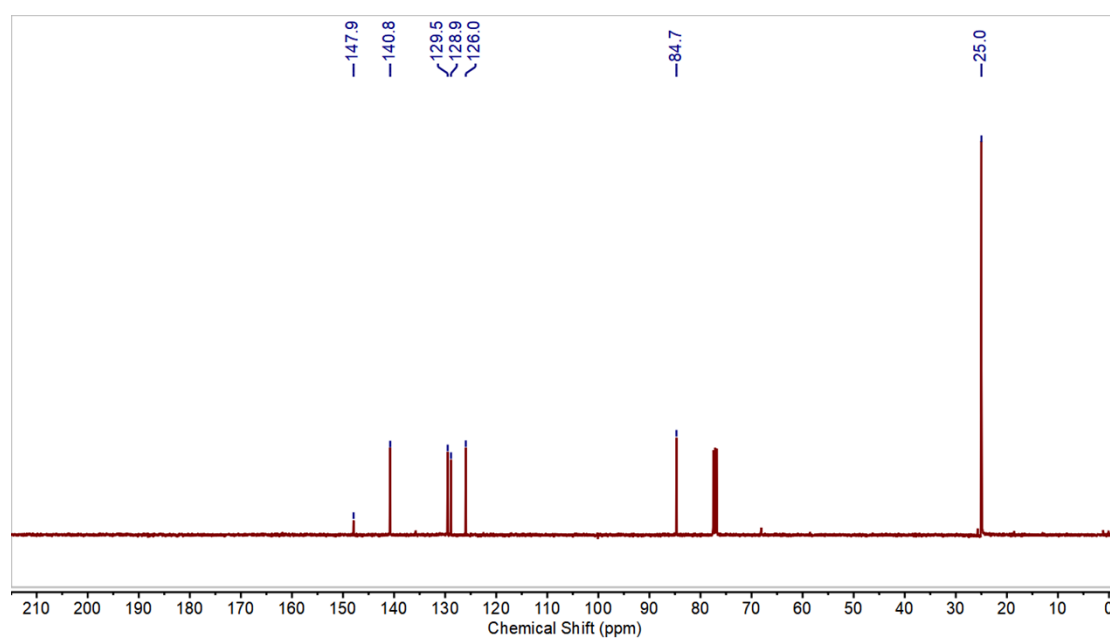
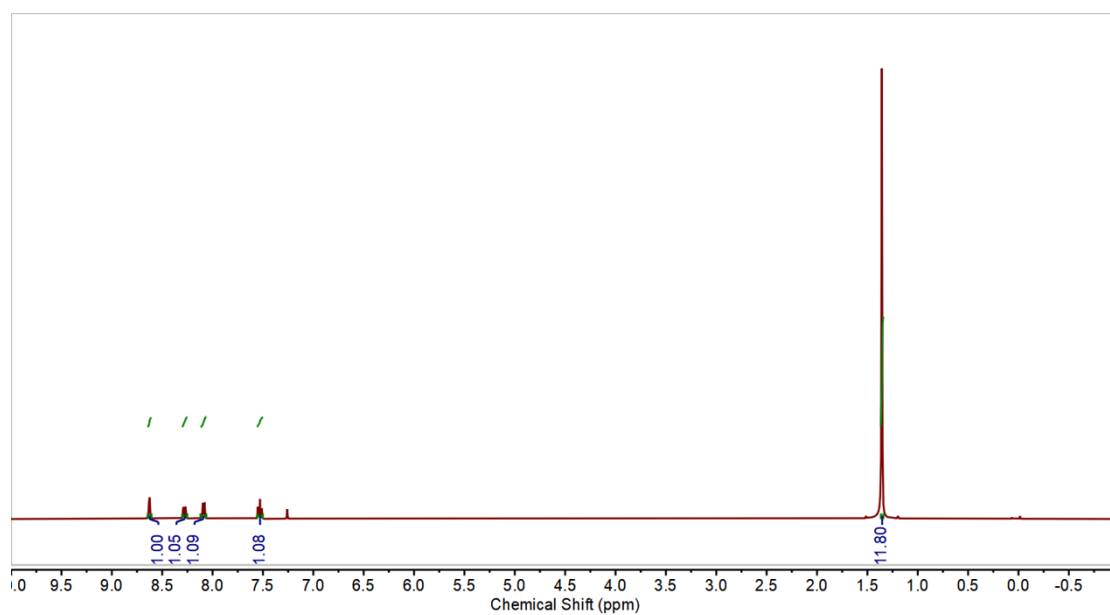
The  $^1\text{H-NMR}$  and  $^{13}\text{C-NMR}$  spectrum of 3h



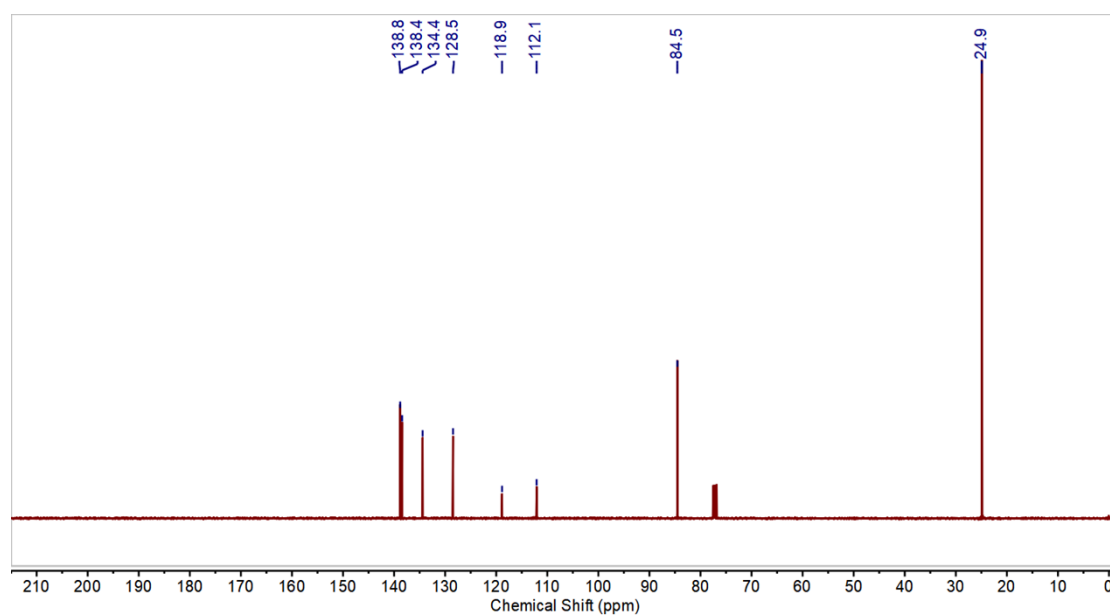
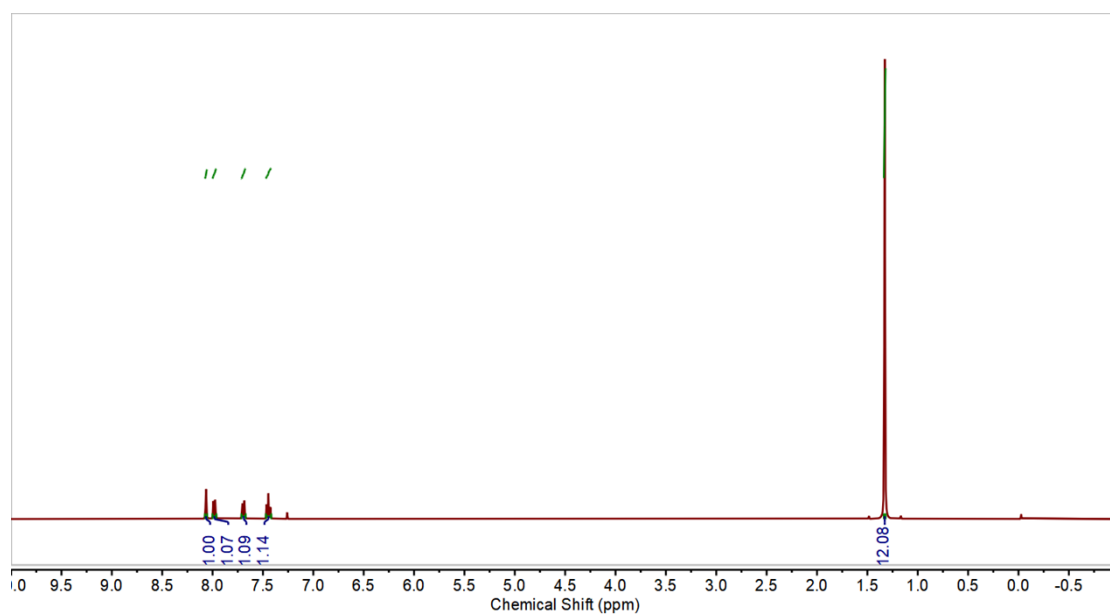
The  $^1\text{H}$ -NMR and  $^{13}\text{C}$ -NMR spectrum of 3i



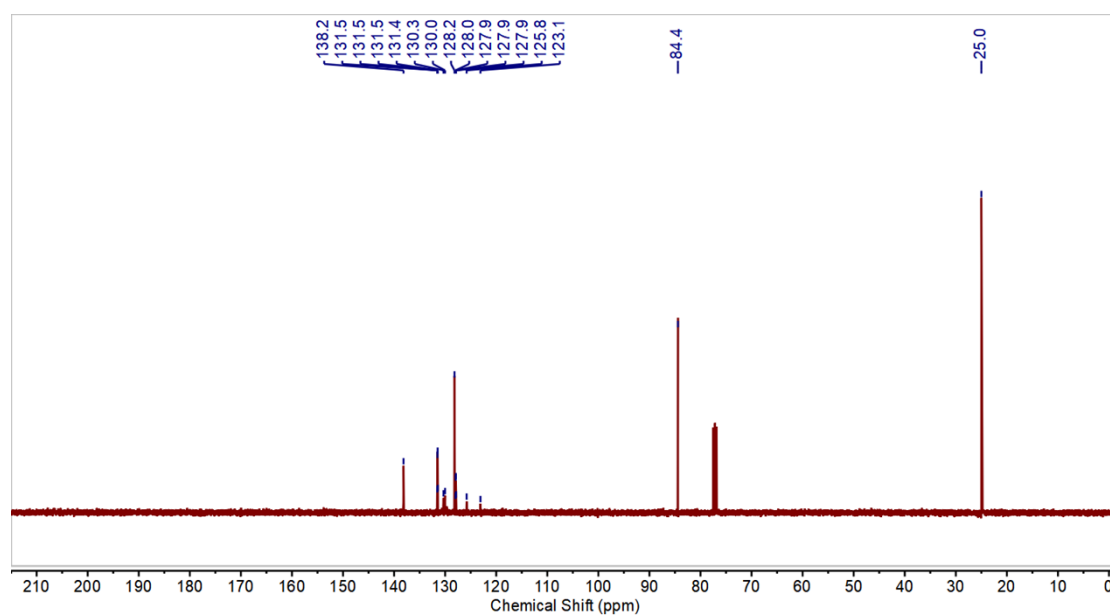
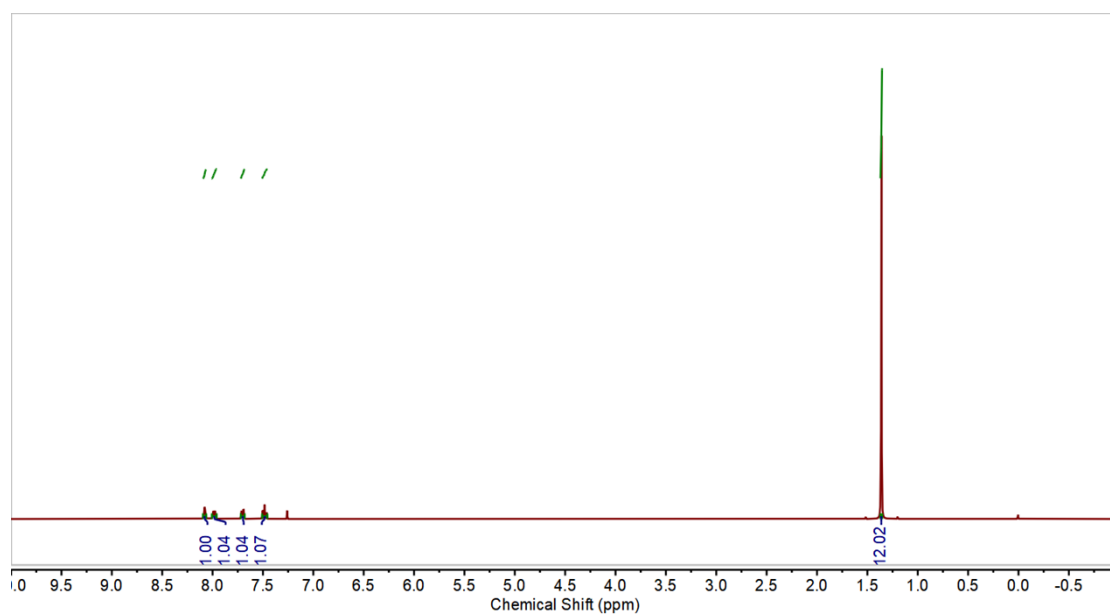
The  $^1\text{H}$ -NMR and  $^{13}\text{C}$ -NMR spectrum of 3j



The  $^1\text{H-NMR}$  and  $^{13}\text{C-NMR}$  spectrum of 3k



The  $^1\text{H}$ -NMR and  $^{13}\text{C}$ -NMR spectrum of 31



The <sup>1</sup>H-NMR and <sup>13</sup>C-NMR spectrum of 3m