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Supporting Information for

H-phosphonate-mediated sulfonylation of heteroaromatic *N*-oxides: a mild and metal-free one-pot synthesis of 2-sulfonyl quinolines/pyridines

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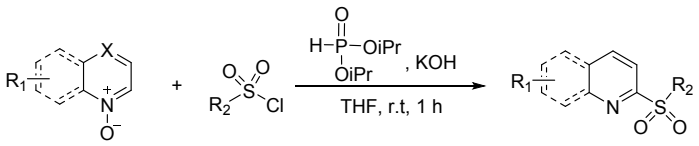
1. General information

Solvents were freshly distilled from respective drying agents before use. TLC was performed on silica gel plates and preparative chromatograph on columns of silica gel (200-300 mesh). ^{1}H, ^{13}C, and ^{31}P NMR spectra were recorded with a Bruker Avance 400 MHz spectrometer operating at 400.13, 100.61, and 161.98 MHz, respectively, with ^{13}C and ^{31}P NMR spectra being recorded with broad band proton decoupled. All NMR spectra were recorded in $CDCl_3$ at room temperature (20 ± 3 °C). ^{1}H and ^{13}C chemical shifts are quoted in parts per million downfield from TMS. ^{31}P chemical shifts are quoted in parts per million relative to 85% H_3PO_4 as an external standard. High resolution mass spectra (HR MS) were obtained with a Waters Micromass Q-Tof Micro instrument using the ESI technique.

2. Experimental procedures

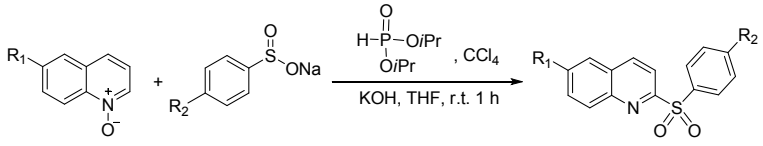
2.1. Synthesis of sulfonylated quinoline derivatives starting from the sulfonyl chloride.



X=C, N R_1= H, CH_3, OCH_3, Br, Cl; R_2= aryl, alkyl

Quinoline *N*-oxides (0.2 mmol), sulfonyl chlorides (0.4 mmol), diisopropyl *H*-phosphonate (0.2 mmol), KOH (0.8 mmol) in THF (7 mL) was stirred at room temperature for 1 h. The solvent was evaporated under vacuum, and the residue was quenched with water (5 mL), extracted with ethyl acetate (3 × 5 mL). The combined organic layers were washed with brine (15 mL) and dried over anhydrous Na_2SO_4. After filtration, the solvent was evaporated in vacuo. The crude product was purified by silica gel chromatography (petroleum ether: ethyl acetate = 3:1) to give the desired product.

2.2. Synthesis of sulfonylated quinoline derivatives starting from the sulfinate salts.



R_1=H, CH_3, OCH_3; R_2= H, CH_3

Quinoline *N*-oxides (1.0 mmol), sulfinate salts (1.0 mmol), diisopropyl *H*-phosphonate (1.0 mmol) KOH (4.0 mmol) and CCl_4 (0.5 mL) in THF (15 mL) at room temperature for 1 h. The solvent

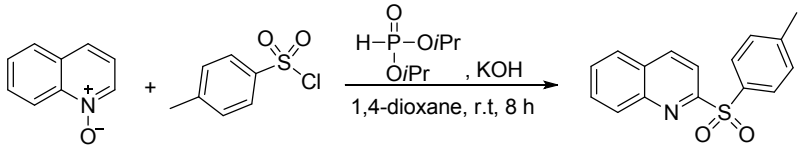
was evaporated under vacuum, and the residue was quenched with water (5 mL), extracted with ethyl acetate (3 × 5 mL). The combined organic layers were washed with brine (15 mL) and dried over anhydrous Na_2SO_4. After filtration, the solvent was evaporated in vacuo. The crude product was purified by silica gel chromatography (petroleum ether: ethyl acetate = 3:1) to give the desired product.

3. For reactions which were performed in dioxane and ethanol.

3.1 Why was the yield so low when THF was replaced with dioxane (Table 1, entry 23)?

As mentioned in our manuscript, without base no product was formed (Table 1, entry 18). The use of KOH brought about a highest yield among the bases tested (Table 1, entry 2). So we do think that the solubility of KOH in reaction solvent should play a very important role in determining the efficiency of the related reaction. As we have known that dioxane is a non-polar aprotic solvent with low dielectric constant (ε=2.25), however THF is a polar aprotic solvent with relatively high dielectric constant (ε=7.58). Thus, the solubility of KOH in dioxane should be relatively lower than that of KOH in THF. Taking the solubility of KOH into consideration, it can be predicted that much longer reaction time would be taken to fulfill the reaction if using dioxane instead of THF as reaction solvent.

Based on the prediction above, we carried out the same reaction in dioxane using much longer reaction time. As shown as the following, after 8 hours, the target product was efficiently obtained in 78% yield as predicted. Of course, we do think the polarity of solvent could also possibly affect the solubility of the starting reactants like quinoline *N*-oxide and TsCl and make some difference on the overall efficiency to some extent.



1a **2a** **3a:** 78%

Reaction conditions: 0.2 mmol of quinoline *N*-oxide, 0.4 mmol of TsCl, diisopropyl *H*-phosphonate (1.0 equiv), KOH (4.0 equiv) and 7 mL of 1,4-dioxane in a 25 mL round-bottom flask at room temperature for 8 h.

3.2 Why was the yield so high when the reaction was performed in ethanol (Table 1, entry 26)?

As we have known from above, the solubility of KOH in reaction solvent should play a very important role in determining the efficiency of the related reaction. Ethanol is a polar protic

solvent with much high dielectric constant (ε = 24.5). The solubility of KOH in ethanol is about 40 g/100 mL. This solubility might well explain why the yield (80%, table 1, entry 26) is so high when the reaction was performed in ethanol. However, this result still could not tell the reason why a relatively high yield (85%, table 1, entry 2) could be obtained when the same reaction was performed in THF (ε = 7.58). Therefore, as shown bellow (Figure 1), we carried out the reaction in ethanol in an enlarged scale to see whether or not there were any other side products which could be formed in ethanol as well. The result showed that, besides the main product **3a**, a side product, 2-ethoxyquinoline (**4a)**, was obtained. As described in the mechanism shown below (Figure1), 2-ethoxyquinoline (**4a)** was formed as ethanol **11** rather than sulfonyl anion acting as nucleophile to attack the intermediate **9**. This result might well explained why a relatively low yield was obtained in ethanol in comparison with that in THF.

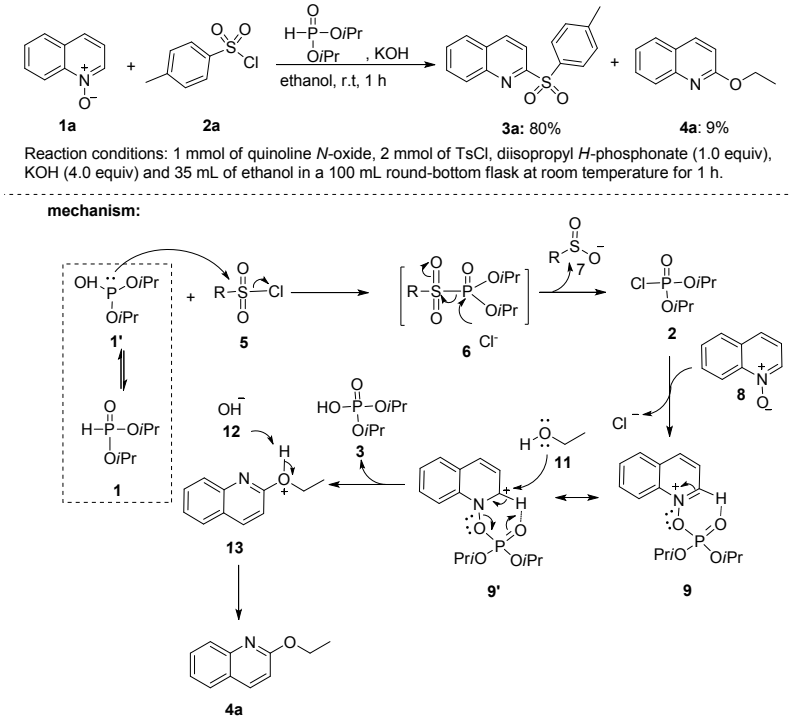
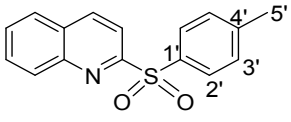


Figure 1

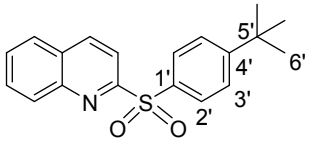
4. Characterization data for products

2-tosylquinoline (**3a**)



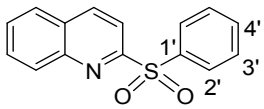
White solid. m.p.140-141 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.42 (s, 3H, 5'-H), 7.35 (d, 2H, *J*=

8.0 Hz, 3'-H), 7.66-7.70 (m, 1H, 6-H), 7.78-7.83 (m, 1H, 7-H), 7.89 (d, 1H, *J*= 8.0 Hz, 3-H), 8.04 (d, 2H, *J*= 8.4 Hz, 2'-H), 8.21(t, 2H, *J*= 8.4 Hz, *J*= 8.0 Hz, 5-8-H), 8.39 (d, 1H, *J*= 8.4 Hz, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 21.6 (C-5'), 117.6 (C-3), 127.7 (C-6), 128.7 (C-10), 128.9 (C-2'), 129.1 (C-5), 129.7 (C-3'), 130.1 (C-8), 130.9 (C-7), 136.1 (C-1'), 138.8 (C-4), 144.8 (C-4'), 147.3 (C-9), 158.2 (C-2). HR MS Calcd for $C_{16}H_{13}NO_2S$ $[M + H]^+$: m/z 284.0745, Found 284.0742. **2-((4-(tert-butyl)phenyl)sulfonyl)quinoline (3b)**



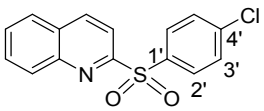
White solid. m.p.199-200 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.29 (s, 9H, 6'-H), 7.54 (d, 2H, *J*= 8.8 Hz, 3'-H), 7.61-7.65 (m, 1H, 6-H), 7.74-7.78 (m, 1H, 7-H), 7.85 (d, 1H, *J*= 8.4 Hz, 3-H), 8.08 (d, 2H, *J*= 8.8 Hz, 2'-H), 8.20 (t, 2H, *J*= 8.4 Hz, *J*= 7.6 Hz, 5-8-H), 8.36 (d, 1H, *J*= 8.4 Hz). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 31.0 (C-6'), 35.2 (C-5'), 117.8 (C-3), 126.1(C-2'), 127.7 (C-6), 128.80 (C-10), 128.86(C-3'), 129.1 (C-5), 130.3 (C-8), 130.9 (C-7), 136.1 (C-1'), 138.7 (C-4), 147.4 (C-9), 157.6 (C-4'), 158.3 (C-2). HR MS Calcd for $C_{19}H_{19}NO_2S$ $[M + H]^+$: m/z 326.1215, Found 326.1212.

2-(phenylsulfonyl)quinoline (3c)



White solid. m.p.160-161 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.54 (t, 2H, *J*= 7.2 Hz, 3'-H), 7.59-7.62 (m, 1H, 6-H), 7.64-7.68 (m, 1H, 7-H), 7.77-7.81 (m, 1H, 4'-H), 7.88 (d, 1H, *J*= 8.0 Hz, 3-H), 8.13-8.18 (m, 3H, 2'-8-H), 8.21 (d, 1H, *J*= 8.8 Hz, 5-H), 8.38 (d, 1H, *J*= 8.0 Hz, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 117.7 (C-3), 127.7 (C-6), 128.8 (C-10), 129.06 (C-2'), 129.08 (C-3'), 129.2 (C-5), 130.4 (C-8), 131.0 (C-7), 133.7 (C-4'), 138.7 (C-4), 139.1 (C-1'), 147.4 (C-9), 158.1 (C-2). HR MS Calcd for $C_{15}H_{11}NO_2S$ $[M + H]^+$: m/z 270.0589, Found 270.0585.

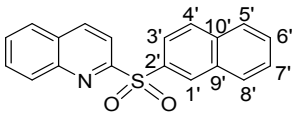
2-((4-chlorophenyl)sulfonyl)quinoline (3d)



White solid: m.p.190-191 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.52 (d, 2H, *J*= 8.8 Hz, 3'-H), 7.66-7.70 (m, 1H, 6-H), 7.79-7.83 (m, 1H, 7-H), 7.90 (d, 1H, *J*= 8.0 Hz, 3-H), 8.10 (d, 2H, *J*= 8.4 Hz,

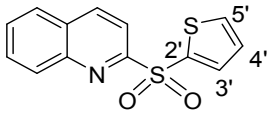
2'-H), 8.16 (d, 1H, *J*= 8.4 Hz, 8-H), 8.22 (d, 1H, *J*= 8.4 Hz, 5-H), 8.41 (d, 1H, *J*= 8.8 Hz, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 117.5 (C-3), 127.7 (C-6), 128.9 (C-10), 129.3 (C-5), 129.4 (C-2'), 130.3 (C-8), 130.5 (C-3'), 131.1 (C-7), 137.5 (C-1'), 138.9 (C-4), 140.5 (C-4'), 147.4 (C-9), 157.7 (C-2). HR MS Calcd for $C_{15}H_{10}ClNO_2S$ $[M + H]^+$: m/z 304.0199, Found 304.0196.

2-(naphthalen-2-ylsulfonyl)quinoline (3e)



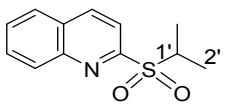
White solid. m.p.136-138 °C: ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 7.55-7.62 (m, 3H, 6-6'-7'-H), 7.70-7.73(m, 1H, 7-H), 7.81-7.84 (m, 2H, 3-8'-H), 7.93 (d, 1H, *J*= 8.8 Hz, 8-H), 7.96 (d, 1H, *J*= 8.8 Hz, 5'-H), 8.08-8.11(m, 1H, 5-H), 8.14 (d, 1H, *J*= 8.4 Hz, 3'-H), 8.27 (d, 1H, *J*= 8.4 Hz, 4'-H), 8.35 (d, 1H, *J*=8.4 Hz, 4-H), 8.75 (d, 1H, *J*= 1.2 Hz, 1'-H). ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 117.8 (C-3), 123.6 (C-3'), 127.5 (C-6'), 127.7 (C-7'), 127.9 (C-6), 128.8 (C-10), 129.2 (C-1'), 129.34 (C-8'), 129.35 (C-5'), 129.4 (C-5), 130.2 (C-8), 130.7 (C-7), 131.0 (C-4'), 132.1 (C-9'), 135.3 (C-2'), 136.0 (C-10'), 138.8 (C-4), 147.4 (C-9), 158.1 (C-2). HR MS Calcd for $C_{19}H_{13}NO_2S$ $[M + H]^+$: m/z 320.0745, Found 320.0742.

2-(thiophen-2-ylsulfonyl)quinoline (3f)



Light yellow solid, m.p.144-146 °C: ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 7.14-7.16 (m, 1H, 4'-H), 7.67-7.69 (m, 1H, 3'-H), 7.74-7.75 (m, 1H, 6-H), 7.80-7.84 (m, 1H, 7-H), 7.90-7.93 (m, 2H, 5'-3-H), 8.22 (d, 2H, *J*= 8.4 Hz, 5-8-H), 8.41 (d, 1H, *J*= 8.8 Hz, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 117.3 (C-3), 127.7 (C-6), 127.8 (C-5'), 128.9 (C-10), 129.3 (C-5), 130.3 (C-8), 131.1(C-7), 135.2 (C-4'), 135.3 (C-3'), 138.8(C-4), 139.7 (C-2'), 147.4 (C-9), 157.9 (C-2). HR MS Calcd for $C_{13}H_9NO2S_2$ $[M + H]^+$: m/z 276.0153, Found 276.0150.

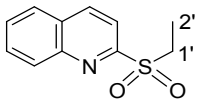
2-(isopropylsulfonyl)quinoline (3g)



Light yellow solid, m.p.80-82 °C: ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 1.32 (d, 6H, *J*= 6.8 Hz, 2'-H), 3.88-3.95 (m, 1H, 1'-H), 7.62-7.66 (m, 1H, 6-H), 7.76-7.78 (m, 1H, 7-H), 7.88 (d, 1H, *J*= 8.0 Hz,

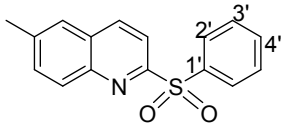
3-H), 8.08 (d, 1H, *J*= 8.8 Hz, 8-H), 8.16 (d, 1H, *J*= 8.4 Hz, 5-H), 8.38 (d, 1H, *J*= 8.8 Hz, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 15.0 (C-2'), 51.9 (C-1'), 118.3 (C-3), 127.9 (C-6), 129.0 (C-10), 129.2 (C-5), 130.1 (C-8), 131.1 (C-7), 138.6 (C-4), 147.3 (C-9), 155.7 (C-2). HR MS Calcd for $C_{12}H_{13}NO_2S$ $[M + H]^+$: m/z 236.0745, Found 236.0744.

2-(ethylsulfonyl)quinoline (**3h**)



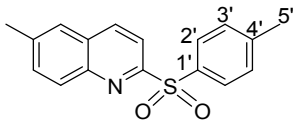
Light yellow solid, m.p.63-65 °C: ^{1}H NMR (40 MHz, $CDCl_3$) *δ*: 1.39 (t, 3H, *J*= 7.6 Hz, *J*= 7.2 Hz, 2'-H), 3.57-3.63 (m, 2H, 1'-H), 7.72-7.76 (m, 1H, 6-H), 7.85-7.90 (m,1H, 7-H), 7.96 (d, 1H, *J*= 8.4 Hz, 3-H), 8.16 (d, 1H, *J*= 8.4 Hz, 8-H), 8.24 (d, 1H, *J*= 8.4 Hz, 5-H), 8.46 (d, 1H, *J*= 8.4 Hz, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 6.9 (C-2'), 46.3 (C-1'), 117.4 (C-3), 127.8 (C-6), 129.1 (C-10), 129.2 (C-5), 130.1 (C-8), 131.1 (C-7), 138.7 (C-4), 147.2 (C-9), 156.4 (C-2). HR MS Calcd for $C_{11}H_{11}NO_2S$ $[M + H]^+$: m/z 222.0589, Found 222.0585.

6-methyl-2-(phenylsulfonyl)quinoline (**3i**)



White solid, m.p.150-151 °C: ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 2.51(s, 3H, CH_3), 7.51 (t, 2H, *J*= 7.60 Hz, *J*= 7.20 Hz, 3'-H), 7.55-7.59 (m, 3H, 4'-5-7-H), 8.03 (d, 1H, *J*= 8.40 Hz, 3-H), 8.12-8.15 (m, 3H, 2'-8-H), 8.24 (d,1H, *J*= 8.40 Hz, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 21.7 (CH_3), 117.7 (C-3), 126.4 (C-5), 128.90 (C-2'), 128.93(C-10), 129.0 (C-3'), 129.8 (C-8), 133.4 (C-7), 133.6 (C-7), 137.9 (C-4), 139.3 (C-1'), 139.7 (C-6), 146.0 (C-9), 157.0 (C-2'). HR MS Calcd for $C_{16}H_{13}NO_2S$ $[M + H]^+$: m/z 284.0745, Found.284.0745.

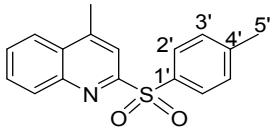
6-methyl-2-tosylquinoline (**3j**)



White solid, m.p.144-146 °C: ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 2.40 (s, 3H, 5'-H), 2.55 (s, 3H, 6-H), 7.32 (d, 2H, *J* = 8.00 Hz, 3'-H), 7.61 (d, 2H, *J*= 9.20 Hz, 5-7-H), 8.02 (d, 2H, *J*= 8.40 Hz, 2'-H), 8.06 (d, 1H, *J*= 8.40 Hz, 3-H), 8.15 (d, 1H, *J*= 8.80 Hz, 8-H), 8.25 (d, 1H, *J*= 8.40 Hz, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 21.6 (C-5'), 21.7 (C-6), 117.7 (C-3), 126.4 (C-5), 128.8(C-10), 128.9

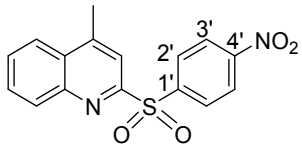
(C-2'), 129.7 (C-3'), 129.9 (C-8), 133.3 (C-7), 136.3 (C-1'), 137.8(C-4), 139.6(C-6), 144.6 (C-4'), 146.0 (C-9), 157.3 (C-2). HR MS Calcd for $C_{17}H_{15}NO_2S$ $[M + H]^+$: m/z 298.0902, Found 298.0900.

4-methyl-2-tosylquinoline (**3k**)



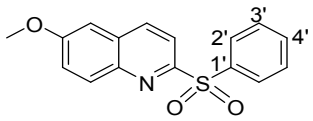
White solid, m.p.143-145 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.39 (s, 3H, 5'-H), 2.78 (s, 3H, CH_3), 7.32 (d, 2H, *J*= 8.00 Hz, 3'-H), 7.63-7.67 (m, 1H, 6-H), 7.73-7.77 (m, 1H, 7-H), 7.99-8.03 (m, 4H, 2'-3-5-H), 8.17 (d, 1H, *J*= 8.40 Hz, 8-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 19.1 (CH_3), 21.6 (C-5'), 118.0 (C-3),123.8 (C-5), 128.7 (C-10), 128.8 (C-6), 129.0 (C-2'), 129.7 (C-3'), 130.5 (C-7), 131.0 (C-8), 136.2 (C-1'), 144.7 (C-4'), 147.2 (C-4), 147.9 (C-9), 157.9 (C-2). HR MS Calcd for $C_{17}H_{15}NO_2S$ $[M + H]^+$: m/z 298.0902, Found 298.0899.

4-methyl-2-((4-nitrophenyl)sulfonyl)quinolone(3l)



yellow solid, m.p.165-166 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.85 (s, 3H, CH_3), 7.70-7.75 (m, 1H, 6-H), 7.79-7.83 (m, 1H, 7-H), 8.06-8.14 (m, 3H, 3-5-8-H), 8.34-8.40 (m, 4H, 2'-3'-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 19.2 (CH_3), 117.8 (C-3), 123.9 (C-5), 124.1 (C-3'), 129.0 (C-10), 129.4 (C-6), 130.5 (C-2'), 130.92 (C-7), 130.98 (C-8), 144.8 (C-1'), 147.2 (C-4), 148.6 (C-9), 150.7 (C-4'), 156.5 (C-1). HR MS Calcd for $C_{16}H_{12}N_2O_4S$ $[M + H]^+$: m/z 329.0596, Found 329.0597

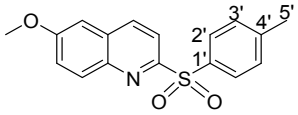
6-methoxy-2-(phenylsulfonyl)quinolone(3m)



White solid, m.p.147-148 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 3.95 (s, 3H, OCH_3), 7.10 (d, 1H, *J*= 2.80 Hz, 5-H), 7.41-7.44 (m, 1H, 7-H), 7.51-7.55 (m, 2H, 3'-H), 7.58-7.62 (m, 1H, 4'-H), 8.06 (d, 1H, *J*= 9.20 Hz, 8-H), 8.13-8.17(m, 3H, 2'-3-H), 8.23(d, 1H, *J*= 8.40 Hz, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 55.7 (OCH_3), 104.6 (C-5), 118.3 (C-3), 124.3 (C-7), 128.8 (C-2'), 129.0 (C-3'), 130.4 (C-10), 131.8 (C-8), 133.5 (C-4'), 136.8 (C-4), 139.5 (C-1'), 143.6 (C-9), 155.4 (C-6),

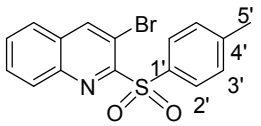
159.8 (C-2). HR MS Calcd for $C_{16}H_{13}NO_3S$ [M + H]$^+$: m/z 300.0694, Found 300.0691.

6-methoxy-2-tosylquinoline (**3n**)



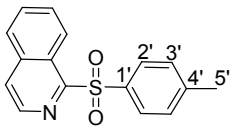
White solid, m.p.165-166°C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.39 (s, 3H, 5'-H), 3.94 (s, 3H, OCH_3), 7.09 (d, *J*= 2.80 Hz, 5-H), 7.32 (d, 2H ,*J*= 8.40 Hz, 3'-H), 7.40-7.43 (m, 1H, 7-H), 8.01 (d, 2H, *J*= 8.00 Hz, 2'-H), 8.05 (d, 1H, *J*= 9.20 Hz, 8-H), 8.13(d, 1H, *J*= 8.40 Hz, 3-H), 8.21(d, 2H, *J*= 8.80 Hz, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 21.6 (C-5'), 55.7 (OCH_3), 104.6 (C-5), 118.2 (C-3), 124.2 (C-7), 128.8 (C-2'), 129.7 (C-3'), 130.3 (C-10), 131.7 (C-8), 136.5 (C-1'), 136.8 (C-4), 143.6 (C-4'), 144.6 (C-9), 155.6 (C-6), 159.7 (C-2). HR MS Calcd for $C_{17}H_{15}NO_3S$ [M + H]$^+$: m/z 314.0851, Found 314.0850.

3-bromo-2-tosylquinoline (**3o**)



White solid, m.p.155-157 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.49 (s, 3H, 5'-H), 7.38 (d, 2H, *J*= 8.00 Hz, 3'-H), 7.66-7.71 (m, 1H, 7-H), 7.77 (m, 1H, 6-H), 7.75-7.81 (m, 1H, 8-H), 7.98-8.02 (m, 3H, 3'-5-H), 8.54 (s, 1H, 4-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 21.7 (C-5'), 111.3 (C-3), 126.5 (C-6), 129.4 (C-2'), 129.7 (C-10), 129.8 (C-3'), 130.0 (C-5), 130.2 (C-8), 131.0 (C-7), 134.9 (C-1'), 142.9 (C-4), 144.4 (C-4'), 144.9 (C-9), 154.4 (C-2). HR MS Calcd for $C_{16}H_{12}BrNO_2S$ [M + H]$^+$: m/z 361.9850, Found 361.9843.

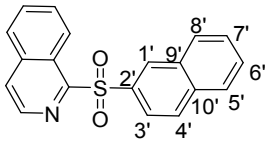
1-tosylisoquinoline (**3p**)



White solid, m.p.177-178 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.45(s, 3H, CH_3), 7.37(d, 2H, *J*= 8.0 Hz, 3'-H), 7.75-7.80 (m, 3H, 4-5-7-H), 7.90-7.93(m, 1H, 6-H), 8.00(d, 2H, *J*= 8.4 Hz, 2'-H), 8.44(d, 1H, *J*= 5.6 Hz, 8-H), 9.17-9.19(m, 1H, 3-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 21.7 (CH_3), 124.3 (C-4), 124.9 (C-5), 125.3 (C-7), 127.5(C-9), 129.21 (C-8), 129.25(C-2'), 129.6 (C-3'), 131.1(C-6), 136.0 (C-10), 137.7 (C-4'), 140.5 (C-3), 144.7 (C-4'), 157.2 (C-1). HR MS Calcd

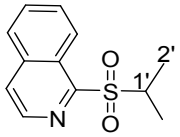
for $C_{16}H_{13}NO_2S$ [M + H]$^+$: m/z 284.0745, Found 284.0743.

1-(naphthalen-2-ylsulfonyl)isoquinoline (**3q**)



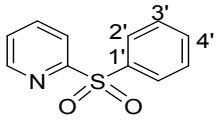
White solid, m.p.183-184 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.59-7.63 (m, 1H, 6-H), 7.64-7.68 (m, 1H, 7-H), 7.77-7.81 (m, 3H, 4-5-7-H), 7.89-7.93 (m, 2H, 6-8-H), 7.79-8.05 (m, 3H, 3'-5'-8'-H), 8.42 (d, 1H, *J*= 5.60 Hz, 4'-H), 8.73 (s, 1H, 1'-H), 9.24-9.27 (m, 1H, 3-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 124.1 (C-3'), 124.3(C-9), 125.0 (C-4), 125.3 (C-5), 127.4 (C-6'), 127.5 (C-7'), 127.9 (C-1'), 128.9 (C-7), 129.2 (C-5'), 129.3 (C-8'), 129.5 (C-8), 130.8 (C-4'), 131.1 (C-6), 132.1 (C-9'), 135.3 (C-2'), 136.1 (C-10), 137.7 (C-10'), 140.5 (C-3), 157.1 (C-1). HR MS Calcd for $C_{19}H_{13}NO_2S$ [M + H]$^+$: m/z 320.0745, Found 320.0743.

1-(isopropylsulfonyl)isoquinoline (3r)



Light yellow solid: m.p.90-93 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.47 (d, 6H, *J*= 7.20 Hz, 2'-H), 4.19-4.29 (m, 1H, 1'-H), 7.73-7.76 (m, 1H, 7-H), 7.78-7.82 (m, 1H, 6-H), 7.88 (d, 1H, *J*= 5.20 Hz, 5-H), 7.94 (d, 1H, *J*= 7.60 Hz, 4-H), 8.56 (d, 1H, *J*= 5.60 Hz, 8-H), 9.11-9.13 (m, 1H, 3-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 15.2 (C-2'), 52.2 (C-1'), 125.13 (C-4), 125.18 (C-10), 125.3 (C-5), 127.5 (C-7), 129.3 (C-8), 131.2 (C-6), 137.7 (C-9), 140.3 (C-3), 155.2 (C-2). HR MS Calcd for $C_{12}H_{13}NO_2S$ [M + H]$^+$: m/z 236.0745, Found 236.0744.

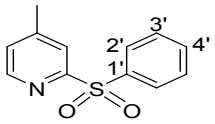
2-(phenylsulfonyl)pyridine (**3s**)



White solid, m.p.94-96 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.48-7.49 (m, 1H, 5-H), 7.56 (t, 2H, *J*= 8.00 Hz, *J*= 7.20 Hz, 3'-H), 7.64 (t, 1H, *J*= 7.60 Hz, *J*= 7.20 Hz, 4'-H), 7.93-7.97 (m, 1H, 4-H), 8.09 (d, 2H, *J*= 7.60 Hz, 2'-H), 8.23(d, 1H, *J*= 8.00 Hz, 3H), 8.70 (d, 1H, *J*= 4.40 Hz, 6-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 122.2 (C-3), 126.8 (C-5), 128.9 (C-2'), 129.1 (C-3'), 133.7 (C-4'), 138.0 (C-4), 138.9 (C-1'), 150.4 (C-6), 158.7 (C-2). HR MS Calcd for $C_{11}H_9NO_2S$ [M + H]$^+$: m/z

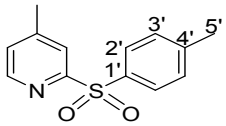
220.0432, Found 220.0428.

4-methyl-2-(phenylsulfonyl)pyridine (**3t**)



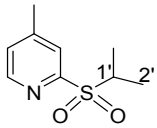
White solid, m.p.116-118 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.47 (s, 3H, 7-H), 7.27 (d, 1H, *J*= 4.40 Hz, 5-H), 7.54 (t, 2H, 3'-H), 7.60-7.63 (m, 1H, 4'-H), 8.04-8.06 (m, 3H, 2'-3-H), 8.52(d, 1H, *J*= 4.80 Hz, 6-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 21.2 (C-7), 122.9 (C-3), 127.6 (C-5), 128.8 (C-2'), 129.0 (C-3'), 133.6 (C-4'), 139.1 (C-1'), 150.0 (C-4), 150.2 (C-6), 158.6 (C-2). HR MS Calcd for $C_{12}H_{11}NO_2S$ $[M + H]^+$: m/z 234.0589, Found 234.0585.

4-methyl-2-tosylpyridine (**3u**)



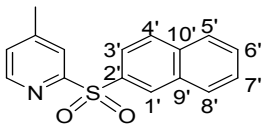
White solid, m.p. 126-128 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.35 (s, 3H, 5'-H), 2.40(s, 3H, CH_3), 7.21(d, 1H, *J*= 4.80 Hz, 5-H), 7.27 (d, 2H, *J*=8.00Hz, 3'-H), 7.89(d, 2H, *J*= 8.00 Hz, 2'-H), 7.96 (s, 1H, 3-H), 8.45(d, 1H, *J*= 4.80 Hz, 6-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 21.2 (C-7), 21.6 (C-5'), 122.7 (C-3), 127.6 (C-5), 128.8 (C-2'), 129.7 (C-3'), 136.0 (C-1'), 144.7 (C-4'), 150.0 (C-4), 150.1 (C-6), 158.7 (C-2). HR MS Calcd for $C_{13}H_{13}NO_2S$ $[M + H]^+$: m/z 248.0745, Found 248.0745.

2-(isopropylsulfonyl)-4-methylpyridine (**3v**):



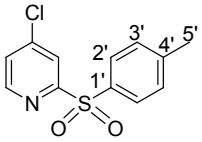
Light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.33 (d, 6H, *J*= 7.20 Hz, 2'-H), 2.49 (s, 3H, CH_3), 3.71-3.82 (m, 1H, 1'-H), 7.35-7.36 (m, 1H, 5-H), 7.92 (s, 1H, 3-H), 8.60 (d, 1H, *J*= 4.80 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.9 (C-2'), 21.2 (CH_3), 51.6 (C-1'), 124.0 (C-3), 128.0 (C-5), 149.9 (C-4), 150.0 (C-6), 155.9 (C-2). HR MS Calcd for $C_9H_{13}NO_2S$ $[M + H]^+$: m/z 200.0745, Found 200.0742.

4-methyl-2-(naphthalen-2-ylsulfonyl)pyridine (**3w**):



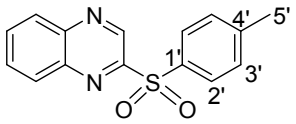
White solid, m.p.183-184 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.47 (s, 3H, CH_3), 7.25 (d, 1H, J= 4.80 Hz, 5-H), 7.59-7.67 (m, 2H, 6'-7'-H), 7.89(d, 1H, J= 8.00 Hz, 3'-H), 7.94-8.01 (m, 3H, 4'-5'-8'-H), 8.10 (s, 1H, 3-H), 8.51 (d, 1H, C-6), 8.69 (s, 1H, 1'-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 21.2 (CH_3), 123.0 (C-3), 123.5 (C-3'), 127.5 (C-6'),127.6 (C-7'), 127.9 (C-1'), 129.2 (C-5'), 129.3 (C-8'), 129.5 (C-4'), 130.6 (C-5), 132.1 (C-9'), 135.3 (C-2'), 136.0 (C-10'), 150.0 (C-4), 150.2 (C-6), 158.6 (C-2). HR MS Calcd for $C_{16}H_{13}NO_2S$ $[M + H]^+$: m/z 284.0745, Found 284.0748.

4-chloro-2-tosylpyridine (3x)



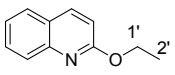
yellow solid, m.p.108-110 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.44 (s, 3H, CH_3), 7.36 (d, 2H, J= 8.40 Hz, 3'-H), 7.44-7.45 (m, 1H, 5-H), 7.95 (d, 2H, J= 8.00 Hz, 2'-H), 8.20 (d, 1H, J= 1.60 Hz, 3-H), 8.57 (d, 1H, J= 5.20 Hz, 6-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 122.5 (C-3), 126.9 (C-5), 129.1 (C-2'), 129.9 (C-3'), 135.3 (C-1'), 145.2 (C-4'), 146.3 (C-4), 151.1 (6-C), 160.4 (C-2). HR MS Calcd for $C_{12}H_{10}ClNO_2S$ $[M + H]^+$: m/z 28.0119, Found 268.0197.

2-tosylquinoxaline (3y)



Light yellow solid, m.p.178-179 °C: ^{1}H NMR (400 MHz, $CDCl_3$) δ:2.45 (s, 3H, 5'-H), 740 (d, 1H, J= 8.00 Hz, 2'-H), 7.83-7.87 (m, 1H, 5-H), 7.88-7.92 (m, 1H, 6-H), 8.03 (d, 1H, J= 8.00 Hz, 3'-H), 8.20-8.22 (m, 1H, 7-H), 8.54-8.57 (m, 1H, 8-H), 9.04 (s, 1H, 3-H). ^{13}C NMR (100 MHz, $CDCl_3$) δ:21.7 (C-5'), 118.9 (C-5), 127.3 (C-6), 129.3(C-2'), 130.1(C-3'), 131.1 (C-7), 132.5 (C-8), 132.9 (C-1'), 134.7 (C-4'), 137.9 (C-10), 144.5 (C-9), 146.0 (C-3), 156.1 (C-2). HR MS Calcd for $C_{11}H_{11}NO_2S$ $[M + H]^+$: m/z 285.0689, Found 285.0696.

2-ethoxyquinoline (4a)



Yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.44 (t, 3H, J=6.80 Hz, 2'-H, -CH_3); 4.53 (m, 2H, 1'-H,

-CH_2CH_3); 6.87 (d, *J*= 8.84 Hz, 1H, 3-H); 7.34 (t, 1H, 6-H); 7.60 (m, 1H, 7-H); 7.67 (d, *J*= 8.00 Hz, 1H, 5-H); 7.83 (d, *J*= 8.40 Hz,1H, 8-H); 7.93 (d, *J*= 8.80 Hz, 1H, 4-H); ^{13}C NMR (100 MHz, CDCl3) δ: 14.6 (C-2', -CH_2CH3); 61.7 (C-1', -OCH_2-); 113.3 (C-3); 123.9 (C-6); 125.1 (C-10);127.2 (C-5); 127.4 (C-8); 129.4 (C-7); 138.6 (C-4); 146.7 (C-9); 162.2 (C-2).HR MS Calcd for C11H11NO [M + H]$^+$:m/z 174.0919, Found 174.0917.

5. ^{1}H NMR, ^{13}C NM R，and HRMS (ESI) copies of products

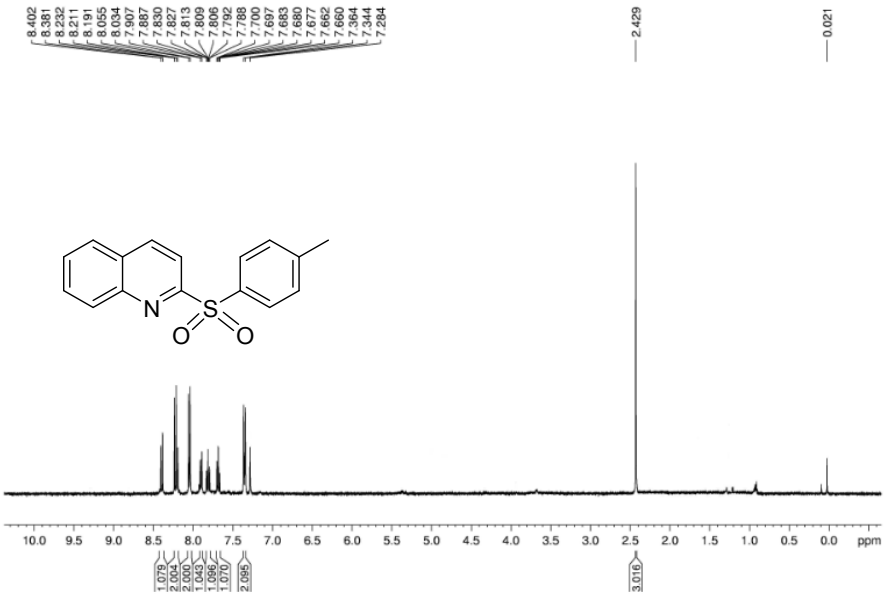


Fig. 1 ^{1}H NMR spectrum of compound **3a**

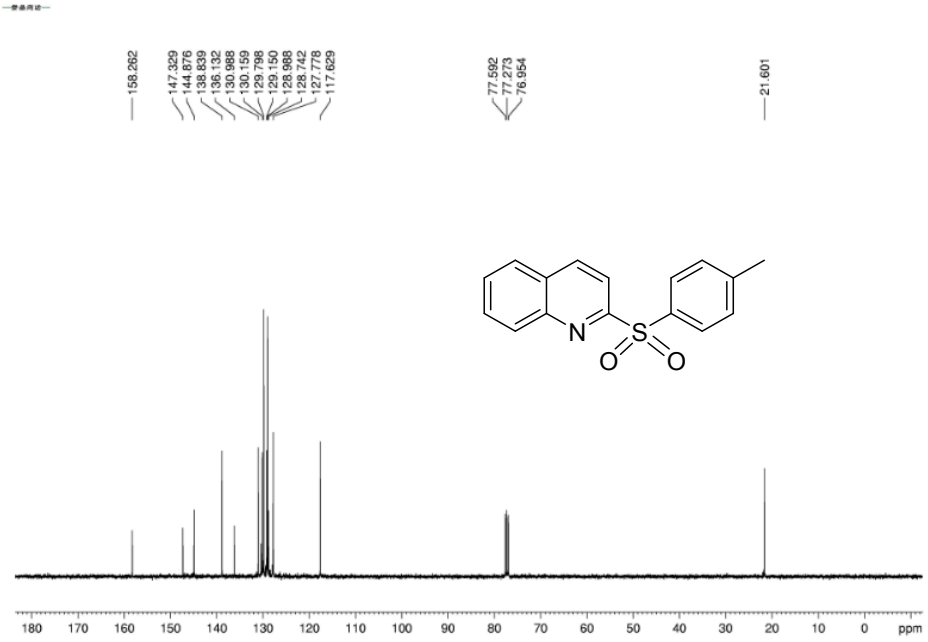


Fig. 2 ^{13}C NMR spectrum of compound **3a**

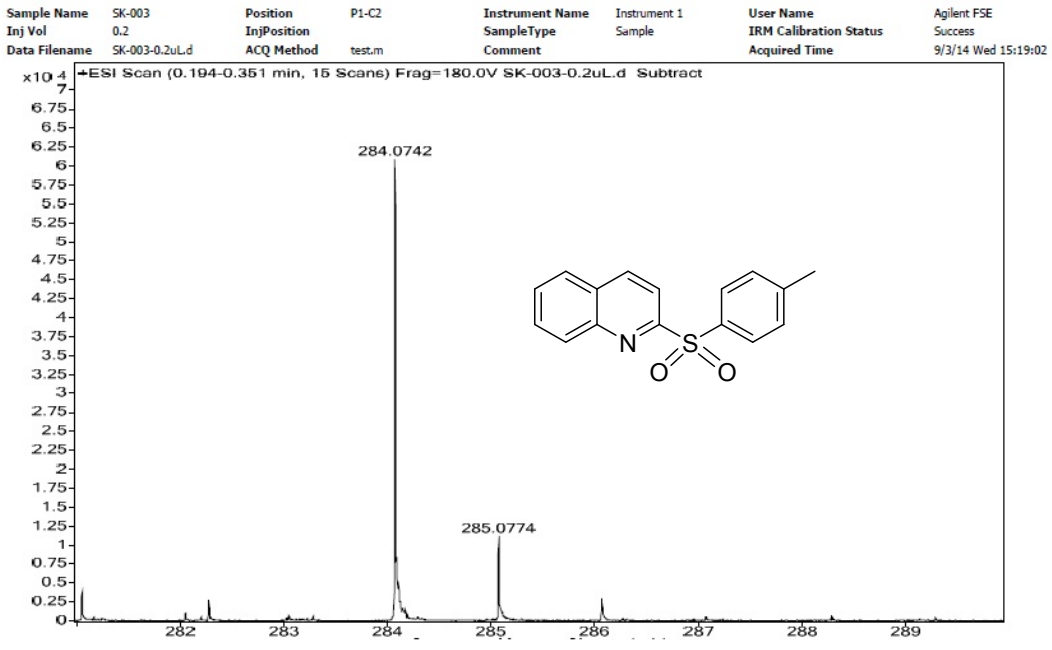


Fig. 3 HRMS spectrum of compound **3a**

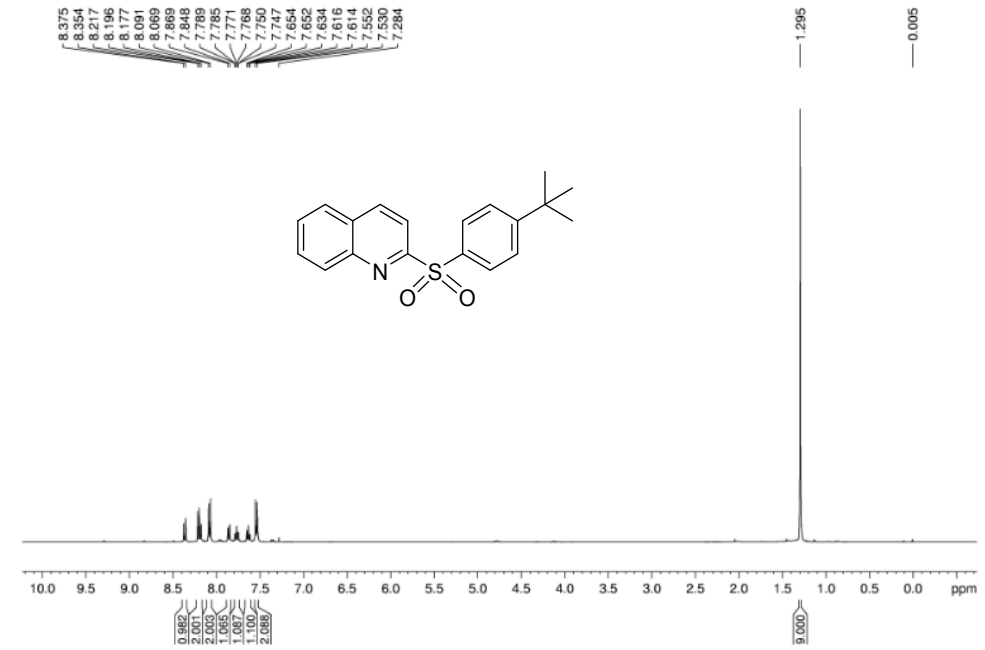


Fig. 4 ^{1}H NMR spectrum of compound **3b**

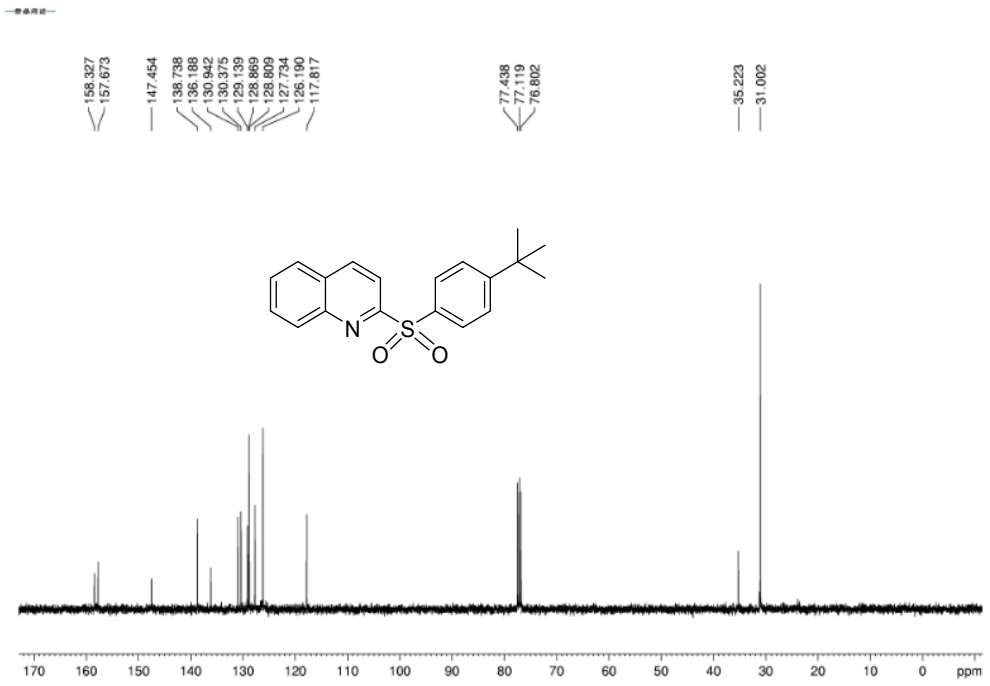


Fig. 5 ^{13}C NMR spectrum of compound **3b**

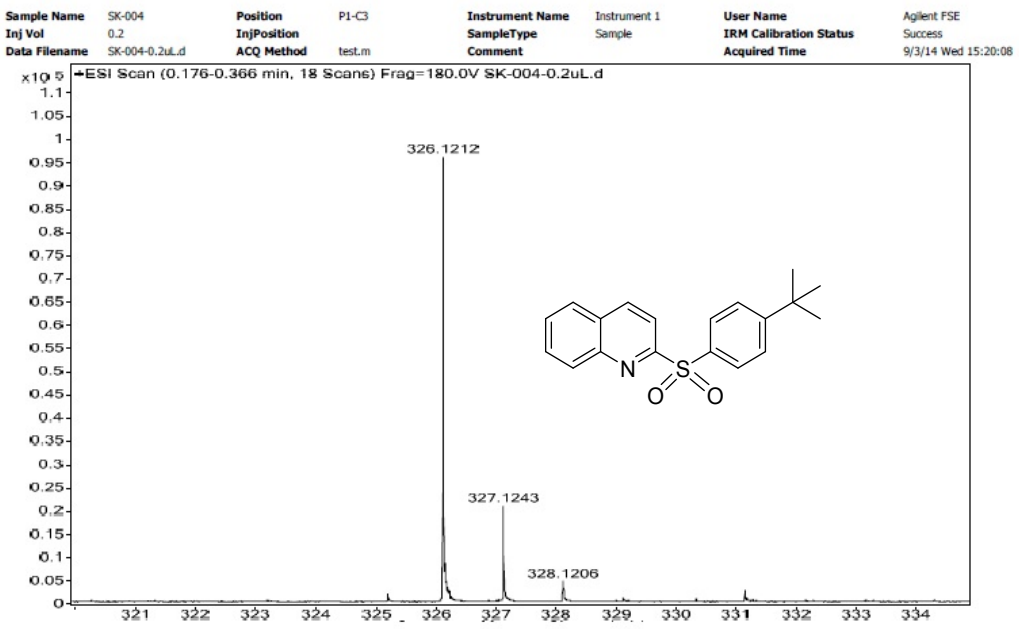


Fig. 6 HRMS spectrum of compound **3b**

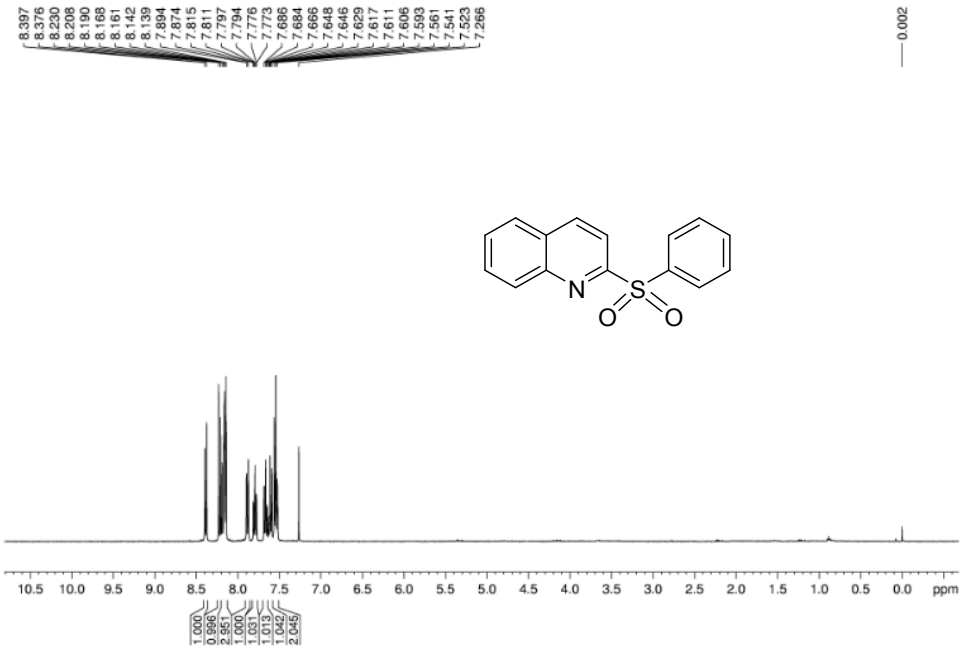


Fig. 7 ^{1}H NMR spectrum of compound **3c**

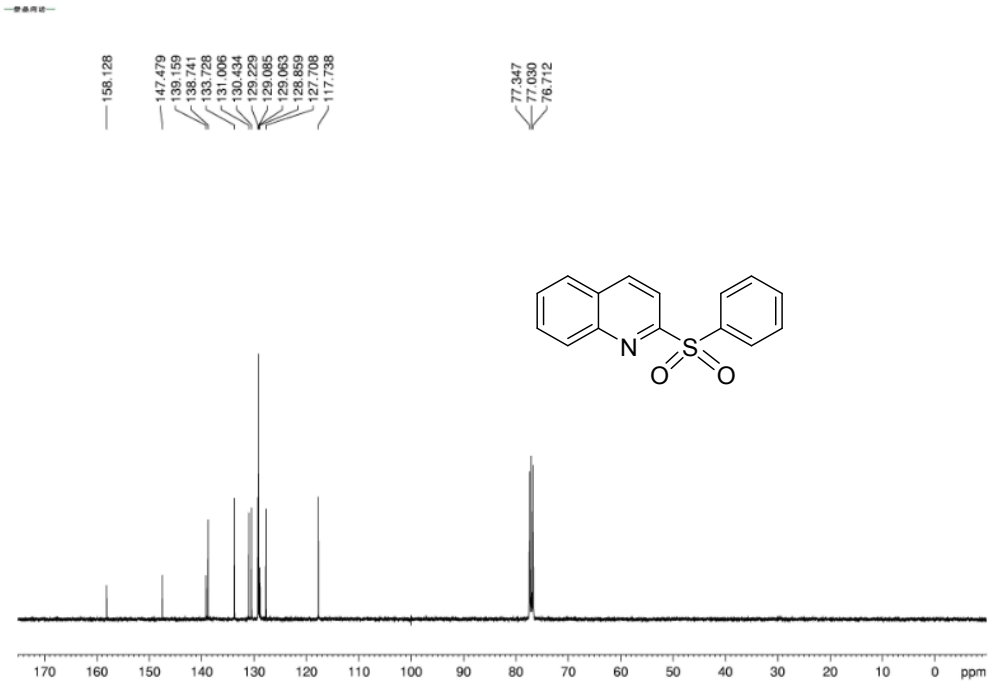


Fig. 8 ^{13}C NMR spectrum of compound **3c**

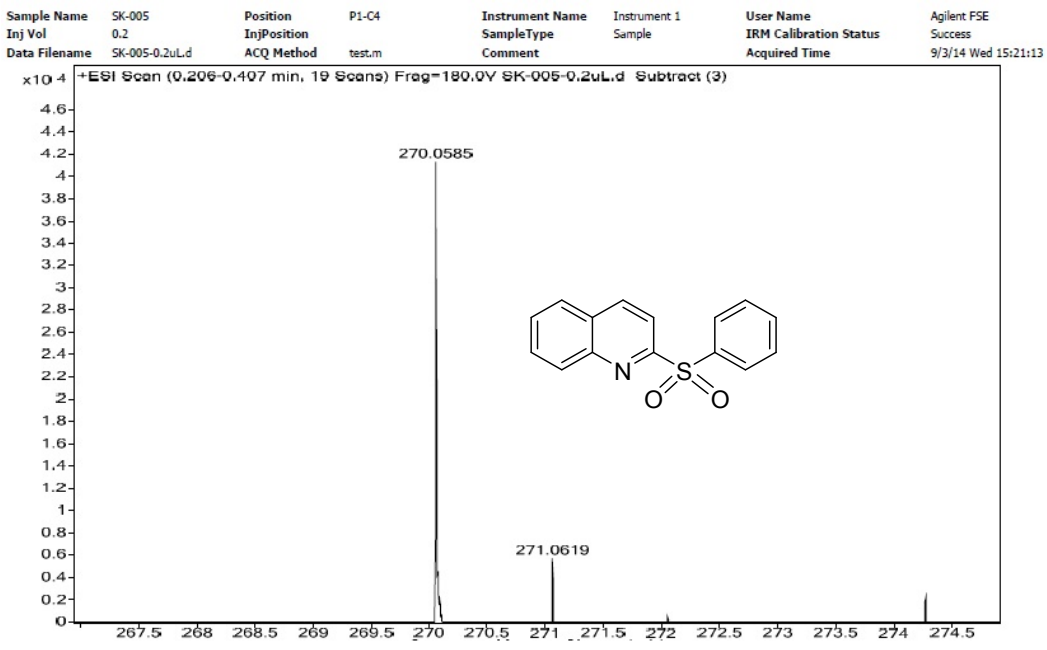


Fig. 9 HRMS spectrum of compound **3c**

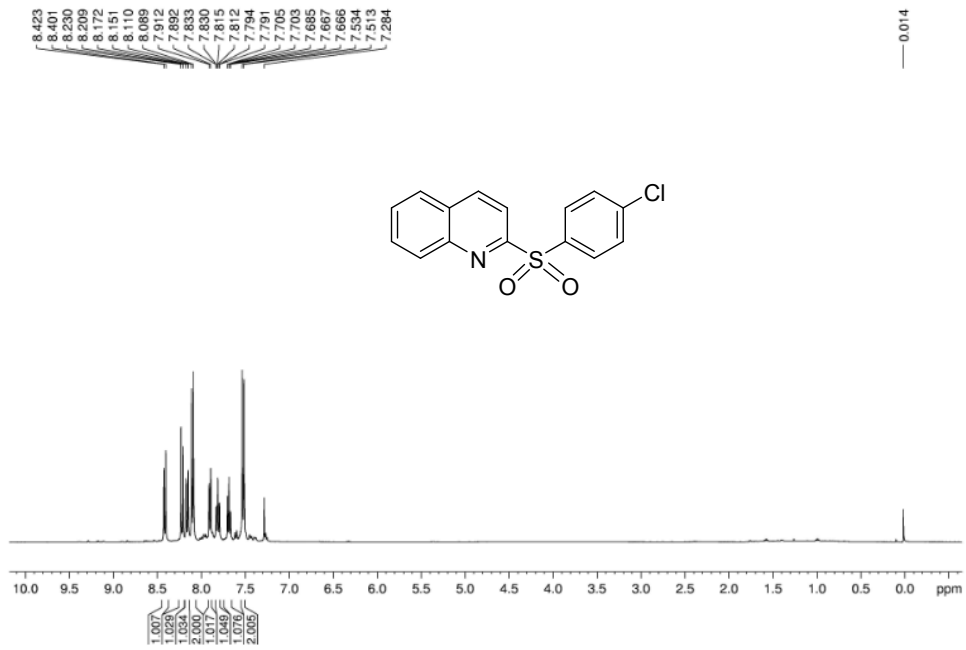


Fig. 10 [1]H NMR spectrum of compound **3d**

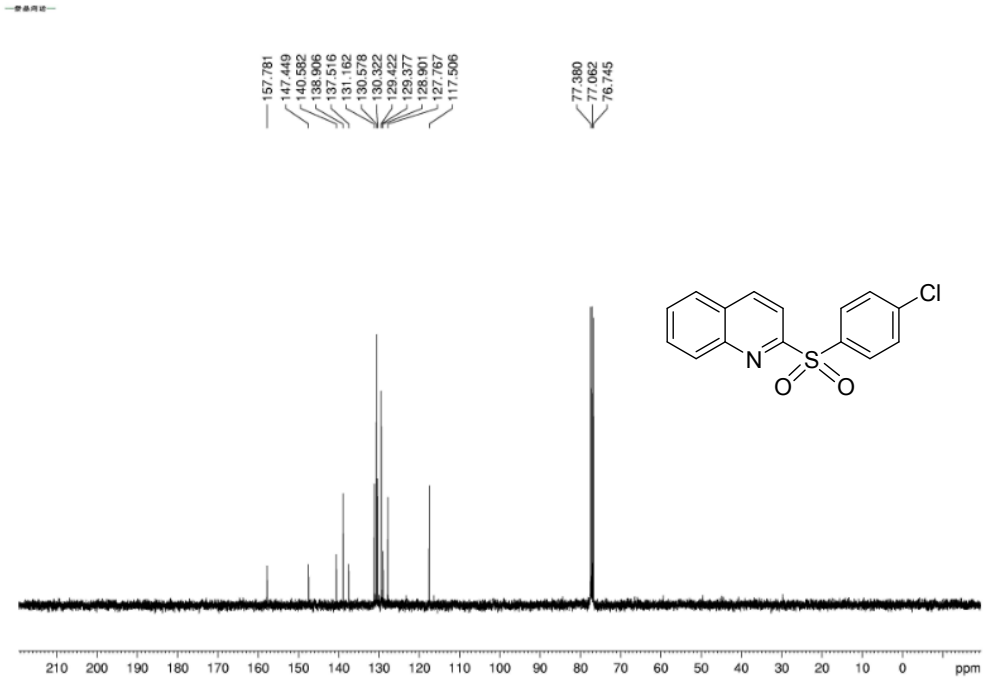


Fig. 11 [13]C NMR spectrum of compound **3d**

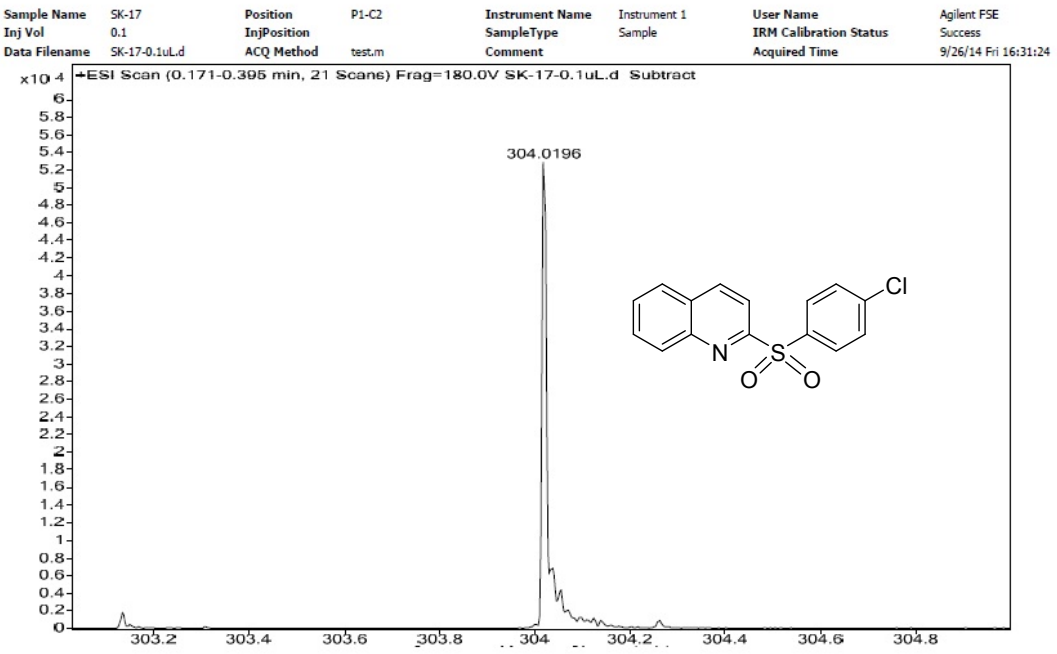


Fig. 12 HRMS spectrum of compound **3d**

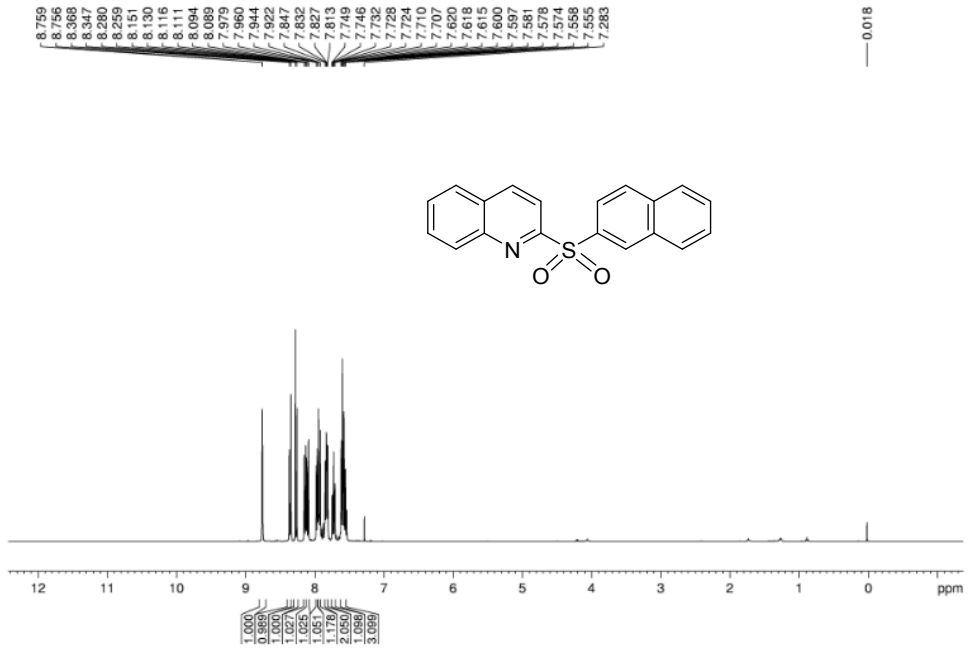


Fig. 13 ^{1}H NMR spectrum of compound **3e**

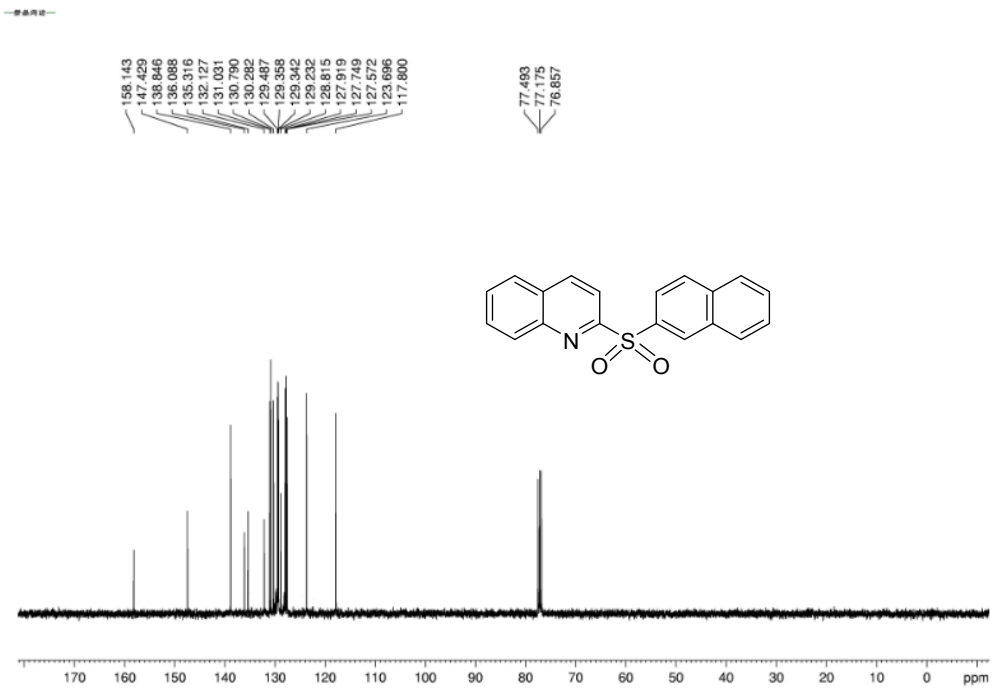


Fig. 14 ^{13}C NMR spectrum of compound **3e**

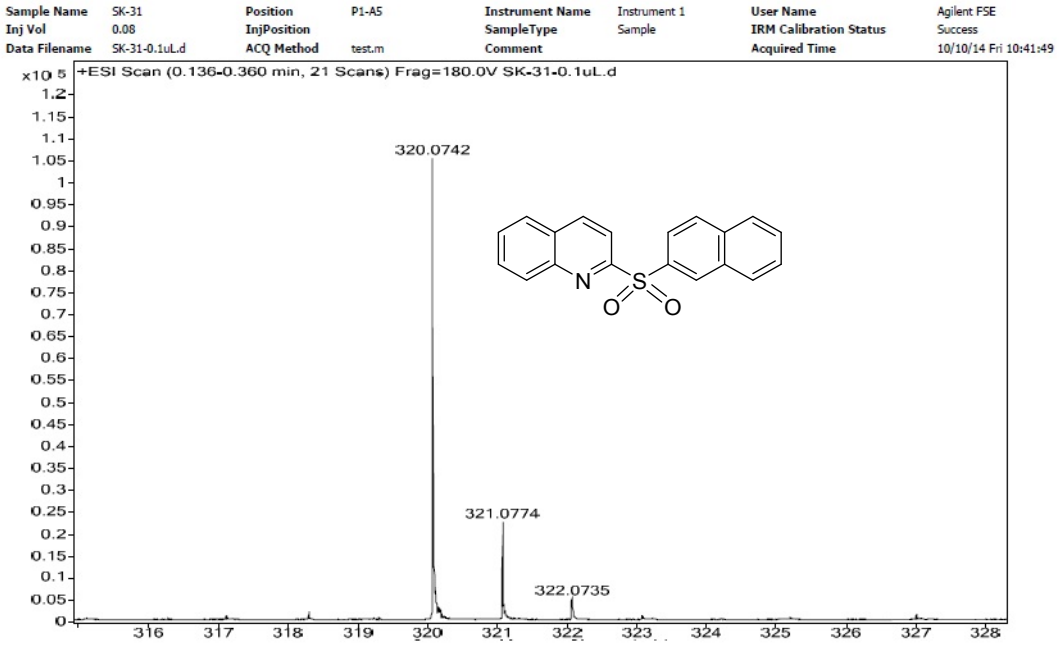


Fig. 15 HRMS spectrum of compound **3e**

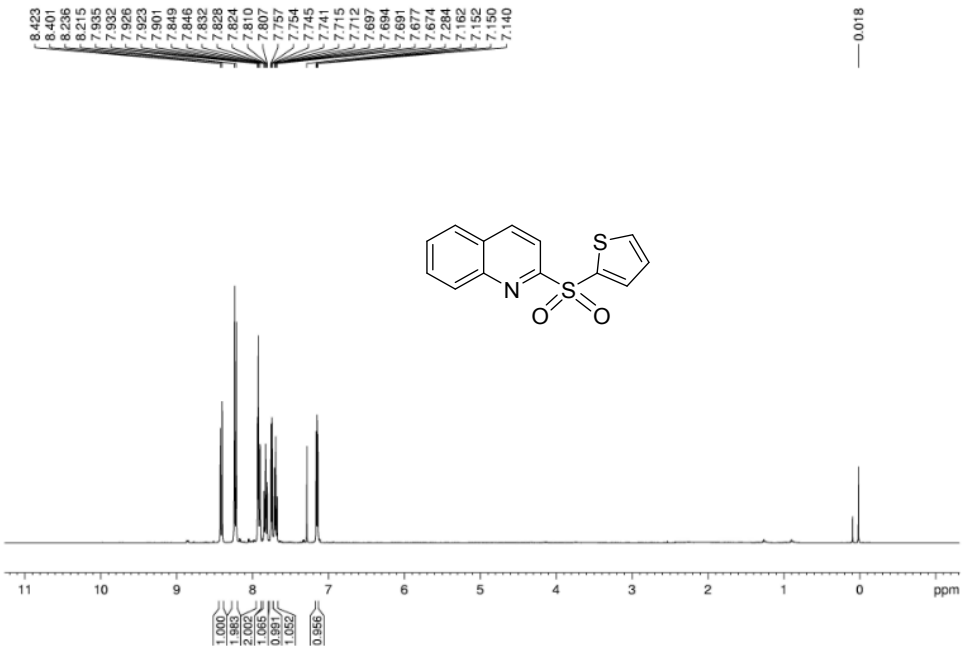


Fig. 16 ^{1}H NMR spectrum of compound **3f**

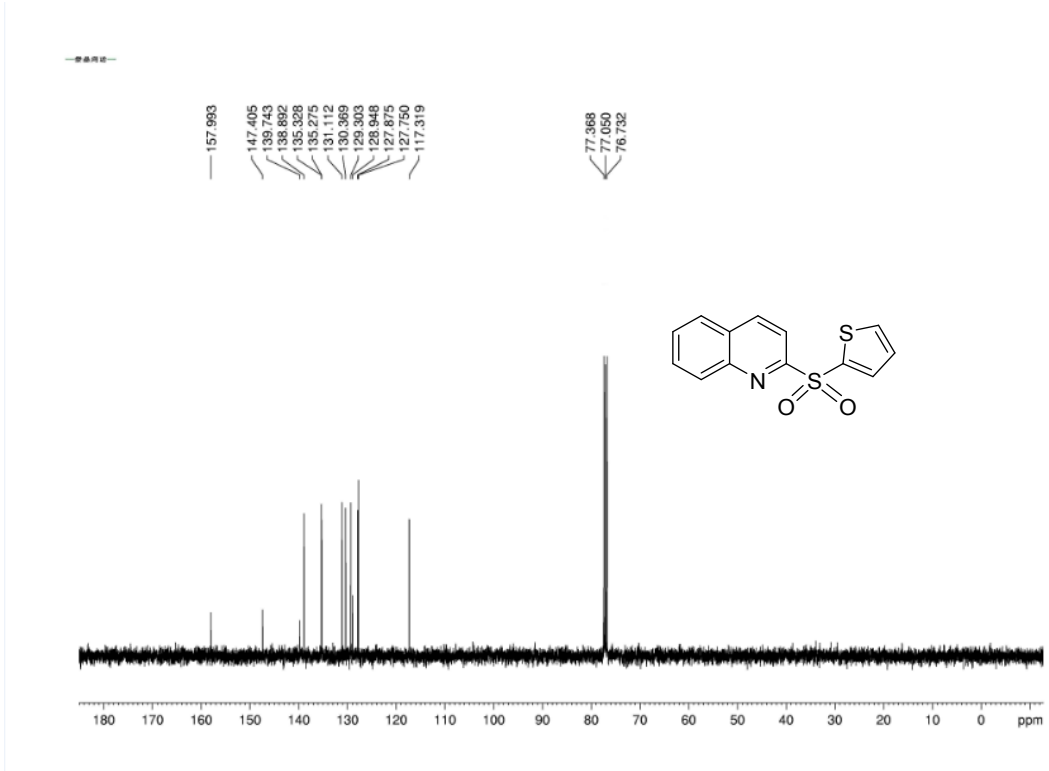


Fig. 17 ^{13}C NMR spectrum of compound **3f**

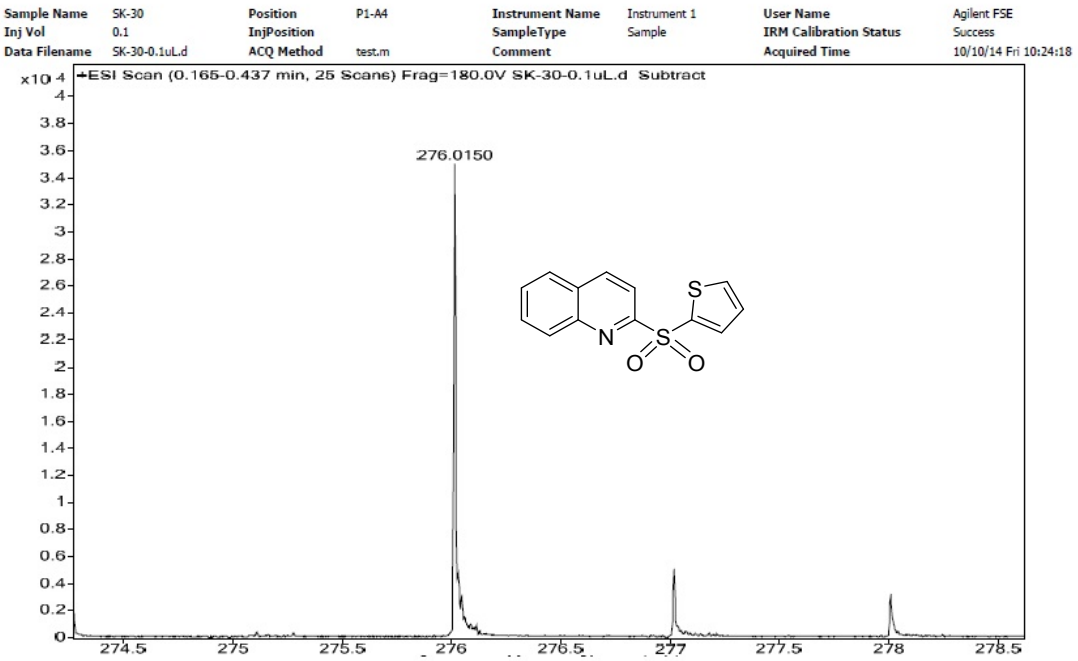


Fig. 18 HRMS spectrum of compound **3f**

Fig. 19 ^{1}H NMR spectrum of compound **3g**

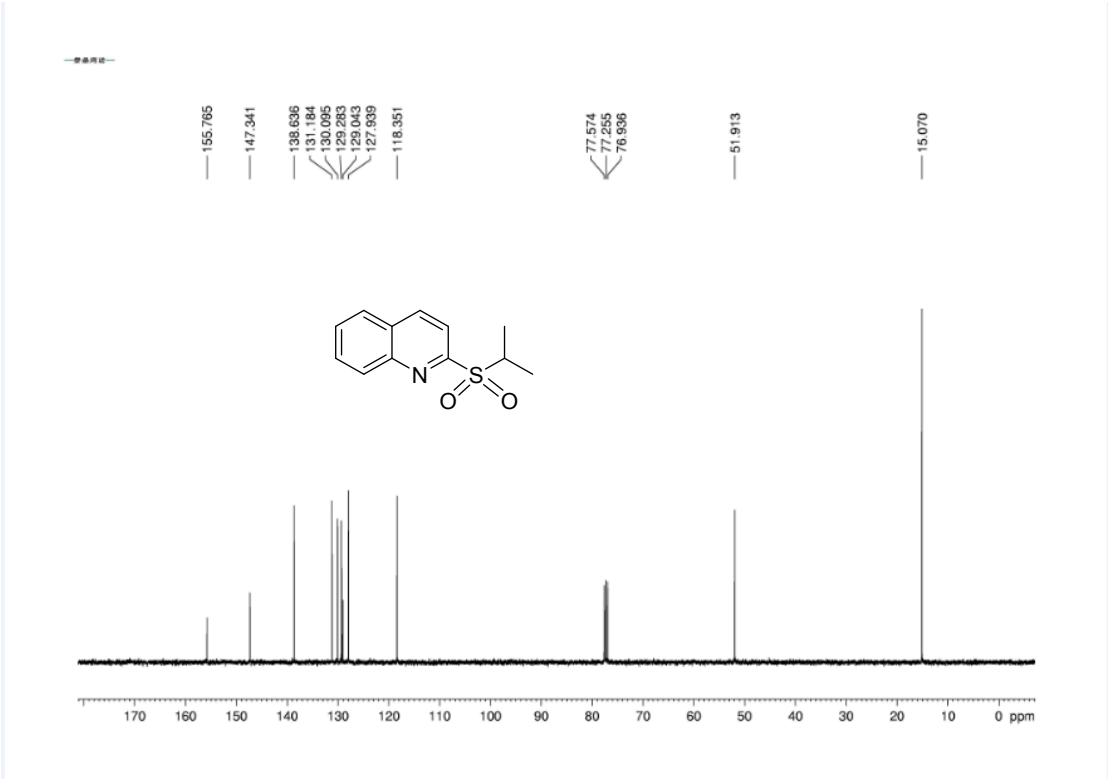


Fig. 20 ^{13}C NMR spectrum of compound **3g**

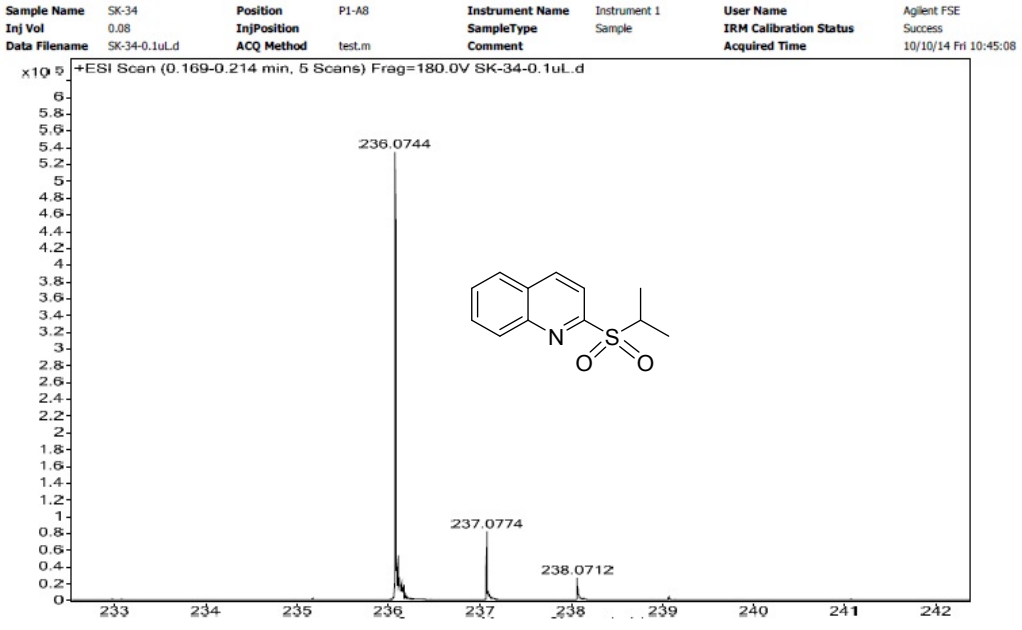


Fig. 21 HRMS spectrum of compound **3g**

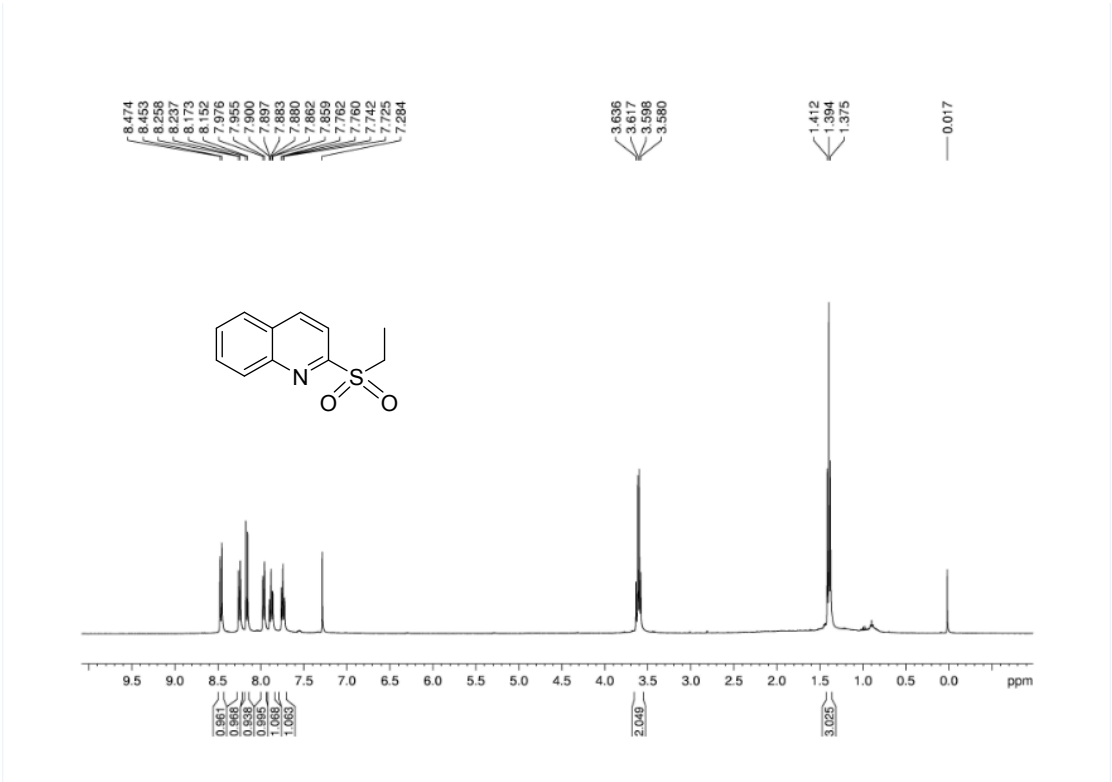


Fig. 22 ^{1}H NMR spectrum of compound **3h**

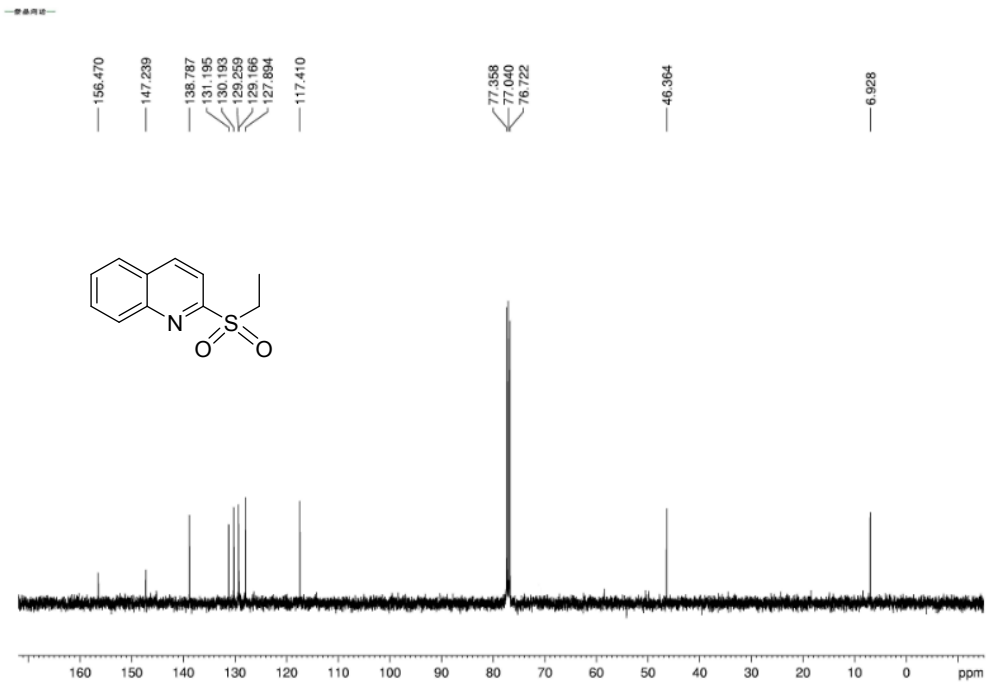


Fig. 23 ^{13}C NMR spectrum of compound **3h**

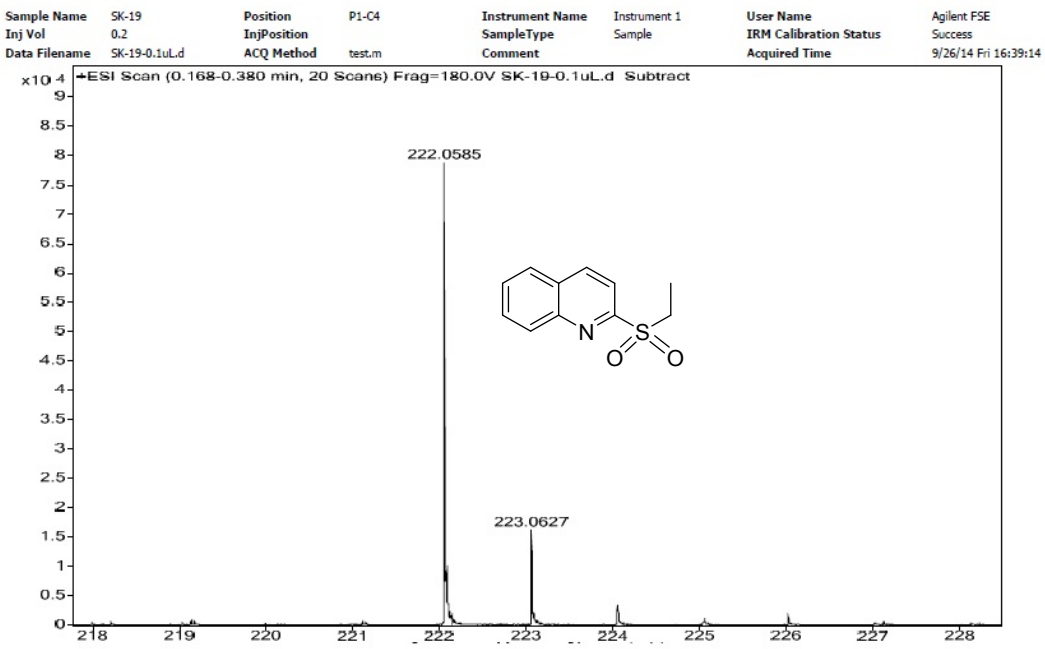


Fig. 24 HRMS spectrum of compound **3h**

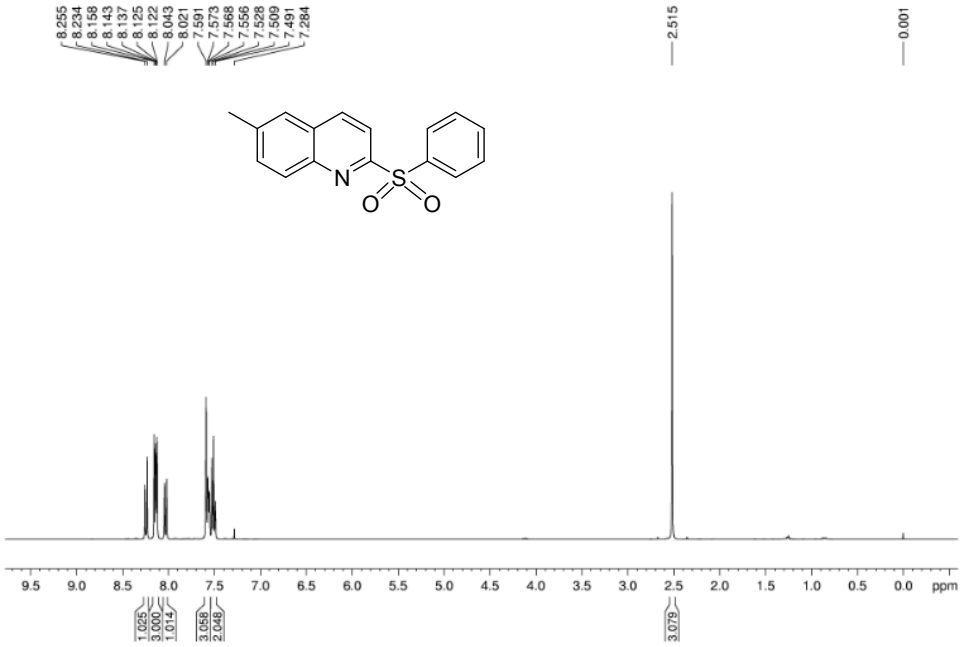


Fig. 25 ^{1}H NMR spectrum of compound **3i**

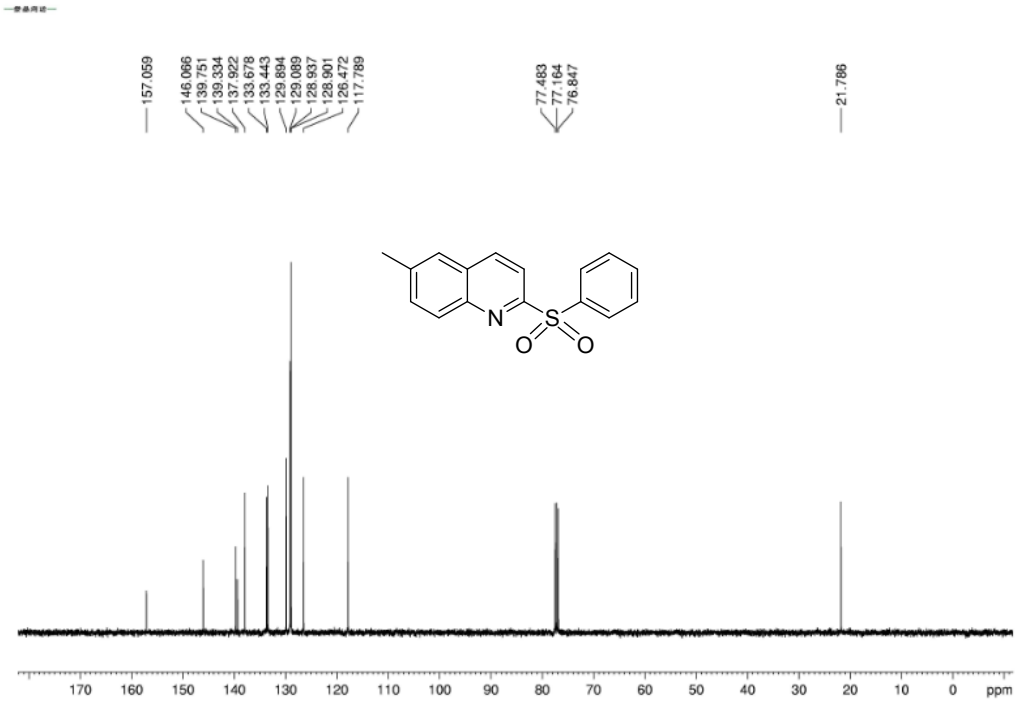


Fig. 26 ^{13}C NMR spectrum of compound **3i**

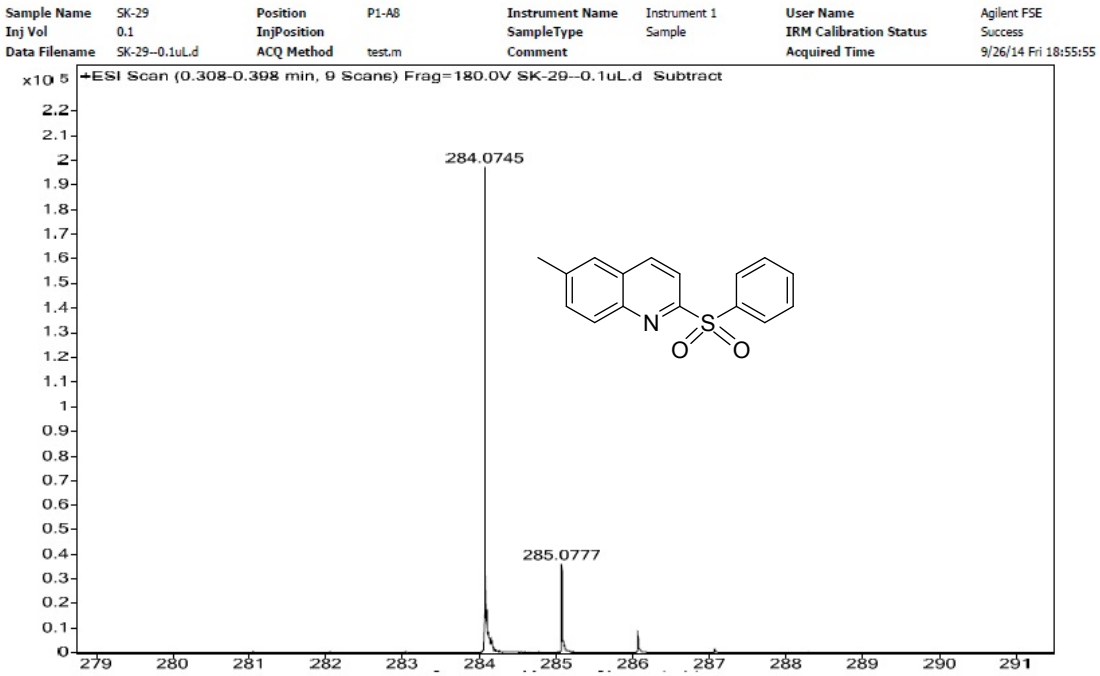


Fig. 27 HRMS spectrum of compound **3i**

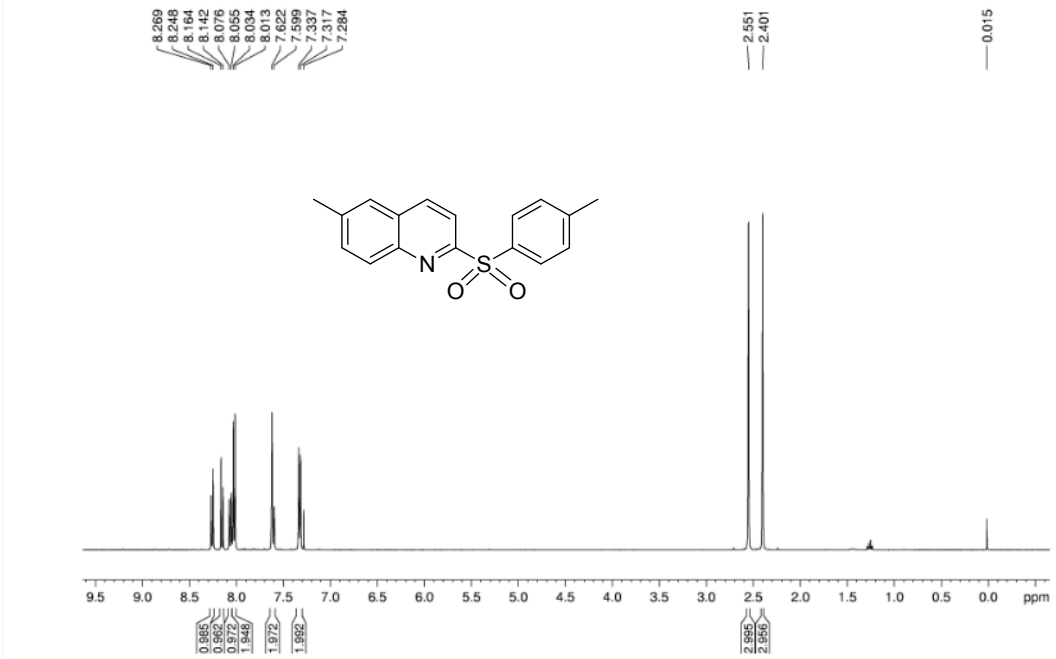


Fig. 28 [1]H NMR spectrum of compound **3j**

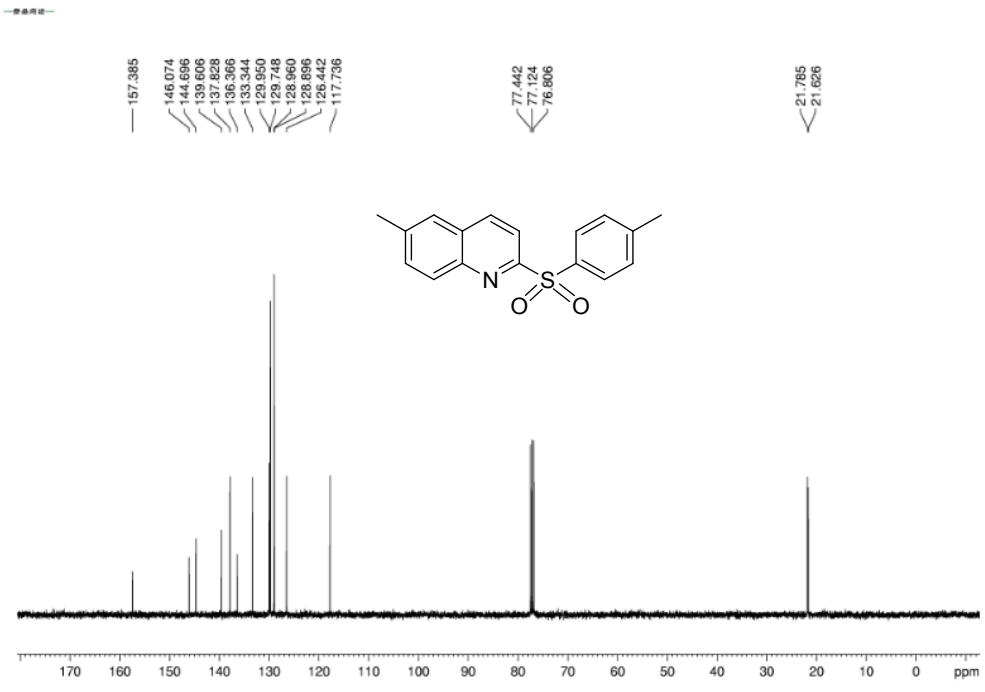


Fig. 29 [13]C NMR spectrum of compound **3j**

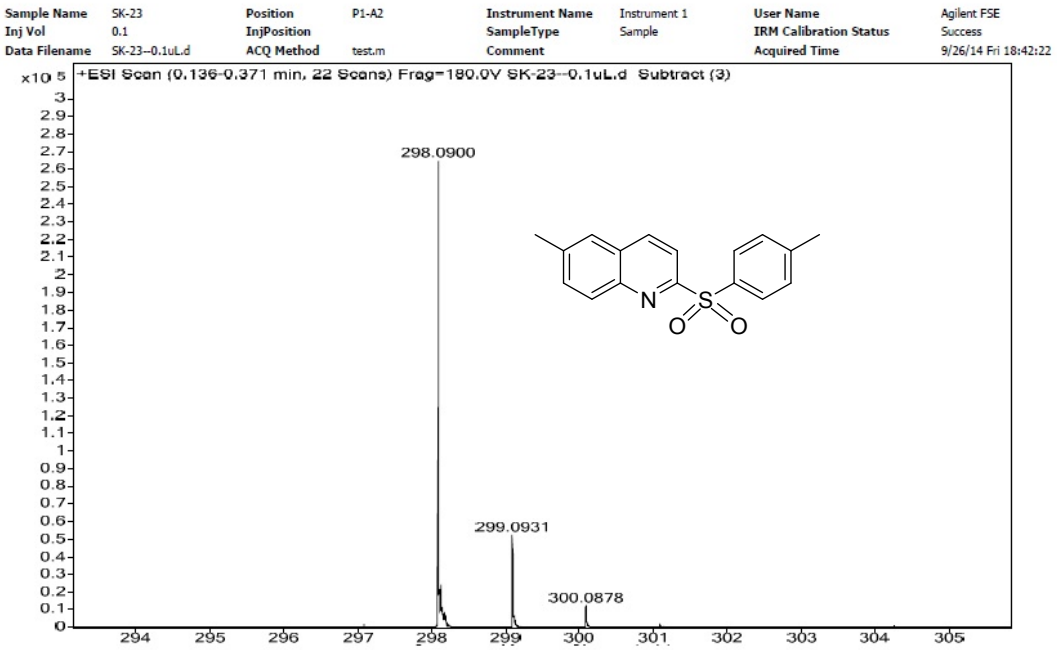


Fig. 30 HRMS spectrum of compound **3j**

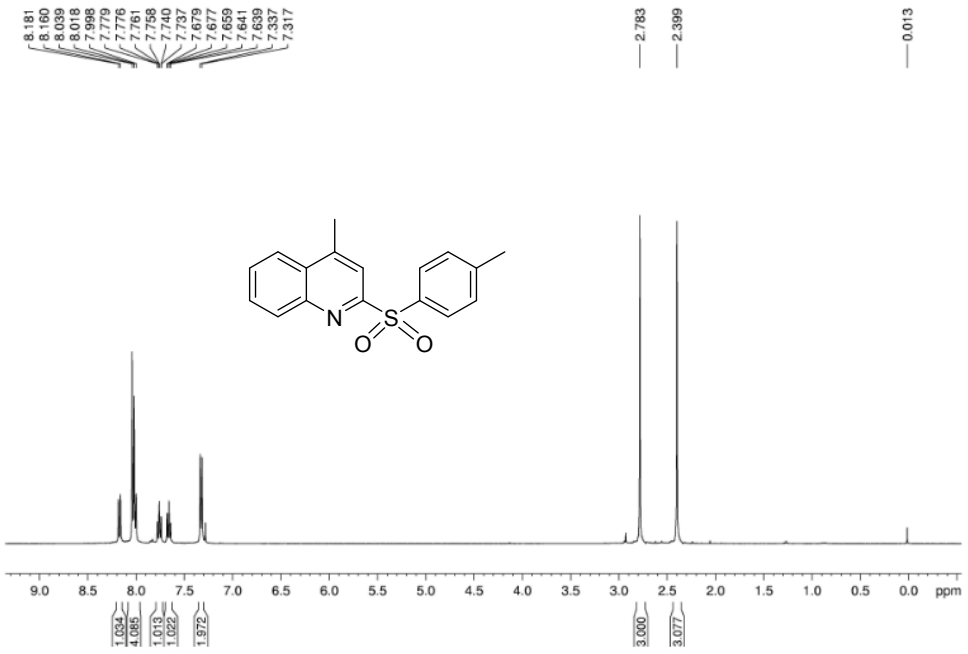


Fig.31 ^{1}H NMR spectrum of compound **3k**

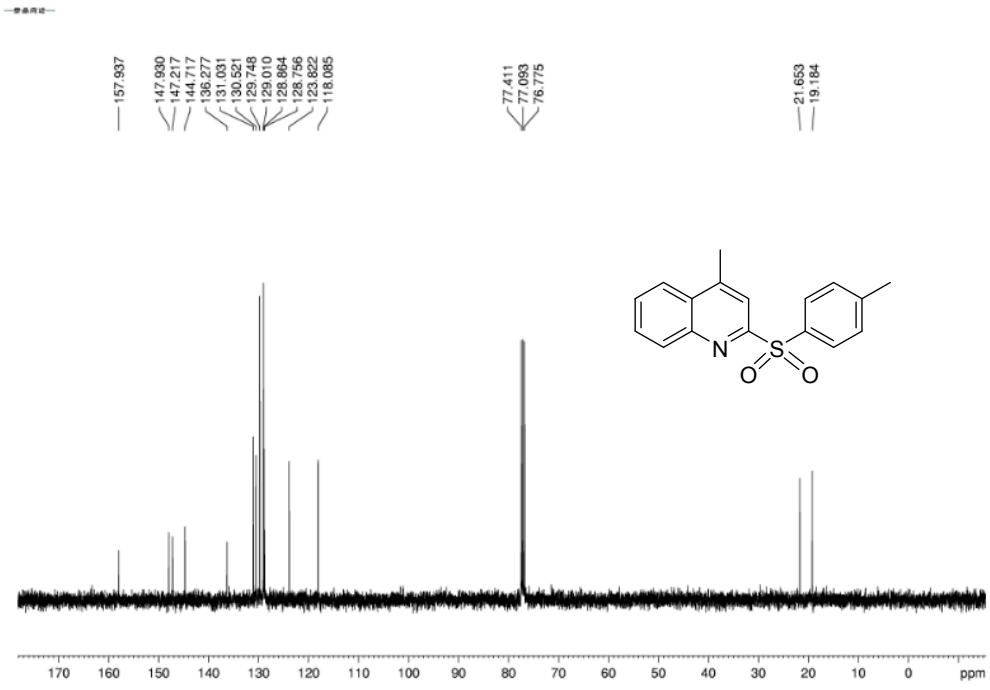


Fig. 32 ^{13}C NMR spectrum of compound **3k**

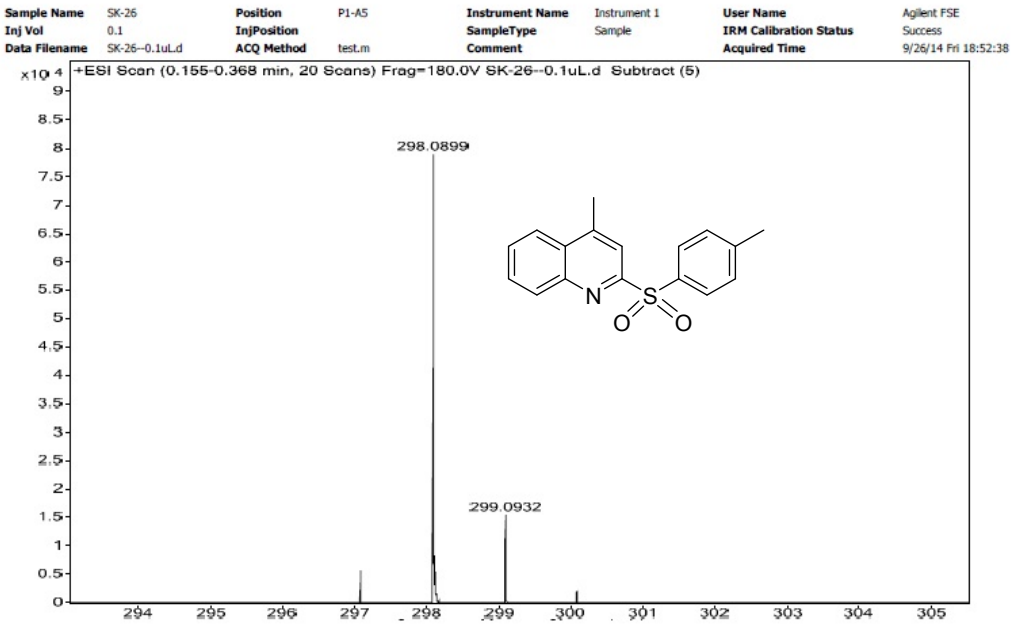


Fig. 33 HRMS spectrum of compound **3k**

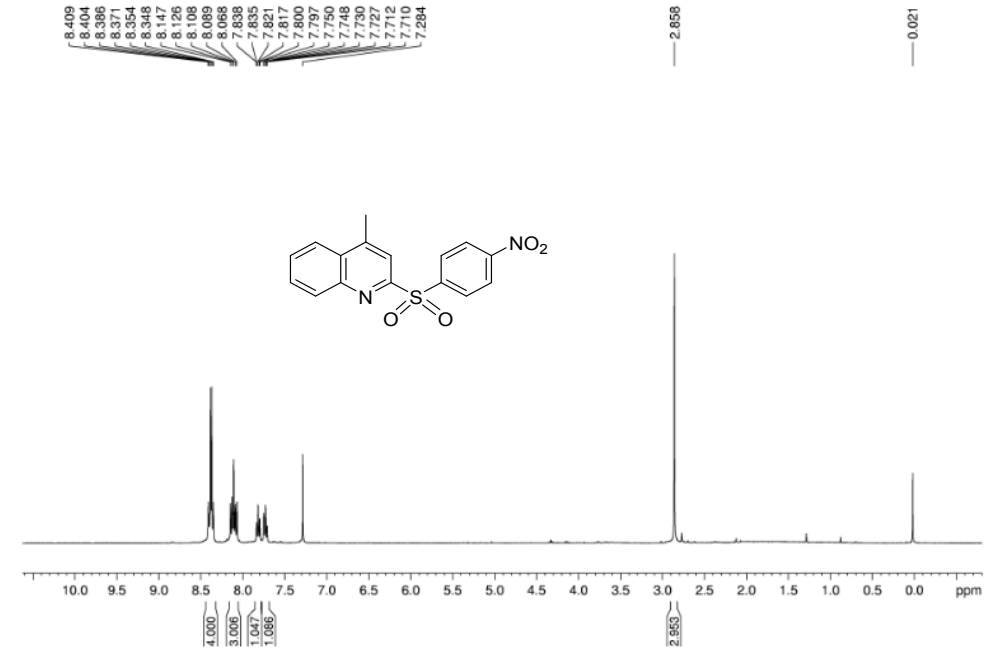


Fig. 34 ^{13}H NMR spectrum of compound **3l**

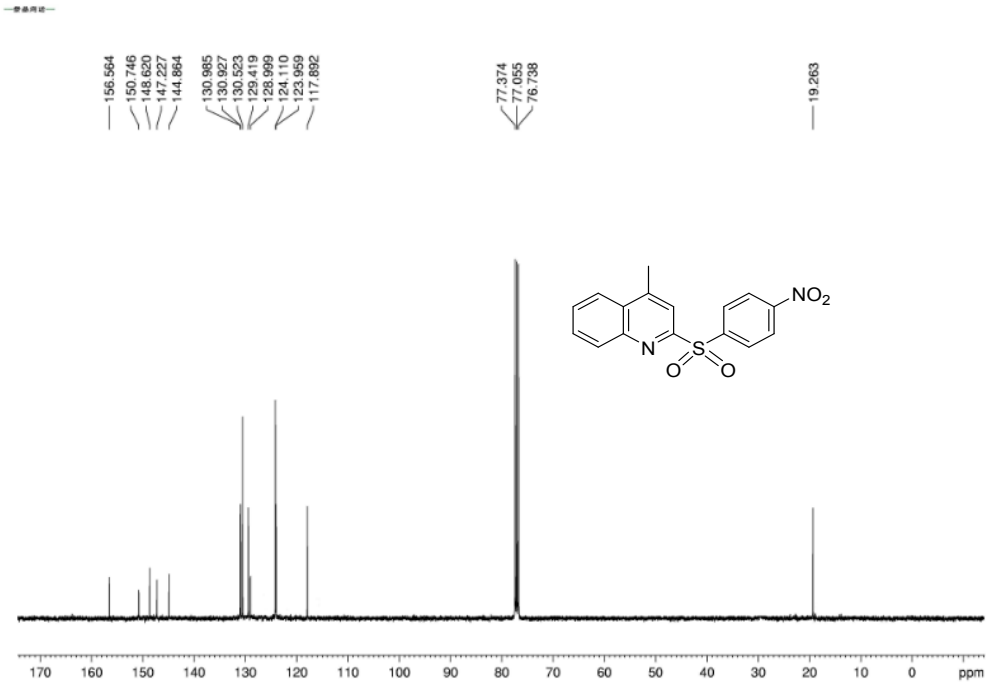


Fig.35 ^{13}H NMR spectrum of compound **3l**

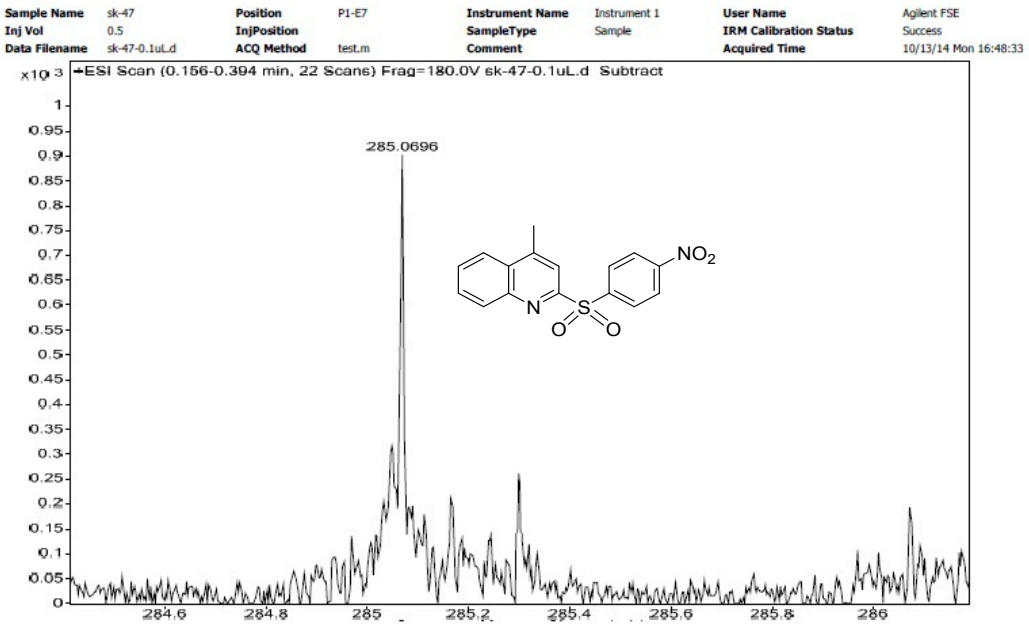


Fig.36 [13]H NMR spectrum of compound **3l**

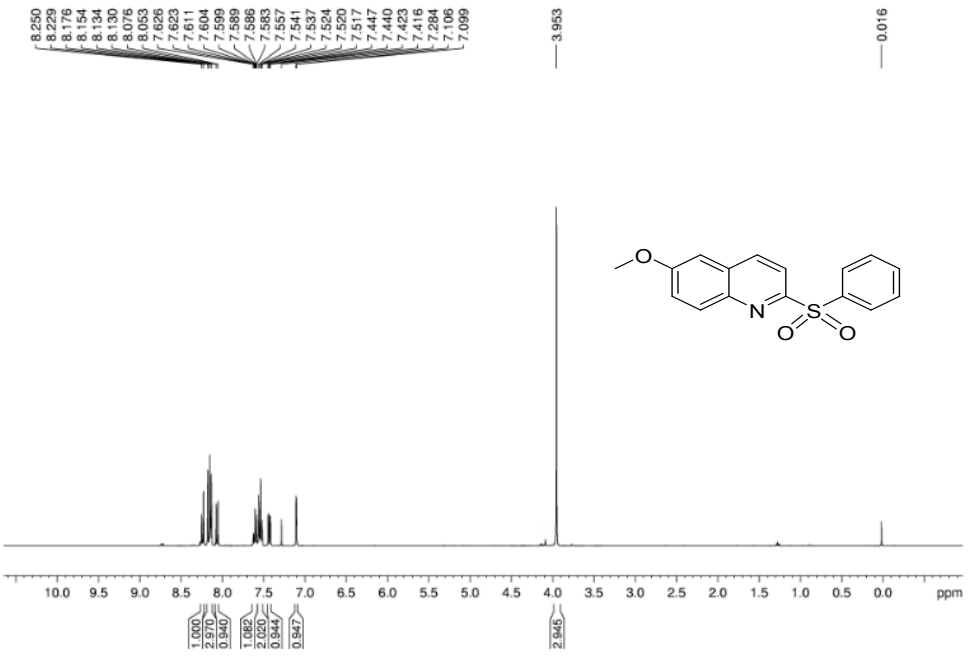


Fig. 37 [1]H NMR spectrum of compound **3m**

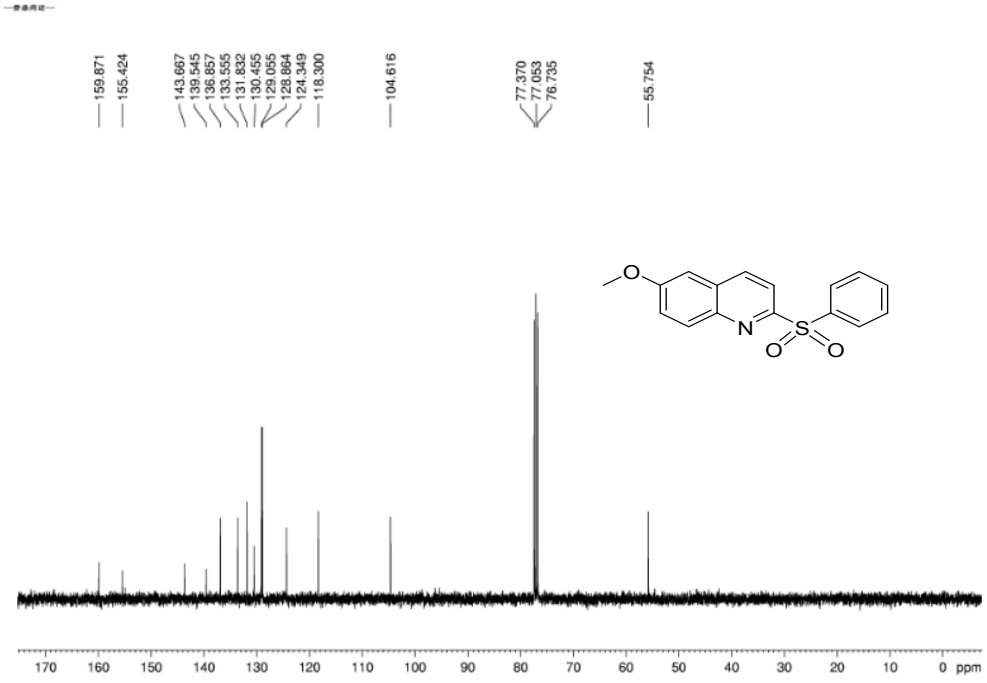


Fig. 38 ^{13}C NMR spectrum of compound **3m**

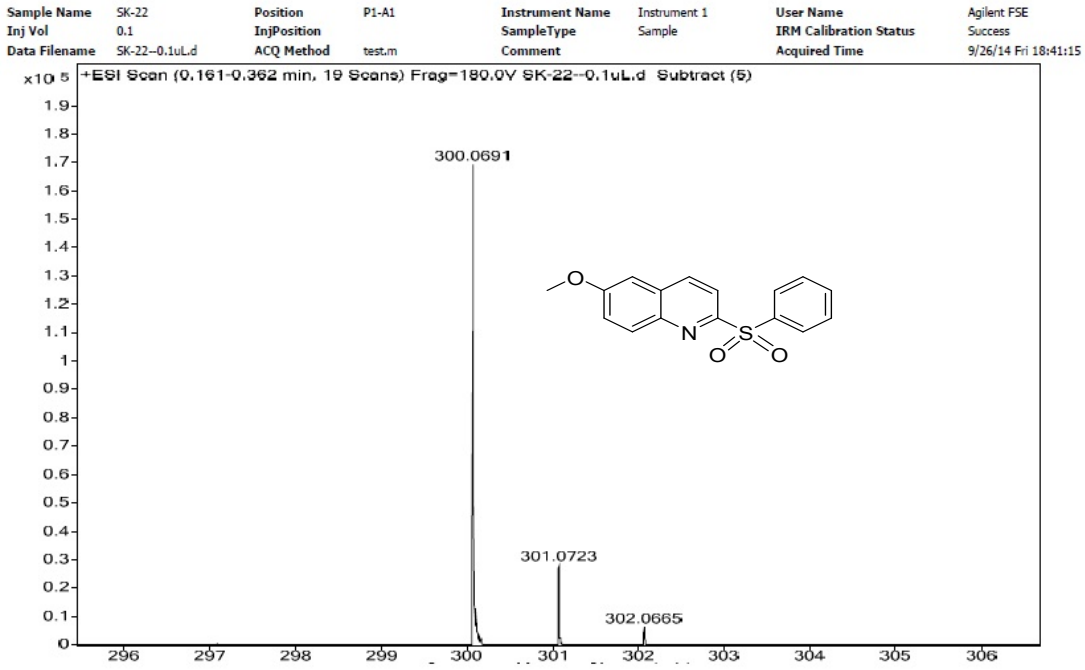


Fig. 39 HRMS spectrum of compound **3m**

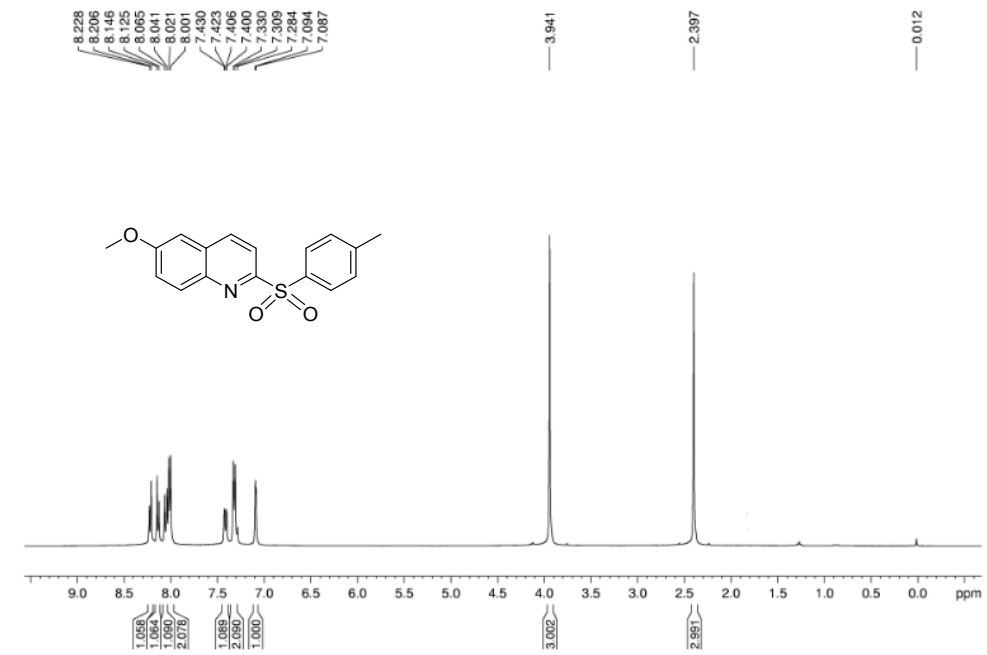


Fig. 40 [1]H NMR spectrum of compound **3n**

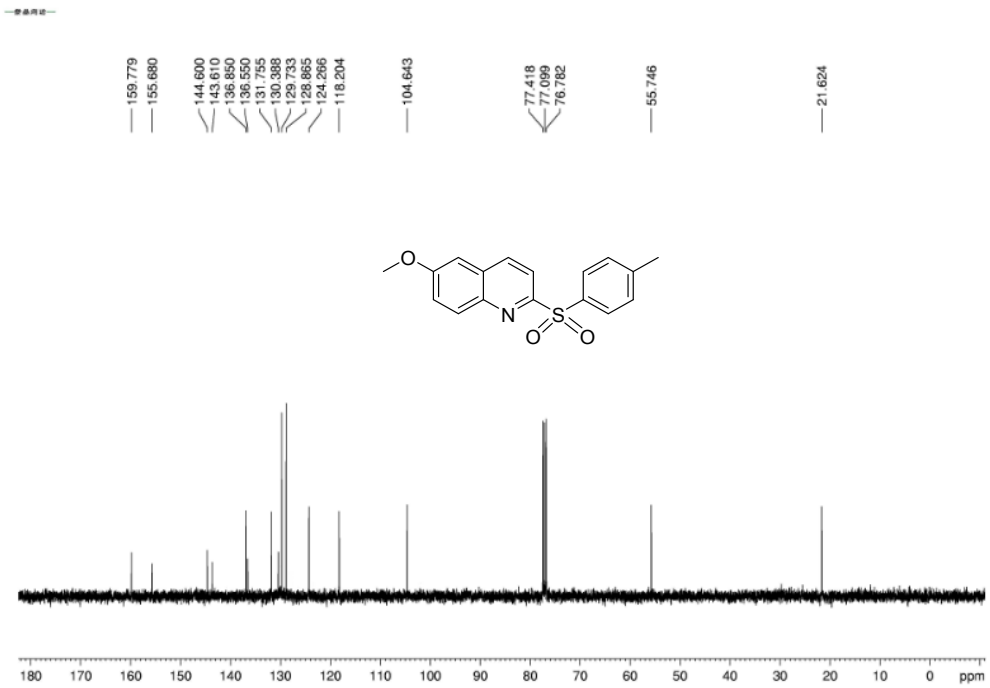


Fig. 41 [13]C NMR spectrum of compound **3n**

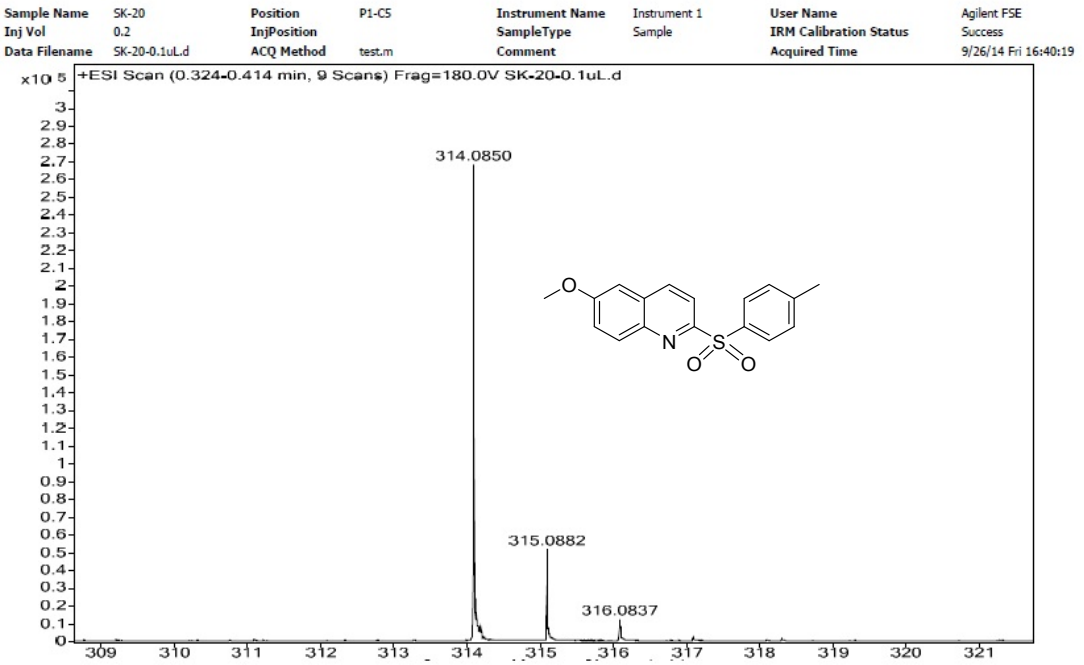


Fig. 42 HRMS spectrum of compound **3n**

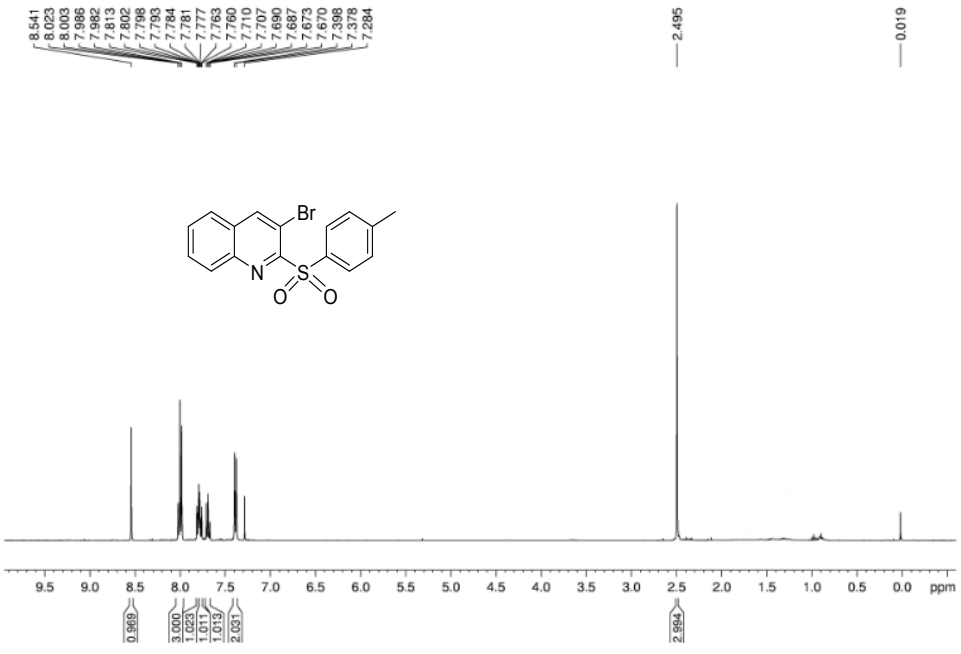


Fig. 43 ^{1}H NMR spectrum of compound **3o**

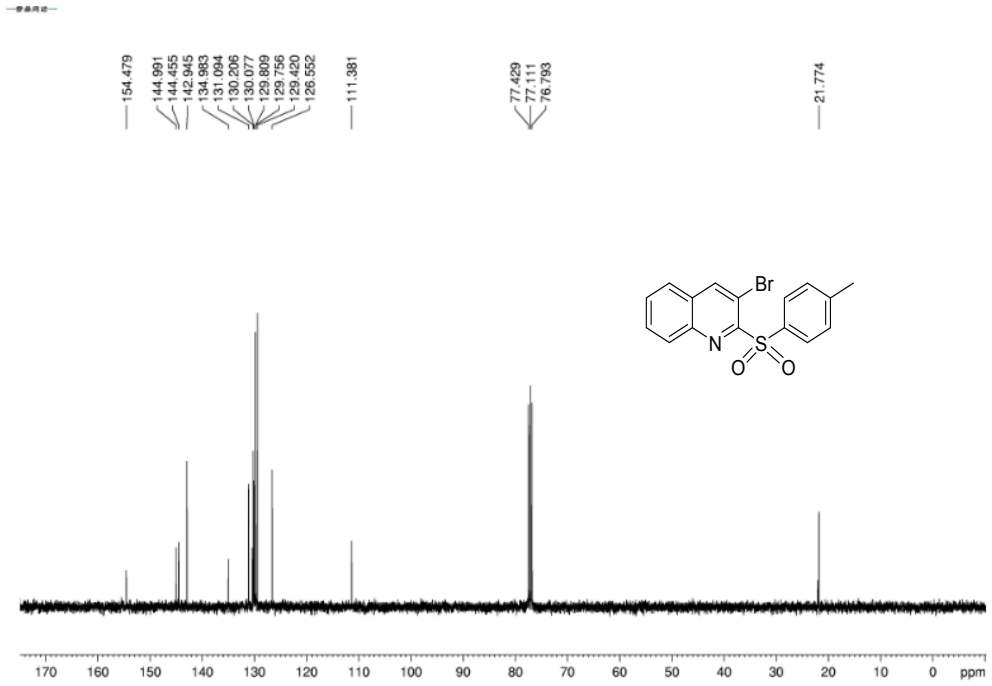


Fig. 44 ^{13}C NMR spectrum of compound **3o**

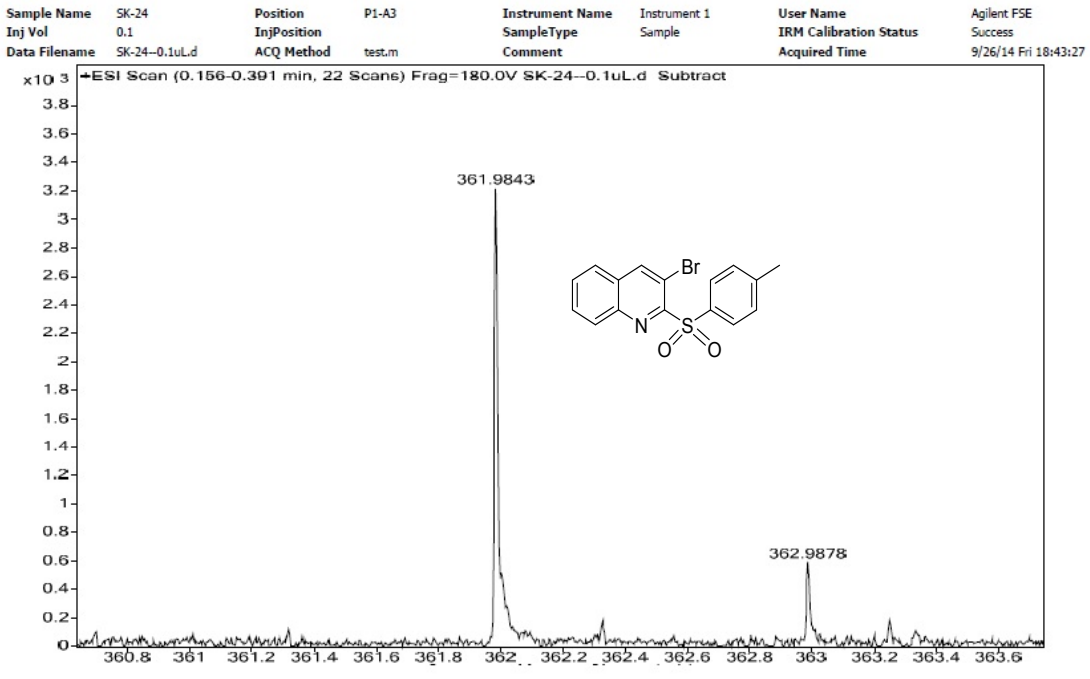


Fig. 45 HRMS spectrum of compound **3o**

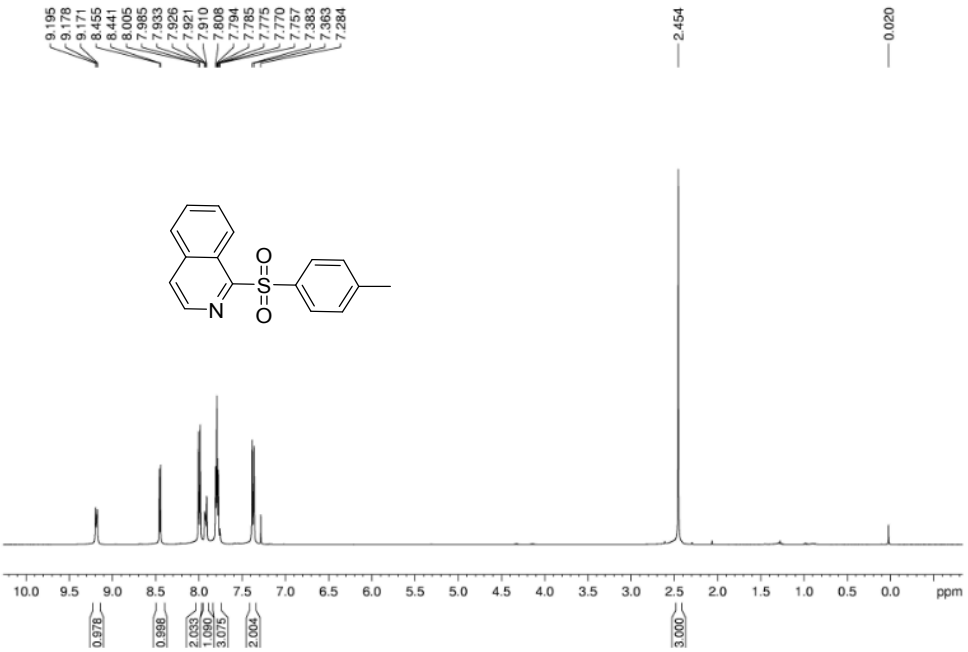


Fig. 46 ^{1}H NMR spectrum of compound **3p**

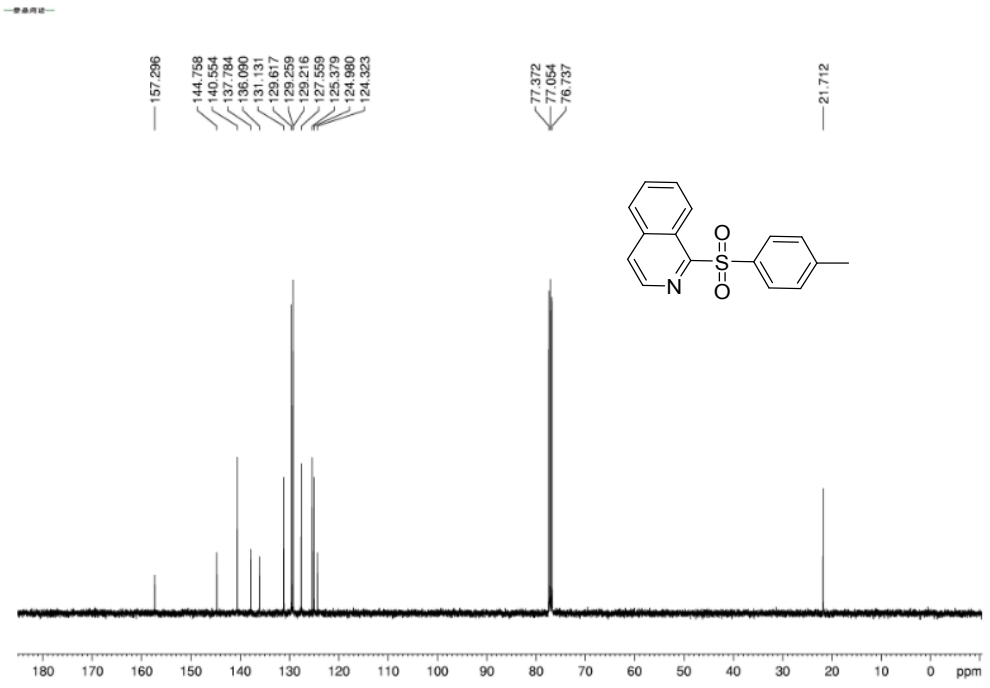


Fig. 47 ^{13}C NMR spectrum of compound **3p**

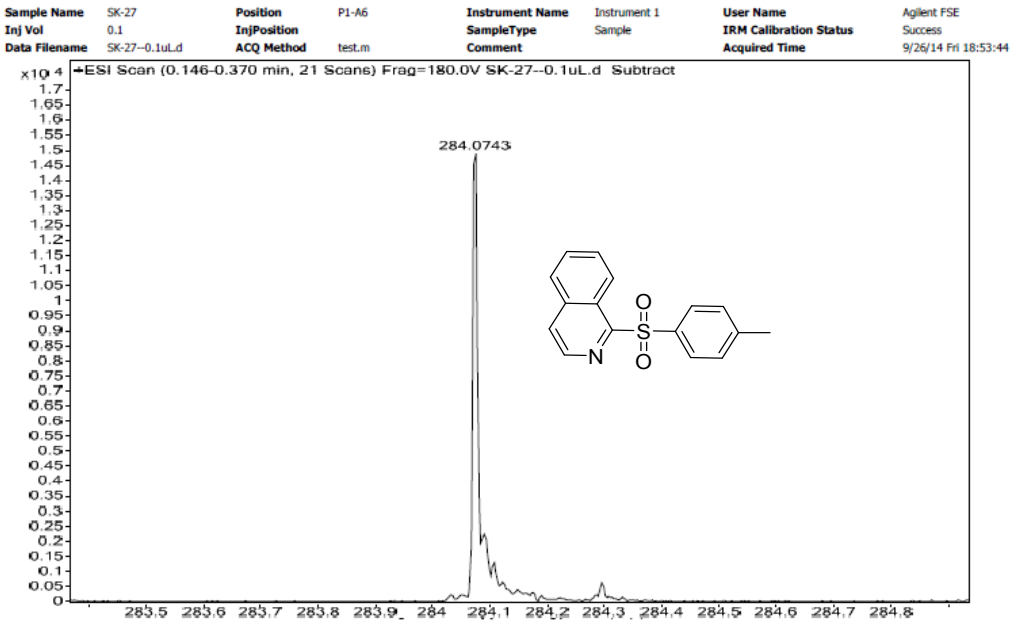


Fig. 48 HRMS spectrum of compound **3p**

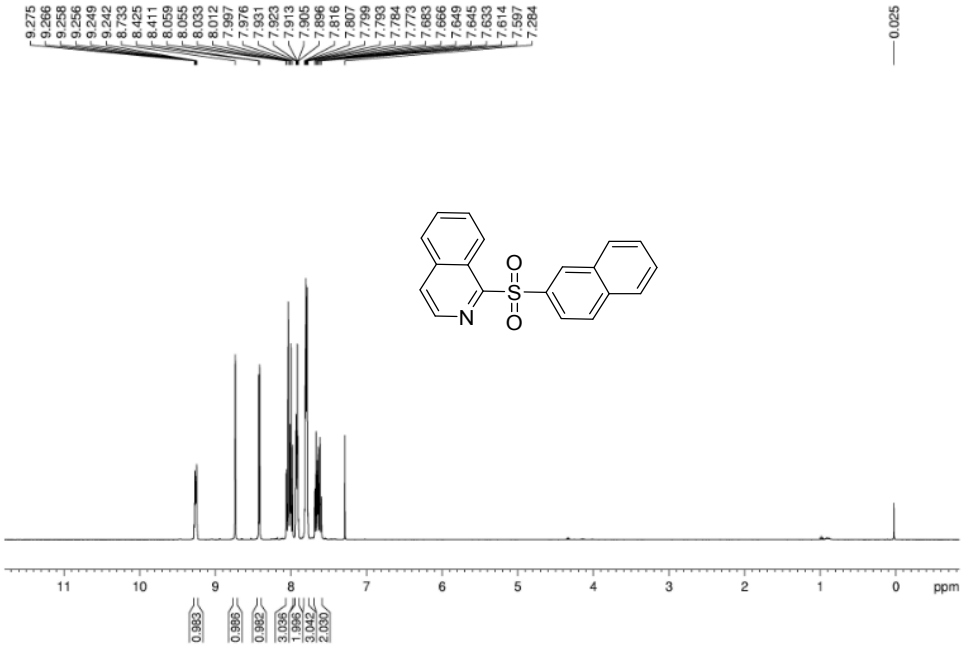


Fig. 49 ^{1}H NMR spectrum of compound **3q**

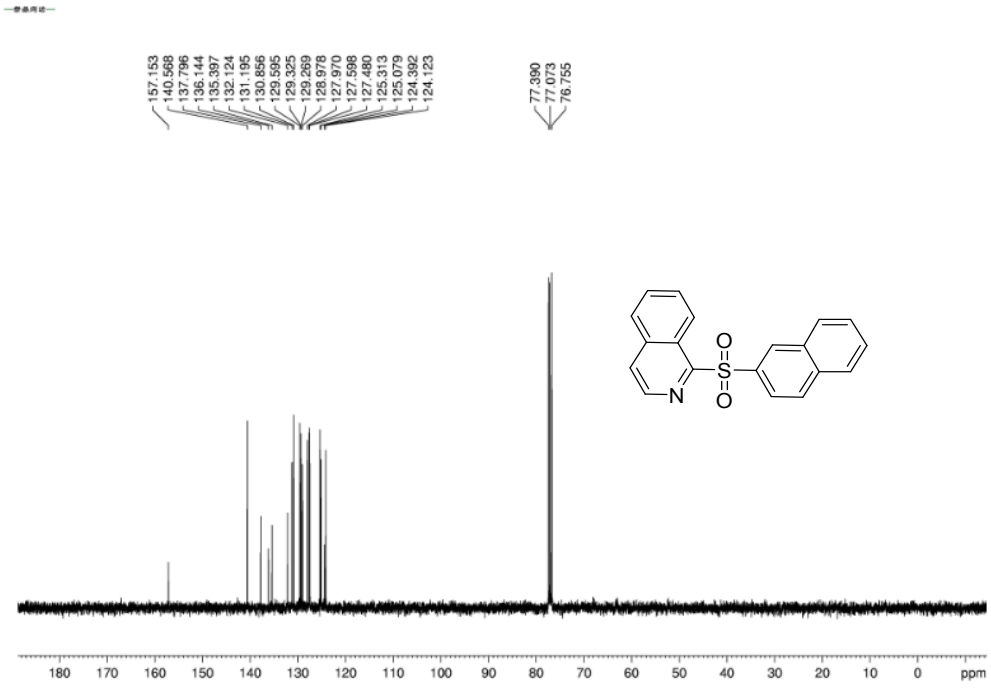


Fig. 50 ^{13}C NMR spectrum of compound **3q**

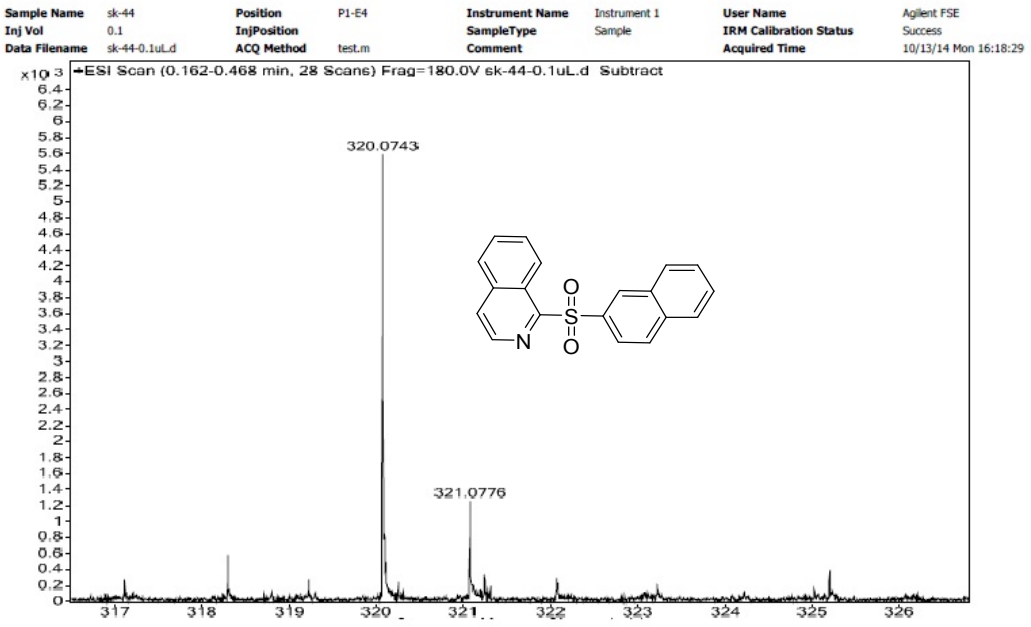


Fig. 51 HRMS spectrum of compound **3q**

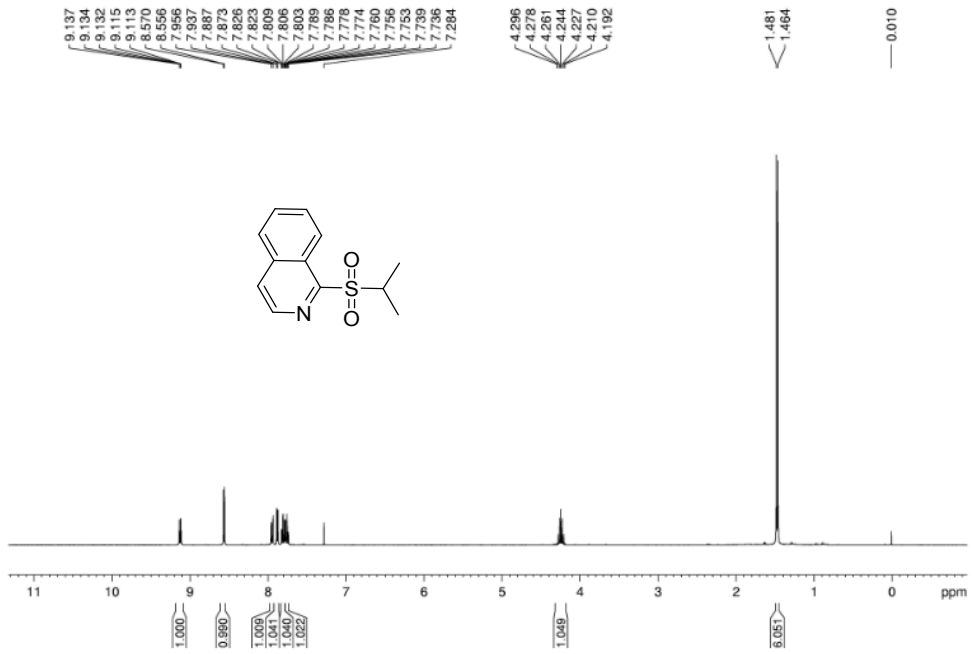


Fig. 52 ^{1}H NMR spectrum of compound **3r**

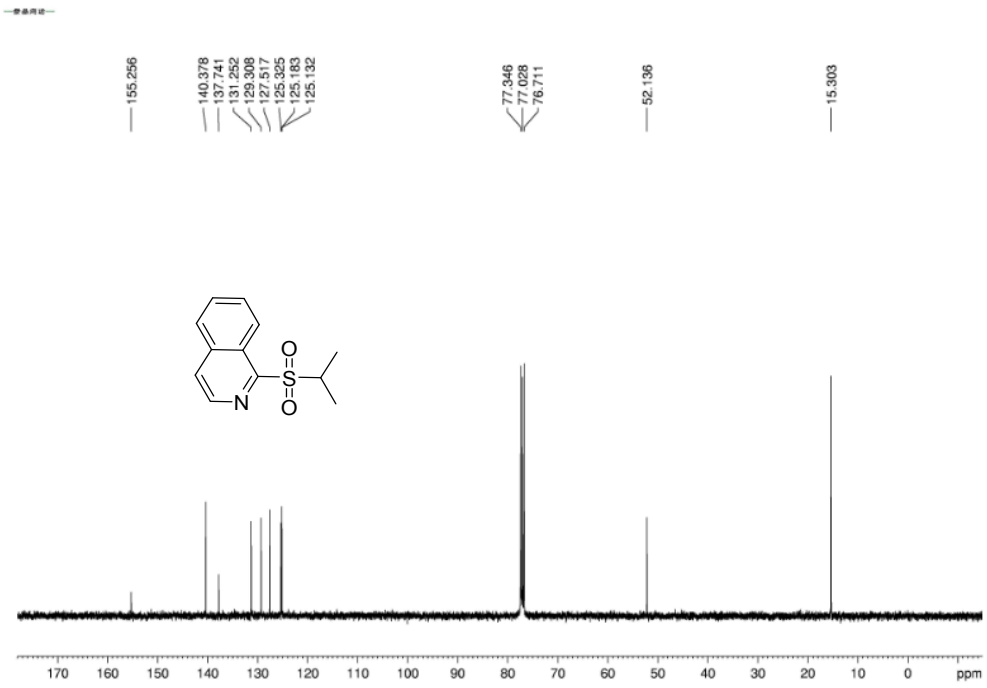


Fig. 53 ^{13}C NMR spectrum of compound **3r**

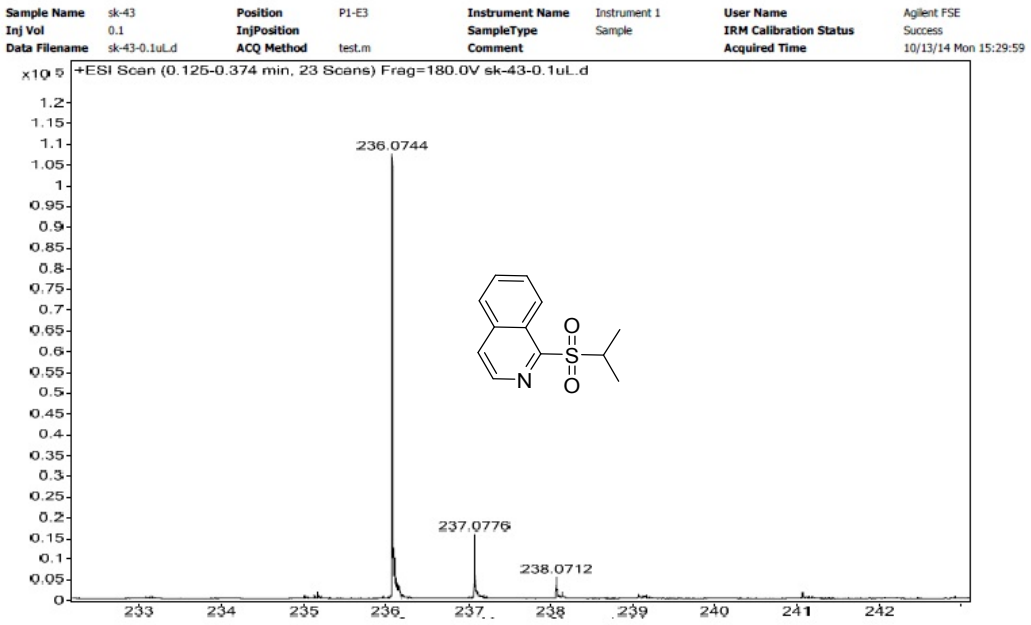


Fig. 54 HRMS spectrum of compound **3r**

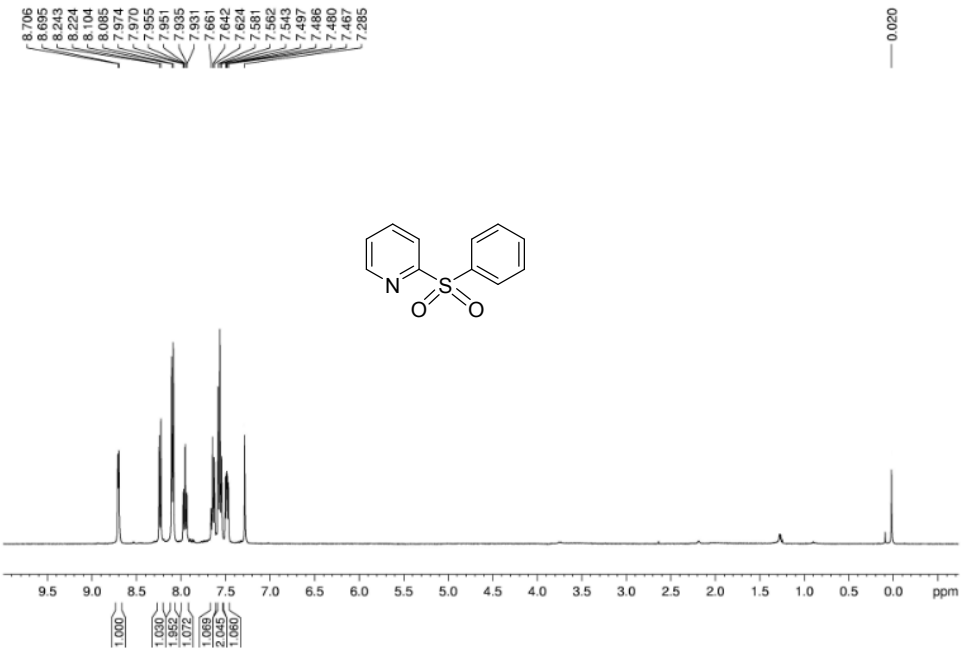


Fig. 55^{1}H NMR spectrum of compound **3s**

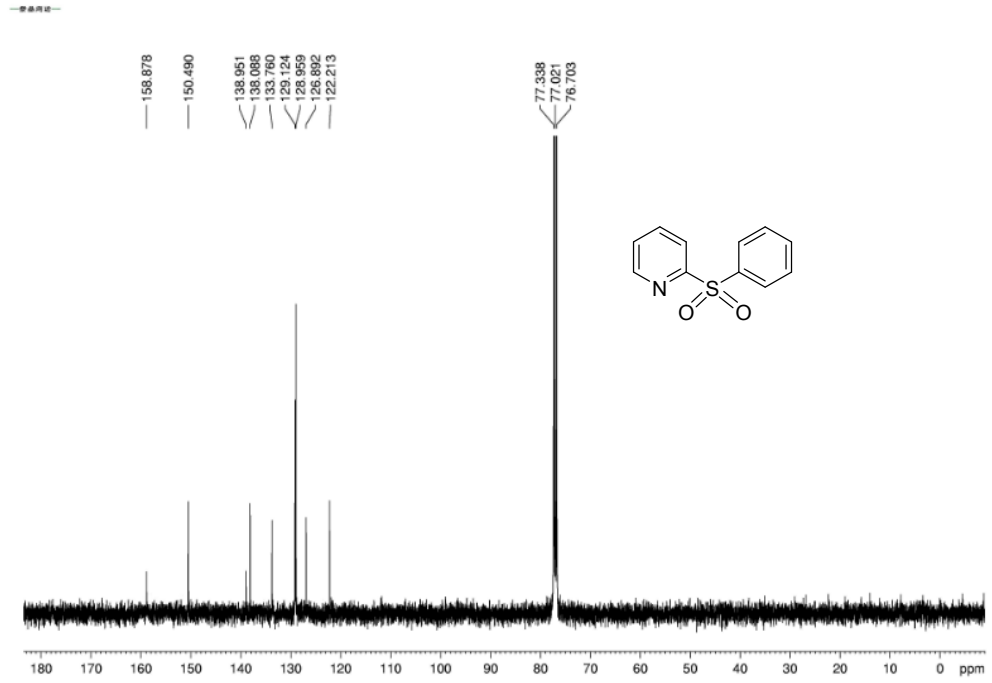


Fig. 56 ^{13}C NMR spectrum of compound **3s**

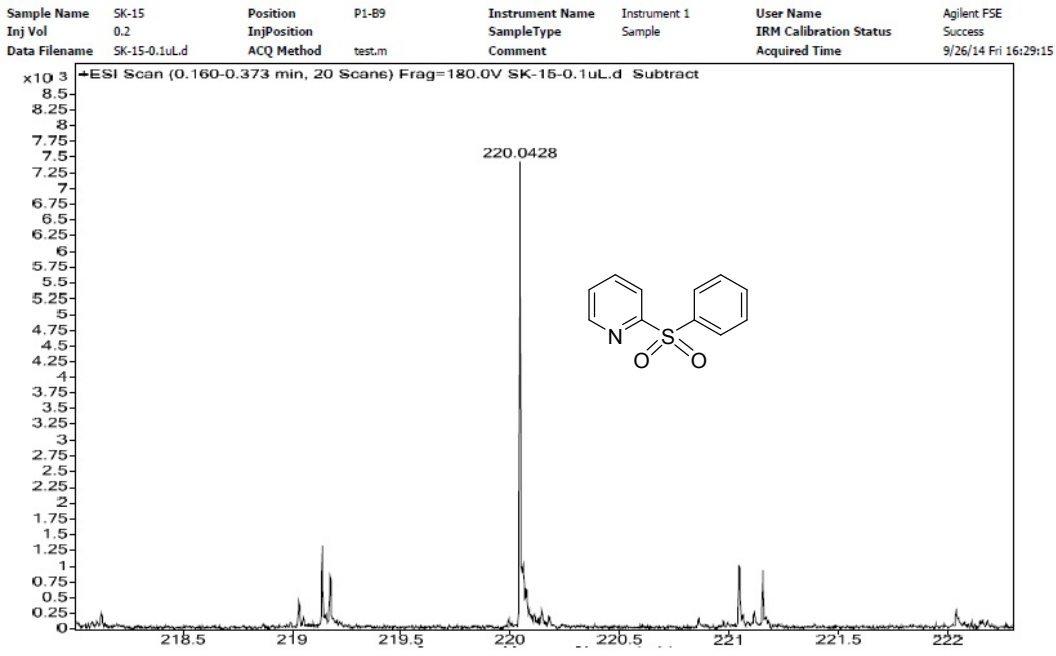


Fig. 57 HRMS spectrum of compound **3s**

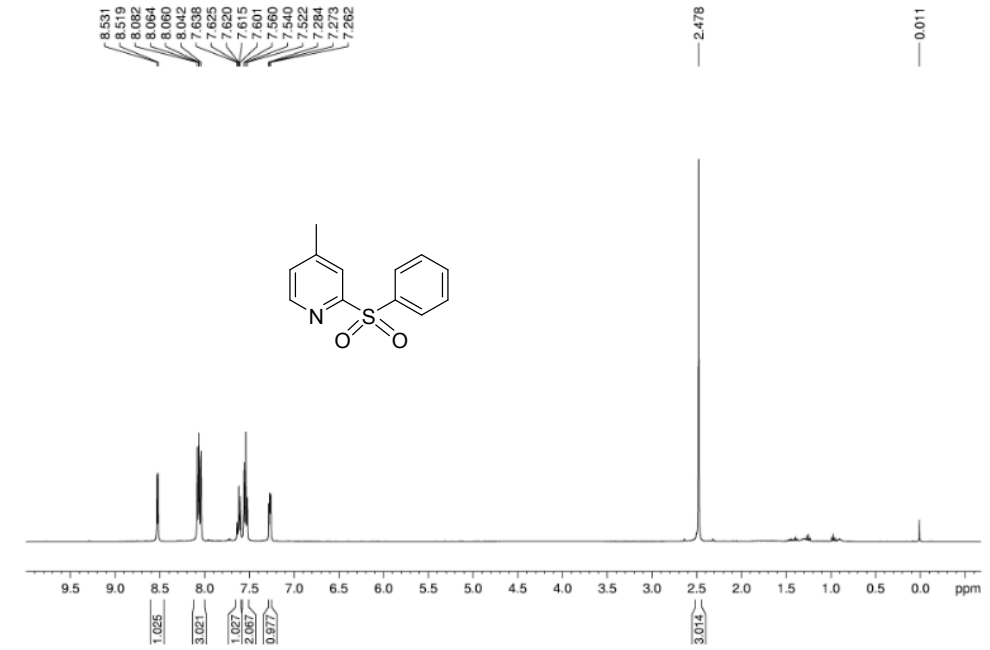


Fig. 58 [1]H NMR spectrum of compound **3t**

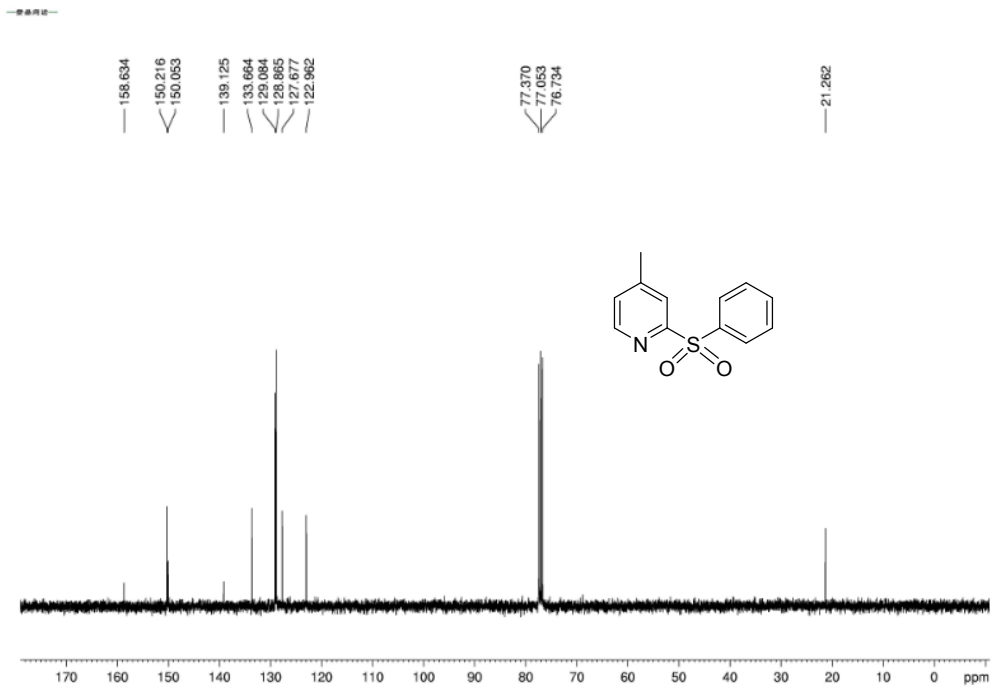


Fig. 59 [13]C NMR spectrum of compound **3t**

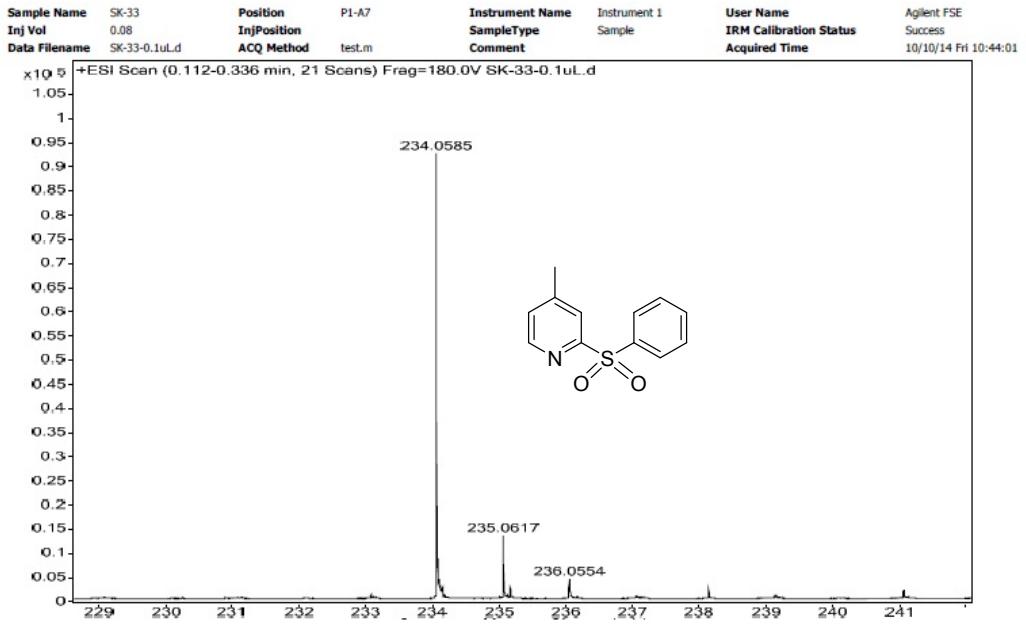


Fig. 60 HRMS spectrum of compound **3t**

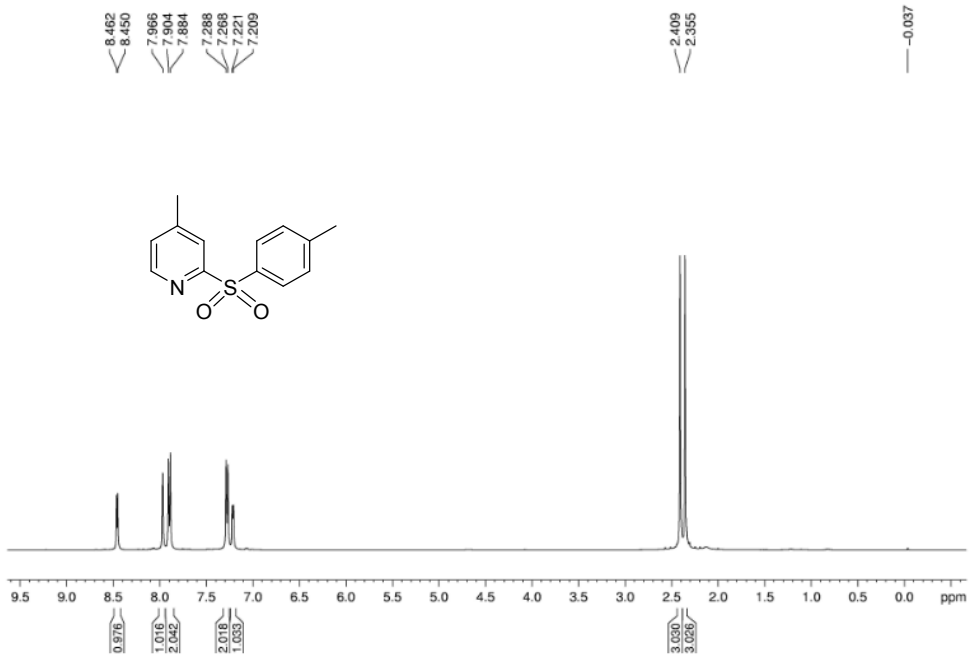


Fig. 61 ^{1}H NMR spectrum of compound **3u**

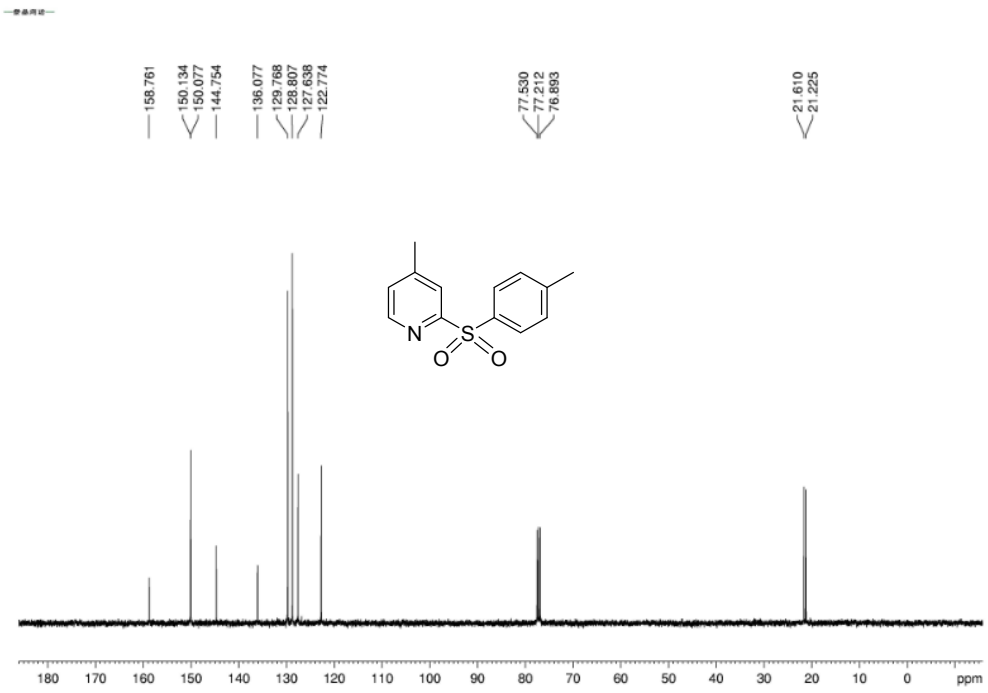


Fig. 62 ^{13}C NMR spectrum of compound **3u**

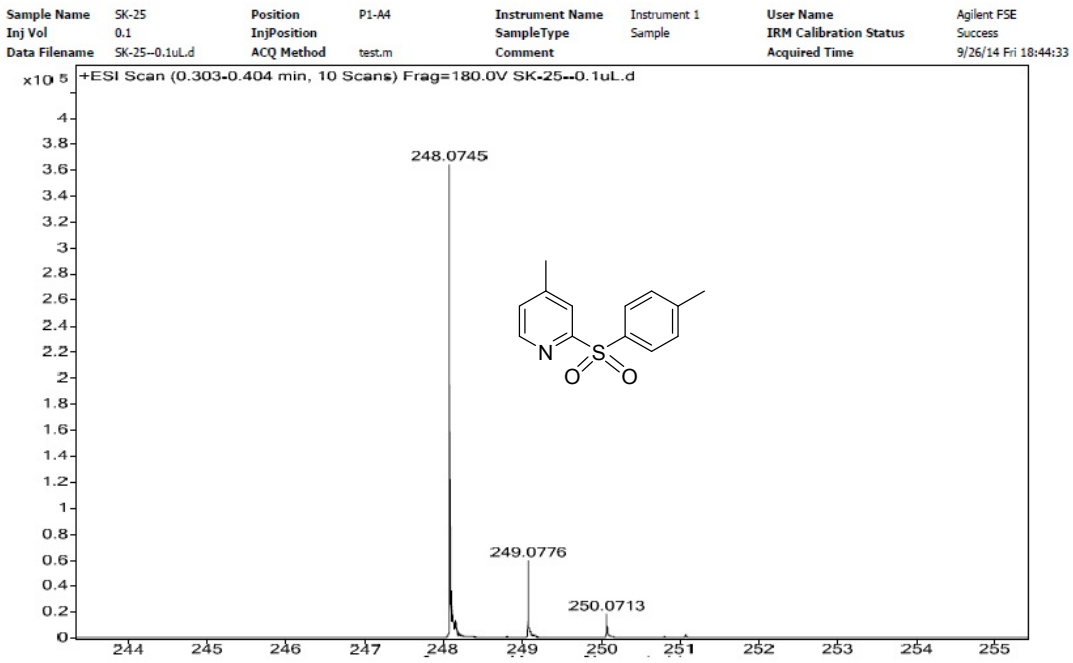


Fig. 63 HRMS spectrum of compound **3u**

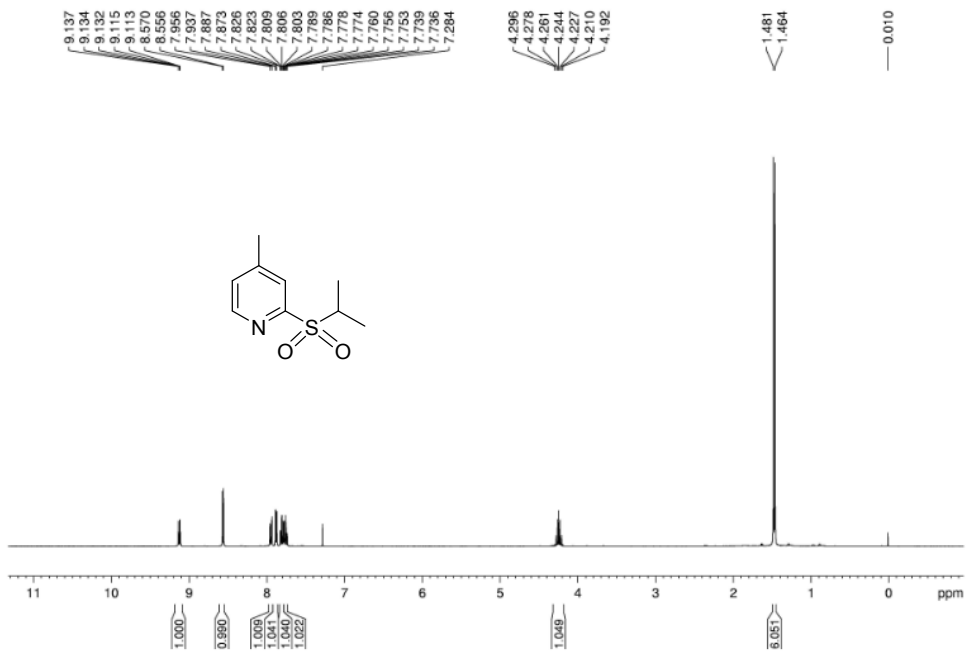


Fig. 64 ^{1}H NMR spectrum of compound **3v**

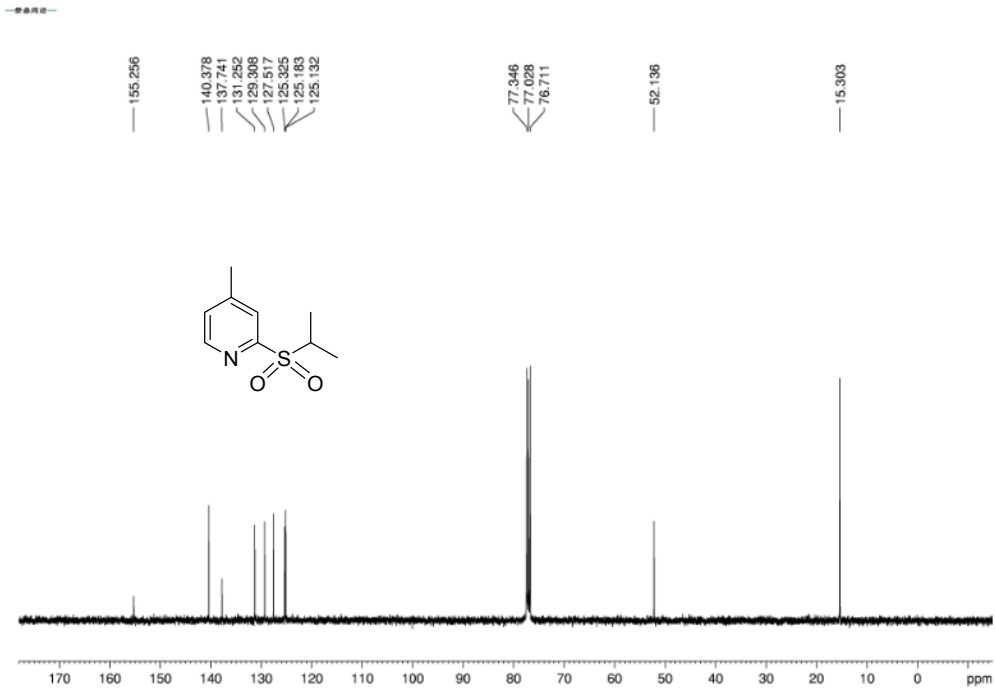


Fig. 65 ^{13}C NMR spectrum of compound **3v**

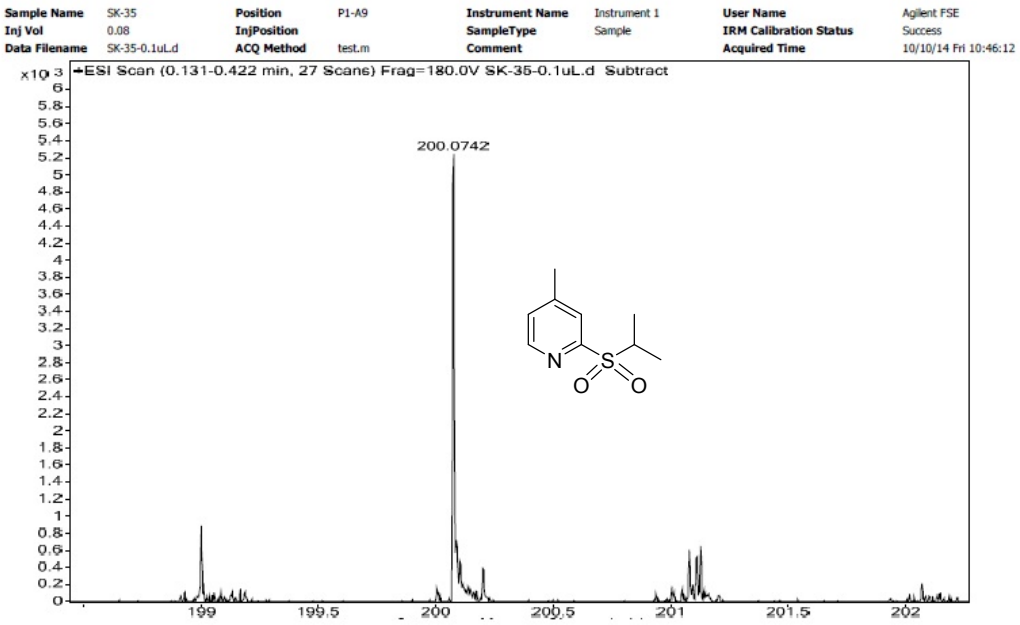


Fig. 66 HRMS spectrum of compound **3v**

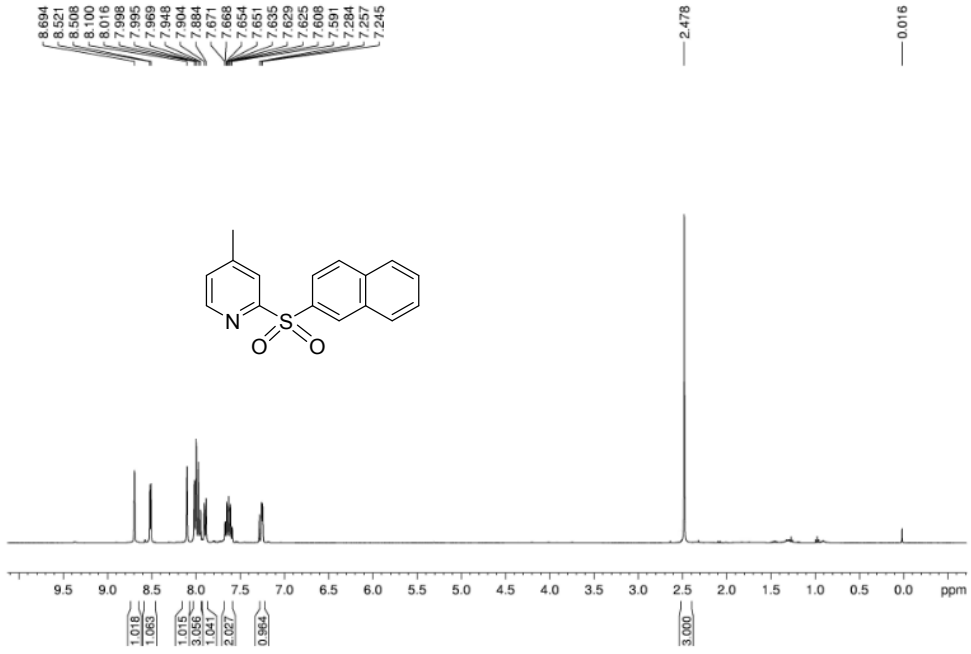


Fig. 67 ^{1}H NMR spectrum of compound **3w**

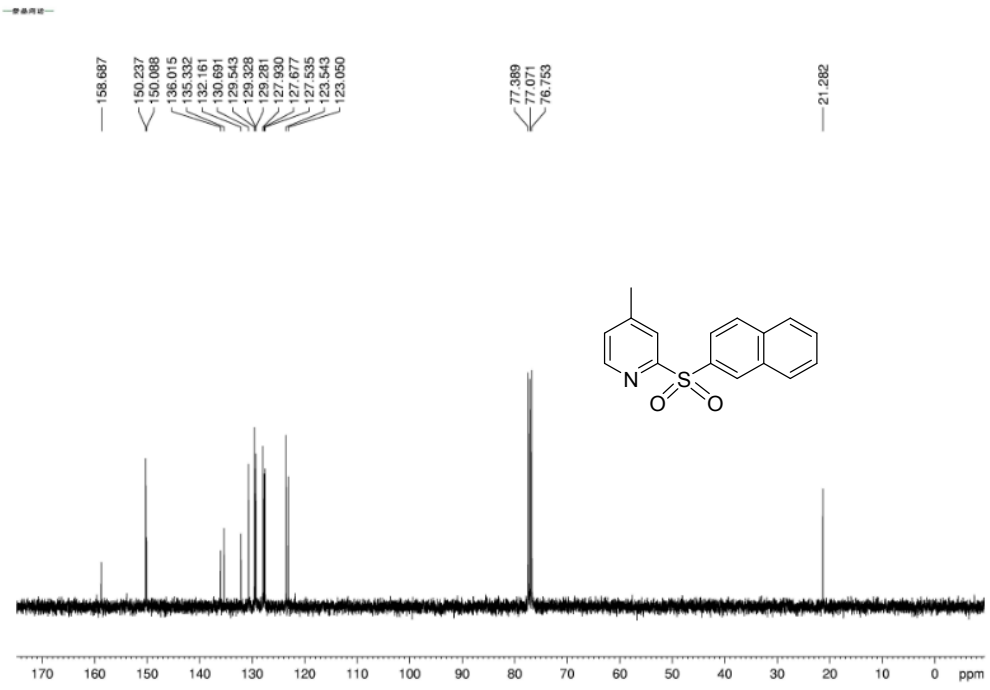


Fig. 68 ^{13}C NMR spectrum of compound **3w**

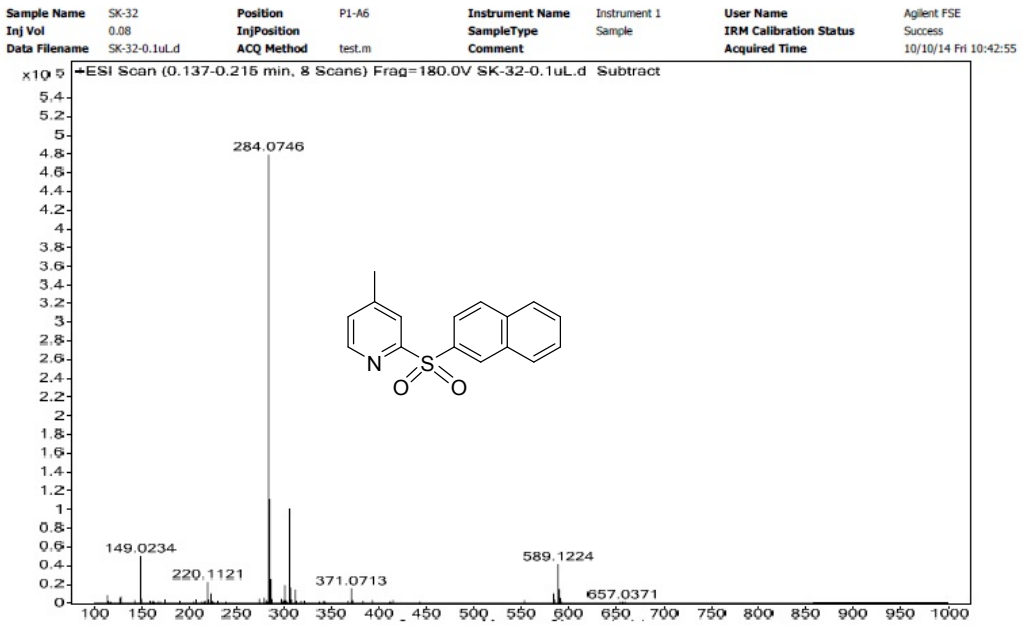


Fig. 69 HRMS NMR spectrum of compound **3w**

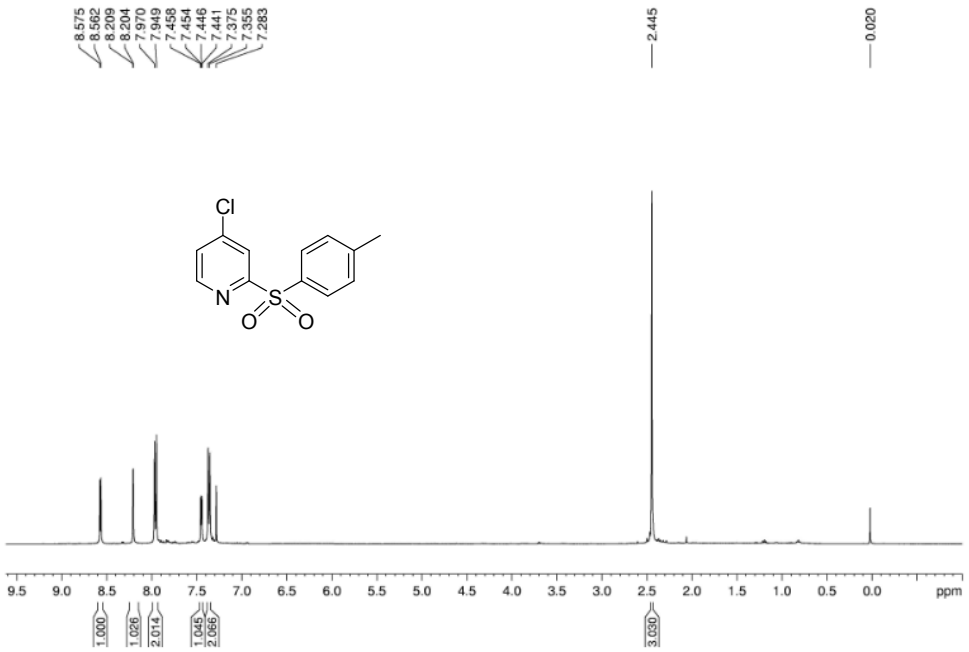


Fig. 70 ^{1}H NMR spectrum of compound **3x**

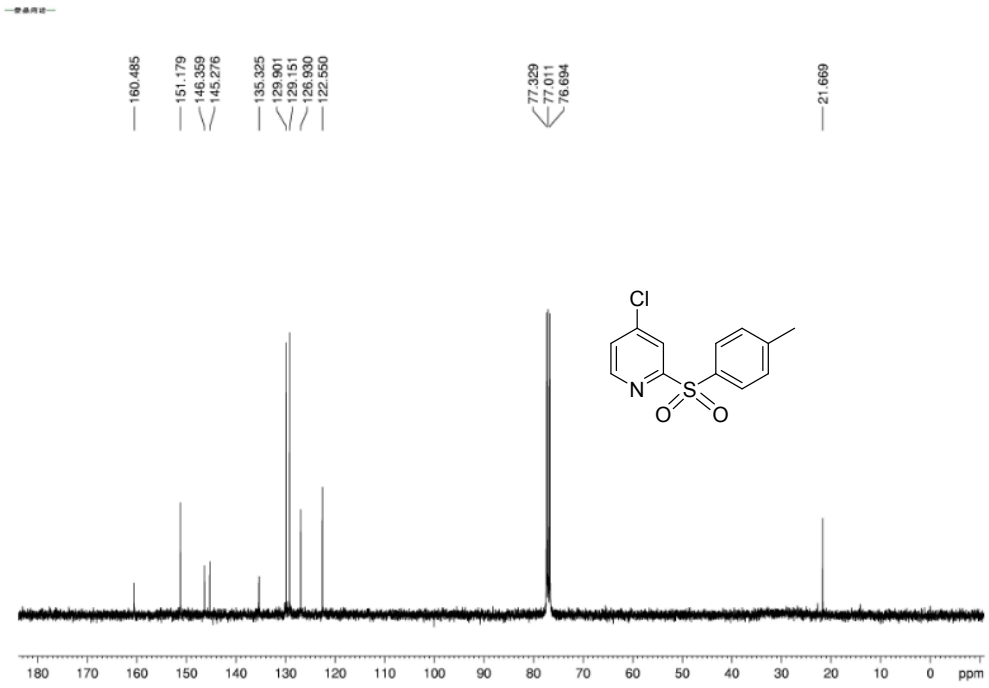


Fig. 71 ^{13}C NMR spectrum of compound **3x**

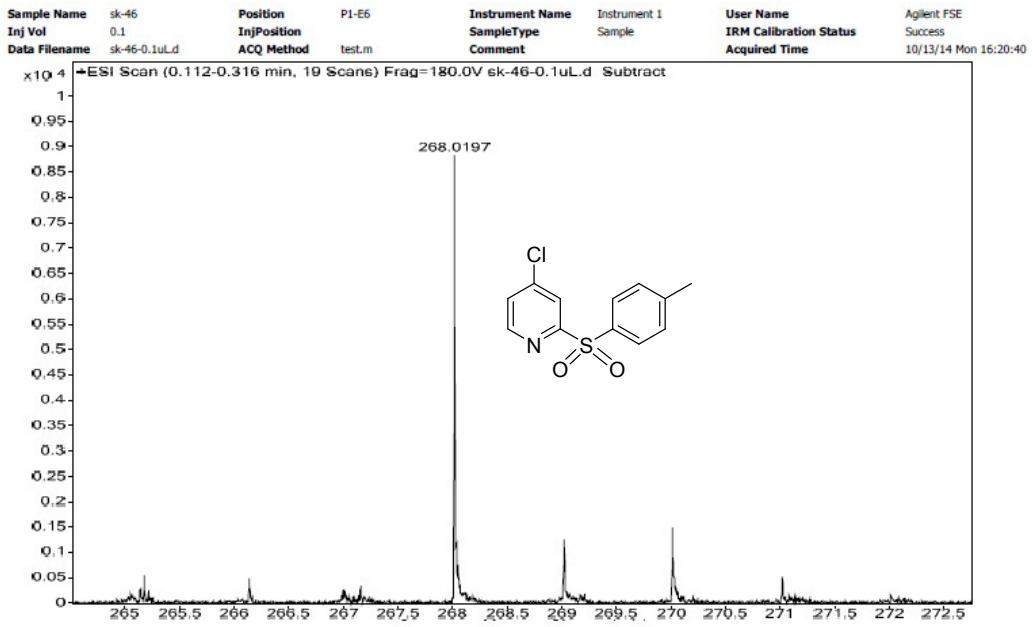


Fig. 72 HRMS spectrum of compound **3x**

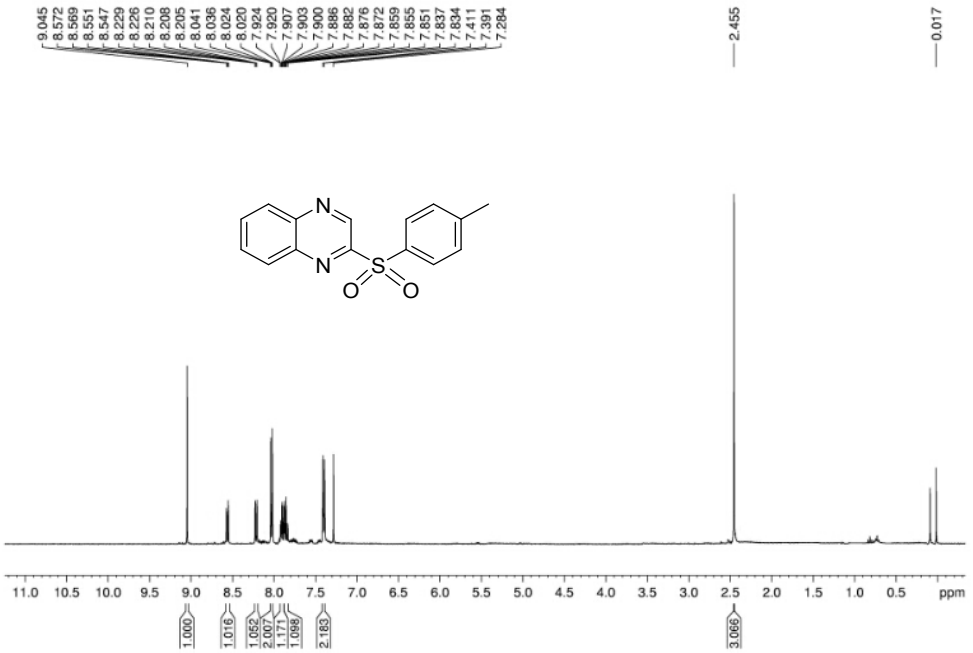


Fig. 73 ^{1}H NMR spectrum of compound **3y**

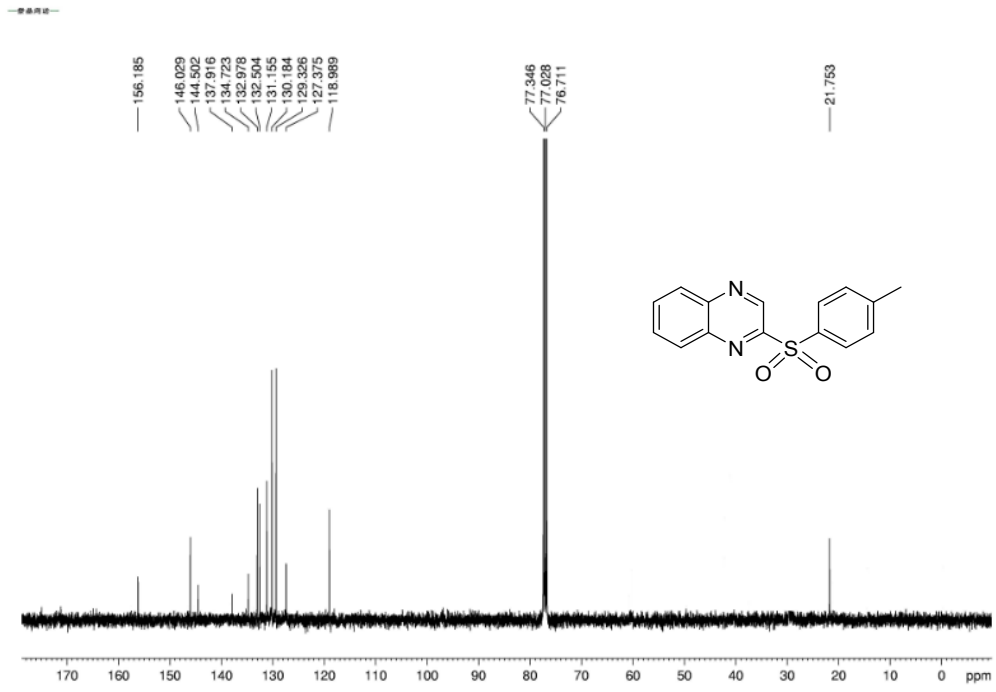


Fig. 74 ^{13}C NMR spectrum of compound **3y**

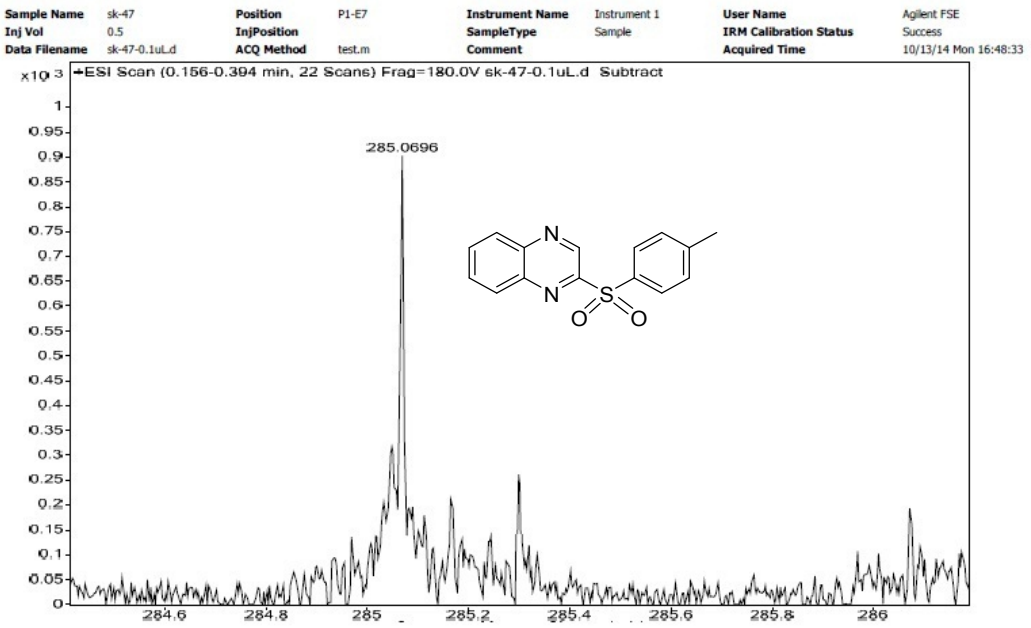


Fig. 75 HRMS spectrum of compound **3y**

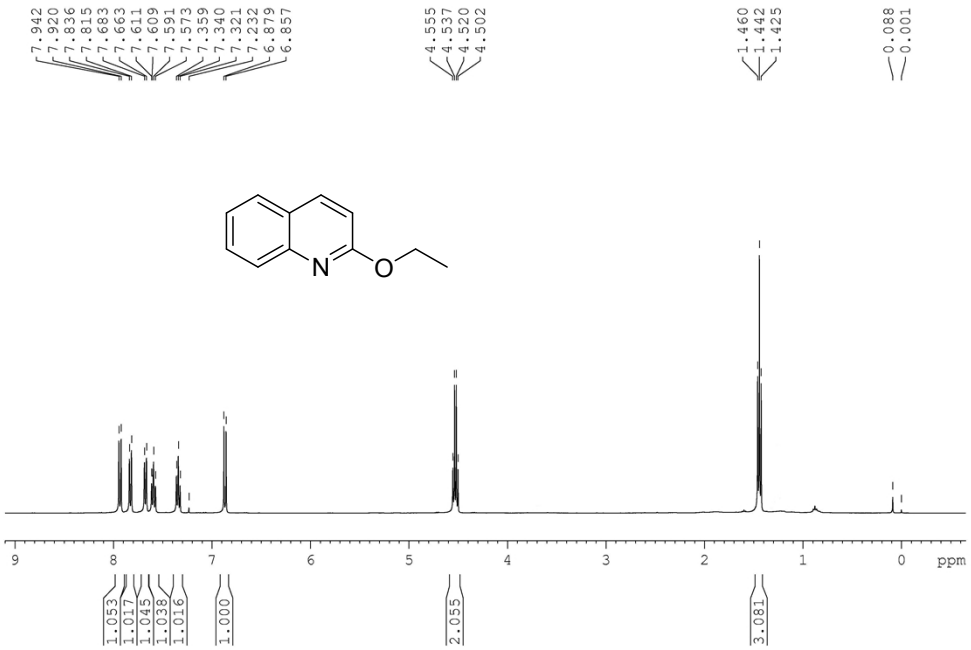


Fig. 76 ^{1}H NMR spectrum of compound **4a**

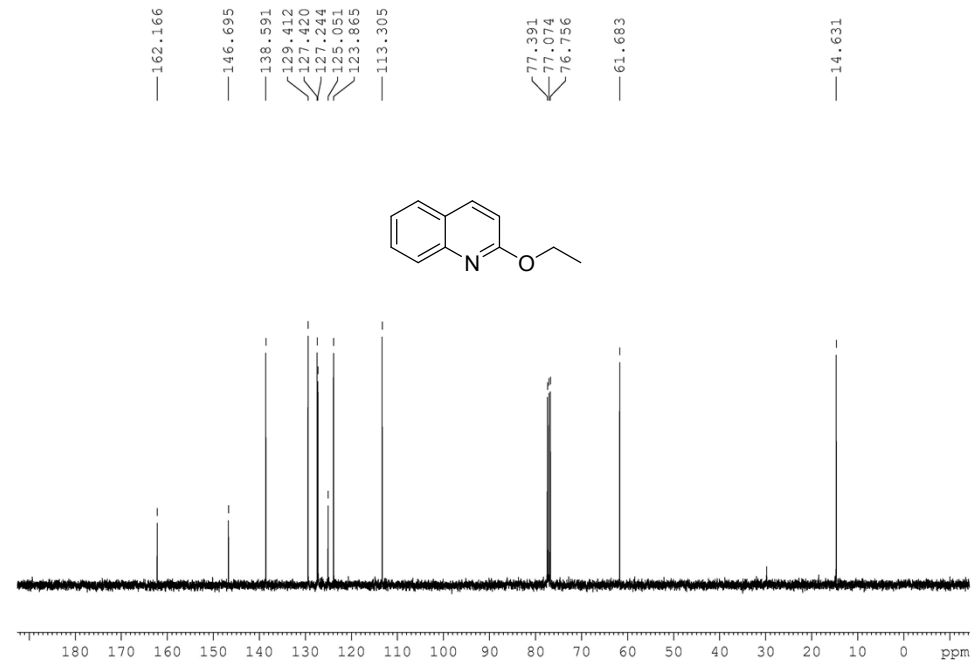


Fig. 77 ^{13}C NMR spectrum of compound **4a**

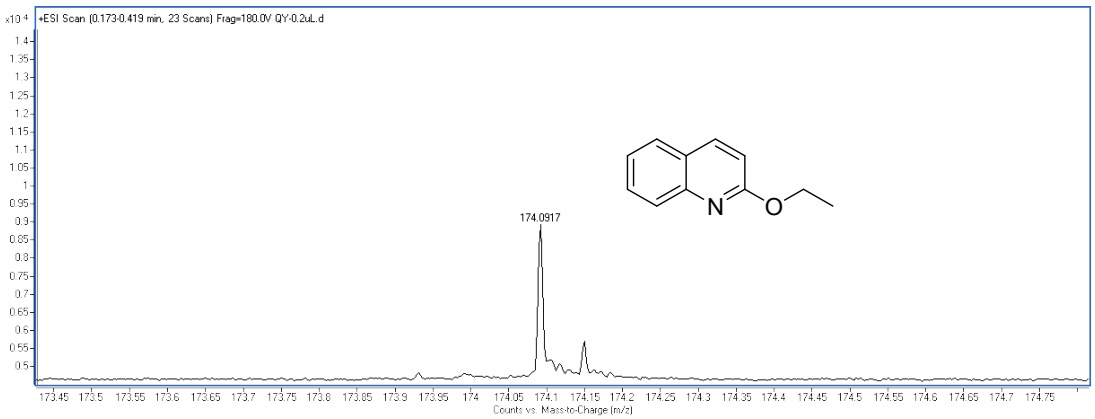


Fig. 78 HRMS spectrum of compound **4a**