Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information

Copper-catalyzed multicomponent cascade synthesis of polyfunctionalization *β*-ketone sulfones

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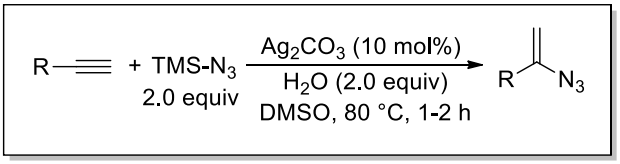
(A) General information

All chemicals were acquired from commercial sources and were employed as received unless otherwise mentioned. The reaction was monitored by TLC with silica gel plates, and the visualization was displayed under UV light (254 nm). ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra were recorded on a Bruker 400 (400, 101, and 376 MHz) or 500 (500, 126, and 471 MHz) advance spectrometer at room temperature in $CDCl_3$ (solvent signals, δ 7.26 and 77.0 ppm) or DMSO-d6 (solvent signals, δ 3.35 and 39.5 ppm) using TMS as internal standard. HRMS spectra were measured on an electrospray ionization quadrupole time-of-flight (ESI-Q-TOF) mass spectrometer.

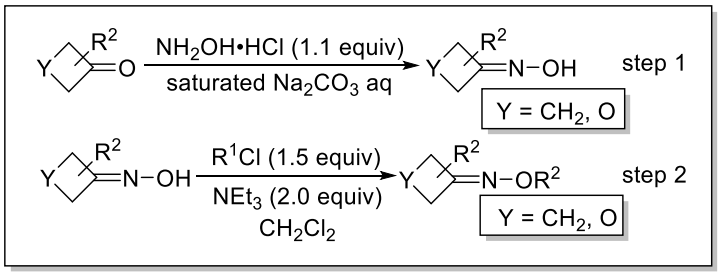
(B) Typical experimental procedures

(1) General procedure for the synthesis of vinyl azides.[1]



To a round bottom flask were added terminal alkyne (2.0 mmol), $TMSN_3$ (2.0 equiv), Ag_2CO_3 (10 mol%) and H_2O (2.0 equiv) in DMSO (5.0 mL) at 80 ^{o}C. And then the mixture stirred for 1-2 h until terminal alkyne consumed as indicated by TLC. The organic layer was washed with brine, dried over $MgSO_4$ and evaporation of the solvent. The mixture was purified by column chromatography over silica gel to afford vinyl azides (petroleum ether).

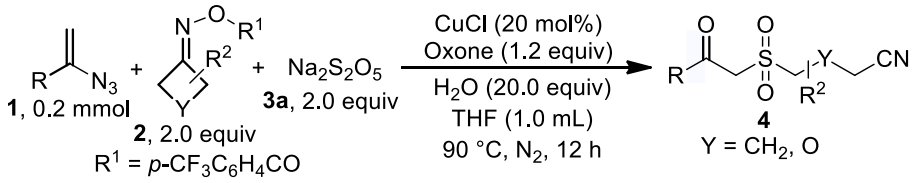
(2) General procedure for the synthesis of oxime esters.[2]



Step 1: The ketone (2.0 mmol) and hydroxylamine hydrochloride (2.2 mmol, 1.1 equiv) were placed in a round bottom flask equipped with stirrer. The pH of the solution was held at 7-8 by adding saturated aq. sodium carbonate (5.0 mL). The resulting solution was stirred at 40 ^{o}C. After extraction with ether, the solution was dried over Na_2SO_4 and evaporated to provide crude products which were used in the next step without further purification.

Step 2: To a mixture of cyclobutanone oxime (1.0 equiv), triethylamine (2.0 equiv) and DCM (5.0 mL) in a round bottom flask was slowly added R^1Cl (1.5 equiv) at 0 ^{o}C and then the mixture was stirred at room temperature for 7 h. The organic layer was washed with water and dried over Na_2SO_4. The solution was concentrated under reduced pressure, and the mixture was purified by flash column chromatography over silica gel to give oxime esters (petroleum ether/ethyl acetate = 5:1~3:1).

(3) General procedure for the synthesis of compounds 4.

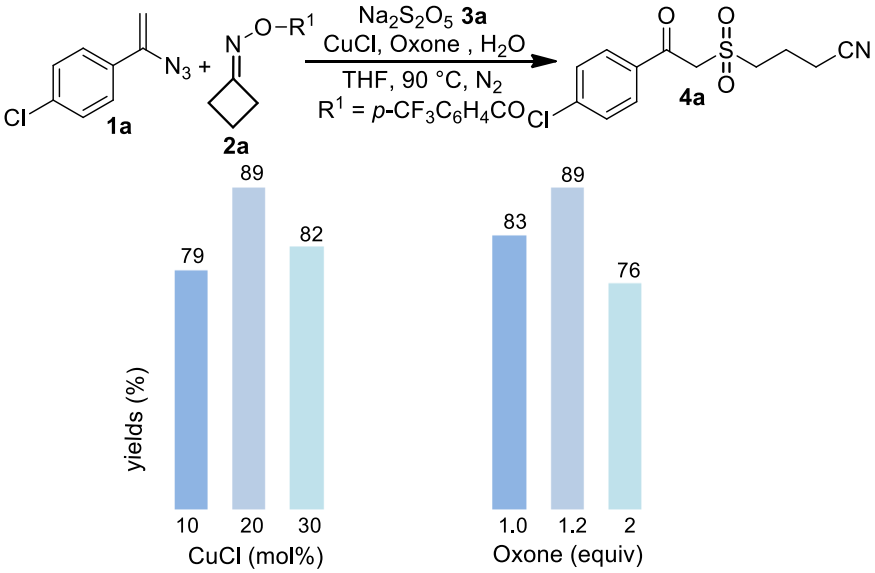


Vinyl azides (**1**, 0.2 mmol), oxime esters (**2**, 2.0 equiv), sodium pyrosulfite (**3a**, 2.0 equiv), CuCl (20 mol%), Oxone (1.2 equiv), H_2O (20.0 equiv) and THF (1.0 mL) were sequentially added to a Schlenk tube (10 mL), and the reaction mixture was

heated with stirring in N_2 at 90 °C for 12 h until complete consumption of starting material was monitored by TLC and/or GC-MS analysis. After the reaction was finished, the mixture was extracted three times with EtOAc, washed in an aqueous solution saturated with sodium bicarbonate, dried over Na_2SO_4 and evaporated under reduced pressure. The resulting mixture purified by flash column chromatography (petroleum ether/ethyl acetate = 2:1~1:1) to give the desired products **4**.

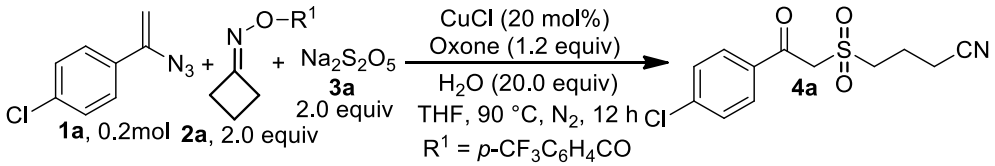
(C) Optimization

Table S1. Evaluation the amount of catalyst and oxidant



Reactions conditions: **1a** (0.2 mmol), **2a** (2.0 equiv), **3a** (2.0 equiv), CuCl, Oxone and H_2O (20.0 equiv) in THF (1.0 mL) under N_2 at 90 °C for 12

(D) Sensitivity Assessments



Standard Conditions: n = 0.2 mmol, c = 0.2 M, V = 1.0 mL, in degassed, T = 90 °C.

Stock Solution: n = 2.0 mmol, c = 0.222 M, V = 9.0 mL, **1a**: 358.1 mg, **2a**: 1028.3 mg, **3a**: 760.4 mg, CuCl: 39.6 mg, Oxone: 1475.4 mg.

Stock Solution 'big scale' : n = 6.02 mmol, c = 0.2 M, V = 30.1 mL, **1a**: 1077.7 mg, **2a**: 3095.1 mg, **3a**: 2288.9 mg, CuCl: 119.2 mg, Oxone: 4441.0 mg, H_2O: 2167.2 µL.

The method is on account of parameter variations in positive and negative direction of reference standard reaction conditions. Only one parameter is consciously changed in each experiment, while maintaining the others at the standard level. The yield of the product is determined by GC-FID analysis. The calibration of the product of the reaction was carried out using the single point calibration technique for gas chromatography (GC) analysis. The preparation of the experiments and the results of the sensitivity assessment are displayed in Tables S2 and S3.

Table S2. Preparation of sensitivity assessment of reaction.

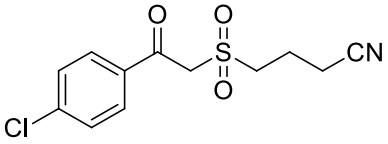
Number	Experiment	Preparation
1	High *c*	0.8 mL stock sol. +72 µL H_2O
2	Low *c*	0.8 mL stock sol. + 0.4 mL THF+72 µL H_2O
3	Low H_2O	0.8 mL stock sol. + 0.2 mL THF
4	High O_2	0.8 mL stock sol. + 0.2 mL THF +72 µL H_2O + air
5	Low O_2	0.8 mL stock sol. + 0.2 mL THF +72 µL H_2O + degassed
6	Low *T*	0.8 mL stock sol. + 0.2 mL THF +72 µL H_2O, T = 80 °C
7	High *T*	0.8 mL stock sol. + 0.2 mL THF +72 µL H_2O, T = 100 °C
8	Control	0.8 mL stock sol. + 0.2 mL THF +72 µL H_2O
9	Big Scale	40.0 mL stock solution 'big scale'

Table S3. Results of sensitivity assessment of reaction.

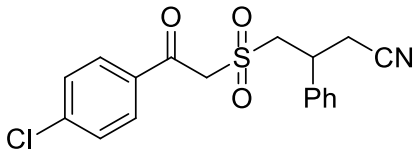
Number	Experiment	Yield / %	Deviation / %
1	High *c*	80	-10
2	Low *c*	83	-7
3	Low H_2O	56	-37
4	High O_2	35	-61
5	Low O_2	89	0
6	High *T*	84	-6
7	Low *T*	76	-15
8	Control	89	0
9	Big Scale	68	-23

(E) Analytical data

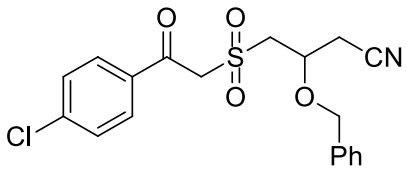
4-((2-(4-Chlorophenyl)-2-oxoethyl)suonyl)butanenit-



rile (4a).[3] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). 0.0507 g, 89% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.92 (d, J = 8.4 Hz, 2H), 7.48 (d, J = 8.4 Hz, 2H), 4.61 (s, 2H), 3.42 (t, J = 7.2 Hz, 2H), 2.62 (t, J = 7.2 Hz, 2H), 2.30-2.23 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 187.9, 141.6, 133.7, 130.6, 129.4, 118.1, 59.9, 51.8, 18.2, 16.2.

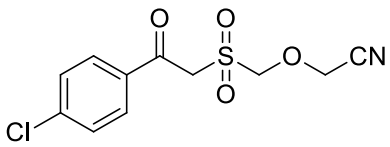


4-((2-(4-Chlorophenyl)-2-oxoethyl)sulfonyl)-3-p henylbutanenitrile (4b). The product was puri fied by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). Yellow oil (0.0585 g, 81% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.80 (d, J = 8.4 Hz, 2H), 7.45 (d, J = 8.4 Hz, 2 H), 7.38-7.30 (m, 5H), 4.44 (d, J = 15.2 Hz, 1H), 4.07 (d, J = 15.2 Hz, 1H), 3.93-3.88 (m, 1H), 3.80-3.73 (m, 1H), 3.68-3.62 (m, 1H), 2.92 (d, J = 6.4 H z, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 187.7, 141.5, 138.2, 133.7, 130.3, 129. 4, 129.3, 128.7, 127.4, 117.1, 60.3, 57.2, 36.4, 24.4; HRMS *m/z* (ESI) calcd fo r $C_{18}H_{17}ClNO_3S$ ($[M+H]^+$) 362.0612 found 362.0617.

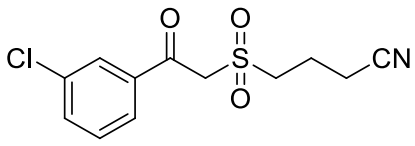


3-(Benzyloxy)-4-((2-(4-chlorophenyl)-2-oxoethyl) sulfonyl)butanenitrile (4c). The product was p urified by silica gel column chromatography wi th petroleum ether/ethyl acetate (2:1, v/v). Brown solid (0.0594 g, 76% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.74 (d, J = 8.4 Hz, 2H), 7.43 (d, J = 8.4 H

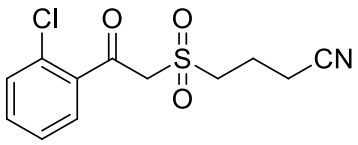
z, 2H), 7.34-7.31 (m, 5H), 4.75 (d, *J* = 10.8 Hz, 1H), 4.64 (d, *J* = 10.8 Hz, 1H), 4.58 (s, 2H), 4.43-4.37 (m, 1H), 3.95-3.89 (m, 1H), 3.44-3.39 (m, 1H), 2.86-2.80 (m, 1H), 2.78-2.72 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 187.7, 141.3, 135.8, 133.7, 130.2, 129.3, 128.7, 128.6, 128.3, 115.9, 73.0, 70.4, 61.3, 56.7, 22.7; HRMS *m/z* (ESI) calcd for $C_{19}H_{19}ClNO_4S$ ($[M+H]^+$) 392.0718, found 392.0716.



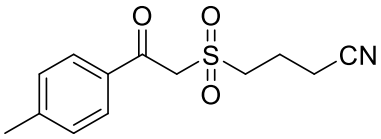
2-(((2-(4-Chlorophenyl)-2-oxoethyl)sulfonyl)methoxy)acetonitrile (4d). The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). White solid (0.0453 g, 79% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.91 (d, *J* = 8.4 Hz, 2H), 7.51 (d, *J* = 8.0 Hz, 2H), 4.83 (s, 2H), 4.70 (s, 2H), 4.66 (s, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 187.3, 141.7, 133.7, 130.4, 129.5, 114.3, 82.3, 57.4, 56.6; HRMS *m/z* (ESI) calcd for $C_{11}H_{11}ClNO_4S$ ($[M+H]^+$) 288.0092, found 288.0098.



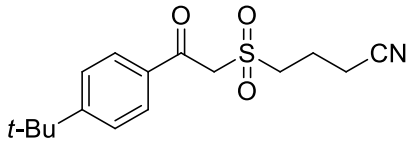
4-((2-(3-Chlorophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4e).[3] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). 0.0467 g, 82% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.94 (s, 1H), 7.85 (d, *J* = 8.0 Hz 1H), 7.61 (d, *J* = 8.0 Hz 1H), 7.46 (t, *J* = 8.0 Hz, 1H), 4.63 (s, 2H), 3.43 (t, *J* = 7.6 Hz, 2H), 2.62 (t, *J* = 7.2 Hz, 2H), 2.30-2.23 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 188.0, 136.9, 135.3, 134.6, 130.3, 128.9, 127.4, 118.2, 59.9, 51.8, 18.1, 16.2.



4-((2-(2-Chlorophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4f).[3] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). 0.0450 g, 79% yield; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.67-7.65 (m, 1H), 7.52-7.46 (m, 2H), 7.41 (t, J = 7.5 Hz 1H), 4.70 (s, 2H), 3.48 (t, J = 7.5 Hz, 2H), 2.65 (t, J = 7.5 Hz, 2H), 2.32-2.26 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 191.1, 136.9, 133.6, 131.6, 130.8, 130.5, 127.4, 118.1, 63.1, 52.2, 18.2, 16.2.

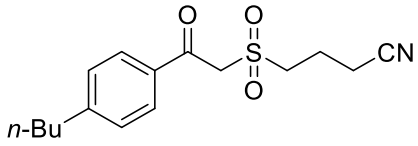


4-((2-*oxo*-2-(*p*-Tolyl)ethyl)sulfonyl)butanenitrile (4g).[3] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). 0.0414 g, 78% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.88 (d, J = 8.0 Hz, 2H), 7.31 (d, J = 8.0 Hz, 2H), 4.59 (s, 2H), 3.42 (t, J = 7.6 Hz, 2H), 2.61 (t, J = 7.2 Hz, 2H), 2.43 (s, 3H), 2.30-2.23 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 188.4, 146.2, 133.0, 129.7, 129.3, 118.1, 59.9, 51.7, 21.8, 18.2, 16.2.

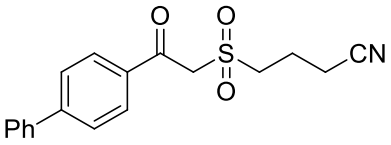


4-((2-(4-(*tert*-Butyl)phenyl)-2-oxoethyl)sulfonyl)butanenitrile (4h). The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). Yellow solid (0.0448 g, 73% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.73 (d, J = 8.0 Hz, 2H), 7.33 (d, J = 8.0 Hz, 2H), 4.40 (s, 2H), 3.24 (t, J = 7.2 Hz, 2H), 2.42 (t, J = 7.2 Hz, 2H), 2.12-2.05 (m, 2H), 1.14 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 188.4, 159.0, 132.9, 129.3, 126.1, 118.1, 59.9, 51.7, 35.3,

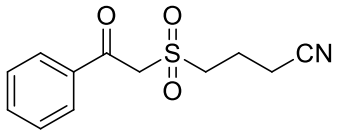
30.9, 18.3, 16.3. HRMS *m/z* (ESI) calcd for $C_{16}H_{22}NO_3S$ ($[M+H]^+$) 308.1315, f ound 308.1220.



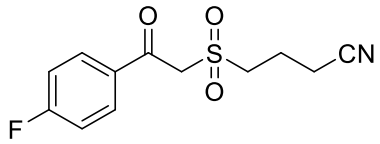
4-((2-(4-Butylphenyl)-2-oxoethyl)sulfonyl)buta nenitrile (4i). The product was purified by sil ica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). Y ellow oil (0.0442 g, 72% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.91 (d, J = 8.5 Hz, 2H), 7.33 (d, J = 8.0 Hz, 2H), 4.59 (s, 2H), 3.44 (t, J = 7.5 Hz, 2H), 2.69 (t, J = 8.0 Hz, 2H), 2.63 (t, J = 7.5 Hz, 2H), 2.32-2.26 (m, 2H), 1. 65-1.59 (m, 2H), 1.38-1.34 (m, 2H), 0.93 (t, J = 7.5 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 188.4, 151.1, 133.2, 129.4, 129.1, 118.1, 60.0, 51.7, 35.8, 33. 0, 22.3, 18.3, 16.3, 13.8; HRMS *m/z* (ESI) calcd for $C_{16}H_{22}NO_3S$ ($[M+H]^+$) 30 8.1315, found 308.1320.



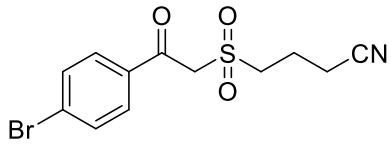
4-((2-([1,1'-Biphenyl]-4-yl)-2-oxoethyl)sulfonyl)bu tanenitrile (4j). The product was purified by sili ca gel column chromatography with petroleum et her/ethyl acetate (1:1, v/v). White solid (0.0412 g, 63% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.07 (d, J = 8.4 Hz, 2H), 7.75 (d, J = 8.4 Hz, 2H), 7.63 (d, J = 7.2 Hz, 2H), 7.51-7.41 (m, 3H), 4.65 (s, 2H), 3.46 (t, J = 7.2 Hz, 2H), 2.65 (t, J = 7.2 Hz, 2H), 2.35-2.28 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 188.4, 147.6, 139.2, 134.1, 129.9, 129.1, 128.7, 127.6, 127.3, 118.0, 60.1, 51. 7, 18.3, 16.3; HRMS *m/z* (ESI) calcd for $C_{18}H_{17}NO_3SNa$ ($[M+Na]^+$) 350.0821, found 350.0950.



4-((2-(4-Chlorophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4k).[3] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). 0.0412 g, 82% yield; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.00 (d, J = 7.0 Hz, 2H), 7.67 (t, J = 7.5 Hz, 1H), 7.54 (t, J = 8.0 Hz, 2H), 4.63 (s, 2H), 3.45 (t, J = 7.5 Hz, 2H), 2.63 (t, J = 7.0 Hz, 2H), 2.32-2.26(m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 189.0, 135.4, 134.8, 129.2, 129.0, 118.1, 59.9, 51.8, 18.2, 16.2.

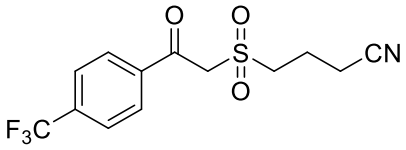


4-((2-(4-Fluorophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4l). The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). Yello oil (0.0436 g, 81% yield); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.06-8.03 (m, 2H), 7.21 (t, J = 8.5 Hz, 2H), 4.60 (s, 2H), 3.44 (t, J = 7.5 Hz, 2H), 2.64 (t, J = 7.5 Hz, 2H), 2.32-2.26 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 187.4, 166.7 (d, $J_{C\text{-}F}$ = 259.2 Hz), 132.2 (d, $J_{C\text{-}F}$ = 9.8 Hz), 132.0 (d, $J_{C\text{-}F}$ = 2.9 Hz), 118.0, 116.4 (d, $J_{C\text{-}F}$ = 22.3 Hz), 60.1, 51.7, 18.3, 16.3; ^{19}F NMR (471 MHz, $CDCl_3$) δ:-101.3; HRMS *m/z* (ESI) calcd for $C_{12}H_{13}FNO_3S$ ($[M+H]^+$) 270.0595, found 270.0591.

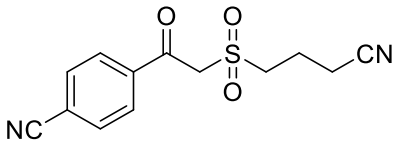


4-((2-(4-Bromophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4m).[3] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). 0.0546 g, 83% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.86 (d, J = 8.4 Hz, 2H), 7.68 (d, J = 8.4 Hz, 2H), 4.60 (s, 2H), 3.43 (t, J = 7.6 Hz, 2H), 2.64 (t, J =

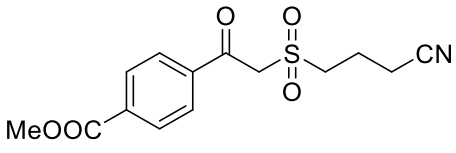
7.2 Hz, 2H), 2.33-2.25 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 188.1, 134. 1, 132.4, 130.6 (2), 118.0, 60.0, 51.7, 18.2, 16.3.



4-((2-*oxo*-2-(4-(Trifluoromethyl)phenyl)ethyl)sulfonyl)butanenitrile (4n).[3] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). 0.0536 g, 84% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.11 (d, J = 8.0 Hz, 2H), 7.78 (d, J = 8.0 Hz, 2H), 4.68 (s, 2H), 3.44 (t, J = 7.2 Hz, 2H), 2.64 (t, J = 7.2 Hz, 2H), 2.32-2.25 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 188.4, 138.0, 135.8 (m, J_{C-F} = 33.1 Hz), 129. 6, 126.1 (m, J_{C-F} = 3.6 Hz), 123.2 (m, J_{C-F} = 274.0 Hz), 118.1, 60.1, 51.8, 18. 1, 16.2; ^{19}F NMR (376 MHz, $CDCl_3$) δ: -63.3.

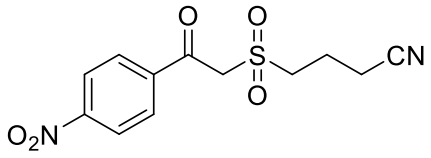


4-(2-((3-Cyanopropyl)sulfonyl)acetyl)benzonitrile (4o).[3] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (1:1, v/v). 0.0442 g, 80% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.11 (d, J = 8.0 Hz, 2H), 7.84 (d, J = 8.0 Hz, 2H), 4.64 (s, 2H), 3.43 (t, J = 7.2 Hz, 2H), 2.65 (t, J = 7.2 Hz, 2H), 2.33-2.26 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 188.0, 138.2, 132.8, 129.7, 127.8, 118.0, 117.4, 60.3, 51.8, 18.2, 16.3.

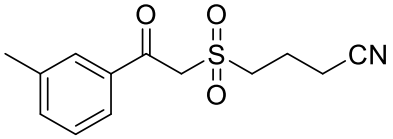


Methyl 4-(2-((3-cyanopropyl)sulfonyl)acetyl)benzoate (4p).[3] The product was purified by silica gel column chromatography with p

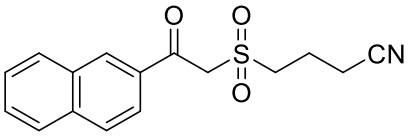
etroleum ether/ethyl acetate (2:1, v/v). 0.0532 g, 86% yield; ^{1}H NMR (400 M Hz, $CDCl_3$) δ: 8.13 (d, J = 6.4 Hz, 2H), 8.02 (t, J = 7.2 Hz, 2H), 4.68 (s, 2 H), 3.94 (s, 3H), 3.44 (t, J = 7.6 Hz, 2H), 2.63 (t, J = 6.8 Hz, 2H), 2.30-2.2 3 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 188.7, 165.7, 138.3, 135.2, 130.0, 129.1, 118.1, 60.0, 52.6, 51.7, 18.1, 16.2.



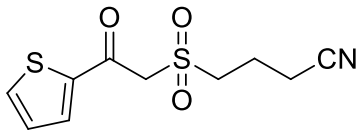
4-((2-(4-Nitrophenyl)-2-oxoethyl)sulfonyl)buta nenitrile (4q).[3] The product was purified by silica gel column chromatography with petrol eum ether/ethyl acetate (1:1, v/v). 0.0468 g, 79% yield; ^{1}H NMR (400 MHz, DMSO-d6) δ: 8.39 (d, J = 8.8 Hz, 2H), 8.28 (d, J = 8.8 Hz, 2H), 5.31 (s, 2 H), 3.44 (t, J = 8.0 Hz, 2H), 2.71 (t, J = 7.2 Hz, 2H), 2.51-2.50 (m, 2H), 2. 12-2.05 (m, 2H); ^{13}C NMR (101 MHz, DMSO-d6) δ: 189.3, 150.5, 140.3, 130. 5, 123.9, 119.7, 59.8, 52.1, 17.8, 15.3.



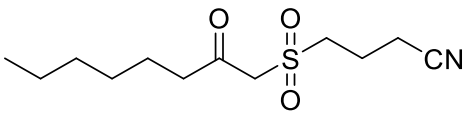
4-((2-*oxo*-2-(*m*-Tolyl)ethyl)sulfonyl)butanenitrile (4r). The product was purified by silica gel c olumn chromatography with petroleum ether/eth yl acetate (2:1, v/v). Yellow solid (0.0387 g, 73% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.79 (s, 1H), 7.77-7.72 (m, 1H), 7.50-7.46 (m, 1H), 7.42 (t, J = 7. 6 Hz, 1H), 4.61 (s, 2H), 3.45 (t, J = 7.2 Hz, 2H), 2.64 (t, J = 7.2 Hz, 2H), 2.44 (s, 3H), 2.33-2.26 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 189.1, 139.1, 135.7, 135.5, 129.6, 128.9, 126.5, 118.0, 60.0, 51.8, 21.3, 18.3, 16.3. HRMS *m/z* (ESI) calcd for $C_{13}H_{15}NO_3SNa$ ($[M+Na]^+$) 288.0665, found 288.0668.



4-((2-(Naphthalen-2-yl)-2-oxoethyl)sulfonyl)butanenitrile (4s).[3] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). 0.0434 g, 72% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.75 (d, J = 8.4 Hz, 1H), 8.10-8.05 (m, 2H), 7.91 (d, J = 8.0 Hz, 1H), 7.66 (t, J = 7.2 Hz, 1H), 7.58-7.55 (m, 2H), 4.72 (s, 2H), 3.51 (t, J = 7.6 Hz, 2H), 2.63 (t, J = 7.2 Hz, 2H), 2.33-2.25 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 191.2, 142.1, 135.3, 133.9, 132.9, 131.1, 129.1, 128.7, 127.0, 125.3, 124.3, 118.1, 62.6, 51.9, 18.3, 16.3.

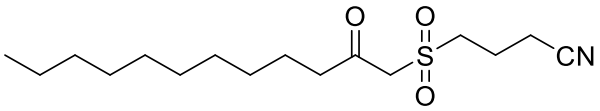


4-((2-*oxo*-2-(Thiophen-2-yl)ethyl)sulfonyl)butanenitrile (4t). The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). Brown solid (0.0380 g, 74% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.85 (t, J = 4.0 Hz, 2H), 7.23 (t, J = 4.4 Hz, 1H), 4.53 (s, 2H), 3.45 (t, J = 7.6 Hz, 2H), 2.65 (t, J = 7.2 Hz, 2H), 2.34-2.27 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 180.9, 142.7, 137.5, 135.6, 129.0, 118.0, 61.0, 51.6, 18.3, 16.3; HRMS *m/z* (ESI) calcd for $C_{10}H_{12}NNaO_3S_2$ ($[M+Na]^+$) 280.0073, found 280.0076.

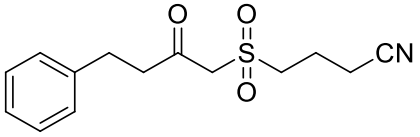


4-((2-Oxooctyl)sulfonyl)butanenitrile (4u). The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). Yellow oil (0.0394 g, 76% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.03 (s, 2H), 3.32 (t,

J = 7.6 Hz, 2H), 2.69 (t, *J* = 7.2 Hz, 2H), 2.62 (t, *J* = 7.2 Hz, 2H), 2.29-2.22 (m, 2H), 1.62-1.57 (m, 4H), 1.33-1.27 (m, 4H), 0.88 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) *δ*: 199.5, 117.9, 63.2, 51.5, 45.1, 31.4, 28.4, 22.9, 22.4, 18.2, 16.3, 14.0; HRMS *m/z* (ESI) calcd for $C_{12}H_{22}NO_3S$ ($[M+H]^+$) 260.1315, found 260.1311.

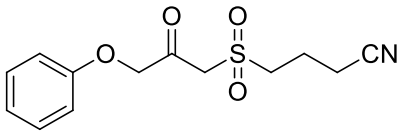


4-((2-Oxododecyl)sulfonyl)butanenitrile (4v). The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). White solid (0.0466 g, 74% yield); ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 3.98 (s, 2H), 3.25 (t, *J* = 7.2 Hz, 2H), 2.62 (t, *J* = 7.2 Hz, 2H), 2.56 (t, *J* = 7.2 Hz, 2H), 2.21-2.14 (m, 2H), 1.54 (t, *J* = 6.4 Hz, 2H), 1.26-1.18 (m, 14H), 0.81 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) *δ*: 199.5, 118.0, 63.1, 51.5, 45.0, 31.8, 29.5, 29.3, 29.2 (2), 28.7, 22.9, 22.6, 18.2, 16.2, 14.1; HRMS *m/z* (ESI) calcd for $C_{16}H_{30}NO_3S$ ($[M+H]^+$) 316.1941, found 316.1947.

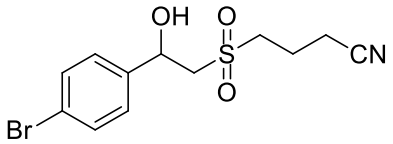


4-((2-*oxo*-4-Phenylbutyl)sulfonyl)butanenitrile (4w). The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). Yellow oil (0.0368 g, 66% yield); ^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 7.23 (t, *J* = 6.8 Hz, 2H), 7.18-7.13 (m, 3H), 3.96 (s, 2H), 3.16 (t, *J* = 7.6 Hz, 2H), 3.00 (t, *J* = 7.2 Hz, 2H), 2.89 (t, *J* = 7.2 Hz, 2H), 2.52 (t, *J* = 7.2 Hz, 2H), 2.17-2.10 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) *δ*: 198.5, 139.7, 128.6, 128.4, 126.4, 118.0, 63.6, 51.4, 46.2, 29.0, 18.1, 16.2; HRMS *m/z* (ESI) calcd for $C_{14}H_{17}NNaO_3S$

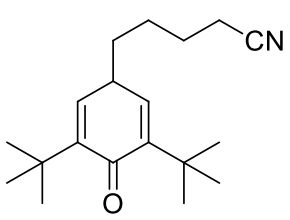
([M+Na]$^+$) 302.0821, found 302.0821.



4-((2-*oxo*-3-Phenoxypropyl)sulfonyl)butanenitrile (4x). The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). Yellow oil (0.0315 g, 56% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.31 (t, J = 7.6 Hz, 2H), 7.03 (t, J = 7.2 Hz, 1H), 6.90 (d, J = 8.0 Hz, 2H), 4.75 (s, 2H), 4.30 (s, 2H), 3.35 (t, J = 7.6 Hz, 2H), 2.60 (t, J = 7.2 Hz, 2H), 2.50-2.18 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 196.4, 156.9, 129.8, 122.3, 118.1, 114.5, 72.8, 59.7, 51.9, 18.0, 16.1; HRMS *m/z* (ESI) calcd for $C_{13}H_{16}NO_4S$ ([M+H]$^+$) 282.0795, found 282.0797.

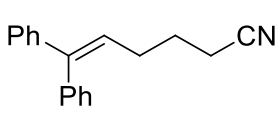


4-((2-(4-Bromophenyl)-2-hydroxyethyl)sulfonyl)butanenitrile (7a). The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). 0.0530 g, 80% yield; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.51 (d, J = 8.5 Hz, 2H), 7.25 (d, J = 8.5 Hz, 2H), 5.27 (d, J = 10.5 Hz, 1H), 3.44-3.39 (m, 2H), 3.39-3.28 (m, 2H), 3.08 (d, J = 14.5 Hz, 1H), 2.61 (t, J = 7.0 Hz, 2H), 2.25-2.20 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 140.0, 132.0, 127.3, 122.5, 118.3, 68.5, 61.0, 52.8, 18.1, 16.3; HRMS *m/z* (ESI) calcd for $C_{12}H_{15}BrNO_3S$ ([M+H]$^+$) 331.9951, found 331.9953.

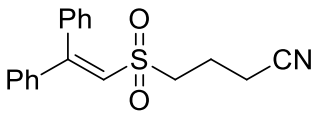


5-(3,5-di-*tert*-Butyl-4-oxocyclohexa-2,5-dien-1-yl)pentanenitrile (9a).[4] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate

(10:1, v/v). 0.0385 g, 67% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 6.36 (s, 2H), 2.26 (t, J = 6.8 Hz, 2H), 1.71 (t, J = 8.4 Hz, 2H), 1.39-1.25 (m, 5H), 1.20 (s, 18H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 186.1, 147.2, 145.3, 119.1, 39.7, 39.5, 34.6, 29.4, 27.2, 20.8, 17.2.



6,6-Diphenylhex-5-enenitrile (10a).[5] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (6:1, v/v). 0.0129 g, 26% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.37 (t, J = 7.6 Hz, 3H), 7.21 (t, J = 10.4 Hz, 5H), 7.15 (d, J = 7.6 Hz, 2H), 6.00 (t, J = 7.6 Hz, 1H), 2.31-2.23 (m, 4H), 1.83-1.75 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 143.8, 142.1, 139.6, 129.7, 128.4, 128.2, 127.2 (2), 126.6, 125.8, 119.5, 28.7, 25.7, 16.7.



4-((2,2-Diphenylvinyl)sulfonyl)butanenitrile (11a).[5] The product was purified by silica gel column chromatography with petroleum ether/ethyl acetate (2:1, v/v). 0.0299 g, 48% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.51-7.46 (m, 4H), 7.42-7.38 (m, 4H), 7.30 (t, J = 6.8 Hz, 2H), 6.82 (s, 1H), 2.89 (t, J = 7.2 Hz, 2H), 2.50 (t, J = 7.2 Hz, 2H), 2.15-2.08 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ: 156.7, 143.8, 138.8, 135.3, 130.7, 129.7, 128.8, 128.7, 128.4, 125.8, 118.1, 52.7, 18.8, 16.2.

(F) References

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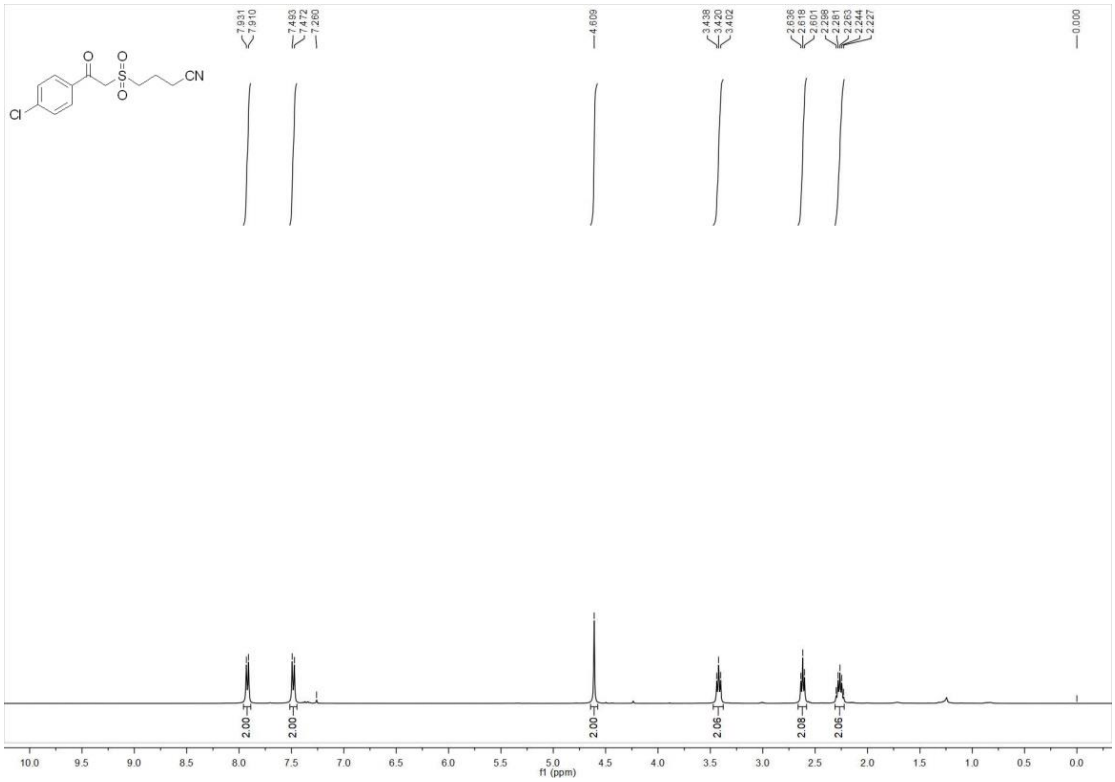
[5] a) N. Zhou, X. Wu, K. Kuang, Z. Xia, Q. Xu and M., Zhang, A Photored ox- or Metal-Catalyzed Three-Component Cyanoalkylsulfonylation Reaction of 1-(allyloxy)-2-(1-arylvinyl)benzenes, Potassium Metabisulfite, and Cycloketone Oxime Esters: Synthesis of Cyanoalkylsulfonylated Benzoxepines, *Org. Chem.*

Front., 2021, **8**, 6032-6037. b) X. Zheng, T. Zhong, X. Yi, Q. Shen, C. Yin, L. Zhang, J. Zhou, J. Chen and C. Yu, Iron-Catalyzed Three-Component Cyan oalkylsulfonylation of 2,3-Allenoic Acids, Sulfur Dioxide, and Cycloketone Ox ime Esters: Access to Cyanoalkylsulfonylated Butenolides, *Adv. Synth. Catal.*, 2021, **363**, 3359-3364.

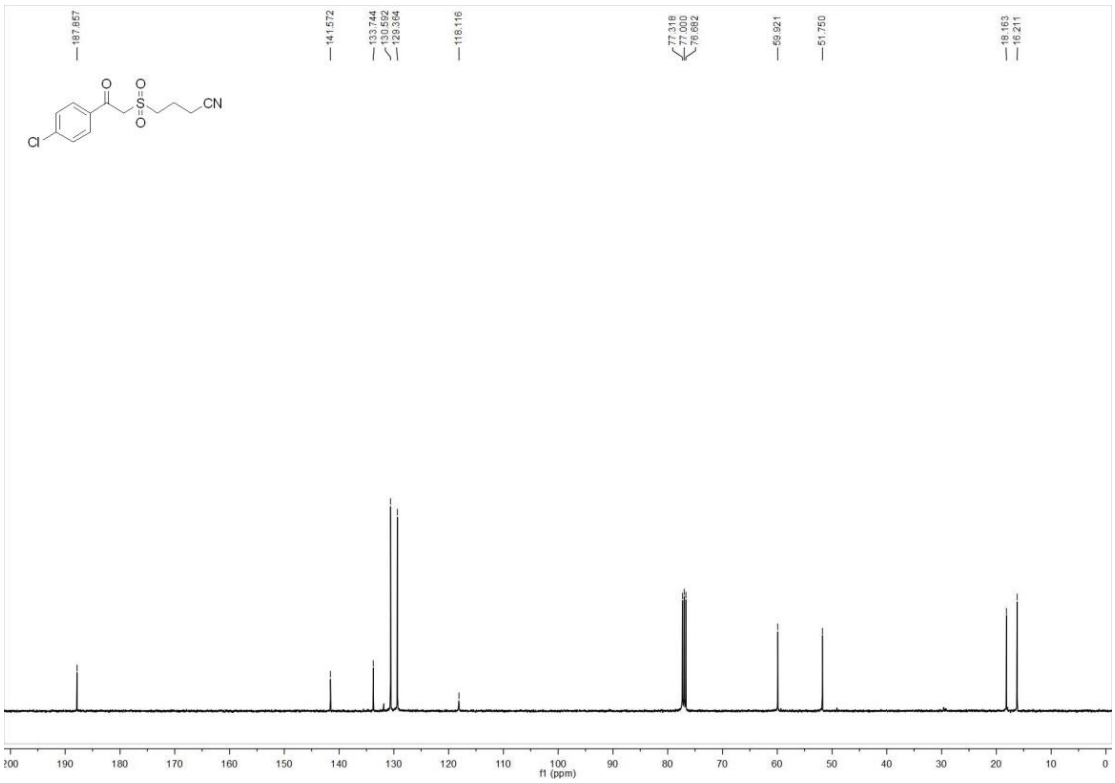
(G) Spectra

4-((2-(4-Chlorophenyl)-2-oxoethyl)suonyl)butanenitrile (4a)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4a**

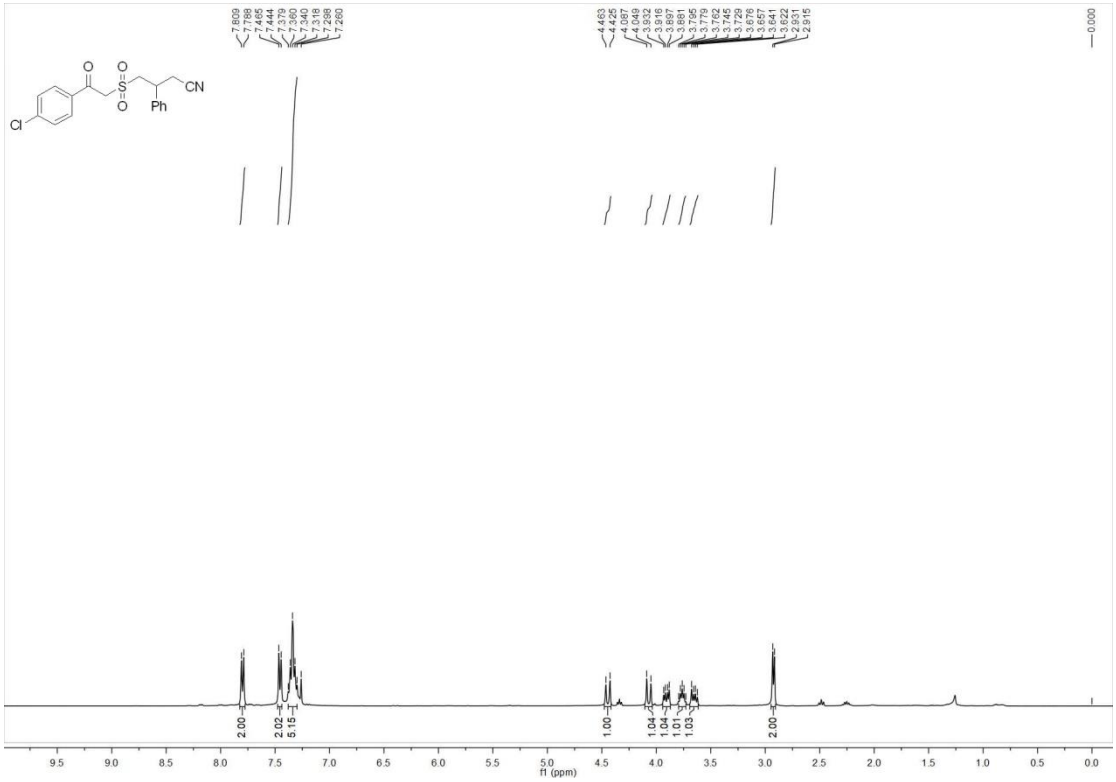


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4a**

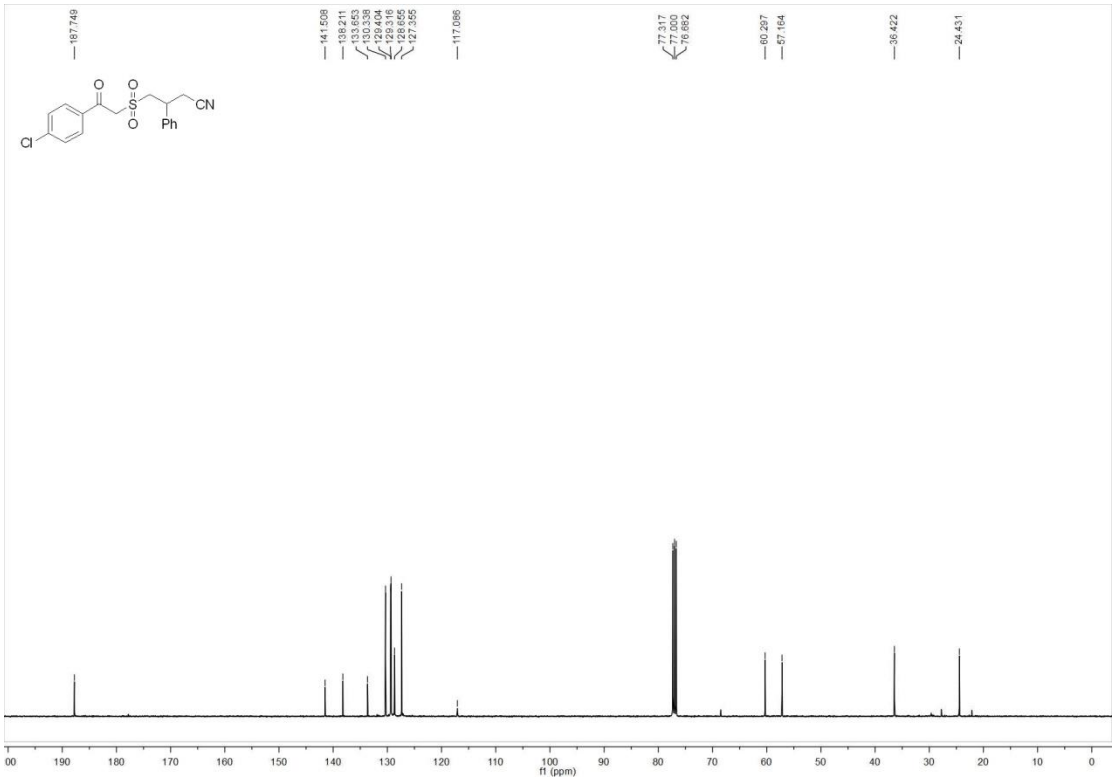


3-4-((2-(4-Chlorophenyl)-2-oxoethyl)sulfonyl)-3-phenylbutanenitrile (4b)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4b**

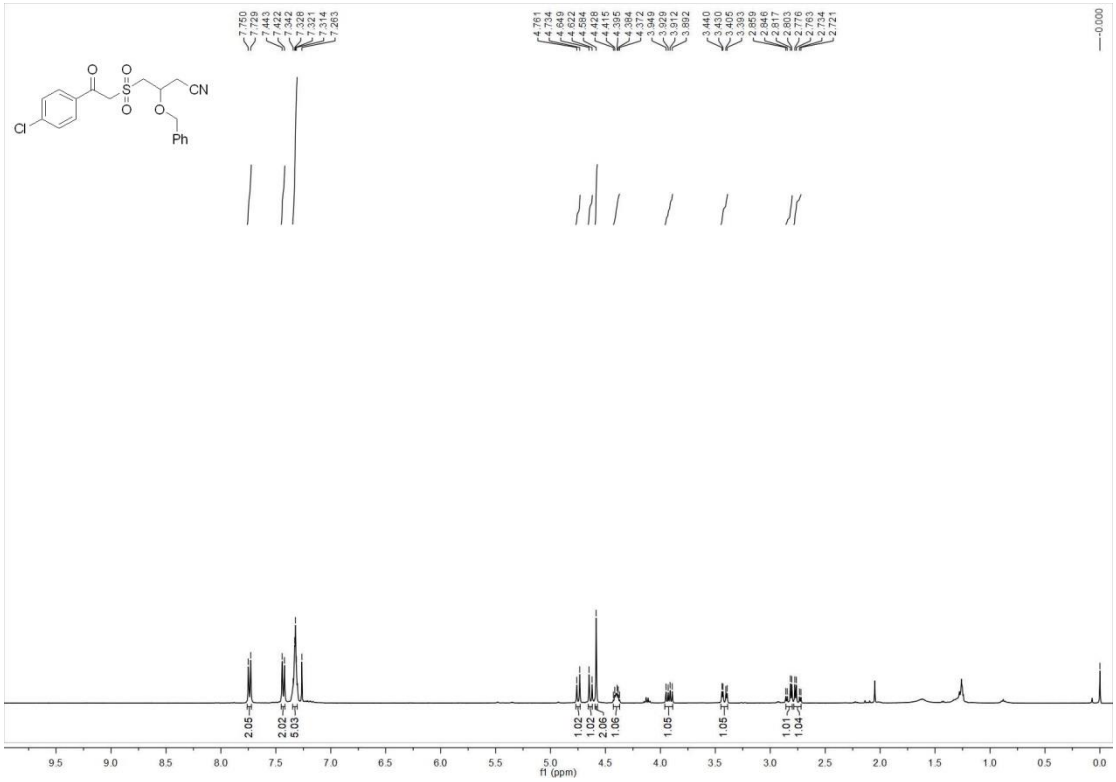


^{13}C NMR-spectrum (101MHz, $CDCl_3$) of **4b**

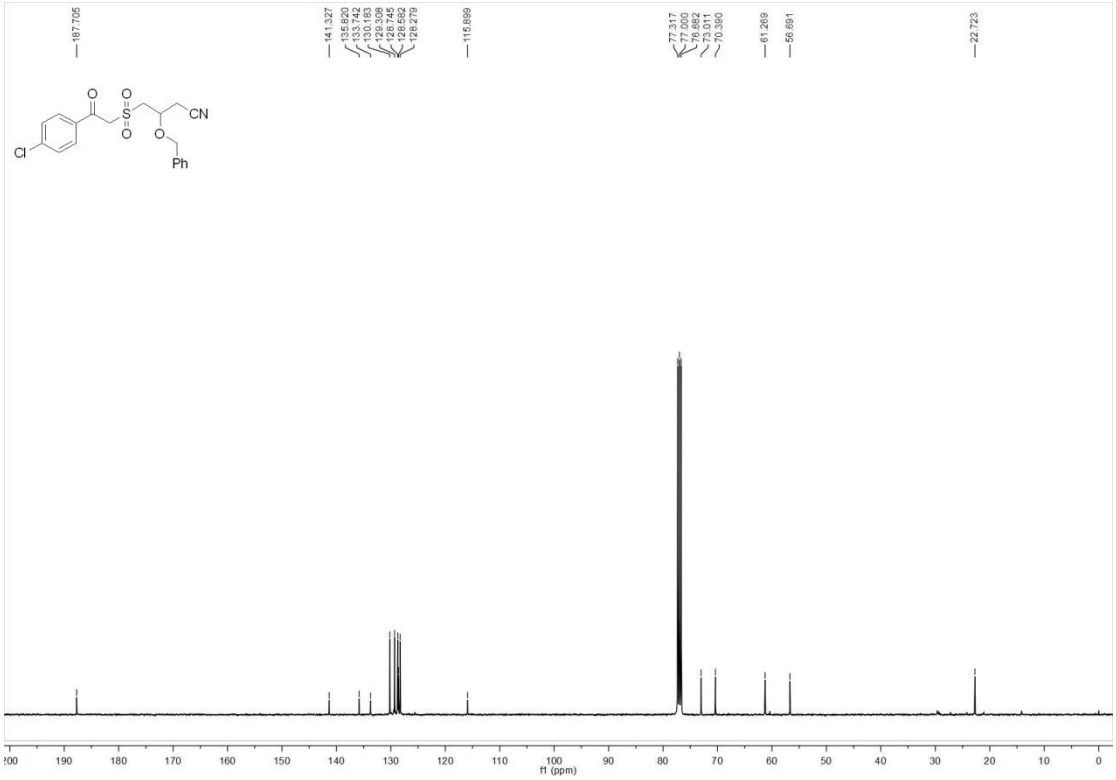


3-(Benzyloxy)-4-((2-(4-chlorophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4c)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4c**

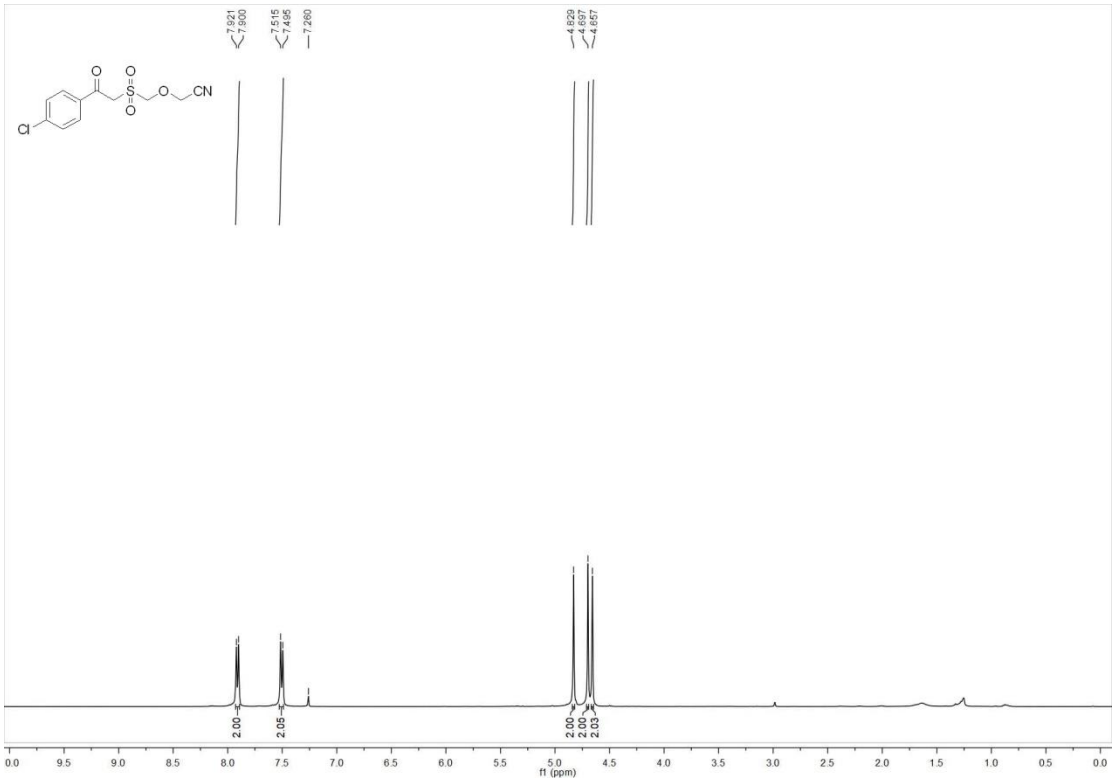


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4c**

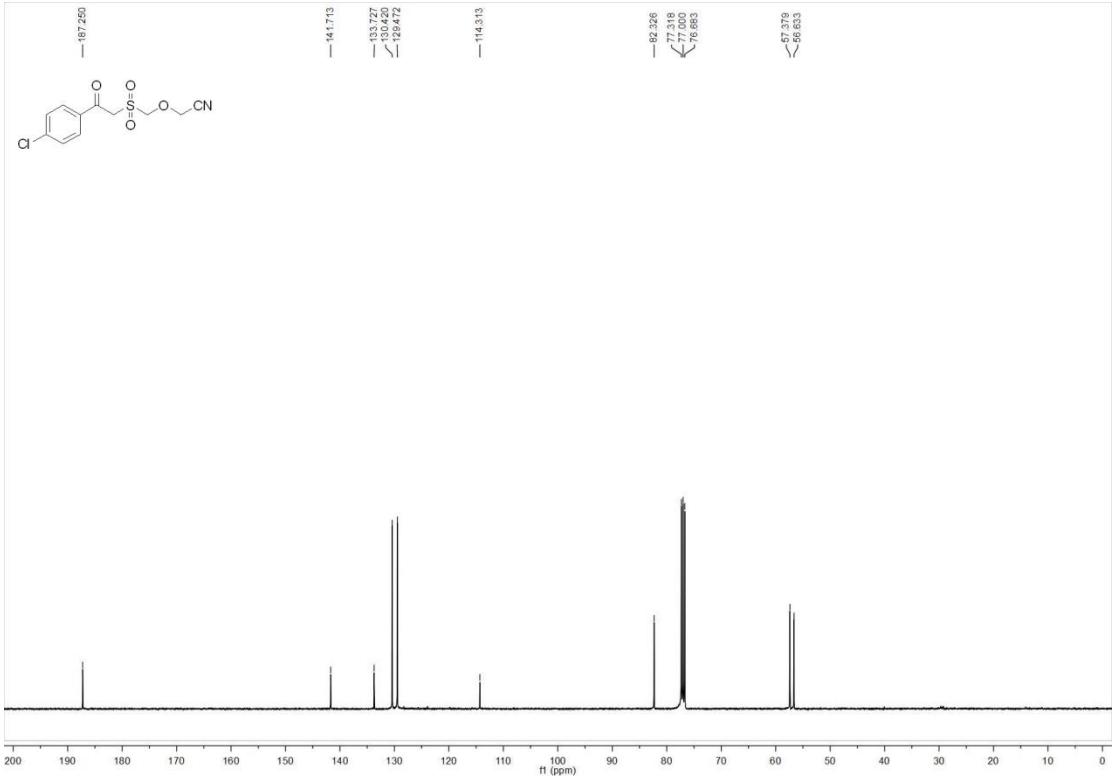


2-(((2-(4-Chlorophenyl)-2-oxoethyl)sulfonyl)methoxy)acetonitrile (4d)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4d**

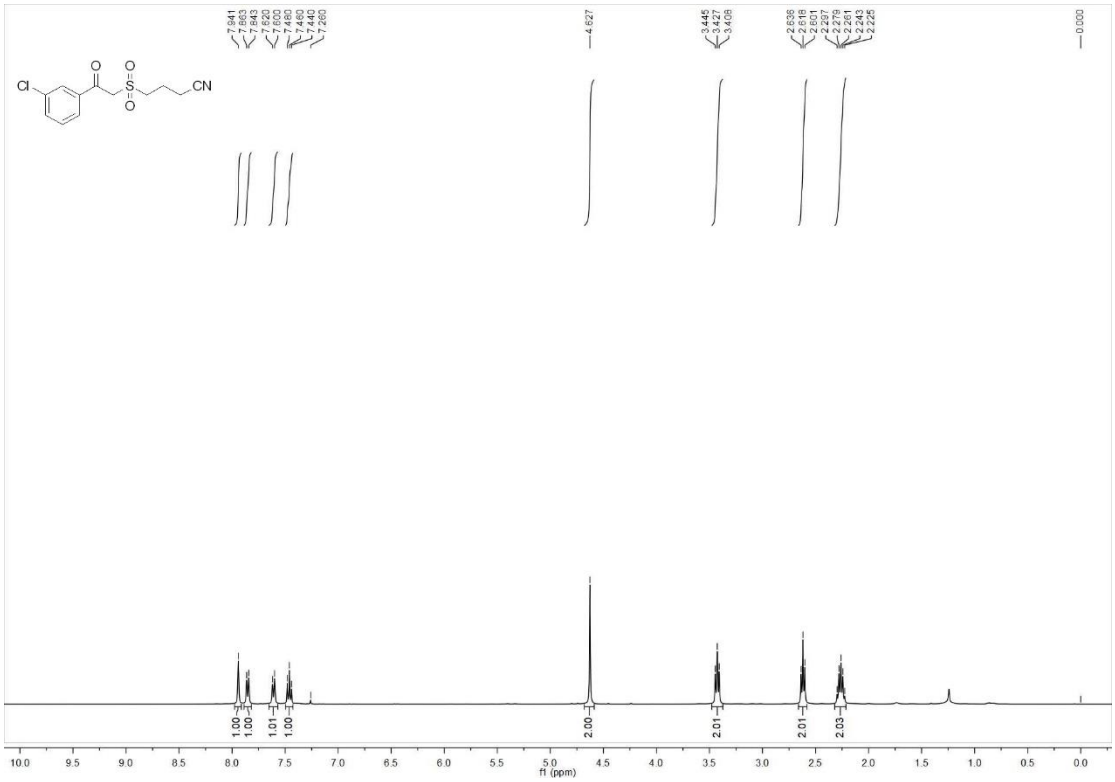


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4d**

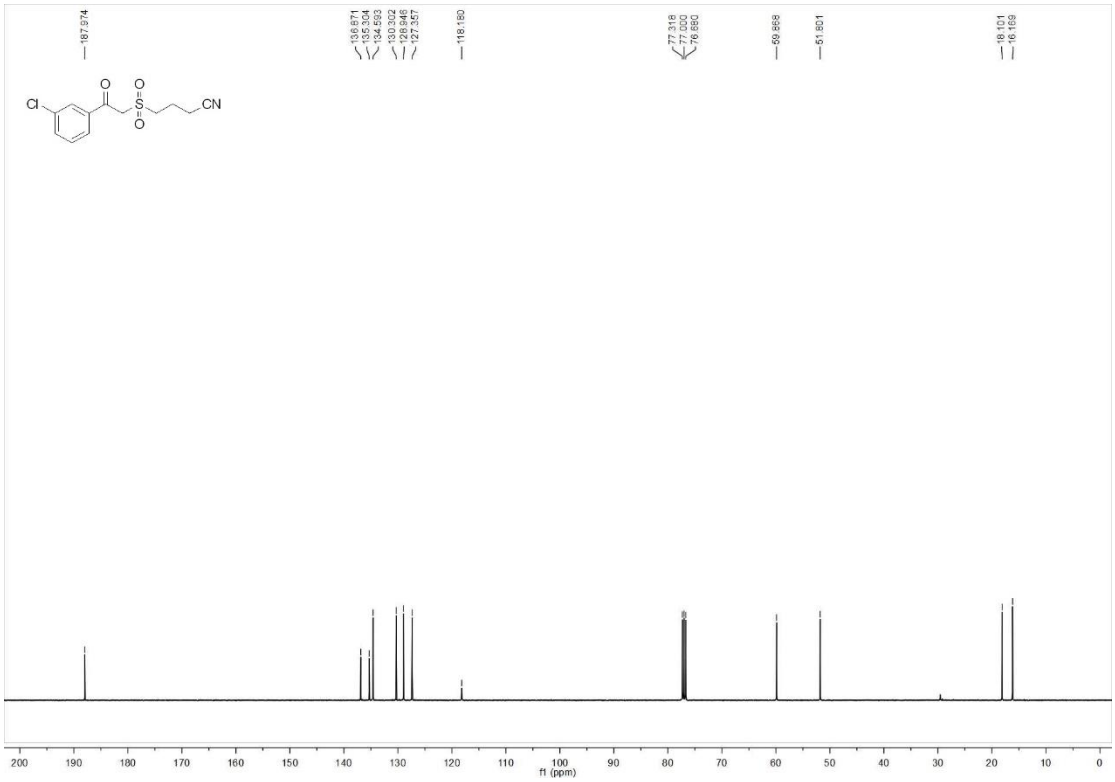


4-((2-(3-Chlorophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4e)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4e**

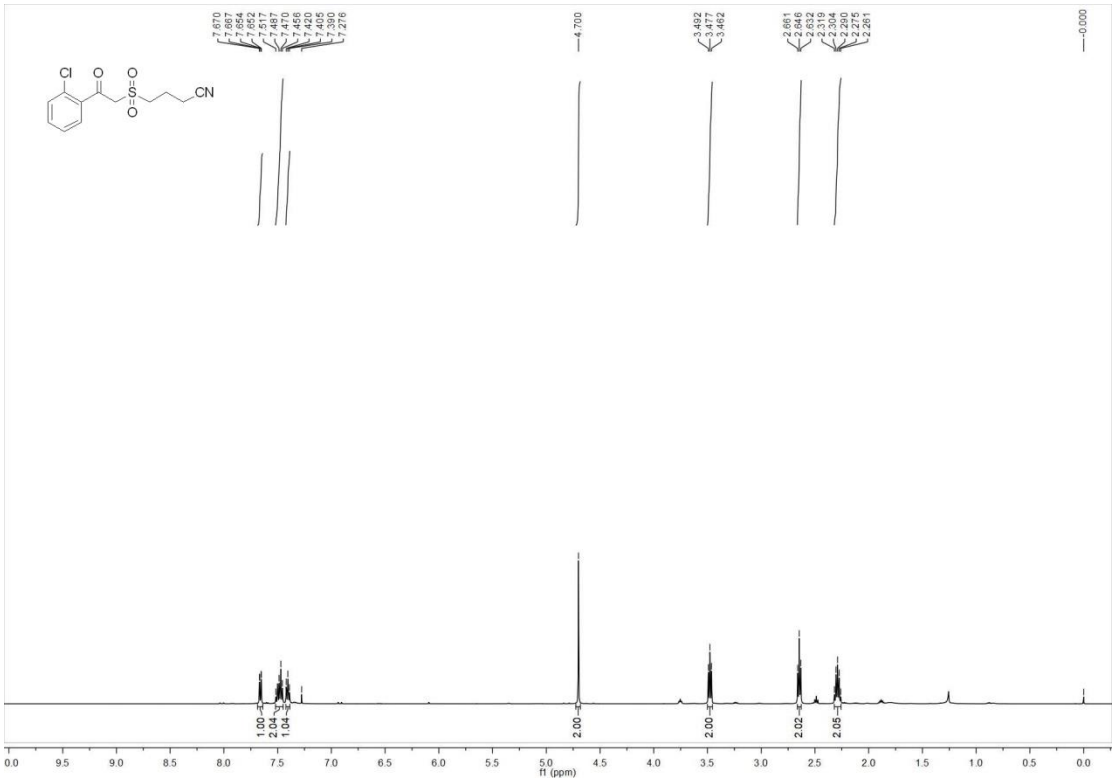


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4e**

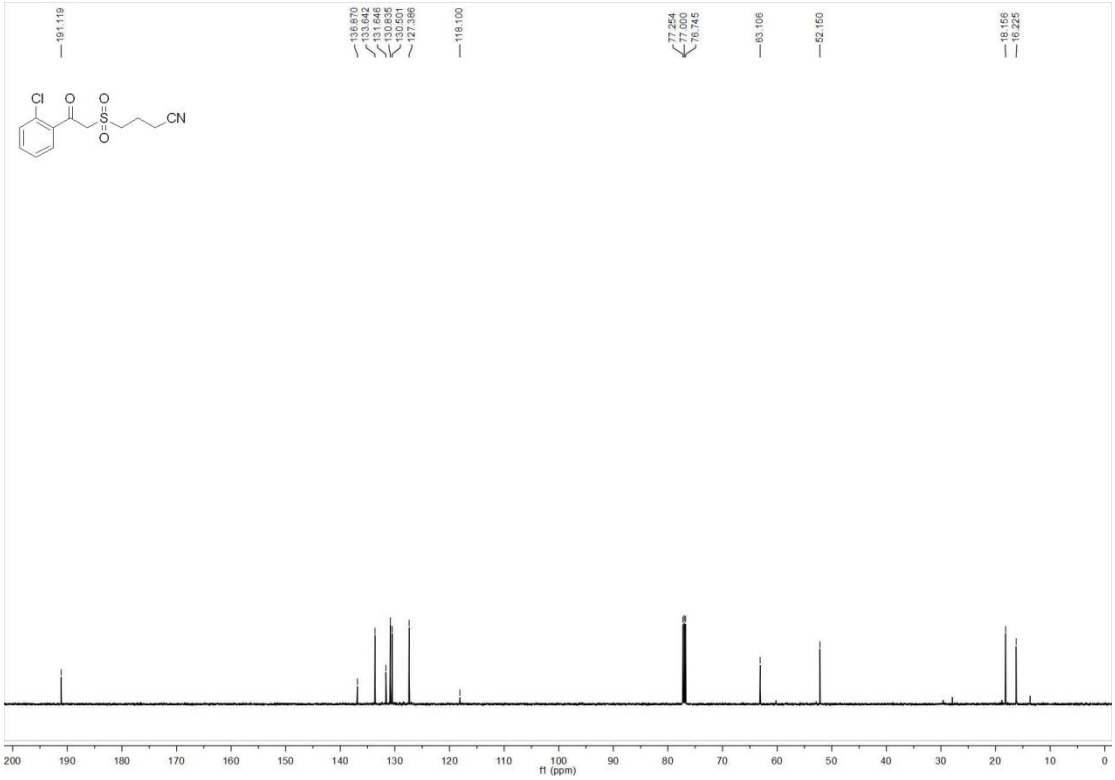


4-((2-(2-Chlorophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4f)

^{1}H NMR-spectrum (500 MHz, $CDCl_3$) of **4f**

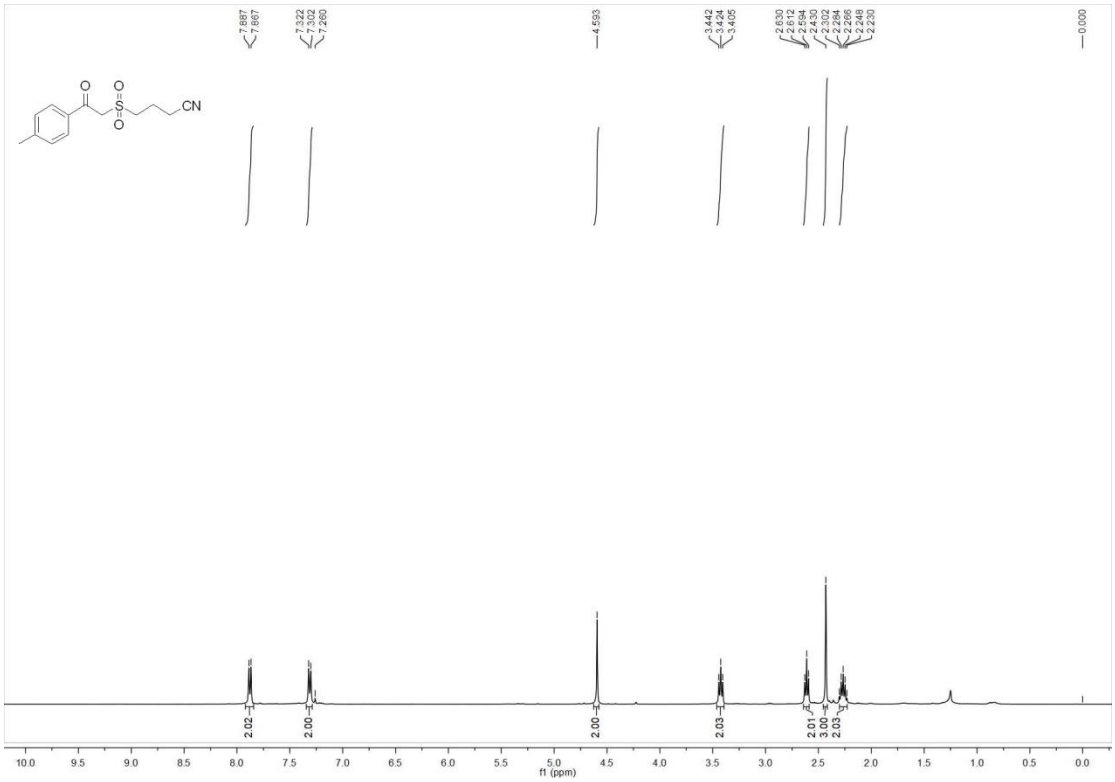


^{13}C NMR-spectrum (126 MHz, $CDCl_3$) of **4f**

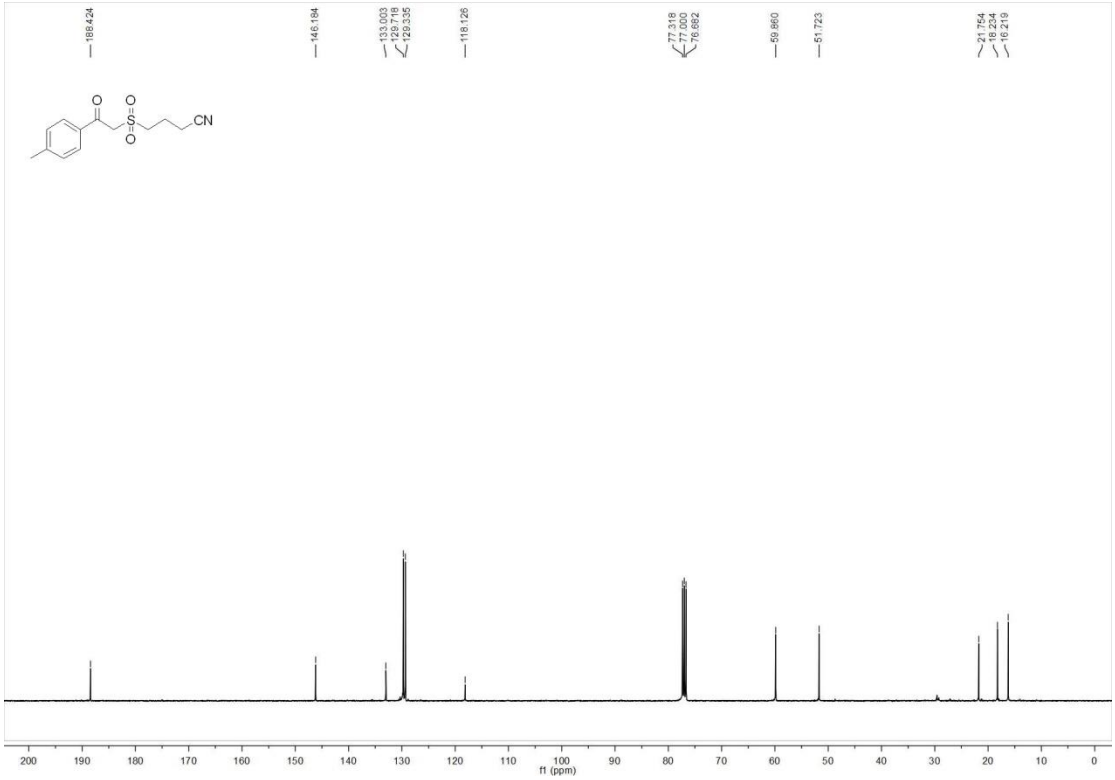


4-((2-*oxo*-2-(*p*-Tolyl)ethyl)sulfonyl)butanenitrile (4g)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4g**

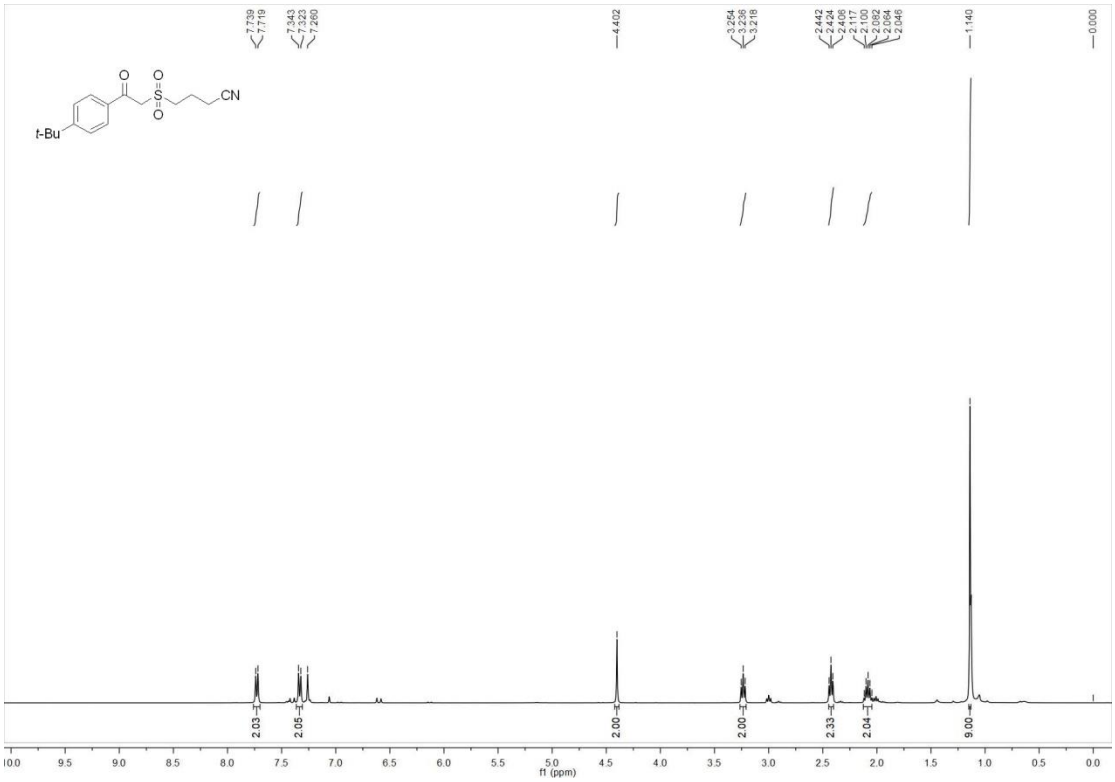


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4g**

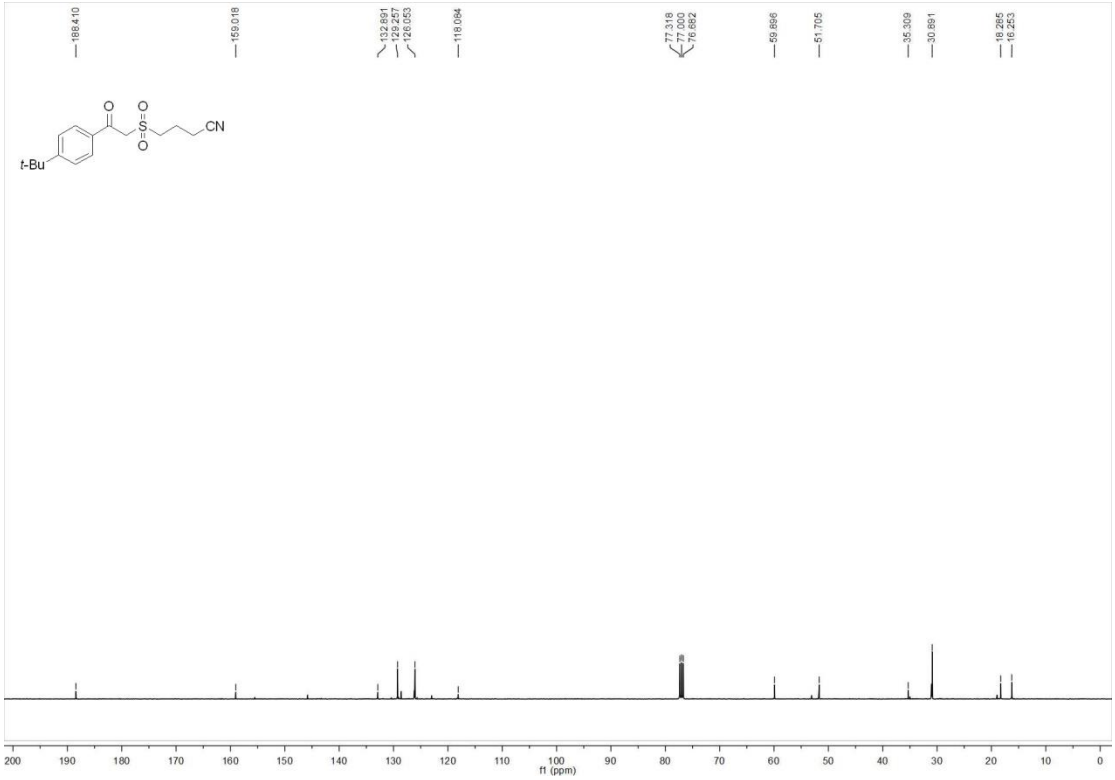


4-((2-(4-(*tert*-Butyl)phenyl)-2-oxoethyl)sulfonyl)butanenitrile (4h)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4h**

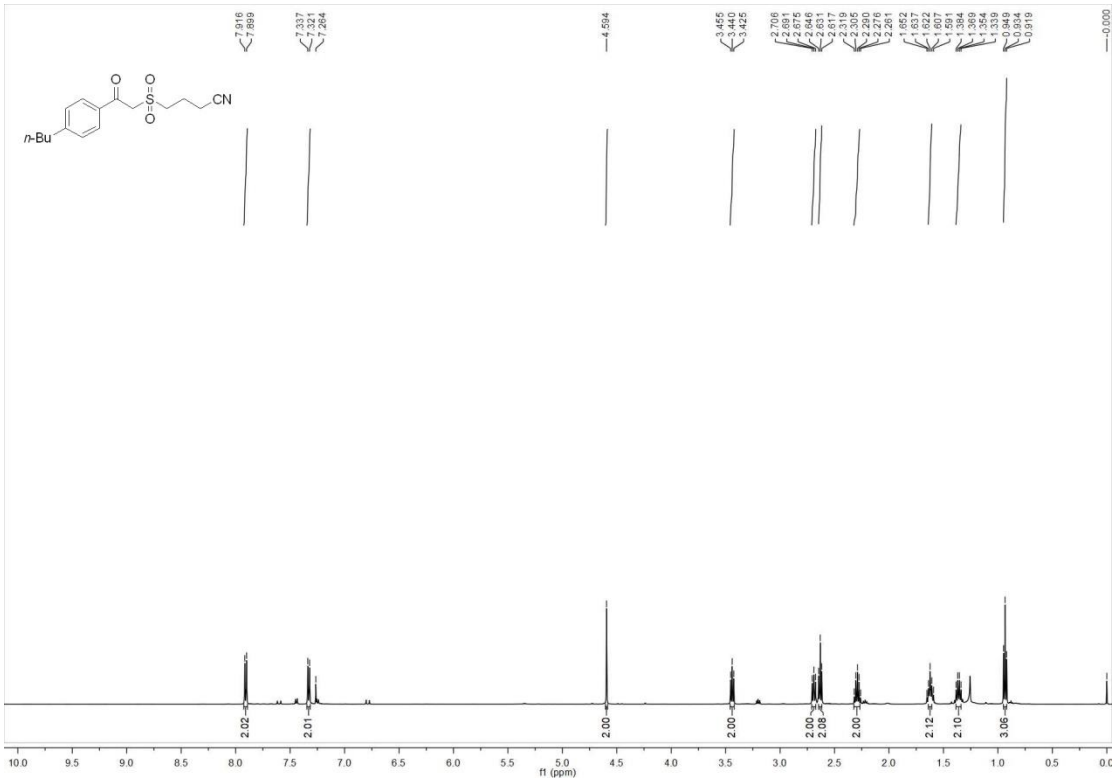


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4h**

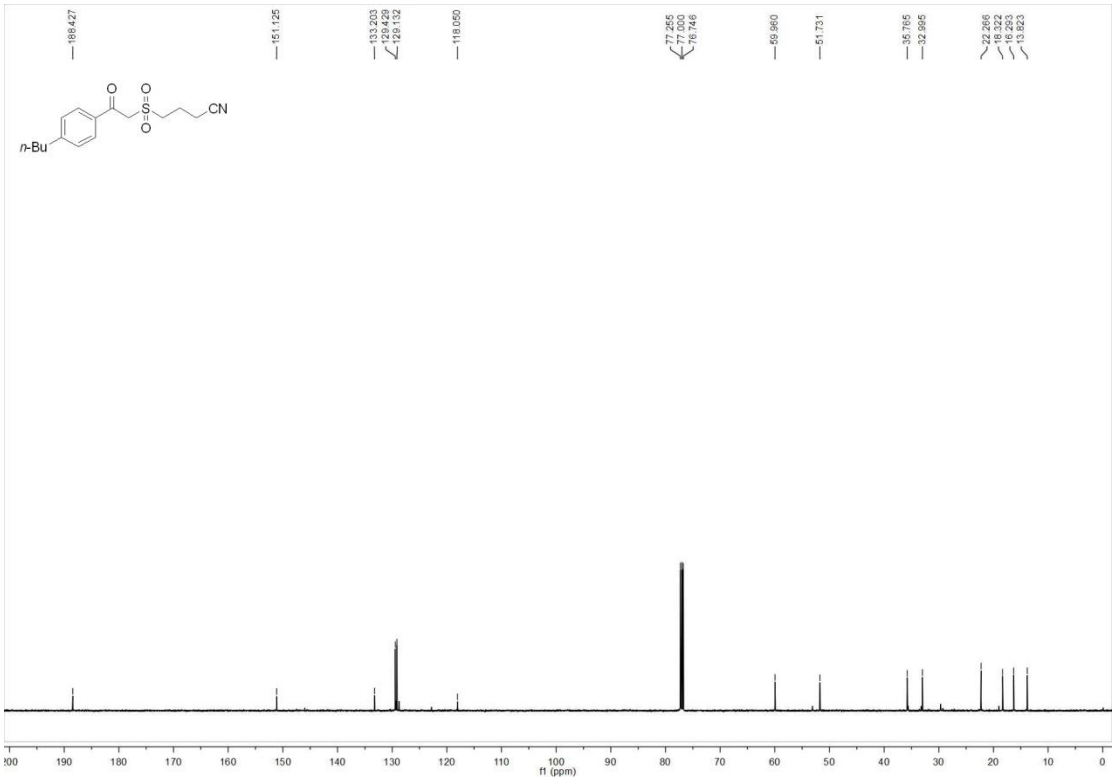


3-4-((2-(4-Butylphenyl)-2-oxoethyl)sulfonyl)butanenitrile (4i)

^{1}H NMR-spectrum (500 MHz, $CDCl_3$) of **4i**

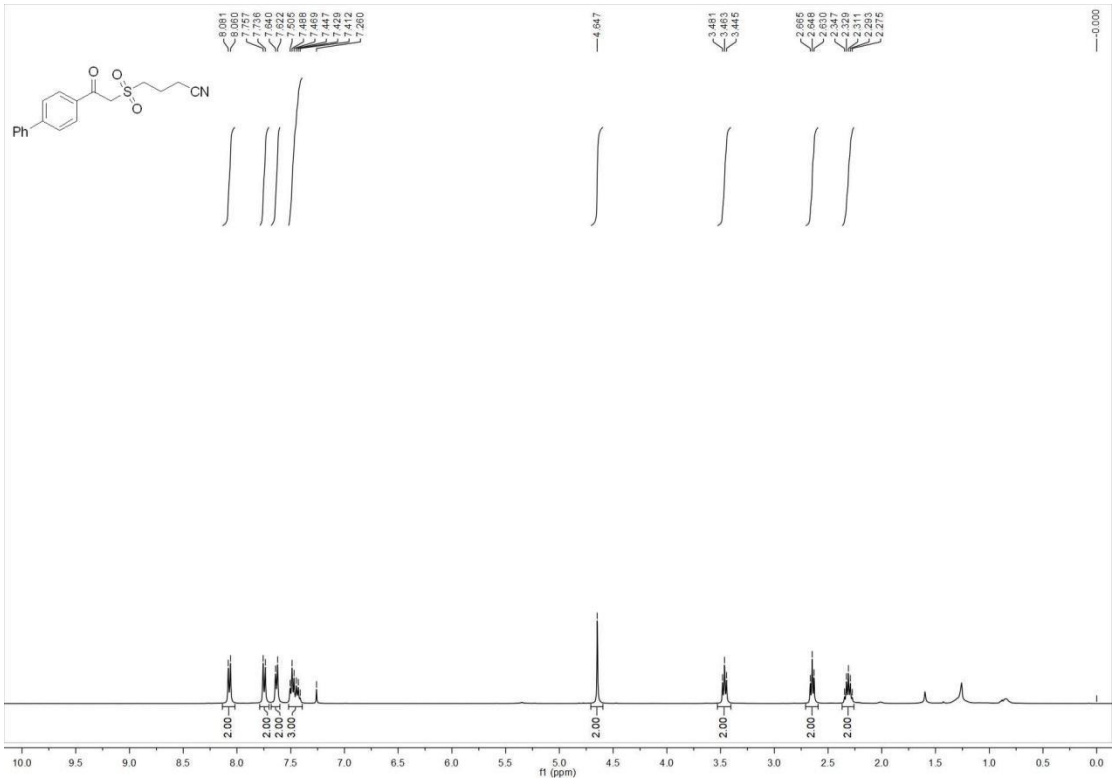


^{13}C NMR-spectrum (126 MHz, $CDCl_3$) of **4i**

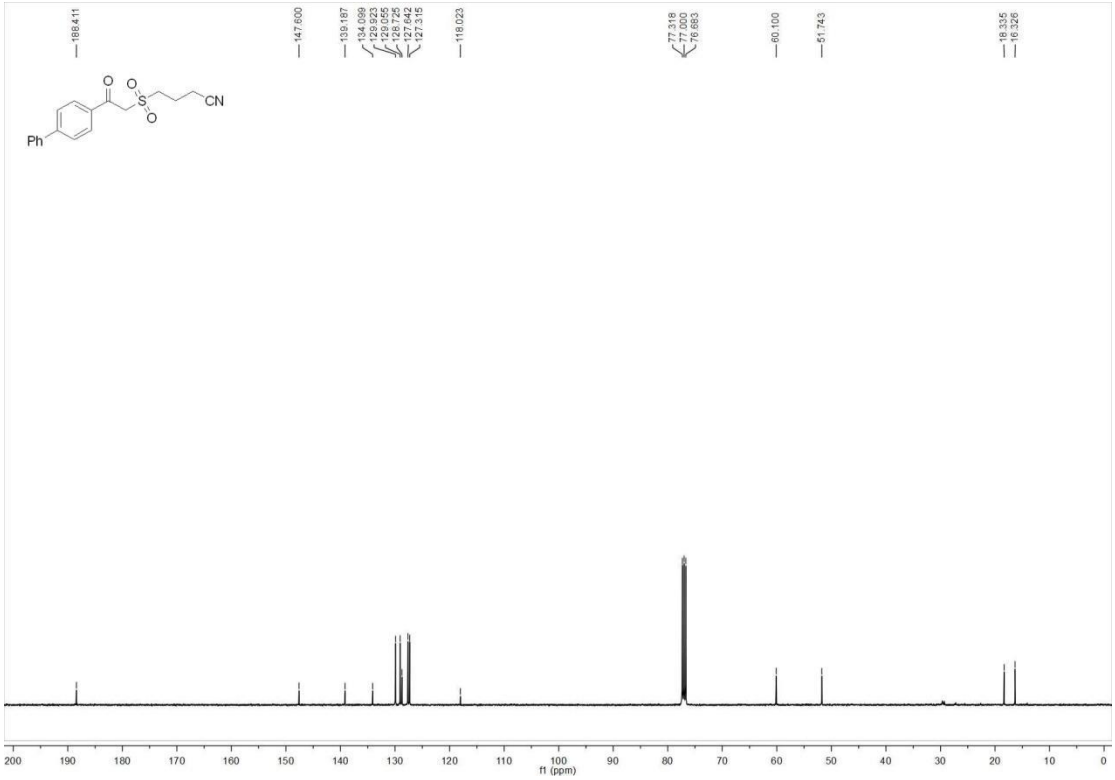


4-((2-([1,1'-Biphenyl]-4-yl)-2-oxoethyl)sulfonyl)butanenitrile (4j)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4j**

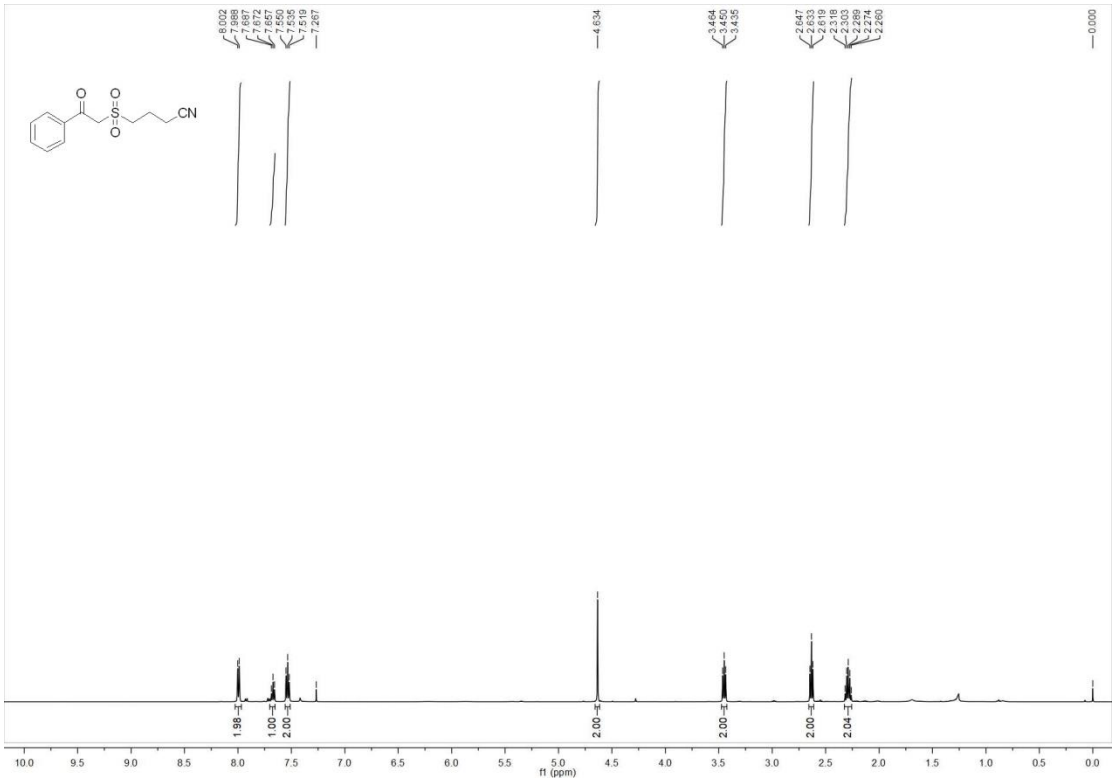


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4j**

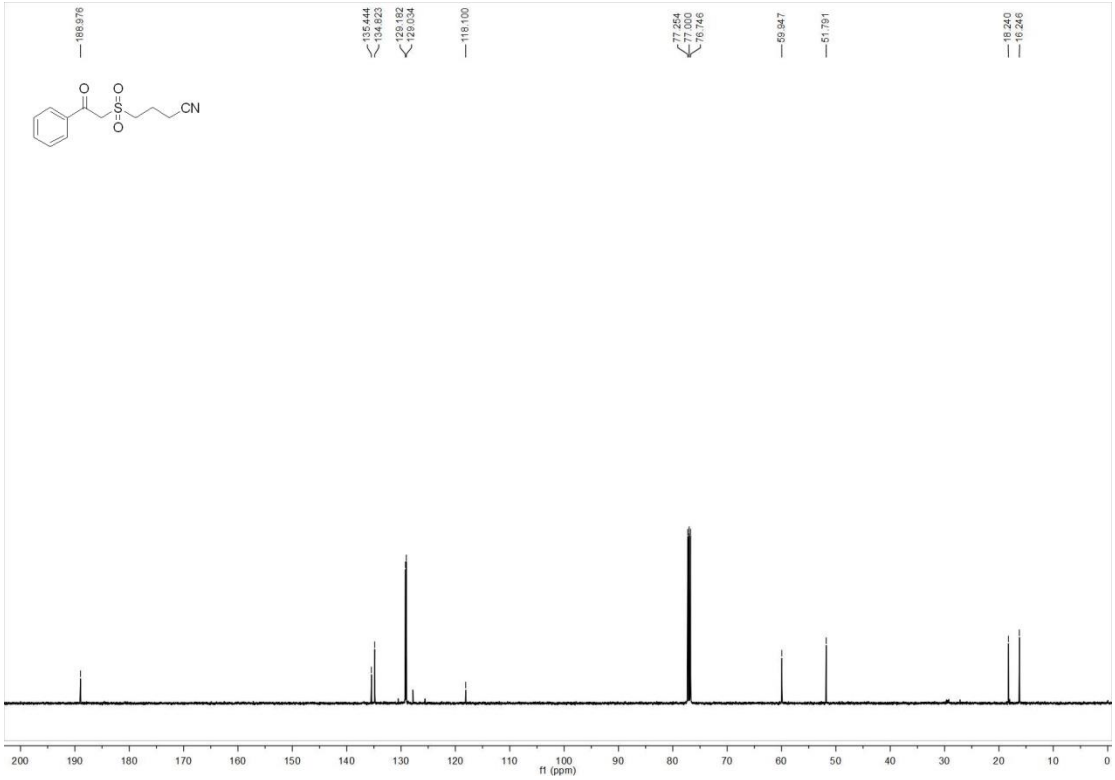


4-((2-(4-Chlorophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4k)

^{1}H NMR-spectrum (500 MHz, $CDCl_3$) of **4k**

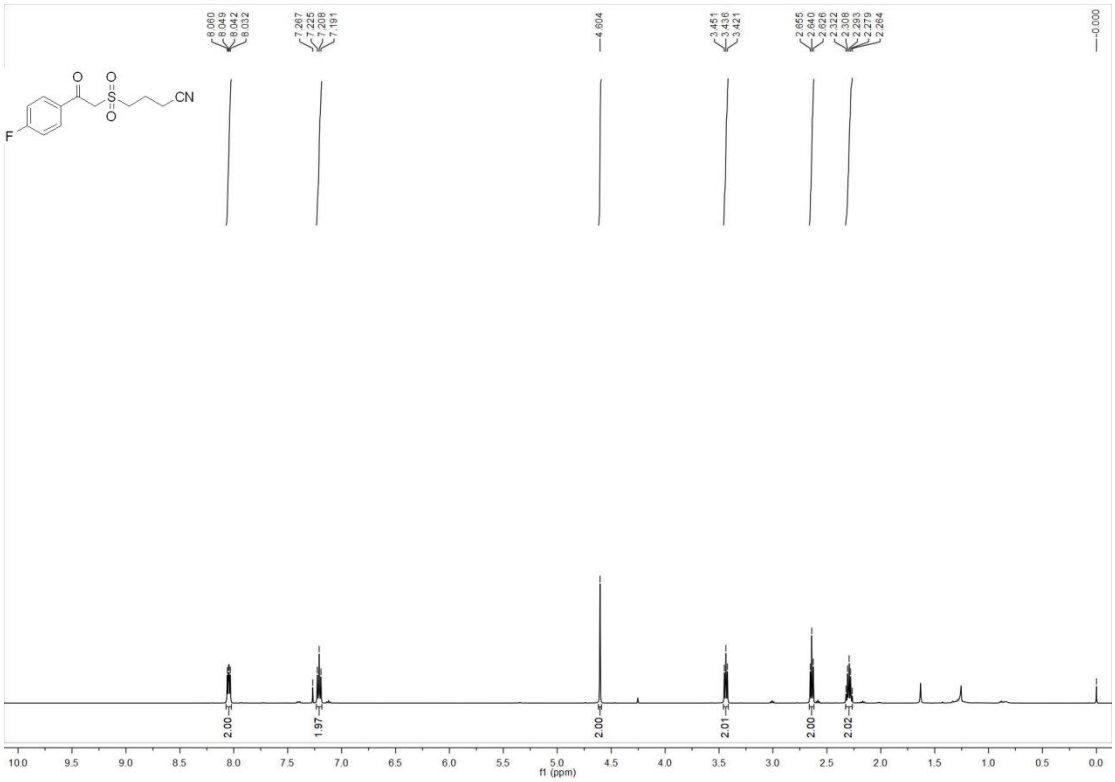


^{13}C NMR-spectrum (126 MHz, $CDCl_3$) of **4k**

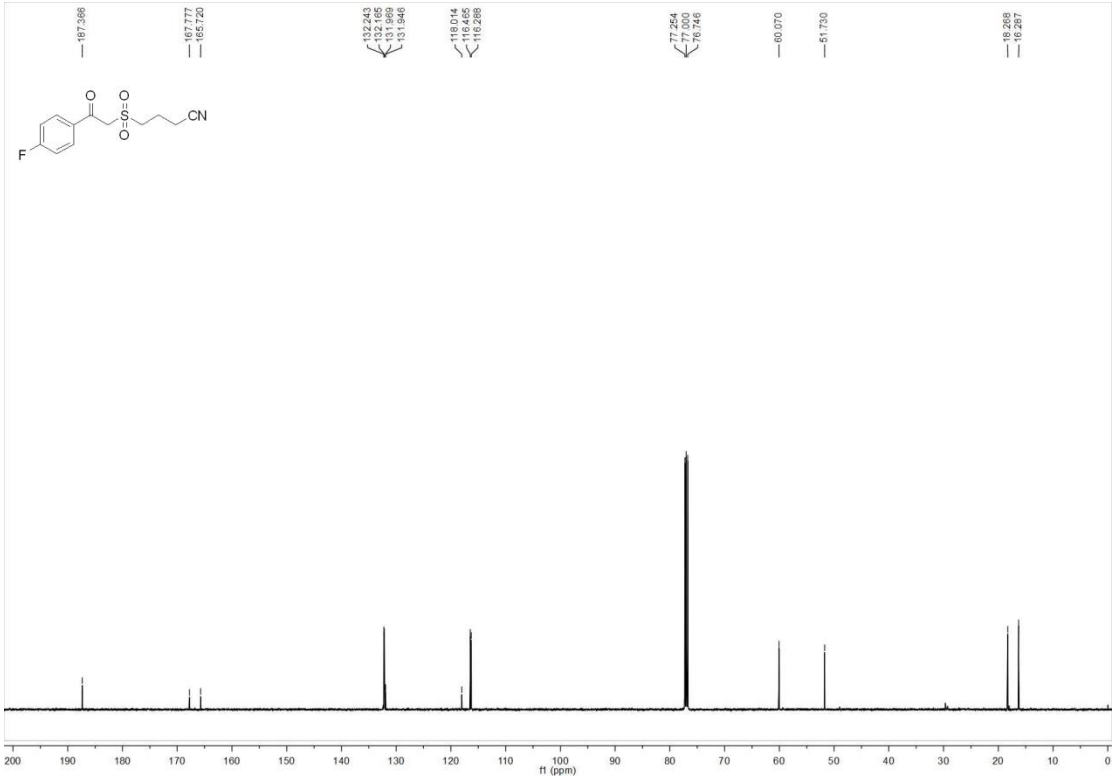


4-((2-(4-Fluorophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4l)

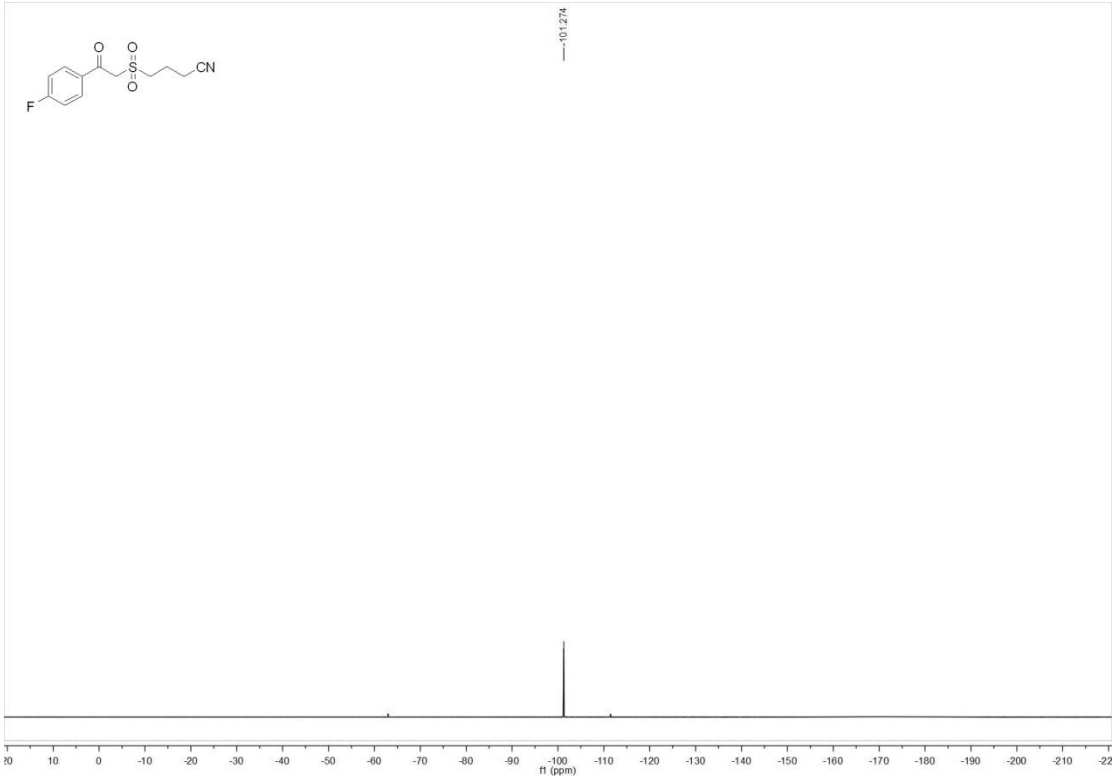
^{1}H NMR-spectrum (500 MHz, $CDCl_3$) of **4l**



^{13}C NMR-spectrum (126 MHz, $CDCl_3$) of **4l**

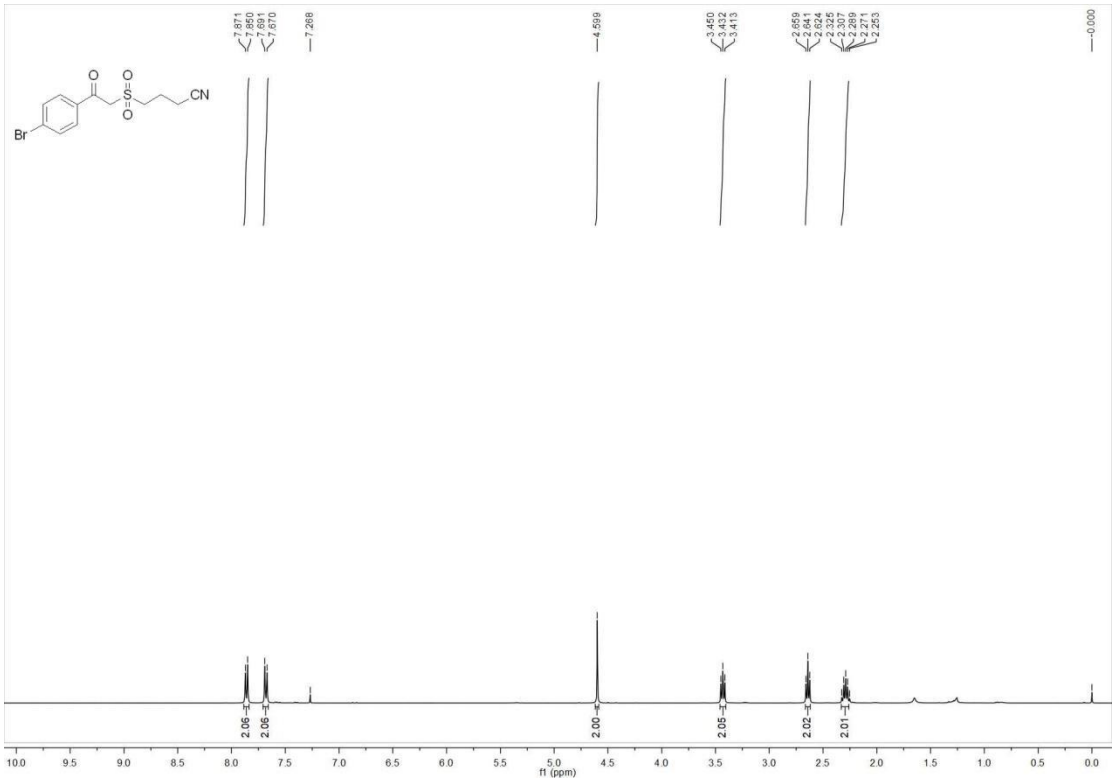


^{19}F NMR-spectrum (471 MHz, $CDCl_3$) of **4l**

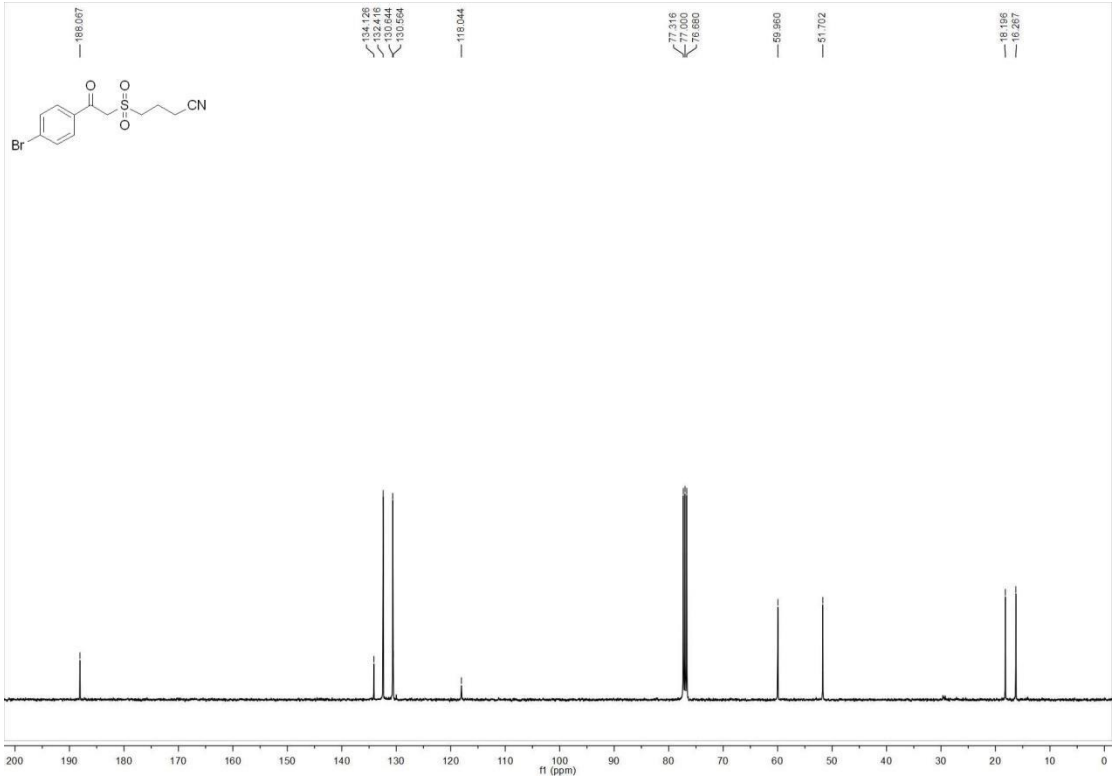


4-((2-(4-Bromophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4m)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4m**

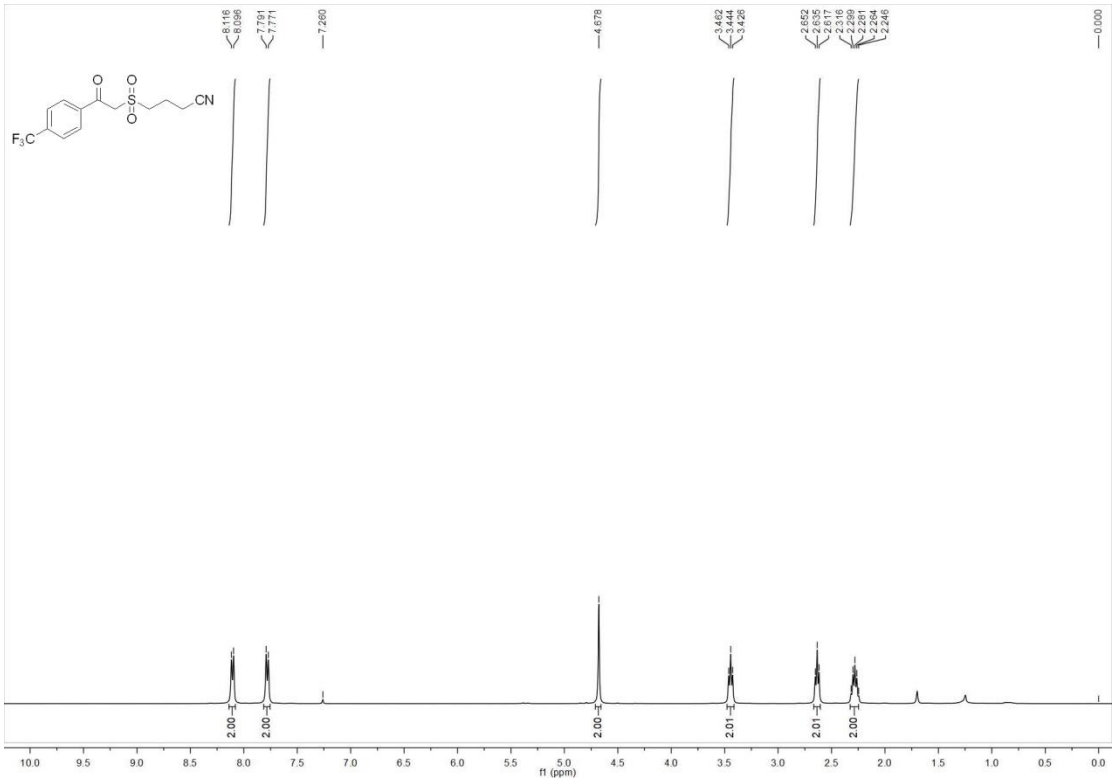


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4m**

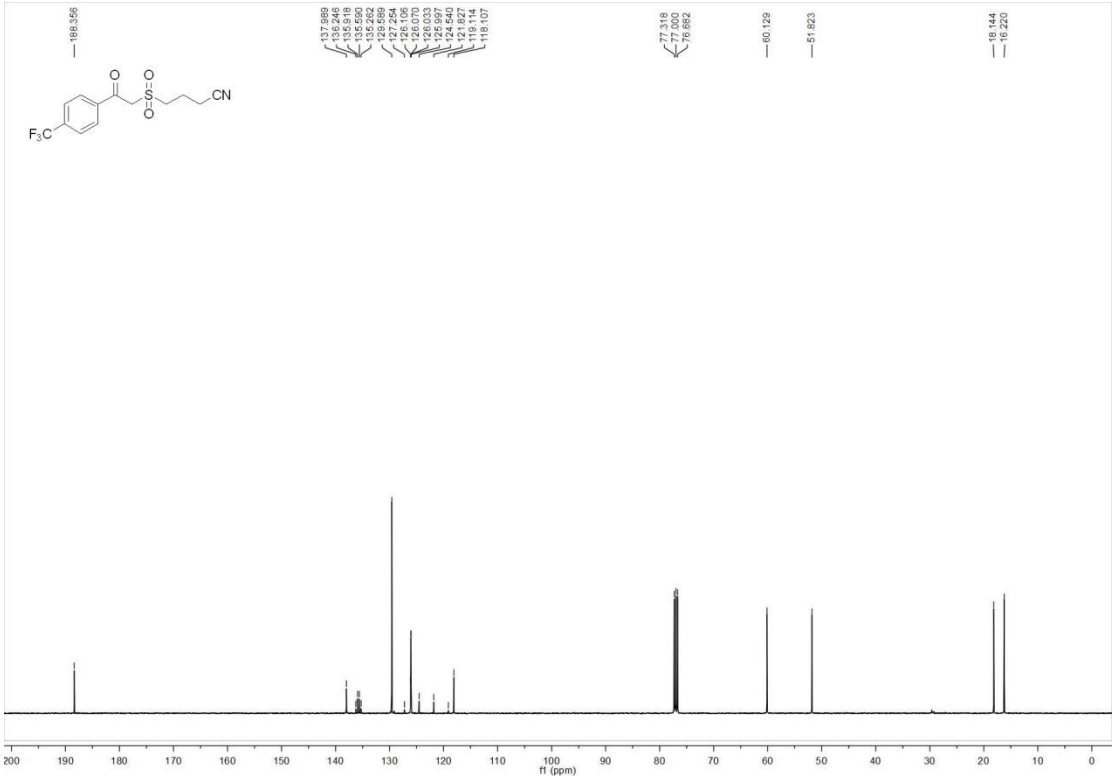


4-((2-*oxo*-2-(4-(Trifluoromethyl)phenyl)ethyl)sulfonyl)butanenitrile (4n)

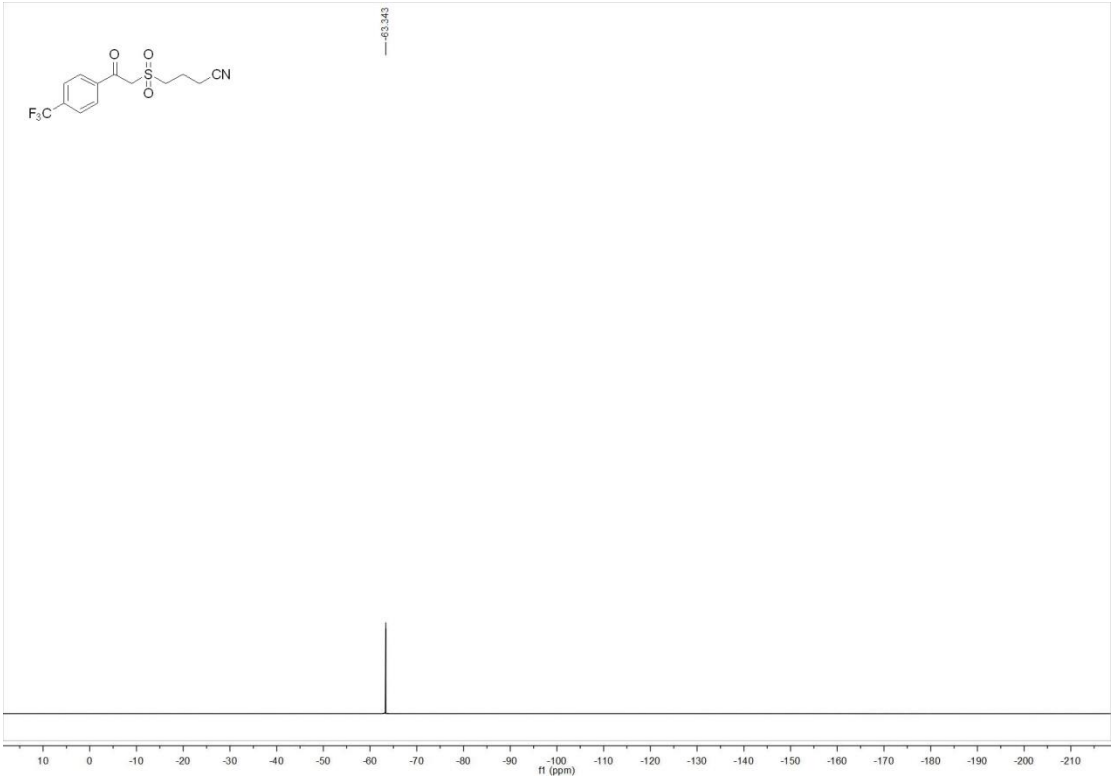
^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4n**



^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4n**

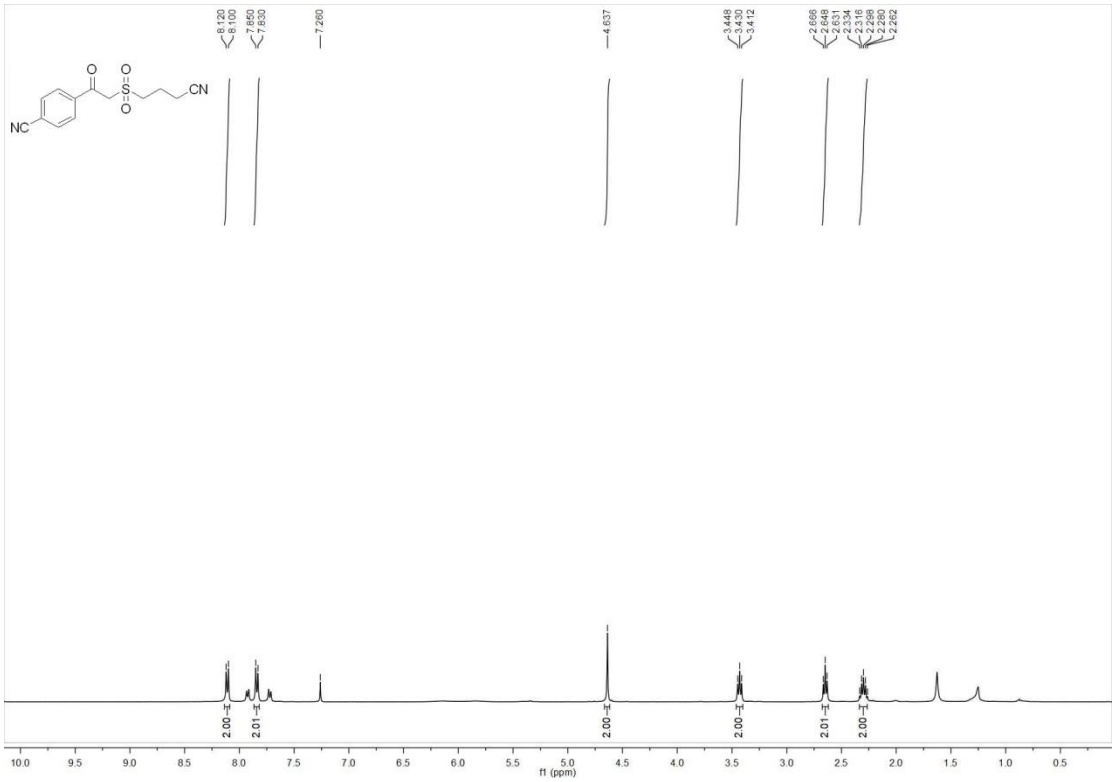


^{19}F NMR-spectrum (376 MHz, $CDCl_3$) of **4n**

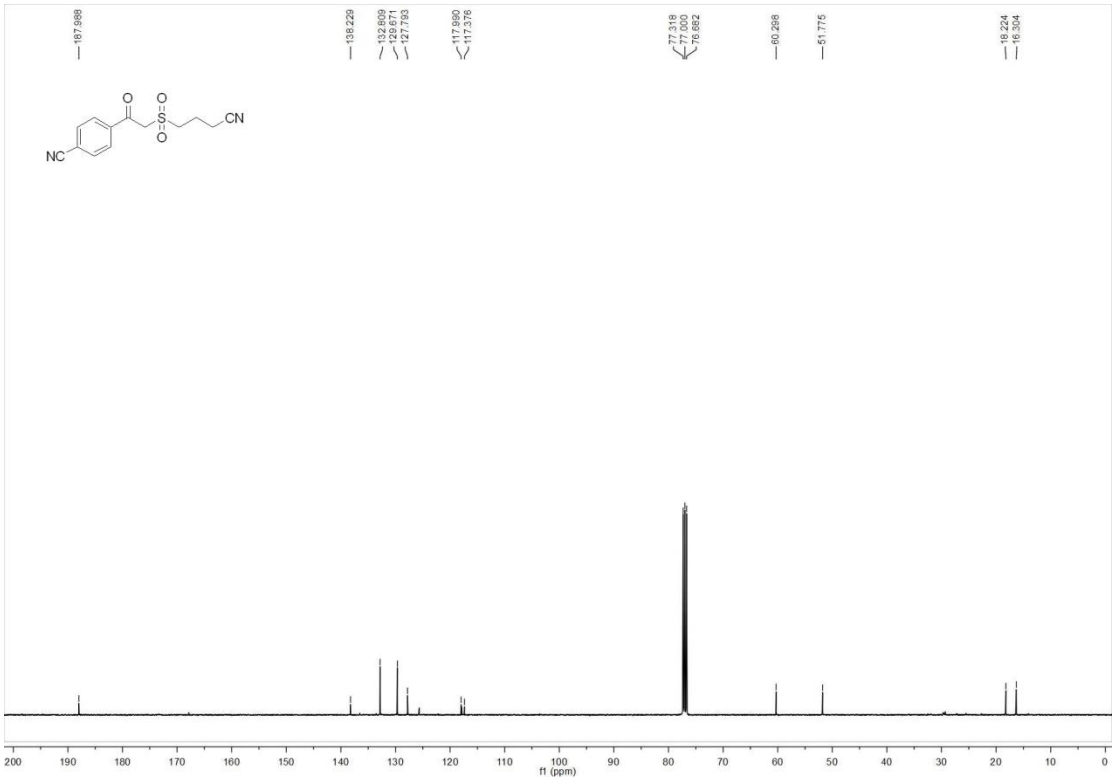


4-(2-((3-Cyanopropyl)sulfonyl)acetyl)benzonitrile (4o)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4o**

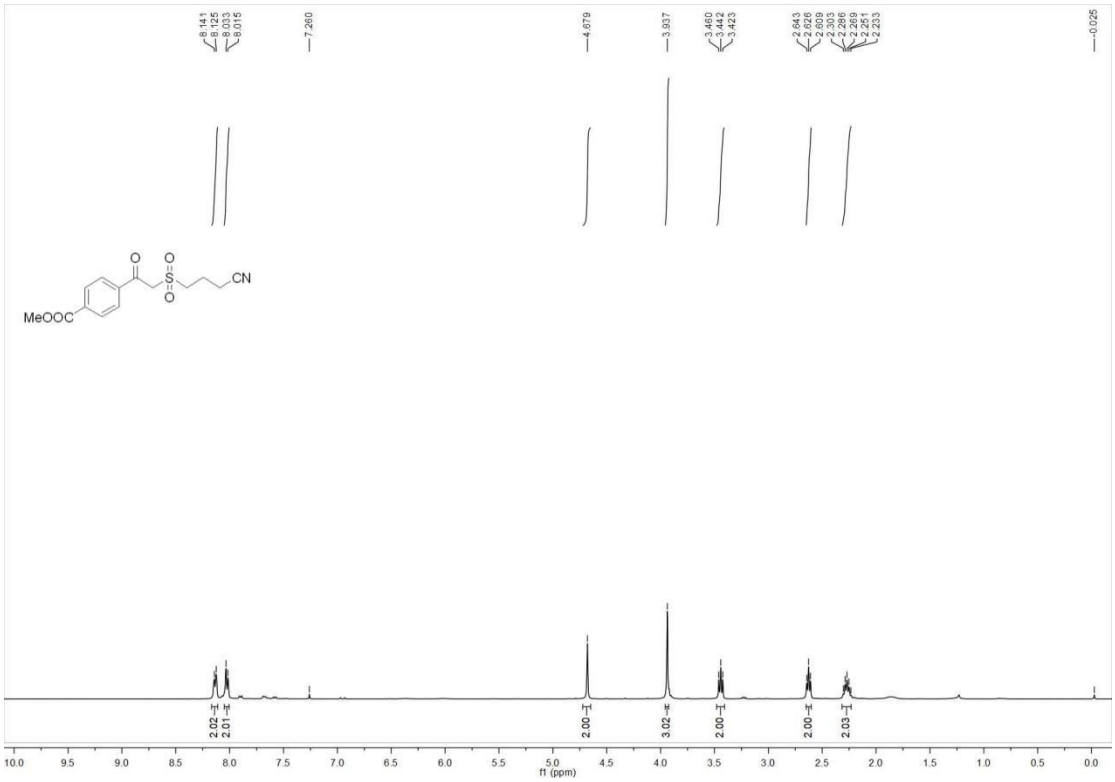


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4o**

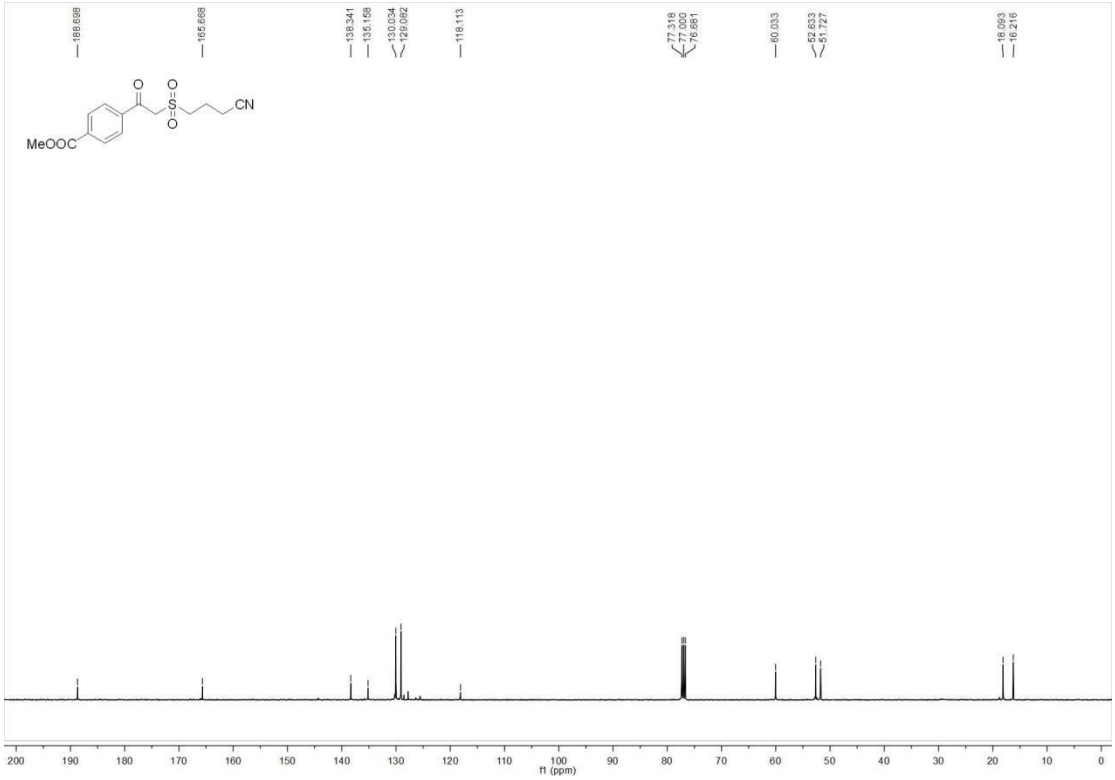


Methyl 4-(2-((3-cyanopropyl)sulfonyl)acetyl)benzoate (4p)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4p**

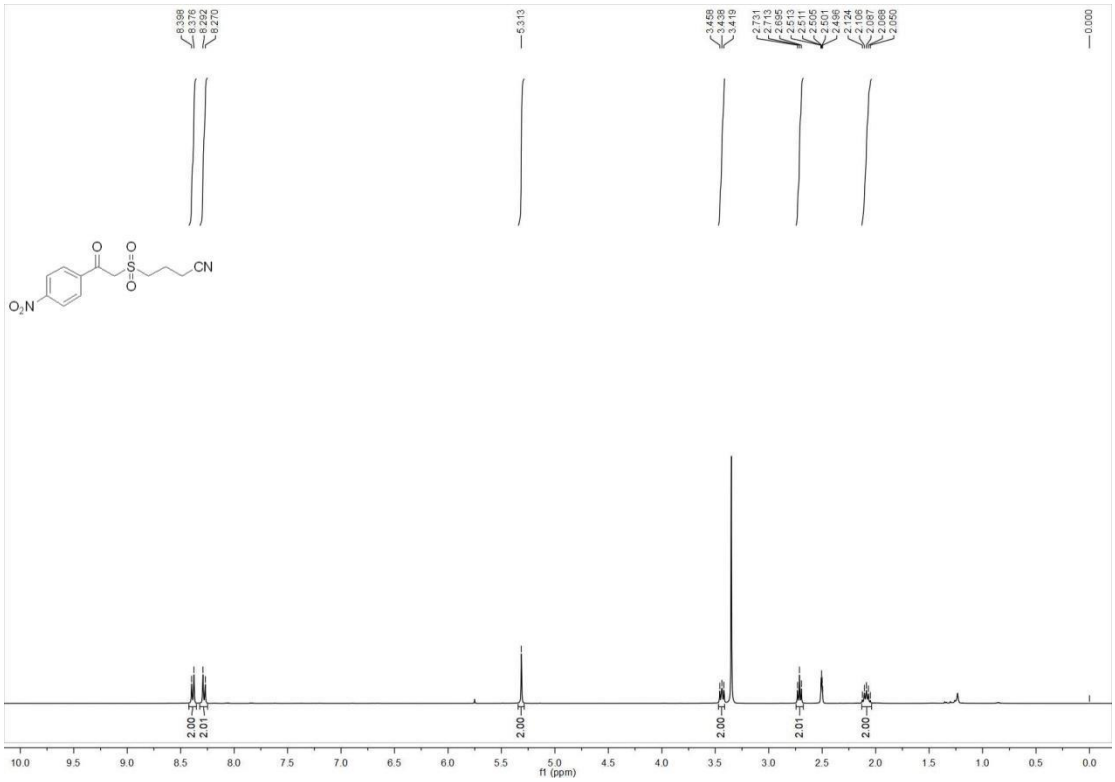


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4p**

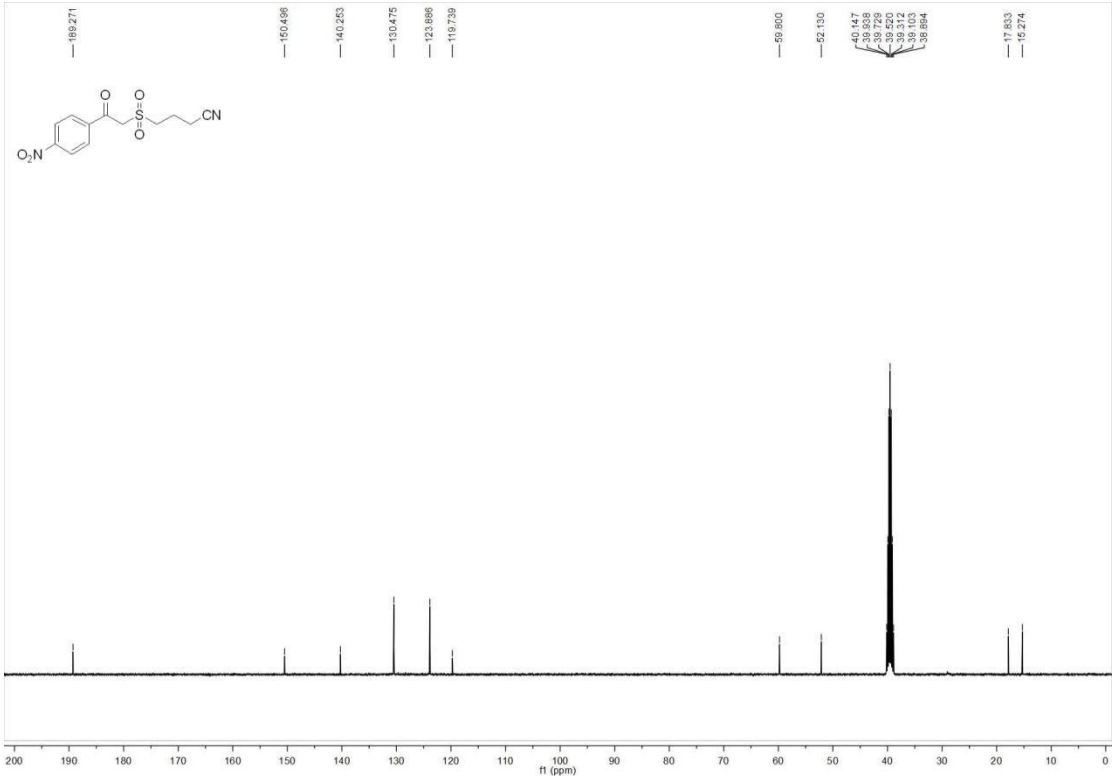


4-((2-(4-Nitrophenyl)-2-oxoethyl)sulfonyl)butanenitrile (4q)

^{1}H NMR-spectrum (400 MHz, DMSO-d6) of **4q**

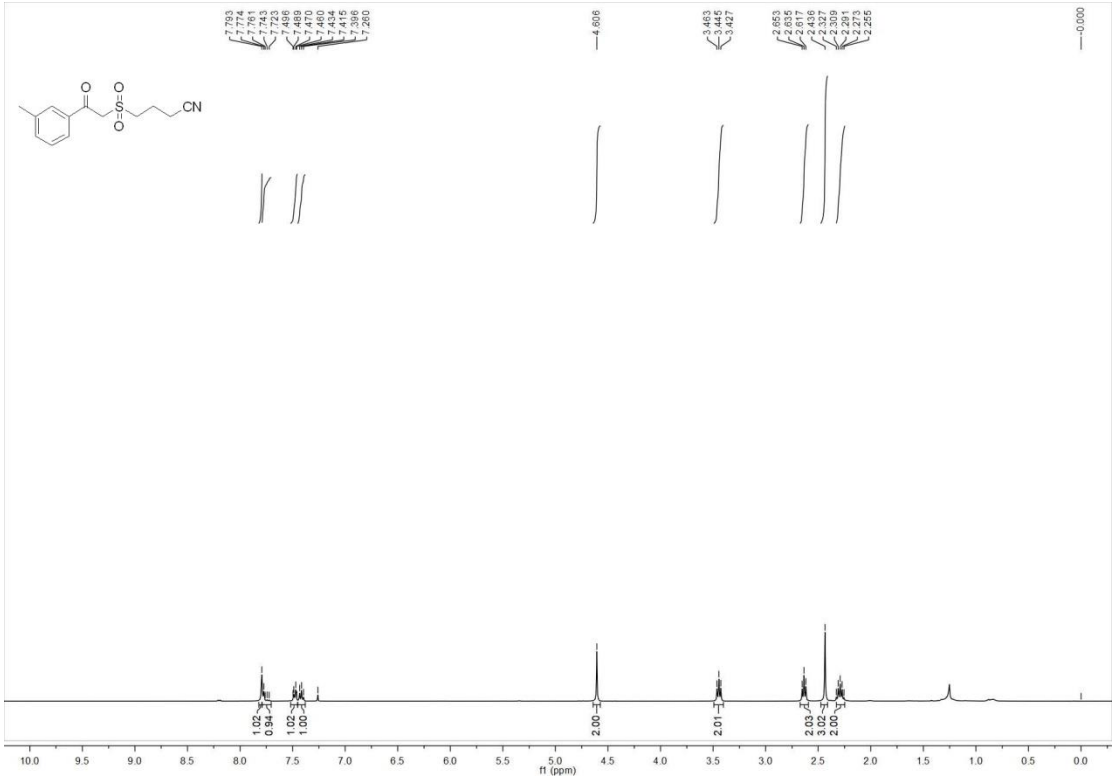


^{13}C NMR-spectrum (101 MHz, DMSO-d6) of **4q**

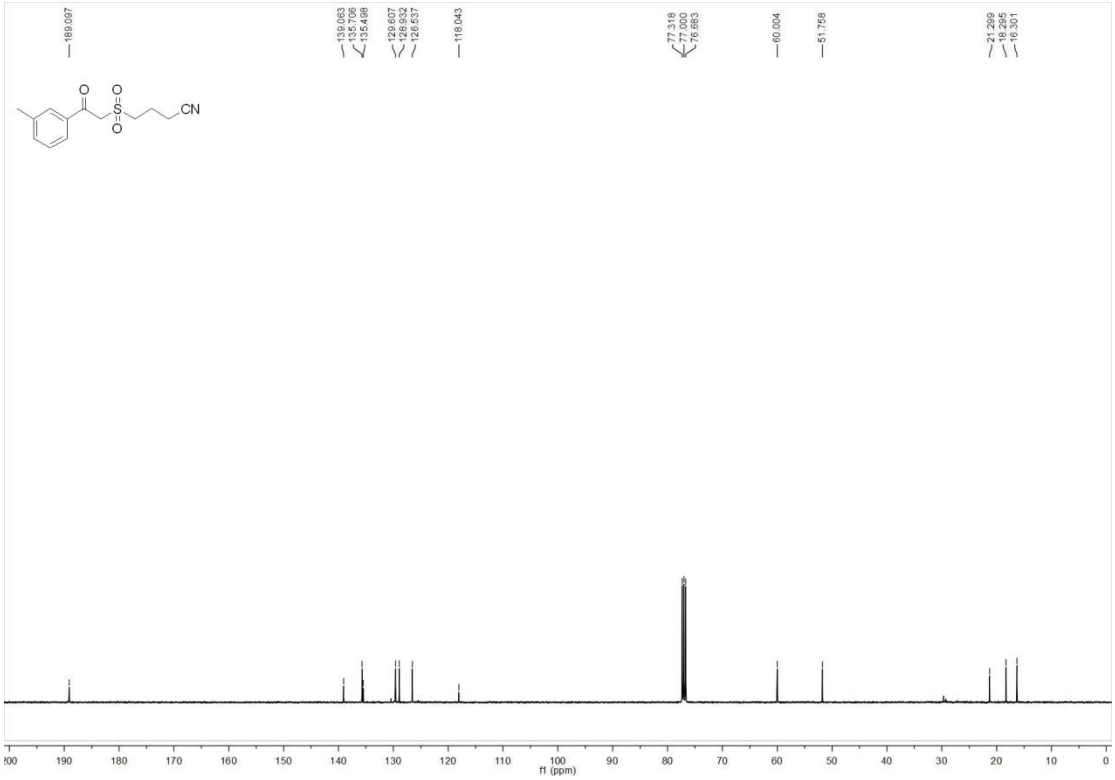


4-((2-*oxo*-2-(*m*-Tolyl)ethyl)sulfonyl)butanenitrile (4r)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4r**

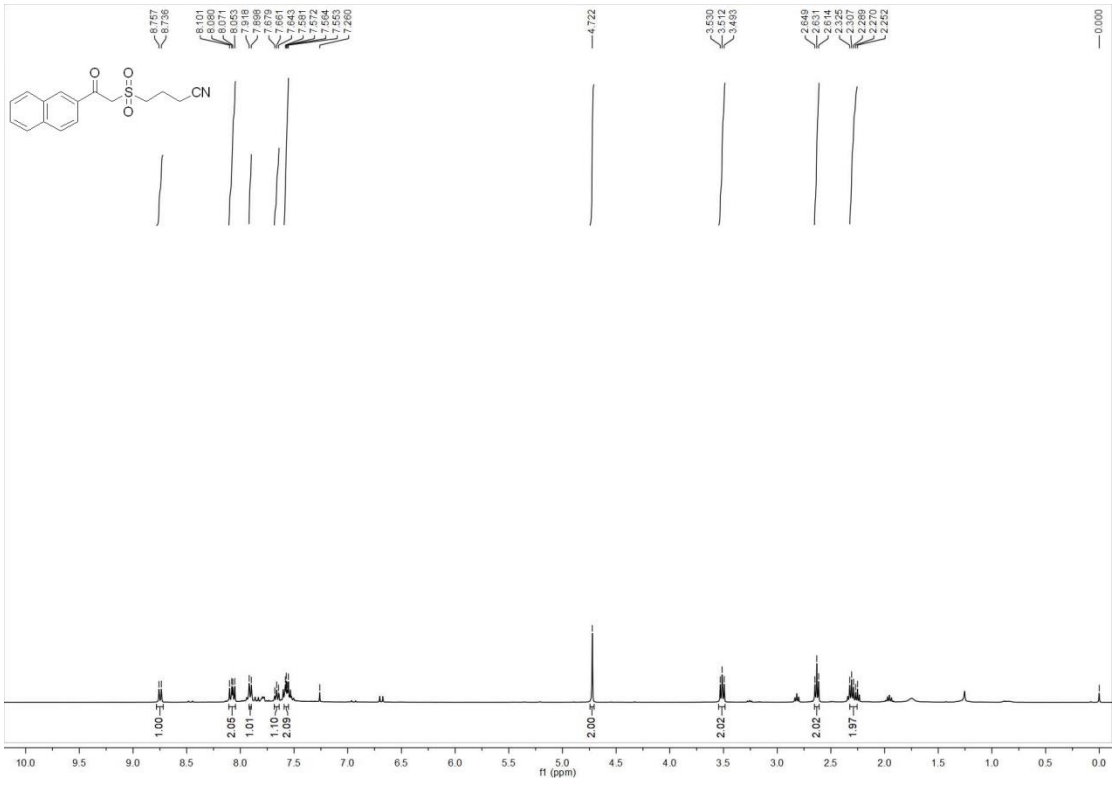


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4r**

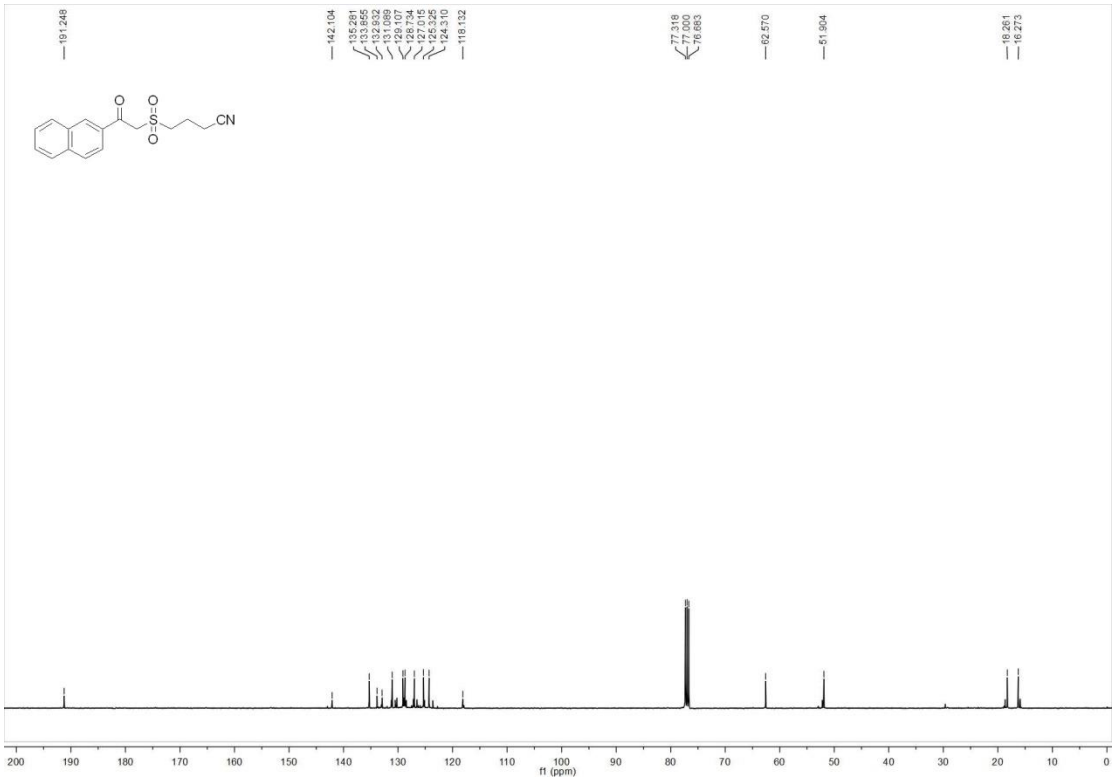


4-((2-(Naphthalen-2-yl)-2-oxoethyl)sulfonyl)butanenitrile (4s)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4s**

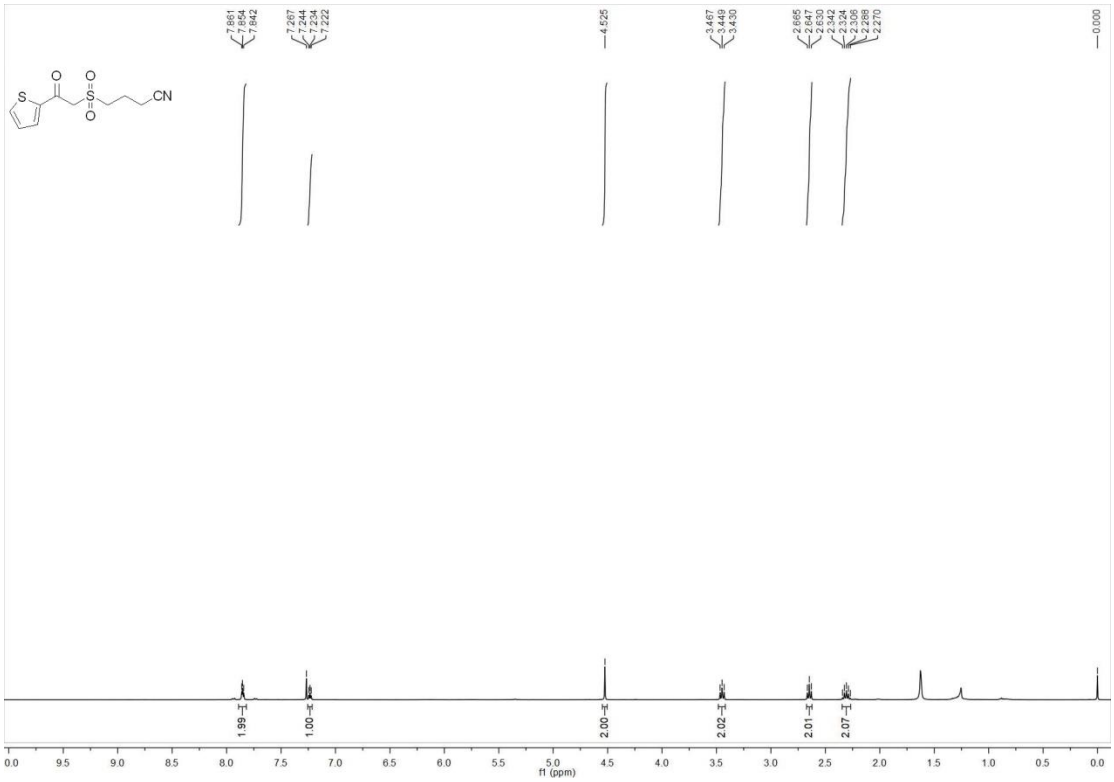


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4s**

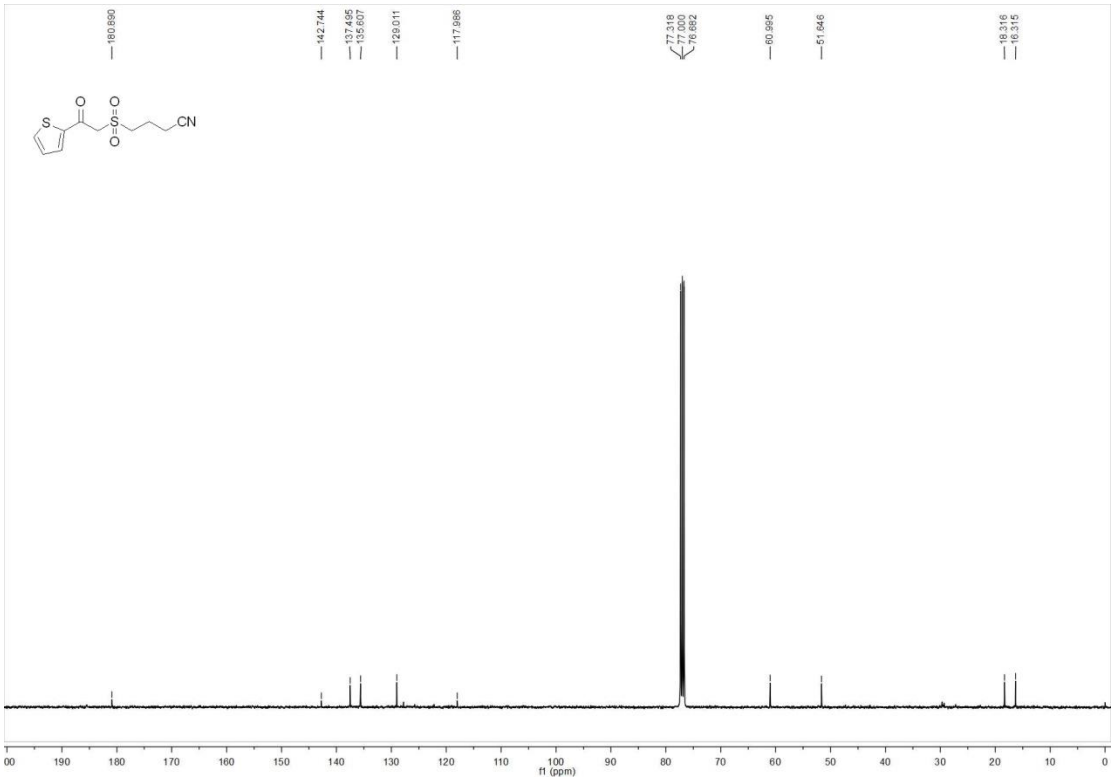


4-((2-*oxo*-2-(Thiophen-2-yl)ethyl)sulfonyl)butanenitrile (4t)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4t**

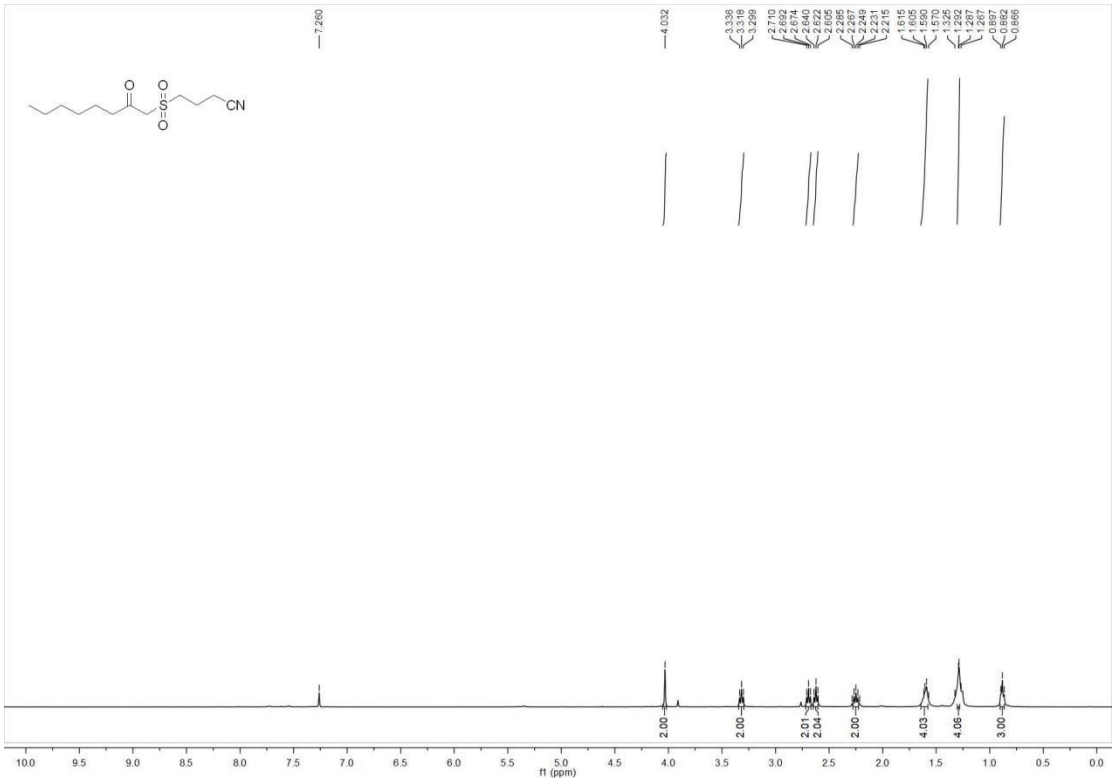


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4t**

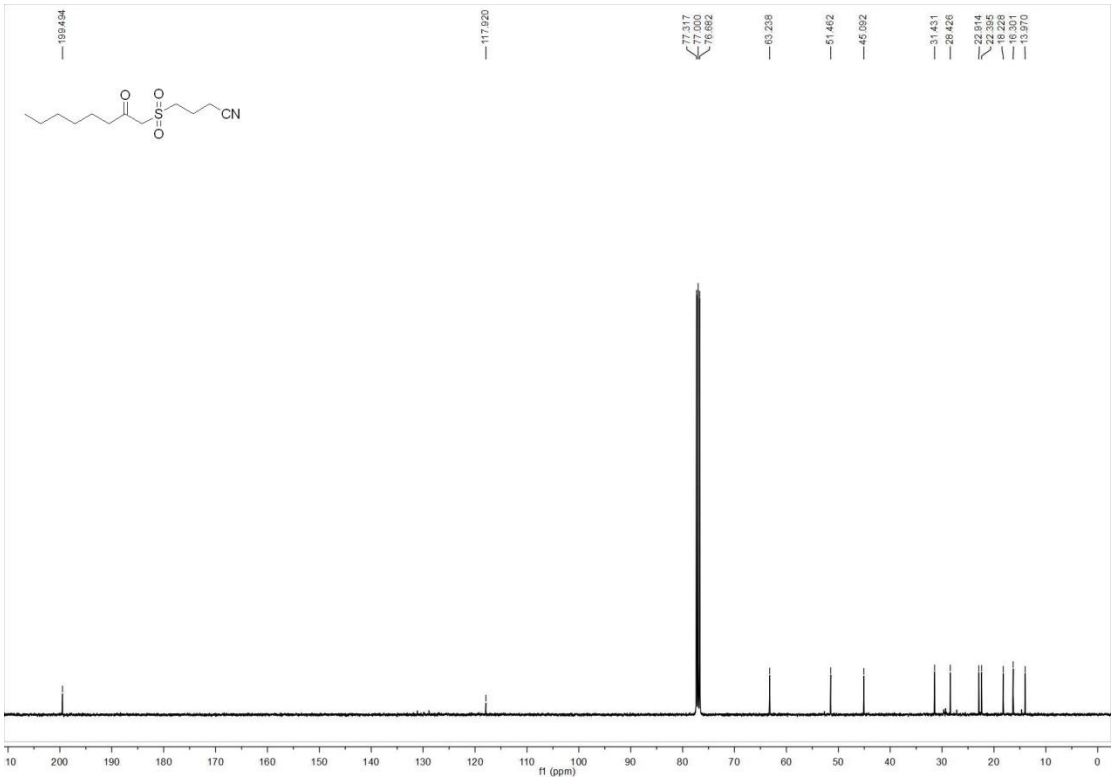


4-((2-Oxooctyl)sulfonyl)butanenitrile (4u)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4u**

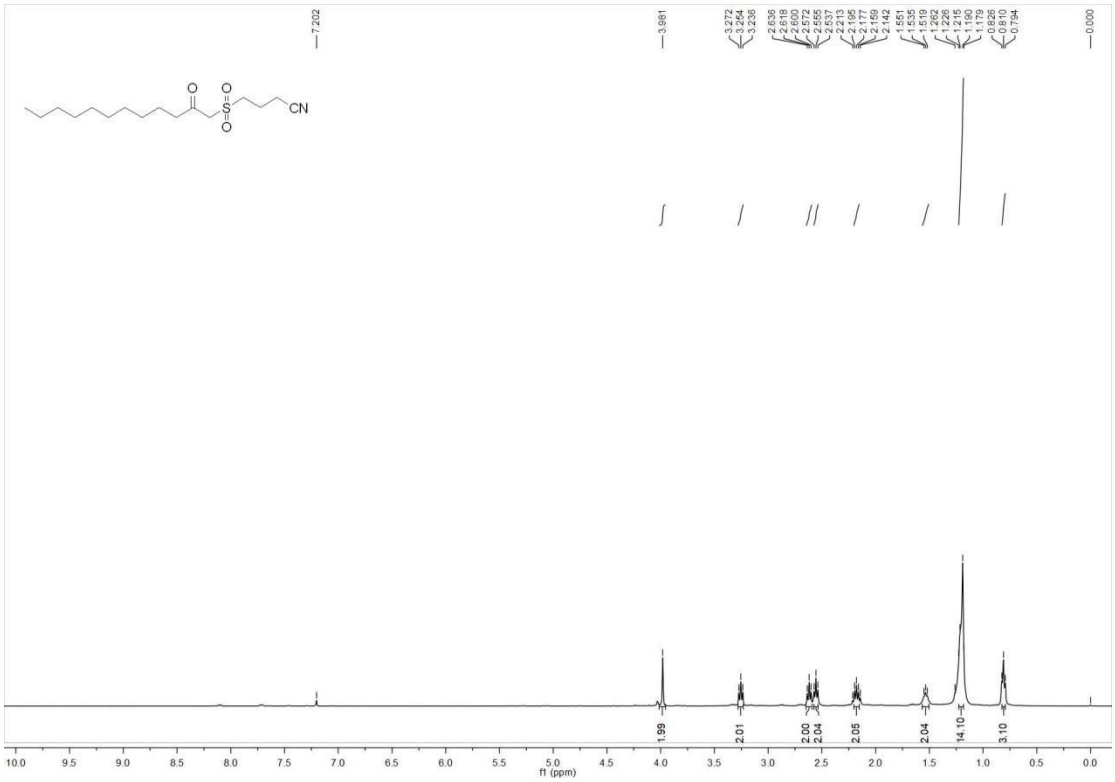


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4u**

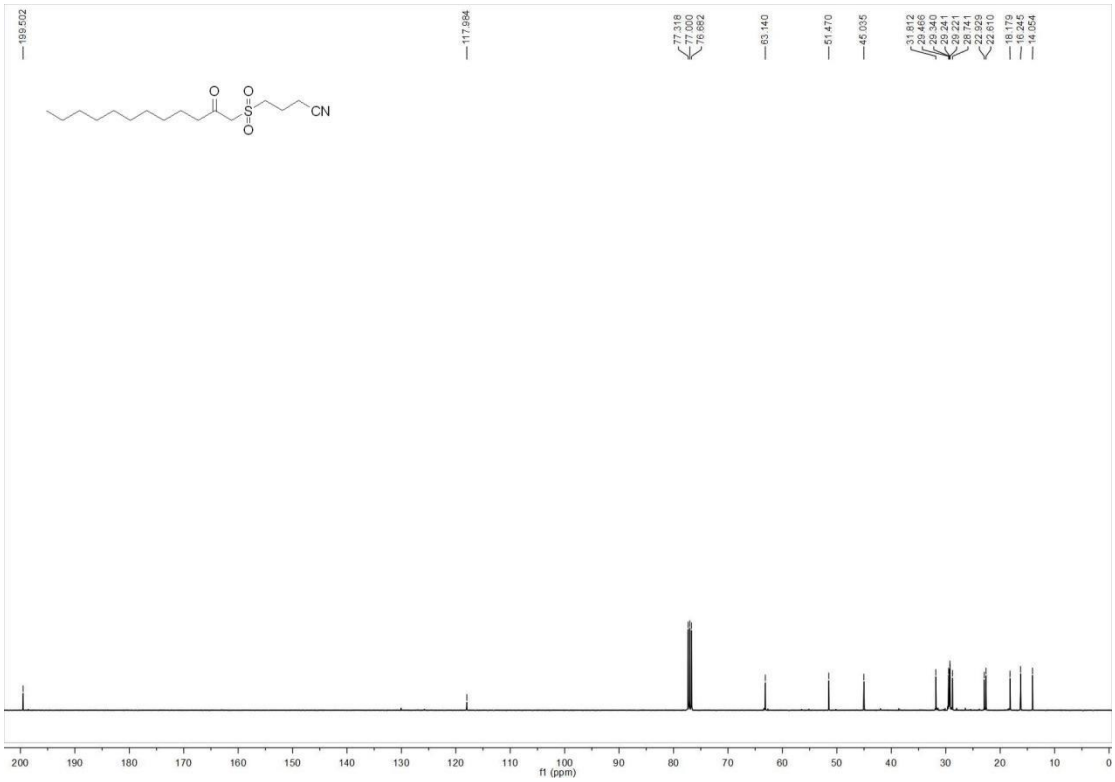


4-((2-Oxododecyl)sulfonyl)butanenitrile (4v)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4v**

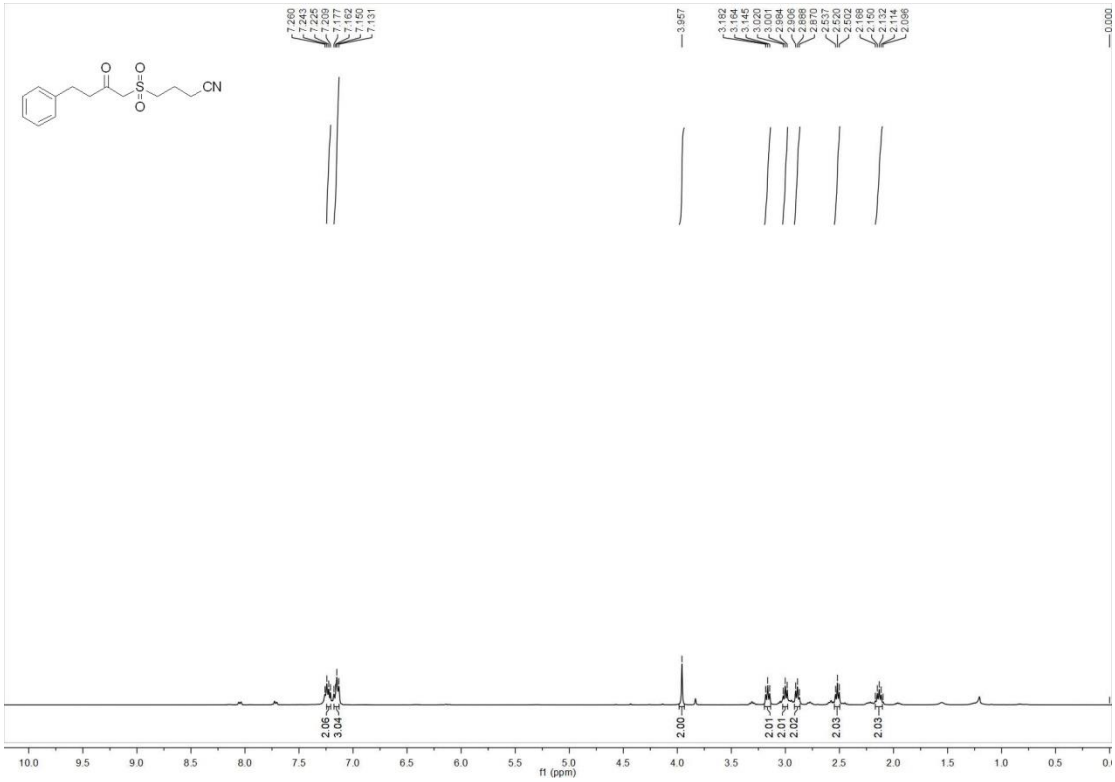


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4v**

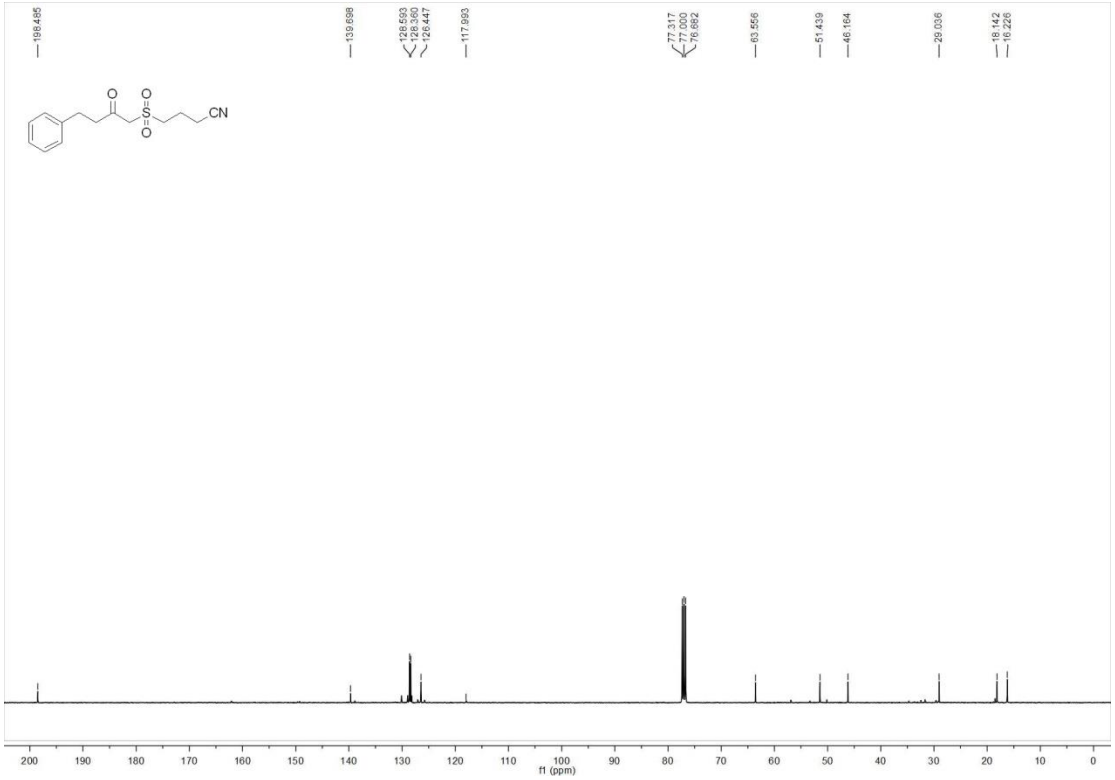


4-((2-*oxo*-4-Phenylbutyl)sulfonyl)butanenitrile (4w)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4w**

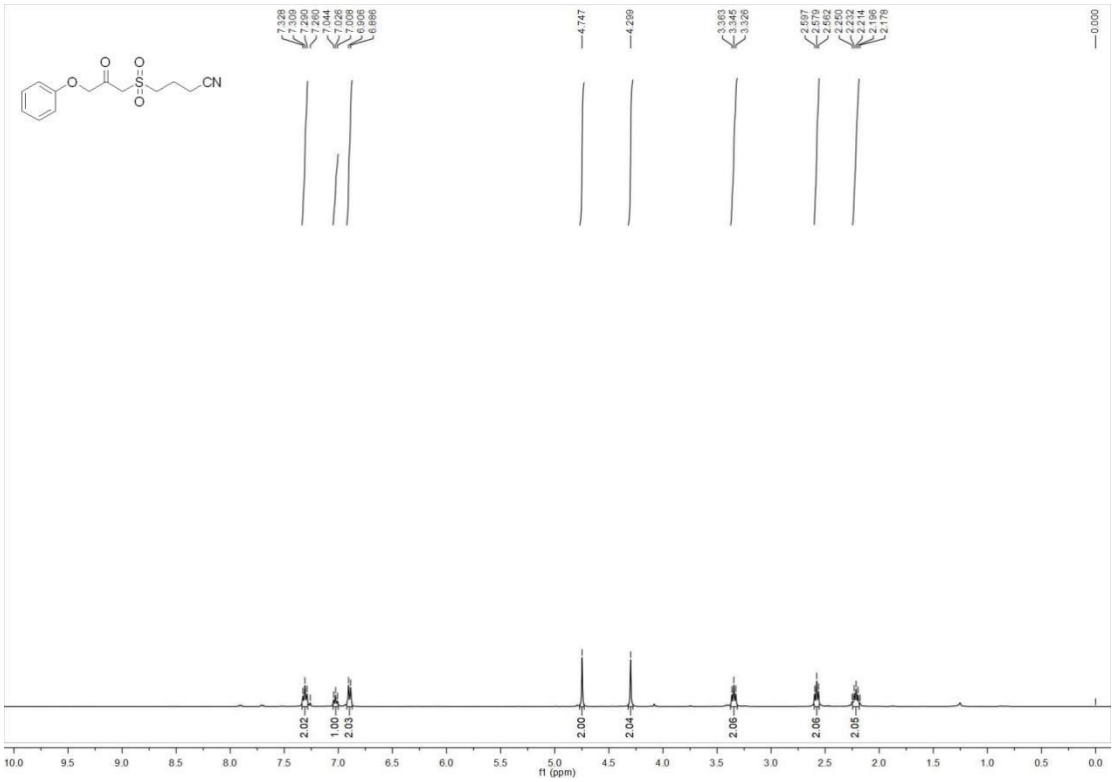


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4w**

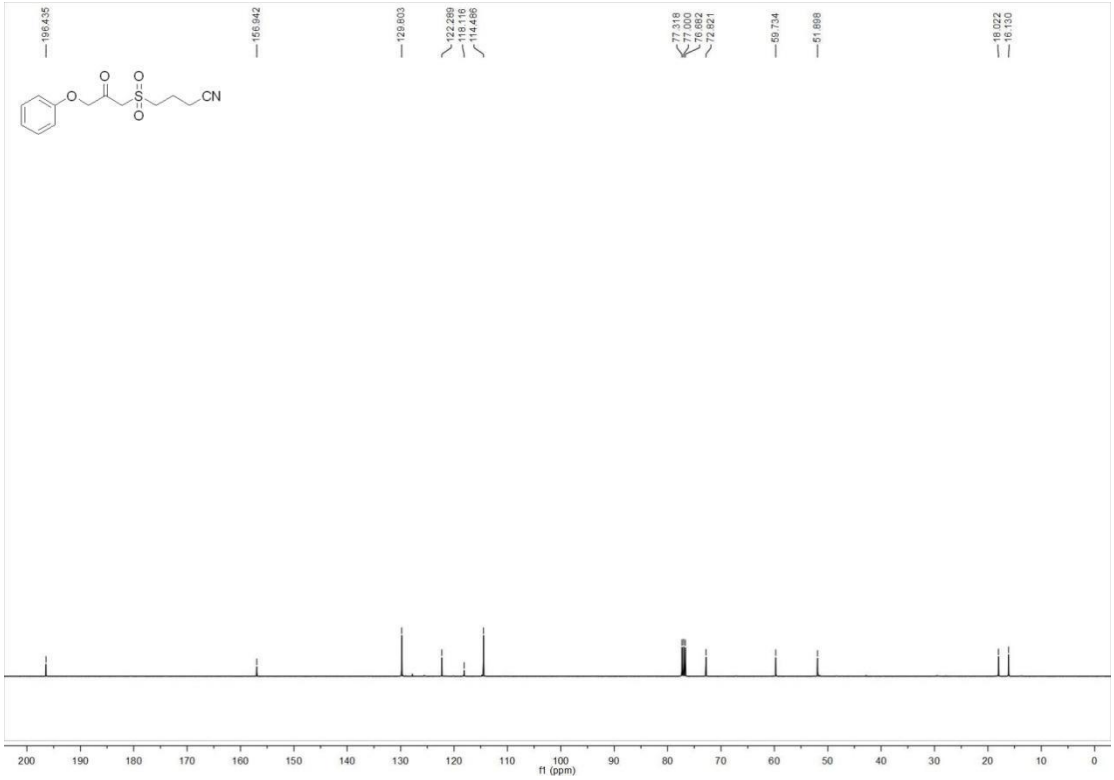


4-((2-*oxo*-3-Phenoxypropyl)sulfonyl)butanenitrile (4x)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **4x**

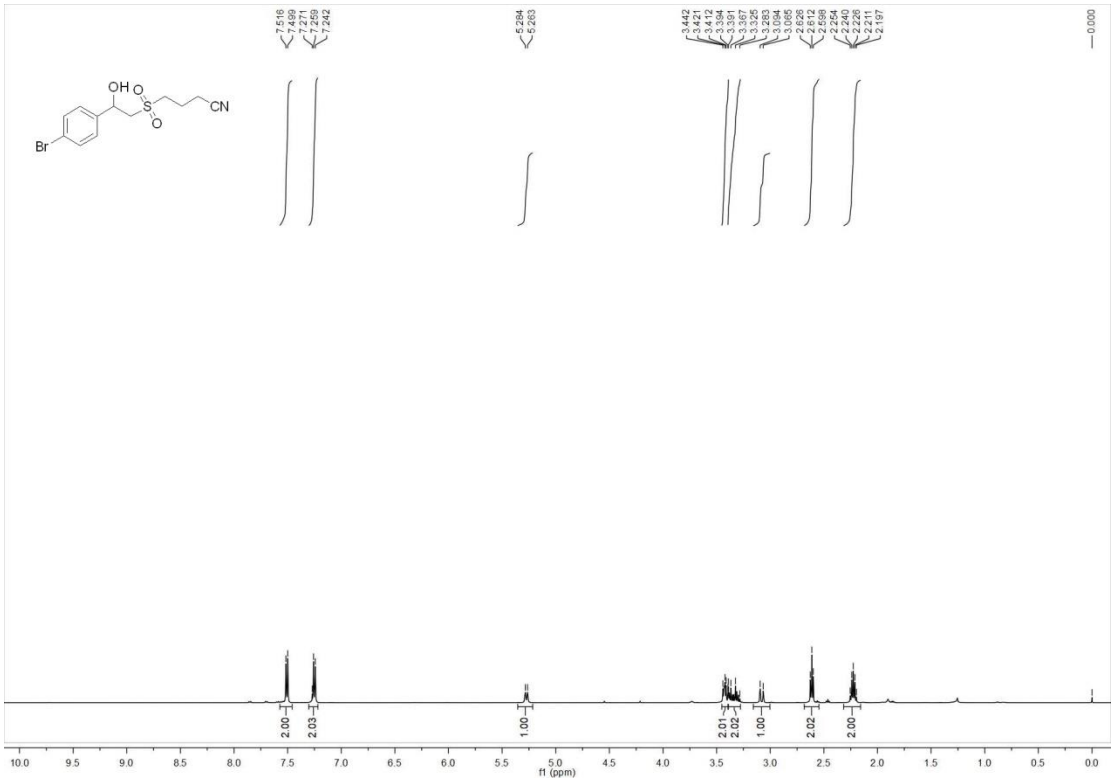


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **4x**

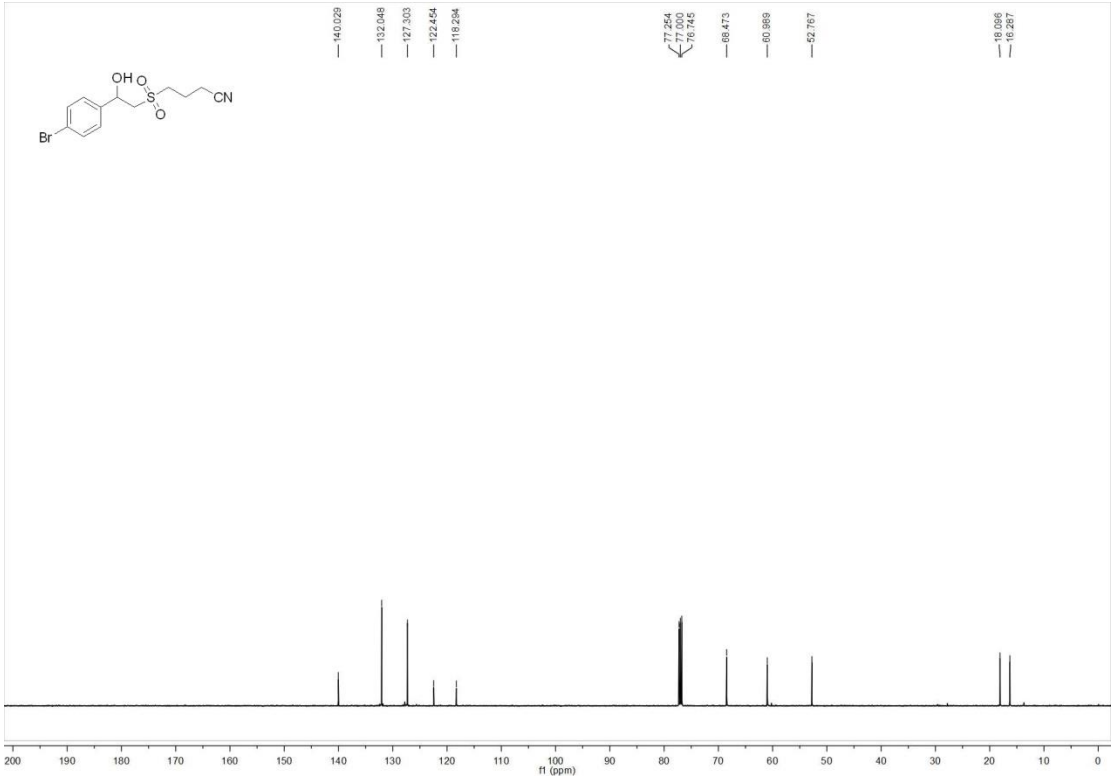


4-((2-(4-Bromophenyl)-2-hydroxyethyl)sulfonyl)butanenitrile (7a)

^{1}H NMR-spectrum (500 MHz, $CDCl_3$) of **7a**

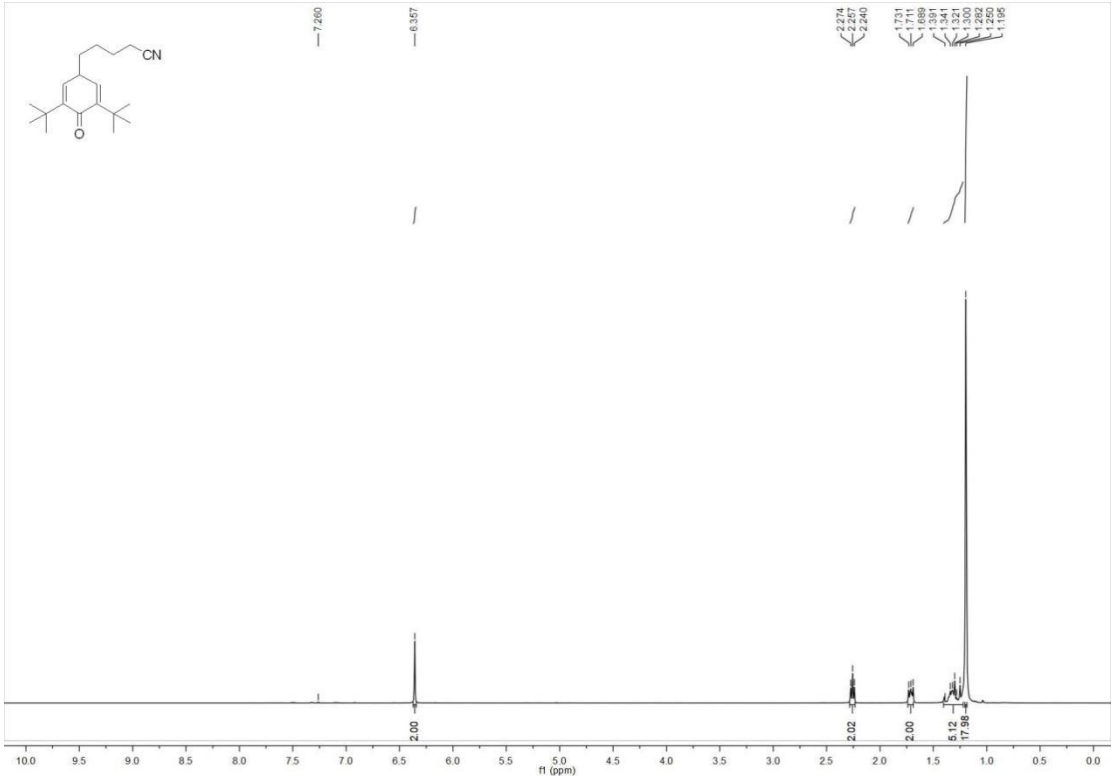


^{13}C NMR-spectrum (126 MHz, $CDCl_3$) of **7a**

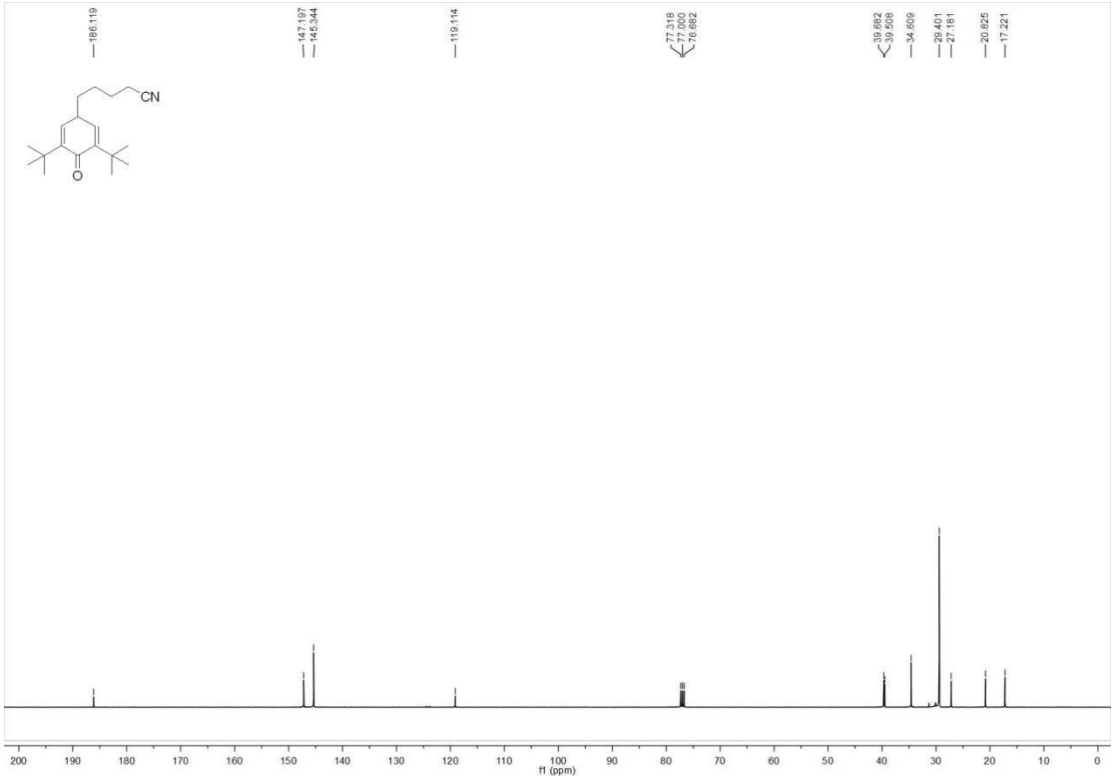


5-(3,5-di-*tert*-Butyl-4-oxocyclohexa-2,5-dien-1-yl)pentanenitrile (9a)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **9a**

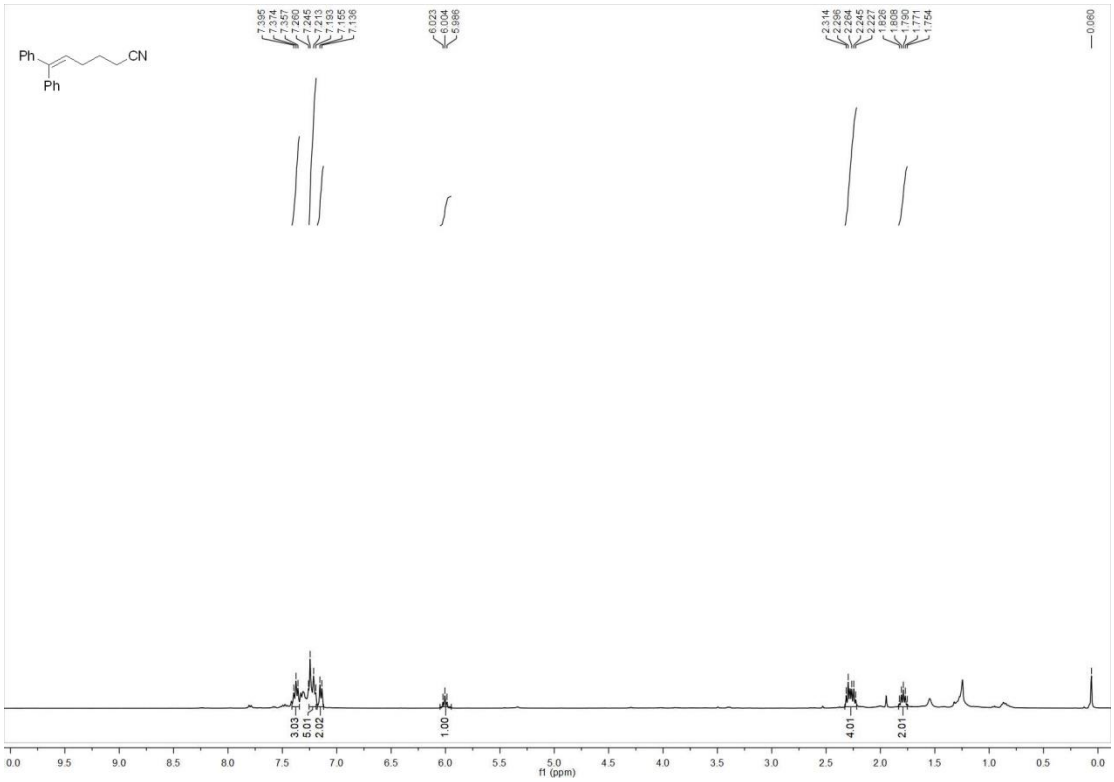


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **9a**

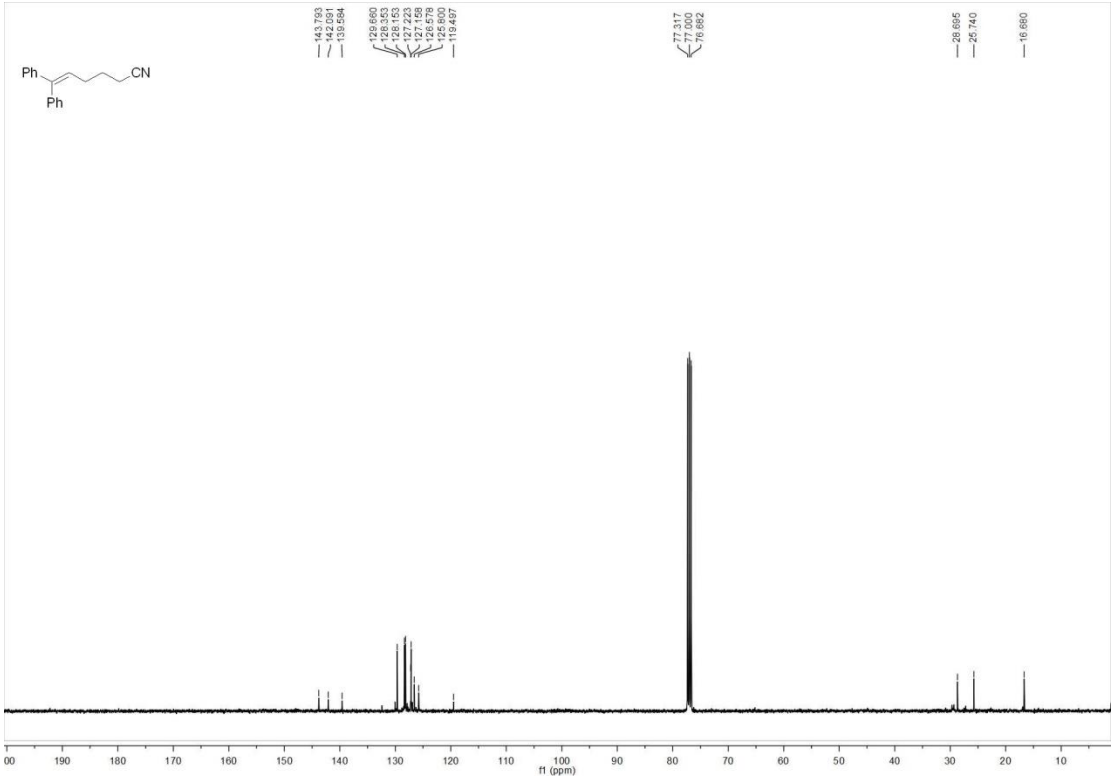


6,6-Diphenylhex-5-enenitrile (10a)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **10a**

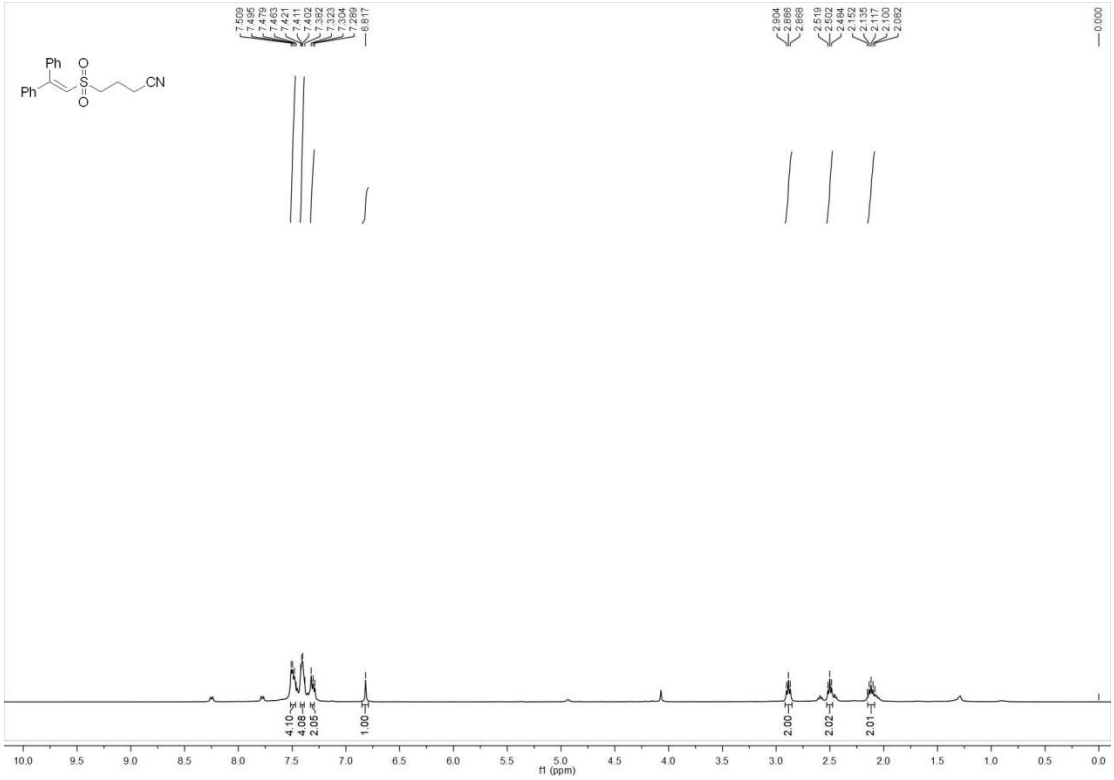


^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **10a**



4-((2,2-Diphenylvinyl)sulfonyl)butanenitrile (11a)

^{1}H NMR-spectrum (400 MHz, $CDCl_3$) of **11a**



^{13}C NMR-spectrum (101 MHz, $CDCl_3$) of **11a**