Sulfonyl Azides as Precursors in Ligand-Free Palladium-Catalyzed Synthesis of Sulfonyl Carbamates and Sulfonyl Ureas and Synthesis of Sulfonamides

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Reaction setup for preparation of sulfonyl ureas and sulfonyl carbamates from sulfonyl azides

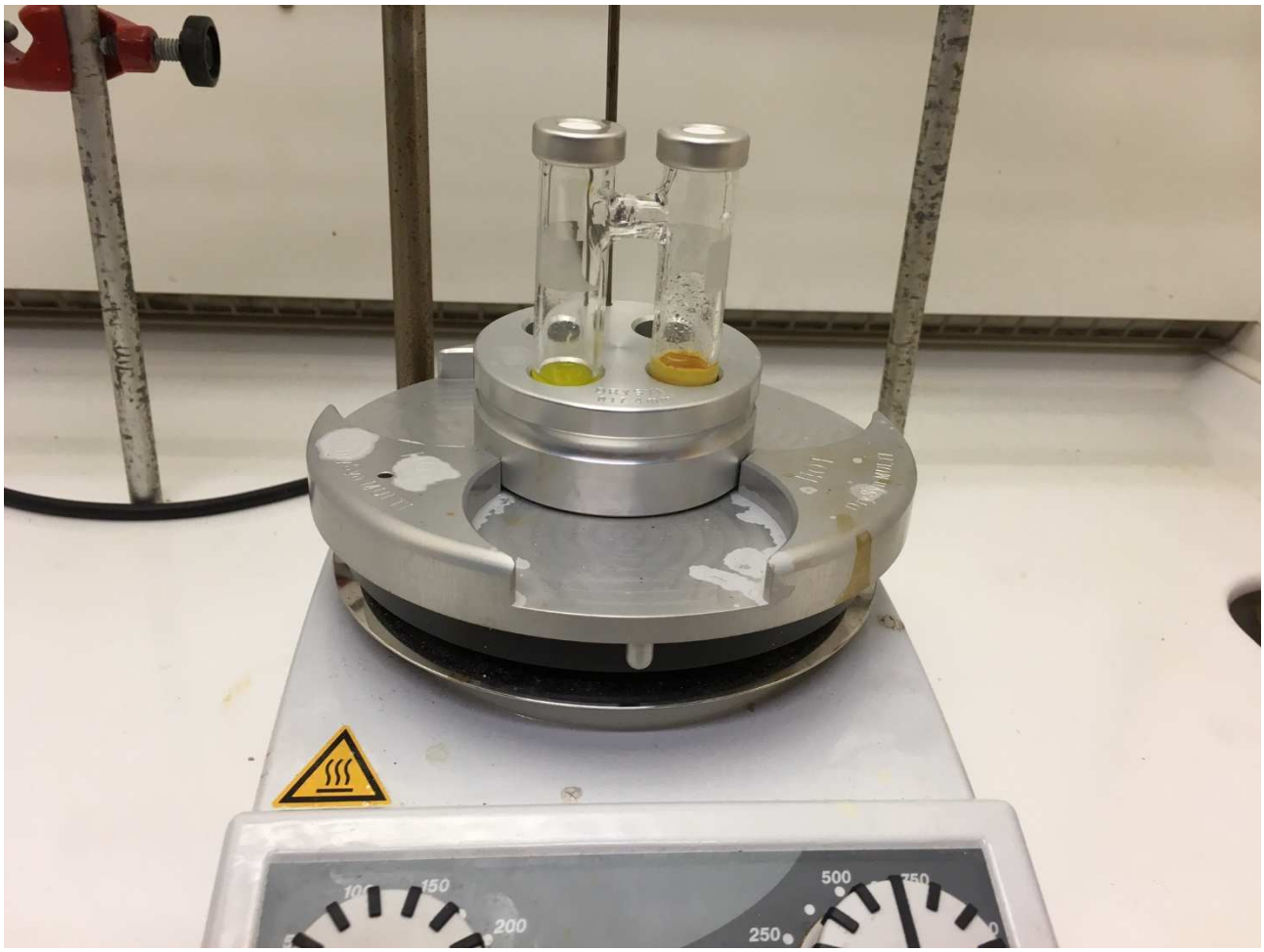


Figure S1. Standard reaction setup for carbonylative synthesis of sulfonyl ureas and sulfonyl carbamates. Left-hand chamber contains sulfonyl azide, nucleophile and $PdCl_2$, right-hand chamber contains $Mo(CO)_6$ and DBU. All reactions were run in DMA.

Stability assay of *p*-nitrobenzenesulfonyl chloride and *p*-nitrobenzenesulfonyl azide at ambient and elevated temperature

On the suggestion of an anonymous reviewer, a stability assay was conducted to evaluate the stability of electron-deficient arylsulfonyl azides and arylsulfonyl chlorides. Heteroarylsulfonyl chlorides such as 2-pyrimidinesulfonyl chlorides are known to undergo decomposition with loss of SO_2 to furnish the corresponding pyrimidine-2-chloride.[1] **Procedure**: a standard 5 mm NMR tube containing a ~ 0.05 mM solution of sulfonyl chloride or sulfonyl azide was analyzed[2] by ^{1}H NMR at 1 h and 18 h. Procedure A=**ambient** temperature. Procedure B= **elevated** temperature (50 °C). The relative degree of decomposition was calculated by comparing the integrals of compound vs. impurities over time (see Figure S2). The substrates were found to be stable under these conditions and no traces of degraded products were observed.

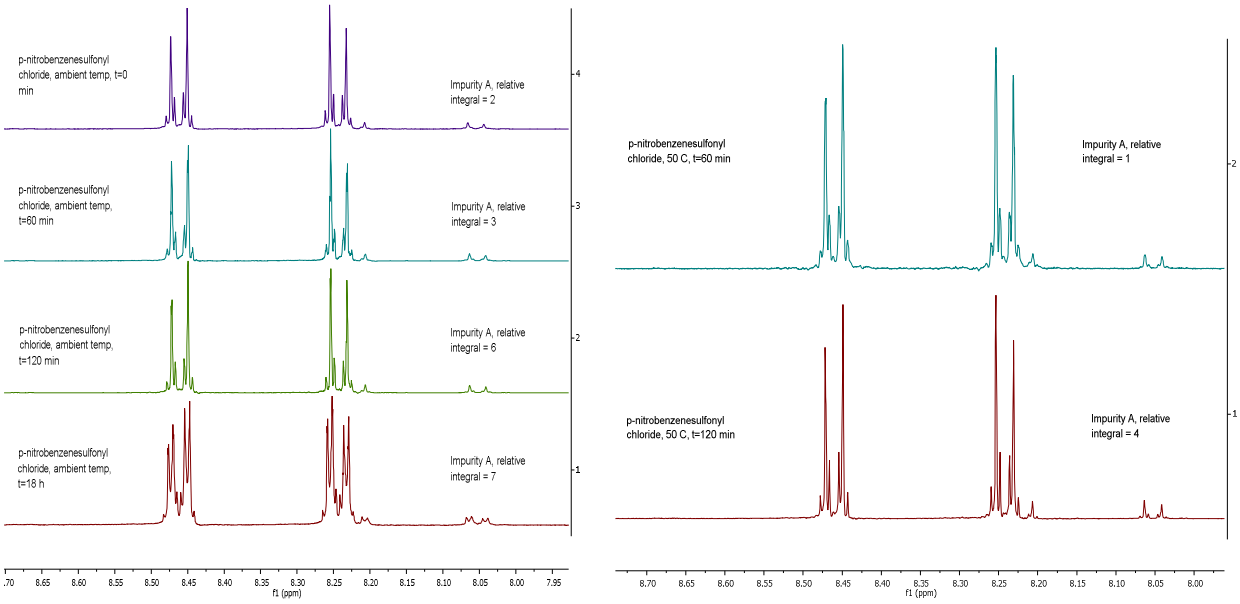
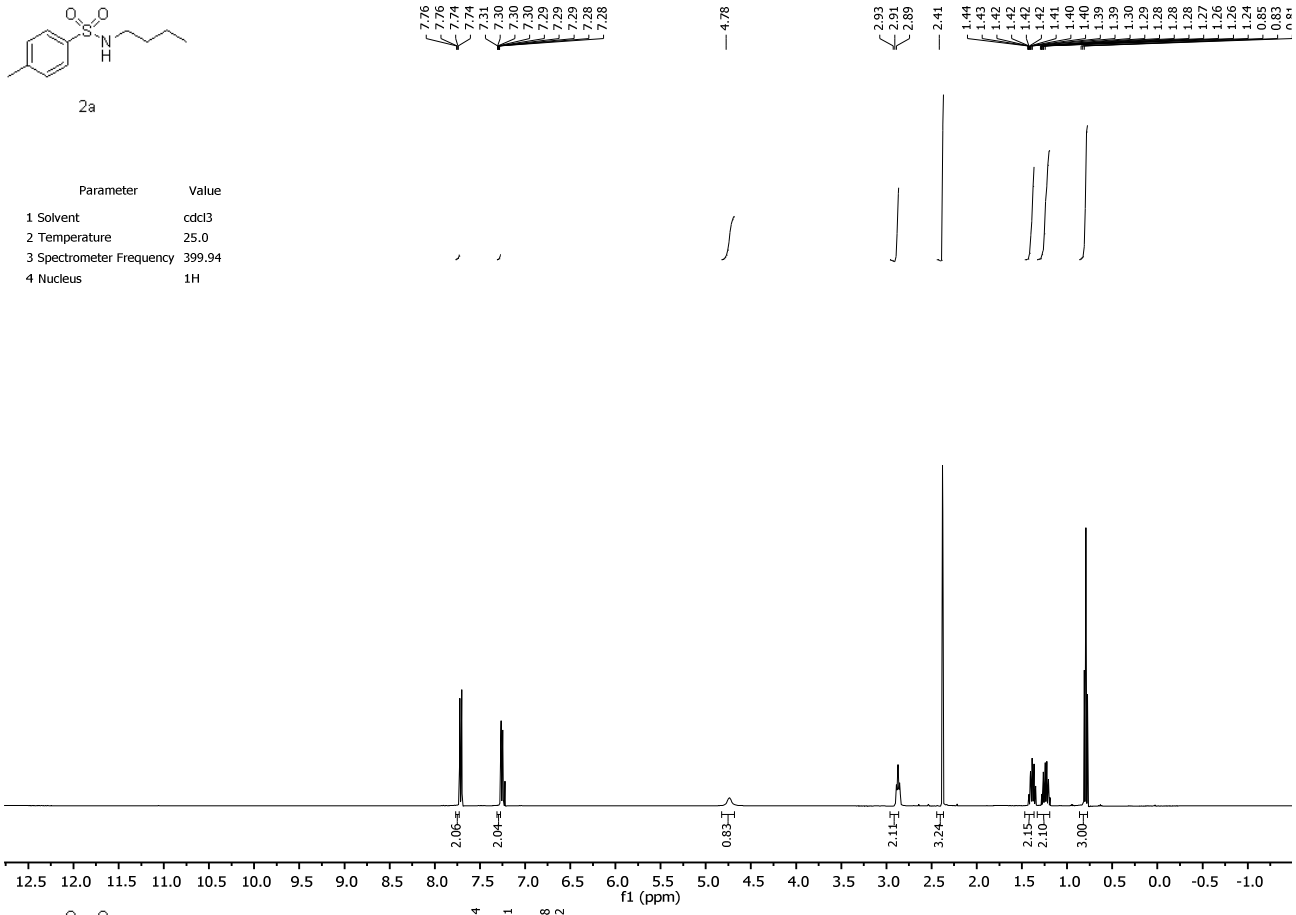


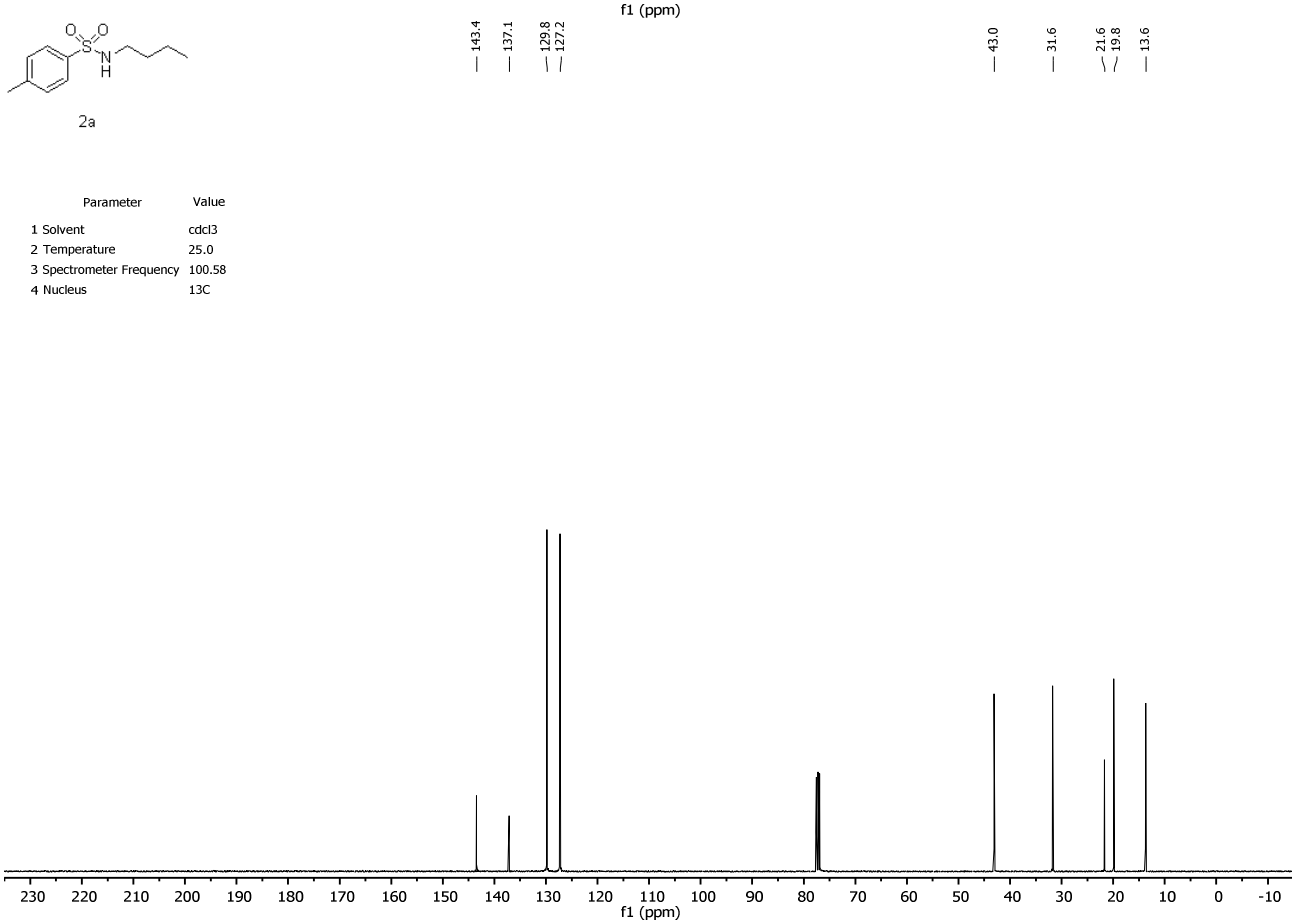
Figure S2. Stability assay of *p*-nitrobenzenesulfonyl chloride in $CDCl_3$ at ambient temperature and 50 °C

[1] Brown, D. J. *The Chemistry of Heterocyclic Compounds, the Pyrimidines: Supplement 2.* Volume 16 of The Chemistry of Heterocyclic Compounds; John Wiley & Sons: New York, 2009; p.342.

[2] NMR acquisition parameters: relaxation delay = 60 s, acquisition time = 5.126 s, number of scans = 1, spectral width = 6398 Hz.

N-butyl-4-methylbenzenesulfonamide (Table 1, entry 8) (2a)

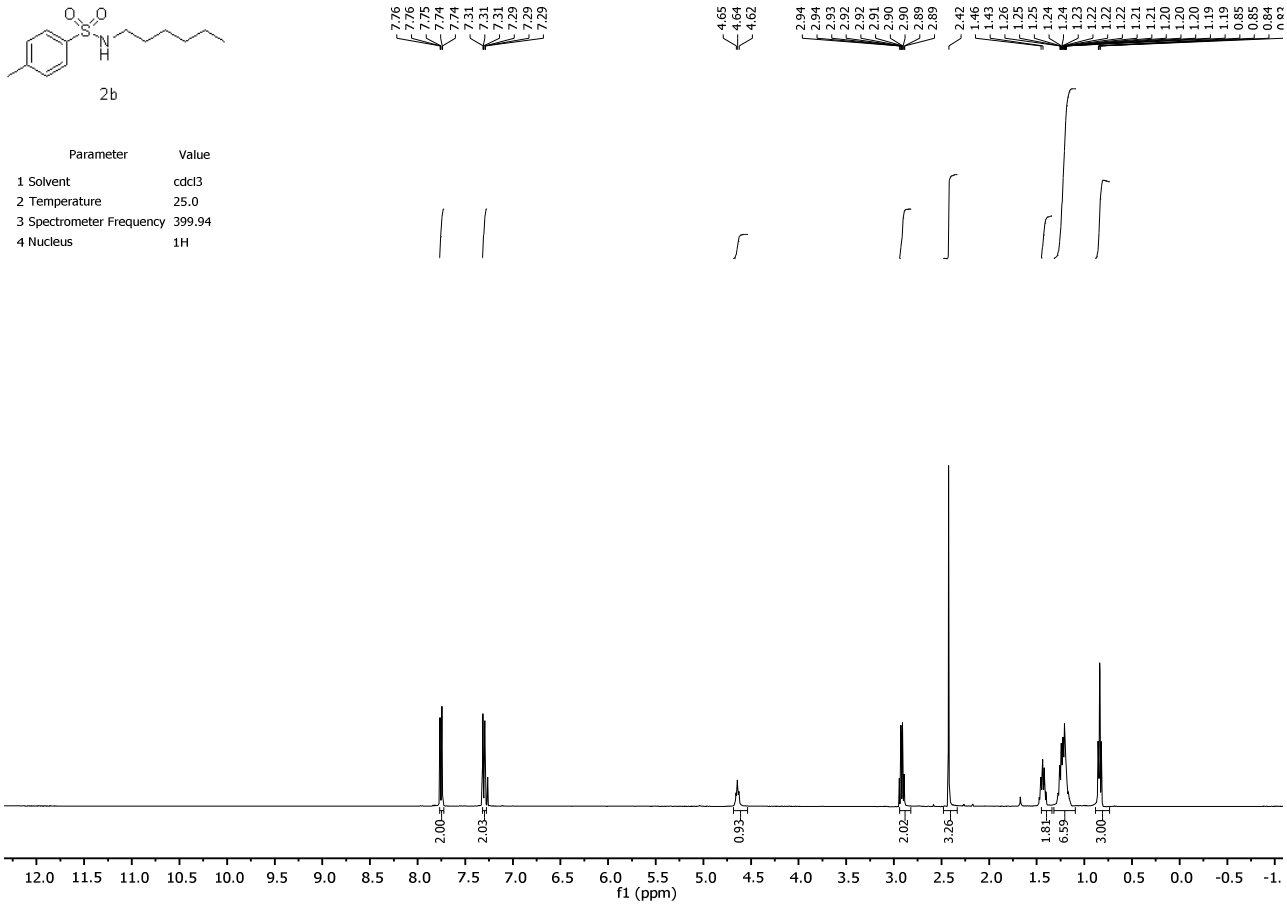




N-hexyl-4-methylbenzenesulfonamide (2b)

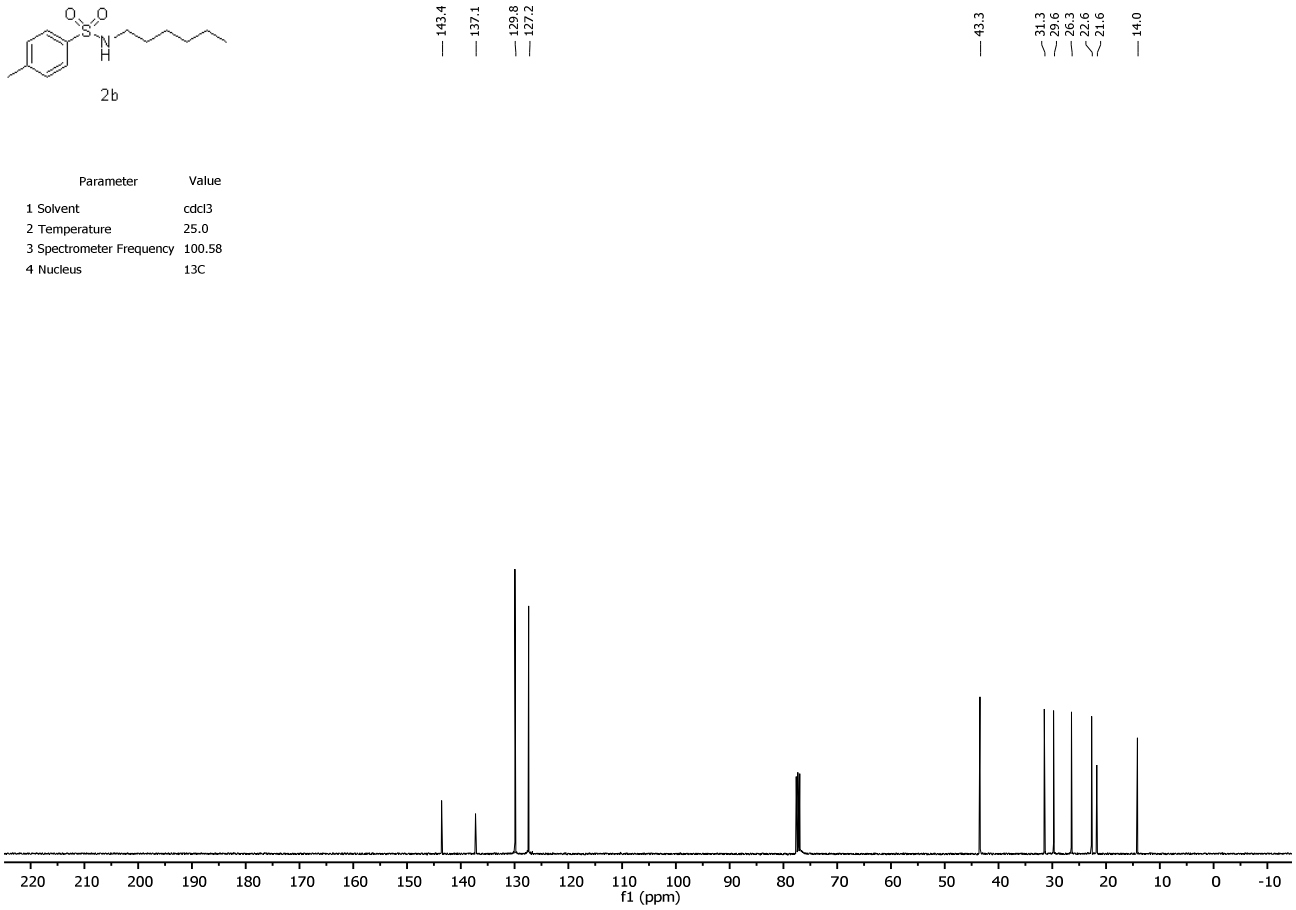
2b

Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	399.94
4 Nucleus	1H

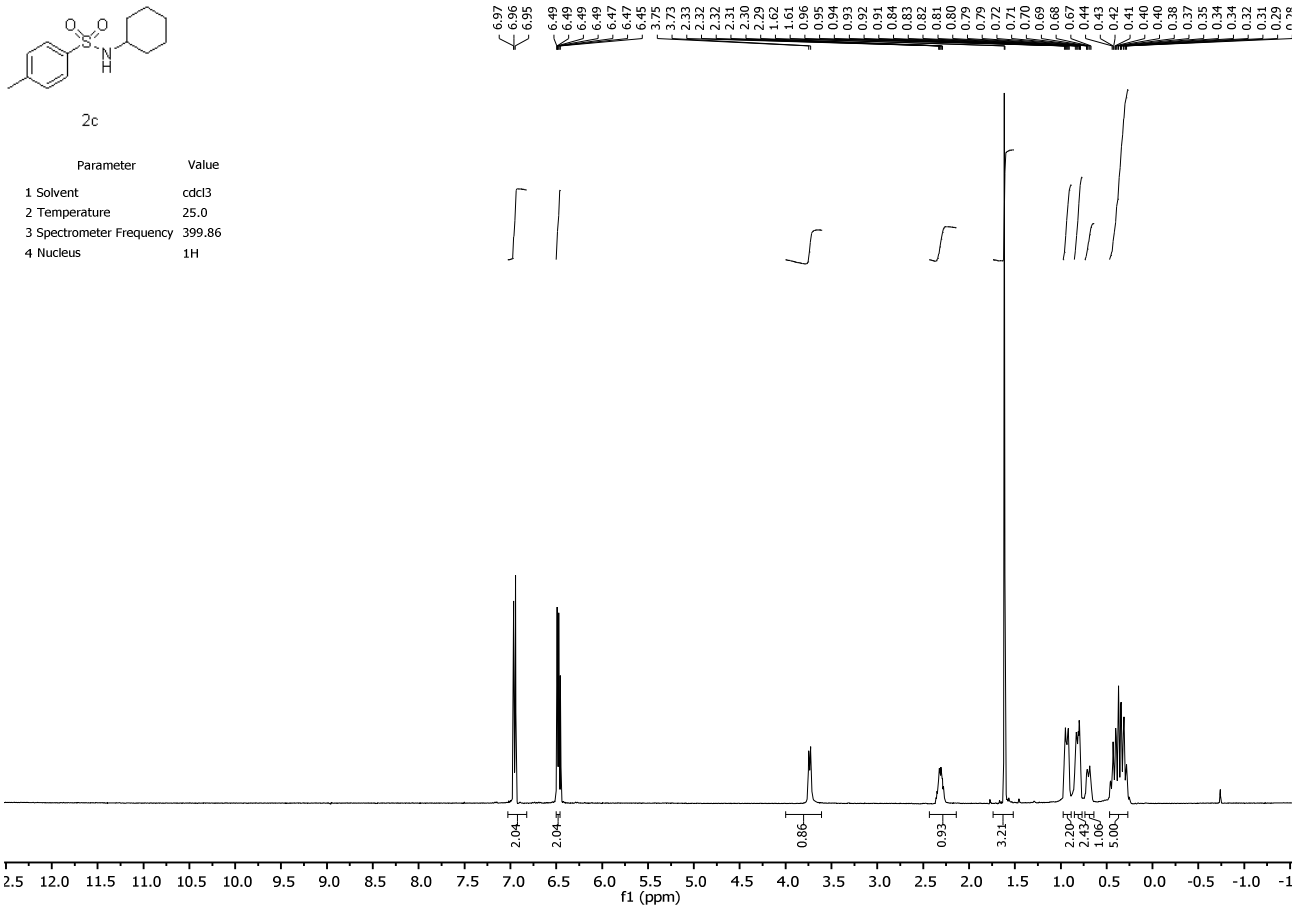


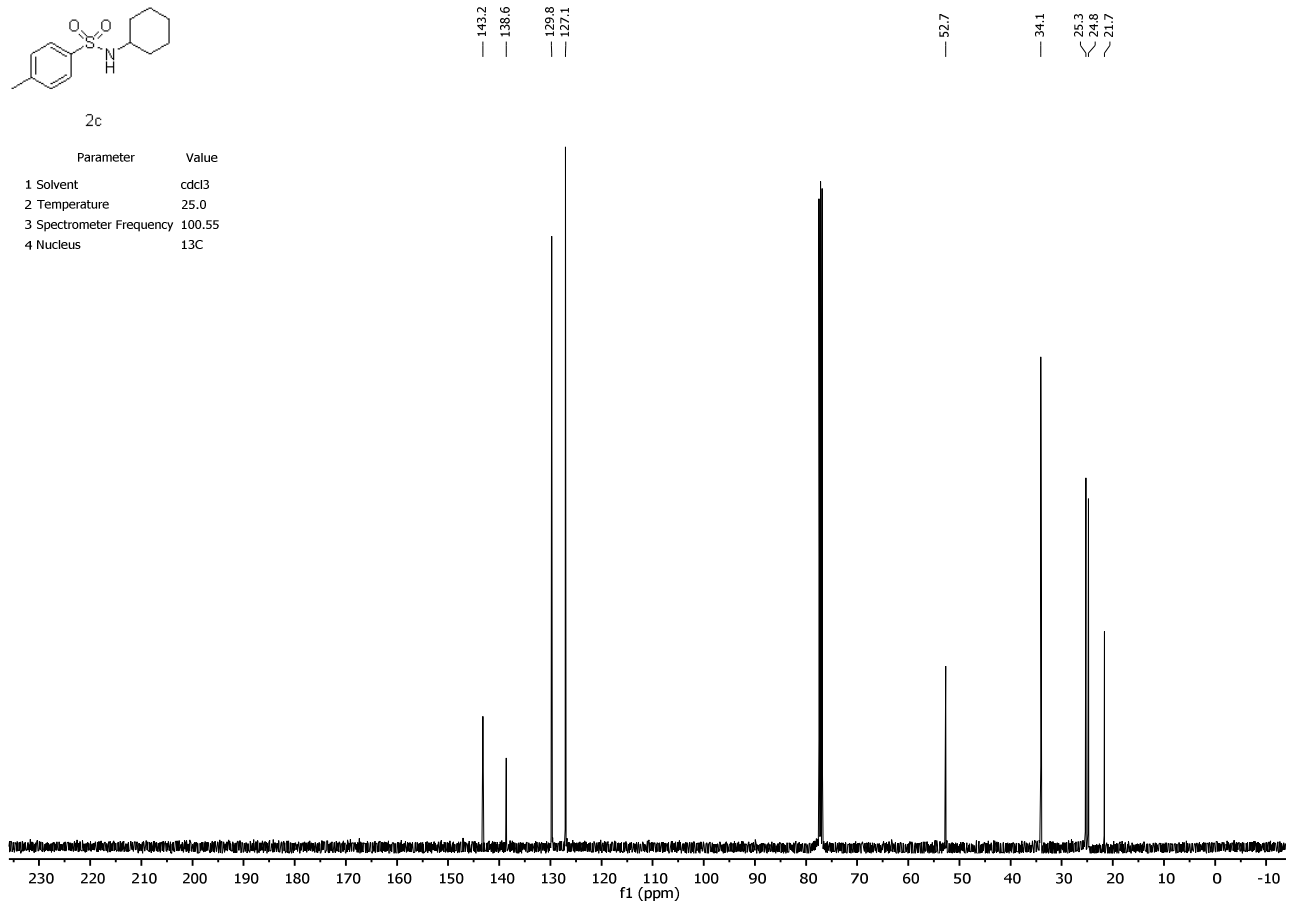
2b

Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	100.58
4 Nucleus	13C

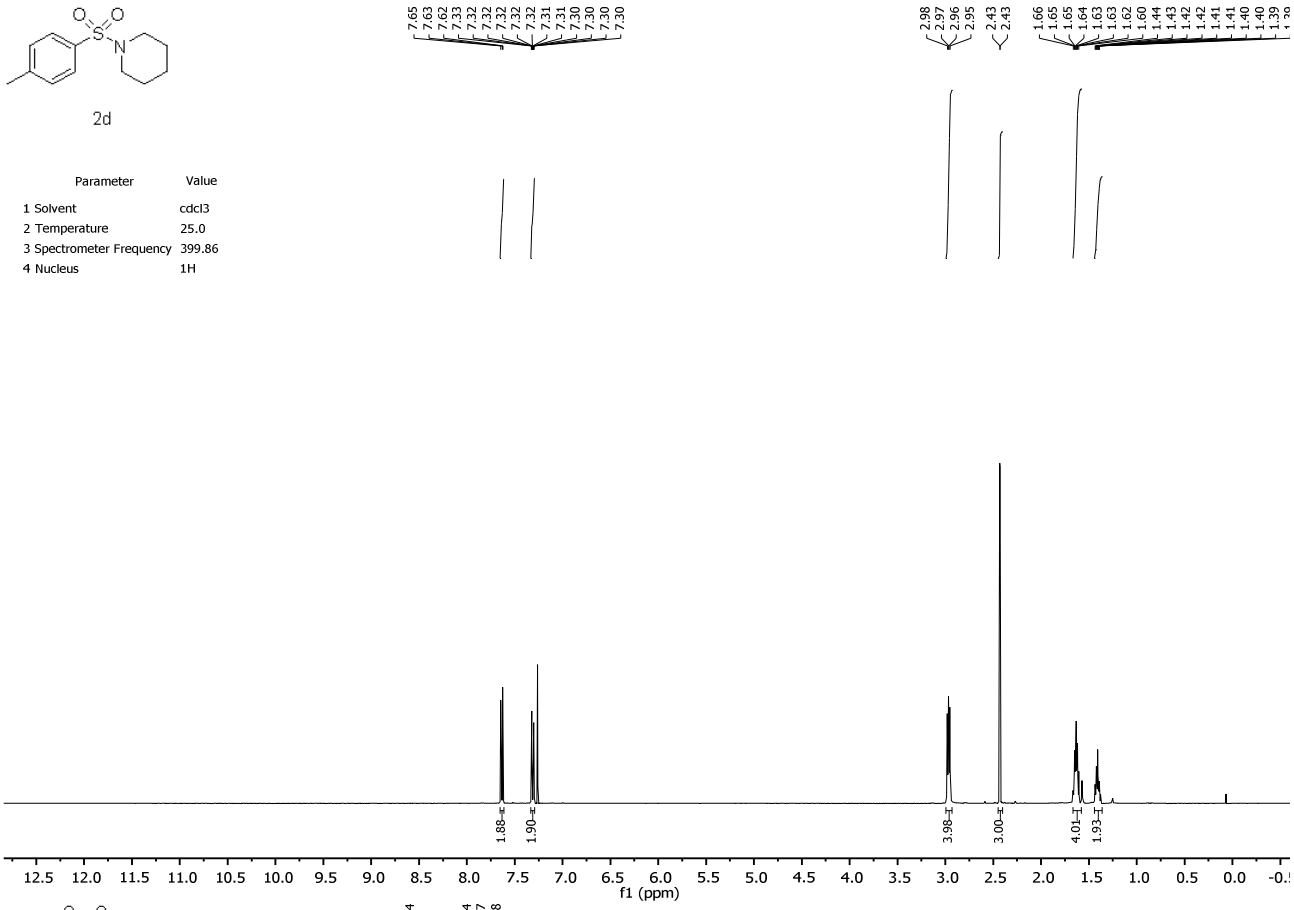


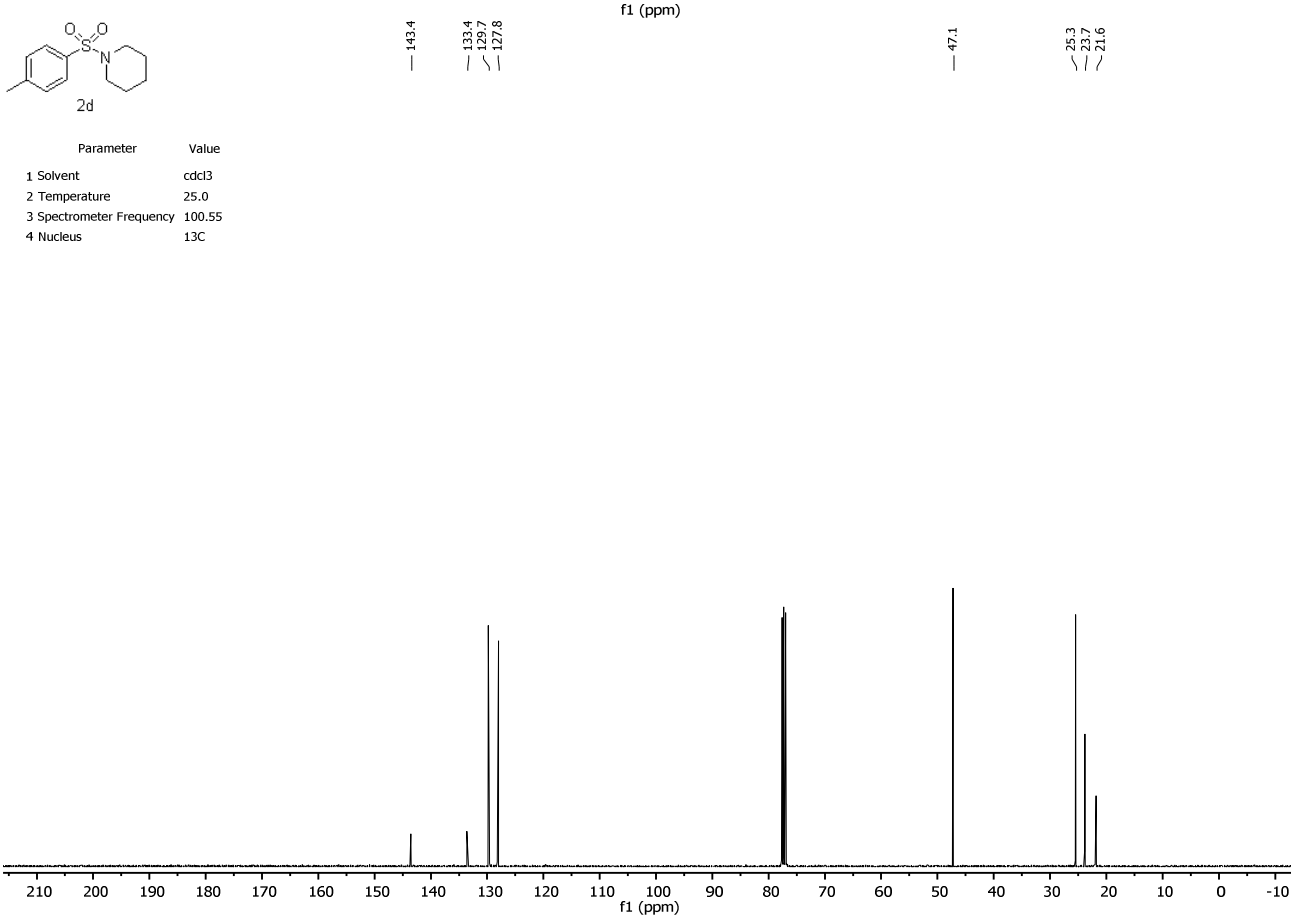
N-cyclohexyl-4-methylbenzenesulfonamide (2c)



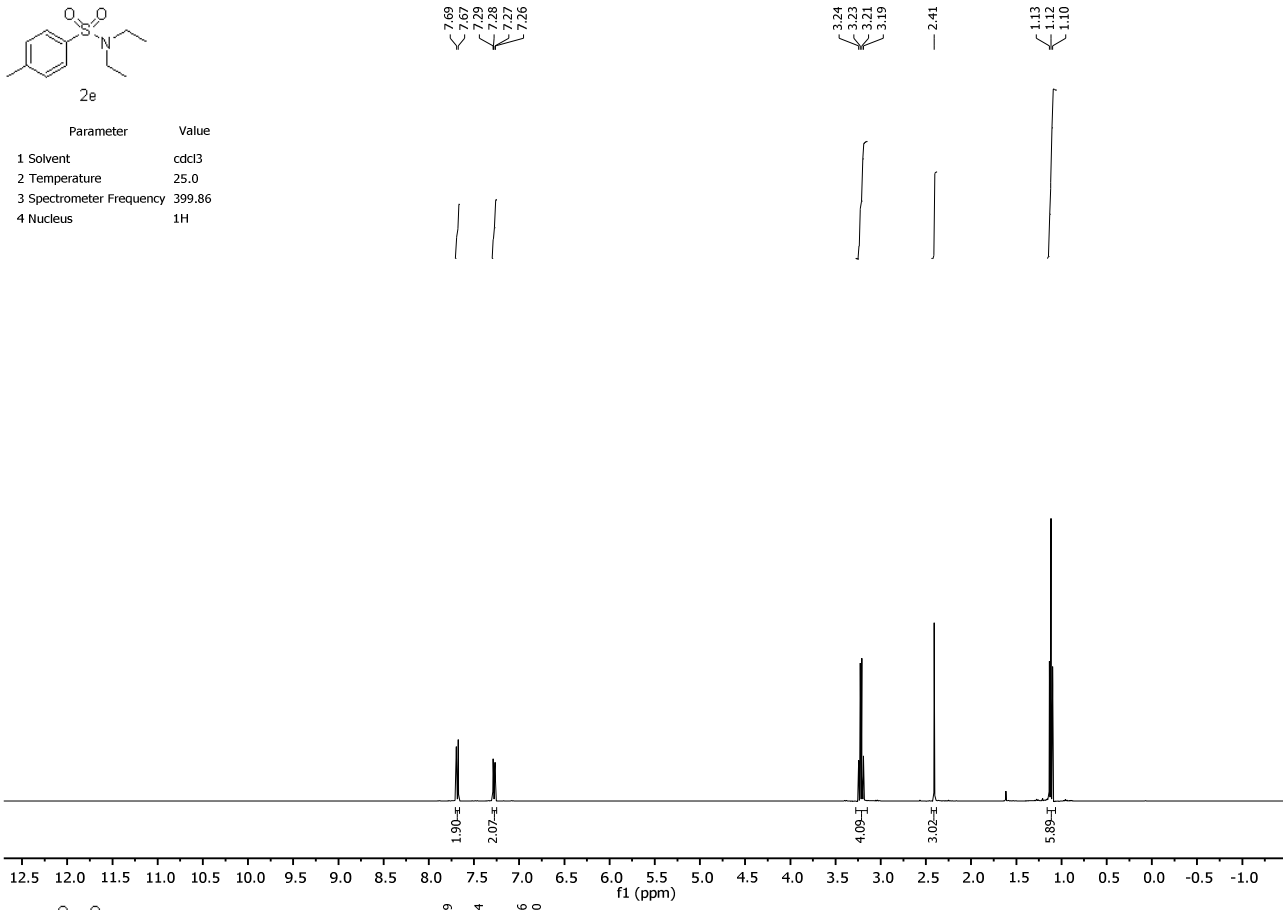


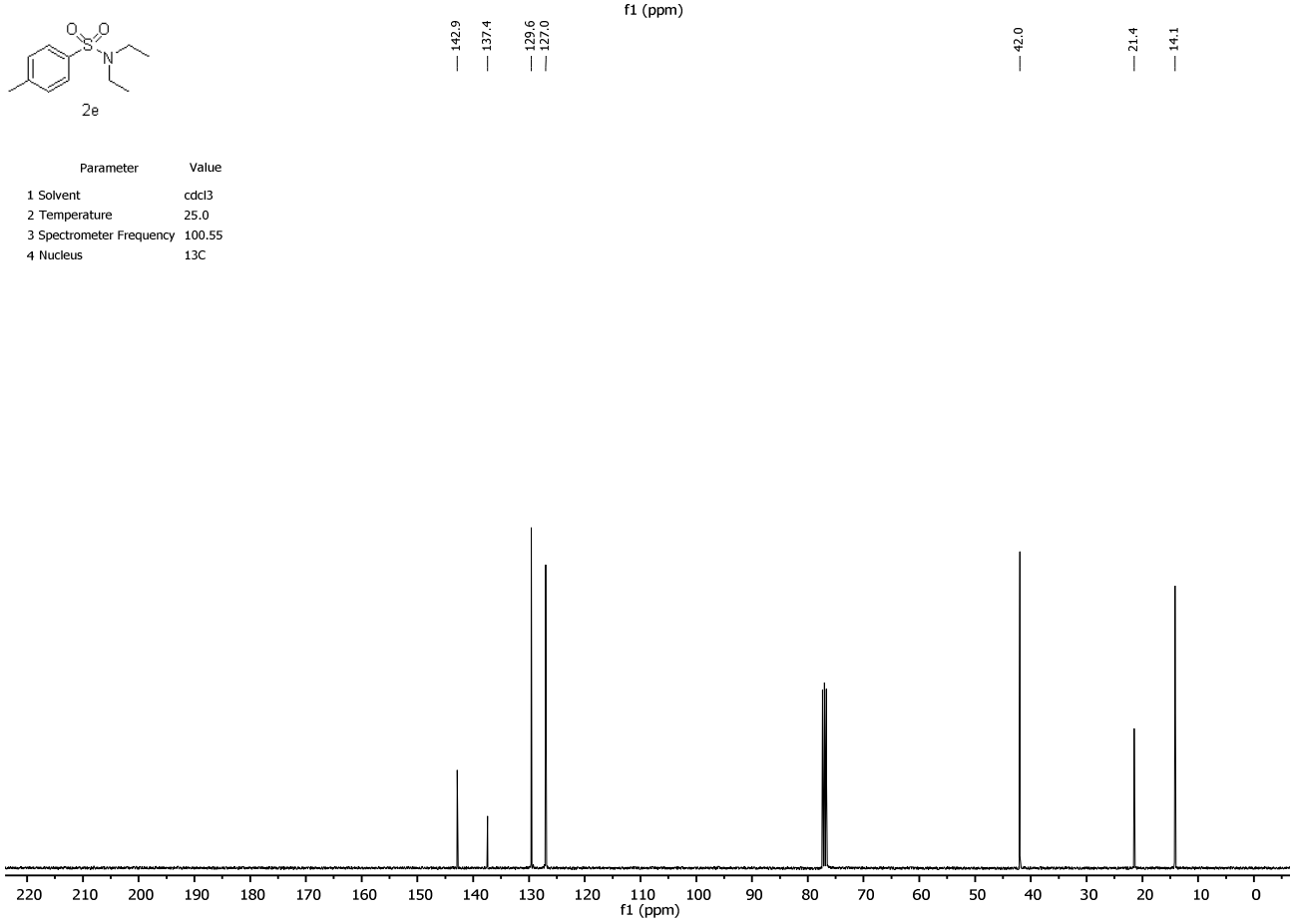
1-tosylpiperidine (2d)



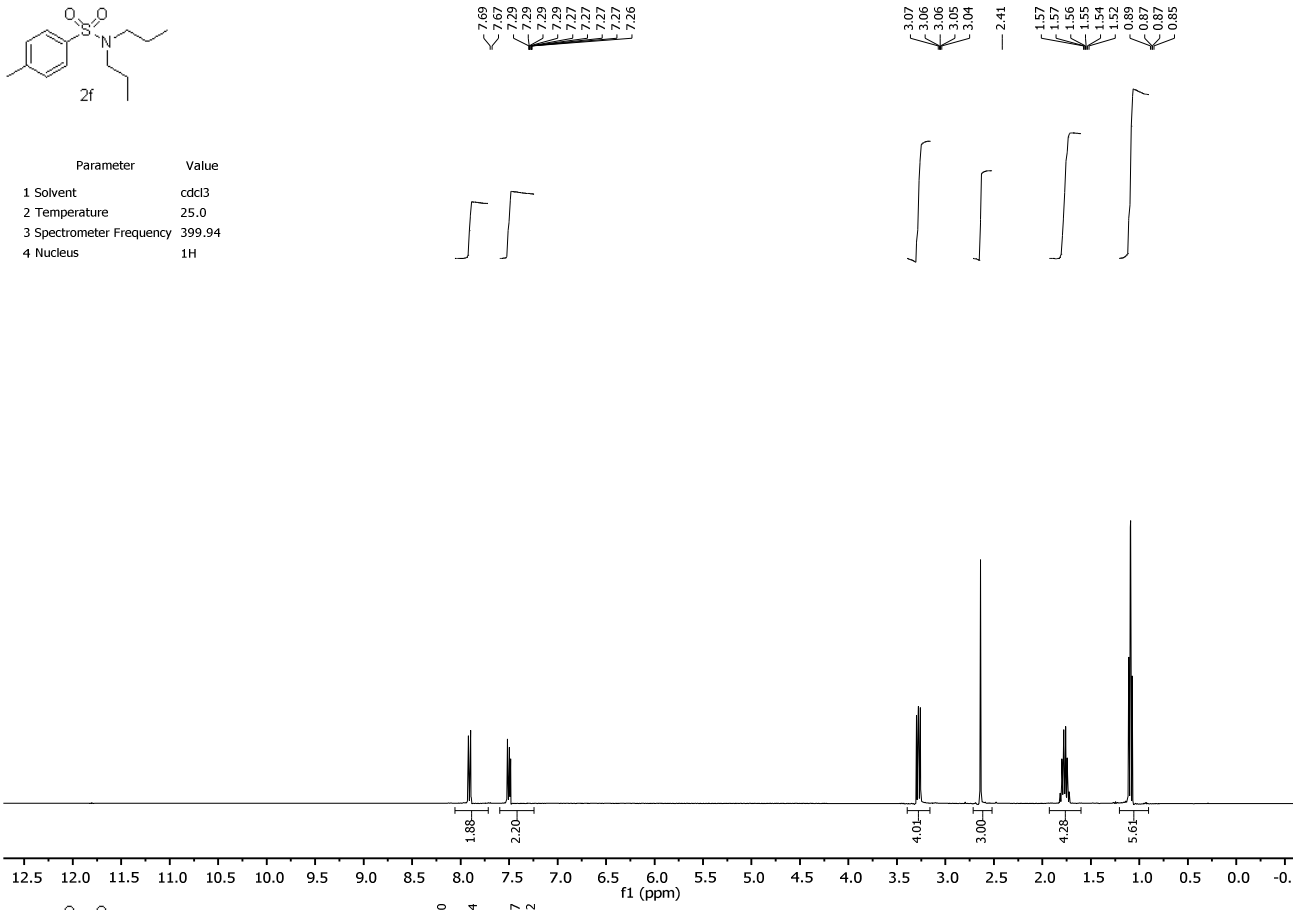


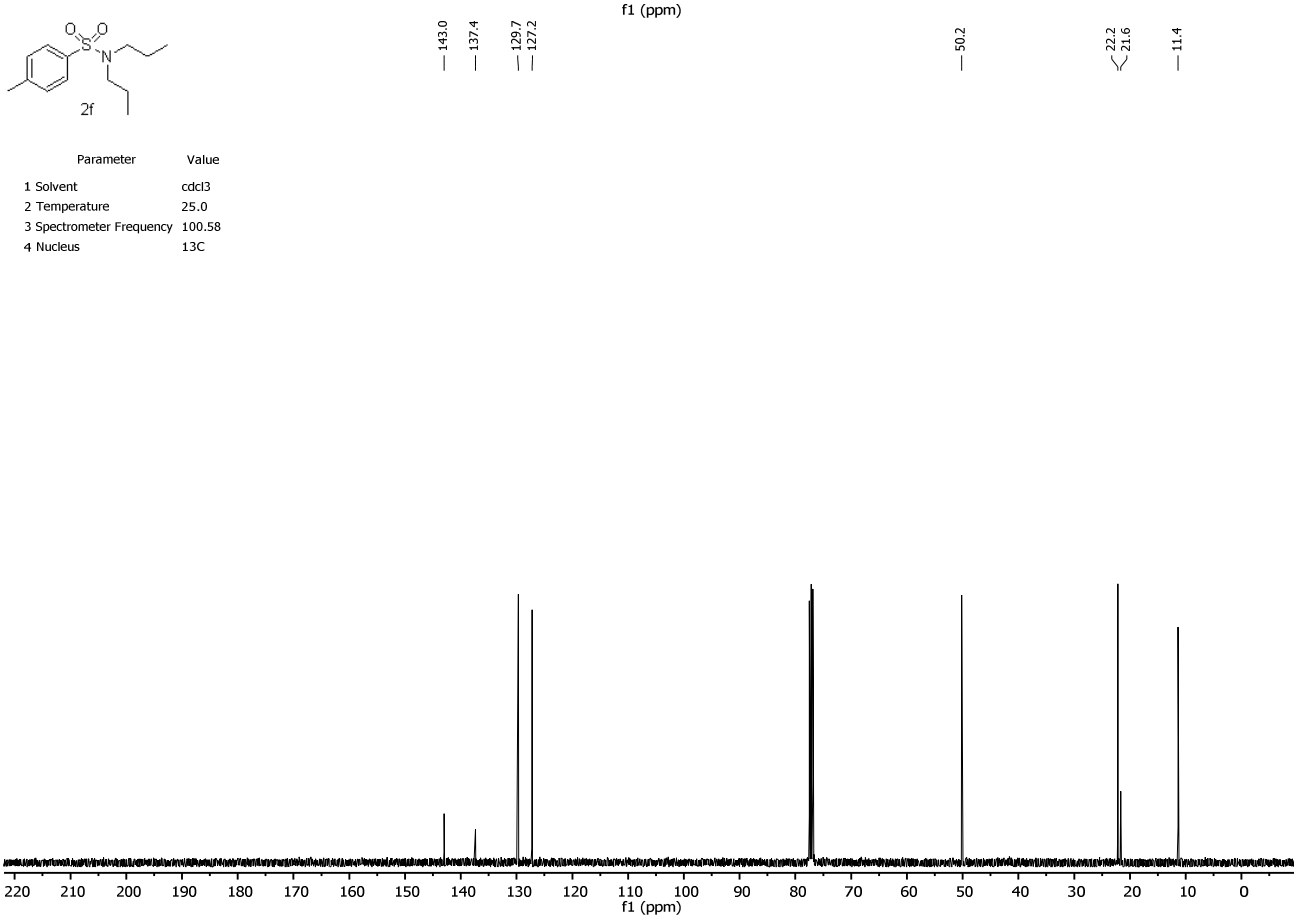
N,N-diethyl-4-methylbenzenesulfonamide (2e)



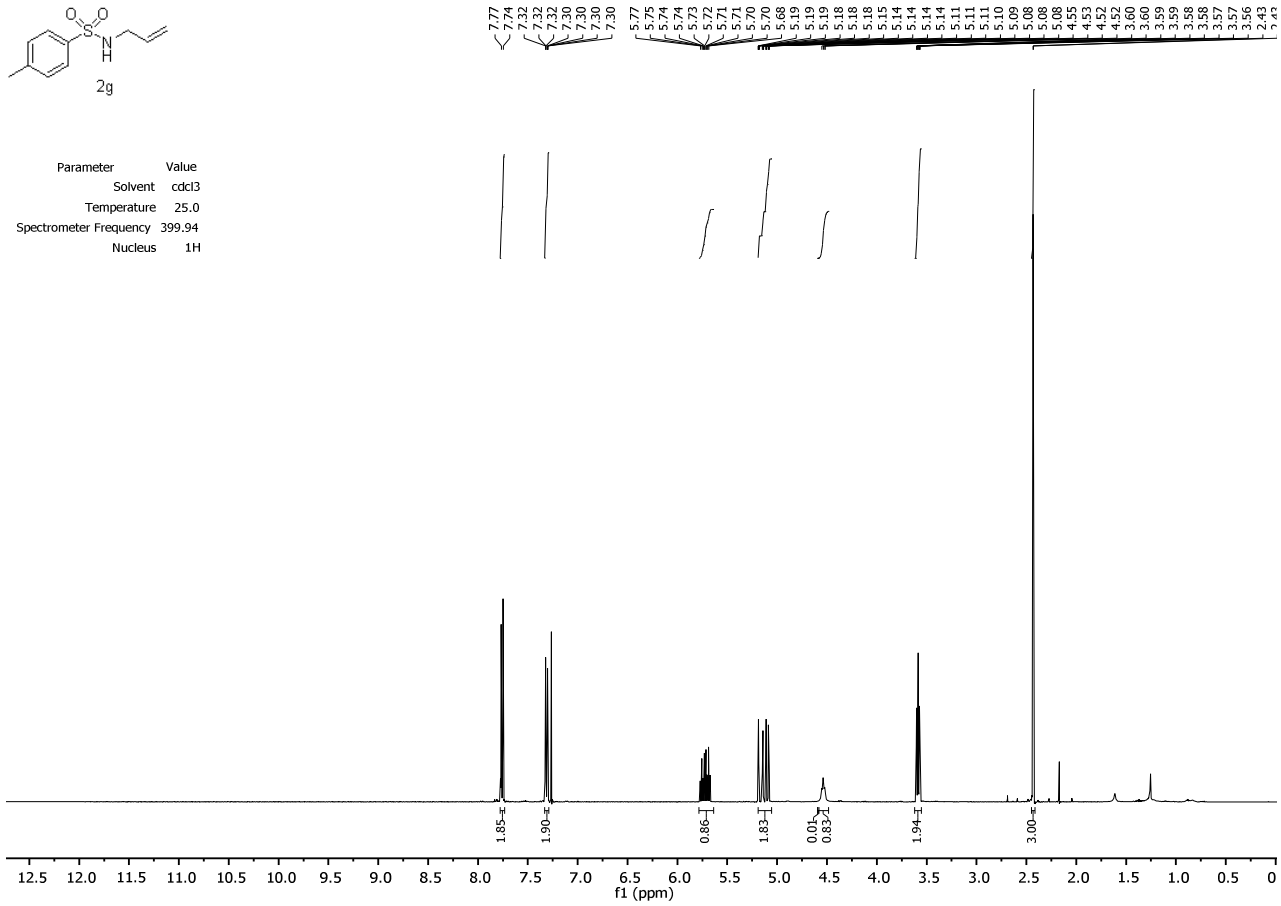


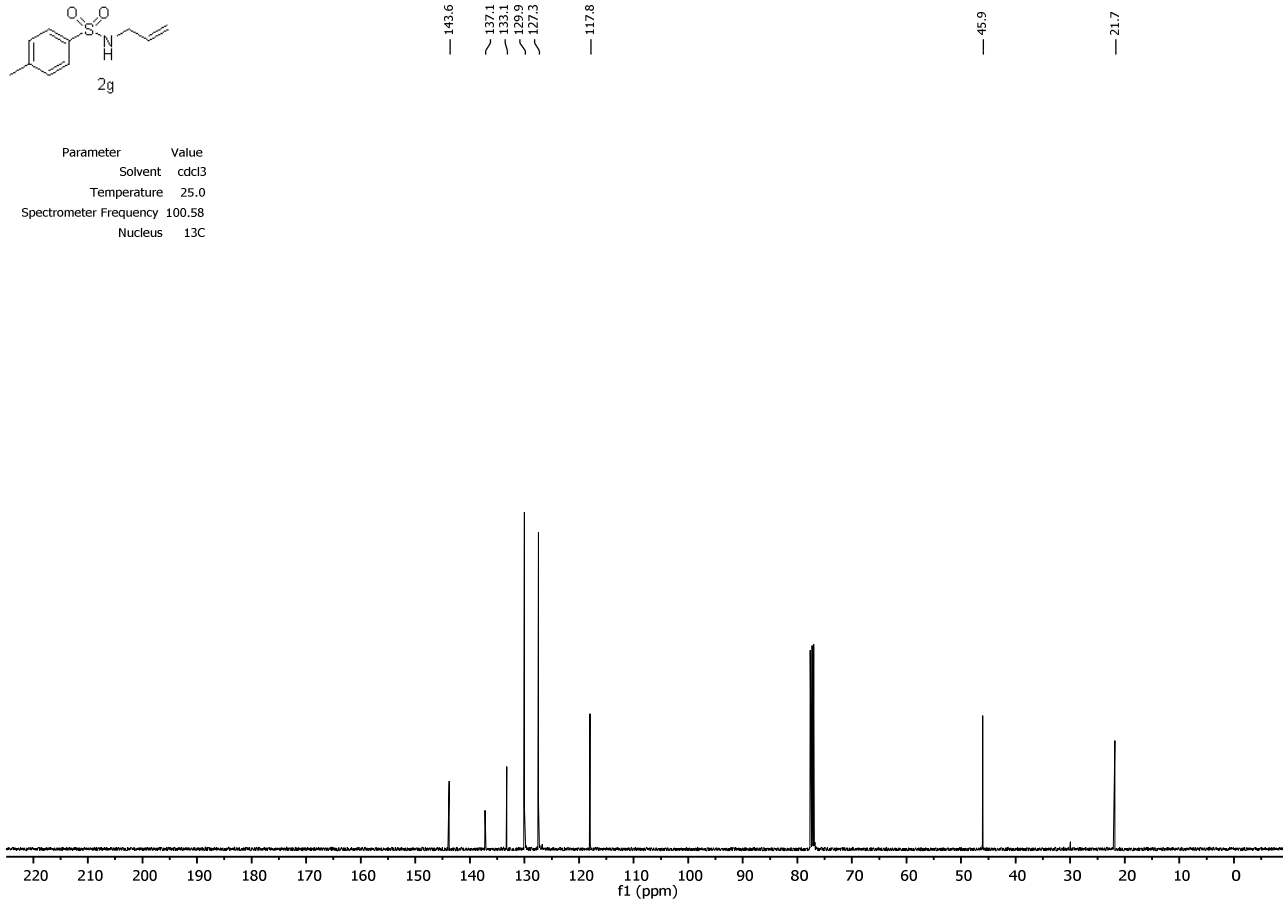
4-methyl-*N*,*N*-dipropylbenzenesulfonamide (2f)



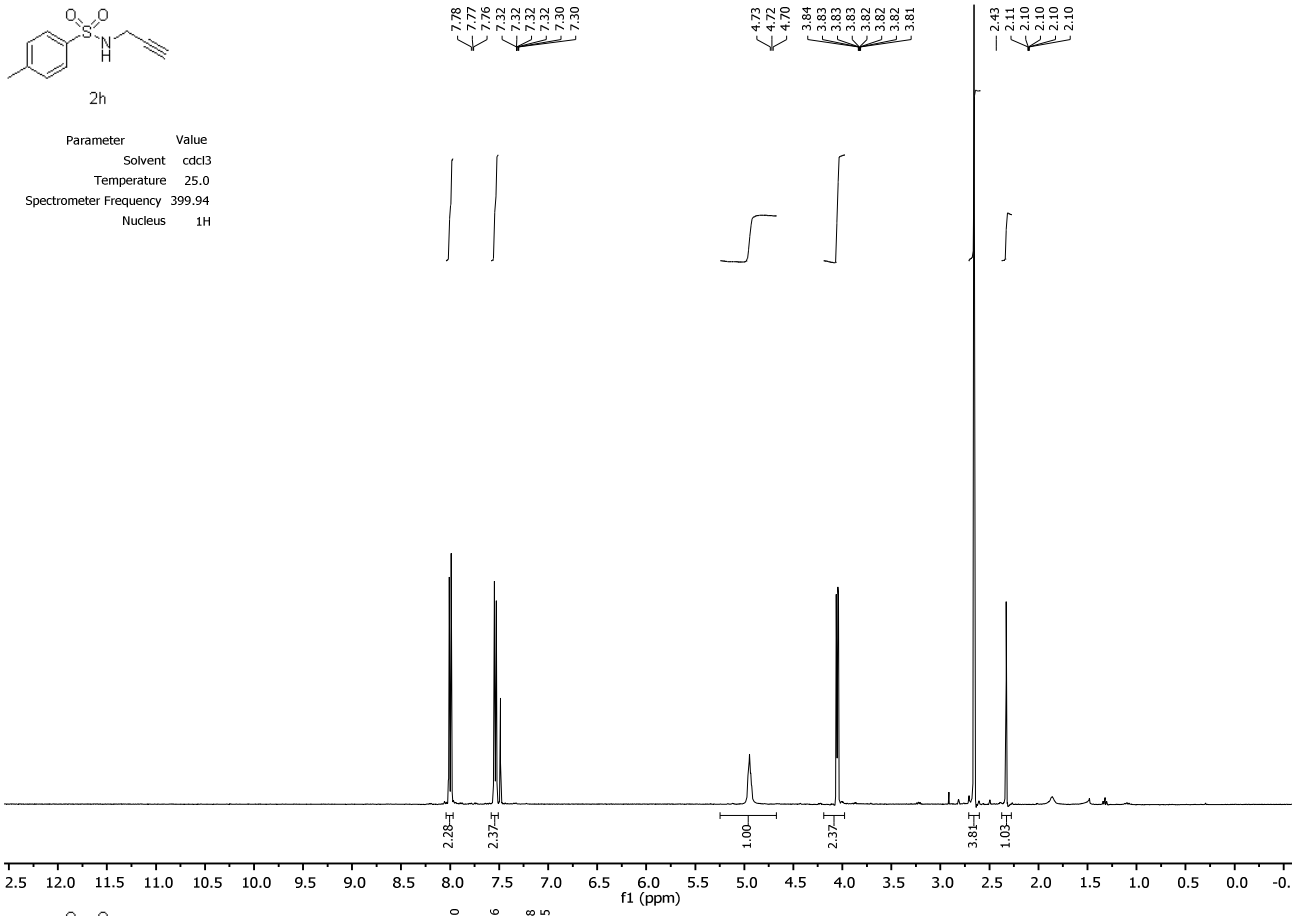


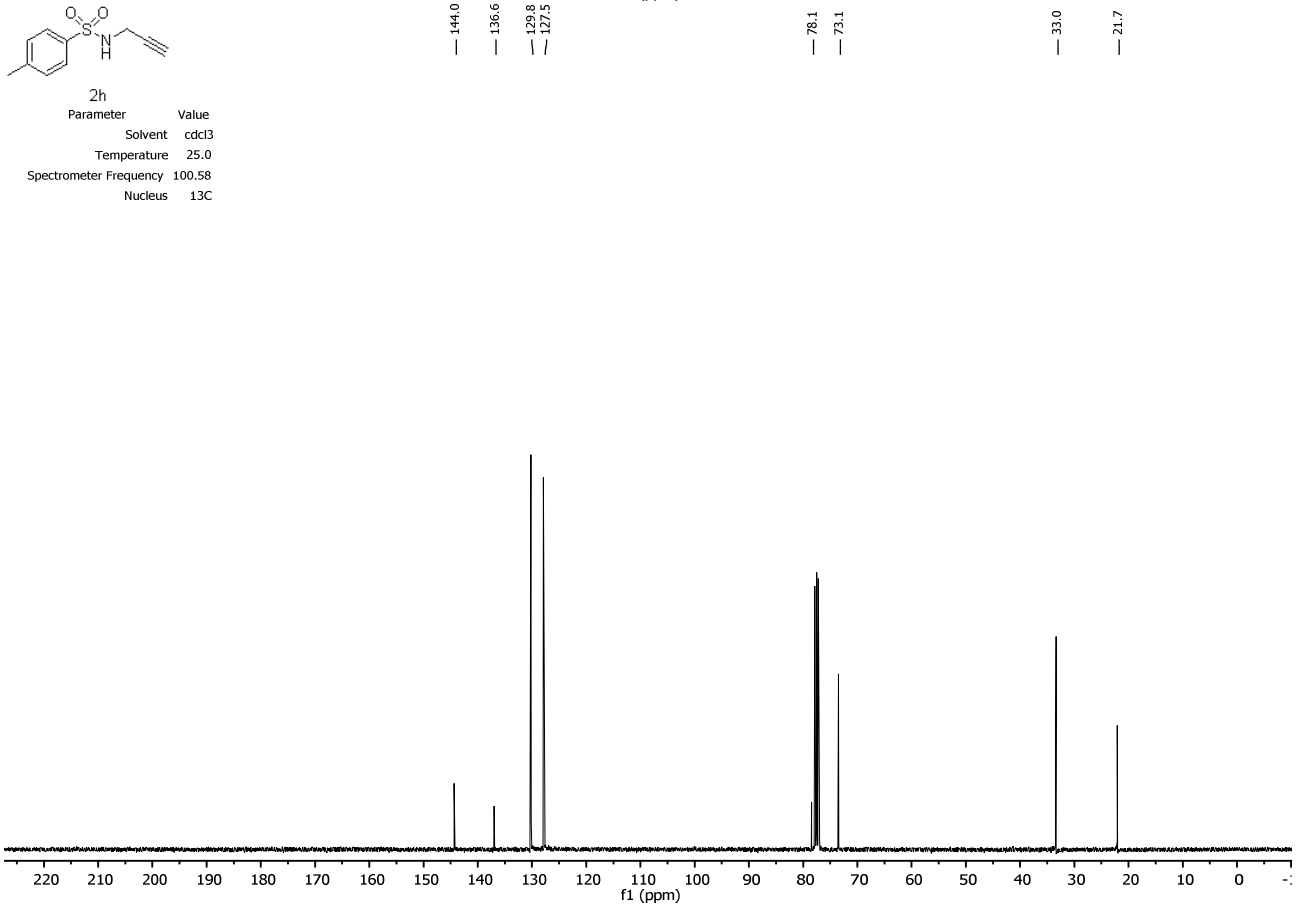
N-allyl-4-methylbenzenesulfonamide (2g)



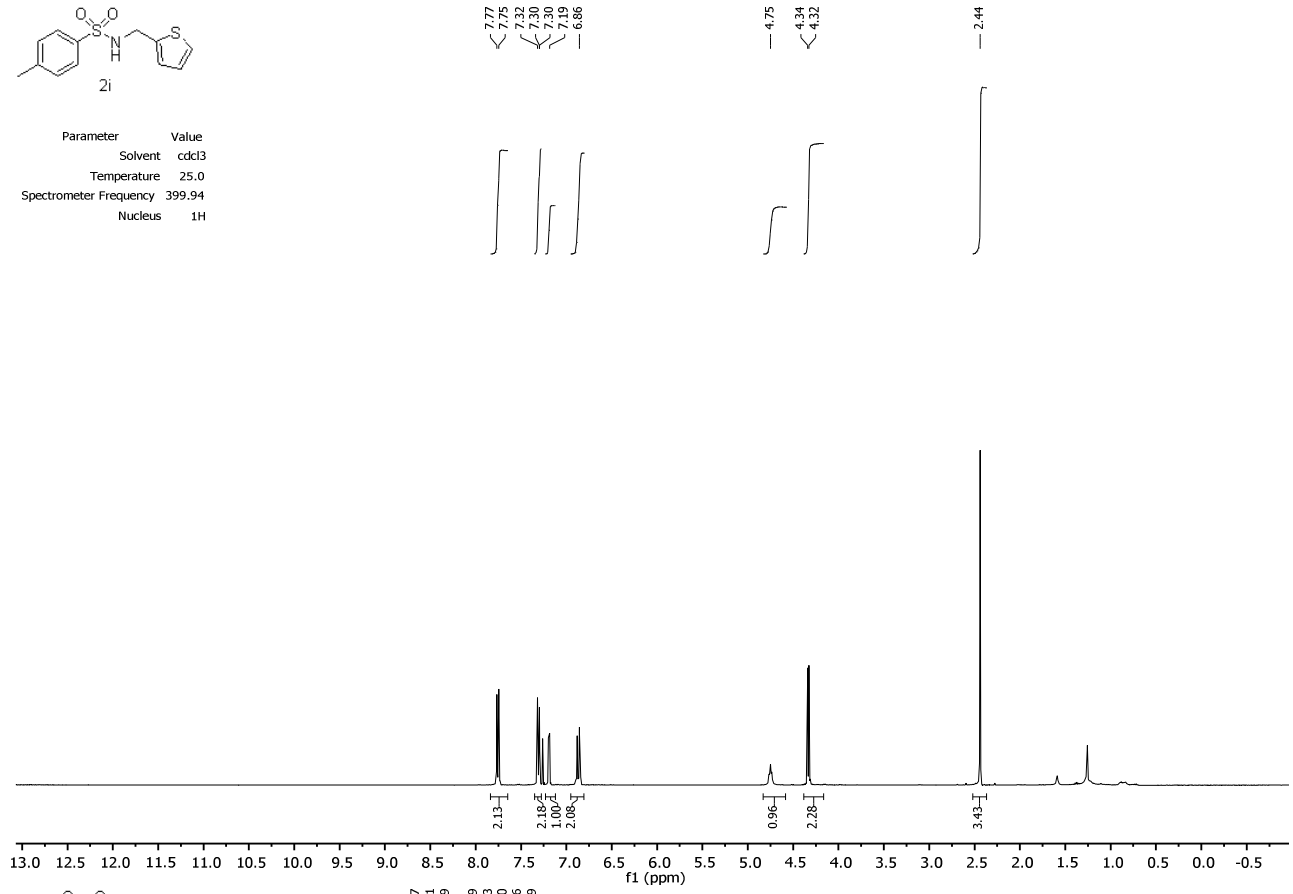


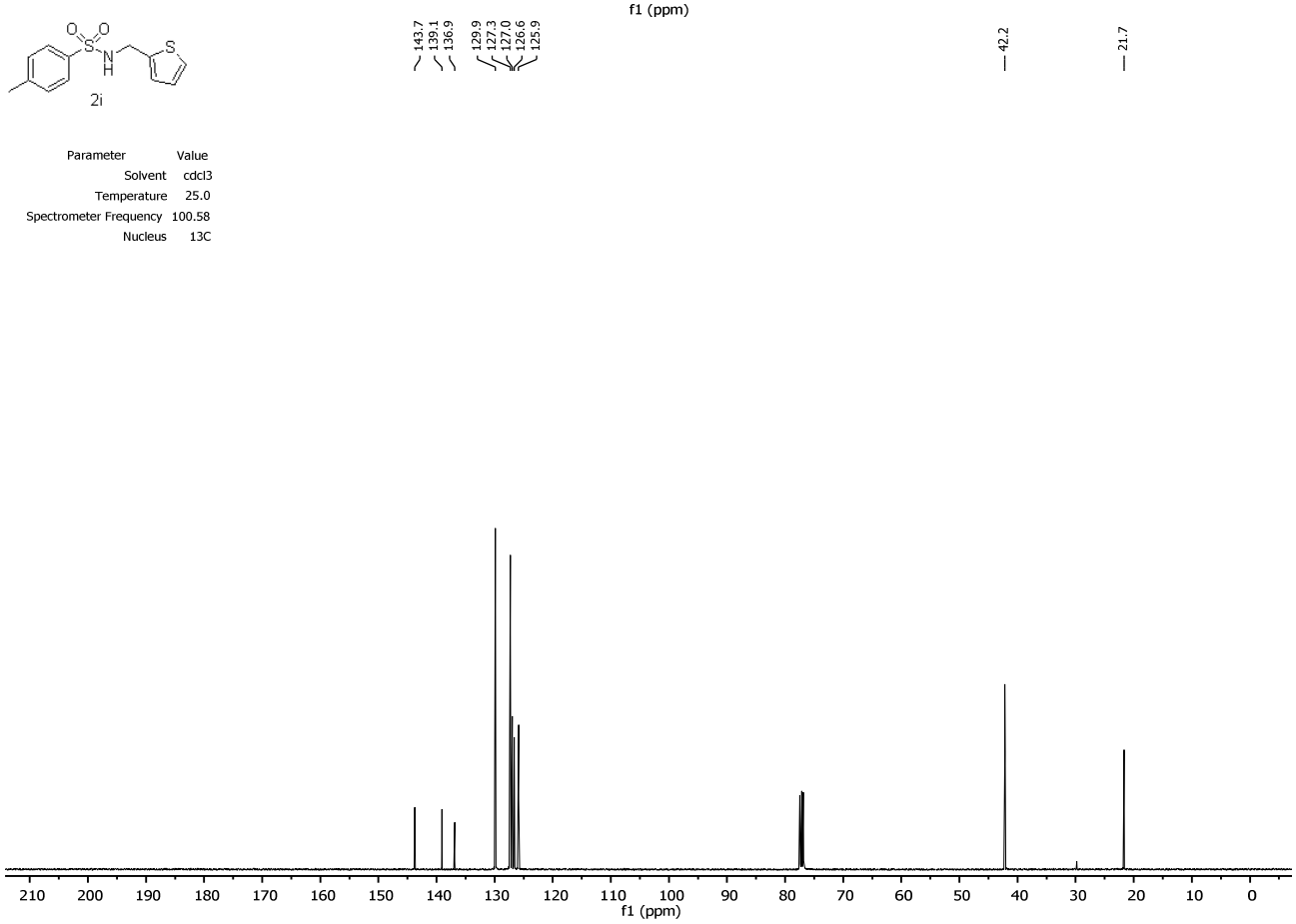
4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (2h)





4-methyl-*N*-(thiophen-2-ylmethyl)benzenesulfonamide (2i)

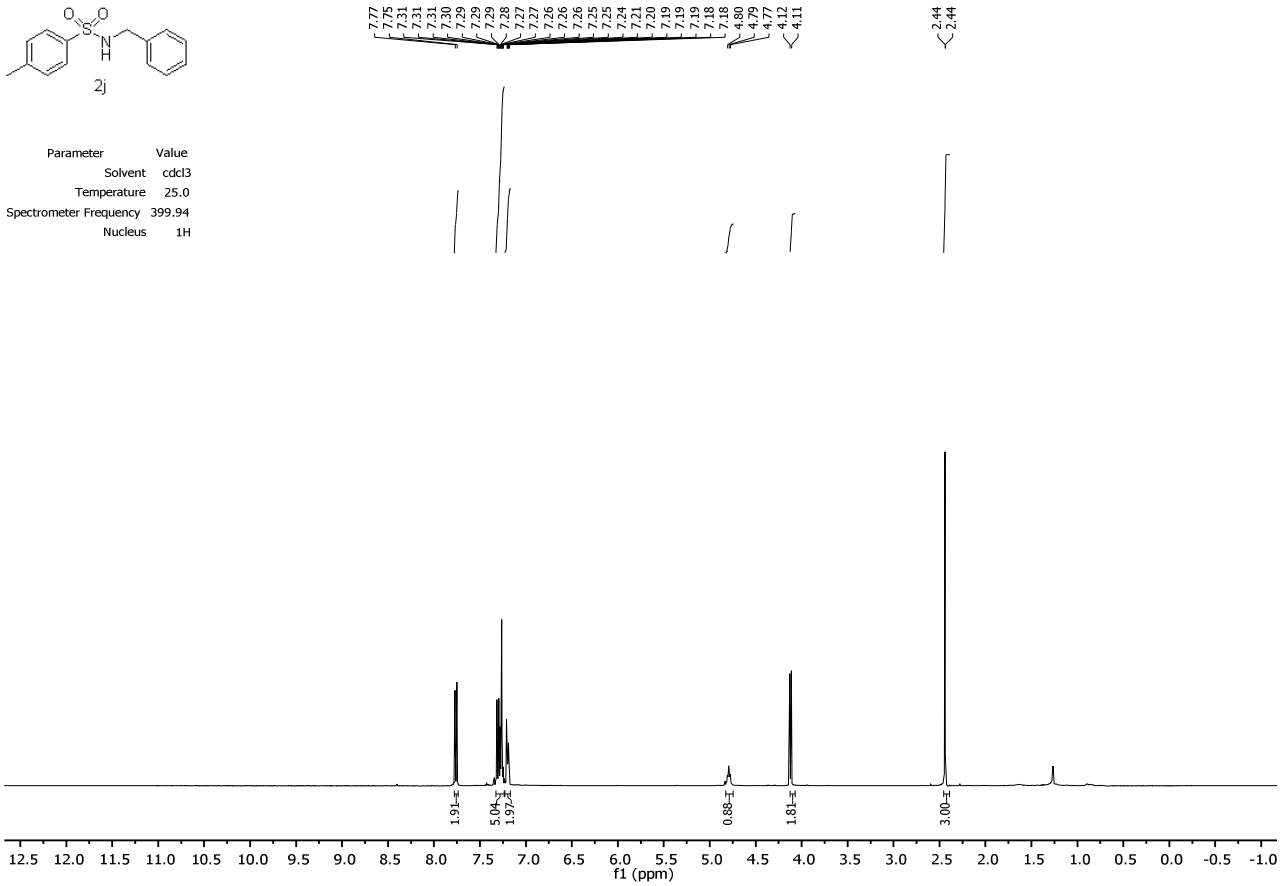




N-benzyl-4-methylbenzenesulfonamide (2j)

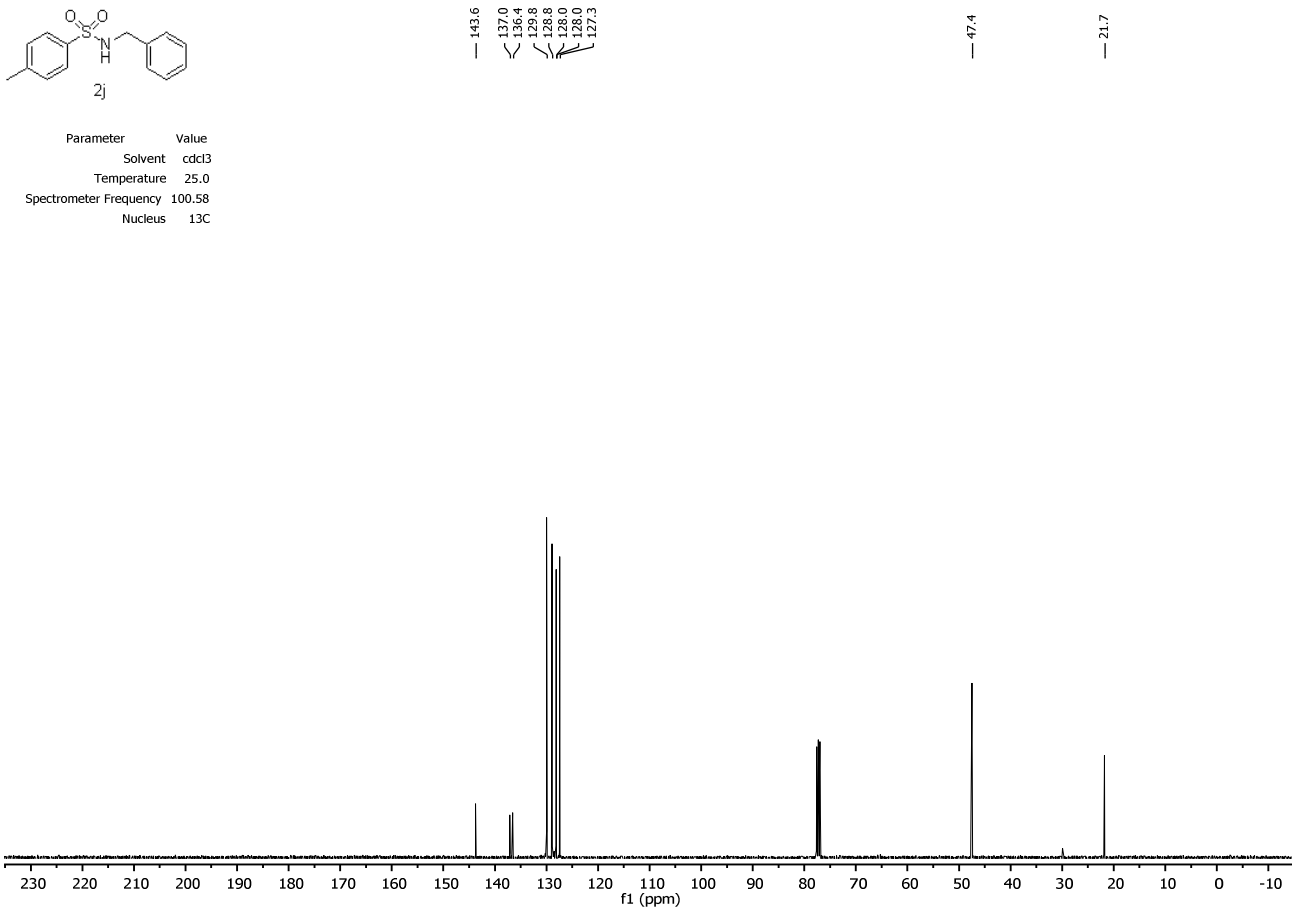
2j

Parameter	Value
Solvent	cdcl3
Temperature	25.0
Spectrometer Frequency	399.94
Nucleus	1H

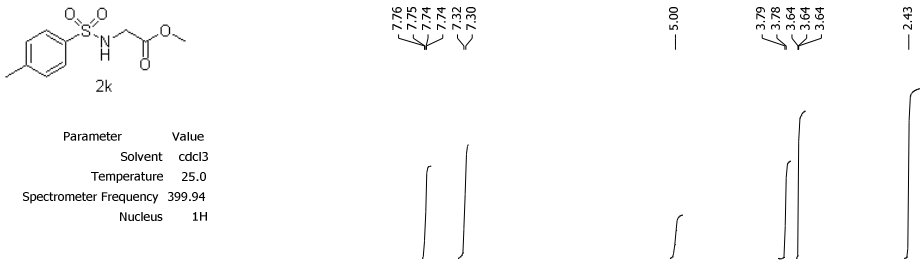


2j

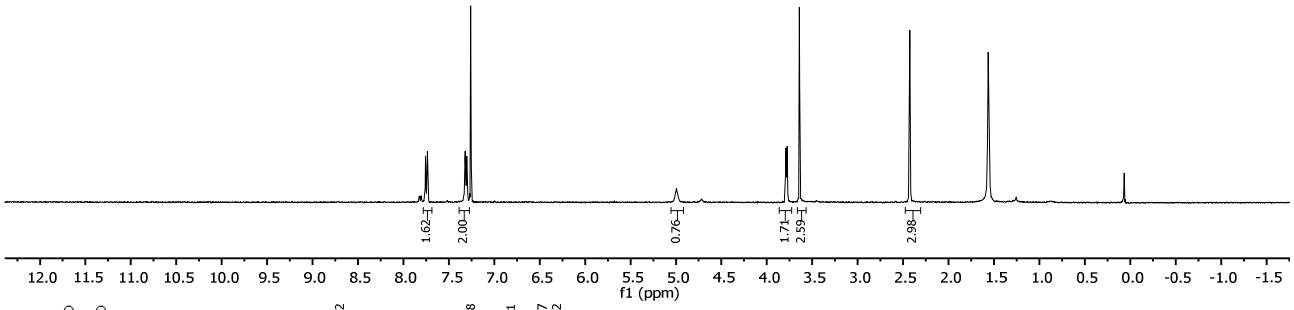
Parameter	Value
Solvent	cdcl3
Temperature	25.0
Spectrometer Frequency	100.58
Nucleus	13C

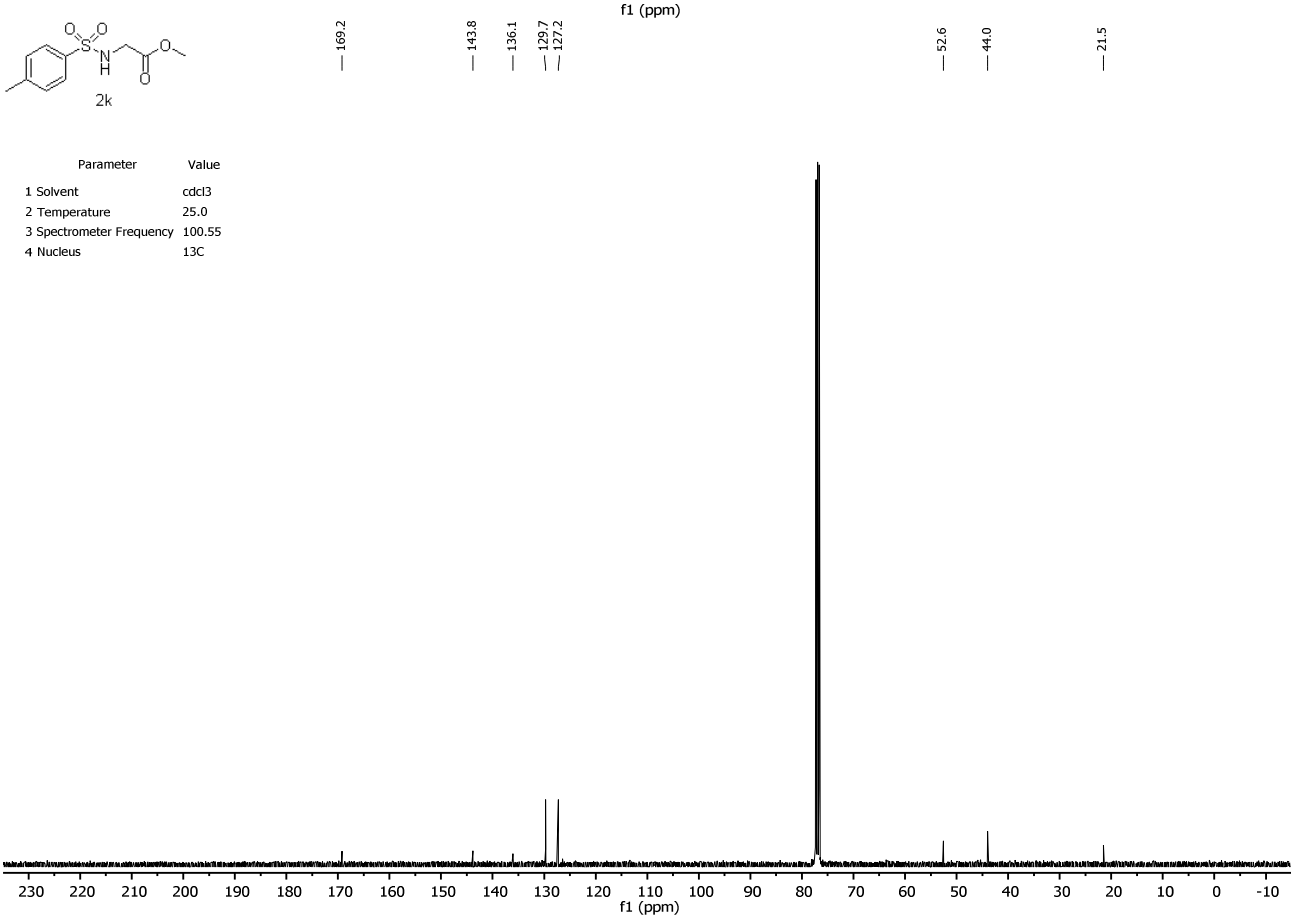


Methyl toluenesulfonylglycinate (2k)



Parameter	Value
Solvent	cdcl3
Temperature	25.0
Spectrometer Frequency	399.94
Nucleus	1H





Parameter	Value
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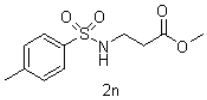
2 Temperature	25.0
3 Spectrometer Frequency	100.55
4 Nucleus	13C

Methyl 3-((4-methylphenyl)sulfonamido)propanoate (2n)



2n

Parameter	Value
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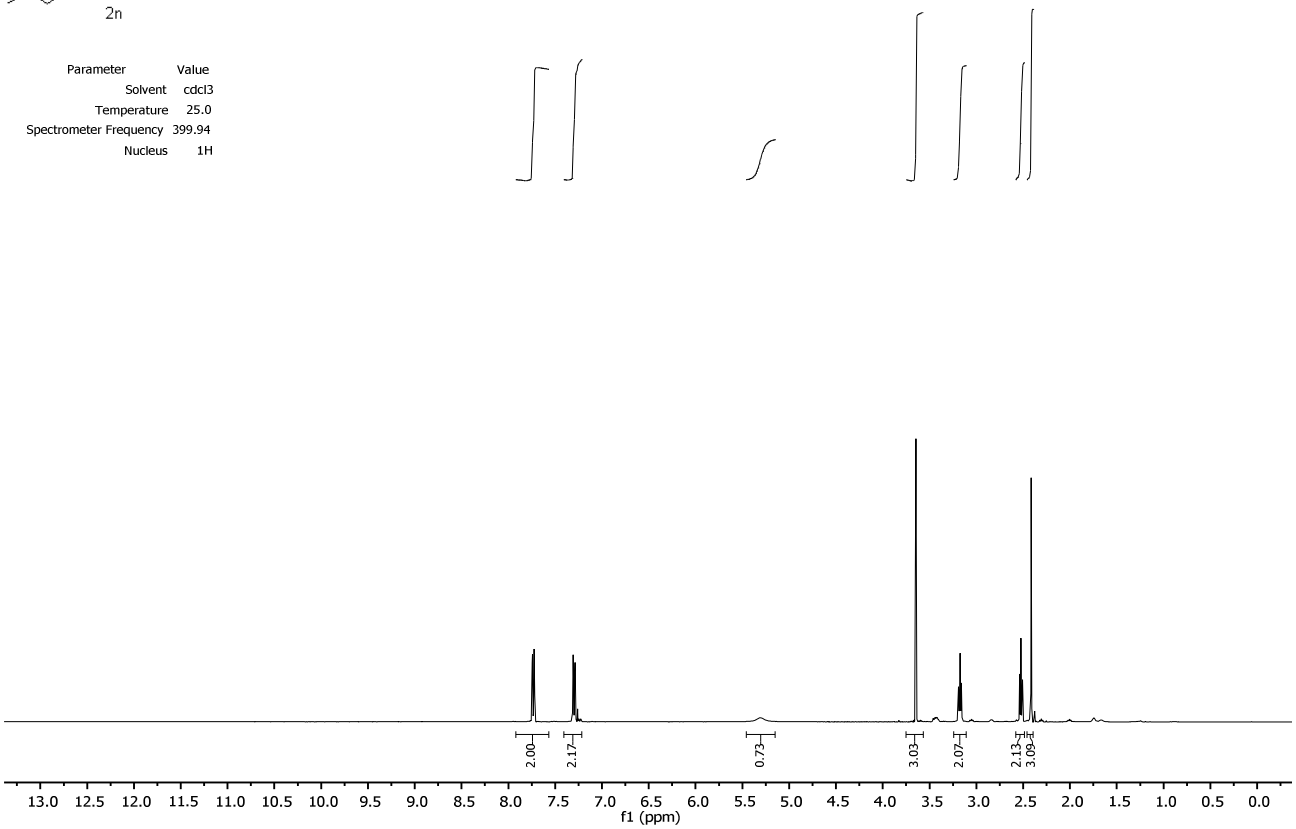
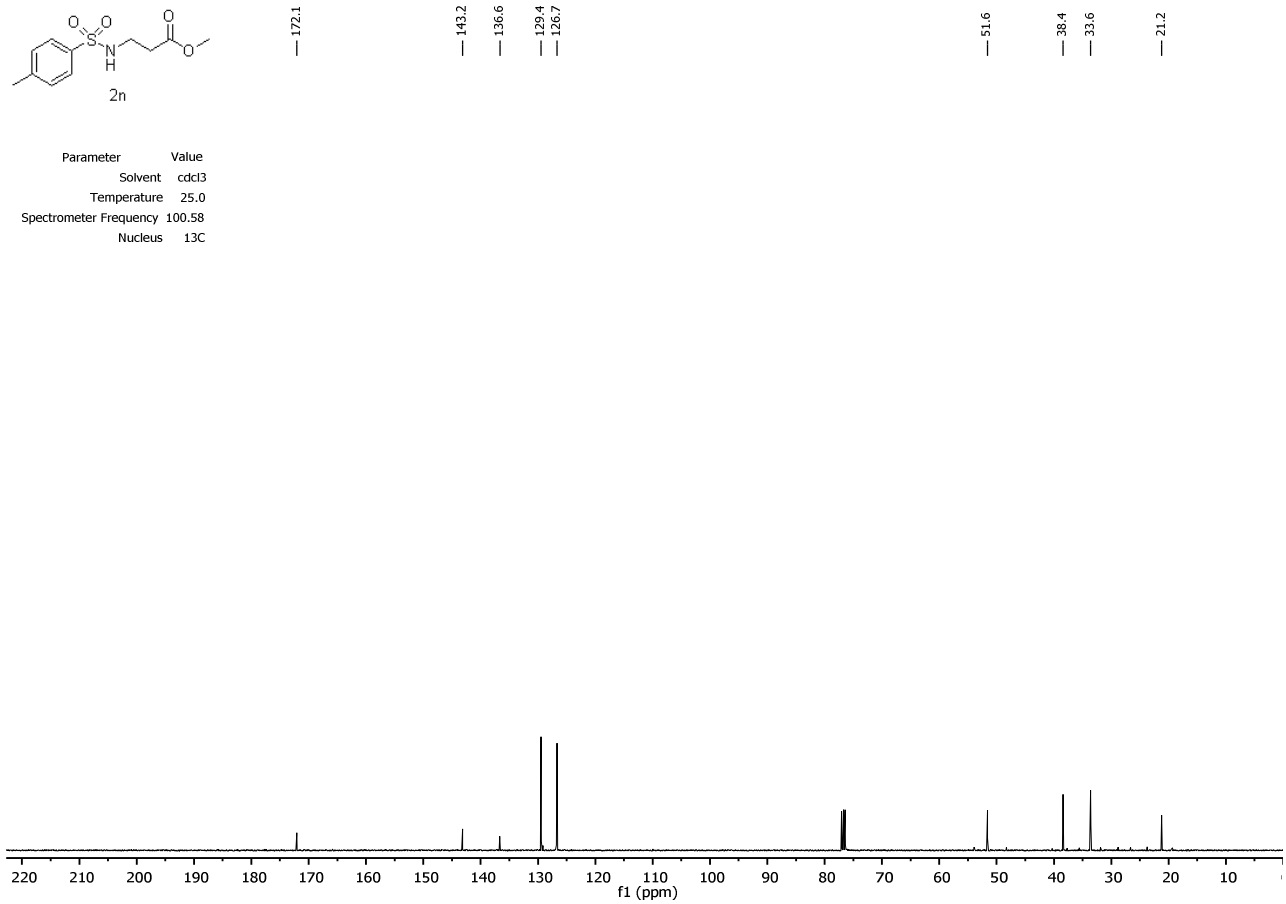
Temperature	25.0
Spectrometer Frequency	399.94
Nucleus	1H

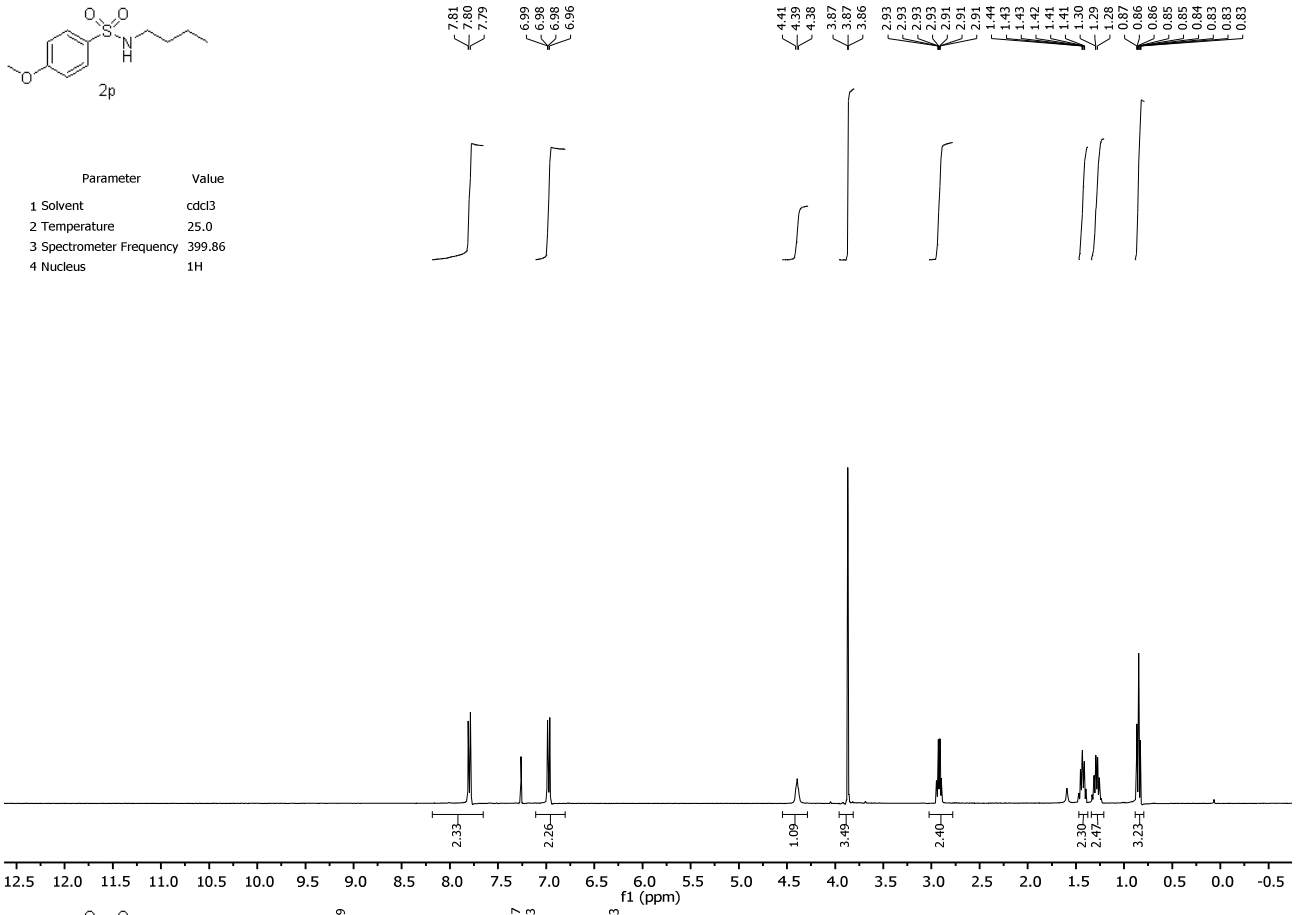


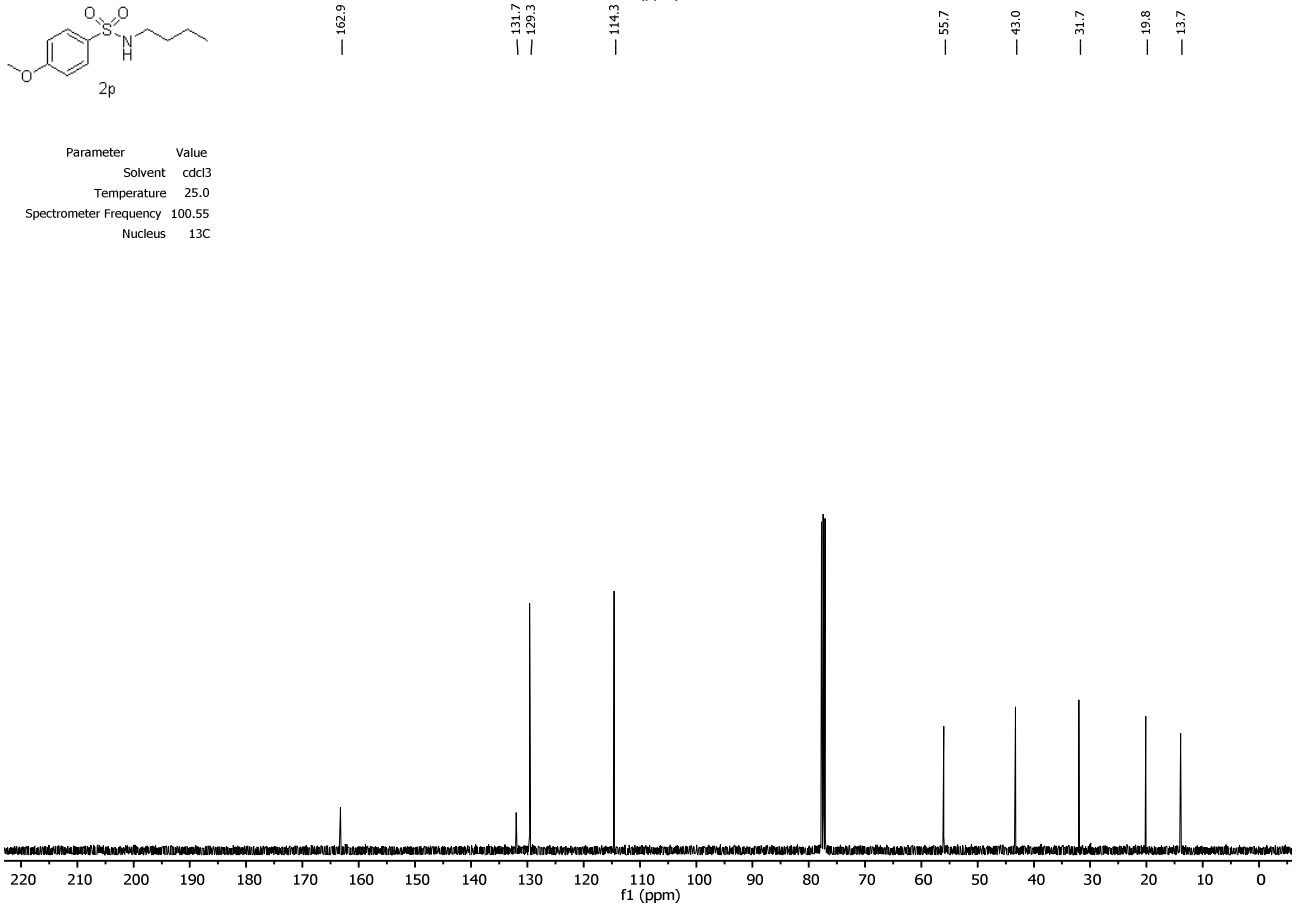
2n

Parameter	Value
Solvent	cdcl3
Temperature	25.0
Spectrometer Frequency	100.58
Nucleus	13C

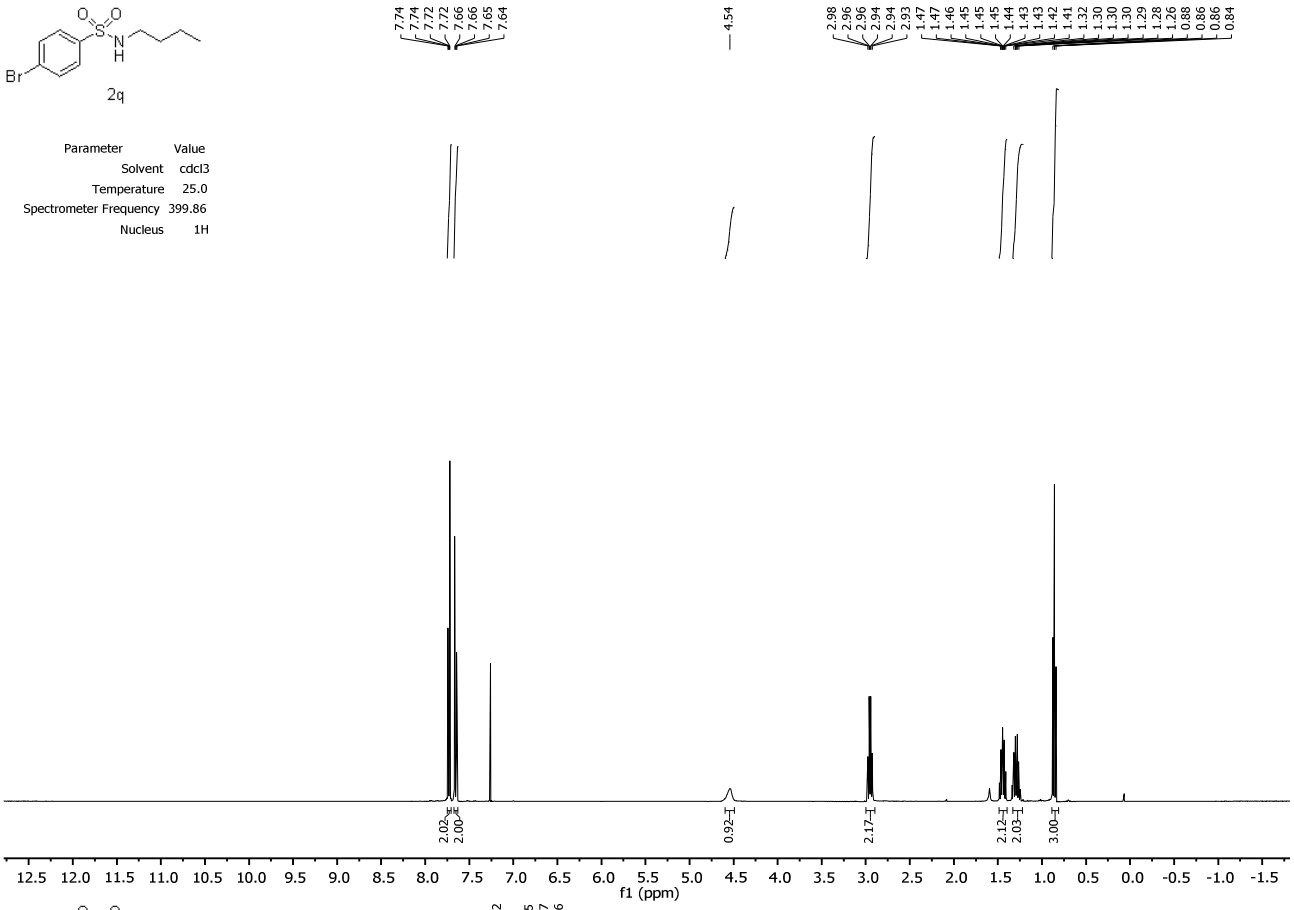


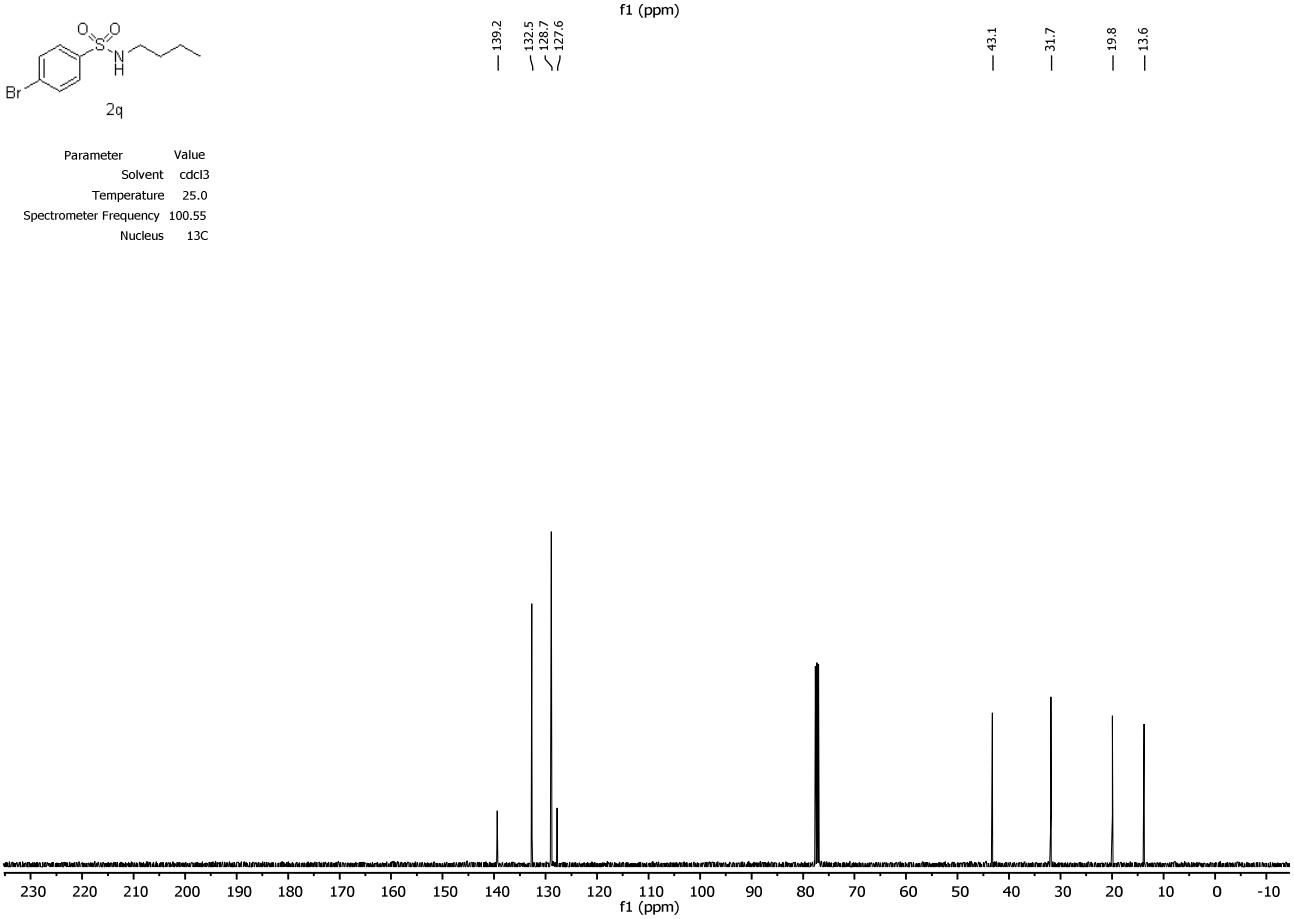
N-butyl-4-methoxybenzenesulfonamide (2p)



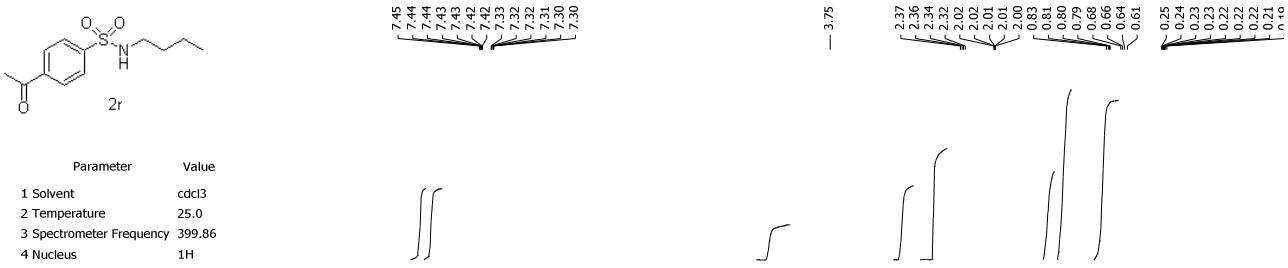


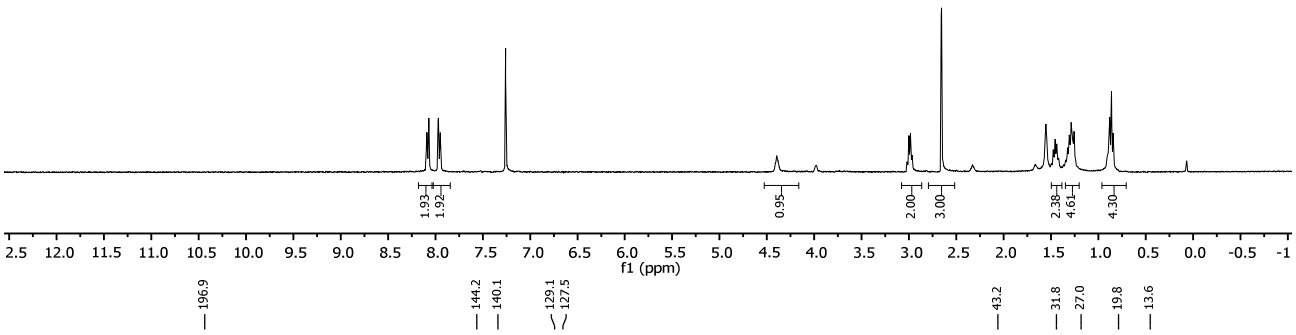
N-butyl-4-bromobenzenesulfonamide (2q)

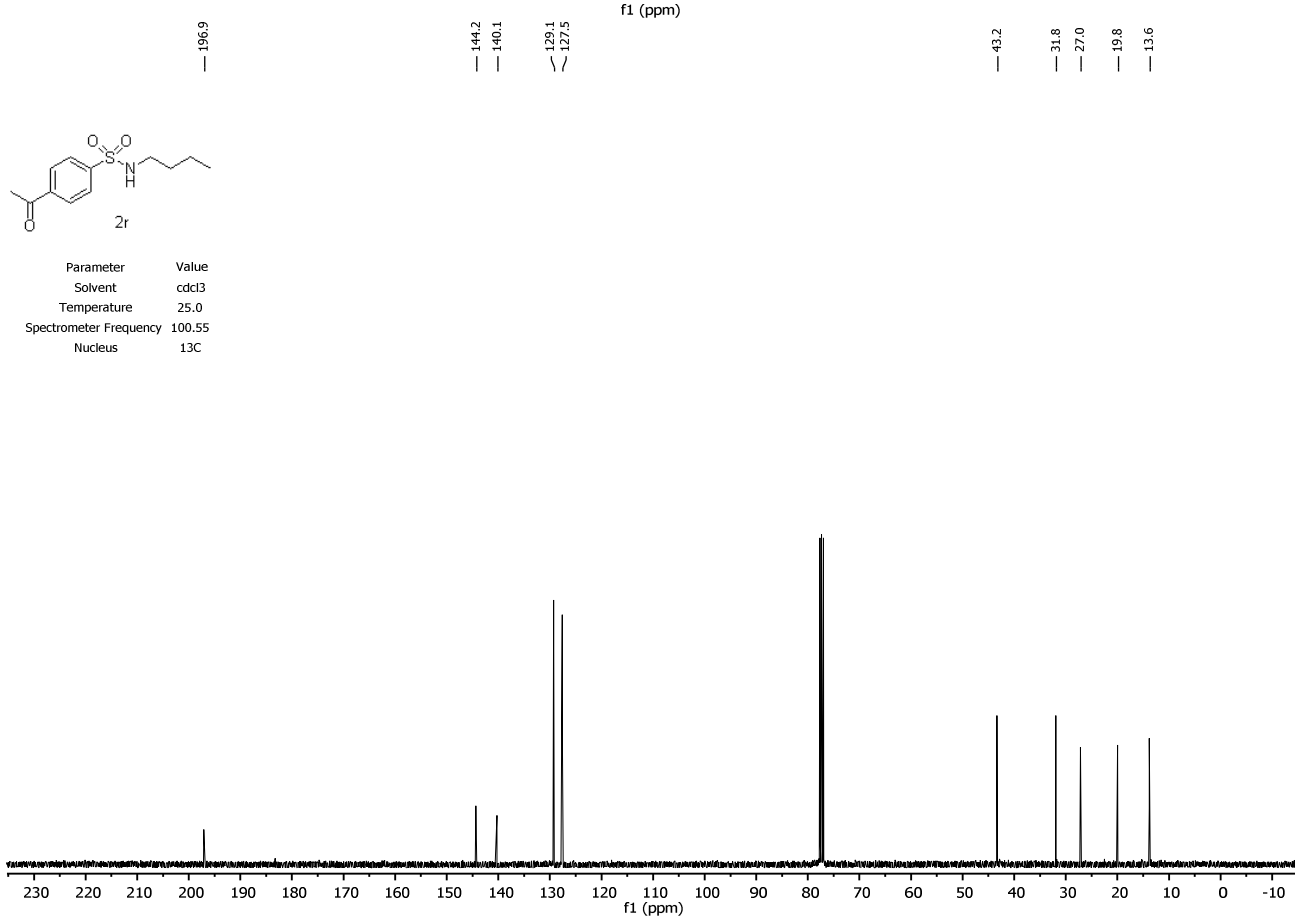




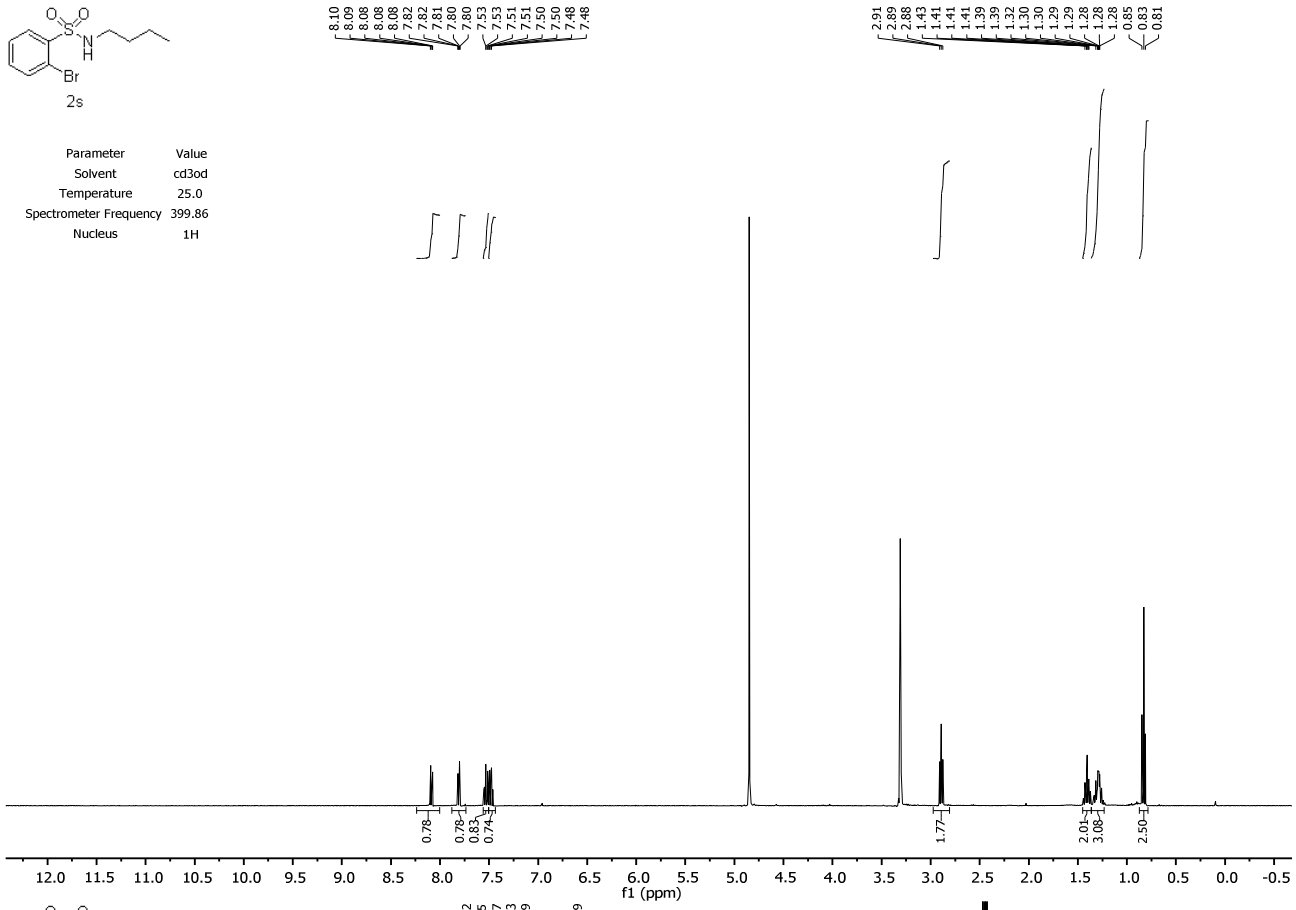
4-Acetyl-*N*-butylbenzenesulfonamide (2r), Table 2 prepared using standard conditions

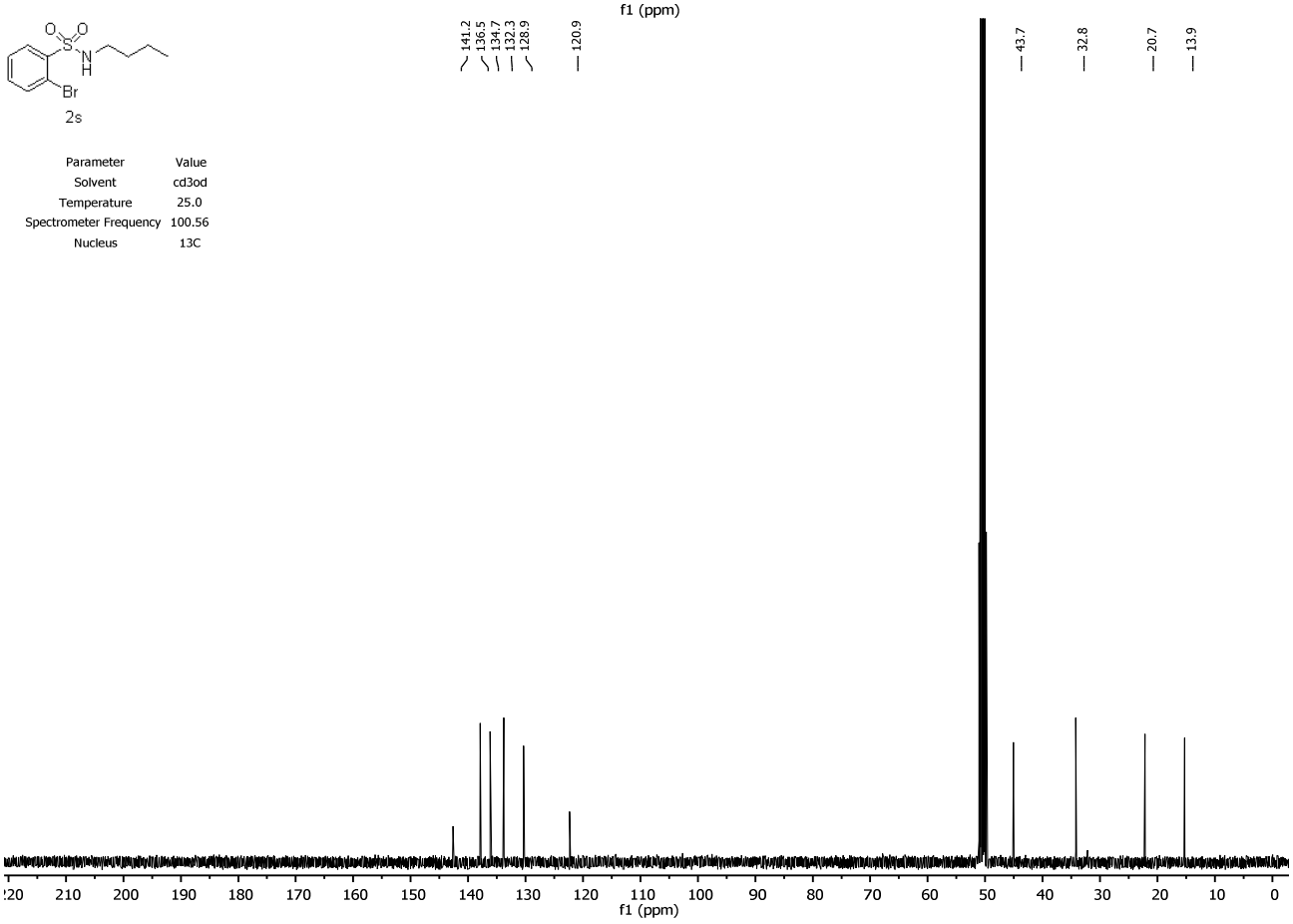




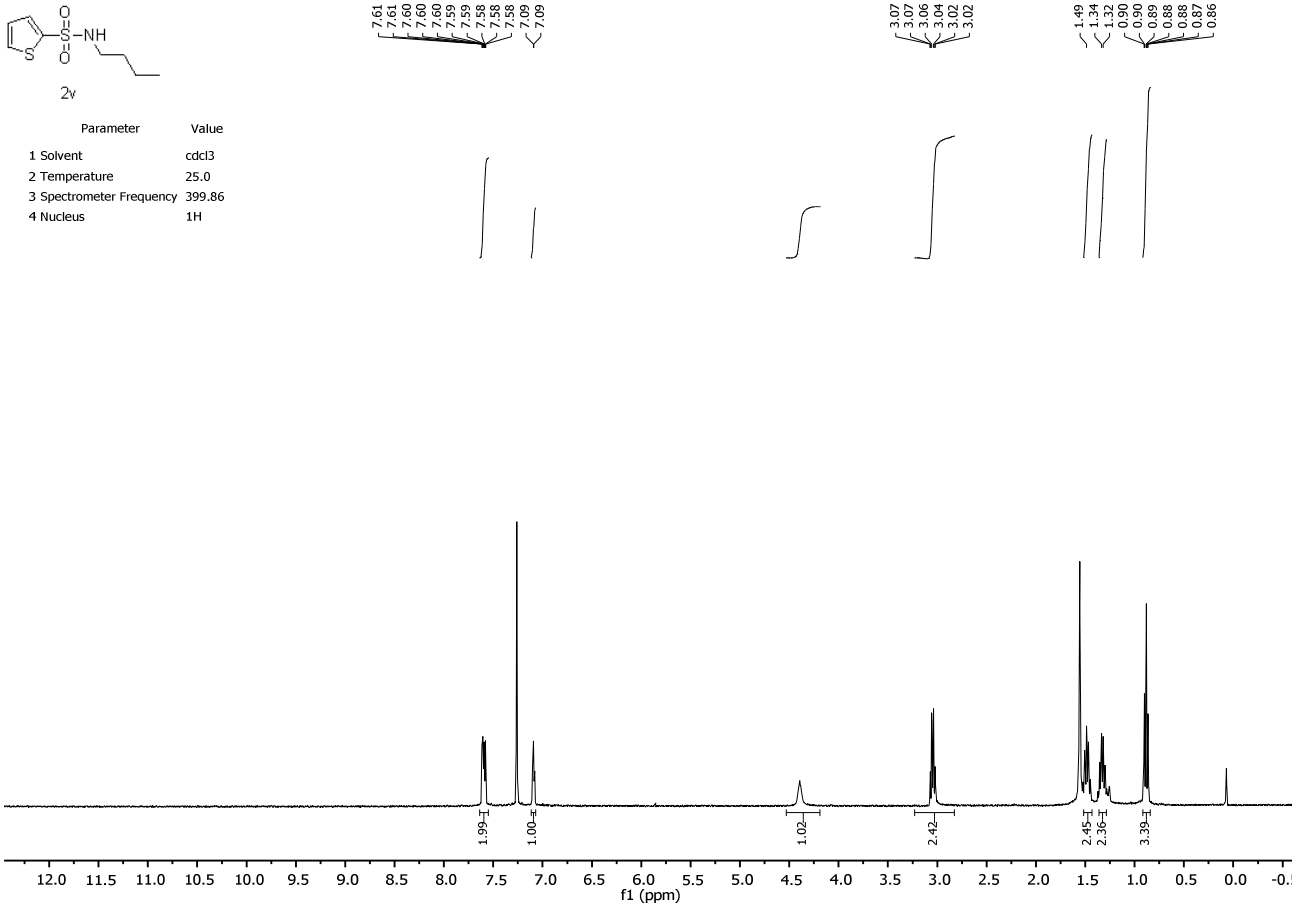


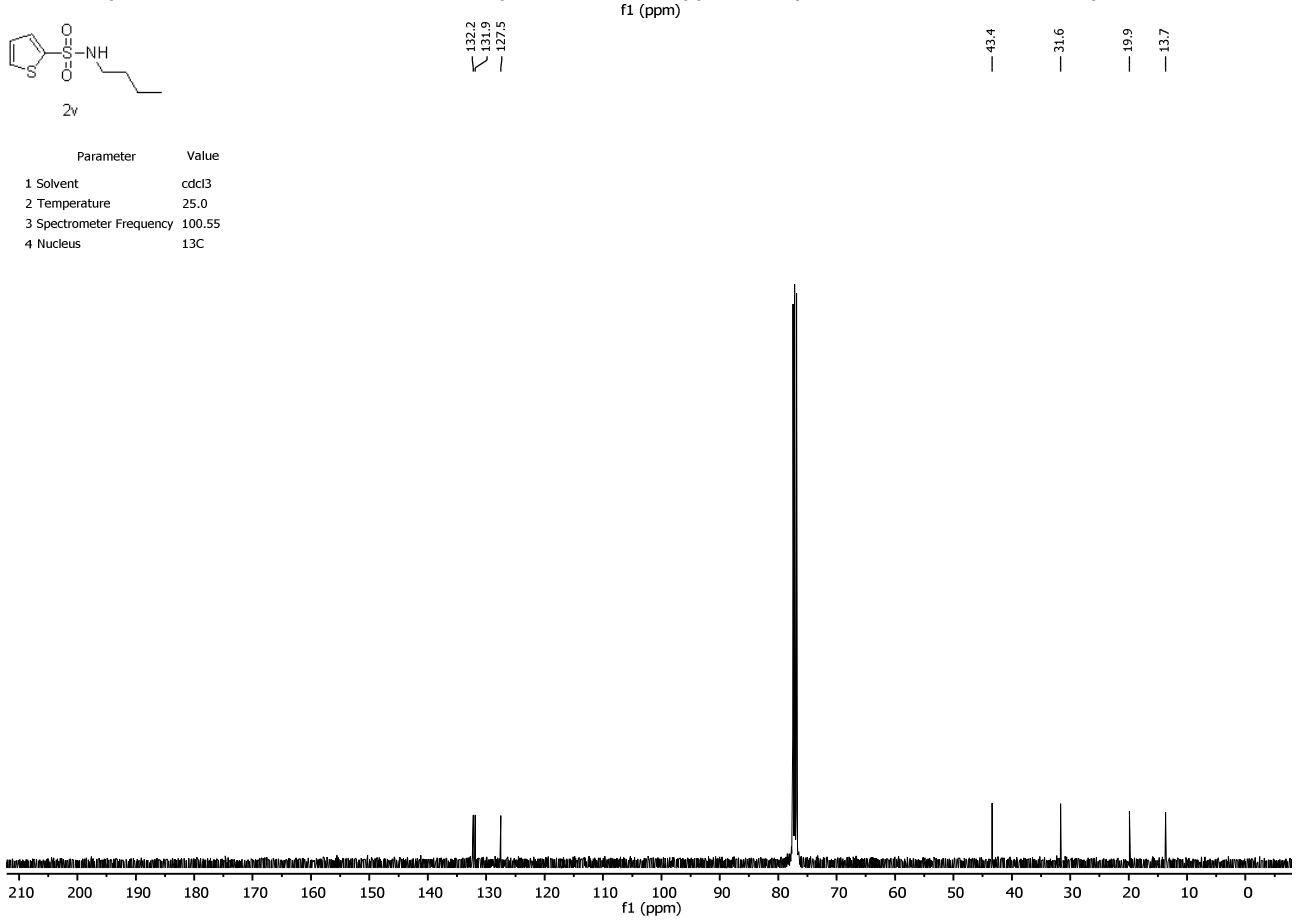
N-butyl-2-bromobenzenesulfonamide (2s)



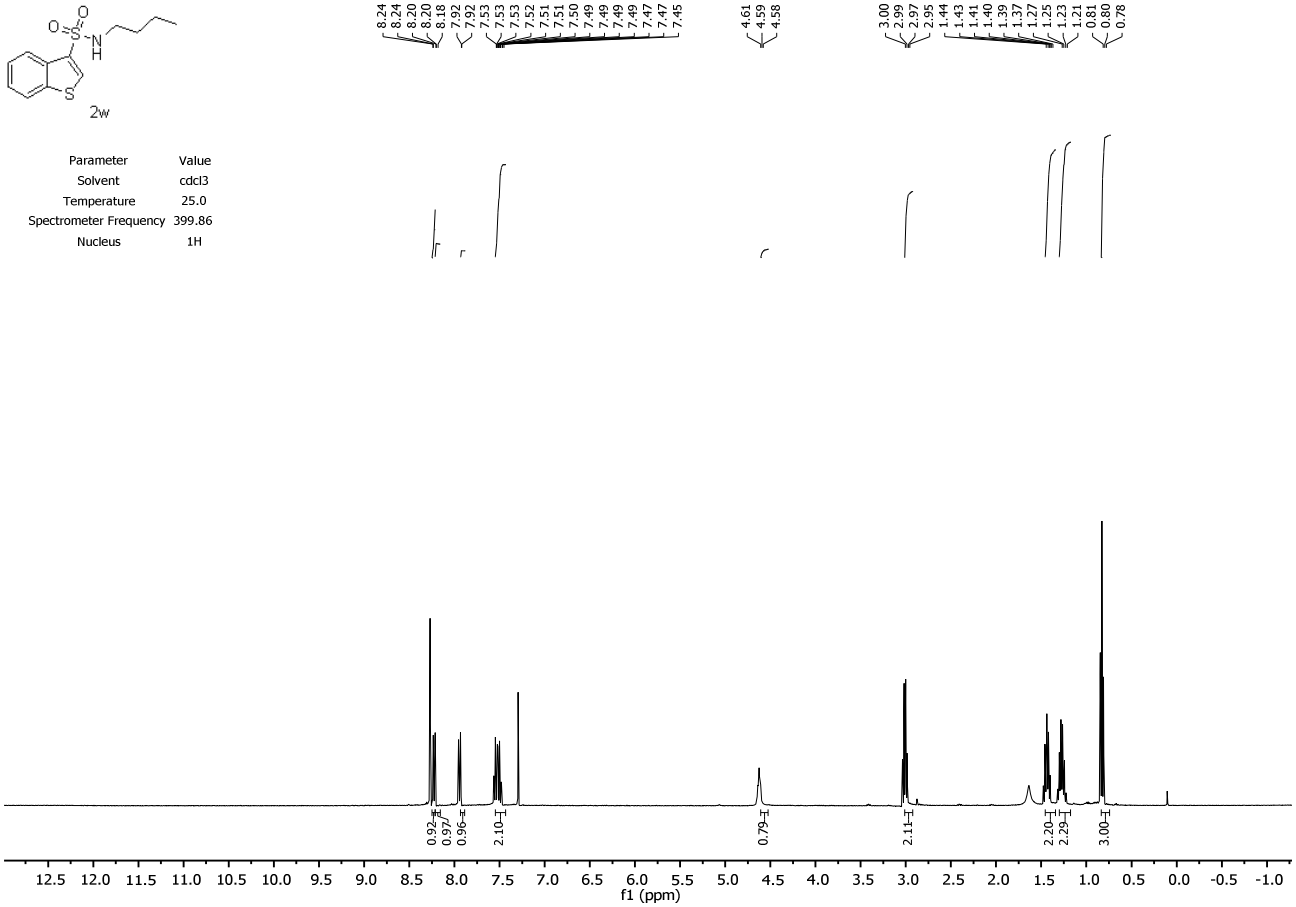


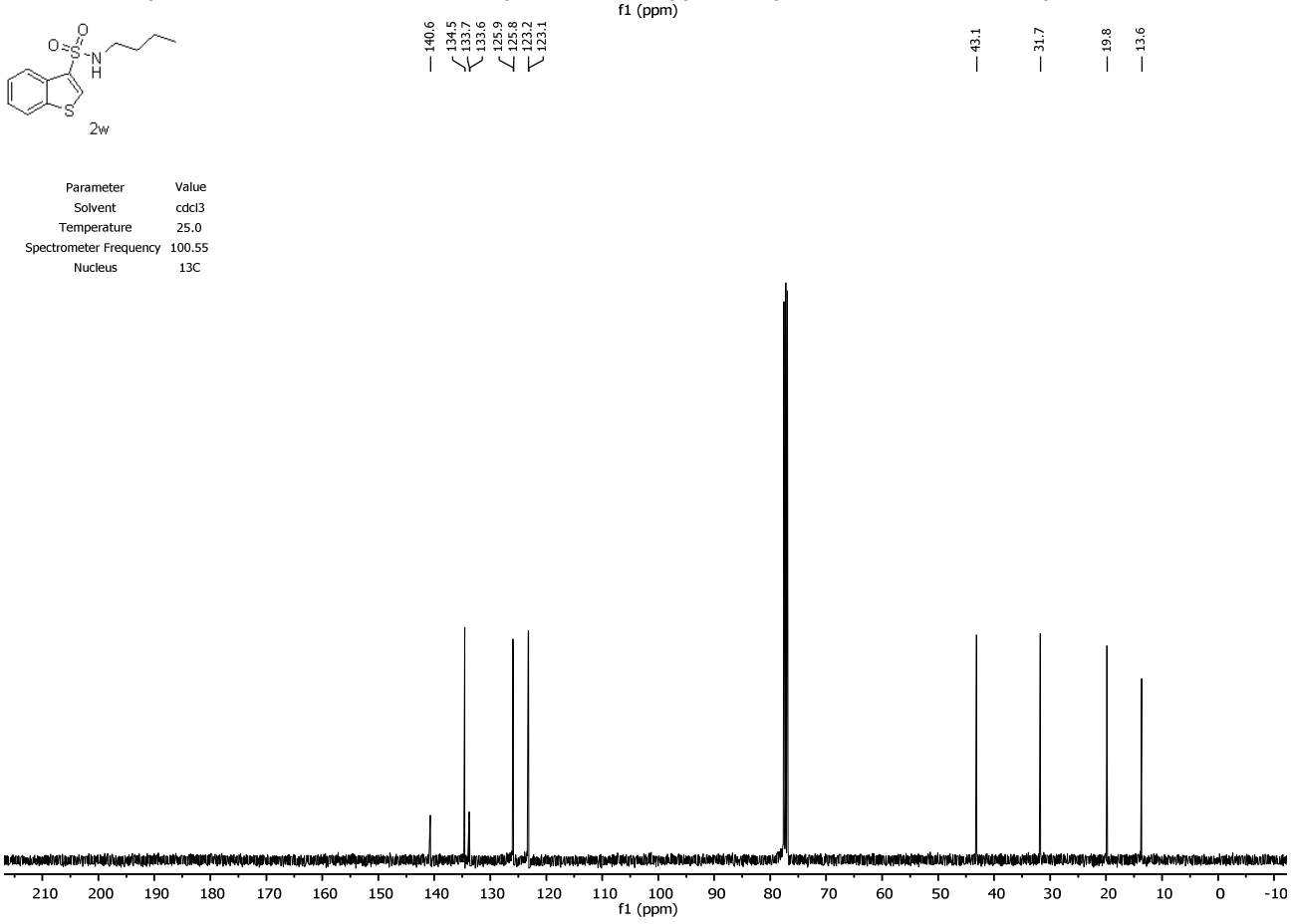
N-butylthiophene-2-sulfonamide (2v)



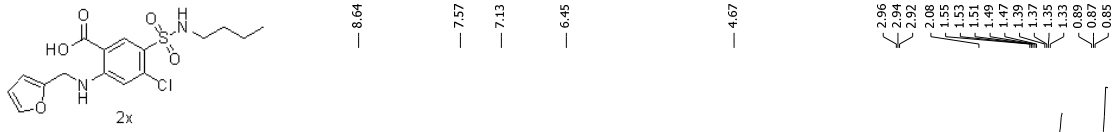


N-butylbenzo[b]thiophene-3-sulfonamide (2w)

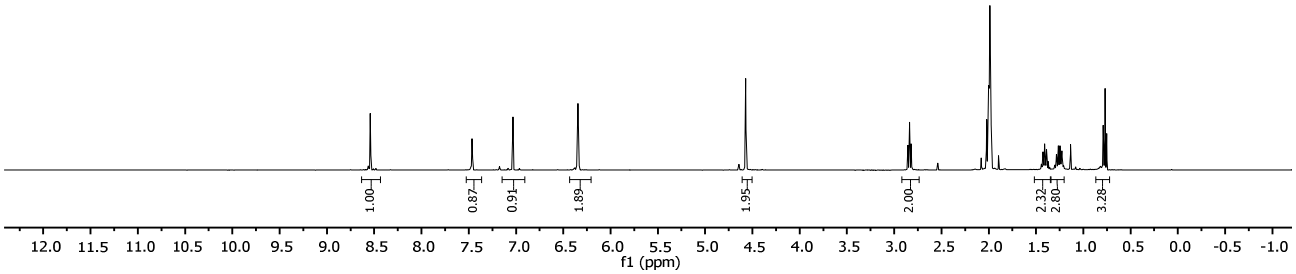


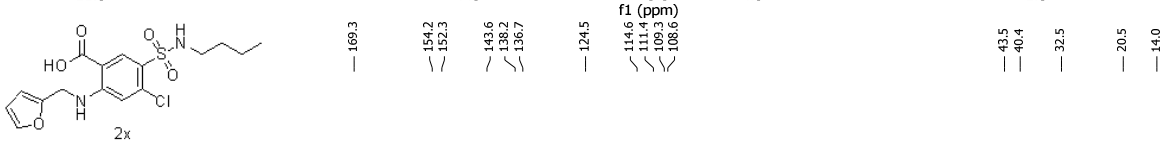


5-(*N*-butylsulfamoyl)-4-chloro-2-((furan-2-ylmethyl)amino)benzoic acid (2x)

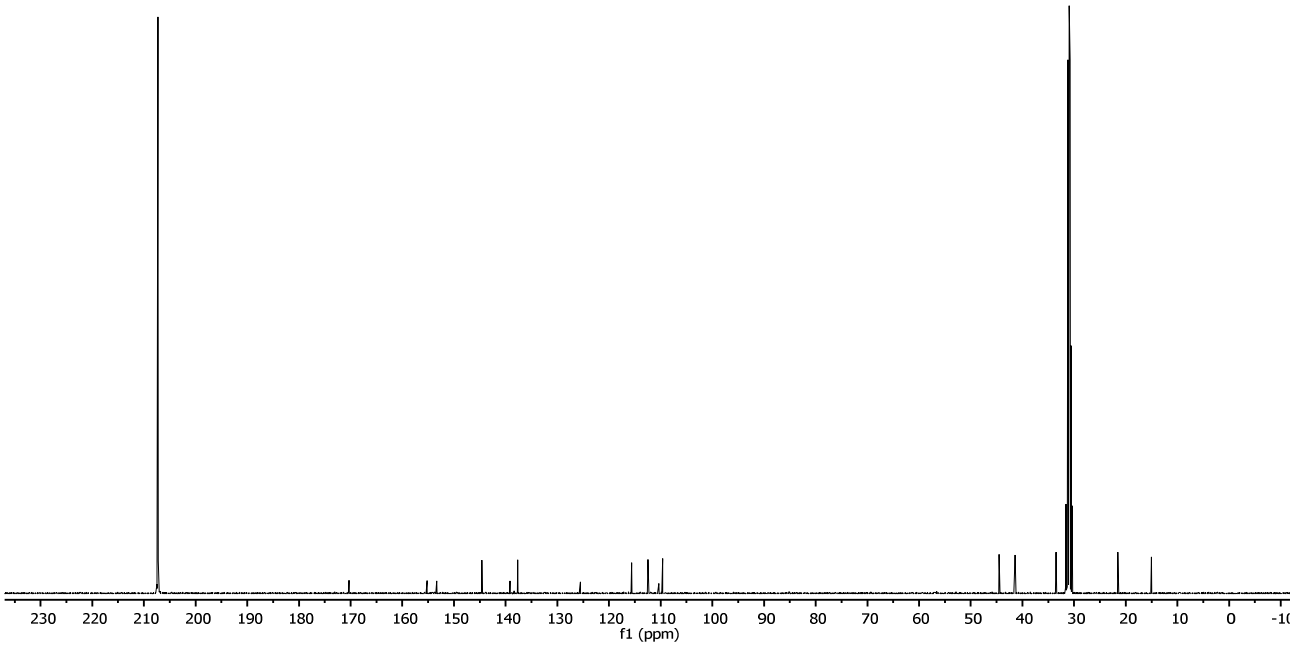


Parameter	Value
1 Solvent	acetone
2 Temperature	25.0
3 Spectrometer Frequency	399.86
4 Nucleus	1H

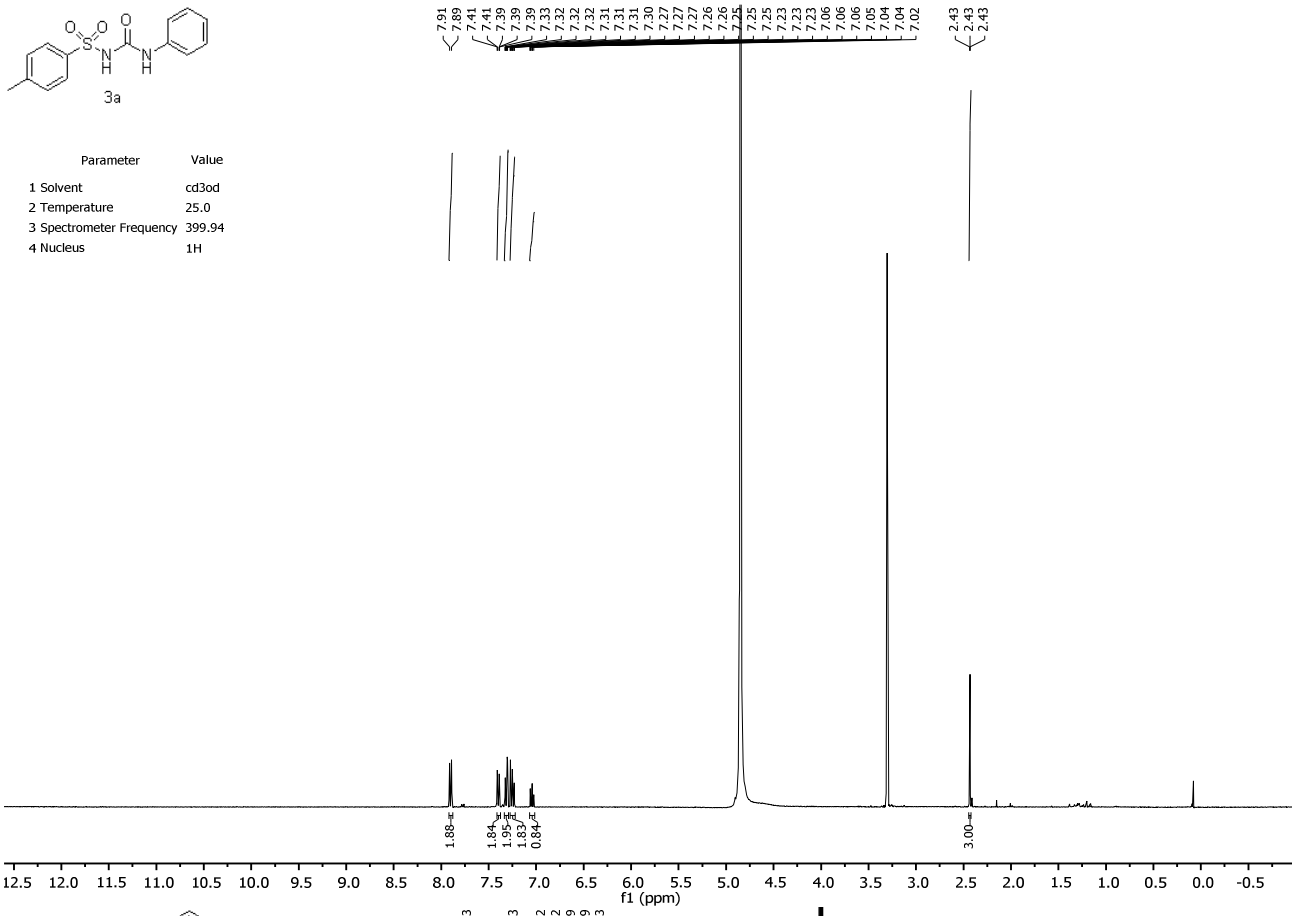


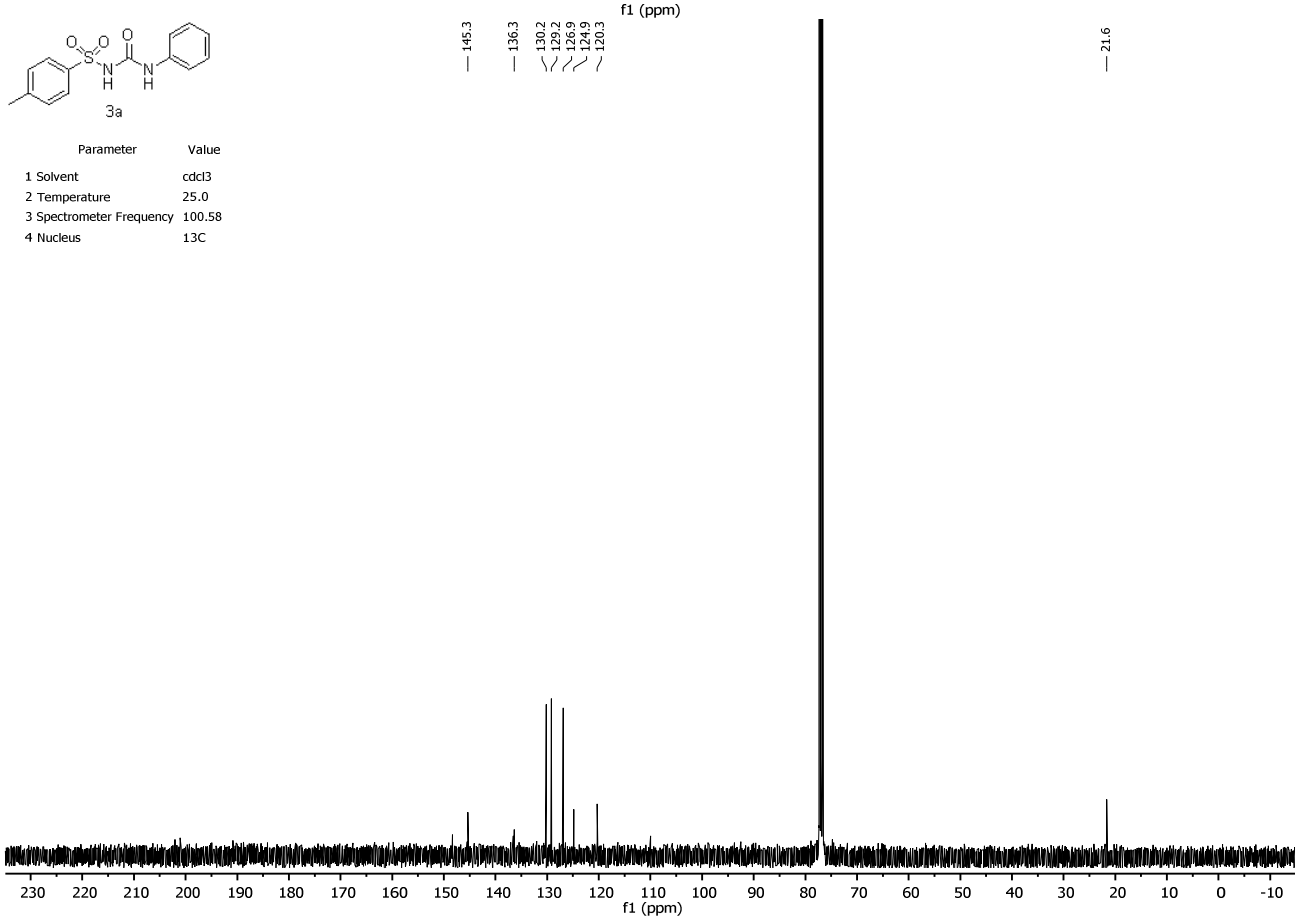


Parameter	Value
1 Solvent	acetone
2 Temperature	25.0
3 Spectrometer Frequency	100.56
4 Nucleus	13C

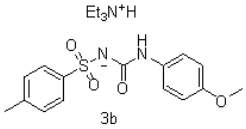


4-Methyl-*N*-(phenylcarbamoyl)benzenesulfonamide (Table 3, entry 3) (3a)

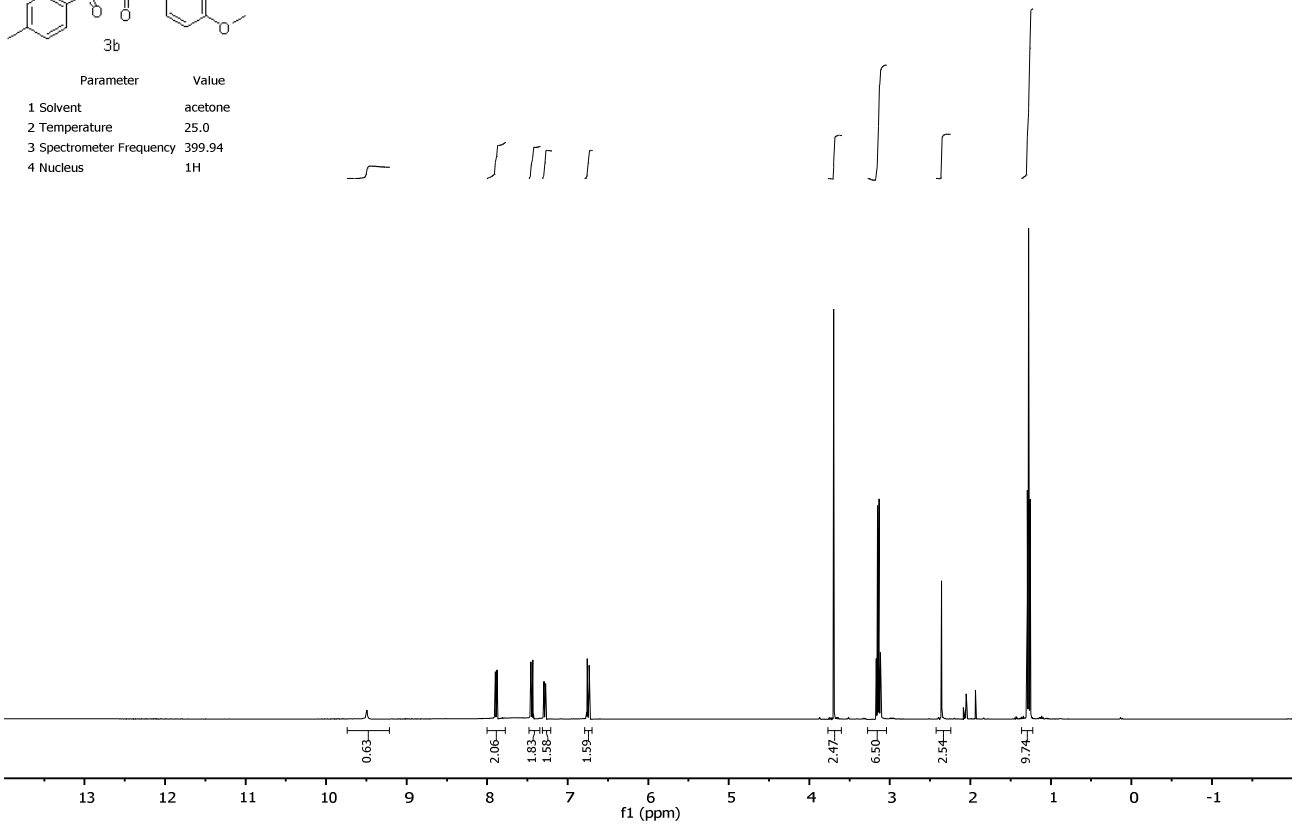




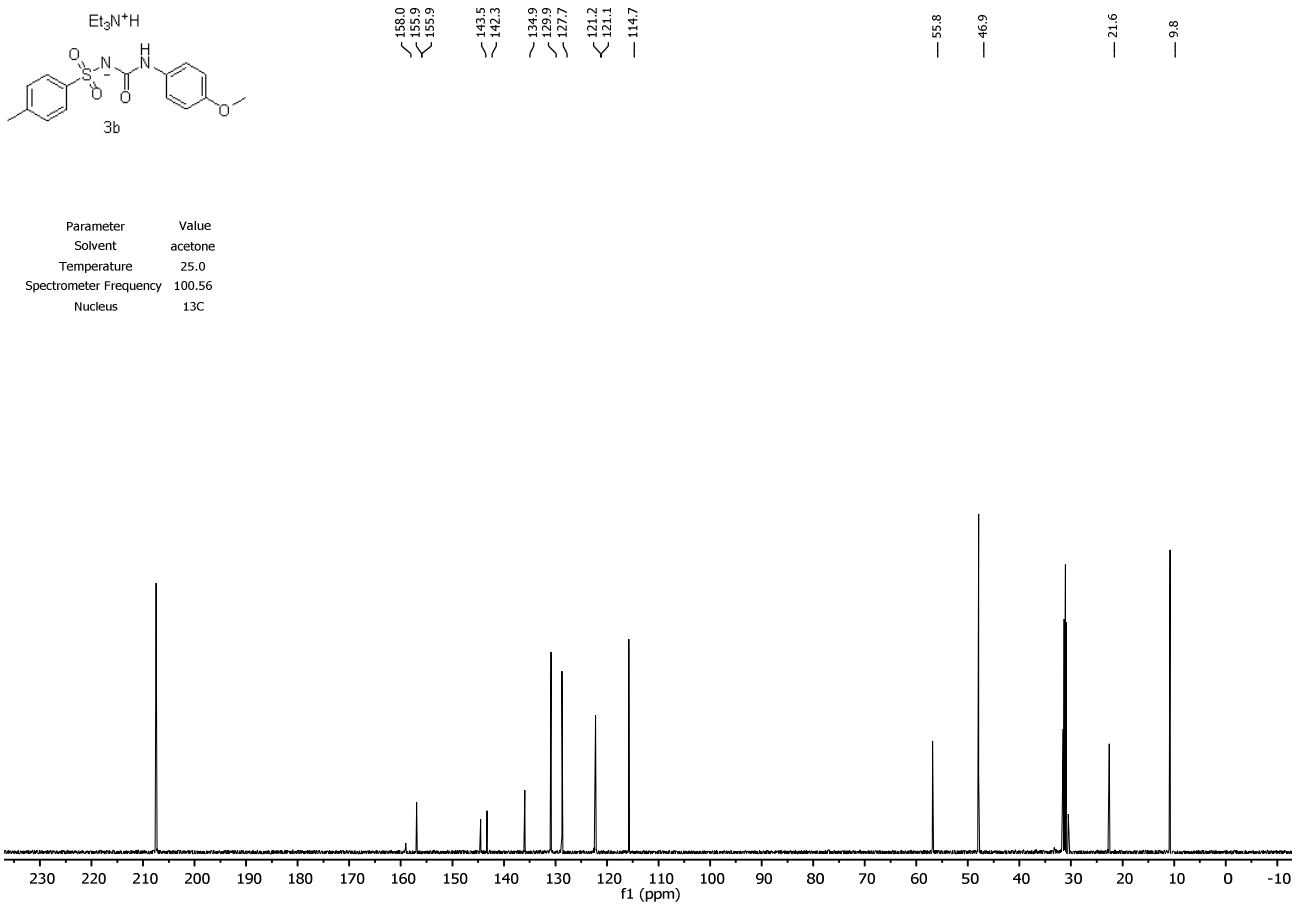
Triethylammonium *N*-((4-methoxyphenyl)carbamoyl)-4-methylbenzenesulfonamide (3b)



Parameter	Value
1 Solvent	acetone
2 Temperature	25.0
3 Spectrometer Frequency	399.94
4 Nucleus	1H

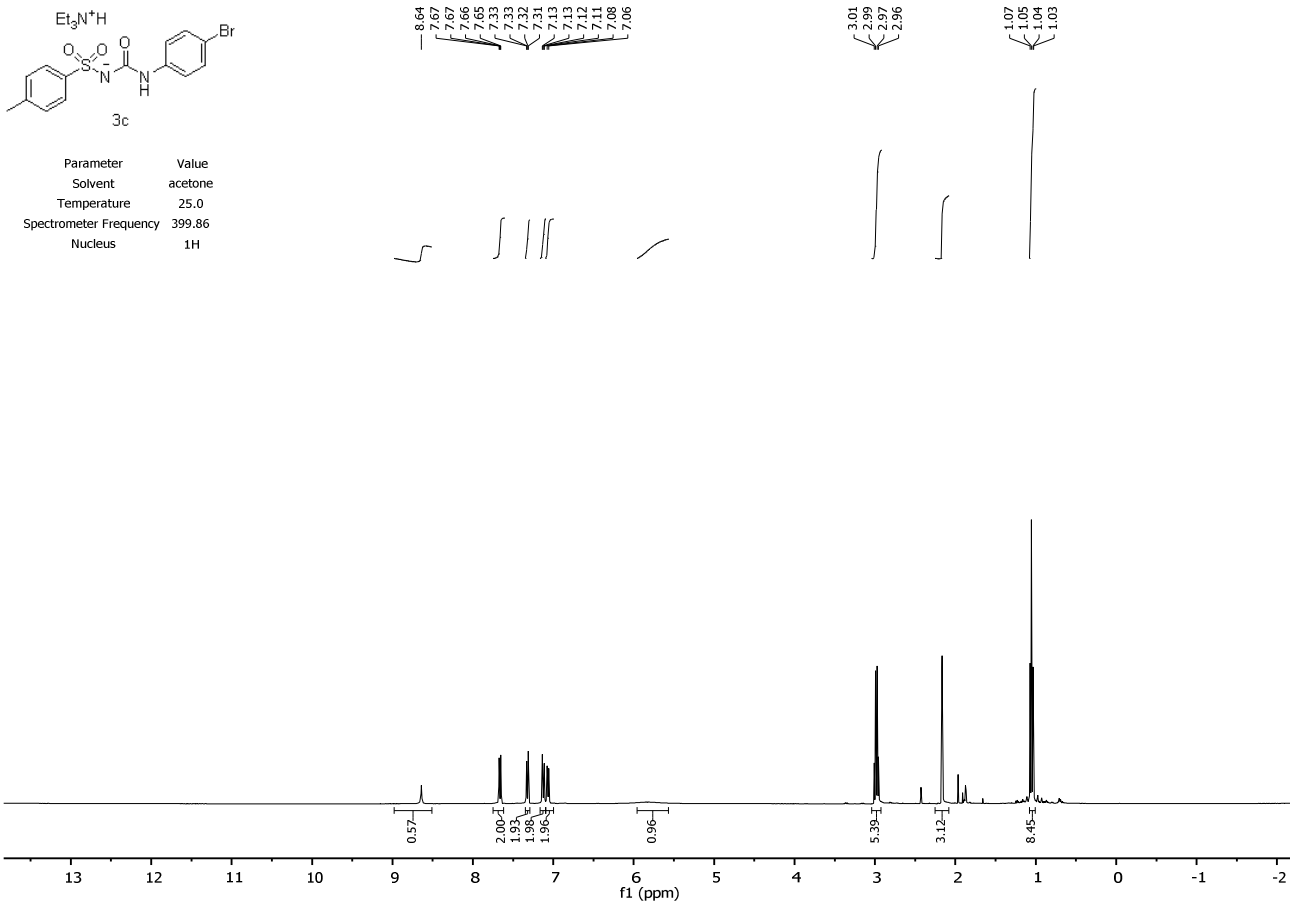


Parameter	Value
Solvent	acetone
Temperature	25.0
Spectrometer Frequency	100.56
Nucleus	13C

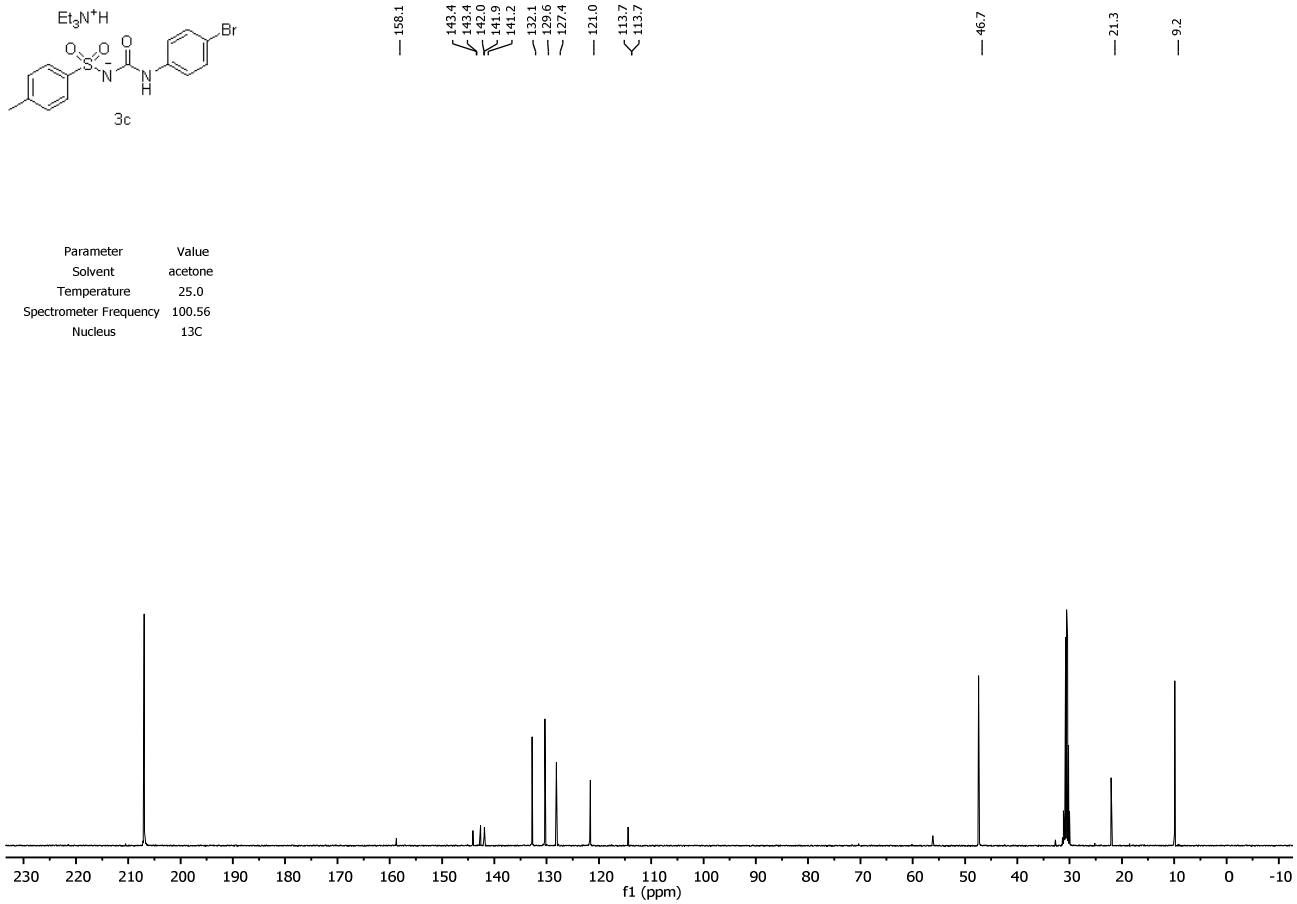


Triethylammonium *N*-((4-bromophenyl)carbamoyl)-4-methylbenzenesulfonamide (3c)

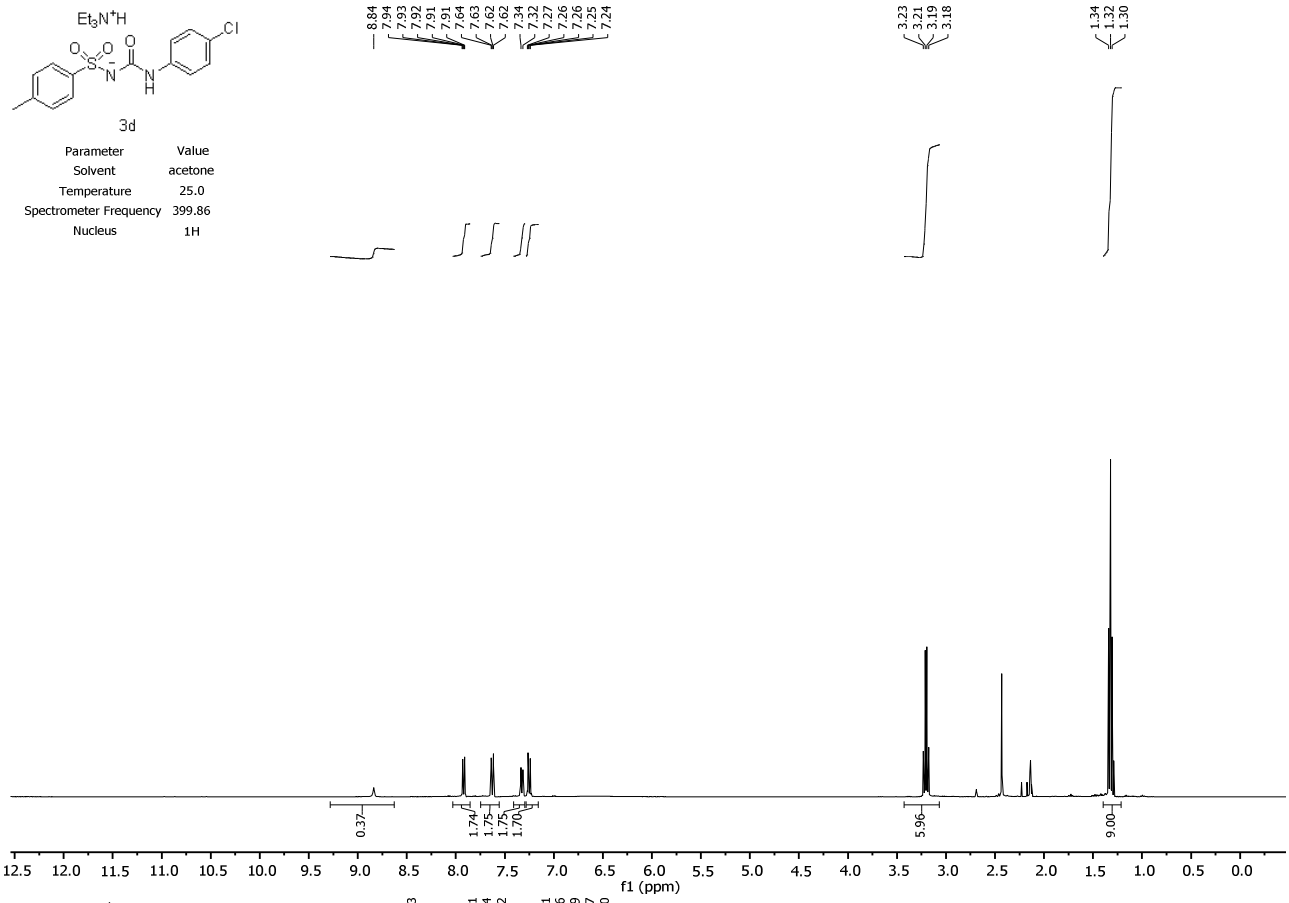
Parameter	Value
Solvent	acetone
Temperature	25.0
Spectrometer Frequency	399.86
Nucleus	1H

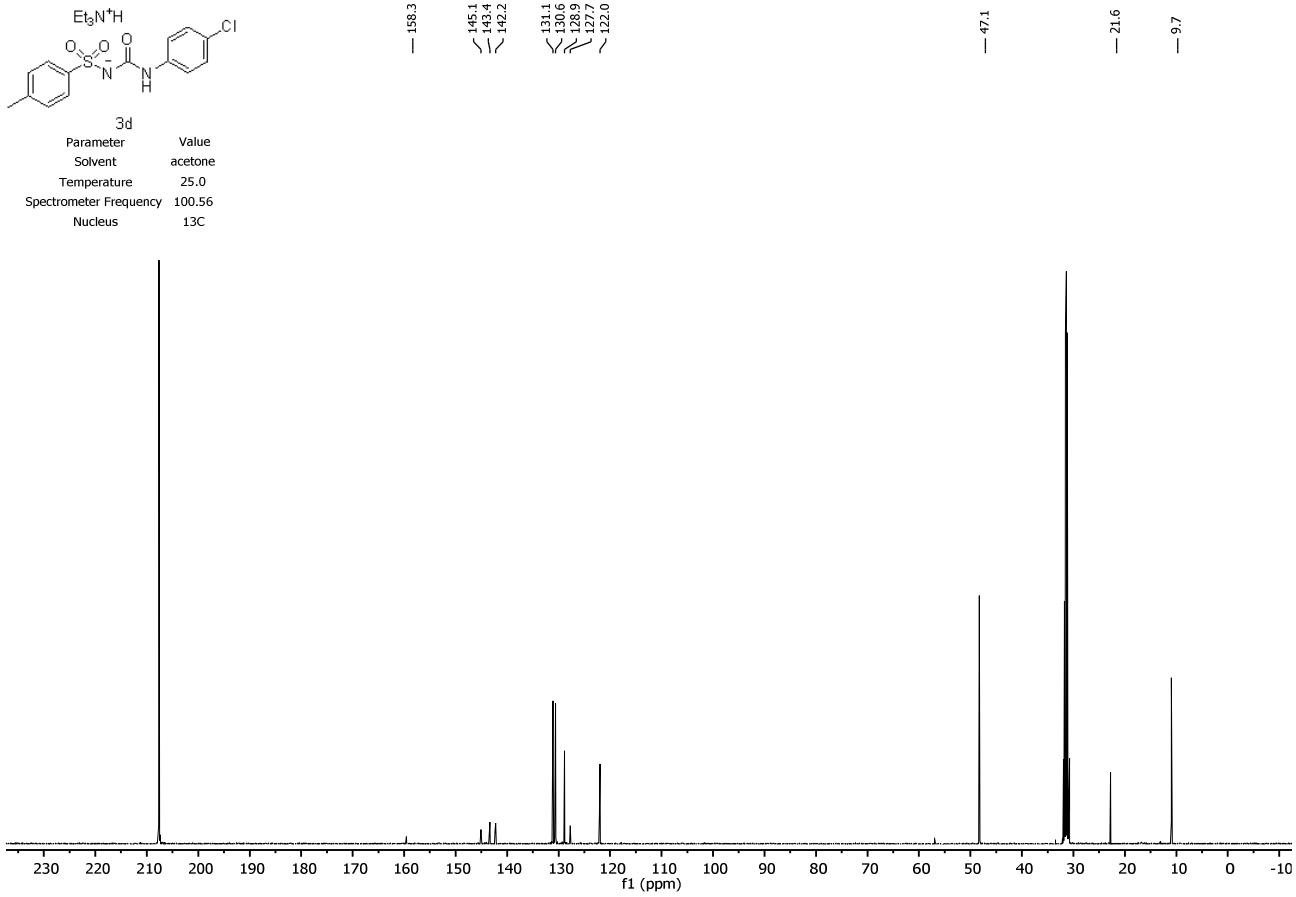


Parameter	Value
Solvent	acetone
Temperature	25.0
Spectrometer Frequency	100.56
Nucleus	13C

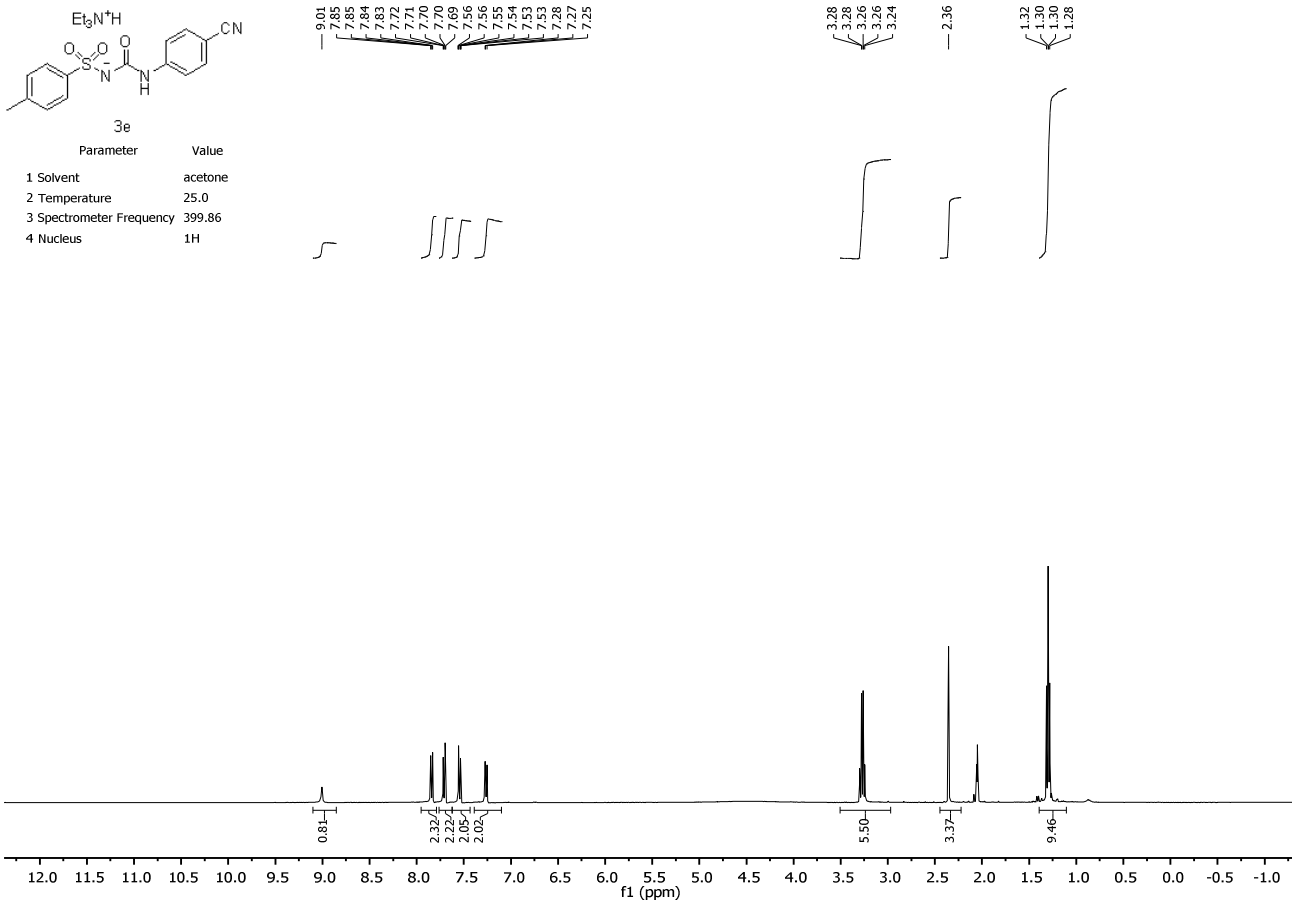


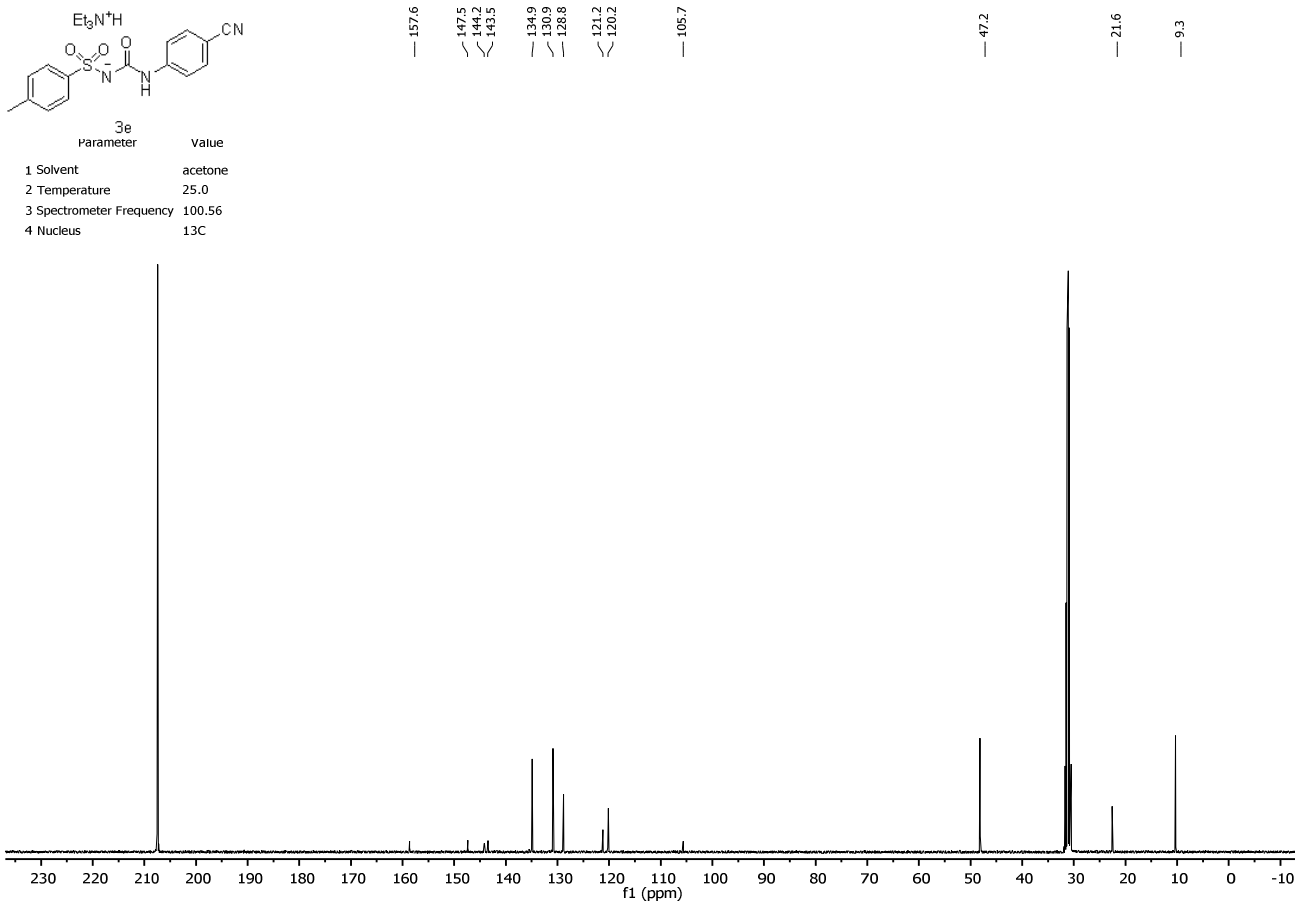
Triethylammonium *N*-((4-chlorophenyl)carbamoyl)-4-methylbenzenesulfonamide (3d)



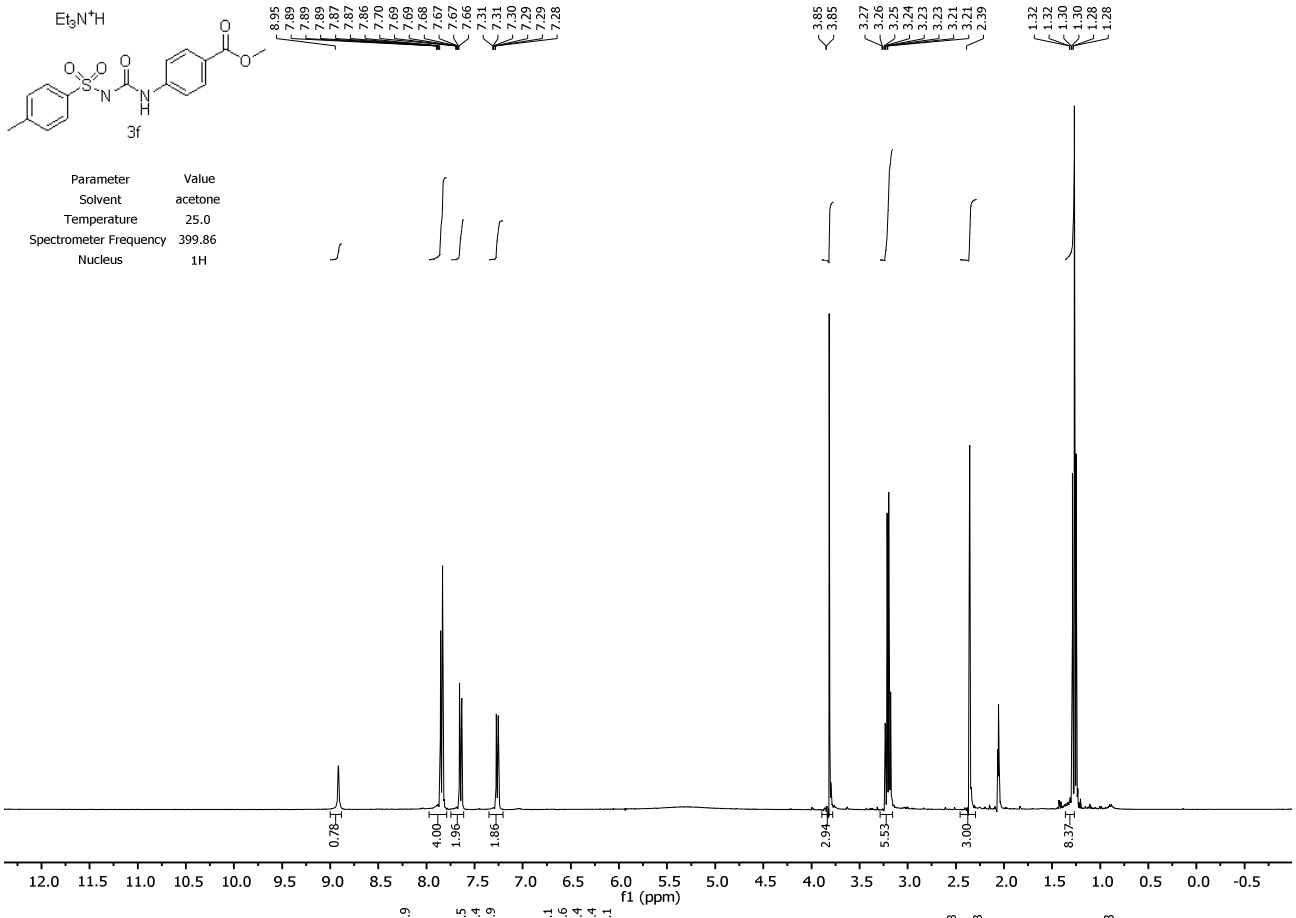


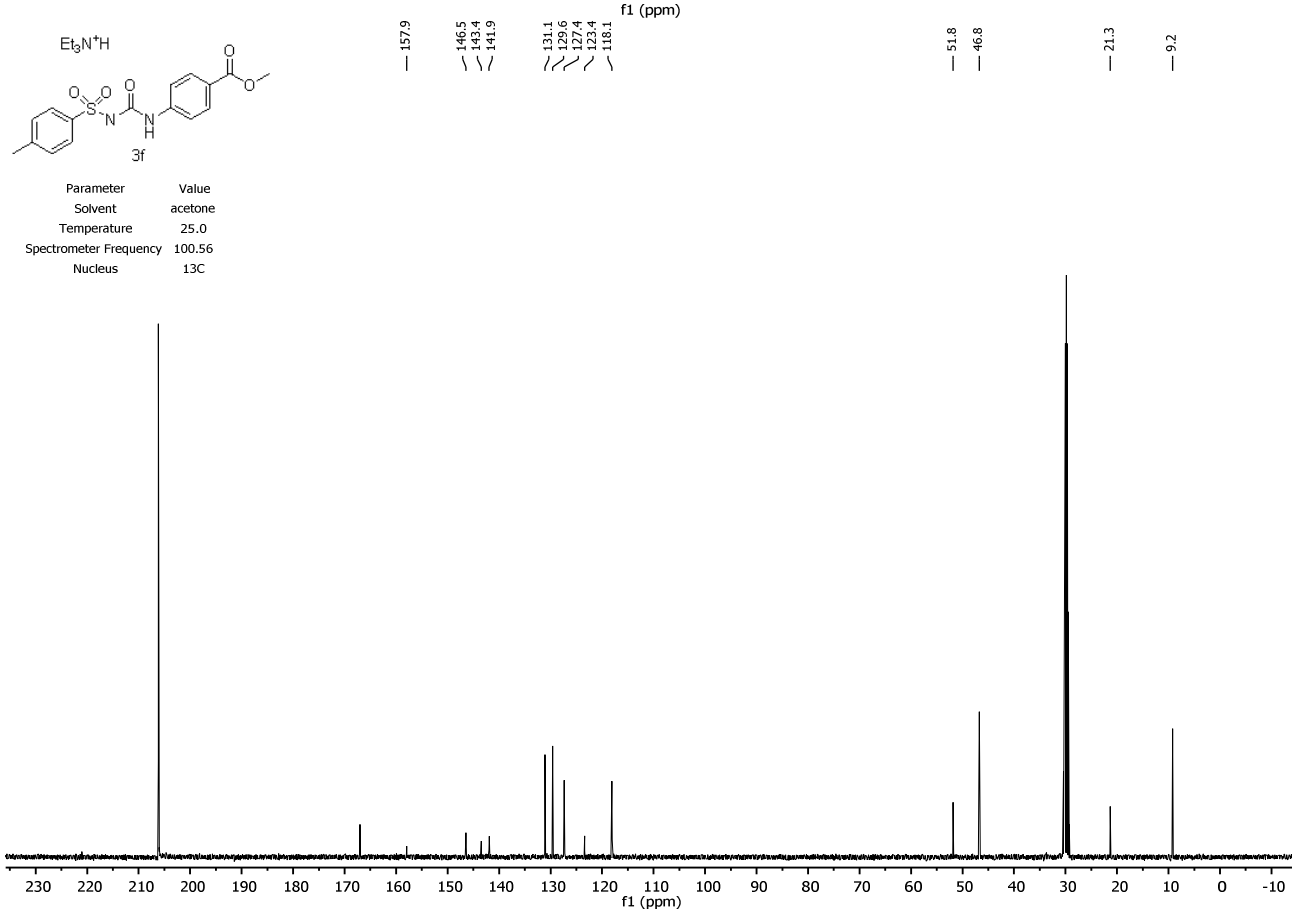
Triethylammonium *N*-((4-cyanophenyl)carbamoyl)-4-methylbenzenesulfonamide (3e)



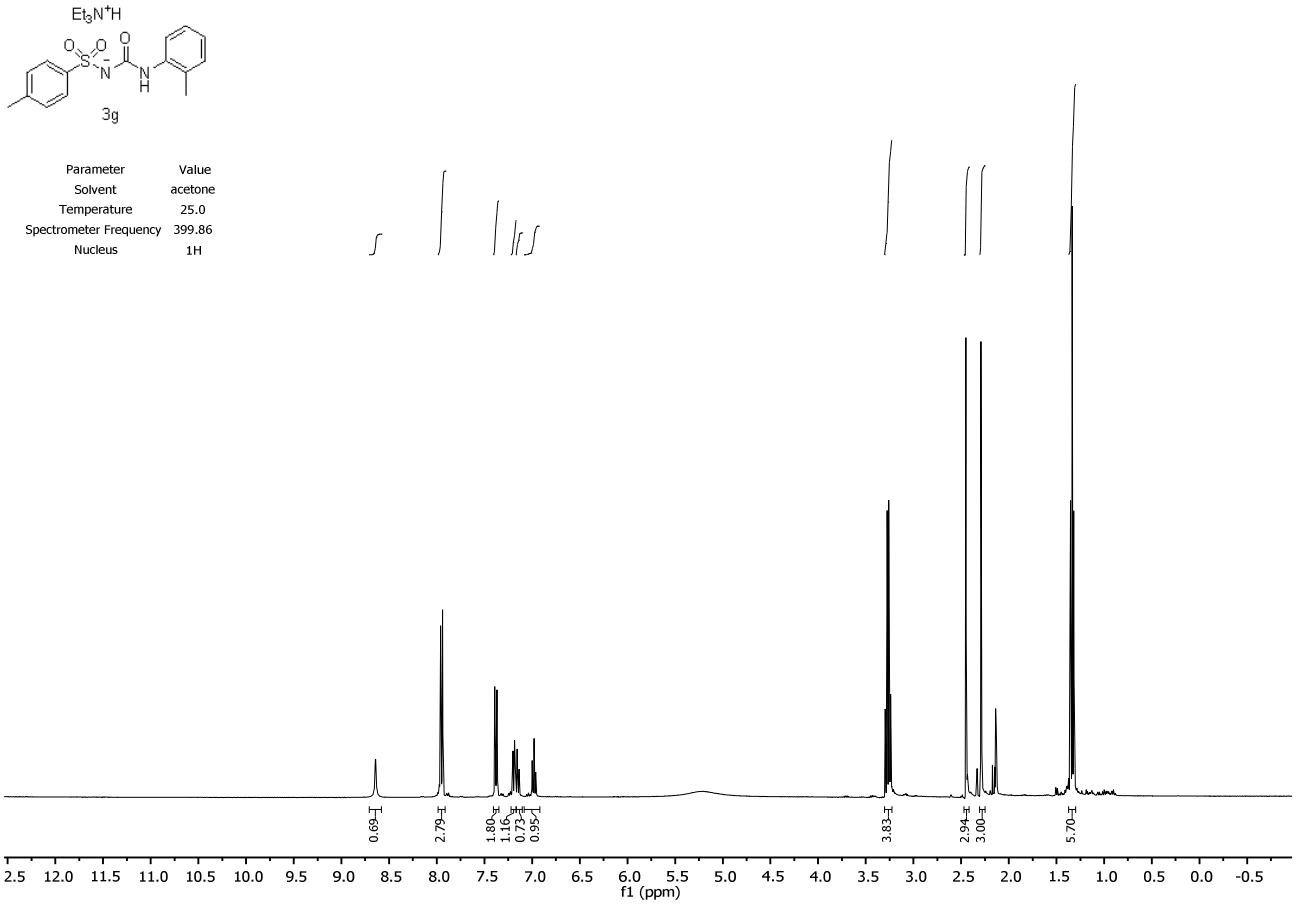


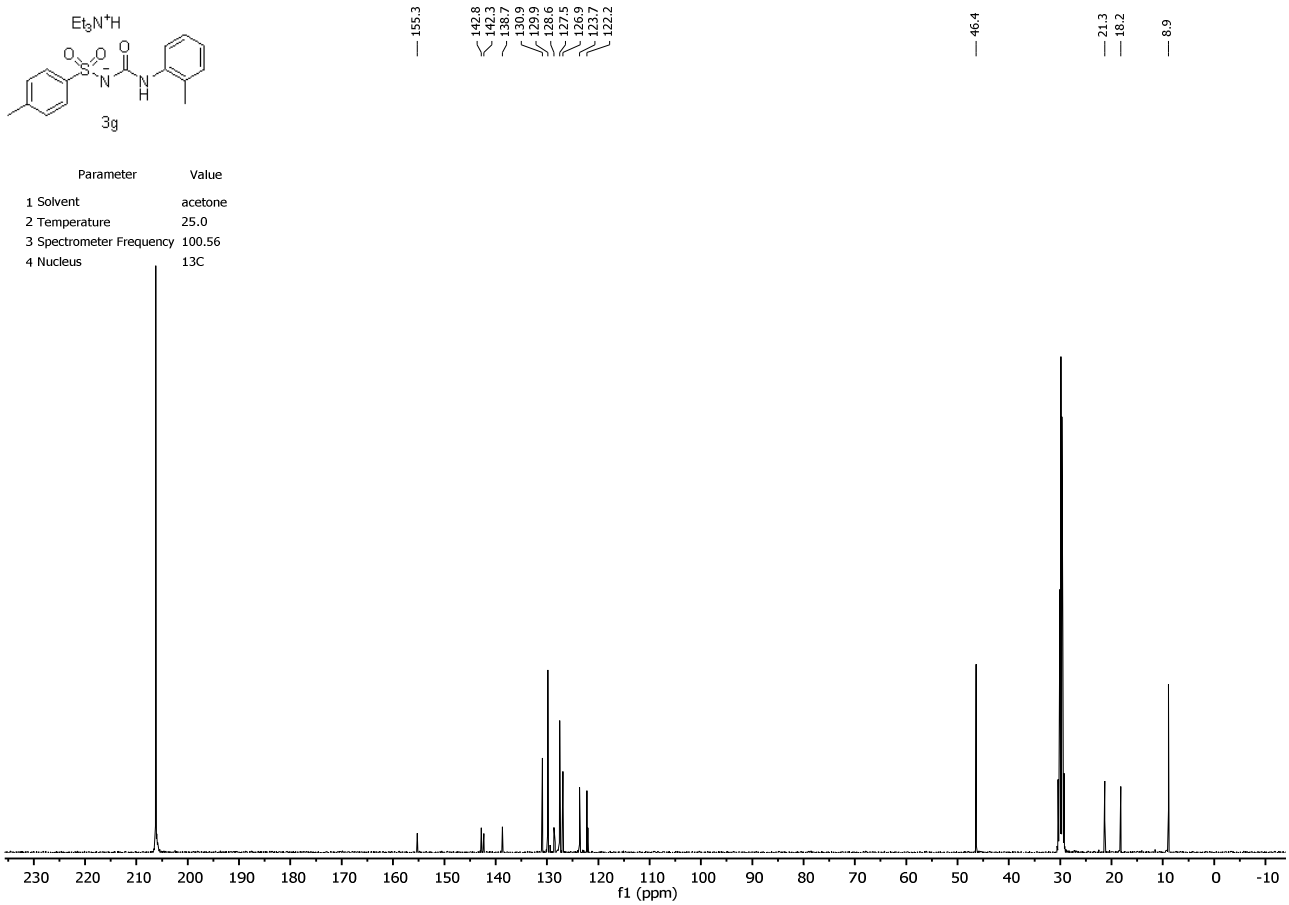
Triethylammonium methyl 4-(3-tosylureido)benzoate (3f)



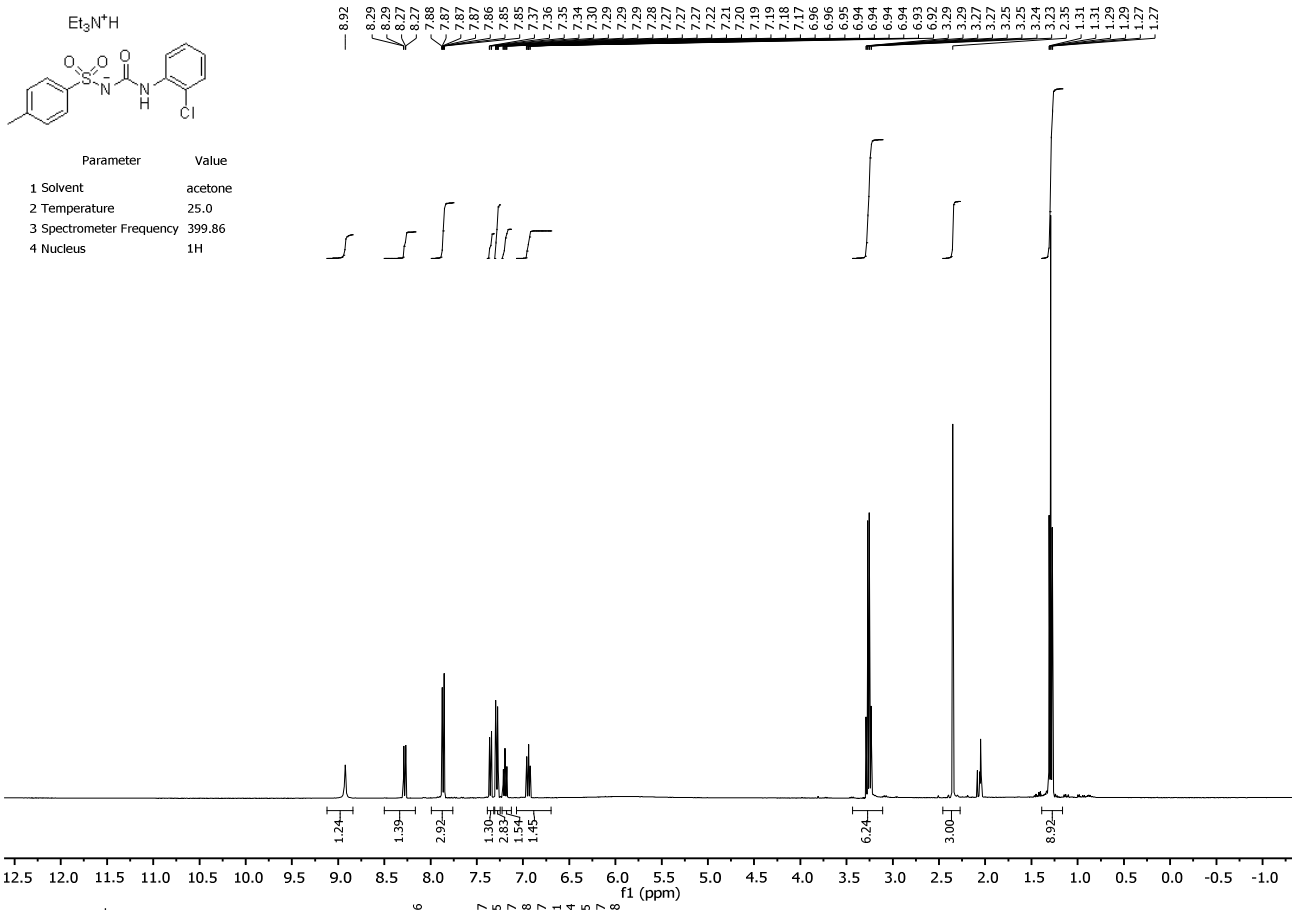


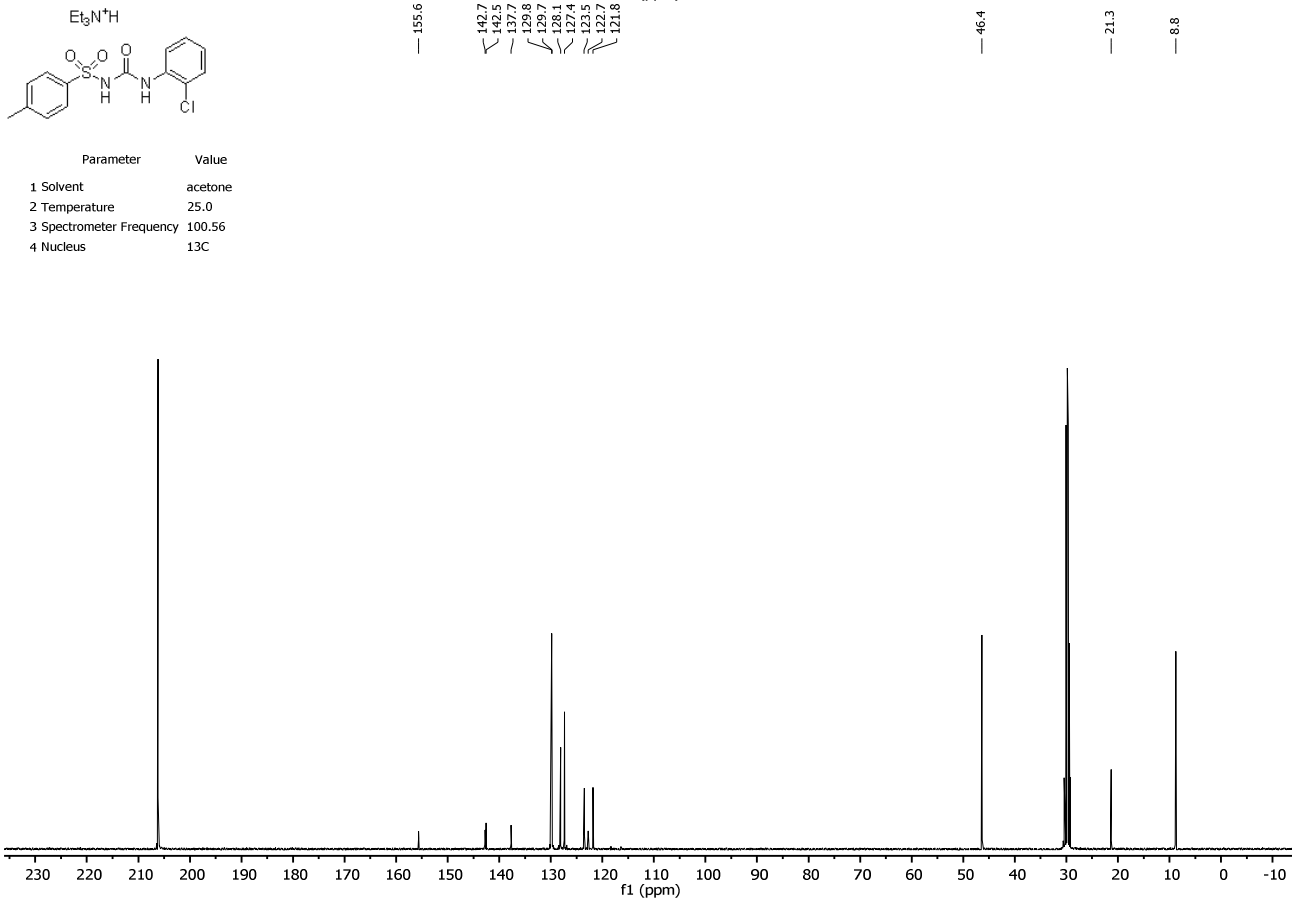
Triethylammonium 4-methyl-*N*-(o-tolylcarbamoyl)benzenesulfonamide (3g)



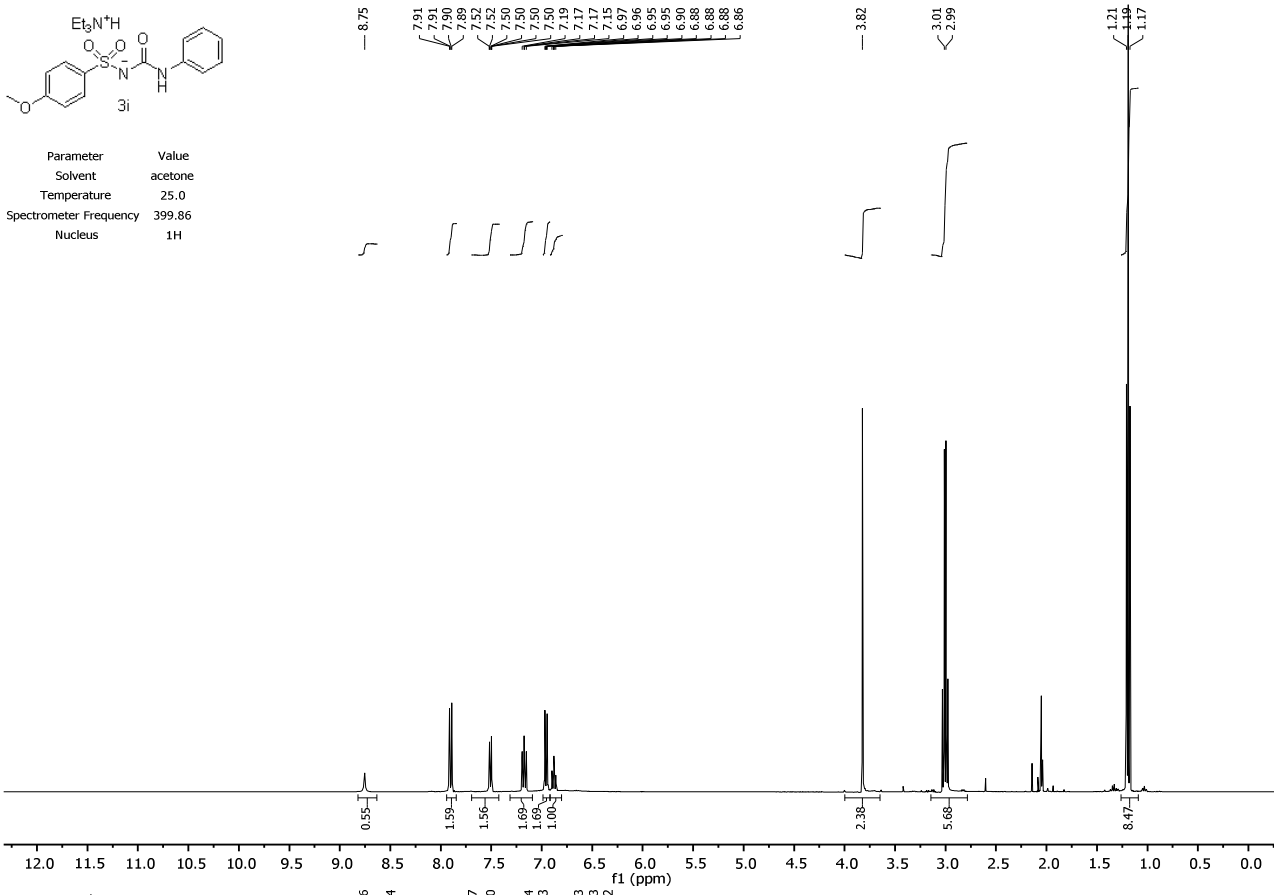


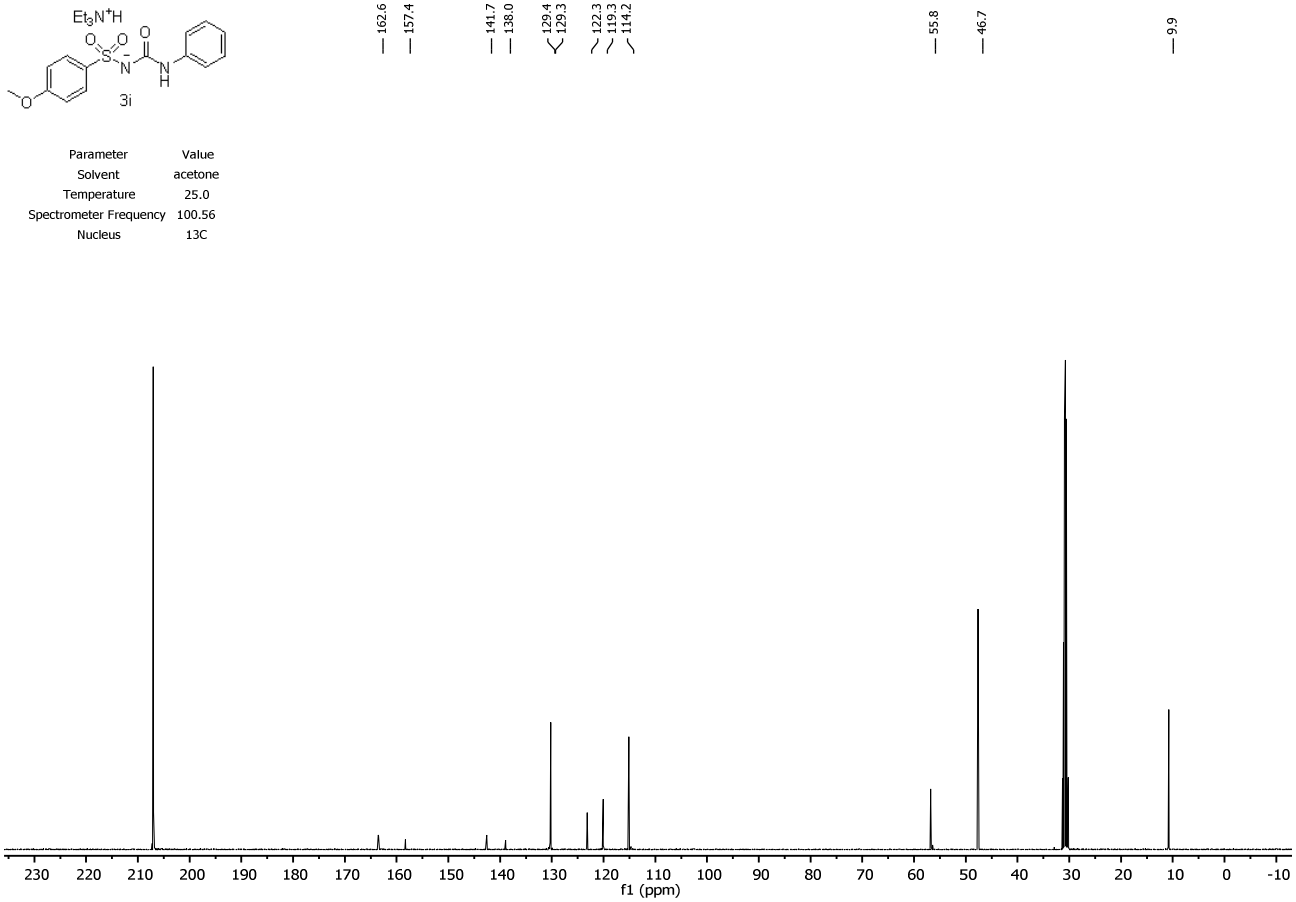
Triethylammonium *N*-((2-chlorophenyl)carbamoyl)-4-methylbenzenesulfonamide (3h)





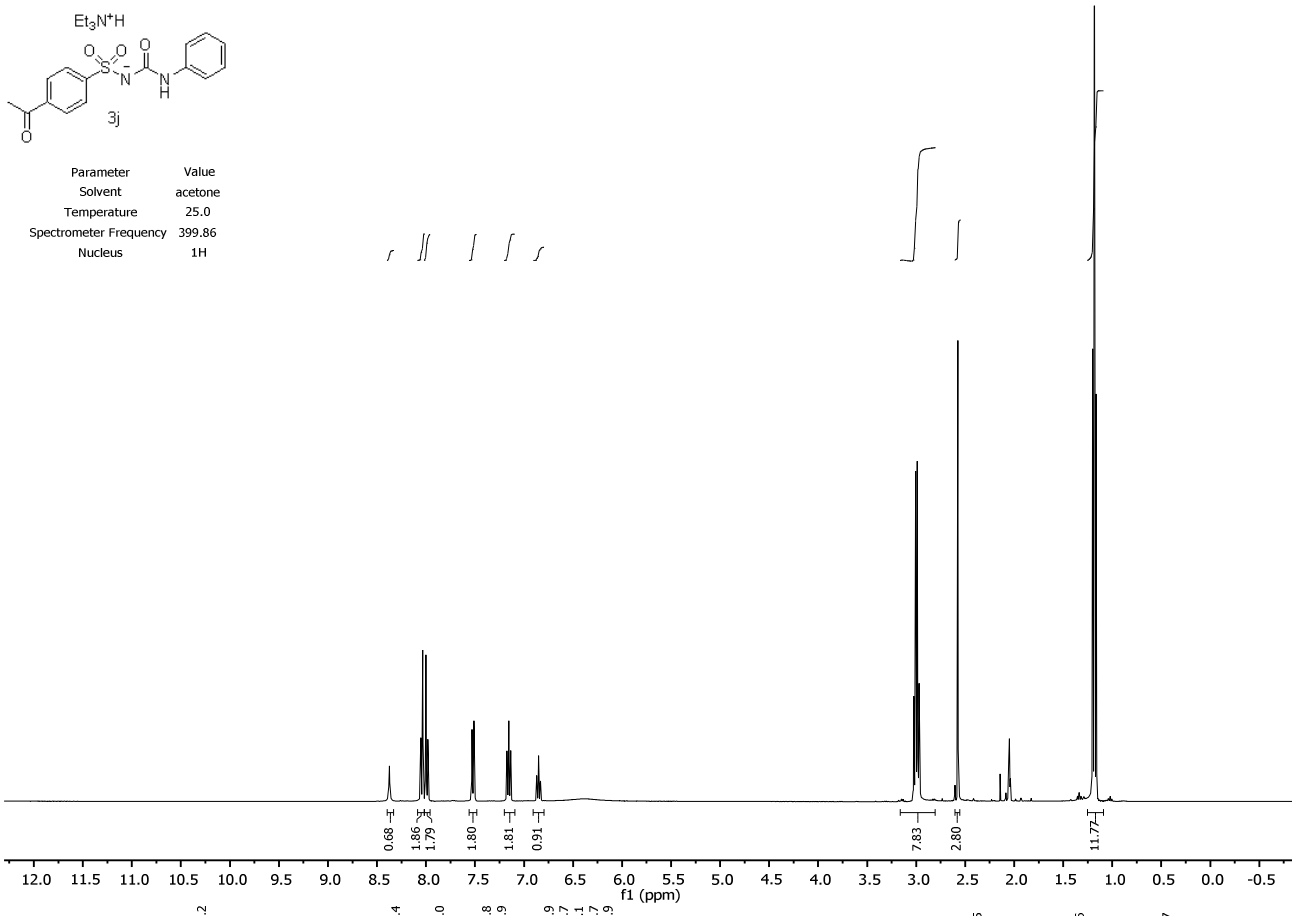
Triethylammonium 4-Methoxy-*N*-(phenylcarbamoyl)benzenesulfonamide (3i)

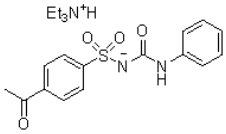




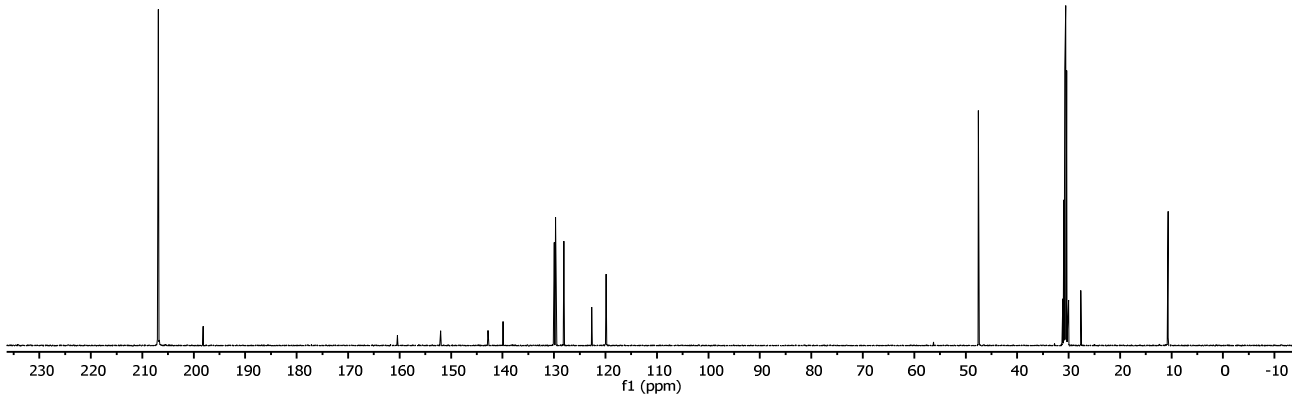
Triethylammonium 4-Acetyl-*N*-(phenylcarbamoyl)benzenesulfonamide (3j)

Parameter	Value
Solvent	acetone
Temperature	25.0
Spectrometer Frequency	399.86
Nucleus	1H

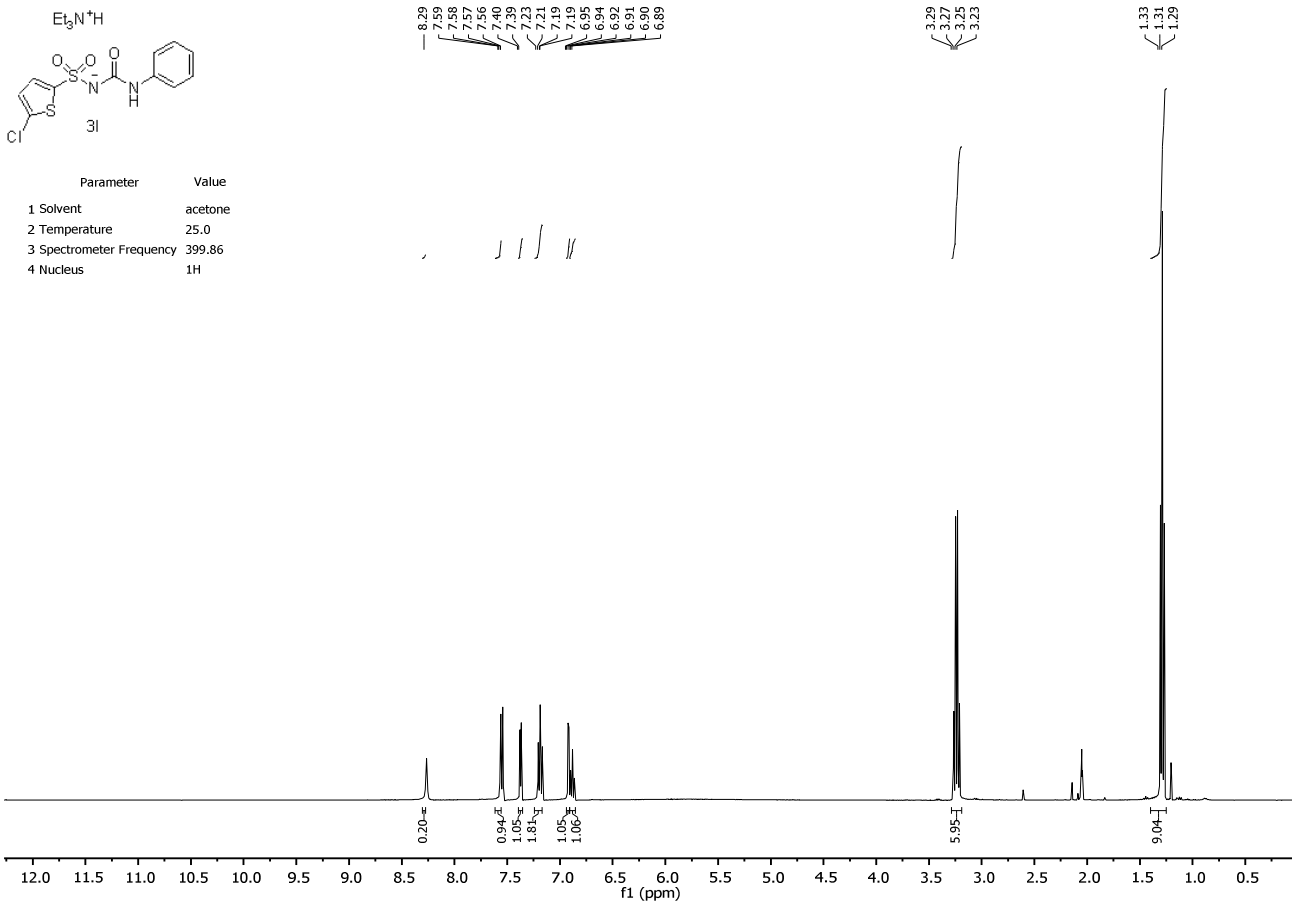


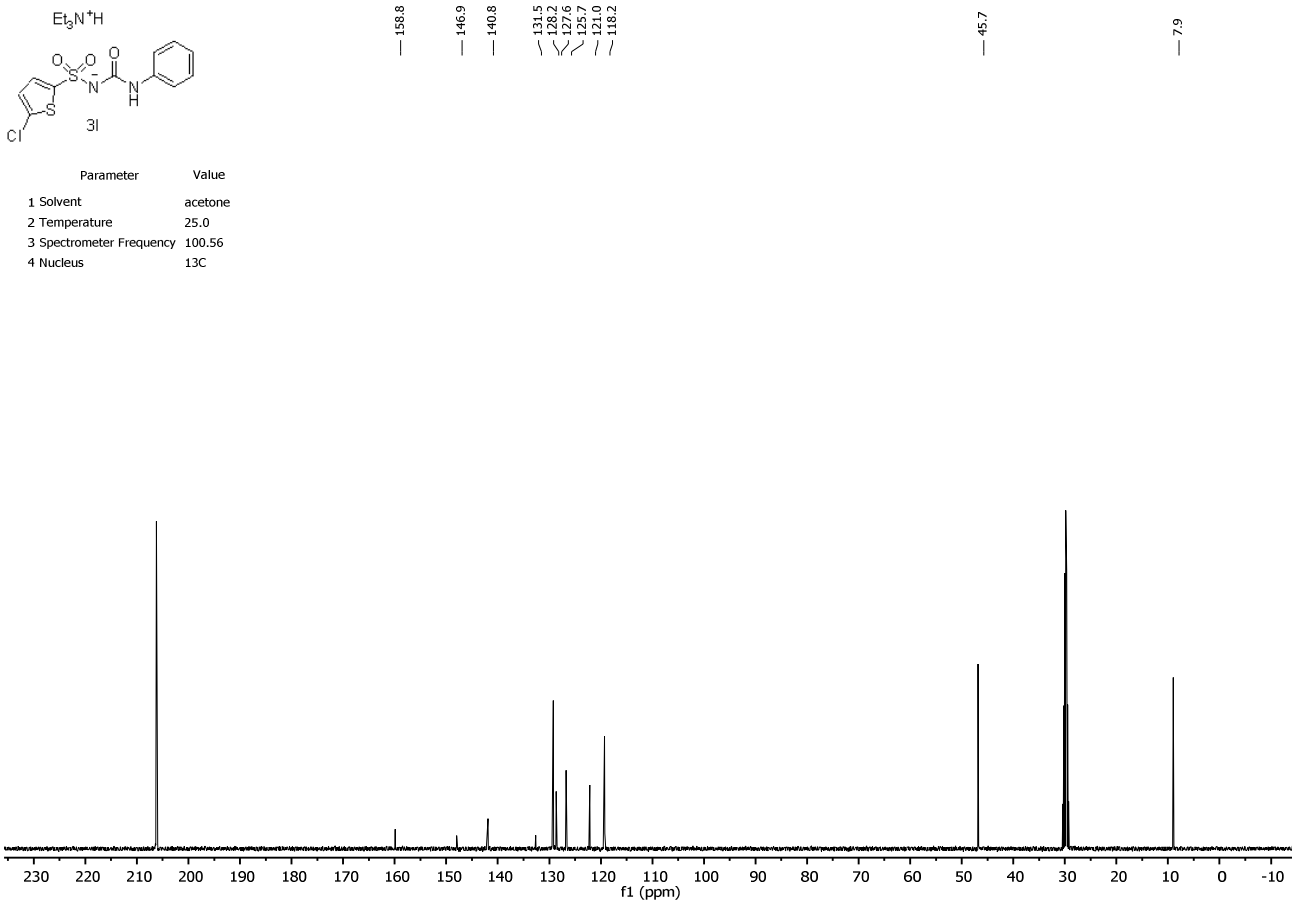


Parameter	Value
1 Solvent	acetone
2 Temperature	25.0
3 Spectrometer Frequency	100.56
4 Nucleus	13C

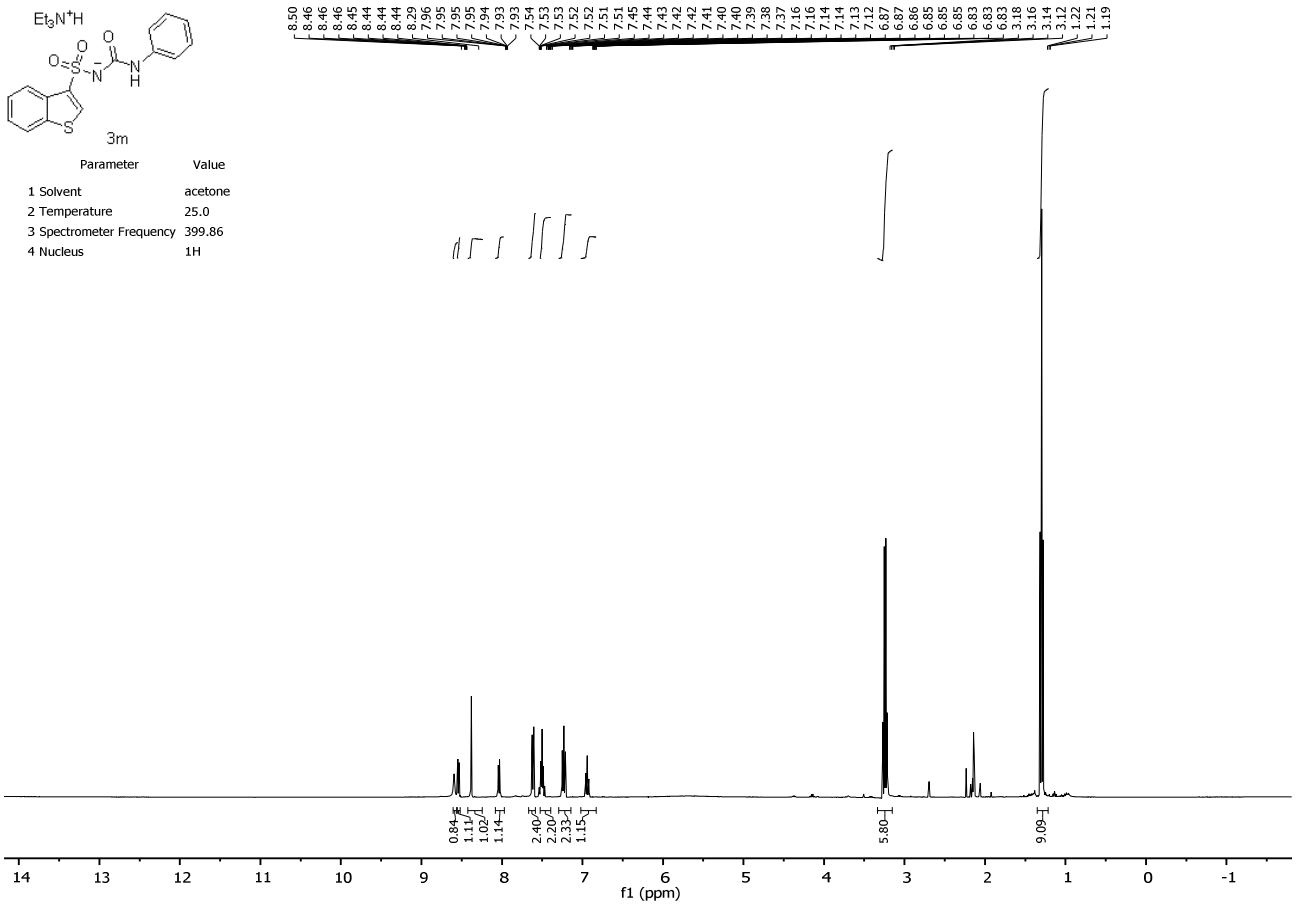


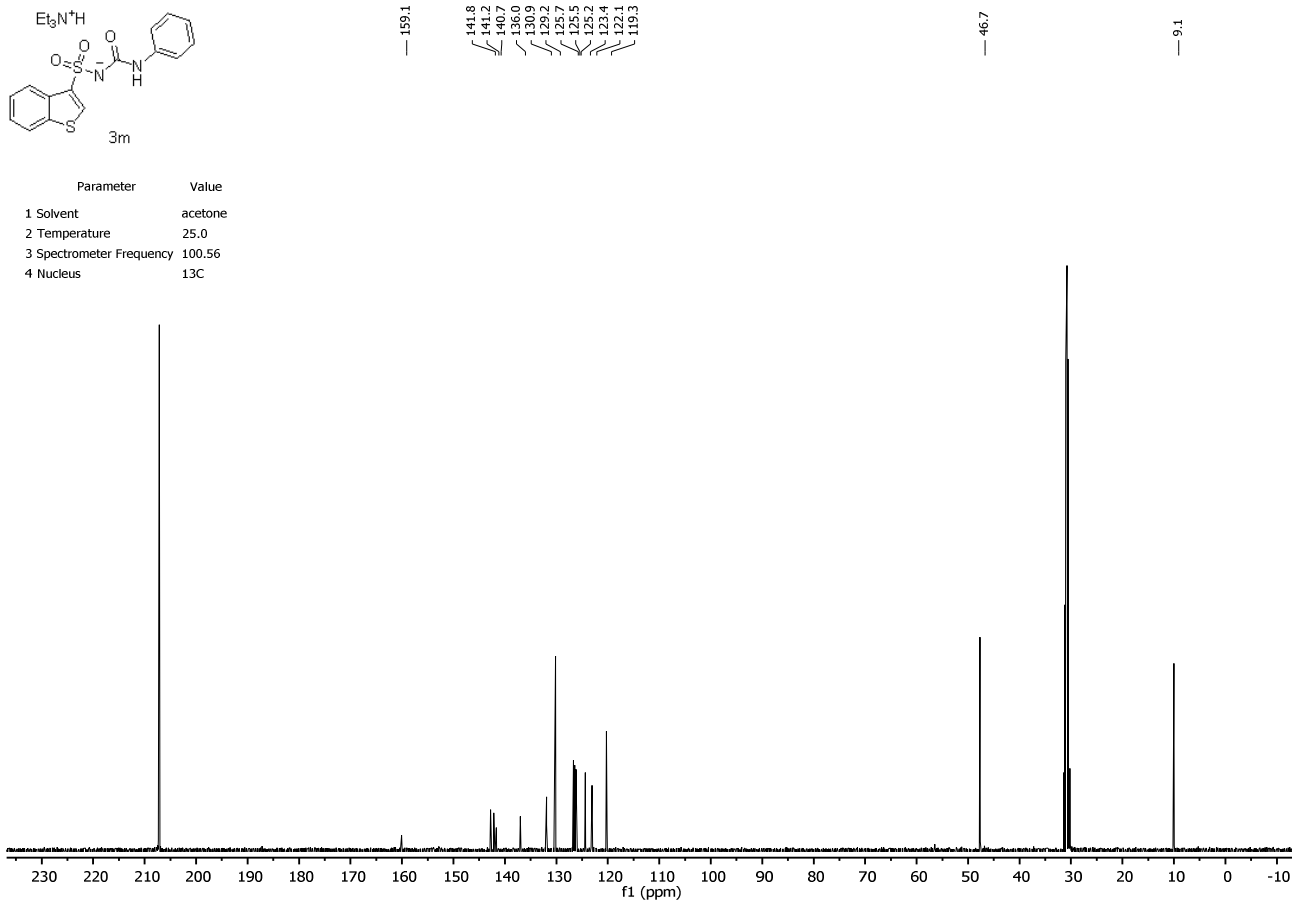
5-Chloro-*N*-(phenylcarbamoyl)thiophene-2-sulfonamide (3k)



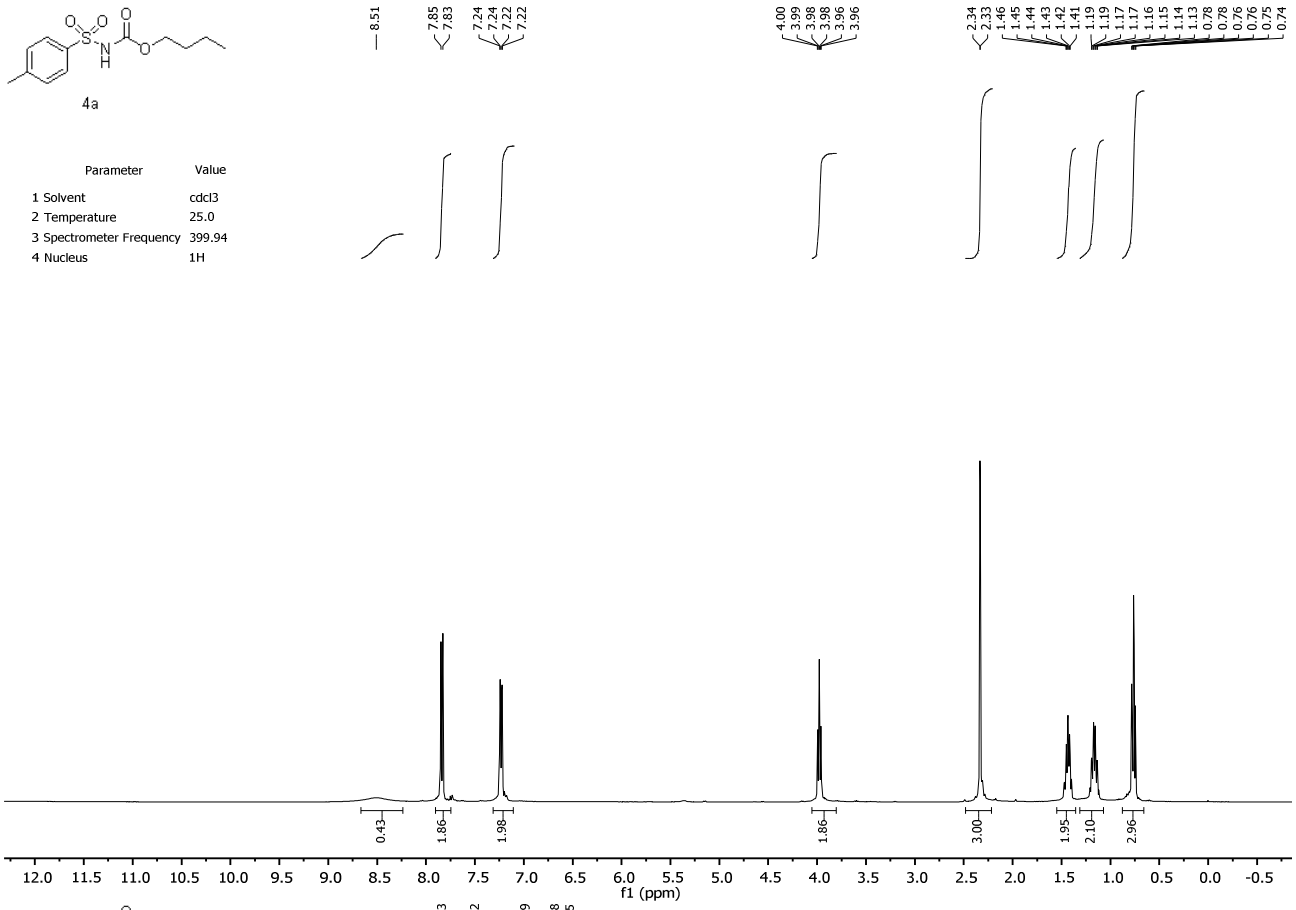


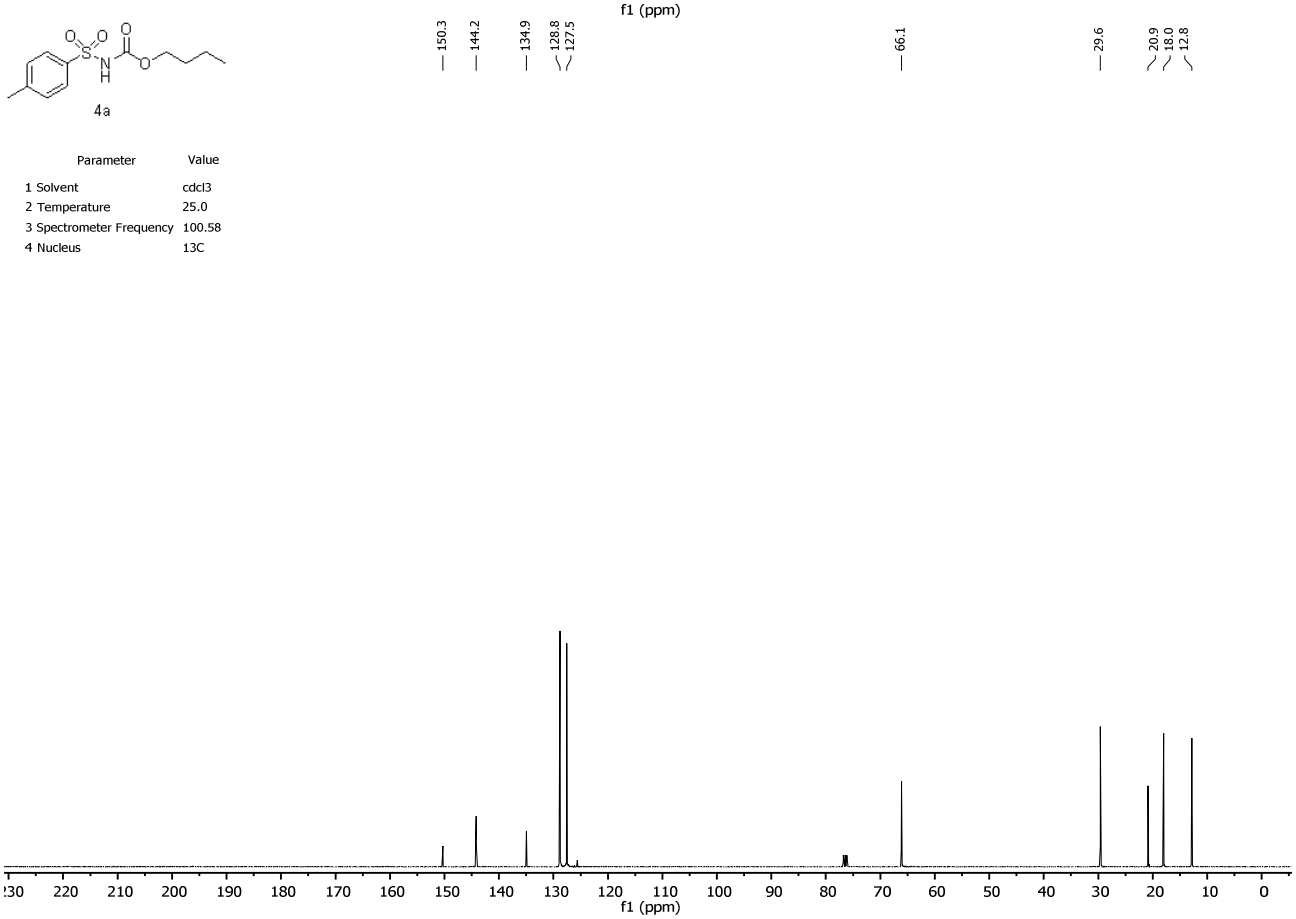
Triethylammonium *N*-(Phenylcarbamoyl)benzo[b]thiophene-3-sulfonamide (3l)



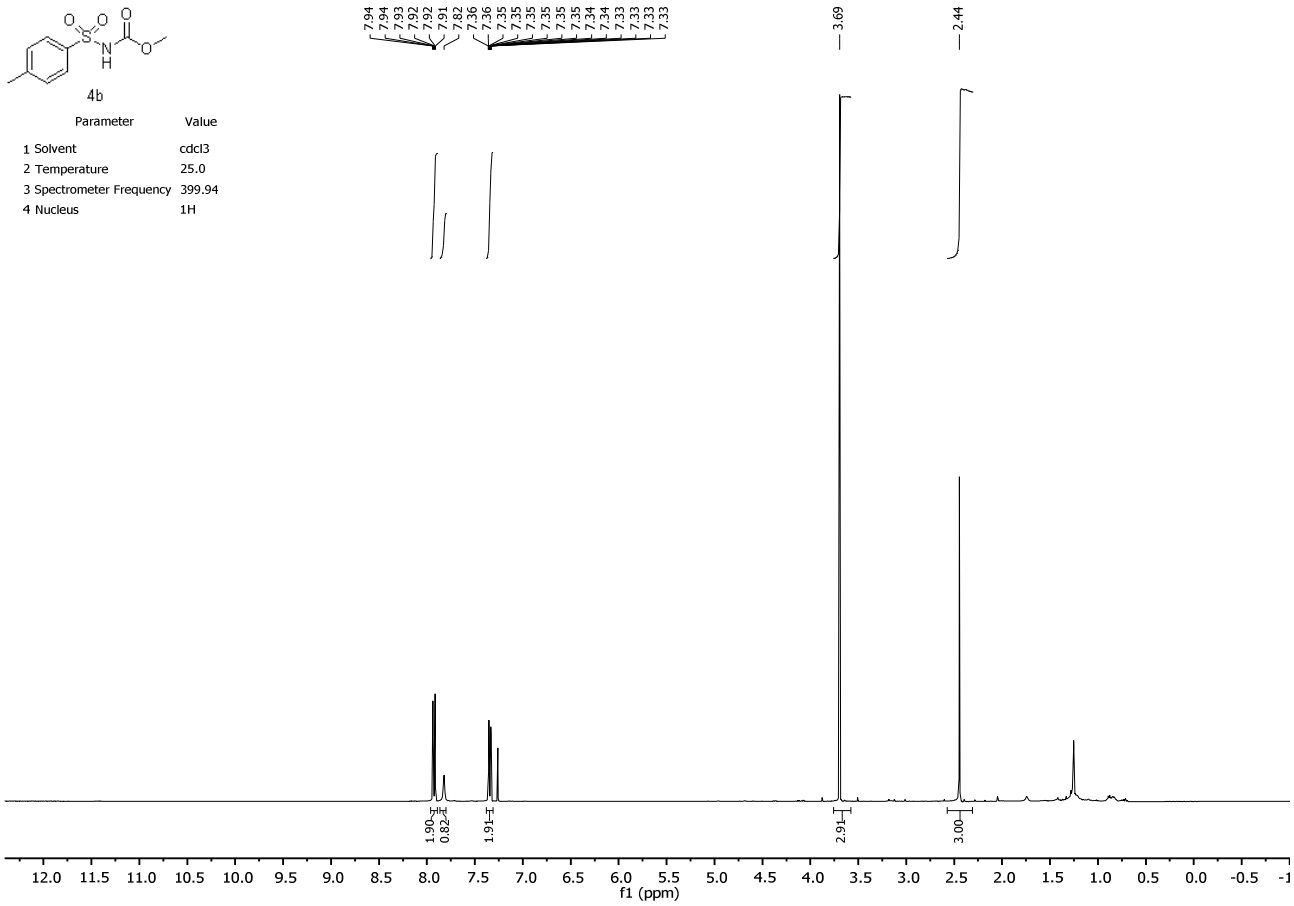


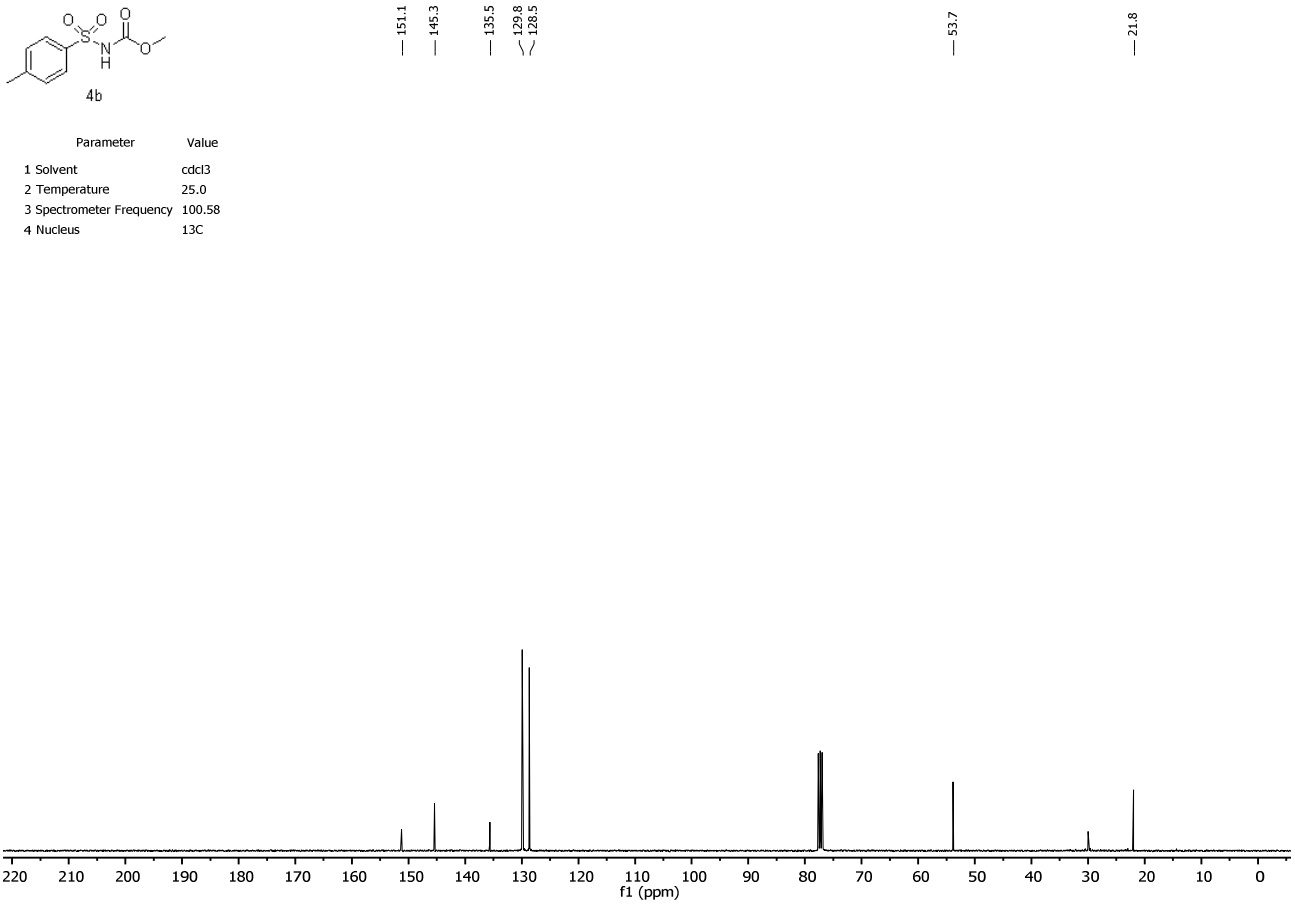
Butyl toluenesulfonylcarbamate (Table 5, entry 3) (4a)



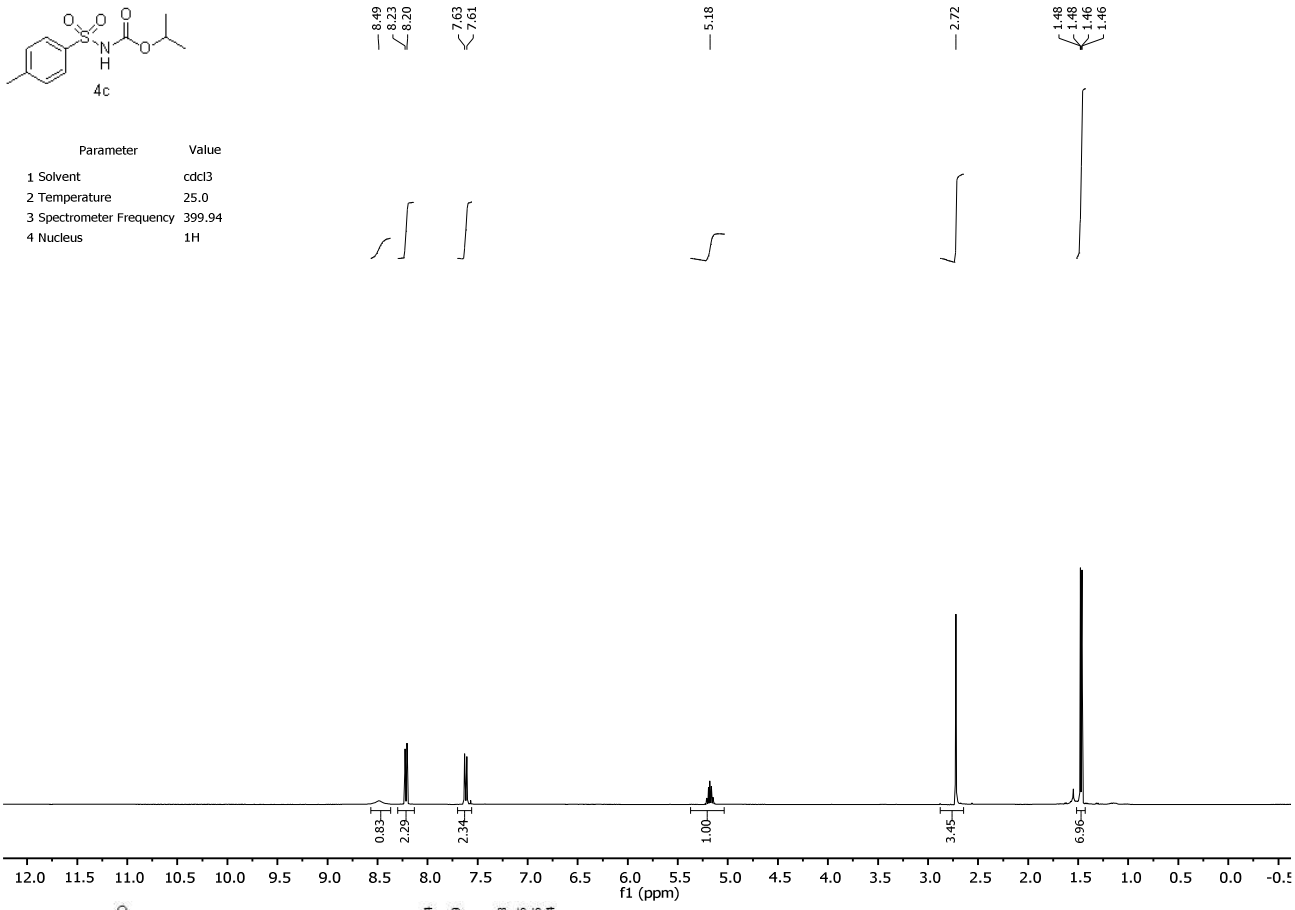


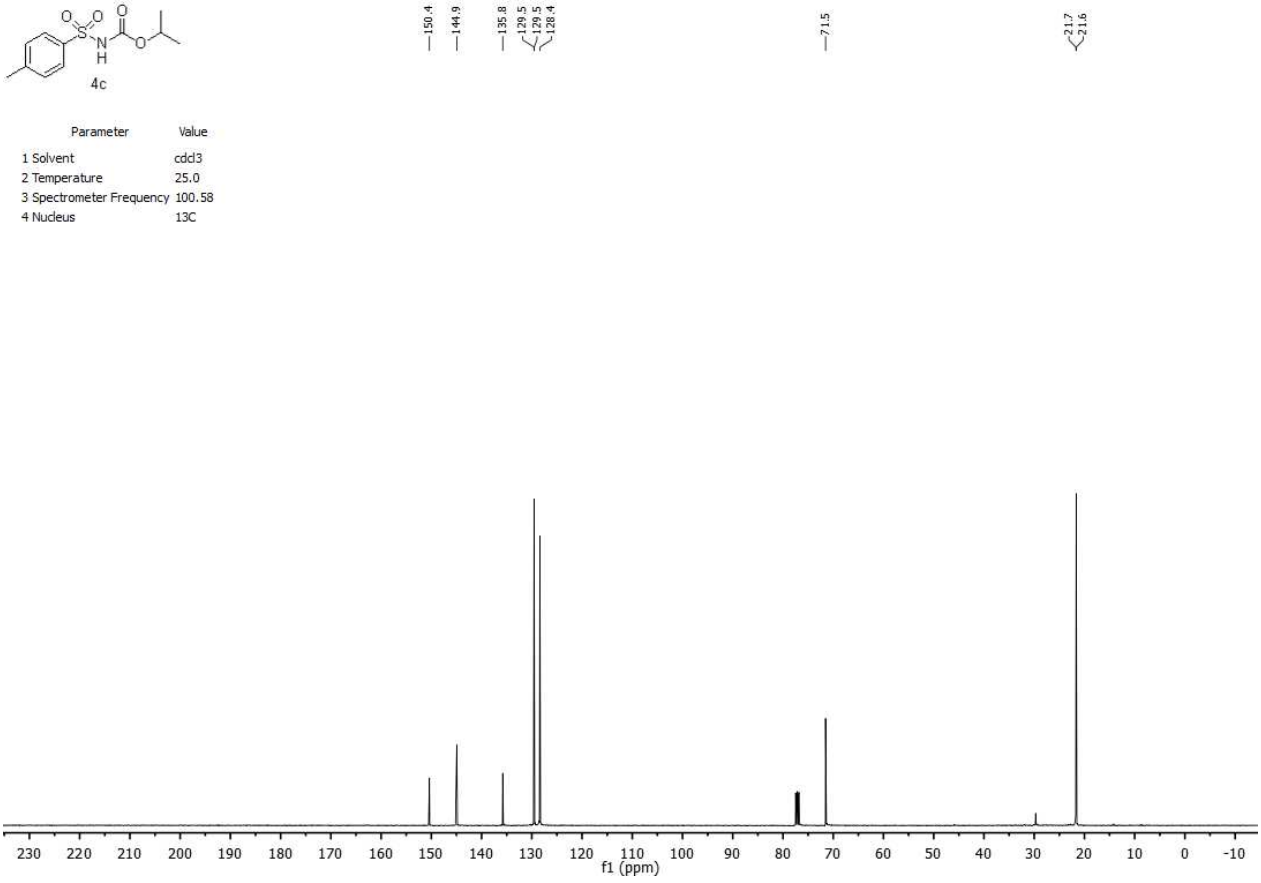
Methyl toluenesulfonylcarbamate (4b)



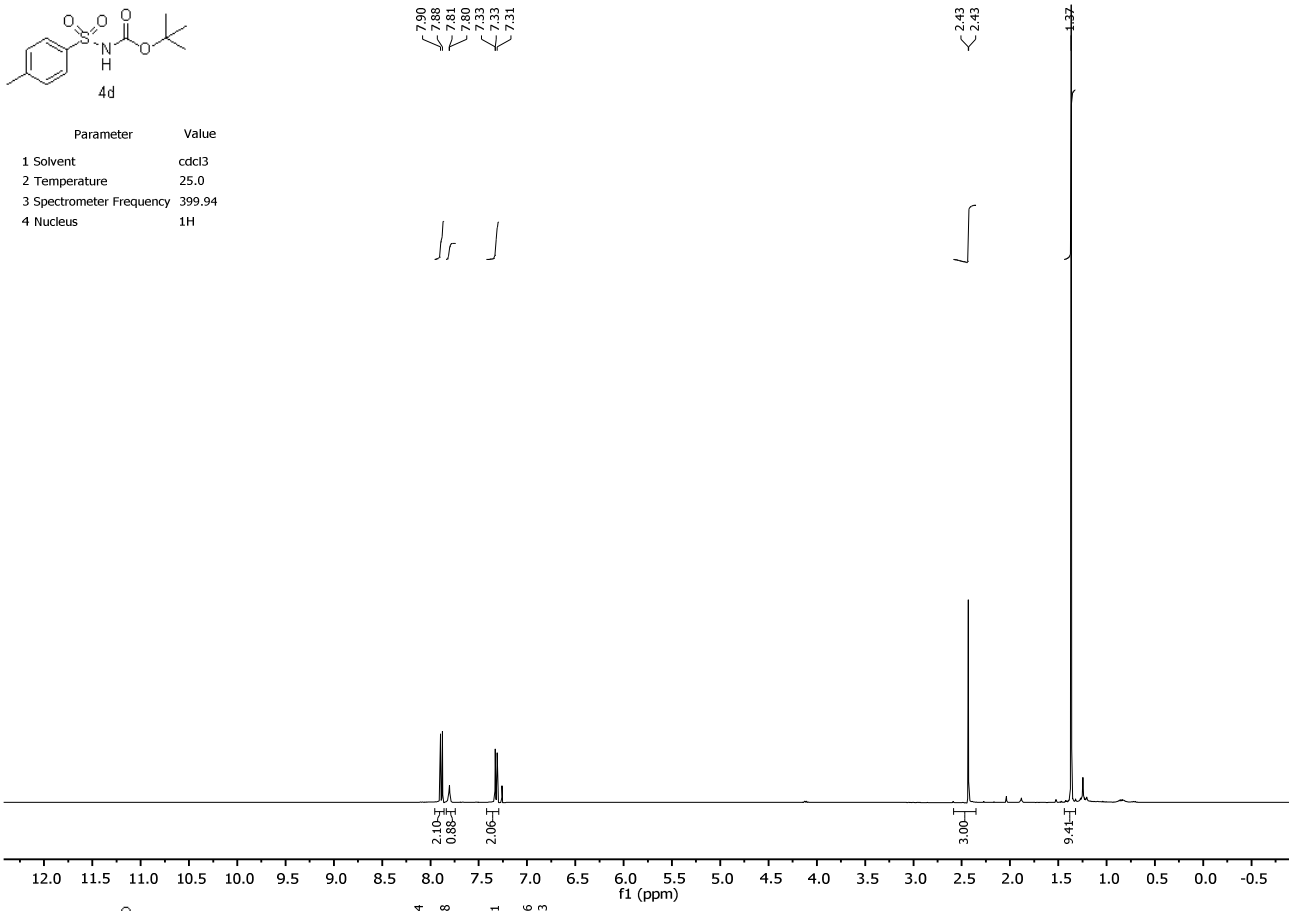


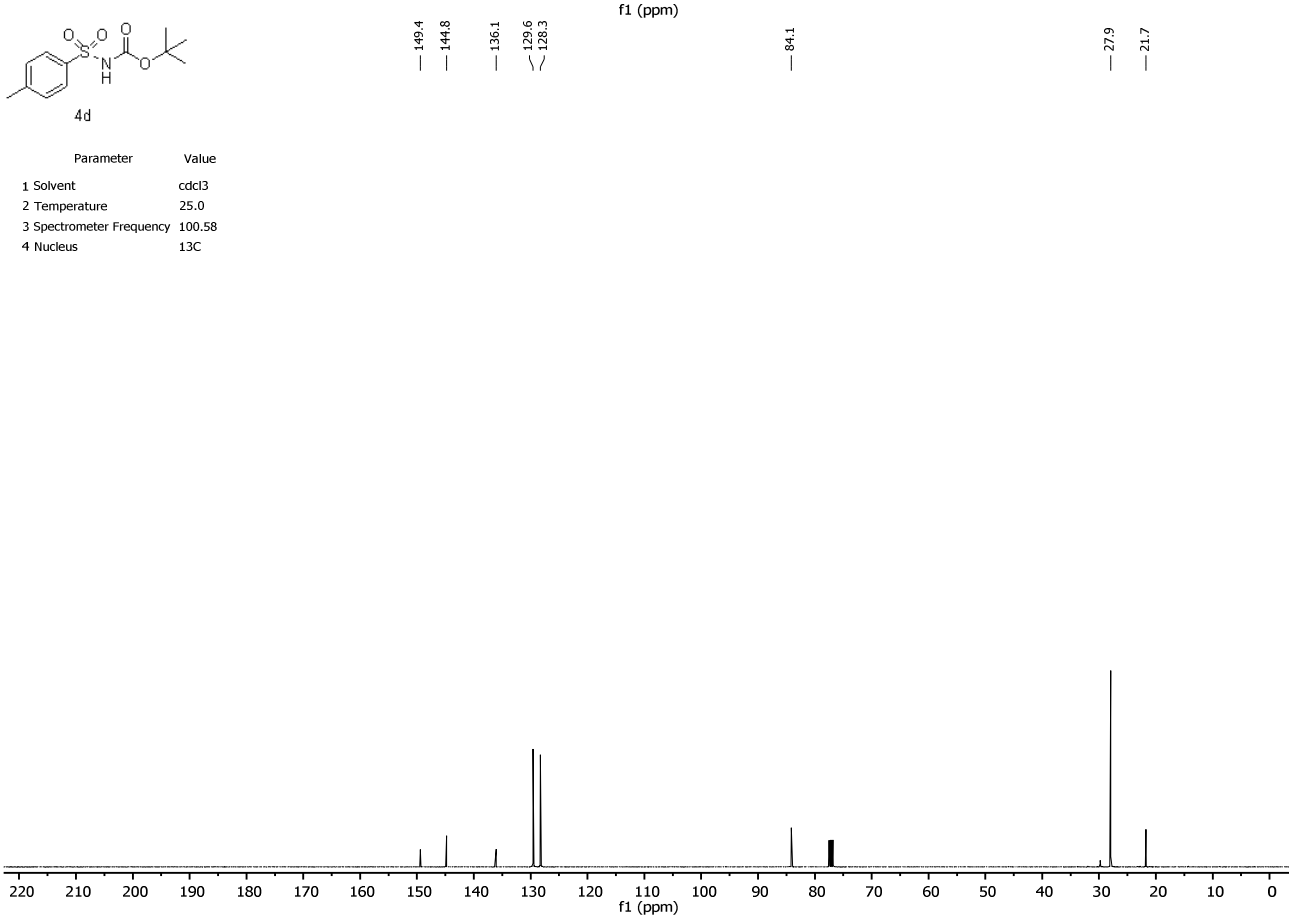
Isopropyl toluenesulfonylcarbamate (4c)



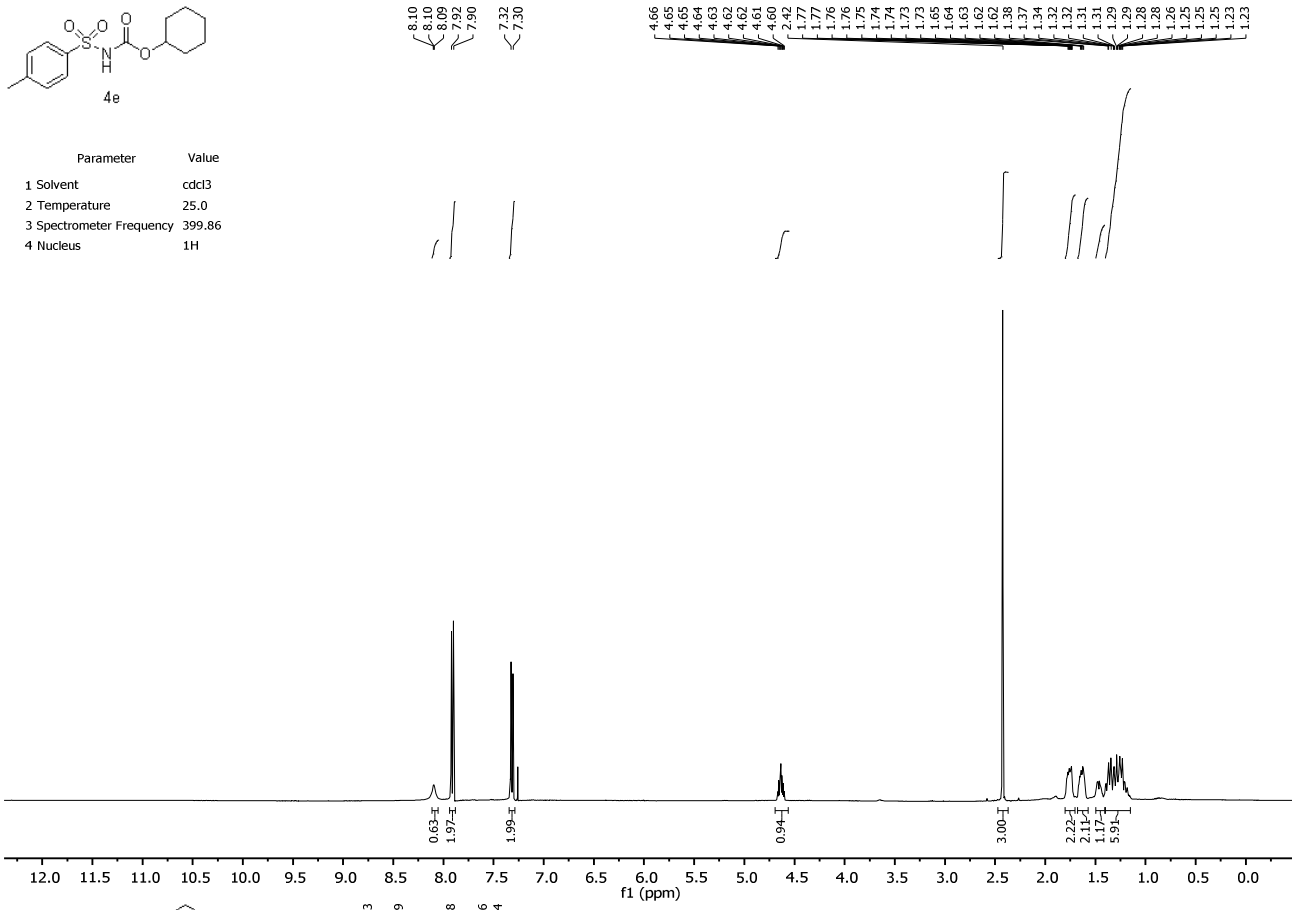


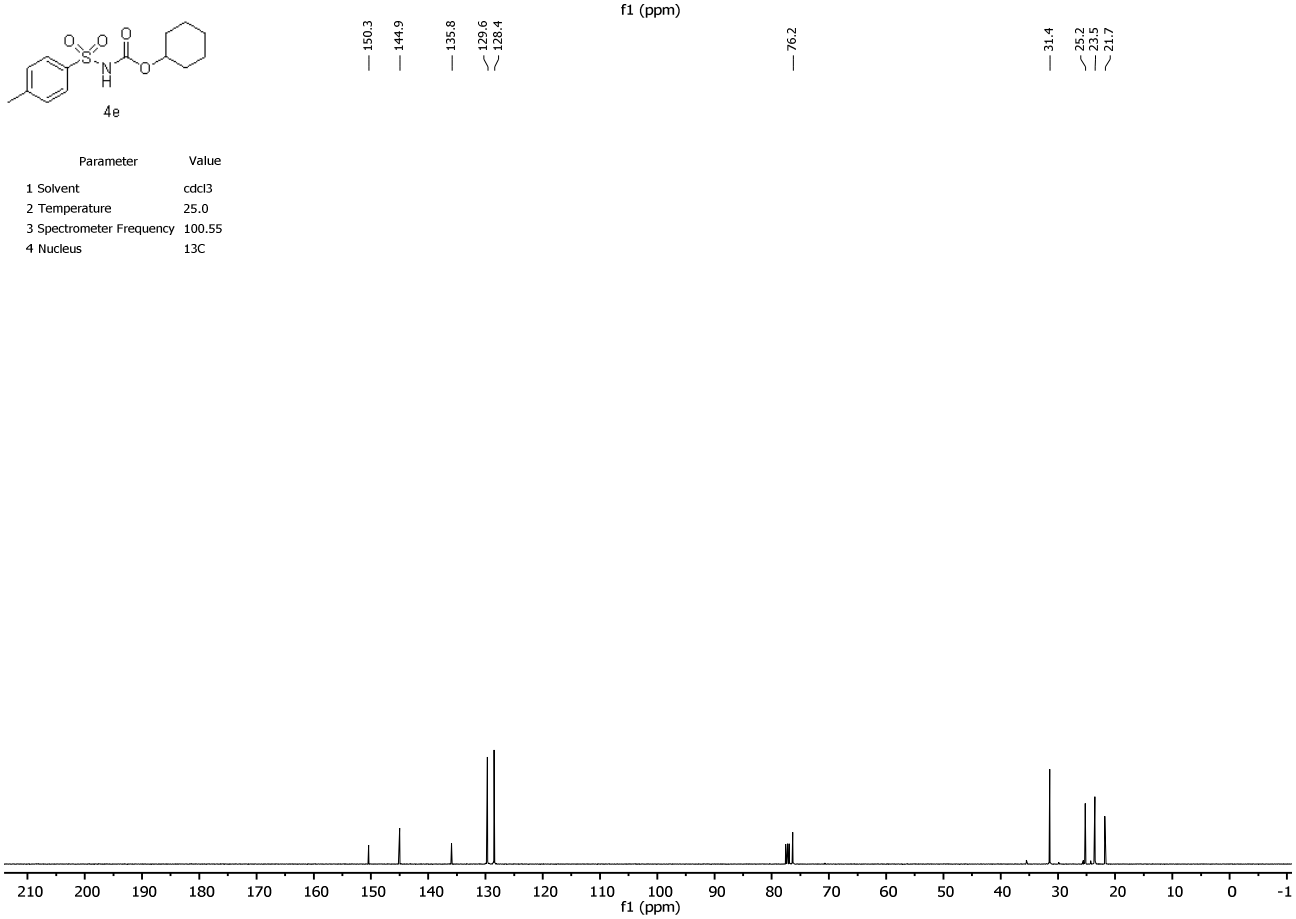
tert-Butyl toluenesulfonylcarbamate (4d)



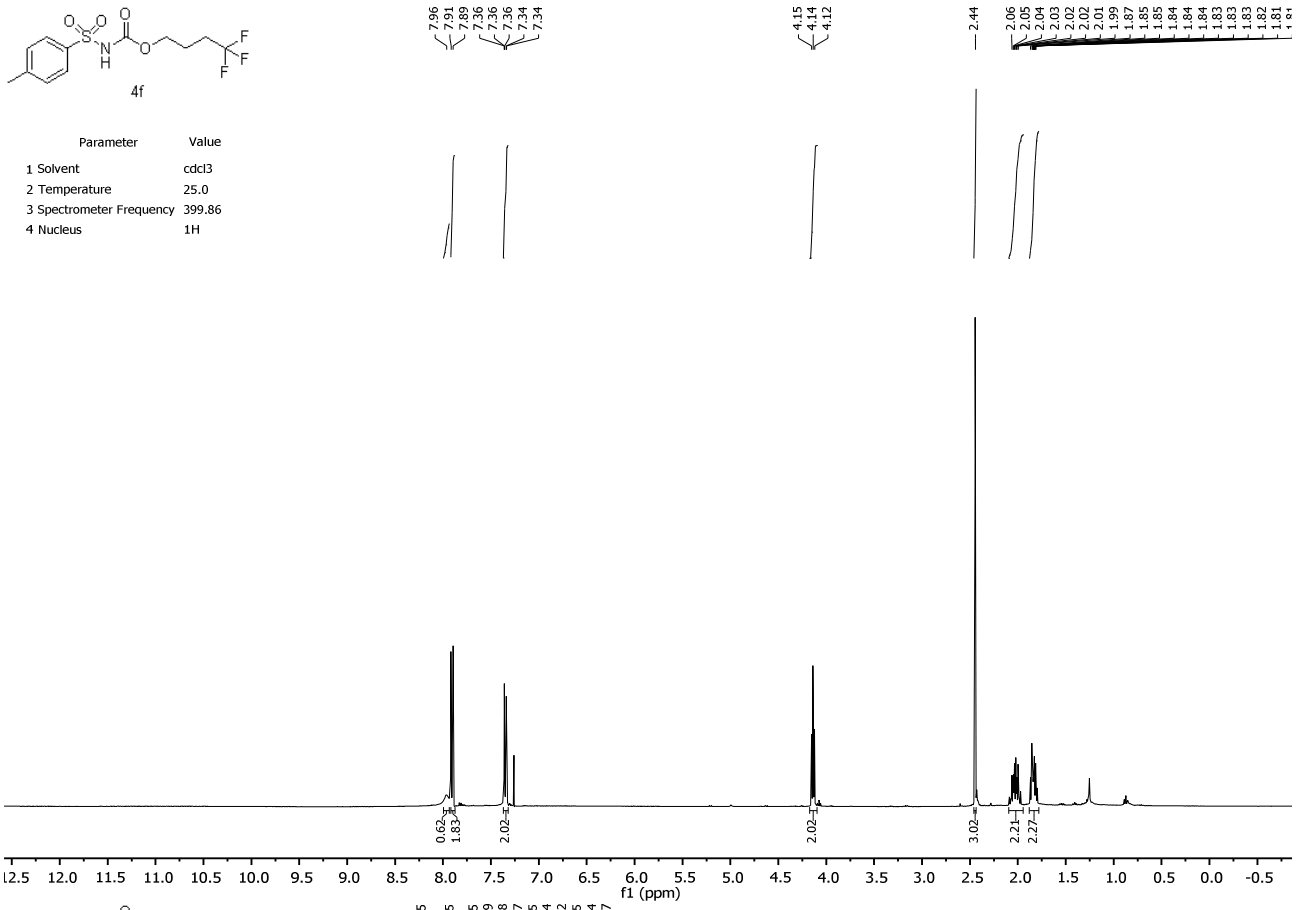


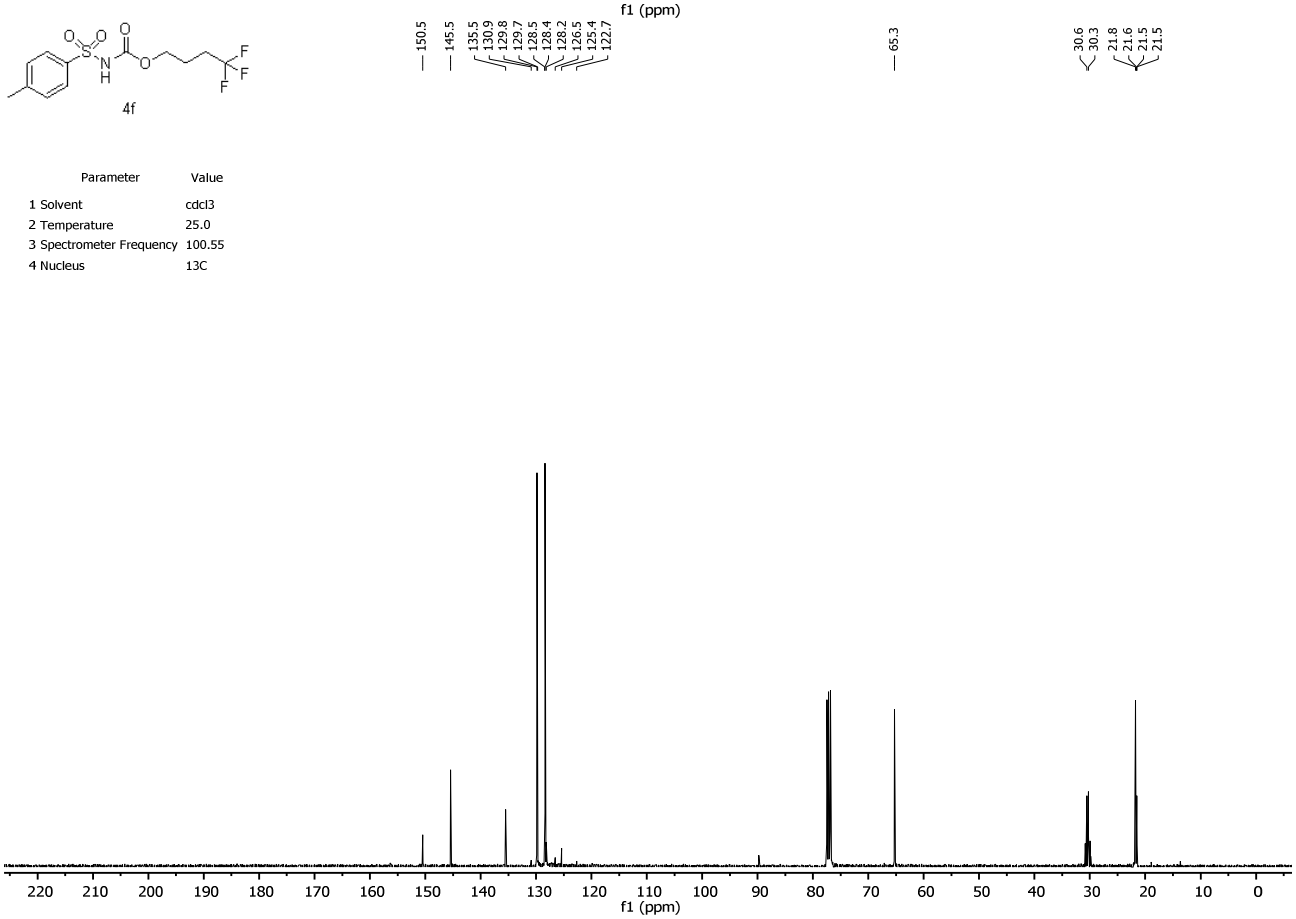
Cyclohexyl toluenesulfonylcarbamate (4e)





4,4,4-trifluorobutyl toluenesulfonylcarbamate (4f)

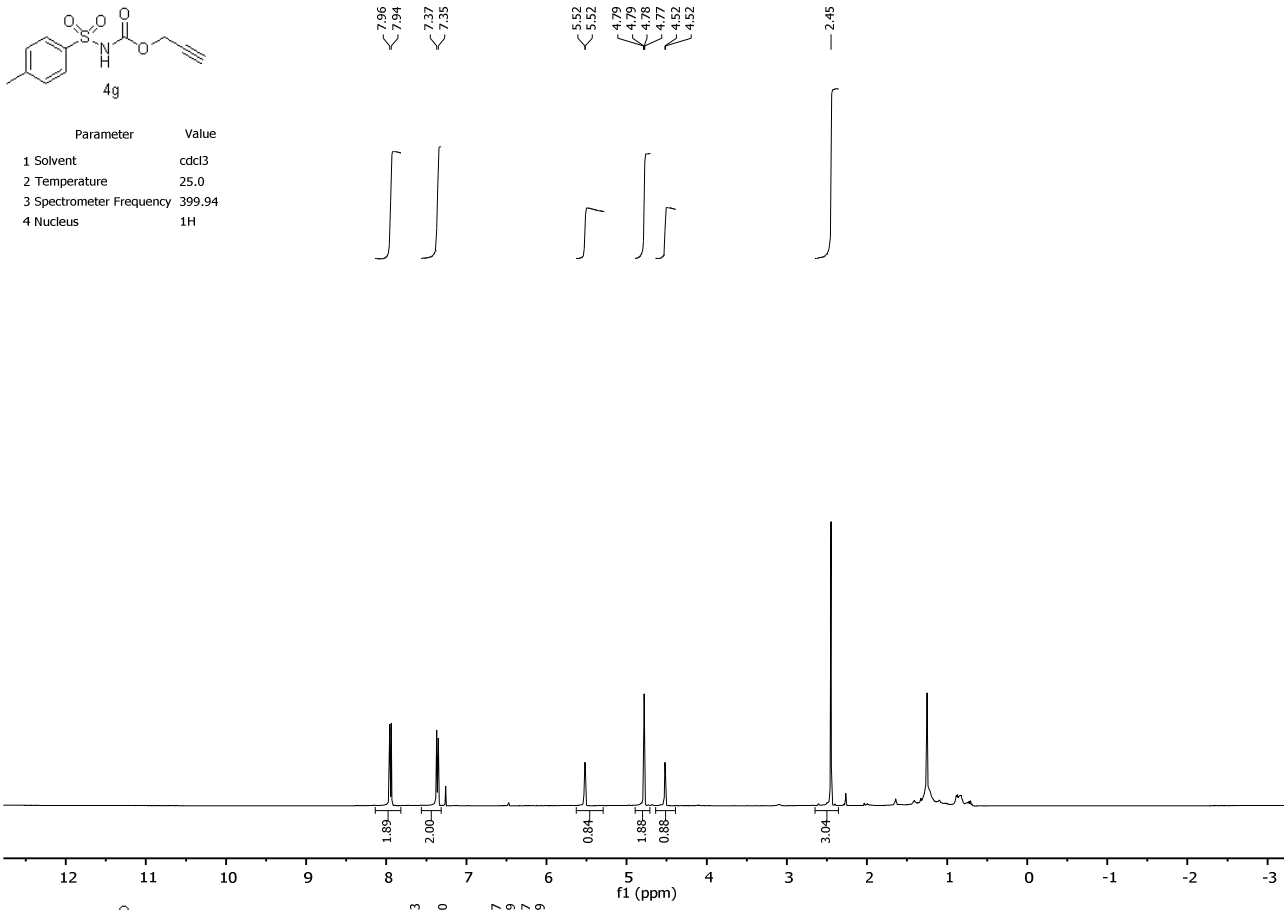




Prop-2-yn-1-yl toluenesulfonylcarbamate (4g)

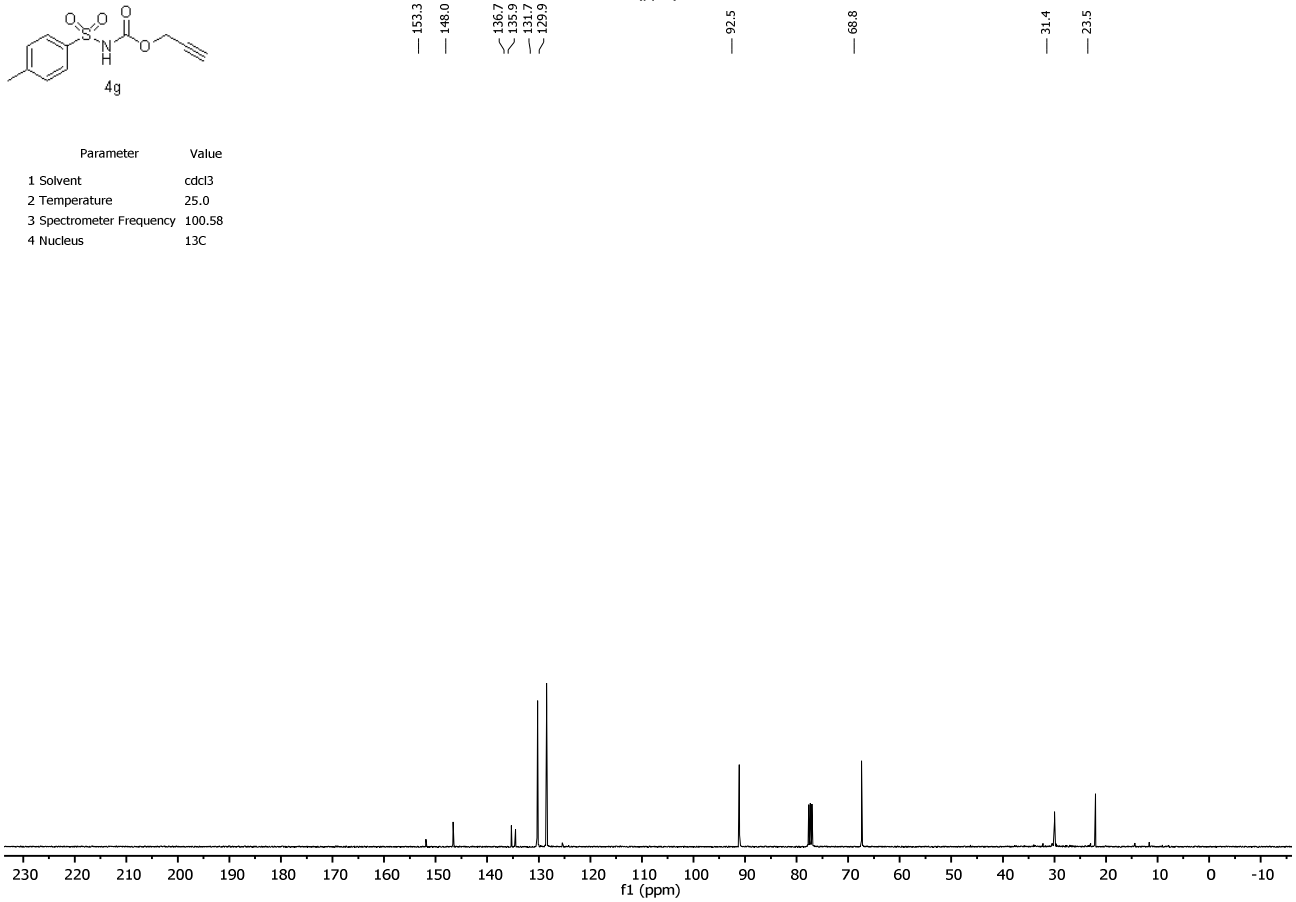
4g

Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	399.94
4 Nucleus	1H



4g

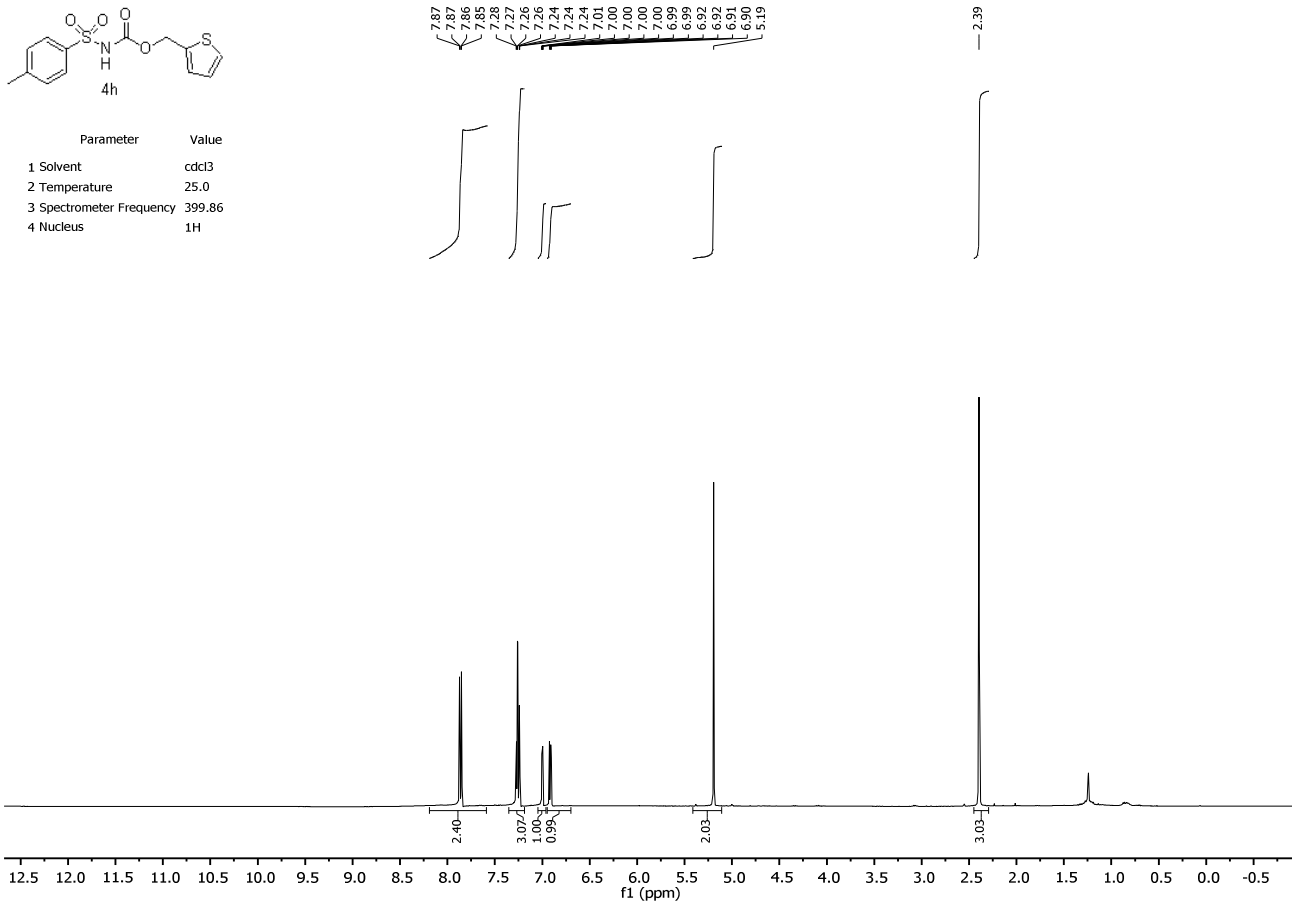
Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	100.58
4 Nucleus	13C



Thiophen-2-ylmethyl toluenesulfonylcarbamate (4h)

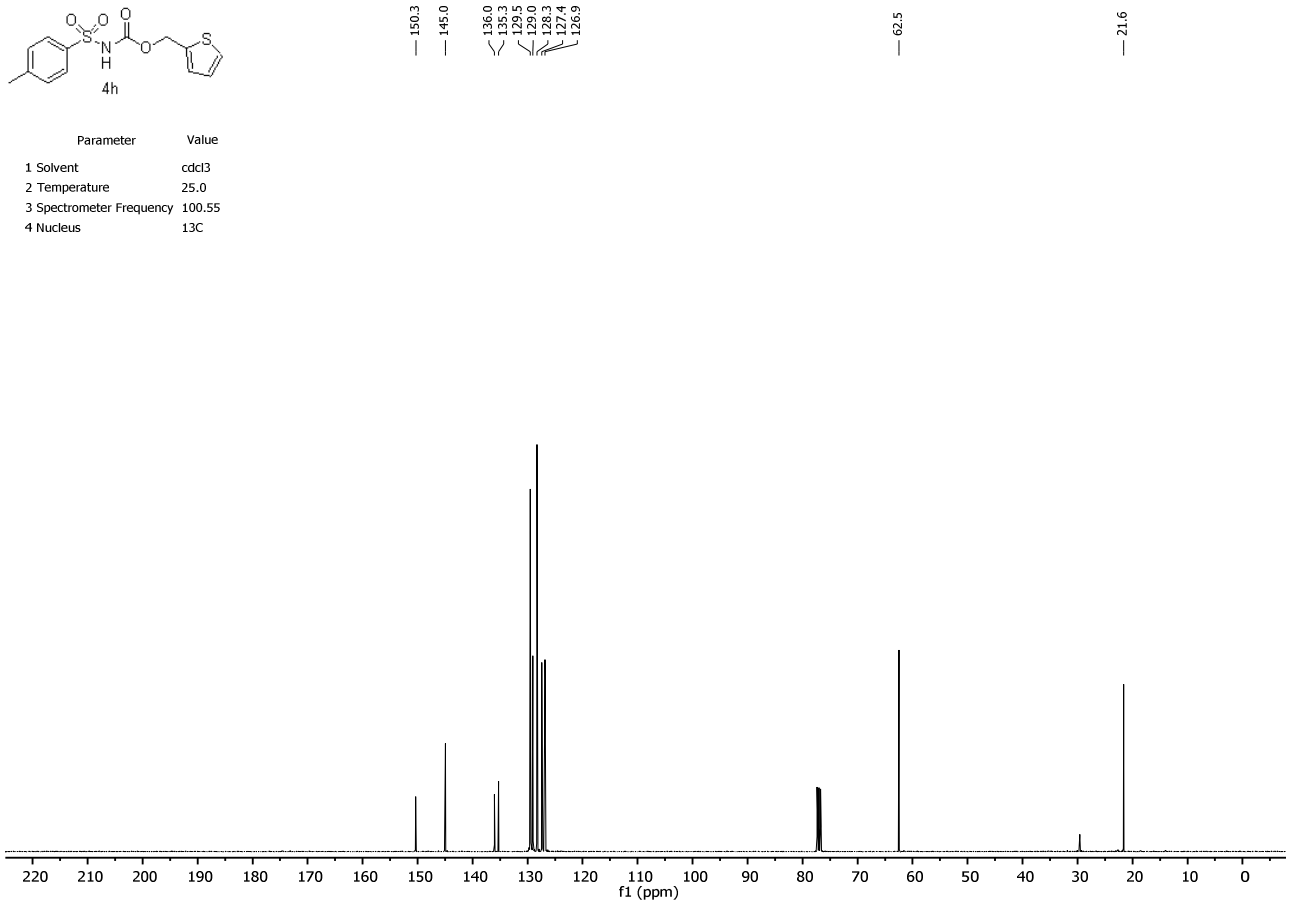
4h

Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	399.86
4 Nucleus	1H

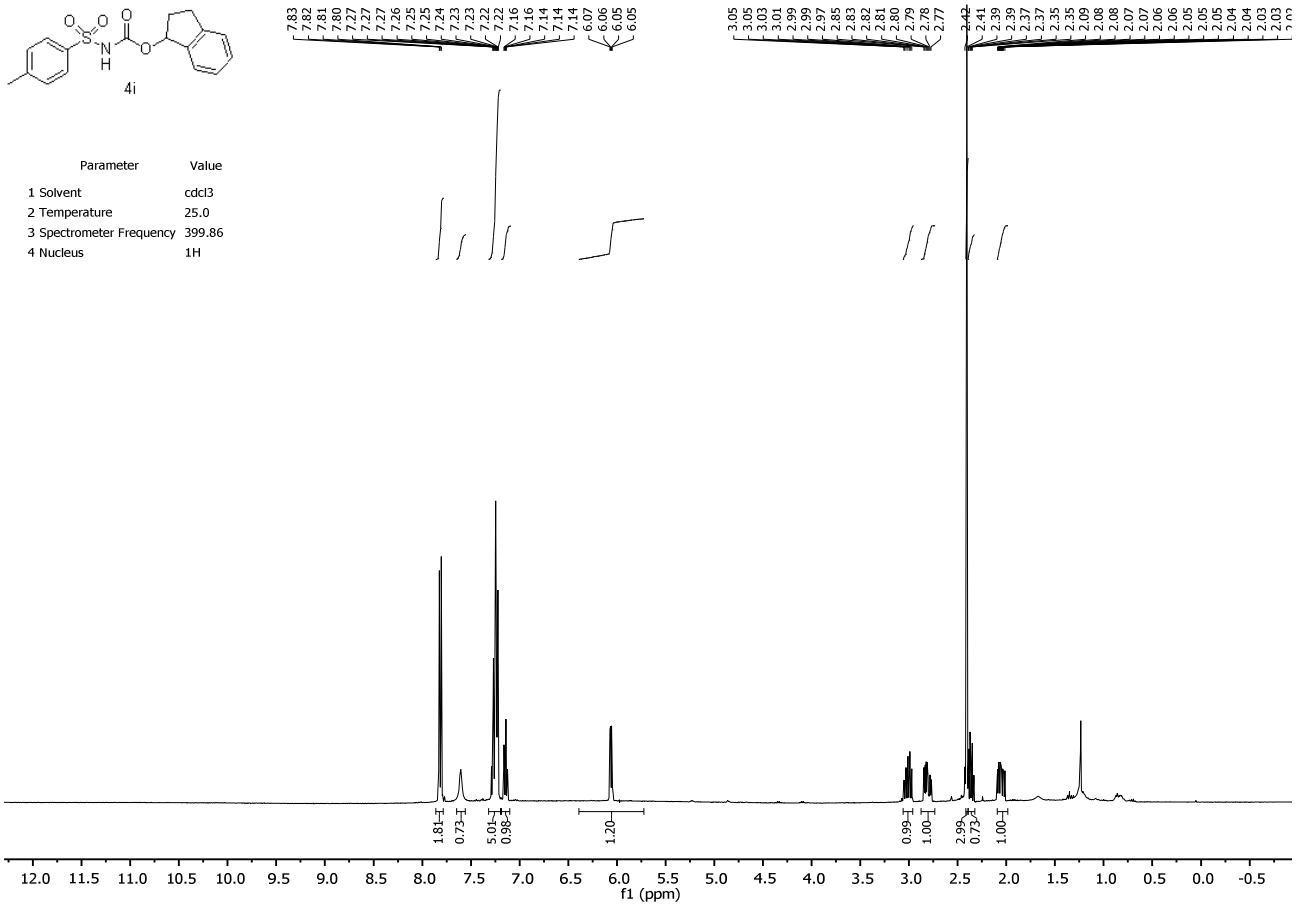


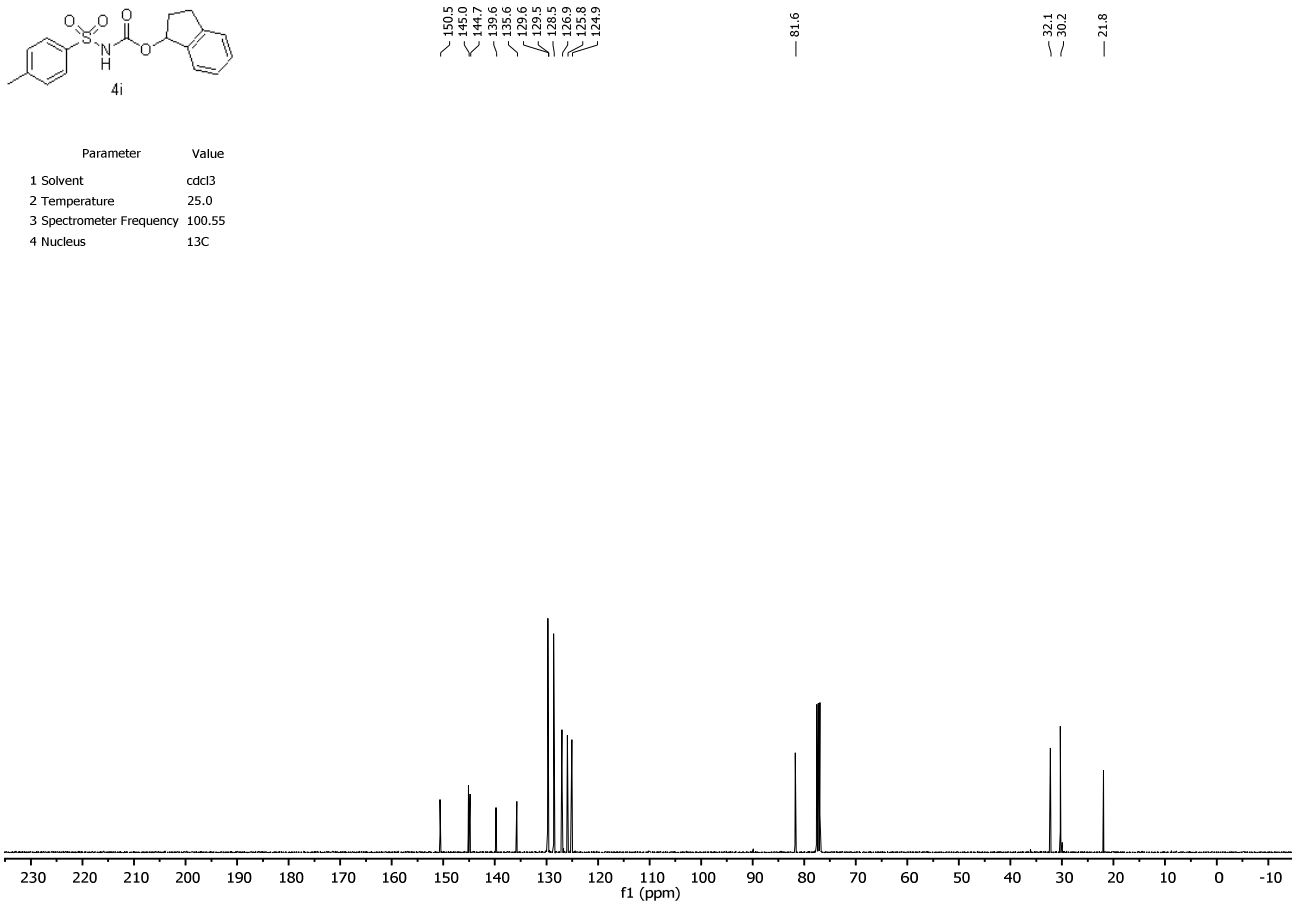
4h

Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	100.55
4 Nucleus	13C

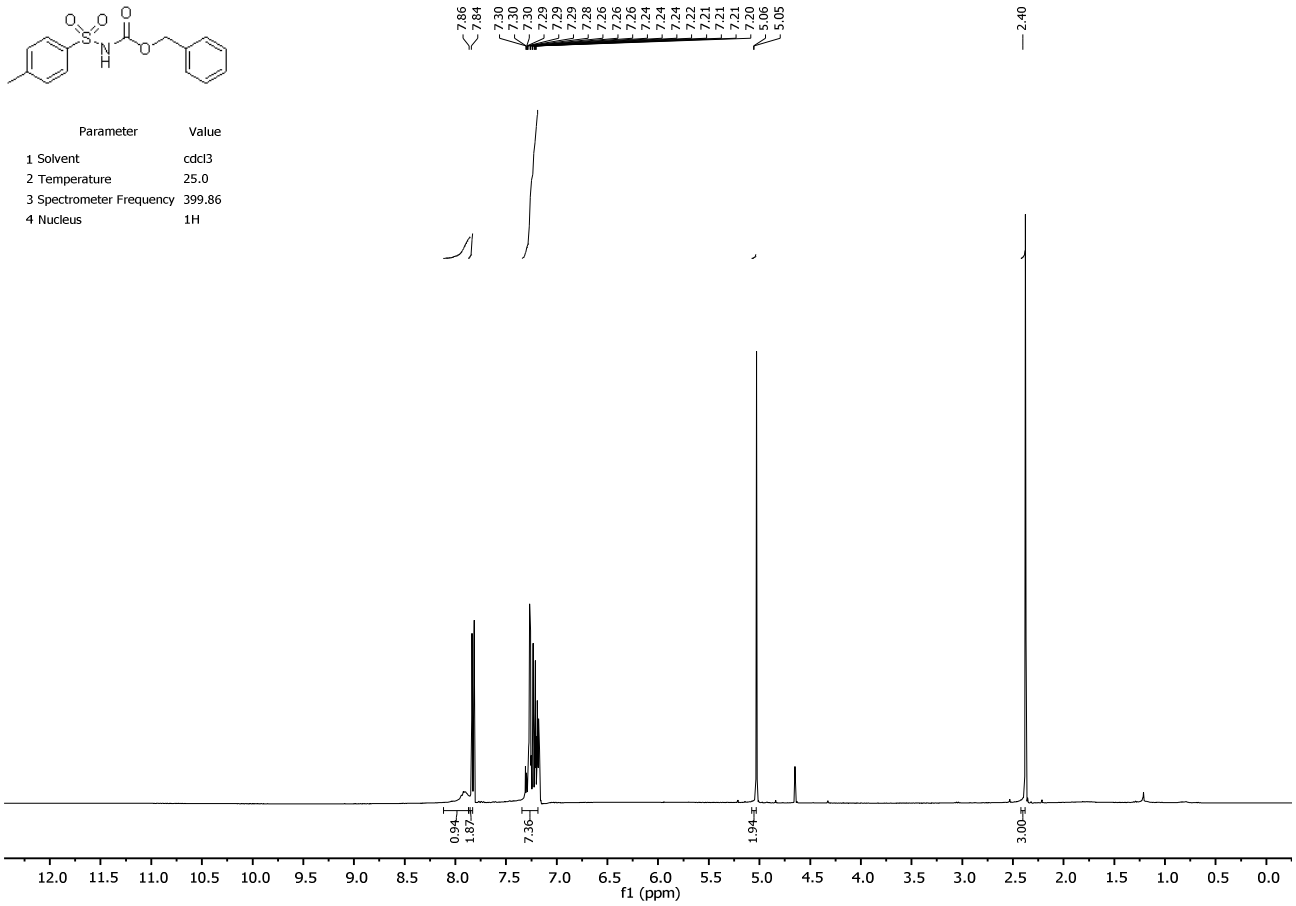


2,3-Dihydro-1*H*-inden-1-yl toluenesulfonylcarbamate (4i)

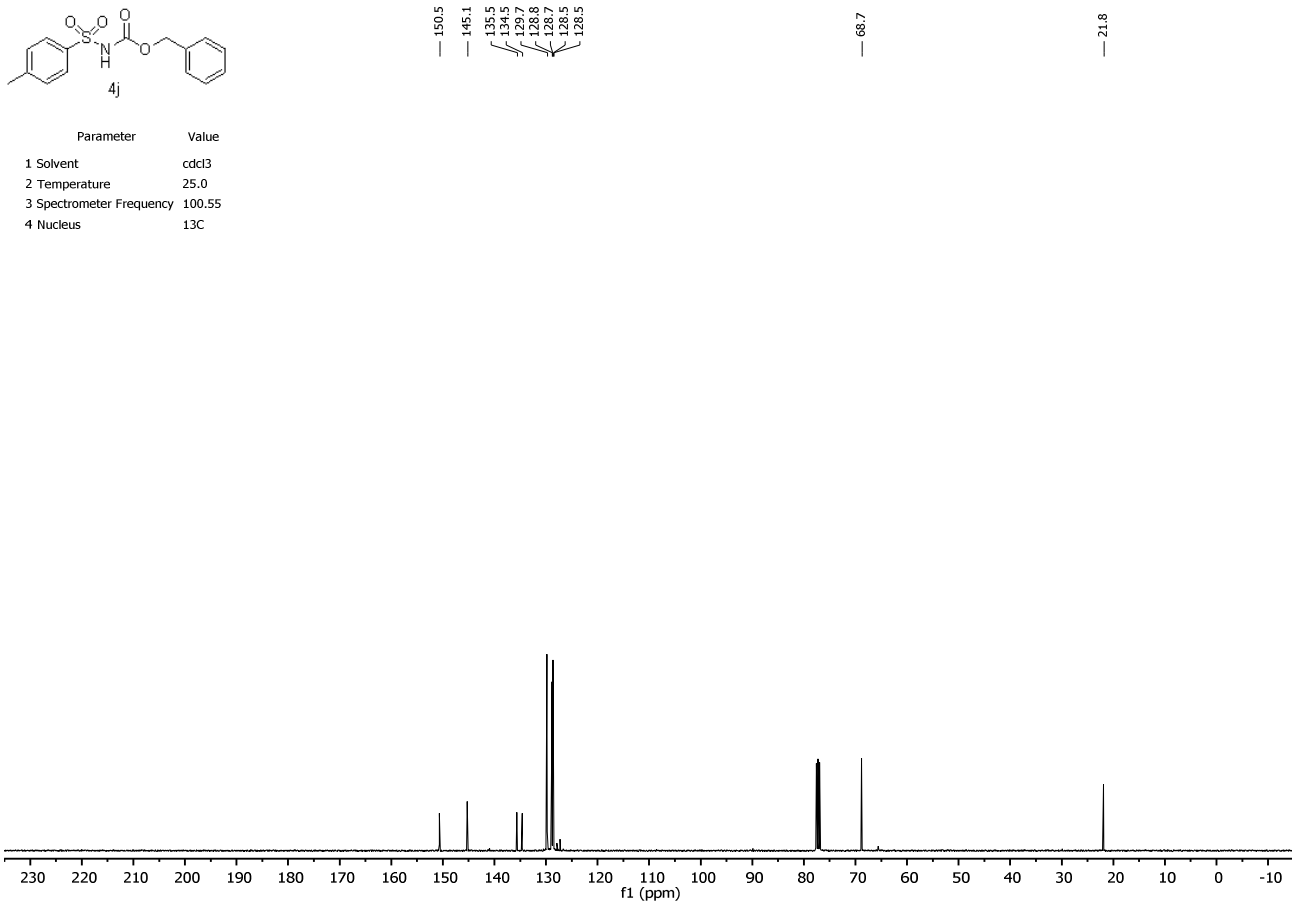




Benzyl toluenesulfonylcarbamate (4j)



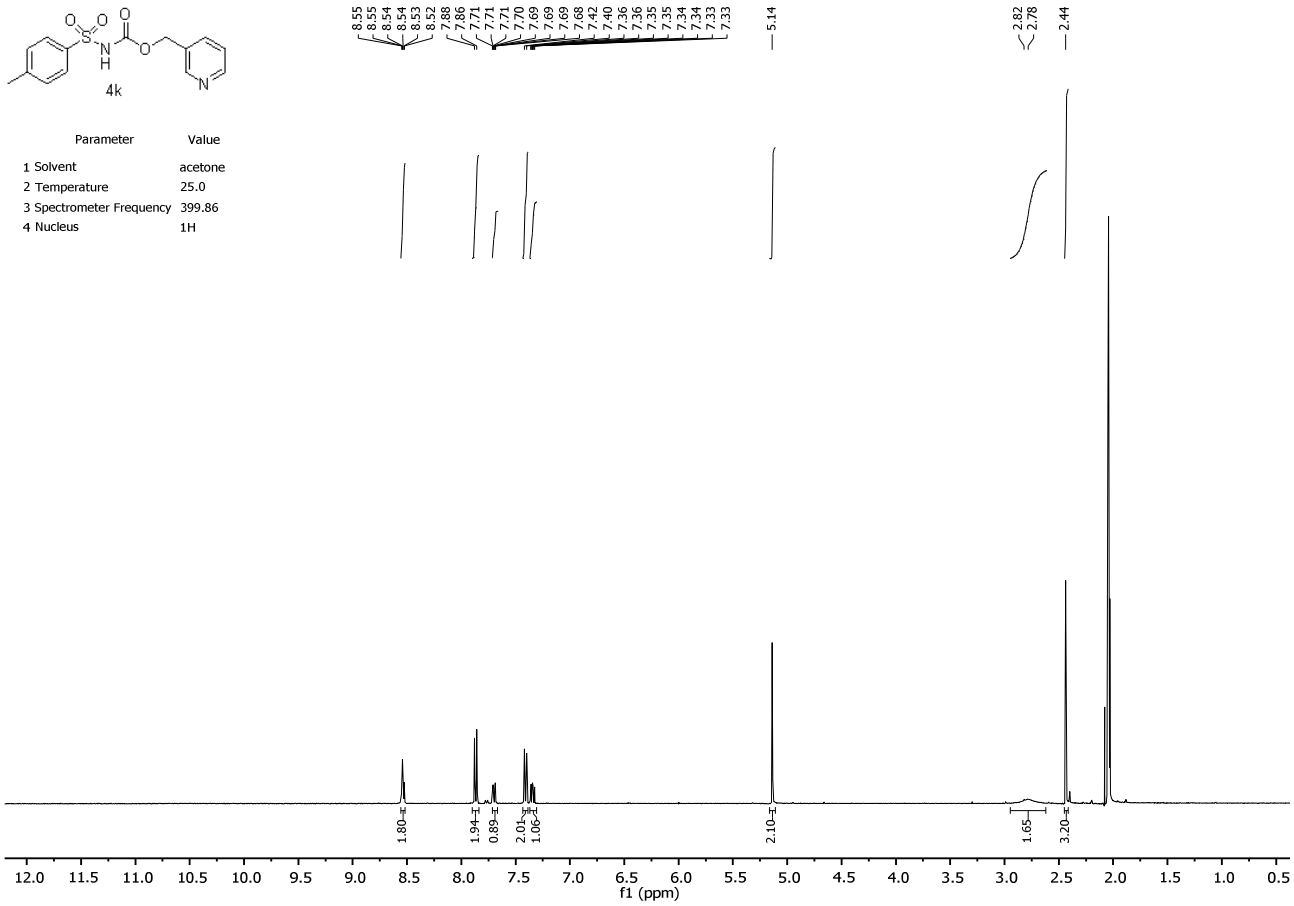
Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	399.86
4 Nucleus	1H

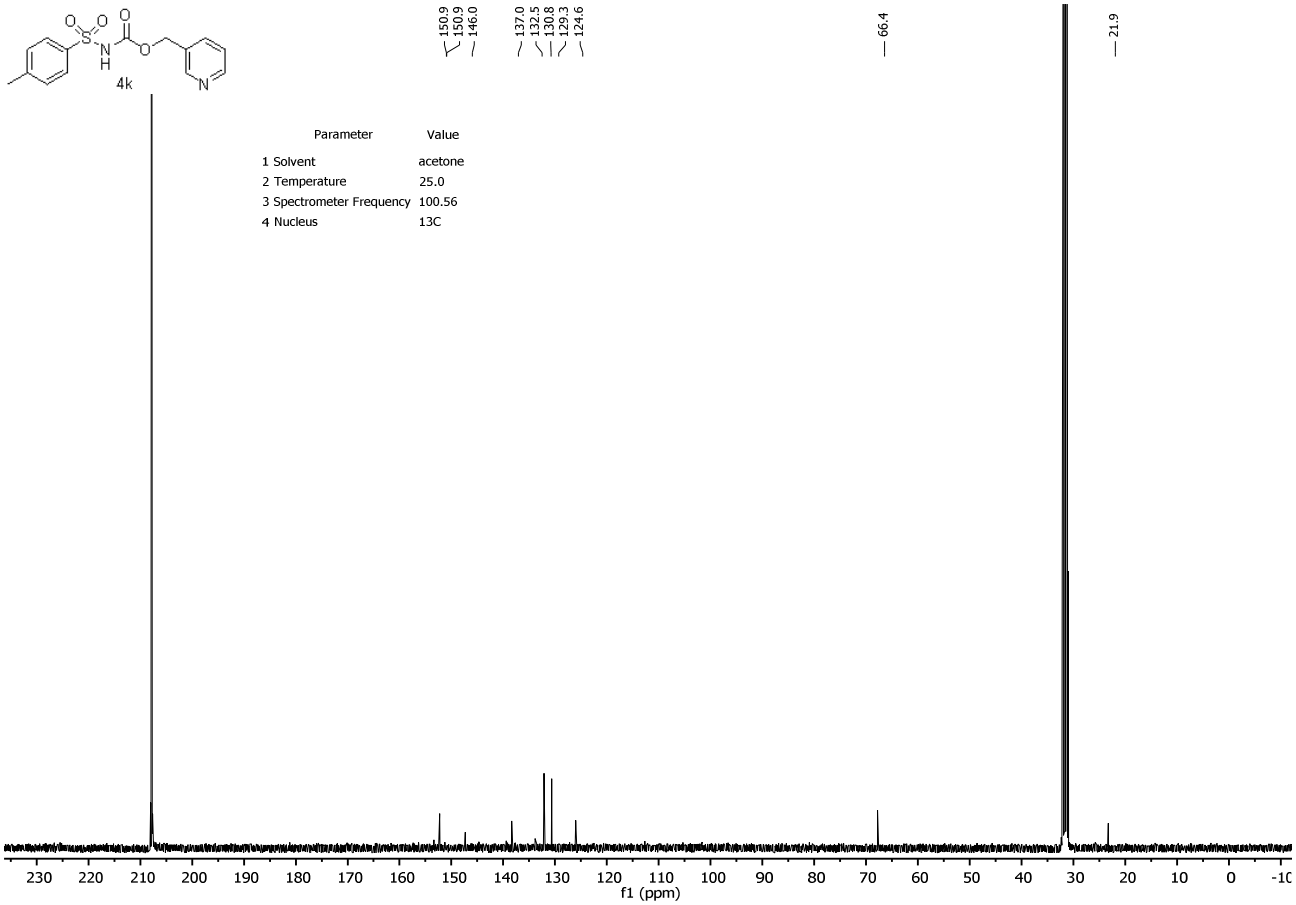


4j

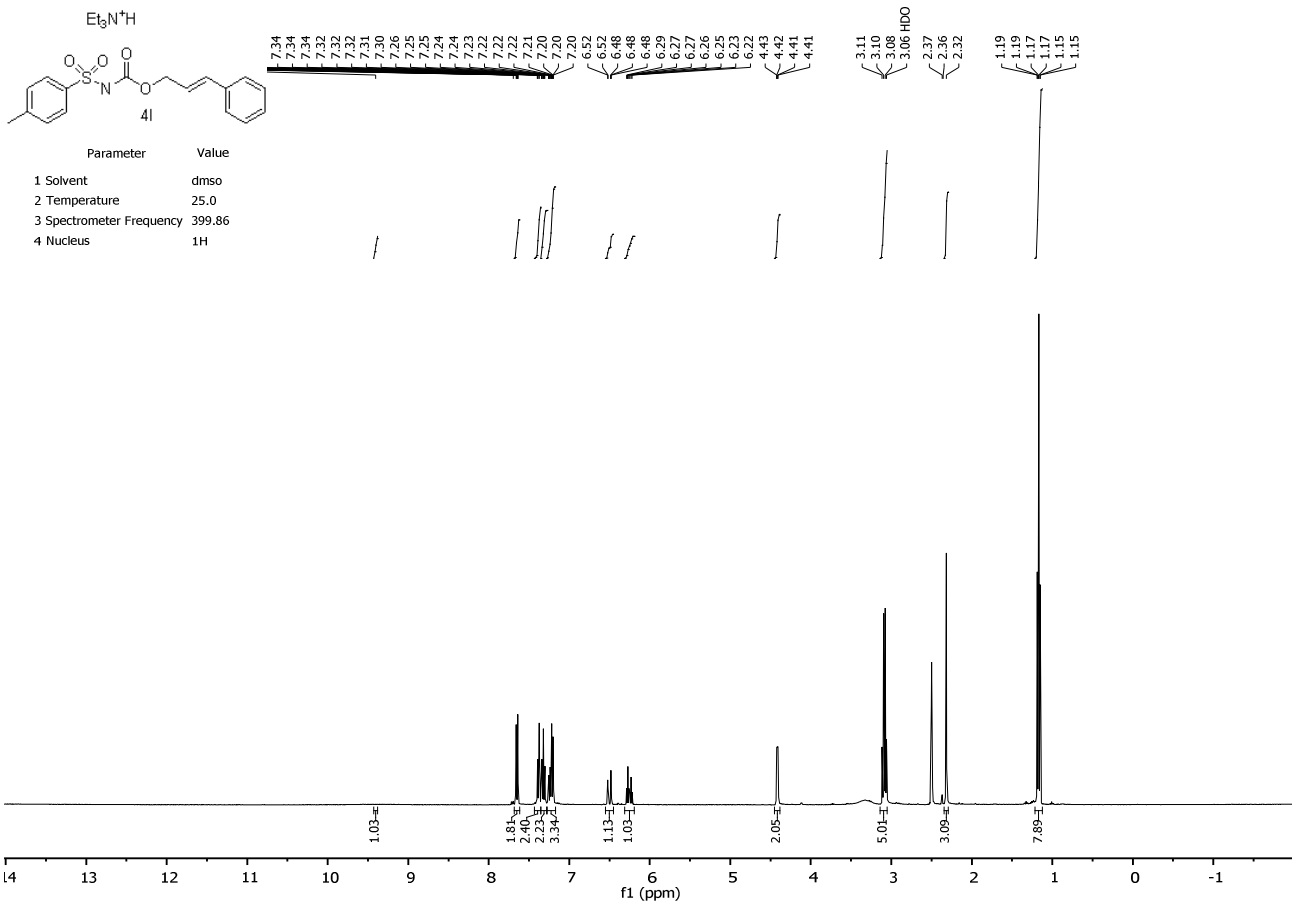
Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	100.55
4 Nucleus	13C

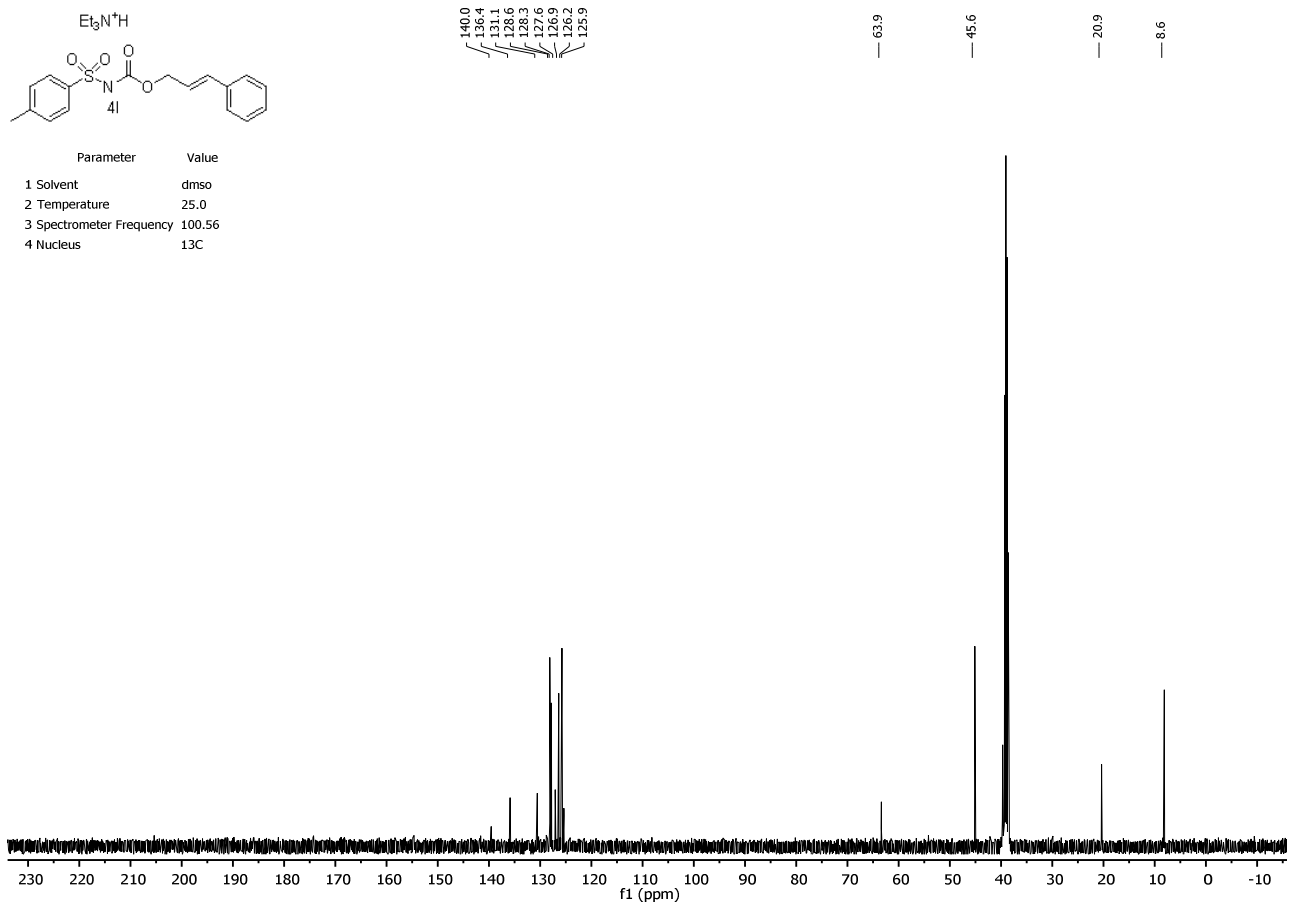
Pyridin-3-ylmethyl toluenesulfonylcarbamate (4k)



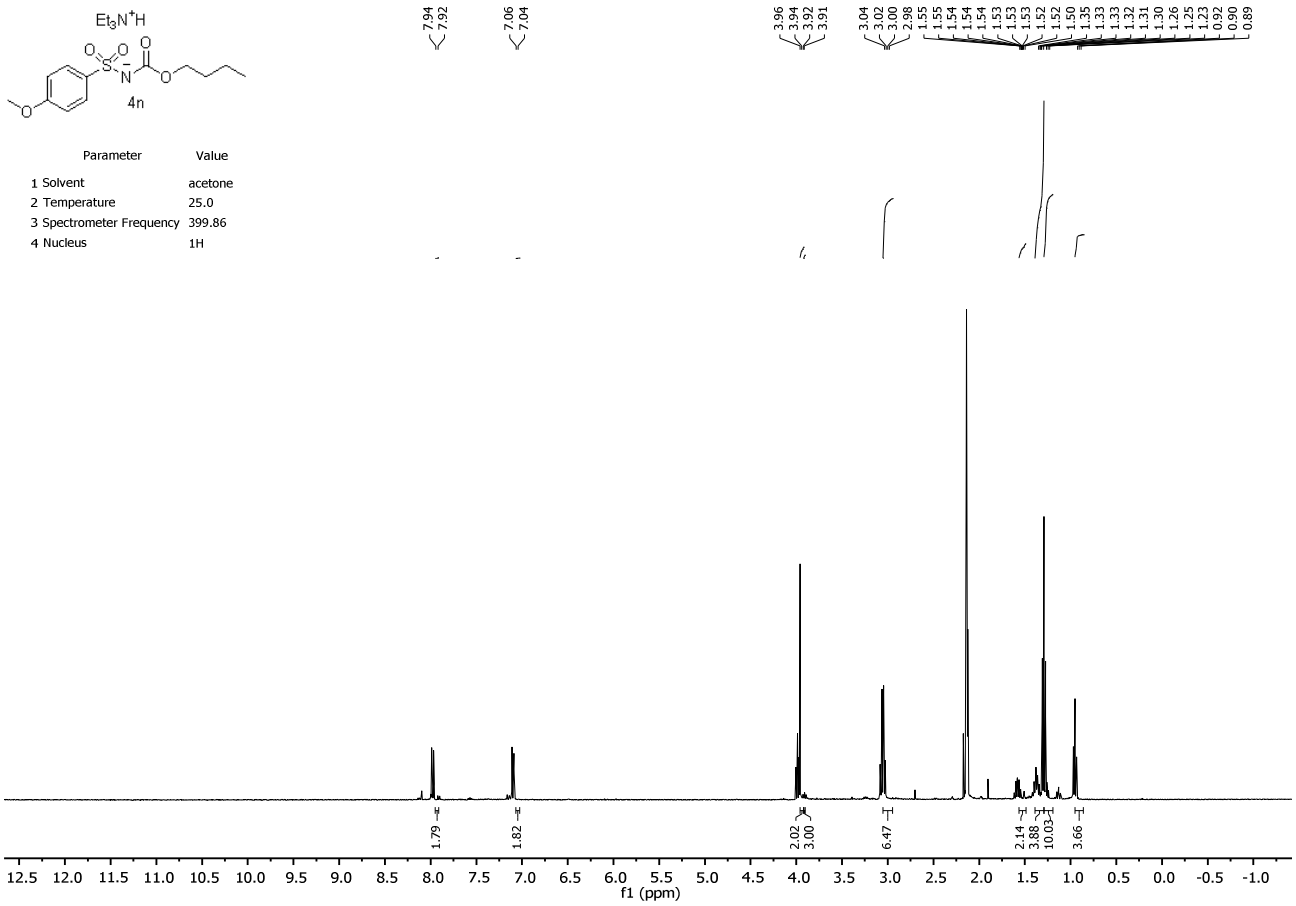


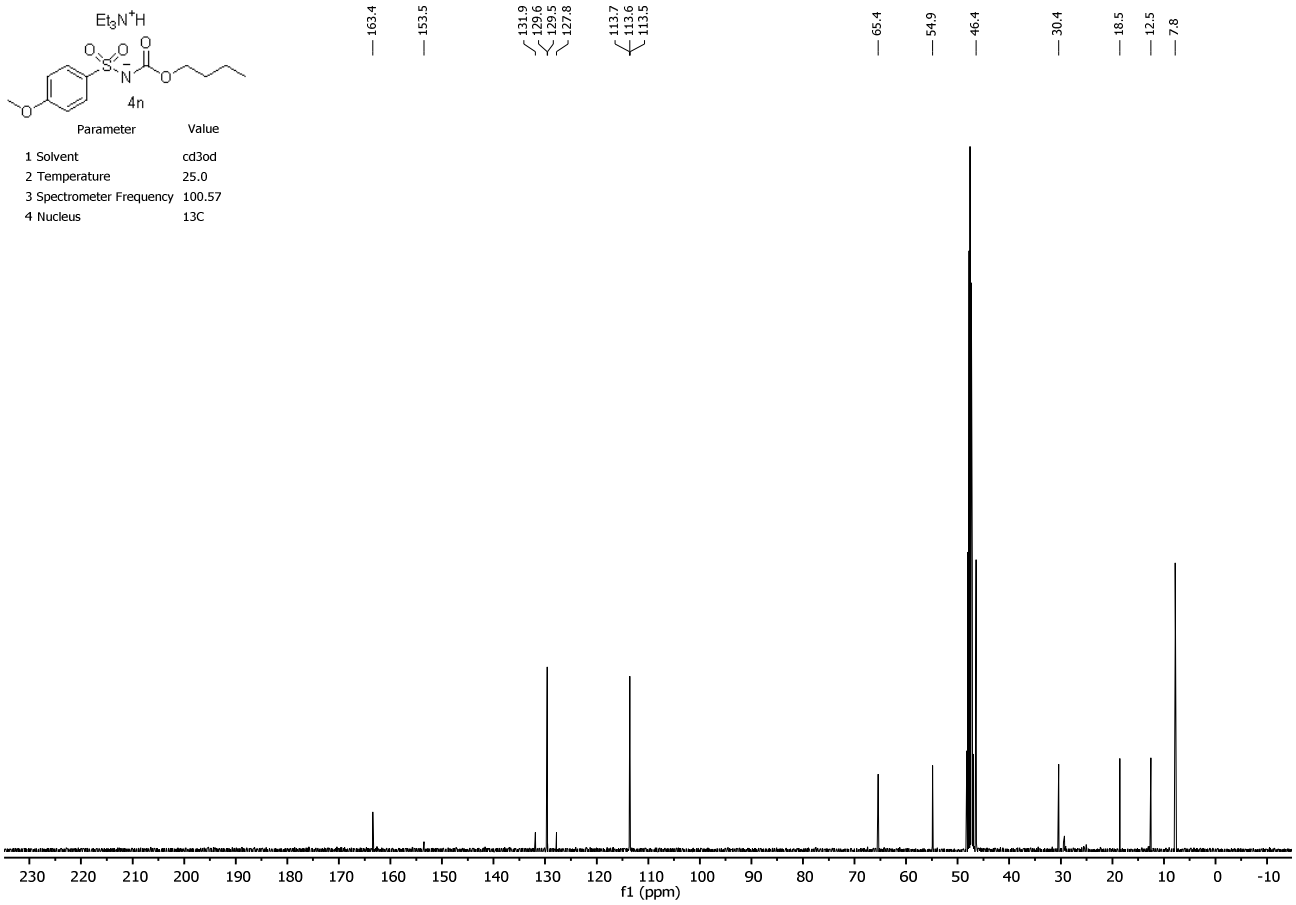
Triethylammonium ((cinnamyloxy)carbonyl)(tosyl)amide (4l)





Triethylammonium (butoxycarbonyl)((4-methoxyphenyl)sulfonyl)amide (4n)

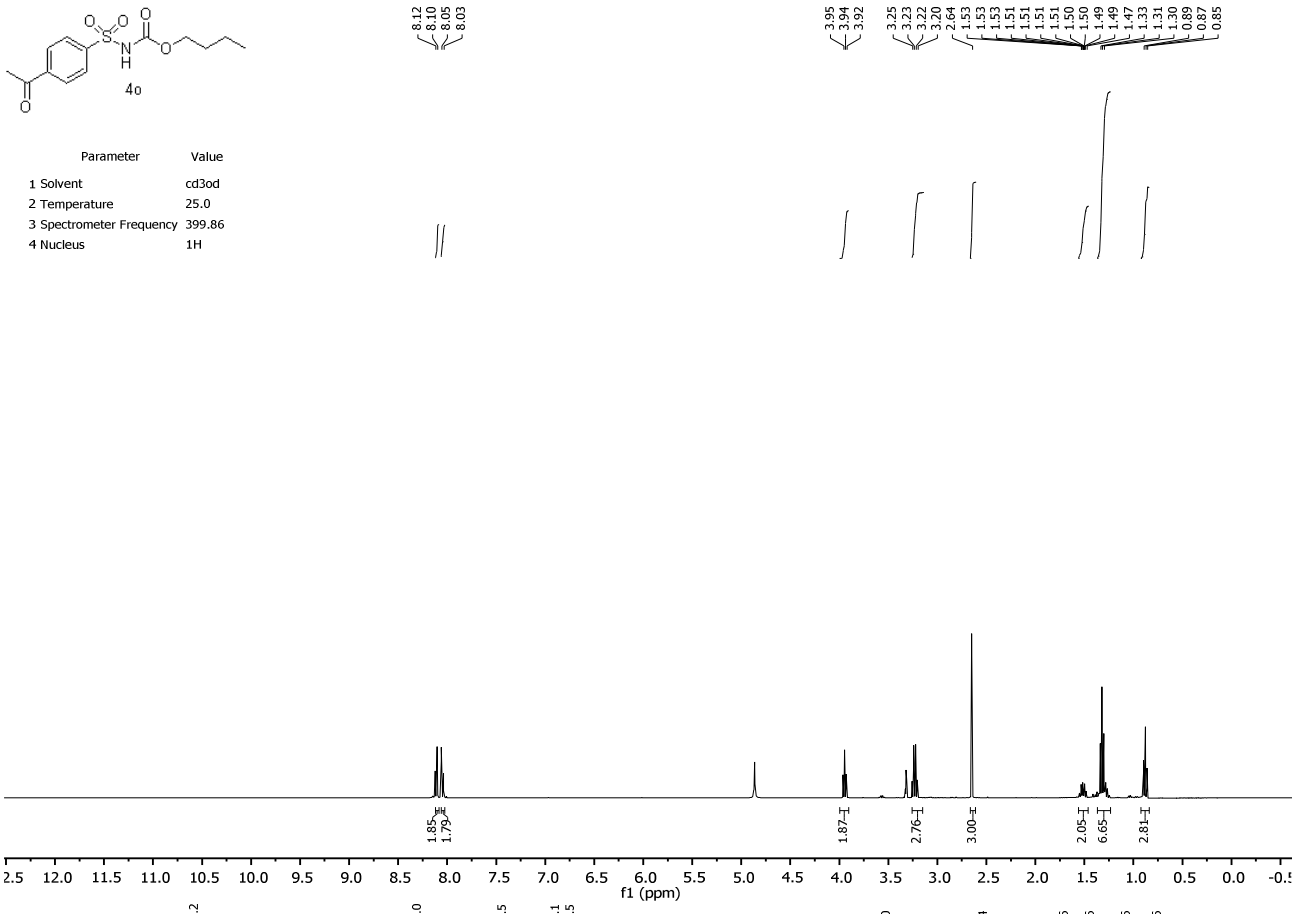


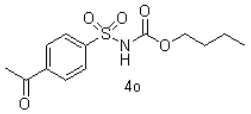


Butyl ((4-acetylphenyl)sulfonyl)carbamate (4o)

4o

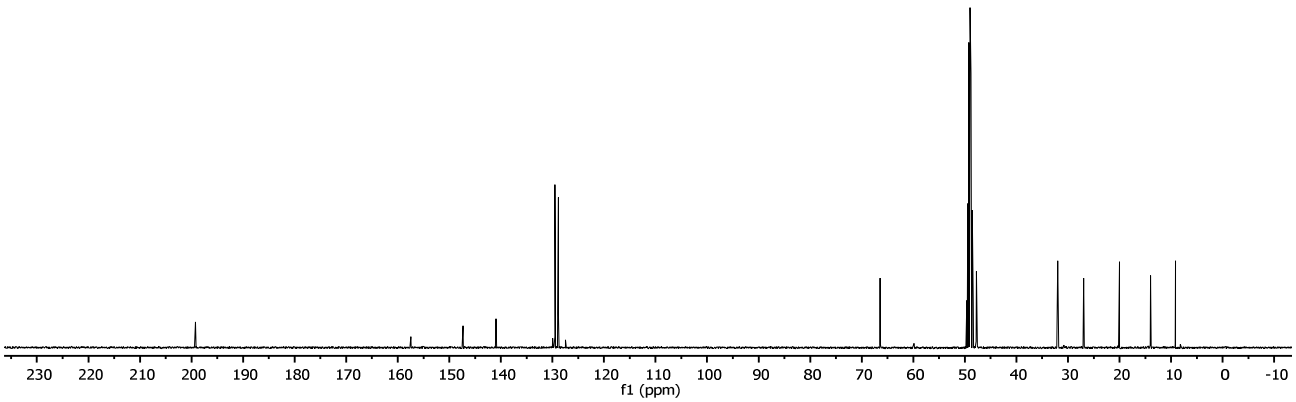
Parameter	Value
1 Solvent	cd3od
2 Temperature	25.0
3 Spectrometer Frequency	399.86
4 Nucleus	1H





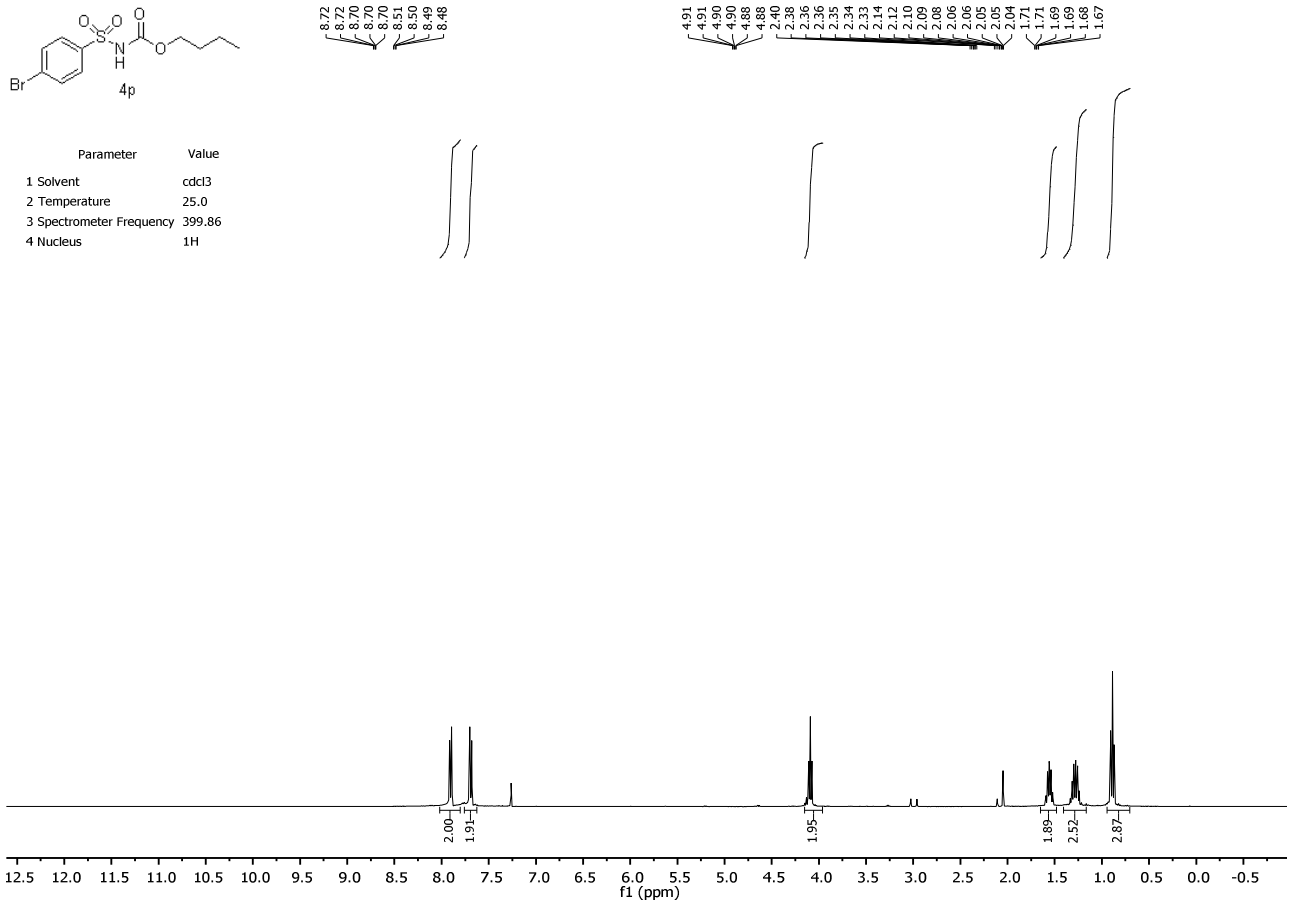
4o

Parameter	Value
1 Solvent	cd3od
2 Temperature	25.0
3 Spectrometer Frequency	100.56
4 Nucleus	13C

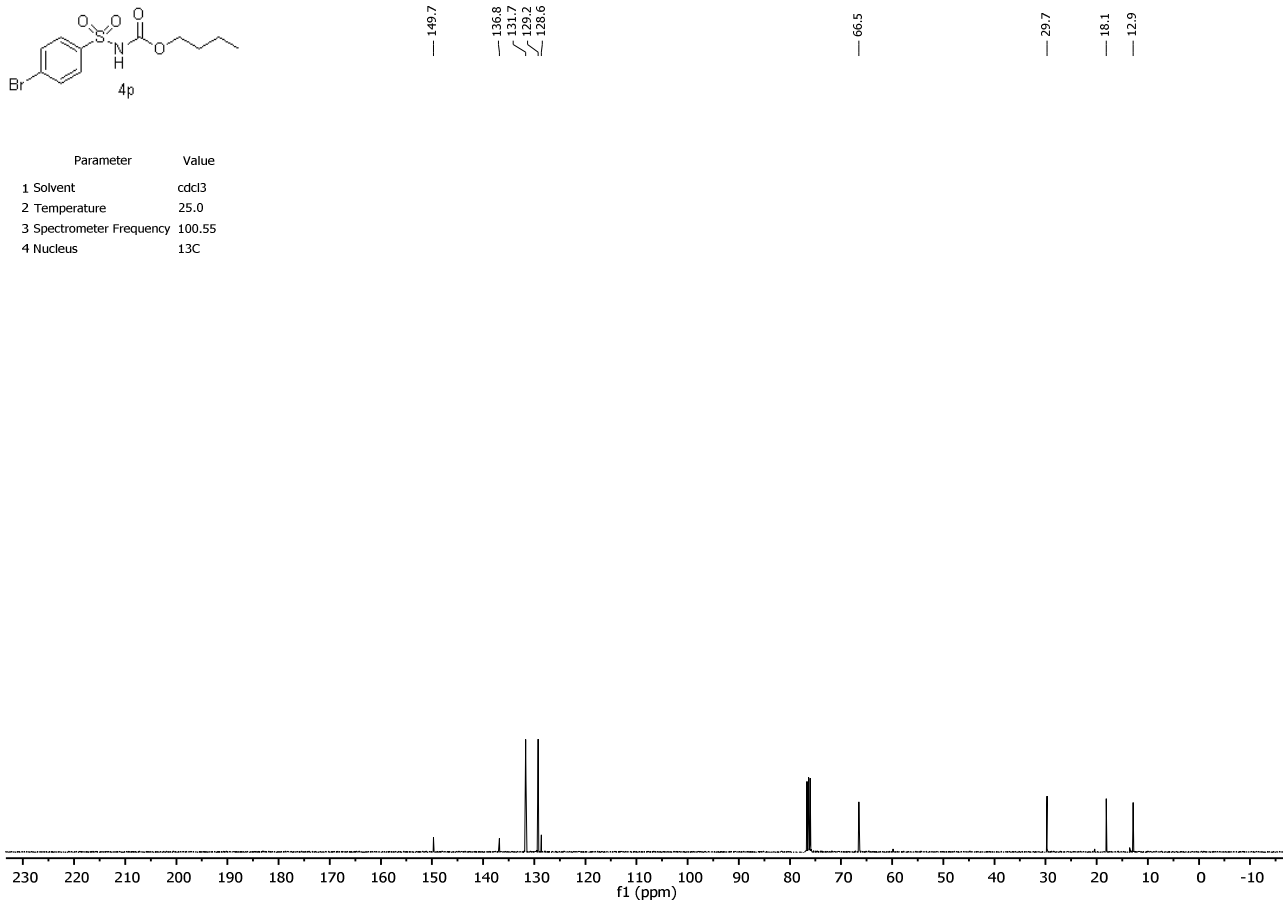


Butyl ((4-bromophenyl)sulfonyl)carbamate (4p)

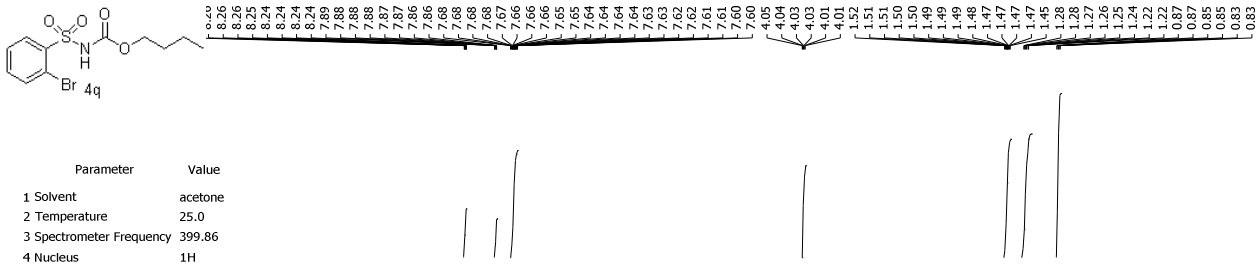
Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	399.86
4 Nucleus	1H

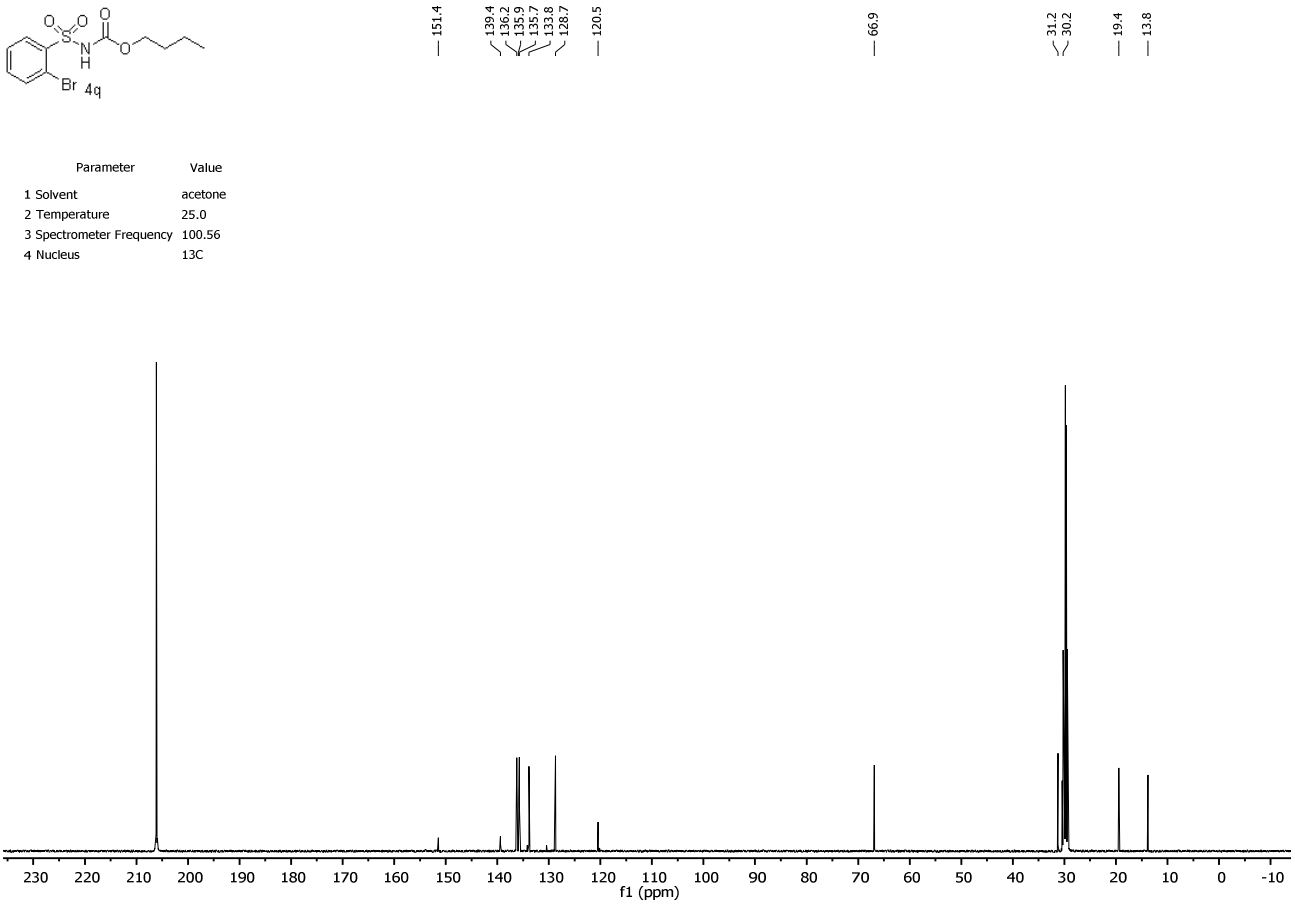


Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	100.55
4 Nucleus	13C

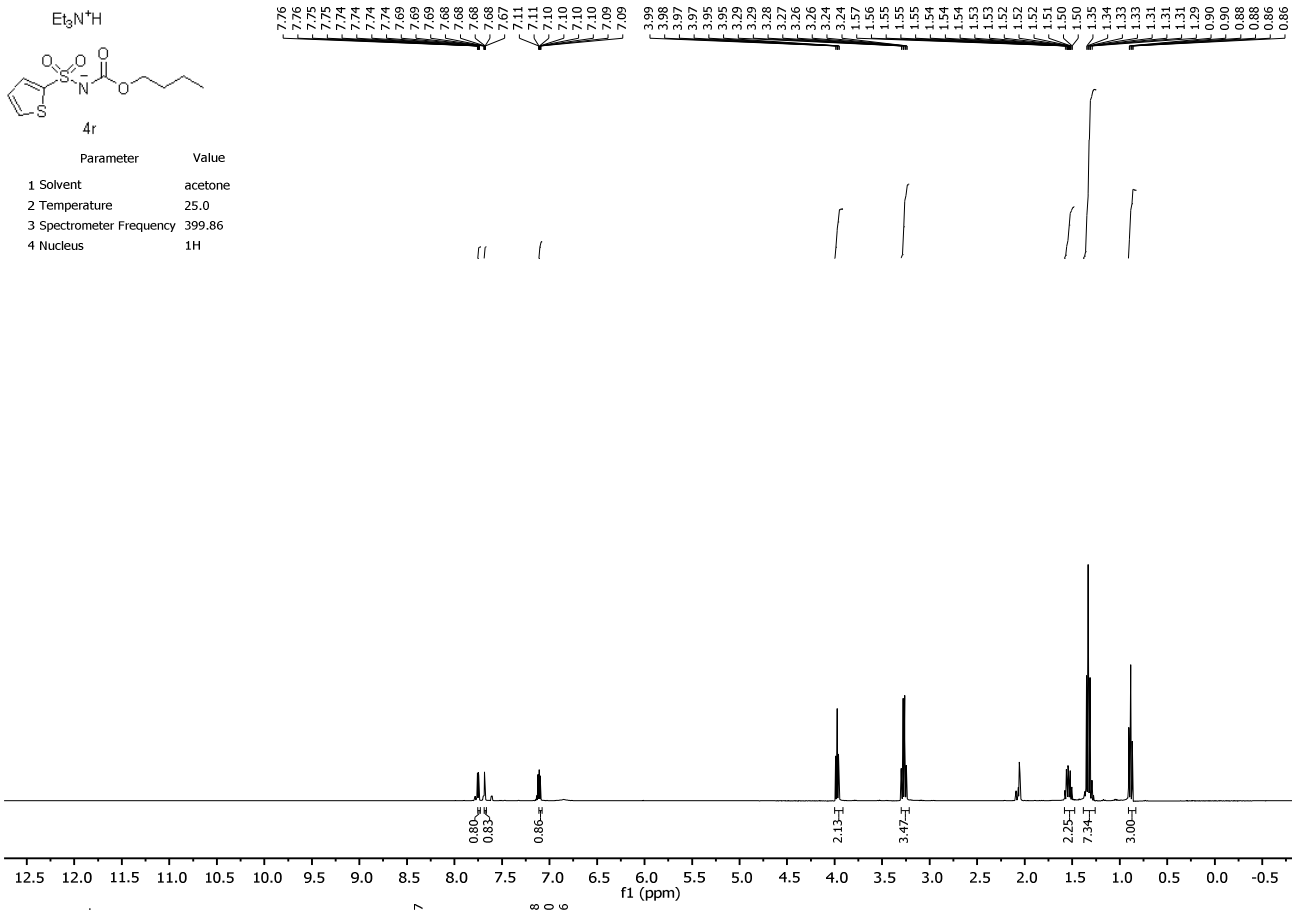


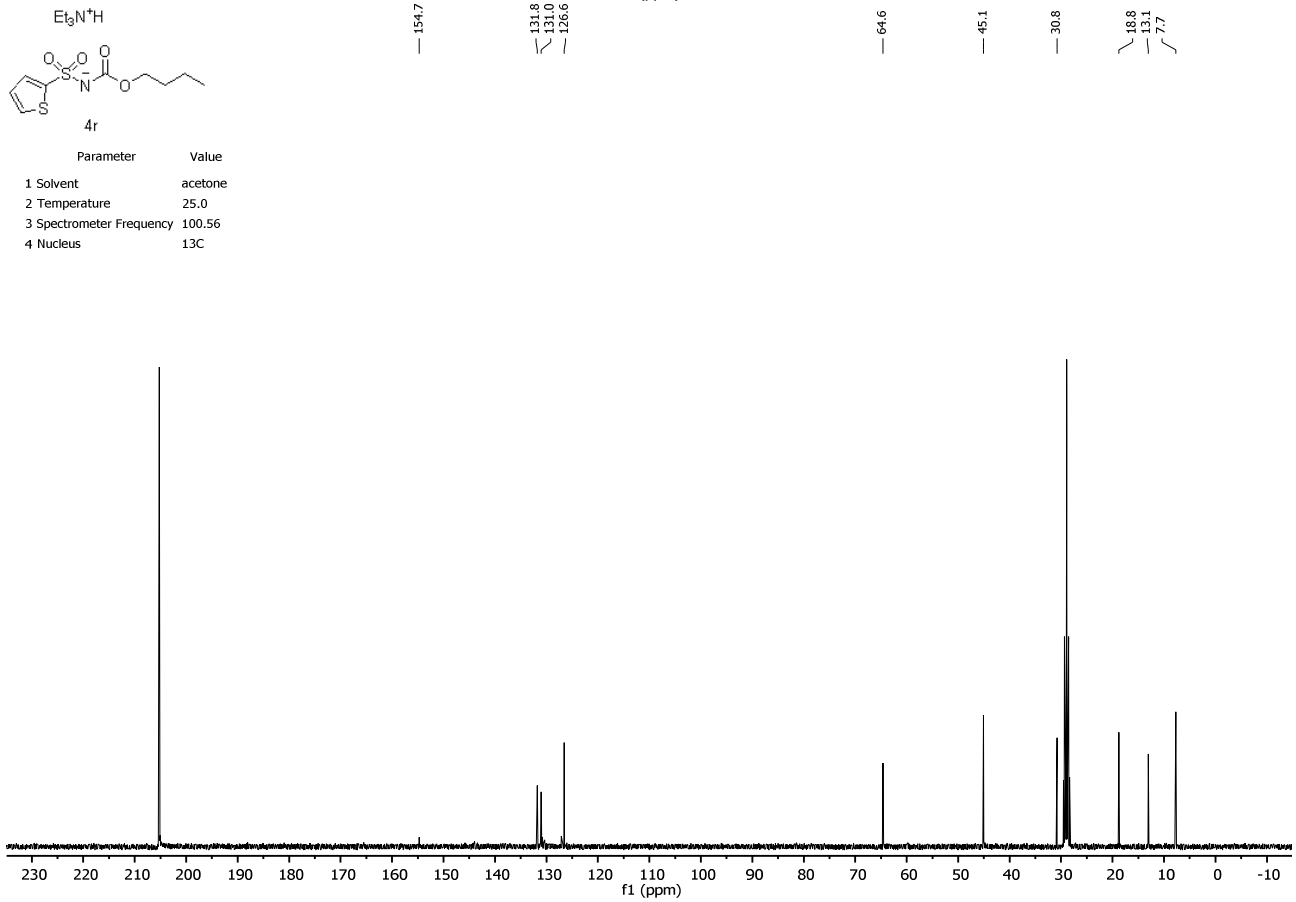
Butyl ((2-bromophenyl)sulfonyl)carbamate (4q)



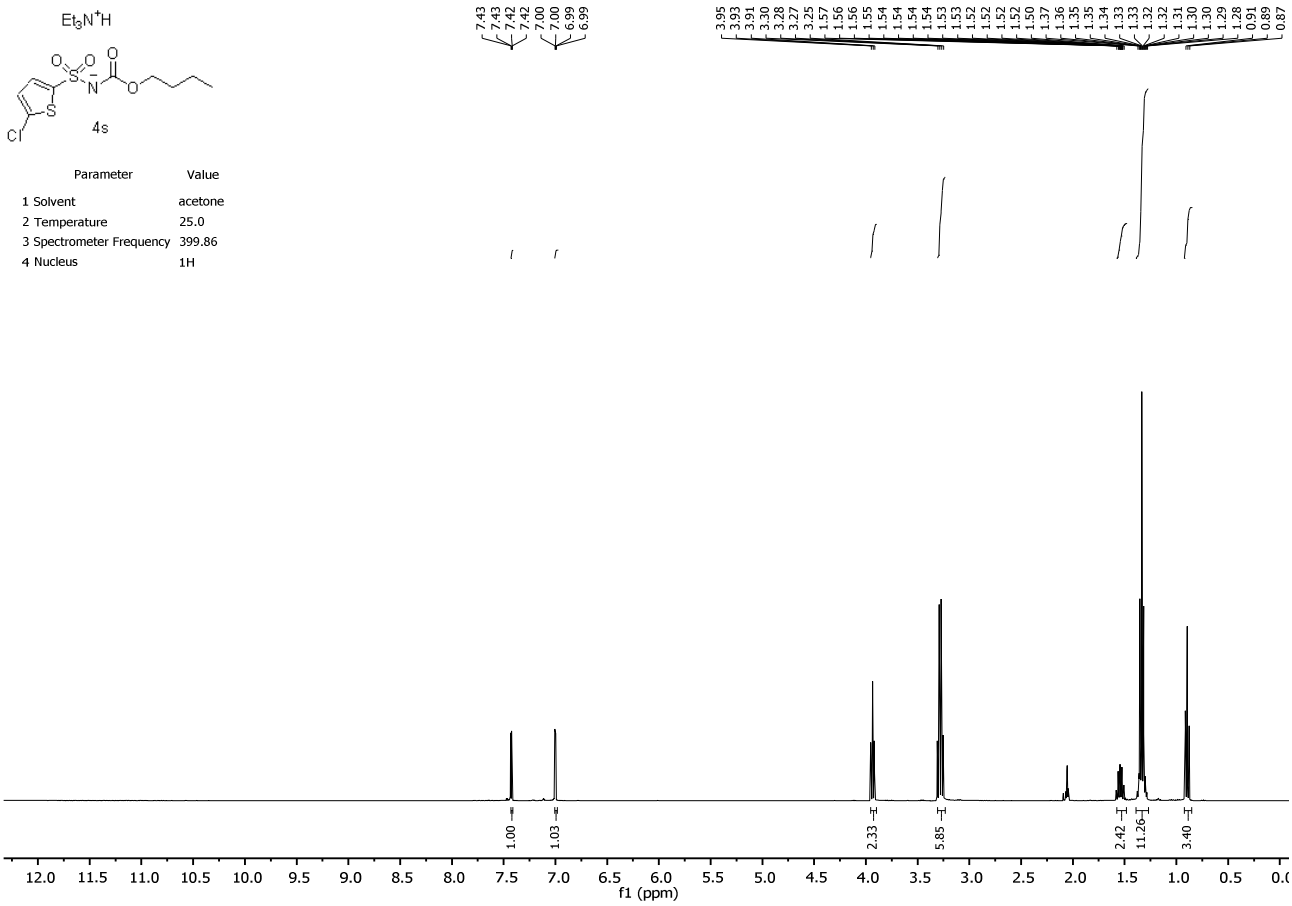


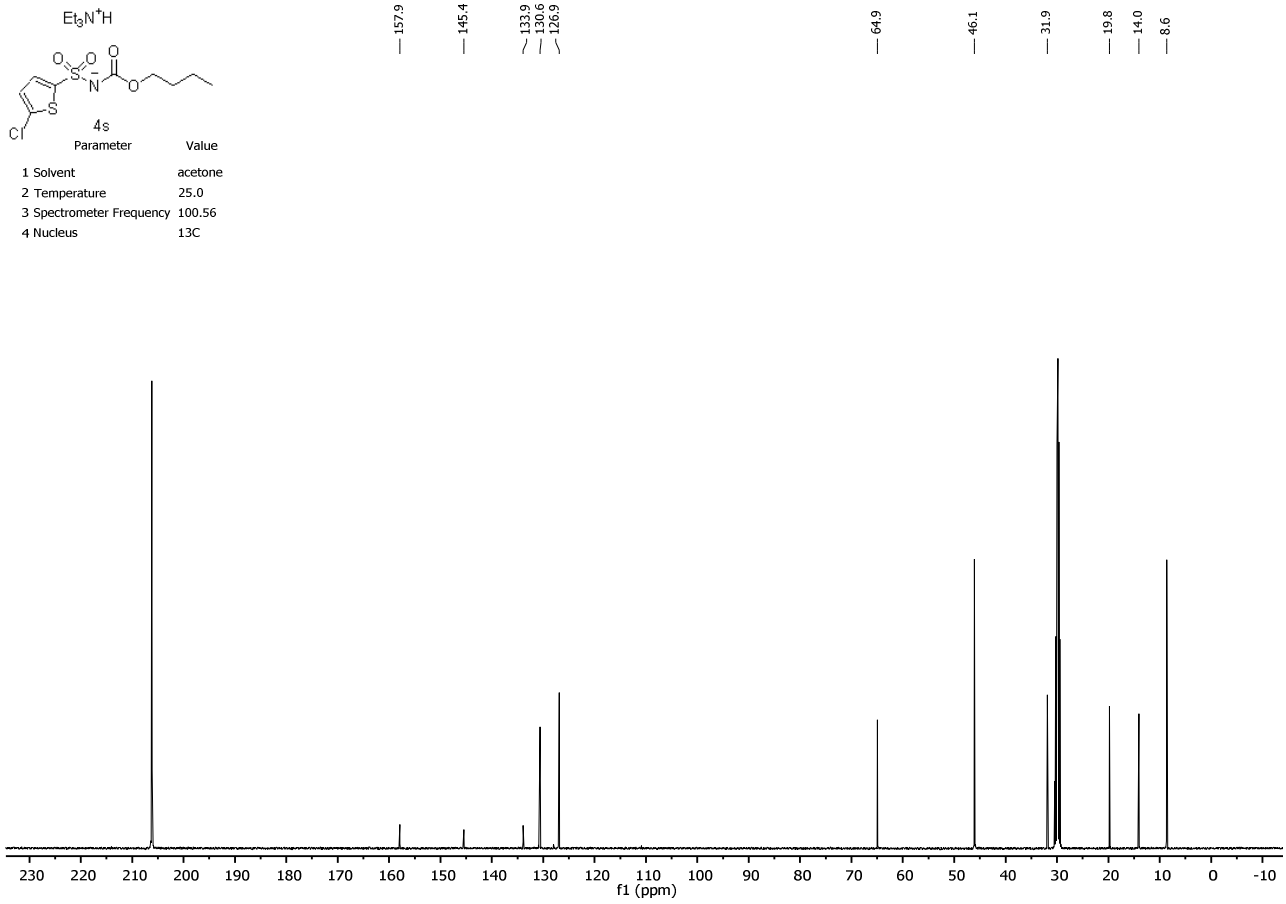
Triethylammonium (butoxycarbonyl)(thiophen-2-ylsulfonyl)amide (4r)



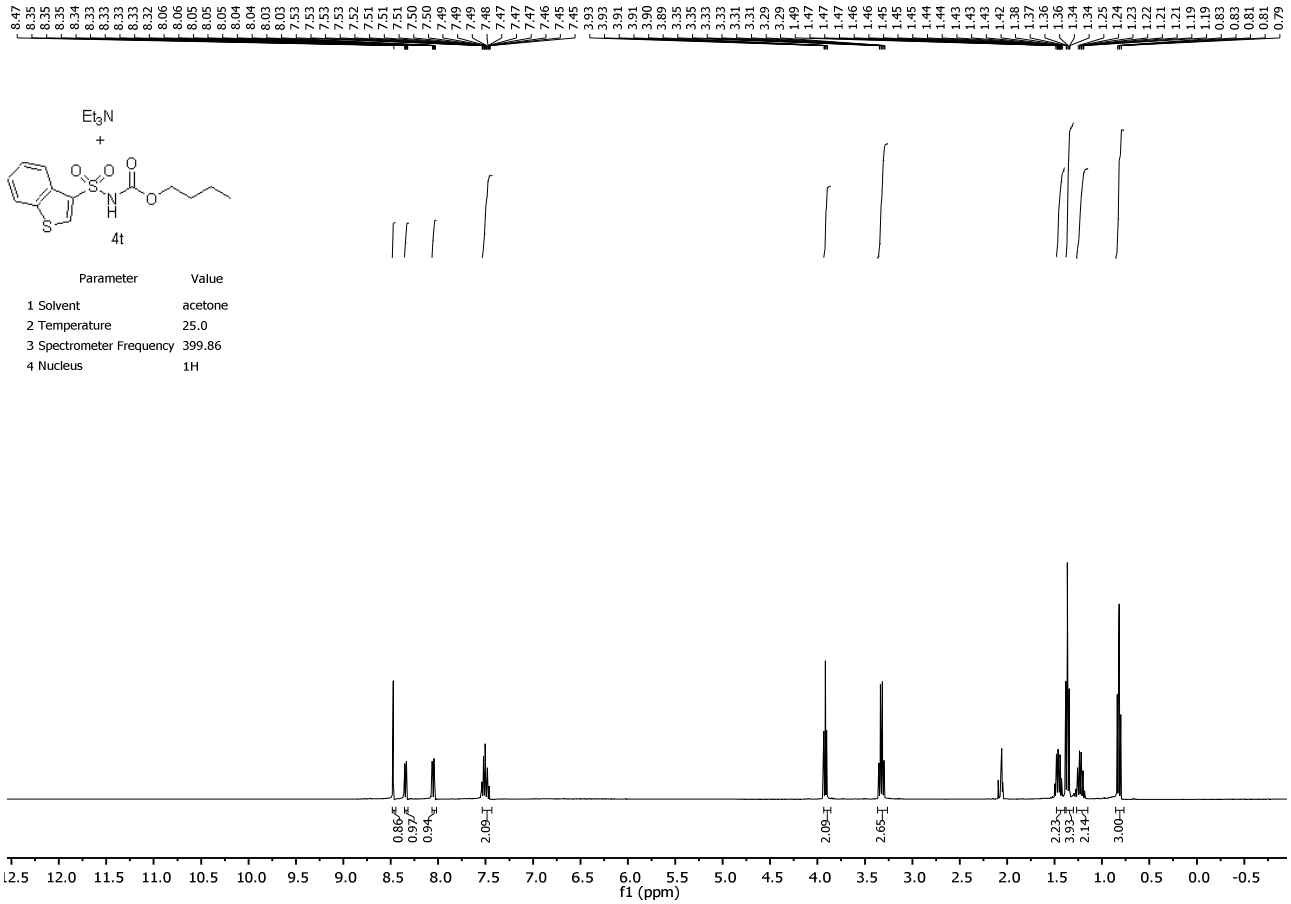


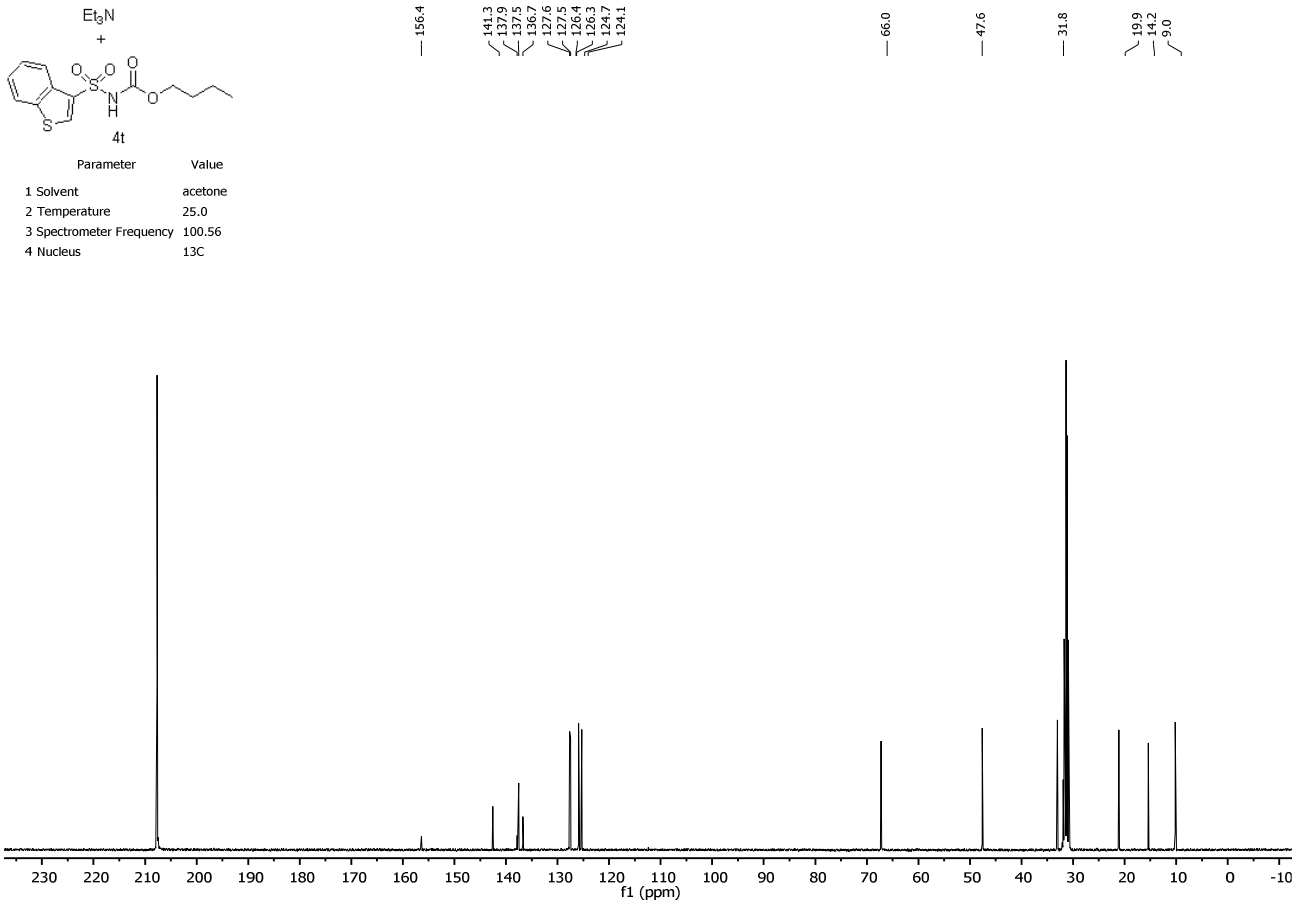
Triethylammonium (butoxycarbonyl)((5-chlorothiophen-2-yl)sulfonyl)amide (4s)





Butyl (benzo[*b*]thiophen-3-ylsulfonyl)carbamate (2:1 mixture with Et_3N) (4t)

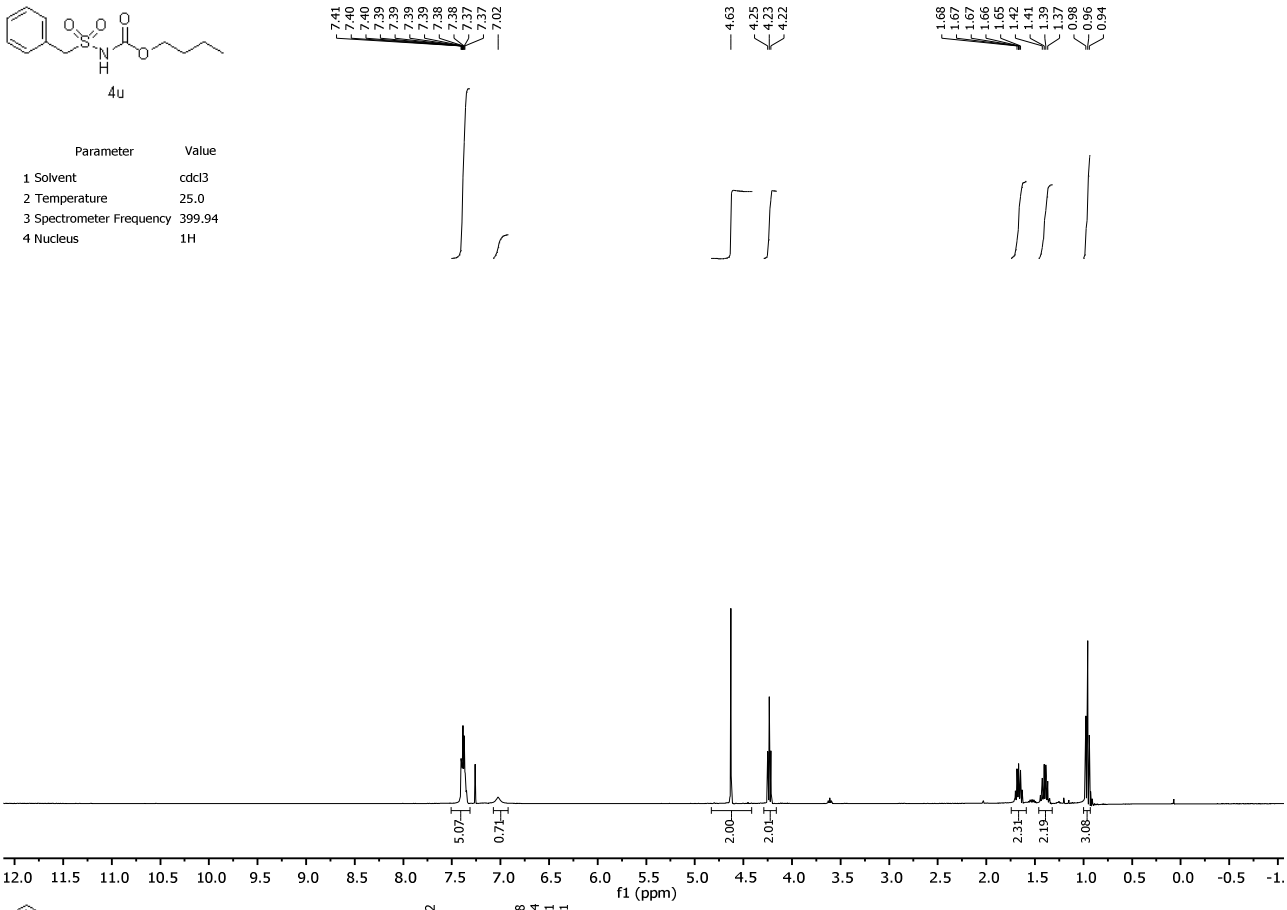




Butyl (benzylsulfonyl)carbamate (4u)

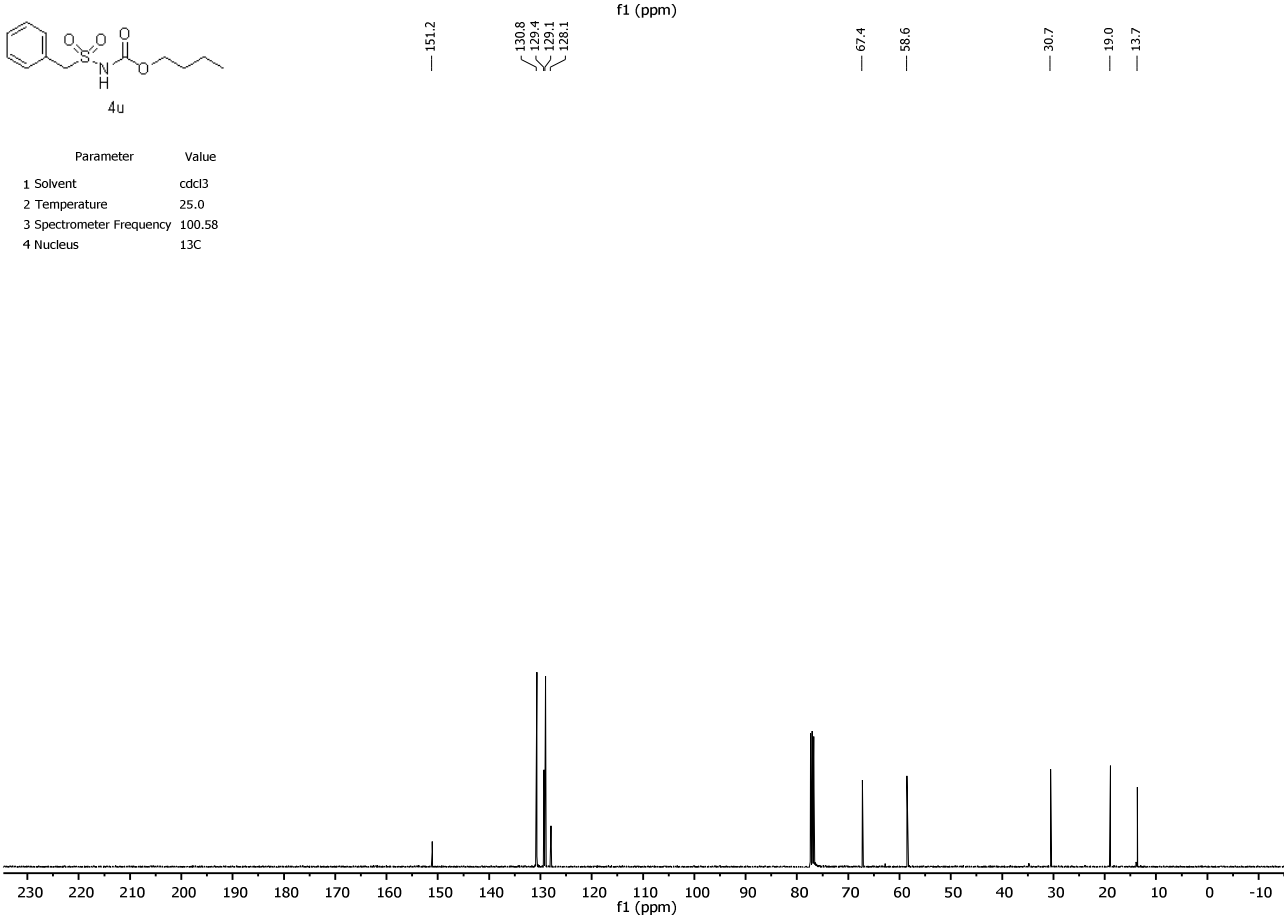
4u

Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	399.94
4 Nucleus	1H

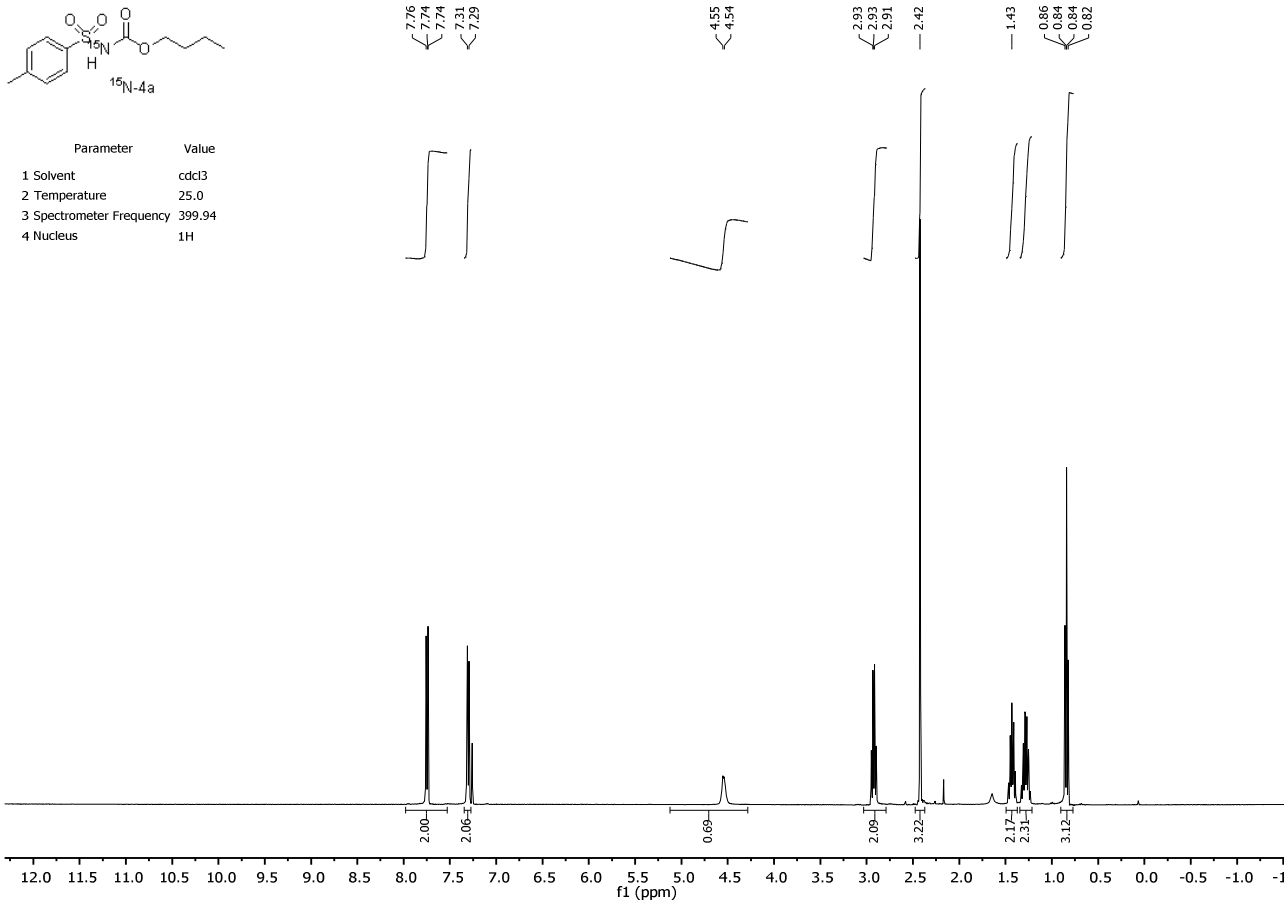


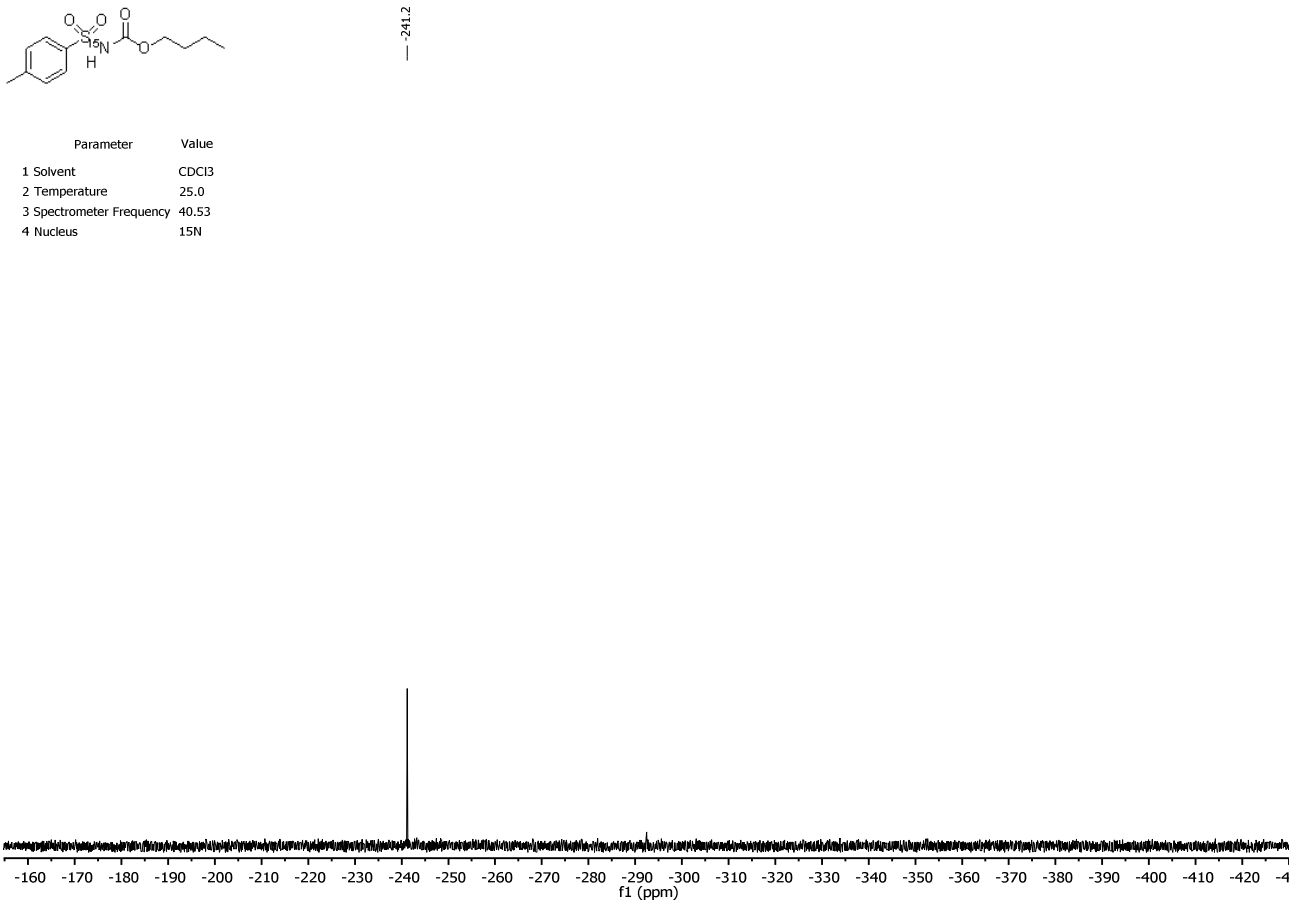
4u

Parameter	Value
1 Solvent	cdcl3
2 Temperature	25.0
3 Spectrometer Frequency	100.58
4 Nucleus	13C

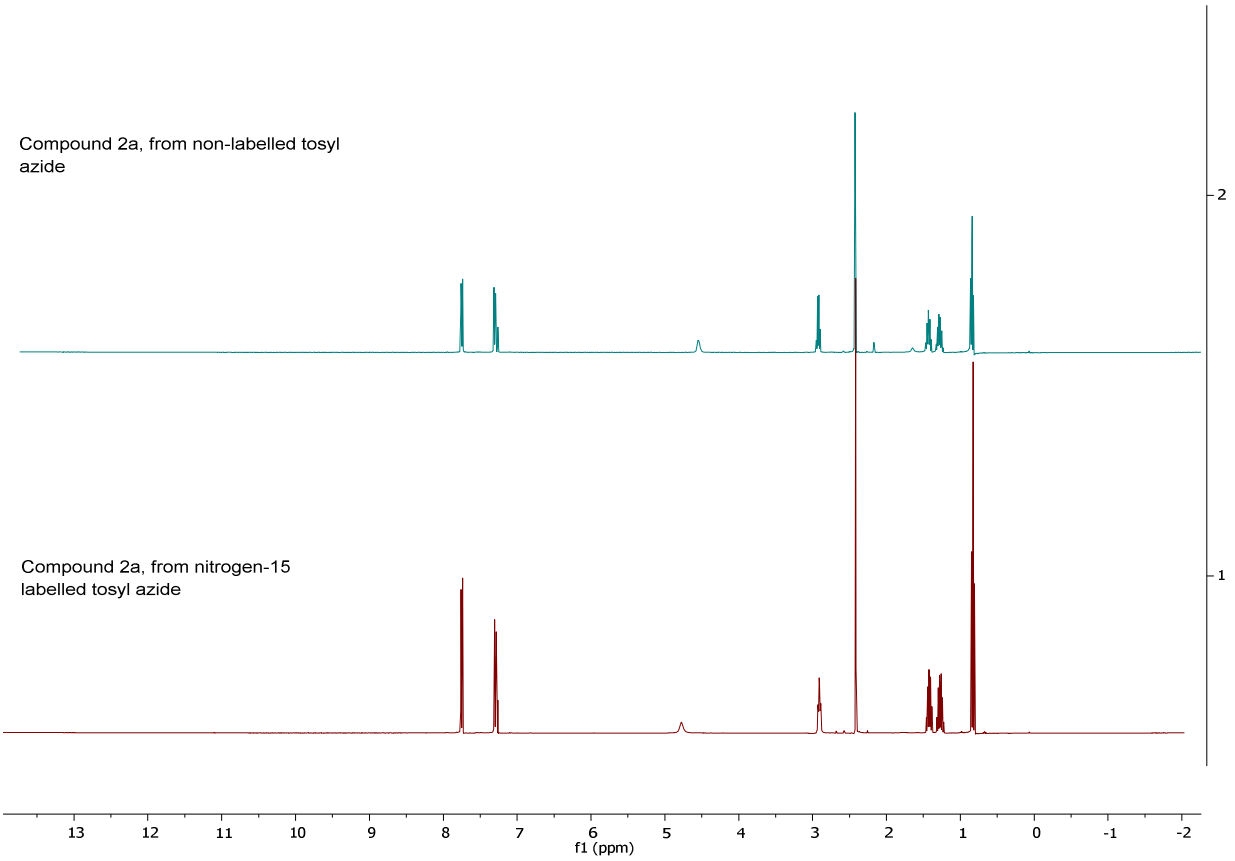


Butyl tosylcarbamate-^{15}N

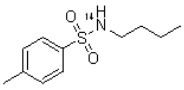
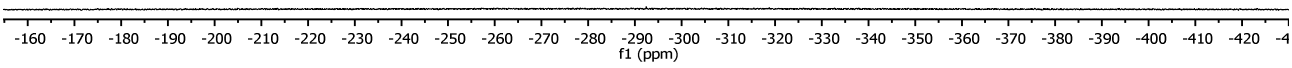




Azide displacement experiment (compound 2a)



Parameter	Value
1 Solvent	CDCl3
2 Temperature	25.0
3 Spectrometer Frequency	40.53
4 Nucleus	15N



^{15}N spectrum of compound **2a**, showing no isotopic label. This indicates that displacement of azide anion (^{15}N-1-N_3^-) has occurred