Electronic Supplementary Material (ESI) for RSC Advances.

SUPPORTING INFORMATION

Copper based on Diaminonaphthalene-coated magnetic nanoparticles as a robust catalyst for the catalytic oxidation reactions and C-S cross-coupling reactions

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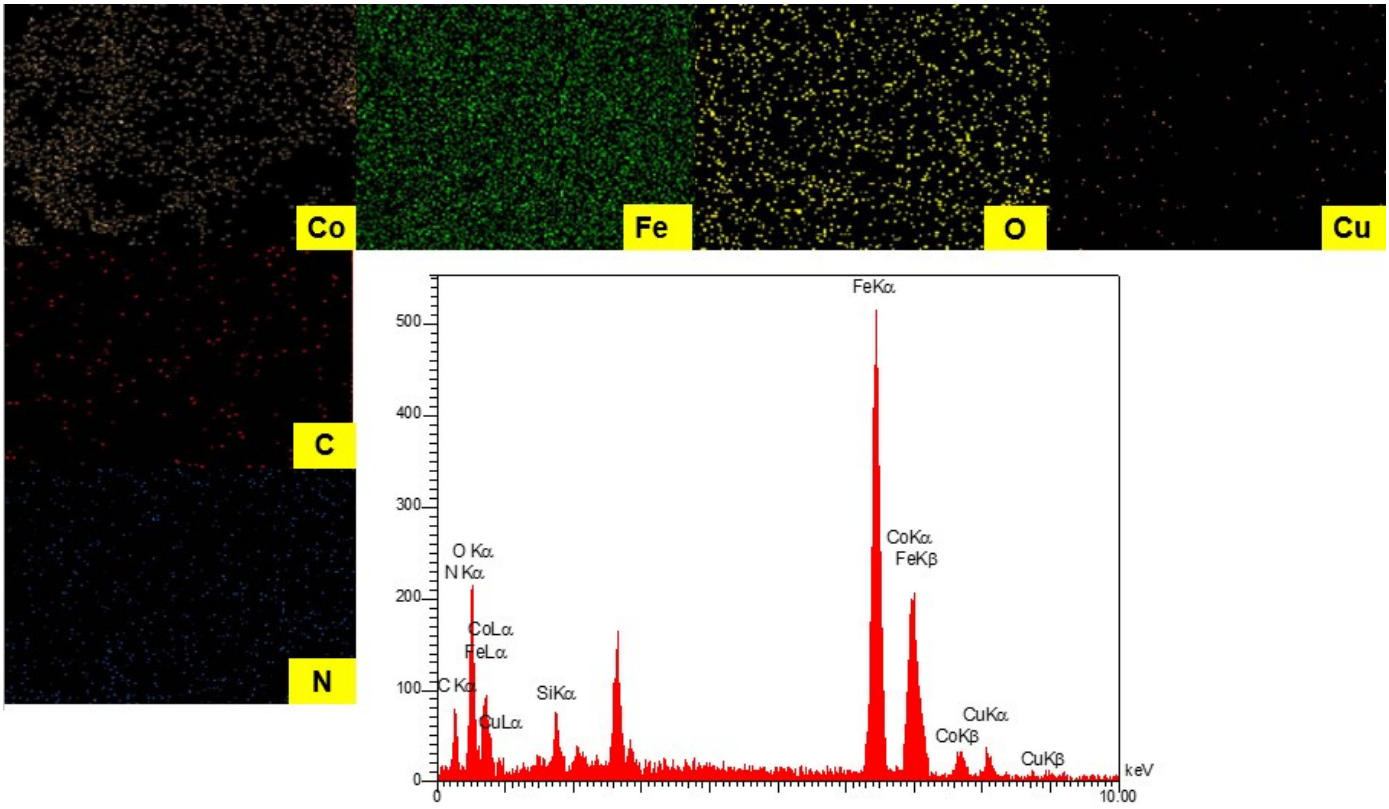


Fig. 1S. EDX image and elemental mapping of $CoFe_2O_4$-DAN-Cu(II)

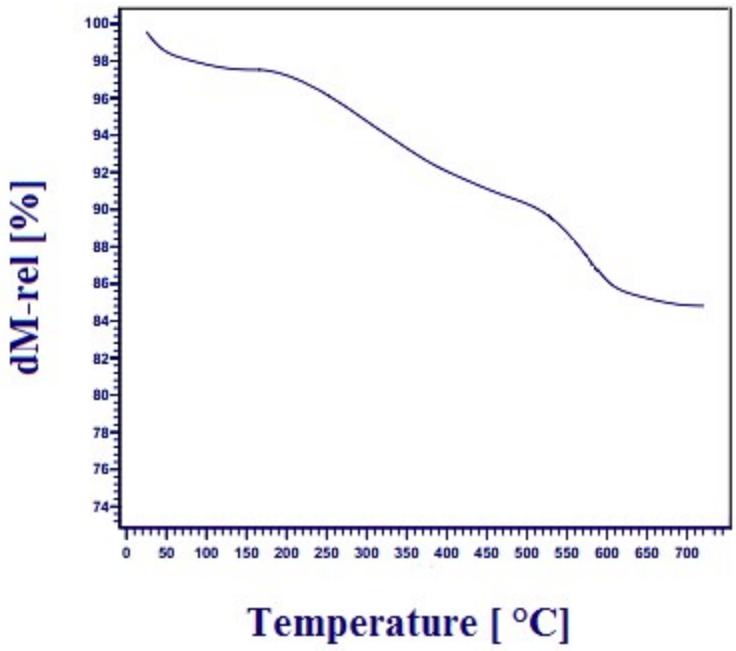


Fig. 2S. The TGA curve of $CoFe_2O_4$-DAN-Cu(II) nanocatalyst

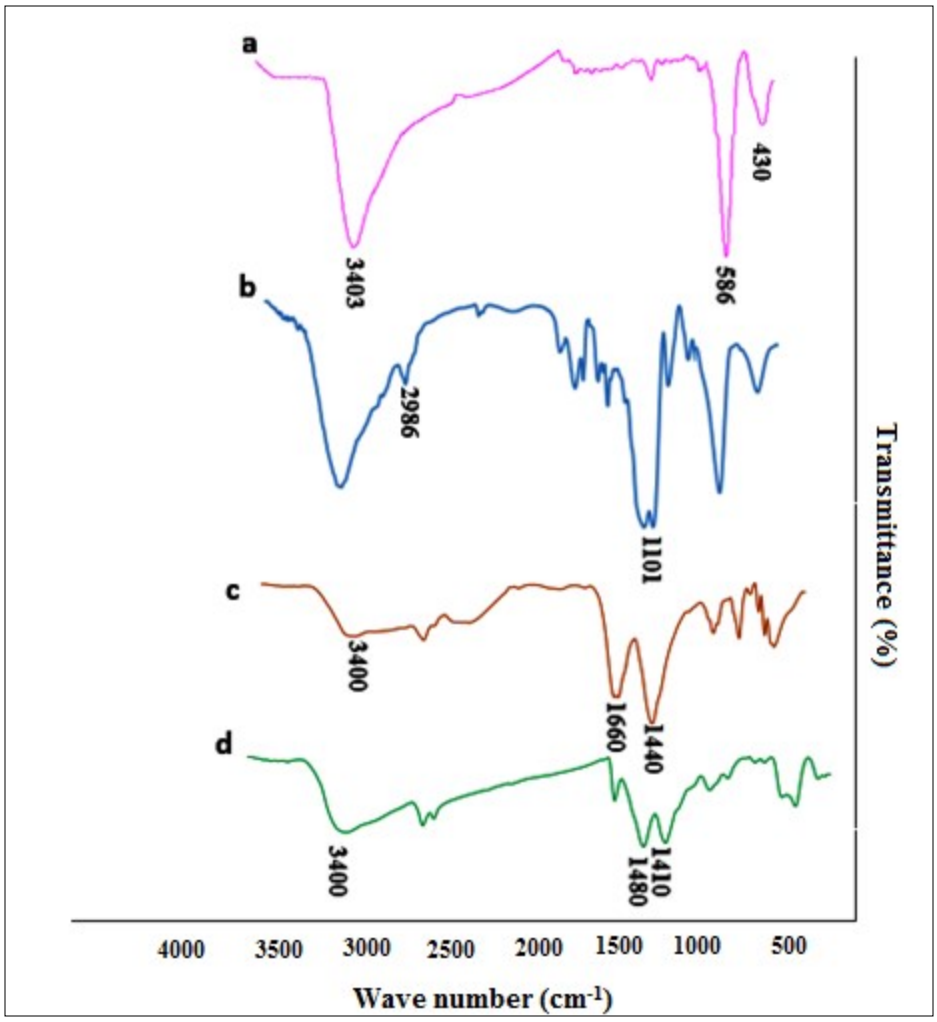
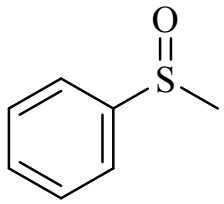


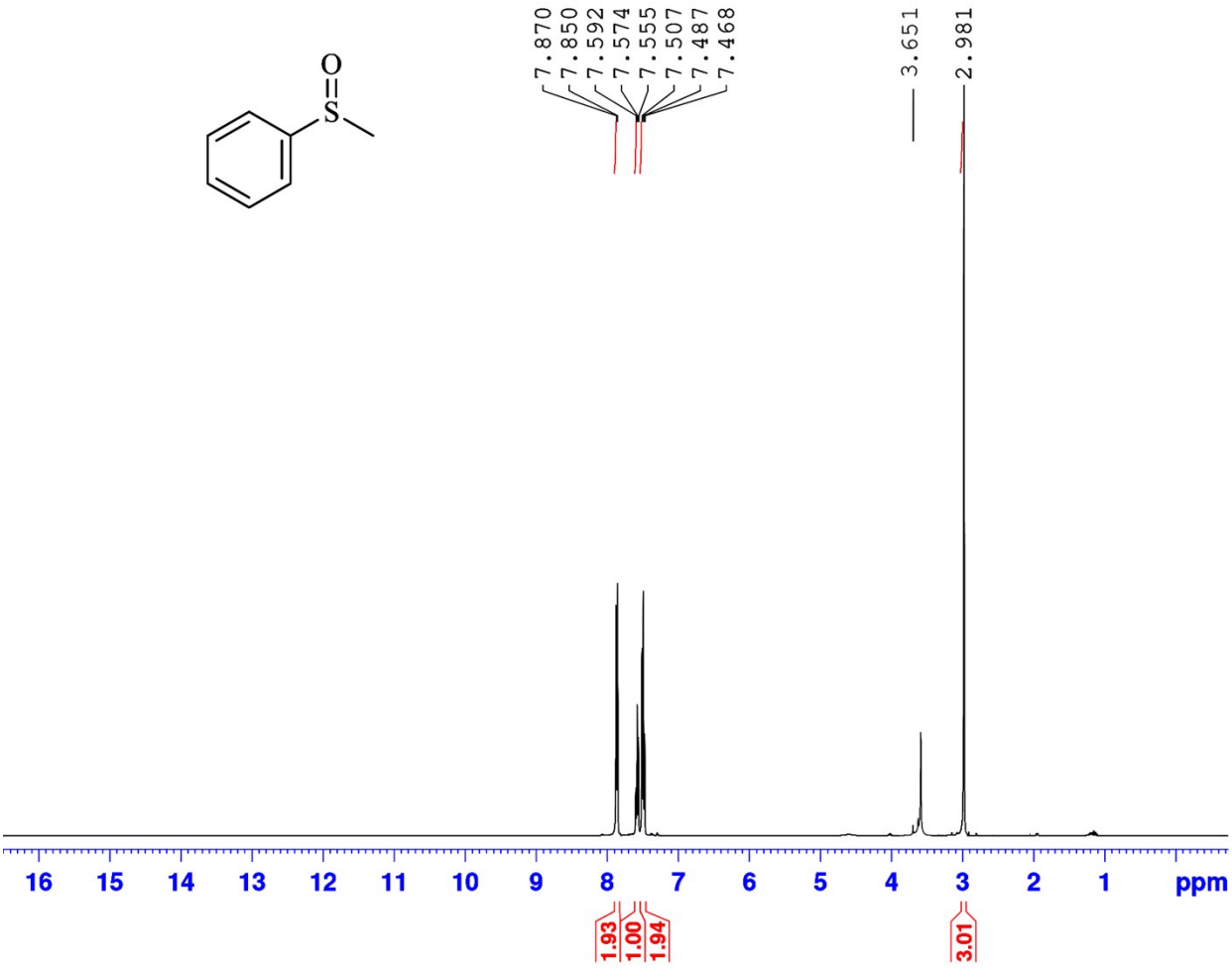
Fig. 3S. FT-IR spectra of $CoFe_2O_4$ (a), $CoFe_2O_4$-Cl (b), $CoFe_2O_4$-DAN (c), $CoFe_2O_4$-DAN-Cu(II) (d)

Spectra data of sulfides from Table 2.

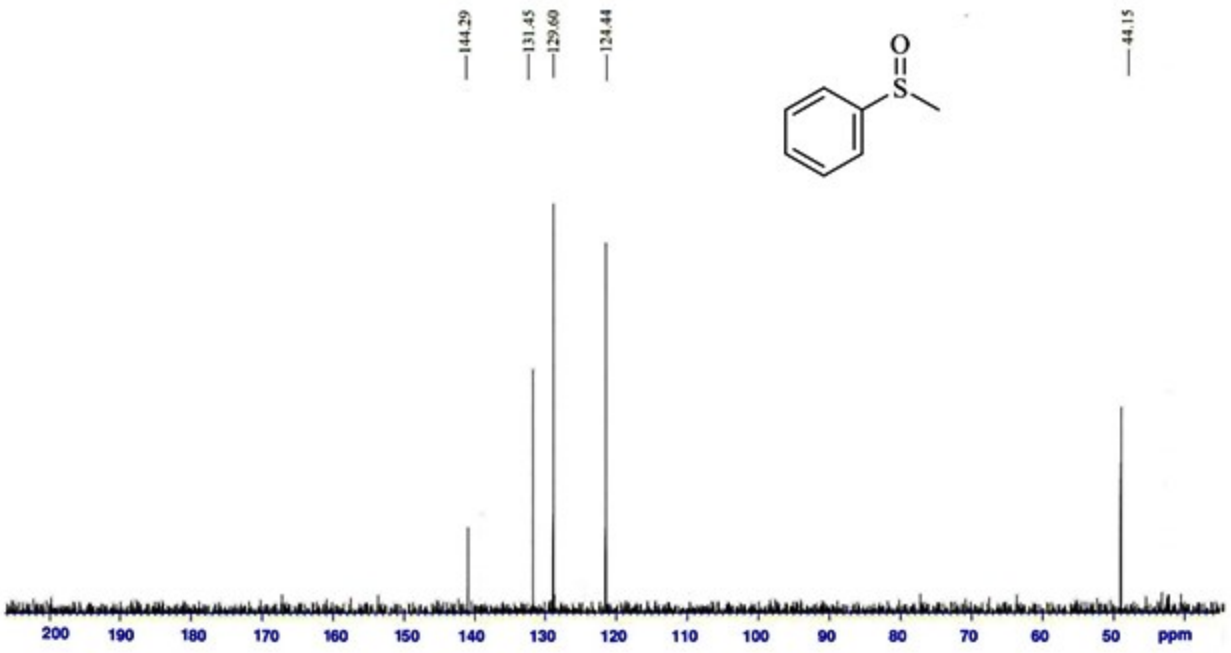
Methyl phenyl sulfoxide (Table 2, entry 1)



Melting point: Oil. ^{1}HNMR (300 MHz, $CDCl_3$, ppm): δ 2.98 (s, 3H), 7.46–7.87 (m, 5H); ^{13}CNMR (75 MHz, $CDCl_3$, ppm): δ 44.15, 124.44, 129.60, 131.45, 144.29. IR (KBr) (cm^{-1}): ν (S═O): 1079.

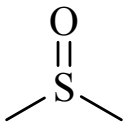


S1. ^{1}HNMR spectrum of methyl phenyl sulfoxide in $CDCl_3$ (Table 2, entry 1)

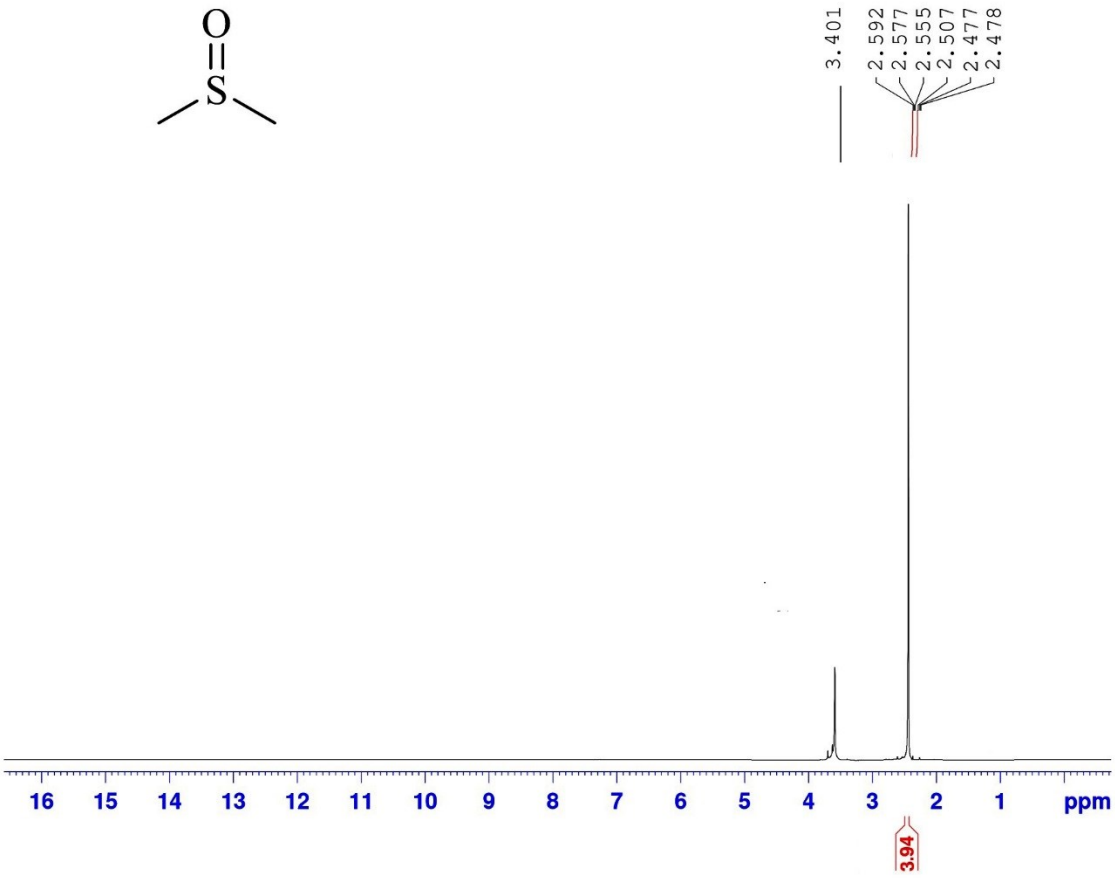


S2. ^{13}CNMR spectrum of methyl phenyl sulfoxide in $CDCl_3$ (Table 2, entry 1)

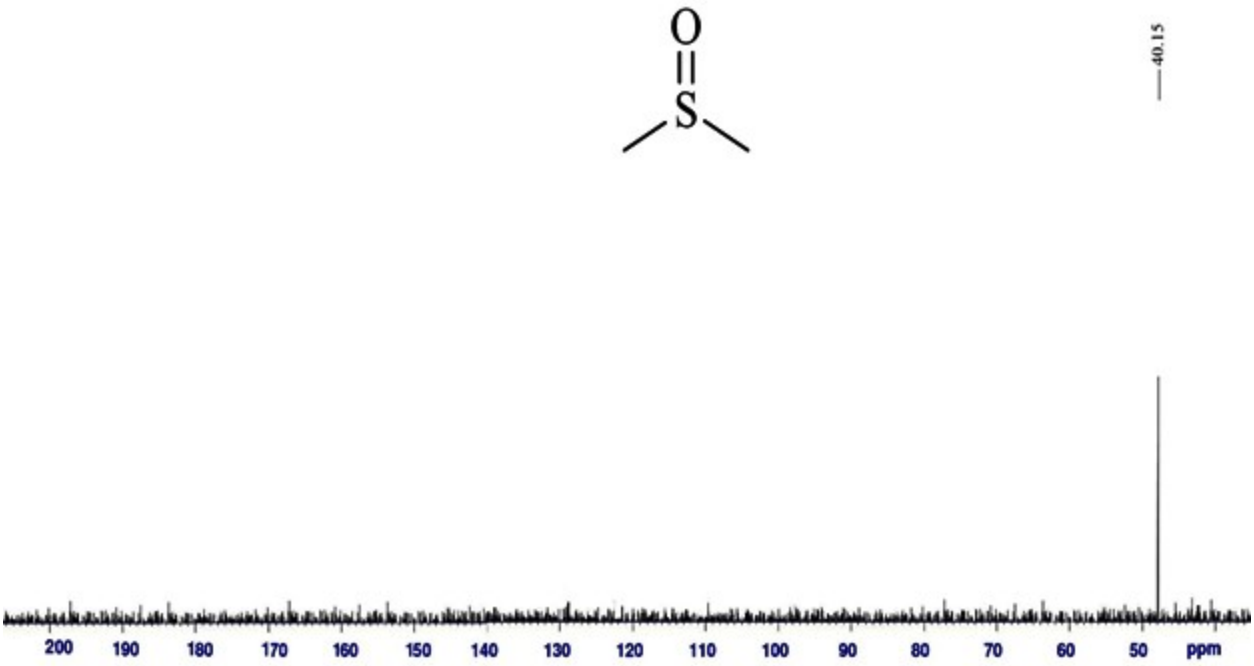
Dimethyl sulfoxide (Table 2, entry 2)



Melting point: Oil. ^{1}HNMR (300 MHz, $CDCl_3$, ppm): δ 2.47-2.59 (s, 6H); ^{13}CNMR (75 MHz, $CDCl_3$, ppm): δ 40.15. IR (KBr) (cm^{-1}): ν (S═O): 1054.

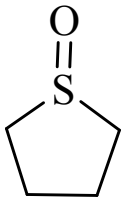


S3. ^{1}HNMR spectrum of dimethyl sulfoxide in $CDCl_3$ (Table 2, entry 2)

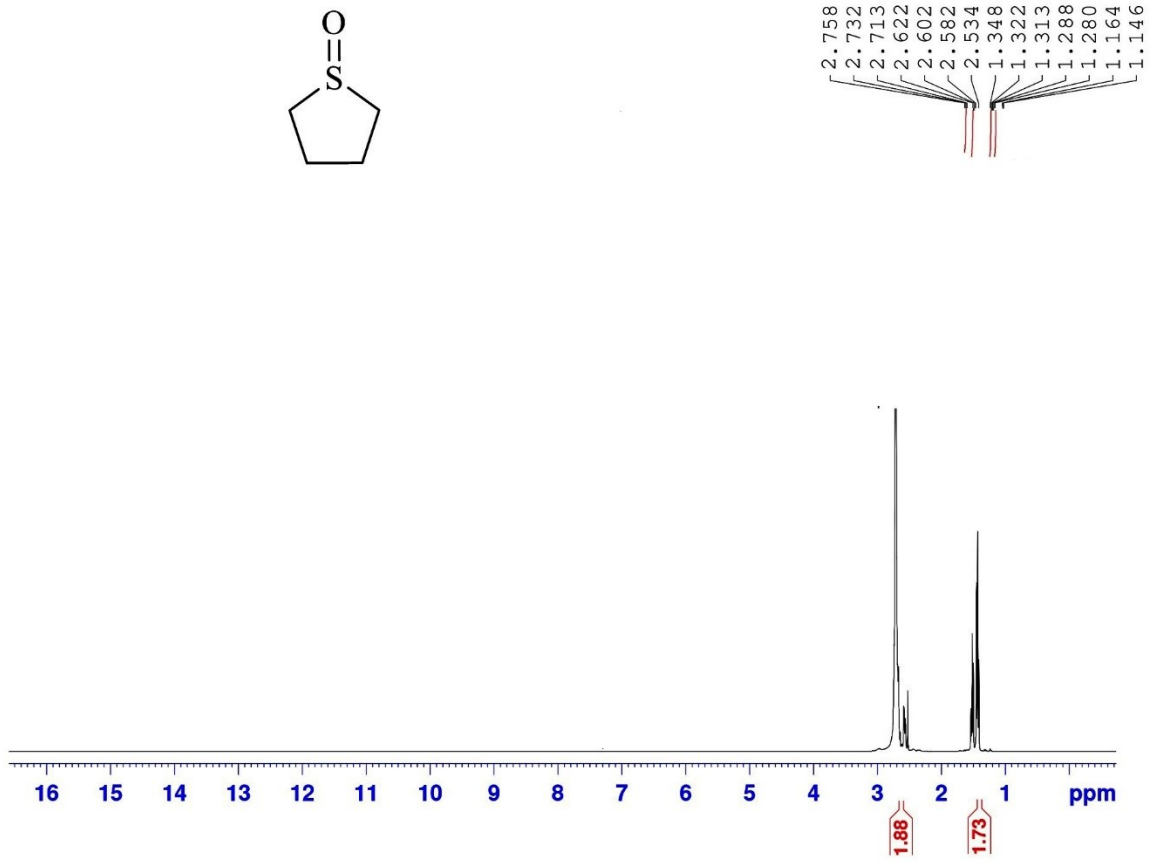


S4. ^{13}CNMR spectrum of dimethyl sulfoxide in $CDCl_3$ (Table 2, entry 2)

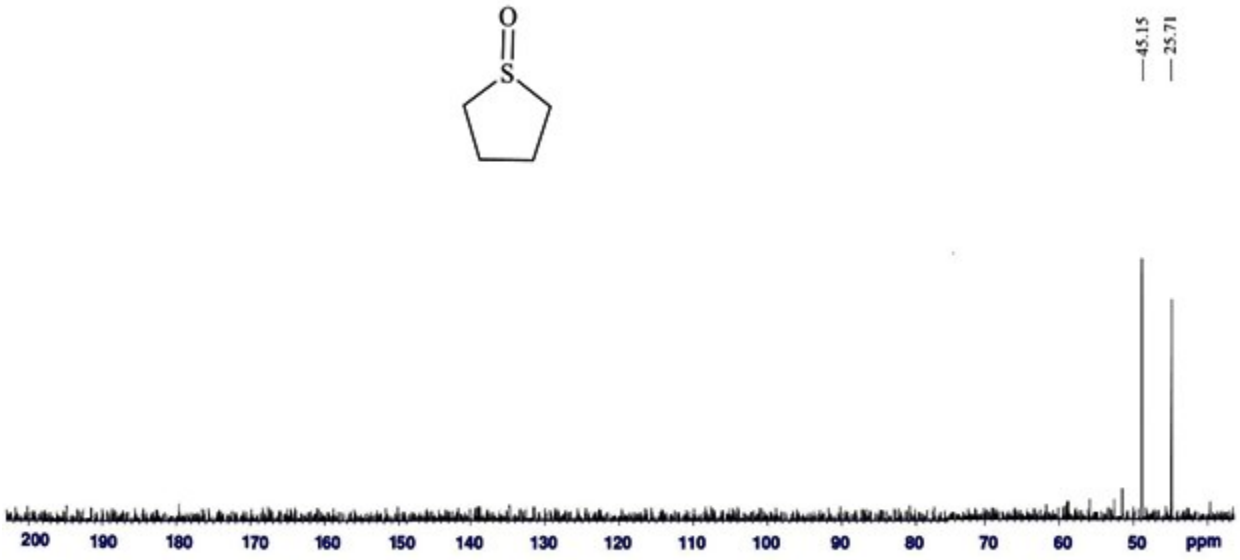
Tetrahydrothiophene 1-oxide (Table 2, entry 3)



Melting point: Oil. ^{1}HNMR (300 MHz, $CDCl_3$, ppm): δ 1.14-1.34 (m, 2H), 2.53–2.75 (m, 2H); ^{13}CNMR (75 MHz, $CDCl_3$, ppm): δ 25.71, 40.15. IR (KBr) (cm^{-1}): ν (S═O): 1058.

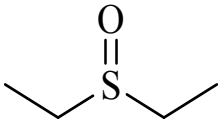


S5. [1]HNMR spectrum of tetrahydrothiophene 1-oxide in $CDCl_3$ (Table 2, entry 3)

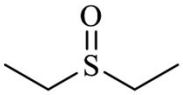


S6. [13]CNMR spectrum of tetrahydrothiophene 1-oxide in $CDCl_3$ (Table 2, entry 3)

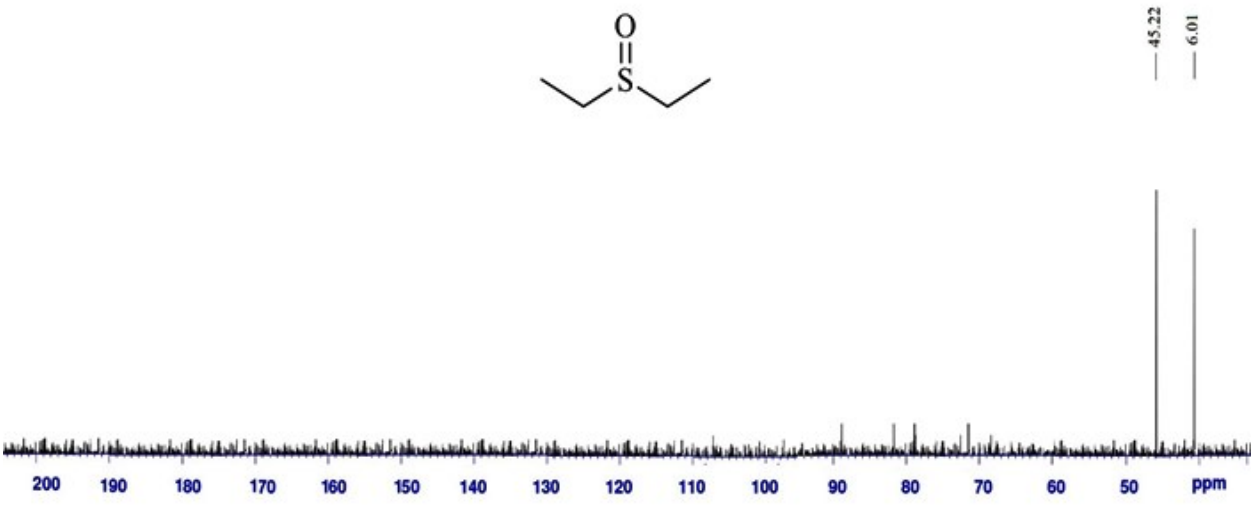
Diethyl sulfoxide (Table 2, entry 4)



Melting point: Oil. ^{1}HNMR (400 MHz, $CDCl_3$, ppm): δ 1.55-1.58 (m, 34H), 2.45–2.58 (m, 3H); ^{13}CNMR (100 MHz, $CDCl_3$, ppm): δ 6.01 , 45.22 . IR (KBr) (cm^{-1}): ν (S═O): 1069.

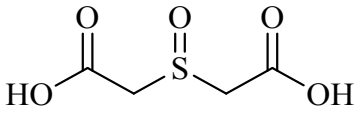


S7. ^{1}HNMR spectrum of diethyl sulfoxide in $CDCl_3$ (Table 2, entry 4)

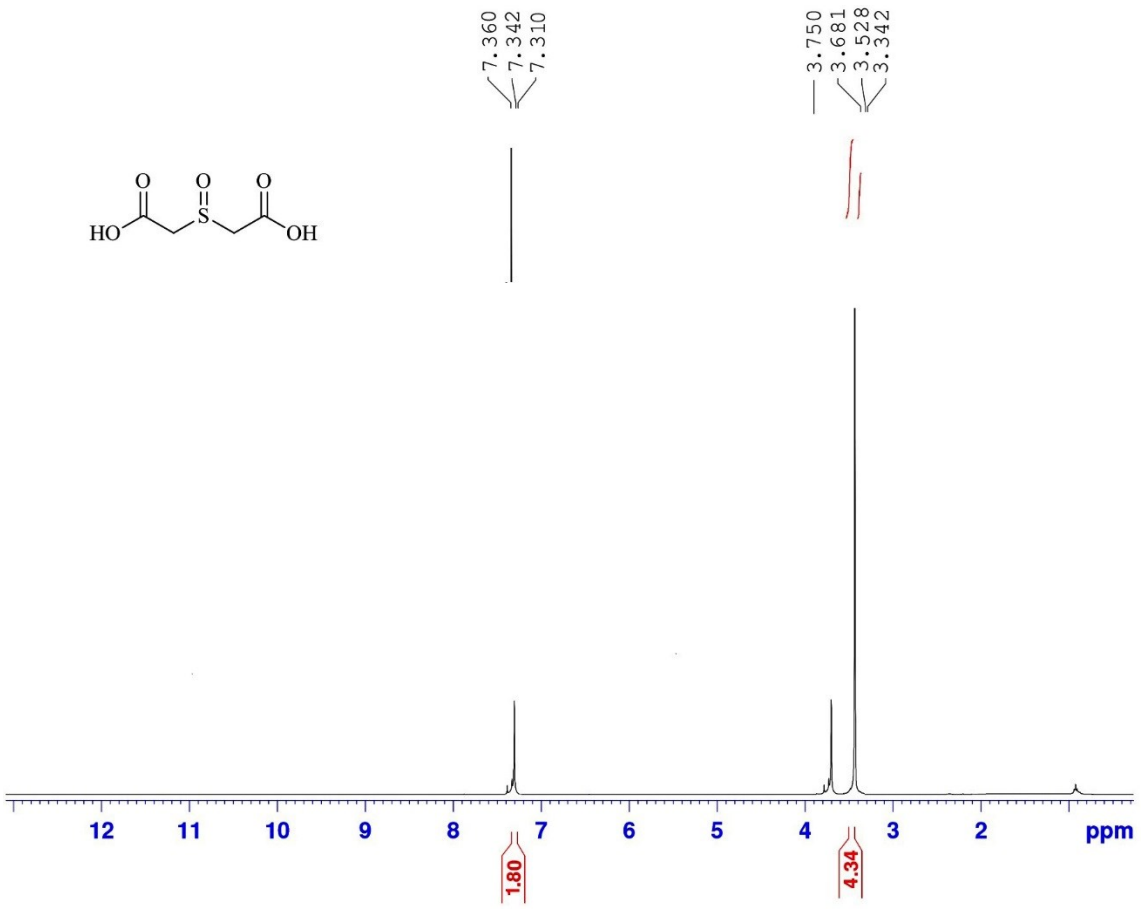


S8. ^{13}CNMR spectrum of diethyl sulfoxide in $CDCl_3$ (Table 2, entry 4)

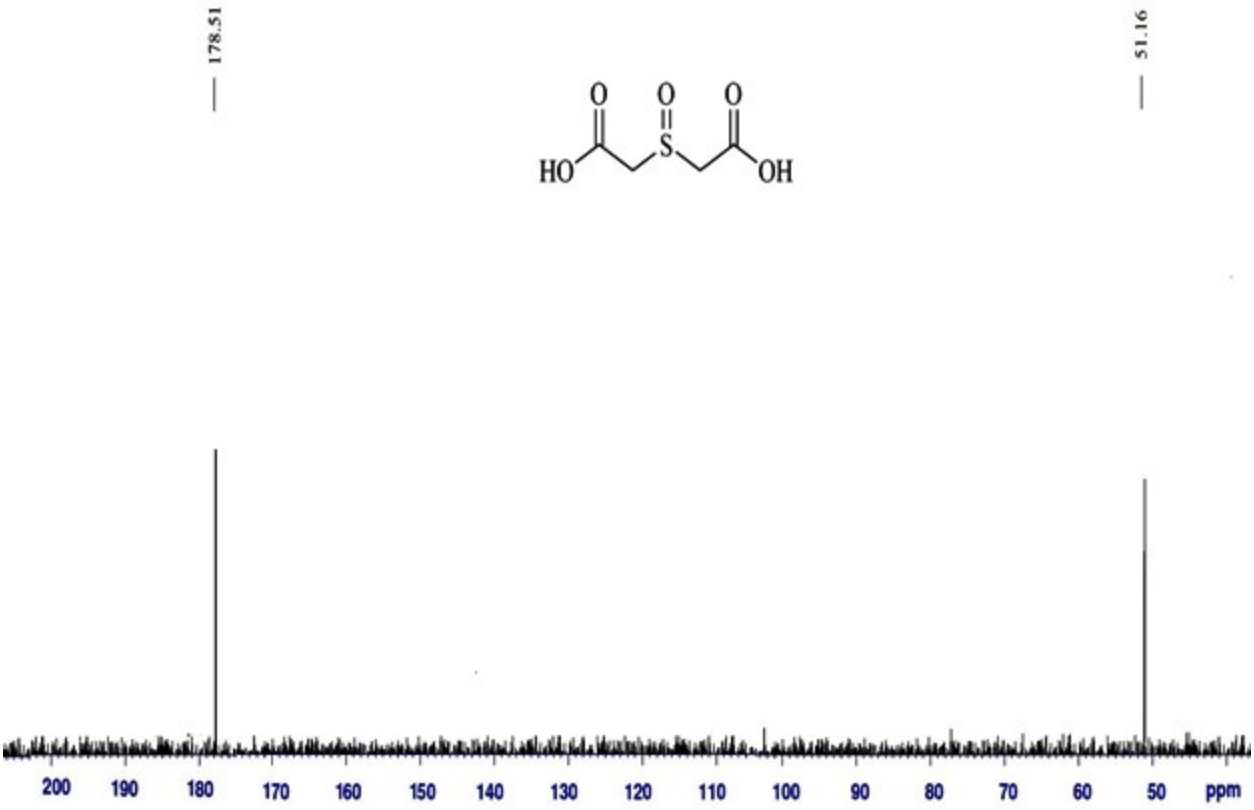
2, 2′-Sulfinyldiacetic acid (Table 2, entry 5)



Melting point: Oil. ^{1}HNMR (300 MHz, $CDCl_3$, ppm): δ 3.34-3.68 (s, 4H), 7.31– 7.36 (s, 2H); ^{13}CNMR (400 MHz, $CDCl_3$, ppm): δ 51.16, 178.51. IR (KBr) (cm^{-1}): ν (S═O): 1044-1108.

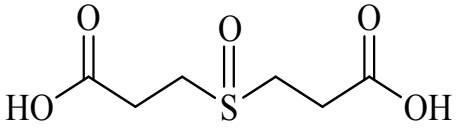


S9. [1]HNMR spectrum of 2, 2′-Sulfinyldiacetic acid in $CDCl_3$ (Table 2, entry 5)

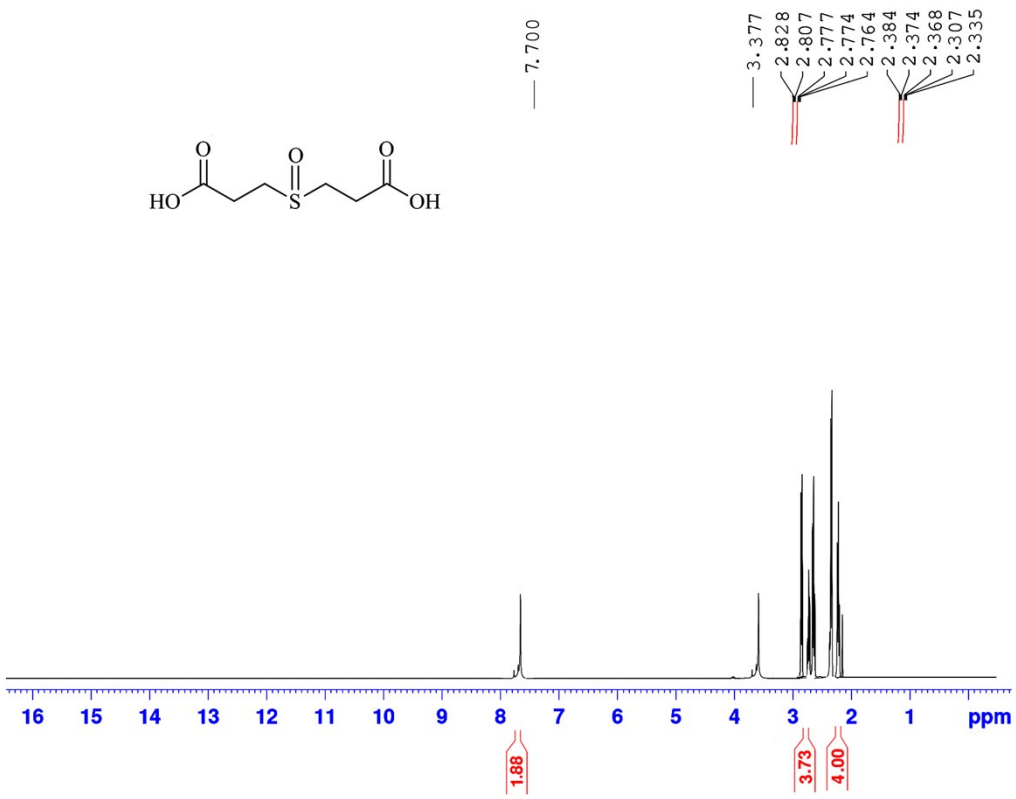


S10. ^{13}CNMR spectrum of 2, 2′-Sulfinyldiacetic acid in $CDCl_3$ (Table 2, entry 5)

3, 3′-Sulfinyldipropionic acid (Table 2, entry 6)



Melting point: 112-114 °C. ^{1}HNMR (400 MHz, DMSO, ppm): δ 2.33-2.38 (s, 4H), 2.76– 2.82 (m, 4H), 7.70 (s, 2H) ; ^{13}CNMR (75 MHz, DMSO, ppm): δ 33.55, 179.29. IR (KBr) (cm^{-1}): ν (S═O): 1117.



S11. [1]HNMR spectrum of 3, 3′-Sulfinyldipropionic acid in DMSO (Table 2, entry 6)

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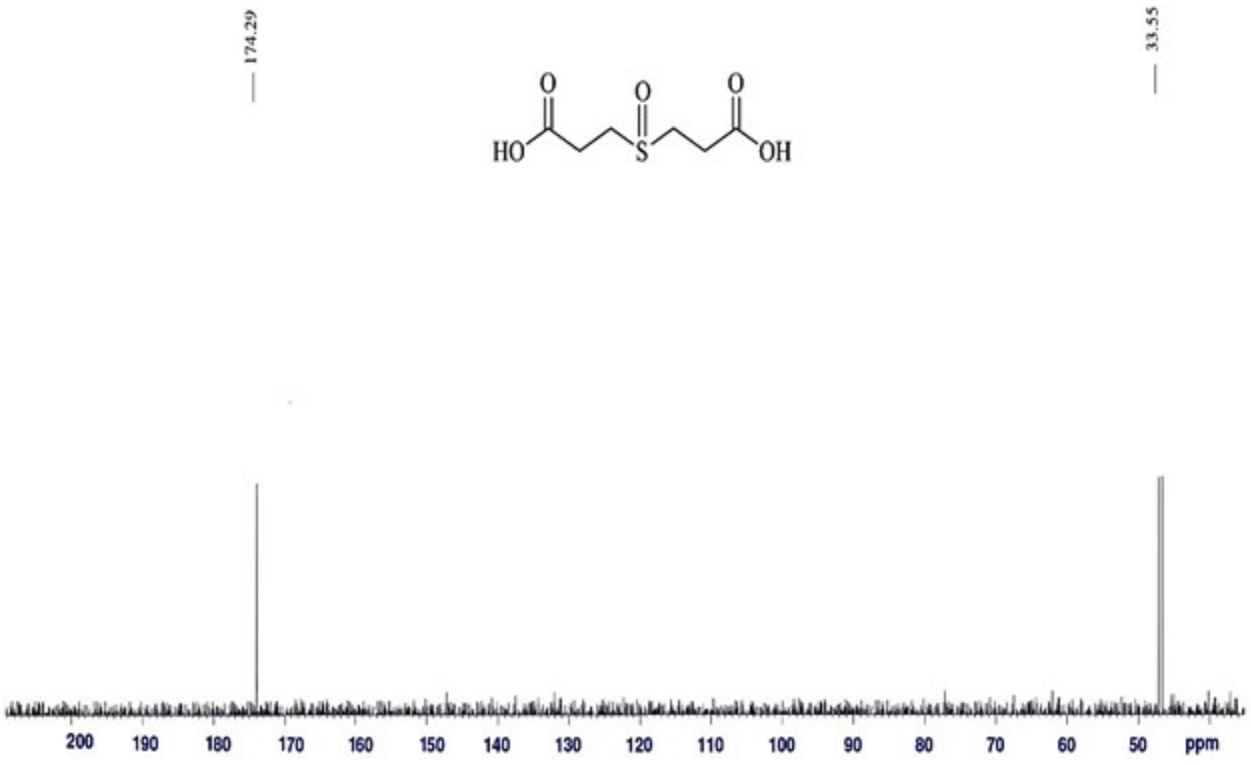
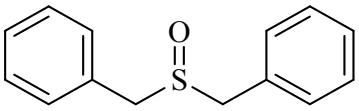
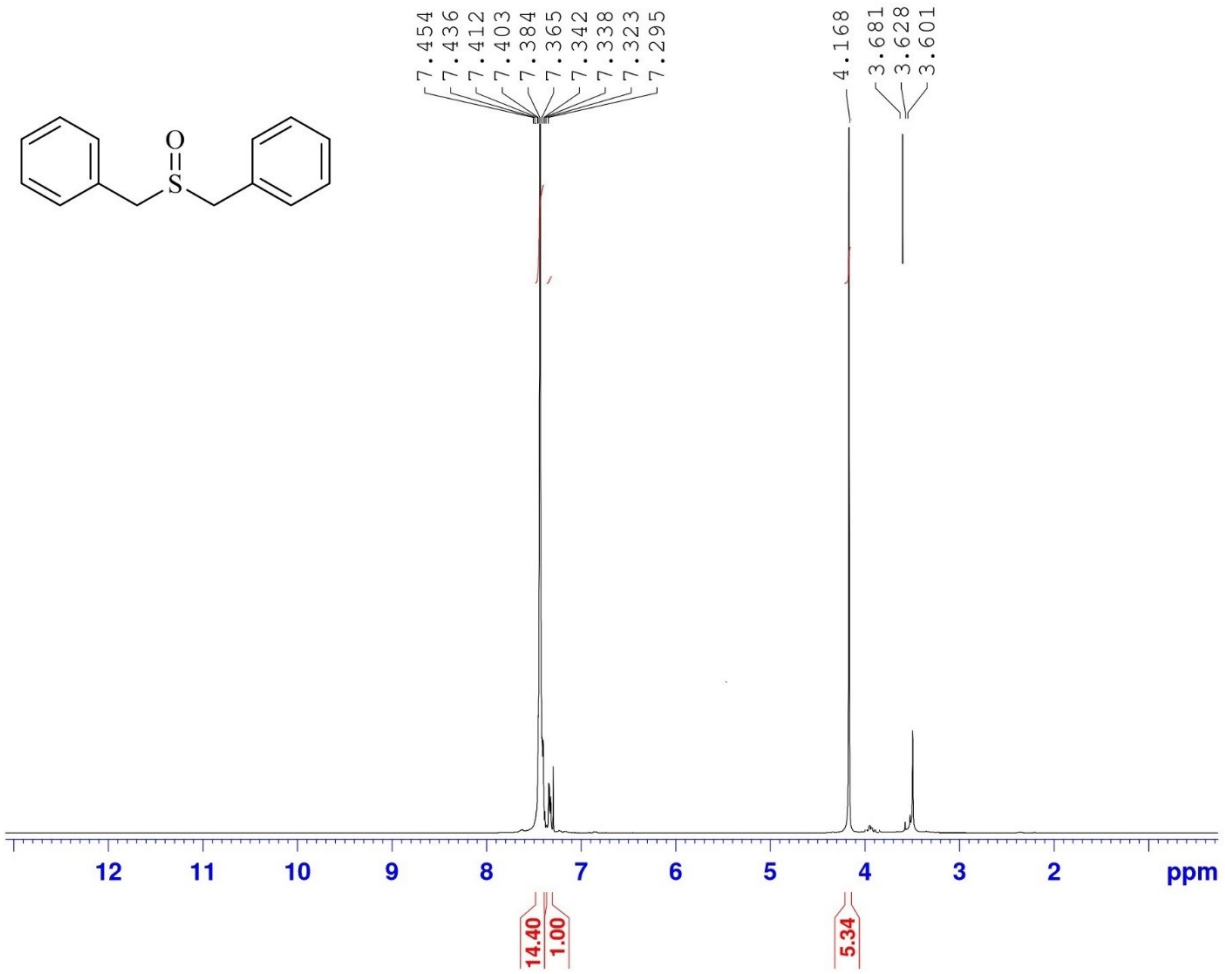


S12. ^{13}CNMR spectrum of 3, 3′-Sulfinyldipropionic acid in DMSO (Table 2, entry 6)

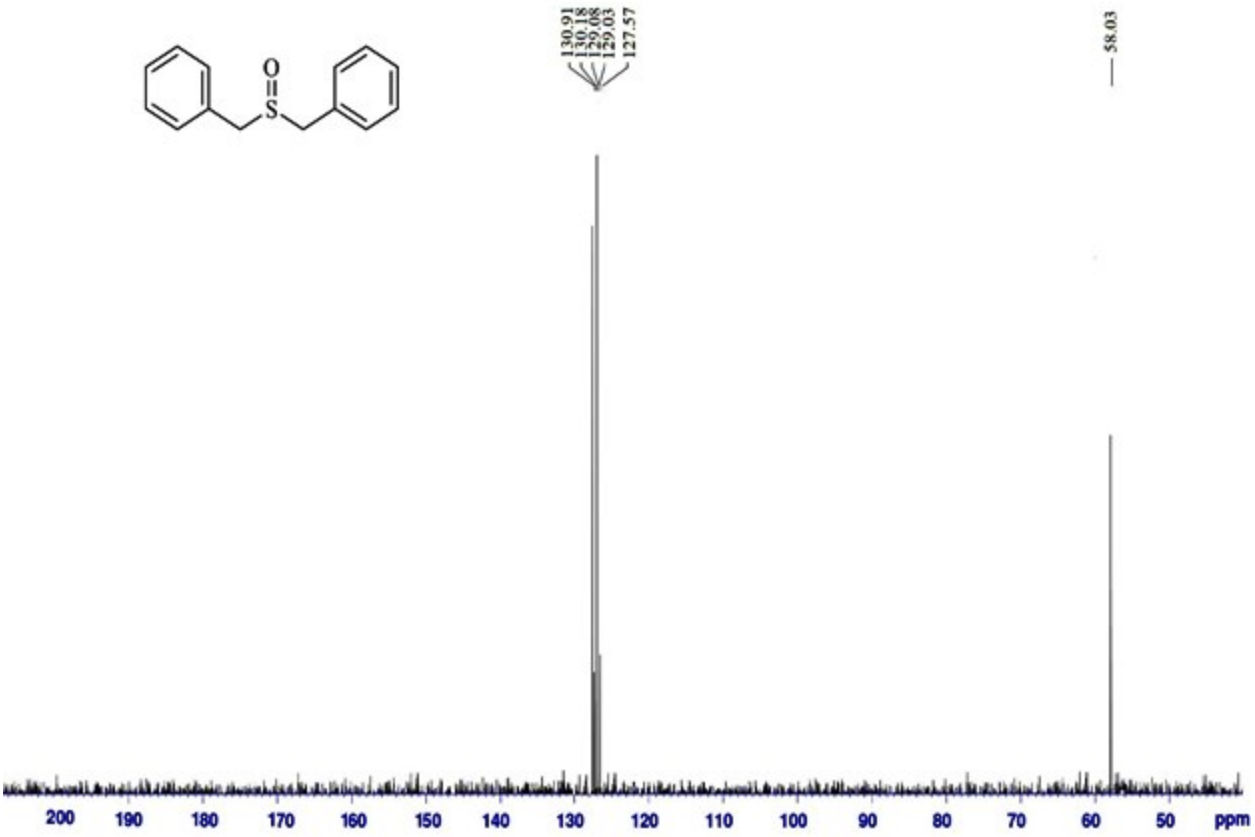
Dibenzyl sulfoxide (Table 2, entry 7)



Melting point: 130-133 °C. ^{1}HNMR (400 MHz, DMSO, ppm): δ 4.16 (S, 4H), 7.29-7.45 (m, 10H); ^{13}CNMR (75 MHz, DMSO, ppm): δ 58.03 , 127.57, 129.03, 130.18, 130.91. IR (KBr) (cm^{-1}): ν (S═O): 1026–1089.

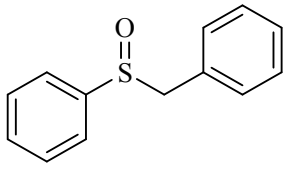


S13. [1]HNMR spectrum of dibenzyl sulfoxide in DMSO (Table 2, entry 7)

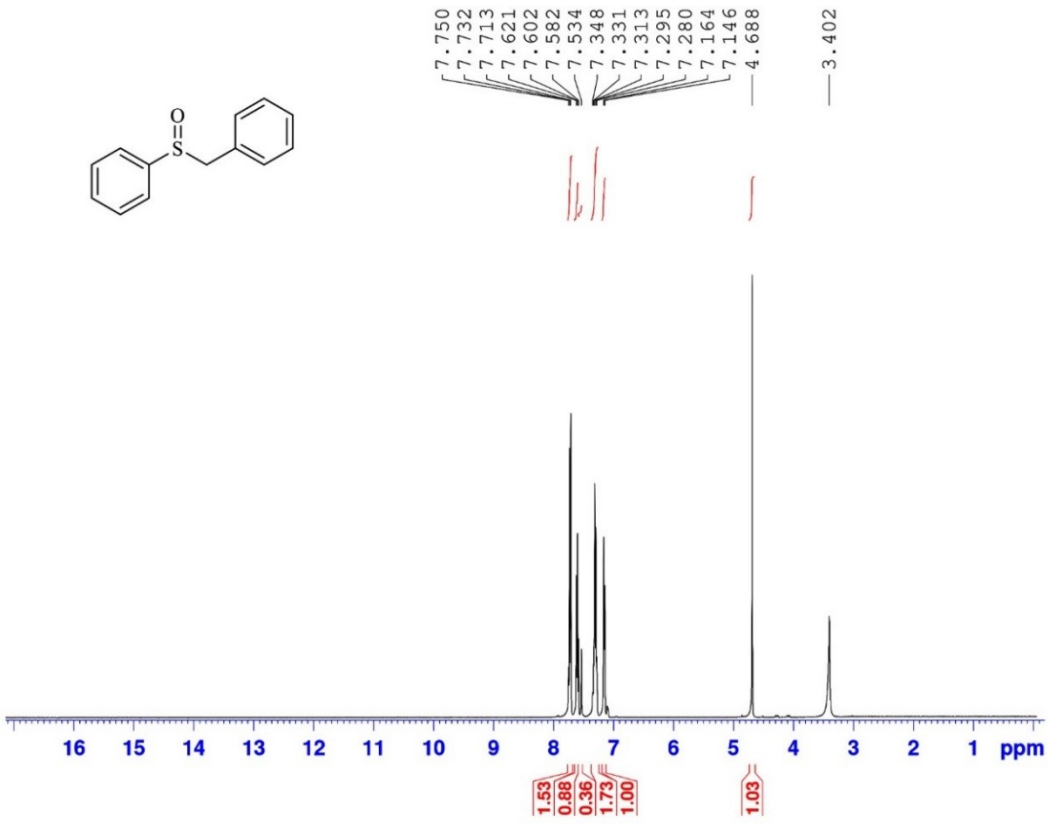


S14. ^{13}CNMR spectrum of dibenzyl sulfoxide in DMSO (table 2, entry 7)

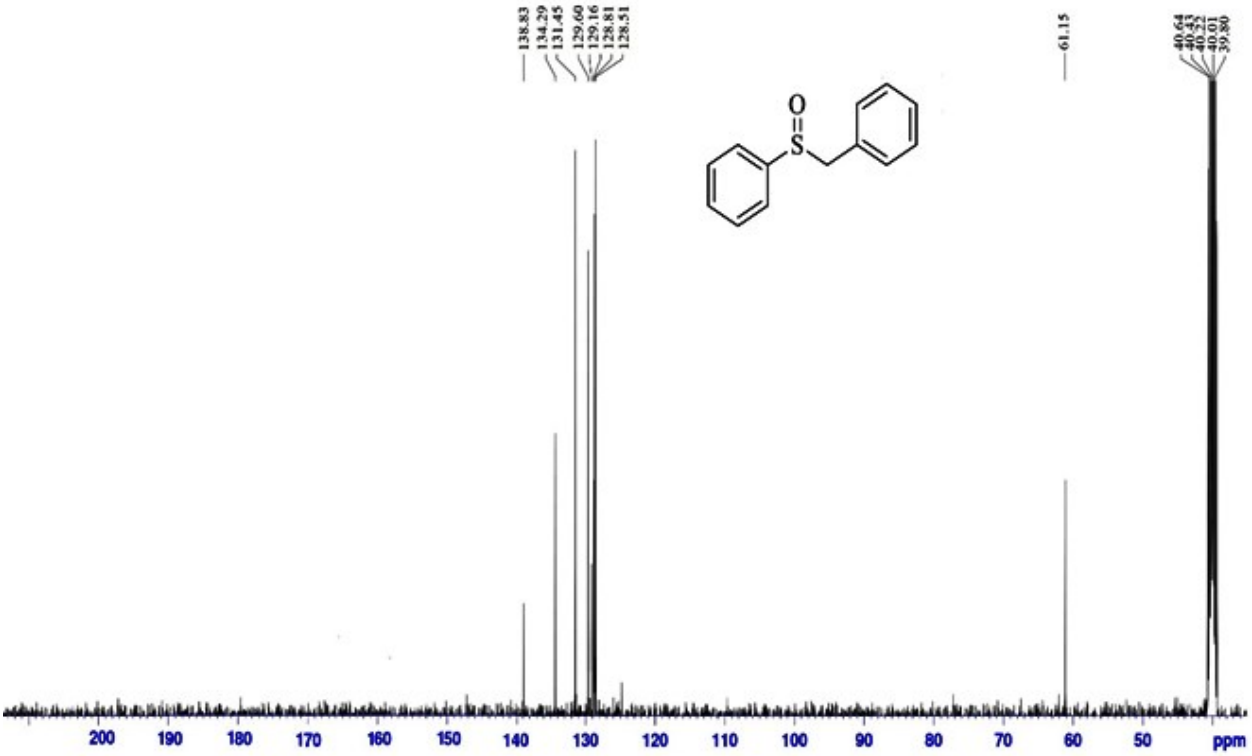
Benzyl phenyl sulfoxide (Table 2, entry 8)



Melting point: 117-119 °C. ^{1}HNMR (400 MHz, DMSO, ppm): δ 4.68 (s, 2H), 7.14-7.34 (m, 4H), 7.53-7.75 (m, 4H). ^{13}CNMR (75 MHz, DMSO, ppm): δ 61.15, 128.51-128.81, 129.16, 129.60-131.45, 138.83. IR (KBr) (cm^{-1}): ν (S═O): 1068.

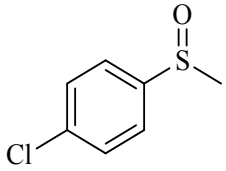


S15. [1]HNMR spectrum of benzyl phenyl sulfoxide in DMSO (Table 2, entry 8)

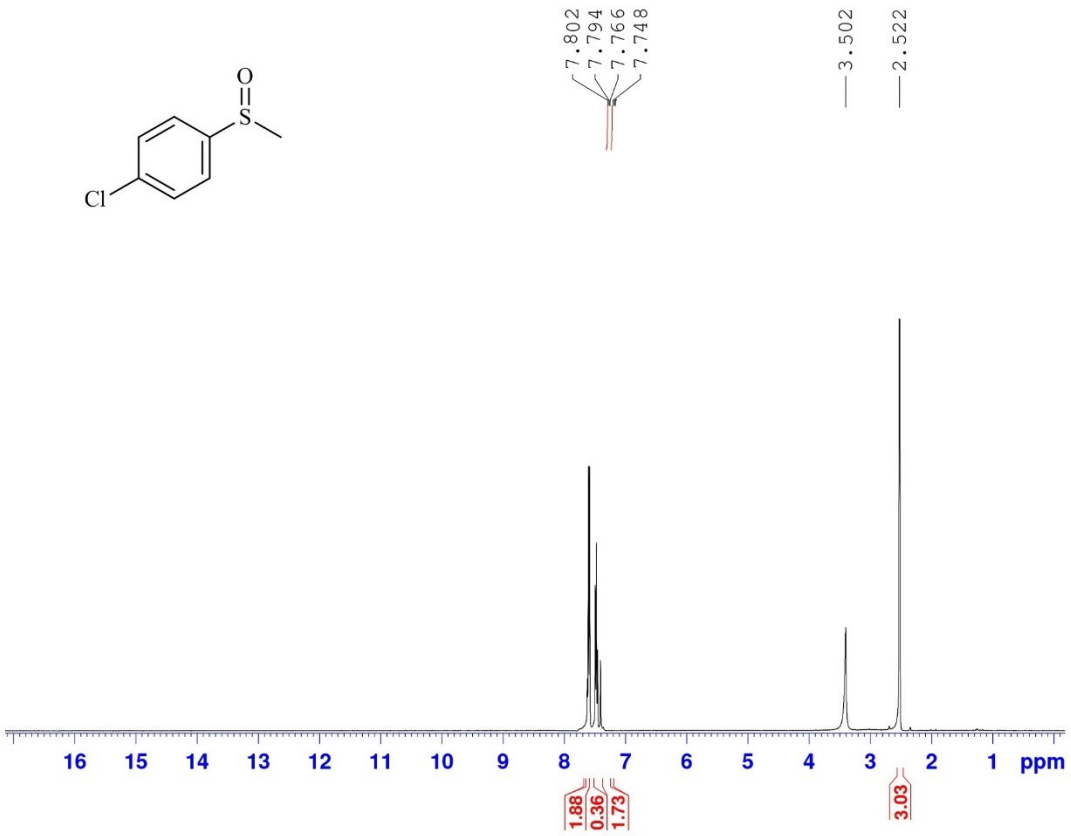


S16. ^{13}CNMR spectrum of benzyl phenyl sulfoxide in DMSO (Table 2, entry 8)

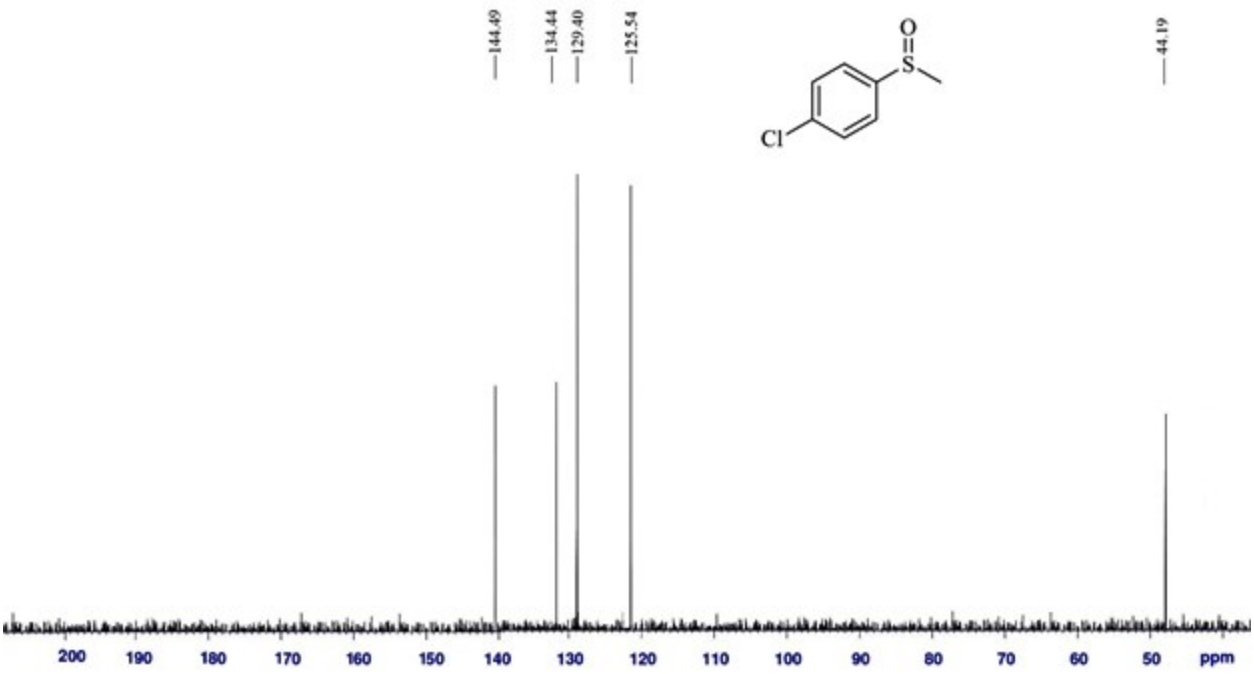
1-chloro-4-(methylsulfinyl)benzene (Table 2, entry 9)



Melting point: Oil. ^{1}HNMR (400 MHz, $CDCl_3$, ppm): δ 2.52 (s, 3H), 7.74-7.80 (m, 4H). ^{13}CNMR (75 MHz, $CDCl_3$, ppm): δ 44.19, 125.54, 129.40, 134.44, 144.49. IR (KBr) (cm^{-1}): ν (S═O): 1036.



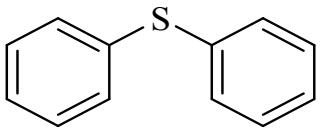
S17. ^{1}HNMR spectrum of 1-chloro-4-(methylsulfinyl) benzene in $CDCl_3$ (Table 2, entry 9)



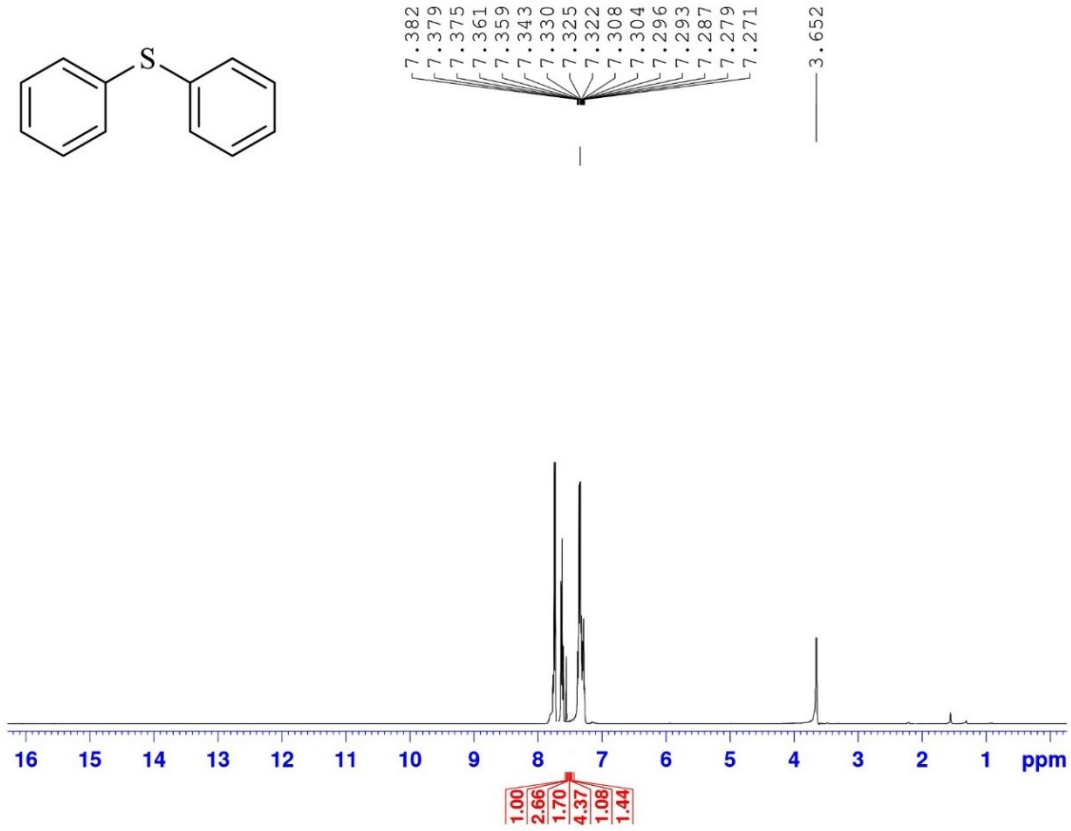
S18. ^{13}CNMR spectrum of 1-chloro-4-(methylsulfinyl) benzene in $CDCl_3$ (Table 2, entry 9)

Spectra data of sulfides from Table 4.

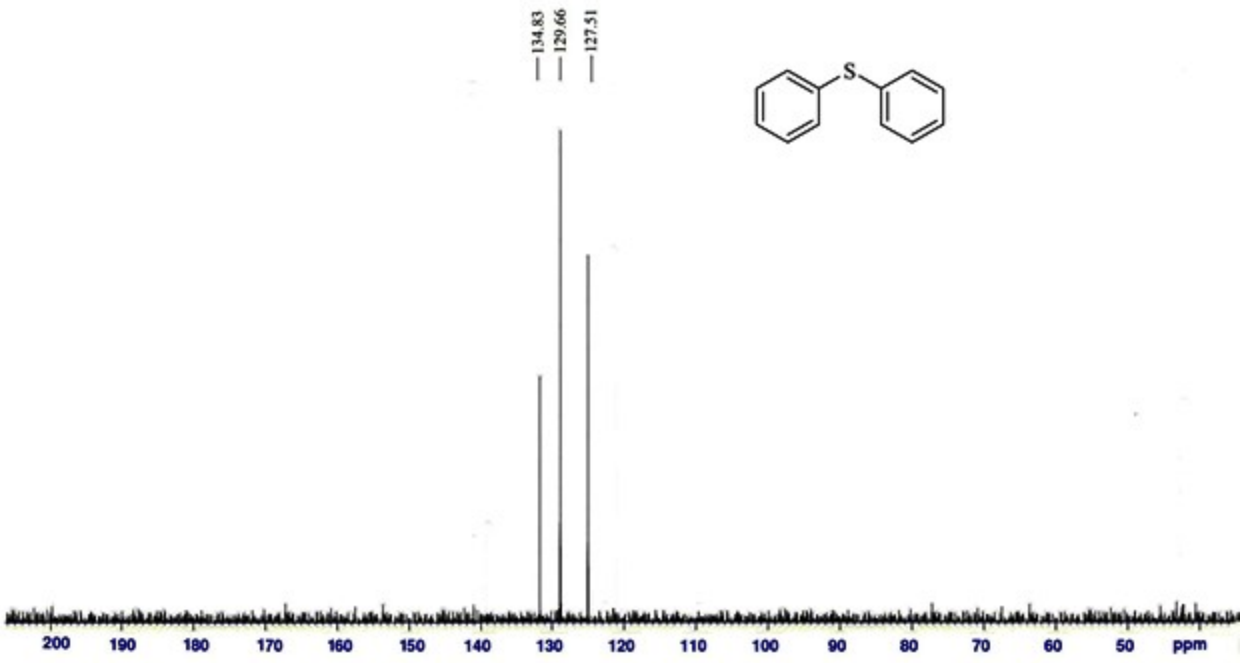
Diphenyl sulfide (Table 4, entries 1-3)



Melting point: Oil. ^{1}HNMR (400 MHz, DMSO, ppm): δ 7.72-7.32 (m, 4H), 7.32–7.38 (m, 4H); ^{13}CNMR (75 MHz, $CDCl_3$, ppm): δ 127.51, 129.66, 134. 83. IR (KBr) (cm^{-1}): 3421, 3080, 1592, 1333, 1108, 1104, 838, 631.

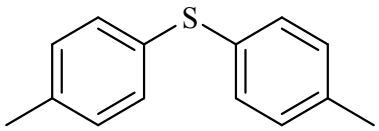


S19. ^{1}H-NMR spectrum of diphenyl sulfide in DMSO (Table 6, entries1-3)

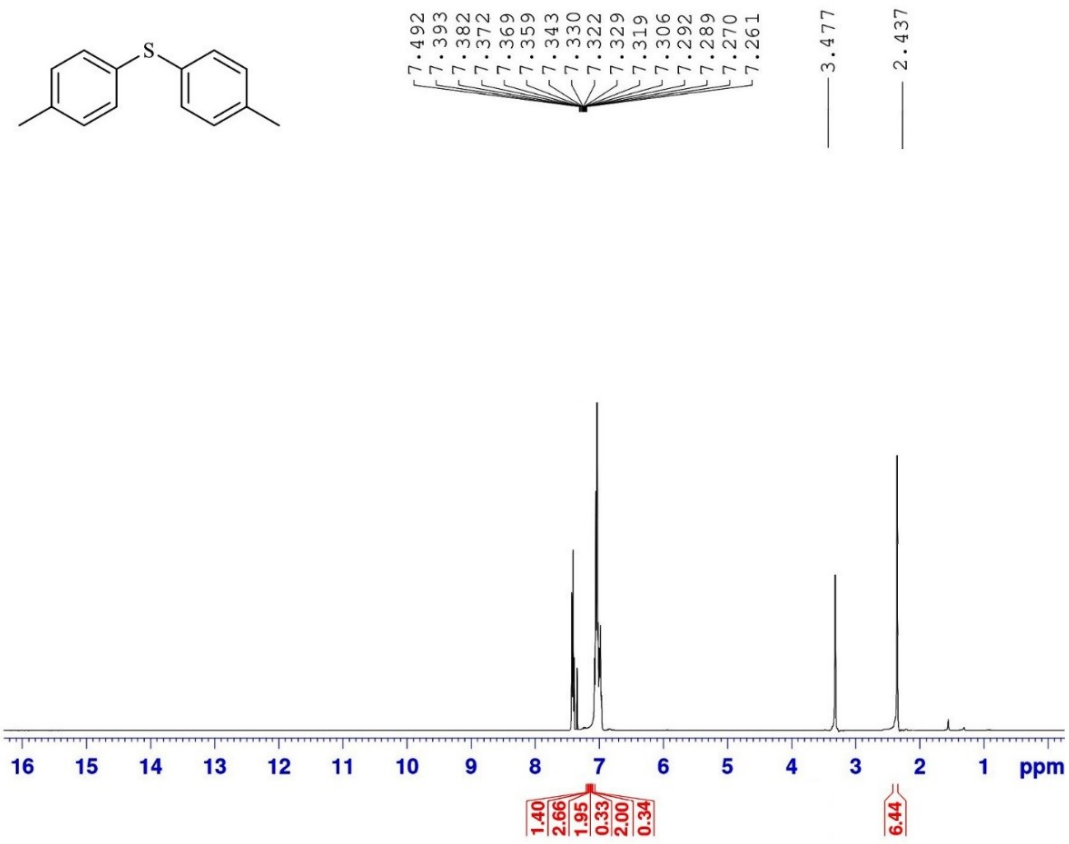


S20. ^{13}CNMR spectrum of diphenyl sulfide in DMSO (Table 6, entries1-3)

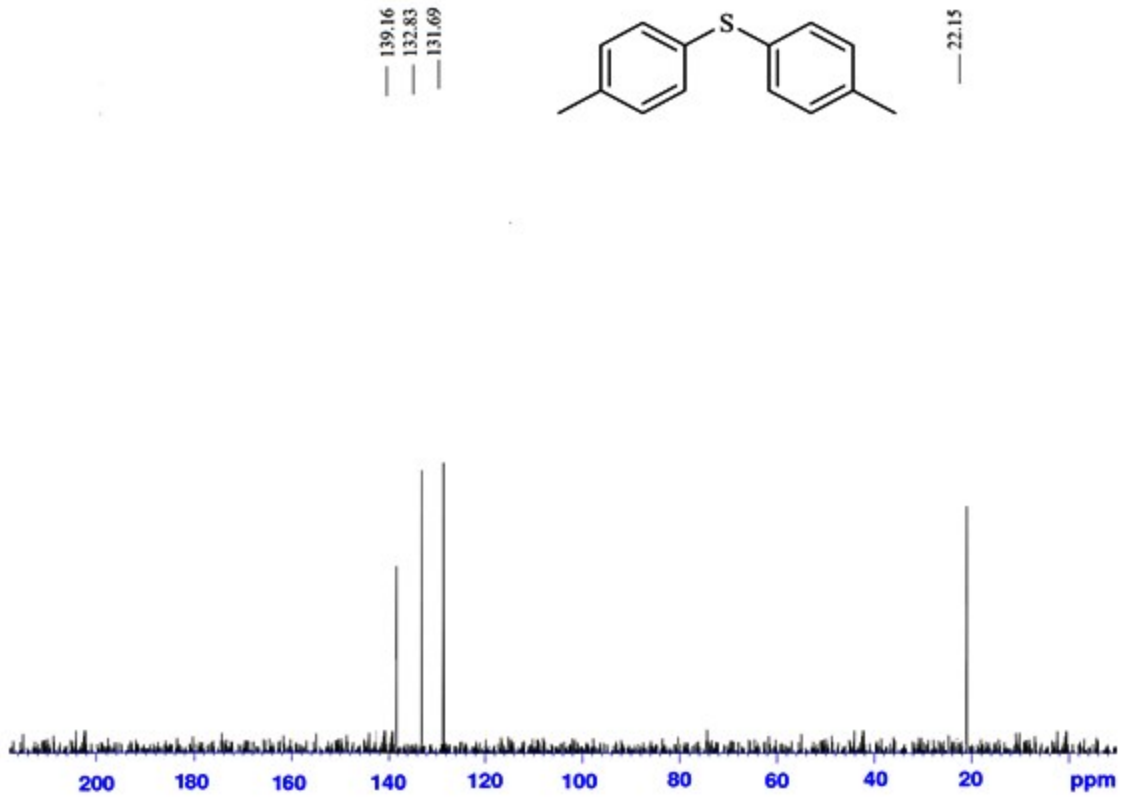
Di-p-tolylsulfane (Table 6, entries 4, and 6)



Melting point: 157-160 °C. ^{1}HNMR (400 MHz, DMSO, ppm): δ 2.43 (s, 6H), 7.26–7.32 (m, 4H), 7.33-7.49 (m, 4H); ^{13}CNMR (400 MHz, $CDCl_3$, ppm): δ 22.15, 131.69, 132. 83, 139.16. IR (KBr) (cm^{-1}): 3333, 2854, 1625, 1425, 1303, 1073, 838, 697.

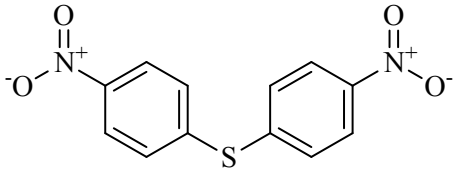


S21. [1]H-NMR spectrum of di-p-tolylsulfane in DMSO (Table 6, entries 4, and 6)

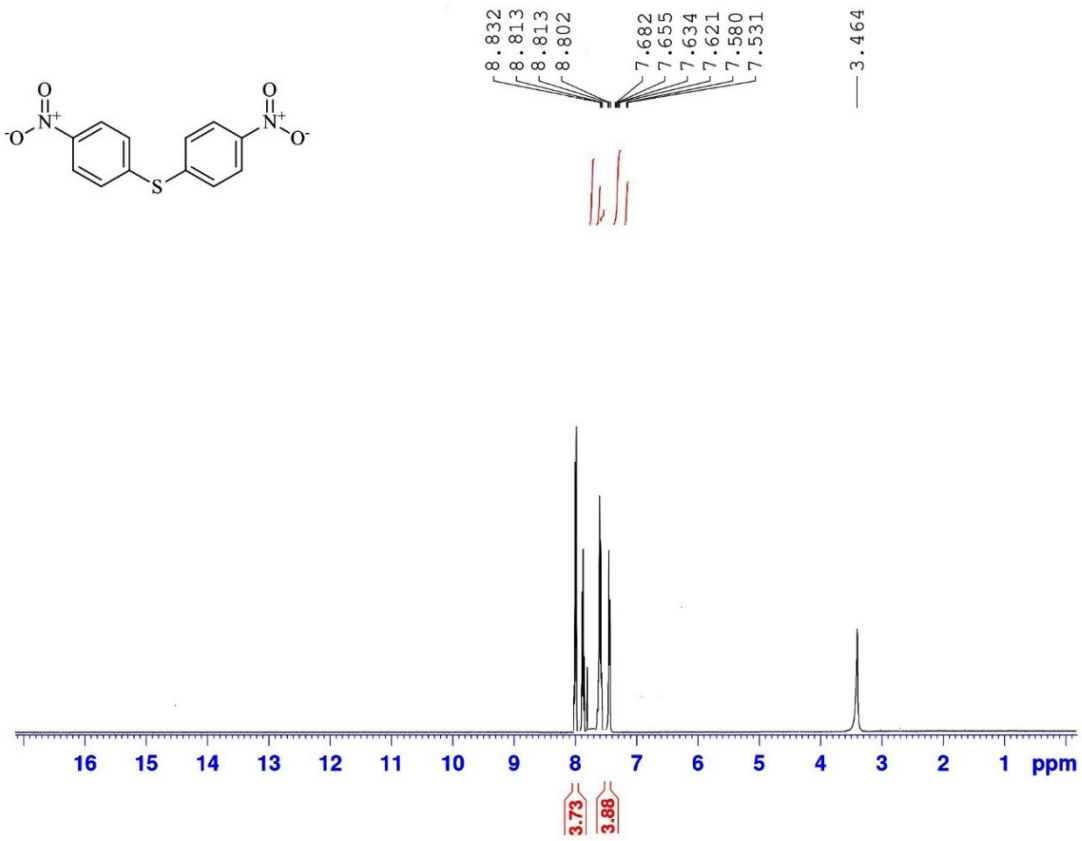


S22. ^{13}CNMR spectrum of di-p-tolylsulfane in DMSO (Table 6, entries 4 and 6)

Bis(4-nitrophenyl)sulfane (Table 4, entries 5, 7, and 8)

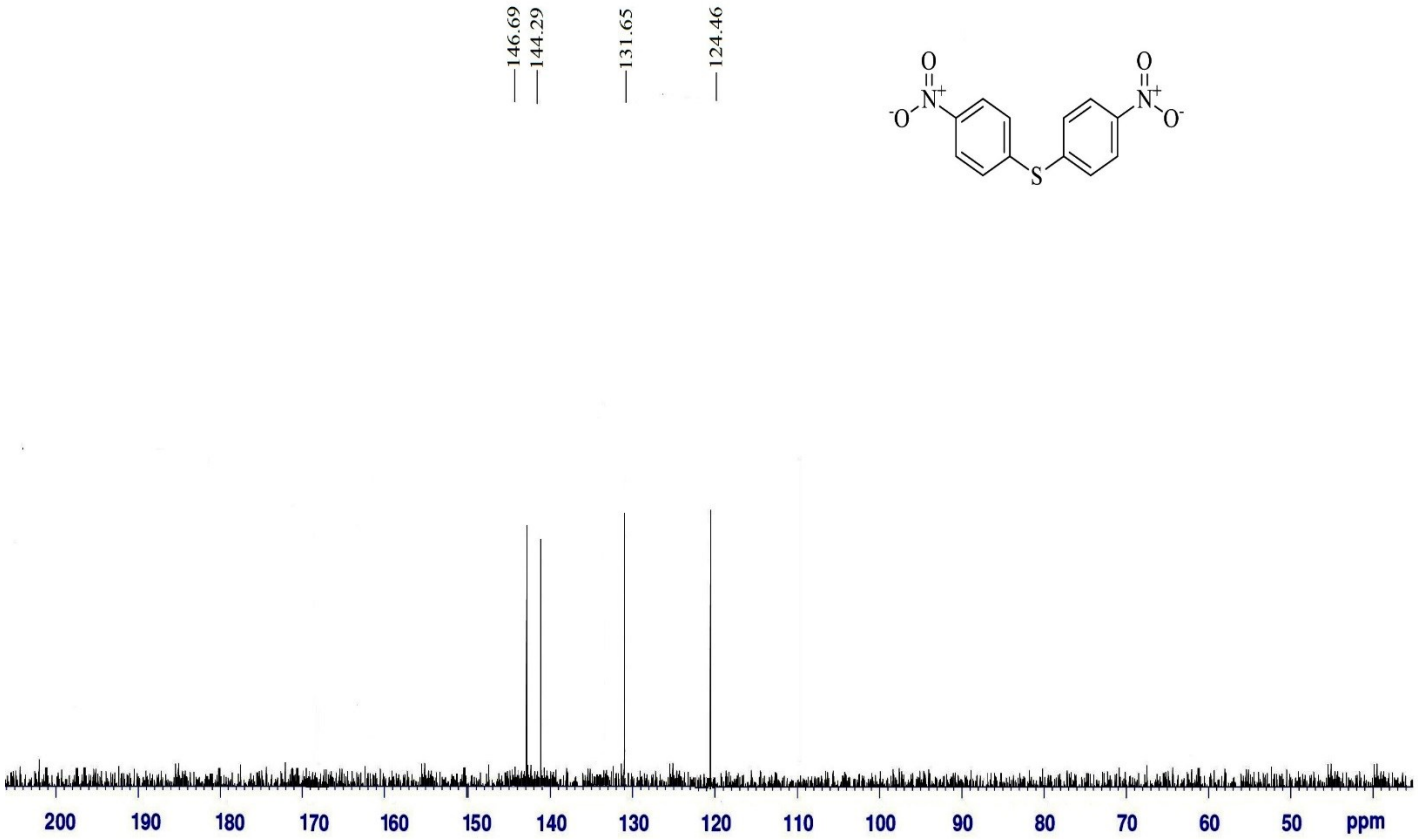


Melting point: 157-160 °C. ^{1}HNMR (400 MHz, DMSO, ppm): δ 7.53–7.68 (m, 4H), 8.80–8.83 (m, 4H); ^{13}CNMR (75 MHz, $CDCl_3$, ppm): δ 124.46, 131.66, 131.69, 144. 29, 146.69. IR (KBr) (cm^{-1}): 3223, 2828, 1595, 1410, 1325, 1085, 898, 650.



S23

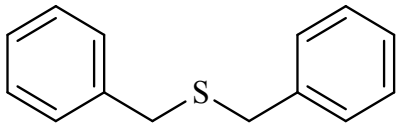
. [1]H-NMR spectrum of diphenyl sulfide in DMSO (Table 4, entries 5, 7 and 8)

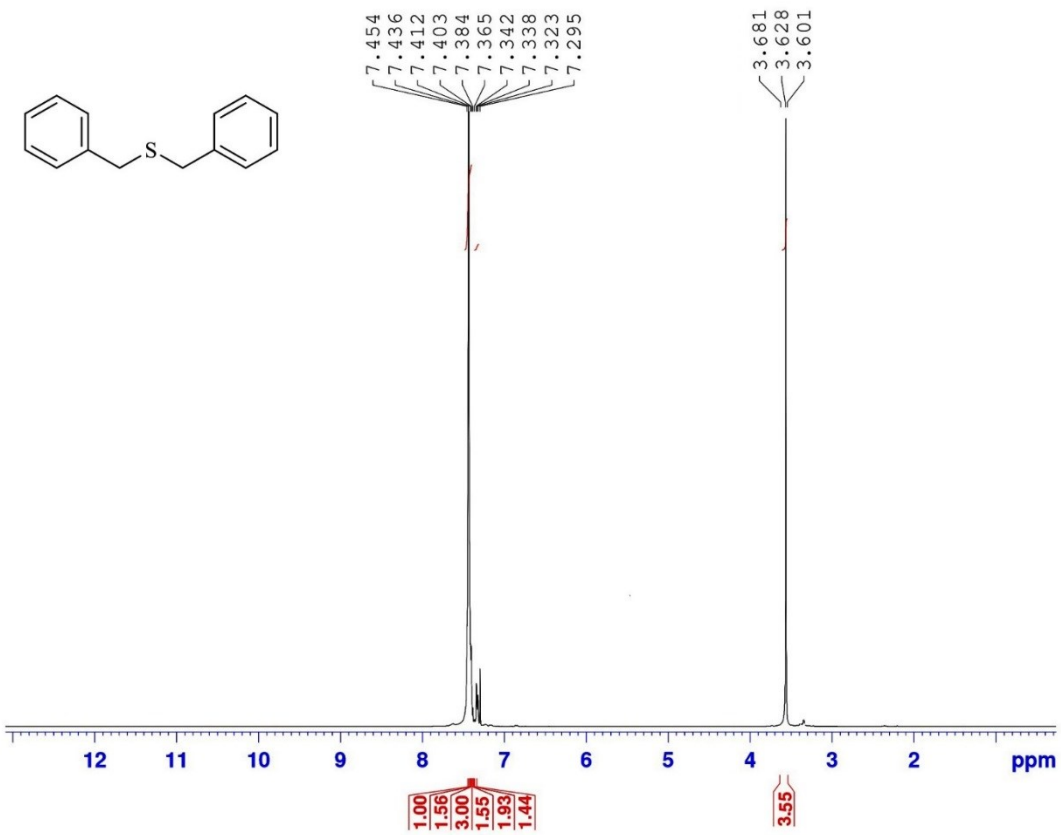


S24. ^{13}CNMR spectrum of diphenyl sulfide in DMSO (Table 4, entries 5, 7 and 8)

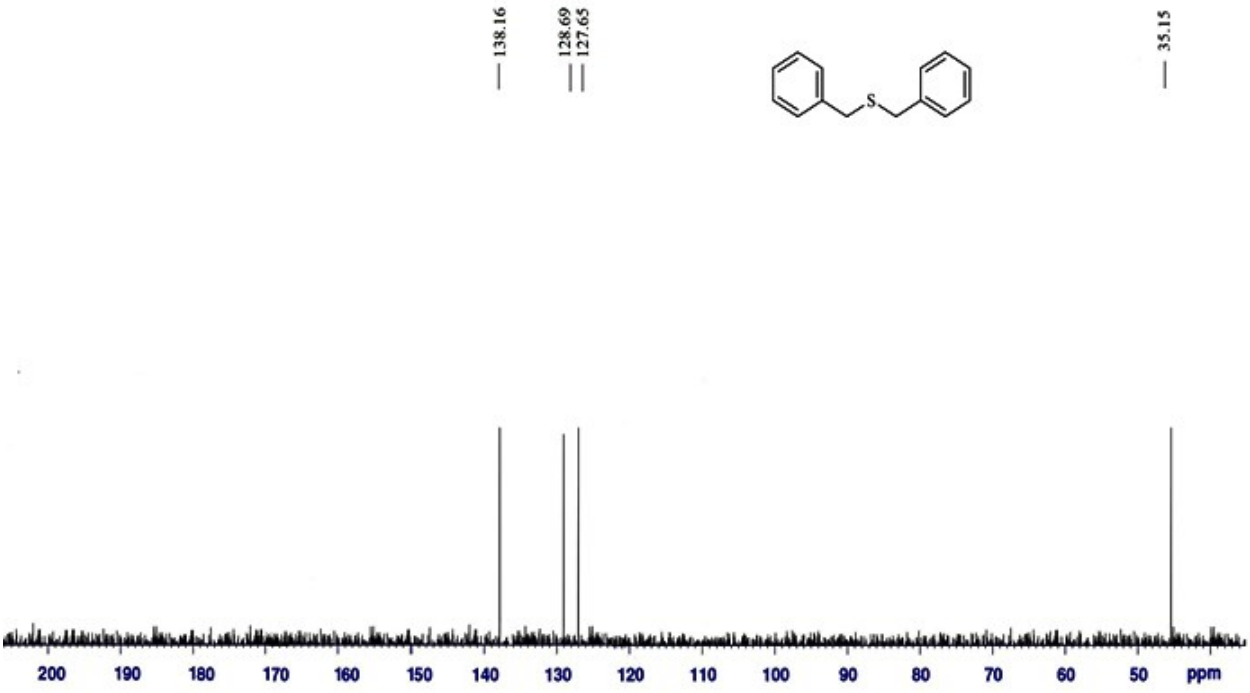
Dibenzylsulfane (Table 2, entry 9)

Melting point: 44-46 °C. ^{1}HNMR (300 MHz, $CDCl_3$, ppm): δ 3.60 (m, 4H), 7.29-7.36 (m, 5H), 7.38– 7.45 (m, 5H); ^{13}CNMR (400 MHz, $CDCl_3$, ppm): δ 35.15, 127.65, 128.69, 138.16. IR (KBr) (cm^{-1}): 3353, 2950, 2844, 1635s, 1415, 1313, 1068, 850, 607.



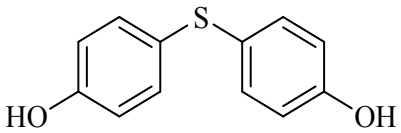


S25. ^{1}H-NMR spectrum of dibenzylsulfane in $CDCl_3$ (Table 2, entry 9)

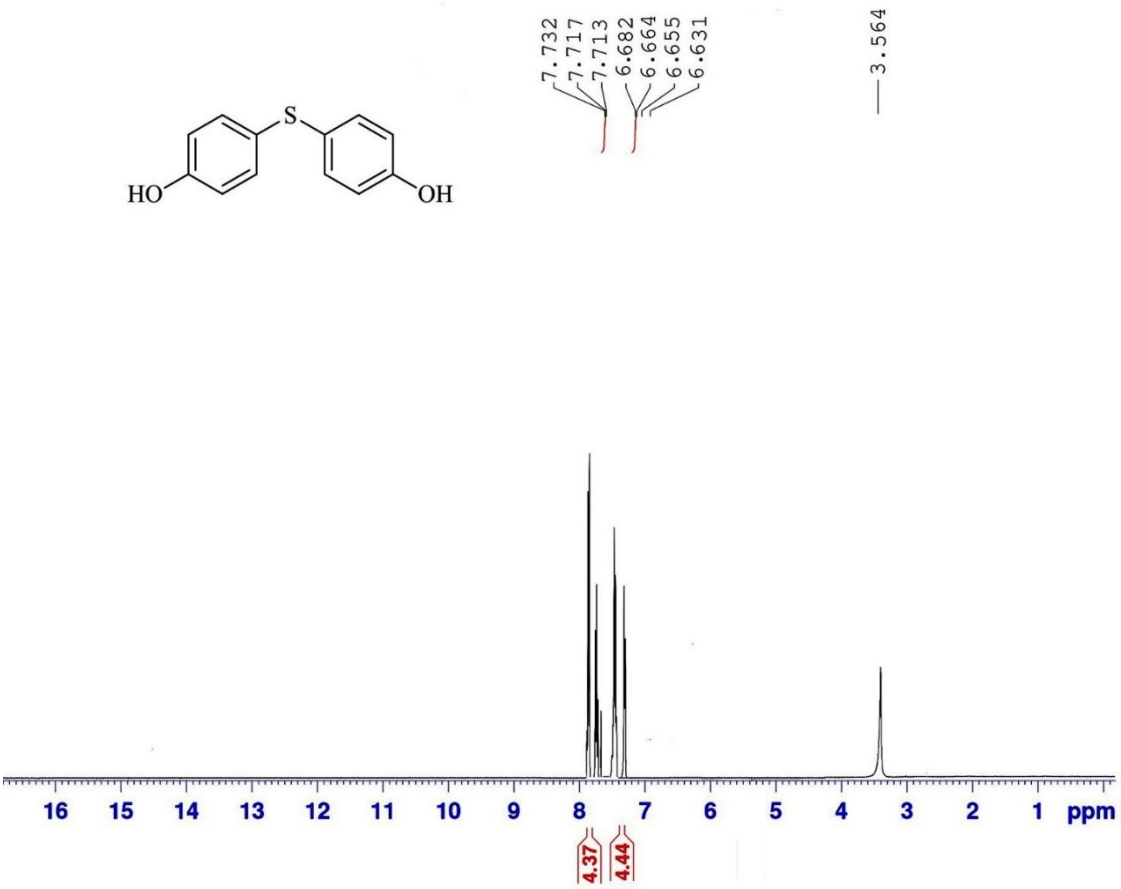


S26. ^{13}CNMR spectrum of dibenzylsulfane in $CDCl_3$ (Table 2, entry 9)

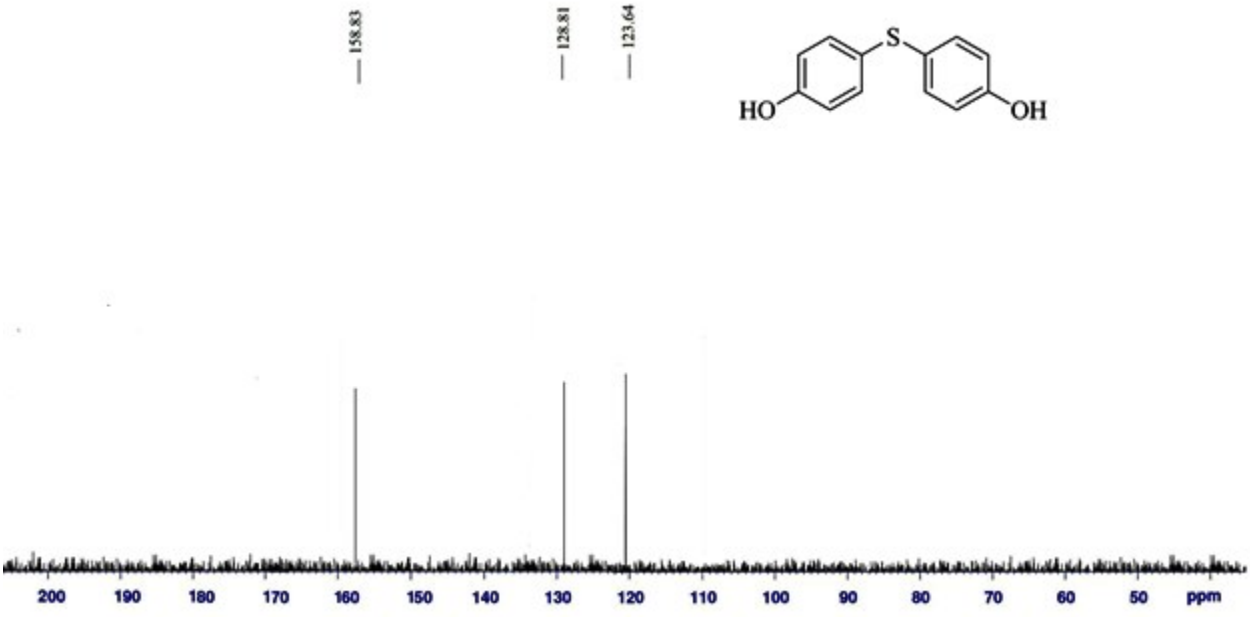
4, 4'-thiodiphenol (Table 4, entry 10)



Melting point: 150-153 °C. ^{1}HNMR (400 MHz, $CDCl_3$, ppm): δ 6.63-6.68 (m, 4H), 7.713-7.732 (m, 4H); ^{13}CNMR (75 MHz, $CDCl_3$, ppm): δ 123.64, 128.81, 158.83. IR (KBr) (cm^{-1}): 3421, 2822, 1625, 1498, 1117, 933, 797, 501.



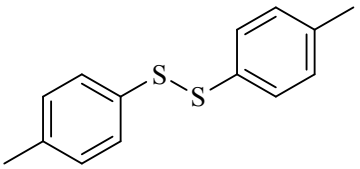
S27. ^{1}H-NMR spectrum of 2, 2′- disulfanediyldiethanol in $CDCl_3$ (Table 4, entry 10)



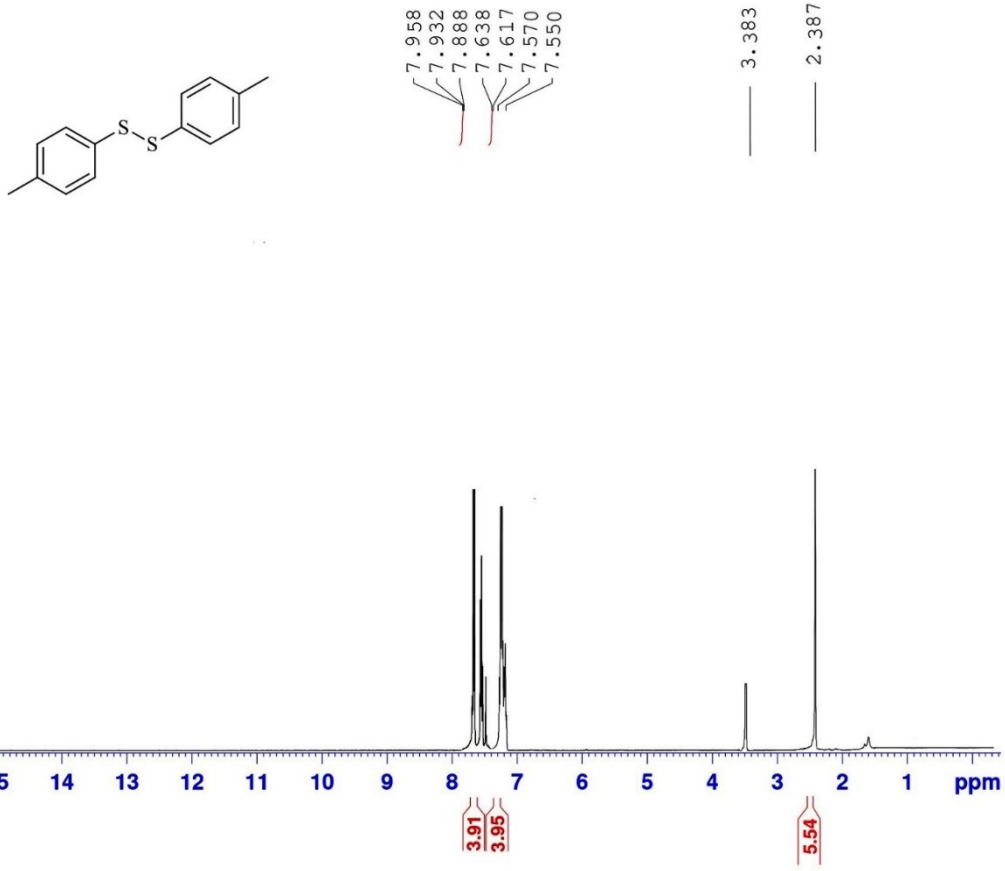
S28. ^{13}CNMR spectrum of 2, 2′- disulfanediyldiethanol in $CDCl_3$ (Table 4, entry 10)

Spectra data of disulfides from Table 6.

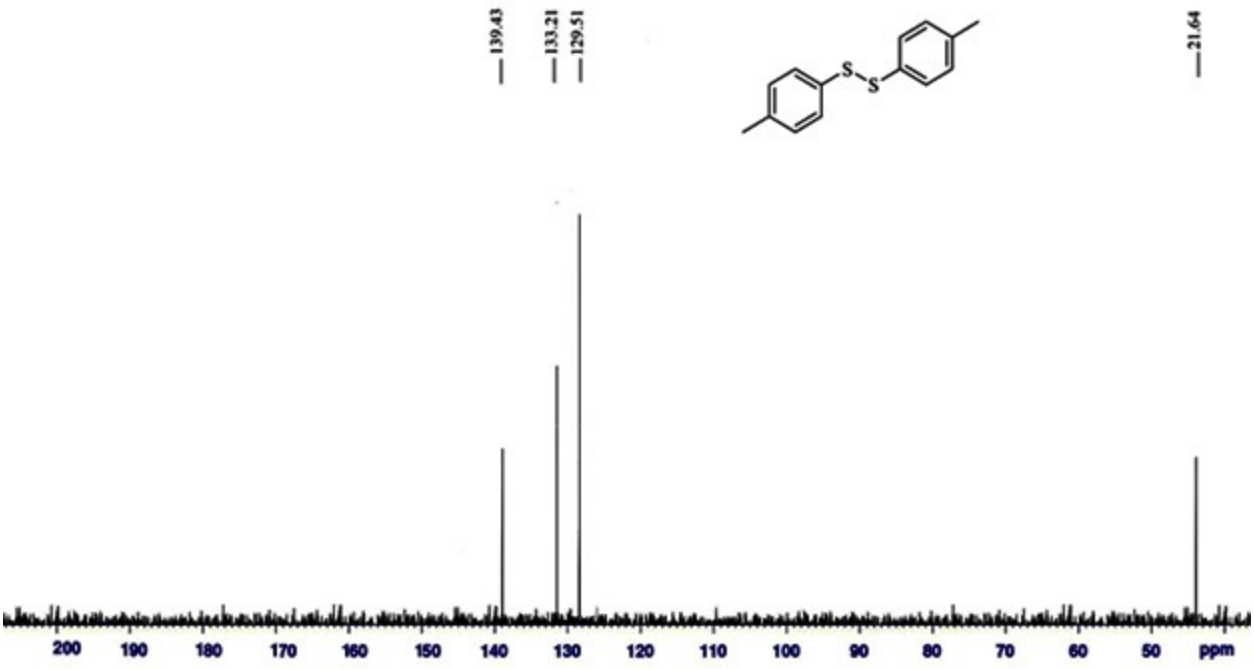
1, 2-di-p-tolyldisulfane (Table 6, entry 1)



Melting point: 38-40 °C. ^{1}HNMR (400 MHz, DMSO, ppm): δ 2.38 (s, 6H) ,7.55-7.63 (m, 4H), 7.88– 7.95 (m, 4H). ^{13}CNMR (100 MHz, DMSO, ppm): δ 21.64, 129.51, 133.21, 139.43. IR (KBr) (cm^{-1}): ν (S-S): 1065.

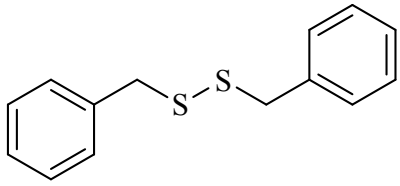


S29. ^{1}HNMR spectrum of 1, 2- di-p-tolyldisulfane in DMSO (Table 6, entry 1)

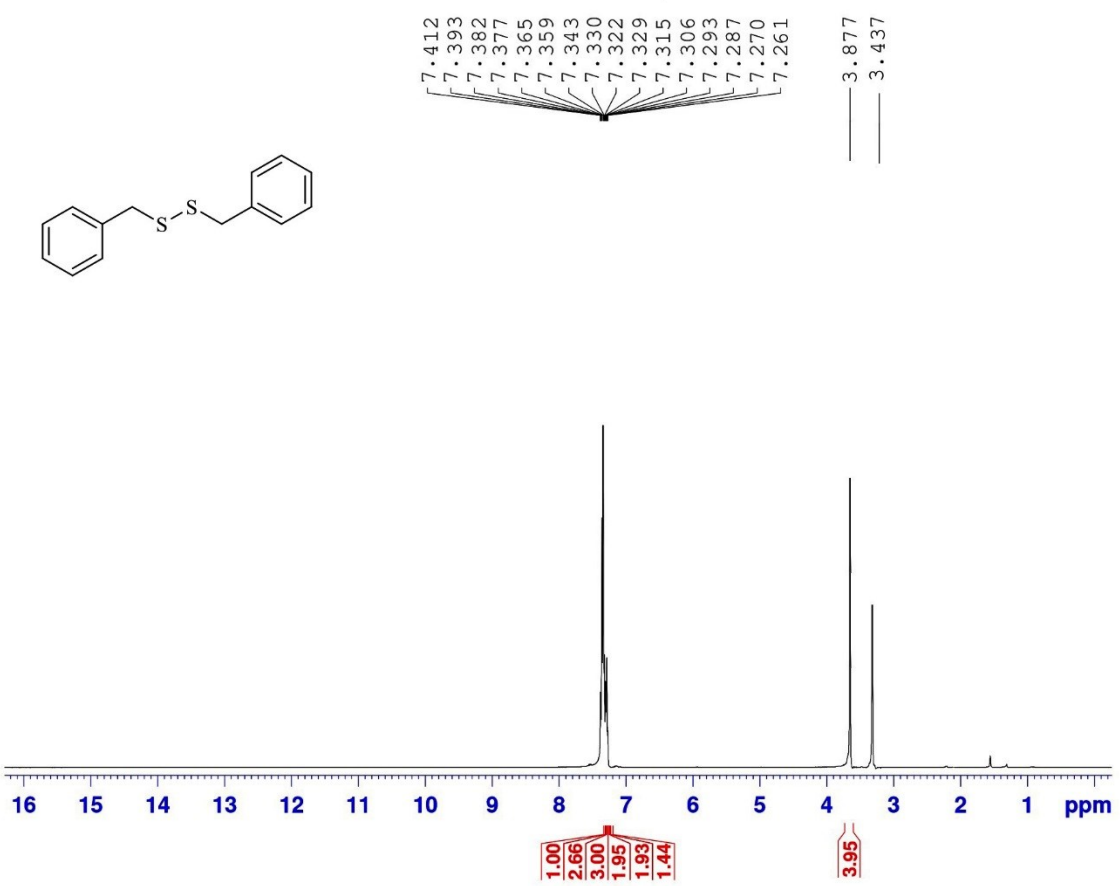


S30. ^{13}CNMR spectrum of 1, 2- di-p-tolyldisulfane in DMSO (Table 6, entry 1)

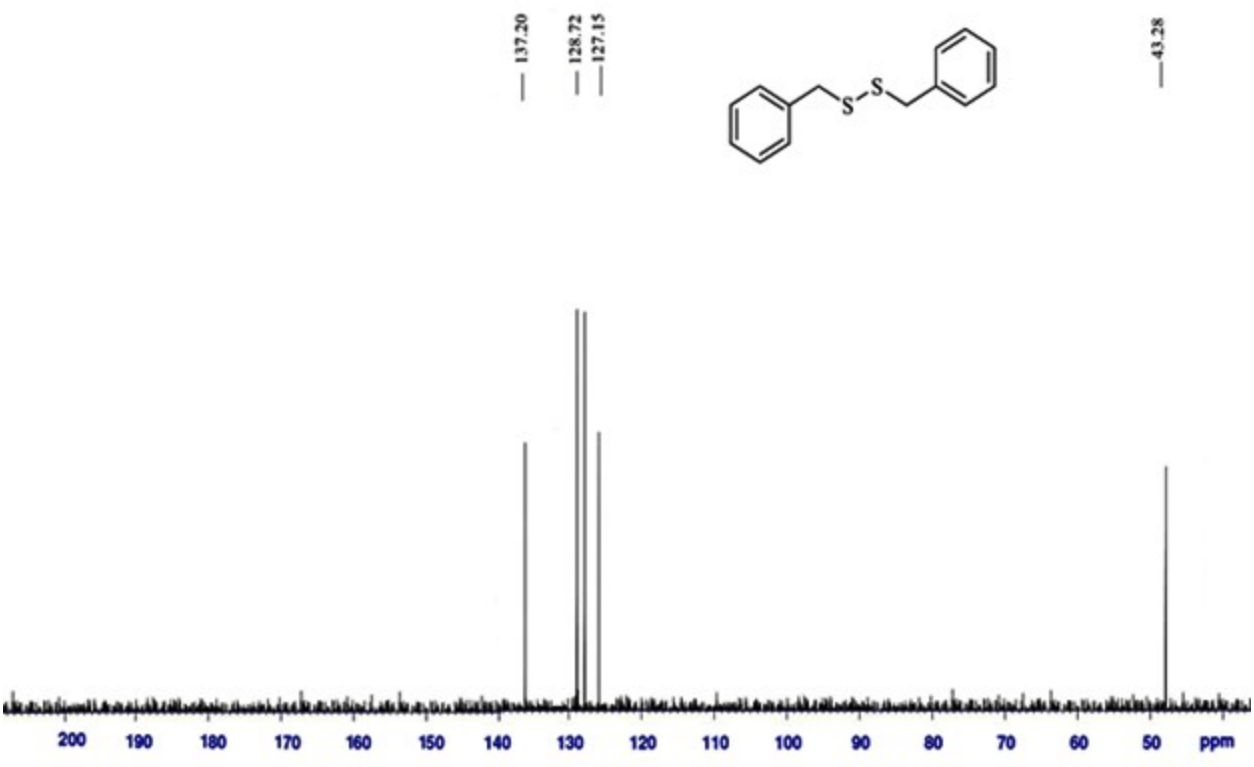
1, 2-dibenzyldisulfane (Table 6, entry 2)



Melting point: 58-60 °C. ^{1}HNMR (300 MHz, DMSO, ppm): δ 3. 377 (s, 4H) ,7.261-7.412 (m, 4H); ^{13}CNMR (100 MHz, DMSO, ppm): δ 43.28, 127.15, 128.72, 137.20. IR (KBr) (cm^{-1}): ν (S-S): 1069.

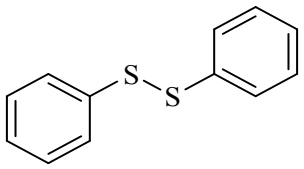


S31. [1]H-NMR spectrum of 1, 2- dibenzyldisulfane in DMSO (Table 6, entry 2)

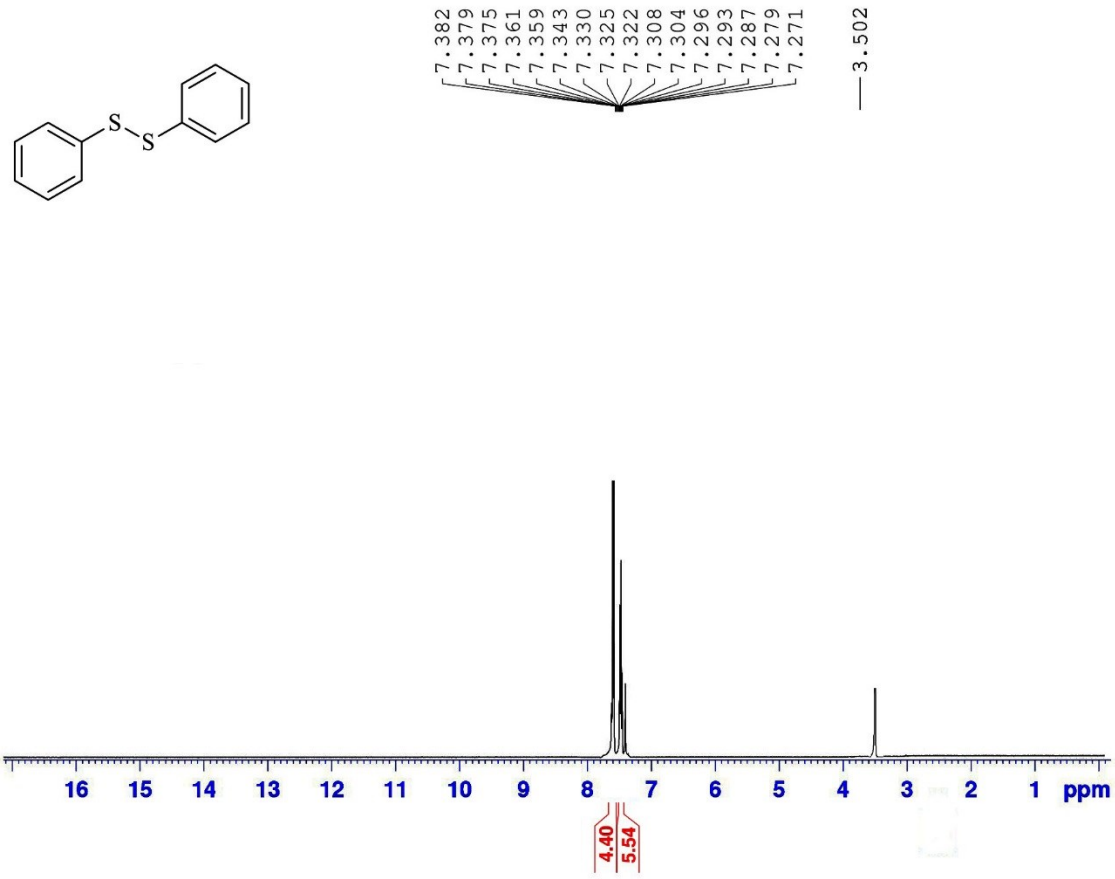


S32. ^{13}CNMR spectrum of 1, 2- dibenzyldisulfane in DMSO (Table 6, entry 2)

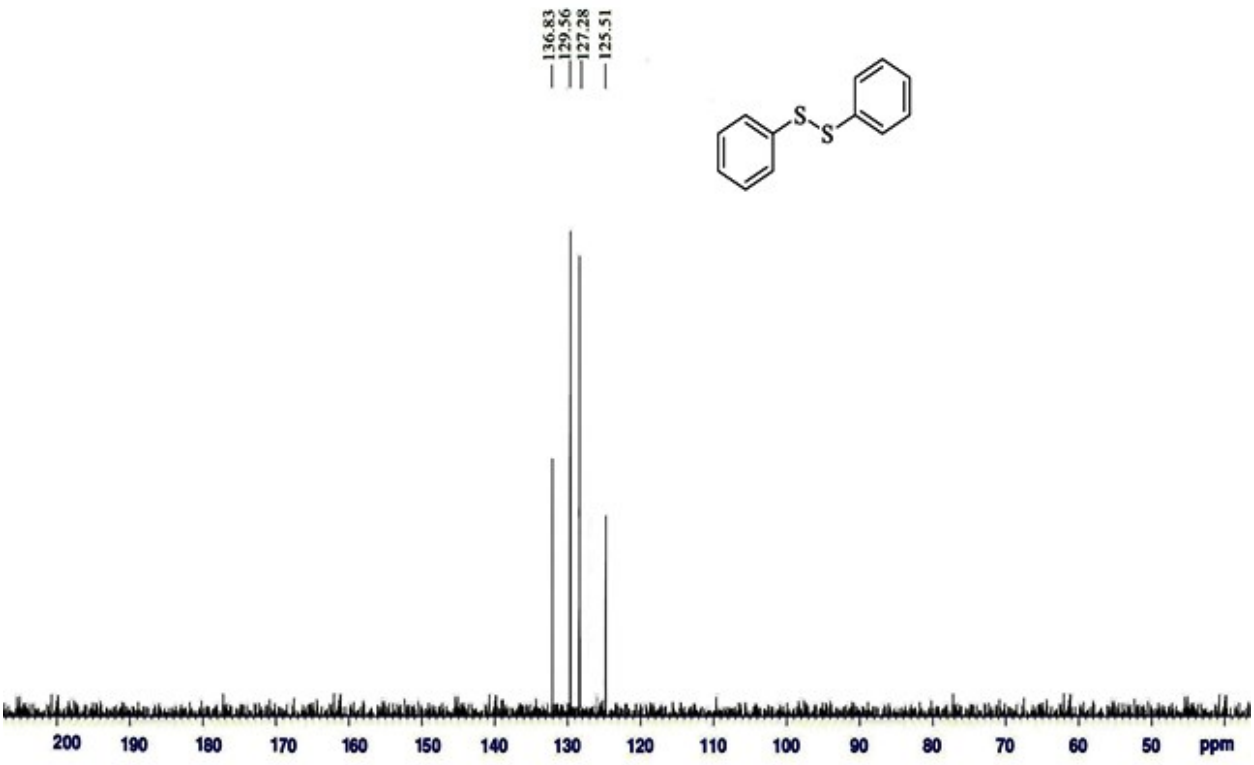
1, 2-diphenyldisulfane (Table 6, entry 3)



Melting point: 58-60 °C. ^{1}HNMR (300 MHz, DMSO, ppm): δ 7.217-7.330 (m, 6H) ,7.343-7.382 (m, 4H); ^{13}CNMR (100 MHz, DMSO, ppm): δ 125.51, 127.28, 129.56 , 136.83. IR (KBr) (cm^{-1}): ν (S-S): 1059.

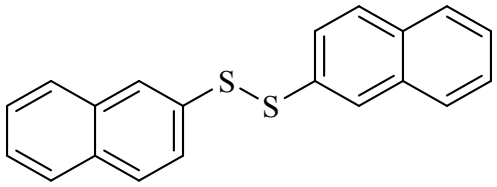


S33. [1]H-NMR spectrum of 1, 2- diphenyldisulfane in DMSO (Table 6, entry 3)

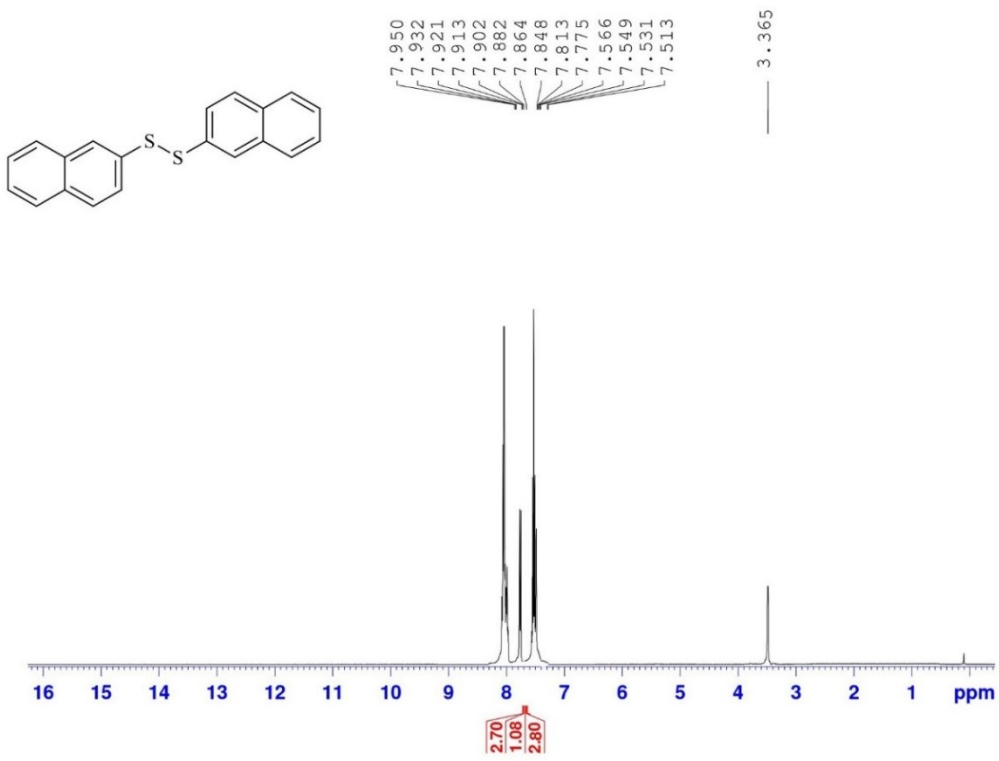


S34. ^{13}CNMR spectrum of 1, 2- diphenyldisulfane in DMSO (Table 6, entry 3)

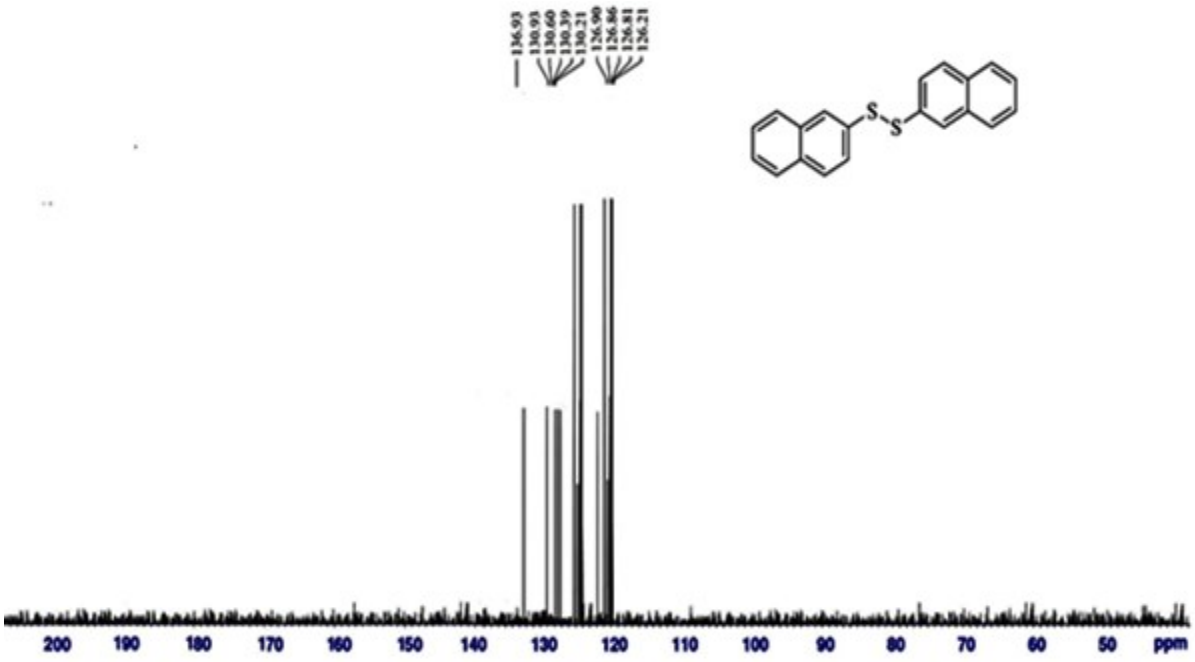
1, 2-di(naphthalen-2-yl)disulfane (Table 6, entry 4)



Melting point: 134-136°C. ^{1}HNMR (400 MHz, DMSO, ppm): δ 7.513-7.775 (m, 6H) ,7.813-7.848 (m, 2H), 7.864– 7.950 (m, 6H); ^{13}CNMR (100 MHz, DMSO, ppm): δ 126.21-126.81, 126.86-126.90, 130.21-130.39, 130.60-130.93. IR (KBr) (cm^{-1}): IR (KBr) (cm^{-1}): ν (S-S): 1033.

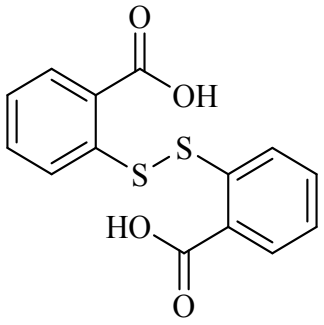


S35. [1]H-NMR spectrum of 1, 2-di(naphthalen-2-yl)disulfane in DMSO (Table 6, entry 4)

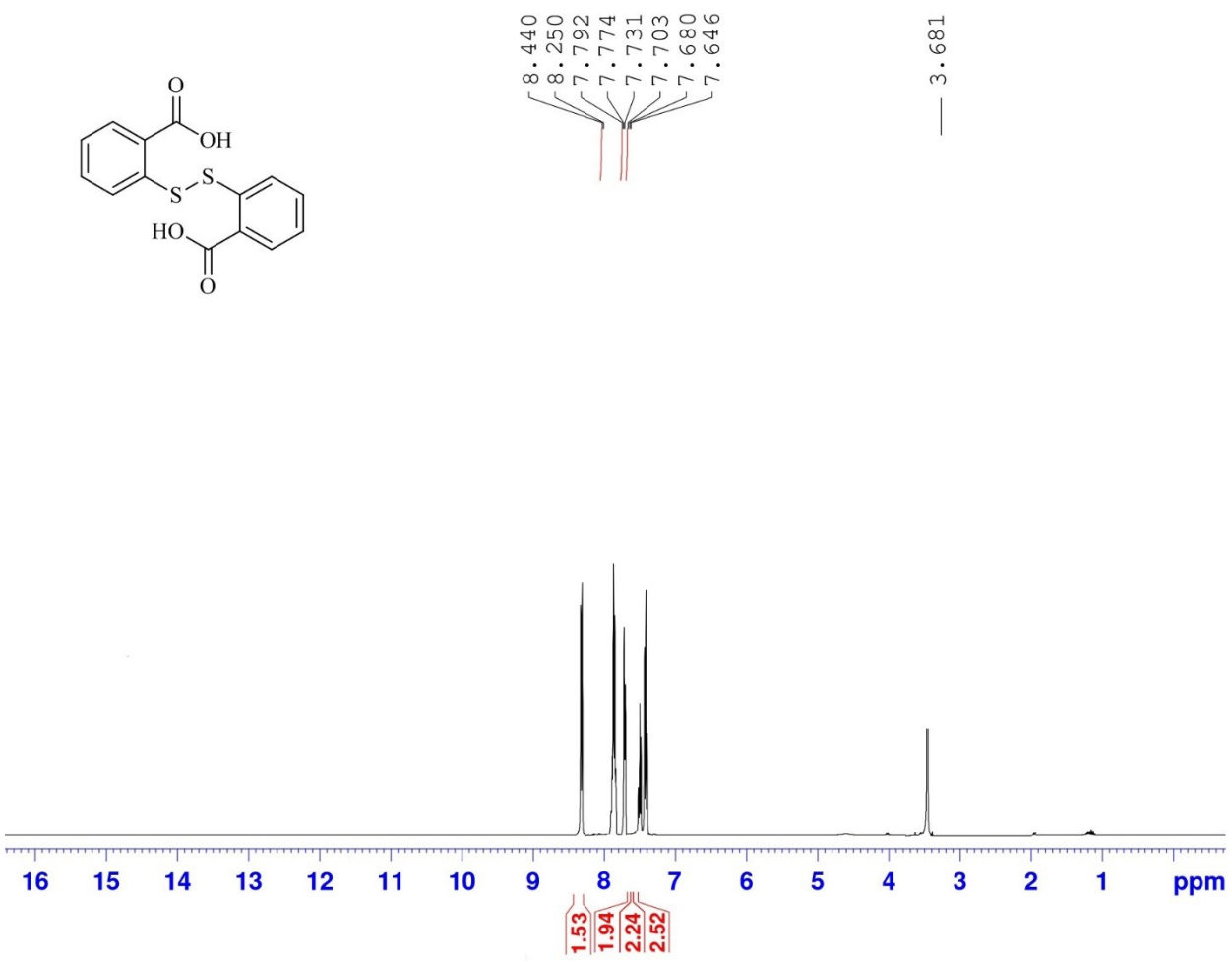


S36. [13]CNMR spectrum of 1, 2-di(naphthalen-2-yl)disulfane in DMSO (Table 6, entry 4)

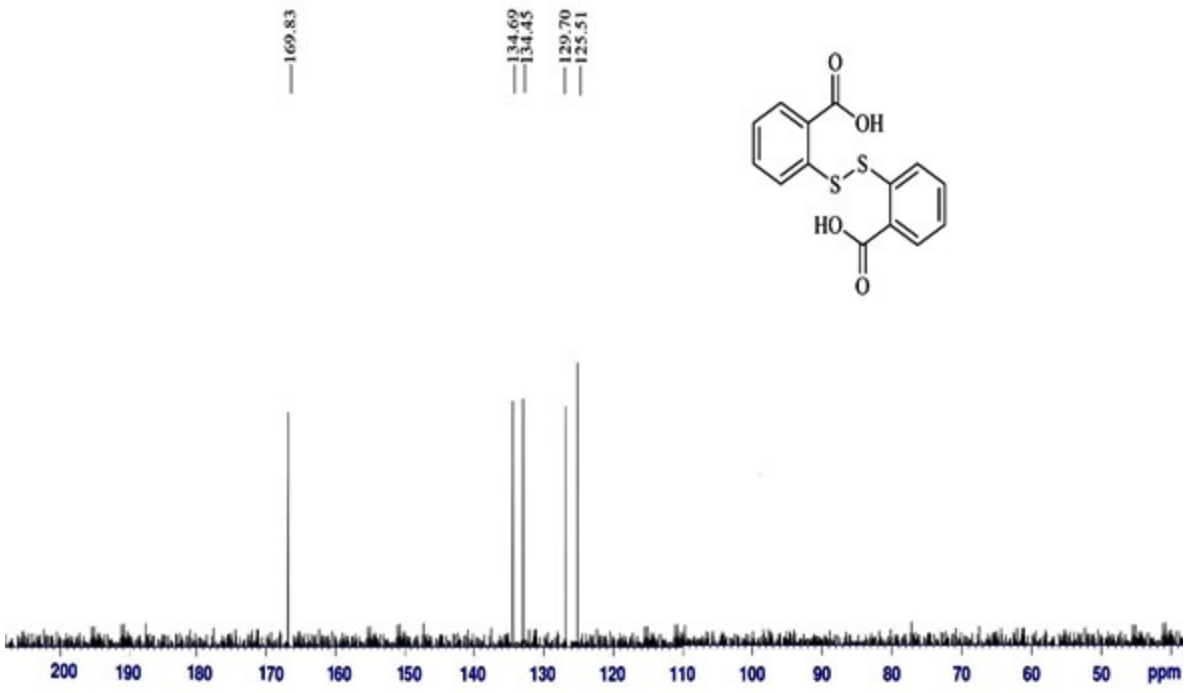
2, 2′-disulfanediyldibenzoic acid (Table 6, entry 5)



Melting point: 276-278 °C. ^{1}HNMR (400 MHz, DMSO, ppm): δ 7.64-7.68 (m, 4H) ,7.70-7.79 (m, 4H), 8.82– 8.44 (m, 2H); ^{13}CNMR (100 MHz, $CDCl_3$, ppm): δ 125.51, 129.70, 134.45, 169.83. IR (KBr) (cm^{-1}): ν (S-S): 1035.

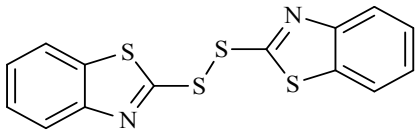


S37. [1]H-NMR spectrum of 2, 2′- disulfanediyldibenzoic acid in DMSO (Table 6, entry 5)

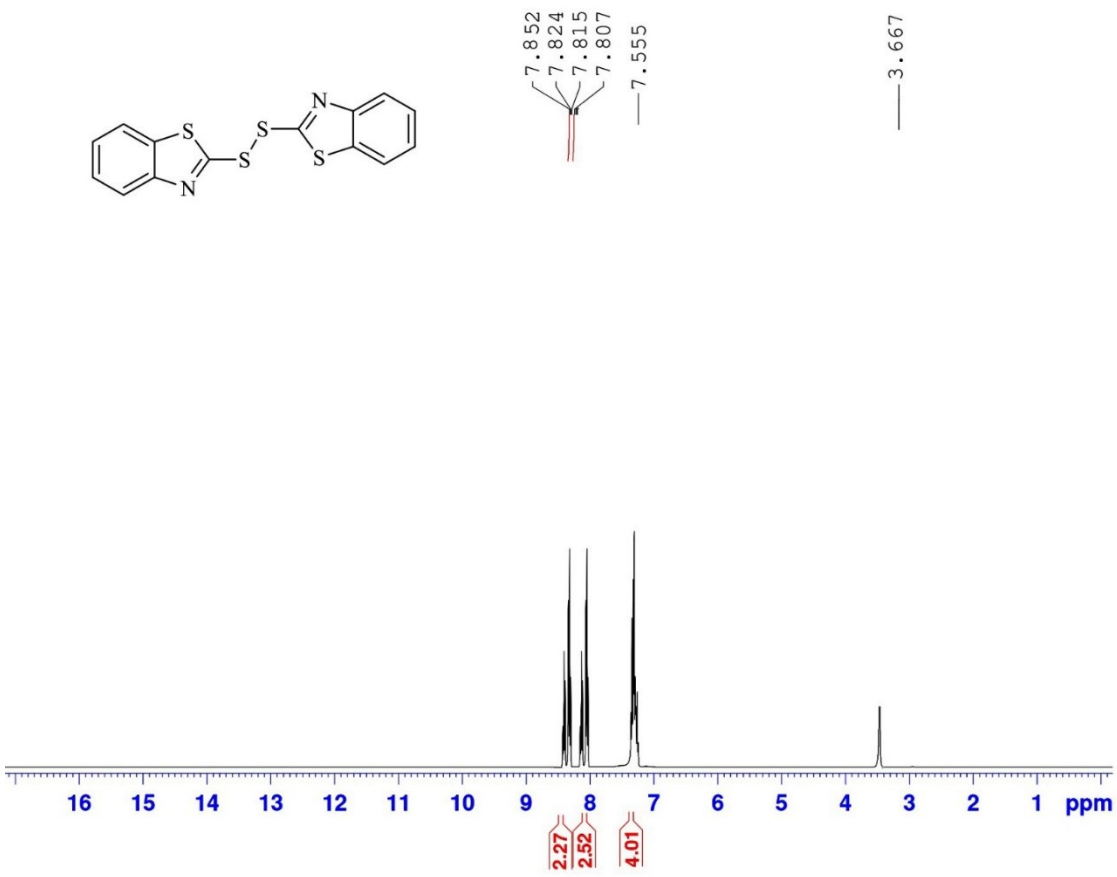


S38. ^{13}CNMR spectrum of 2, 2′- disulfanediyldibenzoic acid in DMSO (Table 6, entry 5)

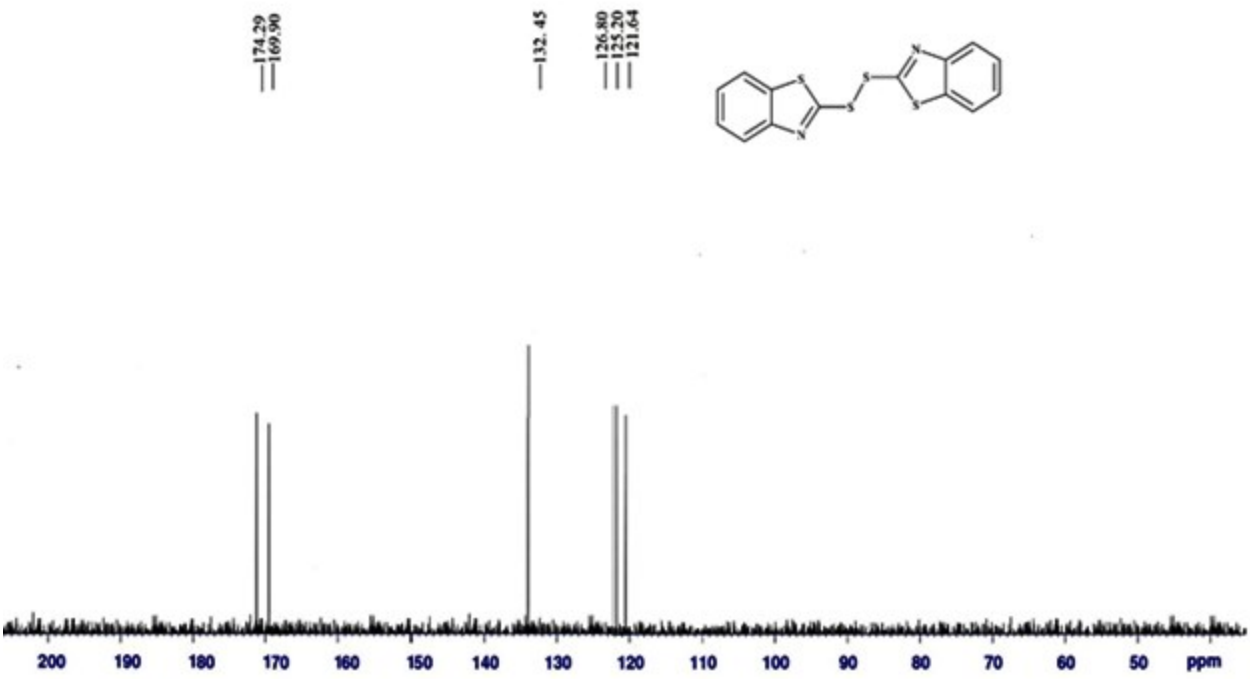
1, 2-bis(benzo[d]thiazol-2-yl)disulfane (Table 6, entry 6)



Melting point: Oil. ^{1}HNMR (400 MHz, $CDCl_3$, ppm): δ 7.555 (m, 4H) ,7.807-7.815 (m, 2H), 7.824– 7.852 (m, 2H); ^{13}CNMR (100 MHz, $CDCl_3$, ppm): δ 121.64, 125.20 , 135.45, 169.90, 174.29. IR (KBr) (cm^{-1}): ν (S-S): 1039.

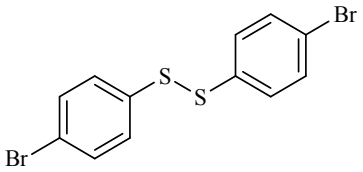


S39. ^{1}HNMR spectrum of 1, 2- bis(benzo[d]thiazol-2-yl)disulfane in $CDCl_3$ (Table 6, entry 6)

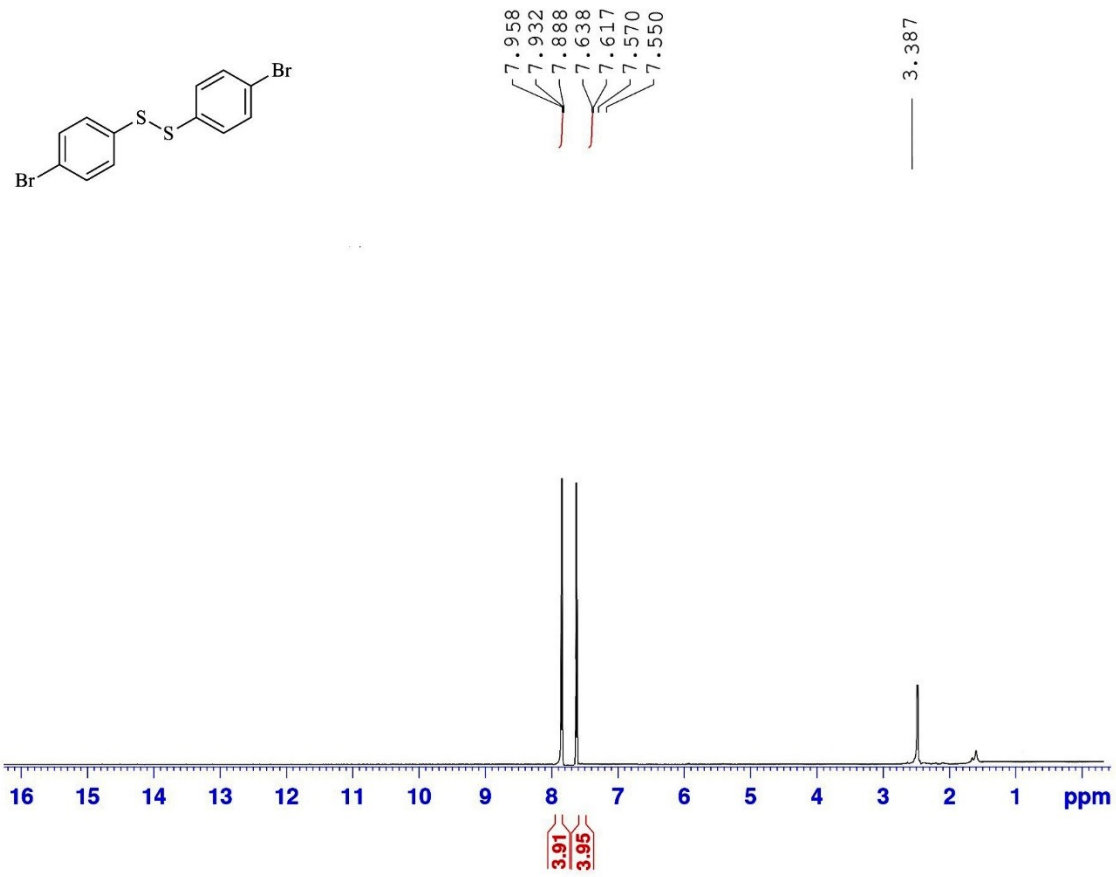


S40. ^{13}CNMR spectrum of 1, 2- bis(benzo[d]thiazol-2-yl)disulfane in $CDCl_3$ (Table 6, entry 6)

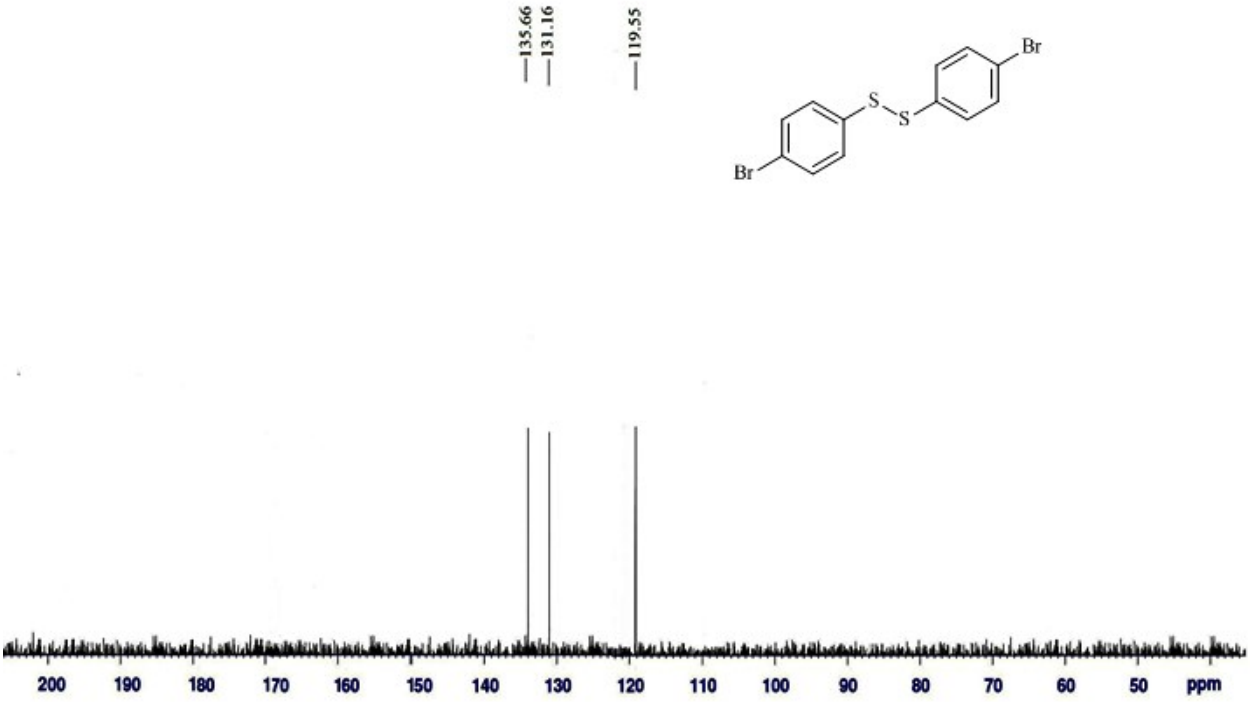
1, 2-bis(4-bromophenyl)disulfane (Table 6, entry 7)



Melting point: 98-99 °C. ^{1}HNMR (400 MHz, DMSO, ppm): δ 7.550-7.638 (m, 4H), 7.888– 7.958 (m, 4H); ^{13}CNMR (100 MHz, DMSO, ppm): δ 119.55, 131.16, 135.66, IR (KBr) (cm^{-1}): ν (S-S): 1019.

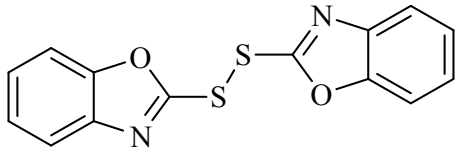


S41. [1]H-NMR spectrum of 1, 2-bis(4-bromophenyl)disulfane in DMSO (Table 6, entry 7)

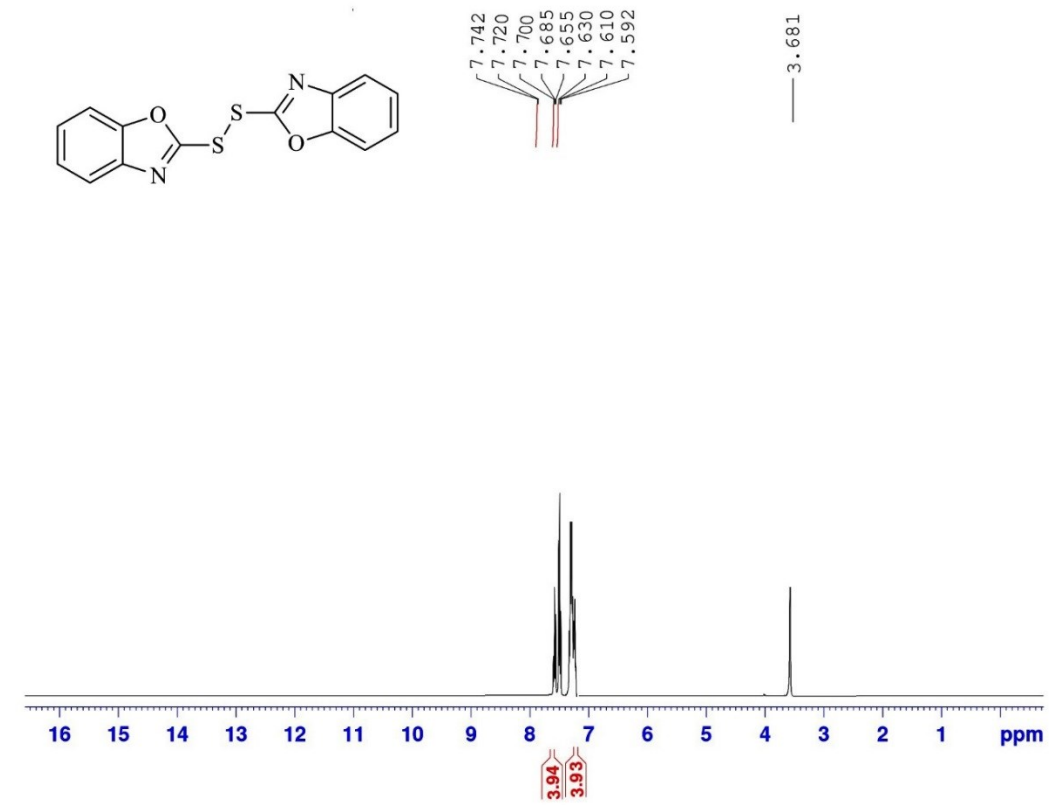


S42. ^{13}CNMR spectrum of 1, 2-bis(4-bromophenyl)disulfane in DMSO (Table 6, entry 7)

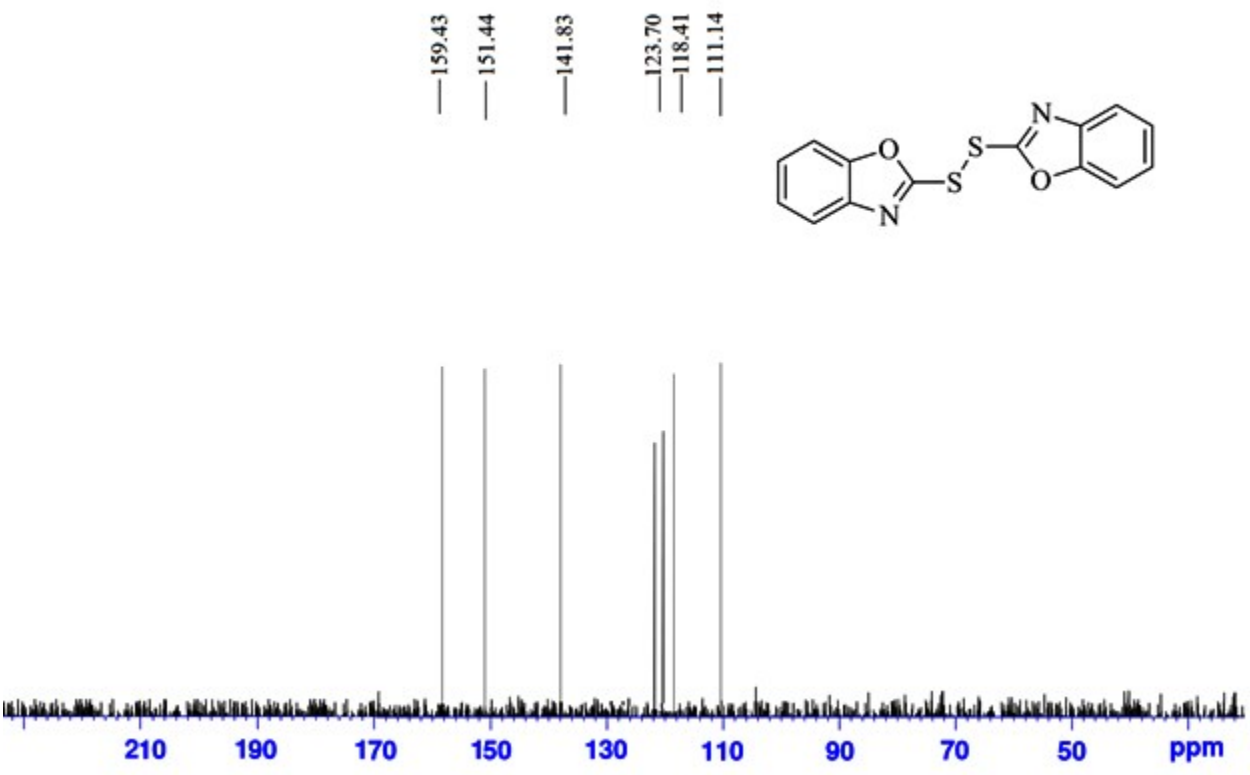
1, 2-bis(benzo[d]oxazol-2-yl)disulfane (Table 6, entry 8)



Melting point: 98-99 °C. ^{1}HNMR (400 MHz, $CDCl_3$, ppm): δ 7.592-7.685 (m, 4H), 7.700– 7. 742 (m, 4H); ^{13}CNMR (75 MHz, $CDCl_3$, ppm): δ 111.14, 118.41, 123.70 , 141.83, 151.44, 159.43. IR (KBr) (cm^{-1}): ν (S-S): 1039.

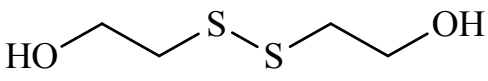


S43. ^{1}H-NMR spectrum of 1, 2-bis(benzo[d]oxazol-2-yl)disulfane in $CDCl_3$ (Table 6, entry 8)

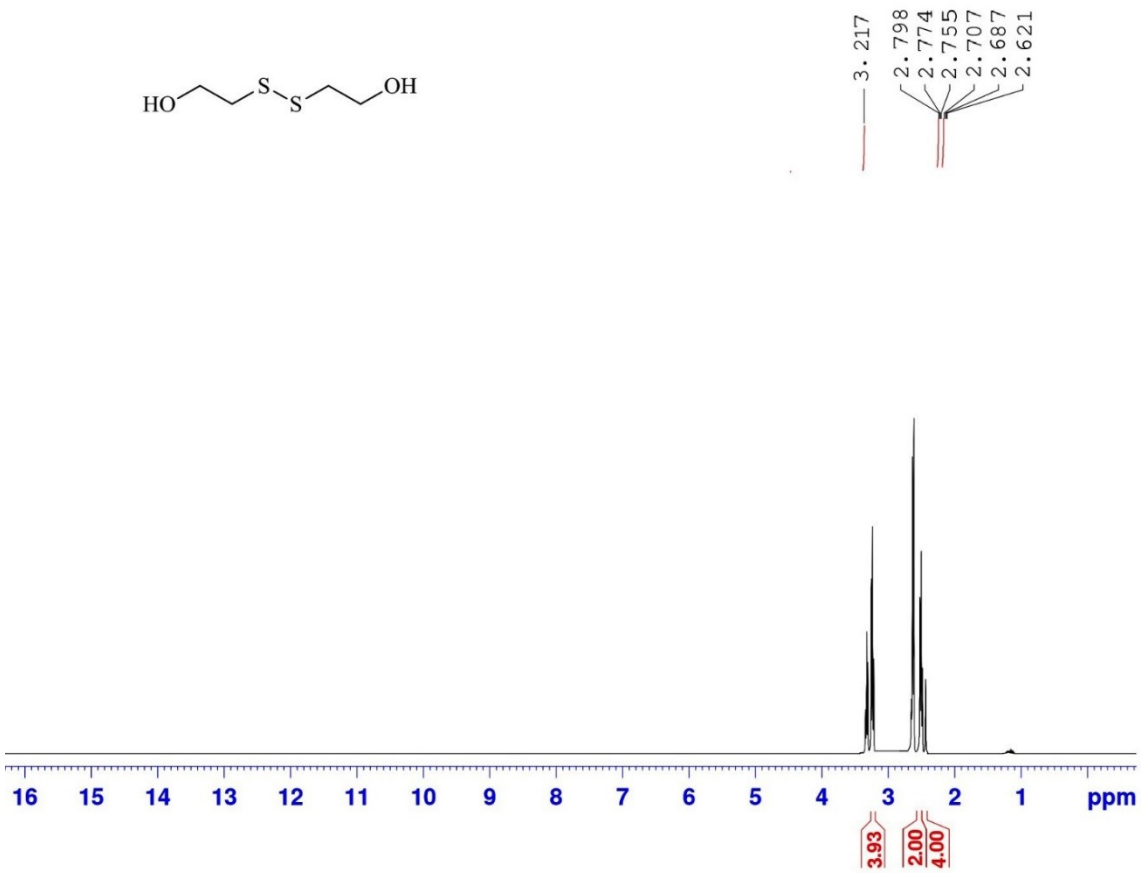


S44. ^{13}CNMR spectrum of 1, 2-bis(benzo[d]oxazol-2-yl)disulfane in $CDCl_3$ (Table 6, entry 8)

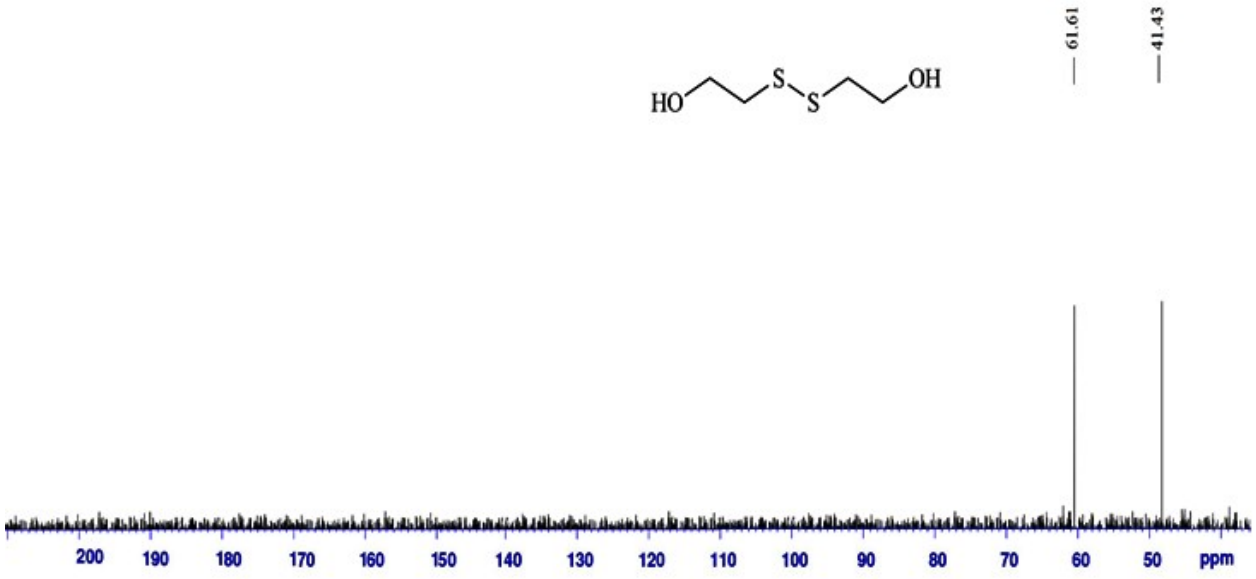
2, 2′-disulfanediyldiethanol (Table 6, entry 9)



Melting point: Oil. ^{1}HNMR (400 MHz, $CDCl_3$, ppm): δ 2.262-2.798 (m, 4H), 3.217 (m, 4H); ^{13}CNMR (100 MHz, $CDCl_3$, ppm): δ 41.43, 61.61. IR (KBr) (cm^{-1}): ν (S-S): 1058.

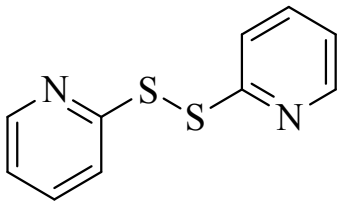


S45. ^{1}H-NMR spectrum of 2, 2′- disulfanediyldiethanol in $CDCl_3$ (Table 6, entry 9)

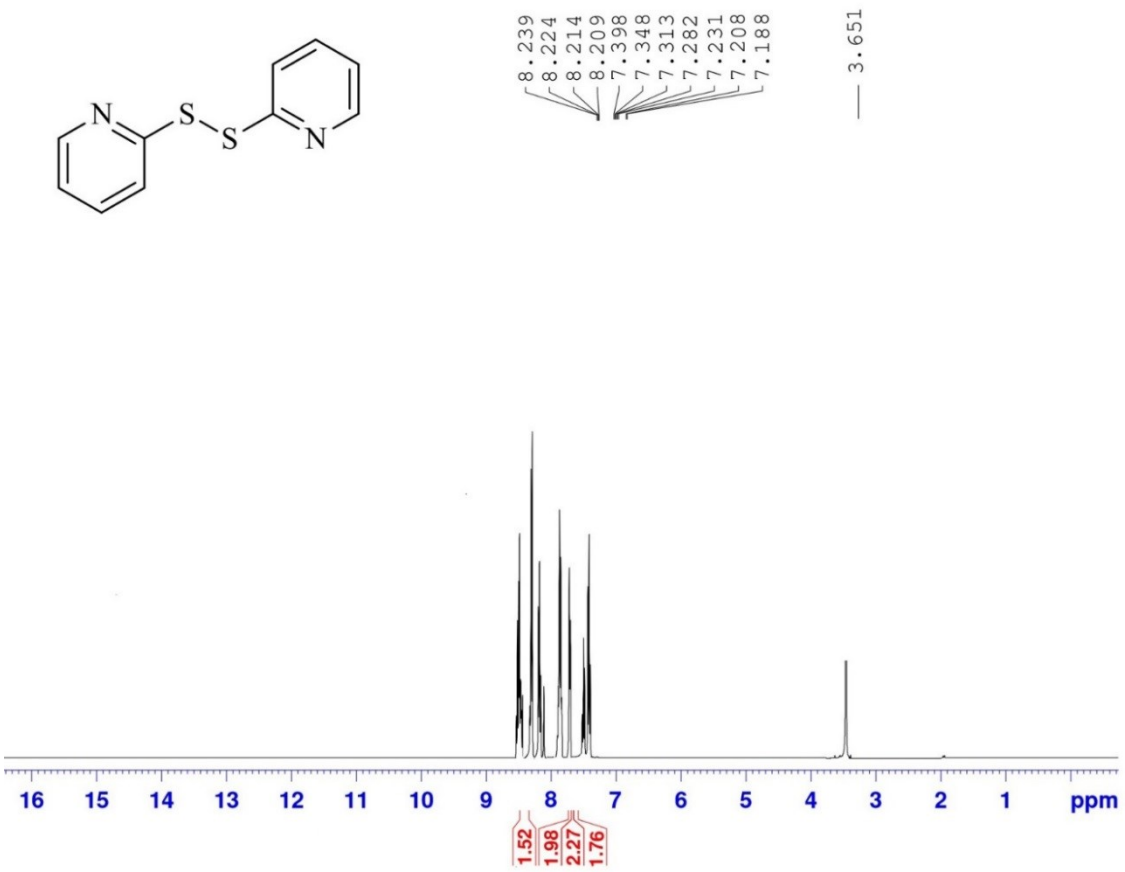


S46. ^{13}CNMR spectrum of 2, 2′- disulfanediyldiethanol in $CDCl_3$ (Table 6, entry 9)

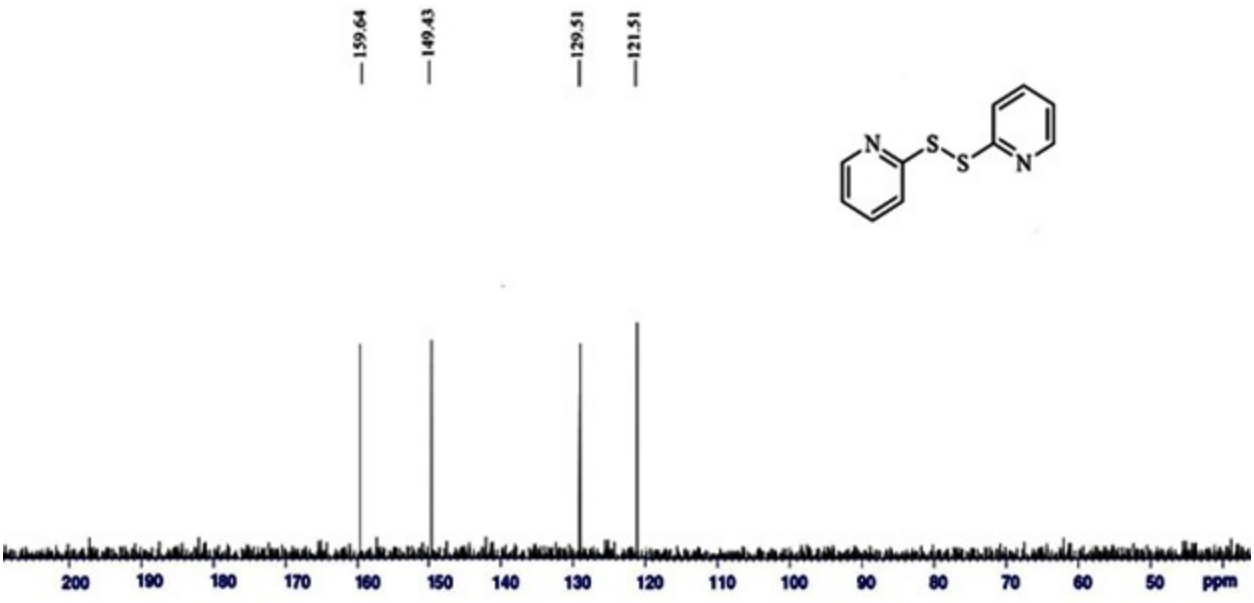
1, 2-di(pyridin-2-yl)disulfane (Table 6, entry 10)



Melting point: 55-57 °C. ^{1}HNMR (400 MHz, $CDCl_3$, ppm): δ 7.118-7.208 (m, 2H), 7.231–7.313 (m, 2H), 7.348–7.391 (m, 2H), 8.209-8.239 (m, 2H); ^{13}CNMR (75 MHz, $CDCl_3$, ppm): δ 121.15, 129.51, 149.43, 159.64. IR (KBr) (cm^{-1}): ν (S-S): 1028.



S47. ^{1}HNMR spectrum of 1, 2-di(pyridin-2-yl)disulfane in $CDCl_3$ (Table 6, entry 10)



S48. ^{13}CNMR spectrum of 1, 2-di(pyridin-2-yl)disulfane in $CDCl_3$ (Table 6, entry 10)