Electronic Supplementary Material (ESI) for RSC Advances.

Supporting Information

Hypervalent iodine mediated direct one pot transformation of aldehydes to ketones

Prateep Singh Sagara, Rajesh Chebolu, Ashish Bahuguna, P. C. Ravikumar*

Indian Institute of Technology-Mandi, Kamand Campus, H.P., INDIA-175005

Table of Contents

Experimental Section

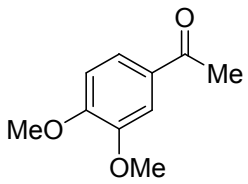
General: All the chemicals were purchased from Aldrich, Merck, Fluka, Loba *etc*. companies and purified prior to their use. Melting points were determined in open capillary method and are incorrect or cited from literature where applicable. NMR spectra were recorded on a JEOL-USA (JNM-ECX500) spectrometer and JEOL-USA (JNM ECS400) in $CDCl_3$-d_1 taking TMS (Tetramethyl Silane) as the internal standard. The NMR chemical shift was reported in ppm relative to 7.26 ppm and 77.00 ppm of $CDCl_3$ solvent as the standards. ^1H spectra were recorded in 500 and 400 MHz frequencies and ^{13}C NMR spectra were recorded in 125 MHz frequencies. Coupling constant '*J*' was calculated in Hz. FT-IR spectra were acquired on a Perkin-Elmer Spectrum Two spectrometer. Mass spectra were recorded on an advance Bruker Daltonics (impact HD) UHR-QqTOF (Ultra-High Resolution Qq-Time-Of-Flight) mass spectrometry.

General procedure for method A (for alkyl-aryl ketones): To an oven dried 25 mL round bottom flask containing 0.5 mmol of aldehyde in THF (1 mL) was added drop wise 0.75 mmol of Grignard reagent (1 M solution in THF) at 0 °C, the reaction mixture was allowed to come to 25 °C and continued stirring until the starting aldehyde has been consumed completely (monitored by TLC). The reaction mixture was recooled to 0 °C and added 1.0 mmol of diacetoxy iodobenzene (DIB), the temperature was then gradually allowed raise from 0 °C to 25 °C and stirred for 1 h. After the completion of the reaction (monitored by TLC), the reaction mixture was diluted with ethyl acetate. The organic layer was taken in separatory funnel and washed with saturated $Na_2S_2O_3$ (5 mL), NH_4Cl (5 mL), and brine solution (5 mL). The organic layer was dried over anhydrous sodium sulfate and the resultant organic layer was filtered and concentrated under reduced pressure. The crude residue was purified through column chromatography with hexane/ethyl acetate as an eluent.

General procedure for method B (for biaryl ketones): To an oven dried 25 mL round bottom flask containing 0.5 mmol of aldehyde in THF (1 mL) was added drop wise 0.75 mmol of Grignard reagent (1 M Solution in THF) at 0 °C, the reaction mixture was allowed to come to 25 °C and continued stirring until the starting aldehyde has been consumed completely (monitored by TLC). The reaction mixture was recooled to 0 °C then 3 equiv of 2-iodoxy benzoic acid (IBX) was added slowly, the temperature was gradually allowed raise from 0 °C to 25 °C and then refluxing in THF for 24 to 36 h. After the completion of the reaction (monitored by TLC), the reaction mixture was allowed to come to room temperature and diluted with ethyl acetate. The organic layer was taken in separatory funnel and washed with saturated $Na_2S_2O_3$ (5 mL), NH_4Cl (5 mL), and brine solution (5 mL). The organic layer was dried over anhydrous sodium sulfate and the resultant organic layer was filtered and concentrated under reduced pressure. The crude residue was purified through column chromatography with hexane/ethyl acetate as an eluent.

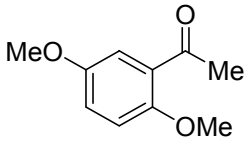
Characterization of some compounds

1. **1-(3,4-dimethoxyphenyl)ethanone (3a):**[1]



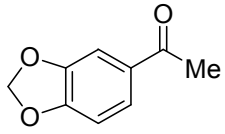
White Solid; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.58 (*dd*, 1H, *J* = 2.0 & 8.3 Hz), 7.53 (*d*, 1H, *J* = 2.0 Hz), 6.89 (*d*, 1H, *J* = 8.3 Hz), 3.96 (*s*, 3H), 3.94 (*s*, 3H), 2.58 (*s*, 3H); IR (Neat) ν:3003, 1673, 1417, 1269, 809 cm^{-1}

2. **1-(2,5-dimethoxyphenyl)ethanone (3b):**[2]



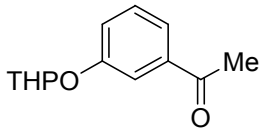
Yellow liquid; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.29 (*d*, 1H, *J* = 3.3 Hz), 7.04 (*dd*, 1H, *J* = 3.8 & 8.9 Hz), 6.91 (*d*, 1H, *J* = 8.9 Hz), 3.87 (*s*, 3H), 3.79 (*s*, 3H), 2.62 (*s*, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* 199.4, 153.5, 153.3, 128.2, 120.4, 113.7, 113.1, 56.0, 55.8, 31.8. IR (Neat) ν: 2936, 2836, 1667, 1266, 1176, 1040 cm^{-1}.

3. **1-(benzo[d][1,3]dioxol-6-yl)ethanone (3c):**[3]



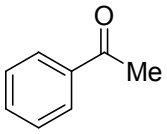
Colorless Solid; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.55 (*dd*, 1H, *J* = 1.6 & 8.2 Hz), 7.43 (*d*, 1H, *J* = 1.6 Hz), 6.85 (*d*, 1H, *J* = 8.2 Hz), 6.04 (*s*, 2H), 2.54 (s, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* 196.2, 151.7, 148.1, 132.0, 124.7, 107.9, 107.7, 101.8, 26.4. IR (Neat) ν: 2921, 2853, 1661, 1255, 1114, 1029 cm^{-1}.

4. **1-(3-(tetrahydro-2H-pyran-2-yloxy)phenyl)ethanone (3d):**



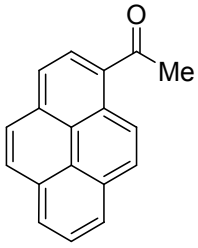
Pale yellow color Liquid; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.63 (*t*, 1H, *J* = 1.4 Hz), 7.59-7.57 (*m*, 1H), 7.37 (*t*, 1H, *J* = 8.0 Hz), 7.27-7.26 (*m*, 1H), 5.49 (*t*, 1H, *J* = 6.3 Hz), 3.92-3.87 (m, 1H), 3.64-3.61 (m, 1H), 2.64 (*s*, 3H), 2.04-1.97 (m, 1H), 1.90-1.87 (m, 2H), 1.72-1.60 (m, 3H).; ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* 198.0, 151.2, 138.4, 129.5, 121.6, 121.3, 116.0, 96.3, 62.1, 30.2, 26.7, 25.1, 18.7. IR (Neat) ν: 3051, 2938, 2853, 1678, 1260, 961 cm^{-1}. HRMS (EI): *m/z* = 243.0994 ($M+Na^+$), calculated for 243.0997, $C_{13}H_{16}NaO_3$.

5. A**cetophenone (3e):**[4]



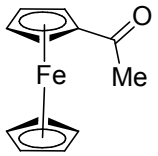
Colorless Liquid; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.90-7.87 (*m*, 2H), 7.58-7.32 (*m*, 3H), 2.53 (*s*, 3H). IR (Neat) ν: 3089, 2969, 1691, 1601, 1246, 1026 cm^{-1}.

6. **1-(pyren-3-yl)ethanone (3f):**[5]



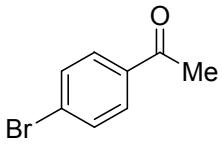
Pale yellow solid; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 9.07(*d*, 1H, *J* = 9.4 Hz), 8.40 (*d*, 1H, *J* = 8.0 Hz), 8.28-8.17 (*m*, 5H), 8.11-8.05 (*m*, 2H), 2.91 (s, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* 202.1, 134.0, 131.9, 131.1, 130.5, 129.8, 129.7, 129.5, 127.1, 127.1, 126.4, 126.3, 126.1, 125.0, 125.0, 124.3, 124.0, 30.5. IR (Neat) ν: 3039, 2921, 2847, 1667, 1221 cm^{-1}.

7. **1-acyl ferrocene (3g):**[2]



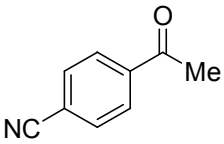
Orange color solid; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 4.77 (*t*, 2H, *J* = 1.8 Hz), 4.50 (*t*, 2H, *J* = 1.8 Hz), 4.20 (*s*, 5H), 2.39 (*s,* 3H). IR (Neat) ν: 3116, 1662, 1615, 1102 , 893 cm^{-1}. HRMS (EI): *m/z* = 251.0130 ($M+Na^+$), calculated for 251.0137, $C_{12}H_{12}FeNaO$.

8. **1-(4-bromophenyl)ethanone (3h):**[6]



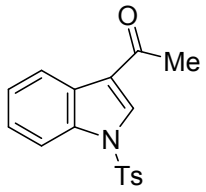
White solid; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.82 (*d*, 2H, *J* = 8.5 Hz), 7.61 (*d*, 2H, *J* = 8.5 Hz), 2.58 (*s*, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* 197.0, 135.8, 131.9, 129.8, 128.3, 26.5. IR (Neat) ν: 2954, 2921, 2853, 1681, 820 cm^{-1}.

9. **4-acetylbenzonitrile (3i):**[7]



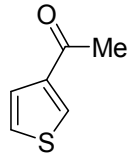
Colorless solid; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.04 (*d*, 2H, *J* = 8.3 Hz), 7.77 (*d*, 2H, *J* = 8.3 Hz), 2.64 (*s*, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* 196.5, 139.8, 132.5, 128.7, 117.9, 116.4, 26.8. IR (Neat) ν: 3051, 2989, 2305, 1695, 1266 cm^{-1}.

10. **1-(1-tosyl-1H-indol-3-yl)ethanone (3j):** [8]



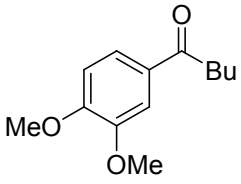
White solid; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.33 (*t*, 1H, *J* = 7.5 Hz), 8.21 (*s*, 1H), 7.92 (*d*, 1H, *J* = 7.8 Hz), 7.83 (*d*, 2H, *J* = 8.2 Hz), 7.39-7.32 (*m*, 2H), 7.29-7.26 (*m*, 2H), 2.58 (*s*, 3H), 2.38 (*s*, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* 193.4, 145.9, 134.9, 134.5, 132.2, 130.2, 127.5, 127.1, 125.7, 124.8, 123.1, 121.4, 113.0, 27.8, 21.6. IR (Neat) ν: 3051, 2983, 1667, 1260 cm^{-1}.

11. **1-(thiophen-3-yl)ethanone (3k):**[4]



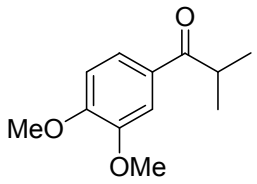
Yellow color oil; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.04 (*dd*, 1H, *J* = 1.5 & 2.8 Hz), 7.54 (*dd*, 1H, *J* = 1.3 & 5.1 Hz), 7.32 (*dd*, 1H, *J* = 1.4 & 4.2 Hz), 2.54 (*s*, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* 192.3, 142.6, 132.3, 126.9, 126.4, 27.5. IR (Neat) ν: 3107, 2921, 1673, 1260 cm^{-1}.

12. **1-(3,4-dimethoxyphenyl)pentanone (3l):**[9]



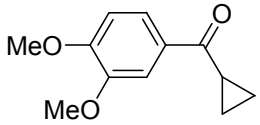
Yellow color liquid; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.58 (*d*, 1H, *J* = 8.4 Hz), 7.52 (*s*, 1H), 6.87 (*d*, 1H, *J* = 8.4 Hz), 3.94 (*s*, 3H), 3.93 (*s*, 3H), 2.91 (*t*, 2H, *J* = 7.4 Hz), 1.70 (*q*, 2H, *J* = 7.4 Hz), 1.40 (*sextet*, 2H, *J* = 7.7 Hz), 0.94 (*t*, 3H, *J* = 7.1 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* 199.4, 153.0, 148.9, 130.3, 122.7, 110.0, 109.8, 56.0, 55.9, 37.8, 26.9, 22.5, 13.9.

13. **1-(3,4-dimethoxyphenyl)-2-methylpropan-1-one (3m):**[10]



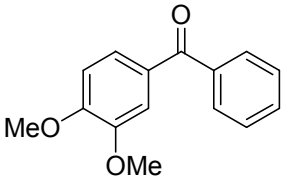
Pale yellow color liquid; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.60 (*dd*, 1H, *J* = 2.0 & 8.4 Hz), 7.55 (*d*, 1H, *J* = 1.9 Hz), 6.90 (*d*, 1H, *J* = 8.4 Hz), 3.95 (*s*, 3H), 3.94 (*s*, 3H), 3.55 (*septet*, 1H, *J* = 6.9 Hz), 1.22 (*d*, 6H, *J* = 6.9 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ* 203.2, 153.0, 149.0, 129.2, 122.6, 110.5, 110.0, 56.0, 55.9, 34.7, 19.4. IR (Neat) ν:3000, 2960, 1680, 1210, 990 cm^{-1}

14. C**yclopropyl(3,4-dimethoxyphenyl)methanone (3n):**[11]



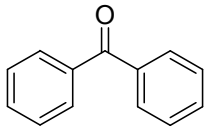
Pale yellow color solid; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.72 (*dd*, 1H, *J* = 2.0 & 8.3 Hz), 7.55 (*d*, 1H, *J* = 2.0 Hz), 6.92 (*d*, 1H, *J* = 8.4 Hz), 3.98 (*s*, 3H), 3.94 (*s*, 3H), 2.67-2.66 (*m*,1H), 1.23-1.21 (*m*, 2H), 1.03-0.99 (*m,*2H). IR (Neat) ν:3077, 3006, 1657, 1587, 1260, 1014, 903 cm^{-1}. HRMS (EI): *m/z* = 229.0835 (M+Na$^+$), calculated for 229.0837, $C_{12}H_{14}NaO_3$.

15. **(3,4-dimethoxyphenyl)(phenyl)methanone (3o):**[12]



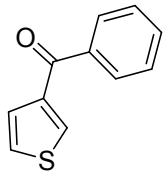
White solid; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.74 (*dd*, 2H, *J* = 1.4 & 8.4 Hz), 7.54 (*tt*, 1H, *J* = 2.0 & 7.5 Hz), 7.48-7.43 (*m*, 3H), 7.35 (*dd*, 1H, *J*= 1.9 & 8.4 Hz), 6.87 (*d*, 1H, *J* = 8.4 Hz), 3.93(*s*, 3H), 3.91 (*s*, 3H). IR (Neat) ν:3067,1681, 1630, 1576,1232, 1078 cm^{-1}. HRMS (EI): *m/z* = 265.0834 (M+Na$^+$), calculated for 265.0837, $C_{15}H_{14}NaO_3$.

16. **(3,4-dimethoxyphenyl)(phenyl)methanone (3p):**[12]



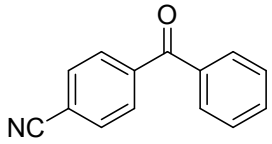
Colorless oil; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.80 (*d*, 4H, *J* = 8.5 Hz), 7.60 (*t*, 2H, *J*= 7.7 Hz), 7.51- 7.49 (*m*, 4H). IR (Neat) ν: 3061, 1657, 1598, 1210, 1177 cm^{-1}

17. P**henyl(thiophen-3-yl)methanone (3q):**[12]



Colorless oil; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.92 (*dd*, 1H, *J* = 1.2 & 2.8 Hz), 7.85 -7.83 (*m*, 2H), 7.61 - 7.56 (*m*, 2H), 7.50 - 7.46 (*m,* 2H), 7.38 (*dd,* 1H, *J*=2.9 & 8.0 Hz). IR (Neat) ν: 3106, 1648, 1598, 1510, 1276, 1178 cm^{-1}

18. **4-Benzoylbenzonitrile (3r):**[12]



White solid; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.89 - 7.77 (*m*, 6H), 7.65 - 7.61 (*m*, 1H), 7.51 (*t,* 2H, *J* = 7.7 Hz). IR (Neat) ν: 3066, 1648, 1594,1276, 1020 cm^{-1}. HRMS (EI): *m/z* = 208.0757 ($M+Na^+$), calculated for 208.0762, $C_{14}H_{10}NO$.

Table 2, (3a)-^{1}H-NMR (400MHz, $CDCl_3$)

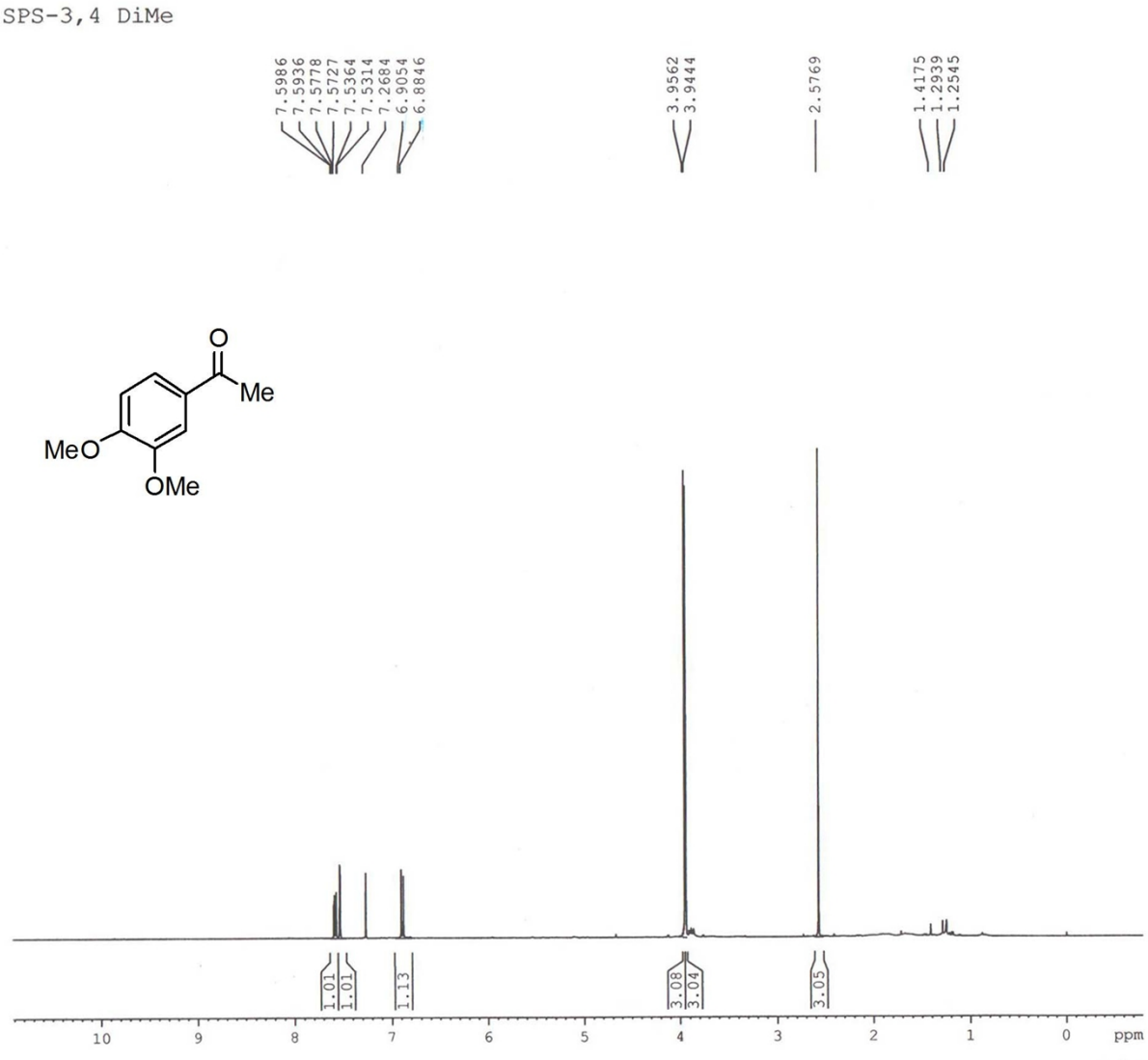


Table 2, (3b)-^{1}H-NMR (500MHz, $CDCl_3$)

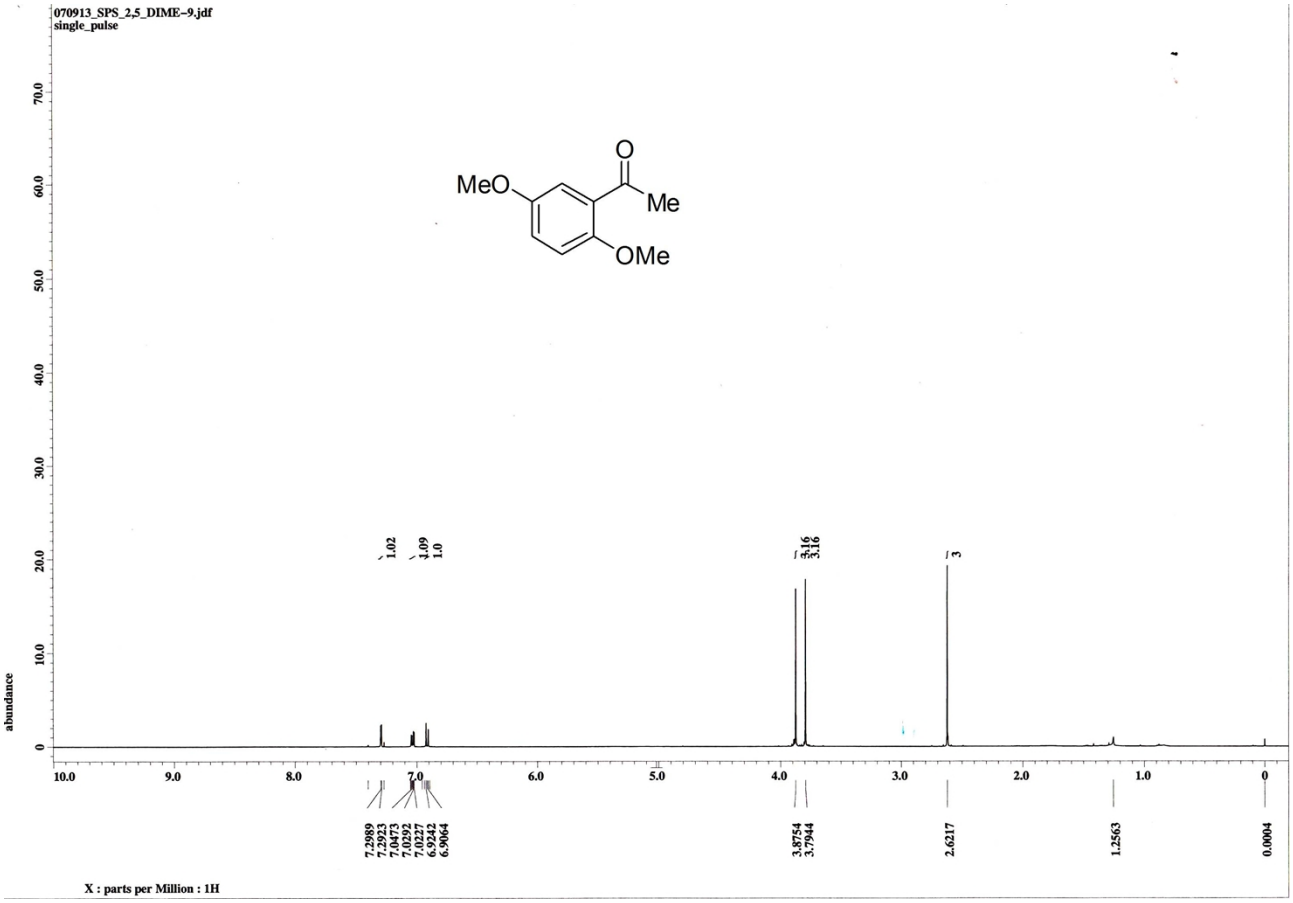


Table 2, (3b)-^{13}C-NMR (125MHz, $CDCl_3$)

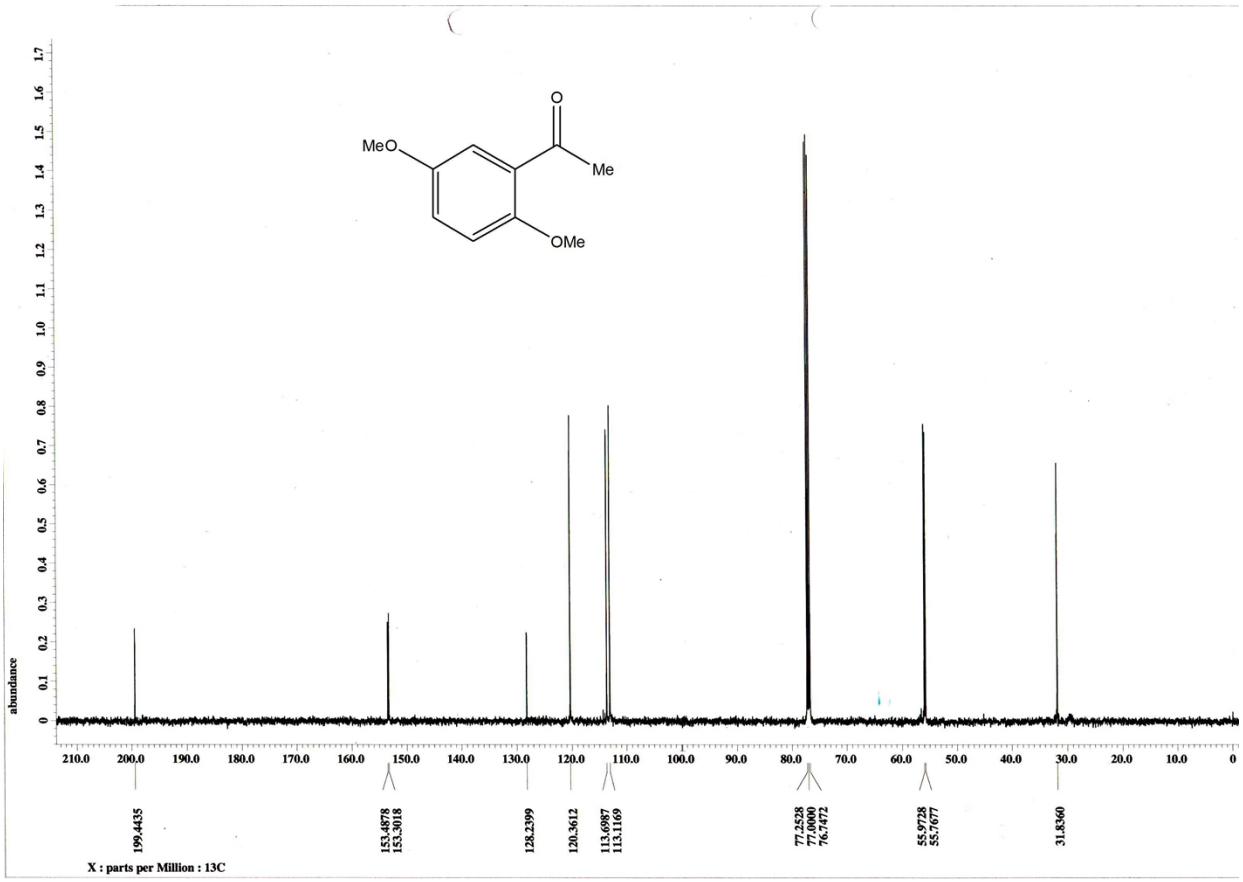


Table 2, (3c)-^{1}H-NMR (500MHz, $CDCl_3$)

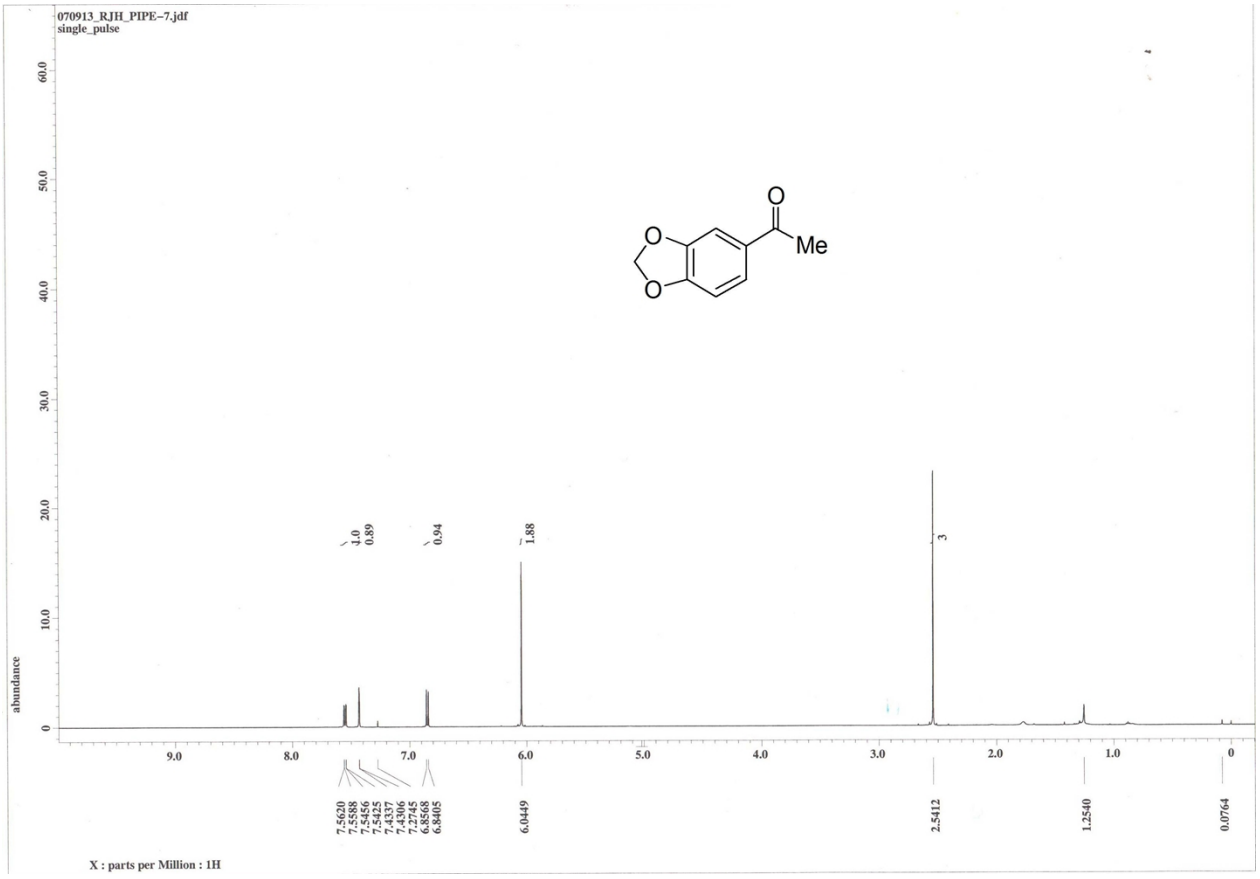


Table 2, (3c)-^{13}C-NMR (125MHz, $CDCl_3$)

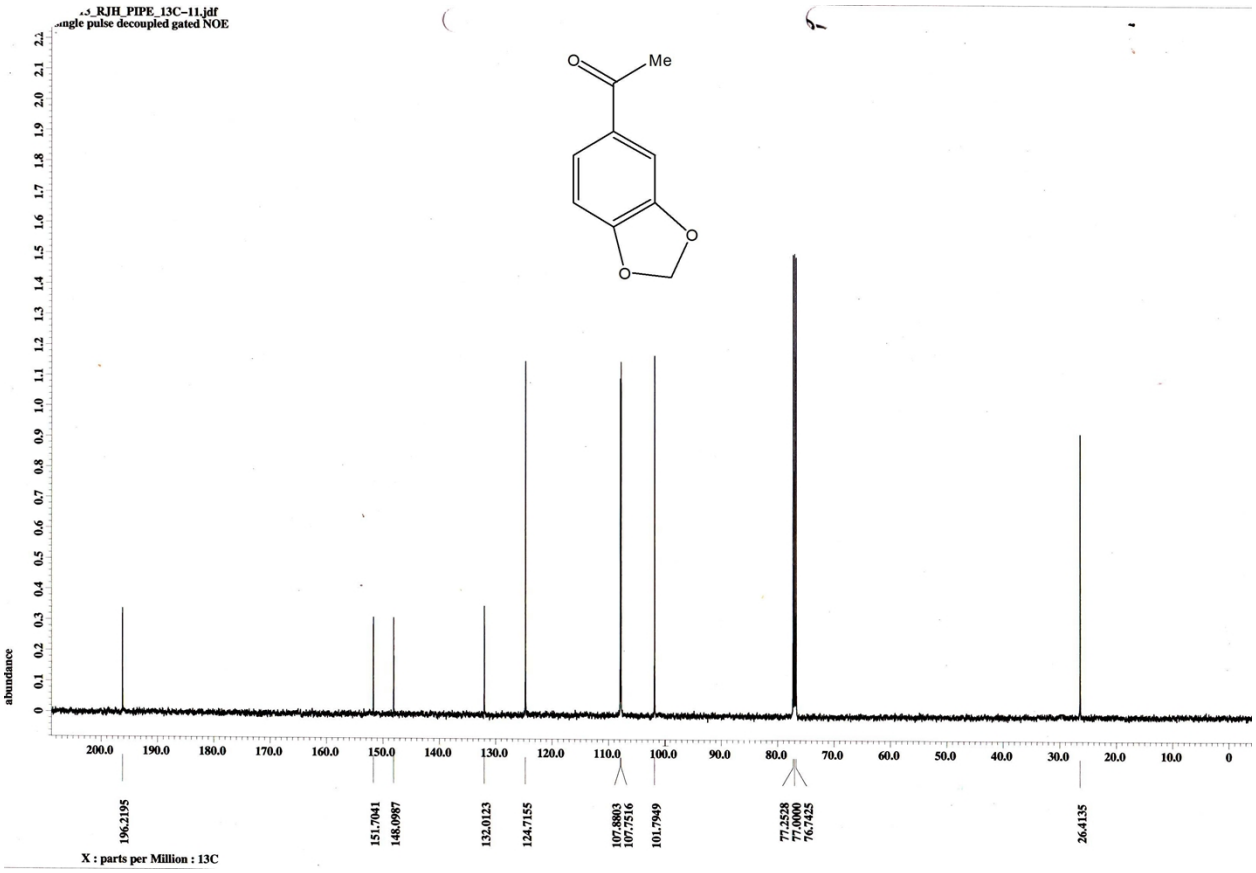


Table 2, (3d)-^{1}H-NMR (500MHz, $CDCl_3$)

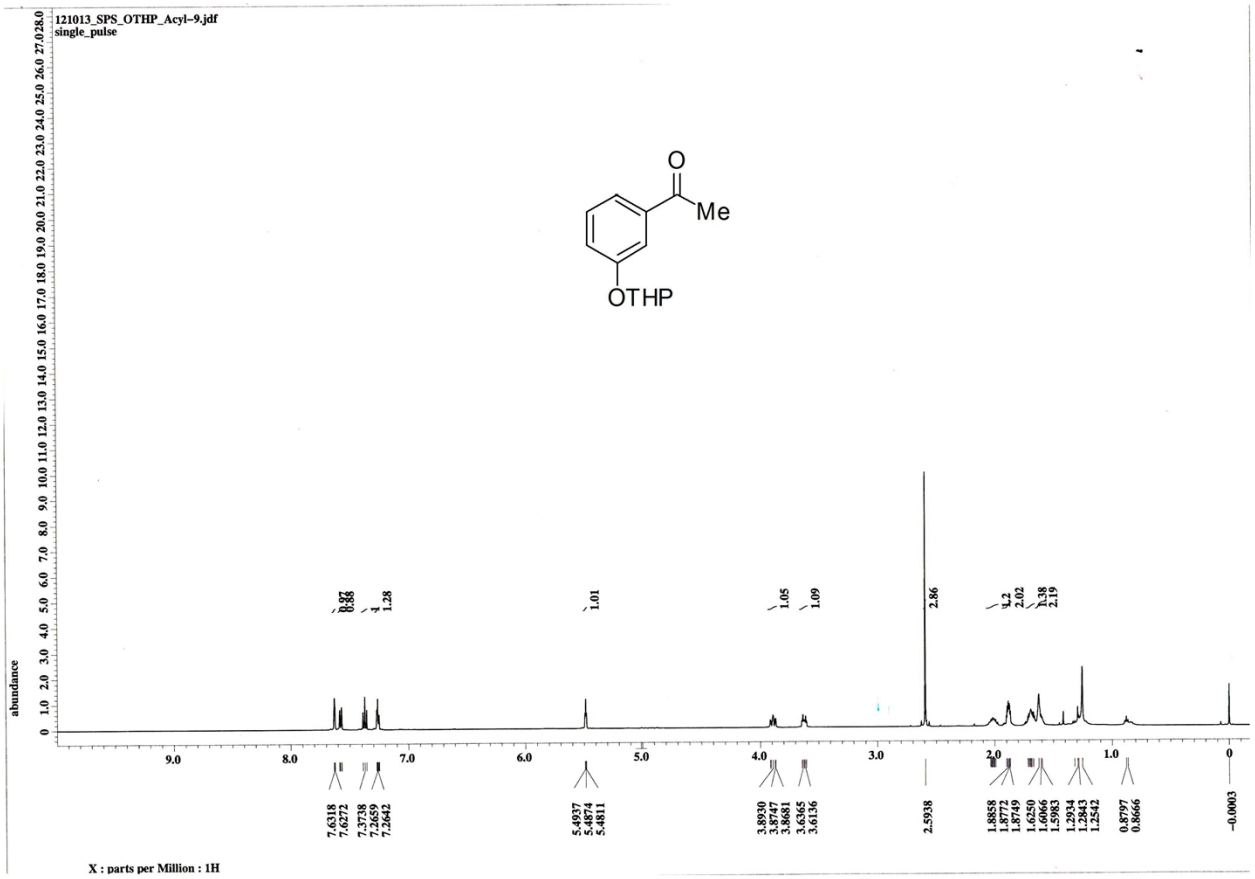


Table 2, (3d)-^{13}C-NMR (125MHz, $CDCl_3$)

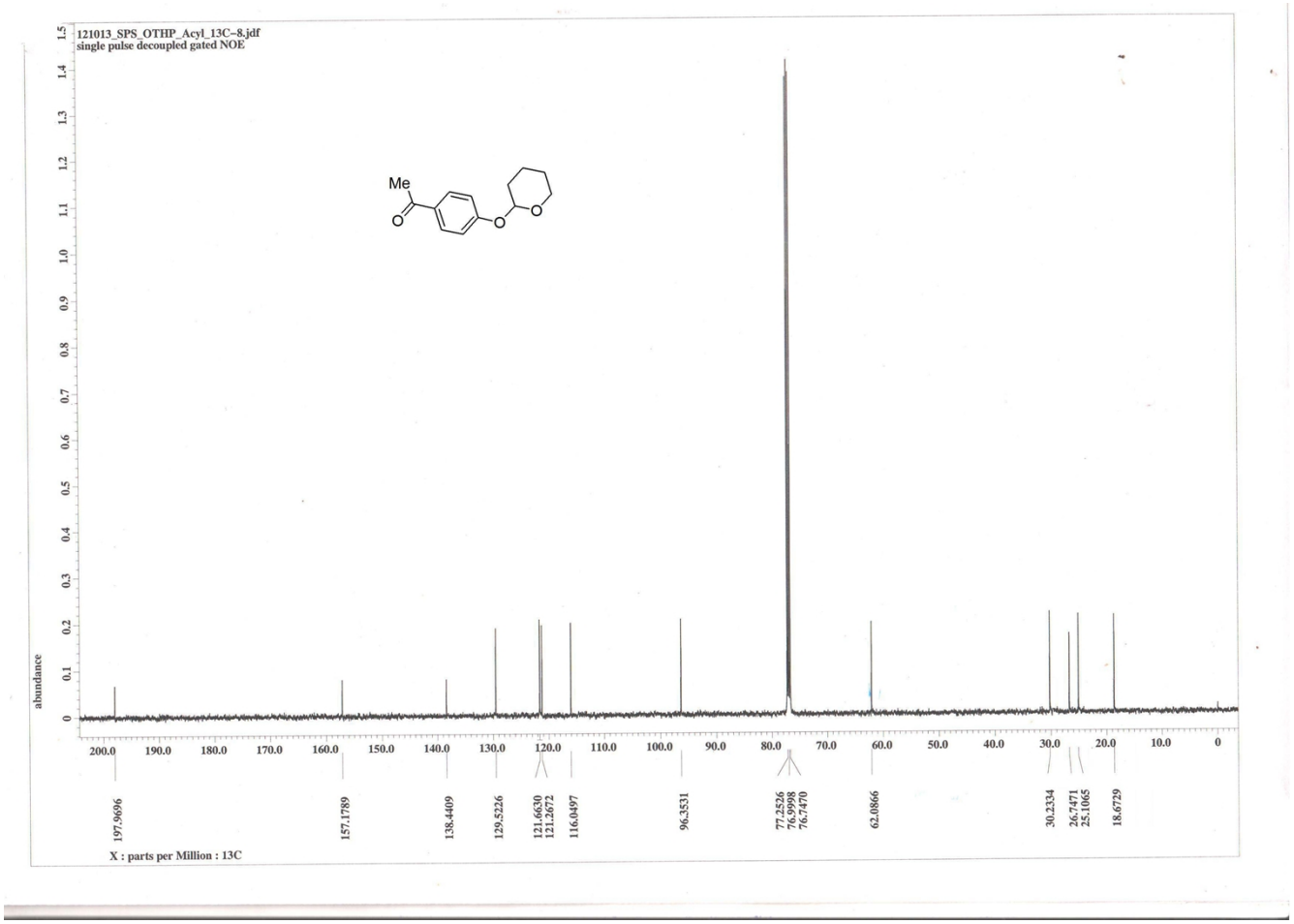


Table 2, (3e)-^{1}H-NMR (400MHz, $CDCl_3$)

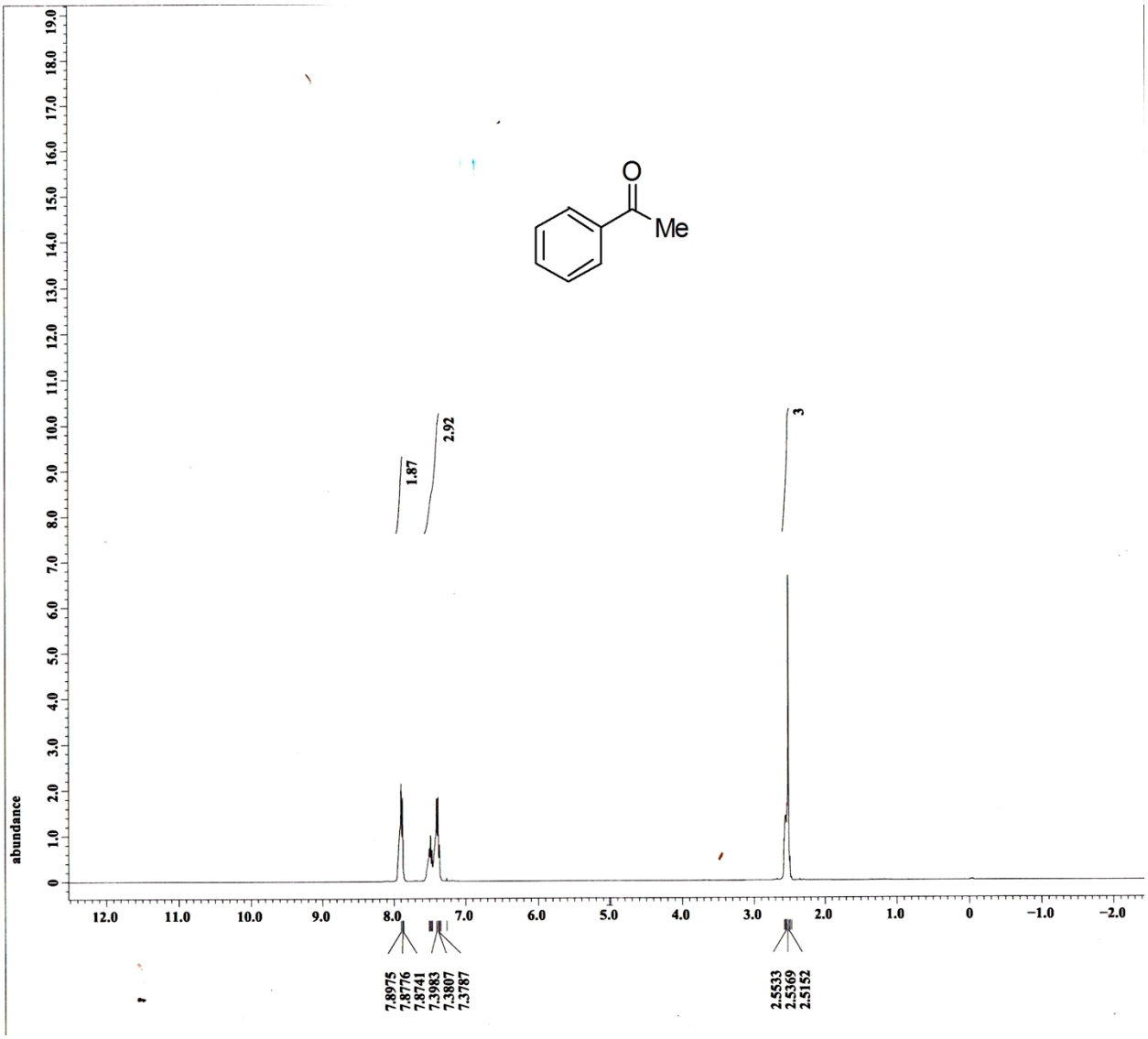


Table 2, (3f)-^{1}H-NMR (500MHz, $CDCl_3$)

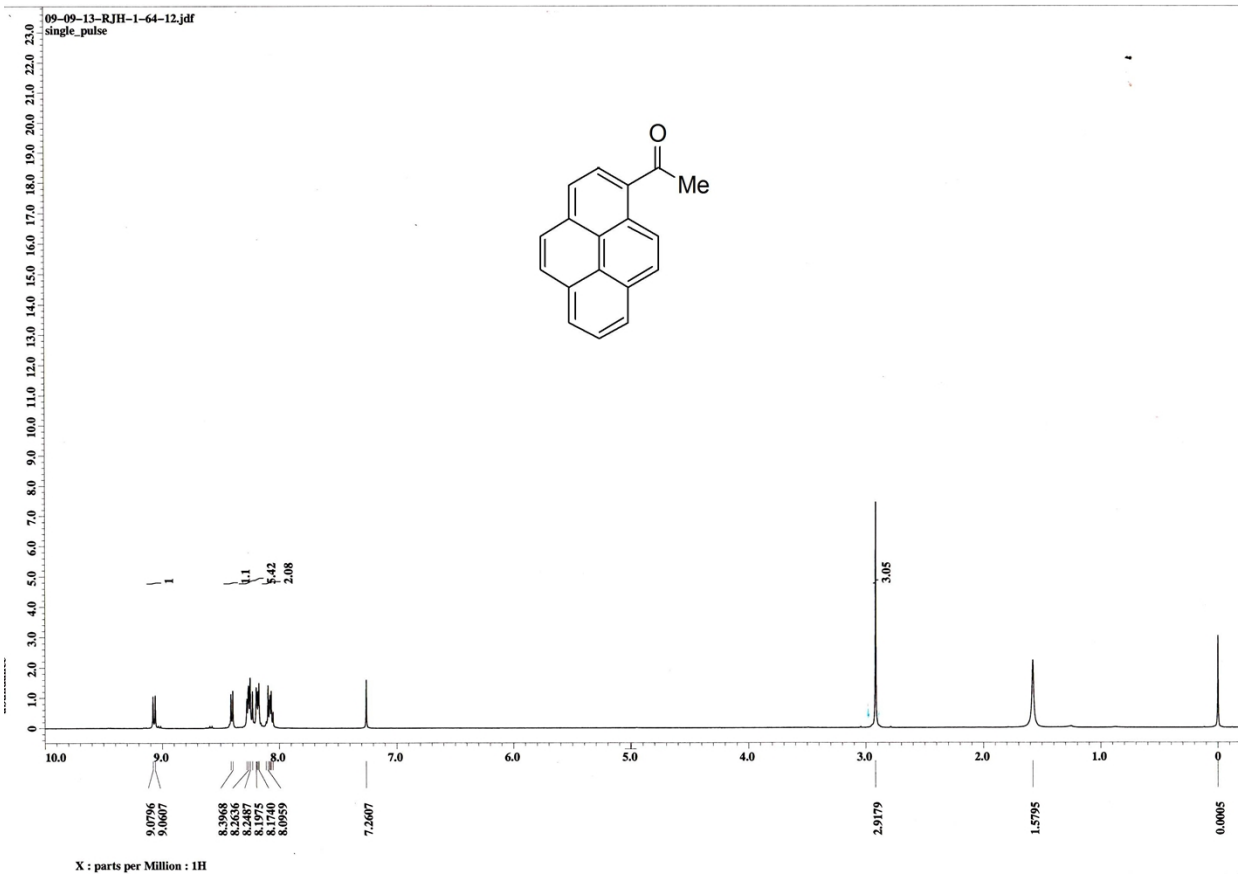


Table 2, (3f)-^{13}C-NMR (125MHz, $CDCl_3$)

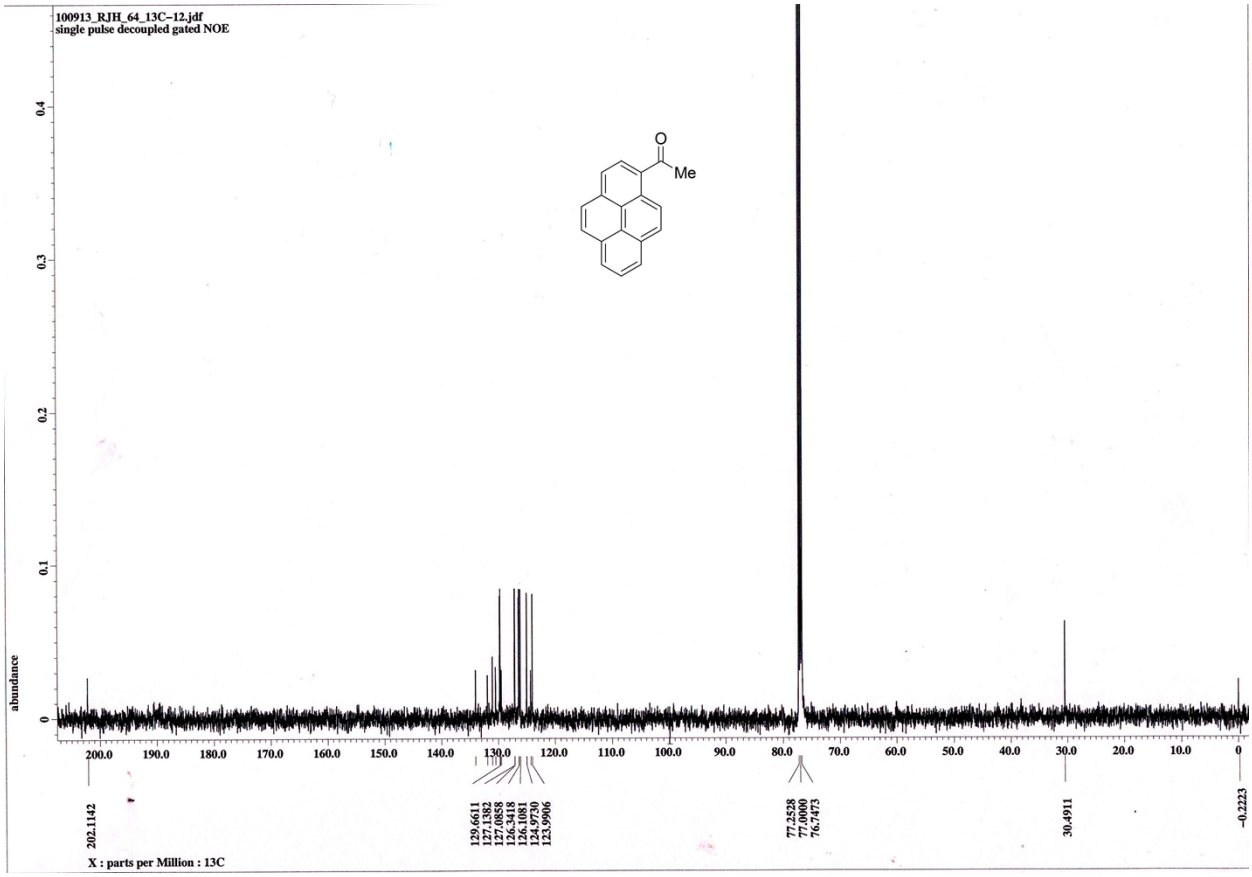


Table 2, (3g)-^{1}H-NMR (400MHz, $CDCl_3$)

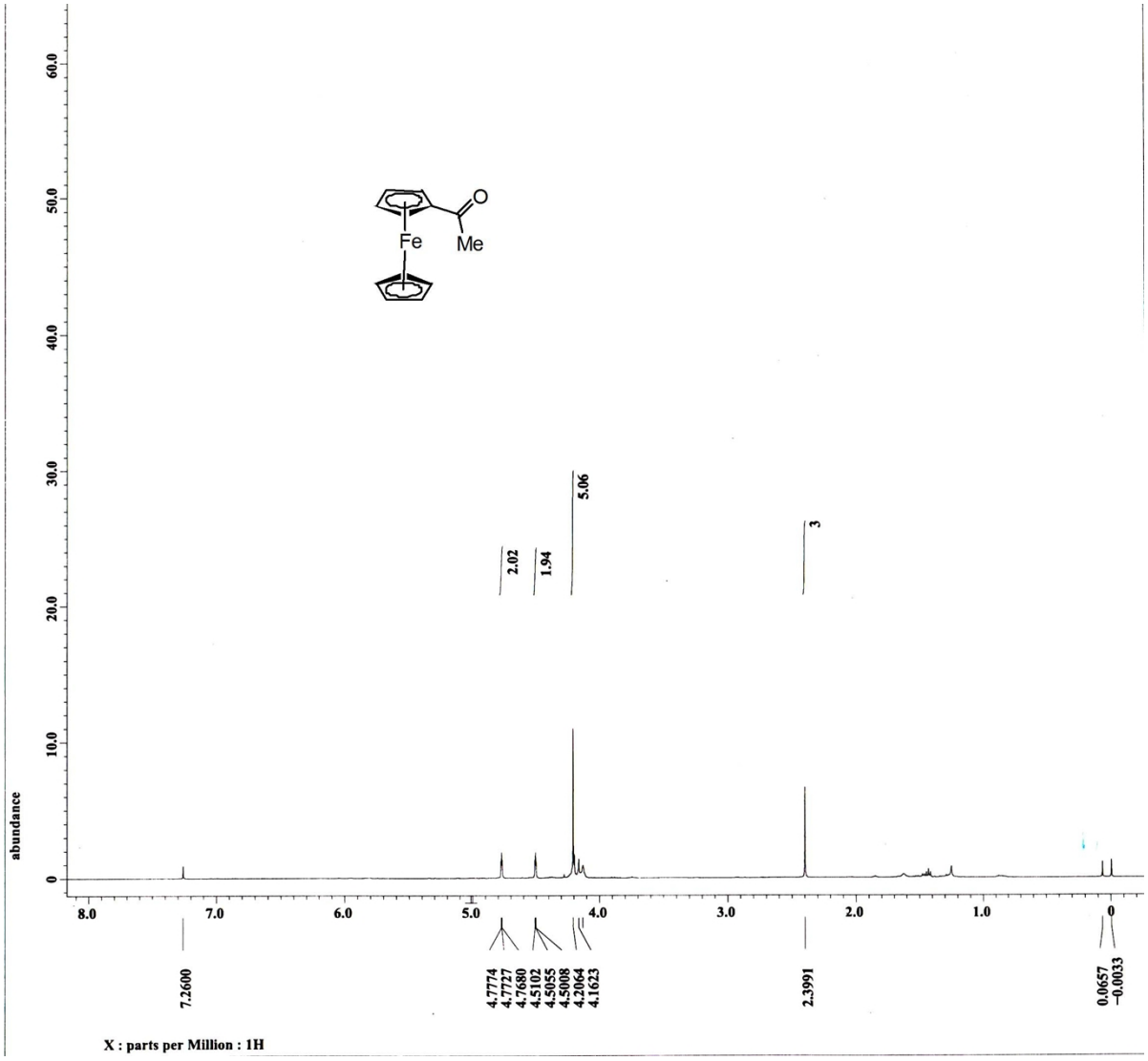


Table 2, (3h)-^{1}H-NMR (500MHz, $CDCl_3$)

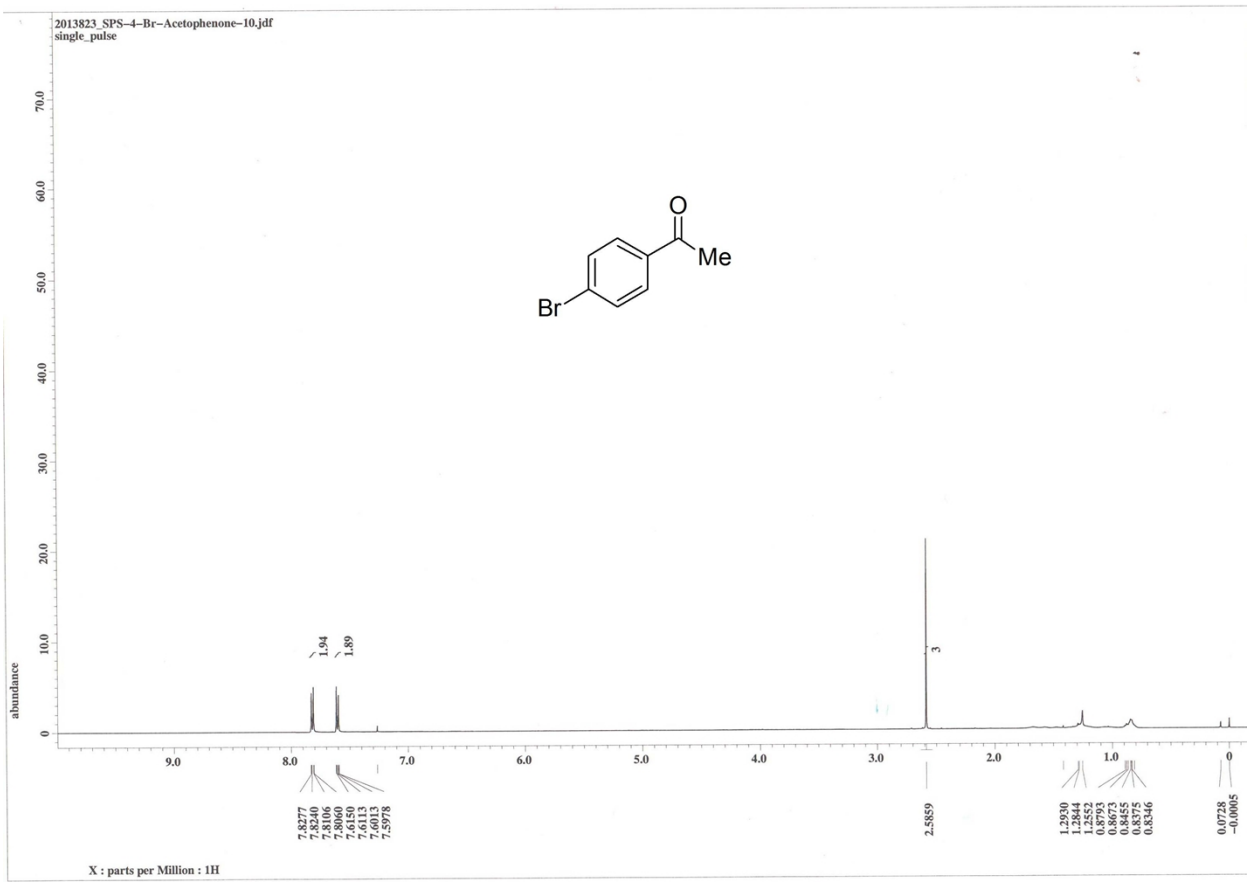


Table 2, (3h)-^{13}C-NMR (125MHz, $CDCl_3$)

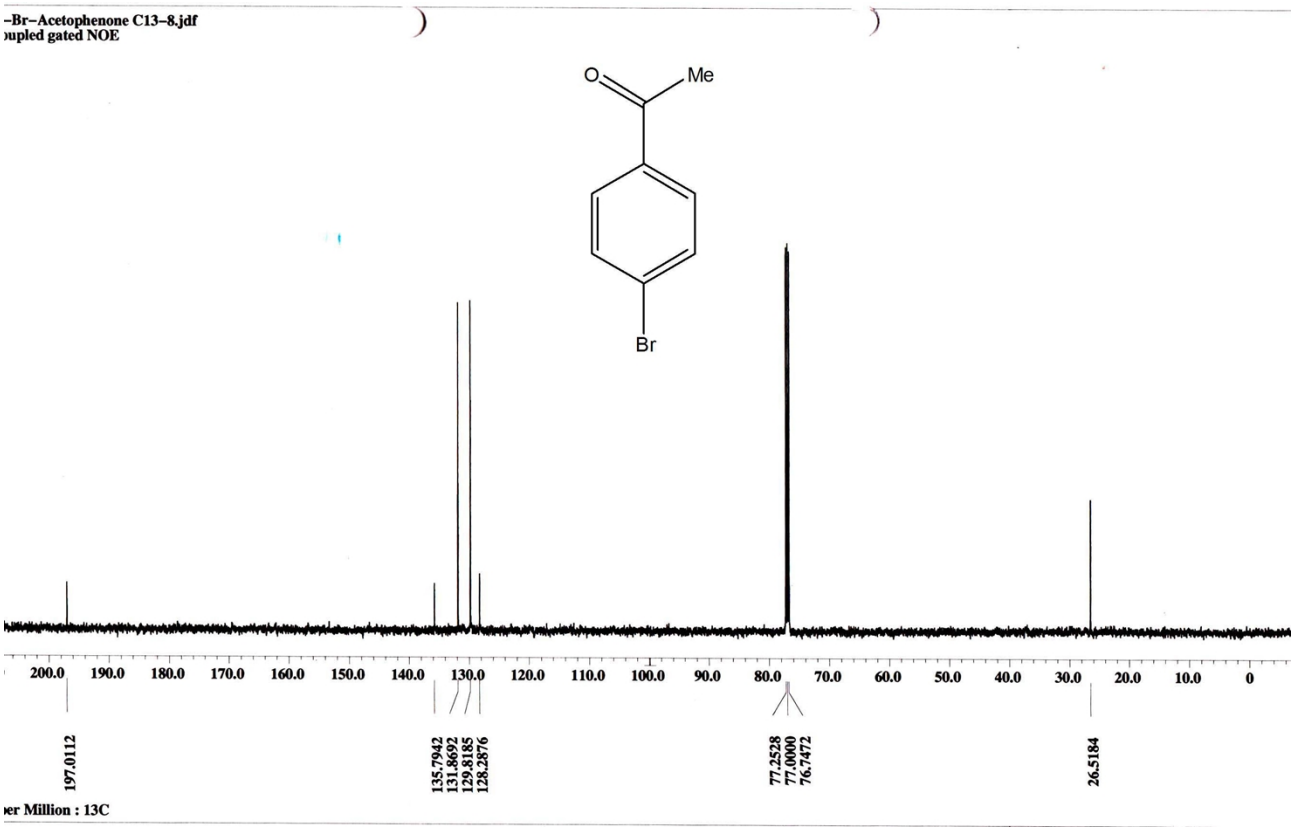


Table 2, (3i)-^{1}H-NMR (500MHz, $CDCl_3$)

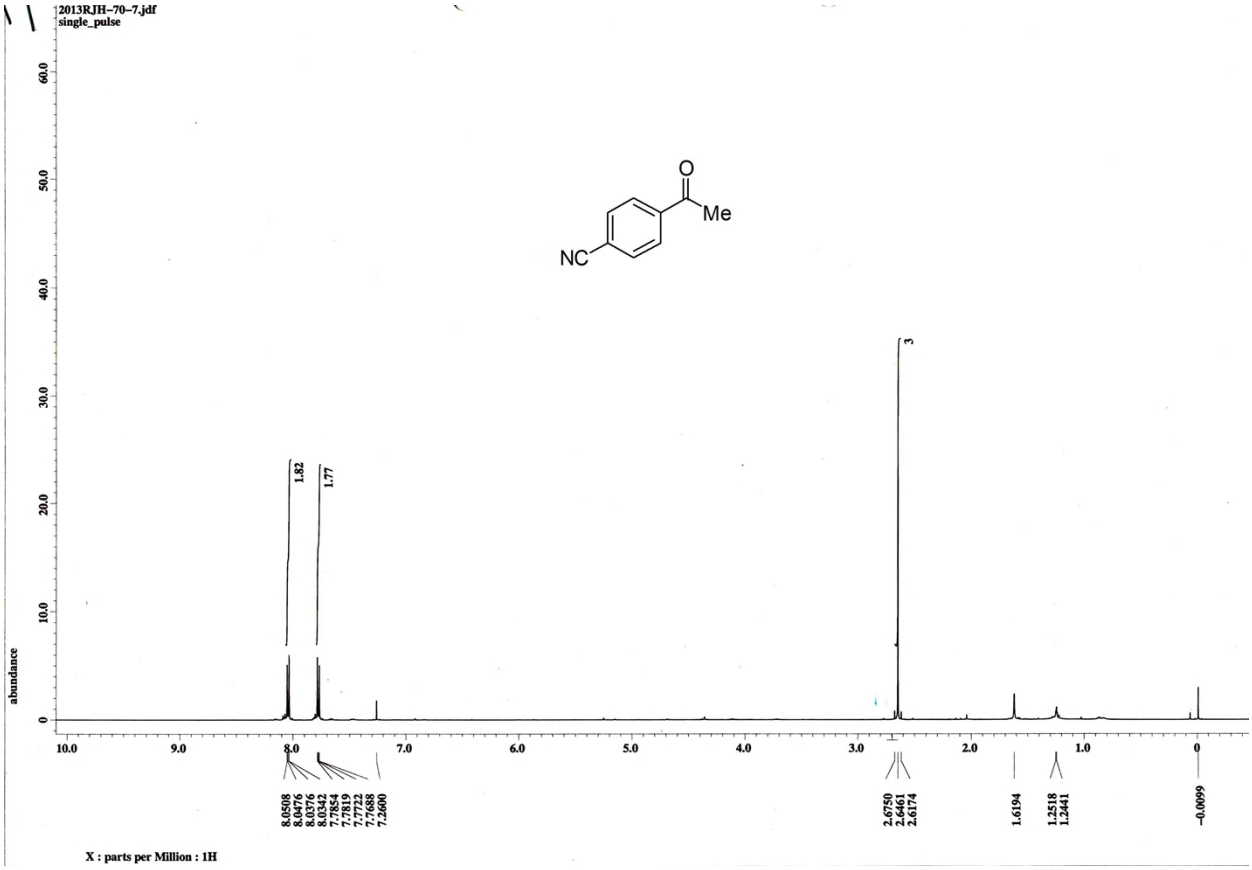


Table 2, (3i)-^{13}C-NMR (125MHz, $CDCl_3$)

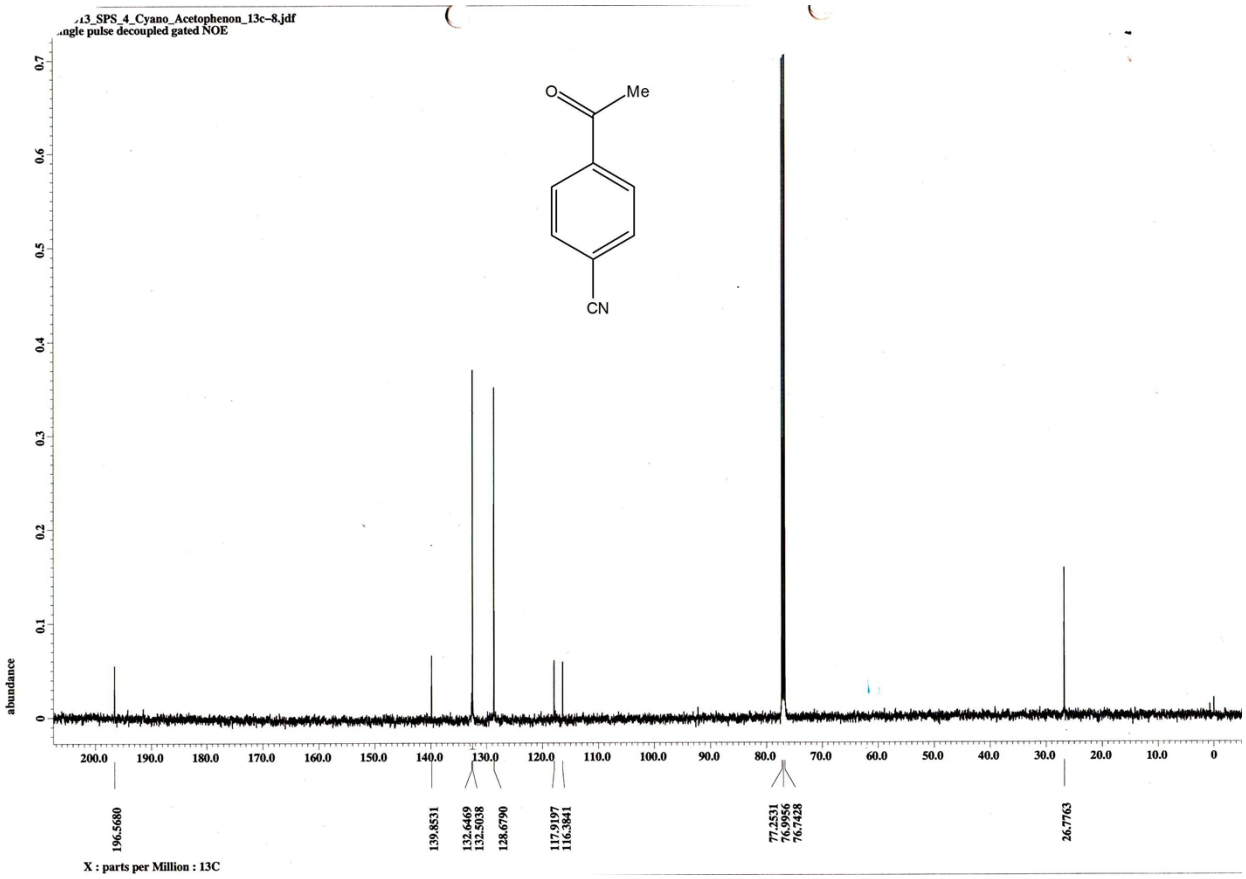


Table 2, (3j)-^{1}H-NMR (500MHz, $CDCl_3$)

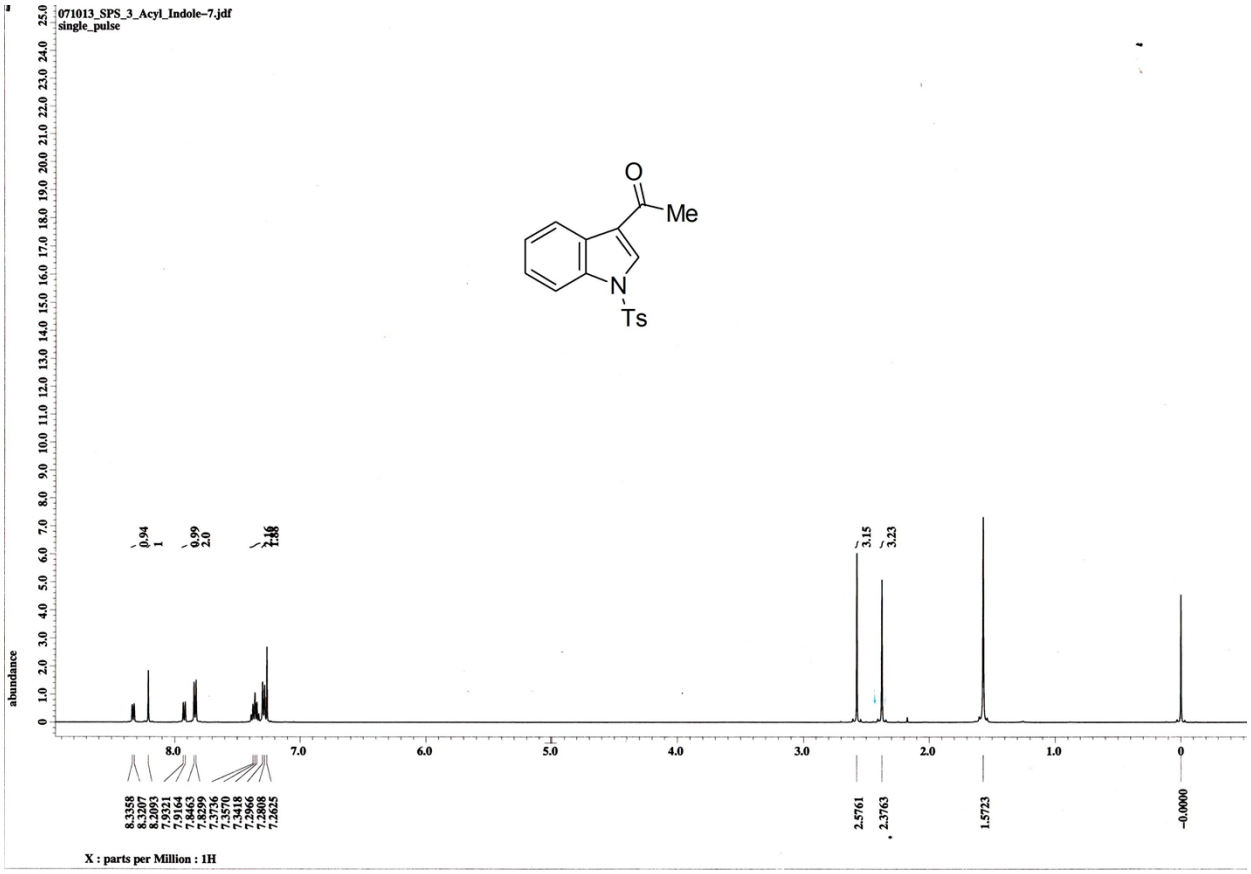


Table 2, (3j)-^{13}C-NMR (125MHz, $CDCl_3$)

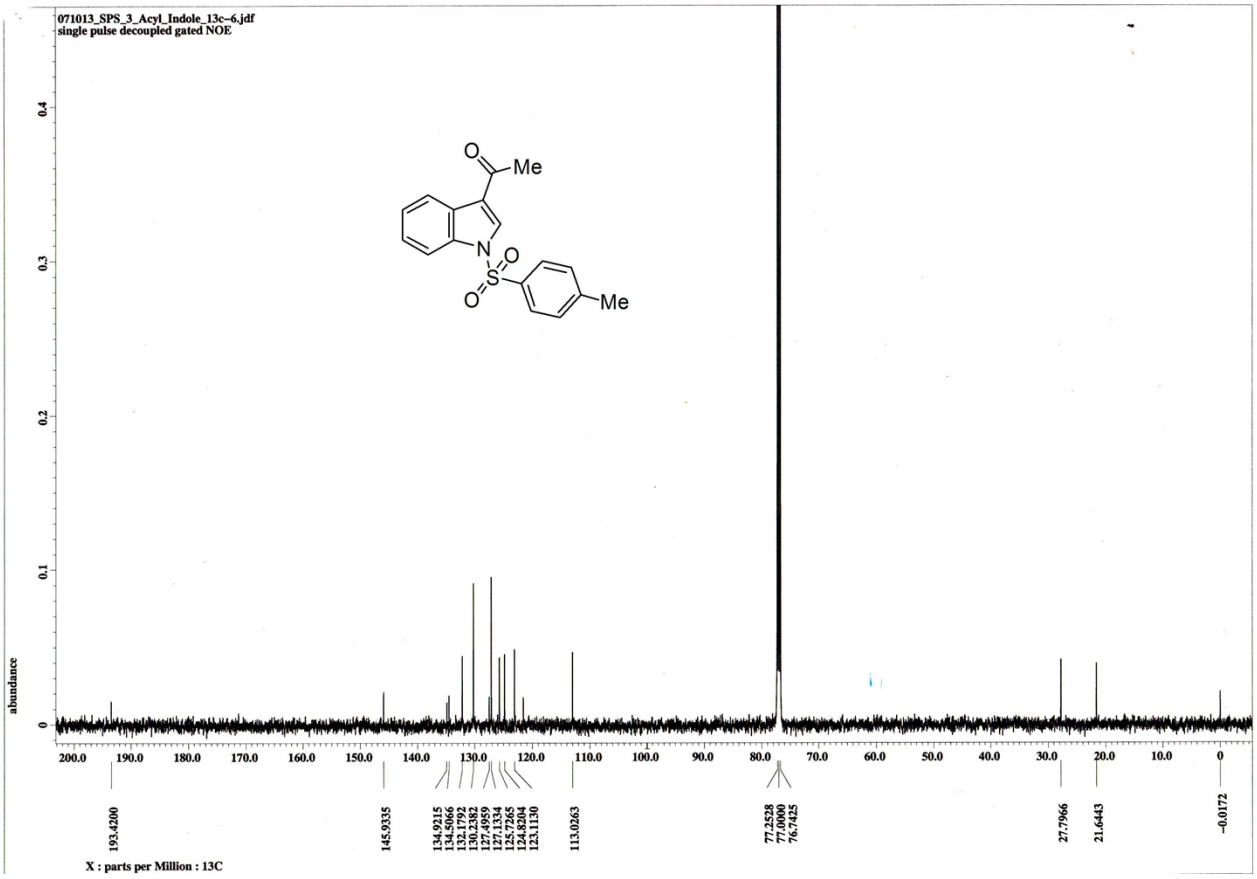


Table 2, (3k)-^{1}H-NMR (500MHz, $CDCl_3$)

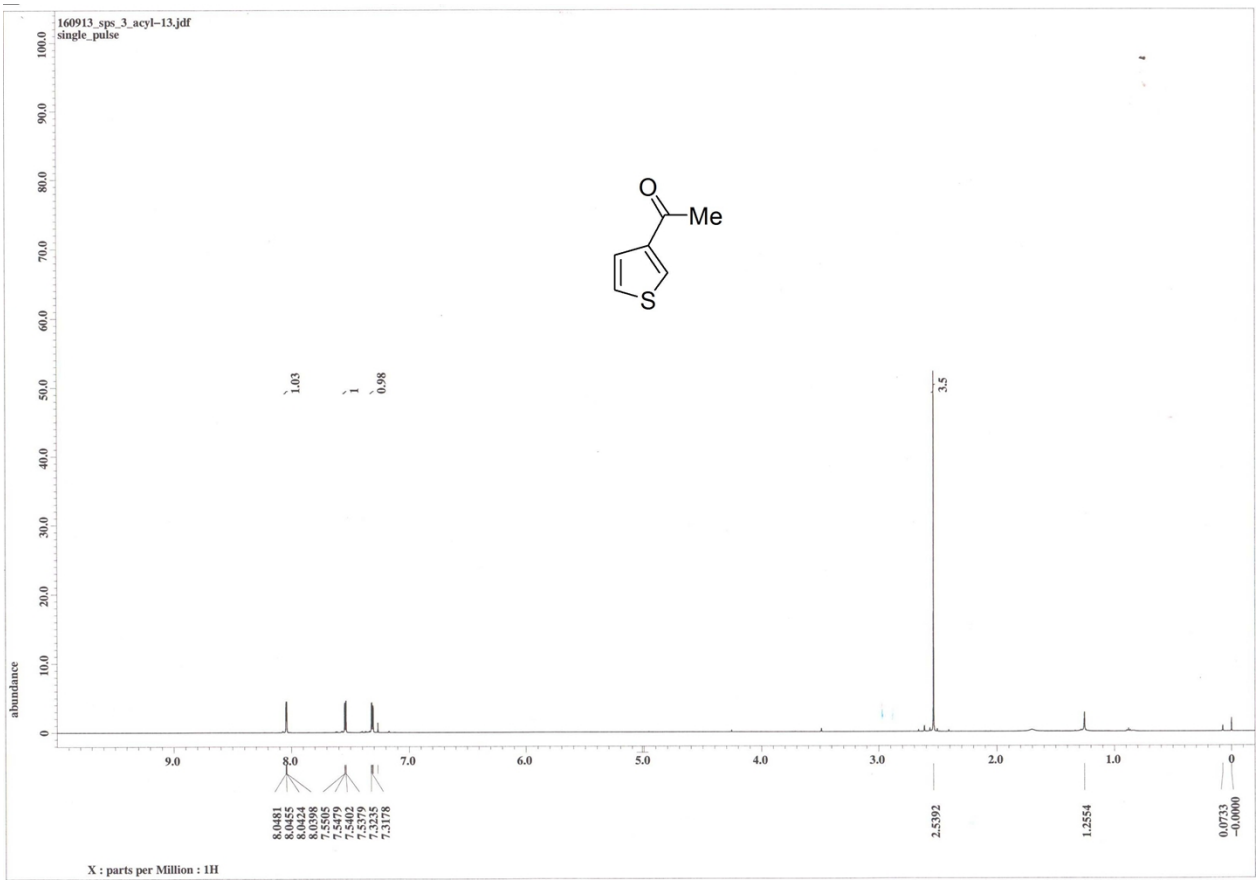


Table 2, (3k)-^{13}C-NMR (125MHz, $CDCl_3$)

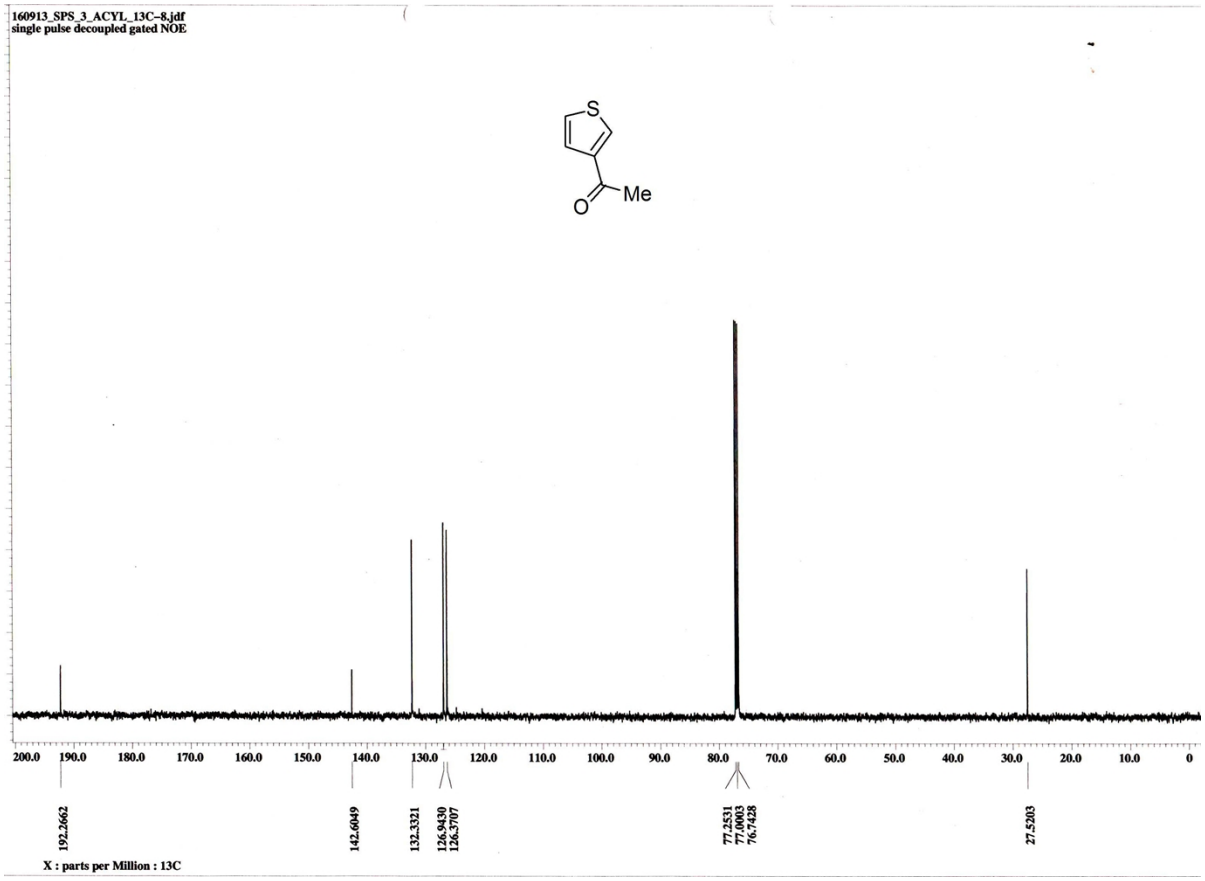


Table 2, (3l)-^{1}H-NMR (500MHz, $CDCl_3$)

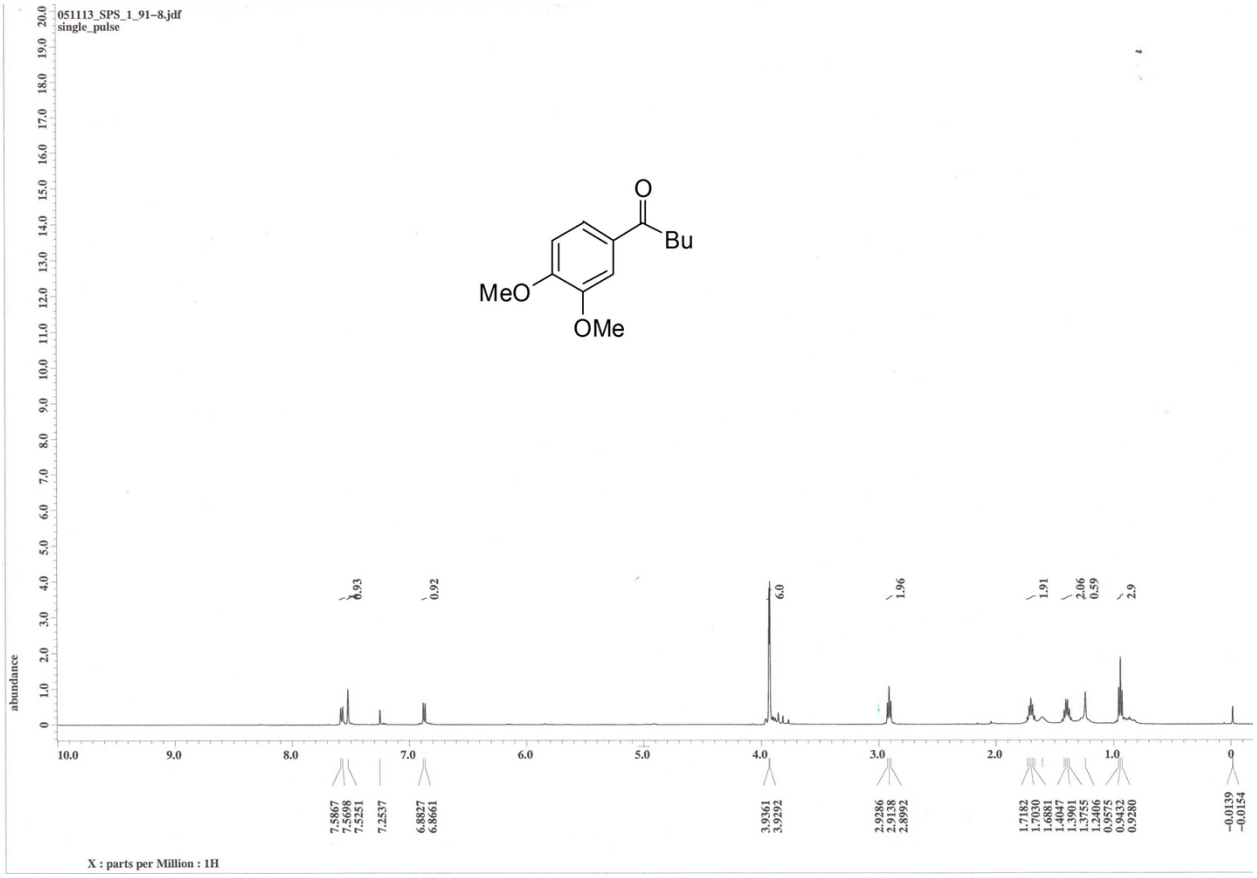


Table 2, (3l)-^{13}C-NMR (125MHz, $CDCl_3$)

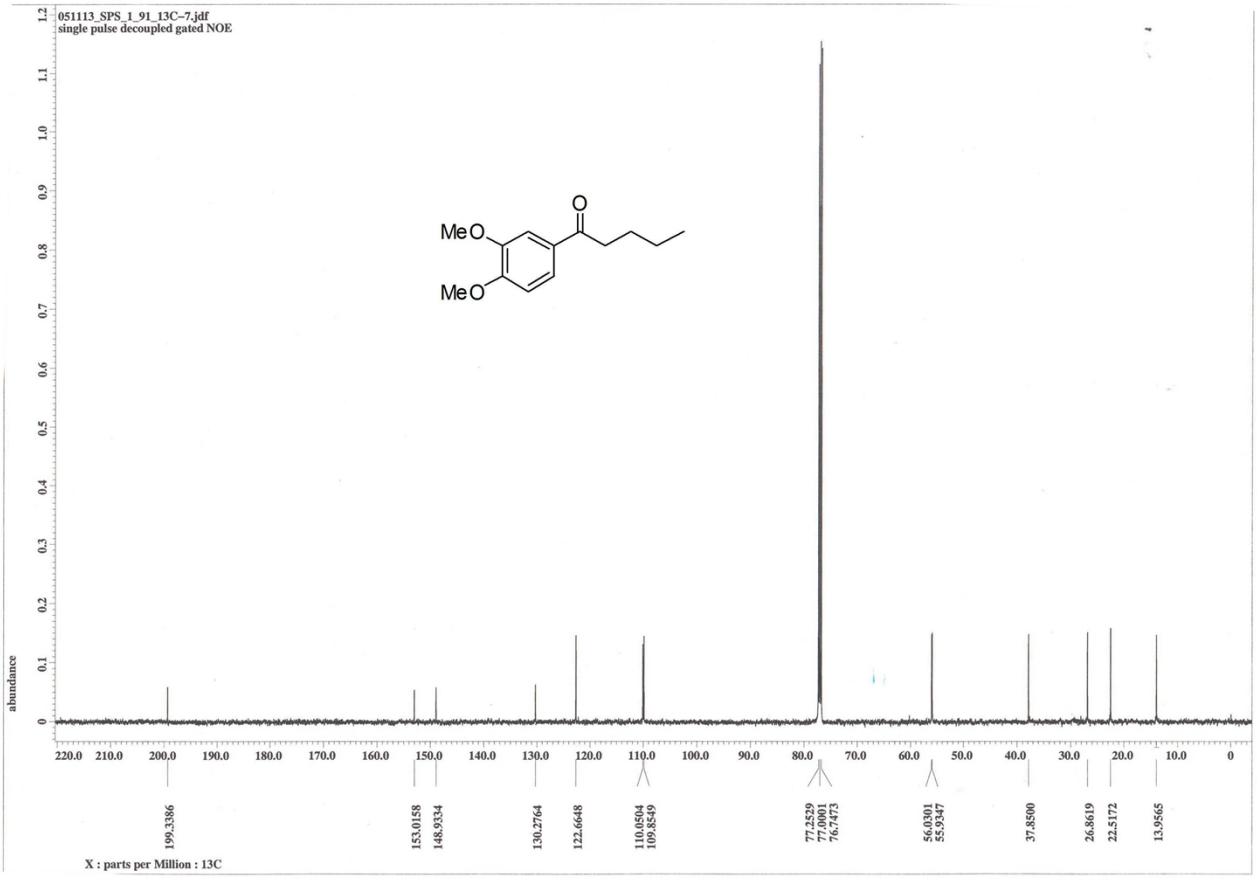


Table 2, (3m)-^{1}H-NMR (500MHz, $CDCl_3$)

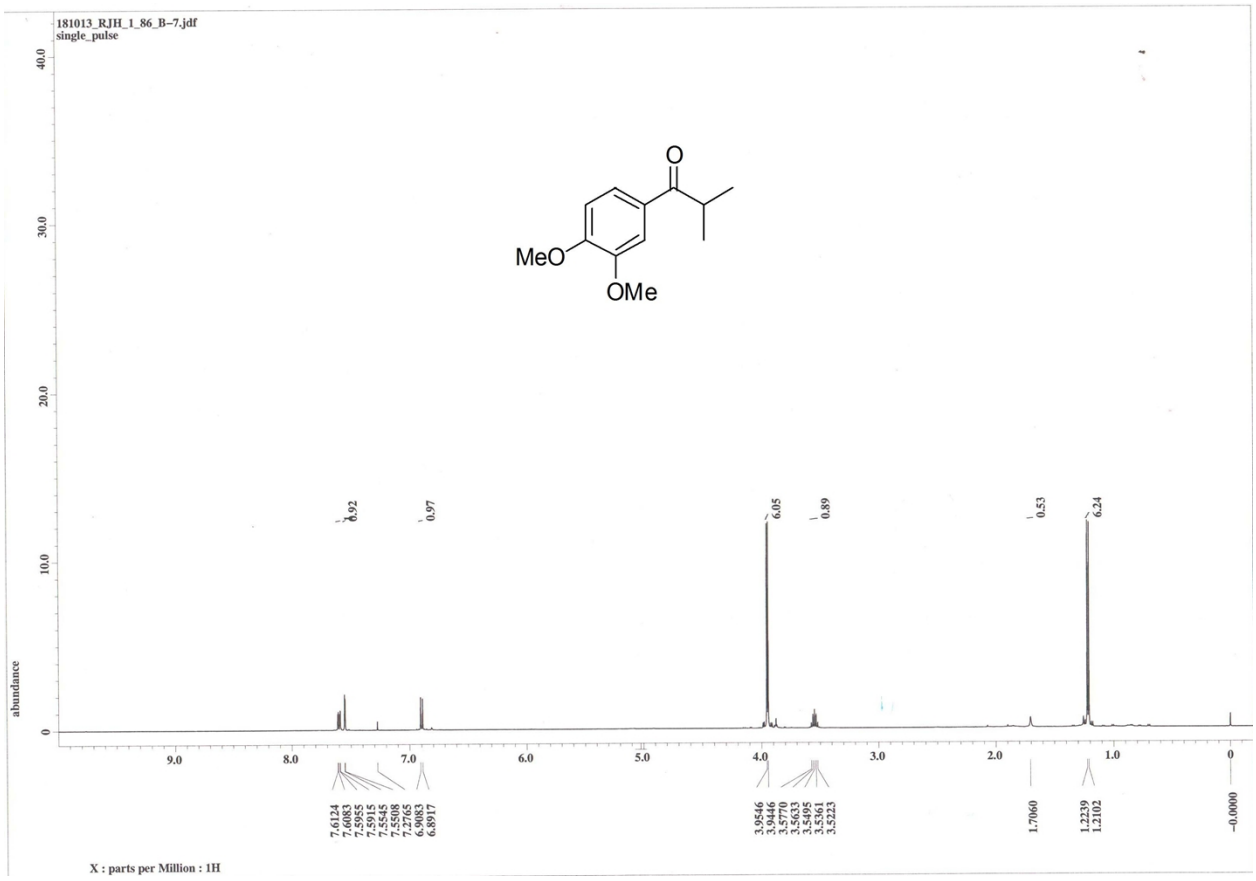


Table 2, (3m)-^{13}C-NMR (125MHz, $CDCl_3$)

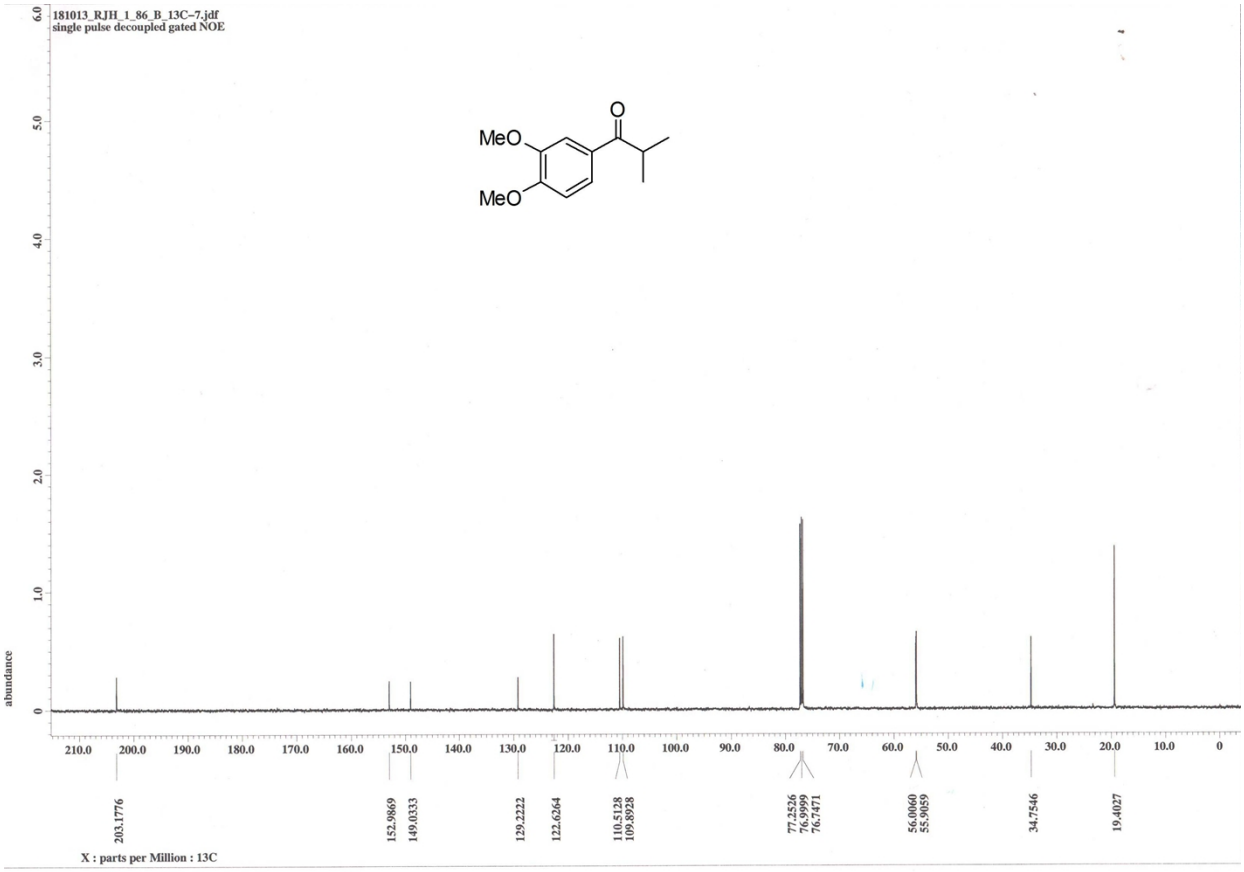


Table 2, (3n)-^{1}H-NMR (500MHz, $CDCl_3$)

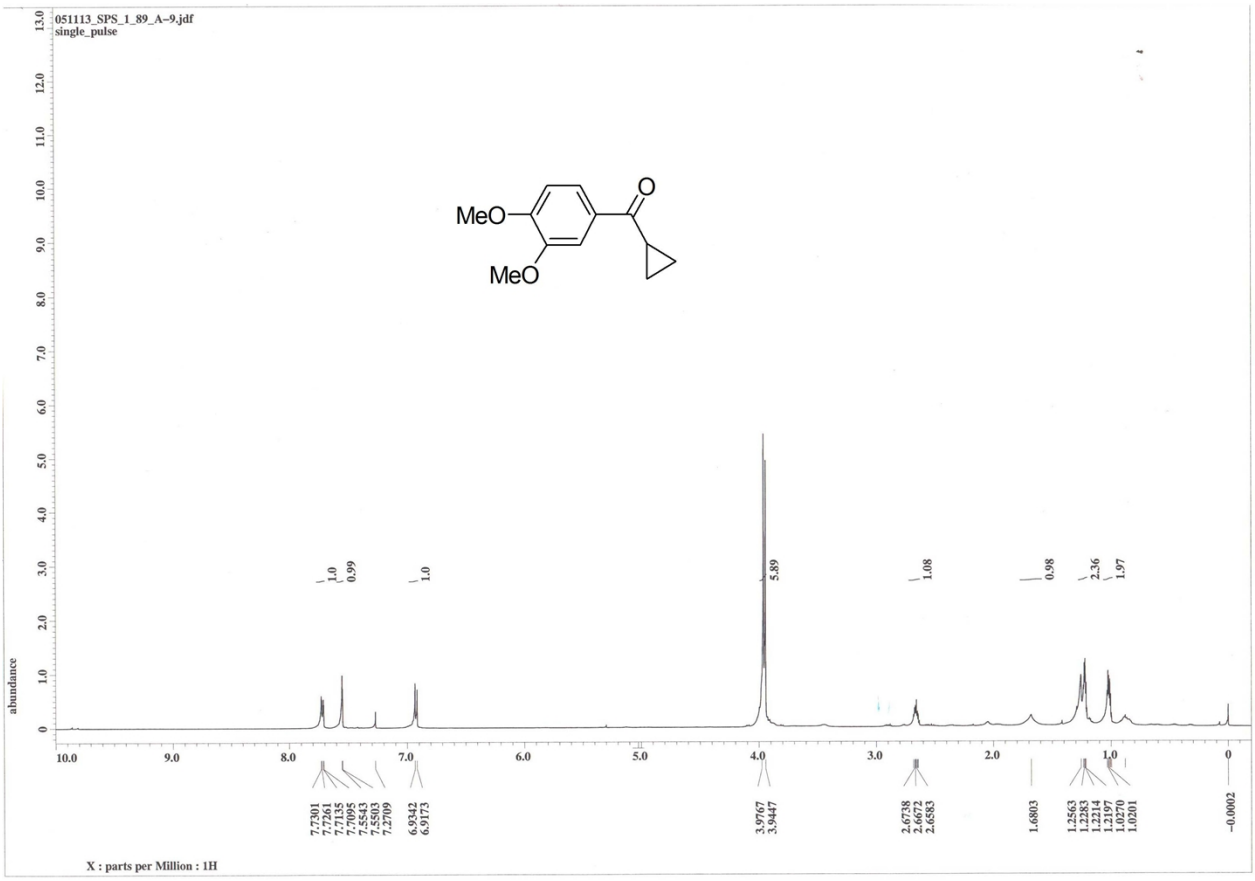


Table 2, (3o)-^{1}H-NMR (400MHz, $CDCl_3$)

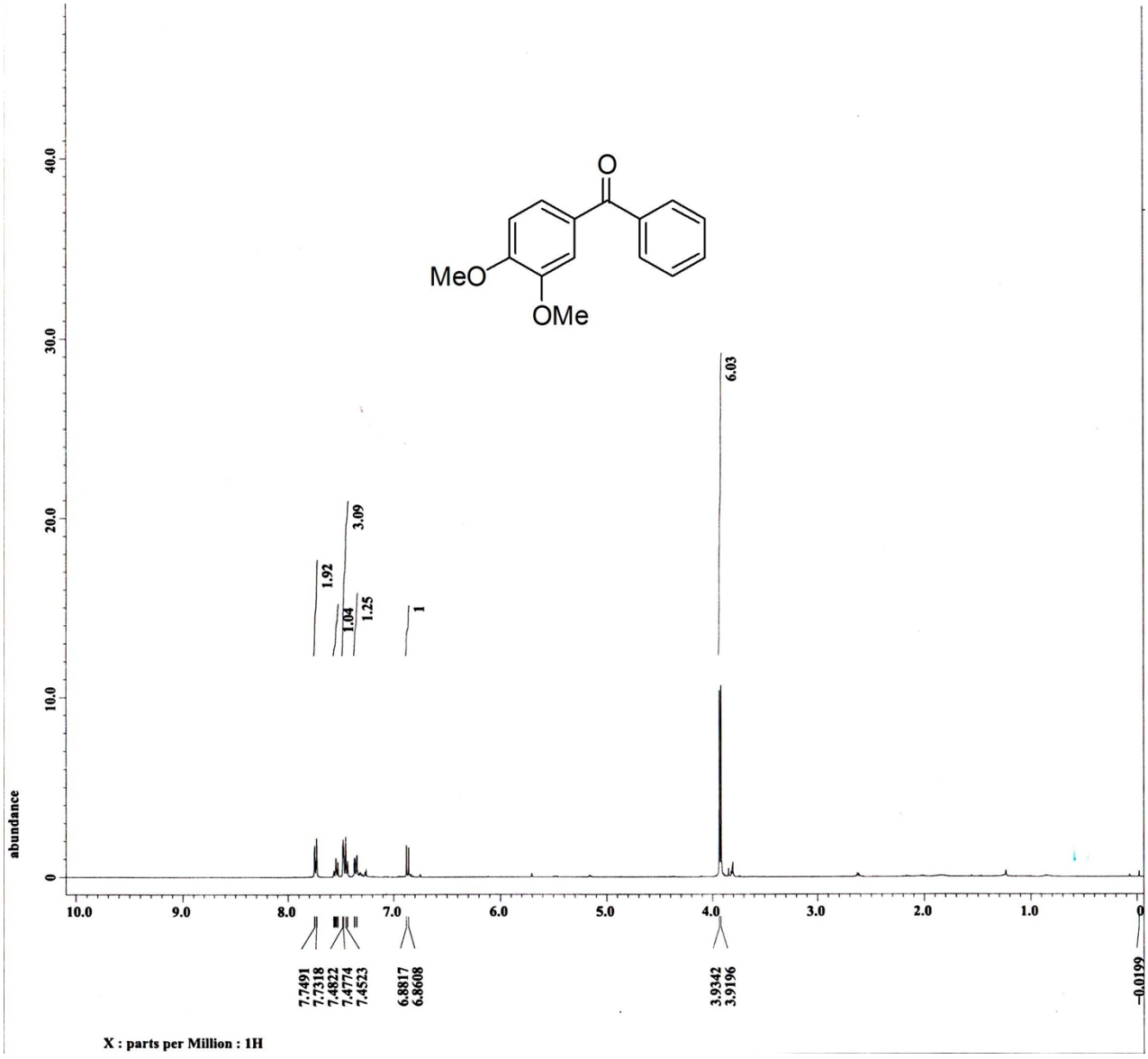


Table 2, (3p)-^{1}H-NMR (400MHz, $CDCl_3$)

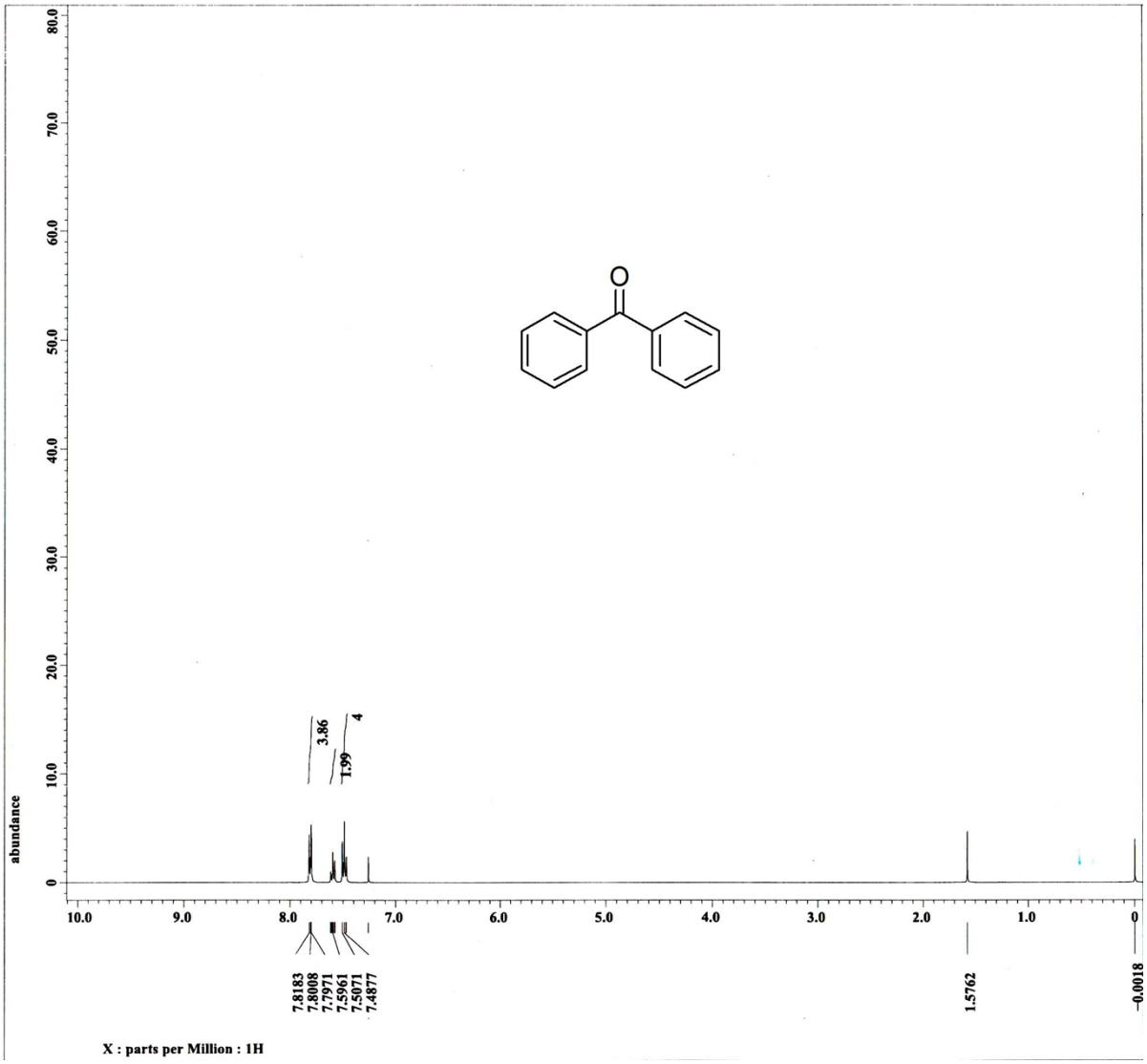


Table 2, (3q)-^{1}H-NMR (400MHz, $CDCl_3$)

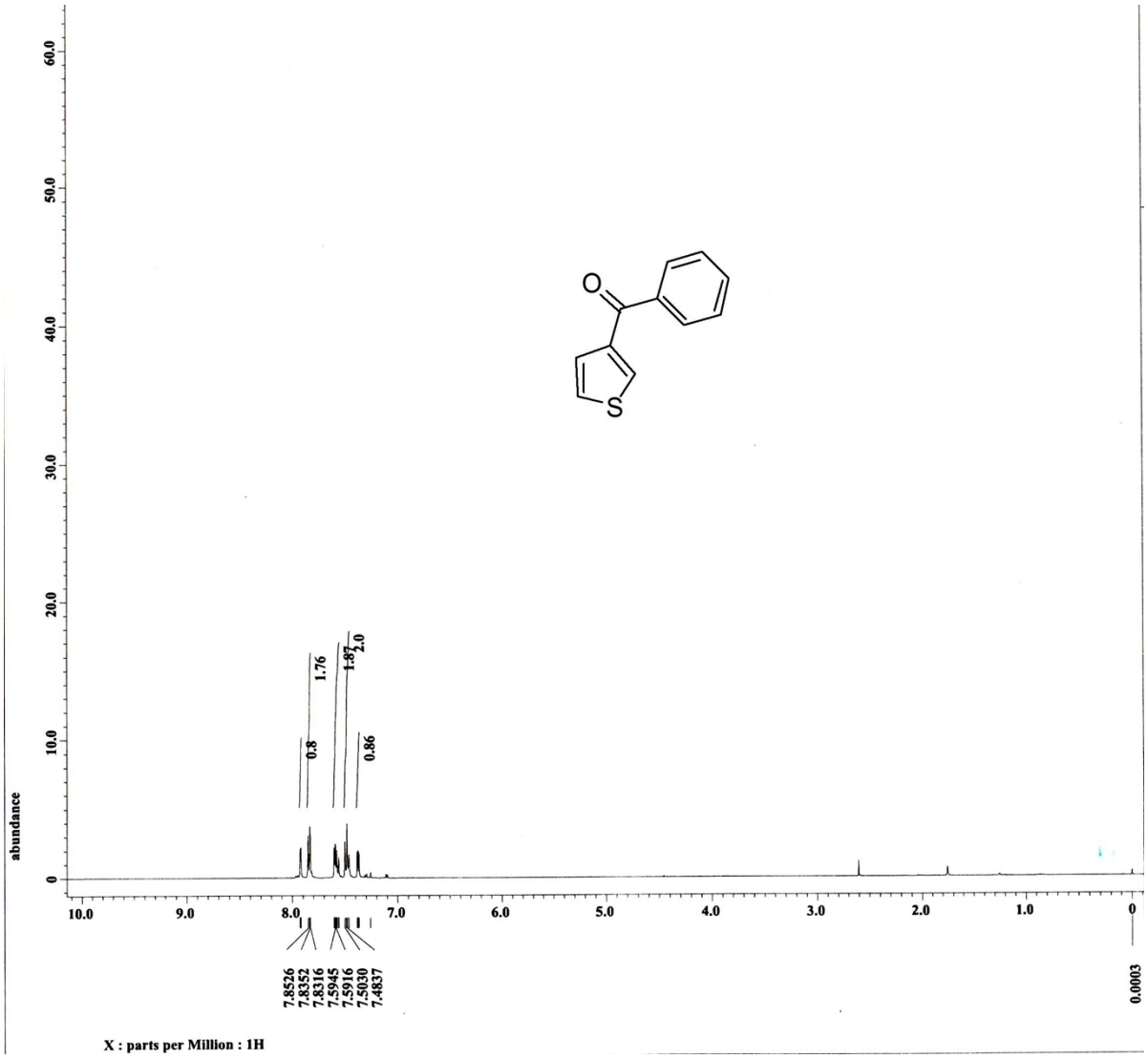
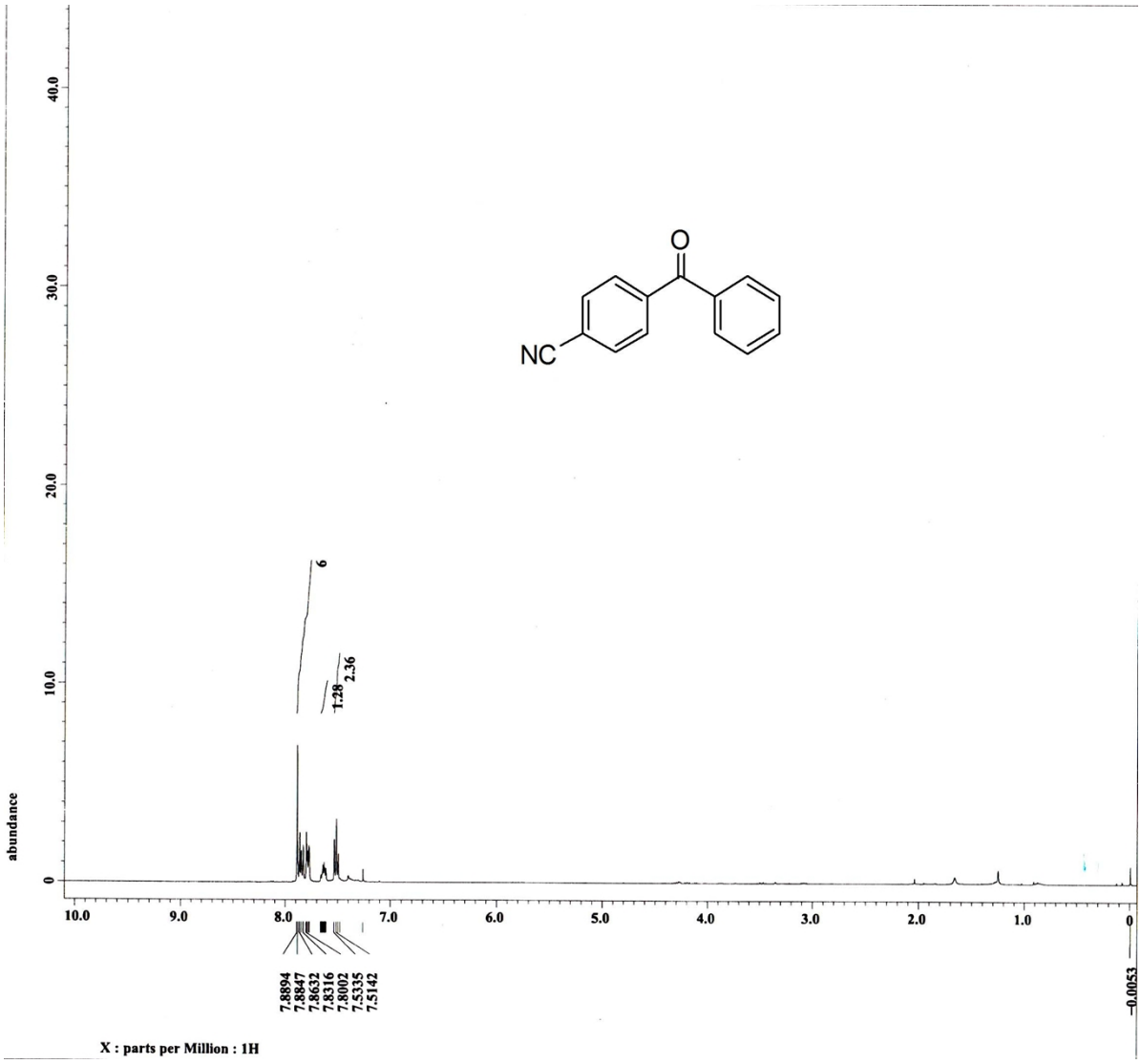


Table 2, (3r)-^{1}H-NMR (400MHz, $CDCl_3$)



References

1. Sharma, U. K.; Sharma, N.; Kumar, R.; Kumar, R.; Sinha, A. K. *Org. Lett.* **2009**, *11,* 4846-4848.
2. Sharghi, H.; Jokar, M.; Doroodmand, M. M.; Khalifeh, R. *Adv. Synth.. Catal.* **2010**, *352*, 3031-3044.
3. Gogsig, T. M.; Kleimark, J.; Lill, S. O. N.; Korsager, S.; Lindhardt, A. T.; Norrby, P.-O.; Skrydstrup, T. *J. Am. Chem. Soc.* **2012**, *134*, 443–452.
4. Qian, W.; Zhang, L.; Sun, H.; Jiang, H.; Liu, H. *Adv. Synth.. Catal.* **2012**, *354*, 3231-3236.
5. Barfield, M.; Collins, M. J.; Gready, J. E.; Sternhell, S.; Tansey, C. W. *J. Am. Chem. Soc.* **1989**, *111*, 4285-4290.
6. Moriyama, K.; Takemura, M.; Togo, H. *Org. Lett.* **2012**, *14,* 2414-2417.
7. Hansen, A. L.; Skrydstrup T. *J. Org. Chem.* **2005**, *70*, 5997-6003.
8. Ran, J.-Q.; Huang, N.; Xu, H.; Yang, L.-M.; Lv, M.; Zheng, Y.-T. *Bioorg. Med. Chem. Lett.* **2010**, *20,* 3534-3536.
9. Barrios, H.; Sandoval, C.; Ortiz, B.; Sanchez-Obregon, R.; Yuste, F. *Org. Prep. Proc. Int.* **1987**, *19*, 427-432.
10. Brenna, E.; Fuganti, C.; Grasselli, P.; Serra, S. *Eur. J. Org. Chem.* **2001**, 1349-1357.
11. Mochalov, S. S.; Khasanov, M. I.; Zefirov, N. S. *Chem. Heterocycl. Compd.* **2009**, *45,* 201-214.
12. Biju, A. T.; Glorius, F. *Angew. Chem. Int. Ed.* **2010**, *49*, 9761 –9764.