Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

Asymmetric synthesis of hetero-1,2,3,4,5-pentasubstituted ferrocenes

William ERB* and Thierry ROISNEL

Univ Rennes, CNRS, ISCR (Institut des Sciences Chimiques de Rennes) – UMR 6226, F-35000 Rennes, France.

Table of contents

EXPERIMENTAL SECTION

General Considerations. Unless otherwise stated, all reactions were performed under an argon atmosphere with anhydrous solvents using Schlenk technics. THF and Et_2O were distilled over sodium/benzophenone. Unless otherwise stated, all reagents were used without prior purification. 2,2,6,6-Tetramethylpiperidine (TMPH) was distilled under vacuum over CaH_2 and was stored over KOH pellets. All organolithiated reagents were titrated before use.[1] Column chromatography separations were achieved on silica gel (40-63 μm). All Thin Layer Chromatographies (TLC) were performed on aluminum backed plates pre-coated with silica gel (Merck, Silica Gel 60 F254). They were visualized by exposure to UV light. Melting points were measured on a Kofler bench. IR spectra were taken on a Perkin-Elmer Spectrum 100 spectrometer. ^{1}H, ^{13}C and ^{19}F Nuclear Magnetic Resonance (NMR) spectra were recorded either (i) on a Bruker Avance III spectrometer at 300 MHz and 75.4 MHz, respectively, or (ii) Bruker Avance III HD at 400 MHz and 100 MHz, respectively. ^{1}H chemical shifts (δ) are given in ppm relative to the solvent residual peak and ^{13}C chemical shifts are relative to the central peak of the solvent signal. Cp refers to the unsubstituted cyclopentadienyl ring of ferrocene. Optical rotations were recorded at 20 °C on a Perkin Elmer 341 polarimeter. Enantiomeric ratios (er) were determined by chiral HPLC on a ThermoFischer Ultimate 3000 apparatus. Racemic Ugi's amine (**(±)-7**) was prepared according to Šebesta and Ugi.[2] 2-Fluoro-1-iodo-3-(trimethylsilyl)ferrocene (**(±)-1**) was prepared according to Erb.[3]

Safety Considerations. Due to their pyrophoric character, BuLi reagents need to be used only under inert conditions (anhydrous, nitrogen or argon atmosphere) and by people well-trained to the manipulation of reactive organometallics. Due to the inherent dangers of using cryogenic temperatures, experiments should be performed by well-trained people.

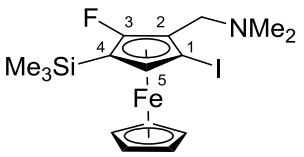
Crystallography. For **(±)-8**, **(±)-10**, **(±)-13**, **(*R*,*S*$_p$)-13**, **(±)-14**, **(*R*,*S*$_p$)-14**, the X-ray diffraction data were collected using D8 VENTURE Bruker AXS diffractometer at the temperature given in the crystal data. The samples were studied with monochromatized Mo-Kα radiation (λ = 0.71073 Å). The structure was solved by dual-space algorithm using the *SHELXT* program,[4] and then refined with full-matrix least-square methods based on F^2 (*SHELXL*).[5] All non-hydrogen atoms were refined with anisotropic atomic displacement parameters. H atoms were finally included in their calculated positions and treated as riding on their parent atom with constrained thermal parameters. The molecular diagrams were generated by MERCURY (version 3.9).

Experimental section.

(±)-2-(Dimethylaminomethyl)-3-fluoro-1-iodo-4-(trimethylsilyl)ferrocene ((±)-2)

*n*BuLi (1.4 M in hexane, 4.70 mL, 6.60 mmol, 1.10 equiv) was added dropwise to a solution of TMPH (1.12 mL, 932 mg, 6.60 mmol, 1.10 equiv) in THF (12.0 mL) at -15 °C. After addition, the reaction was stirred for 5 min at the same temperature before being cooled to -50 °C. After 5 min, compound **(±)-1** was added in one portion and the reaction mixture was stirred at -50 °C for 90 min. Eschenmoser's salt (1.22 g, 6.60 mmol, 1.10 equiv) was added in one portion and the reaction mixture was slowly warmed to rt. Aqueous K_2CO_3 solution (sat., 10 mL) was added and the reaction mixture was extracted with EtOAc (3 x 20 mL). The combined organic layers were dried over $MgSO_4$, filtrated over cotton wool and concentrated under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over SiO_2, using PET-EtOAc (70:30) with 1% of NEt_3 to give the title product as an orange oil (2.31 g, 84%).

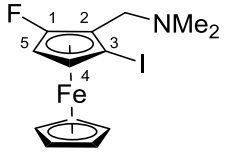
R_f (eluent: PET-EtOAc 70:30 with 5 drops of NEt_3 for 10 mL of eluent) = 0.50. ν_{max} (film)/cm^{-1} 2949, 2815, 2767, 1463, 1409, 1385, 1343, 1246, 1179, 1107, 1095, 1082, 1023, 972, 959, 837, 815, 755, 694. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 4.14 (s, 5H, Cp), 4.00 (d, *J* = 1.6 Hz, 1H, H5), 3.65 (d, *J* = 13.2 Hz, 1H, C*H*H), 3.35 (d, *J* = 13.2 Hz, 1H, CH*H*), 2.27 (s, 6H, $N(CH_3)_2$), 0.27 (s, 9H, $Si(CH_3)_3$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 136.8 (d, *J* = 273.5 Hz, C3), 75.2 (d, *J* = 14.7 Hz, C2), 73.1 (s, Cp), 71.1 (d, *J* = 6.4 Hz, C5), 61.3 (d, *J* = 21.4 Hz, C4), 55.7 (d, *J* = 3.3 Hz, CH_2), 45.5 (s, $N(CH_3)_2$), 43.2 (s, C1), -0.3 (s, $Si(CH_3)_3$). ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) -181.3. Mass: 459 [M], 415 [M-$N(CH_3)_2$], 289 [M-I-$N(CH_3)_2$+H]. Anal. Calcd for $C_{16}H_{23}FFeINSi$: C, 41.85; H, 5.05; N, 3.05. Found: C, 42.07; H, 5.05; N, 3.35.



(±)-2-(Dimethylaminomethyl)-1-fluoro-3-iodoferrocene ((±)-3)

TBAF (1.0 M in THF, 10.7 mL, 10.7 mmol, 2.50 equiv) was added dropwise to a solution of **(±)-2** (2.00 g, 4.30 mmol, 1.00 equiv) in THF (10.0 mL) at rt. After 5 min, water (10 mL) was added and the reaction mixture was extracted with EtOAc (2 x 20 mL). The combined organic layers were dried over $MgSO_4$, filtrated over cotton wool and concentrated under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over SiO_2, using PET-EtOAc (75:25 to 70:30) with 1% of NEt_3 to give the title product as an orange oil (1.48 g, 89%).

R_f (eluent: PET-EtOAc 70:30 with 5 drops of NEt_3 for 10 mL of eluent) = 0.42. ν_{max} (film)/cm^{-1} 2938, 2816, 2768, 1449, 1410, 1371, 1274, 1256, 1179, 1147, 1105, 1015, 1001, 958, 952, 859, 820, 797. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 4.45 (t, *J* = 2.8 Hz, 1H, H5), 4.18 (s, 5H, Cp), 4.15 (dd, *J* = 0.9, 2.2 Hz, 1H, H4), 3.62 (d, *J* = 13.2 Hz, 1H, C*H*H), 3.38 (d, *J* = 13.2 Hz, 1H, CH*H*), 2.26 (s, 6H, $N(CH_3)_2$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 133.0 (d, *J* = 275.6 Hz, C1), 73.3 (d, *J* = 12.6 Hz, C2), 73.0 (s, Cp), 66.7 (d, *J* = 3.4 Hz, C4), 57.3 (d, *J* = 15.8 Hz, C5), 55.7 (d, *J* = 3.3 Hz, CH_2), 45.3 (s, $N(CH_3)_2$), 40.7 (d, *J* = 1.5 Hz, C3). ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) -186.9. Mass: 387 [M], 343 [M-$N(CH_3)_2$], 217 [M-I- $N(CH_3)_2$]. Anal. Calcd for $C_{13}H_{15}FFeIN$: C, 40.35; H, 3.91; N, 3.62. Found: C, 40.47; H, 3.92; N, 3.87.

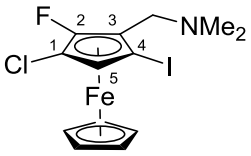


(±)-1-Chloro-3-(dimethylaminomethyl)-2-fluoro-4-iodoferrocene ((±)-4)

*n*BuLi (1.4 M in hexane, 2.70 mL, 3.81 mmol, 1.10 equiv) was added dropwise to a solution of TMPH (642 µL, 538 mg, 3.81 mmol, 1.10 equiv) in THF (10.0 mL) at -15 °C. After addition, the reaction was stirred for 5 min at the same temperature before being cooled to -78 °C. After 5 min, the LiTMP solution was cannulated onto a solution of **(±)-3** (1.34 g, 3.46 mmol, 1.00 equiv) in THF (10.0 mL) at -78 °C. Quantitative transfer was ensured by washing the LiTMP Schlenk tube with THF (1.0 mL). After 1 h at -78 °C, a solution of hexachloroethane (901 mg, 3.81 mmol, 1.10 equiv) in THF (5.0 mL) was added to the reaction mixture which was slowly warmed to rt. Aqueous K_2CO_3 solution (sat., 10 mL) was added

and the reaction mixture was extracted with EtOAc (3 x 20 mL). The combined organic layers were dried over $MgSO_4$, filtrated over cotton wool and concentrated under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over SiO_2, using PET-EtOAc (75:25 to 70:30) with 1% of NEt_3 to give the title product as a red oil (1.26 g, 86%).

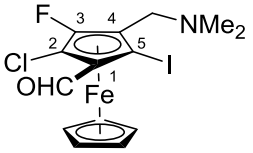
R_f (eluent: PET-EtOAc 70:30 with 5 drops of NEt_3 for 10 mL of eluent) = 0.39. ν_{max} (film)/cm^{-1} 2939, 2817, 2770, 1451, 1270, 1256, 1180, 1133, 1107, 1024, 1002, 942, 822, 689. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 4.51 (s, 1H, H5), 4.23 (s, 5H, Cp), 3.58 (d, *J* = 13.3 Hz, 1H, C*H*H), 3.32 (d, *J* = 13.3 Hz, 1H, CH*H*), 2.25 (s, 6H, $N(CH_3)_2$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 129.4 (d, *J* = 279.6 Hz, C2), 81.6 (d, *J* = 15.9 Hz, C1), 75.2 (s, Cp), 71.9 (d, *J* = 11.7 Hz, C3), 67.4 (s, C5), 55.7 (d, *J* = 3.7 Hz, CH_2), 45.3 (s, $N(CH_3)_2$), 37.1 (s, C4). ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) -191.5. Mass: 421 [M], 377 [M-$N(CH_3)_2$]. Anal. Calcd for $C_{13}H_{14}ClFFeIN$: C, 37.05; H, 3.35; N, 3.32. Found: C, 37.73; H, 3.41; N, 3.68.



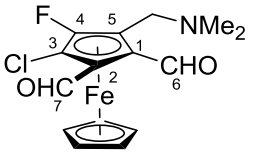
(±)-2-Chloro-4-(dimethylaminomethyl)-3-fluoro-5-iodoferrocenecarboxaldehyde ((±)-5) and (±)-3-chloro-5-(dimethylaminomethyl)-4-fluoroferrocene-1,2-dicarboxaldehyde ((±)-6)

*n*BuLi (1.4 M in hexane, 1.76 mL, 2.47 mmol, 1.10 equiv) was added dropwise to a solution of TMPH (418 µL, 350 mg, 2.47 mmol, 1.10 equiv) in THF (6.6 mL) at -15 °C. After addition, the reaction was stirred for 5 min at the same temperature before being cooled to -78 °C. After 5 min, the LiTMP solution was cannulated onto a solution of **(±)-4** (948 mg, 2.25 mmol, 1.00 equiv) in THF (6.6 mL) at -78 °C. Quantitative transfer was ensured by washing the LiTMP Schlenk tube with THF (1.0 mL). After 1 h at -78 °C, dimethylformamide (192 µL, 181 mg, 2.47 mmol, 1.10 equiv) was added and the reaction mixture was slowly warmed to 0 °C. Methanol (0.5 mL) was added and the reaction mixture was stirred for 15 min at rt. Volatiles were removed under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over SiO_2, using PET-EtOAc (50:50 to 40:60) with 1% of NEt_3 to give **(±)-5** as a red oil (494 mg, 48%) and **(±)-6** as a red oil (69.0 mg, 8%). **Caution**: both compounds are sensitive and decompose upon exposure to air.

Compound (±)-5. R_f (eluent: PET-EtOAc 50:50 with 5 drops of NEt_3 for 10 mL of eluent) = 0.46. ν_{max} (film)/cm^{-1} 2941, 2821, 2772, 1582, 1459, 1412, 1381, 1256, 1179, 1107, 1096, 1021, 909, 829, 776, 728. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 10.16 (s, 1H, CHO), 4.32 (s, 5H, Cp), 3.55 (d, *J* = 13.4 Hz, 1H, C*H*H), 3.46 (d, *J* = 13.3 Hz, 1H, CH*H*), 2.30 (s, 6H, $N(CH_3)_2$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 193.3 (s, CHO), 131.5 (d, *J* = 281.6 Hz, C3), 82.3 (d, *J* = 15.4 Hz, C2), 76.7 (s, Cp), 74.4 (s, C4), 65.2 (s, C1), 55.2 (d, *J* = 3.4 Hz, CH_2), 45.4 (s, $N(CH_3)_2$), 38.9 (s, C5). ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) -184.2.



Compound (±)-6. R_f (eluent: PET-EtOAc 50:50 with 5 drops of NEt_3 for 10 mL of eluent) = 0.28. ν_{max} (film)/cm^{-1} 2941, 2860, 2822, 2774, 1675, 1455, 1412, 1387, 1355, 1179, 1156, 1087, 1022, 1004, 911, 836, 729. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 10.52 (s, 1H, C_6HO), 10.41 (s, 1H, C_7HO), 4.46 (s, 5H, Cp), 4.05 (d, *J* = 13.0 Hz, 1H, C*H*H), 3.54 (d, *J* = 13.0 Hz, 1H, CH*H*), 2.29 (s, 6H, $N(CH_3)_2$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 193.5 (s, CHO), 192.2 (s, CHO), 132.0 (d, *J* = 279.2 Hz, C4), 85.2 (d, *J* = 15.3 Hz, C3), 76.5 (s, FcC), 75.3 (s, Cp), 69.6 (s, FcC), 52.4 (d, *J* = 2.5 Hz, CH_2), 44.8 (s, $N(CH_3)_2$). One signal of FcC missing or overlapping. ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) -182.1.

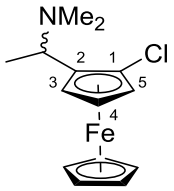


(±)-1-Chloro-2-(α,*N*,*N*-trimethylaminomethyl)ferrocene ((±)-8)

*s*BuLi (1.2 M in cyclohexane-hexane (92:8), 14.0 mL, 16.8 mmol, 1.40 equiv) was added dropwise to a solution of compound **(±)-7** (2.52 mL, 3.08 g, 12.0 mmol, 1.00 equiv) in Et_2O (45.0 mL) at 0 °C. After addition, the reaction was stirred for 1 h at the same temperature before being cooled to -78 °C. After 5 min, a solution of hexachloroethane (3.98 g, 16.8 mmol, 1.40 equiv) in THF (15 mL) was added and the reaction mixture was stirred at the same temperature for 15 min before being warmed to 0 °C. Aqueous

K_2CO_3 solution (sat., 30 mL) was added and the reaction mixture was extracted with EtOAc (3 x 20 mL). The combined organic layers were dried over $MgSO_4$, filtrated over cotton wool and concentrated under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over neutralized SiO_2, using PET-EtOAc (80:20) with 2% of NEt_3 to give the title product as an orange solid (3.35 g, 96%).

R_f (eluent: PET-EtOAc 90:10 with 10 drops of NEt_3 for 10 mL of eluent, 2 developments on TLC plate first dipped into EtOAc-NEt_3 (50:50) and dried) = 0.55. Mp 50-52 °C. ν_{max} (film)/cm^{-1} 2977, 2937, 2824, 2780, 1448, 1393, 1370, 1282, 1255, 1169, 1104, 1072, 1042, 1000, 969, 826, 817, 809, 769, 721. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 4.42 (t, *J* = 1.9 Hz, 1H, H5), 4.16 (s, 5H, Cp), 4.65-4.07 (m, 2H, H3 and H4), 3.80 (q, *J* = 6.9 Hz, 1H, CH), 2.12 (s, 6H, $N(CH_3)_2$), 1.52 (d, *J* = 6.9 Hz, 3H, CH_3). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 92.7 (C1), 85.9 (C2), 71.0 (Cp), 67.6 (C5), 64.9 (C3 or C4), 64.4 (C3 or C4), 55.5 (CH), 41.2 ($N(CH_3)_2$), 17.1 (CH_3). Mass: 291 [M], 276 [M-CH_3], 247 [M-$N(CH_3)_2$], 220 [FcCl]. Anal. Calcd for $C_{14}H_{18}ClFeN$: C, 57.67; H, 6.22; N, 4.80. Found: C, 57.76; H, 6.26; N, 4.81.



Crystal data for (±)-8. $C_{14}H_{18}ClFeN$, *M* = 291.59, *T* = 150 K; monoclinic *P* $2_1/n$ (I.T.#14), *a* = 7.4438(13), *b* = 10.970(2), *c* = 16.145(3) Å, *β* = 94.234(7) °, *V* = 1314.7(4) Å^3. *Z* = 4, *d* = 1.473 g.cm^{-3}, *μ* = 1.326 mm^{-1}. A final refinement on F^2 with 3023 unique intensities and 133 parameters converged at ωR_F^2 = 0.0981 (R_F = 0.0402) for 2713 observed reflections with $I > 2\sigma(I)$. CCDC 1920662.

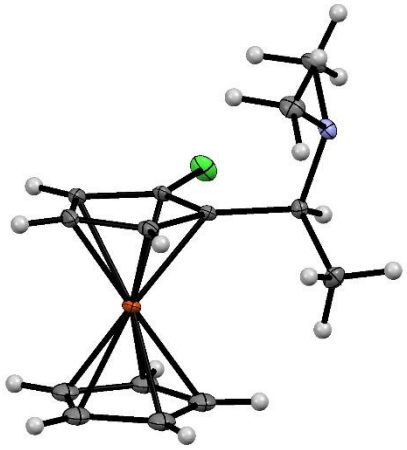


Figure 1. Molecular structure of compound **(±)-8** (thermal ellipsoids shown at the 30% probability level).

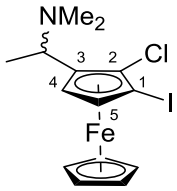
(*R*,*S*$_p$)-1-Chloro-2-(*α*,*N*,*N*-trimethylaminomethyl)ferrocene (*R*,*S*$_p$)-8

By following a similar protocol, starting from **(*R*)-7** (2.52 mL, 3.08 g, 12.0 mmol, 1.00 equiv), the title product was obtained as an orange solid (3.23 g, 92%). Analytical data analogous to racemic compound. $[\alpha]_D$ +0.328 (*c* 0.01 in $CHCl_3$).

(±)-2-Chloro-1-iodo-3-(*α*,*N*,*N*-trimethylaminomethyl)ferrocene ((±)-9)

*n*BuLi (1.3 M in hexane, 13.8 mL, 18.0 mmol, 3.00 equiv) was added dropwise to a solution of TMPH (3.04 mL, 2.54 g, 18.0 mmol, 3.00 equiv) in THF (40.0 mL) at -15 °C. After addition, the reaction was stirred for 5 min at the same temperature before being cooled to -35 °C. After 5 min, the LiTMP solution was cannulated onto a solution of **(±)-8** (1.75 g, 6.00 mmol, 1.00 equiv) in THF (40.0 mL) at -35 °C. Quantitative transfer was ensured by washing the LiTMP Schlenk tube with THF (1.0 mL). After 2 h at -35 °C, iodine (5.33 g, 21.0 mmol, 3.00 equiv) in THF (20 mL) was added and the reaction mixture was stirred for 10 min at -35 °C. At 0 °C, aqueous $Na_2S_2O_3$ (sat., 30 mL) was added. The reaction mixture was warmed to rt and then extracted with EtOAc (2 x 30 mL). The combined organic layers were dried over $MgSO_4$, filtrated over cotton wool and concentrated under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over neutralized SiO_2, using PET-EtOAc (90:10) with 2% of NEt_3 to give the title product as an orange oil (1.99 g, 80%).

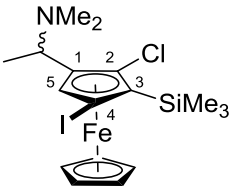
R_f (eluent: PET-EtOAc 90:10 with 10 drops of NEt_3 for 10 mL of eluent, 2 developments on TLC plate first dipped into EtOAc-NEt_3 (50:50) and dried) = 0.43. ν_{max} (film)/cm^{-1} 2972, 2935, 2819, 2774, 1450, 1369, 1322, 1275, 1259, 1195, 1107, 1068, 1001, 976, 943, 875, 820, 770. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 4.39 (d, J = 2.8 Hz, 1H, H5), 4.16 (d, J = 2.8 Hz, 1H, H4), 4.14 (s, 5H, Cp), 3.80 (q, J = 6.9 Hz, 1H, CH), 2.11 (s, 6H, $N(CH_3)_2$), 1.44 (d, J = 6.9 Hz, 3H, CH_3). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 96.7 (C2), 85.4 (C3), 74.1 (Cp), 70.9 (C5), 65.7 (C4), 56.2 (CH), 43.9 (C1), 41.1 ($N(CH_3)_2$), 16.0 (CH_3). Mass: 417 [M], 402 [M-CH_3], 373 [M-$N(CH_3)_2$], 346 [Fc(I)Cl]. Anal. Calcd for $C_{14}H_{17}ClFeIN$: C, 40.28; H, 4.10; N, 3.35. Found: C, 40.45; H, 4.21; N, 3.53.



(±)-2-Chloro-4-iodo-1-(α,*N*,*N*-trimethylaminomethyl)-3-(trimethylsilyl)ferrocene ((±)-10)

*n*BuLi (1.3 M in hexane, 930 µL, 1.21 mmol, 1.10 equiv) was added dropwise to a solution of TMPH (204 µL, 171 mg, 1.21 mmol, 1.10 equiv) in THF (1.00 mL) at -15 °C. After addition, the reaction was stirred for 5 min at the same temperature before being cooled to -50 °C. After 5 min, the LiTMP solution was cannulated onto a solution of **(±)-9** (460 mg, 1.10 mmol, 1.00 equiv) in THF (1.00 mL) at -50 °C. Quantitative transfer was ensured by washing the LiTMP Schlenk tube with THF (0.5 mL). After 2 h at -50 °C, trimethylsilyl chloride (153 µL, 131 mg, 1.21 mmol, 1.10 equiv) was added dropwise and the reaction mixture was warmed to rt. At 0 °C, aqueous K_2CO_3 solution (sat., 5 mL) was added and the reaction mixture was extracted with EtOAc (3 x 5 mL). The combined organic layers were dried over $MgSO_4$, filtrated over cotton wool and concentrated under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over neutralized SiO_2, using PET-EtOAc (90:10) with 2% of NEt_3 to give the title product as an orange solid (319 mg, 59%).

R_f (eluent: PET-EtOAc 90:10 with 10 drops of NEt_3 for 10 mL of eluent, TLC plate first dipped into EtOAc-NEt_3 (50:50) and dried) = 0.35. Mp 97-99 °C. ν_{max} (film)/cm^{-1} 2942, 2895, 2854, 2816, 2775, 1451, 1369, 1325, 1291, 1253, 1243, 1093, 1085, 946, 913, 835, 819, 757, 738. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 4.53 (s, H5), 4.18 (s, 5H, Cp), 3.81 (q, J = 6.9 Hz, 1H, CH), 2.15 (s, 6H, $N(CH_3)_2$), 1.46 (d, J = 6.9 Hz, 3H, CH_3), 0.49 (s, 9H, $Si(CH_3)_3$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 97.7 (C2), 90.4 (C1), 76.1 (C5), 74.0 (Cp), 70.8 (C3), 55.4 (CH), 44.6 (C4), 40.9 ($N(CH_3)_2$), 15.4 (CH_3), 1.9 ($Si(CH_3)_3$). Mass: 489 [M], 474 [M-CH_3], 445 [M-$N(CH_3)_2$], 418 [M-$CH(CH_3)N(CH_3)_2$+H]. Anal. Calcd for $C_{17}H_{25}ClFeINSi$: C, 41.70; H, 5.15; N, 2.86. Found: C, 41.93; H, 5.22; N, 2.94.



Crystal data for (±)-10. $C_{17}H_{28}ClFeINSi$, M = 489.67, T = 150 K; monoclinic P $2_1/n$ (I.T.#14), a = 12.213(2), b = 12.0222(19), c = 14.680(2) Å, β = 112.181(6) °, V = 1996.0(6) Å^3. Z = 4, d = 1.629 g.cm^{-3}, μ = 2.493 mm^{-1}. A final refinement on F^2 with 4498 unique intensities and 167 parameters converged at ωR_F^2 = 0.1336 (R_F = 0.0521) for 3936 observed reflections with $I > 2\sigma(I)$. CCDC 1920661.

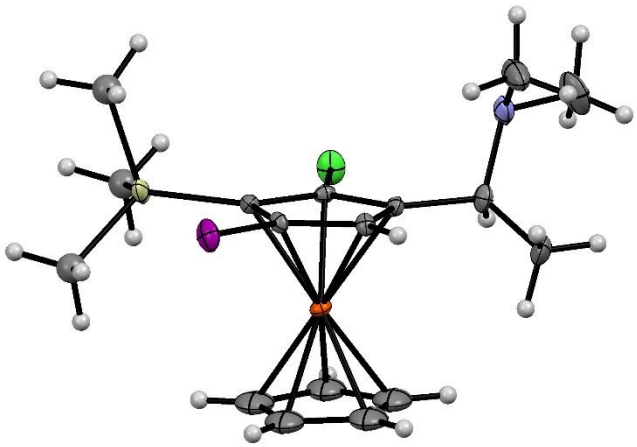
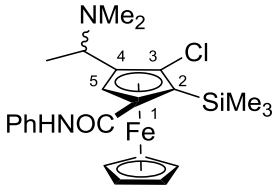


Figure 2. Molecular structure of compound **(±)-10** (thermal ellipsoids shown at the 30% probability level).

(±)-3-Chloro-*N*-phenyl-4-(*α*,*N*,*N*-trimethylaminomethyl)-2-(trimethylsilyl)ferrocenecarboxamide ((±)-11)

*n*BuLi (1.3 M in hexane, 1.60 mL, 2.00 mmol, 2.00 equiv) was added dropwise to a solution of TMPH (338 μL, 283 mg, 2.00 mmol, 2.00 equiv) in THF (4.00 mL) at -15 °C. After addition, the reaction was stirred for 5 min at the same temperature before being cooled to -35 °C. After 5 min, the LiTMP solution was cannulated onto a solution of **(±)-10** (490 mg, 1.00 mmol, 1.00 equiv) in THF (4.00 mL) at -35 °C. Quantitative transfer was ensured by washing the LiTMP Schlenk tube with THF (0.5 mL). After 2 h at -35 °C, phenyl isocyanate (218 μL, 238 mg, 2.00 mmol, 2.00 equiv) was added dropwise and the reaction mixture was warmed to rt. Aqueous K_2CO_3 solution (sat., 10 mL) was added and the reaction mixture was extracted with EtOAc (3 x 10 mL). The combined organic layers were dried over $MgSO_4$, filtrated over cotton wool and concentrated under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over neutralized SiO_2, using PET-EtOAc (90:10) with 2% of NEt_3 to give the title product as an orange solid (46.4 mg, 9.5%, 64.5% brsm).

R_f (eluent: PET-EtOAc 80:20 with 10 drops of NEt_3 for 10 mL of eluent, 3 developments on a TLC plate first dipped into EtOAc-NEt_3 (50:50) and dried) = 0.18. Mp 174-176 °C. ν_{max} (film)/cm^{-1} 3368, 2954, 2819, 2777, 1650, 1594, 1515, 1440, 1369, 1338, 1301, 1239, 1201, 1136, 1109, 1095, 1005, 842, 821, 748, 691. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 7.66 (br s, 1H, NH), 7.53 (d, *J* = 8.6 Hz, 2H, 2 x *o*ArCH), 7.35 (t, *J* = 8.4 Hz, 2H, 2 x *m*ArCH), 7.13 (t, *J* = 7.5 Hz, 1H, *p*ArCH), 4.69 (s, H5), 4.28 (s, 5H, Cp), 3.89 (q, *J* = 6.9 Hz, 1H, CH), 2.18 (s, 6H, $N(CH_3)_2$), 1.54 (d, *J* = 6.9 Hz, 1H, CH_3), 0.47 (s, 9H, $Si(CH_3)_3$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 168.3 (C=O), 18.0 (ArC), 129.3 (2 x *m*ArCH), 124.4 (*p*ArCH), 119.7 (2 x *o*ArCH), 99.7 (C3), 90.3 (C3), 82.4 (C1), 72.7 (Cp), 69.7 (C2), 68.7 (C5), 55.5 (CH), 41.0 ($N(CH_3)_2$), 15.2 (CH_3), 1.7 ($Si(CH_3)_3$). Mass: 482 [M], 467 [M-CH_3], 438 [M-$N(CH_3)_2$], 422, 396. Anal. Calcd for $C_{24}H_{31}ClFeN_2OSi$: C, 59.69; H, 6.47; N, 5.80. Found: C, 60.26; H, 6.50; N, 5.97.

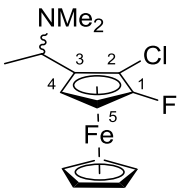


(±)-2-Chloro-1-fluoro-3-(*α*,*N*,*N*-trimethylaminomethyl)ferrocene ((±)-12)

*n*BuLi (1.3 M in hexane, 23.1 mL, 30.0 mmol, 3.00 equiv) was added dropwise to a solution of TMPH (5.10 mL, 4.24 g, 30.0 mmol, 3.00 equiv) in THF (60.0 mL) at -15 °C. After addition, the reaction was stirred for 5 min at the same temperature before being cooled to -35 °C. After 5 min, the LiTMP solution was cannulated onto a solution of **(±)-8** (2.92 g, 10.0 mmol, 1.00 equiv) in THF (60.0 mL) at -35 °C. Quantitative transfer was ensured by washing the LiTMP Schlenk tube with THF (1.0 mL). After 2 h at -35 °C, the reaction mixture was cannulated onto a solution of NFSI (9.46 g, 30.0 mmol, 3.00 equiv) in THF (50 mL) at -35 °C. After addition, the reaction mixture was stirred for 15 min at the same temperature. At 0 °C, an aqueous K_2CO_3 solution (sat., 30 mL) was added and the reaction mixture was

extracted with EtOAc (3 x 30 mL). The combined organic layers were dried over $MgSO_4$, filtrated over cotton wool and concentrated under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over neutralized SiO_2, using PET-EtOAc (90:10) with 2% of NEt_3 to give the title product as an orange solid (807 mg, 26%). Traces of a difluorinated ferrocene derivative were observed by ^{19}F NMR spectroscopy.

R_f (eluent: PET-EtOAc 90:10 with 10 drops of NEt_3 for 10 mL of eluent, 2 developments on TLC plate first dipped into EtOAc-NEt_3 (50:50) and dried) = 0.36. Mp 69-71 °C. ν_{max} (film)/cm^{-1} 3105, 3059, 2970, 2937, 2822, 2781, 1463, 1357, 1288, 1200, 1186, 1105, 1072, 1004, 969, 915, 845, 825, 805, 771, 681. ^1H NMR (300 MHz, $CDCl_3$): δ (ppm) 4.69 (m, 1H, H5), 4.23 (s, 5H, Cp), 3.75-3.68 (m, 2H, H4 and H7), 2.11 (s, 6H, $N(CH_3)_2$), 1.44 (d, J = 6.9 Hz, 3H, CH_3). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 131.2 (d, J = 274.1 Hz, C1), 81.4 (d, J = 13.6 Hz, C2), 78.9 (s, C3), 72.4 (Cp), 56.3 (d, J = 2.9 Hz, C4), 55.6 (s, CH), 52.9 (d, J = 14.0 Hz, C5), 41.2 (s, $N(CH_3)_2$), 16.6 (s, CH_3). Mass: 309 [M], 294 [M-CH_3], 265 [M-$N(CH_3)_2$], 238 [Fc(Cl)F]. ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) -192.2. Anal. Calcd for $C_{14}H_{17}ClFFeN$: C, 54.31; H, 5.53; N, 4.52. Found: C, 54.23; H, 5.53; N, 4.59.



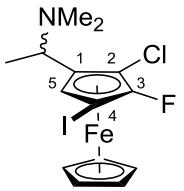
(*R*,*R*$_p$)-2-Chloro-1-fluoro-3-(α,*N*,*N*-trimethylaminomethyl)ferrocene (*R*, *R*$_p$-12)

By following a similar protocol, starting from **(*R*,*S*$_p$)-8** (2.92 g, 10.0 mmol, 1.00 equiv), the title product was obtained as an orange solid (807 mg, 26%). Analytical data analogous to racemic compound. $[\alpha]_D$ +0.527 (*c* 0.01 in $CHCl_3$).

(±)-2-Chloro-3-fluoro-4-iodo-1-(α,*N*,*N*-trimethylaminomethyl)ferrocene ((±)-13)

*n*BuLi (1.4 M in hexane, 1.90 mL, 2.64 mmol, 1.20 equiv) was added dropwise to a solution of TMPH (445 µL, 373 mg, 2.64 mmol, 1.20 equiv) in THF (6.00 mL) at -15 °C. After addition, the reaction was stirred for 5 min at the same temperature before being cooled to -78 °C. After 5 min, the LiTMP solution was cannulated onto a solution of **(±)-12** (681 mg, 2.20 mmol, 1.00 equiv) in THF (6.00 mL) at -78 °C. Quantitative transfer was ensured by washing the LiTMP Schlenk tube with THF (0.5 mL). After 1 h at -78 °C, a solution of iodine (670 mg, 2.64 mmol, 1.20 equiv) was added. The reaction mixture was stirred at the same temperature for 5 min before being warmed to rt and stirred for 10 min. At 0 °C, aqueous $Na_2S_2O_3$ solution (sat., 20 mL) was added and the reaction mixture was extracted with EtOAc (3 x 15 mL). The combined organic layers were dried over $MgSO_4$, filtrated over cotton wool and concentrated under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over neutralized SiO_2, using PET-EtOAc (90:10) with 2% of NEt_3 to give the title product as an orange solid (871 mg, 91%).

R_f (eluent: PET-EtOAc 90:10 with 10 drops of NEt_3 for 10 mL of eluent, 3 developments on TLC plate first dipped into EtOAc-NEt_3 (50:50) and dried) = 0.53. Mp 89-92 °C. ν_{max} (film)/cm^{-1} 2978, 2941, 2860, 1453, 1412, 1372, 1266, 1253, 1196, 1108, 1099, 1069, 1037, 1002, 971, 931, 825, 816, 770, 738, 691. ^1H NMR (300 MHz, $CDCl_3$): δ (ppm) 4.24 (s, 5H, Cp), 4.10 (s, 1H, H5), 3.68 (q, J = 6.9 Hz, 1H, CH), 2.12 (s, 6H, $N(CH_3)_2$), 1.43 (d, J = 6.9 Hz, 3H, CH_3). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 131.4 (d, J = 275.0 Hz, C3), 81.0 (s, C1), 80.0 (d, J = 14.2 Hz, C2), 75.4 (s, Cp), 63.0 (s, C5), 55.6 (s, CH), 41.1 (s, $N(CH_3)_2$), 25.9 (d, J = 14.5 Hz, C4), 16.6 (s, CH_3). ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) -189.9. Mass: 435 [M], 420 [M-CH_3], 391 [M-$N(CH_3)_2$], 364 [Fc(I)F(Cl)]. Anal. Calcd for $C_{14}H_{16}ClFFeIN$: C, 38.61; H, 3.70; N, 3.22. Found: C, 38.70; H, 3.70; N, 3.42.



Crystal data for (±)-13. $C_{14}H_{16}ClFFeIN$, M = 435.48, T = 150 K; orthorhombic *F d d* 2 (I.T.#43), a = 25.124(4), b = 35.336(6), c = 7.0952(13) Å, V = 6299.0(19) Å^3. Z = 16, d = 1.837 g.cm^{-3}, μ = 3.084 mm^{-1}. A final refinement on F^2 with 3353 unique intensities and 175 parameters converged at ωR_F^2 = 0.0485 (R_F = 0.0207) for 3310 observed reflections with $I > 2\sigma(I)$. CCDC 1920663.

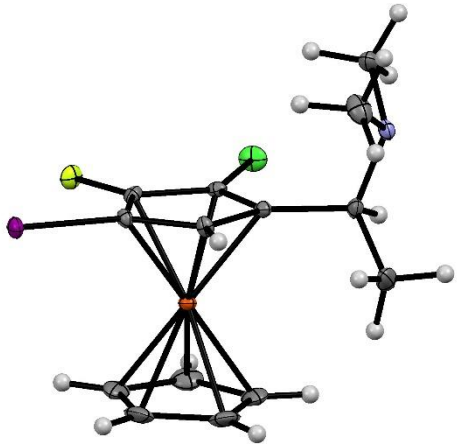


Figure 3. Molecular structure of compound **(±)-13** (thermal ellipsoids shown at the 30% probability level).

(*R*, S_p)-2-Chloro-3-fluoro-4-iodo-1-[α,*N*,*N*-trimethylaminomethyl] ferrocene (*R*, S_p-13)

By following a similar protocol, starting from **(*R*, R_p)-12** (681 mg, 2.20 mmol, 1.00 equiv), the title product was obtained as an orange solid (814 mg, 85%). Analytical data analogous to racemic compound. $[\alpha]_D$ +0.667 (*c* 0.01 in $CHCl_3$).

Crystal data for (*R*, S_p)-13. $C_{14}H_{16}ClFFeIN$, M = 435.48, T = 150 K; orthorhombic $P\ 2_1\ 2_1\ 2_1$ (I.T.#19), a = 7.6115(19), b = 11.500(2), c = 17.886(4) Å, V = 1565.5(6) $Å^3$. Z = 4, d = 1.848 $g.cm^{-3}$, μ = 3.102 mm^{-1}. A final refinement on F^2 with 3540 unique intensities and 175 parameters converged at ωR_F^2 = 0.0581 (R_F = 0.0241) for 3474 observed reflections with $I > 2\sigma(I)$. CCDC 1920665.

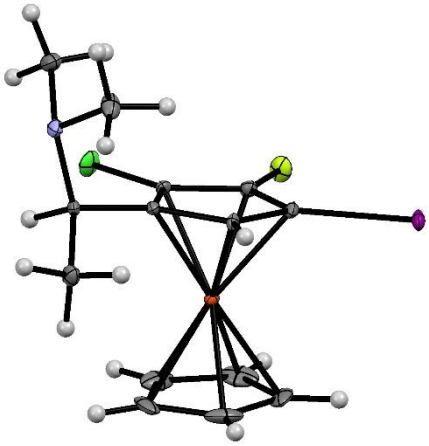


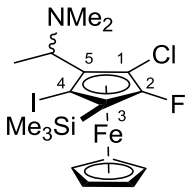
Figure 4. Molecular structure of compound **(*R*, S_p)-13** (thermal ellipsoids shown at the 30% probability level).

(±)-1-Chloro-2-fluoro-4-iodo-5-(α,*N*,*N*-trimethylaminomethyl)-3-(trimethylsilyl)ferrocene ((±)-14) and (±)-2-Chloro-3-fluoro-1-(α,*N*,*N*-trimethylaminomethyl)-4-(trimethylsilyl)ferrocene ((±)-15)

*n*BuLi (1.4 M in hexane, 942 µL, 1.32 mmol, 1.20 equiv) was added dropwise to a solution of TMPH (223 µL, 187 mg, 1.32 mmol, 1.20 equiv) in THF (3.50 mL) at -15 °C. After addition, the reaction was stirred for 5 min at the same temperature before being cooled to -50 °C. After 5 min, **(±)-13** (479 mg, 1.10 mmol, 1.00 equiv) was added in one portion and the reaction mixture was stirred at the same temperature for 4 h. Trimethylsilyl chloride (168 µL, 144 mg, 1.32 mmol, 1.20 equiv) was added dropwise and the reaction mixture was slowly warmed to rt. At 0 °C, aqueous K_2CO_3 solution (sat., 10 mL) was added and the reaction mixture was extracted with EtOAc (2 x 15 mL). The combined organic layers were dried over $MgSO_4$, filtrated over cotton wool and concentrated under vacuum using a rotary

evaporator to give the crude product. This was purified by column chromatography over neutralized SiO_2, using PET-EtOAc (90:10) with 2% of NEt_3 to give **(±)-14** as an orange solid (387 mg, 69%, 80.5% brsm) and **(±)-15** as an orange oil (57.0 mg, 15%, 16% brsm). Traces of a by-product were observed by ^{19}F NMR spectroscopy.

Compound (±)-14. R_f (eluent: PET-EtOAc 90:10 with 10 drops of NEt_3 for 10 mL of eluent, TLC plate first dipped into EtOAc-NEt_3 (50:50) and dried) = 0.51. Mp 61-63 °C. ν_{max} (film)/cm^{-1} 2953, 2818, 2772, 1446, 1384, 1370, 1287, 1248, 1108, 1046, 1003, 840, 818, 758, 731, 714. ^1H NMR (300 MHz, $CDCl_3$): δ (ppm) 4.27 (s, 5H, Cp), 3.68 (q, J = 6.9 Hz, 1H, CH), 2.23 (s, 6H, $N(CH_3)_2$), 1.81 (d, J = 6.9 Hz, 3H, CH_3), 0.46 and 0.45 (2s, 9H, $Si(CH_3)_3$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 134.9 (d, J = 277.6 Hz, C2), 84.3 (s, C5), 83.4 (d, J = 16.7 Hz, C1), 75.1 (s, Cp), 61.0 (d, J = 15.2 Hz, C3), 58.0 (s, CH), 43.2 (s, $N(CH_3)_2$), 38.3 (d, J = 3.2 Hz, C4), 16.8 (s, CH_3), 0.9 (s, $Si(CH_3)_3$). ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) -181.1. Mass: 507 [M], 492 [M-CH_3], 463 [M-$N(CH_3)_2$], 436 [FcI($SiMe_3$)F(Cl)]. Anal. Calcd for $C_{17}H_{24}ClFFeINSi$: C, 40.22; H, 4.77; N, 2.76. Found: C, 40.32; H, 4.70; N, 2.87.



Crystal data for (±)-14. $C_{17}H_{24}ClFFeINSi$, M = 507.66, T = 150 K; orthorhombic $P\ n\ a\ 2_1$ (I.T.#33), a = 10.3652(11), b = 13.2629(14), c = 29.267(3) Å, V = 4023.3(7) Å^3. Z = 8, d = 1.676 g.cm^{-3}, μ = 2.483 mm^{-1}. A final refinement on F^2 with 8585 unique intensities and 427 parameters converged at ωR_F^2 = 0.0513 (R_F = 0.0241) for 8191 observed reflections with $I > 2\sigma(I)$. CCDC 1920664.

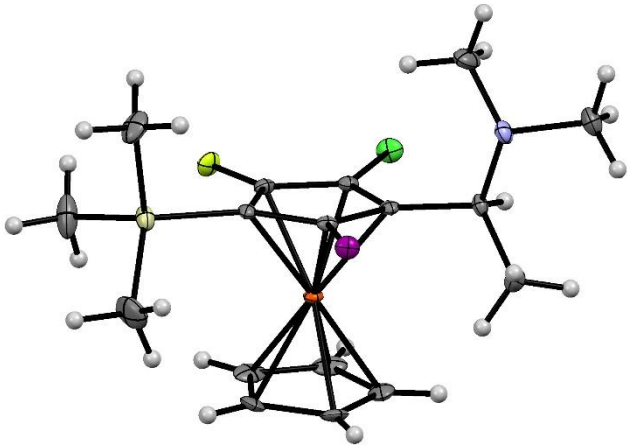
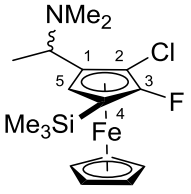


Figure 5. Molecular structure of compound **(±)-14** (thermal ellipsoids shown at the 30% probability level).

Compound (±)-15. R_f (eluent: PET-EtOAc 90:10 with 10 drops of NEt_3 for 10 mL of eluent, TLC plate first dipped into EtOAc-NEt_3 (50:50) and dried) = 0.28. ν_{max} (film)/cm^{-1} 2955, 2820, 2777, 1434, 1394, 1370, 1289, 1248, 1143, 1107, 1063, 1002, 981, 840, 815, 753, 695. ^1H NMR (300 MHz, $CDCl_3$): δ (ppm) 4.19 (s, 5H, Cp), 3.70 (q, J = 6.9 Hz, 1H, CH), 3.59 (d, J = 1.8 Hz, 1H, H5), 2.13 (s, 6H, $N(CH_3)_2$), 1.45 (d, J = 6.9 Hz, 3H, CH_3), 0.29 (s, 9H, $Si(CH_3)_3$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 134.9 (d, J = 271.5 Hz, C3), 82.7 (d, J = 15.9 Hz, C2), 82.5 (s, C1), 72.5 (s, Cp), 60.4 (d, J = 5.7 Hz, C5), 56.2 (d, J = 19.3 Hz, C4), 55.8 (s, CH), 41.4 (s, $N(CH_3)_2$), 16.5 (s, CH_3), -0.3 (s, $Si(CH_3)_3$). ^{19}F NMR (282 MHz, $CDCl_3$): δ (ppm) -186.8. Mass: 381 [M], 366 [M-CH_3], 337 [M-$N(CH_3)_2$], 310 [Fc($SiMe_3$)F(Cl)]. Anal. Calcd for $C_{17}H_{25}ClFFeNSi$: C, 53.48; H, 6.60; N, 3.67. Found: C, 54.16; H, 6.70; N, 3.53.



(*R*,*S*$_p$)-1-Chloro-2-fluoro-4-iodo-5-(α,*N*,*N*-trimethylaminomethyl)-3-(trimethylsilyl)ferrocene (*R*,*S*$_p$-14) and (*R*,*R*$_p$)-2-chloro-3-fluoro-1-(α,*N*,*N*-trimethylaminomethyl)-4-(trimethylsilyl)ferrocene (*R*,*R*$_p$-15)

By following a similar protocol, starting from **(*R*,*S*$_p$)-13** (479 mg, 1.10 mmol, 1.00 equiv), **(*R*,*S*$_p$)-14** was obtained as an orange solid (298 mg, 53%, 61% brsm). Analytical data analogous to racemic

compound. $[\alpha]_D$ +0.465 (*c* 0.01 in $CHCl_3$). Compound **(*R*,*R*$_p$)-15** was obtained as an orange oil (48 mg, 11%, 13% brsm). Analytical data analogous to racemic compound. $[\alpha]_D$ +1.02 (*c* 0.01 in $CHCl_3$).

Crystal data for (*R*,*S*$_p$)-14. $C_{17}H_{24}ClFFeINSi$, M = 507.66, T = 150 K; orthorhombic $P\,2_1\,2_1\,2_1$ (I.T.#19), a = 7.3187(12), b = 12.538(2), c = 21.583(3) Å, V = 1980.5(5) Å^3. Z = 4, d = 1.703 g.cm^{-3}, μ = 2.522 mm^{-1}. A final refinement on F^2 with 4489 unique intensities and 190 parameters converged at ωR_F^2 = 0.0759 (R_F = 0.0303) for 4423 observed reflections with $I > 2\sigma(I)$. CCDC 1920666.

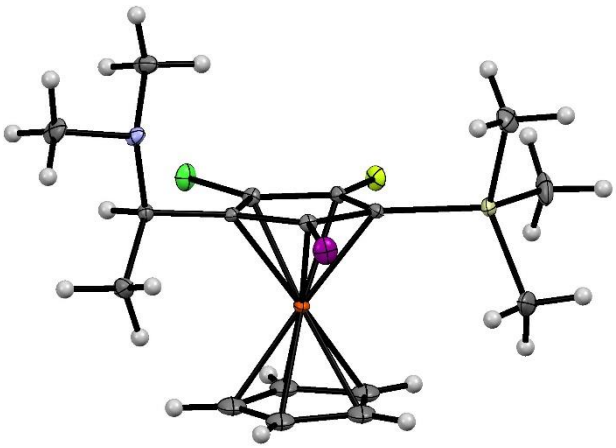
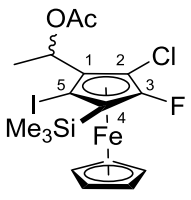


Figure 6. Molecular structure of compound **(*R*,*S*$_p$)-14** (thermal ellipsoids shown at the 30% probability level).

(±)-1-(1-Acetoxyethyl)-2-chloro-3-fluoro-5-iodo-4-(trimethylsilyl)ferrocene ((±)-16)

A solution of **(±)-14** (76.0 mg, 0.15 mmol, 1.00 equiv) in acetic anhydride (425 µL, 460 mg, 4.50 mmol, 30.0 equiv) was stirred at 110 °C for 1 h. The reaction mixture was cooled to rt and poured onto cold aqueous K_2CO_3 solution (sat., 15 mL). Solid K_2CO_3 was added until pH 8-9 was reached and the reaction mixture was extracted with EtOAc (2 x 15 mL). The combined organic layers were dried over K_2CO_3, filtrated over cotton wool and concentrated under vacuum using a rotary evaporator to give the crude product. This was purified by column chromatography over neutralized SiO_2, using PET-EtOAc (90:10) with 2% of NEt_3 to give the title product as an orange oil (63.0 mg, 80%). A mixture of diastereoisomers in a 1:3 ratio was identified by NMR, minor diastereoisomers identified by *.

R_f (eluent: PET-EtOAc 90:10 with 10 drops of NEt_3 for 10 mL of eluent, TLC plate first dipped into EtOAc-NEt_3 (50:50) and dried) = 0.56. ν_{max} (film)/cm^{-1} 2957, 1733, 1438, 1413, 1370, 1239, 1115, 1039, 908, 842, 820, 729, 676. ^{1}H NMR (300 MHz, $CDCl_3$): δ (ppm) 5.95 (q, J = 6.7 Hz, 1H, CH*), 5.89 (q, J = 6.7 Hz, 1H, CH), 4.27 (s, 5H, Cp*), 4.25 (s, 5H, Cp), 2.23 (s, 3H, CH_3CO), 2.11 (s, 3H, CH_3CO*), 1.78 (d, J = 6.7 Hz, 3H, CH_3*), 1.49 (d, J = 6.7 Hz, 3H, CH_3), 0.44 (s, 9H, $Si(CH_3)_3$*), 0.43 (s, 9H, $Si(CH_3)_3$). ^{13}C NMR (75.4 MHz, $CDCl_3$): δ (ppm) 170.0 (s, C=O*), 169.9 (s, C=O), 135.4 (d, J = 278.2 Hz, C3), 135.1 (d, J = 278.2 Hz, C3*), 83.4 (s, C1), 81.1 (s, C1*), 80.0 (d, J = 18.2 Hz, C2 and C2*), 75.3 (s, Cp*), 75.2 (s, Cp), 69.8 (s, CH and CH*), 60.1 (d, J = 15.7 Hz, C4 and C4*), 42.5 (d, J = 3.3 Hz, C5), 41.9 (d, J = 3.3 Hz, C5*), 21.3 (s, *C*H_3CO and *C*H_3CO*), 20.8 (s, CH_3), 19.9 (s, CH_3*), 0.6 ((s, $Si(CH_3)_3$ and $Si(CH_3)_3$*). ^{19}F NMR (376 MHz, $CDCl_3$): δ (ppm) -180.9*, -181.4. Mass: 522 [M], 462 [M-AcOH]. Anal. Calcd for $C_{17}H_{21}ClFFeIO_2Si$: C, 39.07; H, 4.05. Found: C, 43.66; H, 4.77.



(*R*,*S*$_p$-1-(1-Acetoxyethyl)-2-chloro-3-fluoro-5-iodo-4-(trimethylsilyl)ferrocene (*R*,*S*$_p$-16)

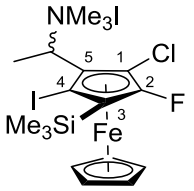
By following a similar protocol, starting from **(*R*,*S*$_p$)-14** (76.0 mg, 0.15 mmol, 1.00 equiv), the title product was obtained as an orange oil (64.0 mg, 81%). A mixture of diastereoisomers in a 1:4.5 ratio was identified by NMR, otherwise analytical data analogous to racemic compound. $[\alpha]_D$ -0.40 (*c* 0.01 in $CHCl_3$). ee = 99.5%, de = 63%. The enantiomeric and diastereoisomeric ratios were determined on

Chiralpak IC-3 column, hexane/iPrOH: 99.5:0.5, 0.25 mL/min, 5 °C, λ = 254 nm, t (*S*, R_p) = 35.71 min, t (*R*, S_p) = 37.91 min, t (*S*, S_p) = 40.72 min, t (*R*, R_p) = 41.83 min.

(±)-1-Chloro-2-fluoro-4-iodo-5-(α,*N*,*N*,*N*-tetramethylaminomethyl)-3-(trimethylsilyl)ferrocene iodide ((±)-17)

Iodomethane (21.8 μL, 49.7 mg, 0.35 mmol, 5.00 equiv) was added dropwise to a solution of **(±)-13** (35.5 mg, 0.07 mmol, 1.00 equiv) in CH_3CN (1.00 mL) at rt. After 1 h, volatiles were removed under vacuum using a rotary evaporator to give the crude product. This was triturated with Et_2O (2 mL) and filtrated. The resulting solids were washed with Et_2O (2 x 2 mL) and dried under high vacuum to give the title product as an orange solid (45.4 mg, quant.).

R_f (eluent: PET-EtOAc 50:50 with 10 drops of NEt_3 for 10 mL of eluent, TLC plate first dipped into EtOAc-NEt_3 (50:50) and dried) = 0.00. Mp 149-153 °C (decomp.). ν_{max} (film)/cm^{-1} 3445 (br), 2959, 1615, 1486, 1443, 1382, 1277, 1264, 1245, 1045, 849, 826, 758, 724, 701. ^{1}H NMR (500 MHz, $CDCl_3$): δ (ppm) 4.91 (q, *J* = 7.2 Hz, 1H, CH), 4.43 (s, 5H, Cp), 3.04 (s, 9H, NMe_3), 2.23 (d, *J* = 7.2 Hz, 1H, CH_3), 0.47 (s, 9H, $Si(CH_3)_3$). ^{13}C NMR (125 MHz, $CDCl_3$): δ (ppm) 134.9 (d, *J* = 276.5 Hz, C2), 83.3 (d, *J* = 17.7 Hz, C1), 76.1 (s, Cp), 76.0 (s, C5), 68.9 (s, CH), 64.5 (d, *J* = 14.9 Hz, C3), 51.8 (s, NMe_3), 36.9 (s, C4), 16.2 (s, CH_3), 0.8 (d, *J* = 1.7 Hz, $Si(CH_3)_3$). ^{19}F NMR (470 MHz, $CDCl_3$): δ (ppm) -177.9.

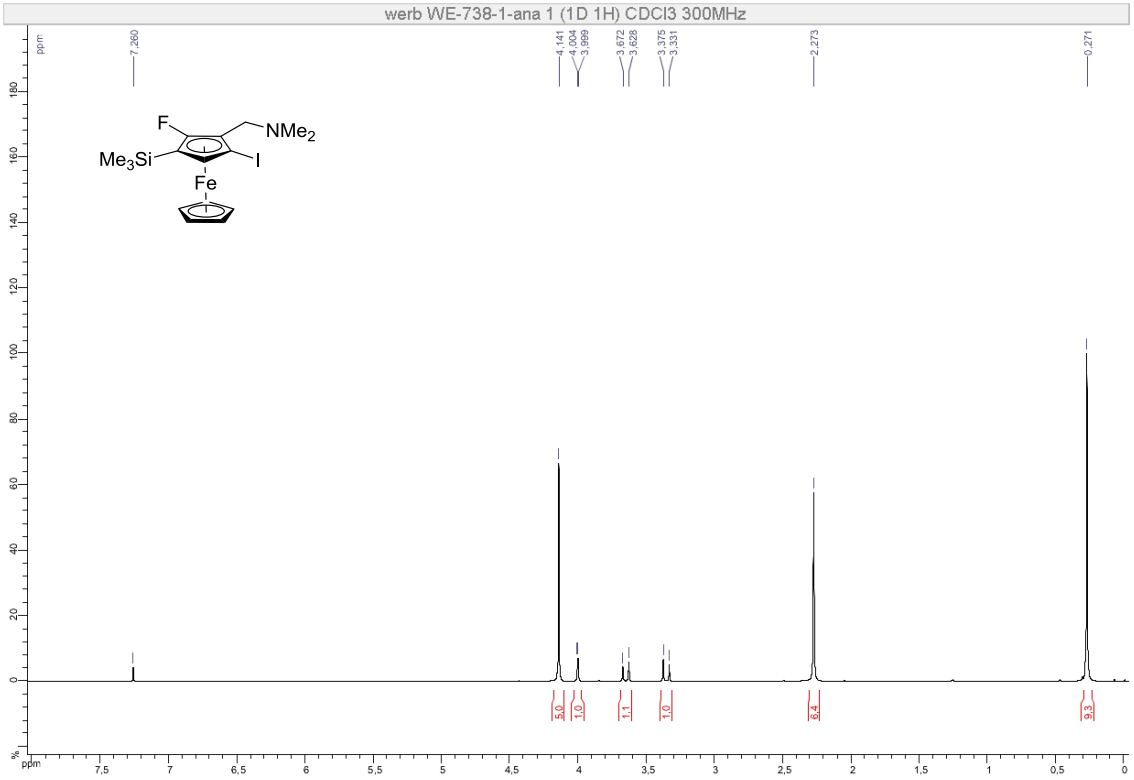


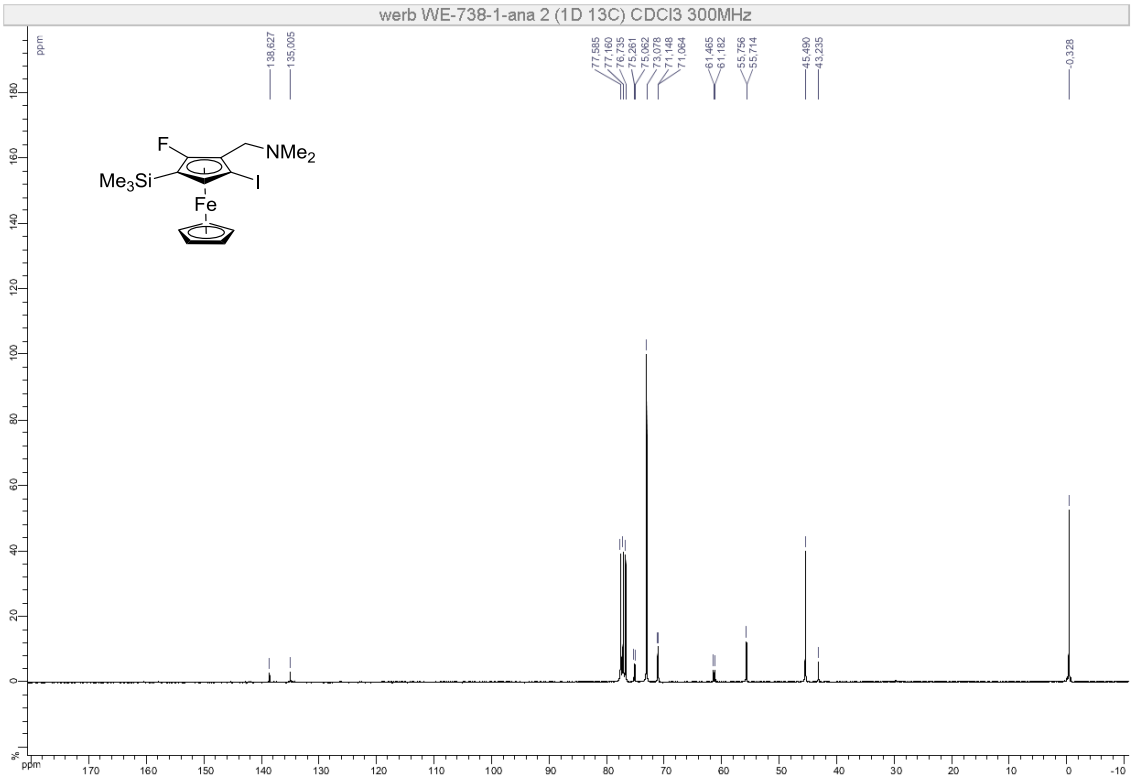
(*R*,S_p)-1-Chloro-2-fluoro-4-iodo-5-(α,*N*,*N*,*N*-tetramethylaminomethyl)-3-(trimethylsilyl)ferrocene iodide ((*R*,S_p)-17)

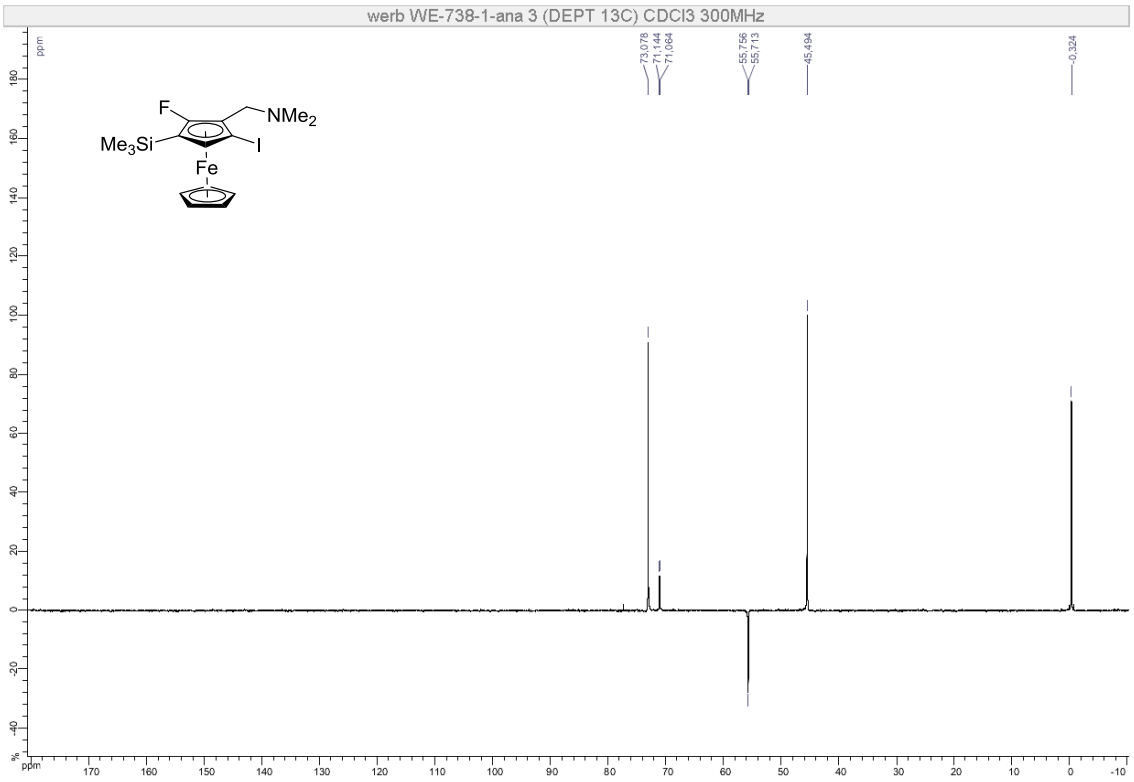
By following a similar protocol, starting from **(*R*,S_p)-14** (35.5 mg, 0.07 mmol, 1.00 equiv), the title product was obtained as an orange solid (45.3 mg, quant.). Analytical data analogous to racemic compound. $[\alpha]_D$ +0.643 (*c* 0.01 in CH_3CN).

NMR Spectra

<u>Compound (±)-2</u>



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Me3Si
I
Fe
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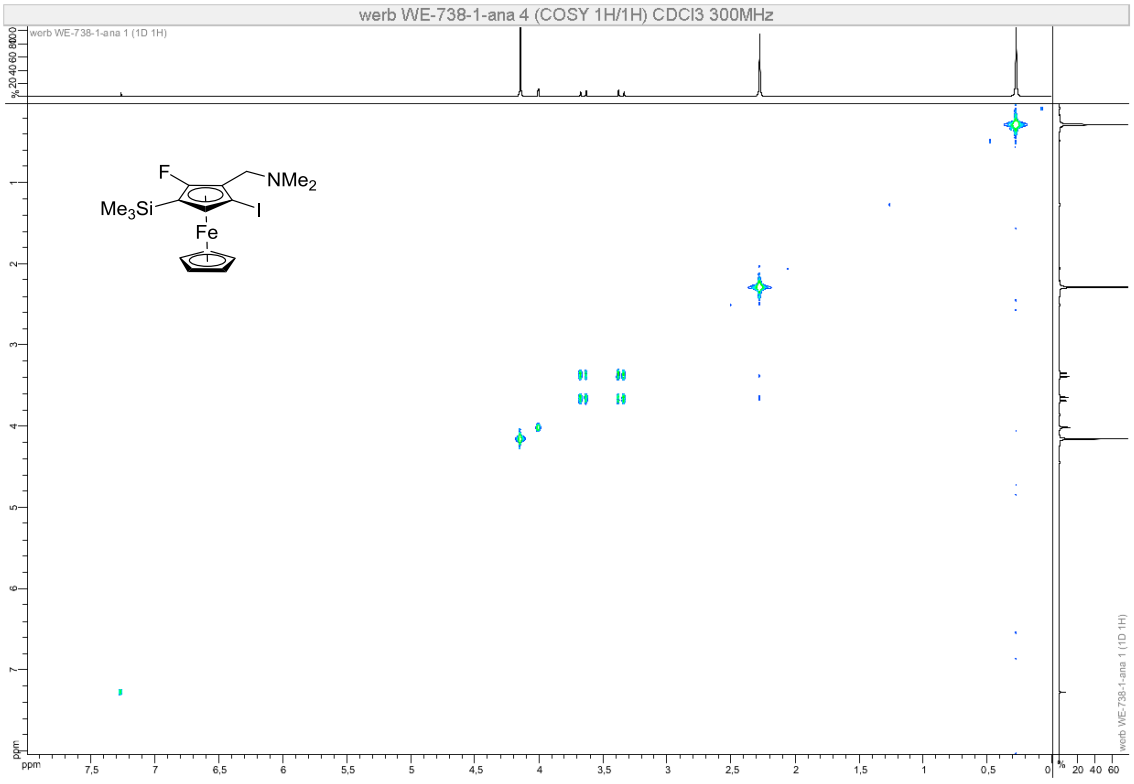
77,084
55,756
55,713
45,494
-0,324
ppm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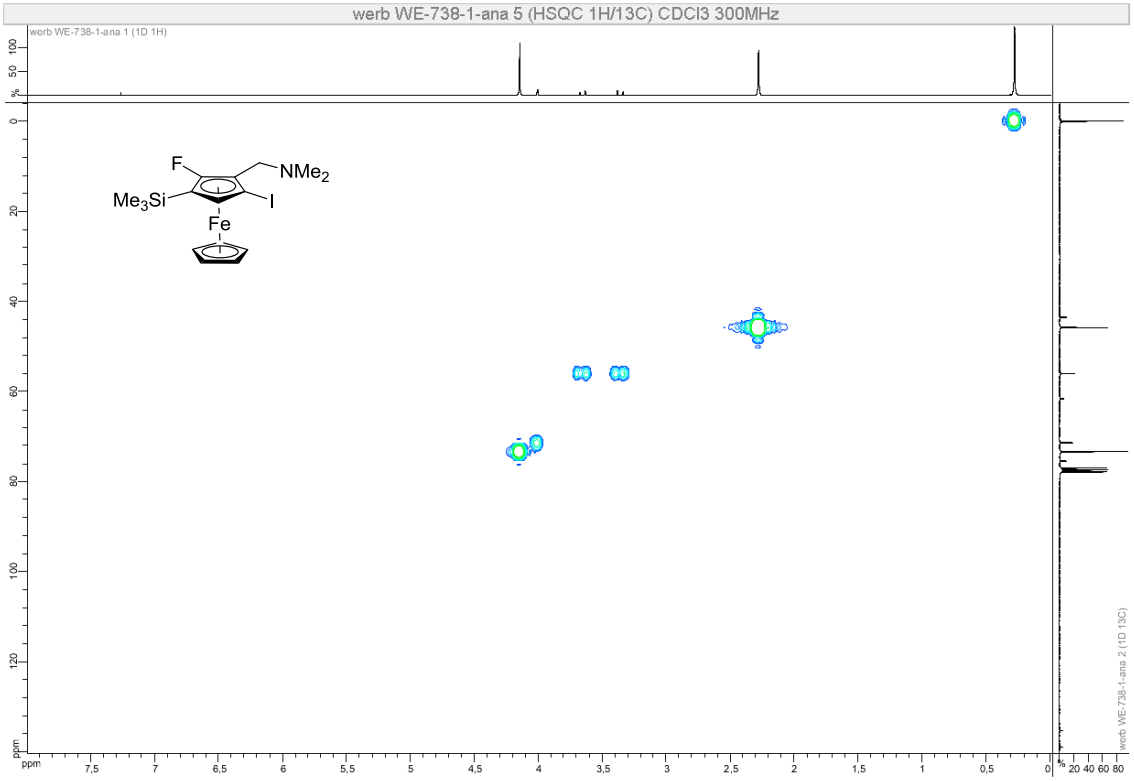
werb WE-738-1-ana 1 (1D 1H)
F
NMe2
Me3Si
I
Fe
ppm


werb WE-738-1-ana 5 (HSQC 1H/13C) CDCl3 300MHz
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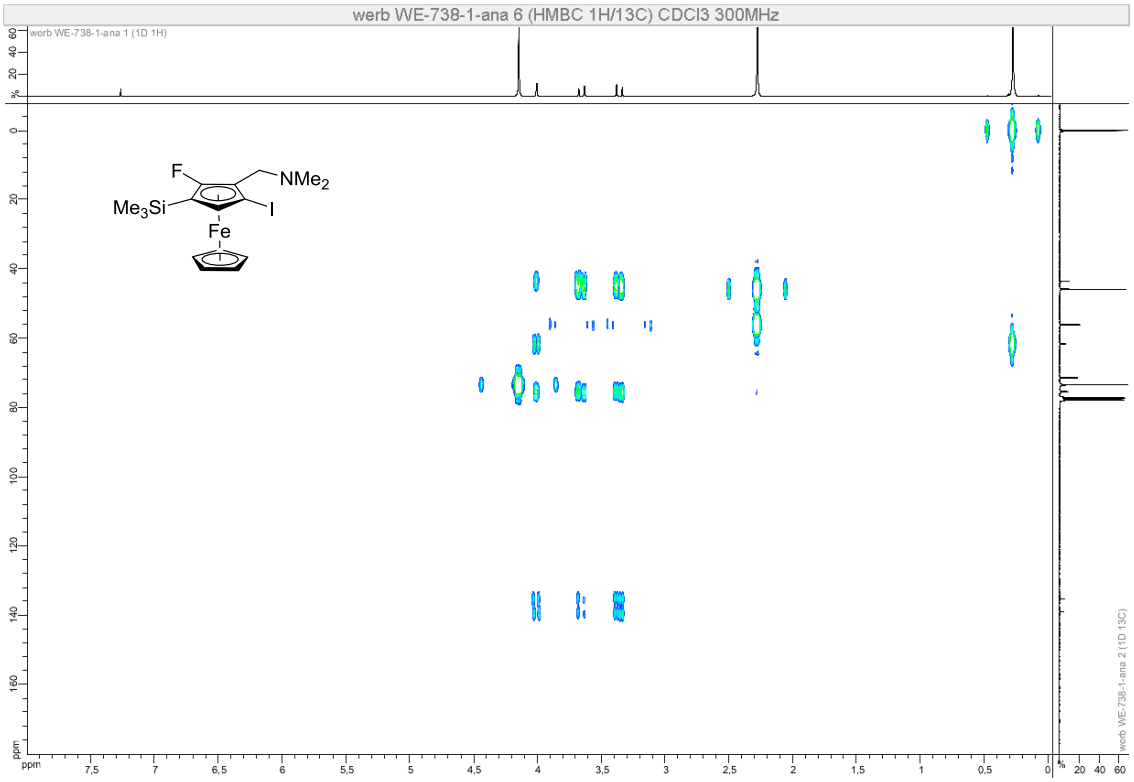
F
NMe2
Me3Si
I
Fe
ppm
werb WE-738-1-ana 2 (1D 13C)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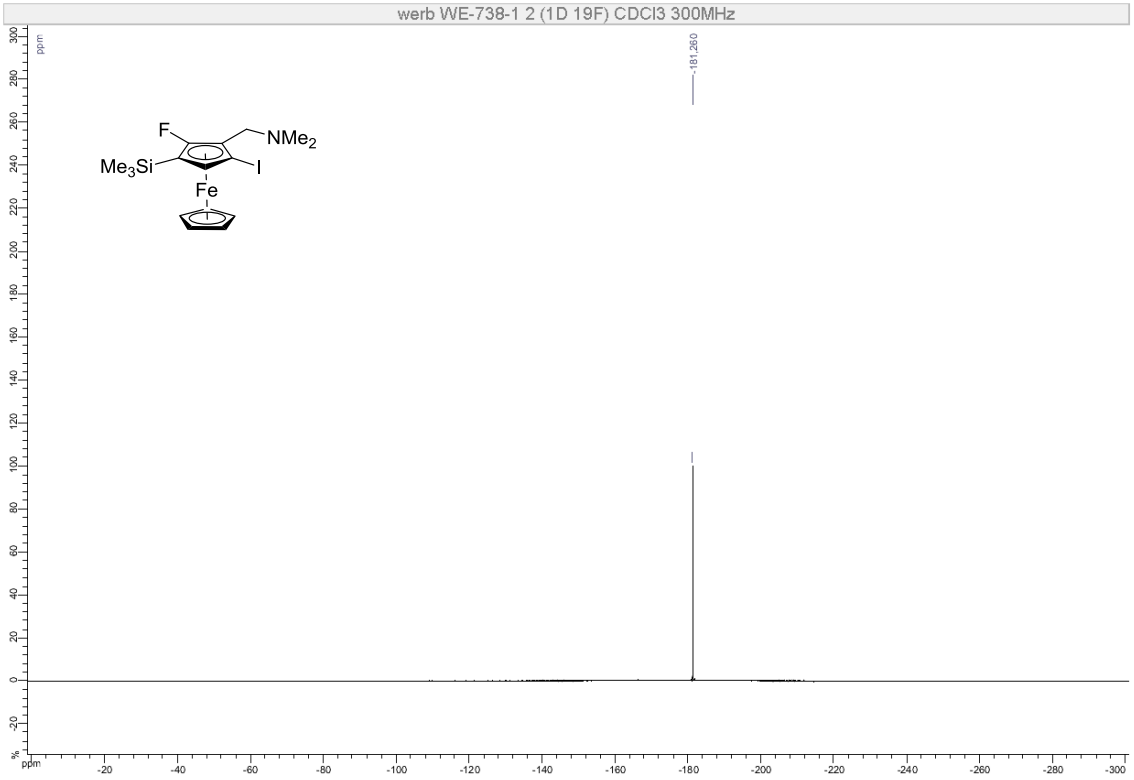
werb WE-738-1-ana 1 (1D 1H)
F
NMe2
Me3Si
I
Fe
ppm
werb WE-738-1-ana 2 (1D 13C)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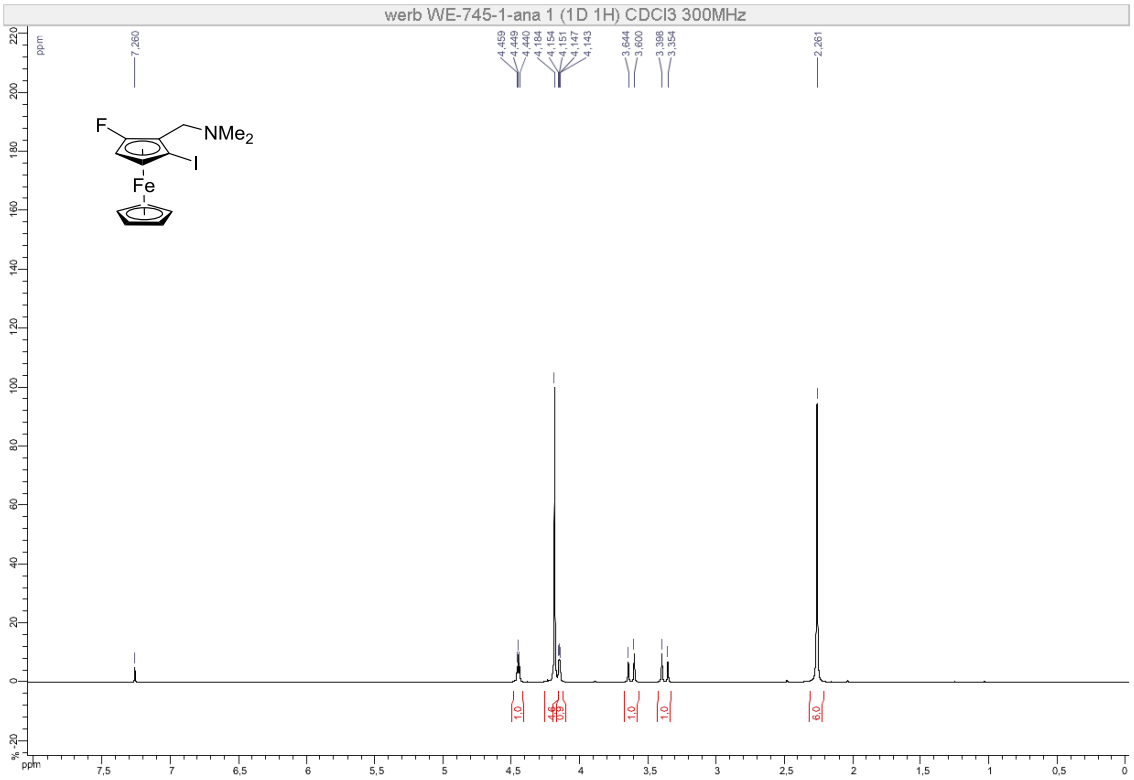
F
NMe2
Me3Si
I
Fe
ppm
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300

Compound (±)-3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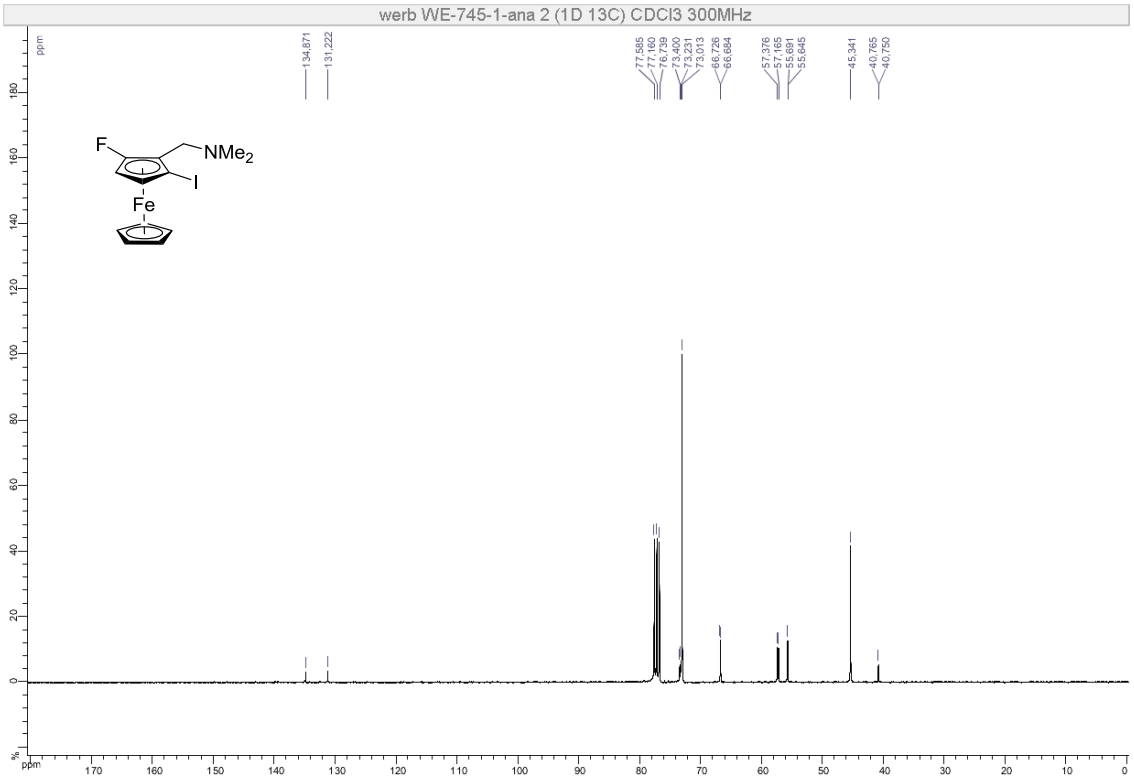
4,449
4,440
4,184
4,154
4,151
4,147
4,143
3,644
3,600
3,398
3,354
2,261
F
NMe2
I
Fe
1,0
4,6
0,9
1,0
1,0
6,0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ppm
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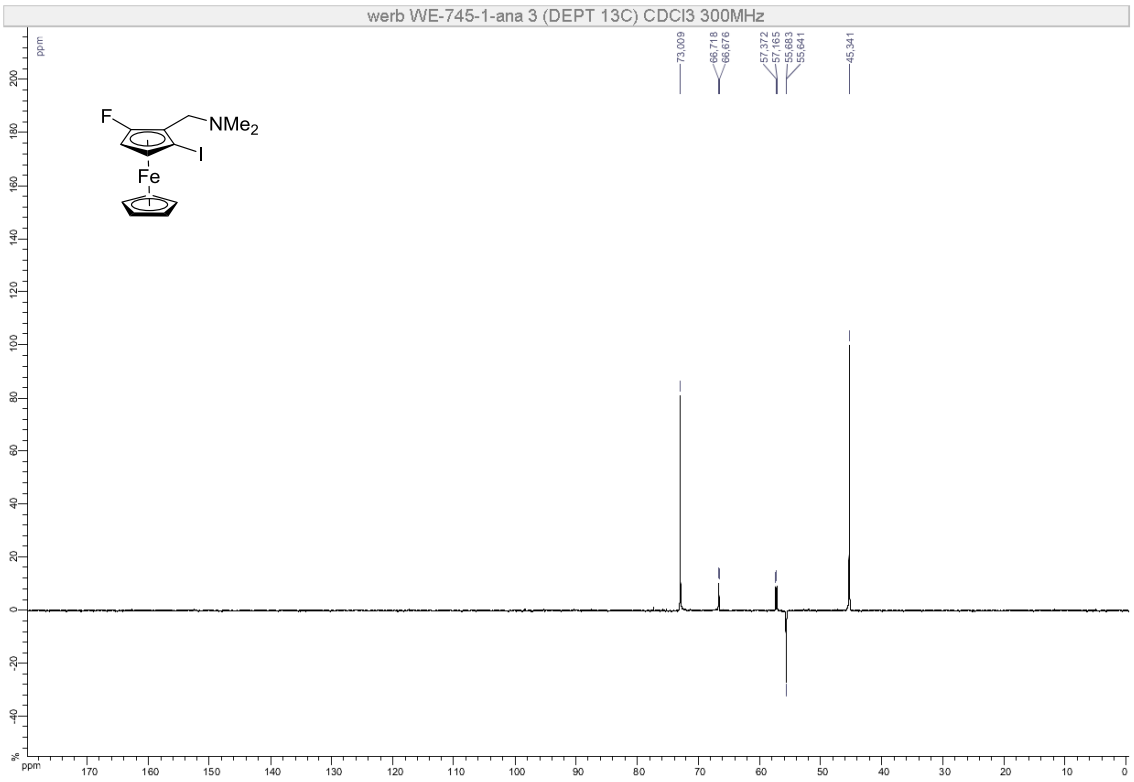
131,222
77,585
77,160
76,739
73,400
73,231
73,013
66,726
66,684
57,376
57,165
55,691
55,645
45,341
40,765
40,750
F
NMe2
I
Fe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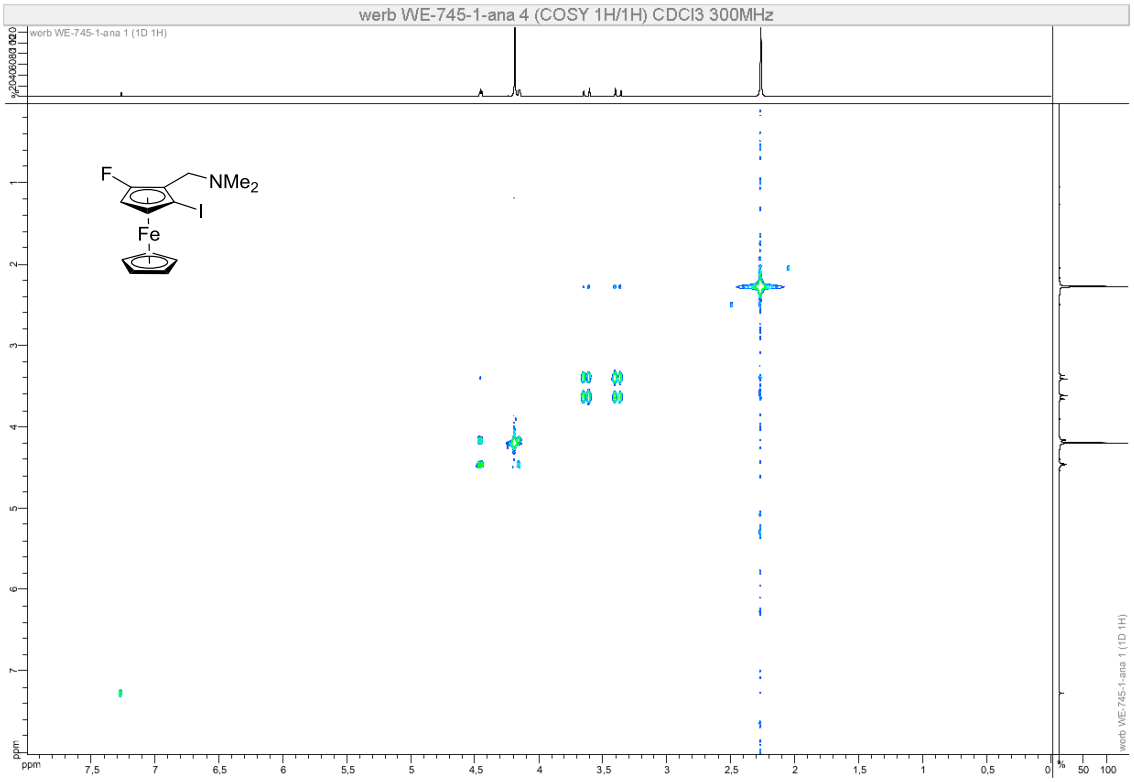
73,009
68,718
68,676
57,372
57,165
55,683
55,641
45,341
F
NMe2
I
Fe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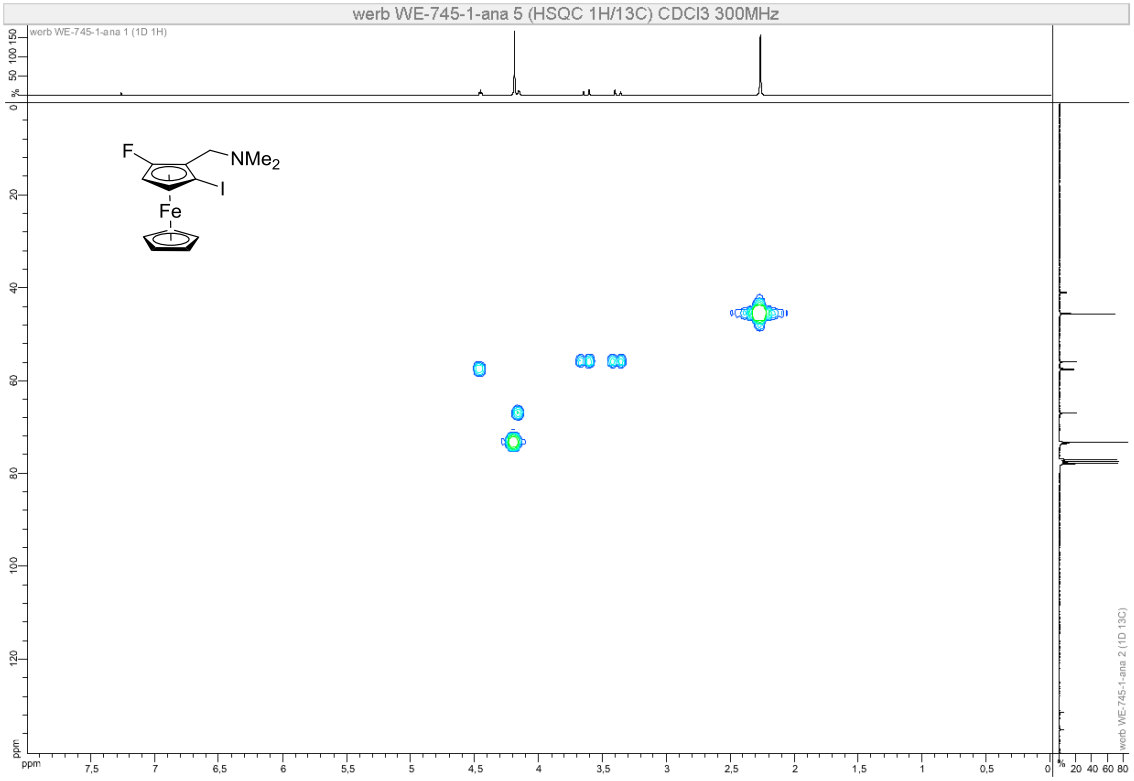
F
NMe2
I
Fe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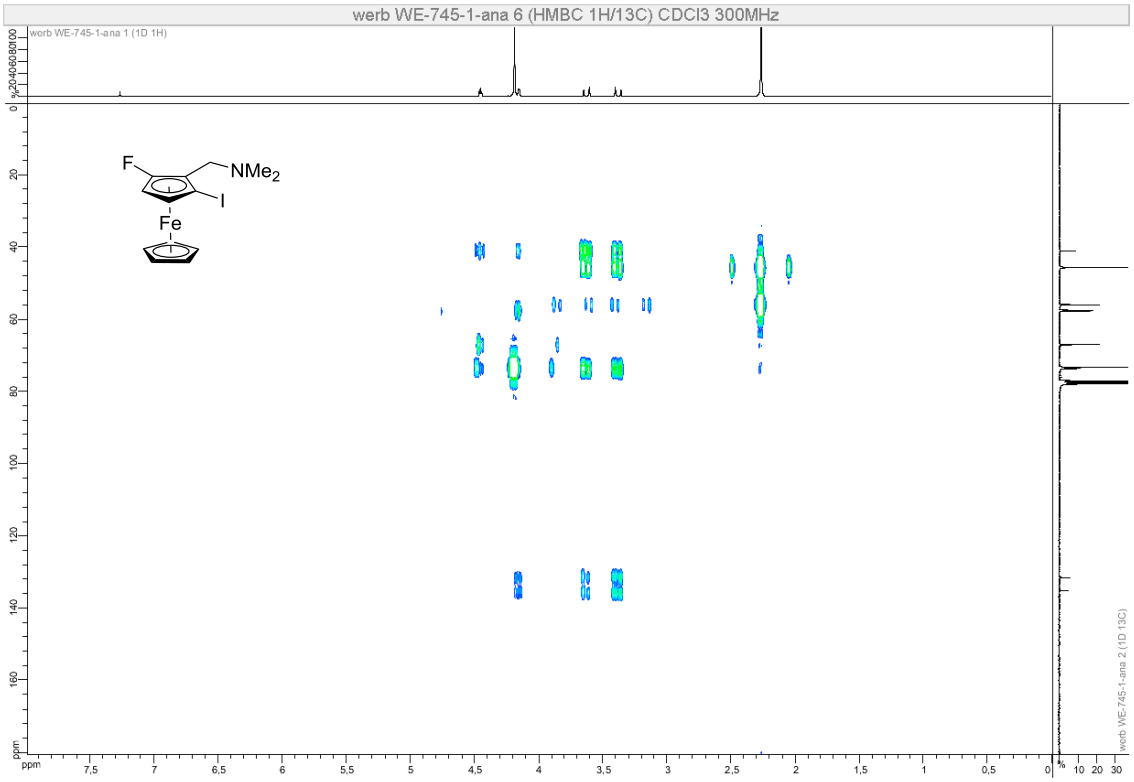
F
NMe2
I
Fe
ppm
werb WE-745-1-ana 2 (1D 13C)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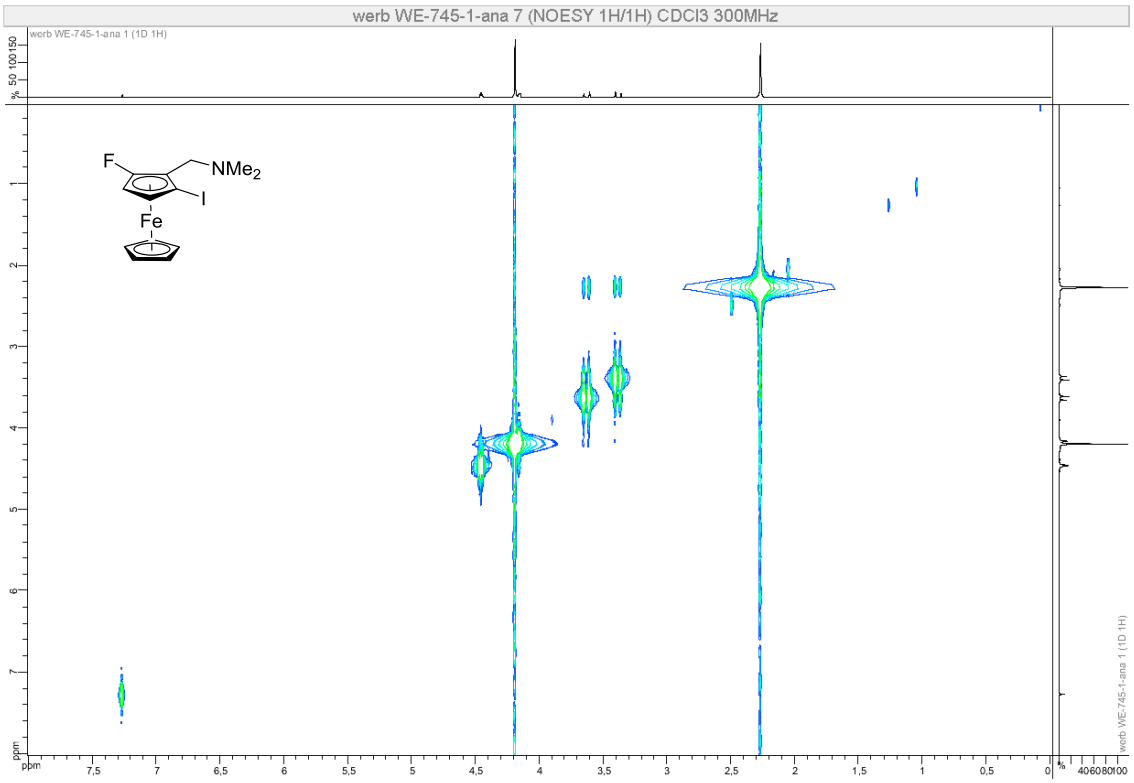
F
NMe2
I
Fe
ppm
werb WE-745-1-ana 2 (1D 13C)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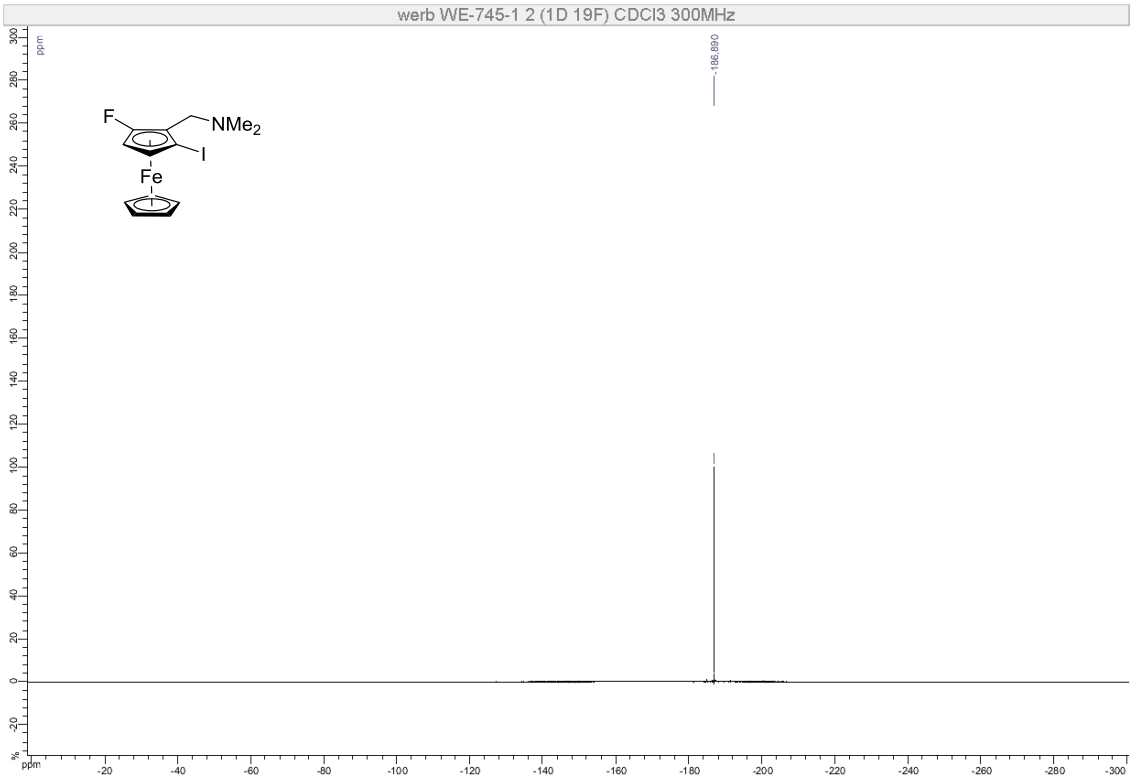
werb WE-745-1-ana 1 (1D 1H)
F
NMe2
I
Fe
ppm
7,5
7
6,5
6
5,5
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
werb WE-745-1-ana 1 (1D 1H)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-186.890
F
NMe2
I
Fe
ppm
-20
-40
-60
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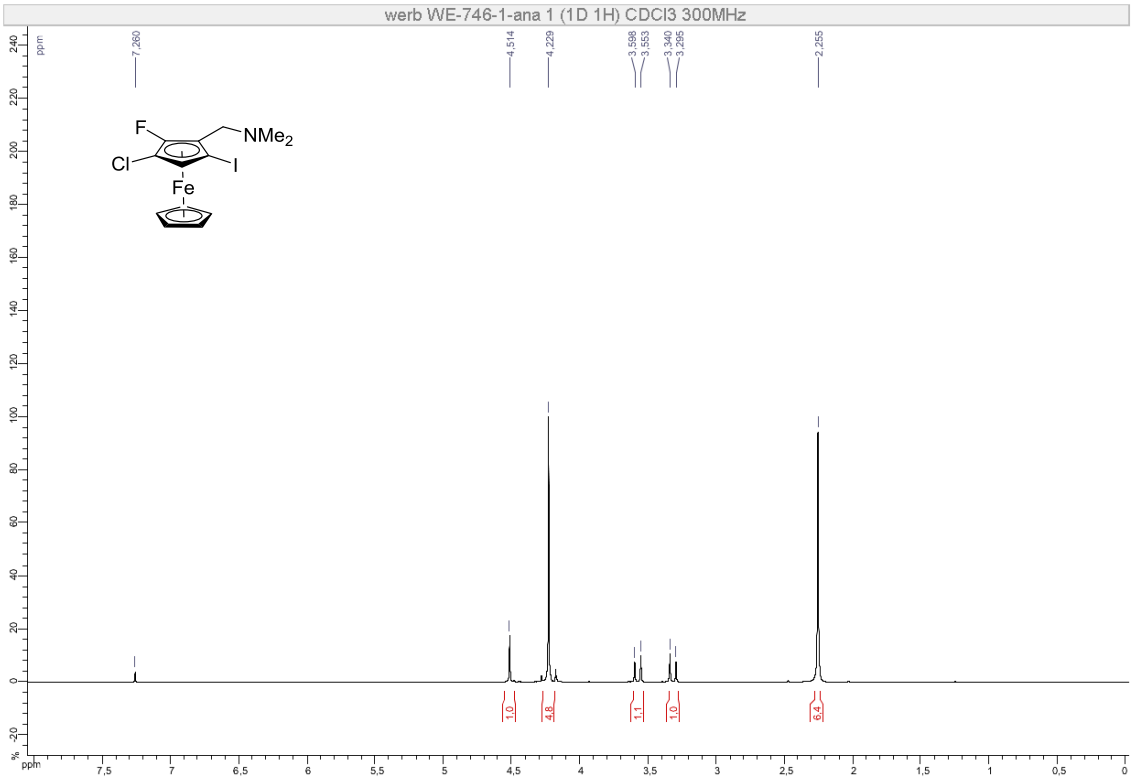
-140
-160
-180
-200
-220
-240
-260
-280
-300

Compound (±)-4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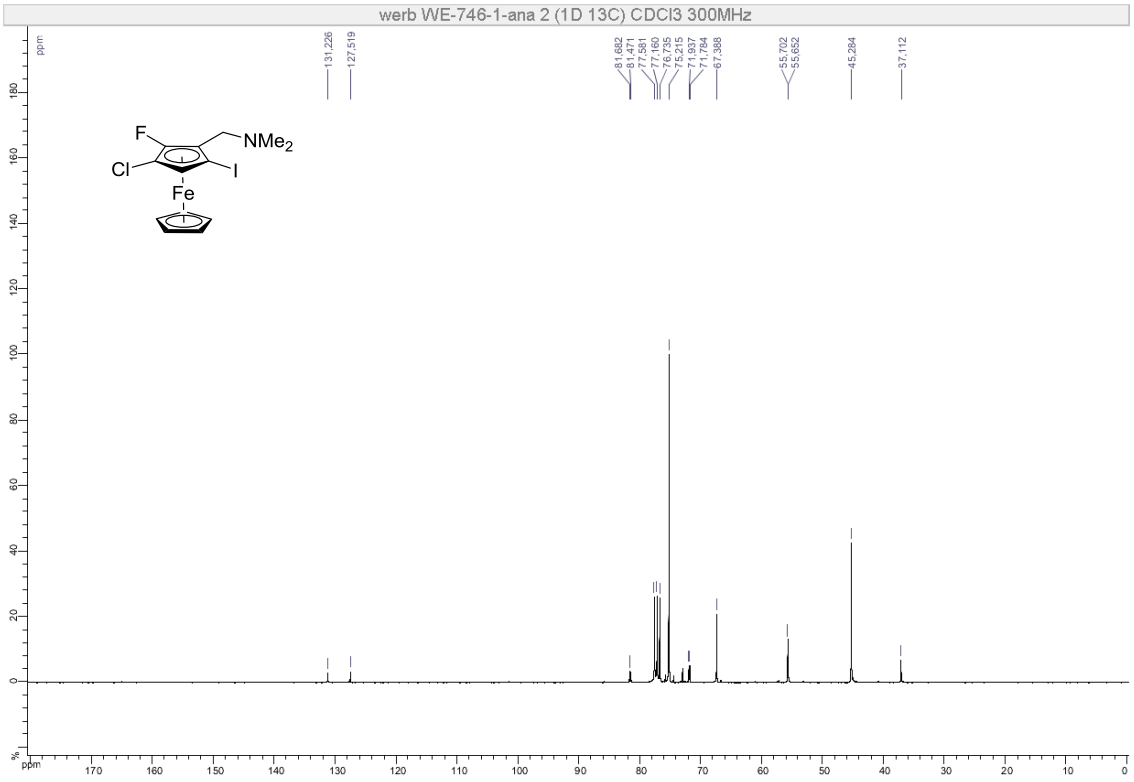
F
NMe2
Cl
I
Fe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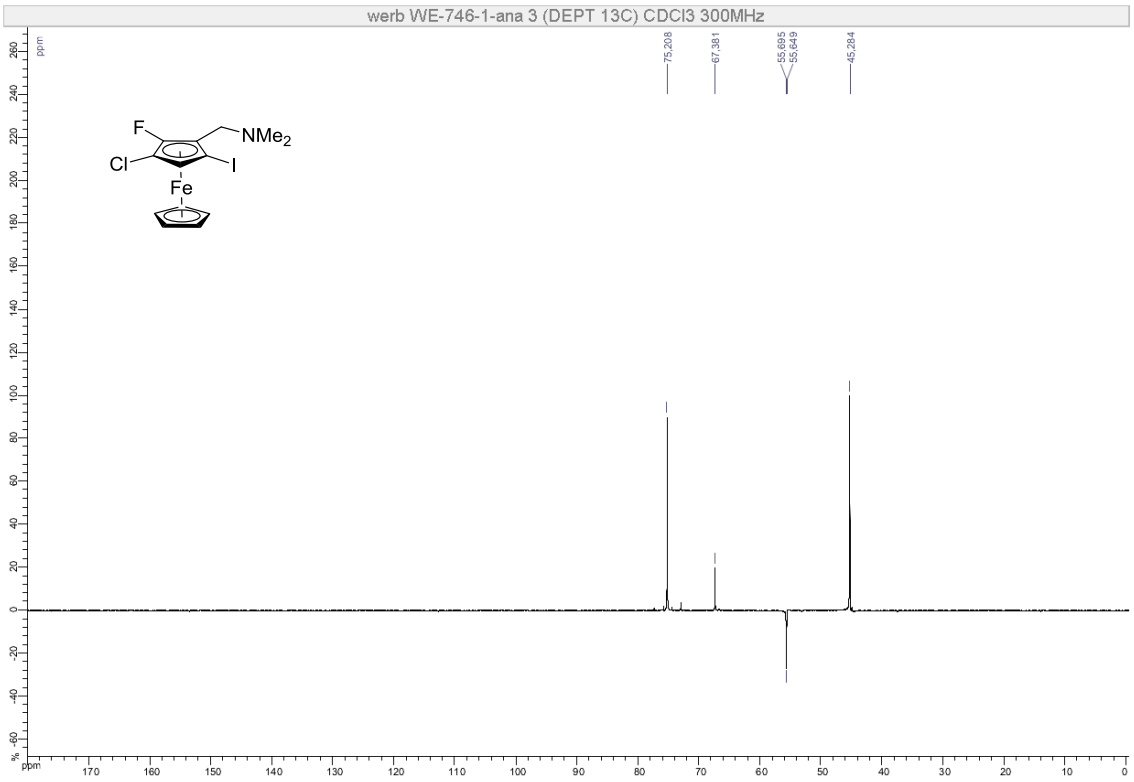
F
NMe2
Cl
I
Fe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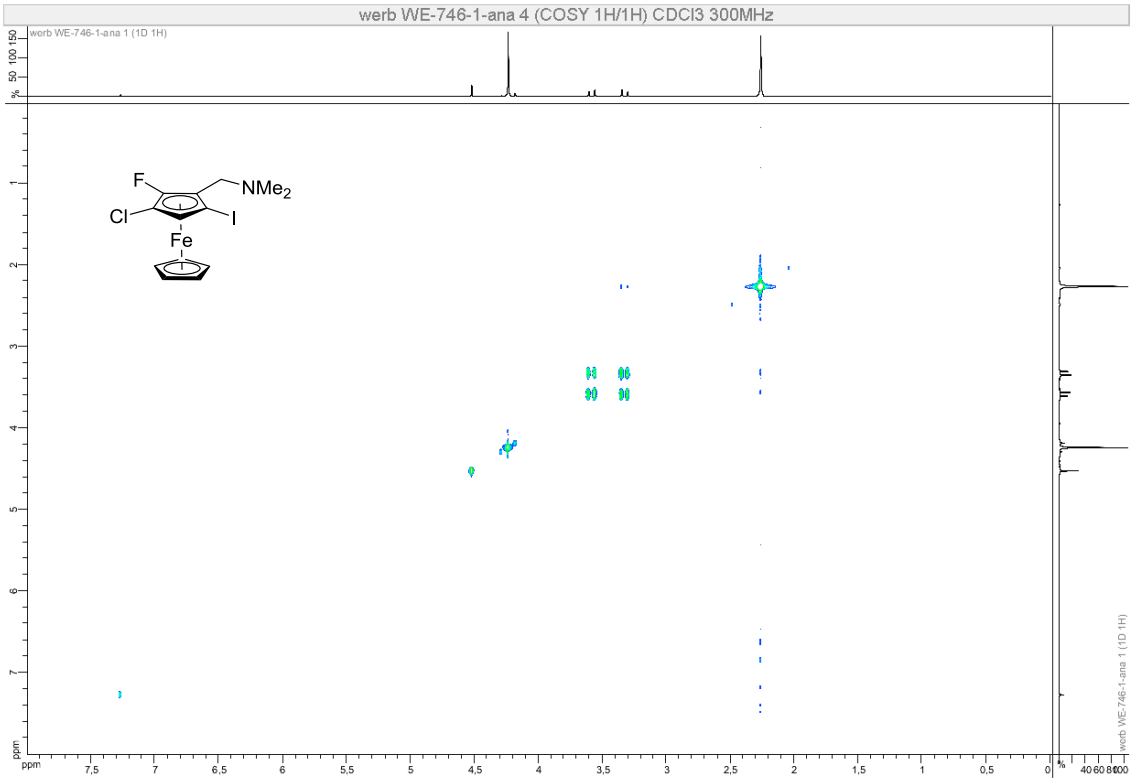
75,208
67,381
55,695
55,649
45,284
F
NMe2
Cl
I
Fe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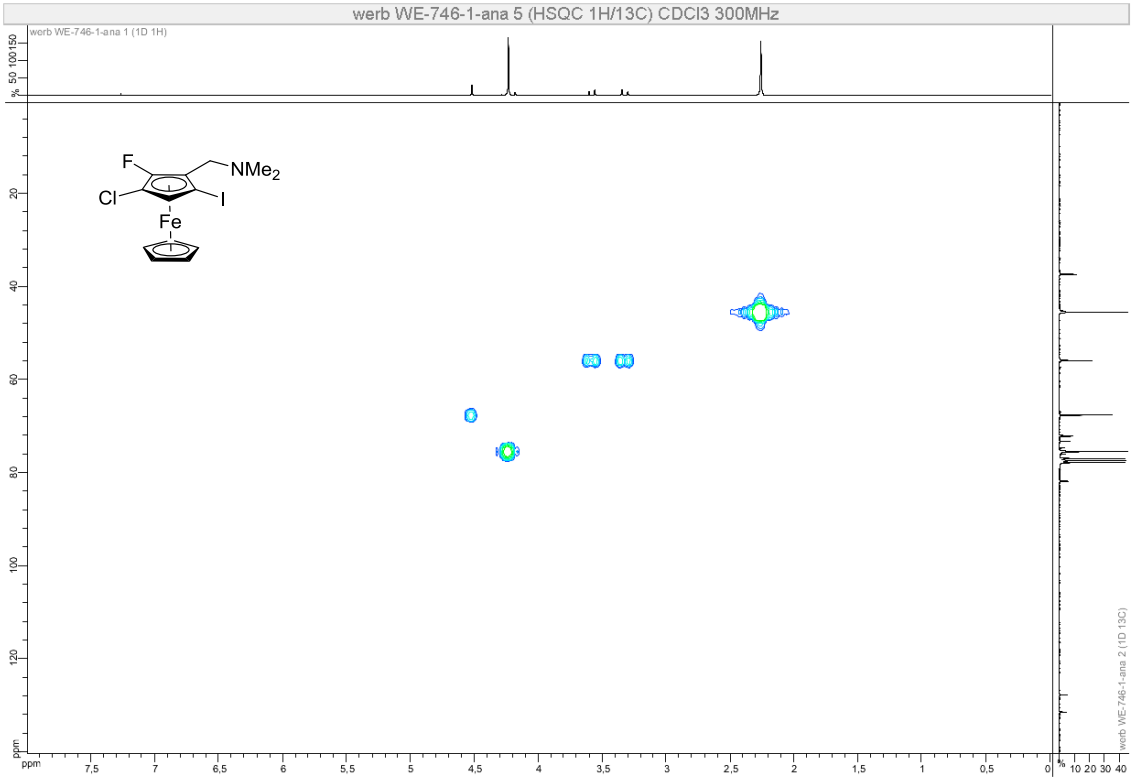
F
NMe2
Cl
I
Fe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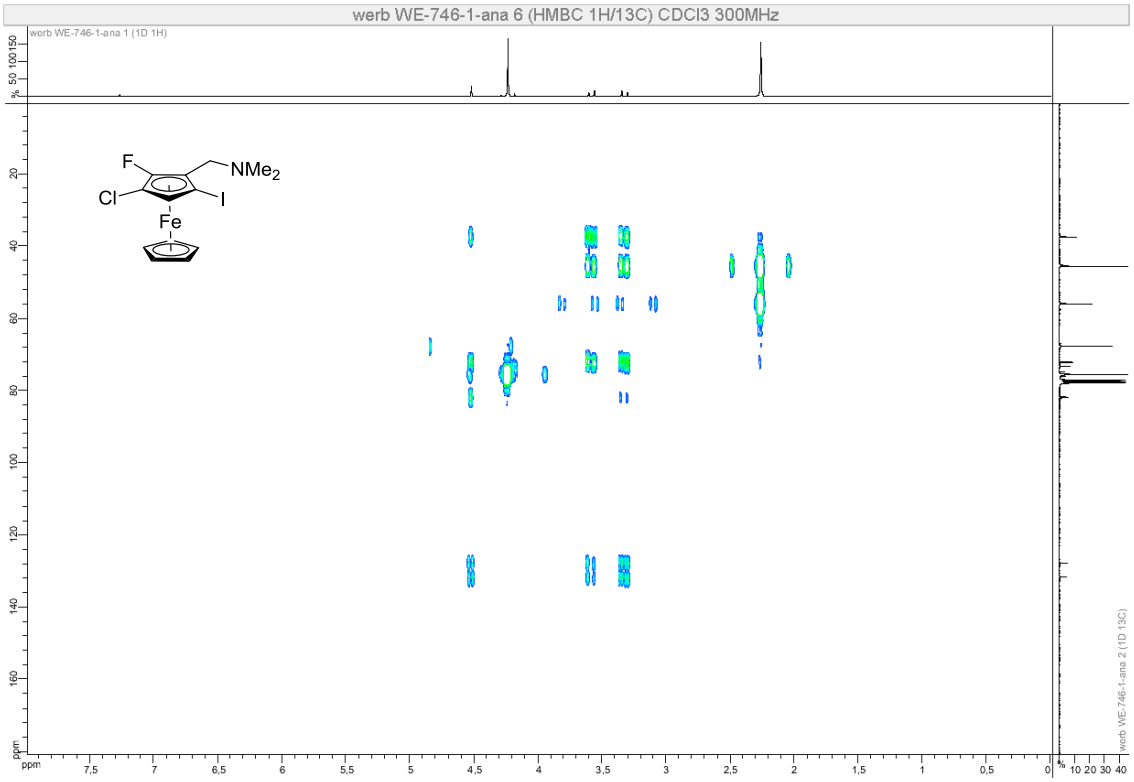
F
NMe2
Cl
I
Fe
ppm
werb WE-746-1-ana 2 (1D 13C)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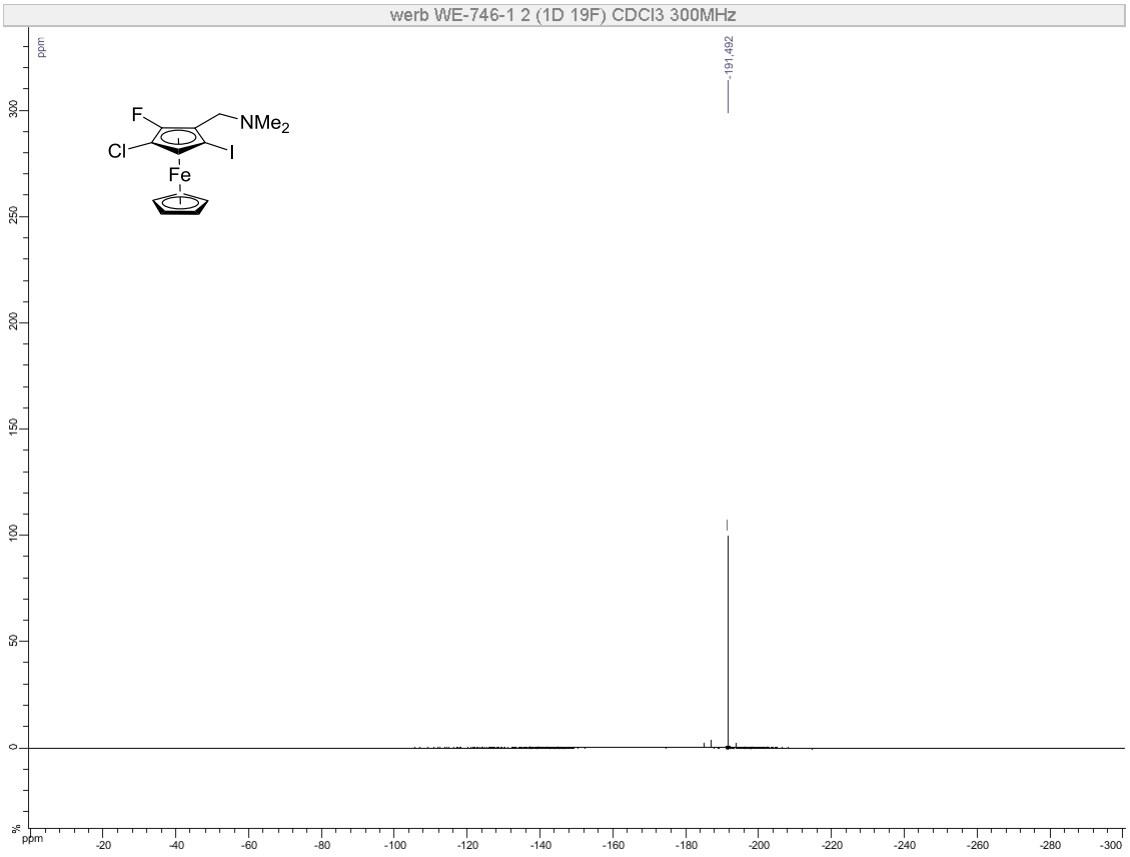
werb WE-746-1-ana 1 (1D 1H)
F
NMe2
Cl
I
Fe
ppm
werb WE-746-1-ana 2 (1D 13C)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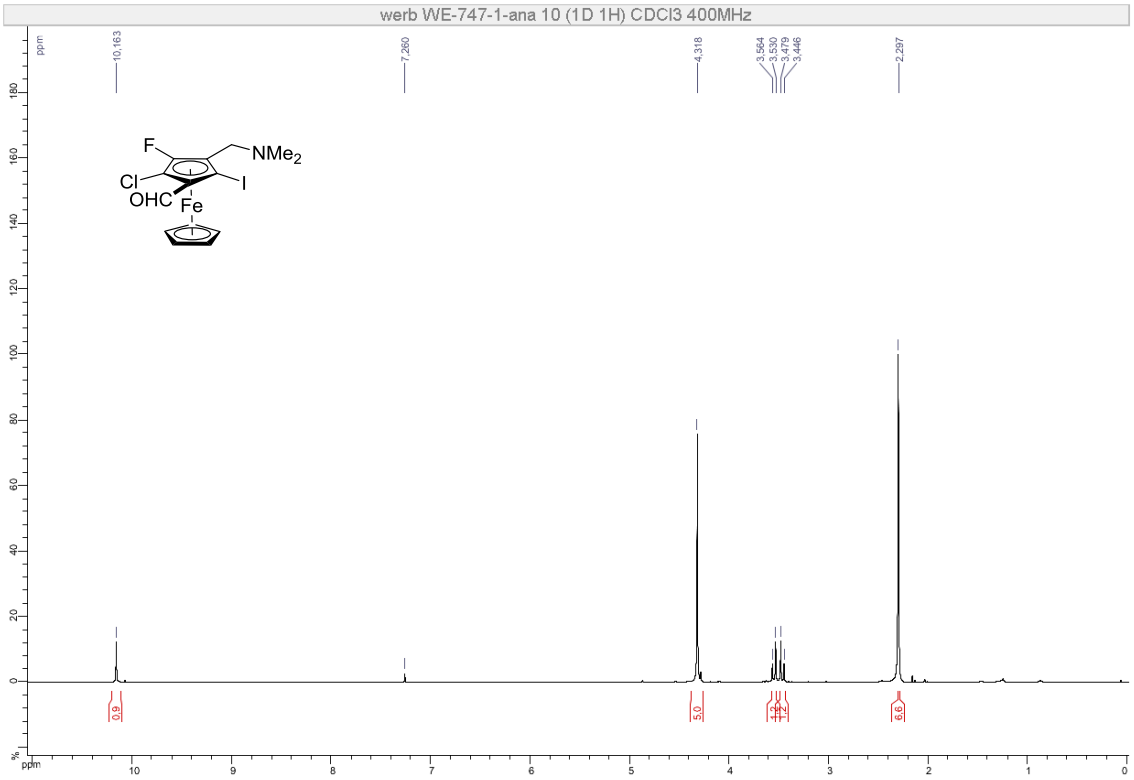
ppm
-191,492
F
NMe2
Cl
I
Fe
300
250
200
150
100
50
0
%
ppm
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300

Compound (±)-5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10,163
7,260
4,318
3,564
3,530
3,479
3,446
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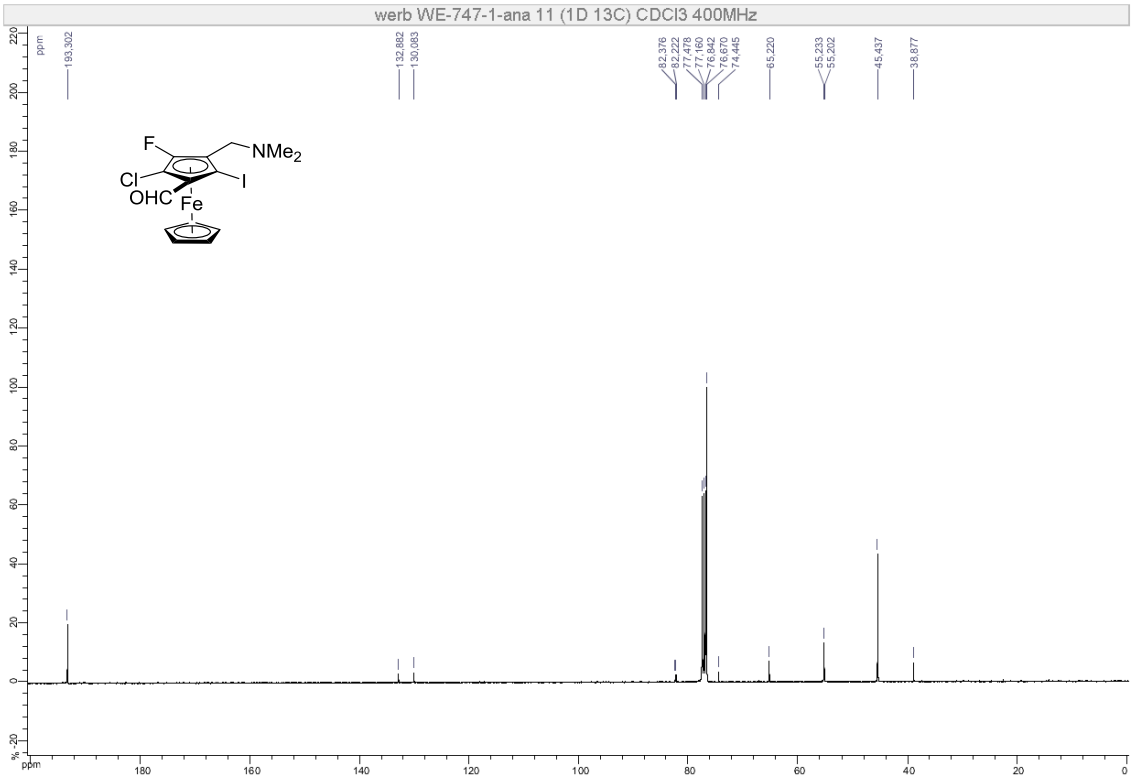
Cl
I
OHC
Fe
0,9
5,0
1,2
6,6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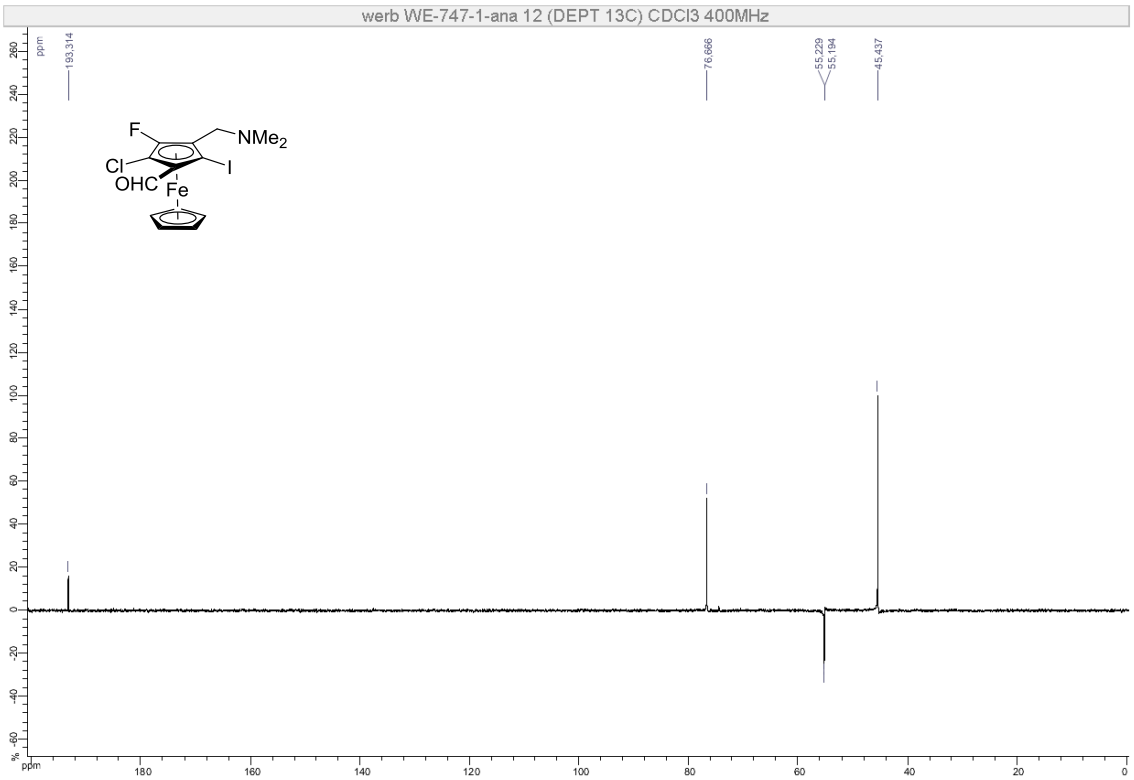
193,302
132,882
130,083
82,376
82,222
77,478
77,160
76,842
76,670
74,445
65,220
55,233
55,202
45,437
38,877
F
NMe2
Cl
I
OHC
Fe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76.666
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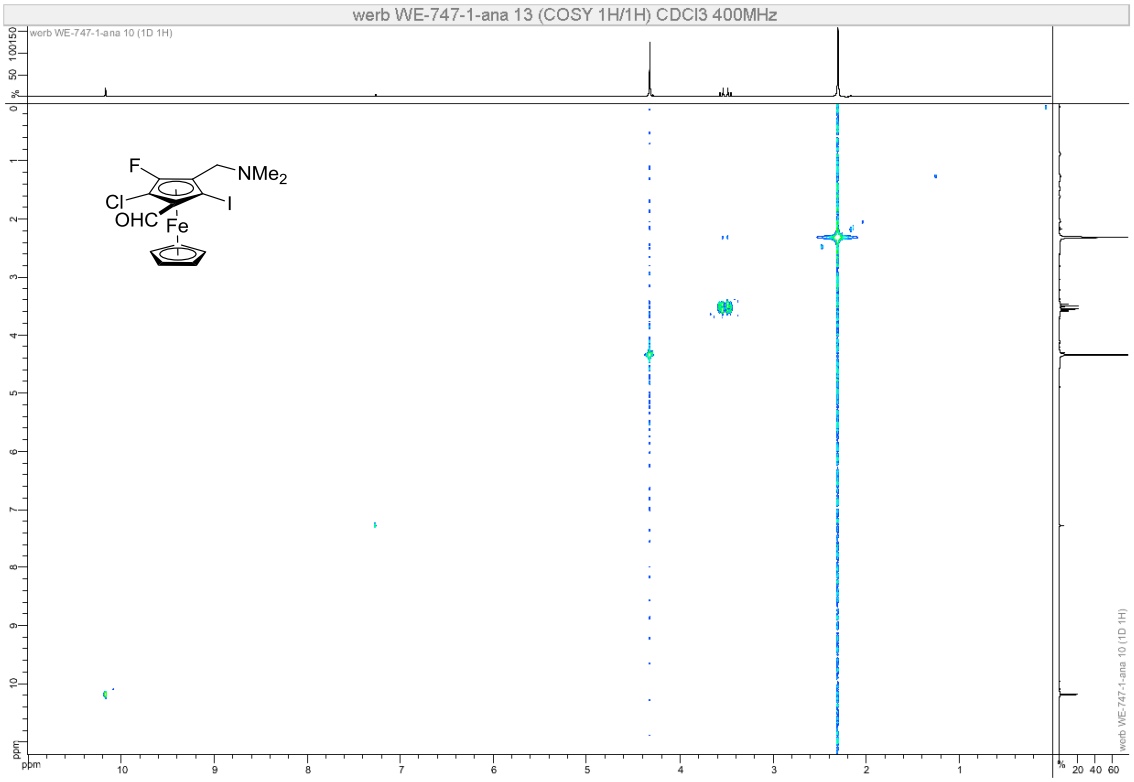
55.194
45.437
F
NMe2
Cl
I
OHC
Fe
ppm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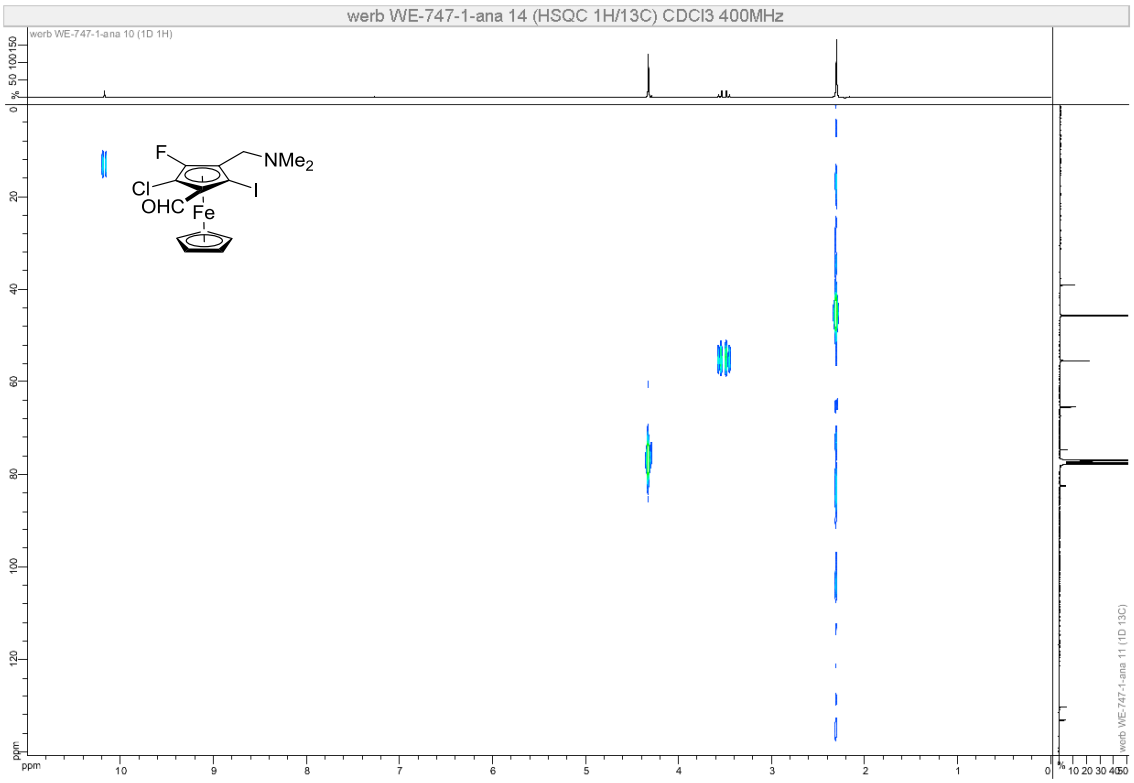
werb WE-747-1-ana 10 (1D 1H)
F
NMe2
Cl
I
OHC
Fe
ppm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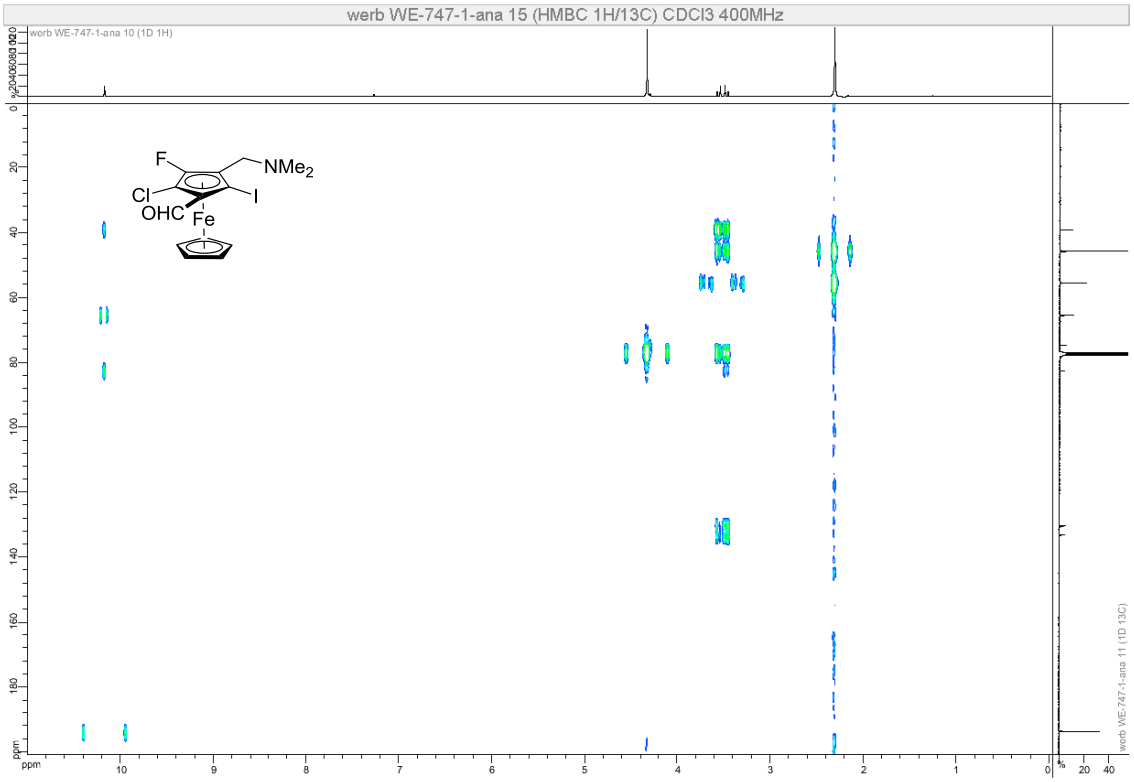
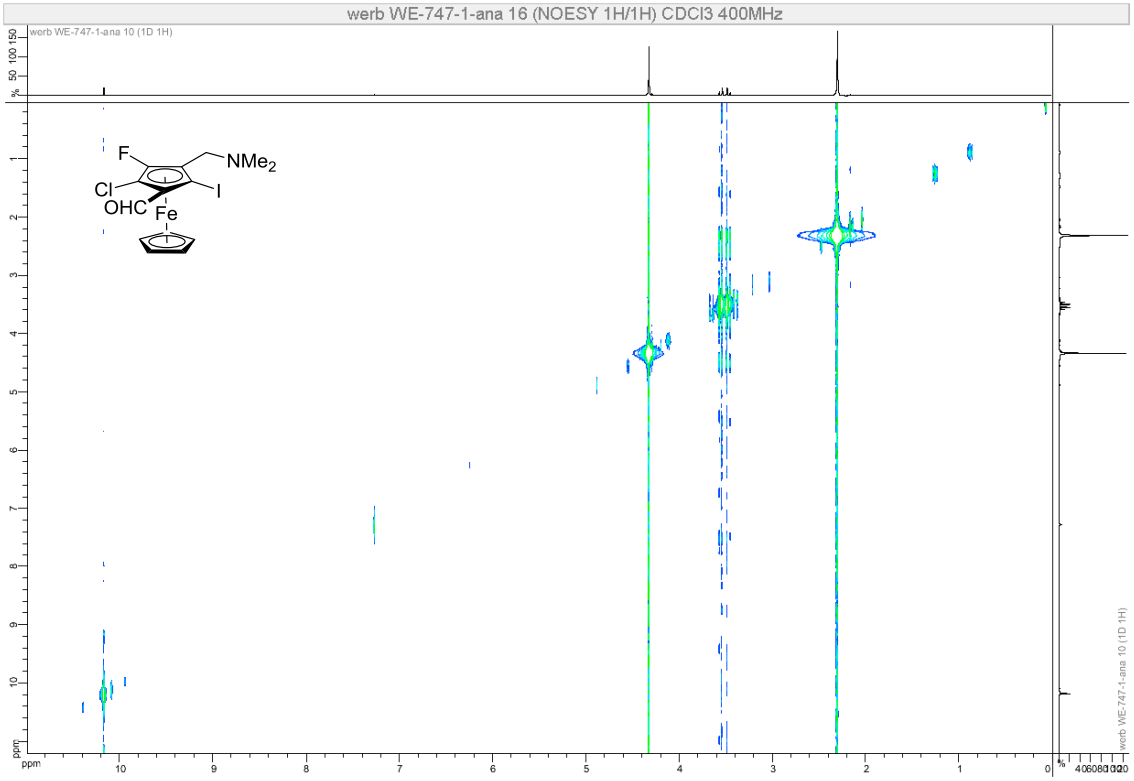
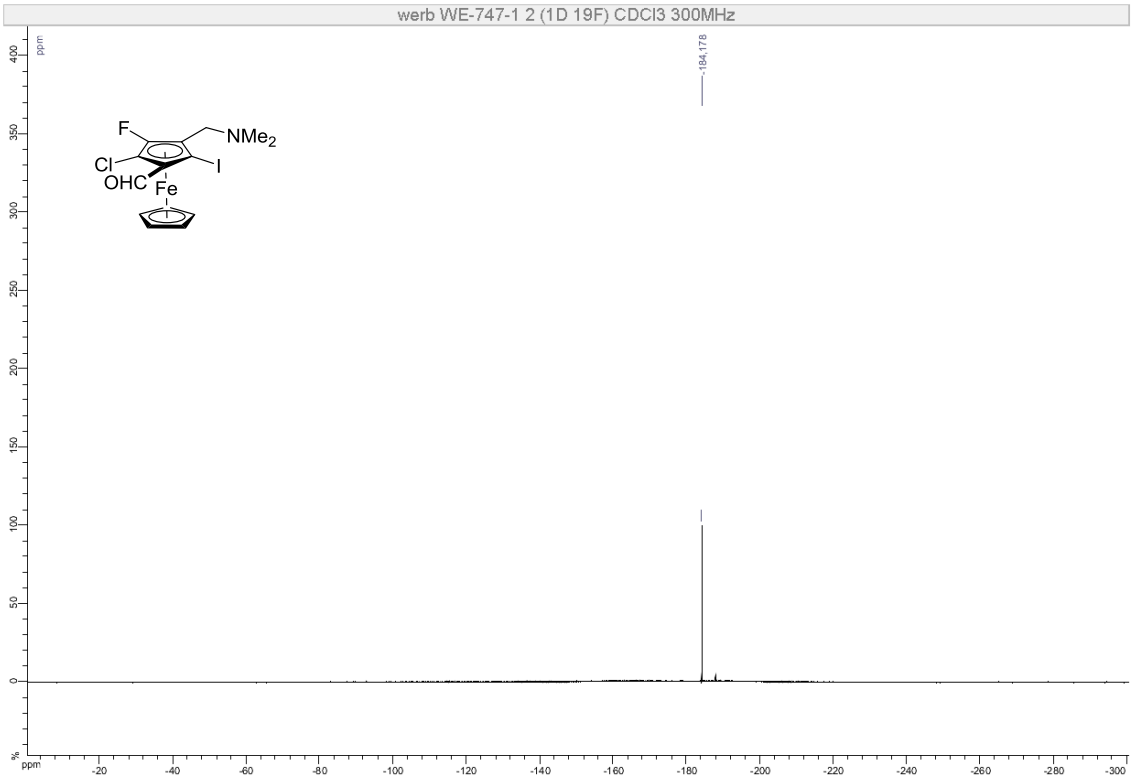
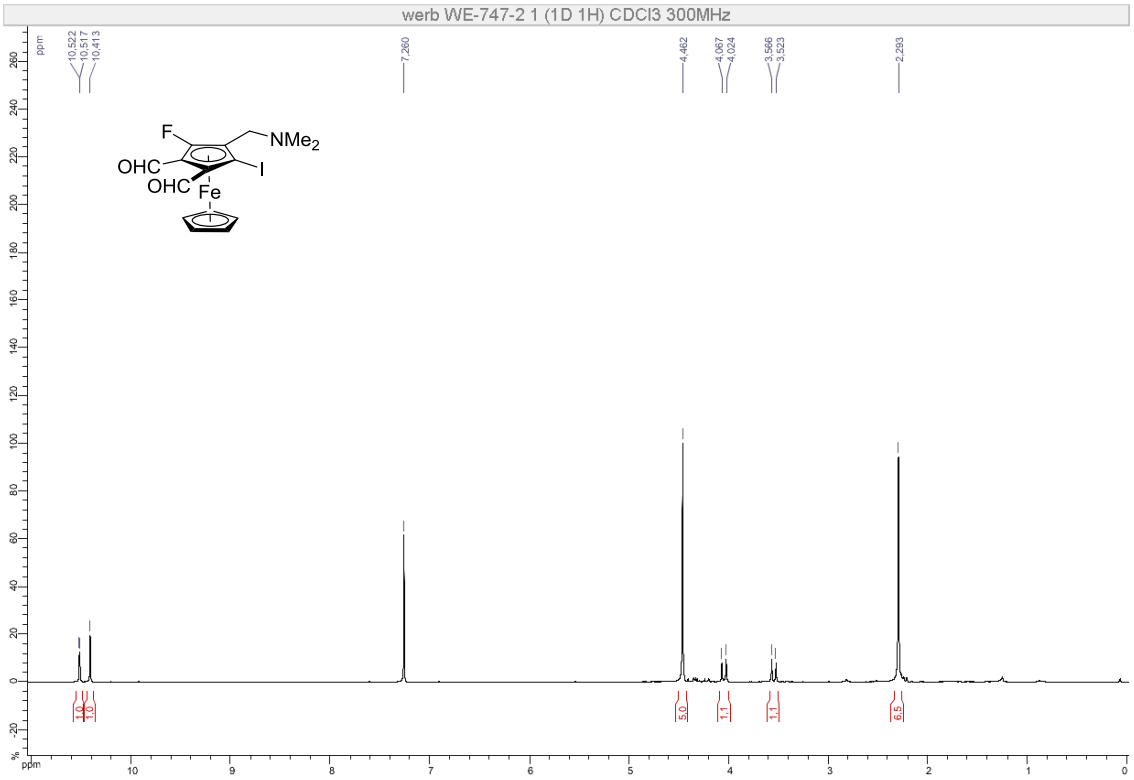
werb WE-747-1-ana 10 (1D 1H)
F
NMe2
Cl
I
OHC
Fe
ppm
werb WE-747-1-ana 11 (1D 13C)

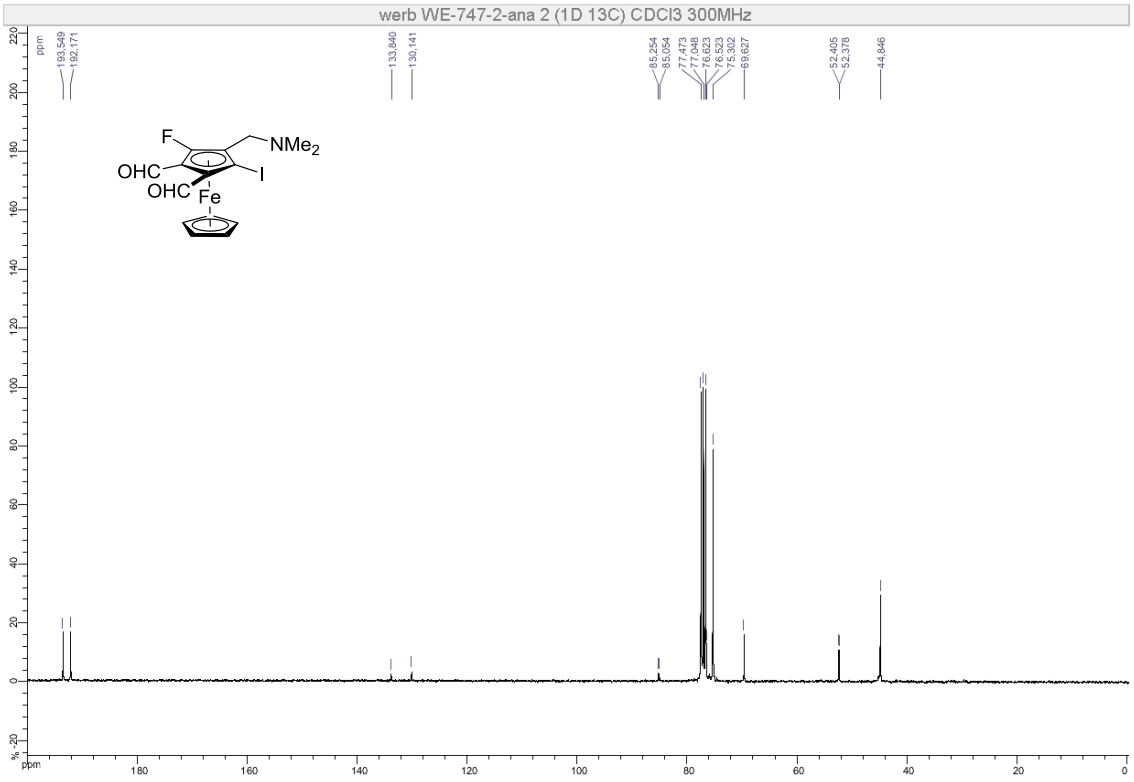

werb WE-747-1-ana 15 (HMBC 1H/13C) CDCl3 400MHz
werb WE-747-1-ana 10 (1D 1H)
F
NMe2
Cl
I
OHC
Fe
ppm
werb WE-747-1-ana 11 (1D 13C)

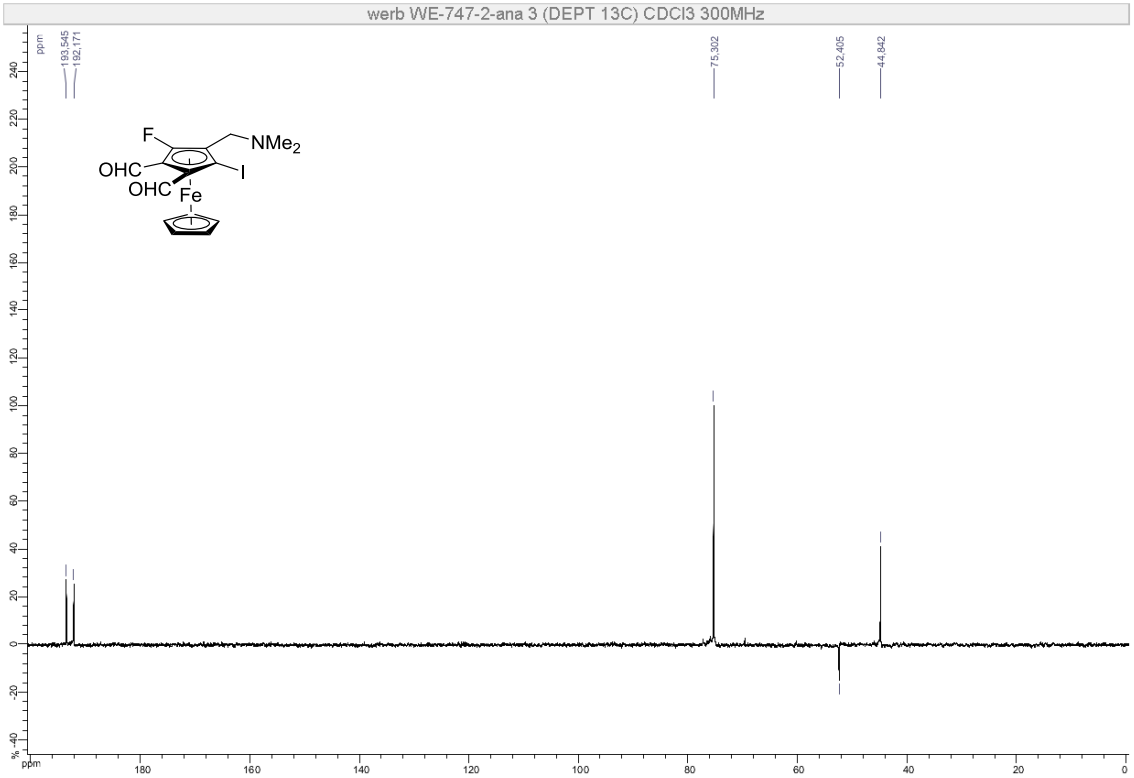

werb WE-747-1-ana 16 (NOESY 1H/1H) CDCl3 400MHz
werb WE-747-1-ana 10 (1D 1H)
F
NMe2
Cl
I
OHC
Fe
ppm

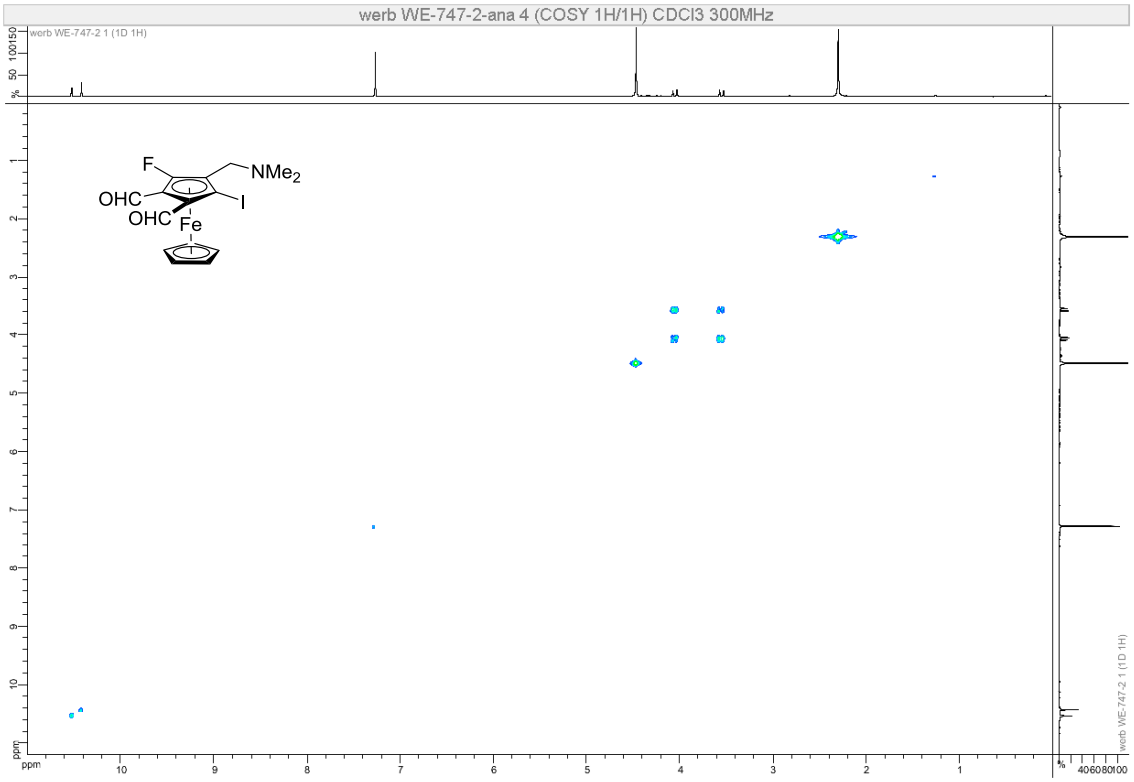

werb WE-747-1 2 (1D 19F) CDCl3 300MHz
ppm
-184.178
F
NMe2
Cl
I
OHC
Fe

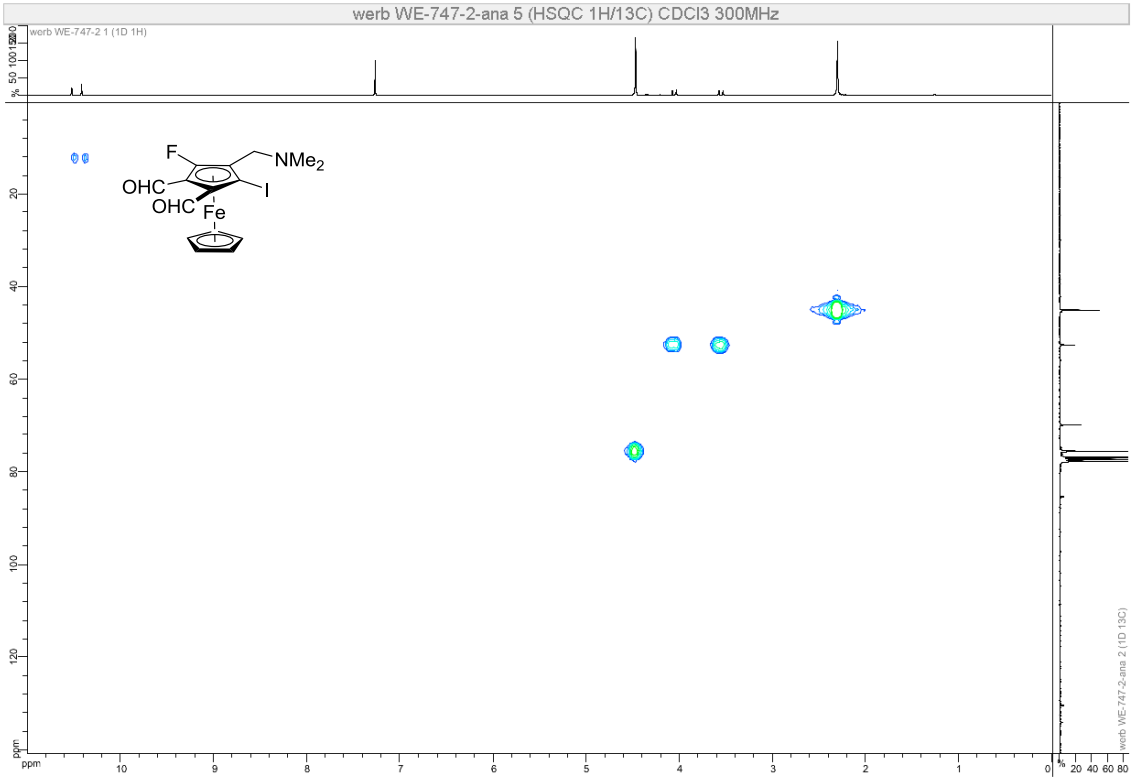
Compound (±)-6

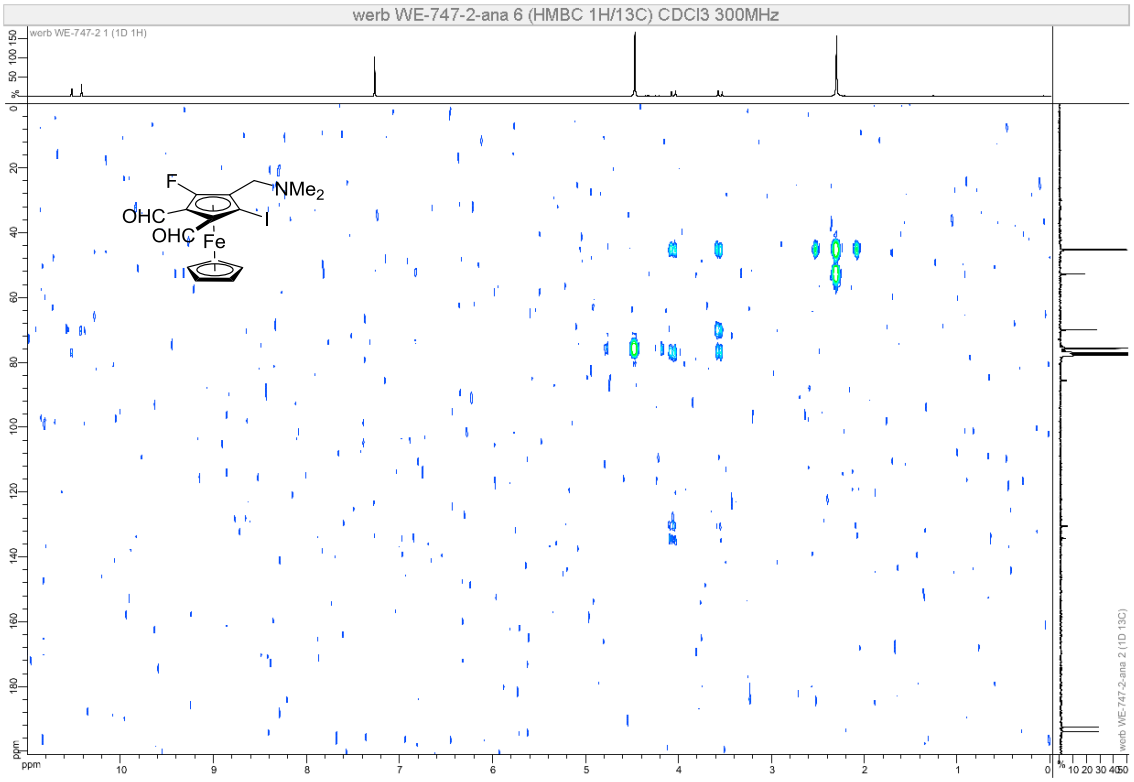

werb WE-747-2 1 (1D 1H) CDCl3 300MHz
F
NMe2
OHC
I
OHC
Fe

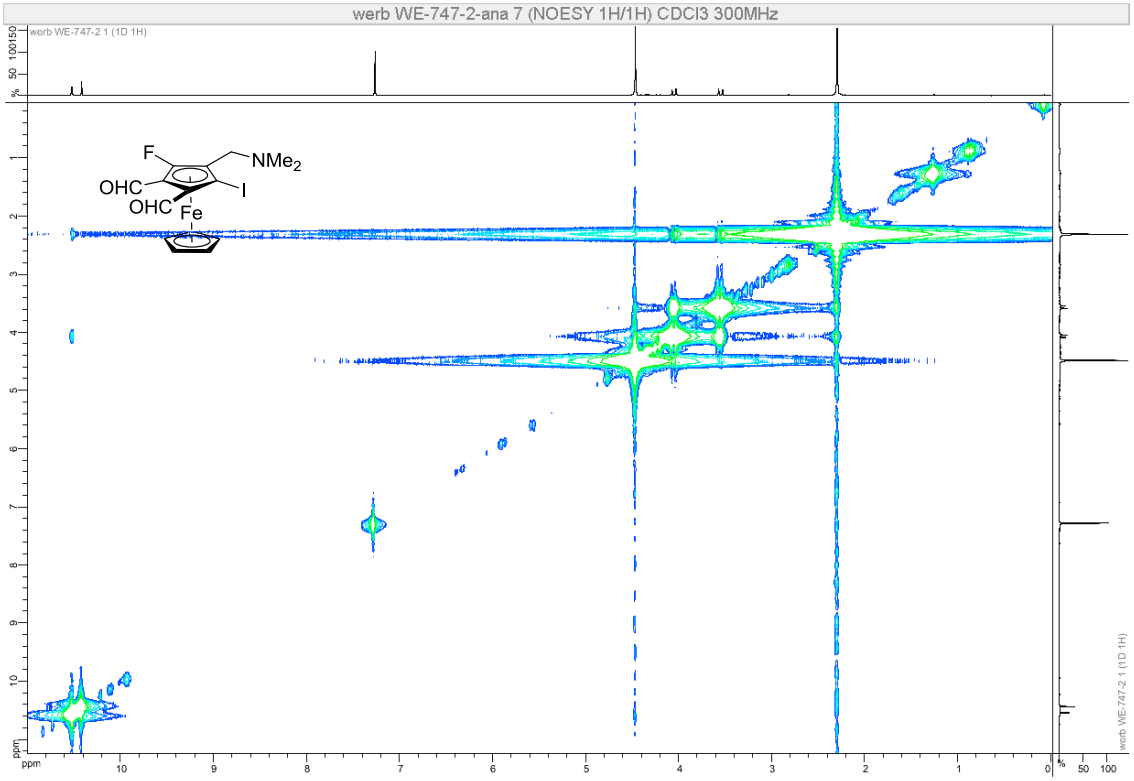

werb WE-747-2-ana 2 (1D 13C) CDCl3 300MHz
F
NMe2
OHC
I
OHC
Fe

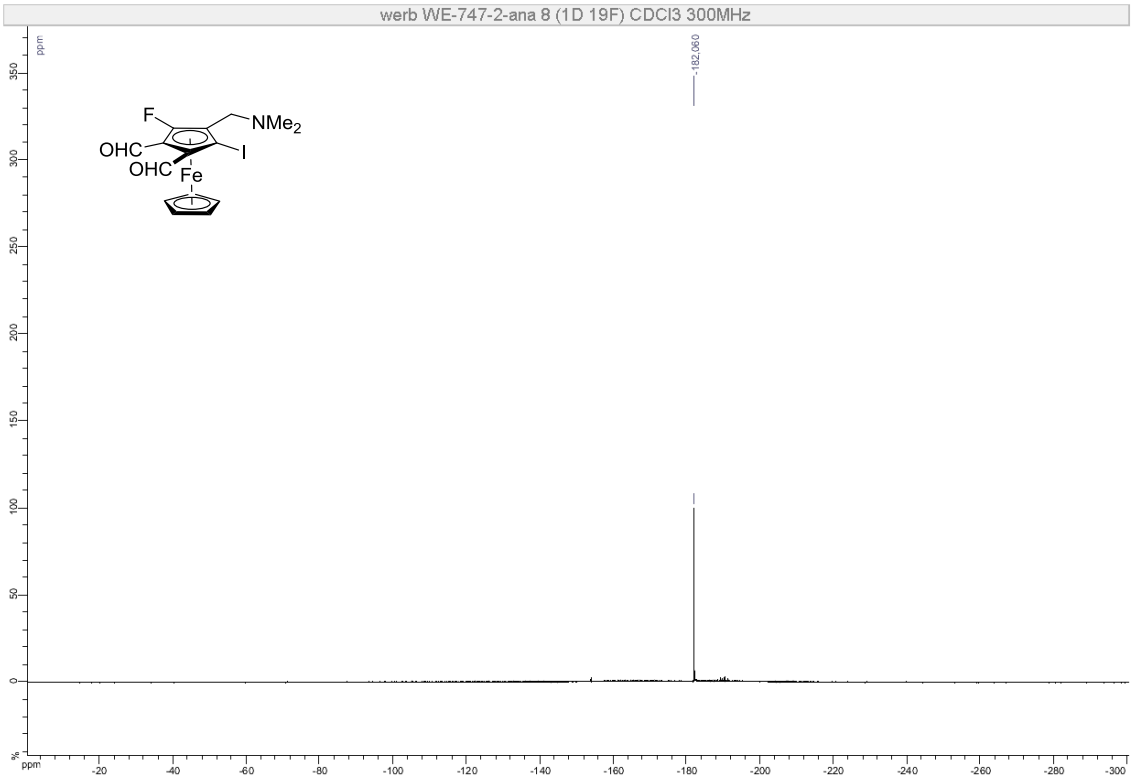

werb WE-747-2-ana 3 (DEPT 13C) CDCl3 300MHz
193,545
192,171
75,302
52,405
44,842
F
NMe2
OHC
I
OHC
Fe
ppm


werb WE-747-2-ana 4 (COSY 1H/1H) CDCl3 300MHz
werb WE-747-2 1 (1D 1H)
F
NMe2
OHC
I
OHC
Fe
ppm

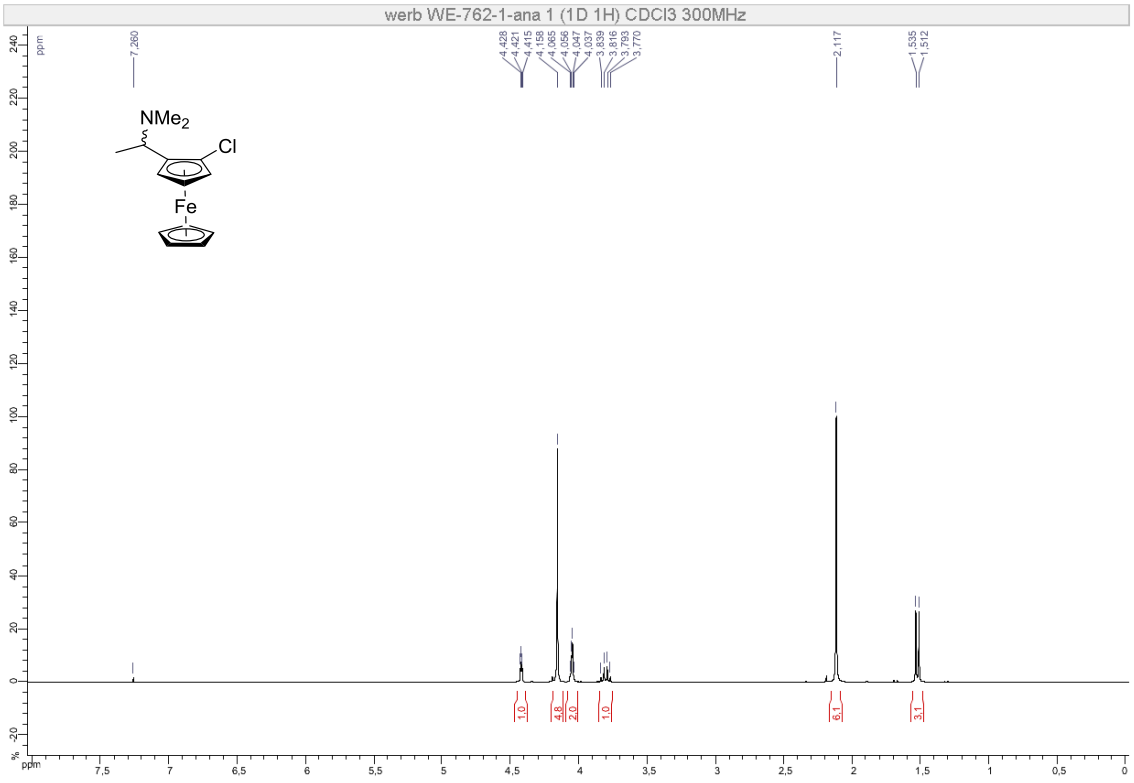

werb WE-747-2-ana 5 (HSQC 1H/13C) CDCl3 300MHz
F
NMe2
OHC
OHC
Fe
I
ppm

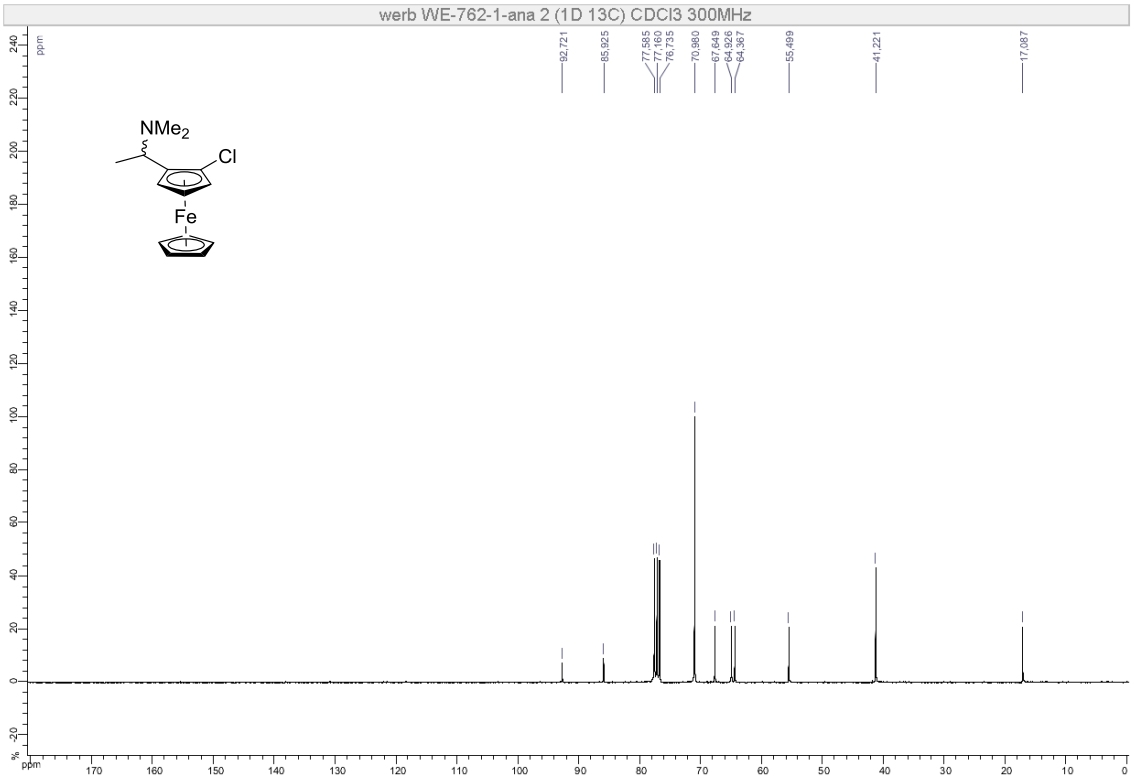

werb WE-747-2-ana 6 (HMBC 1H/13C) CDCl3 300MHz
F
NMe2
OHC
OHC
Fe
I
ppm

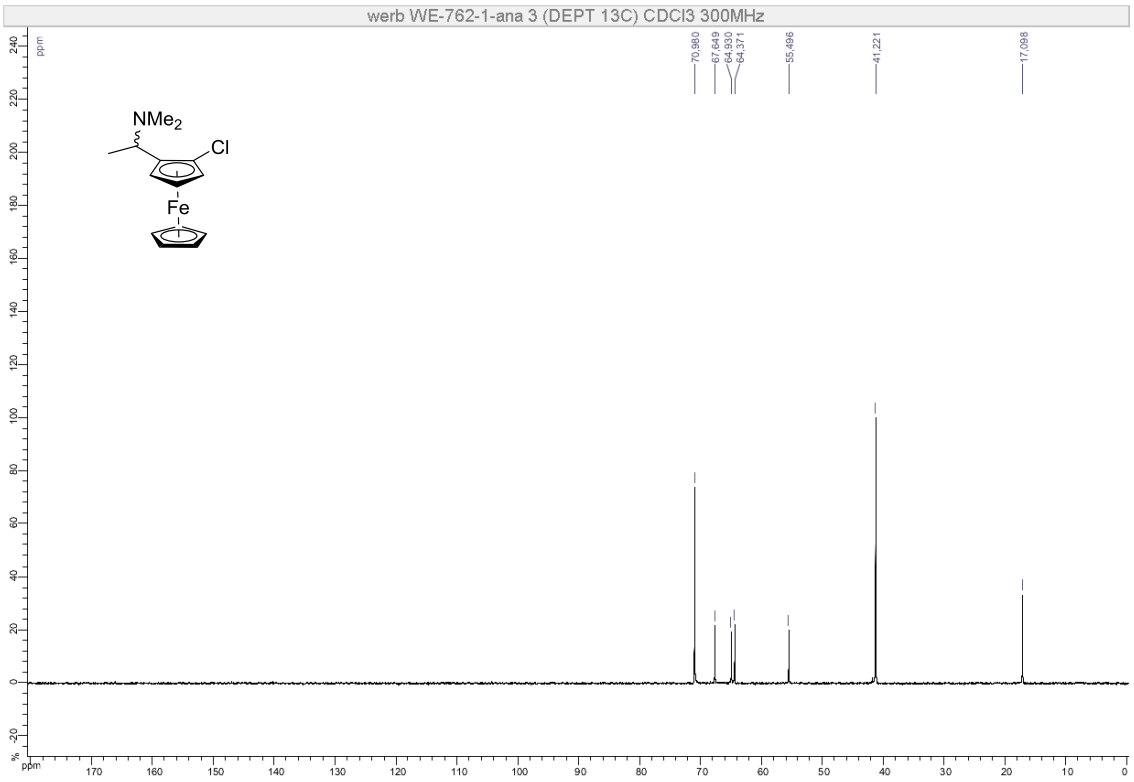

werb WE-747-2-ana 7 (NOESY 1H/1H) CDCl3 300MHz
werb WE-747-2 1 (1D 1H)
F
NMe2
OHC
OHC
Fe
I
ppm
werb WE-747-2 1 (1D 1H)

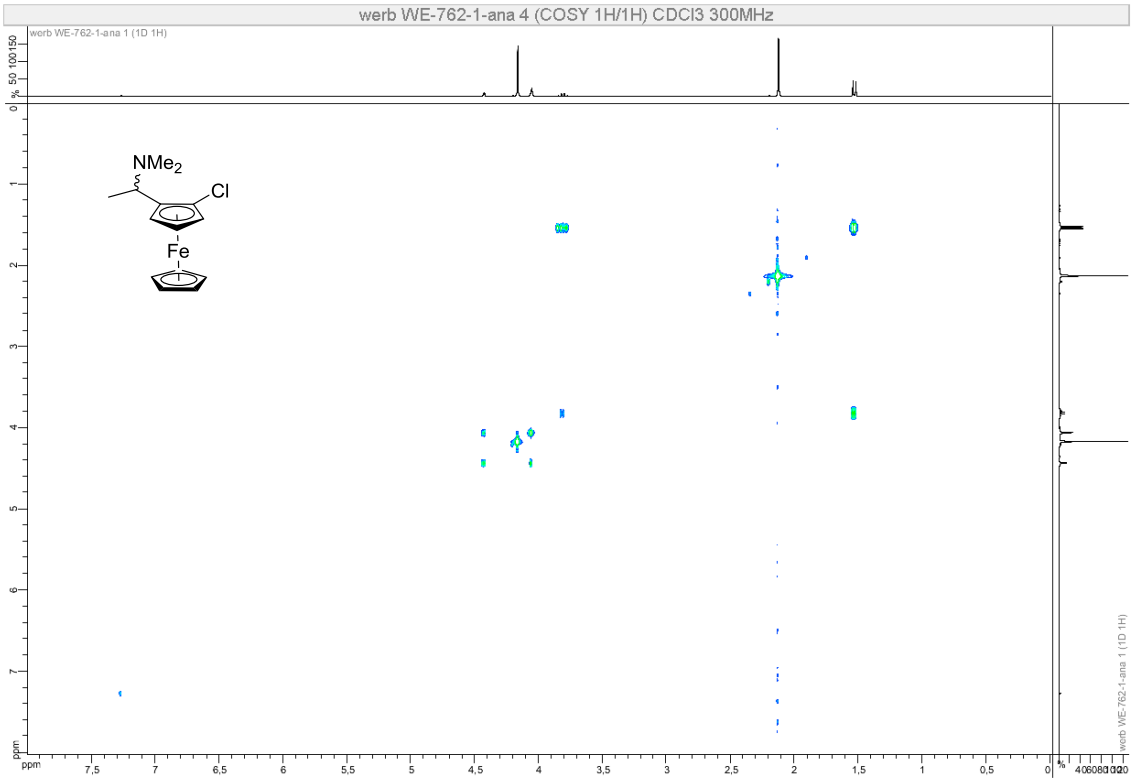

werb WE-747-2-ana 8 (1D 19F) CDCl3 300MHz
ppm
-182.060
F
NMe2
OHC
OHC
Fe
I
ppm

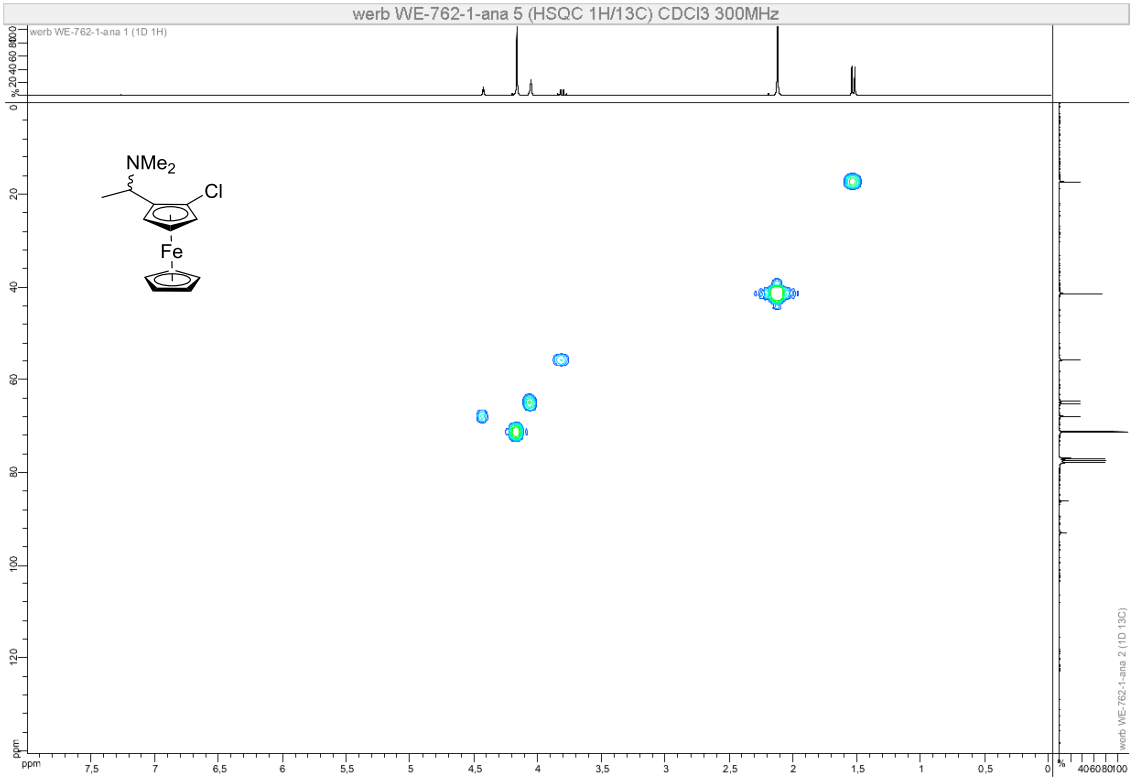
Compound (±)-8

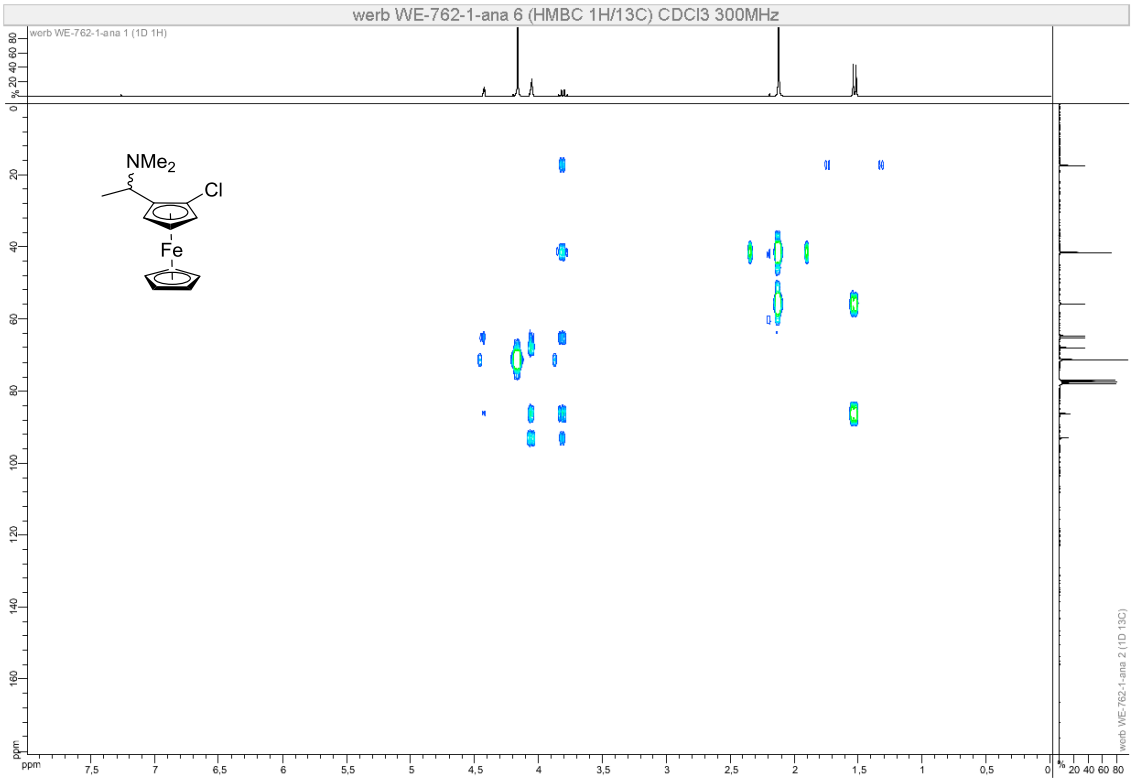

werb WE-762-1-ana 1 (1D 1H) CDCl3 300MHz
NMe2
Cl
Fe

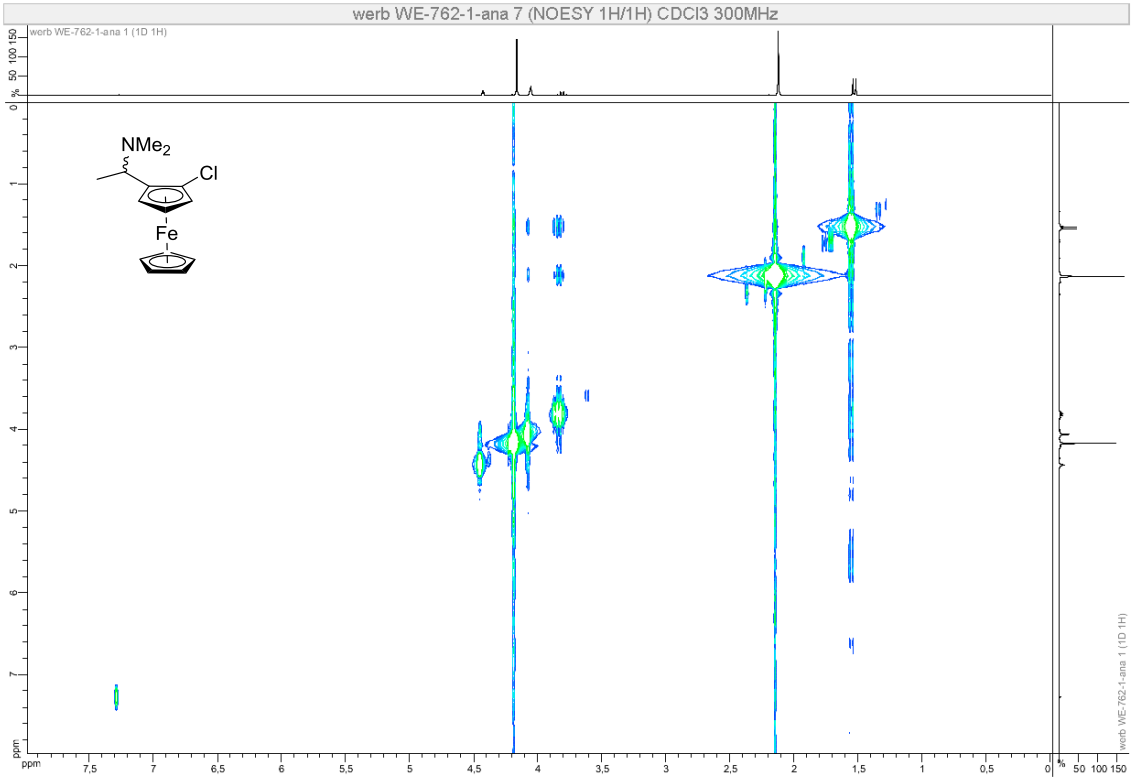

werb WE-762-1-ana 2 (1D 13C) CDCl3 300MHz
NMe2
Cl
Fe


werb WE-762-1-ana 3 (DEPT 13C) CDCl3 300MHz
70,980
67,649
64,330
64,371
55,496
41,221
17,098
NMe2
Cl
Fe
ppm

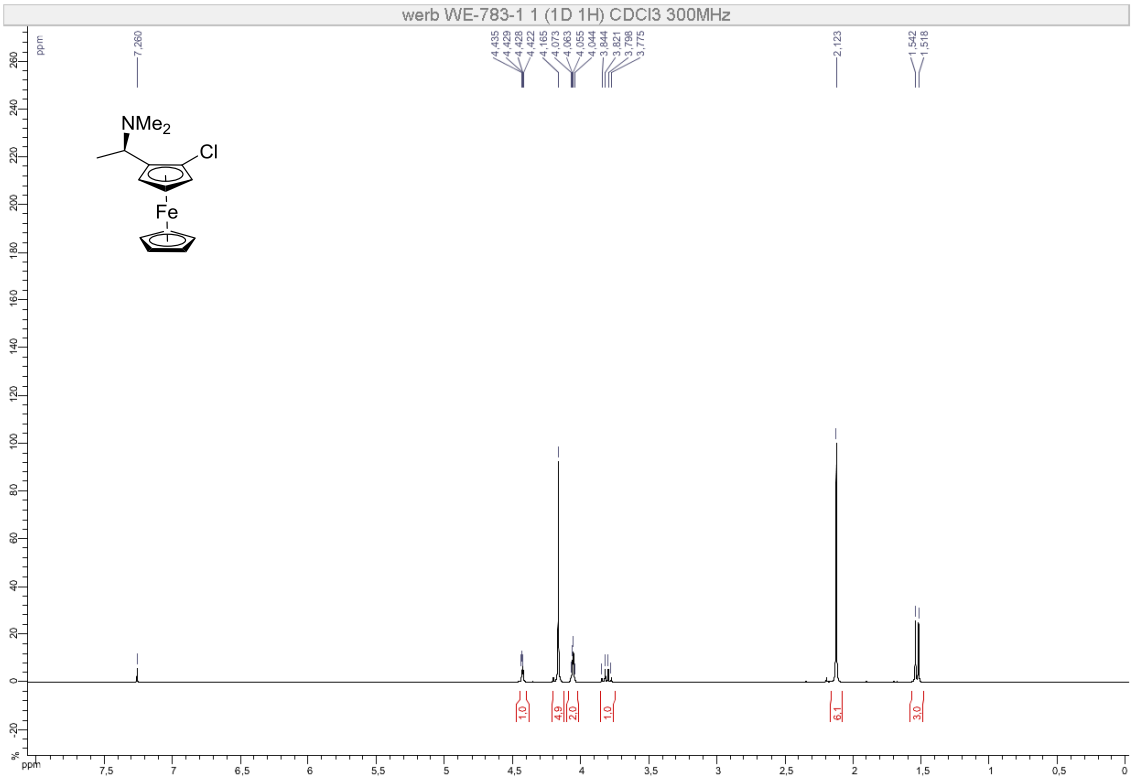

werb WE-762-1-ana 4 (COSY 1H/1H) CDCl3 300MHz
werb WE-762-1-ana 1 (1D 1H)
NMe2
Cl
Fe
ppm


werb WE-762-1-ana 5 (HSQC 1H/13C) CDCl3 300MHz
werb WE-762-1-ana 1 (1D 1H)
NMe2
Cl
Fe
ppm
werb WE-762-1-ana 2 (1D 13C)

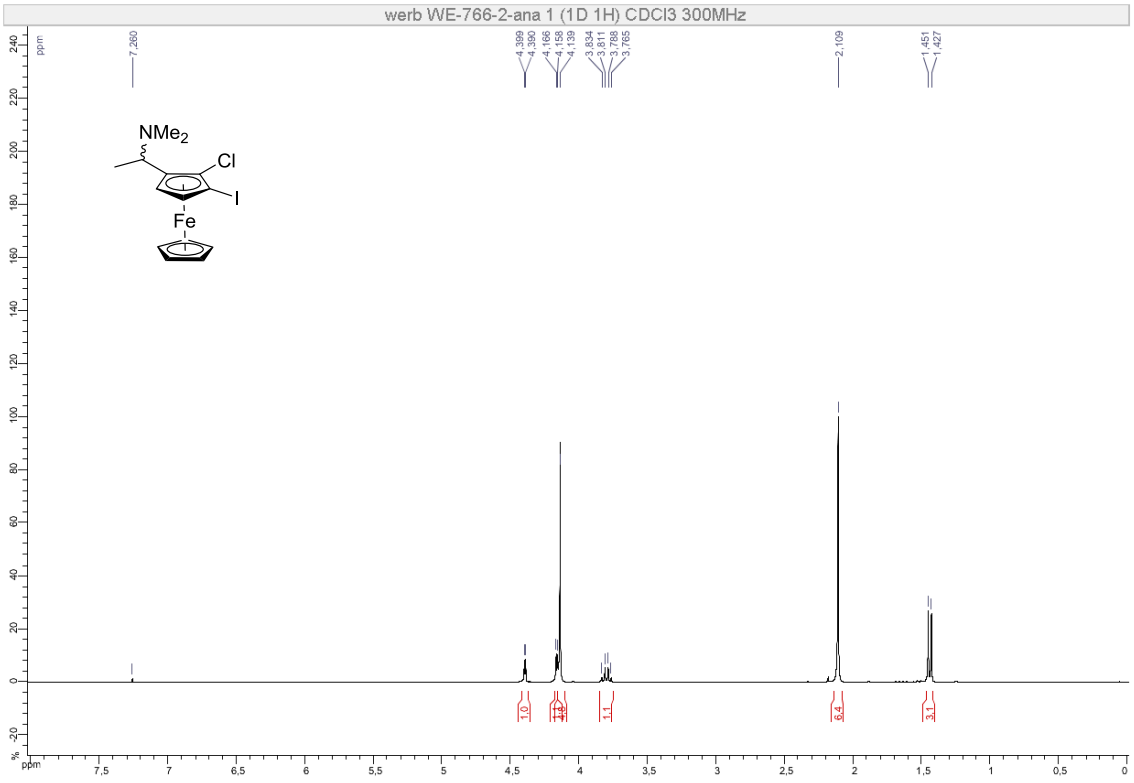

werb WE-762-1-ana 6 (HMBC 1H/13C) CDCl3 300MHz
werb WE-762-1-ana 1 (1D 1H)
NMe2
Cl
Fe
ppm
werb WE-762-1-ana 2 (1D 13C)

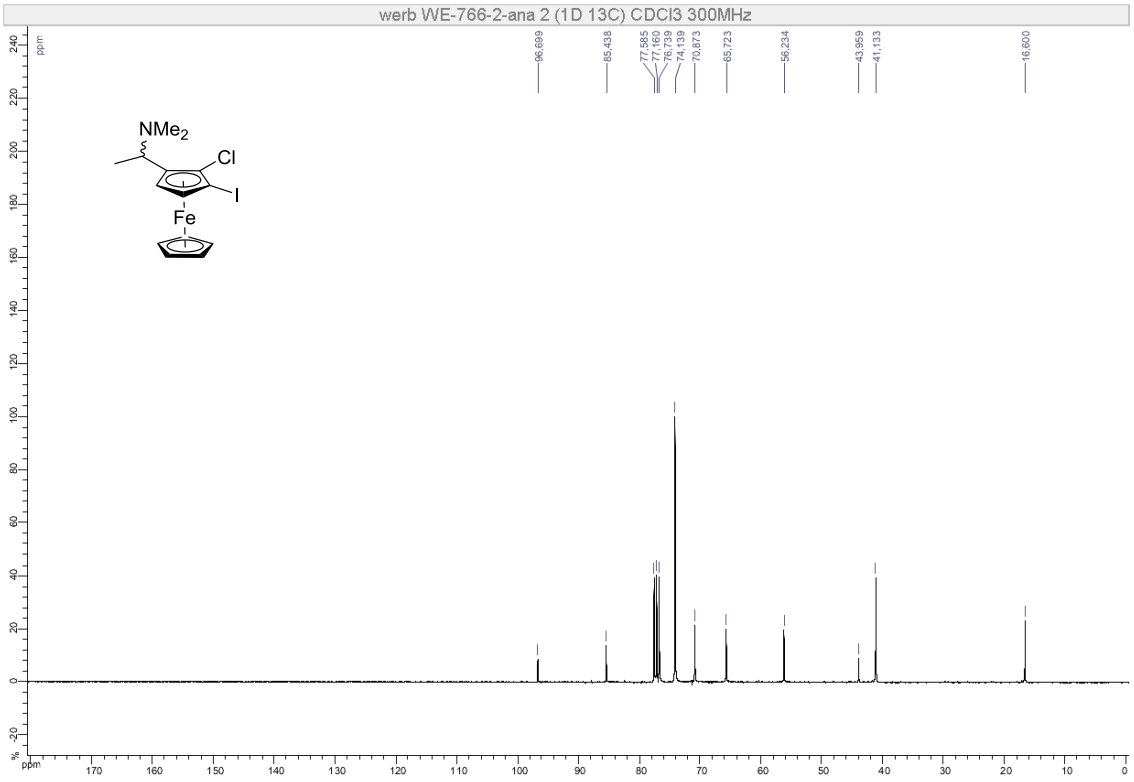


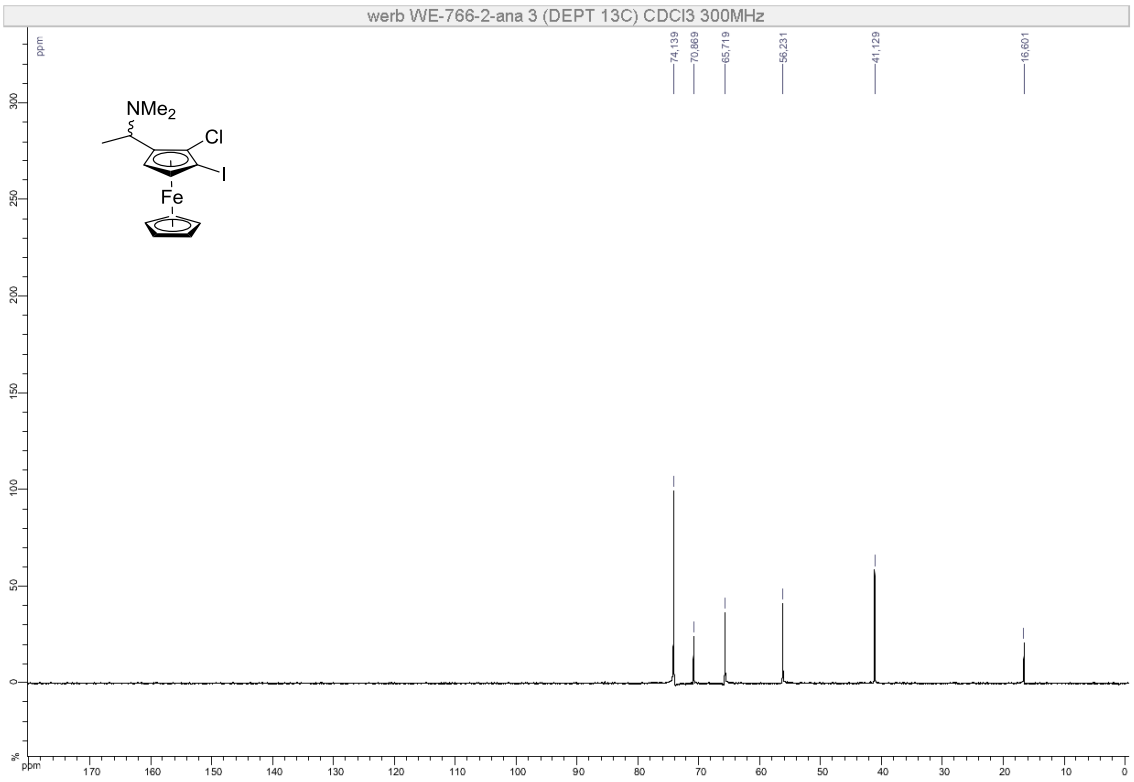
Compound (R,S_p)-8

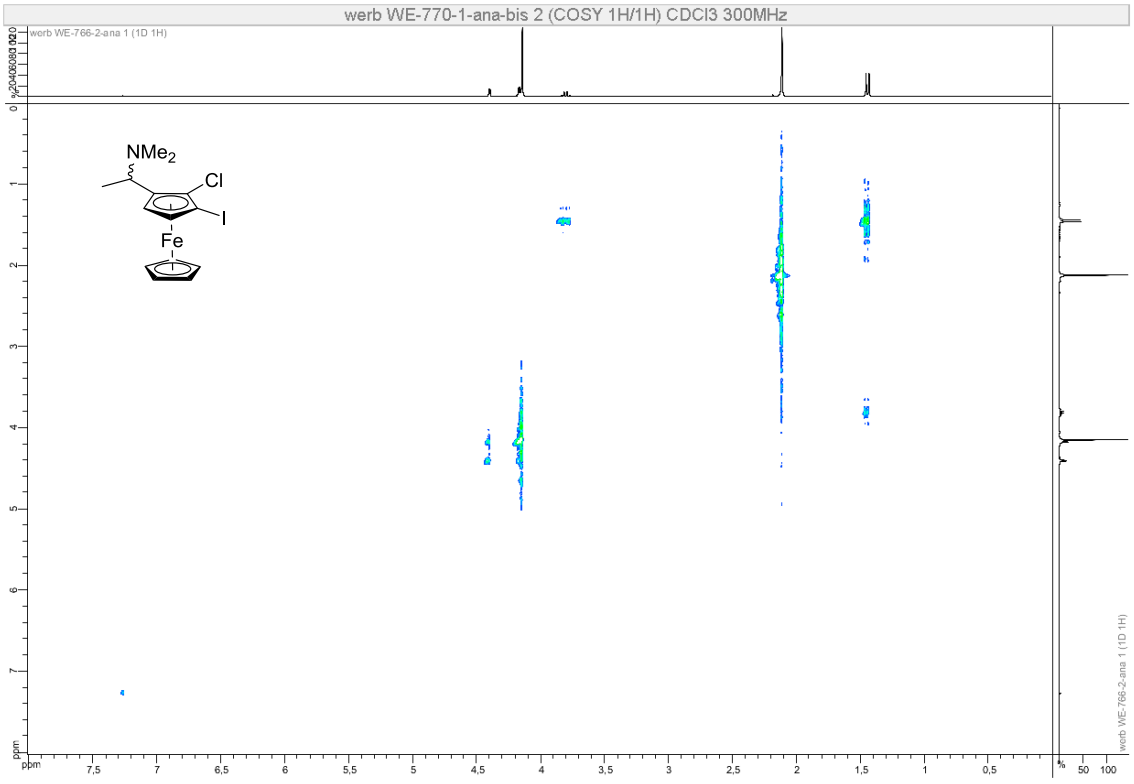


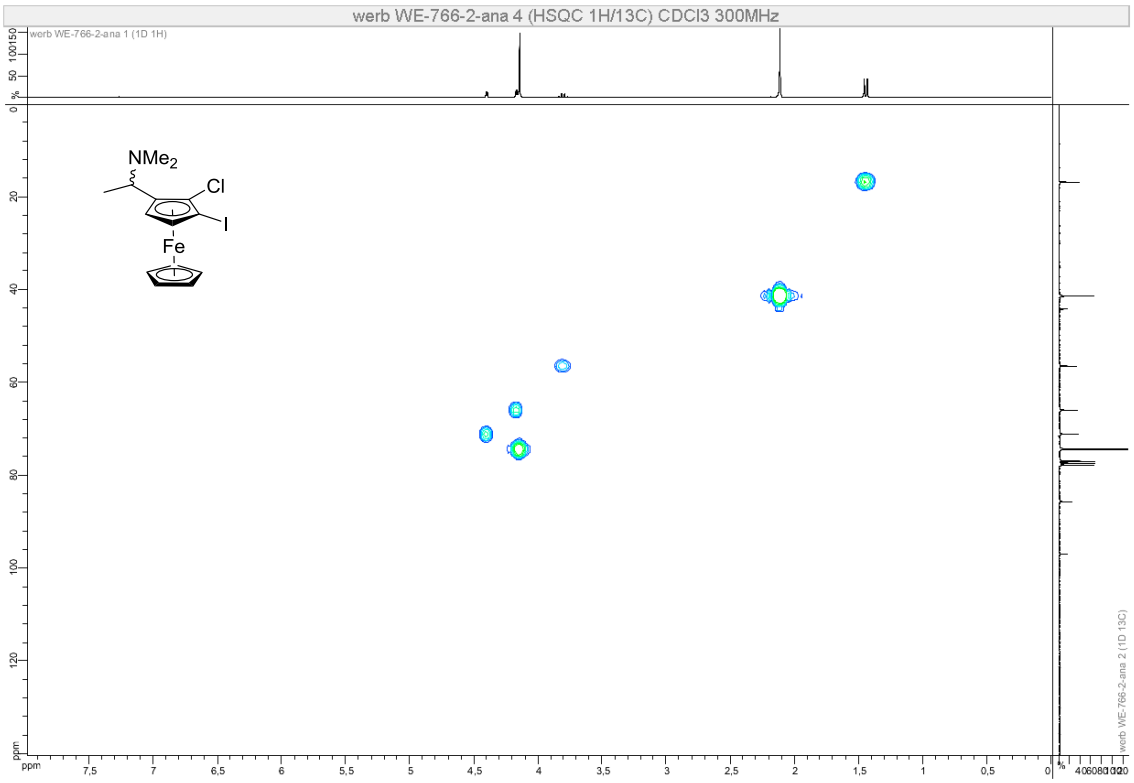
Compound (±)-9

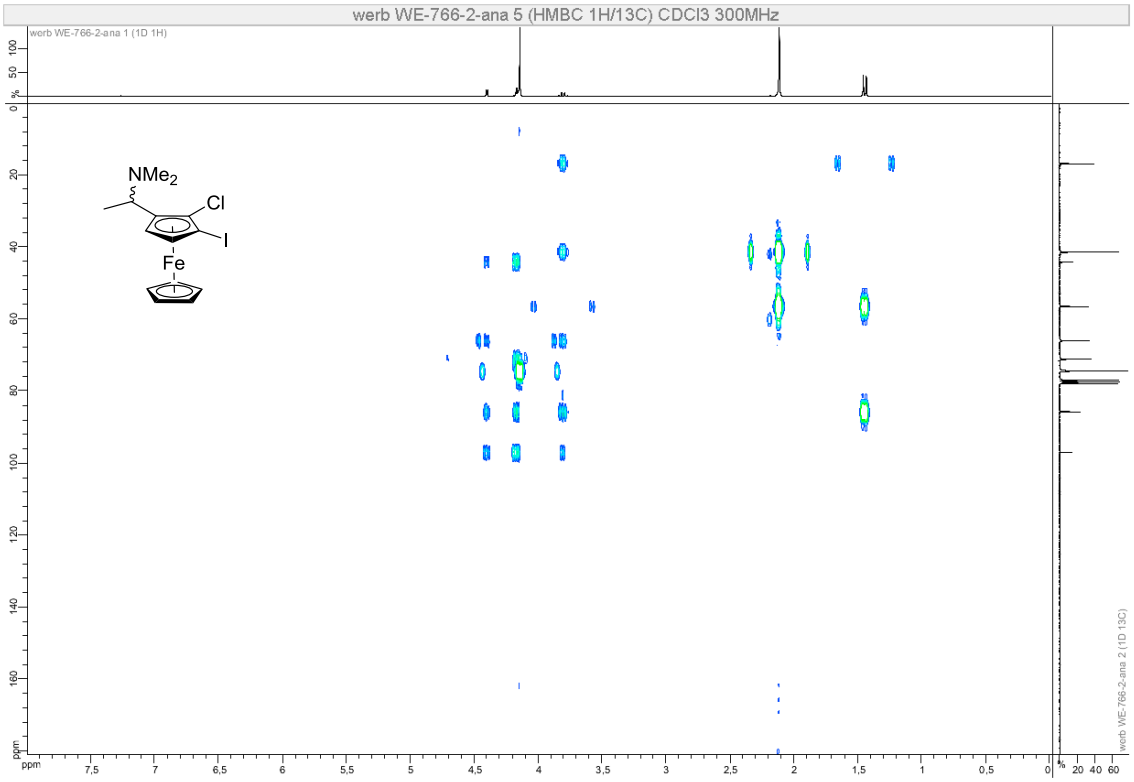

werb WE-766-2-ana 1 (1D 1H) CDCl3 300MHz
NMe2
Cl
I
Fe

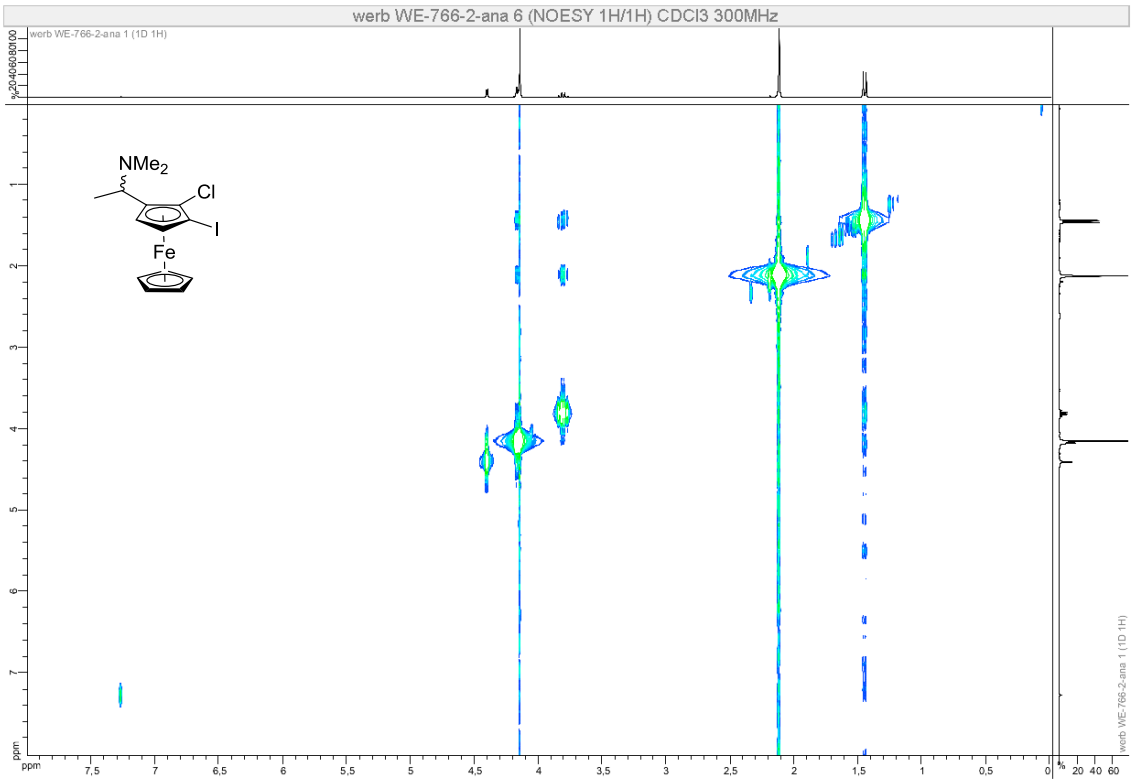

werb WE-766-2-ana 2 (1D 13C) CDCl3 300MHz
NMe2
Cl
I
Fe


werb WE-766-2-ana 3 (DEPT 13C) CDCl3 300MHz
74,139
70,869
65,719
56,231
41,129
16,601
NMe2
Cl
I
Fe

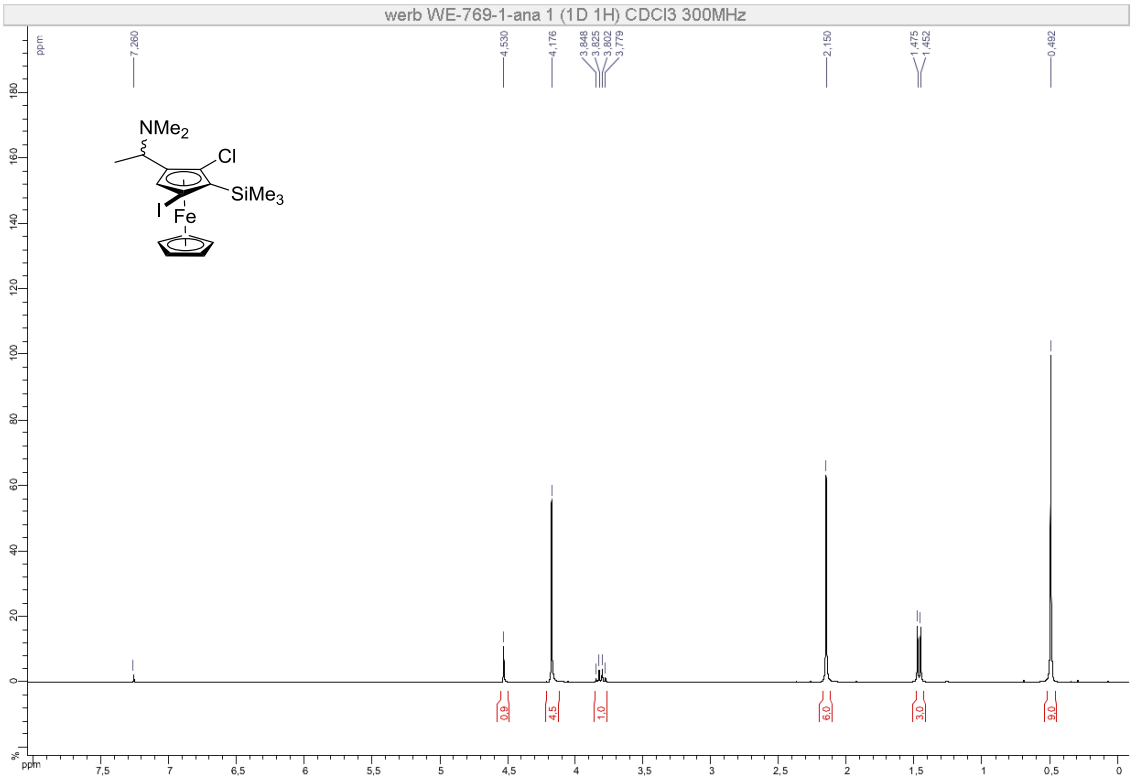

werb WE-770-1-ana-bis 2 (COSY 1H/1H) CDCl3 300MHz
werb WE-766-2-ana 1 (1D 1H)
NMe2
Cl
I
Fe

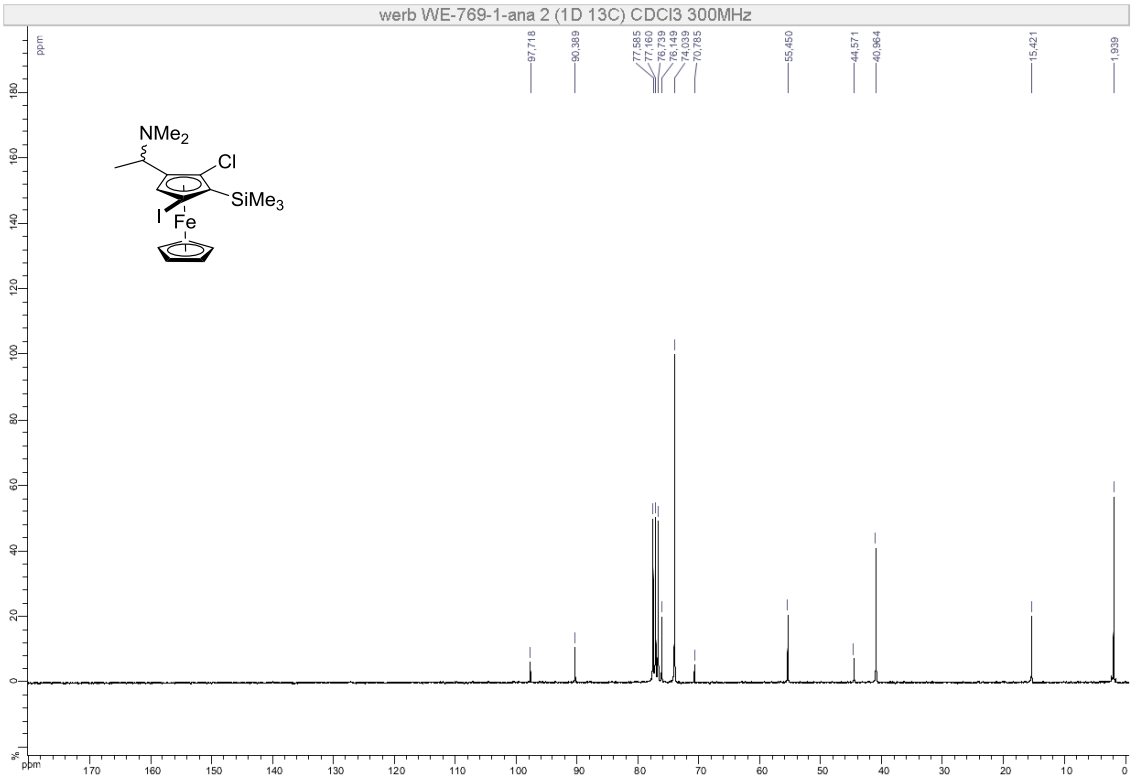

werb WE-766-2-ana 4 (HSQC 1H/13C) CDCl3 300MHz
werb WE-766-2-ana 1 (1D 1H)
NMe2
Cl
I
Fe
ppm
werb WE-766-2-ana 2 (1D 13C)

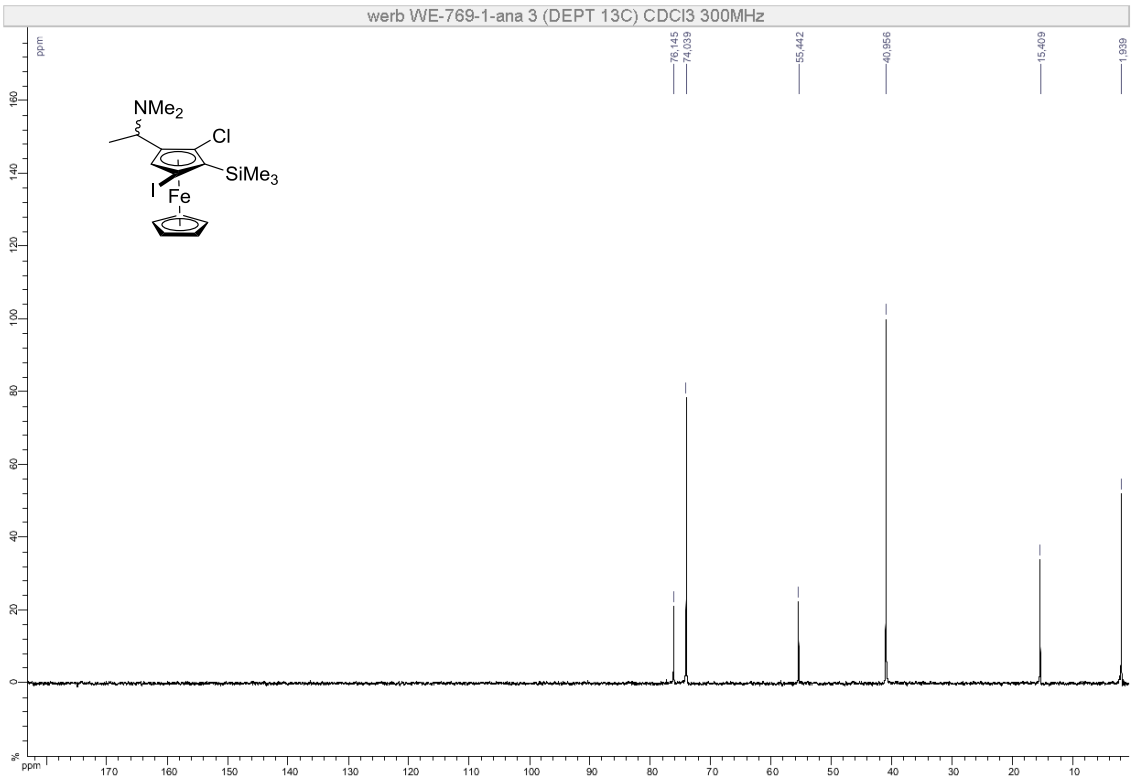

werb WE-766-2-ana 5 (HMBC 1H/13C) CDCl3 300MHz
werb WE-766-2-ana 1 (1D 1H)
NMe2
Cl
I
Fe
ppm
werb WE-766-2-ana 2 (1D 13C)

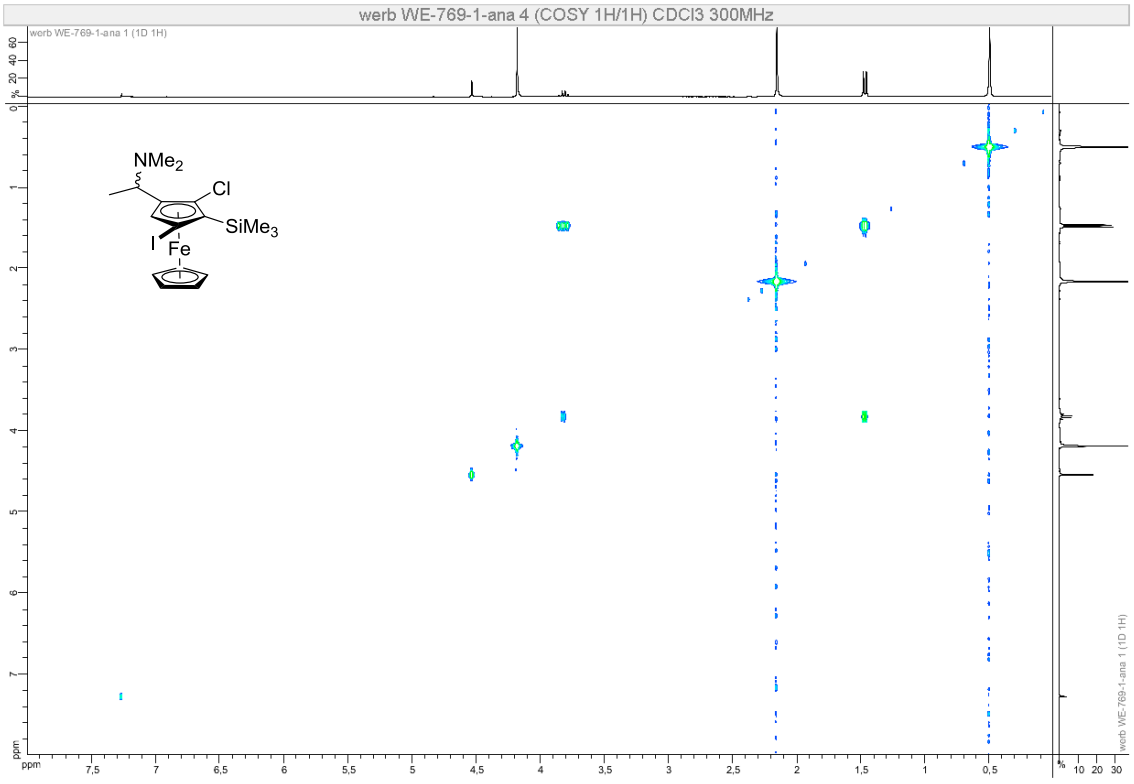

werb WE-766-2-ana 6 (NOESY 1H/1H) CDCl3 300MHz
werb WE-766-2-ana 1 (1D 1H)
NMe2
Cl
I
Fe
ppm
7,5
7
6,5
6
5,5
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
20
40
60
werb WE-766-2-ana 1 (1D 1H)

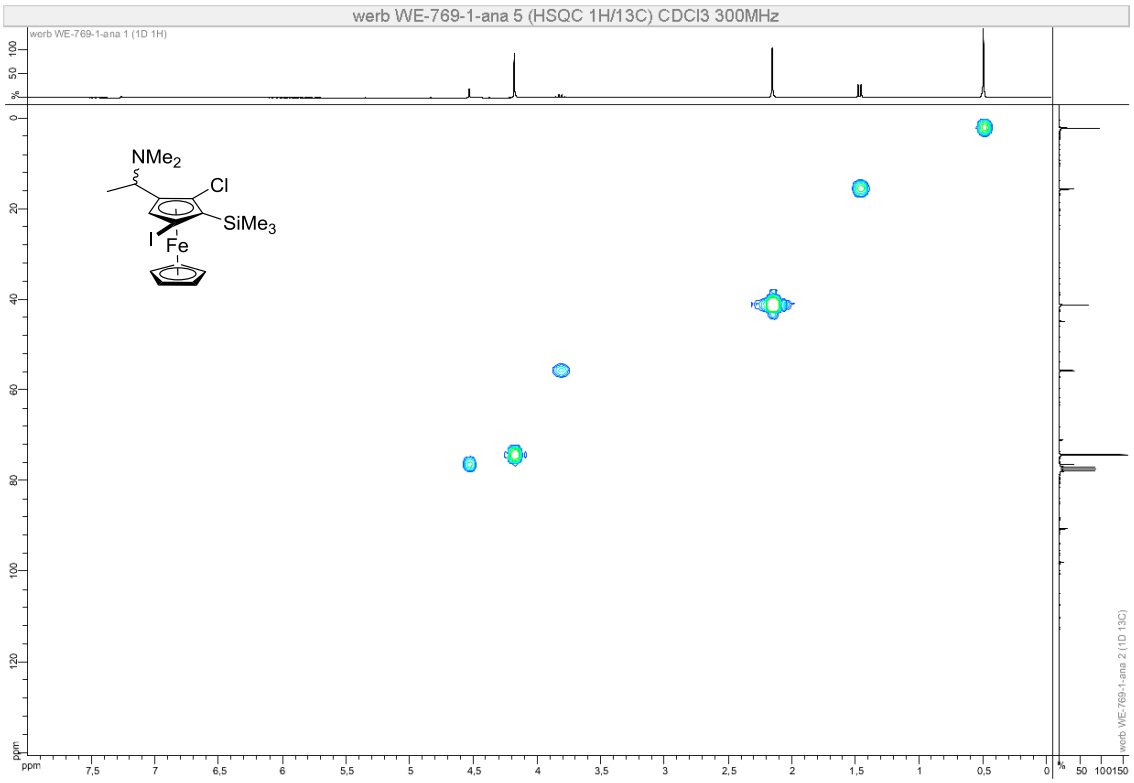
Compound (±)-10

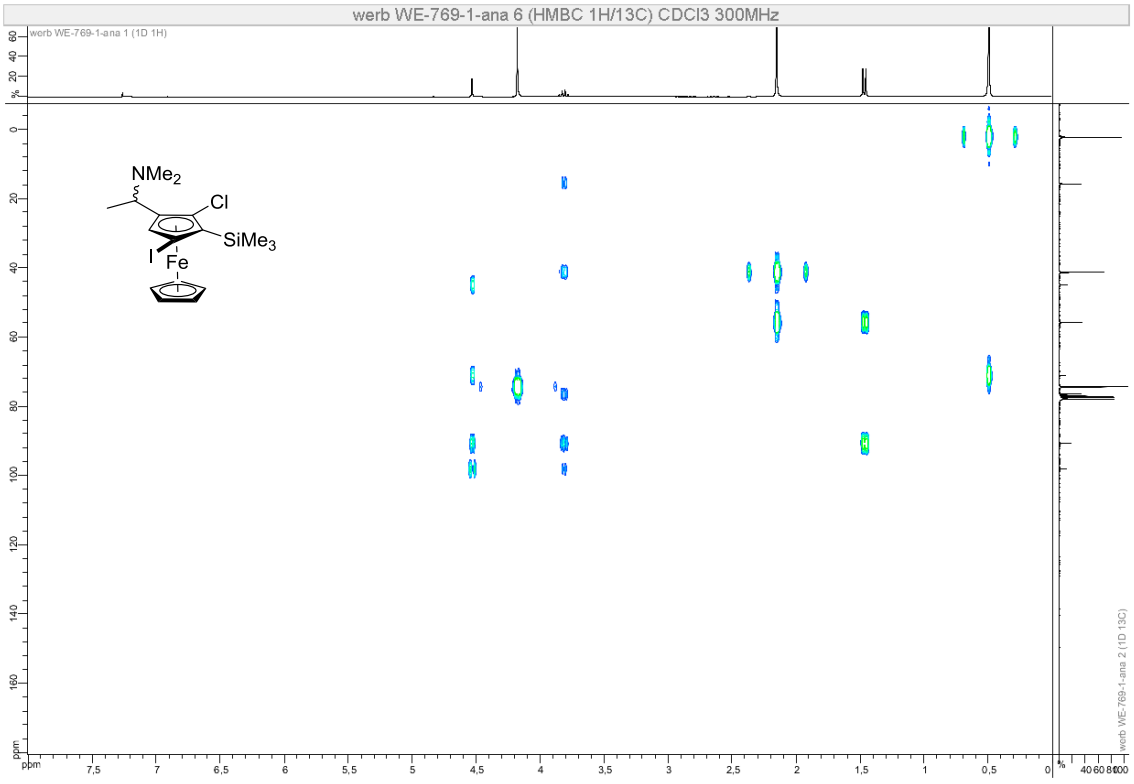

werb WE-769-1-ana 1 (1D 1H) CDCl3 300MHz
NMe2
Cl
SiMe3
Fe

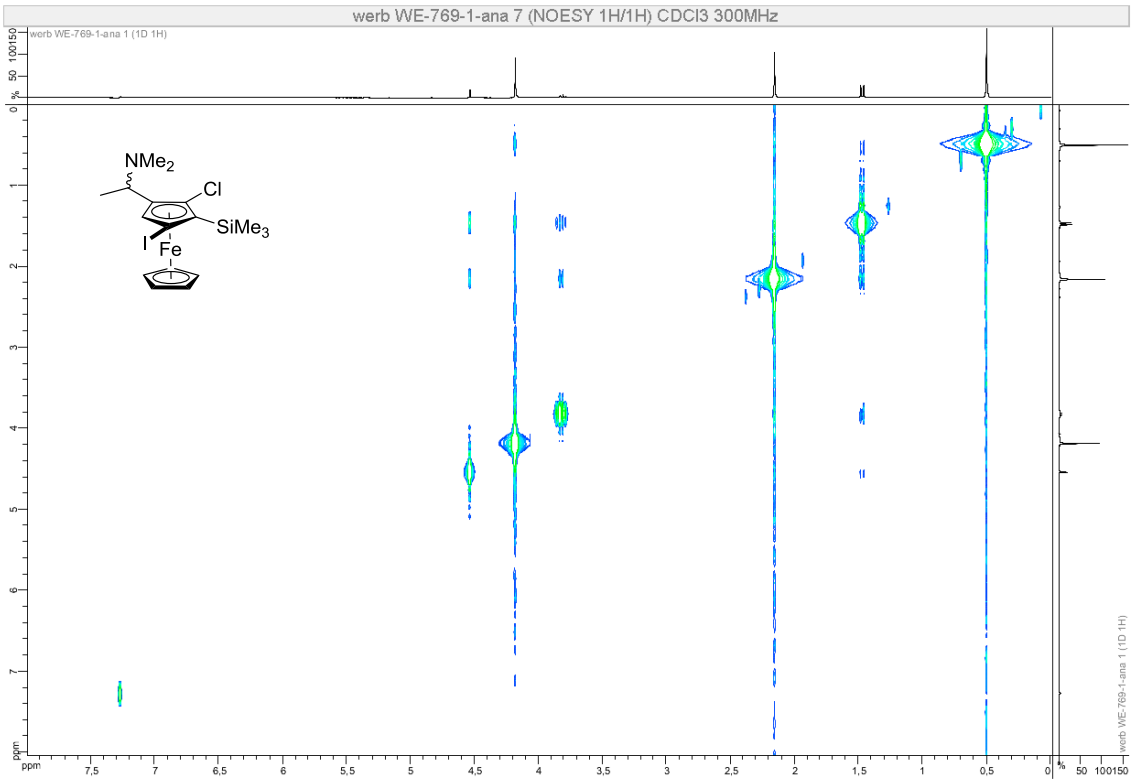

werb WE-769-1-ana 2 (1D 13C) CDCl3 300MHz
NMe2
Cl
SiMe3
Fe


werb WE-769-1-ana 3 (DEPT 13C) CDCl3 300MHz
76,145
74,039
55,442
40,956
15,409
1,939
NMe2
Cl
SiMe3
Fe
ppm

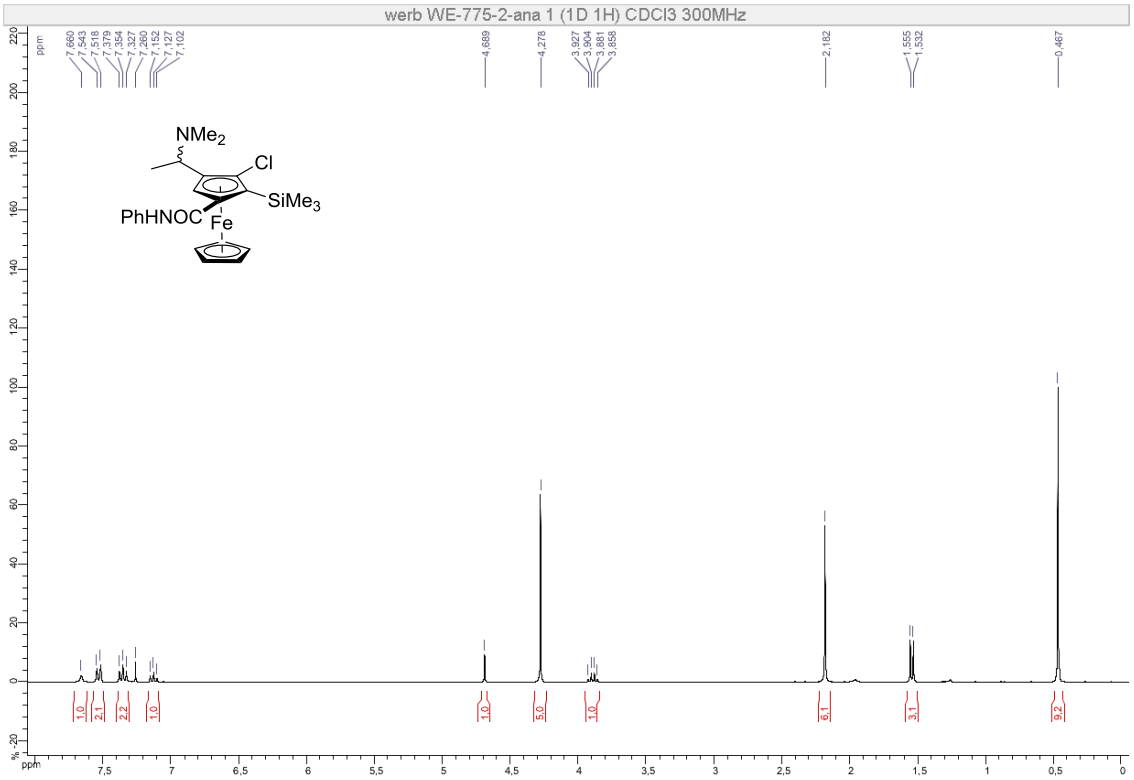

werb WE-769-1-ana 4 (COSY 1H/1H) CDCl3 300MHz
werb WE-769-1-ana 1 (1D 1H)
NMe2
Cl
SiMe3
Fe
ppm

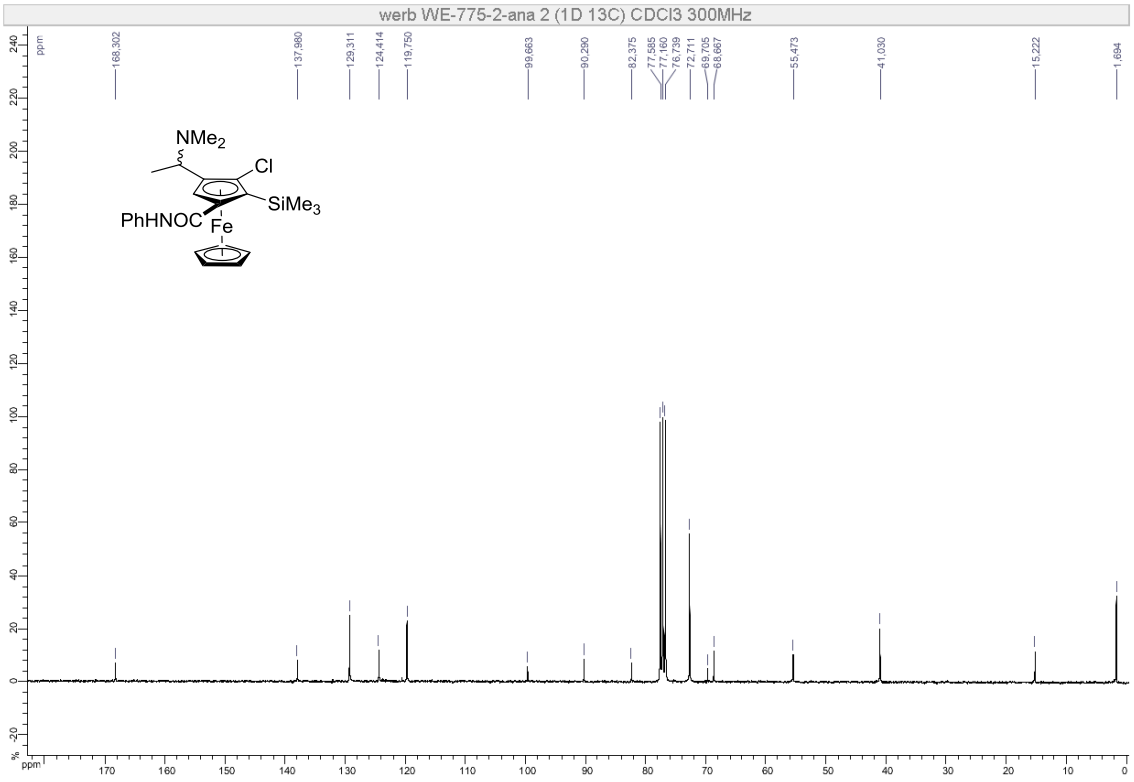

werb WE-769-1-ana 5 (HSQC 1H/13C) CDCl3 300MHz
werb WE-769-1-ana 1 (1D 1H)
NMe2
Cl
SiMe3
I
Fe
ppm
werb WE-769-1-ana 2 (1D 13C)

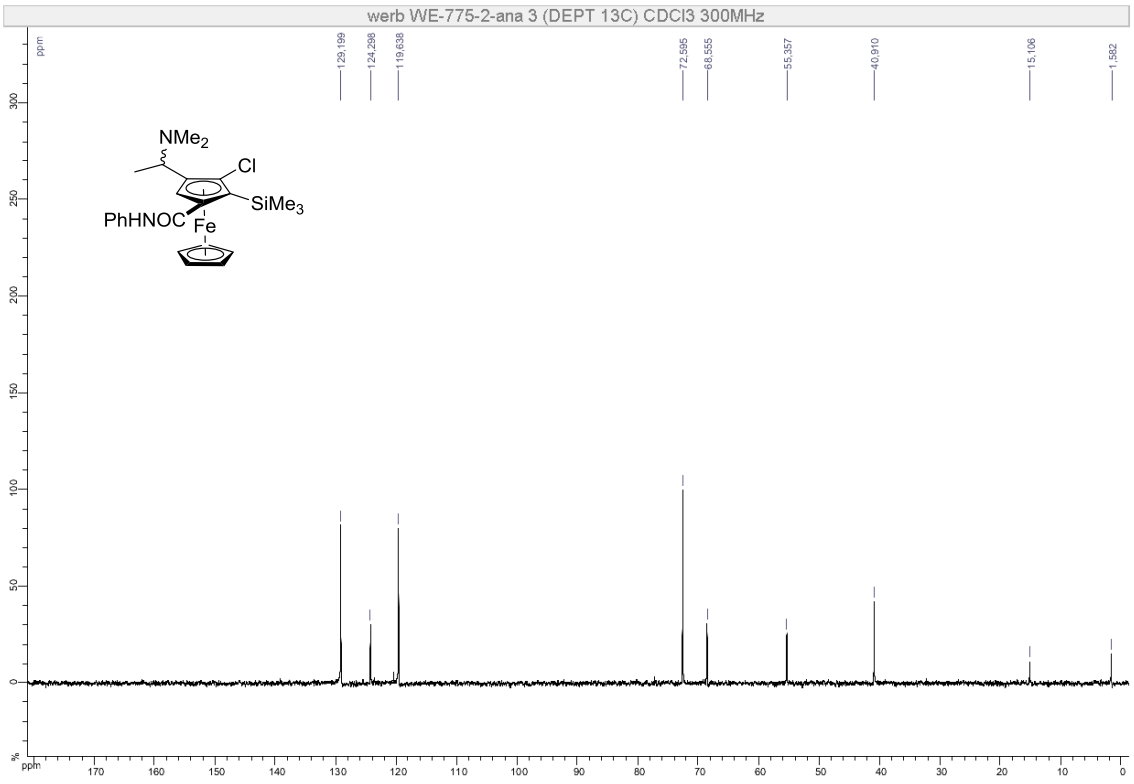

werb WE-769-1-ana 6 (HMBC 1H/13C) CDCl3 300MHz
werb WE-769-1-ana 1 (1D 1H)
NMe2
Cl
SiMe3
I
Fe
ppm
werb WE-769-1-ana 2 (1D 13C)

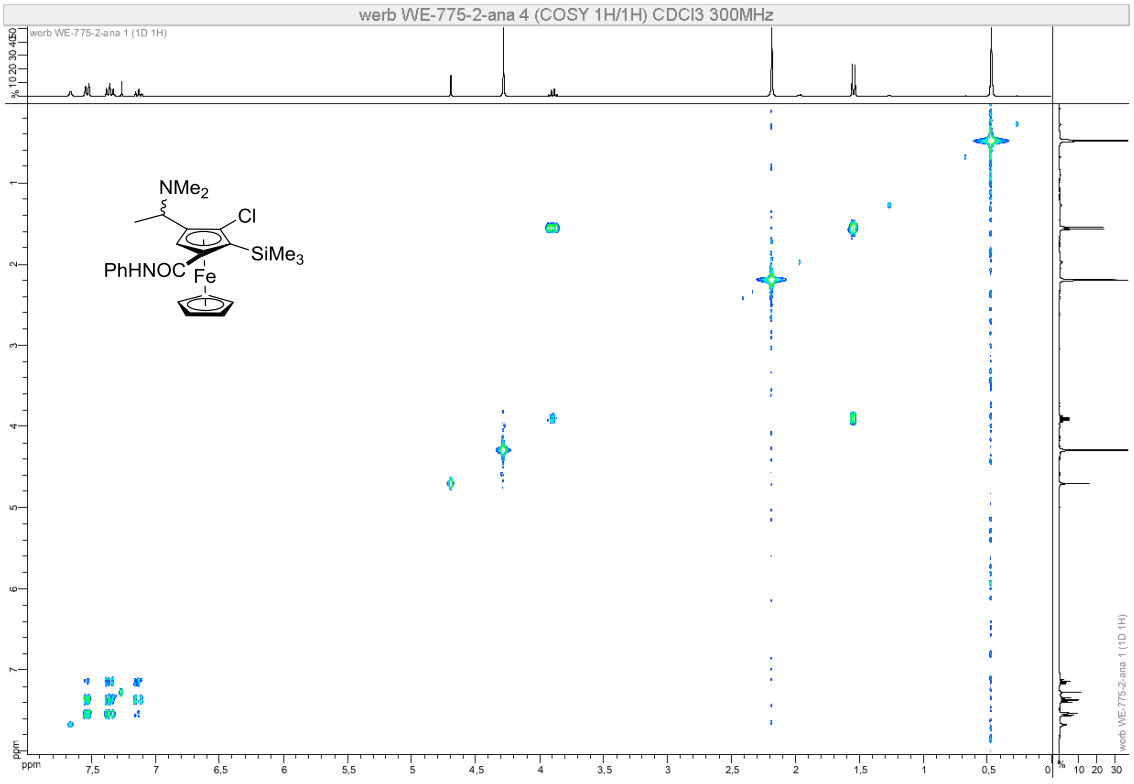

werb WE-769-1-ana 7 (NOESY 1H/1H) CDCl3 300MHz
werb WE-769-1-ana 1 (1D 1H)
NMe2
Cl
SiMe3
Fe
ppm
7,5
7
6,5
6
5,5
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
%
50
100
150
werb WE-769-1-ana 1 (1D 1H)

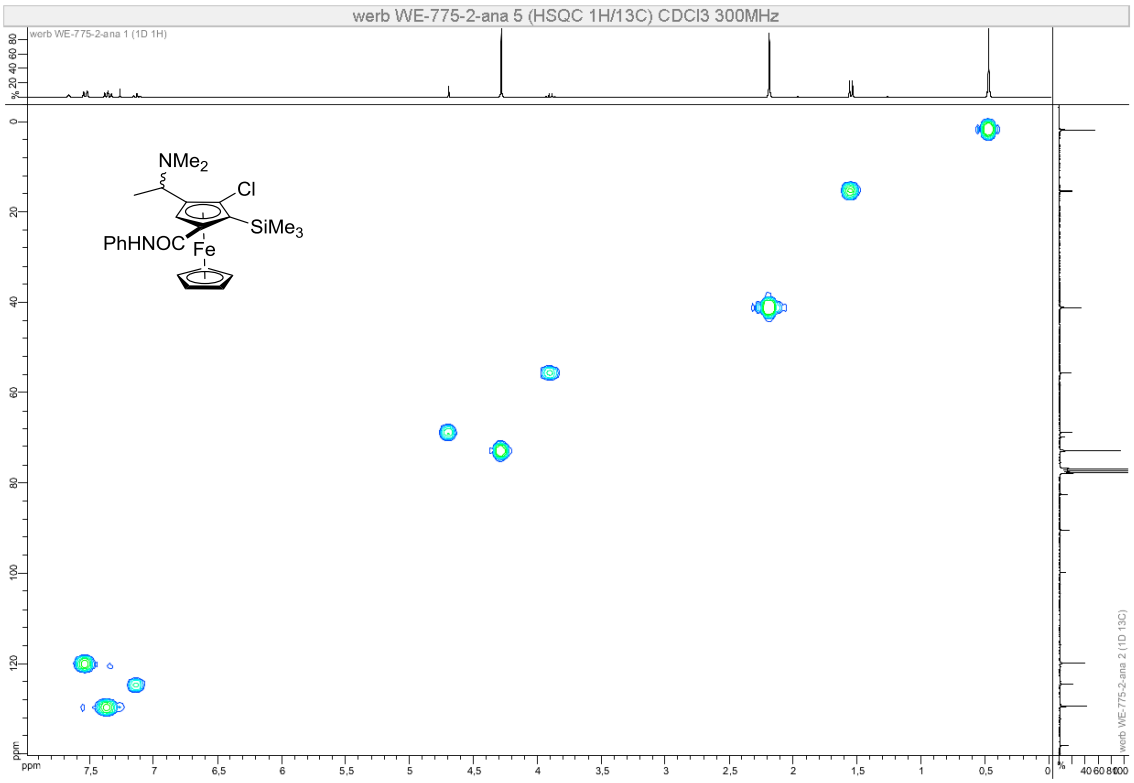
Compound (±)-11

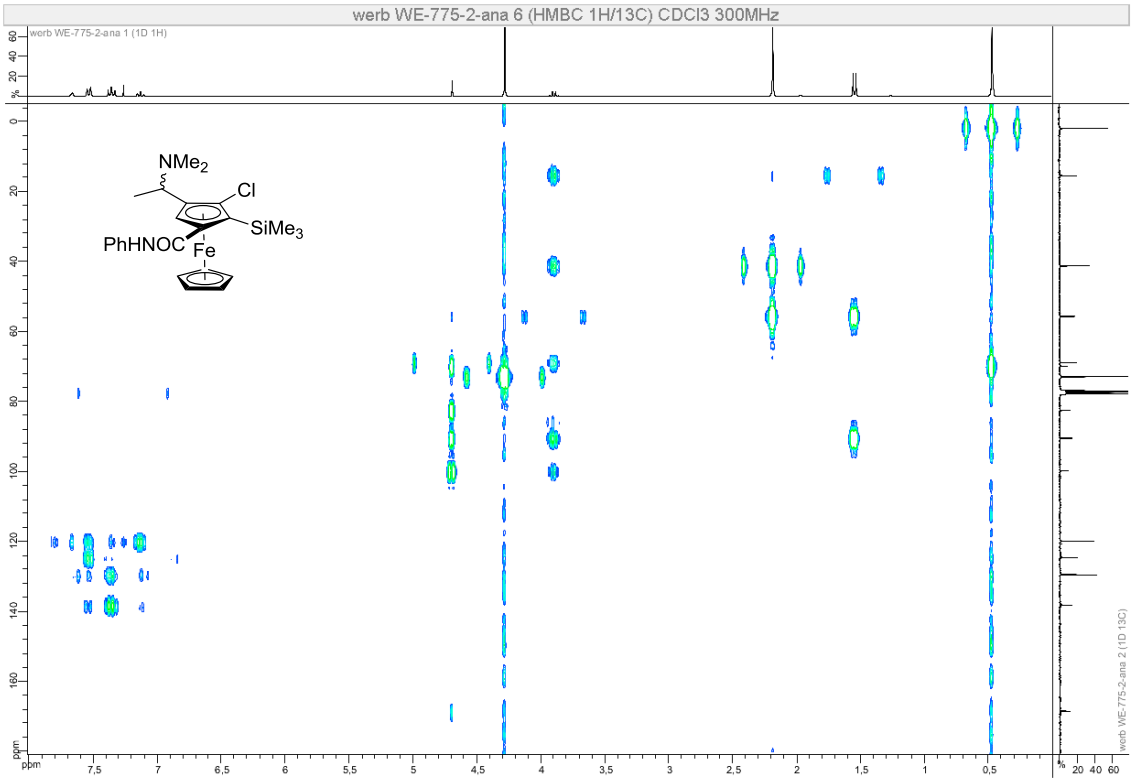

werb WE-775-2-ana 1 (1D 1H) CDCl3 300MHz
NMe2
Cl
SiMe3
PhHNOC
Fe

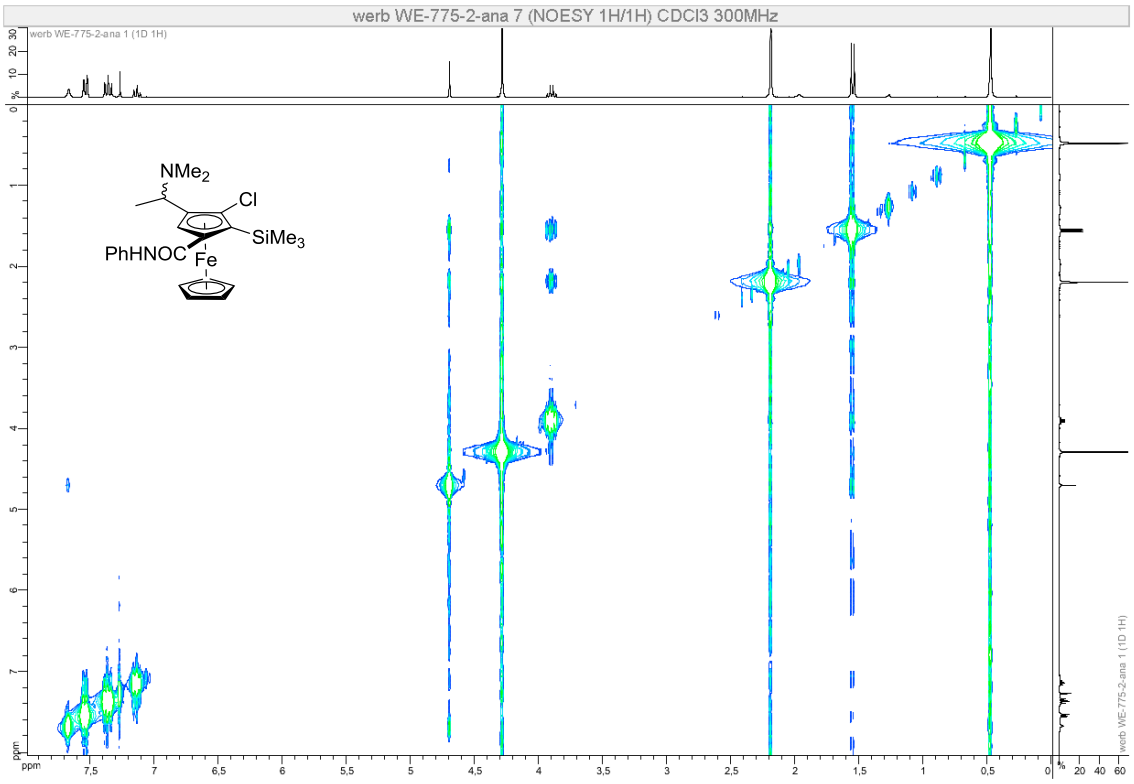

werb WE-775-2-ana 2 (1D 13C) CDCl3 300MHz
NMe2
Cl
SiMe3
PhHNOC
Fe


werb WE-775-2-ana 3 (DEPT 13C) CDCl3 300MHz
ppm
129,199
124,298
119,638
72,595
68,555
55,357
40,910
15,106
1,582
NMe2
Cl
SiMe3
PhHNOC
Fe

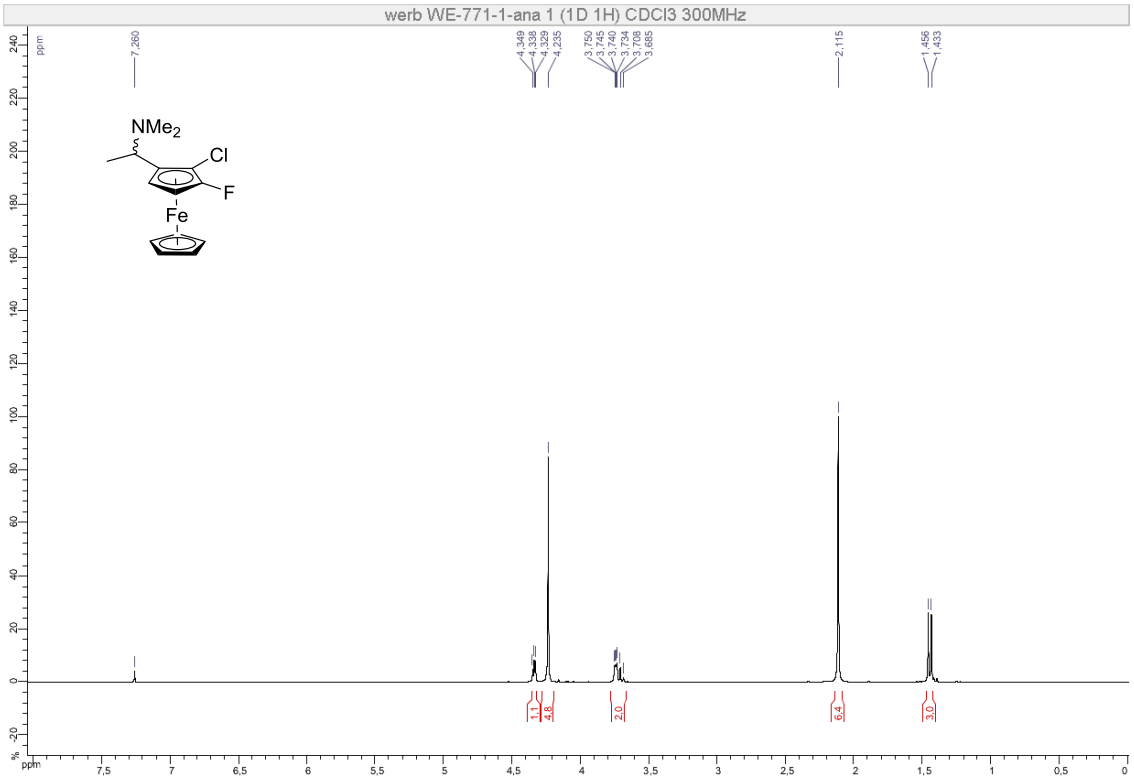

werb WE-775-2-ana 4 (COSY 1H/1H) CDCl3 300MHz
werb WE-775-2-ana 1 (1D 1H)
NMe2
Cl
SiMe3
PhHNOC
Fe
ppm

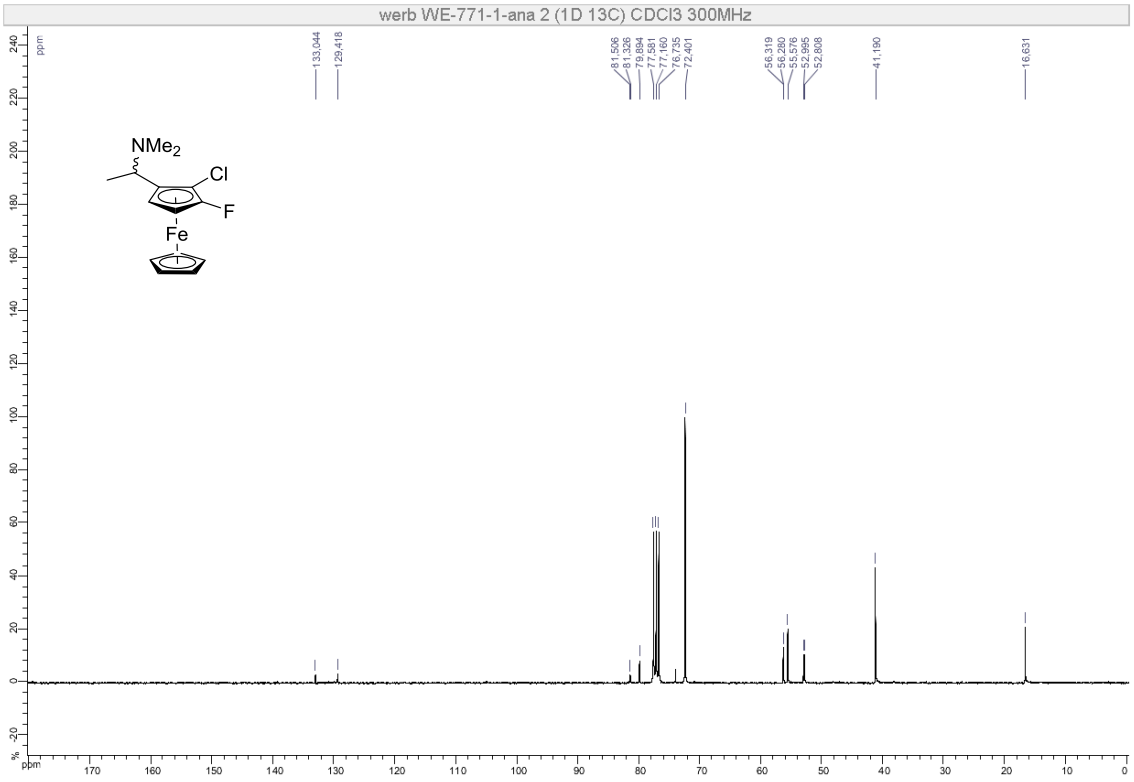

werb WE-775-2-ana 5 (HSQC 1H/13C) CDCl3 300MHz
werb WE-775-2-ana 1 (1D 1H)
NMe2
Cl
SiMe3
PhHNOC
Fe
ppm
werb WE-775-2-ana 2 (1D 13C)

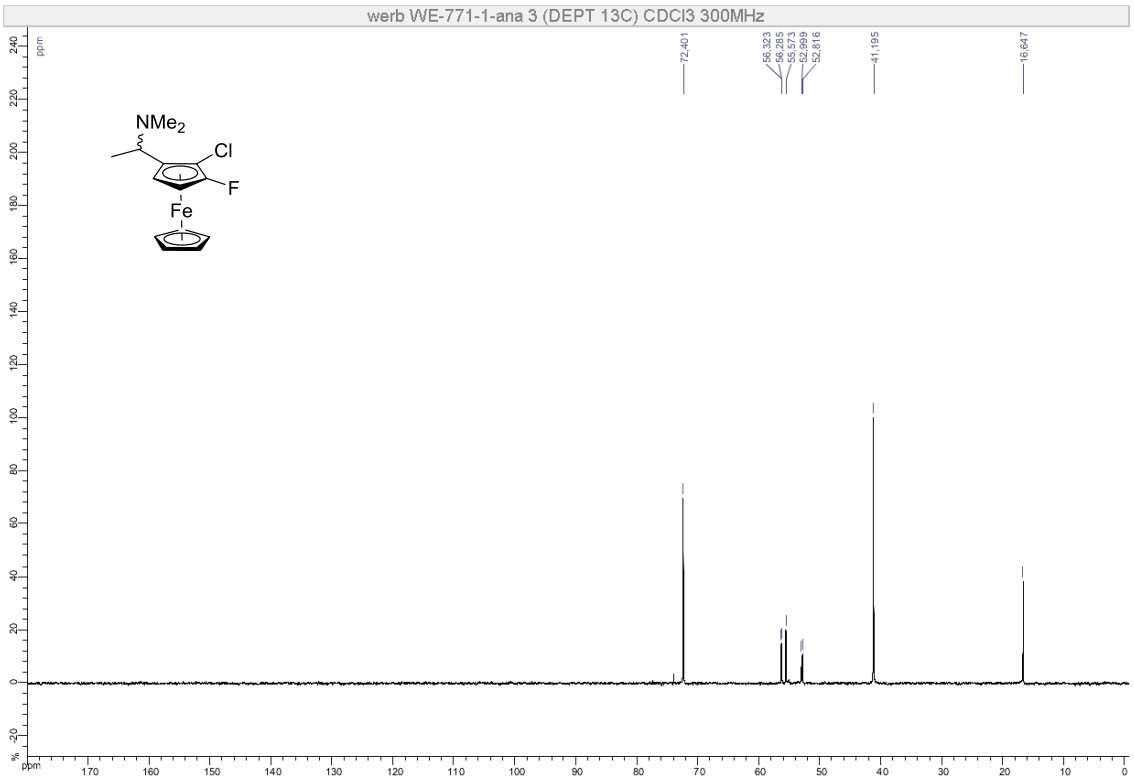

werb WE-775-2-ana 6 (HMBC 1H/13C) CDCl3 300MHz
werb WE-775-2-ana 1 (1D 1H)
NMe2
Cl
SiMe3
PhHNOC
Fe
ppm
werb WE-775-2-ana 2 (1D 13C)

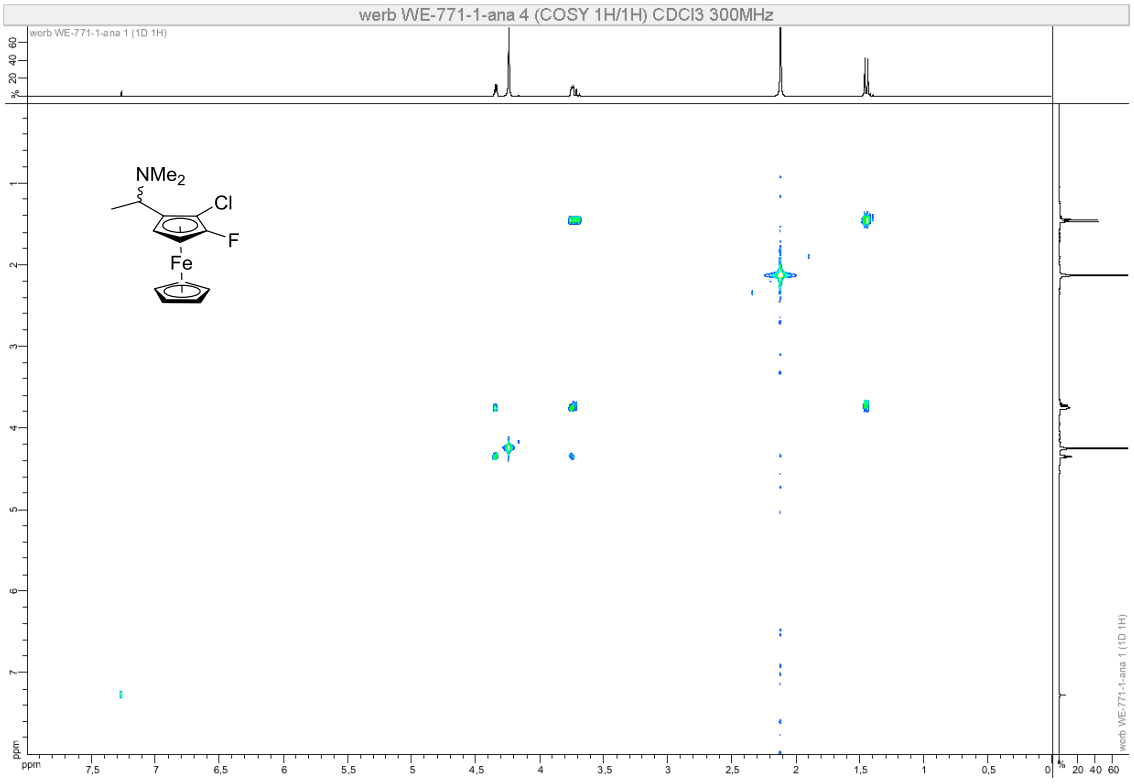

werb WE-775-2-ana 7 (NOESY 1H/1H) CDCl3 300MHz
werb WE-775-2-ana 1 (1D 1H)
NMe2
Cl
SiMe3
PhHNOC
Fe
ppm
7,5
7
6,5
6
5,5
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
20
40
60

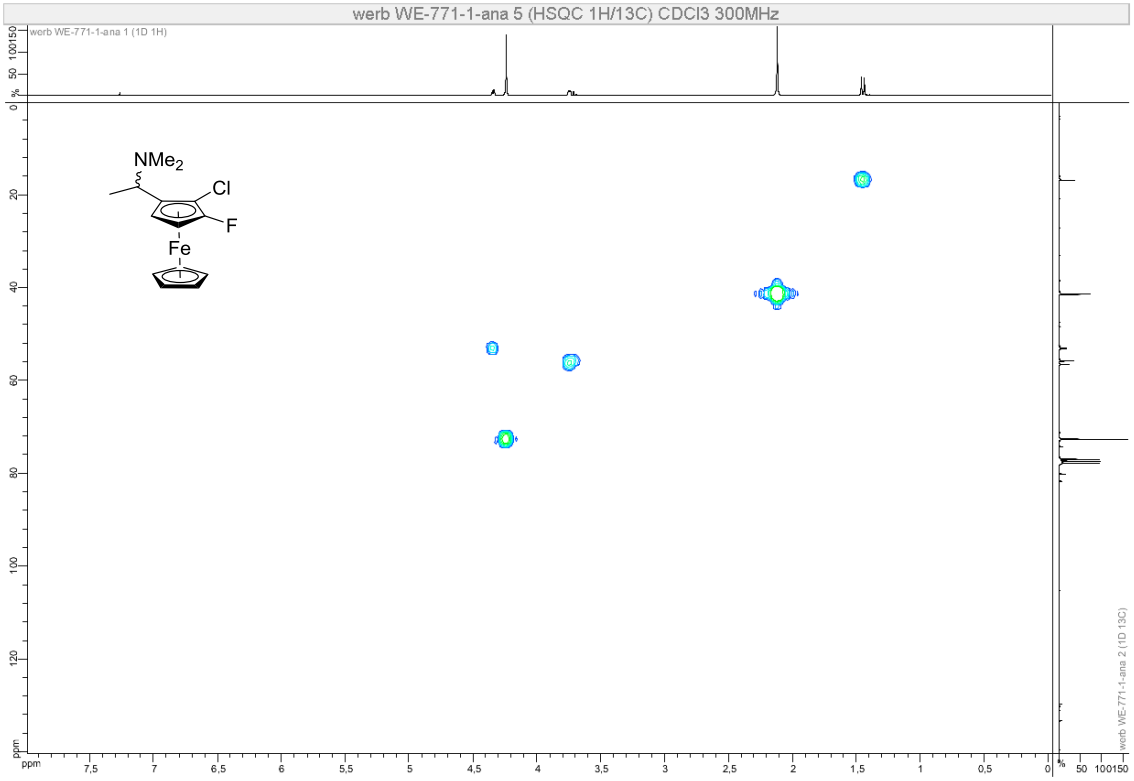
Compound (±)-12

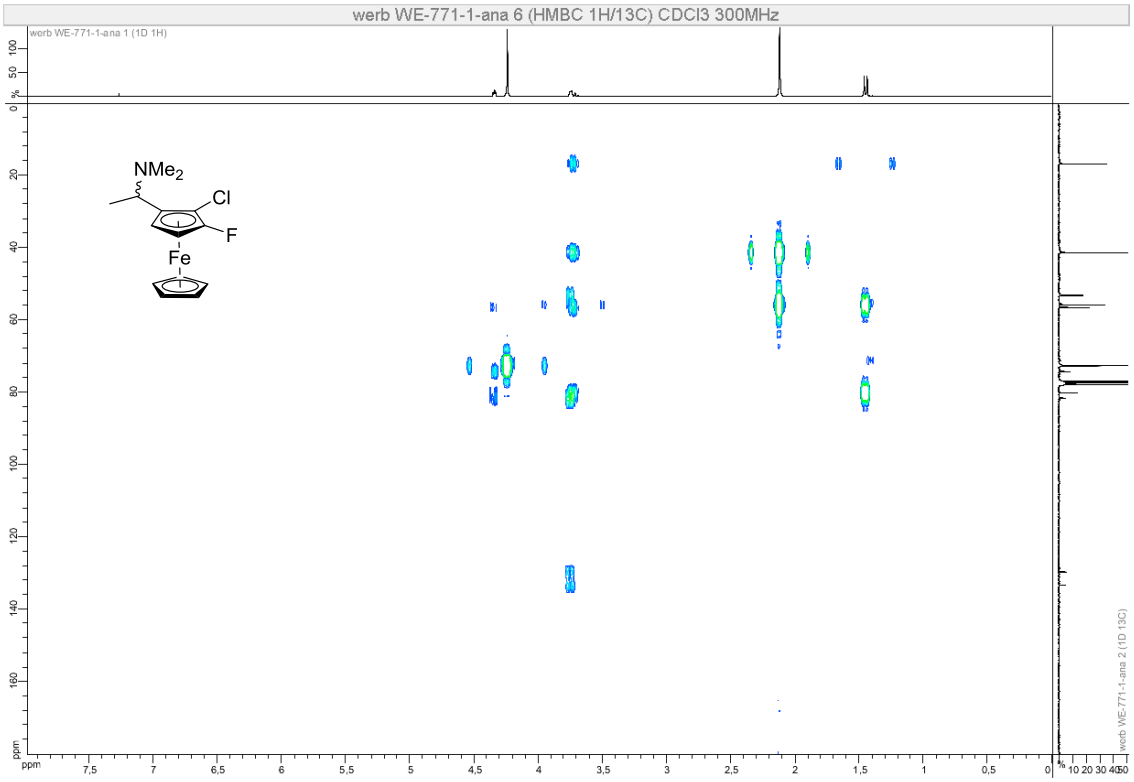

werb WE-771-1-ana 1 (1D 1H) CDCl3 300MHz
NMe2
Cl
F
Fe

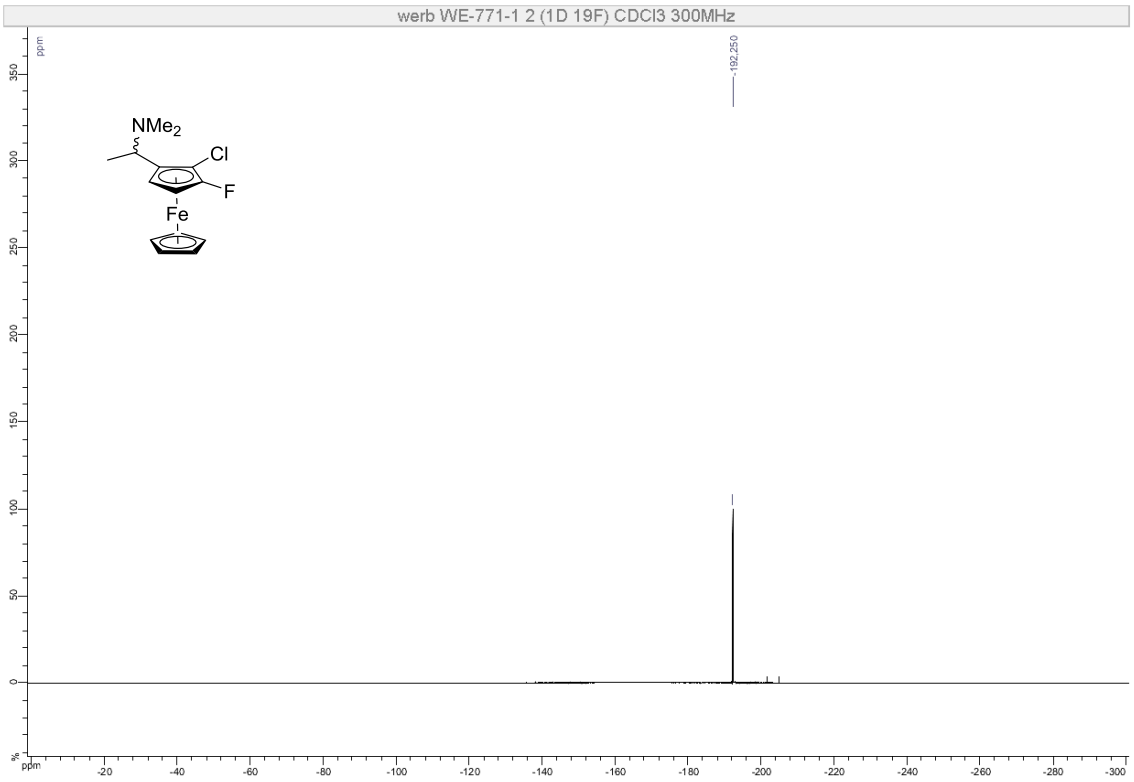

werb WE-771-1-ana 2 (1D 13C) CDCl3 300MHz
NMe2
Cl
F
Fe


werb WE-771-1-ana 3 (DEPT 13C) CDCl3 300MHz
72,401
58,323
56,285
55,573
52,999
52,816
41,195
16,647
NMe2
Cl
F
Fe
ppm

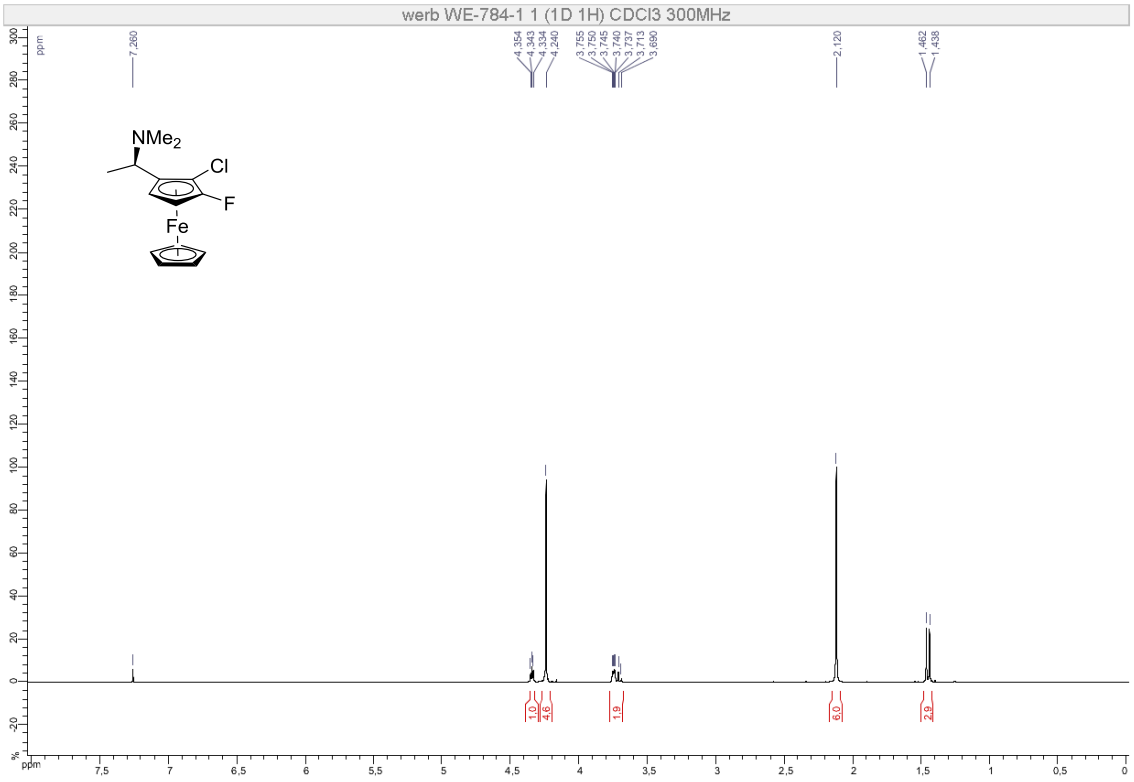

werb WE-771-1-ana 4 (COSY 1H/1H) CDCl3 300MHz
werb WE-771-1-ana 1 (1D 1H)
NMe2
Cl
F
Fe
ppm

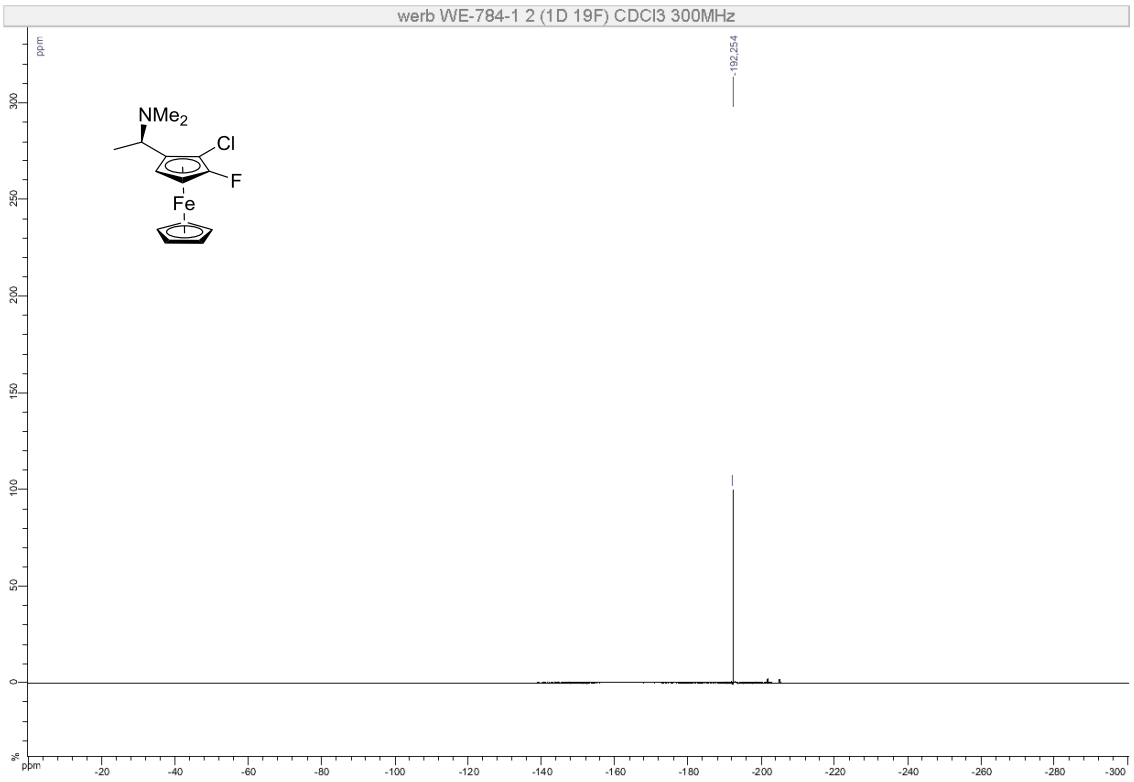

werb WE-771-1-ana 5 (HSQC 1H/13C) CDCl3 300MHz
werb WE-771-1-ana 1 (1D 1H)
NMe2
Cl
F
Fe
ppm
werb WE-771-1-ana 2 (1D 13C)


werb WE-771-1-ana 6 (HMBC 1H/13C) CDCl3 300MHz
werb WE-771-1-ana 1 (1D 1H)
NMe2
Cl
F
Fe
ppm
werb WE-771-1-ana 2 (1D 13C)

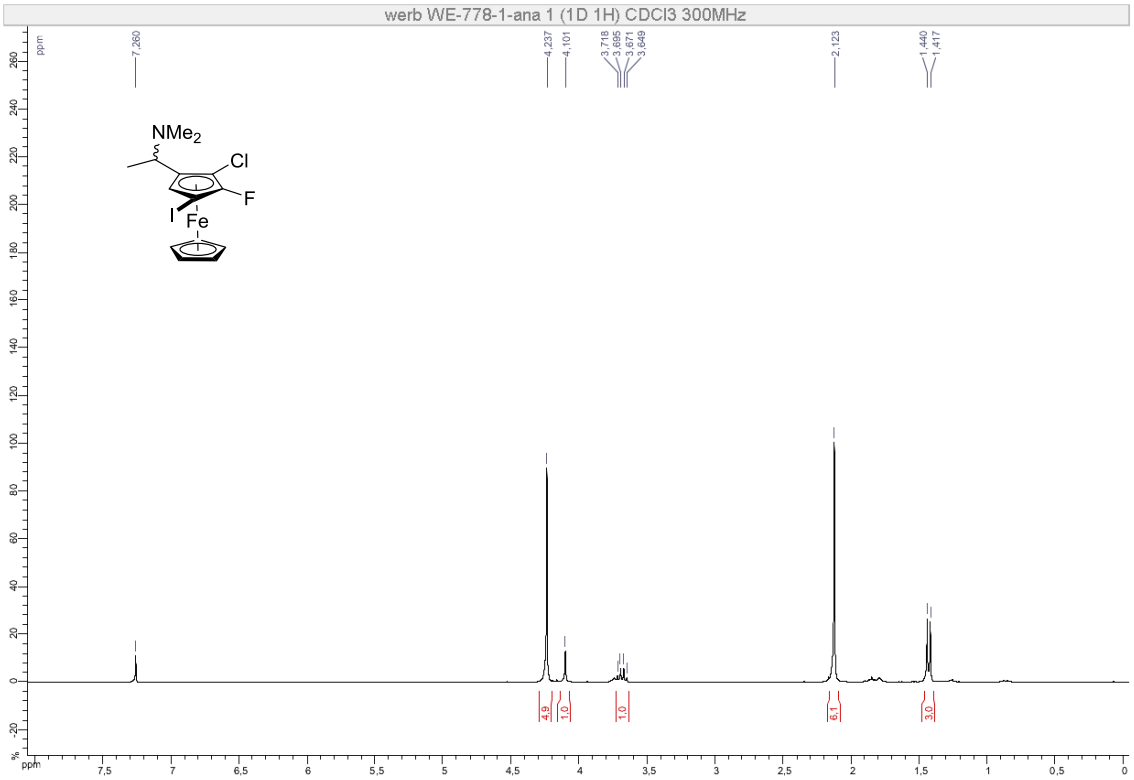


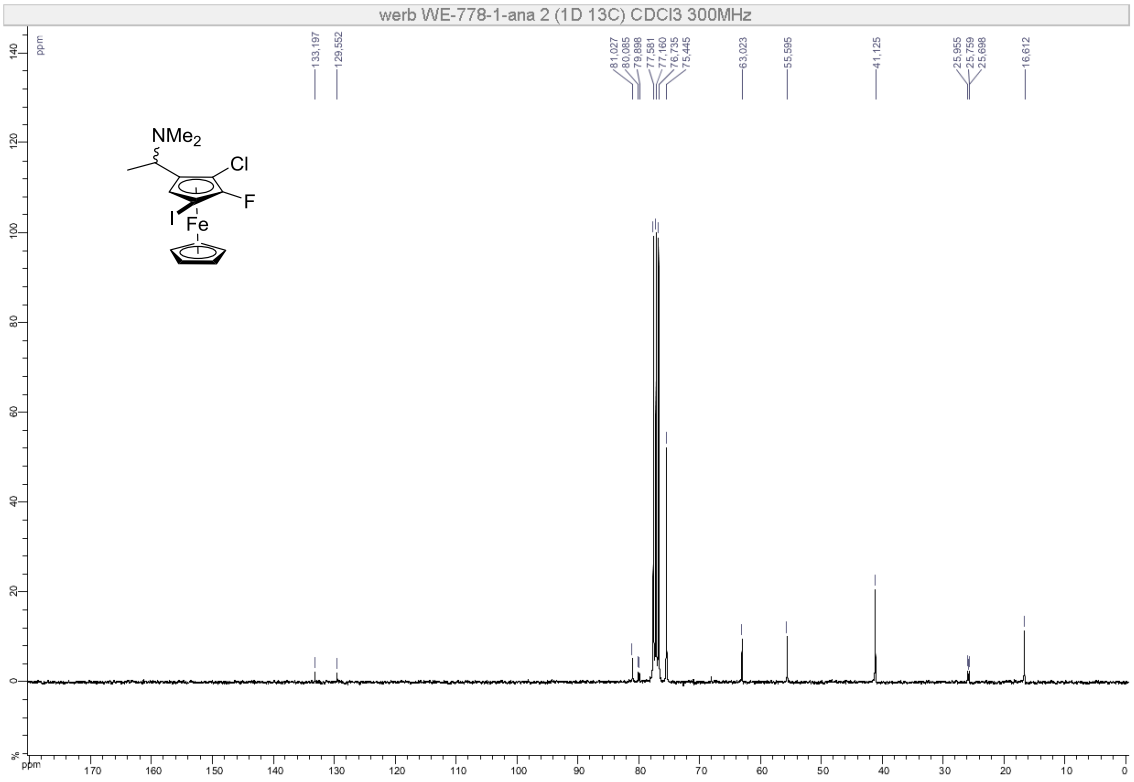
Compound (R,R_p)-12

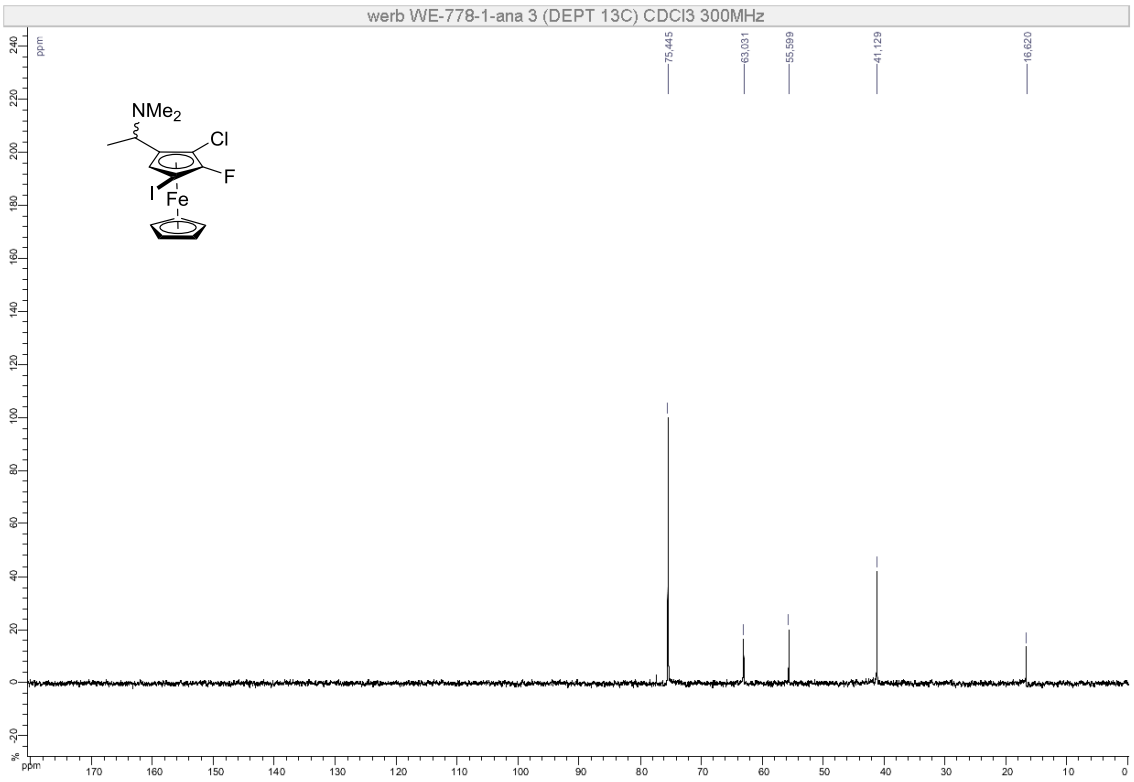


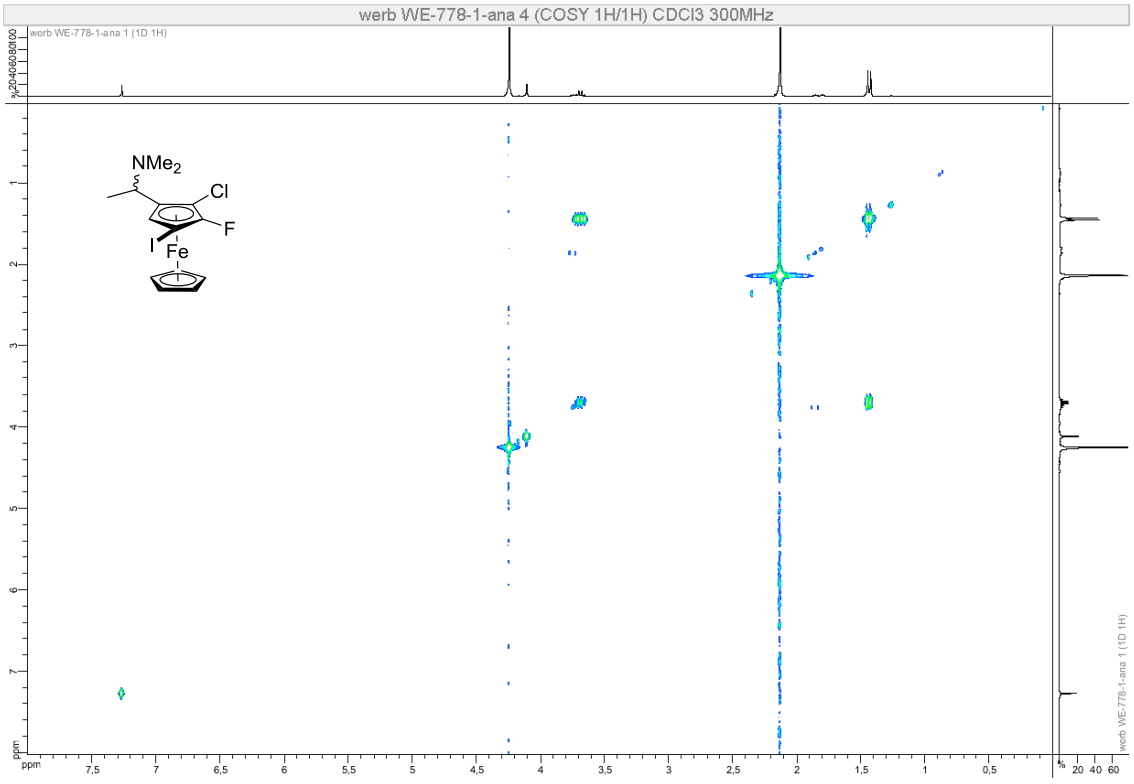

werb WE-784-1 2 (1D 19F) CDCl3 300MHz
ppm
-192.254
NMe2
Cl
F
Fe
300
250
200
150
100
50
0
%
ppm
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300

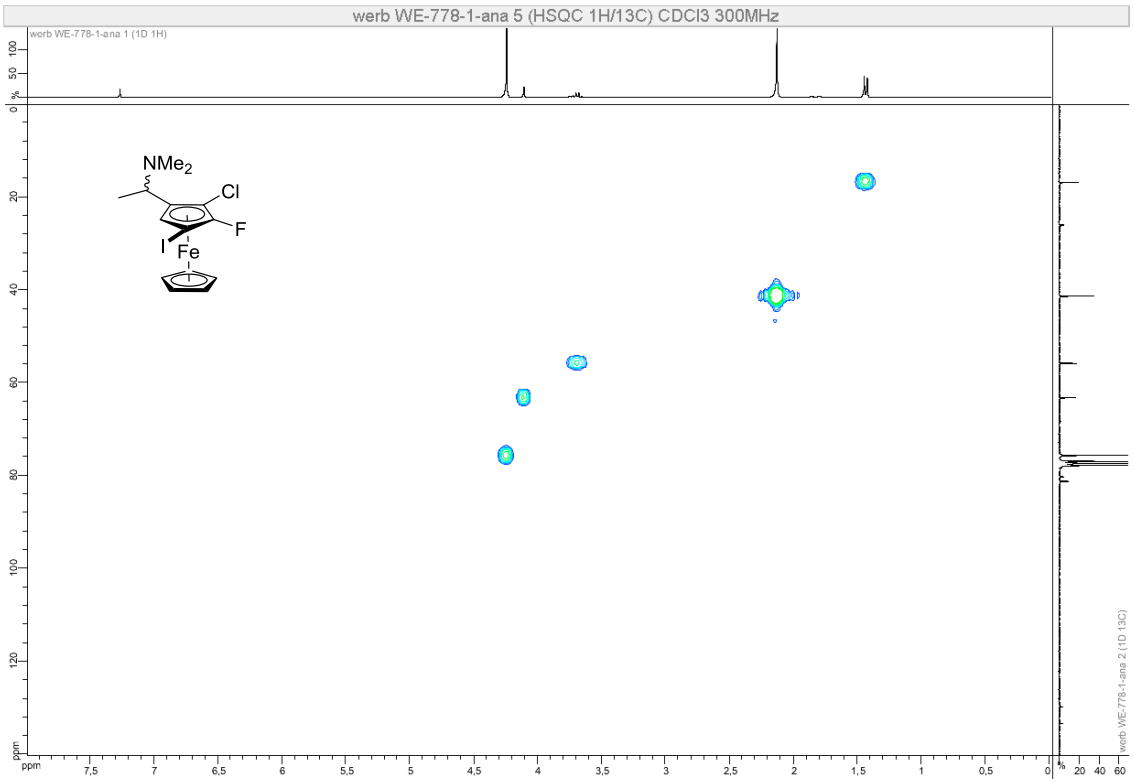
Compound (±)-13

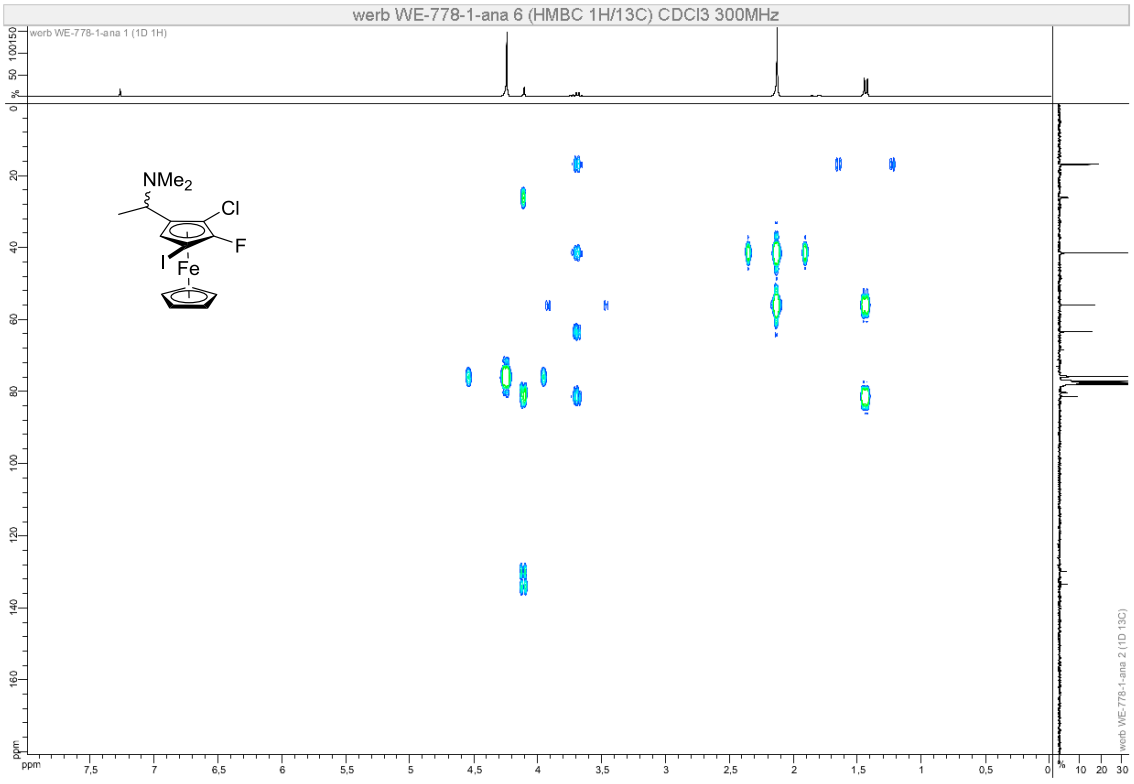

werb WE-778-1-ana 1 (1D 1H) CDCl3 300MHz
NMe2
Cl
F
I
Fe

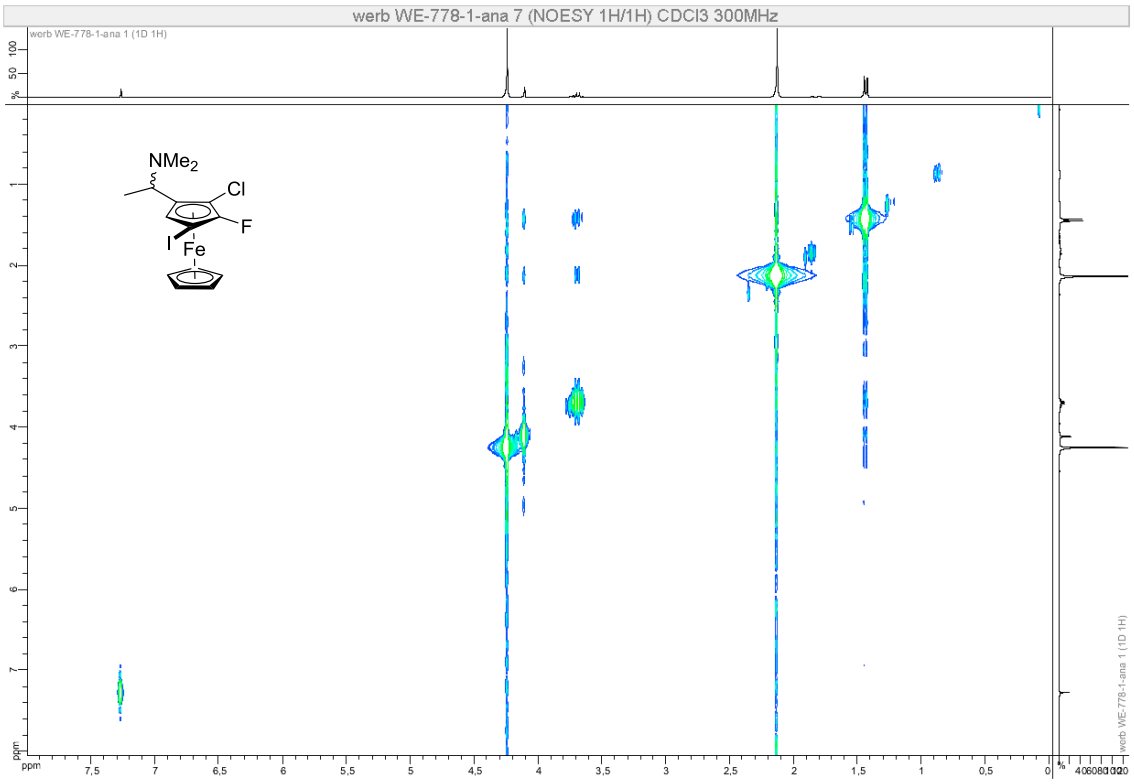

werb WE-778-1-ana 2 (1D 13C) CDCl3 300MHz
NMe2
Cl
F
I
Fe

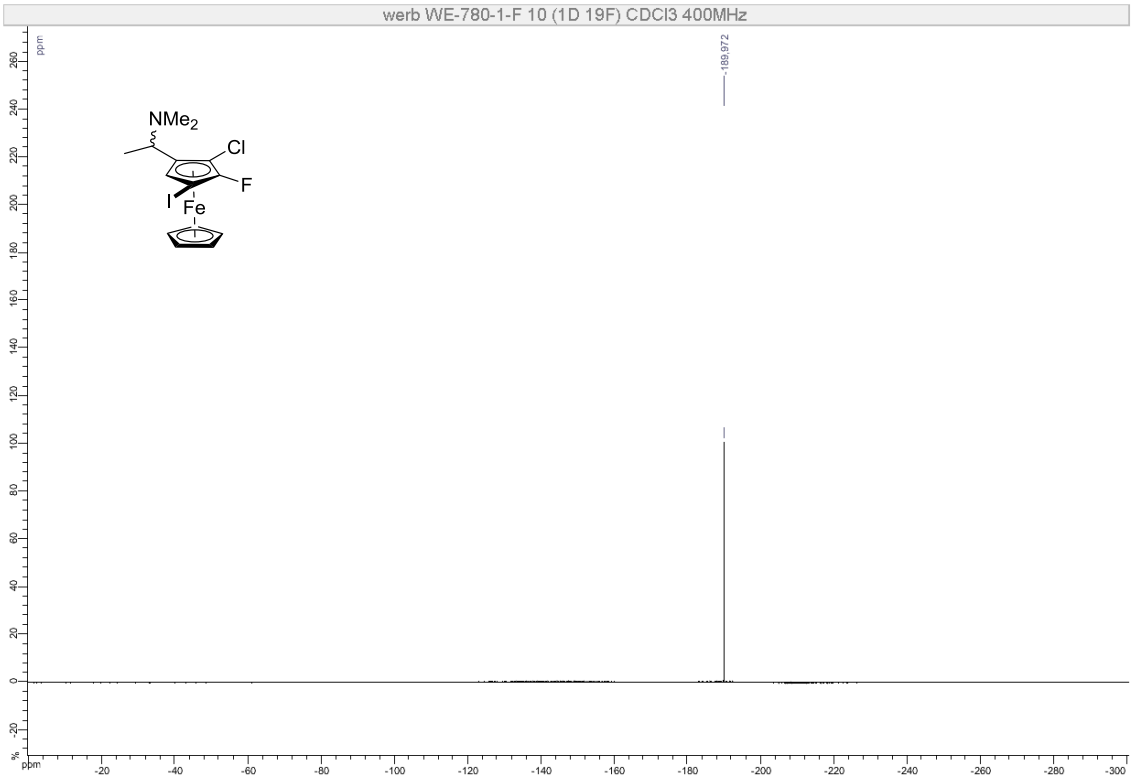

werb WE-778-1-ana 3 (DEPT 13C) CDCl3 300MHz
75,445
63,031
55,599
41,129
16,620
NMe2
Cl
F
I
Fe
ppm


werb WE-778-1-ana 4 (COSY 1H/1H) CDCl3 300MHz
werb WE-778-1-ana 1 (1D 1H)
NMe2
Cl
F
I
Fe
ppm

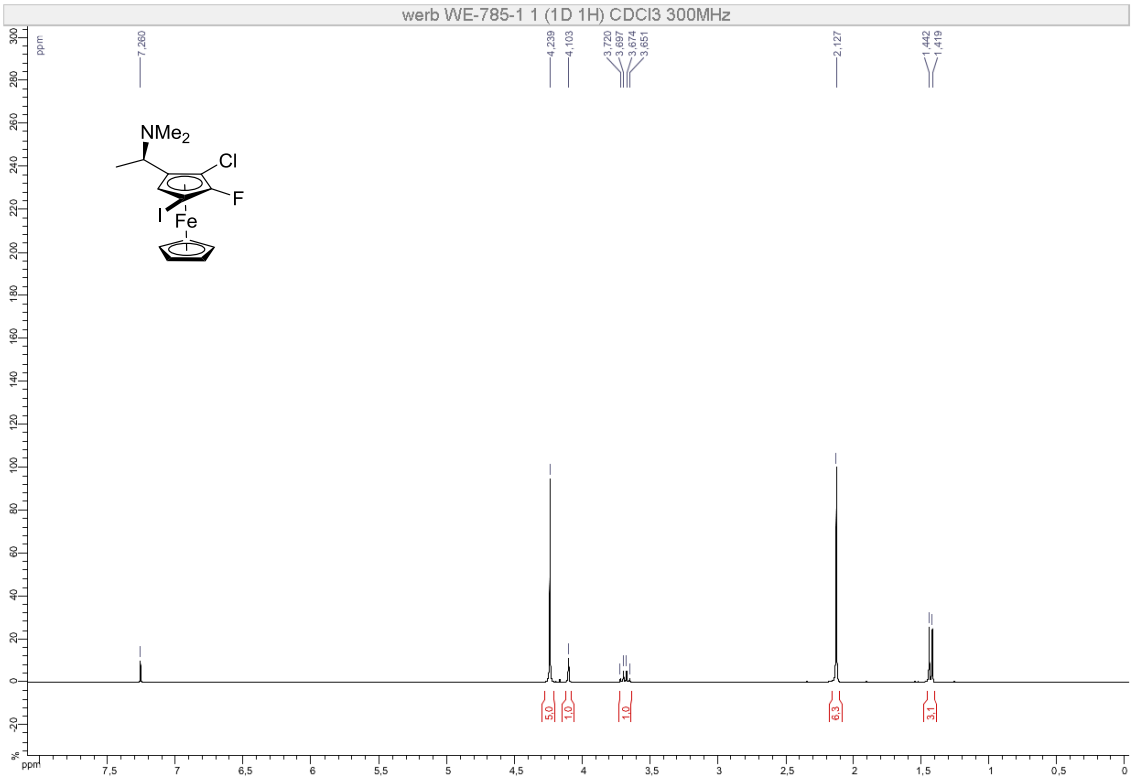

werb WE-778-1-ana 5 (HSQC 1H/13C) CDCl3 300MHz
werb WE-778-1-ana 1 (1D 1H)
NMe2
Cl
F
I
Fe
ppm
werb WE-778-1-ana 2 (1D 13C)

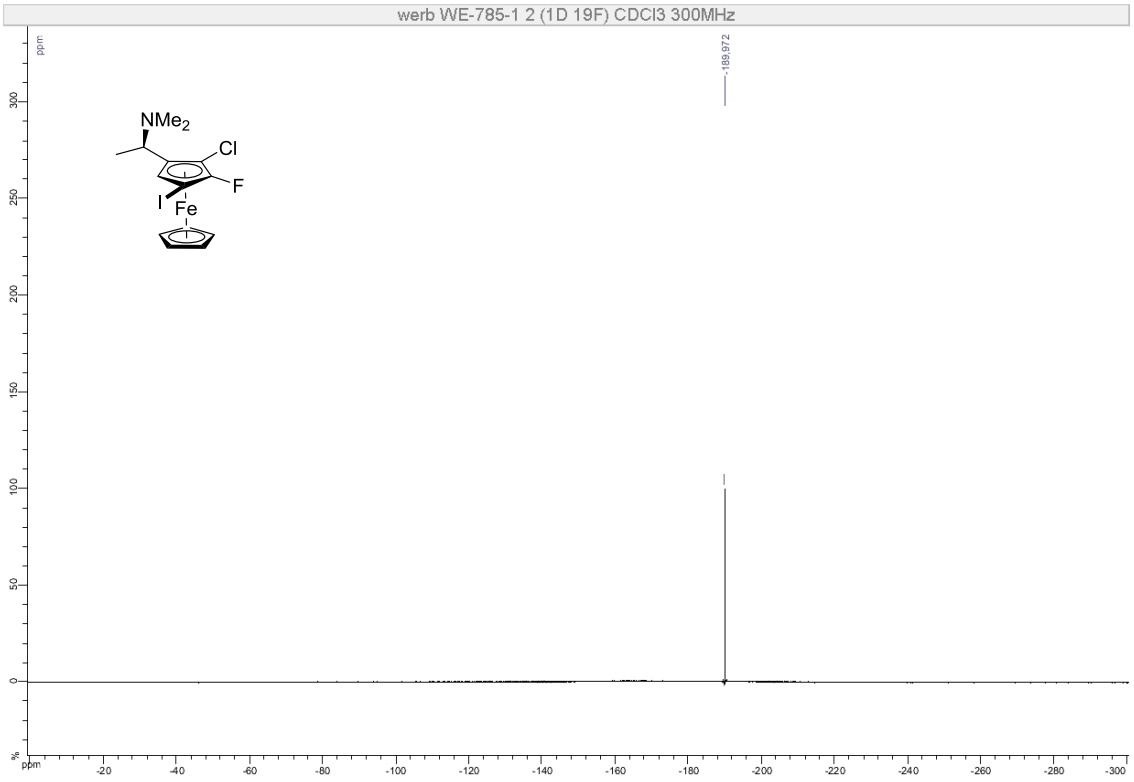

werb WE-778-1-ana 6 (HMBC 1H/13C) CDCl3 300MHz
werb WE-778-1-ana 1 (1D 1H)
NMe2
Cl
F
I
Fe
ppm
werb WE-778-1-ana 2 (1D 13C)


werb WE-778-1-ana 7 (NOESY 1H/1H) CDCl3 300MHz
werb WE-778-1-ana 1 (1D 1H)
NMe2
Cl
F
I
Fe
ppm
7,5
7
6,5
6
5,5
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
werb WE-778-1-ana 1 (1D 1H)

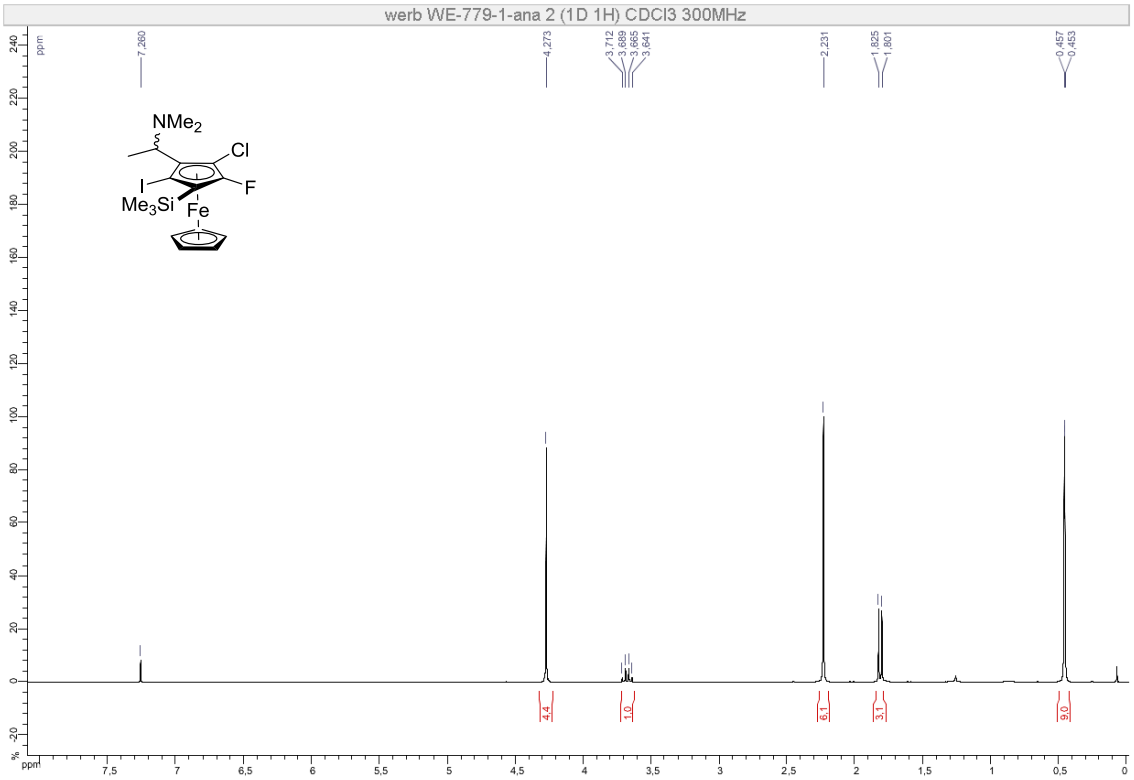

werb WE-780-1-F 10 (1D 19F) CDCl3 400MHz
-189.972
NMe2
Cl
F
I
Fe
ppm
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300

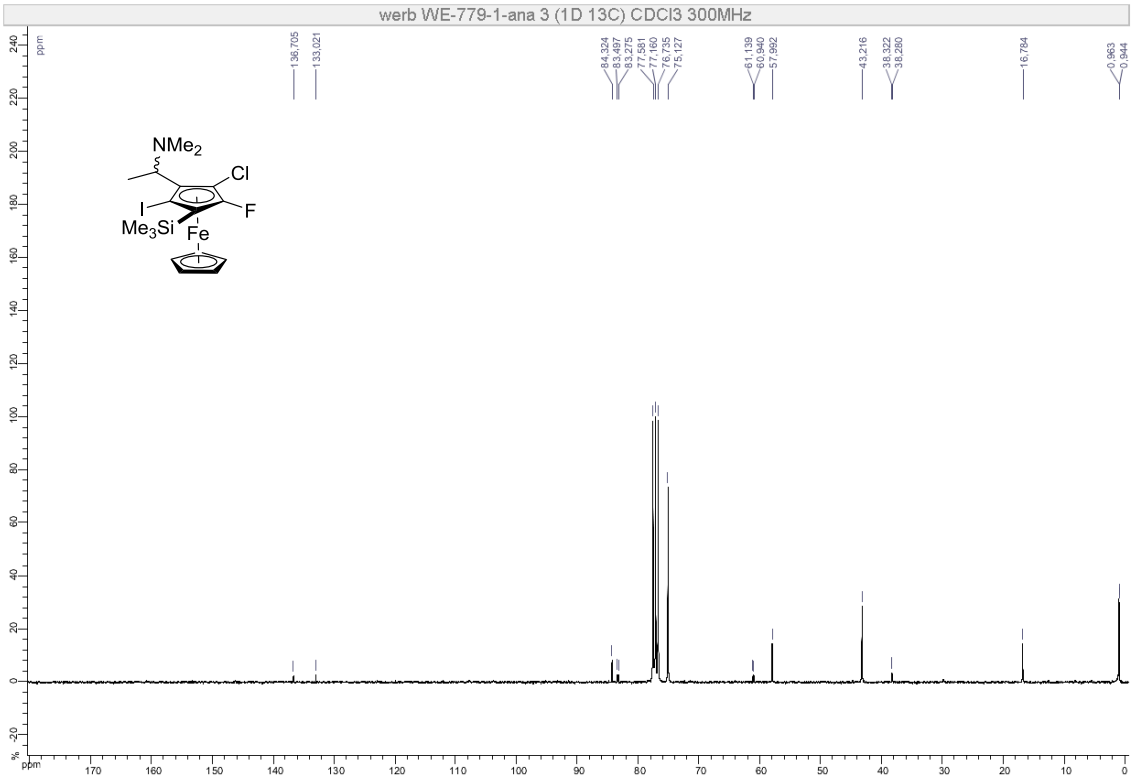
Compound (R,S_p)-13

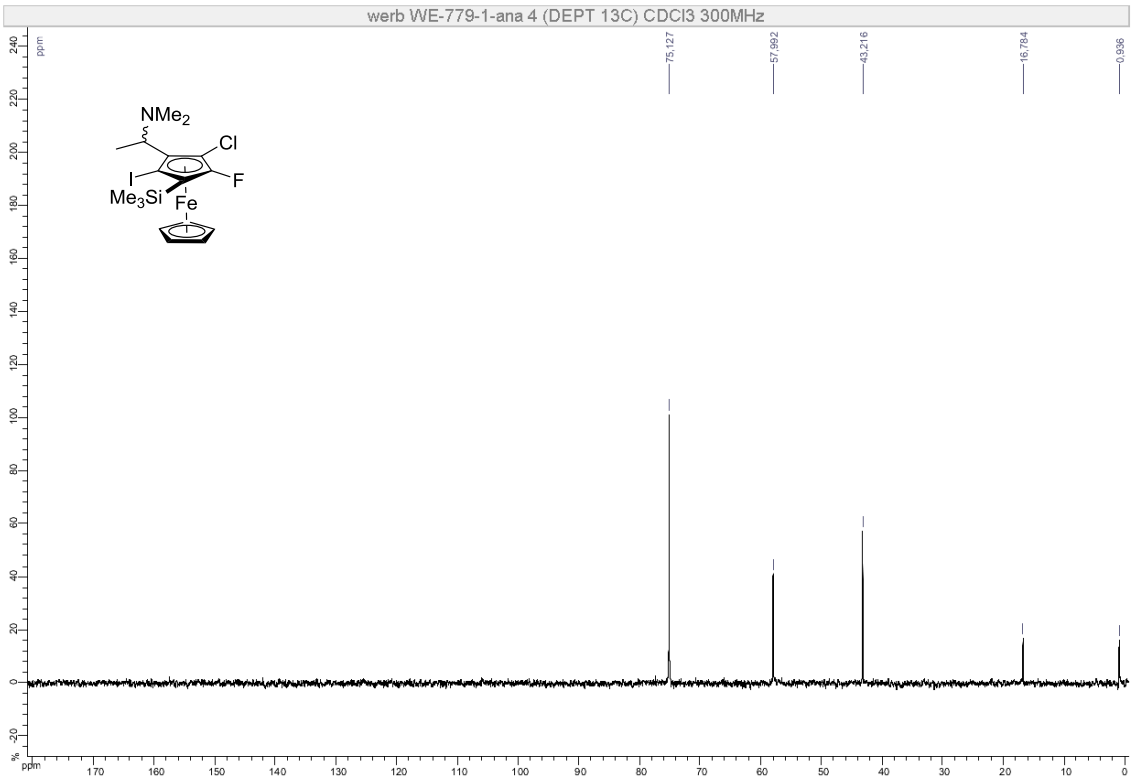


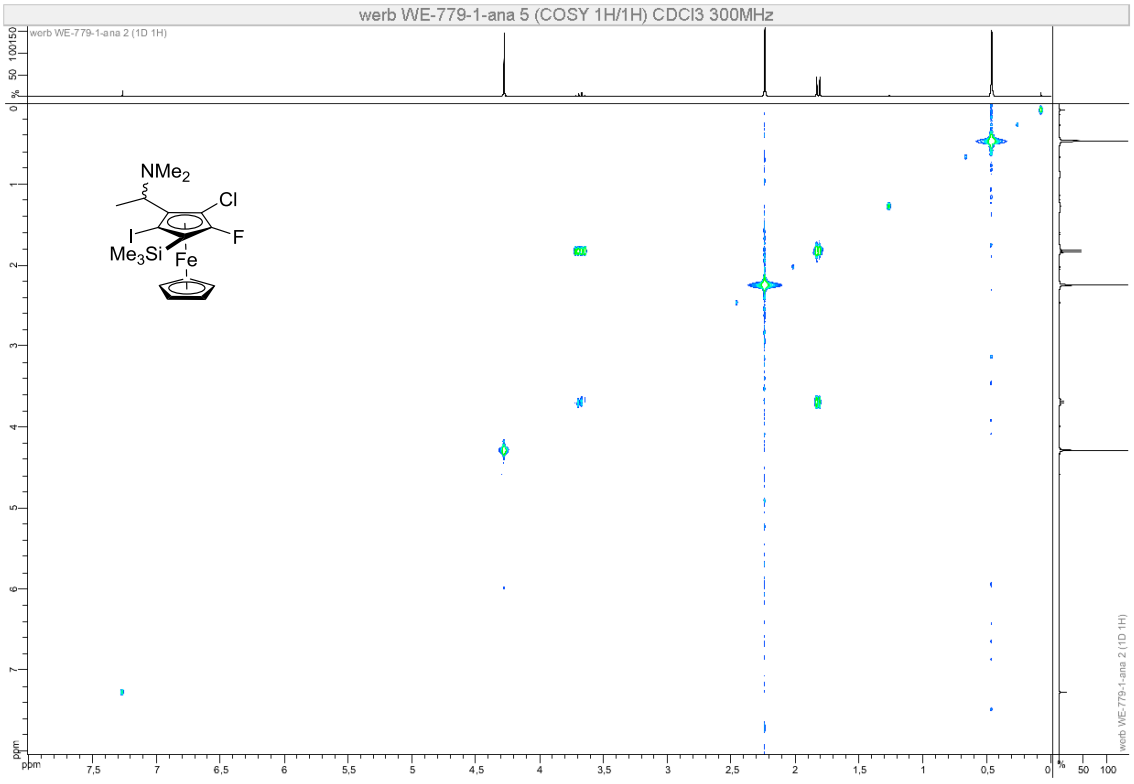


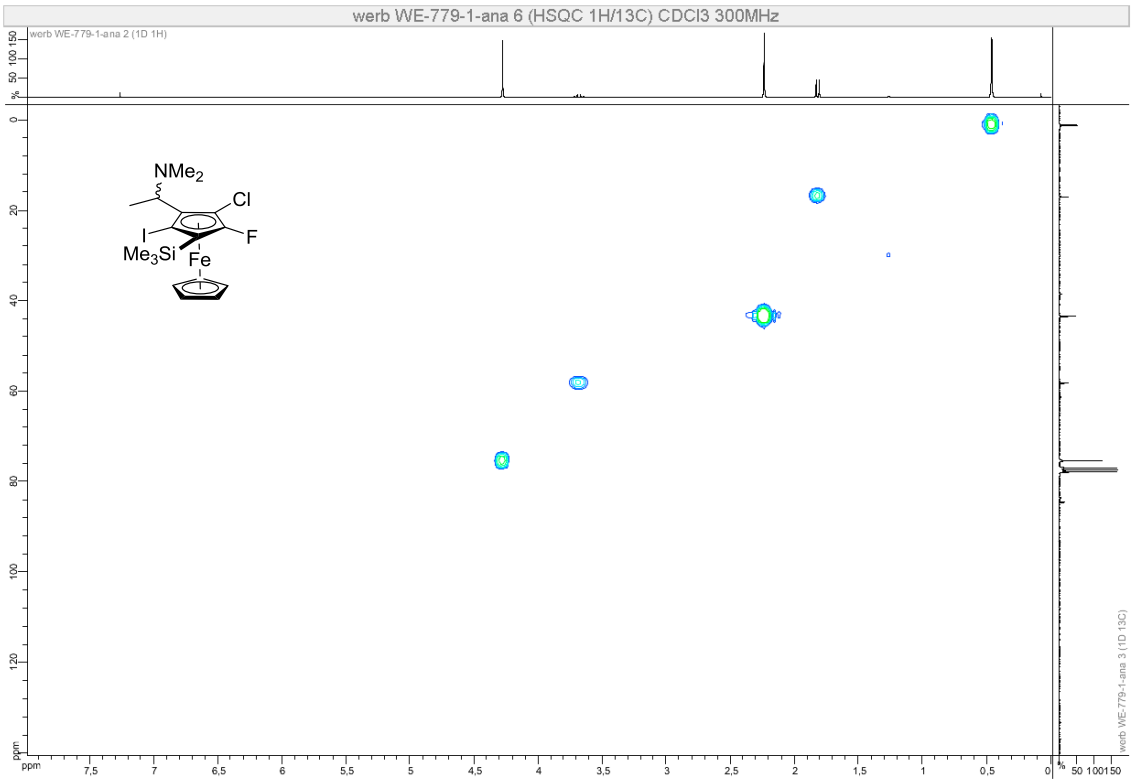
Compound (±)-14

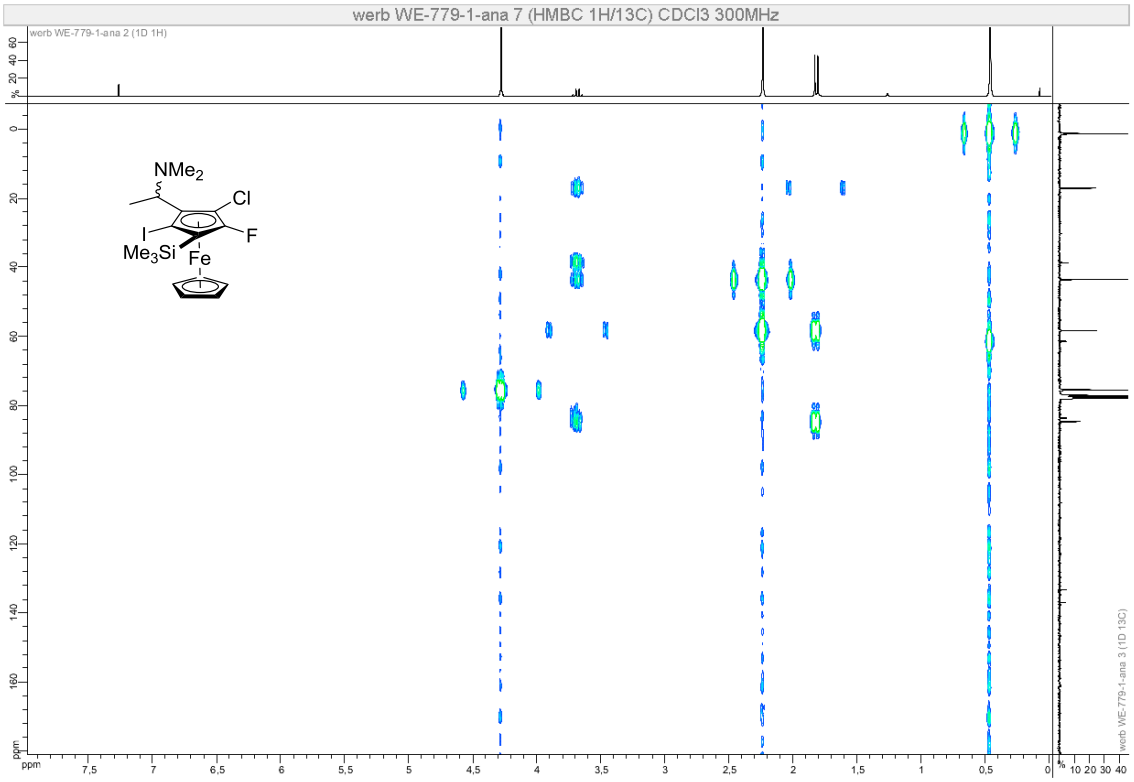

werb WE-779-1-ana 2 (1D 1H) CDCl3 300MHz
NMe2
Cl
I
F
Me3Si
Fe

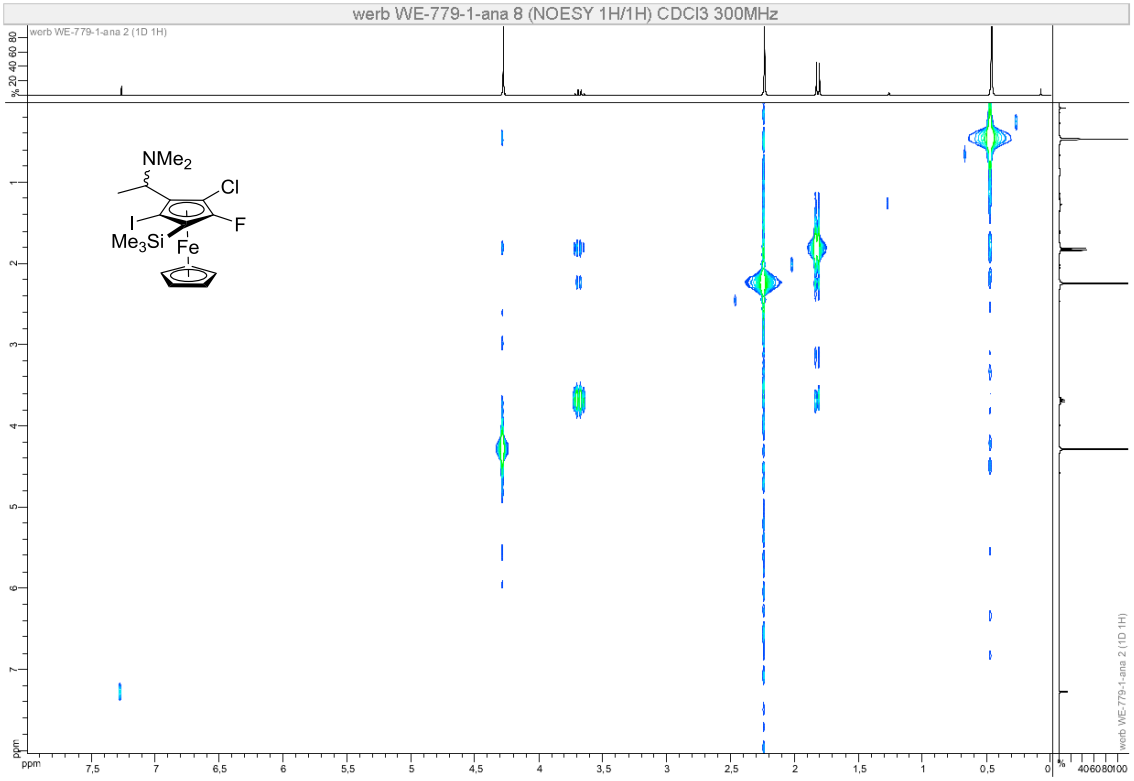

werb WE-779-1-ana 3 (1D 13C) CDCl3 300MHz
NMe2
Cl
I
F
Me3Si
Fe

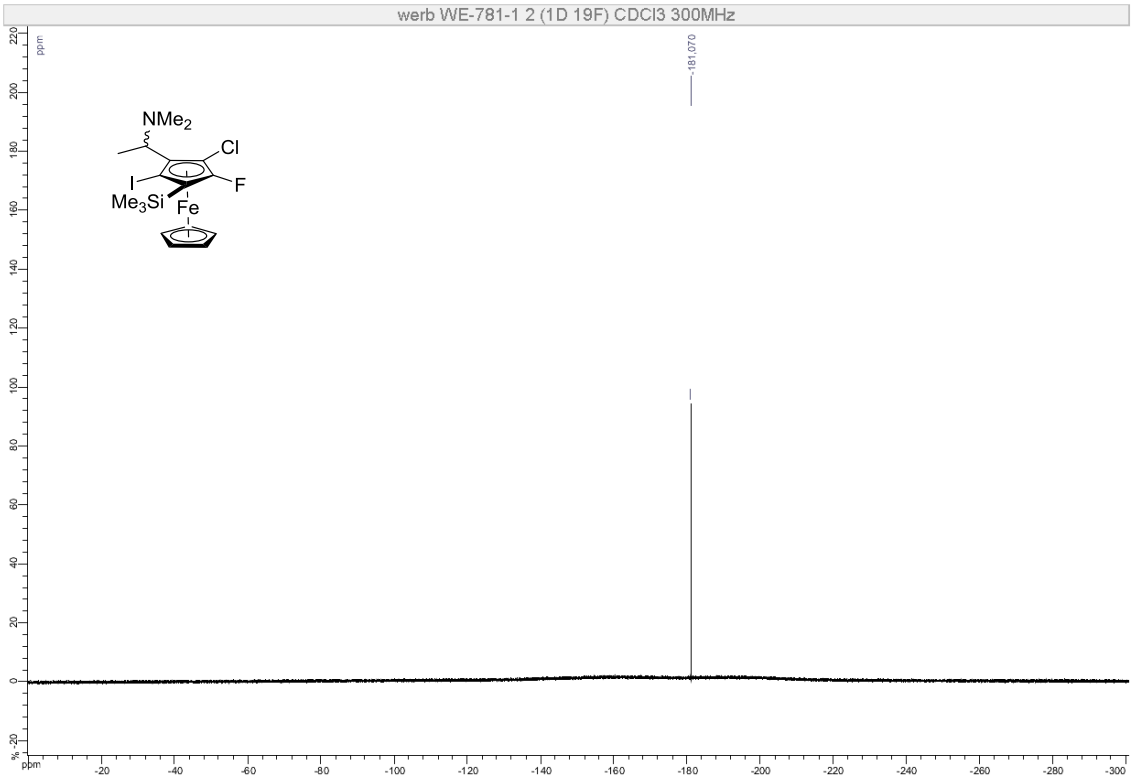

werb WE-779-1-ana 4 (DEPT 13C) CDCl3 300MHz
75,127
57,992
43,216
16,784
0,936
NMe2
Cl
I
F
Me3Si
Fe


werb WE-779-1-ana 5 (COSY 1H/1H) CDCl3 300MHz
werb WE-779-1-ana 2 (1D 1H)
NMe2
Cl
I
F
Me3Si
Fe

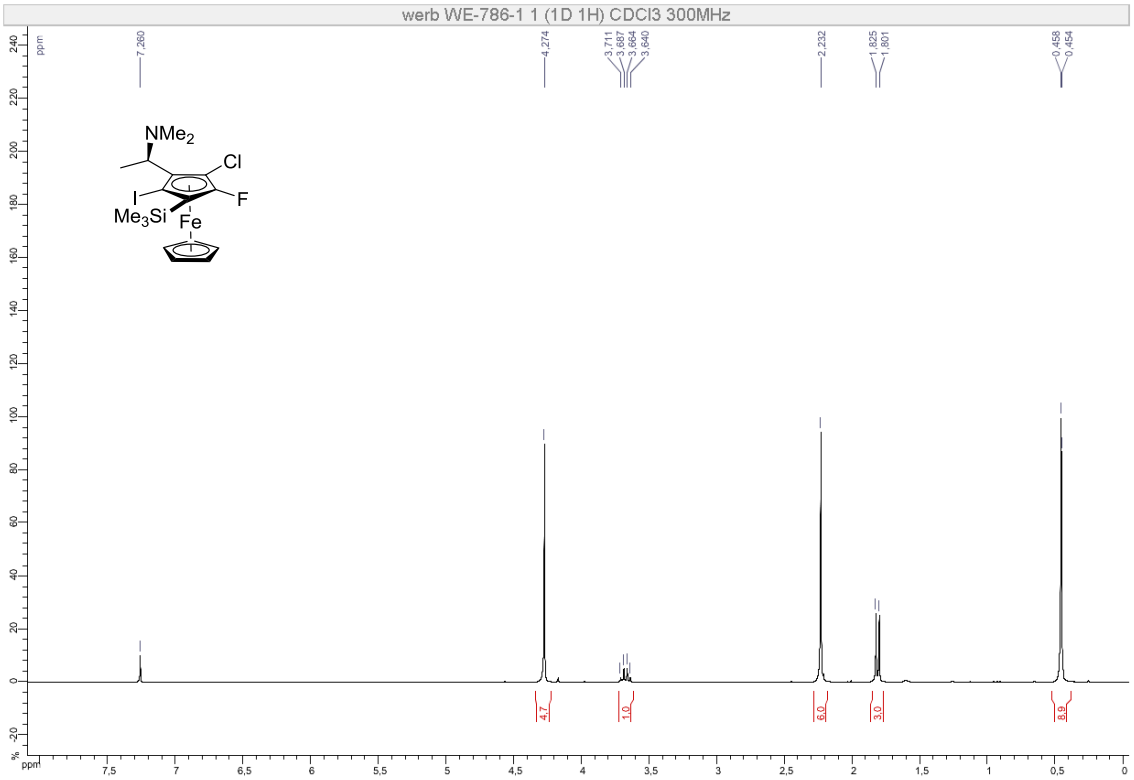

werb WE-779-1-ana 6 (HSQC 1H/13C) CDCl3 300MHz
werb WE-779-1-ana 2 (1D 1H)
NMe2
Cl
I
F
Me3Si
Fe
ppm
werb WE-779-1-ana 3 (1D 13C)

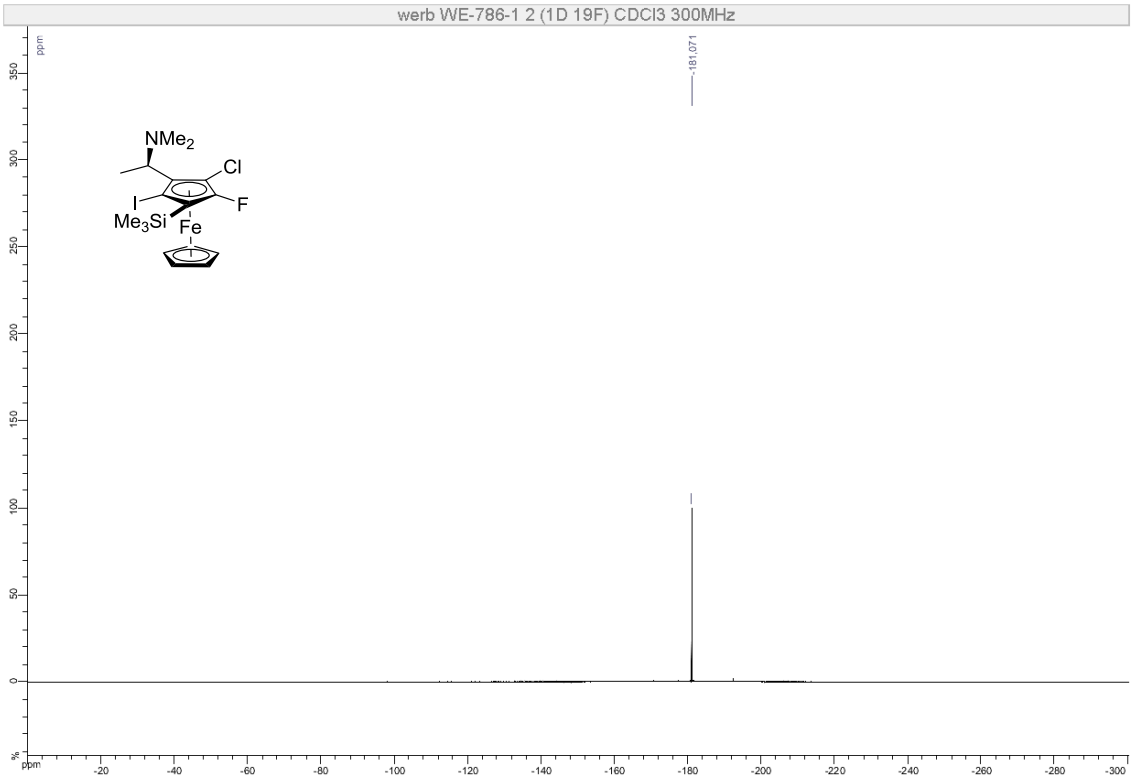

werb WE-779-1-ana 7 (HMBC 1H/13C) CDCl3 300MHz
werb WE-779-1-ana 2 (1D 1H)
NMe2
Cl
I
F
Me3Si
Fe
ppm
werb WE-779-1-ana 3 (1D 13C)


werb WE-779-1-ana 8 (NOESY 1H/1H) CDCl3 300MHz
werb WE-779-1-ana 2 (1D 1H)
NMe2
Cl
I
F
Me3Si
Fe
ppm
7,5
7
6,5
6
5,5
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
werb WE-779-1-ana 2 (1D 1H)

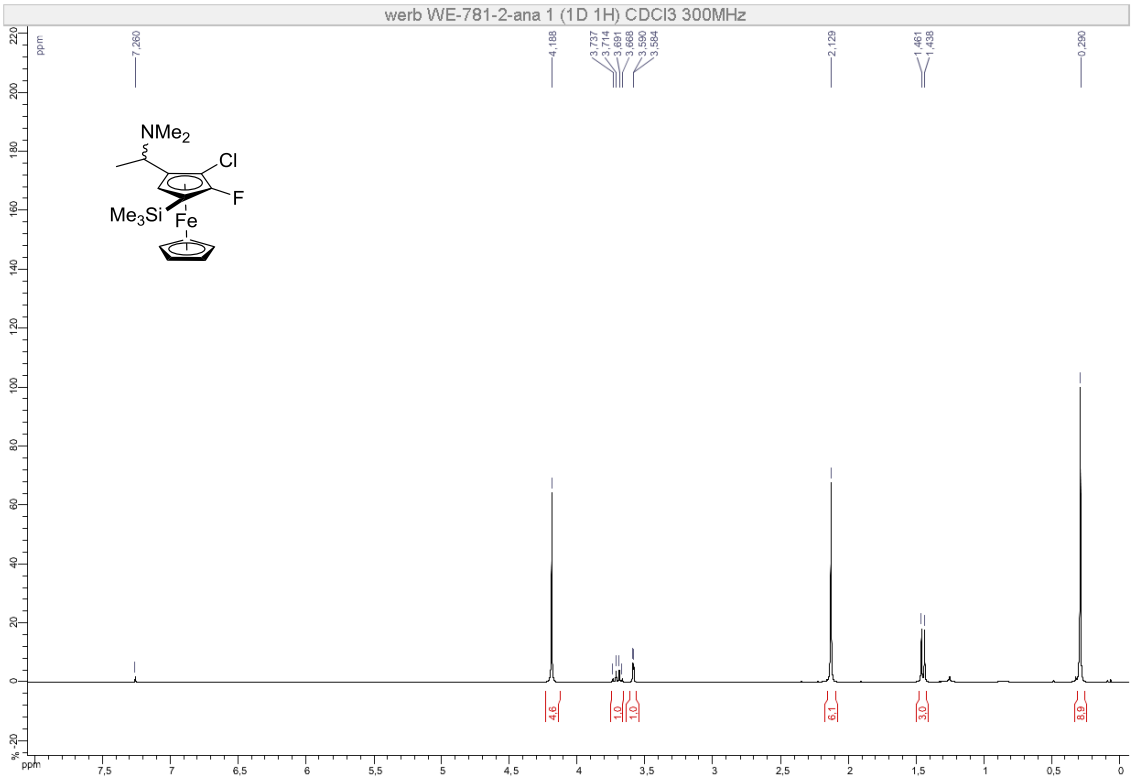

werb WE-781-1 2 (1D 19F) CDCl3 300MHz
ppm
-181.070
NMe2
Cl
I
F
Me3Si
Fe
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300

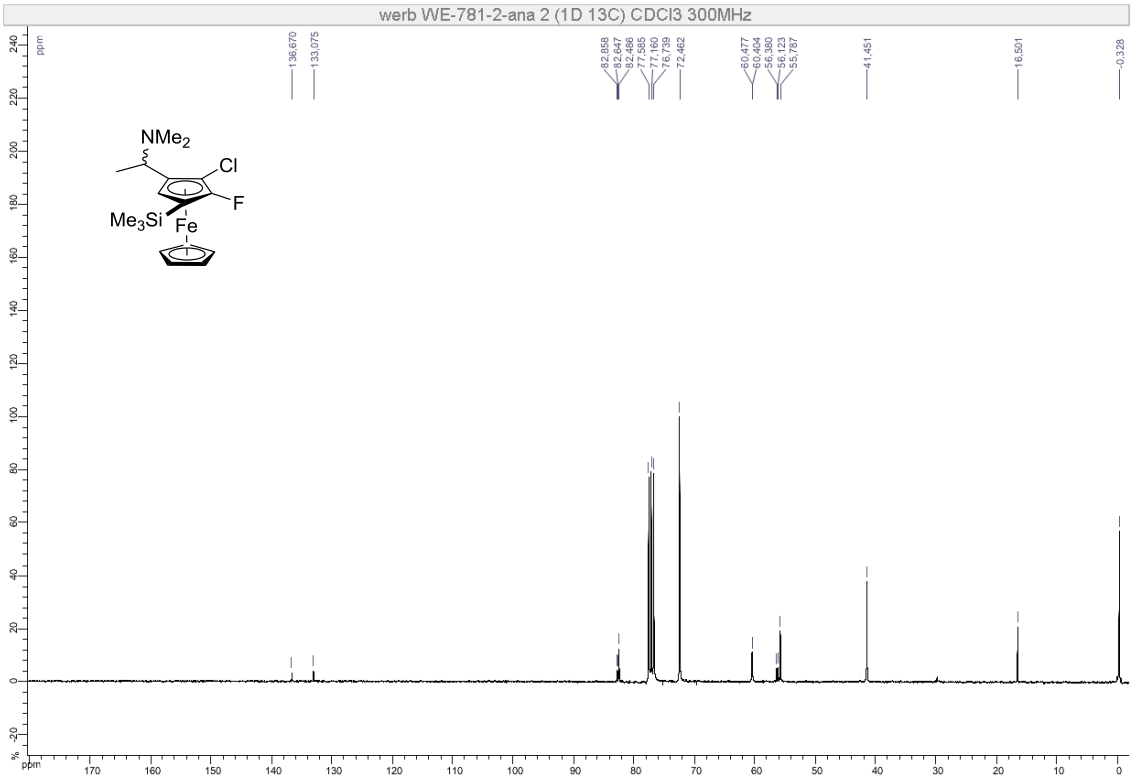
Compound (R,S_p)-14

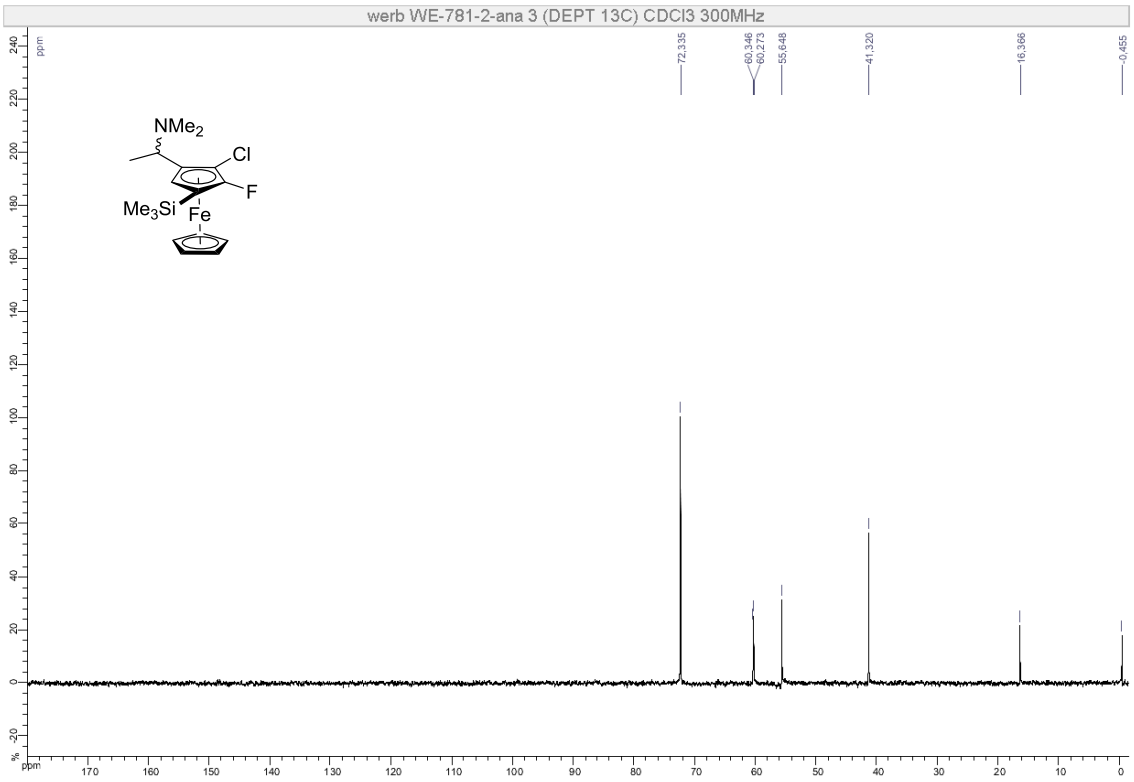


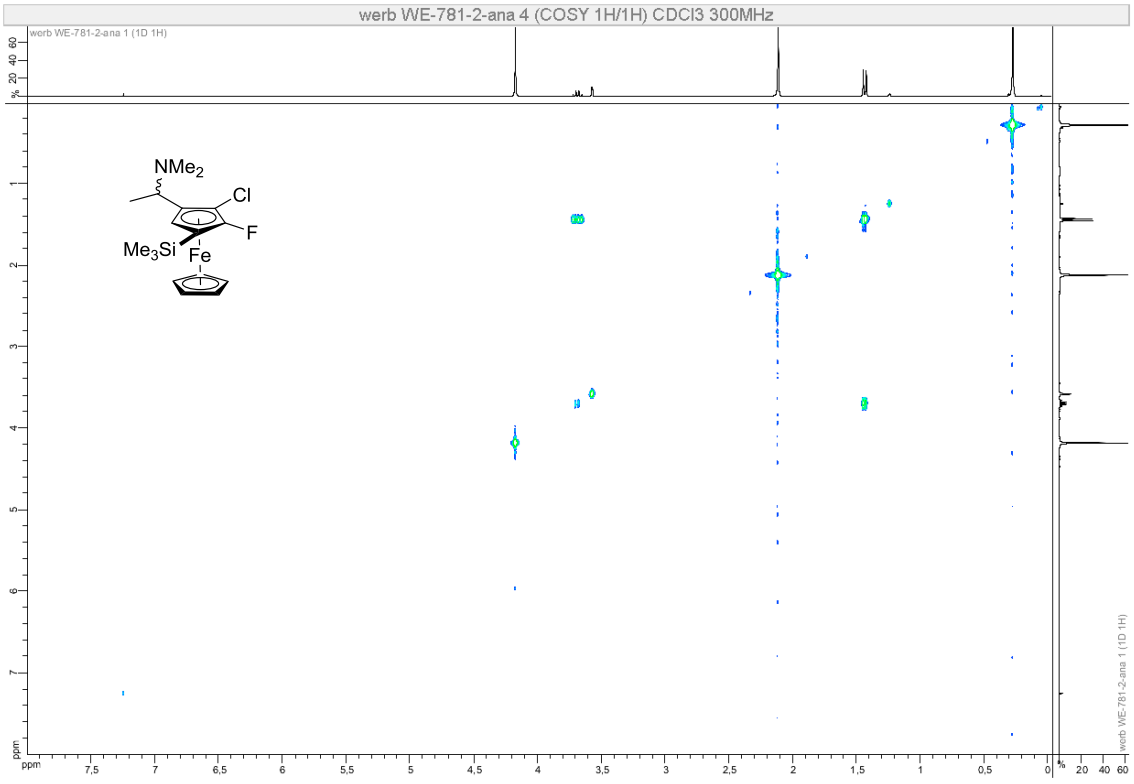


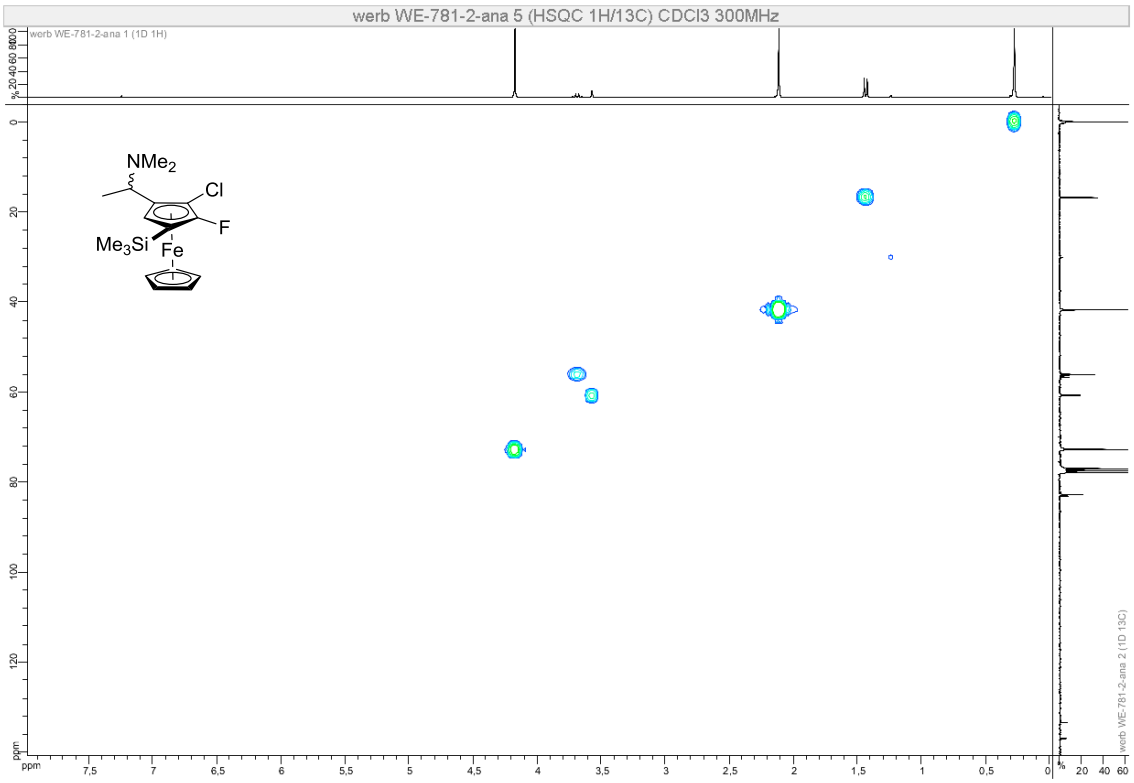
Compound (±)-15

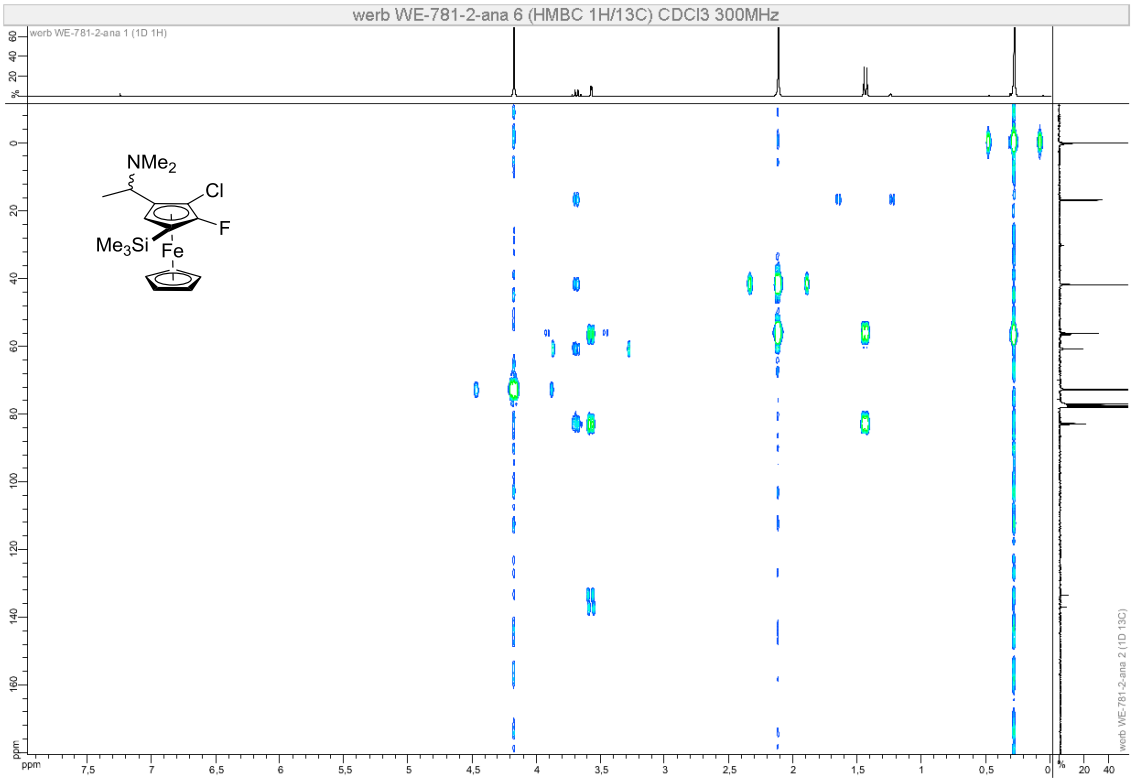

werb WE-781-2-ana 1 (1D 1H) CDCl3 300MHz
NMe2
Cl
F
Me3Si
Fe

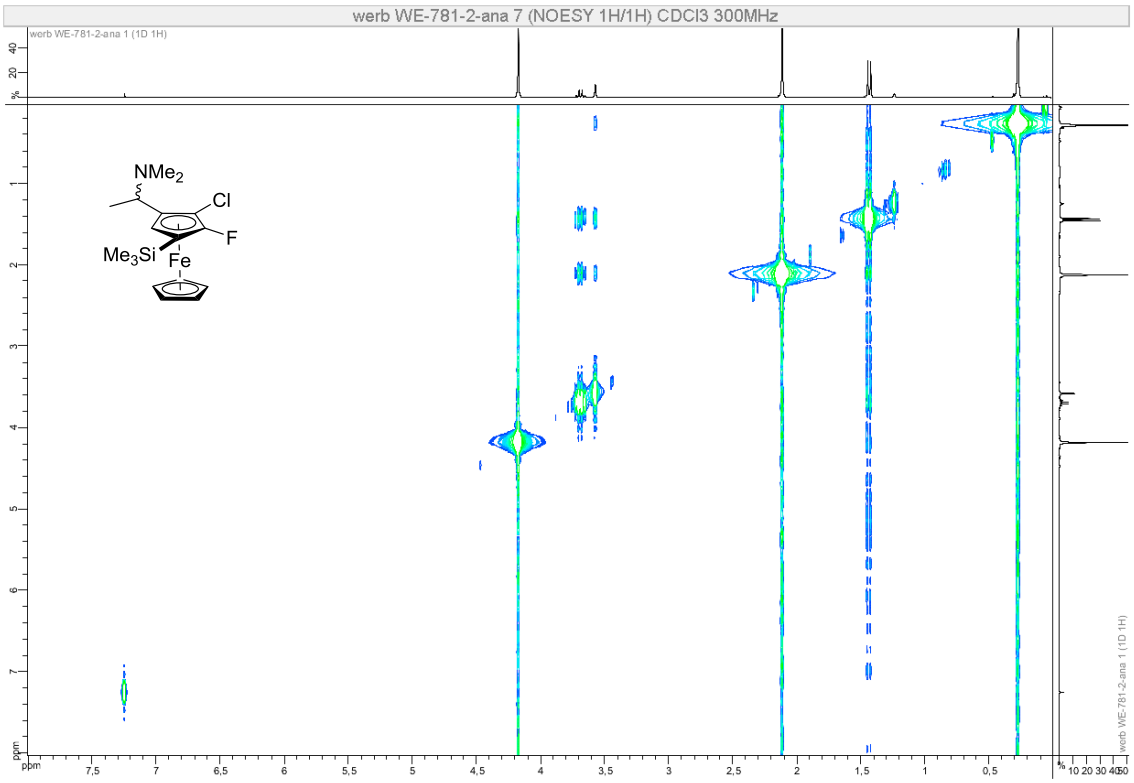

werb WE-781-2-ana 2 (1D 13C) CDCl3 300MHz
NMe2
Cl
F
Me3Si
Fe

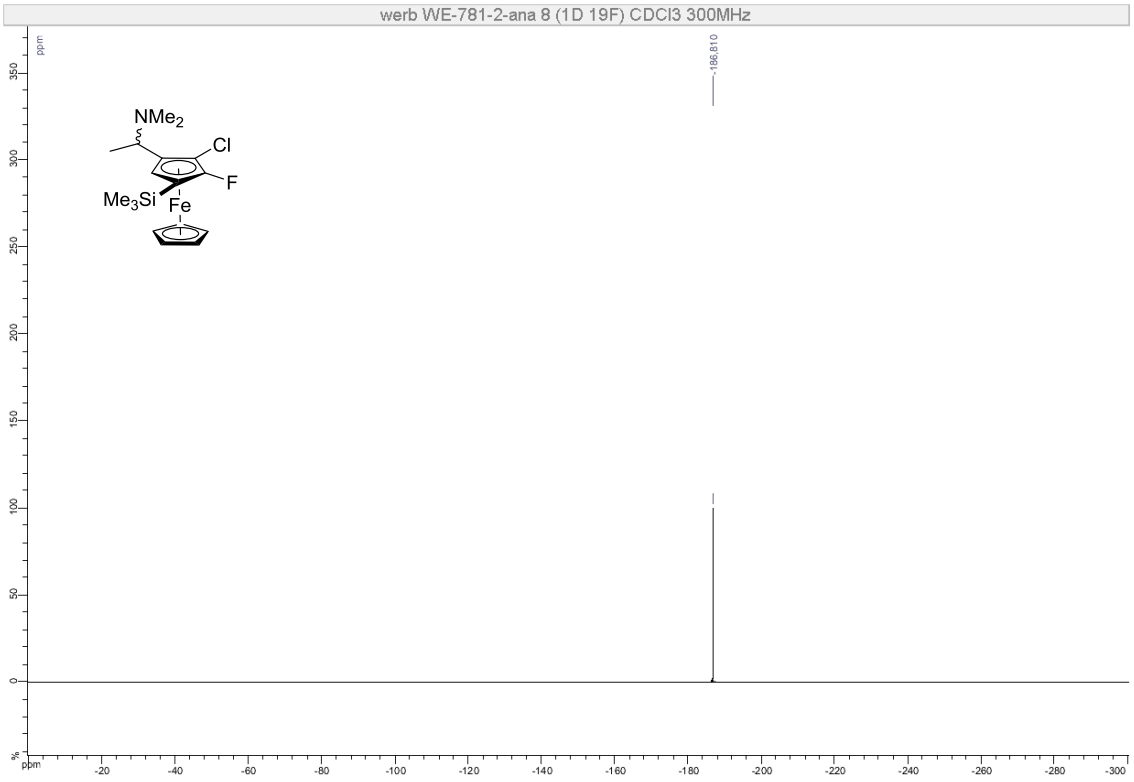

werb WE-781-2-ana 3 (DEPT 13C) CDCl3 300MHz
72,335
60,346
60,273
55,648
41,320
16,366
0,455
NMe2
Cl
F
Me3Si
Fe
ppm


werb WE-781-2-ana 4 (COSY 1H/1H) CDCl3 300MHz
werb WE-781-2-ana 1 (1D 1H)
NMe2
Cl
F
Me3Si
Fe
ppm

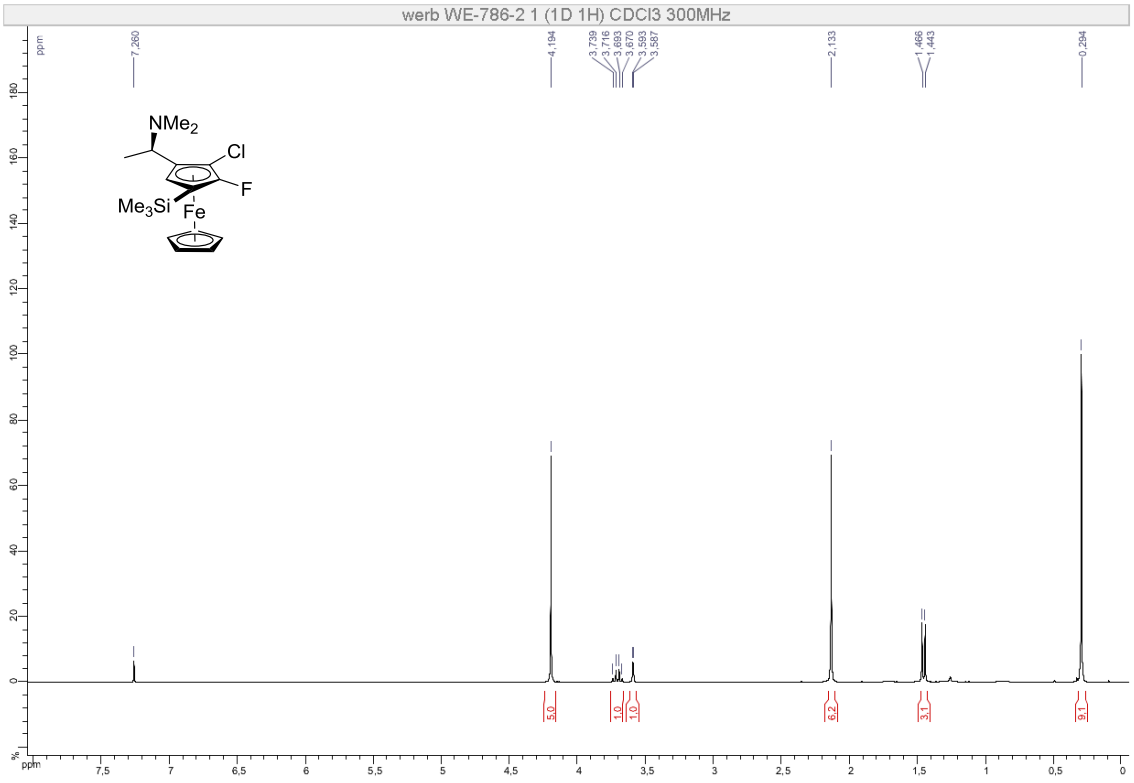

werb WE-781-2-ana 5 (HSQC 1H/13C) CDCl3 300MHz
werb WE-781-2-ana 1 (1D 1H)
NMe2
Cl
F
Me3Si
Fe
ppm
werb WE-781-2-ana 2 (1D 13C)

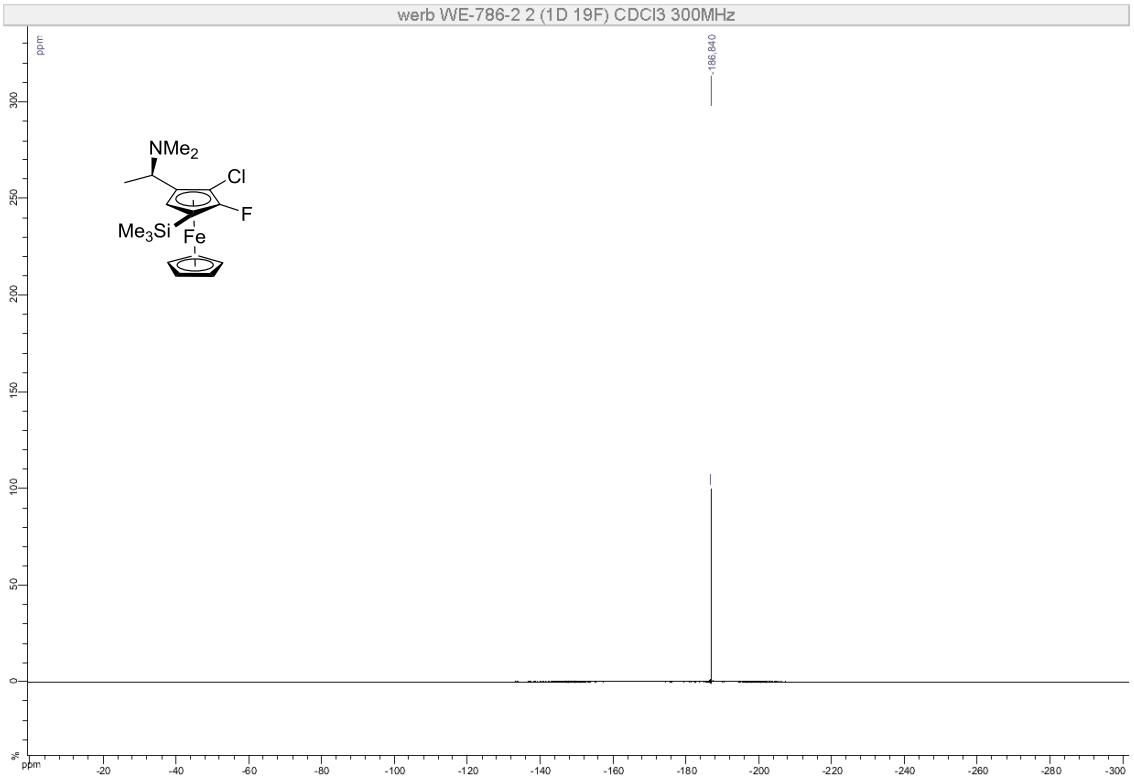

werb WE-781-2-ana 6 (HMBC 1H/13C) CDCl3 300MHz
werb WE-781-2-ana 1 (1D 1H)
NMe2
Cl
F
Me3Si
Fe
ppm
werb WE-781-2-ana 2 (1D 13C)


werb WE-781-2-ana 7 (NOESY 1H/1H) CDCl3 300MHz
werb WE-781-2-ana 1 (1D 1H)
NMe2
Cl
F
Me3Si
Fe
ppm
7,5
7
6,5
6
5,5
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
werb WE-781-2-ana 1 (1D 1H)

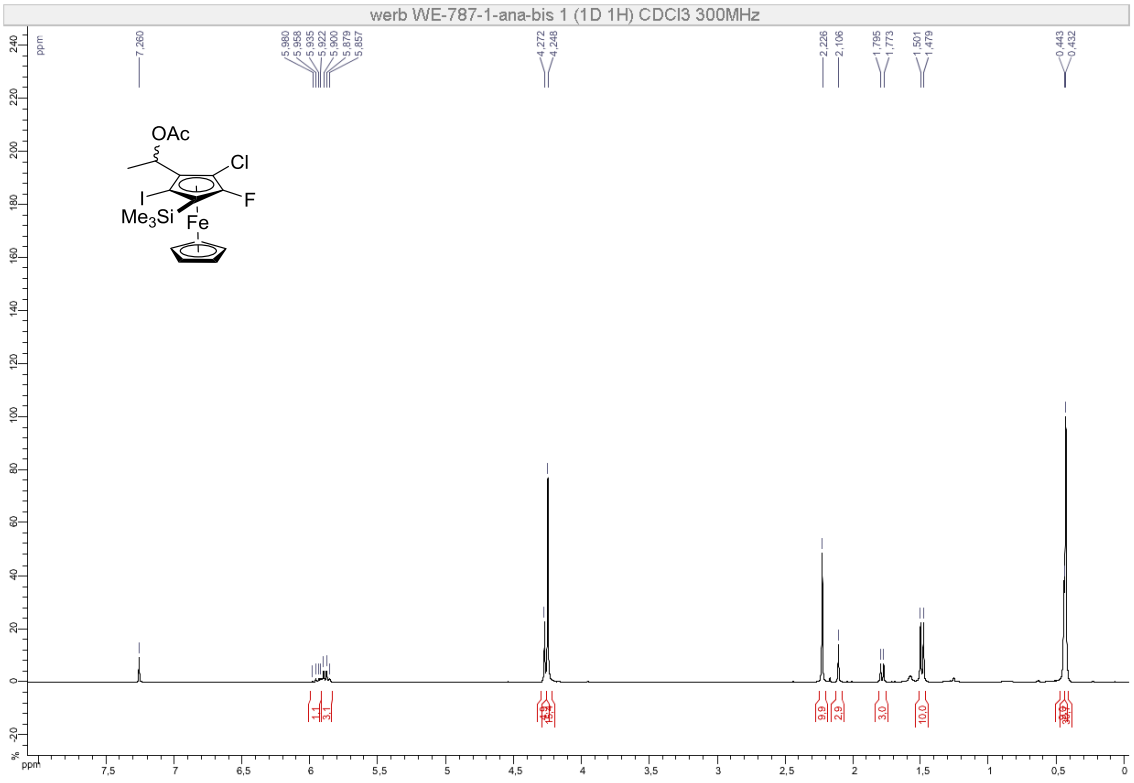

werb WE-781-2-ana 8 (1D 19F) CDCl3 300MHz
-186.810
NMe2
Cl
F
Me3Si
Fe
ppm
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300

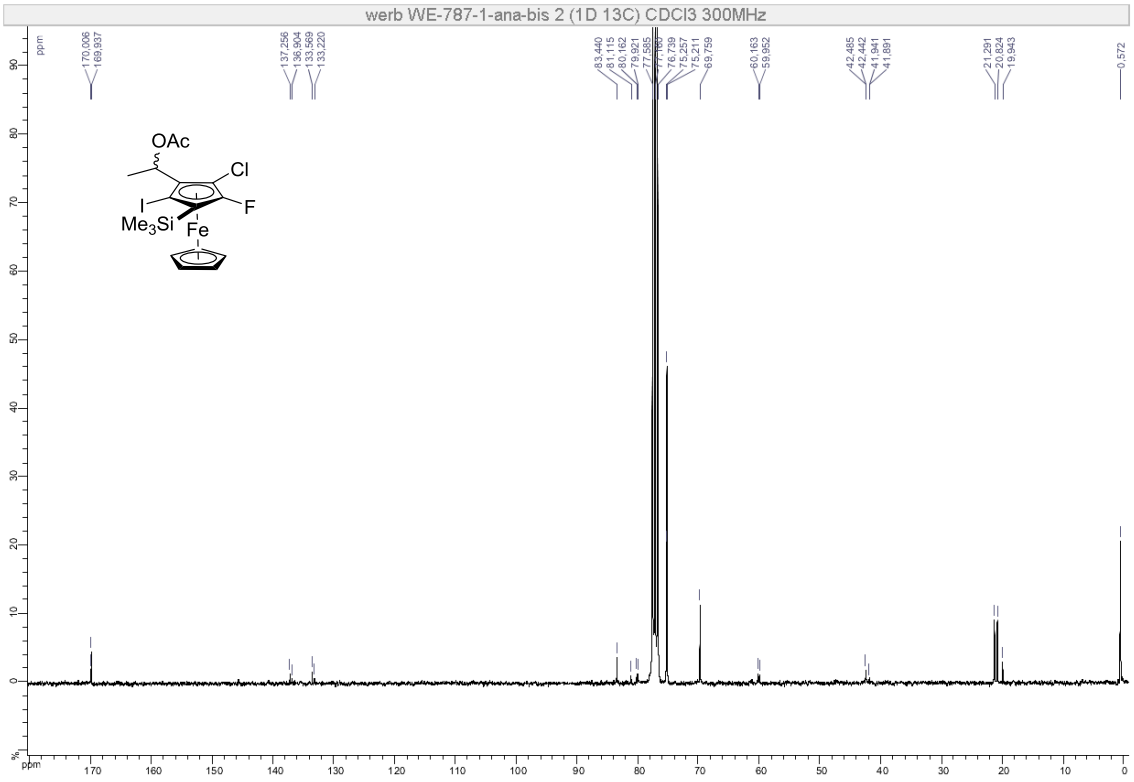
Compound (R,R_p)-15

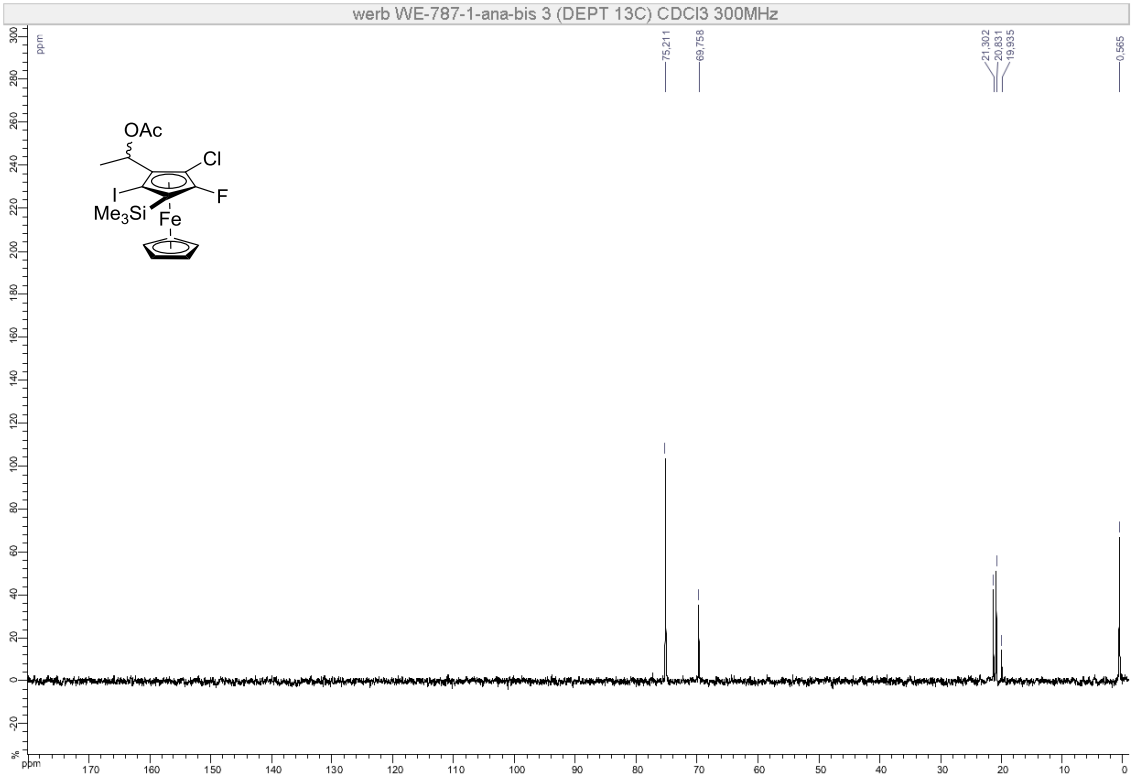


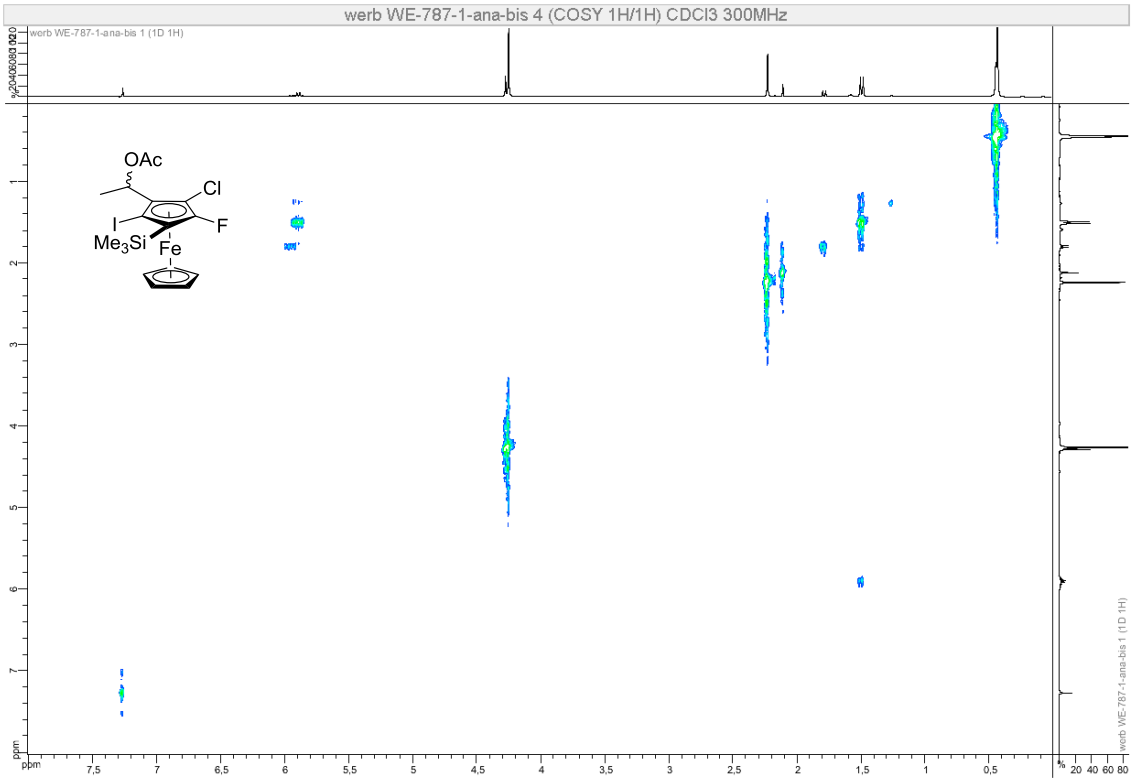


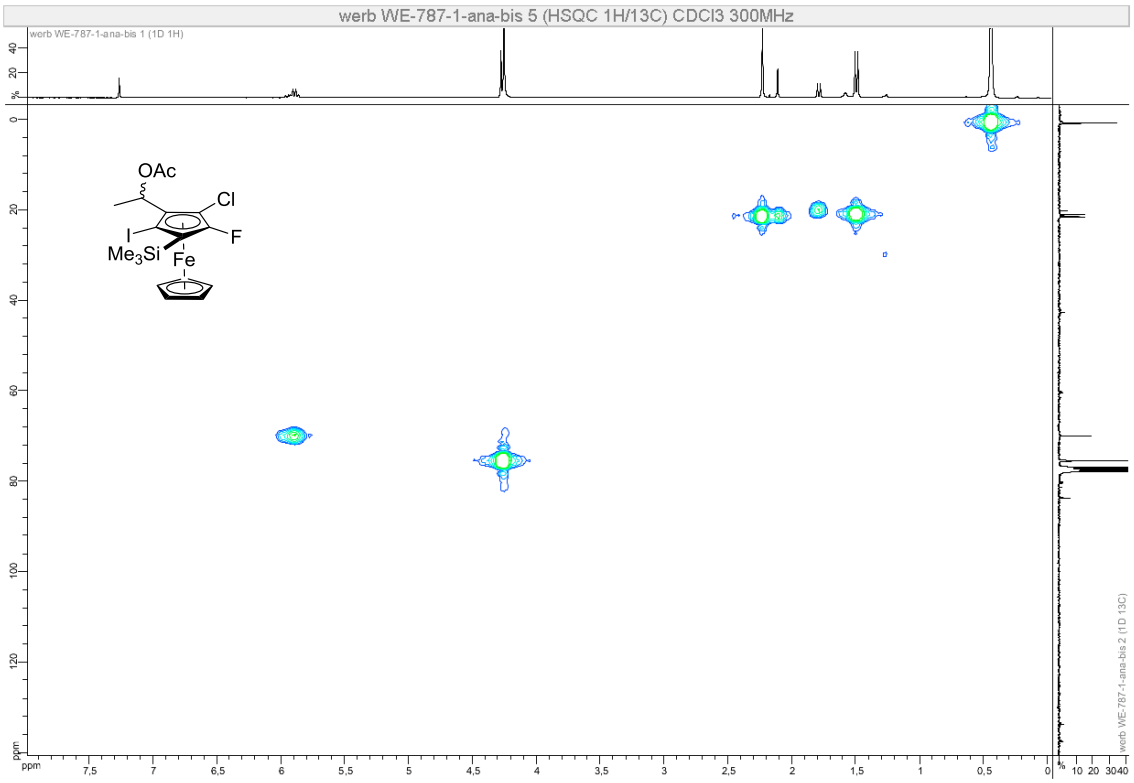
Compound (±)-16

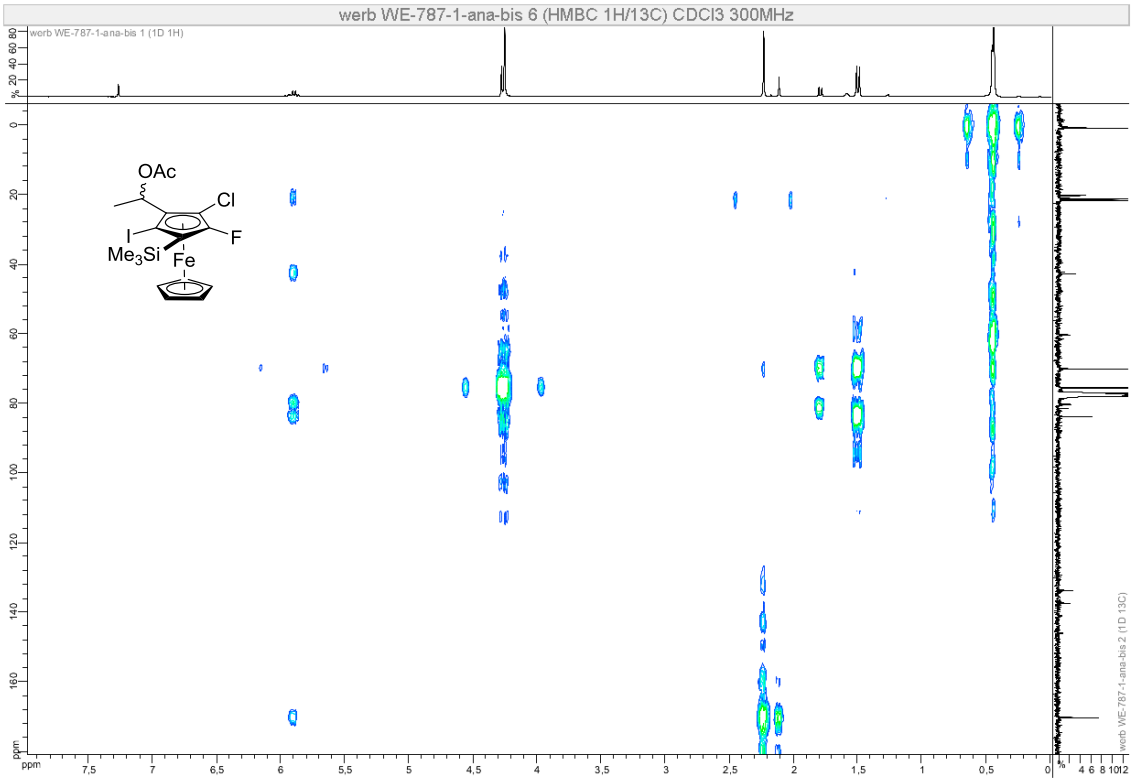

werb WE-787-1-ana-bis 1 (1D 1H) CDCl3 300MHz
OAc
Cl
I
F
Me3Si
Fe

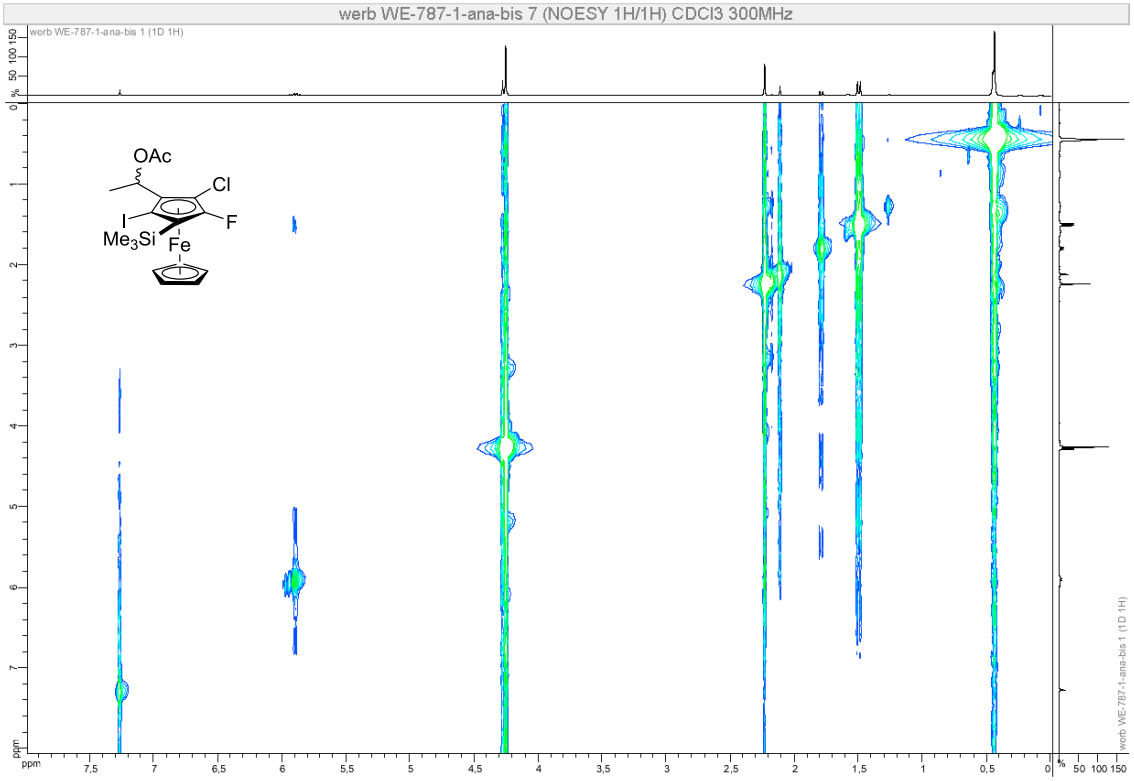

werb WE-787-1-ana-bis 2 (1D 13C) CDCl3 300MHz
OAc
Cl
I
F
Me3Si
Fe

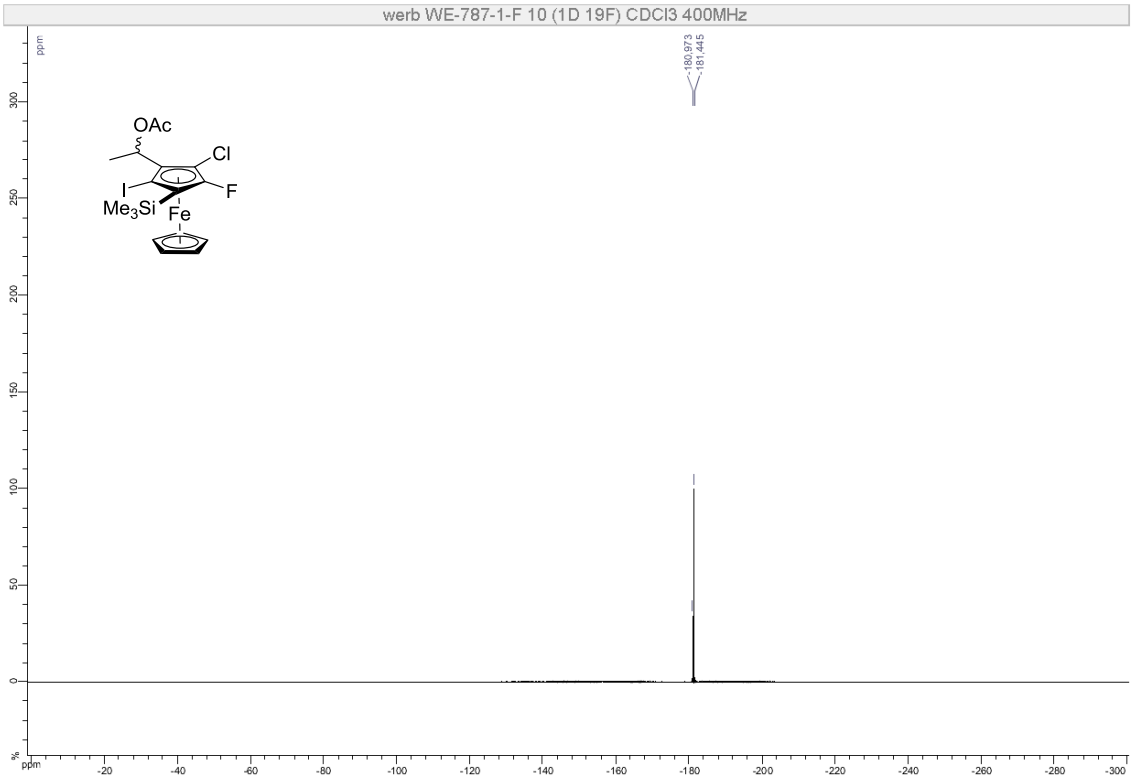

werb WE-787-1-ana-bis 3 (DEPT 13C) CDCl3 300MHz
75,211
69,758
21,302
20,831
19,935
0,565
OAc
Cl
I
F
Me3Si
Fe
ppm


werb WE-787-1-ana-bis 4 (COSY 1H/1H) CDCl3 300MHz
werb WE-787-1-ana-bis 1 (1D 1H)
OAc
Cl
I
F
Me3Si
Fe
ppm

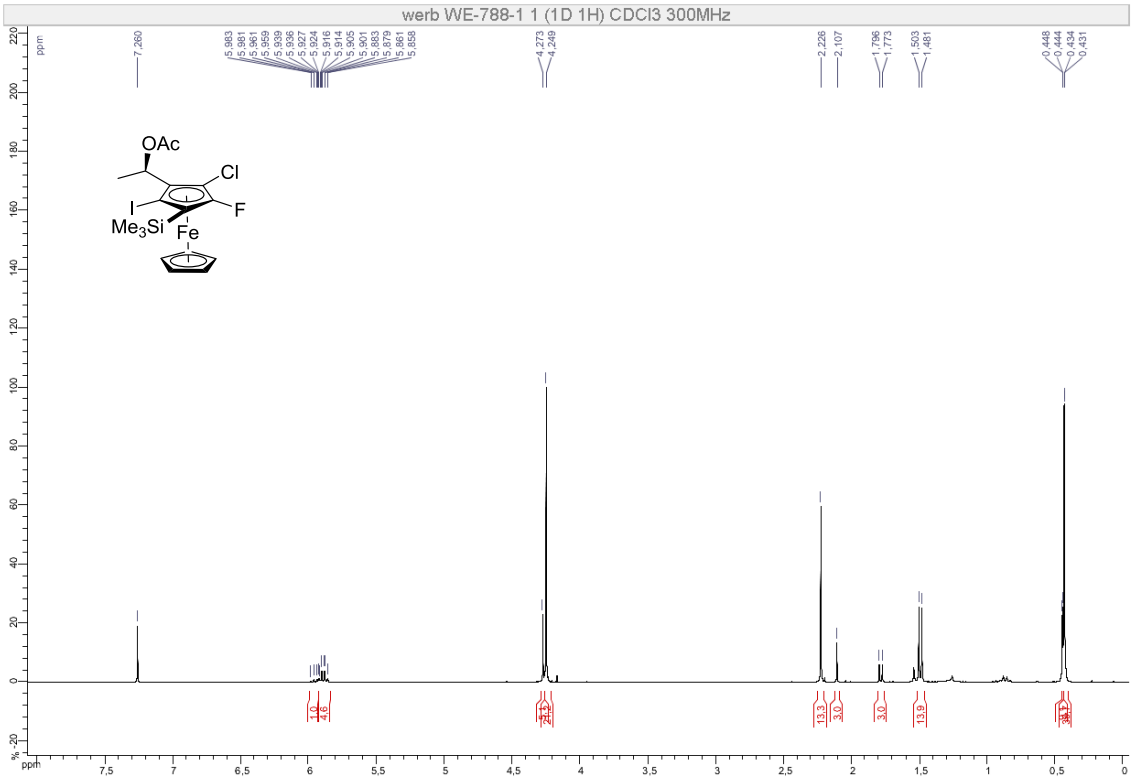

werb WE-787-1-ana-bis 5 (HSQC 1H/13C) CDCl3 300MHz
werb WE-787-1-ana-bis 1 (1D 1H)
OAc
Cl
I
F
Me3Si
Fe
ppm
werb WE-787-1-ana-bis 2 (1D 13C)

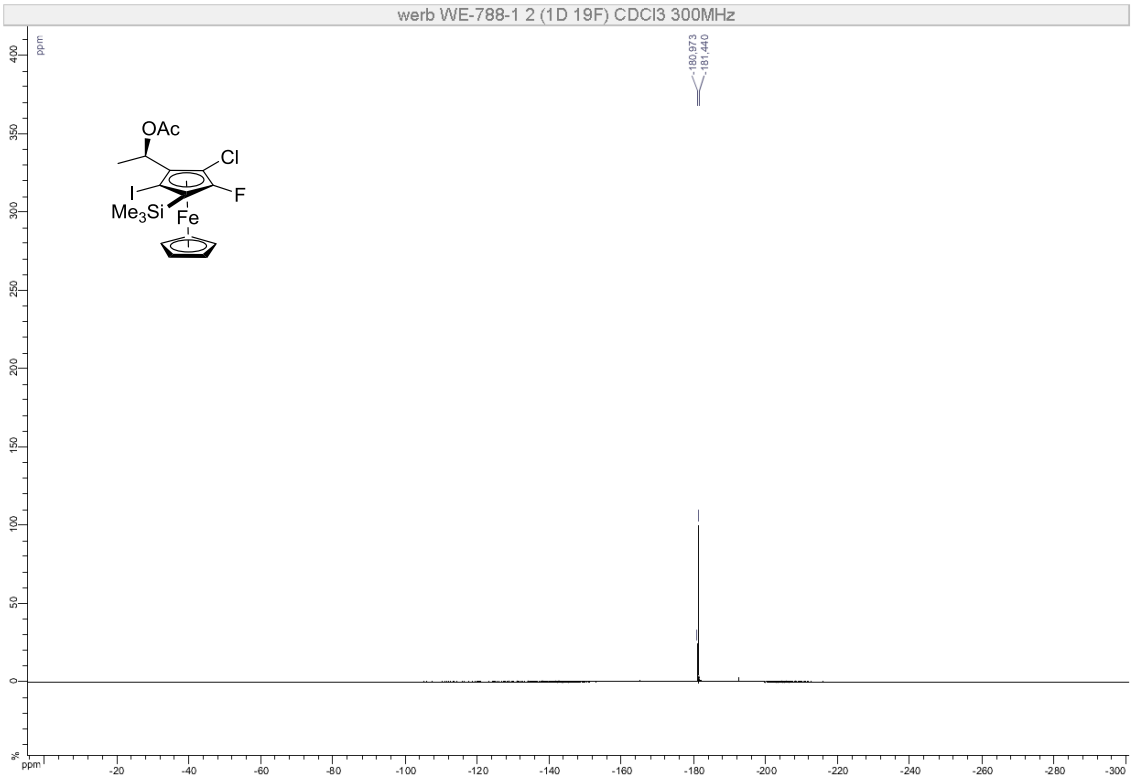

werb WE-787-1-ana-bis 6 (HMBC 1H/13C) CDCl3 300MHz
werb WE-787-1-ana-bis 1 (1D 1H)
OAc
Cl
I
F
Me3Si
Fe
ppm
werb WE-787-1-ana-bis 2 (1D 13C)


werb WE-787-1-ana-bis 7 (NOESY 1H/1H) CDCl3 300MHz
werb WE-787-1-ana-bis 1 (1D 1H)
OAc
Cl
F
I
Me3Si
Fe
ppm
7,5
7
6,5
6
5,5
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
50 100 150
werb WE-787-1-ana-bis 1 (1D 1H)

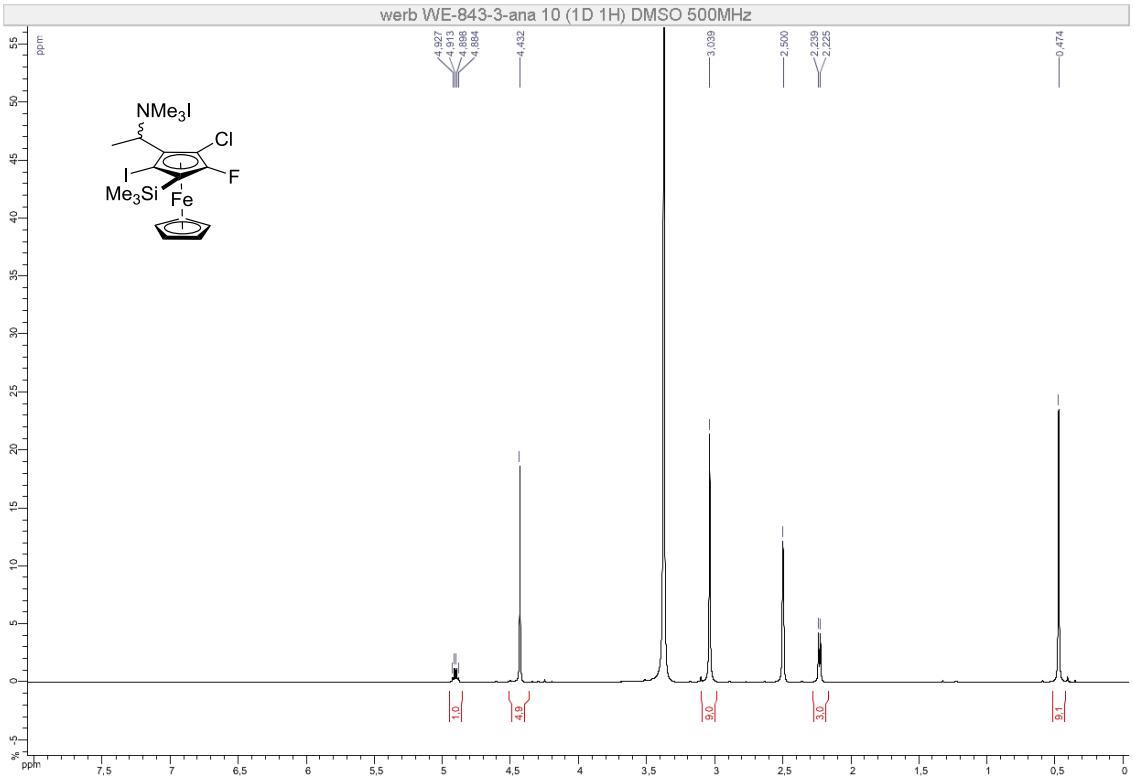

werb WE-787-1-F 10 (1D 19F) CDCl3 400MHz
ppm
-180.973
-181.445
OAc
Cl
F
I
Me3Si
Fe
300
250
200
150
100
50
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300

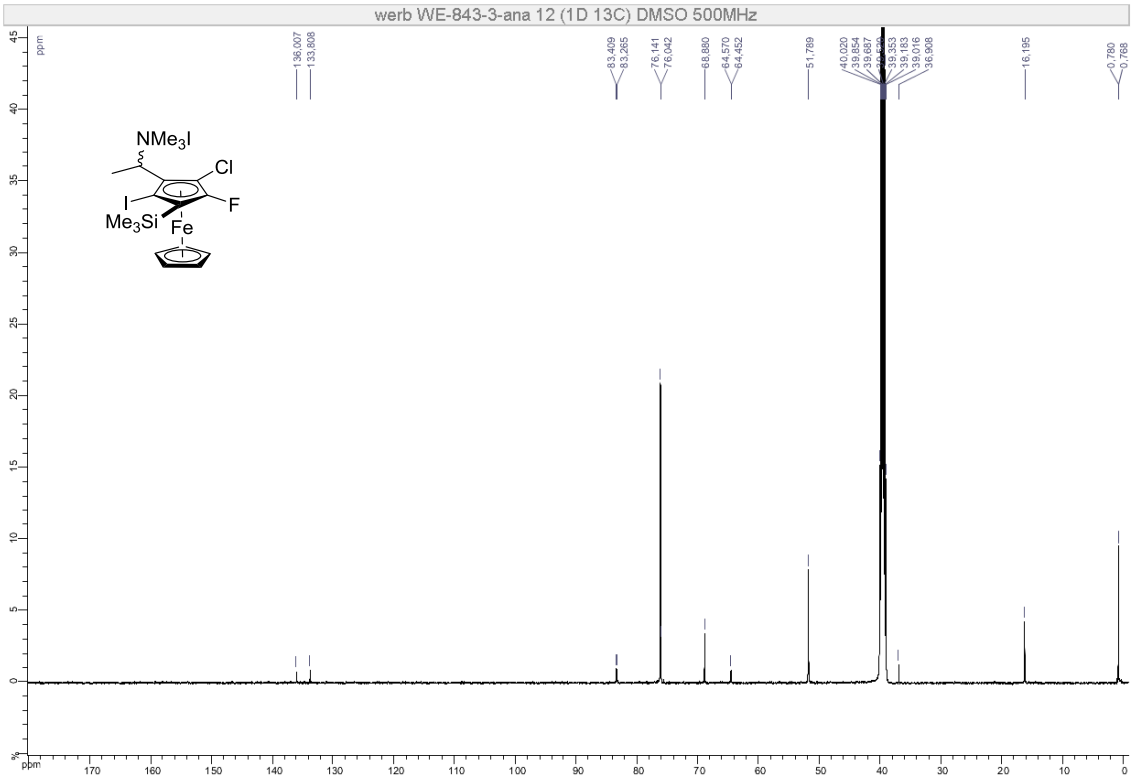
Compound (R,S_p)-16

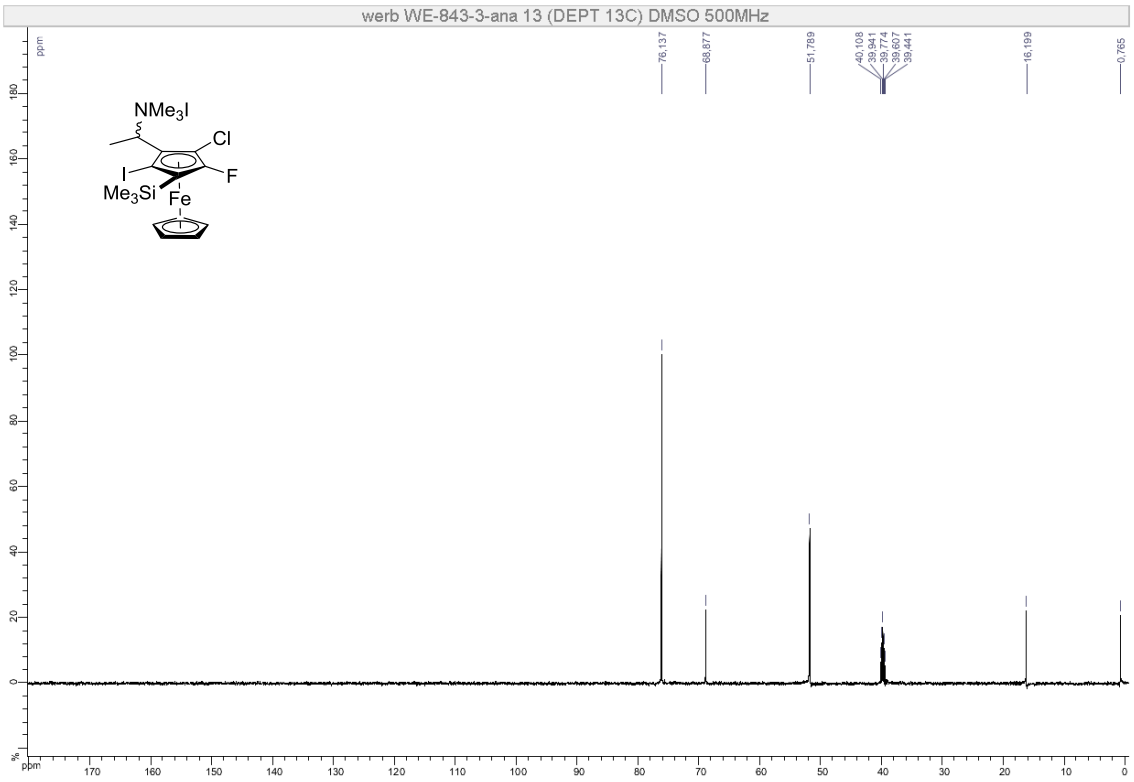


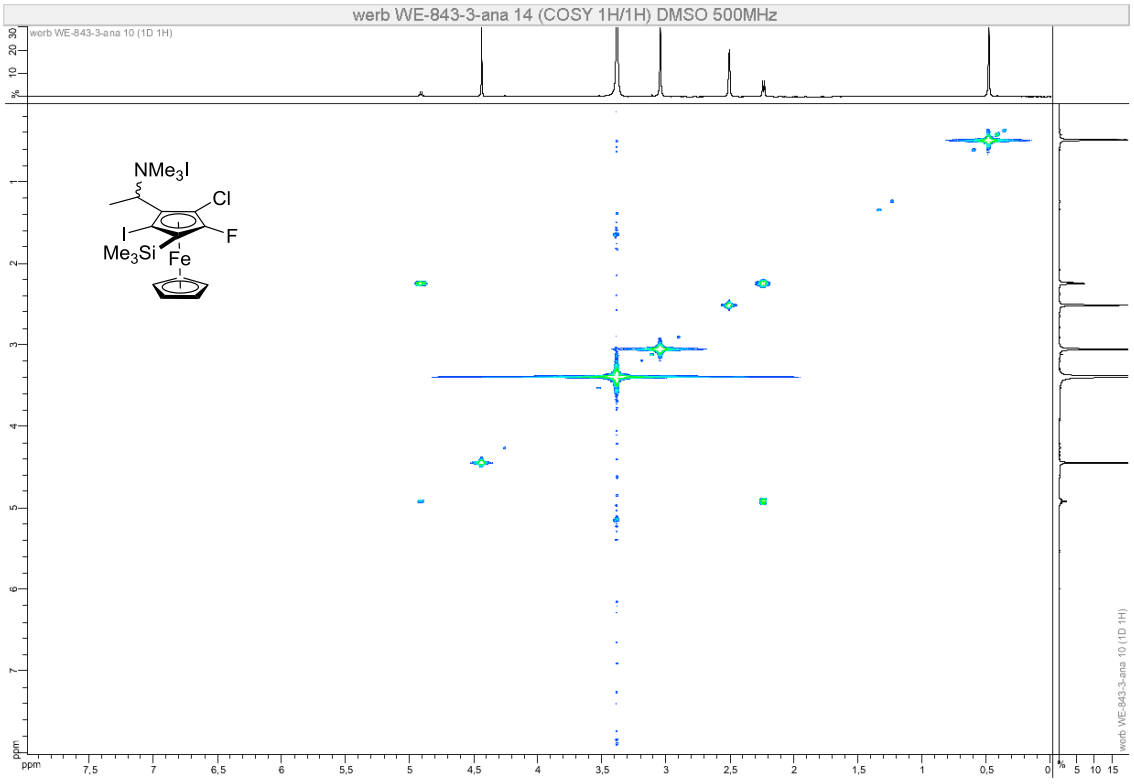


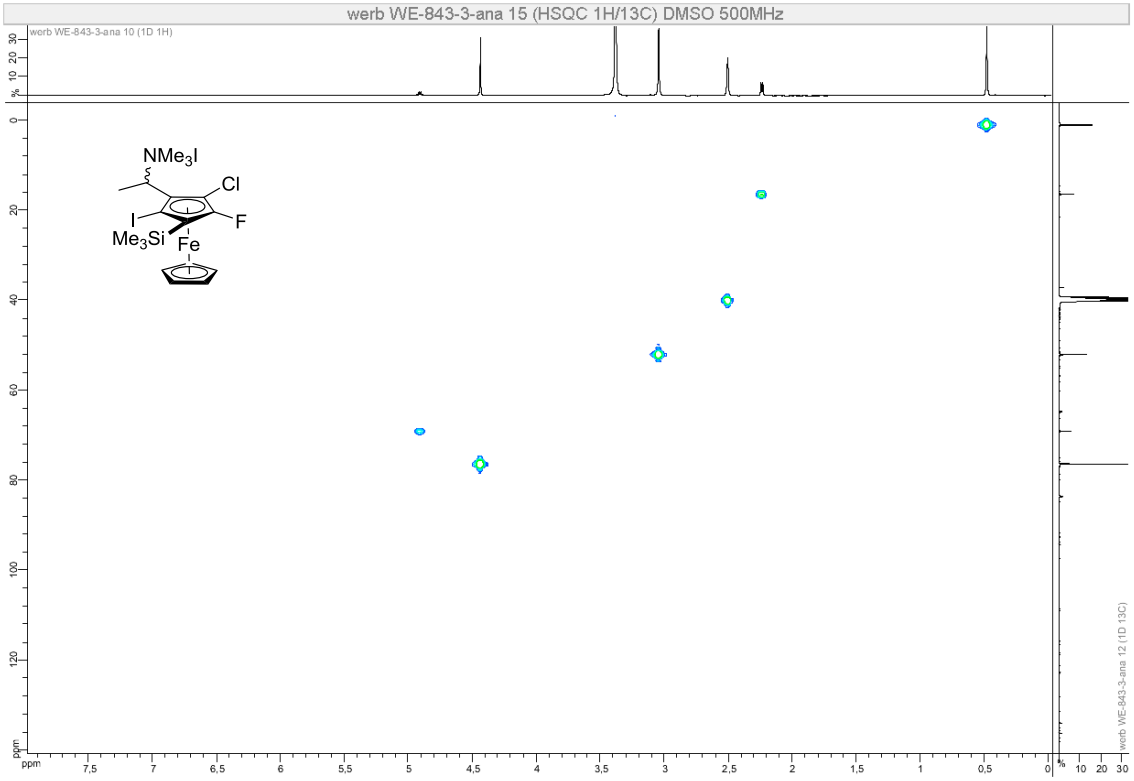
Compound (±)-17

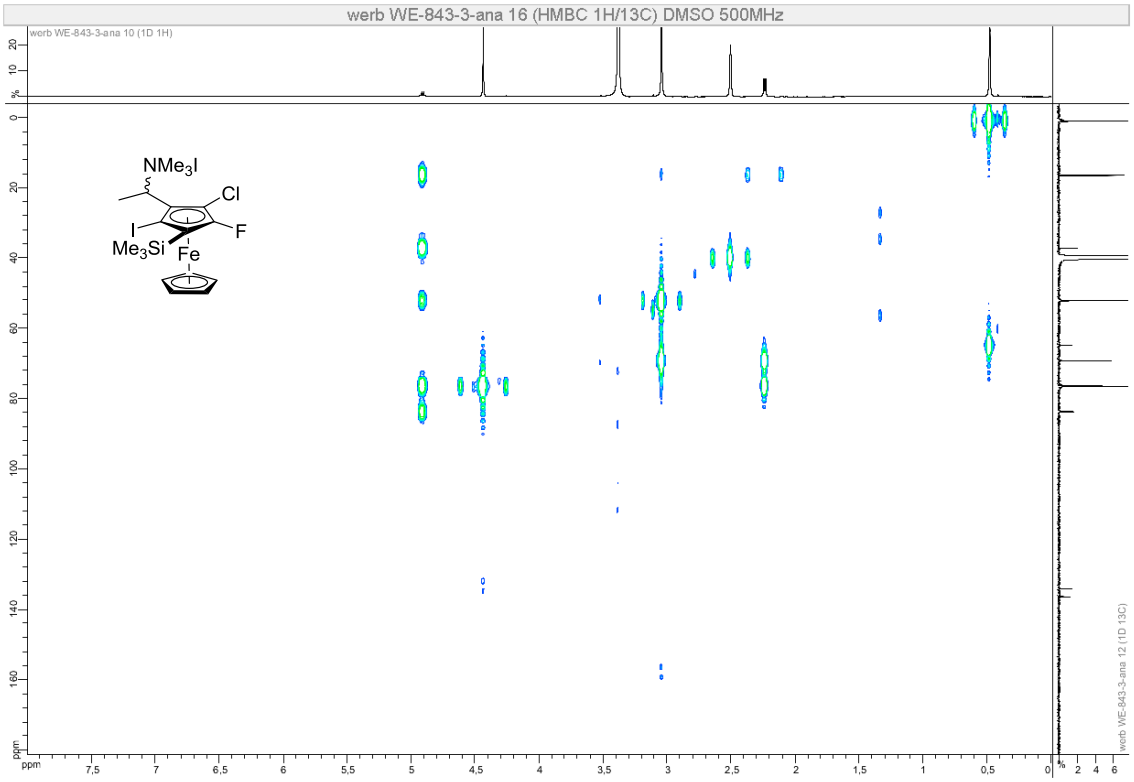

werb WE-843-3-ana 10 (1D 1H) DMSO 500MHz
NMe3I
Cl
F
I
Me3Si
Fe

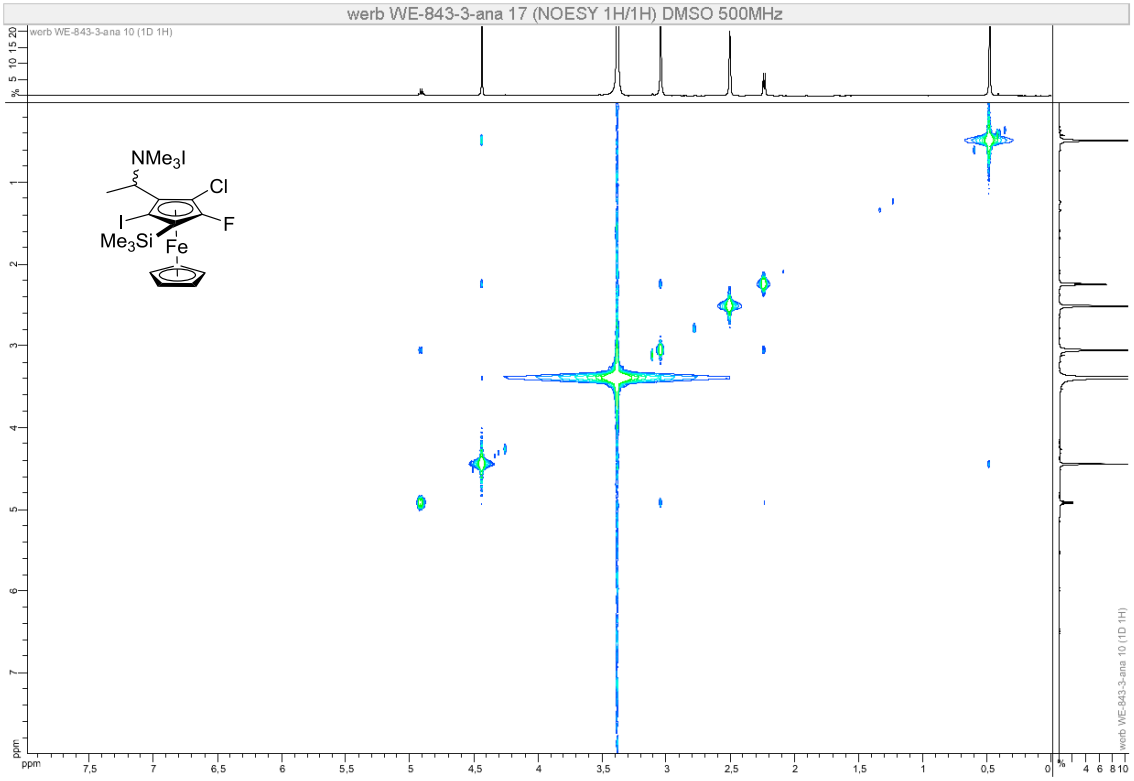

werb WE-843-3-ana 12 (1D 13C) DMSO 500MHz
NMe3I
Cl
F
I
Me3Si
Fe

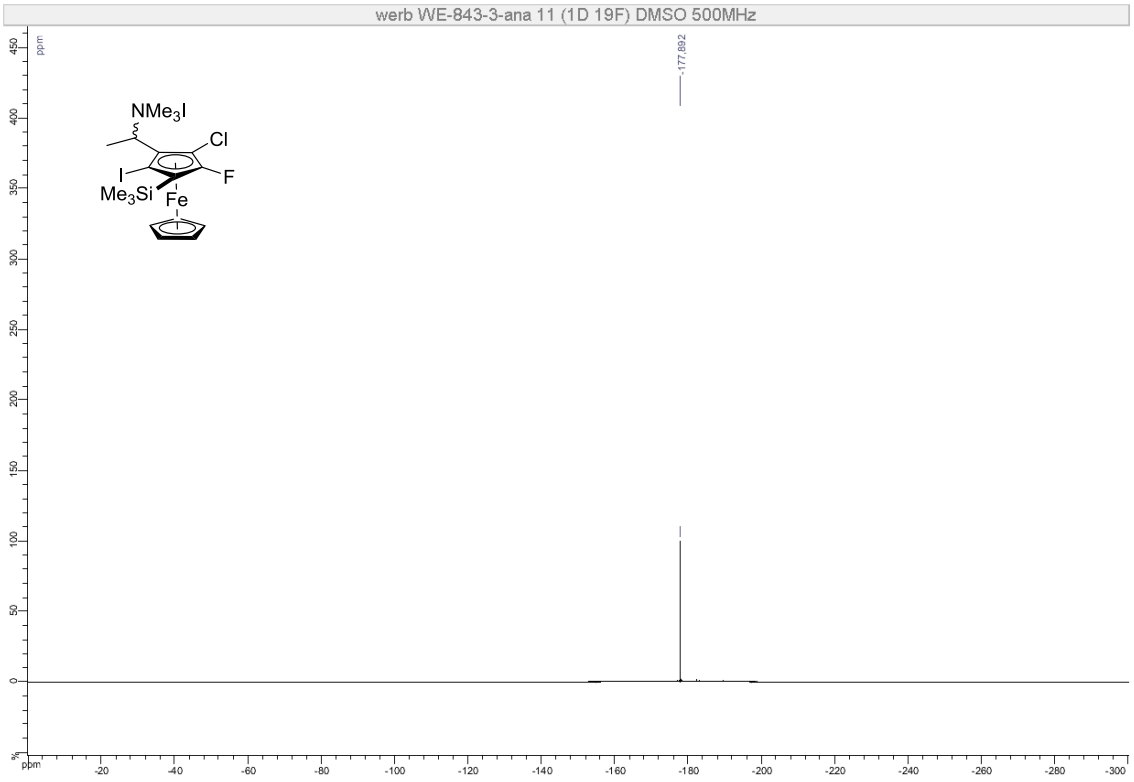

werb WE-843-3-ana 13 (DEPT 13C) DMSO 500MHz
76,137
68,877
51,789
40,108
39,941
39,774
39,607
39,441
16,199
0,765
NMe3I
Cl
I
F
Me3Si
Fe


werb WE-843-3-ana 14 (COSY 1H/1H) DMSO 500MHz
werb WE-843-3-ana 10 (1D 1H)
NMe3I
Cl
I
F
Me3Si
Fe
ppm

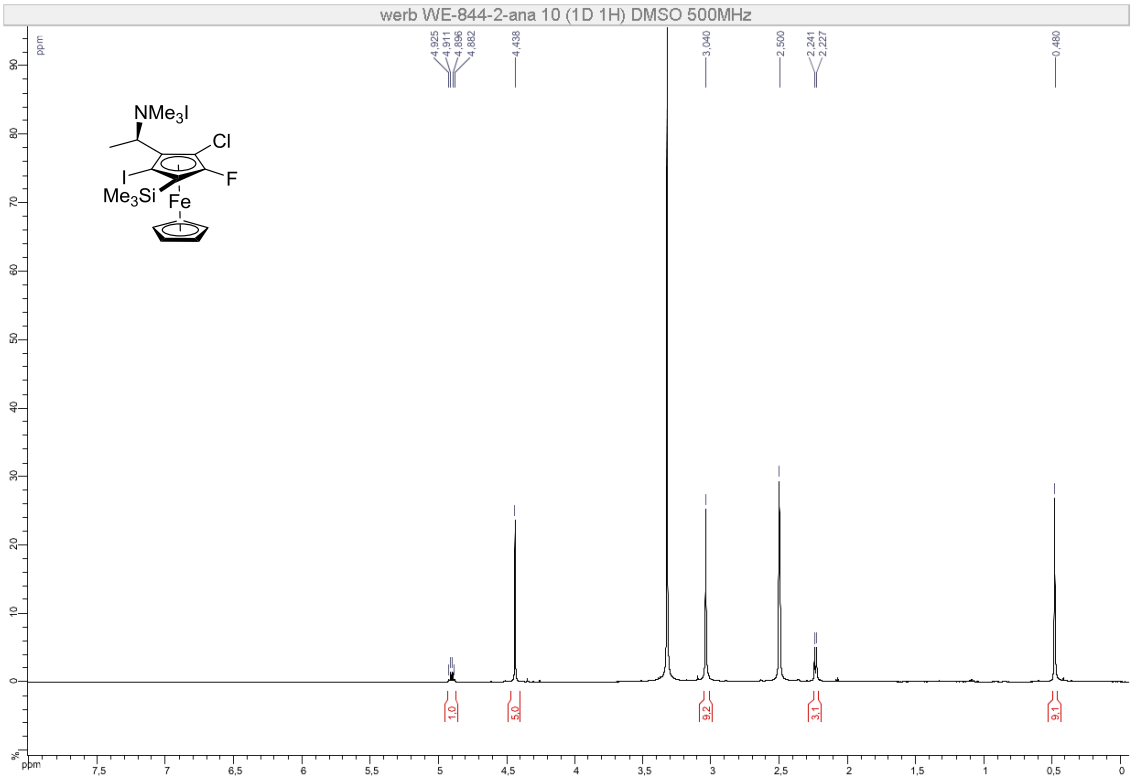

werb WE-843-3-ana 15 (HSQC 1H/13C) DMSO 500MHz
werb WE-843-3-ana 10 (1D 1H)
NMe3I
Cl
I
F
Me3Si
Fe
ppm
werb WE-843-3-ana 12 (1D 13C)

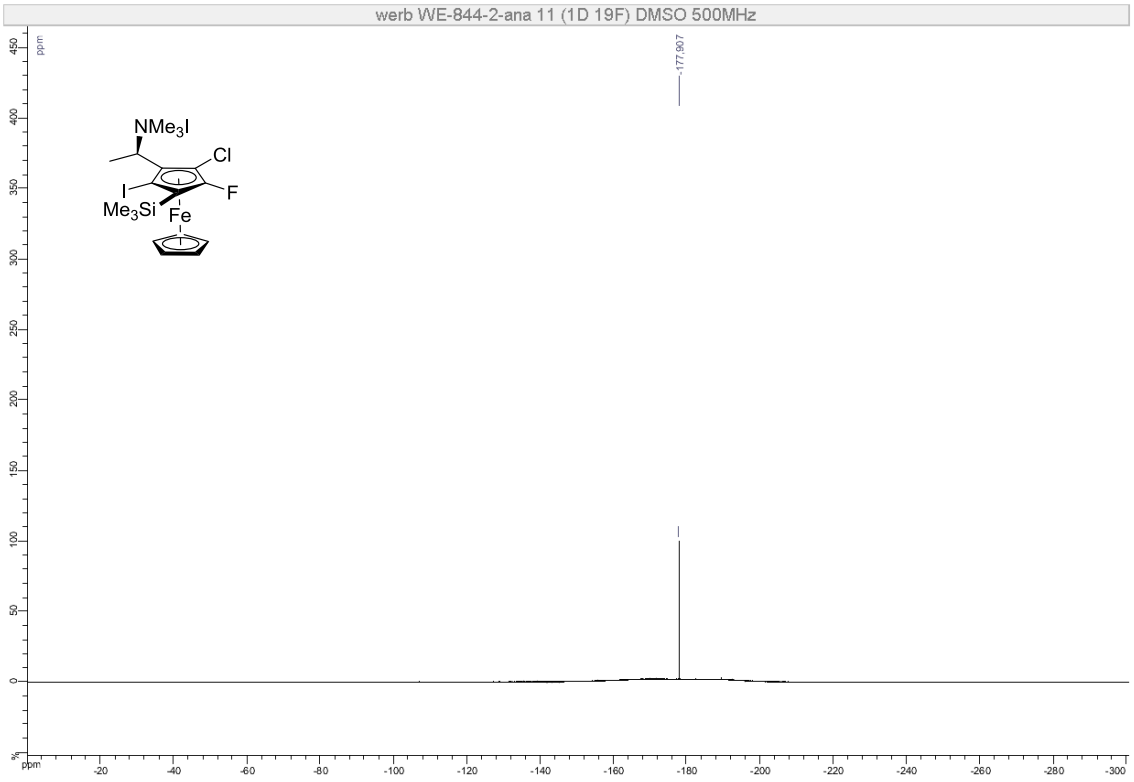

werb WE-843-3-ana 16 (HMBC 1H/13C) DMSO 500MHz
werb WE-843-3-ana 10 (1D 1H)
NMe3I
Cl
I
F
Me3Si
Fe
ppm
werb WE-843-3-ana 12 (1D 13C)


werb WE-843-3-ana 17 (NOESY 1H/1H) DMSO 500MHz
werb WE-843-3-ana 10 (1D 1H)
NMe3I
Cl
F
I
Me3Si
Fe
ppm
werb WE-843-3-ana 10 (1D 1H)


werb WE-843-3-ana 11 (1D 19F) DMSO 500MHz
-177.892
NMe3I
Cl
F
I
Me3Si
Fe
ppm

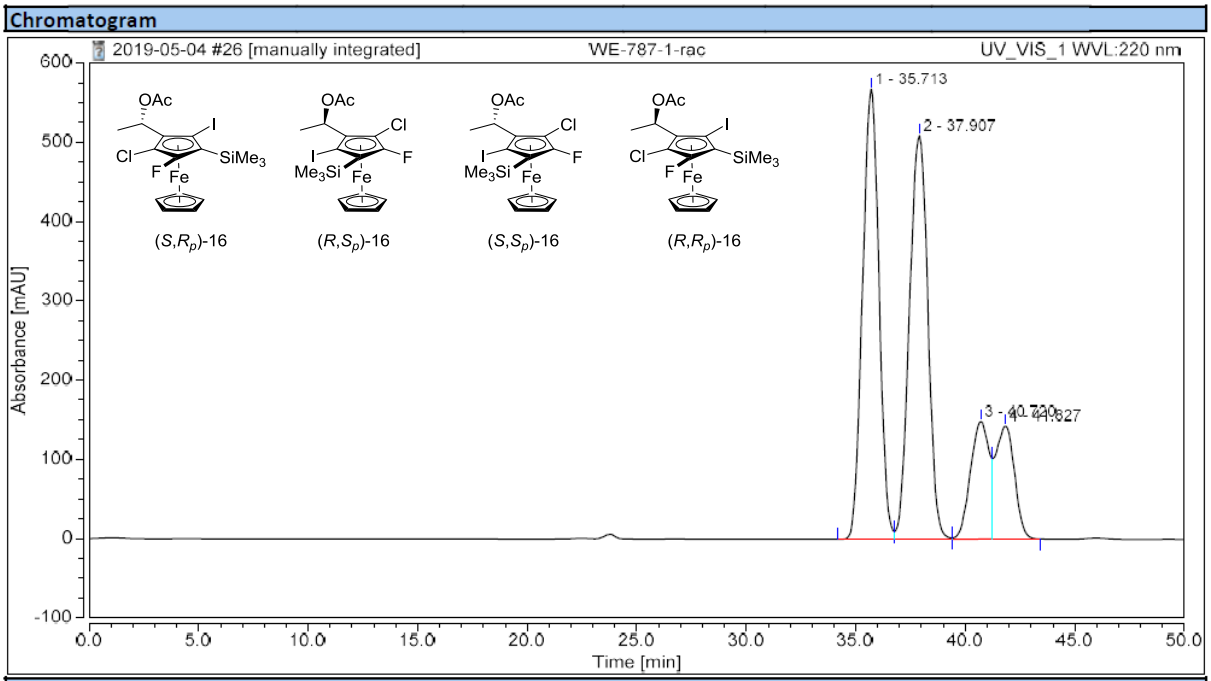
Compound ((*R*,*S*$_p$)-17)





HPLC Chromatograms of compounds (R,S_p)-, (S,R_p)-, (S,S_p)- and (R,R_p)-16.

Chiralpak IC-3 column, hexane/iPrOH: 99.5:0.5, 0.25 mL/min, 5 °C, λ = 254 nm, t (S,R_p) = 35.71 min, t (R,S_p) = 37.91 min, t (S,S_p) = 40.72 min, t (R,R_p) = 41.83 min.

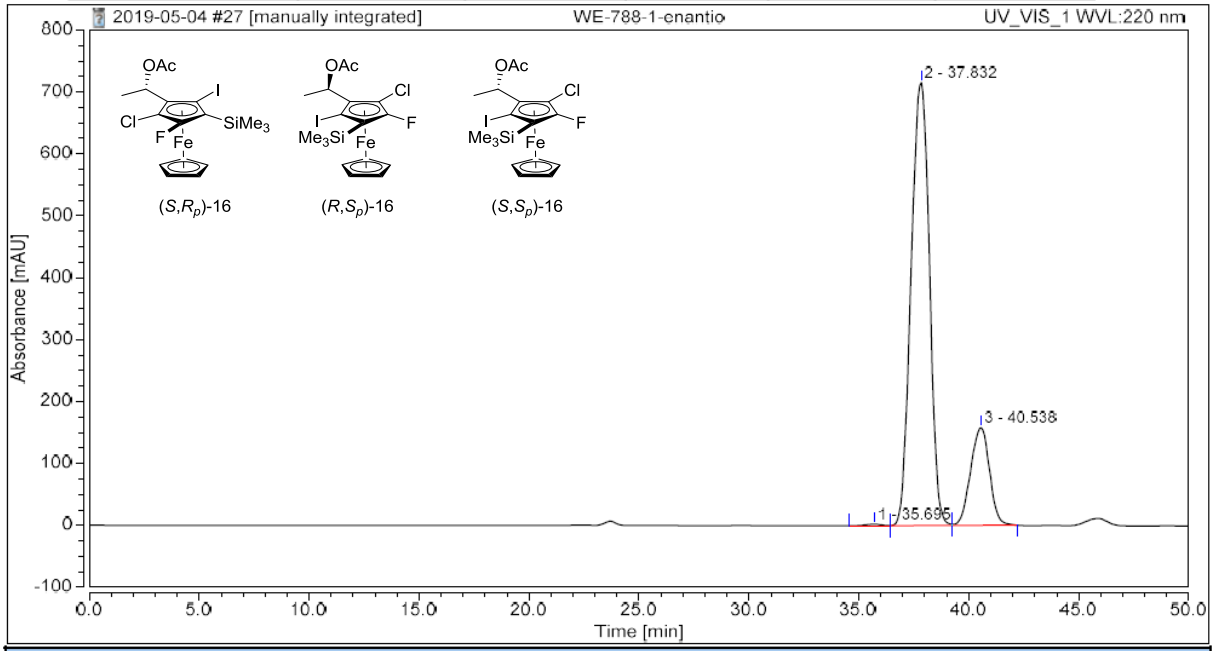


Integration Results

No.	Peak Name	Retention Time min	Area mAU*min	Height mAU	Relative Area %	Relative Height %	Amount n.a.
1		35.713	493.782	567.762	38.54	41.50	n.a.
2		37.907	497.034	509.306	38.80	37.23	n.a.
3		40.720	145.380	148.493	11.35	10.85	n.a.
4		41.827	144.944	142.614	11.31	10.42	n.a.
Total:			**1281.140**	**1368.175**	**100.00**	**100.00**	

Chiralpak IC-3 column, hexane/iPrOH: 99.5:0.5, 0.25 mL/min, 5 °C, λ = 254 nm, t (S,R_p) = 35.71 min, t (R,S_p) = 37.91 min, t (S,S_p) = 40.72 min, (R,R_p) too low to be identified. ee = 99.5%, de = 63%.

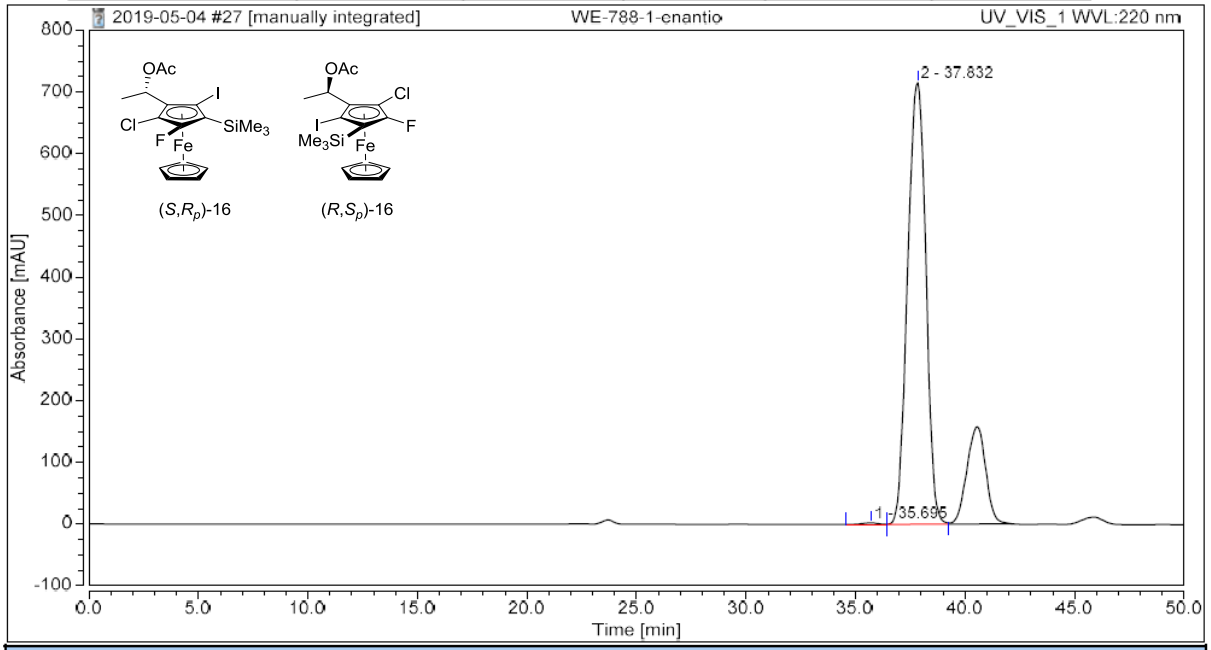
Chromatogram



Integration Results

No.	Peak Name	Retention Time min	Area mAU*min	Height mAU	Relative Area %	Relative Height %	Amount n.a.
1		35.695	1.723	2.164	0.20	0.25	n.a.
2		37.832	691.740	715.591	81.34	81.73	n.a.
3		40.538	156.982	157.820	18.46	18.02	n.a.
Total:			**850.445**	**875.575**	**100.00**	**100.00**	

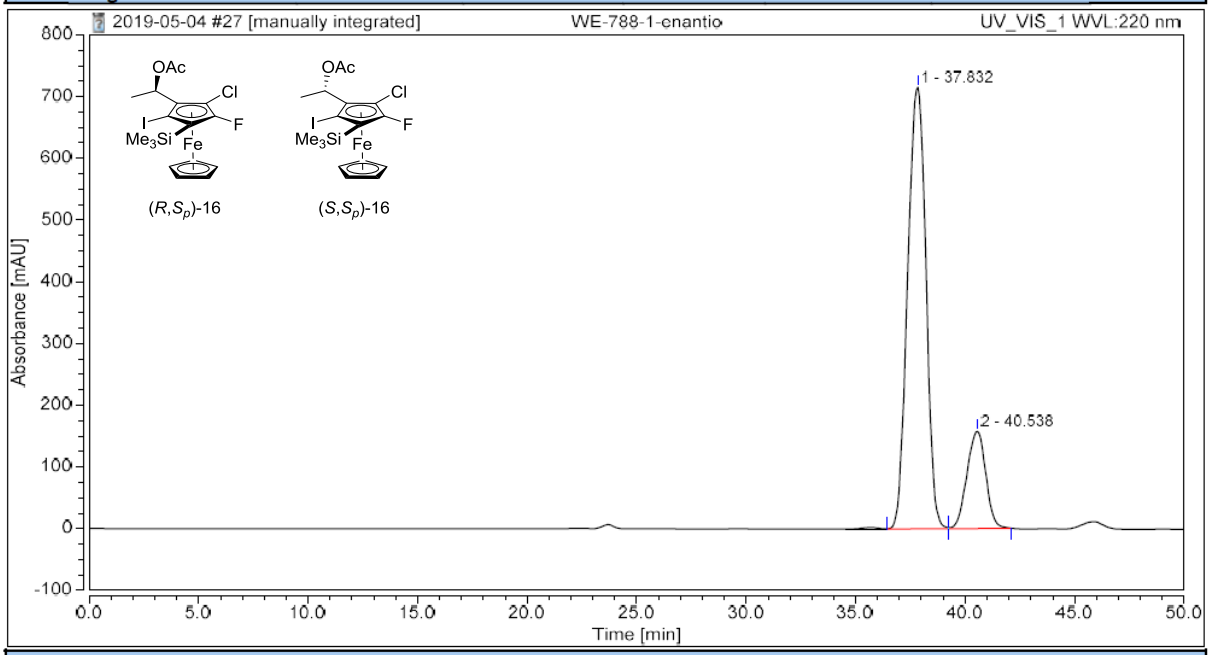
Chromatogram



Integration Results

No.	Peak Name	Retention Time min	Area mAU*min	Height mAU	Relative Area %	Relative Height %	Amount n.a.
1		35.695	1.723	2.164	0.25	0.30	n.a.
2		37.832	691.740	715.591	99.75	99.70	n.a.
Total:			**693.463**	**717.755**	**100.00**	**100.00**	

Chromatogram



Integration Results

No.	Peak Name	Retention Time min	Area mAU*min	Height mAU	Relative Area %	Relative Height %	Amount n.a.
1		37.832	691.771	715.591	81.51	81.93	n.a.
2		40.538	156.925	157.820	18.49	18.07	n.a.
Total:			**848.696**	**873.411**	**100.00**	**100.00**	

References

1. A. F. Burchat, J. M. Chong, N. J. Nielsen *J. Organomet. Chem*. **1997**, *542*, 281-283.
2. K. Plevová, B. Mudráková, R. Šebesta *Synthesis* **2018**, *50*, 760-763.
3. M. Tazi, M. Hedidi, W. Erb, Y. S. Halauko, O. A. Ivashkevich, V. E. Matulis, T. Roisnel, V. Dorcet, G. Bentabed-Ababsa, F. Mongin, *Organometallics* **2018**, *37*, 2207-2211.
4. G. Sheldrick *Acta Crystallogr. Sect. A* **2015**, *71*, 3-8.
5. G. Sheldrick *Acta Crystallogr. C* **2015**, *71*, 3-8.