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SUPPORTING INFORMATION

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Title: A Direct Catalytic Synthesis of Sodium Diarylphosphinates and Their Corresponding Acids from Sodium Phosphinate
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1. General considerations

All reactions were carried out under an atmosphere of dinitrogen. Solvents were dried on molecular sieves and degassed according to standard procedures. All reagents were purchased from commercial sources and used without further purification. Monitoring of the reactions was done by ^{31}P NMR and/or HPLC. Known compounds were identified by comparison of their analytical data with literature data. NMR spectra were recorded at 25°C on a Bruker Avance 500 (^{1}H, ^{13}C{^{1}H}), Bruker Avance 400 (^{1}H, ^{31}P{^{1}H}, ^{13}C{^{1}H}) and internally referenced to the residual solvent resonances (for [D$_4$]methanol ^{1}H at δ 3.31, ^{13}C{^{1}H} at δ 49.00; $CDCl_3$ ^{1}H at δ 7.26, ^{13}C{^{1}H} at δ 77.16; [D$_6$]DMSO ^{1}H at δ 2.5, ^{13}C{^{1}H} at δ 39.52. ^{31}P-NMR spectra were referenced against external 85% H_3PO_4. HPLC was performed on a Shimadzu system, using the column Phenomenex Kinetex 5u C8 (100A 250 x 4.6 mm): $V_{injection}$ = 10 μL, in isocratic flow of 0.5 mL.min^{-1} at 26 bar; eluent: MeCN : water = 75 : 25, buffered with 0.1 % of TFA; oven temperature 40 °C; run time 25 min; detector at λ = 254 nm. LC-MS and Electrospray Ionisation (ESI) mass spectrometry was carried out using a Bruker micrOTOF-Q instrument in negative ion mode (capillary potential of 4500 V), and calculated mass values include a one electron mass to account for the negative charge. Elemental analyses were performed by Mikroanalytisches Laboratorium Kolbe, Mülheim an der Ruhr, DE.

2. General experimental procedure for compounds 2d and 3a-j

$Pd_2(dba)_3$ (1.0 mol %) and xantphos (2.2 mol %) were introduced in reaction flasks which were N_2/vacuum flushed and filled with N_2. Toluene was added, and the mixture was stirred at room temperature for 5 min. Then *i*Pr_2EtN (3.5 equiv.), $NaH_2PO_2.H_2O$ (5.0 mmol) and aryl halide (2.5 equiv.) were added. The flasks were then heated and stirred at 115 °C (reaction temperature) for 20h except if mentioned otherwise. After the reaction, the reaction mixtures were allowed to return to room temperature. The solvent was evaporated and the residue was dissolved in a mixture of aqueous NaOH 1 M (100 mL) and diethyl ether (100 mL). After phase separation, the organic phase was extracted two times with aqueous NaOH 1 M (2x 100 mL). The combined aqueous phases were acidified with concentrated aqueous HCl (30 mL), and the resulting solution was saturated with NaCl (50 g). The mixture was extracted three times with dichloromethane (3x 100 mL), and the combined organic extracts were dried on Na_2SO_4. Evaporation of the solvent and drying under high vacuum yielded products **3a-j**. A wash with cold acetone or recrystallization from ethanol can be used to further purify the products.

3. Reaction monitoring by ^{31}P{^{1}H} NMR

The desired products were identified by comparison with literature NMR data or with pure commercial samples when available. ^{31}P{^{1}H} NMR yields of the desired product [Ar_2P(O)O]Na were determined *in situ* from the reaction mixtures by comparing the integrated signal to the sum of integrations of all ^{31}P{1H} signals, assuming that relaxation times of the compounds are equivalent and that all P-species are dissolved. The yields obtained in this way are comparable with those determined by HPLC (see section 4). Samples were prepared by taking 0.5 mL of the reaction mixture and by adding EtOH (0.5 mL) to obtain homogeneous mixtures.
In the case of [Ph_2P(O)O]Na (**2a**), for example, the yield after 64 h was 95%, and the mass balance was completed by unreacted $NaH_2PO_2.H_2O$ (Figure S1). This is a different experiment than the one of Figures S2-3.

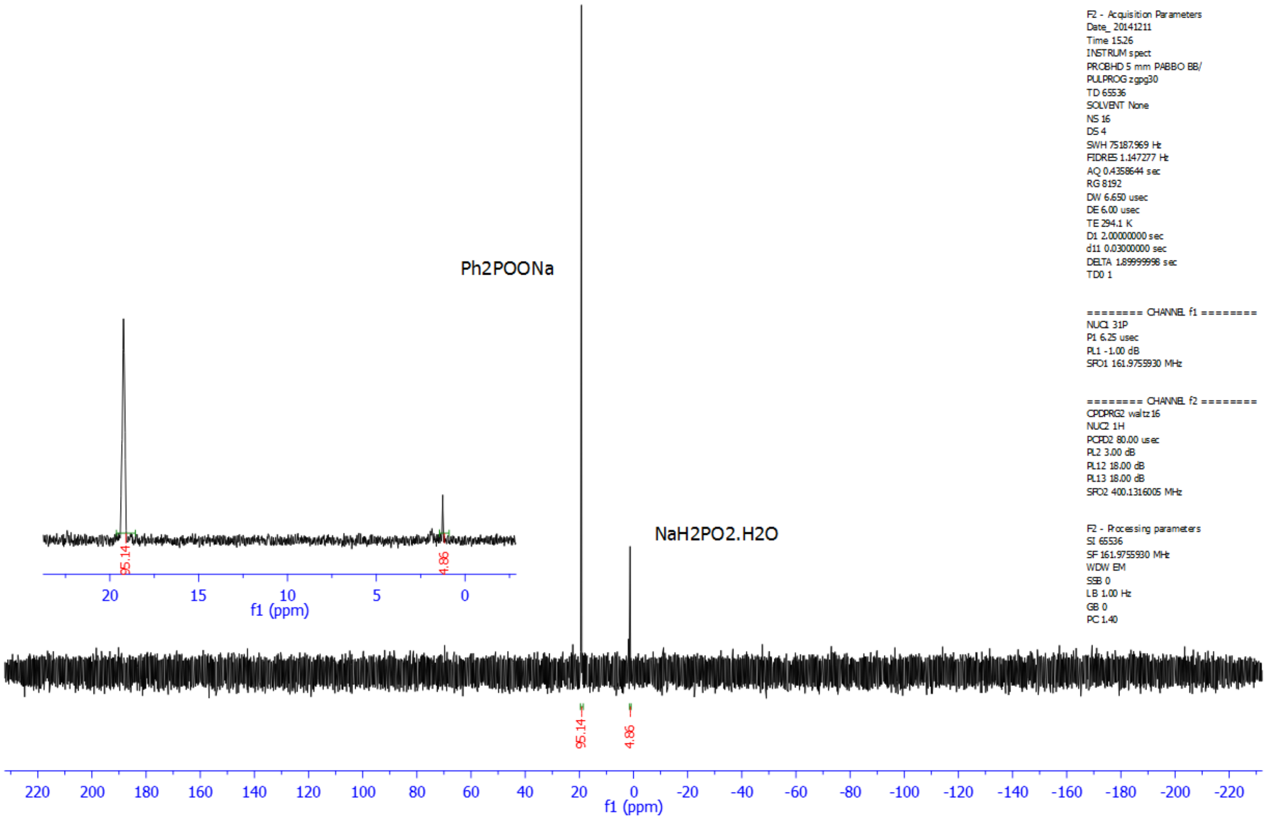


Figure S1) ^{31}P{^{1}H} NMR spectrum (162.0 MHz, in toluene:ethanol = 1:1) of the reaction mixture leading to **2a** after 64 h

4. Reaction monitoring and determination of purity of isolated products by HPLC

The amount of desired product in the reaction mixture was calculated based on the integration area of its absorption signal and compared to a calibration line of four points. This permitted us to determine an *in situ* concentration of desired product [$Ar_2P(O)O$]Na. The *in situ* yield then corresponded to the measured concentration divided by the calculated concentration, taking into account the dilution for the sample preparation. The products were identified by comparison with pure commercial samples when available, or by elimination of the other peaks: toluene and ArX. Samples of the reaction mixture (0.2 mL) were diluted with EtOH (0.8 mL) to obtain homogeneous mixtures. These were then filtered and inserted into the HPLC vial.

The purity of isolated products was determined from the HPLC traces by comparing the area of the product peak to the total area percentage of all observed peaks. Samples were prepared by weighing 1 mg and dissolving it into 1 mL of EtOH.

In the case of **3a**, for example, after 20 h of reaction the concentration was 9.3 $mg.mL^{-1}$ (rt. = 5.11 min) which corresponded to a quantitative yield of [$Ph_2P(O)O$]Na (analysed as $Ph_2P(O)OH$ in the HPLC conditions using a TFA buffer, Figure S2). Unconsumed PhBr (rt. = 7.64 min) was observed along with toluene (rt. = 7.19 min) and what we suspect to be the homocoupling side-product Ph-Ph (rt. = 10.68 min). The reduction product benzene was not observed.
After work up, the purity of **3a** was 93% (Figure S3), and that of **3g** of 98% (Figure S4).

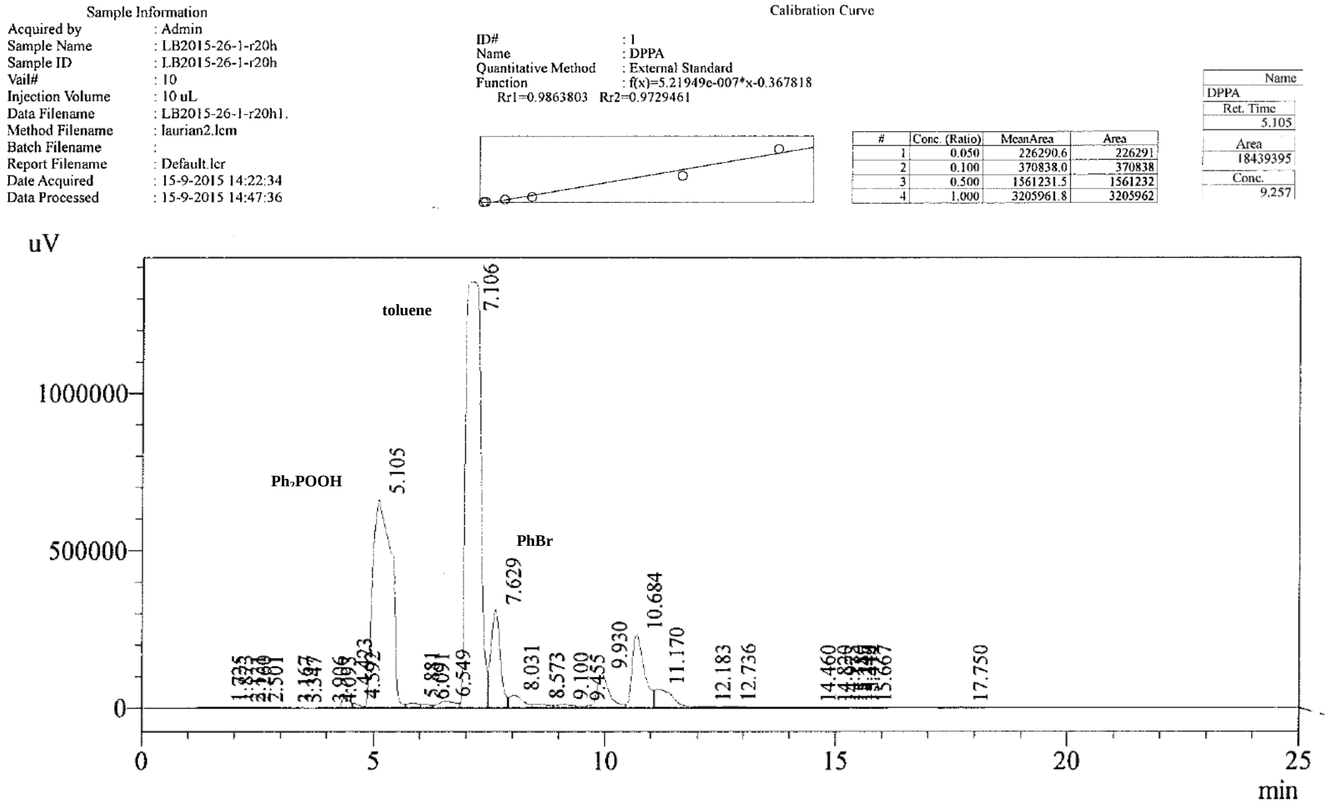


Figure S2) HPLC trace of the reaction mixture after 20h for **3a** (rt = 5.11 min, 98% yield)

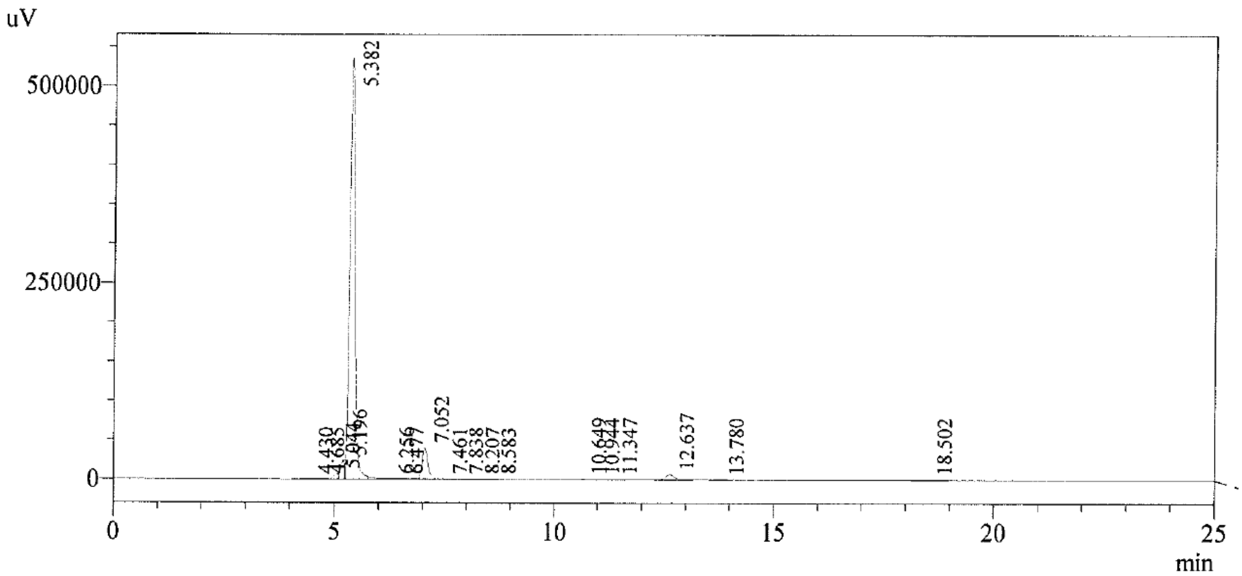


Figure S3) HPLC trace of the isolated **3a** (rt = 5.38 min, 93% pure, the peak at rt = 7.05 min is residual toluene)

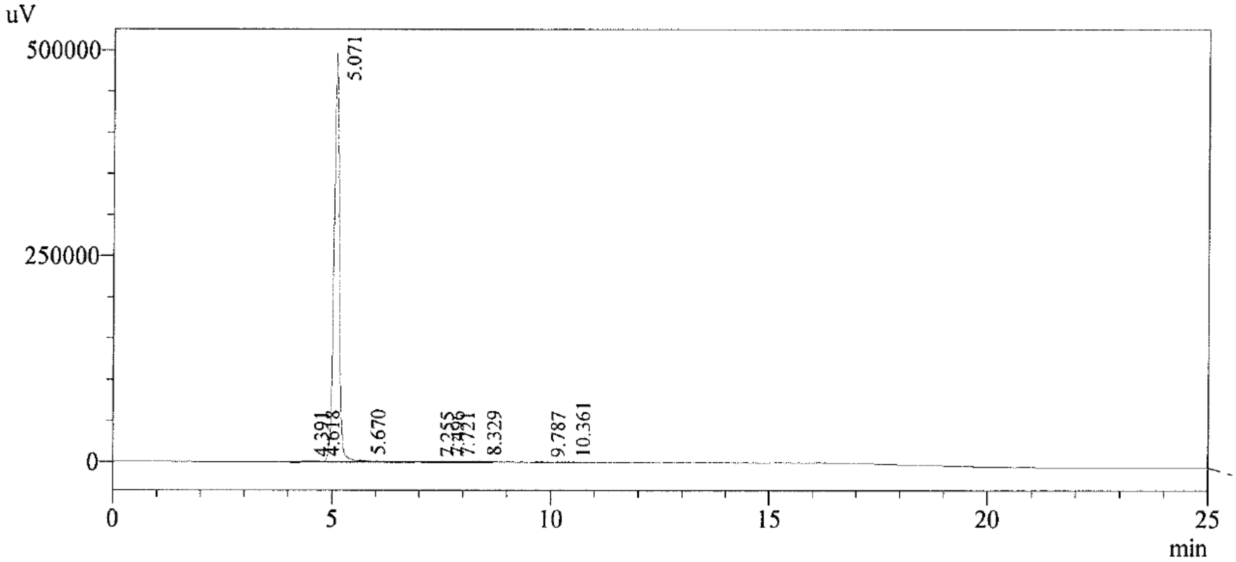
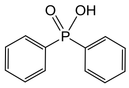
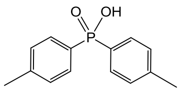
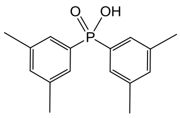
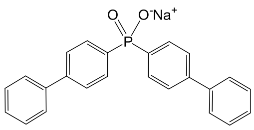
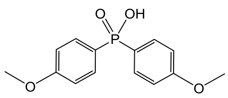
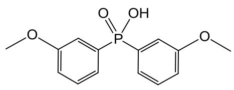
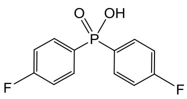
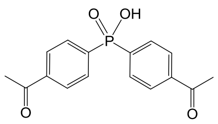
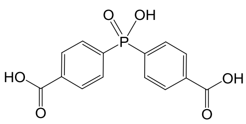
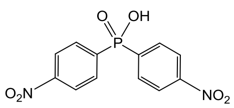


Figure S4) HPLC trace of the isolated **3g** (rt = 5.07 min, 98% pure)

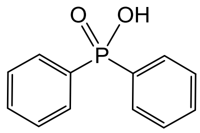
The isolated yields (by weight, and corrected for purity) and the HPLC purities of **2d** and **3a-j** are presented in Table S1.

Table S1. Isolated yields and HPLC purities of Ar_2POOY (Y = H or Na).

Entry	$Ar_2P(O)OH$	Isolated yield %	HPLC purity%
3a		86	93
3b		78	96
3c		81	92
2d		83	90
3e		66	94
3f		61	96
3g		81	98
3h		65	80
3i		41	98
3j		75	92

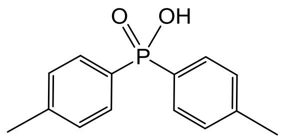
5. Characterization data for compounds 2d and 3a-j

Diphenylphosphinic acid (3a)[1]



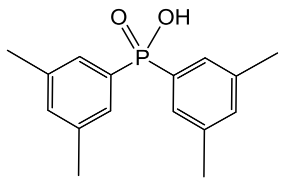
White solid. Yield: 0.94 g (4.3 mmol, 86%). ^{1}H NMR (500.2 MHz, [D$_6$]DMSO): δ 7.74 (~ddd, ^{3}J(H,P) = 12.0 Hz, ^{3}J(H,H) = 7.5 Hz, ^{4}J(H,H) = 2.0 Hz, 4H; *o*-PPh*H*), 7.52 (~td, ^{3}J(H,H) = 7.5 Hz, ^{4}J(H,H) = 2.0 Hz, 2H; *p*-PPh*H*), 7.47 (~td, ^{3}J(H,H) = 7.5 Hz, ^{4}J(H,P) = 3.5 Hz, 4H; *m*-PPh*H*). ^{13}C{^{1}H} NMR (125.8 MHz, [D$_6$]DMSO): δ 135.4 (d, ^{1}J(C,P) = 135.6 Hz; *ipso*-PPh*C*), 131.9 (d, ^{4}J(C,P) = 2.9 Hz; *p*-PPh*C*), 131.4 (d, ^{2}J(C,P) = 10.0 Hz; *o*-PPh*C*), 128.9 (d, ^{3}J(C,P) = 12.7 Hz; *m*-PPh*C*). ^{31}P{^{1}H} NMR (162.0 MHz, [D$_6$]DMSO): δ 23.4 (s). HR ESI-MS: calcd. for $C_{12}H_{10}O_2P^-$ (M-H)$^-$: 217.0424, found: 217.0425. Elemental analysis: calcd. C 66.06, H 5.08, O 14.67, P 14.20, found C 65.75, H 5.14, O 14.98, P 14.13. Known compound.

Bis(4-tolyl)phosphinic acid (3b)[2]



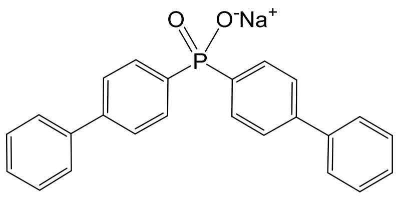
White solid. Yield: 0.96 g (3.90 mmol, 78%). ^{1}H NMR (500.2 MHz, [D$_6$]DMSO): δ 7.60 (dd, ^{3}J(H,P) = 11.5 Hz, ^{4}J(H,H) = 8.0 Hz, 4H; *o*-PAr*H*), 7.26 ppm (~d, ^{3}J(H,H) = 8.0 Hz, unresolved fine coupling with P, 4H; *m*-PAr*H*), 2.31 (s, 6H; C*H*$_3$). ^{13}C{^{1}H} NMR (125.8 MHz, [D$_6$]DMSO): δ 141.7 (d, ^{4}J(C,P) = 2.7 Hz; *p*-PAr*C*), 132.5 (d, ^{1}J(C,P) = 138.0 Hz; *ipso*-PAr*C*), 131.4 (d, ^{2}J(C,P) = 10.0 Hz; *o*-PAr*C*), 129.4 (d, ^{3}J(C,P) = 12.8 Hz; *m*-PAr*C*), 21.5 (s, 6H; *C*H$_3$). ^{31}P{^{1}H} NMR (162.0 MHz, [D$_6$]DMSO): δ 24.1 (s). HR ESI-MS: calcd for $C_{14}H_{14}O_2P^-$ (M-H)$^-$: 245.0737, found: 245.0737. Known compound.

Bis(3,5-dimethylphenyl)phosphinic acid (3c)[3]



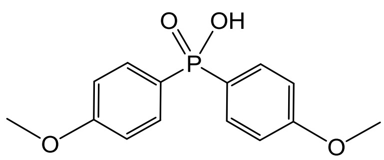
White solid. Yield: 1.11 g (4.05 mmol, 81%). ^{1}H NMR (500.2 MHz, [D$_6$]DMSO): δ 7.33 (d, ^{3}J(H,P) = 12.3 Hz, 4H; *o*-PAr*H*), 7.12 (s, 2H; *p*-PAr*H*), 2.27 (s, 12H; C*H*$_3$). ^{13}C{^{1}H} NMR (125.8 MHz, [D$_6$]DMSO): δ 138.0 (d, ^{3}J(C,P) = 13.6 Hz; *m*-PAr*C*), 135.4 (d, ^{1}J(C,P) = 131.7 Hz; *ipso*-PAr*C*), 133.2 (d, ^{4}J(C,P) = 2.7 Hz; *p*-PAr*C*), 128.9 (d, ^{2}J(C,P) = 10.0 Hz; *o*-PAr*C*), 21.3 (s; *C*H$_3$). ^{31}P{^{1}H} NMR (162.0 MHz, [D$_6$]DMSO): δ 24.1 (s). HR ESI-MS: calcd for $C_{16}H_{18}O_2P^-$ (M-H)$^-$: 273.1050, found: 273.1052. Elemental analysis: calcd. C 70.06, H 6.98, O 11.67, P 11.29, found C 70.23, H 7.05, O 11.61, P 11.11. Known compound.

Bis(4-biphenyl)phosphinic acid, sodium salt (2d)[4]



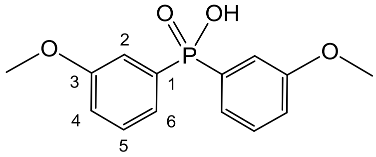
Off-grey solid that was isolated as the sodium salt due to lower solubility during work up. Yield: 1.63 g (4.15 mmol, 83%). ^{1}H NMR (500.2 MHz, [D$_4$]MeOD): δ 7.87 (m, 4H; *o*-PAr*H*), 7.61 (m, 8H; *m*-PAr*H* and *o'*-PAr*H*), 7.41 (m, 4H; *m'*-PAr*H*), 7.32 (m, 2H; *p'*-PAr*H*). ^{13}C{^{1}H} NMR (125.8 MHz, [D$_4$]MeOD): 144.1 (d, ^{4}J(C,P) = 2.7 Hz; *p*-PAr*C*), 142.1 (s, *ipso'*-PAr*C*), 139.8 (d, ^{1}J(C,P) = 132.6 Hz; *ipso*-PAr*C*), 133.1 (d, ^{2}J(C,P) = 10.0 Hz; *o*-PAr*C*), 130.0 (s; *m'*-PAr*C*), 128.8 (s; *o'*-PAr*C*), 128.3 (s; *p'*-PAr*C*), 127.6 (d, ^{3}J(C,P) = 11.8 Hz; *m*-PAr*C*). ^{31}P{^{1}H} NMR (162.0 MHz, [D$_4$]MeOD): δ 20.1 (s). HR ESI-MS: calcd for $C_{24}H_{18}O_2P^-$ (M-Na)$^-$: 369.1050, found: 369.1040. Elemental analysis confirmed the presence of Na. New compound.

Bis(4-methoxyphenyl)phosphinic acid (3e)[1]



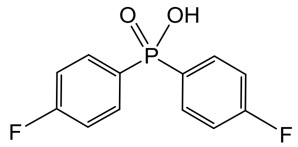
White solid. Yield: 183 mg (0.66 mmol, 66%). ^{1}H NMR (400.1 MHz, CDCl$_3$): δ 7.63 (~dd, ^{3}J(H,P) = 12.0 Hz, ^{3}J(H,H) = 9.0 Hz, 4H; *o*-PAr*H*), 6.85 (~dd, ^{3}J(H,H) = 9.0 Hz, ^{4}J(H,P) = 2.0 Hz, 4H; *m*-PAr*H*), 3.8 (s, 6H; C*H*$_3$). ^{13}C{^{1}H} NMR (125.8 MHz, [D$_6$]DMSO) δ 161.9 (d, ^{4}J(C,P) = 2.7 Hz; *p*-PAr*C*), 133.1 (d, ^{2}J(C,P) = 10.9 Hz; *o*-PAr*C*), 126.9 (d, ^{1}J(C,P) = 140.8 Hz; *ipso*-PAr*C*), 114.2 (d, ^{3}J(C,P) = 13.6 Hz; *m*-PAr*C*), 55.6 (s; *C*H$_3$). ^{31}P{^{1}H} NMR (162.0 MHz, [D$_1$]AcOD): δ 27.0(s). HR ESI-MS: calcd for $C_{16}H_{18}O_2P^-$(M-H)$^-$: 277.0635, found: 277.0635. Known compound.

Bis(3-methoxyphenyl)phosphinic acid (3f)[5]



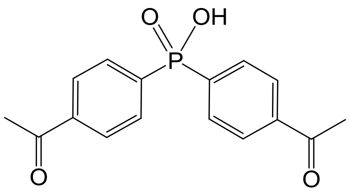
White solid. Yield: 0.85 g (3.05 mmol, 61%). ^{1}H NMR (500.2 MHz, [D$_6$]DMSO) δ 7.39 (td, ^{3}J(H,H) = 7.8 Hz, ^{4}J(H,P) = 4.3 Hz, 2H; *m*-PAr*H*), 7.25 (m, 4H; *o*-PAr*H*), 7.08 (dd, ^{3}J(H,H) = 8.2 Hz, ^{4}J(H,P) = 2.2 Hz, 2H; *p*-PAr*H*), 3.76 (s, 6H; C*H*$_3$). ^{13}C{^{1}H} NMR (125.8 MHz, [D$_6$]DMSO) δ 159.4 (d, ^{3}J(C,P) = 15.4 Hz; *m3*-PAr*C*), 136.9 (d, ^{1}J(C,P) = 134.4 Hz; *ipso*-PAr*C*), 130.3 (d, ^{3}J(C,P) = 15.4 Hz; *m5*-PAr*C*), 123.6 (d, ^{2}J(C,P) = 10.0 Hz; *o2*-PAr*C*), 117.5 (d, ^{4}J(C,P) = 2.7 Hz; *p*-PAr*C*), 116.4 (d, ^{2}J(C,P) = 10.9 Hz; *o6*-PAr*C*), 55.7 (s; *C*H$_3$). ^{31}P{^{1}H} NMR (162.0 MHz, [D$_6$]DMSO): δ 22.8 (s). HR ESI-MS: calcd for $C_{14}H_{14}O_4P^-$(M-H)$^-$: 277.0635, found: 277.0646. Known compound.

Bis(4-fluorophenyl)phosphinic acid (3g)[6]



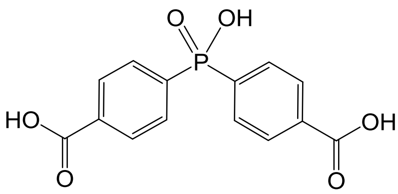
White solid. Yield: 1.03 g (4.05 mmol, 81%). ^{1}H NMR (500.2 MHz, [D$_6$]DMSO): δ 7.79 (ddd, ^{3}J(H,P) = 11.5 Hz, ^{3}J(H,H) = 9.0 Hz, ^{4}J(H,F) = 5.0 Hz, 4H; *o*-PAr*H*), 7.31 (td, ^{3}J(H,H) = ^{3}J(H,F) = 9.0 Hz, ^{4}J(H,P) = 2.0 Hz, 4H; *m*-PAr*H*). ^{13}C{^{1}H} NMR (125.8 MHz, [D$_6$]DMSO): 164.5 (dd, ^{1}J(C,P) = 249.7 Hz, ^{4}J(C,F) = 3.6 Hz; *ipso*-PAr*C*), 134.2 (dd, ^{2}J(C,P) = 10.9 Hz, ^{3}J(C,F) = 9.1 Hz; *o*-PAr*C*), 131.6 (dd, ^{1}J(C,F) = 139.0 Hz, ^{4}J(C,P) = 3.6 Hz; *p*-PAr*C*), 116.1 (dd, ^{2}J(C,F) = 21.8 Hz, ^{3}J(C,P) = 13.6 Hz; *m*-PAr*C*). ^{31}P{^{1}H} NMR (162.0 MHz, [D$_6$]DMSO): δ 21.6 (s). HR ESI-MS: calcd for $C_{12}H_8O_2PF_2^-$ (M-H)$^-$: 253.0235, found: 253.0233. Elemental analysis: calcd. C 56.71, H 3.57, P 12.19, found C 56.27, H 3.79, P 12.07. Known compound.

Bis(4-acetylphenyl)phosphinic acid (3h)[7]



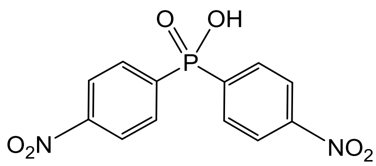
White solid. Yield: 0.98 g (3.25 mmol, 65%). ^{1}H NMR (500.2 MHz, [D$_6$] DMSO) δ 8.02 (dd, ^{3}J(H,H) = 8.2 Hz, ^{4}J(H,P) = 2.8 Hz, 4H; *m*-PAr*H*), 7.87 (dd, ^{3}J(H,P) = 11.7 Hz, ^{3}J(H,H) = 8.2 Hz, 4H; *o*-PAr*H*), 2.58 (s, 6H; C*H*$_3$).^{13}C{^{1}H} NMR (125.8 MHz, [D$_6$]DMSO) δ 198.3 (s; *C*=O), 139.7 (d, ^{1}J(C,P) = 132.6 Hz; *ipso*-PAr*C*), 139.3 (d, ^{4}J(C,P) = 2.7 Hz; *p*-PAr*C*), 131.8 (d, ^{2}J(C,P) = 10.9 Hz; *o*-PAr*C*), 128.6 (d, ^{3}J(C,P) = 12.7 Hz; *m*-PAr*C*), 27.4 (s; *C*H$_3$). ^{31}P{^{1}H} NMR (162.0 MHz, [D$_6$] DMSO): δ 21.2 (s). HR ESI-MS: calcd for $C_{16}H_{14}O_4P^-$ (M-H)$^-$: 301.0635, found: 301.0637. New compound.

4,4'-(hydroxyphosphoryl)dibenzoic acid (3i)[8]



White solid. Yield: 0.63 g (2.06 mmol, 41%) after hydrolysis from ethyl carboxylate diester. ^{1}H NMR (500.2 MHz, [D$_6$]DMSO) δ 8.02 (d, ^{3}J(H,H) = 8.2 Hz, unresolved fine coupling with P, 4H; *m*-PAr*H*), 7.86 (dd, ^{3}J(H,P) = 11.0 Hz, ^{3}J(H,H) = 8.2 Hz, 4H; *o*-PAr*H*). ^{13}C{^{1}H} NMR (125.8 MHz, [D$_6$]DMSO) δ 167.2 (s; *C*=O), 139.4 (d, ^{1}J(C,P) = 132.6 Hz; *ipso*-PAr*C*), 133.9 (m, unresolved fine coupling with P; *p*-PAr*C*), 131.7 (d, ^{2}J(C,P) = 10.0 Hz; *o*-PAr*C*), 129.7 (d, ^{3}J(C,P) = 12.7 Hz; *m*-PAr*C*). ^{31}P{^{1}H} NMR (162.0 MHz, [D$_6$]DMSO): δ 21.5 (s). HR ESI-MS: calcd for $C_{14}H_{10}O_6P^-$ (M-H)$^-$: 305.0220, found: 305.0225. Known compound.

Bis(4-nitrophenyl)phosphinic acid (3j)[9]



Yellow solid. Yield: 1.16 g (3.75 mmol, 75%). ^{1}H NMR (500.2 MHz, [D$_6$]DMSO) δ 8.30 (dd, ^{3}J(H,H) = 8.5 Hz, ^{4}J(H,P) = 1.6 Hz, 4H; *m*-PAr*H*), 8.00 (dd, ^{3}J(H,P) = 11.3 Hz, ^{3}J(H,H) = 8.5 Hz, 4H; *o*-PAr*H*). ^{13}C{^{1}H} NMR (125.8 MHz, [D$_6$]DMSO) δ 149.9 (d, ^{4}J(C,P) = 3.6 Hz; *p*-PAr*C*), 141.7 (d, ^{1}J(C,P) = 131.7 Hz; *ipso*-PAr*C*), 133.1 (d, ^{2}J(C,P) = 10.9 Hz; *o*-PAr*C*), 124.0 (d, ^{3}J(C,P) = 12.7 Hz; *m*-PAr*C*). ^{31}P{^{1}H} NMR (162.0 MHz, [D$_6$]DMSO): δ 18.3 (s). HR ESI-MS: calcd for $C_{12}H_8N_2O_6P^-$ (M-H)$^-$: 307.0125, found: 307.0125. Known compound.

6. ^{1}H, ^{13}C and ^{31}P spectra for compounds 2d and 3a-j.

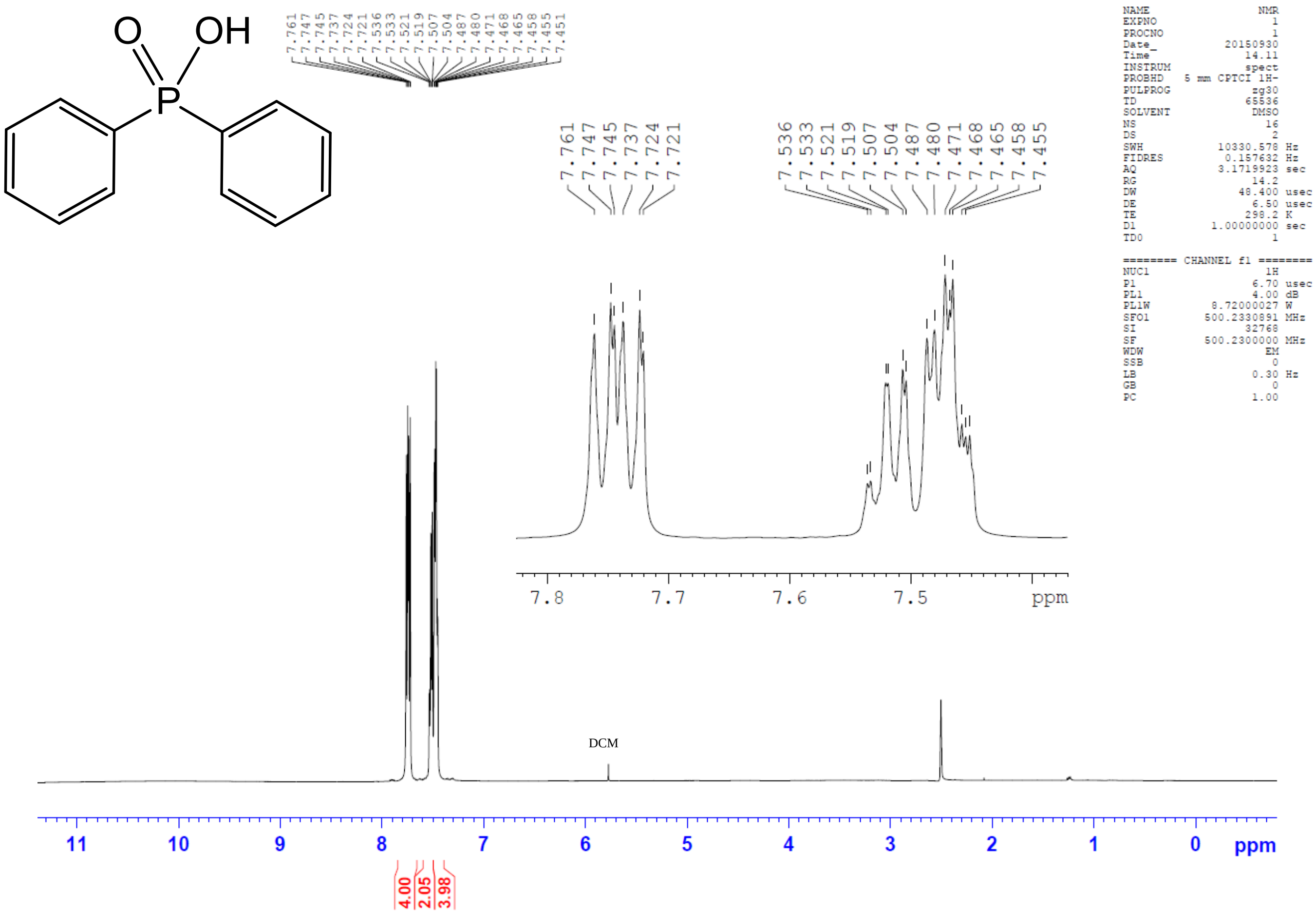


Figure S5) ^{1}H NMR spectrum (500.2 MHz, [D$_6$]DMSO) of **3a**

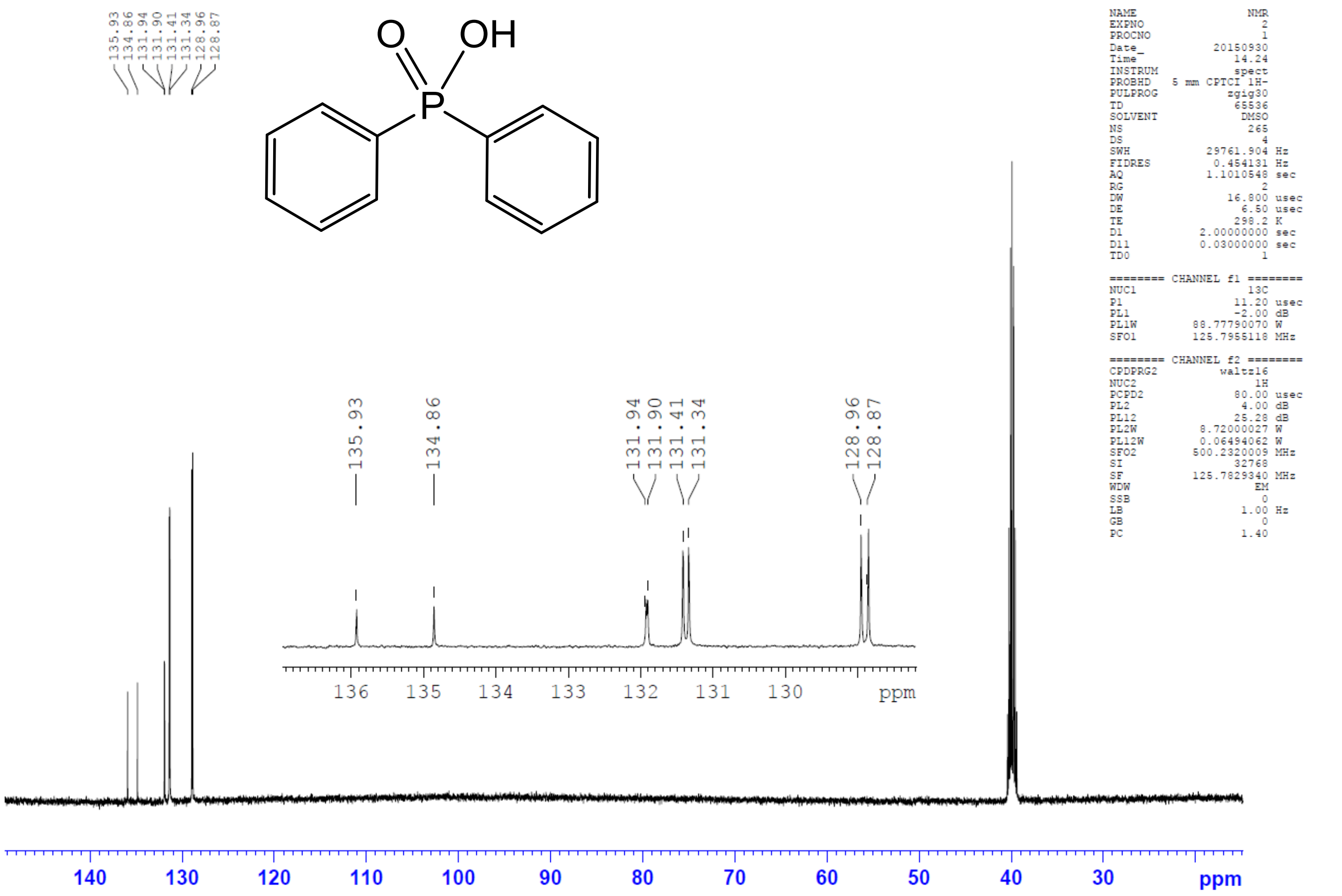


Figure 6) ^{13}C{^{1}H} NMR spectrum (125.8 MHz, [D$_6$]DMSO) of **3a**

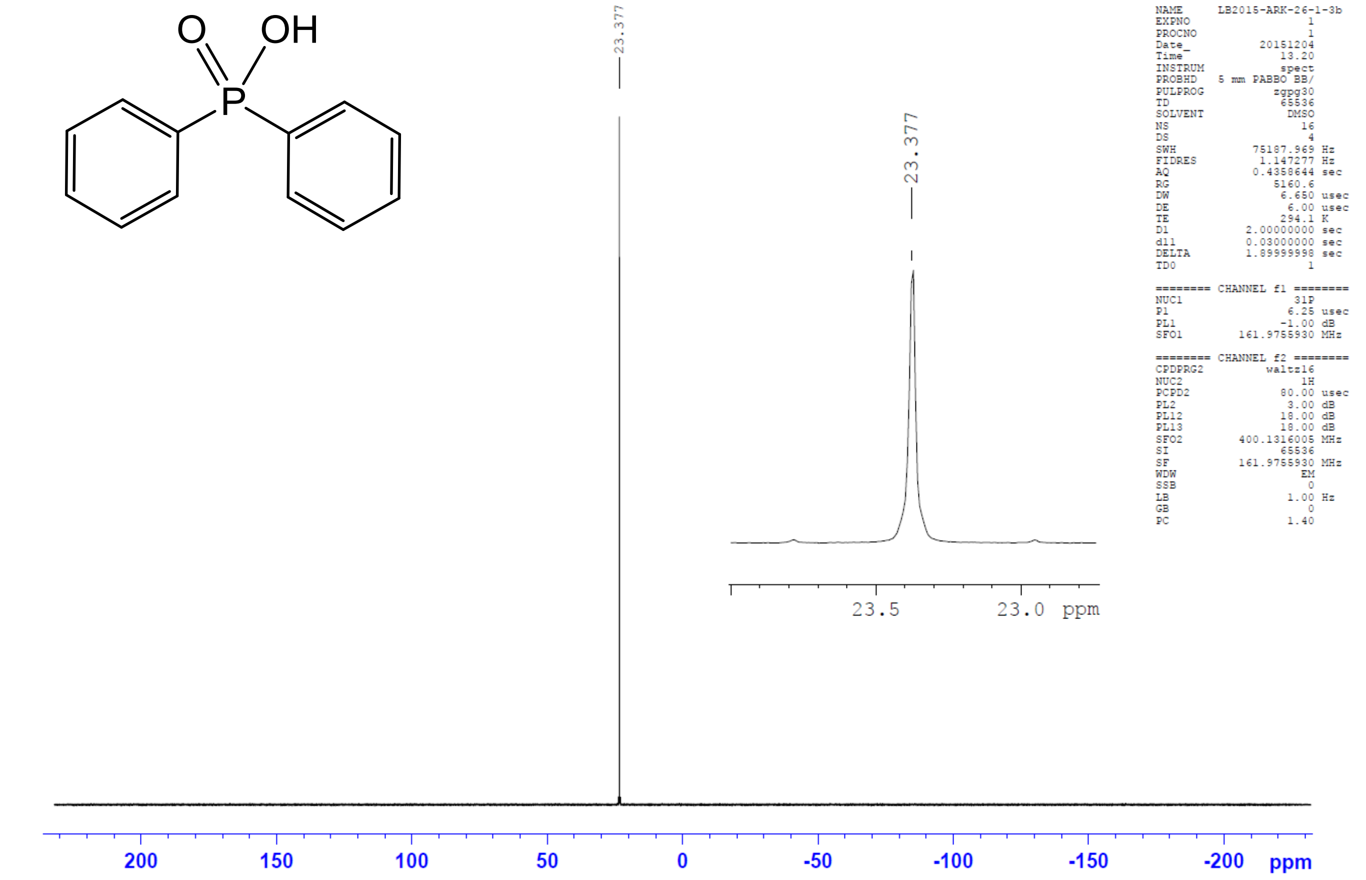


Figure S7) $^{31}P\{^{1}H\}$ NMR spectrum (162.0 MHz, [D$_6$]DMSO) of **3a**

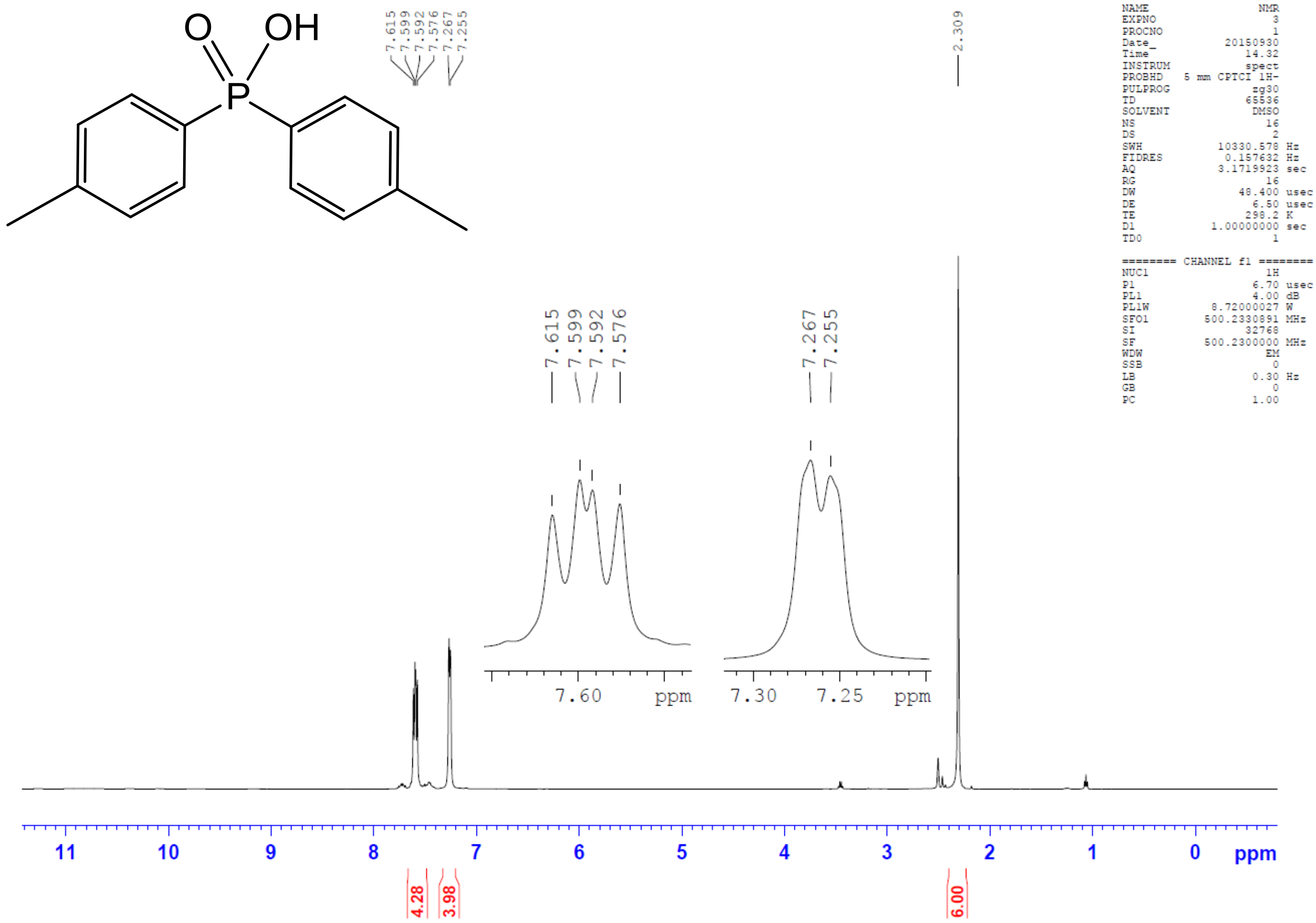


Figure S8) ^{1}H NMR spectrum (500.2 MHz, [D$_6$]DMSO) of **3b**

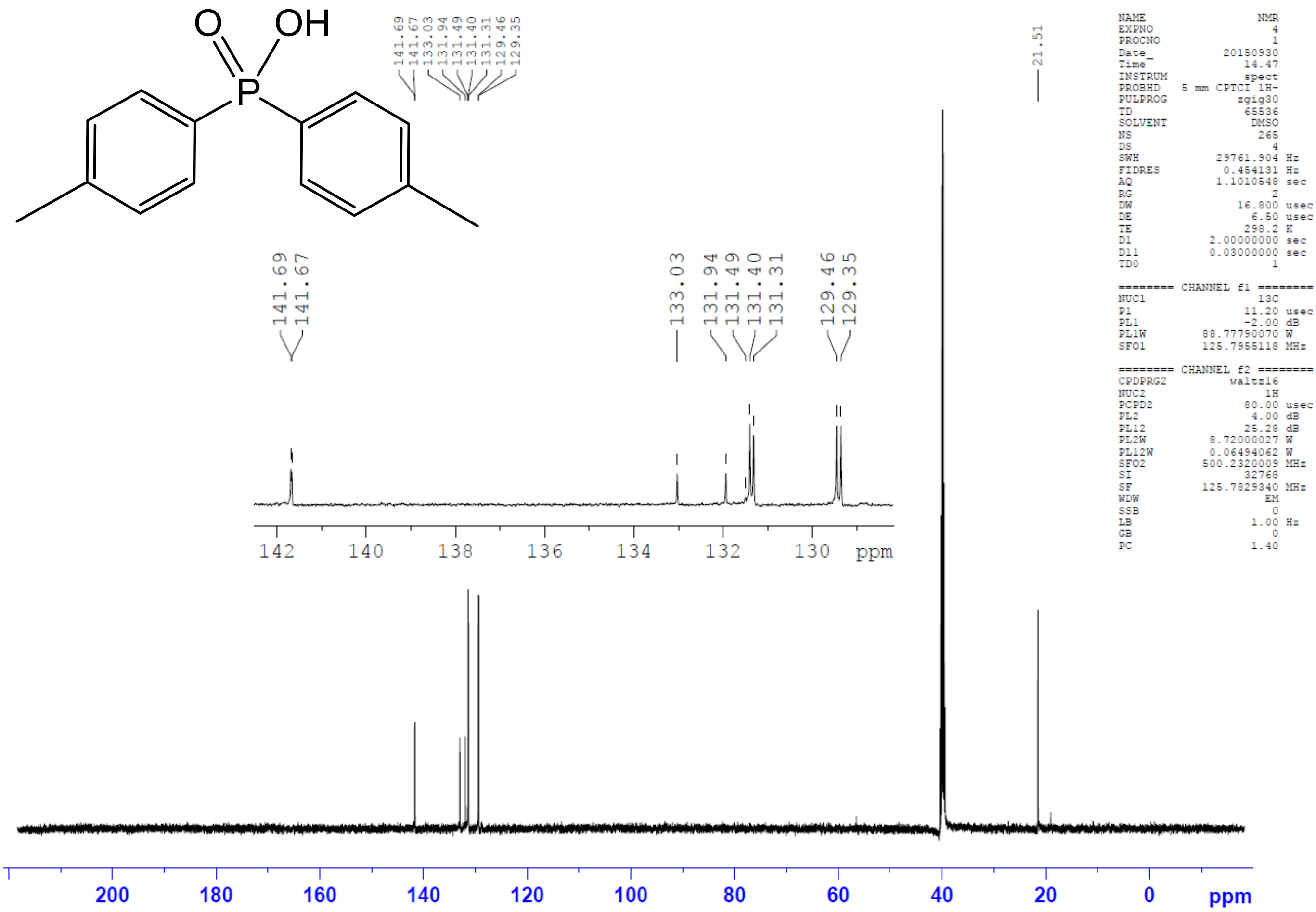


Figure S9) $^{13}C\{^{1}H\}$ NMR spectrum (125.8 MHz, [D$_6$]DMSO) of **3b**

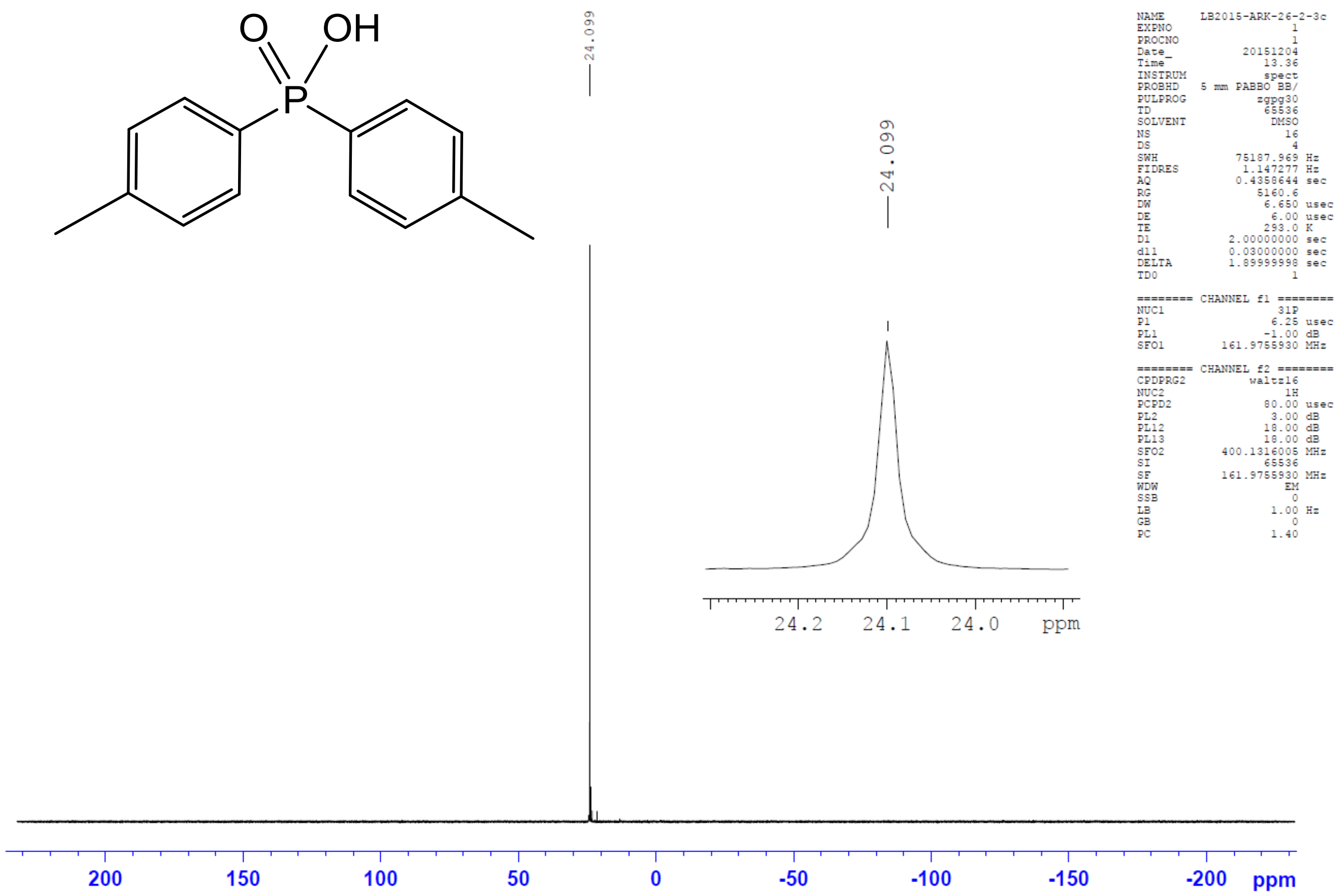


Figure S10) $^{31}P\{^{1}H\}$ NMR spectrum (162.0 MHz, [D$_6$]DMSO) of **3b**

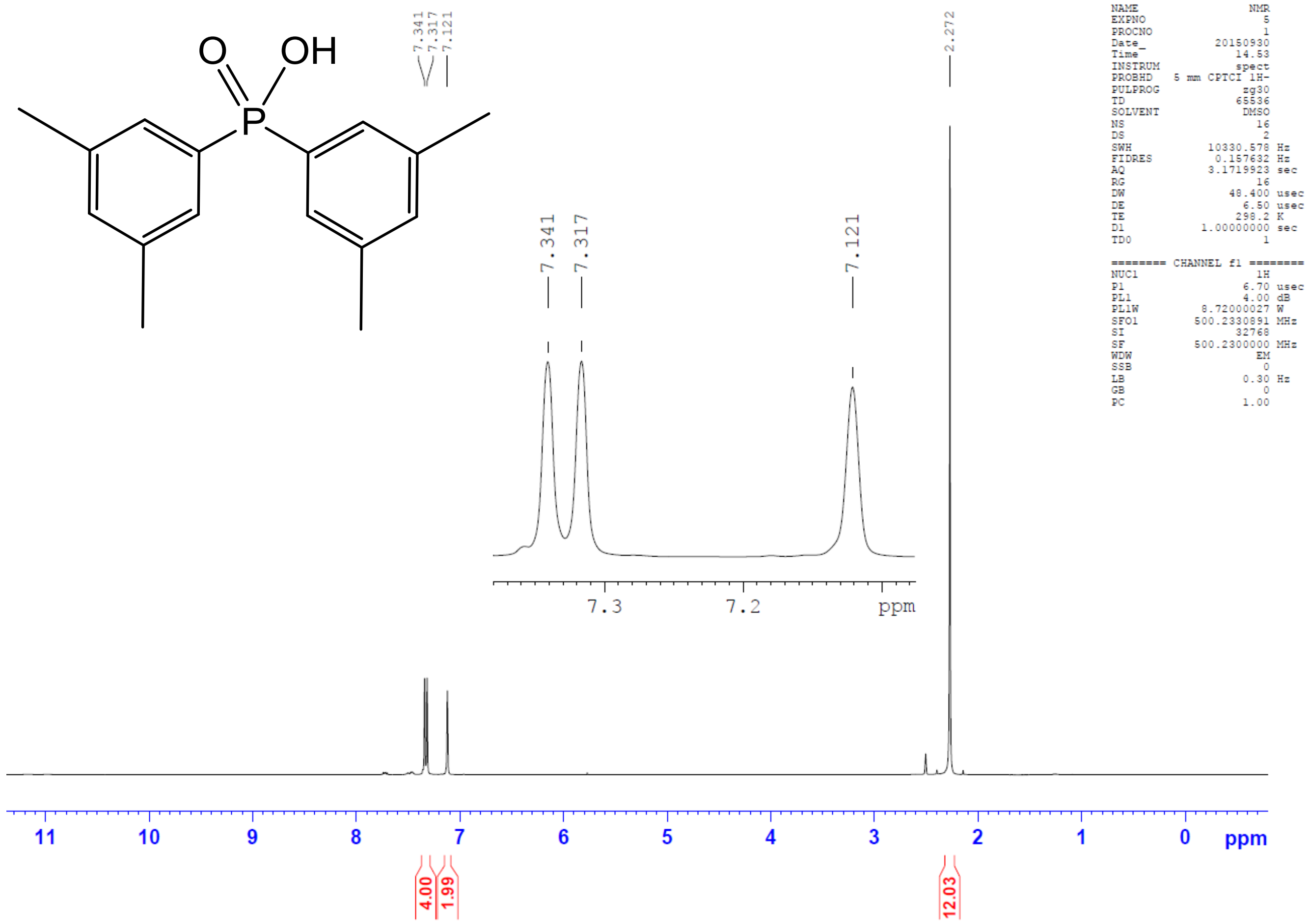


Figure S11) [1]H NMR spectrum (500.2 MHz, [D_6]DMSO) of **3c**

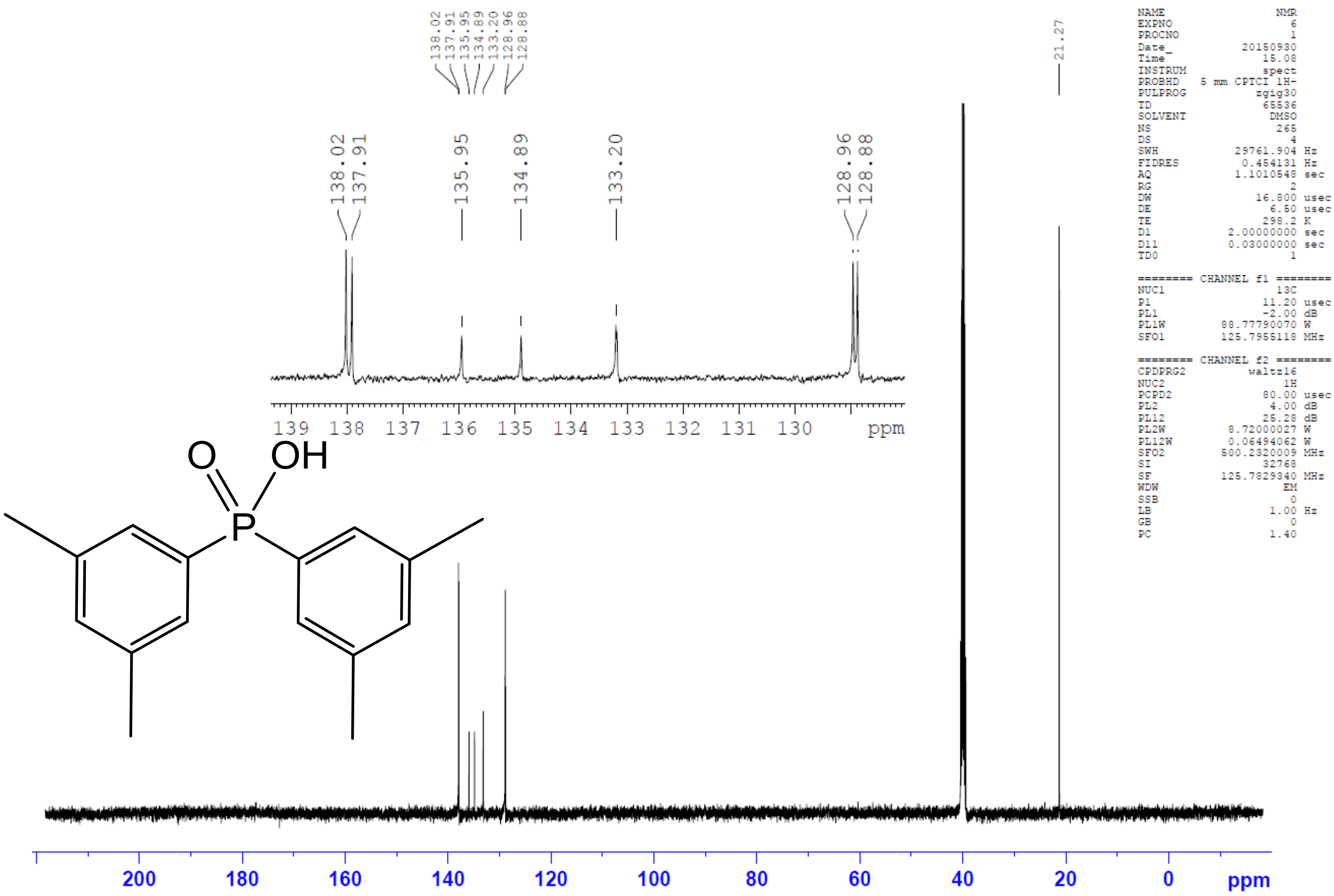


Figure S12) $^{13}C\{^1H\}$ NMR spectrum (125.8 MHz, [D_6]DMSO) of **3c**

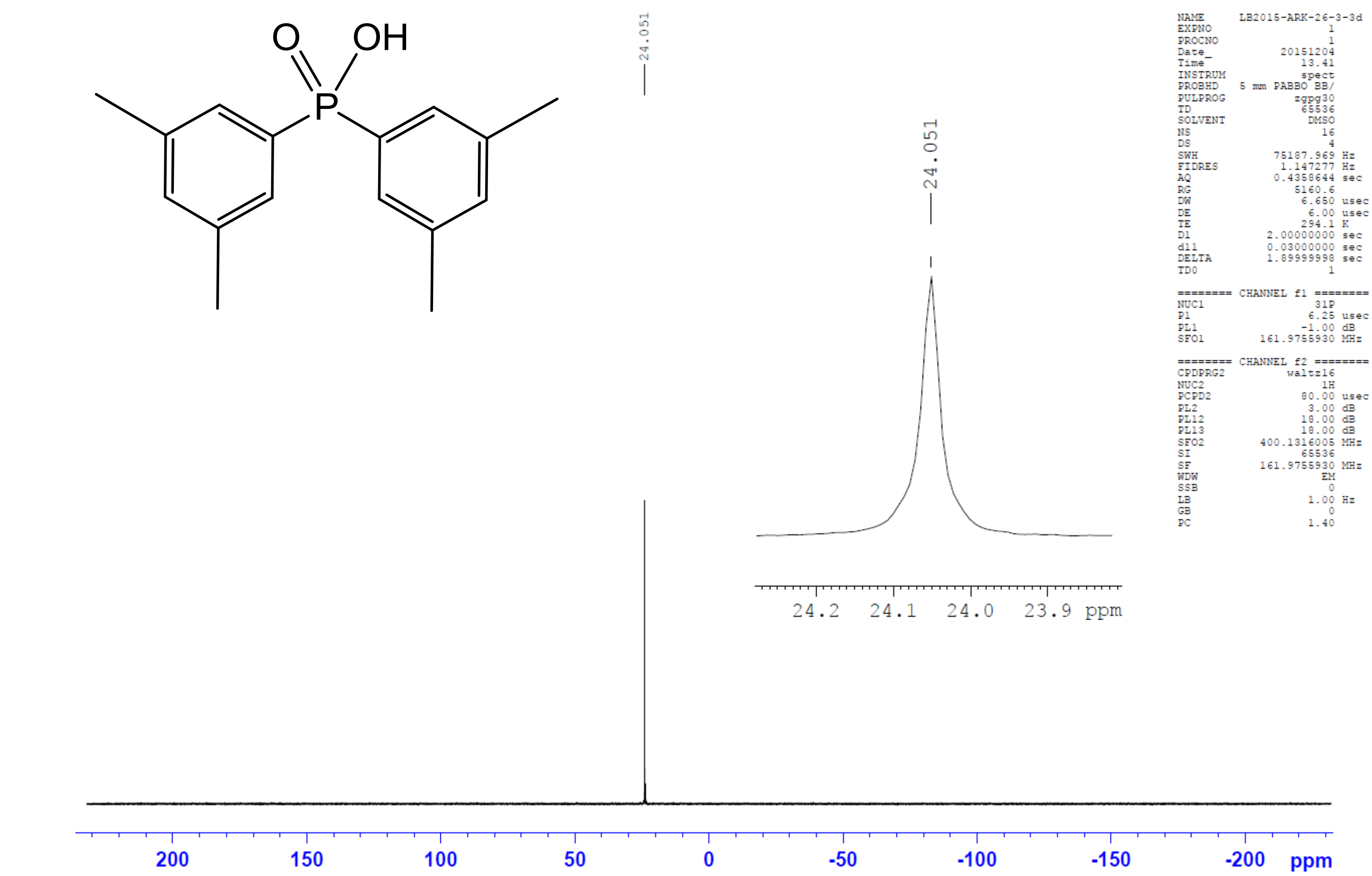


Figure S13) $^{31}P\{^{1}H\}$ NMR spectrum (162.0 MHz, $[D_6]$DMSO) of **3c**

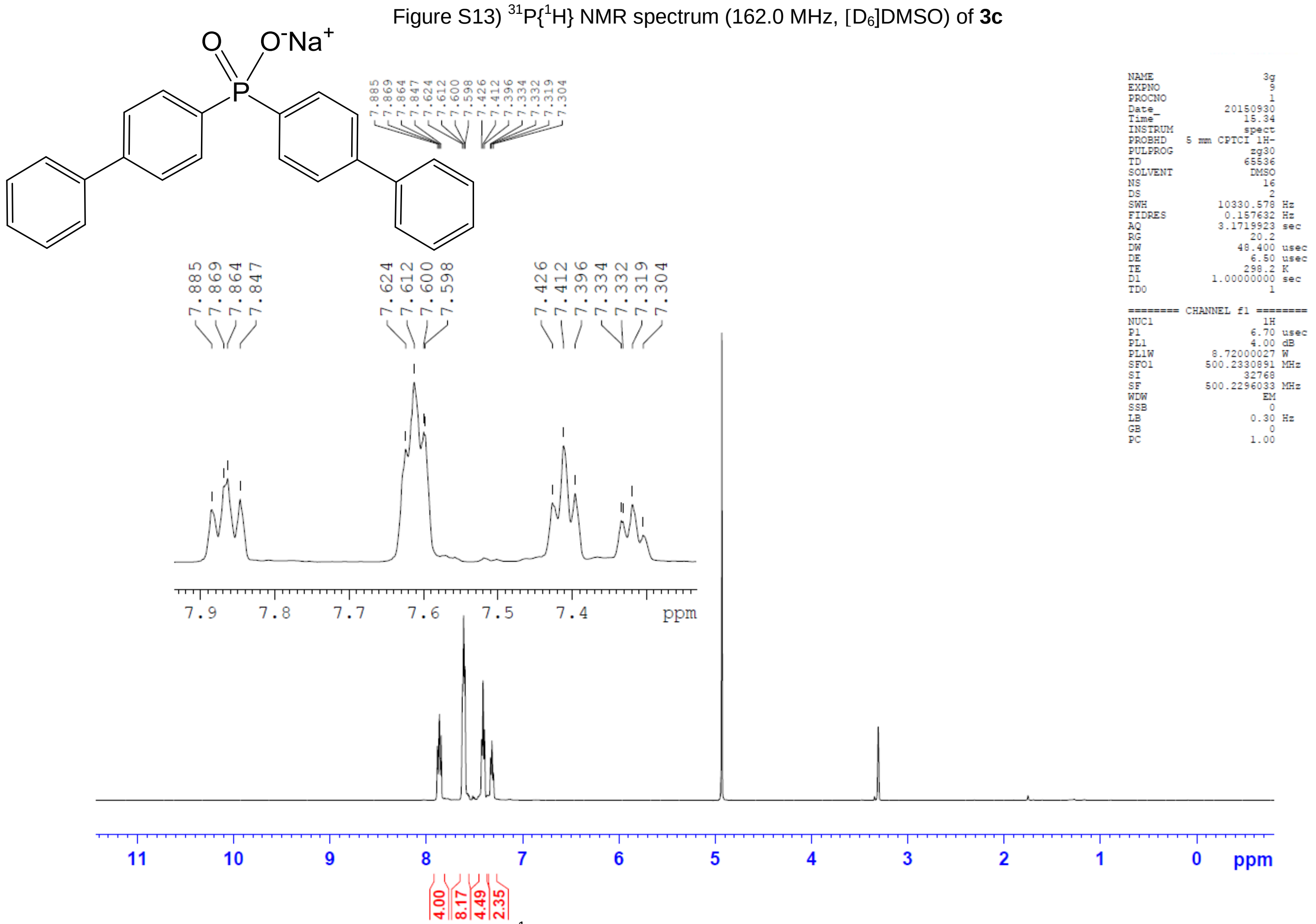


Figure S14) ^{1}H NMR spectrum (500.2 MHz, $[D_4]$methanol) of **2d**

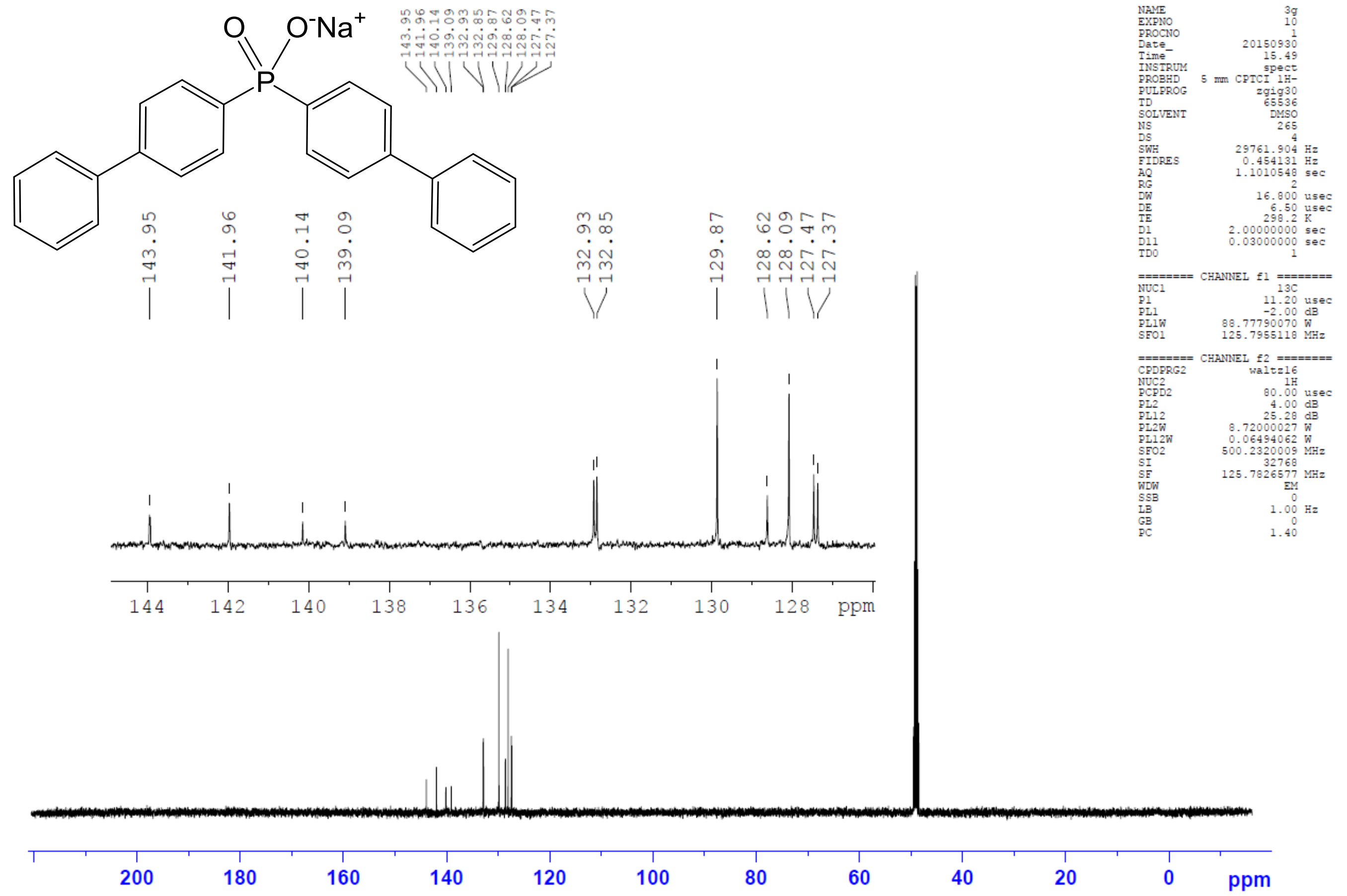


Figure S15) $^{13}C\{^{1}H\}$ NMR spectrum (125.8 MHz, [D$_4$]methanol) of **2d**

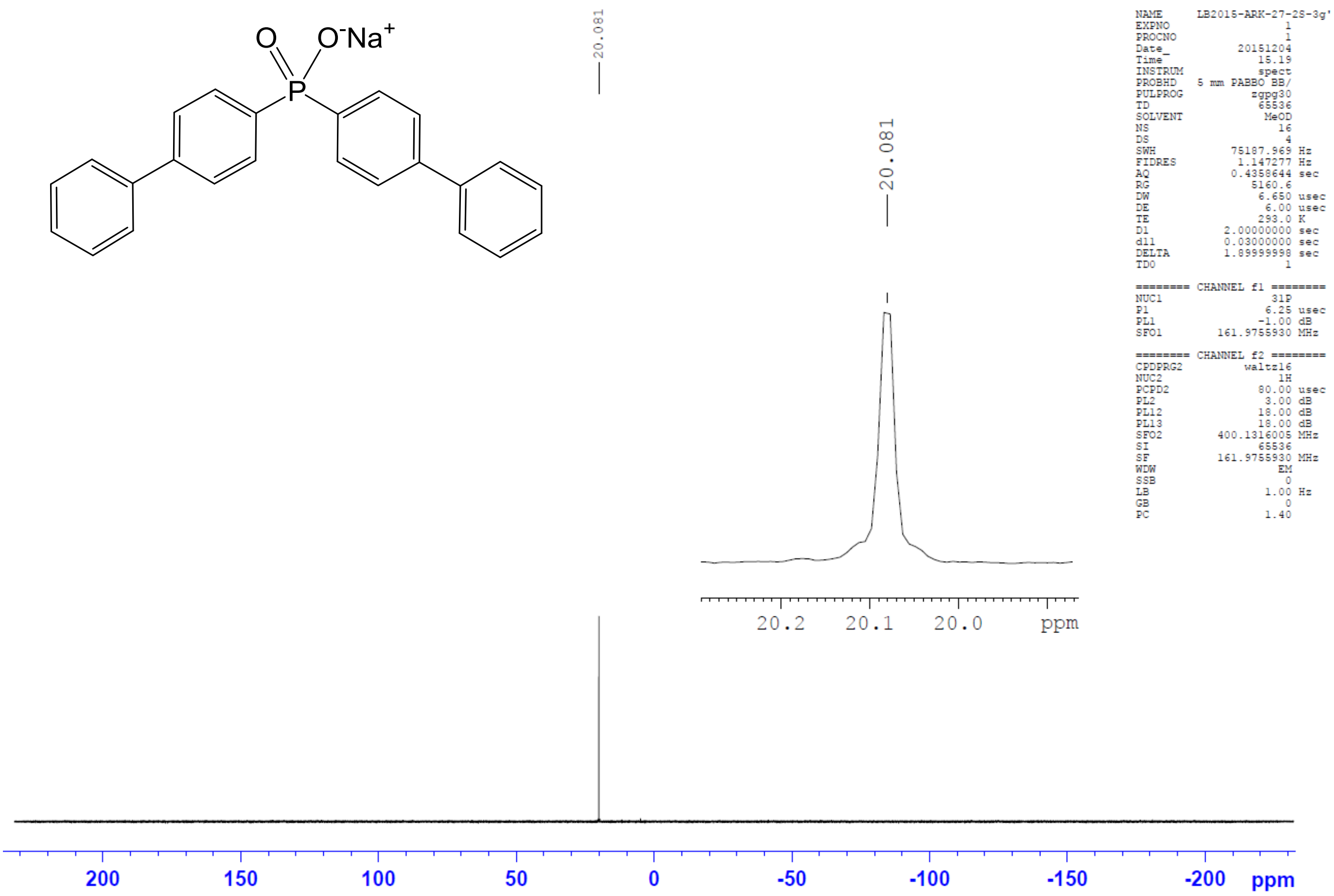


Figure S16) $^{31}P\{^{1}H\}$ NMR spectrum (162.0 MHz, [D$_4$]methanol) of **2d**

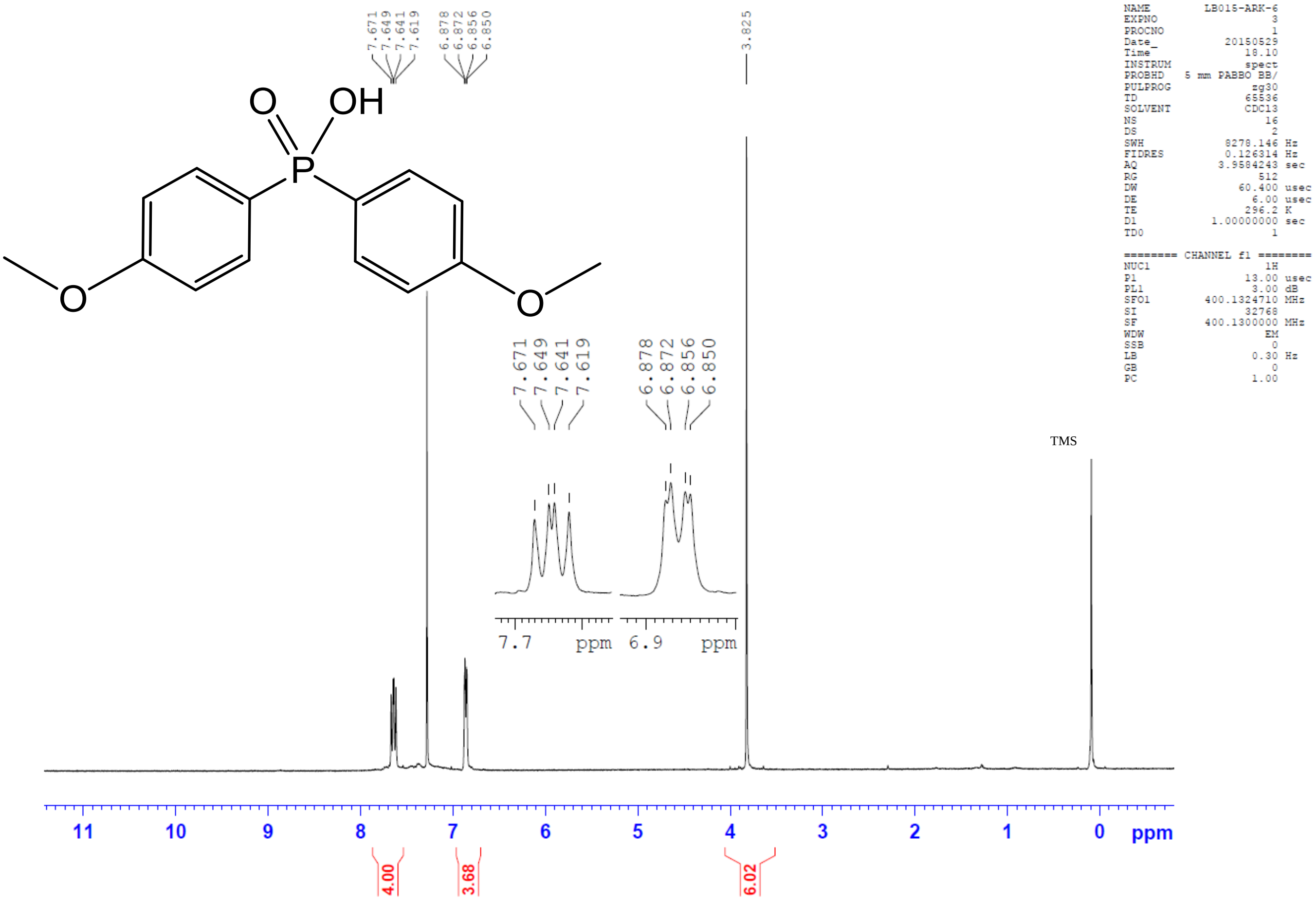


Figure S17) ^{1}H NMR spectrum (400.1 MHz, $CDCl_3$) of **3e**

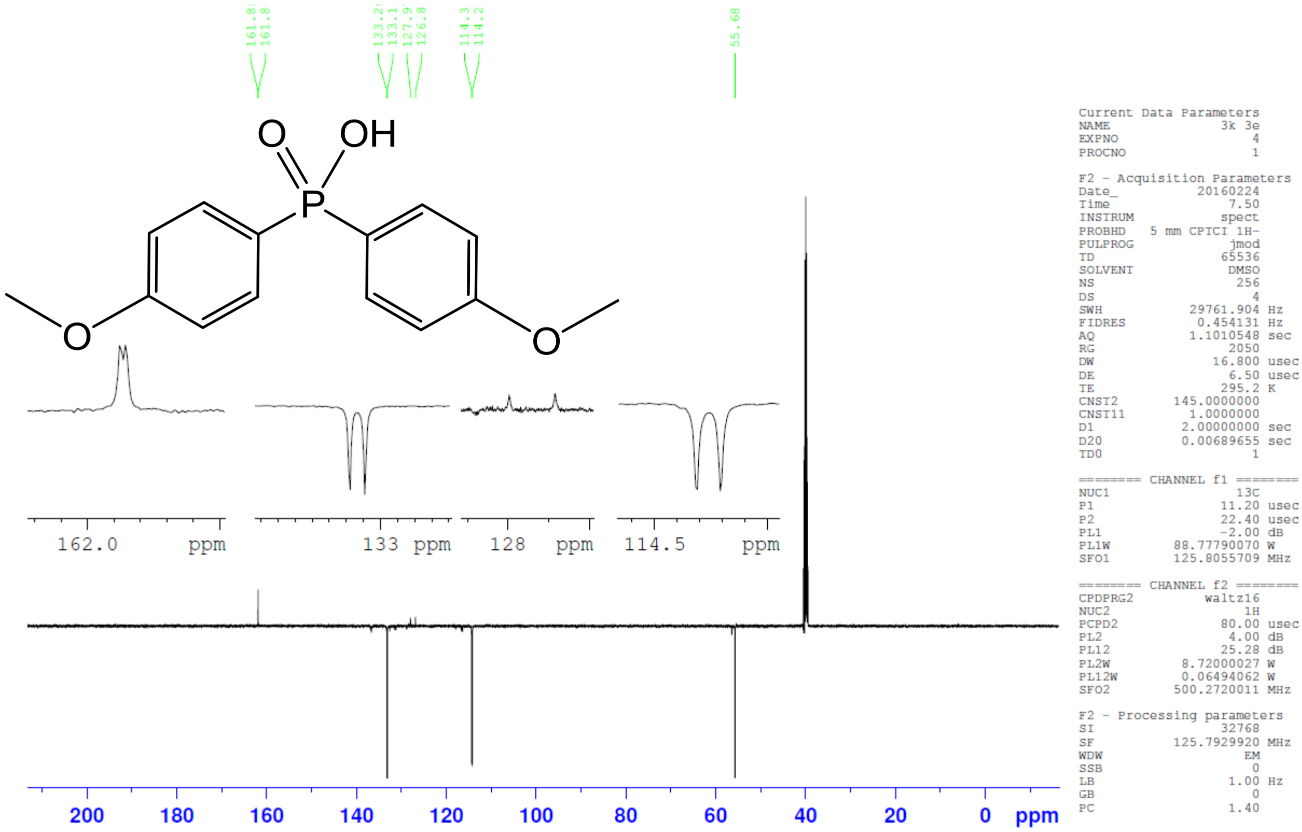


Figure S18) $^{13}C\{^{1}H\}$ J-MOD NMR spectrum (125.8 MHz, [D_6]DMSO) of **3e**

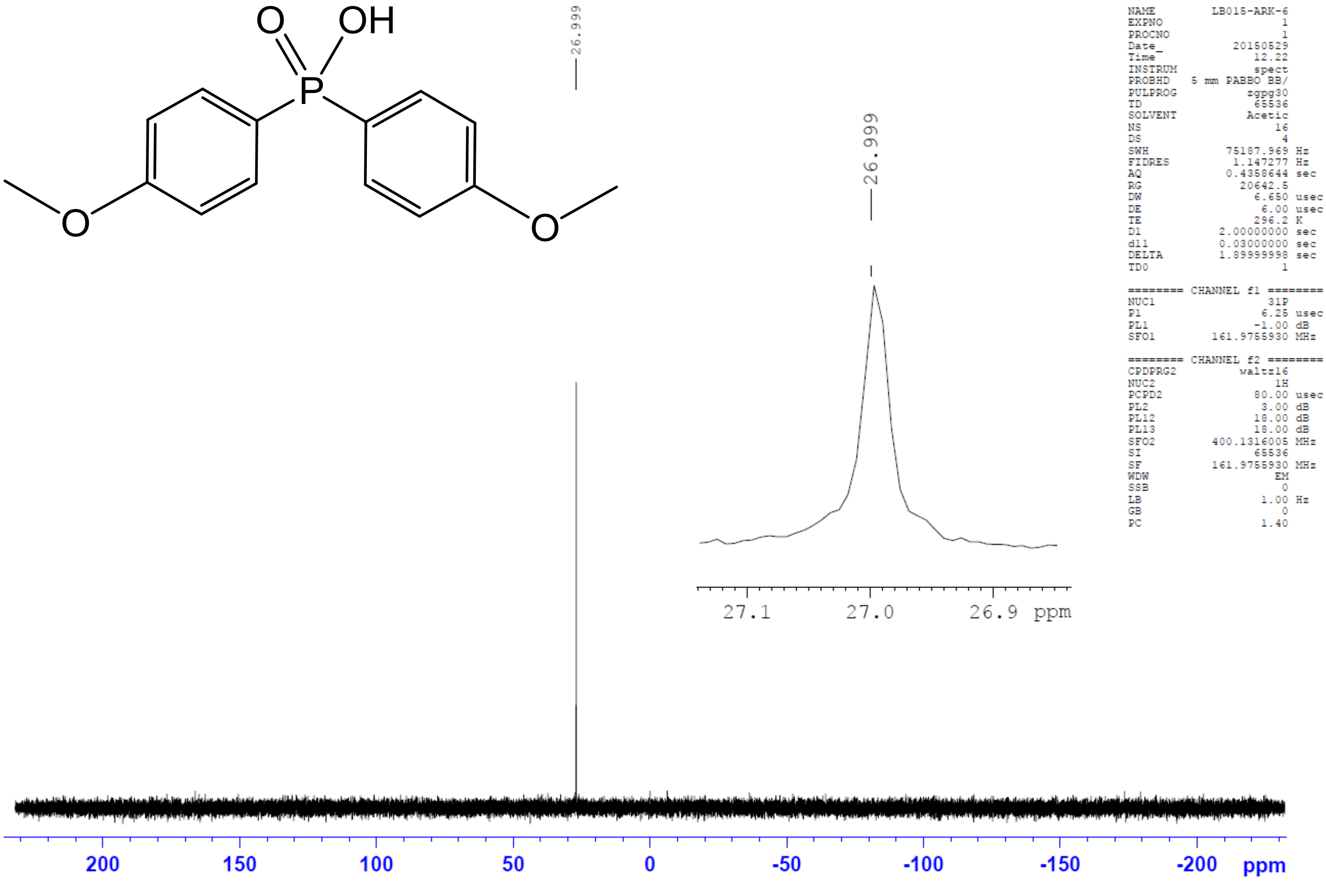


Figure S19) $^{31}P\{^{1}H\}$ NMR spectrum (162.0 MHz, [D$_1$]acetic acid) of **3e**

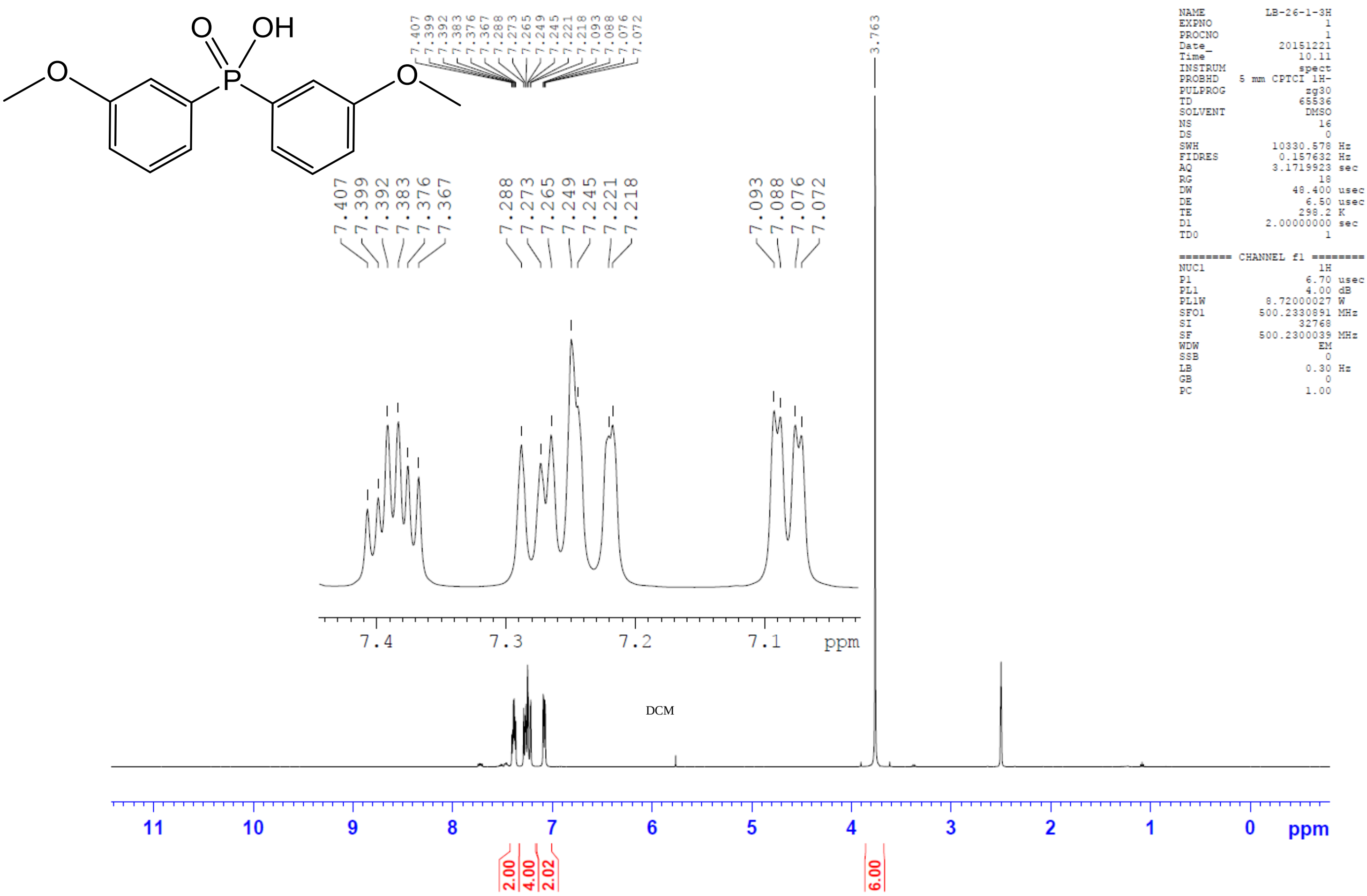


Figure S20) ^{1}H NMR spectrum (500.2 MHz, [D$_6$]DMSO) of **3f**

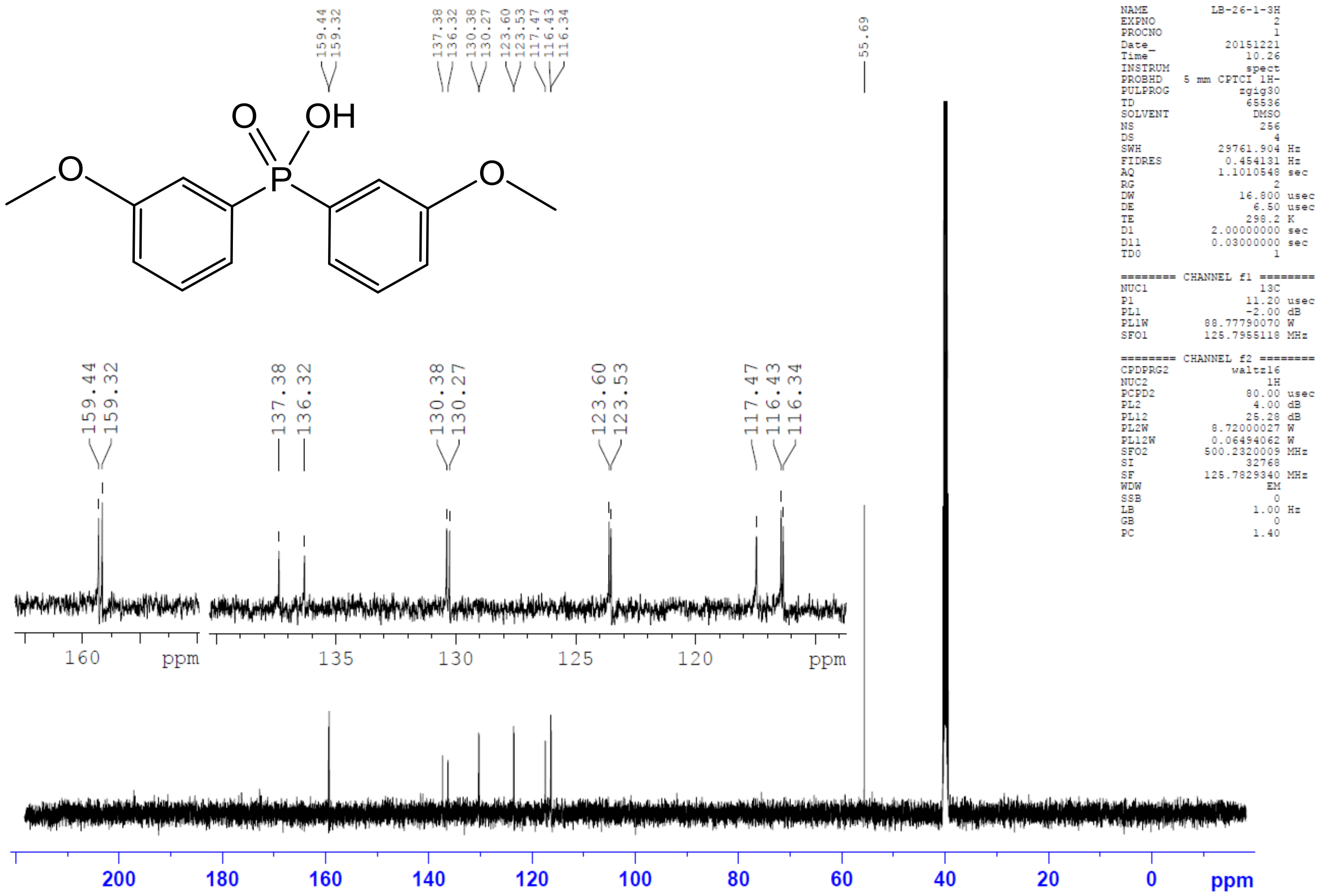


Figure S21) $^{13}C\{^{1}H\}$ NMR spectrum (125.8 MHz, [D$_6$]DMSO) of **3f**

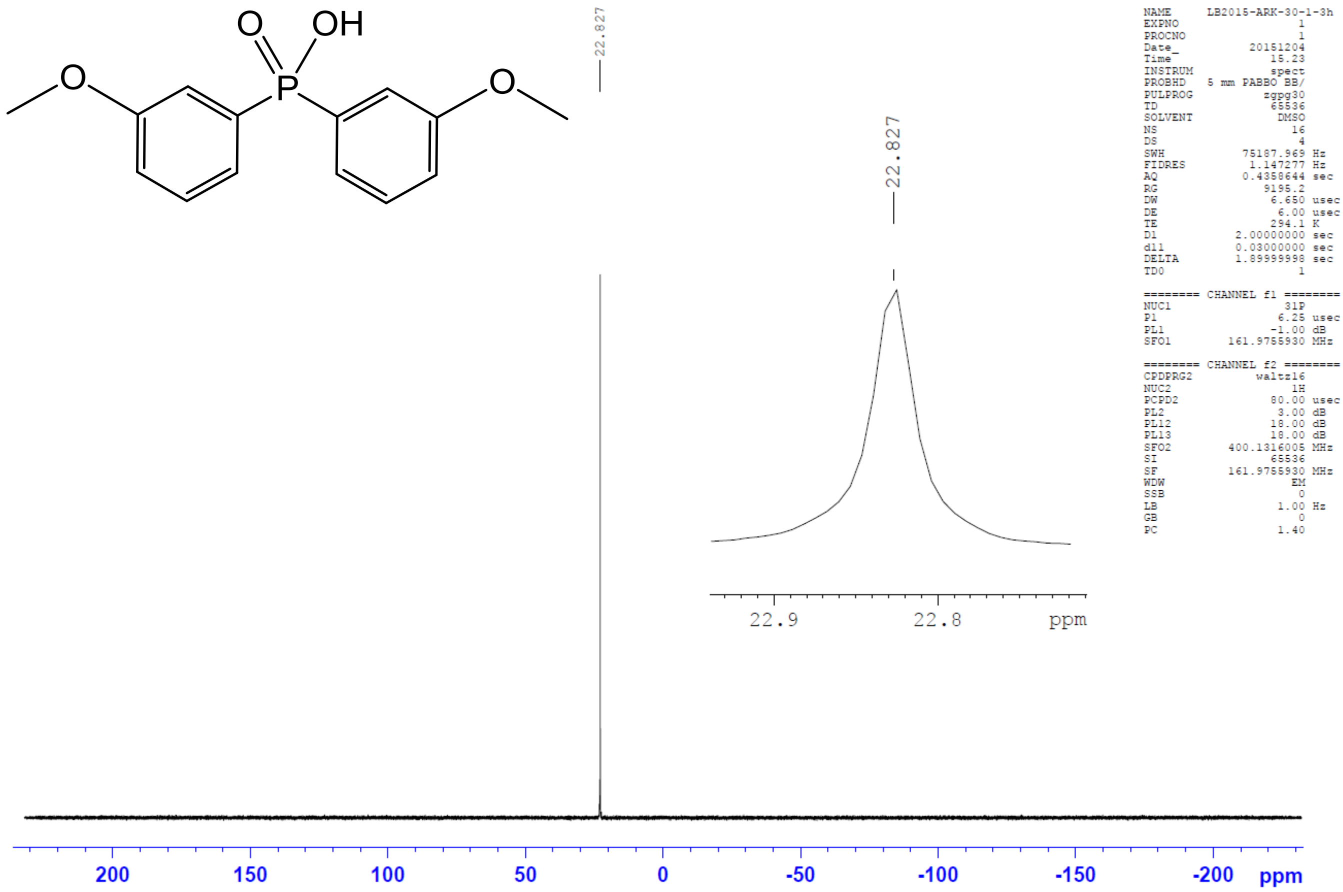


Figure S22) $^{31}P\{^{1}H\}$ NMR spectrum (162.0 MHz, [D$_6$]DMSO) of **3f**

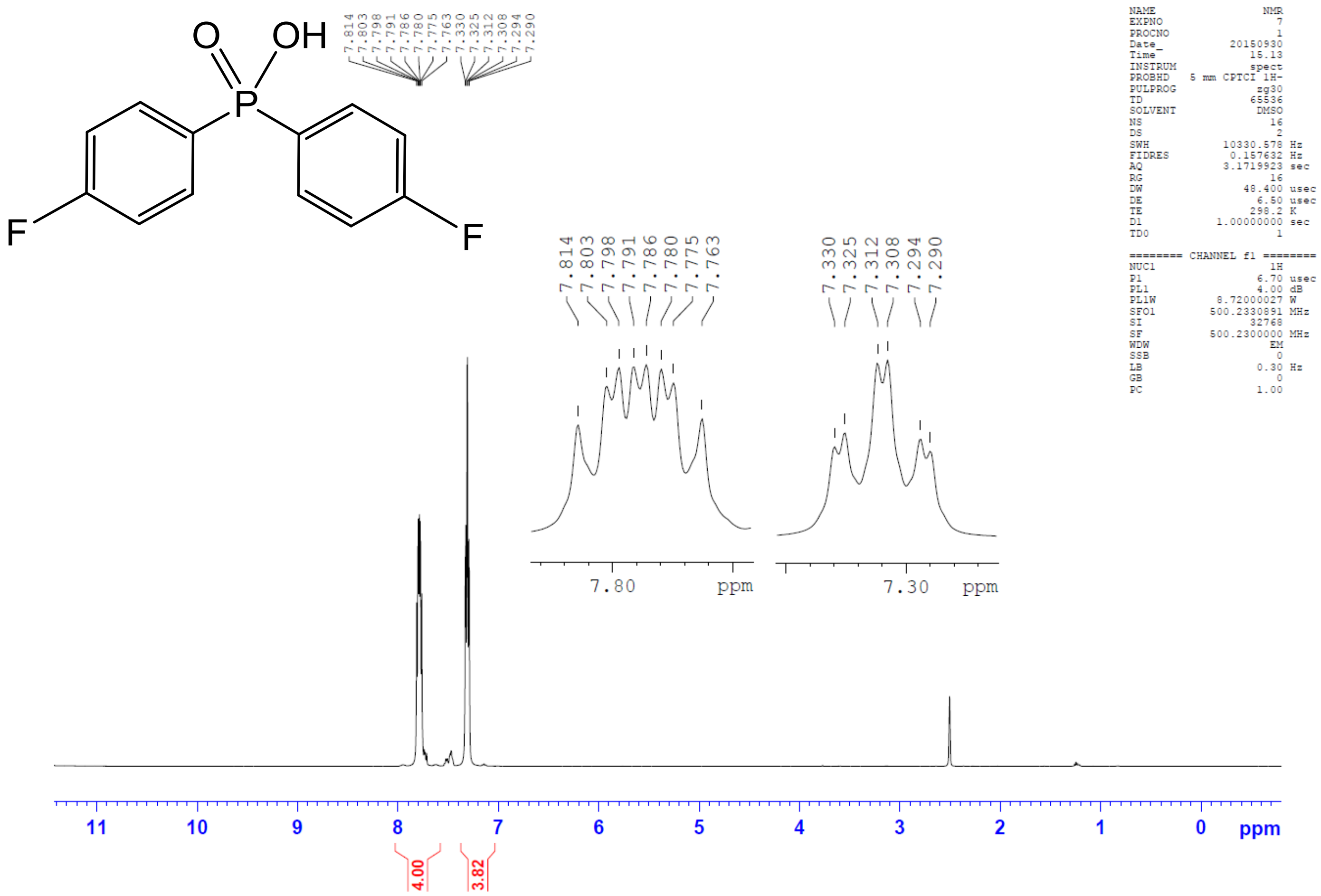


Figure S23) [1]H NMR spectrum (500.2 MHz, [D$_6$]DMSO) of **3g**

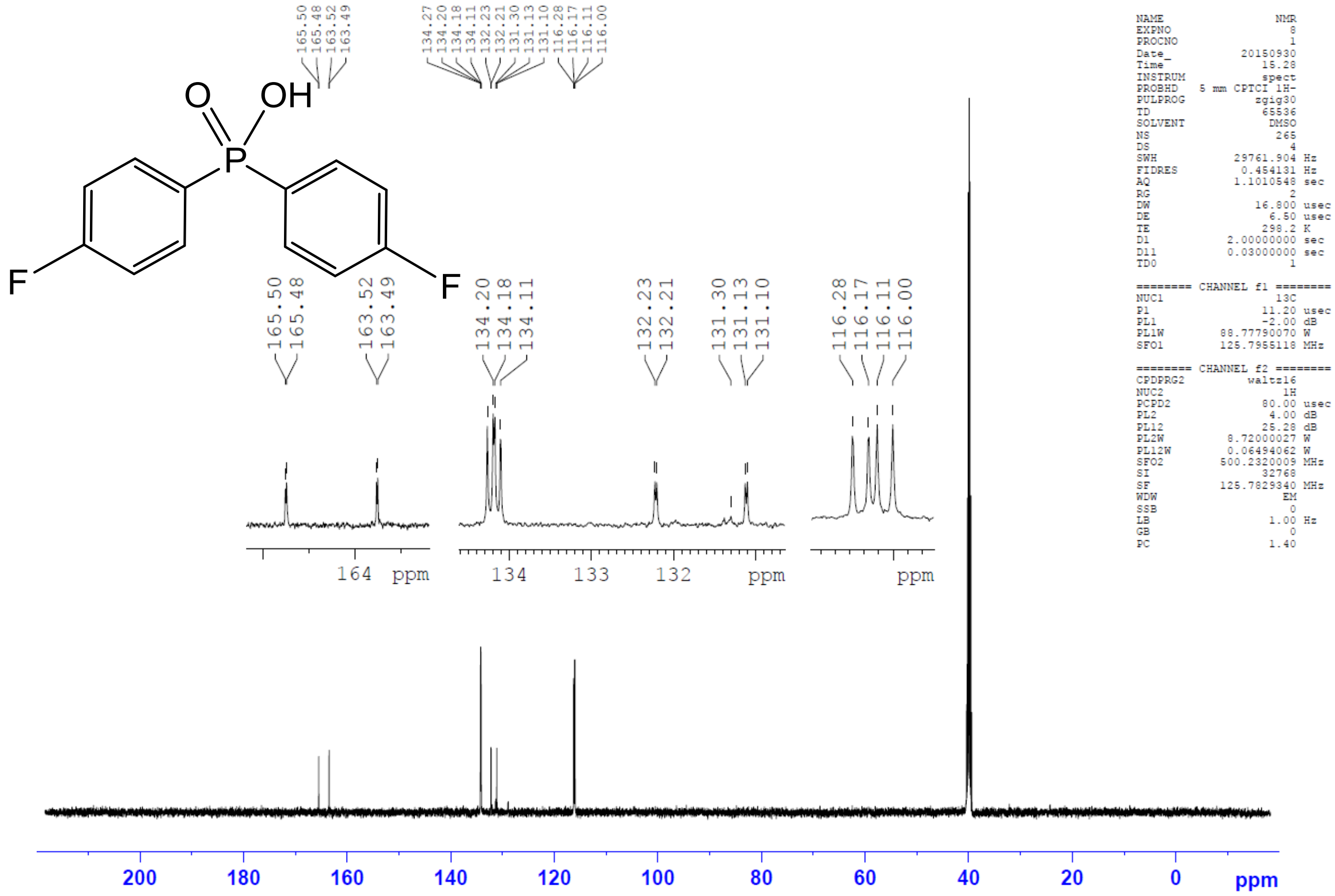


Figure S24) $^{13}C\{^1H\}$ NMR spectrum (125.8 MHz, [D$_6$]DMSO) of **3g**

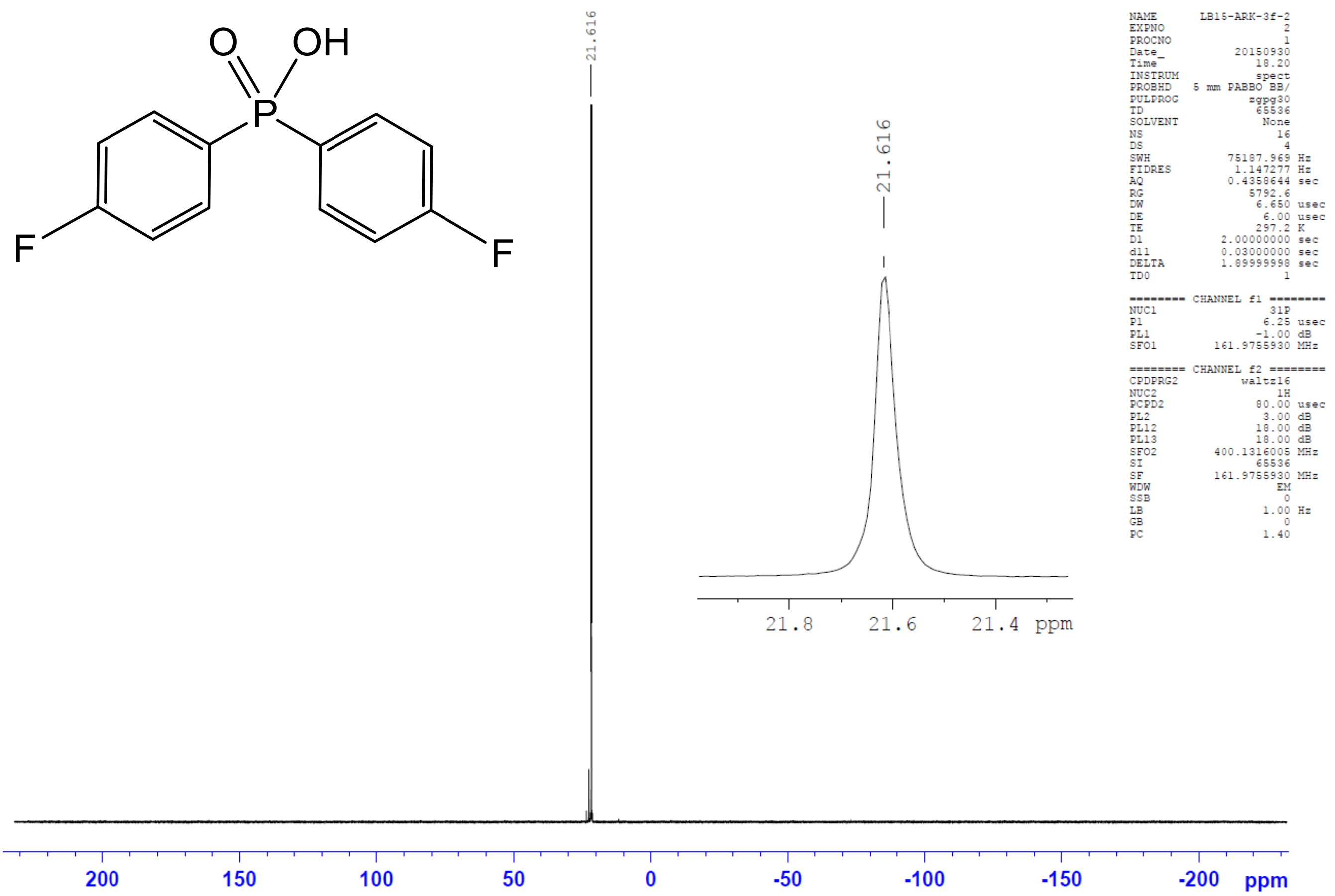


Figure S25) $^{31}P\{^{1}H\}$ NMR spectrum (162.0 MHz, [D$_6$]DMSO) of **3g**

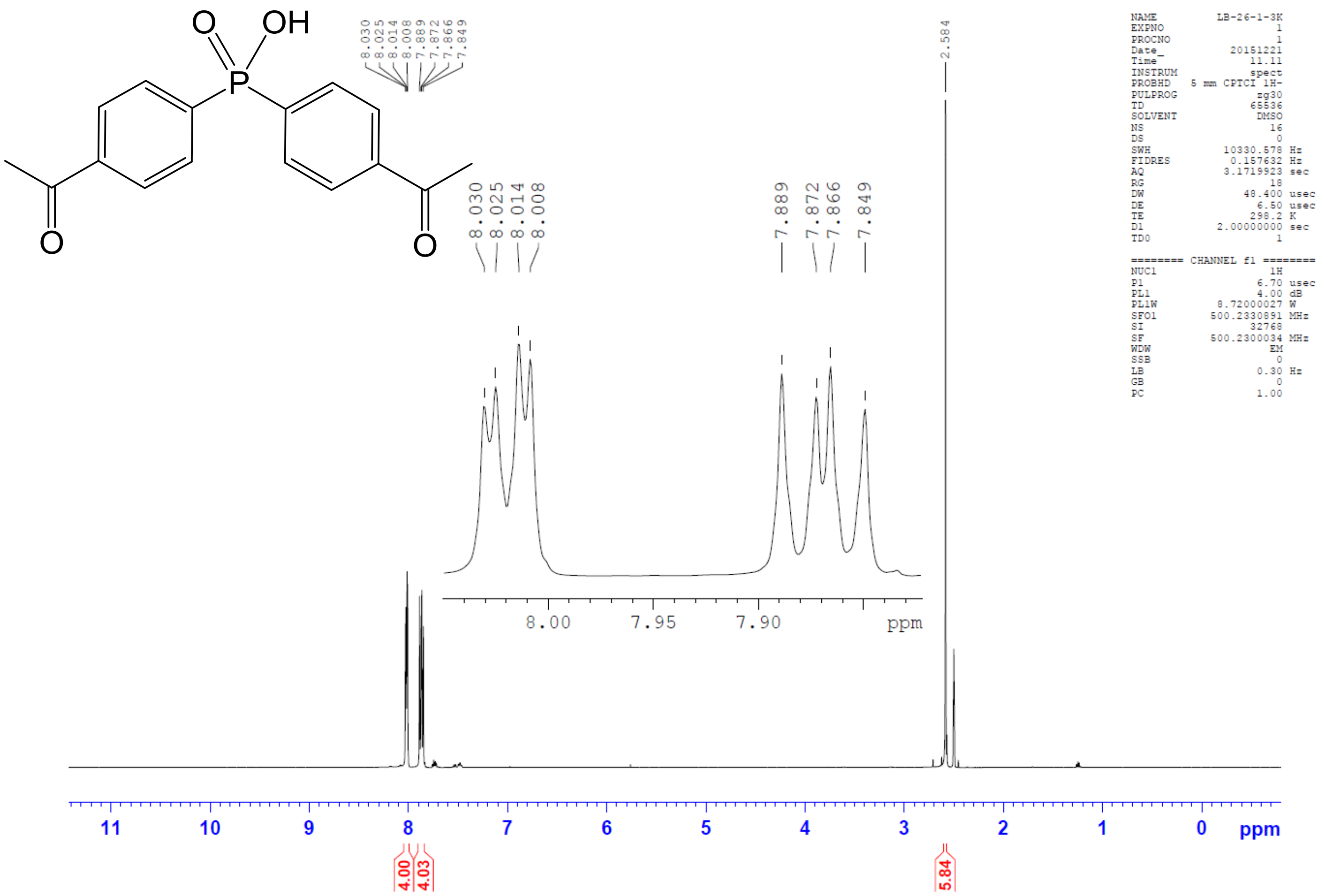


Figure S26) ^{1}H NMR spectrum (500.2 MHz, [D$_6$]DMSO) of **3h**

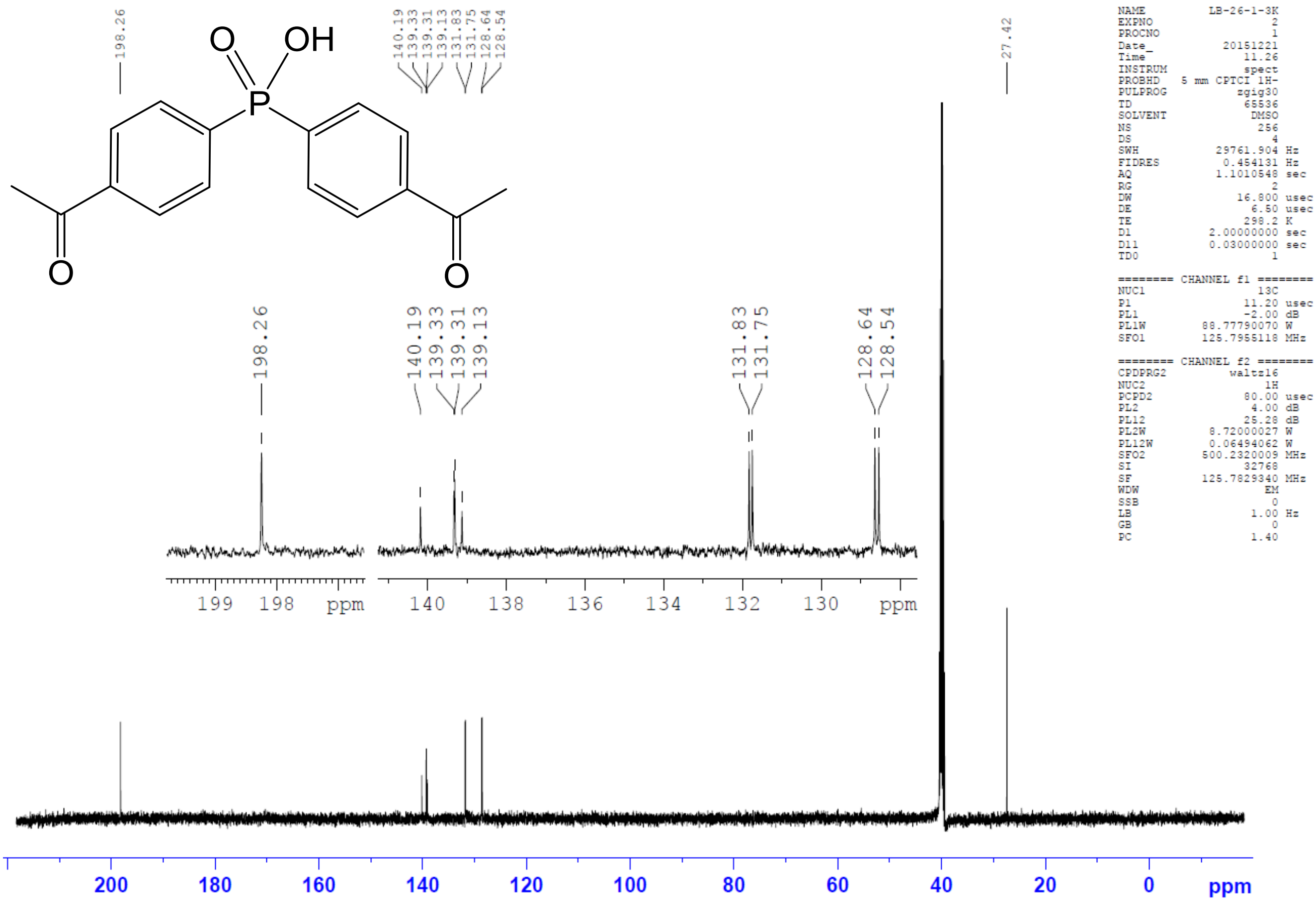


Figure S27) $^{13}C\{^1H\}$ NMR spectrum (125.8 MHz, [D$_6$]DMSO) of **3h**

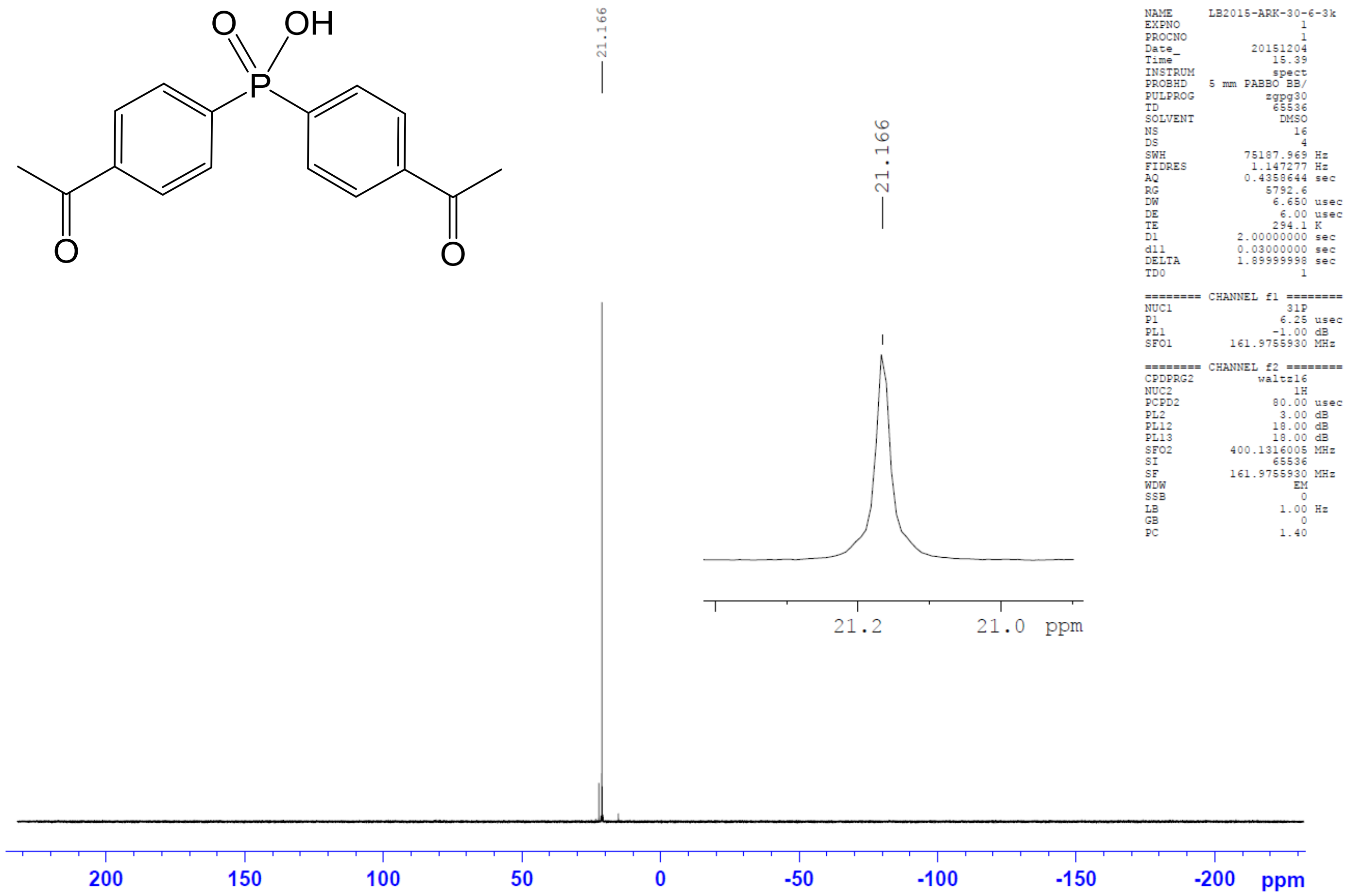


Figure S28) $^{31}P\{^1H\}$ NMR spectrum (162.0 MHz, [D$_6$]DMSO) of **3h**

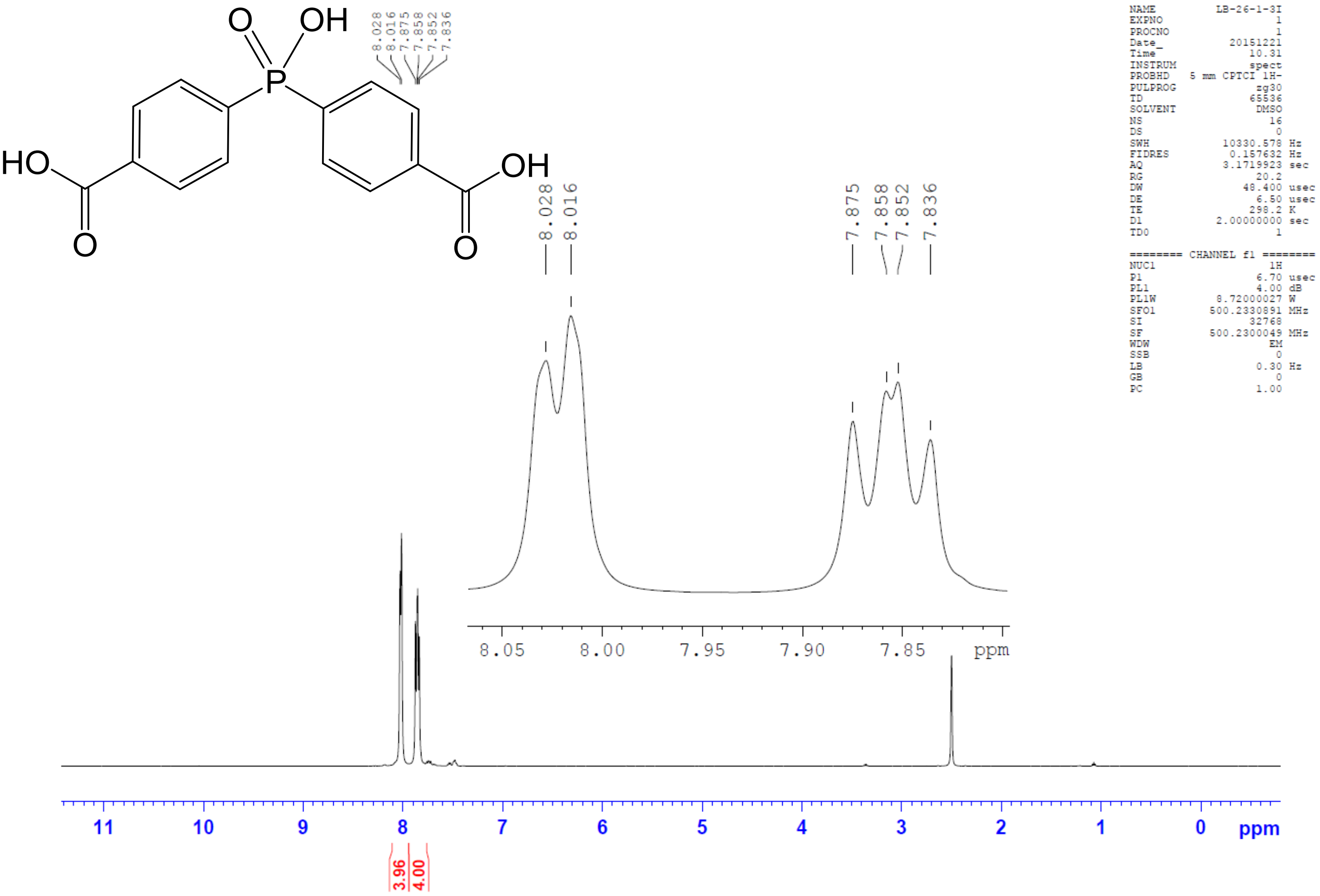


Figure S29) ^{1}H NMR spectrum (500.2 MHz, [D$_6$]DMSO) of **3i**

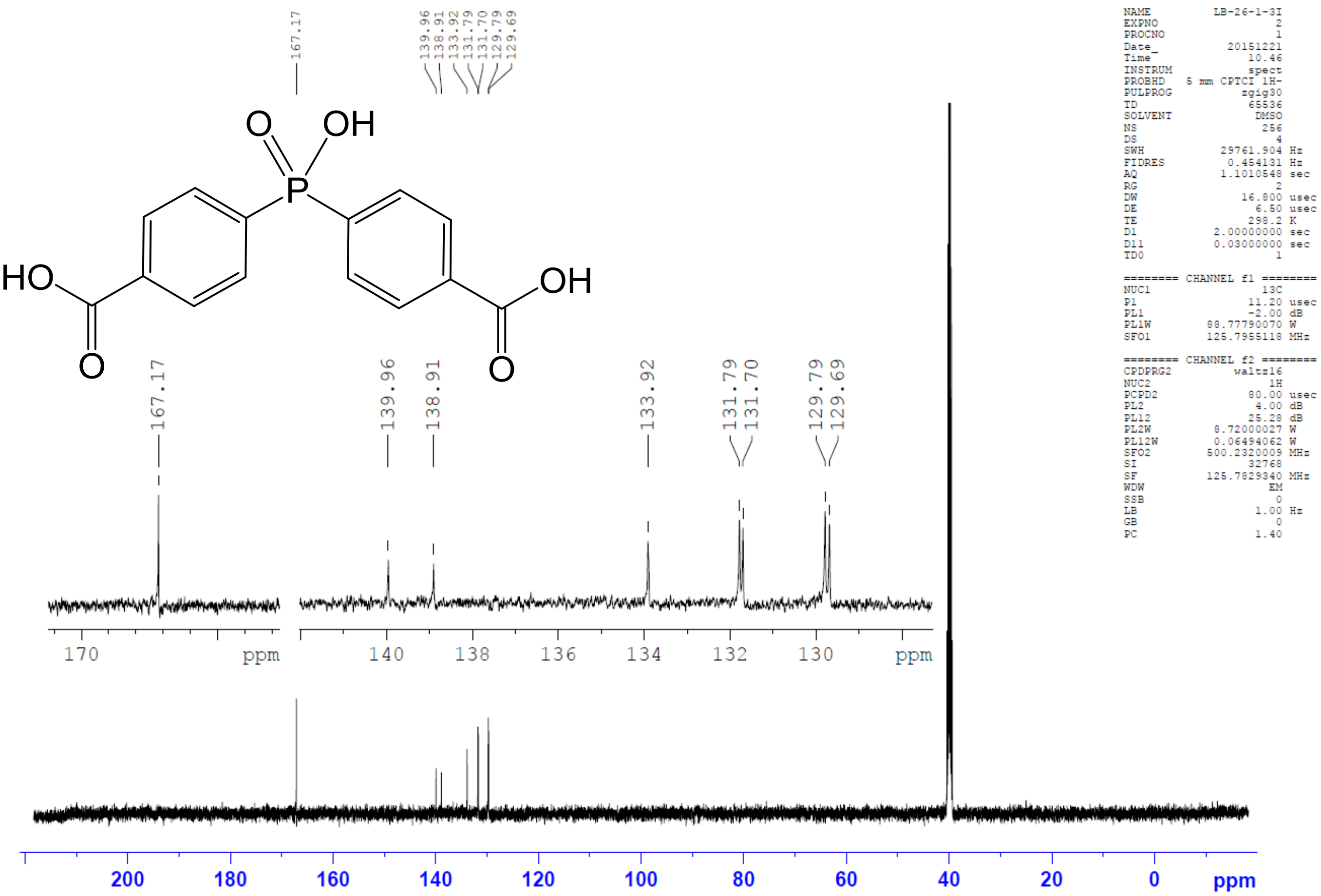


Figure S30) ^{13}C{^{1}H} NMR spectrum (125.8 MHz, [D$_6$]DMSO) of **3i**

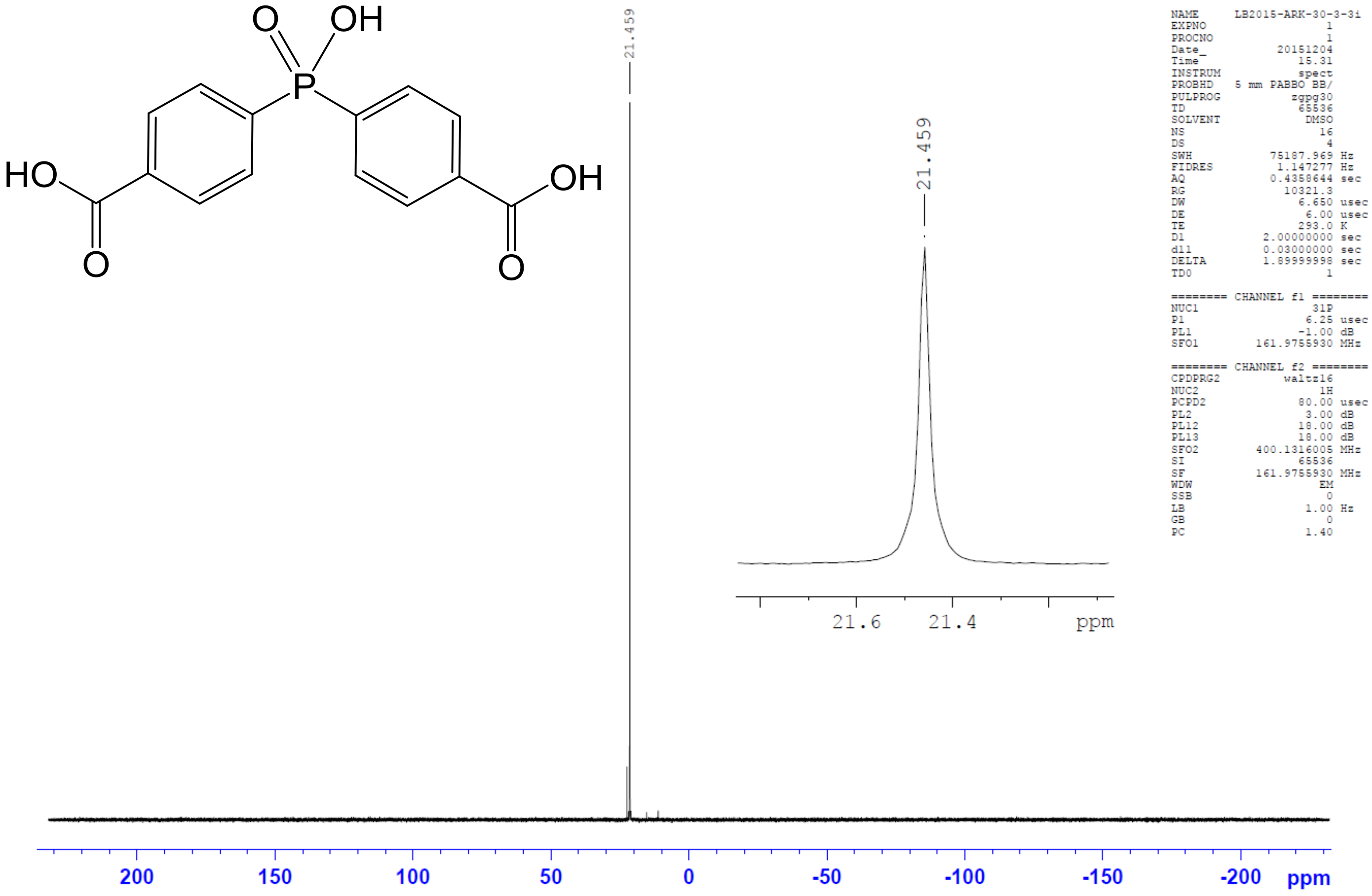


Figure S31) $^{31}P\{^{1}H\}$ NMR spectrum (162.0 MHz, [D$_6$]DMSO) of **3i**

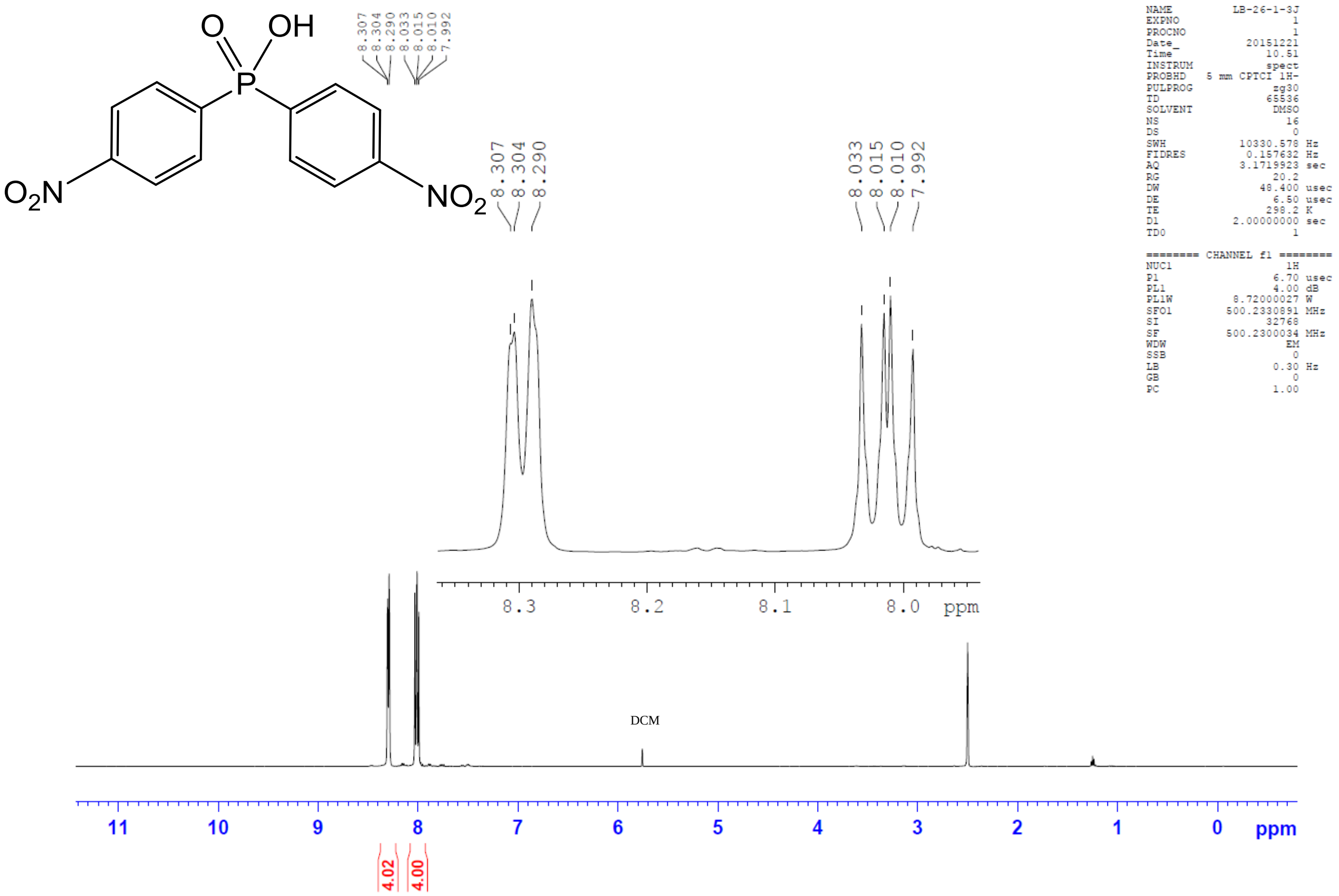


Figure S32) ^{1}H NMR spectrum (500.2 MHz, [D$_6$]DMSO) of **3j**

Figure S33) $^{13}C\{^{1}H\}$ NMR spectrum (125.8 MHz, [D$_6$]DMSO) of **3j**

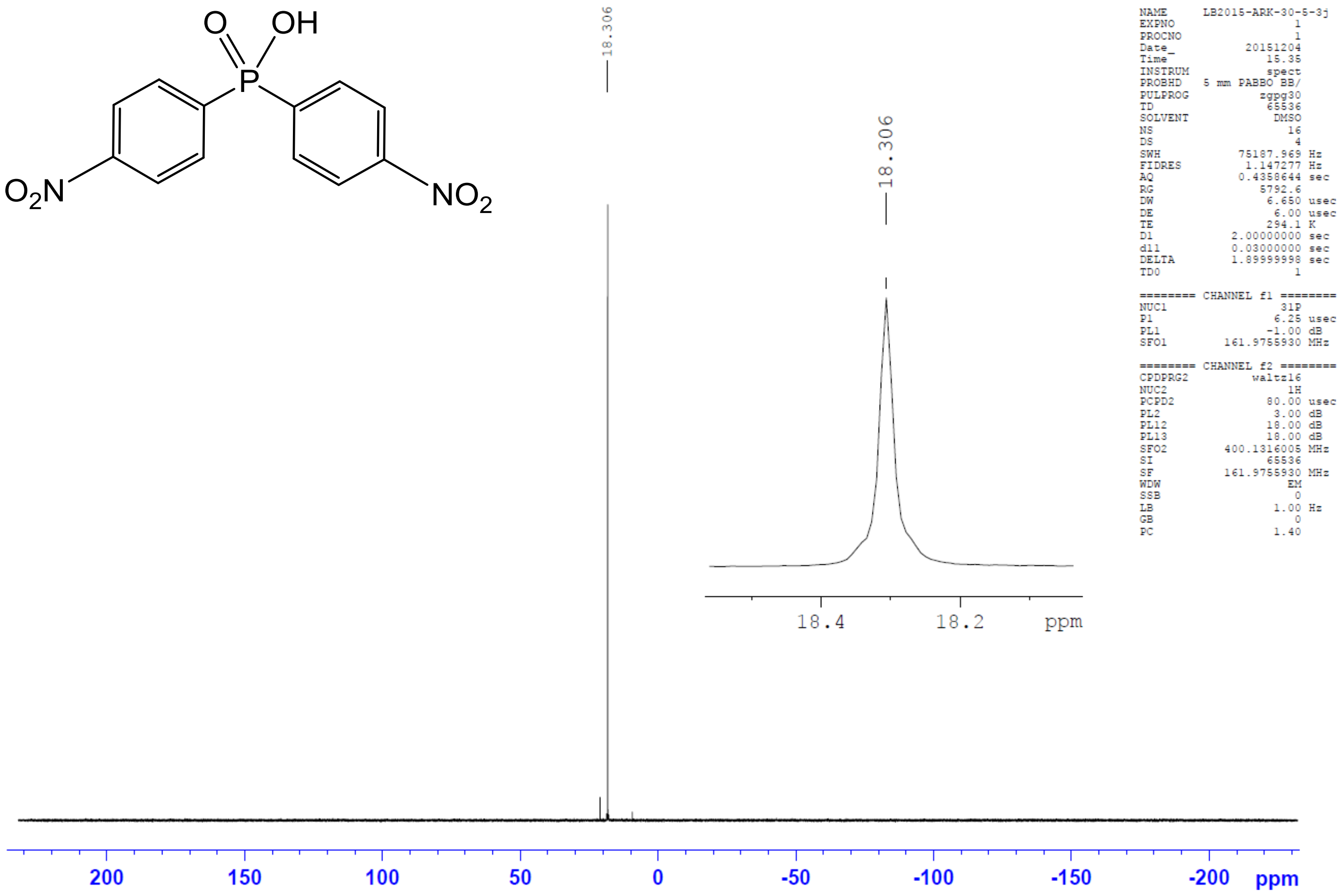


Figure S34) $^{31}P\{^{1}H\}$ NMR spectrum (162.0 MHz, [D$_6$]DMSO) of **3j**

7. References

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