Supporting Information

Click assembly through selective azaylide formation

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Contents

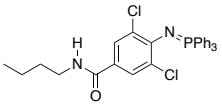
General Information

All reactions were performed with dry glassware under atmosphere of argon, unless otherwise noted. Analytical thin-layer chromatography (TLC) was performed on precoated (0.25 mm) silica-gel plates (Merck Chemicals, Silica Gel 60 F254, Cat. No. 1.05715). Column chromatography was conducted using silica-gel (Kanto Chemical Co., Inc., Silica Gel 60N, spherical neutral, particle size 40–50 μm, Cat. No. 37562-85 or particle size 63–210 μm, Cat. No. 37565-85). Preparative TLC (PTLC) was performed on silica gel (Wako Pure Chemical Industries Ltd., Wakogel B-5F, Cat. No. 230-00043). Melting points (Mp) were measured on an OptiMelt MPA100 (Stanford Research Systems), and are uncorrected. ^{1}H NMR spectra were obtained with a Bruker AVANCE 400 spectrometer at 400 MHz. ^{13}C NMR spectra were obtained with a Bruker AVANCE 400 spectrometer at 101 MHz. ^{19}F NMR spectra were obtained with a Bruker AVANCE 400 spectrometer at 377 MHz. ^{31}P NMR spectra were obtained with a Bruker AVANCE 400 spectrometer at 162 MHz. All NMR measurements were carried out at 25 ºC. $CDCl_3$ (Kanto Chemical Co. Inc., Cat. No. 07663-23) was used as a solvent for obtaining NMR spectra. Chemical shifts (δ) are given in parts per million (ppm) downfield from the solvent peak (δ 7.26 for ^{1}H NMR in $CDCl_3$, δ 77.0 for ^{13}C NMR in $CDCl_3$) as an internal reference or α,α,α-trifluorotoluene (δ –63.0 ppm for ^{19}F NMR in $CDCl_3$) or phosphoric acid (δ 0.00 ppm for ^{31}P NMR in D_2O) as an external standard with coupling constants (J) in hertz (Hz). The abbreviations s, d, t, q, and m signify singlet, doublet, triplet, quartet, and multiplet, respectively. IR spectra were measured on a Shimadzu IRSpirit spectrometer with the absorption band given in cm^{-1}. The absorbance spectra (UV/Vis) and fluorescence spectra (FL) were measured with a JASCO UV-750 spectrophotometer and a JASCO FP-8250 spectrofluorophotometer, respectively, at 25 °C using a quartz cuvette (10 mm light path).High-performance liquid chromatography (HPLC) was performed on a Shimadzu Prominence HPLC system (CBM-20A lite, LC-20AD × 2, DGU-20A3R, SUS316L, and CTO-20A) equipped with a Shimadzu SPD-20A UV/Vis detector. High-resolution mass spectra (HRMS) were measured on a JEOL JMS-T100CS "AccuTOF CS" mass spectrometer under positive electrospray ionization (ESI^+) conditions.

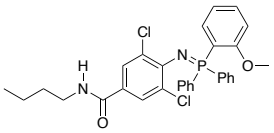
Unless otherwise noted, materials obtained from commercial suppliers were used without further purification. 4-Azido-3,5-dichlorobenzoic acid (**1b**),[S1] 4-azido-2,3,5,6-tetrafluorobenzoic acid,[S2] methyl 2-(diphenylphosphaneyl)benzoate (**3b**),[S3] methyl 2-(diphenylphosphaneyl)benzoate (**3c**),[S3] diphenyl(*o*-tolyl)phosphane (**3d**),[S3] (2-fluorophenyl)diphenylphosphane (**3e**),[S3] (2-chlorophenyl)diphenylphosphane (**3f**),[S3] (2-bromophenyl)diphenylphosphane (**3g**),[S3] methyl 4-(diphenylphosphaneyl)benzoate (**3h**),[S3] dimethyl 2-(diphenylphosphaneyl)terephthalate (**3j**),[S4] methyl 4-(butylcarbamoyl)-2-(diphenylphosphaneyl)benzoate (**3k**),[S5] *tert*-butyl (2-(2-(2-(2-aminoethoxy)ethoxy)ethoxy)ethyl)carbamate (**7**),[S6] *tert*-butyl (2-(2-(2-(2-azidoethoxy)ethoxy)ethoxy)ethyl)carbamate (**12**),[S6] methyl 6-(azidomethyl)nicotinate (**18**),[S7] 2-methoxyethan-1-amine-1-chloropentane,[S8] 9-(azidomethyl)-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-11-one,[S9] and *N*-(4-(2-(2-azidoethoxy)ethoxy)-1-(λ^1-oxidaneyl)butan-2-yl)-5-(2-oxohexahydro-1*H*-thieno[3,4-*d*]imidazol-4-yl)pentanamide (**22**)[S10] were prepared according to the reported method.

CAUTION! Azids are potentially explosive. Although we have never experienced such an explosion, all manipulations should be carefully carried out behind a safety shield in a hood.

Structures of Azaylides 4 and 5



4a



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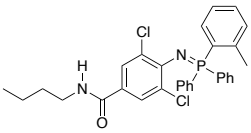

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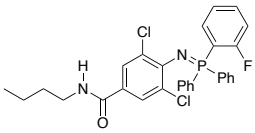

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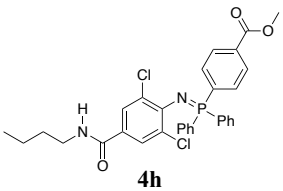

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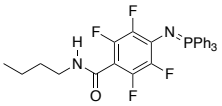
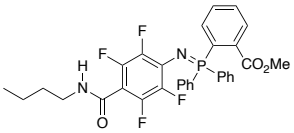


5a



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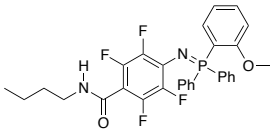

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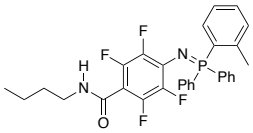

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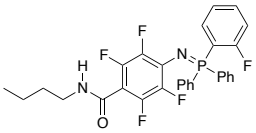

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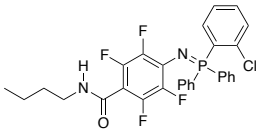

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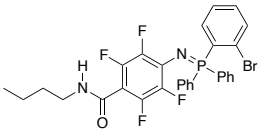

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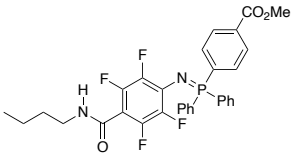

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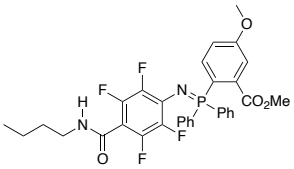

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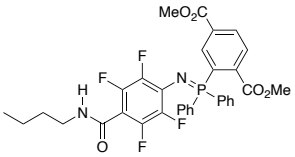

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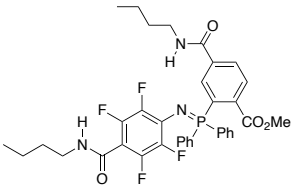
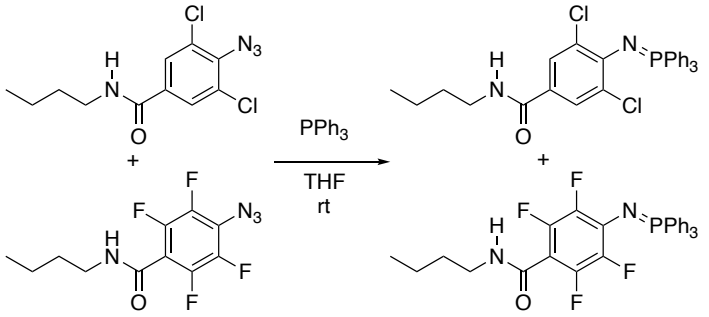


5k

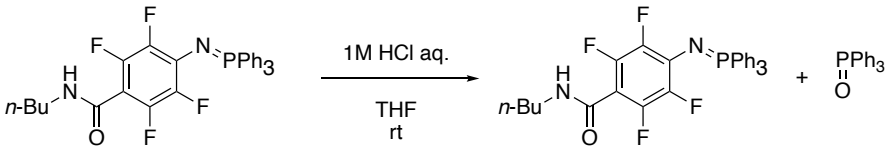
Experimental Procedures

*A typical procedure for the screening of competition experiment between 4-azido-N-butyl-3,5-dichlorobenzamide (**1a**) and 4-azido-N-butyl-2,3,5,6-tetrafluorobenzamide (**2a**) with triphenylphosphine*



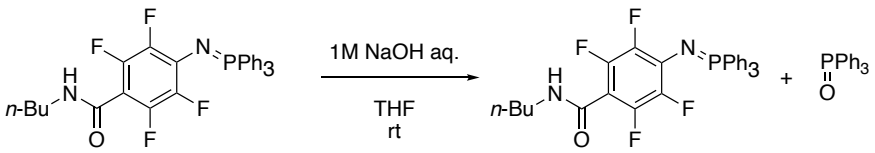
To a mixture of 4-azido-*N*-butyl-3,5-dichlorobenzamide (**1a**) (14.4 mg, 50.2 μmol, 1.1 equiv) and 4-azido-*N*-butyl-2,3,5,6-tetrafluorobenzamide (**2a**) (14.7 mg, 50.7 μmol, 1.1 equiv) dissolved in THF (250 μL) was added a solution of triphenylphosphine (**3a**) (11.8 mg, 45.0 μmol, 1.0 equiv) dissolved in THF (250 μL) at room temperature. After stirring for 4 h at the same temperature, the mixture was concentrated in vacuo. To the mixture was added hexamethylphosphoric triamide (HMPA) (11.5 mg, 68.5 μmol) as an internal standard. The yields of **4a** and **5a** were determined by ^{31}P NMR analysis (162 MHz) to be 19% and 81%, respectively, by comparing the relative values of integration for the peaks observed at 2.1 ppm (for **4a**) and 10.2 ppm (for **5a**) with that of HMPA observed at 25.7 ppm.

A typical procedure for the stability check of azaylides under various conditions



To a solution of *N*-butyl-2,3,5,6-tetrafluoro-4-((triphenyl-λ$_5$-phosphaneylidene)amino)benzamide (**5a**) (15.8 mg, 30.1 μmol) dissolved in THF (150 μL) was added an aqueous solution of HCl (1.0 M, 150 μL, 0.15 mmol, 5.0 equiv) at room temperature. After stirring for 16 h at the same temperature, the mixture was extracted with EtOAc (5 mL × 3). The combined organic extract was dried with Na_2SO_4. After filtration, the filtrate was concentrated under reduced pressure. To the residue was added HMPA (15.5 mg, 86.5 μmol) as an internal standard. Azaylide **5a** was not observed. The yield of triphenylphosphine oxide (**6a**) was determined by ^{31}P NMR analysis (162 MHz) to be quantitative by comparing the relative value of integration for the peak observed at 29.1 ppm (for **6a**) with that of HMPA observed at 25.7 ppm.

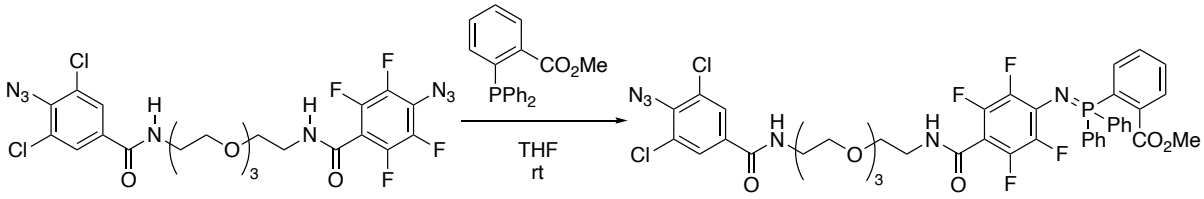
A typical procedure for the stability check of azaylides under various conditions



To a solution of *N*-butyl-2,3,5,6-tetrafluoro-4-((triphenyl-λ$_5$-phosphaneylidene)amino)benzamide (**5a**) (16.0 mg, 30.5 μmol) dissolved in THF (150 μL) was added an aqueous solution of NaOH (1.0 M, 150 μL, 0.15 mmol, 5.0 equiv) at room temperature. After stirring for 16 h at the same temperature, the mixture was extracted with EtOAc (5 mL × 3). The combined organic extract was dried with Na_2SO_4. After filtration, the filtrate was

concentrated under reduced pressure. To the residue was added HMPA (6.6 mg, 37 μmol) as an internal standard. The recovered amount of **5a** was determined by ^{31}P NMR analysis (162 MHz) to be quantitative by comparing the relative value of integration for the peak observed at 10.2 ppm (for **5a**) with that of HMPA observed at 25.7 ppm. Phosphine oxide **6a** was not observed.

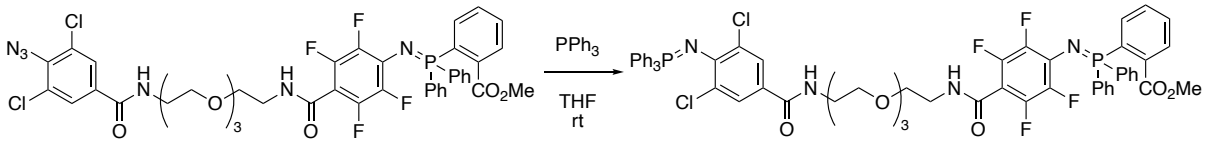
A typical procedure for the preparation of azaylides by selective Staudinger reaction



To a solution of 4-azido-*N*-(1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)-2,3,5,6-tetrafluorobenzamide (**9**) (29.9 mg, 47.9 μmol, 1.2 equiv) in THF (250 μL) was added methyl 2-(diphenylphosphanyl)benzoate (**3b**) (12.9 mg, 40.3 μmol, 1.0 equiv) at room temperature. After stirring for 4 h at the same temperature, the mixture was concentrated under reduced pressure. The residue was purified by preparative TLC (CH_2Cl_2/MeOH = 30/1) to give methyl 2-(*N*-(4-((1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**10**) (38.6 mg, <42.4 μmol, quant.) as a colorless solid.

According to the procedure for preparing methyl 2-(*N*-(4-((1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**10**), methyl 2-(*N*-(4-((12-(4-azido-3,5-dichlorobenzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**S1**) and methyl 2-(*N*-(4-((12-(4-azido-3,5-dichlorobenzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)-4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)benzoate (**S2**) were prepared from diazide **16** and the corresponding phosphines.

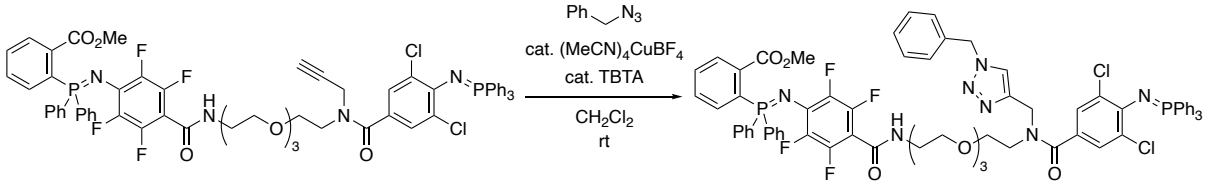
A typical procedure for the preparation of bis(iminophosphorane)s



To a solution of methyl 2-(*N*-(4-((1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (38.6 mg, 42.2 μmol, 1.0 equiv) in THF (250 μL) was added triphenylphosphine (**3a**) (16.1 mg, 61.4 μmol, 1.5 equiv) at room temperature. After stirring for 4 h at the same temperature, the mixture was concentrated under reduced pressure. The residue was purified by preparative TLC (CH_2Cl_2/MeOH = 25/1) to give methyl 2-(*N*-(4-((1-(3,5-dichloro-4-((triphenyl-λ^5-phosphaneylidene)amino)phenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-λ_3-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**11**) (39.4 mg, 34.3 μmol, 81%) as a colorless solid.

According to the procedure for preparing methyl 2-(*N*-(4-((1-(3,5-dichloro-4-((triphenyl-λ^5-phosphaneylidene)amino)phenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-λ_3-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**11**), methyl 2-(*N*-(4-((12-(3,5-dichloro-4-((triphenyl-λ^5-phosphaneylidene)amino)benzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**S3**) and methyl 4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)-2-(*N*-(4-((12-(3,5-dichloro-4-(((4-(((11-oxo-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-9-yl)methyl)carbamoyl)phenyl)diphenyl-λ^5-phosphaneylidene)amino)benzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**S4**) were prepared from the corresponding azides.

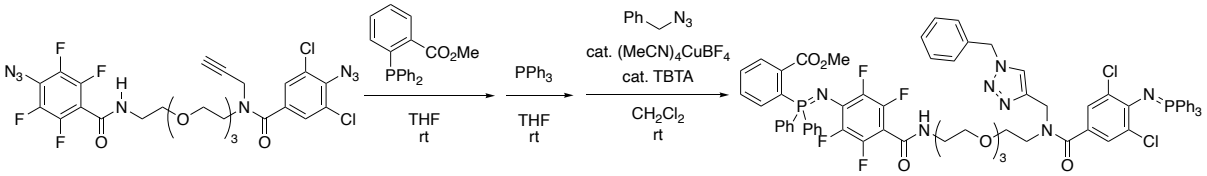
A typical procedure for the copper-catalyzed azide–alkyne cycloaddition



To a solution of methyl 2-(*N*-(4-((12-(3,5-dichloro-4-((triphenyl-l5-phosphaneylidene)amino)benzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**17**) (34.0 mg, 29.0 μmol, 1.0 equiv) in CH_2Cl_2 (500 μL) were added (azidomethyl)benzene (5.0 mg, 35 μmol, 1.5 equiv), $(MeCN)_4CuBF_4$ (0.5 mg, 2 μmol, 7 mol %), and tris[(1-benzyl-1*H*-1,2,3-triazol-4-yl)methyl]amine (TBTA) (0.8 mg, 2 μmol, 7 mol %) at room temperature. After stirring for 24 h at the same temperature, to the mixture was added aqueous solution of NH_3 (15 M, 4 mL). The mixture was extracted with CH_2Cl_2 (10 mL × 4). The combined organic extract was washed with brine (5 mL) and dried with Na_2SO_4. After filtration, the filtrate was concentrated under reduced pressure. The residue was purified by preparative TLC (CH_2Cl_2/MeOH = 25/1) to give methyl 2-(*N*-(4-((2-((1-benzyl-1*H*-1,2,3-triazol-4-yl)methyl)-1-(3,5-dichloro-4-((triphenyl-λ_5-phosphaneylidene)amino)phenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**17**) (39.0 mg, <29.5 μmol, quant.) as a colorless solid.

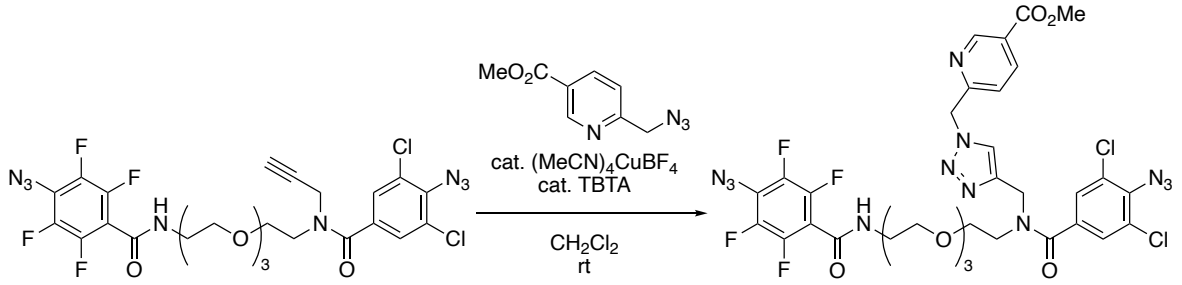
According to the procedure for preparing **17**, methyl 4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)-2-(*N*-(4-((1-(3,5-dichloro-4-(((4-(((11-oxo-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-9-yl)methyl)carbamoyl)phenyl)diphenyl-λ^5-phosphaneylidene)amino)phenyl)-1-oxo-2-((1-(2-(2-(5-(2-oxohexahydro-1*H*-thieno[3,4-*d*]imidazol-4-yl)pentanamido)ethoxy)ethyl)-1*H*-1,2,3-triazol-4-yl)methyl)-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**23**) was prepared from the corresponding alkyne.

*One-pot synthesis of **17***



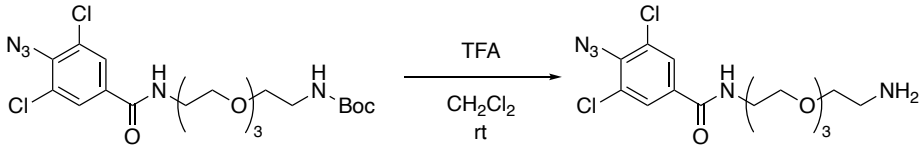
To a solution of 4-azido-*N*-(1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)-2,3,5,6-tetrafluorobenzamide (**16**) (22.9 mg, 34.7 μmol, 1.1 equiv) in THF (150 μL) was added methyl 2-(diphenylphosphanyl)benzoate (**3b**) (10.0 mg, 31.2 μmol, 1.0 equiv) in THF (150 μL) at room temperature. After stirring for 4 h at the same temperature, to the mixture was added triphenylphosphine (**3a**) (9.9 mg, 38 μmol, 1.2 equiv) at room temperature. After stirring for 4 h at the same temperature, to the mixture was added benzyl azide (5.0 mg, 38 μmol, 1.2 equiv), $(MeCN)_4CuBF_4$ (0.5 mg, 2 μmol, 6 mol %), and tris[(1-benzyl-1*H*-1,2,3-triazol-4-yl)methyl]amine (TBTA) (0.8 mg, 2 μmol, 6 mol %) at room temperature. After stirring for 24 h at the same temperature, to the mixture was added aqueous solution of NH_3 (15 M, 4 mL). The mixture was extracted with EtOAc (10 mL × 3). The combined organic extract was washed with brine (5 mL) and dried with Na_2SO_4. After filtration, the filtrate was concentrated under reduced pressure. The residue was purified by preparative TLC (CH_2Cl_2/MeOH = 25/1) to give methyl 2-(*N*-(4-((2-((1-benzyl-1*H*-1,2,3-triazol-4-yl)methyl)-1-(3,5-dichloro-4-((triphenyl-λ_5-phosphaneylidene)amino)phenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**17**) (38.9 mg, 29.4 μmol, 94 %) as a colorless solid.

*A procedure for the preparation of methyl 6-((4-(15-(4-azido-2,3,5,6-tetrafluorophenyl)-2-(4-azido-3,5-dichlorobenzoyl)-15-oxo-5,8,11-trioxa-2,14-diazapentadecyl)-1H-1,2,3-triazol-1-yl)methyl)nicotinate (**19**)*



To a solution of 4-azido-*N*-(12-(4-azido-3,5-dichlorobenzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)-2,3,5,6-tetrafluorobenzamide (**16**) (13.2 mg, 20.0 μmol, 1.0 equiv) in CH_2Cl_2 (500 μL) were added methyl 6-(azidomethyl)nicotinate (**18**) (11.9 mg, 61.6 μmol, 3.1 equiv), $(MeCN)_4CuBF_4$ (0.3 mg, 1 μmol, 5 mol %), and TBTA (0.5 mg, 1 μmol, 5 mol %) at room temperature. After stirring for 24 h at the same temperature, to the mixture was added aqueous solution of NH_3 (15 M, 4 mL). The mixture was extracted with CH_2Cl_2 (10 mL × 4). The combined organic extract was washed with brine (5 mL) and dried with Na_2SO_4. After filtration, the filtrate was concentrated under reduced pressure. The residue was purified by preparative TLC (CH_2Cl_2/MeOH = 25/1) to give methyl 6-((4-(15-(4-azido-2,3,5,6-tetrafluorophenyl)-2-(4-azido-3,5-dichlorobenzoyl)-15-oxo-5,8,11-trioxa-2,14-diazapentadecyl)-1*H*-1,2,3-triazol-1-yl)methyl)nicotinate (**19**) (14.3 mg, 16.8 μmol, 84%) as a colorless solid.

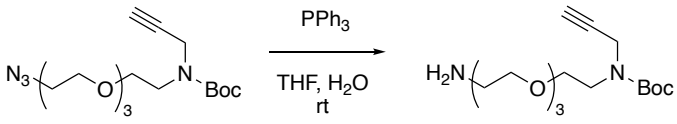
A typical procedure for the deprotection of N-Boc-protected amides



To a mixture of *N*-(2-(2-(2-(2-aminoethoxy)ethoxy)ethoxy)ethyl)-4-azido-3,5-dichlorobenzamide (24.2 mg, 51.0 μmol) in CH_2Cl_2 (530 μL) was added trifluoroacetic acid (100 μL, 1.30 mmol, 25 equiv) at 0 °C. After stirring for 2 h at room temperature, to the mixture was added an aqueous solution of NaOH (1 M, 20 mL). The mixture was extracted with CH_2Cl_2 (15 mL × 3). The combined organic extract was washed with brine (10 mL) and dried with Na_2SO_4. After filtration, the filtrate was concentrated under reduced pressure to give *N*-(2-(2-(2-(2-aminoethoxy)ethoxy)ethoxy)ethyl)-4-azido-3,5-dichlorobenzamide as a colorless oil which was directly used in the next step without further purification.

According to the procedure for preparing *N*-(2-(2-(2-(2-aminoethoxy)ethoxy)ethoxy)ethyl)-4-azido-3,5-dichlorobenzamide, 4-azido-2,3,5,6-tetrafluoro-*N*-(3,6,9-trioxa-12-azapentadec-14-yn-1-yl)benzamide was prepared from the corresponding amide.

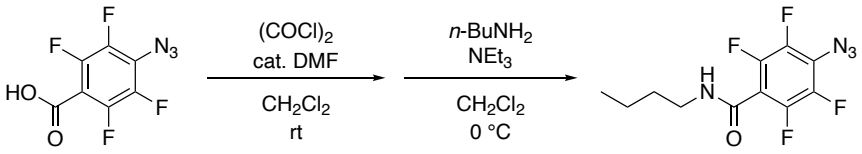
A typical procedure for the preparation of amines by reduction of azides



To a solution of *tert*-butyl (2-(2-(2-(2-azidoethoxy)ethoxy)ethoxy)ethyl)(prop-2-yn-1-yl)carbamate (**14**) (19.3 mg, 54.2 μmol) in THF (250 μL) and H_2O (25 μL) was added triphenylphosphine (14.8 mg, 56.4 μmol, 1.0 equiv) at room temperature. After stirring for 3 days at the same temperature, to the mixture was added a saturated aqueous solution of NH_4Cl (4 mL). The mixture was washed with EtOAc (10 mL × 3). To the resulting aqueous solution was added a saturated aqueous solution of $NaHCO_3$ (10 mL). The mixture was extracted with EtOAc (10 mL × 3). The combined organic extract was washed with brine (10 mL) and dried with Na_2SO_4. After filtration, the filtrate was concentrated under reduced pressure to give *tert*-butyl (2-(2-(2-(2-aminoethoxy)ethoxy)ethoxy)ethyl)(prop-2-yn-1-yl)carbamate as a colorless oil which was directly used in the next step without further purification.

According to the procedure for preparing 9-(aminomethyl)-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-f]pyrido[3,2,1-ij]quinolin-11-one was prepared from the corresponding azide.

*A typical procedure for the preparation of 4-azido-N-butyl-2,3,5,6-tetrafluorobenzamide (**2a**)*

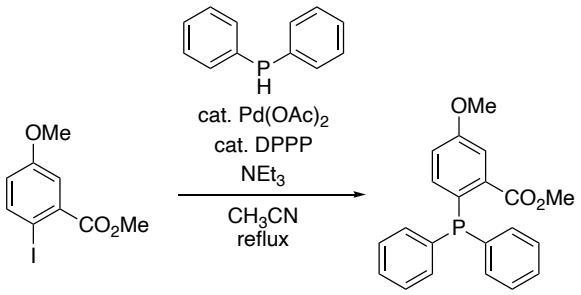


To a solution of 4-azido-2,3,5,6-tetrafluoroenzoic acid (237 mg, 1.01 mmol 1.0 equiv) in CH_2Cl_2 (3.0 mL) was added DMF (4.0 µL, 52 µL, 5 mol %) at 0 °C. After stirring for 5 min at the same temperature, to the mixture was added oxalyl chloride (113 µL, 1.32 mmol, 1.3 equiv) at the same temperature. After stirring the mixture for 12 h at room temperature. The mixture was concentrated under reduced pressure to give 4-azido-2,3,5,6-tetrafluorobenzoyl chloride (**2b**) as brown oil which was directly used in the next step without further purification.

To an aliquot of the mixture containing 4-azido-2,3,5,6-tetrafluorobenzoyl chloride (**2b**) (24.8 mg, 0.100 mmol, 1.0 equiv) in CH_2Cl_2 (188 µL) were successively added triethylamine (33.0 µL, 0.235 mmol, 2.4 equv) and *n*-butylamine (9.8 µL, 0.10 mmol, 1.0 equiv) at 0 °C. After stirring for 2 h at the same temperature, the mixture was concentrated under reduced pressure. After the addition of H_2O (10 mL), the mixture was extracted with CH_2Cl_2 (10 mL × 3). The combined organic extract was washed with brine (10 mL) and dried with Na_2SO_4. After filtration, the filtrate was concentrated under reduced pressure. The residue was purified by preparative TLC (*n*-hexane/EtOAc = 1/1) to give 4-azido-*N*-butyl-2,3,5,6-tetrafluorobenzamide (**2a**) (28.4 mg, 97.9 µmol, 98%) as a pale yellow solid .

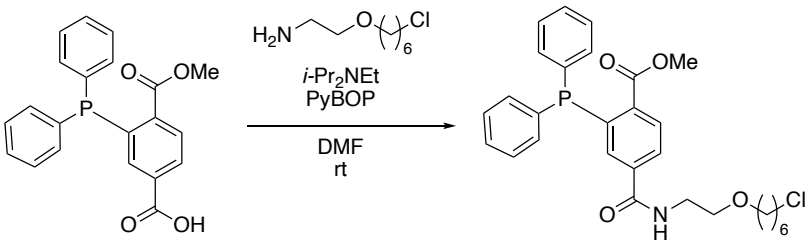
According to the procedure for preparing 4-azido-*N*-butyl-2,3,5,6-tetrafluorobenzamide (**2a**), 4-azido-*N*-butyl-3,5-dichlorobenzamide (**1a**), *N*-(2-(2-(2-(2-aminoethoxy)ethoxy)ethoxy)ethyl)-4-azido-3,5-dichlorobenzamide (**8**), 4-azido-*N*-(1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)-2,3,5,6-tetrafluorobenzamide (**9**), *tert*-butyl (1-(4-azido-2,3,5,6-tetrafluorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)(prop-2-yn-1-yl)carbamate (**15**), and 4-azido-*N*-(12-(4-azido-3,5-dichlorobenzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)-2,3,5,6-tetrafluorobenzamide (**16**) were prepared from the corresponding amines.

A typical procedure for the preparation of methyl 2-(diphenylphosphaneyl)-5-methoxybenzoate



To a solution of methyl 2-iodo-5-methoxybenzoate (400 mg, 1.37 mmol, 1.0 equiv) in CH_3CN (2.0 mL) were added palladium(II) acetate (5.1 mg, 23 µmol, 17 mol %), 1,3-bis(diphenylphosphino)propane (DPPP) (6.8 mg, 17 µmol, 12 mol %), and triethylamine (200 µL, 1.44 mmol, 1.1 equiv) at room temperature. To the mixture was added diphenylphosphine (242 µL, 1.39 mmol, 1.0 equiv) at the same temperature. After stirring at reflux (oil bath; bath temp 80 °C) for 4 h, the reaction mixture was cooled to room temperature and concentrated in vacuo. The residue was purified by silica gel column chromatography (silica-gel 26 g, *n*-hexane/EtOAc = 4/1) to give methyl 2-(diphenylphosphanyl)-5-methoxybenzoate (**3i**) (341 mg, 0.973 mmol, 71%) as a yellow solid.

A typical procedure for the preparation of phosphanyl amides

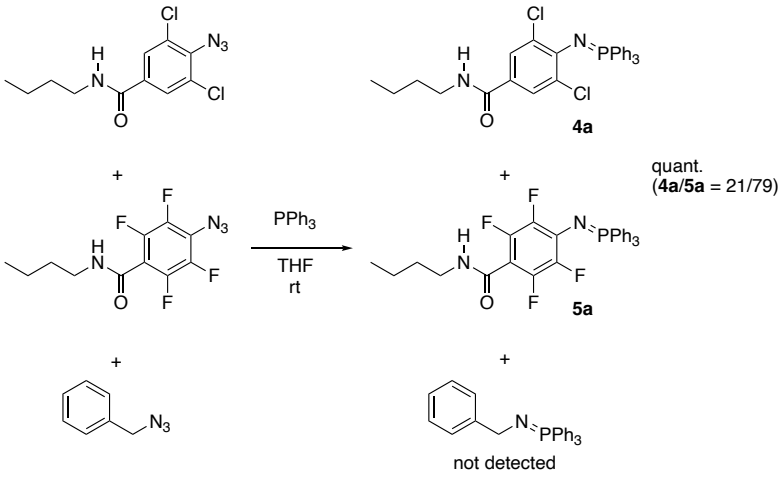


To a solution of 3-(diphenylphosphanyl)-4-(methoxycarbonyl)benzoic acid (714 mg, 1.96 mmol) in DMF (7.0 mL) were added 1-(2-aminoethoxy)-6-chlorohexane (672 mg, 3.00 mmol, 1.5 equiv), *N*,*N*-diisopropylethylamine (830 µL, 4.80 mmol, 2.4 equiv), and benzotriazol-1-yloxy(tripyrrolidin-1-yl)phosphanium hexafluorophosphate (PyBOP) (1.21 g, 2.33 mmol, 1.2 equiv) at 0 °C. After stirring for 16 h at room temperature, to the mixture was added an aqueous saturated solution of sodium bicarbonate (30 mL). The mixture was extracted with EtOAc (20 mL × 3). The combined organic extract was washed with brine (20 mL) and dried with Na_2SO_4. After filtration, the filtrate was concentrated under reduced pressure. The residue was purified by silica gel column chromatography (silica-gel 75 g, *n*-hexane/EtOAc = 1/2) to give methyl 4-((2-((6-chlorohexyl)oxy)ethyl)carbamoyl)-2-(diphenylphosphanyl)benzoate (**20**) (838 mg, 1.60 mmol, 82%) as a yellow oil.

According to the procedure for preparing methyl 4-((2-((6-chlorohexyl)oxy)ethyl)carbamoyl)-2-(diphenylphosphanyl)benzoate (**20**), 4-(diphenylphosphaneyl)-*N*-((11-oxo-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-9-yl)methyl)benzamide (**21**) was prepared from the corresponding carboxylic acid.

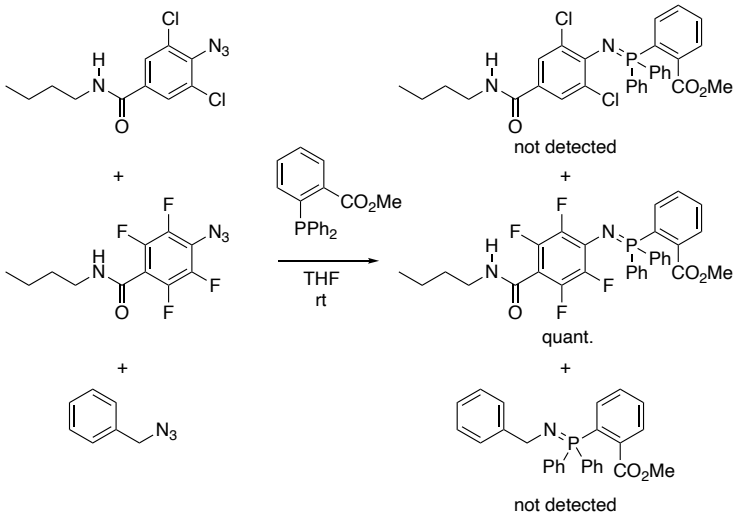
Preliminary studies for the selective azaylide formations

*A competition experiment between 4-azido-N-butyl-3,5-dichlorobenzamide (**1a**), 4-azido-N-butyl-2,3,5,6-tetrafluorobenzamide (**2a**), and benzyl azide with triphenylphosphine (**3a**)*



To a mixture of 4-azido-*N*-butyl-3,5-dichlorobenzamide (**1a**) (14.2 mg, 49.5 μmol, 1.1 equiv), 4-azido-*N*-butyl-2,3,5,6-tetrafluorobenzamide (**2a**) (14.4 mg, 49.6 μmol, 1.1 equiv), and (azidomethyl)benzene (6.8 mg, 51 μmol, 1.1 equiv), dissolved in THF (250 μL) was added a solution of triphenylphosphine (**3a**) (11.9 mg, 45.3 μmol, 1.0 equiv) dissolved in THF (250 μL) at room temperature. After stirring for 4 h at the same temperature, the mixture was concentrated in vacuo. To the mixture was added hexamethylphosphoric triamide (HMPA) (5.8 mg, 32 μmol) as an internal standard. The yields of **4a** and **5a** were determined by ^{31}P NMR analysis (162 MHz) to be quant. (**4a**/**5a** = 21/79), respectively, by comparing the relative values of integration for the peaks observed at 2.3 ppm (for **4a**) and 10.2 ppm (for **5a**) with that of HMPA observed at 25.6 ppm.

*A competition experiment between 4-azido-N-butyl-3,5-dichlorobenzamide (**1a**), 4-azido-N-butyl-2,3,5,6-tetrafluorobenzamide (**2a**), and (azidomethyl)benzene with methyl 2-(diphenylphosphaneyl)benzoate (**3b**)*

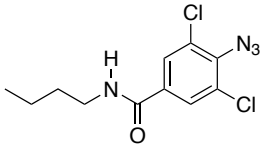


To a mixture of 4-azido-*N*-butyl-3,5-dichlorobenzamide (**1a**) (14.2 mg, 49.5 μmol, 1.1 equiv), 4-azido-*N*-butyl-2,3,5,6-tetrafluorobenzamide (**2a**) (14.4 mg, 49.6 μmol, 1.1 equiv), and benzyl azide (6.5 mg, 49 μmol, 1.1 equiv), dissolved in THF (250 μL) was added a solution of methyl 2-(diphenylphosphaneyl)benzoate (**3b**) (14.4 mg, 45.0 μmol, 1.0 equiv) dissolved in THF (250 μL) at room temperature. After stirring for 4 h at the same temperature, the mixture was concentrated in vacuo. To the mixture was added hexamethylphosphoric triamide (HMPA) (4.6 mg, 25.7 μmol) as an internal standard. The yield of **5b** was determined by ^{31}P NMR analysis (162 MHz) to be quant. by comparing the relative values of integration for the peaks observed at 11.3 ppm (for **5b**) with that of HMPA observed at 25.6 ppm.

Characterization Data of New Compounds

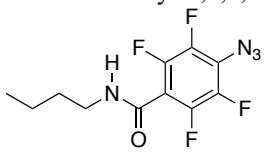
Methyl 2-(diphenylphosphaneyl)benzoate (**3c**),[S11] diphenyl(*o*-tolyl)phosphane (**3d**),[S11] (2-fluorophenyl)diphenylphosphane (**3e**),[S12] (2-chlorophenyl)diphenylphosphane (**3f**),[S13] (2-bromophenyl)diphenylphosphane (**3g**),[S11] methyl 4-(diphenylphosphaneyl)benzoate (**3h**),[S13] triphenylphosphine oxide (**6a**),[S14] methyl 2-(diphenylphosphoryl)benzoate (**6b**),[S15] and 9-(aminomethyl)-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-11-one [S16] were identical in spectra data with those reported in the literature.

4-Azido-*N*-butyl-3,5-dichlorobenzamide (**1a**)



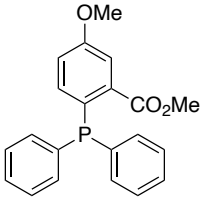
Yellow solid; TLC R_f 0.48 (*n*-hexane/EtAOc = 4/1); Mp 105–107 ºC ; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.95 (t, 3H, *J* = 7.3 Hz), 1.34–1.45 (m, 2H), 1.54–1.63 (m, 2H), 3.43 (td, 2H, *J* = 5.7, 5.7 Hz), 6.13–6.22 (br, 1H), 7.67 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.7, 20.1, 31.5, 40.1, 127.7, 129.3, 132.7, 136.5, 164.2; IR (NaCl, cm^{-1}) 1455, 1538, 1548, 1634, 2123; HRMS (ESI) *m/z*: $[M + H]^+$ Calcd for $C_{11}H_{13}{}^{35}Cl_2N_4O^+$ 287.0461; Found 287.0461.

4-Azido-*N*-butyl-2,3,5,6-tetrafluorobenzamide (**2a**)



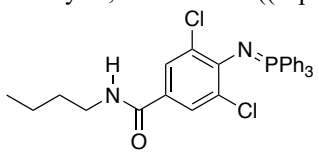
Pale yellow solid; TLC R_f 0.47 (*n*-hexane/EtAOc = 4/1); Mp 152–155 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.95 (t, 3H, *J* = 7.4 Hz), 1.35–1.46 (m, 2H), 1.54–1.64 (m, 2H), 3.45 (td, 2H, *J* = 6.0, 6.0 Hz), 5.91–6.05 (br, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.6, 19.9, 31.2, 40.0, 111.6, 121.7, 138.9–141.8 (m), 142.5–145.5 (m), 157.6; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –150.7– –150.4 (2F, m), –141.0– –140.9 (2F, m); IR (NaCl, cm^{-1}) 992, 1020, 1276, 1488, 1557, 1646, 1651, 2935, 2962, 3288; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{11}H_{10}F_4N_4NaO^+$ 313.0688; Found 313.0688.

Methyl 2-(diphenylphosphaneyl)-5-methoxybenzoate (**3i**)



Colorless solid; TLC R_f 0.40 (*n*-hexane/ EtAOc = 10/1); Mp 138–140 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 3.77 (s, 3H), 3.84 (s, 3H), 6.82–6.88 (m, 1H), 6.91–6.96 (m, 1H), 7.23–7.36 (m, 10H), 7.57–7.62 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 52.1, 55.4, 115.6 (d, *J* = 3.4 Hz), 118.0, 128.4 (d, *J* = 7.1 Hz), 128.4, 130.8 (d, *J* = 23.3 Hz), 133.6 (d, *J* = 20.5 Hz), 135.6, 135.8, 138.2 (d, *J* =11.3 Hz), 159.5, 167.0 (d, *J* = 1.9 Hz); ^{31}P NMR ($CDCl_3$, 162 MHz): δ –6.7 (m); IR (NaCl, cm^{-1}) 1060, 1225, 1252, 1291, 1434, 1478, 1597, 1717, 1721; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{21}H_{19}O_3NaP^+$ 373.0970; Found 373.0969.

N-Butyl-3,5-dichloro-4-((triphenyl-λ^5-phosphanylidene)amino)benzamide (**4a**)

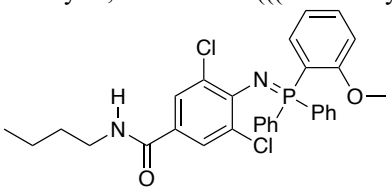


Colorless solid; TLC R_f 0.38 (*n*-hexane/EtAOc = 2/1); Mp 188–190 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.93 (t, 3H, *J* = 7.3 Hz), 1.32–1.44 (m, 2H), 1.50–1.60 (m, 2H), 3.38 (td, 2H, *J* = 5.8, 5.8 Hz), 5.91 (t, 1H, *J* = 5.2 Hz), 7.39–7.46 (m, 6H), 7.48–7.54 (m, 3H), 7.57 (d, 2H, *J* = 1.3 Hz), 7.70–7.78 (m, 6H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.8, 20.1, 31.7, 39.7, 124.7, 126.5 (d, *J* = 1.3 Hz), 128.3 (d, *J* = 12.7 Hz), 131.1 (d, *J* = 9.1 Hz), 131.6 (d, *J* = 2.8 Hz), 131.8 (d, *J* = 105 Hz), 132.5 (d, *J* = 10.1 Hz), 147.9, 165.7; ^{31}P NMR ($CDCl_3$, 162 MHz): δ 2.1

(m); IR (NaCl, cm^{-1}) 1116, 1435, 1464, 1471, 1481, 1484, 3260; HRMS (ESI) *m/z*: $[M + H]^+$ Calcd for $C_{29}H_{28}{}^{35}Cl_2N_2OP^+$ 521.1311; Found 521.1310.

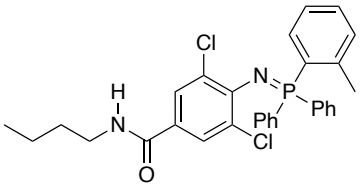
.

N-Butyl-3,5-dichloro-4-(((2-methoxyphenyl)diphenyl-λ^5-phosphaneylidene)amino)benzamide (**4c**)



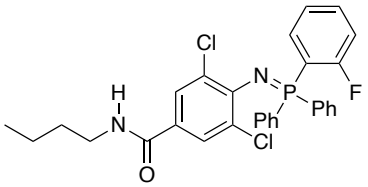
Colorless solid; TLC R_f 0.28 (*n*-hexane/EtAOc = 2/1); Mp 220–222 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.94 (t, 3H, *J* = 7.3 Hz), 1.33–1.44 (m, 2H), 1.50–1.59 (m, 2H), 3.26 (s, 3H), 3.38 (td, 2H, *J* = 5.8, 5.8 Hz), 5.85–5.91 (br, 1H), 6.77–6.83 (m, 1H), 6.94–7.01 (m, 1H), 7.31–7.38 (m, 1H), 7.39–7.45 (m, 4H), 7.46–7.53 (m, 3H), 7.54 (d, 2H, *J* = 1.4 Hz), 7.77–7.84 (m, 4H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.8, 20.1, 31.7, 39.7, 54.8, 110.9 (d, *J* = 6.3 Hz), 119.0 (d, *J* = 53.4 Hz), 120.8 (d, *J* = 11.3 Hz), 124.3 (d, *J* = 3.5 Hz), 126.2 (d, *J* = 2.5 Hz), 128.0 (d, *J* = 12.9 Hz), 131.3 (d, *J* = 2.8 Hz), 131.5 (d, *J* = 13.8 Hz), 132.1 (d, *J* = 119 Hz), 132.5 (d, *J* = 10.5 Hz), 134.0 (d, *J* = 2.0 Hz), 134.6 (d, *J* = 7.3 Hz), 149.3, 161.0 (d, *J* = 3.3 Hz), 165.7; ^{31}P NMR ($CDCl_3$, 162 MHz): δ 3.3 (m); IR (NaCl, cm^{-1}) 1435, 1464, 1471, 1475, 1481, 1485, 1494; HRMS (ESI) *m/z*: $[M + H]^+$ Calcd for $C_{30}H_{30}{}^{35}Cl_2N_2O_2P^+$ 551.1416; Found 551.1417.

N-Butyl-3,5-dichloro-4-((diphenyl(*o*-tolyl)-λ^5-phosphaneylidene)amino)benzamide (**4d**)



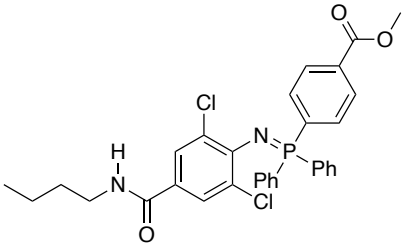
Pale yellow solid; TLC R_f 0.45 (*n*-hexane/EtAOc = 2/1); Mp 206–208 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.93 (t, 3H, *J* = 7.3 Hz), 1.32–1.43 (m, 2H), 1.50–1.59 (m, 2H), 2.17 (s, 3H), 3.37 (td, 2H, *J* = 1.2, 1.2 Hz), 5.98 (t, 1H, *J* = 5.4 Hz), 7.12–7.27 (m, 3H), 7.37–7.47 (m, 5H), 7.49–7.55 (m, 2H), 7.58 (d, 2H, *J* = 1.3 Hz), 7.75–7.84 (m, 4H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.8, 20.1, 21.4 (d, *J* = 4.6 Hz), 31.7, 39.7, 124.1 (d, *J* = 2.0 Hz), 125.3 (d, *J* = 12.3 Hz), 126.6, 128.4 (d, *J* = 12.7 Hz), 130.4 (d, *J* = 9.1 Hz), 130.7 (d, *J* = 88.1 Hz), 131.5 (d, *J* = 2.8 Hz), 131.8, 131.8 (d, *J* = 13.6 Hz), 132.0 (d, *J* = 112 Hz), 132.4 (d, *J* = 10.2 Hz), 133.3 (d, *J* = 12.2 Hz), 142.8, 147.9, 165.7; ^{31}P NMR ($CDCl_3$, 162 MHz): δ 3.0 (m); IR (NaCl, cm^{-1}) 1435, 1464, 1471, 1481, 1487, 1494, 1505; HRMS (ESI) *m/z*: $[M + H]^+$ Calcd for $C_{30}H_{30}{}^{35}Cl_2N_2OP^+$ 535.1467; Found 535.1464.

N-Butyl-3,5-dichloro-4-(((2-fluorophenyl)diphenyl-λ^5-phosphanylidene)amino)benzamide (**4e**)



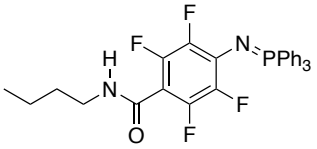
Colorless solid; TLC R_f 0.41 (*n*-hexane/EtAOc = 2/1); Mp 185–187 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.93 (t, 3H, *J* = 7.3 Hz), 1.32–1.43 (m, 2H), 1.50–1.59 (m, 2H), 3.37 (td, 2H, *J* = 5.6, 5.6 Hz), 5.90 (t, 1H, *J* = 5.6 Hz), 7.01–7.08 (m, 1H), 7.25–7.31 (m, 1H), 7.40–7.47 (m, 4H), 7.49–7.58 (m, 5H), 7.76–7.84 (m, 4H), 7.95–8.04 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.8, 20.1, 31.7, 39.7, 116.0 (d, *J* = 5.9 Hz), 116.2, 124.4 (d, *J* = 10.4 Hz), 125.0, 126.4, 128.3 (d, *J* = 13.0 Hz), 131.0 (d, *J* = 109 Hz), 131.1 (d, *J* = 9.1 Hz), 131.8 (d, *J* = 3.0 Hz), 132.2 (d, *J* = 10.8 Hz), 134.5 (d, *J* = 10.6 Hz), 135.2 (d, *J* = 5.0 Hz), 147.7, 162.8 (d, *J* = 251 Hz), 165.7; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –99.1 (d, *J* = 6.2 Hz); ^{31}P NMR ($CDCl_3$, 162 MHz): δ –2.0 (m); IR (NaCl, cm^{-1}) 1438, 1455, 1471, 1480, 1484, 1494; HRMS (ESI) *m/z*: $[M + H]^+$ Calcd for $C_{29}H_{27}{}^{35}Cl_2FN_2OP^+$ 539.1217; Found 539.1217.

Methyl 4-(*N*-(4-(butylcarbamoyl)-2,6-dichlorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**4h**)



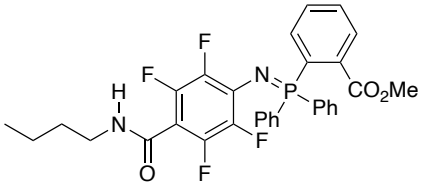
Colorless solid; TLC R_f 0.31 (*n*-hexane/EtAOc = 2/1); Mp 67–69 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.92 (t, 3H, J = 7.3 Hz), 1.37–1.42 (m, 2H), 1.50–1.59 (m, 2H), 3.37 (td, 2H, J = 5.6, 5.6 Hz), 3.92 (s, 3H), 5.98 (t, 1H, J = 5.6 Hz), 7.40–7.47 (m, 4H), 7.50–7.55 (m, 2H), 7.57 (d, 2H, J = 1.3 Hz), 7.68–7.76 (m, 4H), 7.80–7.88 (m, 2H), 8.05–8.10 (m, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.7, 20.1, 31.7, 39.7, 52.4, 125.0 (d, J = 2.6 Hz), 126.5, 128.5 (d, J = 12.7 Hz), 129.2 (d, J = 12.6 Hz), 131.0 (d, J = 105 Hz), 131.0 (d, J = 9.1 Hz), 131.9 (d, J = 2.8 Hz), 132.5 (d, J = 10.2 Hz), 132.7 (d, J = 3.1 Hz), 136.8, 137.8, 147.4, 165.6, 166.3; ^{31}P NMR ($CDCl_3$, 162 MHz) δ –1.1 (m); IR (NaCl, cm^{-1}) 1286, 1435, 1464, 1471, 1481, 1487, 1494, 1504, 1727; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{31}H_{29}{}^{35}Cl_2N_2NaO_3P^+$ 601.1191; Found 601.1194.

N-Butyl-2,3,5,6-tetrafluoro-4-((triphenyl-λ^5-phosphanylidene)amino)benzamide (**5a**)



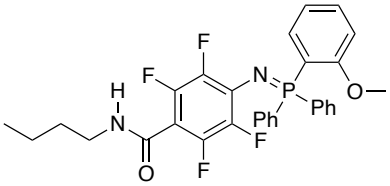
Colorless solid; TLC R_f 0.44 (*n*-hexane/EtAOc = 2/1); Mp 176–178 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.92 (t, 3H, J = 7.3 Hz), 1.31–1.42 (m, 2H), 1.49–1.58 (m, 2H), 3.39 (td, 2H, J = 5.9, 5.9 Hz), 5.92–6.01 (br, 1H), 7.43–7.50 (m, 6H), 7.51–7.58 (m, 3H), 7.68–7.76 (m, 6H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.6, 19.9, 31.4, 39.6, 102.2, 128.6 (d, J = 12.4 Hz), 130.5 (d, J = 104 Hz), 132.0 (d, J = 2.8 Hz), 132.3 (d, J = 10.2 Hz), 132.7–133.3 (m), 141.0–143.9 (m), 143.3–146.4 (m), 160.0; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.5– –152.1 (2F, m), –146.2– –145.9 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 10.2 (m); IR (NaCl, cm^{-1}) 979, 1110, 1205, 1265, 1288, 1435, 1505, 1515, 1646; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{29}H_{25}F_4N_2NaOP^+$ 547.1538; Found 547.1533.

Methyl 2-(*N*-(4-(butylcarbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**5b**)



Colorless solid; TLC R_f 0.23 (*n*-hexane/EtAOc = 2/1); Mp 132–134 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.92 (t, 3H, J = 7.3 Hz), 1.32–1.43 (m, 2H), 1.49–1.59 (m, 2H), 3.28(s, 3H), 3.39 (td, 2H, J = 6.2, 6.2 Hz), 5.91–6.01 (br, 1H), 7.43–7.57 (m, 8H), 7.60–7.66 (m, 1H), 7.69–7.77 (m, 4H), 7.86–7.91 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.7, 19.9, 31.4, 39.6, 52.0, 102.3, 128.6 (d, J = 13.0 Hz), 130.7 (d, J = 88.9 Hz), 130.7 (d, J = 7.8 Hz), 131.2 (d, J = 11.9 Hz), 131.3 (d, J = 110 Hz), 131.6–131.9 (m, two signals overlapped), 132.0 (d, J = 2.4 Hz), 133.1–133.5 (m), 135.0 (d, J = 10.9 Hz), 135.6 (d, J = 6.2 Hz), 141.0–143.8 (m), 143.4–146.3 (m), 160.0, 167.2 (d, J = 2.6 Hz); ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.6– –152.3 (2F, m), –146.4– –146.1 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 11.3 (m); IR (NaCl, cm^{-1}) 1282, 1438, 1481, 1484, 1505, 1511, 1515, 1520, 1644, 1651, 1728; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{31}H_{27}F_4N_2NaO_3P^+$ 605.1593; Found605.1597.

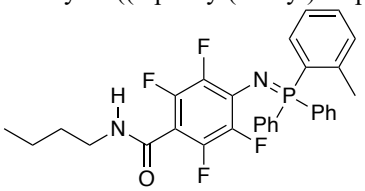
N-Butyl-2,3,5,6-tetrafluoro-4-(((2-methoxyphenyl)diphenyl-λ^5-phosphanylidene)amino)benzamide (**5c**)



Colorless solid; TLC R_f 0.31 (*n*-hexane/EtAOc = 2/1); Mp 209–211 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.91 (t, 3H, J = 7.3 Hz), 1.30–1.41 (m, 2H), 1.47–1.57 (m, 2H), 3.36 (td, 2H, J = 6.0, 6.0 Hz), 3.42 (s, 3H), 6.02–6.10 (br, 1H), 6.84–6.91 (m, 1H), 7.04–7.11 (m, 1H), 7.38–7.47 (m, 4H), 7.47–7.56 (m, 3H), 7.69–7.80 (m, 5H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.6, 19.2, 31.4, 39.6, 55.0, 101.9 (t, J = 15.9 Hz), 111.4 (d, J = 6.8 Hz), 118.4 (d, J

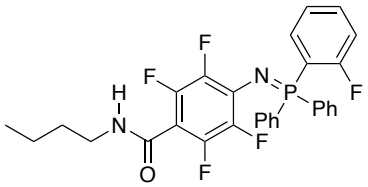
= 99.5 Hz), 121.1 (d, *J* = 11.6 Hz), 128.2 (d, *J* = 13.0 Hz), 130.8 (d, *J* = 109 Hz), 131.6 (d, *J* = 2.9 Hz), 132.0 (d, *J* = 10.6 Hz), 133.6–134.1 (m), 134.3 (d, *J* = 1.7 Hz), 134.9 (d, *J* = 6.7 Hz), 141.2–144.0 (m), 143.5–146.3 (m), 160.1, 161.5 (d, *J* = 3.8 Hz); $^{19}F\{^{1}H\}$ NMR ($CDCl_3$, 377 MHz): δ –152.7– –152.4 (2F, m), –146.8– –146.5 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 10.1 (m); IR (NaCl, cm^{-1}) 1199, 1275, 1435, 1477, 1505, 1511, 1514, 1634, 1640; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{30}H_{27}F_4N_2$ Na O_2P^+ 577.1644; Found 577.1640.

N-Butyl-4-((diphenyl(*o*-tolyl)-λ^5-phosphanylidene)amino)-2,3,5,6-tetrafluorobenzamide (**5d**)



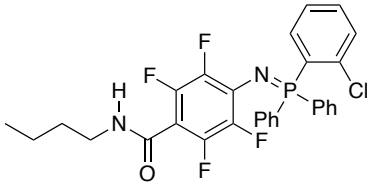
Colorless solid; TLC R_f 0.47 (*n*-hexane/EtAOc = 2/1); Mp 216–218 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.92 (t, 3H, *J* = 7.4 Hz), 1.32–1.43 (m, 2H), 1.50–1.59 (m, 2H), 2.17(s, 3H), 3.40 (td, 2H, *J* = 6.0 Hz, 6.0 Hz), 5.95–6.03 (br, 1H), 7.17–7.34 (m, 3H), 7.40–7.51 (m, 5H), 7.51–7.58 (m, 2H), 7.68–7.77 (m, 4H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): δ 13.7, 20.0, 21.3 (d, *J* = 4.4 Hz), 31.4, 39.6, 101.7 (t, *J* = 16.5 Hz), 125.5 (d, *J* = 12.6 Hz), 128.7 (d, *J* = 12.8 Hz), 128.7 (d, *J* = 90.4 Hz), 131.0 (d, *J* = 109 Hz), 131.9 (d, *J* = 2.8 Hz), 132.0 (d, *J* = 10.1 Hz), 132.1 (d, *J* = 10.7 Hz), 132.3 (d, *J* = 2.5 Hz), 133.2–133.5 (m), 133.8 (d, *J* = 12.5 Hz), 140.9–144.1 (m), 142.7 (d, *J* = 8.7 Hz), 143.2–146.5 (m), 160.1; $^{19}F\{^{1}H\}$ NMR ($CDCl_3$, 377 MHz): δ –153.1– –152.8 (2F, m), –146.1– –145.9 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 11.8 (m); IR (NaCl, cm^{-1}) 976, 1198, 1265, 1285, 1435, 1455, 1471, 1505, 1640; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{30}H_{27}F_4N_2NaOP^+$ 561.1695; Found 561.1693.

N-Butyl-2,3,5,6-tetrafluoro-4-(((2-fluorophenyl)diphenyl-λ^5-phosphanylidene)amino)benzamide (**5e**)



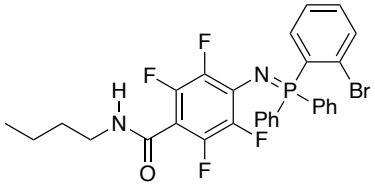
Colorless solid; TLC R_f 0.41 (*n*-hexane/ EtAOc = 2/1); Mp 177–179 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.91 (t, 3H, *J* = 7.3 Hz), 1.31–1.42 (m, 2H), 1.49–1.58 (m, 2H), 3.39 (td, 2H, *J* = 6.0, 6.0 Hz), 5.96–6.03 (br, 1H), 7.04–7.12 (m, 1H), 7.29–7.36 (m, 1H), 7.43–7.51 (m, 4H), 7.52–7.62 (m, 3H), 7.73–7.83(m, 4H), 7.95–8.05 (m, 1H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): δ 13.7, 19.9, 31.4, 39.6, 102.5 (t, *J* = 16.7 Hz), 116.3 (dd, *J* = 28.7, 6.2 Hz), 118.7 (dd, *J* = 102, 17.6 Hz), 124.8 (dd, *J* = 10.6, 3.3 Hz), 128.6 (d, *J* = 13.0 Hz), 129.9 (d, *J* = 107 Hz), 131.9 (d, *J* = 10.6 Hz), 132.2 (d, *J* = 2.9 Hz), 132.4–133.0 (m), 134.9 (d, *J* = 2.2 Hz), 135.0 (d, *J* = 2.6 Hz), 140.9–143.8 (m), 143.3–146.2 (m), 159.9, 162.6 (dd, *J* =250, 2.8 Hz); $^{19}F\{^{1}H\}$ NMR ($CDCl_3$, 377 MHz): δ –152.6– –152.3 (2F, m), –146.2– –145.9 (2F, m), –98.6– –98.4 (1F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 6.0 (m); IR (NaCl, cm^{-1}) 1269, 1439, 1471, 1497, 1505, 1634, 1640, 1644; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{29}H_{24}F_5N_2$ NaOP$^+$ 565.1444; Found 565.1446.

N-Butyl-4-(((2-chlorophenyl)diphenyl-λ^5-phosphanylidene)amino)-2,3,5,6-tetrafluorobenzamide (**5f**)



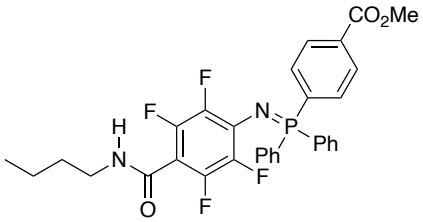
Colorless solid; TLC R_f 0.36 (*n*-hexane/EtAOc = 2/1); Mp 183–185 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.93 (t, 3H, *J* = 7.3 Hz), 1.33–1.44 (m, 2H), 1.50–1.60 (m, 2H), 3.41 (td, 2H, *J* = 7.0, 7.0 Hz), 5.92–6.01 (br, 1H), 7.33–7.42 (m, 2H), 7.45–7.53 (m, 5H), 7.54–7.66 (m, 3H), 7.73–7.82 (m, 4H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): δ 13.7, 20.0, 31.4, 39.6, 102.3, 126.8 (d, *J* = 11.1 Hz), 128.7 (d, *J* = 13.1 Hz), 129.5 (d, *J* = 92.6 Hz), 129.8 (d, *J* = 113 Hz), 131.2 (d, *J* = 7.0 Hz), 132.1 (d, *J* = 3.0 Hz), 132.2, 132.5–133.2 (m), 133.6 (d, *J* = 2.0 Hz), 135.7 (d, *J* = 9.1 Hz), 137.6 (d, *J* = 5.0 Hz), 141.1–143.9 (m), 143.5–146.3 (m), 160.0; $^{19}F\{^{1}H\}$ NMR ($CDCl_3$, 377 MHz): δ –152.9– –152.6 (2F, m), –146.3– –146.0 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 8.7 (m); IR (NaCl, cm^{-1}) 1424, 1429, 1437, 1455, 1472, 1477, 1481, 1505; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{29}H_{24}{}^{35}ClF_4N_2NaOP^+$ 581.1149; Found 581.1148.

4-(((2-Bromophenyl)diphenyl-λ^5-phosphanylidene)amino)-*N*-butyl-2,3,5,6-tetrafluorobenzamide (**5g**)



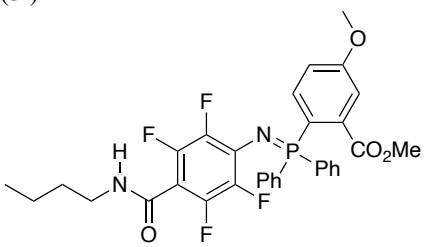
Colorless solid; TLC R_f 0.39 (*n*-hexane/EtAOc = 2/1); Mp 147–150 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.93 (t, 3H, *J* = 7.3 Hz), 1.33–1.44 (m, 2H), 1.50–1.60 (m, 2H), 3.41 (td, 2H, *J* = 6.0, 6.0 Hz), 5.94–6.02 (br, 1H), 7.34–7.43 (m, 2H), 7.44–7.53 (m, 5H), 7.54–7.63 (m, 3H), 7.73–7.82 (m, 4H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.7, 20.0, 31.4, 39.6, 102.2 (d, *J* = 16.4 Hz), 126.5 (d, *J* = 5.8 Hz), 127.2 (d, *J* = 10.7 Hz), 128.7 (d, *J* = 13.1 Hz), 129.9 (d, *J* = 115 Hz), 131.4 (d, *J* = 89.9 Hz), 132.1 (d, *J* = 2.9 Hz), 132.2 (d, *J* = 10.2 Hz), 132.8–133.3 (m), 133.5 (d, *J* = 2.3 Hz), 134.9 (d, *J* = 7.4 Hz), 136.1 (d, *J* =10.1 Hz), 141.1–143.9 (m), 143.5–146.4 (m), 160.0; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –153.0– –152.8 (2F, m), –146.2– –146.0 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 10.4 (m); IR (NaCl, cm^{-1}) 1418, 1424, 1429, 1435, 1455, 1471, 1481, 1505, 1515, 1520, 1644; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{29}H_{24}{}^{79}BrF_4N_2NaOP^+$ 625.0643; Found 625.0641.

Methyl 4-(*N*-(4-(butylcarbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**5h**)



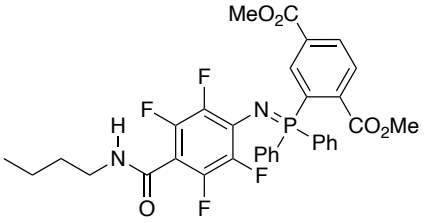
Colorless solid; TLC R_f 0.27 (*n*-hexane/EtAOc = 2/1); Mp 60–63 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.91 (t, 3H, *J* = 7.3 Hz), 1.31–1.42 (m, 2H), 1.49–1.58 (m, 2H), 3.39 (td, 2H, *J* = 6.0, 6.0 Hz), 3.92 (s, 3H), 5.98–6.05 (br, 1H), 7.44–7.51 (m, 4H), 7.53–7.60 (m, 2H), 7.66–7.75 (m, 4H), 7.79–7.87 (m, 2H), 8.03–8.13 (m, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.6, 19.9, 31.4, 39.6, 52.5, 102.7, 128.8 (d, *J* = 12.6 Hz), 129.5 (d, *J* = 12.6 Hz), 129.8 (d, *J* = 103 Hz), 132.2, 132.3 (d, *J* = 6.8 Hz), 132.3 (d, *J* = 6.3 Hz), 132.5–132.7 (m), 133.2 (d, *J* = 2.9 Hz), 135.9 (d, *J* =102 Hz), 141.0–143.8 (m), 143.5–146.4 (m), 159.8, 160.0; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.4– –152.1 (2F, m), –146.0– –145.7 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 9.2 (m); IR (NaCl, cm^{-1}) 1282, 1484, 1505, 1511, 1644, 1651; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{31}H_{27}F_4N_2NaO_3P^+$ 605.1593; Found 605.1595.

Methyl 2-(*N*-(4-(butylcarbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)-5-methoxybenzoate (**5i**)



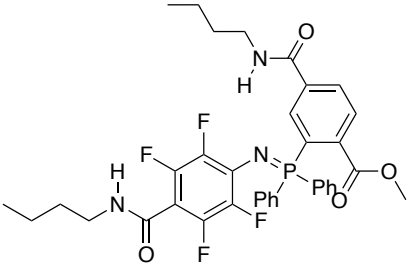
Colorless solid; TLC R_f 0.23 (*n*-hexane/EtAOc = 2/1); Mp 69–71 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.91 (t, 3H, *J* = 7.3 Hz), 1.30–1.41 (m, 2H), 1.47–1.57 (m, 2H), 3.23 (s, 3H), 3.36 (td, 2H, *J* = 6.0, 6.0 Hz), 3.87 (s, 3H), 6.03–6.10 (br, 1H), 6.97–7.03 (m, 1H), 7.36–7.55 (m, 8H), 7.68–7.77 (m, 4H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.6, 19.9, 31.4, 39.6, 51.9, 55.6, 102.2 (t, *J* = 15.4 Hz), 116.4, 116.5 (d, *J* = 1.8 Hz), 121.2 (d, *J* = 93.5 Hz), 128.5 (d, *J* = 12.8 Hz), 131.6 (d, *J* = 3.0 Hz), 131.7 (d, *J* = 10.2 Hz), 131.8 (d, *J* = 113 Hz), 133.3–133.7 (m), 137.2 (d, *J* = 12.2 Hz), 137.4 (d, *J* = 7.6 Hz), 140.9–143.9 (m), 143.4–146.3 (m), 160.0, 162.2 (d, *J* = 2.4 Hz), 166.9 (d, *J* = 2.2 Hz); ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.7– –152.4 (2F, m), –146.5– –146.2 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 11.1 (m); IR (NaCl, cm^{-1}) 976, 1233, 1261, 1291, 1438, 1481, 1505, 1511, 1597, 1644, 1728; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{32}H_{29}F_4N_2NaO_4P^+$ 635.1699; Found 635.1697.

Dimethyl 2-(*N*-(4-(butylcarbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)terephthalate (**5j**)



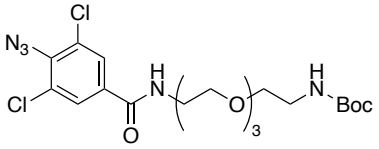
Pale yellow solid; TLC R_f 0.30 (CH_2Cl_2/MeOH = 20/1); Mp 68–72 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.90 (t, 3H, *J* = 7.3 Hz), 1.30–1.41 (m, 2H), 1.48–1.57 (m, 2H), 3.33 (s, 3H), 3.37 (td, 2H, *J* = 6.0, 6.0 Hz), 3.86 (s, 3H), 6.00–6.08 (br, 1H), 7.44–7.52 (m, 4H), 7.53–7.59 (m, 2H), 7.66–7.75 (m, 4H), 7.87–7.92 (m, 1H), 8.17–8.23 (m, 1H), 8.23–8.27 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.6, 19.9, 31.3, 39.6, 52.3, 52.6, 102.6 (t, *J* =16.7 Hz), 128.7 (d, *J* =13.0 Hz), 130.4 (d, *J* =111 Hz), 130.6 (d, *J* = 8.5 Hz), 131.8 (d, *J* =91.7 Hz), 131.8 (d, *J* =10.3 Hz), 132.1 (d, *J* =2.8 Hz), 132.2 (d, *J* = 12.0 Hz), 132.8 (d, *J* = 2.2 Hz), 132.6–133.0 (m), 135.5 (d, *J* =12.0 Hz), 139.6 (d, *J* = 6.3 Hz), 140.9–143.8 (m), 143.3–146.2 (m), 159.9, 165.2, 166.8 (d, *J* = 2.8 Hz); ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.5– –152.2 (2F, m), –146.3– –145.9 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 10.8 (m); IR (NaCl, cm^{-1}) 1285, 1481, 1484, 1505, 1515, 1520, 1644, 1651, 1728, 1731; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{33}H_{29}F_4N_2NaO_5P^+$ 663.1642; Found 663.1622.

Methyl 4-(butylcarbamoyl)-2-(*N*-(4-(butylcarbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**5k**)



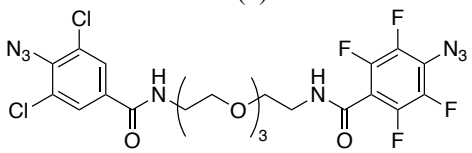
Colorless solid; TLC R_f 0.30 (*n*-hexane/EtAOc = 1/1); Mp 195–197 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.89 (t, 3H, *J* = 7.3 Hz), 0.90 (t, 3H, *J* = 7.3 Hz), 1.27–1.39 (m, 4H), 1.46–1.56 (m, 4H), 3.29 (s, 3H), 3.34 (td, 4H, *J* = 5.9, 5.9 Hz), 6.17 (t, 1H, *J* = 5.9 Hz), 6.59 (t, 1H, *J* = 5.6 Hz), 7.43–7.49 (m, 4H), 7.50–7.57 (m, 2H), 7.64–7.72 (m, 4H), 7.81–7.86 (m, 1H), 8.00–8.04 (m, 1H), 8.16–8.22 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 13.6 (two signals overlapped), 19.9, 20.0, 31.3, 31.3, 39.6, 39.9, 52.2, 102.7 (t, *J* = 17.1 Hz), 130.2 (d, *J* = 110 Hz), 130.4 (d, *J* = 2.1 Hz), 130.7 (d, *J* = 8.6 Hz), 131.7 (d, *J* = 92.4 Hz), 131.8 (d, *J* = 10.4 Hz), 132.0 (d, *J* = 2.7 Hz), 132.5–133.0 (m), 133.4 (d, *J* = 10.9 Hz), 137.0 (d, *J* = 11.0 Hz), 137.7 (d, *J* = 6.7 Hz), 141.0–143.8 (m), 143.3–146.1 (m), 159.9 (two signals overlapped), 165.4, 166.8 (d, *J* =2.3 Hz); ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.5– –152.2 (2F, m), –146.0– –145.7 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 11.4 (m); IR (NaCl, cm^{-1}) 1286, 1435, 1505, 1515, 1520, 1538, 1646, 1651; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{36}H_{36}F_4N_3NaO_4P^+$ 704.2277; Found 704.2262.

tert-Butyl (1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamate (**8**)



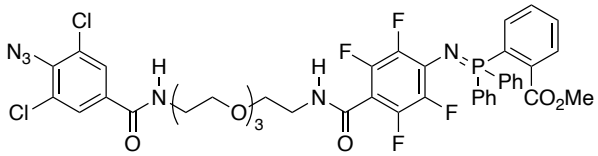
Pale yellow oil; TLC R_f 0.37 (CH_2Cl_2/MeOH = 20/1); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 1.45 (s, 9H), 3.25–3.33 (br, 2H), 3.51–3.57 (br, 2H), 3.61–3.72 (m, 12H), 5.02 (br, 1H), 7.00 (br, 1H), 7.80 (br, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 28.4, 29.7, 40.1, 40.3, 69.5, 70.1, 70.2, 70.3, 70.4, 79.3, 125.8, 128.0, 129.2, 132.5, 155.9, 164.1; IR (NaCl, cm^{-1}) 1455, 1538, 1548, 1694, 1712, 2125, 2872, 2919, 2923, 2965, 3337; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{20}H_{29}{}^{35}Cl_2N_5NaO_6^+$ 528.1392; Found 528.1393.

4-Azido-*N*-(1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)-2,3,5,6-tetrafluorobenzamide (**9**)



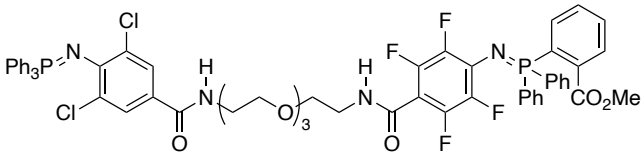
Yellow oil; TLC R_f 0.35 (CH_2Cl_2/MeOH = 20/1); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 3.50–3.65 (m, 16H), 7.07–7.13 (br, 1H), 7.19–7.25 (br, 1H), 7.68 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 39.9, 39.9, 69.2, 69.3, 70.0, 70.1, 70.2 (two signals overlapped), 111.4 (t, J =18.7 Hz), 121.3–121.7 (m), 127.7, 129.0, 132.1, 136.3, 138.7–141.5 (m), 142.3–145.2 (m), 157.7, 164.1; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –150.9– –150.6 (2F, m), –141.2– –140.9 (2F, m); IR (NaCl, cm^{-1}) 994, 1269, 1286, 1305, 1324, 1455, 1487, 1548, 1651, 1657, 1667, 2126; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{22}H_{20}{}^{35}Cl_2F_4N_8NaO_5^+$ 645.0768; Found 645.0765.

Methyl 2-(*N*-(4-((1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**10**)



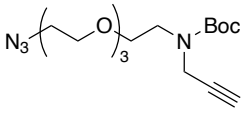
Colorless oil; TLC R_f 0.30 (CH_2Cl_2/MeOH = 20/1); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 3.27, (s, 3H), 3.53–3.67 (m, 16H), 6.55–6.62 (br, 1H), 7.05–7.13 (br, 1H), 7.43–7.57 (m, 8H), 7.60–7.77 (m, 7H), 7.83–7.89 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 39.6, 39.9, 52.0, 69.3, 69.5, 70.1, 70.2, 70.3, 70.3, 101.9 (t, J = 16.4 Hz), 125.7, 127.9, 128.6 (d, J = 13.0 Hz), 129.1, 130.7 (d, J = 8.6 Hz), 131.0 (d, J = 155.7 Hz), 131.1 (d, J = 11.8 Hz), 131.2 (d, J = 111.8 Hz) 131.7 (d, J = 10.5 Hz), 132.1 (d, J = 2.1 Hz), 132.5, 133.3–133.8 (m), 135.0 (d, J = 11.0 Hz), 135.6 (d, J = 6.1 Hz), 136.3, 141.0–143.8 (m), 143.3–146.3 (m), 160.1, 164.1, 167.3 (d, J = 2.6 Hz); ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.6– –152.3 (2F, m), –146.2– –145.9 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 10.8 (br); IR (NaCl, cm^{-1}) 1115, 1294, 1438, 1455, 1484, 1505, 1511, 1515, 1644, 1651, 1728, 2125; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{42}H_{37}{}^{35}Cl_2F_4N_6NaO_7P^+$ 937.1672; Found 937.1667.

Methyl 2-(*N*-(4-((1-(3,5-dichloro-4-((triphenyl-λ^5-phosphaneylidene)amino)phenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**11**)



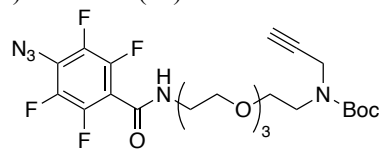
Colorless solid; TLC R_f 0.36 (CH_2Cl_2/MeOH = 20/1); Mp 68–70 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 3.27 (s, 3H), 3.51–3.66 (m, 16H), 6.54–6.65 (br, 2H), 7.38–7.56 (m, 17H), 7.59–7.65 (m, 3H), 7.68–7.77 (m, 10H), 7.84–7.90 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 39.5, 39.6, 52.0, 69.5, 69.7, 70.1, 70.3, 70.3, 70.3, 102.1, 124.5, 126.7, 128.3 (d, J = 12.4 Hz), 128.6 (d, J = 13.0 Hz), 130.2–131.9 (m, eight signals are observed as multiplet peaks), 132.1 (d, J = 2.6 Hz), 132.2, 132.5 (d, J = 10.1 Hz), 133.1–133.5 (m), 135.0 (d, J = 10.9 Hz), 135.7 (d, J = 6.2 Hz) , 141.0–143.9 (m), 143.4–146.3 (m), 147.9, 160.1, 165.7, 167.3 (d, J = 2.7 Hz); ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.7– –152.3 (2F, m), –146.3– –145.9 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 2.2 (1P, m), 11.3 (1P, m); IR (NaCl, cm^{-1}) 1115, 1266, 1286, 1438, 1484, 1495, 1504, 1644; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{60}H_{52}{}^{35}Cl_2F_4N_4NaO_7P_2^+$ 1171.2522; Found 1171.2519.

tert-Butyl (2-(2-(2-(2-azidoethoxy)ethoxy)ethoxy)ethyl)(prop-2-yn-1-yl)carbamate (**14**)



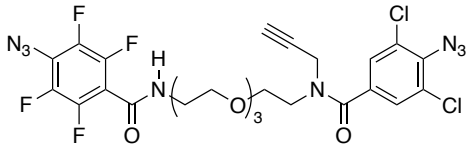
Color less oil; TLC R_f 0.42 (*n*-hexane/EtAOc = 1/1); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 1.39 (s, 9H), 2.14 (s, 1H), 3.29–3.34 (m, 2H), 3.39–3.45 (m, 2H), 3.50–3.63 (m, 12H), 3.99–4.11 (br, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 28.1, 36.5, 37.4, 45.5, 50.4, 69.5, 69.8, 70.2, 70.4 (d, J = 2.6 Hz), 70.8, 71.3, 79.8, 80.0, 154.7; IR (NaCl, cm^{-1}) 1143, 1172, 1249, 1266, 1366, 1409, 1459, 1693, 1697, 2109, 2870; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{16}H_{28}N_4O_5^+$ 379.1957; Found 379.1958.

tert-Butyl (1-(4-azido-2,3,5,6-tetrafluorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)(prop-2-yn-1-yl)carbamate (**15**)



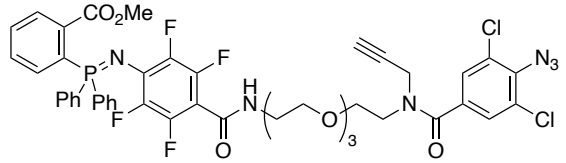
Yellow oil; TLC R_f 0.38 (CH_2Cl_2/MeOH = 20/1); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 1.45 (s, 9H), 2.17 (s, 1H), 3.44–3.69 (m, 15H), 3.92–3.97 (m, 2H), 4.02–4.15 (br, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 28.3, 36.7, 37.5, 45.9, 47.1, 68.7, 69.7, 70.3, 70.4, 70.8, 71.3, 79.9, 80.2, 110.3–111.0 (m), 122.6–123.1 (m), 138.9–141.7 (m), 142.1–144.9 (m), 154.8, 161.0; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –150.7– –150.4 (2F, m), –141.0– –140.4 (2F, m); IR (NaCl, cm^{-1}) 993, 1143, 1251, 1269, 1414, 1485, 1494, 1651, 1660, 1667, 2128, 3305; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{23}H_{29}F_4N_5NaO_6^+$ 570.1952; Found 875.1574.

4-Azido-*N*-(12-(4-azido-3,5-dichlorobenzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)-2,3,5,6-tetrafluorobenzamide (**16**)



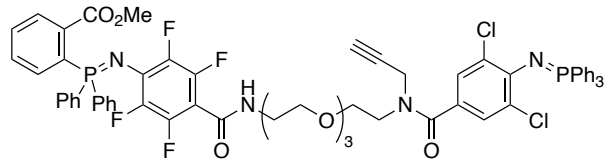
Yellow oil; TLC R_f 0.41 (CH_2Cl_2/MeOH = 20/1); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 2.27–2.44 (br, 1H), 3.45–3.80 (m, 16H), 4.06–4.31 (br, 2H), 7.47 (s, 2H), 7.72 (br s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 33.8, 40.1, 48.0, 53.4, 66.8, 69.7, 70.3, 70.5, 72.9, 73.1, 77.9, 110.8, 121.4, 127.6, 128.3, 129.1, 133.9, 138.8–141.7 (m), 142.6–145.3 (m), 157.8, 169.3; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –151.4– –150.6 (2F, m), –141.1– –140.5 (2F, m); IR (NaCl, cm^{-1}) 1488, 1494, 1623, 1634, 1646, 1651, 1668, 1674, 1683, 2125; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{25}H_{22}{}^{35}Cl_2F_4N_8NaO_5^+$ 683.0924; Found 683.0921.

Methyl 2-(*N*-(4-((12-(4-azido-3,5-dichlorobenzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**S1**)



Pale yellow oil; TLC R_f 0.36 (CH_2Cl_2/MeOH = 20/1); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 2.23–2.44 (br, 1H), 3.27 (s, 3H), 3.47–3.82 (m, 16H), 4.04–4.40 (br, 2H), 6.52–6.70 (br, 1H), 7.43–7.56 (m, 10H), 7.60–7.65 (m, 1H), 7.68–7.76 (m, 4H), 7.85–7.90 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 29.6, 39.5, 40.6, 47.9, 52.0, 53.4, 67.5, 69.6, 70.2, 70.4, 72.7, 78.3, 102.1, 128.5 (d, J = 12.8 Hz), 129.2, 130.7, 130.7, 130.7 (d, J = 89.8 Hz), 131.1 (d, J = 12.0 Hz), 131.4–131.9 (m, five signals are observed as multiplet peaks), 132.0 (d, J = 2.5 Hz), 133.2–133.6 (m), 135.0 (d, J = 11.1 Hz), 135.6 (d, J = 6.1 Hz), 141.0–143.8 (m), 143.4–146.3 (m), 160.1, 167.2, 167.2; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.7– –152.4 (2F, m), –146.2–145.9 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 11.0; IR (NaCl, cm^{-1}) 1505, 1515, 1634, 1644, 2123, 2873, 2916, 3300, 3583; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{45}H_{39}{}^{35}Cl_2F_4N_6NaO_7P^+$ 975.1829; Found 975.1829.

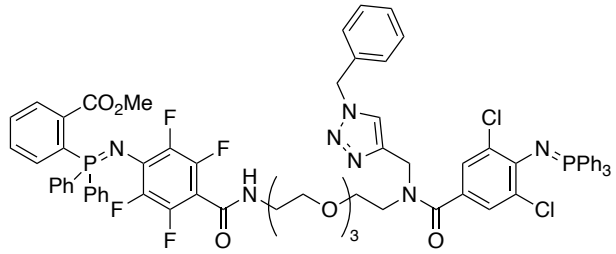
Methyl 2-(*N*-(4-((12-(3,5-dichloro-4-((triphenyl-λ^5-phosphanylidene)amino)benzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**S3**)



Pale yellow oil; TLC R_f 0.41 (CH_2Cl_2/MeOH = 20/1); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 2.27 (s, 1H), 3.27 (s, 3H), 3.43–3.71 (m, 16H), 4.16–4.30 (br, 2H), 6.56–6.62 (br, 1H), 7.33–7.57 (m, 19H), 7.59–7.66 (m, 1H), 7.68–7.78 (m, 10H), 7.85–7.90 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 29.7, 39.6, 50.8, 52.1, 69.1, 69.7, 70.4, 70.4, 70.5, 70.5, 72.6, 79.1, 102.3 (d, J =16.0 Hz), 125.2, 127.2, 128.4 (d, J = 12.5 Hz), 128.7 (d, J = 13.0 Hz), 130.8, 130.8 (d, J = 16.9 Hz), 130.8 (d, J = 91.5 Hz), 131.2 (d, J = 11.8 Hz), 131.4, 131.6 (d, J = 2.8 Hz), 131.8 (d, J =10.0 Hz), 131.9 (d, J =12.8 Hz), 132.1 (d, J = 2.5 Hz), 132.5, 132.6 (d, J = 10.1 Hz), 133.3–133.7 (m), 135.1 (d, J = 11.1 Hz), 135.7 (d, J = 6.2 Hz), 141.1–144.0 (m), 143.5–146.4 (m), 146.7, 160.2, 167.3, 167.3; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.6– –152.4 (2F, m), –146.2– –145.9 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 1.6 (1P,

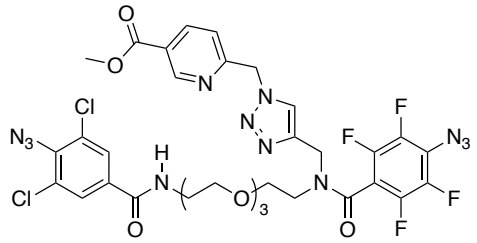
m), 11.2 (1P, m); IR (NaCl, cm^{-1}) 1113, 1266, 1278, 1417, 1435, 1454, 1485, 1495, 1504, 1514, 1641; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{63}H_{54}{}^{35}Cl_2F_4N_4NaO_7P_2^+$ 875.1571; Found 875.1574.

Methyl 2-(*N*-(4-((2-((1-benzyl-1*H*-1,2,3-triazol-4-yl)methyl)-1-(3,5-dichloro-4-((triphenyl-λ^5-phosphaneylidene)amino)phenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**17**)



Pale yellow oil; TLC R_f 0.32 (CH_2Cl_2/MeOH = 20/1); ^1H NMR ($CDCl_3$, 400 MHz): δ 1.73–1.88 (br, 1H), 3.26 (s, 3H), 3.30–3.70 (m, 16H), 4.46 (s, 2H), 5.46 (s, 2H), 6.71–6.82 (br, 1H), 7.00–7.36 (m, 7H), 7.38–7.56 (m, 17H), 7.58–7.66 (m, 1H), 7.68–7.77 (m, 10H), 7.84–7.90 (m, 1H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 101 MHz): δ 29.7, 39.6, 41.3, 44.9, 49.4, 52.1, 53.5, 54.1, 68.2, 69.7, 70.3, 70.5, 70.5, 102.4, 125.8, 127.4, 128.0, 128.4 (d, J = 12.4 Hz), 128.6 (d, J = 12.9 Hz), 128.7, 129.1, 130.4, 130.8, 130.9, 131.0 (d, J = 51.7 Hz), 131.2, 131.4, 131.6 (d, J = 2.7 Hz), 131.8 (d, J = 10.1 Hz), 131.8 (d, J = 3.0 Hz), 132.0, 132.1 (d, J = 1.5 Hz), 132.6 (d, J =10.1 Hz), 134.6–134.8 (m), 135.1 (d, J = 11.1 Hz), 135.7 (d, J = 6.4 Hz), 141.0–143.8 (m), 143.5–146.3 (m), 144.8, 160.2, 167.3, 167.3; $^{19}F\{^1H\}$ NMR ($CDCl_3$, 377 MHz): δ –152.7– –152.4 (2F, m), –146.1– –145.9 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 1.6 (1P, m), 11.2 (1P, m); IR (NaCl, cm^{-1}) 1113, 1266, 1435, 1455, 1484, 1505, 1515, 1641, 3448; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{70}H_{61}{}^{35}Cl_2F_4N_7NaO_7P_2^+$ 1342.3319; Found 1342.3314.

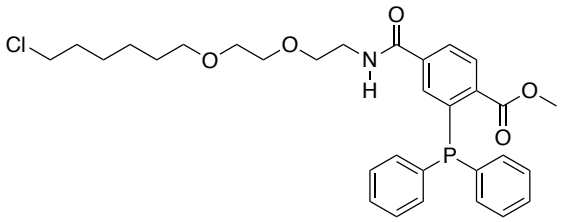
Methyl 6-((4-(15-(4-azido-2,3,5,6-tetrafluorophenyl)-2-(4-azido-3,5-dichlorobenzoyl)-15-oxo-5,8,11-trioxa-2,14-diazapentadecyl)-1*H*-1,2,3-triazol-1-yl)methyl)nicotinate (**19**)



Pale yellow solid; TLC R_f 0.23 (CH_2Cl_2/MeOH = 20/1); Mp 91–93 ºC; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.97–3.02 (m, 2H), 3.16 (t, 2H, J = 4.8 Hz), 3.35–3.72 (m, 12H), 3.96 (s, 3H), 4.71 (s, 2H), 5.79 (s, 2H), 7.12 (d, 1H, J = 8.2 Hz), 7.39 (s, 2H), 8.13 (s, 1H), 8.27 (dd, 1H, J = 8.2 Hz, 2.1 Hz), 8.52 (t, 1H, J = 4.9 Hz), 9.15 (d, 1H, J = 1.5 Hz); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 101 MHz): δ 40.4, 43.2, 51.1, 52.6, 54.8, 59.3, 63.4, 67.9, 69.7, 69.9, 70.2, 70.3, 70.5, 121.0, 125.3, 125.5, 127.9, 129.0, 134.2, 134.8, 138.4–138.8 (m), 138.3, 142.0–142.5 (m), 144.7, 150.6, 157.9, 159.3, 165.1, 169.9; $^{19}F\{^1H\}$ NMR ($CDCl_3$, 377 MHz): δ –151.4– –151.2 (2F, m), –141.0– –140.7 (2F, m); IR (NaCl, cm^{-1}) 1122, 1292, 1437, 1487, 1627, 1651, 1683, 1728, 2125; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{33}H_{30}{}^{35}Cl_2F_4N_{12}NaO_7^+$ 875.1571; Found 875.1574

.

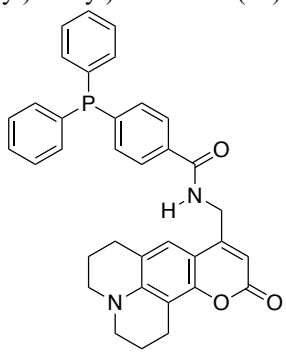
Methyl 4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)-2-(diphenylphosphanyl)benzoate (**20**)



Yellow oil; TLC R_f 0.52 (CH_2Cl_2/MeOH = 20/1); ^1H NMR ($CDCl_3$, 400 MHz): δ 1.27–1.45 (m, 4H), 1.50–1.59 (m, 2H), 1.67–1.77 (m, 2H), 3.43 (t, 2H, J = 6.7 Hz), 3.47–3.60 (m, 10H), 3.73 (s, 3H), 6.52 (t, 1H, J = 5.0 Hz), 7.24–7.36 (m, 11H), 7.76 (dd, 1H, J = 8.0, 1.4 Hz), 8.05–8.09 (m, 1H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 101 MHz): δ 25.3, 26.5, 29.3, 32.3, 39.7, 44.9, 52.2, 69.4, 69.9, 70.1, 71.2, 126.6, 128.5 (d, J = 7.4 Hz), 128.9, 130.7 (d, J = 2.3 Hz), 132.6, 133.8 (d, J = 21.0 Hz), 136.4 (d, J = 18.5 Hz), 137.1 (d, J = 10.5 Hz), 137.3, 141.4 (d, J = 29.0 Hz), 166.3, 166.5 (d, J = 2.3 Hz); ^{31}P NMR ($CDCl_3$, 162 MHz): δ –3.8 (m); IR (NaCl, cm^{-1}) 1116, 1253, 1288, 1434, 1537,

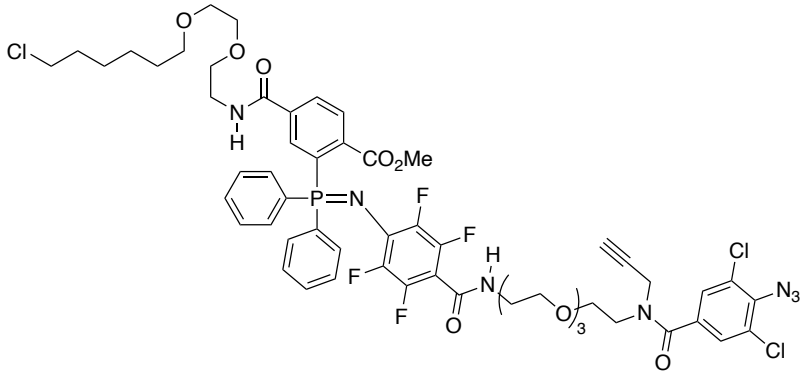
1650, 1656, 1660, 1664, 1721, 2863, 2936; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{31}H_{37}{}^{35}ClNNaO_5P^+$ 592.1996; Found 592.1997.

4-(Diphenylphosphanyl)-*N*-((11-oxo-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-9-yl)methyl)benzamide (**21**)



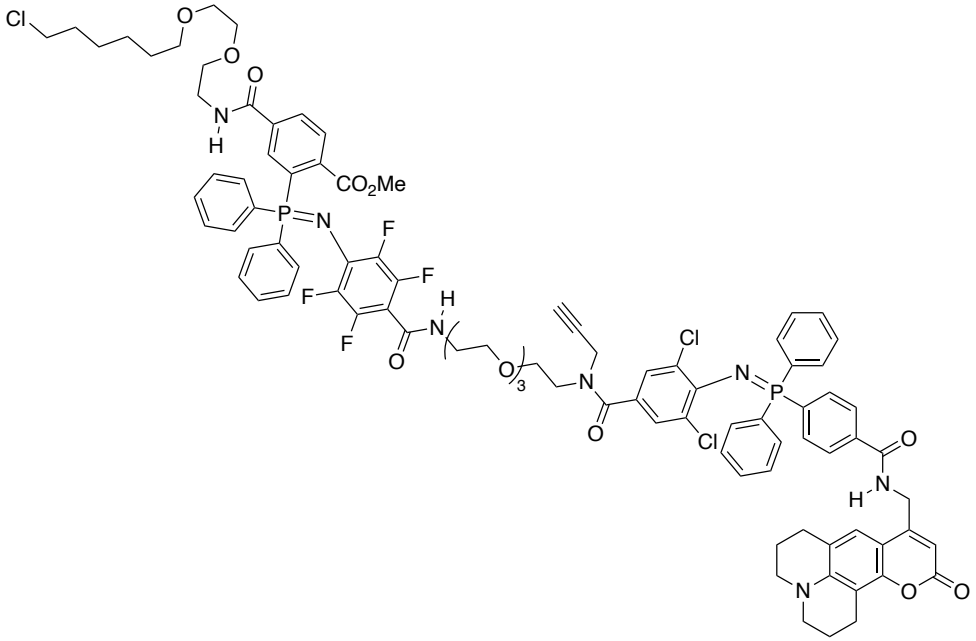
Yellow solid; TLC R_f 0.42 (CH_2Cl_2/MeOH = 20/1); Mp 158–160 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 1.84–1.98 (m, 4H), 2.67–2.78 (m, 4H), 3.16–3.28 (m, 4H), 4.71 (d, 2H, J = 5.8 Hz), 5.95 (s, 1H), 7.04 (s, 1H), 7.27–7.40 (m, 12H), 7.82 (d, 2H, J = 6.8 Hz); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 20.3, 20.5, 21.4, 27.7, 40.1, 49.4, 49.9, 105.9, 106.6, 106.7, 118.3, 121.0, 127.0, 127.0, 128.7 (d, J = 7.2 Hz), 129.1, 133.5 (d, J = 18.7 Hz), 133.7 (d, J = 13.4 Hz), 133.9 (d, J = 19.8 Hz), 136.2 (d, J = 10.6 Hz), 146.0, 151.1, 152.4, 162.7, 167.0; ^{31}P NMR ($CDCl_3$, 162 MHz): δ –5.5 (m); FL (MeOH) λ_{max} = 525 nm; IR (NaCl, cm^{-1}) 1182, 1312, 1557, 1603, 1614, 1700, 1704, 1713; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{35}H_{31}N_2NaO_3P^+$ 581.1970; Found 581.1973.

Methyl 2-(*N*-(4-((12-(4-azido-3,5-dichlorobenzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)-4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)benzoate (**S2**)



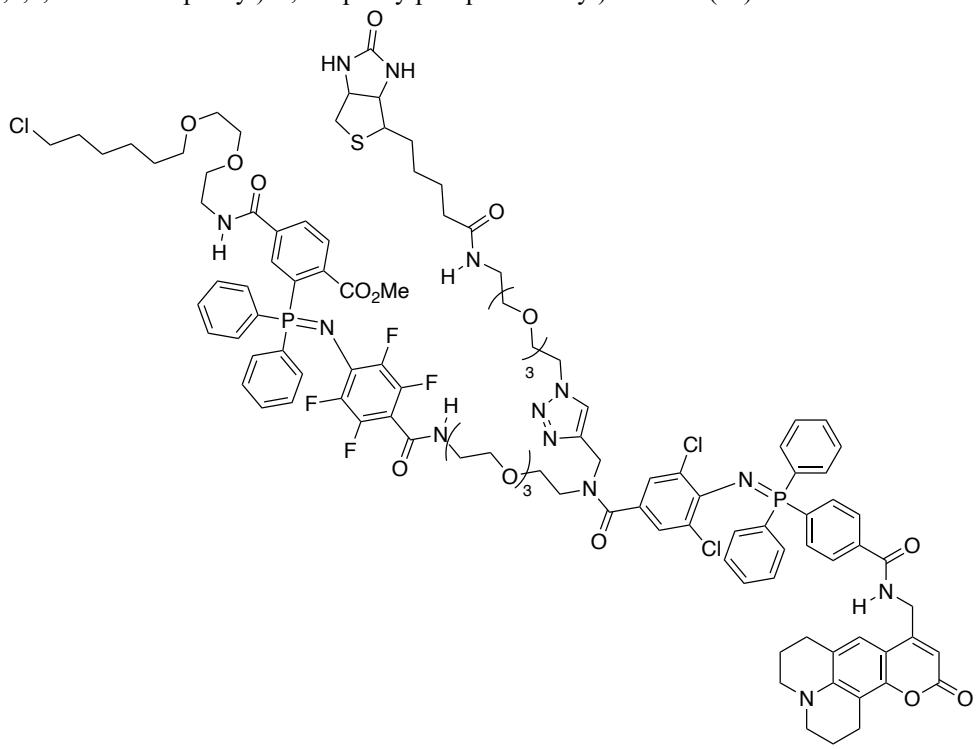
Yellow solid; TLC R_f 0.23 (CH_2Cl_2/MeOH = 20/1); Mp 47–49 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 1.19–1.44 (m, 4H), 1.48–1.58 (m, 2H), 1.66–1.75 (m, 2H), 2.12–2.45 (br, 1H), 3.31 (s, 3H), 3.44–3.65 (m, 30H), 4.10–4.34 (br, 1H), 6.87–6.94 (br, 1H), 7.42–7.57 (m, 8H), 7.64–7.73 (m, 4H), 7.84–7.90 (m, 1H), 7.96–8.02 (m, 1H), 8.15–8.29 (m, 1H); ^{13}C{^{1}H}NMR ($CDCl_3$, 101 MHz): δ 14.0, 14.1, 21.0, 22.6, 25.3, 26.5, 29.3, 31.5, 32.4, 39.6, 39.9, 40.6, 45.0, 52.2, 60.3, 69.3, 69.6, 69.9, 70.2, 70.2, 70.4, 71.2,102.4, 128.5–132.5 (m), 133.7 (d, J = 11.3 Hz), 136.7 (d, J = 11.3 Hz), 138.0 (d, J = 6.5 Hz), 140.9–143.2 (m), 143.8–146.4 (m), 160.0, 165.3, 166.8; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –136.9– –137.3 (2F, m), –150.5– –150.9 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 10.9 (m); HPLC analysis: Rt = 33.1 min [column: Shiseido CAPCELL PAK MG II (4.6 mm i.d. × 250 mm); mobile phase: MeOH:H_2O = 40:60 (0−5 min), linear gradient from 40:60 to 99:1 (5−30 min), 99:1 (30−50 min); flow rate: 1.00 mL/min; detection: UV at 254 nm]; IR (NaCl, cm^{-1}) 977, 1116, 1282, 1437, 1481, 1505, 1511, 1644, 1651, 1657, 1731, 2123, 2867, 2936; HRMS (ESI) *m/z*: $[M + Na]^+$ Calcd for $C_{56}H_{59}{}^{35}Cl_3F_4N_7NaO_{10}P^+$ 1224.2960; Found 1224.2964.

Methyl 4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)-2-(*N*-(4-((12-(3,5-dichloro-4-(((4-(((11-oxo-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-9-yl)methyl)carbamoyl)phenyl)diphenyl-λ^5-phosphanylidene)amino)benzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**S4**)



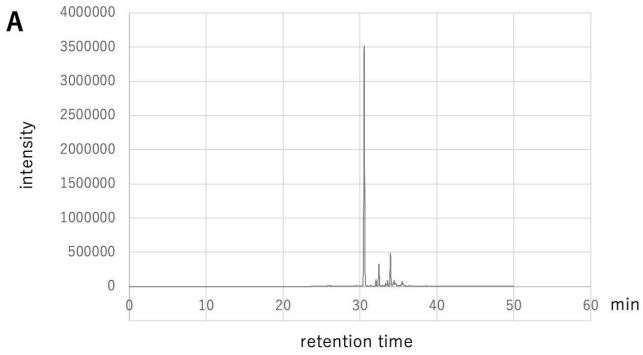
Yellow solid; TLC R_f 0.22 (CH_2Cl_2/MeOH = 20/1); Mp 98–100 ºC; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 1.20–1.44 (m, 4H), 1.48–1.58 (m, 2H), 1.66–1.76 (m, 2H), 1.82–1.95 (m, 4H), 1.96–2.33 (br, 3H), 2.66–2.74 (m, 4H), 3.15–3.25 (m, 4H), 3.29 (s, 3H), 3.38–3.44 (m, 4H), 3.45–3.67 (m, 21H), 4.12–4.32 (br, 2H), 4.64 (d, 2H, J = 5.6 Hz), 5.92 (s, 1H), 6.80–6.88 (br, 1H), 7.01 (s, 1H), 7.25–7.34 (m, 2H), 7.39–7.56 (m, 12H), 7.65–7.87 (m, 12H), 7.91–7.96 (m, 2H), 7.97–8.02 (m, 1H), 8.13–8.20 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 14.0, 20.2, 20.4, 21.3, 22.6, 25.2, 26.5, 27,6, 29.2, 31.5, 32.4, 39.6–40.0 (m), 44.9, 49.3, 49.8, 50.6, 52.2, 69.4–71.2 (m), 105.6, 106.6 (d, J =2.8 Hz), 127.1−137.9 (m), 145.9, 151.0, 152.3, 160.1, 162.7, 165.5, 166.6, 166.8; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.4– –152.1 (2F, m), –145.9– –145.6 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 1.0 (1P, m), 11.1 (1P, m); HPLC analysis: Rt = 34.7 min [column: Shiseido CAPCELL PAK MG II (4.6 mm i.d. × 250 mm); mobile phase: MeOH:H2O = 40:60 (0−5 min), linear gradient from 40:60 to 99:1 (5−30 min), 99:1 (30−50 min); flow rate: 1.00 mL/min; detection: UV at 254 nm]; FL (MeOH) λ_{max} = 525 nm; IR (NaCl, cm^{-1}) 1118, 1265, 1312, 1437, 1517, 1521, 1532, 1540, 1646, 1653, 2865, 2935; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{91}H_{90}{}^{35}Cl_3F_4N_7NaO_{13}P_2{}^+$ 1754.4971; Found 1754.4973.

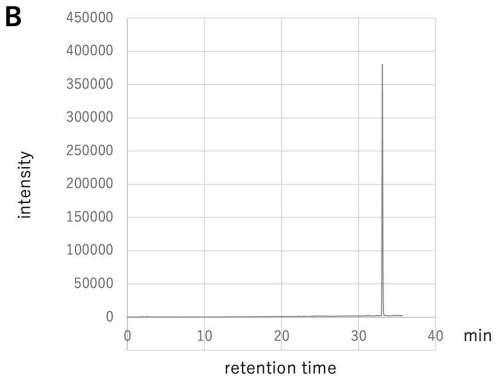
Methyl 4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)-2-(*N*-(4-((1-(3,5-dichloro-4-(((4-(((11-oxo-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-9-yl)methyl)carbamoyl)phenyl)diphenyl-λ^5-phosphanylidene)amino)phenyl)-1-oxo-2-((1-(2-(2-(5-(2-oxohexahydro-1*H*-thieno[3,4-*d*]imidazol-4-yl)pentanamido)ethoxy)ethyl)-1*H*-1,2,3-triazol-4-yl)methyl)-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**23**)

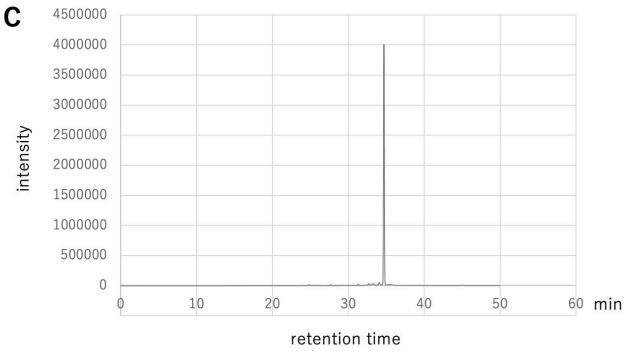


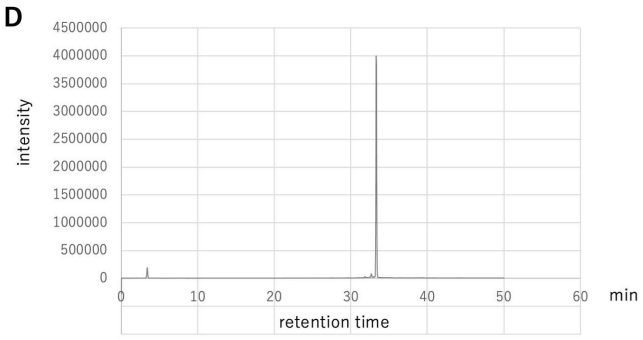
Brown oil; TLC R_f 0.34 (CH_2Cl_2/MeOH = 10/1); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 0.80–0.94 (m, 4H), 1.20–2.25 (m, 28H), 2.61–2.92 (m, 8H), 3.02–3.16 (m, 2H), 3.20–3.71 (m, 33H), 3.83 (t, 2H, J = 4.8 Hz), 4.18–4.32 (m, 2H), 4.36–4.42 (m, 1H), 4.44–4.52 (m, 2H), 4.64–4.73 (m, 4H), 5.20 (s, 1H), 5.95 (s, 1H), 5.99 (s, 1H), 6.11 (s, 1H), 6.60 (t, 1H, J = 4.9 Hz), 7.06 (s, 1H), 7.31 (d, 2H, J = 1.2 Hz), 7.41–7.95 (m, 25H), 7.99–8.04 (m, 1H), 8.12–8.19 (m, 1H), 8.29–8.35 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): δ 25.3, 26.6, 27.7, 28.0, 29.4, 29.7, 32.4, 39.1, 39.9, 45.0, 49.9, 50.6, 52.3, 55.3, 60.0, 61.7, 69.4, 69.5, 69.9, 70.0, 70.2, 70.4, 70.6, 71.2, 118.2, 128.4, 128.5, 128.6, 128.8, 131.0, 131.8, 131.9, 132.1, 132.5, 132.6, 162.6; ^{19}F{^{1}H} NMR ($CDCl_3$, 377 MHz): δ –152.6– –152.2 (2F, m), –145.9– –145.6 (2F, m); ^{31}P NMR ($CDCl_3$, 162 MHz): δ 1.2 (1P, m), 11.1 (1P, m); HPLC analysis: Rt = 33.3 min [column: Shiseido CAPCELL PAK MG II (4.6 mm i.d. × 250 mm); mobile phase: MeOH:H_2O = 40:60 (0−5 min), linear gradient from 40:60 to 99:1 (5−30 min), 99:1 (30−50 min); flow rate: 1.00 mL/min; detection: UV at 254 nm]; FL (MeOH) λ_{max} = 525 nm; IR (NaCl, cm^{-1}) 984, 1294, 1296, 1457, 1507, 1663, 1700; HRMS (ESI) *m/z*: [M + Na]$^+$ Calcd for $C_{109}H_{122}{}^{35}Cl_3F_4N_{13}NaO_{18}P_2S^+$ 2198.7126; Found 2198.7133.

HPLC Charts. (A) 16 (B) S2 (C) S4 (D) 23









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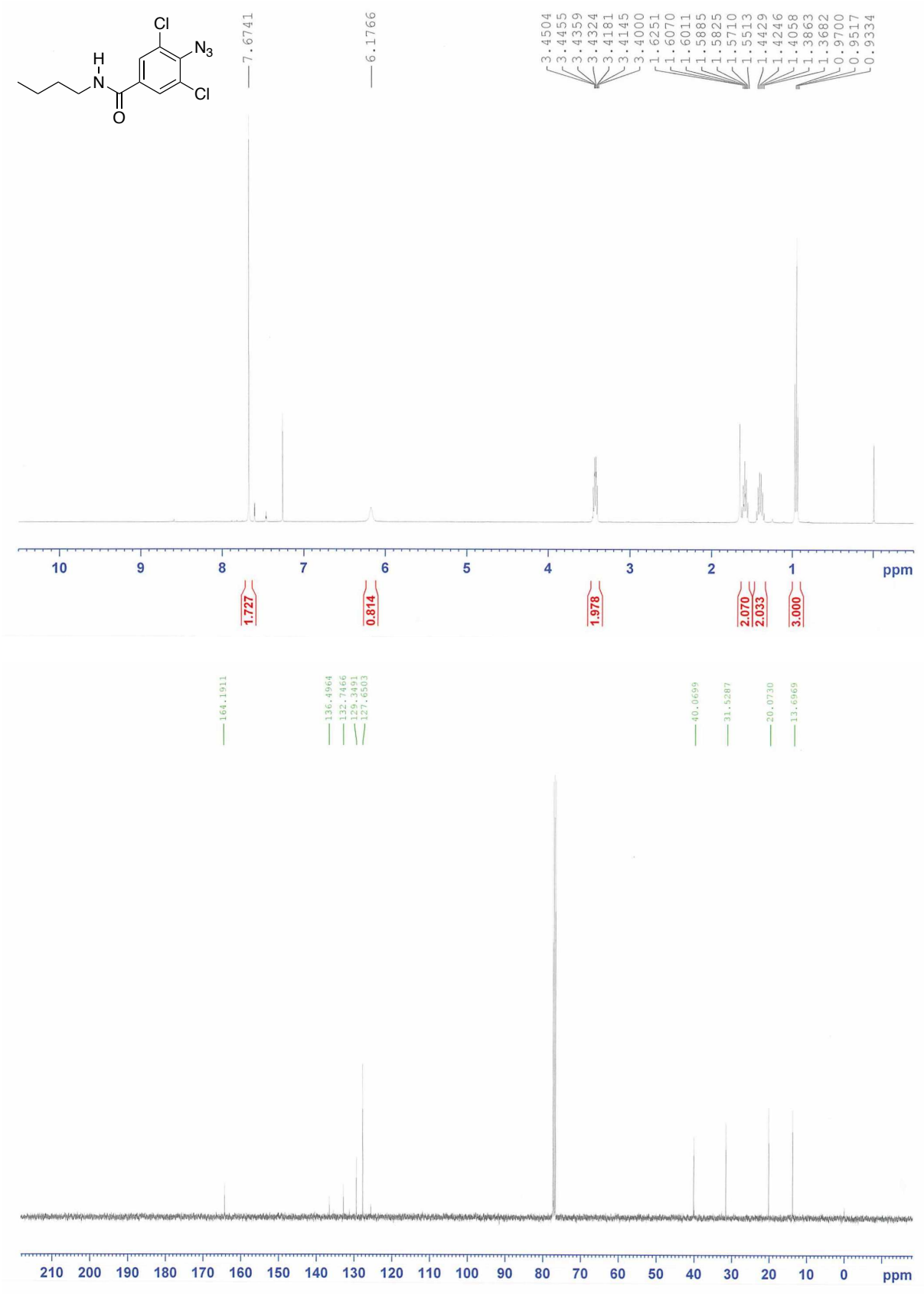
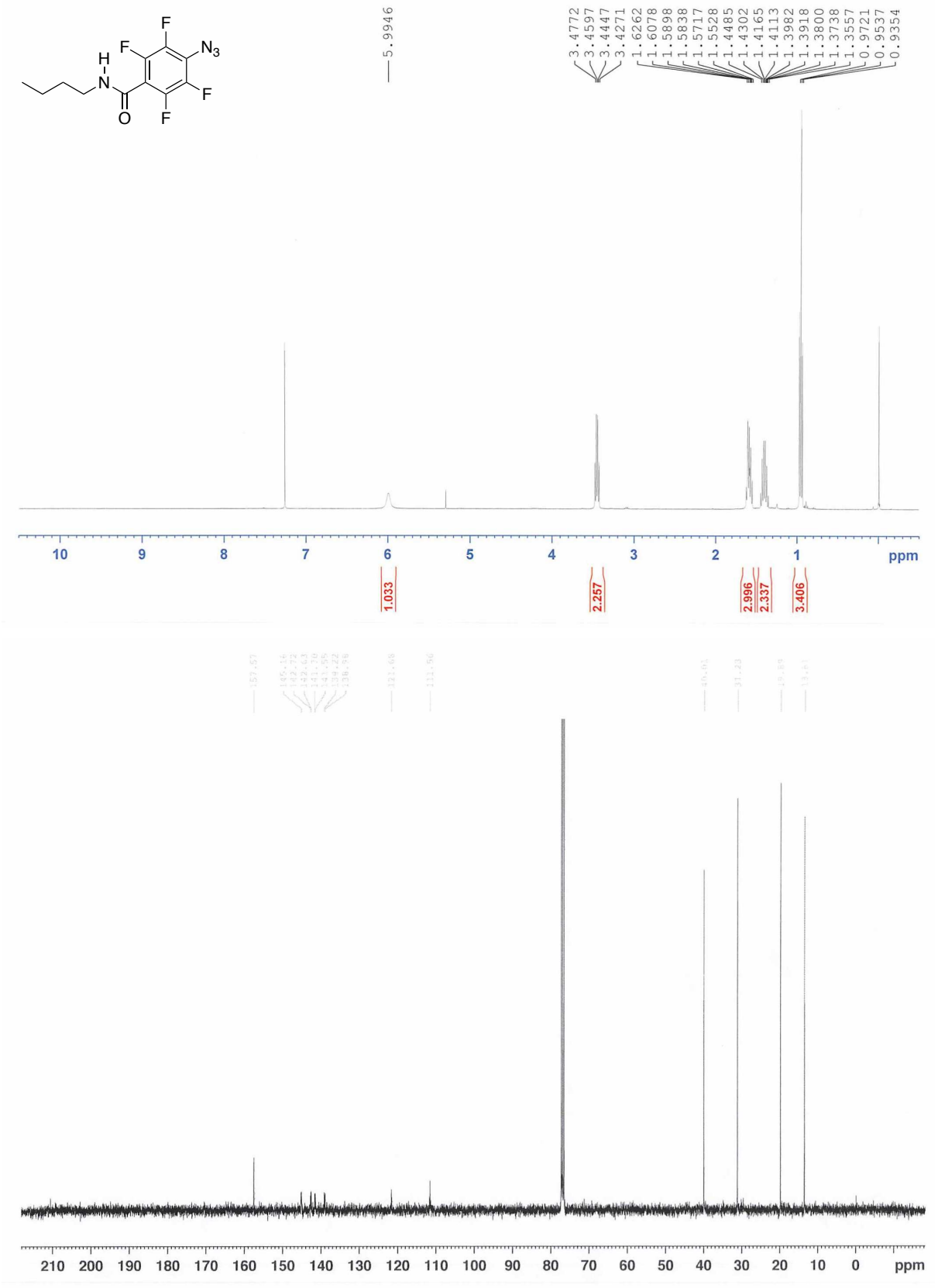
H and ^{13}C NMR Spectra of Compounds

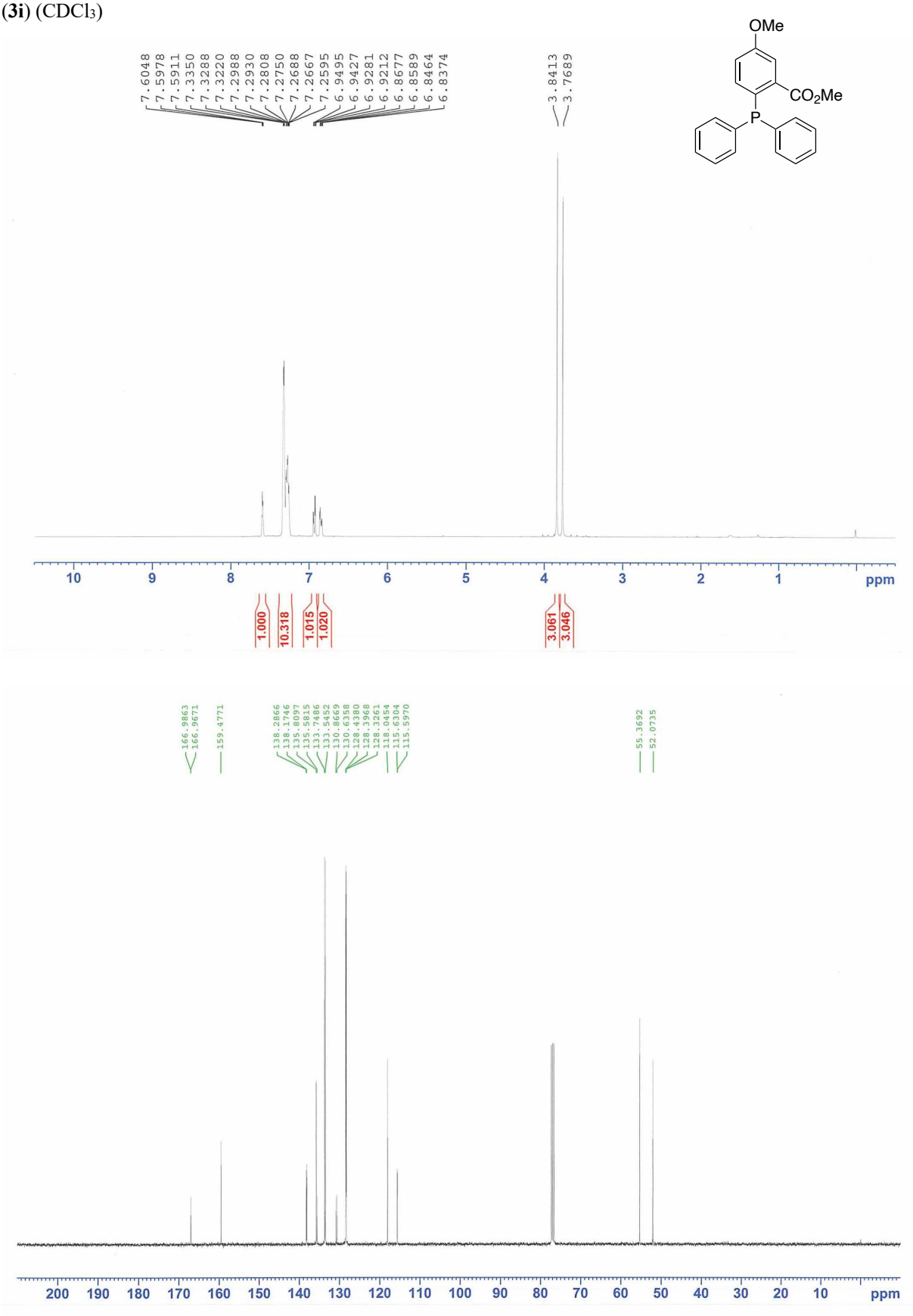
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of 4-azido-*N*-butyl-3,5-dichlorobenzamide (**1a**) ($CDCl_3$)



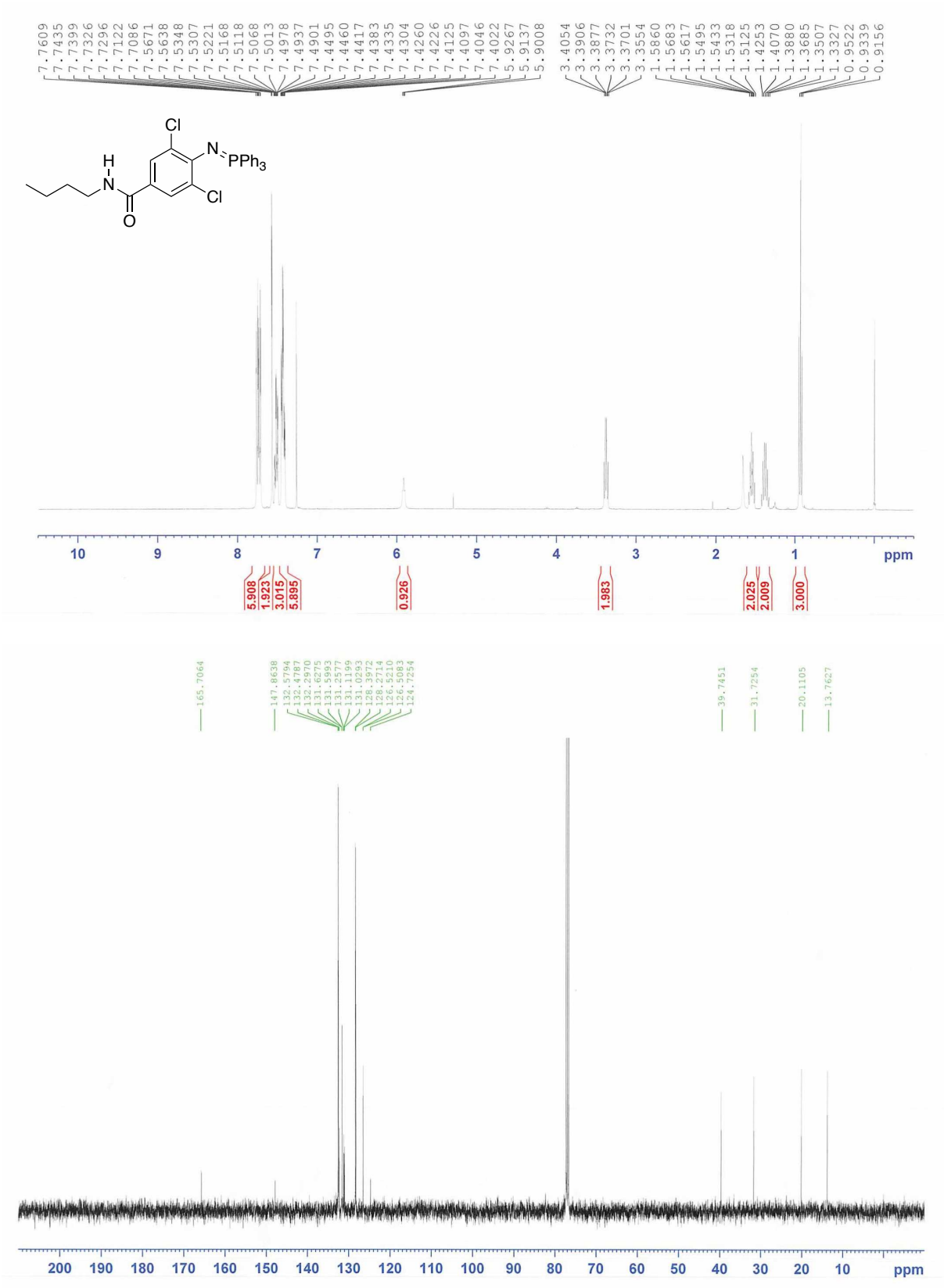
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of 4-azido-*N*-butyl-2,3,5,6-tetrafluorobenzamide (**2a**) ($CDCl_3$)



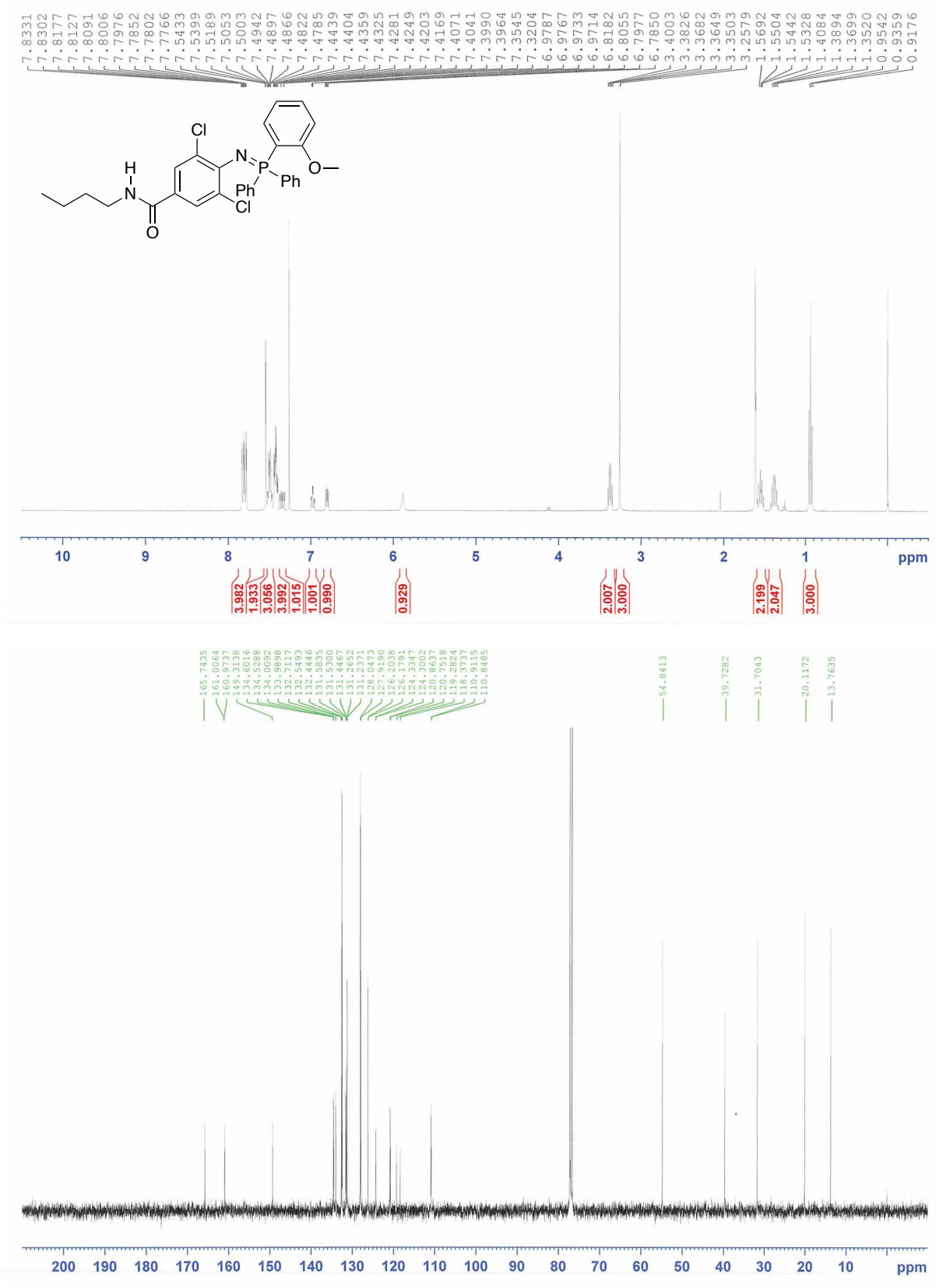
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 2-(diphenylphosphaneyl)-5-methoxybenzoate (**3i**) ($CDCl_3$)



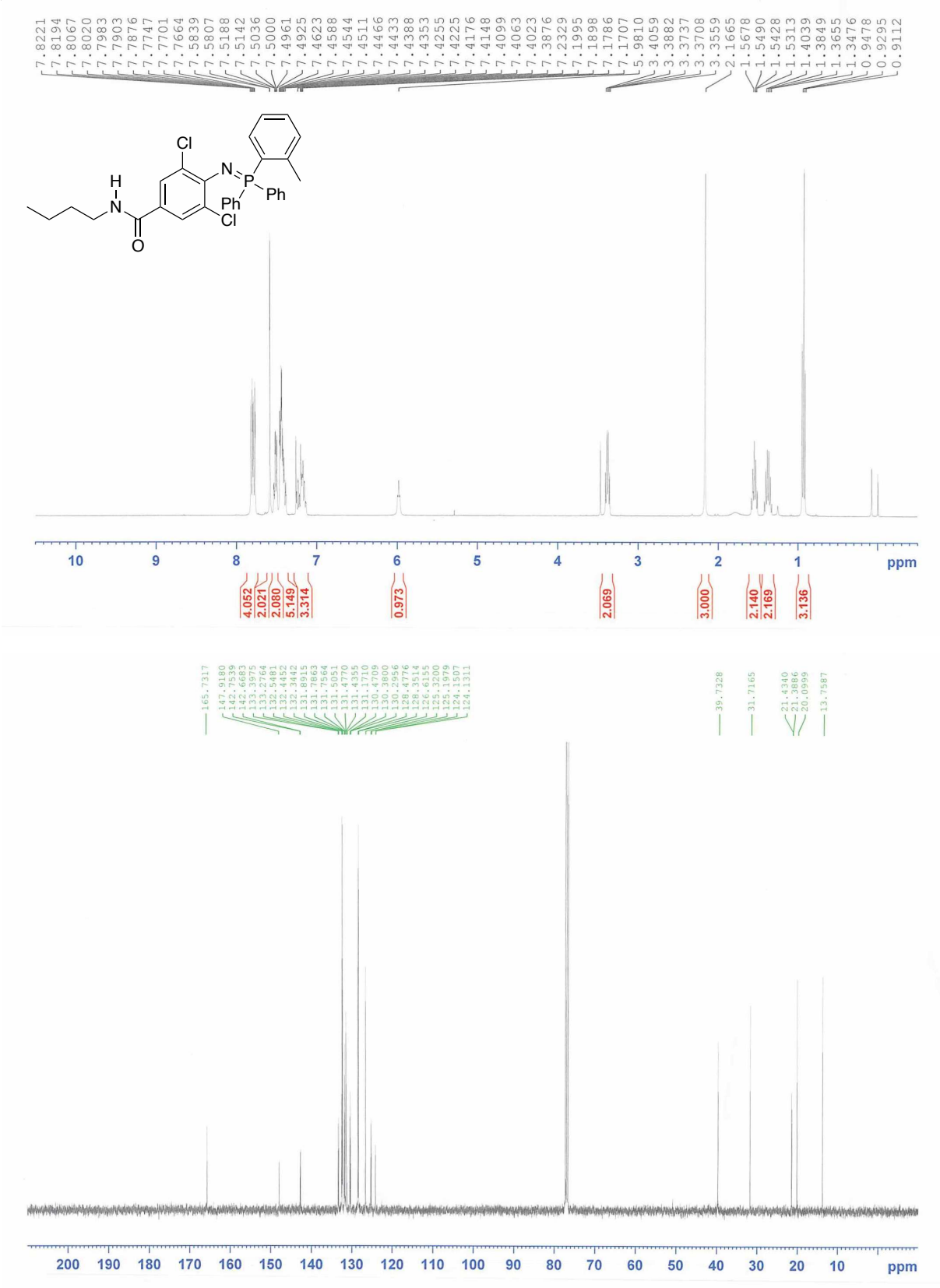
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *N*-butyl-3,5-dichloro-4-((triphenyl-λ^5-phosphanylidene)amino)benzamide (**4a**) ($CDCl_3$)



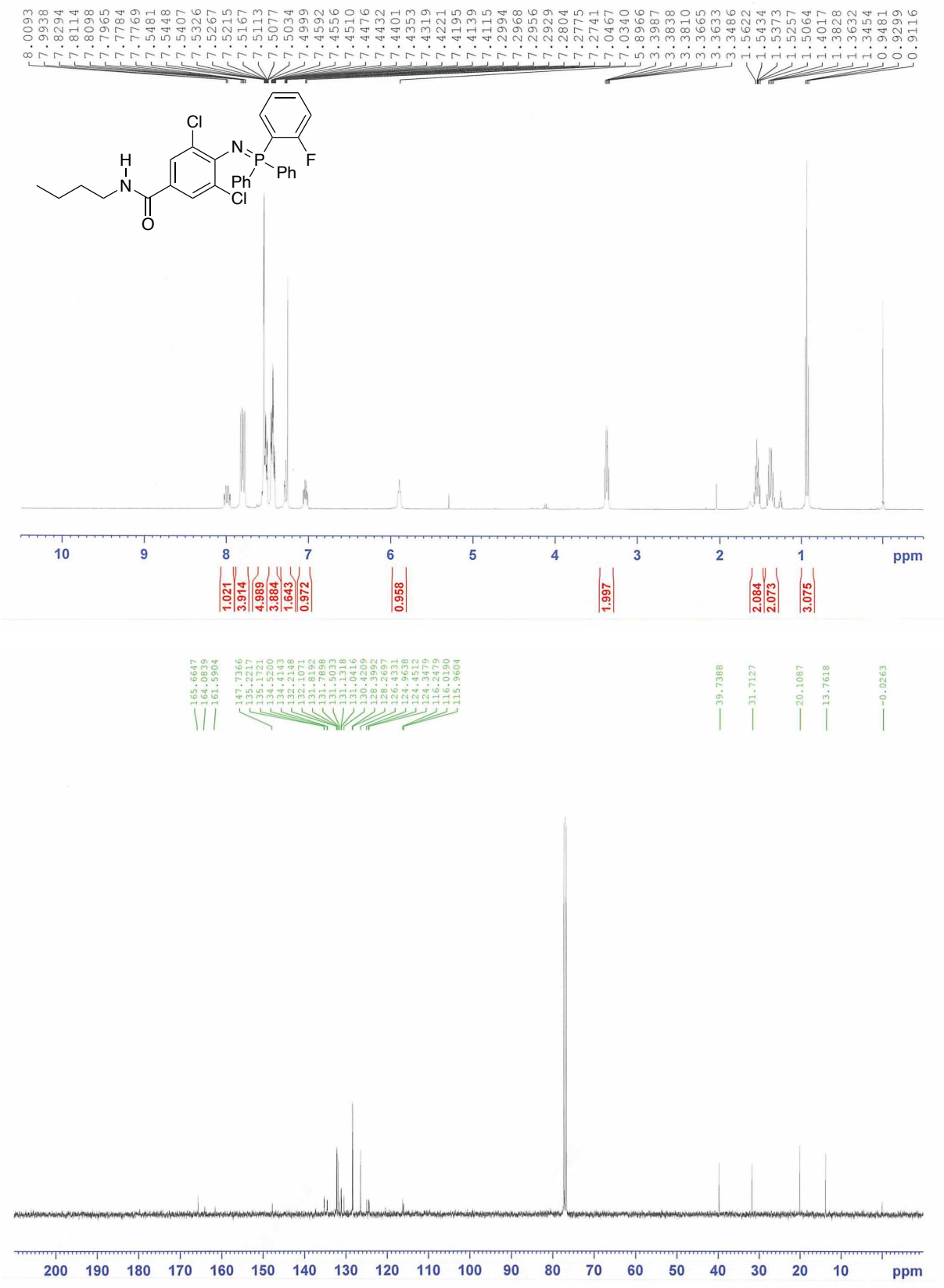
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *N*-butyl-3,5-dichloro-4-(((2-methoxyphenyl)diphenyl-λ^{5}-phosphaneylidene)amino)benzamide (**4c**) ($CDCl_3$)



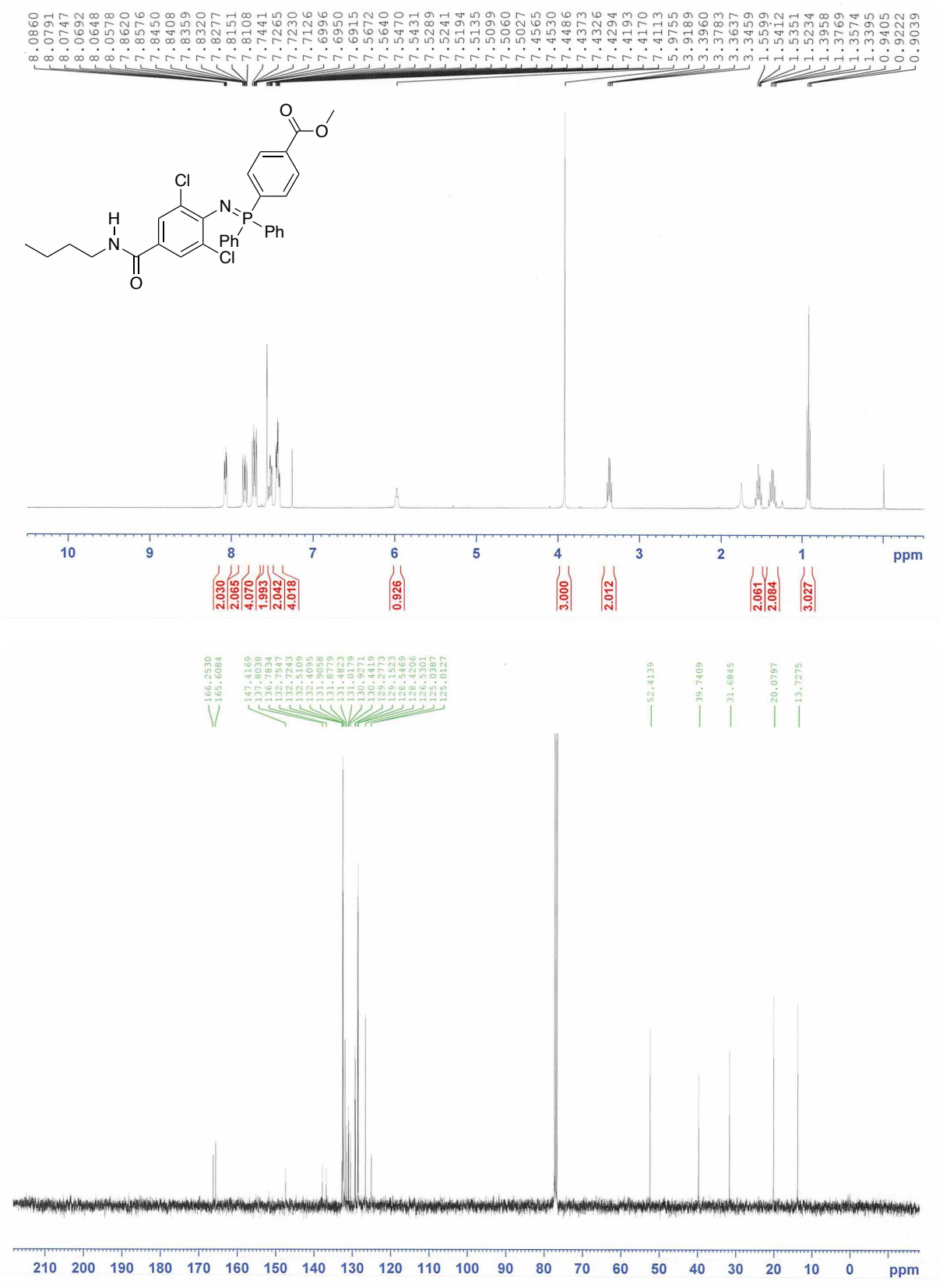
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *N*-butyl-3,5-dichloro-4-((diphenyl(*o*-tolyl)-λ^5-phosphaneylidene)amino)benzamide (**4d**) ($CDCl_3$)



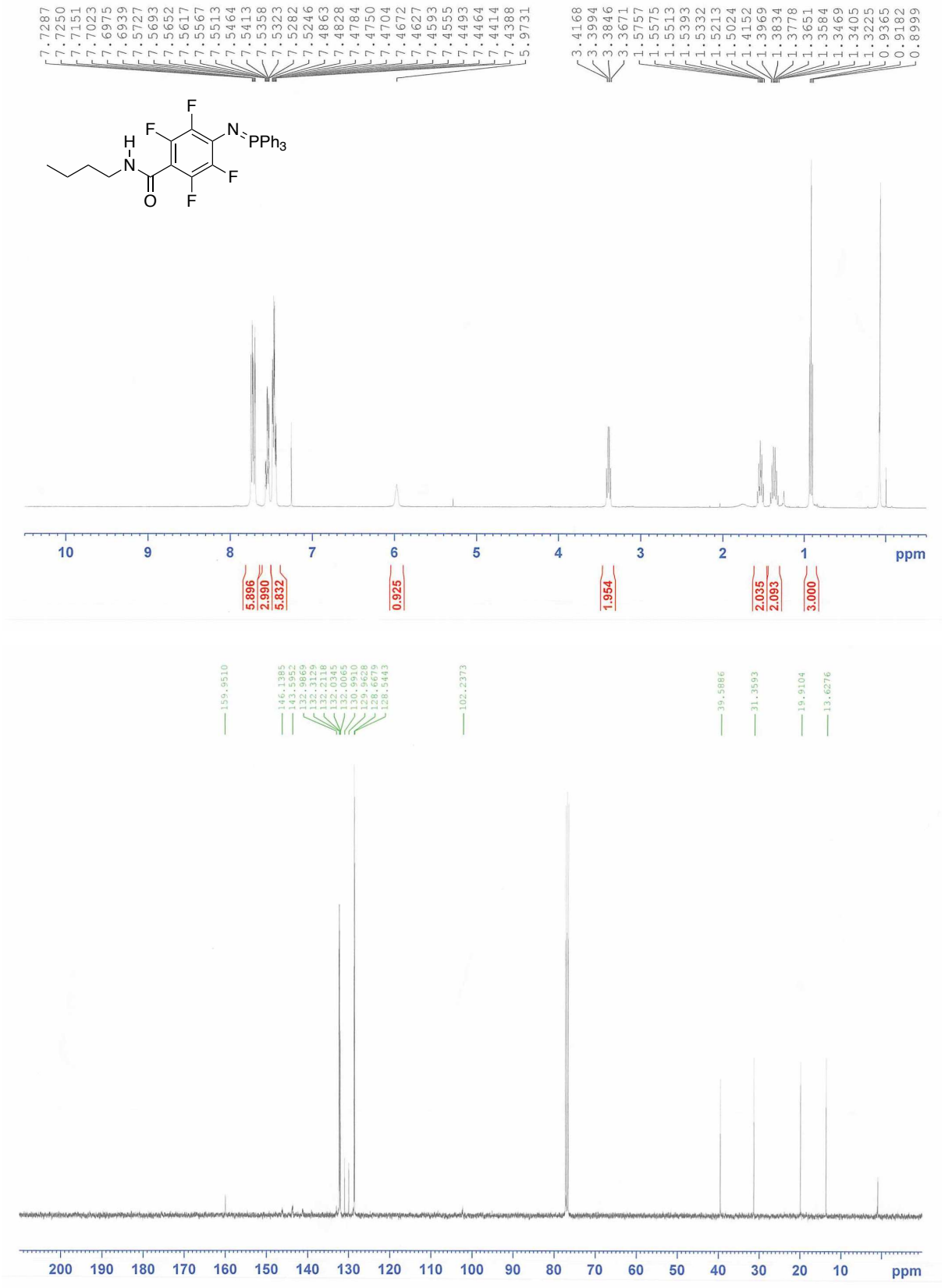
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *N*-butyl-3,5-dichloro-4-(((2-fluorophenyl)diphenyl-λ^{5}-phosphanylidene)amino)benzamide (**4e**) ($CDCl_3$)



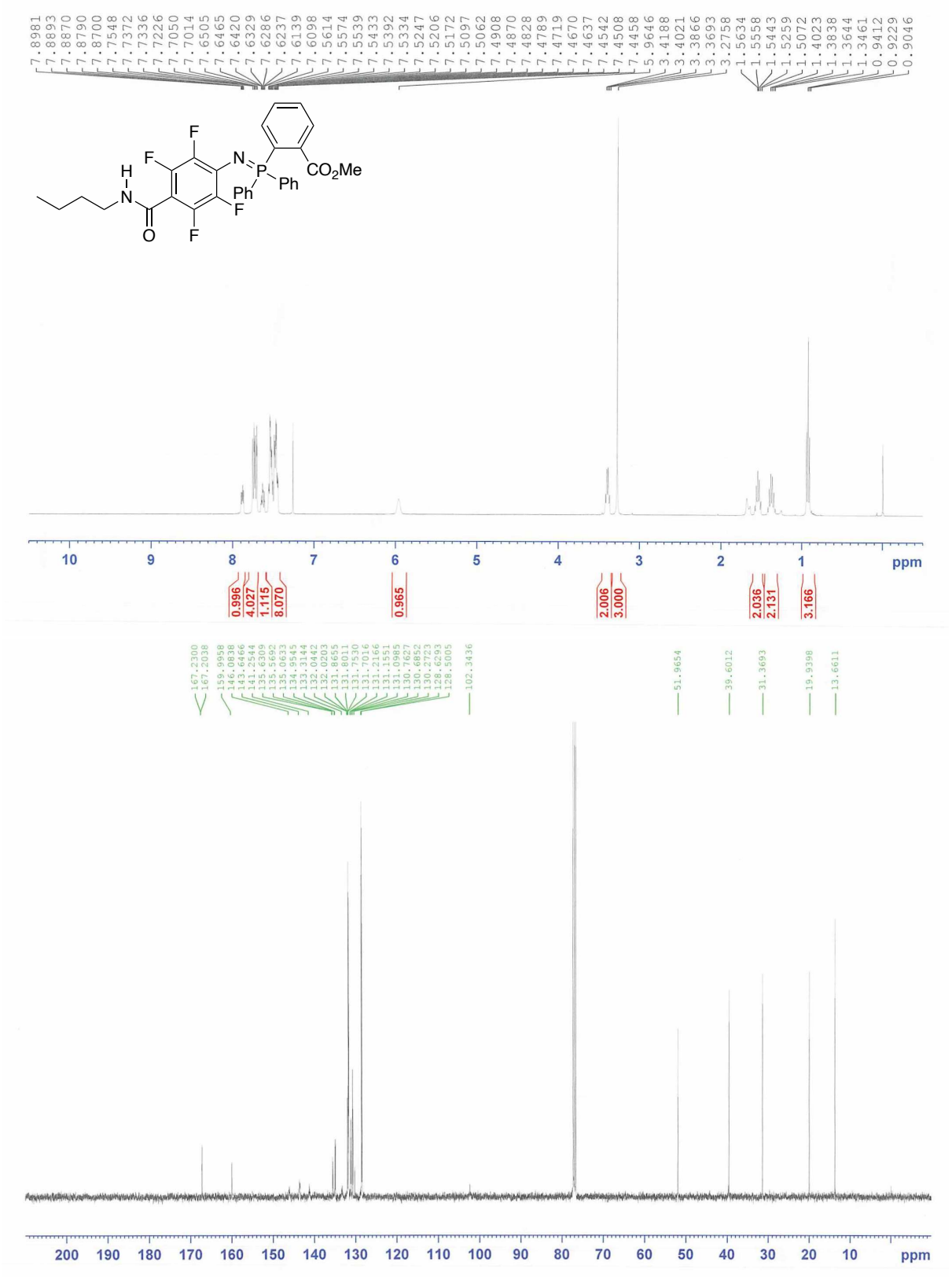
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 4-(*N*-(4-(butylcarbamoyl)-2,6-dichlorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**4h**) ($CDCl_3$)



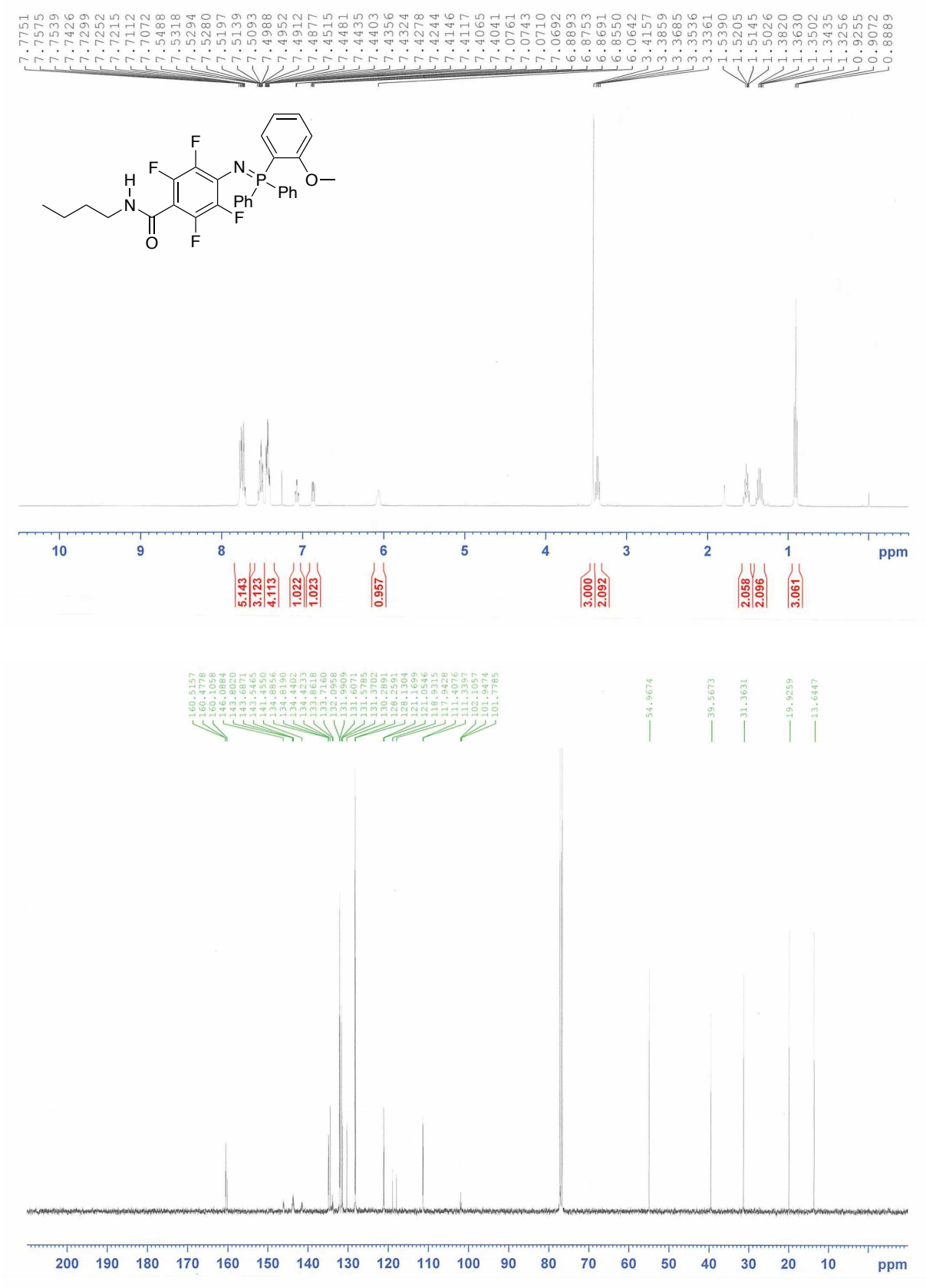
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *N*-butyl-2,3,5,6-tetrafluoro-4-((triphenyl-λ^5-phosphanylidene)amino)benzamide (**5a**) ($CDCl_3$)



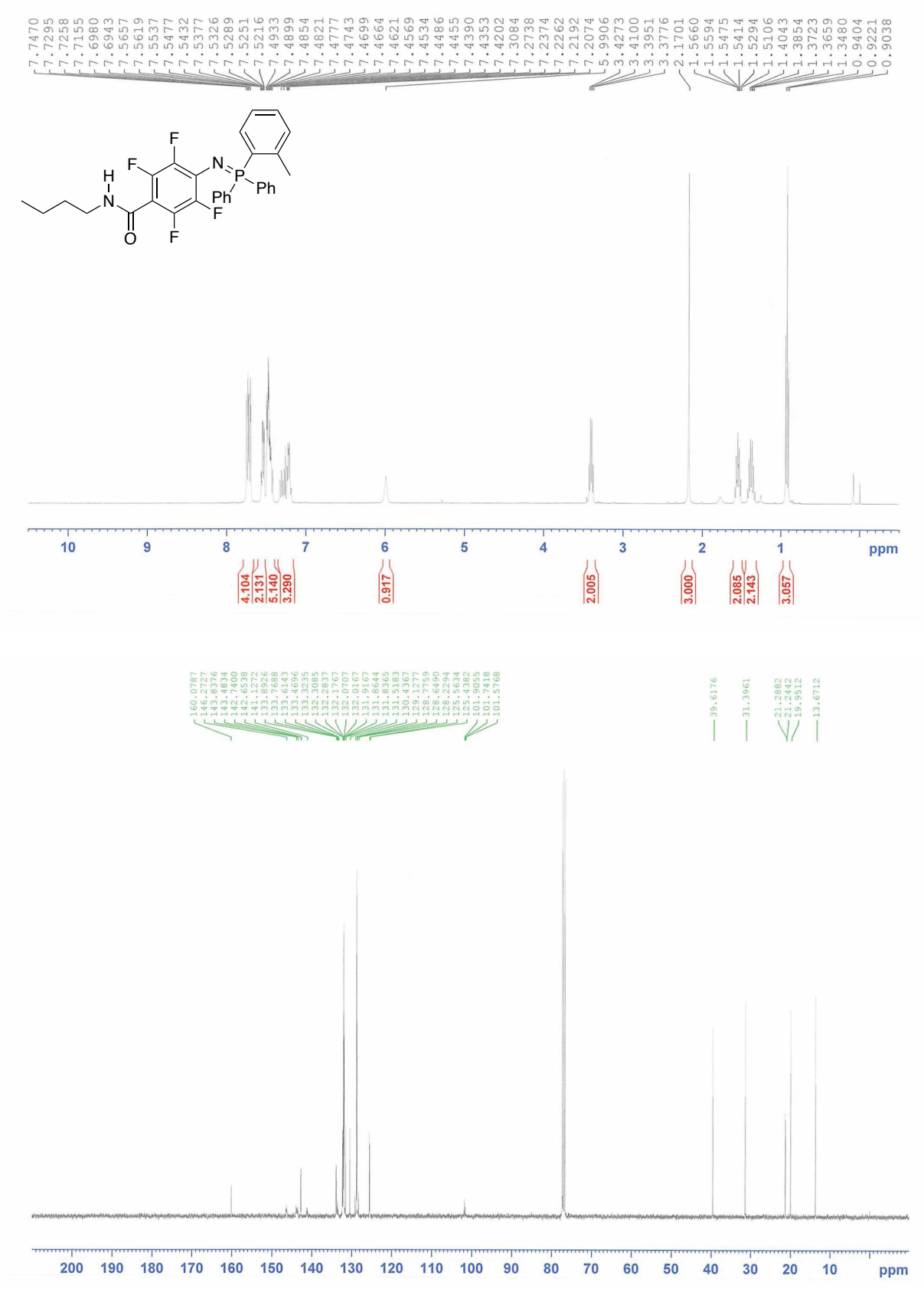
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 2-(*N*-(4-(butylcarbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**5b**) ($CDCl_3$)



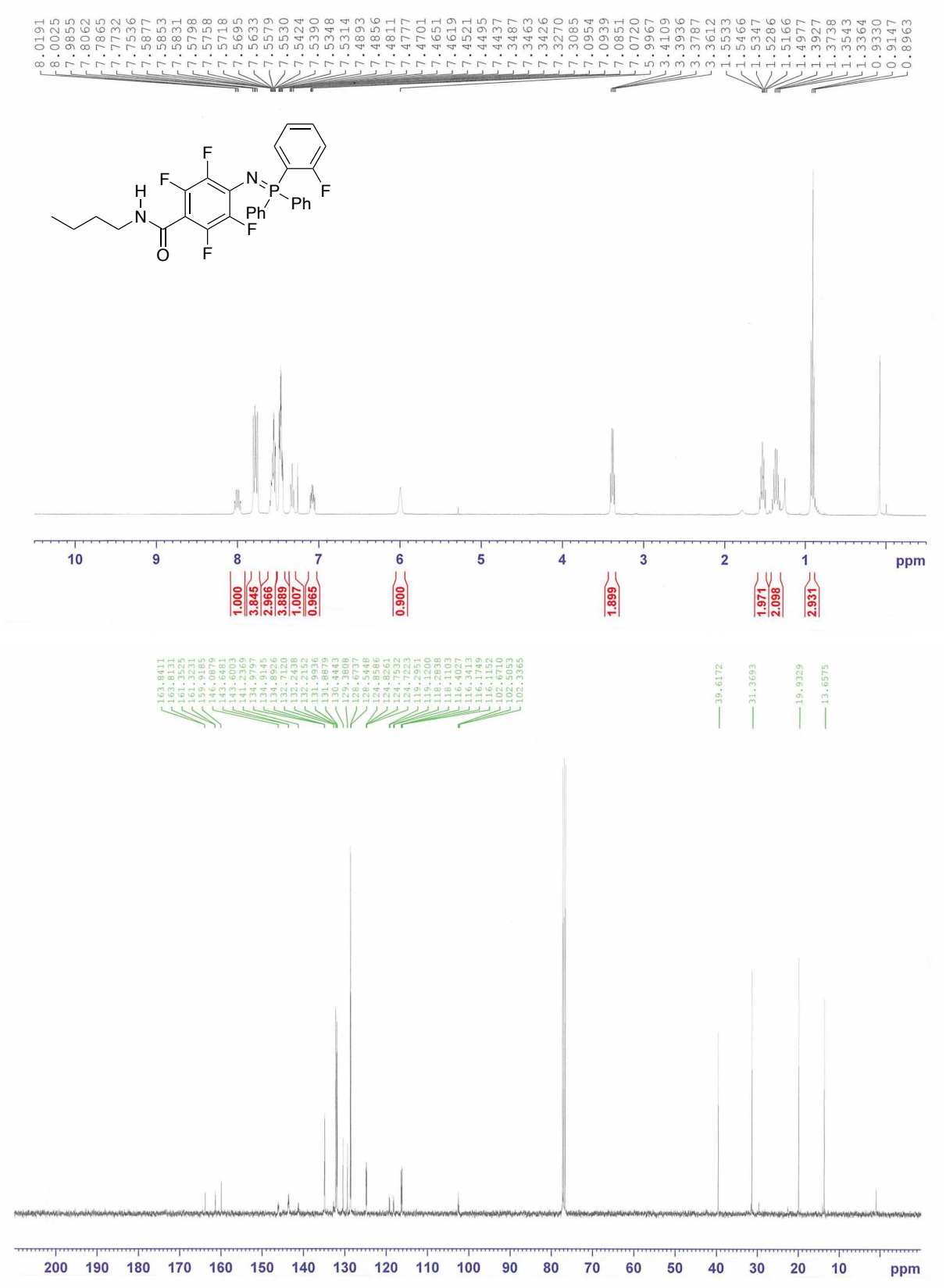
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *N*-butyl-2,3,5,6-tetrafluoro-4-(((2-methoxyphenyl)diphenyl-λ^{5}-phosphanylidene)amino)benzamide (**5c**) ($CDCl_3$)



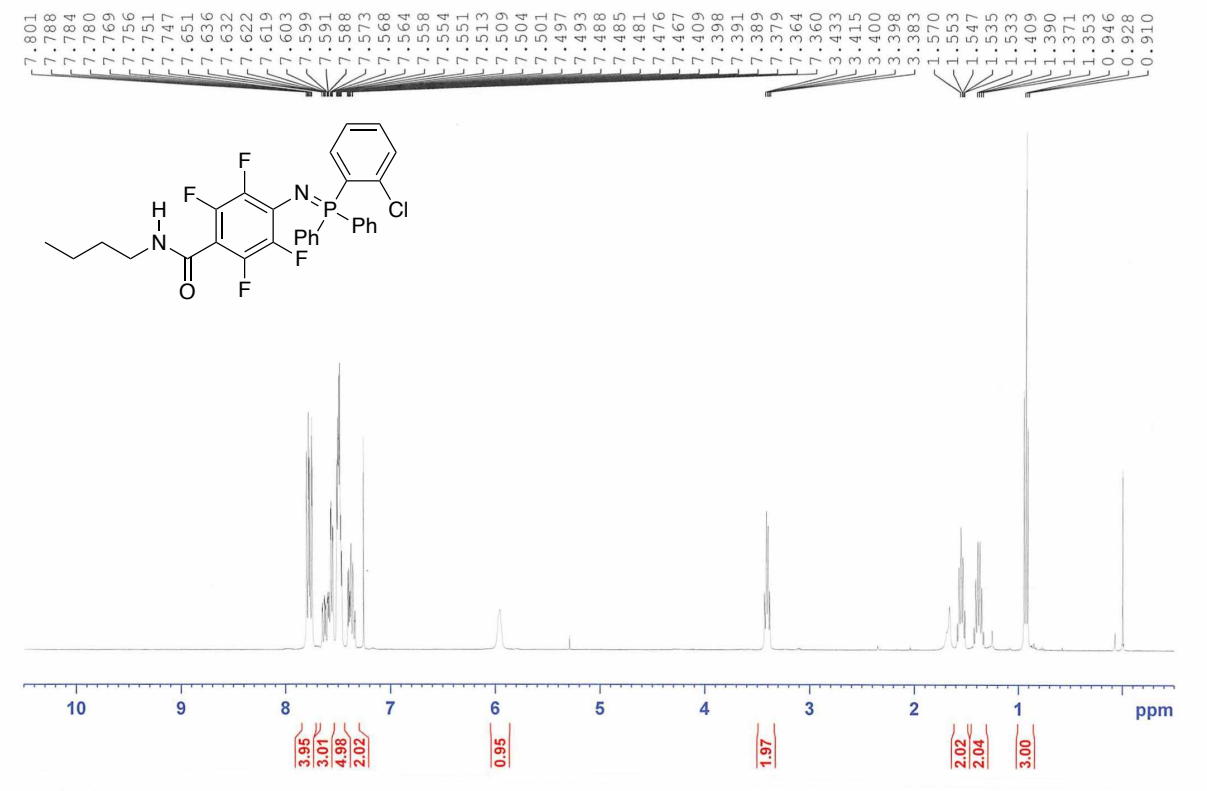
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *N*-butyl-4-((diphenyl(*o*-tolyl)-λ^{5}-phosphanylidene)amino)-2,3,5,6-tetrafluorobenzamide (**5d**) ($CDCl_3$)

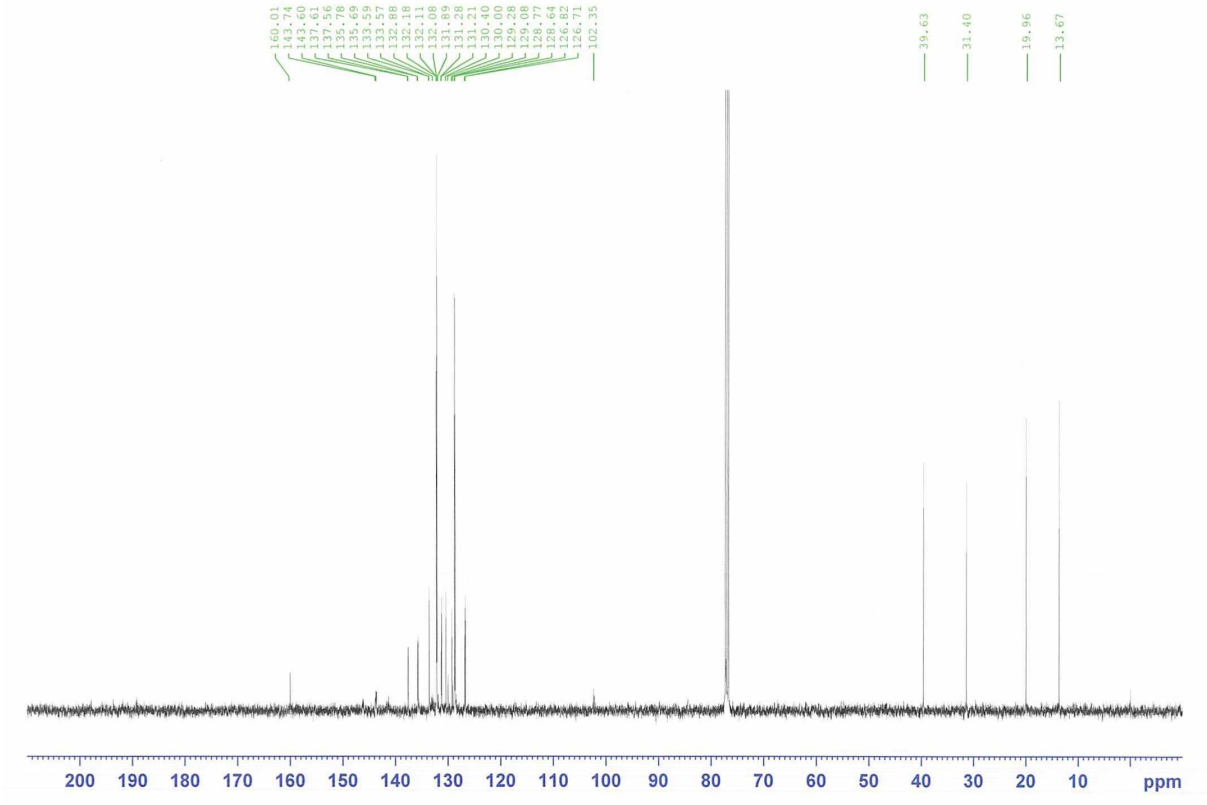


^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *N*-butyl-2,3,5,6-tetrafluoro-4-(((2-fluorophenyl)diphenyl-λ^{5}-phosphanylidene)amino)benzamide (**5e**) ($CDCl_3$)

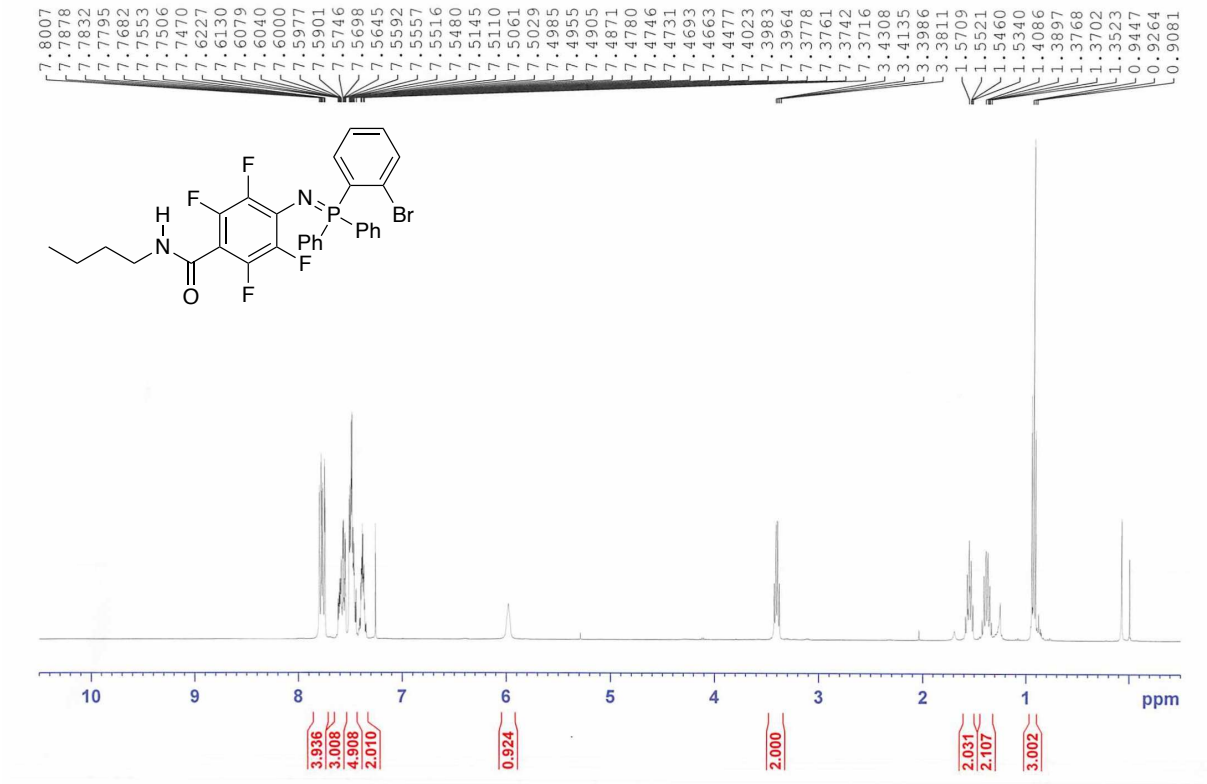


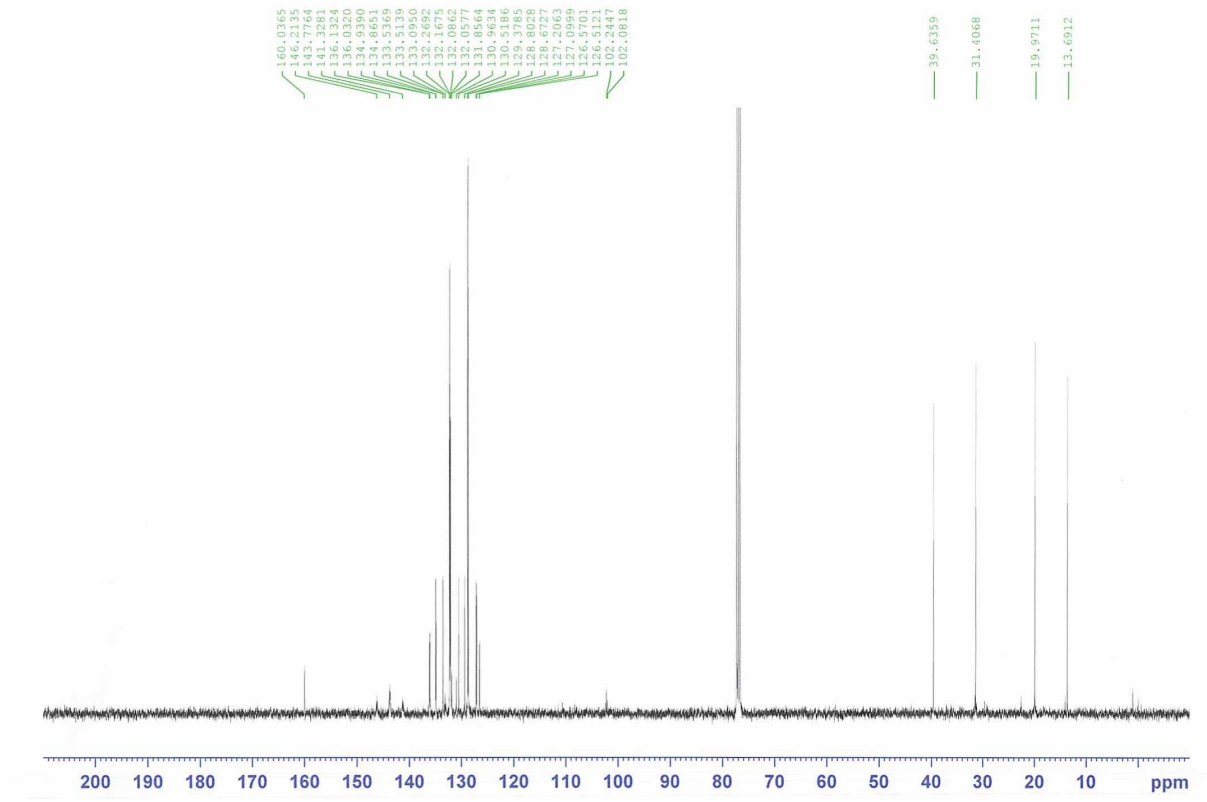
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *N*-butyl-4-(((2-chlorophenyl)diphenyl-λ^{5}-phosphanylidene)amino)-2,3,5,6-tetrafluorobenzamide (**5f**) ($CDCl_3$)



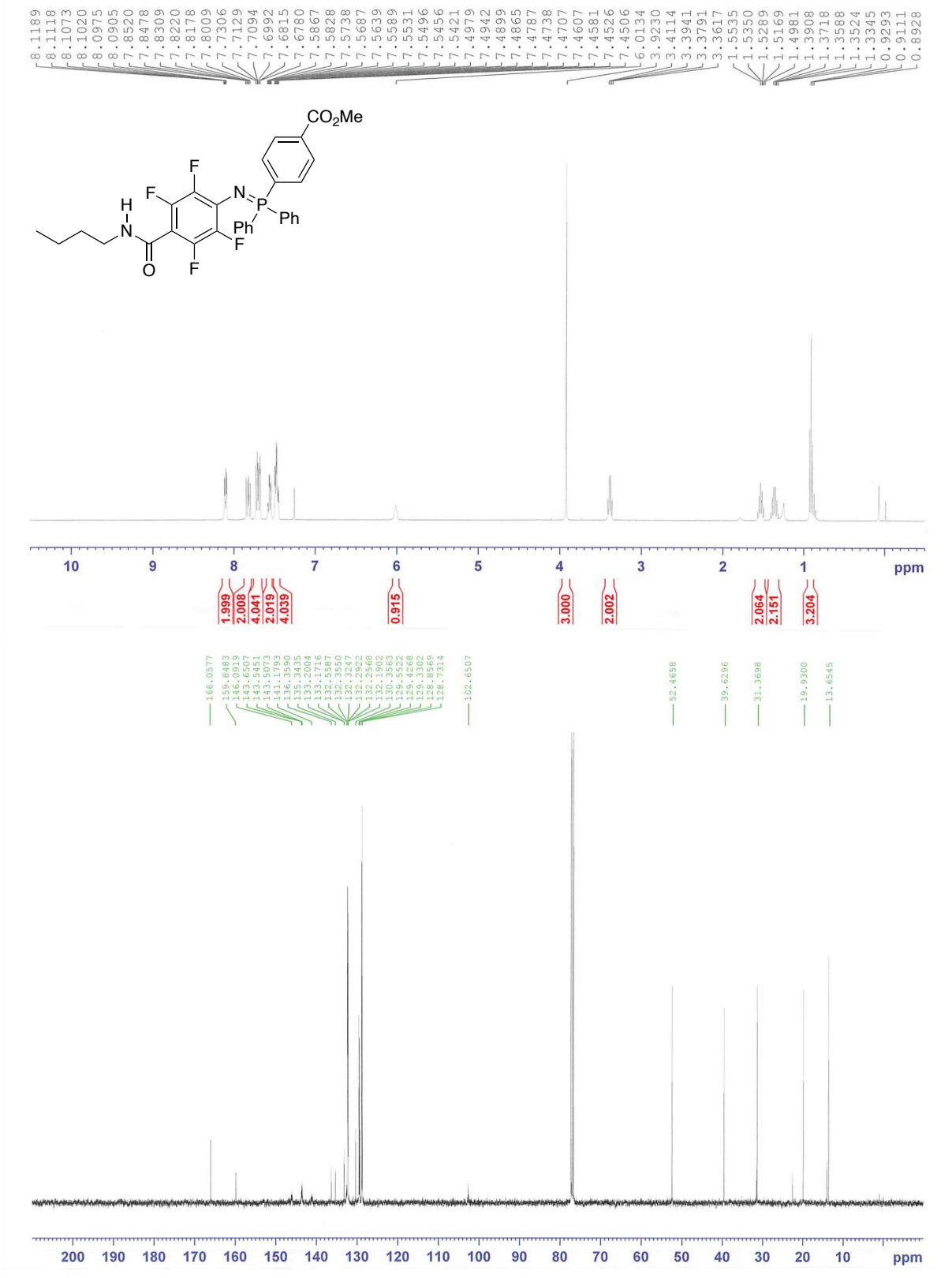


^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of 4-(((2-bromophenyl)diphenyl-λ^{5}-phosphanylidene)amino)-*N*-butyl-2,3,5,6-tetrafluorobenzamide (**5g**) ($CDCl_3$)

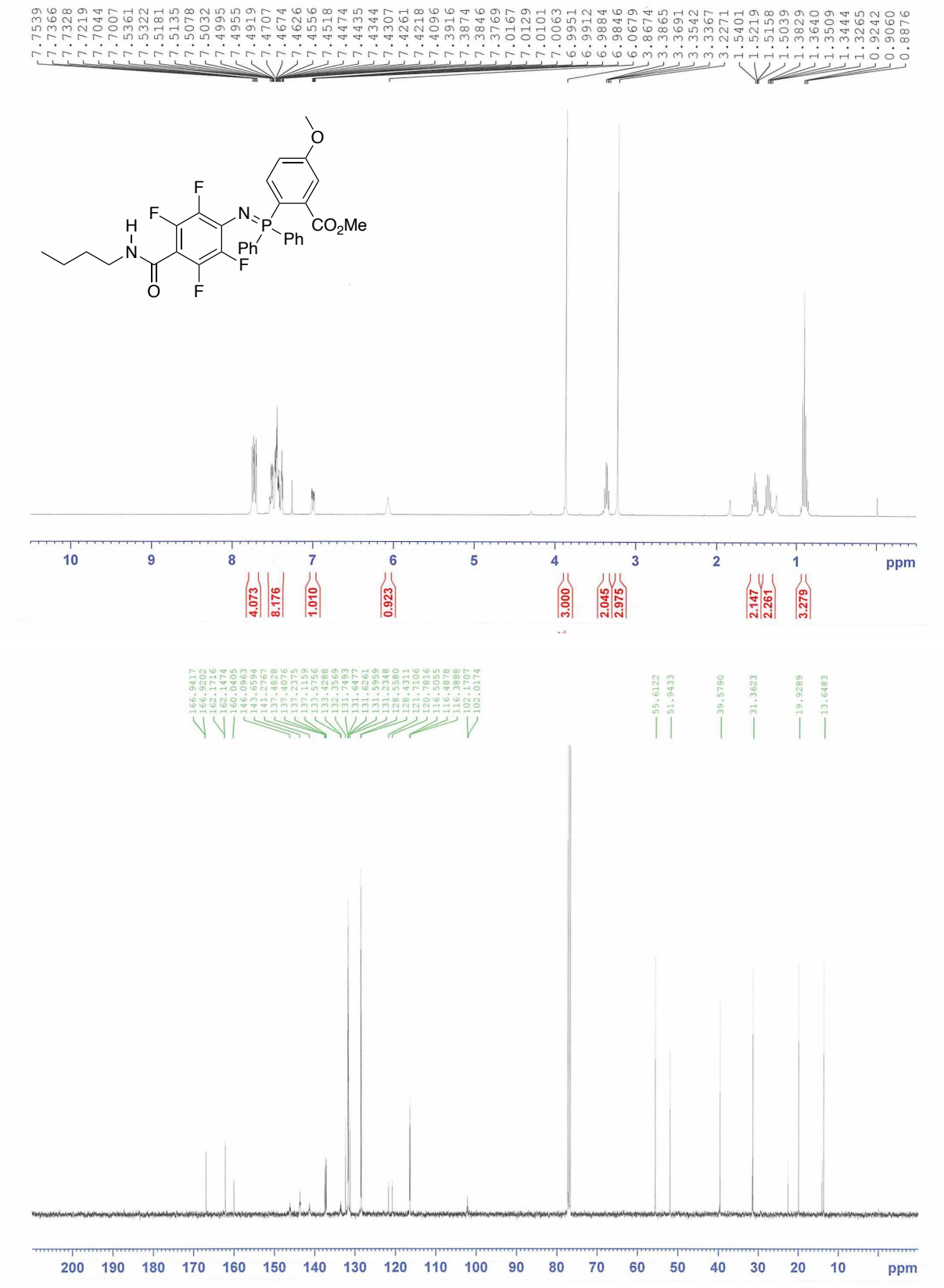




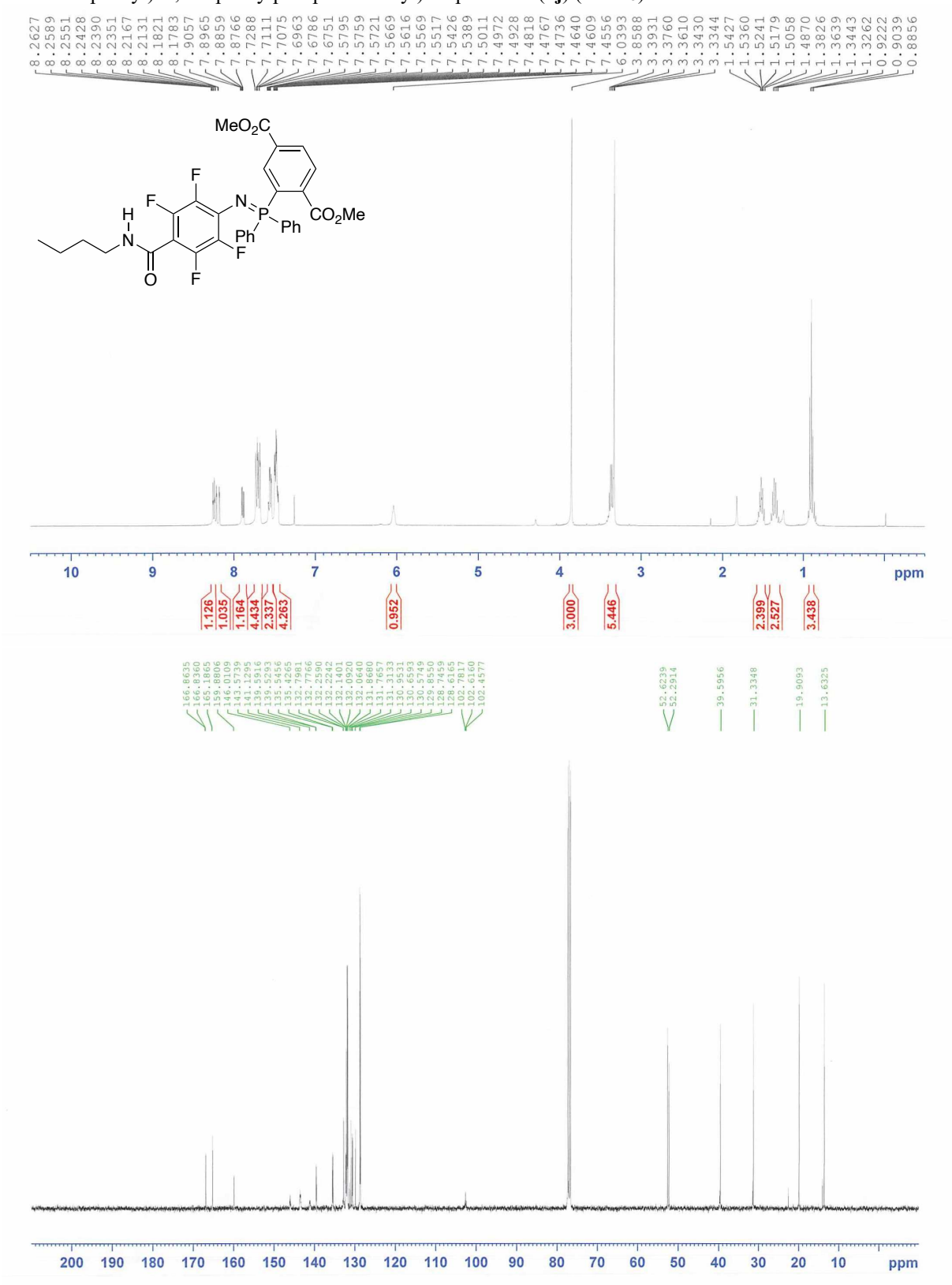
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 4-(*N*-(4-(butylcarbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**5h**) ($CDCl_3$)



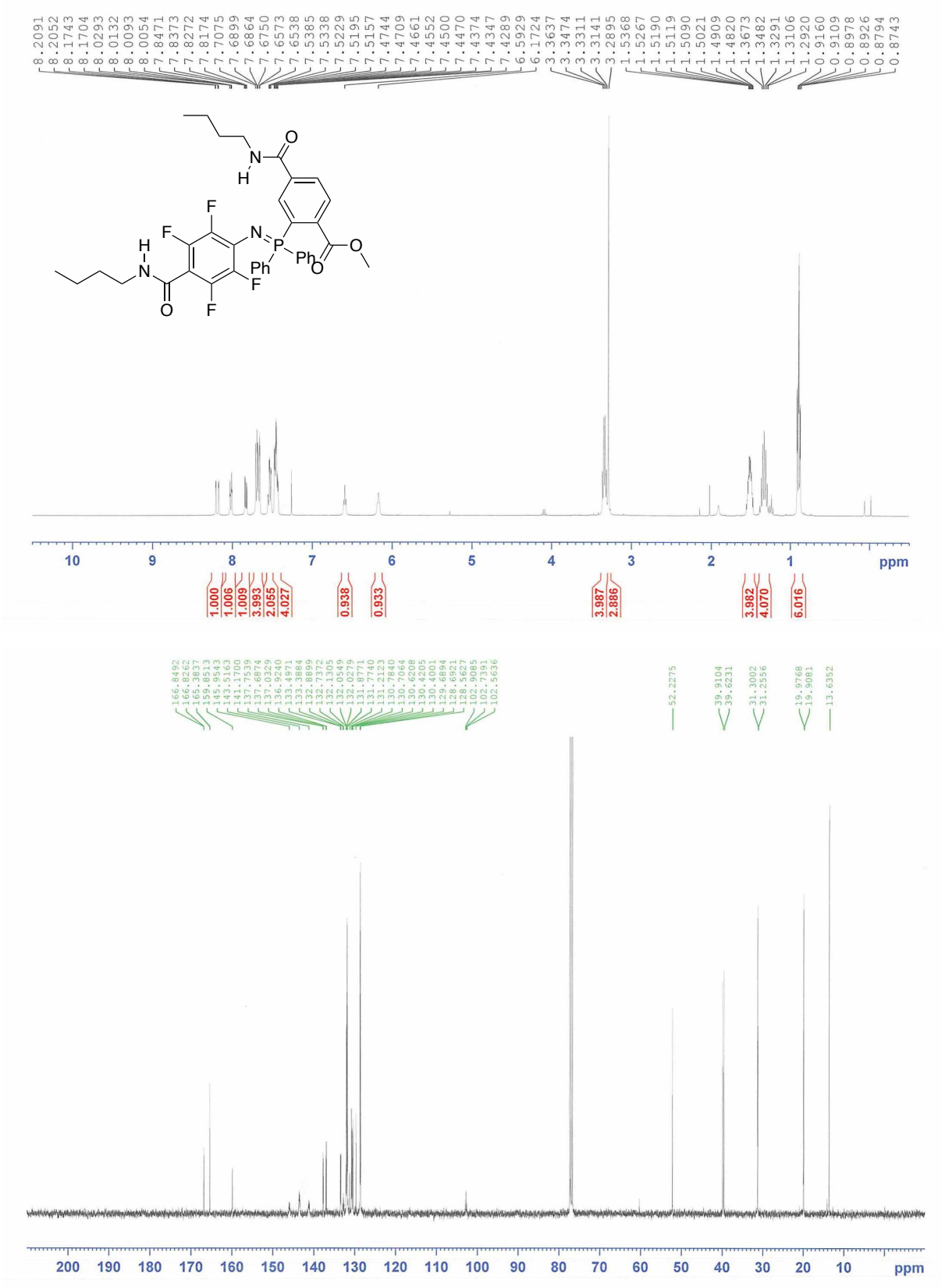
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 2-(*N*-(4-(butylcarbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)-5-methoxybenzoate (**5i**) ($CDCl_3$)



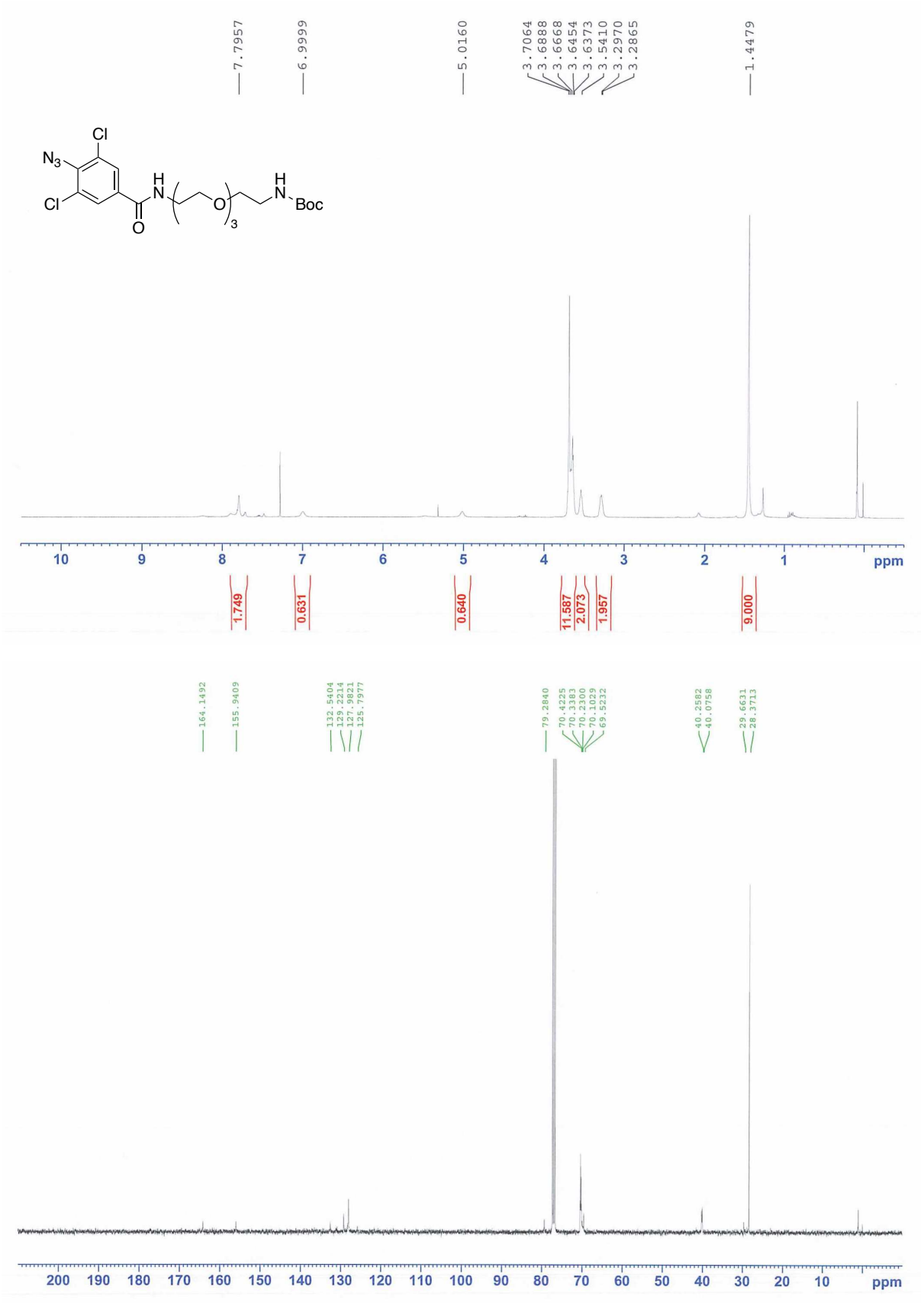
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of dimethyl 2-(*N*-(4-(butylcarbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)terephthalate (**5j**) ($CDCl_3$)



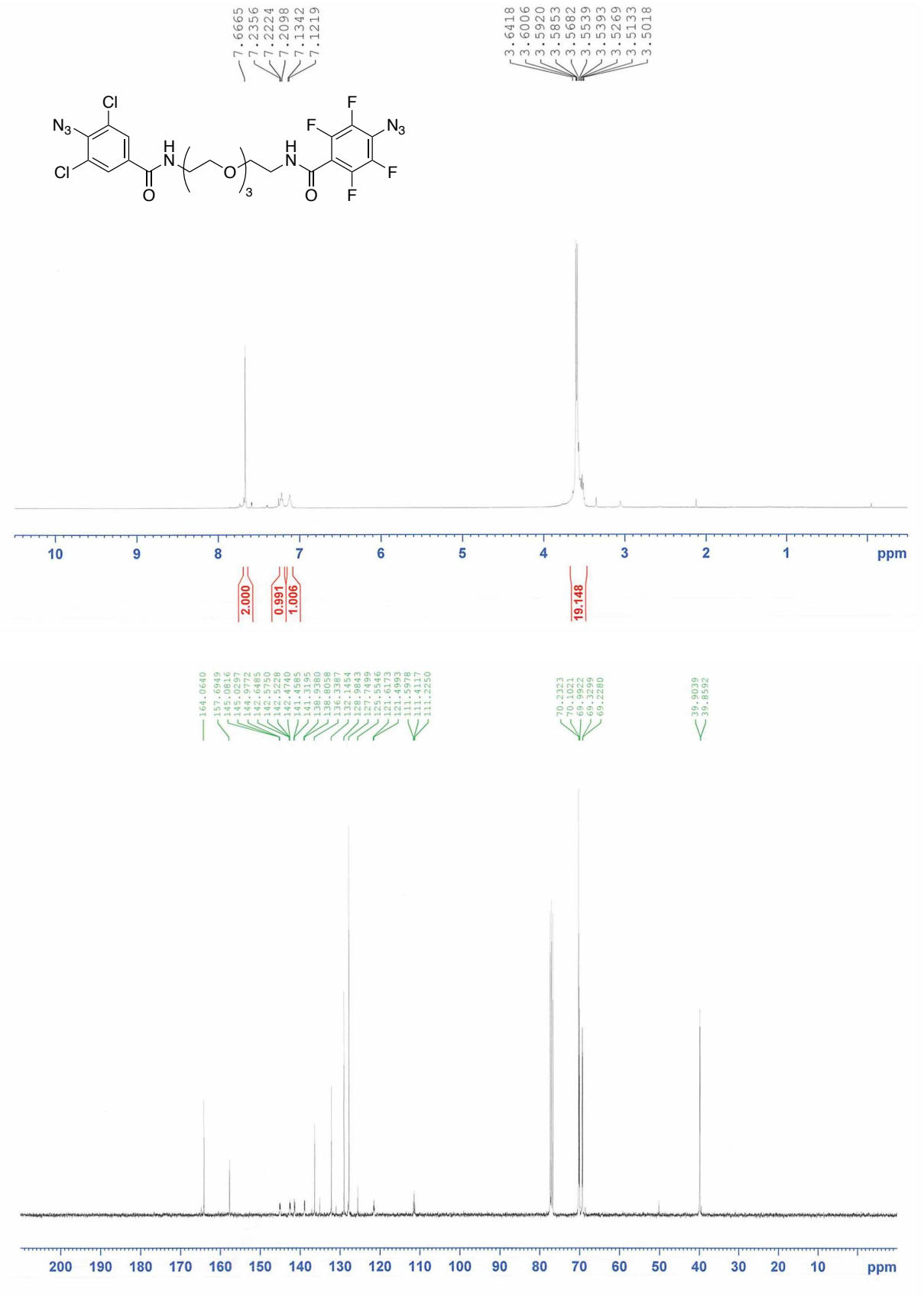
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 4-(butylcarbamoyl)-2-(*N*-(4-(butylcarbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**5k**) ($CDCl_3$)



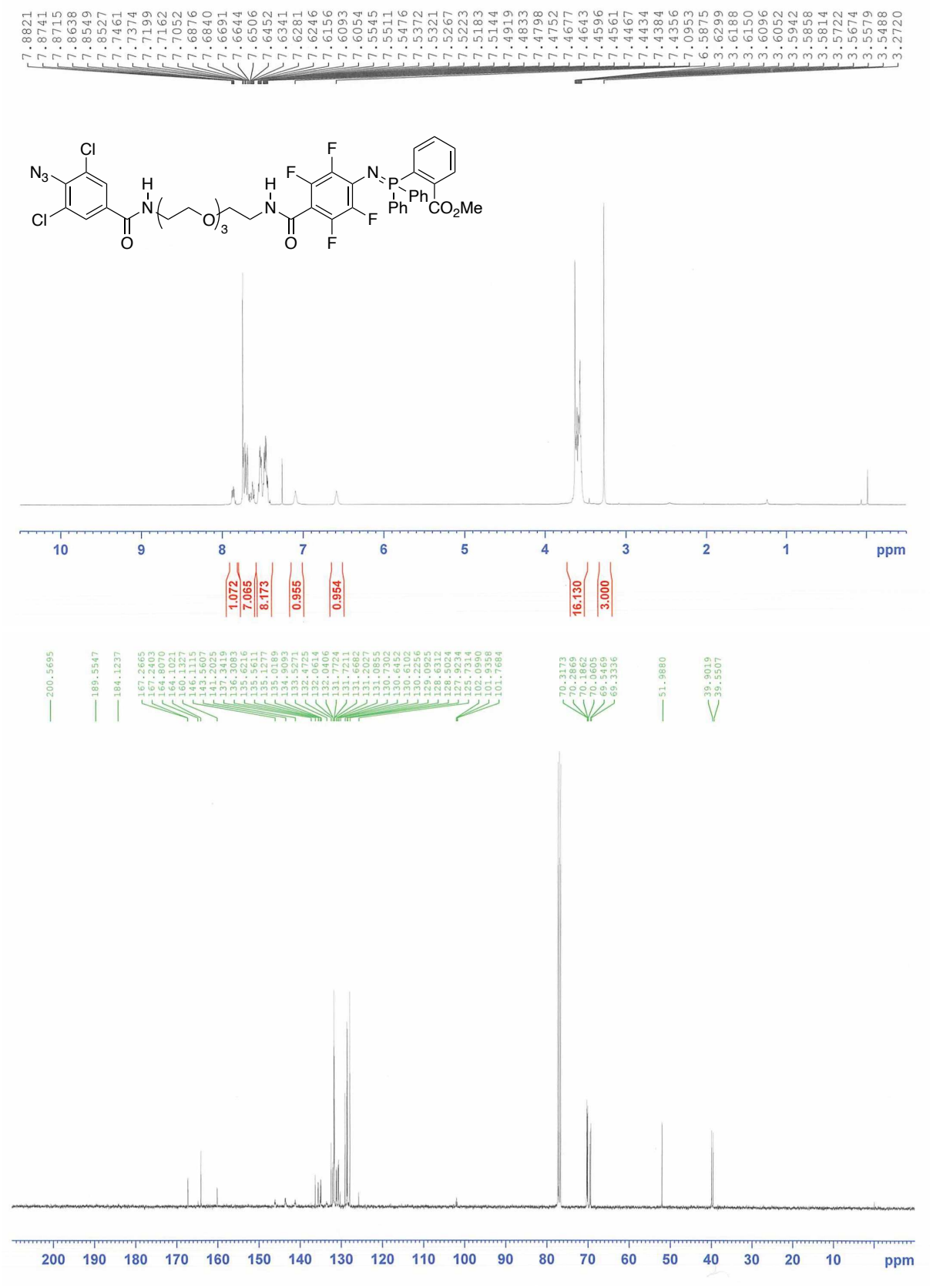
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *tert*-butyl (1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamate (**8**) ($CDCl_3$)



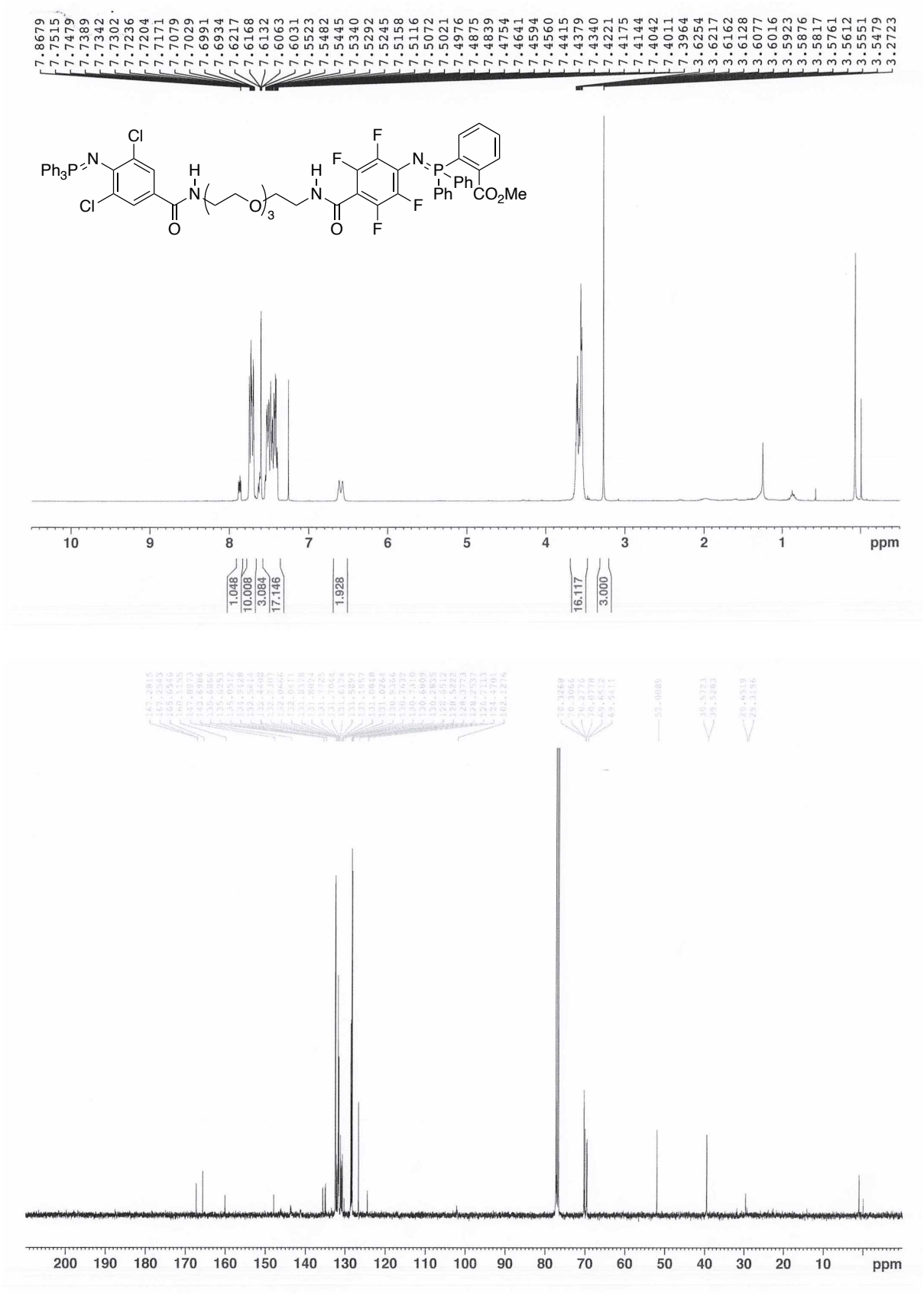
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of 4-azido-*N*-(1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)-2,3,5,6-tetrafluorobenzamide (**9**) ($CDCl_3$)



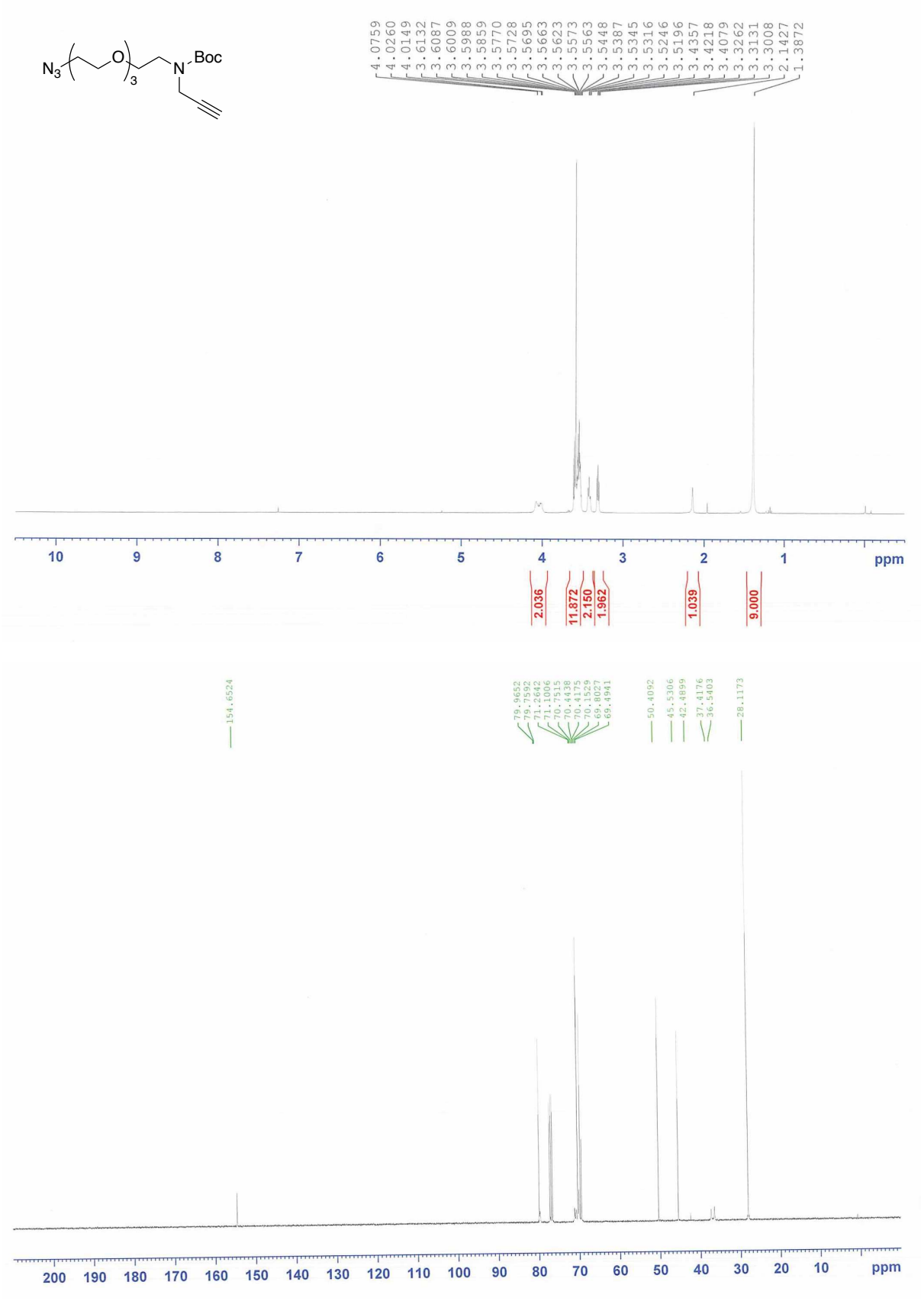
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 2-(*N*-(4-((1-(4-azido-3,5-dichlorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**10**) ($CDCl_3$)



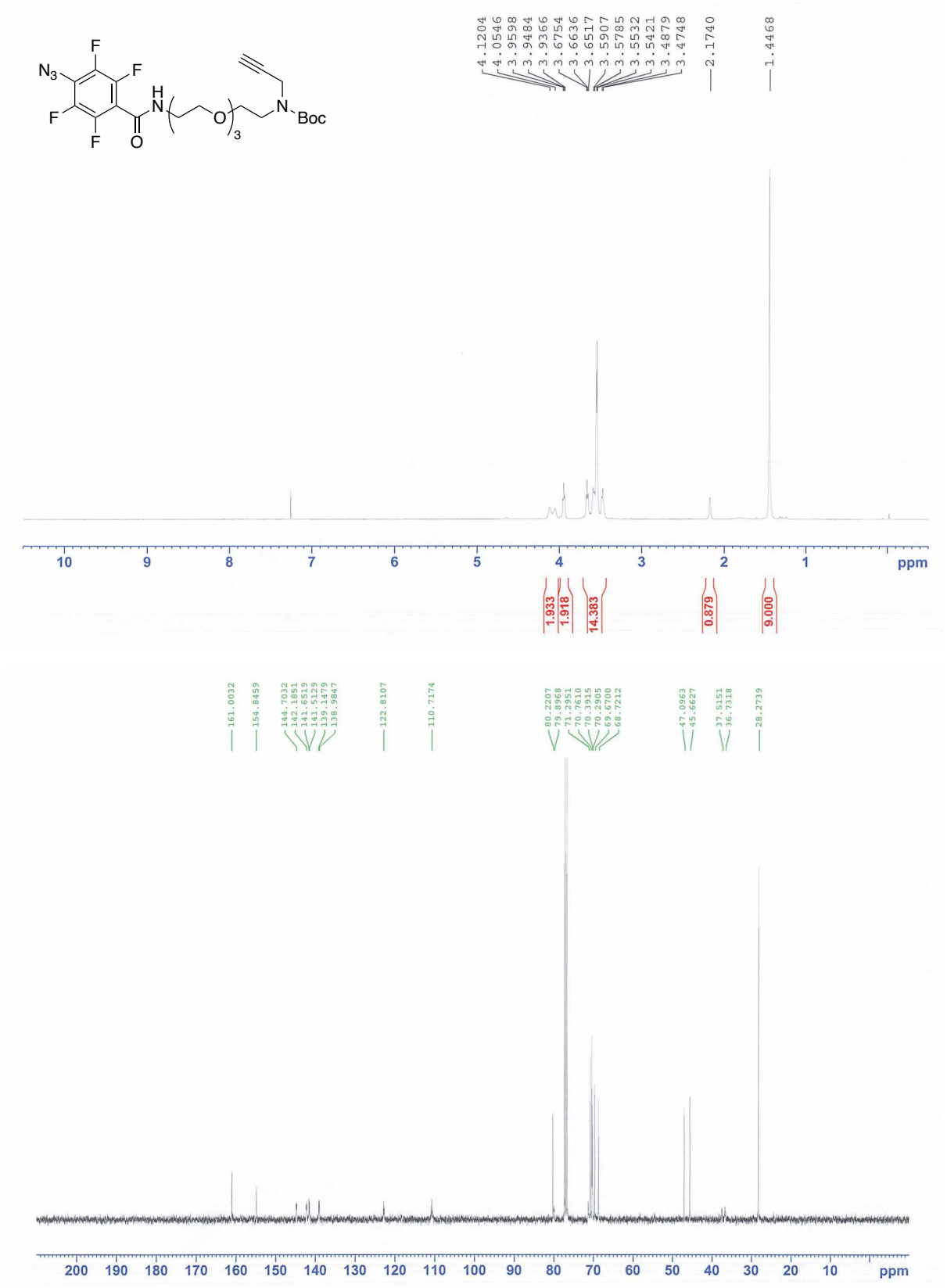
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 2-(*N*-(4-((1-(3,5-dichloro-4-((triphenyl-λ^5-phosphaneylidene)amino)phenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**11**) ($CDCl_3$)



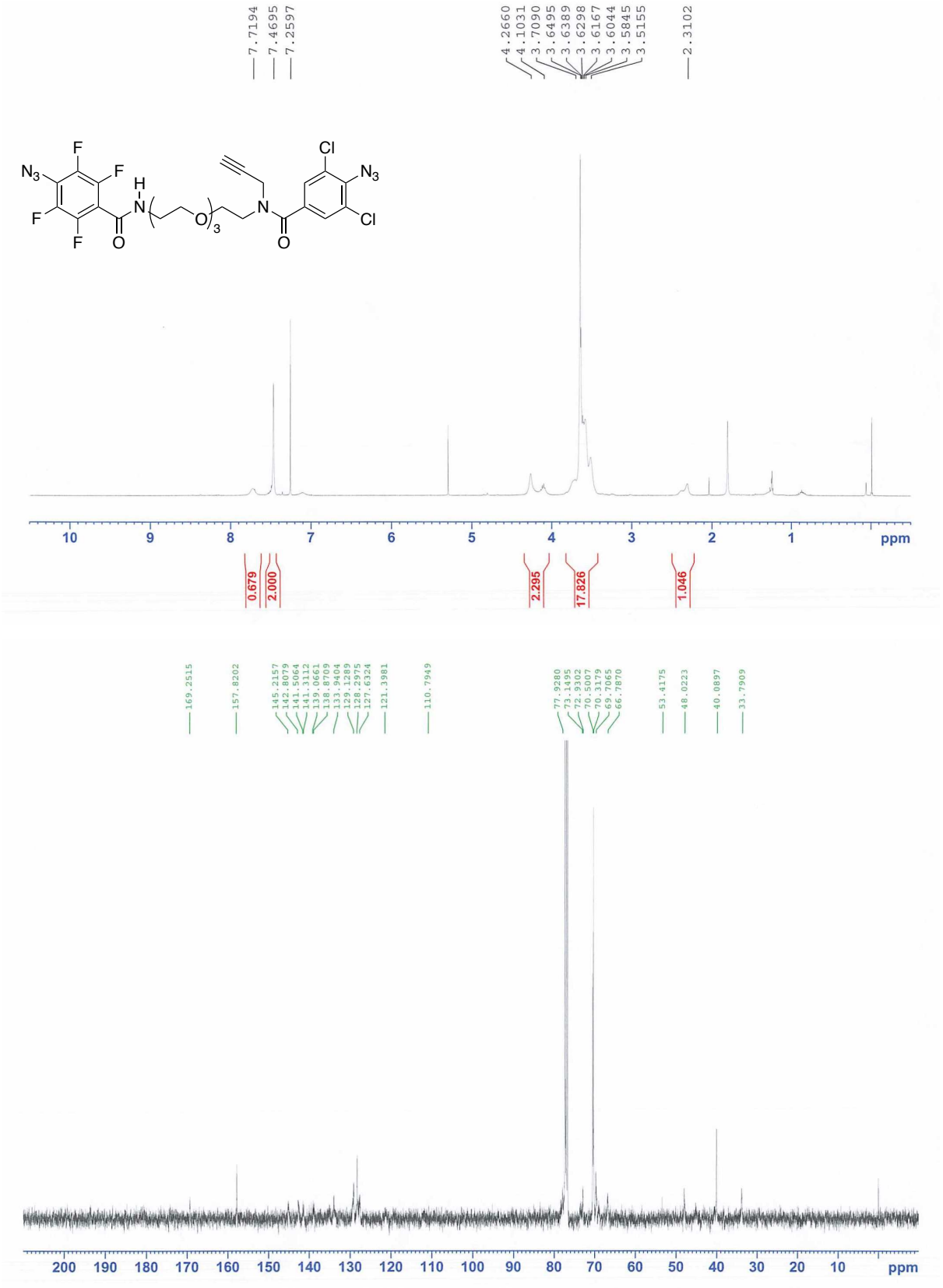
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *tert*-butyl (2-(2-(2-(2-azidoethoxy)ethoxy)ethoxy)ethyl)(prop-2-yn-1-yl)carbamate (**14**) ($CDCl_3$)



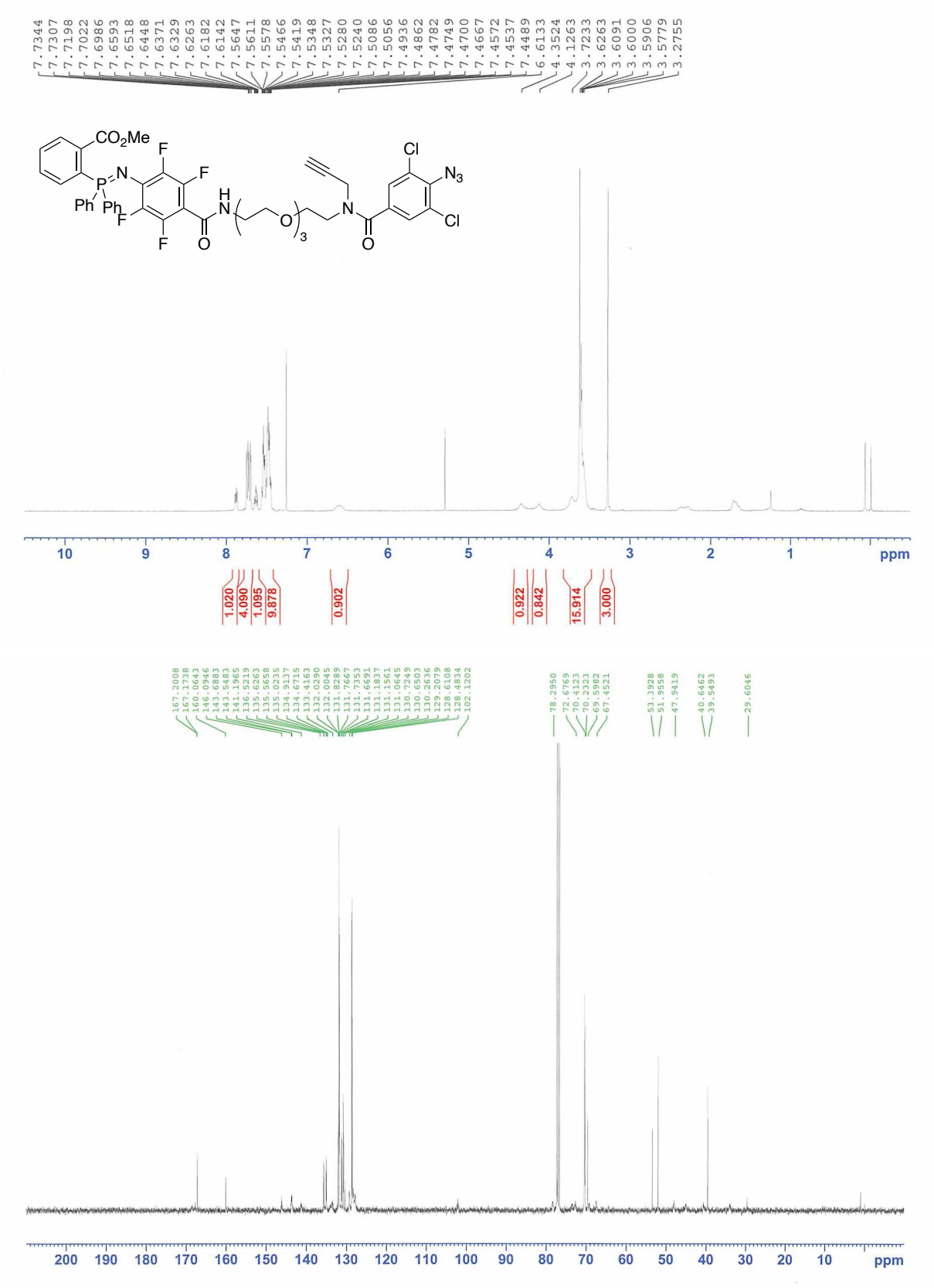
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of *tert*-butyl (1-(4-azido-2,3,5,6-tetrafluorophenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)(prop-2-yn-1-yl)carbamate (**15**) ($CDCl_3$)



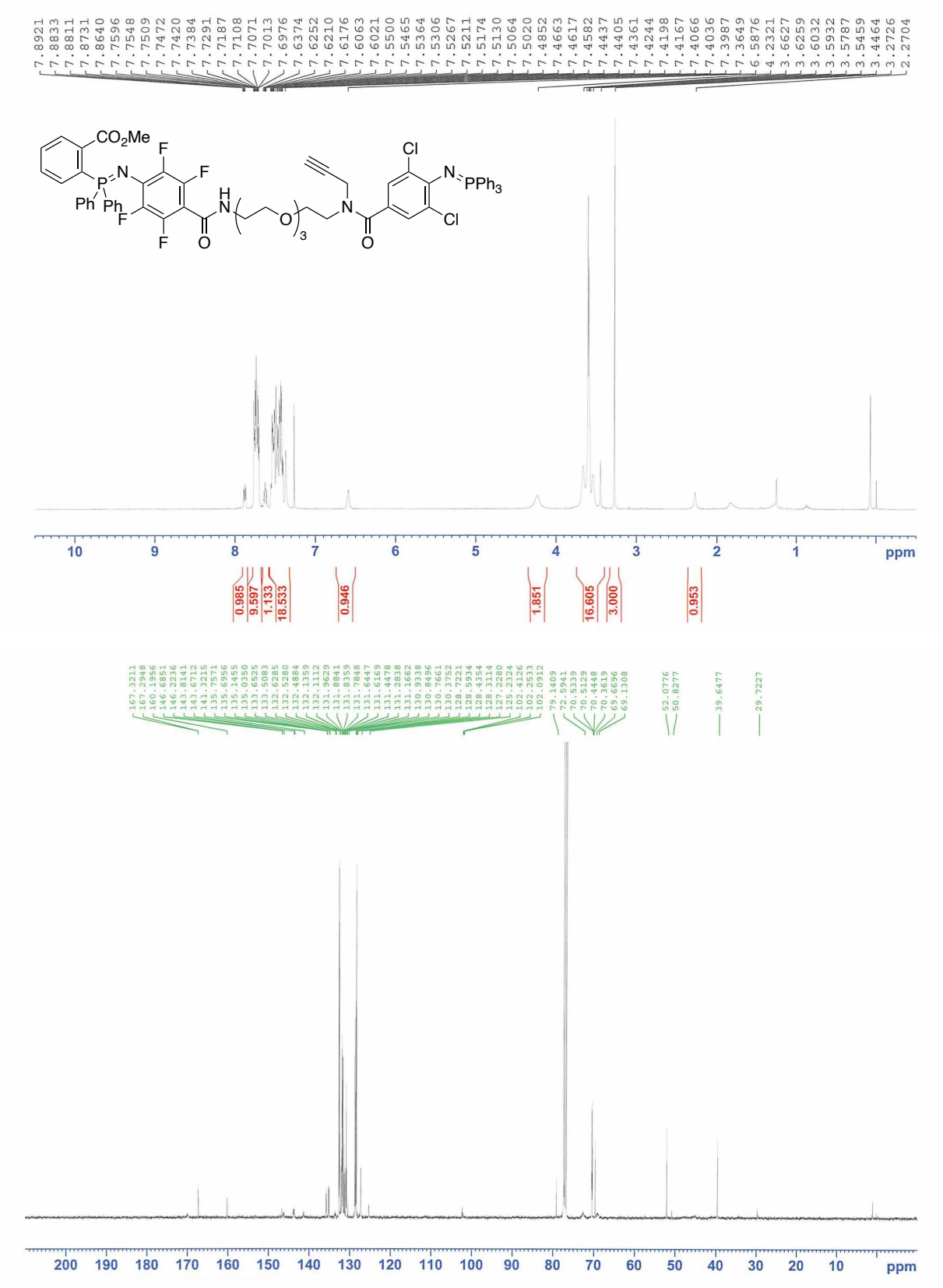
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of 4-azido-*N*-(12-(4-azido-3,5-dichlorobenzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)-2,3,5,6-tetrafluorobenzamide (**16**) ($CDCl_3$)



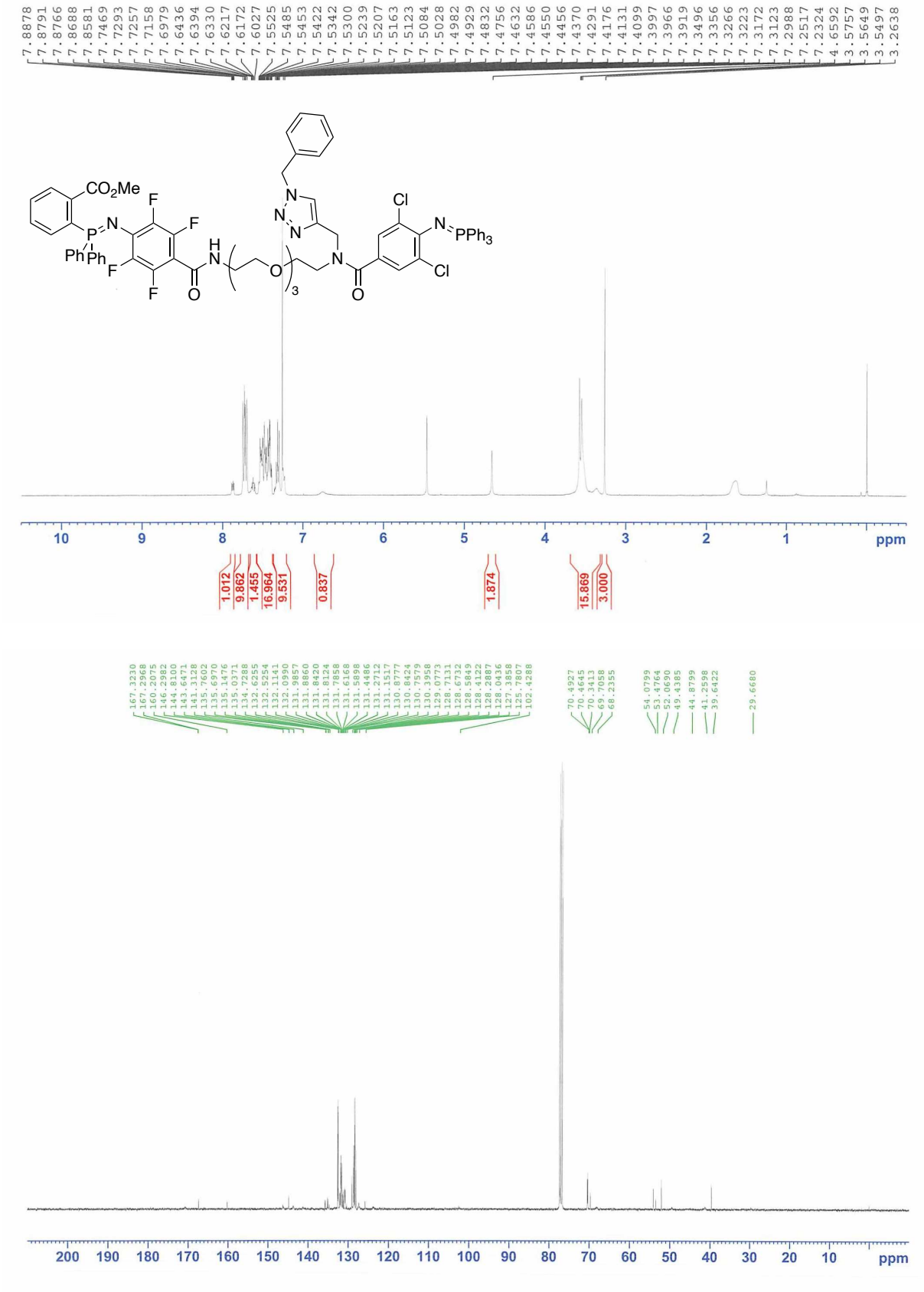
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 2-(*N*-(4-((12-(4-azido-3,5-dichlorobenzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**S1**) ($CDCl_3$)



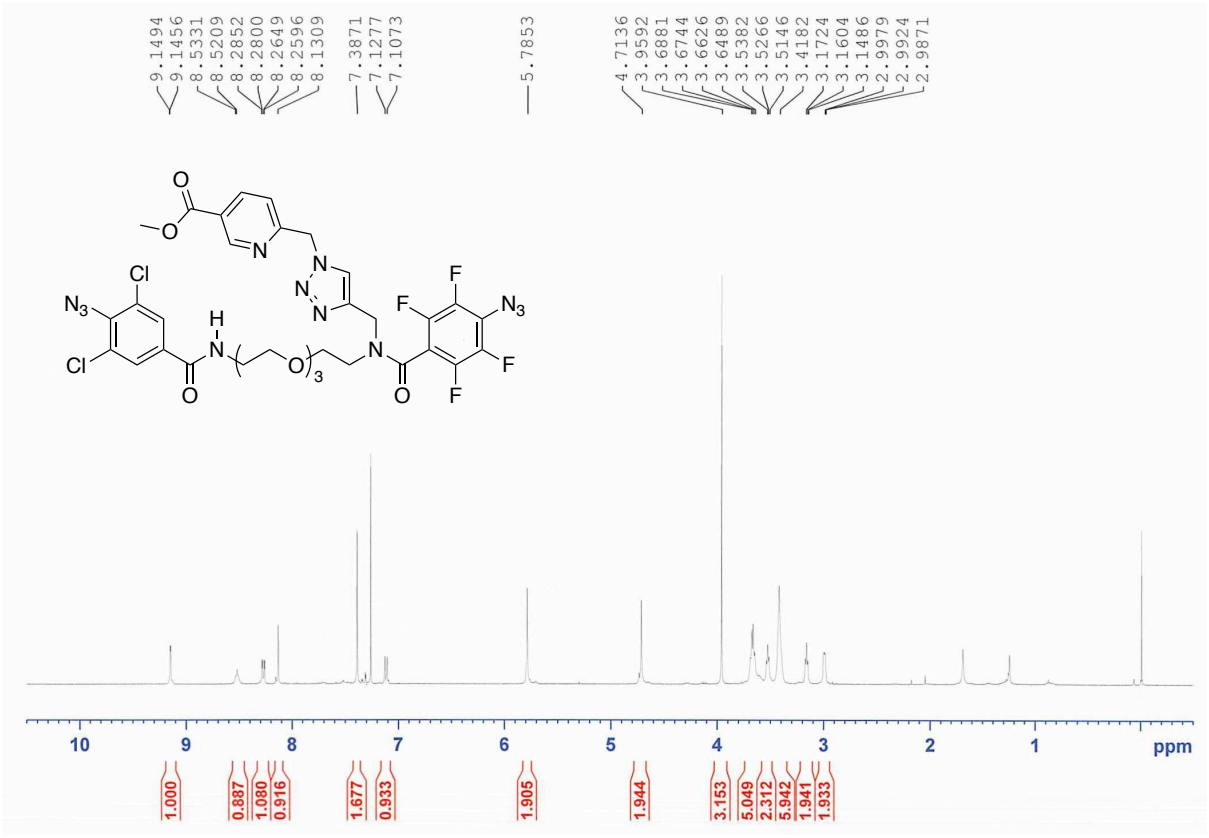
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 2-(*N*-(4-((12-(3,5-dichloro-4-((triphenyl-λ^5-phosphanylidene)amino)benzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**S3**) ($CDCl_3$)

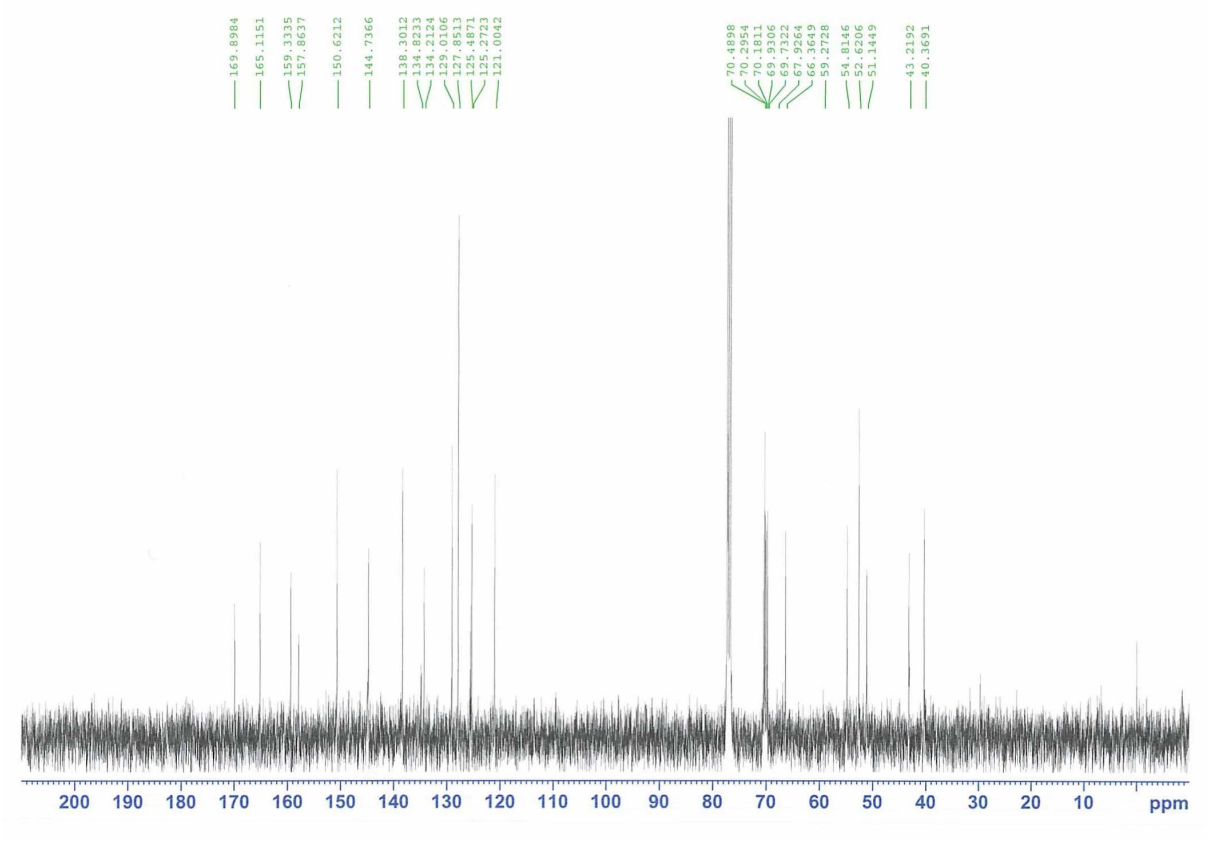


^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 2-(*N*-(4-((2-((1-benzyl-1*H*-1,2,3-triazol-4-yl)methyl)-1-(3,5-dichloro-4-((triphenyl-λ^5-phosphaneylidene)amino)phenyl)-1-oxo-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**17**) ($CDCl_3$)

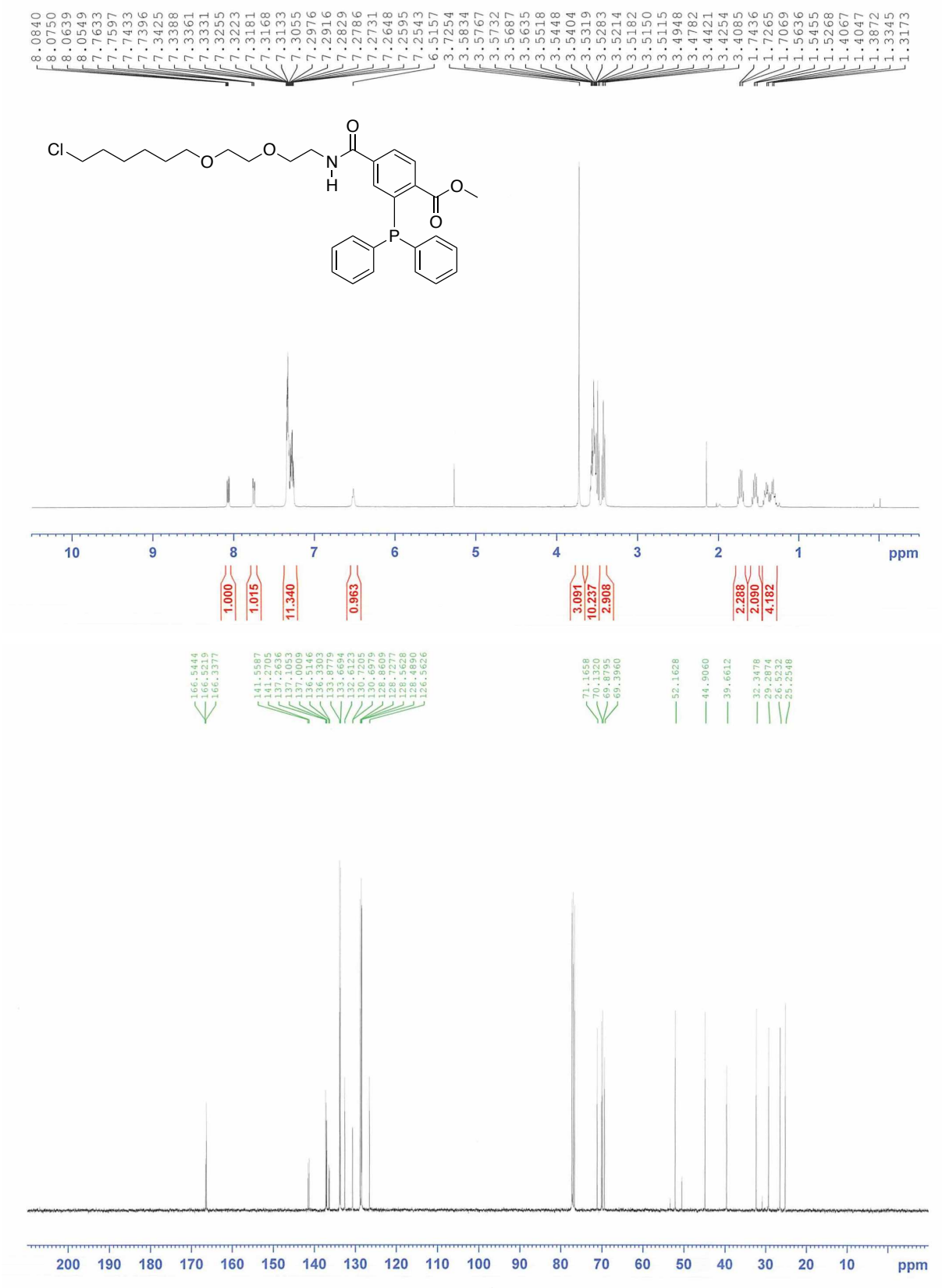


^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 6-((4-(15-(4-azido-2,3,5,6-tetrafluorophenyl)-2-(4-azido-3,5-dichlorobenzoyl)-15-oxo-5,8,11-trioxa-2,14-diazapentadecyl)-1*H*-1,2,3-triazol-1-yl)methyl)nicotinate (**19**)($CDCl_3$)

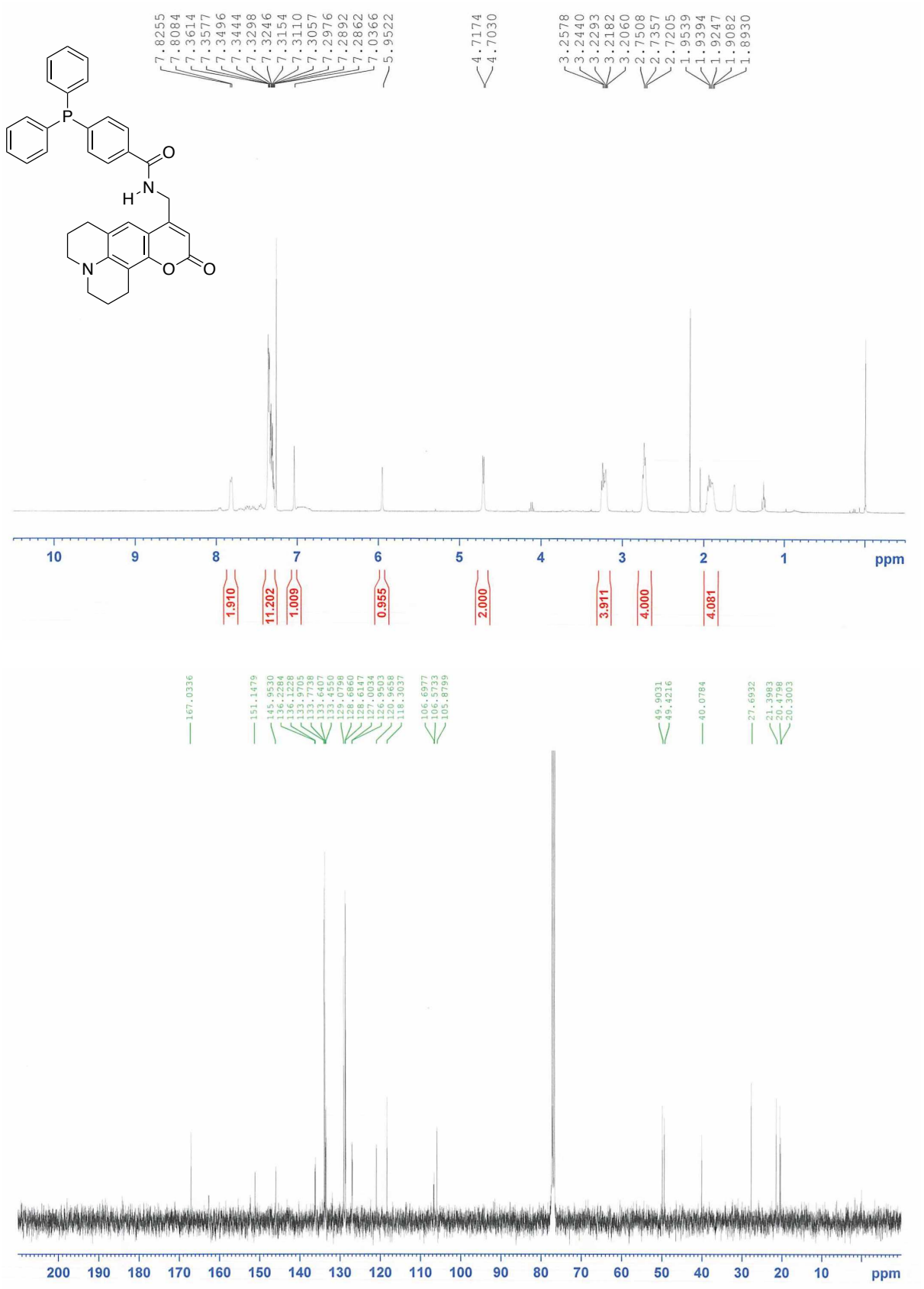




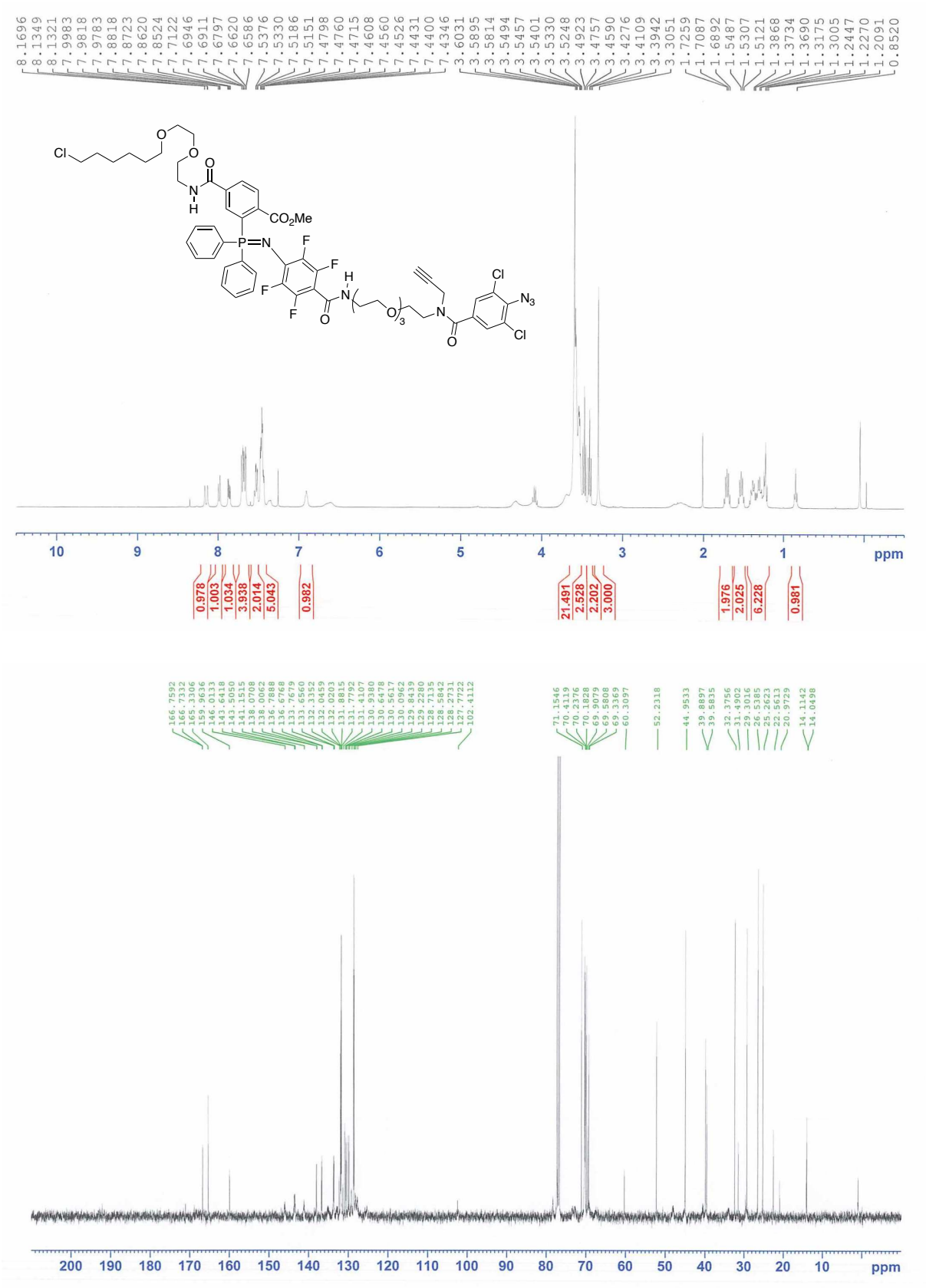
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)-2-(diphenylphosphanyl)benzoate (**20**) ($CDCl_3$)



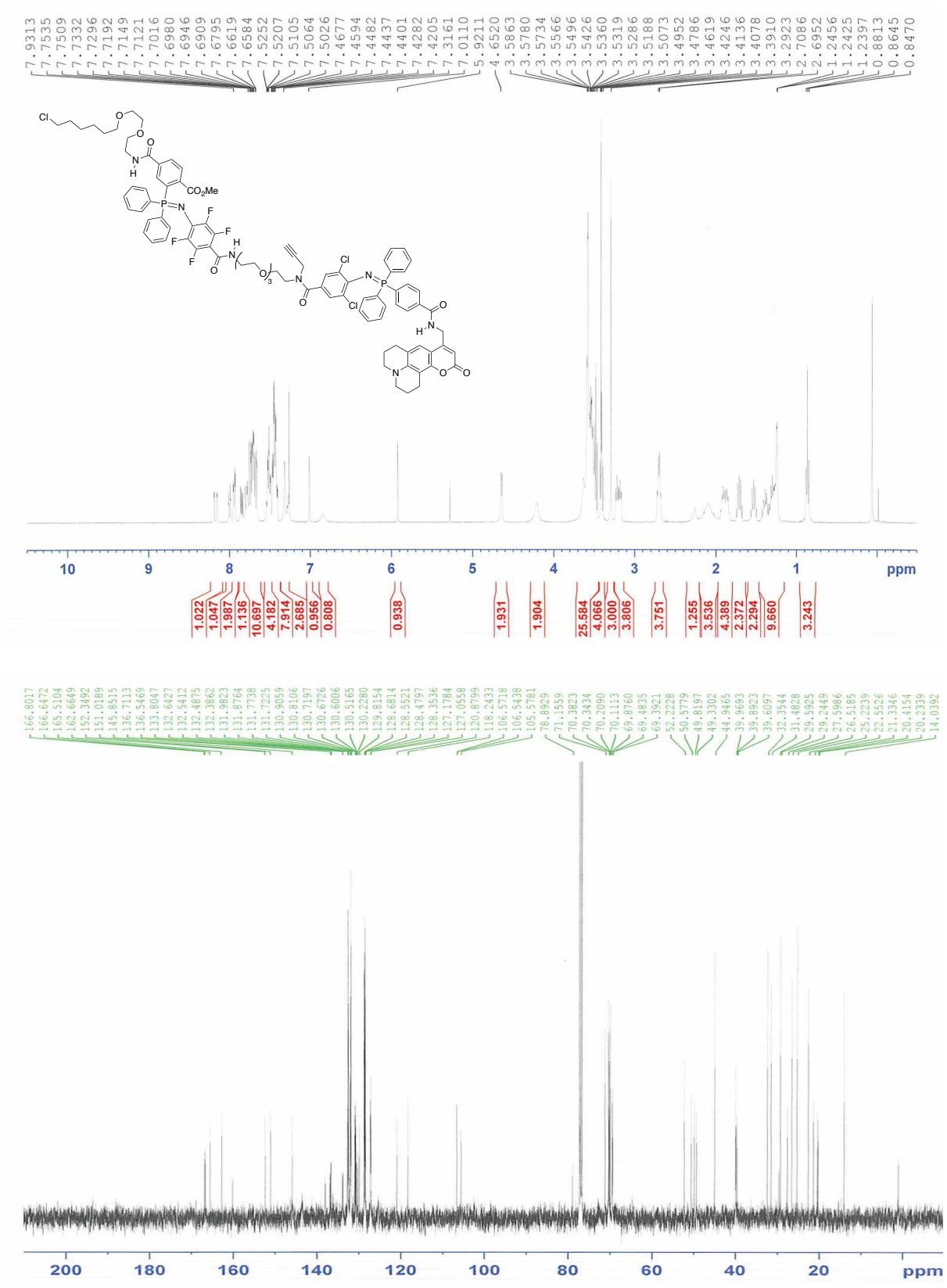
^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of 4-(diphenylphosphanyl)-*N*-((11-oxo-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-9-yl)methyl)benzamide (**21**) ($CDCl_3$)



^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 2-(*N*-(4-((12-(4-azido-3,5-dichlorobenzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)-4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)benz-oate (**S2**) ($CDCl_3$)



^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)-2-(*N*-(4-((12-(3,5-dichloro-4-(((4-(((11-oxo-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-9-yl)methyl)carbamoyl)phenyl)diphenyl-λ^{5}-phosphanylidene)amino)benzoyl)-3,6,9-trioxa-12-azapentadec-14-yn-1-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**S4**) ($CDCl_3$)



^{1}H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra of methyl 4-((2-(2-((6-chlorohexyl)oxy)ethoxy)ethyl)carbamoyl)-2-(*N*-(4-(((1-(3,5-dichloro-4-(((4-(((11-oxo-2,3,6,7-tetrahydro-1*H*,5*H*,11*H*-pyrano[2,3-*f*]pyrido[3,2,1-*ij*]quinolin-9-yl)methyl)carbamoyl)phenyl)diphenyl-λ^{5}-phosphanylidene)amino)phenyl)-1-oxo-2-((1-(2-(2-(5-(2-oxohexahydro-1*H*-thieno[3,4-*d*]imidazol-4-yl)pentanamido)ethoxy)ethyl)-1*H*-1,2,3-triazol-4-yl)methyl)-5,8,11-trioxa-2-azatridecan-13-yl)carbamoyl)-2,3,5,6-tetrafluorophenyl)-*P*,*P*-diphenylphosphorimidoyl)benzoate (**23**) ($CDCl_3$)