Supporting Information

Enantioselective Construction of Imidazolines Having Vicinal Tetra-substituted Stereocenters by Direct Mannich Reaction of α-Substituted α-Isocyanoacetates with Ketimines

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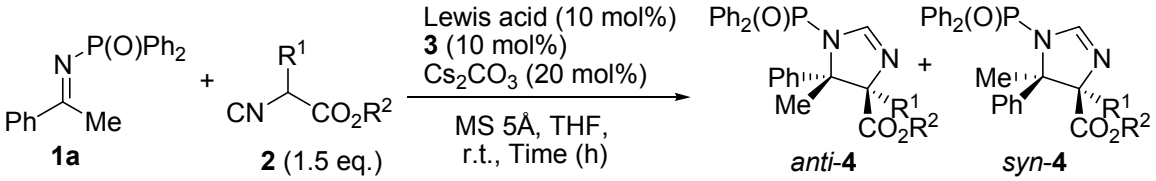
CONTENTS:

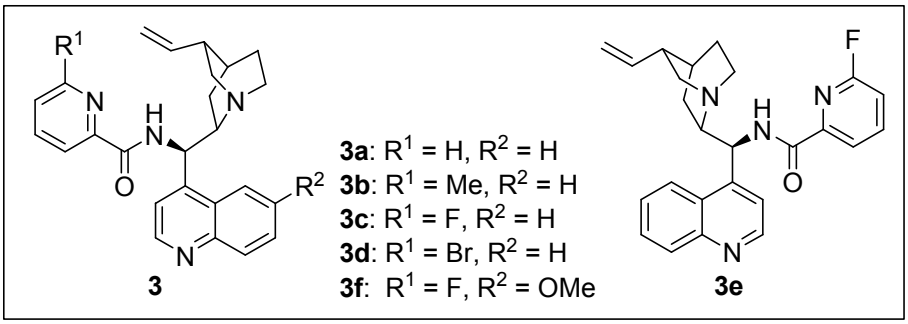
General method……..……S2
Optimization of reaction condition…… S3
Characterization data of compounds……. S4-S14
ESI-Mass spectroscopic analysis……. S15
The picture for the reaction mixture of $CNCH(CH_3)CO_2iPr$……. S16
References……S16
^1H, ^{13}C NMR Spectra……..S17-S39
HPLC Charts…….S40-S58

General Methods:

All reactions were performed in oven-dried glassware under a positive pressure of argon. Solvents were transferred via syringe and were introduced into the reaction vessels through a rubber septum. All reactions were monitored by thin-layer chromatography (TLC) carried out on 0.25 mm Merck silica-gel (60-F254). The TLC plates were visualized with UV light and 7% phosphomolybdic acid or *p*-anisaldehyde in ethanol/heat. Column chromatography was carried out on a column packed with silica-gel 60N spherical neutral size 63-210 μm. The ^{1}H NMR (300 MHz), ^{19}F NMR (282 MHz), ^{13}C NMR (75.5 MHz) and ^{31}P NMR (121 MHz) spectra for solution in $CDCl_3$, were recorded on a Varian Gemini-300. Chemical shifts (δ) are expressed in ppm downfield from internal TMS or $CHCl_3$. HPLC analyses were performed on a SHIMADZU LC-2010A HT using 4.6 x 250 mm DAICEL CHIRALPAK® AD-3, AY-3, IC-3, ID-3, IE-3, IF-3, IA column. ESI Mass spectra were recorded on a SHIMADZU LCMS-2020 using positive mode. Optical rotations were measured on a JASCO P-2200. Infrared spectra were recorded on a JASCO FT/IR-4600 spectrometer with ZnSe ATR unit. *N*-Diphenylphosphinoyl imines[1)] and α-substituted isocyanides[2)] were synthesized according to literature procedures.

Optimization of reaction conditions:

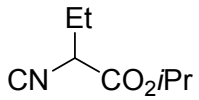




Entry	Lewis acid	3	R^1	R^2	Time (h)	Yield (%)	*Anti/Syn*[a]	Er (%)[b]
1	$Ni(acac)_2$	**3a**	Me	O*i*Pr	47	96	86:14	37:63
2	$Ni(ClO_4)_2(H_2O)_6$	**3a**	Me	O*i*Pr	72	trace	-	-
3	$Ni(OAc)_2(H_2O)_4$	**3a**	Me	O*i*Pr	-	-	-	-
4	$Ni(OAc)_2(H_2O)_4$	**3c**	Me	O*i*Pr	48	trace	-	-
5	NiI_2	**3b**	Me	O*i*Pr	67	trace	-	-
6	$NiCl_2$	**3c**	Me	OMe	24	91	97: 3	9:91
7	$NiCl_2$	**3e**	Me	OMe	48	97	98: 2	95:5
8	$NiCl_2$	**3c**	Me	OEt	24	96	97: 3	10:90
9	$NiCl_2$	**3c**	Me	O*i*Bu	24	96	94: 6	9:91
10	$NiCl_2$	**3c**	Me	OBn	-	-	-	-
11	$NiCl_2$	**3c**	Me	cyclopenthyl	96	53	>99: 1	6:94
12	$NiCl_2$	**3c**	Me	SEt	72	trace	-	-
13	$NiCl_2$	**3c**	Ph	Me	72	trace	-	-
14	$NiCl_2$	**3f**	Me	O*i*Pr	24	83	92: 8	21:79
15[c]	$NiCl_2$	**3e**	Me	O*i*Pr	48	97	98: 2	96:4
16[d]	$NiCl_2$	**3c**	Me	O*i*Pr	48	85	99: 1	12:88
17[e]	$NICl_2$	**3c**	Me	O*i*Pr	21	>99	93: 7	9:91

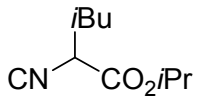
[a] Diastereomer ratio was determined by NMR spectra. [b] Ee for major enantiomer.
[c] At 10 °C. [d] 0.2 M. [e] TMSOH (1.0 eq.) was added.

Isopropyl 2-isocyanobutanoate (2b);



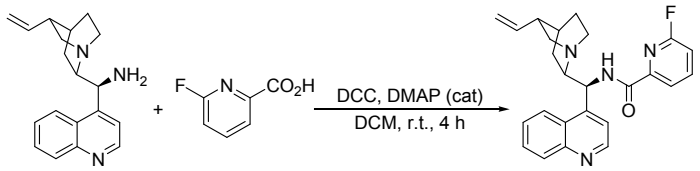
^{1}H NMR (300 MHz, $CDCl_3$) δ 1.09 (t, *J* = 7.2 Hz, 3H), 1.30 (d, *J* = 6.0 Hz, 6H), 1.88-2.02 (m, 2H), 4.20 (dd, *J* = 5.7, 5.7 Hz, 1H), 5.10 (sep, *J* = 6.0 Hz, 1H), **^{13}C NMR** (150 MHz, $CDCl_3$) δ 9.6, 21.68, 21.72, 26.4, 58.1, 70.7, 159.6, 166.3; **IR** (ATR) 2982, 2147, 1745, 1388, 1376, 1286, 1252, 1206, 1252, 1206, 1102, 971, 903, 818 cm^{-1}; **HRMS** (ESI) calcd. for $[C_8H_{13}NO_2+Na]^+$: 178.0844, Found: 178.0855.

Isopropyl 2-isocyano-4-methylpentanoate (2c);



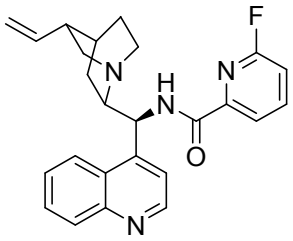
^{1}H NMR (300 MHz, $CDCl_3$) δ 0.995 (d, *J* = 7.5 Hz, 6H), 1.30 (d, *J* = 6.0 Hz, 6H), 1.67-1.70 (m, 1H), 1.80-1.96 (m, 2H), 4.21-4.25 (m, 1H), 5.09 (sep, *J* = 6.0 Hz, 1H). **^{13}C NMR** (150 MHz, $CDCl_3$) δ 21.0, 21.66, 21.68, 22.7, 24.9, 41.3, 55.5, 70.7, 159.6, 166.8; **IR** (ATR) 2962, 2146, 1744, 1469, 1375, 1273, 1233, 1199, 1143, 1104, 989, 829 cm^{-1}; **HRMS** (ESI) calcd. for $[C_{10}H_{17}NO_2+Na]^+$: 206.1157, Found: 206.1164.

General procedure for synthesis of cinchona alkaloid picolinamide ligands:



9-Deoxy-9-*epi*-cinchonidineamine (160 mg, 0.55 mmol), 6-fluoropyridine-2-carboxylic acid (95 mg, 0.5 mmol), 4-dimethylaminopyridine (6.1 mg, 0.05 mmol) and *N*,*N*'-dicyclohexylcarbodiimide (110 mg, 0.55 mmol) was dissolved in CH_2Cl_2 (5.0 mL) and stirred for 4 h. The precipitate was filtrated off through celite, and the residue was concentrated under reduce pressure. The crude product was purified by flash column chromatography (AcOEt/MeOH=90:10 to 70:30) to afford *N*-(9-deoxy-*epi*-cinchonin-9-yl)-4-(trifluoromethyl)picolinamide **3e** (181 mg, 79%) yield as a white solid.

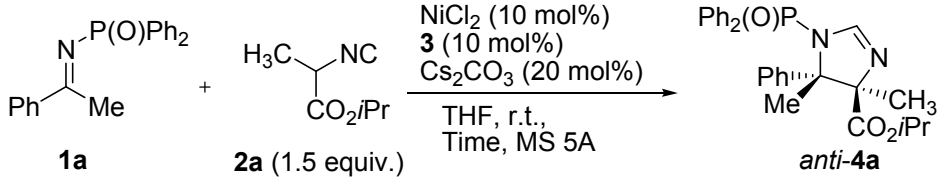
***N*-(9-Deoxy-*epi*-cinchonidin-9-yl)-6-fluoropicolinamide (3e)**;



$[\alpha]_D^{25}$ −123.6 (*c* 0.677, $CHCl_3$); mp = 91.1–92.2 ºC; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.90-0.97 (m, 1H), 1.39-1.47 (m, 1H), 1.64-1.66 (m, 3H), 2.31 (br, 1H), 2.72-2.84 (m, 2H), 3.17 (br, 1H), 3.28-3.35 (m, 2H), 4.94-5.03 (m, 2H), 5.62 (br, 1H), 5.70-5.81 (m, 1H), 7.05 (d, *J* = 7.2 Hz, 1H), 7.35-7.36 (m, 4H), 7.50-7.51 (m, 1H), 7.62-7.76 (m, 2H), 7.83-7.95 (m, 2H), 8.14 (d, *J* = 8.7 Hz, 1H), 8.48 (d, *J* = 8.4 Hz, 1H), 8.74 (br, 1H), 8.89-8.91 (m, 1H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 26.2, 27.5, 27.9, 39.6, 41.0, 51.1, 56.1, 60.0, 112.7 (d, $J_{C\text{-}F}$ = 36.5 Hz), 114.6, 119.5, 120.0 (d, $J_{C\text{-}F}$ = 3.9 Hz), 123.4, 127.0, 127.4, 129.3, 130.6, 141.5, 142.4 ($J_{C\text{-}F}$ = 7.8 Hz), 146.7, 148.3 (d, $J_{C\text{-}F}$ = 11.1 Hz), 148.6,

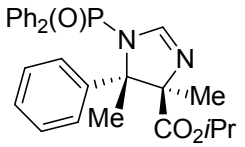
150.2, 162.1 (d, $J_{C\text{-}F}$ = 243 Hz), 162.9; **^{19}F NMR** (282 MHz, $CDCl_3$) δ −67.4; **IR** (ATR) 1675, 1576, 1507, 1441, 1317, 1267, 1240, 1047, 994, 962, 912, 845, 820, 762, 660 cm^{-1}; **HRMS** (ESI) calcd. for $[C_{25}H_{26}N_4OF+H]^+$: 417.2091, Found: 417.2105.

General procedure for the direct asymmetric Mannich-type reaction of α-isocyanoacetate with ketimines:



MS 5Å (20 mg) was heated at 140 °C under reduced pressure for 1 h. Isopropyl 2-isocyanopropanoate **2a** (23 μL, 0.15 mmol) was added to a solution of ketimine **1a** (32 mg, 0.1 mmol), $NiCl_2$ (1.3 mg, 0.01 mmol), **3e** (4.2 mg, 0.01 mmol), MS 5Å (20 mg) and Cs_2CO_3 (6.5 mg, 0.02 mmol) in THF (1.0 mL) at room temperature. After stirred for 24 h, the reaction mixture was diluted with AcOEt (2.0 mL). Filtration of the reaction mixture through celite pad, and the filtrate was concentrated under reduced pressure. The solution was extracted with CH_2Cl_2 three times. The combined organic layer was dried over Na_2SO_4 and concentrated under reduced pressure, and the diastereomer ratio was determined by ^{1}H and ^{31}P NMR analysis. The crude product was purified by silica gel column chromatography (Hexane/AcOEt=3/7, AcOEt only) to give *anti*-**4a** (*anti*:*syn*=98:2).

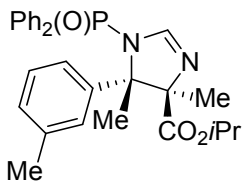
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4a)



The reaction was carried out as described above except for using ketimine **1a** (32 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4a** as a yellow solid (99% yield, *anti*:*syn*=98:2).

(4*R*,5*S*)-**4a**: $[\alpha]_D^{25}$ −4.9 (*c* 1.21, $CHCl_3$, er = 95:5); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.93 (s, 3H), 1.23-1.36 (m, 6H), 1.75 (s, 3H), 5.09 (sep, *J* = 6.0 Hz, 1H), 7.21 (s, 1H), 7.26-7.29 (m, 4H), 7.33-7.36 (m, 2H), 7.41-7.52 (m, 4H), 7.54-7.62 (m, 2H), 7.65-7.75 (m, 3H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.88, 21.92, 22.3, 22.6, 69.4, 73.6, 83.2, 126.9, 127.8, 128.0, 128.4, 128.6, 128.7, 128.9, 129.0, 130.3, 130.8, 132.06, 132.2, 132.7, 132.8, 132.9, 141.2, 152.15, 152.2, 171.8; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.6; **IR** (ATR) 3451, 2970, 1738, 1725, 1228, 1216, 1102, 752, 726, 694, 669, 617 cm^{-1}; **HRMS** (ESI) calcd. for $C_{27}H_{30}N_2O_3P$ $[M+H]^+$: 461.1991, Found: 461.1994; **HPLC** (DAICEL CHIRALPAK AD-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(major)}$ = 10.2, $t_{(minor)}$ = 11.4 min.

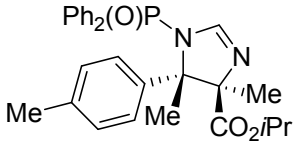
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(3-methyl)phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4b)



The reaction was carried out as described above except for using ketimine **1b** (33 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4b** as a yellow solid (99% yield, *anti*:*syn*=96:4).

(4*R*,5*S*)-**4b**: $[\alpha]_D^{25}$ −6.2 (*c* 1.52, $CHCl_3$, er = 94:6); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.94 (s, 3H), 1.26-1.39 (m, 6H), 1.79 (s, 3H), 2.29 (s, 3H), 5.10 (sep, *J* = 6.0 Hz, 1H), 7.01 (s, 1H), 7.05-7.09 (m, 1H), 7.17-7.22 (m, 2H), 7.35-7.36 (m, 2H), 7.41-7.55 (m, 5H), 7.57-7.76 (m, 4H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.7, 21.9, 21.9, 22.3, 22.7, 69.4, 73.7, 83.1, 83.2, 124.0, 127.7, 127.8, 128.4, 128.5, 128.6, 128.77, 128.81, 129.0, 130.6, 131.0, 132.0, 132.1, 132.2, 132.4, 132.7, 132.76, 132.83, 132.9, 137.2, 141.1, 152.1, 152.2, 171.8; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.8; **IR** (ATR) 3649, 1869, 1829, 1733, 1670, 1569, 1507, 1457, 1375, 1262, 1103, 1049, 832, 754, 696 cm^{-1}; **HRMS** (ESI) calcd. for $C_{28}H_{32}N_2O_3P$ $[M+H]^+$: 475.2159, Found: 475.2151; **HPLC** (DAICEL CHIRALPAK IA, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 8.63, $t_{(major)}$ = 9.88 min.

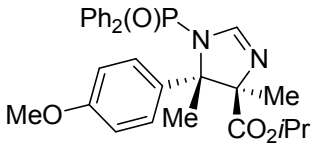
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(4-methyl)phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4c)



The reaction was carried out as described above except for using ketimine **1c** (33 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4c** as a yellow solid (87% yield, *anti*:*syn*=95:5).

(4*R*,5*S*)-**4c**: $[\alpha]_D^{25}$ −10.8 (*c* 1.21, $CHCl_3$, er = 96:4); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.95 (s, 3H), 1.26-1.33 (m, 6H), 1.72 (s, 3H), 2.35 (s, 3H), 5.09 (sep, *J* = 6.0 Hz, 1H), 7.09-7.18 (m, 4H), 7.36 (s, 2H), 7.41-7.62 (m, 6H), 7.65-7.76 (m, 3H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.1, 21.88, 21.92, 22.3, 22.6, 69.4, 73.5, 83.1, 83.2, 126.8, 128.4, 128.6, 128.66, 128.74, 128.8, 129.0, 130.5, 130.9, 132.1, 132.2, 132.3, 132.4, 132.60, 132.68, 132.72, 132.8, 132.9, 137.4, 138.3, 152.1, 152.2, 171.9; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.4; **IR** (ATR) 3649, 1943, 1890, 1793, 1670, 1577, 1508, 1457, 1375, 1260, 1048, 879, 799, 671 cm^{-1}; **HRMS** (ESI) calcd. for $C_{28}H_{32}N_2O_3P$ $[M+H]^+$: 475.2151, Found: 475.2157; **HPLC** (DAICEL CHIRALPAK AD-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(major)}$ = 8.40, $t_{(minor)}$ = 10.1 min.

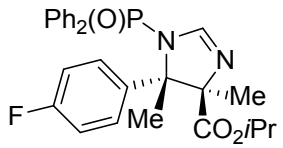
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(4-methoxy)phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4d)



The reaction was carried out as described above except for using ketimine **1d** (35 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4d** as a yellow solid (98% yield, *anti*:*syn*=97:3).

(4*R*,5*S*)-**4d**: $[\alpha]_D^{25}$ −10.9 (*c* 1.43, $CHCl_3$, er = 96:4); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.95 (s, 3H), 1.26-1.36 (m, 6H), 1.70 (s, 3H), 3.82 (s, 3H), 5.09 (sep, *J* = 6.0 Hz, 1H), 6.83 (d, *J* = 7.8 Hz, 2H), 7.17-7.23 (m, 3H), 7.35 (s, 1H), 7.42-7.52 (m, 4H), 7.54-7.62 (m, 1H), 7.66-7.73 (m, 4H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.89, 21.92, 22.2, 22.6, 55.3, 69.4, 73.4, 83.3, 83.4, 113.2, 128.1, 128.4, 128.5, 128.7, 128.9, 129.0, 130.3, 130.9, 132.1, 132.2, 132.3, 132.4, 132.5, 132.7, 132.8, 132.86, 132.90, 133.4, 152.2, 152.3, 159.0, 171.9; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.5; **IR** (ATR) 1717, 1609, 1509, 1457, 1438, 1252, 1226, 1183, 1070, 1047, 1029, 839, 801, 753 cm^{-1}; **HRMS** (ESI) calcd. for $C_{28}H_{32}N_2O_4P$ $[M+H]^+$: 491.2107, Found: 491.2100; **HPLC** (DAICEL CHIRALPAK AD-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(major)}$ = 9.57, $t_{(minor)}$ = 12.7 min.

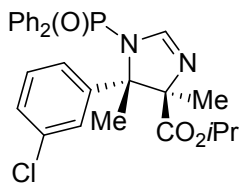
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(4-fluoro)phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4e)



The reaction was carried out as described above except for using ketimine **1e** (34 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4e** as a yellow solid (91% yield, *anti*:*syn*=94:6).

(4*R*,5*S*)-**4e**: $[\alpha]_D^{25}$ −1.20 (*c* 1.23, $CHCl_3$, er = 94:6); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.93 (s, 3H), 1.26-1.36 (m, 6H), 1.75 (s, 3H), 5.10 (sep, *J* = 6.0 Hz, 1H), 7.00 (t, *J* = 8.4 Hz, 1H), 7.18 (s, 1H), 7.23-7.27 (m, 2H), 7.36 (s, 1H), 7.48-7.51 (m, 4H), 7.53-7.77 (m, 6H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.88, 21.9, 22.5, 22.6, 69.6, 73.2, 83.05, 83.14, 128.1, 128.3, 128.4, 128.7, 128.9, 129.0, 129.2, 130.3, 130.7, 131.9, 132.1, 132.2, 132.3, 132.89, 132.9, 133.07, 133.1, 133.7, 139.9, 152.0, 152.1, 171.5; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.8; **IR** (ATR) 3734, 2981, 2938, 1718, 1613, 1510, 1438, 1375, 1202, 1069, 930, 843 cm^{-1}; **HRMS** (ESI) calcd. for $C_{27}H_{29}N_2O_3FP$ $[M+H]^+$: 479.1889, Found: 479.1900; **HPLC** (DAICEL CHIRALPAK AD-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(major)}$ = 7.77, $t_{(minor)}$ = 12.3 min.

(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(3-chloro)phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4f)

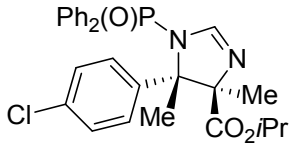


The reaction was carried out as described above except for using ketimine **1f** (35 mg, 0.1 mmol) and THF (1.0 mL) to give anti-**4f** as a yellow solid (98% yield, *anti*:*syn*=95:5).

(4*R*,5*S*)-**4f**: $[\alpha]_D^{25}$ −3.2 (*c* 1.46, $CHCl_3$, er = 93:7); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.96 (s, 3H), 1.29-1.34 (m, 6H), 1.80 (s, 3H), 5.10 (sep, *J* = 6.0 Hz, 1H), 7.14 (s, 1H), 7.21-7.30 (m, 4H), 7.36 (s, 2H), 7.51-7.53 (m, 3H), 7.59-7.69 (m, 3H), 7.75-7.82 (m, 2H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.87, 21.91, 22.4, 22.5, 69.6, 73.3, 76.7, 77.2, 77.6, 83.06, 83.15, 125.1, 127.2, 127.9, 128.4, 128.7, 128.9, 129.0, 129.2, 129.2, 130.4, 130.7, 131.9, 132.0, 132.1, 132.3, 132.90, 132.93, 133.07, 133.10,

134.1, 143.5, 151.9, 152.0, 171.4; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 22.0; **IR** (ATR) 3649, 2982, 1718, 1613, 1510, 1438, 1375, 1202, 1069, 1037, 998, 903, 843, 813, 752 cm^{-1}; **HRMS** (ESI) calcd. for $C_{27}H_{29}N_2O_3PCl$ $[M+H]^+$: 495.1612, Found: 495.1604; **HPLC** (DAICEL CHIRALPAK IA, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 9.82, $t_{(major)}$ = 11.6 min.

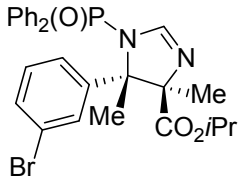
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(4-chloro)phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4g)



The reaction was carried out as described above except for using ketimine **1g** (35 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4g** as a yellow solid (97% yield, *anti*:*syn*=99:1).

(4*R*,5*S*)-**4g**: $[\alpha]_D^{25}$ −13.0 (*c* 1.33, $CHCl_3$, er = 93:7); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.94 (s, 3H), 1.24-1.33 (m, 6H), 1.75 (s, 3H), 5.09 (sep, *J* = 6.0 Hz, 1H), 7.15 (s, 1H), 7.20-7.30 (m, 4H), 7.36 (s, 2H), 7.47-7.54 (m, 3H), 7.57-7.78 (m, 5H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.88, 21.9, 22.5, 22.6, 69.6, 73.2, 83.05, 83.14, 128.1, 128.3, 128.4, 128.7, 128.9, 129.0, 129.2, 130.3, 130.7, 131.9, 132.1, 132.2, 132.3, 132.89, 132.9, 133.07, 133.1, 133.7, 139.9, 152.0, 152.1, 171.5; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.8; **IR** (ATR) 3649, 1869, 1829, 1793, 1771, 1698, 1616, 1521, 1490, 1418, 1259, 1048, 844, 774, 697 cm^{-1}; **HRMS** (ESI) calcd. for $C_{27}H_{29}N_2O_3PCl$ $[M+H]^+$: 495.1601, Found: 495.1604; **HPLC** (DAICEL CHIRALPAK AD-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(major)}$ = 7.77, $t_{(minor)}$ = 12.3 min.

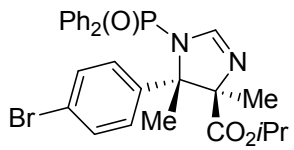
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(4-bromo)phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4h);



The reaction was carried out as described above except for using ketimine **1h** (40 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4h** as a yellow solid (98% yield, *anti*:*syn*=98:2).

(4*R*,5*S*)-**4h**: $[\alpha]_D^{25}$ −0.003 (*c* 1.45, $CHCl_3$, er = 93:7); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.97 (s, 3H), 1.23-1.39 (m, 6H), 1.80 (s, 3H), 5.10 (sep, *J* = 6.0 Hz, 1H), 7.14 (s, 1H), 7.18-7.27 (m, 2H), 7.31-7.38 (m, 3H), 7.41-7.44 (m, 1H), 7.52-7.54 (m, 3H), 7.59-7.67 (m, 3H), 7.70-7.82 (m, 2H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.86, 21.9, 22.5, 69.6, 73.2, 76.7, 77.2, 77.6, 83.1, 83.2, 122.4, 125.5, 128.4, 128.7, 128.9, 129.0, 129.2, 129.5, 130.1, 130.4, 130.7, 130.8, 131.8, 132.0, 132.1, 132.26, 132.3, 132.90, 132.93, 133.07, 133.1, 143.8, 151.9, 152.0, 171.4; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 22.1; **IR** (ATR) 3649, 1869, 1829, 1771, 1717, 1684, 1541, 1507, 1489, 1375, 1259, 1102, 902, 834, 703, 670 cm^{-1}; HRMS (ESI) calcd. for $C_{27}H_{29}N_2O_3PBr$ $[M+H]^+$: 539.1108, Found: 539.1099; **HPLC** (DAICEL CHIRALPAK IA, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 10.1, $t_{(major)}$ = 11.8 min.

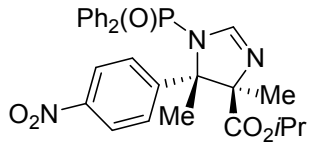
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(4-bromo)phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4i)



The reaction was carried out as described above except for using ketimine **1i** (40 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4i** as a yellow solid (96% yield, *anti*:*syn*=96:4).

(4*R*,5*S*)-**4i**: $[\alpha]_D^{25}$ +0.91 (*c* 1.39, $CHCl_3$, er = 94:6); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.94 (s, 3H), 1.28-1.33 (m, 6H), 1.75 (s, 3H), 5.09 (sep, *J* = 6.0 Hz, 1H), 7.15-7.27 (m, 3H), 7.36 (s, 2H), 7.42-7.50 (m, 5H), 7.59-7.78 (m, 5H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.86, 21.9, 22.5, 69.6, 73.2, 76.7, 77.2, 77.6, 83.0, 83.1, 122.0, 128.4, 128.6, 128.7, 128.9, 129.0, 129.2, 130.2, 130.6, 131.1, 131.4, 131.5, 131.6, 131.9, 132.0, 132.2, 132.3, 132.90, 132.94, 133.08, 133.1, 140.4, 151.9, 152.0, 171.5; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.8; **IR** (ATR) 3734, 1869, 1771, 1717, 1684, 1616, 1558, 1489, 1418, 1374, 1259, 1102, 930, 772, 669 cm^{-1}; **HRMS** (ESI) calcd. for $C_{27}H_{29}N_2O_3PBr$ $[M+H]^+$: 539.1103, Found: 539.1099; **HPLC** (DAICEL CHIRALPAK IF-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 15.0, $t_{(major)}$ = 17.4 min.

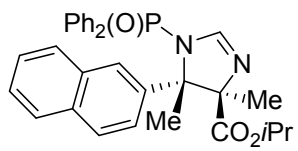
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(4-nitro)phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4j)



The reaction was carried out as described above except for using ketimine **1j** (36 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4j** as a yellow solid (93% yield, *anti*:*syn*=94:6).

(4*R*,5*S*)-**4j**: $[\alpha]_D^{25}$ −15.9 (*c* 1.30, $CHCl_3$, er = 93:7); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.94 (s, 3H), 1.26-1.38 (m, 6H), 1.85 (s, 3H), 5.12 (sep, *J* = 6.0 Hz, 1H), 7.13 (s, 1H), 7.33-7.40 (m, 4H), 7.49-7.57 (m, 5H), 7.63-7.70 (m, 3H), 7.77-7.84 (m, 2H), 8.20 (d, *J* = 7.2 Hz, 1H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.86, 21.9, 22.6, 22.7, 69.9, 73.2, 76.7, 77.2, 77.6, 82.9, 83.0, 123.1, 127.9, 128.4, 128.9, 129.1, 129.2, 129.4, 130.2, 130.4, 131.7, 131.9, 132.0, 132.1, 132.2, 133.09, 133.13, 133.35, 133.39, 147.3, 148.8, 151.7, 151.8, 171.0; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 22.2; **IR** (ATR) 3591, 2969, 2927, 1630, 1619, 1204, 1120, 987, 752, 669, 560, 482, 462, 445, 410 cm^{-1}; **HRMS** (ESI) calcd. for $C_{27}H_{29}N_3O_5P$ $[M+H]^+$: 506.1847, Found: 506.1845; **HPLC** (DAICEL CHIRALPAK AD-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(major)}$ = 13.9, $t_{(minor)}$ = 26.3 min.

(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(2-)naphthyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4k)

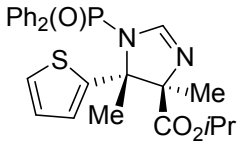


The reaction was carried out as described above except for using ketimine **1k** (37 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4k** as a yellow solid (99%

yield, *anti*:*syn*=95:5).

(4*R*,5*S*)-**4k**: $[\alpha]_D^{25}$ −21.8 (*c* 1.40, $CHCl_3$, er = 96:4); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.96 (s, 3H), 1.25-1.37 (m, 6H), 1.93 (s, 3H), 5.13 (sep, *J* = 6.0 Hz, 1H), 7.36 (s, 3H), 7.43-7.50 (m, 6H), 7.53-7.56 (m, 2H), 7.64 (s, 1H), 7.67-7.83 (m, 6H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.9, 22.0, 22.3, 22.8, 69.5, 73.8, 76.7, 77.2, 77.6, 83.2, 83.3, 125.2, 125.8, 126.1, 126.3, 127.4, 127.5, 128.4, 128.5, 128.6, 128.78, 128.85, 129.0, 130.5, 130.9, 132.0, 132.1, 132.2, 132.3, 132.6, 132.77, 132.8, 132.90, 132.93, 138.8, 152.2, 152.3, 171.8; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.4; **IR** (ATR) 1719, 1613, 1437, 1375, 1260, 1224, 1121, 1100, 1049, 998, 890, 860, 814, 725, 697 cm^{-1}; **HRMS** (ESI) calcd. for $C_{31}H_{32}N_2O_3P$ $[M+H]^+$: 511.2151, Found: 511.2158; **HPLC** (DAICEL CHIRALPAK IF-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 17.8, $t_{(major)}$ = 23.4 min.

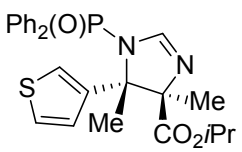
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(2-)thienyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4l)



The reaction was carried out as described above except for using ketimine **1l** (33 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4l** as a yellow solid (85% yield, *anti*:*syn*=92:8).

(4*R*,5*S*)-**4l**: $[\alpha]_D^{25}$ −20.3 (*c* 1.23, $CHCl_3$, er = 93:7); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 1.12 (s, 3H), 1.23-1.30 (m, 6H), 1.75 (s, 3H), 5.07 (sep, *J* = 6.0 Hz, 1H), 6.89-6.96 (m, 2H), 7.10 (s, 1H), 7.24 (d, *J* = 5.1 Hz, 1H), 7.36 (s, 1H), 7.47-7.52 (m, 4H), 7.57-7.62 (m, 2H), 7.69-7.82 (m, 4H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 20.8, 21.8, 23.1, 69.6, 71.9, 76.7, 77.2, 77.6, 83.2, 83.3, 124.9, 125.8, 126.7, 128.4, 128.6, 128.8, 129.0, 130.2, 130.5, 131.9, 132.1, 132.2, 132.3, 132.5, 132.76, 132.8, 132.9, 133.0, 146.5, 152.0, 152.1, 171.4; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.1; **IR** (ATR) 3426, 1721, 1224, 1199, 1122, 1100, 725, 693, 669, 661, 644, 629, 617, 591 cm^{-1}; **HRMS** (ESI) calcd. for $C_{25}H_{28}N_2O_3SP$ $[M+H]^+$: 467.1558, Found: 467.1562; **HPLC** (DAICEL CHIRALPAK AY-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 8.62, $t_{(major)}$ = 10.6 min.

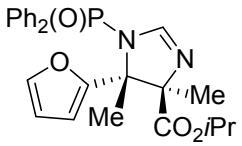
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(3-)thienyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4m)



The reaction was carried out as described above except for using ketimine **1m** (33 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4m** as a yellow solid (94% yield, *anti*:*syn*=97:3). (4*R*,5*S*)-**4m**: $[\alpha]_D^{25}$ −30.1 (*c* 0.746, $CHCl_3$, er = 96:4); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 1.05 (s, 3H), 1.26-1.33 (m, 6H), 1.66 (s, 3H), 5.09 (sep, *J* = 6.0 Hz, 1H), 6.96-6.99 (m, 2H), 7.19-7.25 (m, 2H), 7.36 (s, 1H), 7.42-7.59 (m, 6H), 7.62-7.73 (m, 4H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.3, 21.88, 21.91, 22.7, 69.4, 71.6, 82.9, 83.0, 122.4, 125.3, 127.5, 128.4, 128.5, 128.7, 128.8, 129.0, 130.0, 130.5, 131.7, 132.1, 132.2, 132.3, 132.4, 132.75, 132.79, 132.8,

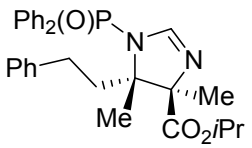
132.9, 143.2, 152.2, 152.3, 171.6; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.4; **IR** (ATR) 3413, 2979, 1721, 1611, 1438, 1375, 1225, 1121, 1101, 819, 751, 725, 628, 618 cm^{-1}; **HRMS** (ESI) calcd. for $C_{25}H_{28}N_2O_3SP$ $[M+H]^+$: 467.1558, Found: 467.1569; **HPLC** (DAICEL CHIRALPAK AY-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 8.50, $t_{(major)}$ = 11.5 min.

(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-(2-)fulyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4n)



The reaction was carried out as described above except for using ketimine **1n** (31 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4n** as a yellow solid (90% yield, *anti*:*syn*=96:4). (4*R*,5*S*)-**4n**: $[\alpha]_D^{25}$ −54.3 (*c* 1.17, $CHCl_3$, er = 95:5); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 1.12 (s, 3H), 1.28-1.35 (m, 6H), 1.72 (s, 3H), 5.07 (sep, *J* = 6.0 Hz, 1H), 6.12 (d, *J* = 2.1 Hz, 1H), 6.26 (d, *J* = 2.1 Hz, 1H), 7.05 (s, 1H), 7.24 (s, 1H), 7.35-7.36 (m, 2H), 7.51-7.64 (m, 5H), 7.78-7.85 (m, 2H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 20.2, 20.7, 21.86, 21.88, 69.3, 69.5, 83.0, 83.1, 108.4, 110.7, 128.4, 128.5, 128.71, 128.74, 128.9, 130.0, 130.5, 131.6, 132.0, 132.1, 132.2, 132.4, 132.61, 132.65, 132.8, 132.9, 141.6, 152.0, 152.1, 154.1, 171.0; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.4; **IR** (ATR) 3414, 2980, 2938, 1722, 1612, 1439, 1269, 1223, 1122, 1102, 694, 669, 617, 557, 495 cm^{-1}; **HRMS** (ESI) calcd. for $C_{25}H_{28}N_2O_4P$ $[M+H]^+$: 451.1787, Found: 451.1788; **HPLC** (DAICEL CHIRALPAK AD-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 9.42, $t_{(major)}$ = 10.5 min.

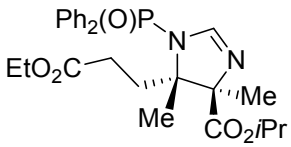
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-phenethyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-**4o**)



The reaction was carried out as described above except for using ketimine **1o** (35 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4o** as a yellow solid (90% yield, *anti*:*syn*=90:10).

(4*R*,5*S*)-**4o**: $[\alpha]_D^{25}$ −55.6 (*c* 0.89, $CHCl_3$, er = 95:5); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 1.25-1.30 (m, 6H), 1.40 (s, 3H), 1.54 (s, 3H), 2.22 (t, *J* = 9.0 Hz, 2H), 2.70-2.76 (m, 1H), 2.87-2.93 (m, 1H), 5.06 (sep, *J* = 6.3 Hz, 1H), 6.69 (s, 1H), 7.14-7.19 (m, 3H), 7.23-7.26 (m, 2H), 7.52-7.60 (m, 6H), 7.72-7.85 (m, 4H); **^{13}C NMR** (150 MHz, $CDCl_3$) δ 19.7, 21.8, 21.9, 23.0, 31.4, 39.3, 69.3, 72.7, 81.1, 81.2, 125.8, 125.9, 128.4, 128.5, 128.8, 129.0, 129.2, 130.6, 131.9, 132.0, 132.2, 132.3, 132.87, 132.9, 132.95, 141.9, 151.7, 151.8, 171.9; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.0; **IR** (ATR) 2979, 1722, 1608, 1438, 1374, 1227, 1174, 1121, 1099, 928, 751 cm^{-1}; **HRMS** (ESI) calcd. for $C_{29}H_{34}N_2O_3P$ $[M+H]^+$: 489.2307, Found: 489.2320; **HPLC** (DAICEL CHIRALPAK IA, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 7.2, $t_{(major)}$ = 9.1 min.

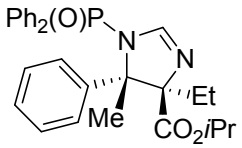
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4,5-dimethyl-5-ethylpropanoate-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4p)



The reaction was carried out as described above except for using ketimine **1p** (34 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4p** as a yellow oil (92% yield, *anti*:*syn*=85:15).

(4*R*,5*S*)-**4p**: **^{1}H NMR** (300 MHz, $CDCl_3$) δ 1.19-1.27 (m, 9H), 1.38 (s, 3H), 1.45 (s, 3H), 2.11-2.22 (m, 1H), 2.31-2.42 (m, 1H), 2.48-2.58 (m, 1H), 2.65 -2.72 (m, 1H), 4.08 (q, *J* = 7.2 Hz, 2H), 5.06 (sep, *J* = 6.3 Hz, 1H), 6.64 (s, 1H), 7.36 (s, 1H), 7.54-7.60 (m, 6H), 7.74-7.80 (m, 4H); **^{13}C NMR** (150 MHz, $CDCl_3$) δ 14.3, 20.3, 21.7, 21.8, 22.7, 30.0, 30.2, 31.4, 60.5, 69.4, 72.0, 81.3, 128.3, 128.4, 128.9, 129.0, 129.04, 129.2, 130.4, 131.9, 132.0, 132.2, 133.0, 151.2, 151.3, 171.8, 172.9; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.2; **IR** (ATR) 2979, 1729, 1610, 1439, 1375, 1278, 1217, 1179, 1121, 1102, 753, 726, 698 cm^{-1}; **HRMS** (ESI) calcd. for $C_{26}H_{34}N_2O_5P$ $[M+H]^+$: 485.2205, Found: 485.2205; **HPLC** (DAICEL CHIRALPAK IC-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 28.1, $t_{(major)}$ = 30.7 min.

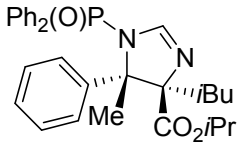
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4-ethyl-5-methyl-5-phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-**4q**)



The reaction was carried out as described above except for using ketimine **1a** (32 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4q** as a yellow solid (98% yield, *anti*:*syn*=98:2).

(4*R*,5*S*)-**4q**: $[\alpha]_D^{25}$ +20.4 (*c* 1.22, $CHCl_3$, er = 94:6); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.81-0.85 (m, 4H), 1.27-1.37 (m, 7H), 1.79 (s, 3H), 5.14 (sep, *J* = 6.0 Hz, 1H), 7.21 (s, 1H), 7.29-7.30 (m, 4H), 7.36-7.37 (m, 2H), 7.40-7.49 (m, 3H), 7.52-7.59 (m, 2H), 7.65-7.76 (m, 4H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 9.9, 21.9, 22.0, 23.2, 29.8, 69.3, 74.1, 87.16, 87.25, 127.1, 127.7, 127.8, 128.4, 128.6, 128.8, 128.9, 129.0, 130,6, 130.9, 132.0, 132.11, 132.14, 132.3, 132.5, 132.7, 132.9, 140.9, 151.7, 151.8, 171.0; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.7; **IR** (ATR) 3414, 2978, 1722, 1438, 1226, 1121, 1101, 1049, 997, 836, 725, 694 cm^{-1}; **HRMS** (ESI) calcd. for $C_{28}H_{32}N_2O_3P$ $[M+H]^+$:475.2151, Found: 475.2159; **HPLC** (DAICEL CHIRALPAK IA, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 8.5, $t_{(major)}$ = 9.4 min.

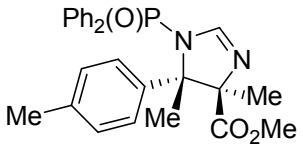
(4*R*,5*S*)-Isopropyl 4,5-dihydro-4-isobuthyl-5-methyl-5-phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-**4r**)



The reaction was carried out as described above except for using ketimine **1a** (32 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4r** as a yellow solid (78% yield, *anti*:*syn*=93:7).

(4*R*,5*S*)-**4r**: $[\alpha]_D^{25}$ +19.7 (*c* 1.14, $CHCl_3$, er = 90:10); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.66-0.70 (m, 1H), 0.73-0.83 (m, 6H),, 1.24-1.25 (m, 1H), 1.33 (s, 3H), 1.60-1.65 (m, 1H), 1.75 (s, 3H), 5.12 (sep, *J* = 6.0 Hz, 1H), 7.29 (s, 4H), 7.34-7.36 (m, 2H), 7.41-7.49 (m, 3H), 7.51-7.59 (m, 2H), 7.61-7.76 (m, 4H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.89, 22.0, 23.2, 24.2, 24.4, 26.3, 44.3, 69.4, 74.6, 86.8, 86.9, 127.1, 127.7, 127.8, 128.4, 128.6, 128.8, 128.9, 129.1, 130.7, 131.0, 132.0, 132.1, 132.2, 132.3, 132.67, 132.71, 132.85, 132.89, 141.0, 151.5, 151.6, 171.6; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.6; **IR** (ATR) 3414, 2970, 2953, 1738, 1726, 1439, 1366, 1227, 1102, 1008, 789, 677 cm^{-1}; **HRMS** (ESI) calcd. for $C_{30}H_{36}N_2O_3P$ $[M+H]^+$: 503.2464, Found: 503.2466; **HPLC** (DAICEL CHIRALPAK IF-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(minor)}$ = 9.5, $t_{(major)}$ = 12.5 min.

(4*R*,5*S*)-Methyl 4,5-dihydro-4,5-dimethyl-5-(4-methyl)phenyl-1-diphenyphoshinoyl-1*H*-imidazole-4-carboxylate (*anti*-4s)

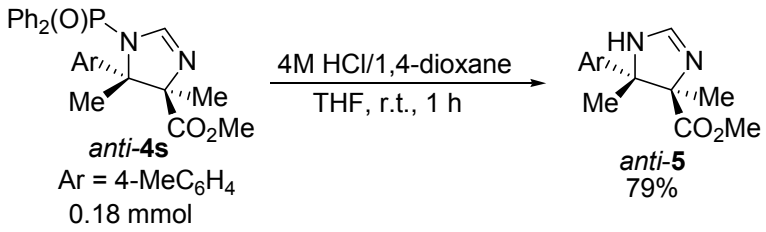


The reaction was carried out as described above except for using ketimine **1a** (33 mg, 0.1 mmol) and THF (1.0 mL) to give *anti*-**4s** as a yellow solid (68% yield, *anti*:*syn*=96:4).

(4*R*,5*S*)-**4s**: $[\alpha]_D^{25}$ +0.991 (*c* 0.91, $CHCl_3$, er = 95:5); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.96 (s, 3H), 1.67 (s, 3H), 2.35 (s, 3H), 3.76 (s, 3H), 7.10-7.17 (m, 4H), 7.35-7.36 (m, 2H), 7.47-7.51 (m, 4H), 7.55-7.59 (m, 1H), 7.66-7.78 (m, 4H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.1, 22.1, 22.4, 52.3, 73.5, 83.5, 83.6, 126.6, 128.6, 128.8, 128.9, 129.1, 130.8, 132.0, 132.1, 132.3, 132.4, 132.8, 132.9, 137.5, 138.1, 152.6, 152.7, 172.8; **^{31}P NMR** (121 MHz, $CDCl_3$) δ 21.3; **IR** (ATR) 3734, 2990, 2948, 1732, 1614, 1437, 1260, 1224, 1122, 1109, 725, 697 cm^{-1}; **HRMS** (ESI) calcd. for $C_{26}H_{28}N_2O_3P$ $[M+H]^+$: 447.1838, Found: 447.1831; **HPLC** (DAICEL CHIRALPAK AD-3, Hexane:*i*PrOH = 70:30, 1.0 mL/min, 225 nm, temp = 50 °C) $t_{(major)}$ = 9.4, $t_{(minor)}$ = 10.5 min.

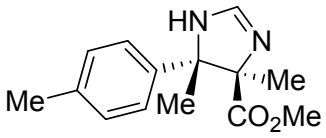
General procedure for synthetic application of products:

(4*R*,5*S*)-Methyl 4,5-dimethyl-5-(4-methylphenyl)-4,5-dihydro-1H-imidazole-4-carboxylate (5)



To a solution of *anti*-**4s** (79.0 mg, 0.18 mmol) in THF (1.5 mL), 4 M HCl/1,4-dioxane (100 μL) was added, and the mixture was stirred for 1 h. The reaction mixture was quenched with saturated $NaHCO_3$, and the solution was extracted with CH_2Cl_2 in three times. The combined organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by silica gel column chromatography (AcOEt/MeOH=90/10, and 1% Et_3N) to give to give **5** in 79% yield as a white solid without further purification.

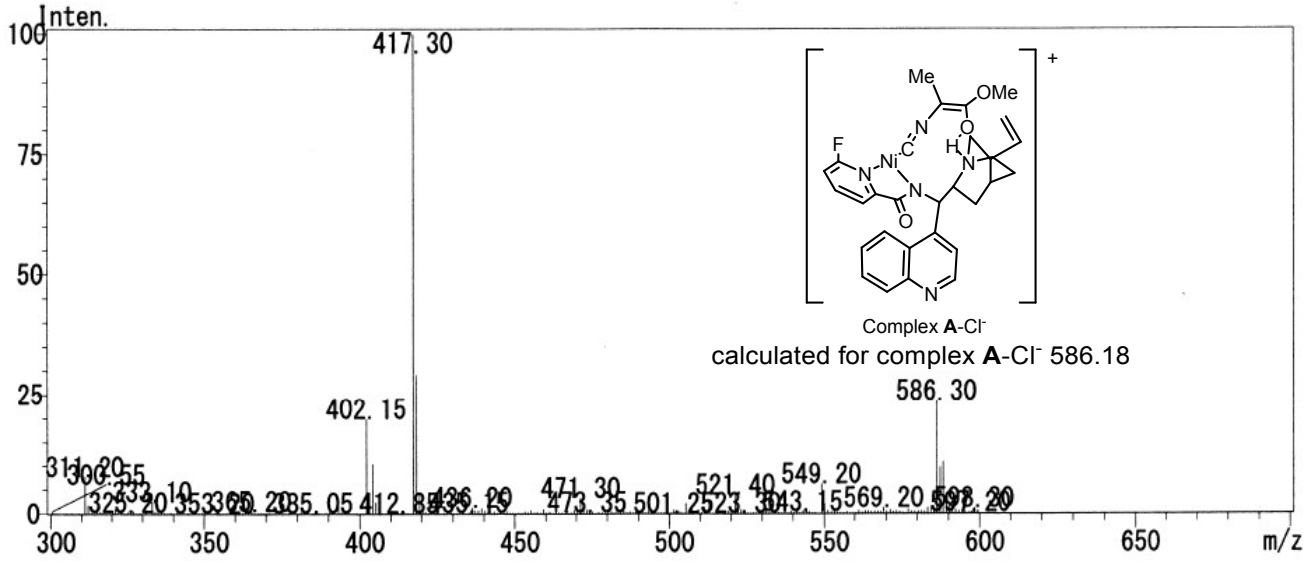
(4*R*,5*S*)-Methyl 4,5-dimethyl-5-(4-methylphenyl)-4,5-dihydro-1H-imidazole-4-carboxylate (*anti*-5);

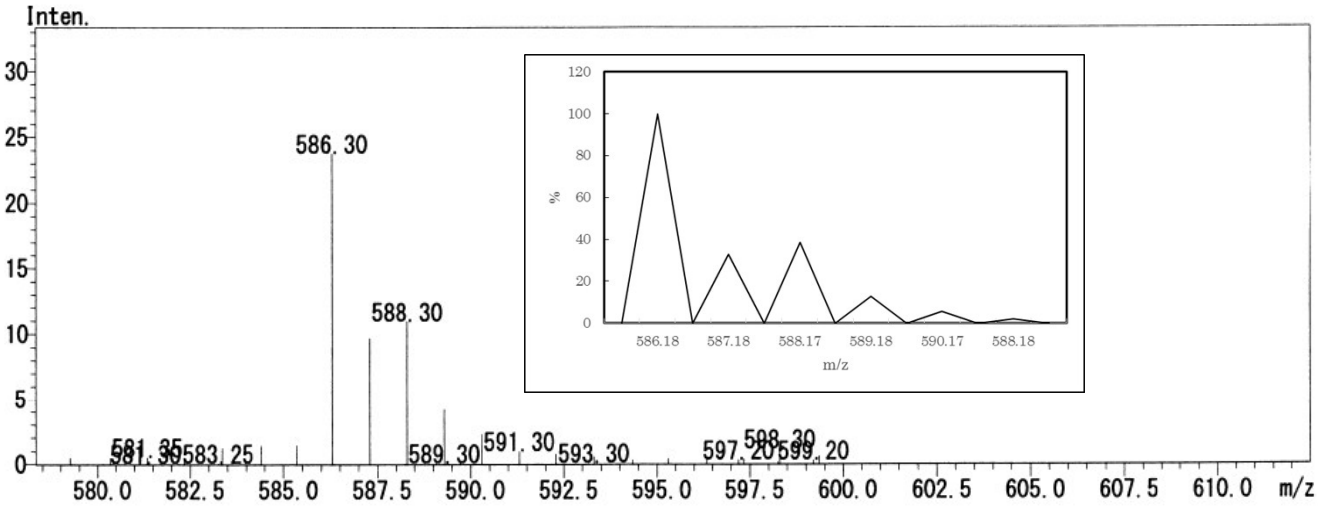


(4*R*,5*S*)-**5**: $[\alpha]_D^{25}$ +145.8 (*c* 0.80, $CHCl_3$); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 0.90 (s, 3H), 1.48 (s, 3H), 2.35 (s, 3H), 3.83 (s, 3H), 4.63 (br s, 1H), 7.14-7.16 (m, 3H), 7.36-7.47 (m, 2H); **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ 21.1, 24.3, 25.9, 52.5, 73.1, 74.9, 126.8, 128.8, 137.1, 138.3, 152.3, 173.7; **IR** (ATR) 3064, 2976, 1731, 1603, 1446, 1273, 1131, 977, 806, 729 cm^{-1}; **HRMS** (ESI) calcd. for $C_{14}H_{19}N_2O_2$ $[M+H]^+$: 247.1447, Found: 247.1461.

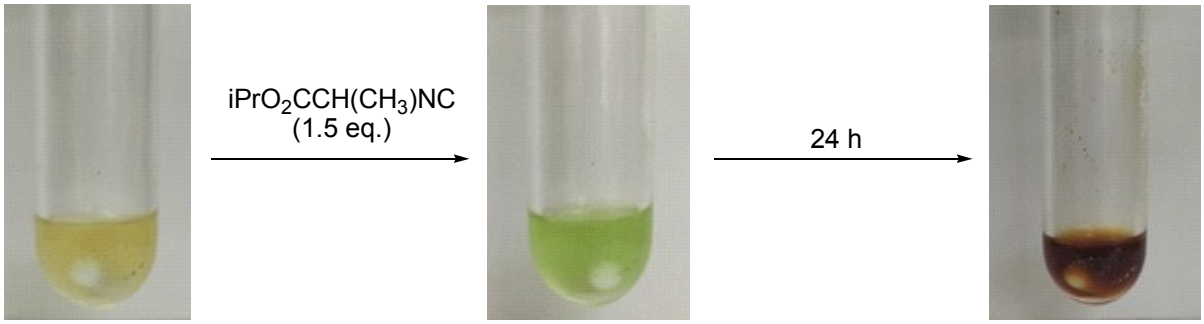
ESI-Mass spectroscopic analysis:

In order to clarify the assumed reaction mechanism, we also investigated some other spectroscopic analysis. The ESI-Mass spectroscopic analysis of complex **A**; (**2**, **3e**, $NiCl_2$, and Cs_2CO_3 in a 1:0.1:0.1:0.2 ratio in THF, cation mode)





The picture for the reaction mixture of $CNCH(CH_3)CO_2iPr$.



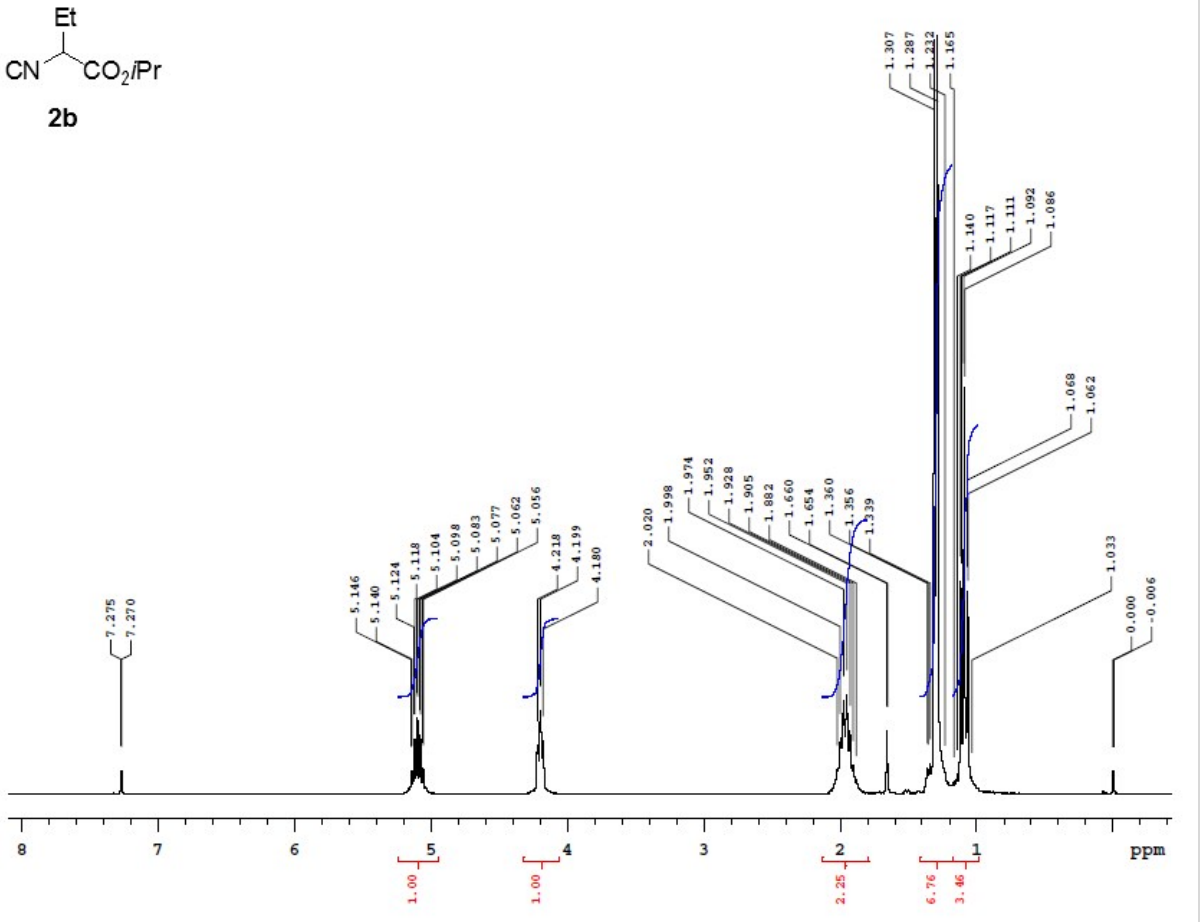
1a
$NiCl_2$ (10 mol%)
3e (10 mol%)
Cs_2CO_3 (20 mol%)
MS 5Å

The addition of isopropyl 2-isocyanopropanoate (1.5 eq.) to the mixture of **1a**, $NiCl_2$, **3e**, Cs_2CO_3, and MS 5Å changed the color of the reaction from yellow to green. After stirring for 24 h, the color of the reaction changed to dark red.

References:

1) a) S. Matsumoto, H. Usuda, M. Suzuki, M. Kanai, M. Shibasaki, *J. Am. Chem. Soc.* **2003**, *125*, 5634–5635; b) K. Shen, X. Liu, Y. Cai, L. Lin, X. Feng, *Chem. Eur. J.* **2009**, *15*, 6008–6014; c) W. B. Jennings, S. P. Watson, *Tetrahedron Lett.* **1989**, *30*, 235–238; d) Y.-J. Chen, C. Chen, *Tetrahedron: Asymmetry* **2008**, *19*, 2201–2209; e) R. Reingruber, S. Bräse, *Chem. Commun*, **2008**, 105–107.

2) a) N. Elder, R. F. Schmitz, F. J. J. D. Kanter, E. Ruijter, M. B. Groen, R. V. A. Orru, *J. Org. Chem.* **2007**, *72*, 6135–6142; b) M. Wang, X. Liu, P. He, L. Lin, X. Feng, *Chem. Commun,* **2013**, *49*, 2572–2574; c) B. H. Rotstein, D. J. Winternheimer, L. M. Yin, C. M. Deber, A. K. Yudin, *Chem. Commun.* **2012**, *48*, 3775–3777.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5.056
4.218
4.199
4.180
2.020
1.998
1.974
1.952
1.928
1.905
1.882
1.660
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1.307
1.287
1.212
1.165
1.140
1.117
1.111
1.092
1.086
1.068
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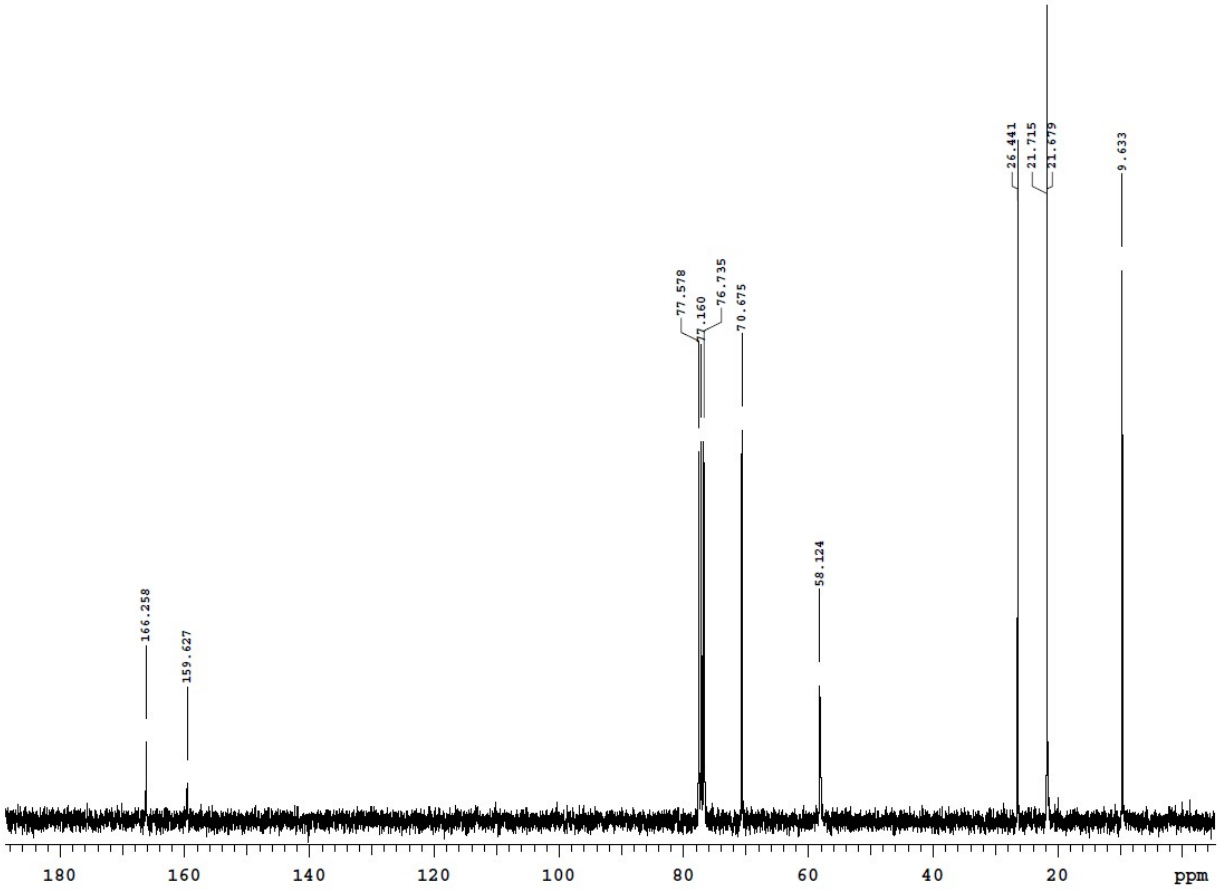
3.46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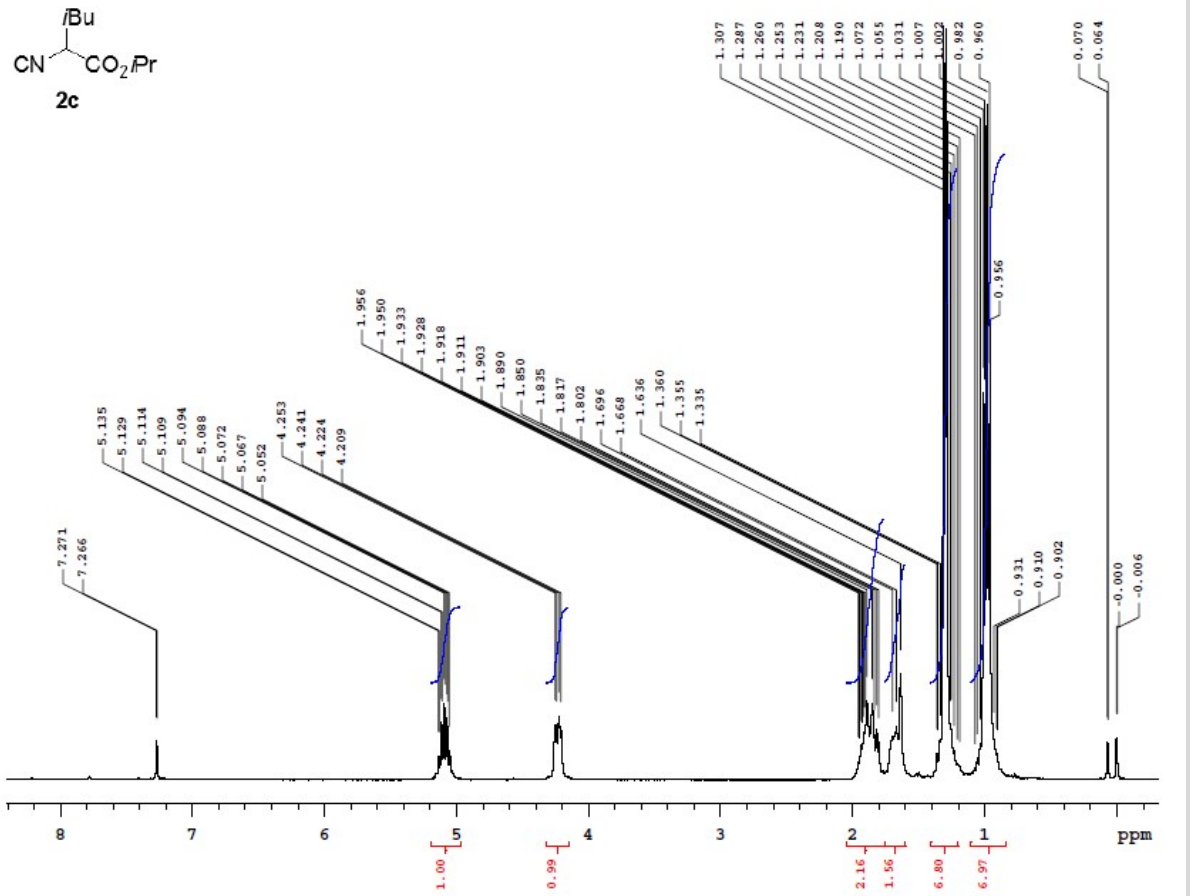
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1.002
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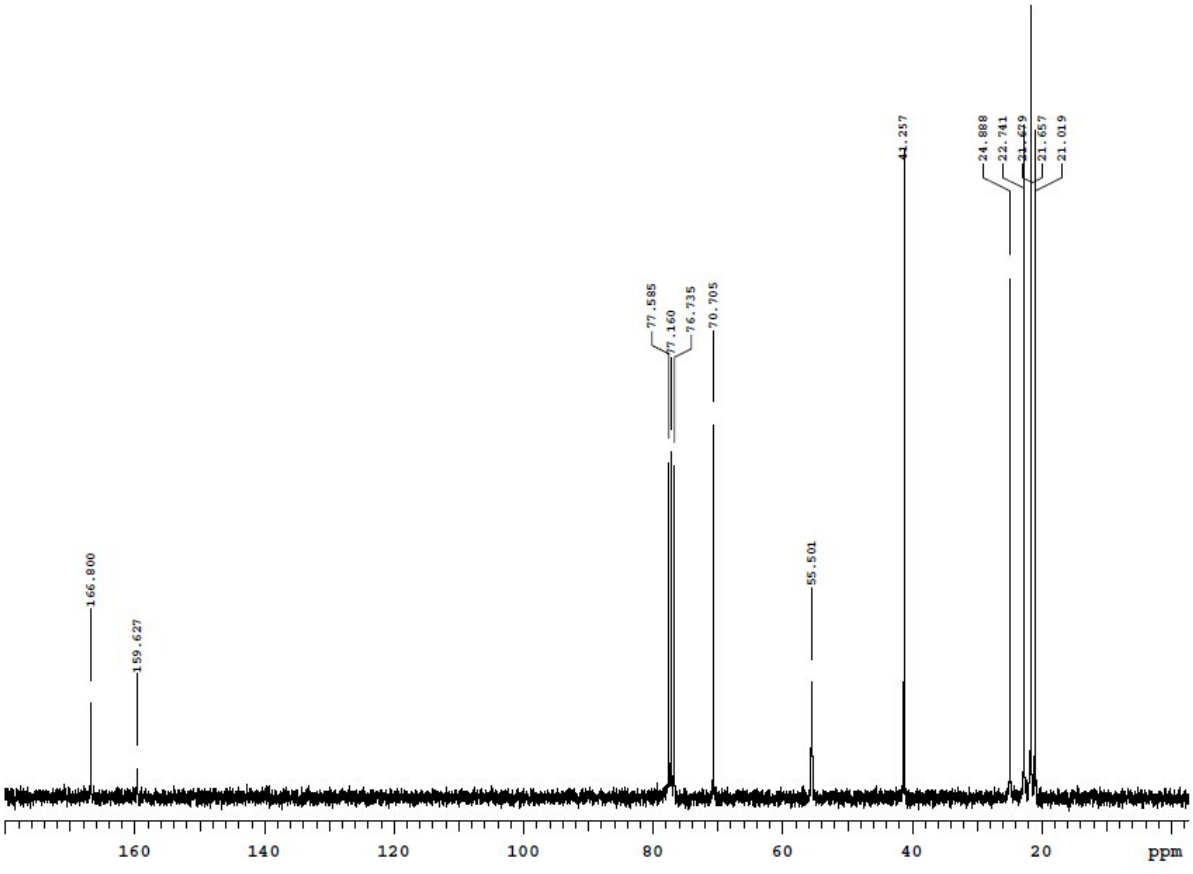
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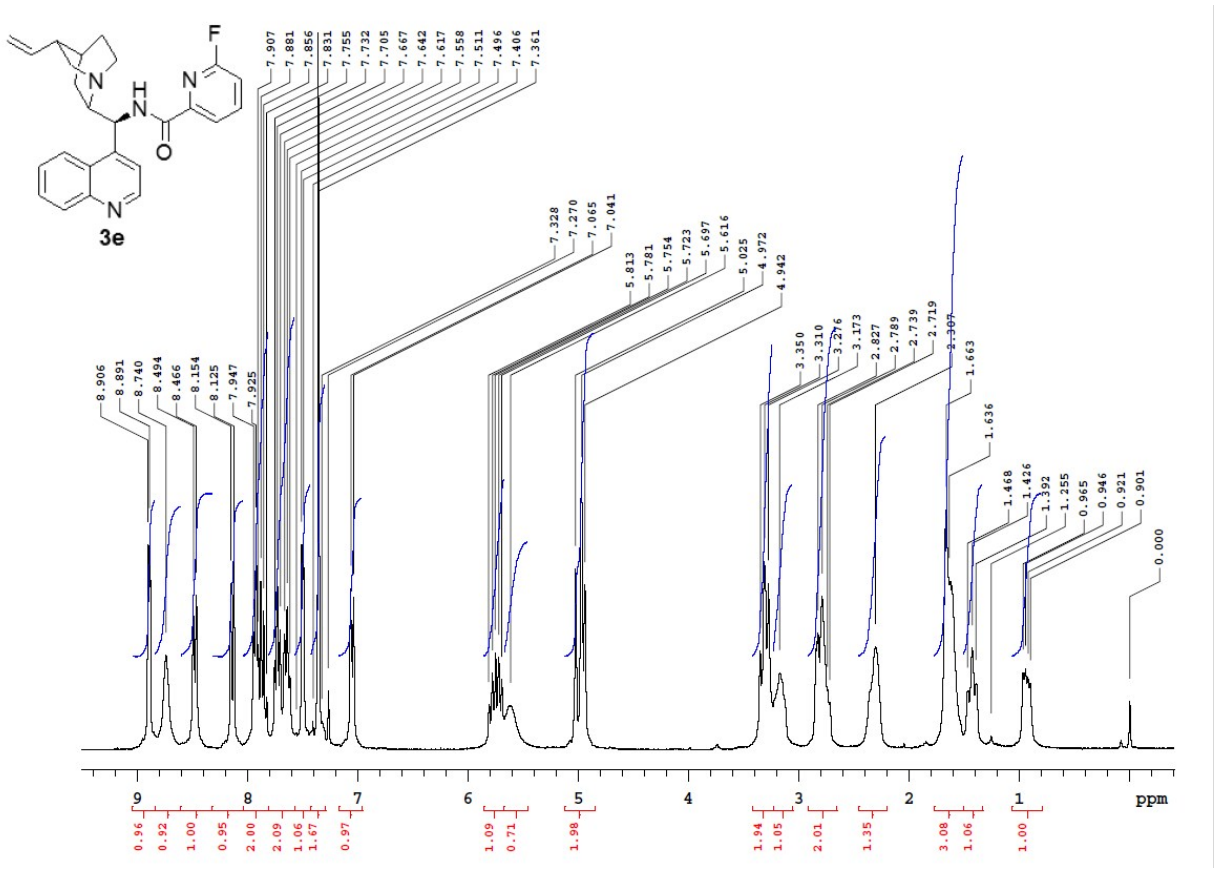
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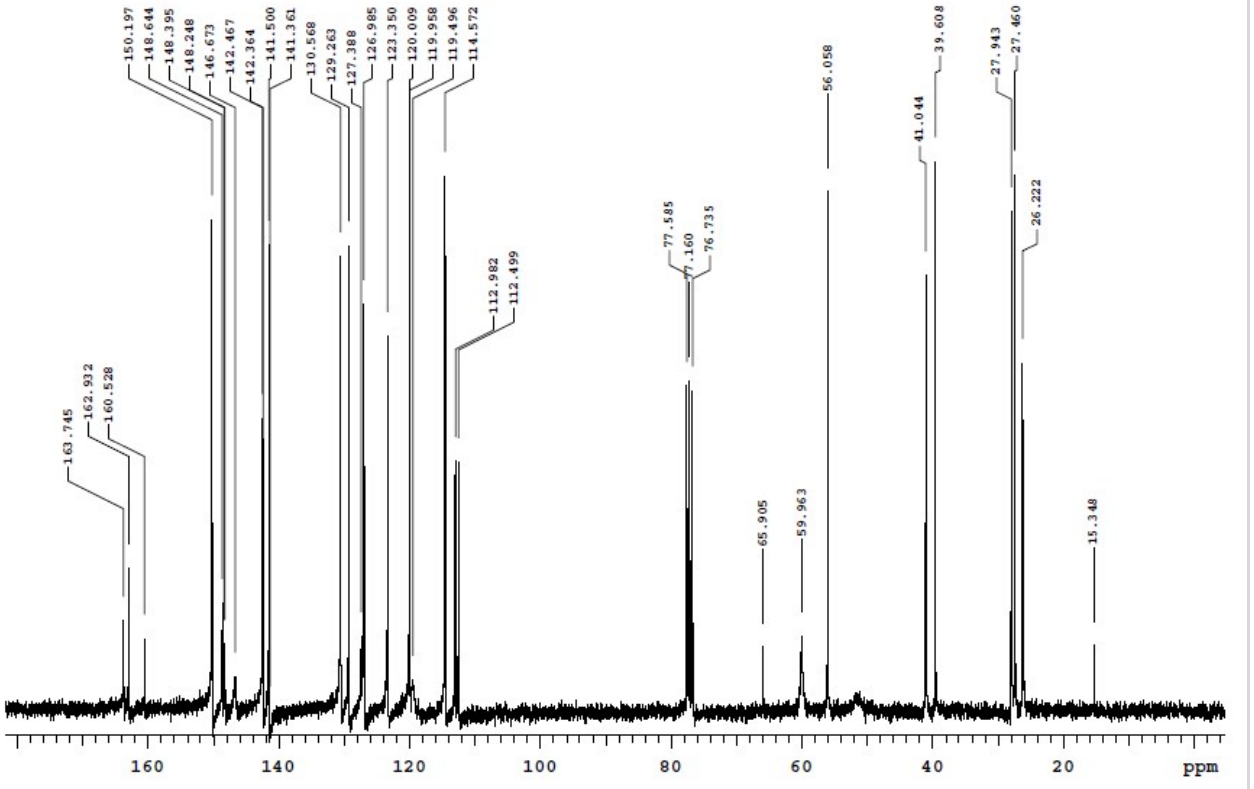
1.00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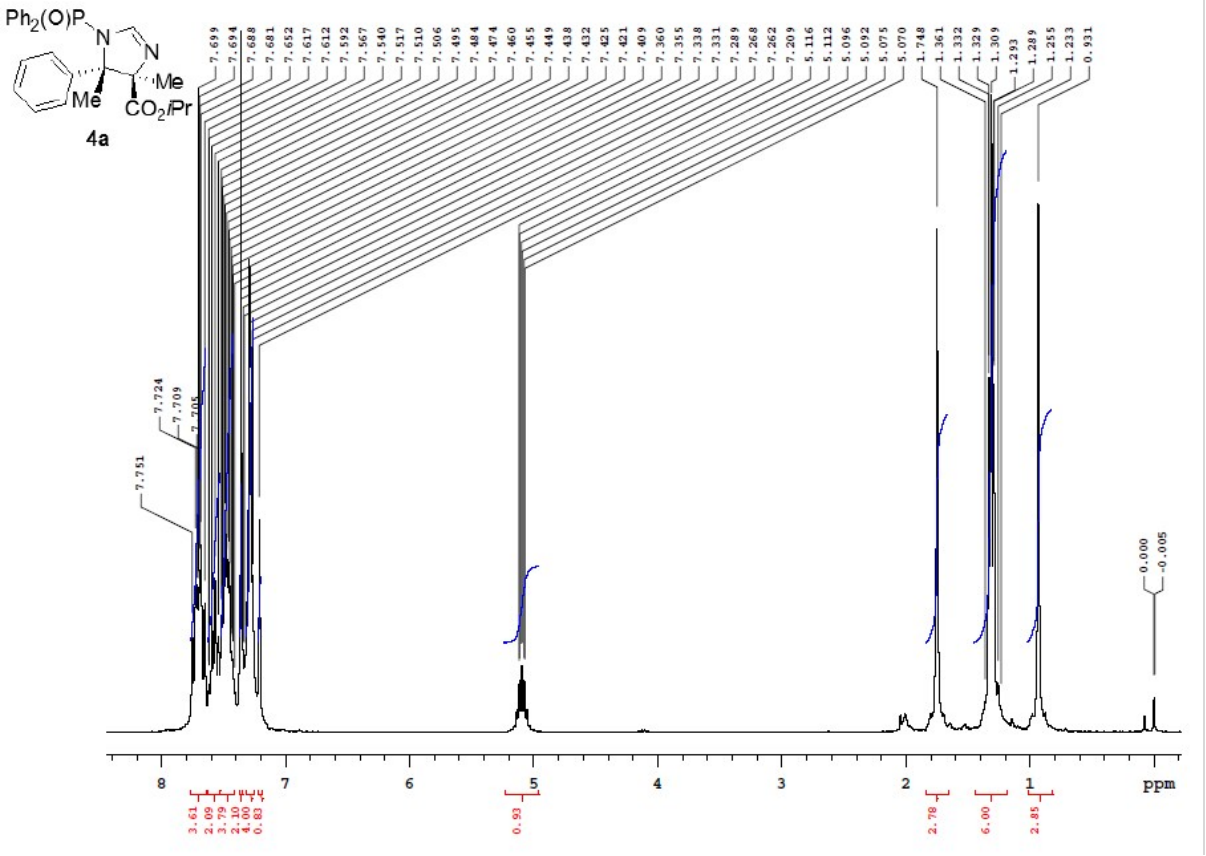
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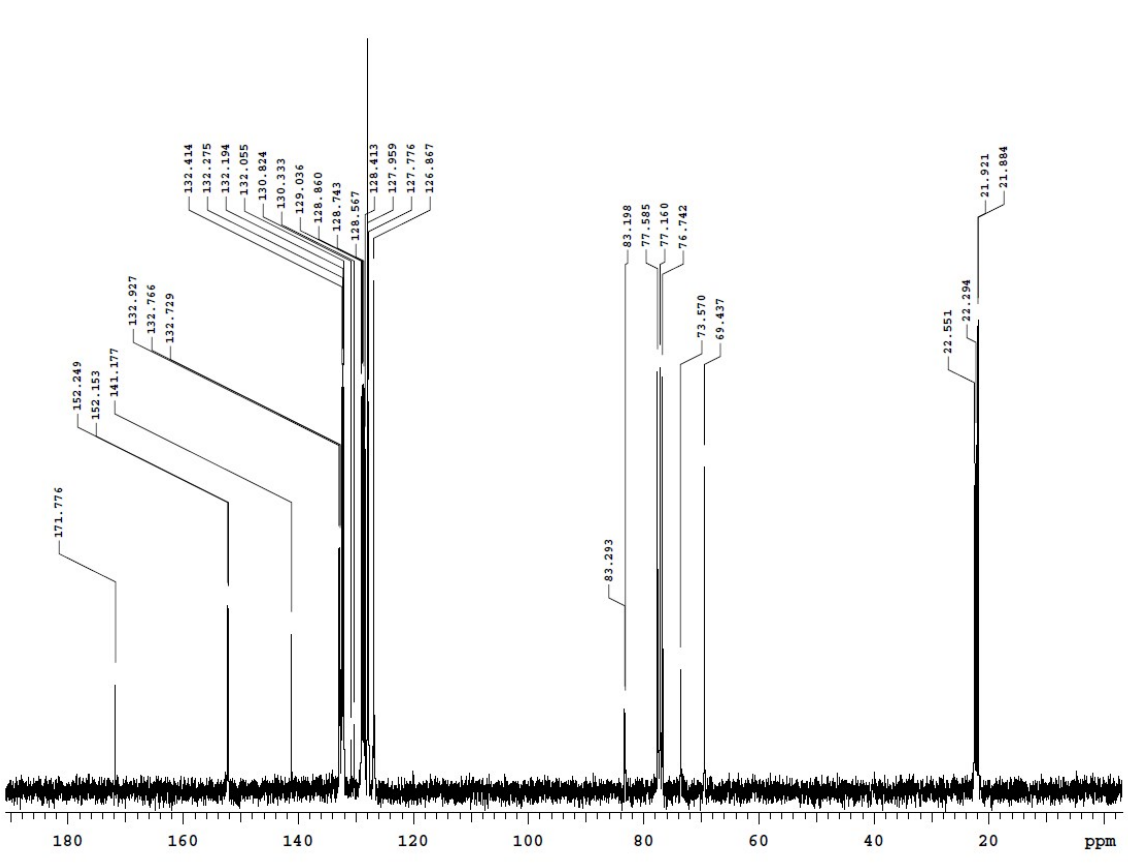
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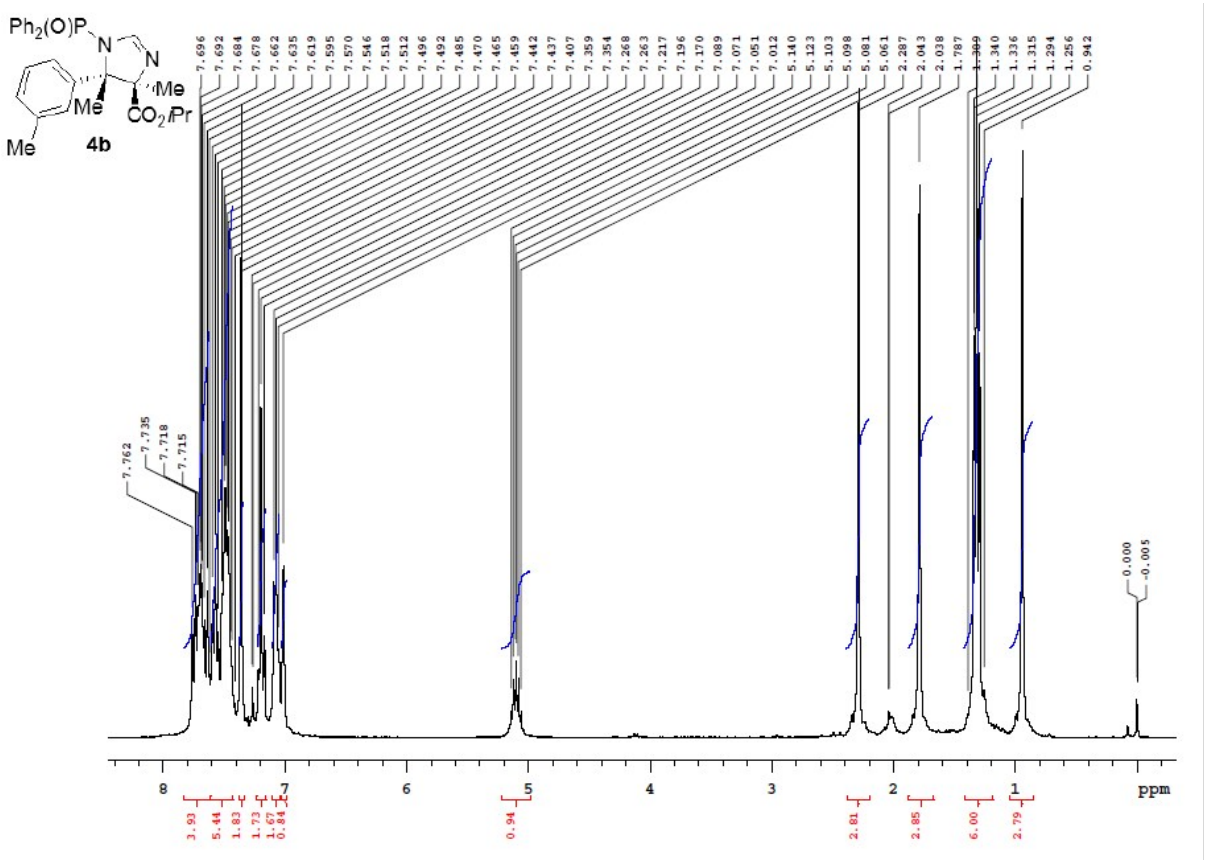
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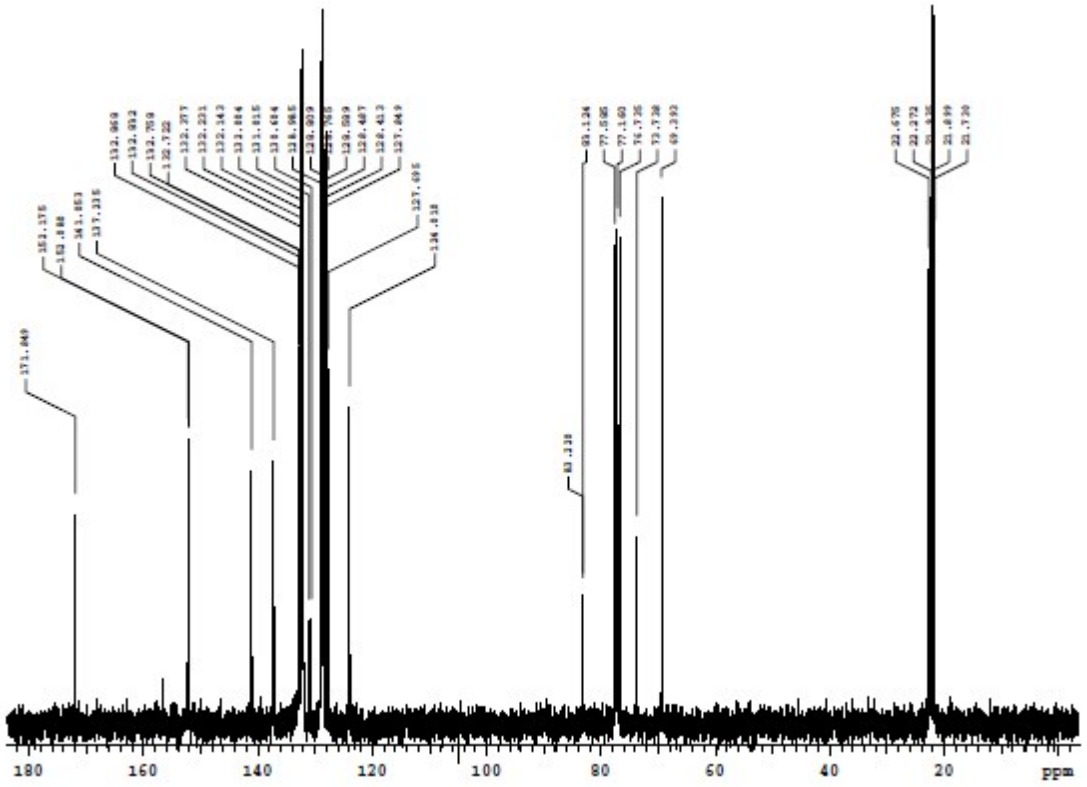
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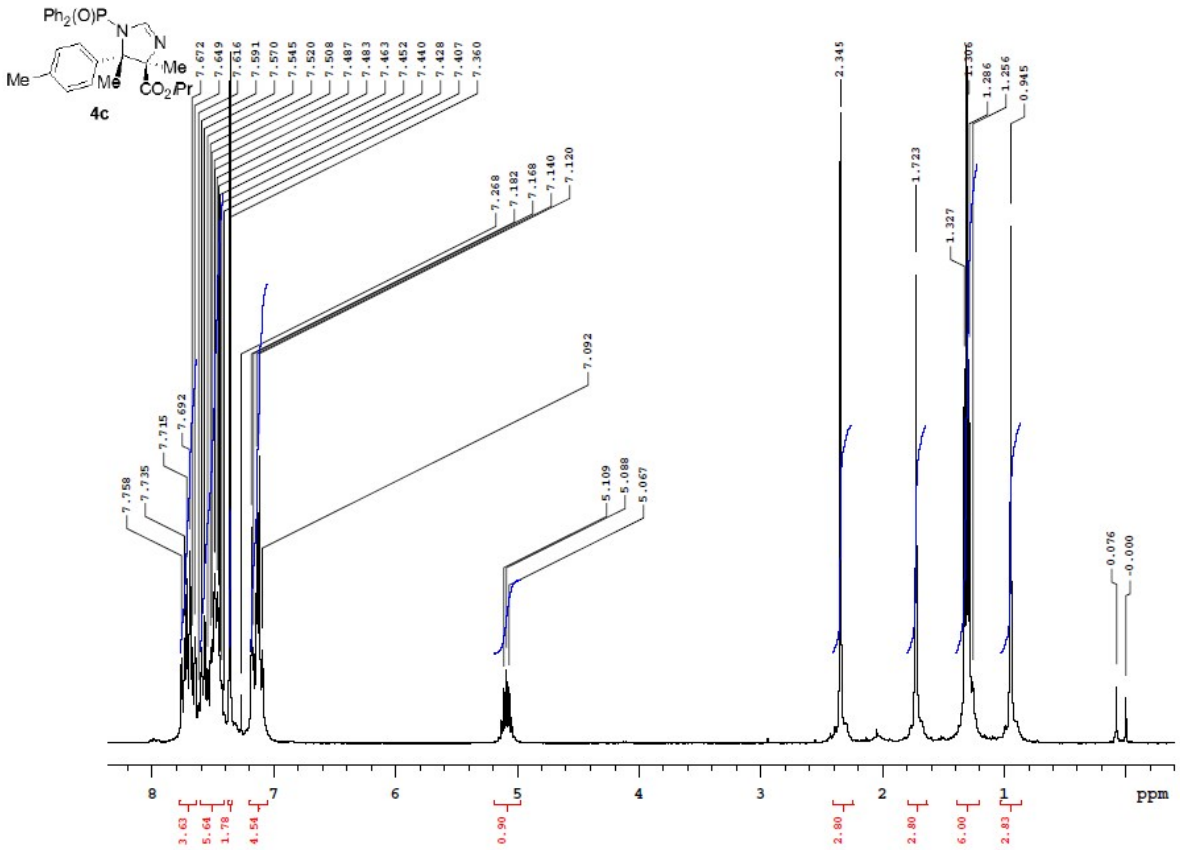
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N
Me
Me
Me
CO2iPr
4c
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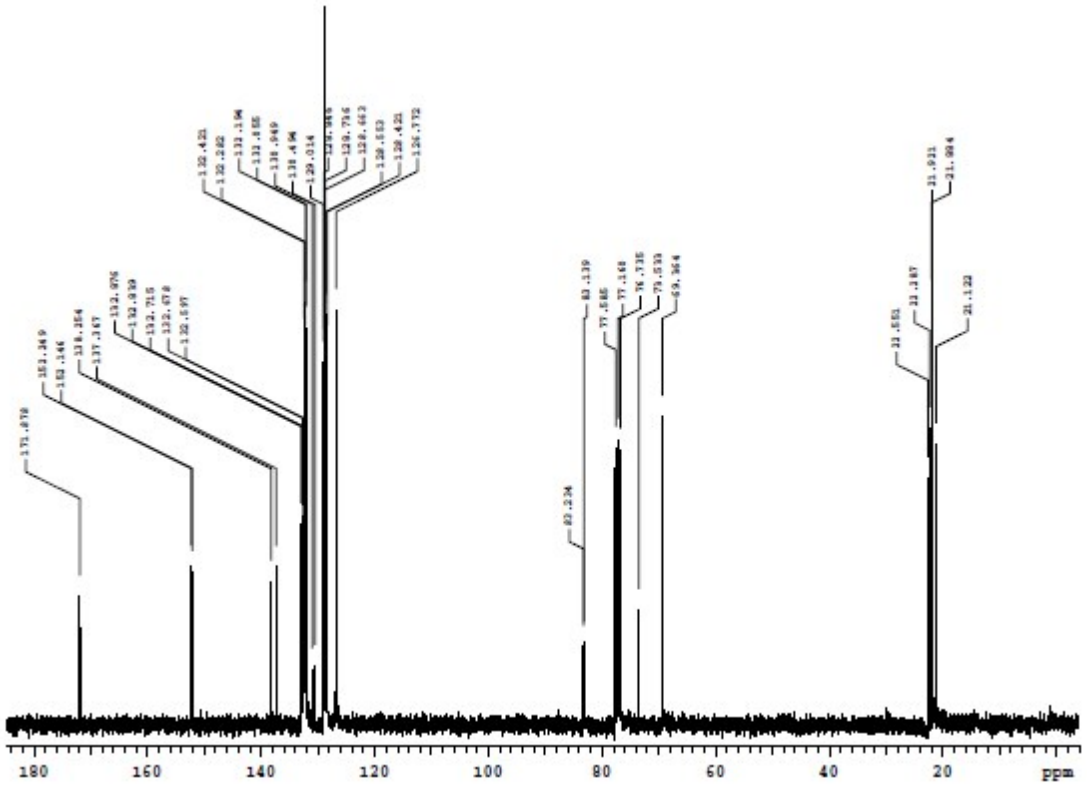
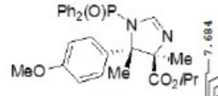
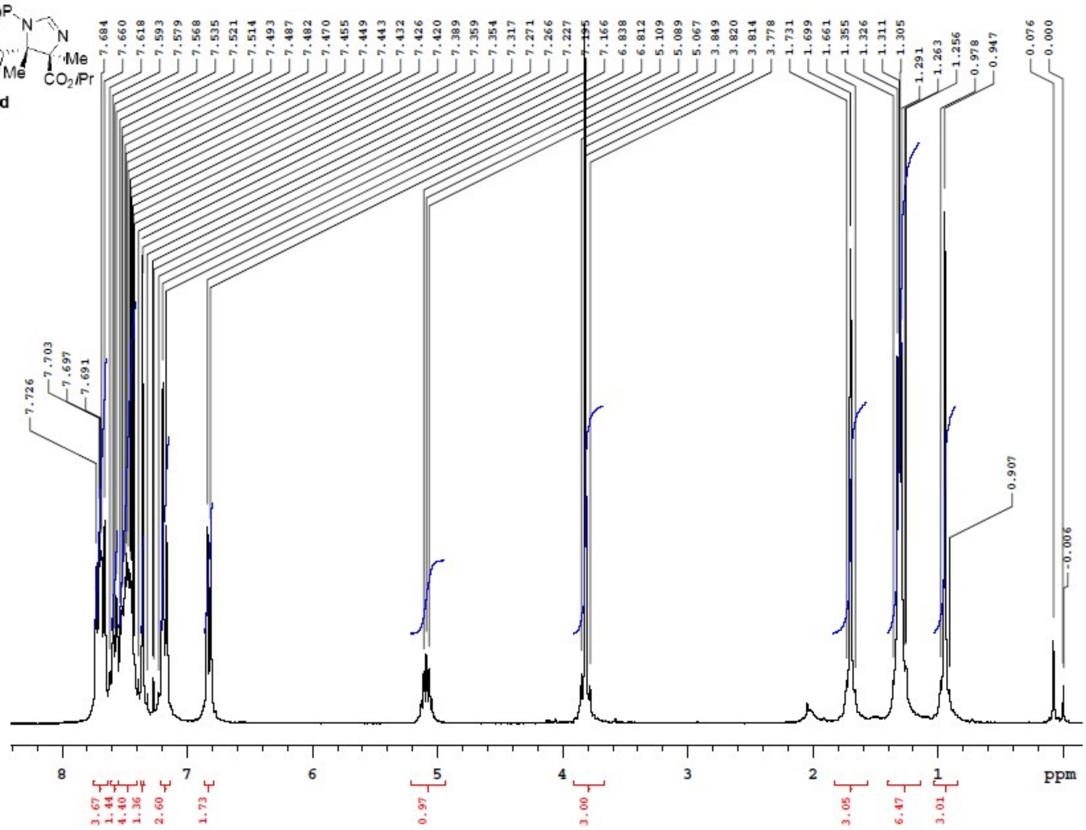
7.649
7.616
7.591
7.570
7.545
7.520
7.508
7.487
7.483
7.463
7.452
7.440
7.428
7.407
7.360
7.268
7.182
7.168
7.140
7.120
7.758
7.735
7.715
7.692
7.092
5.109
5.088
5.067
2.345
1.723
1.327
1.306
1.286
1.256
0.945
0.076
-0.000
8
7
6
5
4
3
2
1
ppm
3.63
5.64
1.78
4.54
0.90
2.80
2.80
6.00
2.83


180
160
140
120
100
80
60
40
20
ppm


Ph2(O)P
N
N
Me
MeO
Me
CO2iPr

4d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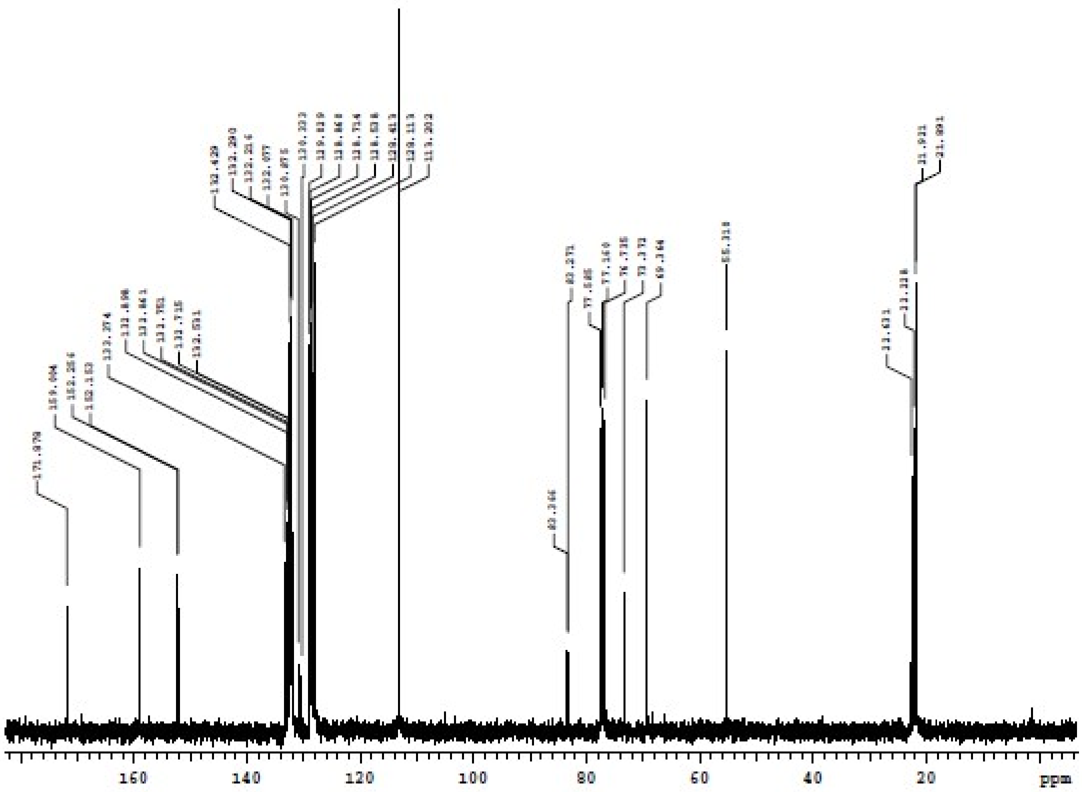
7.660
7.618
7.593
7.579
7.568
7.535
7.521
7.514
7.493
7.487
7.482
7.470
7.455
7.449
7.443
7.432
7.426
7.420
7.389
7.359
7.354
7.317
7.271
7.266
7.227
7.195
7.166
6.838
6.812
5.109
5.089
5.067
3.849
3.820
3.814
3.778
1.731
1.699
1.661
1.355
1.326
1.311
1.305
1.291
1.263
1.256
0.978
0.947
0.076
0.000
7.726
7.703
7.697
7.691
0.907
-0.006
8
7
6
5
4
3
2
1
ppm
3.67
1.44
4.40
1.36
2.60
1.73
0.97
3.00
3.05
6.47
3.01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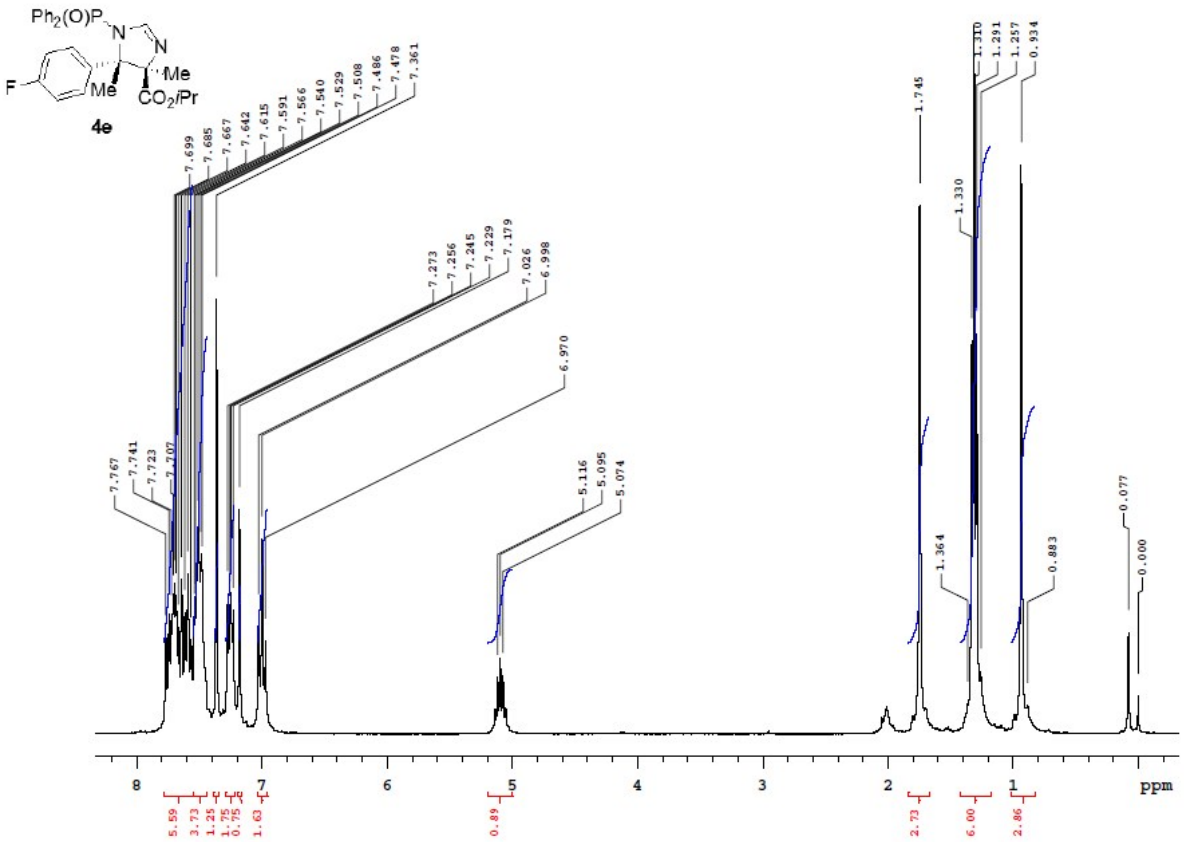
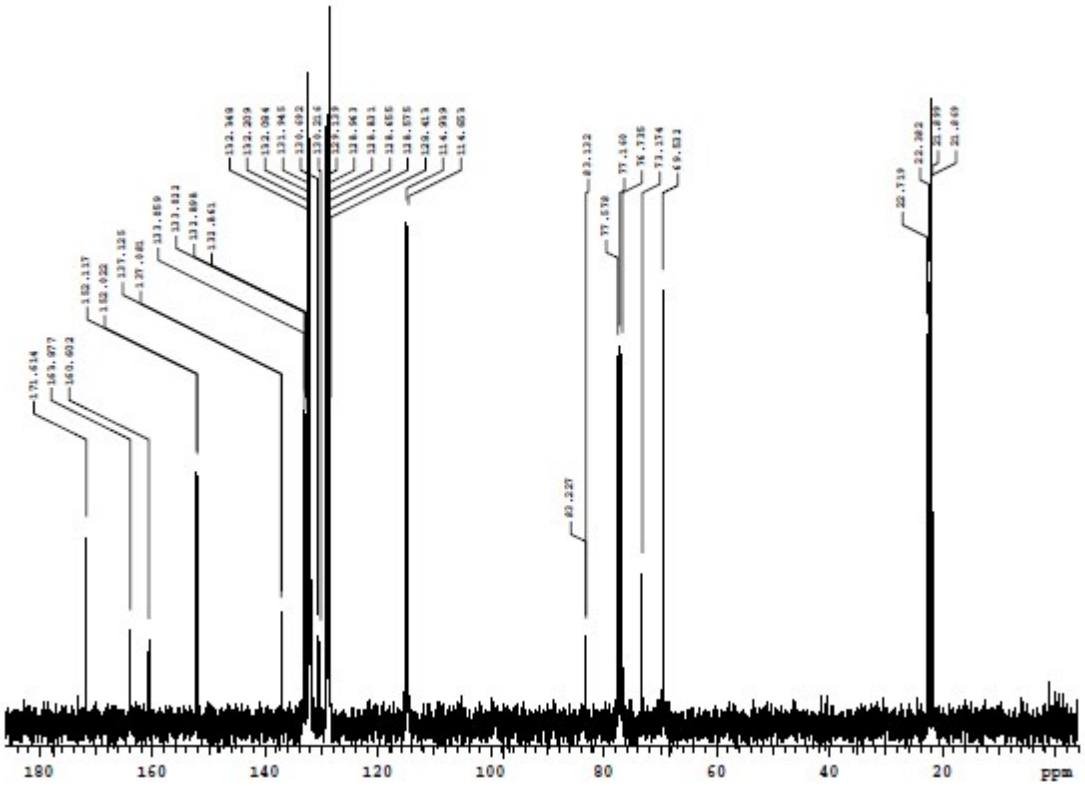
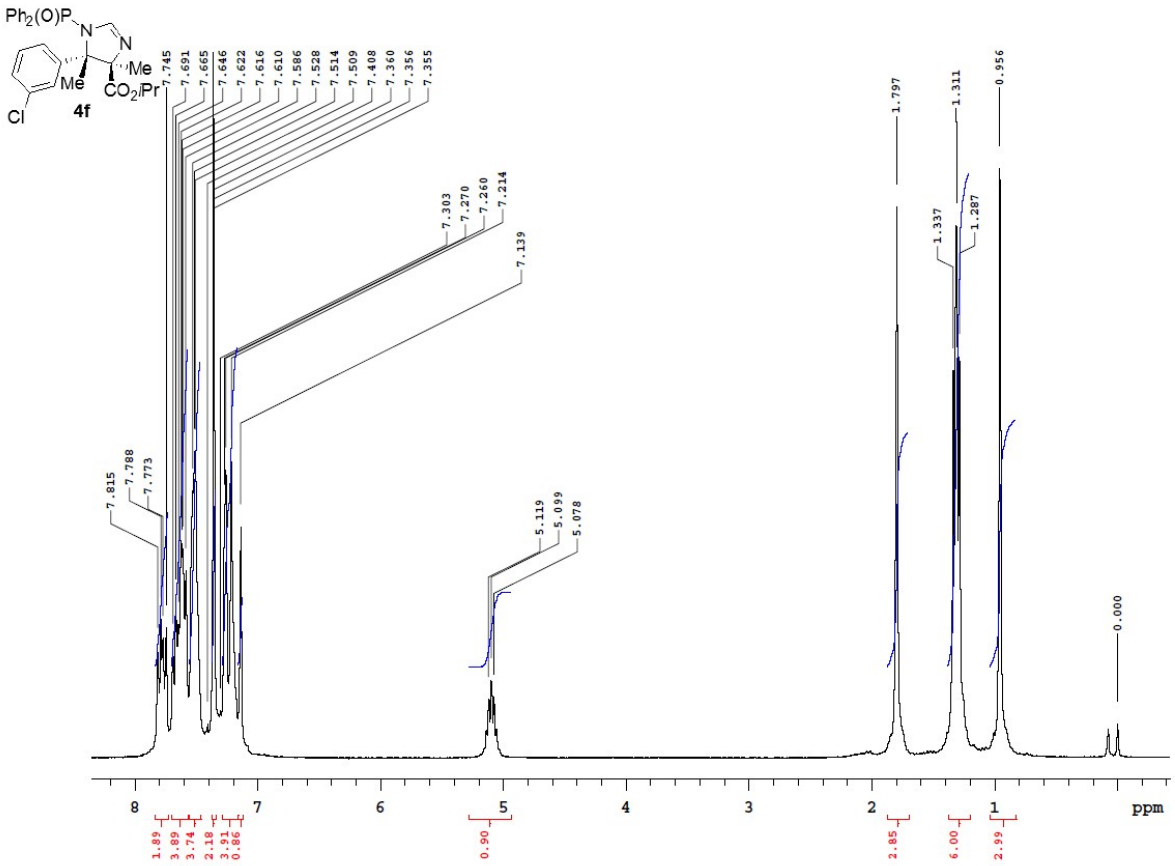
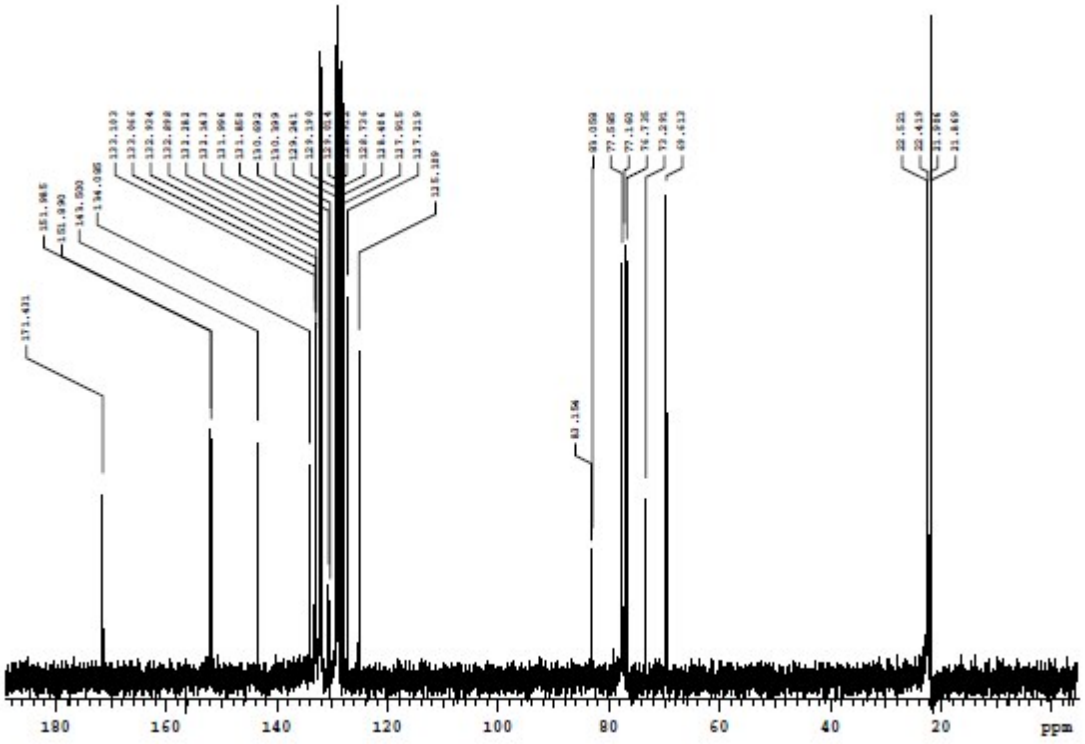
152.266
152.152
132.429
132.290
132.216
132.077
130.875
82.271
77.586
77.160
76.735
73.372
69.364
55.318
21.931
21.891
160
140
120
100
80
60
40
20
ppm


Ph2(O)P
N
N
Me
CO2iPr
Me
F
4e
7.767
7.741
7.723
7.707
7.699
7.685
7.667
7.642
7.615
7.591
7.566
7.540
7.529
7.508
7.486
7.478
7.361
7.273
7.256
7.245
7.229
7.179
7.026
6.998
6.970
5.116
5.095
5.074
1.745
1.330
1.310
1.291
1.257
0.934
1.364
0.883
0.077
0.000
ppm


ppm


Ph2(O)P
N
N
Me
Me
CO2iPr
Cl
4f
7.815
7.788
7.773
7.745
7.691
7.665
7.646
7.622
7.616
7.610
7.586
7.528
7.514
7.509
7.408
7.360
7.356
7.355
7.303
7.270
7.260
7.214
7.139
5.119
5.099
5.078
1.797
1.337
1.311
1.287
0.956
0.000
8
7
6
5
4
3
2
1
ppm
1.89
3.89
3.74
2.18
3.91
0.86
0.90
2.85
6.00
2.99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151.490
149.000
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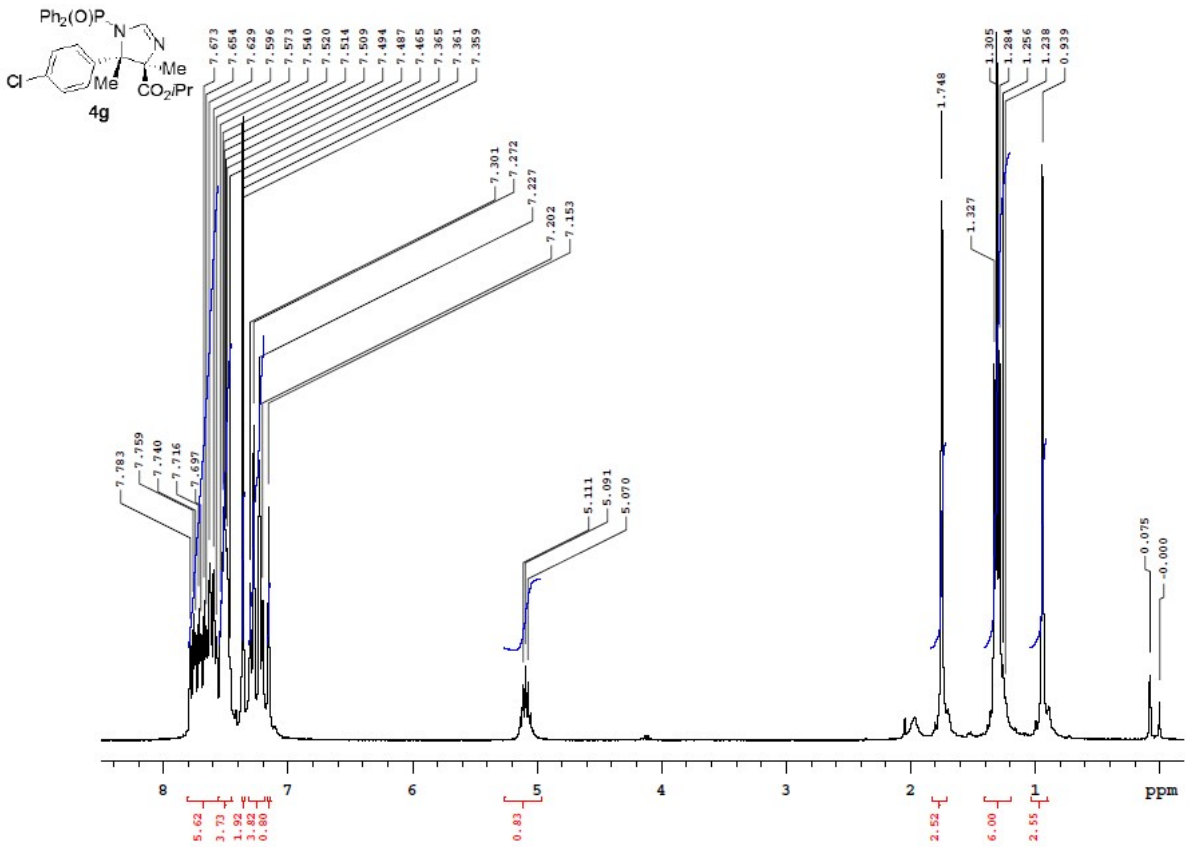
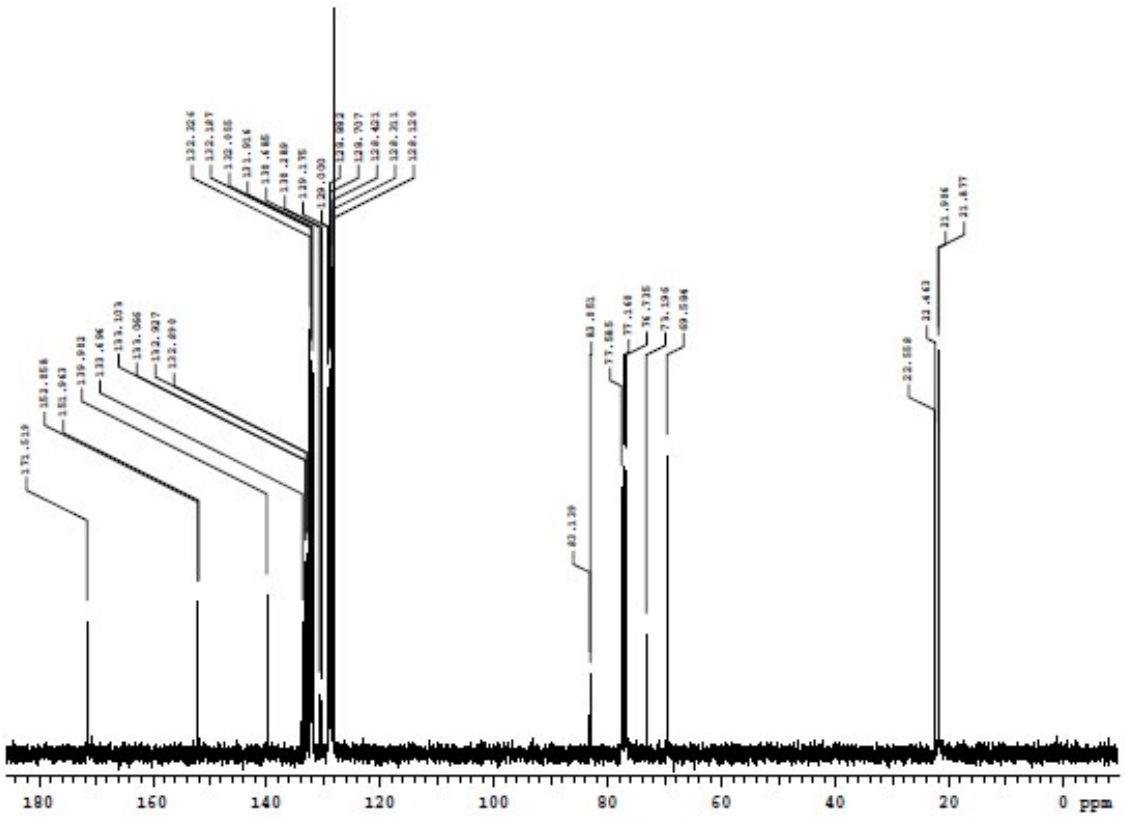
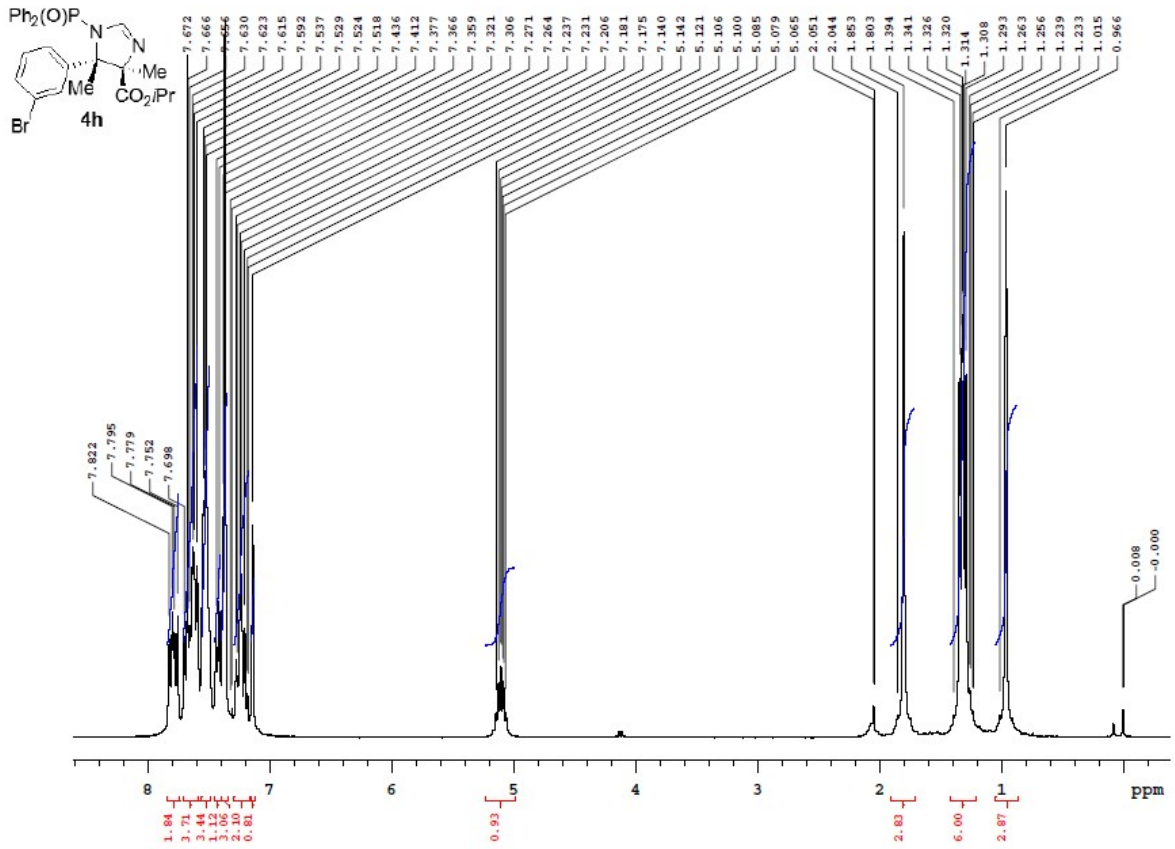
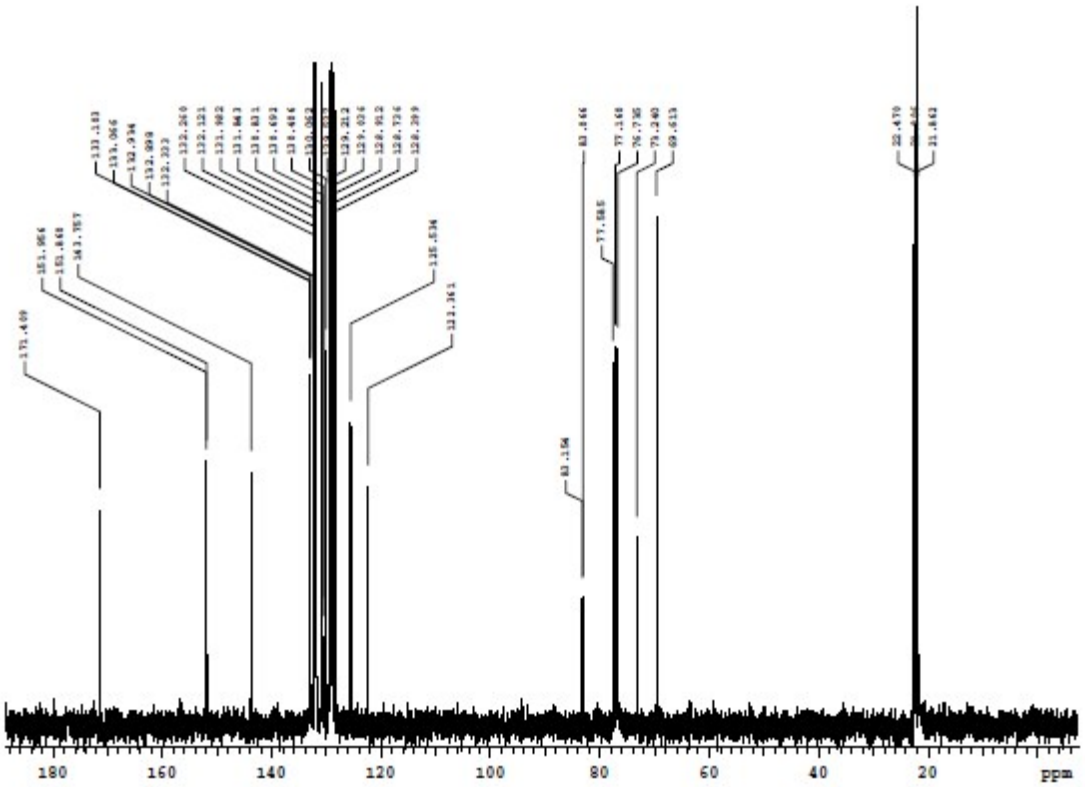
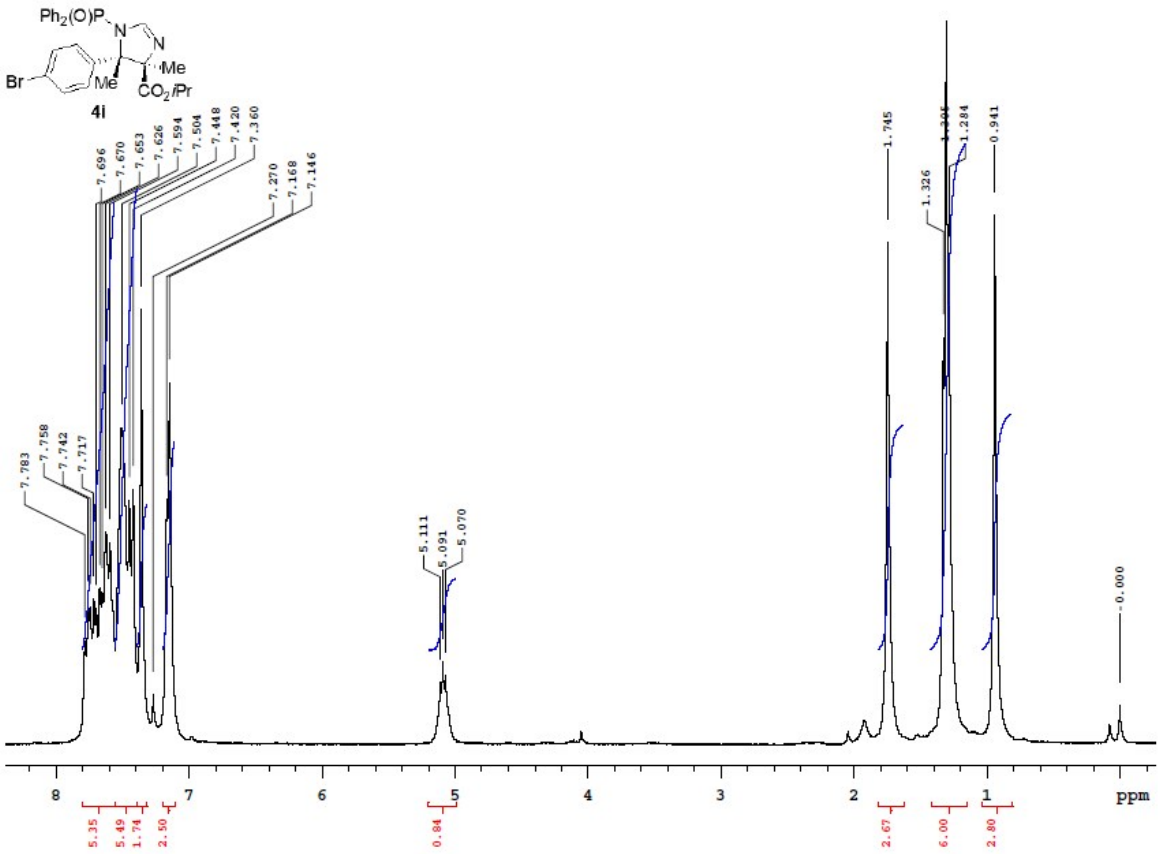
132.103
132.044
132.024
132.000
132.283
131.343
131.994
131.868
130.692
130.399
129.241
129.190
128.724
118.484
117.915
117.219
115.189
83.154
77.586
77.160
76.735
72.291
69.433
22.521
22.439
21.994
21.869
180
160
140
120
100
80
60
40
20
ppm

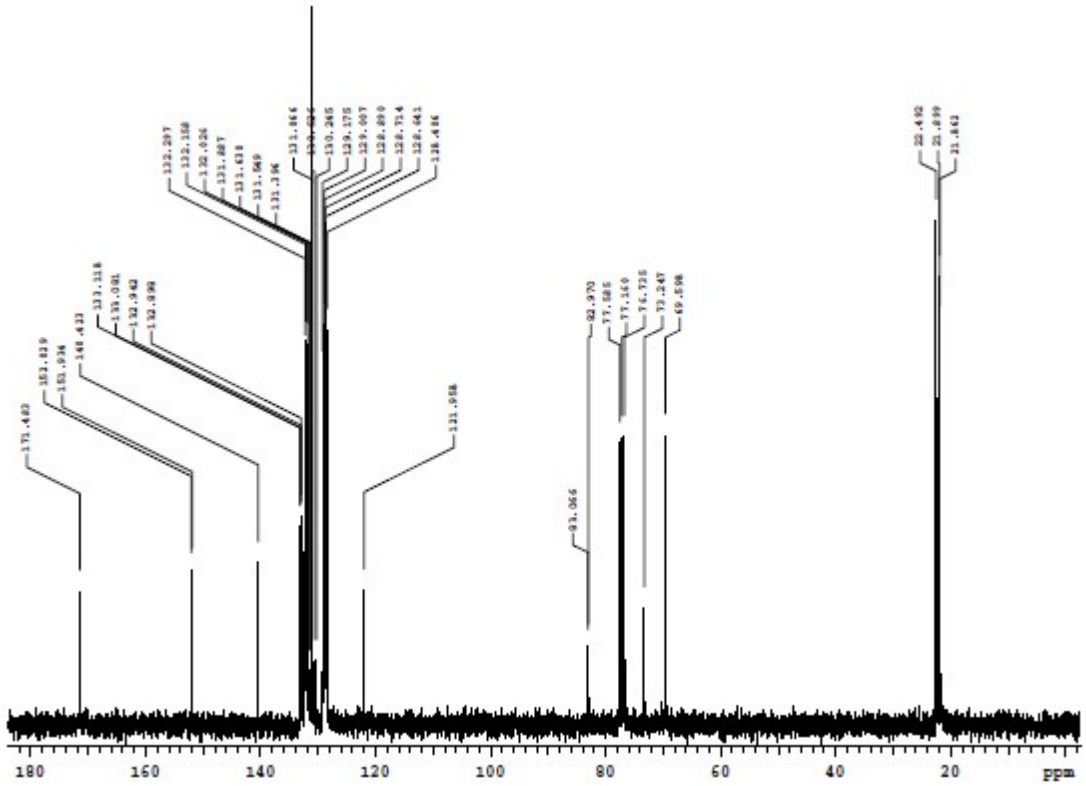

Ph2(O)P
N
N
Me
Cl
Me
CO2iPr
4g
7.783
7.759
7.740
7.716
7.697
7.673
7.654
7.629
7.596
7.573
7.540
7.520
7.514
7.509
7.494
7.487
7.465
7.365
7.361
7.359
7.301
7.272
7.227
7.202
7.153
5.111
5.091
5.070
1.748
1.327
1.305
1.284
1.256
1.238
0.939
0.075
-0.000
8
7
6
5
4
3
2
1
ppm
5.62
3.73
1.92
1.82
0.80
0.83
2.52
6.00
2.55

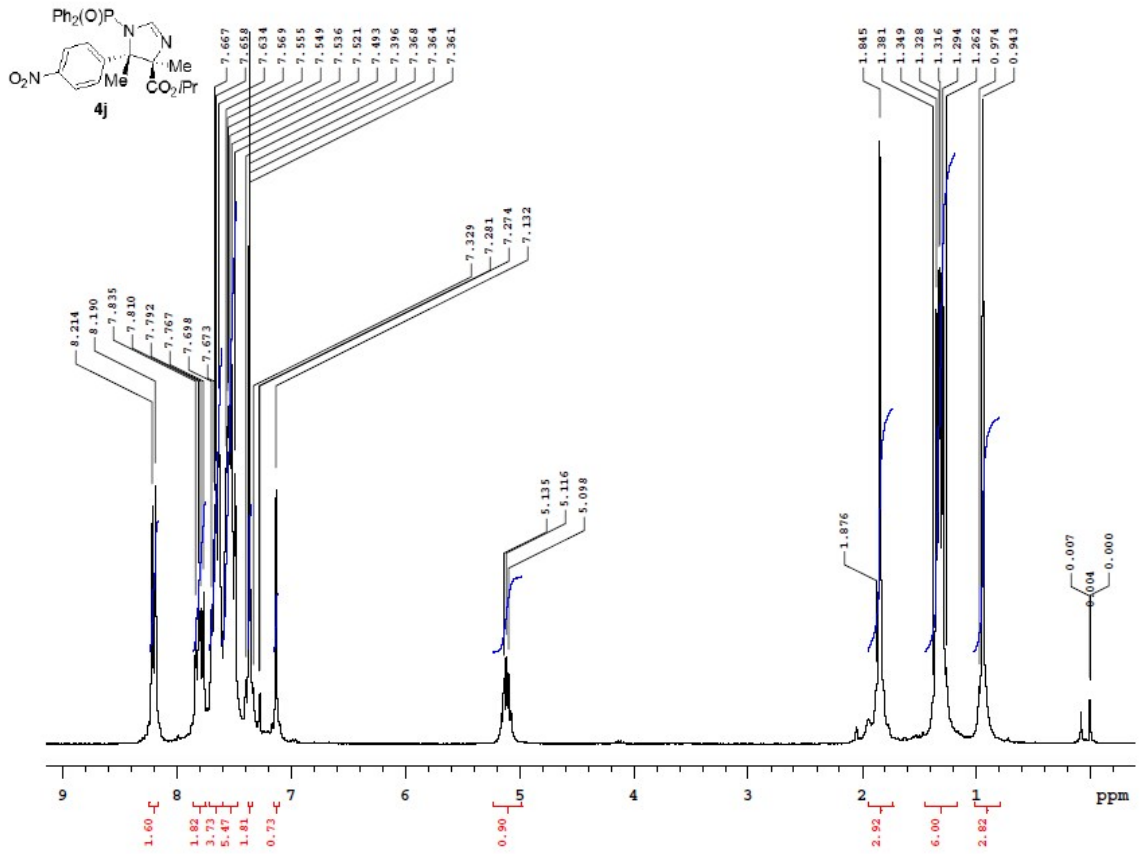

180
160
140
120
100
80
60
40
20
0 ppm

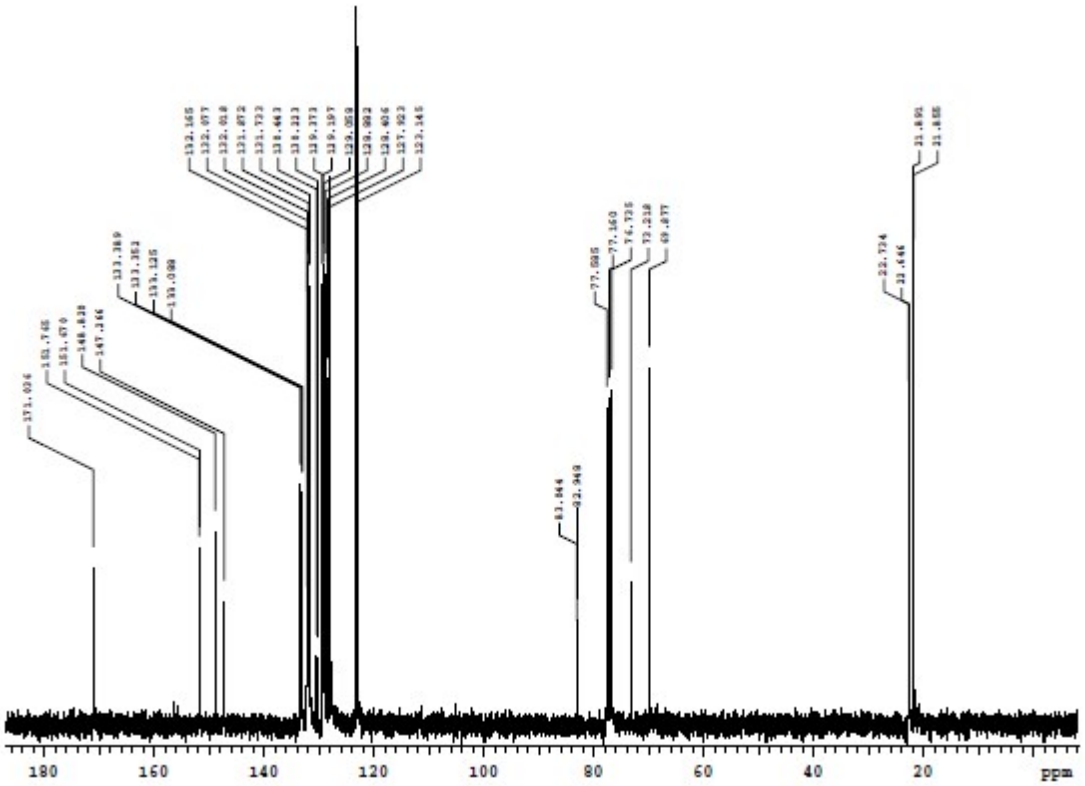

Ph2(O)P
N
N
Me
Me
CO2iPr
Br
4h
7.822
7.795
7.779
7.752
7.698
7.672
7.666
7.656
7.630
7.623
7.615
7.592
7.537
7.529
7.524
7.518
7.436
7.412
7.377
7.366
7.359
7.321
7.306
7.271
7.264
7.237
7.231
7.206
7.181
7.175
7.140
5.142
5.121
5.106
5.100
5.085
5.079
5.065
2.051
2.044
1.853
1.803
1.394
1.341
1.326
1.320
1.314
1.308
1.293
1.263
1.256
1.239
1.233
1.015
0.966
0.008
-0.000
ppm
1.84
3.71
3.44
1.12
3.06
2.10
0.81
0.93
2.83
6.00
2.87

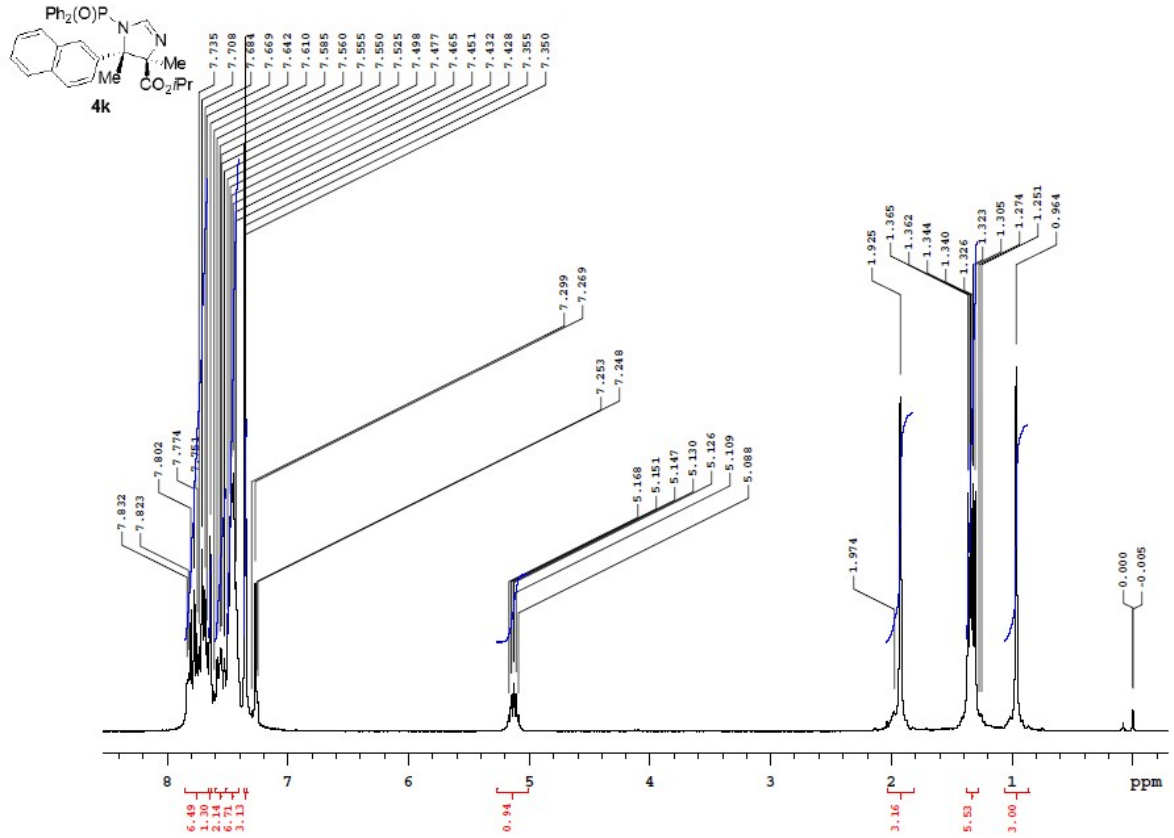

ppm

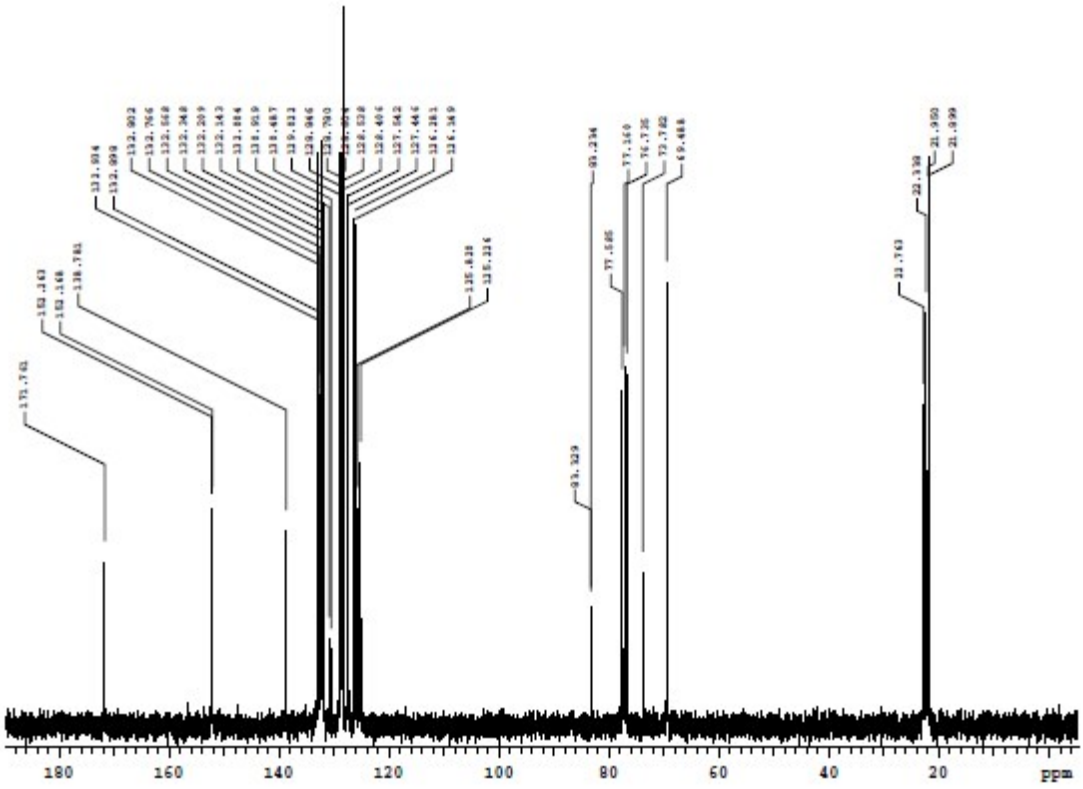

Ph2(O)P
N
N
Me
Me
Br
CO2iPr
4i
7.783
7.758
7.742
7.717
7.696
7.670
7.653
7.626
7.594
7.504
7.448
7.420
7.360
7.270
7.168
7.146
5.111
5.091
5.070
1.745
1.326
1.284
0.941
0.000
ppm
5.35
5.49
1.74
2.50
0.84
2.67
6.00
2.80

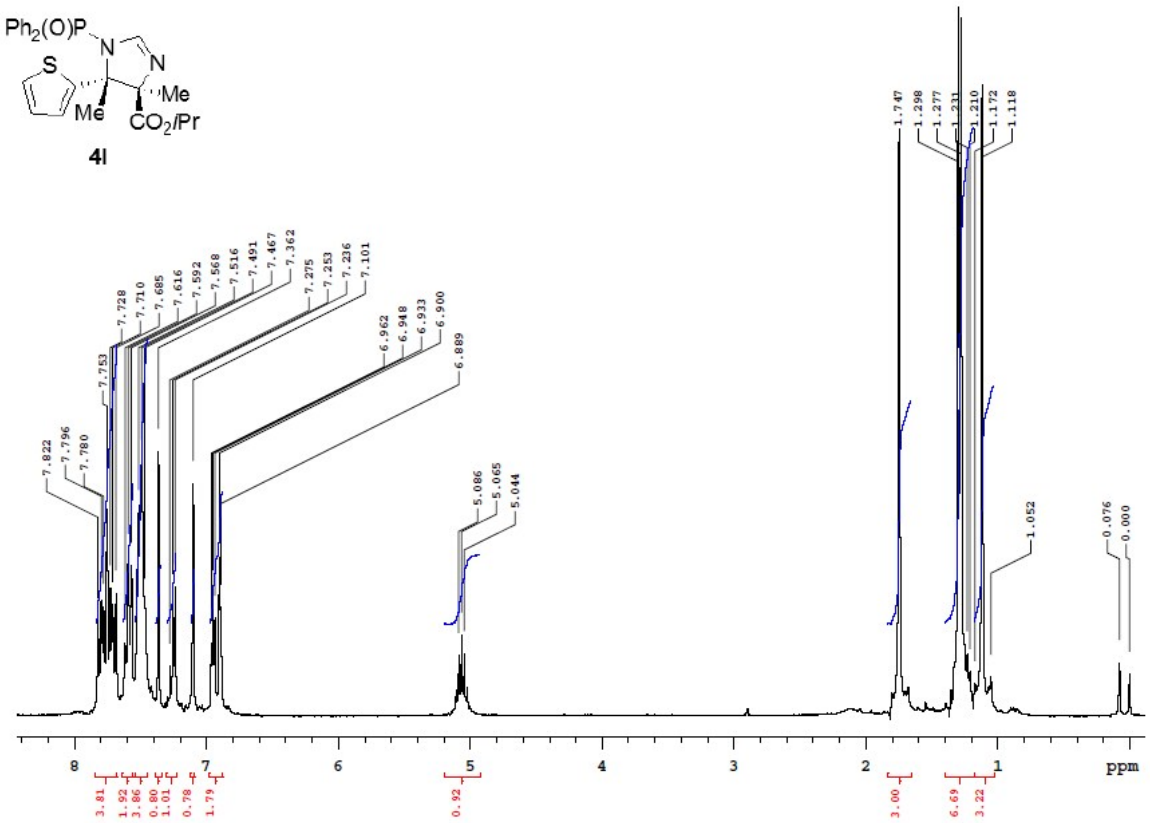

ppm

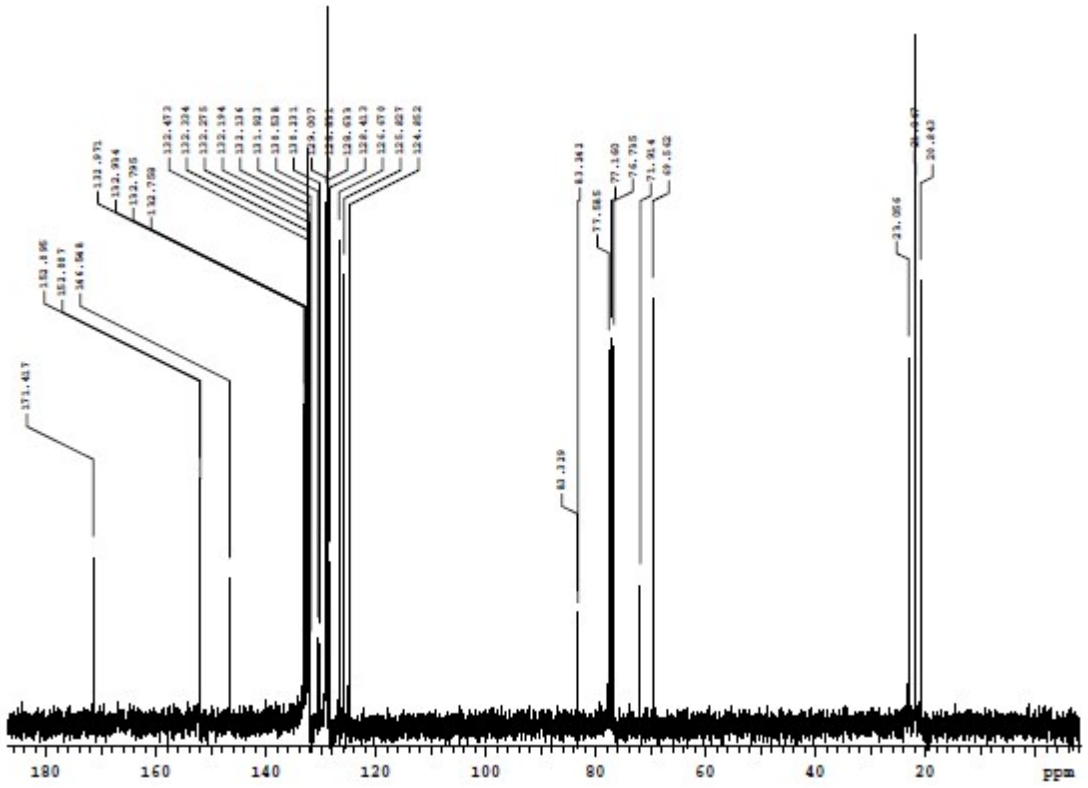

Ph2(O)P
N
N
Me
CO2iPr
O2N
Me
4j
8.214
8.190
7.835
7.810
7.792
7.767
7.698
7.673
7.667
7.658
7.634
7.569
7.555
7.549
7.536
7.521
7.493
7.396
7.368
7.364
7.361
7.329
7.281
7.274
7.132
5.135
5.116
5.098
1.876
1.845
1.381
1.349
1.328
1.316
1.294
1.262
0.974
0.943
0.007
0.004
0.000
ppm

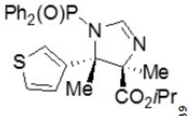

ppm


Ph2(O)P
N
N
Me
Me
CO2iPr
4k
7.735
7.708
7.684
7.669
7.642
7.610
7.585
7.560
7.555
7.550
7.525
7.498
7.477
7.465
7.451
7.432
7.428
7.355
7.350
7.299
7.269
7.253
7.248
7.832
7.823
7.802
7.774
5.168
5.151
5.147
5.130
5.126
5.109
5.088
1.925
1.365
1.362
1.344
1.340
1.326
1.323
1.305
1.274
1.251
0.964
1.974
0.000
-0.005
ppm

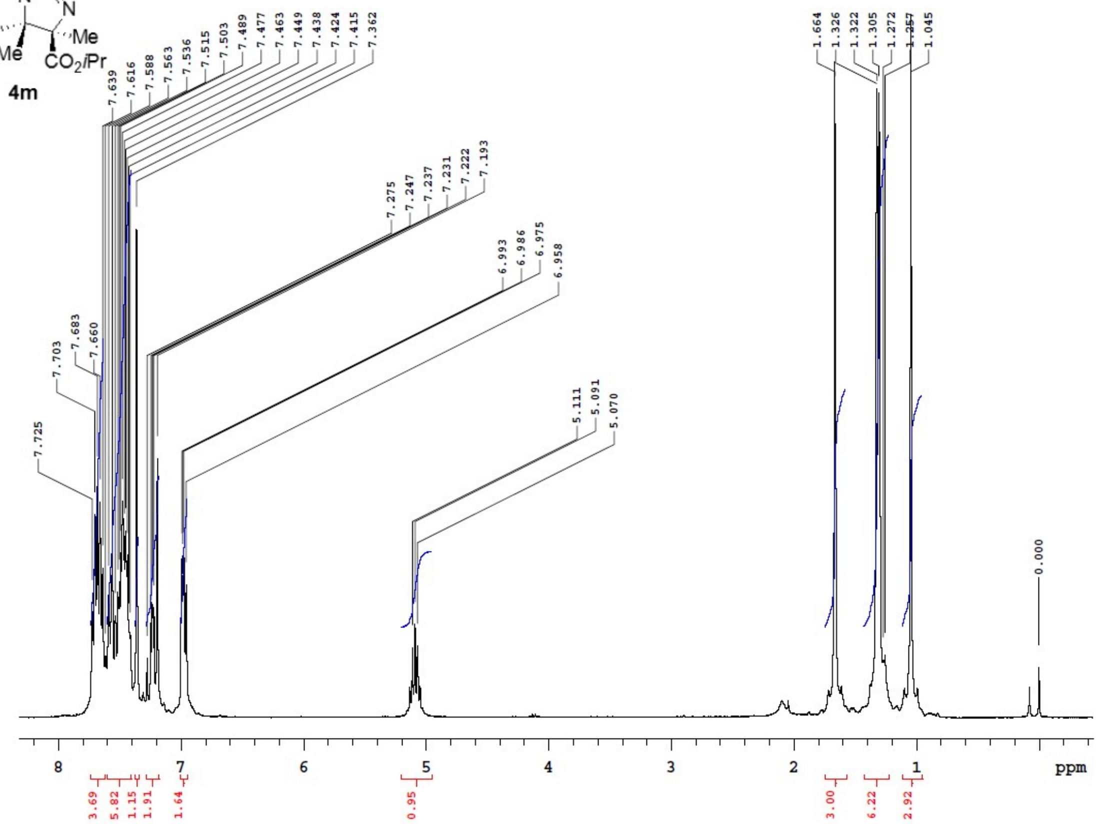

ppm

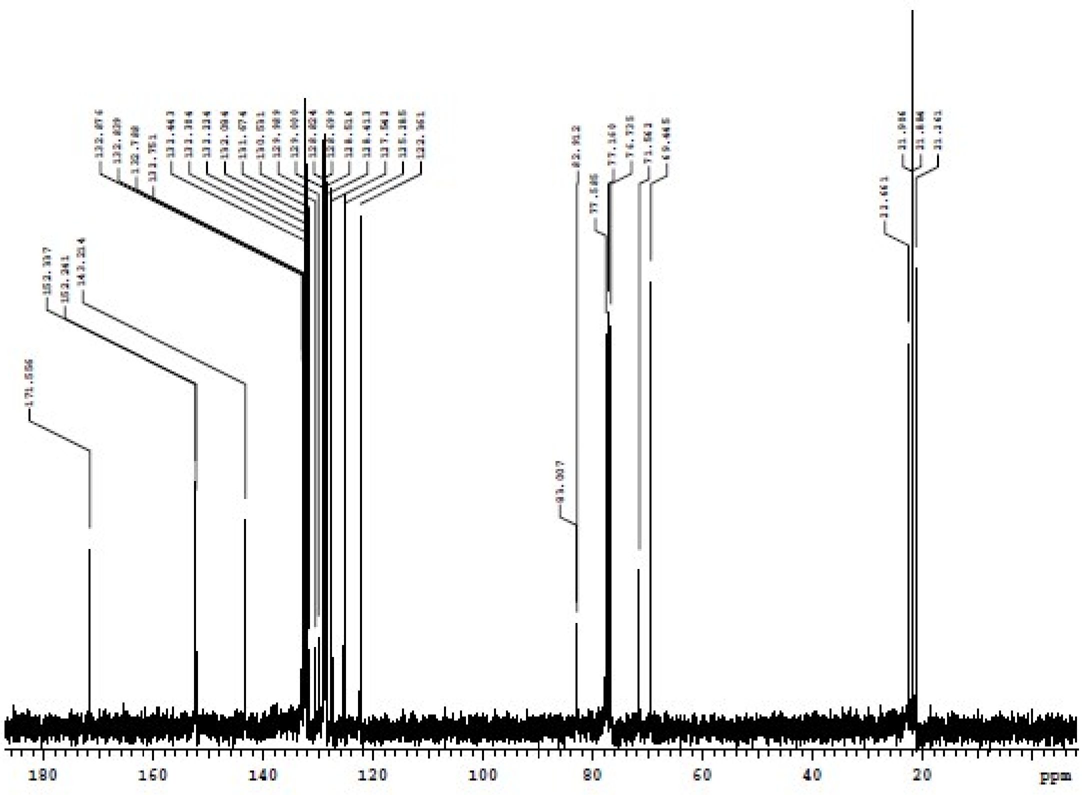

Ph2(O)P
N
S
N
Me
Me
CO2iPr
4l
7.822
7.796
7.780
7.753
7.728
7.710
7.685
7.616
7.592
7.568
7.516
7.491
7.467
7.362
7.275
7.253
7.226
7.101
6.962
6.948
6.933
6.900
6.889
5.086
5.065
5.044
1.747
1.298
1.277
1.231
1.210
1.172
1.118
1.052
0.076
0.000
ppm

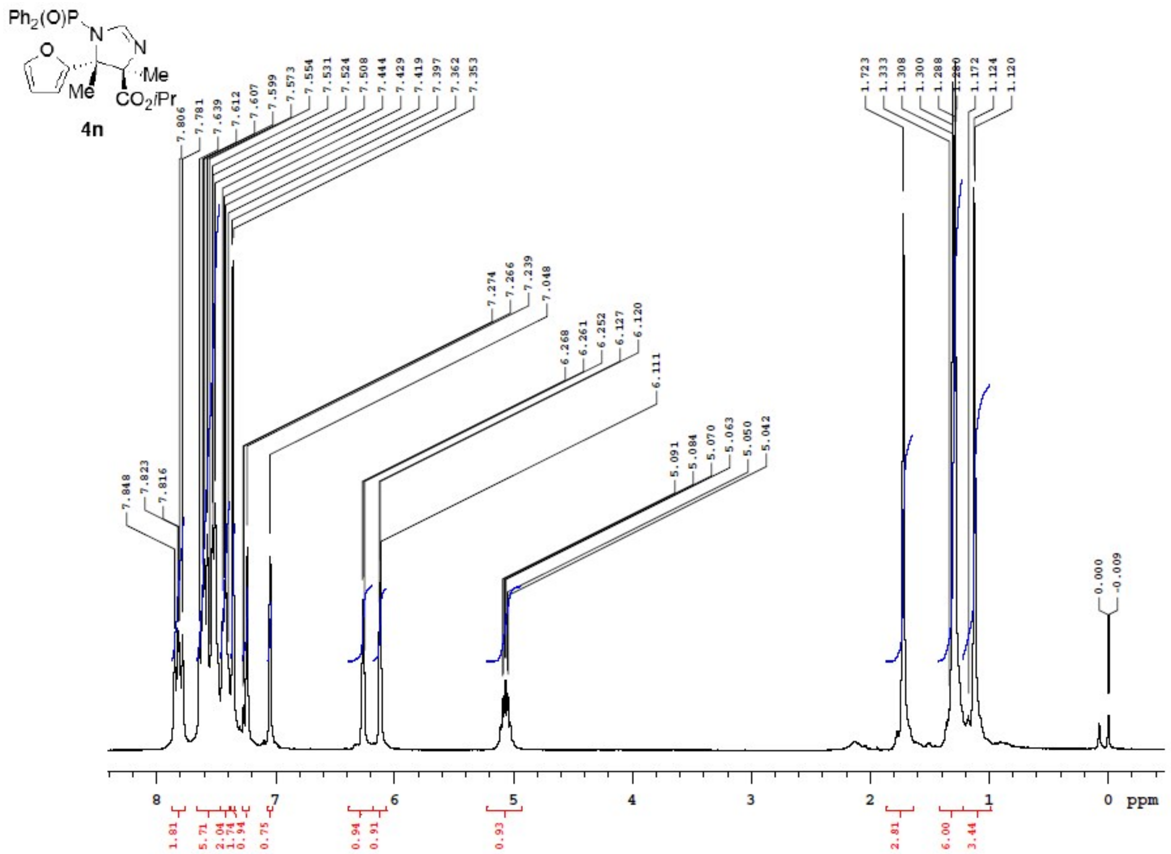

171.417
83.339
77.585
77.160
76.735
71.914
69.562
20.843
ppm

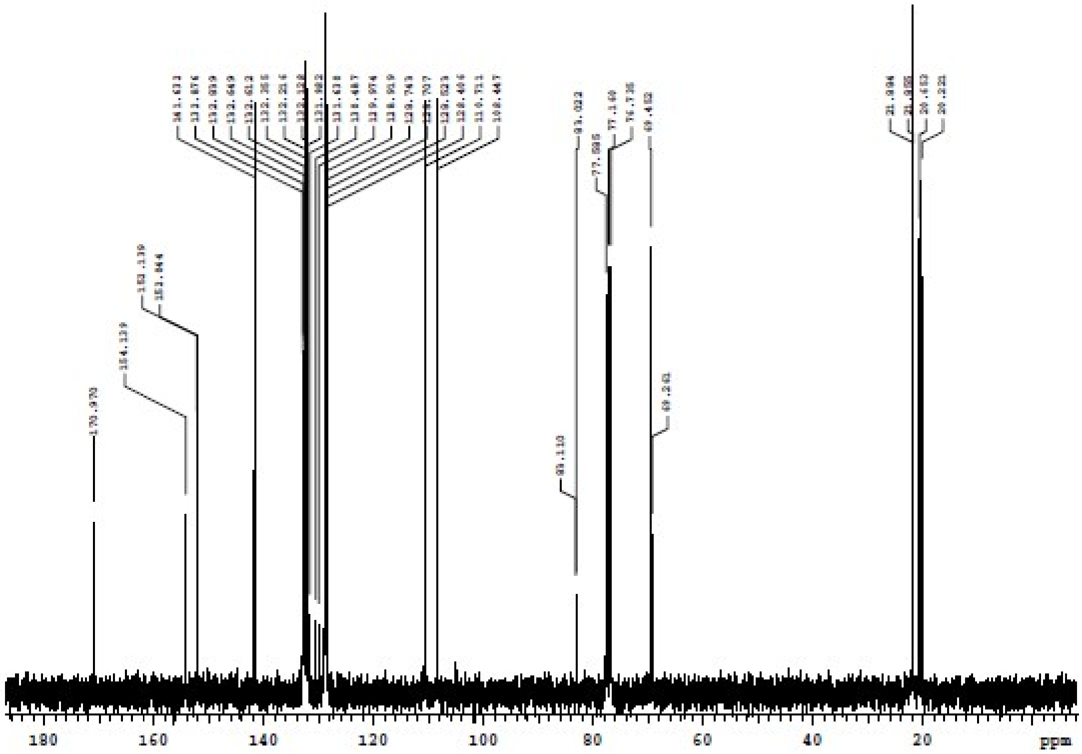


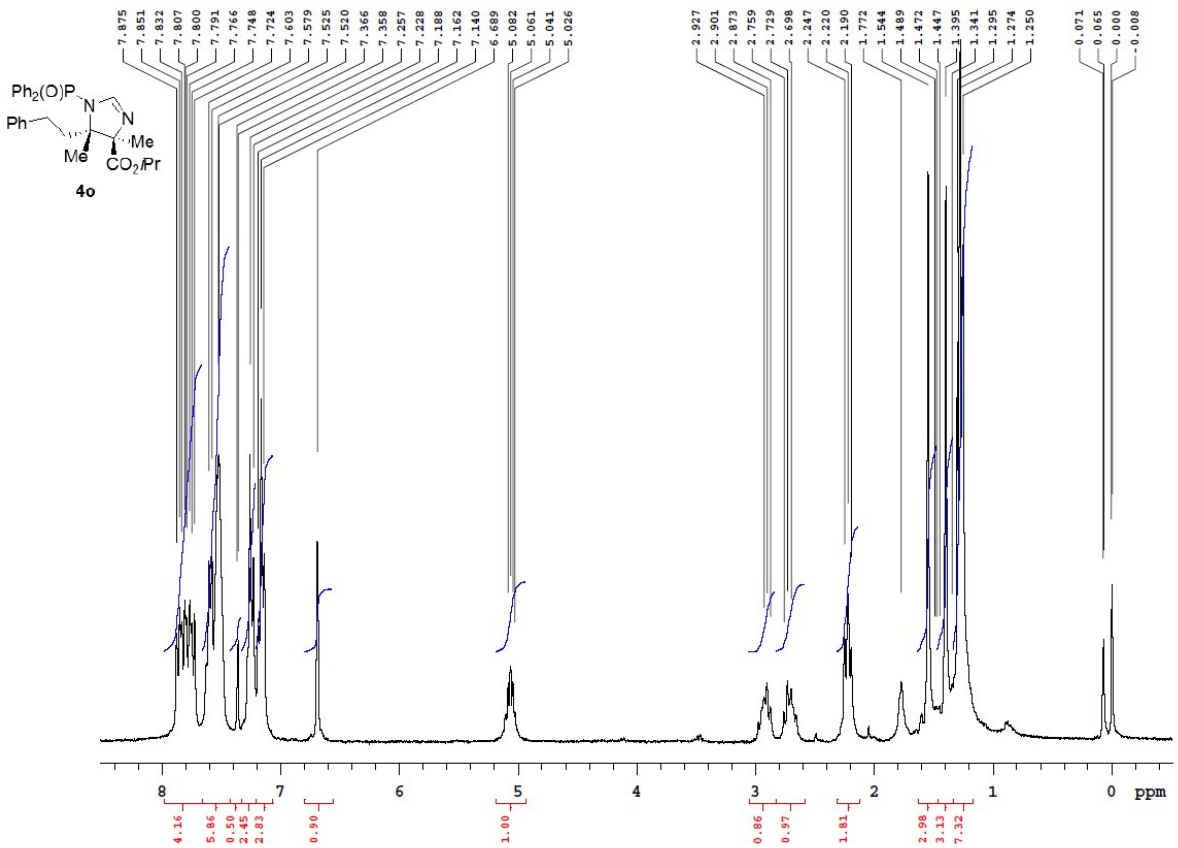
4m






Ph2(O)P
N
N
O
Me
Me
CO2iPr
4n
8
7
6
5
4
3
2
1
0 ppm


180
160
140
120
100
80
60
40
20
ppm


Ph2(O)P
Ph
Me
Me
CO2iPr
4o
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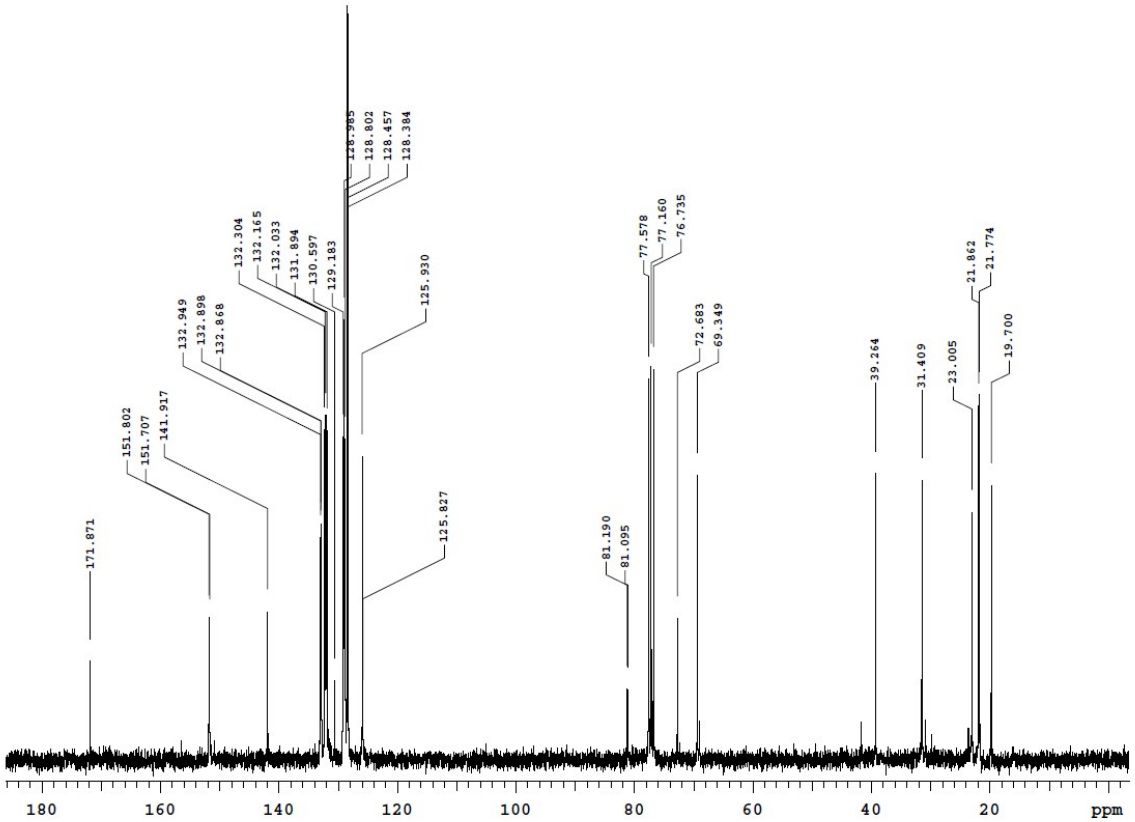
7.851
7.832
7.807
7.800
7.791
7.766
7.748
7.724
7.603
7.579
7.525
7.520
7.366
7.358
7.257
7.228
7.188
7.162
7.140
6.689
5.082
5.061
5.041
5.026
2.927
2.901
2.873
2.759
2.729
2.698
2.247
2.220
2.190
1.772
1.544
1.489
1.472
1.447
1.395
1.341
1.295
1.274
1.250
0.071
0.065
0.000
-0.008
8
7
6
5
4
3
2
1
0
ppm
4.16
5.86
0.50
2.45
2.83
0.90
1.00
0.86
0.97
1.81
2.98
3.13
7.32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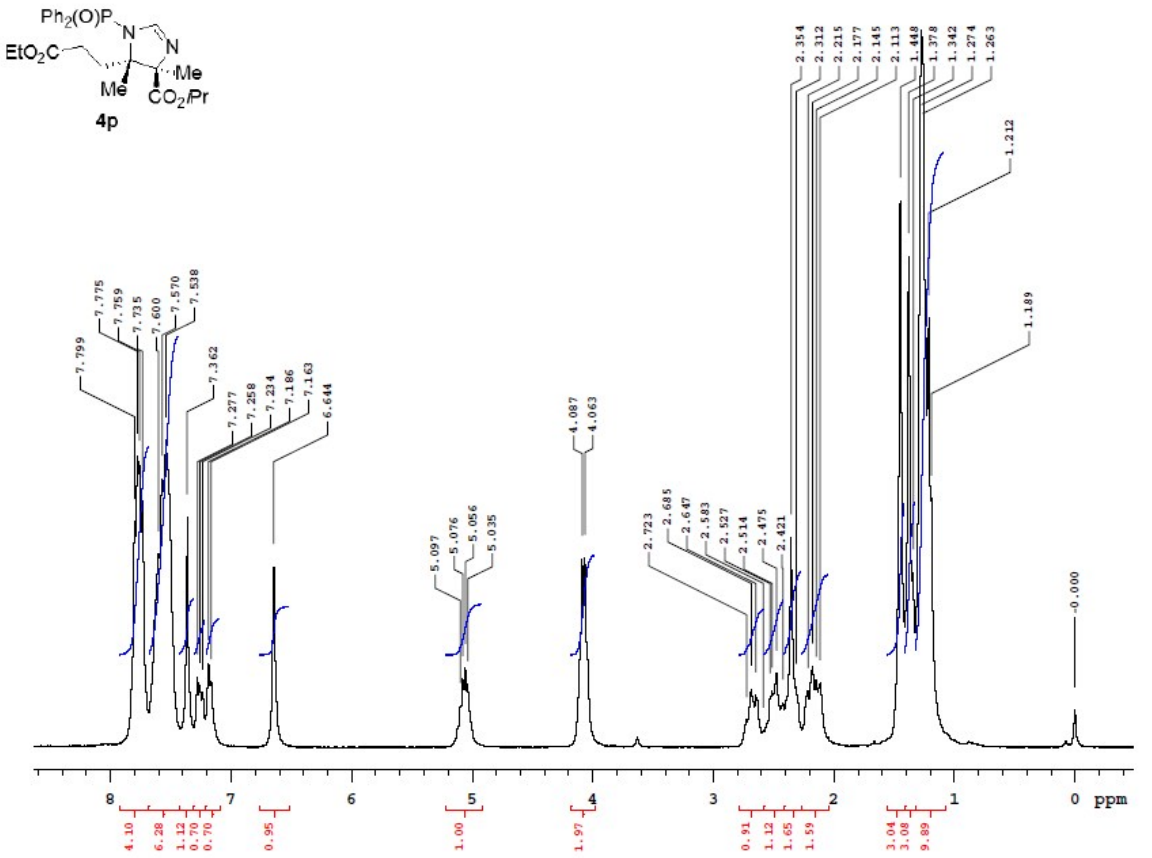
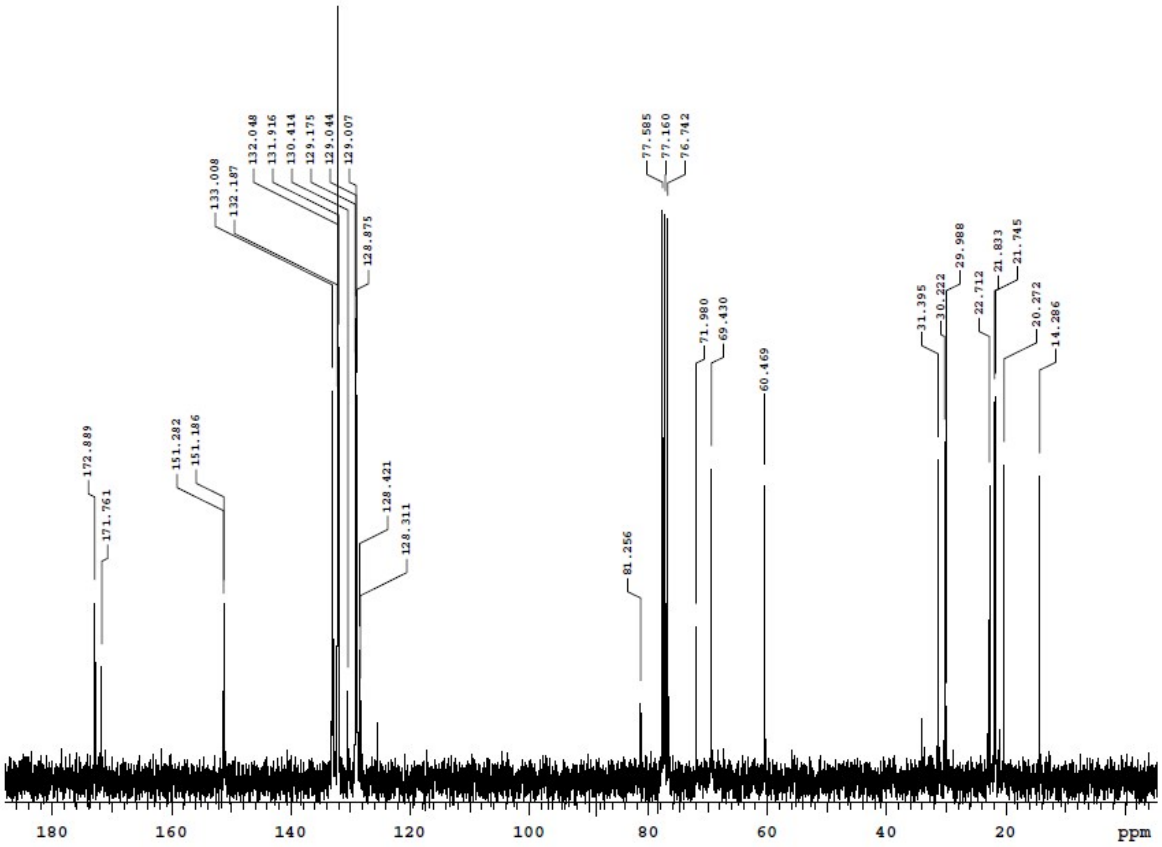
151.707
141.917
132.949
132.898
132.868
132.304
132.165
132.033
131.894
130.597
129.183
128.985
128.802
128.457
128.384
125.930
125.827
81.190
81.095
77.578
77.160
76.735
72.683
69.349
39.264
31.409
23.005
21.862
21.774
19.700
180
160
140
120
100
80
60
40
20
ppm


Ph2(O)P
N
N
EtO2C
Me
Me
CO2iPr
4p
7.799
7.775
7.759
7.735
7.600
7.570
7.538
7.362
7.277
7.258
7.234
7.186
7.163
6.644
5.097
5.076
5.056
5.035
4.087
4.063
2.723
2.685
2.647
2.583
2.527
2.514
2.475
2.421
2.354
2.312
2.215
2.177
2.145
2.113
1.448
1.378
1.342
1.274
1.263
1.212
1.189
-0.000
ppm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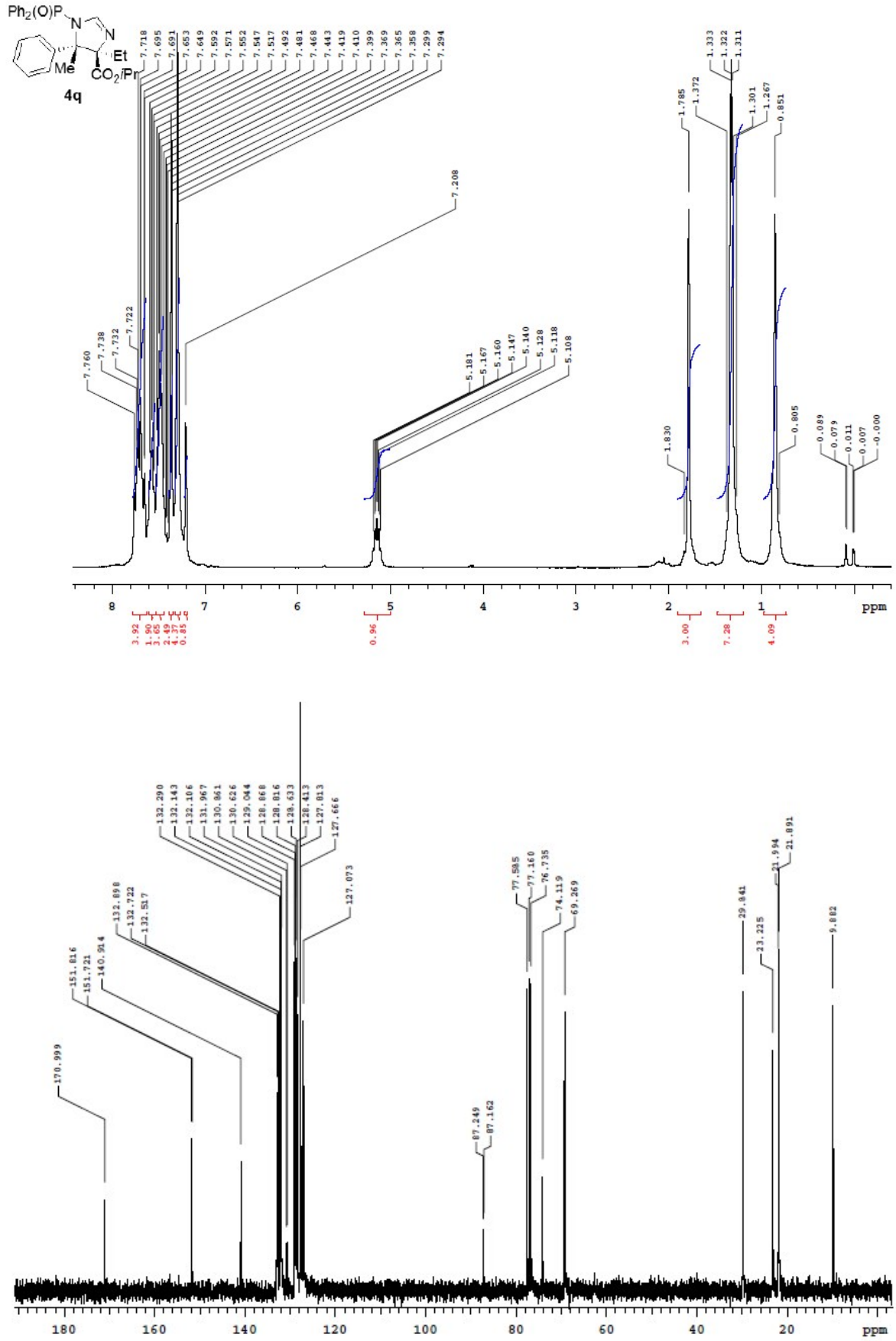
133.008
132.187
132.048
131.916
130.414
129.175
129.044
129.007
128.875
128.421
128.311
81.256
77.585
77.160
76.742
71.980
69.430
60.469
31.395
30.222
29.988
22.712
21.833
21.745
20.272
14.286
ppm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N
Et
Me
CO2iPr
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7.722
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7.691
7.653
7.649
7.592
7.571
7.552
7.547
7.517
7.492
7.481
7.468
7.443
7.419
7.410
7.399
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7.365
7.358
7.299
7.294
7.208
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5.167
5.160
5.147
5.140
5.128
5.118
5.108
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1.785
1.372
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1.322
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1.301
1.267
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0.011
0.007
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128.633
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127.813
127.666
127.073
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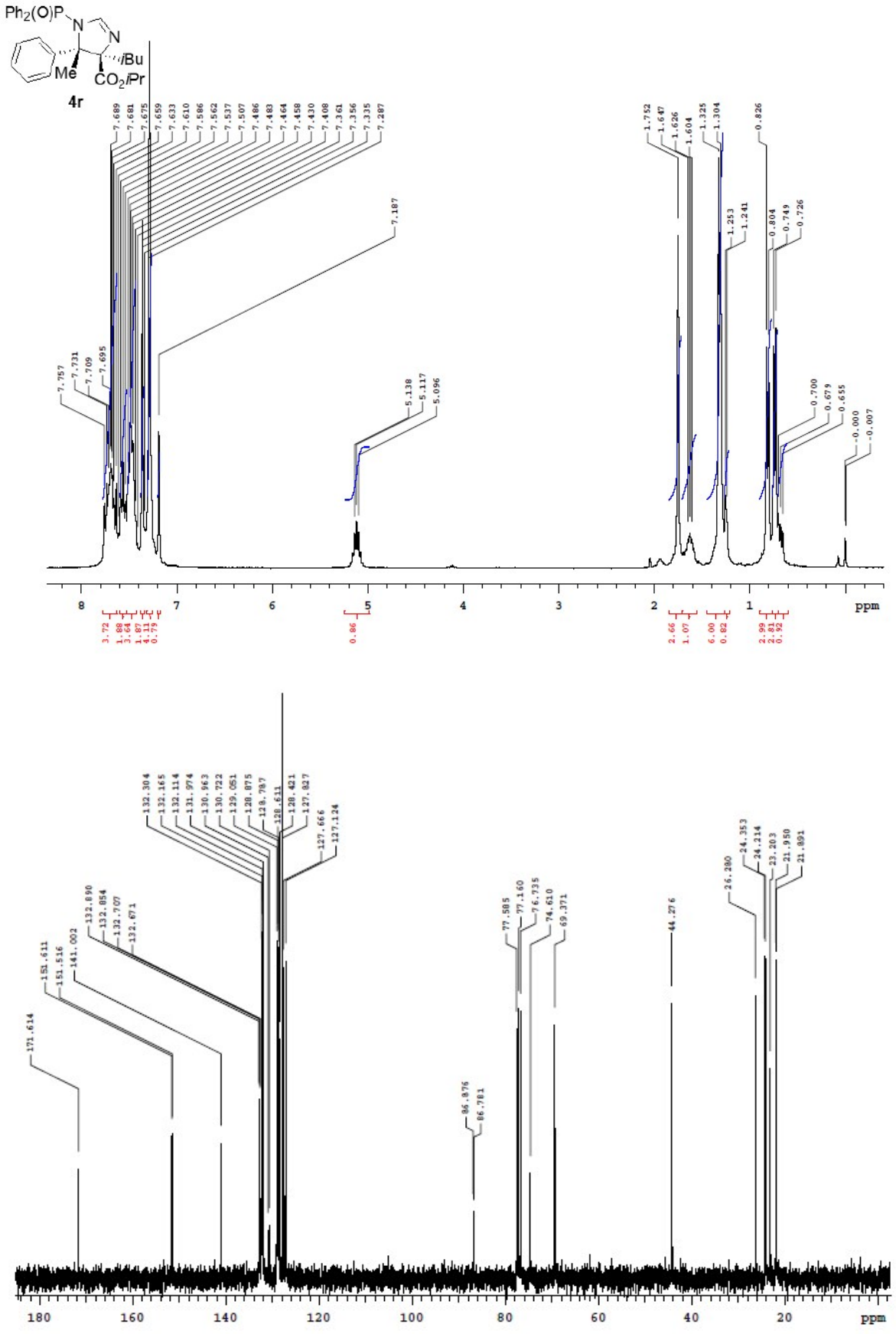
9.882
ppm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iBu
CO2iPr
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7.430
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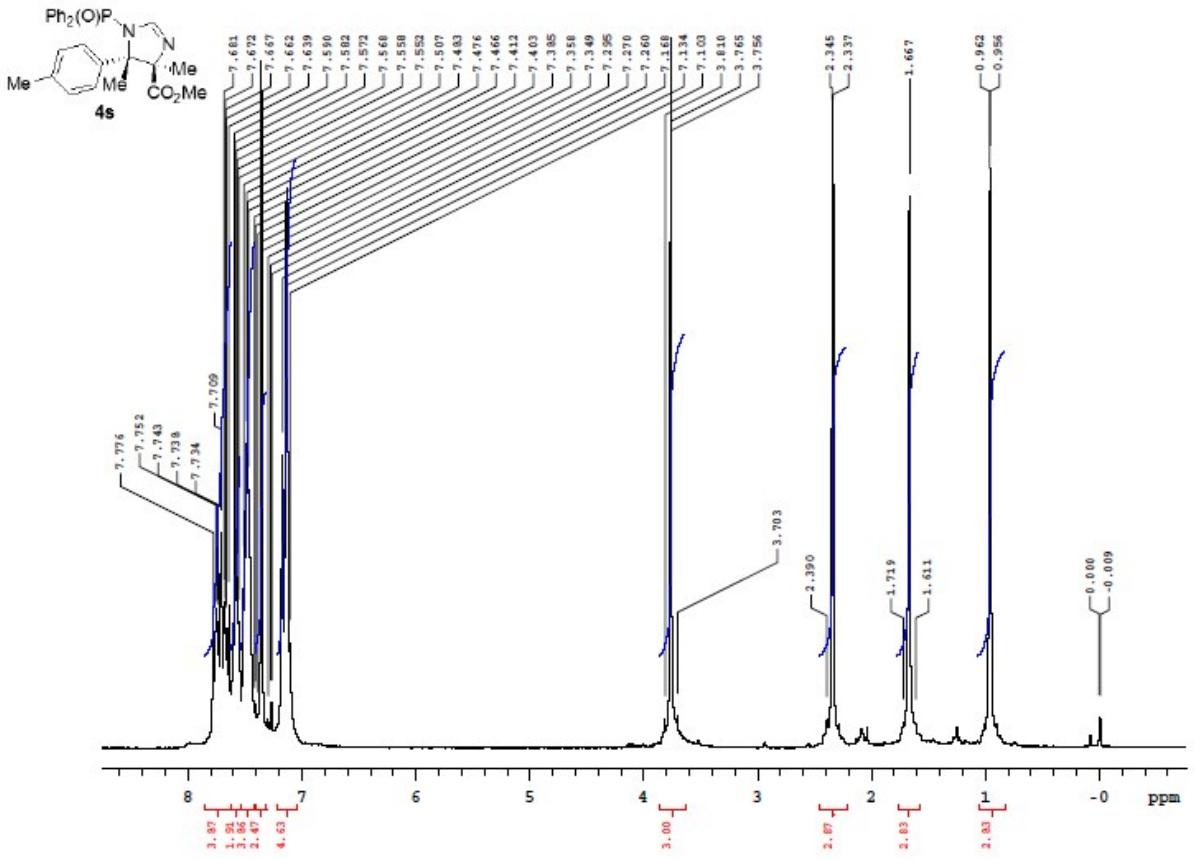
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Me
Me
CO2Me
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7.672
7.667
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7.639
7.590
7.582
7.572
7.568
7.558
7.552
7.507
7.483
7.476
7.466
7.412
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7.385
7.358
7.349
7.295
7.270
7.260
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7.134
7.103
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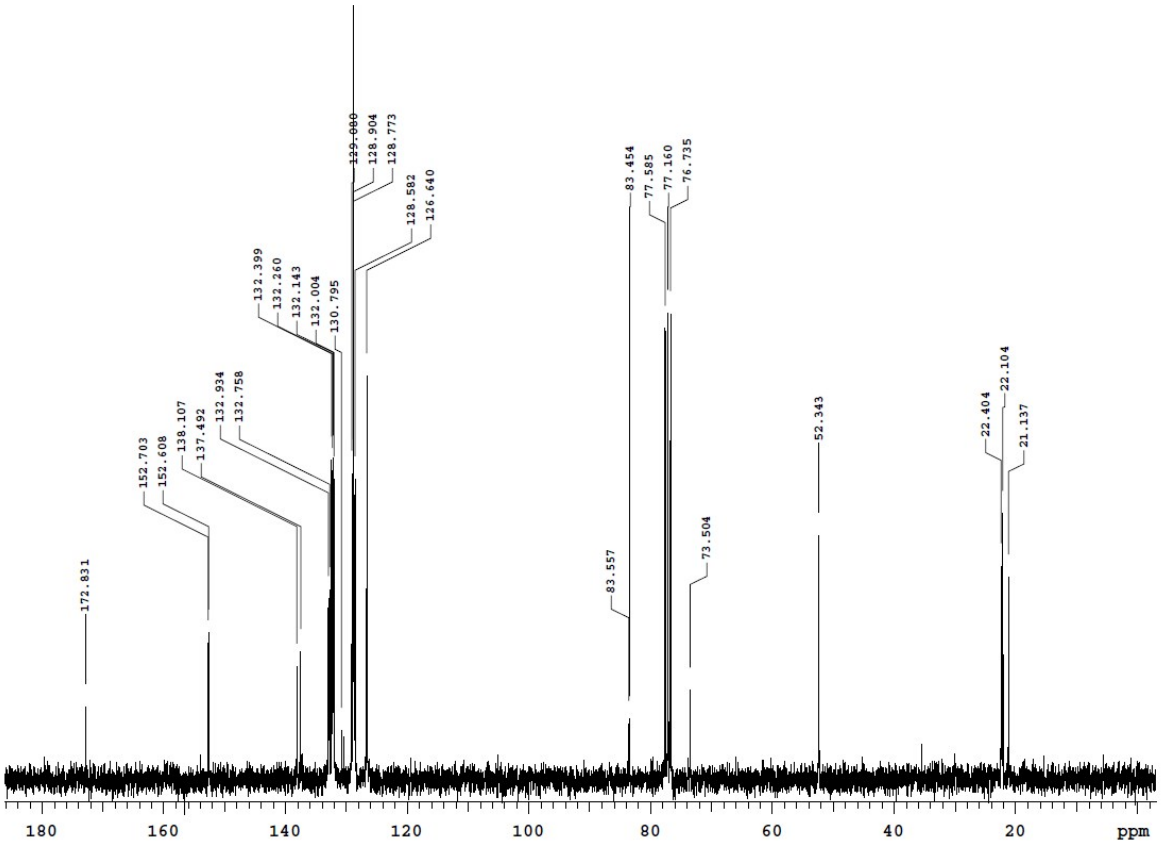
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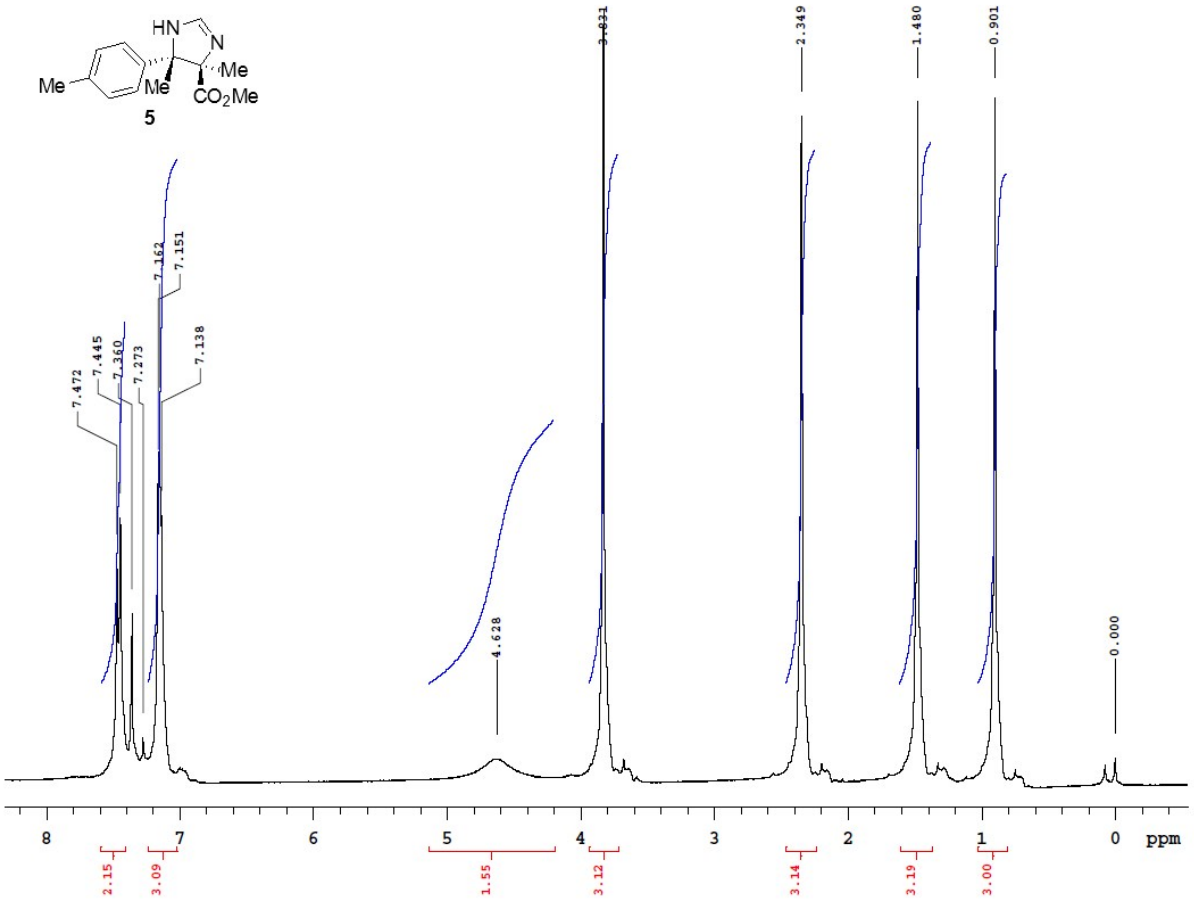
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Me
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8
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5
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3
2
1
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ppm
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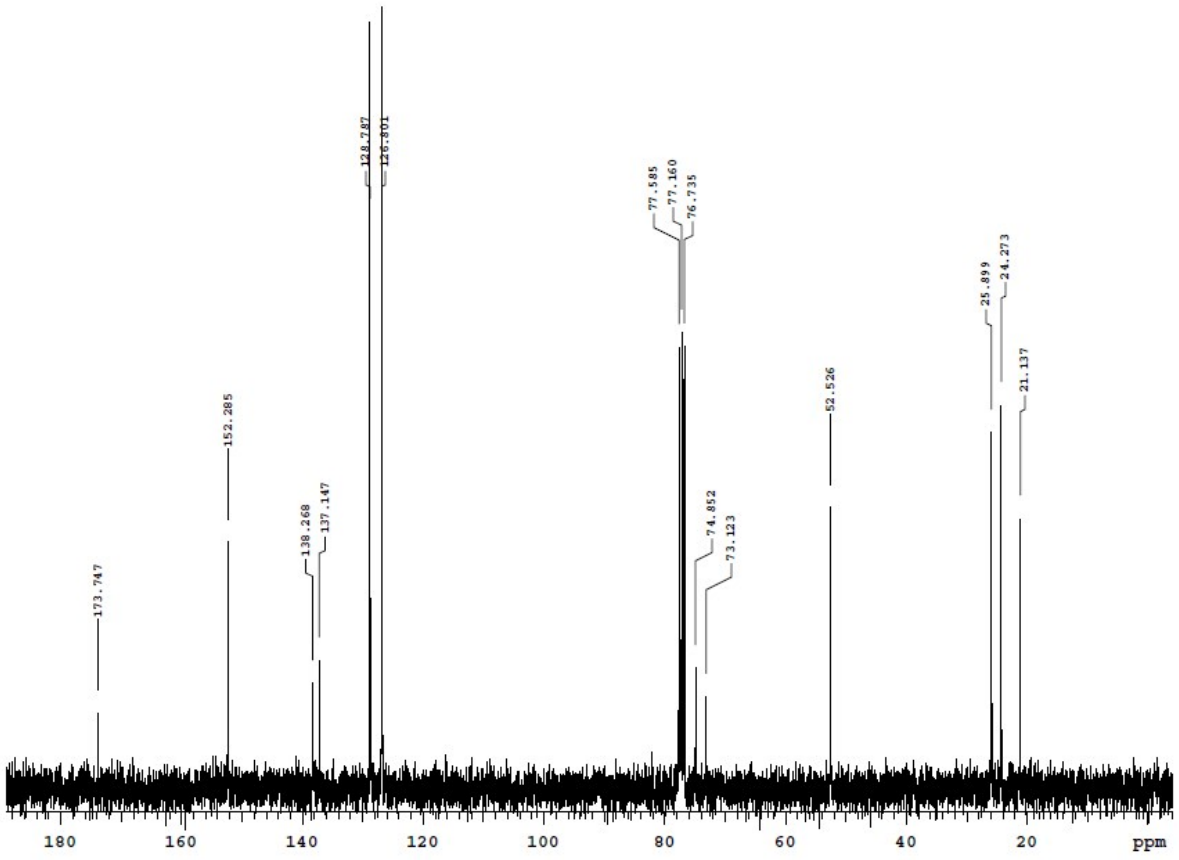
3.09
1.55
3.12
3.14
3.19
3.00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74.852
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52.526
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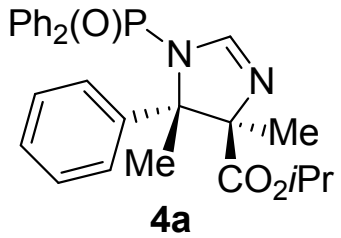
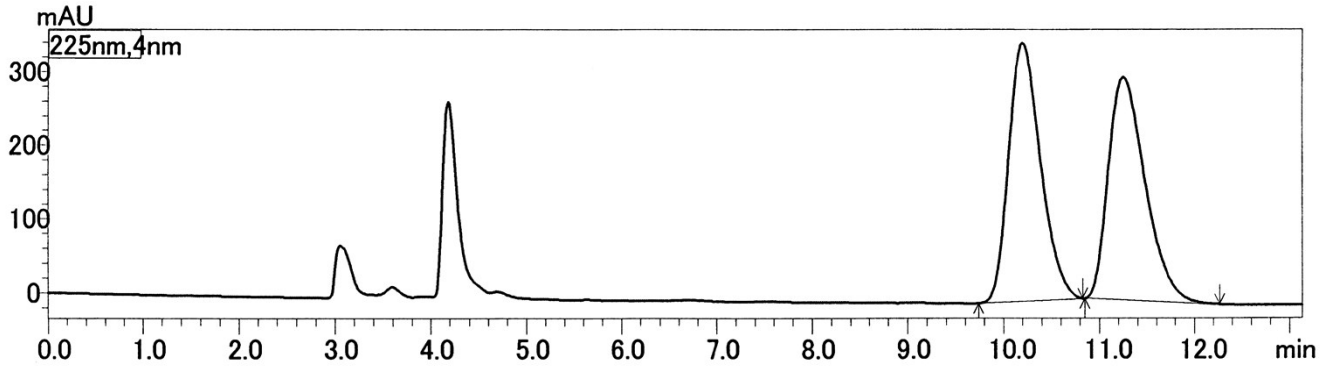
24.273
21.137
180
160
140
120
100
80
60
40
20
ppm

HPLC Charts:

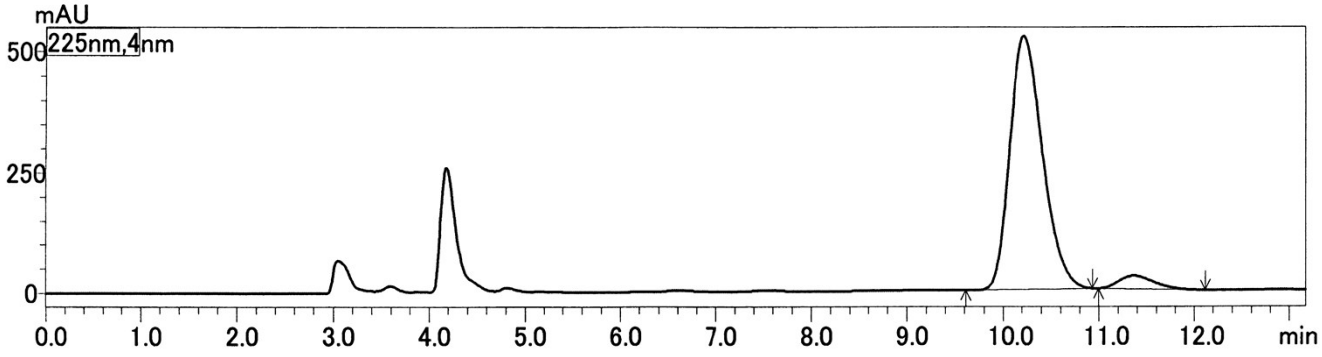


4a

racemic-**4a**



(4*R*,5*S*)-**4a**

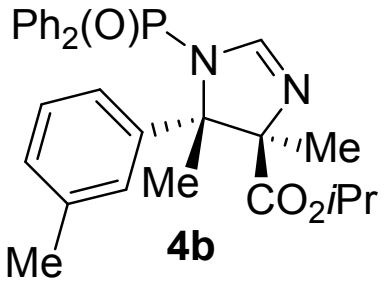


racemic-**4a**

Peak	tR (min)	Area (%)
1	10.2	50.2
2	11.2	49.8

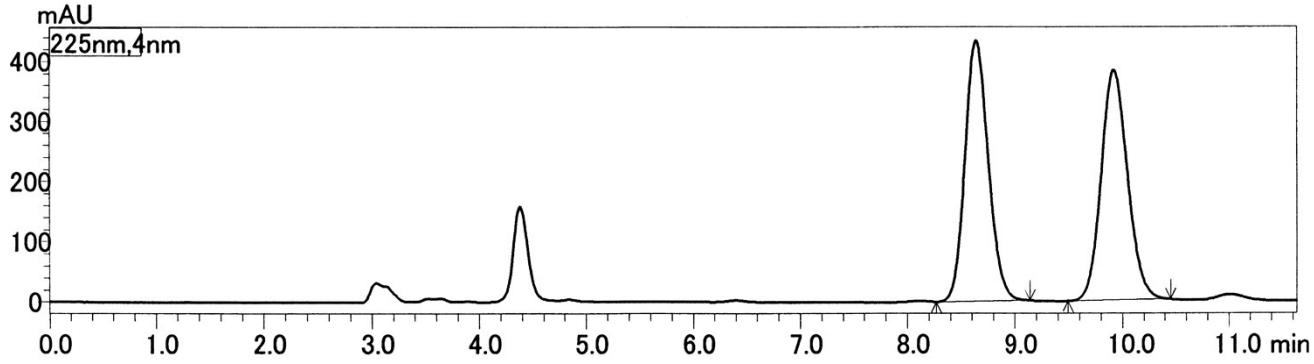
(4*R*,5*S*)-**4a**

Peak	tR (min)	Area (%)
1	10.2	94.7
2	11.4	5.3

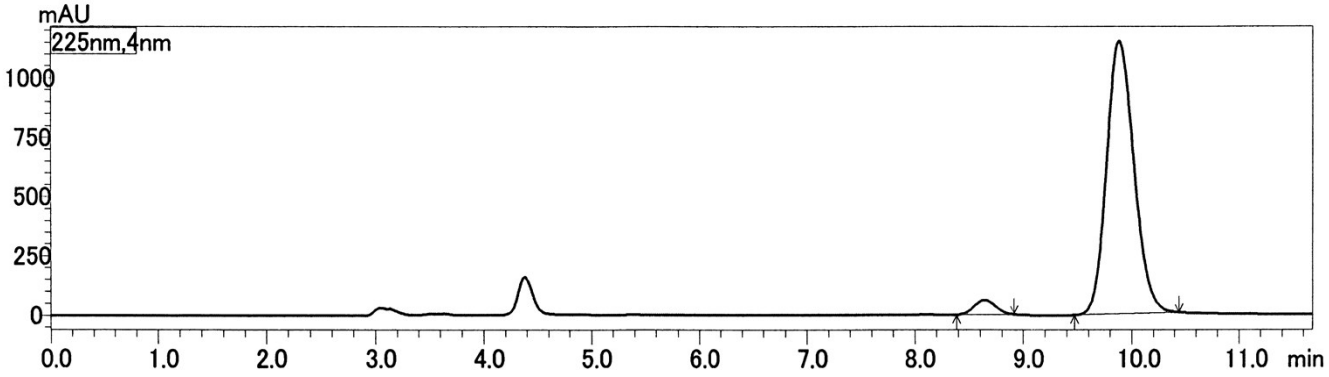


4b

racemic-**4b**



(4*R*,5*S*)-**4b**

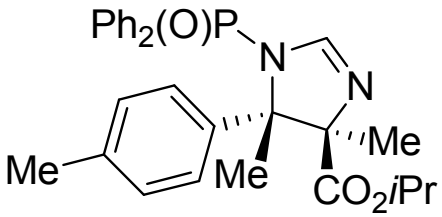


racemic-**4b**

Peak	tR (min)	Area (%)
1	8.6	49.9
2	9.9	50.1

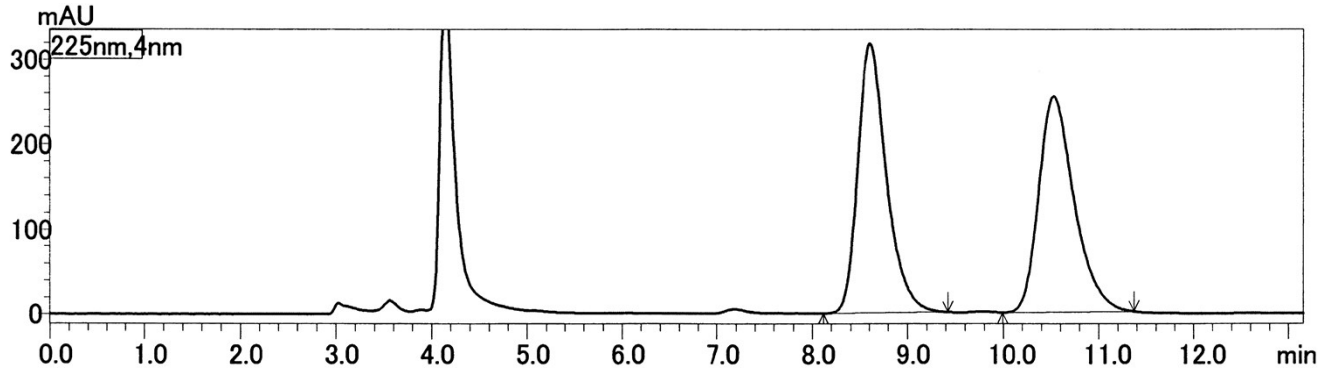
(4*R*,5*S*)-**4b**

Peak	tR (min)	Area (%)
1	8.6	4.1
2	9.9	95.9

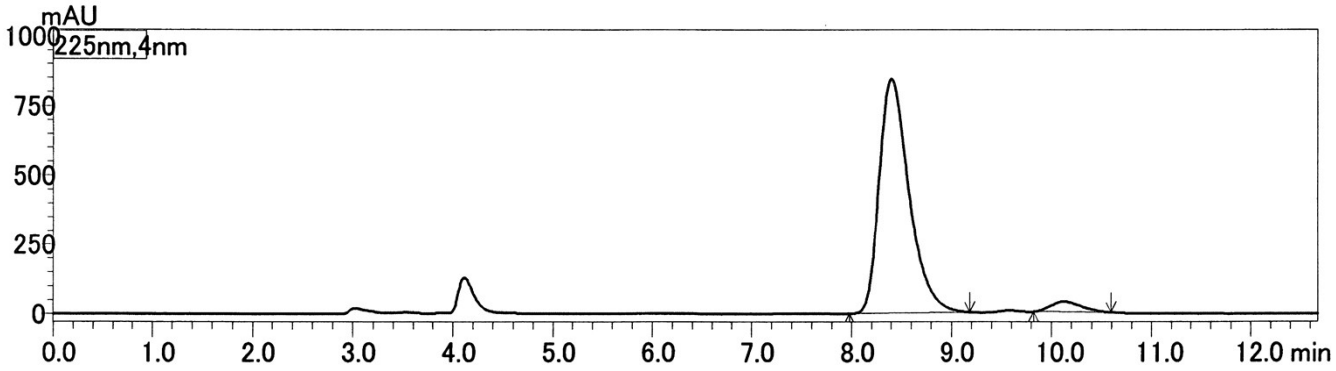


4c

racemic-**4c**



(4*R*,5*S*)-**4c**

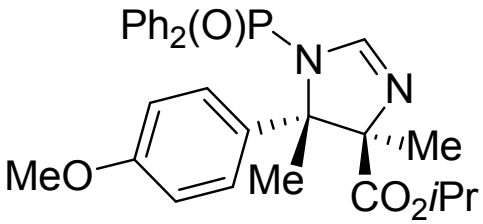


racemic-**4c**

Peak	tR (min)	Area (%)
1	8.6	50.5
2	10.5	49.5

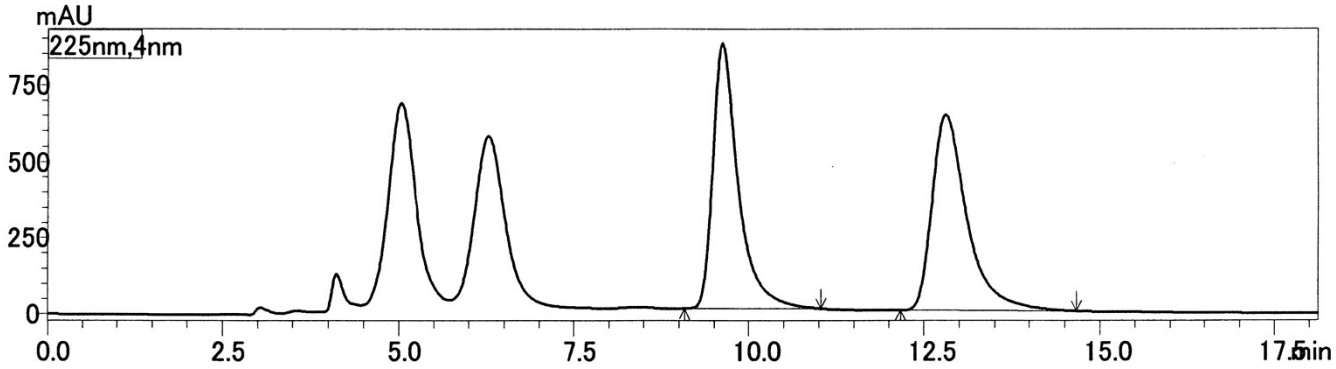
(4*R*,5*S*)-**4c**

Peak	tR (min)	Area (%)
1	8.4	95.6
2	10.1	4.4

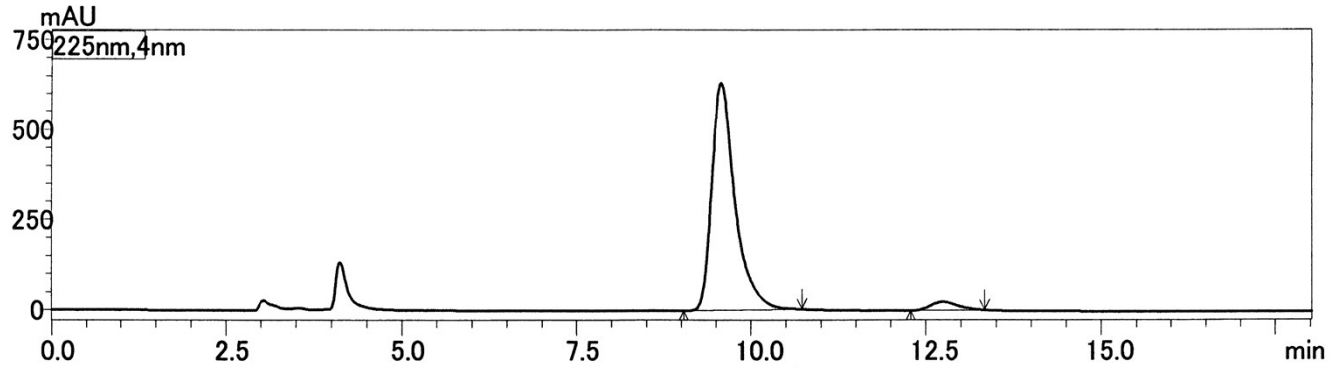


4d

racemic-**4d**



(4*R*,5*S*)-**4d**

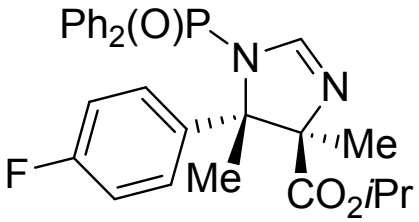


racemic-**4d**

Peak	tR (min)	Area (%)
1	9.6	50.2
2	12.8	49.8

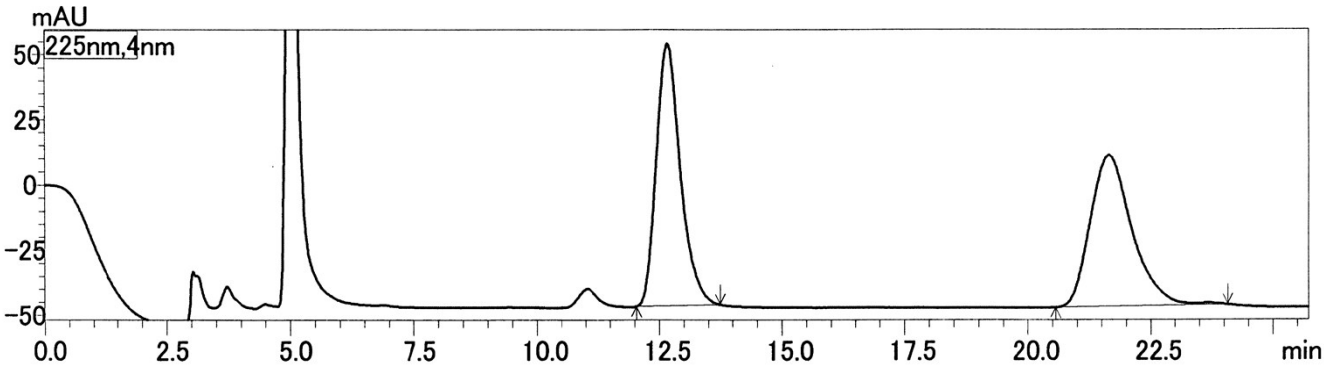
(4*R*,5*S*)-**4d**

Peak	tR (min)	Area (%)
1	9.6	95.7
2	12.7	4.2

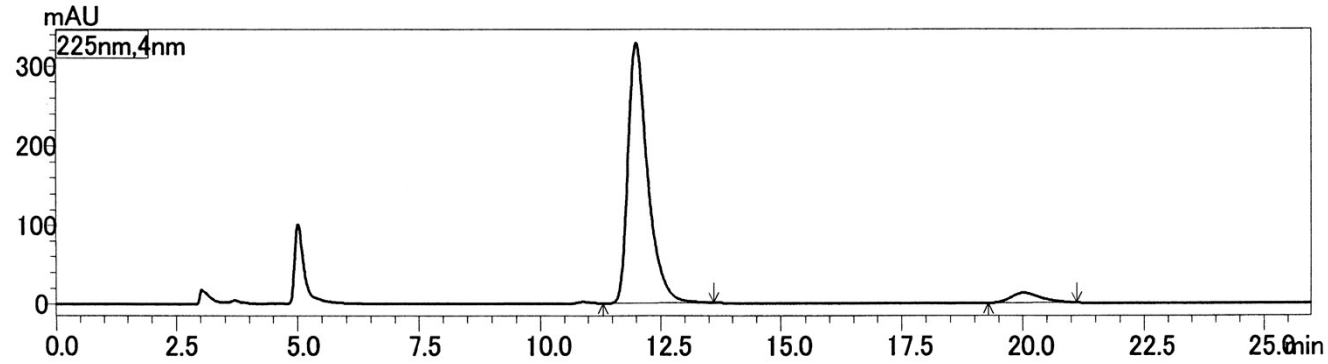


4e

racemic-**4e**



(4*R*,5*S*)-**4e**

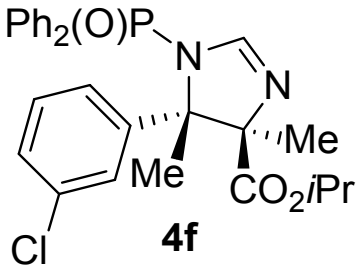


racemic-**4e**

Peak	tR (min)	Area (%)
1	12.7	50.5
2	21.6	49.5

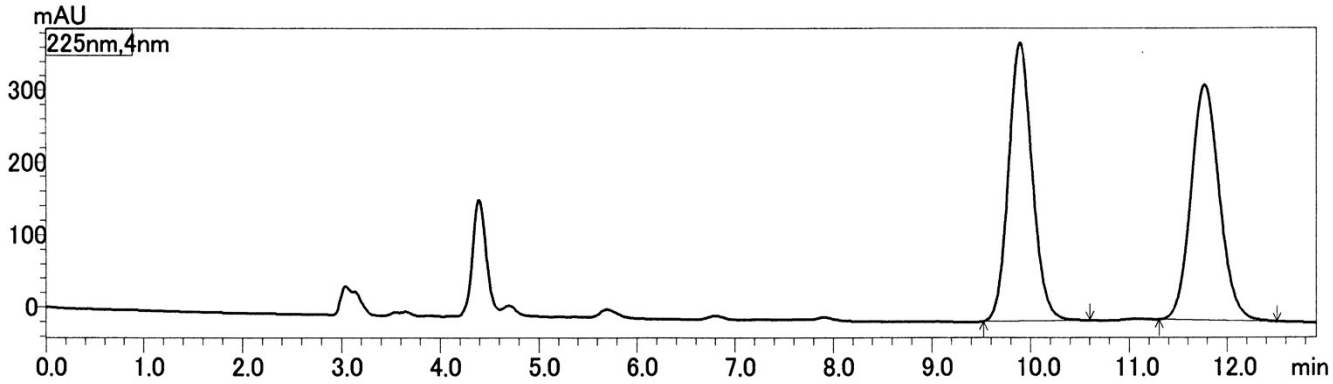
(4*R*,5*S*)-**4e**

Peak	tR (min)	Area (%)
1	12.0	94.2
2	20.0	5.8

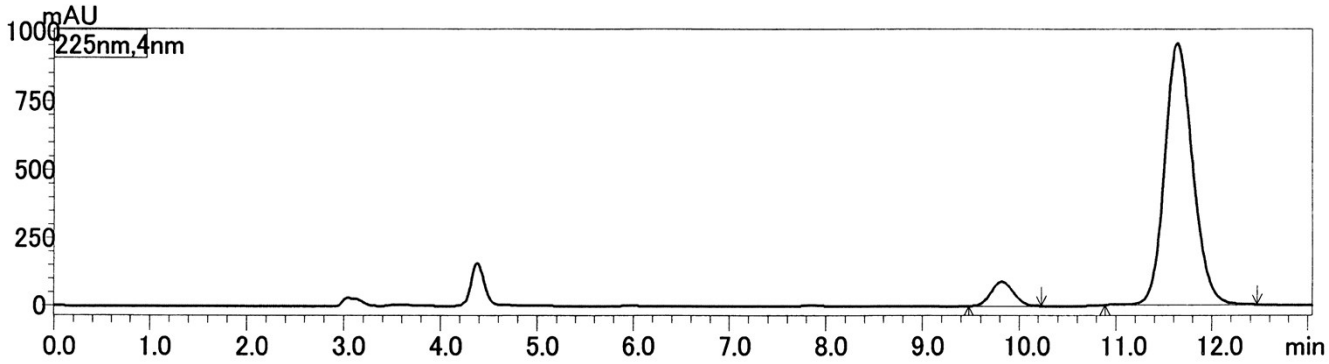


4f

racemic-**4f**



(4*R*,5*S*)-**4f**

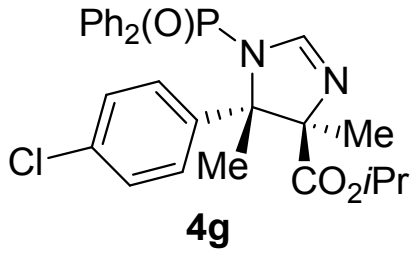


racemic-**4f**

Peak	tR (min)	Area (%)
1	9.9	49.9
2	11.8	50.1

(4*R*,5*S*)-**4f**

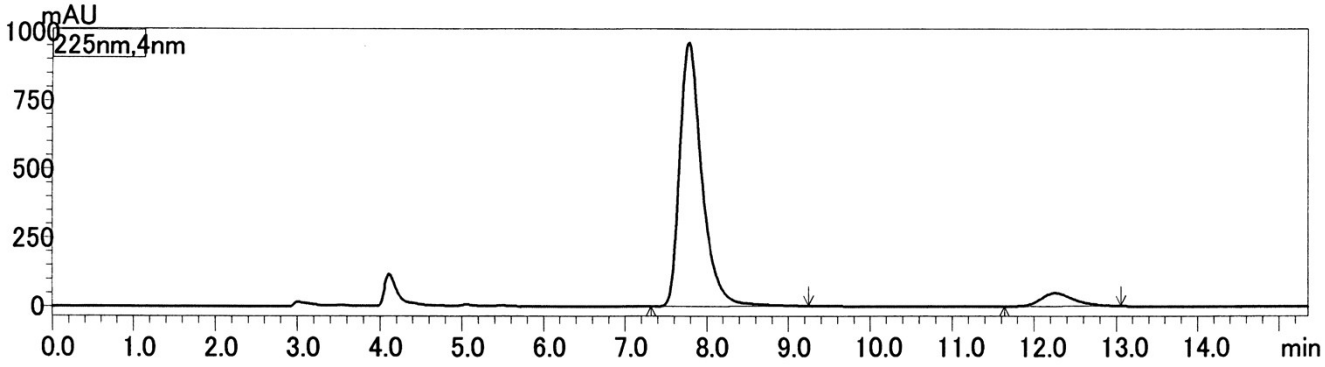
Peak	tR (min)	Area (%)
1	9.8	7.0
2	11.6	93.0



4g

racemic-**4g**

(4*R*,5*S*)-**4g**

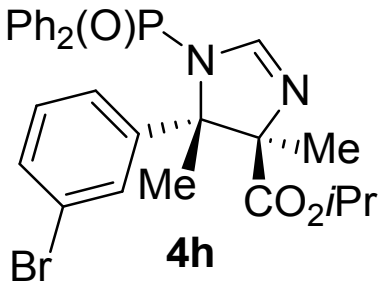


racemic-**4g**

Peak	tR (min)	Area (%)
1	8.0	50.5
2	12.7	49.5

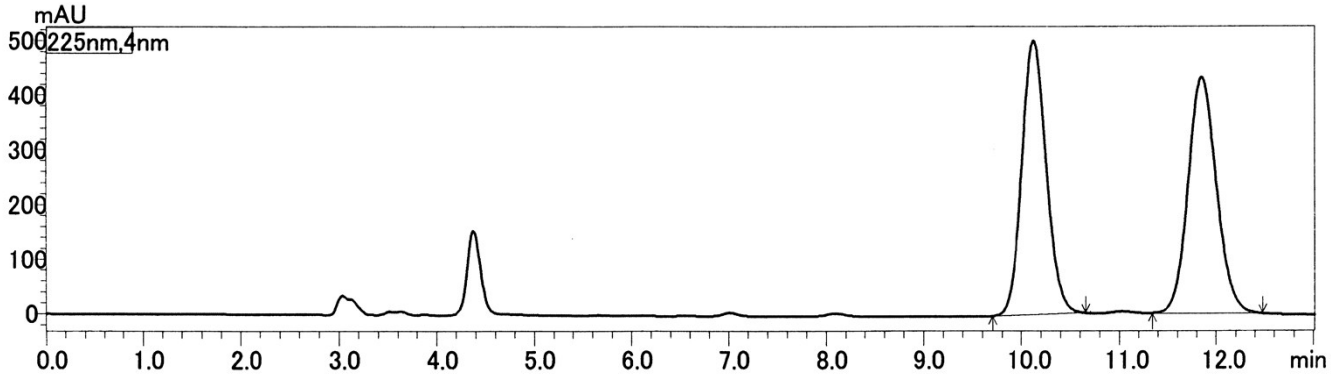
(4*R*,5*S*)-**4g**

Peak	tR (min)	Area (%)
1	7.8	92.9
2	12.3	7.1

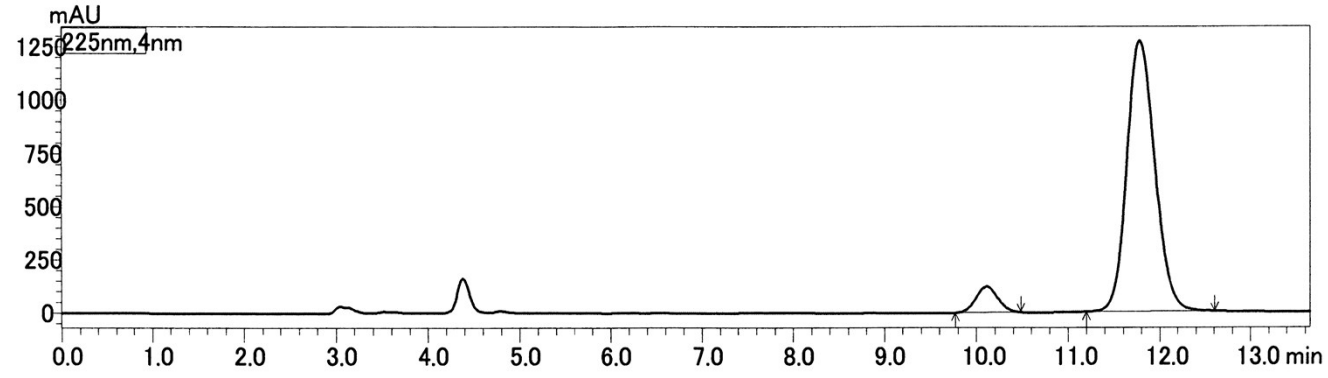


4h

racemic-**4h**



(4*R*,5*S*)-**4h**

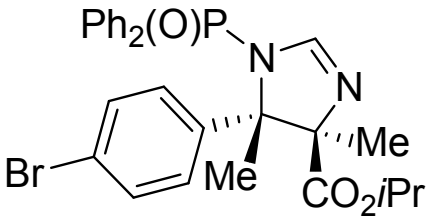


racemic-**4h**

Peak	tR (min)	Area (%)
1	10.1	49.9
2	11.8	50.1

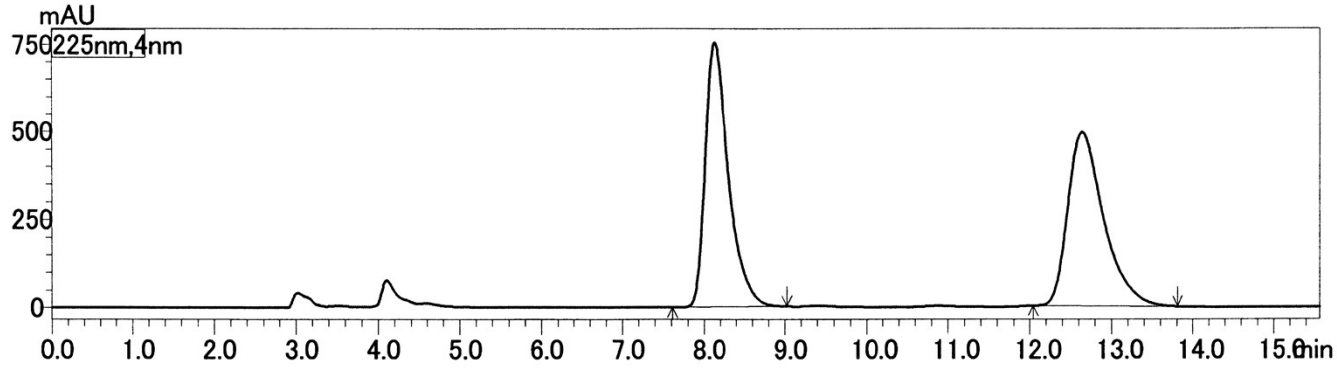
(4*R*,5*S*)-**4h**

Peak	tR (min)	Area (%)
1	10.1	6.9
2	11.8	93.1

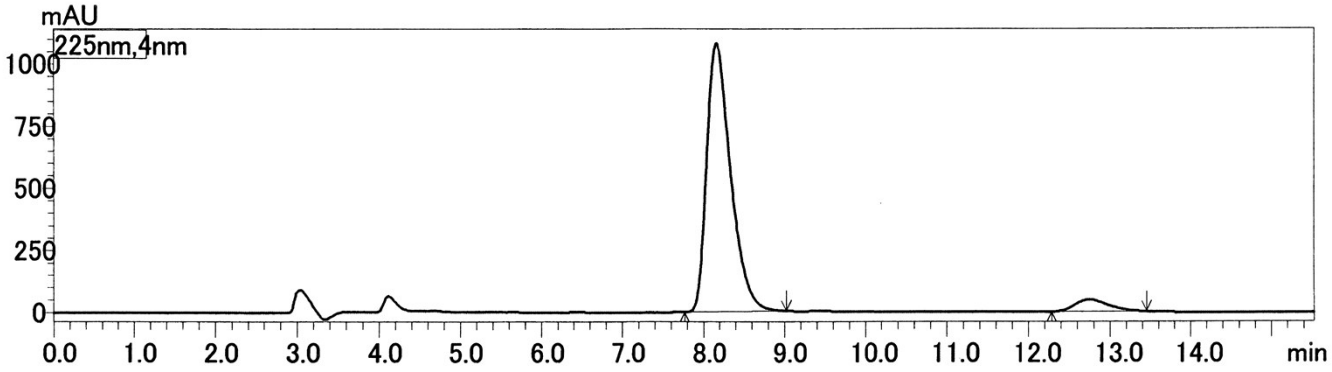


4i

racemic-**4i**



(4*R*,5*S*)-**4i**

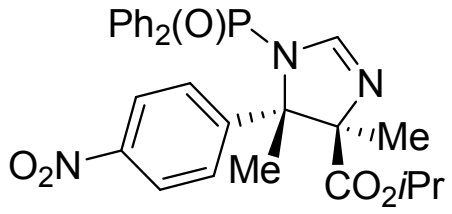


racemic-**4i**

Peak	tR (min)	Area (%)
1	14.9	49.9
2	17.4	50.1

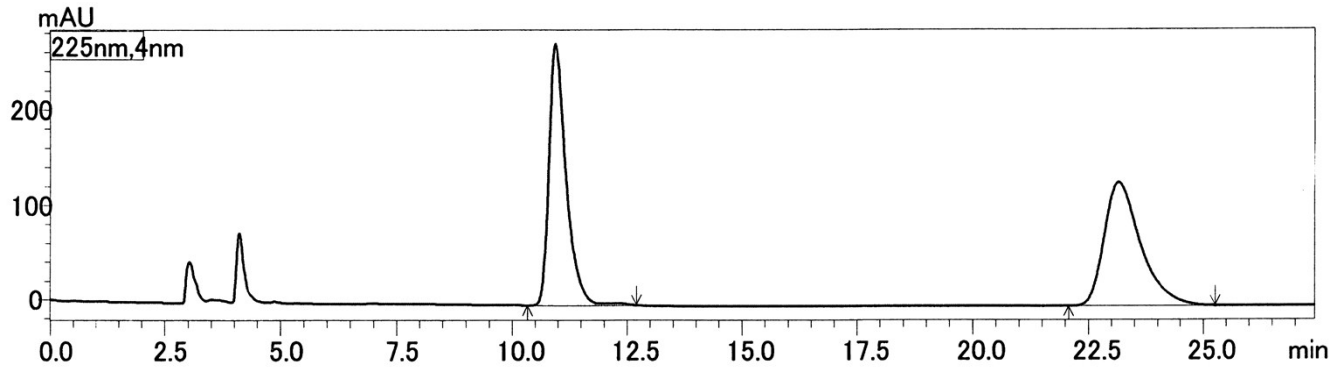
(4*R*,5*S*)-**4i**

Peak	tR (min)	Area (%)
1	15.0	5.8
2	17.4	94.2

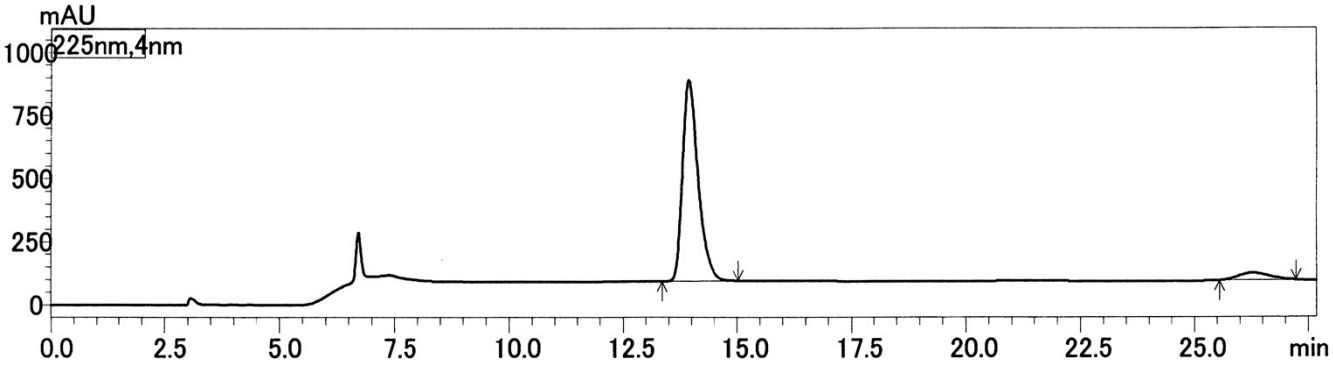


4j

racemic-**4j**



(4*R*,5*S*)-**4j**

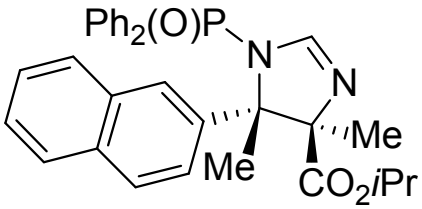


racemic-**4j**

Peak	tR (min)	Area (%)
1	10.9	50.4
2	23.2	49.6

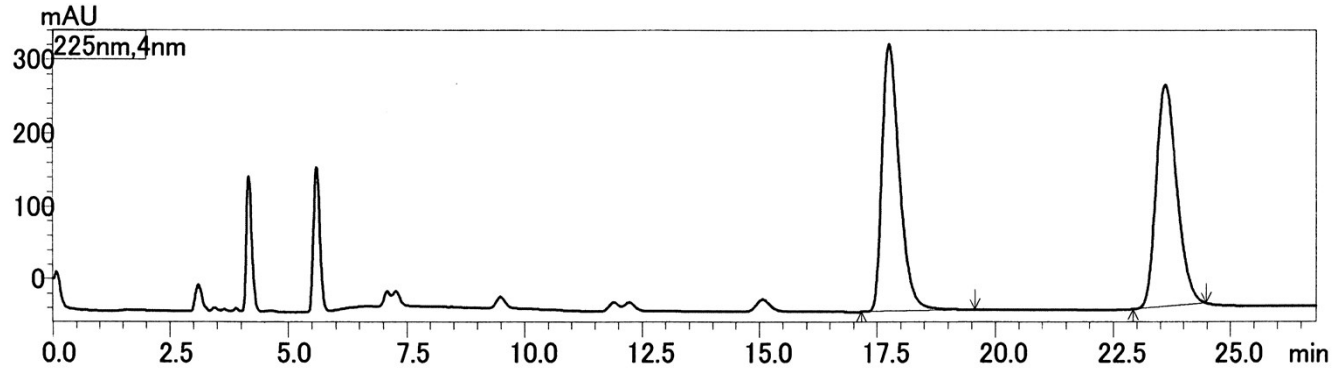
(4*R*,5*S*)-**4j**

Peak	tR (min)	Area (%)
1	13.9	93.4
2	26.3	6.6

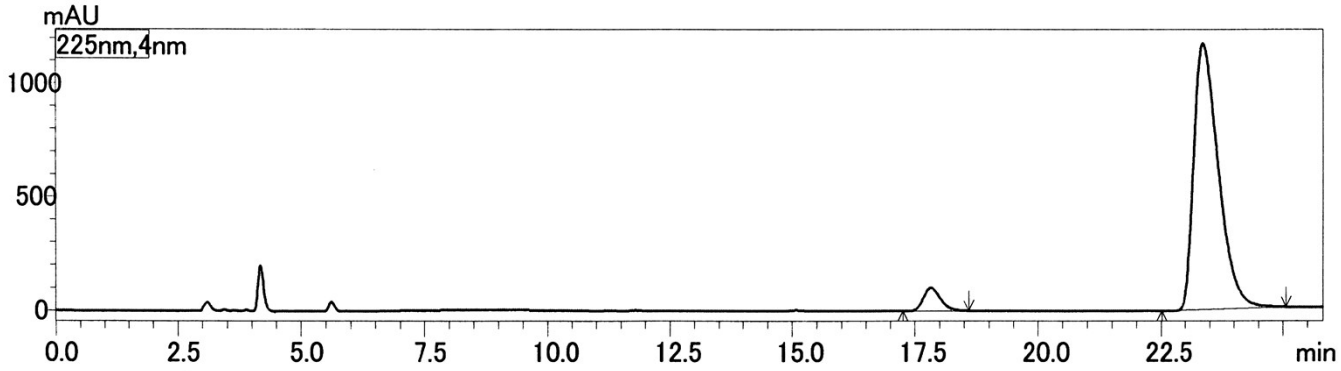


4k

racemic-**4k**



(4*R*,5*S*)-**4k**

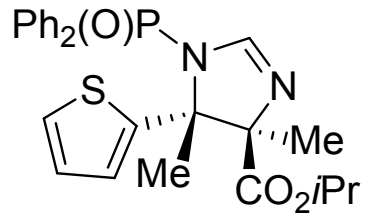


racemic-**4k**

Peak	tR (min)	Area (%)
1	17.8	49.8
2	23.6	50.2

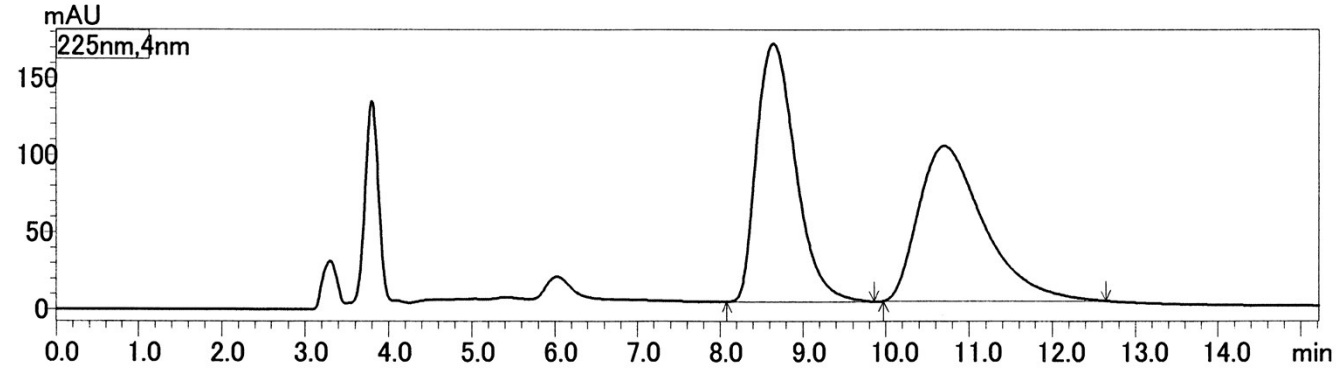
(4*R*,5*S*)-**4k**

Peak	tR (min)	Area (%)
1	17.8	5.6
2	23.4	94.4

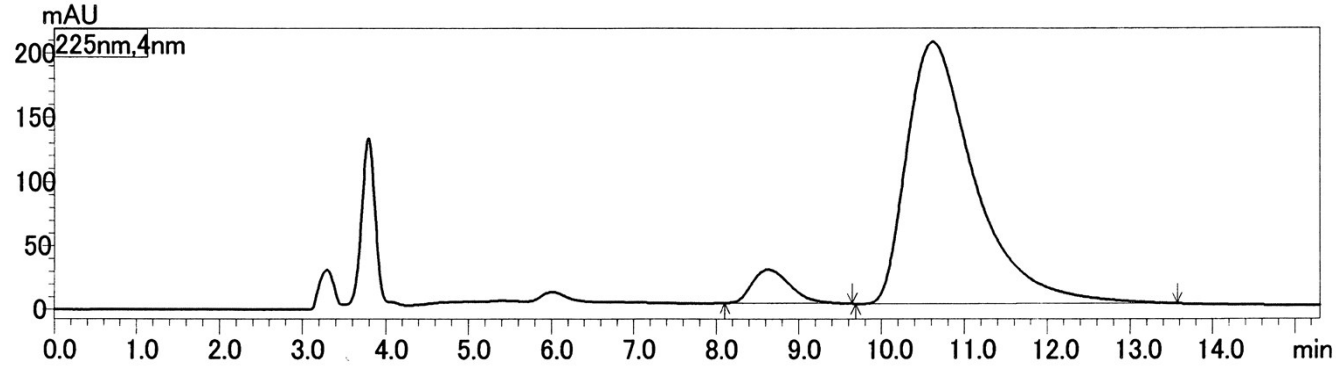


4l

racemic-**4l**



(4*R*,5*S*)-**4l**

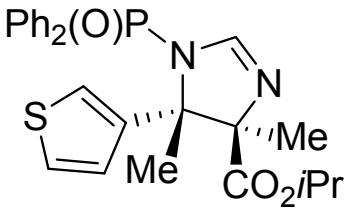


racemic-**4l**

Peak	tR (min)	Area (%)
1	8.6	50.0
2	10.7	50.0

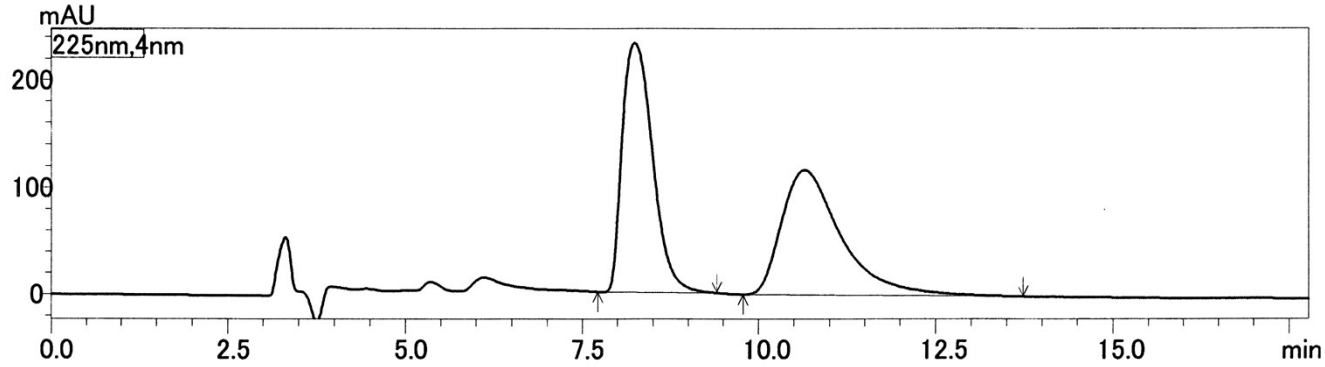
(4*R*,5*S*)-**4l**

Peak	tR (min)	Area (%)
1	8.6	6.9
2	10.6	93.1

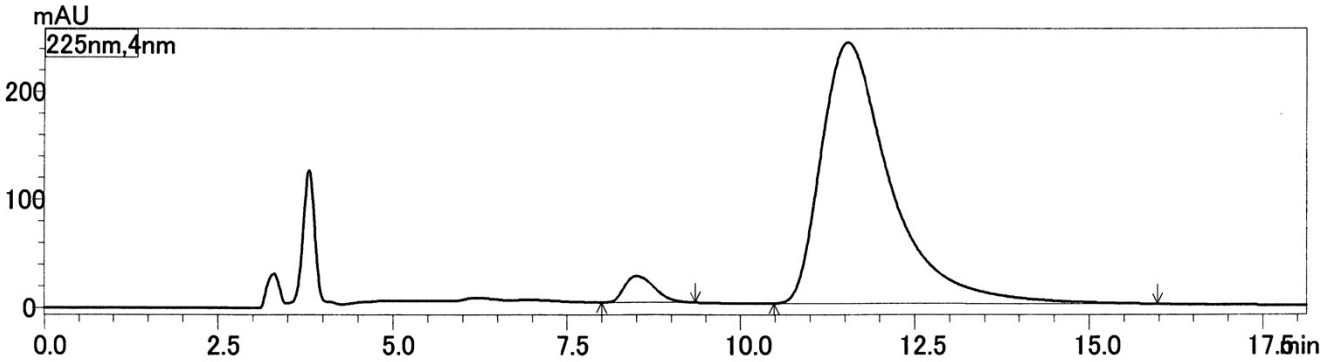


4m

racemic-**4m**



(4*R*,5*S*)-**4m**

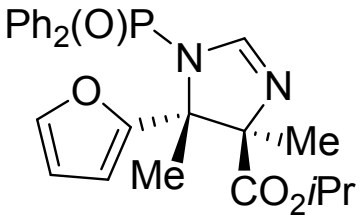


racemic-**4m**

Peak	tR (min)	Area (%)
1	8.5	50.5
2	11.6	49.5

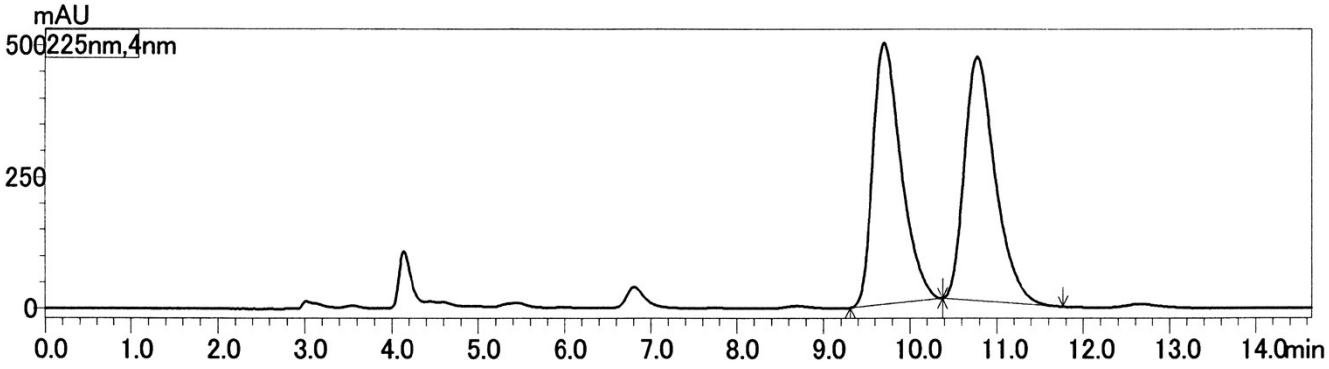
(4*R*,5*S*)-**4m**

Peak	tR (min)	Area (%)
1	8.5	4.2
2	11.5	95.8

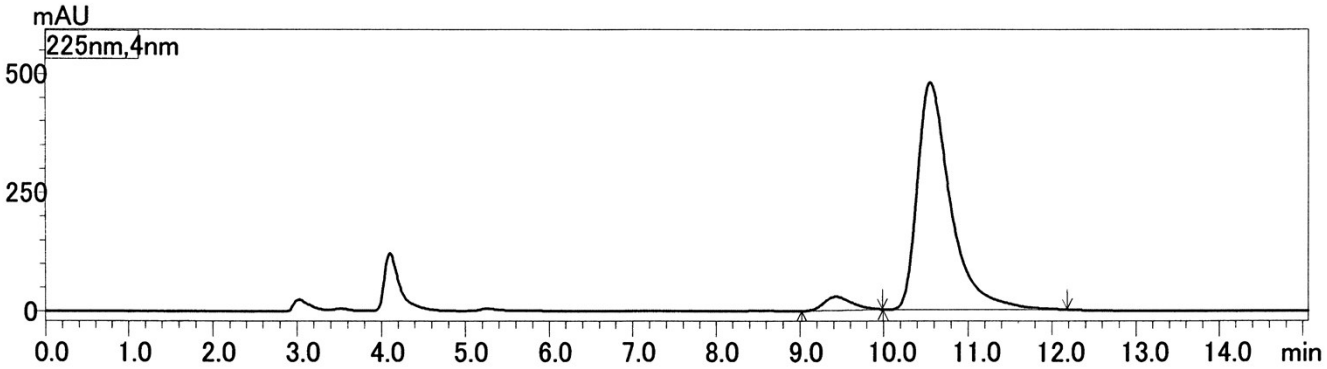


4n

racemic-**4n**



(4*R*,5*S*)-**4n**

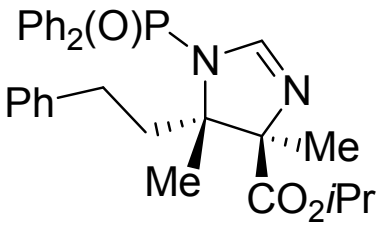


racemic-**4n**

Peak	tR (min)	Area (%)
1	9.7	49.7
2	10.8	50.3

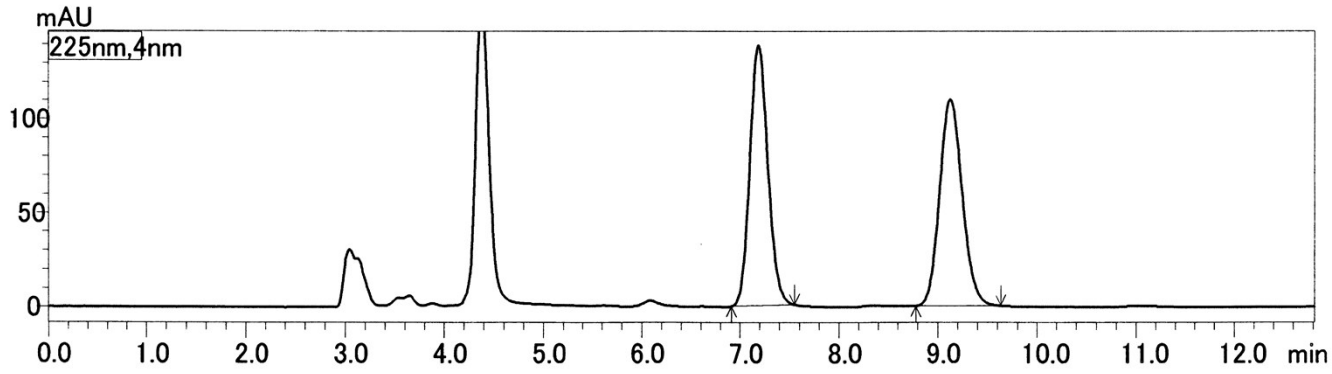
(4*R*,5*S*)-**4n**

Peak	tR (min)	Area (%)
1	9.4	4.9
2	10.5	95.1

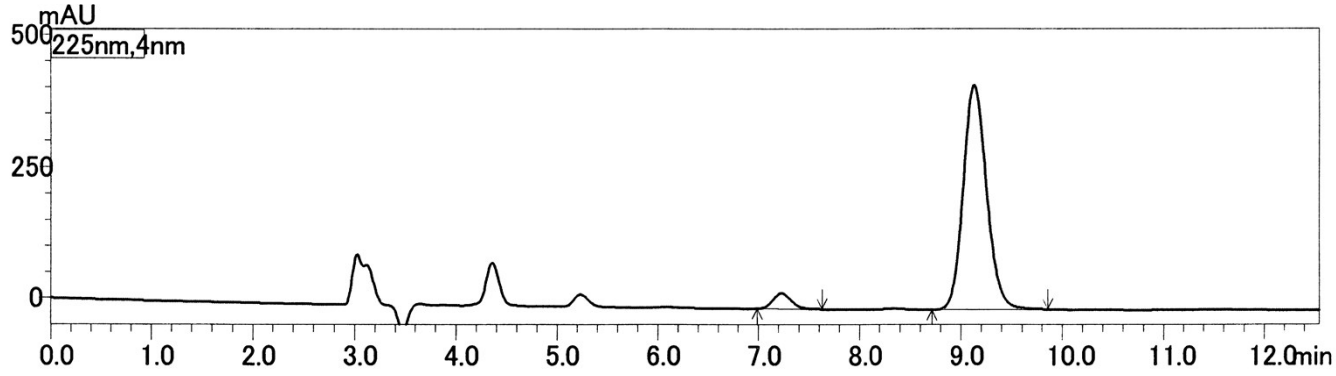


4o

racemic-**4o**



(4*R*,5*S*)-**4o**

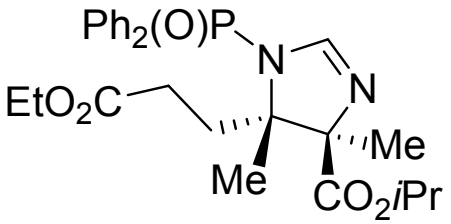


racemic-**4o**

Peak	tR (min)	Area (%)
1	7.2	50.3
2	9.1	49.7

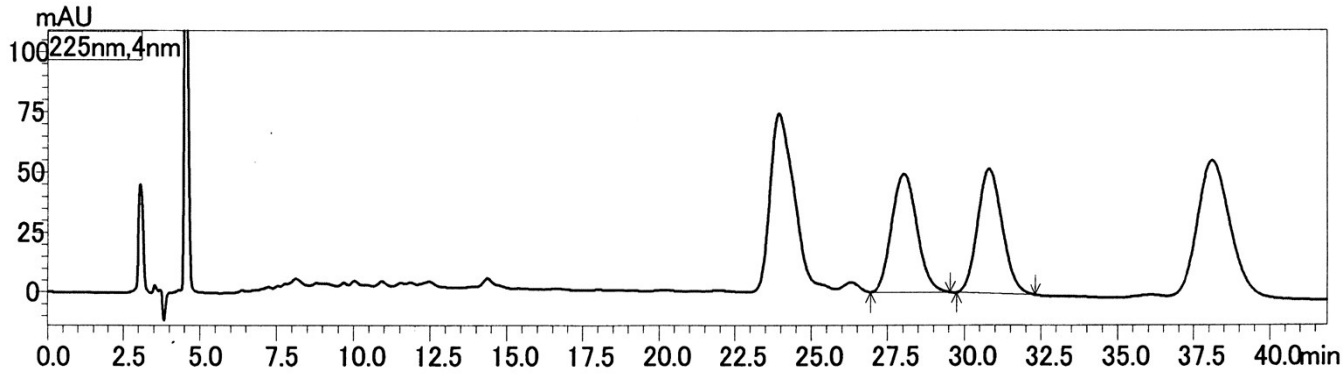
(4*R*,5*S*)-**4o**

Peak	tR (min)	Area (%)
1	7.2	5.2
2	9.1	94.8

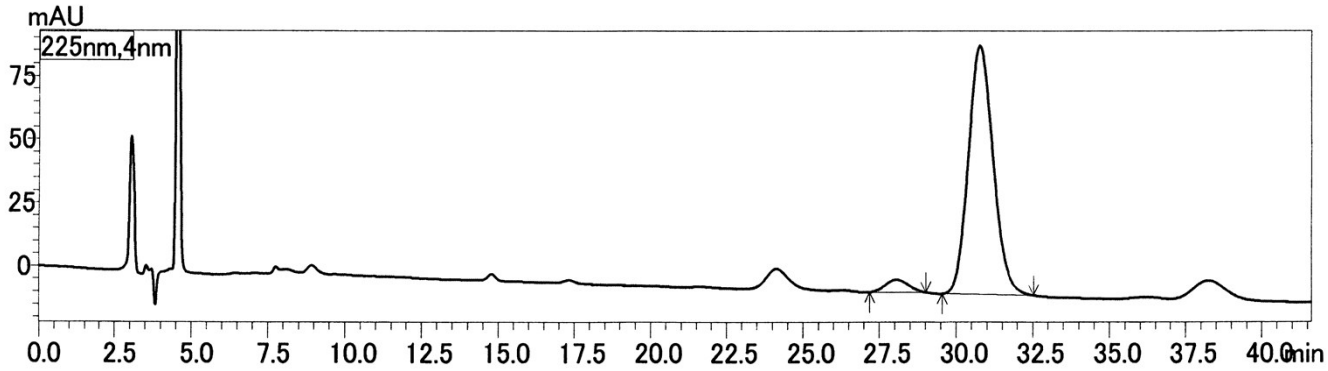


4p

racemic-**4p**



(4*R*,5*S*)-**4p**

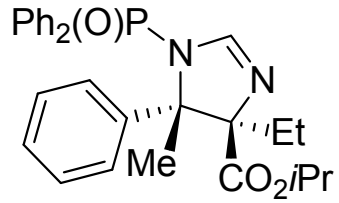


racemic-**4p**

Peak	tR (min)	Area (%)
1	28.0	49.6
2	30.8	50.4

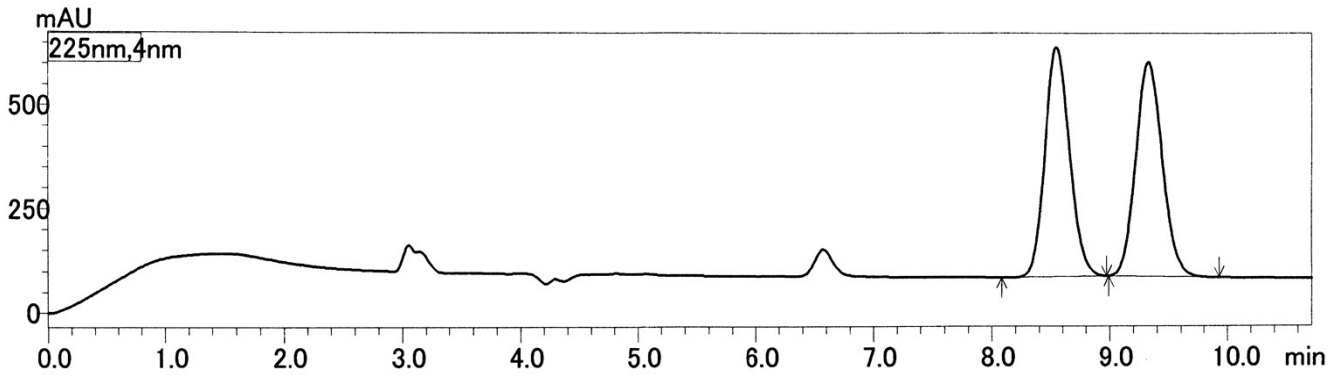
(4*R*,5*S*)-**4p**

Peak	tR (min)	Area (%)
1	28.1	4.5
2	30.7	95.5

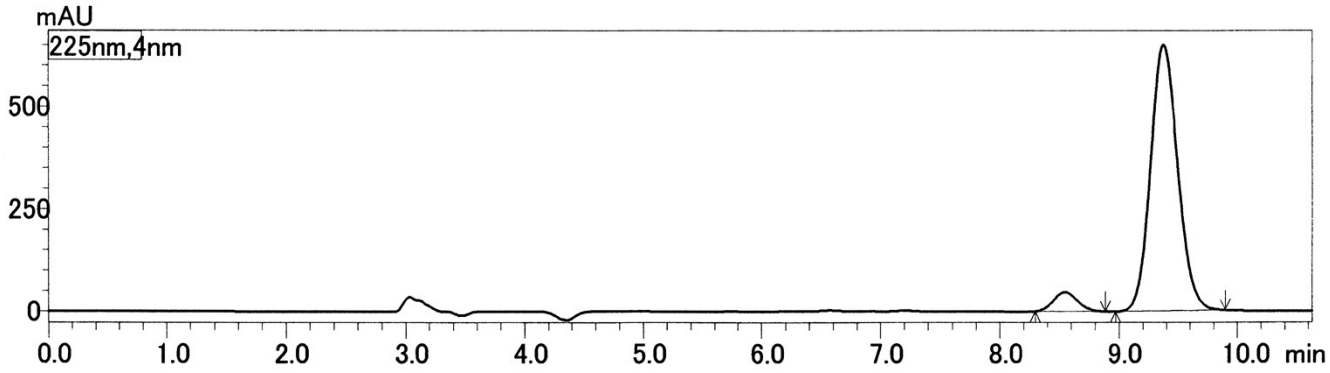


4q

racemic-**4q**



(4*R*,5*S*)-**4q**

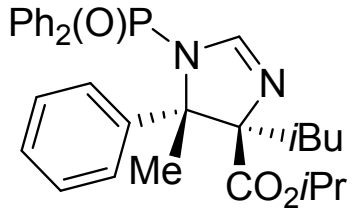


racemic-**4q**

Peak	tR (min)	Area (%)
1	8.6	50.1
2	9.4	49.9

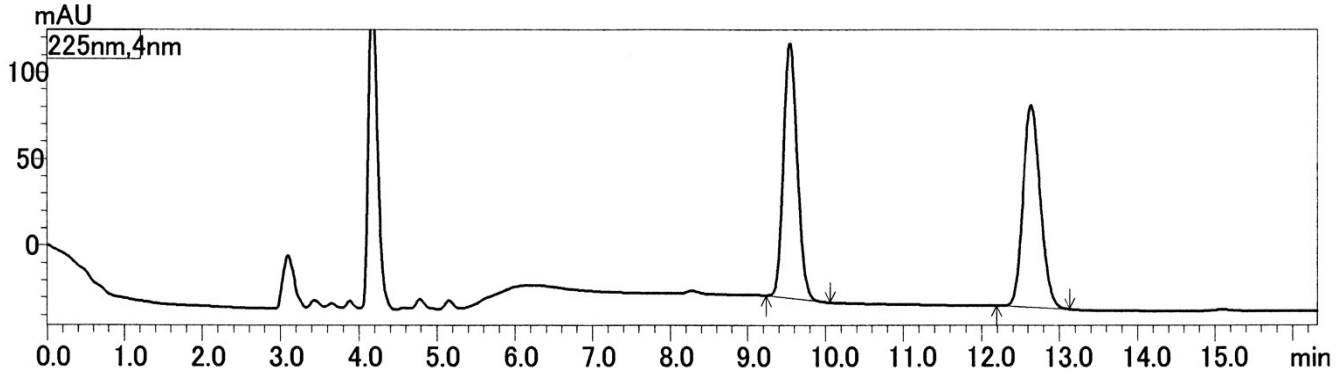
(4*R*,5*S*)-**4q**

Peak	tR (min)	Area (%)
1	8.5	6.0
2	9.4	94.0

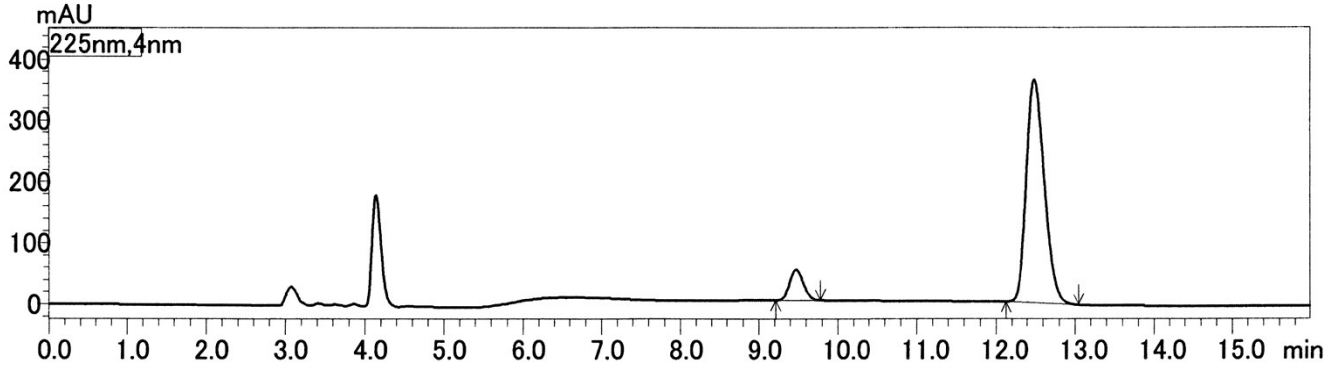


4r

racemic-**4r**



(4*R*,5*S*)-**4r**

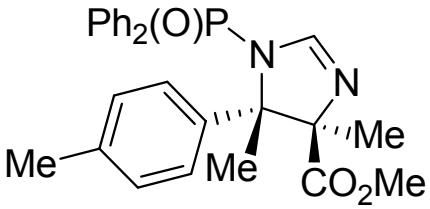


racemic-**4r**

Peak	tR (min)	Area (%)
1	9.5	49.8
2	12.6	50.2

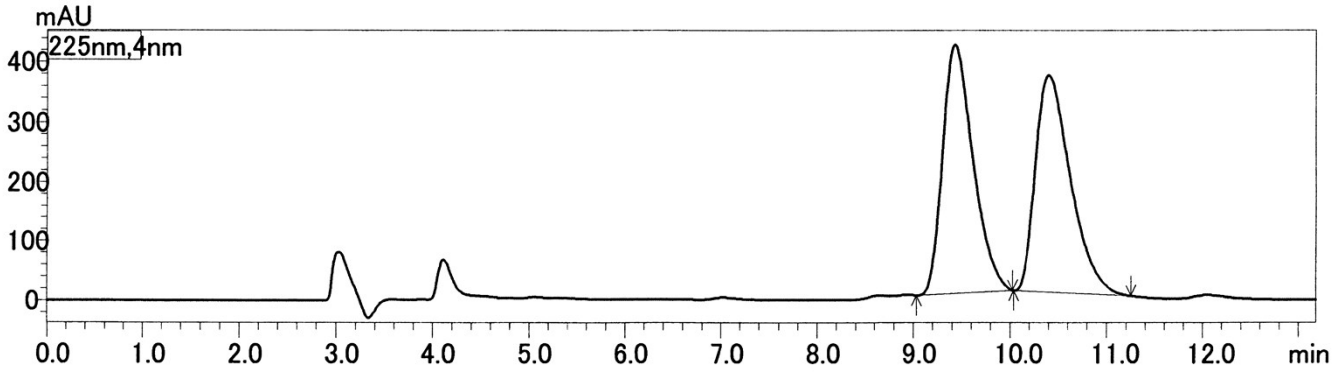
(4*R*,5*S*)-**4r**

Peak	tR (min)	Area (%)
1	9.5	9.6
2	12.5	90.4

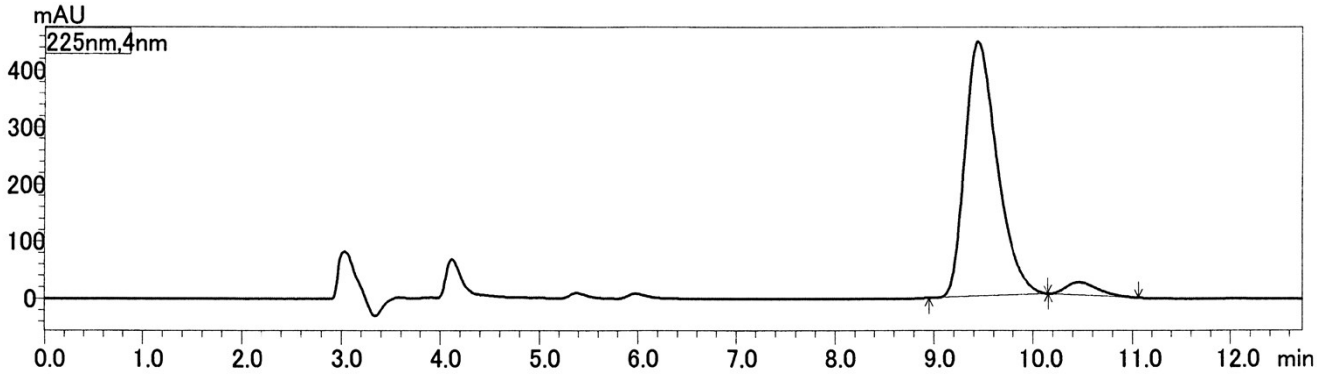


4s

racemic-**4s**



(4*R*,5*S*)-**4s**



racemic-**4s**

Peak	tR (min)	Area (%)
1	9.4	49.8
2	10.4	50.2

(4*R*,5*S*)-**4s**

Peak	tR (min)	Area (%)
1	9.4	95.2
2	10.5	4.8