Asymmetric Fluorination of α-Branched Cyclohexanones Enabled by a Combination of Chiral Anion Phase-Transfer Catalysis and Enamine Catalysis using Protected Amino Acids

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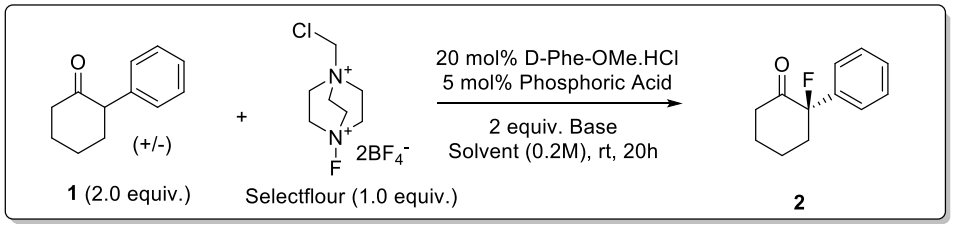
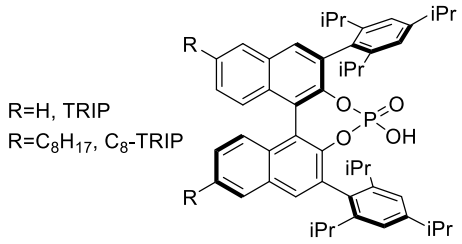
Table of Contents

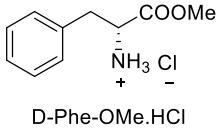
General Information:

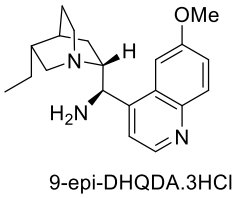
Unless otherwise noted, all commercial reagents were used without further purification. Selectfluor® (Sigma Aldrich, 95%) was ground in a pestle and mortar and dried at 80°C under high vacuum for 30 minutes prior to use. $Na_2CO_3.H_2O$ was obtained from J. T. Baker (99.7%) and ground in a pestle and mortar prior to use without further drying procedure. $NaHCO_3$, Na_2HPO_4 and $Na_3PO_4.H_2O$ were grounded in a pestle and mortar prior to use. Fluorination reactions were run in 1 dram (15 mm x 45 mm) vials fitted with a screw cap and stirred using an 8 mm magenetic stirrer bar. Dichloromethane, toluene, ether, toluene and triethylamine were purified by passage through an activated alumina column under argon. Thin-layer chromatography (TLC) analysis of reaction mixtures was performed using Merck silica gel 60 F254 TLC plates, and visualized under UV or by staining with ceric ammonium molybdate. Flash column chromatography was carried out on Merck Silica Gel 60 Å, 230 X 400 mesh. Nuclear magnetic resonance (NMR) spectra were recorded using Bruker AV-600, AV-500, AVQ-400, AVB-400 and AV-300 spectrometers. ^{1}H and ^{13}C chemical shifts are reported in ppm downfield of tetramethylsilane and referenced to residual solvent peak ($CHCl_3$; $\delta H = 7.26$ and $\delta C = 77.16$, CH_3OH; $\delta H = 3.31$ and $\delta C = 49.00$). Multiplicities are reported using the following abbreviations: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad resonance. Mass spectral data were obtained from the Micro-Mass/Analytical Facility operated by the College of Chemistry, University of California, Berkeley. Enantiomeric excesses were determined on a Shimadzu VP Series Chiral HPLC using IA, IB or IC columns. The synthesis of phosphoric acids **(*R*)-C_8-TRIP**, **(*R*)-TRIP**, **(*R*)-TCYP**, **(*R*)-P1** and **(*R*)-P2** has been previously described[1]. Racemic products were synthesized by carrying out the fluorination reactions with achiral phosphoric acid (**AP**) and glycine methyl ester (**A1**) in toluene.

Optimization of bases, solvents and amine catalysts on substrates 1a









Entry	Phosphoric Acid	Amine Catalyst	Base	Solv.	Yield **2** based on: Ketone (Selectfluor)[a]	ee **2**[b]
1	(*R*)-C_8 TRIP	D-Phe-OMe	$Na_2CO_3.H_2O$	Toluene	37 (74)	+88
2	(*R*)-C_8 TRIP	D-Phe-OMe	$NaHCO_3$	Toluene	12 (24)	+29
3	(*R*)-C_8 TRIP	D-Phe-OMe	Na_2HPO_4	Toluene	24 (49)	+29
4	(*R*)-C_8 TRIP	D-Phe-OMe	$Na_3PO_4.H_2O$	Toluene	27 (55)	+73
5	(*R*)-C_8 TRIP	D-Phe-OMe	$Na_2CO_3.H_2O$	Benzene	26 (53)	+71
6	(*R*)-C_8 TRIP	D-Phe-OMe	$Na_2CO_3.H_2O$	Hexane	31 (62)	+59
7	(*R*)-C_8 TRIP	D-Phe-OMe	$Na_2CO_3.H_2O$	$PhCF_3$	41 (83)	+73
8	(*R*)-C_8 TRIP	D-Phe-OMe	$Na_2CO_3.H_2O$	o-Xylene	32 (65)	+85
9	(*R*)-C_8 TRIP	D-Phe-OMe	$Na_2CO_3.H_2O$	m-Xylene	37 (75)	+83
10	(*R*)-C_8 TRIP	D-Phe-OMe	$Na_2CO_3.H_2O$	p-Xylene	37 (74)	+82
11	(*R*)-C_8 TRIP	D-Phe-OMe	$Na_2CO_3.H_2O$	MTBE	23 (46)	+34
12	(*R*)-C_8 TRIP	9-epi DHQDA[c]	$Na_2CO_3.H_2O$	Toluene	3 (7)	-29
13	(*S*)- TRIP	9-epi DHQDA	$Na_2CO_3.H_2O$	Toluene	4 (9)	+20

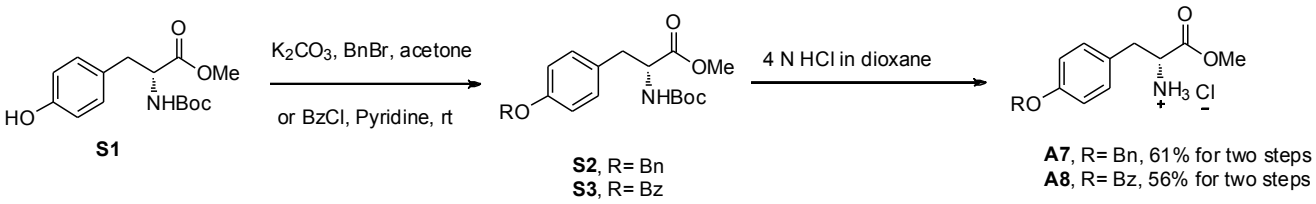
[a]Yield was determined by ^{19}F-NMR spectroscopy by comparison with the internal standard. [b]Determined by chiral HPLC analysis of the crude reaction mixture after a short plug of silica gel. [c]Catalyst 9-epi DHQDA was synthesized according literature[2].

Synthesis of Amine catalyst:

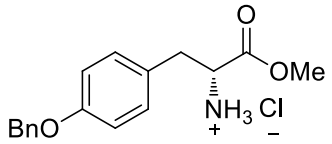
The hydrochloride salts of amino acid methyl esters **A1**, **A2**, **A4**, **A5**, **A6**, **A9** were commercially available and used directly.

Catalyst **A3** was synthesized according literature[3].

Amine catalyst **A7** and **A8** were synthesized according to the following procedure:

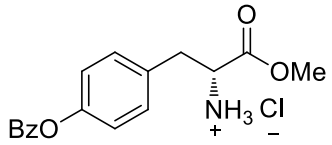


O-Benzyl (D)-Tyrosine methyl ester hydrochloride (**A7**)



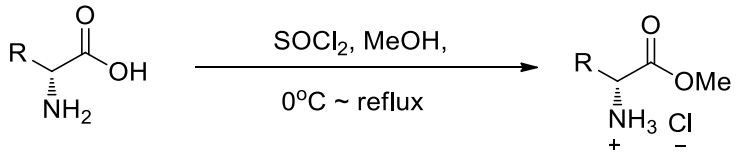
^{1}H NMR (600 MHz, Methanol-*d*4) δ 7.42 (d, *J* = 7.5 Hz, 2H), 7.36 (dd, *J* = 8.4, 6.7 Hz, 2H), 7.30 (t, *J* = 7.4 Hz, 1H), 7.18 (d, *J* = 8.6 Hz, 2H), 6.99 (d, *J* = 8.4 Hz, 2H), 5.07 (s, 2H), 4.27 (t, *J* = 6.6 Hz, 1H), 3.79 (s, 3H), 3.20 (dd, *J* = 14.5, 6.1 Hz, 1H), 3.14 (dd, *J* = 14.5, 7.2 Hz, 1H). ^{13}C NMR (151 MHz, Methanol-*d*4) δ 170.42, 159.88, 138.59, 131.57, 129.48, 128.86, 128.50, 127.28, 116.56, 70.94, 55.31, 53.55, 36.53. m/z HRMS (ESI) found $[M]^+$ 286.1437, $C_{17}H_{20}NO_3^+$ requires 286.1438.

O-Benzoyl (D)-Tyrosine methyl ester hydrochloride (**A8**)



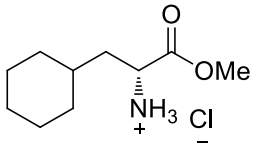
^{1}H NMR (600 MHz, Methanol-*d*4) δ 8.18 (d, *J* = 7.7 Hz, 1H), 7.70 (t, *J* = 7.5 Hz, 1H), 7.57 (t, *J* = 7.7 Hz, 2H), 7.39 (d, *J* = 8.0 Hz, 2H), 7.26 (d, *J* = 8.0 Hz, 2H), 4.39 (t, *J* = 6.8 Hz, 1H), 3.84 (s, 3H), 3.34 (dd, *J* = 14.4, 6.0 Hz, 1H), 3.24 (dd, *J* = 14.4, 7.5 Hz, 1H). ^{13}C NMR (151 MHz, Methanol-*d*4) δ 170.32, 166.79, 152.09, 135.05, 133.25, 131.75, 131.04, 130.54, 129.86, 123.59 55.19, 53.67, 36.68. m/z HRMS (ESI) found $[M]^+$ 300.1232, $C_{17}H_{18}NO_4^+$ requires 300.1230.

Amine catalysts **A10**, **A11** and **A13** were synthesized by esterification of the corresponding amino acids (which were purchased from Chem-Impex Int'l Inc.)



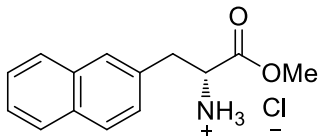
To a solution of amino acid (2.0 mmol) in MeOH (5 mL) was added $SOCl_2$ (435 uL, 6.0 mmol) at 0℃. After refluxing overnight, the mixture was concentrated under vacuum to afford the amine catalyst as white powder.

(D)-cyclohexylalanine methyl ester hydrochloride (**A10**)



^{1}H NMR (600 MHz, Methanol-*d*4) δ 4.03 – 3.68 (m, 4H), 2.09 – 1.45 (m, 7H), 1.42 – 0.92 (m, 6H). ^{13}C NMR (151 MHz, Methanol-*d*4) δ 170.33, 58.98, 40.46, 29.51, 26.97, 26.89, 26.73. m/z HRMS (ESI) found $[M]^+$ 172.1332, $C_{10}H_{20}NO_2^+$ requires 172.1332.

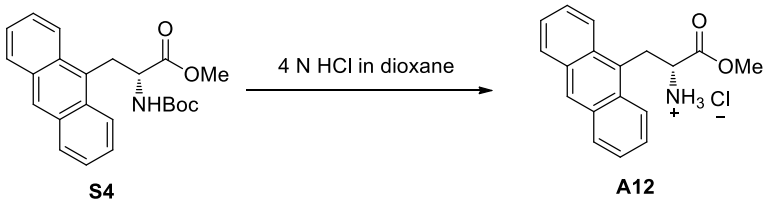
(D)-2-naphthylalanine methyl ester hydrochloride **(A11**)



^{1}H NMR (600 MHz, Methanol-*d*4) δ 7.91 – 7.83 (m, 3H), 7.79 (d, *J* = 2.0 Hz, 1H), 7.49 (tt, *J* = 6.8, 5.2 Hz, 2H), 7.39 (dd, *J* = 8.4, 1.7 Hz, 1H), 4.45 (t, *J* = 6.8 Hz, 1H), 3.79 (s, 3H), 3.44 (dd, *J* = 14.4, 6.3 Hz, 1H), 3.39 (dd, *J* = 14.3, 7.2 Hz, 1H). ^{13}C NMR (151 MHz, Methanol-*d*4) δ

170.38, 134.95, 134.24, 132.74, 129.87, 129.59, 128.75, 128.67, 127.91, 127.43, 127.20, 55.14, 53.61, 37.47. m/z HRMS (ESI) found $[M]^+$ 230.1176, $C_{14}H_{16}NO_2^+$ requires 230.1176.

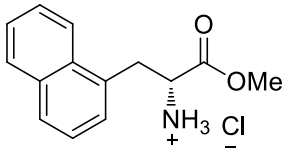
(D)-9-anthracylalanine methyl ester hydrochloride **(A12**)



S4 **A12**

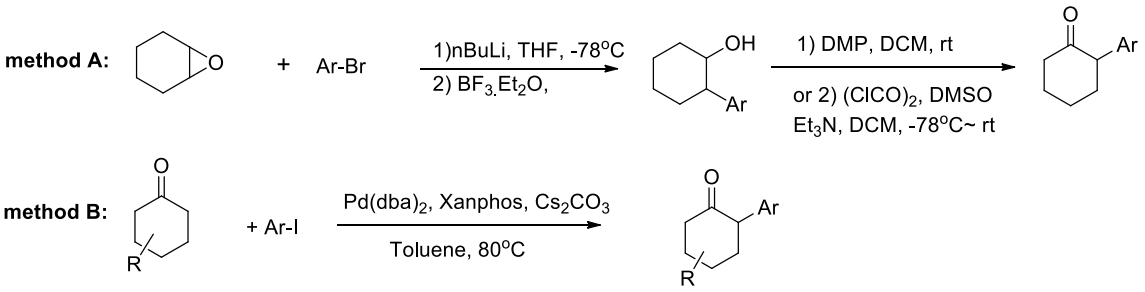
Amine catalyst **A12** was synthesized by deprotection of **S4**[4] with 4 N HCl in dioxane. The **S4** (100 mg, 0.26 mmol) was dissolved in 4 N HCl (3 mL). After stirring for 1 h, the mixture was concentrated *in vacuo* to afford **A12** as a yellow powder (70 mg, 85% yield). ^{1}H NMR (400 MHz, Methanol-*d*4) δ 8.46 (s, 1H), 8.23 (d, *J* = 9.1 Hz, 2H), 8.05 (d, *J* = 8.4 Hz, 2H), 7.59 (ddd, *J* = 8.7, 6.6, 1.4 Hz, 2H), 7.52 – 7.47 (m, 2H), 4.33 (t, *J* = 8.1 Hz, 1H), 4.27 – 4.15 (m, 2H), 3.17 (s, 3H). ^{13}C NMR (151 MHz, Methanol-*d*4) δ 170.55, 132.87, 131.59, 130.64, 129.09, 127.87, 126.84, 126.13, 124.23, 54.46, 53.22, 29.57. m/z HRMS (ESI) found $[M]^+$ 280.1331, $C_{18}H_{18}NO_2^+$ requires 280.1332.

(D)-1-naphthylalanine methyl ester hydrochloride **(A13**)



^{1}H NMR (600 MHz, $CDCl_3$) δ 8.08 (d, *J* = 8.5 Hz, 1H), 7.93 (d, *J* = 8.1 Hz, 1H), 7.87 (d, *J* = 8.1 Hz, 1H), 7.62 (t, *J* = 7.8 Hz, 1H), 7.54 (t, *J* = 7.6 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 1H), 7.43 (d, *J* = 7.0 Hz, 1H), 4.39 (t, *J* = 7.6 Hz, 1H), 3.78 (dd, *J* = 14.6, 7.0 Hz, 1H), 3.67 (s, 3H), 3.60 (dd, *J* = 14.4, 8.1 Hz, 1H). ^{13}C NMR (151 MHz, Methanol-*d*4) δ 170.56, 135.59, 132.91, 131.46, 130.30, 129.86, 129.28, 127.88, 127.11, 126.59, 123.88, 54.64, 53.33, 34.91. m/z HRMS (ESI) found $[M]^+$ 230.1175, $C_{14}H_{16}NO_2^+$ requires 230.1176.

Synthesis of substrates:

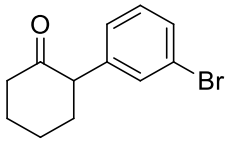


The substrates were synthesized in two ways. For phenyl substituted substrates, the substrates were synthesized in **method A**: Addition of the aryl lithium to the cyclohexene oxide afforded the alcohol, which was oxidized to the ketone by Dess-Martin Oxidation or Swern Oxidation. For cyclohexanone substituted substrates, they were synthesized according to **method B**: Direct α-arylation of the ketone substrates with phenyl iodide catalyzed by $Pd(dba)_2$ and Xantphos to afford the desired products.[5]

Substrates **1a**, **1o** were commercial available (**1o** was used after careful chromatography to remove an isomeric impurity). Substrates **1b**, **1c**, **1d**, **1e**, **1f**, **1g**, **1h**, **1i**, **1j**, **1o**, **1p** and **1q** were synthesized according to **method A**; substrates **1k**, **1l**, **1m** were synthesized according to **method B**.

The ^{1}H NMR of **1b**[6], **1c**[6], **1d**[7], **1e**[8], **1f**[7], **1h**[7], **1k**[9], **1l**[10] and **1m**[11] matched the literature data. Data for the remaining compounds is given below:

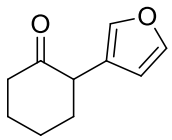
2-(3-bromophenyl)cyclohexanone (**1g**)



^{1}H NMR (600 MHz, $CDCl_3$) δ 7.39 (d, *J* = 7.9 Hz, 1H), 7.29 (s, 1H), 7.20 (t, *J* = 7.8 Hz, 1H), 7.07 (d, *J* = 7.6 Hz, 1H), 3.58 (dd, *J* = 12.5, 5.4 Hz, 1H), 2.53 (dd, *J* = 13.3, 3.5 Hz, 1H), 2.45 (td, *J* = 13.0, 6.0 Hz, 1H), 2.30 – 2.22 (m, 1H), 2.16 (ddt, *J* = 9.9, 6.3, 3.8 Hz, 1H), 2.05 – 1.92 (m, 2H), 1.88 – 1.76 (m, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 209.58, 141.14, 131.74, 130.07,

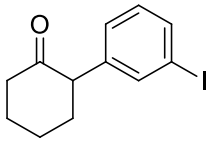
129.94 127.45, 122.48, 57.13, 42.28, 35.22, 27.84, 25.42. m/z HRMS (EI) found $[M]^+$ 252.0153, $C_{12}H_{13}BrO^+$ requires 252.0150.

2-(furan-3-yl)cyclohexanone (**1i**)



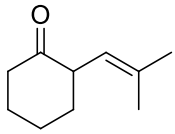
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.38 (s, 1H), 7.34 (s, 1H), 6.29 (s, 1H), 3.53 (dd, *J* = 11.5, 5.4 Hz, 1H), 2.53 – 2.44 (m, 1H), 2.40 (td, *J* = 12.5, 5.9 Hz, 1H), 2.33 – 2.24 (m, 1H), 2.12 – 2.05 (m, 1H), 1.98 – 1.91 (m, 1H), 1.90 – 1.82 (m, 1H), 1.82 – 1.71 (m, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 209.89, 142.73, 139.57, 122.63, 110.69, 48.03, 41.84, 34.67, 27.81, 24.94. m/z HRMS (EI) found $[M]^+$ 164.0841, $C_{10}H_{12}O_2^+$ requires 164.0837.

2-(3-iodophenyl)cyclohexanone (**1j**)



^{1}H NMR (600 MHz, $CDCl_3$) δ 7.59 (d, *J* = 7.7 Hz, 1H), 7.49 (s, 1H), 7.10 (d, *J* = 7.6 Hz, 1H), 7.06 (t, *J* = 7.7 Hz, 1H), 3.54 (dd, *J* = 12.5, 5.4 Hz, 1H), 2.52 (dt, *J* = 14.0, 3.5 Hz, 1H), 2.44 (td, *J* = 12.8, 5.8 Hz, 1H), 2.29 – 2.20 (m, 1H), 2.18 – 2.12 (m, 1H), 2.05 – 1.91 (m, 2H), 1.87 – 1.75 (m, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 209.53, 141.20, 137.59, 135.96, 130.09, 128.05, 94.43, 56.99, 42.24, 35.19, 27.79, 25.39. m/z HRMS (EI) found $[M]^+$ 300.0013, $C_{12}H_{13}IO^+$ requires 300.0011.

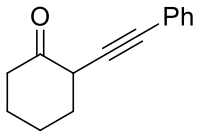
2-(2-methylprop-1-en-1-yl)cyclohexanone (**1o**)



^{1}H NMR (400 MHz, $CDCl_3$) δ 5.30 (dt, *J* = 8.7, 1.4 Hz, 1H), 3.17 (td, *J* = 9.6, 5.7 Hz, 1H), 2.51 – 2.37 (m, 1H), 2.30 (dddd, *J* = 13.5, 11.1, 5.6, 1.3 Hz, 1H), 2.05 – 1.95 (m, 2H), 1.87 (dddd, *J* =

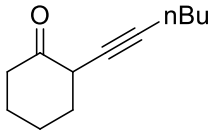
12.3, 8.6, 4.6, 2.5 Hz, 1H), 1.75 (d, J = 1.4 Hz, 3H), 1.78 – 1.67 (m, 2H), 1.59 (d, J = 1.4 Hz, 3H), 1.62 – 1.53 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 211.90, 134.42, 121.81, 50.43, 41.81, 34.95, 27.90, 26.02, 24.47, 18.20. m/z HRMS (EI) found $[M]^+$ 152.1204, $C_{10}H_{16}O^+$ requires 152.1201.

2-(phenylethynyl)cyclohexanone (**1p**)



^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 – 7.39 (m, 2H), 7.34 – 7.26 (m, 3H), 3.54 (ddd, J = 7.8, 5.1, 1.3 Hz, 1H), 2.75 (dt, J = 13.3, 6.5 Hz, 1H), 2.33 (dtd, J = 13.7, 7.0, 1.3 Hz, 1H), 2.26 – 2.16 (m, 1H), 2.13 – 1.99 (m, 2H), 1.96 – 1.86 (m, 2H), 1.81 – 1.67 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 206.76, 131.83, 128.30, 128.20, 123.22, 86.43, 85.34, 44.75, 42.20, 34.60, 27.65, 23.25. m/z HRMS (EI) found $[M]^+$ 198.1048, $C_{14}H_{14}O^+$ requires 198.1045.

2-(hex-1-yn-1-yl)cyclohexanone (**1q**)



^{1}H NMR (600 MHz, $CDCl_3$) δ 3.27 (t, J = 6.2 Hz, 1H), 2.66 (dt, J = 13.1, 6.3 Hz, 1H), 2.30 – 2.18 (m, 3H), 2.13 – 2.04 (m, 1H), 1.99 – 1.80 (m, 4H), 1.65 (dtd, J = 12.7, 8.4, 4.7 Hz, 1H), 1.47 (q, J = 7.3 Hz, 2H), 1.40 (q, J = 7.4 Hz, 2H), 0.90 (t, J = 7.4 Hz, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 207.71, 85.62, 76.81, 44.23, 40.00, 34.88, 31.00, 27.65, 23.21, 22.01, 18.61, 13.68. m/z HRMS (EI) found $[M]^+$ 178.1358, $C_{12}H_{18}O^+$ requires 173.1358.

Synthesis of Products

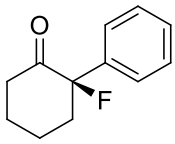
General procedure for asymmetric fluorination:

To the substrate **1** (0.20 mmol) in a 1 dram (15 x 45 mm) vial equipped with an 8 mm magnetic stirrer bar was added toluene (1.0 ml). Subsequently, $Na_2CO_3.H_2O$ (24.8 mg, 0.20 mmol), Selectfluor (95%, 36.0 mg, 0.10 mmol), (D)-amino acid methyl ester hydrochloride salt (0.02 mmol) and **(*R*)-C$_8$-TRIP** (5.0 mg, 0.005 mmol) were added. The vial was capped with a screw cap and stirred rapidly for 40 h at room temperature, the vial standing on the stirrer plate. During this time, the vial was shaken every 10 hours to agitate material adhered to the sides of the vial. After this time, the reaction was diluted with ethyl acetate and poured into satd. $NaHCO_3$ solution. After extraction, the aqueous layer was extracted with further EtOAc and the combined organics were, dried (Na_2SO_4) and evaporated *in vacuo*. The crude residue was purified by flash column chromatography. It is notable that fast and efficient stirring should be maintained in order to achieve reliable results.

Treatment of reagents: Selectfluor® (Sigma Aldrich, 95%) was ground in a pestle and mortar and dried at 80℃ under high vacuum for 30 minutes. $Na_2CO_3.H_2O$ was obtained from J. T. Baker (99.7%) and ground in a pestle without further treatment.

The relevant racemic products were synthesized in the same procedure expect **AP** (0.005 mmol) and glycine methyl ester hydrochloride salt (0.02 mmol) was used as catalysts.

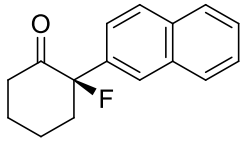
(*R*)-2-fluoro-2-phenylcyclohexanone (**2a**)



Reaction carried out according to general procedure using **1a** (35 mg, 0.20 mmol) as substrate and **A13** (5.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (7 : 3, Hexane : DCM) gave the title compound **2a** as an oil (11.7 mg, 0.0609 mmol, 30% based on ketone, 61% based on Selectfluor) with recovered **1a** (14.1 mg, 40%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 – 7.35 (m, 5H), 2.75 (dq, *J* = 12.5, 6.0 Hz, 1H), 2.64 (dddd, *J* = 19.3, 14.3, 7.7, 4.0 Hz, 1H), 2.40 (ddd, *J* = 13.7, 8.0, 6.1 Hz, 1H), 2.30 (tdd, *J* = 13.3, 8.6, 4.1 Hz, 1H), 2.13 –

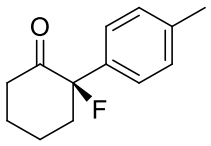
2.01 (m, 1H), 2.01 – 1.89 (m, 2H), 1.81 (ddq, *J* = 12.8, 8.5, 4.2 Hz, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -140.90 (t, *J* = 16.3 Hz).^{13}C NMR (151 MHz, $CDCl_3$) δ 206.33 (d, *J* = 22.2 Hz), 136.13 (d, *J* = 21.6 Hz), 129.12 (d, *J* = 2.6 Hz), 128.70 (s), 126.41 (d, *J* = 6.2 Hz), 98.29 (d, *J* = 184.0 Hz), 39.97 (s), 37.91 (d, *J* = 22.7 Hz), 27.57 (s), 22.25 (d, *J* = 6.9 Hz). m/z HRMS (EI) found $[M]^+$ 192.0948, $C_{12}H_{13}FO^+$ requires 192.0950. HPLC (Chiralpak IA column, 99:1 hexanes/ isopropanol, 1 ml/min; tr= 15.1 min (major), 16.6 min (minor); 94% ee. Recovered **1a:** HPLC (Chiralpak IA column, 98:2 hexanes/ isopropanol, 1 ml/min; tr= 10.8 min (major), 11.3 min (minor); 4% ee.

(*R*)-2-fluoro-2-(naphthalen-2-yl)cyclohexanone (**2b**)



Reaction carried out according to general procedure using **1b** (44.8 mg, 0.20 mmol) as substrate and **A13** (5.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (7 : 3, Hexane : DCM) gave the title compound **2b** as an oil (13.8 mg, 0.0570 mmol, 29% based on ketone, 57% based on Selectfluor). ^{1}H NMR (600 MHz, CDCl3) δ 7.85-7.91 (m, 4 H), 7.52 (m, 2 H), 7.47 (d, *J* = 8.6 Hz, 1H), 2.79 (m, 2 H), 2.35-2.46 (m, 2 H), 2.11 (m, 1 H), 1.98 (m, 2 H), 1.89 (m, 1 H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -140.37 (t, *J* = 16.3 Hz). ^{13}C NMR (151 MHz, $CDCl_3$) δ 206.44 (d, *J* = 22.3 Hz), 133.69 (d, *J* = 21.5 Hz), 133.49 (d, *J* = 1.8 Hz), 133.10 (s), 128.56(s), 127.77 (s), 127.00 (s), 126.59(s), 125.98 (d, *J* = 7.5 Hz), 123.96 (d, *J* = 5.1 Hz), 98.51 (d, *J* = 184.0 Hz), 40.12 (s), 38.09 (d, *J* = 22.5 Hz), 27.67 (s), 22.42 (d, *J* = 6.6 Hz). m/z HRMS (EI) found $[M]^+$ 242.1111, $C_{16}H_{15}FO^+$ requires 242.1107. HPLC (Chiralpak IC column, 95:5 hexanes/ isopropanol, 1 ml/min; tr= 15.4 min (major), 18.5 min (minor); 91% ee.

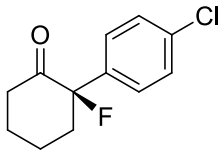
(*R*)-2-fluoro-2-(p-tolyl)cyclohexanone (**2c**)



Reaction carried out according to general procedure using **1c** (37.6 mg, 0.20 mmol) as substrate and **A13** (5.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (7 : 3,

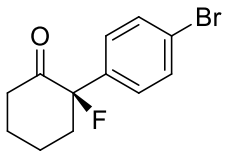
Hexane : DCM) gave the title compound **2c** as an oil (12.8 mg, 0.0621 mmol, 31% based on ketone, 62% based on Selectfluor). ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.29 (d, *J* = 7.8 Hz, 2H), 7.23 (d, *J* = 7.9 Hz, 2H), 2.68 (m, 2 H), 2.40 (m, 1 H), 2.37 (s, 3 H), 2.26 (tdd, *J* = 13.5, 9.4, 3.9 Hz, 1H), 2.03 (m, 1 H), 1.92 (m, 2 H), 1.79 (dtt, *J* = 13.1, 8.6, 4.4 Hz, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -138.44 (t, *J* = 15.0 Hz). ^{13}C NMR (151 MHz, $CDCl_3$) δ 206.58 (d, *J* = 21.8 Hz), 139.23 (d, *J* = 2.8 Hz), 133.15 (d, *J* = 21.8 Hz), 129.53 (s), 126.50 (d, *J* = 5.7 Hz), 98.28 (d, *J* = 184.1 Hz), 40.06 (s), 37.74 (d, *J* = 22.7 Hz), 27.65 (s), 22.47 (d, *J* = 7.2 Hz), 21.29 (s). m/z HRMS (EI) found $[M]^+$ 206.1111, $C_{13}H_{15}FO^+$ requires 206.1107. HPLC (Chiralpak IC column, 96:4 hexanes/ isopropanol, 1 ml/min; tr= 14.8 min (major), 18.3 min (minor); 90% ee.

(*R*)-2-(4-chlorophenyl)-2-fluorocyclohexanone (**2d**)



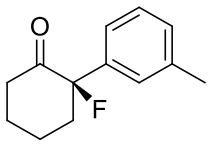
Reaction carried out according to general procedure using **1d** (41.6 mg, 0.20 mmol) as substrate and **A13** (5.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (7 : 3, Hexane : DCM) gave the title compound **2d** as white solid (14.2 mg, 0.0628 mmol, 31% based on ketone, 63% based on selectfluor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 (dd, *J* = 8.6, 1.1 Hz, 2H), 7.31 (dd, *J* = 8.6, 1.1 Hz, 2H), 2.81 (ddt, *J* = 14.3, 9.5, 5.5 Hz, 1H), 2.59 – 2.24 (m, 3H), 2.14 – 1.96 (m, 2H), 1.97 – 1.84 (m, 1H), 1.79 (m, 1 H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -144.91 (m). ^{13}C NMR (151 MHz, $CDCl_3$) δ 205.78 (d, *J* = 23.4 Hz), 135.12 (d, *J* = 25.0 Hz), 135.05 (s), 128.82 (s), 127.76 (d, *J* = 7.0 Hz), 97.96 (d, *J* = 183.3 Hz), 39.80 (s), 38.57 (d, *J* = 22.9 Hz), 27.63 (s), 21.90 (d, *J* = 5.8 Hz). m/z HRMS (EI) found $[M]^+$ 226.0564, $C_{12}H_{12}ClFO^+$ requires 226.0561. HPLC (Chiralpak IC column, 95:5 hexanes/ isopropanol, 1 ml/min; tr= 6.6 min (major), 7.0 min (minor); 90% ee.

(*R*)-2-(4-bromophenyl)-2-fluorocyclohexanone (**2e**)



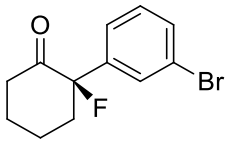
Reaction carried out according to general procedure using **1e** (50.4 mg, 0.20 mmol) as substrate and **A2** (4.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (7 : 3, Hexane : DCM) gave the title compound **2e** as white solid (16.5 mg, 0.0611 mmol, 31% based on ketone, 61% based on Selectfluor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, *J* = 8.0 Hz, 1H), 7.24 (dd, *J* = 8.6, 1.1 Hz, 1H), 2.82 (ddt, *J* = 14.5, 9.2, 5.5 Hz, 1H), 2.56 – 2.37 (m, 2H), 2.32 (ddddd, *J* = 14.3, 12.4, 7.1, 3.9, 1.7 Hz, 1H), 2.15 – 1.97 (m, 2H), 1.90 (dddt, *J* = 10.4, 9.0, 6.0, 2.9 Hz, 1H), 1.79 (dtd, *J* = 13.8, 7.0, 3.7 Hz, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -145.56 (m). ^{13}C NMR (151 MHz, $CDCl_3$) δ 205.73 (d, *J* = 23.6 Hz), 135.65 (d, *J* = 21.9 Hz), 131.77 (s), 128.03 (d, *J* = 7.1 Hz), 123.27 (d, *J* = 2.7 Hz), 98.02 (d, *J* = 183.3 Hz), 39.78 (s), 38.57 (d, *J* = 22.8 Hz), 27.63, 21.87 (d, *J* = 5.7 Hz). m/z HRMS (EI) found $[M]^+$ 270.0063, $C_{12}H_{12}BrFO^+$ requires 270.0056. HPLC (Chiralpak IC column, 95:5 hexanes/ isopropanol, 1 ml/min; tr= 9.5 min (major), 10.2 min (minor); 83% ee.

(*R*)-2-fluoro-2-(m-tolyl)cyclohexanone (**2f**)



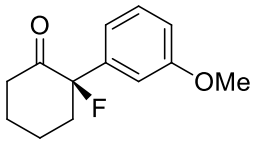
Reaction carried out according to general procedure using **1f** (37.6 mg, 0.20 mmol) as substrate and **A13** (5.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (7 : 3, Hexane : DCM) gave the title compound **2f** as an oil (12.2 mg, 0.0592 mmol, 30% based on ketone, 59% based on Selectfluor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (dd, *J* = 8.6, 7.5 Hz, 1H), 7.22 – 7.18 (m, 3H), 2.79 – 2.55 (m, 2H), 2.39 (m, 1 H), 2.37 (s, 3 H), 2.27 (dddd, *J* = 13.5, 12.2, 9.3, 4.1 Hz, 1H), 2.05 (dddt, *J* = 12.1, 7.7, 4.8, 1.4 Hz, 1H), 1.99 – 1.89 (m, 2H), 1.82 (ddt, *J* = 13.0, 10.3, 3.8 Hz, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -139.28 (t, *J* = 13.3 Hz). ^{13}C NMR (151 MHz, $CDCl_3$) δ 206.45 (d, *J* = 21.5 Hz), 138.54 (s), 136.10 (d, *J* = 21.5 Hz), 129.99 (d, *J* = 2.7 Hz), 128.68 (s), 127.22 (d, *J* = 6.0 Hz), 123.50 (d, *J* = 5.9 Hz), 98.37 (d, *J* = 184.0 Hz), 40.09 (s), 37.87 (d, *J* = 22.6 Hz), 27.64 (s), 22.44 (d, *J* = 7.0 Hz), 21.64 (s). m/z HRMS (EI) found $[M]^+$ 206.1107, $C_{13}H_{15}FO^+$ requires 206.1107. HPLC (Chiralpak IB column, 99:1 hexanes/ isopropanol, 1 ml/min; tr= 9.2 min (minor), 10.0 min (major); 92% ee.

(*R*)-2-(3-bromophenyl)-2-fluorocyclohexanone (**2g**)



Reaction carried out according to general procedure using **1g** (50.4 mg, 0.20 mmol) as substrate and **A2** (4.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (7 : 3, Hexane : DCM) gave the title compound **2g** as white solid (16.7 mg, 0.0619 mmol, 31% based on ketone, 62% based on selectfluor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 – 7.48 (m, 2H), 7.31 – 7.27 (m, 2H), 2.91 – 2.77 (m, 1H), 2.55 – 2.25 (m, 3H), 2.14 – 1.98 (m, 2H), 1.91 (tdd, *J* = 13.4, 6.6, 3.5 Hz, 1H), 1.80 (dtd, *J* = 13.3, 6.7, 3.5 Hz, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -146.31 (m). ^{13}C NMR (151 MHz, $CDCl_3$) δ 205.49 (d, *J* = 23.5 Hz), 138.89 (d, *J* = 21.9 Hz), 132.00 (d, *J* = 2.1 Hz), 130.10 (s), 129.35 (d, *J* = 7.9 Hz), 124.98 (d, *J* = 7.0 Hz), 122.75 (s), 97.82 (d, *J* = 183.8 Hz), 39.78 (s), 38.68 (d, *J* = 22.7 Hz), 27.60 (s), 21.80 (d, *J* = 5.6 Hz).). m/z HRMS (EI) found $[M]^+$ 270.0060, $C_{12}H_{12}BrFO^+$ requires 270.0056. HPLC (Chiralpak IC column, 98:2 hexanes/ isopropanol, 1 ml/min; tr= 9.6 min (major), 10.7 min (minor); 93% ee.

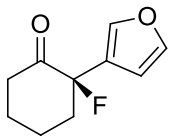
(*R*)-2-fluoro-2-(3-methoxyphenyl)cyclohexanone (**2h**)



Reaction carried out according to general procedure using **1h** (40.8 mg, 0.20 mmol) as substrate and **A13** (5.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (4 : 6, Hexane : DCM) gave the title compound **2h** as an oil (16.2 mg, 0.0730 mmol, 36% based on ketone, 73% based on selectfluor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 (tt, *J* = 7.8, 1.0 Hz, 1H), 6.98 (m, 1H), 6.96 – 6.88 (m, 2H), 3.81 (s, 3H), 2.78 – 2.68 (m, 1H), 2.63 (tdd, *J* = 14.2, 7.4, 3.5 Hz, 1H), 2.40 (dt, *J* = 13.8, 7.2 Hz, 1H), 2.35 – 2.21 (m, 1H), 2.11 – 2.00 (m, 1H), 2.00 – 1.89 (m, 2H), 1.88 – 1.76 (m, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -140.55 (t, *J* = 13.8 Hz). ^{13}C NMR (151 MHz, $CDCl_3$) δ 206.15 (d, *J* = 22.1 Hz), 159.89 (s), 137.70 (d, *J* = 21.6 Hz), 129.79 (s), 118.72 (d, *J* = 6.0 Hz), 114.53 (d, *J* = 2.4 Hz), 112.38 (d, *J* = 6.7 Hz), 98.21 (d, *J* = 184.3 Hz), 55.41 (s), 40.00 (s), 37.98 (d, *J* = 22.5 Hz), 27.55 (s), 22.35 (d, *J* = 6.9 Hz). m/z HRMS (EI)

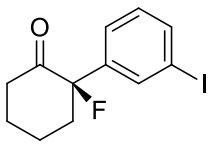
found $[M]^+$ 222.1060, $C_{12}H_{15}FO^+$ requires 222.1056. HPLC (Chiralpak IC column, 94:6 hexanes/ isopropanol, 1 ml/min; tr= 17.4 min (major), 19.4 min (minor); 93% ee.

(*R*)-2-fluoro-2-(furan-3-yl)cyclohexanone (**2i**)



Reaction was carried out according to general procedure using **1i** (32.8 mg, 0.20 mmol) as substrate and **A12** (6.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (5 : 5, Hexane : DCM) gave the title compound **2i** as an oil (11.3 mg, 0.0621 mmol, 31% based on ketone, 62% based on selectfluor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 3.4 Hz, 1H), 7.45 (s, 1H), 6.42 (d, *J* = 2.1 Hz, 1H), 2.75 – 2.63 (m, 1H), 2.54 – 2.39 (m, 2H), 2.30 (tdd, *J* = 13.7, 9.7, 4.1 Hz, 1H), 2.08 – 1.83 (m, 3H), 1.77 (ddt, *J* = 13.5, 8.9, 4.4 Hz, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -138.12 (t, *J* = 13.8 Hz). ^{13}C NMR (151 MHz, $CDCl_3$) δ 205.49 (d, *J* = 21.7 Hz), 143.82 (s), 141.29 (d, *J* = 8.3 Hz), 122.79 (d, *J* = 25.2 Hz), 94.20 (d, *J* = 181.4 Hz), 39.57 (s), 38.44 (d, *J* = 22.9 Hz), 27.34 (s), 22.37 (d, *J* = 6.6 Hz). m/z HRMS (EI) found $[M]^+$ 182.0742, $C_{10}H_{11}FO_2^+$ requires 182.0743 HPLC (Chiralpak IA column, 98:2 hexanes/ isopropanol, 1 ml/min; tr= 9.5 min (major), 11.0 min (minor); 89% ee.

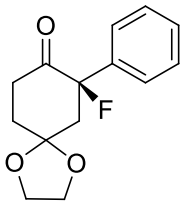
(*R*)-2-fluoro-2-(3-iodophenyl)cyclohexanone (**2j**)



Reaction carried out according to general procedure using **1j** (60.0 mg, 0.20 mmol) as substrate and **A2** (4.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (7 : 3, Hexane : DCM) gave the title compound **2j** as white solid (17.8 mg, 0.0560 mmol, 28% based on ketone, 56% based on selectfluor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.75 – 7.67 (m, 2H), 7.32 (d, *J* = 7.9 Hz, 1H), 7.14 (t, *J* = 7.9 Hz, 1H), 2.83 (ddt, *J* = 14.5, 9.6, 5.5 Hz, 1H), 2.53 – 2.37 (m, 2H), 2.37 – 2.26 (m, 1H), 2.14 – 1.97 (m, 2H), 1.96 – 1.85 (m, 1H), 1.85 – 1.74 (m, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -146.10 (m). ^{13}C NMR (151 MHz, $CDCl_3$) δ 205.55 (d, *J* = 23.6 Hz),

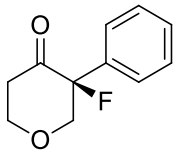
138.86 (d, J = 21.7 Hz), 137.98 (d, J = 2.1 Hz), 135.15 (d, J = 7.8 Hz), 130.23 (s), 125.61 (d, J = 6.9 Hz), 97.69 (d, J = 184.0 Hz), 94.42 (s), 39.80 (s), 38.63 (d, J = 22.8 Hz), 27.61 (s), 21.82 (d, J = 5.6 Hz).). m/z HRMS (EI) found $[M]^+$ 317.9912, $C_{12}H_{12}IFO^+$ requires 317.9917. HPLC (Chiralpak IC column, 96:4 hexanes/ isopropanol, 1 ml/min; tr= 8.0 min (major), 8.6 min (minor); 90% ee.

(*R*)-7-fluoro-7-phenyl-1,4-dioxaspiro[4.5]decan-8-one (**2k**)



Reaction was carried out according to general procedure using **1k** (46.4 mg, 0.20 mmol) as substrate and **A13** (5.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (2: 8, Hexane : DCM) gave the title compound **2k** as an oil (15.8 mg, 0.0632 mmol, 32% based on ketone, 63% based on selectfluor). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.35 (m, 5H), 4.21 – 3.95 (m, 4H), 2.95 – 2.77 (m, 2H), 2.67 – 2.52 (m, 2H), 2.26 – 2.04 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -139.16 (t, J = 20.4 Hz).^{13}C NMR (151 MHz, $CDCl_3$) δ 204.45 (d, J = 22.3 Hz), 136.38 (d, J = 21.9 Hz), 129.12 (d, J = 2.4 Hz), 128.45 (s), 126.30 (d, J = 7.3 Hz), 107.01 (d, J = 6.3 Hz), 96.34 (d, J = 184.0 Hz), 64.98(s), 64.74 (s), 53.56 (s), 45.79 (d, J = 22.7 Hz), 35.13 (d, J = 77.7 Hz). m/z HRMS (EI) found $[M]^+$ 250.1008, $C_{14}H_{15}FO_3^+$ requires 250.1005. HPLC (Chiralpak IA column, 97:3 hexanes/ isopropanol, 1 ml/min; tr= 14.2 min (major), 20.5 min (minor); 92% ee.

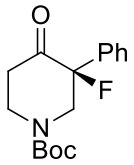
(*S*)-3-fluoro-3-phenyldihydro-2H-pyran-4(3H)-one (**2l**)



Reaction was carried out according to general procedure using **1l** (36.2 mg, 0.20 mmol) as substrate and **A13** (5.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (3: 7, Hexane : DCM) gave the title compound **2l** as an oil (10.7 mg, 0.0552

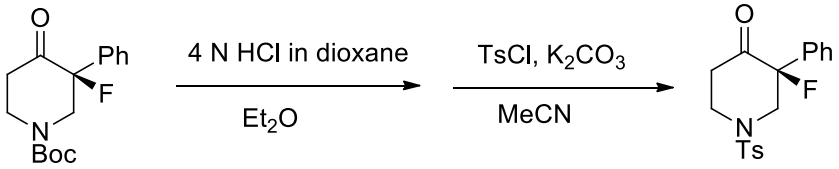
mmol, 28% based on ketone, 55% based on selectfluor). ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.62 (d, *J* = 7.4 Hz, 2H), 7.46 – 7.37 (m, 3H), 4.58 (dd, *J* = 12.1, 5.7 Hz, 1H), 4.25 (dt, *J* = 10.3, 4.5 Hz, 1H), 4.01 – 3.89 (m, 2H), 2.71 (ddd, *J* = 16.1, 10.2, 6.4 Hz, 1H), 2.63 (dd, *J* = 14.9, 4.0 Hz, 1H).). ^{19}F NMR (376 MHz, $CDCl_3$) δ -155.69 (m). ^{13}C NMR (151 MHz, $CDCl_3$) δ 201.43 (d, *J* = 19.7 Hz), 135.08 (d, *J* = 22.1 Hz), 129.53 (d, *J* = 2.0 Hz), 128.89 (s), 126.31 (d, *J* = 6.6 Hz), 94.94 (d, *J* = 189.8 Hz), 74.37 (d, *J* = 29.5 Hz), 68.71 (s), 40.90 (s). m/z HRMS (EI) found $[M]^+$ 194.0744, $C_{11}H_{11}FO_2^+$ requires 194.0743. HPLC (Chiralpak IC column, 95:5 hexanes/ isopropanol, 1 ml/min; tr= 9.9 min (major), 10.7 min (minor); 86% ee.

(*S*)-tert-butyl 3-fluoro-4-oxo-3-phenylpiperidine-1-carboxylate (**1m**)



Reaction was carried out according to general procedure using **1m** (55.0 mg, 0.20 mmol) as substrate and **A13** (5.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (1: 9, Hexane : DCM) gave the title compound **1m** as two rotamers (14.1 mg, 0.048 mmol, 24% based on ketone, 48% based on selectfluor) without characterization.

(*S*)-3-fluoro-3-phenyl-1-tosylpiperidin-4-one (**1m'**)



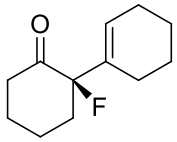
1m **1m'**

To a solution of **1m** (14.1 mg, 0.048 mmol) in Et_2O (1 mL) was added 4 N HCl in dioxane (1 mL). After consumption of the S.M. by TLC, the mixture was concentrated under vacuum to afford the product as oil.

To the solution of this oil in MeCN (2 ml) was added TsCl (18 mg, 0.096 mmol) and K_2CO_3 (20 mg, 0.144 mmol). After stirring overnight, the mixture was diluted with EA and washed with brine. The organic layer was then dried with Na_2SO_4, filtered and concentrated *in vacuo* to afford

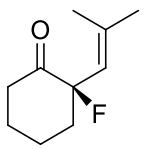
a residue, which was purified by column chromatography (2: 8, Hexane : DCM) to give the title compound **1m'** as an oil (11.3 mg, 68%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.74 – 7.63 (m, 4H), 7.48 – 7.42 (m, 3H), 7.39 (d, *J* = 8.0 Hz, 2H), 4.56 (ddd, *J* = 12.3, 4.8, 2.3 Hz, 1H), 3.94 (ddt, *J* = 12.0, 5.9, 2.9 Hz, 1H), 3.05 (t, *J* = 11.4 Hz, 1H), 2.90 (td, *J* = 11.4, 3.6 Hz, 1H), 2.70 (ddd, *J* = 14.3, 11.2, 6.1 Hz, 1H), 2.60 – 2.51 (m, 1H), 2.46 (s, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -146.46 (m). ^{13}C NMR (151 MHz, $CDCl_3$) δ 201.08 (d, *J* = 19.8 Hz), 144.80 (s), 134.07 (d, *J* = 21.5 Hz), 132.39 (s), 130.26 (s), 130.02 (d, *J* = 2.7 Hz), 129.17 (s), 127.84 (s), 126.77 (d, *J* = 5.6 Hz), 94.05 (d, *J* = 189.6 Hz), 53.71 (d, *J* = 32.9 Hz), 46.77 (s), 38.32 (s), 21.74 (s). m/z HRMS (EI) found $[M]^+$ 347.0997, $C_{18}H_{18}FNO_3S^+$ requires 347.0091. HPLC (Chiralpak IA column, 95:5 hexanes/ isopropanol, 1 ml/min; tr= 26.3 min (minor), 28.1 min (major); 86% ee.

(*R*)-1-fluoro-[1,1'-bi(cyclohexan)]-1'-en-2-one (**2n**)



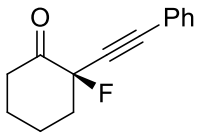
Reaction was carried out according to general procedure using **1n** (35.6 mg, 0.20 mmol) as substrate and **A13** (5.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (6: 4, Hexane : DCM) gave the title compound **2n** as an oil (10.2 mg, 0.0520 mmol, 26% based on ketone, 52% based on selectfluor). ^{1}H NMR (600 MHz, $CDCl_3$) δ 5.91 (d, *J* = 4.2 Hz, 1H), 2.56 (dt, *J* = 14.2, 5.0 Hz, 1H), 2.49 – 2.39 (m, 2H), 2.18 – 2.02 (m, 3H), 1.97 – 1.81 (m, 4H), 1.81 – 1.72 (m, 1H), 1.72 – 1.62 (m, 3H), 1.61 – 1.54 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -144.37 (s). ^{13}C NMR (151 MHz, $CDCl_3$) δ 207.65 (d, *J* = 19.9 Hz), 133.75 (d, *J* = 19.9 Hz), 128.95 (d, *J* = 8.9 Hz), 99.57 (d, *J* = 182.5 Hz), 40.48 (s), 35.82 (d, *J* = 22.8 Hz), 27.54 (s), 25.54 (d, *J* = 1.5 Hz), 24.04 (d, *J* = 2.0 Hz), 22.74 (d, *J* = 8.3 Hz), 22.55 (s), 21.96 (s). m/z HRMS (EI) found $[M]^+$ 196.1207, $C_{12}H_{17}FO^+$ requires 196.1203. HPLC (Chiralpak IC column, 95:5 hexanes/ isopropanol, 1 ml/min; tr= 10.4 min (minor), 11.5 min (major); 86% ee.

(*R*)-2-fluoro-2-(2-methylprop-1-en-1-yl)cyclohexanone (**2o**)



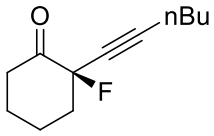
Reaction was carried out according to general procedure using **1o** (30.4 mg, 0.20 mmol) as substrate and **A12** (6.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (300: 1, Toluene : EA) gave the title compound **2o** as an **volatile liquid** (11.9 mg, 0.0700 mmol, 35% based on ketone, 70% based on selectfluor). ^{1}H NMR (600 MHz, $CDCl_3$) δ 5.41 (d, *J* = 13.5 Hz, 1H), 2.52 – 2.43 (m, 2H), 2.21 (td, *J* = 8.2, 6.7, 3.8 Hz, 1H), 2.04 – 1.92 (m, 2H), 1.93 – 1.86 (m, 1H), 1.79 (d, *J* = 4.4 Hz, 3H), 1.76 – 1.67 (m, 5H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -145.27 (s). ^{13}C NMR (125 MHz, $CDCl_3$) δ 206.78 (d, *J* = 19.9 Hz), 144.25 (d, *J* = 3.8 Hz), 120.78 (dd, *J* = 18.0, 2.0 Hz), 96.85 (d, *J* = 190.0 Hz), 40.68 (d, *J* = 21.4 Hz), 39.99 (s), 27.80 (s), 26.98 (d, *J* = 1.8 Hz), 22.52 (d, *J* = 8.7 Hz), 19.38 (d, *J* = 2.3 Hz). m/z HRMS (EI) found $[M]^+$ 170.1107, $C_{10}H_{15}FO^+$ requires 170.1107. HPLC (Chiralpak IA column, 99.5:0.5 hexanes/ isopropanol, 1 ml/min; tr= 13.4 min (major), 15.6 min (minor); 85% ee.

(*R*)-2-fluoro-2-(phenylethynyl)cyclohexanone (**2p**)



Reaction was carried out according to general procedure using **1p** (39.6 mg, 0.20 mmol) as substrate and **A12** (6.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (6: 4, Hexane : DCM) gave the title compound **2p** as an oil (18.6 mg, 0.0861 mmol, 43% based on ketone, 86% based on Selectfluor). ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47 (d, *J* = 6.8 Hz, 2H), 7.41 – 7.30 (m, 3H), 2.85 (td, *J* = 13.3, 6.0 Hz, 1H), 2.63 – 2.47 (m, 2H), 2.16 – 2.04 (m, 3H), 2.04 – 1.95 (m, 2H), 1.78 – 1.67 (m, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -145.56 (s). ^{13}C NMR (151 MHz, $CDCl_3$) δ 201.66 (d, *J* = 18.9 Hz), 132.06 (d, *J* = 2.5 Hz), 129.61 (s), 128.55 (s), 121.19 (d, *J* = 3.3 Hz), 92.10 (d, *J* = 189.1 Hz), 91.46 (d, *J* = 9.0 Hz), 83.44 (d, *J* = 30.8 Hz), 40.49 (d, *J* = 22.6 Hz), 38.92 (s), 27.14 (s), 22.92 (d, *J* = 7.5 Hz). m/z HRMS (EI) found $[M]^+$ 216.0954, $C_{14}H_{13}FO^+$ requires 216.0950. HPLC (Chiralpak IC column, 95:5 hexanes/ isopropanol, 1 ml/min; tr= 12.0 min (major), 12.6 min (minor); 78% ee.

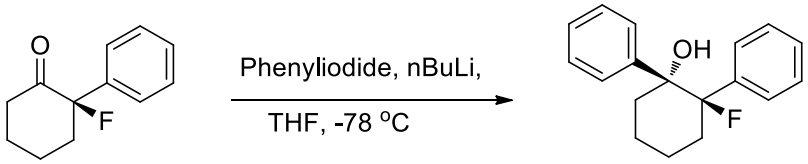
(*R*)-2-fluoro-2-(hex-1-yn-1-yl)cyclohexanone (**2q**)



Reaction was carried out according to general procedure using **1q** (35.6 mg, 0.20 mmol) as substrate and **A12** (6.3 mg, 0.02 mmol) as amine catalyst. Purification by column chromatography (6: 4, Hexane : DCM) gave the title compound **2q** as an oil (15.1 mg, 0.077mmol, 39% based on ketone, 77% based on Selectfluor). ^{1}H NMR (600 MHz, $CDCl_3$) δ 2.77 (td, *J* = 13.4, 6.0 Hz, 1H), 2.49 (dt, *J* = 13.9, 4.2 Hz, 1H), 2.37 (td, *J* = 8.2, 6.3, 3.4 Hz, 1H), 2.28 (q, *J* = 6.8 Hz, 2H), 2.06 – 1.94 (m, 2H), 1.94 – 1.87 (m, 2H), 1.71 – 1.60 (m, 1H), 1.56 – 1.47 (m, 2H), 1.44 – 1.35 (m, 2H), 0.91 (t, *J* = 7.4 Hz, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -144.57 (s). ^{13}C NMR (151 MHz, $CDCl_3$) δ 202.35 (d, *J* = 18.8 Hz), 93.24 (d, *J* = 9.0 Hz), 92.00 (d, *J* = 187.3 Hz), 75.28 (d, *J* = 30.7 Hz), 40.58 (d, *J* = 22.8 Hz), 38.76 (s), 30.29 (d, *J* = 2.3 Hz), 27.13 (s), 22.92 (d, *J* = 7.5 Hz), 22.05 (s), 18.63 (d, *J* = 2.8 Hz), 13.63 (s). m/z HRMS (EI) found $[M]^+$ 196.1265, $C_{12}H_{17}FO^+$ requires 196.1263. HPLC (Chiralpak IA column, 99.9: 0.01 hexanes/ isopropanol, 1 ml/min; tr= 13.5 min (major), 14.7 min (minor); 77% ee.

Functionalization of product:

(*1R,2R*)-2-fluoro-1,2-diphenylcyclohexanol (**3a**)

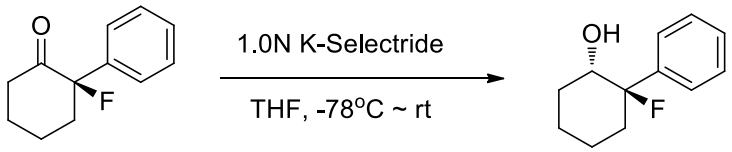


2a, 94% ee **3a,** 94% ee

To a solution of phenyliodide (61 uL, 0.547 mmol) in THF (2 mL) was added nBuLi (2.5 N solution in hexane, 219 uL, 0.547 mmol) at -78 ℃. After stirring for 1 h at this temperature, a solution of **2a** (35 mg, 0.182 mmol) in THF (0.5 mL) was added to the mixture. After stirring for another 2 h at this temperature, the mixture was quenched by saturated NH_4Cl solution. The mixture was extracted with Et_2O for three times. The combined organic layer was then washed with brine, filtered, concentrated *in vacuo* to afford a residue, which was purified by column chromatography (7 :3, Hexane : DCM) to afford **3a** as a white solid (40 mg, 81%). ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.18 – 7.08 (m, 8H), 7.02 (dd, *J* = 7.5, 1.7 Hz, 2H),

2.78 – 2.53 (m, 2H), 2.01 – 1.88 (m, 3H), 1.83 – 1.69 (m, 4H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -161.94 (dd, *J* = 41.2, 7.2 Hz). ^{13}C NMR (151 MHz, $CDCl_3$) δ 143.82 (d, *J* = 1.4 Hz), 140.93 (d, *J* = 21.9 Hz), 127.32 (s), 127.30 (s), 127.19 (d, *J* = 1.7 Hz), 127.04 (s), 126.44 (d, *J* = 3.0 Hz), 126.01 (d, *J* = 10.0 Hz), 97.83 (d, *J* = 180.2 Hz), 75.90 (d, *J* = 29.5 Hz), 35.51, 33.01 (d, *J* = 21.4 Hz), 20.93 (d, *J* = 2.9 Hz), 20.65 (s). m/z HRMS (EI) found $[M]^+$ 270.1416, $C_{18}H_{19}FO^+$ requires 270.1420. HPLC (Chiralpak IA column, 99:1 hexanes/ isopropanol, 1 ml/min; tr= 23.0 min (minor), 25.8 min (major); 94% ee.

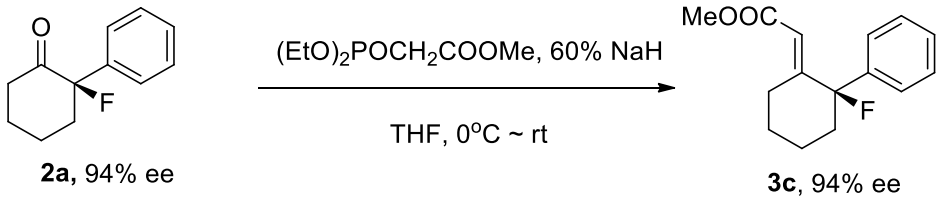
(*1S,2R*)-2-fluoro-2-phenylcyclohexanol (**3b**)



2a, 94% ee **3b**, 94% ee

To a solution of **2a** (20 mg, 0.104 mmol) in THF (2 mL) was added K-Selectride (1.0 N solution in THF, 156 uL, 0.156 mmol) at -78 ℃. After slowly warming to rt and stirring overnight, the mixture was quenched with 1 N HCl solution. The mixture was extracted with Et_2O for three times. The combined organic layer was then washed with brine, filtered, concentrated *in vacuo* to afford a residue, which was purified by column chromatography (5 :5, Hexane : DCM) to afford **3b** as an oil (14.0 mg, 69%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, *J* = 7.3 Hz, 2H), 7.40 (t, *J* = 7.5 Hz, 2H), 7.34 (t, *J* = 7.2 Hz, 1H), 3.85 (s, 1H), 2.38 (dddd, *J* = 42.5, 14.0, 12.0, 4.8 Hz, 1H), 2.10 – 1.98 (m, 1H), 1.97 – 1.80 (m, 2H), 1.80 – 1.61 (m, 3H), 1.59 – 1.49 (m, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -155.11 (d, *J* = 42.6 Hz). ^{13}C NMR (151 MHz, $CDCl_3$) δ 142.57 (d, *J* = 21.7 Hz), 128.55 (s), 128.27 (d, *J* = 1.9 Hz), 125.60 (d, *J* = 8.4 Hz), 95.94 (d, *J* = 174.1 Hz), 71.46 (d, *J* = 34.9 Hz), 29.66 (d, *J* = 20.9 Hz), 28.94 (s), 21.07 (d, *J* = 2.8 Hz), 18.65 (s). m/z HRMS (EI) found $[M]^+$ 194.1112, $C_{12}H_{15}FO^+$ requires 194.1110. HPLC (Chiralpak IA column, 98:2 hexanes/ isopropanol, 1 ml/min; tr= 16.9 min (major), 19.0 min (minor); 94% ee.

(*S,E*)-methyl 2-(2-fluoro-2-phenylcyclohexylidene)acetate (**3c**)

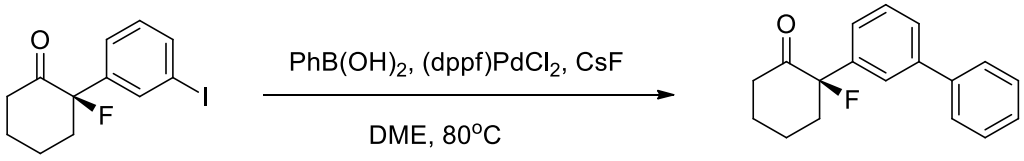


2a, 94% ee

3c, 94% ee

To a solution of $(EtO)_2POCH_2COOMe$ (43 ul, 0.234 mmol) in THF was add NaH (60%, 13 mg, 0.234 mmol) at 0 ℃. After stirring for 0.5 h at this temperature, a solution of **2a** (13.0 mg, 0.0678 mmol) in THF (0.5 mL) was added. After stirring for another 2 h, the mixture was quenched with saturated NH_4Cl solution. The mixture was extracted with Et_2O for three times. The combined organic layer was then washed with brine, filtered, concentrated *in vacuo* to afford a residue, which was purified by column chromatography (25 :1, Hexane : EA) to afford **3c** as an oil (15.0 mg, 89%). ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.44 (d, *J* = 8.2 Hz, 2H), 7.40 (t, *J* = 7.5 Hz, 2H), 7.38 – 7.32 (m, 1H), 5.87 (s, 1H), 3.71 (s, 3H), 3.39 (ddt, *J* = 13.3, 6.3, 3.0 Hz, 1H), 2.63 (dddd, *J* = 17.2, 13.5, 6.9, 3.6 Hz, 1H), 2.46 (ddd, *J* = 13.9, 9.2, 4.6 Hz, 1H), 2.10 (dtd, *J* = 14.0, 10.0, 4.1 Hz, 1H), 1.97 – 1.89 (m, 1H), 1.77 – 1.58 (m, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.21 (s). ^{13}C NMR (151 MHz, $CDCl_3$) δ 167.23 (s), 160.68 (d, *J* = 17.6 Hz), 138.91 (d, *J* = 22.0 Hz), 128.88 (d, *J* = 2.9 Hz), 128.75 (d, *J* = 1.2 Hz), 126.87 (d, *J* = 5.7 Hz), 114.66 (d, *J* = 12.1 Hz), 97.25 (d, *J* = 178.7 Hz), 51.36 (s), 37.72 (d, *J* = 23.0 Hz), 27.64 (d, *J* = 1.4 Hz), 27.46 (s), 22.94 (d, *J* = 7.9 Hz). m/z HRMS (EI) found $[M]^+$ 248.1220, $C_{15}H_{17}FO_2^+$ requires 248.1213. HPLC (Chiralpak IC column, 98:2 hexanes/ isopropanol, 1 ml/min; tr= 17.4 min (minor), 18.5 min (major); 94% ee.

(*R*)-2-([1,1'-biphenyl]-3-yl)-2-fluorocyclohexanone (**3d**)



2j, 90% ee

3d, 90% ee

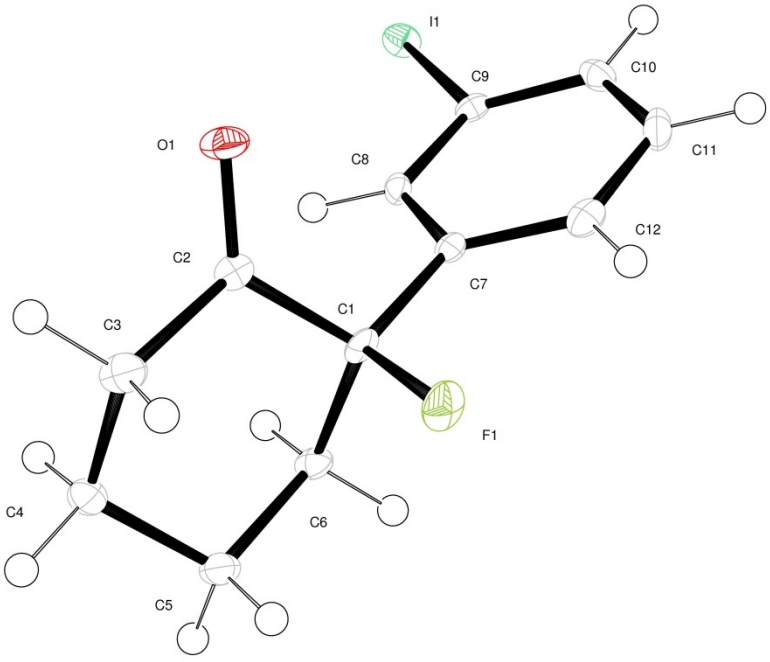
To a 10 ml flask was added **2j** (53 mg, 0.167 mmol), $PhB(OH)_2$ (41 mg, 0.333 mmol), $(dppf)PdCl_2$ (18 mg, 0.025 mmol) and CsF (152 mg, 1.00 mmol). After degassed with N_2 for three times, DME (3 mL) was added and the mixture was warmed to 80 ℃. After stirring overnight at this temperature, the mixture was cooled to rt and filtered. The filtrate was then

concentrated *in vacuo* to afford a residue, which was purified by column chromatography (7 : 3, Hexane : DCM) to afford **3d** as an oil (33 mg, 74%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 – 7.56 (m, 4H), 7.54 – 7.42 (m, 3H), 7.41 – 7.33 (m, 2H), 2.87 – 2.73 (m, 1H), 2.68 (dddd, *J* = 18.9, 11.8, 7.1, 4.0 Hz, 1H), 2.45 (ddd, *J* = 13.7, 8.1, 5.8 Hz, 1H), 2.35 (tdd, *J* = 13.2, 8.5, 4.1 Hz, 1H), 2.16 – 2.04 (m, 1H), 2.04 – 1.91 (m, 2H), 1.86 (ddt, *J* = 13.0, 8.7, 4.2 Hz, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -141.35 (dd, *J* = 16.7, 9.4 Hz). ^{13}C NMR (151 MHz, $CDCl_3$) δ 206.26 (d, *J* = 22.5 Hz), 141.86 (s), 140.84 (s), 136.83 (d, *J* = 21.6 Hz), 129.16 (s), 128.94 (s), 127.98 (d, *J* = 2.4 Hz), 127.70 (s), 127.40 (s), 125.33 (d, *J* = 6.5 Hz), 125.31 (d, *J* = 6.2 Hz), 98.41 (d, *J* = 184.1 Hz), 40.05 (s), 38.24 (d, *J* = 22.7 Hz), 27.68 (s), 22.32 (d, *J* = 6.7 Hz). m/z HRMS (EI) found $[M]^+$ 268.1264, $C_{18}H_{17}FO^+$ requires 268.1263. HPLC (Chiralpak IC column, 96:4 hexanes/ isopropanol, 1 ml/min; tr= 11.3 min (minor), 12.0 min (major); 90% ee.

References:

1) a) Hamilton, G. L.; Kang, E. J.; Mba, M.; Toste, F. D. *Science* **2007**, *317*, 496. b) Rauniyar, V.; Lackner, A. D.; Hamilton, G. L.; Toste, F. D. *Science* **2011**, *334*, 1681. c) Wang, Y.-M.; Wu, J.; Hoong, C.; Rauniyar, V.; Toste, F. D. *J. Am. Chem. Soc.* **2012**, *134*, 12928. d) Rauniyar, V.; Wang, Z. J.; Burks, H. E.; Toste, F. D. *J. Am. Chem. Soc.* **2011**, *133*, 8486. e) Akiyama, T.; Morita, H.; Fuchibe, K. *J. Am. Chem. Soc.* **2006**, *128*, 13070.
2) McCooy, S. H.; Connon, S. J. *Org. Lett.* **2007**, *9*, 599.
3) Cho, J. H.; Kim, B. M. *Tetrahedron Letters* **2002**, *43*, 1273.
4) Ross, A. J.; Lang, H. L.; Jackson, R. F. W. *J. Org. Chem.* **2010**, *75*, 245.
5) Fox, J. M.; Huang, X.; Chieffi, A.; Buchwald, S. L. *J. Am. Chem. Soc.* **2000**, *122*, 1360.
6) Cheon, C. H.; Kanno, O.; Toste, F. D. *J. Am. Chem. Soc.* **2011**, *133*, 13248.
7) Xie, J.-H.; Liu, S.; Huo, X.-H.; Cheng, X.; Duan, H.-F.; Fan, B.-M.; Wang, L.-X.; Zhou, Q.-L. *J. Org. Chem.* **2005**, *70*, 2967.
8) Wang, X.; Pei, T.; Han, X.; Windenhoefer, R. A. *Org. Lett.* **2003**, *5*, 2699.
9) Cheng. L.-J.; Xie, J.-H.; Wang L.-X.; Zhou Q.-L *Adv. Synth. Catal.* **2012**, *354*, 1105.
10) Rosiak, A.; Frey, W.; Christoffers, J. *Eur. J. Org. Chem.* **2006**, 4044.
11) Rosiak, A.; Hoenke, C.; Christoffer, J. *Eur. J. Org. Chem.* **2007**, 4376.

X-Ray Crystal Structure Data for 2j



A colorless needle 0.060 x 0.030 x 0.010 mm in size was mounted on a Cryoloop with Paratone oil. Data were collected in a nitrogen gas stream at 100(2) K using phi and omega scans. Crystal-

to-detector distance was 60 mm and exposure time was 5 seconds per frame using a scan width of 1.0°. Data collection was 99.7% complete to 25.000° in θ. A total of 16326 reflections were collected covering the indices, -7<=*h*<=7, -11<=*k*<=11, -22<=*l*<=21. 2012 reflections were found to be symmetry independent, with an R_{int} of 0.0266. Indexing and unit cell refinement indicated a primitive, orthorhombic lattice. The space group was found to be P 21 21 21 (No. 19). The data were integrated using the Bruker SAINT software program and scaled using the SADABS software program. Solution by iterative methods (SHELXT) produced a complete heavy-atom phasing model consistent with the proposed structure. All non-hydrogen atoms were refined anisotropically by full-matrix least-squares (SHELXL-2013). All hydrogen atoms were placed using a riding model. Their positions were constrained relative to their parent atom using the appropriate HFIX command in SHELXL-2013.

Table 1. Crystal data and structure refinement for toste92.

X-ray ID	toste92	
Sample/notebook ID	YXY3-45-1	
Empirical formula	C12 H12 F I O	
Formula weight	318.12	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	P 21 21 21	
Unit cell dimensions	a = 6.1659(2) Å	α= 90°.
	b = 9.8138(3) Å	β= 90°.
	c = 18.5821(5) Å	γ = 90°.
Volume	1124.42(6) $Å^3$	
Z	4	
Density (calculated)	1.879 Mg/m^3	
Absorption coefficient	2.832 mm^{-1}	
F(000)	616	
Crystal size	0.060 x 0.030 x 0.010 mm^3	

Crystal color/habit	colorless needle
Theta range for data collection	2.192 to 25.344°.
Index ranges	-7<=h<=7, -11<=k<=11, -22<=l<=21
Reflections collected	16326
Independent reflections	2012 [R(int) = 0.0266]
Completeness to theta = 25.000°	99.7 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.862 and 0.740
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	2012 / 0 / 136
Goodness-of-fit on F^2	1.102
Final R indices [I>2sigma(I)]	R1 = 0.0145, wR2 = 0.0276
R indices (all data)	R1 = 0.0153, wR2 = 0.0278
Absolute structure parameter	-0.034(9)
Extinction coefficient	n/a
Largest diff. peak and hole	0.294 and -0.276 e.$Å^{-3}$

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$x 10^3) for toste92. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
C(1)	6512(5)	5056(3)	9825(2)	12(1)
C(2)	6562(5)	6292(3)	10345(2)	11(1)
C(3)	5645(6)	6026(3)	11081(2)	18(1)
C(4)	3468(6)	5282(3)	11062(2)	15(1)
C(5)	3595(5)	4000(3)	10606(2)	15(1)
C(6)	4325(5)	4349(3)	9841(2)	13(1)
C(7)	7272(5)	5405(3)	9075(2)	10(1)
C(8)	6000(5)	6261(3)	8646(2)	11(1)
C(9)	6696(5)	6595(3)	7959(2)	11(1)
C(10)	8665(5)	6118(3)	7692(2)	14(1)
C(11)	9903(5)	5261(3)	8116(2)	16(1)
C(12)	9216(5)	4900(3)	8801(2)	14(1)
O(1)	7351(3)	7361(2)	10166(1)	17(1)
F(1)	8039(3)	4148(2)	10141(1)	19(1)

I(1)	4737(1)	7814(1)	7297(1)	16(1)

Table 3. Bond lengths [Å] and angles [°] for toste92.

C(1)-F(1)	1.423(4)	C(5)-H(5B)	0.9900
C(1)-C(7)	1.509(4)	C(6)-H(6A)	0.9900
C(1)-C(6)	1.516(4)	C(6)-H(6B)	0.9900
C(1)-C(2)	1.551(4)	C(7)-C(12)	1.393(4)
C(2)-O(1)	1.204(4)	C(7)-C(8)	1.399(4)
C(2)-C(3)	1.501(4)	C(8)-C(9)	1.386(4)
C(3)-C(4)	1.529(5)	C(8)-H(8)	0.9500
C(3)-H(3A)	0.9900	C(9)-C(10)	1.393(4)
C(3)-H(3B)	0.9900	C(9)-I(1)	2.098(3)
C(4)-C(5)	1.519(4)	C(10)-C(11)	1.383(4)
C(4)-H(4A)	0.9900	C(10)-H(10)	0.9500
C(4)-H(4B)	0.9900	C(11)-C(12)	1.387(4)
C(5)-C(6)	1.531(4)	C(11)-H(11)	0.9500
C(5)-H(5A)	0.9900	C(12)-H(12)	0.9500

F(1)-C(1)-C(7)	108.5(3)	C(5)-C(4)-H(4A)	109.4
F(1)-C(1)-C(6)	107.1(2)	C(3)-C(4)-H(4A)	109.4
C(7)-C(1)-C(6)	113.4(3)	C(5)-C(4)-H(4B)	109.4
F(1)-C(1)-C(2)	102.7(2)	C(3)-C(4)-H(4B)	109.4
C(7)-C(1)-C(2)	113.0(2)	H(4A)-C(4)-H(4B)	108.0
C(6)-C(1)-C(2)	111.3(3)	C(4)-C(5)-C(6)	110.3(2)
O(1)-C(2)-C(3)	123.7(3)	C(4)-C(5)-H(5A)	109.6
O(1)-C(2)-C(1)	121.2(3)	C(6)-C(5)-H(5A)	109.6
C(3)-C(2)-C(1)	115.1(3)	C(4)-C(5)-H(5B)	109.6
C(2)-C(3)-C(4)	113.1(3)	C(6)-C(5)-H(5B)	109.6
C(2)-C(3)-H(3A)	109.0	H(5A)-C(5)-H(5B)	108.1
C(4)-C(3)-H(3A)	109.0	C(1)-C(6)-C(5)	112.4(2)
C(2)-C(3)-H(3B)	109.0	C(1)-C(6)-H(6A)	109.1
C(4)-C(3)-H(3B)	109.0	C(5)-C(6)-H(6A)	109.1
H(3A)-C(3)-H(3B)	107.8	C(1)-C(6)-H(6B)	109.1
C(5)-C(4)-C(3)	111.3(3)	C(5)-C(6)-H(6B)	109.1

H(6A)-C(6)-H(6B)	107.8
C(12)-C(7)-C(8)	119.2(3)
C(12)-C(7)-C(1)	121.6(3)
C(8)-C(7)-C(1)	119.2(3)
C(9)-C(8)-C(7)	119.6(3)
C(9)-C(8)-H(8)	120.2
C(7)-C(8)-H(8)	120.2
C(8)-C(9)-C(10)	121.2(3)
C(8)-C(9)-I(1)	119.8(2)
C(10)-C(9)-I(1)	119.0(2)
C(11)-C(10)-C(9)	118.9(3)
C(11)-C(10)-H(10)	120.6
C(9)-C(10)-H(10)	120.6
C(10)-C(11)-C(12)	120.6(3)
C(10)-C(11)-H(11)	119.7
C(12)-C(11)-H(11)	119.7
C(11)-C(12)-C(7)	120.5(3)
C(11)-C(12)-H(12)	119.8
C(7)-C(12)-H(12)	119.8

Symmetry transformations used to generate equivalent atoms:

Table 4. Anisotropic displacement parameters ($Å^2 x\ 10^3$) for toste92. The anisotropic displacement factor exponent takes the form: $-2\pi^2[\ h^2\ a^{*2}U^{11} + ...\ + 2\ h\ k\ a^*\ b^*\ U^{12}\ ]$

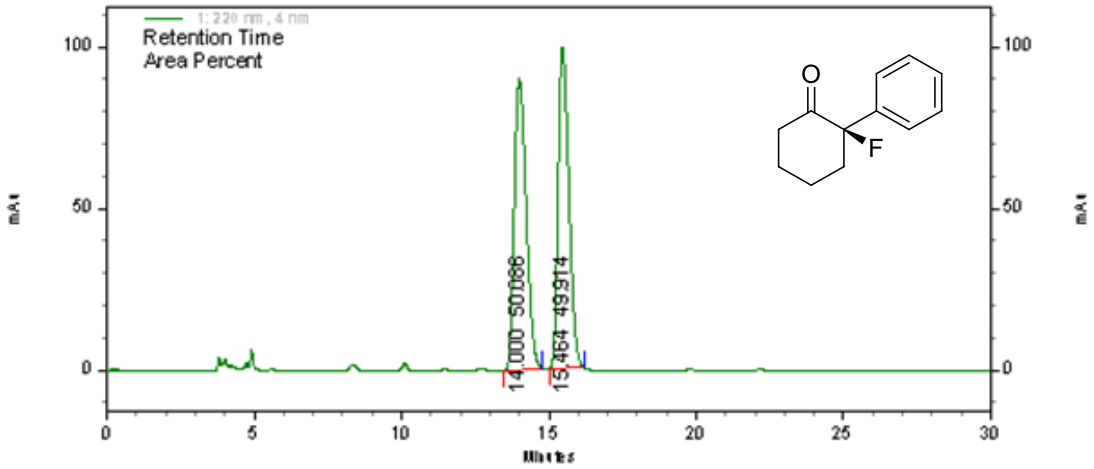
	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
C(1)	16(2)	7(2)	11(2)	3(1)	-2(1)	6(1)
C(2)	9(2)	11(2)	12(2)	0(1)	-5(1)	0(1)
C(3)	28(2)	15(2)	10(2)	0(1)	-2(2)	-4(2)
C(4)	20(2)	14(2)	10(2)	2(1)	2(1)	-1(2)
C(5)	17(2)	11(2)	16(2)	2(1)	1(2)	-1(1)
C(6)	17(2)	10(2)	11(2)	-1(1)	-1(1)	-3(1)
C(7)	12(2)	8(2)	10(2)	-3(1)	0(1)	-2(1)
C(8)	10(2)	10(2)	13(2)	-4(1)	1(1)	0(1)
C(9)	12(2)	8(1)	12(2)	-1(1)	-4(1)	-2(1)
C(10)	16(2)	16(2)	11(2)	-2(2)	3(2)	-5(1)
C(11)	11(2)	16(2)	20(2)	-7(1)	2(2)	2(2)
C(12)	14(2)	12(2)	16(2)	-3(1)	-5(1)	-1(1)
O(1)	22(1)	13(1)	16(1)	0(1)	-1(1)	-7(1)
F(1)	20(1)	17(1)	18(1)	4(1)	-2(1)	9(1)
I(1)	16(1)	17(1)	13(1)	5(1)	-2(1)	0(1)

Table 5. Hydrogen coordinates ($x\ 10^4$) and isotropic displacement parameters ($Å^2 x\ 10^{\ 3}$) for toste92.

	x	y	z	U(eq)
H(3A)	5458	6906	11334	21
H(3B)	6695	5474	11359	21
H(4A)	3035	5037	11558	18
H(4B)	2345	5896	10862	18
H(5A)	2155	3555	10591	18

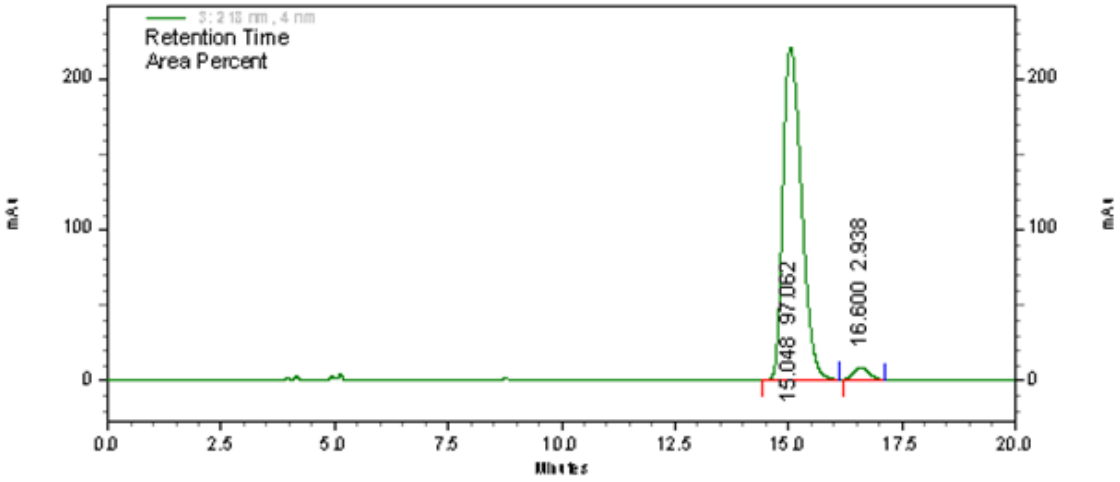
H(5B)	4636	3353	10826	18
H(6A)	4410	3501	9554	15
H(6B)	3229	4949	9614	15
H(8)	4668	6611	8825	13
H(10)	9149	6377	7226	17
H(11)	11238	4916	7937	19
H(12)	10076	4304	9085	17

(*R*)-2-fluoro-2-phenylcyclohexanone (2a)



1: 220 nm, 4 nm
Results

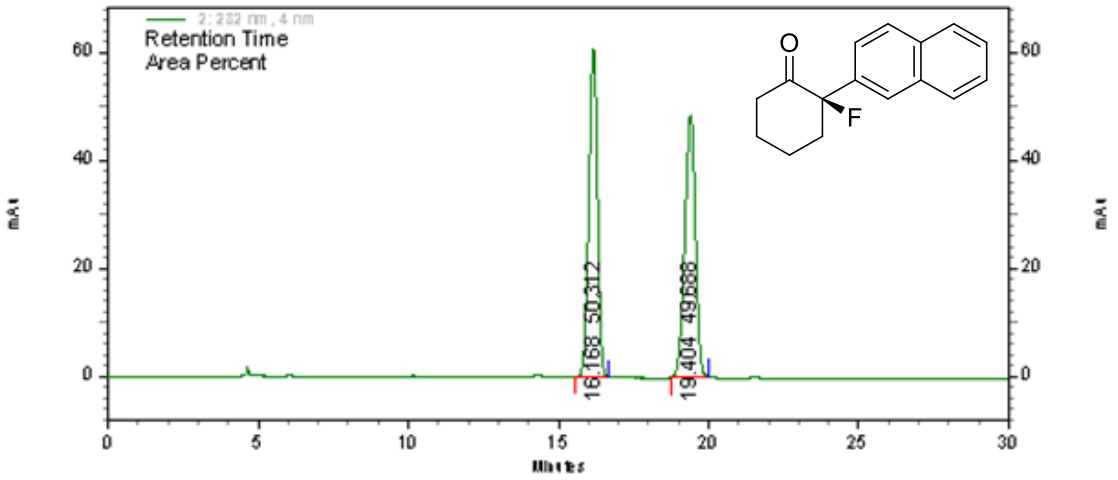
Pk #	Retention Time	Area Percent	Lambda Max
1	14.000	50.086	207
2	15.464	49.914	207



3: 218 nm, 4 nm
Results

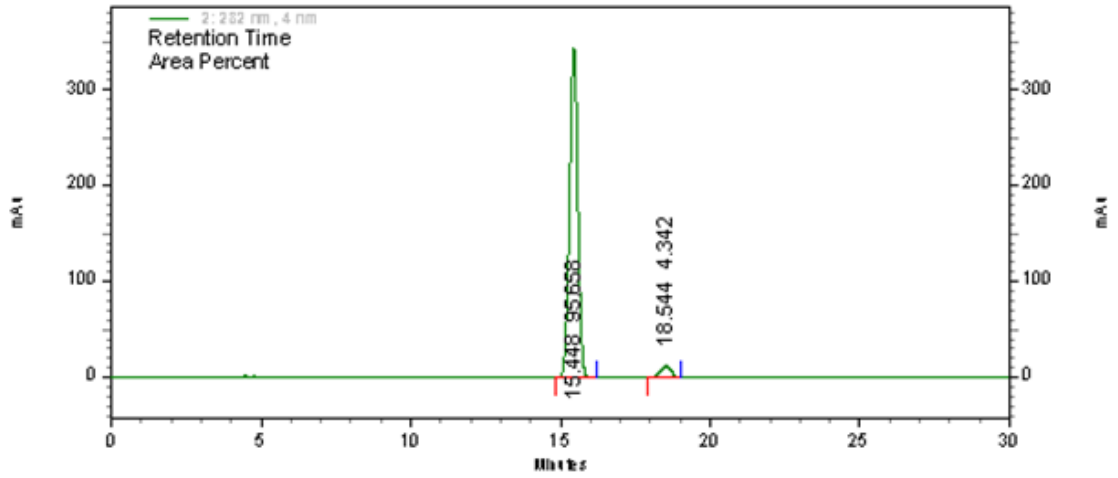
Pk #	Retention Time	Area Percent	Lambda Max
1	15.048	97.062	257
2	16.600	2.938	209

(*R*)-2-fluoro-2-(naphthalen-2-yl)cyclohexanone (2b)



2: 282 nm, 4 nm
Results

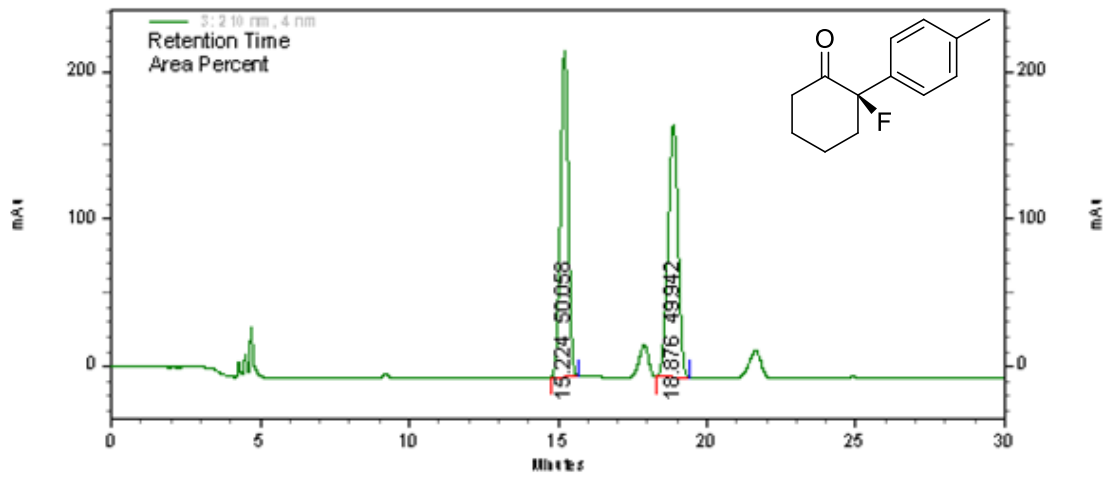
Pk #	Retention Time	Area Percent	Lambda Max
1	16.168	50.312	196
2	19.404	49.688	222



2: 282 nm, 4 nm
Results

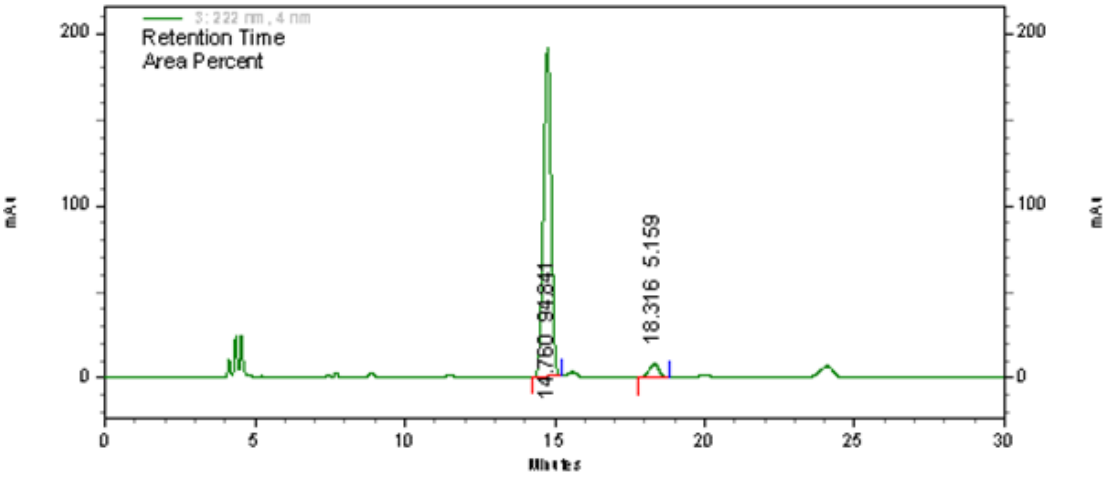
Pk #	Retention Time	Area Percent	Lambda Max
1	15.448	95.658	213
2	18.544	4.342	222

(*R*)-2-fluoro-2-(p-tolyl)cyclohexanone (2c)



3: 210 nm, 4 nm
Results

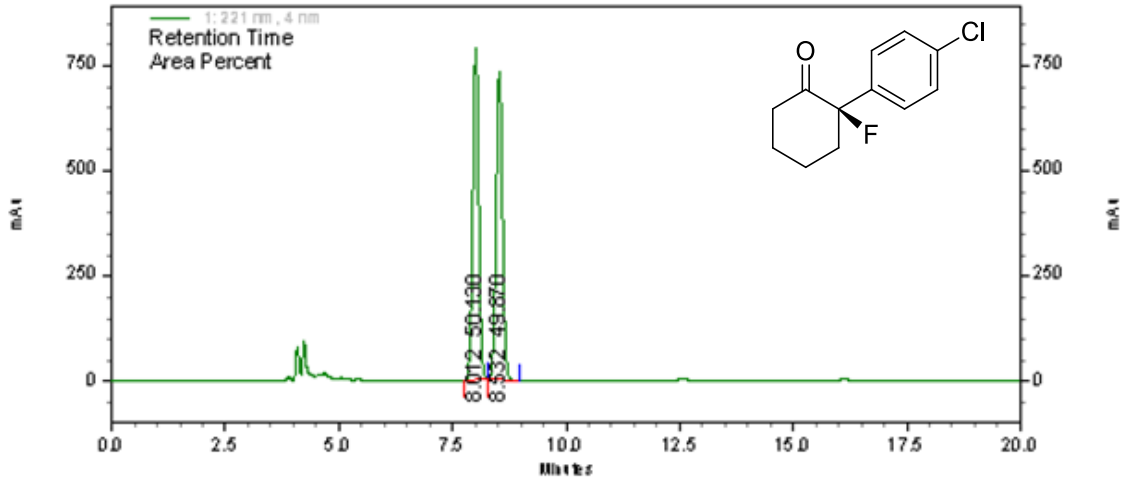
Pk #	Retention Time	Area Percent	Lambda Max
1	15.224	50.058	260
2	18.876	49.942	212



3: 222 nm, 4 nm
Results

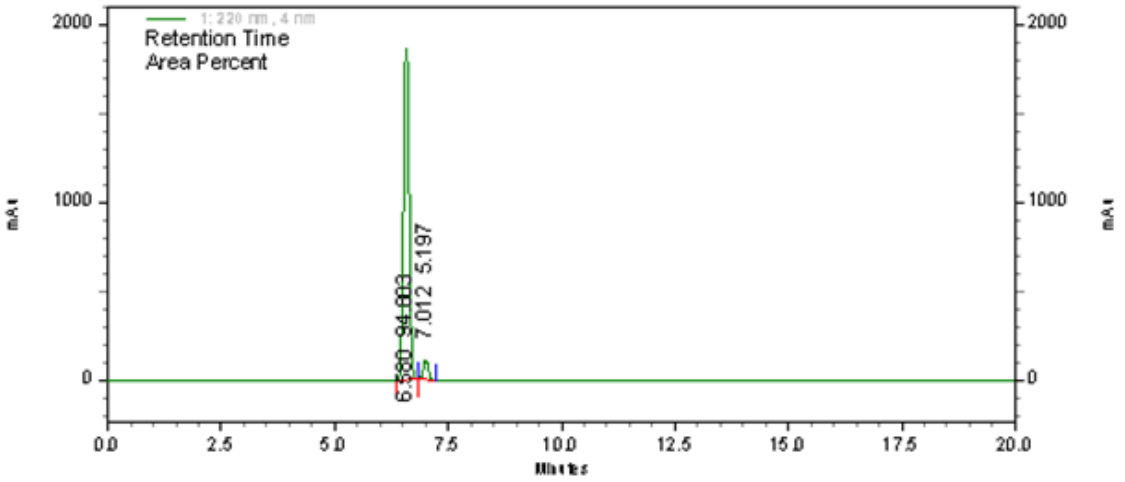
Pk #	Retention Time	Area Percent	Lambda Max
1	14.760	94.841	643
2	18.316	5.159	643

(*R*)-2-(4-chlorophenyl)-2-fluorocyclohexanone (2d)



1: 221 nm, 4 nm
Results

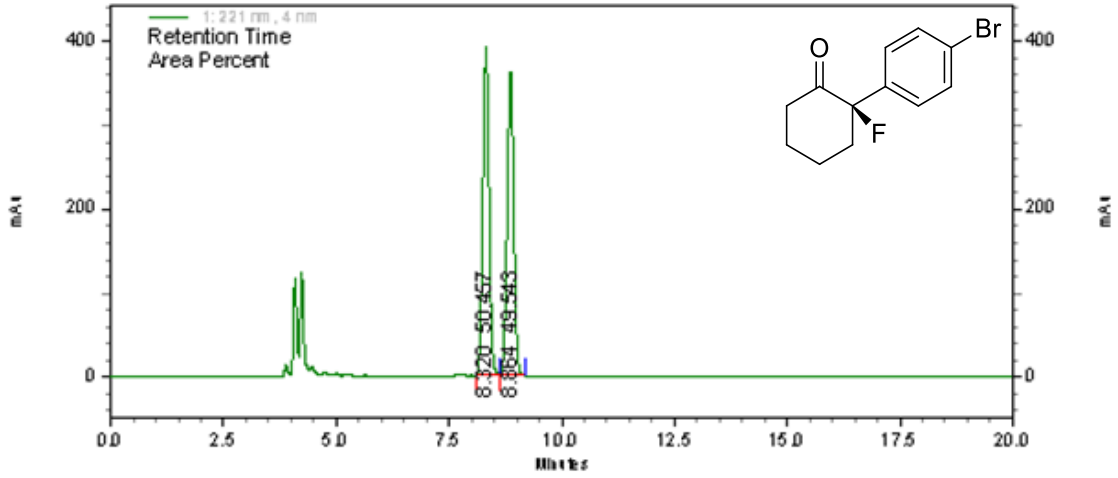
Pk #	Retention Time	Area Percent	Lambda Max
1	8.012	50.130	196
2	8.532	49.870	194



1: 220 nm, 4 nm
Results

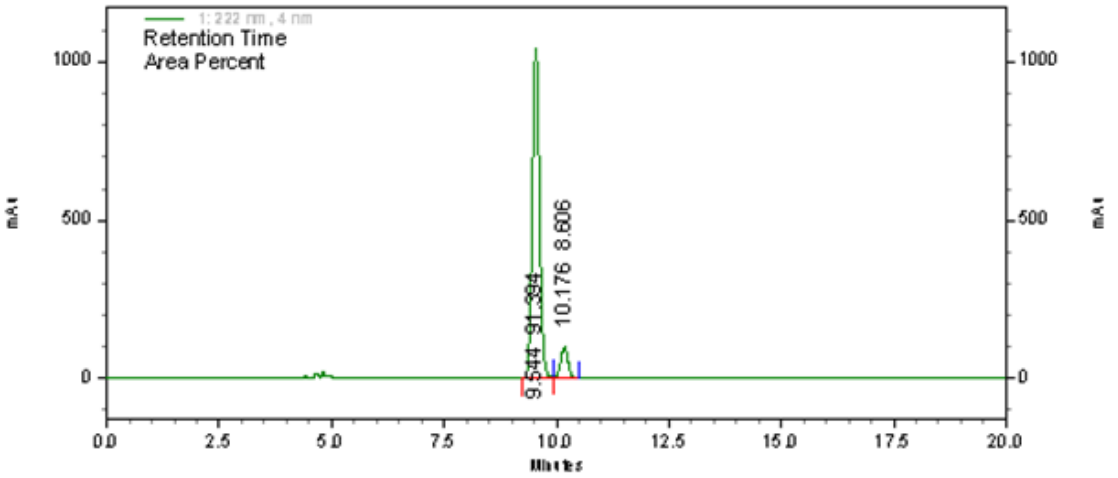
Pk #	Retention Time	Area Percent	Lambda Max
1	6.580	94.803	205
2	7.012	5.197	220

(*R*)-2-(4-bromophenyl)-2-fluorocyclohexanone (2e)



1: 221 nm, 4 nm
Results

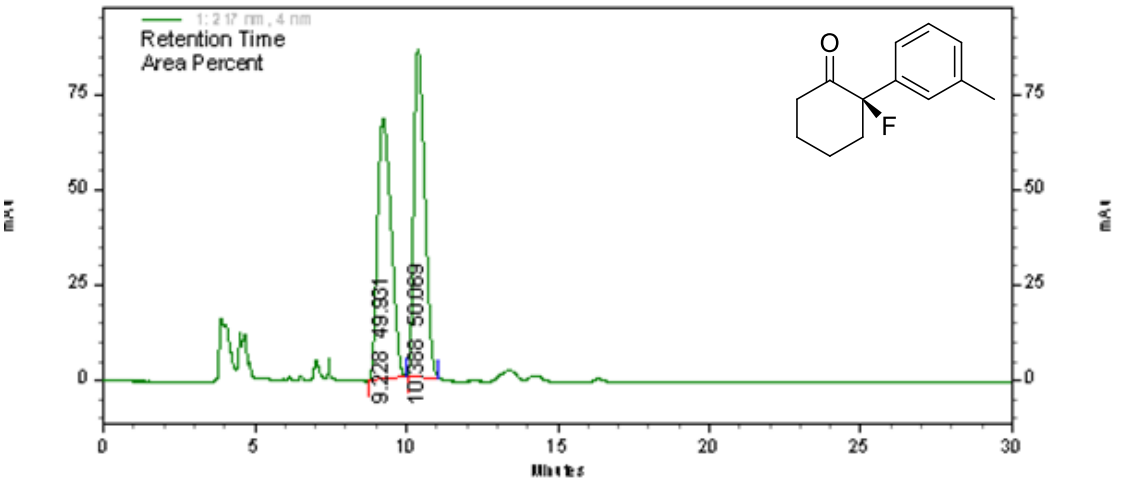
Pk #	Retention Time	Area Percent	Lambda Max
1	8.320	50.457	221
2	8.864	49.543	221



1: 222 nm, 4 nm
Results

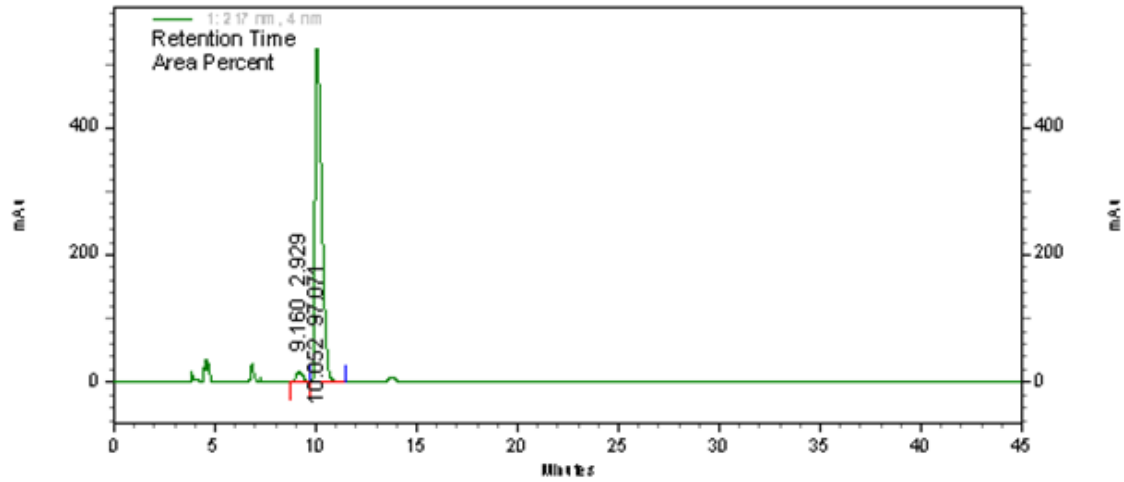
Pk #	Retention Time	Area Percent	Lambda Max
1	9.544	91.394	199
2	10.176	8.606	201

(*R*)-2-fluoro-2-(m-tolyl)cyclohexanone (2f)



1: 217 nm, 4 nm
Results

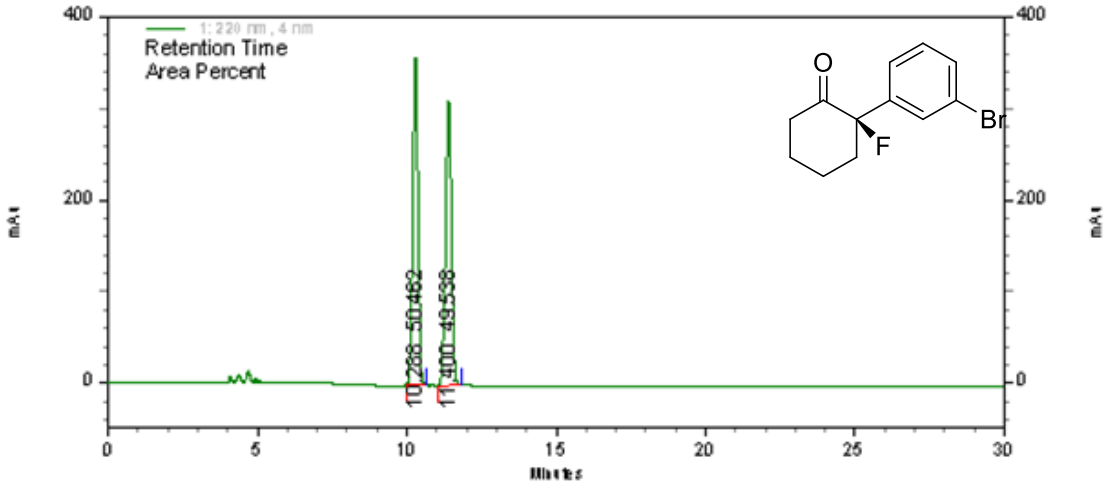
Pk #	Retention Time	Area Percent	Lambda Max
1	9.228	49.931	673
2	10.388	50.069	673



1: 217 nm, 4 nm
Results

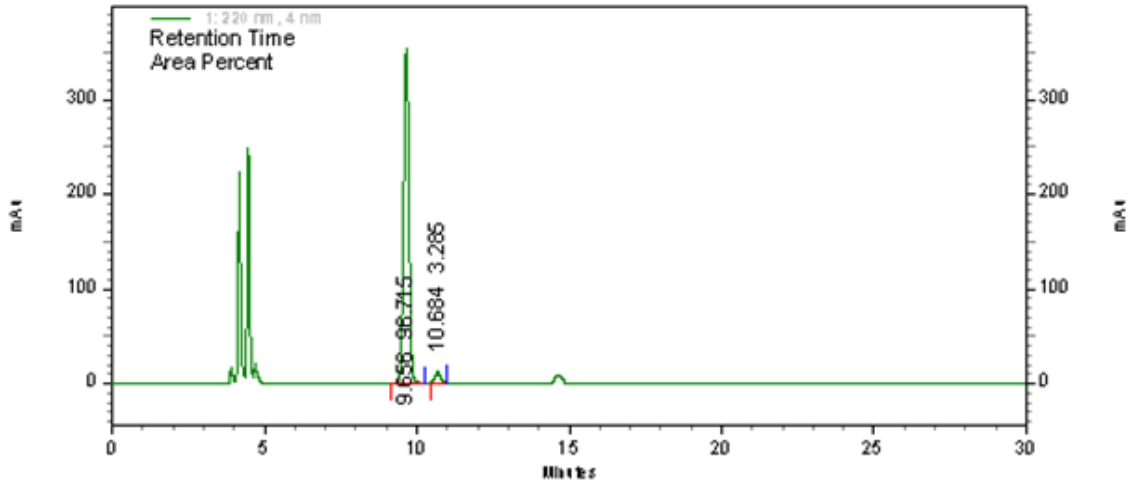
Pk #	Retention Time	Area Percent	Lambda Max
1	9.160	2.929	211
2	10.052	97.071	190

(*R*)-2-(3-bromophenyl)-2-fluorocyclohexanone (2g)



1: 220 nm, 4 nm
Results

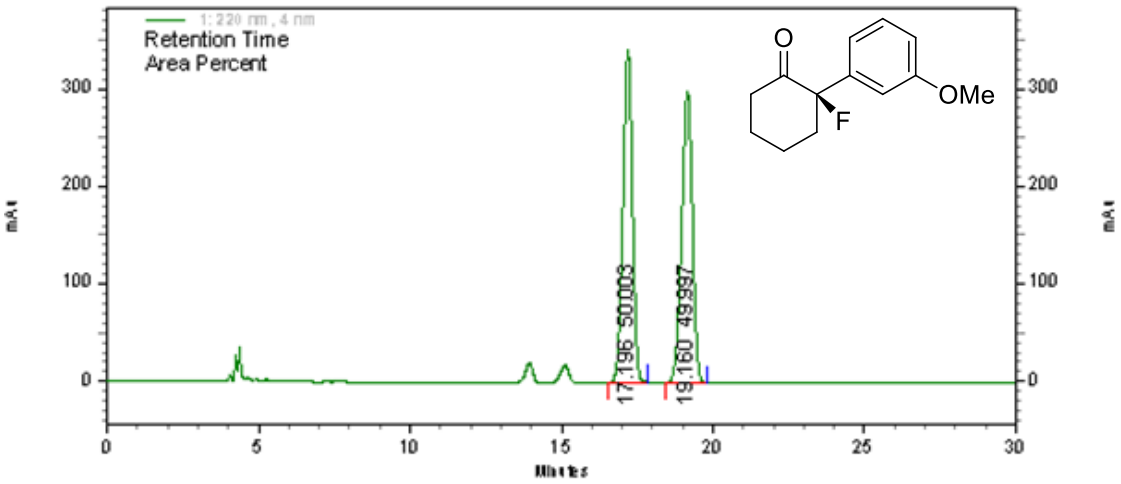
Pk #	Retention Time	Area Percent	Lambda Max
1	10.288	50.462	191
2	11.400	49.538	202



1: 220 nm, 4 nm
Results

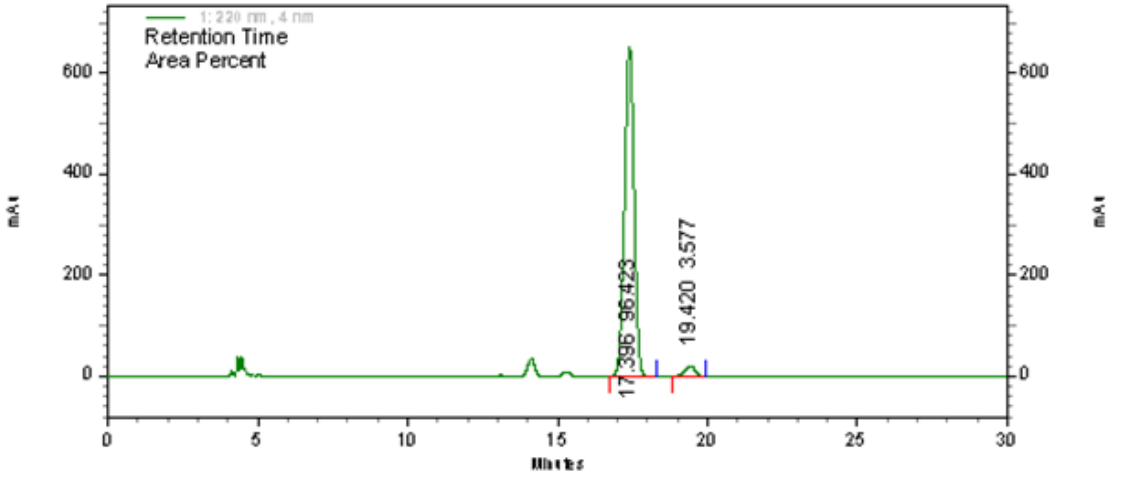
Pk #	Retention Time	Area Percent	Lambda Max
1	9.656	96.715	191
2	10.684	3.285	204

(*R*)-2-fluoro-2-(3-methoxyphenyl)cyclohexanone (2h)



1: 220 nm, 4 nm
Results

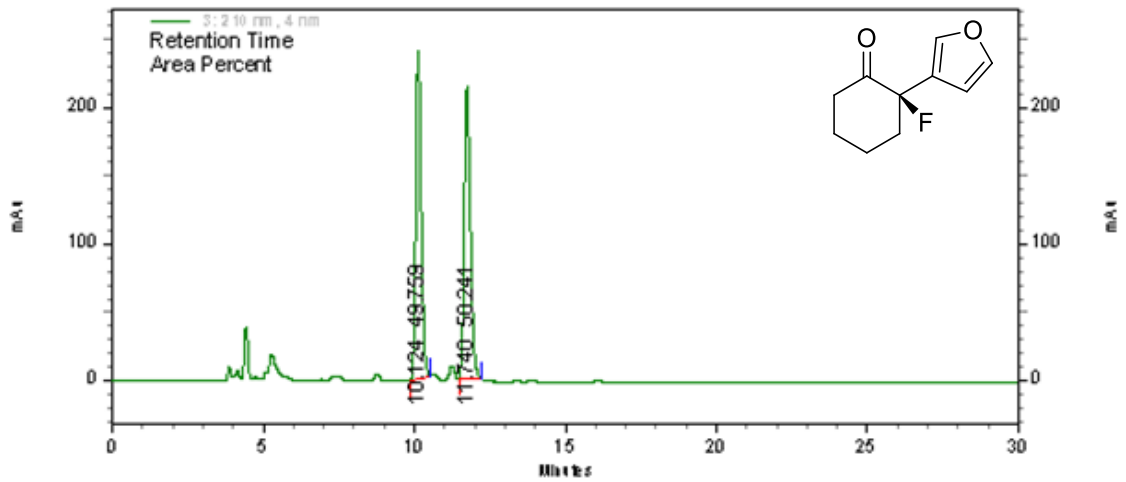
Pk #	Retention Time	Area Percent	Lambda Max
1	17.196	50.003	204
2	19.160	49.997	204



1: 220 nm, 4 nm
Results

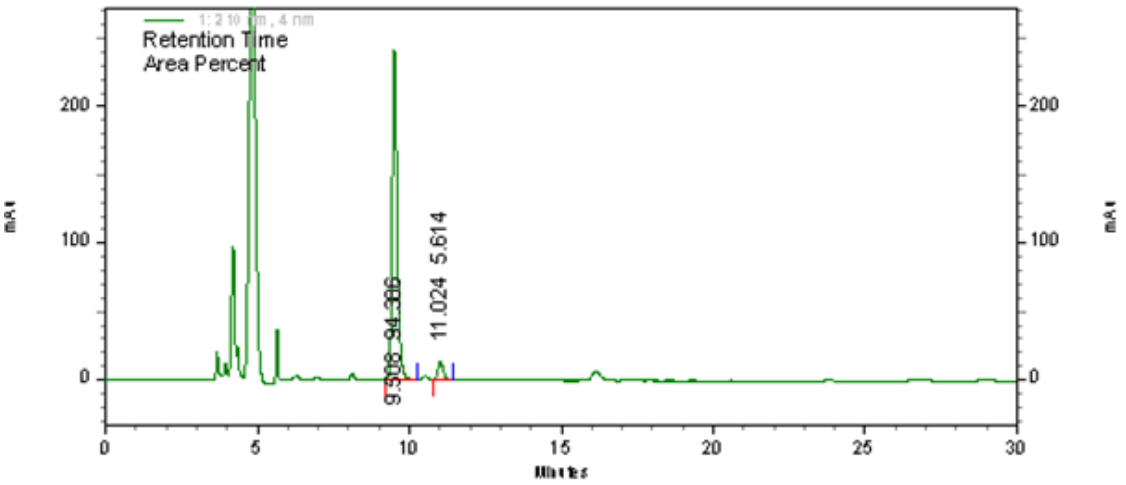
Pk #	Retention Time	Area Percent	Lambda Max
1	17.396	96.423	195
2	19.420	3.577	204

(*R*)-2-fluoro-2-(furan-3-yl)cyclohexanone (2i)



3: 210 nm, 4 nm
Results

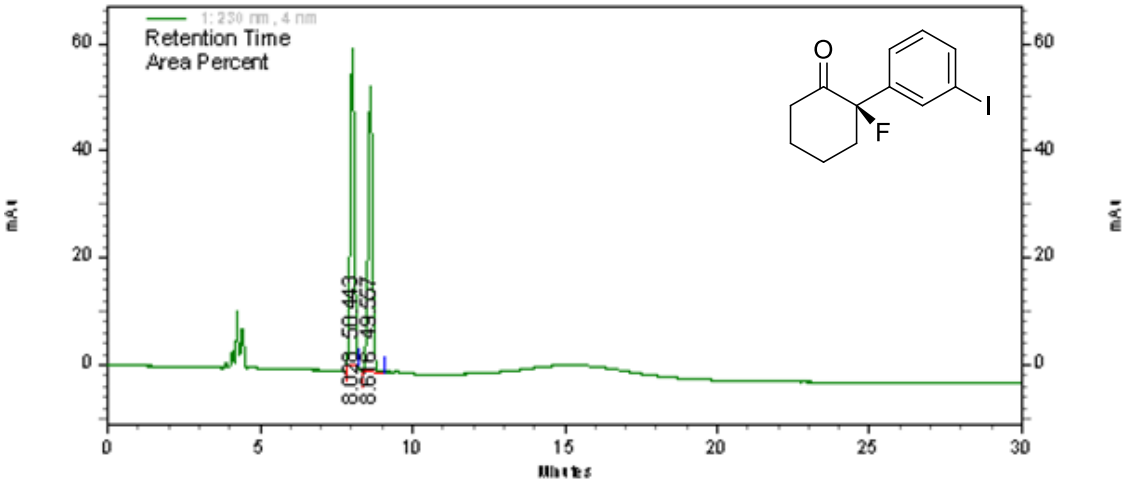
Pk #	Retention Time	Area Percent	Lambda Max
1	10.124	49.759	207
2	11.740	50.241	207



1: 210 nm, 4 nm
Results

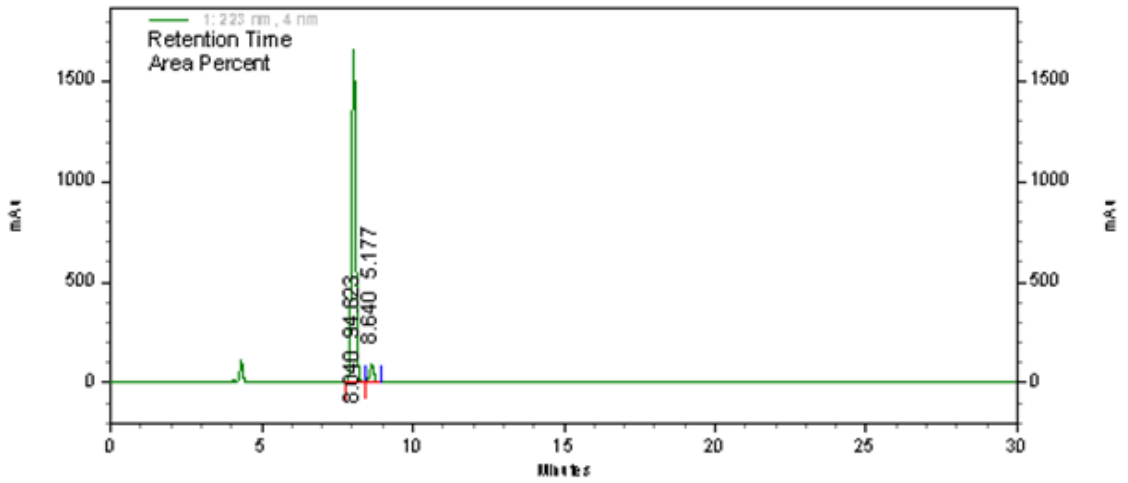
Pk #	Retention Time	Area Percent	Lambda Max
1	9.508	94.386	207
2	11.024	5.614	669

(*R*)-2-fluoro-2-(3-iodophenyl)cyclohexanone (2j)



1: 230 nm, 4 nm
Results

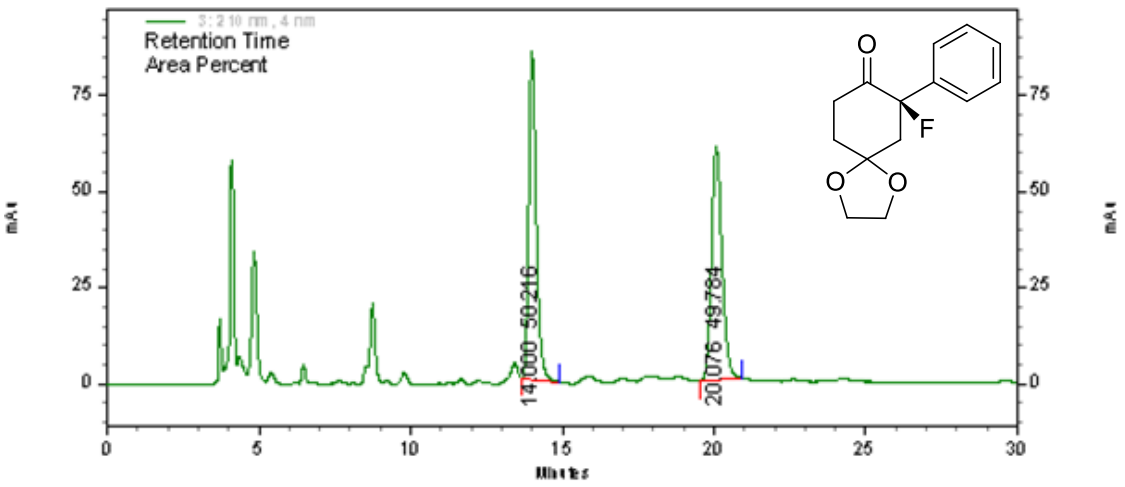
Pk #	Retention Time	Area Percent	Lambda Max
1	8.028	50.443	206
2	8.616	49.557	206



1: 223 nm, 4 nm
Results

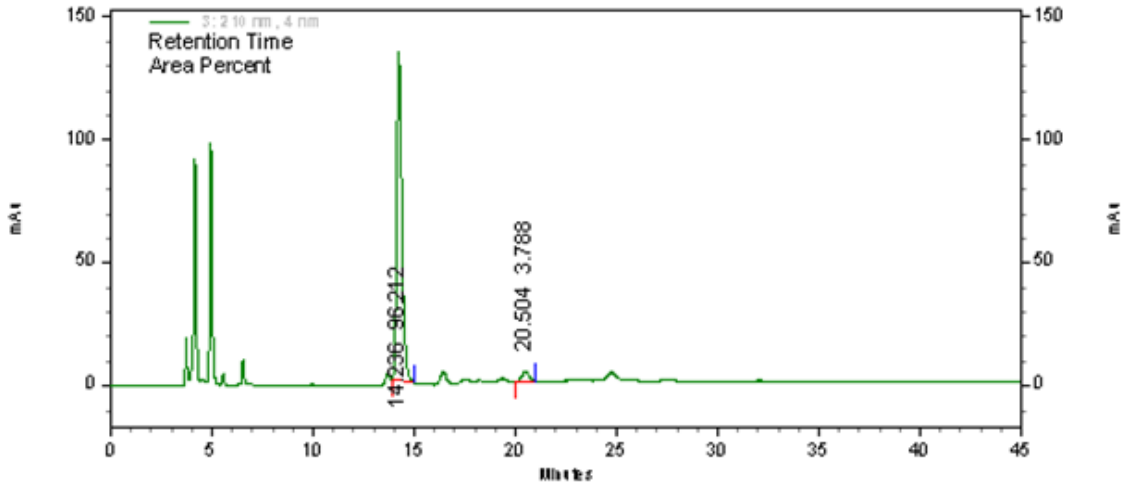
Pk #	Retention Time	Area Percent	Lambda Max
1	8.040	94.823	210
2	8.640	5.177	205

(*R*)-7-fluoro-7-phenyl-1,4-dioxaspiro[4.5]decan-8-one (2k)



3: 210 nm, 4 nm
Results

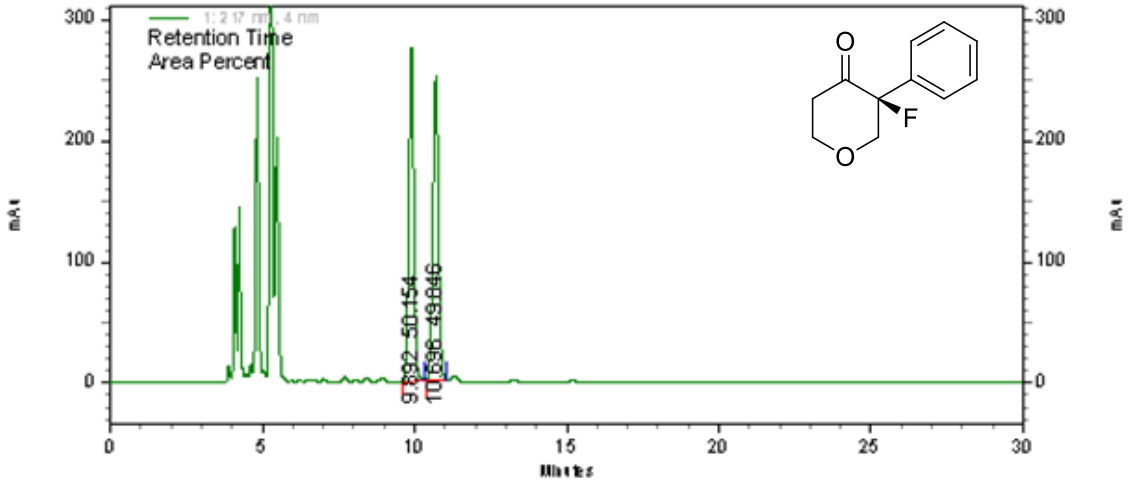
Pk #	Retention Time	Area Percent	Lambda Max
1	14.000	50.216	205
2	20.076	49.784	205



3: 210 nm, 4 nm
Results

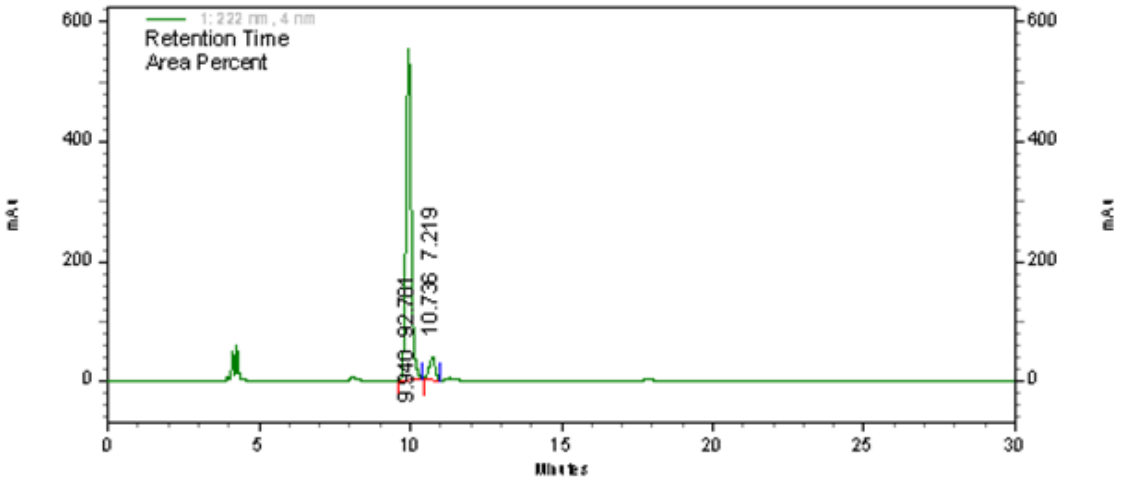
Pk #	Retention Time	Area Percent	Lambda Max
1	14.236	96.212	205
2	20.504	3.788	681

(*S*)-3-fluoro-3-phenyldihydro-2H-pyran-4(3H)-one (2l)



1: 217 nm, 4 nm
Results

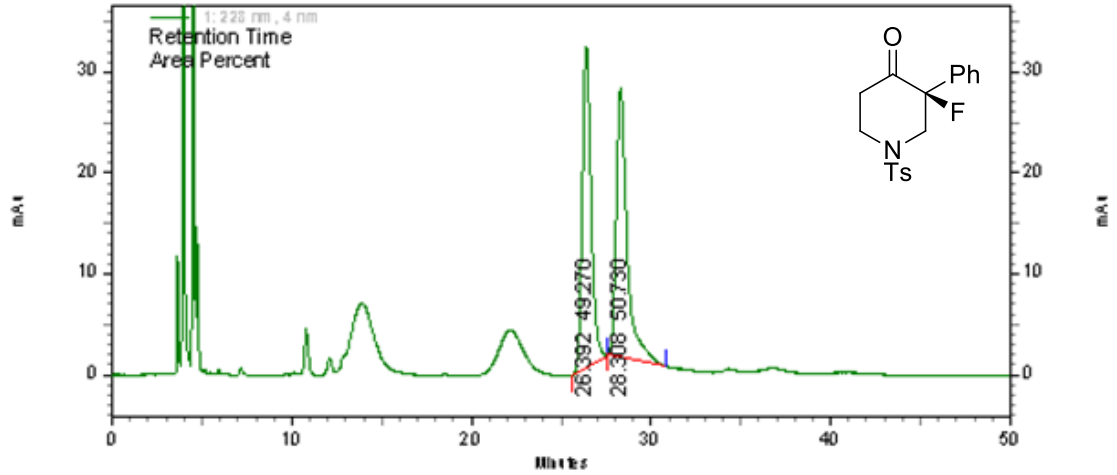
Pk #	Retention Time	Area Percent	Lambda Max
1	9.892	50.154	202
2	10.696	49.846	203



1: 222 nm, 4 nm
Results

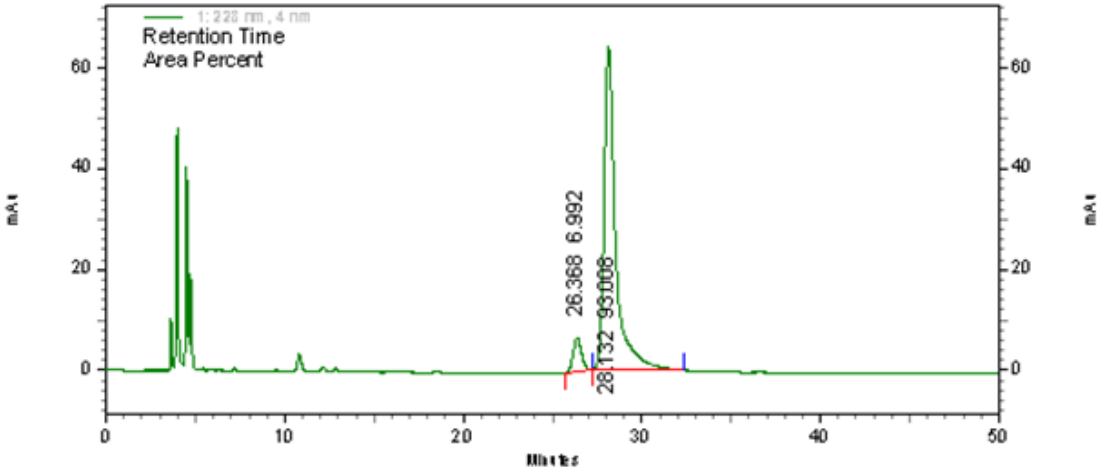
Pk #	Retention Time	Area Percent	Lambda Max
1	9.940	92.781	196
2	10.736	7.219	204

(*S*)-3-fluoro-3-phenyl-1-tosylpiperidin-4-one (1m')



1: 228 nm, 4 nm
Results

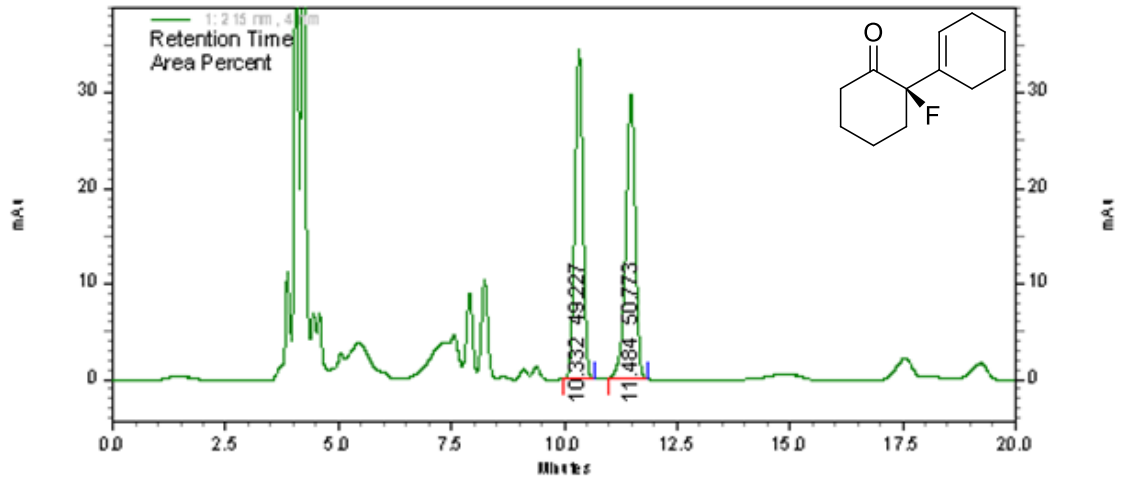
Pk #	Retention Time	Area Percent	Lambda Max
1	26.392	49.270	203
2	28.308	50.730	192



1: 228 nm, 4 nm
Results

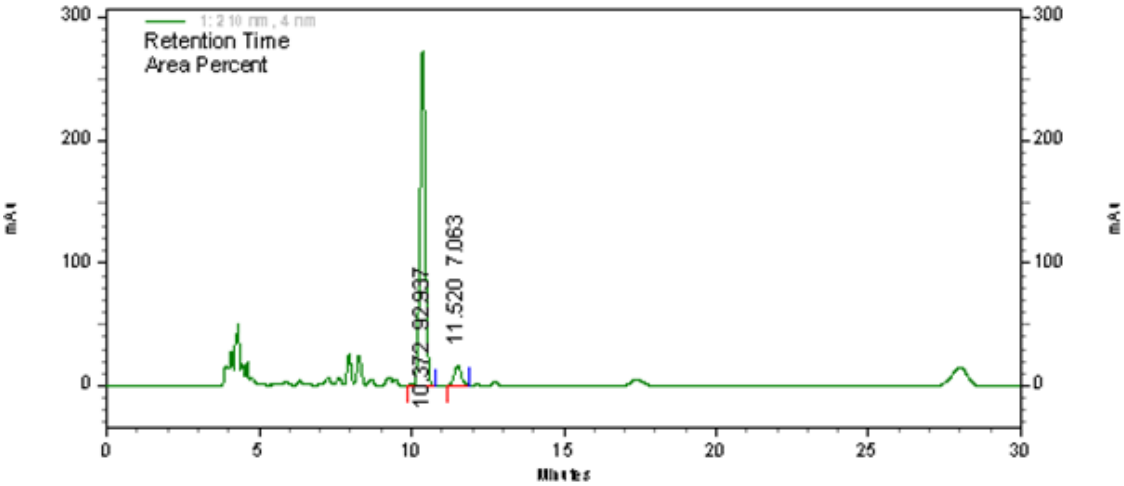
Pk #	Retention Time	Area Percent	Lambda Max
1	26.368	6.992	674
2	28.132	93.008	203

(*R*)-1-fluoro-[1,1'-bi(cyclohexan)]-1'-en-2-one (2n)



1: 215 nm, 4 nm
Results

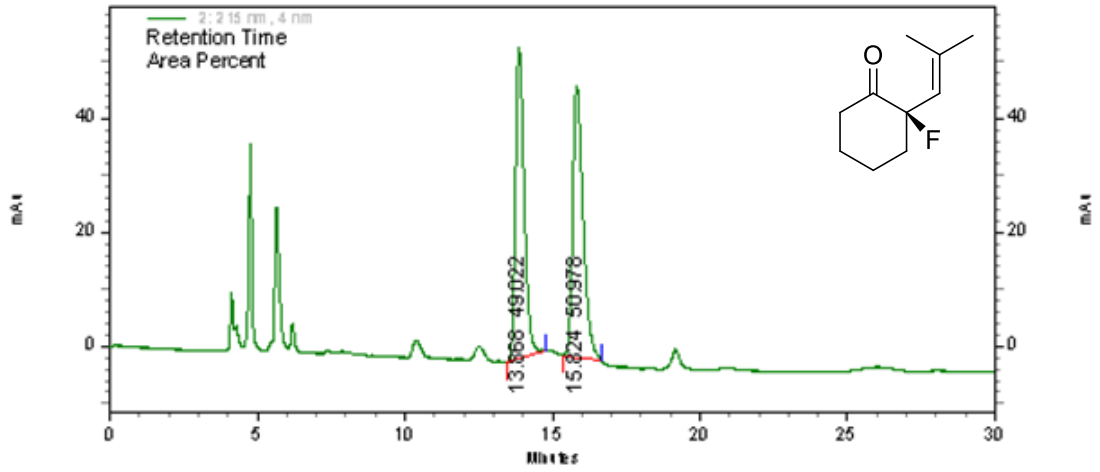
Pk #	Retention Time	Area Percent	Lambda Max
1	10.332	49.227	205
2	11.484	50.773	205



1: 210 nm, 4 nm
Results

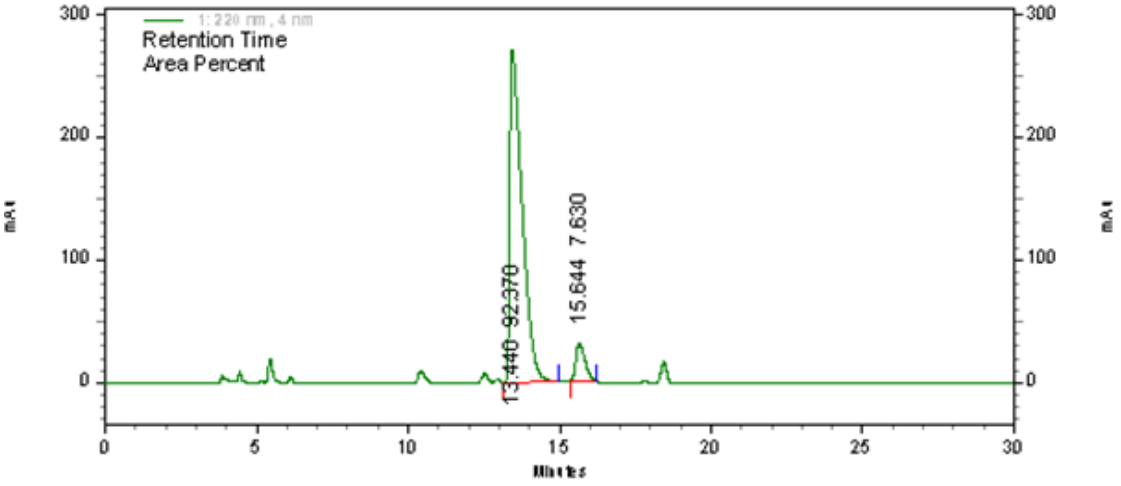
Pk #	Retention Time	Area Percent	Lambda Max
1	10.372	92.937	206
2	11.520	7.063	205

(*R*)-2-fluoro-2-(2-methylprop-1-en-1-yl)cyclohexanone (2o)



2: 215 nm, 4 nm
Results

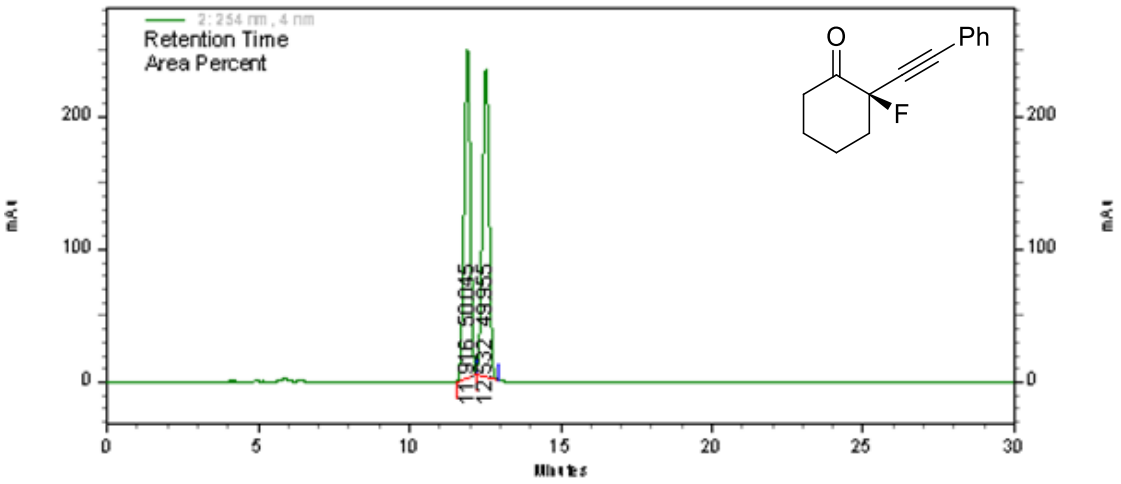
Pk #	Retention Time	Area Percent	Lambda Max
1	13.868	49.022	211
2	15.824	50.978	212



1: 220 nm, 4 nm
Results

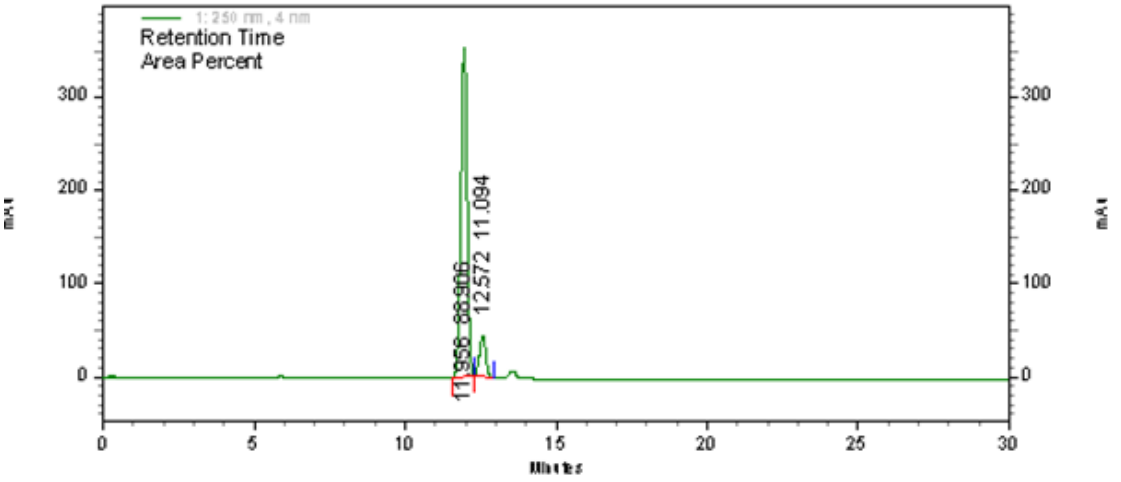
Pk #	Retention Time	Area Percent	Lambda Max
1	13.440	92.370	191
2	15.644	7.630	212

(*R*)-2-fluoro-2-(phenylethynyl)cyclohexanone (2p)



2: 254 nm, 4 nm
Results

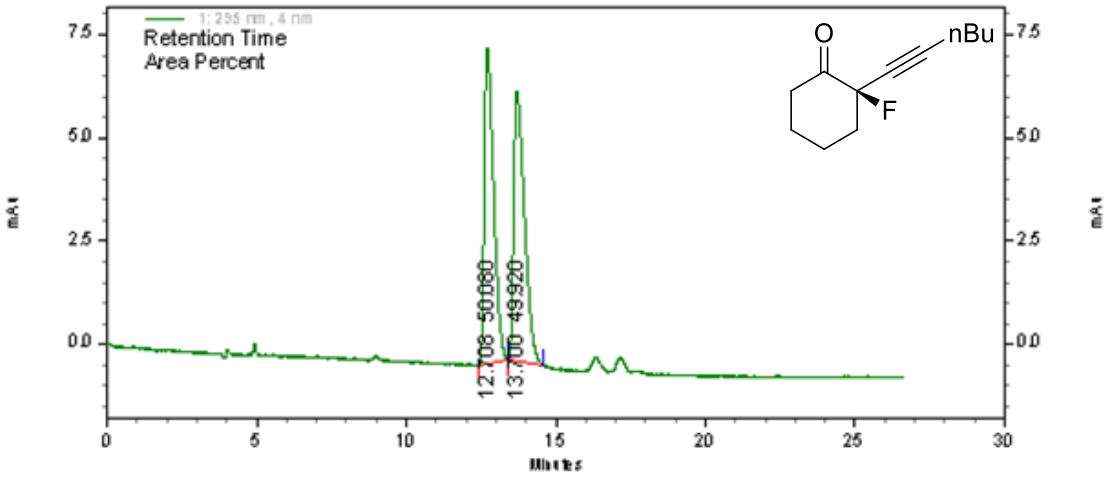
Pk #	Retention Time	Area Percent	Lambda Max
1	11.916	50.045	205
2	12.532	49.955	205



1: 250 nm, 4 nm
Results

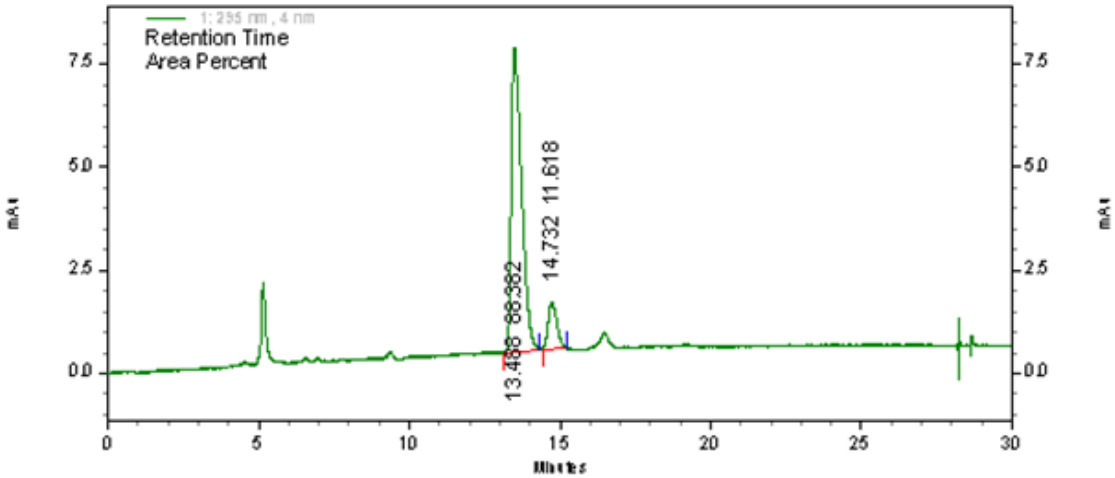
Pk #	Retention Time	Area Percent	Lambda Max
1	11.956	88.906	205
2	12.572	11.094	205

(*R*)-2-fluoro-2-(hex-1-yn-1-yl)cyclohexanone (2q)



1: 295 nm, 4 nm
Results

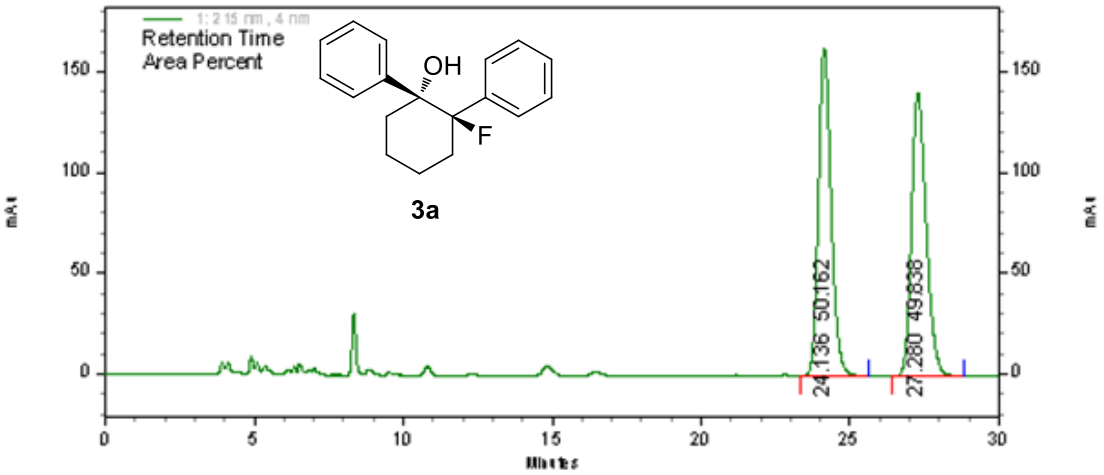
Pk #	Retention Time	Area Percent	Lambda Max
1	12.708	50.080	295
2	13.700	49.920	295



1: 295 nm, 4 nm
Results

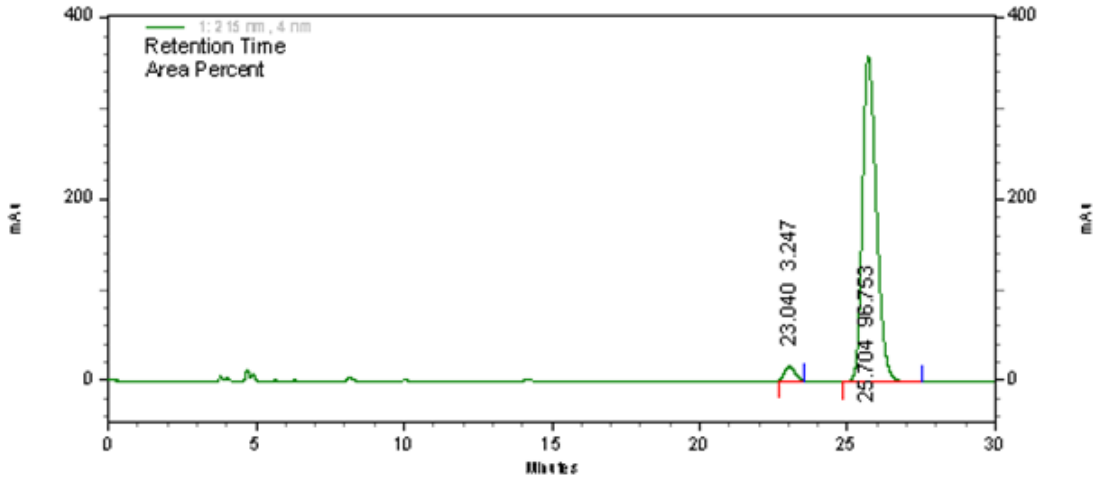
Pk #	Retention Time	Area Percent	Lambda Max
1	13.488	88.382	295
2	14.732	11.618	648

(*1R,2R*)-2-fluoro-1,2-diphenylcyclohexanol (3a)



1: 215 nm, 4 nm
Results

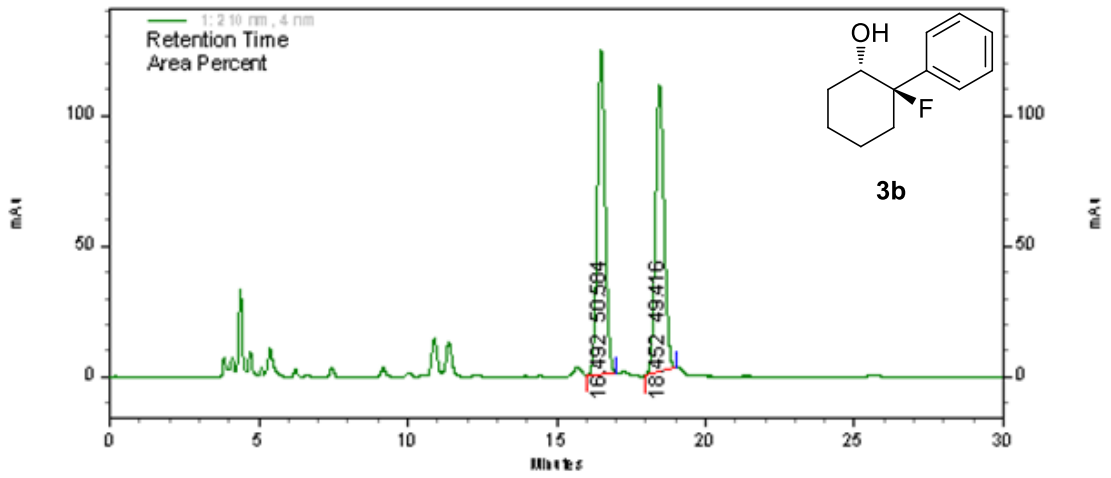
Pk #	Retention Time	Area Percent	Lambda Max
1	24.136	50.162	209
2	27.280	49.838	209



1: 215 nm, 4 nm
Results

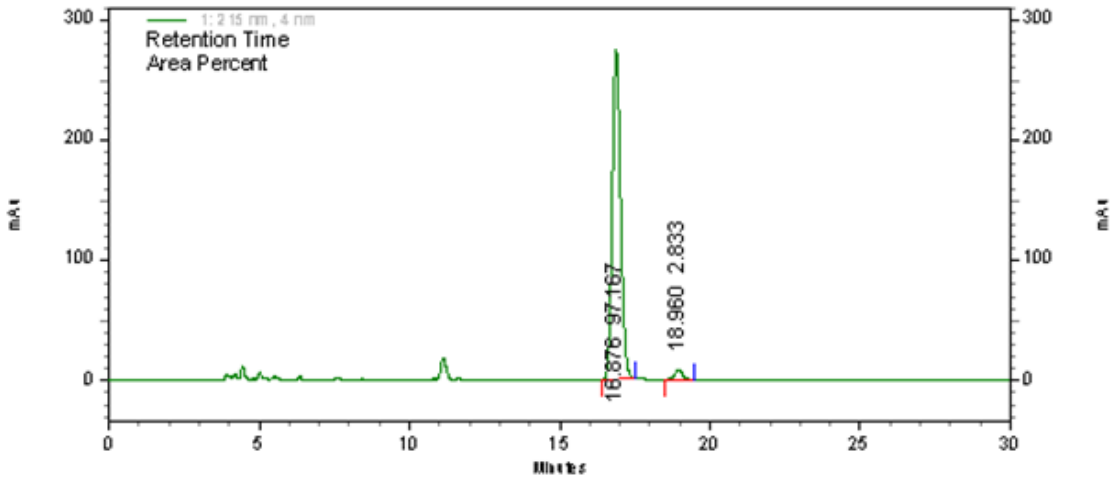
Pk #	Retention Time	Area Percent	Lambda Max
1	23.040	3.247	661
2	25.704	96.753	207

(*1S,2R*)-2-fluoro-2-phenylcyclohexanol (3b)



1: 210 nm, 4 nm
Results

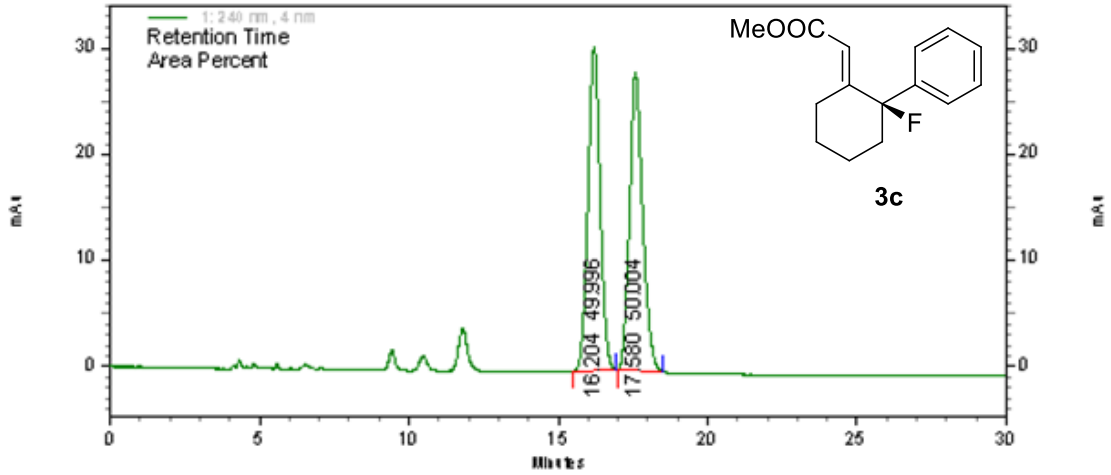
Pk #	Retention Time	Area Percent	Lambda Max
1	16.492	50.584	207
2	18.452	49.416	207



1: 215 nm, 4 nm
Results

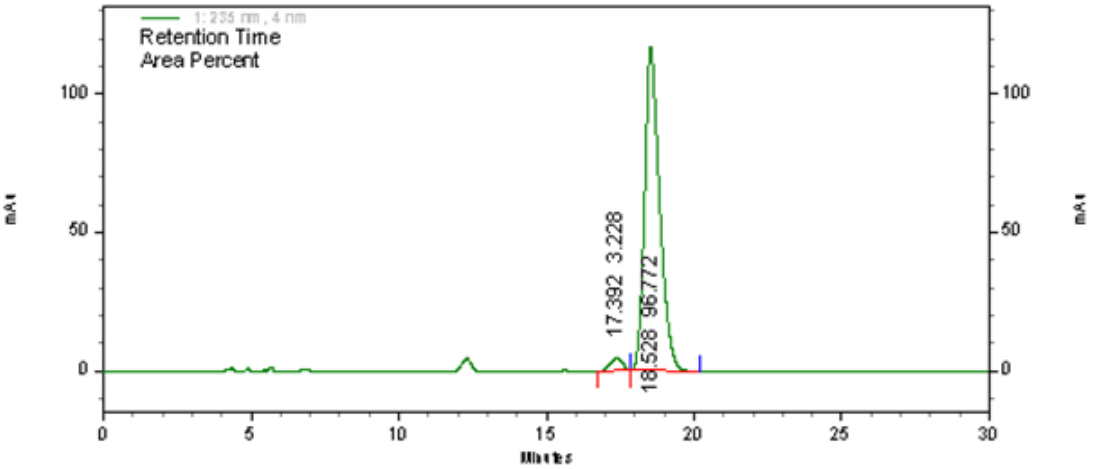
Pk #	Retention Time	Area Percent	Lambda Max
1	16.876	97.167	207
2	18.960	2.833	675

(*S*,*E*)-methyl 2-(2-fluoro-2-phenylcyclohexylidene)acetate (3c)



1: 240 nm, 4 nm
Results

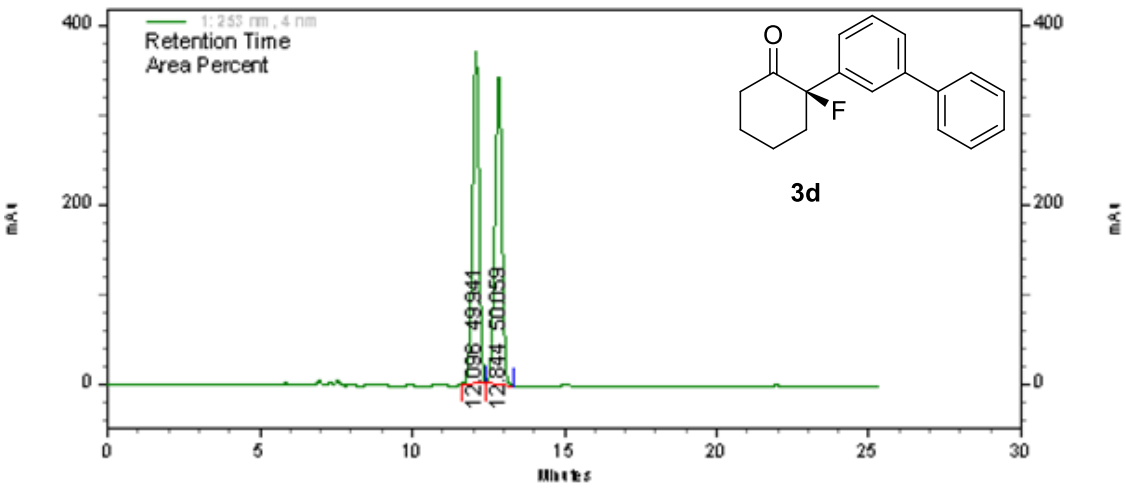
Pk #	Retention Time	Area Percent	Lambda Max
1	16.204	49.996	208
2	17.580	50.004	209



1: 235 nm, 4 nm
Results

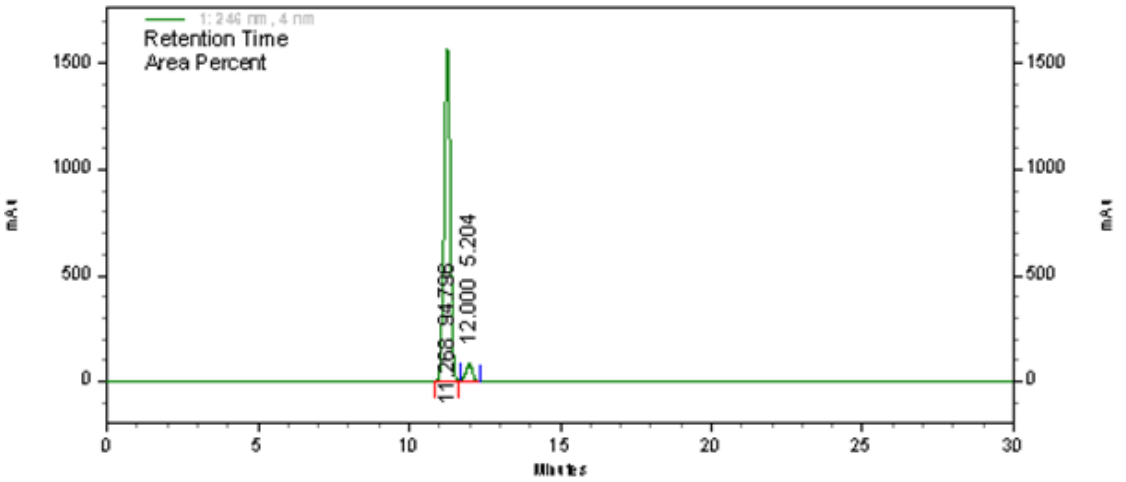
Pk #	Retention Time	Area Percent	Lambda Max
1	17.392	3.228	215
2	18.528	96.772	208

(*R*)-2-([1,1'-biphenyl]-3-yl)-2-fluorocyclohexanone (3d)



1: 253 nm, 4 nm
Results

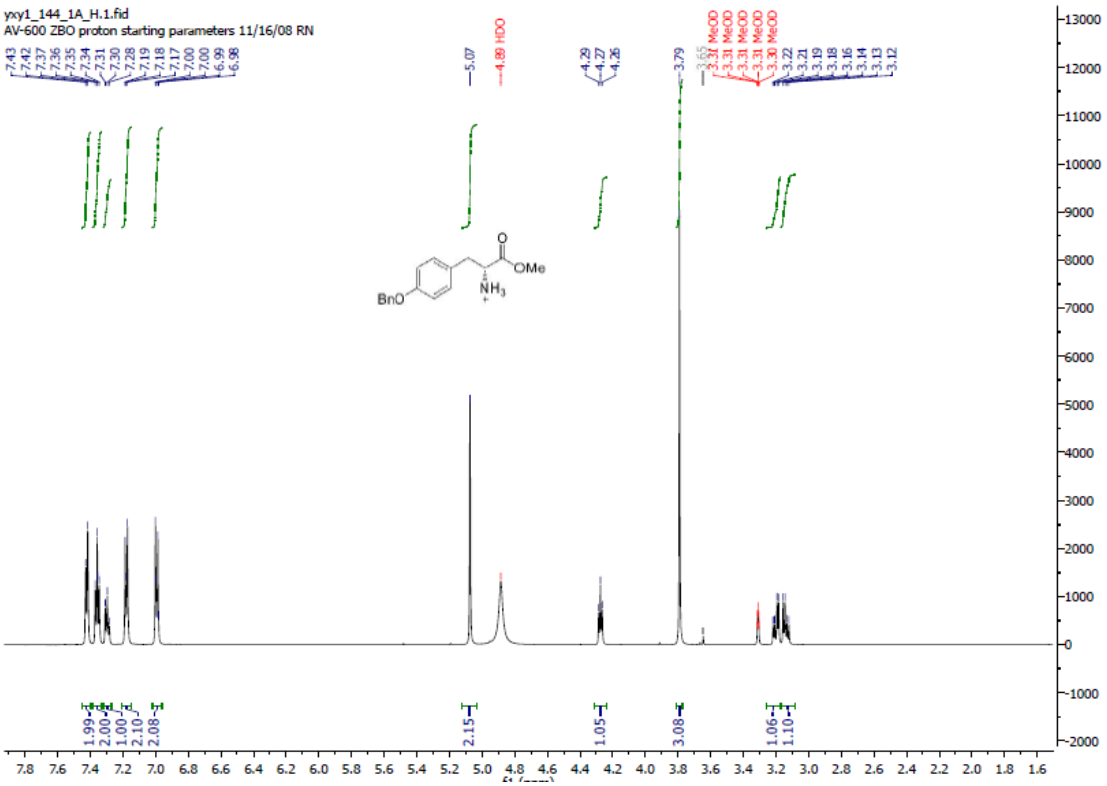
Pk #	Retention Time	Area Percent	Lambda Max
1	12.096	49.941	194
2	12.844	50.059	193

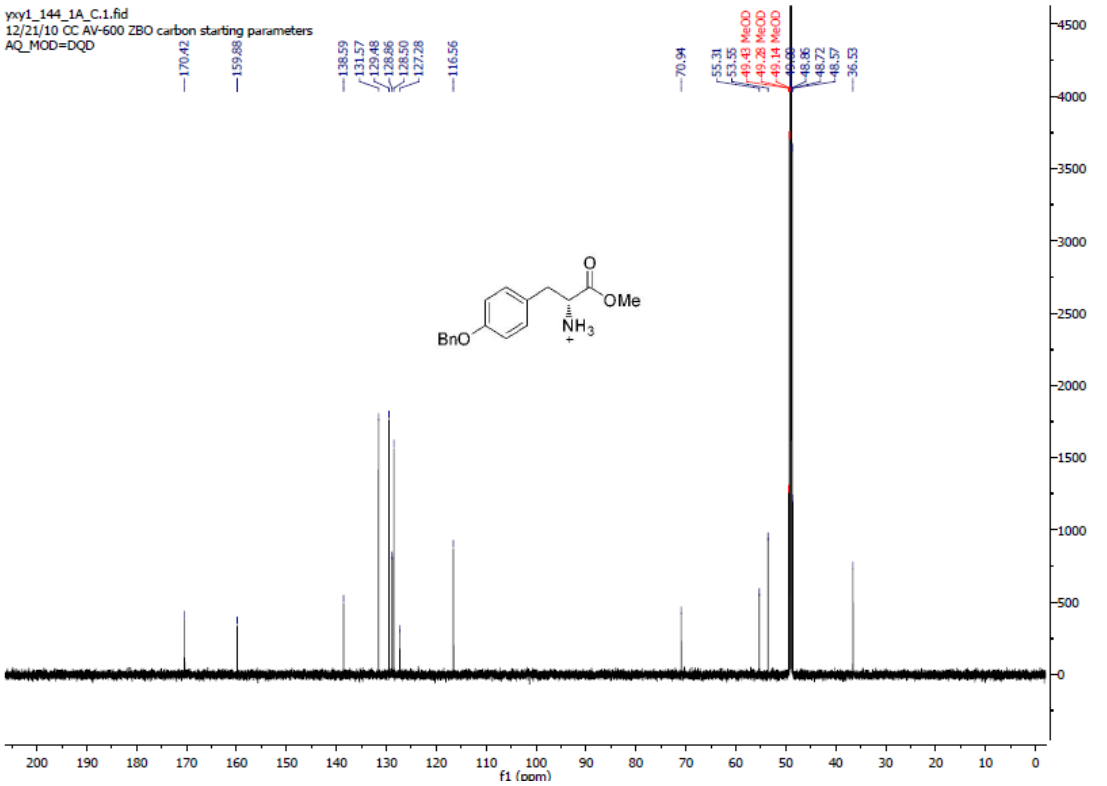


1: 246 nm, 4 nm
Results

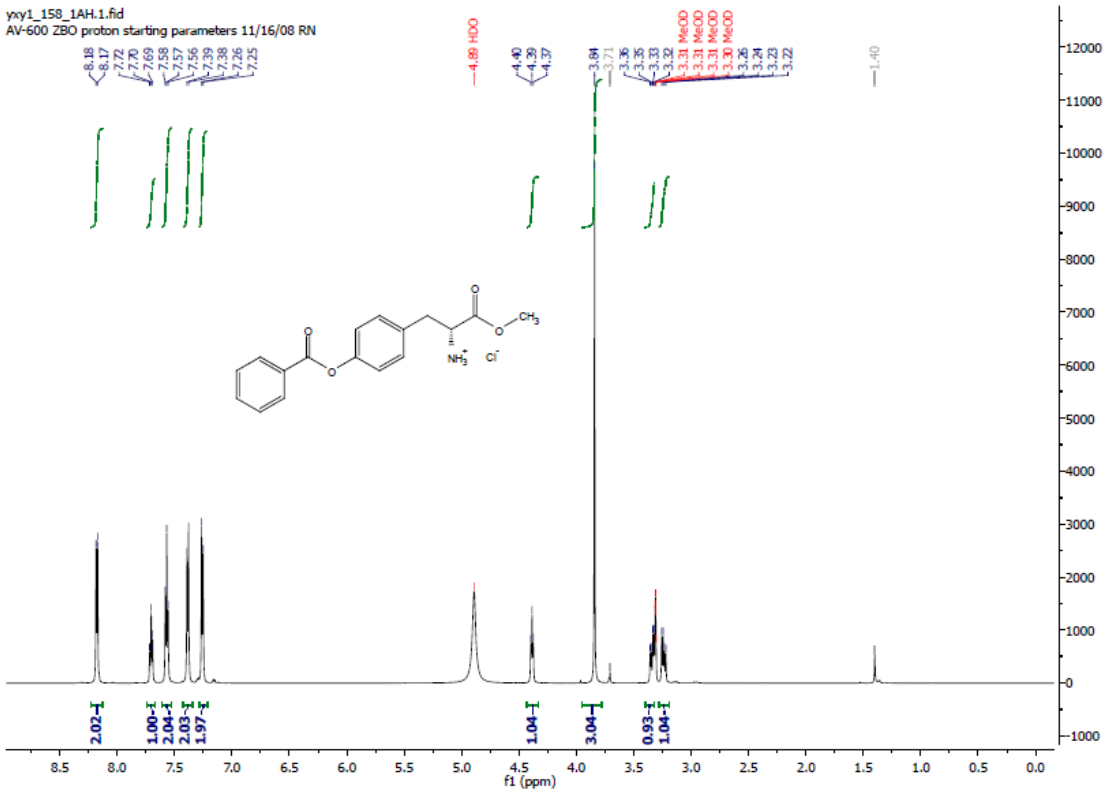
Pk #	Retention Time	Area Percent	Lambda Max
1	11.268	94.796	209
2	12.000	5.204	206

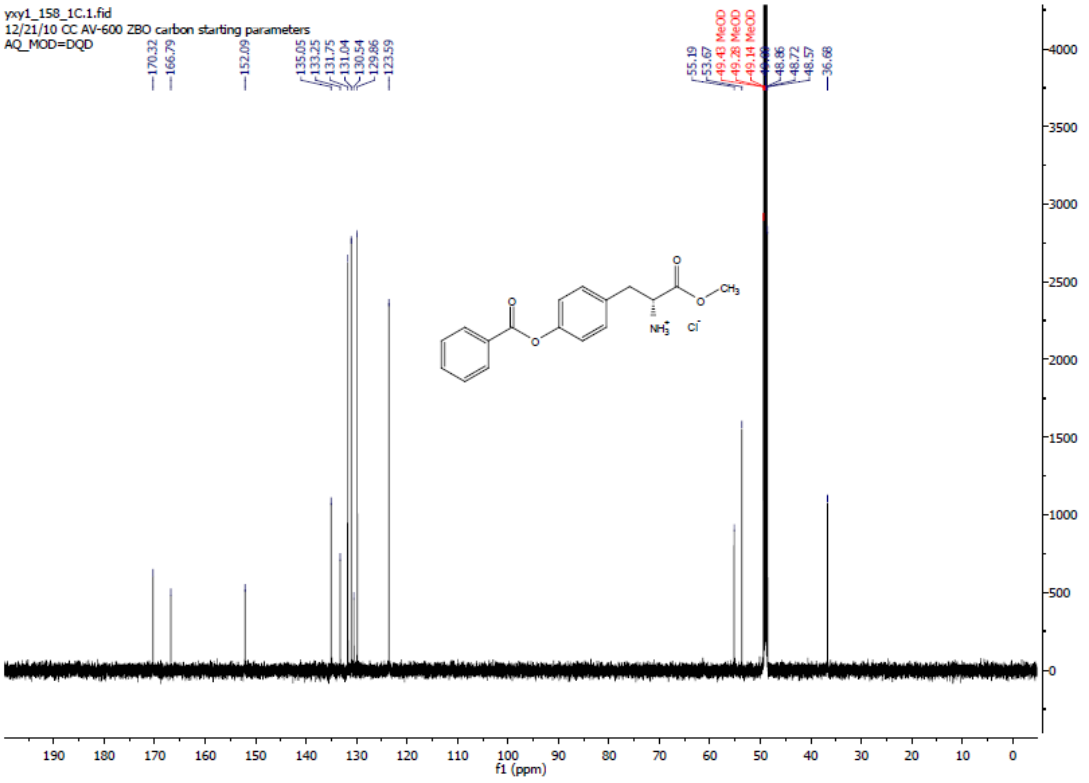
O-Benzyl (D)-Tyrosine methyl ester hydrochloride (**A7**)



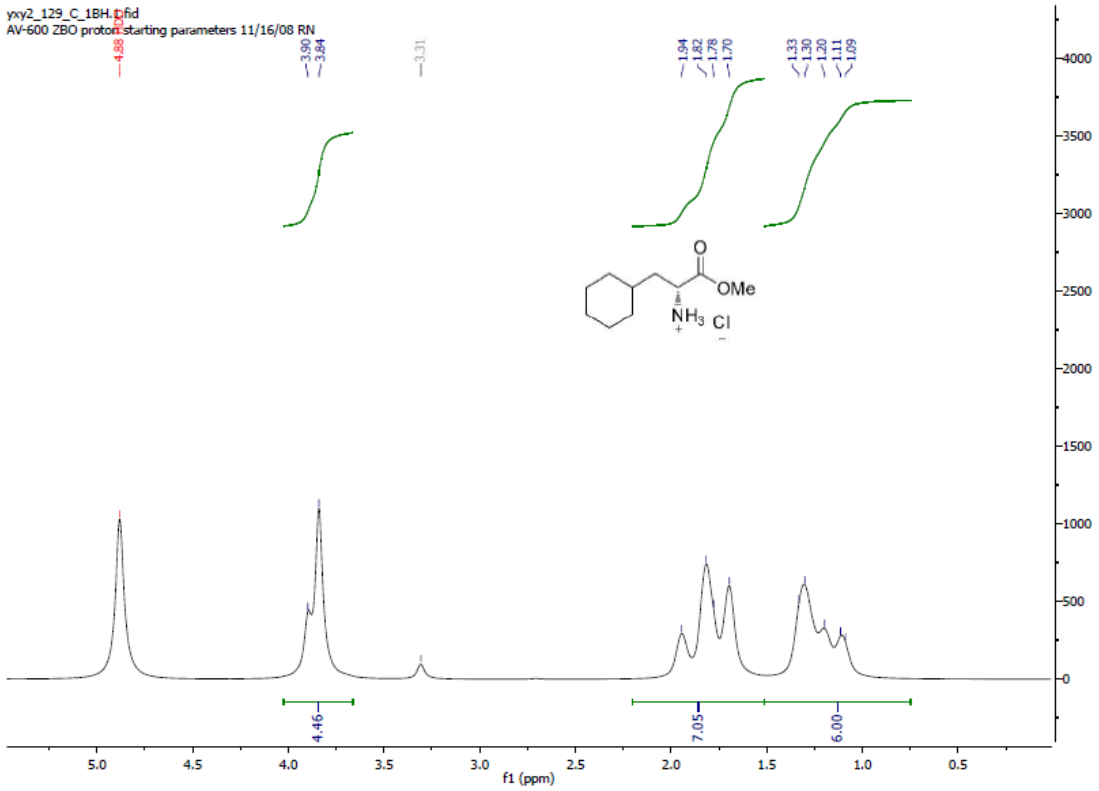


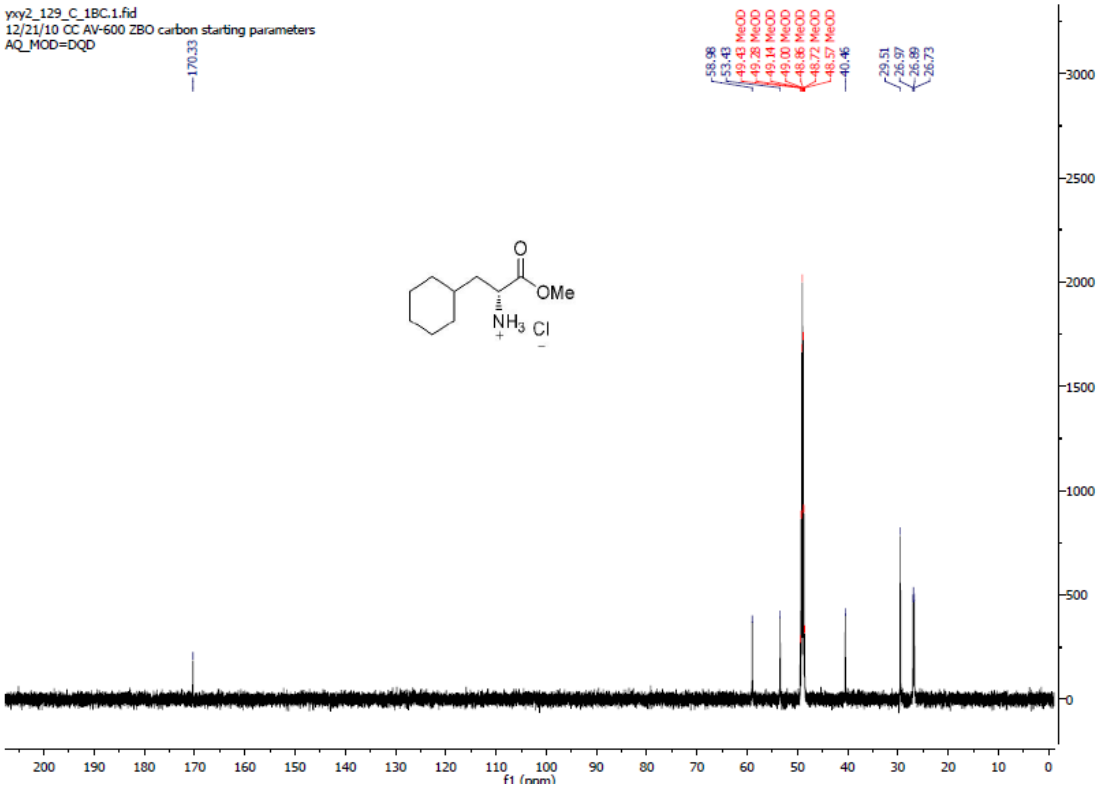
O-Benzoyl (D)-Tyrosine methyl ester hydrochloride (**A8**)



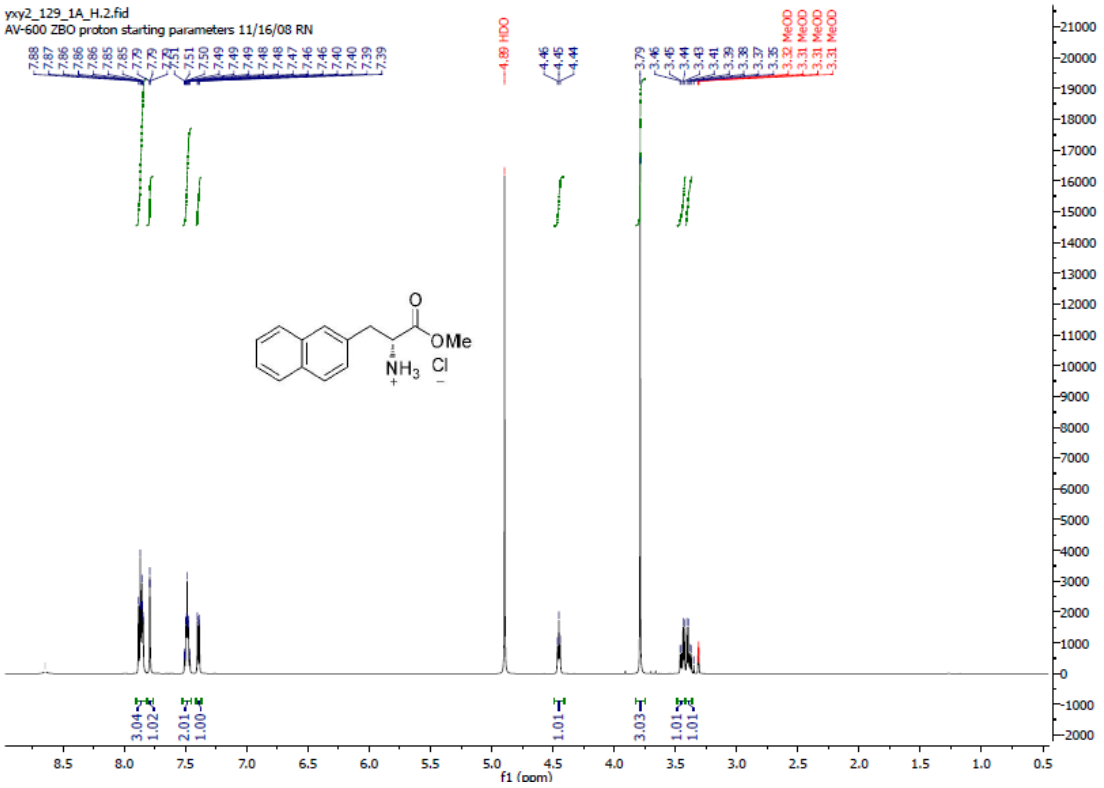


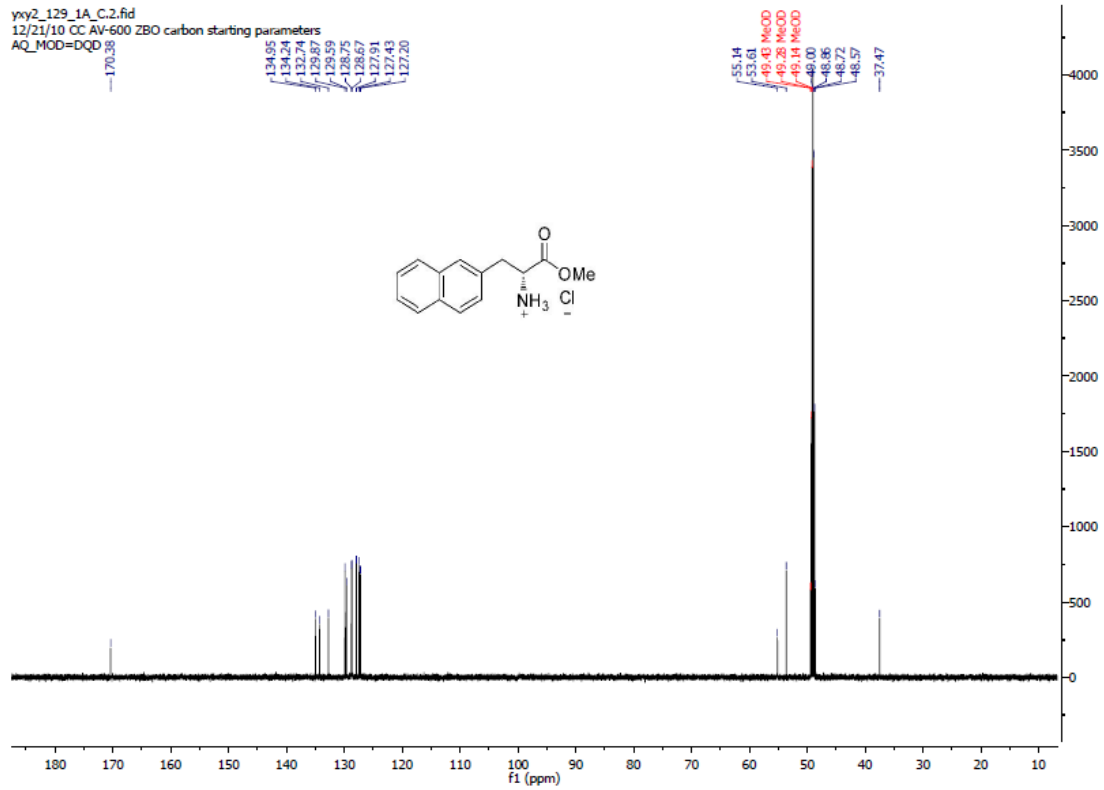
(D)-cyclohexylalanine methyl ester hydrochloride (**A10**)



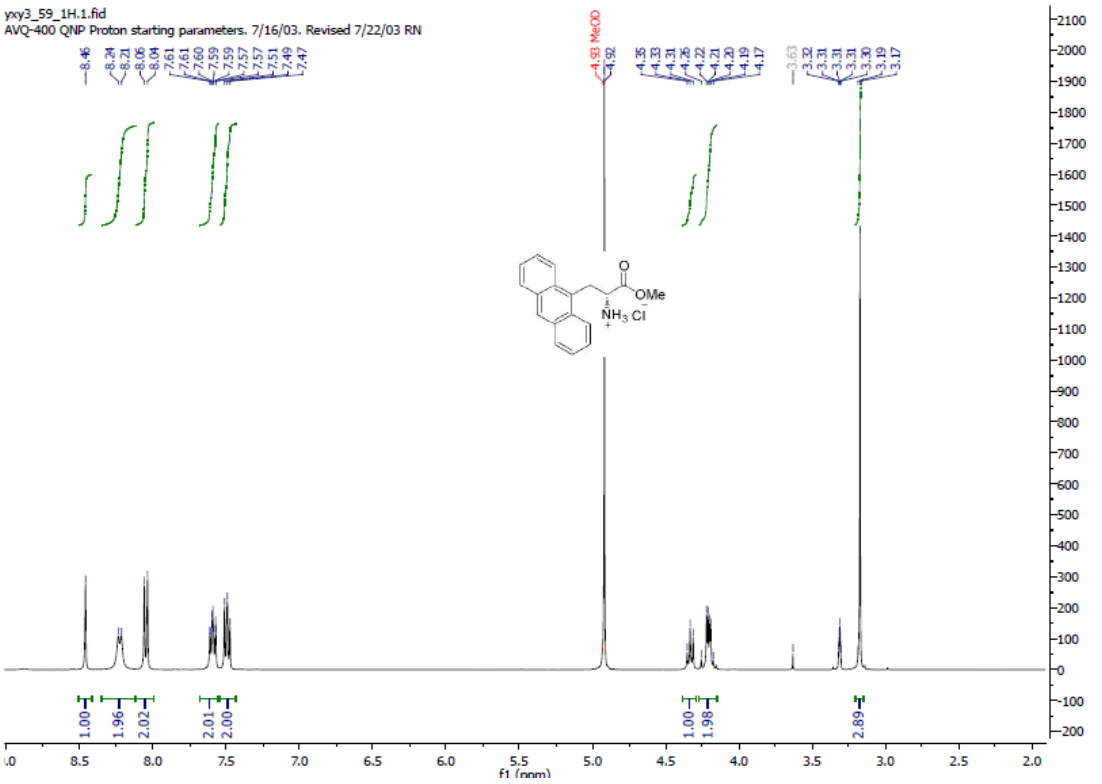


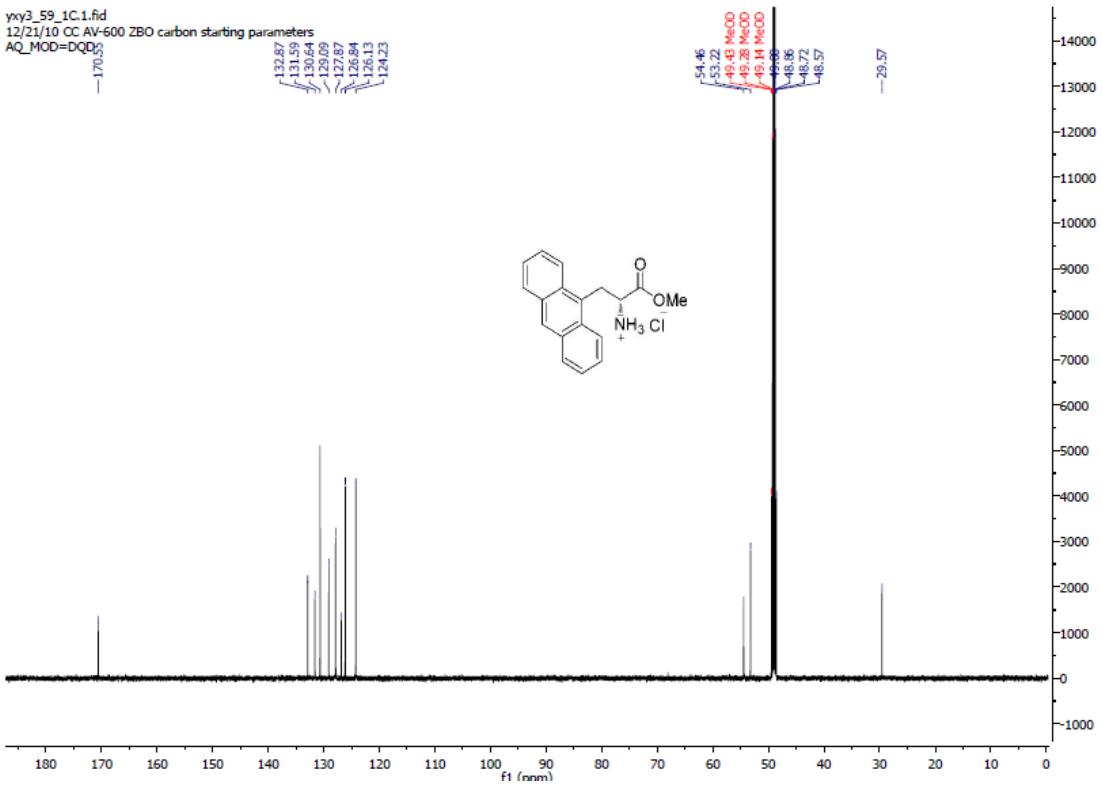
(D)-2-naphthylalanine methyl ester hydrochloride **(A11)**



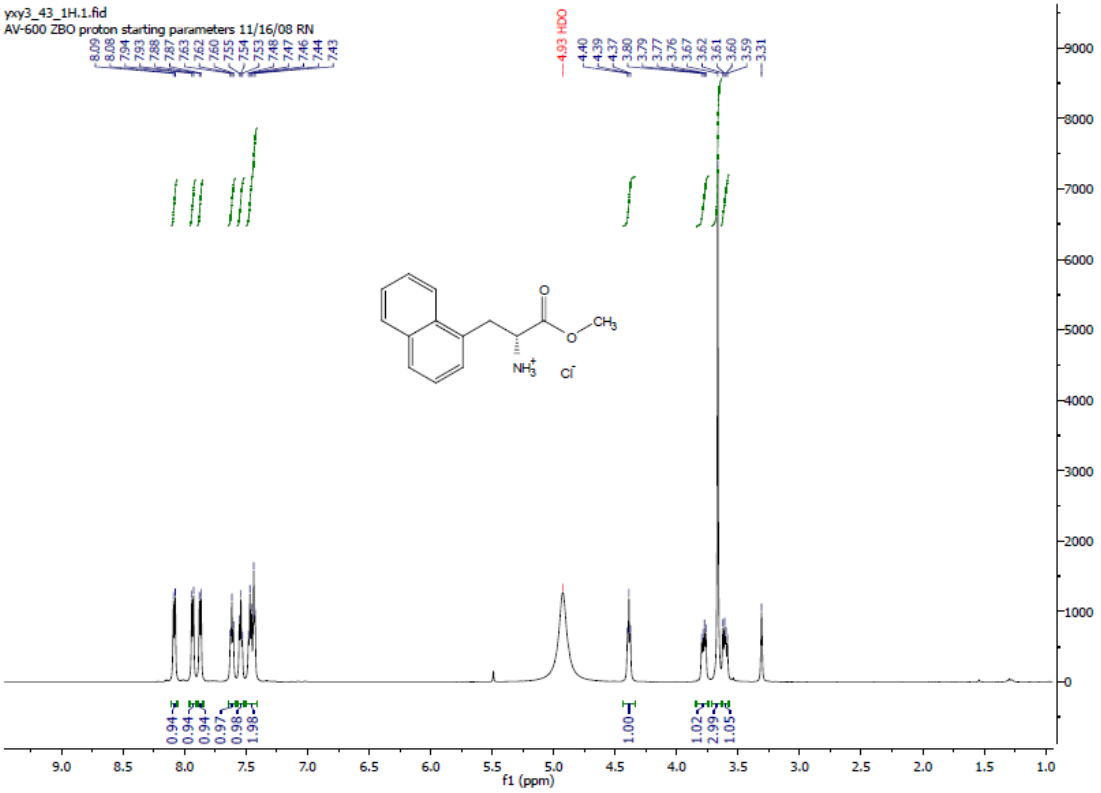


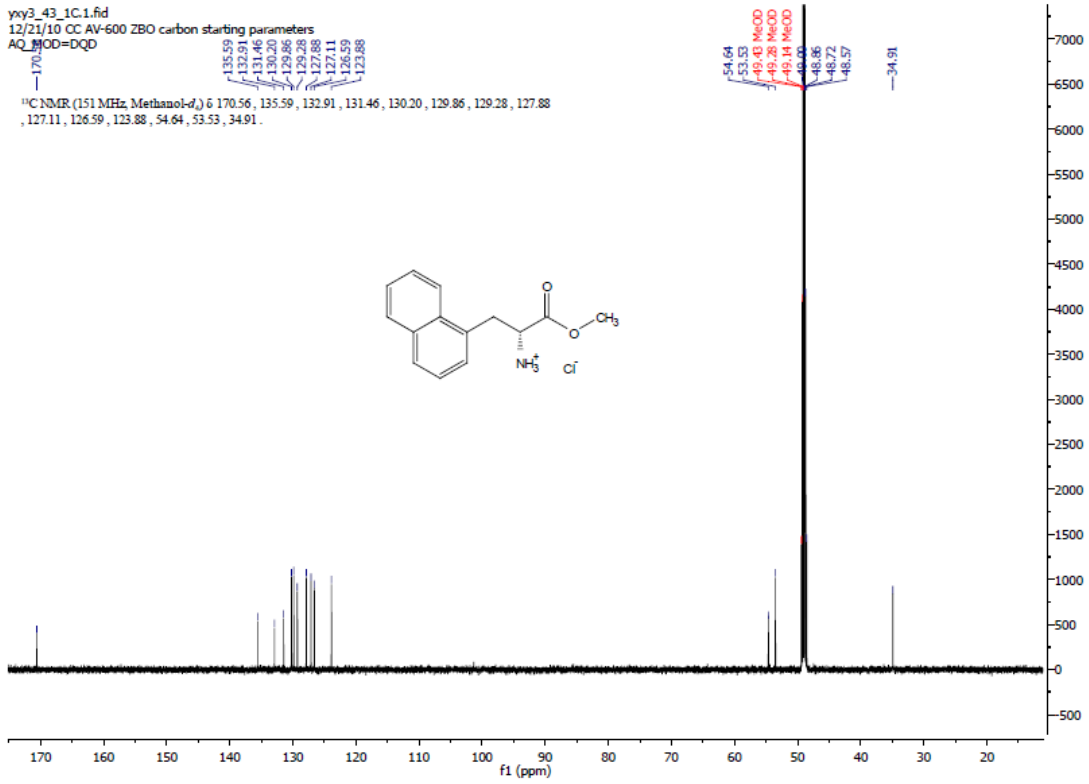
(D)-9-anthracylalanine methyl ester hydrochloride **(A12)**



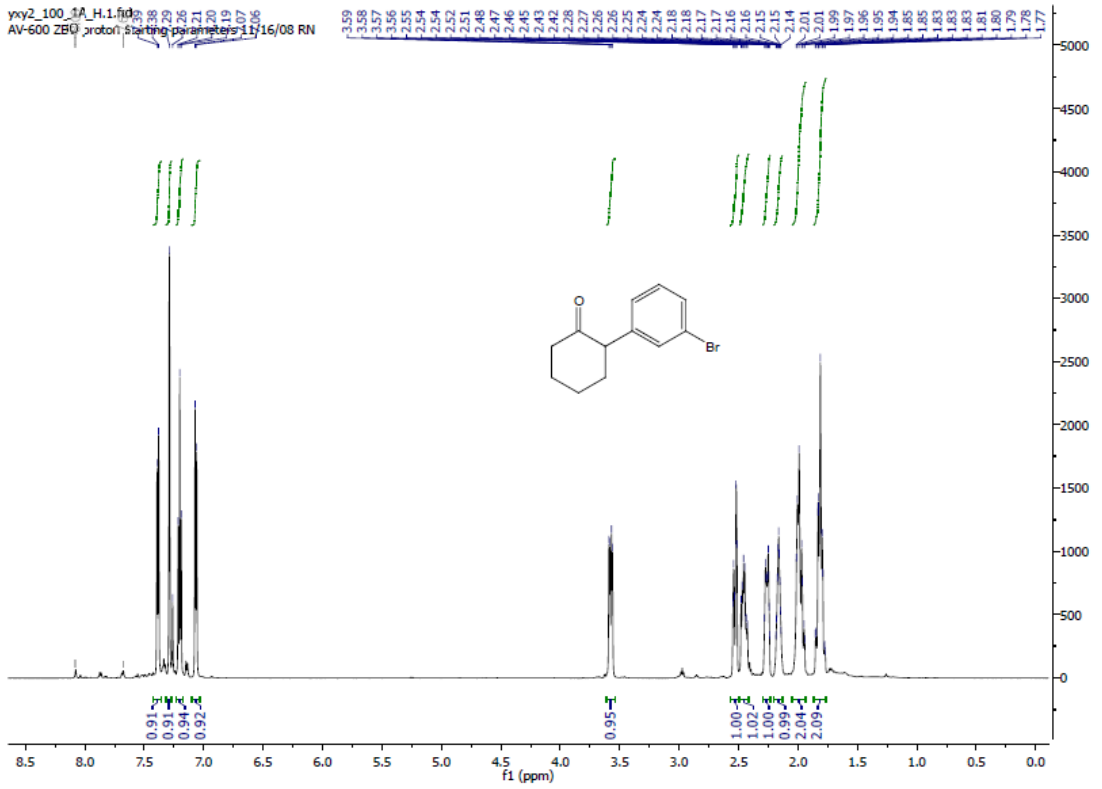


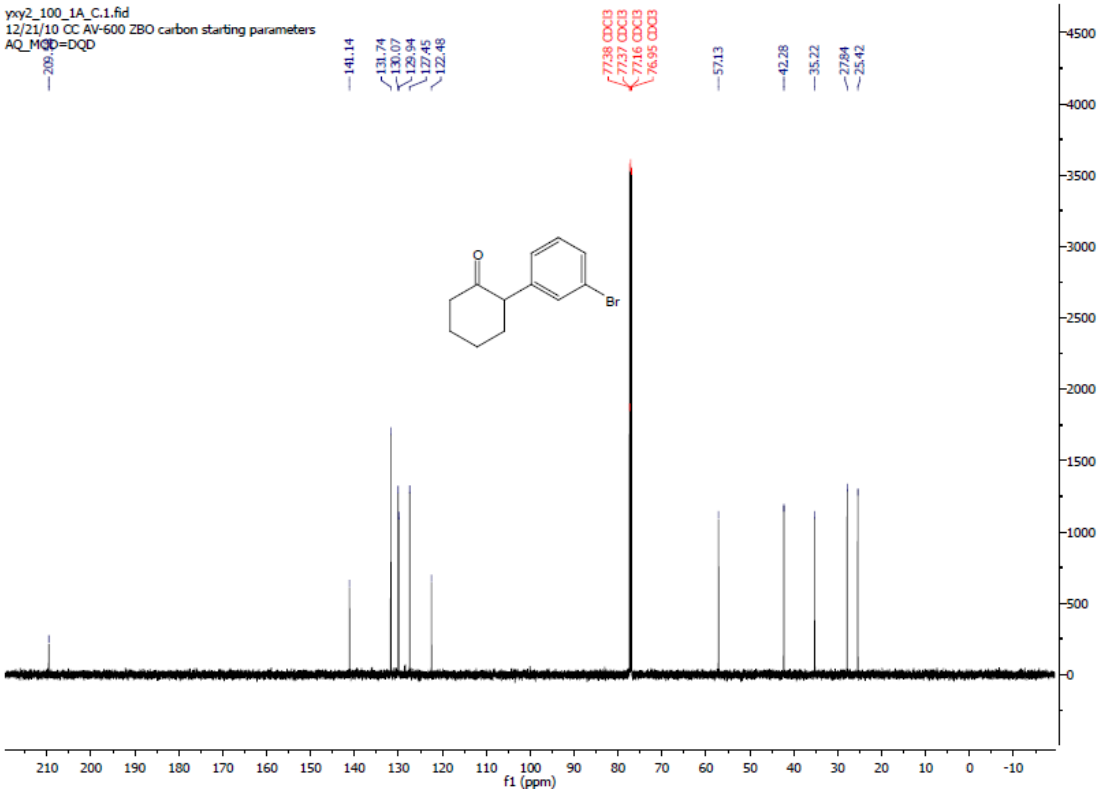
(D)-1-naphthylalanine methyl ester hydrochloride **(A13)**



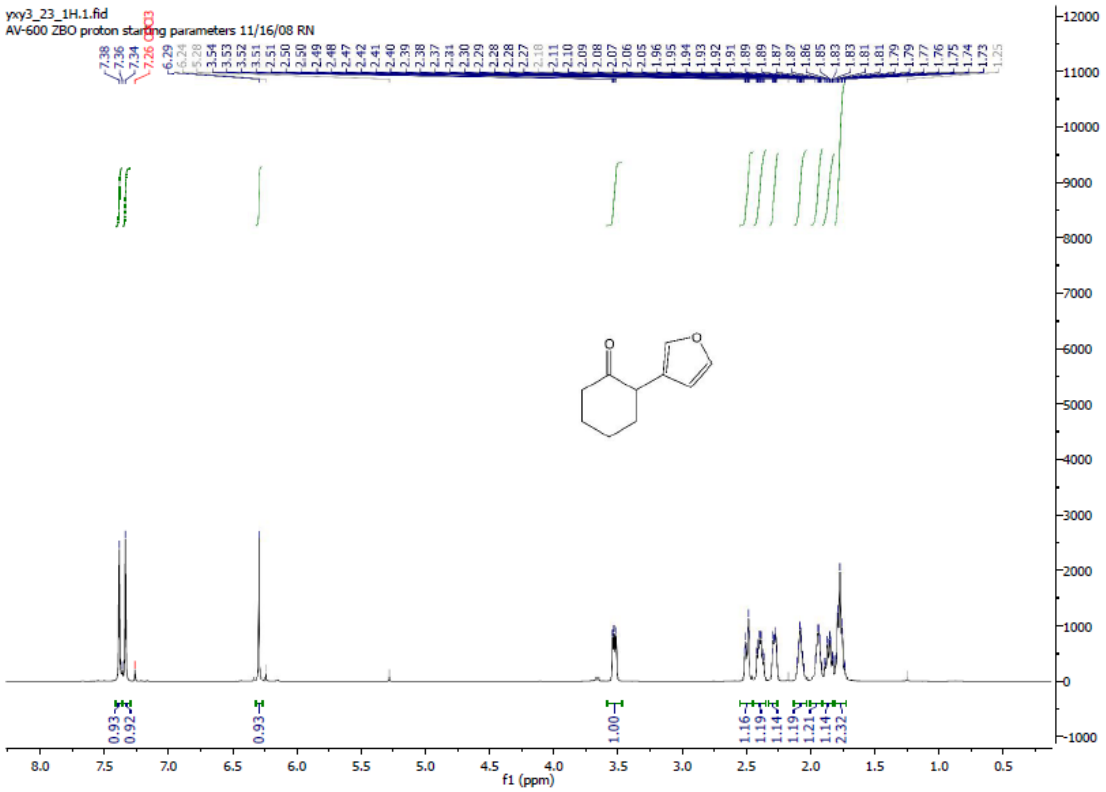


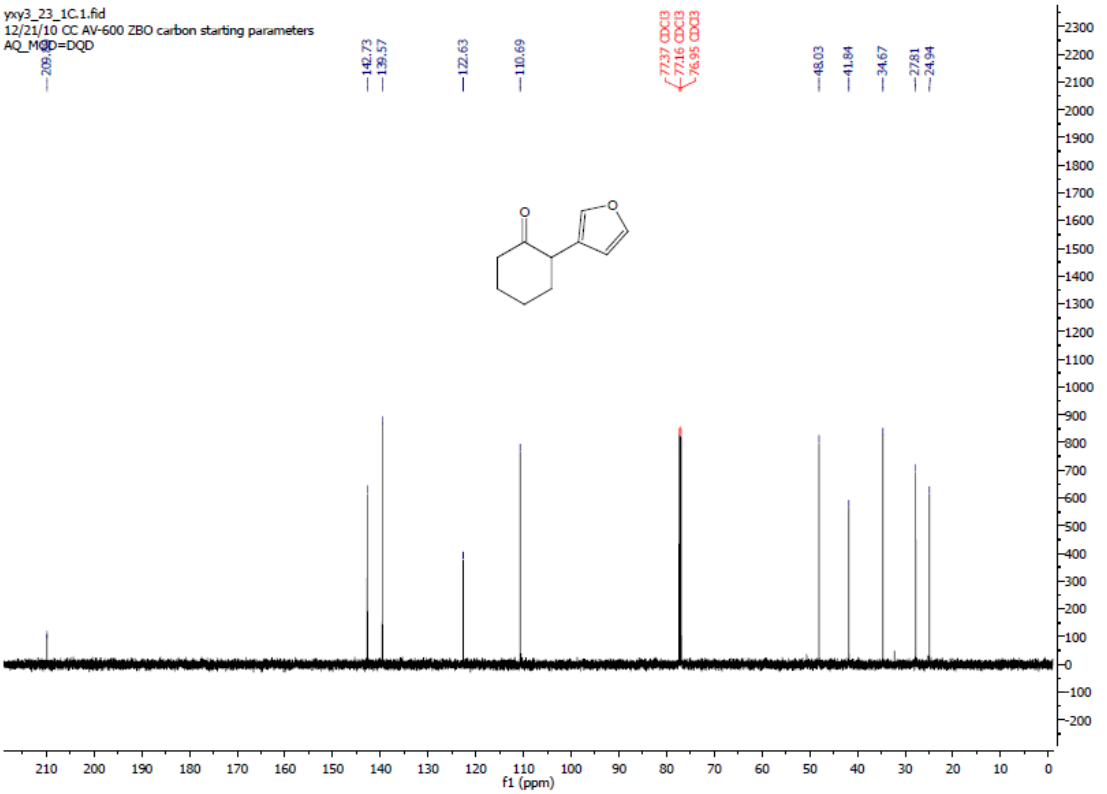
2-(3-bromophenyl)cyclohexanone (**1g**)



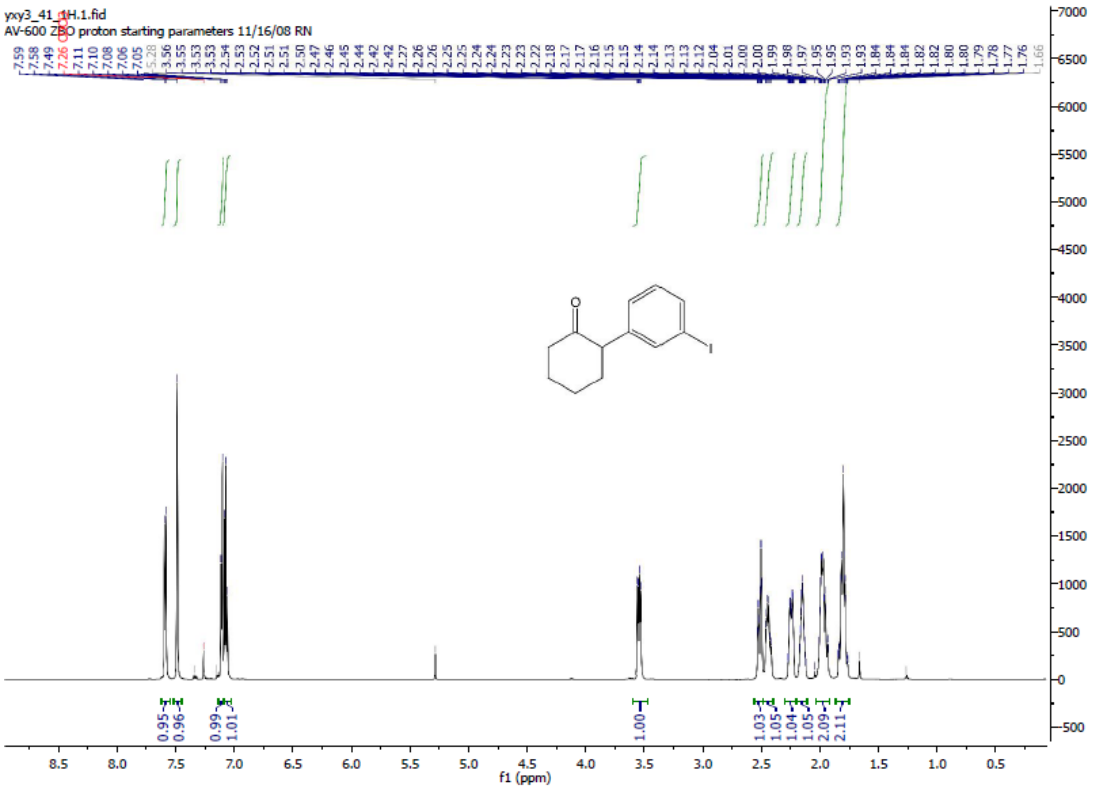


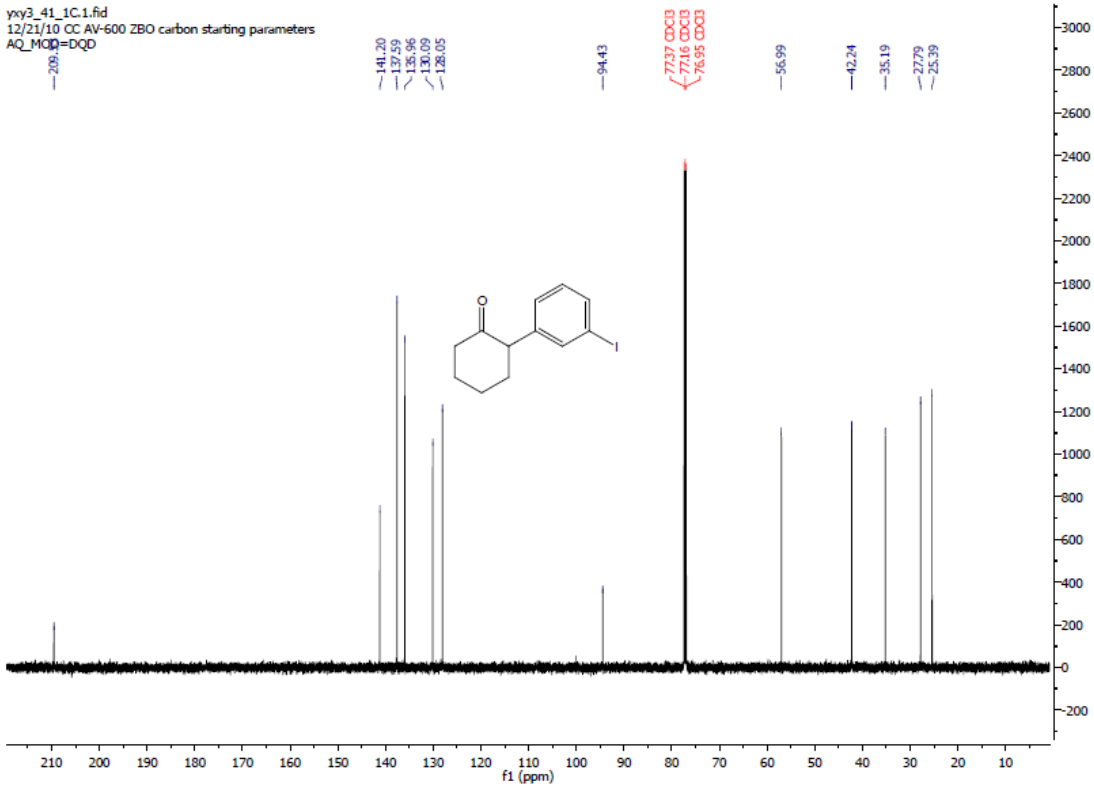
2-(furan-3-yl)cyclohexanone (**1i**)



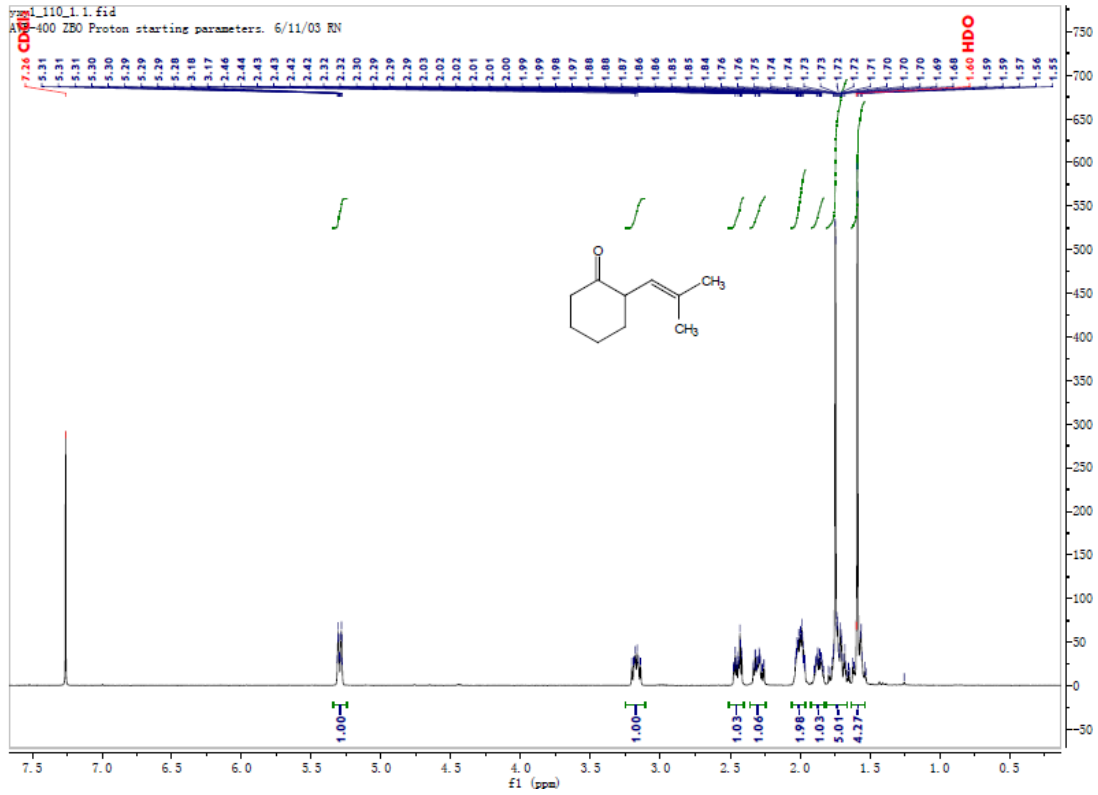


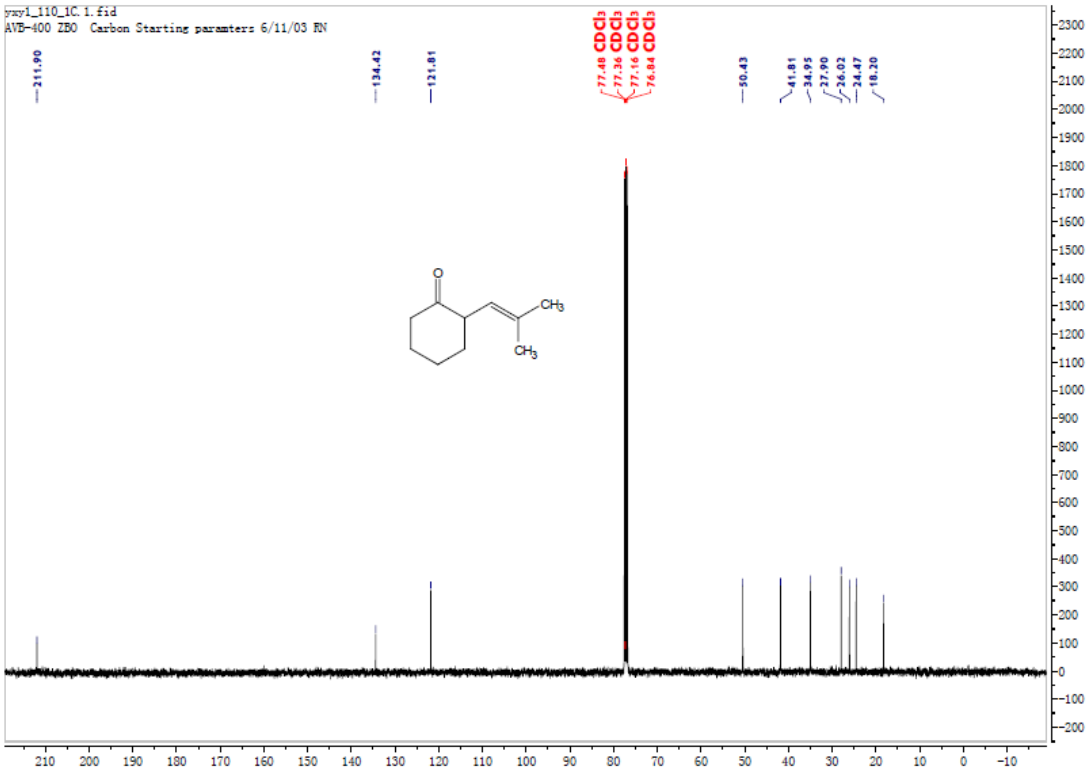
2-(3-iodophenyl)cyclohexanone (**1j**)



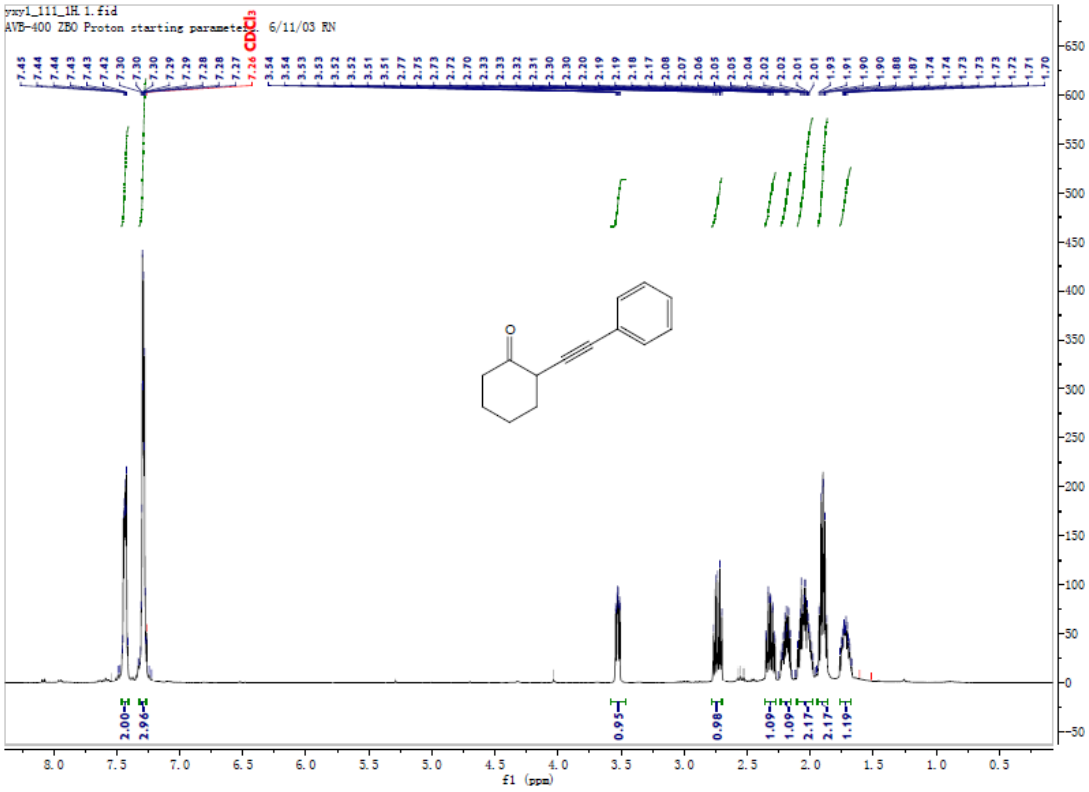


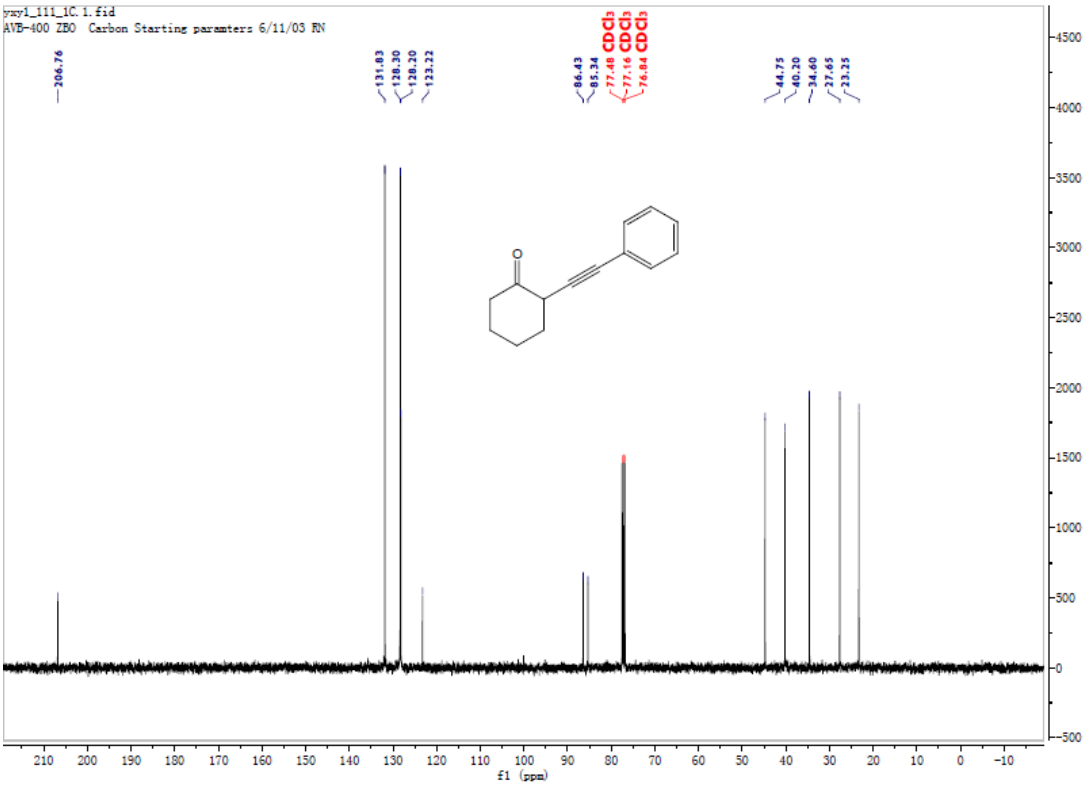
2-(2-methylprop-1-en-1-yl)cyclohexanone (**1o**)



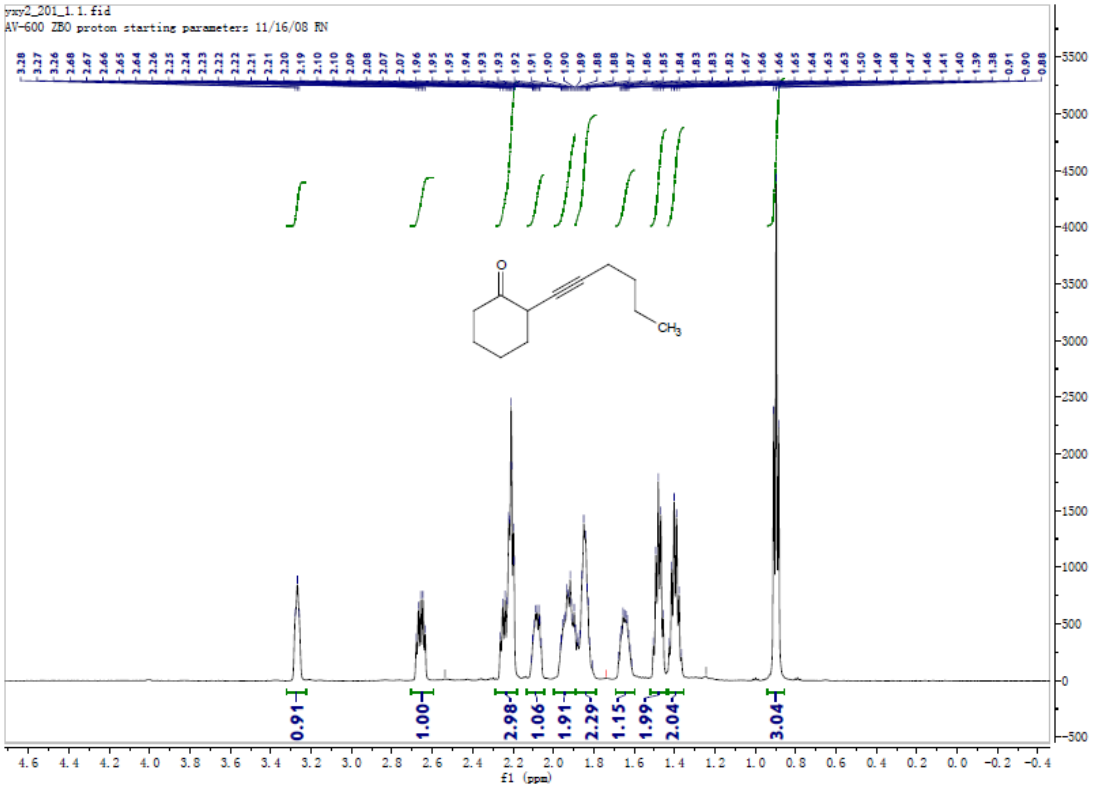


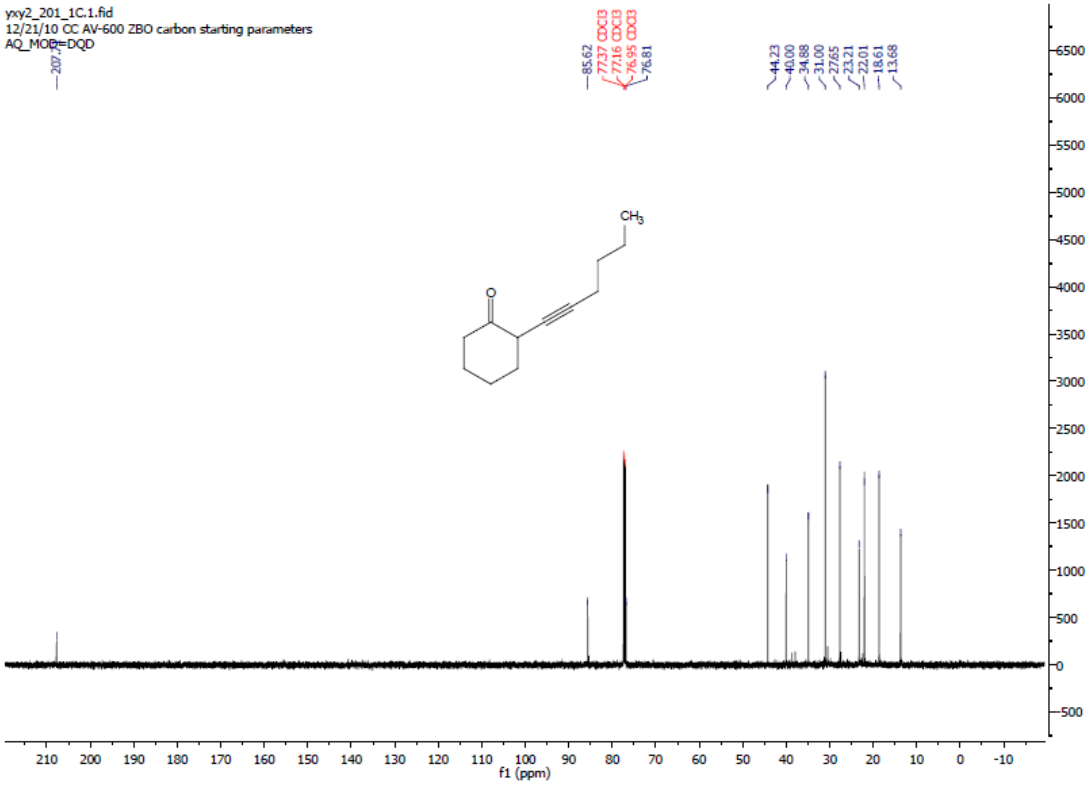
2-(phenylethynyl)cyclohexanone (**1p**)



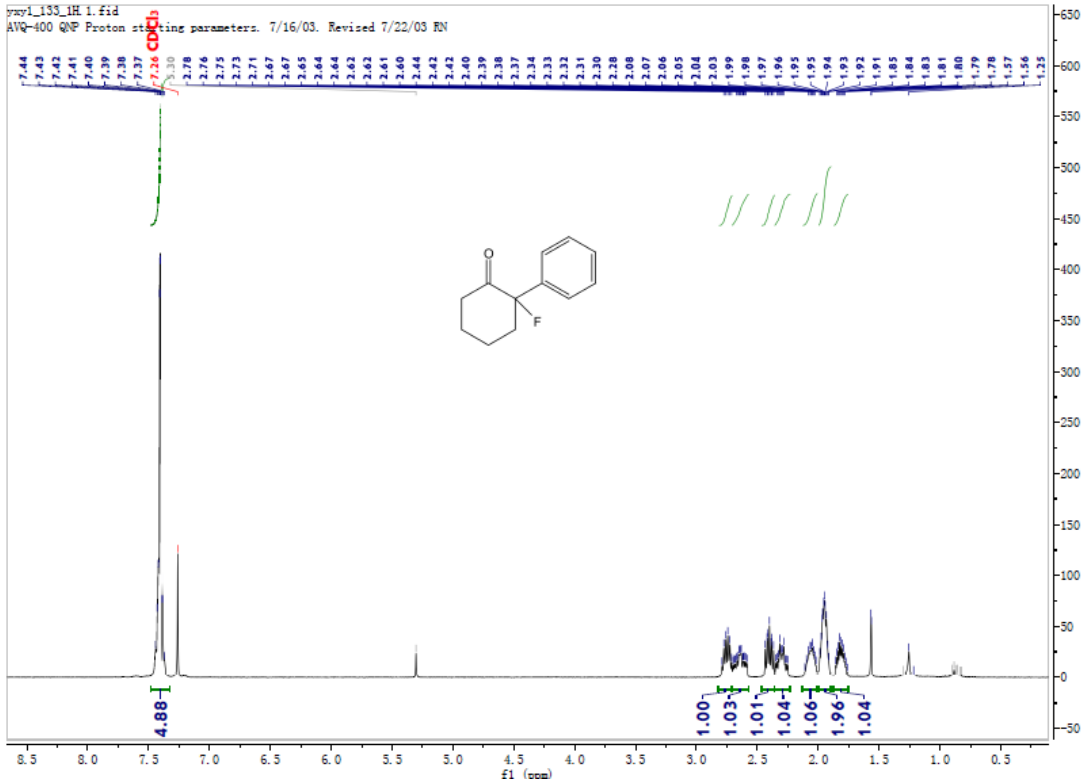


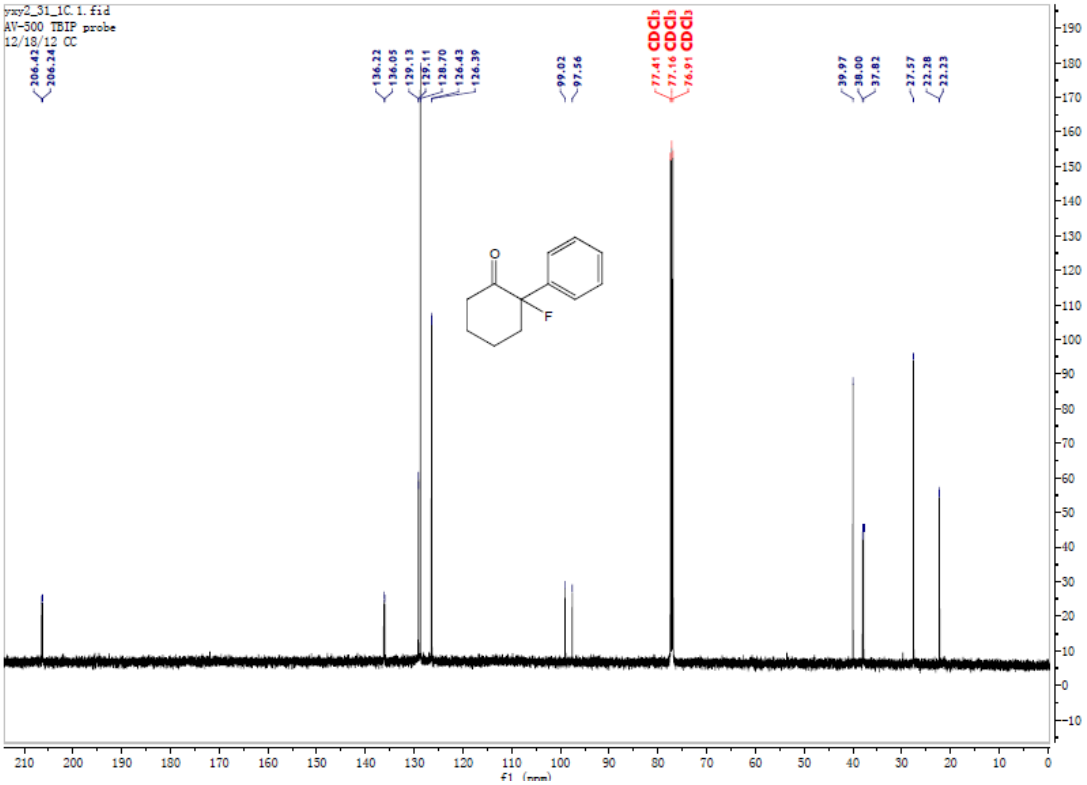
2-(hex-1-yn-1-yl)cyclohexanone (**1q**)

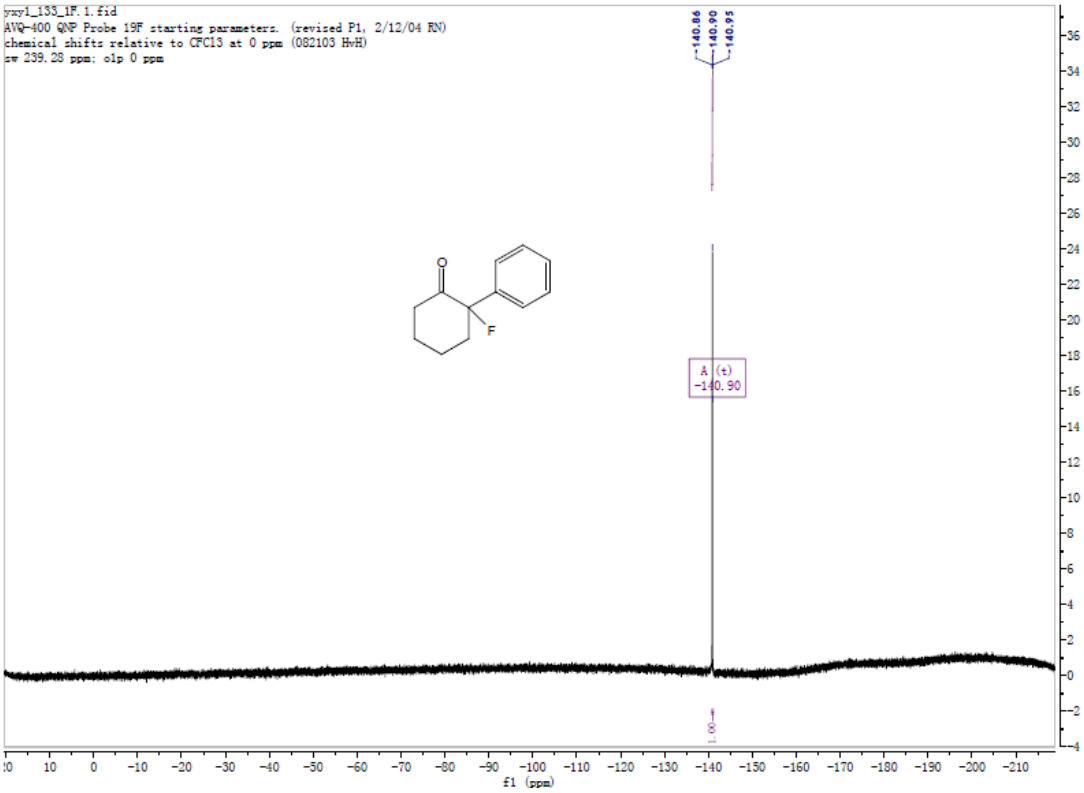




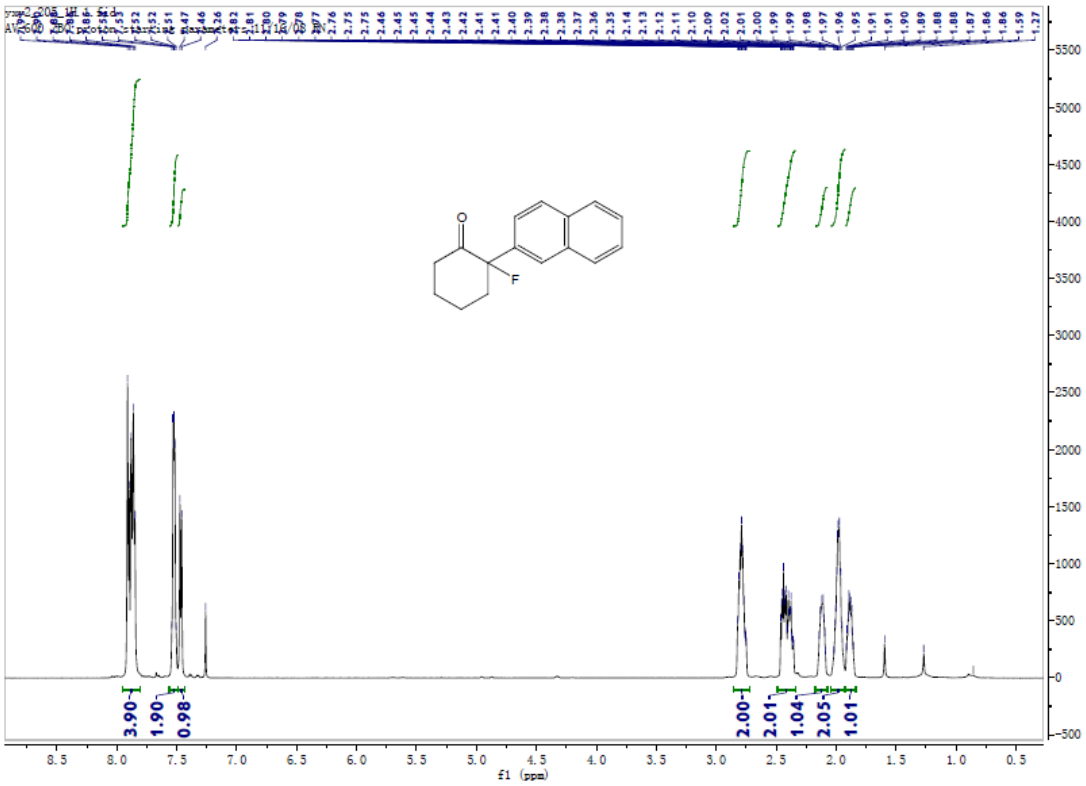
(*R*)-2-fluoro-2-phenylcyclohexanone (**2a**)

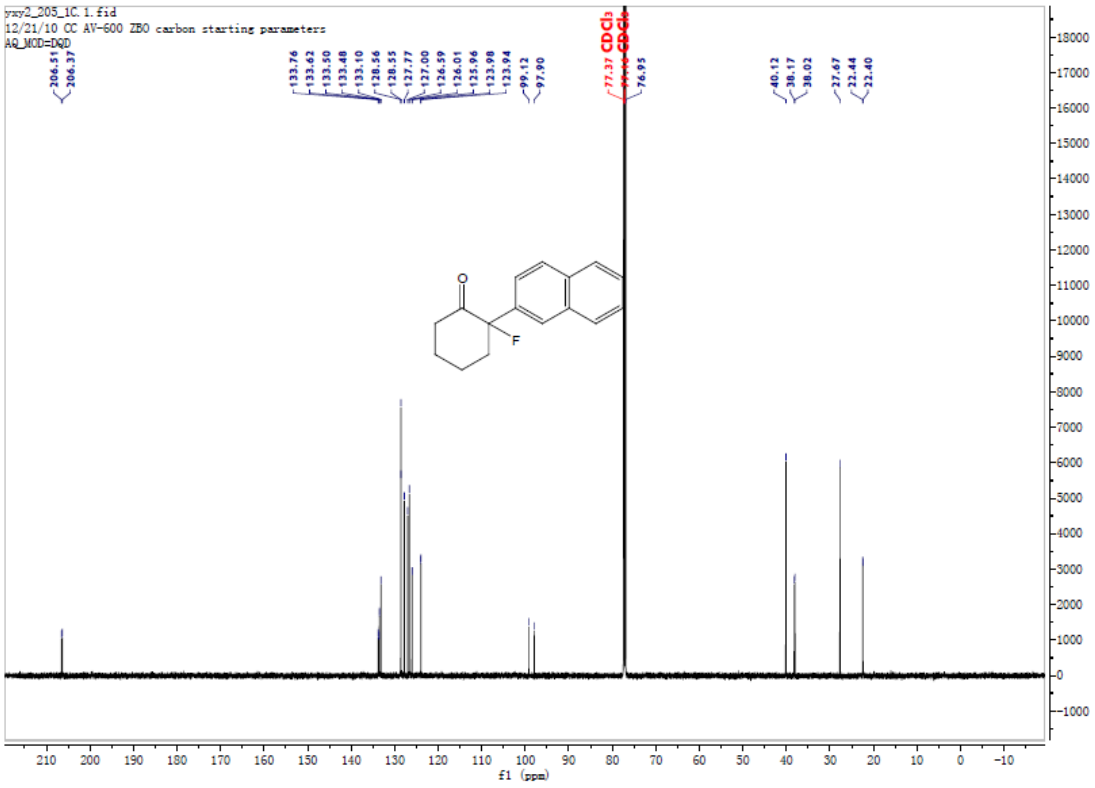


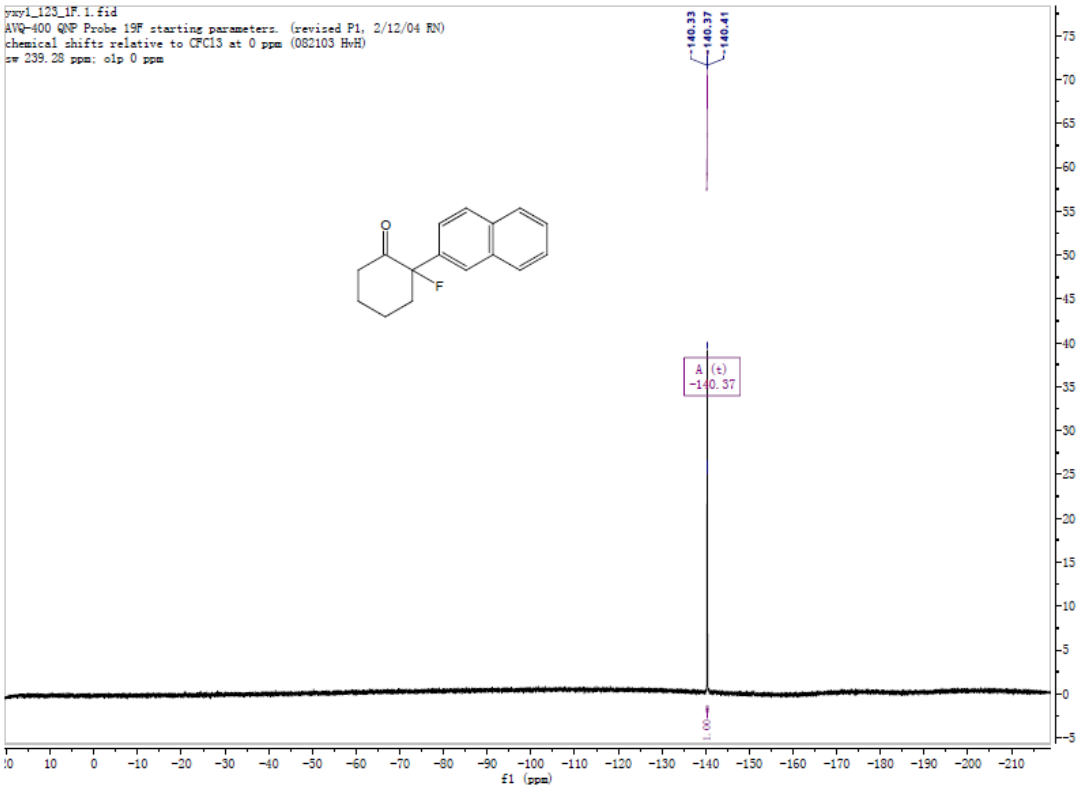




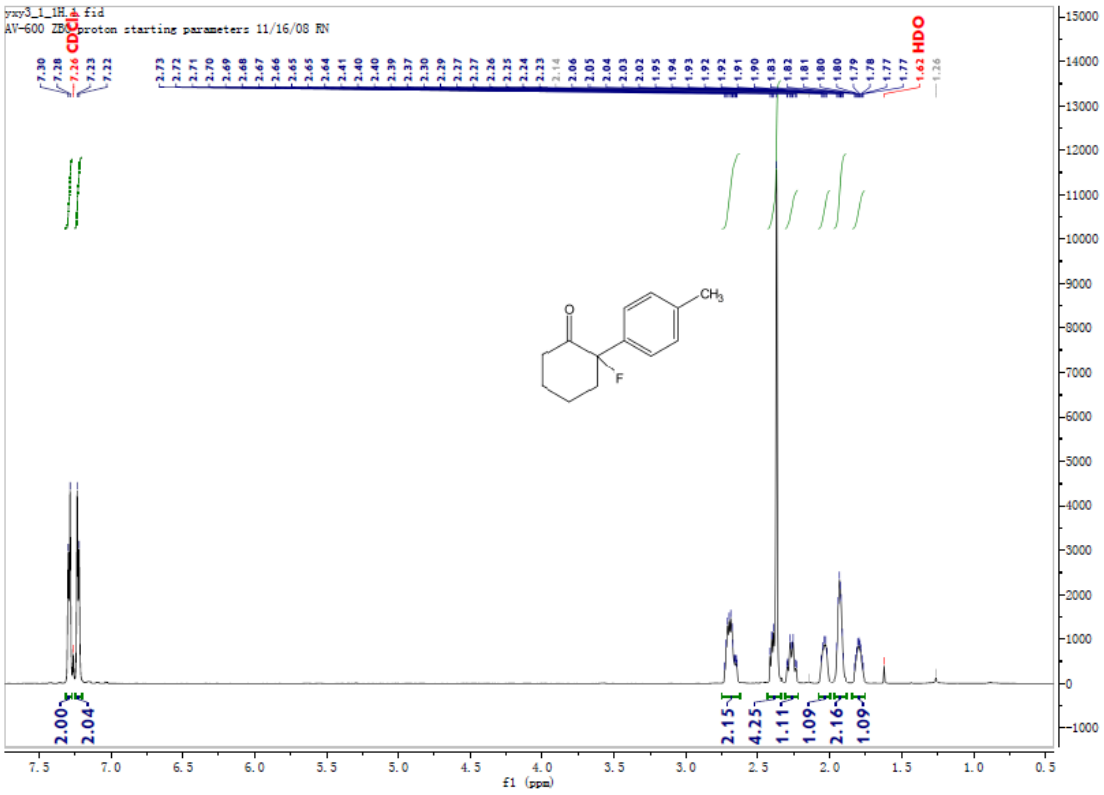
(*R*)-2-fluoro-2-(naphthalen-2-yl)cyclohexanone (**2b**)

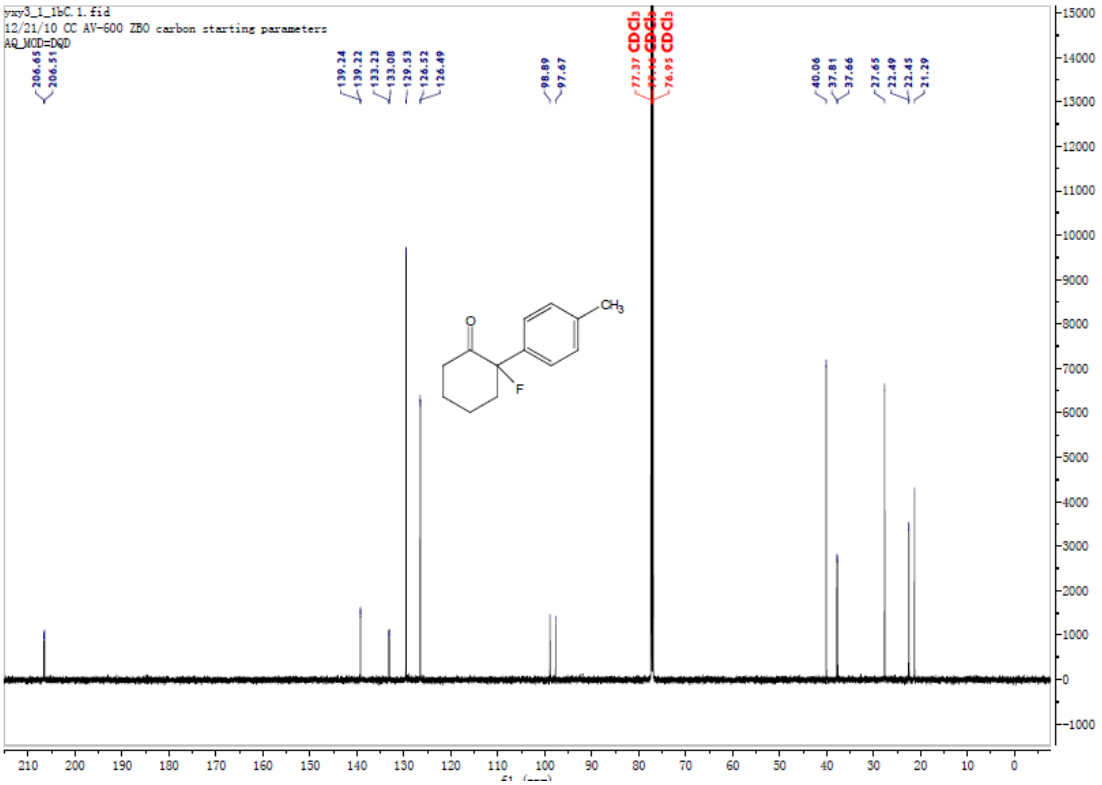


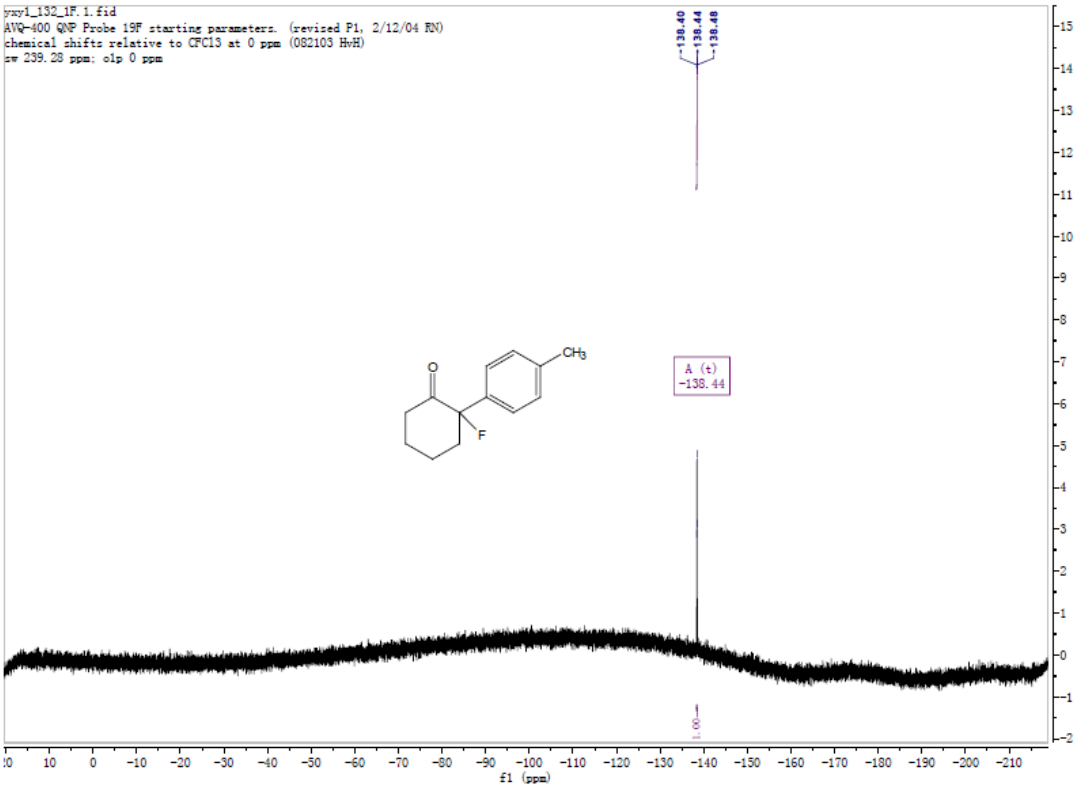

yxy2_205_1C.1.fid
12/21/10 CC AV-600 ZBO carbon starting parameters
AQ_MOD=DQD
206.51
206.37
133.76
133.62
133.50
133.48
133.10
128.56
128.55
127.77
127.00
126.59
126.01
125.96
123.98
123.94
99.12
97.90
77.37
CDCl3
76.95
40.12
38.17
38.02
27.67
22.44
22.40
O
F
f1 (ppm)


yxy1_123_1F.1.fid
AVQ-400 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
chemical shifts relative to CFCl3 at 0 ppm (082103 HvH)
sw 239.28 ppm; olp 0 ppm
-140.33
-140.37
-140.41
A (t)
-140.37
1.00
O
F
f1 (ppm)

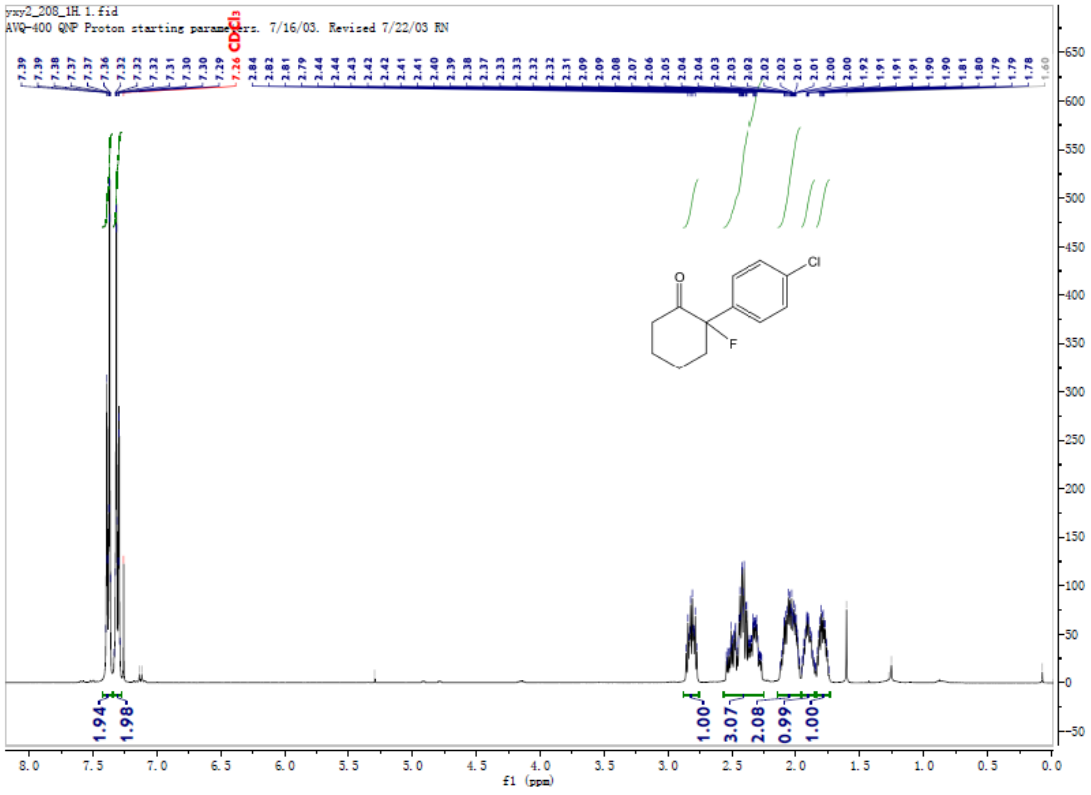
(*R*)-2-fluoro-2-(p-tolyl)cyclohexanone (**2c**)

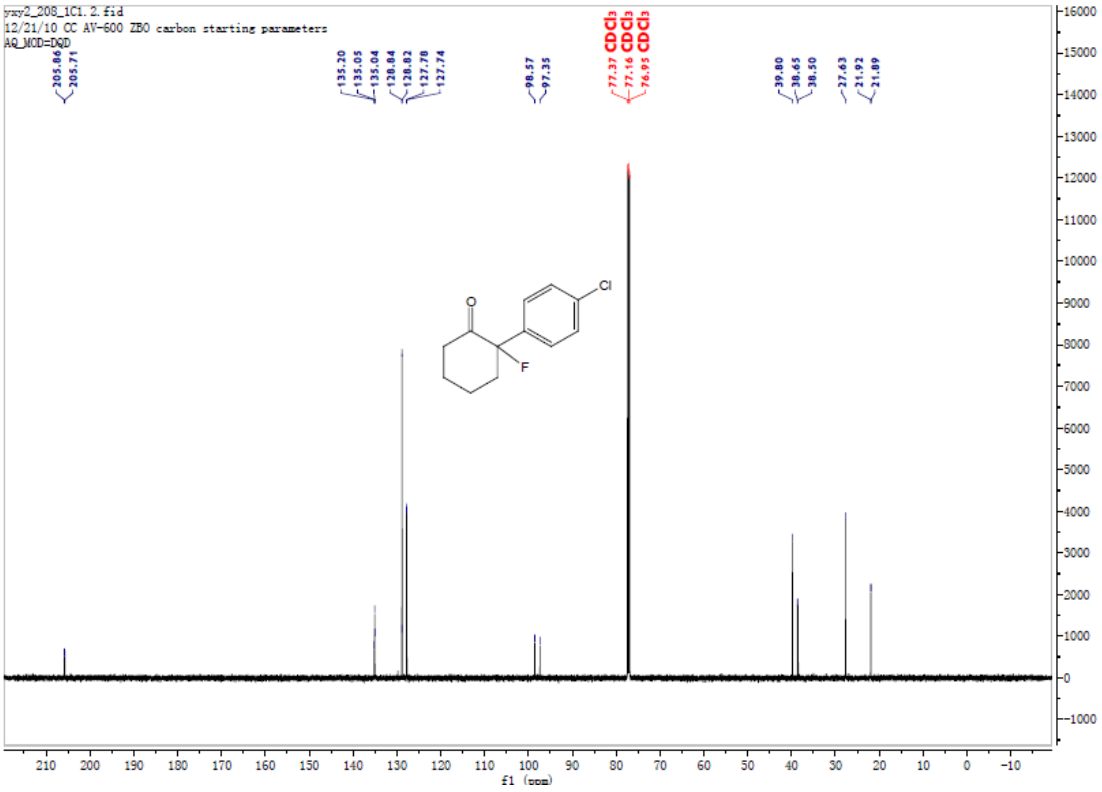


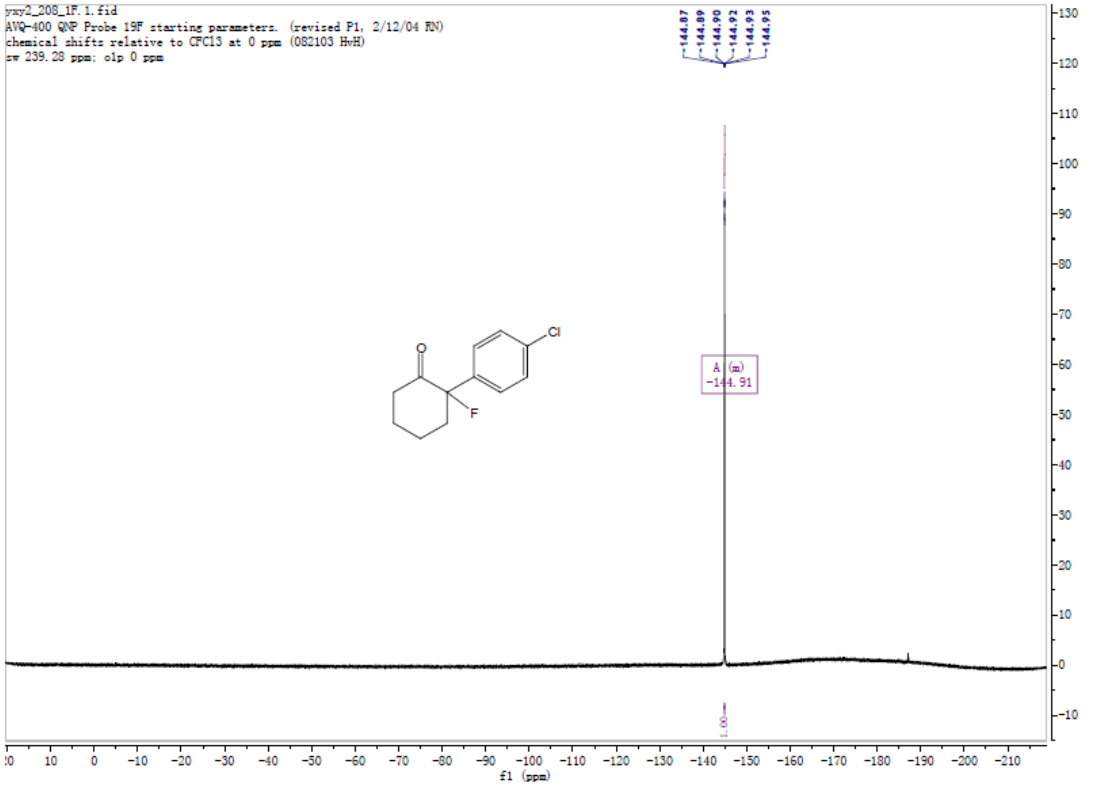




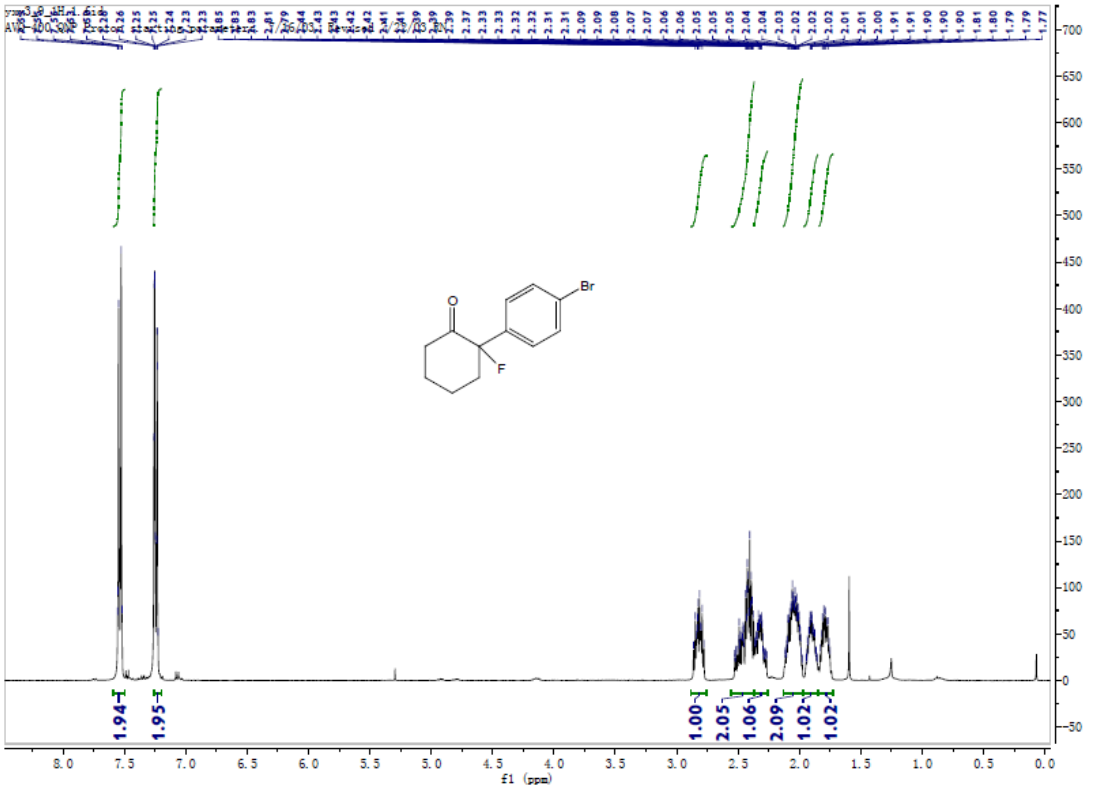
(*R*)-2-(4-chlorophenyl)-2-fluorocyclohexanone (**2d**)

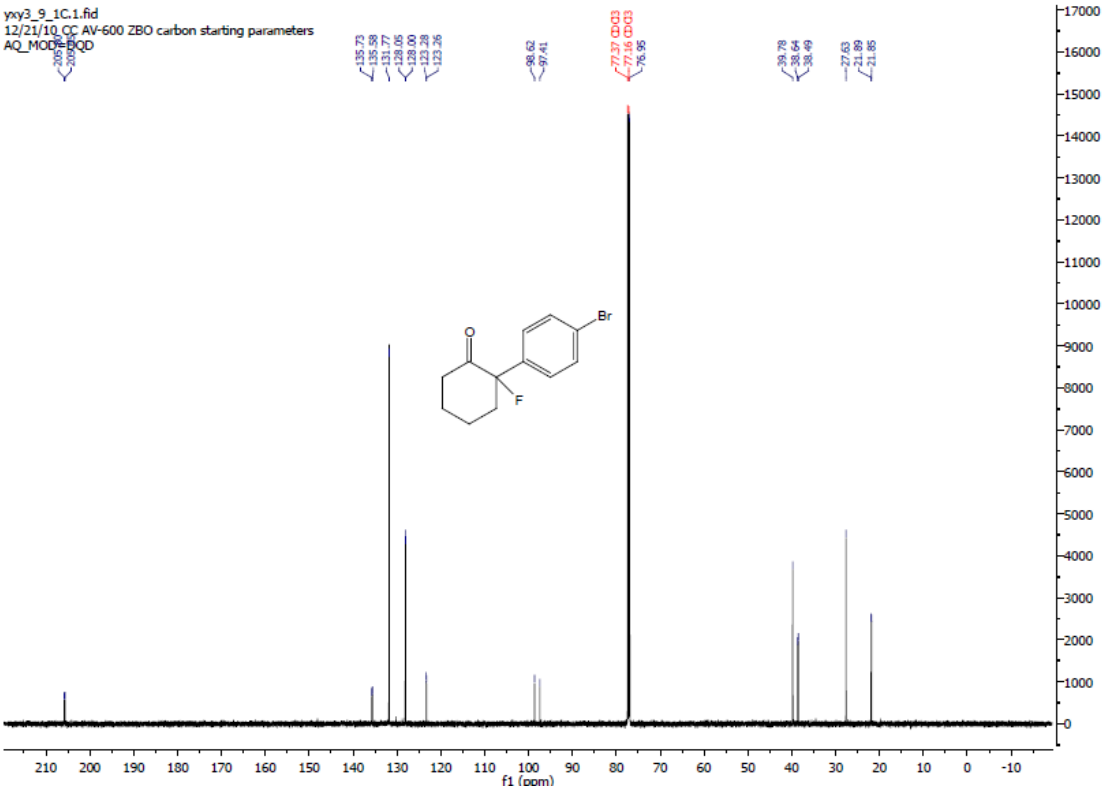


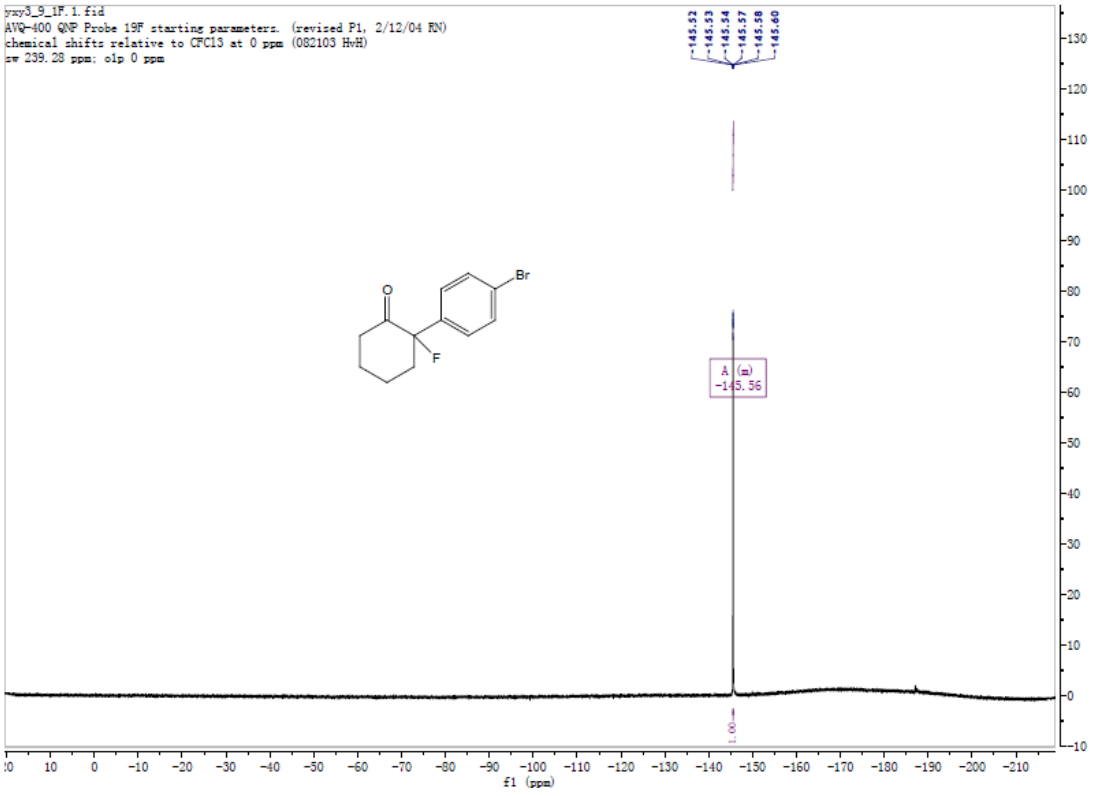

yxy2_208_1C1.2.fid
12/21/10 CC AV-600 ZBO carbon starting parameters
AQ_MOD=DQD
205.86
205.71
135.20
135.05
135.04
128.84
128.82
127.78
127.74
98.57
97.35
77.37 CDCl3
77.16 CDCl3
76.95 CDCl3
39.80
38.65
38.50
27.63
21.92
21.89
O
Cl
F
f1 (ppm)


yxy2_208_1F.1.fid
AVQ-400 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
chemical shifts relative to CFCl3 at 0 ppm (082103 HvH)
sw 239.28 ppm; olp 0 ppm
-144.87
-144.89
-144.90
-144.92
-144.93
-144.95
A (m)
-144.91
1.00
O
Cl
F
f1 (ppm)

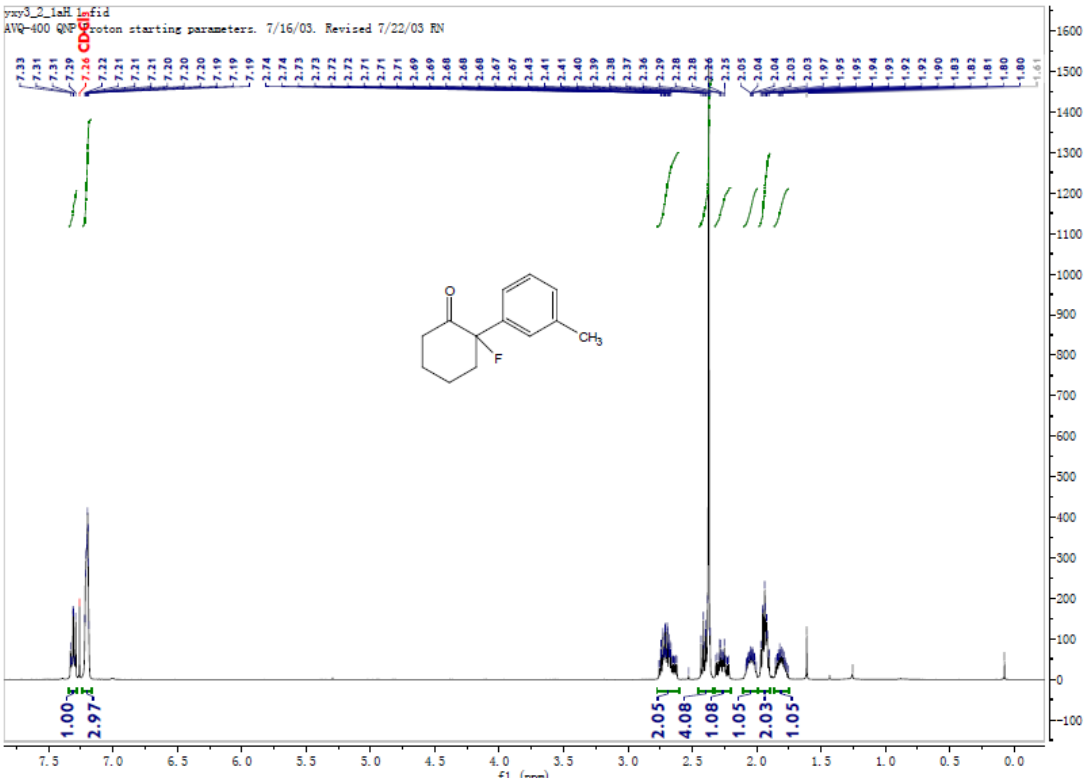
(*R*)-2-(4-bromophenyl)-2-fluorocyclohexanone (**2e**)

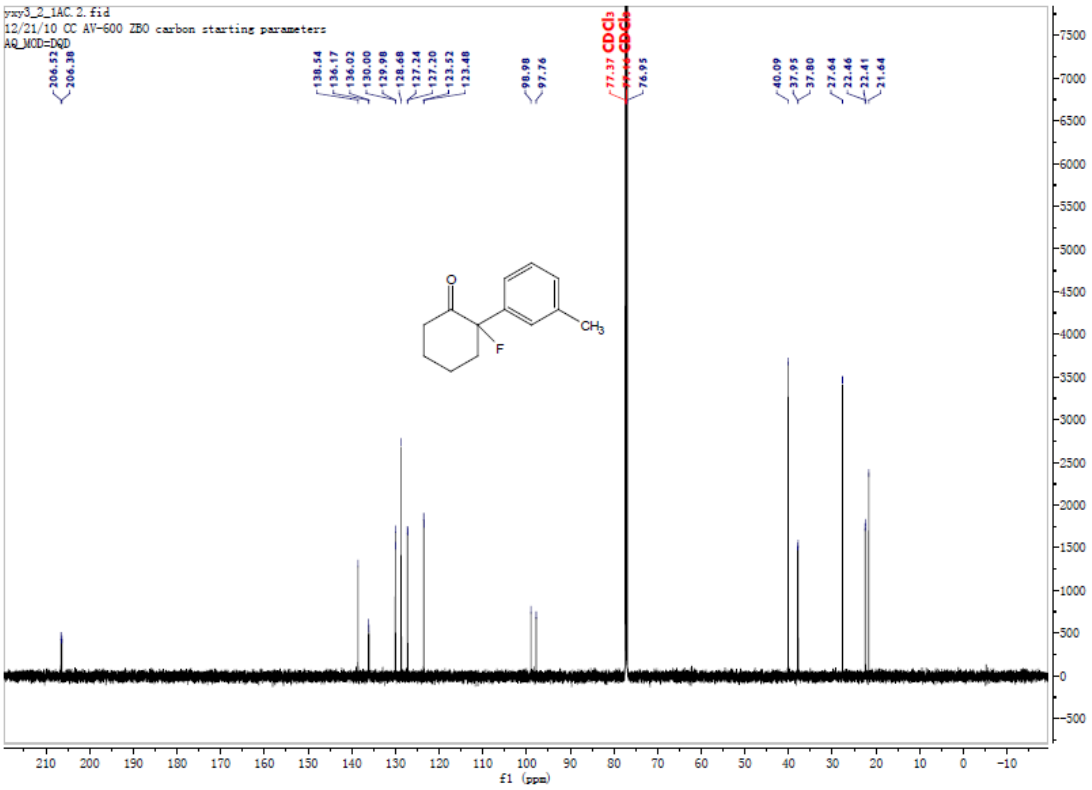


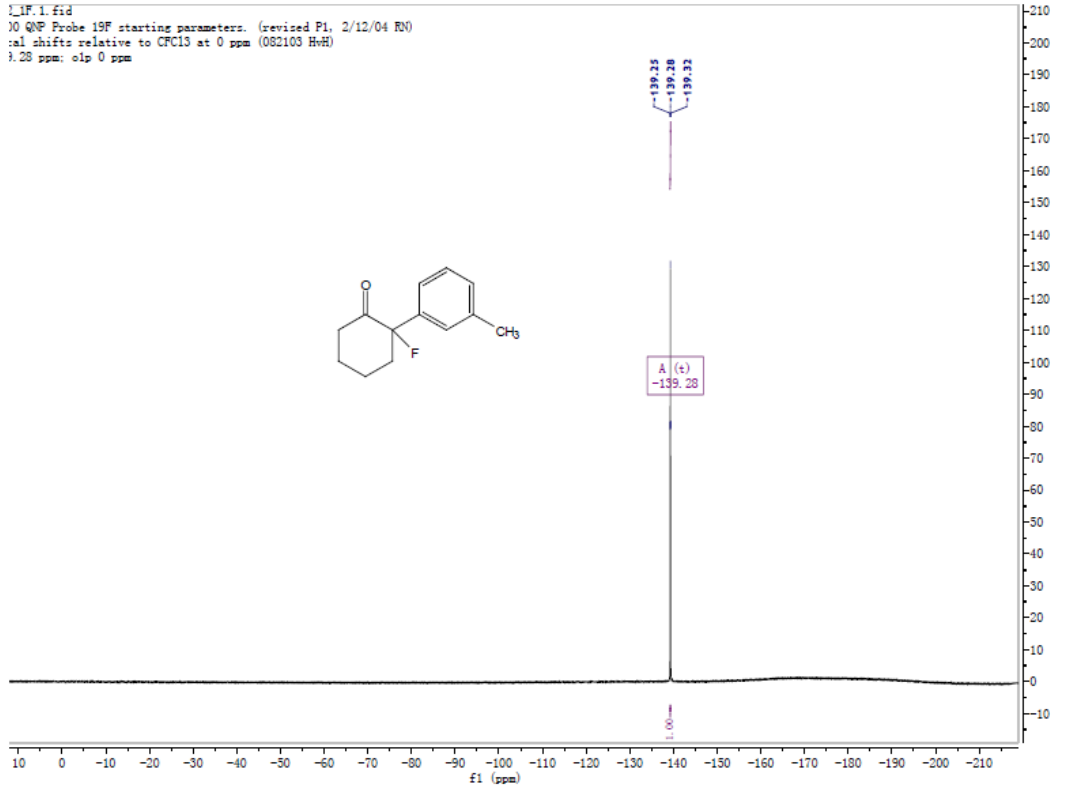




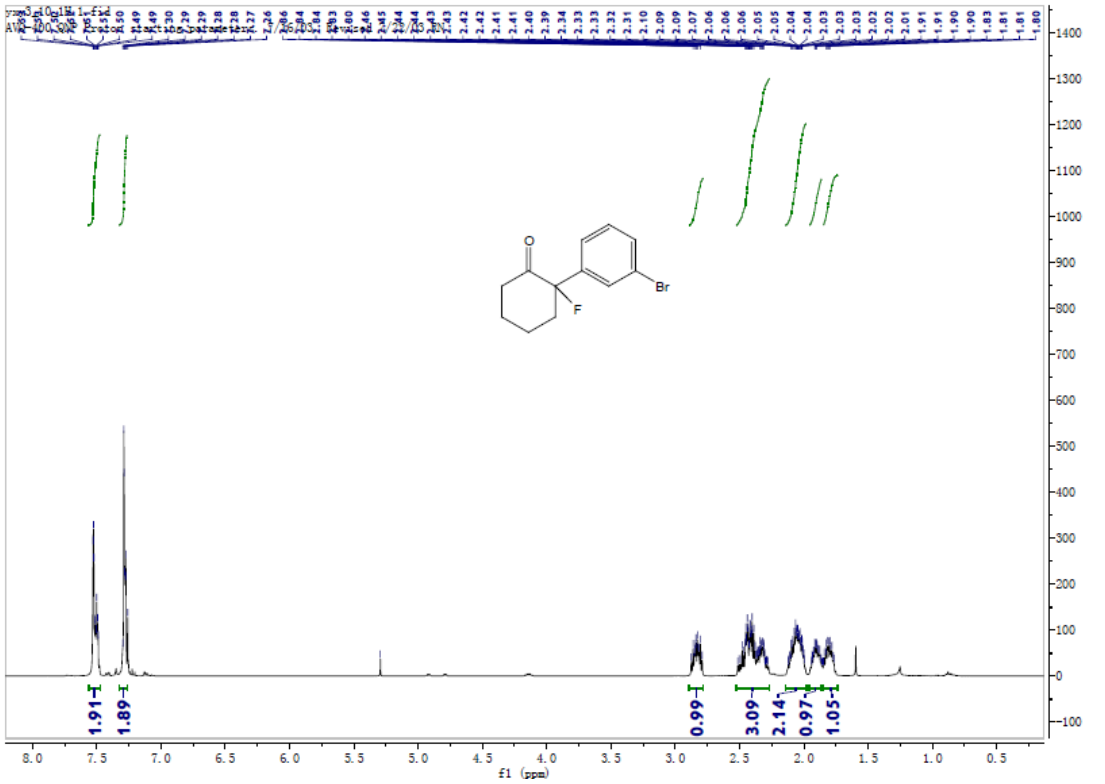
(*R*)-2-fluoro-2-(m-tolyl)cyclohexanone (**2f**)

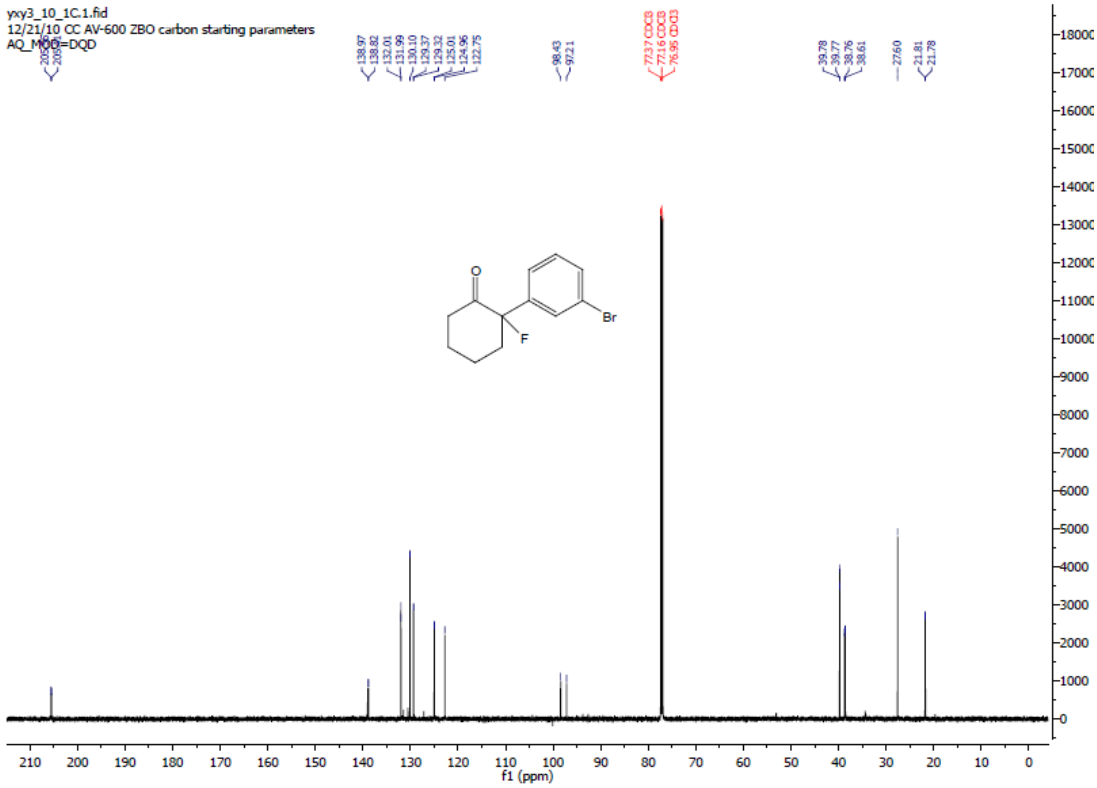


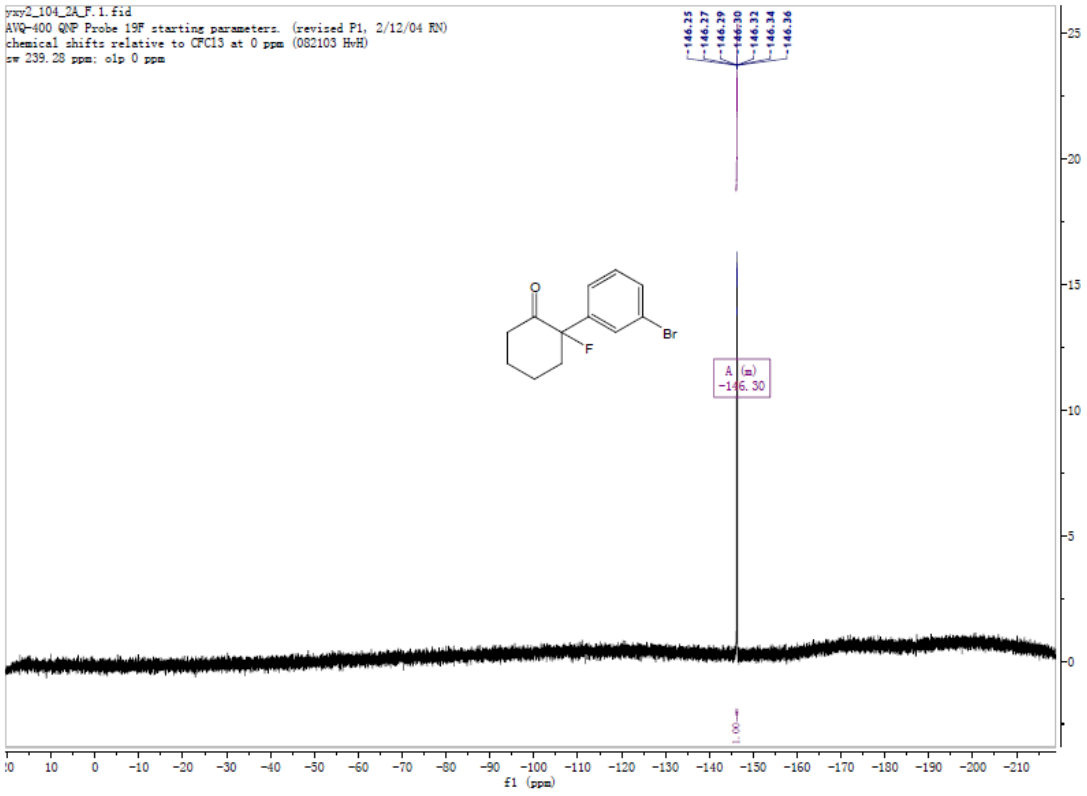

yxy3_2_1AC.2.fid
12/21/10 CC AV-600 ZBO carbon starting parameters
AQ_MOD=DQD
206.52
206.38
138.54
136.17
136.02
130.00
129.98
128.68
127.24
127.20
123.52
123.48
98.98
97.76
77.37
CDCl3
76.95
40.09
37.95
37.80
27.64
22.46
22.41
21.64
O
CH3
F
f1 (ppm)


1_1F.1.fid
)0 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
:al shifts relative to CFCl3 at 0 ppm (082103 HvH)
).28 ppm; olp 0 ppm
-139.25
-139.28
-139.32
O
CH3
F
A (t)
-139.28
f1 (ppm)

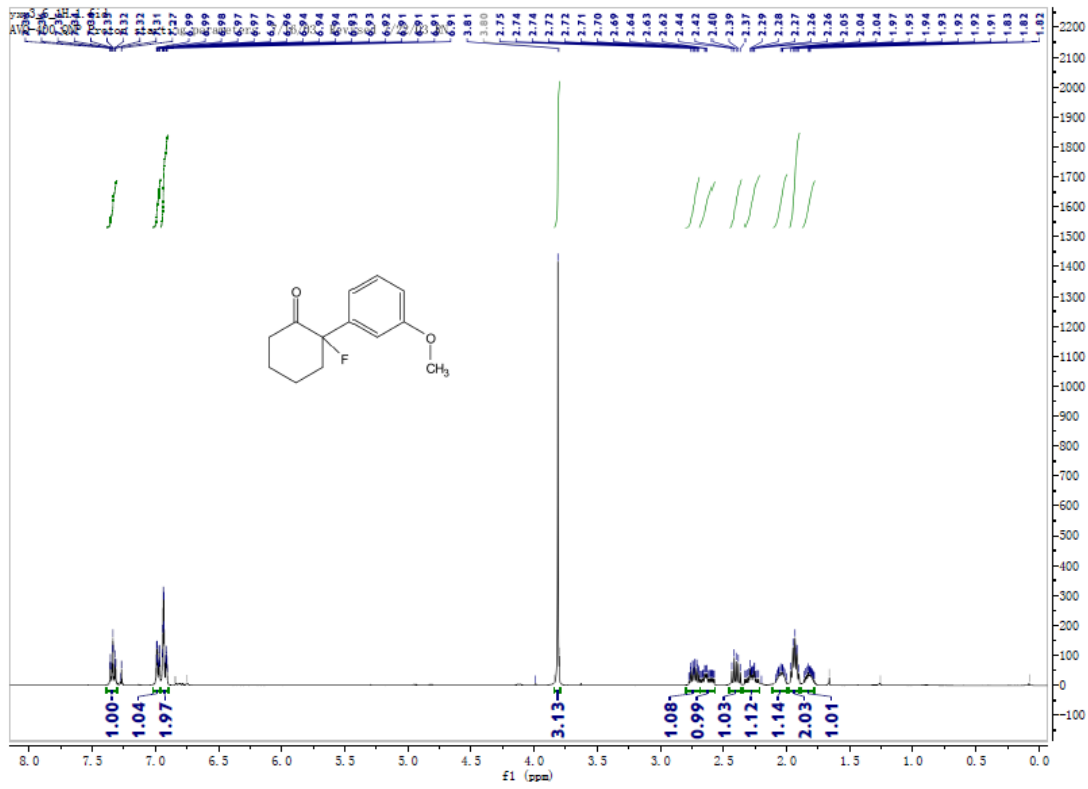
(*R*)-2-(3-bromophenyl)-2-fluorocyclohexanone (**2g**)

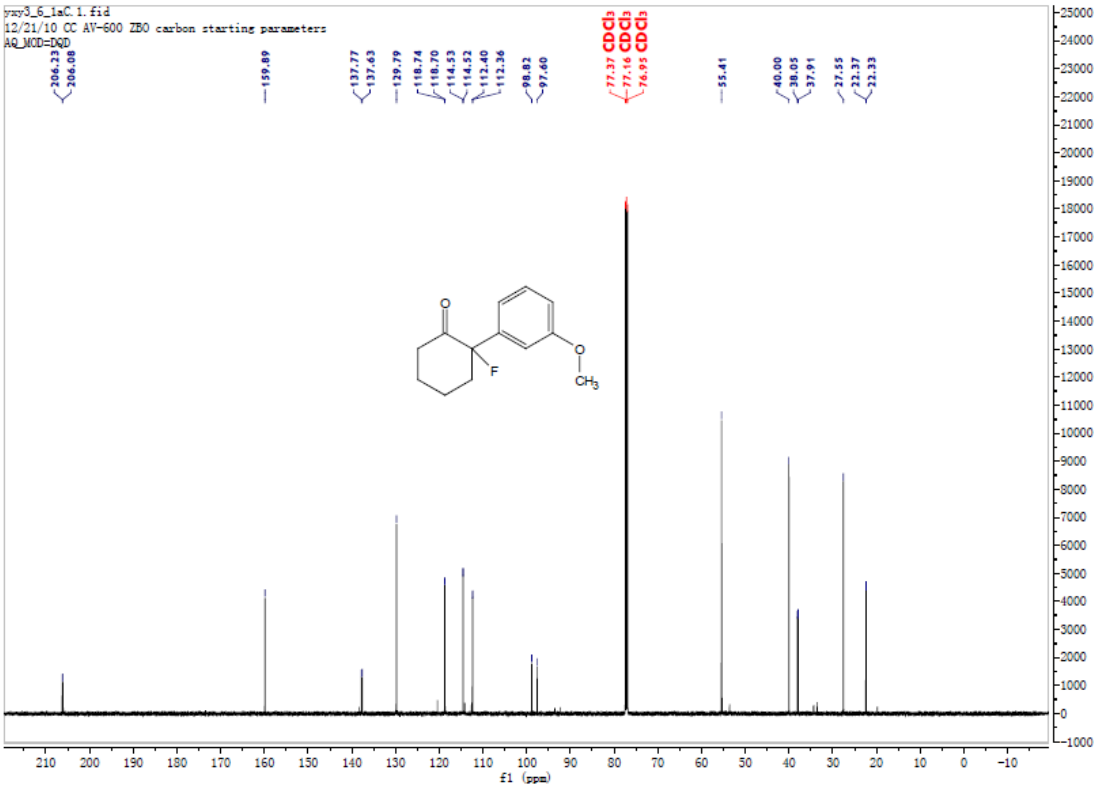


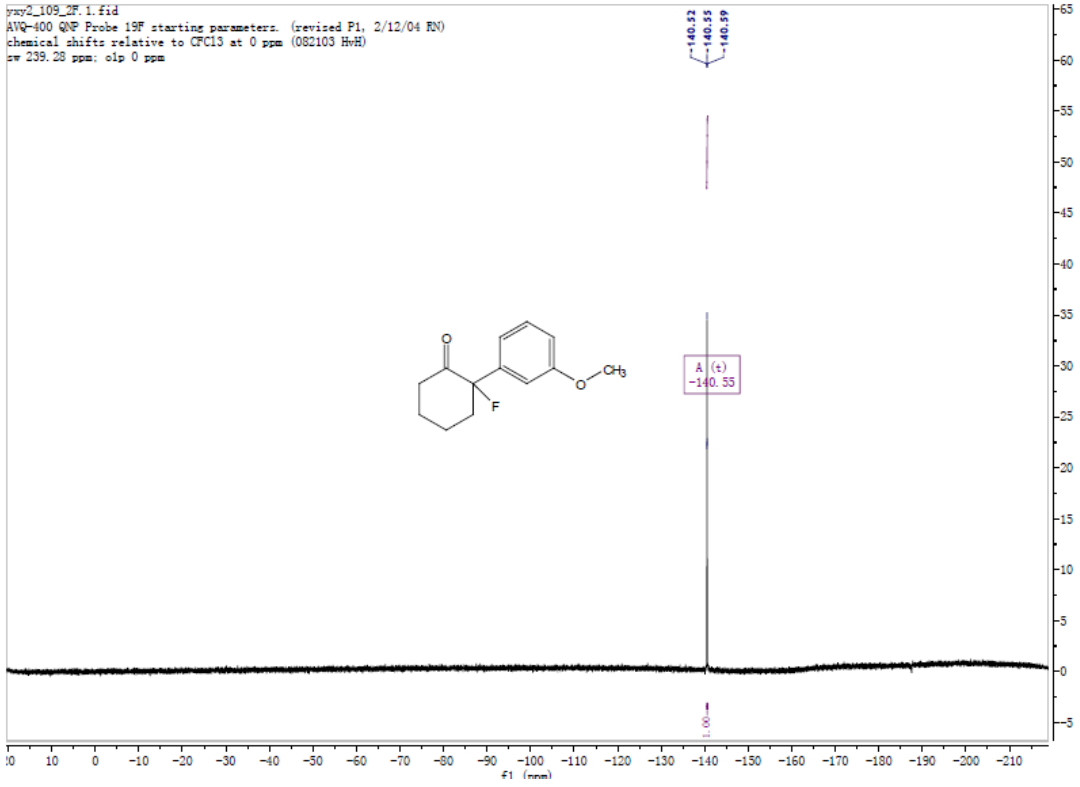




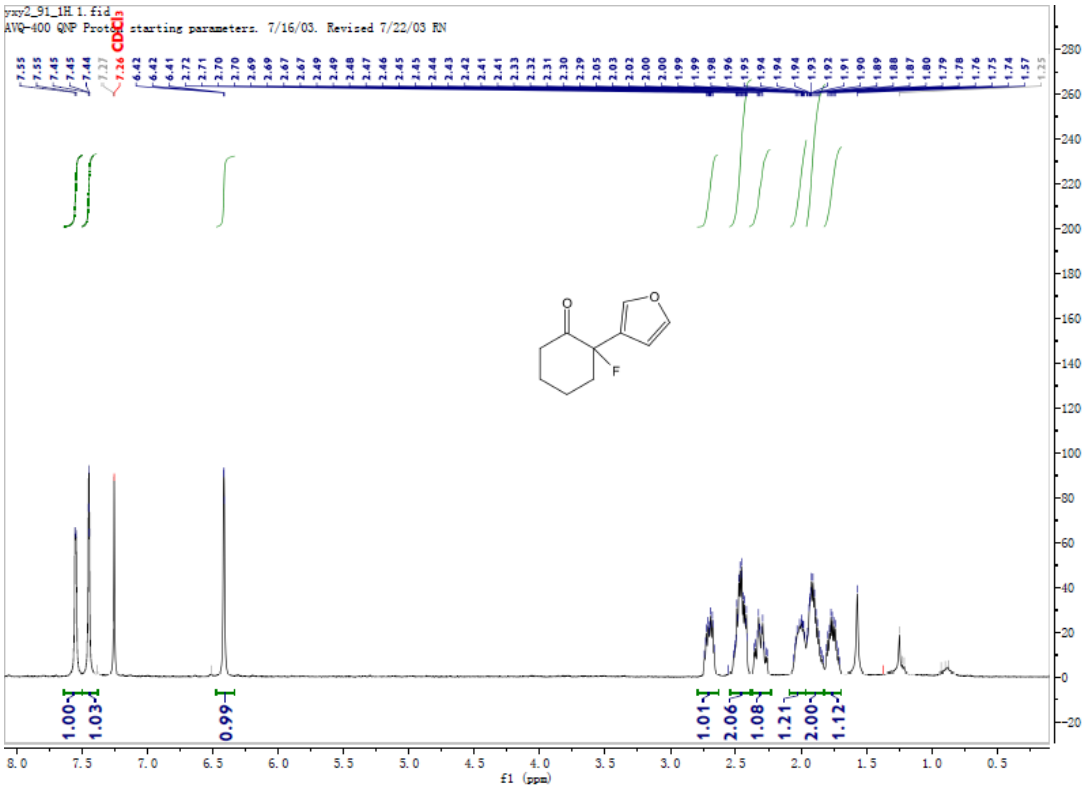
(*R*)-2-fluoro-2-(3-methoxyphenyl)cyclohexanone (**2h**)

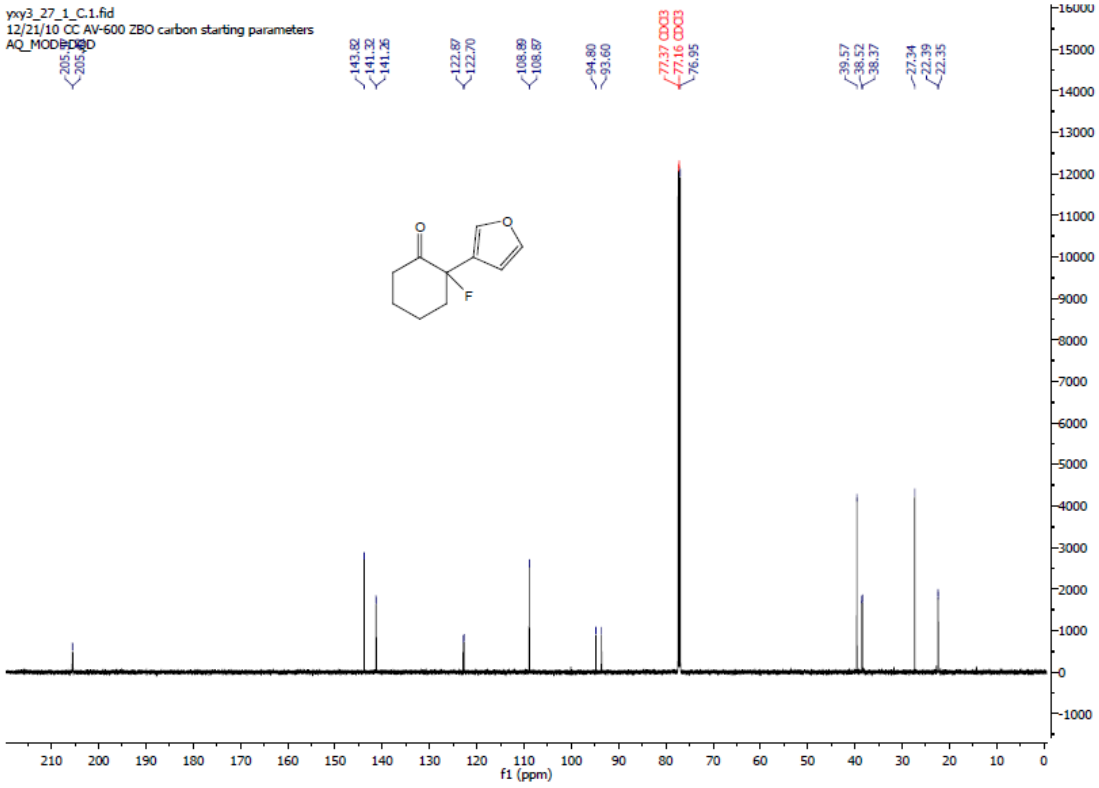


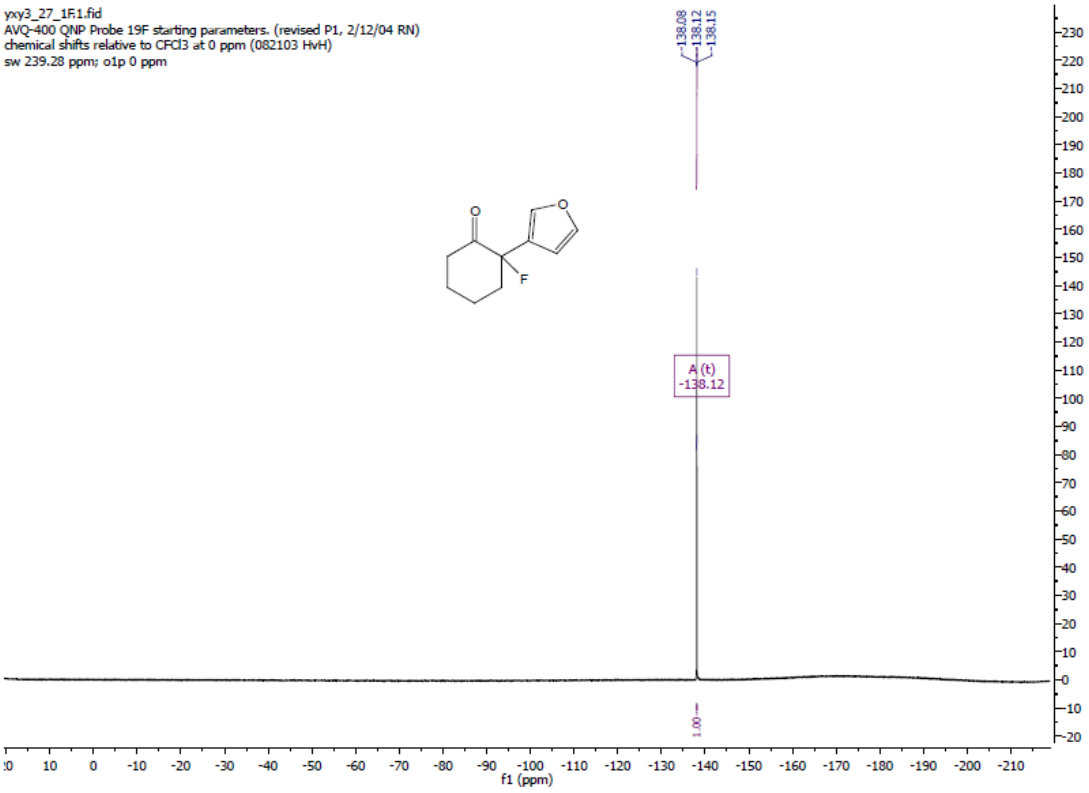

yxy3_6_1aC.1.fid
12/21/10 CC AV-600 ZBO carbon starting parameters
AQ_MOD=DQD
206.23
206.08
159.89
137.77
137.63
129.79
118.74
118.70
114.53
114.52
112.40
112.36
98.82
97.60
77.37 CDCl3
77.16 CDCl3
76.95 CDCl3
55.41
40.00
38.05
37.91
27.55
22.37
22.33
O
F
O
CH3
f1 (ppm)


yxy2_109_2F.1.fid
AVQ-400 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
chemical shifts relative to CFCl3 at 0 ppm (082103 HvH)
sw 239.28 ppm; olp 0 ppm
-140.52
-140.55
-140.59
A (+)
-140.55
O
F
O
CH3
f1 (ppm)

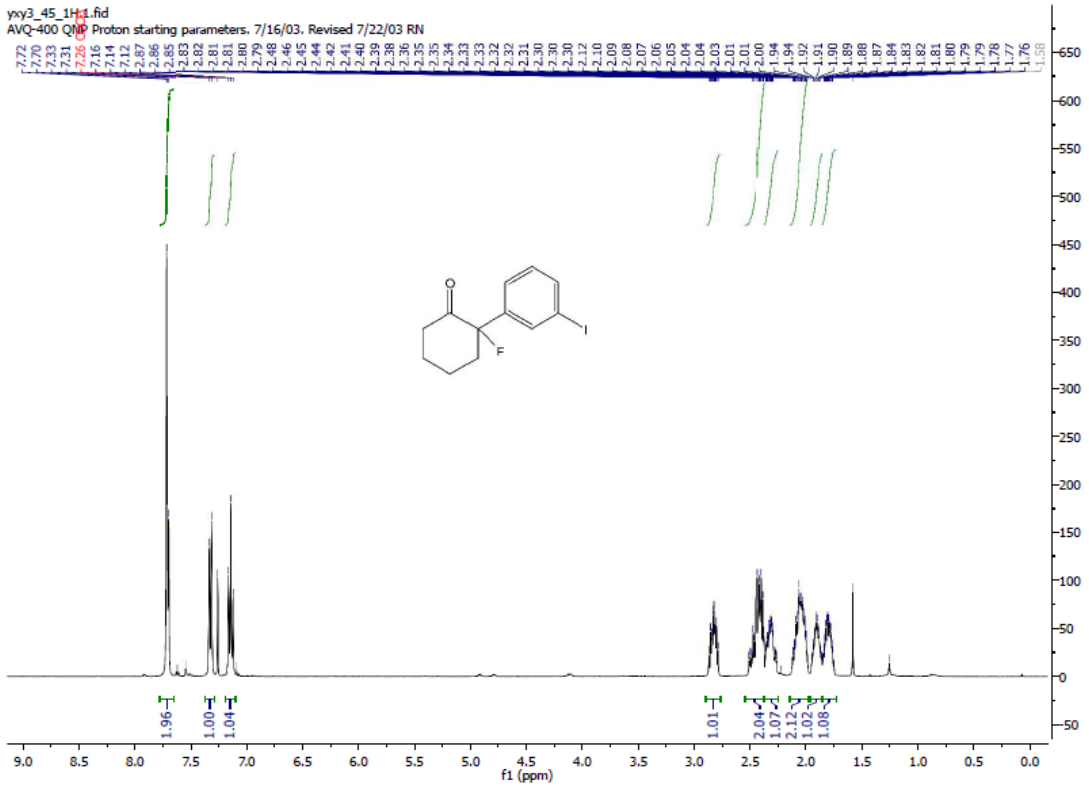
(*R*)-2-fluoro-2-(furan-3-yl)cyclohexanone (**2i**)

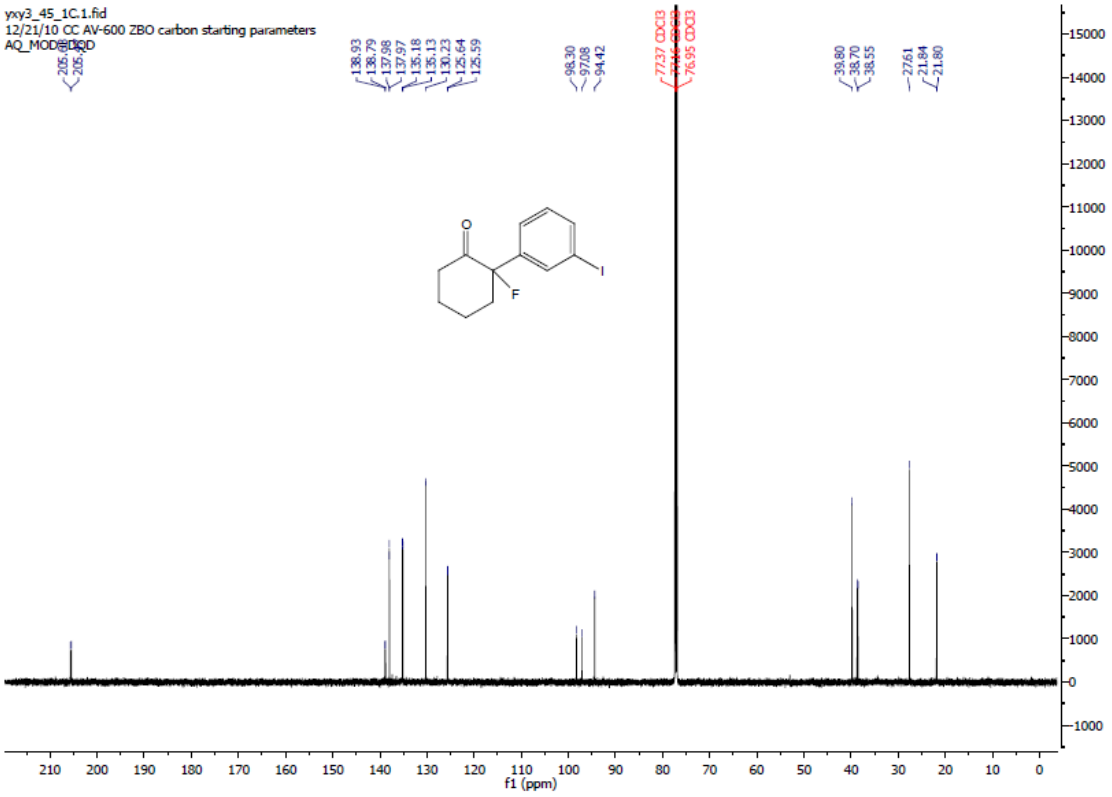


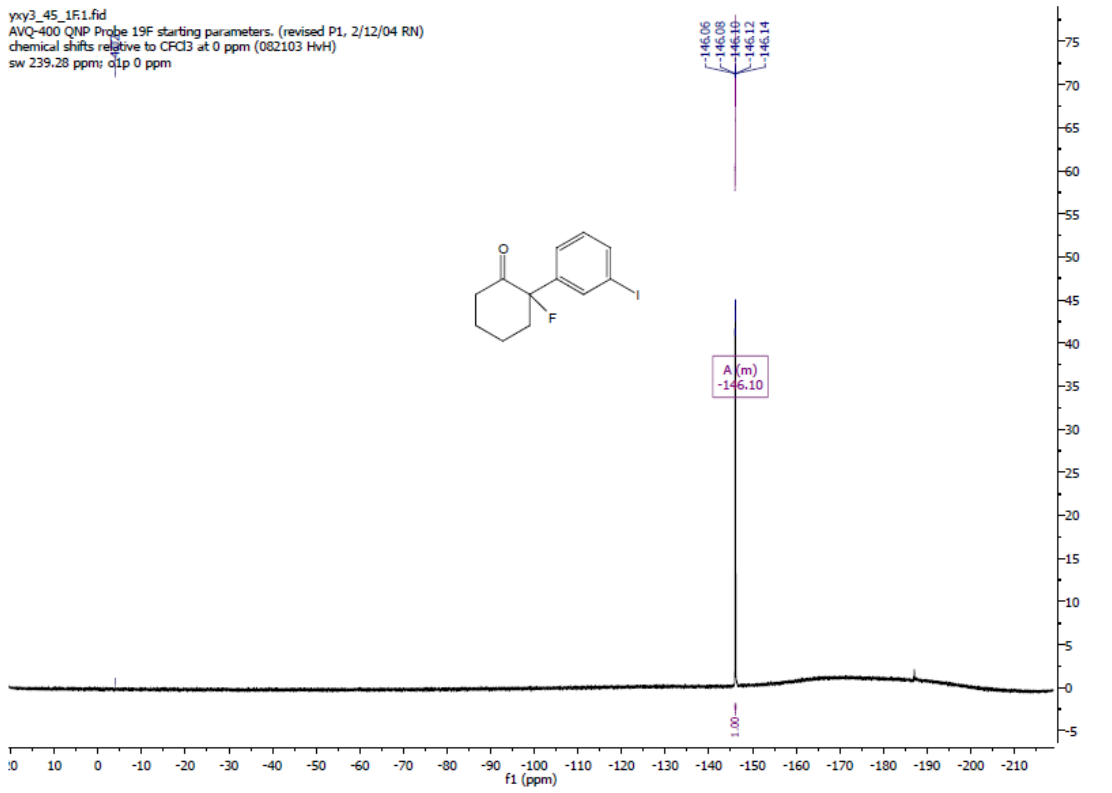




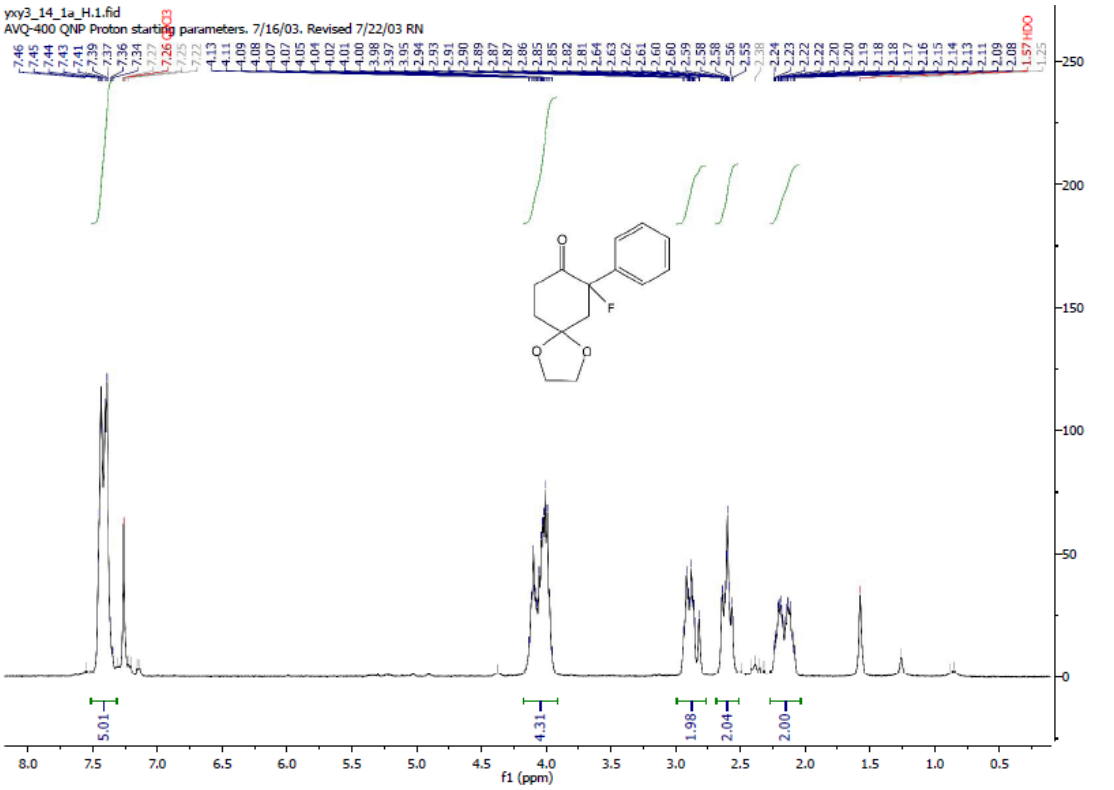
(*R*)-2-fluoro-2-(3-iodophenyl)cyclohexanone (**2j**)

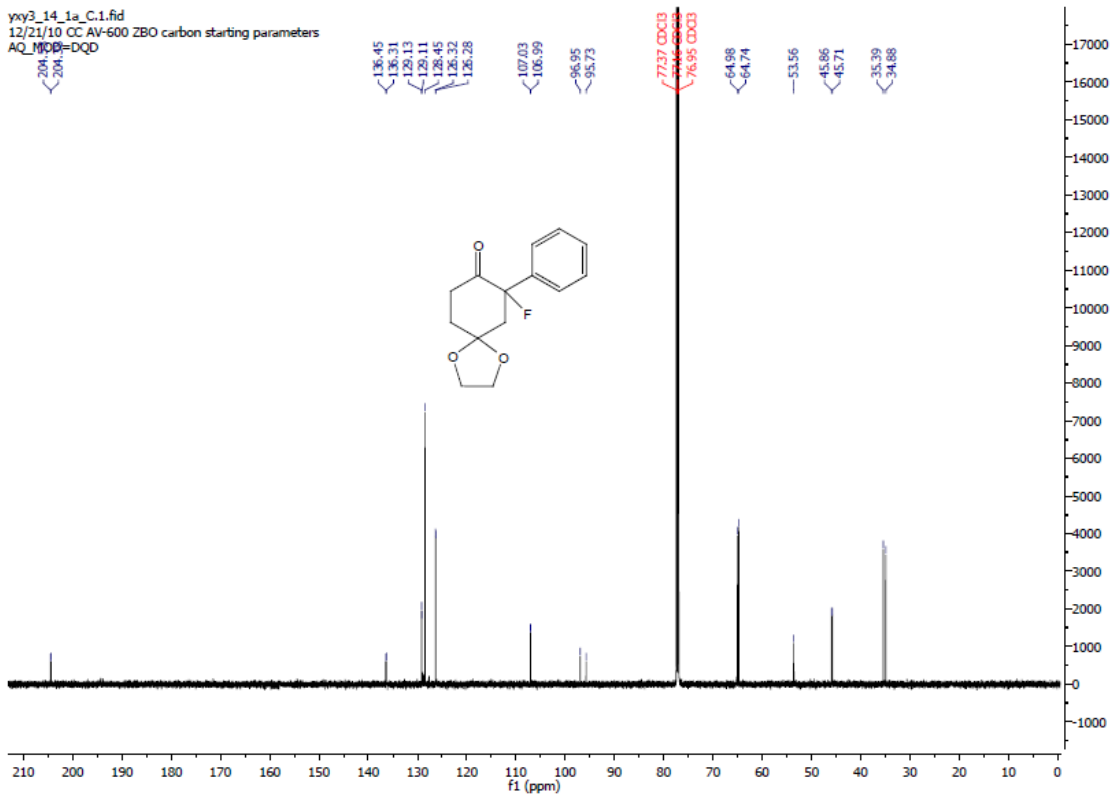


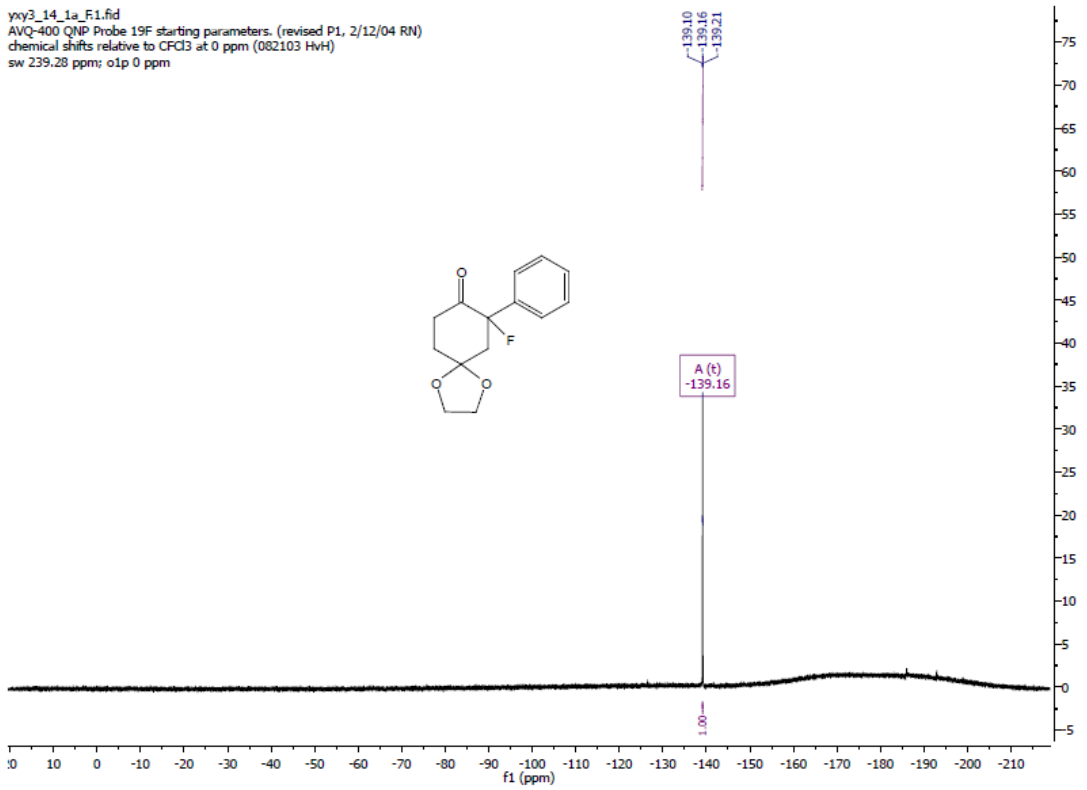

yxy3_45_1C.1.fid
12/21/10 CC AV-600 ZBO carbon starting parameters
AQ_MOD
138.93
138.79
137.98
137.97
135.18
135.13
130.23
125.64
125.59
98.30
97.08
94.42
77.37 CDCl3
76.95 CDCl3
39.80
38.70
38.55
27.61
21.84
21.80
O
F
I
f1 (ppm)


yxy3_45_1F.1.fid
AVQ-400 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
chemical shifts relative to CFCl3 at 0 ppm (082103 HvH)
sw 239.28 ppm; o1p 0 ppm
-146.06
-146.08
-146.10
-146.12
-146.14
O
F
I
A (m)
-146.10
1.00
f1 (ppm)

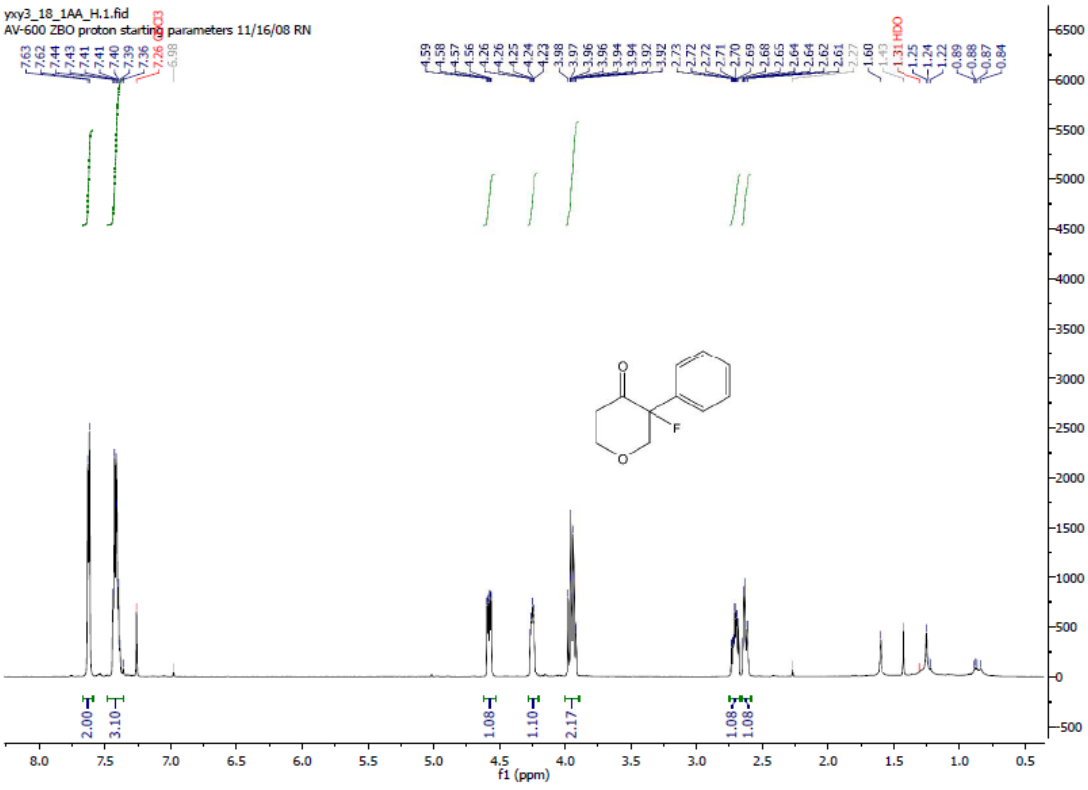
(*R*)-7-fluoro-7-phenyl-1,4-dioxaspiro[4.5]decan-8-one (**2k**)

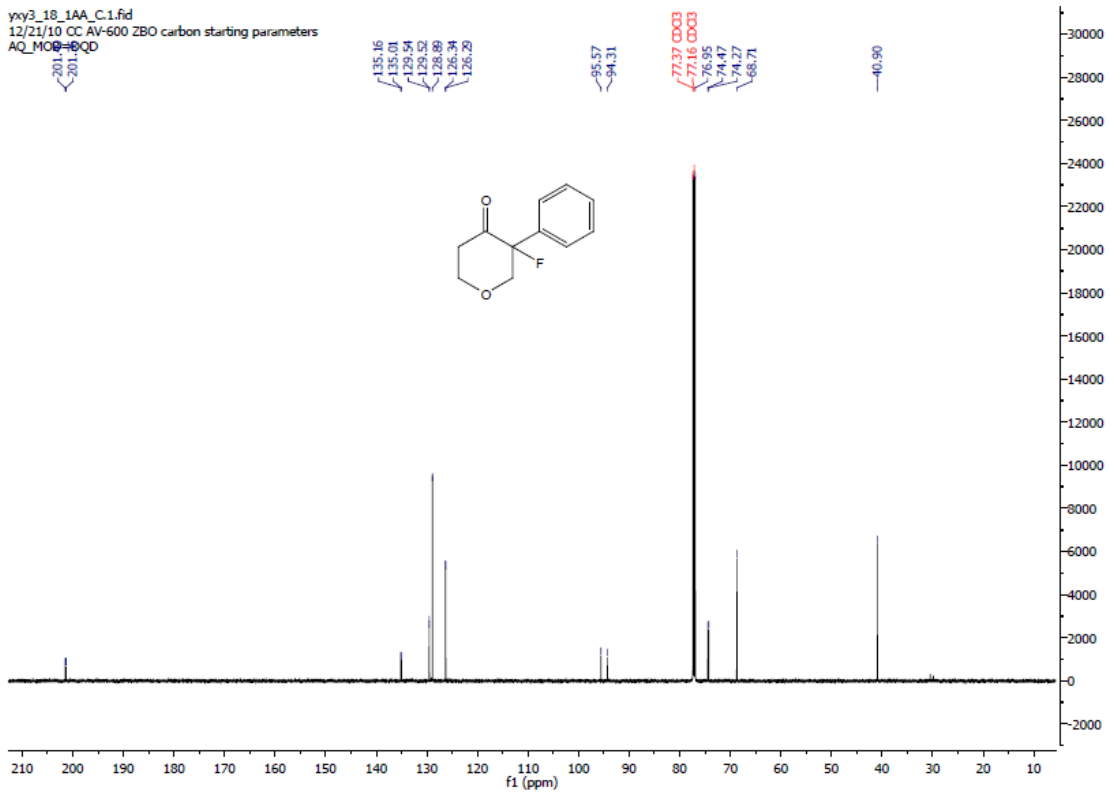


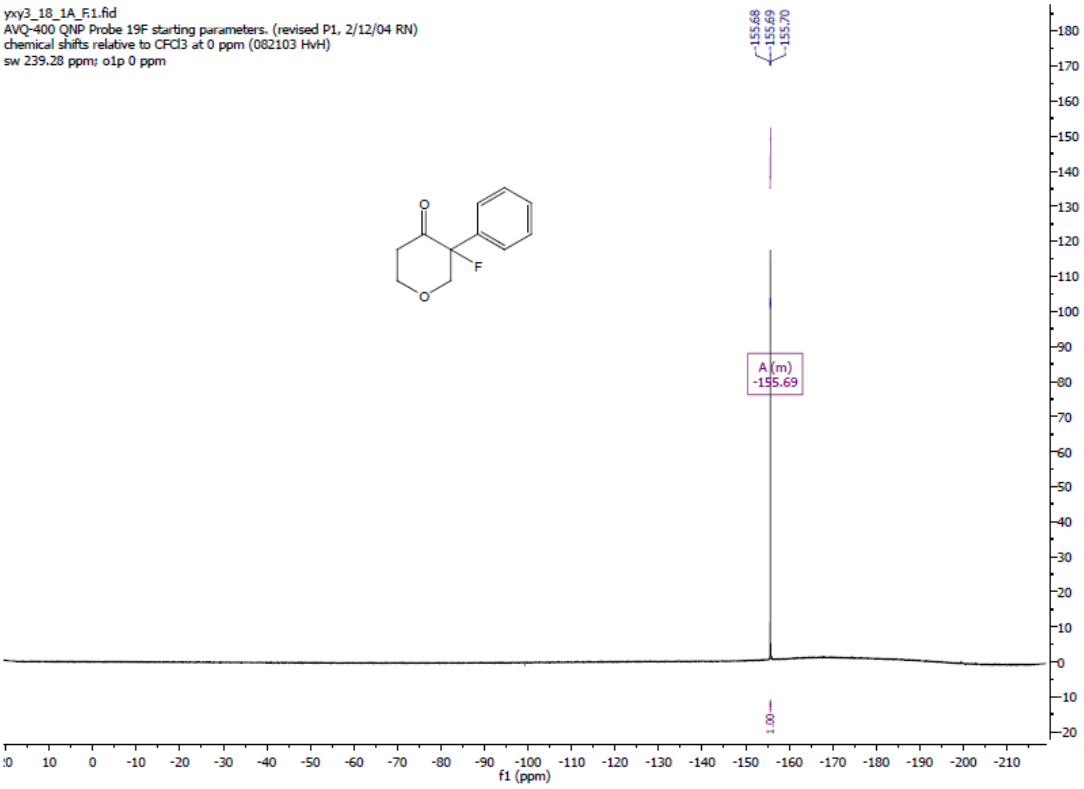




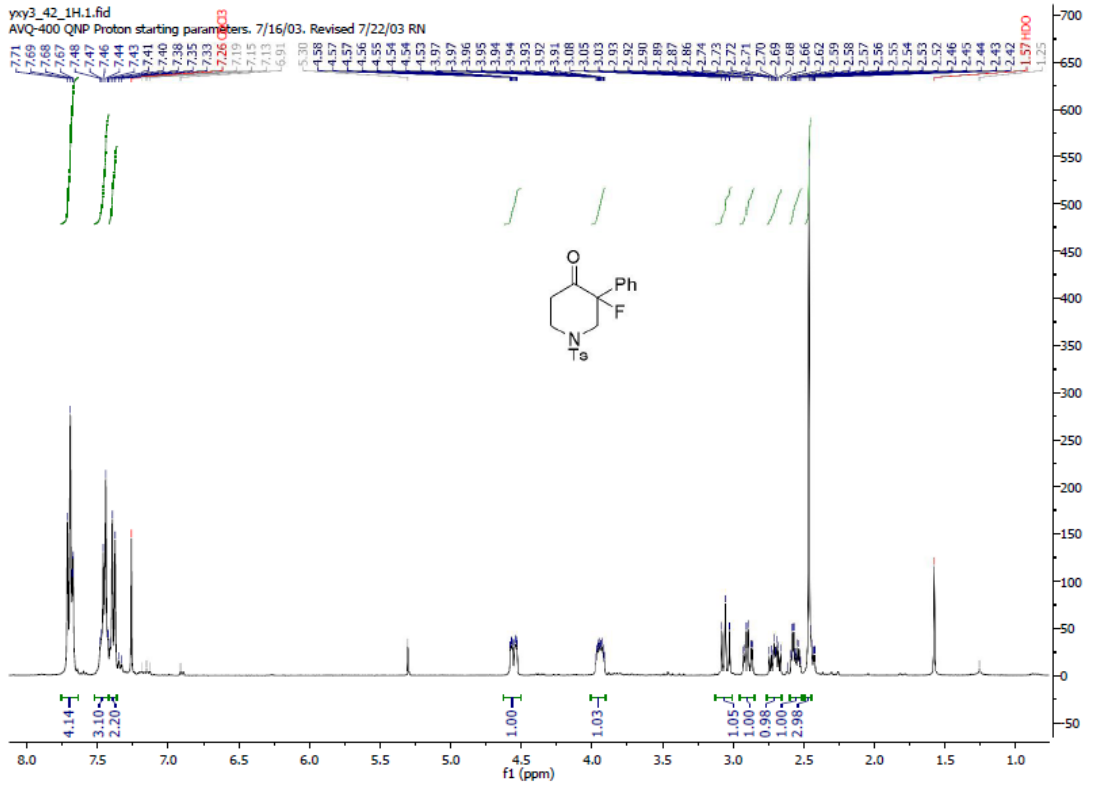
(*S*)-3-fluoro-3-phenyldihydro-2H-pyran-4(3H)-one (**2l**)

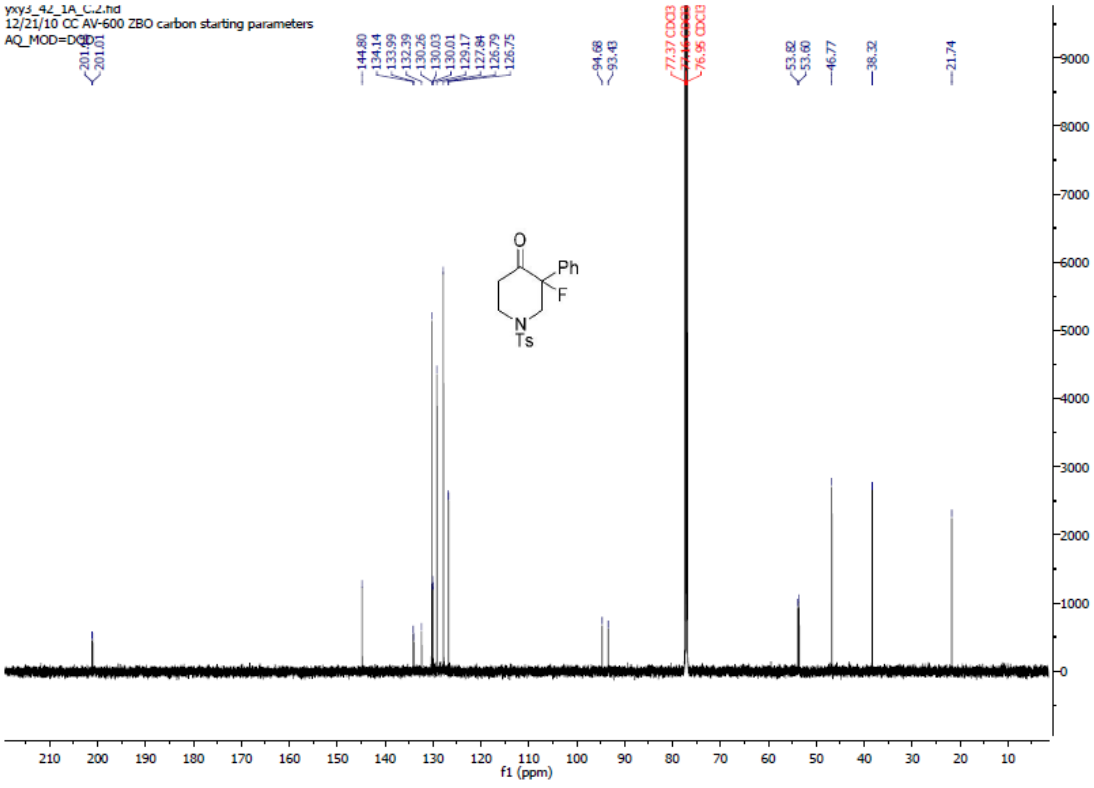


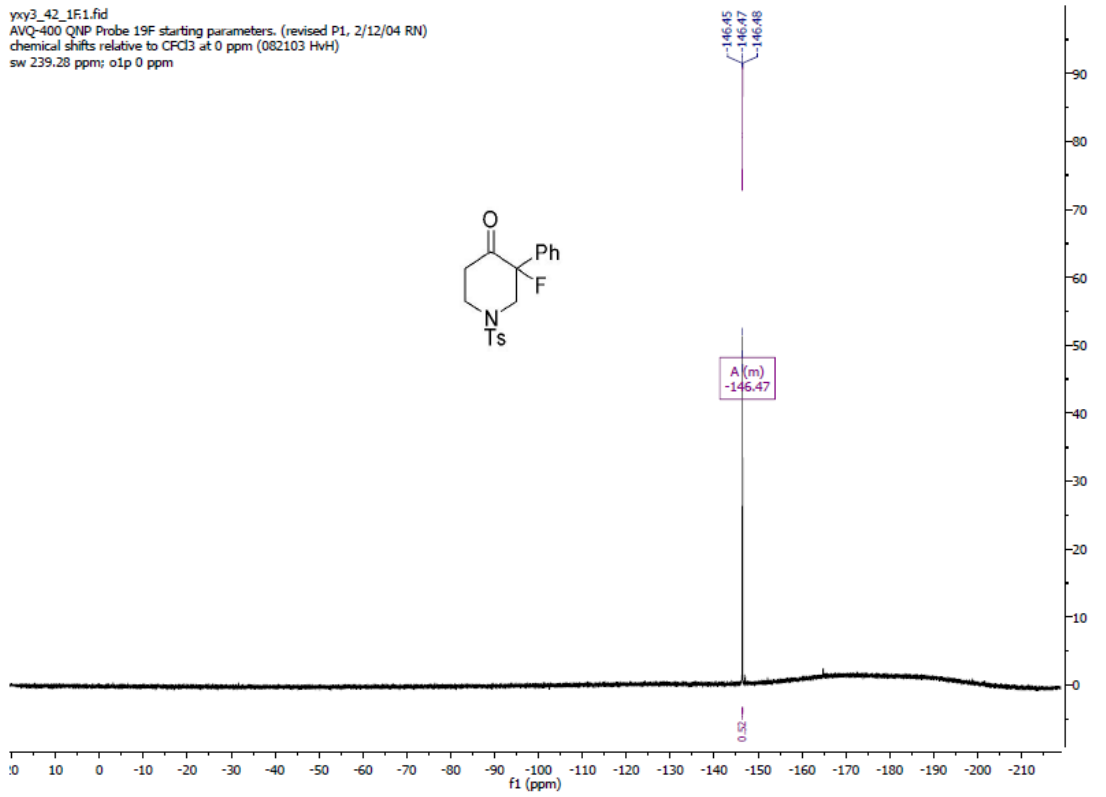

yxy3_18_1AA_C.1.fid
12/21/10 CC AV-600 ZBO carbon starting parameters
201.46
201.08
135.16
135.01
129.54
129.52
128.89
126.34
126.29
95.57
94.31
77.37 CDCl3
77.16 CDCl3
76.95
74.47
74.27
68.71
40.90
O
F
O
f1 (ppm)


yxy3_18_1A_F.1.fid
AVQ-400 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
chemical shifts relative to CFCl3 at 0 ppm (082103 HvH)
sw 239.28 ppm; o1p 0 ppm
155.68
155.69
155.70
A (m)
-155.69
1.00
O
F
O
f1 (ppm)

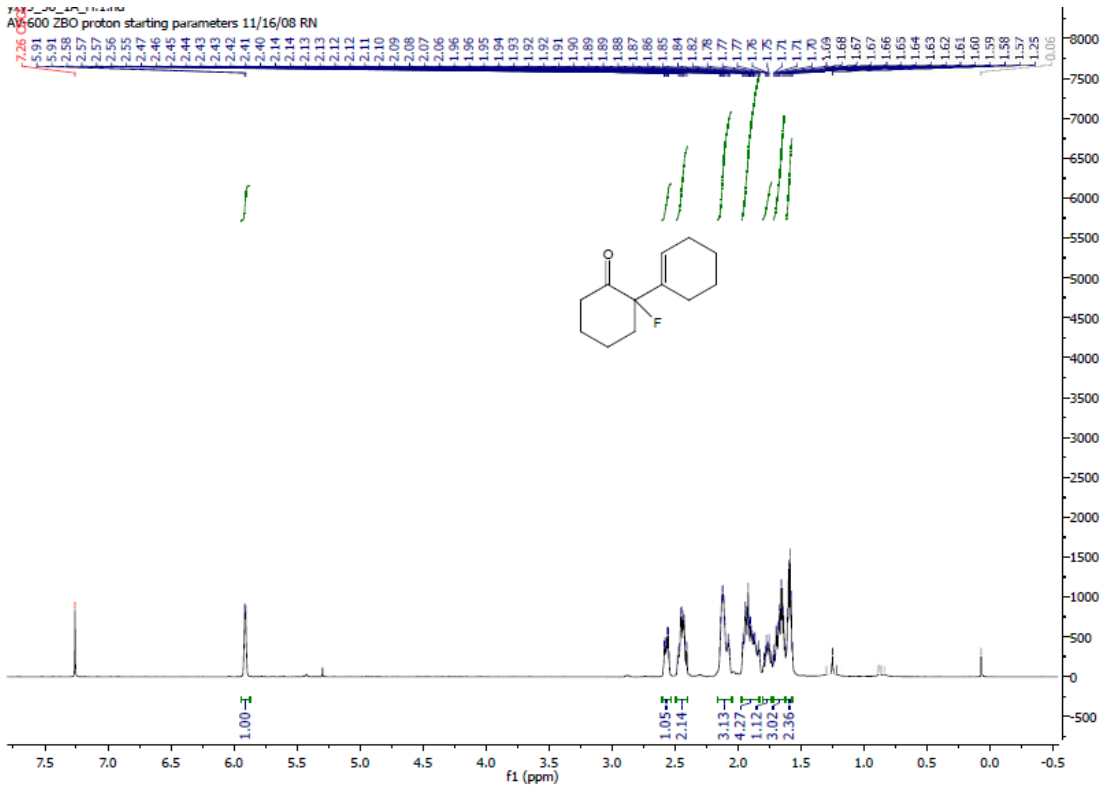
(*S*)-3-fluoro-3-phenyl-1-tosylpiperidin-4-one (**2m'**)

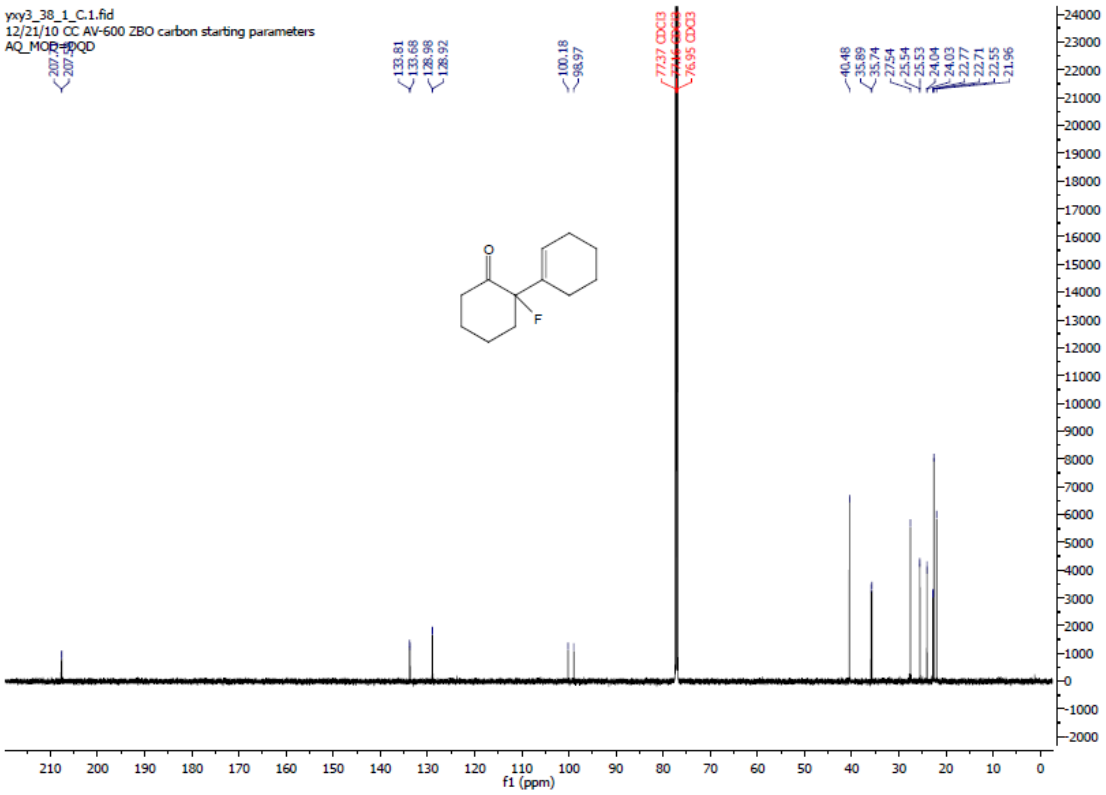


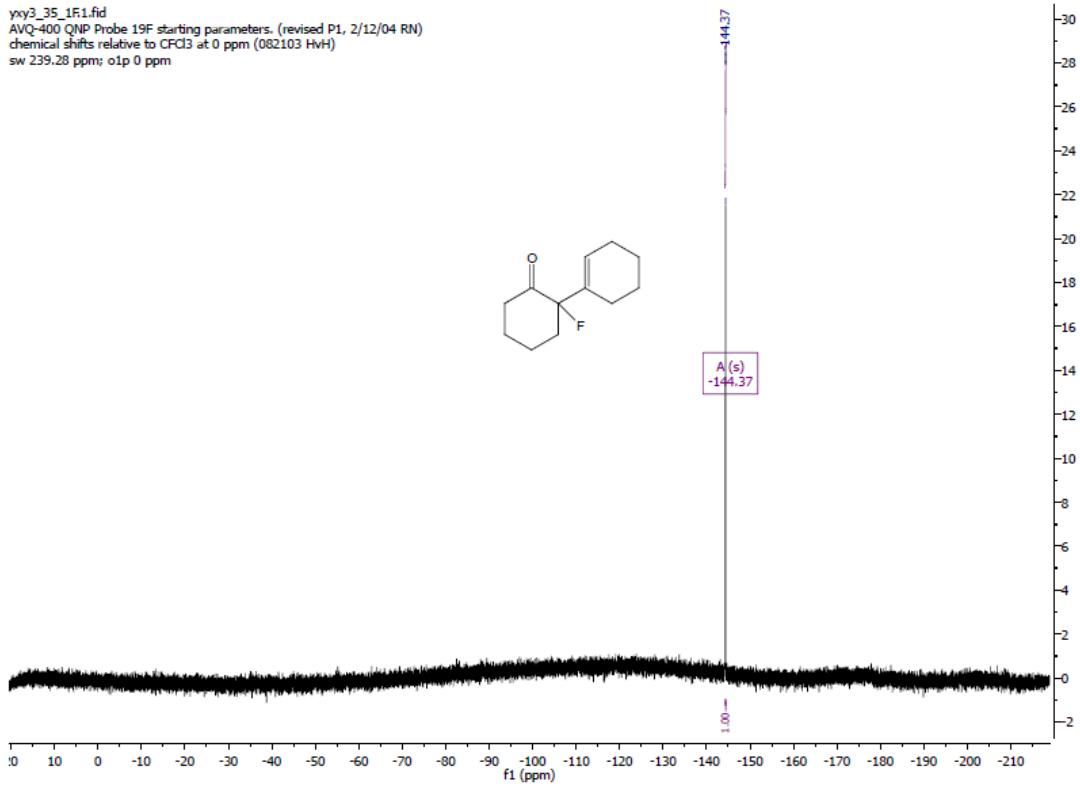




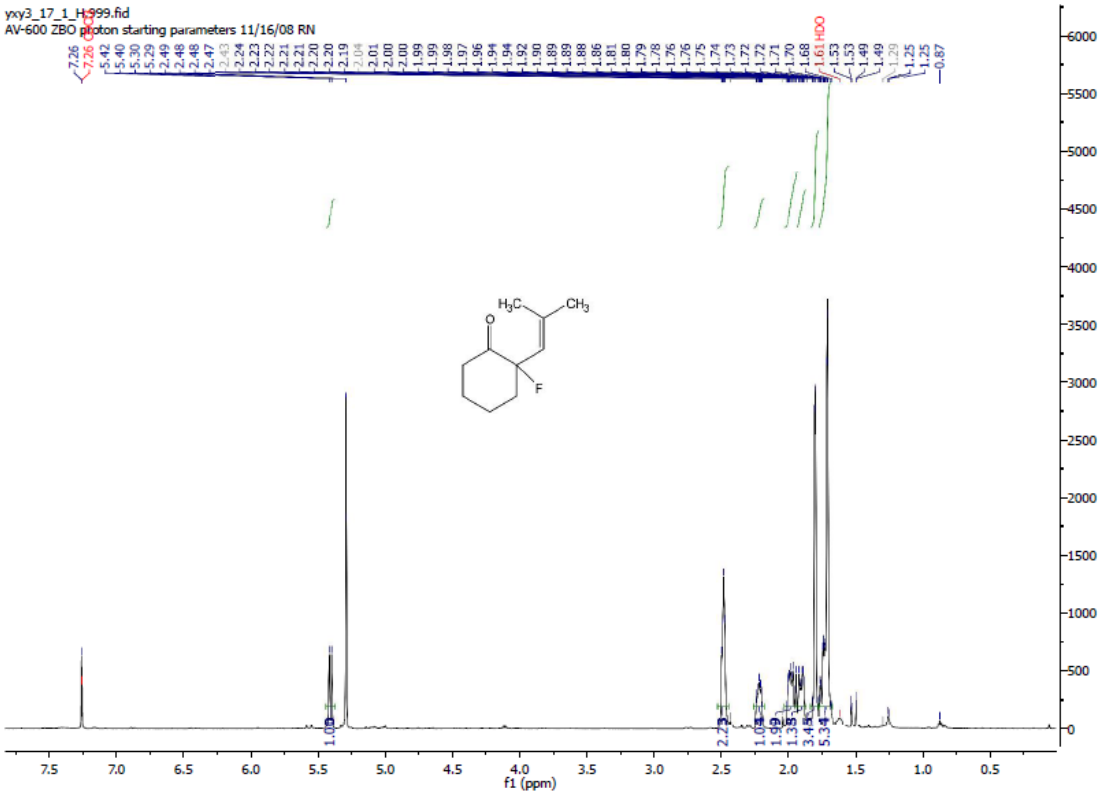
(*R*)-1-fluoro-[1,1'-bi(cyclohexan)]-1'-en-2-one (**2n**)

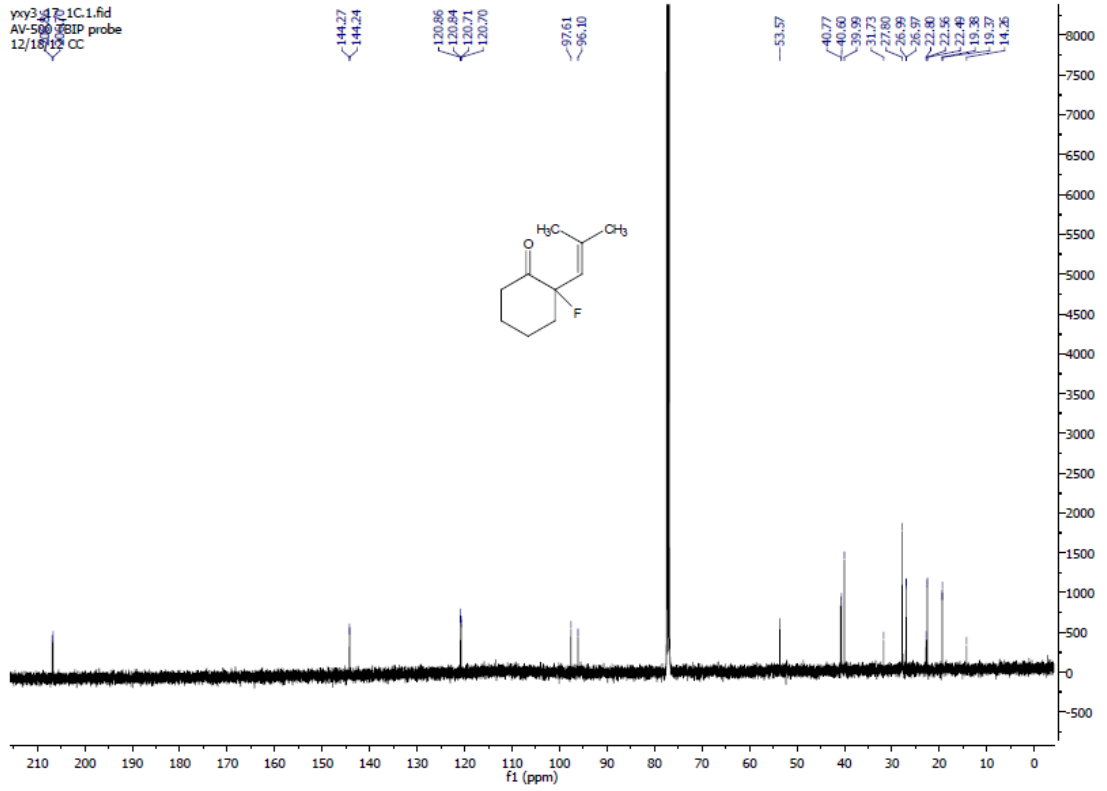


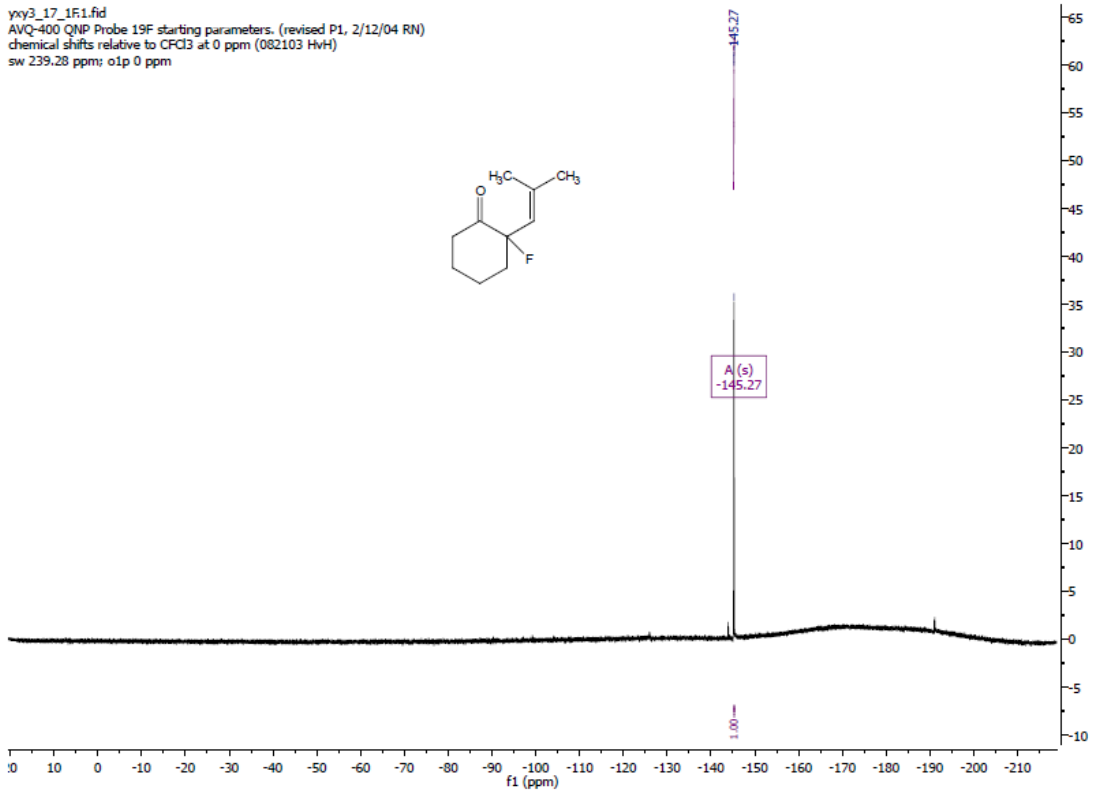

yxy3_38_1_C.1.fid
12/21/10 CC AV-600 ZBO carbon starting parameters
AQ_MOD=QQD
133.81
133.68
128.98
128.92
100.18
98.97
77.37 CDCl3
76.95 CDCl3
40.48
35.89
35.74
27.54
25.54
25.53
24.04
24.03
22.77
22.71
23.55
21.96
O
F
f1 (ppm)


yxy3_35_1F1.fid
AVQ-400 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
chemical shifts relative to CFCl3 at 0 ppm (082103 HvH)
sw 239.28 ppm; o1p 0 ppm
-144.37
A(s)
-144.37
1.00
O
F
f1 (ppm)

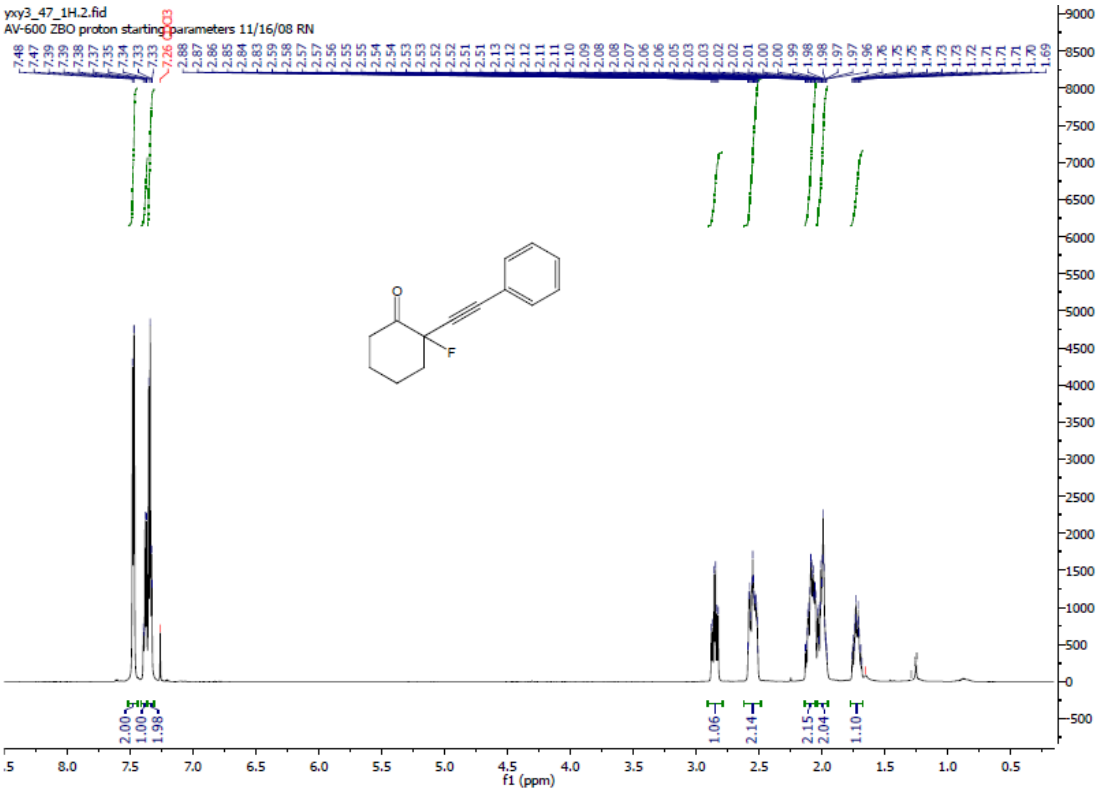
(*R*)-2-fluoro-2-(2-methylprop-1-en-1-yl)cyclohexanone (**2o**)

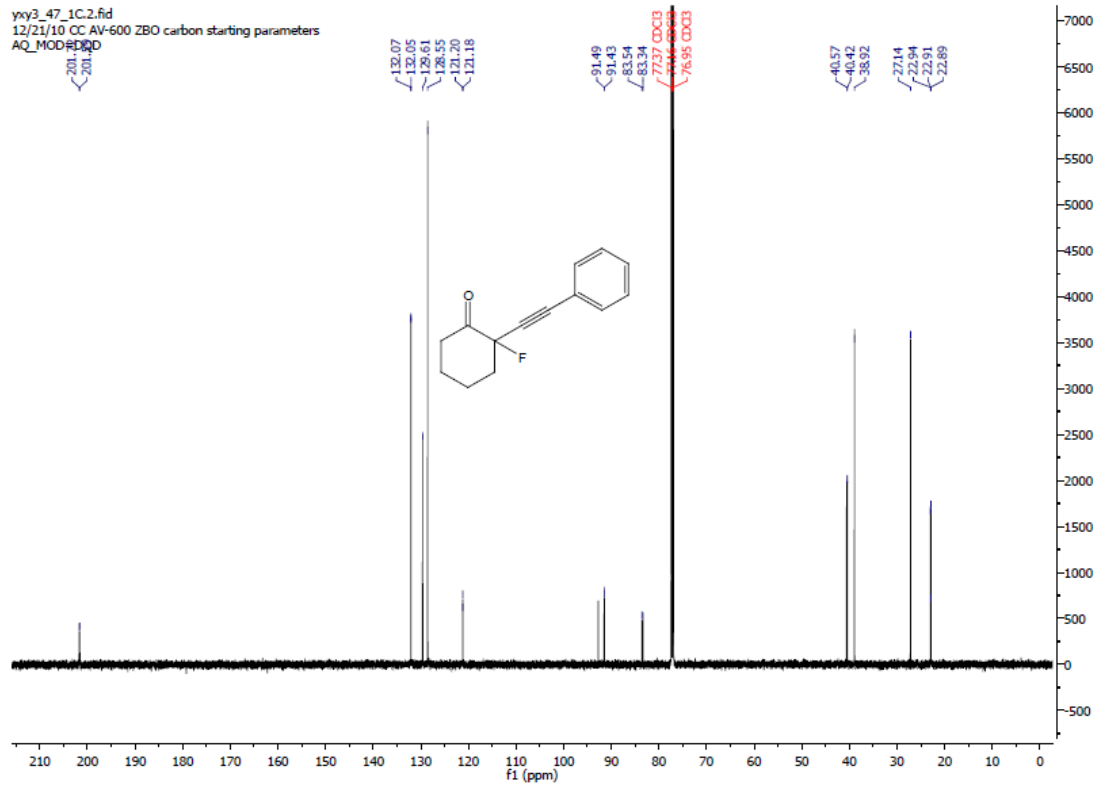


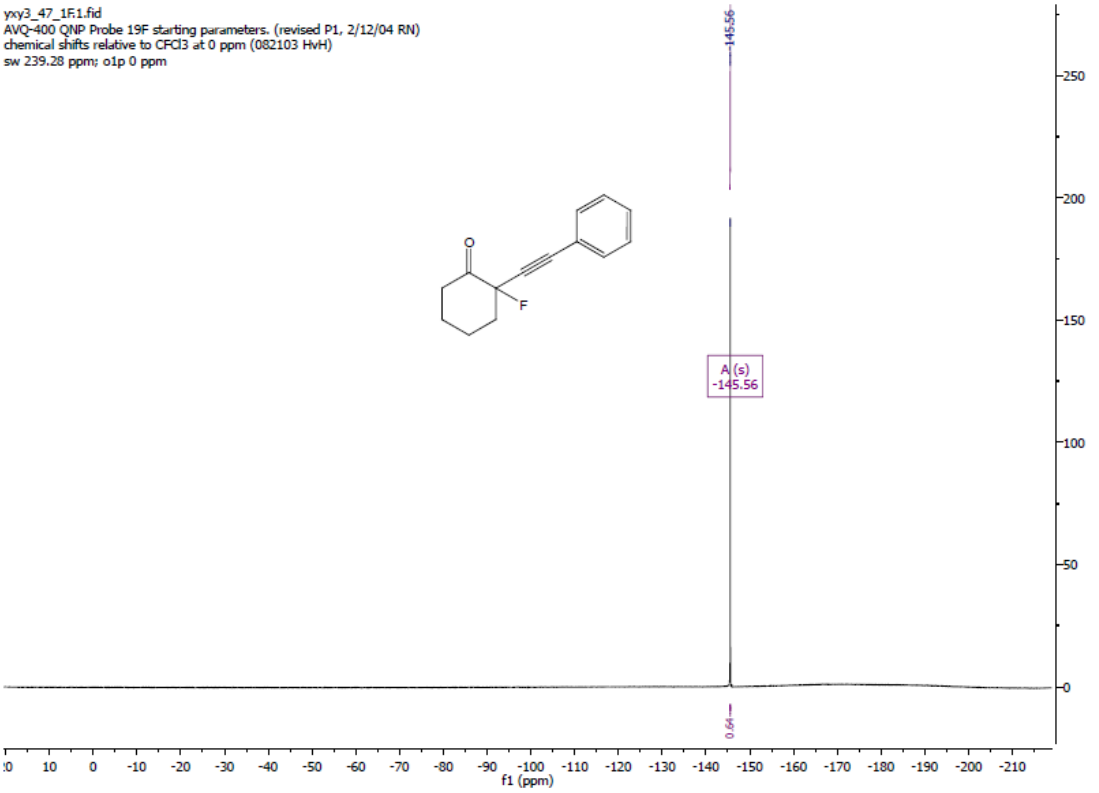




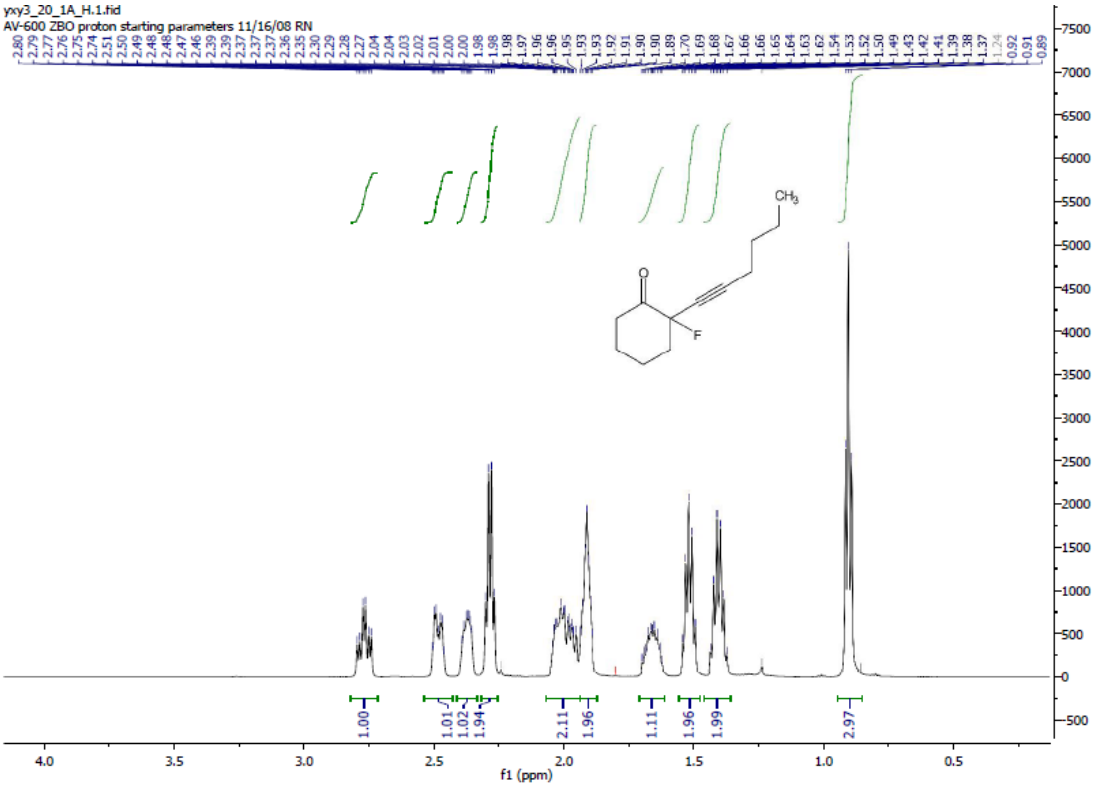
(*R*)-2-fluoro-2-(phenylethynyl)cyclohexanone (**2p**)

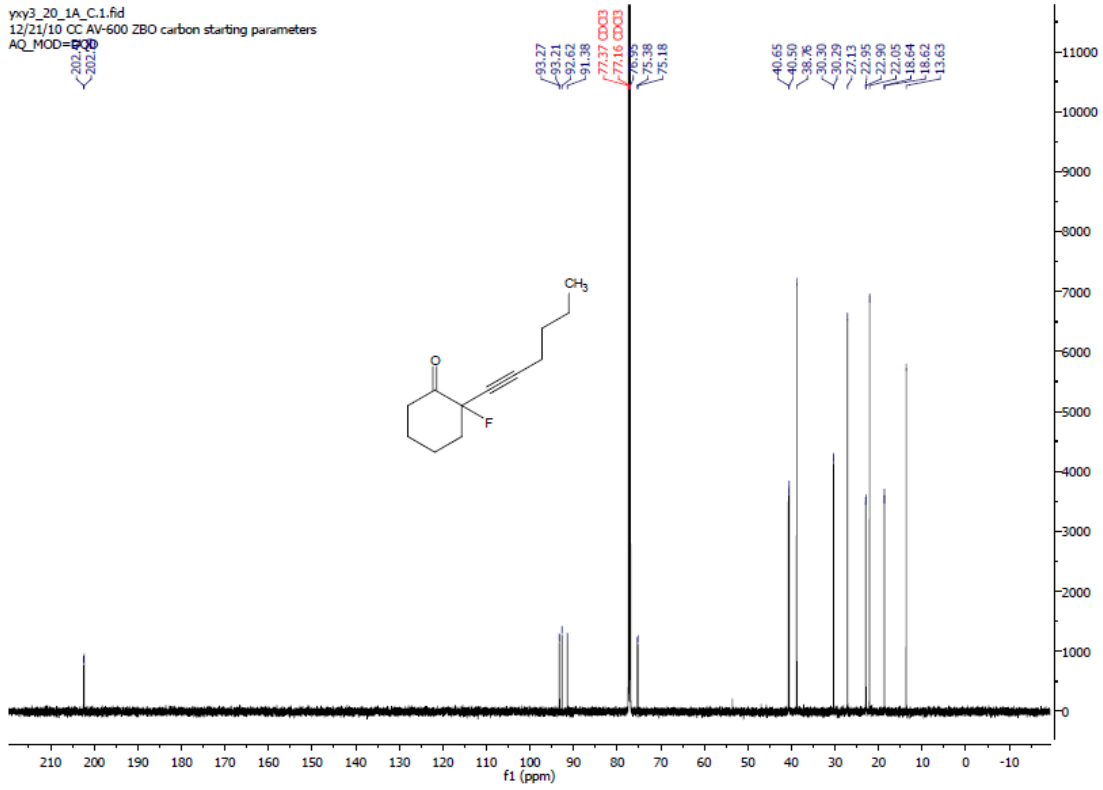


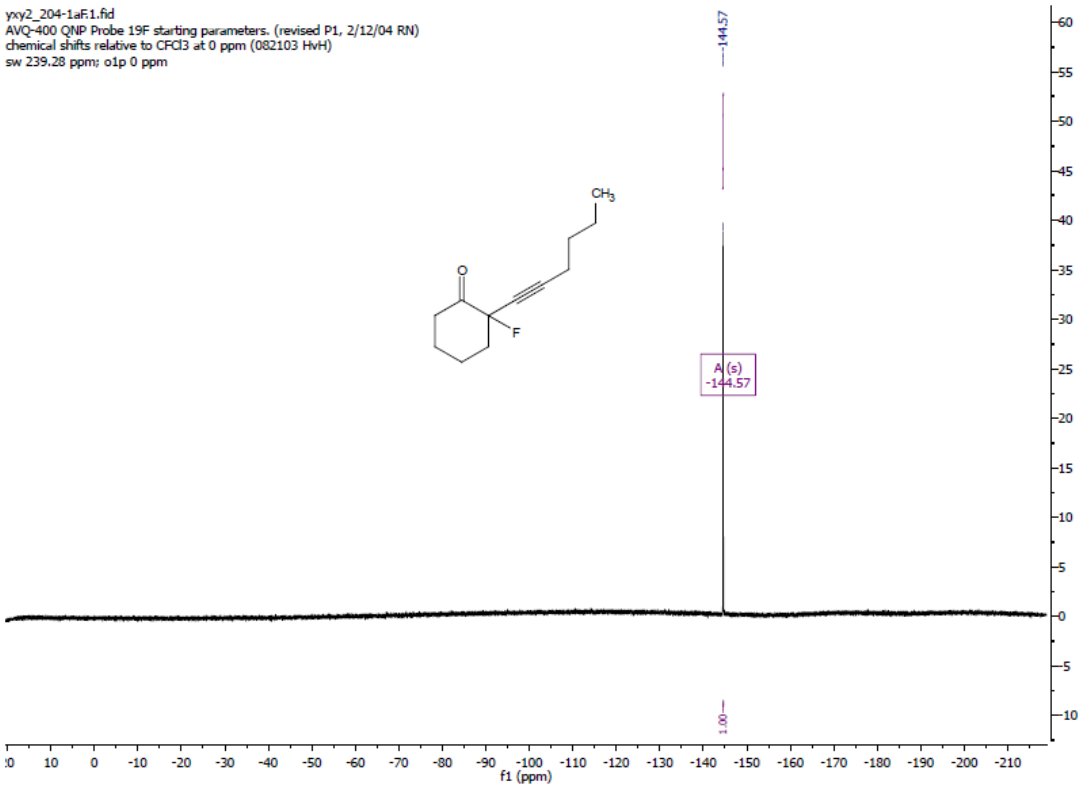

yxy3_47_1C.2.fid
12/21/10 CC AV-600 ZBO carbon starting parameters
AQ_MOD=DQD
201.71
201.41
132.07
132.05
129.61
128.55
121.20
121.18
91.49
91.43
83.54
83.34
77.37 CDCl3
76.95 CDCl3
40.57
40.42
38.92
27.14
22.94
22.91
22.89
O
F
f1 (ppm)


yxy3_47_1F.1.fid
AVQ-400 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
chemical shifts relative to CFCl3 at 0 ppm (082103 HvH)
sw 239.28 ppm; o1p 0 ppm
-145.56
A (s)
-145.56
0.64
O
F
f1 (ppm)

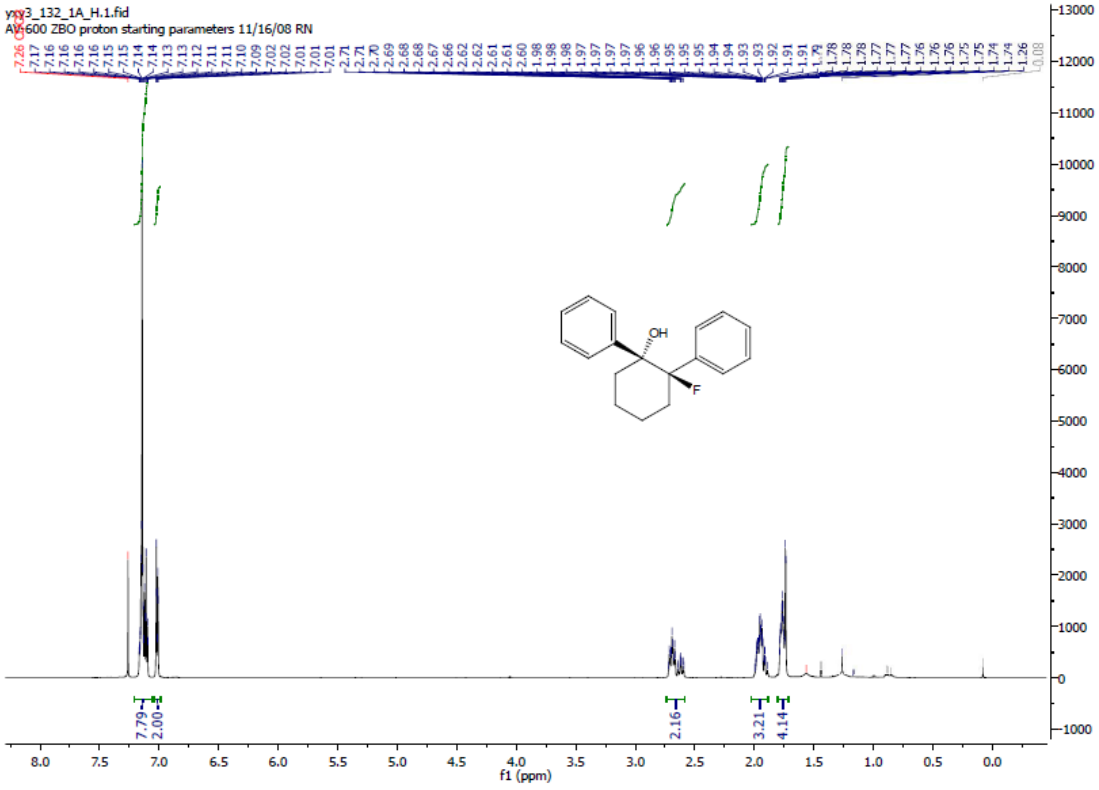
(*R*)-2-fluoro-2-(hex-1-yn-1-yl)cyclohexanone (**2q**)

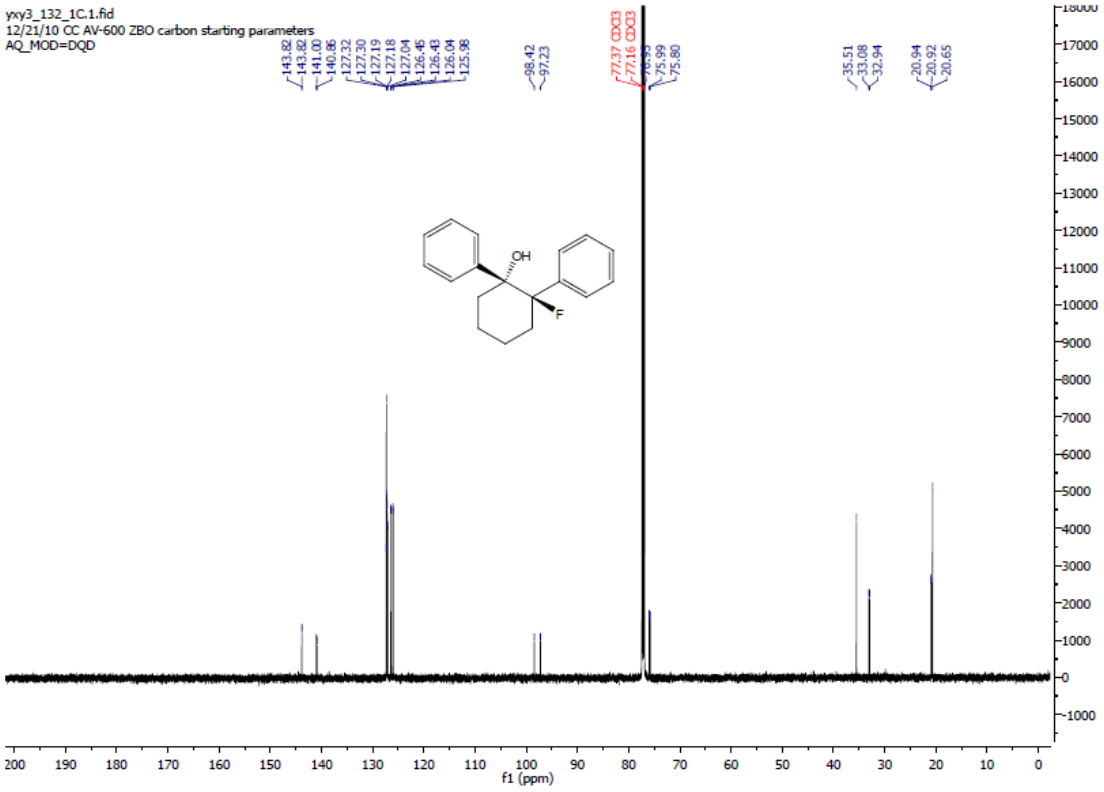


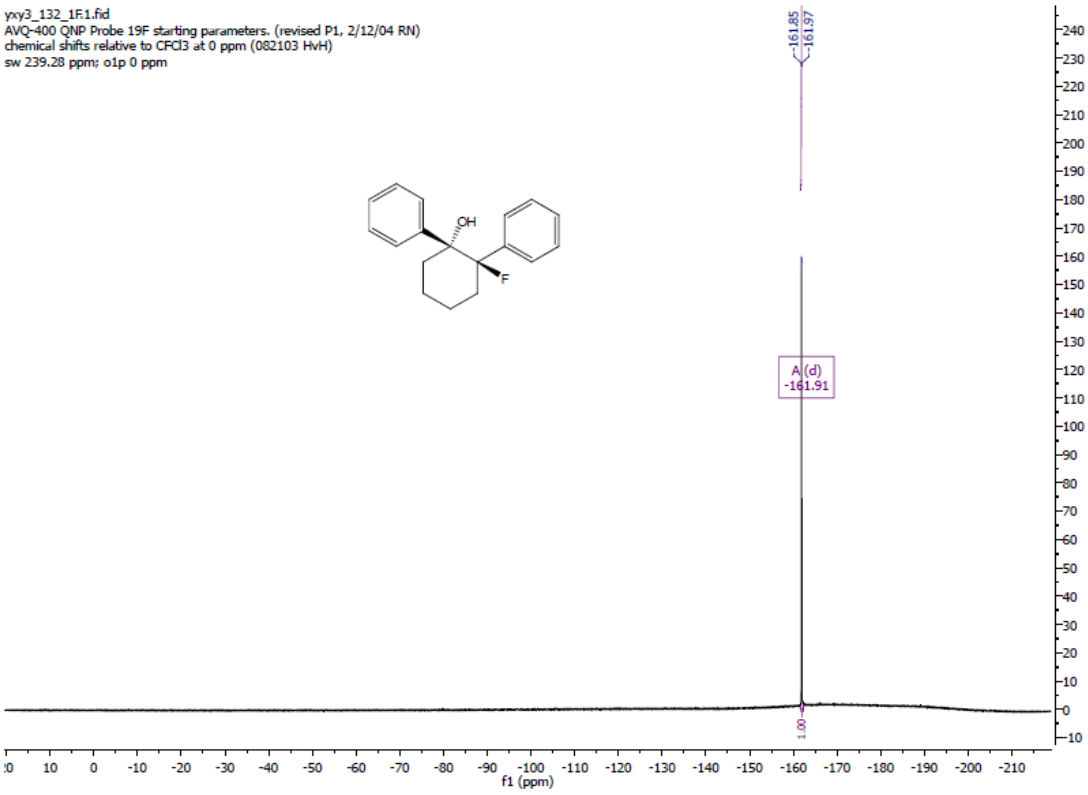




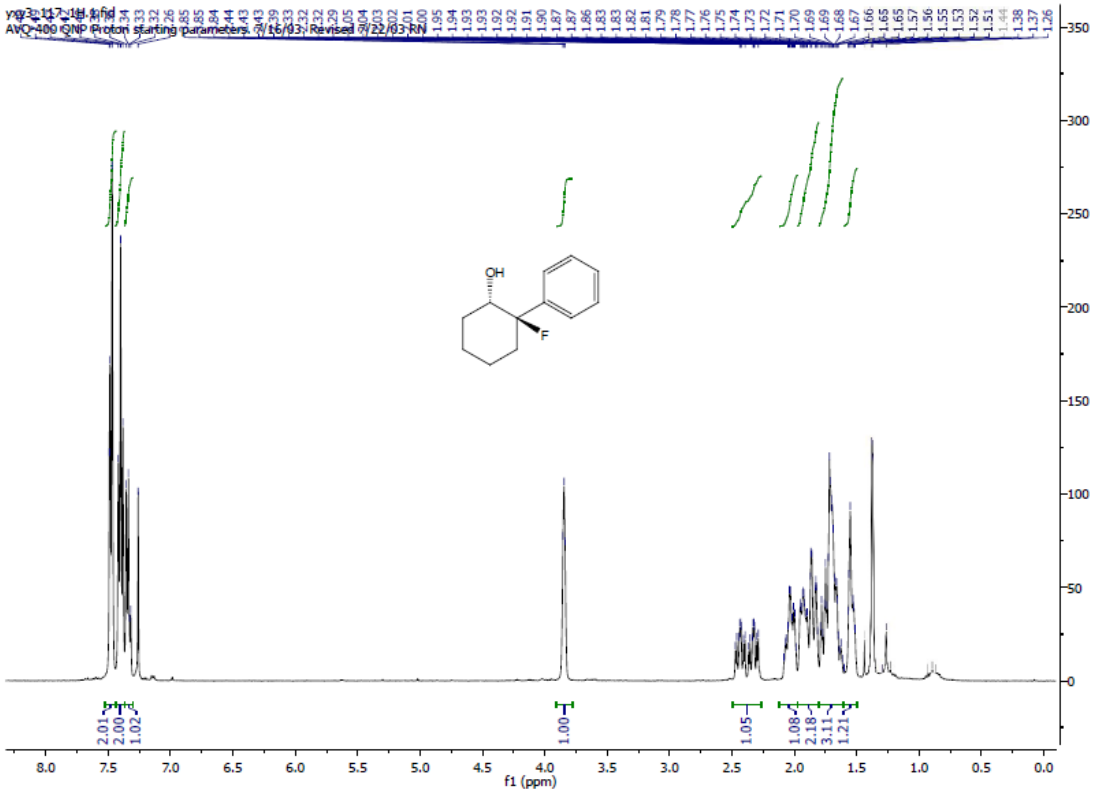
(*1R,2R*)-2-fluoro-1,2-diphenylcyclohexanol (**3a**)

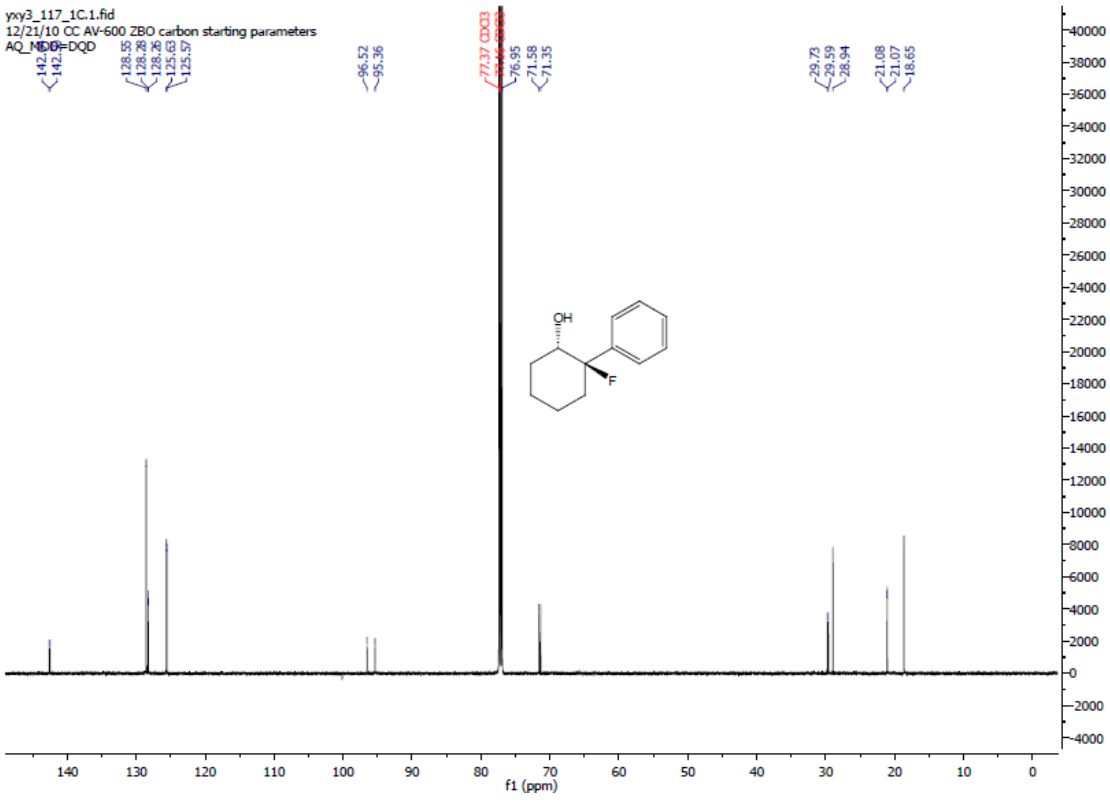


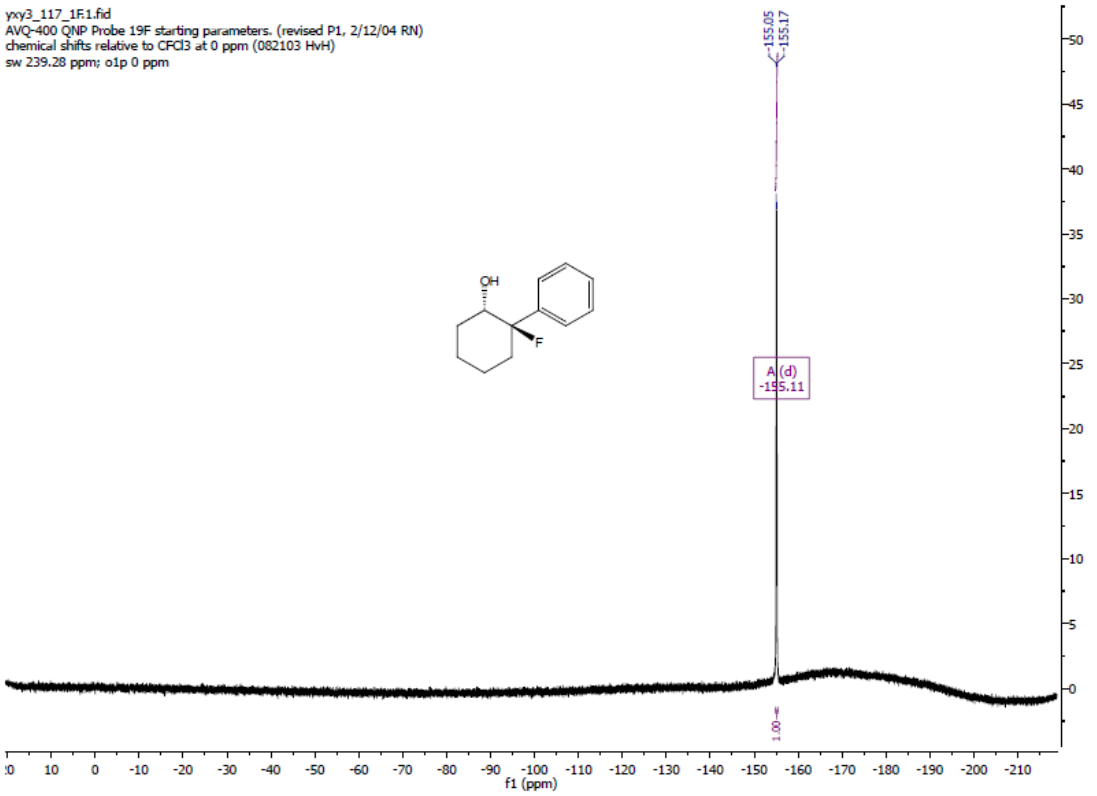

yxy3_132_1C.1.fid
12/21/10 CC AV-600 ZBO carbon starting parameters
AQ_MOD=DQD
143.82
143.82
141.00
140.86
127.32
127.30
127.19
127.18
127.04
126.46
126.43
126.04
125.98
98.42
97.23
77.37 CDCl3
77.16 CDCl3
76.93
75.99
75.80
35.51
33.08
32.94
20.94
20.92
20.65
OH
F
f1 (ppm)


yxy3_132_1F1.fid
AVQ-400 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
chemical shifts relative to CFCl3 at 0 ppm (082103 HvH)
sw 239.28 ppm; o1p 0 ppm
-161.85
-161.97
A (d)
-161.91
1.00
OH
F
f1 (ppm)

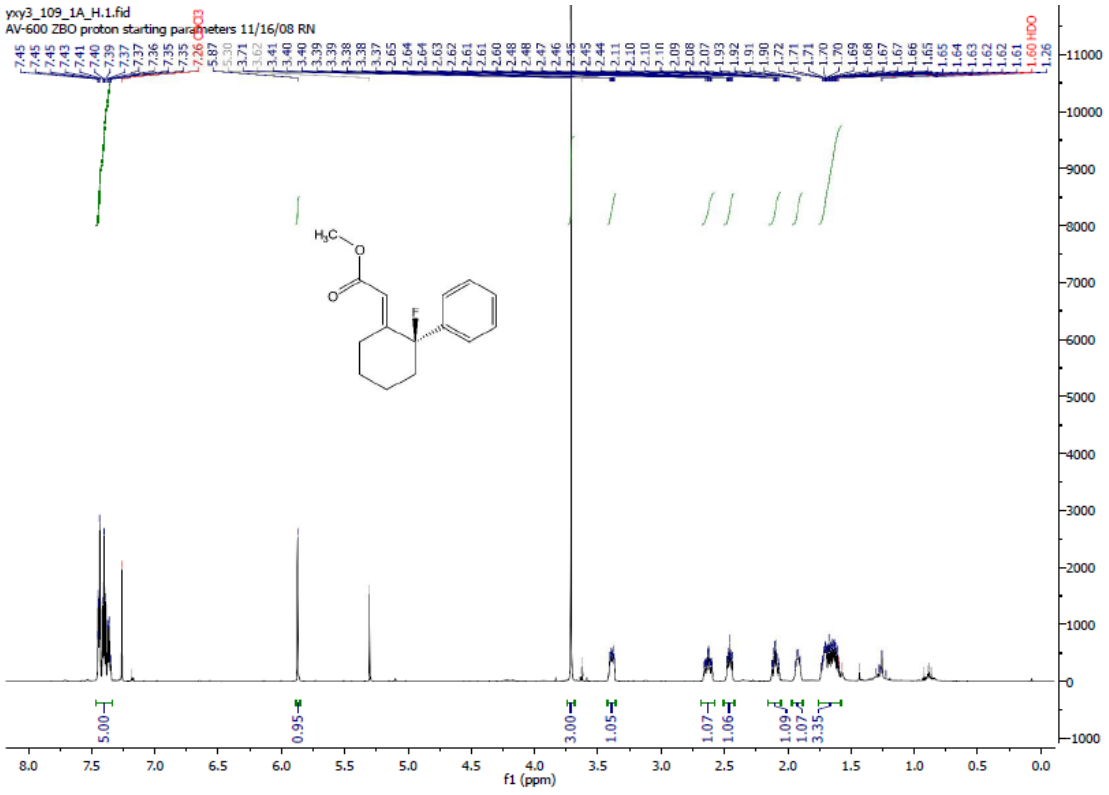
(*1S,2R*)-2-fluoro-2-phenylcyclohexanol (**3b**)

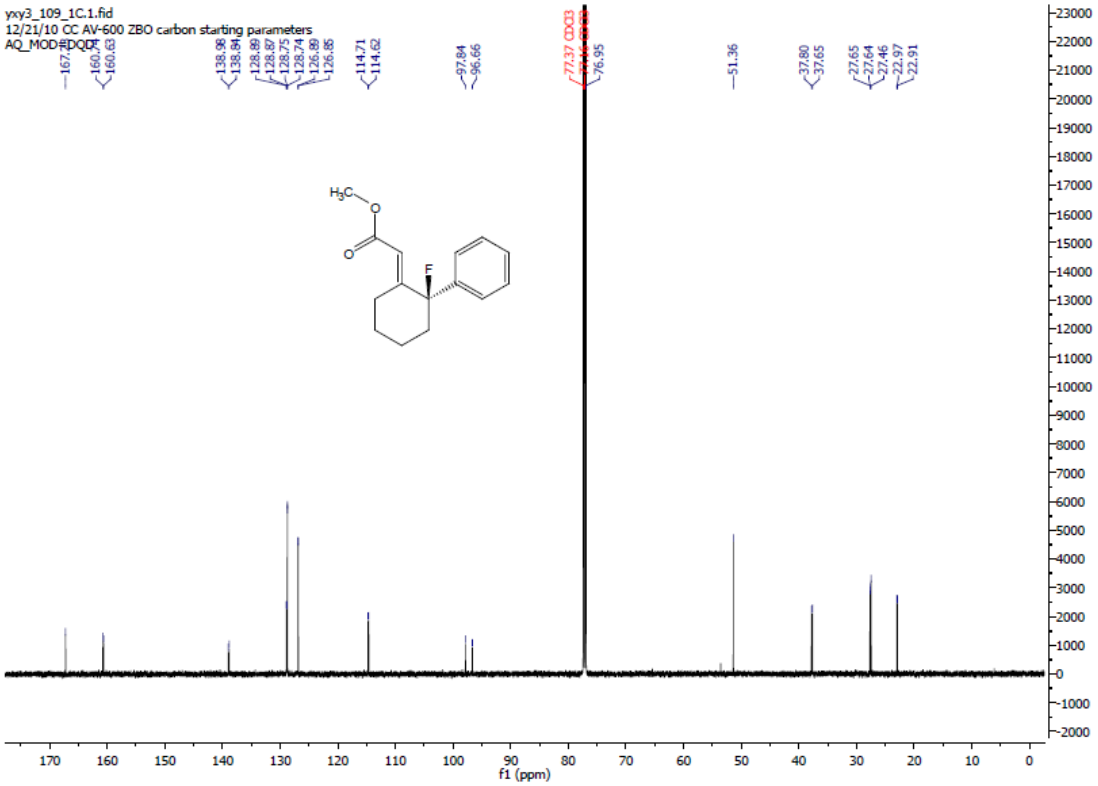


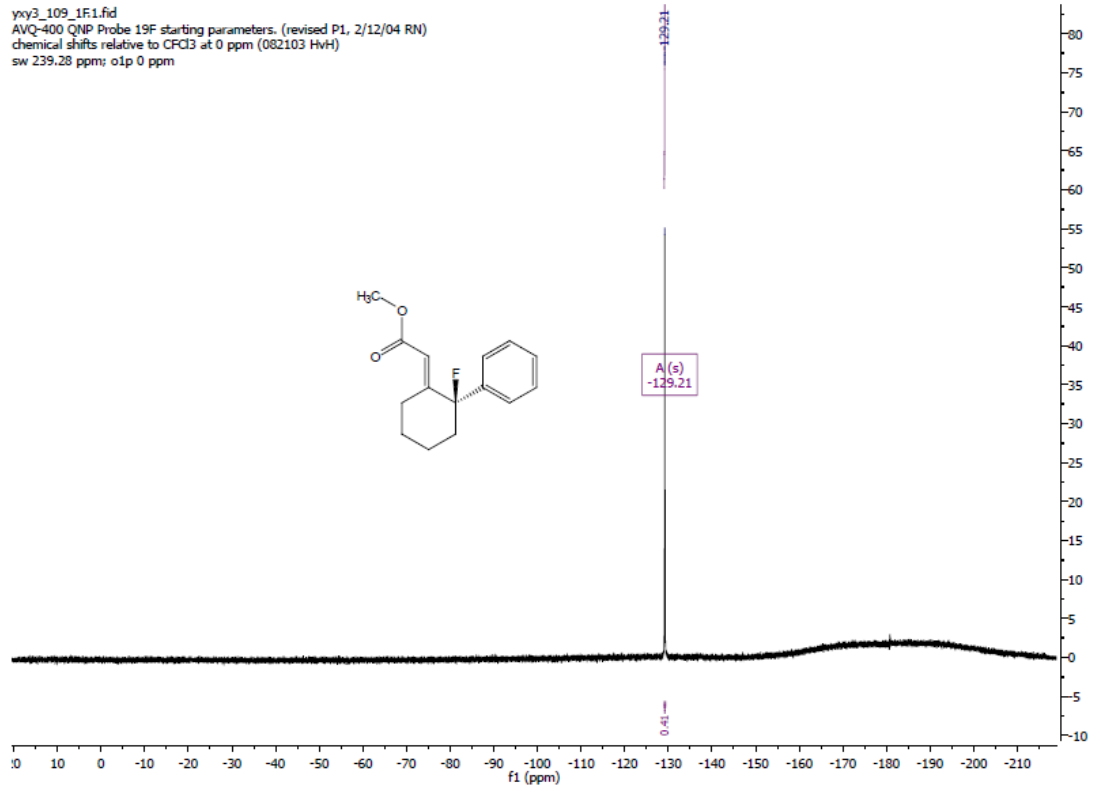




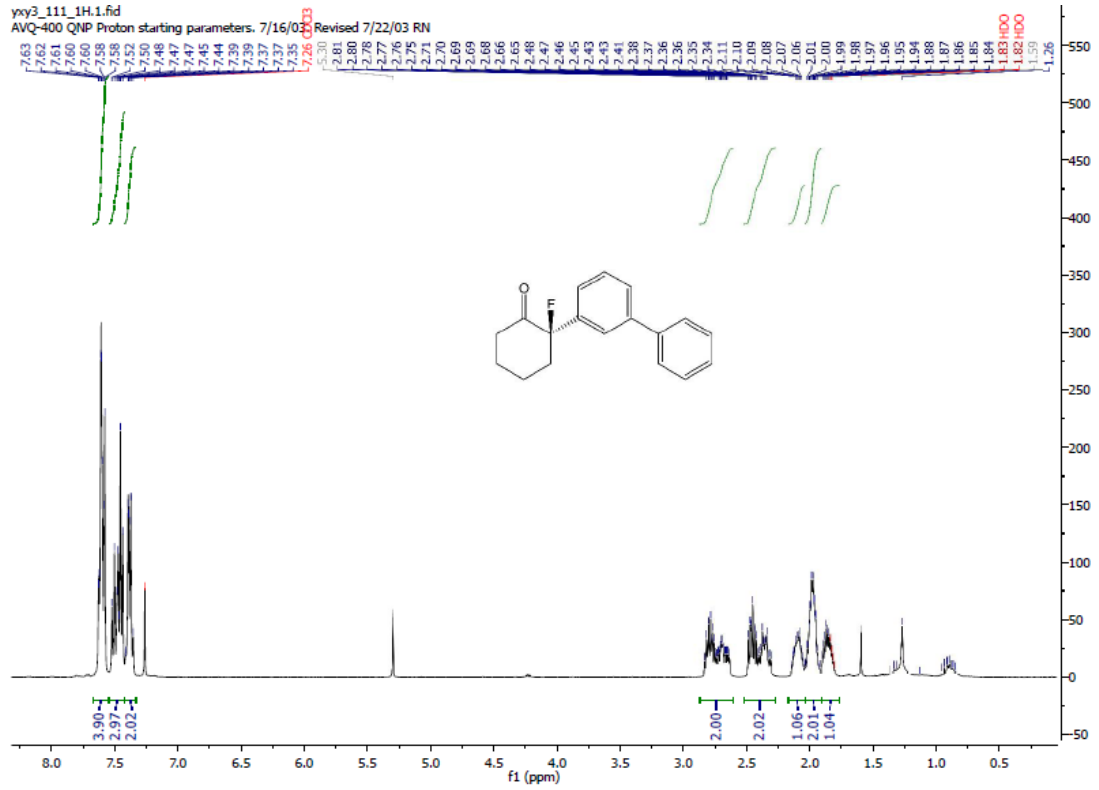
(*S,E*)-methyl 2-(2-fluoro-2-phenylcyclohexylidene)acetate (**3c**)

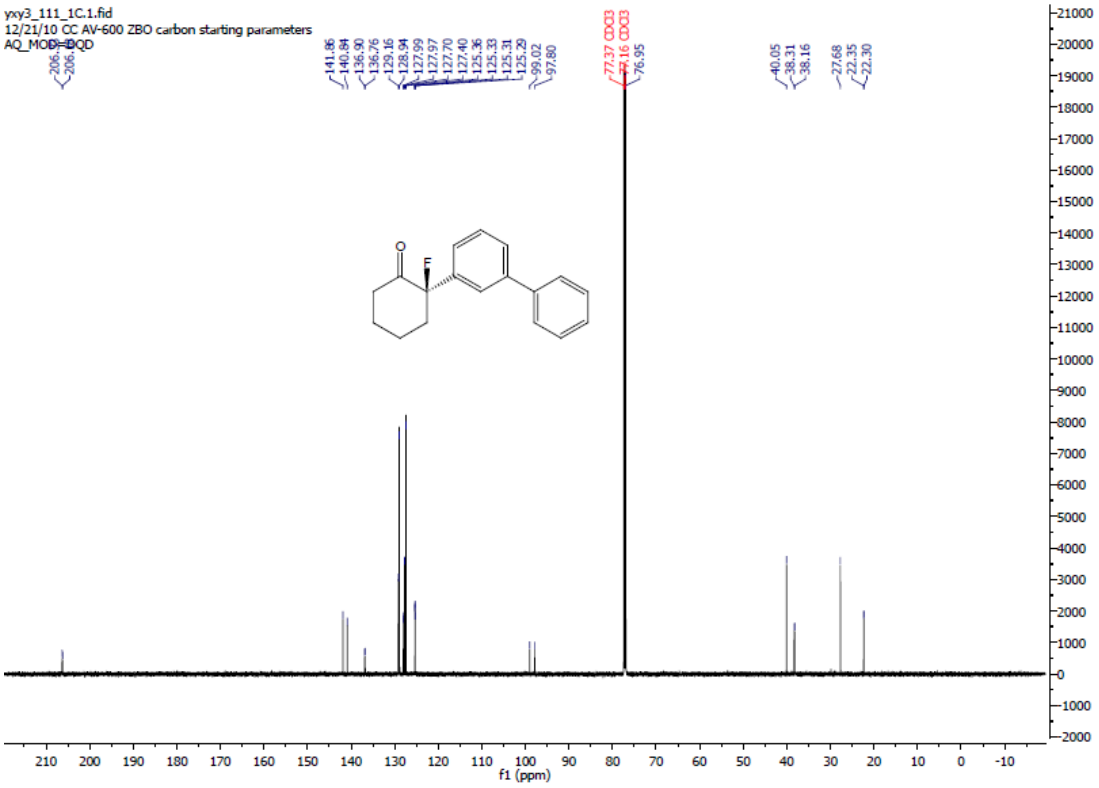


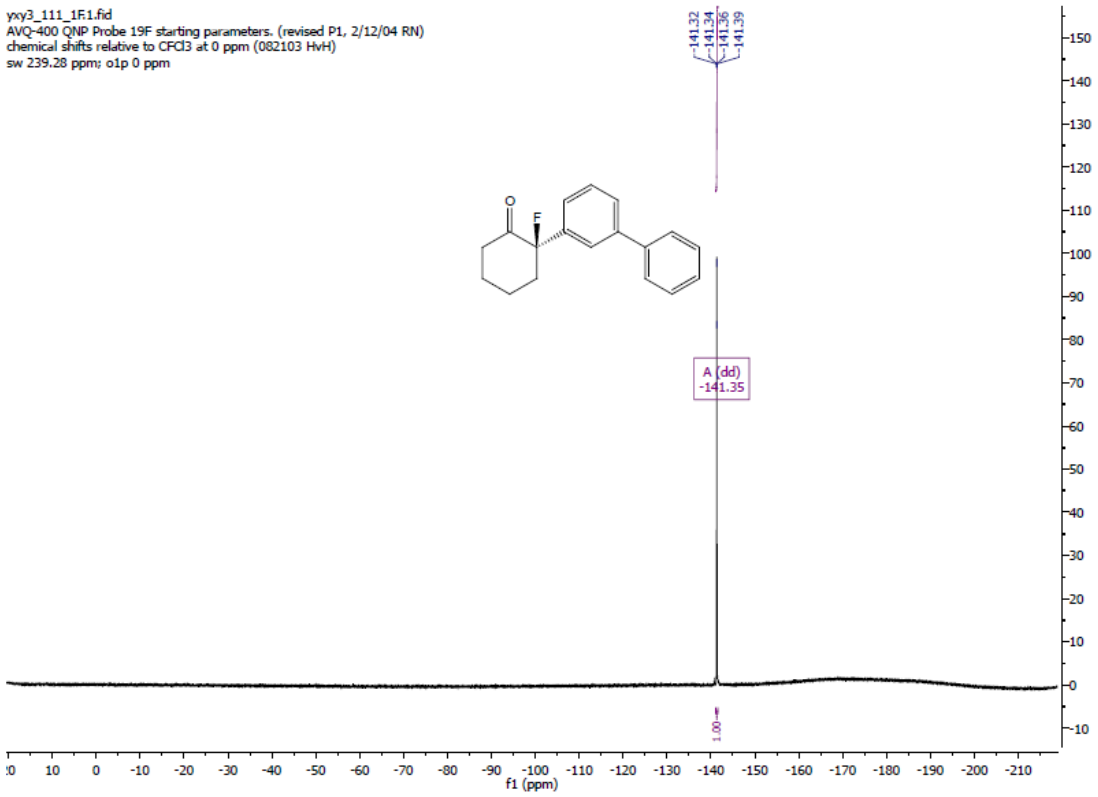

yxy3_109_1C.1.fid
12/21/10 CC AV-600 ZBO carbon starting parameters
AQ_MOD=DQD
167.
160.74
160.63
138.96
138.84
128.88
128.87
128.75
128.74
126.89
126.85
114.71
114.62
97.84
96.66
77.37 CDCl3
76.95
51.36
37.80
37.65
27.65
27.64
27.46
22.97
22.91
H3C
O
O
F
f1 (ppm)


yxy3_109_1F.1.fid
AVQ-400 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
chemical shifts relative to CFCl3 at 0 ppm (082103 HvH)
sw 239.28 ppm; o1p 0 ppm
-129.21
A(s)
-129.21
0.41
H3C
O
O
F
f1 (ppm)

(*R*)-2-([1,1'-biphenyl]-3-yl)-2-fluorocyclohexanone (**3d**)






yxy3_111_1F1.fid
AVQ-400 QNP Probe 19F starting parameters. (revised P1, 2/12/04 RN)
chemical shifts relative to CFCl3 at 0 ppm (082103 HvH)
sw 239.28 ppm; o1p 0 ppm
141.32
141.34
141.36
141.39
O
F
A (dd)
-141.35
1.00
f1 (ppm)