

*Supplementary Information for:*

Highly Efficient Asymmetric Hydrogenation of Cyano-substituted  
Acrylate Esters for Synthesis of Chiral  $\gamma$ -Lactams and Amino Acids

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## 1. General Information:

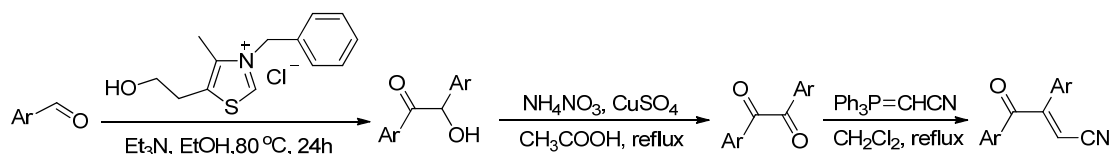
All the air or moisture sensitive reactions and manipulations were performed by using standard Schlenk techniques and in a nitrogen-filled glovebox. DME, THF, dioxane and toluene were distilled from sodium benzophenone ketyl.  $\text{CH}_2\text{Cl}_2$  was distilled from calcium hydride. Anhydrous MeOH was distilled from magnesium.  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR spectra were recorded on Bruker AV (400 MHz) spectrometers.  $\text{CDCl}_3$  was the solvent used for the NMR analysis, with TMS as the internal standard. Chemical shifts were reported upfield to TMS (0.00 ppm) for  $^1\text{H}$  NMR. Data is represented as follows: chemical shift, integration, multiplicity (s = singlet, d = doublet, dd = double of doublets, t = triplet, q = quartet, m = multiplet) and coupling constants ( $J$ ) in Hertz (Hz). Optical rotation was determined using a Perkin Elmer 241 MC polarimeter. GC analysis was conducted on an Agilent 7890A series instrument. HPLC analysis was conducted on Agilent 1260 series instrument. HRMS were recorded on a Waters LCT Premier XE mass spectrometer with APCI or ESI.

## 2. General procedure for the preparation of compounds 1 and 3.

### General Procedure for the synthesis of compounds 1: <sup>[1]</sup>

The appropriate  $\alpha$ -keto esters (0.02 mmol) and 2-(triphenylphosphoranylidene)-acetonitrile (0.024 mmol) were dissolved in toluene (30 ml) in a round bottle flask equipped with a reflux condenser. The mixture was heated to reflux for 4-8h after which the solvent was removed in vacuo. The residue was purified by silica gel column chromatography, using petroleum ether with increasing percentage of AcOEt or  $\text{Et}_2\text{O}$  as an eluent, in order to separate (*E*)- and (*Z*)-stereoisomers.

### General Procedure for the synthesis of compounds 3:



An 100 mL Schlenk tube equipped with a magnetic stir bar was charged with aromatic

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aldehyde (30 mmol) and 3-benzyl-5-(2-hydroxyethyl)-4-methylthiazolium chloride (1.5 mmol) in 20 mL of ethanol, and then sealed tightly with a rubber septum. The tube was evacuated and backfilled with argon three times. Et<sub>3</sub>N (9 mmol) was added via a syringe. The mixture was stirred for 24 h at 80 °C under N<sub>2</sub>. After the reaction was completed, the mixture was concentrated and extracted with ethyl acetate, washed with water and brine, and then dried with anhydrous Na<sub>2</sub>SO<sub>4</sub>. The solvent was removed under reduced pressure. The residue was used directly in next step without further purification. [2]

An 50 mL round-bottom flask equipped with a magnetic stir bar was charged with the resulting crude product, glacial acetic acid (20 mL), NH<sub>4</sub>NO<sub>3</sub> (37.5 mmol) and 2% aqueous solution of CuSO<sub>4</sub> (3.75 mL). The resulting mixture was stirred at reflux until no materials was detected by TLC, and then poured into ice water. The precipitated product was filtered, washed with cold water, dried and recrystallization from ethanol to afford the corresponding benzil.

The appropriate benzil (0.02 mol) and 2-(triphenylphosphoranylidene)-acetonitrile (0.024 mol) were dissolved in CH<sub>2</sub>Cl<sub>2</sub> (30 ml) in a round bottle flask equipped with a reflux condenser. The solution was stirred at reflux temperature until no starting material was detected by TLC. After the solvent was removed in vacuo, the residue was purified by silica gel column chromatography using petroleum ether/ AcOEt as an eluent.

### **3. General procedure for asymmetric hydrogenation of compounds 1 and 3.**

A stock solution was made by mixing Rh(COD)<sub>2</sub>BF<sub>4</sub> or [Rh(COD)Cl]<sub>2</sub> with (*S,S*)-f-spiroPhos in a 1:1.1 molar ratio of Rh/(*S,S*)-f-spiroPhos in CH<sub>2</sub>Cl<sub>2</sub> at room temperature for 20 min in a nitrogen-filled glovebox. An aliquot of the catalyst solution (1.0 mL, 0.001 mmol) was transferred by syringe into the vials charged with different substrates (0.1 mmol for each) in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (2.0 mL). The vials were then placed into a steel autoclave. The inert atmosphere was replaced by H<sub>2</sub> and the reaction mixture was stirred under H<sub>2</sub> (30 atm) at 40 °C for 8 h. The hydrogen gas was released slowly and carefully. The solution was concentrated and passed through

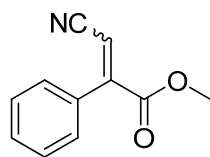
a short column of silica gel to remove the metal complex. The ee values of all products were determined by GC or HPLC analysis on a chiral stationary phase.

#### 4. General procedure for the synthesis of compounds 5.

To a stirring solution of the hydrogenation product **4** (0.1 mmol) in MeOH (3 mL) NaBH<sub>4</sub> (0.2 mmol) was added portionwise at 0 °C. The mixture was stirred at 0 °C until no starting material was detected by TLC and carefully quenched with H<sub>2</sub>O. The aqueous layer was extracted with ethyl acetate, dried over MgSO<sub>4</sub>. The solvent was removed under reduced pressure. Diastereomeric ratios were determined by <sup>1</sup>H NMR of crude products. The ee values of all products were determined by HPLC analysis on a chiral stationary phase.

#### 5. Characterization data for compounds 1 and 3.

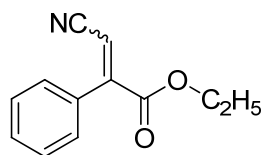
**methyl 3-cyano-2-phenylacrylate: 1a** (*Z*): colorless liquid; Yield: 33%; <sup>1</sup>H NMR



(CDCl<sub>3</sub>, 400 MHz)  $\delta$ : 7.48-7.42 (m, 5H), 5.94 (s, 1H), 3.97 (s, 3H).

**1a'** (*E*): white solid; MP: 52-54°C; Yield: 59%; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz)  $\delta$ : 7.50-7.45 (m, 5H), 6.53 (s, 1H), 3.86 (s, 3H).<sup>[1]</sup>

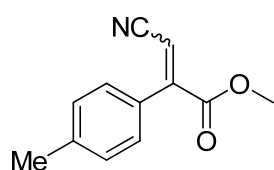
**ethyl 3-cyano-2-phenylacrylate: 1b** (*Z*): yellow liquid; Yield: 28%; <sup>1</sup>H NMR (CDCl<sub>3</sub>,



400 MHz)  $\delta$ : 7.46-7.40 (m, 5H), 5.92 (s, 1H), 4.45 (q, *J* = 7.2 Hz, 2H), 1.42 (t, *J* = 7.2 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz)  $\delta$ : 164.8, 152.7, 133.1, 131.0, 128.9, 127.5, 115.6, 101.1, 62.6,

13.9. **1b'** (*E*): yellow liquid; Yield: 56%; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz)  $\delta$ : 7.51-7.45 (m, 5H), 6.51 (s, 1H), 4.33 (q, *J* = 7.1 Hz, 2H), 1.33 (t, *J* = 7.1 Hz, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz)  $\delta$ : 164.5, 151.7, 132.4, 130.3, 129.2, 128.4, 115.9, 107.1, 62.6, 14.0.<sup>[3]</sup>

**methyl 3-cyano-2-(*p*-tolyl)acrylate: 1c** (*Z*): colorless liquid; Yield: 30%; <sup>1</sup>H NMR

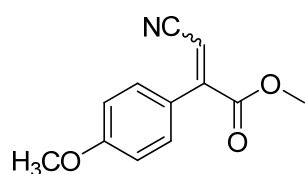


(CDCl<sub>3</sub>, 400 MHz)  $\delta$ : 7.15 (d, *J* = 8.2 Hz, 2H), 7.03 (d, *J* = 8.0 Hz, 2H), 5.72 (s, 1H), 3.76 (s, 3H), 2.20 (s, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz)  $\delta$ : 165.5, 152.6, 141.7, 130.1, 129.7, 127.4,

115.8, 100.0, 53.0, 21.3. **1c'** (*E*): white solid; MP: 55-57°C; Yield: 64%; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz)  $\delta$ : 7.29 (d, *J* = 8.2 Hz, 2H), 7.13 (d, *J* = 8.0 Hz, 2H), 6.33 (s, 1H),

3.69 (s, 3H), 2.26 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.2, 151.5, 140.8, 129.4, 129.2, 129.1, 116.0, 106.5, 53.2, 21.4. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{12}\text{NO}_2$  [ $\text{M}+\text{H}^+$ ]: 202.0868, found 202.0869.

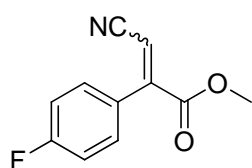
**methyl 3-cyano-2-(4-methoxyphenyl)acrylate: 1d** (*Z*): yellow liquid; Yield: 24%;



$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.39 (dd,  $J = 6.8$  Hz, 2.1 Hz, 2H), 6.91 (dd,  $J = 6.8$  Hz, 2.1 Hz, 2H), 5.83 (s, 1H), 3.96 (s, 3H), 3.84 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.7, 162.0, 152.2, 129.1, 125.1, 116.0, 114.4, 98.2, 55.5, 53.0.

**1d'** (*E*): yellow solid; MP: 62-64°C; Yield: 56%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.49 (dd,  $J = 6.8$  Hz, 2.1 Hz, 2H), 6.97 (dd,  $J = 6.8$  Hz, 2.2 Hz, 2H), 6.40 (s, 1H), 3.86 (s, 3H), 3.85 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.5, 161.3, 150.9, 130.9, 124.4, 116.3, 113.9, 105.1, 55.4, 53.3. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{12}\text{NO}_3$  [ $\text{M}+\text{H}^+$ ]: 218.0817, found 218.0819.

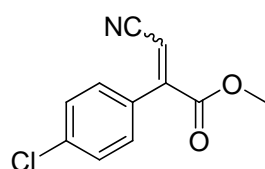
**methyl 3-cyano-2-(4-fluorophenyl)acrylate: 1e** (*Z*): yellow liquid; Yield: 32%;  $^1\text{H}$



NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.46-7.42 (m, 2H), 7.10 (t,  $J = 8.6$  Hz, 2H), 5.91 (s, 1H), 3.96 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 164.9, 164.2 (d,  $J = 251.0$  Hz), 151.2, 129.9 (d,  $J = 9.0$  Hz),

129.4 (d,  $J = 4.0$  Hz), 116.1 (d,  $J = 22.0$  Hz), 115.5, 102.1, 53.1. **1e'** (*E*): white solid; MP: 62-64°C; Yield: 47%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.51-7.48 (m, 2H), 7.17-7.13 (m, 2H), 6.53 (s, 1H), 3.86 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.0, 164.8, 162.5, 150.3, 131.4 (d,  $J = 9.0$  Hz), 128.2 (d,  $J = 4.0$  Hz), 115.7 (d,  $J = 22.0$  Hz), 107.5, 53.4. APCI-HRMS Calcd. for  $\text{C}_{11}\text{H}_9\text{NO}_2\text{F}$  [ $\text{M}+\text{H}^+$ ]: 206.0617, found 206.0617.

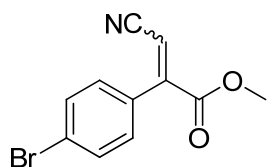
**methyl 2-(4-chlorophenyl)-3-cyanoacrylate: 1f** (*Z*): white solid; MP: 58-60°C; Yield:



33%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.41-7.36 (m, 4H), 5.94 (s, 1H), 3.97 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 164.7, 151.2, 137.2, 131.7, 129.2, 129.1, 115.3, 102.8, 53.3. **1f'** (*E*):

white solid; MP: 55-58°C; Yield: 51%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.37 (s, 4H), 6.48 (s, 1H), 3.80 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 164.6, 150.2, 136.6, 130.6, 130.5, 128.8, 115.5, 107.9, 53.4. APCI-HRMS Calcd. for  $\text{C}_{11}\text{H}_9\text{NO}_2\text{Cl}$  [ $\text{M}+\text{H}^+$ ]:

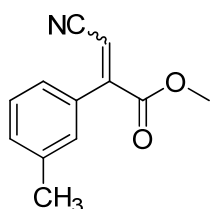
222.0322, found 222.0323.



**methyl 2-(4-bromophenyl)-3-cyanoacrylate: 1g** (*Z*): white solid; MP: 62-64°C; Yield: 37%; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ: 7.54 (t, *J* = 2.4 Hz, 2H), 7.32-7.29 (m, 2H), 5.95 (s, 1H), 3.96 (s, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ: 164.6, 151.2,

132.1, 129.3, 125.6, 115.3, 102.9, 53.3. **1g'** (*E*): white solid; MP: 74-77°C; Yield: 48%; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ: 7.41-7.36 (m, 4H), 5.94 (s, 1H), 3.97 (s, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ: 164.5, 150.4, 131.8, 130.9, 130.7, 125.1, 115.5, 107.9, 53.5. APCI-HRMS Calcd. for C<sub>11</sub>H<sub>9</sub>NO<sub>2</sub>Br [M+H<sup>+</sup>]: 265.9817, found 265.9818.

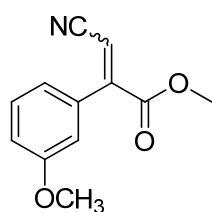
**methyl 3-cyano-2-(*m*-tolyl)acrylate: 1h** (*Z*): colorless liquid; Yield: 32%; <sup>1</sup>H NMR



(CDCl<sub>3</sub>, 400 MHz) δ: 7.26-7.16 (m, 4H), 5.85 (s, 1H), 3.90 (s, 3H), 2.31 (s, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ: 165.4, 152.9, 138.8, 133.0, 131.9, 128.9, 128.1, 124.7, 115.6, 101.2, 53.1, 21.3.

**1h'** (*E*): white solid; MP: 68-70°C; Yield: 57%; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ: 7.28-7.18 (m, 4H), 6.41 (s, 1H), 3.76 (s, 3H), 2.31 (s, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ: 165.1, 151.6, 138.2, 132.2, 131.2, 129.6, 128.4, 126.2, 115.8, 107.2, 53.2, 21.3. APCI-HRMS Calcd. for C<sub>12</sub>H<sub>12</sub>NO<sub>2</sub> [M+H<sup>+</sup>]: 202.0868, found 202.0869.

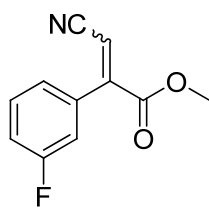
**methyl 3-cyano-2-(3-methoxyphenyl)acrylate: 1i** (*Z*): white solid; MP: 69-71°C;



Yield: 39%; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ: 7.23 (t, *J* = 8.0 Hz, 1H), 6.91-6.84 (m, 3H), 5.84 (s, 1H), 3.85 (s, 3H), 3.72 (s, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ: 165.1, 159.8, 152.6, 134.4, 130.0, 120.0, 116.4, 115.5, 113.2, 101.9, 55.4, 53.1. **1i'** (*E*): colorless

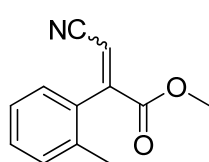
liquid; Yield: 43%; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ: 7.29-7.25 (m, 1H), 6.97-6.90 (m, 3H), 6.42 (s, 1H), 3.75 (s, 3H), 3.73 (s, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ: 165.0, 159.4, 151.4, 133.3, 129.6, 121.4, 116.2, 115.7, 114.5, 107.5, 55.4, 53.3. APCI-HRMS Calcd. for C<sub>12</sub>H<sub>12</sub>NO<sub>3</sub> [M+H<sup>+</sup>]: 218.0817, found 218.0819.

**methyl 3-cyano-2-(3-fluorophenyl)acrylate: 1j** (*Z*): white solid; MP: 42-44°C; Yield: 28%; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ: 7.36-7.30 (m, 1H), 7.19-7.08 (m, 3H), 5.90 (s, 1H), 3.90 (s, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ: 163.5, 161.5 (d, *J* = 246.0 Hz),



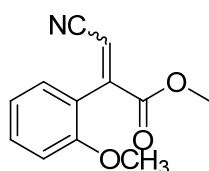
150.0 (d,  $J = 3.0$  Hz), 134.2 (d,  $J = 8.0$  Hz), 129.6 (d,  $J = 8.0$  Hz), 122.5 (d,  $J = 3.0$  Hz), 116.8 (d,  $J = 27.0$  Hz), 714.1, 113.8 (d,  $J = 23.0$  Hz), 102.6, 52.2. **1j'** (*E*): colorless liquid; Yield: 50%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.21-7.08 (m, 4H), 6.51 (s, 1H), 3.80 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 164.3, 162.2 (d,  $J = 245.0$  Hz), 150.0 (d,  $J = 2.0$  Hz), 134.2 (d,  $J = 8.0$  Hz), 130.2 (d,  $J = 8.0$  Hz), 125.0 (d,  $J = 3.0$  Hz), 117.2 (d,  $J = 21.0$  Hz), 116.3 (d,  $J = 23.0$  Hz), 115.4, 108.6, 53.3. APCI-HRMS Calcd. for  $\text{C}_{11}\text{H}_9\text{NO}_2\text{F}$  [ $\text{M}+\text{H}^+$ ]: 206.0617, found 206.0617.

**methyl 3-cyano-2-(*o*-tolyl)acrylate: 1k** (*Z*): white solid; MP: 56-58°C; Yield: 34%;



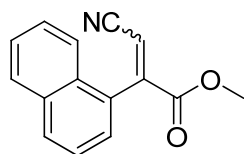
$^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.28-7.06 (m, 4H), 5.73 (s, 1H), 3.80 (s, 3H), 2.14 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 164.4, 153.0, 136.0, 134.5, 130.6, 130.1, 129.0, 126.2, 115.0, 107.1, 53.1, 19.8. **1k'** (*E*): colorless liquid; Yield: 48%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.28-7.11 (m, 4H), 6.56 (s, 1H), 3.74 (s, 3H), 2.13 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 164.8, 152.7, 136.0, 132.5, 130.5, 130.0, 128.9, 126.1, 115.2, 109.8, 53.3, 19.6. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{12}\text{NO}_2$  [ $\text{M}+\text{H}^+$ ]: 202.0868, found 202.0869.

**methyl 3-cyano-2-(2-methoxyphenyl)acrylate: 1l** (*Z*): white solid; MP: 58-60°C;



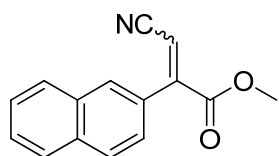
Yield: 13%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.39-7.35 (m, 1H), 7.19-7.16 (m, 1H), 6.94 (t,  $J = 7.5$  Hz, 1H), 6.86 (d,  $J = 8.0$  Hz, 1H), 5.83 (s, 1H), 3.82 (s, 3H), 3.75 (s, 3H),  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.5, 157.0, 151.2, 132.5, 129.5, 123.7, 121.1, 115.6, 111.5, 103.0, 55.9, 52.7. **1l'** (*E*): white solid; MP: 43-44°C; Yield: 70%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.43-7.38 (m, 2H), 7.04-7.00 (m, 1H), 6.94 (d,  $J = 8.3$  Hz, 1H), 6.42 (s, 1H), 3.75 (d,  $J = 3.8$  Hz, 6H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.5, 157.0, 150.4, 132.0, 130.2, 122.2, 120.8, 115.7, 111.3, 107.4, 55.7, 53.0. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{12}\text{NO}_3$  [ $\text{M}+\text{H}^+$ ]: 218.0817, found 218.0819.

**methyl 3-cyano-2-(naphthalen-1-yl)acrylate: 1m** (*Z*): yellow solid; MP: 128-130°C; Yield: 31%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.92-7.89 (m, 2H), 7.67-7.26 (m, 5H), 6.00 (s, 1H), 3.84 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 164.8, 152.3, 133.4, 132.5, 130.8, 130.6, 128.8, 127.3, 127.2, 126.6, 125.2, 124.3, 115.0, 108.0, 53.2. **1m'** (*E*):



yellow liquid; Yield: 46%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.97-7.90 (m, 2H), 7.57-7.47 (m, 5H), 6.83 (s, 1H), 3.76 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.3, 152.1, 133.5, 131.0, 130.6, 130.5, 128.9, 127.5, 127.1, 126.6, 125.3, 124.4, 115.3, 110.9, 53.3. APCI-HRMS Calcd. for  $\text{C}_{15}\text{H}_{12}\text{NO}_2$  [ $\text{M}+\text{H}^+$ ]: 238.0868, found 238.0870.

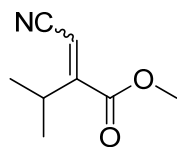
**methyl 3-cyano-2-(naphthalen-2-yl)acrylate: 1n** (*Z*): yellow solid; MP: 116-118°C;



Yield: 32%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.80-7.72 (m, 4H), 7.47-7.34 (m, 3H), 5.91 (s, 1H), 3.9 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.4, 152.7, 134.2, 132.8, 130.3, 128.9, 128.4, 128.0, 127.8, 127.2, 123.6, 115.7, 101.4, 53.3.

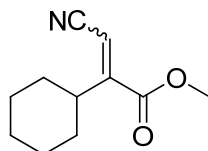
**1n'** (*E*): yellow solid; MP: 104-106°C; Yield: 37%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.92-7.75 (m, 4H), 7.47-7.41 (m, 3H), 6.49 (s, 1H), 3.76 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.2, 151.5, 133.9, 132.7, 129.6, 129.5, 128.7, 128.3, 127.8, 127.7, 126.8, 125.7, 115.9, 107.5, 53.4. APCI-HRMS Calcd. for  $\text{C}_{15}\text{H}_{12}\text{NO}_2$  [ $\text{M}+\text{H}^+$ ]: 238.0868, found 238.0870.

**methyl 2-(cyanomethylene)-3-methylbutanoate: 1o** (*Z*): colorless liquid; Yield:



34%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 5.58 (d,  $J = 1.4$  Hz, 1H), 3.86 (s, 3H), 2.93-2.86 (m, 1H), 1.11 (s, 3H), 1.09 (s, 3H). **1o'** (*E*): yellow liquid; Yield: 38%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 6.12 (s, 1H), 3.75 (s, 3H), 3.19-3.12 (m, 1H), 1.23 (s, 3H), 1.21 (s, 3H).<sup>[1]</sup>

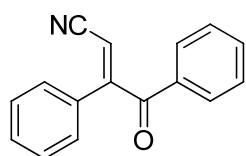
**methyl 3-cyano-2-cyclohexylacrylate: 1p** (*Z*): colorless liquid; Yield: 35%;  $^1\text{H}$  NMR



( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 5.50 (s, 1H), 3.81 (s, 3H), 2.52-2.46 (m, 1H), 1.76-1.64 (m, 5H), 1.32-1.02 (m, 5H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.3, 159.4, 115.6, 101.5, 52.6, 41.1, 31.4, 26.0, 25.6. **1p'** (*E*): white solid; MP: 38-40°C; Yield: 27%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 6.11 (s, 1H), 3.74 (s, 3H), 2.81-2.74 (m, 1H), 1.78-1.60 (m, 7H), 1.32-1.17 (m, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 165.3, 158.4, 115.4, 105.5, 52.6, 42.3, 30.3, 26.2, 25.4. APCI-HRMS Calcd. for  $\text{C}_{11}\text{H}_{16}\text{NO}_2$  [ $\text{M}+\text{H}^+$ ]: 194.1181, found 194.1182.<sup>[1]</sup>

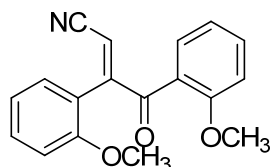
**(E)-4-oxo-3,4-diphenylbut-2-enenitrile (3a)**: yellow liquid; Yield: 88%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.76-7.74 (m, 2H), 7.55-7.50 (m, 3H), 7.48-7.34 (m, 5H), 5.69





(s, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 194.1, 159.3, 135.0, 134.4, 133.1, 130.9, 130.1, 129.1, 128.9, 128.2, 116.1, 100.4.

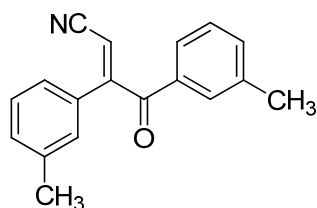
**(E)-3,4-bis(2-methoxyphenyl)-4-oxobut-2-enitrile (3b)**: yellow solid; MP:



123-125°C; Yield: 87%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.57 (dd,  $J = 7.6$  Hz, 1.6 Hz, 2H), 7.53-7.29 (m, 2H), 7.02-6.92 (m, 2H), 6.73-6.69 (m, 2H), 6.09 (s, 1H), 3.64 (s, 3H), 358 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 194.1, 158.8, 157.6,

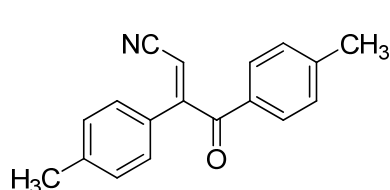
156.6, 133.4, 131.8, 130.9, 130.7, 127.0, 123.0, 120.4, 120.3, 116.7, 110.8, 110.7, 103.6, 55.2, 55.1.

**(E)-4-oxo-3,4-di-*m*-tolylbut-2-enitrile (3c)**: yellow liquid; Yield: 82%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.72 (s, 1H), 7.63 (d,  $J = 7.7$  Hz, 1H), 7.47-7.25 (m, 6H), 5.71



(s, 1H), 2.39 (s, 3H), 2.37 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 194.4, 159.7, 138.9, 138.8, 135.2, 135.1, 133.0, 131.7, 130.4, 129.0, 128.7, 128.6, 127.6, 125.4, 116.1, 99.7, 21.4, 21.3.

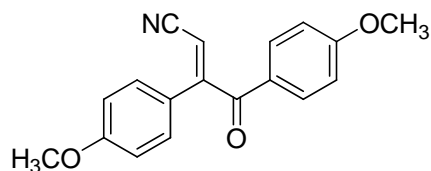
**(E)-4-oxo-3,4-di-*p*-tolylbut-2-enitrile (3d)**: yellow liquid; Yield: 67%;  $^1\text{H}$  NMR



( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.75 (d,  $J = 8.0$  Hz, 2H), 7.55 (d,  $J = 8.0$  Hz, 2H), 7.24 (d,  $J = 8.0$  Hz, 4H), 5.67 (s, 1H), 2.40 (s, 3H), 2.37 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 194.0, 159.6, 145.5, 141.5, 132.5, 130.3,

130.2, 129.8, 129.6, 128.2, 116.4, 98.5, 21.8, 21.5.

**(E)-3,4-bis(4-methoxyphenyl)-4-oxobut-2-enitrile (3e)**: yellow liquid; Yield:

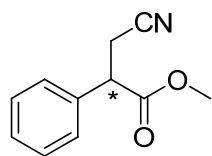


82%;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.84-7.81 (m, 2H), 7.65-7.61 (m, 2H), 6.95-6.88 (m, 4H), 5.55 (s, 1H), 3.85 (s, 3H), 3.82 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ ,

100 MHz)  $\delta$ : 193.1, 164.5, 161.6, 159.2, 132.6, 130.0, 127.9, 125.6, 116.8, 114.5, 114.2, 96.1, 55.6, 55.4.

## 6. Characterization data for compounds 2, 4 and 5.

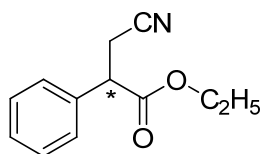
**methyl 3-cyano-2-phenylpropanoate:** white solid; MP: 58-60°C; (*R*)-**2a**: Yield: 98%;



98% ee;  $[\alpha]_D^{25} = -138.0$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250 × 4.60mm), ipa : hex = 20:80, 1mL/min, 225 nm;  $t_R = 15.9$  min (major),  $t_R = 22.4$  min (minor). (*S*)-**2a'**: Yield: 98%;

97% ee;  $[\alpha]_D^{25} = +132.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250 × 4.60mm), ipa : hex = 20:80, 1mL/min, 225 nm;  $t_R = 17.3$  min (minor),  $t_R = 27.1$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.32-7.18 (m, 5H), 3.87 (t,  $J = 7.2$  Hz, 1H), 3.64 (s, 3H), 2.95 (q,  $J = 7.6$  Hz, 1H), 2.73 (q,  $J = 7.3$  Hz, 1H).<sup>[1]</sup> The absolute configuration of (*R*)-**2a** and (*S*)-**2a'** was determined by comparison with optical rotation data for the reported literature.<sup>[1]</sup>

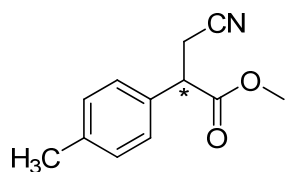
**ethyl 3-cyano-2-phenylpropanoate:** colorless liquid; **2b**: Yield: 97%; 96% ee;  $[\alpha]_D^{25} = -106.4$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_R = 9.2$  min (major),  $t_R = 10.9$  min (minor). **2b'**: Yield: 98%; 97% ee;  $[\alpha]_D^{25} = +121.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u



Cellulose-3 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_R = 17.3$  min (minor),  $t_R = 27.1$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.30-7.18 (m, 5H), 4.16-4.64 (m, 2H), 3.84 (t,  $J = 7.6$  Hz, 1H), 2.94 (dd,  $J = 16.8$  Hz, 7.6 Hz,

1H), 2.71 (dd,  $J = 16.8$  Hz, 7.6 Hz, 1H), 1.13 (t,  $J = 7.1$  Hz, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.0, 136.0, 129.2, 128.5, 127.5, 117.7, 61.8, 47.7, 21.7, 14.0. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{14}\text{NO}_2$   $[\text{M}+\text{H}^+]$ : 204.1025, found 204.1026.

**methyl 3-cyano-2-(*p*-tolyl)propanoate:** white solid; MP: 55-57°C; **2c**: Yield: 97%; 96% ee;  $[\alpha]_D^{25} = -134.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition:

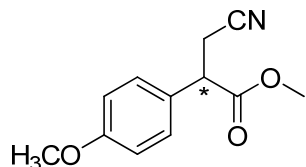


Lux 5u Cellulose-3 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_R = 10.3$  min (major),  $t_R = 14.0$  min (minor). **2c'**: Yield: 96%; 97% ee;  $[\alpha]_D^{25} = +135.2$  ( $c = 0.5$ ,

$\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_R = 9.6$  min (minor),  $t_R = 12.5$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.11-7.06 (m, 4H), 3.82 (t,  $J = 7.6$  Hz, 1H), 3.62 (s, 3H), 2.92 (dd,  $J = 16.8$

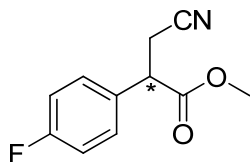
Hz, 7.5 Hz, 1H), 2.70 (dd,  $J = 16.8$  Hz, 7.7 Hz, 1H), 2.25 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.7, 138.4, 132.8, 129.9, 127.4, 117.7, 52.8, 47.2, 21.8, 21.1. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{14}\text{NO}_2$  [ $\text{M}+\text{H}^+$ ]: 204.1025, found 204.1029.

**methyl 3-cyano-2-(4-methoxyphenyl)propanoate**: white solid; MP: 60-62°C; **2d**:



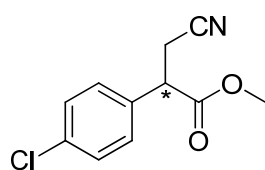
Yield: 96%; 97% ee;  $[\alpha]_{\text{D}}^{25} = -147.4$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250  $\times$  4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_{\text{R}} = 15.4$  min (major),  $t_{\text{R}} = 17.5$  min (minor). **2d'**: Yield: 96%; 97% ee;  $[\alpha]_{\text{D}}^{25} = +149.4$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250  $\times$  4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_{\text{R}} = 16.1$  min (minor),  $t_{\text{R}} = 18.1$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.12 (d,  $J = 8.7$  Hz, 2H), 6.82 (d,  $J = 8.7$  Hz, 2H), 3.82 (t,  $J = 7.6$  Hz, 1H), 3.71 (s, 3H), 3.63 (s, 3H), 2.92 (dd,  $J = 16.8$  Hz, 7.4 Hz, 1H), 2.71 (dd,  $J = 16.8$  Hz, 7.4 Hz, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.8, 159.7, 128.7, 127.8, 117.7, 114.6, 55.3, 52.7, 46.8, 21.9. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{14}\text{NO}_3$  [ $\text{M}+\text{H}^+$ ]: 220.0974, found 220.0971.

**methyl 3-cyano-2-(4-fluorophenyl)propanoate**: colorless liquid; **2e**: Yield: 96%; 97%



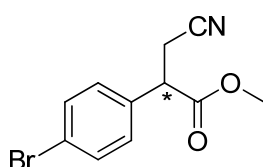
ee;  $[\alpha]_{\text{D}}^{25} = -114.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250  $\times$  4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_{\text{R}} = 10.2$  min (major),  $t_{\text{R}} = 12.1$  min (minor). **2e'**: Yield: 97%; 97% ee;  $[\alpha]_{\text{D}}^{25} = +120.2$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250  $\times$  4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_{\text{R}} = 11.1$  min (minor),  $t_{\text{R}} = 12.7$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.21-7.17 (m, 2H), 7.01-6.97 (m, 2H), 3.86 (t,  $J = 7.6$  Hz, 1H), 3.64 (s, 3H), 2.93 (dd,  $J = 16.8$  Hz, 7.2 Hz, 1H), 2.73 (dd,  $J = 16.8$  Hz, 7.2 Hz, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.3, 162.7 (d,  $J = 246.0$  Hz), 131.6 (d,  $J = 4.0$  Hz), 129.4 (d,  $J = 9.0$  Hz), 117.4, 116.3 (d,  $J = 21.0$  Hz), 52.9, 46.8, 21.8. APCI-HRMS Calcd. for  $\text{C}_{11}\text{H}_{11}\text{NO}_2\text{F}$  [ $\text{M}+\text{H}^+$ ]: 208.0774, found 208.0776.

**methyl 2-(4-chlorophenyl)-3-cyanopropanoate**: white solid; MP: 68-70°C; **2f**: Yield: 97%; 98% ee;  $[\alpha]_{\text{D}}^{25} = -128.0$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco gamma DexTM 225 column (30 m  $\times$  0.25 mm  $\times$  0.25  $\mu\text{m}$ ),  $\text{N}_2$  1.0 mL/min, programmed 100  $^\circ\text{C}$  - 1  $^\circ\text{C}/\text{min}$  - 210  $^\circ\text{C}$  - 50 min;  $t_{\text{R}} = 79.4$  min (major),  $t_{\text{R}} = 80.2$  min (minor). **2f'**:



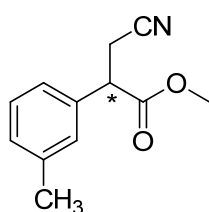
Yield: 96%; 96% ee;  $[\alpha]_{\text{D}}^{25} = +123.8$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco gamma DexTM 225 column (30 m  $\times$  0.25 mm  $\times$  0.25  $\mu\text{m}$ ),  $\text{N}_2$  1.0 mL/min, programmed 100  $^\circ\text{C}$  - 1  $^\circ\text{C}/\text{min}$  - 210  $^\circ\text{C}$  - 50 min;  $t_{\text{R}} = 79.7$  min (minor),  $t_{\text{R}} = 80.1$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.28 (d,  $J = 1.9$  Hz, 2H), 7.15 (d,  $J = 1.7$  Hz, 2H), 3.85 (t,  $J = 7.6$  Hz, 1H), 3.66 (s, 3H), 2.94 (dd,  $J = 16.9$  Hz, 7.2 Hz, 1H), 2.74 (dd,  $J = 16.9$  Hz, 7.2 Hz, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.1, 134.7, 134.1, 129.5, 129.0, 117.3, 53.0, 46.9, 21.6. APCI-HRMS Calcd. for  $\text{C}_{11}\text{H}_{11}\text{NO}_2\text{Cl}$  [ $\text{M}+\text{H}^+$ ]: 224.0478, found 224.0476.

**methyl 2-(4-bromophenyl)-3-cyanopropanoate:** white solid; MP: 70-72 $^\circ\text{C}$ ; **2g**:



Yield: 97%; 97% ee;  $[\alpha]_{\text{D}}^{25} = -122.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco gamma DexTM 225 column (30 m  $\times$  0.25 mm  $\times$  0.25  $\mu\text{m}$ ),  $\text{N}_2$  1.0 mL/min, programmed 100  $^\circ\text{C}$  - 1  $^\circ\text{C}/\text{min}$  - 200  $^\circ\text{C}$  - 100 min;  $t_{\text{R}} = 88.6$  min (major),  $t_{\text{R}} = 89.3$  min (minor). **2g'**: Yield: 97%; 96% ee;  $[\alpha]_{\text{D}}^{25} = +118.0$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco gamma DexTM 225 column (30 m  $\times$  0.25 mm  $\times$  0.25  $\mu\text{m}$ ),  $\text{N}_2$  1.0 mL/min, programmed 100  $^\circ\text{C}$  - 1  $^\circ\text{C}/\text{min}$  - 200  $^\circ\text{C}$  - 100 min;  $t_{\text{R}} = 88.8$  min (minor),  $t_{\text{R}} = 89.1$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.44 (dd,  $J = 6.7$  Hz, 1.8 Hz, 2H), 7.09 (dd,  $J = 6.7$  Hz, 1.8 Hz, 2H), 3.84 (t,  $J = 7.6$  Hz, 1H), 3.65 (s, 3H), 2.93 (dd,  $J = 16.8$  Hz, 7.2 Hz, 1H), 2.73 (dd,  $J = 16.8$  Hz, 7.2 Hz, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.0, 134.7, 132.4, 129.3, 122.8, 117.3, 53.0, 47.0, 21.6. APCI-HRMS Calcd. for  $\text{C}_{11}\text{H}_{11}\text{NO}_2\text{Br}$  [ $\text{M}+\text{H}^+$ ]: 267.9973, found 267.9975.

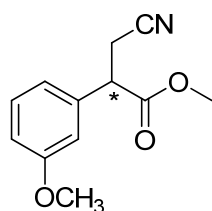
**methyl 3-cyano-2-(*m*-tolyl)propanoate:** white solid; MP: 57-59 $^\circ\text{C}$ ; **2h**: Yield: 98%;



97% ee;  $[\alpha]_{\text{D}}^{25} = -144.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250  $\times$  4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_{\text{R}} = 8.6$  min (major),  $t_{\text{R}} = 10.4$  min (minor). **2h'**: Yield: 98%; 96% ee;  $[\alpha]_{\text{D}}^{25} = +142.2$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250  $\times$  4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_{\text{R}} = 9.2$  min (minor),  $t_{\text{R}} = 11.0$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.20-6.98 (m, 4H), 3.82 (t,  $J = 7.6$  Hz, 1H), 3.64 (s, 3H), 2.94 (dd,  $J = 16.8$  Hz, 7.6 Hz, 1H), 2.71 (dd,  $J =$

16.8 Hz, 7.6 Hz, 1H), 2.27 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.6, 139.1, 135.7, 129.3, 129.1, 128.2, 124.6, 117.7, 52.8, 47.5, 21.7, 21.4. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{14}\text{NO}_2$  [ $\text{M}+\text{H}^+$ ]: 204.1025, found 204.1029.

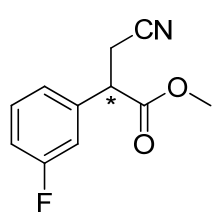
**methyl 3-cyano-2-(3-methoxyphenyl)propanoate:** colorless liquid; **2i**: Yield: 96%;



97% ee;  $[\alpha]_{\text{D}}^{25} = -130.8$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250  $\times$  4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_{\text{R}} = 15.1$  min (major),  $t_{\text{R}} = 20.3$  min (minor). **2i'**: Yield: 98%; 95% ee;  $[\alpha]_{\text{D}}^{25} = +116.0$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u

Cellulose-3 (250  $\times$  4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_{\text{R}} = 14.6$  min (minor),  $t_{\text{R}} = 19.1$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.20 (t,  $J = 8.0$  Hz, 1H), 6.80-6.73 (m, 3H), 3.83 (t,  $J = 7.6$  Hz, 1H), 3.71 (s, 3H), 3.63 (s, 3H), 2.93 (dd,  $J = 16.8$  Hz, 7.6 Hz, 1H), 2.71 (dd,  $J = 16.8$  Hz, 7.6 Hz, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.4, 160.1, 137.2, 130.3, 119.7, 117.6, 113.8, 113.5, 55.3, 52.8, 47.5, 21.6. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{14}\text{NO}_3$  [ $\text{M}+\text{H}^+$ ]: 220.0974, found 220.0971.

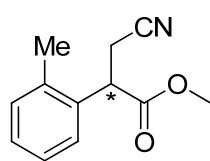
**methyl 3-cyano-2-(3-fluorophenyl)propanoate:** colorless liquid; **2j**: Yield: 98%; 97%



ee;  $[\alpha]_{\text{D}}^{25} = -121.8$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco beta DexTM 120 column (30 m  $\times$  0.25 mm  $\times$  0.25  $\mu\text{m}$ ),  $\text{N}_2$  1.0 mL/min, programmed 100  $^\circ\text{C}$  - 1  $^\circ\text{C}/\text{min}$  - 210  $^\circ\text{C}$  - 100 min;  $t_{\text{R}} = 61.9$  min (minor),  $t_{\text{R}} = 62.6$  min (major). **2j'**: Yield: 97%; 96% ee;  $[\alpha]_{\text{D}}^{25} =$

+117.8 ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco gamma DexTM 120 column (30 m  $\times$  0.25 mm  $\times$  0.25  $\mu\text{m}$ ),  $\text{N}_2$  1.0 mL/min, programmed 100  $^\circ\text{C}$  - 1  $^\circ\text{C}/\text{min}$  - 210  $^\circ\text{C}$  - 100 min;  $t_{\text{R}} = 62.2$  min (major),  $t_{\text{R}} = 62.5$  min (minor).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.31-7.19 (m, 1H), 7.01-6.87 (m, 3H), 3.87 (t,  $J = 7.6$  Hz, 1H), 3.66 (s, 3H), 2.95 (dd,  $J = 16.9$  Hz, 7.3 Hz, 1H), 2.75 (dd,  $J = 16.9$  Hz, 7.3 Hz, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.0, 163.0 (d,  $J = 247.0$  Hz), 137.9 (d,  $J = 8.0$  Hz), 130.9 (d,  $J = 8.0$  Hz), 123.4 (d,  $J = 2.0$  Hz), 117.2, 115.7 (d,  $J = 21.0$  Hz), 114.7 (d,  $J = 22.0$  Hz), 53.0, 47.2 (d,  $J = 1.0$  Hz), 21.6. APCI-HRMS Calcd. for  $\text{C}_{11}\text{H}_{11}\text{NO}_2\text{F}$  [ $\text{M}+\text{H}^+$ ]: 208.0774, found 208.0776.

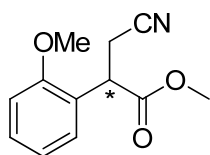
**methyl 3-cyano-2-(*o*-tolyl)propanoate:** white solid; MP: 79-81°C; **2k**: Yield: 97%;



95% ee;  $[\alpha]_D^{25} = -140.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 20:80, 1mL/min, 225 nm;  $t_R = 12.0$  min (minor),  $t_R = 22.3$  min (major). **2k'**: Yield: 96%; 98%

ee;  $[\alpha]_D^{25} = +147.4$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 20:80, 1mL/min, 225 nm;  $t_R = 12.0$  min (major),  $t_R = 22.4$  min (minor).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.15-7.07 (m, 4H), 4.17 (t,  $J = 7.5$  Hz, 1H), 3.64 (s, 3H), 2.97 (dd,  $J = 16.8$  Hz, 7.7 Hz, 1H), 2.68 (dd,  $J = 16.8$  Hz, 7.4 Hz, 1H), 2.36 (s, 3H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.9, 136.1, 134.4, 131.2, 128.4, 126.9, 126.3, 117.7, 52.8, 43.2, 21.1, 19.6. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{14}\text{NO}_2$   $[\text{M}+\text{H}^+]$ : 204.1025, found 204.1029.

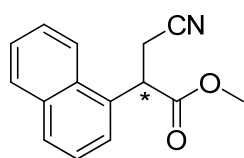
**methyl 3-cyano-2-(2-methoxyphenyl)propanoate:** colorless liquid; **2l**: Yield: 95%;



98% ee;  $[\alpha]_D^{25} = -120.2$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_R = 9.3$  min (major),  $t_R = 13.2$  min (minor). **2l'**: Yield: 96%;

98% ee;  $[\alpha]_D^{25} = +122.2$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_R = 11.7$  min (minor),  $t_R = 16.6$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.21-7.08 (m, 2H), 6.90-6.82 (m, 2H), 4.13 (t,  $J = 7.2$  Hz, 1H), 3.75 (s, 3H), 3.63 (s, 3H), 2.95 (dd,  $J = 16.8$  Hz, 7.0 Hz, 1H), 2.73 (dd,  $J = 16.8$  Hz, 7.0 Hz, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.9, 156.6, 129.7, 129.2, 124.6, 121.1, 118.2, 111.1, 55.5, 52.6, 42.6, 20.2. APCI-HRMS Calcd. for  $\text{C}_{12}\text{H}_{14}\text{NO}_3$   $[\text{M}+\text{H}^+]$ : 220.0974, found 220.0971.

**methyl 3-cyano-2-(naphthalen-1-yl)propanoate:** white solid; MP: 78-80°C; **2m**:

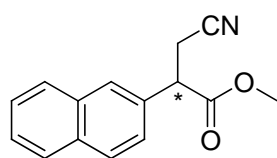


Yield: 98%; 98% ee;  $[\alpha]_D^{25} = -162.0$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_R = 20.8$  min (minor),  $t_R = 30.3$  min

(major). **2m'**: Yield: 98%; 95% ee;  $[\alpha]_D^{25} = +156.8$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 225 nm;  $t_R = 20.7$  min (major),  $t_R = 30.4$  min (minor).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 8.01-7.84 (m, 3H), 7.62-7.40 (m, 4H), 4.75 (t,  $J = 7.8$  Hz, 1H), 3.71 (s, 3H), 3.22 (dd,  $J = 16.8$  Hz, 8.1 Hz,

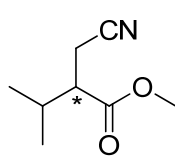
1H), 2.93 (dd,  $J = 16.8$  Hz, 6.7 Hz, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 172.1, 134.2, 132.1, 130.8, 129.4, 129.3, 127.2, 126.2, 125.5, 125.4, 122.3, 117.8, 52.9, 43.7, 21.2. APCI-HRMS Calcd. for  $\text{C}_{15}\text{H}_{14}\text{NO}_2$  [ $\text{M}+\text{H}^+$ ]: 240.1024, found 240.1025.

**methyl 3-cyano-2-(naphthalen-2-yl)propanoate**: white solid; MP: 88-90°C; **2n**:



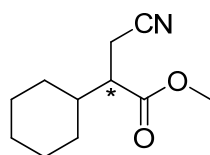
Yield: 98%; 97% ee;  $[\alpha]_{\text{D}}^{25} = -146.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250  $\times$  4.60mm), ipa : hex = 50:50, 1mL/min, 225 nm;  $t_{\text{R}} = 14.5$  min (major),  $t_{\text{R}} = 25.3$  min (minor). **2n'**: Yield: 98%; 95% ee;  $[\alpha]_{\text{D}}^{25} = +142.2$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-3 (250  $\times$  4.60mm), ipa : hex = 50:50, 1mL/min, 225 nm;  $t_{\text{R}} = 14.1$  min (minor),  $t_{\text{R}} = 24.5$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.75-7.70 (m, 3H), 7.64 (s, 1H), 7.40-7.24 (m, 3H), 4.00 (t,  $J = 7.6$  Hz, 1H), 3.60 (s, 3H), 2.99 (dd,  $J = 16.8$  Hz, 7.5 Hz, 1H), 2.77 (dd,  $J = 16.8$  Hz, 7.6 Hz, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 171.6, 133.4, 133.2, 133.1, 129.3, 128.0, 127.8, 127.1, 126.8, 126.7, 124.8, 117.7, 52.9, 47.7, 21.7. APCI-HRMS Calcd. for  $\text{C}_{15}\text{H}_{14}\text{NO}_2$  [ $\text{M}+\text{H}^+$ ]: 240.1024, found 240.1025.

**methyl 2-(cyanomethyl)-3-methylbutanoate**: colorless liquid; **2o**: Yield: 97%; 97%



ee;  $[\alpha]_{\text{D}}^{25} = -90.2$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco gamma DexTM 225 column (30 m  $\times$  0.25 mm  $\times$  0.25  $\mu\text{m}$ ),  $\text{N}_2$  2.0 mL/min, programmed 90 °C – 0.5 °C/min - 210 °C - 100 min;  $t_{\text{R}} = 38.8$  min (major),  $t_{\text{R}} = 41.9$  min (minor). **2o'**: Yield: 96%; 96% ee;  $[\alpha]_{\text{D}}^{25} = +87.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco gamma DexTM 225 column (30 m  $\times$  0.25 mm  $\times$  0.25  $\mu\text{m}$ ),  $\text{N}_2$  2.0 mL/min, programmed 90 °C – 0.5 °C/min - 210 °C - 100 min;  $t_{\text{R}} = 39.6$  min (minor),  $t_{\text{R}} = 40.8$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 3.68 (s, 3H), 2.63-2.43 (m, 3H), 2.07-1.99 (m, 1H), 0.91 (t,  $J = 6.6$  Hz, 6H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 172.6, 118.3, 52.0, 48.0, 30.0, 19.5, 17.0. APCI-HRMS Calcd. for  $\text{C}_8\text{H}_{14}\text{NO}_2$  [ $\text{M}+\text{H}^+$ ]: 156.1025, found 156.1028.

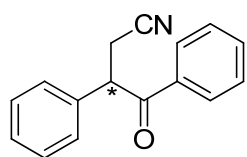
**methyl 3-cyano-2-cyclohexylpropanoate**: colorless liquid; **2p**: Yield: 95%; 97% ee;



$[\alpha]_{\text{D}}^{25} = -22.8$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco gamma DexTM 225 column (30 m  $\times$  0.25 mm  $\times$  0.25  $\mu\text{m}$ ),  $\text{N}_2$  0.8 mL/min,

programmed 90 °C – 0.8 °C/min - 200 °C - 50 min;  $t_R = 78.3$  min (major),  $t_R = 79.6$  min (minor). **2p'**: Yield: 96%; 94% ee;  $[\alpha]_D^{25} = +20.6$  (c = 0.5, CHCl<sub>3</sub>); GC condition: Supelco gamma Dex™ 225 column (30 m × 0.25 mm × 0.25 μm), N<sub>2</sub> 0.8 mL/min, programmed 90 °C – 0.8 °C/min - 200 °C - 50 min;  $t_R = 78.5$  min (minor),  $t_R = 79.0$  min (major). <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ: 3.68 (s, 3H), 2.62-2.45 (m, 3H), 1.71-1.55 (m, 6H), 1.23-0.95 (m, 5H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ: 172.8, 118.3, 52.0, 47.6, 39.6, 30.1, 30.0, 26.0, 25.9, 25.8, 17.1.<sup>[4]</sup>

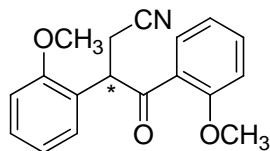
**4-oxo-3,4-diphenylbutanenitrile (4a)**: colorless liquid; Yield: 96%; 95% ee;  $[\alpha]_D^{25} =$



+76.0 (c = 0.5, CHCl<sub>3</sub>); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 254 nm;  $t_R = 10.2$  min (major),  $t_R = 19.4$  min (minor). <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz)

δ: 7.81 (d,  $J = 1.2$  Hz, 2H), 7.39-7.16 (m, 8H), 4.78 (t,  $J = 7.4$  Hz, 1H), 2.98 (dd,  $J = 16.8$  Hz, 6.6 Hz, 1H), 2.78 (dd,  $J = 16.8$  Hz, 6.6 Hz, 1H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ: 196.0, 136.5, 135.0, 133.7, 129.7, 129.0, 128.7, 128.5, 128.0, 118.4, 50.3, 22.1.

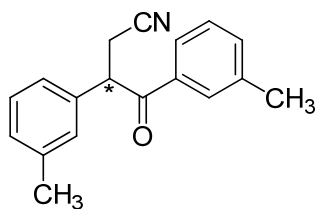
**3,4-bis(2-methoxyphenyl)-4-oxobutanenitrile (4b)**: colorless liquid; Yield: 97%; 96%



ee;  $[\alpha]_D^{25} = +50.8$  (c = 0.5, CHCl<sub>3</sub>); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 10:90, 1mL/min, 254 nm;  $t_R = 14.4$  min (major),  $t_R = 20.3$  min (minor). <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ: 7.61 (d,  $J = 1.2$  Hz, 1H), 7.59-7.05 (m,

3H), 6.91-6.71 (m, 4H), 5.11 (t,  $J = 6.7$  Hz, 1H), 3.74 (s, 3H), 3.71 (s, 3H), 3.20 (dd,  $J = 16.8$  Hz, 6.2 Hz, 1H), 2.78 (dd,  $J = 16.8$  Hz, 6.2 Hz, 1H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ: 199.4, 157.6, 156.7, 133.4, 130.7, 130.0, 129.3, 126.9, 125.3, 120.7, 120.5, 119.2, 111.0, 110.6, 55.1, 49.5, 19.3.

**4-oxo-3,4-di-*m*-tolylbutanenitrile (4c)**: colorless liquid; Yield: 95%; 91% ee;  $[\alpha]_D^{25}$



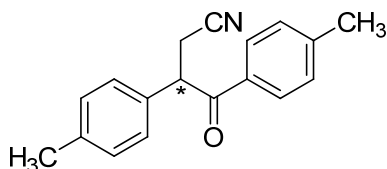
= +73.3 (c = 0.5, CHCl<sub>3</sub>); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 254 nm;  $t_R = 6.3$  min (major),  $t_R = 11.2$  min (minor). <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ: 7.77-7.69 (m,

2H), 7.31-7.20 (m, 3H), 7.12-7.07 (m, 3H), 4.83 (t,  $J = 7.3$  Hz, 1H), 3.06 (dd,  $J = 16.8$  Hz, 6.7 Hz, 1H), 2.68 (dd,  $J = 16.8$  Hz, 6.7 Hz, 1H), 2.33 (s, 3H), 2.30 (s, 3H). <sup>13</sup>C



NMR (CDCl<sub>3</sub>, 100 MHz)  $\delta$ : 196.3, 139.4, 138.6, 136.5, 135.1, 134.4, 129.5, 129.4, 129.2, 128.5, 128.4, 126.3, 125.2, 118.5, 50.3, 22.1, 21.4, 21.3.

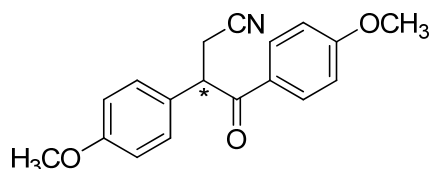
**4-oxo-3,4-di-*p*-tolylbutanenitrile (4d)**: colorless liquid; Yield: 95%; 92% ee;  $[\alpha]_D^{25} =$



+67.1 (c = 0.5, CHCl<sub>3</sub>); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 254 nm;  $t_R = 8.9$  min (major),  $t_R = 9.8$

min (minor). <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz)  $\delta$ : 7.82 (d,  $J = 8.3$  Hz, 2H), 7.19-7.12 (m, 6H), 4.81 (t,  $J = 7.7$  Hz, 1H), 3.03 (dd,  $J = 16.8$  Hz, 6.5 Hz, 1H), 2.84 (dd,  $J = 16.8$  Hz, 6.5 Hz, 1H), 2.33 (s, 3H), 2.28 (s, 3H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz)  $\delta$ : 195.7, 144.5, 138.2, 133.7, 132.6, 130.3, 129.4, 129.1, 127.8, 118.5, 49.9, 22.1, 21.6, 21.1.

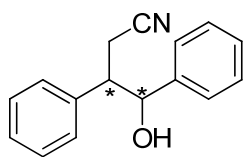
**3,4-bis(4-methoxyphenyl)-4-oxobutanenitrile (4e)**: colorless liquid; Yield: 96%; 94%



ee;  $[\alpha]_D^{25} = +63.2$  (c = 0.5, CHCl<sub>3</sub>); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 254 nm;  $t_R = 20.8$  min

(major),  $t_R = 26.3$  min (minor). <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz)  $\delta$ : 7.88 (d,  $J = 9.0$  Hz, 2H), 7.19 (d,  $J = 8.7$  Hz, 2H), 6.86-6.82 (m, 4H), 4.75 (t,  $J = 6.2$  Hz, 1H), 3.79 (s, 3H), 3.74 (s, 3H), 3.01 (dd,  $J = 16.8$  Hz, 6.4 Hz, 1H), 2.83 (dd,  $J = 16.8$  Hz, 6.4 Hz, 1H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz)  $\delta$ : 194.6, 163.7, 159.5, 131.3, 129.0, 128.9, 128.0, 118.6, 115.0, 113.9, 55.5, 55.2, 49.2, 22.2.

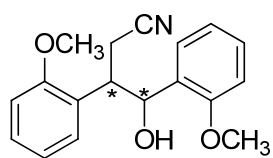
**4-hydroxy-3,4-diphenylbutanenitrile (5a)**: white solid; MP: 88-90°C; Yield: 92%;



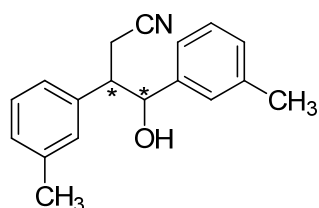
95% ee;  $[\alpha]_D^{25} = -52.6$  (c = 0.5, CHCl<sub>3</sub>); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 10:90, 1mL/min, 254 nm;  $t_R = 25.0$  min (major),  $t_R = 33.9$  min (minor). <sup>1</sup>H

NMR (CDCl<sub>3</sub>, 400 MHz)  $\delta$ : 7.27-7.12 (m, 10H), 4.90 (d,  $J = 7.1$  Hz, 1H), 3.14 (dd,  $J = 14.0$  Hz, 7.9 Hz, 1H), 2.58 (dd,  $J = 16.8$  Hz, 5.8 Hz, 1H), 2.41 (q,  $J = 8.3$  Hz, 1H), 2.03 (s, 1H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz)  $\delta$ : 140.9, 137.6, 128.8, 128.6, 128.5, 128.4, 128.0, 126.5, 118.4, 76.1, 49.7, 21.1.

**4-hydroxy-3,4-bis(2-methoxyphenyl)butanenitrile (5b)**: colorless liquid; Yield: 89%; 96% ee;  $[\alpha]_D^{25} = -41.4$  (c = 0.5, CHCl<sub>3</sub>); HPLC condition: Lux 5u Cellulose-1 (250 × 4.60mm), ipa : hex = 30:70, 1mL/min, 254 nm;  $t_R = 15.8$  min (major),  $t_R =$



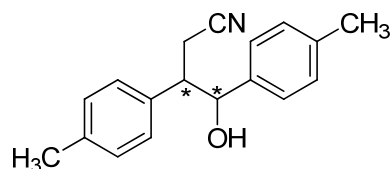
23.2 min (minor).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.13-7.01 (m, 4H), 6.84-6.69 (m, 4H), 5.19 (s, 1H), 3.79-3.71 (m, 1H), 3.68 (s, 3H), 3.54 (s, 3H), 2.69 (s, 1H), 2.56-2.50 (m, 2H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 157.5, 156.6, 129.6, 129.3, 128.8, 128.7, 127.5, 126.4, 120.8, 120.7, 119.0, 110.9, 110.4, 71.5, 55.4, 55.3, 19.9.



**4-hydroxy-3,4-di-*m*-tolylbutanenitrile (5c):** colorless liquid; Yield: 90%; 90% ee;  $[\alpha]_{\text{D}}^{25} = -42.2$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-1 (250  $\times$  4.60mm), ipa : hex = 10:90, 1mL/min, 254 nm;  $t_{\text{R}} = 17.4$

min (major),  $t_{\text{R}} = 19.8$  min (minor).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.14-7.09 (m, 2H), 7.01-6.92 (m, 6H), 4.75 (d,  $J = 7.6$  Hz, 1H), 3.07-3.02 (m, 1H), 2.43 (dd,  $J = 16.8$  Hz, 5.4 Hz, 1H), 2.31 (q,  $J = 8.6$  Hz, 1H), 2.22 (d,  $J = 1.0$  Hz, 6H), 1.99 (s, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 140.8, 138.5, 138.4, 137.8, 129.2, 129.1, 128.9, 128.8, 128.5, 127.3, 125.4, 123.8, 118.4, 76.4, 49.8, 21.5, 21.4, 21.2.

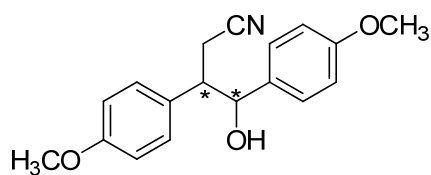
**4-hydroxy-3,4-di-*p*-tolylbutanenitrile (5d):** colorless liquid; Yield: 89%; 92% ee;  $[\alpha]_{\text{D}}^{25} = -43.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-1 (250  $\times$  4.60mm),



ipa : hex = 10:90, 1mL/min, 254 nm;  $t_{\text{R}} = 9.4$  min (major),  $t_{\text{R}} = 11.5$  min (minor).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.18-7.13 (m, 8H), 4.90 (d,  $J = 20.7$  Hz, 1H), 3.21-3.16 (m, 1H), 2.59 (dd,  $J = 16.8$  Hz, 5.5

Hz, 1H), 2.44 (q,  $J = 8.0$  Hz, 1H), 2.36 (s, 6H), 2.14 (s, 1H).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ , 100 MHz)  $\delta$ : 138.2, 137.9, 137.7, 134.8, 129.6, 129.3, 128.3, 126.5, 118.5, 76.2, 49.4, 21.3, 21.2, 21.1.

**4-hydroxy-3,4-bis(4-methoxyphenyl)butanenitrile (5e):** white solid; MP:

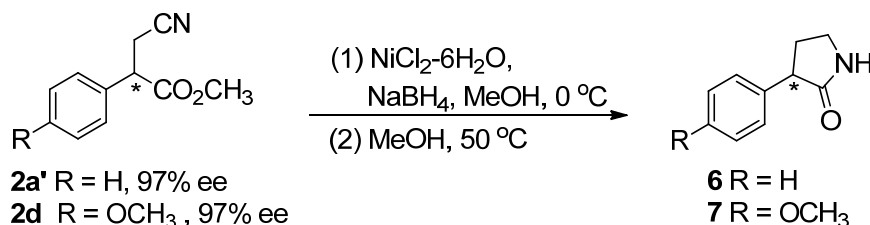


118-120°C; Yield: 91%; 94% ee;  $[\alpha]_{\text{D}}^{25} = -51.0$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); HPLC condition: Lux 5u Cellulose-1 (250  $\times$  4.60mm), ipa : hex = 10:90, 1mL/min, 254 nm;  $t_{\text{R}} = 9.5$  min (major),  $t_{\text{R}} = 17.9$

min (minor).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400 MHz)  $\delta$ : 7.16 (dd,  $J = 8.6$  Hz, 1.9 Hz, 4H), 6.89-6.85 (m, 4H), 4.89 (d,  $J = 7.2$  Hz, 1H), 3.80 (s, 6H), 3.18-3.13 (m, 1H), 2.62 (dd,

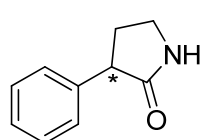
$J = 16.8$  Hz,  $5.6$  Hz,  $1\text{H}$ ),  $2.45$  (q,  $J = 8.2$  Hz,  $1\text{H}$ ),  $205$  (s,  $1\text{H}$ ).  $^{13}\text{C}$  NMR ( $\text{CDCl}_3$ ,  $100$  MHz)  $\delta$ :  $159.6$ ,  $159.3$ ,  $133.0$ ,  $129.7$ ,  $129.5$ ,  $127.8$ ,  $118.5$ ,  $114.3$ ,  $114.0$ ,  $75.9$ ,  $55.3$ ,  $55.2$ ,  $49.1$ ,  $21.3$ .

### 7. Procedure for the synthesis of compound 6 and 7.<sup>[5]</sup>



To a stirring solution of the hydrogenation product ( $0.2$  mmol) in MeOH ( $3$  mL)  $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$  ( $0.4$  mmol) was first added, then  $\text{NaBH}_4$  ( $1.6$  mmol) was added portionwise at  $0$  °C over  $1$  h. The mixture was stirred at room temperature for  $15$  min and carefully quenched with  $\text{H}_2\text{O}$ . The aqueous layer was extracted with ethyl acetate, dried over  $\text{MgSO}_4$ . The solvent was removed in vacuo, the residue was heated and stirred at  $40$  °C in MeOH for  $1$  h. After the usual workup, the residue was purified by silica gel column chromatography using petroleum ether/ AcOEt as an eluent.

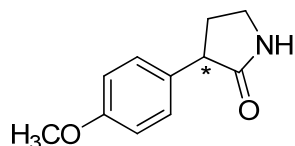
**3-phenylpyrrolidin-2-one (6):** Yield:  $83\%$ ; white solid; MP:  $84$ - $86$ °C;  $94\%$  ee;



$[\alpha]_{\text{D}}^{25} = +22.0$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco gamma DexTM 225 column ( $30$  m  $\times$   $0.25$  mm  $\times$   $0.25$   $\mu\text{m}$ ),  $\text{N}_2$   $5.0$  mL/min, programmed  $100$  °C –  $8$  °C/min -  $200$  °C -  $100$  min;  $t_{\text{R}} = 15.3$  min

(minor),  $t_{\text{R}} = 16.2$  min (major).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ,  $400$  MHz)  $\delta$ :  $7.30$ - $7.17$  (m,  $5\text{H}$ ),  $6.75$  (s,  $1\text{H}$ ),  $3.58$ - $3.40$  (m,  $1\text{H}$ ),  $3.39$ - $3.33$  (m,  $2\text{H}$ ),  $2.57$ - $2.50$  (m,  $1\text{H}$ ),  $2.23$ - $2.15$  (m,  $1\text{H}$ ).<sup>[6]</sup>

**3-(4-methoxyphenyl)pyrrolidin-2-one (7):** Yield:  $85\%$ ; white solid; MP:  $122$ - $124$ °C;

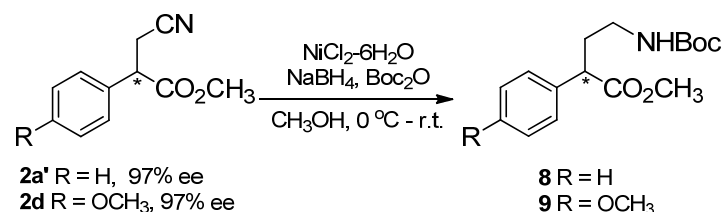


$96\%$  ee;  $[\alpha]_{\text{D}}^{25} = -28.6$  ( $c = 0.5$ ,  $\text{CHCl}_3$ ); GC condition: Supelco gamma DexTM 225 column ( $30$  m  $\times$   $0.25$  mm  $\times$   $0.25$   $\mu\text{m}$ ),  $\text{N}_2$   $5.0$  mL/min, programmed  $100$  °C –  $8$  °C/min -

$200$  °C -  $50$  min;  $t_{\text{R}} = 24.8$  min (major),  $t_{\text{R}} = 28.9$  min (minor).  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ,  $400$  MHz)  $\delta$ :  $7.22$ - $7.18$  (m,  $2\text{H}$ ),  $6.90$ - $6.87$  (m,  $2\text{H}$ ),  $6.70$  (s,  $1\text{H}$ ),  $3.79$  (s,  $3\text{H}$ ),  $3.57$  (t,  $J = 9.1$  Hz,  $1\text{H}$ ),  $3.48$ - $3.39$  (m,  $2\text{H}$ ),  $2.62$ - $2.53$  (m,  $1\text{H}$ ),  $2.26$ - $2.16$  (m,  $1\text{H}$ ).  $^{13}\text{C}$  NMR

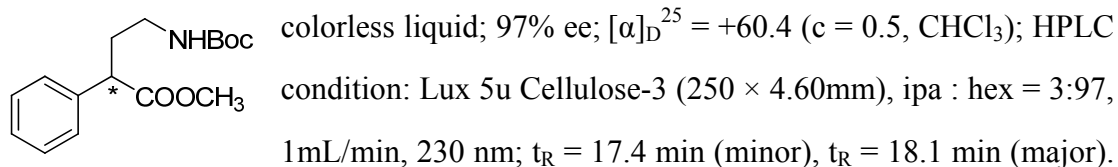
(CDCl<sub>3</sub>, 100 MHz)  $\delta$ : 179.1, 158.7, 131.4, 129.0, 114.2, 55.3, 46.7, 40.5, 30.8.  
 APCI-HRMS Calcd. for C<sub>11</sub>H<sub>14</sub>NO<sub>2</sub> [M+H<sup>+</sup>]: 192.1025, found 192.1029.

### 8. Procedure for the synthesis of compound 8 and 9.<sup>[1]</sup>



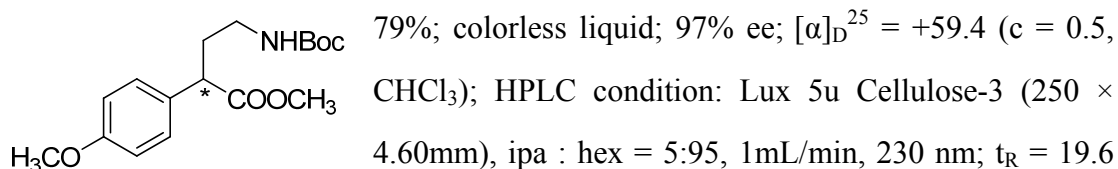
To a stirring solution of the hydrogenation product (0.2 mmol) in MeOH (3 mL) Boc<sub>2</sub>O (0.4 mmol) and NiCl<sub>2</sub>·6H<sub>2</sub>O (0.4 mmol) were first added, then NaBH<sub>4</sub> (1.6 mmol) was added portionwise at 0 °C over 1 h. The mixture was stirred at room temperature until no starting material was detected by TLC and carefully quenched with H<sub>2</sub>O. The aqueous layer was extracted with ethyl acetate, dried over MgSO<sub>4</sub>. After the solvent was removed in vacuo, the residue was purified by silica gel column chromatography using petroleum ether/ AcOEt as an eluent.

**methyl 4-((*tert*-butoxycarbonyl)amino)-2-phenylbutanoate (8):** Yield: 83%;



<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz)  $\delta$ : 7.31-7.23 (m, 5H), 4.58 (s, 1H), 3.65-3.59 (m, 4H), 3.11-3.06 (m, 2H), 2.32-2.23 (m, 1H), 1.99-1.91 (m, 1H), 1.42 (s, 9H).<sup>[7]</sup>

**methyl 4-((*tert*-butoxycarbonyl)amino)-2-(4-methoxyphenyl)butanoate (9):** Yield:



<sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz)  $\delta$ : 7.20 (dd,  $J = 6.7$  Hz, 2.0 Hz, 2H), 6.85 (dd,  $J = 6.7$  Hz, 2.0 Hz, 2H), 4.55 (s, 1H), 3.77 (s, 3H), 3.64 (s, 3H), 3.55 (t,  $J = 7.6$  Hz, 1H), 3.09-3.04 (m, 2H), 2.28-2.19 (m, 1H), 1.96-1.88 (m, 1H), 1.42 (s, 9H). <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz)  $\delta$ : 174.3, 158.9, 155.8, 130.4, 128.9,

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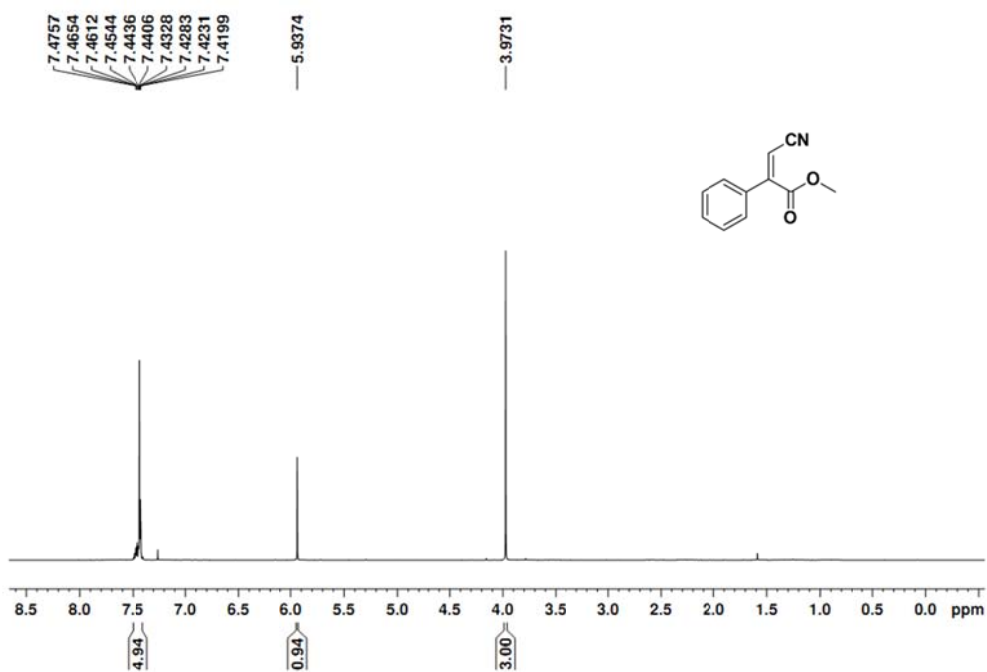
114.2, 79.2, 55.2, 52.1, 48.2, 38.8, 33.6, 28.4. APCI-HRMS Calcd. for C<sub>17</sub>H<sub>26</sub>NO<sub>5</sub> [M+H<sup>+</sup>]: 324.1811, found 324.1807.

## References

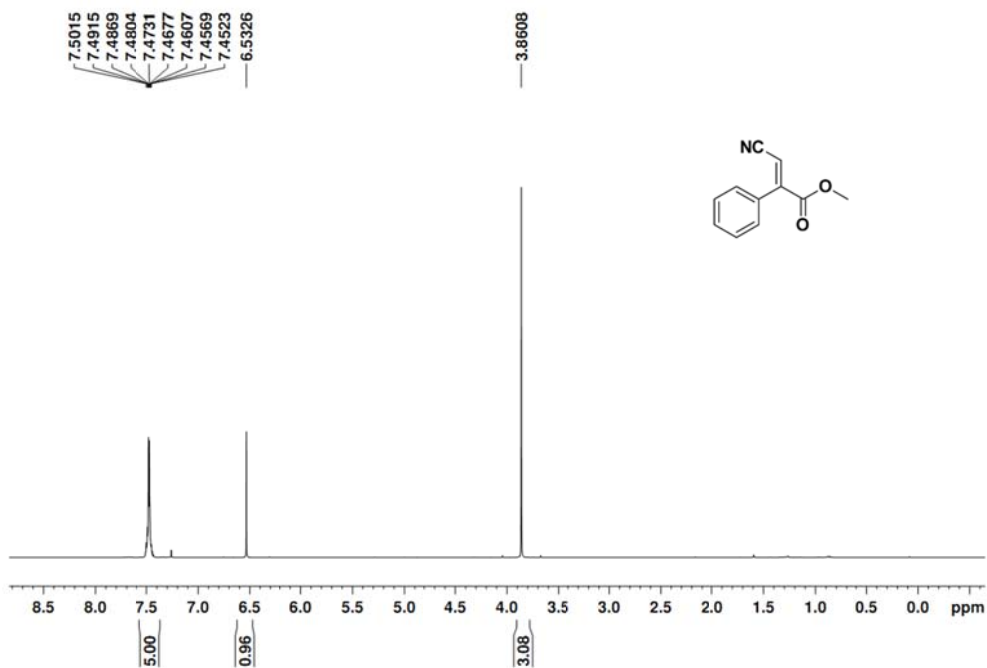
- [1] E. Brenna, F. G. Gatti, A. Manfredi, D. Monti and F. Parmeggiani, *Catal. Sci. Technol.* 2013, **3**, 1136.
- [2] J. Meng, M. Gao, H. Lv, X. Zhang, *Org. Lett.* **2015**, *17*, 1842.
- [3] A. Spencer, *J. Organomet. Chem.* 1982, **240**, 209.
- [4] R. Giovannini and Petrini, M. *Tetrahedron Lett.* 1997, **38**, 3781.
- [5] E. Dieter and N. Oliver, *Heterocycles* 2005, **66**, 385.
- [6] B. J. Kim, Y. S. Park and P. Beak, *J. Org. Chem.* 1999, **64**, 1705.
- [7] R. D. Clark and Jahangir, *Tetrahedron* 1993, **49**, 1351.

## 9. NMR, GC and HPLC spectra of compounds 1-9.

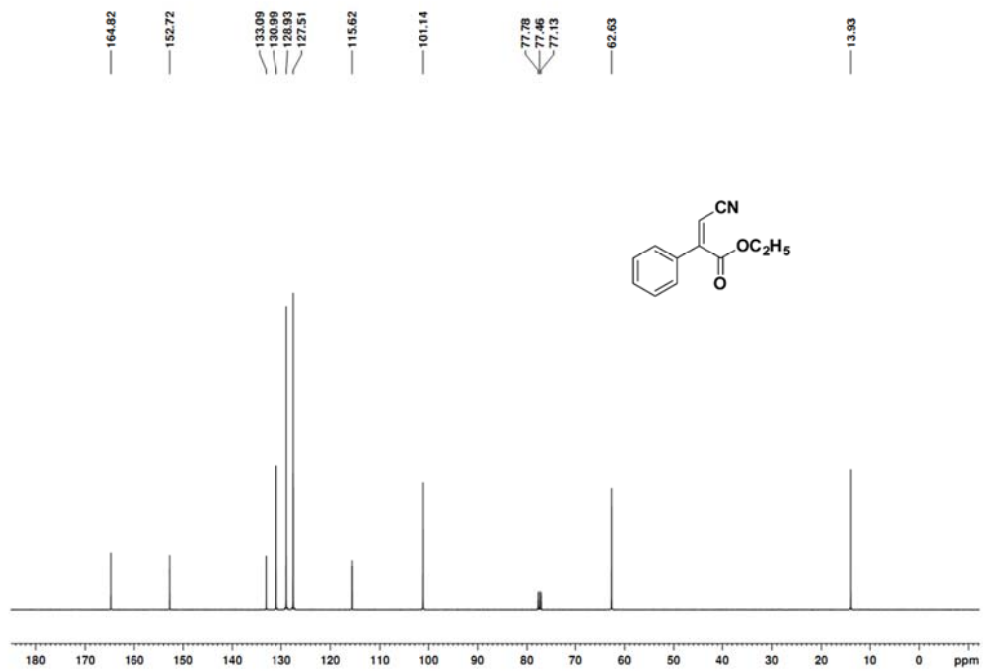
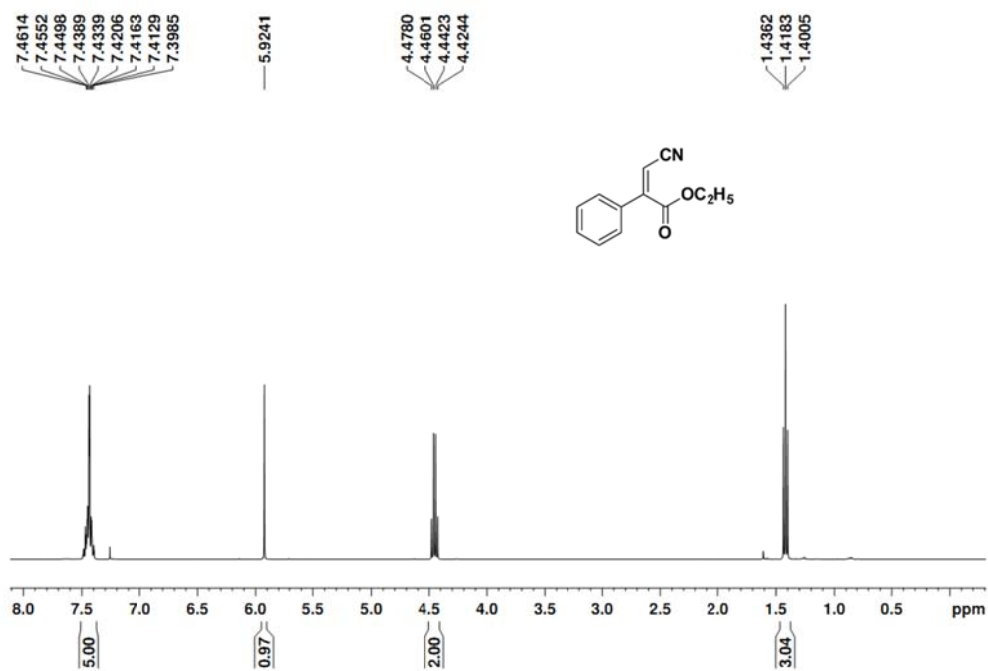
### (Z)-methyl 3-cyano-2-phenylacrylate (1a)



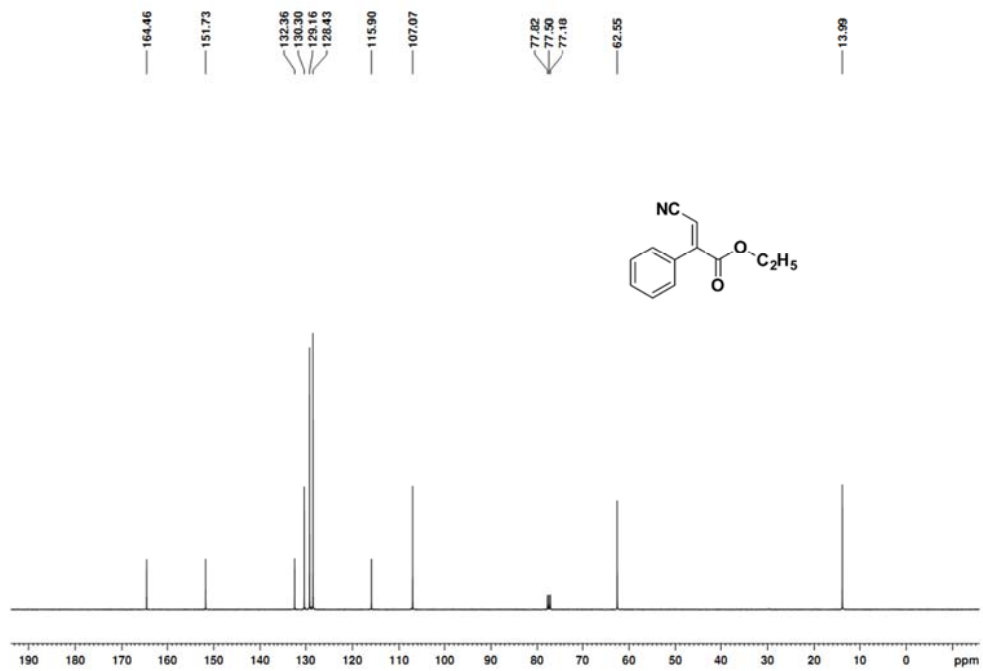
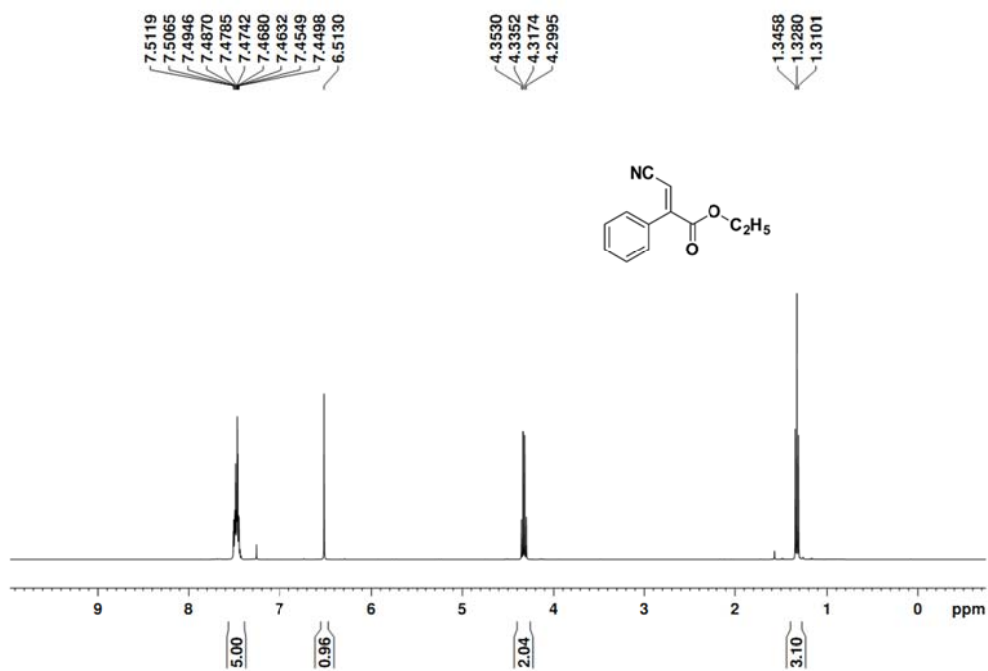
### (E)-methyl 3-cyano-2-phenylacrylate (1a')



**(Z)-ethyl 3-cyano-2-phenylacrylate (1b)**

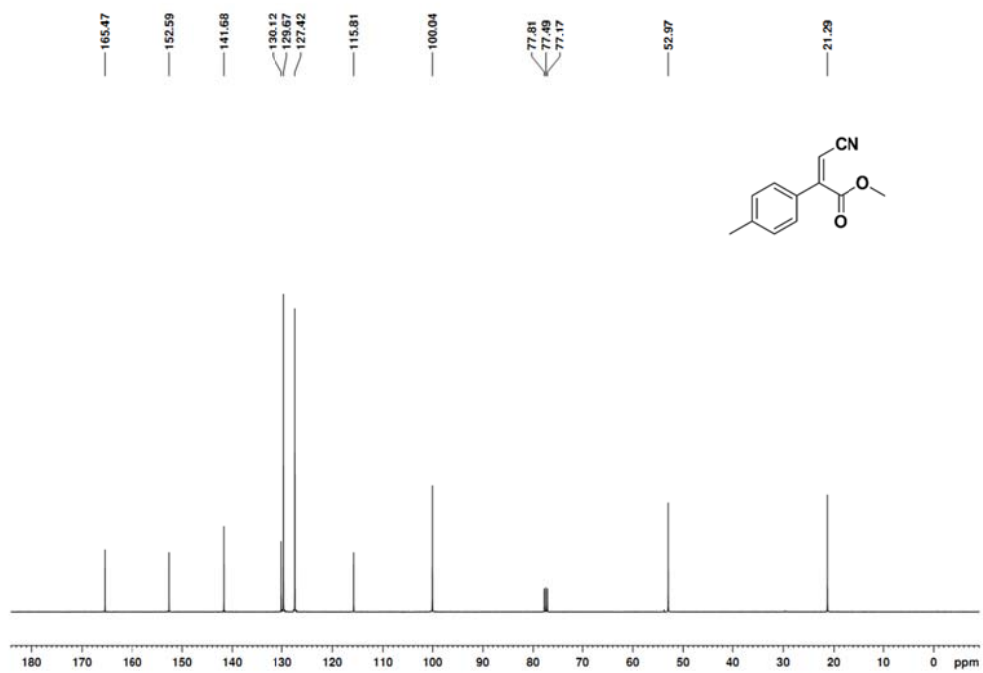
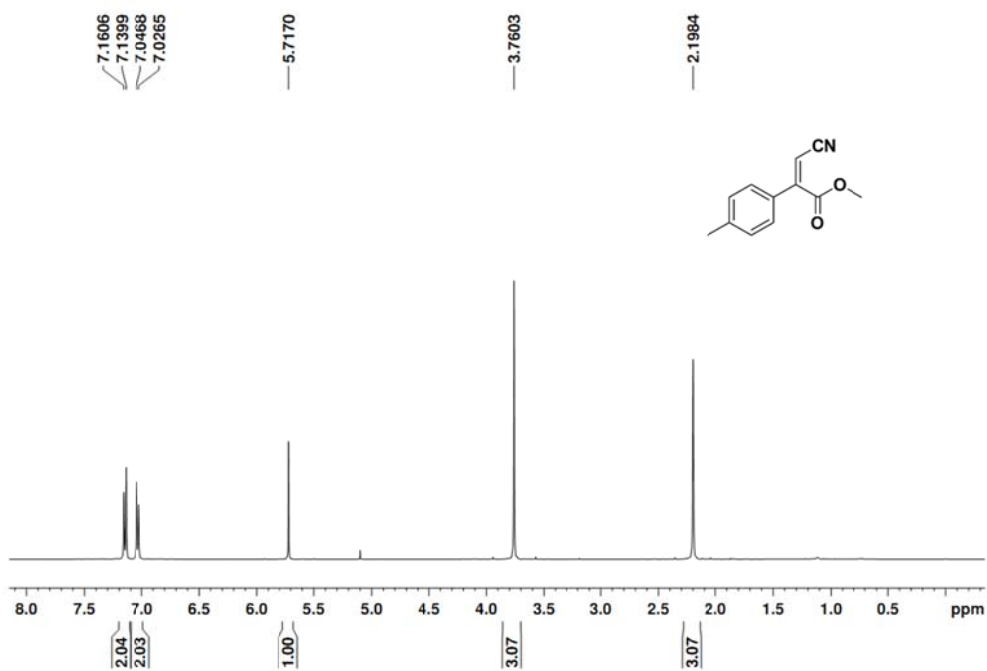


**(E)-ethyl 3-cyano-2-phenylacrylate (1b')**

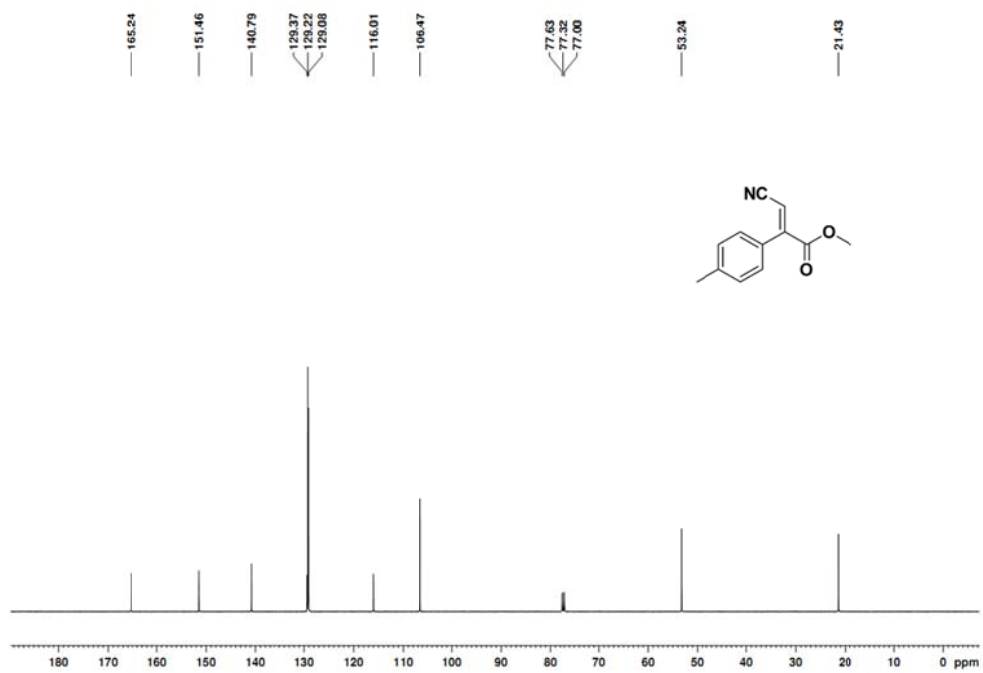
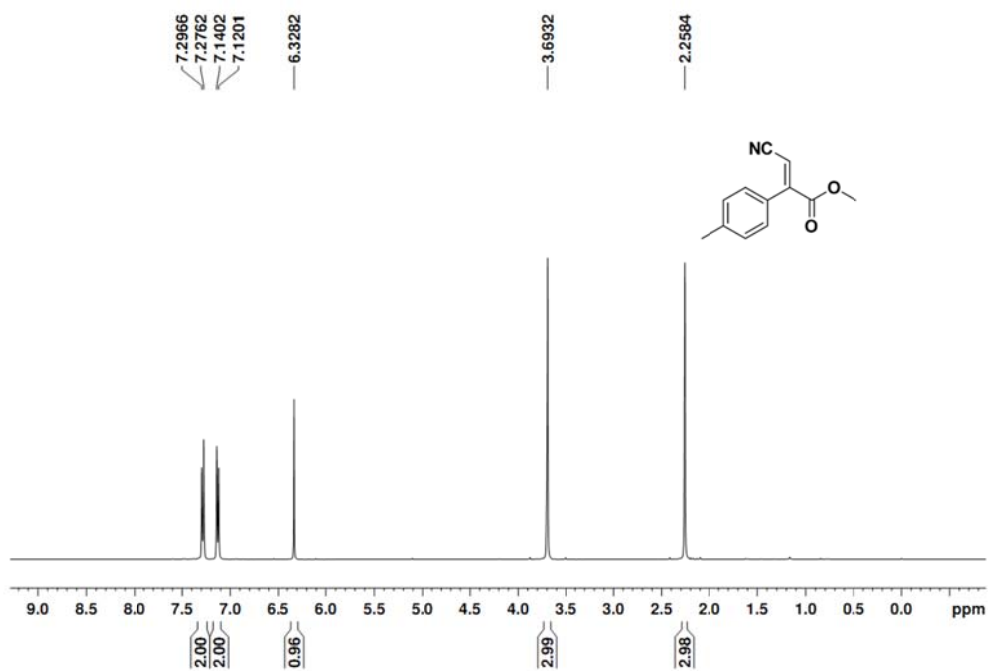




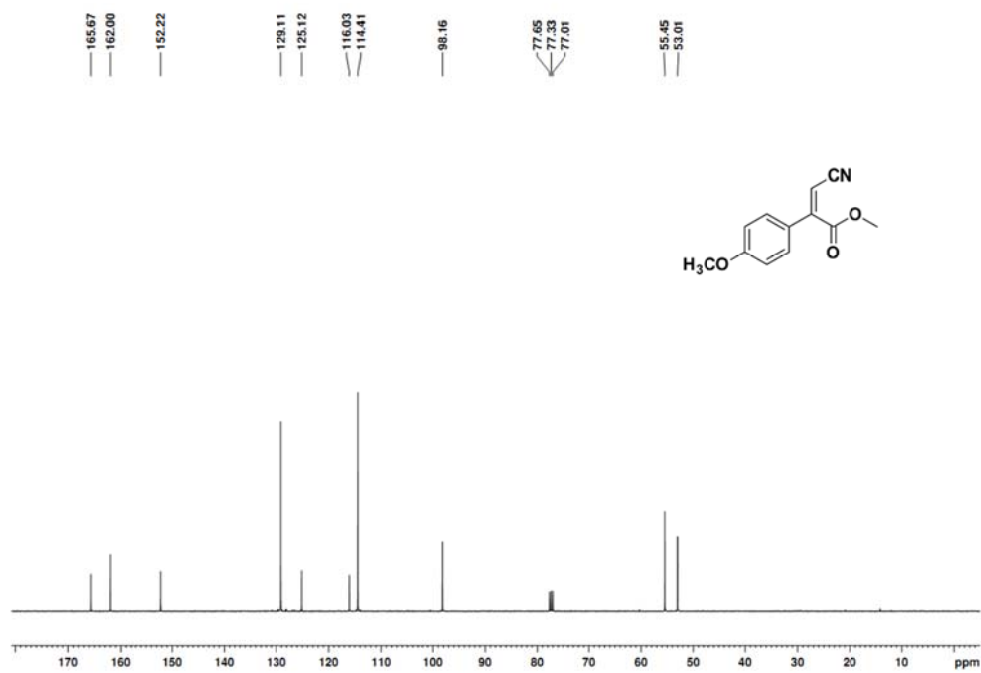
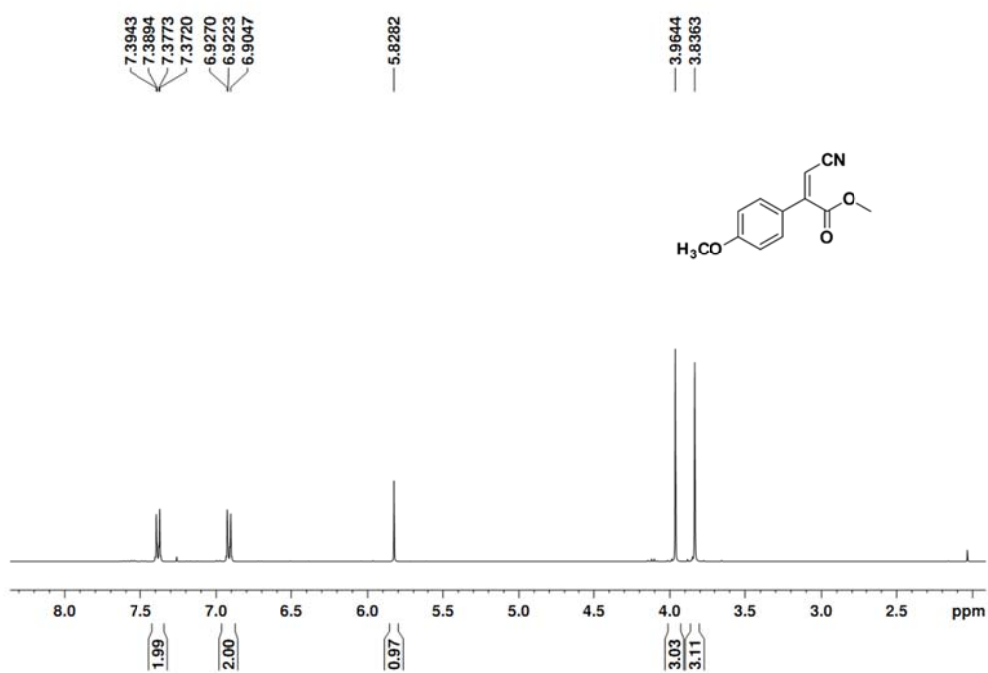
(Z)-methyl 3-cyano-2-(p-tolyl)acrylate (1c)



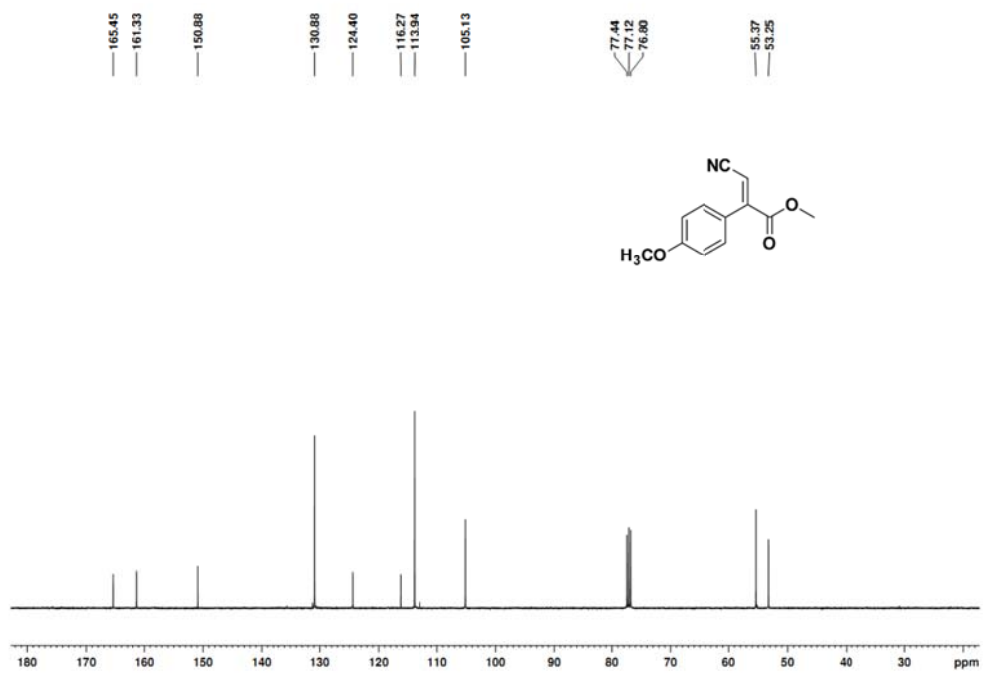
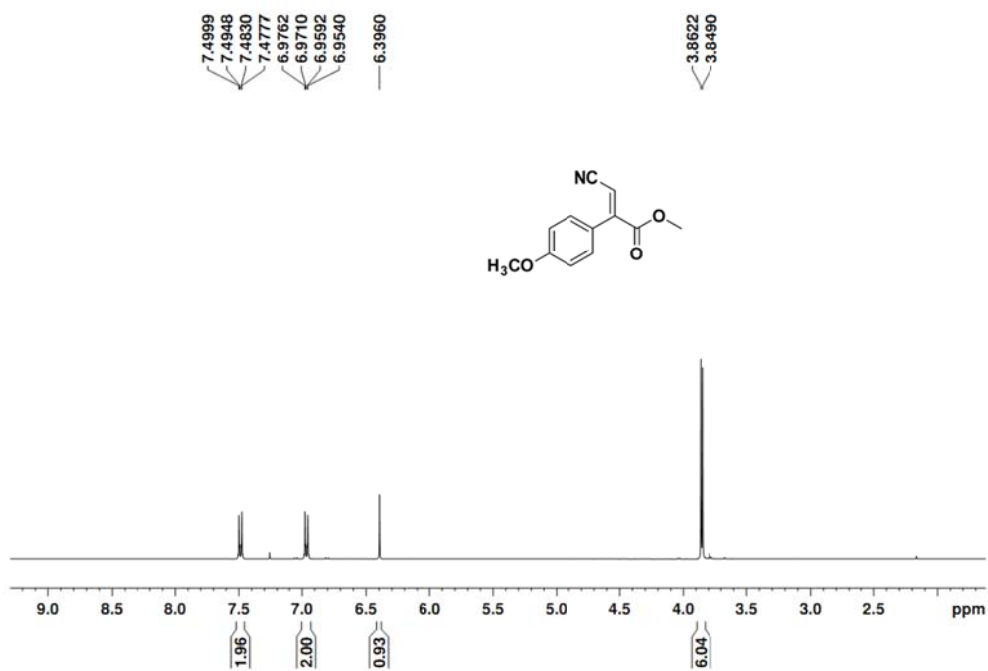
**(E)-methyl 3-cyano-2-(p-tolyl)acrylate (1c')**



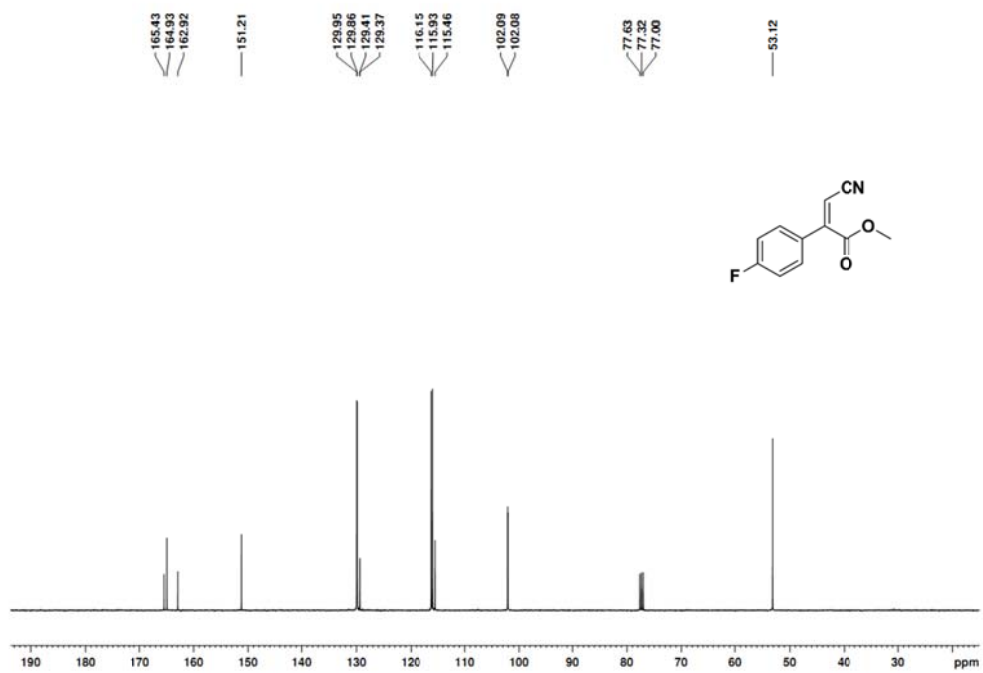
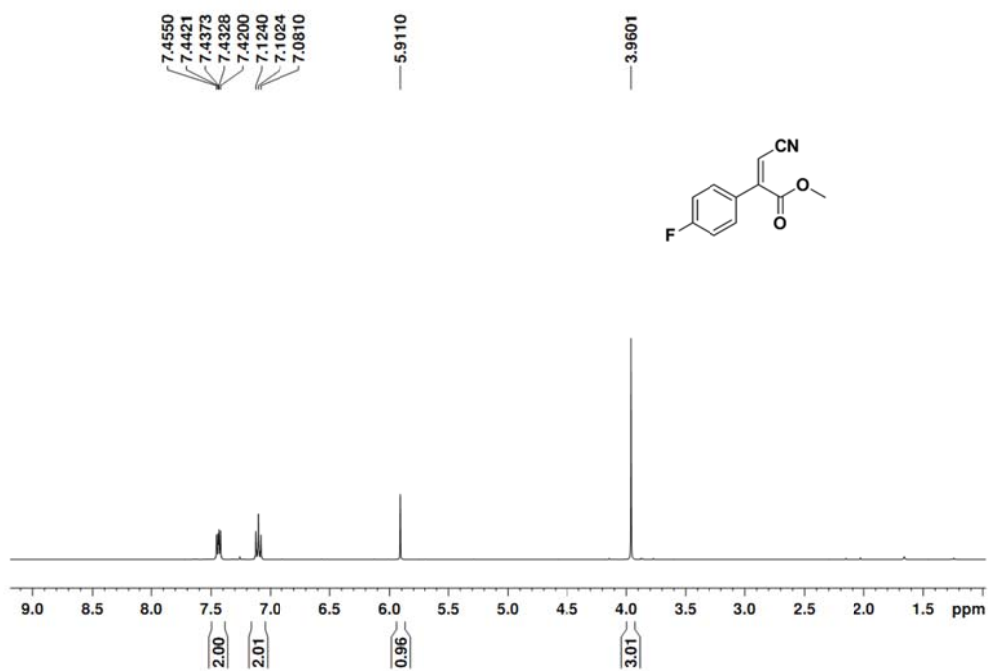
**(Z)-methyl 3-cyano-2-(4-methoxyphenyl)acrylate (1d)**



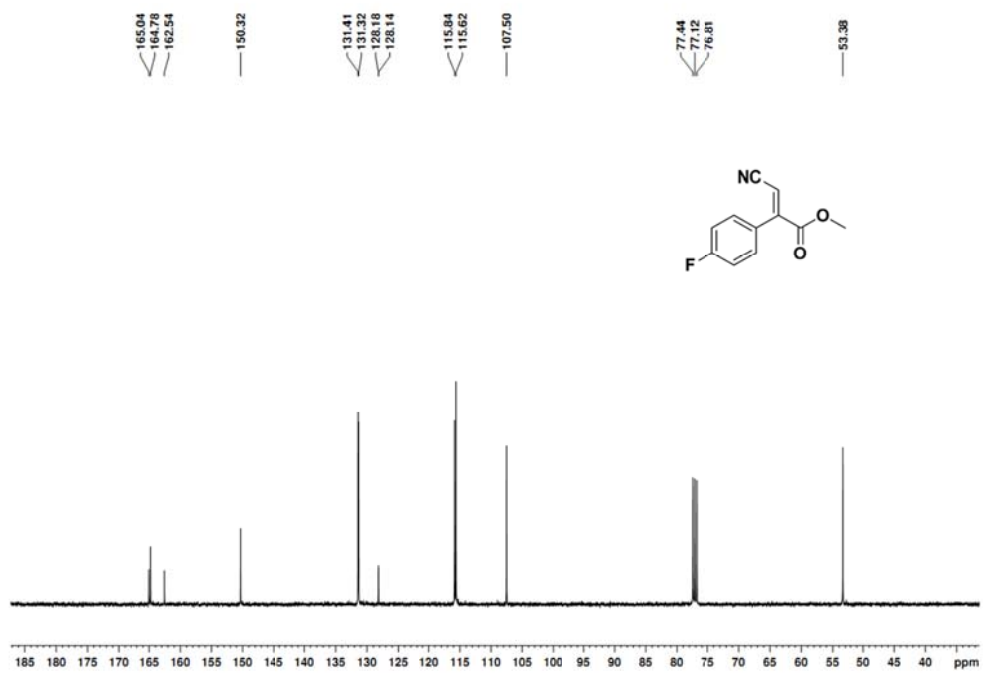
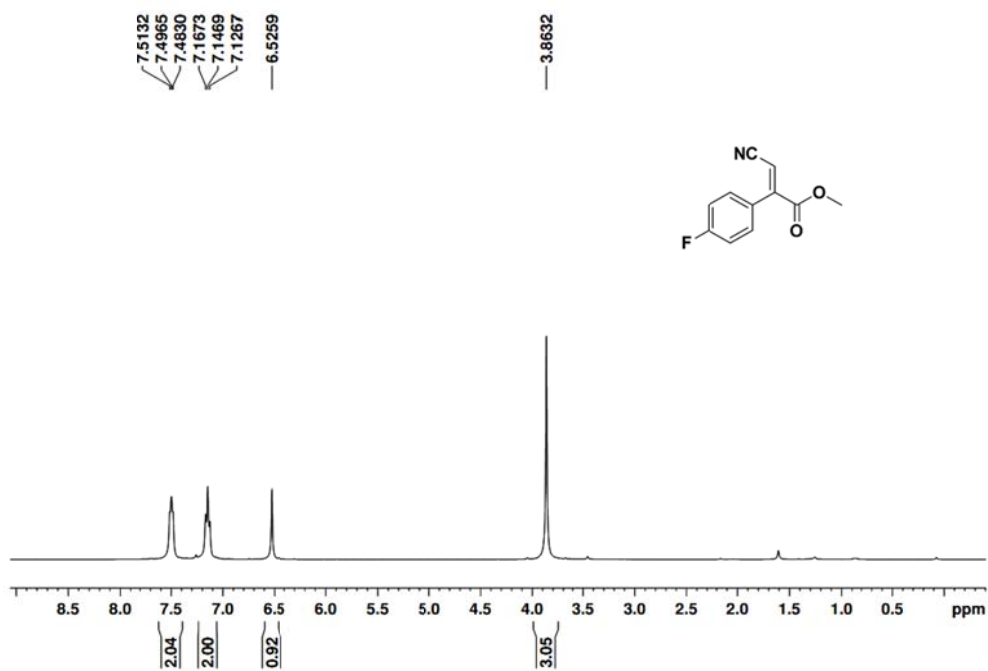
**(E)-methyl 3-cyano-2-(4-methoxyphenyl)acrylate (1d')**



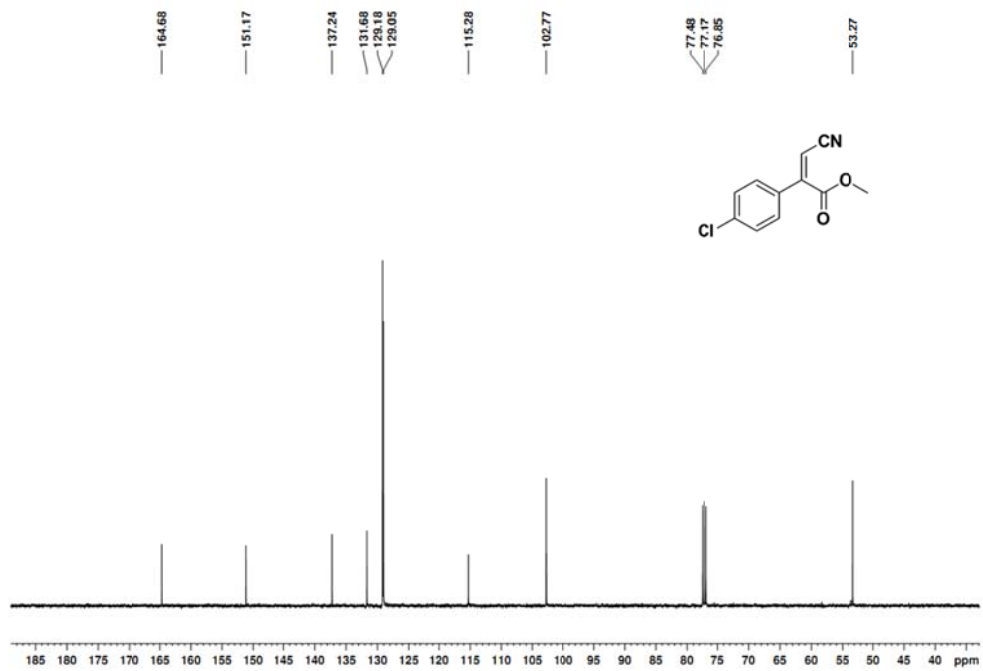
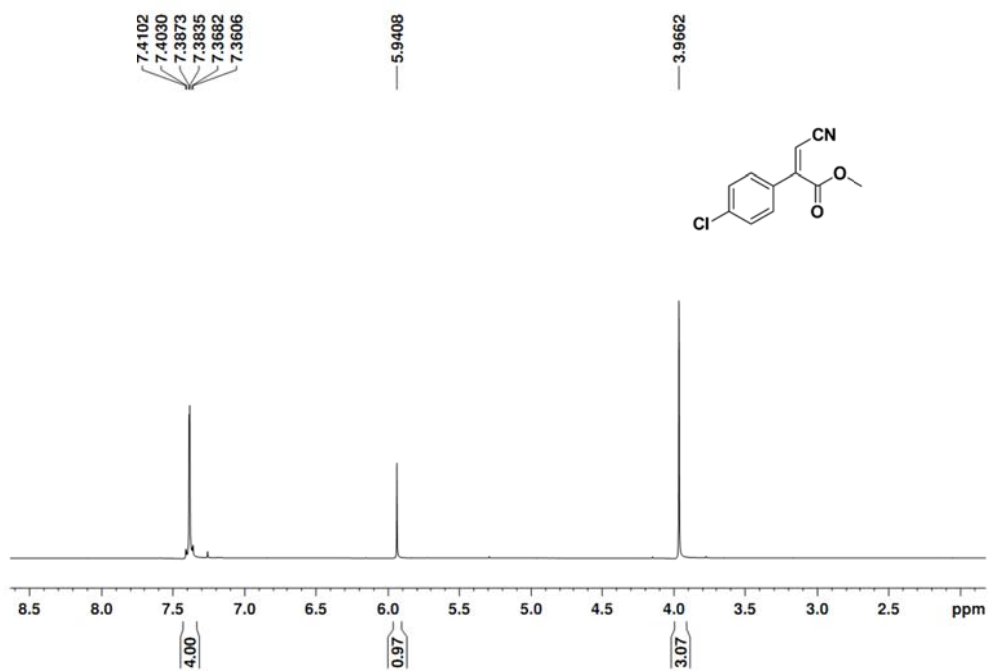
**(Z)-methyl 3-cyano-2-(4-fluorophenyl)acrylate (1e)**



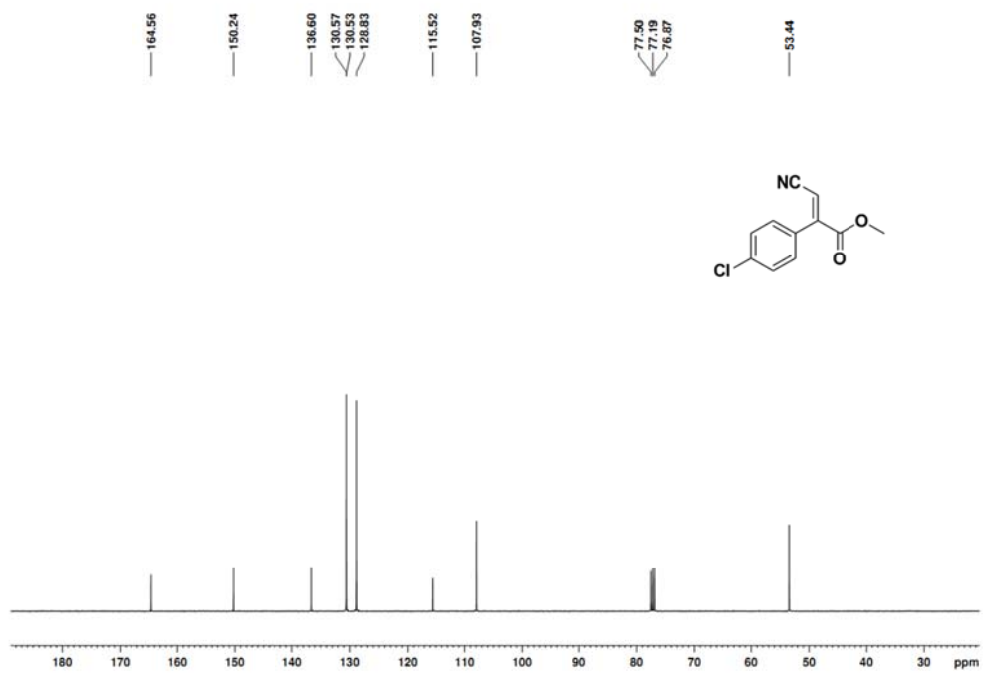
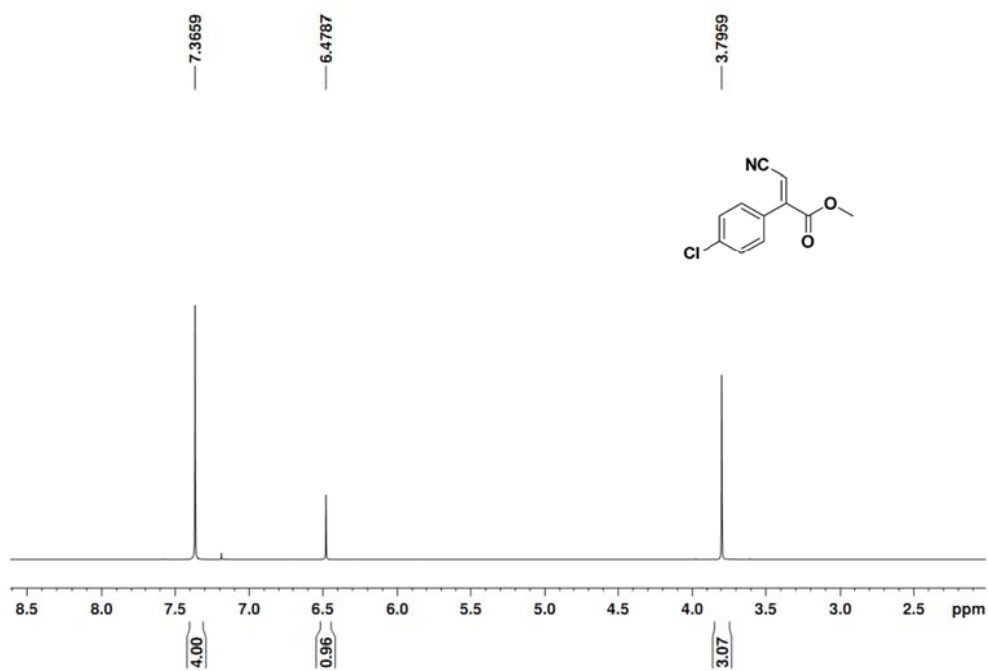
**(E)-methyl 3-cyano-2-(4-fluorophenyl)acrylate (1e')**



**(Z)-methyl 2-(4-chlorophenyl)-3-cyanoacrylate (1f)**

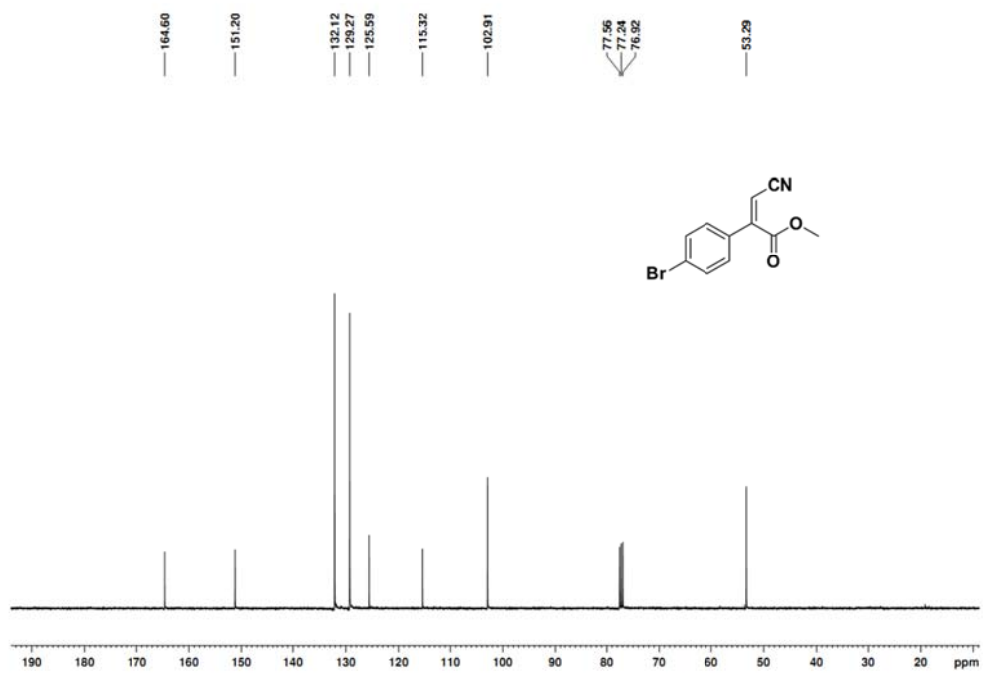
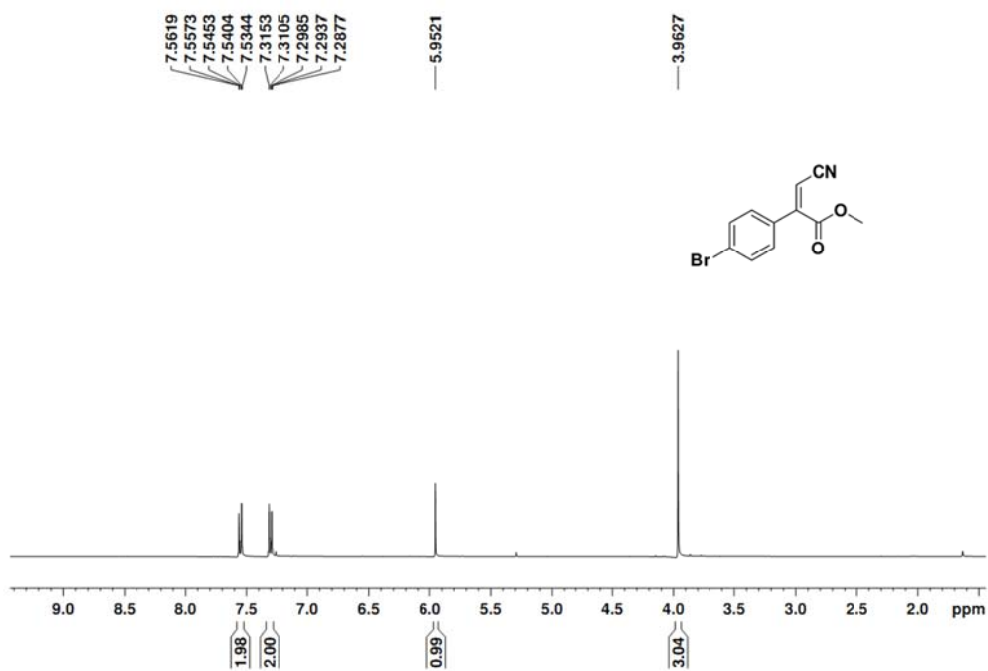


**(E)-methyl 2-(4-chlorophenyl)-3-cyanoacrylate (1f')**

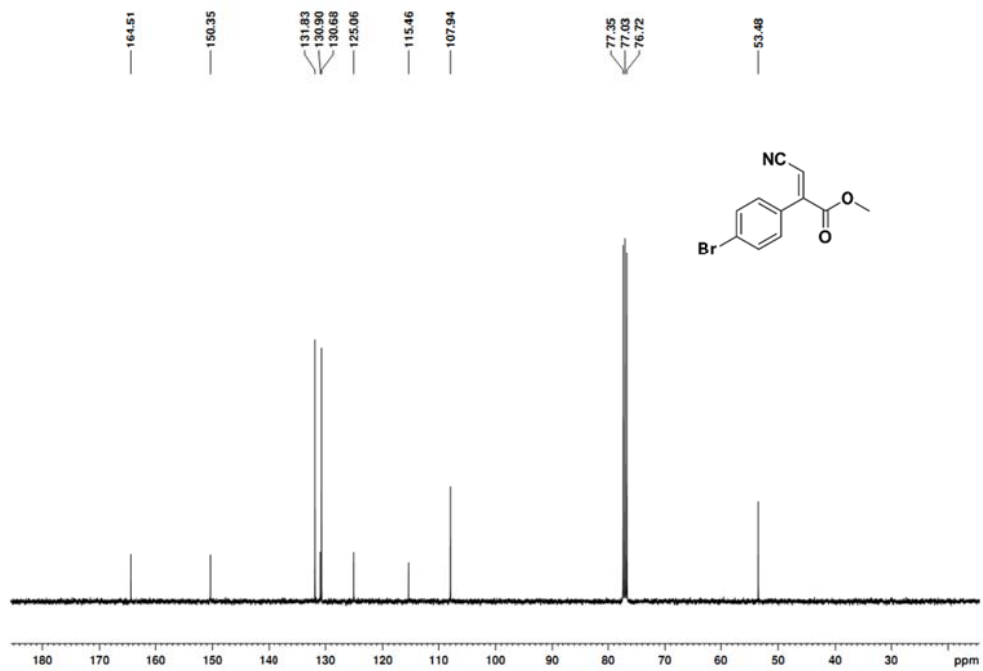
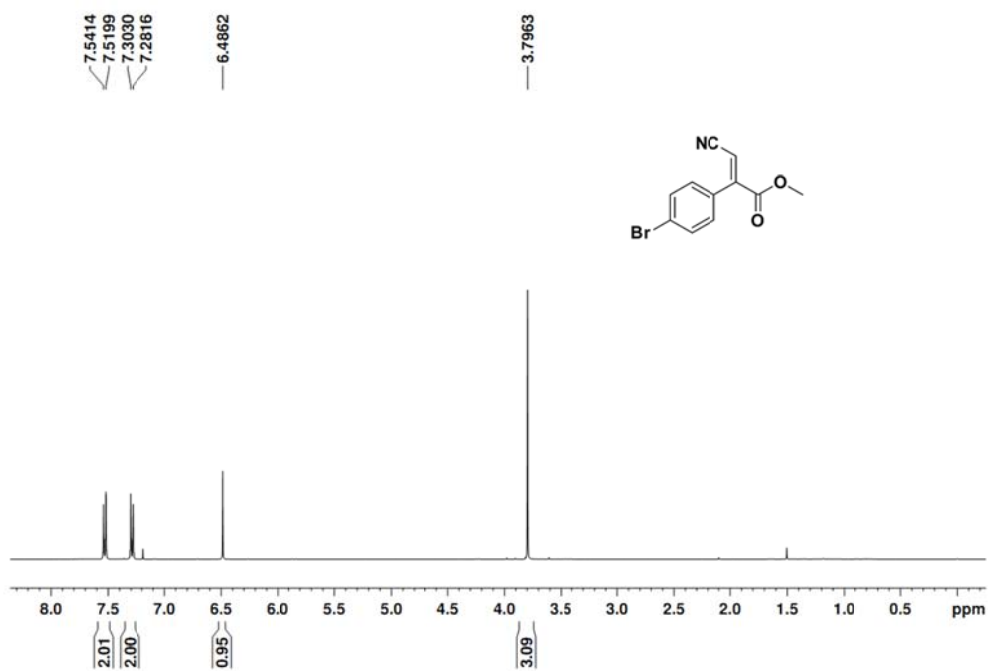




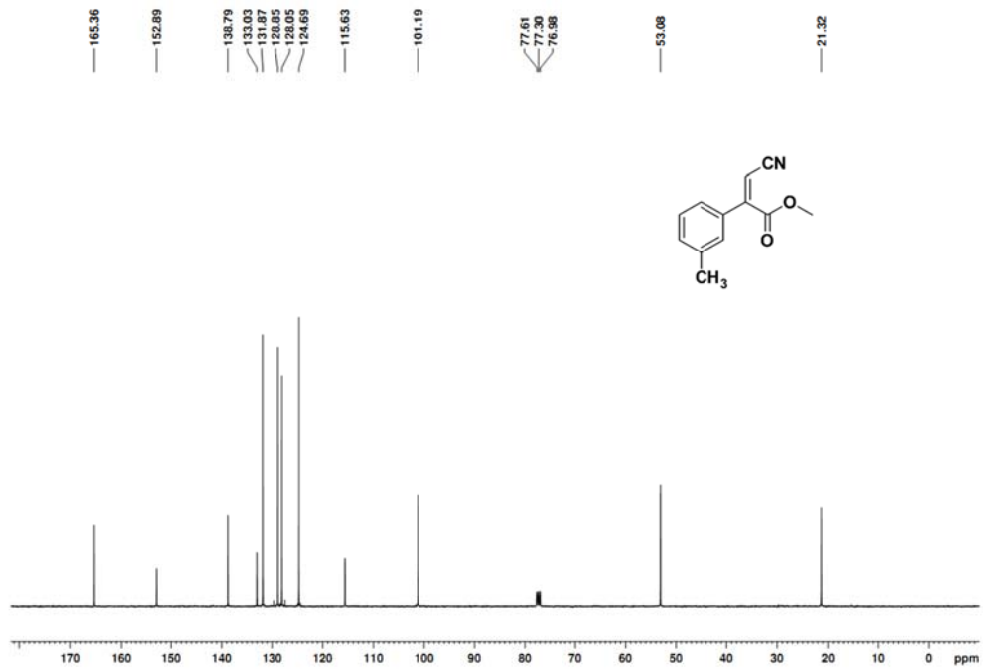
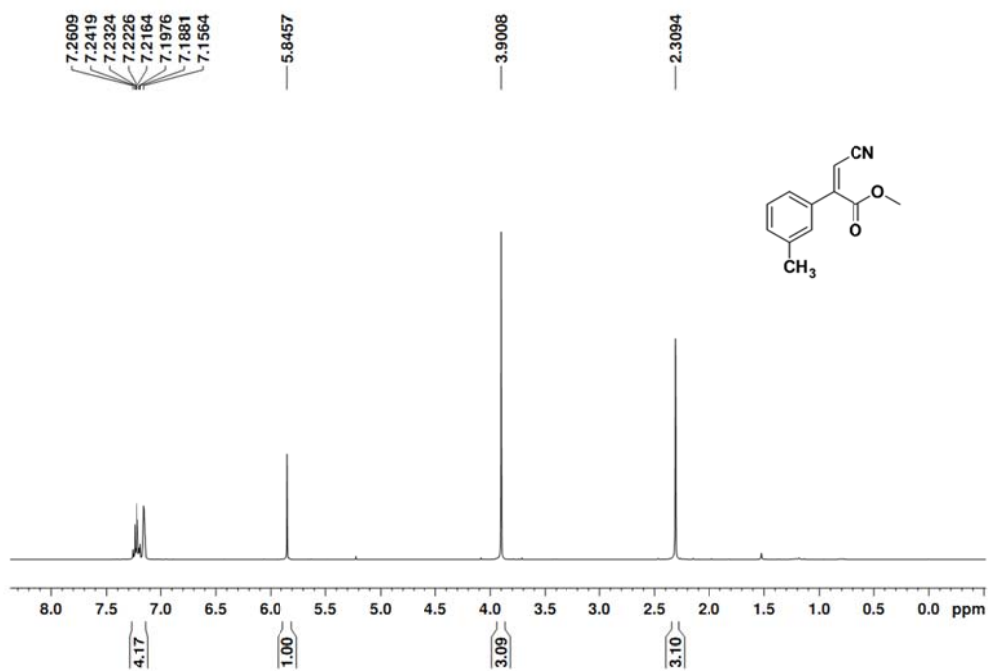
(Z)-methyl 2-(4-bromophenyl)-3-cyanoacrylate (1g)



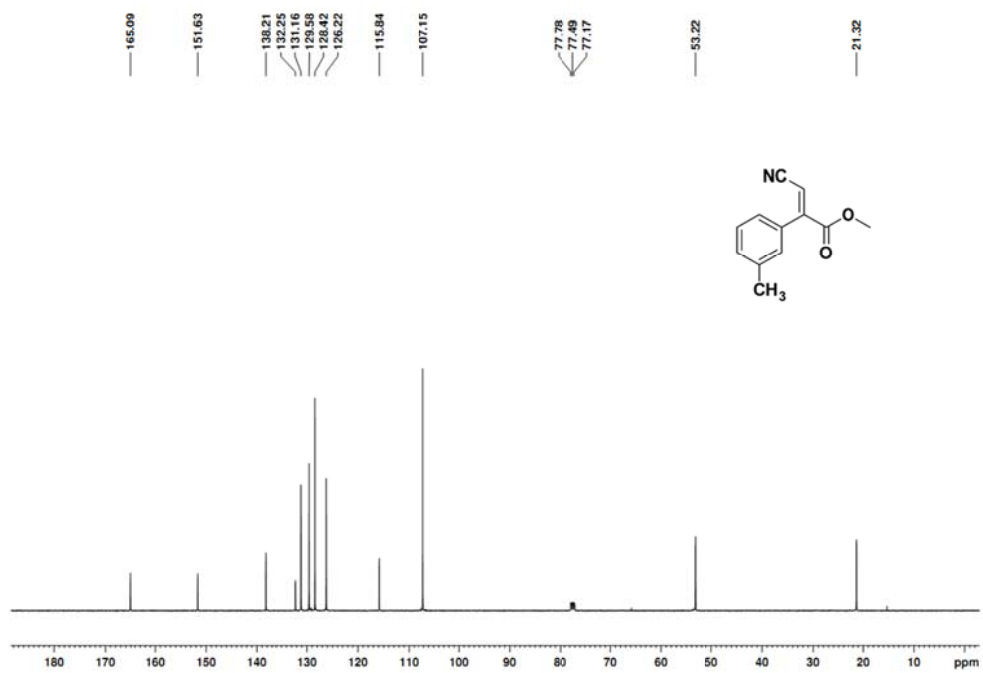
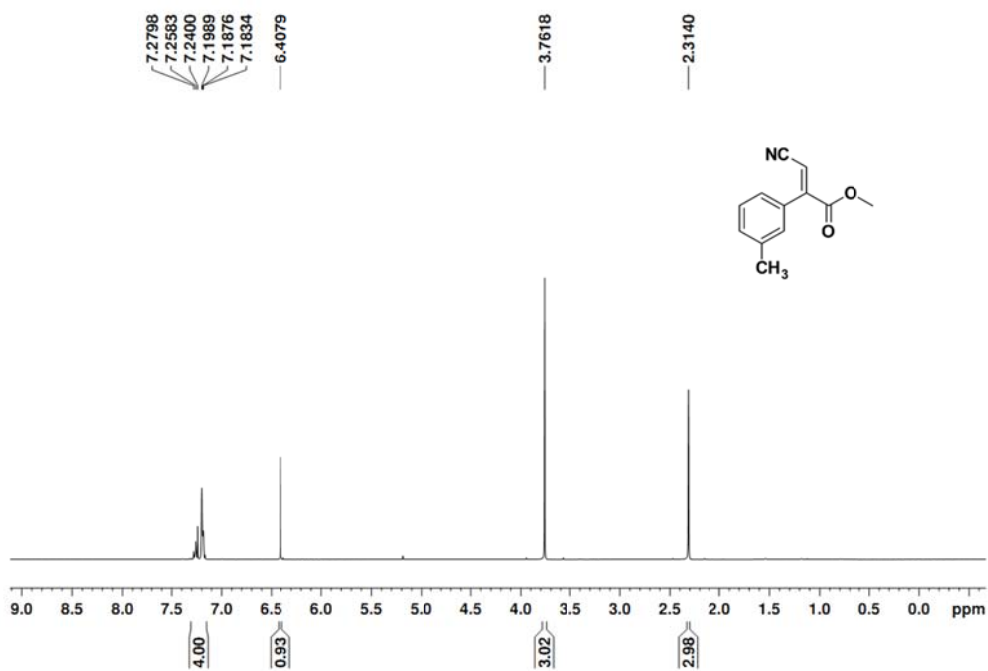
**(E)-methyl 2-(4-bromophenyl)-3-cyanoacrylate (1g')**



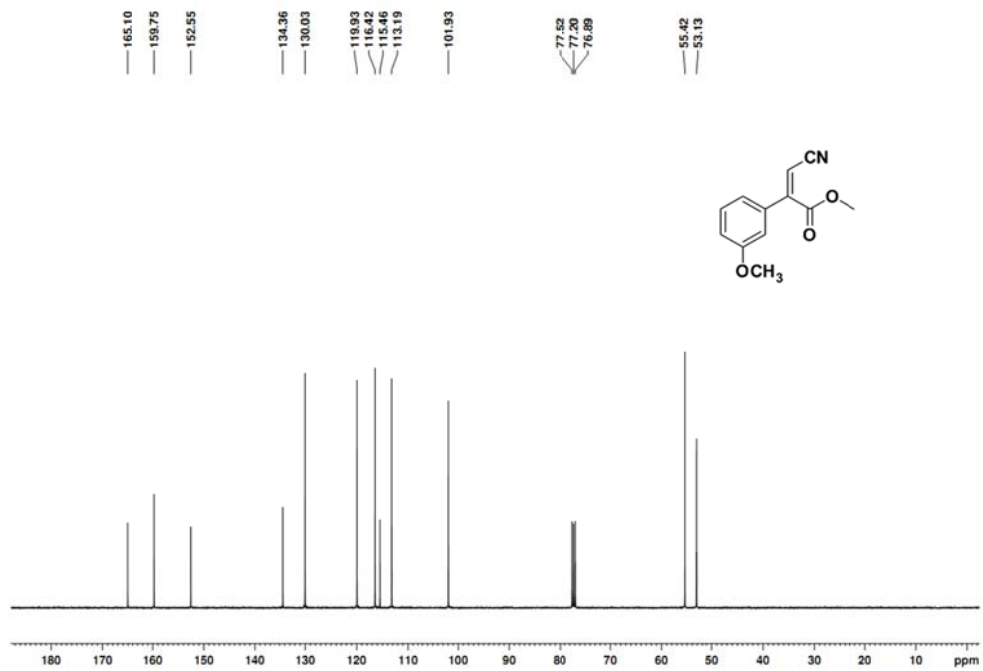
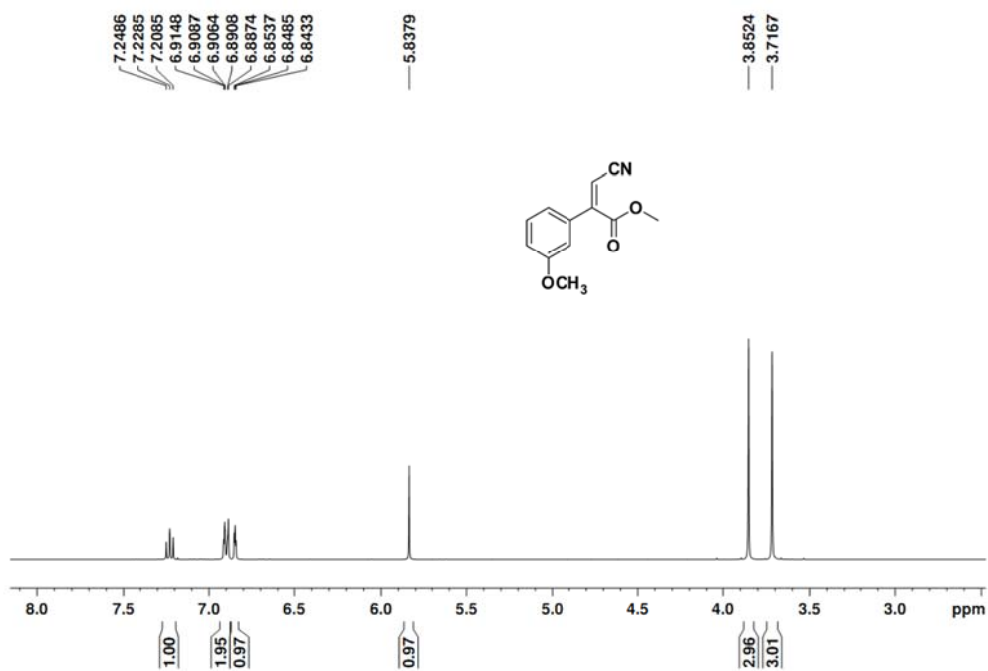
(Z)-methyl 3-cyano-2-(*m*-tolyl)acrylate (1h)



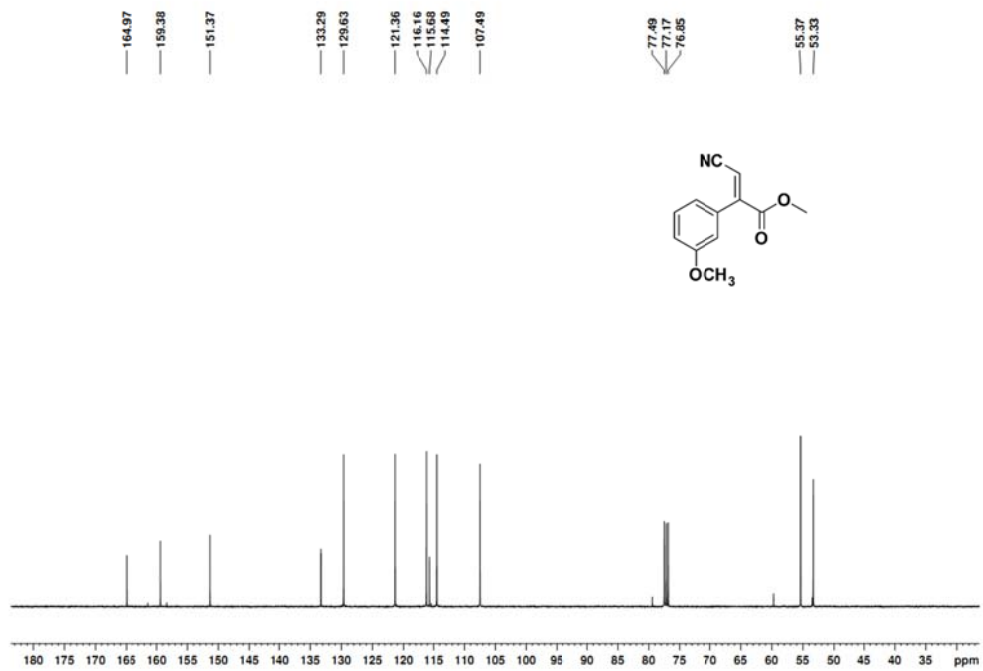
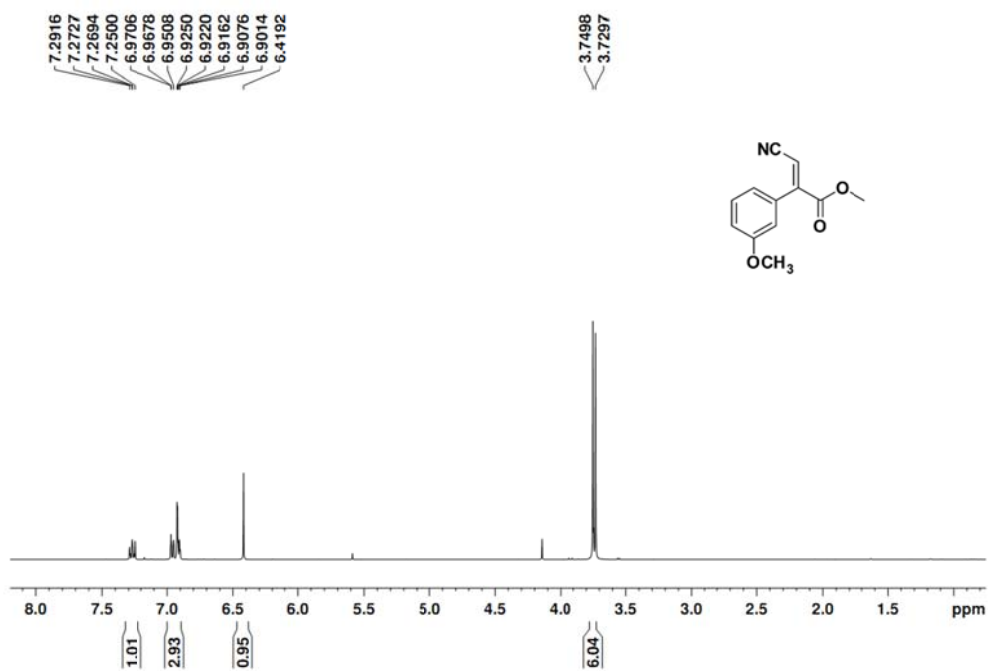
**(E)-methyl 3-cyano-2-(*m*-tolyl)acrylate (1h')**



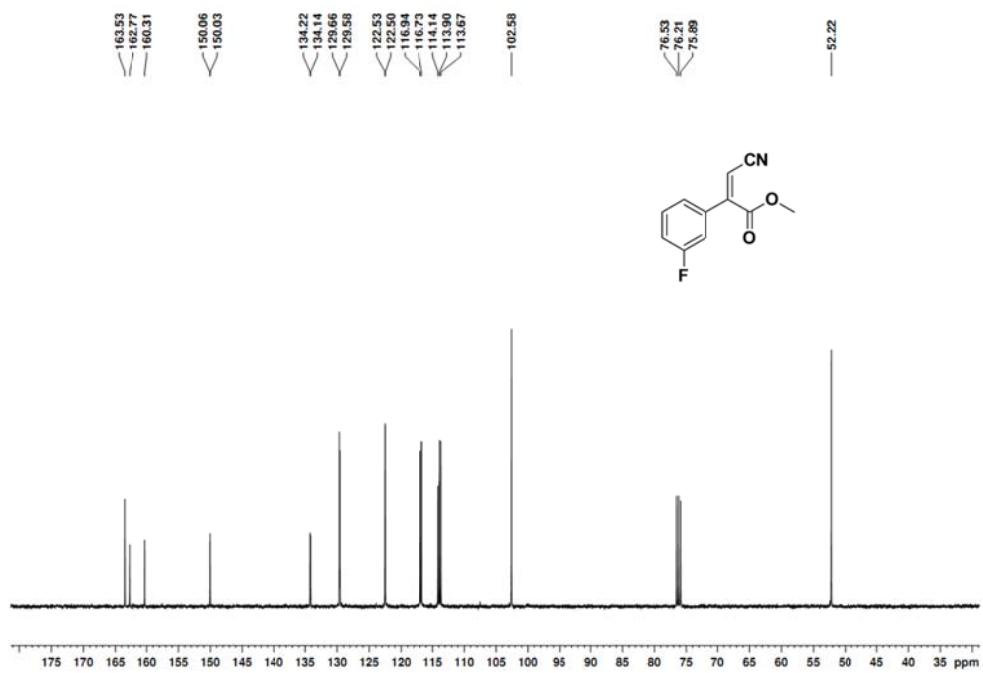
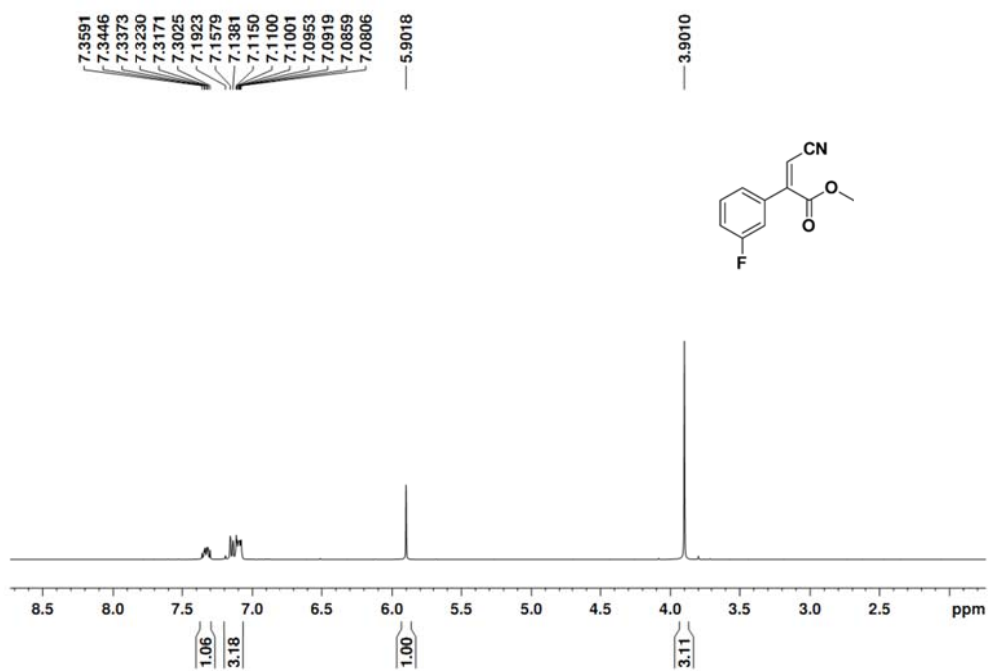
**(Z)-methyl 3-cyano-2-(3-methoxyphenyl)acrylate (1i)**



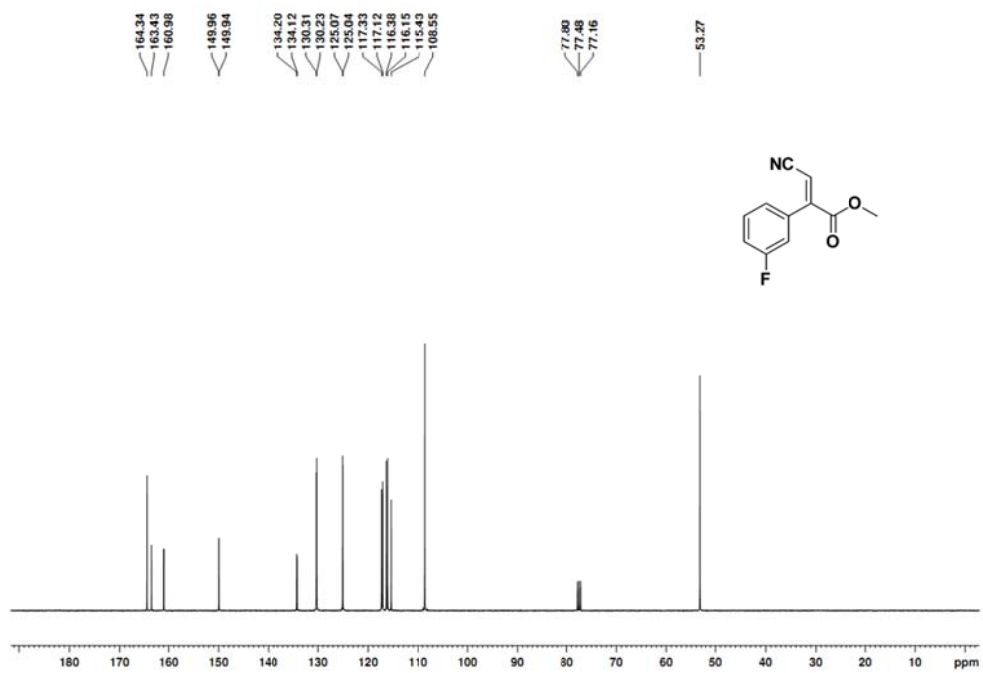
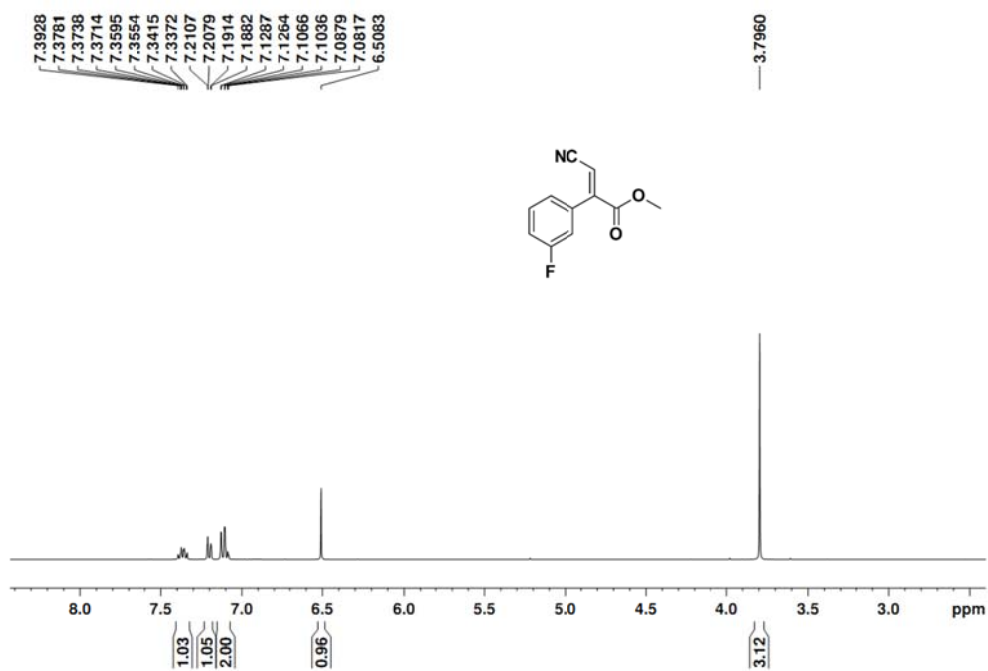
**(E)-methyl 3-cyano-2-(3-methoxyphenyl)acrylate (1i')**



**(Z)-methyl 3-cyano-2-(3-fluorophenyl)acrylate (1j)**

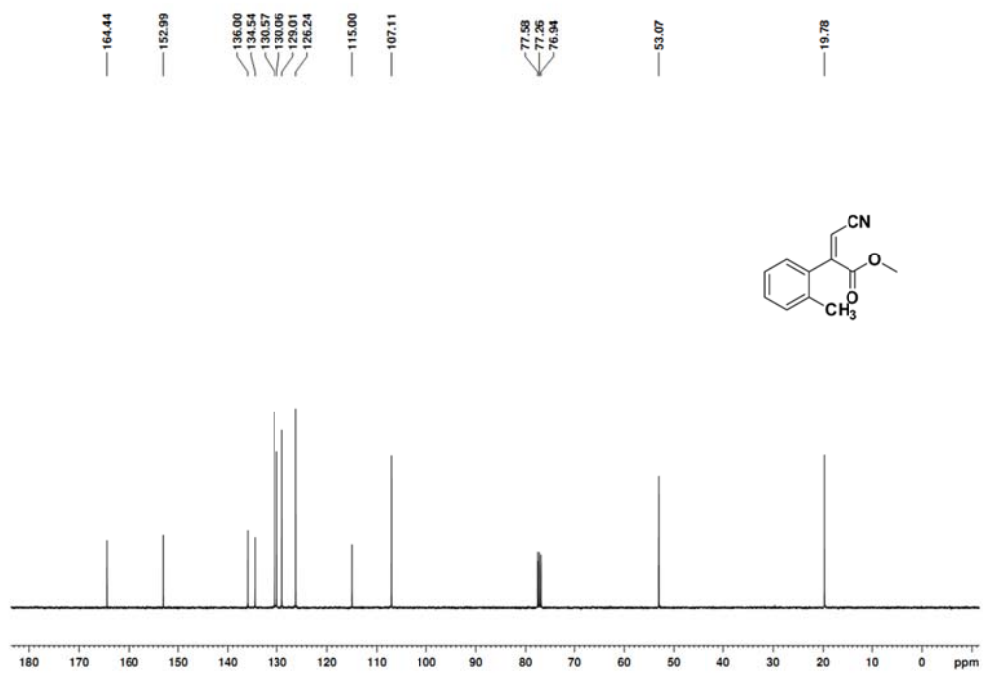
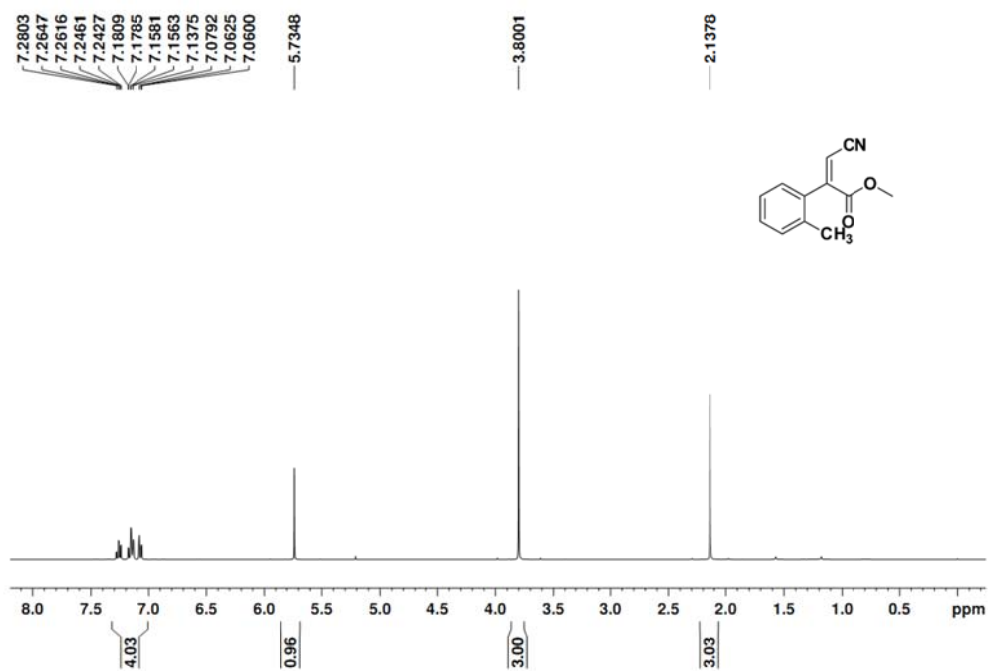


**(E)-methyl 3-cyano-2-(3-fluorophenyl)acrylate (1j')**

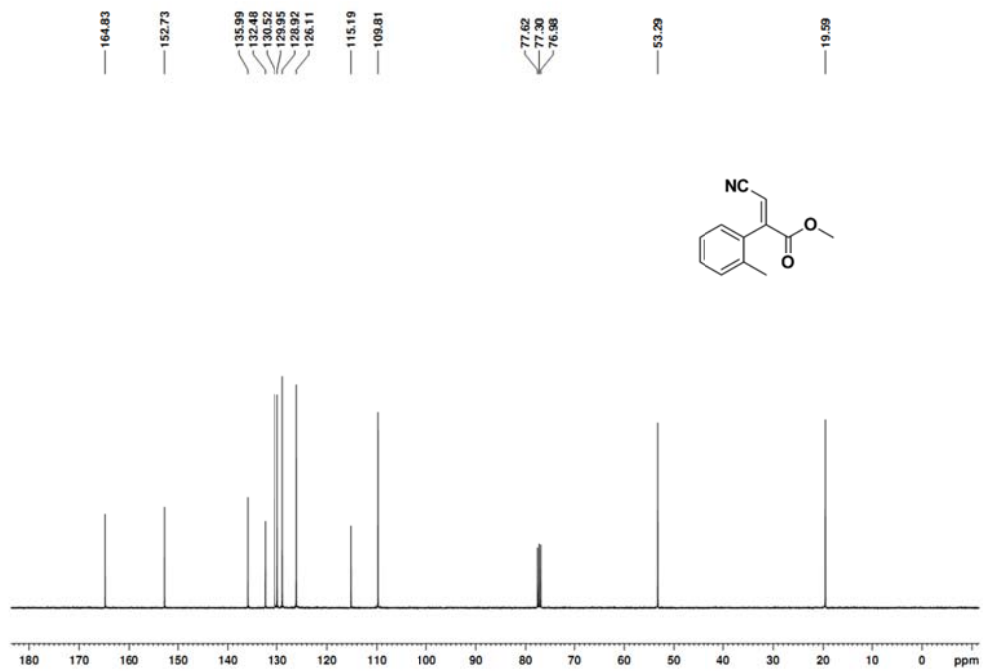
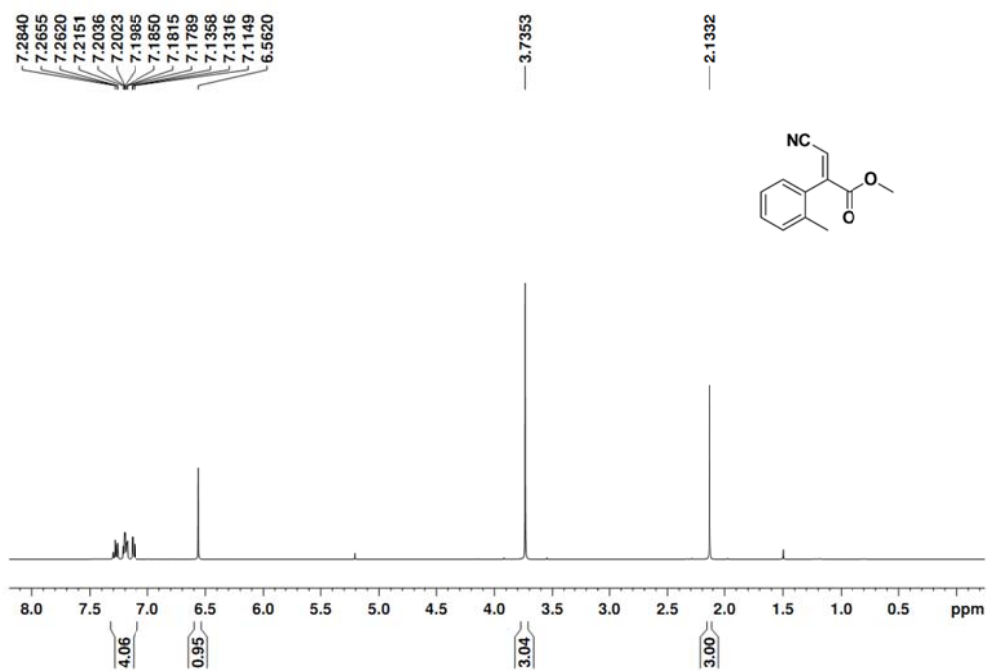




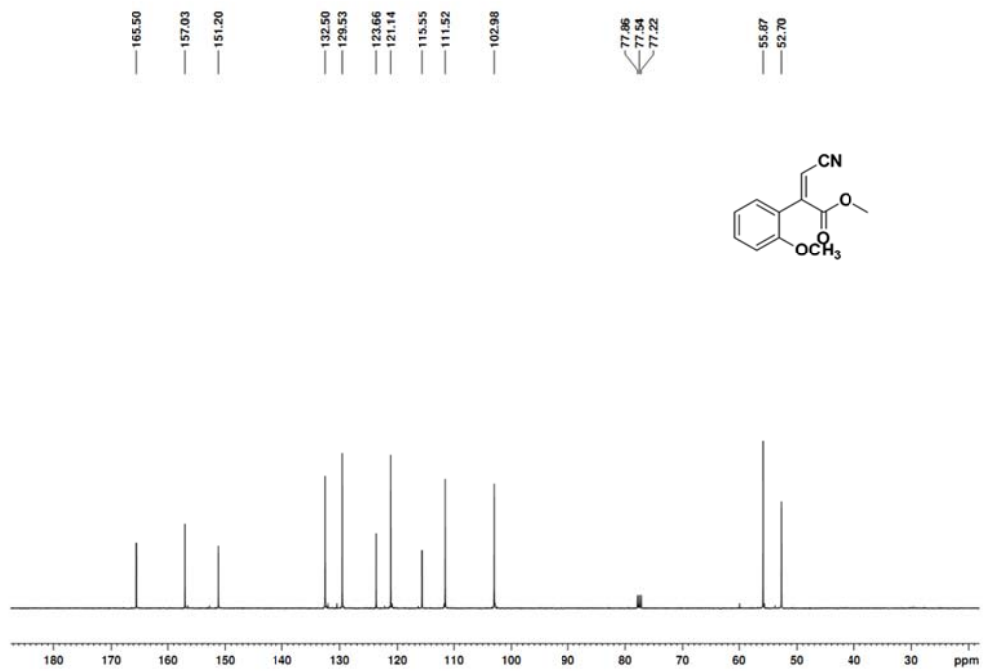
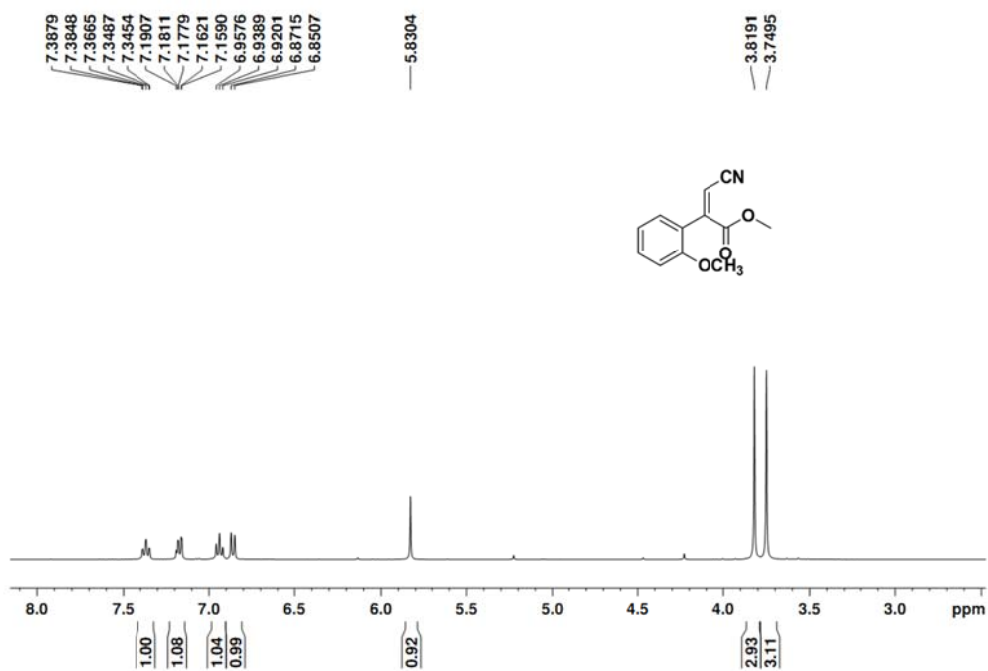
(Z)-methyl 3-cyano-2-(*o*-tolyl)acrylate (1k)



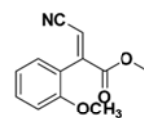
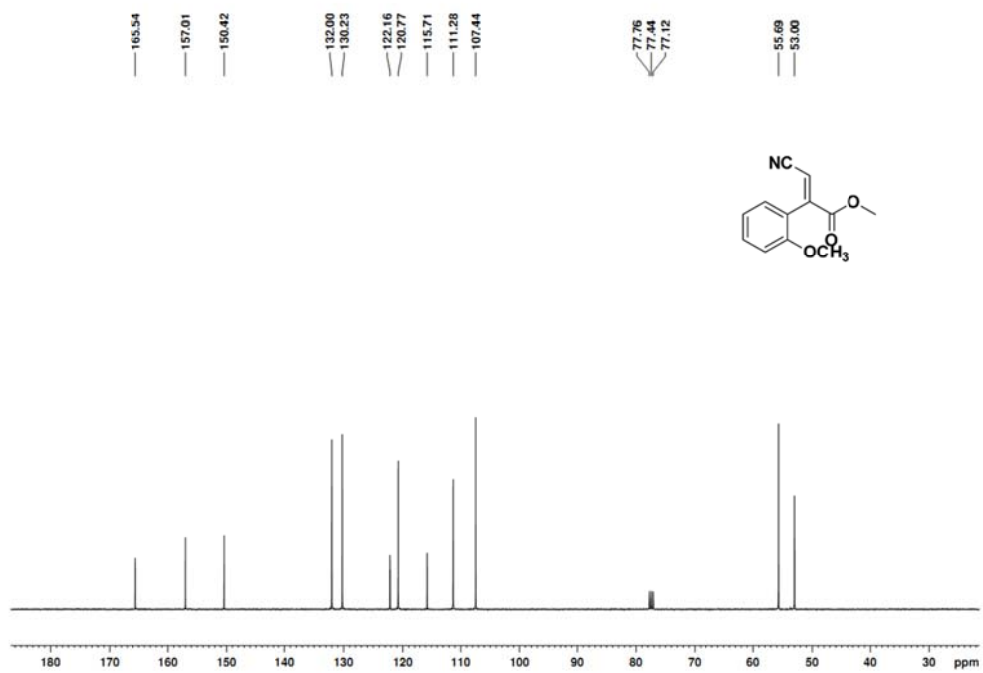
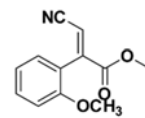
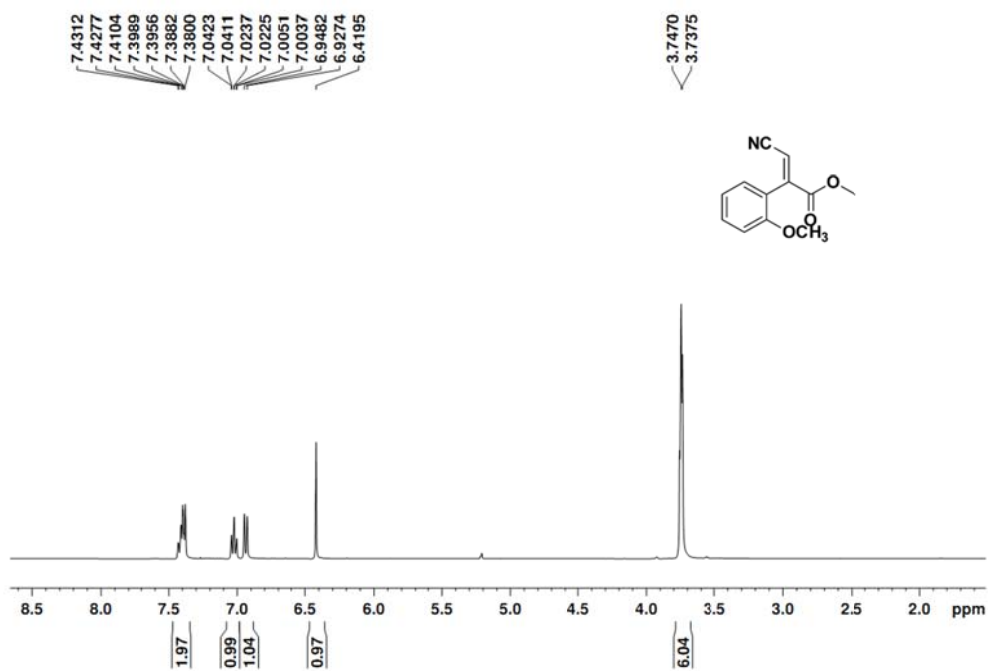
**(E)-methyl 3-cyano-2-(*o*-tolyl)acrylate (1k')**



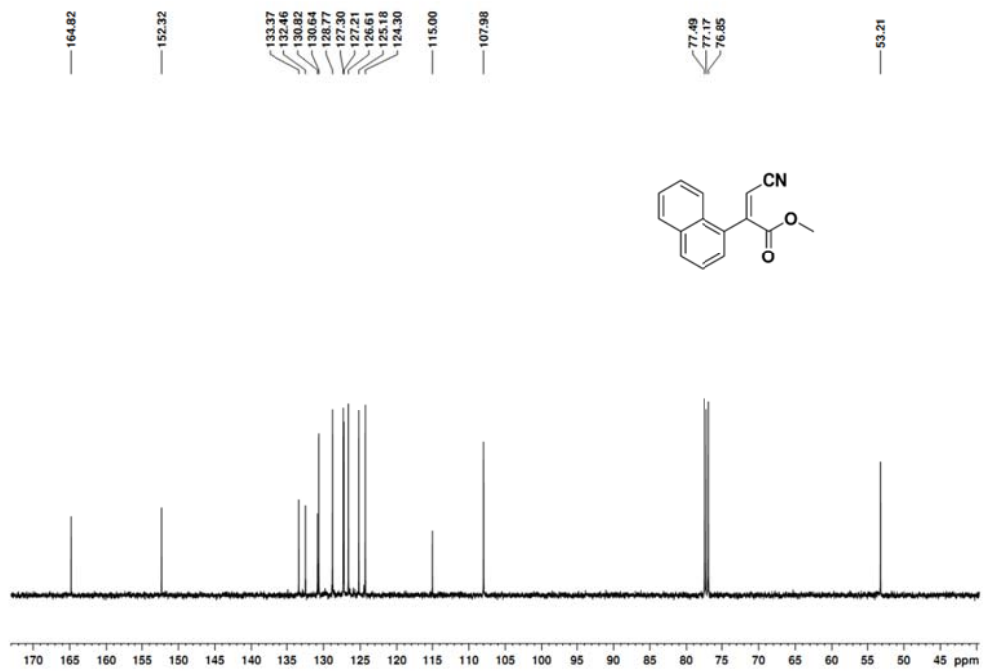
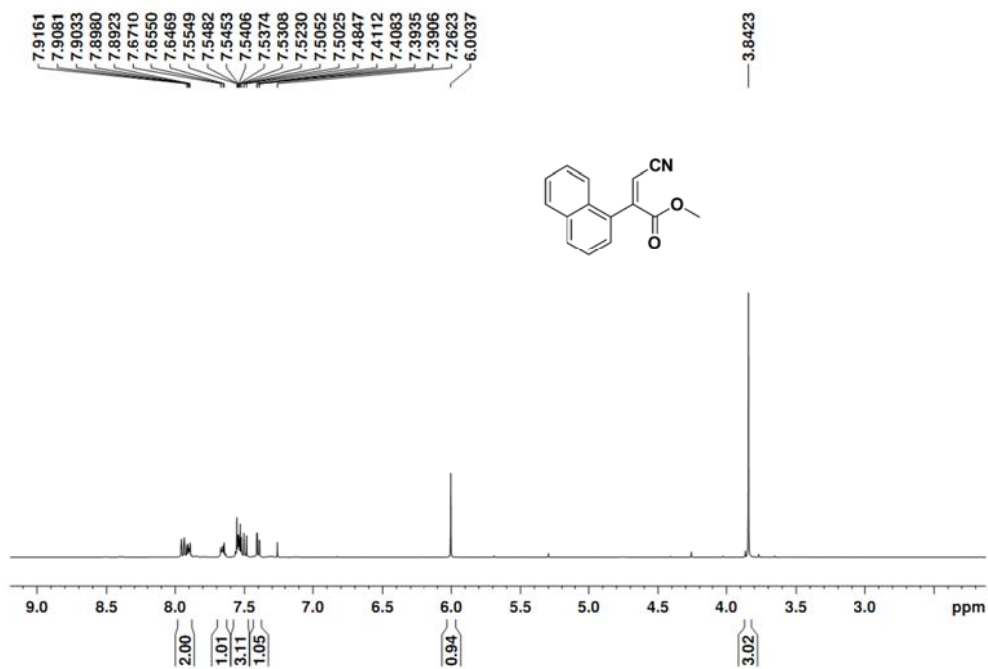
**(Z)-methyl 3-cyano-2-(2-methoxyphenyl)acrylate (1I)**



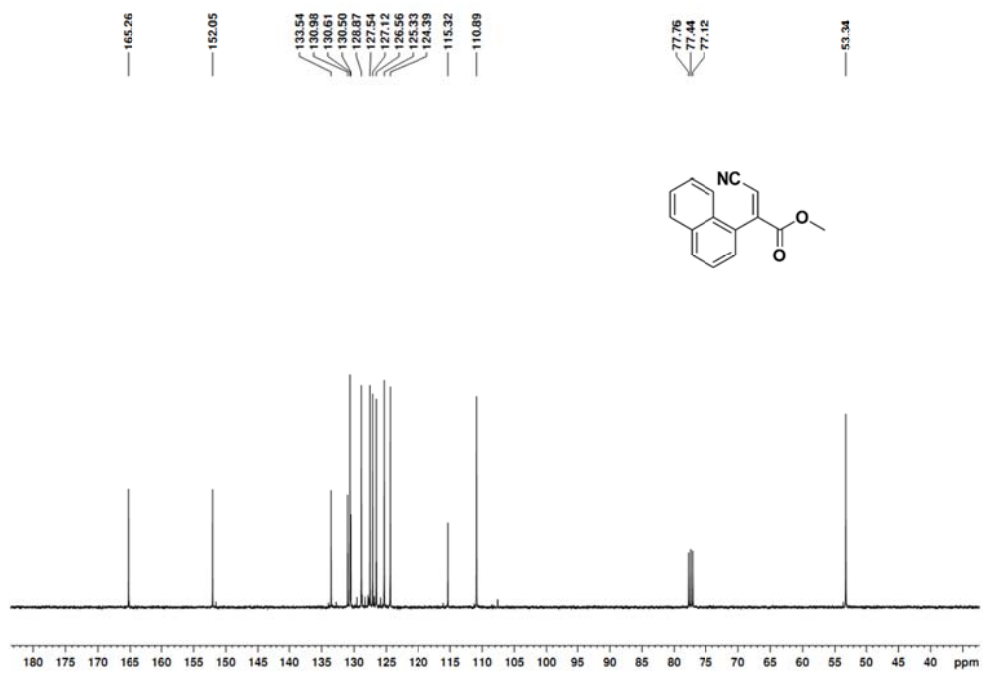
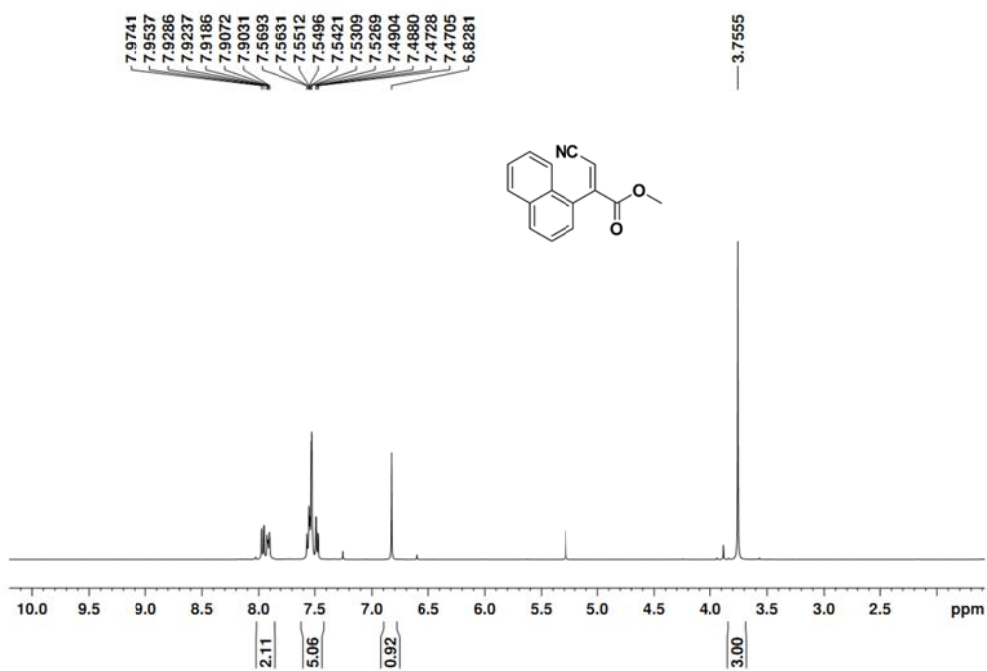
**(E)-methyl 3-cyano-2-(2-methoxyphenyl)acrylate (11')**



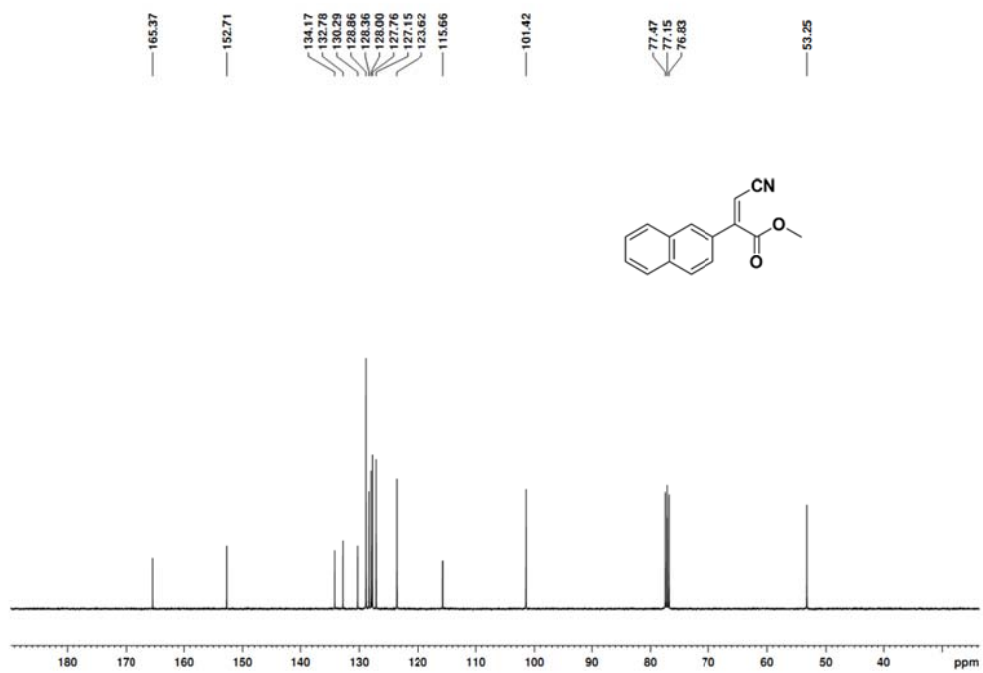
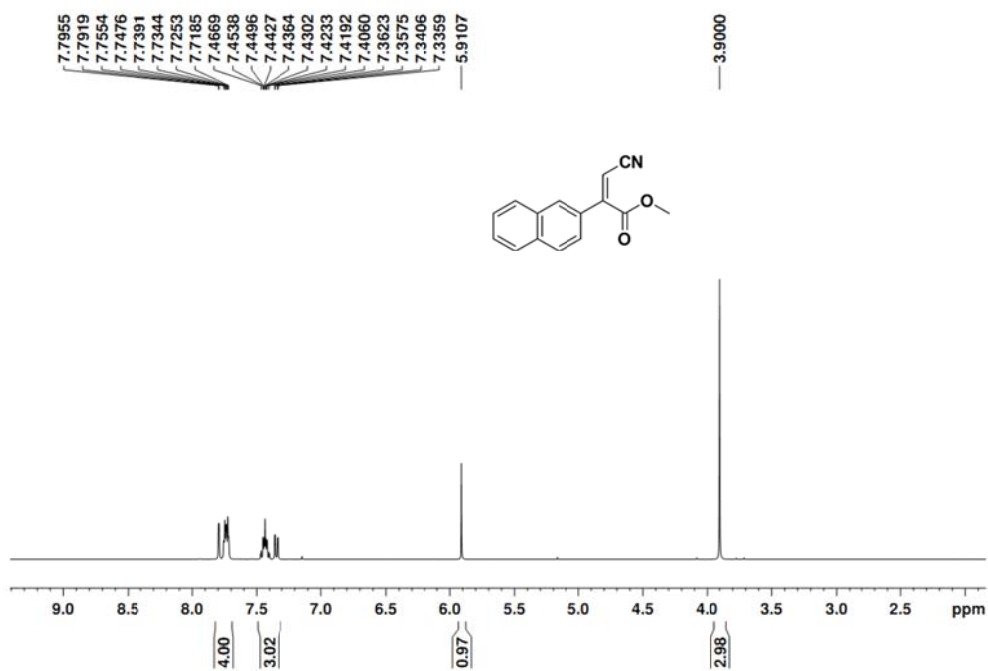
**(Z)-methyl 3-cyano-2-(naphthalen-1-yl)acrylate (1m)**



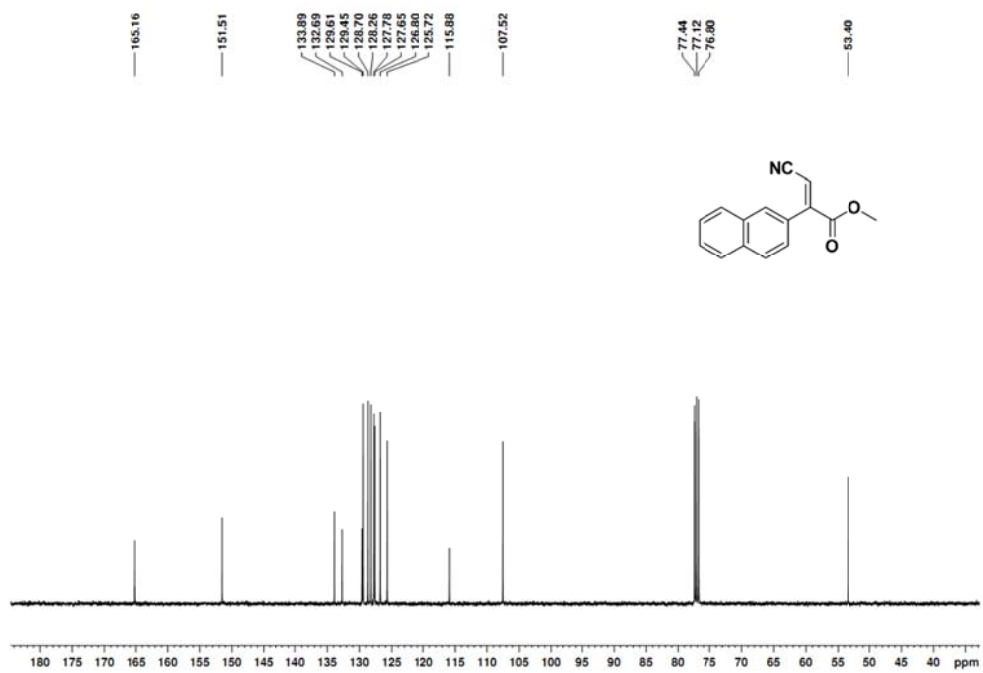
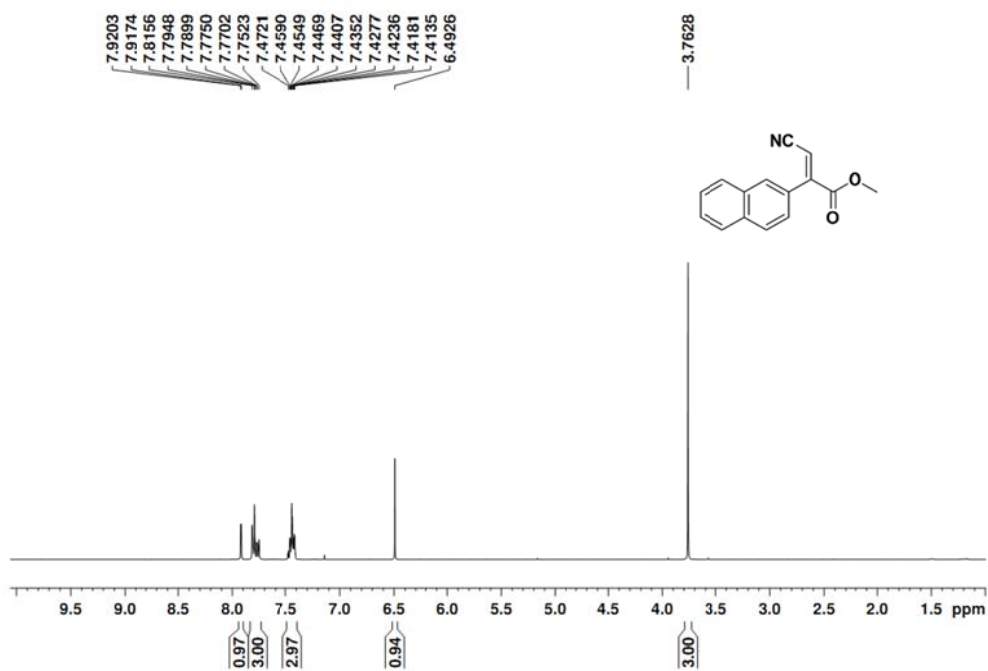
**(E)-methyl 3-cyano-2-(naphthalen-1-yl)acrylate (1m')**



**(Z)-methyl 3-cyano-2-(naphthalen-2-yl)acrylate (1n)**

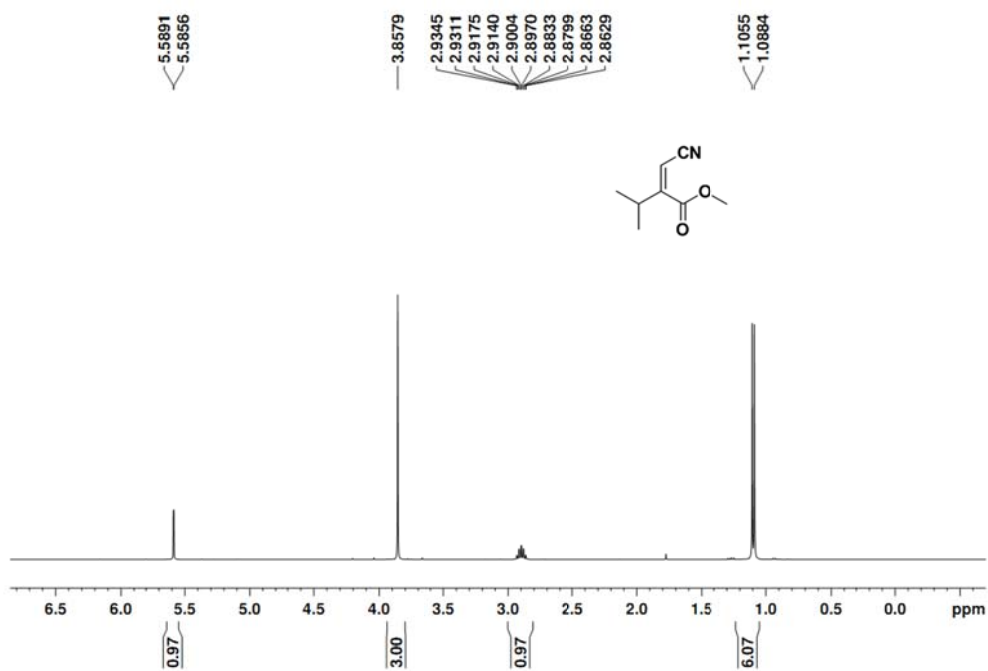


**(E)-methyl 3-cyano-2-(naphthalen-2-yl)acrylate (1n')**

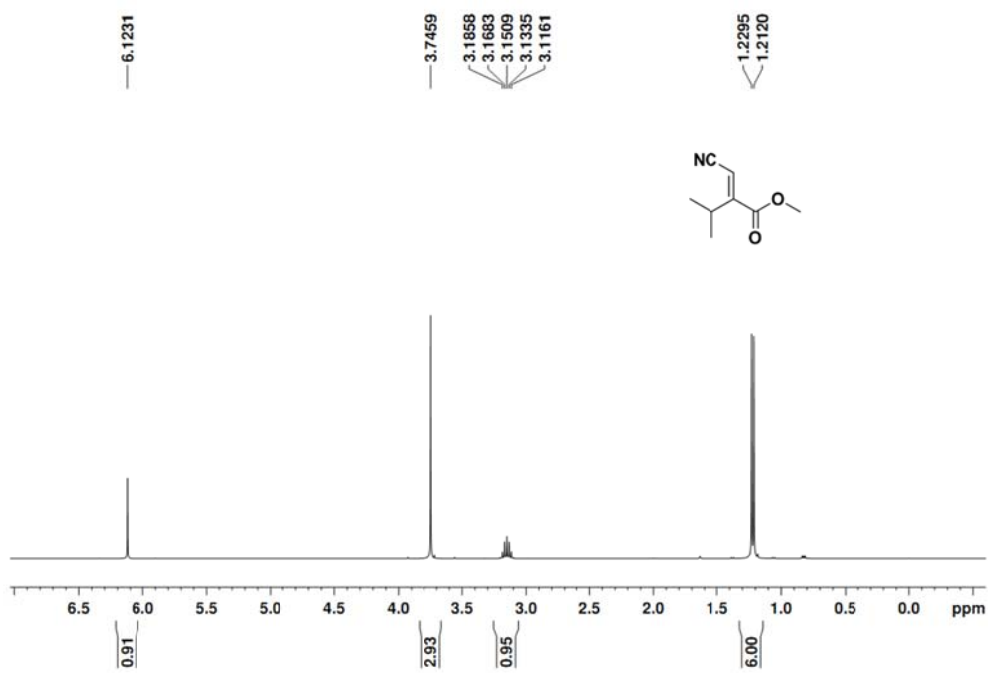




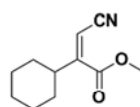
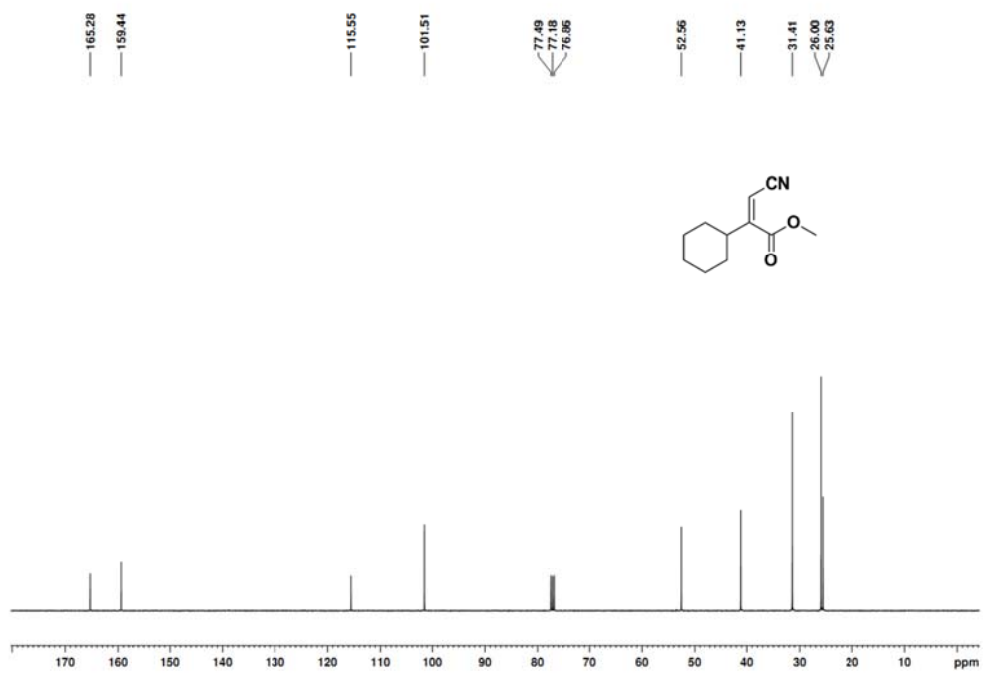
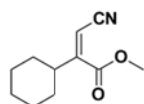
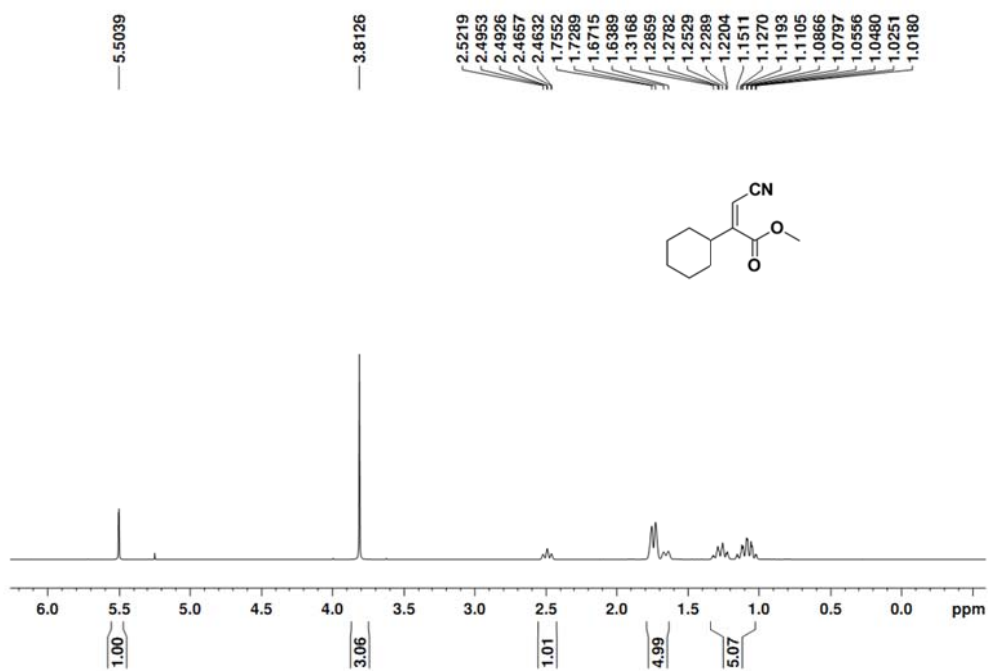
**(Z)-methyl 2-(cyanomethylene)-3-methylbutanoate (1o)**



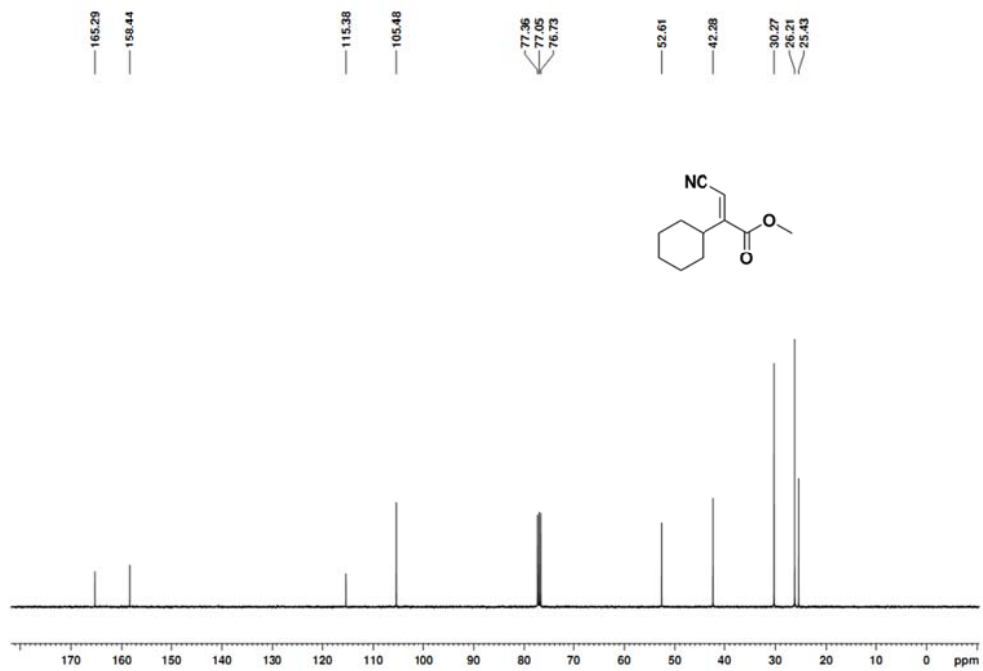
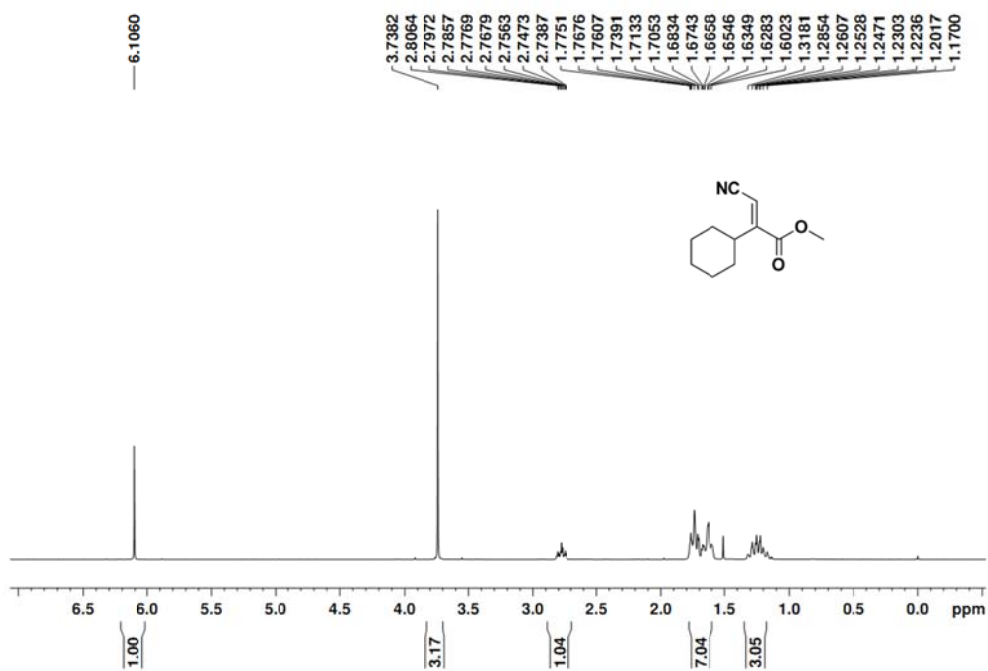
**(E)-methyl 2-(cyanomethylene)-3-methylbutanoate (1o')**



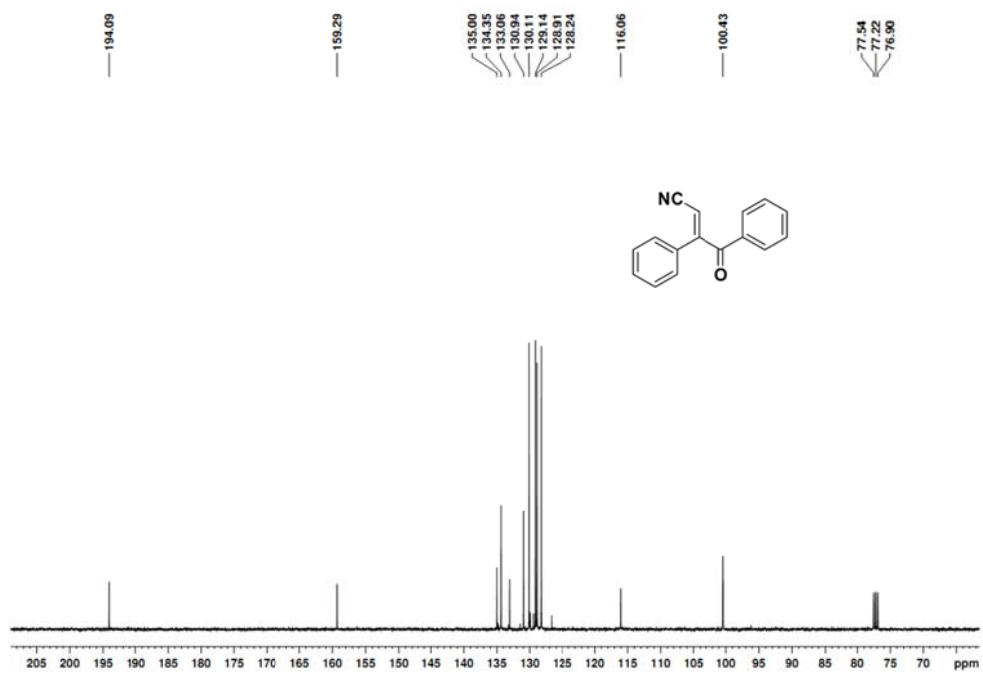
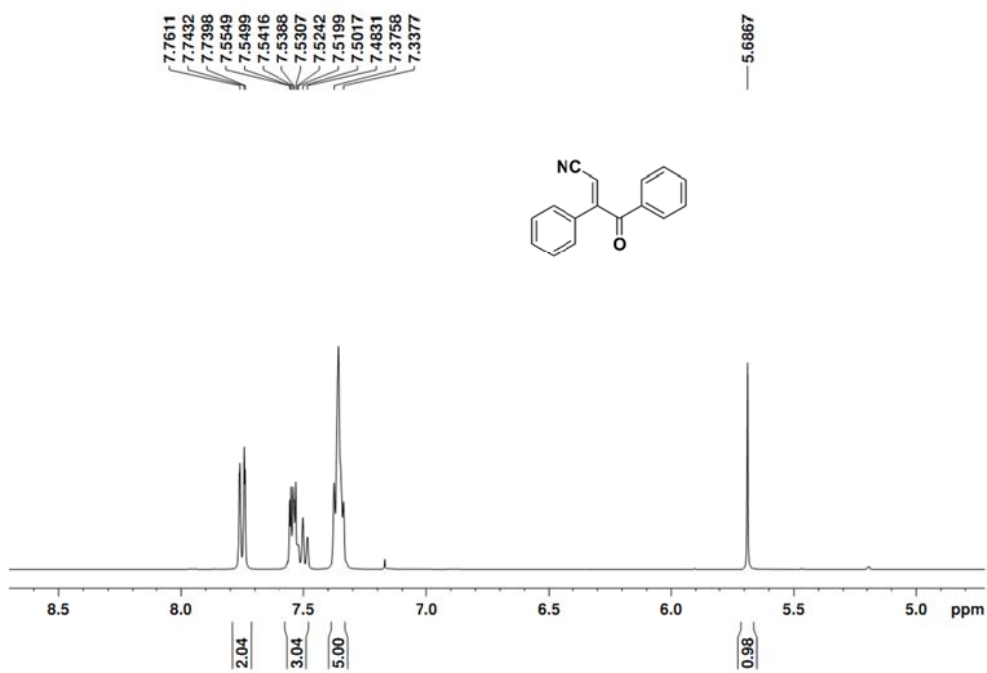
**(Z)-methyl 3-cyano-2-cyclohexylacrylate (1p)**



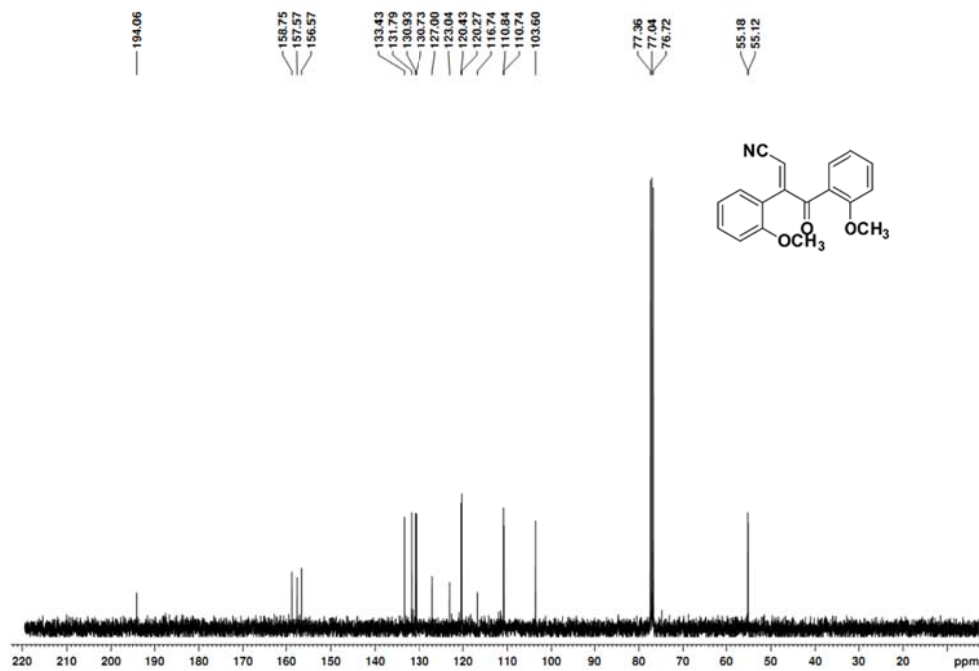
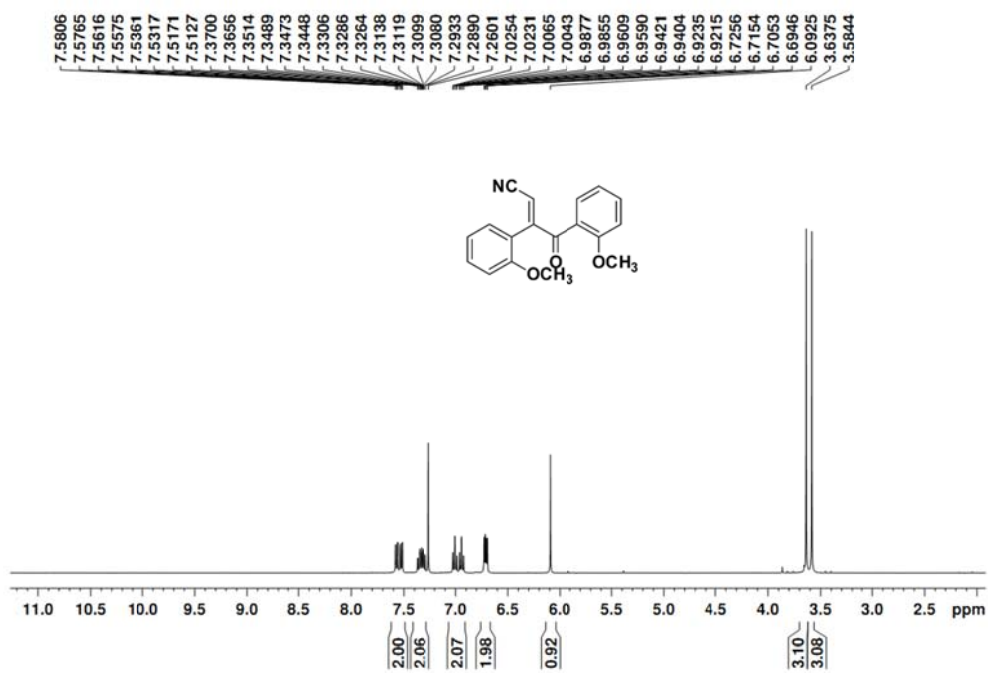
**(E)-methyl 3-cyano-2-cyclohexylacrylate (1p')**



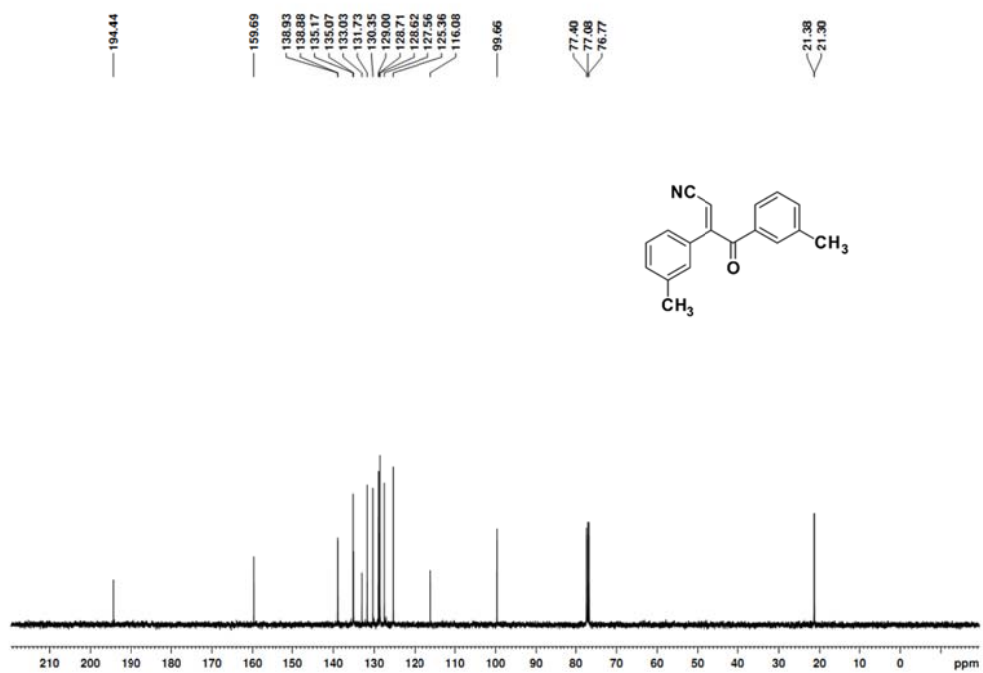
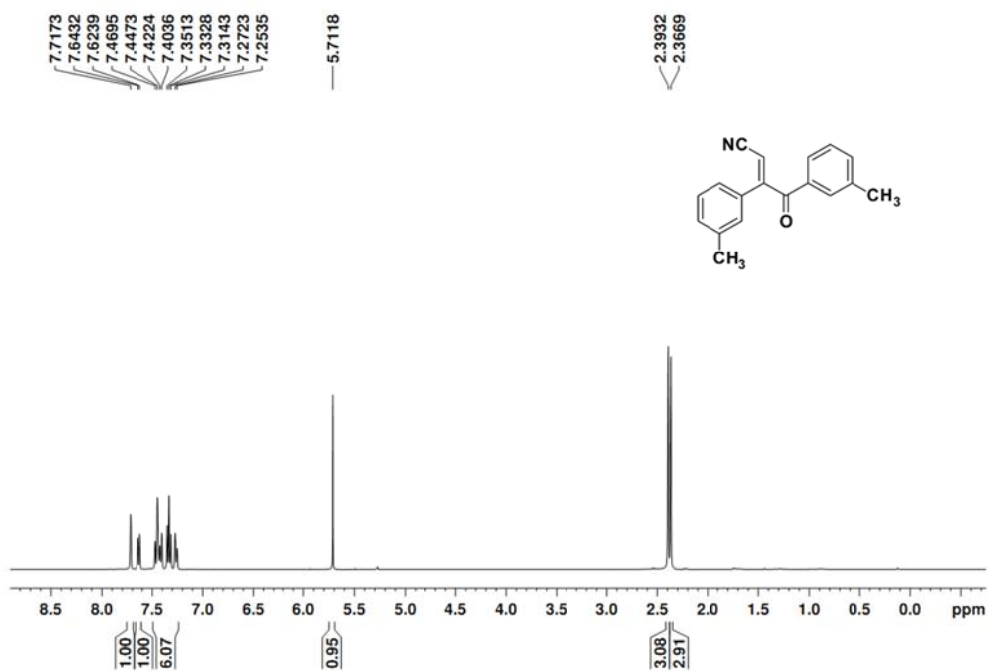
**(E)-4-oxo-3,4-diphenylbut-2-enitrile (3a)**



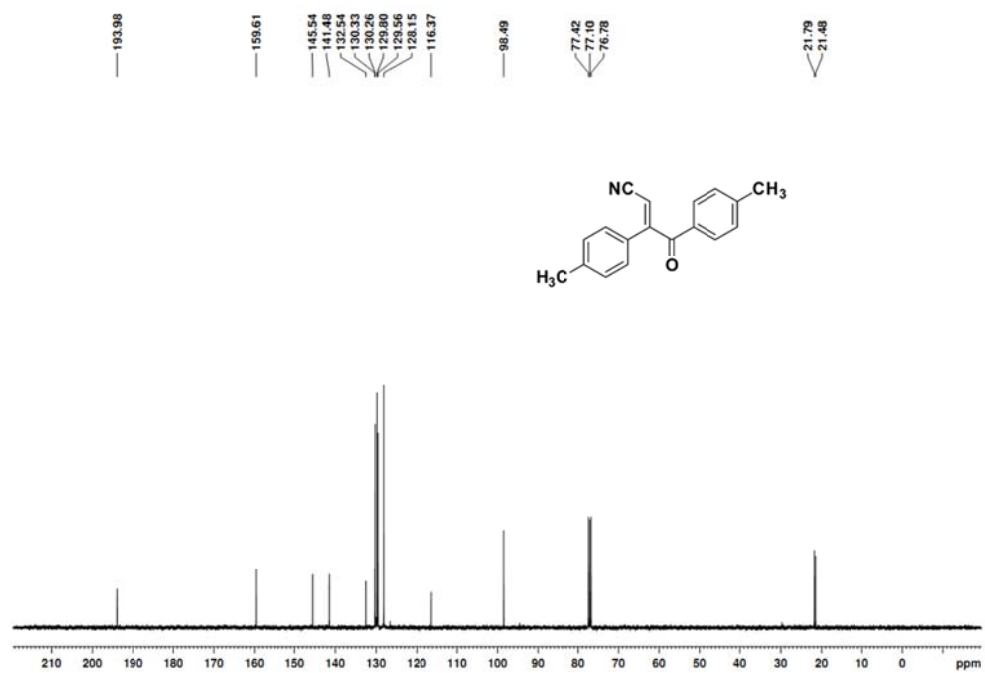
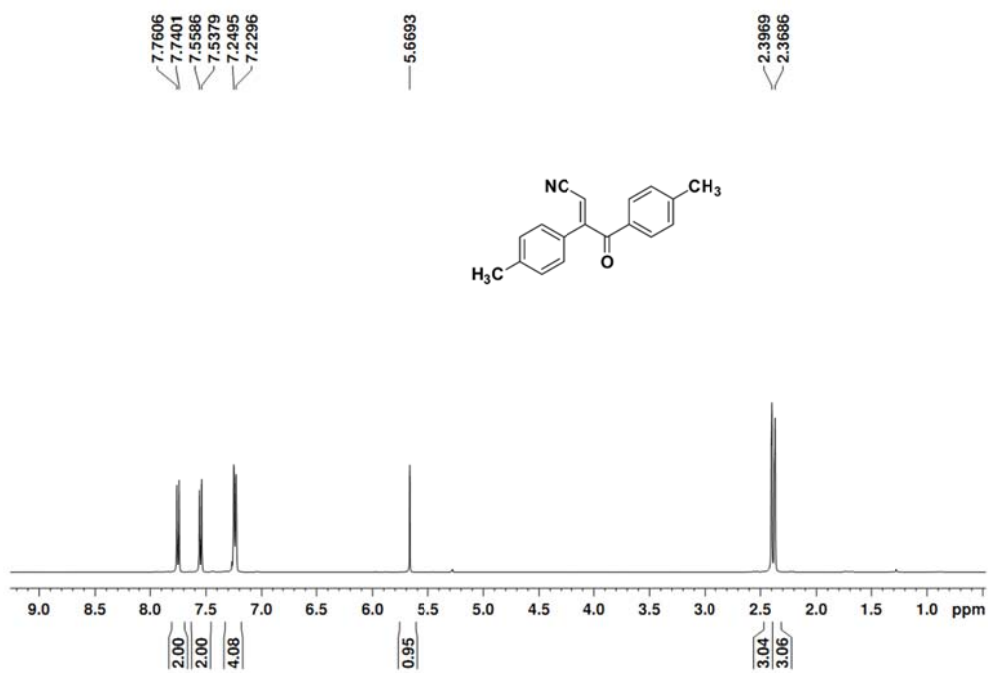
**(E)-3,4-bis(2-methoxyphenyl)-4-oxobut-2-enitrile (3b)**



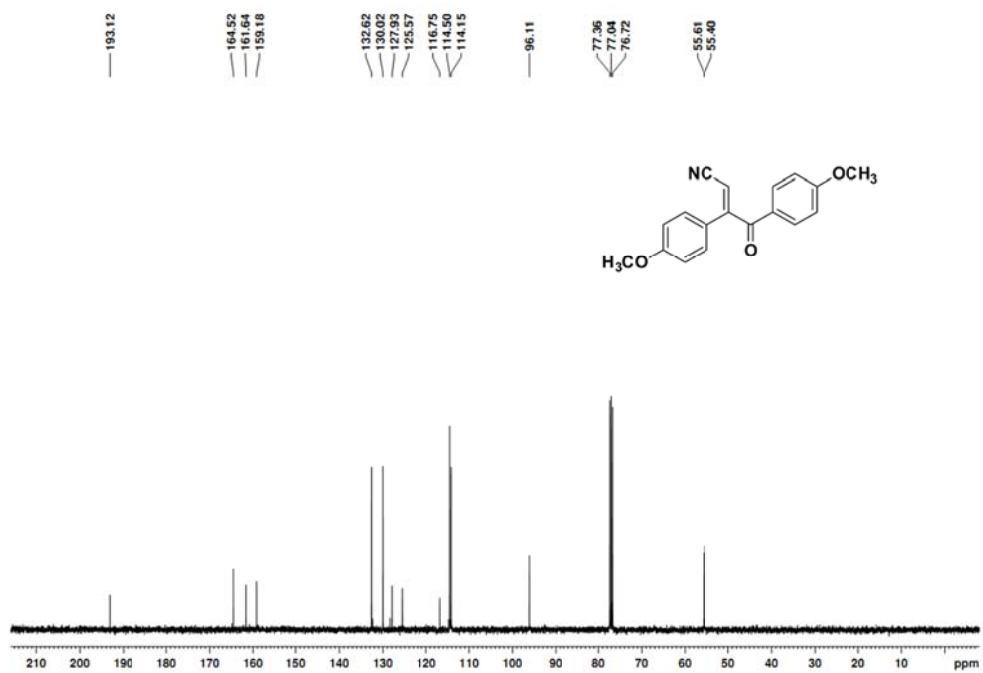
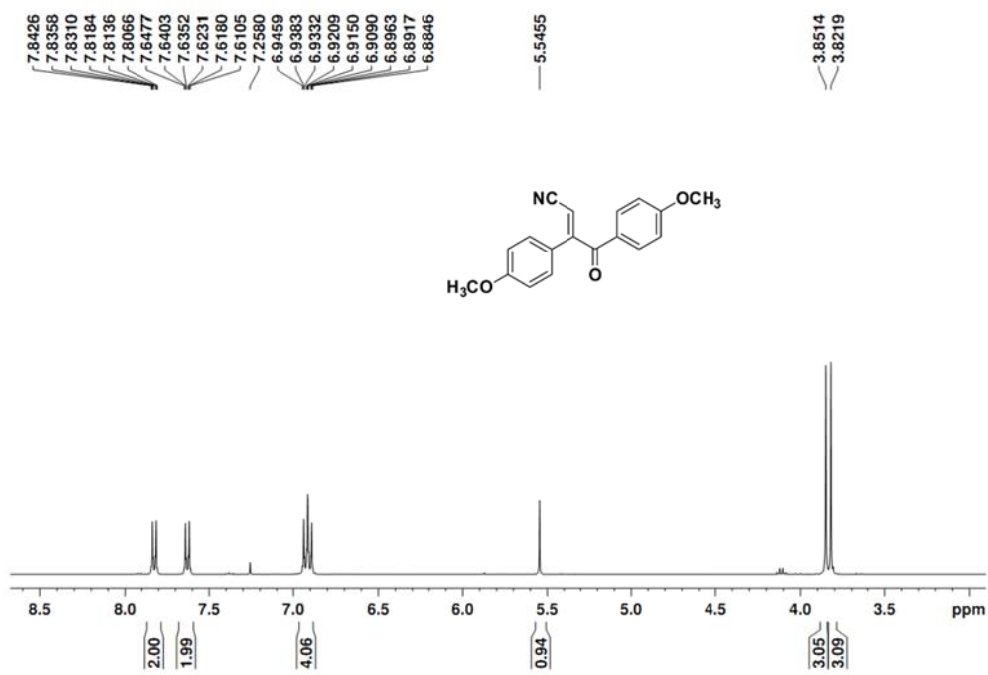
**(E)-4-oxo-3,4-di-*m*-tolylbut-2-enitrile (3c)**



**(E)-4-oxo-3,4-di-*p*-tolylbut-2-enitrile (3d)**

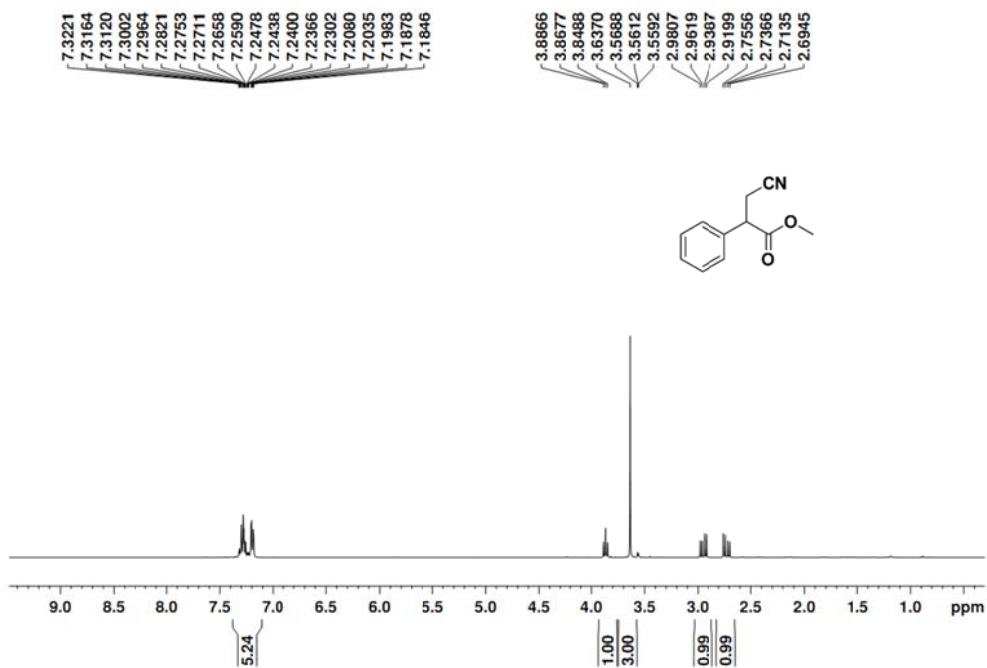


**(E)-3,4-bis(4-methoxyphenyl)-4-oxobut-2-enitrile (3e)**

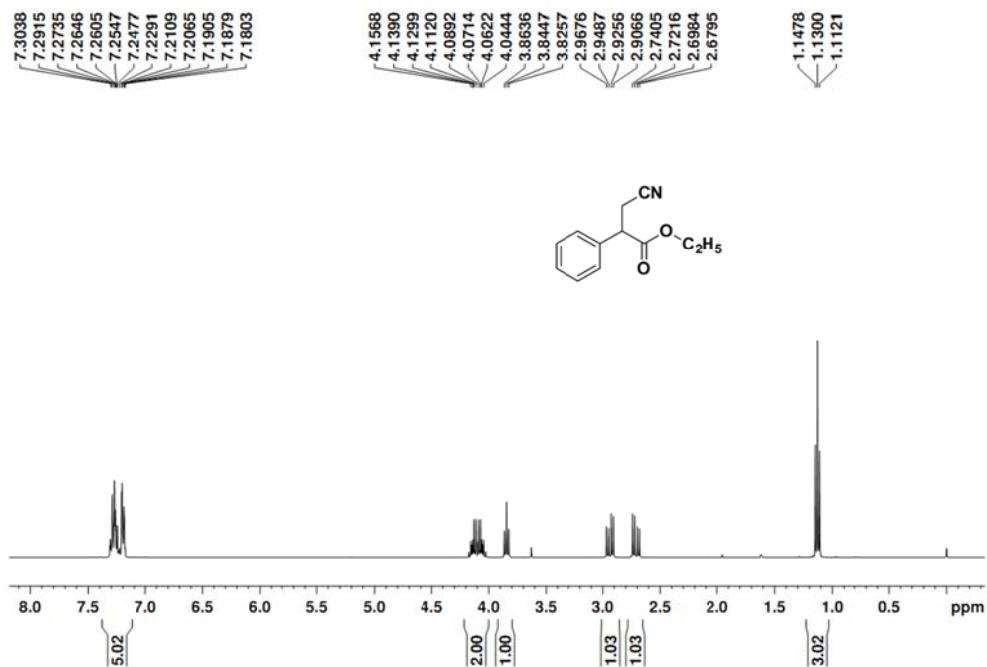


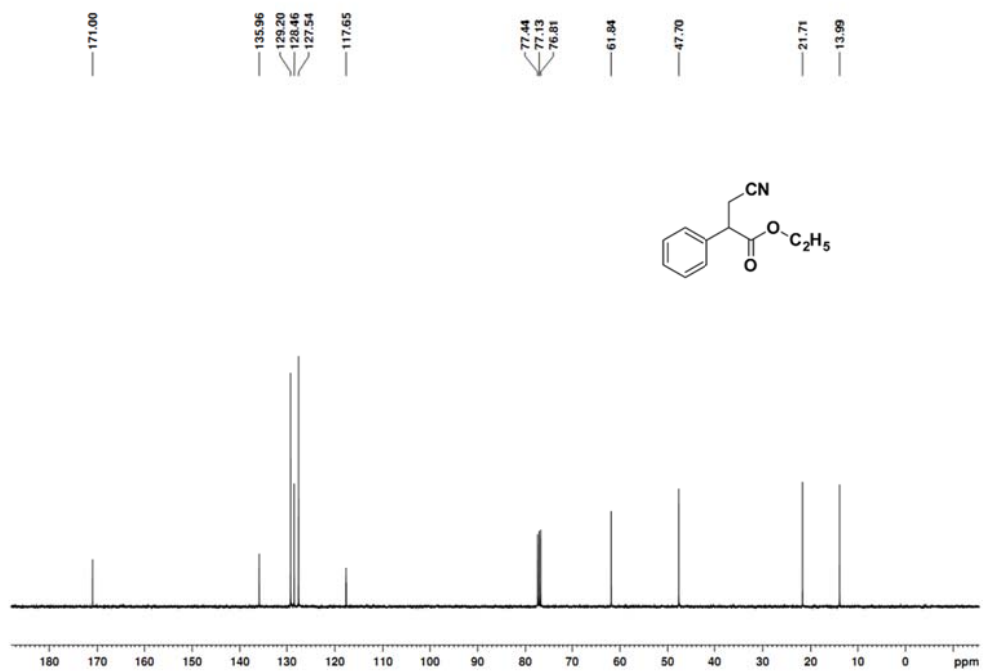


## methyl 3-cyano-2-phenylpropanoate

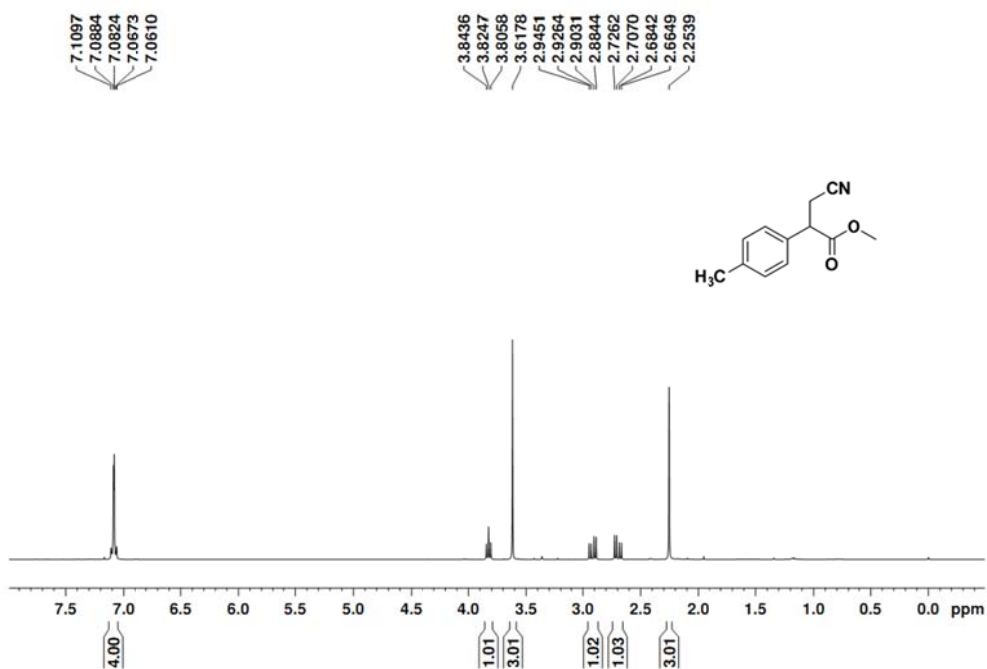


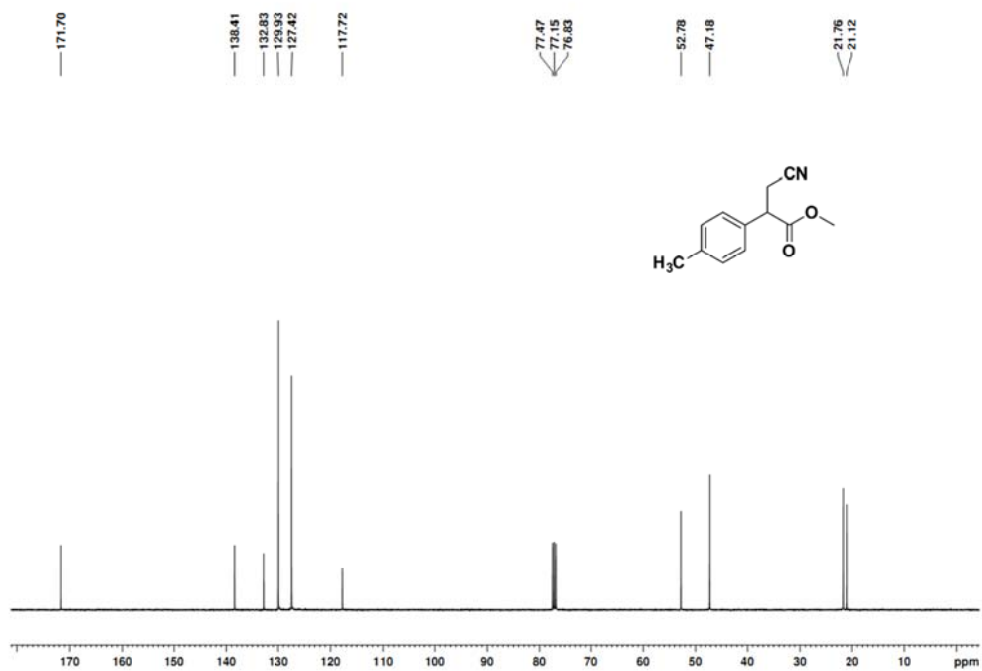
## ethyl 3-cyano-2-phenylpropanoate



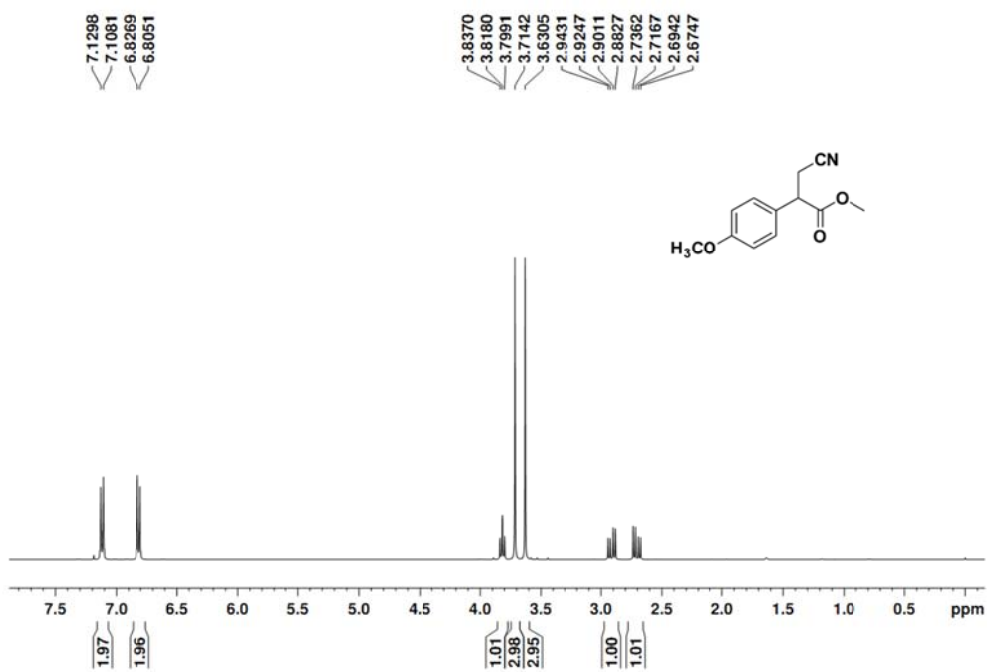


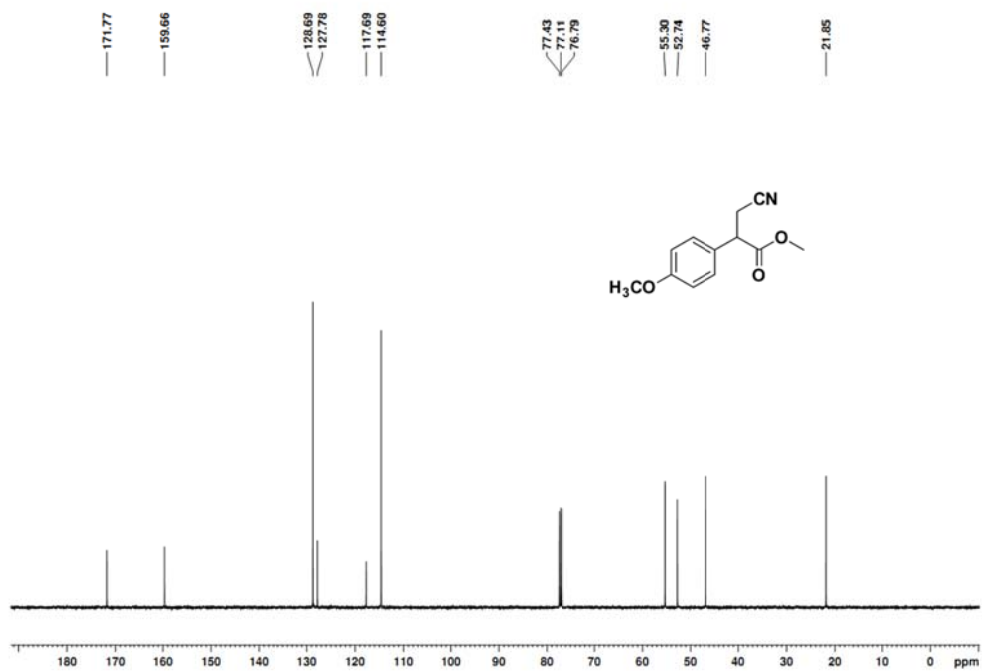
**methyl 3-cyano-2-(*p*-tolyl)propanoate**



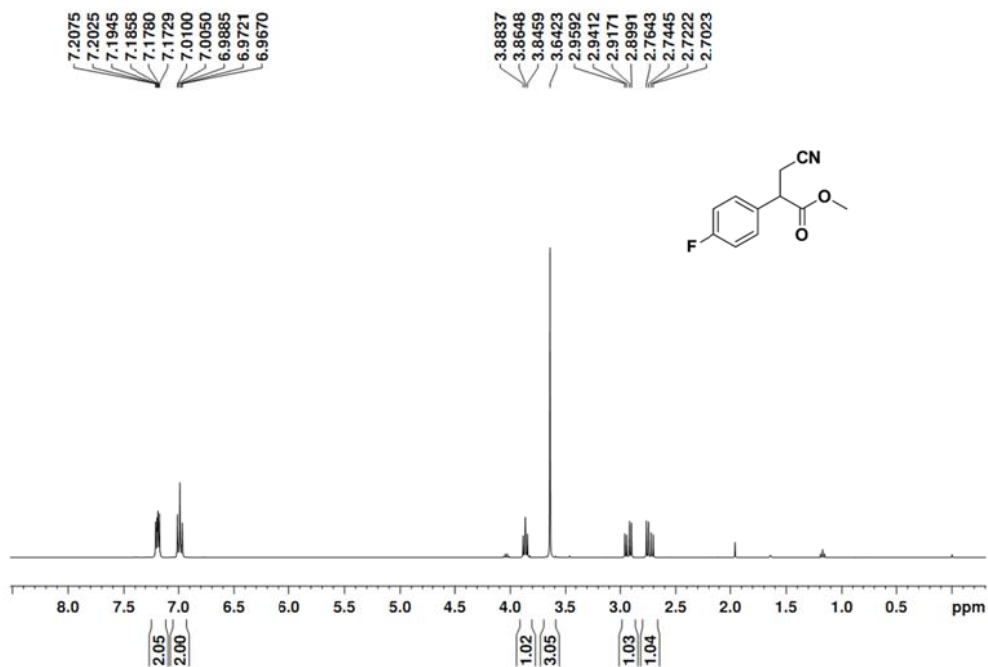


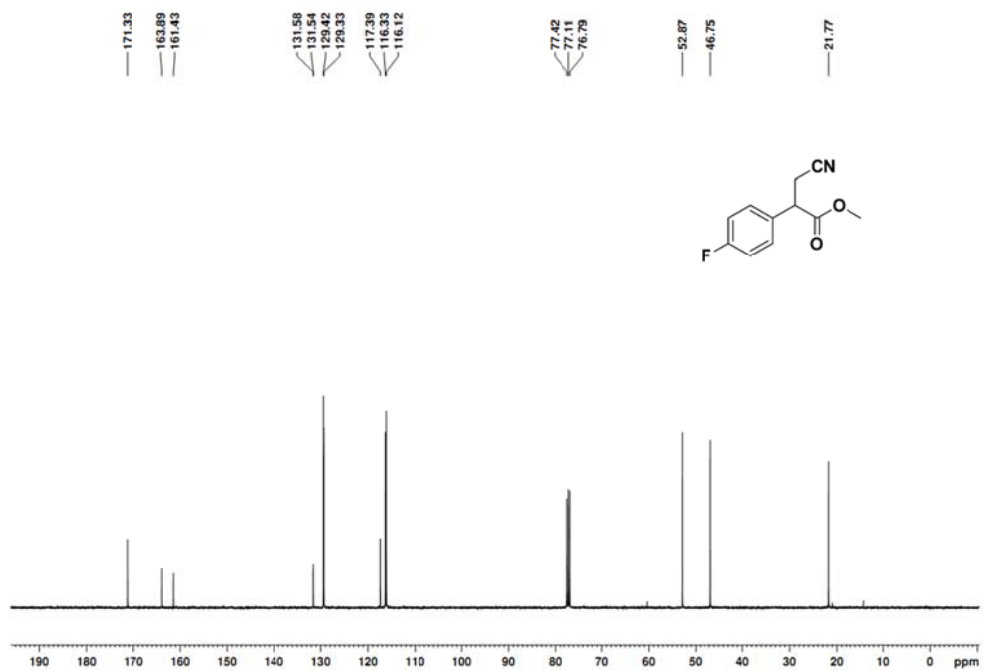
**methyl 3-cyano-2-(4-methoxyphenyl)propanoate**



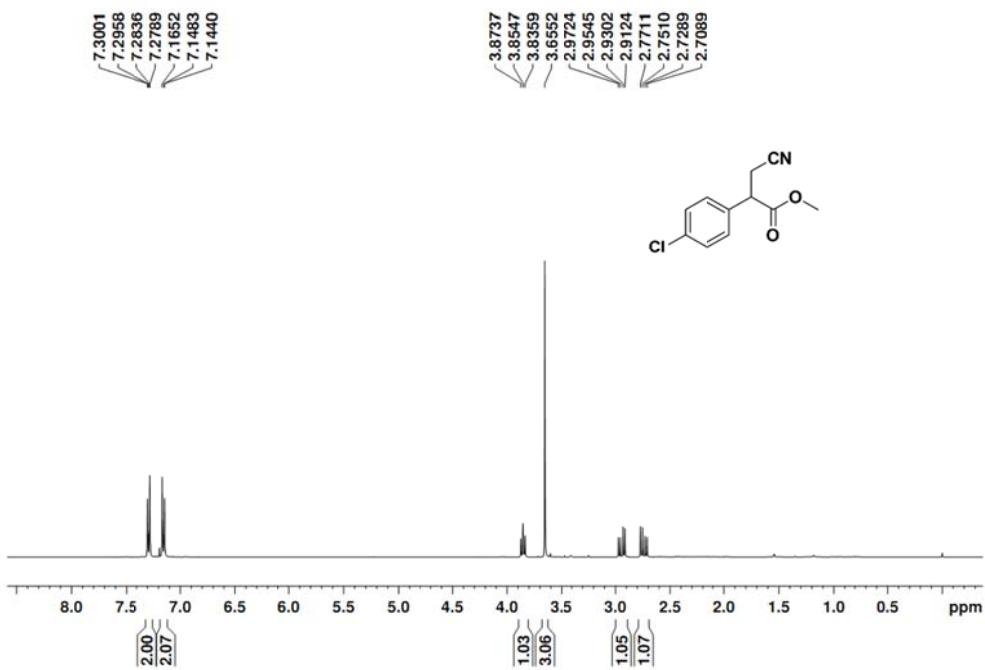


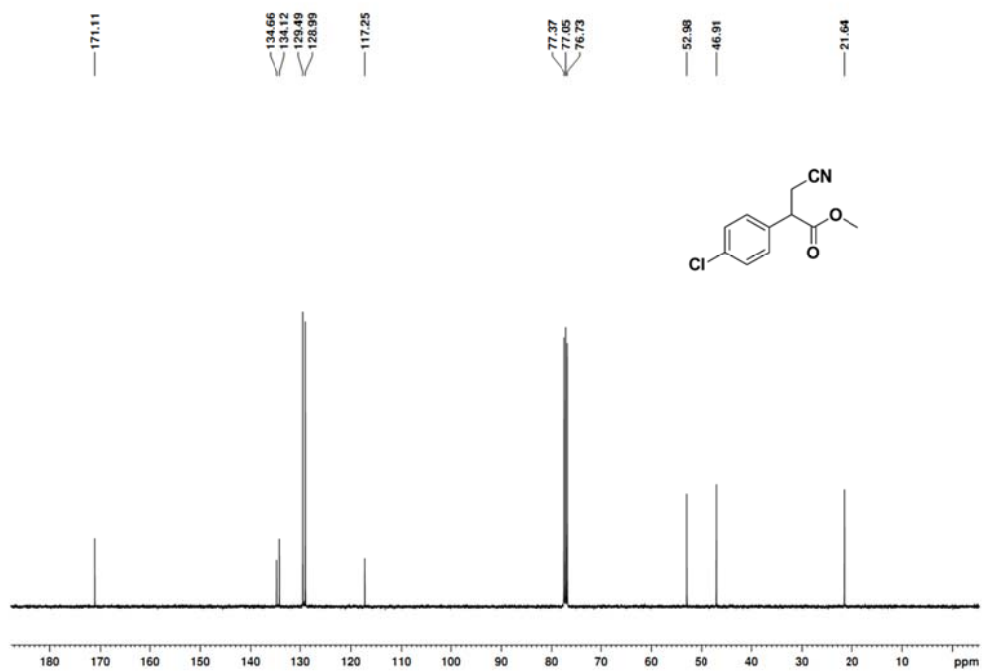
**methyl 3-cyano-2-(4-fluorophenyl)propanoate**



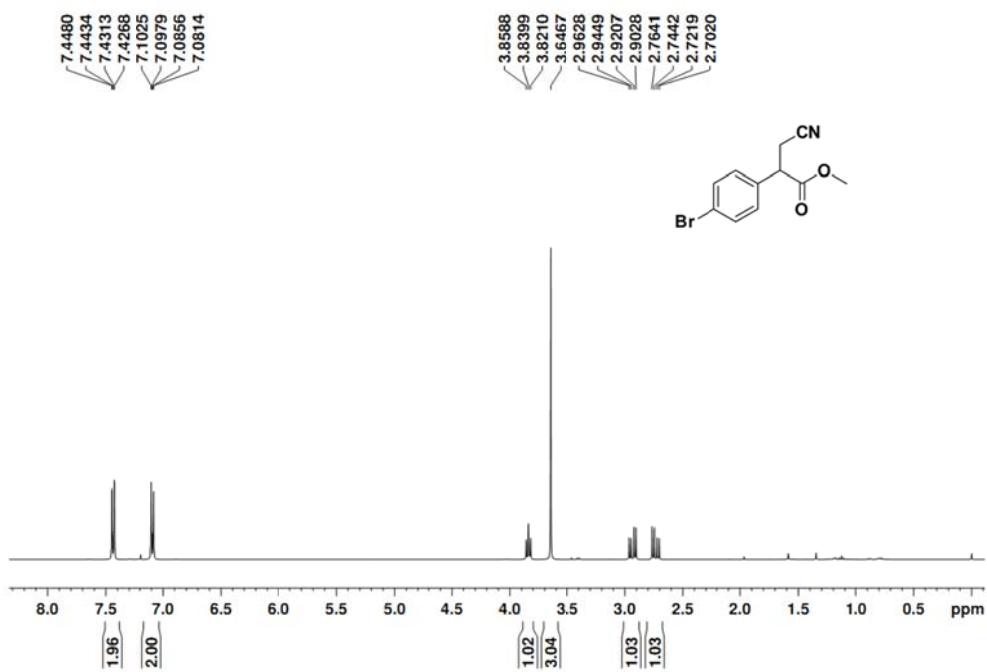


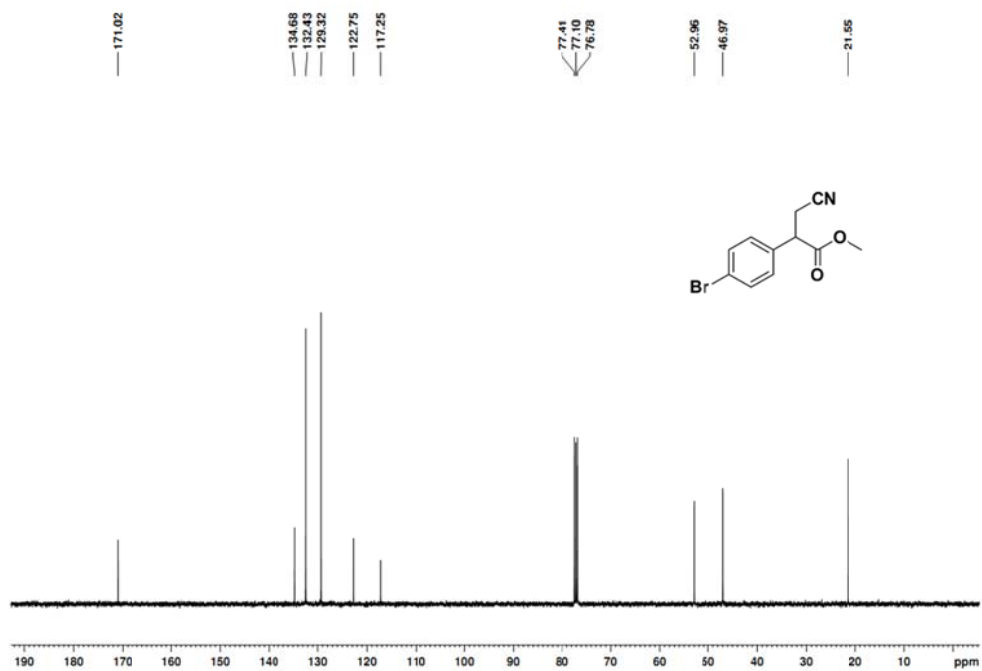
**methyl 2-(4-chlorophenyl)-3-cyanopropanoate**



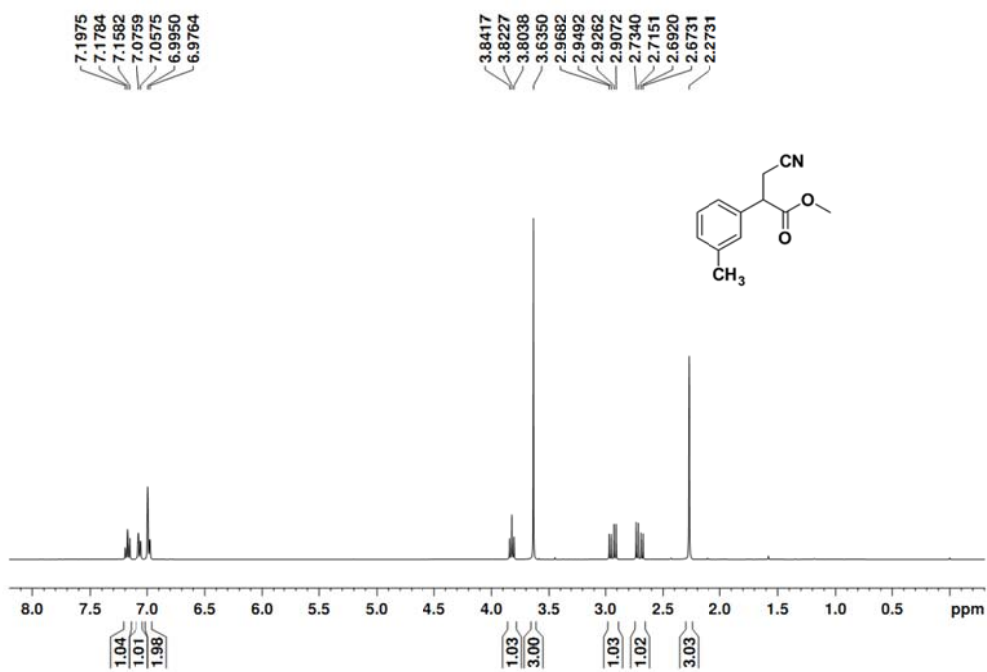


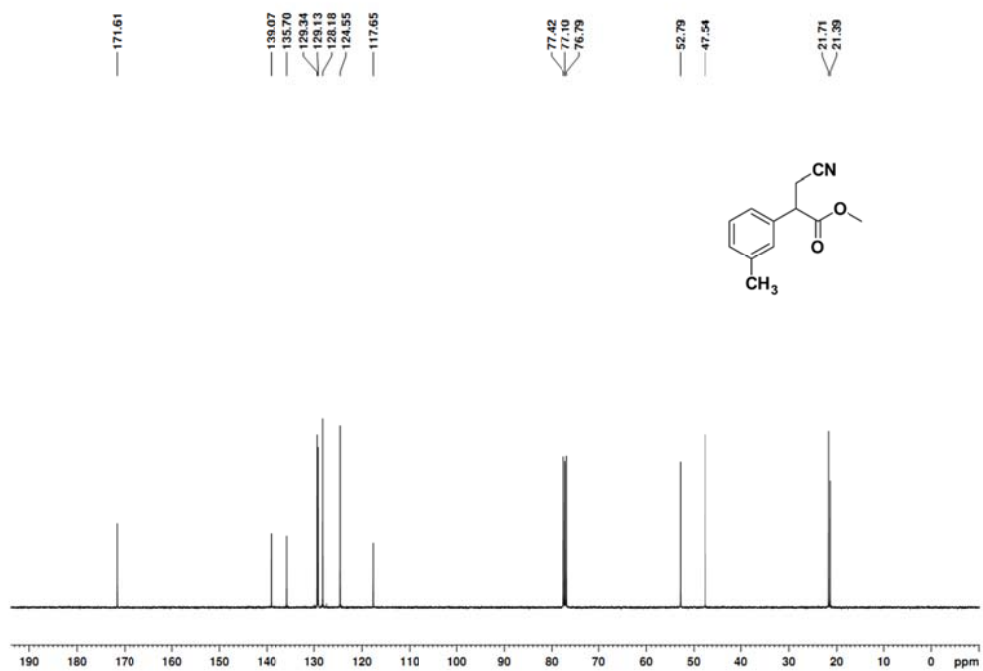
**methyl 2-(4-bromophenyl)-3-cyanopropanoate**



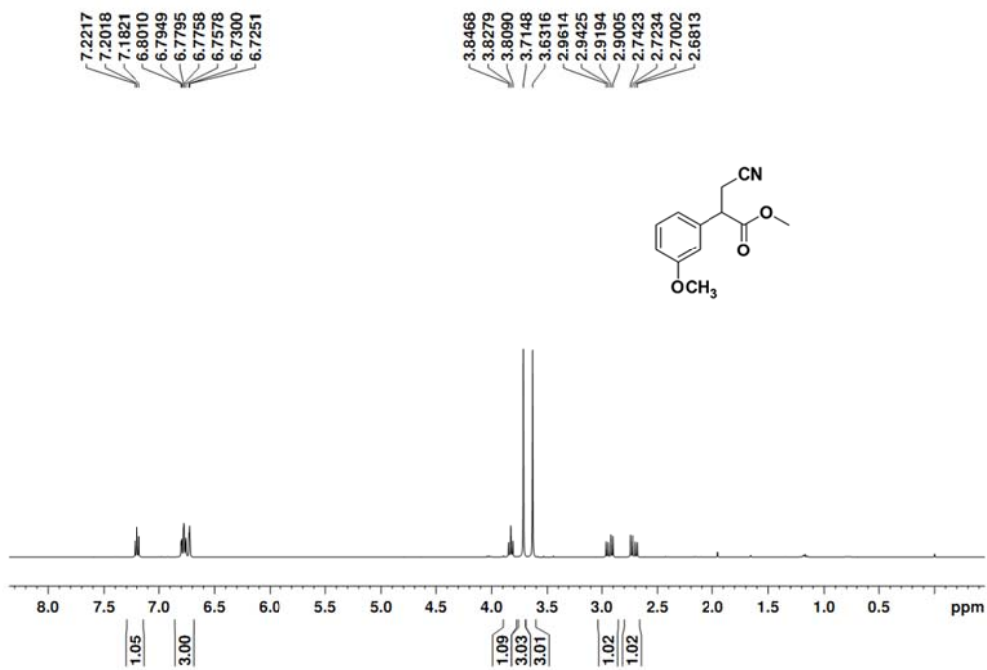


methyl 3-cyano-2-(*m*-tolyl)propanoate

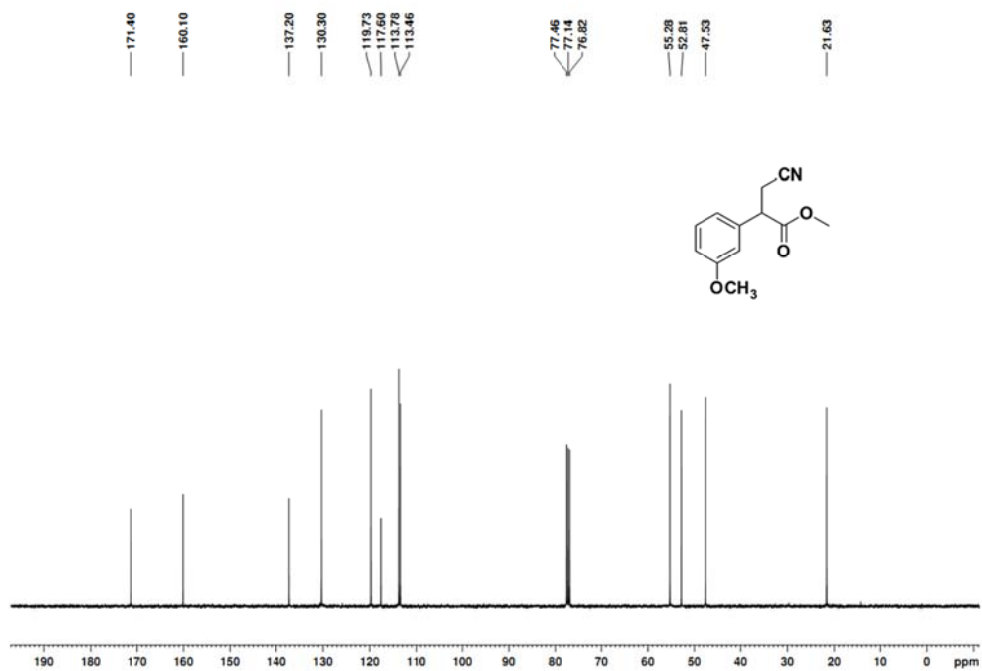




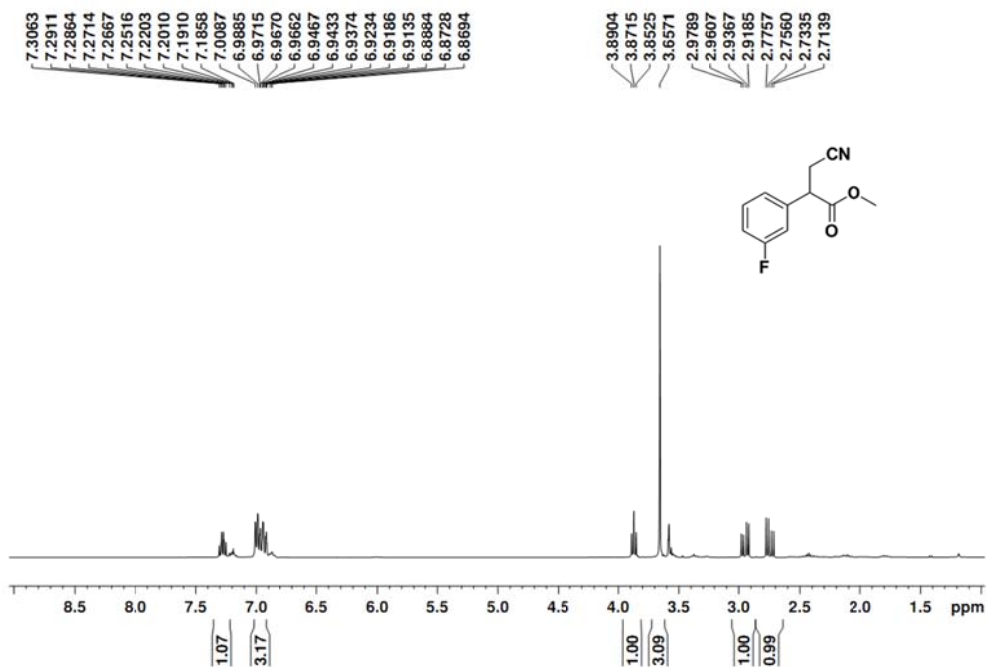
**methyl 3-cyano-2-(3-methoxyphenyl)propanoate**

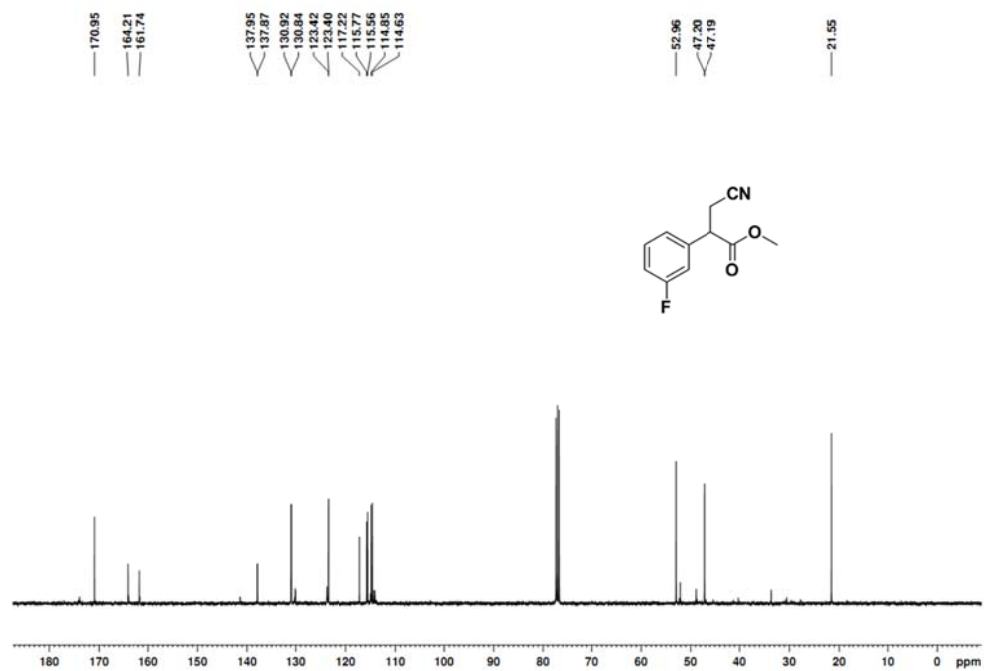




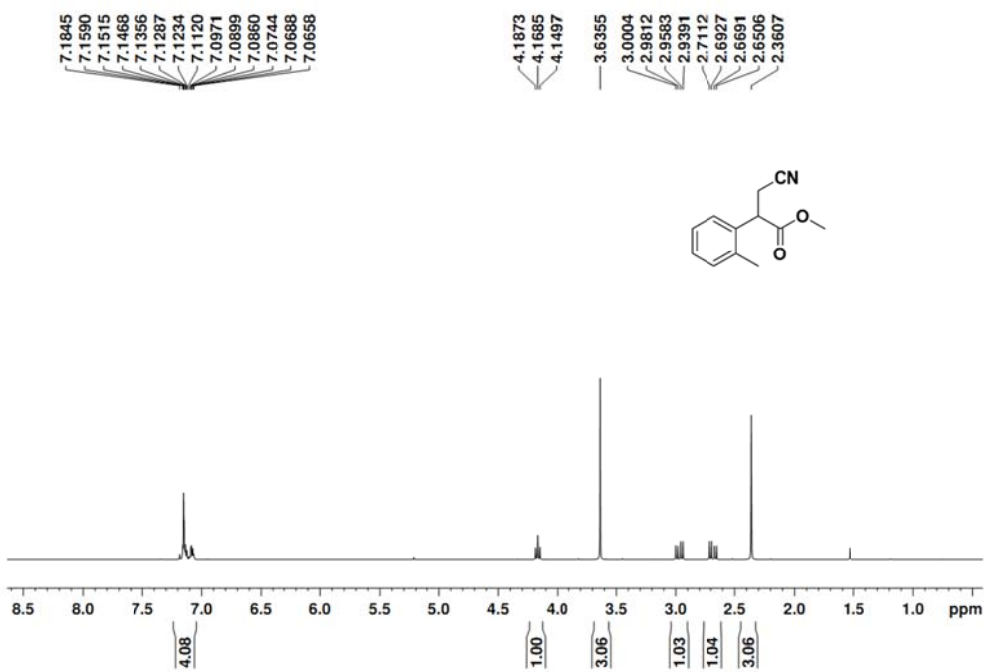


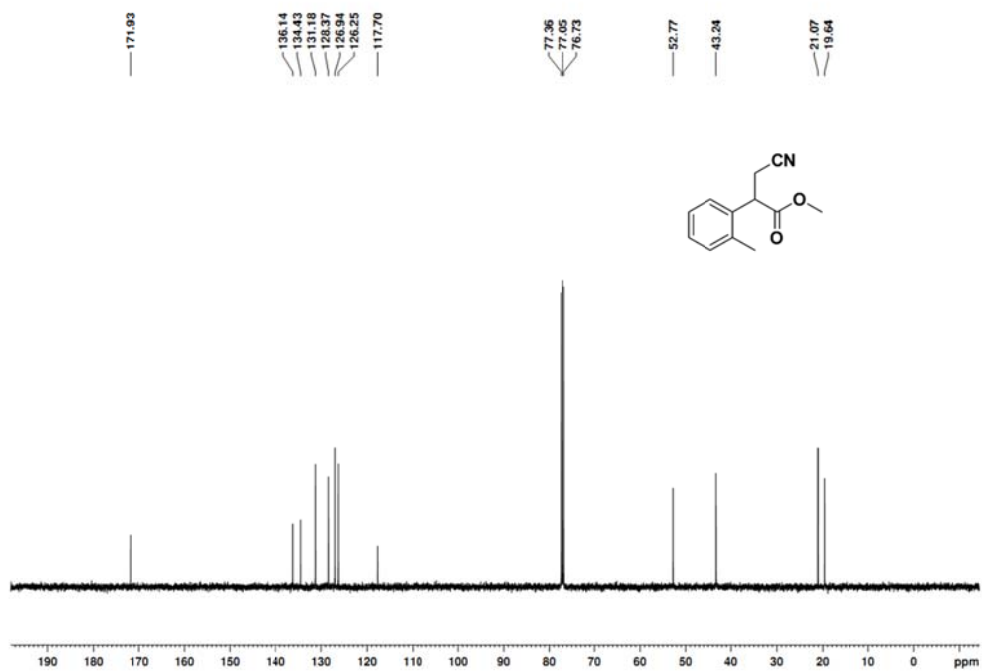
**methyl 3-cyano-2-(3-fluorophenyl)propanoate**



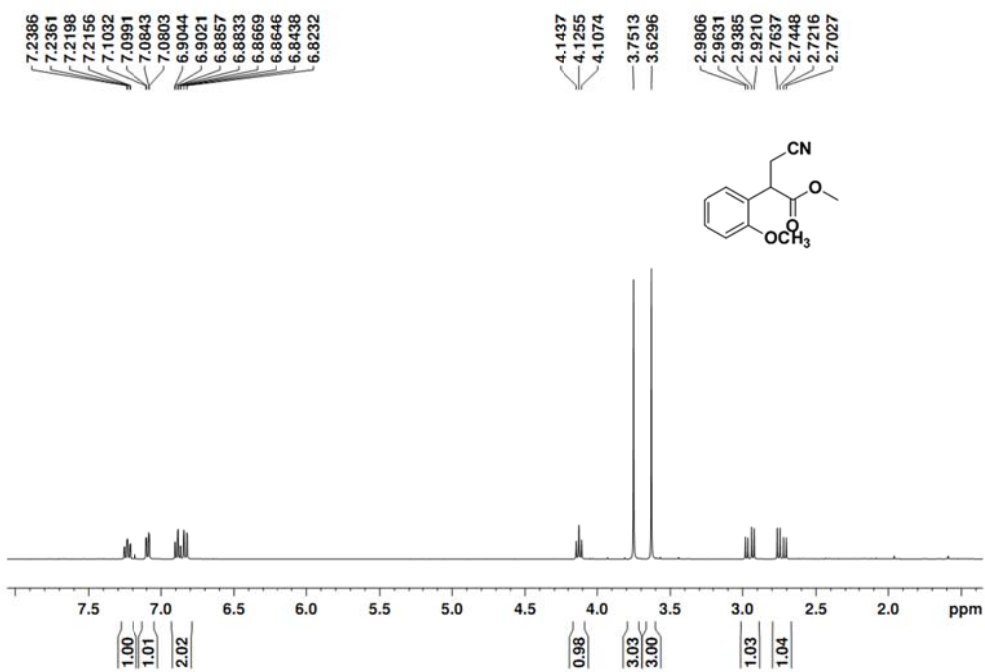


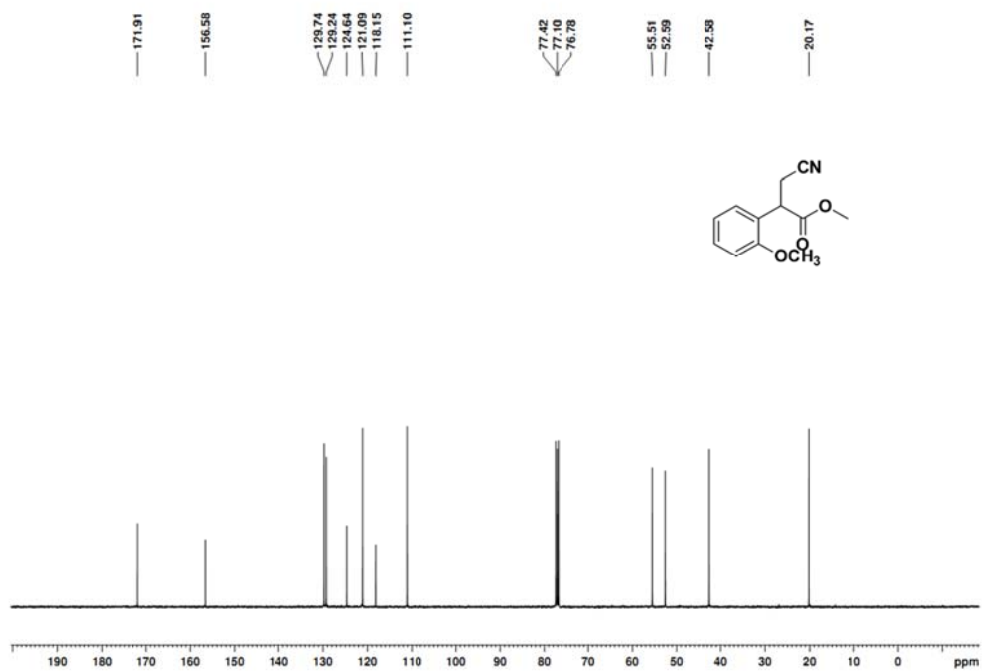
**methyl 3-cyano-2-(*o*-tolyl)propanoate**



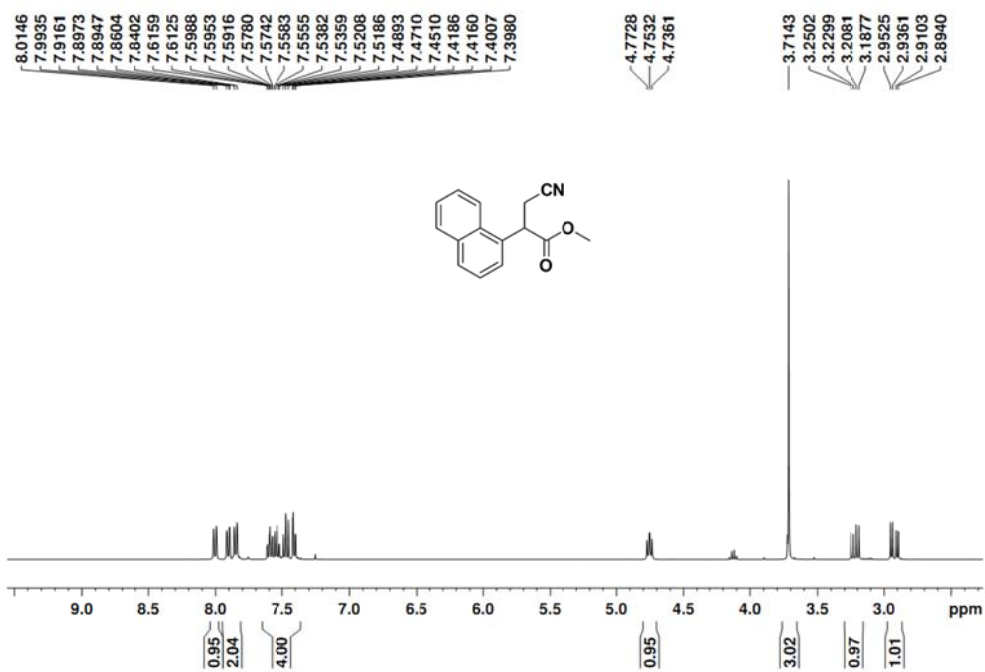


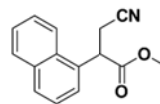
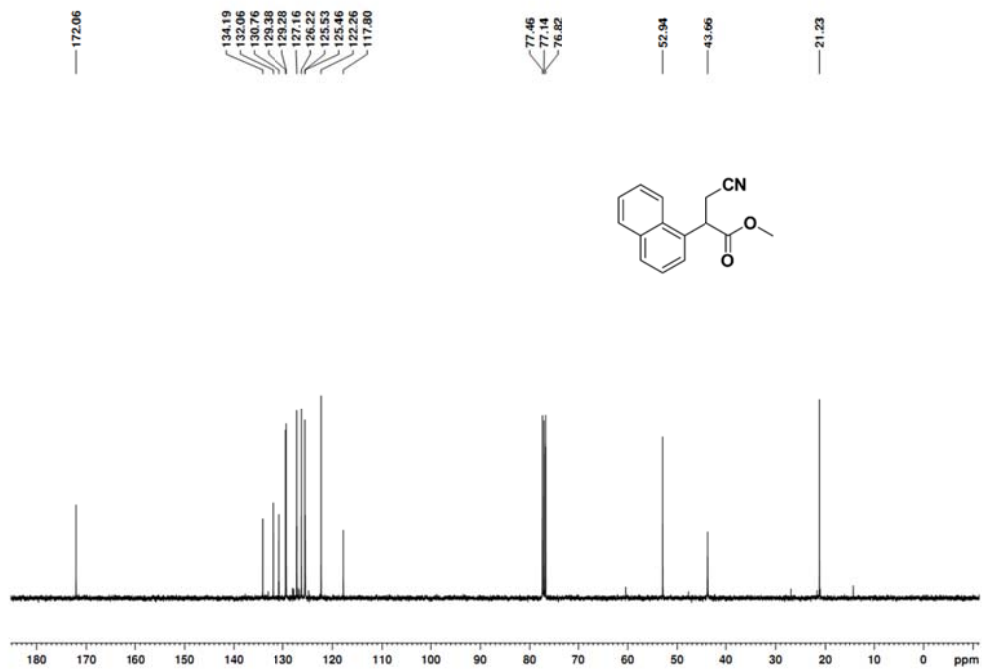
**methyl 3-cyano-2-(2-methoxyphenyl)propanoate**



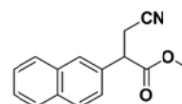
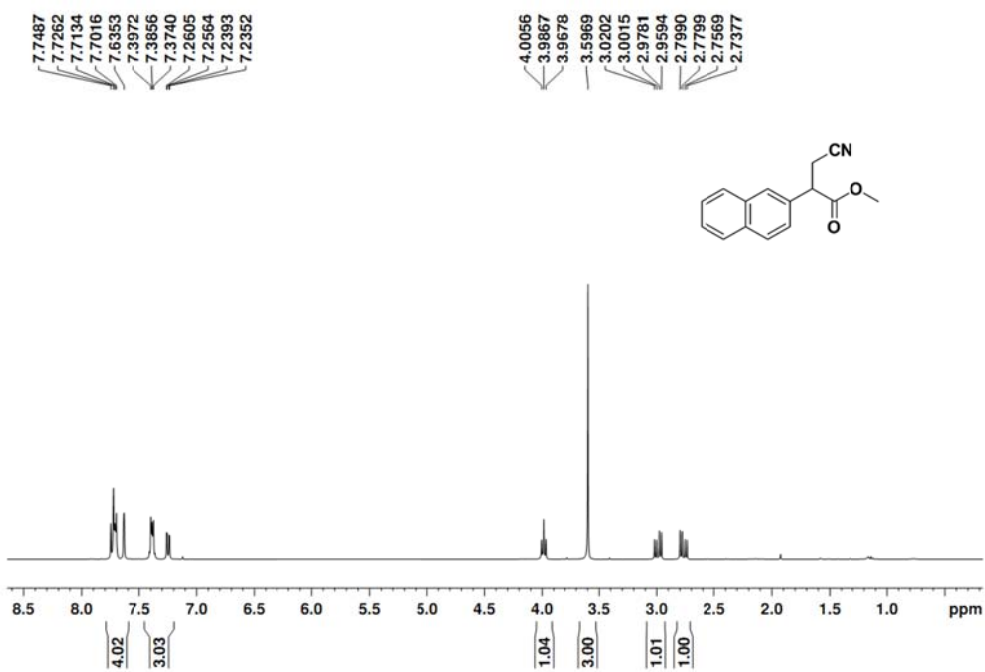


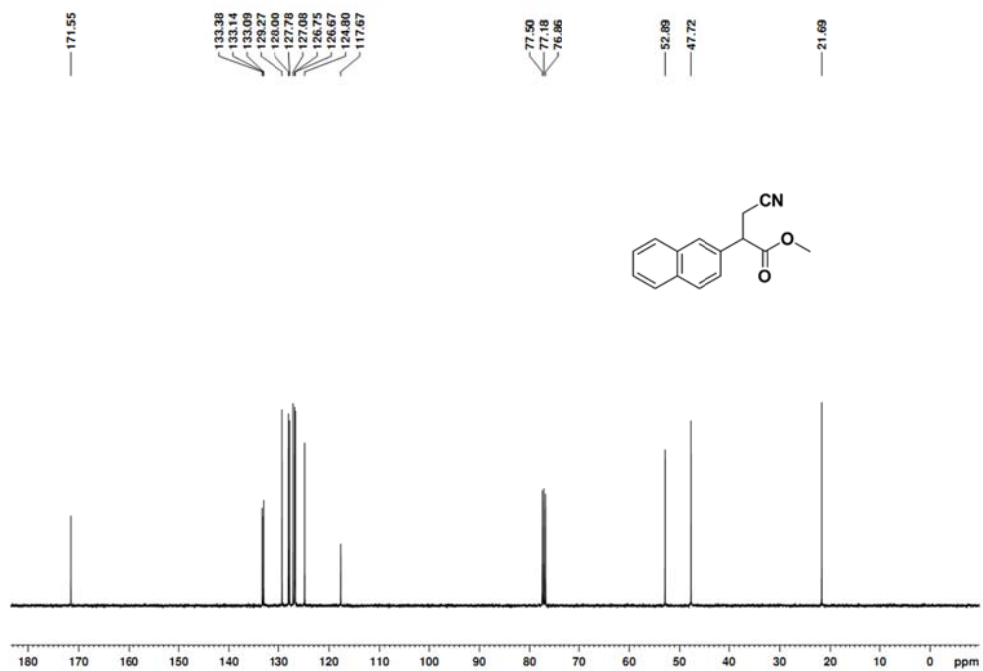
**methyl 3-cyano-2-(naphthalen-1-yl)propanoate**



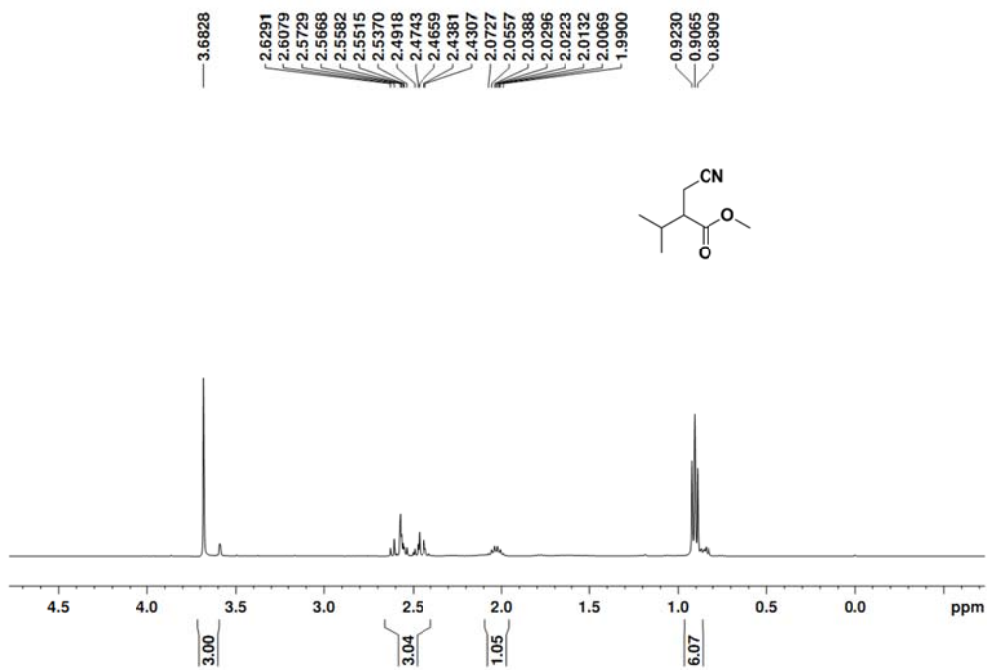


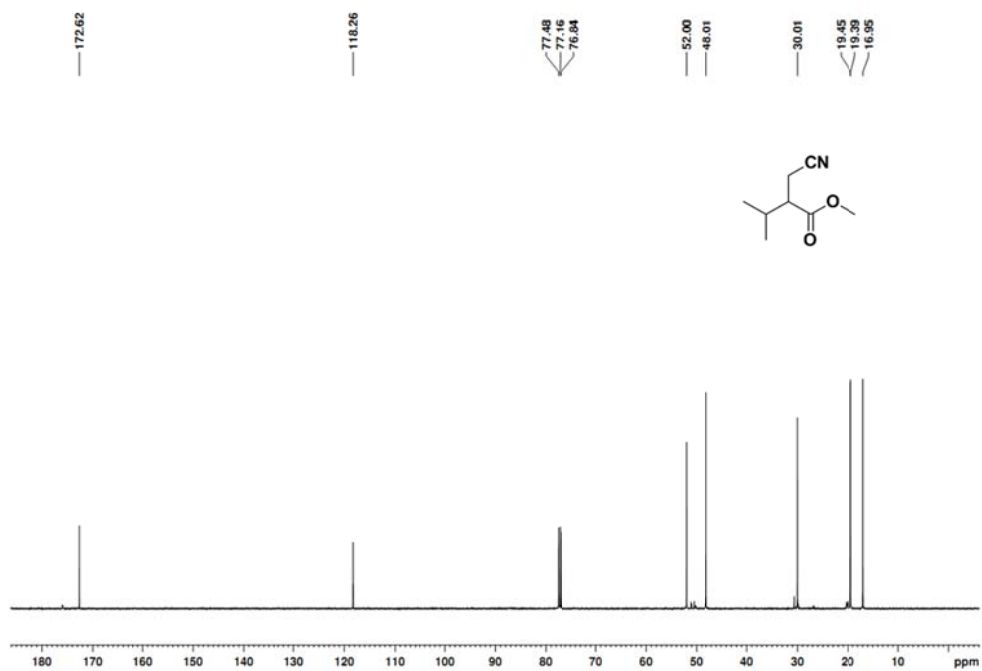
**methyl 3-cyano-2-(naphthalen-2-yl)propanoate**



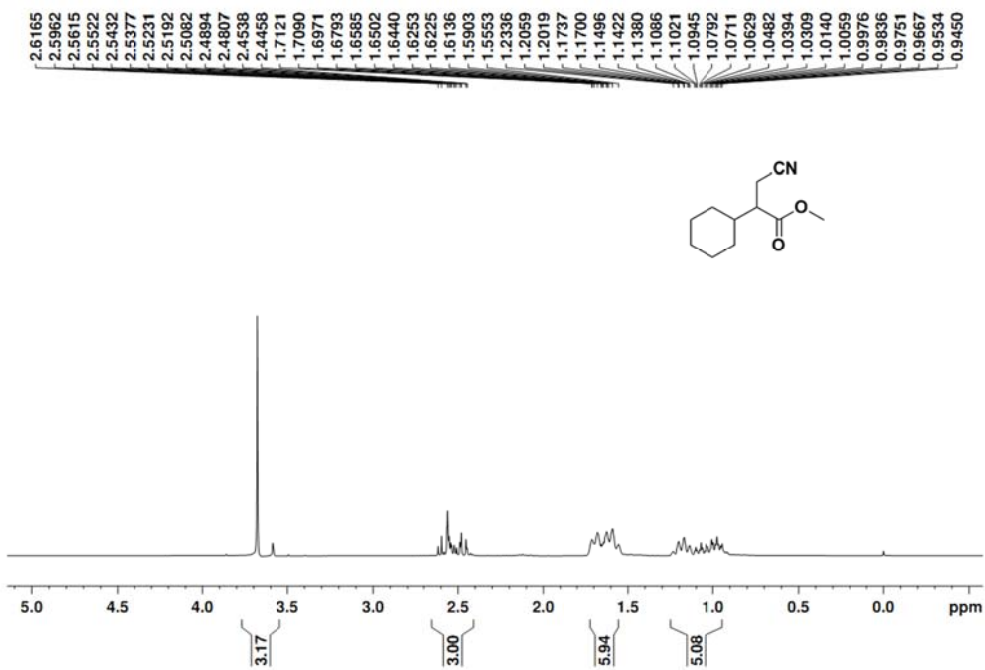


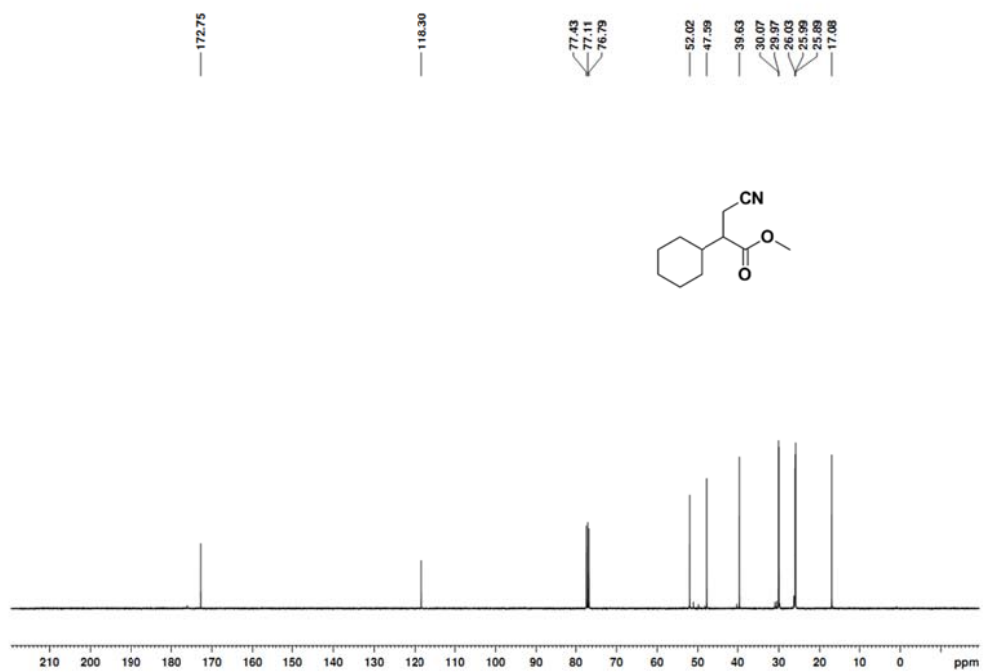
**methyl 2-(cyanomethyl)-3-methylbutanoate**



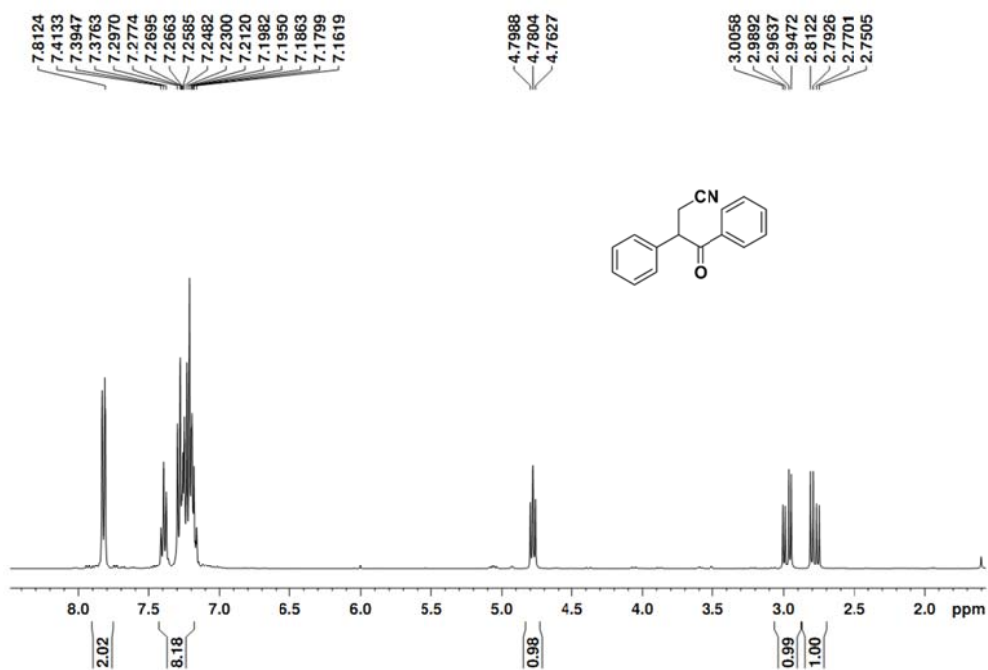


**methyl 3-cyano-2-cyclohexylpropanoate**

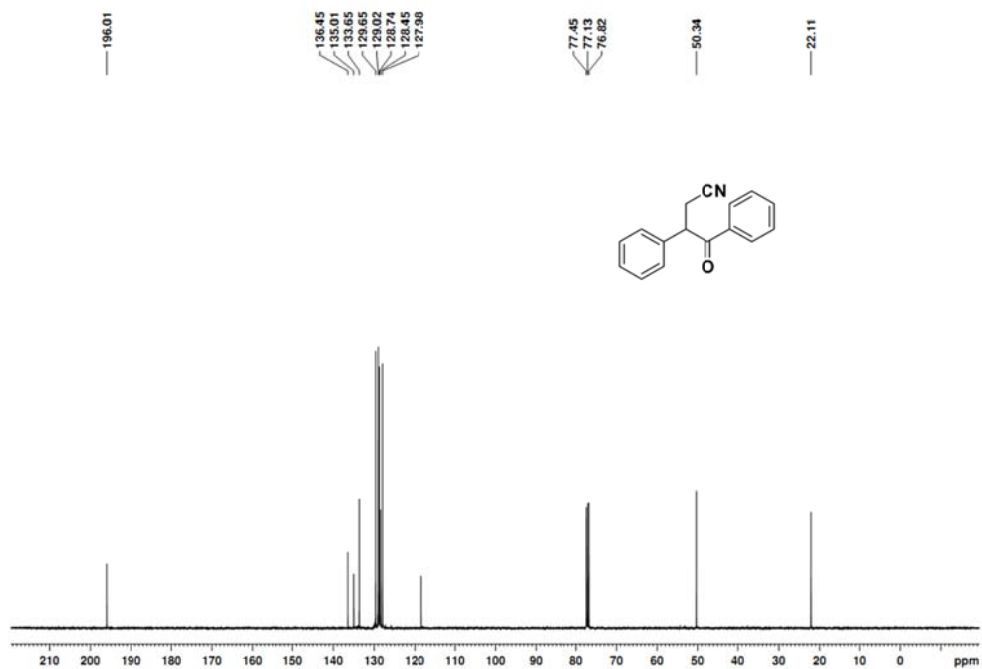




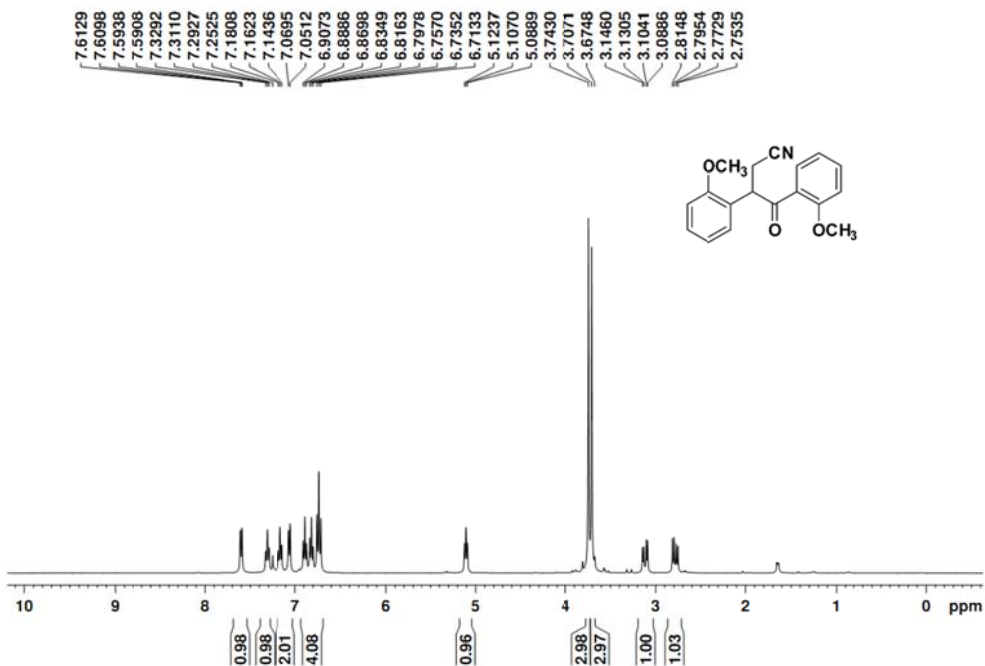
#### 4-oxo-3,4-diphenylbutanenitrile (4a)

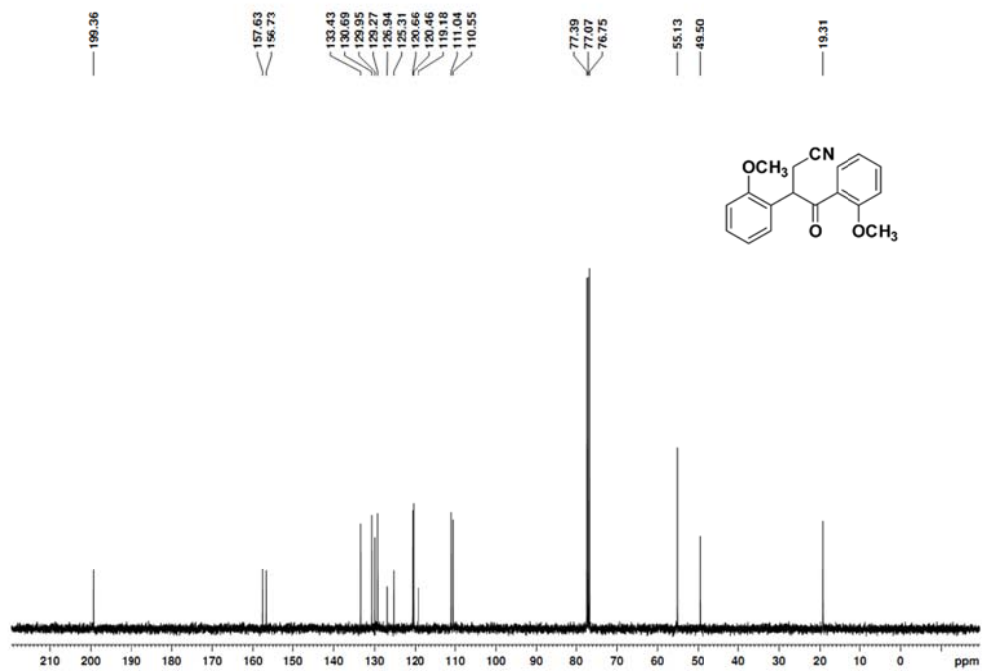




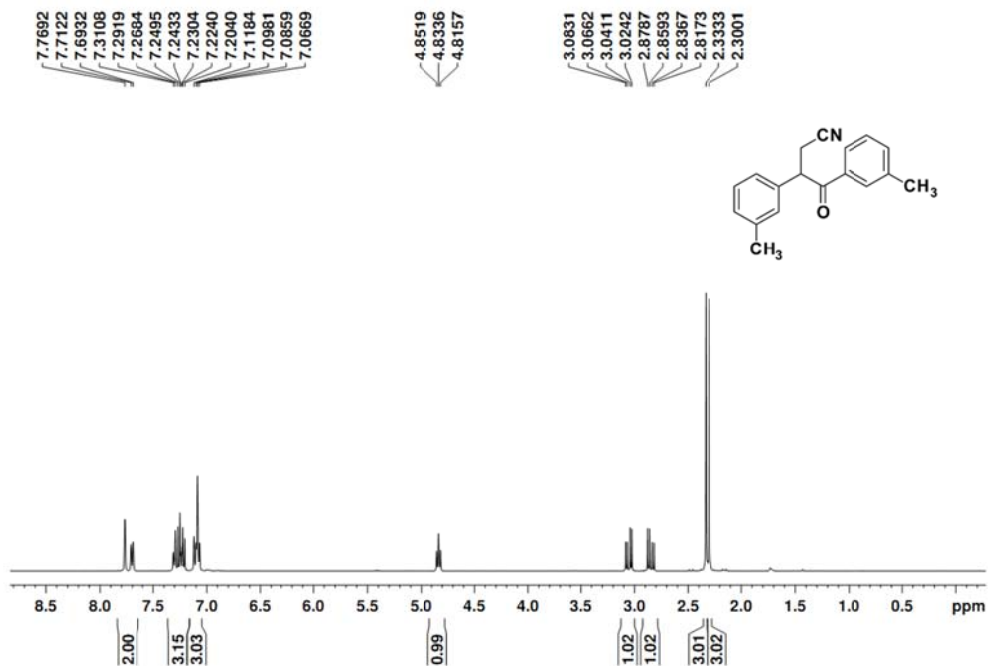


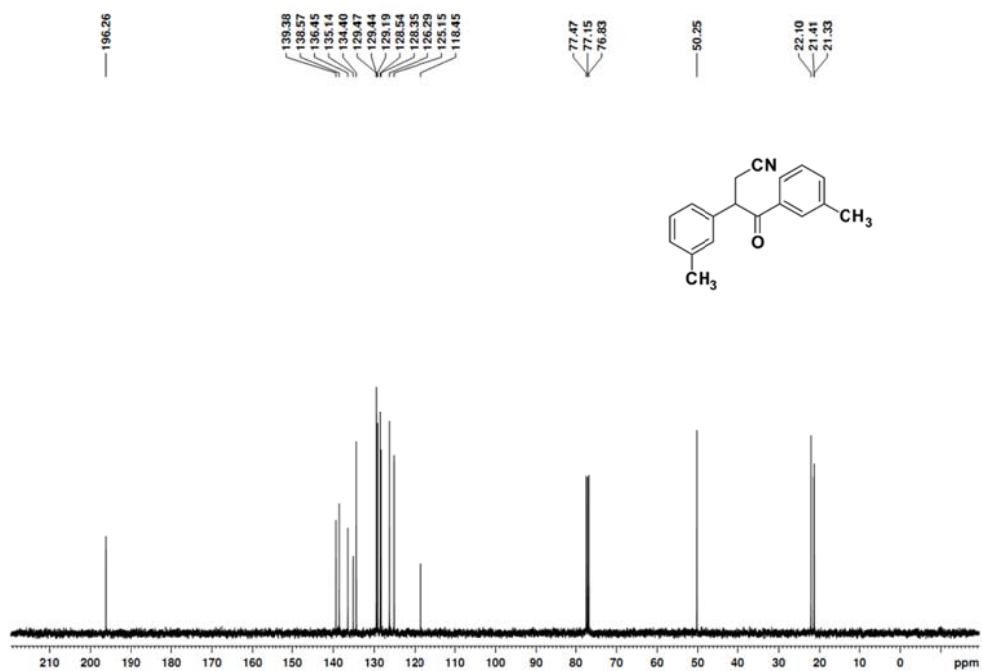
### 3,4-bis(2-methoxyphenyl)-4-oxobutanenitrile (4b)



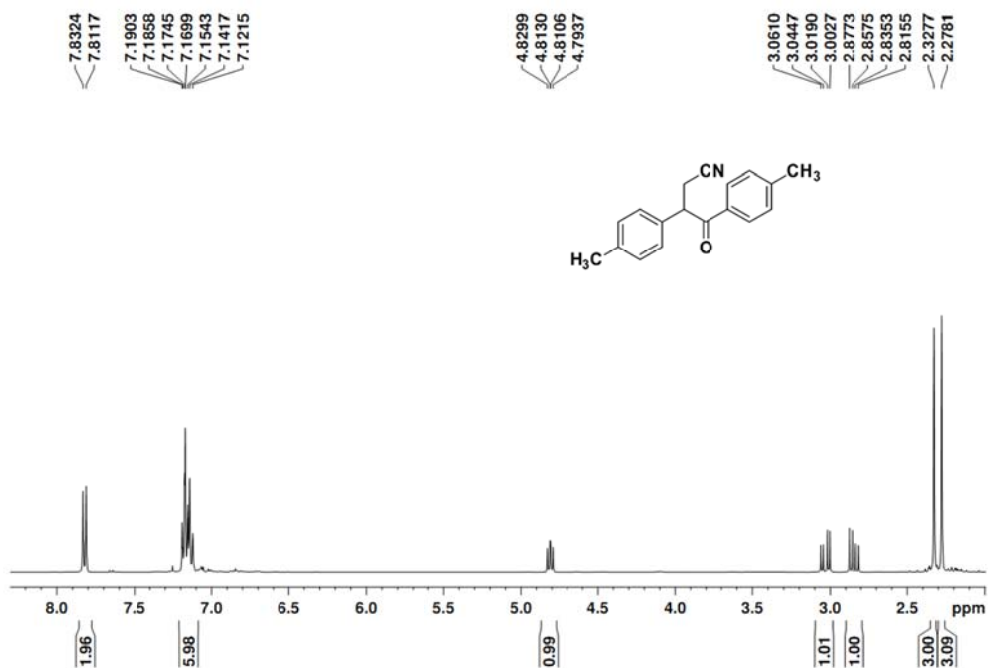


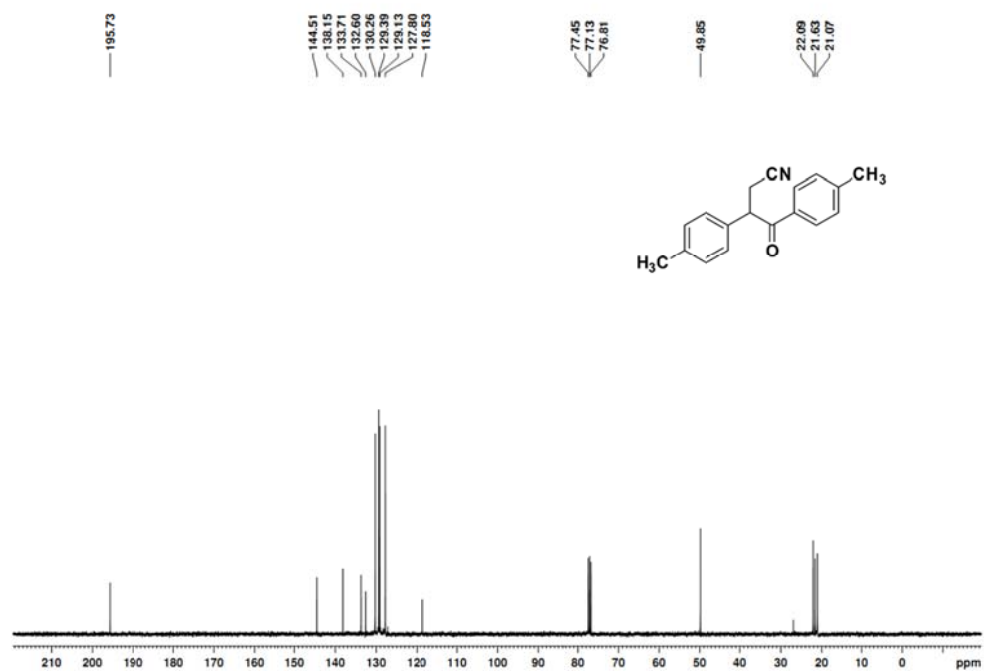
### 4-oxo-3,4-di-*m*-tolylbutanenitrile (4c)



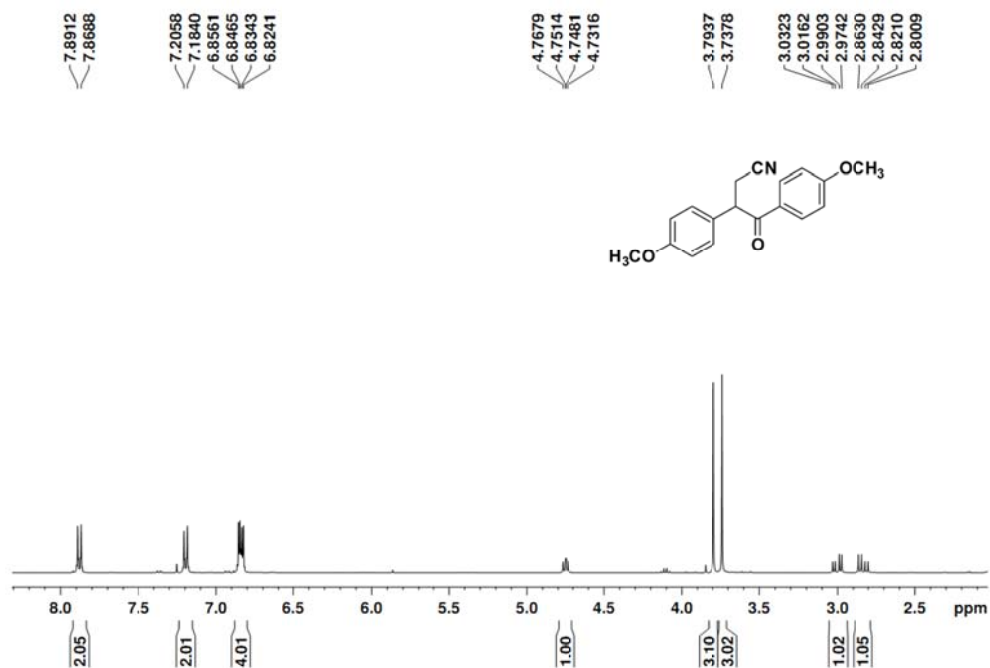


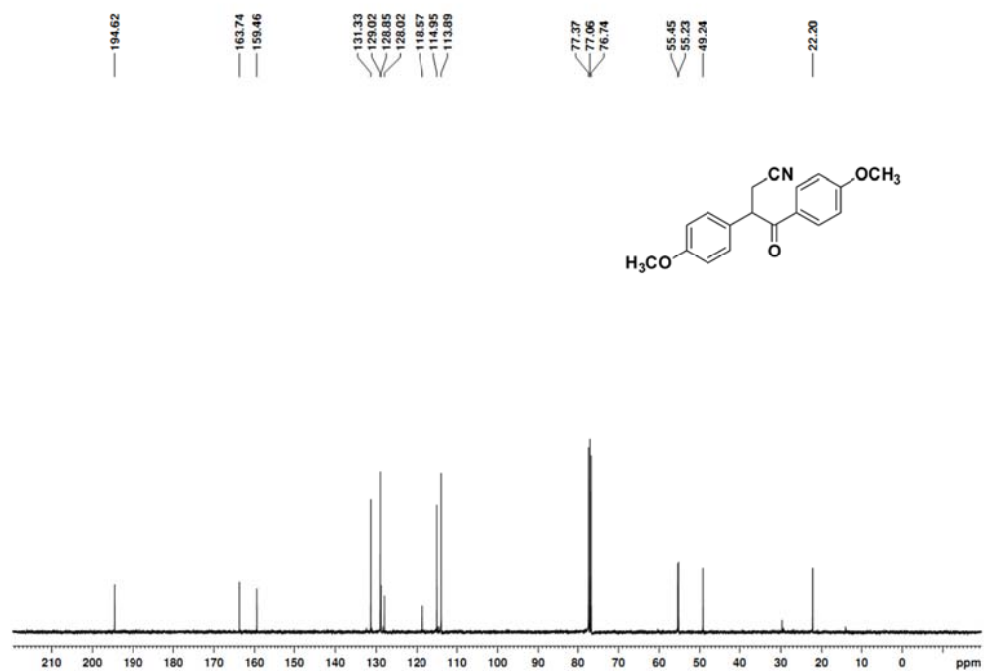
#### 4-oxo-3,4-di-*p*-tolylbutanenitrile (4d)



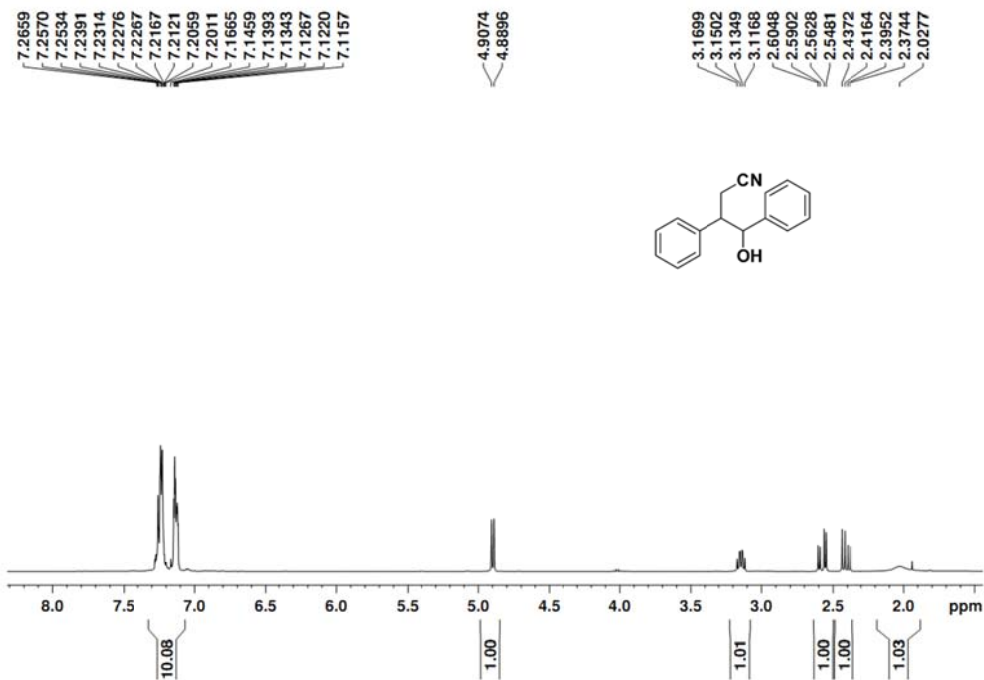


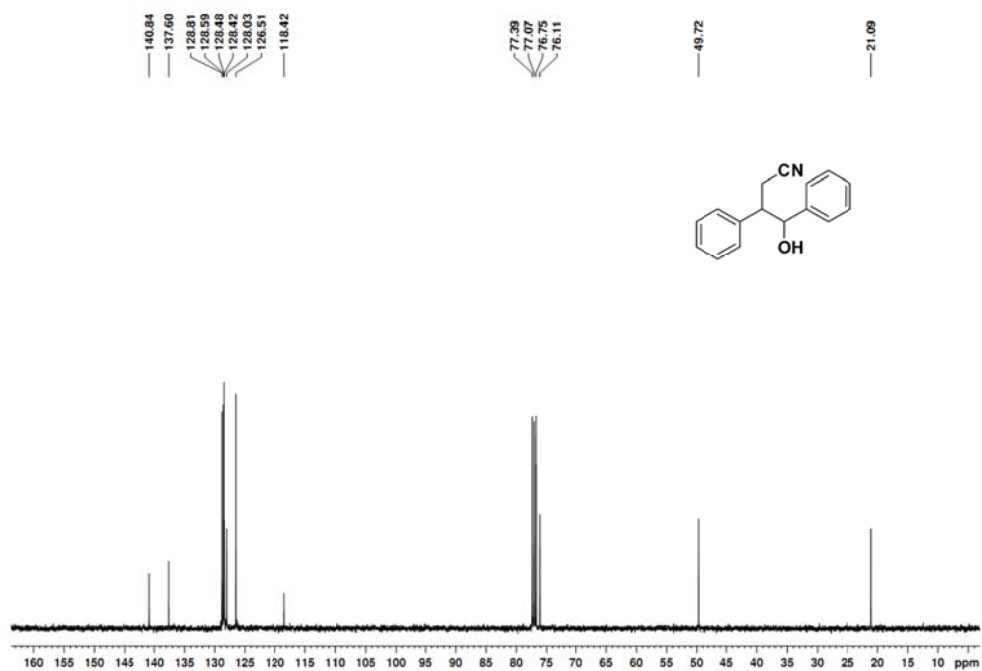
### 3,4-bis(4-methoxyphenyl)-4-oxobutanenitrile (4e)



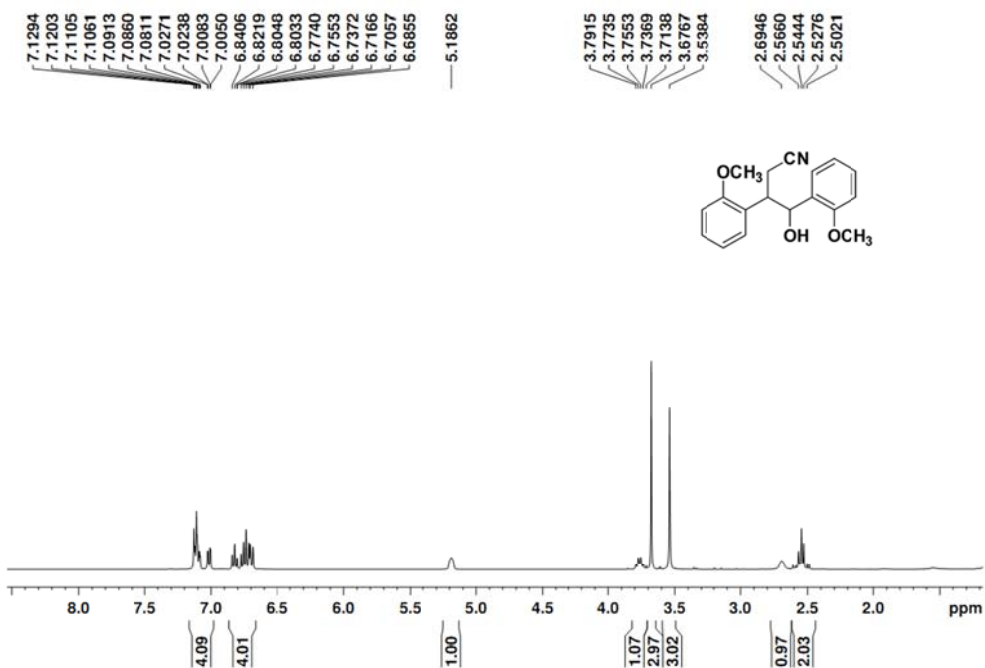


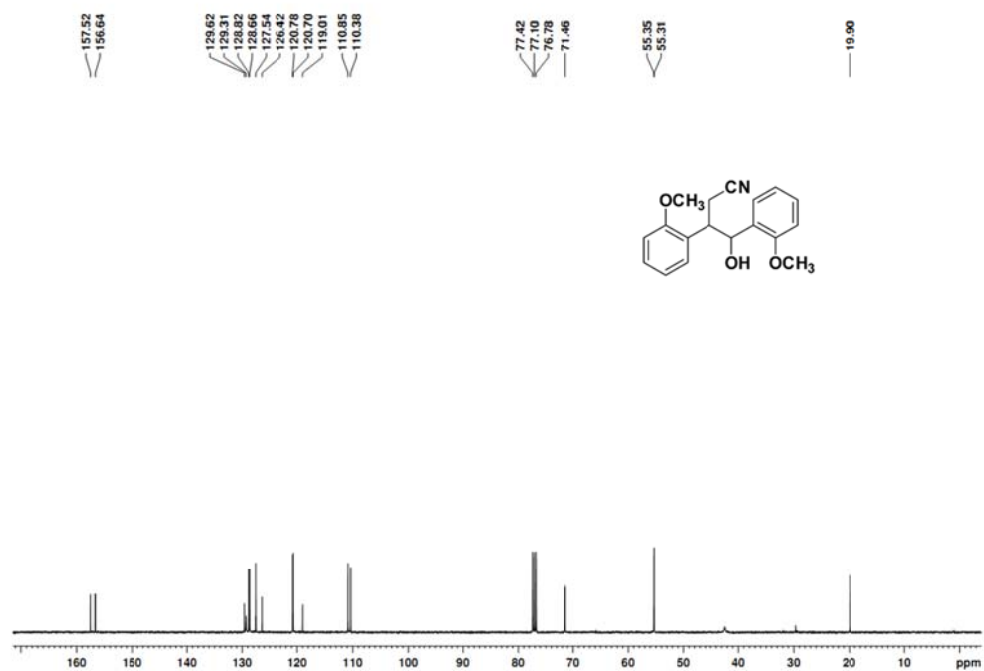
#### 4-hydroxy-3,4-diphenylbutanenitrile (5a)



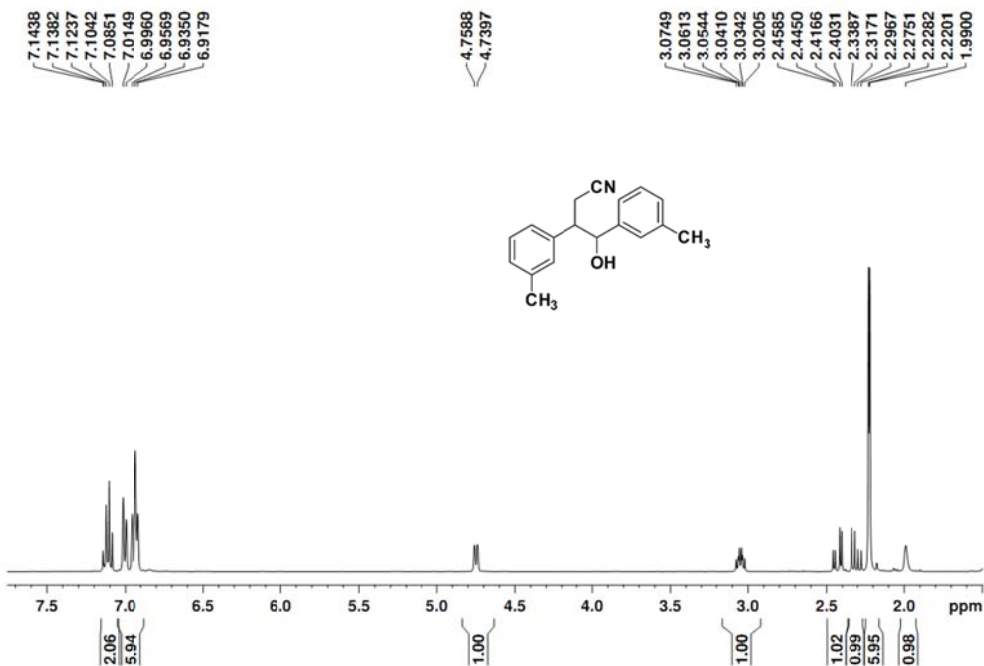


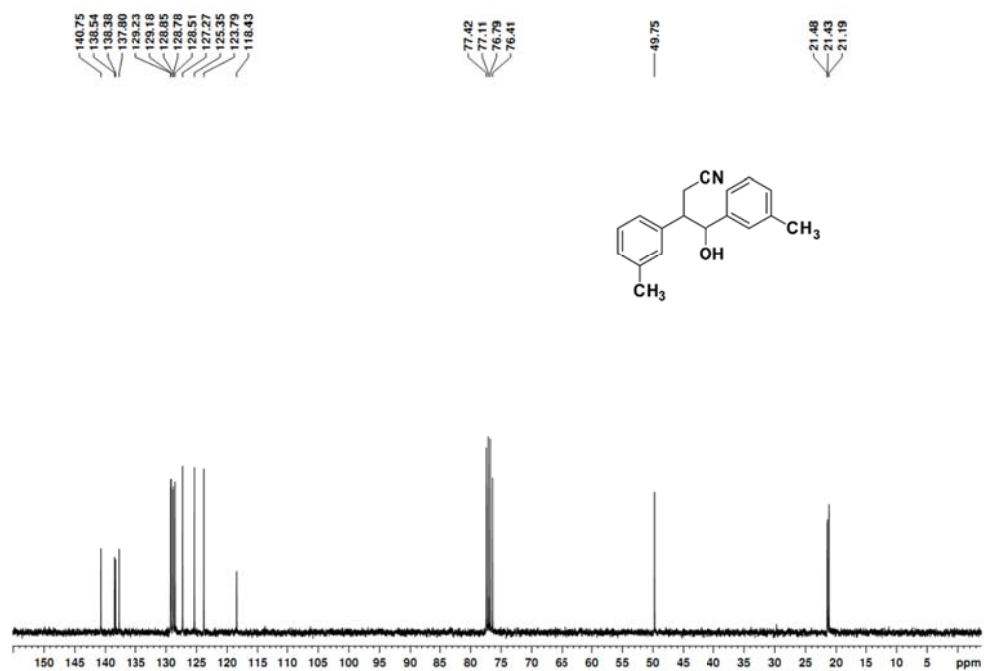
#### 4-hydroxy-3,4-bis(2-methoxyphenyl)butanenitrile (5b)



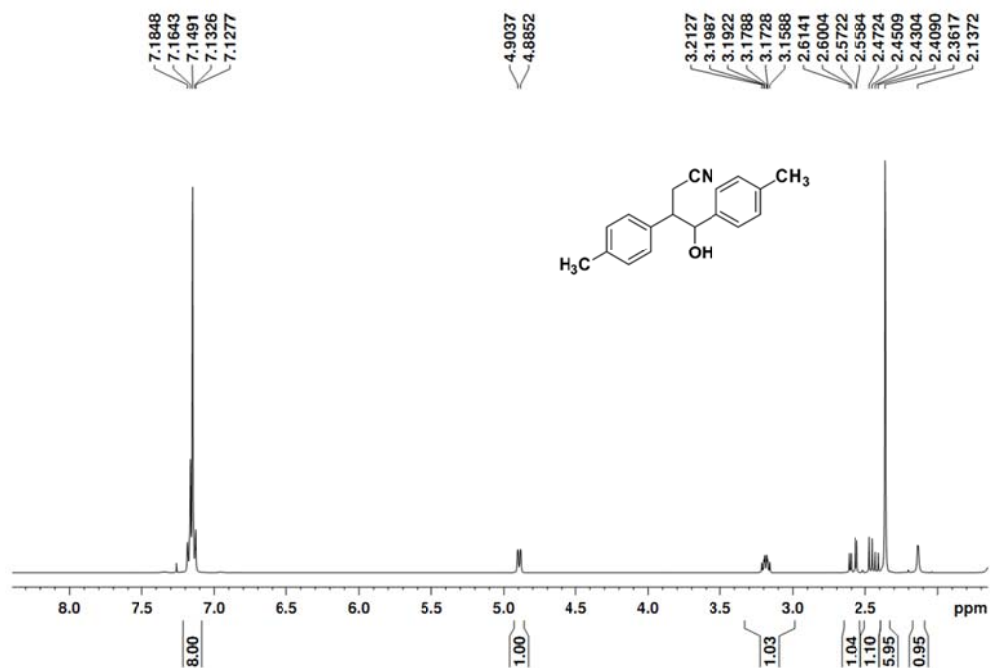


#### 4-hydroxy-3,4-di-*m*-tolylbutanenitrile (5c)

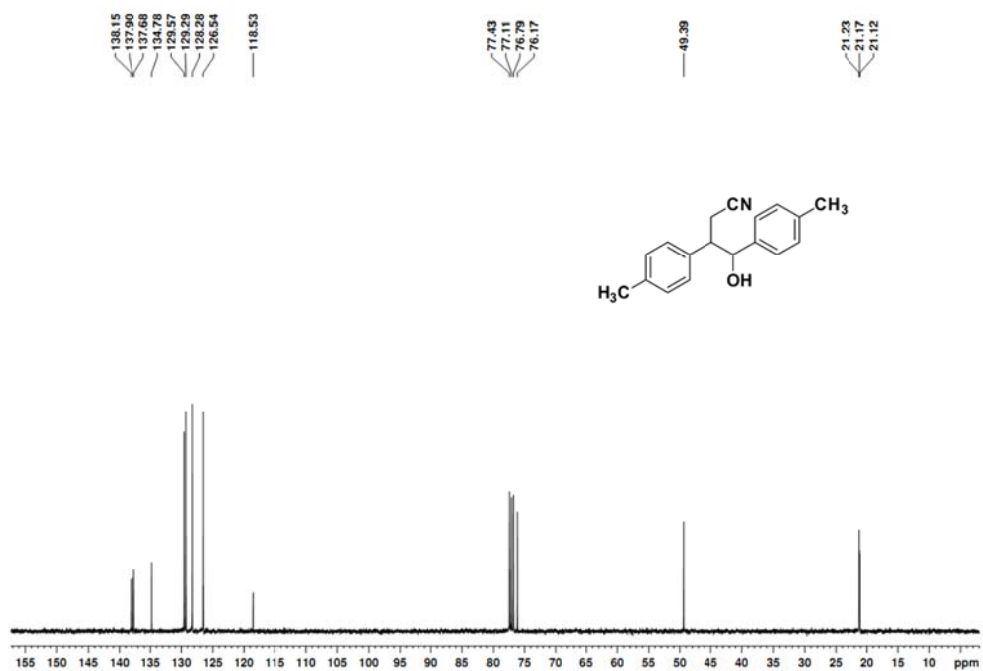




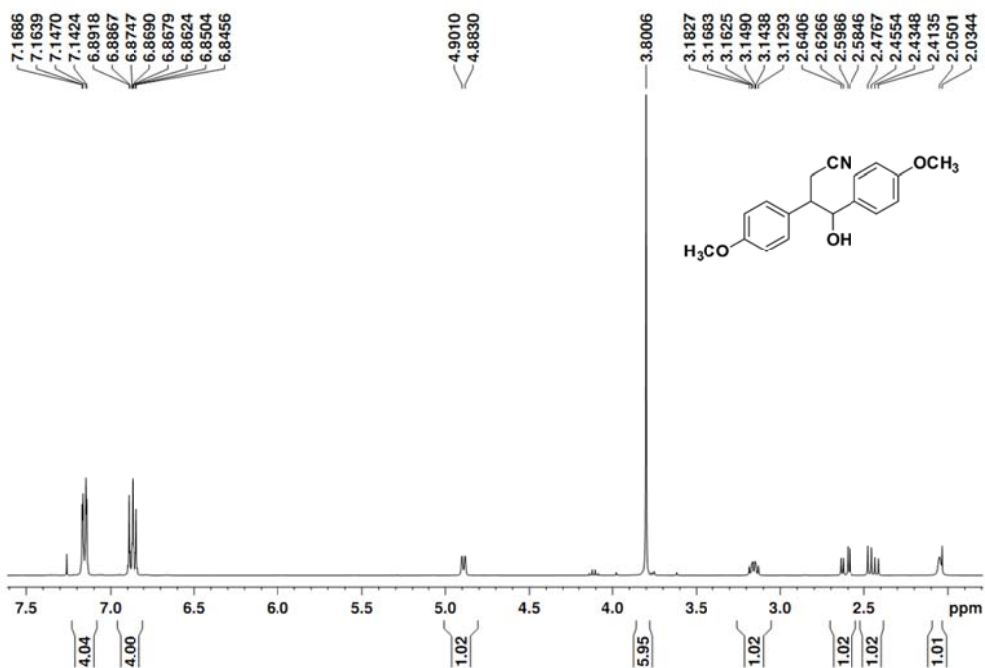
#### 4-hydroxy-3,4-di-p-tolylbutanenitrile (5d)

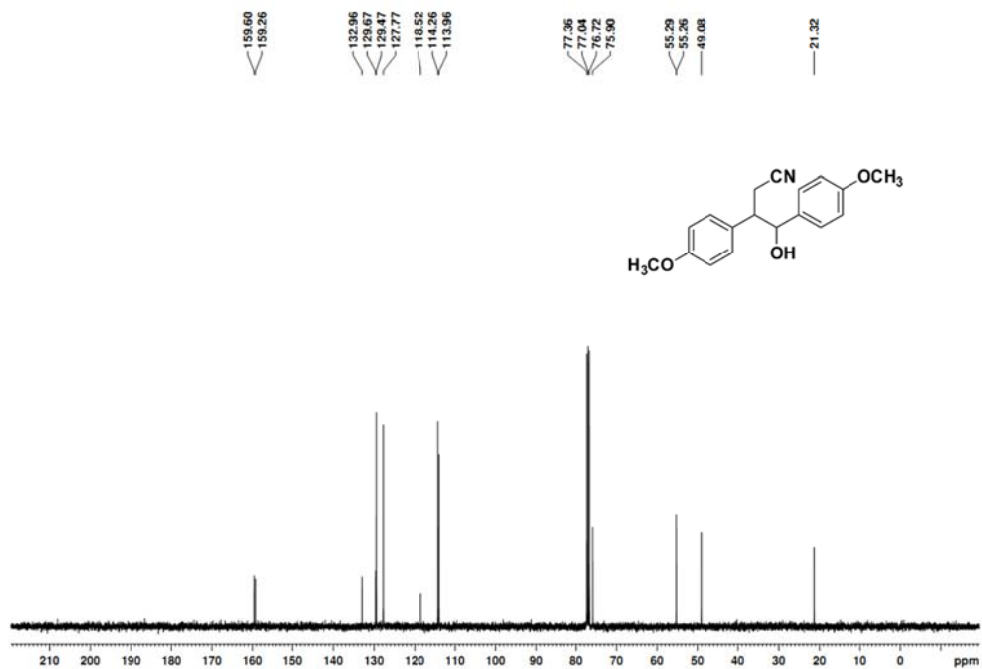




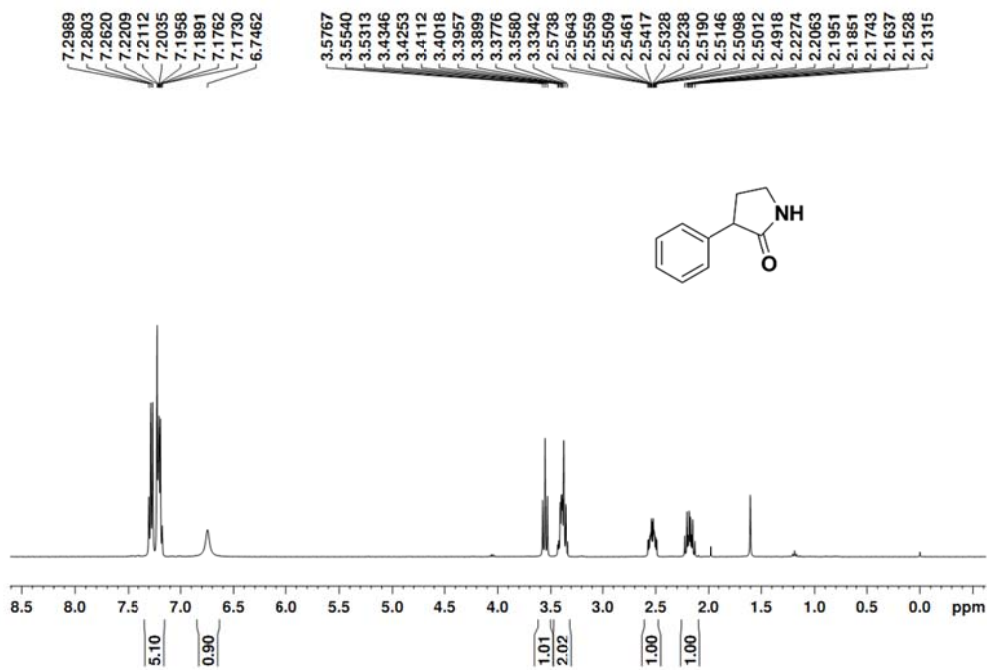


**4-hydroxy-3,4-bis(4-methoxyphenyl)butanenitrile (5e)**

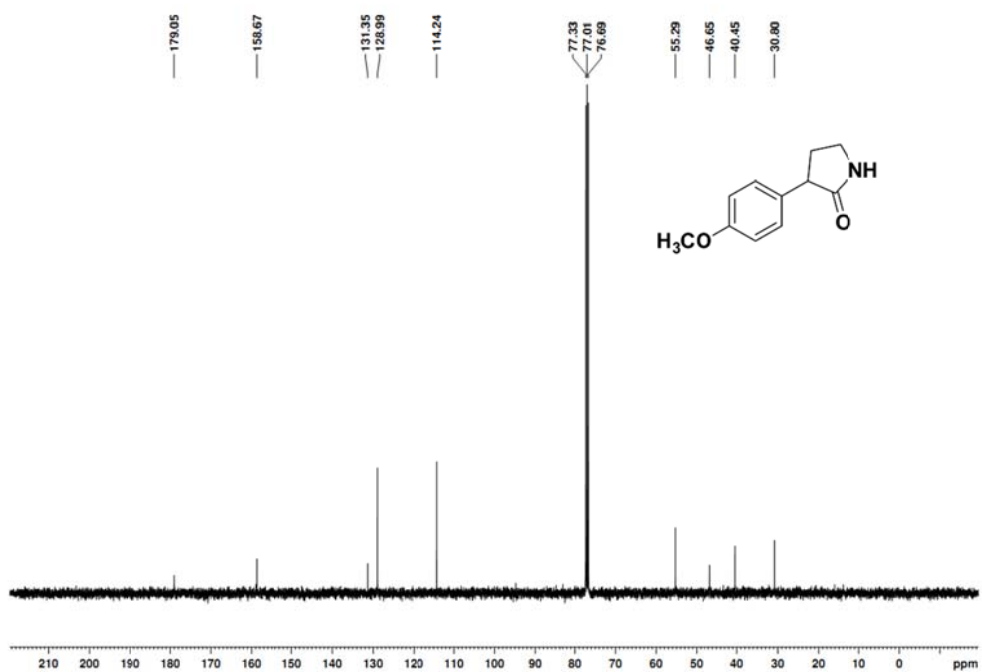
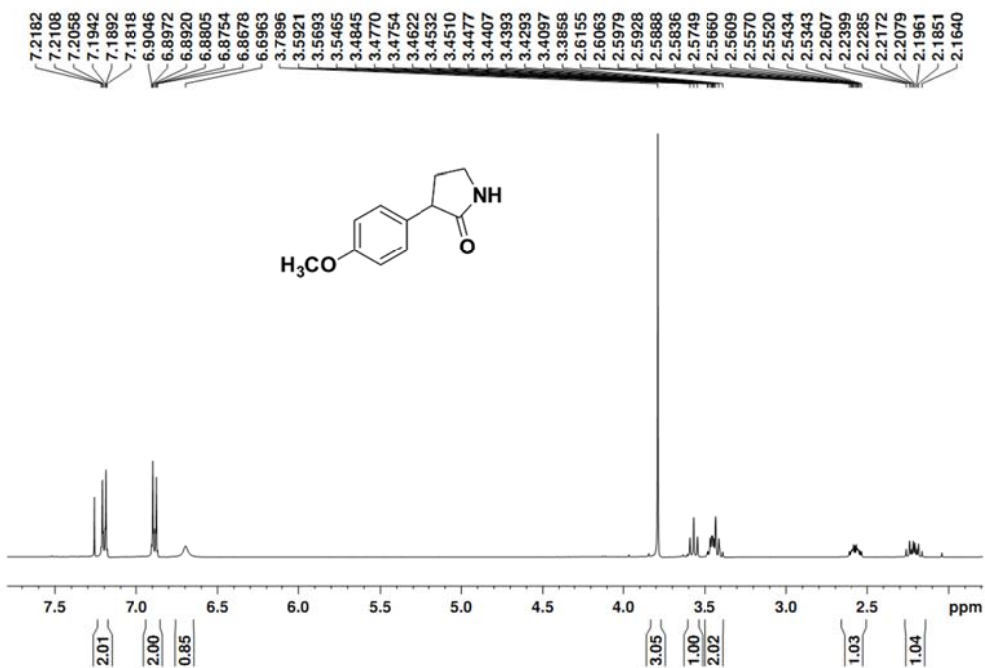




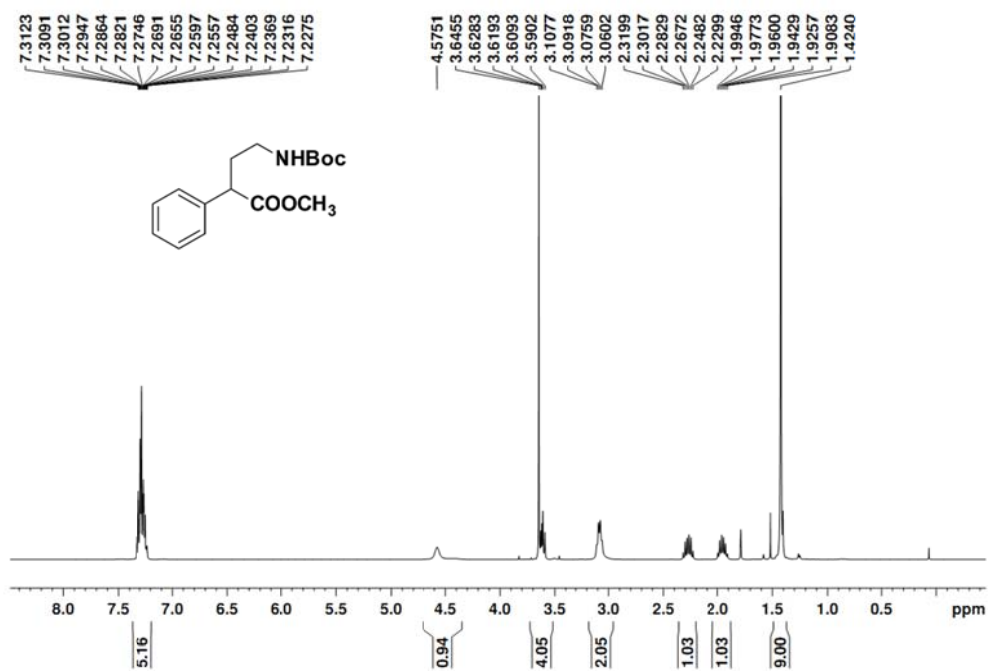
### 3-phenylpyrrolidin-2-one (6)



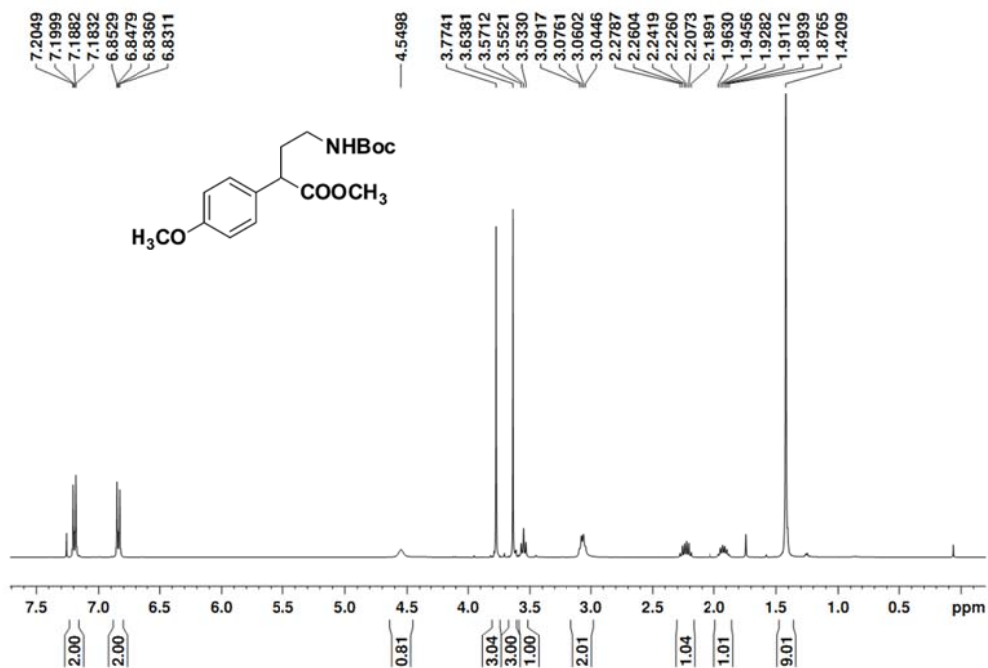
### 3-(4-methoxyphenyl)pyrrolidin-2-one (7)

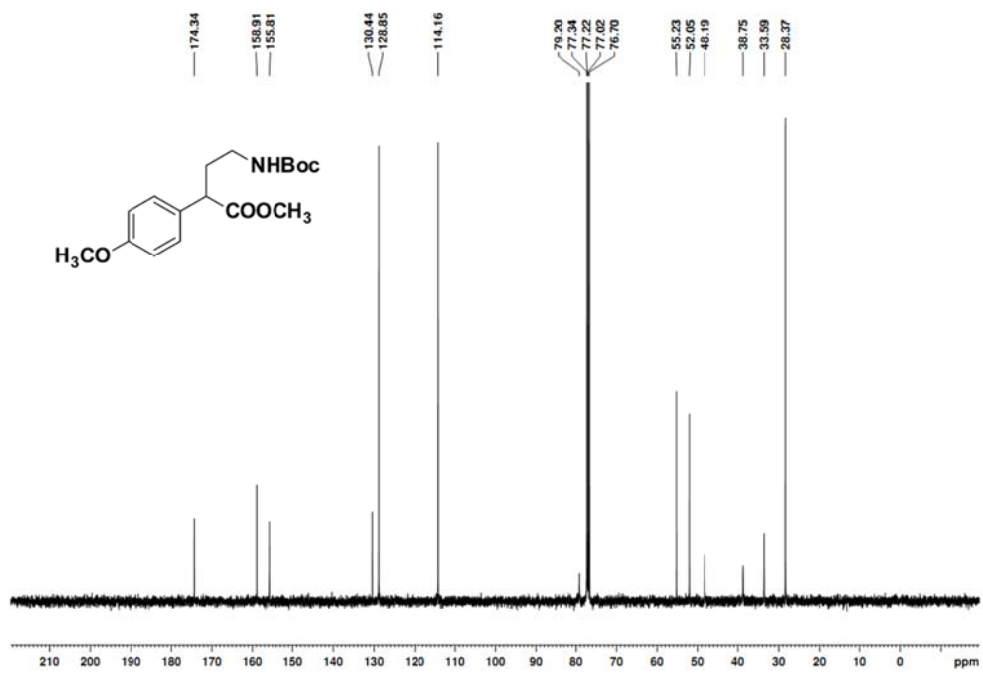


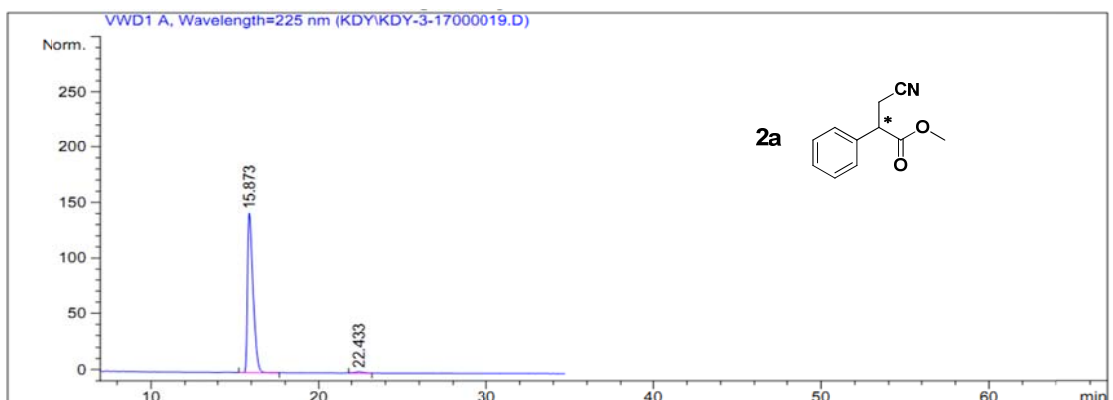
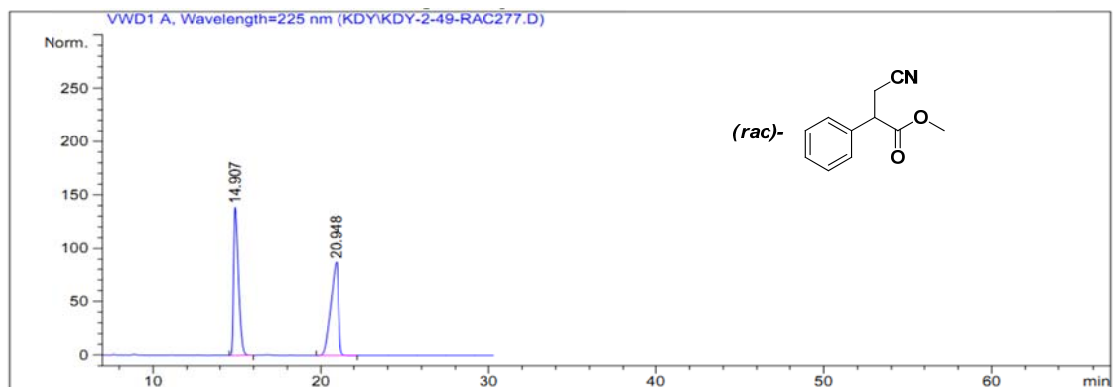
methyl 4-((*tert*-butoxycarbonyl)amino)-2-phenylbutanoate (8)



methyl 4-((*tert*-butoxycarbonyl)amino)-2-(4-methoxyphenyl)butanoate (9)

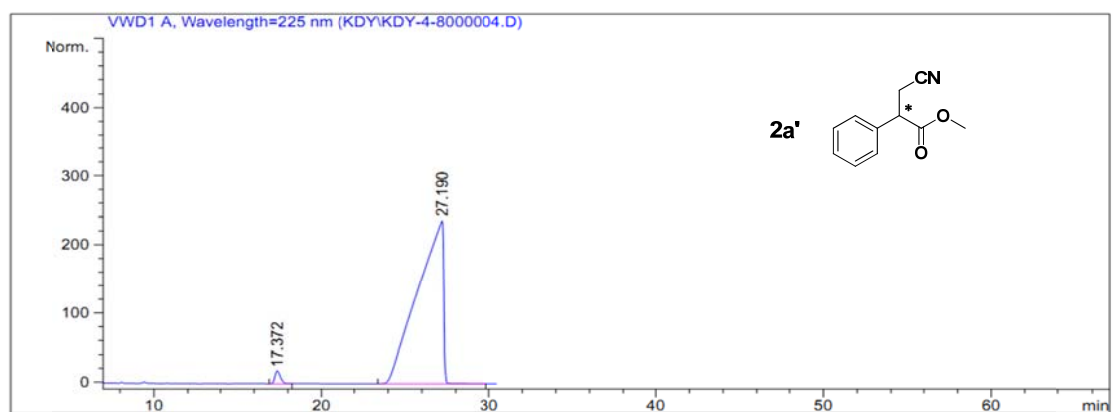






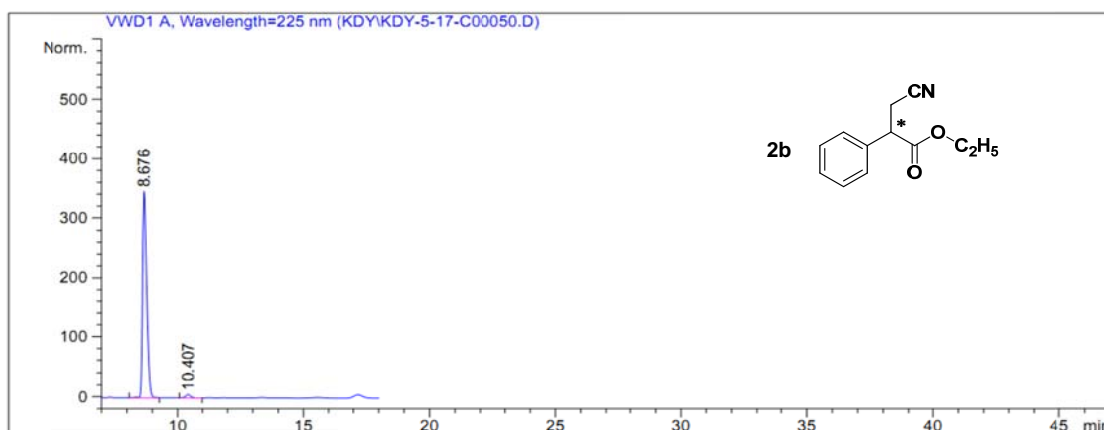
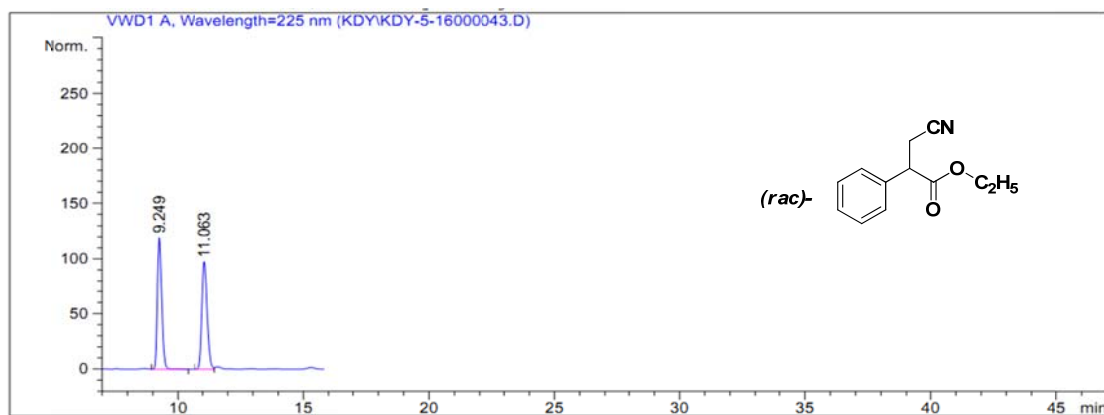
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.873	BB	0.3424	3241.85156	143.03450	98.9010
2	22.433	BB	0.4694	36.02296	1.19599	1.0990

Totals : 3277.87452 144.23049



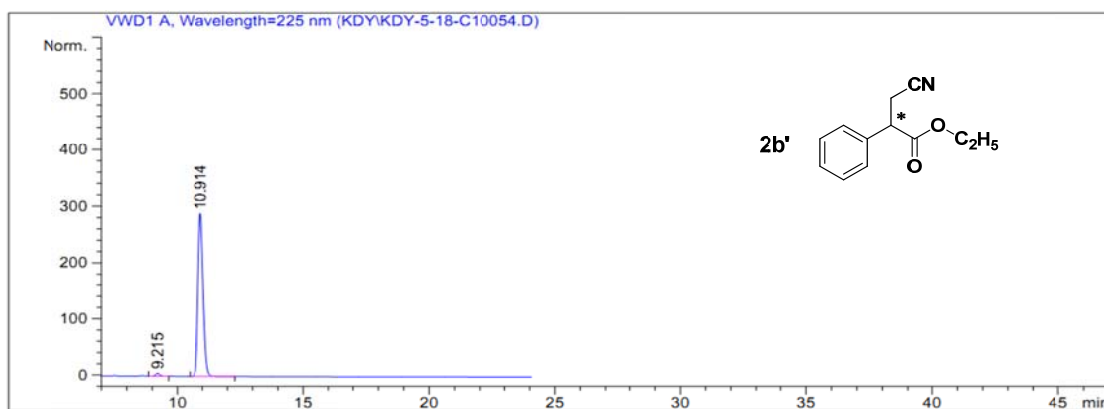
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.372	BB	0.3523	424.35785	18.58949	1.6652
2	27.190	BB	1.3030	2.50592e4	237.10426	98.3348

Totals : 2.54835e4 255.69375



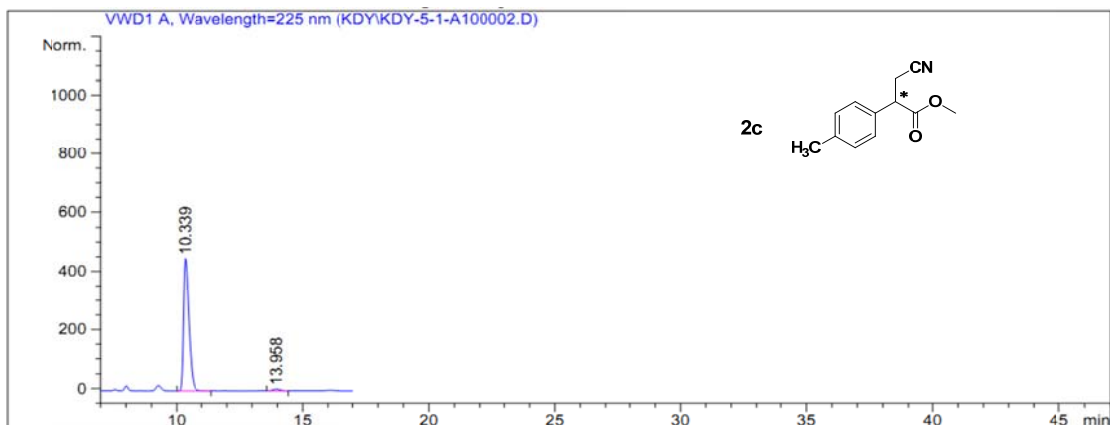
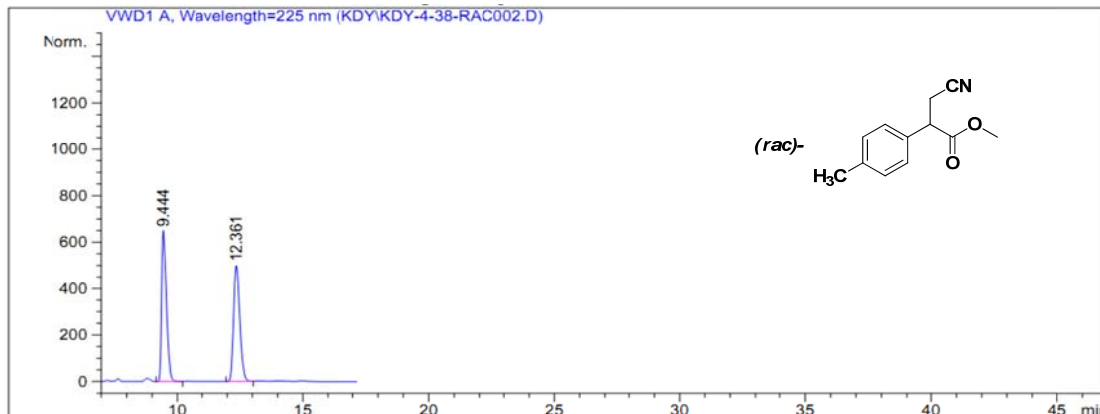
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.676	BB	0.1747	3939.56421	346.34445	98.1576
2	10.407	BB	0.2077	73.94509	5.54214	1.8424

Totals : 4013.50930 351.88659



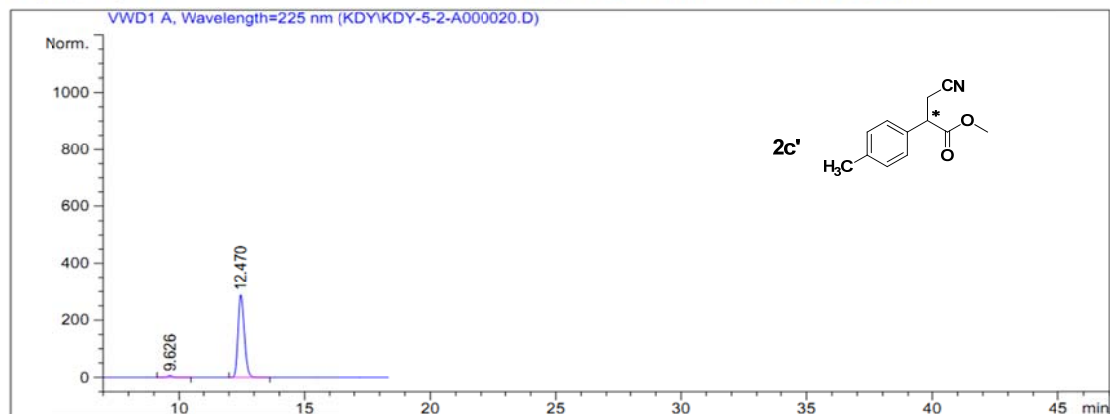
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.215	BB	0.1844	60.21594	5.07763	1.4240
2	10.914	BB	0.2240	4168.49805	289.41656	98.5760

Totals : 4228.71399 294.49420



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.339	BB	0.2285	6766.64014	452.45413	98.1829
2	13.958	VB	0.3123	125.23140	6.23571	1.8171

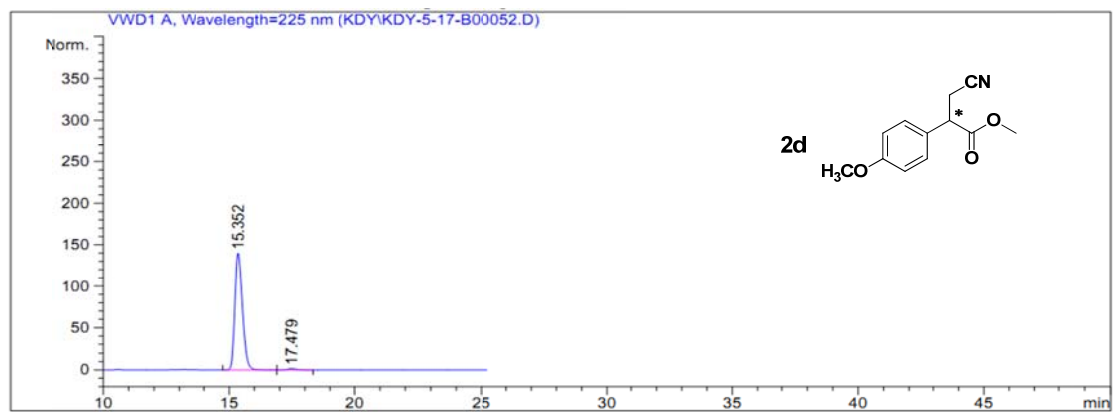
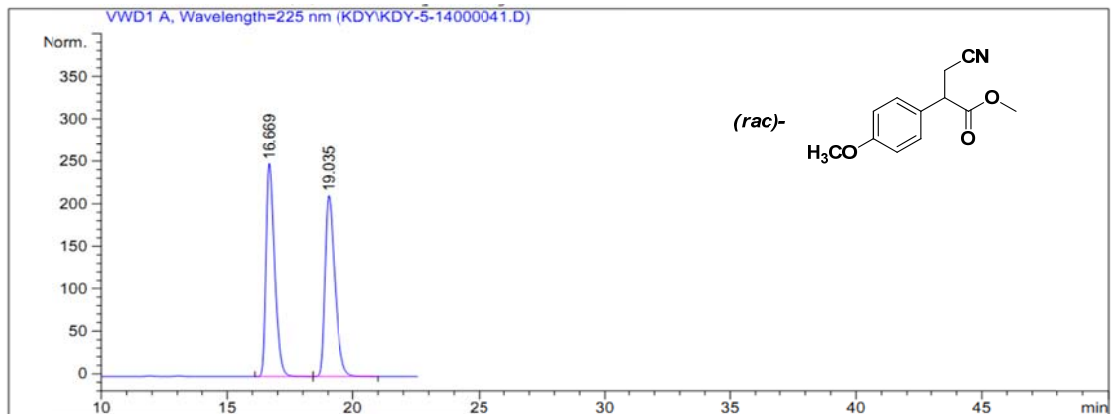
Totals : 6891.87154 458.68984



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.626	BB	0.2159	88.79823	6.17083	1.7572
2	12.470	BB	0.2669	4964.63623	288.37769	98.2428

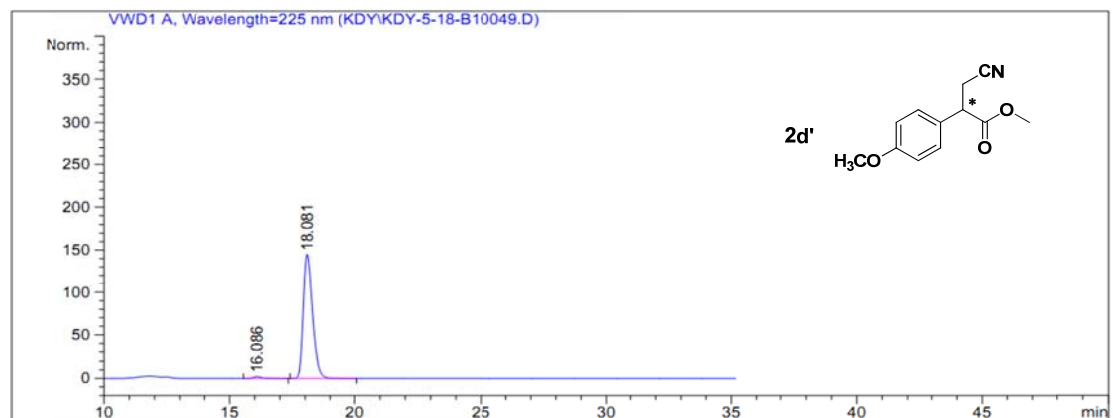
Totals : 5053.43446 294.54852





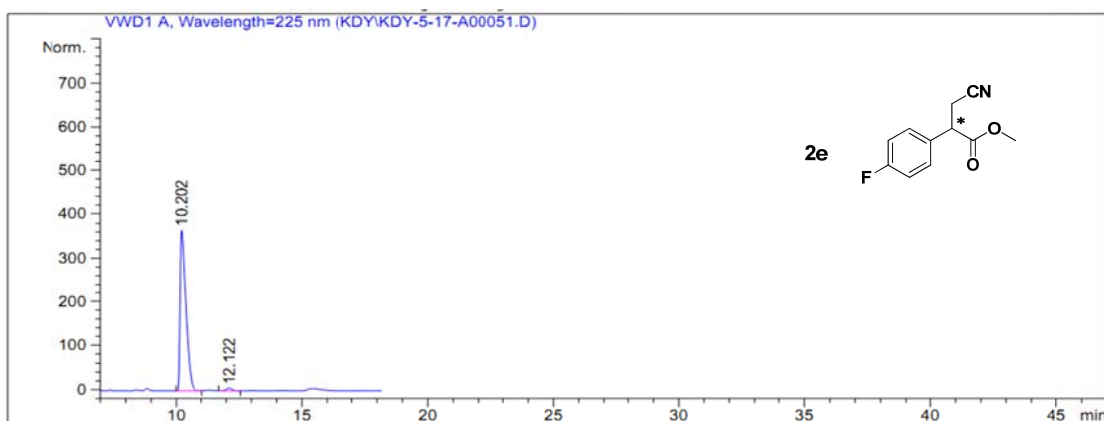
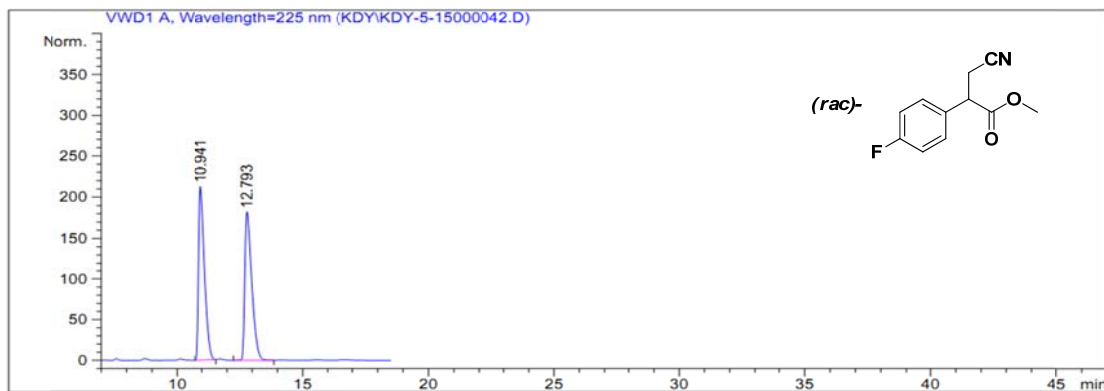
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.352	BB	0.3215	2911.17456	140.06287	98.7160
2	17.479	BB	0.3804	37.86663	1.51601	1.2840

Totals : 2949.04119 141.57888



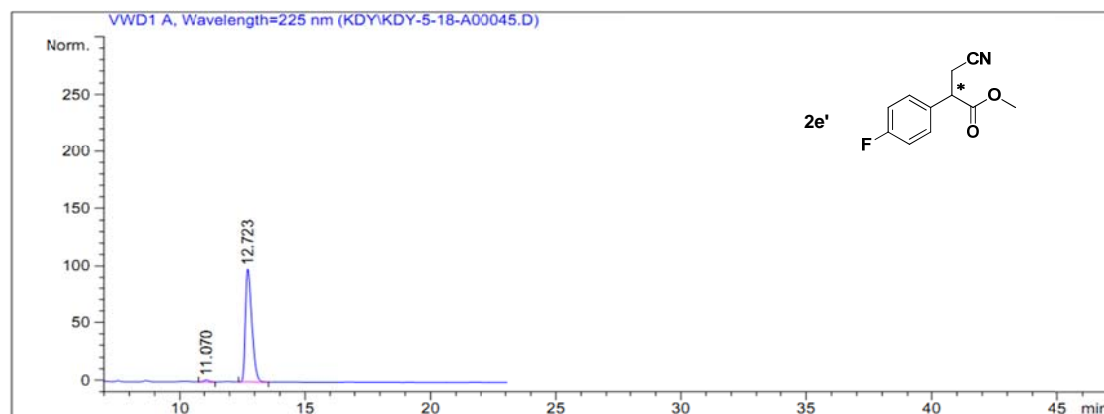
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.086	BB	0.3781	54.34576	2.13400	1.4488
2	18.081	BB	0.3922	3696.61987	145.12761	98.5512

Totals : 3750.96564 147.26161



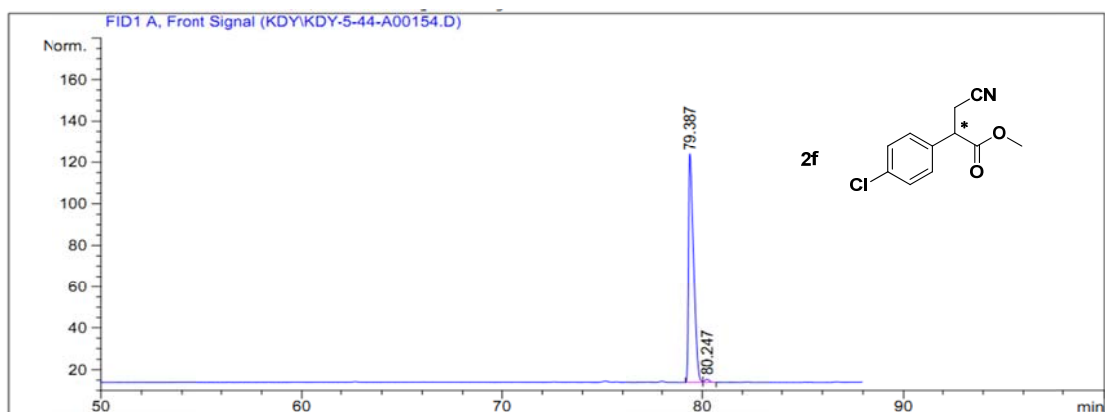
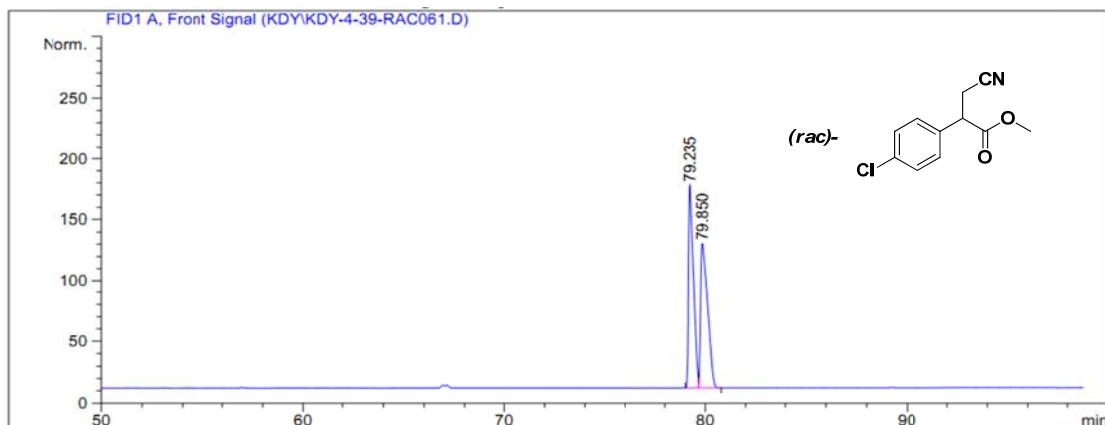
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.202	BB	0.2340	5787.26855	367.01065	98.4031
2	12.122	BB	0.2477	93.91683	5.80670	1.5969

Totals : 5881.18539 372.81735



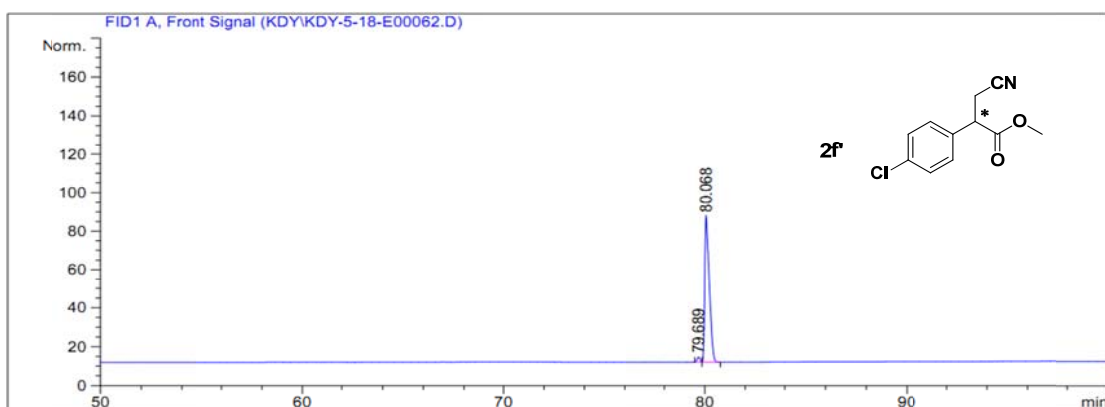
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.070	BB	0.2153	24.27419	1.75537	1.3833
2	12.723	BB	0.2683	1730.53809	98.80063	98.6167

Totals : 1754.81228 100.55600



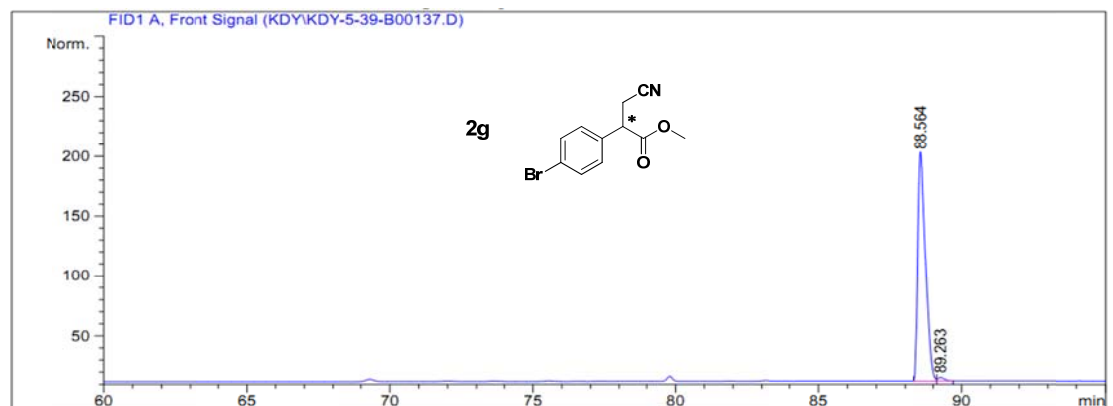
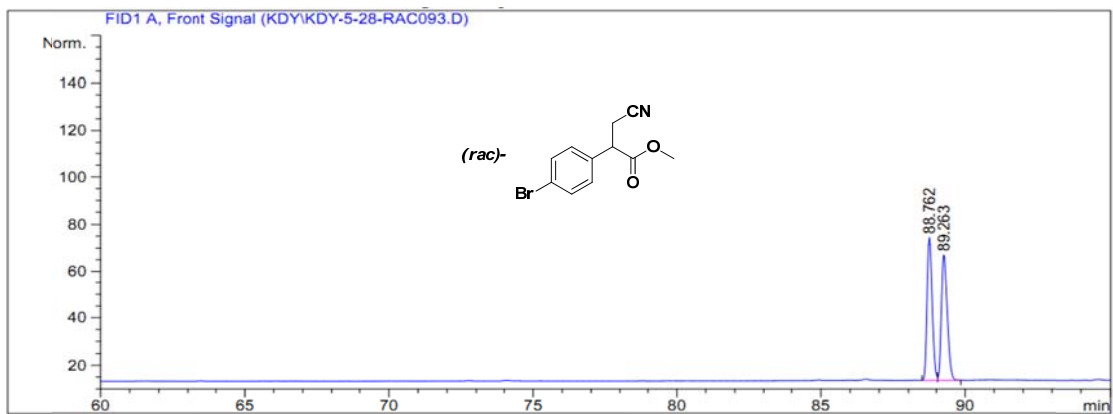
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	79.387	BV	0.2382	1911.01758	109.82911	98.83949
2	80.247	VB	0.2259	22.43789	1.45876	1.16051

Totals : 1933.45547 111.28787



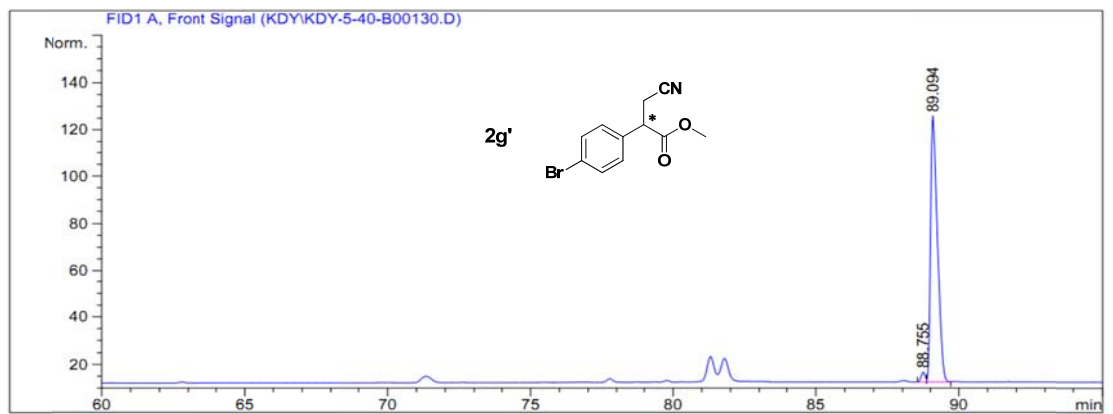
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	79.689	BV	0.1528	27.23461	2.74018	2.24538
2	80.068	VB	0.2142	1185.68140	75.93608	97.75462

Totals : 1212.91601 78.67627



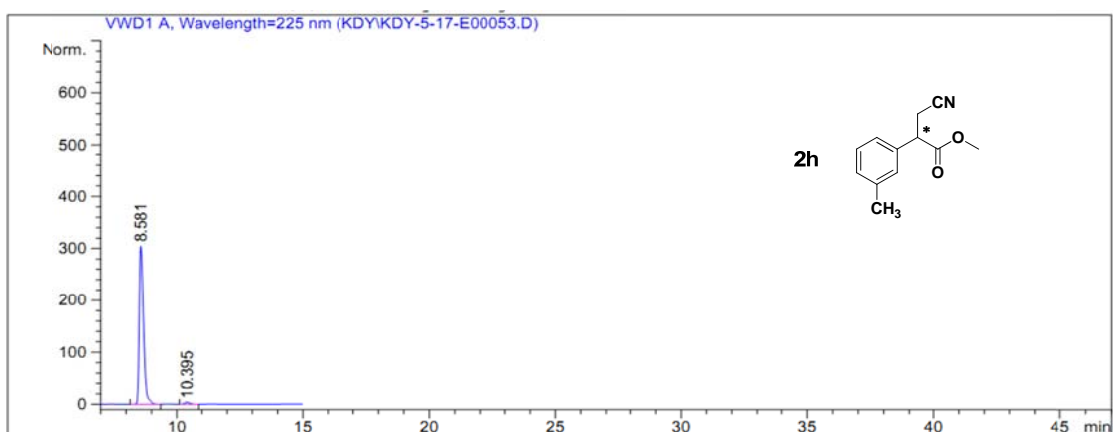
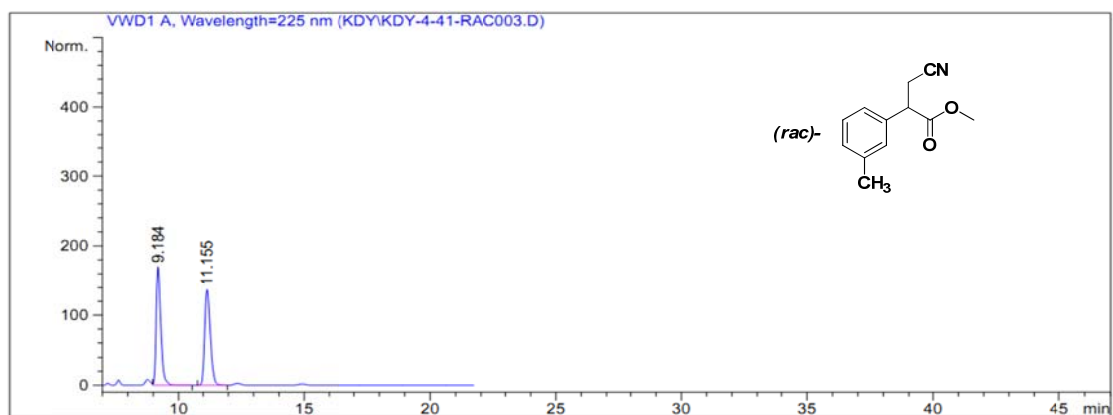
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	88.564	BV	0.2619	3536.63452	190.01071	98.70361
2	89.263	VB	0.2511	46.45083	2.92079	1.29639

Totals : 3583.08535 192.93150



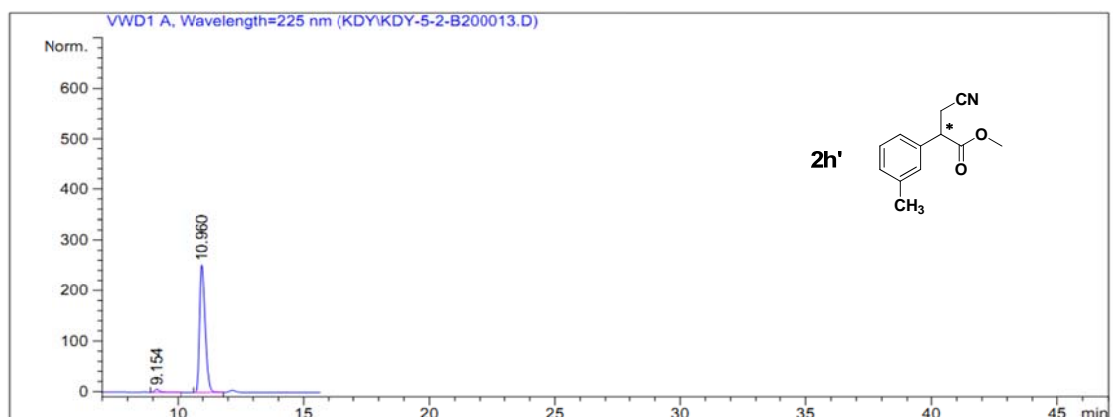
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	88.755	BV	0.1518	40.58226	4.23605	2.11004
2	89.094	VV	0.2450	1882.71082	113.35958	97.88996

Totals : 1923.29307 117.59563



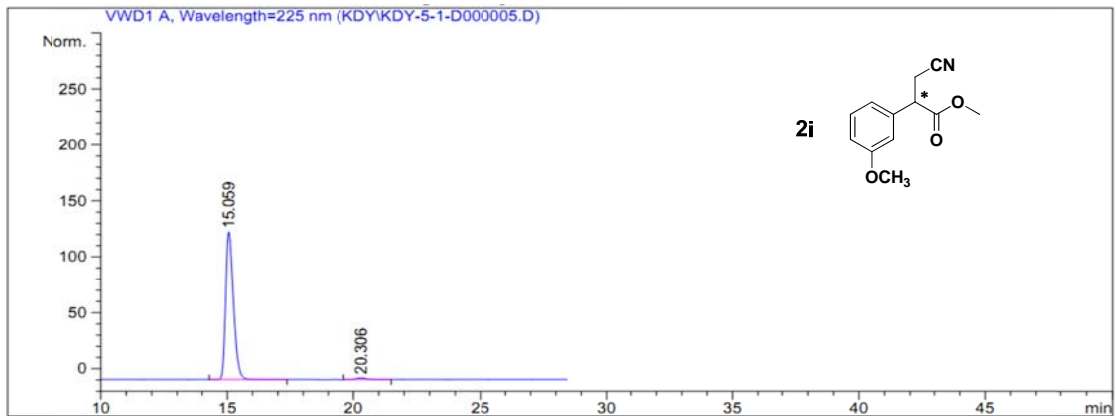
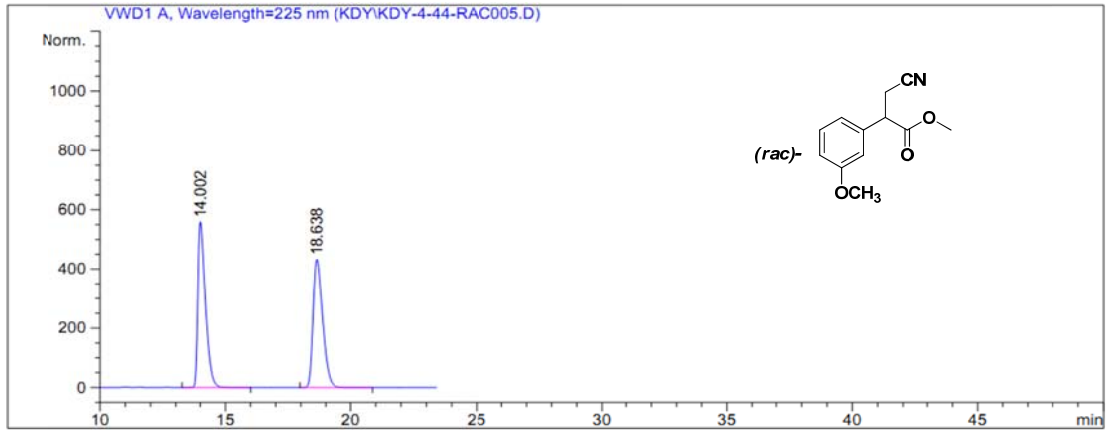
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.581	BB	0.1774	3533.03247	304.37949	98.4946
2	10.395	BB	0.2168	53.99898	3.84631	1.5054

Totals : 3587.03145 308.22580



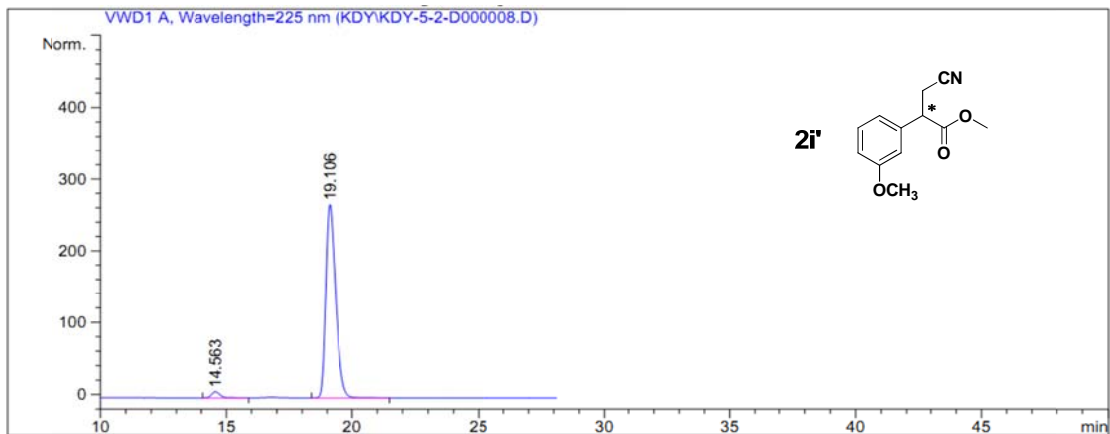
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.154	BB	0.1937	76.93291	6.03612	1.9520
2	10.960	BB	0.2368	3864.22168	252.20273	98.0480

Totals : 3941.15459 258.23884



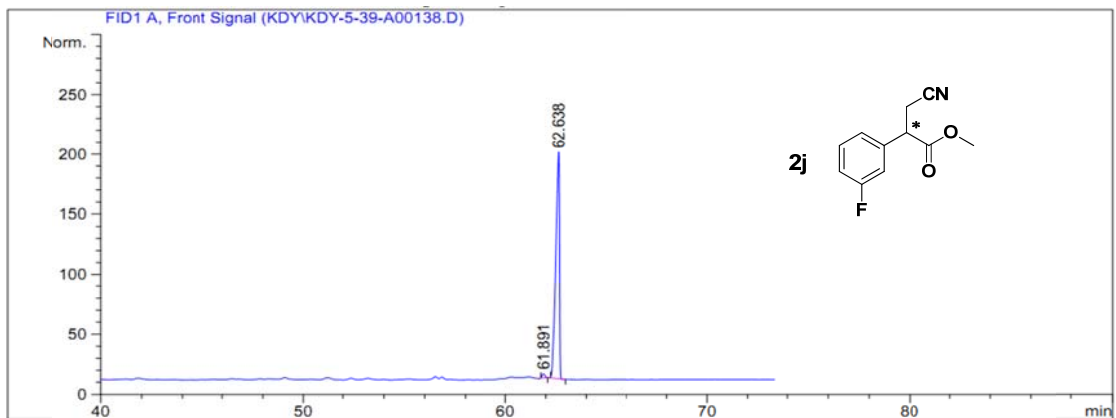
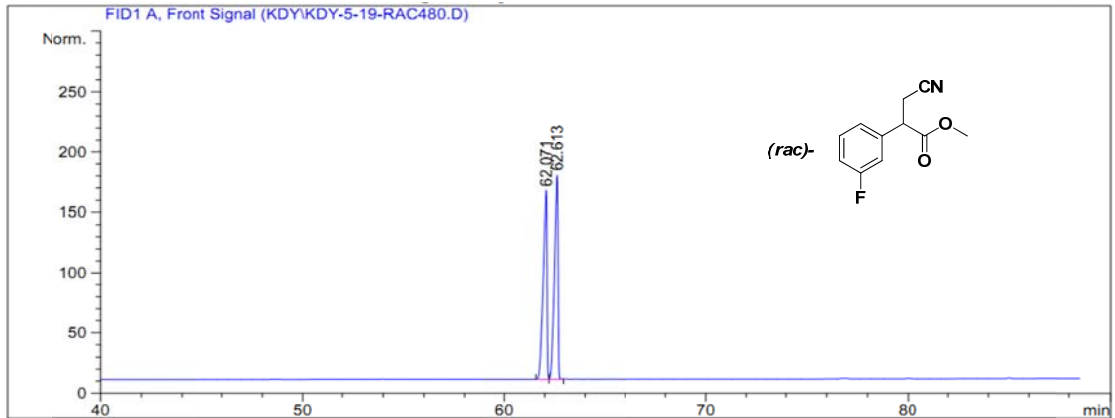
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.059	BB	0.3270	2815.07251	131.90784	98.3890
2	20.306	BB	0.4649	46.09264	1.46182	1.6110

Totals : 2861.16515 133.36966



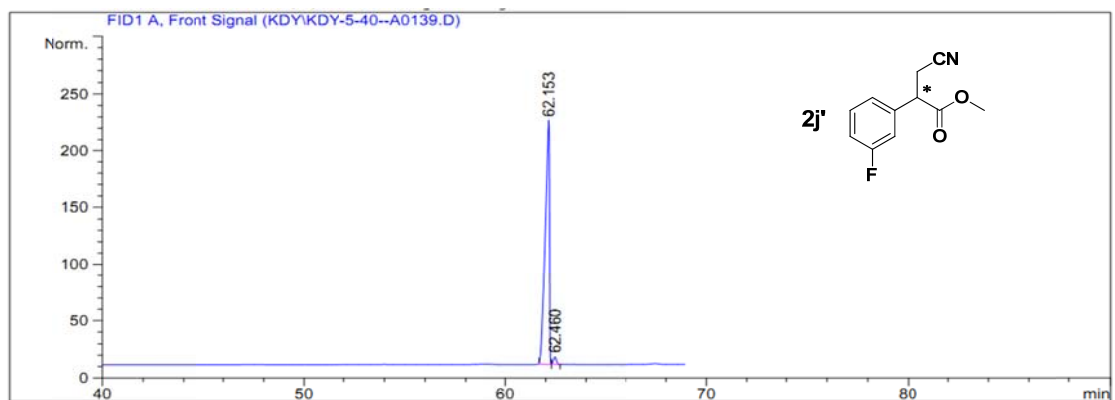
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.563	BB	0.3530	189.13026	8.32678	2.4916
2	19.106	BB	0.4243	7401.45557	268.78909	97.5084

Totals : 7590.58583 277.11587



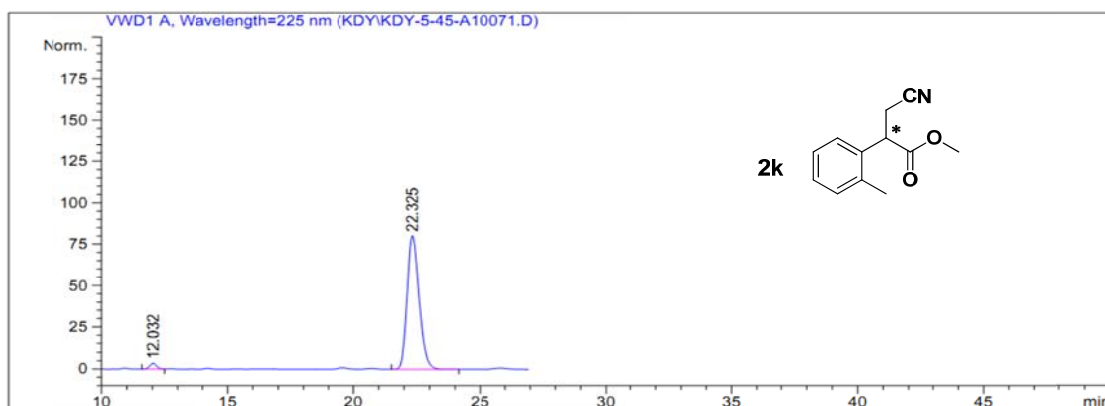
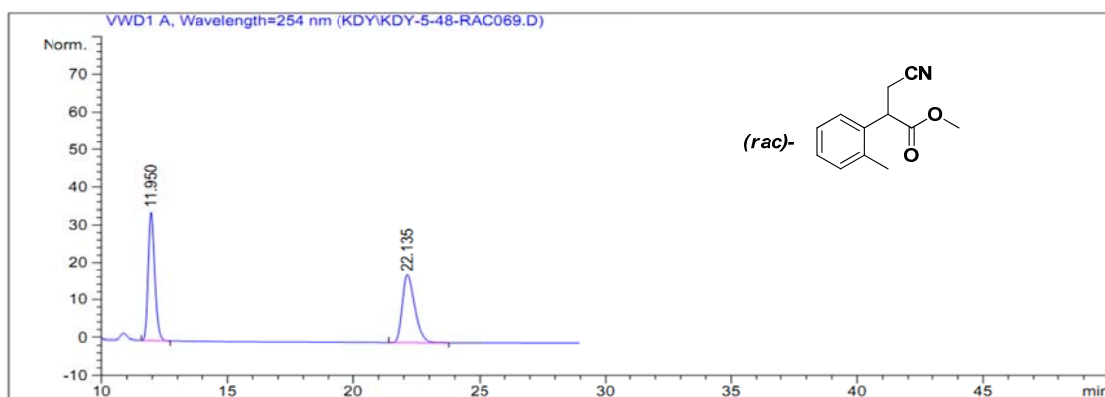
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	61.891	BB	0.1397	33.57148	3.50766	1.40908
2	62.638	BB	0.1717	2348.93384	188.63130	98.59092

Totals : 2382.50532 192.13896



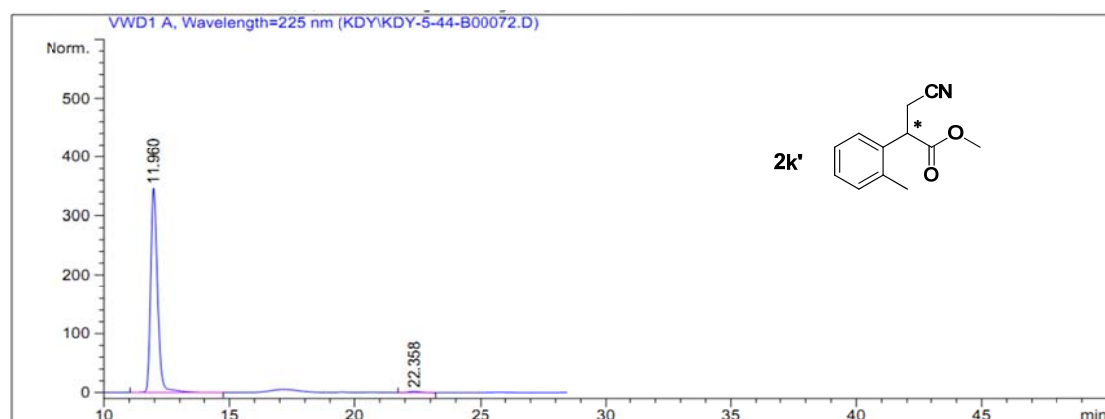
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	62.153	BV	0.1893	3161.77979	214.87210	97.92123
2	62.460	VB	0.1575	67.12135	6.48967	2.07877

Totals : 3228.90114 221.36177



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.032	BB	0.2804	63.37100	3.48141	2.3506
2	22.325	BB	0.5063	2632.54102	80.33986	97.6494

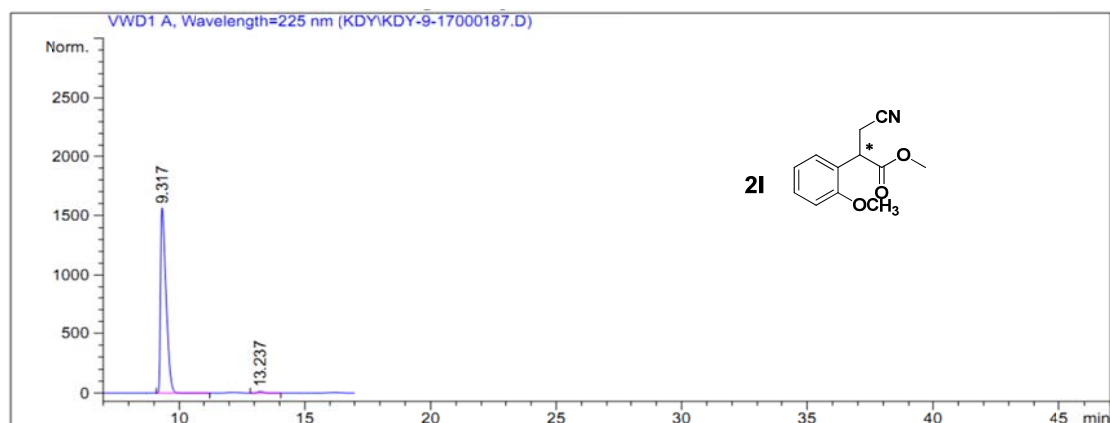
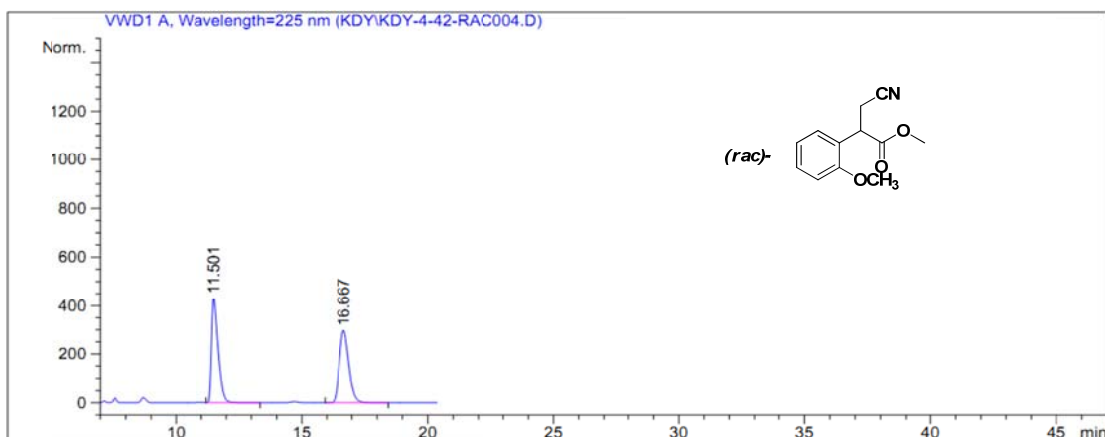
Totals : 2695.91202 83.82126



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.960	BB	0.2903	6575.87451	346.62399	99.0335
2	22.358	BB	0.4789	64.17606	2.04043	0.9665

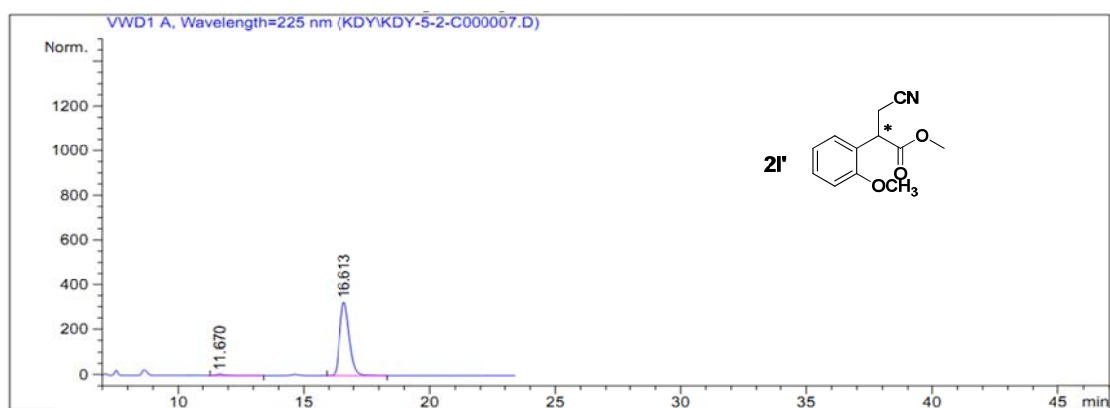
Totals : 6640.05057 348.66443





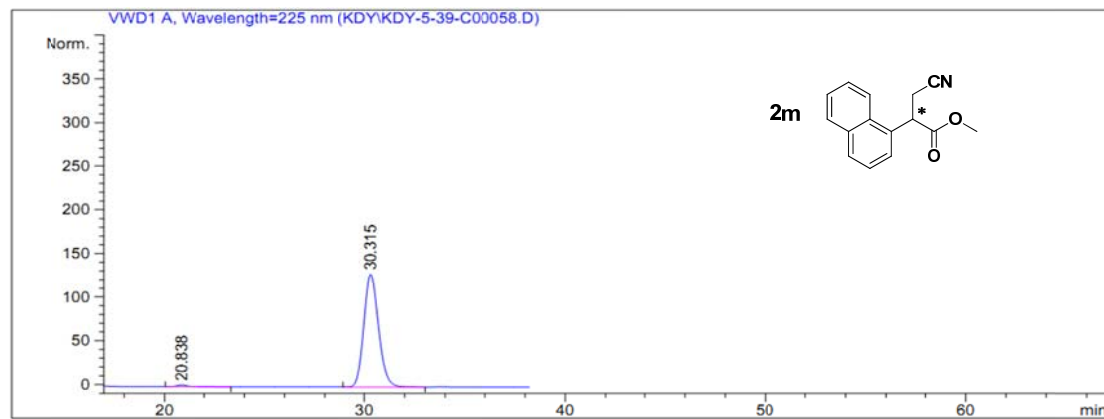
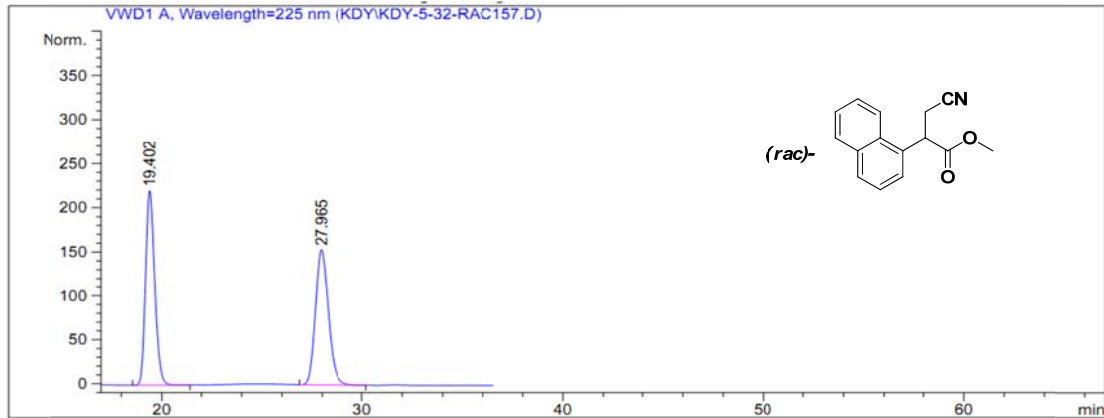
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.317	BB	0.2310	2.35985e4	1564.02197	98.9183
2	13.237	BB	0.2963	258.04868	13.47935	1.0817

Totals : 2.38566e4 1577.50132



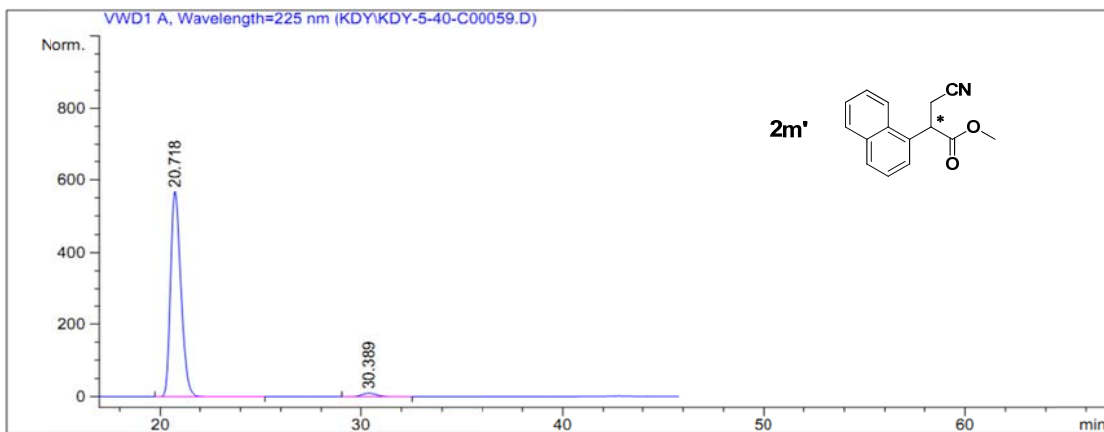
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.670	BB	0.2880	98.81751	5.21548	1.1297
2	16.613	BB	0.4132	8648.57422	324.18219	98.8703

Totals : 8747.39173 329.39767



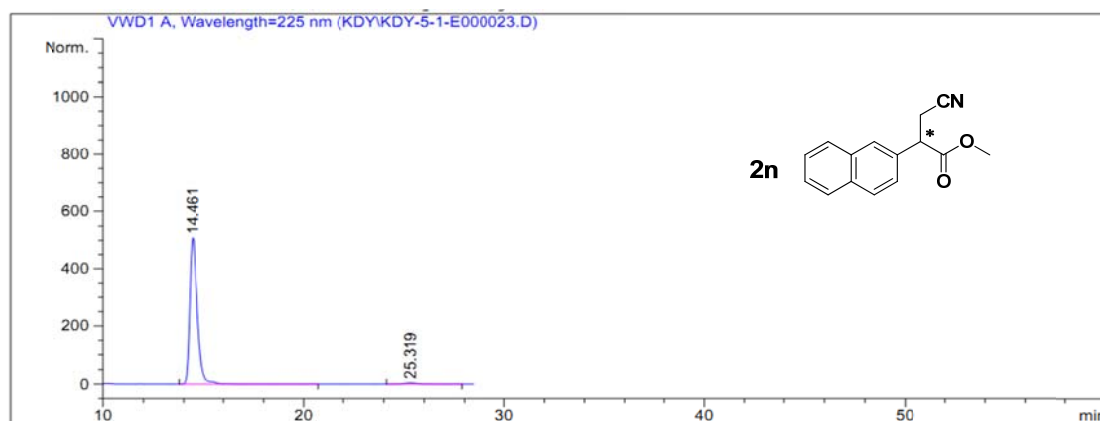
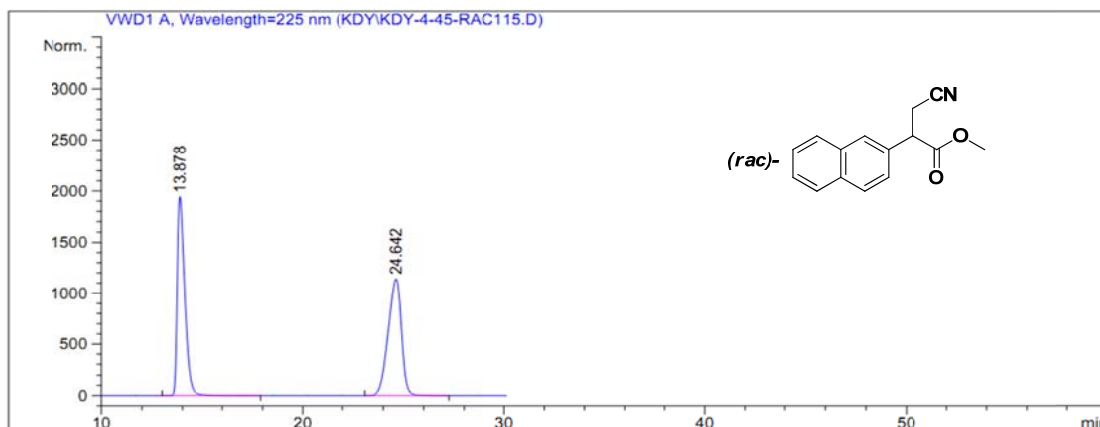
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.838	BB	0.5471	67.64568	1.91977	1.0304
2	30.315	BB	0.7803	6497.66455	128.85123	98.9696

Totals : 6565.31023 130.77100



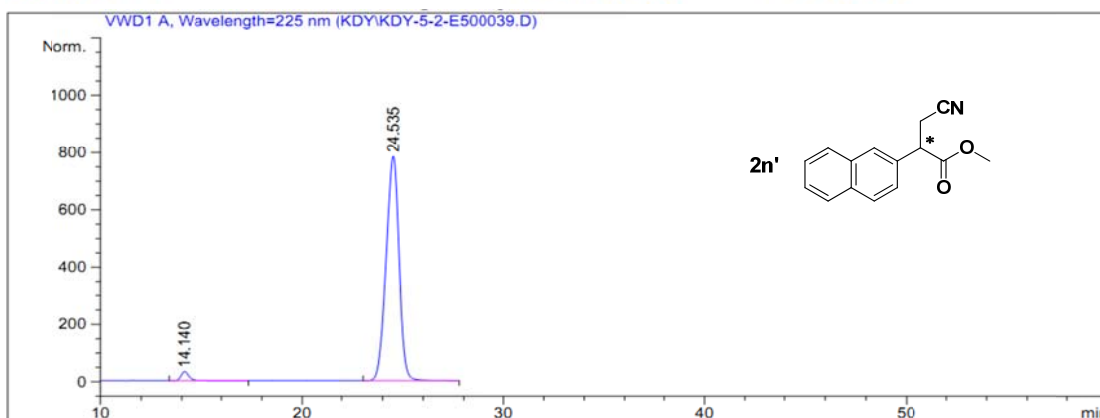
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.718	BB	0.5541	2.01478e4	567.59796	97.6317
2	30.389	BB	0.7907	488.73932	9.52407	2.3683

Totals : 2.06365e4 577.12203



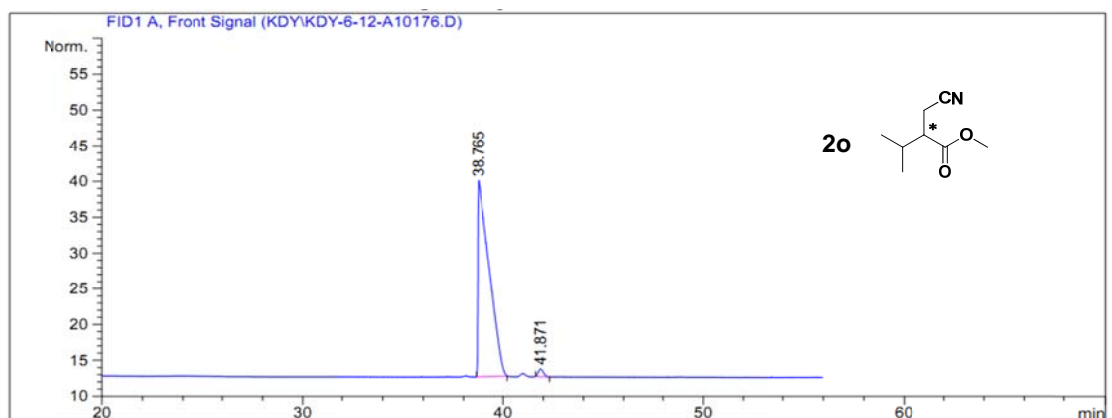
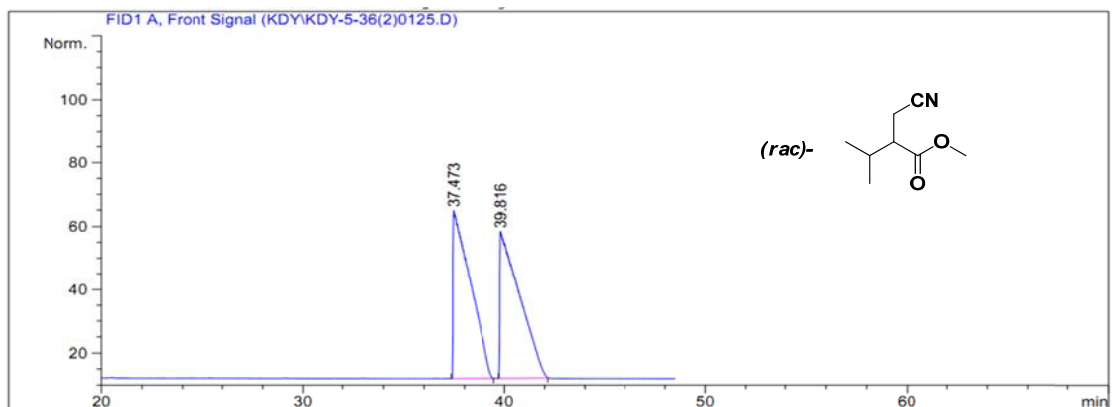
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.461	BB	0.4060	1.35195e4	508.84369	98.4749
2	25.319	BB	0.7354	209.37592	4.39823	1.5251

Totals : 1.37289e4 513.24192



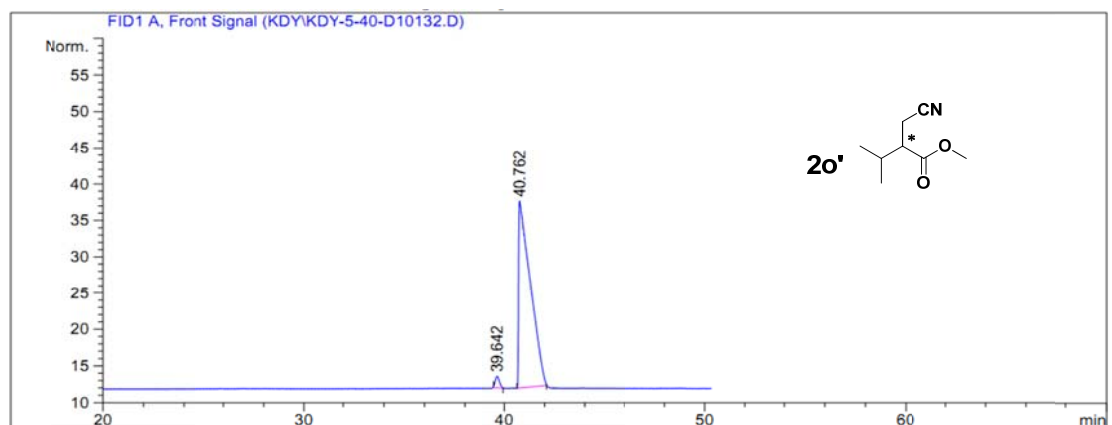
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.140	VB	0.4170	860.56268	31.67190	2.4228
2	24.535	BBA	0.6926	3.46588e4	782.71899	97.5772

Totals : 3.55194e4 814.39090



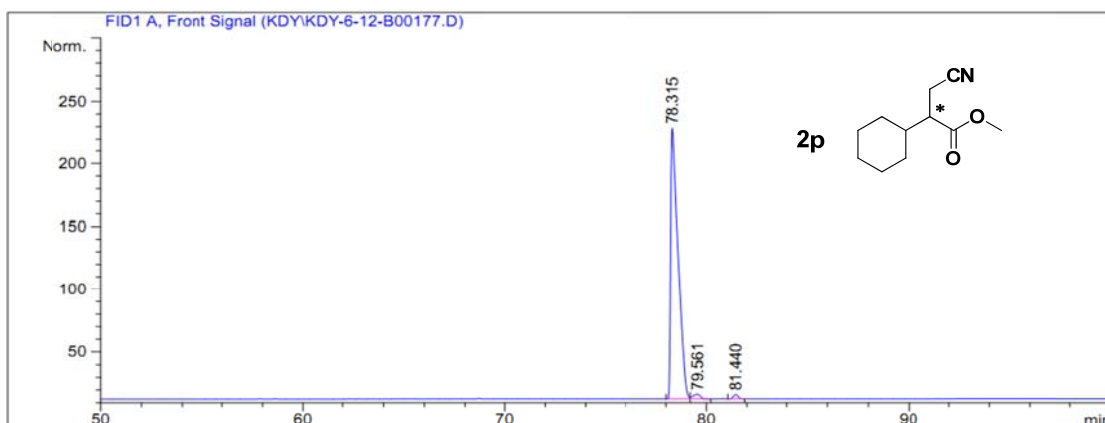
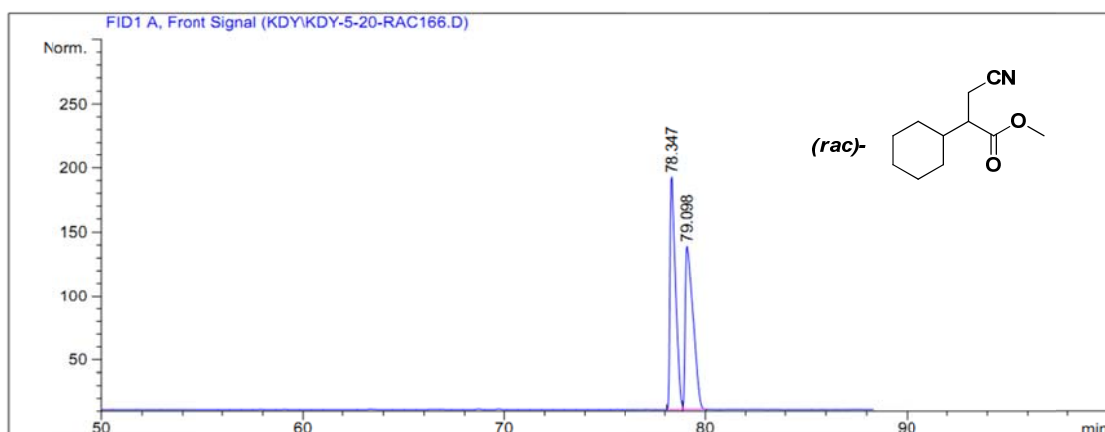
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	38.765	BB	0.4837	1099.64038	27.43000	98.28924
2	41.871	BB	0.2096	19.13959	1.07764	1.71076

Totals : 1118.77997 28.50764

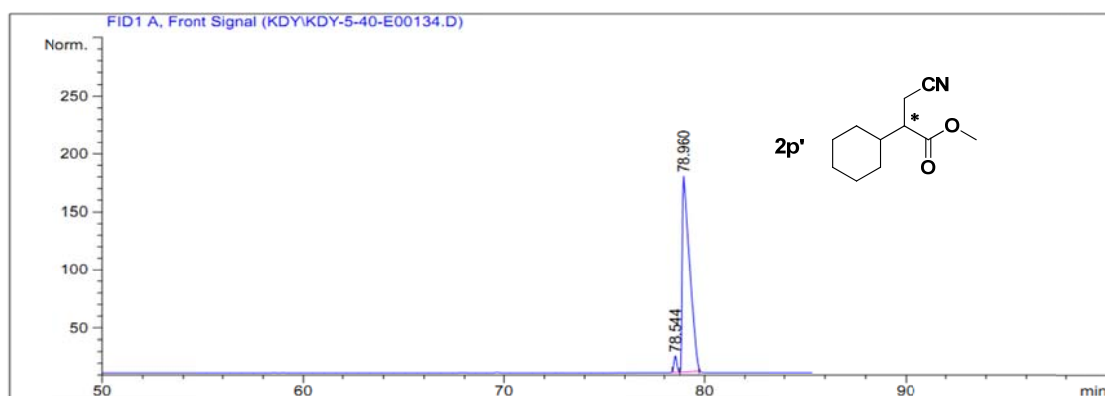


Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	39.642	BB	0.1762	22.53975	1.57064	2.13341
2	40.762	BB	0.4876	1033.97437	25.66373	97.86659

Totals : 1056.51411 27.23437

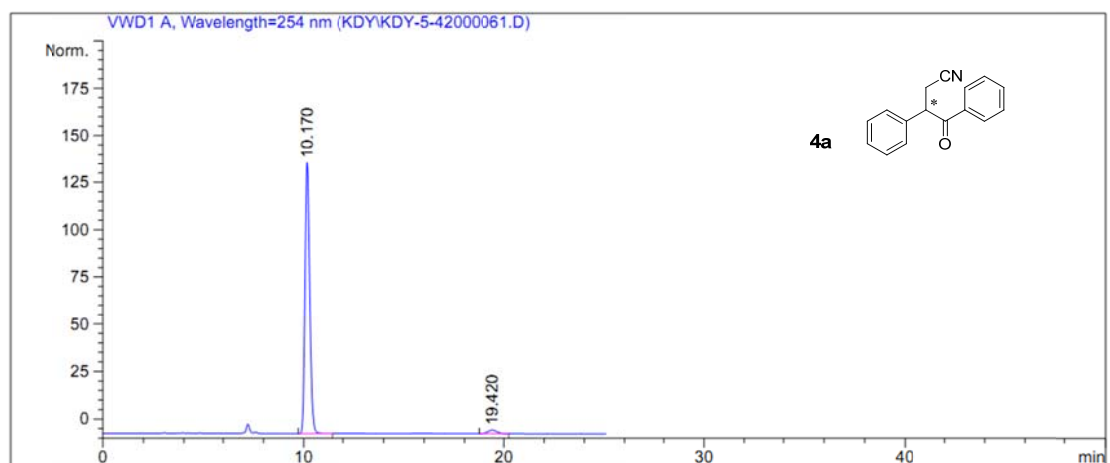
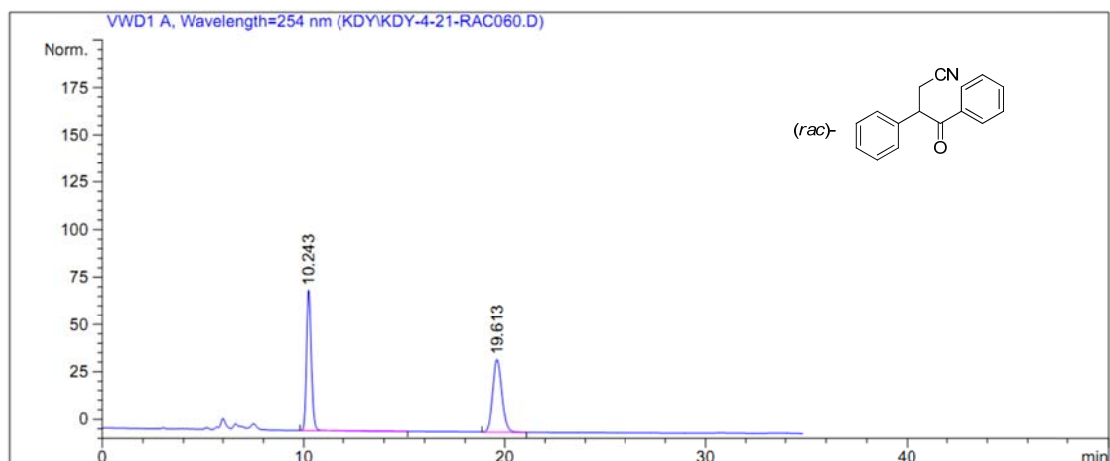


Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	78.315	BV	0.3243	5452.37500	215.85544	97.23323
2	79.561	VB	0.3068	96.46202	3.79746	1.72023
3	81.440	VB	0.2037	58.68530	3.63291	1.04655



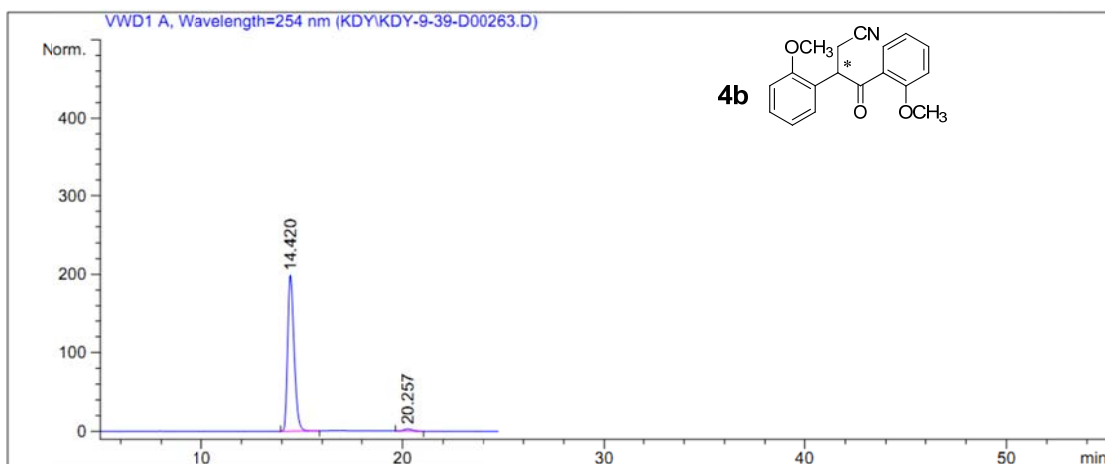
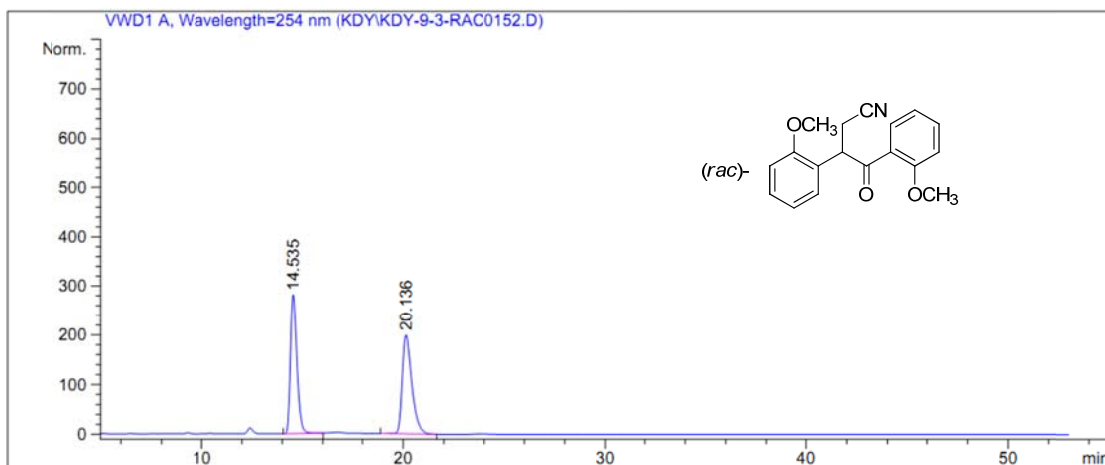
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	78.544	BV	0.1595	140.97063	13.95383	3.19948
2	78.960	VB	0.3266	4265.07764	167.97549	96.80052

Totals : 4406.04826 181.92933

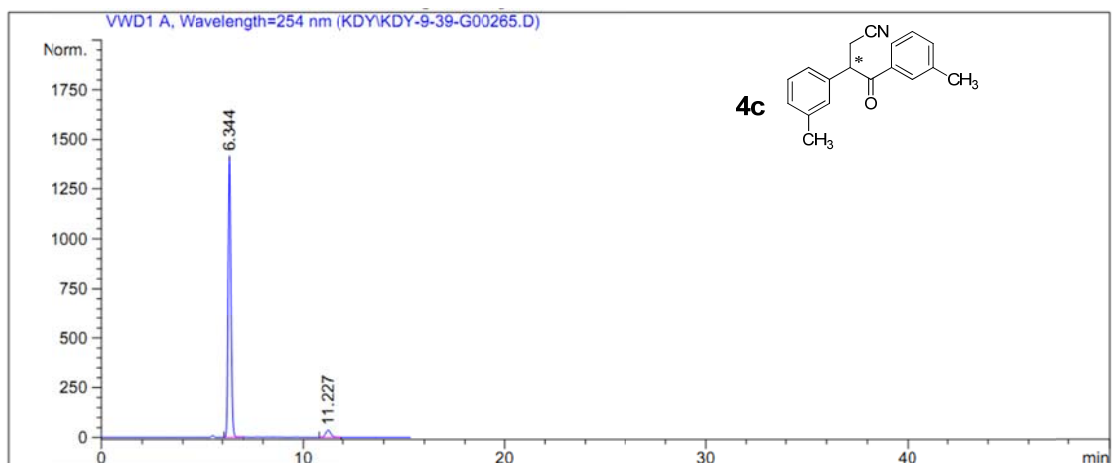
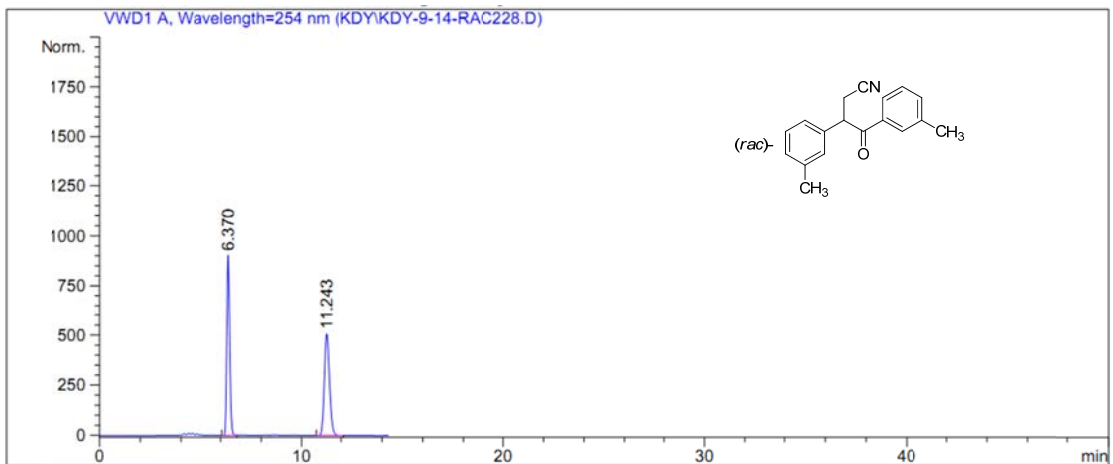


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.170	BB	0.2499	2321.73071	143.42116	97.5703
2	19.420	BB	0.4623	57.81685	1.88788	2.4297

Totals : 2379.54757 145.30904



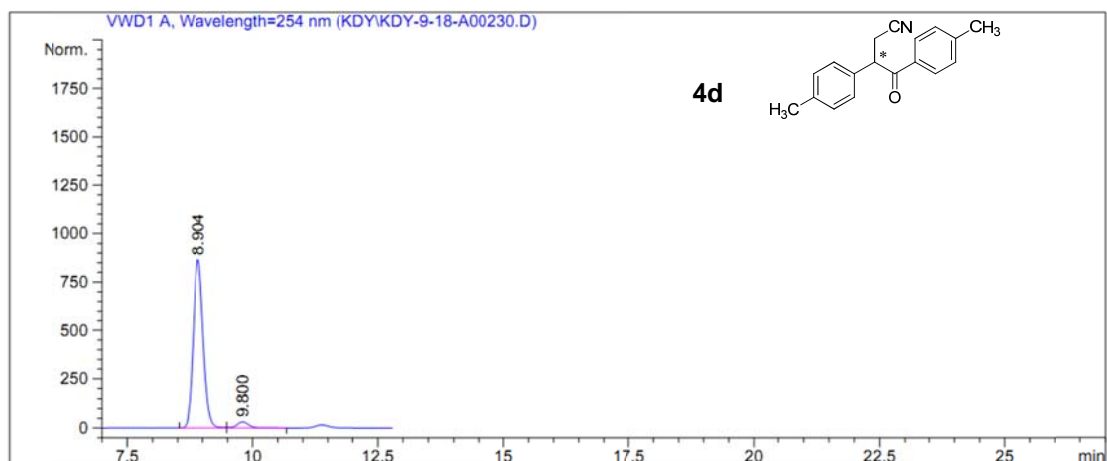
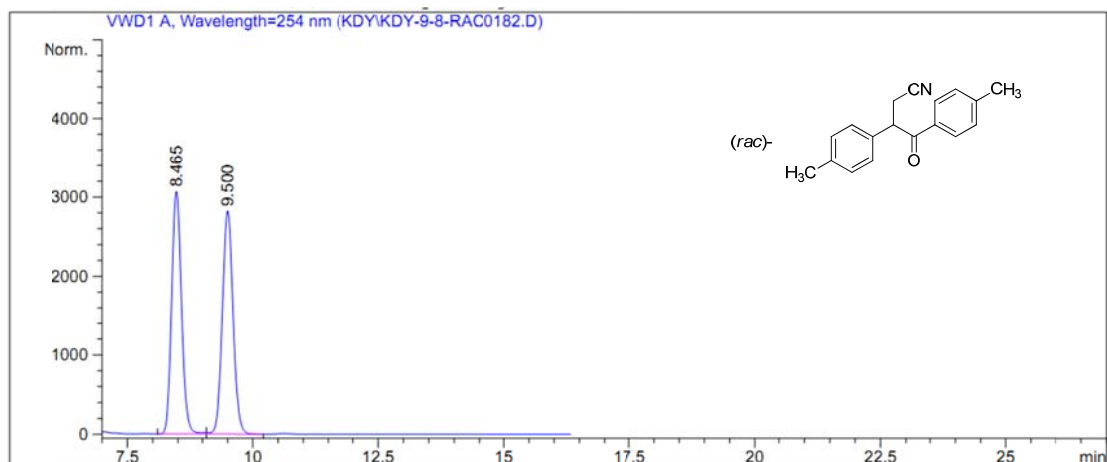
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.420	BB	0.3390	4380.46484	198.85118	98.2108
2	20.257	BB	0.4545	79.80190	2.69495	1.7892
Totals :				4460.26674	201.54614	



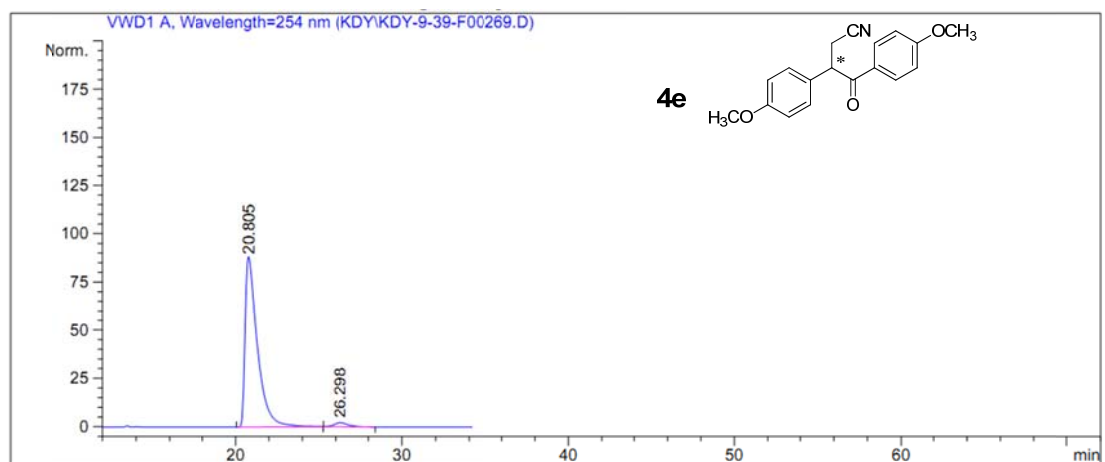
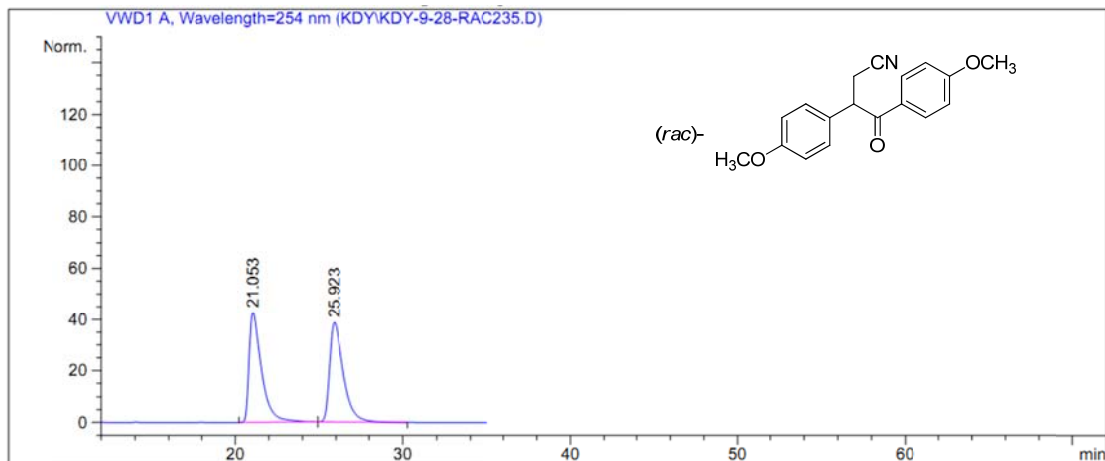
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	6.344	BV	0.1483	1.36531e4	1418.04810	95.5451
2	11.227	BB	0.2688	636.59882	36.62025	4.4549

Totals : 1.42897e4 1454.66834

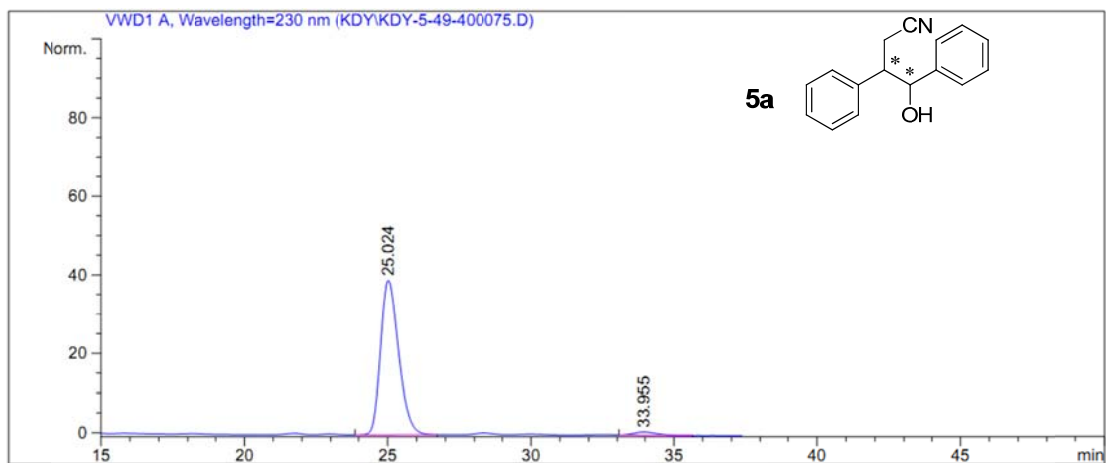
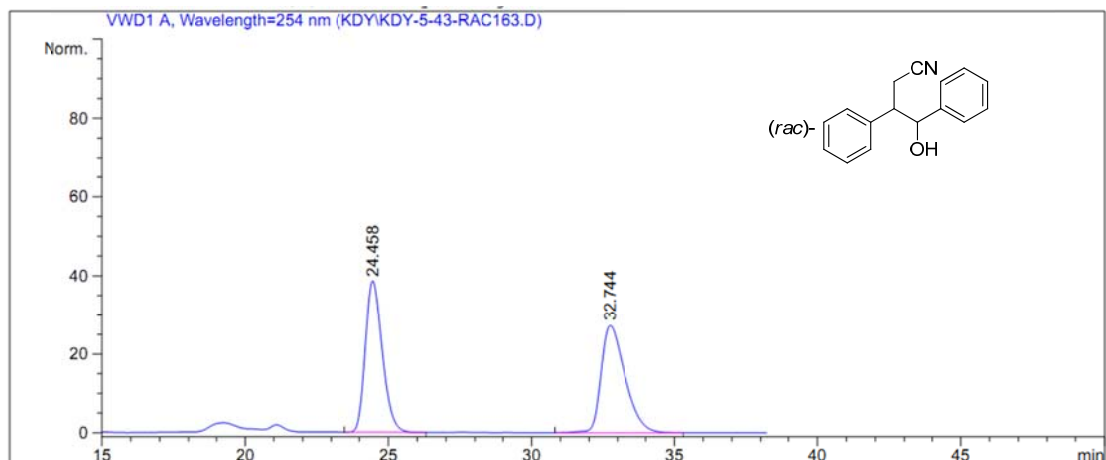




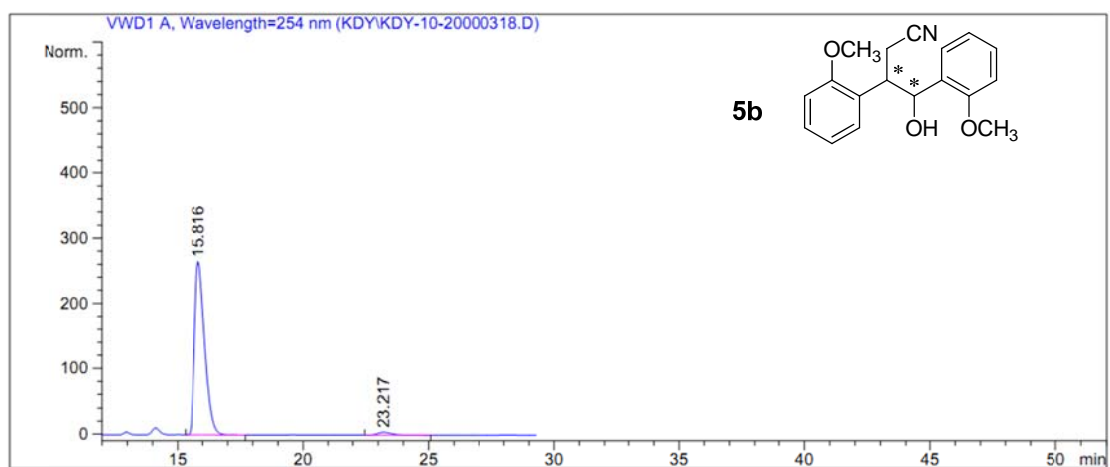
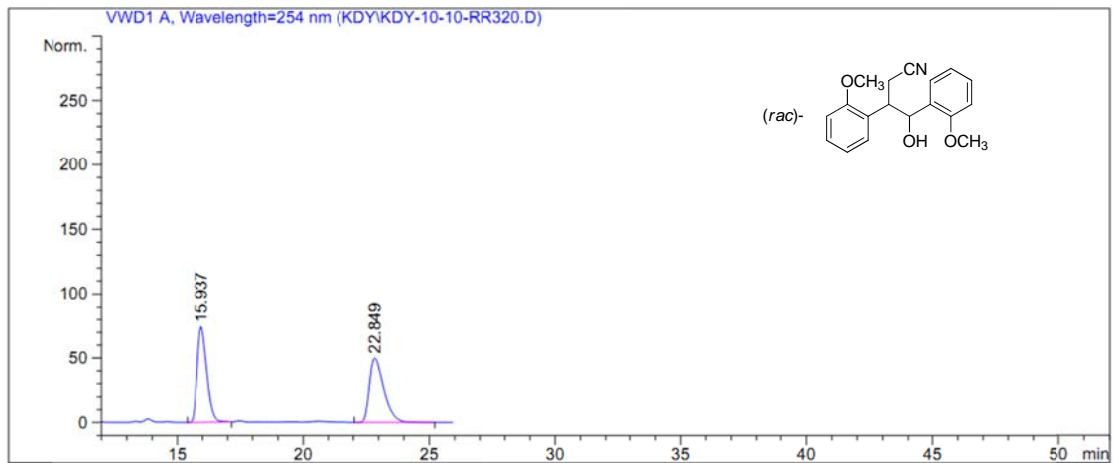
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.904	VV	0.2154	1.20632e4	866.40869	95.8829
2	9.800	VB	0.2498	517.97742	31.50006	4.1171
Totals :				1.25811e4	897.90875	



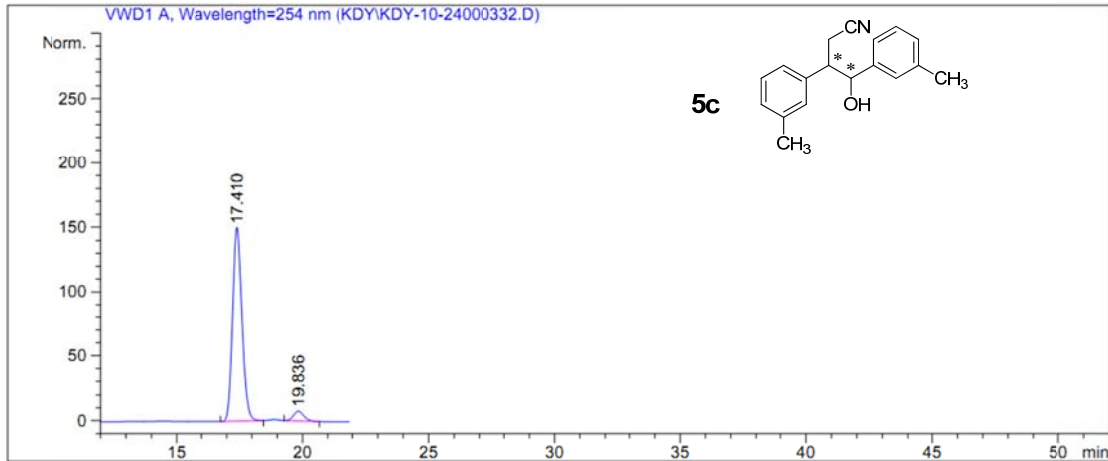
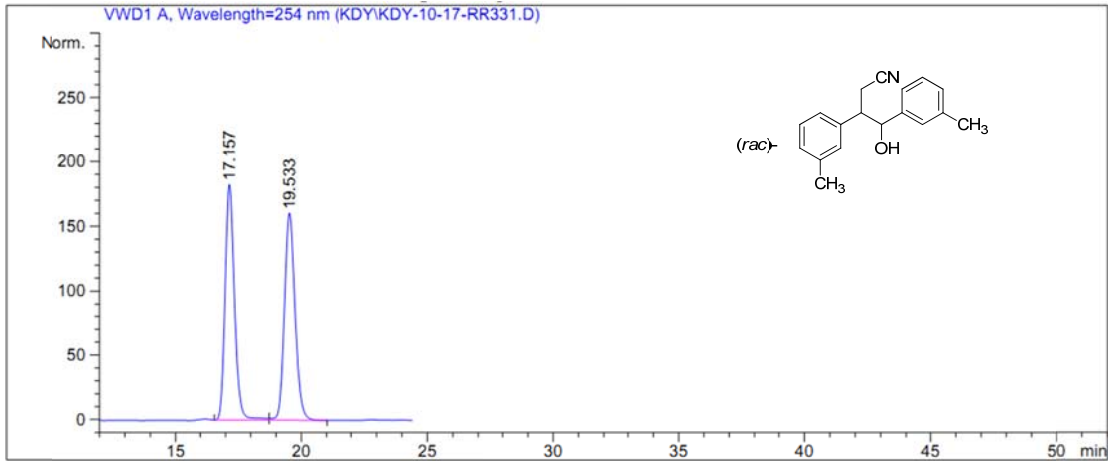
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.805	BB	0.7618	4498.27637	87.20359	97.3174
2	26.298	BB	0.9238	123.99644	2.06733	2.6826
Totals :				4622.27280	89.27092	



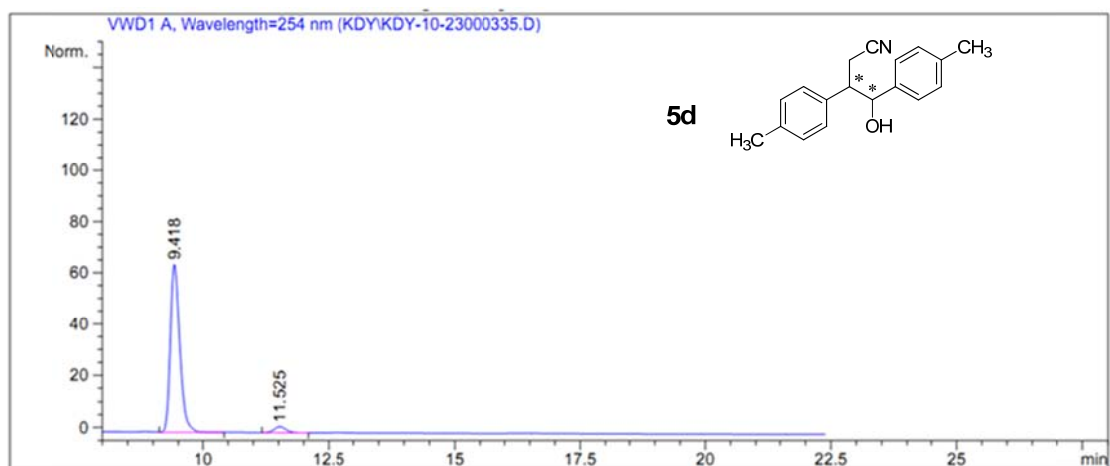
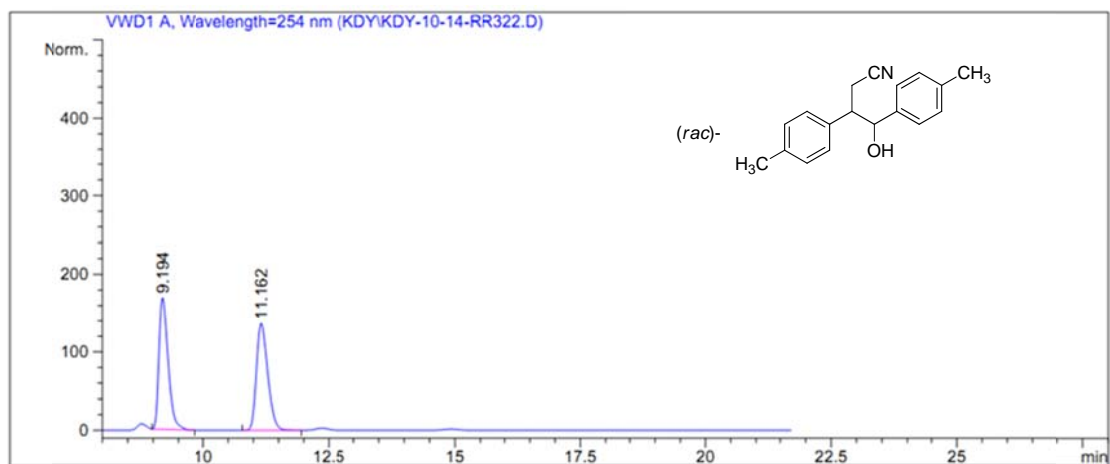
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	25.024	BV	0.6731	1698.60938	39.08026	97.5591
2	33.955	BB	0.6479	42.49799	7.77201e-1	2.4409
Totals :				1741.10736	39.85746	



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.816	BB	0.4306	7464.45410	265.00516	97.8619
2	23.217	BB	0.5793	163.08755	4.19751	2.1381
Totals :				7627.54166	269.20266	

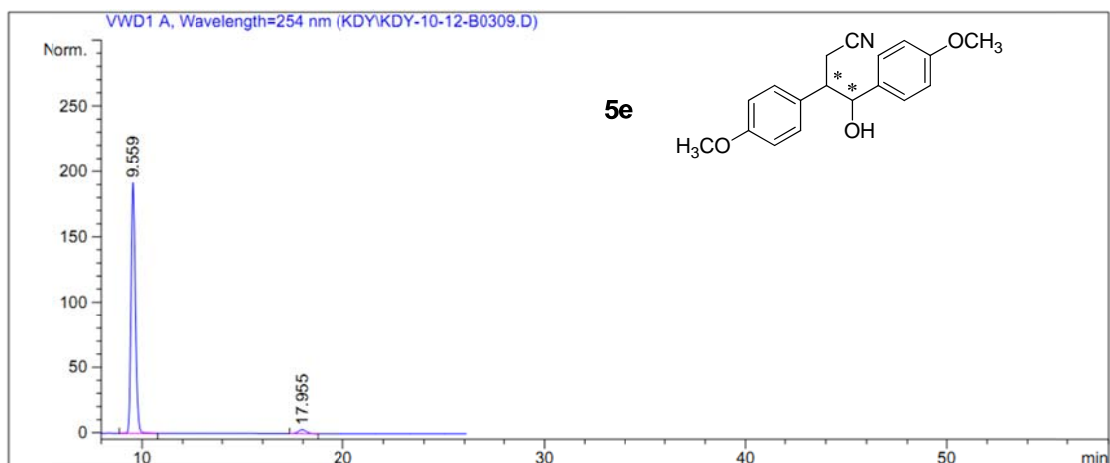
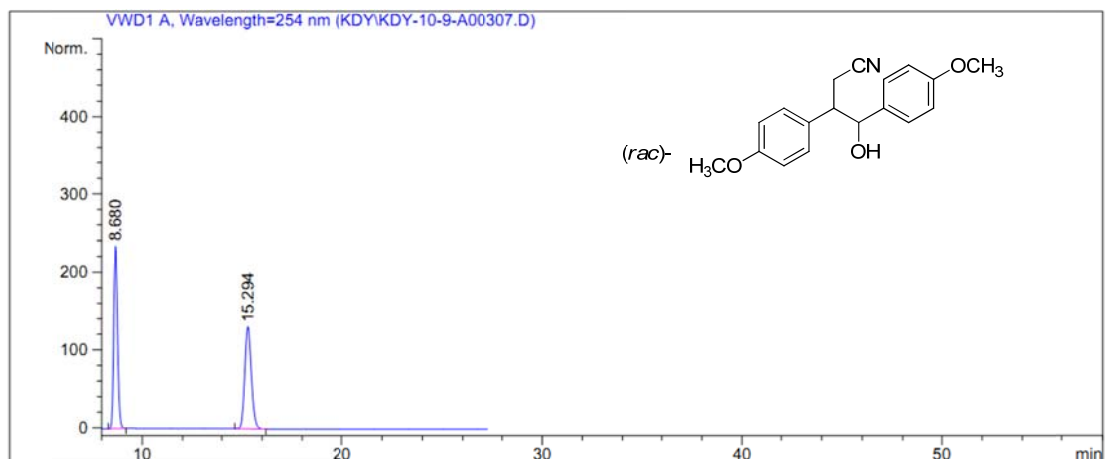


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.410	BB	0.4144	3870.70020	149.33983	94.7531
2	19.836	BBA	0.4613	214.33755	7.50307	5.2469
Totals :				4085.03775	156.84290	

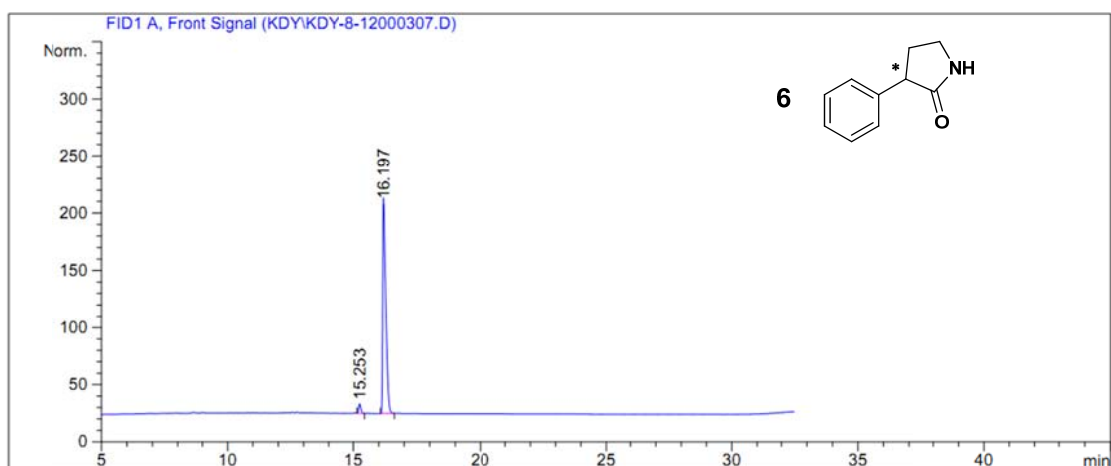
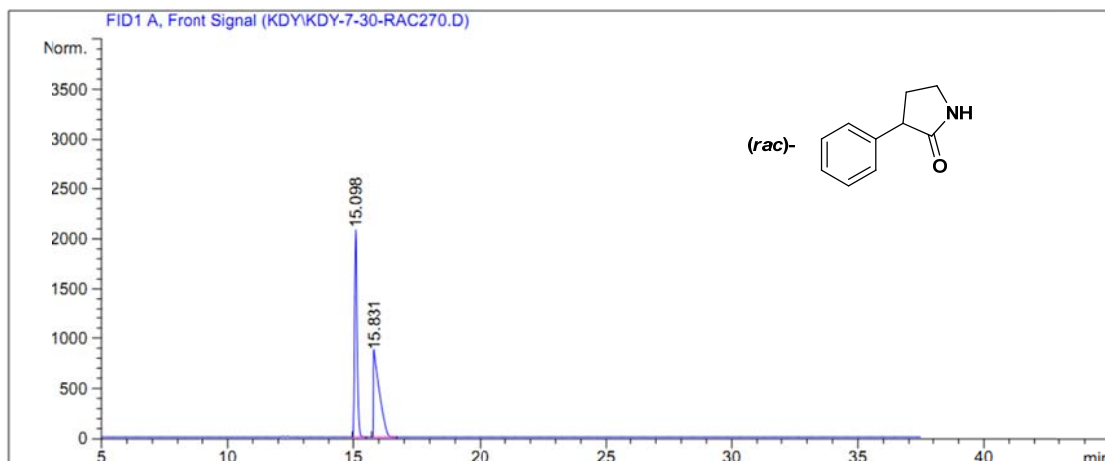


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.418	BB	0.1980	842.00226	65.05693	95.7846
2	11.525	BB	0.2512	37.05603	2.28509	4.2154

Totals : 879.05829 67.34202

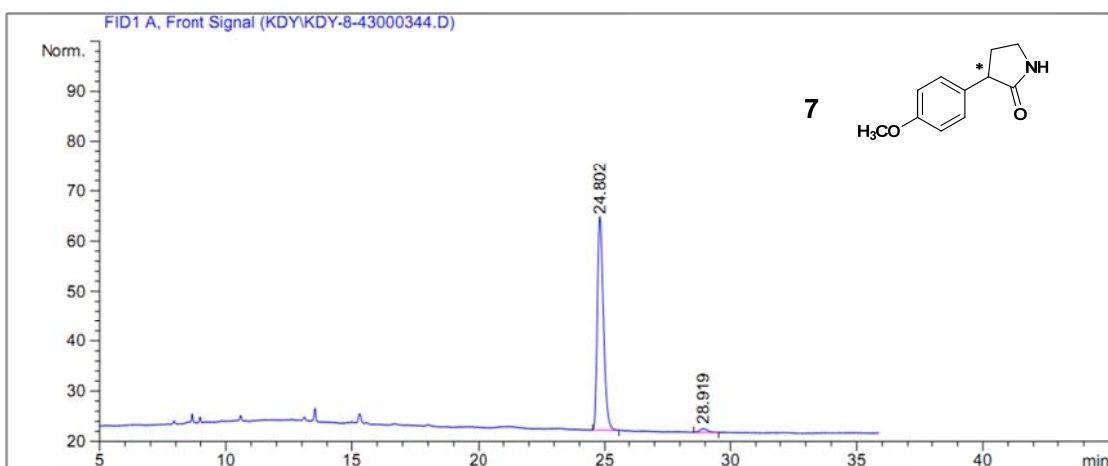
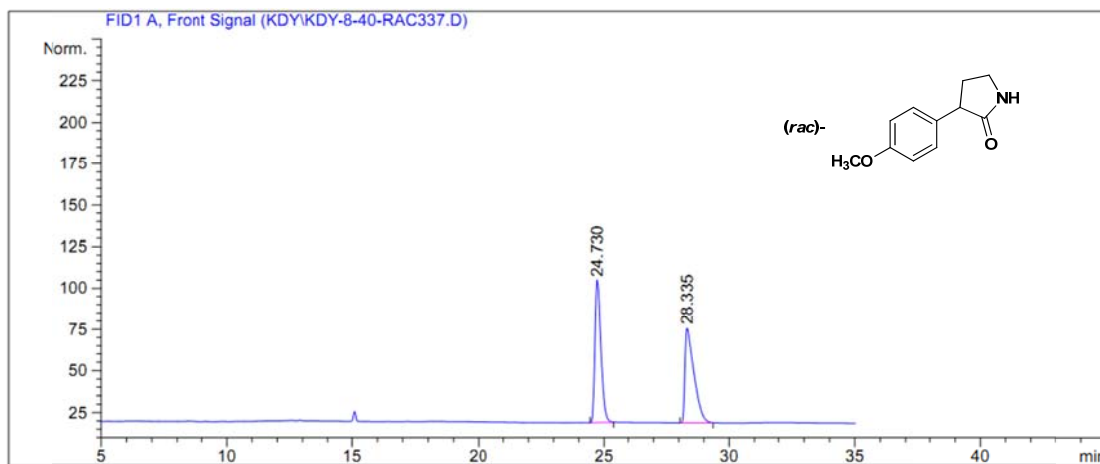


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.559	BB	0.2254	2804.29175	192.05591	97.0839
2	17.955	BB	0.4213	84.23180	3.03948	2.9161
Totals :				2888.52354	195.09539	

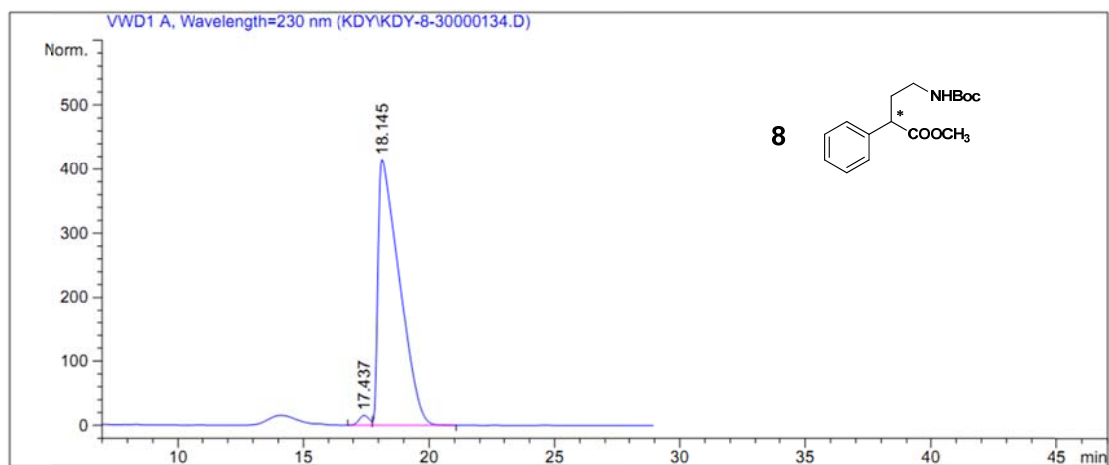
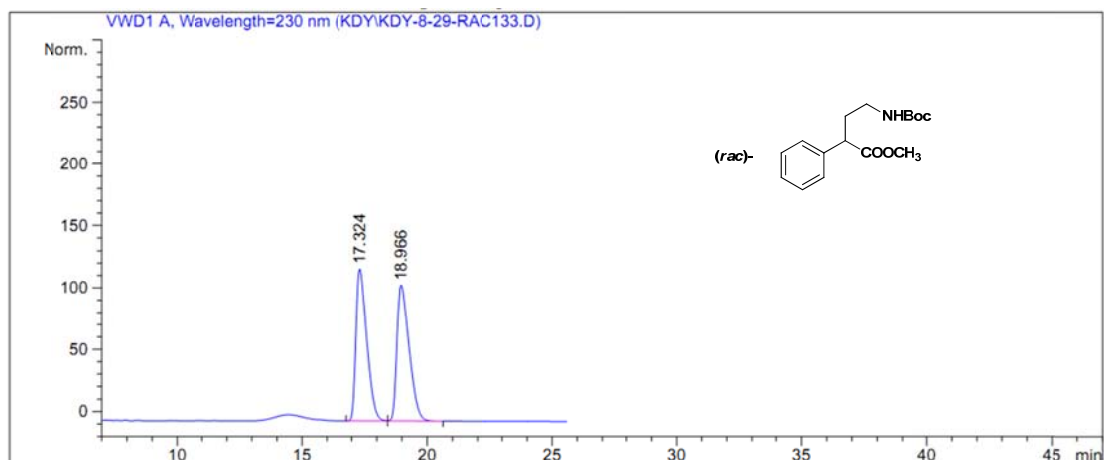


Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	15.253	BB	0.0940	48.78241	8.31724	3.02409
2	16.197	BB	0.1285	1564.34644	183.06644	96.97591
Totals :				1613.12884	191.38368	

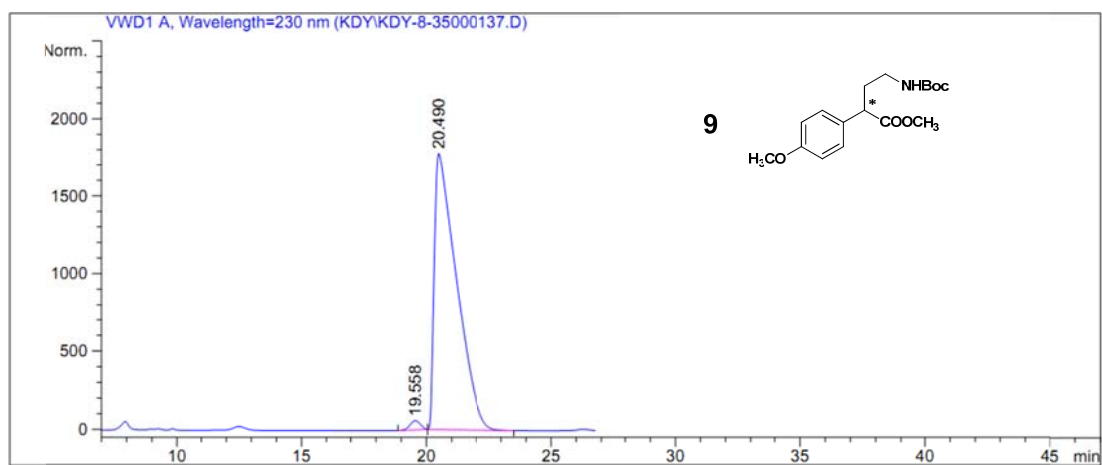
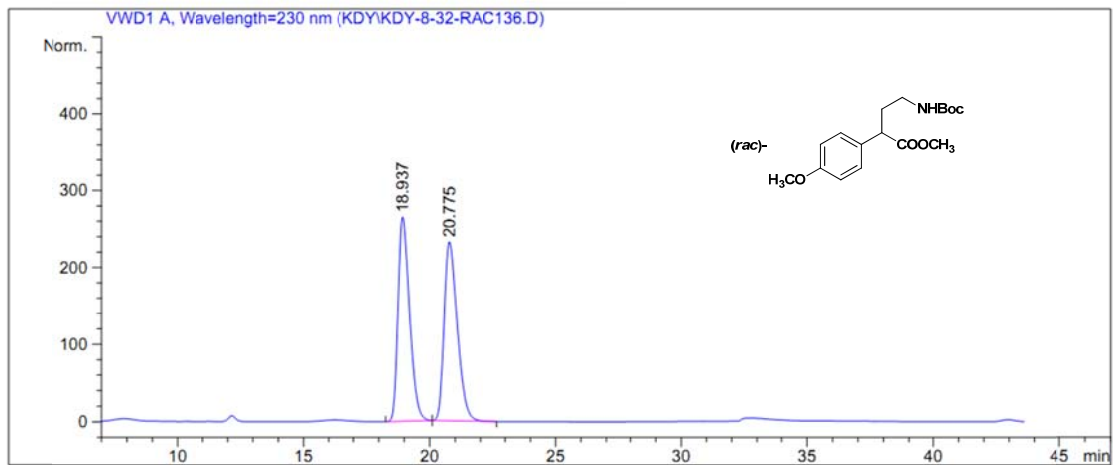




Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	24.802	BB	0.2564	708.02380	42.22035	98.04952
2	28.919	BB	0.3092	14.08457	6.97533e-1	1.95048
Totals :				722.10837	42.91789	



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.437	BV	0.4393	421.31314	15.25087	1.7136
2	18.145	VB	0.8621	2.41646e4	415.11633	98.2864
Totals :				2.45859e4	430.36721	



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.558	BB	0.4558	1680.73022	58.56921	1.5170
2	20.490	BB	0.9350	1.09111e5	1777.79150	98.4830
Totals :				1.10792e5	1836.36071	