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Diastereodivergent synthesis of 4-oxocyclohexanecarbaldehydes by using the modularly designed organocatalysts upon switching on their iminium catalysis

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Supporting Information

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1. General Information

Unless otherwise specified, all reactions were conducted in 17 × 60 mm glass vials and monitored by TLC on silica gel plates (200 μm) and visualized by UV. Column chromatography was performed on silica gel (32-63 μ). ^{1}H NMR spectra was recorded on a 500 MHz or a 300 MHz spectrometer (126 MHz or 75 MHz for ^{13}C NMR). Infrared spectra were measured on a Bruker Vector 22 instrument. Enantiomeric excesses (ee) were determined by chiral HPLC analysis using a Shimadzu instrument. ChiralPak IC, ID, IB, AD-H, and OD-H columns (4.6 mm × 250 mm) were purchased from Daicel Chemical Industries. Melting points were recorded on MEL-TEMP melting point apparatus in open capillaries and uncorrected. HRMS were conducted by the RCMI Core Facilities, Department of Chemistry, UTSA. Unless specified below, all chemicals are commercial products and were used as received. All the catalysts used in this study are known compounds and were synthesized according to the literature procedures.[15] Toluene was dried over sodium metal under argon atmosphere and distilled before prior to use. Ethanol was dried over magnesium turnings under argon atmosphere and distilled before prior to use.

2. Detailed Experimental Procedures

General Procedure for the Purification of *trans*-Cinnamaldehydes

Since *trans*-cinnamic acid was found to be an activator in our reaction and the corresponding acid may be present in commercial samples of *trans*-cinnamaldehydes as an impurity (formed through air oxidation of the aldehyde), the commercial samples were carefully purified before we put them into the reaction: *trans*-Cinnamaldehyde (5.0 g) was dissolved in dichloromethane (30 mL) and washed with 0.1 N NaOH solution (5 mL). Then dichloromethane solution was washed with brine solution (3 ×5 mL) and dried over anhydrous Na_2SO_4. The solution was filtered and concentrated under reduced pressure. The crude *trans*-cinnamaldehyde obtained was then further purified by fractional distillation under reduced pressure and was obtained as a colorless oil. The purity of the fraction collected was verified with ^{1}H NMR. The freshly distilled *trans*-cinnamaldehyde was used directly for the reactions.

Procedure for the Purification of Acetone

To acetone (200 mL) was added 1 M NaOH solution (2 mL) and the mixture was shaken for 10 min to quenched any acidic impurities present in acetone. Then anhydrous $CaSO_4$ was added to the mixture, which was vigorously stirred for 2 h. The mixture was filtered through Celite and distilled under N_2 atmosphere to yield pure acetone. The distilled acetone was stored under N_2 in a flask covered with aluminum foil.

General Procedure for the Synthesis of Diastereomer 7

A mixture of **9a** (7.2 mg, 0.010 mmol) and **10a** (L-proline, 1.1 mg, 0.010 mmol) in freshly distilled EtOH (1.0 mL) was stirred for 15 min. at room temperature. Then acetone (**6a**, 0.10 mL, 1.29 mmol) was added and the mixture was further stirred for 10 min. at room temperature. The reaction mixture was cooled to -5 ℃ and after 5 min. α, β-unsaturated aldehyde **1** (0.10 mmol) and *trans*-cinnamic acid (**11a**, 1.5 mg, 0.010 mmol) were added. The reaction mixture was further stirred at -5 ℃ until the complete consumption of α, β-unsaturated aldehyde **1** (TLC monitoring). After the completion of the reaction, the solvent was evaporated in a rotary evaporator under reduced pressure and the crude product obtained was purified by flash column chromatography using 70:30 to 95:5 hexane/EtOAc as an eluent.

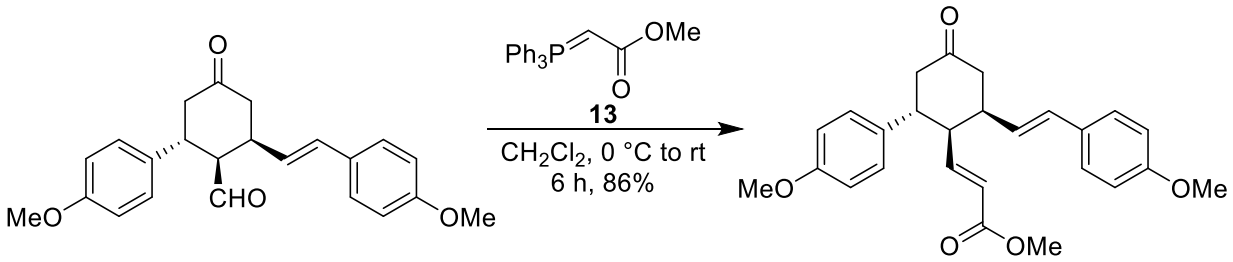
General Procedure for the Synthesis of Diastereomer 7'

A mixture of **9e** (QDT, 5.9 mg, 0.010 mmol) and **10a** (L-proline, 1.1 mg, 0.010 mmol) in freshly distilled toluene (0.5 mL) was stirred for 15 min. at room temperature. Then acetone (**6a**, 0.10 mL, 1.29 mmol) was added and the mixture was further stirred for 10 min. at room temperature. The reaction mixture was cooled to 0 ℃ and after 5 min. α, β-unsaturated aldehyde **1** (0.10 mmol) and *trans*-cinnamic acid (**11a**, 1.5 mg, 0.010 mmol) were added. The reaction mixture was further stirred at 0 ℃ until the complete consumption of α, β-unsaturated aldehyde **1** (TLC monitoring). After the completion of the reaction, the solvent was evaporated in a rotary evaporator under reduced pressure and the crude product obtained was purified by flash column chromatography using 70:30 to 95:5 hexane/EtOAc as an eluent.

Synthesis of Compound 12

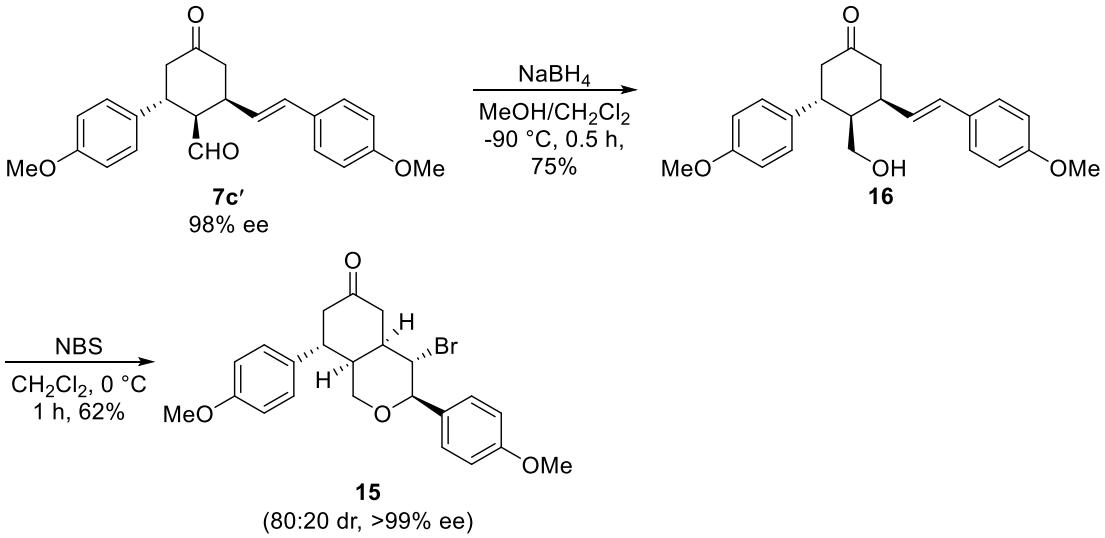
Compound **12** was obtained as a yellow solid in 60% yield (10.3 mg) from the reaction of *trans*-cinnamaldehyde (**1a**) and acetone (**6a**) by following the general procedure for synthesizing diastereomer **7**, except that the reaction was conducted in toluene (1.0 mL) at rt for 24 h without adding *trans*-cinnamic acid. This compound has identical spectroscopic data as the authentic sample synthesized below.

Synthesis of Compound 14



Methyl (triphenylphosphoranylidene)acetate (**13**, 25.0 mg, 0.075 mmol) was added in one portion to a solution of **7c'** (9.0 mg, 0.025 mmol, 98% ee) in anhydrous dichloromethane (1.0 mL) at 0 ℃ with stirring. The reaction mixture allowed to warm up to room temperature slowly. After 6 h, the solvent was evaporated in a rotary evaporator under reduced pressure and the crude product obtained was purified by flash column chromatography using 80:20 to 95:5 hexane/EtOAc as an eluent. The desired product was obtained **14** as a white solid (9.0 mg, 86% yield, >99% ee).

Synthesis of Compound 15

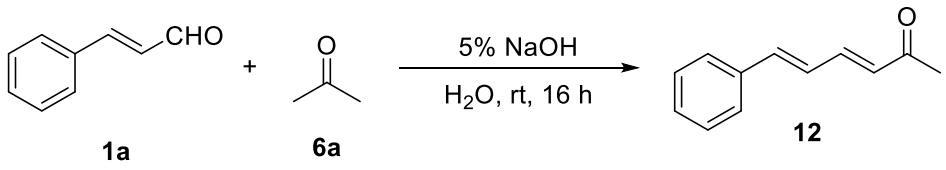


$NaBH_4$ (2.59 mg, 0.068 mmol) was added in one portion to a solution of **7c'** (10.0 mg, 0.027 mmol, 98% ee) in anhydrous MeOH/CH_2Cl_2 (1:1, 2.0 mL) at -90 ℃ with stirring. The reaction mixture was stirred at this temperature for 0.5 h. Then the reaction was quenched with excessive acetaldehyde and the solvent was evaporated in a rotary evaporator under reduced pressure. The crude product obtained was purified by flash column chromatography using 60:40 to 90:10 hexane/EtOAc as an eluent. The desired selective reduction product **16** was obtained as a colorless oil (7.5 mg, 75% yield).

Compound **15** was achieved by treatment of **16** with NBS in dichloromethane: NBS (8.5 mg, 0.0478 mmol) was added in one portion to a solution of **16** (14.0 mg, 0.038 mmol) in anhydrous dichloromethane (1.0 mL) at 0 ℃ with stirring. The reaction mixture was stirred at the same temperature for 1 h. Then the solvent was evaporated in a rotary evaporator under reduced pressure and the crude product obtained was purified by flash column chromatography using 80:20 to 95:5 hexane/EtOAc as an eluent. The desired product was obtained **15** as a colorless oil (10.5 mg, 62% yield, 80:20 dr, >99% ee). The structure of the major diastereomer was confirmed by HSQC, HMBC, and COSY experiments.

Synthesis of Compounds for Mechanistic Studies

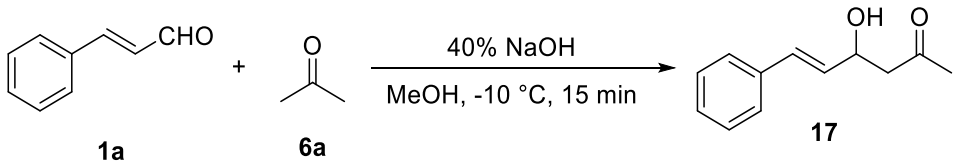
a) Synthesis of Compound 12[16]



1a **6a** **12**

An authentic sample of compound **12** was synthesized by following the literature procedure: To a solution of *trans*-cinnamaldehyde (**1a**, 1.32 g, 10 mmol) in acetone (**6a**, 638 mg, 11 mmol) and EtOH (10 mL) was added dropwise 5% aqueous NaOH solution (10 mL) slowly at room temperature. After stirring at room temperature for 16 h, the pH value was adjusted to 6-7 with 10% HCl, and the resulting solution was extracted with CH_2Cl_2 (20 mL × 3). The combined organic phase was washed with saturated brine before dried over anhydrous Na_2SO_4, and the concentration was conducted under vacuum. The crude product obtained was purified by flash column chromatography using 90:10 to 95:05 hexane/EtOAc as an eluent. Compound **12** was obtained as a yellow solid (980 mg, 57% yield).

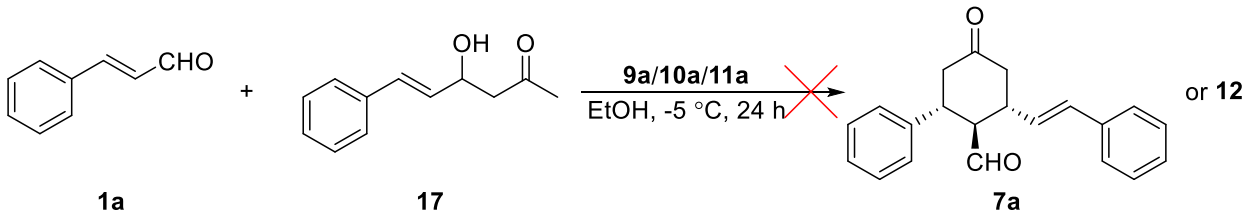
b) Synthesis of Compound 17[17]



The aldol product was synthesized according to the literature procedure: A stirred solution of acetone (**6a**, 726 mg, 12.5 mmol) and *trans*-cinnamaldehyde (**1a**, 1.65 g, 12.5 mmol) in methanol (10 mL) was treated at -10 °C with aqueous sodium hydroxide (40%, 0.1 mL). After 15 min the slightly yellow solution was poured into excess ice/water containing acetic acid (0.2 mL). The reaction mixture was extracted with a mixture of ethyl acetate/hexane (2:1). The organic phase was washed with saturated $NaHCO_3$ solution and dried with sodium sulfate. The residue obtained upon evaporation of the solvent was chromatographed with increasing amounts of ethyl acetate in hexane, affording desired aldol product **17** (400 mg, 17% yield).

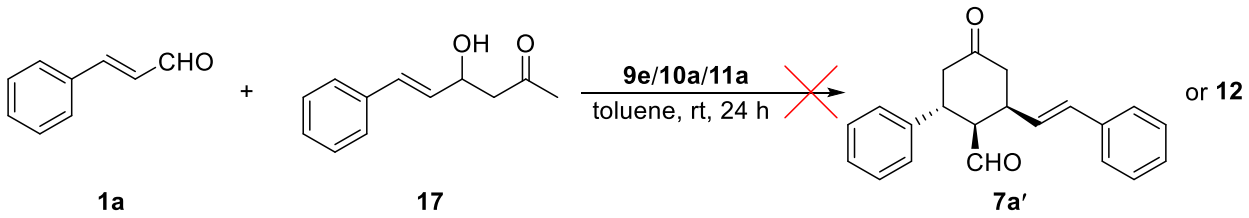
Procedures for Mechanistic Studies

a)



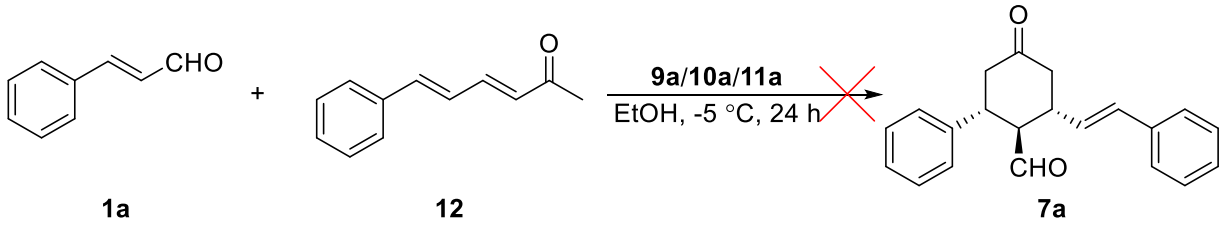
A mixture of **9a** (7.2 mg, 0.010 mmol) and **10a** (L-proline, 1.1 mg, 0.010 mmol) in freshly distilled EtOH (1.0 mL) was stirred for 15 min. at room temperature. Then compound **17** (19.0 mg, 0.10 mmol) was added and the mixture was further stirred for 10 min. at room temperature. The reaction mixture was cooled to -5 °C. After 5 min., *trans*-cinnamaldehyde (**1a**, 19.8 mg, 0.15 mmol) and **11a** (*trans*-cinnamic acid, 1.5 mg, 0.01 mmol) were added. The reaction mixture was stirred at -5 °C for 24 h. No reaction was observed and the expected formation of the desired product **7a** or the condensation product **12** did not happen.

b)



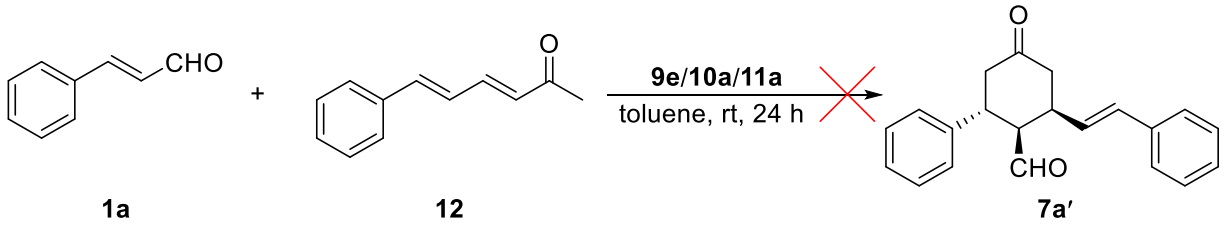
A mixture of **9e** (QDT, 5.94 mg, 0.010 mmol) and **10a** (L-proline, 1.1 mg, 0.010 mmol) in freshly distilled toluene (0.5 mL) was stirred for 15 min. at room temperature. Then compound **17** (19.0 mg, 0.10 mmol) was added the mixture was further stirred for 10 min. at room temperature. Then *trans*-cinnamaldehyde (**1a**, 19.8 mg, 0.15 mmol) and **11a** (*trans*-cinnamic acid, 1.5 mg, 0.010 mmol) were added. The reaction mixture was stirred at room temperature for 24 h. No reaction was observed and the expected formation of the desired product **7a'** or the condensation product **12** did not happen.

c)



A mixture of **9a** (7.2 mg, 0.010 mmol) and **10a** (L-proline, 1.1 mg, 0.010 mmol) in freshly distilled EtOH (1.0 mL) was stirred for 15 min. at room temperature. Then compound **12** (17.2 mg, 0.10 mmol) was added and the mixture was further stirred for 10 min. at room temperature. The reaction mixture was cooled to -5 ℃. After 5 min., *trans*-cinnamaldehyde (**1a**, 19.8 mg, 0.15 mmol) and **11a** (*trans*-cinnamic acid, 1.5 mg, 0.010 mmol) were added. The reaction mixture was further stirred at -5 ℃ for 24 h. No reaction was observed and the expected formation of the desired product **7a** did not happen.

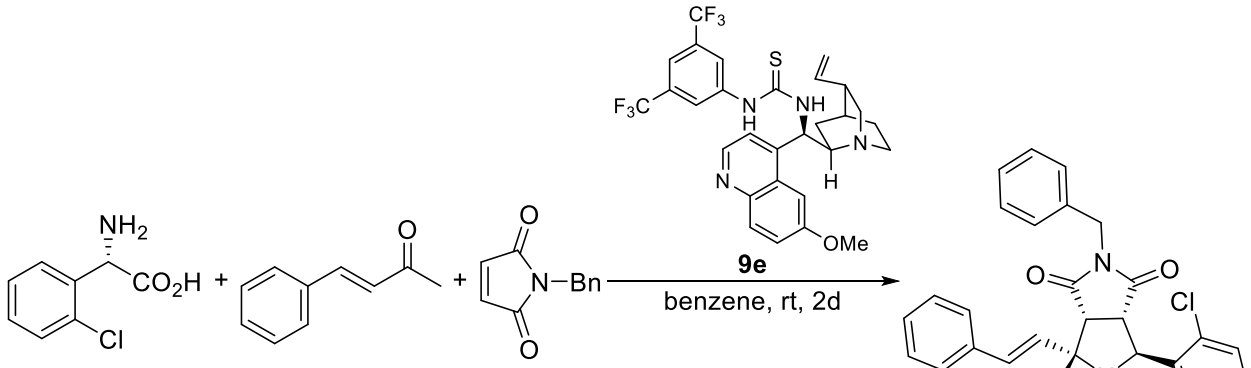
d)



1a 12 7a′

A mixture of **9e** (QDT, 5.94 mg, 0.010 mmol) and **10a** (L-proline, 1.1 mg, 0.010 mmol) in freshly distilled toluene (0.5 mL) was stirred for 15 min. at room temperature. Then compound **12** (17.2 mg, 0.1 mmol) was added and the mixture was further stirred for 10 min. at room temperature. *trans*-Cinnamaldehyde (**1a**, 19.8 mg, 0.15 mmol) and **11a** (*trans*-cinnamic acid, 1.5 mg, 0.010 mmol) were added, and the reaction mixture was further stirred at room temperature for 24 h. No reaction was observed and the expected formation of the desired product **7a'** did not happen.

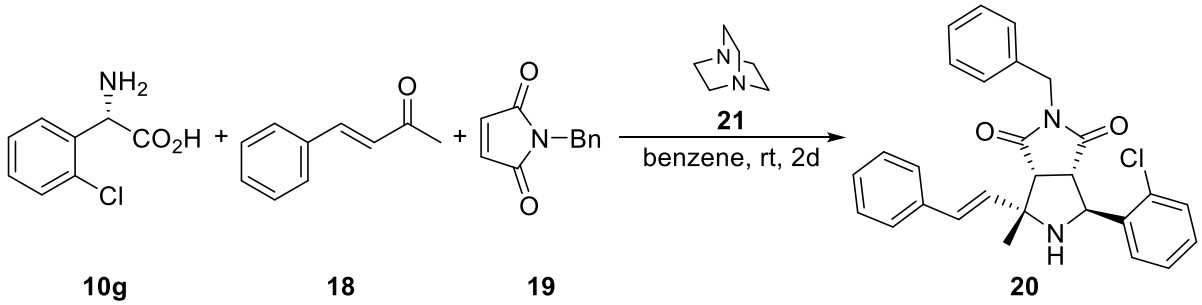
e) QDT-catalyzed decarboxylation of the iminium intermediate formed from L-2-chlorophenylglycine and trapping the 1,3-dipolar intermediate



10g 18 19 20

A solution of *trans*-4-phenyl-but-3-en-2-one (**18**, 29.2 mg, 0.20 mmol), 2-chlorophenylglycine (**10g**, 37.2 mg, 0.20 mmol), *N*-benzylmaleimide (**19**, 37.4 mg, 0.20 mmol) and QDT (**9e**, 23.8 mg, 0.040 mmol) in benzene (0.4 mL) were stirred at rt for 2 d (The progress of the reaction was monitored by TLC). After the reaction was completed, the volatile components were removed under reduced pressure and the residue was purified by column chromatography on silica gel (1:5 EtOAc/hexane as the eluent) to afford the cycloaddition product **20** as almost racemic mixture (70.4 mg, 77% yield, 3% ee according to HPLC analysis). The relative stereochemistry of this compound was determined by X-ray crystallography (CCDC deposition No. **859678**).

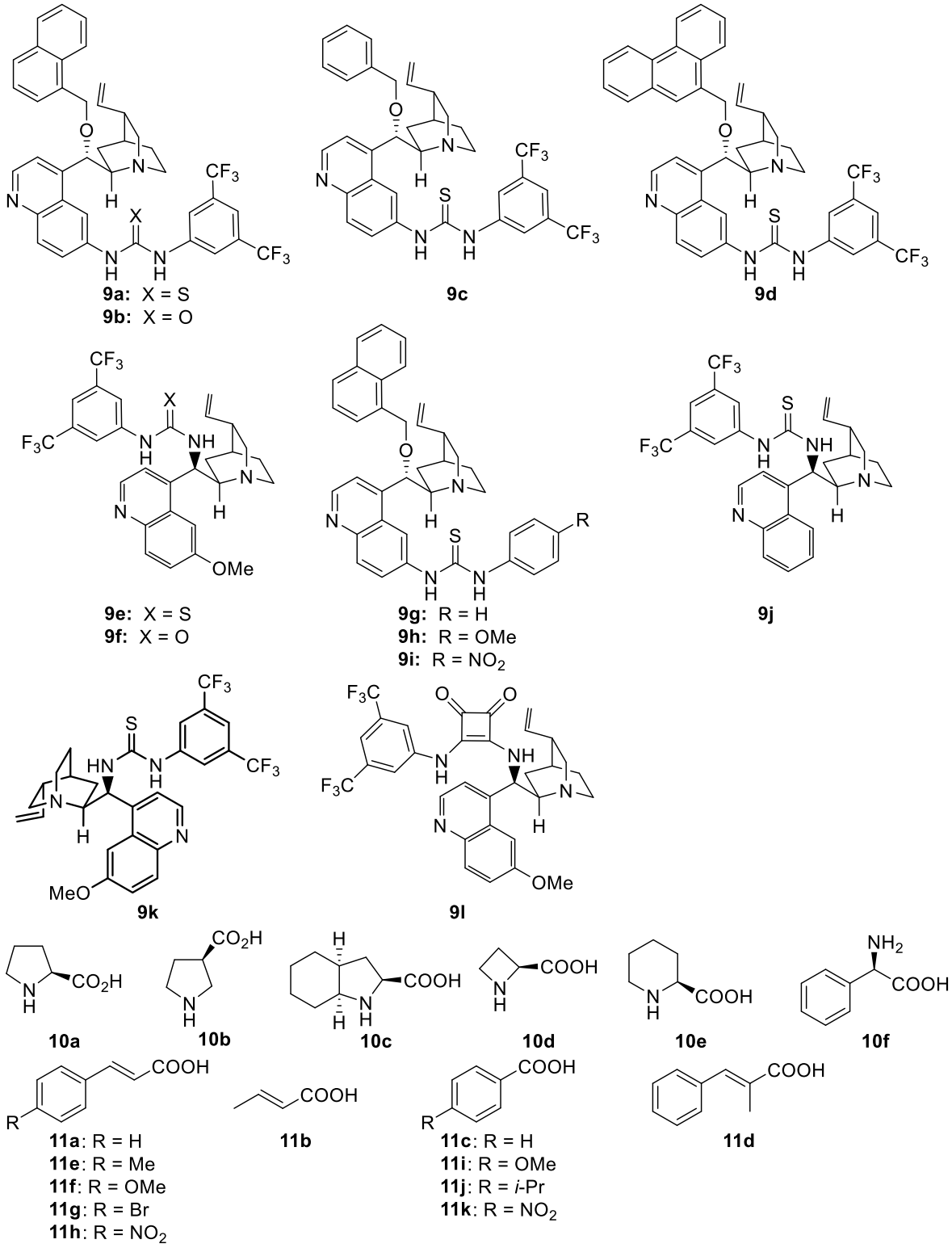
f) Trapping the 1,3-dipolar intermediate formed through a DABCO-induced decarboxylation of the iminium intermediate of L-2-chlorophenylglycine



10g **18** **19** **20**

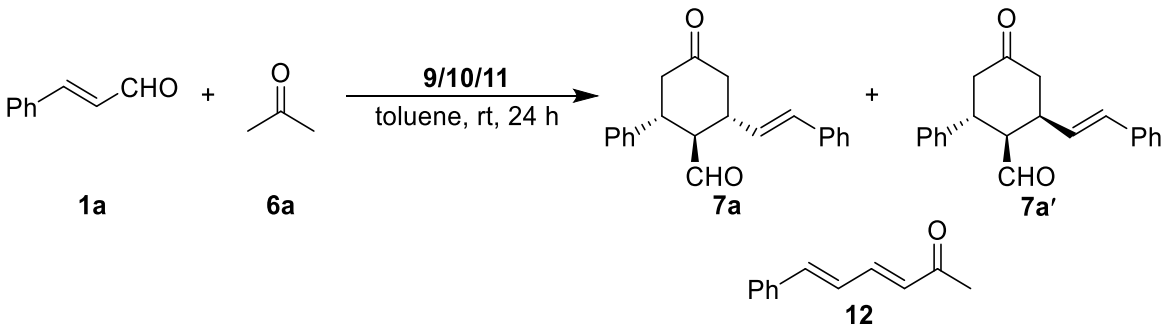
A solution of *trans*-4-phenyl-but-3-en-2-one (**18**, 29.2 mg, 0.20 mmol), 2-chlorophenylglycine (**10g**, 37.2 mg, 0.20 mmol), *N*-benzylmaleimide (**19**, 37.4 mg, 0.20 mmol) and DABCO (**21**, 22.4 mg, 0.20 mmol) in benzene (0.4 mL) were stirred at rt for 2 d (The progress of the reaction was monitored by TLC). After the reaction was completed, the volatile components were removed under reduced pressure and the residue was purified by column chromatography on silica gel (1:5 EtOAc/hexane as the eluent) to afford the cycloaddition product **20** as a racemic mixture (73.1 mg, 80% yield).

3. Full Results of Catalyst Screen and Reaction Condition Optimizations



Scheme S-1. Structure of precatalyst modules and acids used in the screening

Table S-1. Screening of the precatalyst modules and acids for the domino reaction[a]



entry	9	10	11	yield (%)[b]	dr (**7a**/**7a'**)[c]	ee (%)[d]
1	**9a**	**10a**	**11a**	**77**	**75:25**	**95**
2	**9a**	**-**	**11a**	-	-	-
3[e]	**-**	**10a**	**11a**	-	-	-
4[f]	**9a**	**10a**	**-**	-	-	-
5	**9b**	**10a**	**11a**	70	91:29	39
6	**9c**	**10a**	**11a**	70	71:29	54
7	**9d**	**10a**	**11a**	65	63:37	86
8	**9e**	**10a**	**11a**	**83**	**8:92**	**>99**
9	**9f**	**10a**	**11a**	60	32:68	40
10	**9g**	**10a**	**11a**	63	71:29	90
11	**9h**	**10a**	**11a**	60	73:27	71
12	**9i**	**10a**	**11a**	67	70:30	62
13	**9j**	**10a**	**11a**	52	57: 43	51
14	**9k**	**10a**	**11a**	47	40:60	96
15	**9l**	**10a**	**11a**	53	40:60	48
16	**9a**	**10b**	**11a**	51	70:30	37
17	**9a**	**10c**	**11a**	-	-	-
18	**9a**	**10d**	**11a**	-	-	-
19	**9a**	**10e**	**11a**	-	-	-
20	**9a**	**10f**	**11a**	-	-	-
21	**9a**	**10a**	**11e**	70	71:29	91

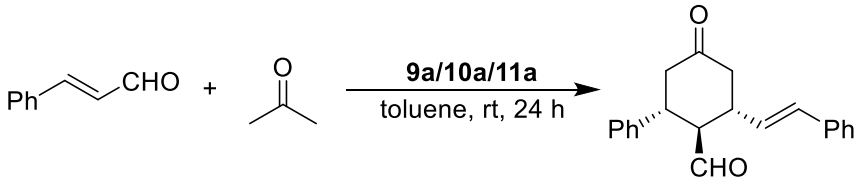
To be continued

Table S-1 continued

22	**9a**	**10a**	**11f**	42	61:39	76
23	**9a**	**10a**	**11g**	70	74:26	91
24	**9a**	**10a**	**11h**	57	50:50	84
25	**9a**	**10a**	**11b**	67	76:24	72
26	**9a**	**10a**	**11c**	42	70:30	71
27	**9a**	**10a**	**11i**	30	58:42	67
28	**9a**	**10a**	**11j**	65	70:30	86
29	**9a**	**10a**	**11k**	37	66:34	80
30	**9a**	**10a**	**11d**	50	70:30	90

[a]All reactions were carried out with **1a** (0.10 mmol), **6a** (0.10 mL), the precatalyst modules **9** and/or **10** (0.010 mmol each, 10 mol %), acid **11** (0.010 mmol) in dry toluene (1.0 mL) at room temperature for 24 h. [b]Yield of the isolated product after column chromatography. [c]Determined by ^{1}H NMR analysis of the crude product. [d]Determined by HPLC analysis of the major diastereomer. [e]The condensation product **12** was obtained in 29% yield. [f]The condensation product **12** was obtained in 60% yield.

Table S-2. Screening of the loading of acid 11a[a]

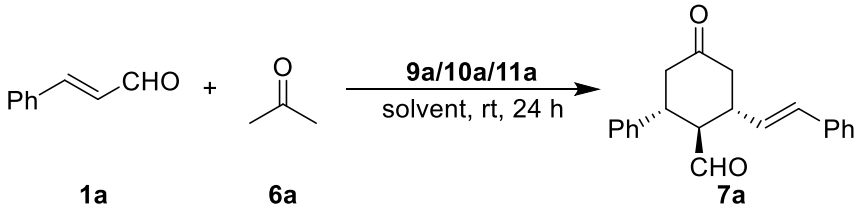


1a **6a** **7a**

entry	**11a** (mol %)	yield (%)[b]	dr[c]	ee (%)[d]
1	2.5	40	40:60	90
2	5	53	46:54	92
3	**10**	**77**	**75:25**	**95**
4	15	79	72:28	95

[a]All reactions were carried out with **1a** (0.10 mmol), **6a** (0.10 mL), the precatalyst modules **9a** and **10a** (0.010 mmol each, 10 mol %), and **11a** in dry toluene (1.0 mL) at room temperature for 24 h. [b]Yield of the isolated product after column chromatography. [c]Determined by ^{1}H NMR analysis of the crude product. [d]Determined by HPLC analysis of the major diastereomer.

Table S-3. Solvent effects on the formation of diastereomer 7a using 9a/10a/11a as the catalyst[a]

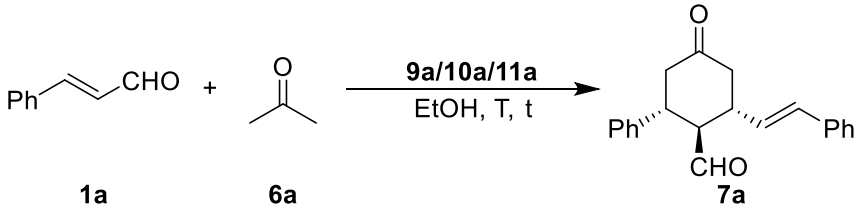


1a **6a** **7a**

entry	solvent	yield (%)[b]	dr[c]	ee (%)[d]
1	toluene	77	75:25	95
2	benzene	67	67:33	92
3	CH_2Cl_2	68	57:43	90
4	$CHCl_3$	60	63:37	92
5	$ClCH_2CH_2Cl$	50	55:45	90
6	dioxane	48	58:42	94
7	H_2O	trace	---	---
8	**EtOH**	**86**	**84:16**	**97**
9	MeOH	73	79:22	92
10	*i*-PrOH	72	79:21	93
11	*t*-BuOH	77	70:30	97

[a]All reactions were carried out with **1a** (0.10 mmol), **6a** (0.10 mL), the precatalyst modules **9a** and **10a** (0.010 mmol each, 10 mol%), and **11a** (0.010 mmol, 10 mol %) in the specified dry solvent (1.0 mL) at room temperature for 24 h. [b]Yield of the isolated product after column chromatography. [c]Determined by ^{1}H NMR analysis of the crude product. [d]Determined by HPLC analysis of the major diastereomer.

Table S-4. Effects of the amount of solvent and temperature on the formation of diastereomer 7a using 9a/10a/11a as the catalyst[a]

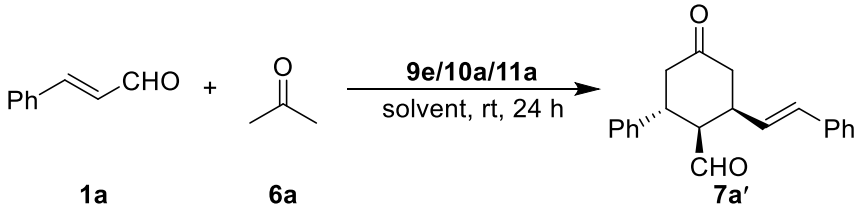


1a **6a** **7a**

entry	EtOH (mL)	temperature (°C)	time (h)	yield (%)[b]	dr[c]	ee (%)[d]
1	0	rt	5	75	62:38	94
2	0.2	rt	24	84	80:20	97
3	0.5	rt	24	88	82:18	96
4	1.0	rt	24	86	84:16	97
5	1.0	0	24	90	89:11	98
6	**1.0**	**-5**	**24**	**90**	**90:10**	**>99**

[a]All reactions were carried out with **1a** (0.10 mmol), **6a** (0.10 mL), the precatalyst modules **9a** and **10a** (0.010 mmol each, 10 mol%), and **11a** (0.010 mmol, 10 mol %) in dry EtOH at the specified temperature. [b]Yield of the isolated product after column chromatography. [c]Determined by ^{1}H NMR analysis of the crude product. [d]Determined by HPLC analysis of the major diastereomer.

Table S-5. Solvent effects on the formation of diastereomer 7a' using 9e/10a/11a as the catalyst[a]

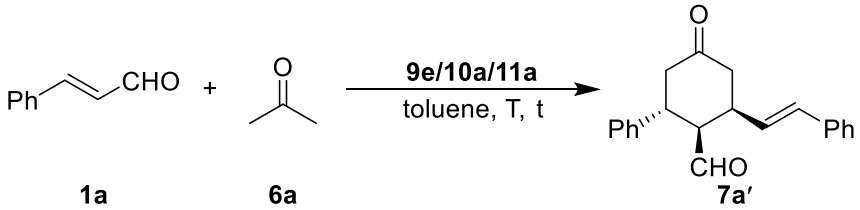


1a **6a** **7a′**

entry	solvent	yield (%)[b]	dr[c]	ee (%)[d]
1	**toluene**	**83**	**92:8**	**>99**
2	CH_2Cl_2	43	81:19	94
3	$CHCl_3$	47	85:15	93
4	EtOH	57	59:41	92
5	H_2O	trace	---	---
6	Et_2O	50	50:50	95
7	dioxane	27	65:35	92

[a]All reactions were carried out with **1a** (0.10 mmol), **6a** (0.10 mL), the precatalyst modules **9e** and **10a** (0.010 mmol each, 10 mol%), and **11a** (0.010 mmol, 10 mol %) in the specified dry solvent (1.0 mL) at room temperature for 24 h. [b]Yield of the isolated product after column chromatography. [c]Determined by ^{1}H NMR analysis of the crude product. [d]Determined by HPLC analysis of the major diastereomer.

Table S-6. Effects of the amount of solvent and temperature on the formation of diastereomer 7a' using 9e/10a/11a as the catalyst[a]



1a **6a** **7a′**

entry	toluene (mL)	temperature (°C)	time (h)	yield (%)[b]	dr[c]	ee (%)[d]
1	0	rt	5	80	88:12	>99
2	0.2	rt	24	82	89:11	>99
3	0.5	rt	24	88	94:6	>99
4	1.0	rt	24	83	92:8	>99
5	**0.5**	**0**	**24**	**91**	**94:6**	**>99**
6	0.5	-5	24	91	94:6	>99

[a]All reactions were carried out with **1a** (0.10 mmol), **6a** (0.10 mL), the precatalyst modules **9e** and **10a** (0.010 mmol each, 10 mol %), and **11a** (0.010 mmol, 10 mol %) in dry toluene. [b]Yield of the isolated product after column chromatography. [c]Determined by ^{1}H NMR analysis of the crude product. [d]Determined by HPLC analysis of the major diastereomer.

4. ORTEP Drawing of the Reaction Products

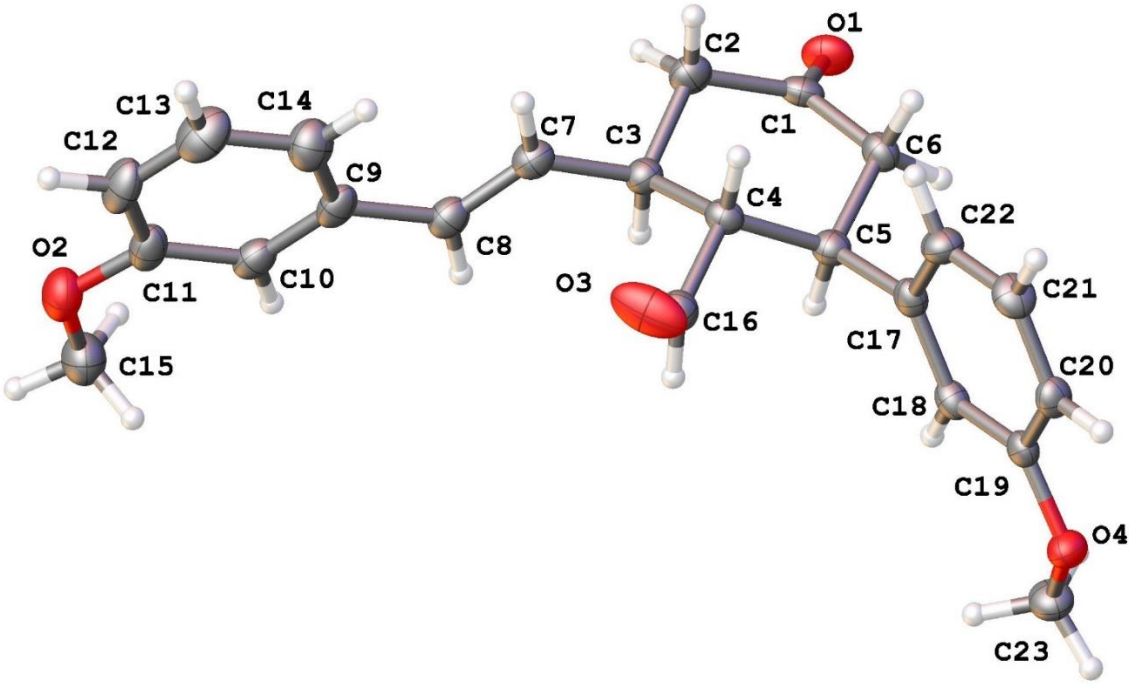


Figure S-1. ORTEP drawing of compound 7c (CCDC deposition number: 1976271).

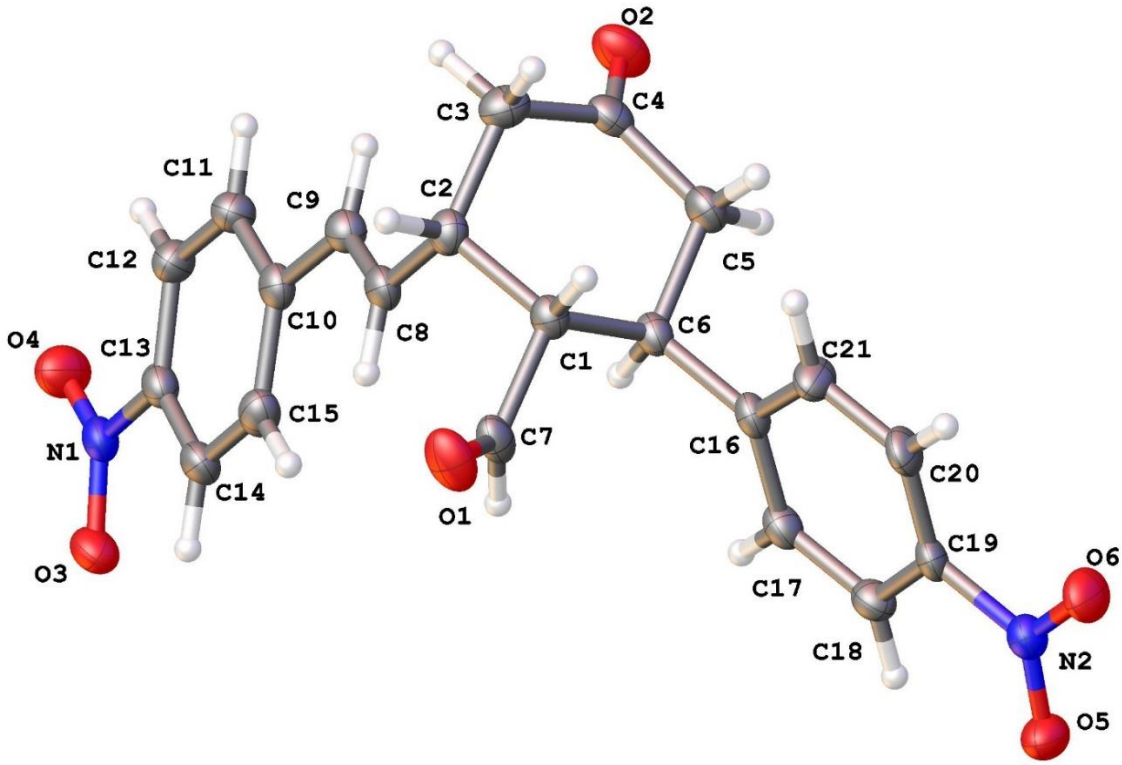


Figure S-2. ORTEP drawing of compound 7h' (CCDC deposition number: 2043408).

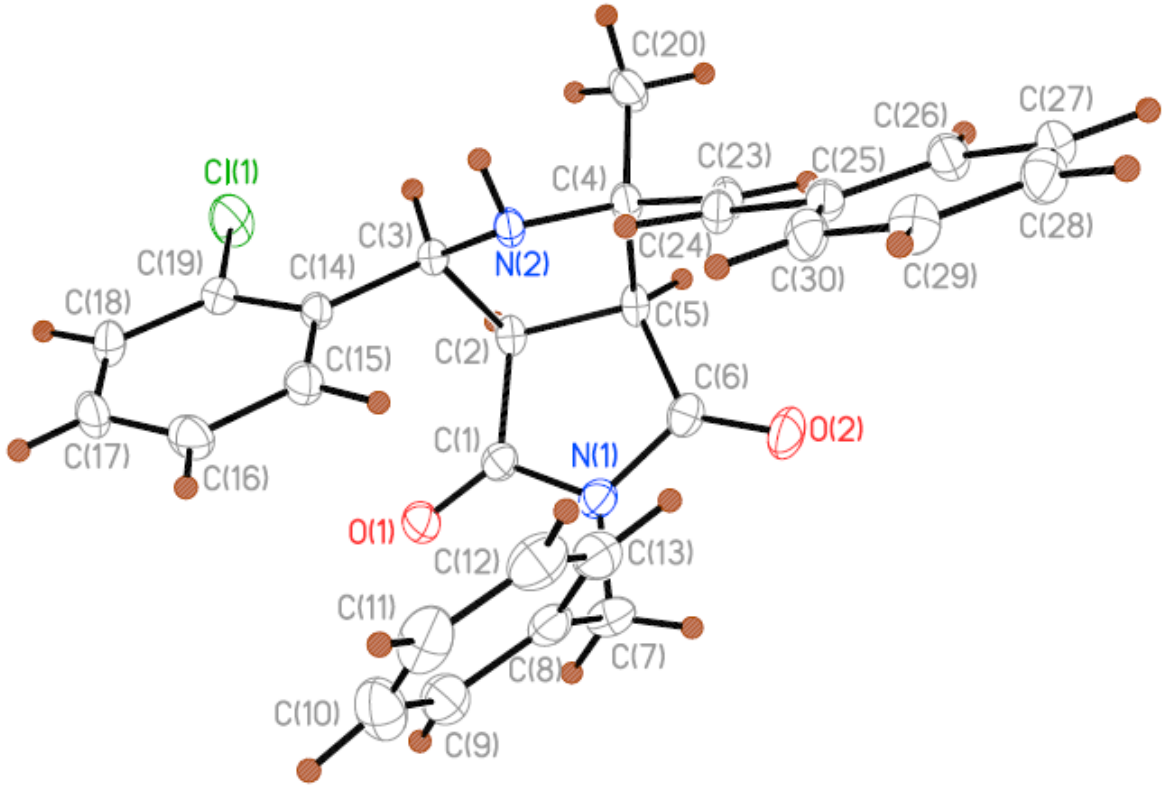
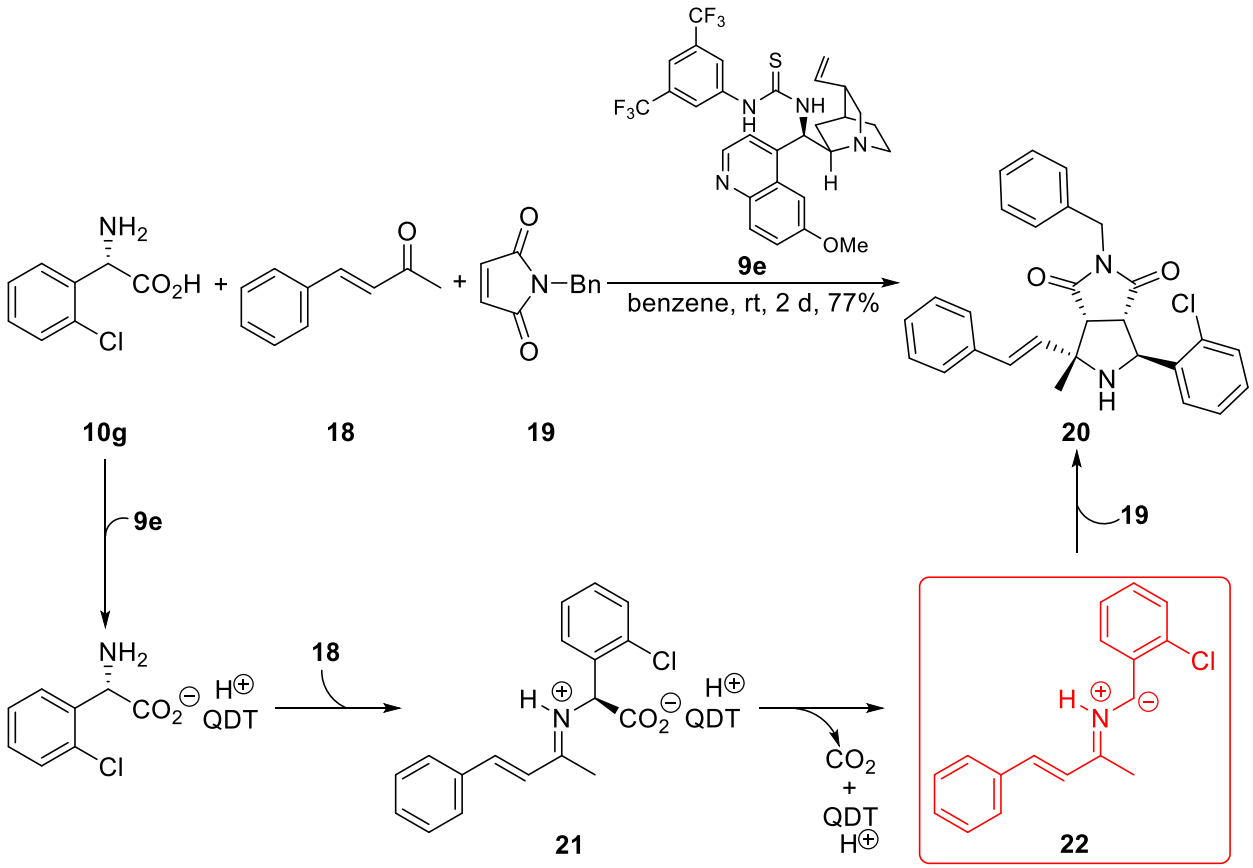


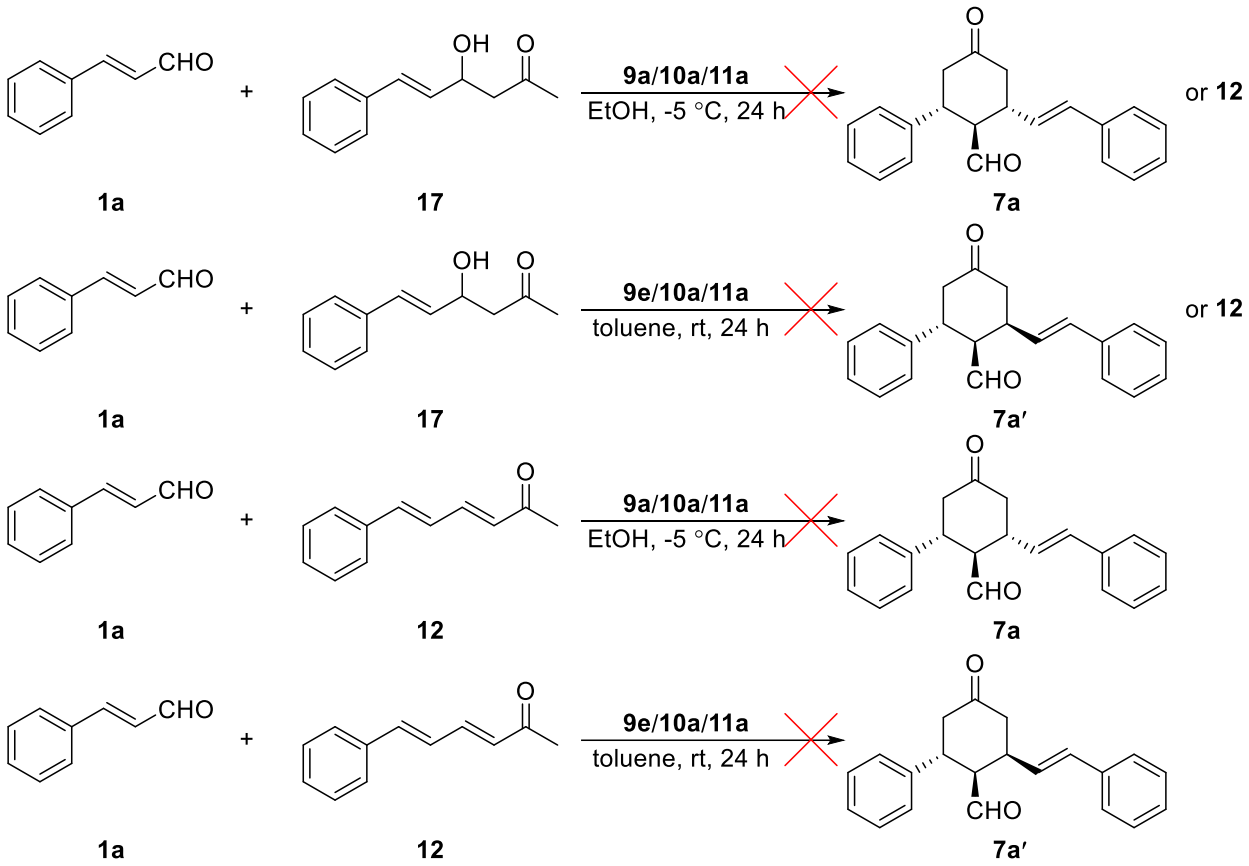
Figure S-3. ORTEP drawing of compound 20 (CCDC deposition number: 859678).

5. Mechanistic Study and Proposed Mechanisms

While we were not able to trap the decarboxylation intermediate **4** formed from *trans*-cinnamaldehyde and L-proline, we were able to trap a similar decarboxylation intermediate **22** formed from the reaction of L-2-chlorophenylglycine (**10g**) and **18** that was catalyzed by QDT (**9e**) (Scheme S-2). The trapping product **20** was fully characterized by its NMR spectra and X-ray (for details, please see the experimental part above). Similar reaction may also be conducted with DABCO as a reagent (for details, please see the experimental part above.), showing the reaction is facilitated by the base-induced deprotonation of the amino acid. These results suggest QDT can act as an inhibitor of the proline iminium catalysis via a similar decarboxylation pathway, too.



Scheme S-2. Trapping the decarboxylation intermediate 22 (QDT = 9e).

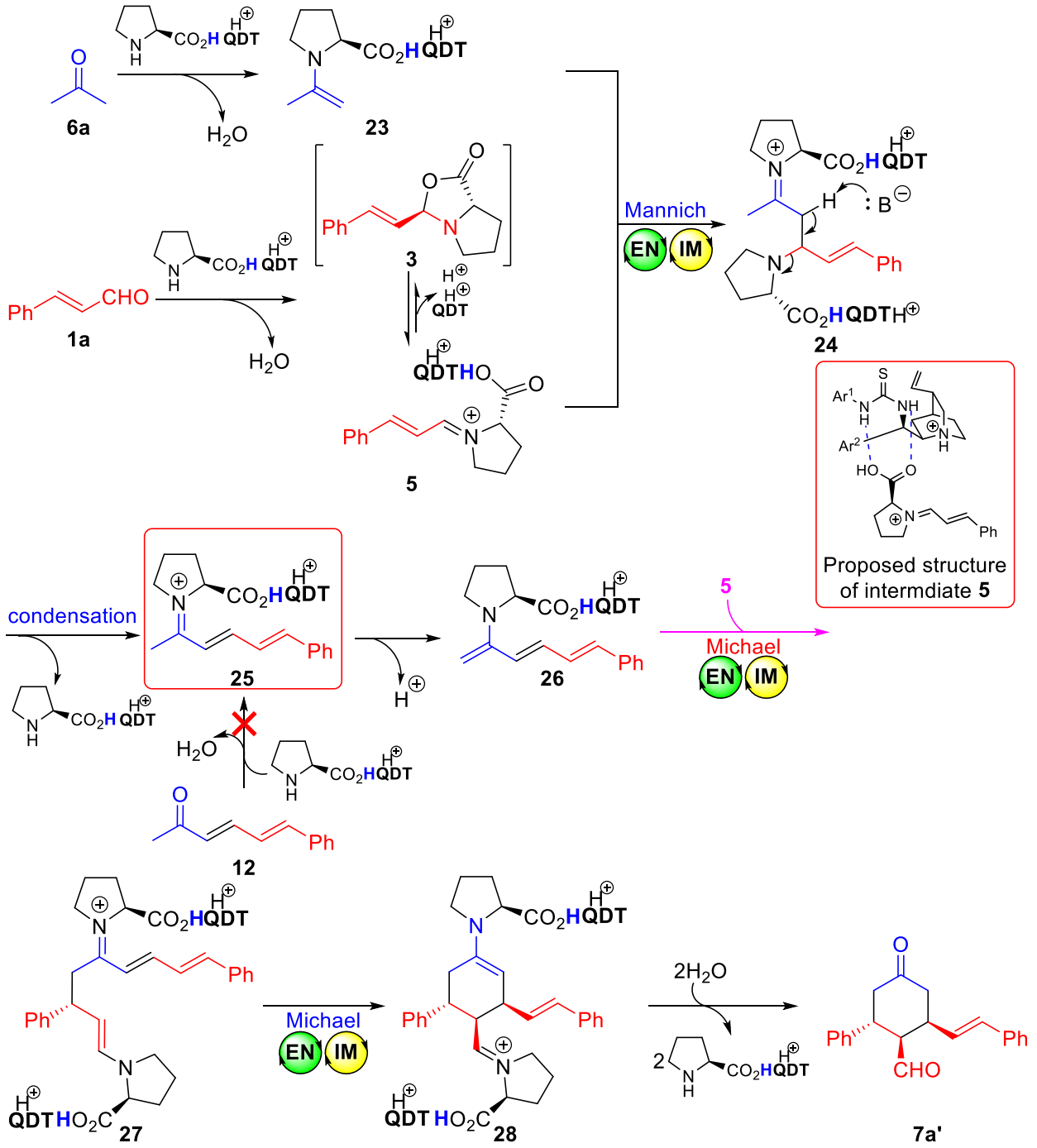


Scheme S-3. Control reactions that eliminate the involvement of compounds 12 and 17 in the reported domino reaction.

While Kong and coworker proposed a domino aldol condensation/Michael/Michael mechanism for this reaction,[8a] based on our experience, aldol condensation is unlikely to happen under our reaction conditions. In order to understand the reaction mechanism, we conducted some control experiments (Scheme S-3). We synthesized an authentic sample of the proposed aldol product of this reaction (i.e., compound **17**, for details, please see the experimental part above) and reacted this compound with **1a** under the optimized reaction conditions of both catalytic systems. As shown in Scheme S-3, we did not obtain any product from these reactions (no formation of the condensation product **12** or desired domino products **7a** or **7a'**). **These negative results exclude aldol condensation as the first step of this reaction mechanism**.

Since we obtained the mono-condensation product **12** when no acid was used in the reaction (Table 1, entry 1 of the main text), we also conducted control reactions using an authentic sample of compound **12** (for details, please the experimental part above). As shown in Scheme S-3, the

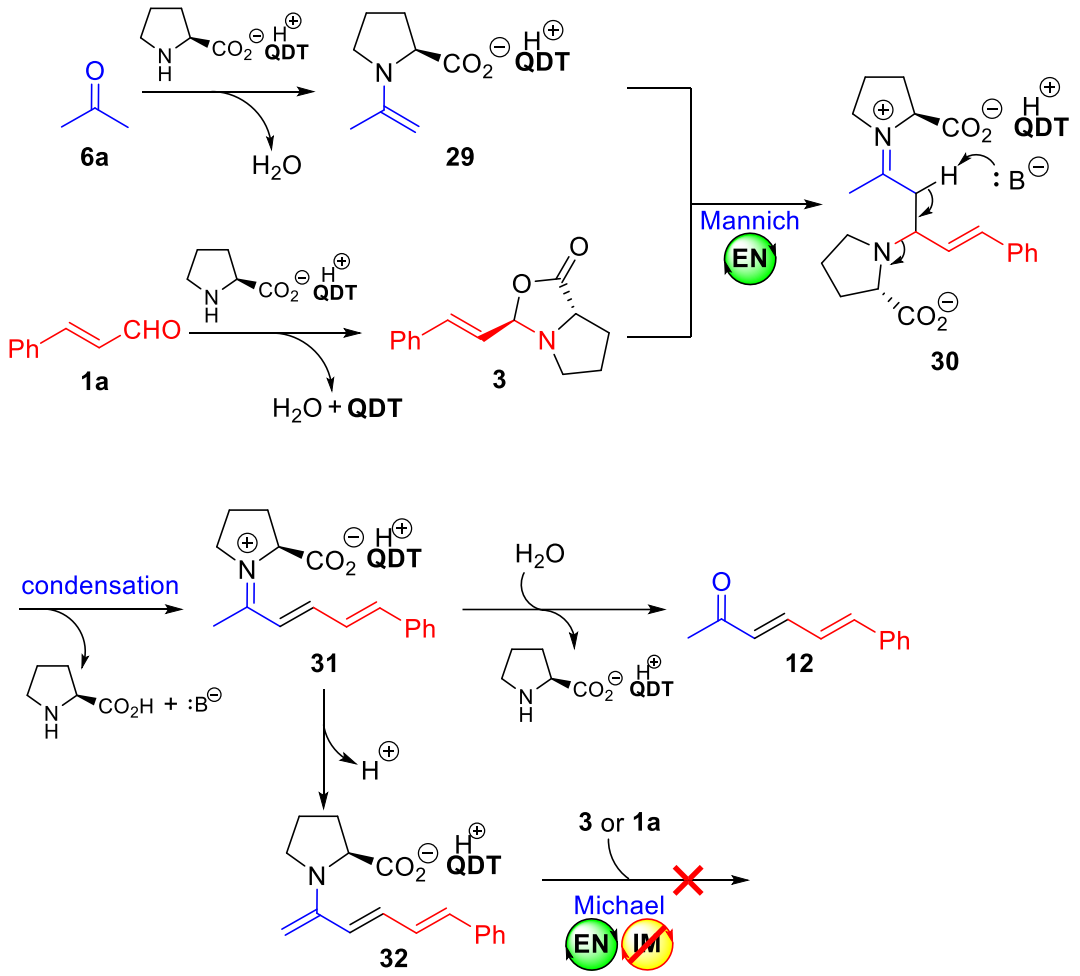
reaction of **1a** and **12** with both catalytic systems under the optimized conditions both gave negative results. **These negative results exclude the mono-condensation product 12 as an intermediate of this reaction**.



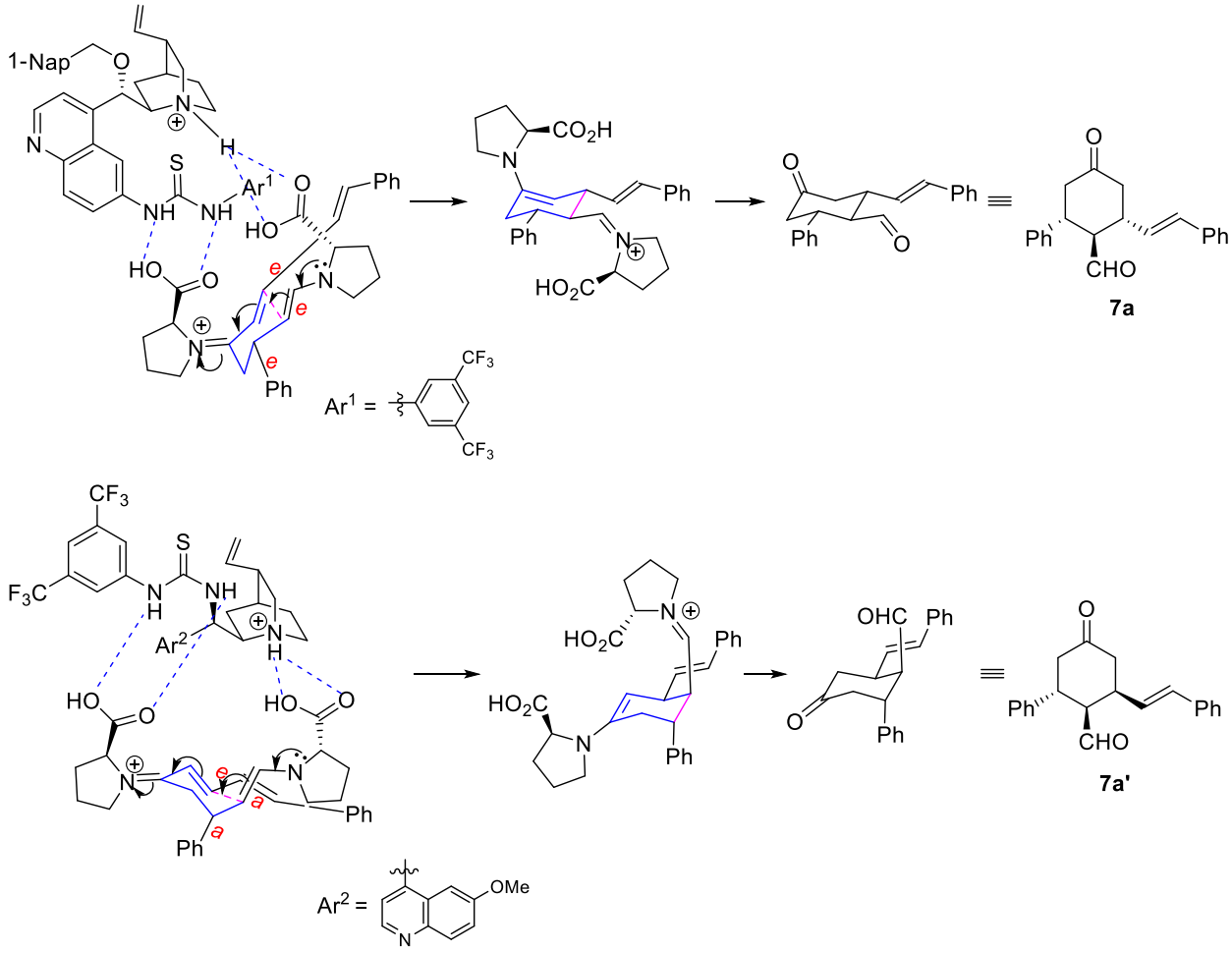
Scheme S-4. Proposed mechanism for the domino reaction (QDT = 9e) in the presence of an appropriate acid (represented by H in the proline moiety of the MDO).

Based on the above results, we propose a domino Mannich condensation/Michael/Michael reaction mechanism for our current reaction (Scheme S-4, see also Scheme 5 of the main text). It should be pointed out that proline-catalyzed condensation reactions between aldehydes is known to proceed through the Mannich mechanism instead of aldol condensation.[13] As shown in Scheme S-4, in the presence of a suitable acid, *trans*-cinnamaldehyde (**1a**) reacts with the protonated MDO (L-proline/QDT self-assembly) to yield the iminium intermediate **5**. While **5** is in equilibrium with the oxazolidinone intermediate **3**, we propose that the equilibrium favors **5** more than **3** in the presence of the acid. Similarly, acetone (**6a**) reacts with the MDO to yield the enamine intermediate **23**. The Mannich reaction between intermediate **23** and **5** (less likely with **3** in this case due to its low concentration and less reactivity) to yield the intermediate **24**, which undergoes an elimination reaction to give key iminium intermediate **25**. Iminium intermediate **25** then tautomerizes to become the enamine intermediate **26**, which is a **key intermediate** for this reaction. Intermediate **26** reacts with the iminium intermediate **5** again through a Michael reaction to give the enamine-iminium intermediate **27**. The later cyclizes through an intramolecular Michael reaction to give intermediate **28**, which after hydrolysis yields the desired product **7a'**. It should be pointed out that, while the Mannich condensation product **12** can be formed from intermediate **25** through hydrolysis (though this is not an important pathway in the presence of the weak acid), the reverse reaction is not possible, as our control reaction shows.

In the absence of an acid (Scheme S-5), **6a** reacts with the MDO to give the enamine intermediate **29** (which is similar to **23**, except that the proline moiety is not protonated). However, the reaction of **1a** and the MDO now mainly leads to the oxazolidinone intermediate **3** as there is no acid. The Mannich reaction between **29** and **3** leads to intermediate **30** (, which is similar to intermediate **24**). Elimination of one the proline moieties from **30** leads to the iminium intermediate **31** (, which is similar to **25**). Hydrolysis of **31** leads to the observed condensation product **12** (Table 1, entry 1 of the main text). Thus, the Mannich-condensation is still possible without any acid, because the enamine catalysis of the MDO is intact without an acid (Scheme S-5). On the other hand, the Michael reaction is not possible because there is no sufficient concentration of the iminium intermediate (an intermediate that is similar to **5**), while the oxazolidinone intermediate **3** (or cinnamaldehyde **1a**) cannot participate in the Michael reaction with the enamine intermediate **32** (Scheme S-5).



Scheme S-5. Proposed mechanism for the Mannich condensation reaction in the absence of an appropriate acid (QDT = 9e).



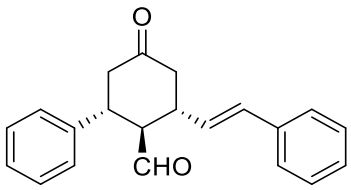
Scheme S-6. Proposed favored transition states for the intramolecular Michael reaction that leads to diastereodivergence.

From the absolute stereochemistry of the two diastereomeric products and the above proposed mechanism, it is evident that, for both catalytic systems, intermediates with exactly the same absolute stereochemistry (see the structure of intermediate **27** in Scheme S-4) is produced in the intermolecular Michael reaction (i.e., the first Michael reaction). The diastereodivergence is produced in the intramolecular Michael reaction (i.e., the second Michael reaction) when two different cinchona alkaloid thioureas are used (i.e., **9a** leads to **7a**, while **9e** leads to **7a'**). To explain these observations, favored transition states are proposed for both catalytic systems (Scheme S-6, see also Scheme 5 of the main text) on the basis of our previous study of the MDO enamine catalysis[4d,18] and a computational study of the MDO catalysis.[14] As shown in Scheme S-6, in both cases, the intermediate adopted a chair conformation in the favored transition states; however, to

better accommodate the hydrogen bonding between the two proline moieties of the intermediate and the cinchona alkaloid thiourea, the substrate adopted different chair conformations in these favored transition states: In the case of **9a**, the phenyl, enamine, and styryl groups are all at equatorial position. In contrast, in the case of **9e**, the phenyl, enamine, and styryl groups adopt axial, axial, and equatorial positions, respectively. Because of these differences, two product diastereomers **7a** and **7a'** are subsequently obtained (Scheme S-6). It should be pointed out that, although two proline/cinchona thioureas are required for the formation of the intermediate **27** before the final cyclization (see Scheme S-4), **we** believe only a **single cinchona moiety** is involved in the transition states for the formation of **7a** and **7a'** (Scheme S-6) because there is not enough space in the transition states to accommodate two such big alkaloid molecules and a single cinchona alkaloid also allows a more compact transition state to achieve the observed high stereoselectivities.

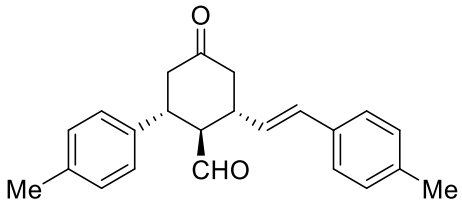
6. Compound Characterization Data

(1*R*,2*R*,6*R*)-4-Oxo-2-phenyl-6-[(*E*)-styryl]cyclohexane-1-carbaldehyde (7a)



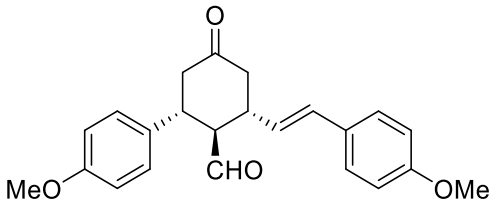
Reaction time: 24 h, white solid; 13.7 mg, 90% yield, m.p. 159-160 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.47 (d, *J* = 3.4 Hz, 1H), 7.37-7.29 (m, 5H), 7.29-7.20 (m, 5H), 6.45 (d, *J* = 15.8 Hz, 1H), 6.08 (dd, *J* = 15.8, 7.8 Hz, 1H), 3.37- 3.31 (m, 1H), 3.14-3.04 (m, 2H), 2.68-2.64 (m, 3H), 2.58-2.53 (m, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 206.9, 202.4, 140.3, 136.1, 132.1, 129.2, 128.9, 128.6, 127.9, 127.7, 127.2, 126.4, 59.1, 48.2, 46.3, 44.8, 42.6. ν_{max} (neat, cm^{-1}): 1068, 1109, 1240, 1289, 1334, 1417, 1452, 1491, 1706, 1721; HRMS (ESI, m/z) calcd for $C_{22}H_{21}O_2$ ($[M+H]^+$): 305.1536; found: 305.1541. Enantiomeric excess of **7a** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (80:20 hexanes/*i*-PrOH at 0.7 mL/min, λ = 254 nm); major isomer: t_R = 18.1 min, minor isomer: t_R = 28.3 min.

(1*R*,2*R*,6*R*)-2-[(*E*)-4-Methylstyryl]-4-oxo-6-(*p*-tolyl)cyclohexane-1-carbaldehyde (7b)



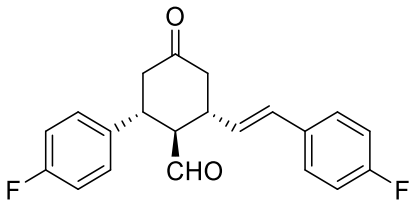
Reaction time: 48 h, white solid, 11.0 mg, 66% yield, m.p. 182-183 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.48 (d, *J* = 3.4 Hz, 1H), 7.23 (d, *J* = 8.0 Hz, 2H), 7.19 -7.09 (m, 6H), 6.42 (d, *J* = 15.8 Hz, 1H), 6.03 (dd, *J* = 15.8, 7.8 Hz, 1H), 3.39-3.24 (m, 1H), 3.16-2.95 (m, 2H), 2.69-2.62 (m, 3H), 2.55 (dd, *J* = 14.4, 12.0 Hz, 1H), 2.34 (s 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 207.2, 202.6, 137.8, 137.4, 133.4, 131.9, 129.8, 129.3, 127.9, 127.0, 126.3, 59.3, 48.3, 46.4, 44.5, 42.6, 21.2, 21.0. ν_{max} (neat, cm^{-1}): 1107, 1205, 1240, 1255, 1351, 1508, 1706, 1717. HRMS (ESI): m/z calcd for $C_{23}H_{25}O_2$ ($[M+H]^+$): 333.1849; Found 333.1852. Enantiomeric excess of **7b** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (80:20 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm), major enantiomer: t_R = 11.5 min, minor enantiomer: t_R = 15.2 min

(1*R*,2*R*,6*R*)-2-(4-Methoxyphenyl)-6-[(*E*)-4-methoxystyryl]-4-oxocyclohexane-1-carbaldehyde (7c)



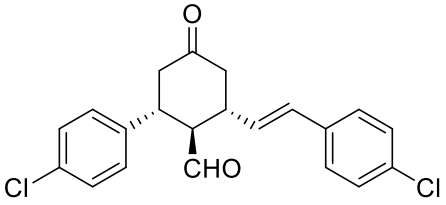
Reaction time: 32 h, white solid; 14.1 mg, 78% yield, m.p. 157-159 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.45 (d, *J* = 3.3 Hz, 1H), 7.24 (d, *J* = 8.7 Hz, 2H), 7.14 (d, *J* = 8.7 Hz, 2H), 6.86 (d, *J* = 8.7 Hz, 2H), 6.83 (d, *J* = 8.7 Hz, 2H), 6.37 (d, *J* = 15.8 Hz, 1H), 5.91 (dd, *J* = 15.8, 7.7 Hz, 1H), 3.79 (d, *J* = 7.4 Hz, 6H), 3.32-3.24 (m, 1H), 3.01 (ddd, *J* = 12.1, 7.3, 3.8 Hz, 2H), 2.68-2.58 (m, 3H), 2.54-2.46 (m, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 207.2, 202.7, 159.4, 158.9, 132.4, 131.4, 128.9, 128.2, 127.6, 126.8, 114.5, 114.0, 59.5, 55.3, 55.3, 48.5, 46.4, 44.1, 42.6. ν_{max} (neat, cm^{-1}): 1029, 1111, 1174, 1245, 1463, 1509, 1606, 1704, 1712; HRMS (ESI, m/z) calcd for $C_{23}H_{25}O_4$ ($[M+H]^+$): 365.1747; found: 365.1753. Enantiomeric excess of **7c** was determined by chiral stationary phase HPLC analysis using a ChiralPak IC column (70:30 hexanes/*i*-PrOH at 1 mL/min, λ = 254 nm); major isomer: t_R = 24.0 min, minor isomer: t_R = 30.9 min.

(1*R*,2*R*,6*R*)-2-(4-Fluorophenyl)-6-[(*E*)-4-fluorostyryl]-4-oxocyclohexane-1-carbaldehyde (7d)



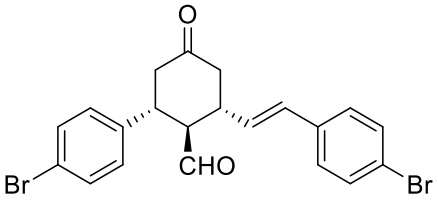
Reaction time: 40 h, white solid; 14.5 mg, 85% yield, m.p. 181-182 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.46 (d, *J* = 2.9 Hz, 1H), 7.34-7.26 (m, 2H), 7.21-7.18 (m, 2H), 7.04-6.97 (m, 4H), 6.40 (d, *J* = 15.8 Hz, 1H), 5.97 (dd, *J* = 15.8, 7.3 Hz, 1H), 3.36-3.30 (m, 1H), 3.13-2.93 (m, 2H), 2.67-2.56 (m, 3H), 2.58-2.50 (m, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 206.7, 202.5 163.1 (*J* = 63.0 Hz), 161.1 (*J* = 62.0 Hz), 135.9 (*J* = 2.5 Hz), 132.0 (*J* = 2.5 Hz), 130.9, 128.6 (*J* = 7.5 Hz), 128.2, 127.9 (*J* = 7.5 Hz), 116.1 (*J* = 21.4 Hz), 115.5 (*J* = 22.7 Hz), 59.1, 48.2, 46.2, 43.8, 42.6. ν_{max} (neat, cm^{-1}): 1092, 1110, 1162, 1222, 1248, 1349, 1508, 1600, 1706, 1715; HRMS (ESI, m/z) calcd for $C_{21}H_{19}F_2O_2$($[M+H]^+$): 341.1348; found: 341.1352. Enantiomeric excess of **7d** was determined by chiral stationary phase HPLC analysis using a ChiralPak IC column (80:20 hexanes/*i*-PrOH at 0.7 mL/min, λ = 254 nm); minor isomer: t_R = 19.9 min, major isomer: t_R = 21.0 min.

(1*R*,2*R*,6*R*)-2-(4-Chlorophenyl)-6-[(*E*)-4-chlorostyryl]-4-oxocyclohexane-1-carbaldehyde (7e)



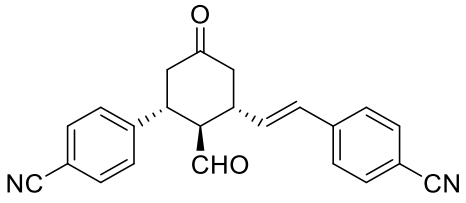
Reaction time: 32 h, white solid; 11.7 mg, 63% yield, m.p. 198-199 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.47 (s, 1H), 7.31 (d, *J* = 8.5 Hz, 2H), 7.28 -7.23 (m, 4H), 7.16 (d, *J* = 8.5 Hz, 2H), 6.39 (d, *J* = 15.8 Hz, 1H), 6.03 (dd, *J* = 15.8, 7.4 Hz, 1H), 3.36-3.30 (m, 1H), 3.08 -3.01 (m, 2H), 2.67-2.50 (m, 4H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 206.2, 202.1, 138.8, 134.5, 133.7, 133.5, 131.1, 129.4, 129.3, 128.8, 128.5, 127.6, 58.9, 48.0, 46.1, 44.0, 42.6. ν_{max} (neat, cm^{-1}): 1011, 1089, 1108, 1238, 1405, 1488, 1708, 1715; HRMS (ESI, m/z) calcd for $C_{21}H_{19}Cl_2O_2$ ($[M+H]^+$): 373.0757; found: 373.0758. Enantiomeric excess of **7e** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (80:20 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm); major isomer: t_R = 12.1 min, minor isomer: t_R = 14.8 min.

(1*R*,2*R*,6*R*)-2-(4-Bromophenyl)-6-[(*E*)-4-bromostyryl]-4-oxocyclohexane-1-carbaldehyde (7f)



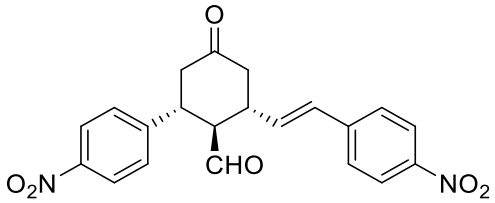
Reaction time: 45 h, white solid; 16.2 mg, 70% yield, m.p. 181-182 ˚C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.46 (d, *J* = 3.0 Hz, 1H), 7.47 (d, *J* = 8.5 Hz, 2H), 7.42 (d, *J* = 8.5 Hz, 2H), 7.17 (d, *J* = 8.5 Hz, 2H), 7.11 (d, *J* = 8.5 Hz, 2H), 6.38 (d, *J* = 15.8 Hz, 1H), 6.05 (dd, *J* = 15.8, 7.6 Hz, 1H), 3.34-3.28 (m, 1H), 3.09-3.01 (m, 2H), 2.67-2.50 (m, 4H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 206.1, 202.0, 139.3, 135.0, 132.3, 131.7, 131.2, 129.4, 128.9, 127.9, 121.8, 121.6, 58.8, 47.9, 46.1, 44.1, 42.6. ν_{max} (neat, cm^{-1}): 1008, 1069, 1238, 1216, 1354, 1420, 1485, 1676, 1706, 1716; HRMS (ESI, m/z) calcd for $C_{21}H_{19}Br_2O_2$ ($[M+H]^+$): 460.9746; found: 460.9747. Enantiomeric excess of **7f** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (80:20 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm); major isomer: t_R = 14.6 min, minor isomer: t_R = 13.3 min.

(1*R*,2*R*,6*R*)-2-(4-Cyanophenyl)-6-[(*E*)-4-cyanostyryl]-4-oxocyclohexane-1-carbaldehyde (7g)



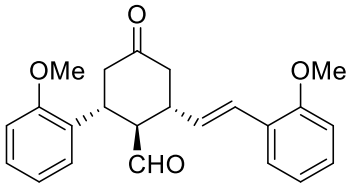
Reaction time: 48 h, white solid, 11.0 mg, 62% yield, m.p. 168-170 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.51 (d, *J* = 3.1 Hz, 1H), 7.68 (d, *J* = 8.3 Hz, 2H), 7.62 (d, *J* = 8.4 Hz, 2H), 7.42 (d, *J* = 8.4 Hz, 2H), 7.38 (d, *J* = 8.0 Hz, 2H), 6.50 (d, *J* = 15.8 Hz, 1H), 6.23 (dd, *J* = 15.9, 7.9 Hz, 1H), 3.50 – 3.37 (m, 1H), 3.13 (ddd, *J* = 21.3, 9.4, 3.6 Hz, 2H), 2.78-2.50 (m, 4H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 205.0, 201.3, 145.5, 140.3, 133.1, 132.5, 132.1, 131.1, 128.1, 126.9, 118.7, 118.2, 111.9, 111.5, 58.3, 47.4, 45.8, 44.4, 42.7. ν_{max} (neat, cm^{-1}): 1017, 1102, 1216, 1365, 1412, 1605, 1704, 1718, 2226, 2849, 2920. HRMS (ESI): m/z calcd for $C_{23}H_{19}N_2O_2$ ($[M+H]^+$): 355.1441; Found 355.1441. Enantiomeric excess of **7g** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (70:30 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm), major enantiomer: t_R = 36.8 min, minor enantiomer: t_R = 45.4 min

(1*R*,2*R*,6*R*)-2-(4-Nitrophenyl)-6-[(*E*)-4-nitrostyryl)]-4-oxocyclohexane-1-carbaldehyde (7h)



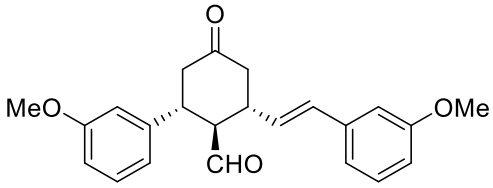
Reaction time: 48 h, yellowish solid; 15.2 mg, 77% yield; m.p. 155-156 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.51 (d, *J* = 3.1 Hz, 1H), 8.22 (d, *J* = 8.6 Hz, 2H), 8.18 (d, *J* = 8.6 Hz, 2H), 7.46 (d, *J* = 8.5 Hz, 2H), 7.43 (d, *J* = 8.5 Hz, 2H), 6.55 (d, *J* = 15.8 Hz, 1H), 6.27 (dd, *J* = 15.8, 8.2 Hz, 1H), 3.54-3.48 (m, 1H), 3.22-3.10 (m, 2H), 2.72-2.58 (m, 4H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 204.7, 201.2, 147.4, 142.1, 132.9, 130.8, 128.2, 127.0, 124.5, 124.1, 58.3, 47.4, 45.8, 44.2, 42.8. ν_{max} (neat, cm^{-1}): 1057, 1107, 1241, 1298, 1342, 1517, 1593, 1705, 1718; HRMS (ESI, m/z) calcd for $C_{21}H_{19}N_2O_6$ ($[M+H]^+$): 395.1238; found: 395.1246. Enantiomeric excess of **7h** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (70:30 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm); major isomer: t_R = 58.6 min, minor isomer: t_R = 78.0 min.

(1*R*,2*R*,6*R*)-2-(2-Methoxyphenyl)-6-[(*E*)-2-methoxystyryl]-4-oxocyclohexane-1-carbaldehyde (7i)



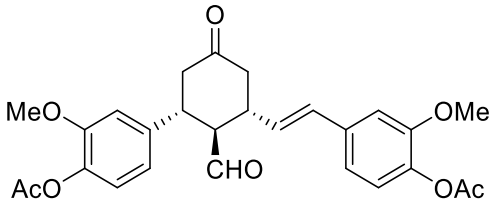
Reaction time: 32 h, white solid; 14.1 mg, 78% yield, m.p. 154-156 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.43 (d, *J* = 4.0 Hz, 1H), 7.35 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.24-7.18 (m, 3H), 6.95-6.83 (m, 4H), 6.77 (d, *J* = 15.8 Hz, 1H), 6.08 (dd, *J* = 15.8, 7.8 Hz, 1H), 3.84 (s, 3H), 3.83 (s, 3H), 3.76-3.72 (m, 1H), 3.14-3.07 (m, 2H), 2.81-2.72 (m, 1H), 2.63-2.53 (m, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.0, 202.5, 156.7, 156.6, 129.8, 128.9, 128.6, 128.3, 128.0, 126.8, 126.6, 125.3, 121.1, 120.6, 111.0, 110.9, 58.4, 55.5, 55.3, 46.4, 45.9, 42.7, 38.4. ν_{max} (neat, cm^{-1}): 1025, 1049, 1106, 1241, 1360, 1437, 1463, 1492, 1599, 1711; HRMS (ESI, m/z) calcd for $C_{23}H_{25}O_4$ ($[M+H]^+$): 365.1747; found: 365.1749. Enantiomeric excess of **7i** was determined by chiral stationary phase HPLC analysis using a ChiralPak IC column (85:15 hexanes/*i*-PrOH at 0.7 mL/min, λ = 220 nm); major isomer: t_R = 40.8 min, minor isomer: t_R = 44.2 min.

(1*R*,2*R*,6*R*)-2-(3-Methoxyphenyl)-6-[(*E*)-3-methoxystyryl]-4-oxocyclohexane-1-carbaldehyde (7j)



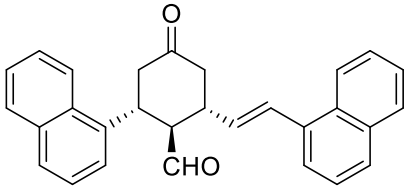
Reaction time: 32 h, white solid; 14.9 mg, 83% yield, m.p. 161-162 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.48 (d, *J* = 3.5 Hz, 1H), 7.27-7.25 (m, 1H), 7.24-7.20 (m, 1H), 6.92-6.90 (m, 1H), 6.85-6.77 (m, 4H), 6.76-6.75 (m, 1H), 6.41 (d, *J* = 15.5 Hz, 1H), 6.06 (dd, *J* = 15.5, 8.0 Hz, 1H), 3.81 (s, 3H), 3.81 (s, 3H), 3.33-3.27 (m, 1H), 3.12-3.02 (m, 2H), 2.66-2.63 (m, 3H), 2.56-2.51 (m, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 206.9, 202.4, 160.1, 159.8, 141.9, 137.6, 132.0, 130.2, 129.6, 129.2, 119.3, 119.0, 113.6, 113.3, 112.5, 111.7, 58.9, 55.2, 55.2, 48.1, 46.2, 44.9, 42.5. ν_{max} (neat, cm^{-1}): 1033, 1080, 1185, 1244, 1262, 1292, 1427, 1450, 1488, 1567, 1704, 1720; HRMS (ESI, m/z) calcd for $C_{23}H_{25}O_4$ ($[M+H]^+$): 365.1747; found: 366.1337. Enantiomeric excess of **7j** was determined by chiral stationary phase HPLC analysis using a ChiralPak IB column (90:10 hexanes/*i*-PrOH at 1 mL/min, λ = 220 nm); major isomer: t_R = 66.0 min, minor isomer: t_R = 82.5 min.

(1*R*,2*R*,6*R*)-2-(4-Acetoxy-3-methoxyphenyl)-6-[(*E*)-4-acetoxy-3-methoxystyryl]-4-oxocyclohexane-1-carbaldehyde (7k)



Reaction time: 48 h, white solid; 17.0 mg, 71% yield, m.p. 180-182 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.50 (d, *J* = 3.4 Hz, 1H), 7.00 (d, *J* = 8.2 Hz, 1H), 6.97 (d, *J* = 8.2 Hz, 1H), 6.93-6.88 (m, 2H), 6.83 (dd, *J* = 8.2, 2.0 Hz, 1H), 6.79 (d, *J* = 2.0 Hz, 1H), 6.41 (d, *J* = 15.7 Hz, 1H), 6.02 (dd, *J* = 15.7, 8.1 Hz, 1H), 3.84 (d, *J* = 5.5 Hz, 6H), 3.33 (ddd, *J* = 12.7, 11.1, 4.9 Hz, 1H), 3.18-2.96 (m, 2H), 2.70-2.47 (m, 4H), 2.30 (d, *J* = 1.9 Hz, 6H).^{13}C NMR (126 MHz, $CDCl_3$) δ 206.5, 202.3, 169.0, 168.9, 151.4, 151.1, 139.5, 139.1, 139.0, 135.2, 131.6, 129.1, 123.4, 122.9, 119.0, 111.5, 110.1, 58.8, 55.9, 55.9, 48.2, 46.1, 44.6, 42.5, 20.6. νmax (neat, cm^{-1}): 1031, 1121, 1155, 1197, 1268, 1368, 1418, 1464, 1508, 1602, 1703, 1713, 1759; HRMS (ESI, m/z) calcd for $C_{27}H_{29}O_8$ ($[M+H]^+$): 481.1857; found: 481.1856. Enantiomeric excess of **7k** was determined by chiral stationary phase HPLC analysis using a ChiralPak IB column (60:40 hexanes/*i*-PrOH at 1 mL/min, λ = 254 nm); minor isomer: t_R = 34.5 min, major isomer: t_R = 37.8 min.

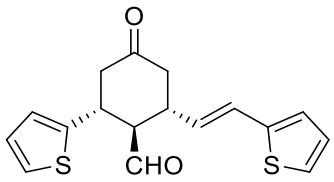
(1*R*,2*R*,6*R*)-2-(Naphthalen-1-yl)-6-[(*E*)-2-(naphthalen-1-yl)vinyl]-4-oxocyclohexane-1-carbaldehyde (7l)



7l

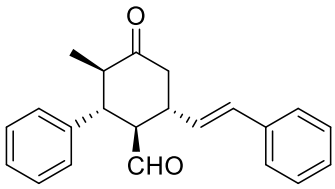
Reaction time: 48 h, white solid; 16.0 mg, 79% yield, m.p. 185-186 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.54 (d, *J* = 3.7 Hz, 1H), 8.10 (d, *J* = 8.5 Hz, 1H), 7.91 – 7.82 (m, 2H), 7.78 (d, *J* = 8.2 Hz, 2H), 7.61 – 7.40 (m, 8H), 7.23 (d, *J* = 15.5 Hz, 1H), 6.15 (dd, *J* = 15.5, 8.2 Hz, 1H), 4.32 (t, *J* = 11.2 Hz, 1H), 3.54 – 3.26 (m, 2H), 2.90 – 2.64 (m, 4H). ^{13}C NMR (125 MHz, $CDCl_3$) 206.9, 202.0, 134.1, 133.5, 132.4, 131.0, 130.7, 129.7, 129.2, 128.5, 128.3, 128.1, 126.7, 126.2, 126.0, 125.8, 125.5, 124.1, 123.6, 122.1, 58.7, 46.5, 43.1, 29.7. ν_{max} (neat, cm^{-1}): 964, 1014, 1052, 1237, 1395, 1508, 1591, 1703. HRMS (ESI, m/z) calcd for $C_{29}H_{25}O_2$ ($[M+H]^+$): 405.1849; found: 405.1848. Enantiomeric excess of **7l** was determined by chiral stationary phase HPLC analysis using a ChiralPak IC column (80:20 hexanes/*i*-PrOH at 1.0 mL/min, λ = 220 nm); minor isomer: t_R = 36.3 min, major isomer: t_R = 27.0 min.

(1*R*,2*R*,6*R*)-4-Oxo-2-(thiophen-2-yl)-6-[(*E*)-2-(thiophen-2-yl)vinyl]cyclohexane-1-carbaldehyde (7m)



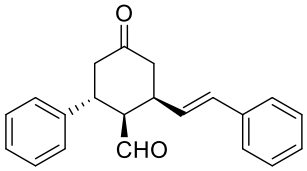
Reaction time: 72 h, white solid, 7.9 mg, 50% yield, m.p. 161-163 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.61 (d, *J* = 3.2 Hz, 1H), 7.35-7.06 (m, 3H), 7.00-6.80 (m, 3H), 6.58 (d, *J* = 15.6 Hz, 1H), 5.90 (dd, *J* = 15.6, 8.2 Hz, 1H), 3.71 (ddd, *J* = 12.9, 10.9, 4.4 Hz, 1H), 3.17-2.88 (m, 2H), 2.85-2.37 (m, 4H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 205.9, 202.1, 144.1, 141.0, 128.0, 127.4, 127.1, 126.2, 125.5, 124.8, 124.6, 124.5, 60.0, 49.1, 46.1, 42.4, 39.7. ν_{max} (neat, cm^{-1}): 1010, 1216, 1227, 1365, 1389, 1719, 1735, 2918. HRMS (ESI): m/z calcd for $C_{17}H_{17}O_2S_2$ ($[M+H]^+$): 317.0664; Found 317.0667. Enantiomeric excess of **7m** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (80:20 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm), major enantiomer: t_R = 18.5 min, minor enantiomer: t_R = 31.4 min

(1*R*,2*S*,3*R*,6*R*)-3-Methyl-4-oxo-2-phenyl-6-[(*E*)-styryl]cyclohexane-1-carbaldehyde (7n)



Reaction time: 168 h, white solid; 6.0 mg, 38% yield, m.p. 147-148 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.37 (d, *J* = 3.7 Hz, 1H), 7.35-7.29 (m, 5H), 7.27-7.19 (m, 5H), 6.43 (d, *J* = 15.8 Hz, 1H), 6.07 (dd, *J* = 15.8, 8.1 Hz, 1H), 3.17 (td, *J* = 11.2, 3.7 Hz, 1H), 3.04 (tdd, *J* = 12.2, 8.0, 4.6 Hz, 1H), 3.07-3.00 (m, 1H), 2.78-2.60 (m, 3H), 0.84 (d, *J* = 6.4 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.6, 202.3, 139.5, 136.2, 131.9, 129.1, 129.0, 128.6, 127.9, 127.7, 127.6, 126.4, 60.3, 52.2, 49.4, 46.6, 42.9, 11.7. ν_{max} (neat, cm-1): 1001, 1071, 1134, 1224, 1282, 1343, 1448, 1490, 1708, 1716; HRMS (ESI, m/z) calcd for $C_{22}H_{23}O_2$ ($[M+H]^+$): 319.1693; found: 319.1697. Enantiomeric excess of **7n** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (85:15 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm); major isomer: t_R = 23.3 min, minor isomer: t_R = 28.5 min.

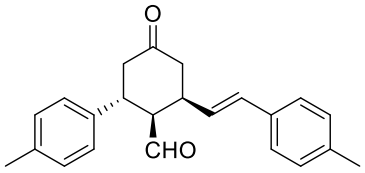
(1*R*,2*R*,6*S*)-4-Oxo-2-phenyl-6-[(*E*)-styryl]cyclohexane-1-carbaldehyde (7a')



Reaction time: 24 h, white solid; 13.8 mg, 91% yield, m.p. 154-155 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.66 (d, *J* = 2.0 Hz, 1H), 7.36-7.28 (m, 5H), 7.27-7.23 (m, 5H), 6.45 (dd, *J* = 16.0, 1.3 Hz, 1H), 6.23 (dd, *J* = 16.0, 7.5 Hz, 1H), 3.76-3.71 (m, 1H), 3.43-3.40 (m, 1H), 3.20-3.17 (m, 1H), 2.81-2.62 (m, 4H).

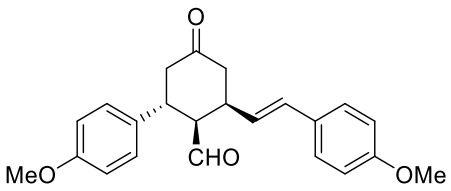
^{13}C NMR (126 MHz, $CDCl_3$) δ 208.3, 203.1, 141.4, 136.2, 133.4, 129.1, 128.6, 128.0, 127.4, 127.3, 126.5, 126.4, 57.0, 47.0, 45.1, 39.8, 39.4. ν_{max} (neat, cm^{-1}): 1072, 1110, 1239, 1398, 1454, 1492, 1606, 1708, 1720; HRMS (ESI, m/z) calcd for $C_{21}H_{21}O_2$ ($[M+H]^+$): 305.1536; found: 305.1535. Enantiomeric excess of **7a'** was determined by chiral stationary phase HPLC analysis using a ChiralPak IC column (80:20 hexanes/*i*-PrOH at 0.7 mL/min, λ = 254 nm); major isomer: t_R = 13.4 min, minor isomer: t_R = 18.1 min.

(1*R*,2*R*,6*S*)-2-[(*E*)-4-Methylstyryl]-4-oxo-6-(*p*-tolyl)cyclohexane-1-carbaldehyde (7b')



Reaction time: 48 h, white solid, 12.1 mg, 73% yield, m.p. 178-179 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.66 (d, *J* = 2.0 Hz, 1H), 7.33-7.04 (m, 8H), 6.43 (d, *J* = 15.9 Hz, 1H), 6.19 (dd, *J* = 15.9, 7.5 Hz, 1H), 3.71 (q, *J* = 4.4 Hz, 1H), 3.42 (dd, *J* = 7.7, 4.7 Hz, 1H), 3.21 - 3.04 (m, 1H), 2.85-2.57 (m, 4H), 2.35 (s, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.5, 203.5, 138.4, 137.9, 137.1, 133.5, 133.2, 129.8, 129.3, 127.2, 126.3, 125.4, 57.1, 47.2, 45.2, 39.5, 39.5, 21.2, 21.0. ν_{max} (neat, cm^{-1}): 1017, 1107, 1240, 1255, 1356, 1412, 1514, 1708, 1717. HRMS (ESI): m/z calcd for $C_{23}H_{25}O_2$ ($[M+H]^+$): 333.1849; Found 333.1844. Enantiomeric excess of **7b'** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (80:20 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm), major enantiomer: t_R = 8.7 min, minor enantiomer: t_R = 10.1 min.

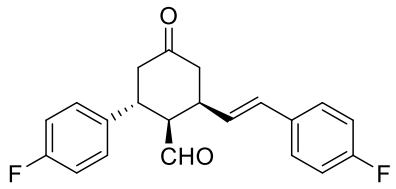
(1*R*,2*R*,6*S*)-2-(4-Methoxyphenyl)-6-[(*E*)-4-methoxystyryl]-4-oxocyclohexane-1-carbaldehyde (7c')



Reaction time: 30 h, white solid; 14.5 mg, 80% yield, m.p. 151-152 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.63 (d, *J* = 2.2 Hz, 1H), 7.27 (d, *J* = 8.7 Hz, 2H), 7.15 (d, *J* = 8.7 Hz, 2H), 6.87 (d, *J* = 8.7 Hz, 2H), 6.84 (d, *J* = 8.7 Hz, 2H), 6.37 (dd, *J* = 16.0, 1.3 Hz, 1H), 6.07 (dd, *J* = 16.0, 7.6 Hz, 1H), 3.81 (s, 3H), 3.79 (s, 3H), 3.70 – 3.65 (m, 1H), 3.39 – 3.35 (m, 1H), 3.10 (ddd, *J* = 9.8, 4.2, 2.3 Hz, 1H), 2.78-2.57 (m, 4H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.6, 203.6, 159.5, 158.7, 133.4, 132.7, 129.0, 128.3, 127.6, 124.1, 114.5, 114.0,

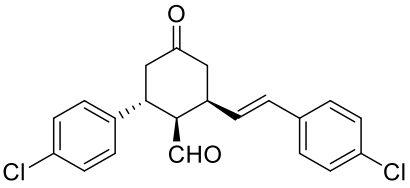
57.2, 55.3, 55.3, 47.4, 45.3, 39.6, 39.1. ν_{max} (neat, cm^{-1}): 1029, 1053, 1109, 1197, 1247, 1283, 1303, 1461, 1442, 1606, 1719, 1702; HRMS (ESI, m/z) calcd for $C_{23}H_{25}O_4$ ($[M+H]^+$): 365.1747; found: 365.1752. Enantiomeric excess of **7c'** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (70:30 hexanes/*i*-PrOH at 0.7 mL/min, λ = 254 nm); major isomer: t_R = 15.8 min, minor isomer: t_R = 19.1 min.

(1*R*,2*R*,6*S*)-2-(4-Fluorophenyl)-6-[(*E*)-4-fluorostyryl]-4-oxocyclohexane-1-carbaldehyde (7d')



Reaction time: 30 h, white solid; 15.0 mg, 90% yield, m.p. 145-146 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.66 (d, *J* = 1.9 Hz, 1H), 7.31-7.28 (m, 2H), 7.22-7.19 (m, 2H), 7.05-6.98 (m, 4H), 6.40 (d, *J* = 16.0 Hz, 1H), 6.11 (dd, *J* = 16.0, 7.5 Hz, 1H), 3.73-3.68 (m, 1H), 3.41-3.39 (m, 1H), 3.17-3.14 (m, 1H), 2.80-2.67 (m, 3H), 2.63-2.58 (m, 1H). ^{3}C NMR (126 MHz, $CDCl_3$) δ 206.7, 202.5, 163.1 (*J* = 63.0 Hz), 161.1 (*J* = 62.0 Hz), 135.8 (*J* = 2.5 Hz), 132.0 (*J* = 2.5 Hz), 130.97, 128.6 (*J* = 7.6 Hz), 128.19, 127.9 (*J* = 7.6 Hz), 116.1 (*J* = 21.4 Hz), 115.5 (*J* = 22.7 Hz), 59.09, 48.17, 46.19, 43.83, 42.61.νmax (neat, cm-1): 1043, 1074, 1159, 1225, 1365, 1420, 1509, 1600, 1704, 1713; HRMS (ESI, m/z) calcd for $C_{21}H_{19}F_2O_2$ ($[M+H]^+$): 341.1348; found: 341.1353. Enantiomeric excess of **7d'** was determined by chiral stationary phase HPLC analysis using a ChiralPak IC column (80:20 hexanes/*i*-PrOH at 0.7 mL/min, λ = 254 nm); minor isomer: t_R = 13.6 min, major isomer: t_R = 16.0 min.

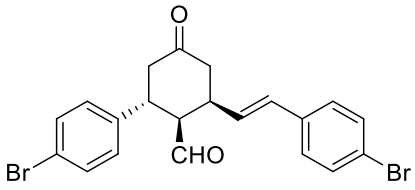
(1*R*,2*R*,6*S*)-2-(4-Chlorophenyl)-6-[(*E*)-4-chlorostyryl)]-4-oxocyclohexanecarbaldehyde (7e')



Reaction time: 48 h, white solid, 13.8 mg, 74% yield, m.p. 165-167 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.69 (d, *J* = 1.7 Hz, 1H), 7.34 (d, *J* = 8.4 Hz, 2H), 7.32-7.25 (m, 4H), 7.20 (d, *J* = 8.4 Hz, 2H), 6.42 (d, *J* = 15.9 Hz, 1H), 6.19 (dd, *J* = 15.9, 7.4 Hz, 1H), 3.71 (td, *J* = 9.7, 5.4 Hz, 1H), 3.42 (td, *J* = 5.5, 2.5 Hz, 1H), 3.20 (ddd, *J* = 9.5, 4.2, 1.8 Hz, 1H), 2.91-2.53 (m, 4H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 207.7, 202.2, 139.9, 134.6, 133.8, 133.3, 132.3, 129.3, 128.8, 128.7, 127.6, 127.0, 57.0, 46.7, 45.0, 39.3, 39.0. ν_{max} (neat, cm^{-1}): 1013, 1091, 1216, 1227, 1356, 1491, 1591, 1725, 1735. HRMS (ESI): m/z calcd for $C_{21}H_{19}Cl_2O_2$ ($[M+H]^+$):

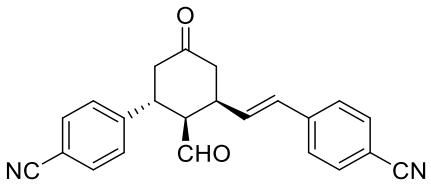
373.0757; Found 373.0748. Enantiomeric excess of **7e'** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (80:20 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm), major enantiomer: t_R = 8.9 min, minor enantiomer: t_R = 10.2 min

(1*R*,2*R*,6*S*)-2-(4-Bromophenyl)-6-[(*E*)-4-bromostyryl)]-4-oxocyclohexanecarbaldehyde (7f')



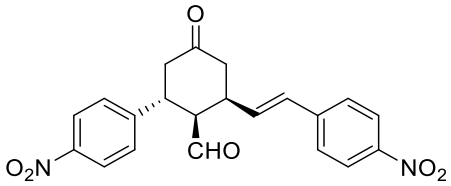
Reaction time: 48 h, white solid, 16.4 mg, 71% yield, m.p. 175-177 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.69 (d, *J* = 1.6 Hz, 1H), 7.48 (dd, *J* = 20.6, 8.4 Hz, 4H), 7.18 (dd, *J* = 34.7, 8.4 Hz, 4H), 6.40 (d, *J* = 15.9 Hz, 1H), 6.21 (dd, *J* = 15.9, 7.3 Hz, 1H), 3.69 (d, *J* = 5.4 Hz, 1H), 3.45-3.30 (m, 1H), 3.19 (ddd, *J* = 9.6, 4.2, 1.8 Hz, 1H), 2.91-2.49 (m, 4H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 207.7, 202.1, 140.5, 135.0, 132.4, 132.3, 131.8, 129.0, 127.9, 127.1, 121.9, 121.3, 56.9, 46.7, 44.9, 39.3, 39.0. ν_{max} (neat, cm^{-1}): 1009, 1072, 1216, 1365, 1408, 1488, 1587, 1706, 1718. HRMS (ESI): m/z calcd for $C_{21}H_{19}Br_2O_2$ ($[M+H]^+$): 460.9746; found 460.9731. Enantiomeric excess of **7f'** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (80:20 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm), major enantiomer: t_R = 10.4 min, minor enantiomer: t_R = 11.3 min

(1*R*,2*R*,6*S*)-2-(4-Cyanophenyl)-6-[(*E*)-4-cyanostyryl)]-4-oxocyclohexanecarbaldehyde (7g')



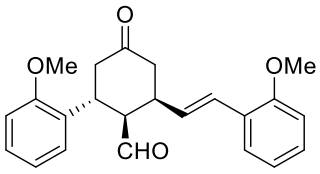
Reaction time: 48 h, white solid, 12.4 mg, 70% yield, m.p. 164-166 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.73 (s, 1H), 7.68 (d, *J* = 8.0 Hz, 2H), 7.62 (d, *J* = 8.1 Hz, 2H), 7.48 -7.41 (m, 2H), 7.39 (m, 2H), 6.50 (d, *J* = 15.9 Hz, 1H), 6.32 (dd, *J* = 15.9, 7.1 Hz, 1H), 3.76 (td, *J* = 9.6, 5.3 Hz, 1H), 3.49 (d, *J* = 6.4 Hz, 1H), 3.34 (dd, *J* = 9.4, 4.0 Hz, 1H), 2.91-2.58 (m, 4H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 206.7, 200.7, 146.8, 140.3, 132.9, 132.5, 132.2, 130.1, 128.2, 127.0, 118.7, 118.3, 111.6, 111.5, 56.7, 46.2, 44.6, 39.8, 38.6. ν_{max} (neat, cm^{-1}): 1009, 1176, 1216, 1356, 1412, 1605, 1703, 1713, 2226. HRMS (ESI): m/z calcd for $C_{23}H_{19}N_2O_2$ ([M+H]+): 355.1441; Found 355.1433. Enantiomeric excess of **7g'** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (70:30 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm), minor enantiomer: t_R = 28.9 min, major enantiomer: t_R = 31.6 min

(1*R*,2*R*,6*S*)-2-(4-Nitrophenyl)-6-[(*E*)-4-nitrostyryl]-4-oxocyclohexane-1-carbaldehyde (7h')



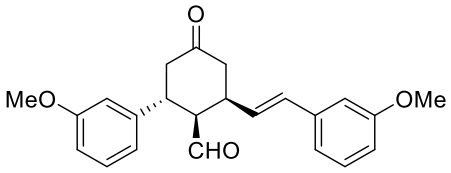
Reaction time: 48 h, pale yellow solid; 15.2 mg, 77% yield, m.p. 150-151 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.74 (d, *J* = 1.2 Hz, 1H), 8.23 (d, *J* = 8.7 Hz, 2H), 8.18 (d, *J* = 8.7 Hz, 2H), 7.46 (d, *J* = 8.7 Hz, 2H), 7.44 (d, *J* = 8.7 Hz, 2H), 6.54 (dd, *J* = 16.0, 1.3 Hz, 1H), 6.35 (dd, *J* = 16.0, 7.2 Hz, 1H), 3.83-3.78 (m, 1H), 3.52-3.48 (m, 1H), 3.37 (ddd, *J* = 9.5, 4.1, 1.3 Hz, 1H), 2.89-2.74 (m, 3H), 2.66 (dd, *J* = 15.2, 10.0 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 206.5, 200.5, 148.8, 147.3, 147.2, 142.2, 131.9, 130.9, 128.3, 127.1, 124.4, 124.1, 56.8, 46.2, 44.6, 39.7, 38.6. ν_{max} (neat, cm^{-1}): 1010, 1107, 1241, 1298, 1342, 1517, 1593, 1706, 1718; HRMS (ESI, m/z) calcd for $C_{21}H_{19}N_2O_6$ ($[M+H]^+$): 395.1238; found: 395.1243. Enantiomeric excess of **7h'** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (70:30 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm); minor isomer: t_R = 42.6 min, major isomer: t_R = 44.9 min.

(1*R*,2*R*,6*S*)-2-(2-Methoxyphenyl)-6-[(*E*)-2-methoxystyryl]-4-oxocyclohexane-1-carbaldehyde (7i')



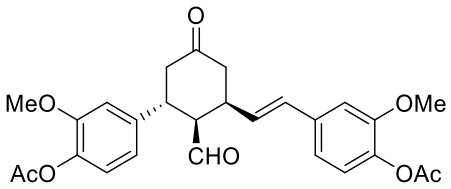
Reaction time: 30 h, white solid; 15.6 mg, 86% yield, m.p. 150-152 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.71 (d, *J* = 2.0 Hz, 1H), 7.38 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.27-7.20 (m, 2H), 7.14 (dd, *J* = 7.6, 1.7 Hz, 1H), 6.95-6.84 (m, 4H), 6.74 (dd, *J* = 16.0, 1.3 Hz, 1H), 6.30 (dd, *J* = 16.0, 7.5 Hz, 1H), 4.13 (q, *J* = 7.6 Hz, 1H), 3.84 (s, 3H), 3.82 (s, 3H), 3.31-3.25 (m, 2H), 2.76 – 2.72 (m, 3H), 2.68-2.64 (m, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 209.5, 204.1, 156.7, 156.6, 129.7, 128.9, 128.6, 128.4, 127.9, 127.5, 126.8, 125.5, 120.9, 120.6, 110.9, 110.8, 55.4, 55.3, 55.2, 45.2, 44.5, 39.7, 34.2. ν_{max} (neat, cm^{-1}): 1030, 1107, 1185, 1240, 1269, 1291, 1423, 1455, 1486, 1577, 1705, 1719; HRMS (ESI, m/z) calcd for $C_{23}H_{25}O_4$ ($[M+H]^+$): 365.1746; found: 365.1747. Enantiomeric excess of **7i'** was determined by chiral stationary phase HPLC analysis using a ChiralPak IC column (85:15 hexanes/*i*-PrOH at 0.7 mL/min, λ = 254 nm); major isomer: t_R = 24.4 min, minor isomer: t_R = 29.9 min.

(1*R*,2*R*,6*S*)-2-(3-Methoxyphenyl)-6-[(*E*)-3-methoxystyryl]-4-oxocyclohexane-1-carbaldehyde (7j')



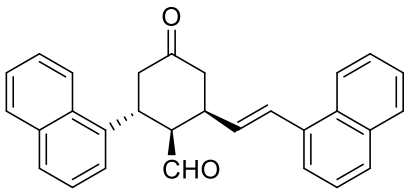
Reaction time: 30 h, white solid; 14.6 mg, 81% yield, m.p. 157-158 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.65 (d, *J* = 1.9 Hz, 1H), 7.28-7.21 (m, 2H), 6.93 (d, *J* = 7.6 Hz, 1H), 6.86 (t, *J* = 2.0 Hz, 1H), 6.83-6.79 (m, 3H), 6.77-6.76 (m, 1H), 6.41 (d, *J* = 15.9 Hz, 1H), 6.21 (dd, *J* = 15.9, 7.4 Hz, 1H), 3.81 (s, 3H), 3.80 (s, 3H), 3.71-3.66 (m, 1H), 3.43-3.40 (m, 1H), 3.17-3.14 (m, 1H), 2.79-2.61 (m, 4H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.2, 203.1, 160.1, 159.8, 143.0, 137.7, 133.3, 130.2, 129.6, 126.9, 119.5, 119.0, 113.6, 113.4, 112.5, 111.8, 56.9, 55.3, 55.2, 47.0, 45.1, 39.8, 39.3. ν_{max} (neat, cm^{-1}): 1033, 1185, 1244, 1292, 1262, 1427, 1450, 1488, 1587, 1704, 1720; HRMS (ESI, m/z) calcd for $C_{23}H_{25}O_4$ ($[M+H]^+$): 365.1747; found: 365.1754. Enantiomeric excess of **7j'** was determined by chiral stationary phase HPLC analysis using a ChiralPak IB column (90:10 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm); minor isomer: t_R = 42.5 min, major isomer: t_R = 63.2 min.

(1*R*,2*R*,6*S*)-2-(4-Acetoxy-3-methoxyphenyl)-6-[(*E*)-4-acetoxy-3-methoxystyryl]-4-oxocyclohexane-1-carbaldehyde (7k')



Reaction time: 32 h, white solid; 20.0 mg, 83% yield, m.p. 175-176 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.69 (d, *J* = 1.7 Hz, 1H), 7.02-6.97 (m, 2H), 6.94-6.90 (m, 2H), 6.81-6.80 (m, 2H), 6.41 (dd, *J* = 16.0, 1.3 Hz, 1H), 6.16 (dd, *J* = 16.0, 7.1 Hz, 1H), 3.85 (s, 3H), 3.83 (s, 3H), 3.77-3.67 (m, 1H), 3.42-3.38 (m, 1H), 3.17-3.14 (m, 1H), 2.78-2.71 (m, 3H), 2.65-2.60 (m, 1H), 2.31 (s, 3H), 2.30 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.2, 202.9, 169.1, 169.0, 151.4, 151.2, 140.3, 139.5, 138.9, 135.3, 132.8, 127.0, 123.4, 122.9, 119.0, 118.9, 111.8, 110.3, 56.9, 55.9, 46.8, 44.8, 39.7, 39.0, 20.7. ν_{max} (neat, cm^{-1}): 1063, 1072, 1213, 1365, 1202, 1216, 1226, 1478, 1597, 1664, 1701, 1725, 1735, 1751; HRMS (ESI, m/z) calcd for $C_{27}H_{29}O_8$ ([M+H]+): 481.1857; found: 481.1868. Enantiomeric excess of **7k'** was determined by chiral stationary phase HPLC analysis using a ChiralPak IB column (60:40 hexanes/*i*-PrOH at 1 mL/min, λ = 254 nm); minor isomer: t_R = 18.2 min, major isomer: t_R = 26.9 min.

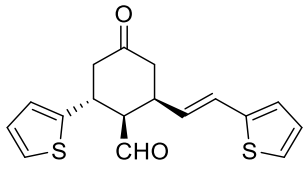
(1*R*,2*R*,6*S*)-2-(Naphthalen-1-yl)-6-[(*E*)-2-(naphthalen-1-yl)vinyl]-4-oxocyclohexane-1-carbaldehyde (7l')



7l'

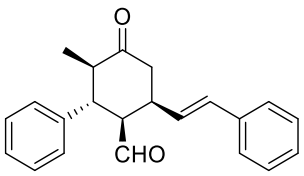
Reaction time: 48 h, white solid; 16.5 mg, 82% yield, m.p. 154-155 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.88 (d, *J* = 1.5 Hz, 1H), 8.06 – 7.96 (m, 2H), 7.93 – 7.87 (m, 1H), 7.87 – 7.76 (m, 3H), 7.56 – 7.46 (m, 6H), 7.45 – 7.35 (m, 2H), 7.24 – 7.16 (m, 1H), 6.33 (dd, *J* = 15.7, 6.8 Hz, 1H), 4.75 (q, *J* = 7.0 Hz, 1H), 3.52 – 3.37 (m, 2H), 2.97 (dddd, *J* = 29.7, 14.9, 5.5, 1.4 Hz, 2H), 2.81 (dddd, *J* = 35.7, 15.7, 7.6, 1.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.9, 203.3, 137.7, 134.2, 134.1, 133.5, 131.0, 130.8, 130.6, 130.5, 129.3, 128.5, 128.3, 128.1, 126.8, 126.3, 126.0, 125.9, 125.5, 125.5, 124.4, 123.9, 123.6, 122.2, 55.9, 45.7, 44.8, 39.1. ν_{max} (neat, cm^{-1}): 969, 1013, 1234, 1394, 1508, 1596, 1709. HRMS (ESI, m/z) calcd for $C_{29}H_{25}O_2$ ($[M+H]^+$): 405.1849; found: 405.1845. Enantiomeric excess of **7l'** was determined by chiral stationary phase HPLC analysis using a ChiralPak IC column (80:20 hexanes/*i*-PrOH at 1.0 mL/min, λ = 220 nm); minor isomer: t_R = 23.0 min, major isomer: t_R = 15.1 min.

(1*R*,2*R*,6*S*)-4-Oxo-2-(thiophen-2-yl)-6-[(*E*)-2-(thiophen-2-yl)vinyl]cyclohexanecarbaldehyde (7m')



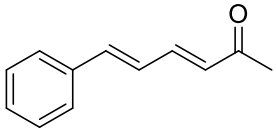
Reaction time: 72 h, white solid, 7.9 mg, 50% yield, m.p. 161-163 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.83 (d, *J* = 1.6 Hz, 1H), 7.28-7.10 (m, 2H), 7.01-6.85 (m, 4H), 6.59 (dd, *J* = 15.8, 1.4 Hz, 1H), 6.11 (dd, *J* = 15.8, 7.2 Hz, 1H), 4.14-4.02 (m, 1H), 3.40-3.25 (m, 1H), 3.20-3.08 (m, 1H), 2.89 (ddd, *J* = 15.4, 5.8, 1.5 Hz, 1H), 2.79-2.57 (m, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 207.4, 202.5, 145.1, 141.2, 127.5, 127.2, 126.3, 126.3, 126.2, 125.3, 124.7, 124.6, 57.9, 46.5, 44.6, 38.8, 35.5. ν_{max} (neat, cm^{-1}): 1008, 1216, 1227, 1365, 1426, 1725, 1735. HRMS (ESI): m/z calcd for $C_{17}H_{17}O_2S_2$ ($[M+H]^+$): 317.0664; Found 317.0659. Enantiomeric excess of **7m'** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (80:20 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm), minor enantiomer: t_R = 12.8 min, major enantiomer: t_R = 14.7 min

(1*R*,2*S*,3*R*,6*S*)-3-Methyl-4-oxo-2-phenyl-6-[(*E*)-styryl)]cyclohexane-1-carbaldehyde (7n')



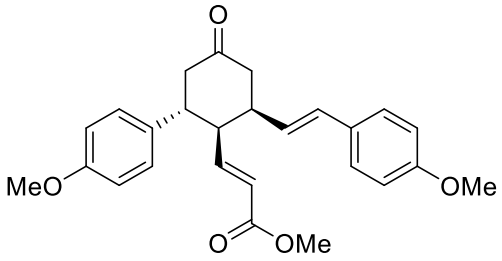
Reaction time: 168 h, white solid, 3.5 mg, 22% yield, m.p. 147-148 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.96 (s, 1H), 7.37-7.20 (m, 10H), 7.09 (d, *J* = 7.2 Hz, 4H), 6.38-6.35 (m, 1H), 3.95-3.93 (m, 1H), 3.30-3.26 (m, 1H), 3.01-2.99 (s, 1H), 2.87-2.80 (m, 2H), 2.71-2.66 (m, 1H), 1.01 (d, *J* = 6.8 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 211.5, 203.2, 139.8, 136.4, 131.9, 128.8, 128.7, 128.6, 128.2, 127.8, 127.2, 126.4, 126.3, 56.9, 45.9, 45.1, 43.6, 12.4. ν_{max} (neat, cm^{-1}): 1002, 1173, 1226, 1249, 1365, 1410, 1419, 1512, 1701, 1719. HRMS (ESI): m/z calcd for $C_{22}H_{23}O_2$ ([M+H]+): 319.1693; Found 319.1694. Enantiomeric excess of **7n'** was determined by chiral stationary phase HPLC analysis using a ChiralPak IB column (85:15 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm), minor enantiomer: t_R = 10.1 min, major enantiomer: t_R = 18.6 min

(3*E*,5*E*)-6-Phenylhexa-3,5-dien-2-one (12)[16]



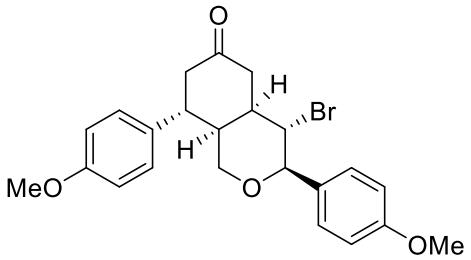
Yellow solid, 980 mg, 57% yield. ^{1}H NMR (500 MHz, $CDCl_3$) *δ* 7.50 (dt, *J* = 6.2, 1.4 Hz, 2H), 7.42 – 7.26 (m, 4H), 7.01 – 6.86 (m, 2H), 6.28 (d, *J* = 15.5 Hz, 1H), 2.34 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) *δ* 198.4, 143.4, 141.3, 136.0, 130.5, 129.2, 128.9, 127.3, 126.7, 27.4.

Methyl (*E*)-3-((1*R*,2*R*,6*S*)-2-(4-Methoxyphenyl)-6-[(*E*)-4-methoxystyryl)]-4-oxocyclohexyl)acrylate (14)



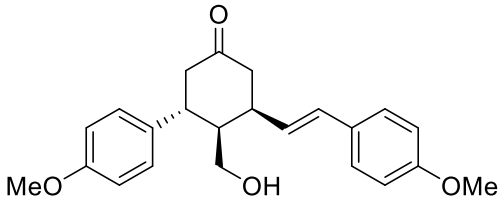
White solid; 9.0 mg, 86% yield, m.p. 180-182 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34-7.24 (m, 2H), 7.11-6.93 (m, 2H), 6.86-6.82 (m, 5H), 6.35 (d, *J* = 15.9 Hz, 1H), 6.01 (dd, *J* = 15.9, 7.2 Hz, 1H), 5.78 (d, *J* = 15.7 Hz, 1H), 3.80 (d, *J* = 16.2 Hz, 6H), 3.66 (s, 3H), 3.26-321 (m, 1H), 3.14-2.97 (m, 2H), 2.82-2.51 (m, 4H).^{13}C NMR (126 MHz, $CDCl_3$) δ 209.3, 166.5, 159.5, 158.6, 148.9, 134.3, 132.8, 129.6, 128.4, 127.7, 124.9, 123.4, 114.4, 114.1, 55.5, 55.4, 51.7, 49.3, 48.1, 45.7, 43.5, 43.4. ν_{max} (neat, cm^{-1}): 1033, 1175, 1249, 1304, 1437, 1512, 1582, 1653, 1685, 1718, 1751, 2953; HRMS (ESI, m/z) calcd for $C_{26}H_{29}O_5$ ([M+H]+): 421.2010; found: 421.2017. Enantiomeric excess of **14** was determined by chiral stationary phase HPLC analysis using a ChiralPak ID column (70:30 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm), major enantiomer: t_R = 14.4 min, minor enantiomer: t_R = 19.6 min

(3*R*,4*S*,4a*R*,8*R*,8a*S*)-4-Bromo-3,8-bis(4-methoxyphenyl)octahydro-6*H*-isochromen-6-one (15)



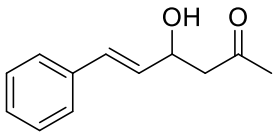
Colorless oil, 10.5 mg, 62% yield; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 (d, J = 8.7 Hz, 2H), 7.21 (d, J = 8.7 Hz, 2H), 6.92 (dd, J = 13.9, 8.7 Hz, 4H), 4.41 (d, J = 10.0 Hz, 1H), 4.04 (dd, J = 11.6, 10.0 Hz, 1H), 3.83 (d, J = 11.1 Hz, 6H), 3.75 (dd, J = 11.8, 1.3 Hz, 1H), 3.66 (dd, J = 11.8, 2.3 Hz, 1H), 3.55 (td, J = 12.8, 4.6 Hz, 1H), 3.14 – 3.07 (m, 1H), 2.86 (ddd, J = 11.5, 4.5, 1.8 Hz, 1H), 2.81 – 2.73 (m, 2H), 2.67 (ddd, J = 14.0, 4.8, 2.4 Hz, 1H), 2.34 (ddt, J = 12.2, 4.0, 1.7 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.6, 159.8, 158.7, 133.6, 131.4, 128.7, 128.4, 114.3, 113.8, 85.6, 68.9, 55.5, 55.3, 48.4, 46.4, 45.2, 44.5, 41.2. ν_{max} (neat, cm^{-1}): 1211, 1219, 1259, 1354, 1369, 1460, 1472, 1566, 1718, 2971, 3280; HRMS (ESI, m/z) calcd for $C_{23}H_{25}NaBrO_4$ ([M+Na]$^+$): 467.0828; found: 467.0826. Enantiomeric excess of **16** was determined by chiral stationary phase HPLC analysis using a ChiralPak OD-H column (70:30 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm); major isomer: t_R = 16.5 min, minor isomer: t_R = 22.5 min.

(3*R*,4*R*,5*S*)-4-(Hydroxymethyl)-3-(4-methoxyphenyl)-5-[(*E*)-4-methoxystyryl]cyclohexan-1-one (16)



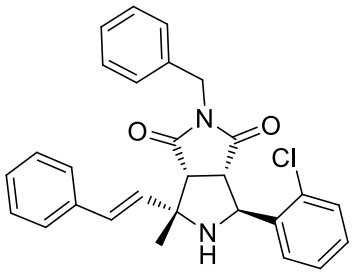
Colorless oil, 7.5 mg, 75% yield; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33 (d, J = 8.7 Hz, 2H), 7.16 (d, J = 8.6 Hz, 2H), 6.88 (dd, J = 8.8, 2.6 Hz, 4H), 6.50 (d, J = 15.8 Hz, 1H), 6.09 (dd, J = 15.8, 8.6 Hz, 1H), 3.83 (d, J = 6.1 Hz, 7H), 3.42 (dd, J = 25.6, 4.5 Hz, 3H), 3.03 (td, J = 11.0, 6.4 Hz, 1H), 2.81 (dd, J = 14.1, 5.7 Hz, 1H), 2.68 – 2.57 (m, 3H), 2.45 (dt, J = 11.2, 5.7 Hz, 1H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 210.2, 159.3, 158.6, 134.4, 132.3, 129.6, 128.3, 128.1, 127.5, 125.2, 114.3, 114.0, 63.1, 55.3, 55.3, 49.2, 47.7, 46.4, 41.9, 40.6. ν_{max} (neat, cm-1): 1048, 1169, 1235, 1305, 1350, 1471, 1523, 1606, 1620, 1709, 2931, 3269. HRMS (ESI, m/z) calcd for $C_{23}H_{27}O_4$ ([M+H]$^+$): 367.1904; found: 367.1903.

(*E*)-4-Hydroxy-6-phenylhex-5-en-2-one (17)[17]



Colorless oil, 400 mg, 17% yield. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40 (d, J = 7.1 Hz, 2H), 7.34 (t, J = 7.6 Hz, 2H), 7.29 – 7.26 (m, 1H), 6.66 (dd, J = 15.9, 1.4 Hz, 1H), 6.23 (dd, J = 15.9, 6.1 Hz, 1H), 4.78 (dd, J = 6.1, 1.4 Hz, 1H), 2.78 (d, J = 6.1 Hz, 2H), 2.23 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 209.0, 136.5, 130.4, 130.1, 128.6, 127.8, 126.5, 68.5, 50.0, 30.9.

(3a*R,4*R**,6*S**,6a*S**)-2-Benzyl-6-(2-chlorophenyl)-4-methyl-4-[(*E*)-styryl)tetrahydro-pyrrolo[3,4-*c*]pyrrole-1,3(2*H*,3a*H*)-dione (20)**



White solid, 70.4 mg, 77% yield, m.p. 150-152 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.48 – 7.30 (m, 6H), 7.30 – 7.09 (m, 8H), 6.63 (d, J = 16.0 Hz, 1H), 6.48 (d, J = 15.9 Hz, 1H), 5.12 (d, J = 7.8 Hz, 1H), 4.45 (q, J = 14.0 Hz, 2H), 3.76 (t, J = 7.8 Hz, 1H), 3.14 (d, J = 7.8 Hz, 1H), 1.59 (s, 3H), 1.50 (s, 1H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 175.2, 174.4, 136.9, 136.1, 135.8, 133.5, 133.3, 128.8, 128.6, 128.6, 128.4, 128.1, 127.6, 127.5, 127.3, 126.5, 62.9, 57.9, 55.0, 47.3, 42.1, 27.5; ν_{max}: (neat, cm^{-1}): 3688 (br), 3313, 2929, 2851, 2323, 1774, 1701, 1492, 1396, 1334, 1311, 1282, 1198, 1101, 1038, 1027. Analytic calcld. for $C_{28}H_{25}ClN_2O_2$: C, 73.60; H, 5.51; N, 6.13; found: C, 73.72; H, 5.67; N, 6.04. Enantiomeric excess of **20** was determined by chiral stationary phase HPLC analysis using a ChiralPak AD-H column (90:10 hexanes/*i*-PrOH at 1.0 mL/min, λ = 254 nm); major isomer: t_R = 13.09 min, minor isomer: t_R = 10.50 min.

7. Additional References

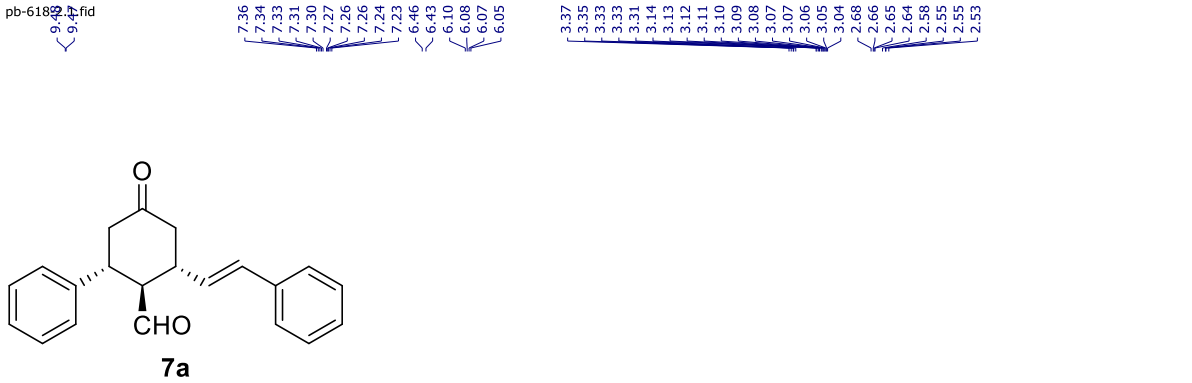
(15) (a) Vakulya, B.; Varga, S.; Csámpai, A.; Soós, T. *Org. Lett*. **2005**, *7*, 1967-1969; (b) Liu, Y.; Sun, B.; Wang, B.; Wakem, M.; Deng, L. *J. Am. Chem. Soc*. **2009**, *131*, 418-419; (c) Malerich, J. P.; Hagihara, K.; Rawal, V. H. *J. Am. Chem. Soc.* **2008**, *130*, 14416–14417; (d) Hajra, S.; Jana, B. *Org. Lett.* **2017**, 19, 4778-4781; (e) Pozo, S. Del.; Vera, S.; Oiarbide, M.; Palomo, C. *J. Am. Chem. Soc.* **2017**, *139*, 15308-15311.

(16) Li, C.; Lu, W.; Lu, B.; Li, W.; Xie, X.; Zhang, Z. *J. Org. Chem.* **2019**, *84*, 16086-16094.

(17) Acetti, D.; Brenna, E.; Fuganti, C.; Gatti, F. G.; Serra, S. *Eur. J. Org. Chem*. **2010**, 142-151.

(18) (a) Parella, R.; Jakkampudi, S.; Arman, H.; Zhao, J. C.-G. *Adv. Synth. Catal*., **2019**, *361*, 208-213. (b) Jakkampudi, S.; Parella, R.; Zhao, John C.-G. *Org. Biomol. Chem*., **2019**, *17*, 151-155.

8. NMR Spectra



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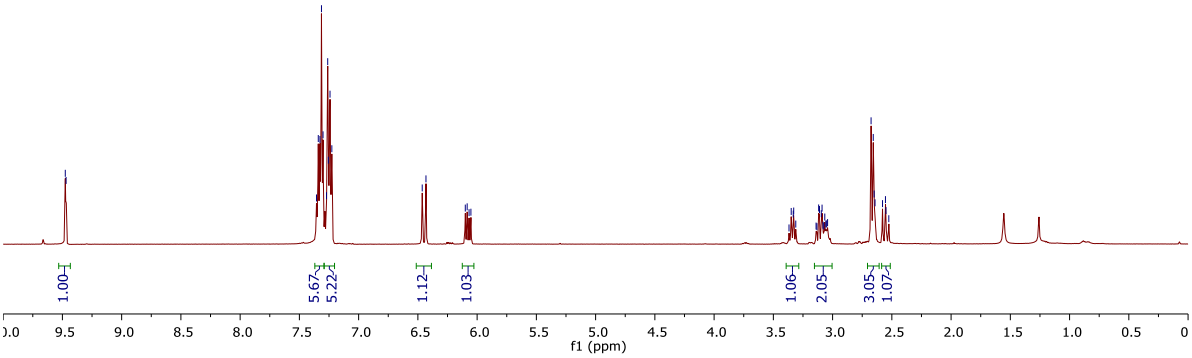

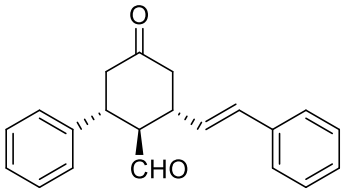

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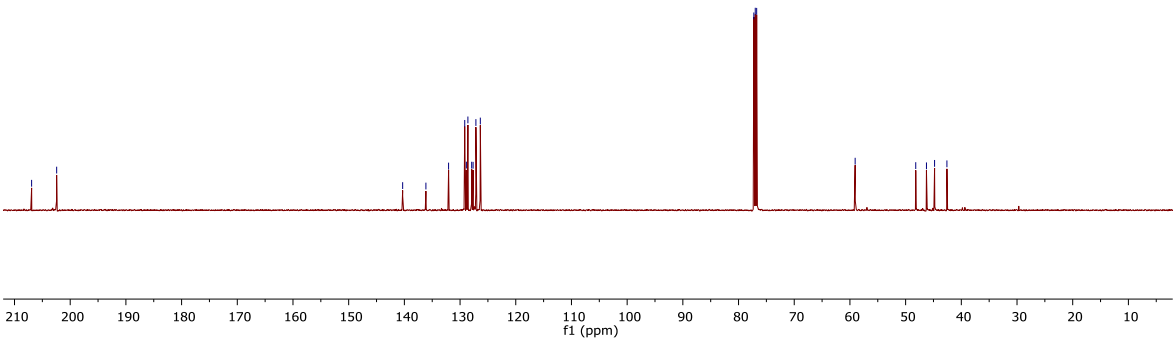

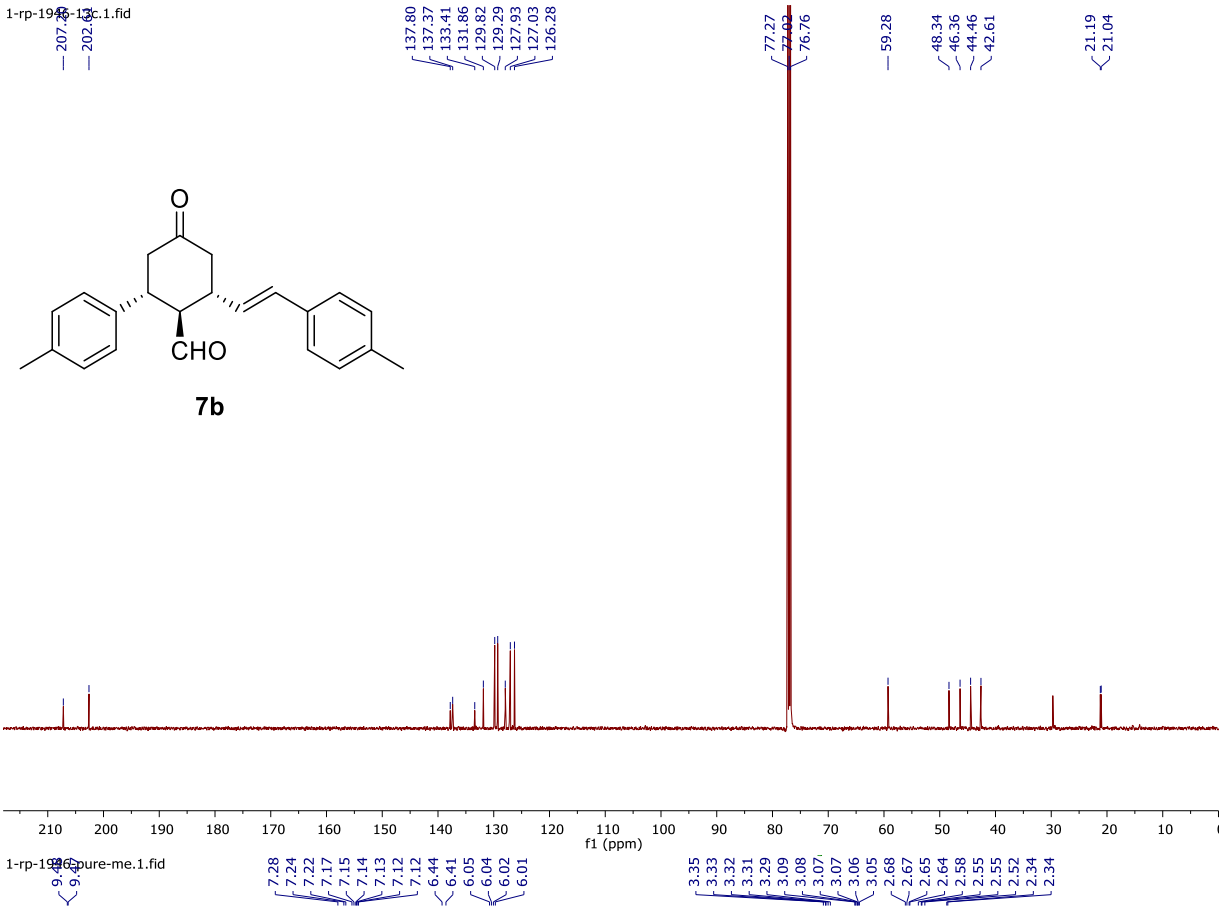
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129.82
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127.93
127.03
126.28
77.27
77.02
76.76
59.28
48.34
46.36
44.46
42.61
21.19
21.04
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CHO
7b
f1 (ppm)
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7.24
7.22
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7.15
7.14
7.13
7.12
7.12
6.44
6.41
6.05
6.04
6.02
6.01
3.35
3.33
3.32
3.31
3.29
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3.07
3.07
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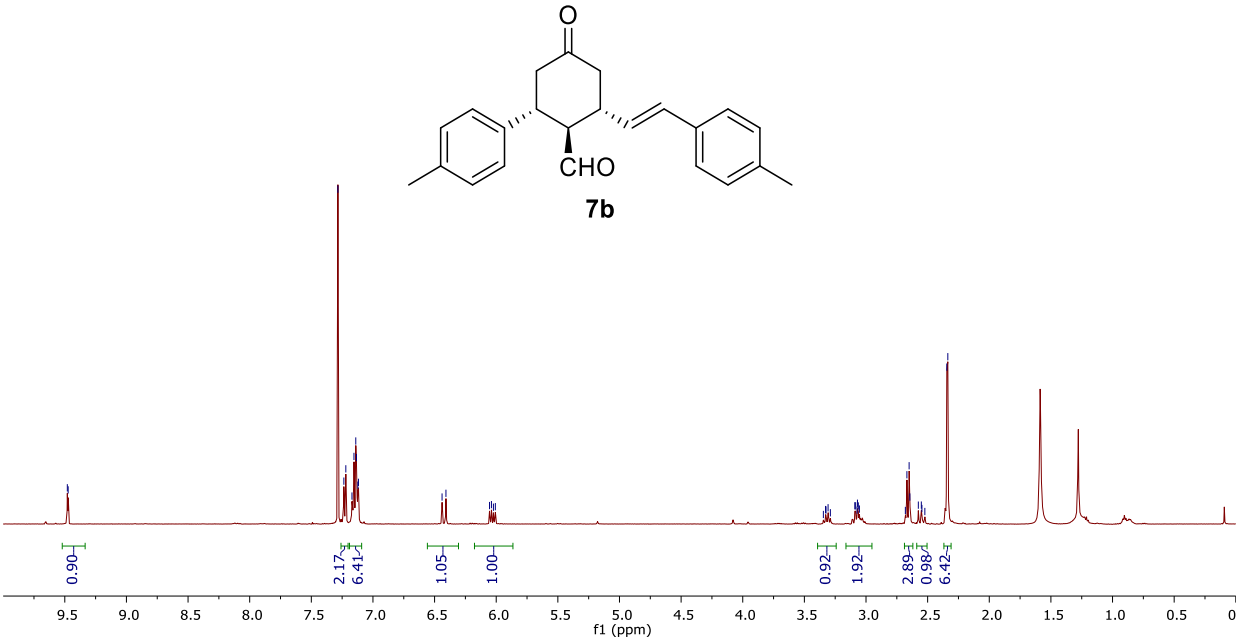
2.34
2.34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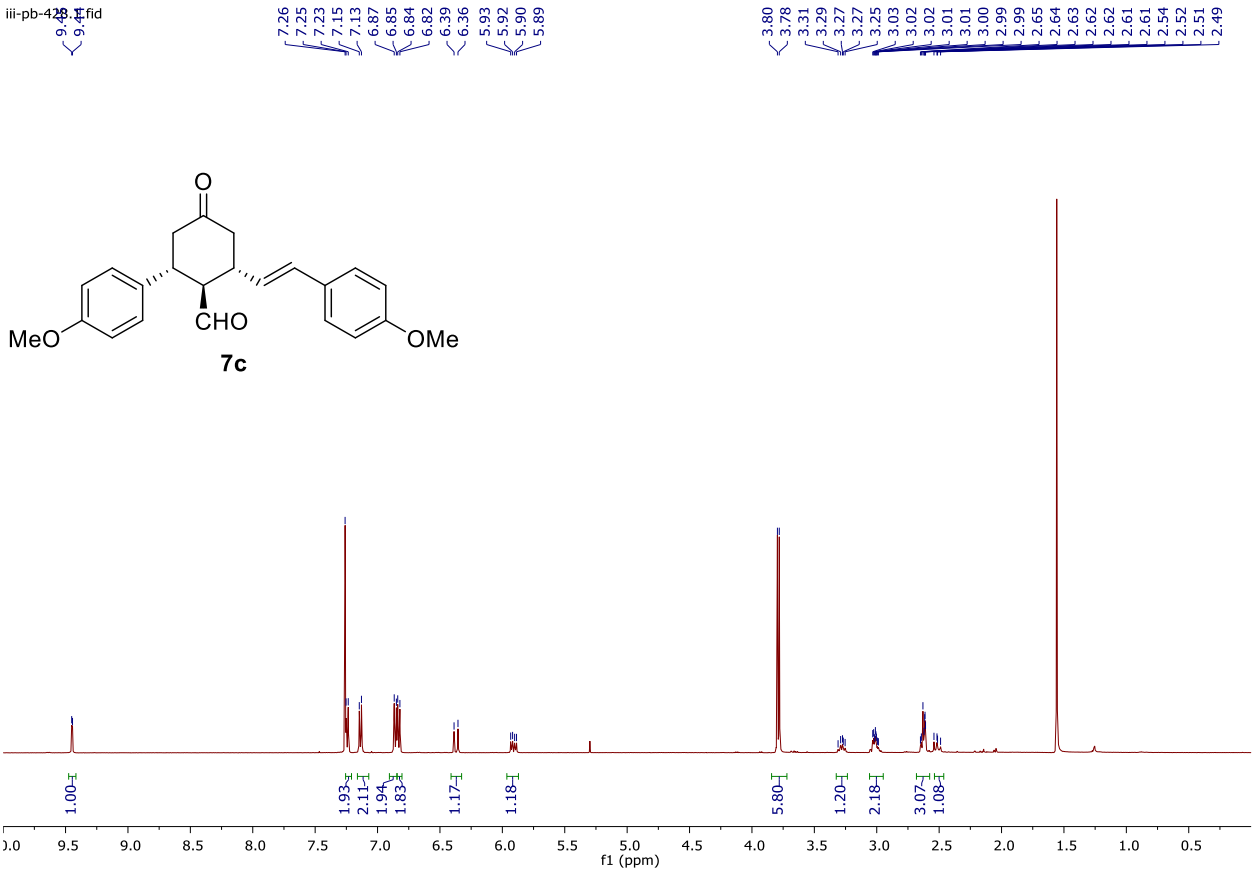
f1 (ppm)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OMe
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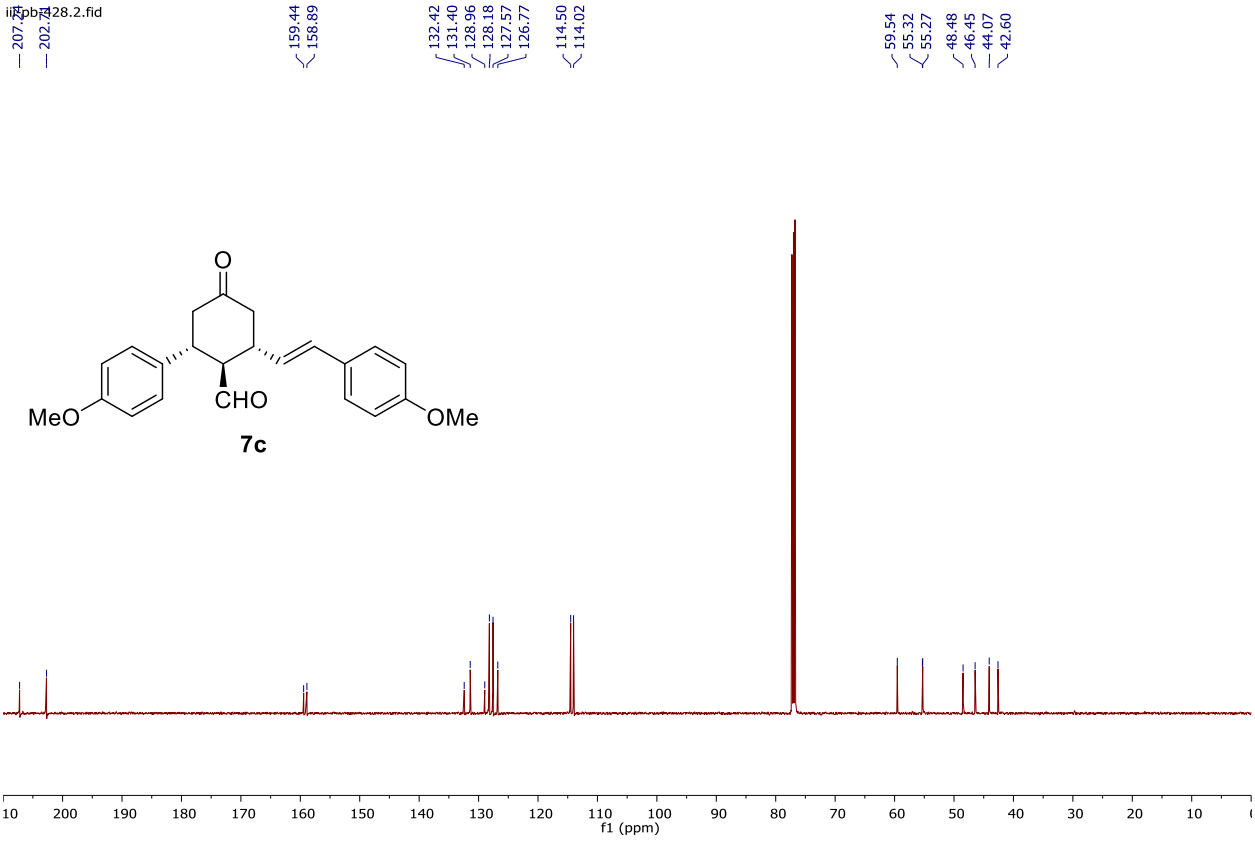
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44.07
42.60
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MeO
OMe
7c
f1 (ppm)


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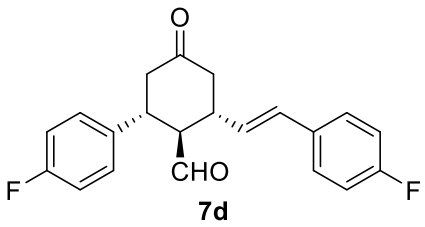
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CHO
F
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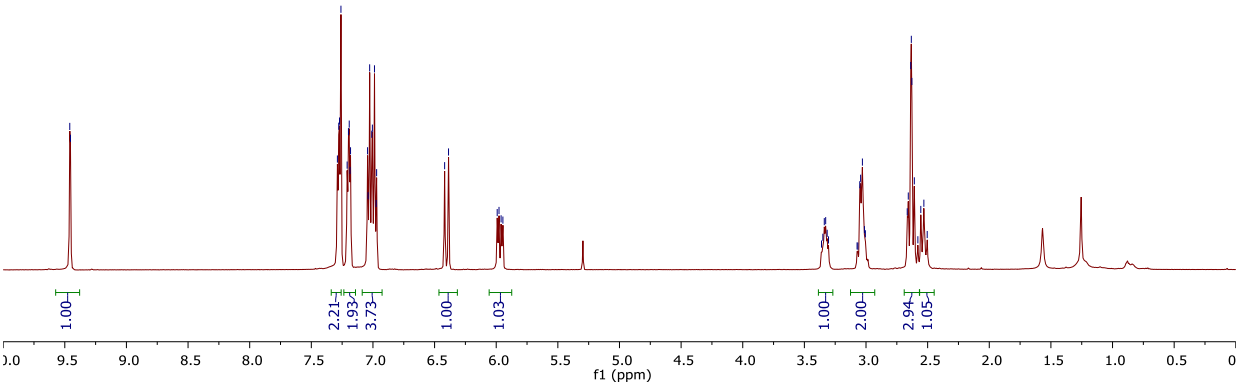
7d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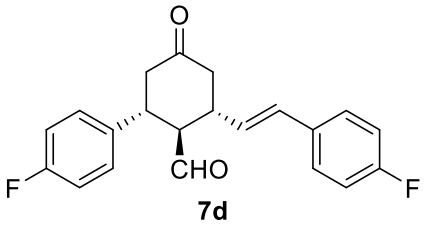
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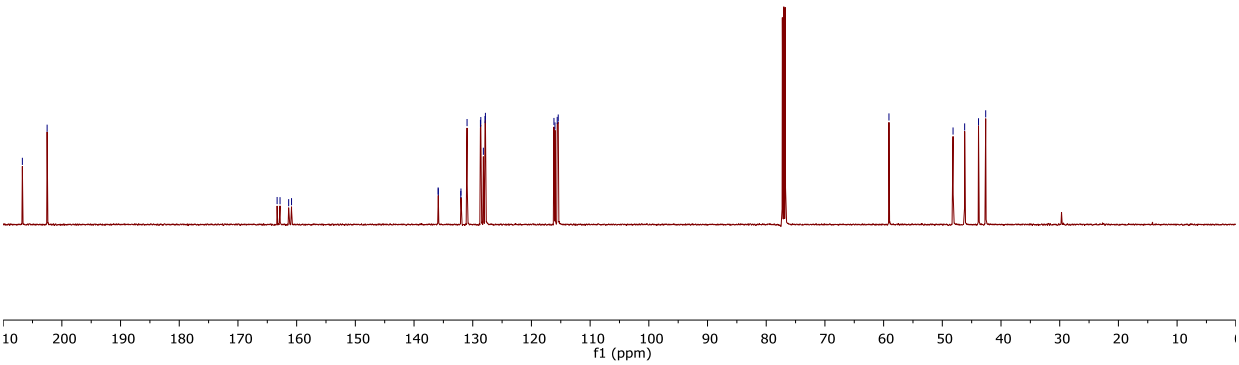
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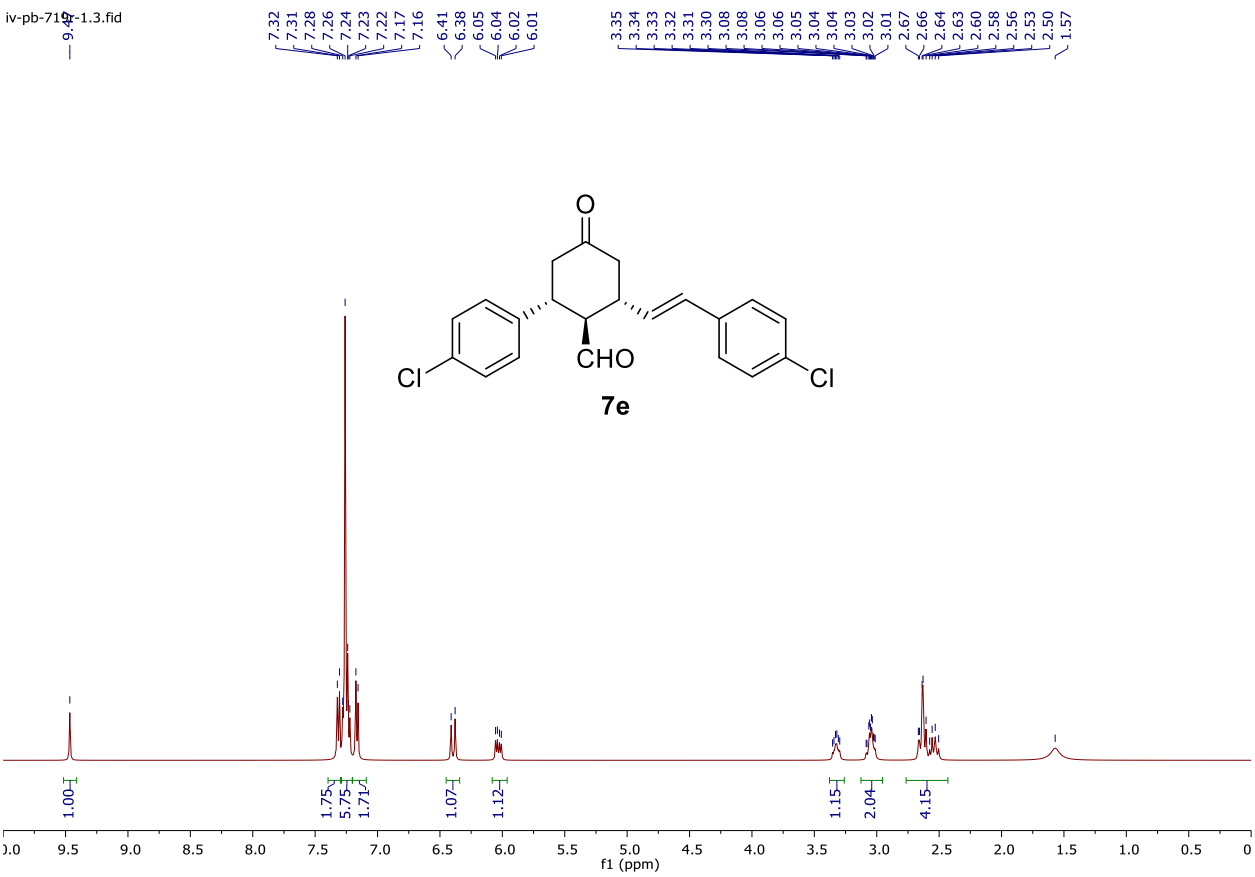
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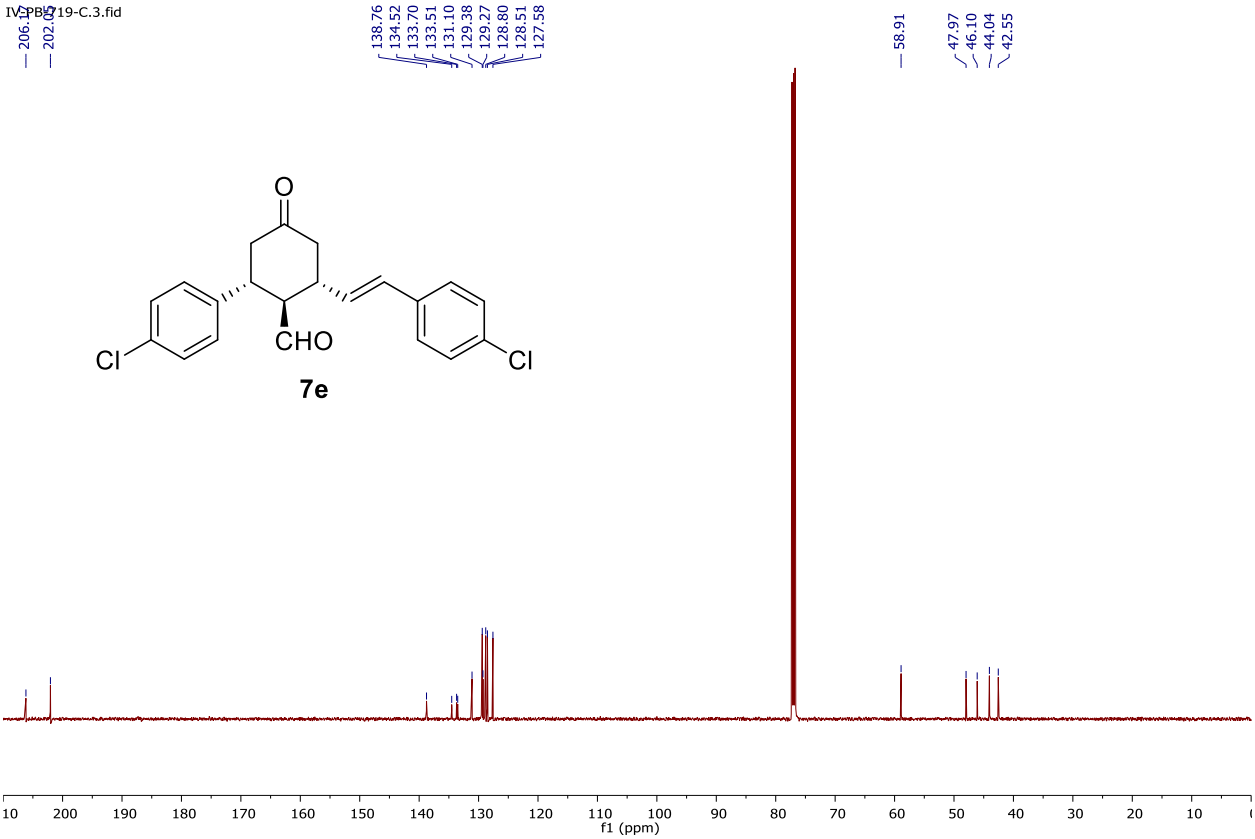
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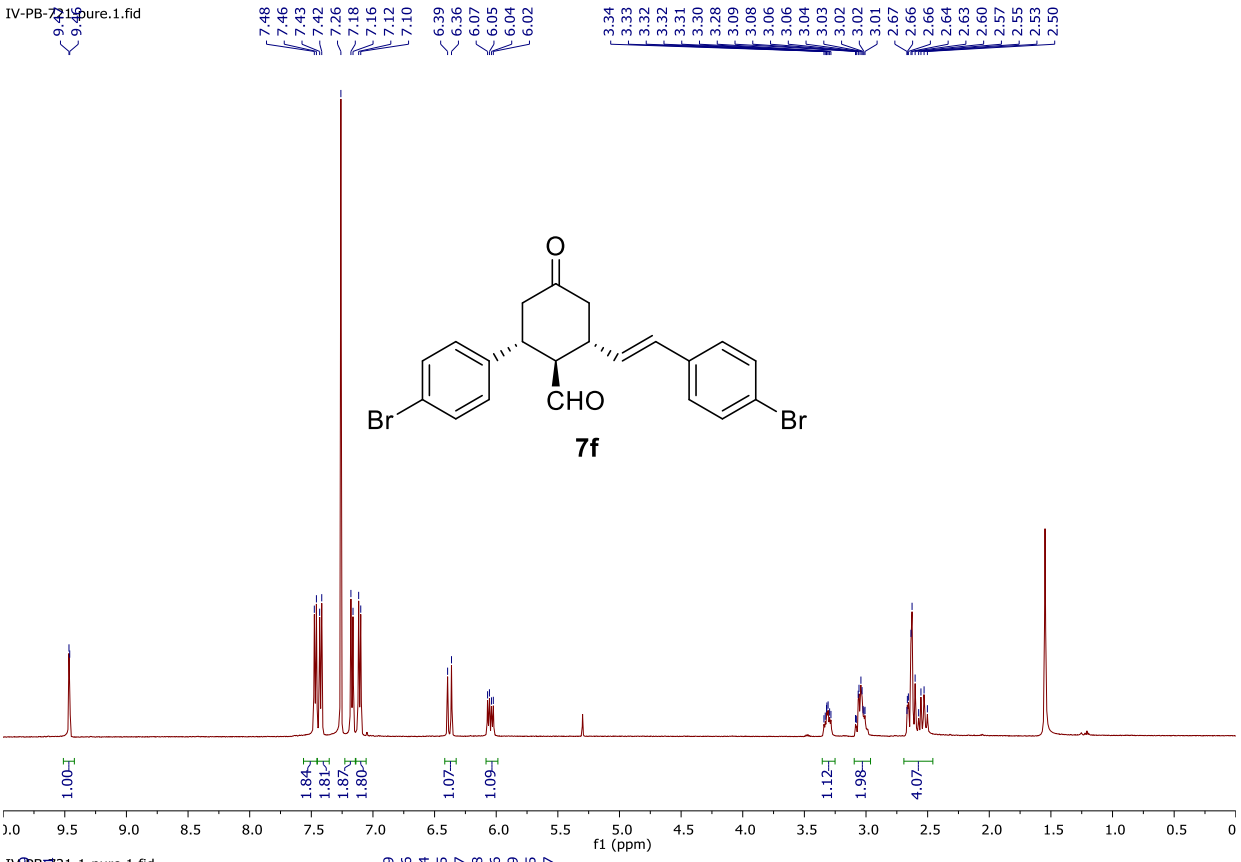
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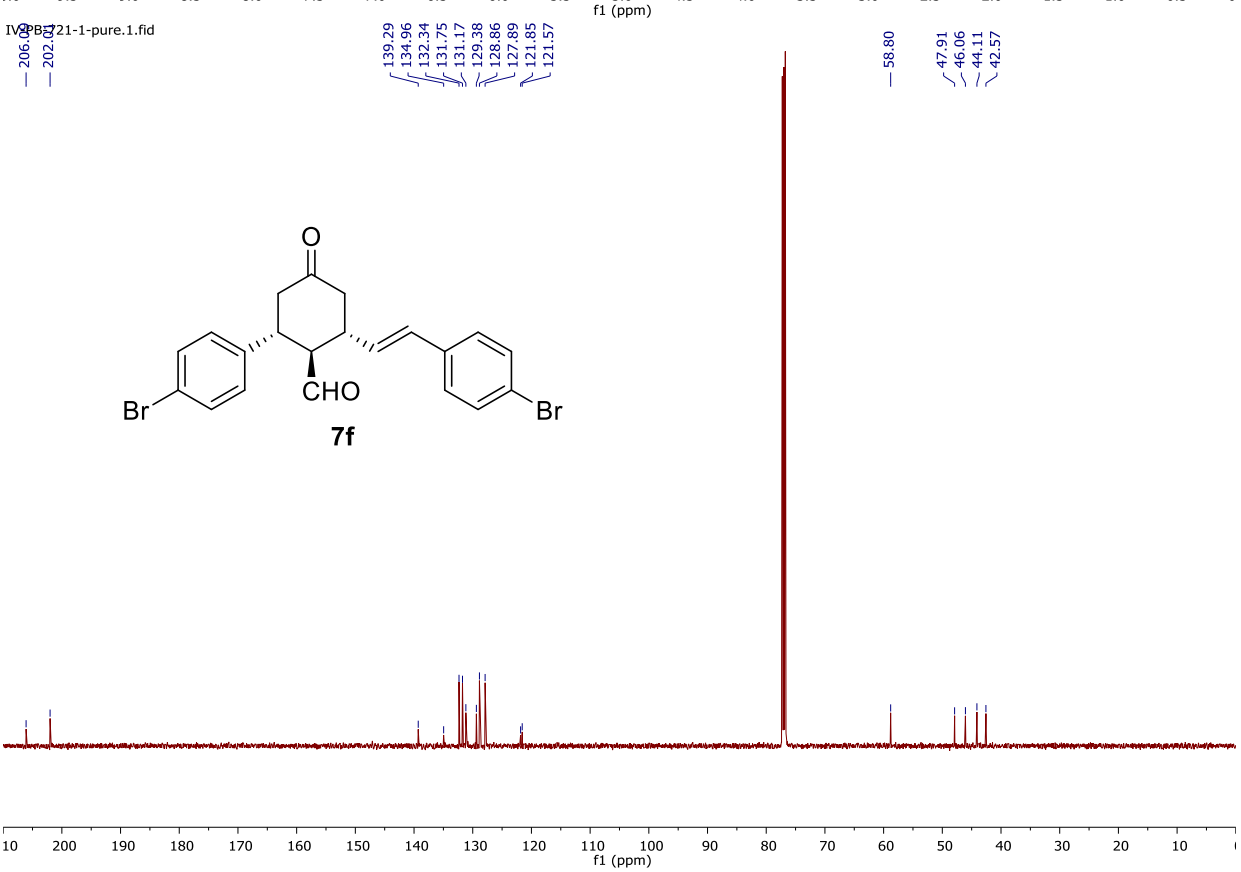
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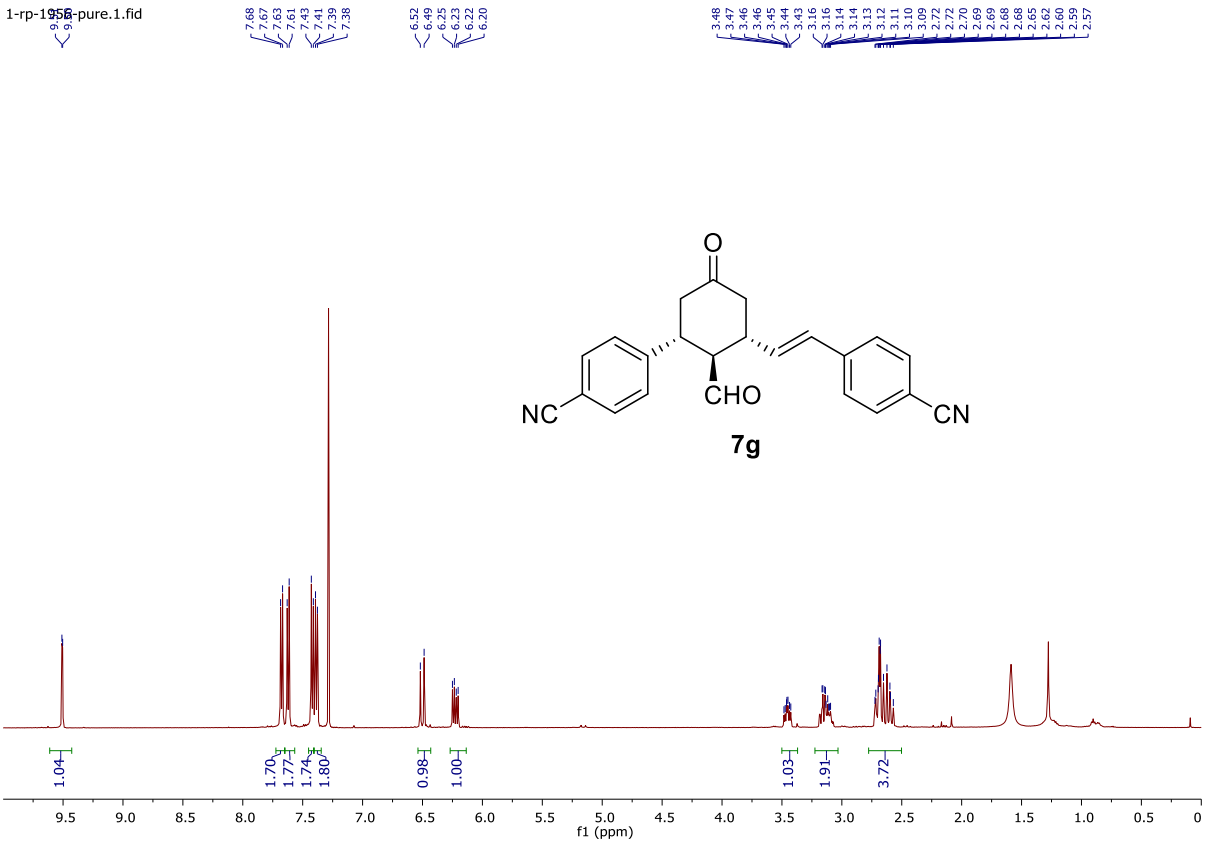
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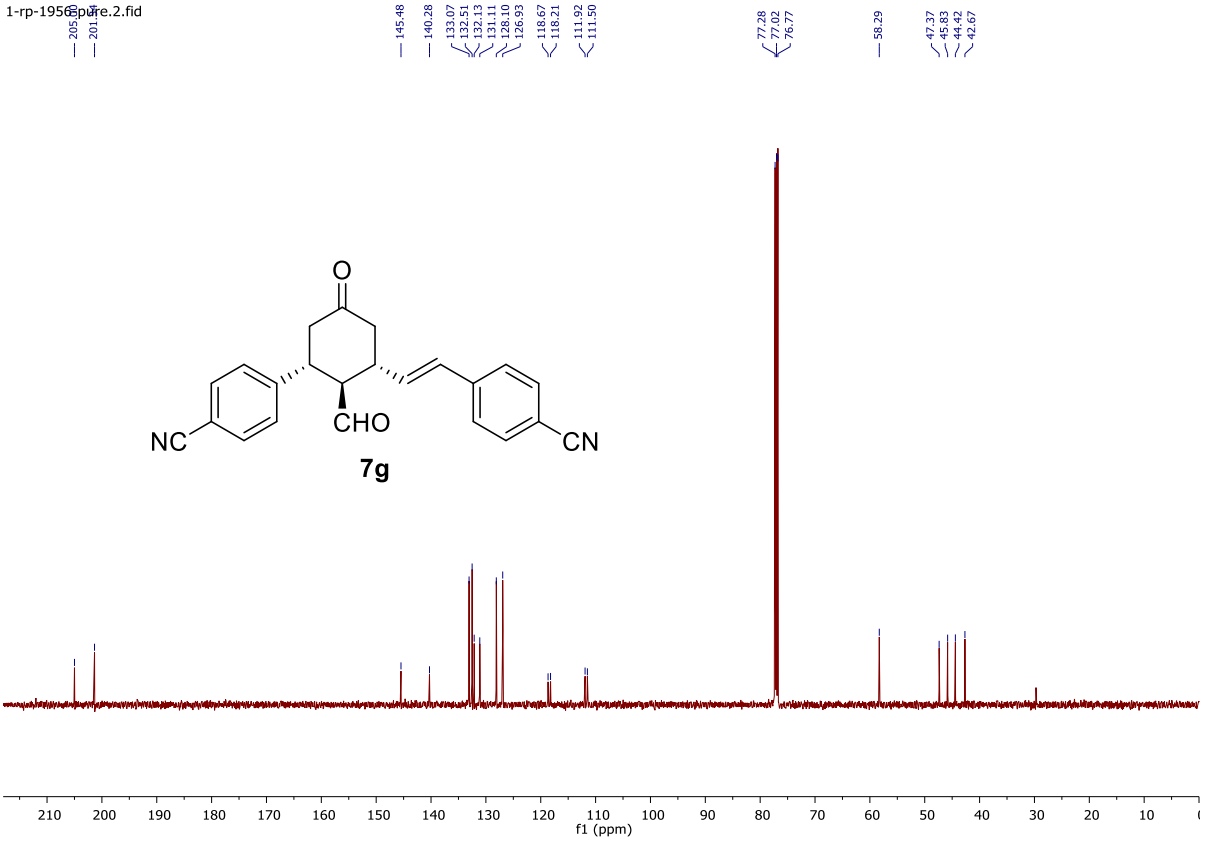
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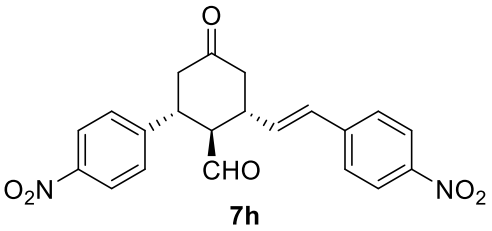
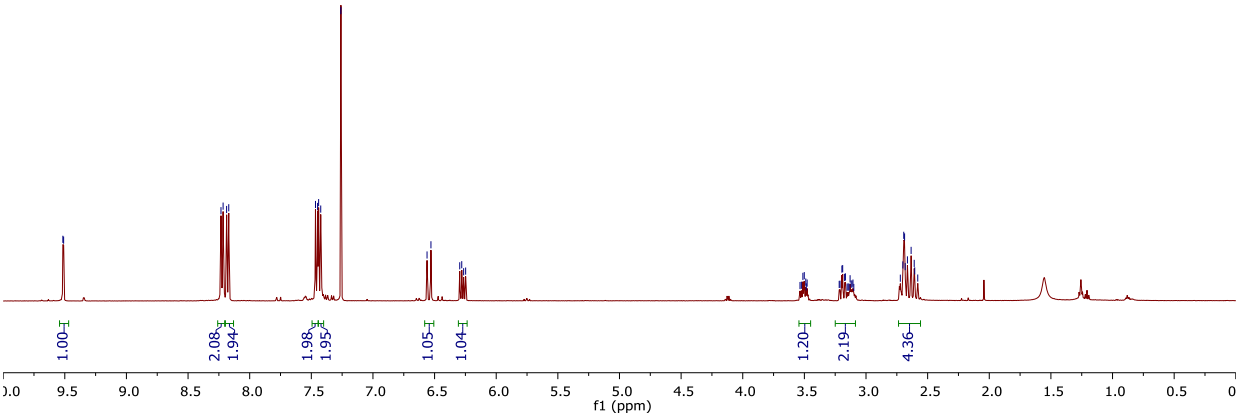
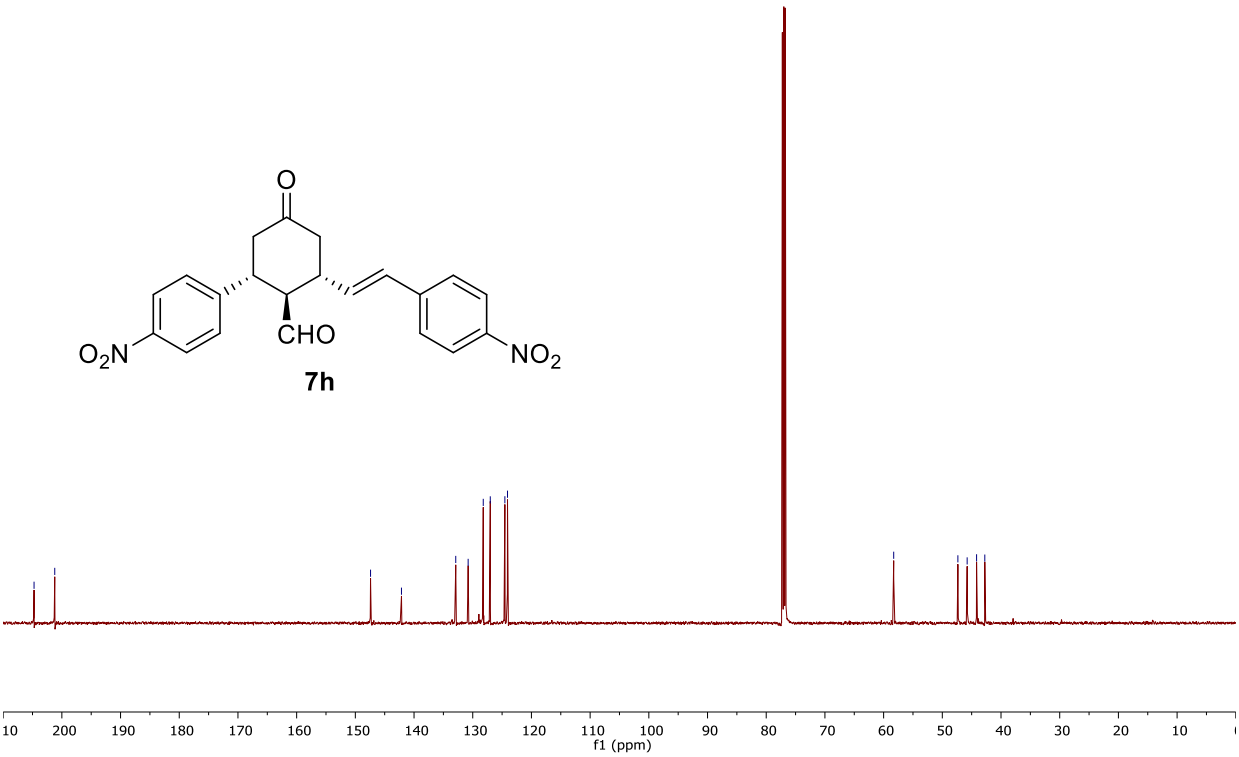
7g
f1 (ppm)

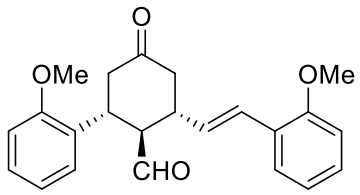

O
CHO
O_2N
NO_2

7h

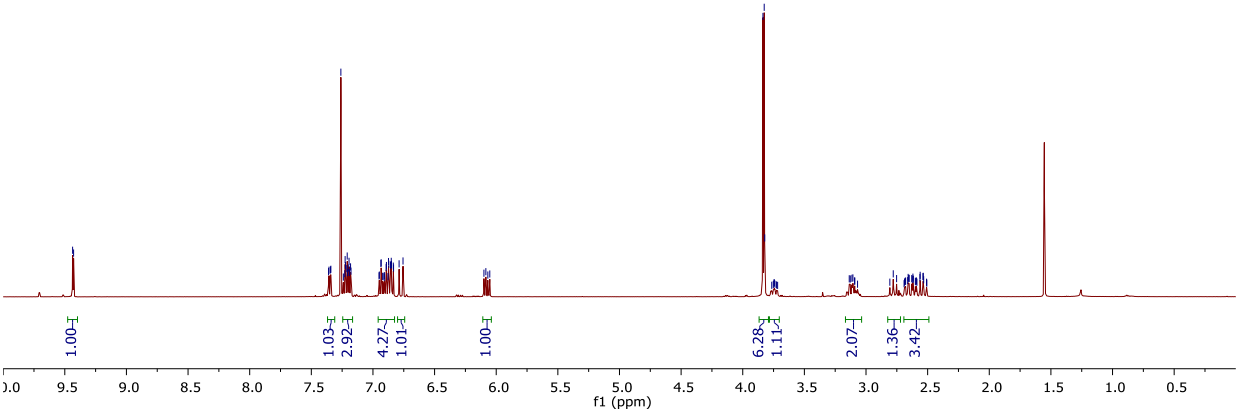

1.00
2.08
1.94
1.98
1.95
1.05
1.04
1.20
2.19
4.36
f1 (ppm)

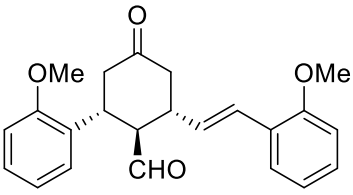

O
CHO
O_2N
NO_2
f1 (ppm)

7h

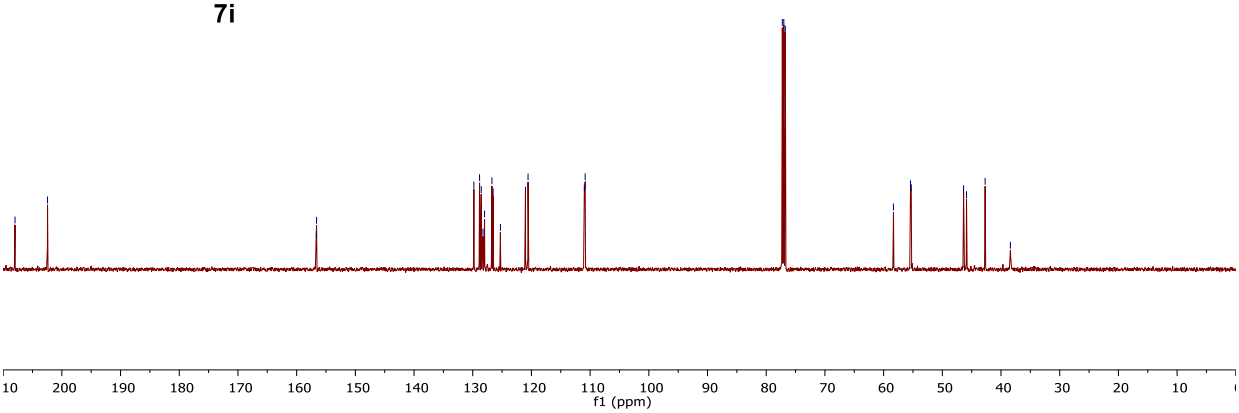


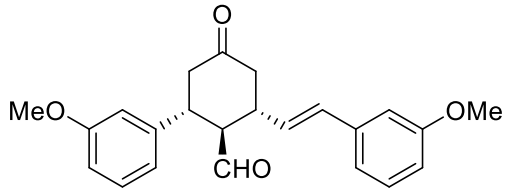
7i



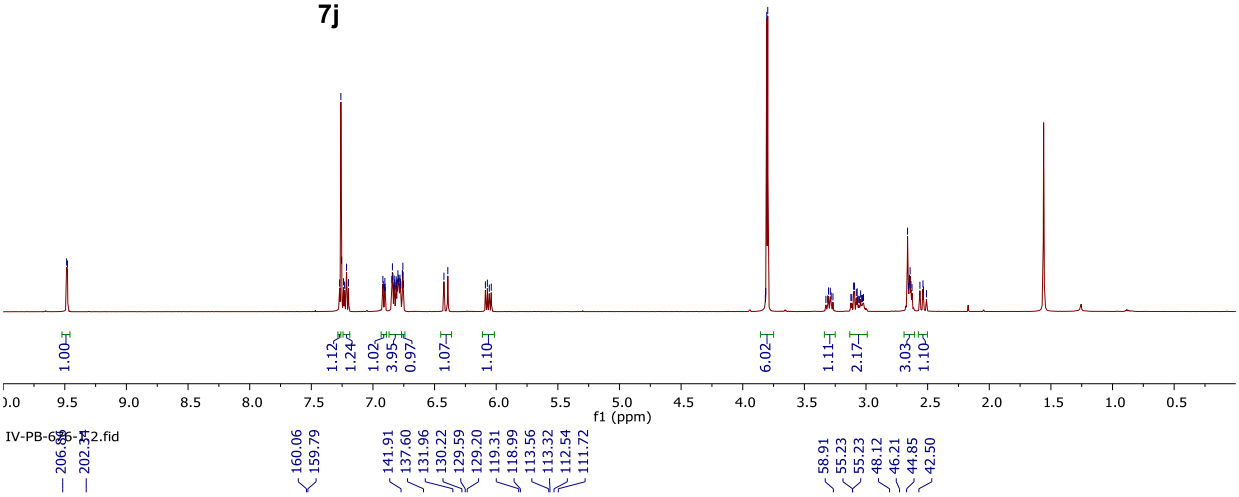


7i

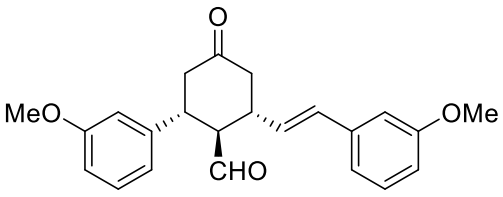



O
MeO
OMe
CHO

7j

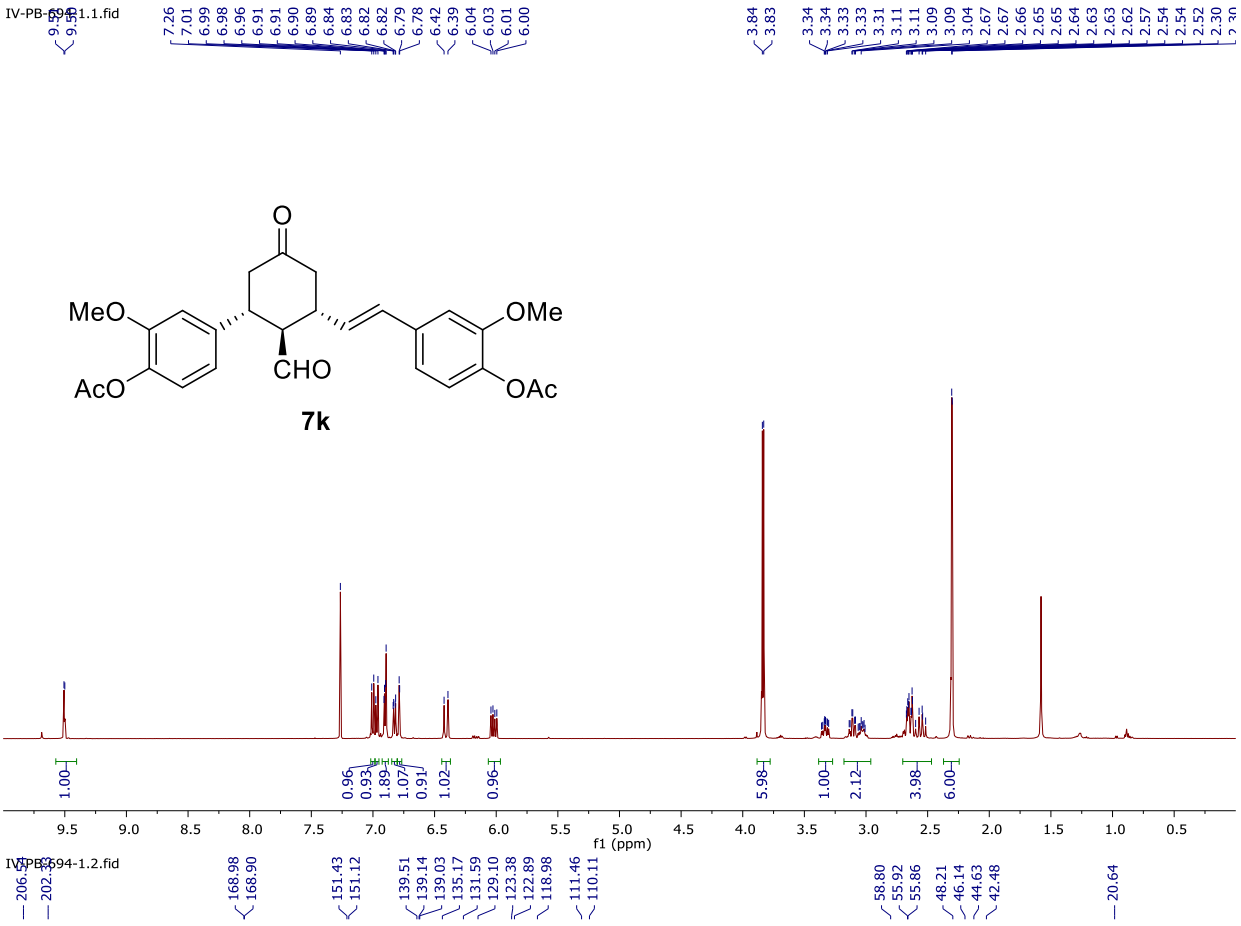

1.00
1.12
1.24
1.02
3.95
0.97
1.07
1.10
6.02
1.11
2.17
3.03
1.10
f1 (ppm)

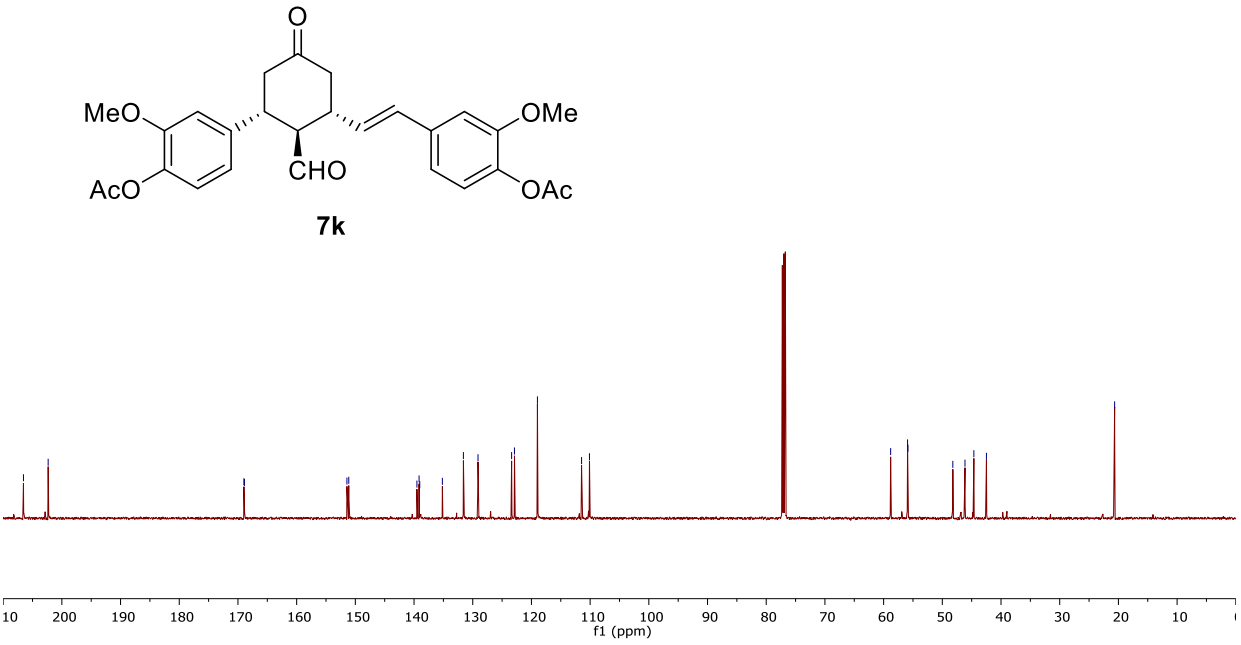
IV-PB-6-26-1-2.fid
206.82
202.34
160.06
159.79
141.91
137.60
131.96
130.22
129.59
129.20
119.31
118.99
113.56
113.32
112.54
111.72
58.91
55.23
55.23
48.12
46.21
44.85
42.50

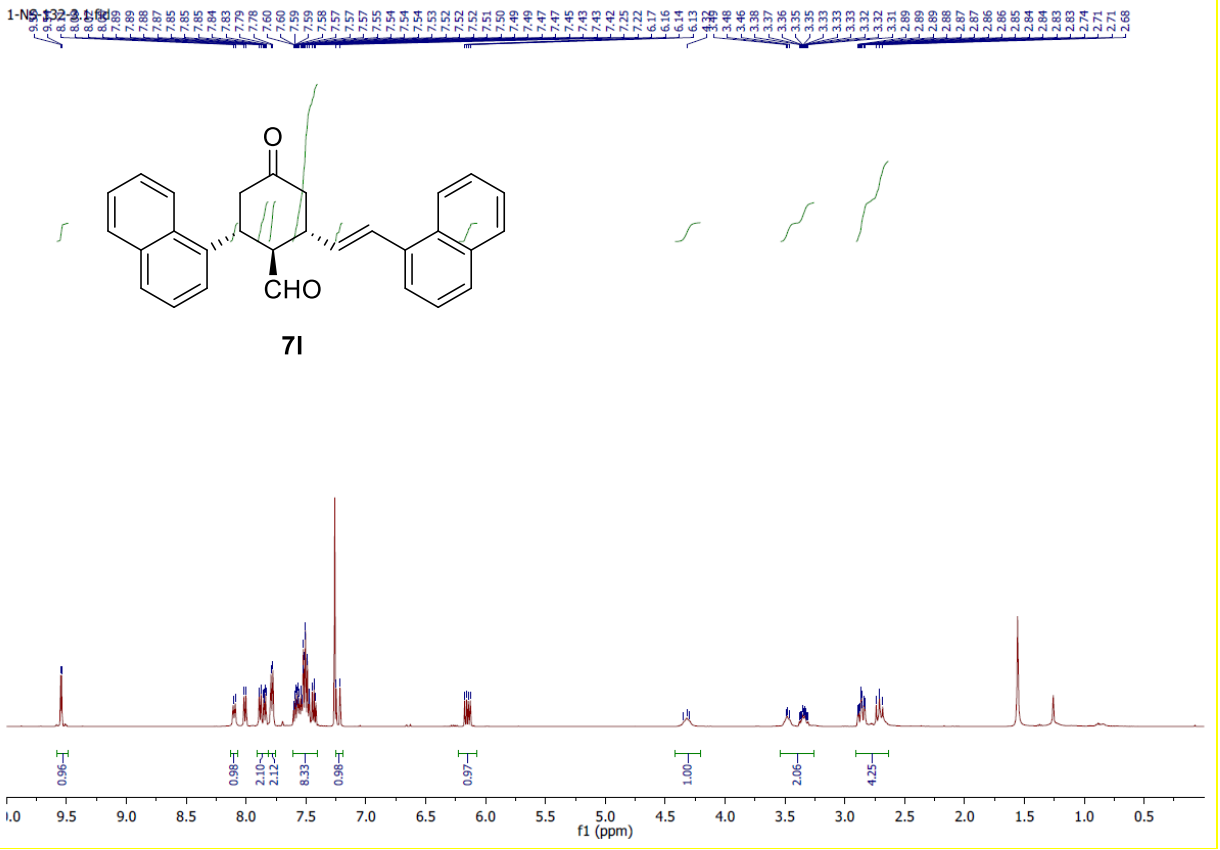

O
MeO
OMe
CHO

7j

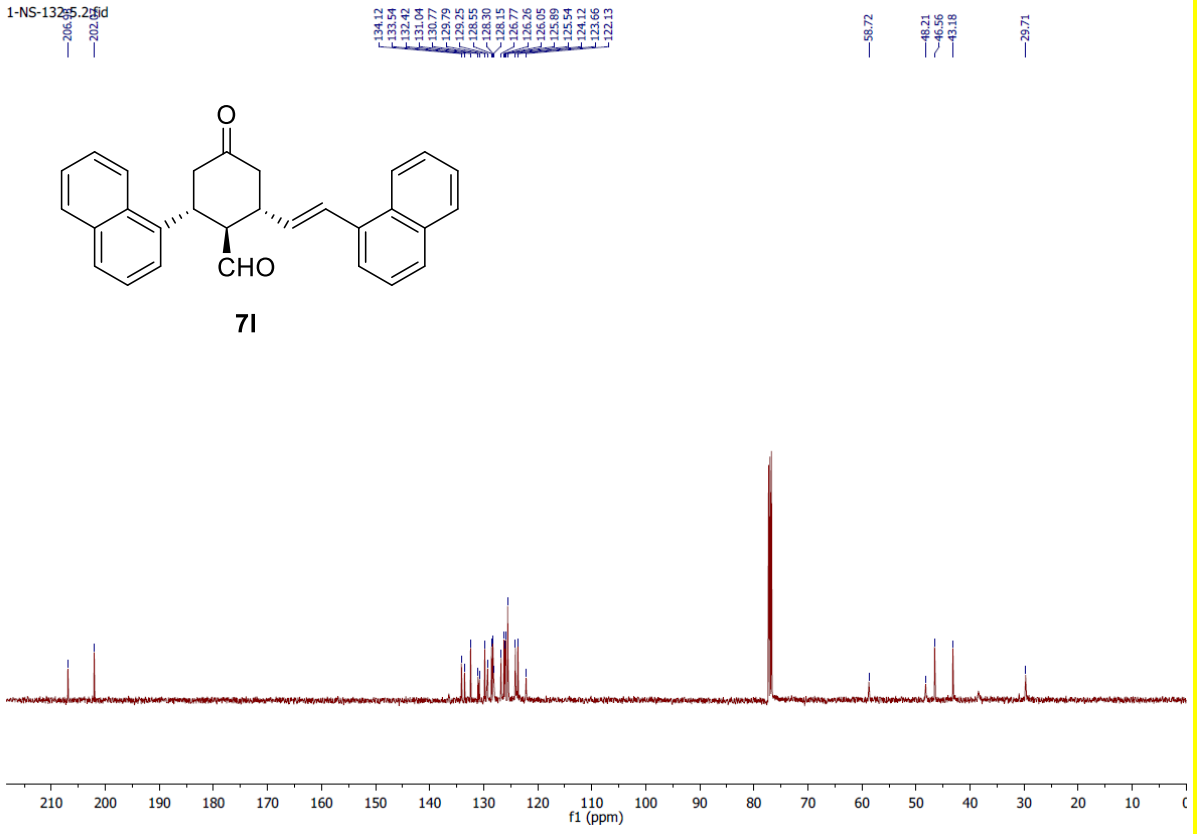
f1 (ppm)


IV-PB-694-1.1.fid
MeO
OMe
CHO
AcO
OAc
7k
f1 (ppm)


IV-PB-694-1.2.fid
MeO
OMe
CHO
AcO
OAc
7k
f1 (ppm)

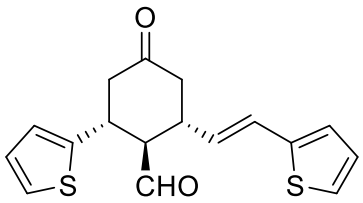


7l

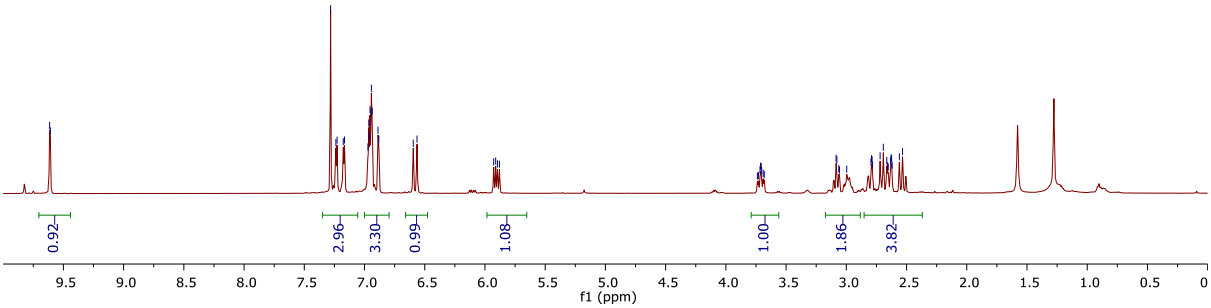


7l

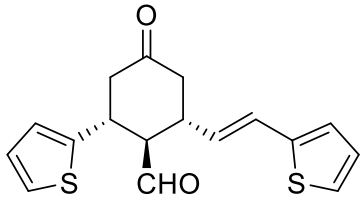

1-rp-1988-pure.1.fid
9.68
9.67
7.28
7.24
7.23
7.18
7.17
6.97
6.96
6.96
6.95
6.95
6.94
6.94
6.89
6.88
6.60
6.56
5.93
5.91
5.90
5.88
3.74
3.73
3.72
3.71
3.71
3.70
3.69
3.68
3.08
3.08
3.06
3.06
3.06
3.00
2.80
2.79
2.79
2.78
2.72
2.69
2.66
2.66
2.65
2.63
2.63
2.62
2.62
2.56
2.53


O
S
CHO
S

7m


0.92
2.96
3.30
0.99
1.08
1.00
1.86
3.82
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
f1 (ppm)

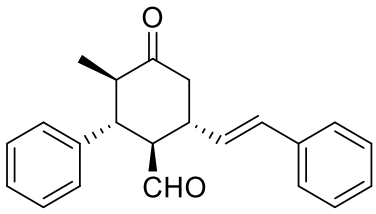

1-rp-1988-pure.2.fid
205.88
202.21
144.09
141.04
128.01
127.42
127.11
126.25
125.49
124.85
124.62
124.54
77.27
77.02
76.76
59.98
49.10
46.06
42.36
39.75


O
S
CHO
S

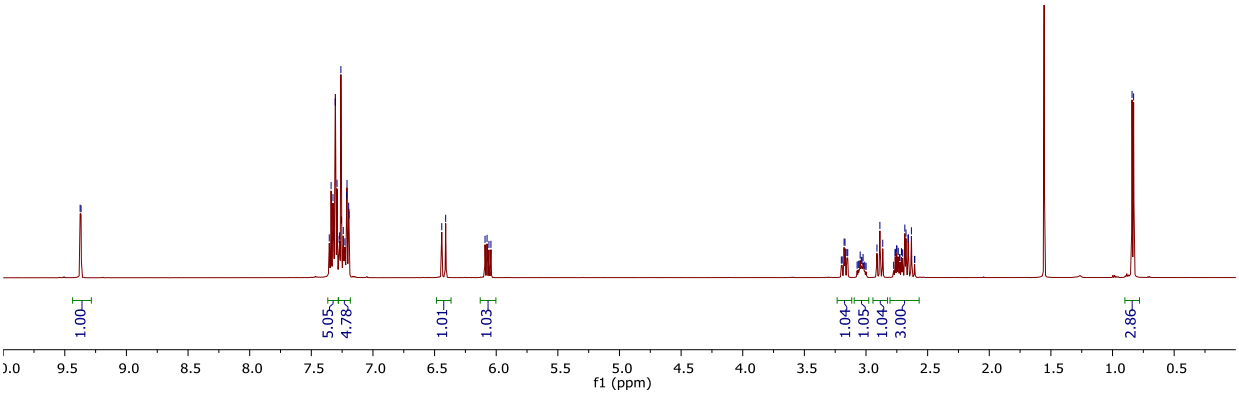
7m

210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

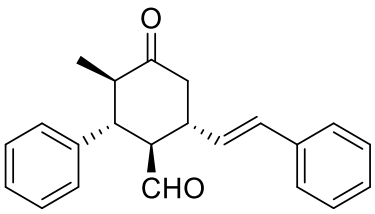

IV-PB-705-11.fid
9.51
9.41
7.35
7.34
7.32
7.32
7.31
7.30
7.29
7.27
7.27
7.26
7.26
7.24
7.23
7.21
7.21
7.20
7.19
6.44
6.41
6.09
6.07
6.06
6.04
3.20
3.19
3.18
3.17
3.16
3.15
3.07
3.06
3.06
3.05
3.04
3.03
3.02
3.02
3.01
3.00
2.91
2.89
2.86
2.78
2.76
2.76
2.75
2.75
2.74
2.73
2.72
2.71
2.70
2.69
2.68
2.66
2.66
2.63
2.61
2.60
0.84
0.83


O
CHO

7n

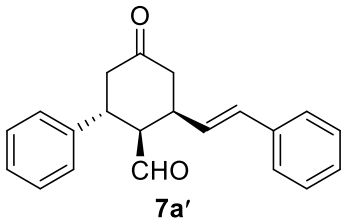

1.00
5.05
4.78
1.01
1.03
1.04
1.05
1.04
3.00
2.86
f1 (ppm)


IV-PB-705-12.fid
208.37
202.31
139.52
136.22
131.87
129.10
129.02
128.58
127.86
127.75
127.63
126.35
60.30
52.15
49.36
46.59
42.94
11.65

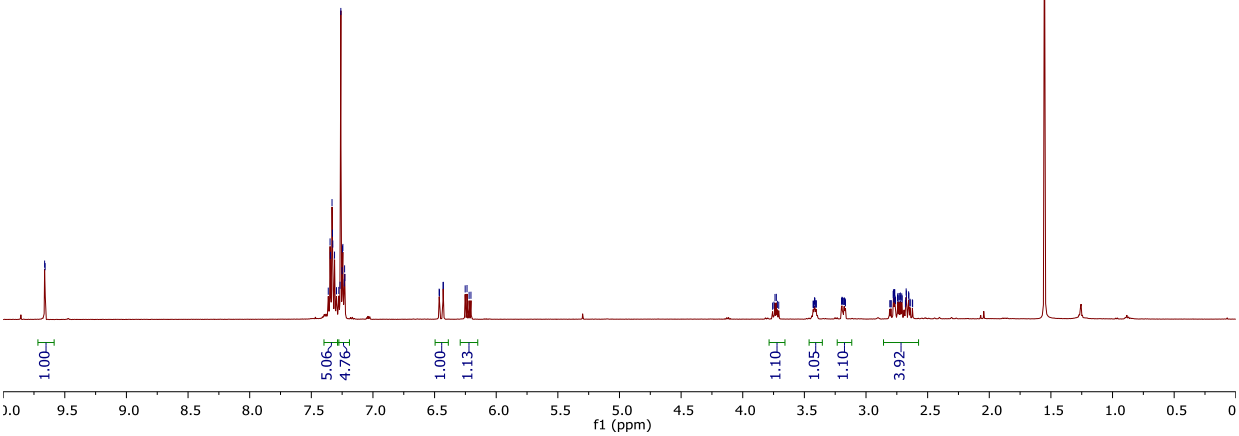

O
CHO

7n

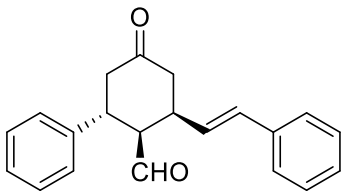
f1 (ppm)


O
CHO

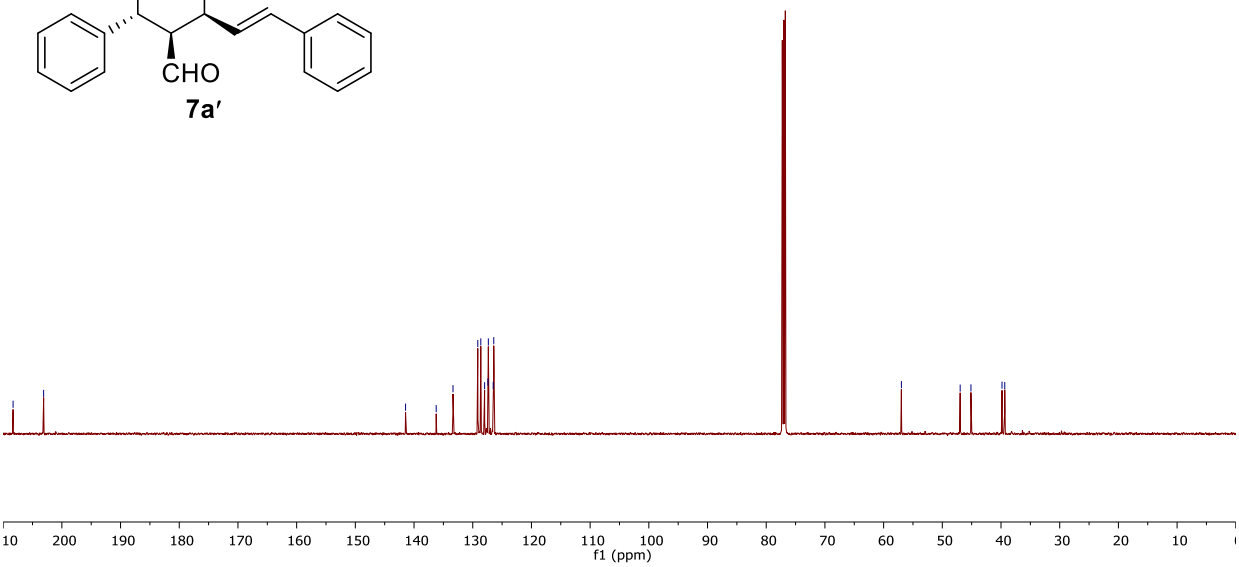
7a′

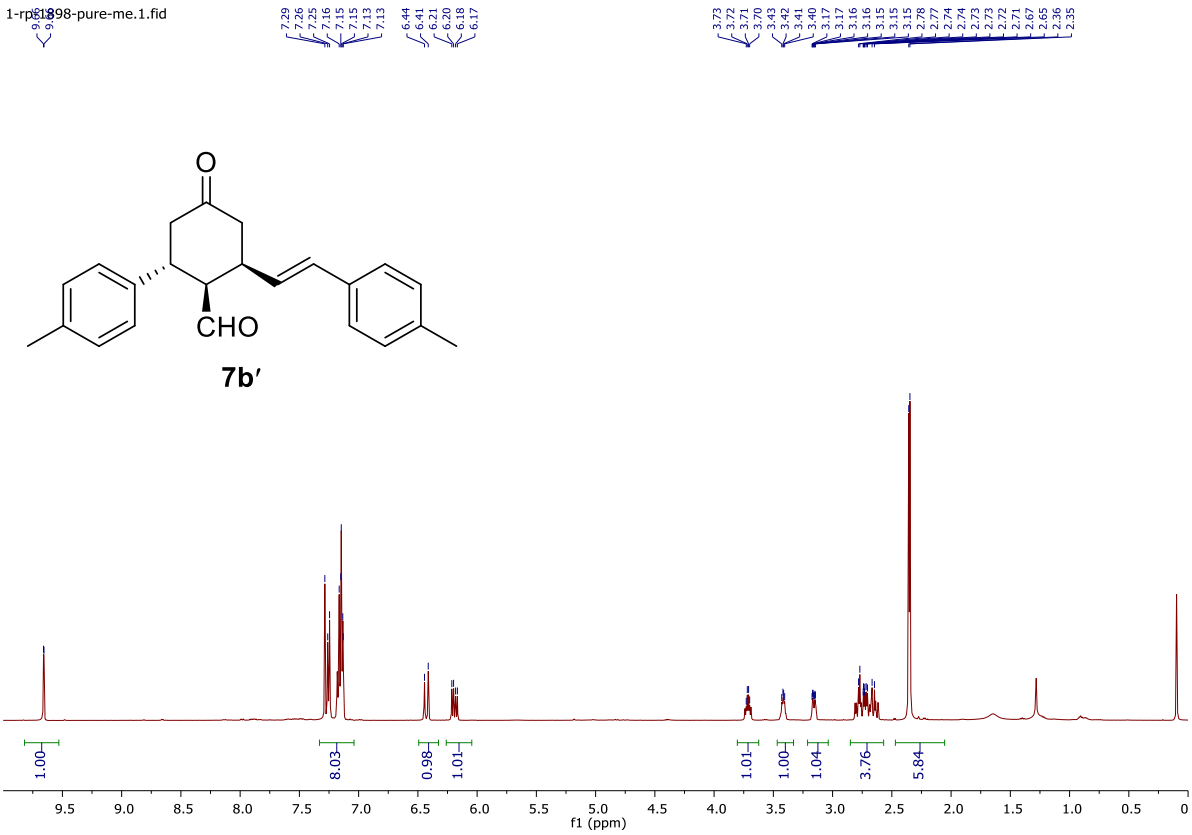

1.00
5.06
4.76
1.00
1.13
1.10
1.05
1.10
3.92
f1 (ppm)

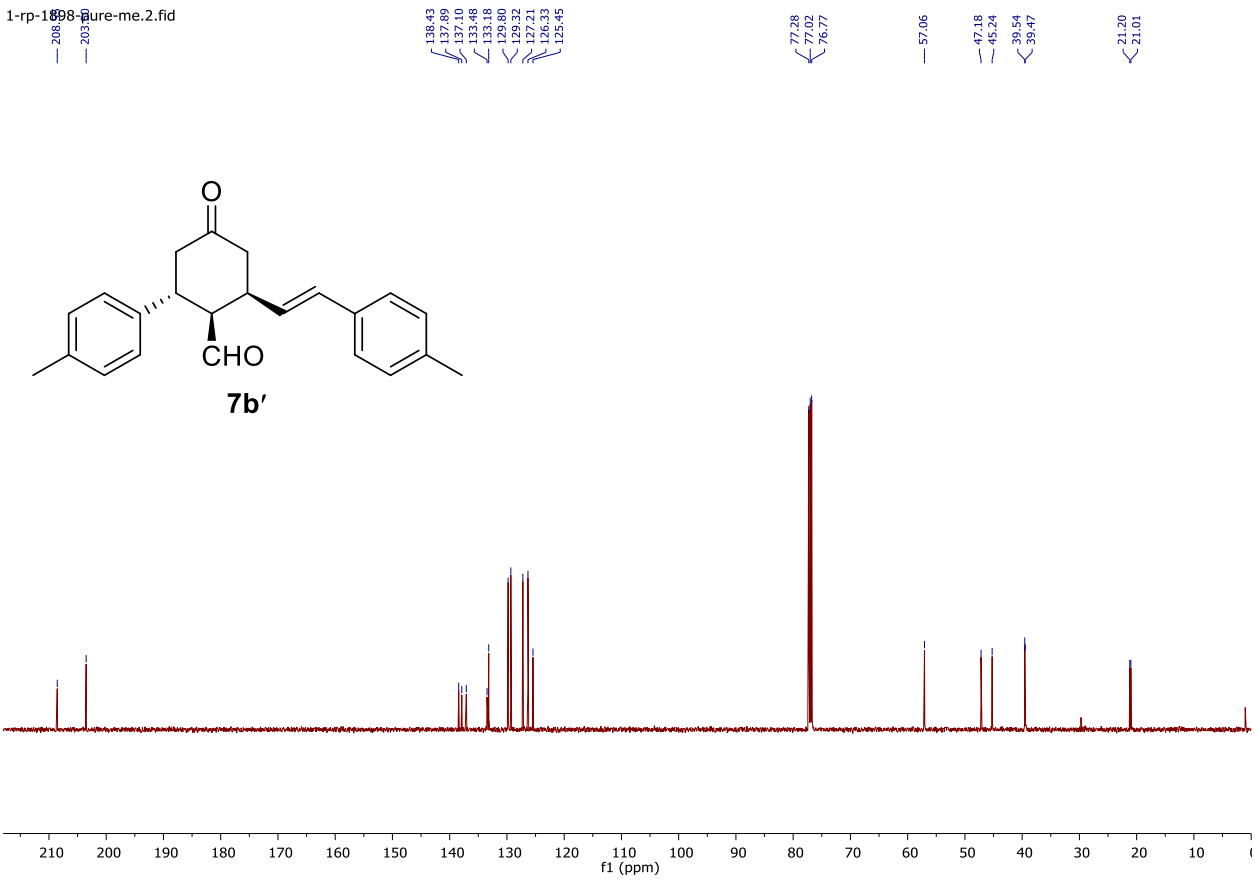

208.37
203.11
141.44
136.22
133.36
129.14
128.63
127.98
127.41
127.34
126.51
126.42
56.97
46.96
45.12
39.83
39.36

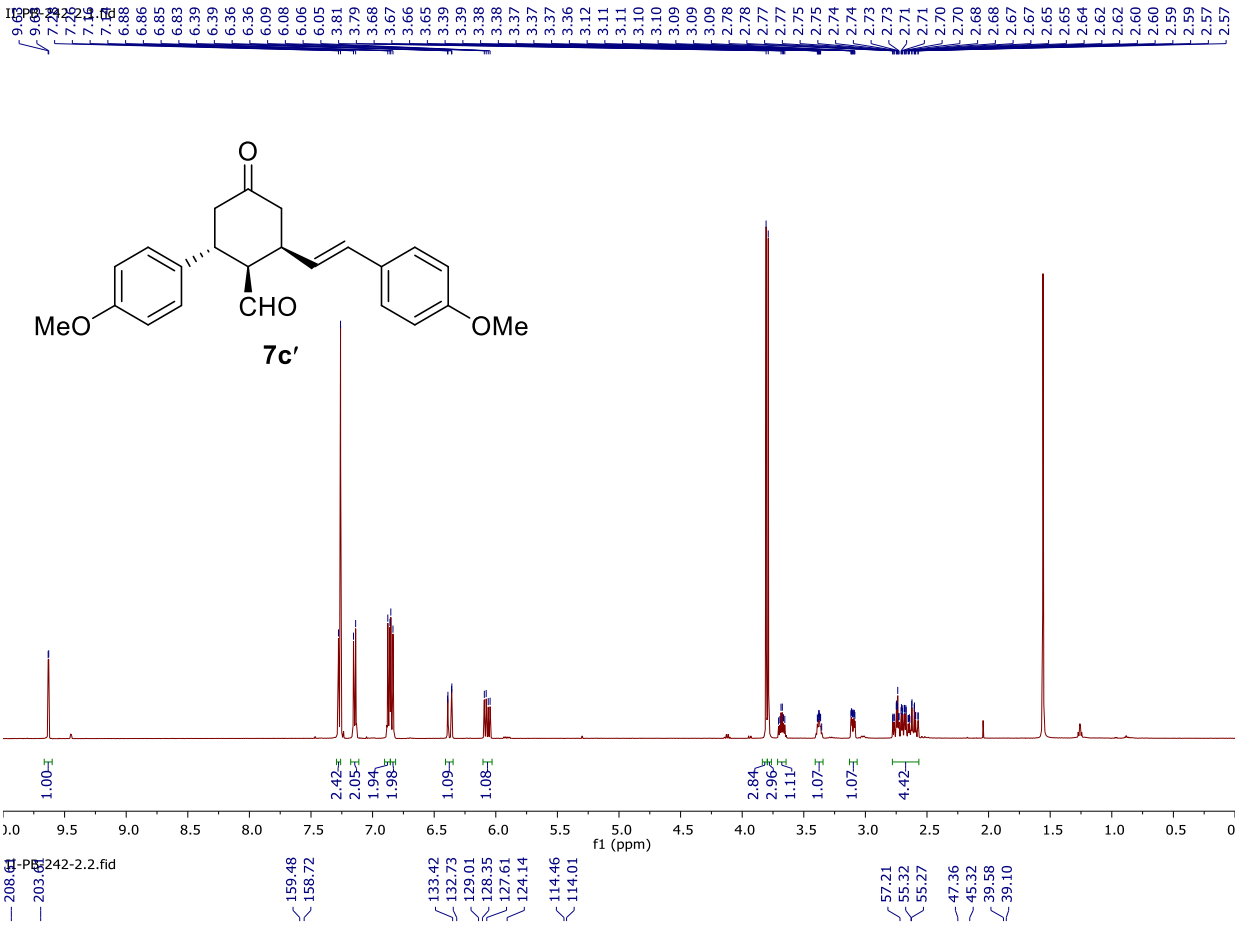

O
CHO

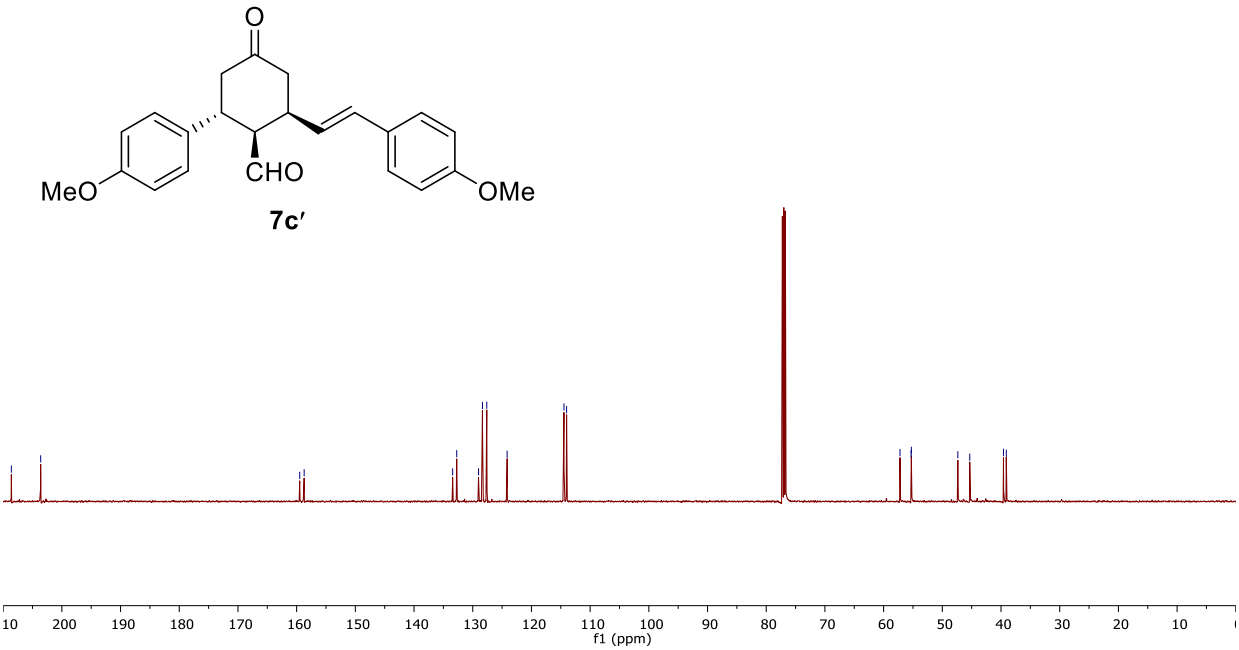
7a′

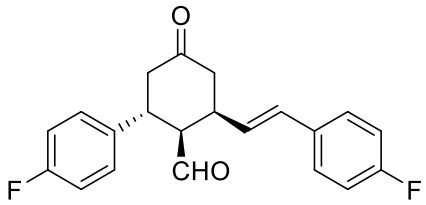

f1 (ppm)


1-rp-1898-pure-me.1.fid
O
CHO
7b′
1.00
8.03
0.98
1.01
1.01
1.00
1.04
3.76
5.84
f1 (ppm)

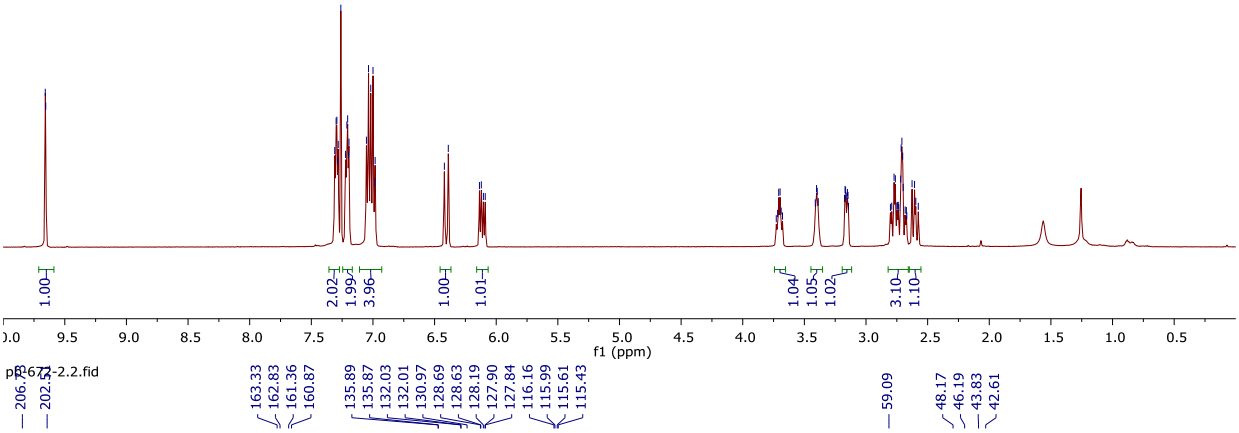

1-rp-1898-pure-me.2.fid
O
CHO
7b′
f1 (ppm)

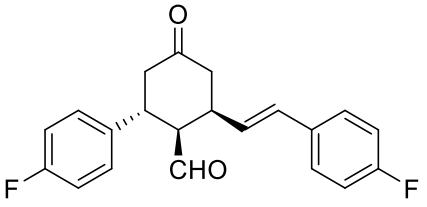

O
CHO
MeO
OMe
7c′
f1 (ppm)


O
CHO
MeO
OMe
7c′
f1 (ppm)

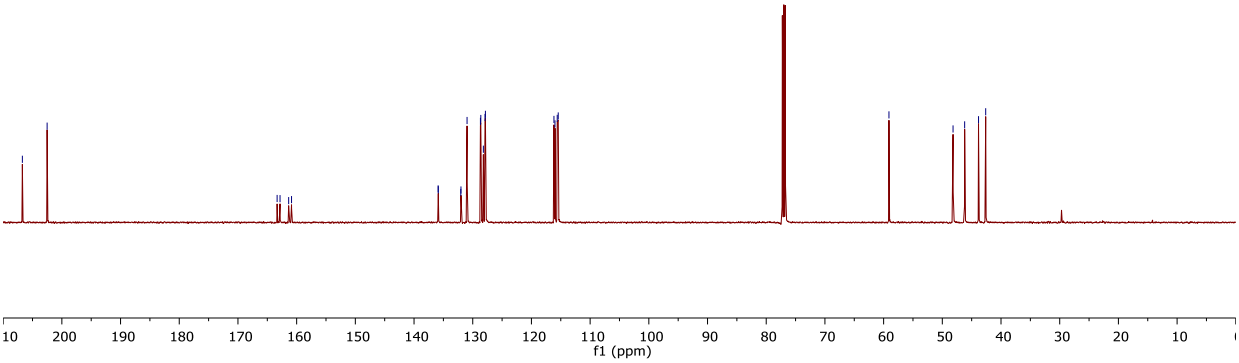


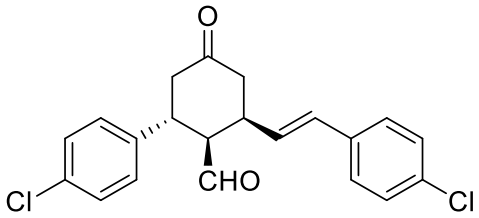
7d′



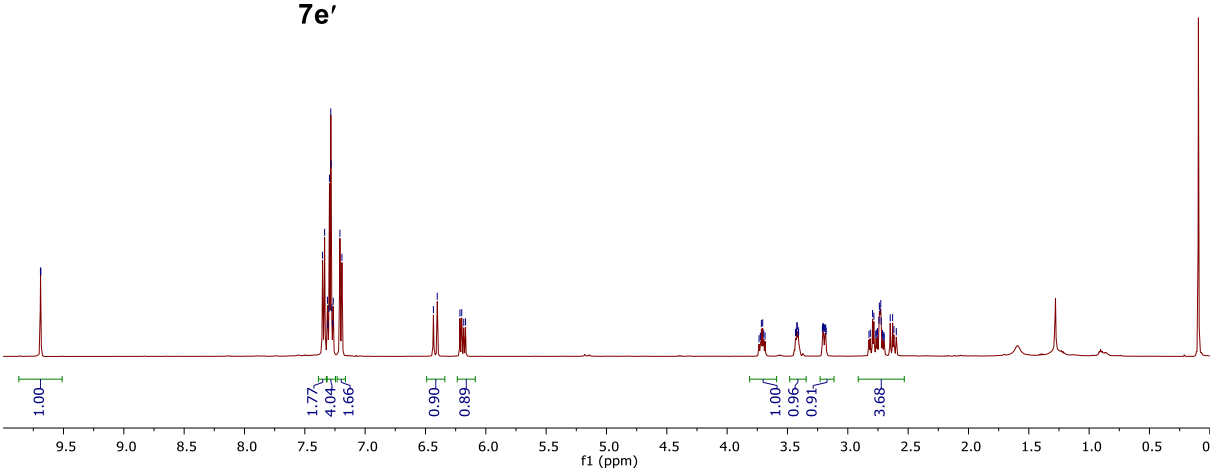


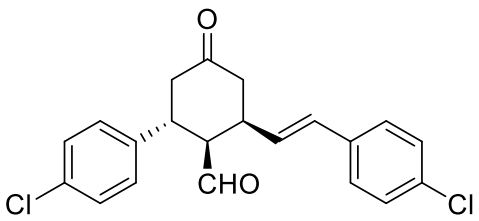
7d′




O
CHO
Cl
Cl

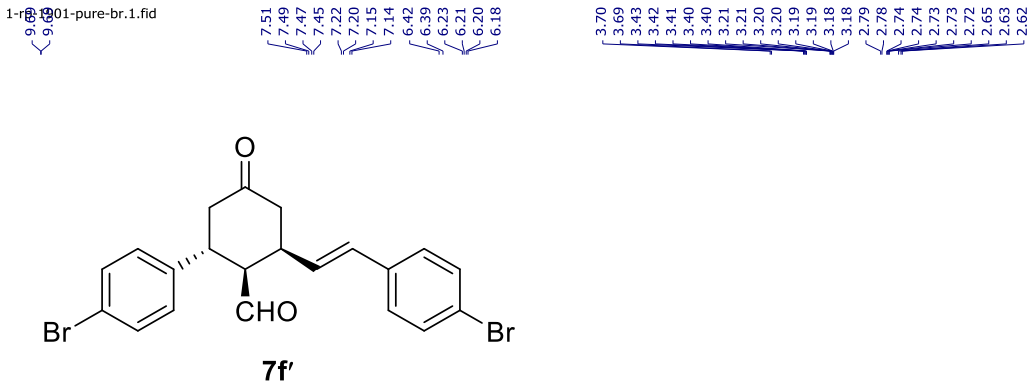
7e′


1.00
1.77
4.04
1.66
0.90
0.89
1.00
0.96
0.91
3.68
f1 (ppm)


O
CHO
Cl
Cl

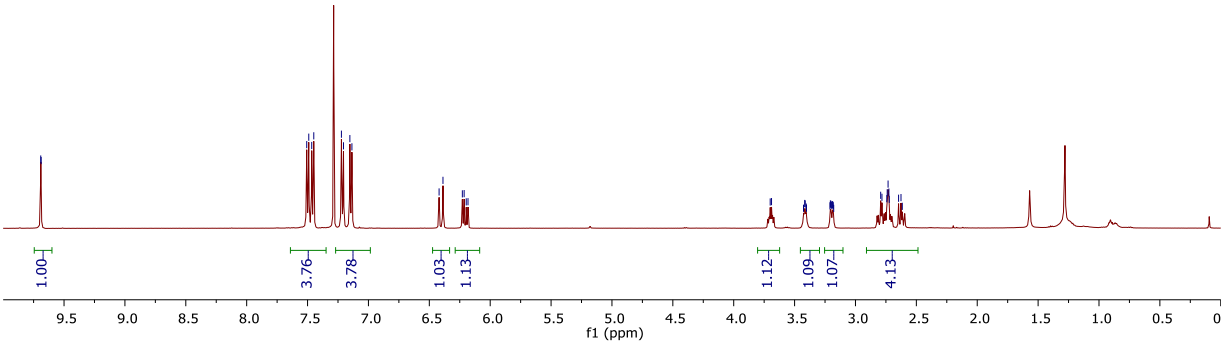
7e′

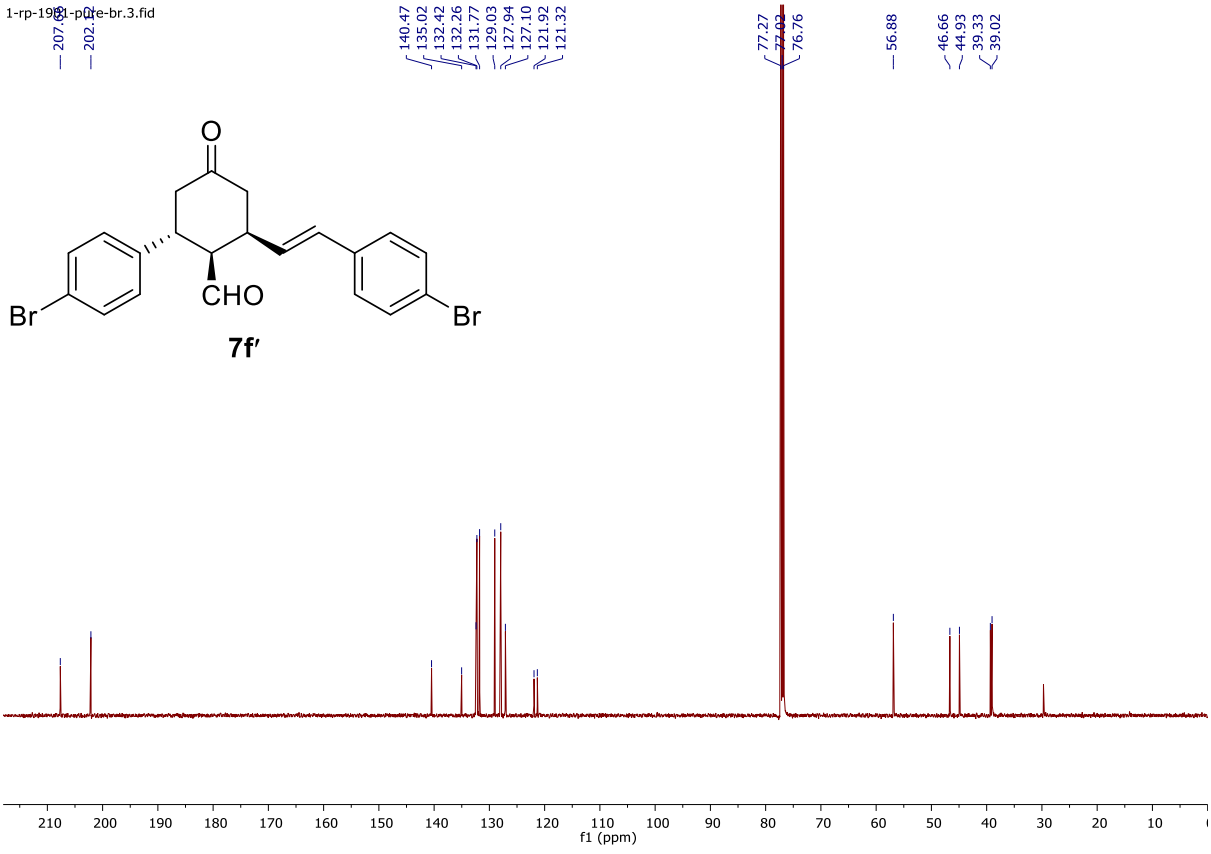
f1 (ppm)


1-rp-1901-pure-br.1.fid
9.74
9.73
7.51
7.49
7.47
7.45
7.22
7.20
7.15
7.14
6.42
6.39
6.23
6.21
6.20
6.18
3.70
3.69
3.43
3.42
3.41
3.40
3.40
3.21
3.21
3.20
3.20
3.19
3.19
3.18
3.18
2.79
2.78
2.74
2.74
2.73
2.73
2.72
2.65
2.63
2.62

O
CHO
Br
Br

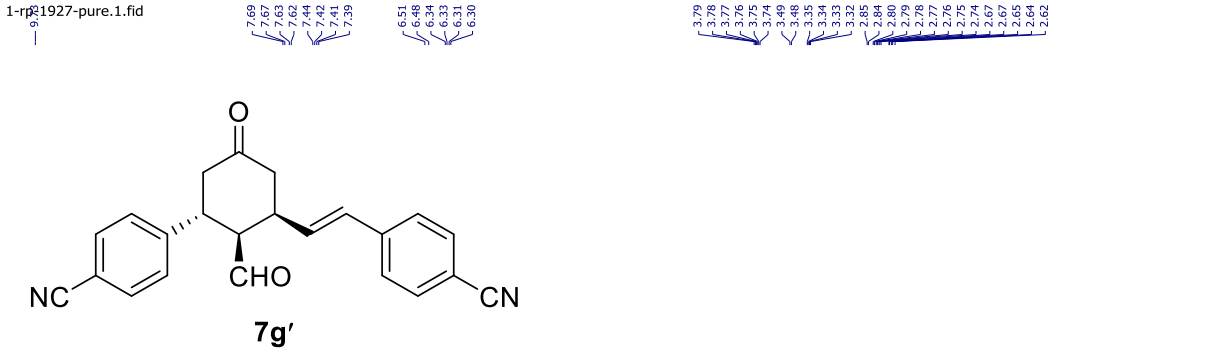
7f′


1.00
3.76
3.78
1.03
1.13
1.12
1.09
1.07
4.13
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
f1 (ppm)


1-rp-1901-pure-br.3.fid
207.61
202.77
140.47
135.02
132.42
132.26
131.77
129.03
127.94
127.10
121.92
121.32
77.27
77.03
76.76
56.88
46.66
44.93
39.33
39.02
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

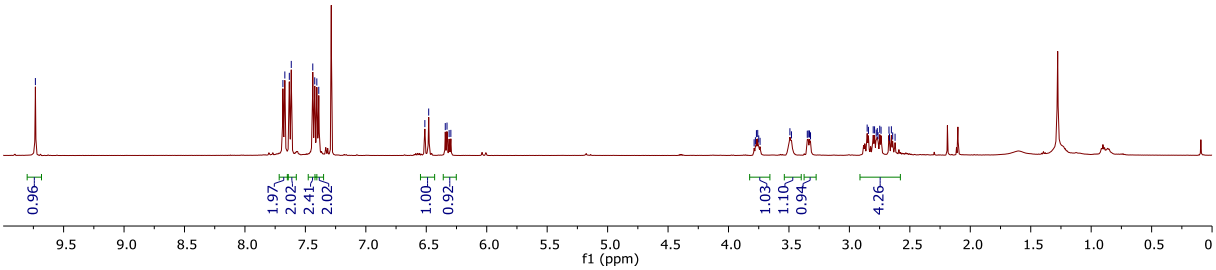
O
CHO
Br
Br

7f′

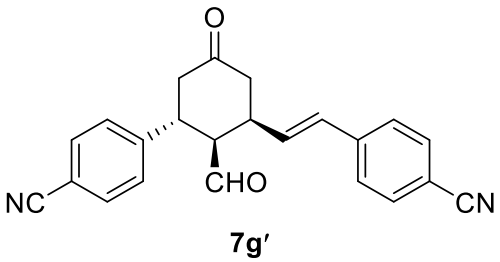

1-rp-21927-pure.1.fid
9.51
7.69
7.67
7.63
7.62
7.44
7.42
7.41
7.39
6.51
6.48
6.34
6.33
6.31
6.30
3.79
3.78
3.77
3.76
3.75
3.74
3.49
3.48
3.35
3.34
3.33
3.32
2.85
2.84
2.80
2.79
2.78
2.77
2.76
2.75
2.74
2.67
2.67
2.65
2.64
2.62

O
CHO
NC
CN

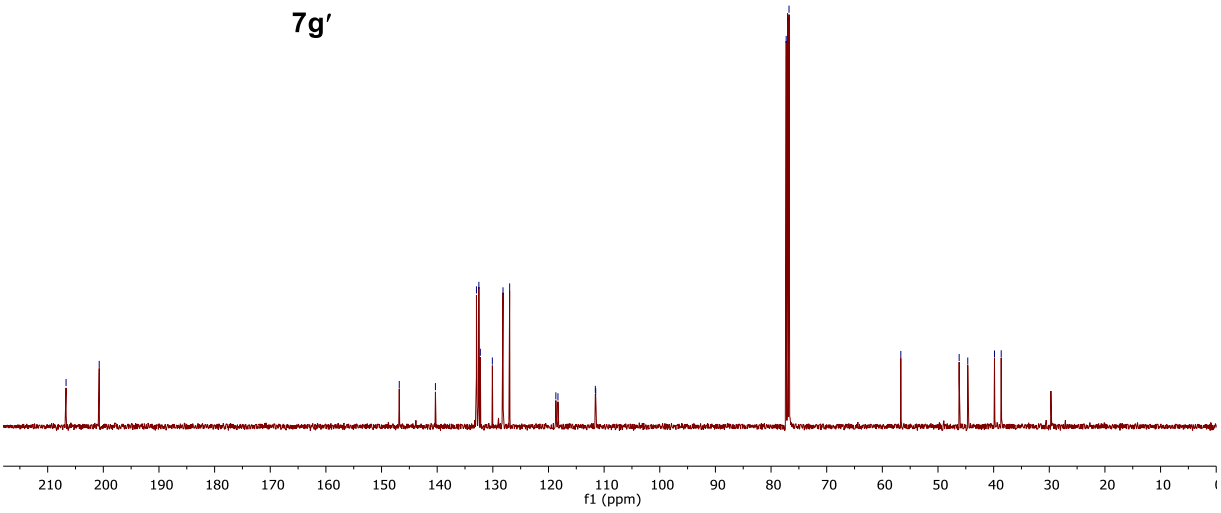
7g′

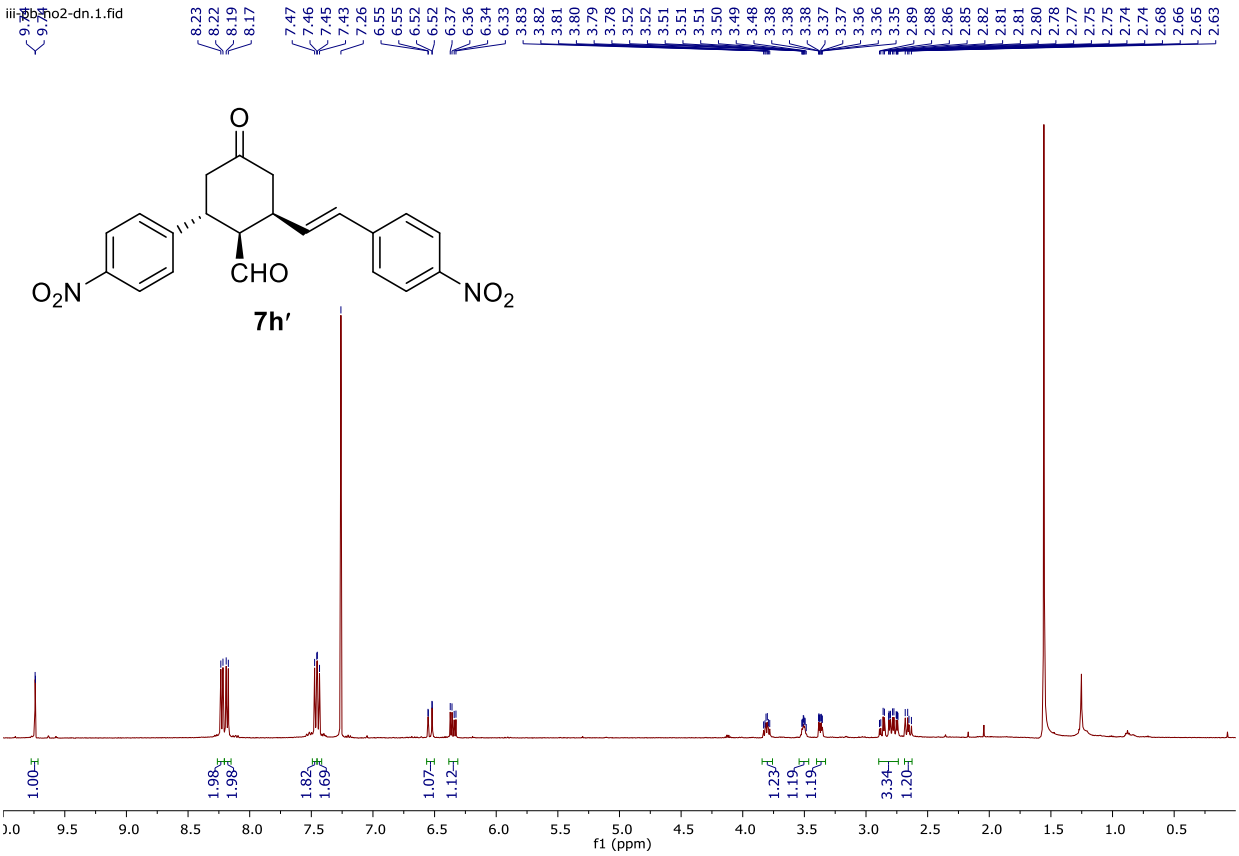

0.96
1.97
2.02
2.41
2.02
1.00
0.92
1.03
1.10
0.94
4.26
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
f1 (ppm)

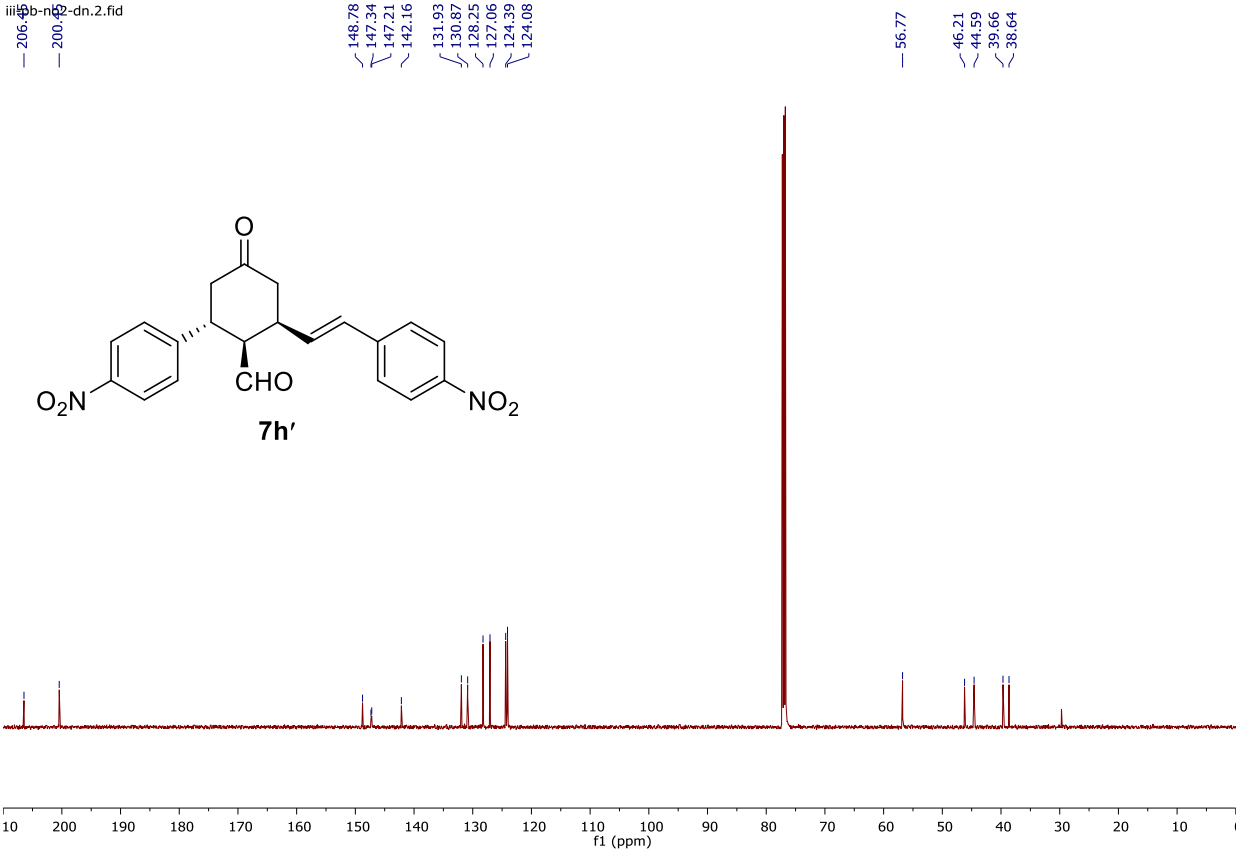

1-rp-1927-pure.3.fid
206.72
200.71
146.82
140.32
132.94
132.51
132.25
130.09
128.17
126.98
118.67
118.30
111.58
111.51
77.28
77.03
76.77
56.68
46.20
44.65
39.85
38.64

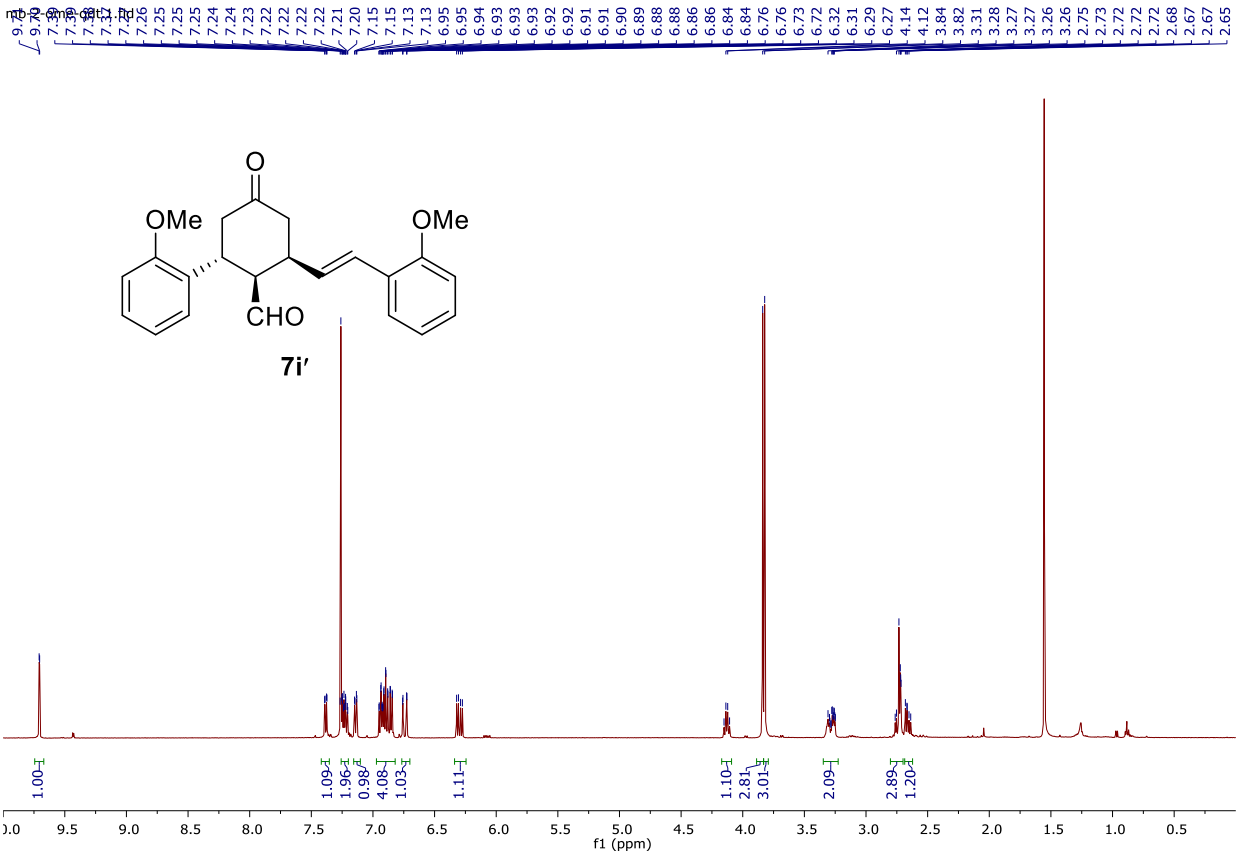

O
CHO
NC
CN

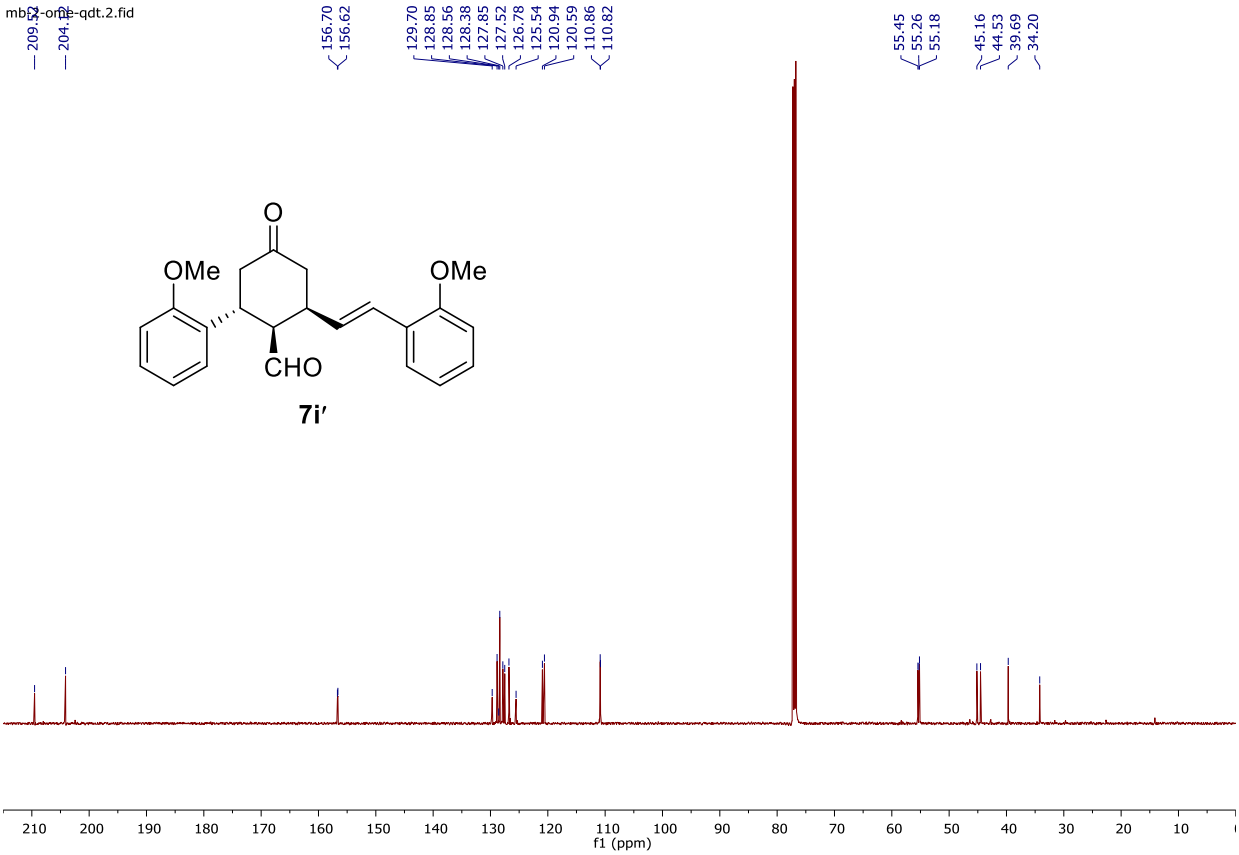
7g′

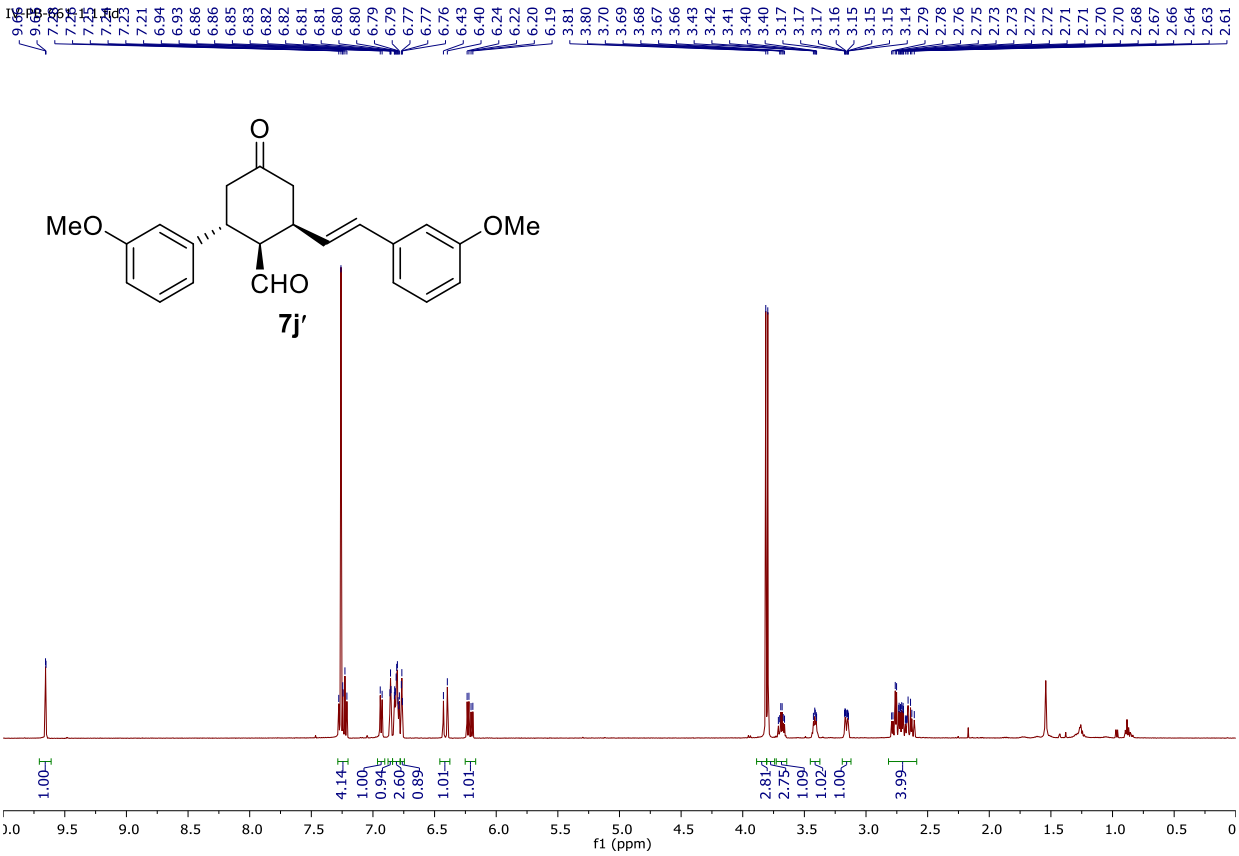

210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

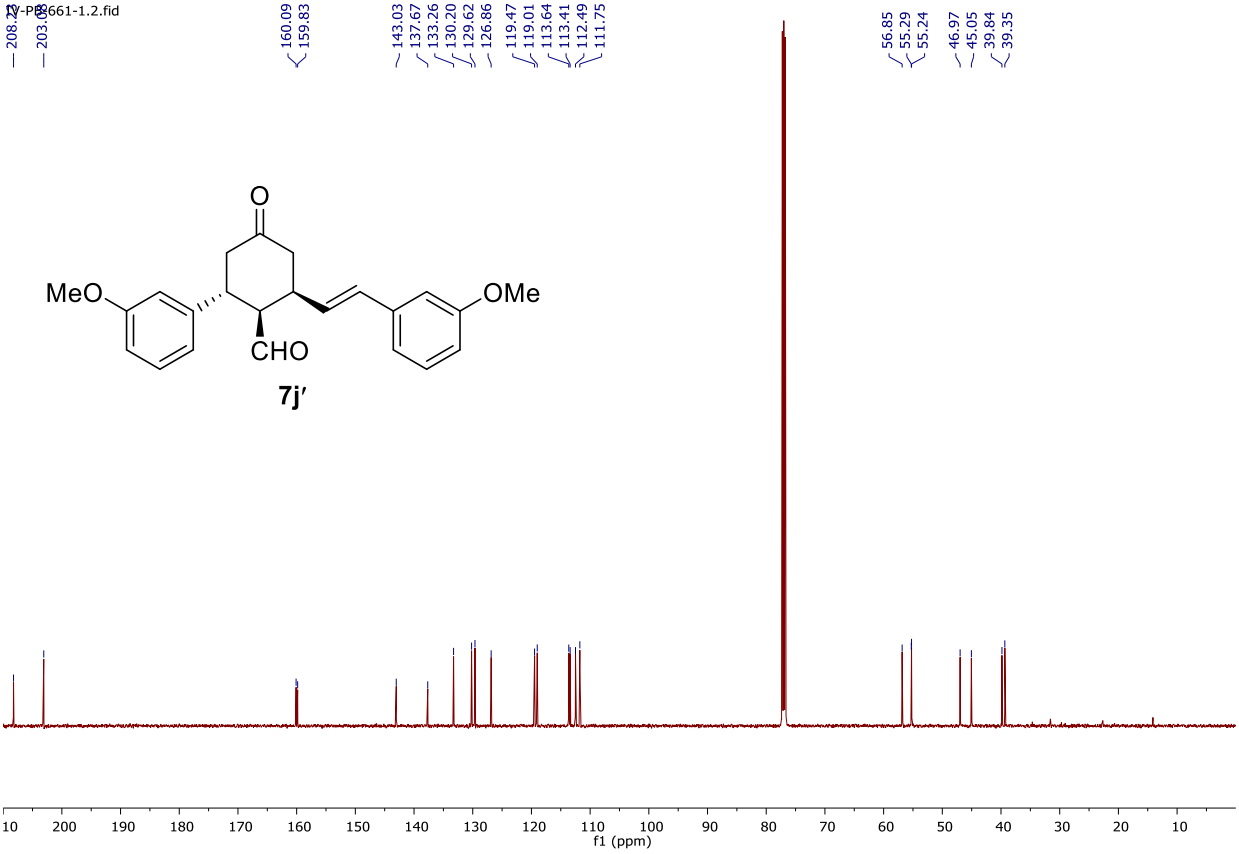

iii-pb-no2-dn.1.fid
O
CHO
O_2N
NO_2
7h′
f1 (ppm)

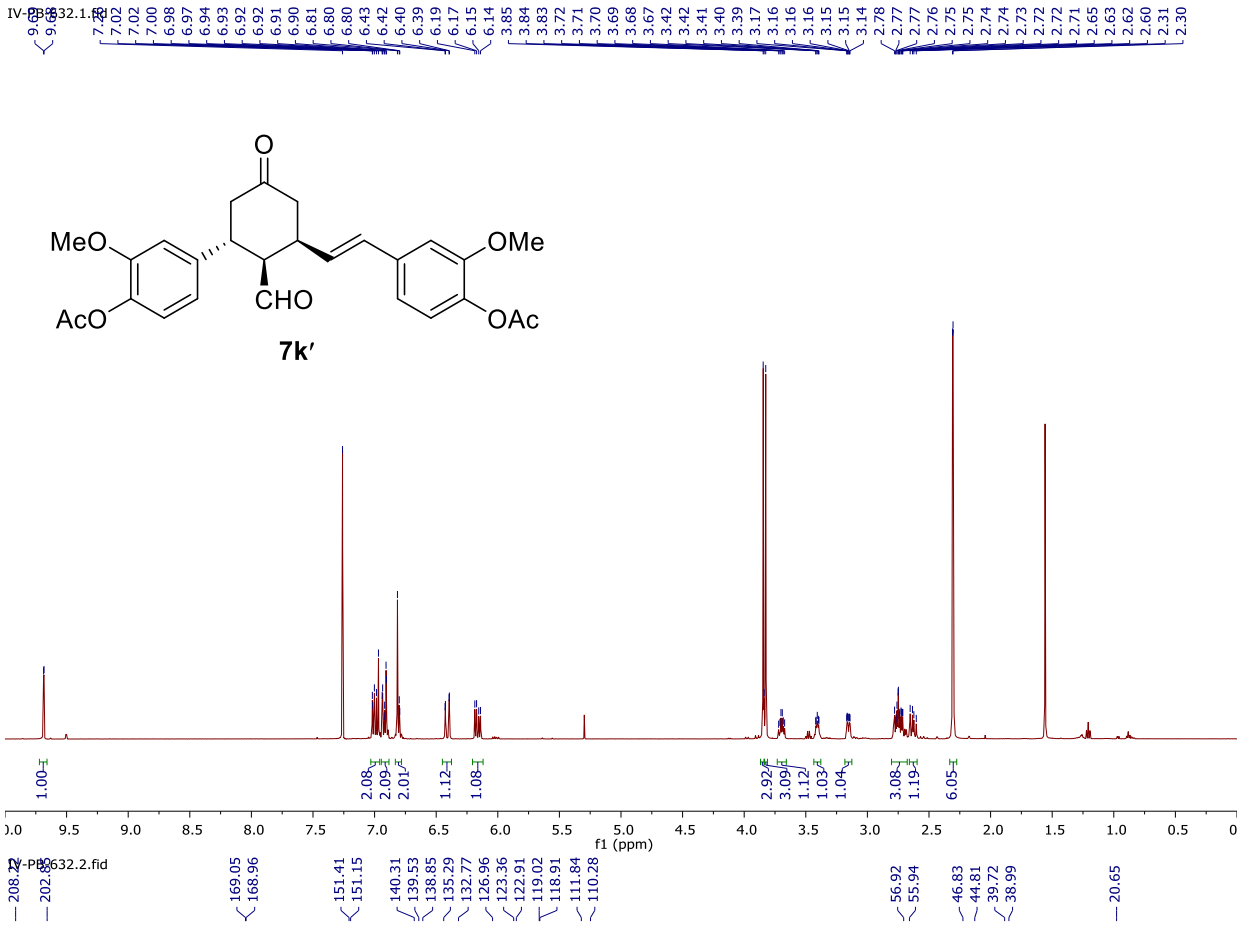

iii-pb-no2-dn.2.fid
O
CHO
O_2N
NO_2
7h′
f1 (ppm)

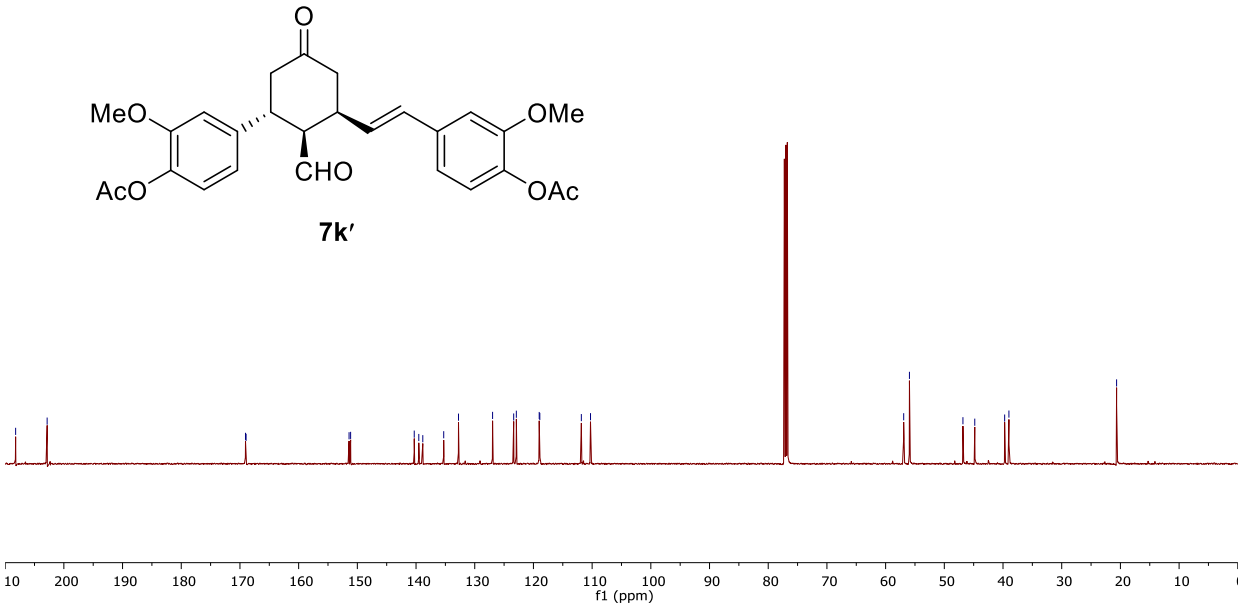

mb2-ome-qdt.1.fid
OMe
OMe
CHO
O
7i′
1.00
1.09
1.96
0.98
4.08
1.03
1.11
1.10
2.81
3.01
2.09
2.89
1.20
f1 (ppm)

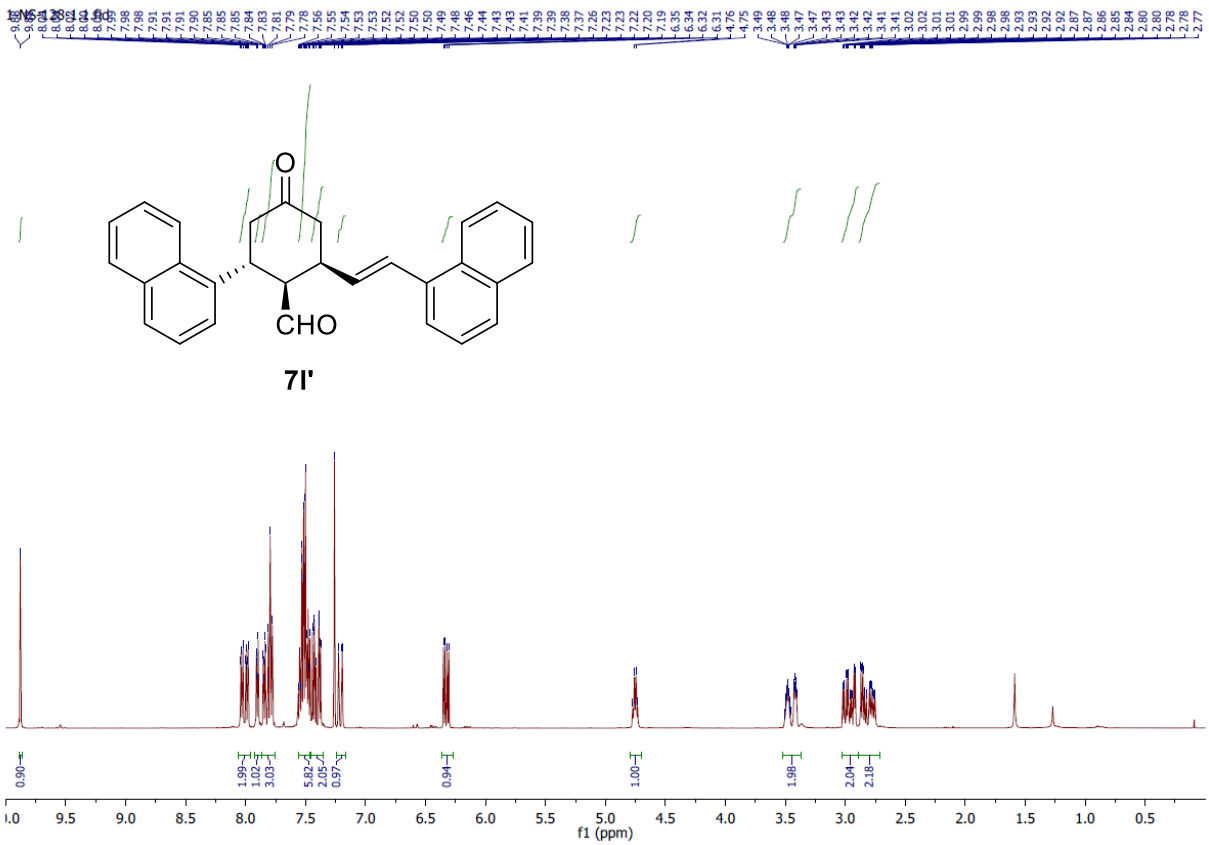

mb2-ome-qdt.2.fid
209.52
204.11
156.70
156.62
129.70
128.85
128.56
128.38
127.85
127.52
126.78
125.54
120.94
120.59
110.86
110.82
55.45
55.26
55.18
45.16
44.53
39.69
34.20
OMe
OMe
CHO
O
7i′
f1 (ppm)


MeO
OMe
CHO
7j′
f1 (ppm)

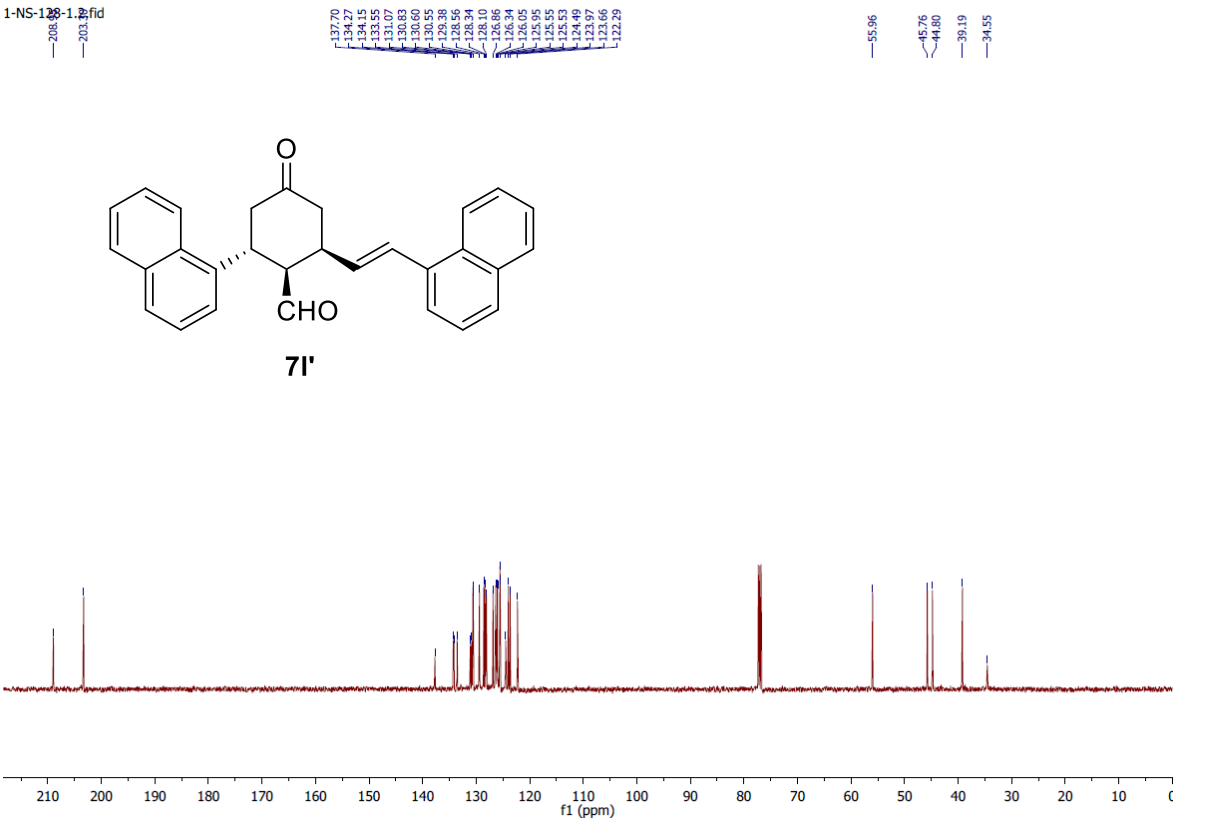

MeO
OMe
CHO
7j′
f1 (ppm)


MeO
OMe
AcO
OAc
CHO
O
7k′
f1 (ppm)

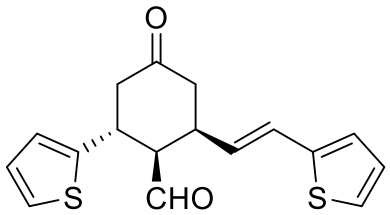

MeO
OMe
AcO
OAc
CHO
O
7k′
f1 (ppm)



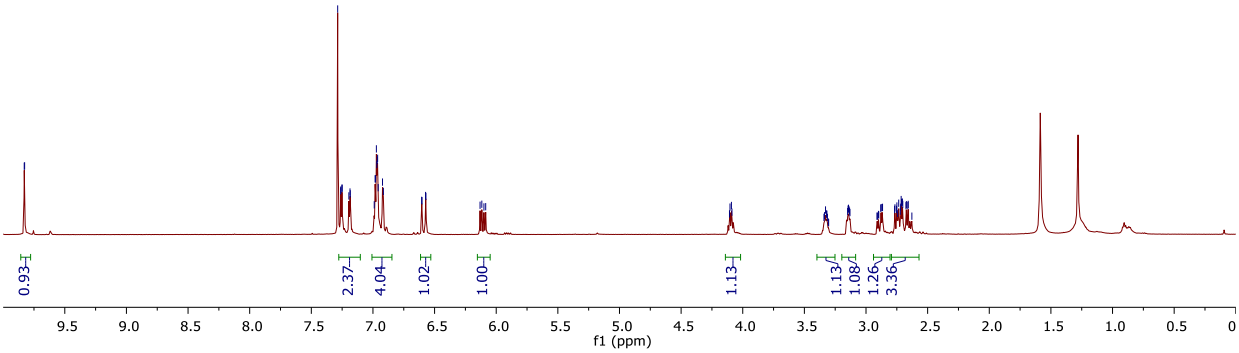
7l'

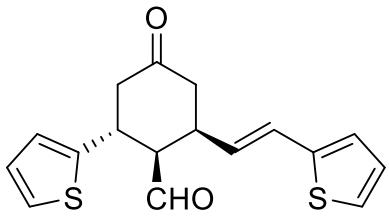


7l'


O
S
CHO
S

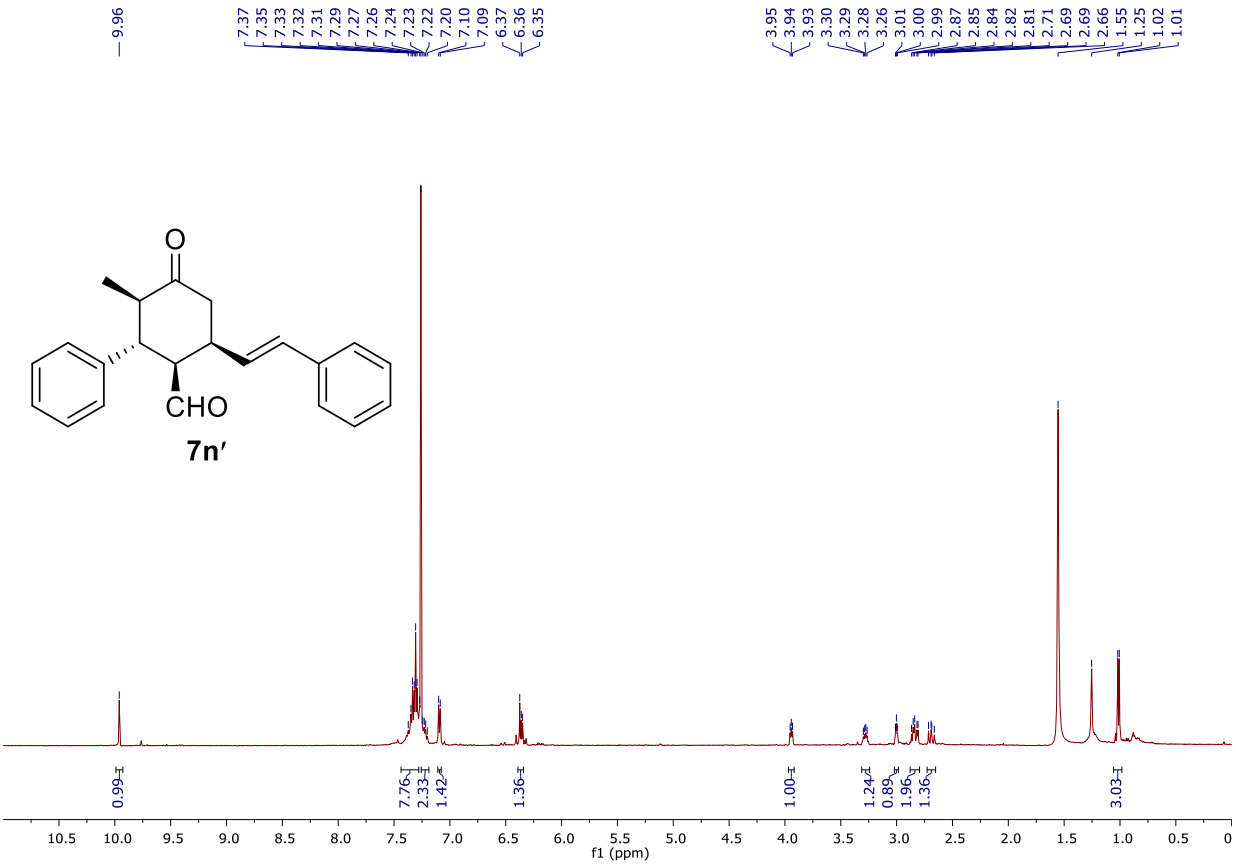
7m′

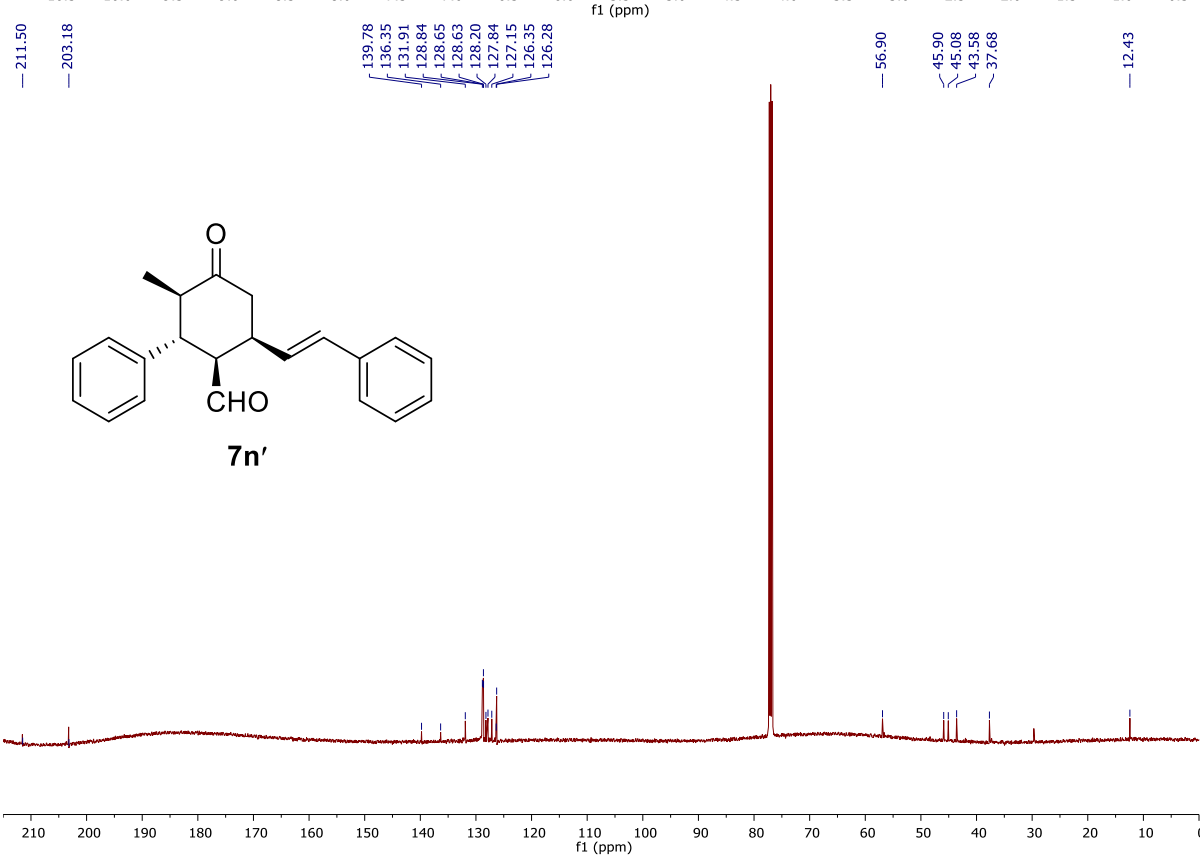

0.93
2.37
4.04
1.02
1.00
1.13
1.13
1.08
1.26
3.36
f1 (ppm)

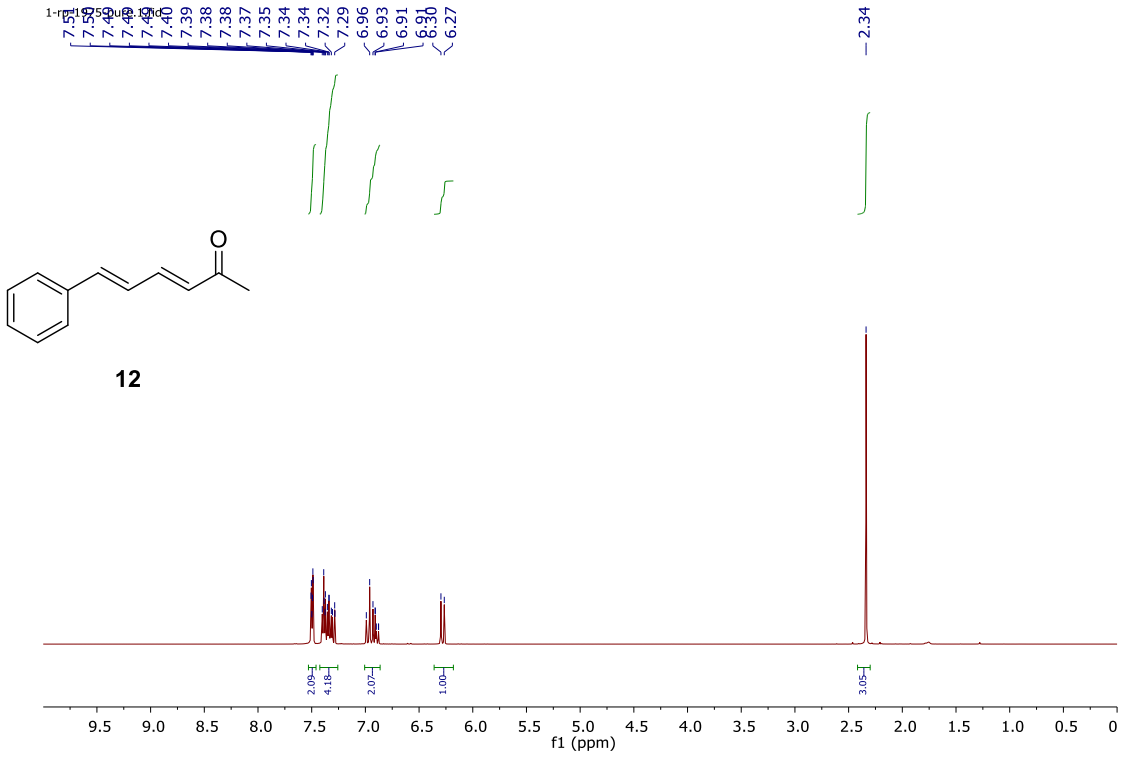

O
S
CHO
S

7m′

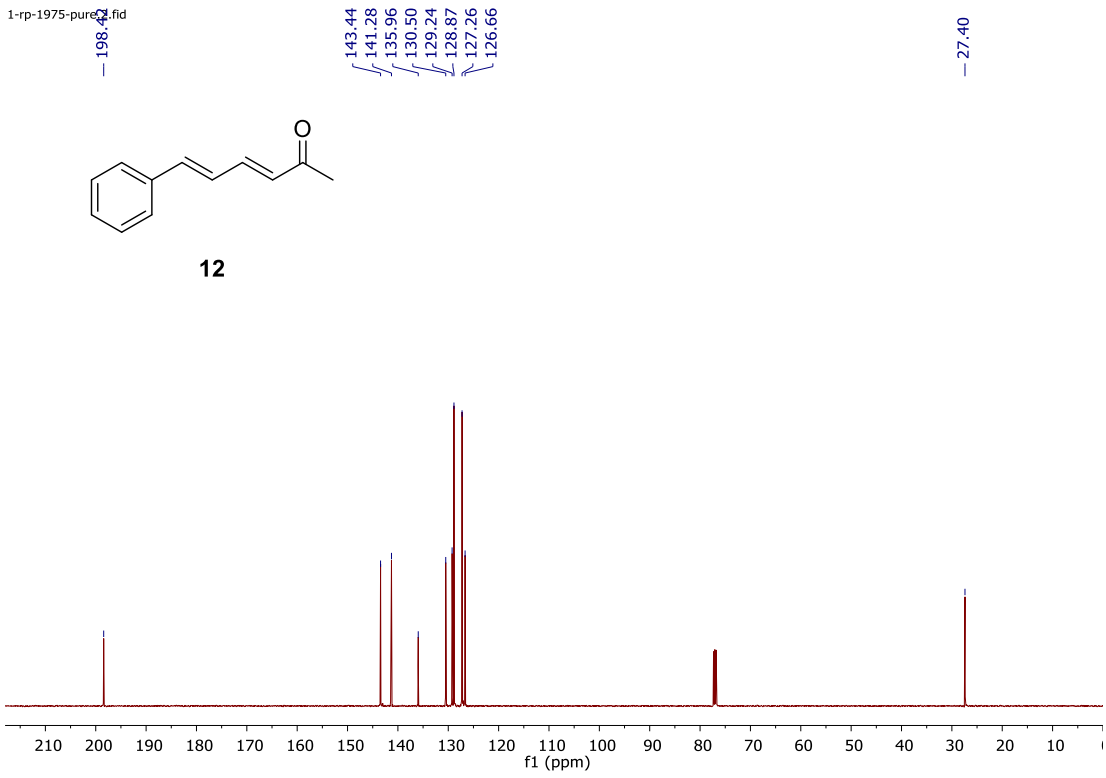
f1 (ppm)


9.96
7.37
7.35
7.33
7.32
7.31
7.29
7.27
7.26
7.24
7.23
7.22
7.20
7.10
7.09
6.37
6.36
6.35
3.95
3.94
3.93
3.30
3.29
3.28
3.26
3.01
3.00
2.99
2.87
2.85
2.84
2.82
2.81
2.71
2.69
2.69
2.66
1.55
1.25
1.02
1.01
O
CHO
7n′
0.99
7.76
2.33
1.42
1.36
1.00
1.24
0.89
1.96
1.36
3.03
f1 (ppm)


211.50
203.18
139.78
136.35
131.91
128.84
128.65
128.63
128.20
127.84
127.15
126.35
126.28
56.90
45.90
45.08
43.58
37.68
12.43
O
CHO
7n′
f1 (ppm)

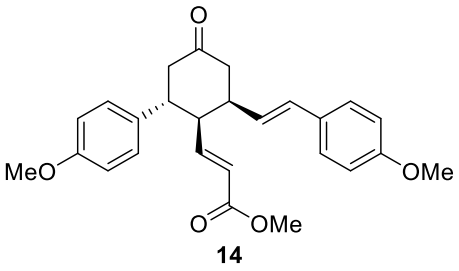

7.55
7.55
7.44
7.44
7.40
7.39
7.38
7.38
7.37
7.35
7.34
7.34
7.32
7.29
6.96
6.93
6.91
6.91
6.30
6.27
2.34
O
2.09
4.18
2.07
1.00
3.05
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
f1 (ppm)

12

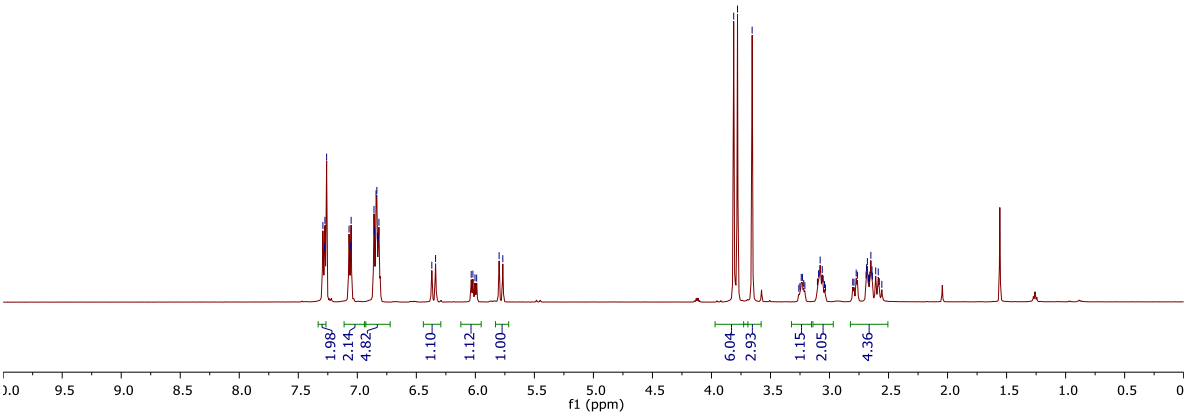

198.42
143.44
141.28
135.96
130.50
129.24
128.87
127.26
126.66
27.40
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

12

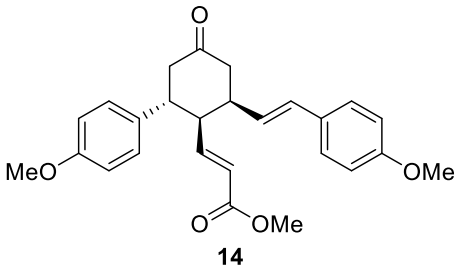
IV-PB-744.1.fid



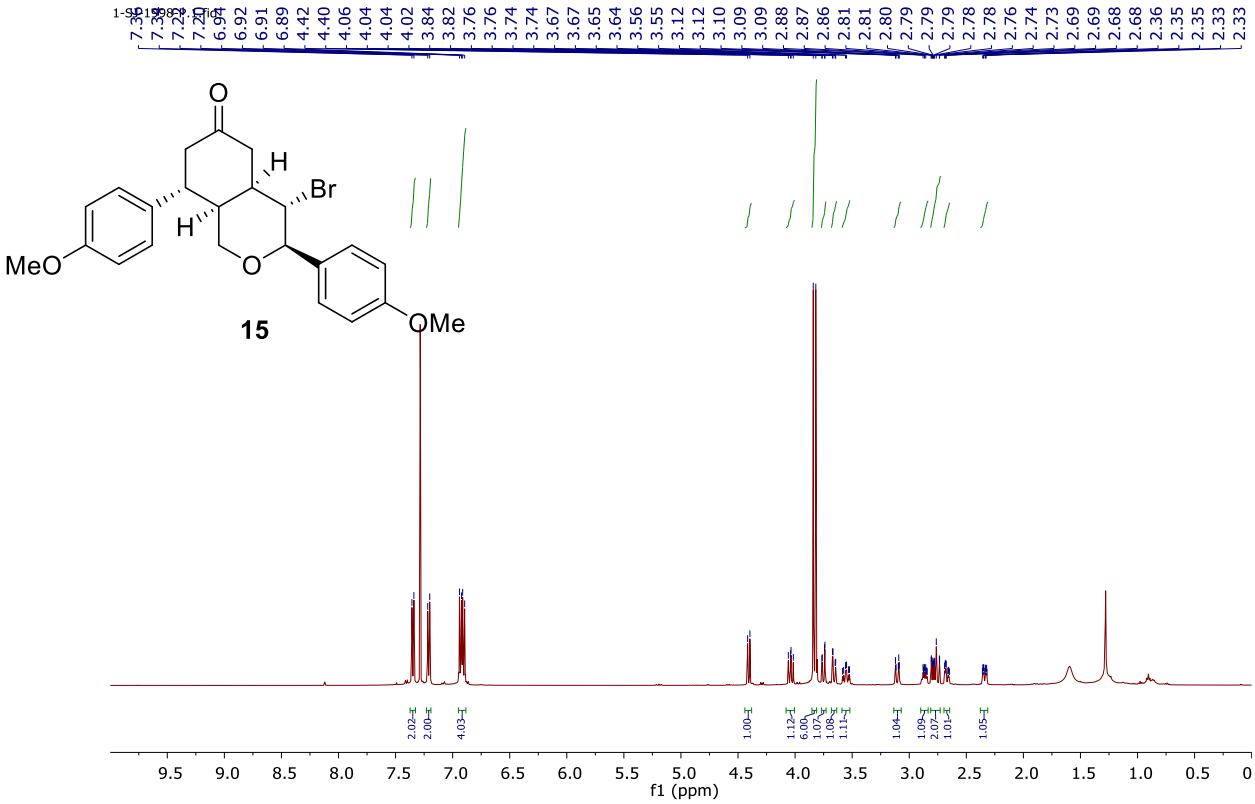
14

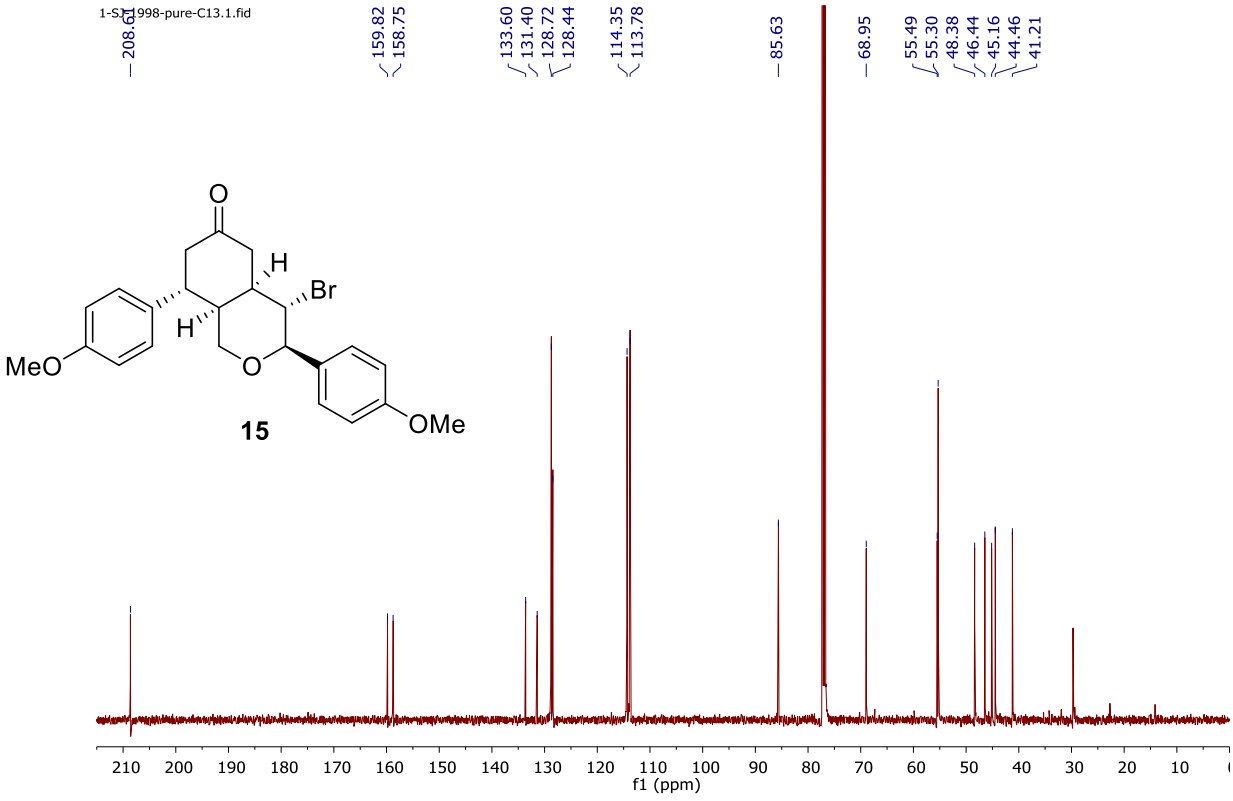


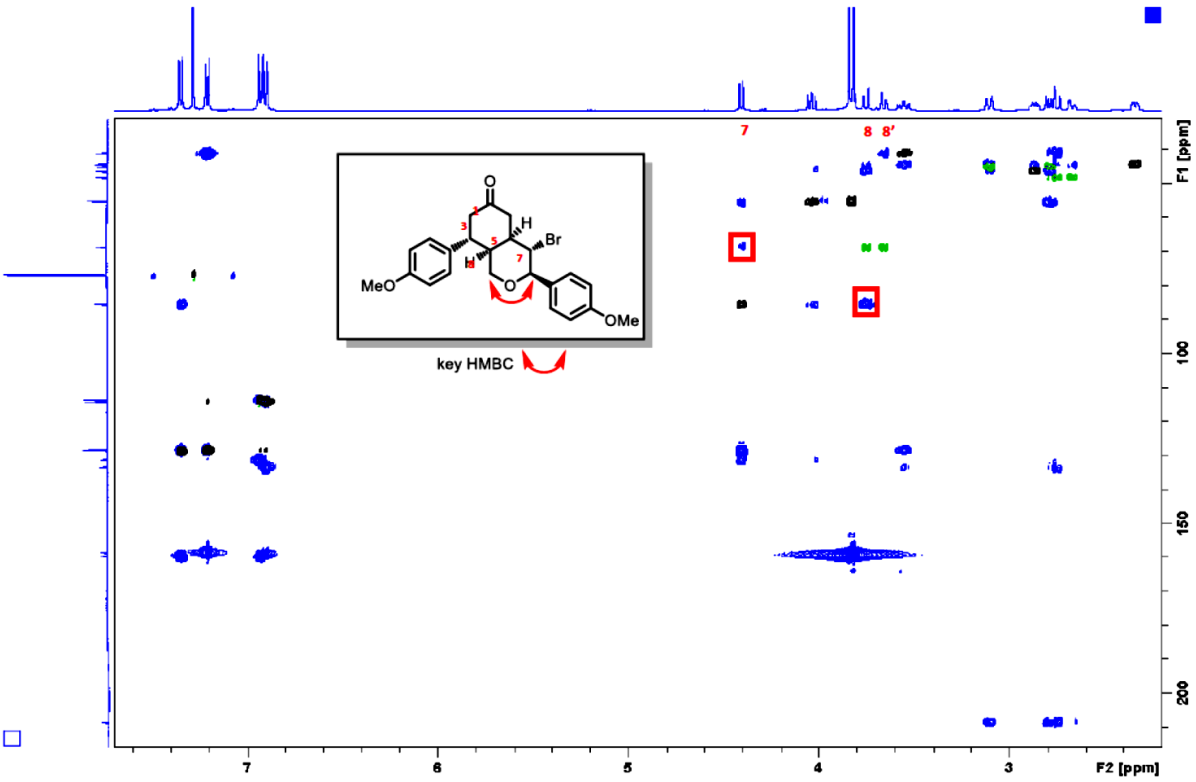
IV-PB-744.3.fid

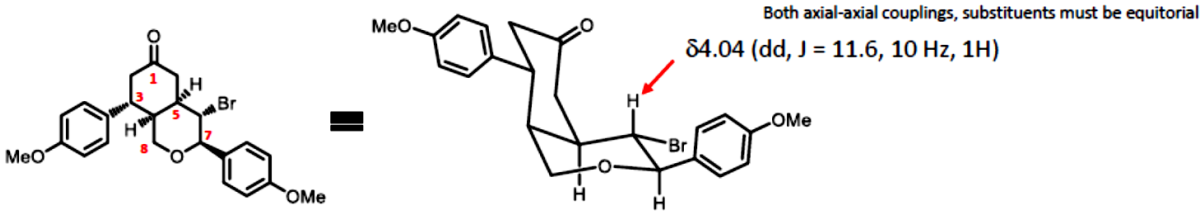


14

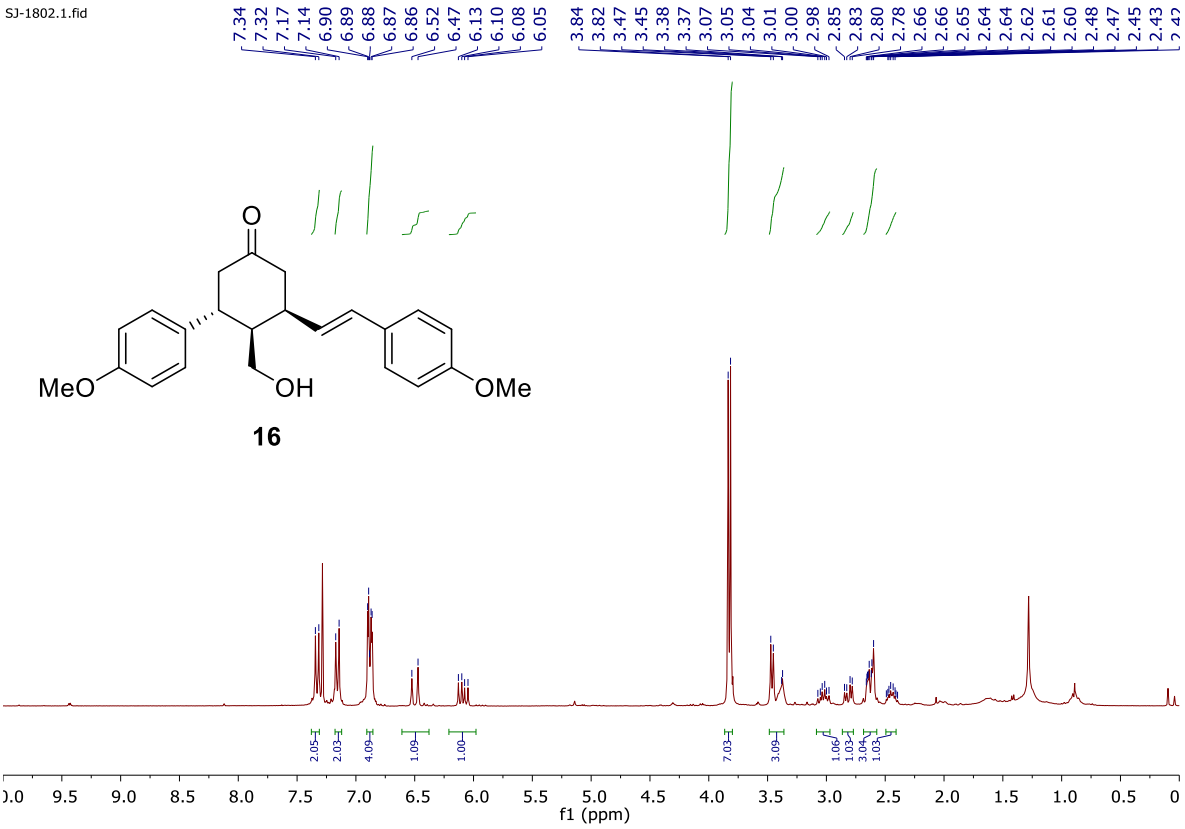

O
H
Br
H
MeO
O
OMe
15
f1 (ppm)

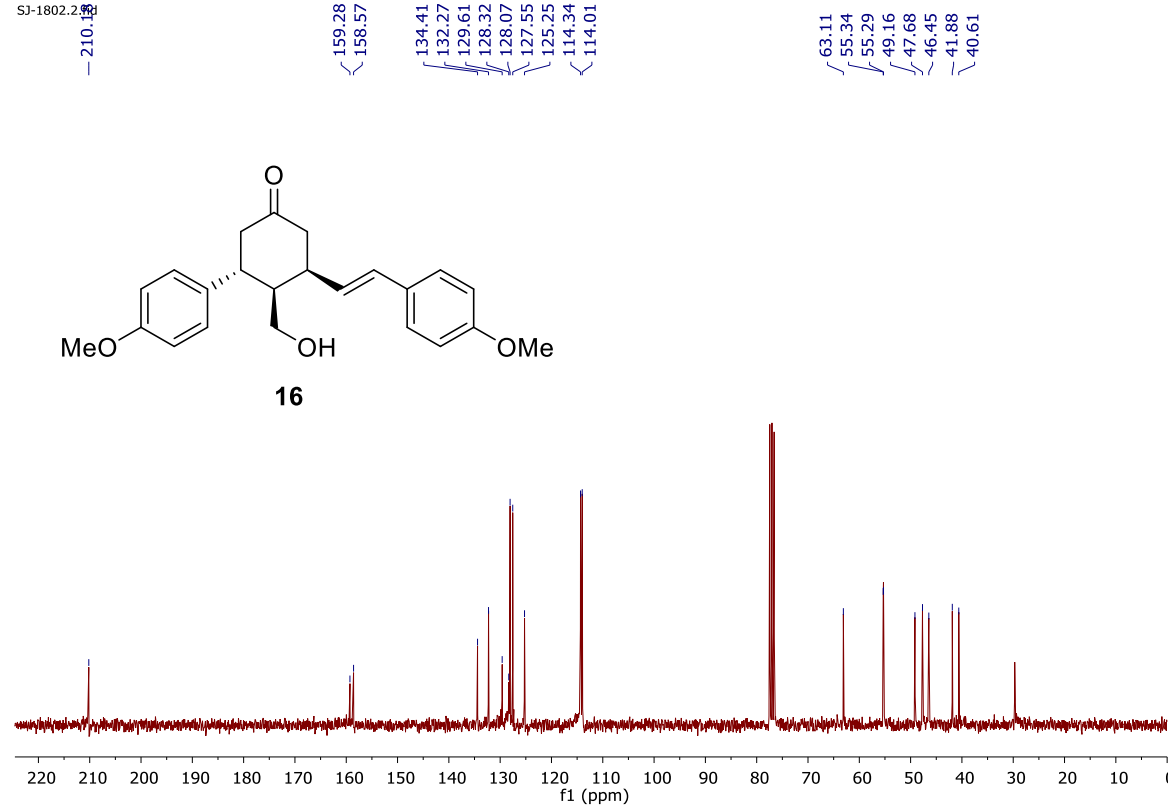

208.62
159.82
158.75
133.60
131.40
128.72
128.44
114.35
113.78
85.63
68.95
55.49
55.30
48.38
46.44
45.16
44.46
41.21
O
H
Br
H
MeO
O
OMe
15
f1 (ppm)

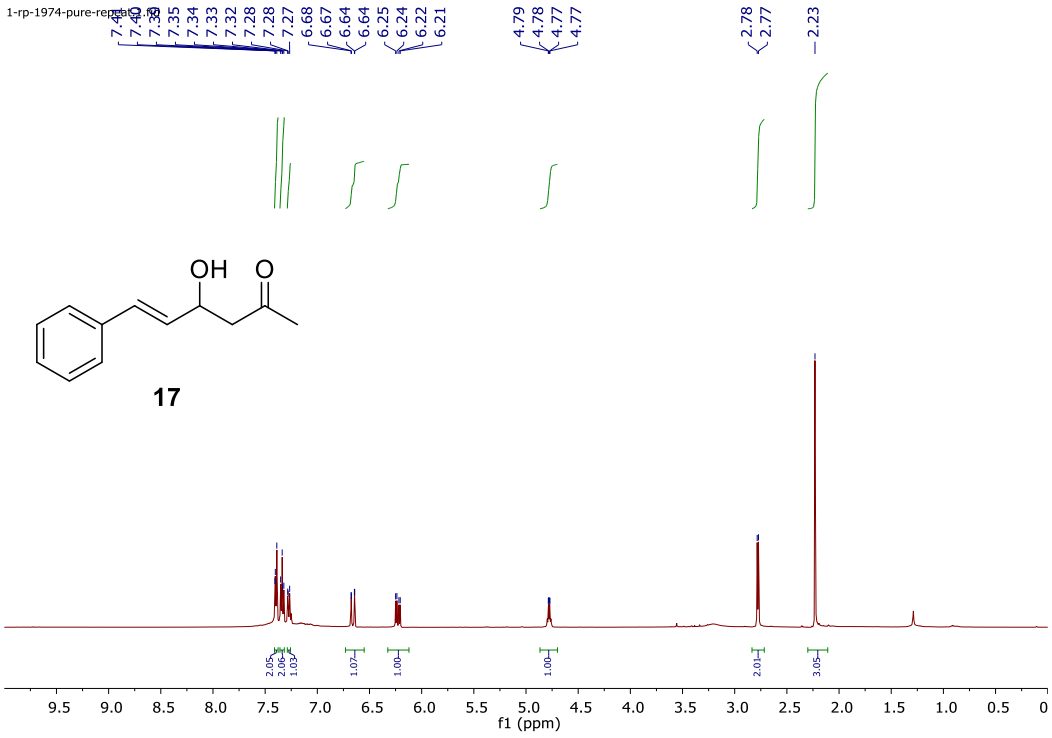


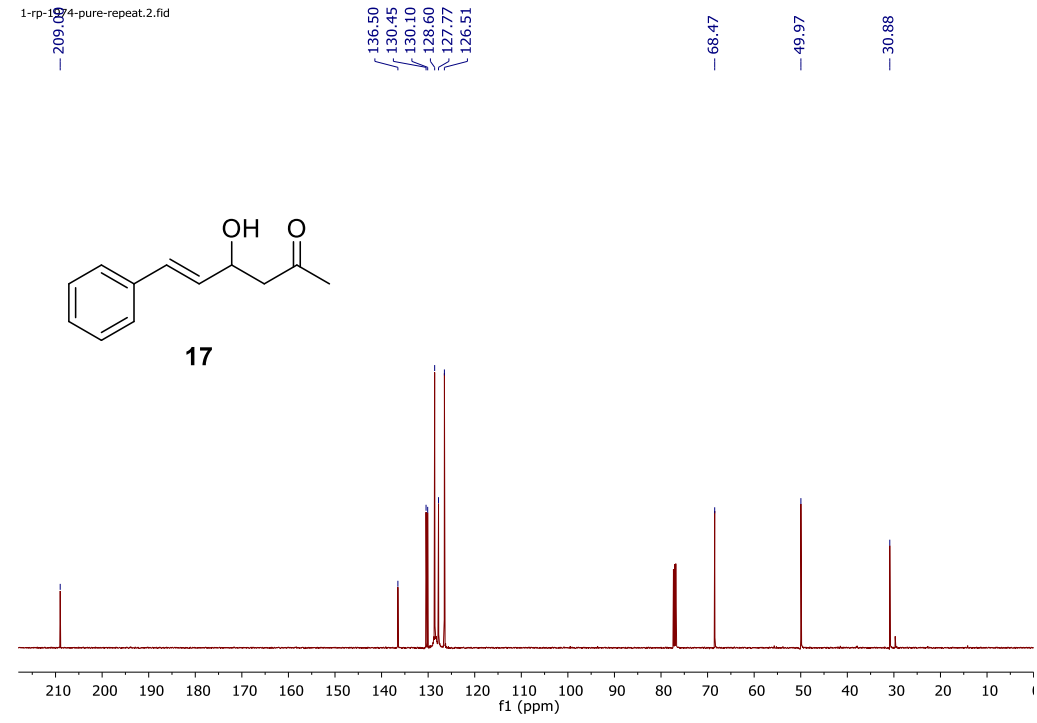


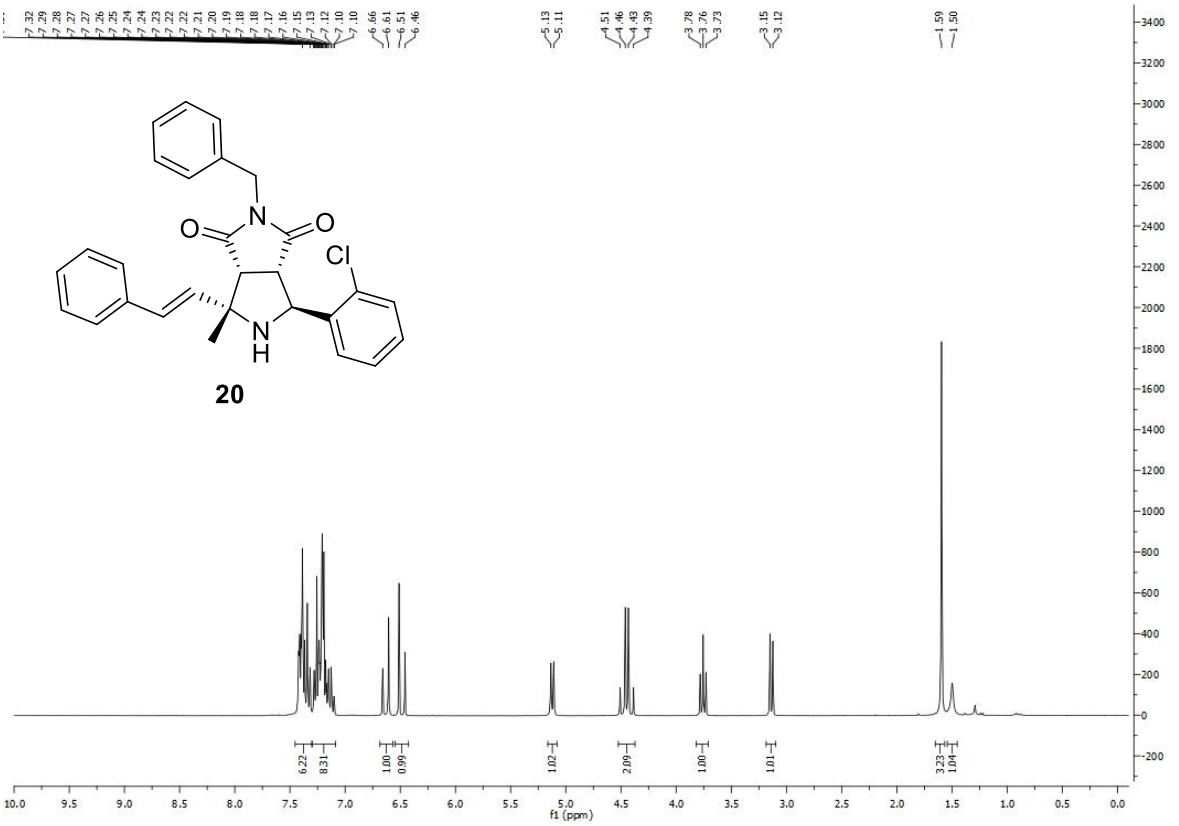
Stereochemistry assignment of compound 15

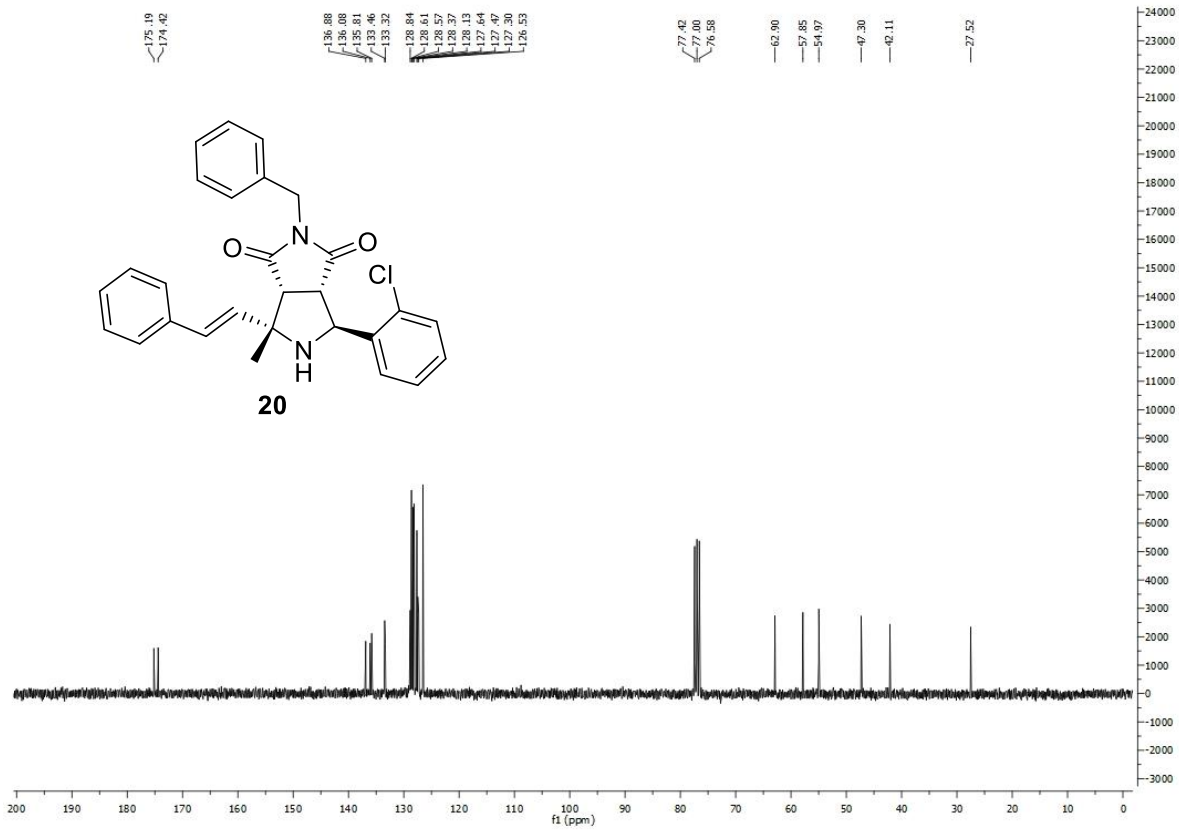

SJ-1802.1.fid
7.34 7.32 7.17 7.14 6.90 6.89 6.88 6.87 6.86 6.52 6.47 6.13 6.10 6.08 6.05
3.84 3.82 3.47 3.45 3.38 3.37 3.07 3.05 3.04 3.01 3.00 2.98 2.85 2.83 2.80 2.78 2.66 2.66 2.65 2.64 2.64 2.62 2.61 2.60 2.48 2.47 2.45 2.43
O
MeO
OH
OMe
16
2.05 2.03 4.09 1.09 1.00 7.03 3.09 1.06 1.03 3.04 1.03
f1 (ppm)


SJ-1802.2.fid
210.12
159.28 158.57 134.41 132.27 129.61 128.32 128.07 127.55 125.25 114.34 114.01
63.11 55.34 55.29 49.16 47.68 46.45 41.88 40.61
O
MeO
OH
OMe
16
f1 (ppm)


1-rp-1974-pure-repeat.1.fid
7.40
7.39
7.35
7.34
7.33
7.32
7.28
7.28
7.27
6.68
6.67
6.64
6.64
6.25
6.24
6.22
6.21
4.79
4.78
4.77
4.77
2.78
2.77
2.23
OH
O
17
2.05
2.06
1.03
1.07
1.00
1.00
2.01
3.05
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
f1 (ppm)


1-rp-1974-pure-repeat.2.fid
209.07
136.50
130.45
130.10
128.60
127.77
126.51
68.47
49.97
30.88
OH
O
17
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)


20


20

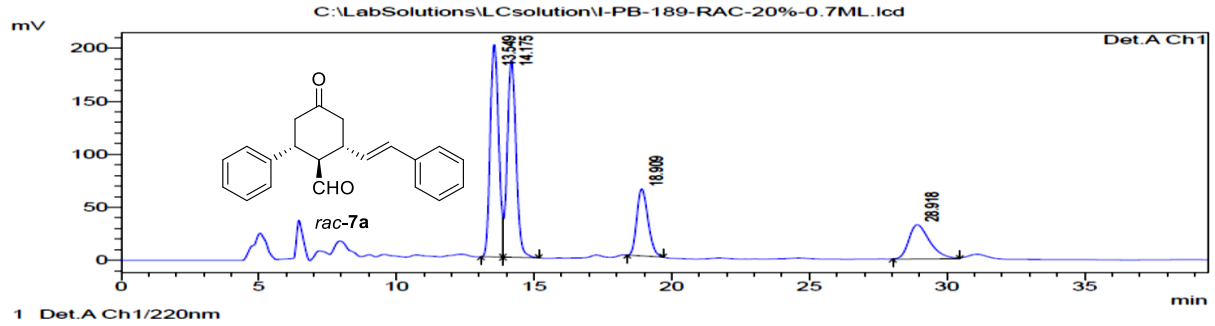
9. HPLC Chromatograms

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\I-PB-189-RAC-20%-0.7ML.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: I-PB-189-RAC-20%-0.7ML.lcd
Method File Name	: ChiralPak ID-20.0%-0.7 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 8/16/2019 1:16:42 PM
Data Processed	: 9/5/2019 2:05:31 PM

<Chromatogram>



PeakTable

Detector A Ch1 220nm

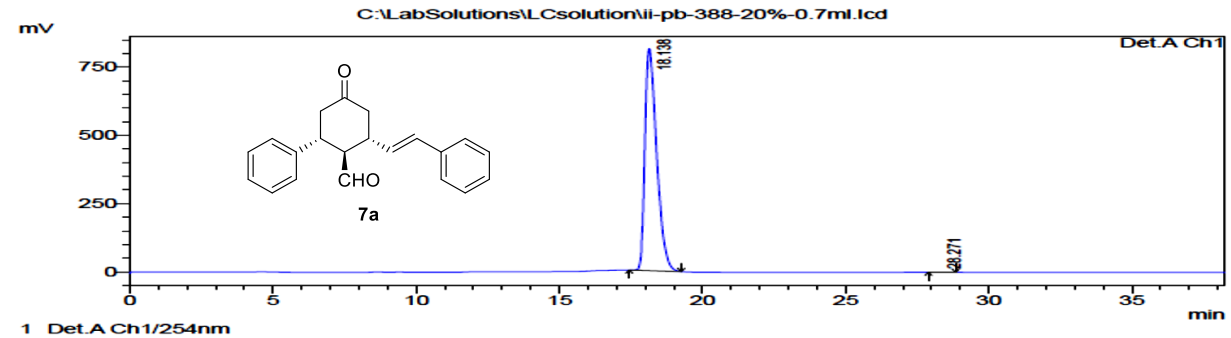
Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.549	4270538	200394	35.738	41.599
2	14.175	4178528	185846	34.968	38.579
3	18.909	1794547	63219	15.018	13.123
4	28.918	1706086	32272	14.277	6.699
Total		11949699	481730	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\ii-pb-388-20%-0.7ml.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: ii-pb-388-20%-0.7ml.lcd
Method File Name	: ChiralPak ID-20%-0.7 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 9/5/2019 2:40:07 PM
Data Processed	: 9/5/2019 3:18:25 PM

<Chromatogram>



PeakTable

Detector A Ch1 254nm

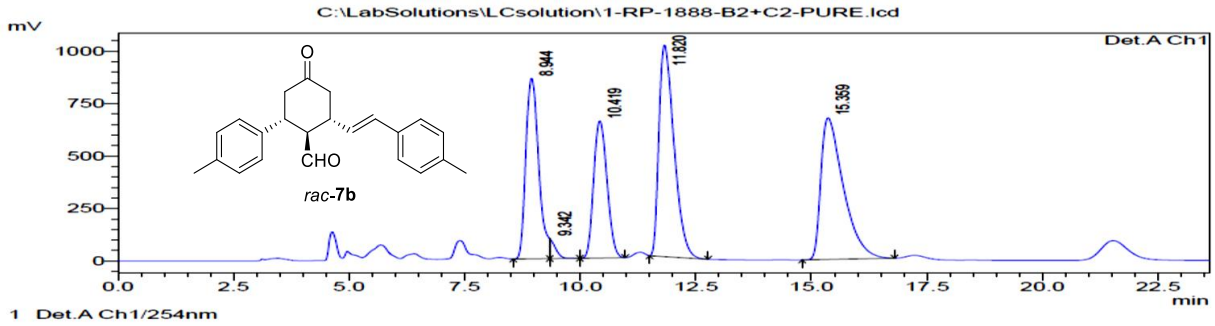
Peak#	Ret. Time	Area	Height	Area %	Height %
1	18.138	23273414	813326	99.915	99.928
2	28.271	19850	586	0.085	0.072
Total		23293264	813912	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1888-B2+C2-PURE.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1888-B2+C2-PURE.lcd
Method File Name	: ChiralPak ID-20%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/11/2019 9:08:44 AM
Data Processed	: 12/11/2019 9:32:59 AM

<Chromatogram>



PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.944	16755699	861002	21.881	26.146
2	9.342	777682	94496	1.016	2.870
3	10.419	13176751	653432	17.207	19.843
4	11.820	22960535	1008808	29.984	30.635
5	15.359	22906112	675297	29.913	20.507
Total		76576778	3293034	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1946-PURE-254.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1946-PURE-254.lcd
Method File Name	: ChiralPak ID-20%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/9/2020 4:01:12 PM
Data Processed	: 1/9/2020 4:23:44 PM

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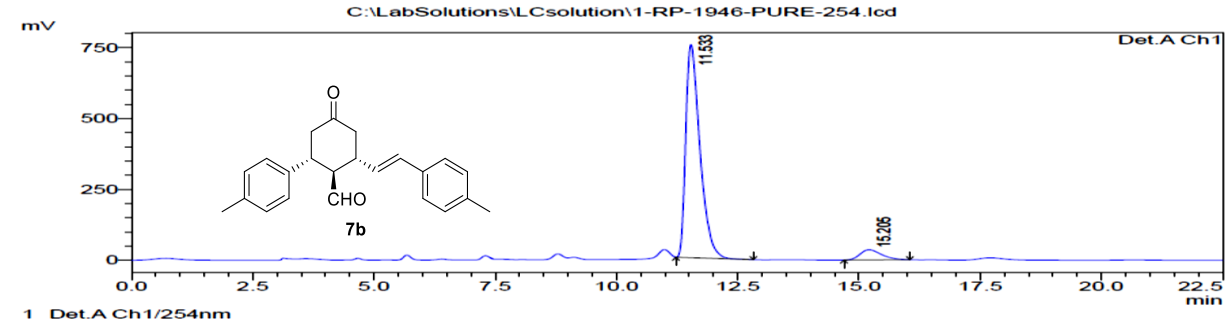

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.533	15299655	751885	93.299	95.470
2	15.205	1098892	35679	6.701	4.530
Total		16398547	787564	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\III-PB-424-rac-ID.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: III-PB-424-rac-ID.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 9/24/2019 3:50:52 PM
Data Processed	: 9/24/2019 4:28:24 PM

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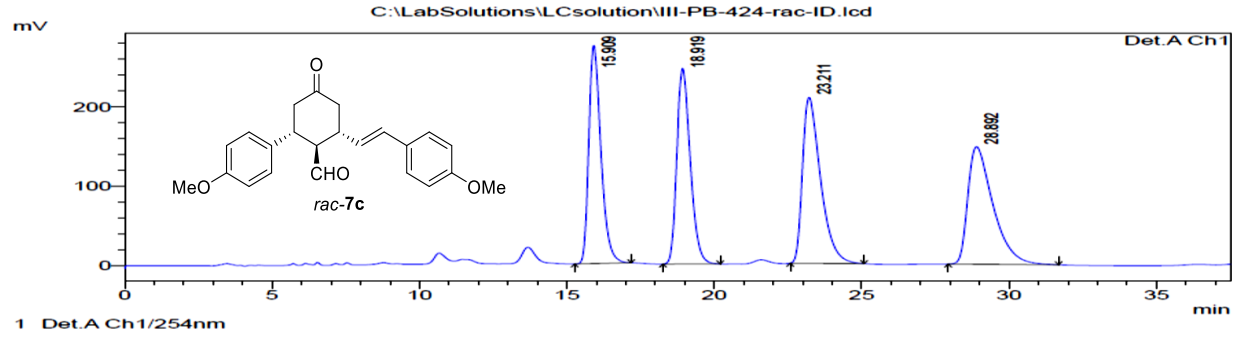

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.909	7884233	274490	23.628	31.276
2	18.919	7793904	246307	23.357	28.065
3	23.211	8912112	208986	26.709	23.812
4	28.892	8777809	147853	26.306	16.847
Total		33368057	877636	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-709.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-709.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/21/2020 4:24:23 PM
Data Processed	: 1/21/2020 5:09:03 PM

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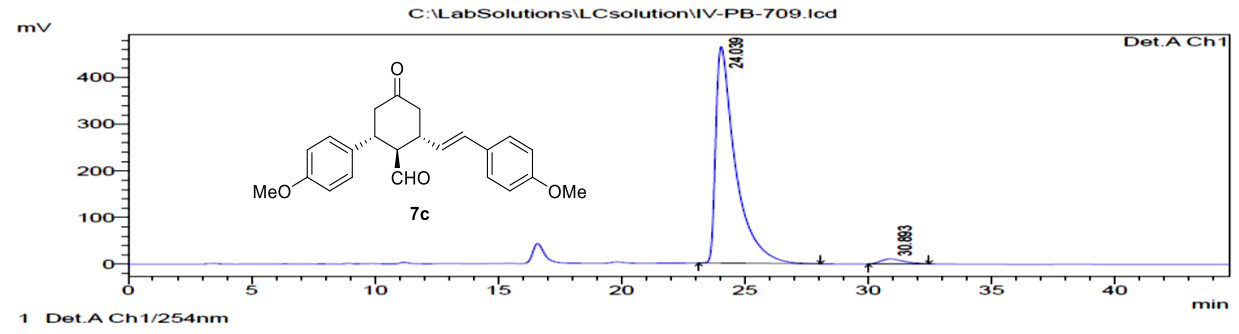

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	24.039	25732722	463808	97.423	97.752
2	30.893	680551	10668	2.577	2.248
Total		26413273	474476	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\III-PB-422-rac-20%-0.7 ml.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: III-PB-422-rac-20%-0.7 ml.lcd
Method File Name	: ChiralPak IC-20%-0.7 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 9/19/2019 11:19:03 AM
Data Processed	: 9/19/2019 2:51:29 PM

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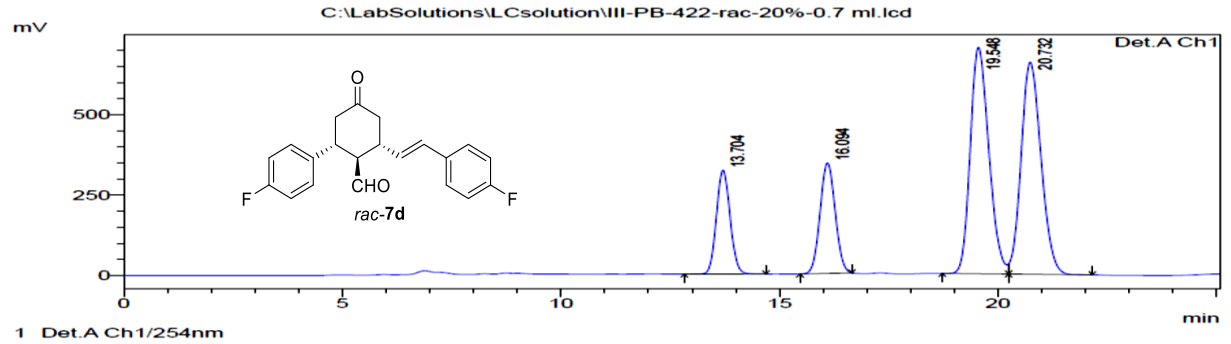

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.704	7028226	323038	12.305	15.914
2	16.094	8260708	343585	14.463	16.926
3	19.548	20887760	703822	36.572	34.672
4	20.732	20938141	659476	36.660	32.488
Total		57114836	2029922	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-672.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-672.lcd
Method File Name	: ChiralPak IC-20%-0.7 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/22/2020 12:13:16 PM
Data Processed	: 1/22/2020 12:40:40 PM

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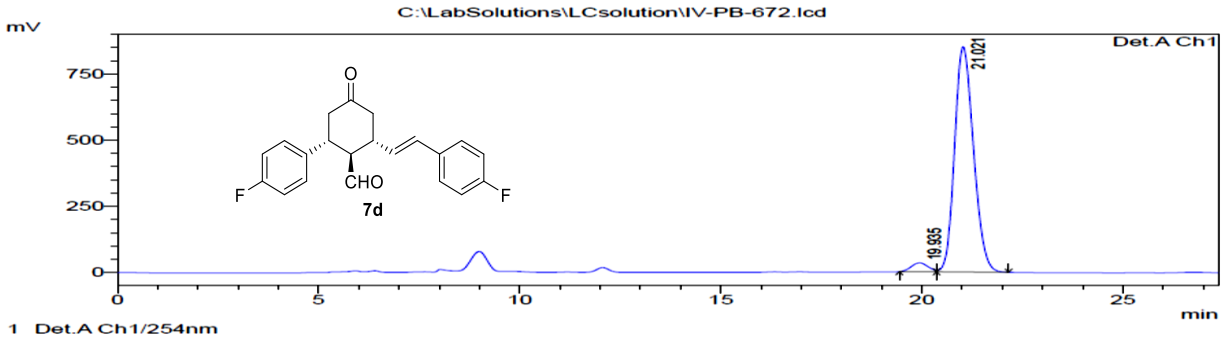

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	19.935	981006	33824	3.397	3.820
2	21.021	27895733	851533	96.603	96.180
Total		28876739	885357	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1892-C2-PURE.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1892-C2-PURE.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/12/2019 9:23:58 AM
Data Processed	: 12/12/2019 9:47:45 AM

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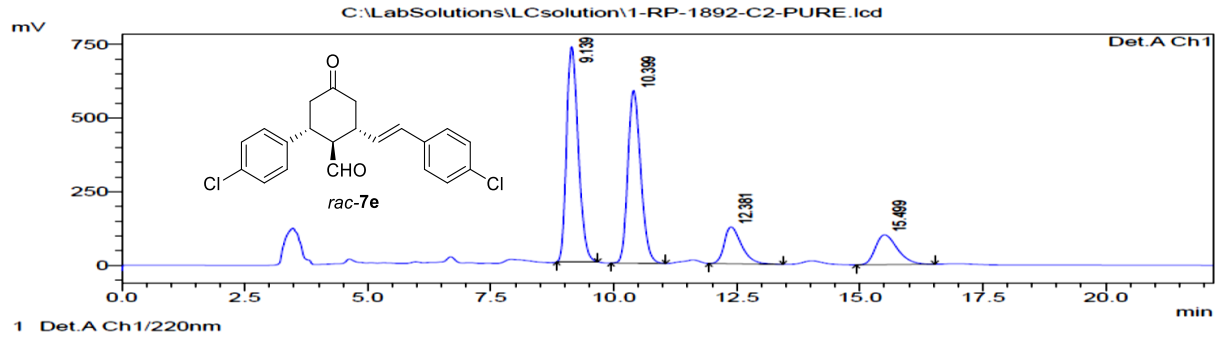

PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.139	12109035	730845	41.798	47.356
2	10.399	10669290	586303	36.828	37.990
3	12.381	3046998	125057	10.518	8.103
4	15.499	3145254	101109	10.857	6.551
Total		28970577	1543314	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-719-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-719-1.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 2/1/2020 11:41:53 AM
Data Processed	: 2/1/2020 12:11:24 PM

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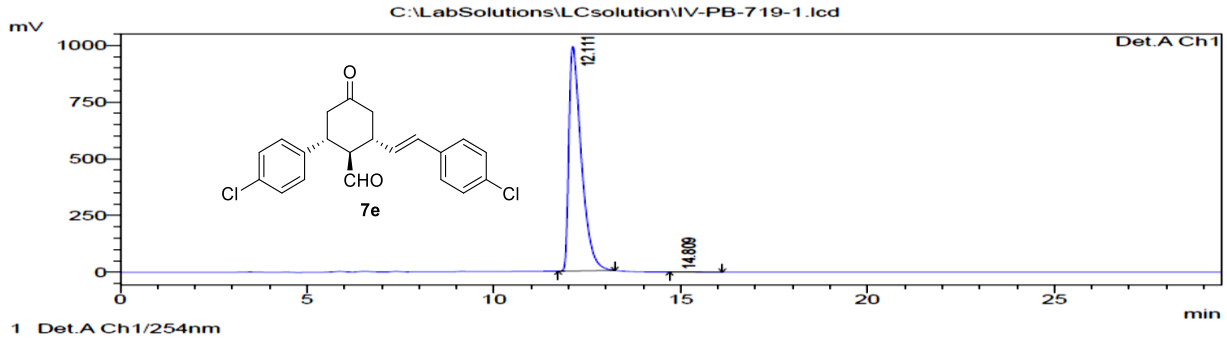

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.111	22924937	989036	99.974	99.990
2	14.809	6063	96	0.026	0.010
Total		22930999	989132	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1893-C2-PURE.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1893-C2-PURE.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/12/2019 9:54:41 AM
Data Processed	: 12/12/2019 11:04:23 AM

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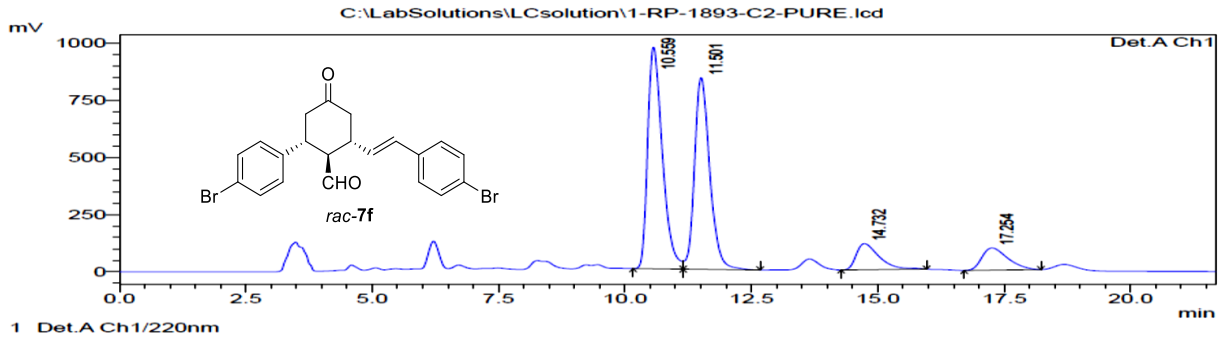


PeakTable

Detector A Ch1 220nm

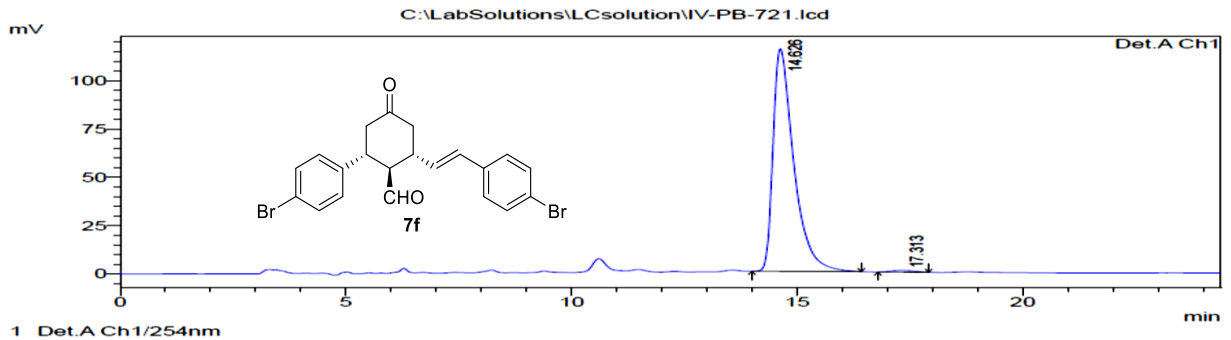
Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.559	19658119	968772	44.393	48.010
2	11.501	17596876	838021	39.738	41.530
3	14.732	3600297	114138	8.130	5.656
4	17.254	3427001	96937	7.739	4.804
Total		44282292	2017868	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-721.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-721.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 2/1/2020 11:02:38 AM
Data Processed	: 2/1/2020 11:27:03 AM

<Chromatogram>



PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.626	3683302	115151	99.150	99.187
2	17.313	31571	944	0.850	0.813
Total		3714873	116095	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1926-PURE-RM-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1926-PURE-RM-1.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/31/2019 11:19:30 AM
Data Processed	: 12/31/2019 12:19:35 PM

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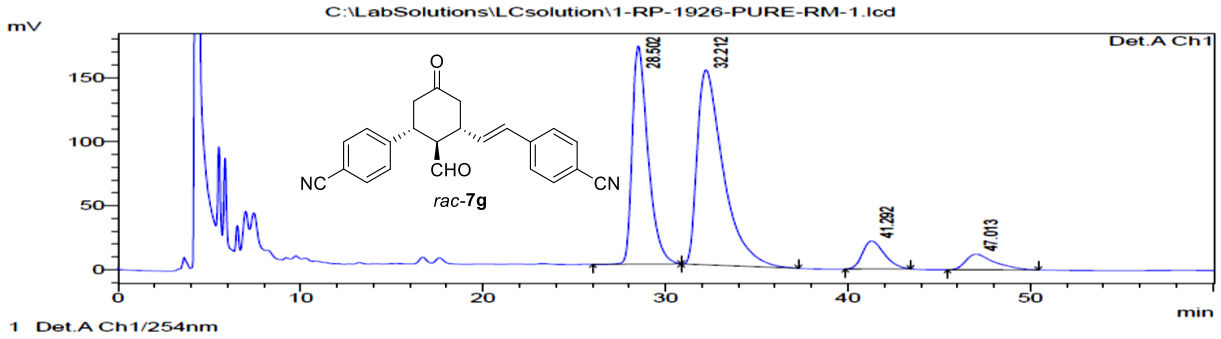

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	28.502	10252448	170267	35.883	47.733
2	32.212	15154639	152271	53.040	42.688
3	41.292	1812763	21857	6.345	6.128
4	47.013	1352257	12310	4.733	3.451
Total		28572107	356705	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1956-PURE-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1956-PURE-1.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/15/2020 9:25:40 AM
Data Processed	: 1/15/2020 10:25:56 AM

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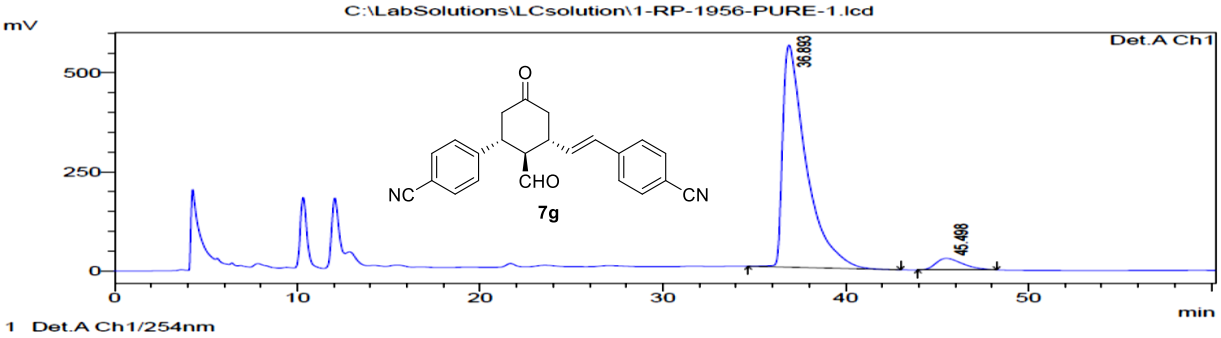

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	36.893	50149069	560432	94.410	95.073
2	45.498	2969580	29044	5.590	4.927
Total		53118649	589476	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-665-UP-RAC-ID.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-665-UP-RAC-ID.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/2/2020 1:43:47 PM
Data Processed	: 1/2/2020 3:19:29 PM

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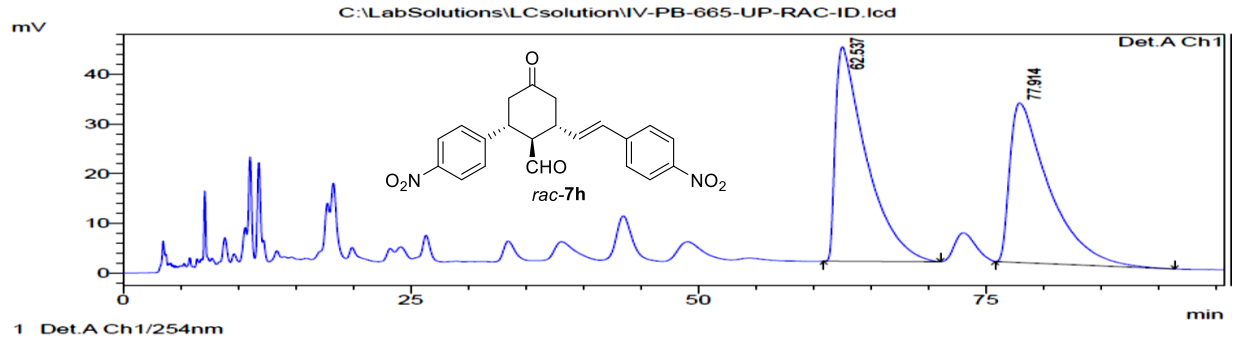

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	62.537	8022489	43177	51.257	57.317
2	77.914	7628954	32153	48.743	42.683
Total		15651443	75330	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-671.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-671.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/6/2020 1:00:25 PM
Data Processed	: 1/6/2020 2:38:54 PM

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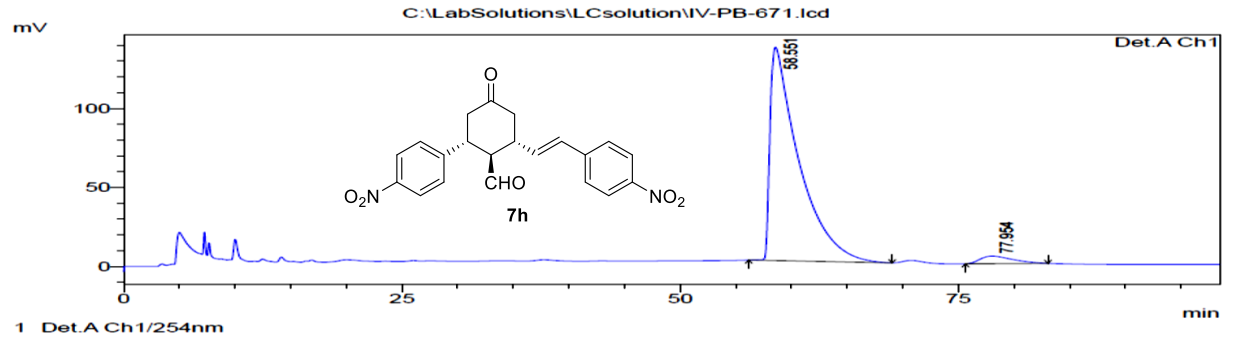

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	58.551	24273169	135092	96.131	96.568
2	77.954	976919	4801	3.869	3.432
Total		25250088	139894	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\MB-2-OMe-RAC-15%-0.7-IC-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: MB-2-OMe-RAC-15%-0.7-IC-1.lcd
Method File Name	: ChiralPak IC-15.0%-0.70 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 10/2/2019 3:10:12 PM
Data Processed	: 10/2/2019 4:07:26 PM

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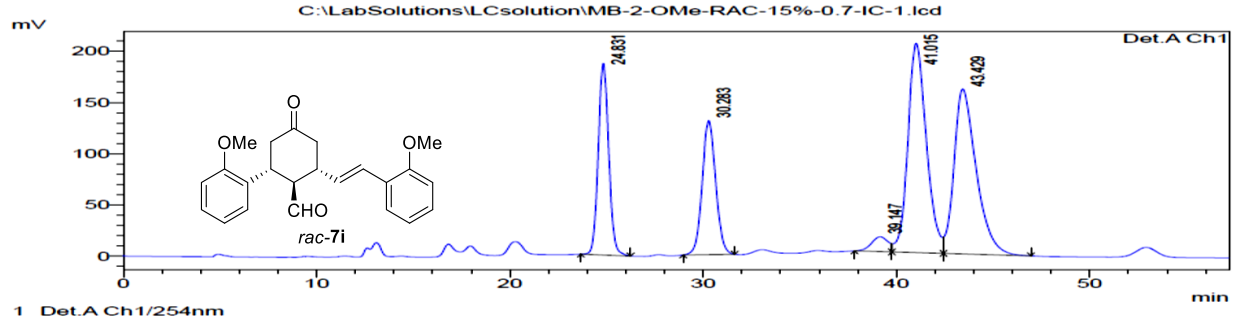

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	24.831	7067251	187150	17.318	26.817
2	30.283	6358099	130867	15.580	18.752
3	39.147	870193	14513	2.132	2.080
4	41.015	13657376	204365	33.466	29.284
5	43.429	12856505	160972	31.504	23.066
Total		40809425	697867	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-683-IC-15%.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-683-IC-15%.lcd
Method File Name	: ChiralPak IC-15.0%-0.70 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/17/2020 1:10:25 PM
Data Processed	: 1/17/2020 2:10:33 PM

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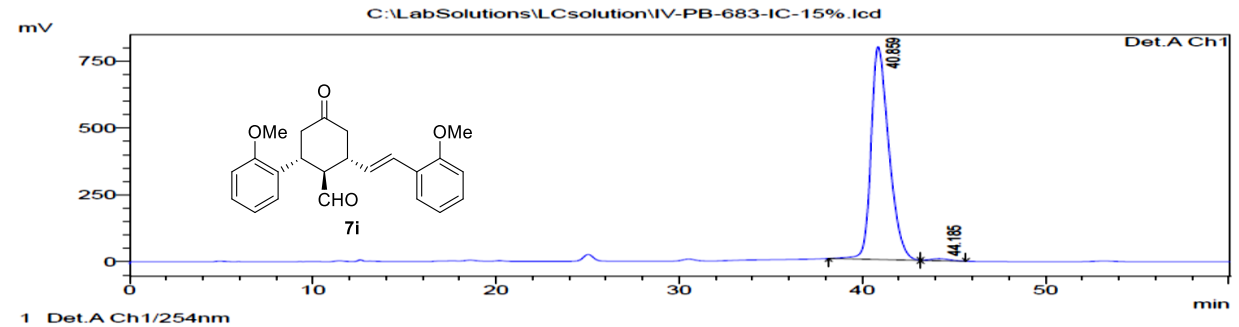


PeakTable

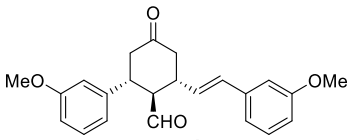
Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	40.859	53909270	795174	98.949	98.993
2	44.185	572835	8093	1.051	1.007
Total		54482105	803266	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-653-3-0MeRAC-IB-10%.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-653-3-0MeRAC-IB-10%.lcd
Method File Name	: ChiralPak IB-10%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/14/2020 10:42:04 AM
Data Processed	: 1/14/2020 12:28:46 PM



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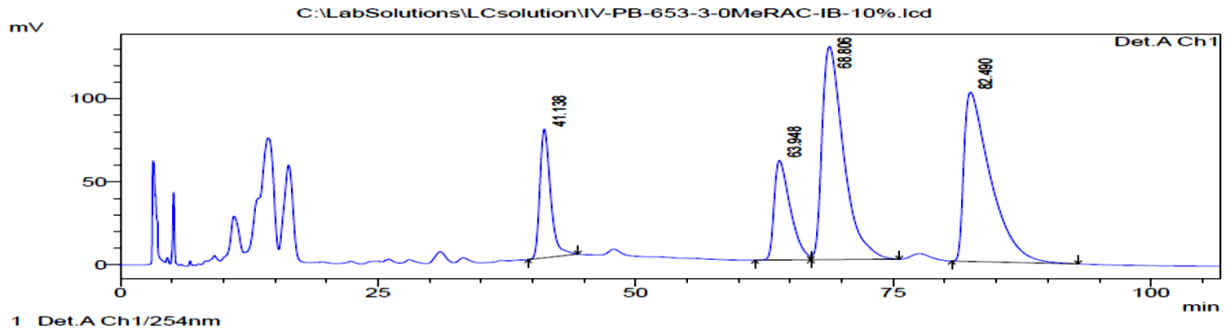
<Chromatogram>



PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	41.138	5627367	77458	11.417	21.063
2	63.948	6536745	59980	13.262	16.311
3	68.806	18747203	128387	38.034	34.913
4	82.490	18379041	101914	37.287	27.714
Total		49290356	367739	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-667-3-0Me-C6QDT.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-667-3-0Me-C6QDT.lcd
Method File Name	: ChiralPak IB-10%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/14/2020 2:18:30 PM
Data Processed	: 1/14/2020 4:06:17 PM

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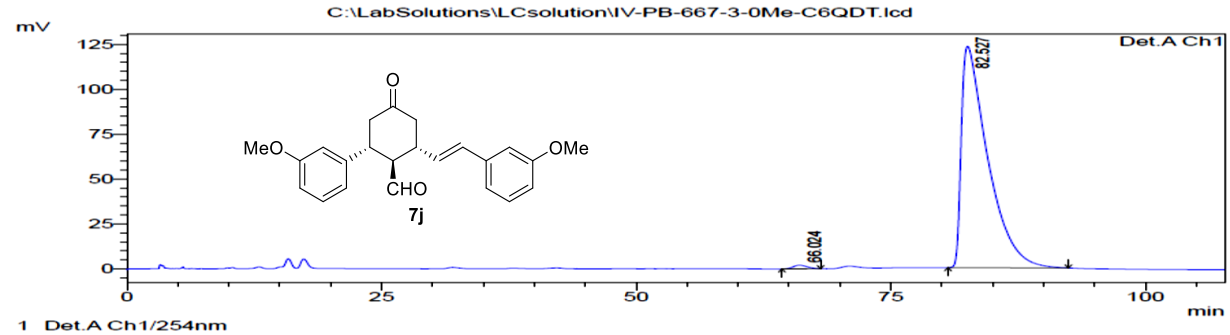


PeakTable

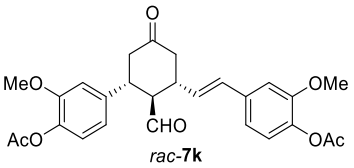
Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	66.024	194239	2033	0.865	1.621
2	82.527	22268641	123349	99.135	98.379
Total		22462881	125382	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\III-PB-439-RAC-IB.lcd

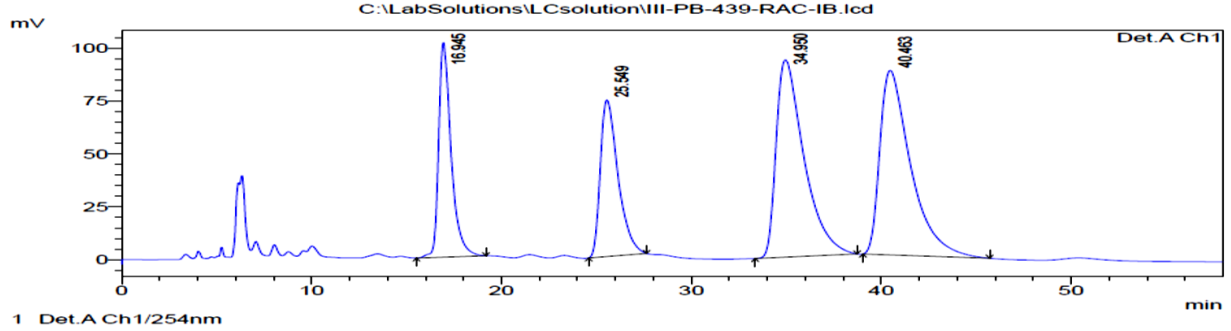
Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: III-PB-439-RAC-IB.lcd
Method File Name	: ChiralPak IB-40%-1 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 10/4/2019 2:39:32 PM
Data Processed	: 10/4/2019 3:37:31 PM



rac-**7k**

<Chromatogram>

C:\LabSolutions\LCsolution\III-PB-439-RAC-IB.lcd



PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.945	4642998	101609	16.088	28.491
2	25.549	4821022	74170	16.705	20.797
3	34.950	9529607	93441	33.020	26.201
4	40.463	9866874	87416	34.188	24.511
Total		28860501	356636	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-694.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-694.lcd
Method File Name	: ChiralPak IB-40%-1 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/16/2020 3:10:12 PM
Data Processed	: 1/16/2020 4:15:26 PM

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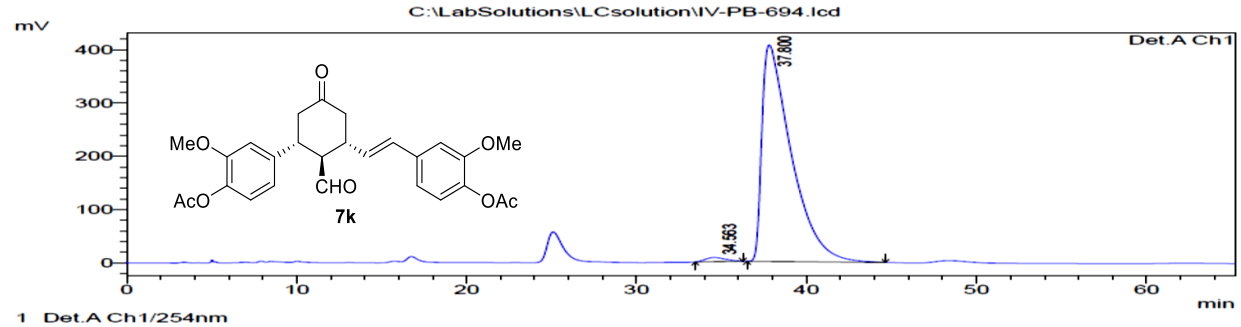
C:\LabSolutions\LCsolution\IV-PB-694.lcd



PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	34.563	657616	7942	1.329	1.916
2	37.800	48835109	406494	98.671	98.084
Total		49492725	414436	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\I-NS-143 RACEMIC2.lcd

Acquired by	: Admin
Sample Name	: I-NS-143-IC
Sample ID	:
Vail #	:
Injection Volume	: 2 uL
Data File Name	: I-NS-143 RACEMIC2.lcd
Method File Name	: ChiralPak IC-20%-1.0 mL-220nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 4/3/2021 4:16:50 PM
Data Processed	: 4/3/2021 5:16:54 PM

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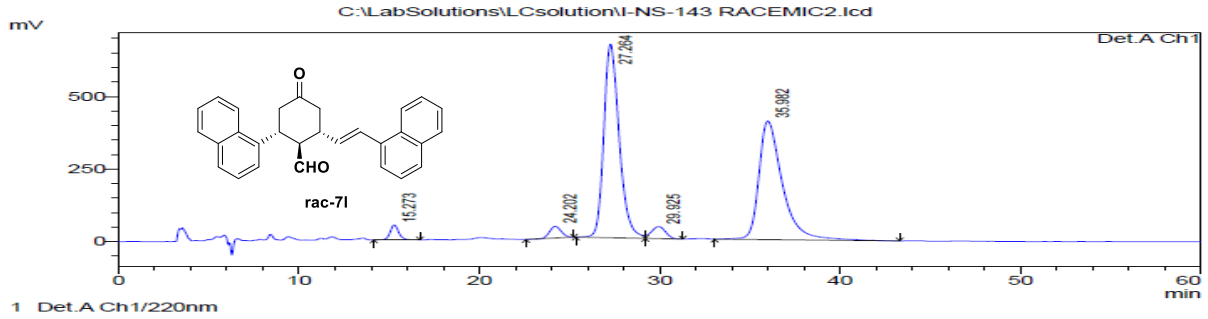

PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.273	1702491	51634	2.065	4.265
2	24.202	1755266	40448	2.129	3.341
3	27.264	39653049	667323	48.091	55.127
4	29.925	2278022	41951	2.763	3.466
5	35.982	37066172	409170	44.953	33.801
Total		82455000	1210526	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\I-NS-133.lcd

Acquired by	: Admin
Sample Name	: I-NS-132
Sample ID	:
Vail #	:
Injection Volume	: 3 uL
Data File Name	: I-NS-133.lcd
Method File Name	: ChiralPak IC-20%-1.0 mL-220nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 3/31/2021 6:04:56 PM
Data Processed	: 4/1/2021 2:43:30 PM

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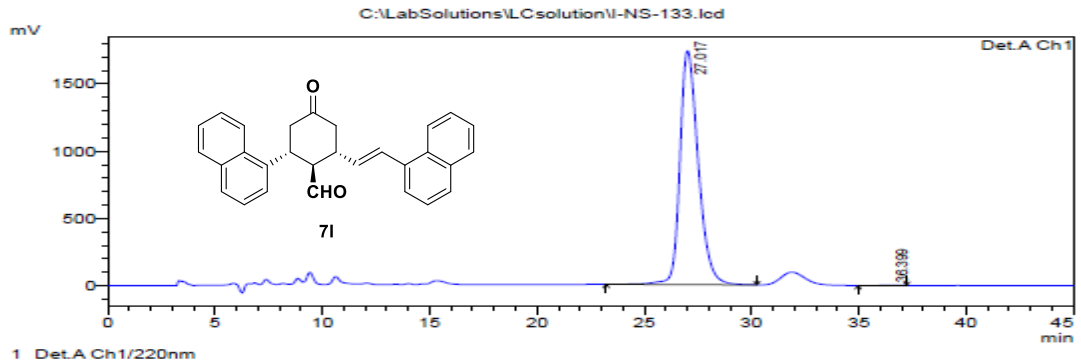

PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	27.017	103437809	1739115	99.939	99.934
2	36.399	63166	1146	0.061	0.066
Total		103500974	1740260	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1985-PURE-RM-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1985-PURE-RM-1.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/23/2020 1:04:46 PM
Data Processed	: 1/28/2020 2:22:16 PM

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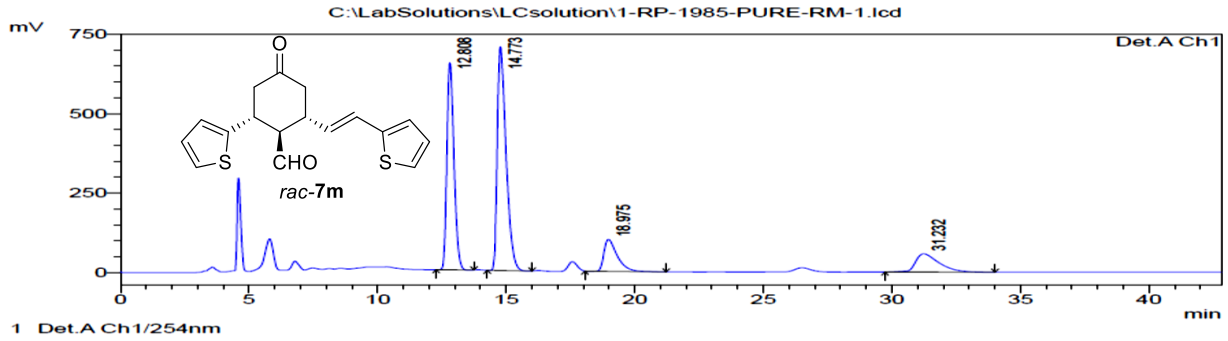

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.808	12465893	651609	34.159	43.028
2	14.773	16745782	704521	45.887	46.522
3	18.975	3586929	100665	9.829	6.647
4	31.232	3695106	57594	10.125	3.803
Total		36493710	1514389	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1988-PURE.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1988-PURE.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/28/2020 9:53:56 AM
Data Processed	: 1/28/2020 2:23:14 PM

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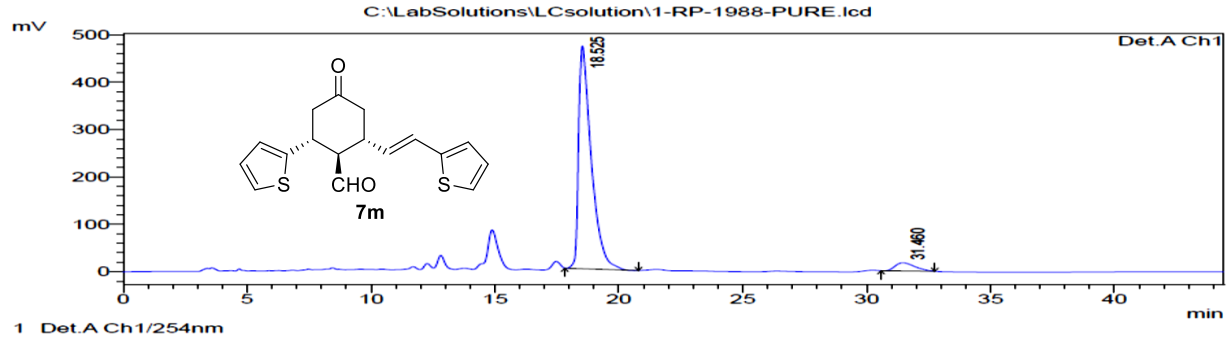

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	18.525	16783731	470250	94.643	96.442
2	31.460	949926	17349	5.357	3.558
Total		17733657	487599	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-705-RAC-ID.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-705-RAC-ID.lcd
Method File Name	: ChiralPak ID-15.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/21/2020 1:00:56 PM
Data Processed	: 1/21/2020 2:06:41 PM

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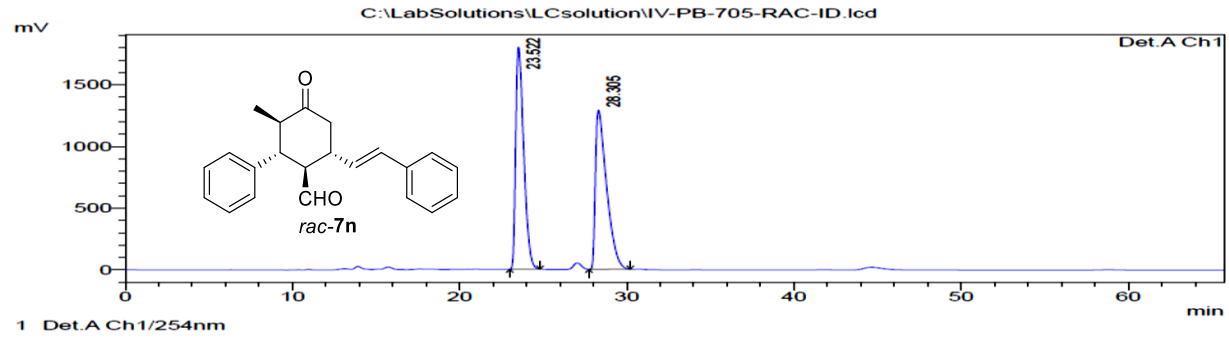

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	23.522	60313784	1802268	50.065	58.253
2	28.305	60156885	1291588	49.935	41.747
Total		120470669	3093857	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-710-2.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-710-2.lcd
Method File Name	: ChiralPak ID-15.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/27/2020 4:46:31 PM
Data Processed	: 1/27/2020 5:49:46 PM

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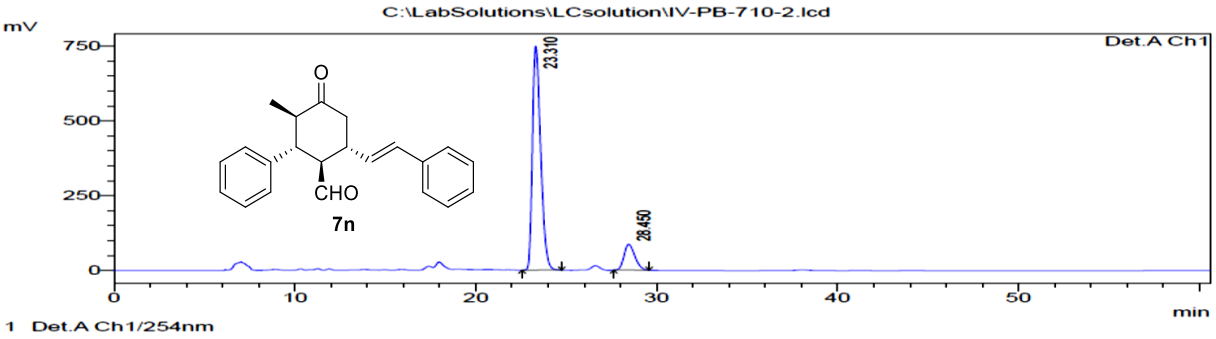

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	23.310	23793541	748193	86.876	89.659
2	28.450	3594504	86293	13.124	10.341
Total		27388045	834485	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\I-PB-189-RAC-20%-0.7ML.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: I-PB-189-RAC-20%-0.7ML.lcd
Method File Name	: ChiralPak ID-20.0%-0.7 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 8/16/2019 1:16:42 PM
Data Processed	: 9/5/2019 2:05:31 PM

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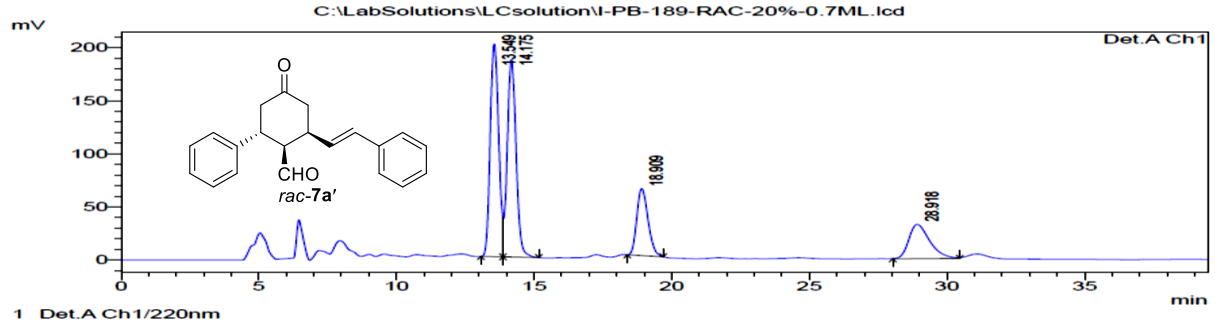


PeakTable

Detector A Ch1 220nm

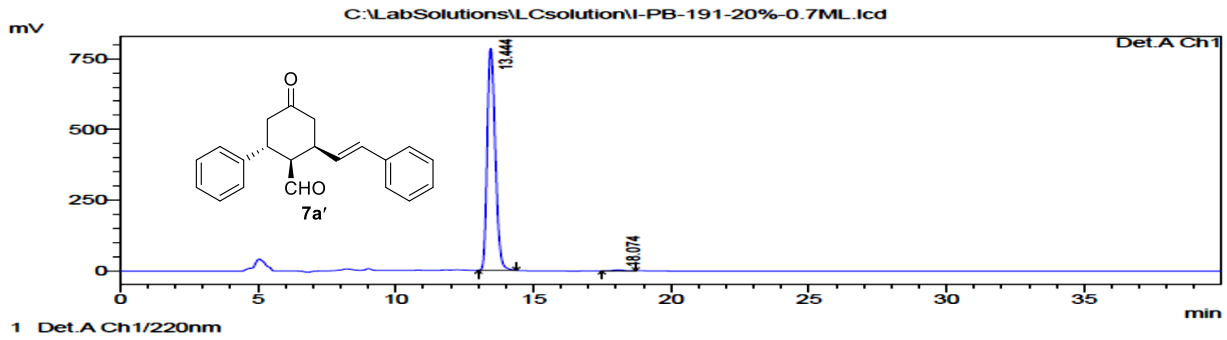
Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.549	4270538	200394	35.738	41.599
2	14.175	4178528	185846	34.968	38.579
3	18.909	1794547	63219	15.018	13.123
4	28.918	1706086	32272	14.277	6.699
Total		11949699	481730	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\I-PB-191-20%-0.7ML.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: I-PB-191-20%-0.7ML.lcd
Method File Name	: ChiralPak ID-20.0%-0.7 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 8/16/2019 3:14:57 PM
Data Processed	: 8/16/2019 3:56:41 PM

<Chromatogram>



PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.444	16028874	783281	99.589	99.559
2	18.074	66167	3468	0.411	0.441
Total		16095041	786749	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1888-B2+C2-PURE.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1888-B2+C2-PURE.lcd
Method File Name	: ChiralPak ID-20%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/11/2019 9:08:44 AM
Data Processed	: 12/11/2019 9:32:59 AM

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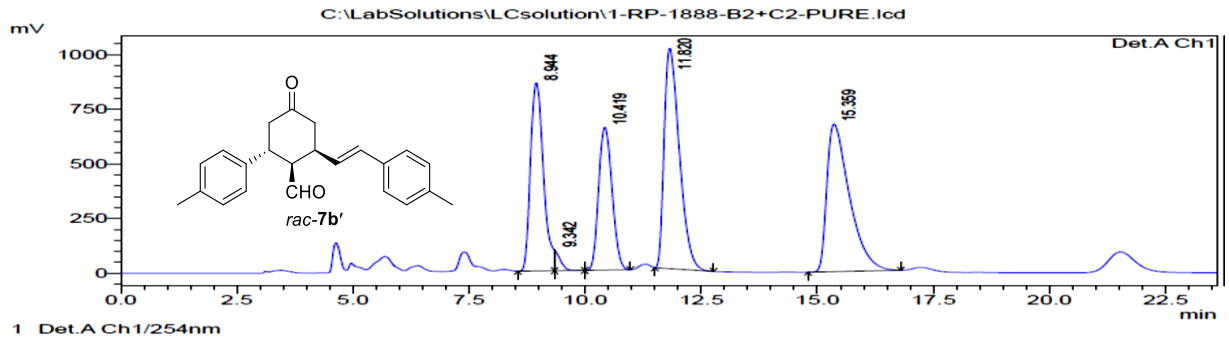

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.944	16755699	861002	21.881	26.146
2	9.342	777682	94496	1.016	2.870
3	10.419	13176751	653432	17.207	19.843
4	11.820	22960535	1008808	29.984	30.635
5	15.359	22906112	675297	29.913	20.507
Total		76576778	3293034	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1899-PURE-ME-C-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1899-PURE-ME-C-1.lcd
Method File Name	: ChiralPak ID-20%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/16/2019 3:29:09 PM
Data Processed	: 12/16/2019 3:53:59 PM

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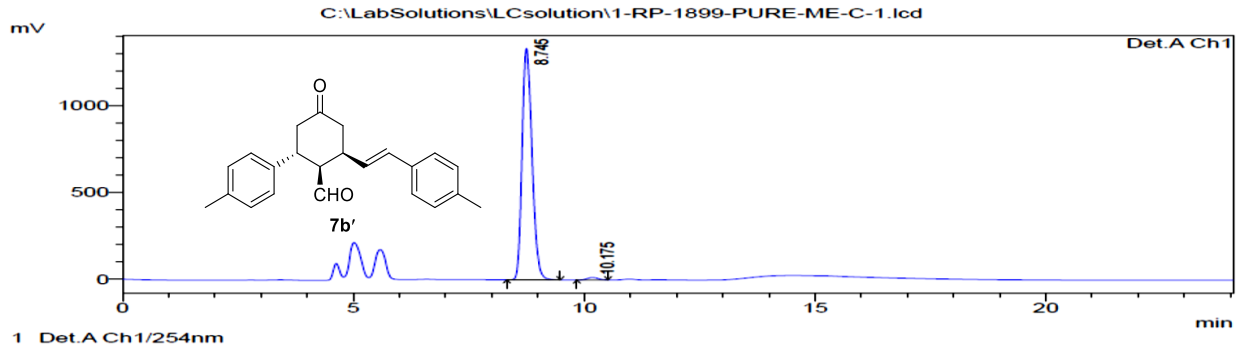

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.745	20005328	1333501	98.868	98.971
2	10.175	229153	13871	1.132	1.029
Total		20234481	1347372	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\III-PB-424-rac-ID.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: III-PB-424-rac-ID.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 9/24/2019 3:50:52 PM
Data Processed	: 9/24/2019 4:28:24 PM

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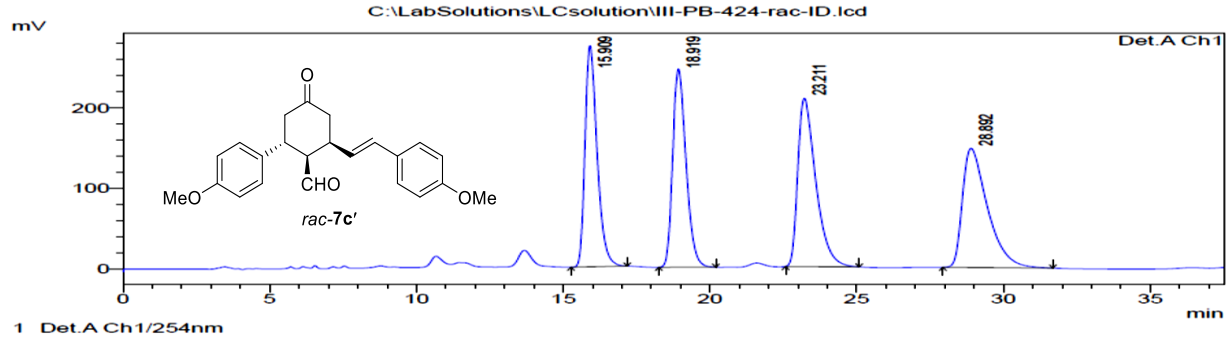

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.909	7884233	274490	23.628	31.276
2	18.919	7793904	246307	23.357	28.065
3	23.211	8912112	208986	26.709	23.812
4	28.892	8777809	147853	26.306	16.847
Total		33368057	877636	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-631.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-631.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/14/2019 12:46:54 PM
Data Processed	: 12/14/2019 1:22:22 PM

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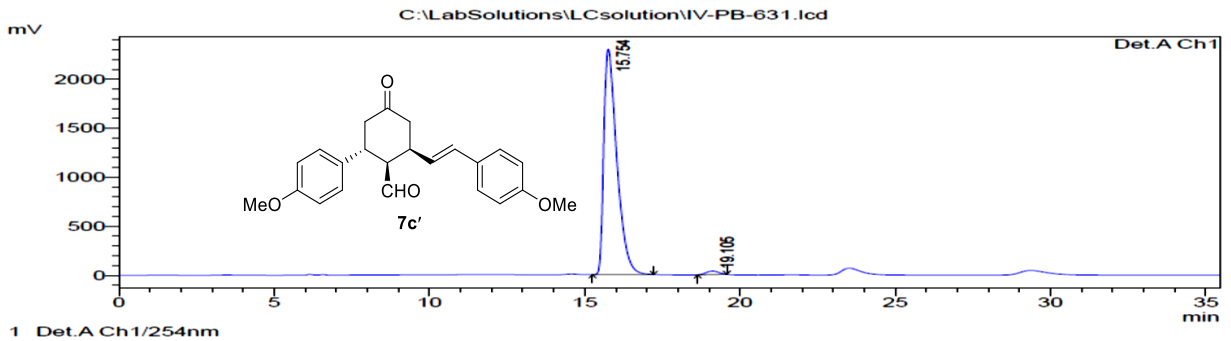

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.754	67170871	2298358	98.507	98.442
2	19.105	1018023	36365	1.493	1.558
Total		68188894	2334723	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\III-PB-422-rac-20%-0.7 ml.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: III-PB-422-rac-20%-0.7 ml.lcd
Method File Name	: ChiralPak IC-20%-0.7 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 9/19/2019 11:19:03 AM
Data Processed	: 9/19/2019 2:51:29 PM

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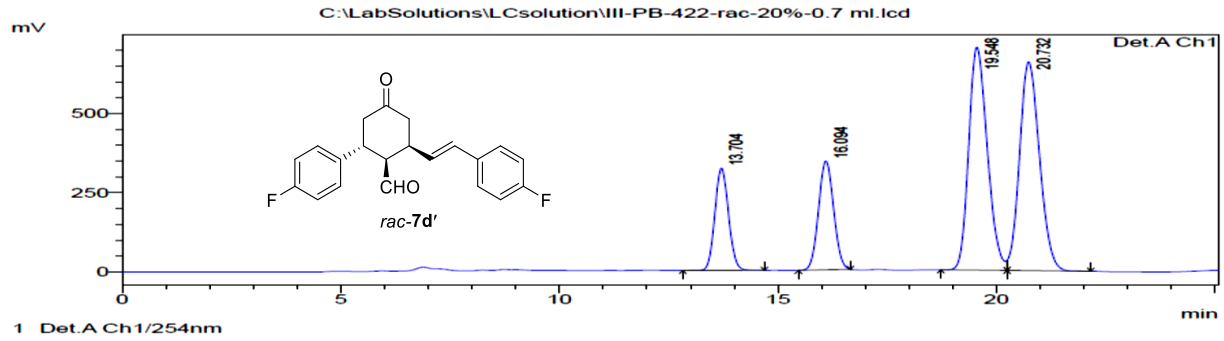

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.704	7028226	323038	12.305	15.914
2	16.094	8260708	343585	14.463	16.926
3	19.548	20887760	703822	36.572	34.672
4	20.732	20938141	659476	36.660	32.488
Total		57114836	2029922	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-630.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-630.lcd
Method File Name	: ChiralPak IC-20%-0.7 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/13/2019 12:35:06 PM
Data Processed	: 12/13/2019 1:08:58 PM

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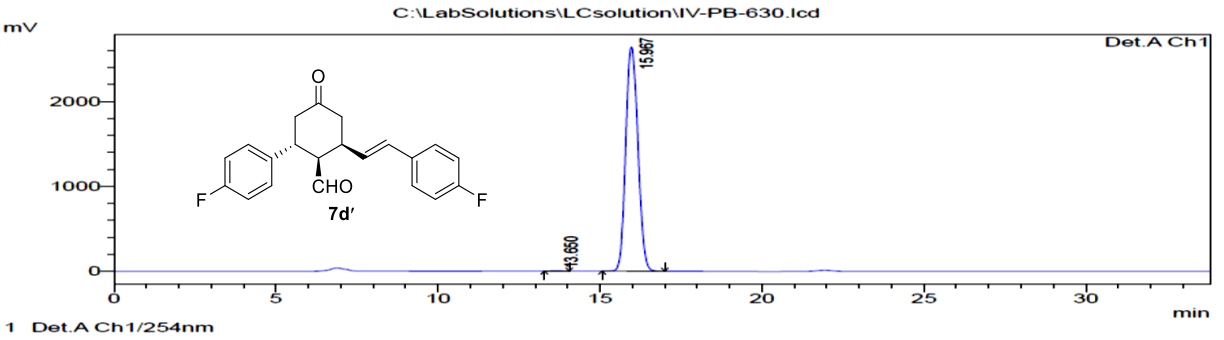

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.650	71460	3359	0.103	0.127
2	15.967	69195105	2636154	99.897	99.873
Total		69266565	2639514	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1892-C2-PURE.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1892-C2-PURE.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/12/2019 9:23:58 AM
Data Processed	: 12/12/2019 9:47:45 AM

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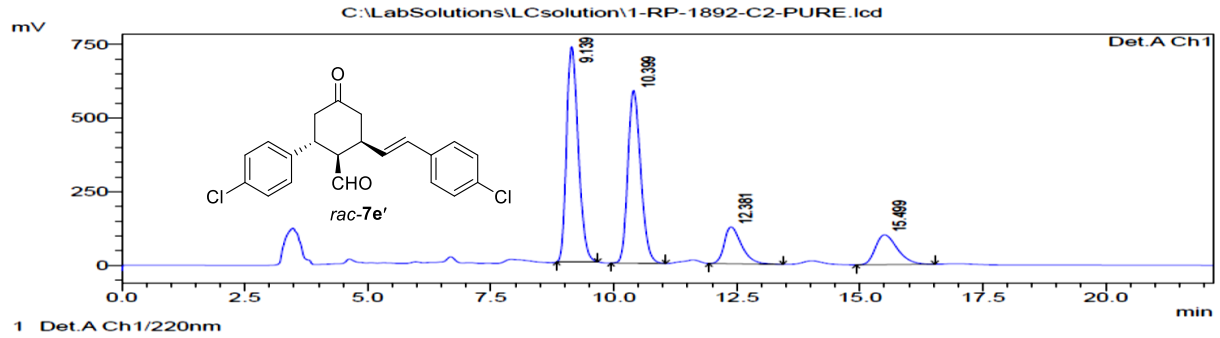

PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.139	12109035	730845	41.798	47.356
2	10.399	10669290	586303	36.828	37.990
3	12.381	3046998	125057	10.518	8.103
4	15.499	3145254	101109	10.857	6.551
Total		28970577	1543314	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1899-PURE-CL-C.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1899-PURE-CL-C.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/13/2019 3:28:26 PM
Data Processed	: 12/13/2019 3:50:55 PM

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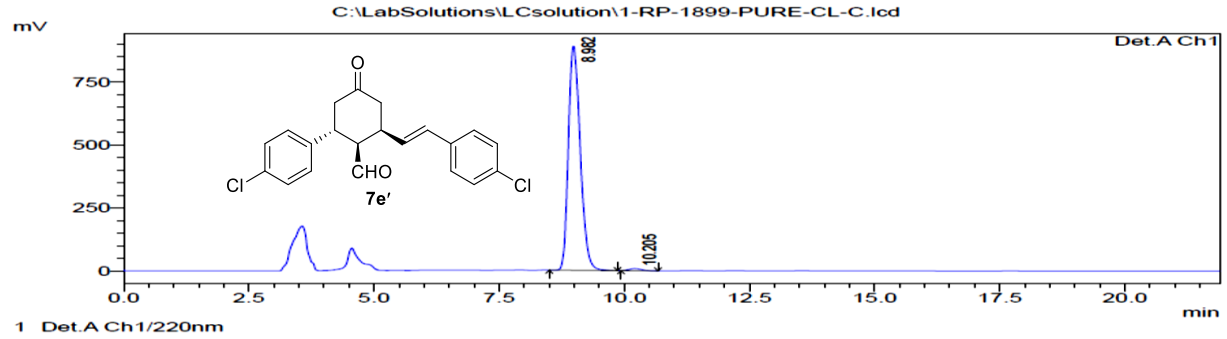

PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.982	14697511	889697	99.025	99.041
2	10.205	144666	8611	0.975	0.959
Total		14842178	898309	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1893-C2-PURE.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1893-C2-PURE.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/12/2019 9:54:41 AM
Data Processed	: 12/12/2019 11:04:23 AM

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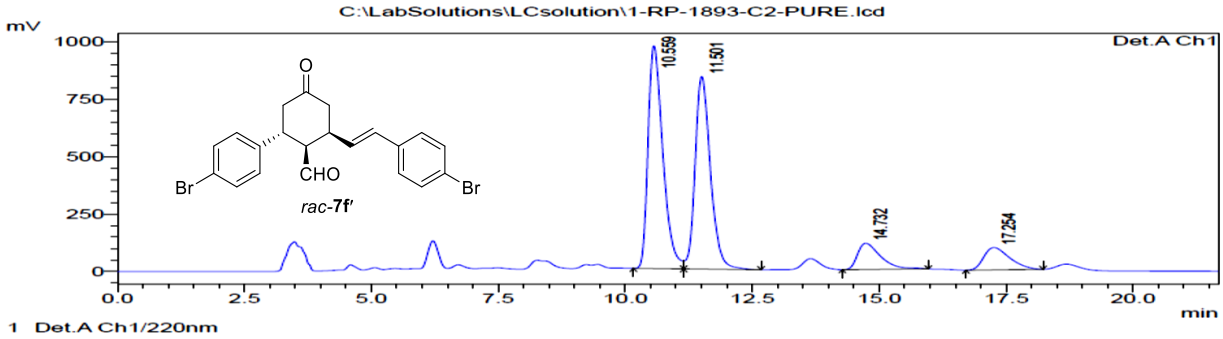

PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.559	19658119	968772	44.393	48.010
2	11.501	17596876	838021	39.738	41.530
3	14.732	3600297	114138	8.130	5.656
4	17.254	3427001	96937	7.739	4.804
Total		44282292	2017868	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1901-PURE-BR-C-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1901-PURE-BR-C-1.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/18/2019 4:22:20 PM
Data Processed	: 12/18/2019 5:06:11 PM

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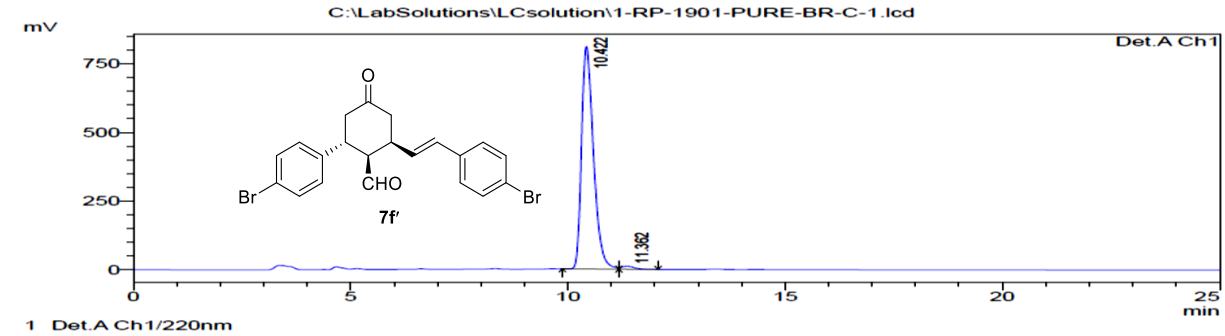

PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.422	15470060	810854	98.600	98.713
2	11.362	219581	10572	1.400	1.287
Total		15689641	821427	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1926-PURE-RM-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1926-PURE-RM-1.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/31/2019 11:19:30 AM
Data Processed	: 12/31/2019 12:19:35 PM

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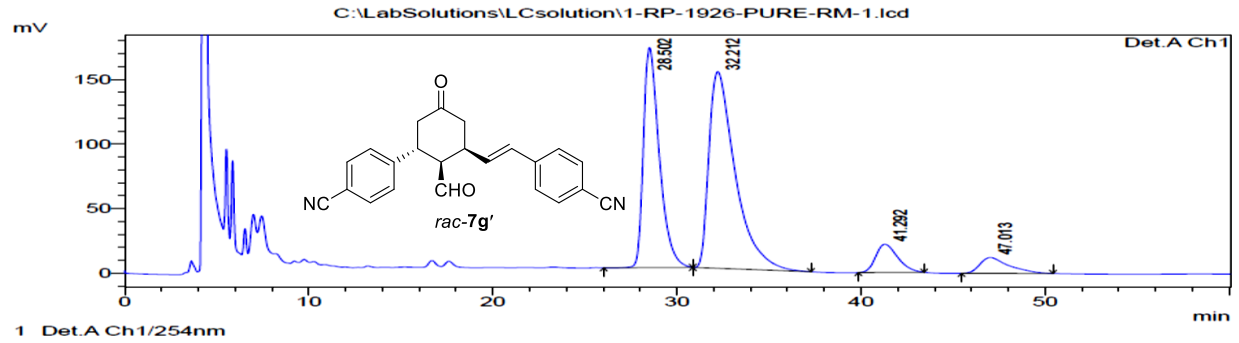

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	28.502	10252448	170267	35.883	47.733
2	32.212	15154639	152271	53.040	42.688
3	41.292	1812763	21857	6.345	6.128
4	47.013	1352257	12310	4.733	3.451
Total		28572107	356705	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1927-PURE-CHIRAL.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1927-PURE-CHIRAL.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/31/2019 12:19:59 PM
Data Processed	: 12/31/2019 1:27:57 PM

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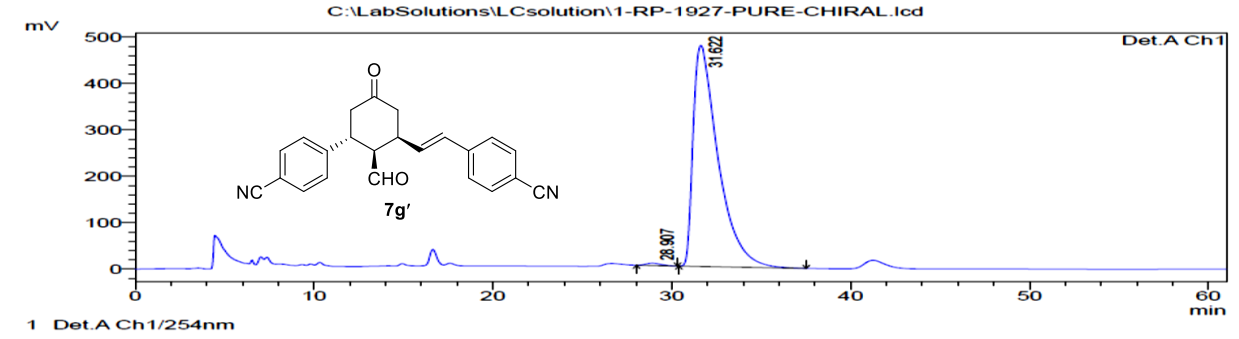

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	28.907	295099	5035	0.634	1.046
2	31.622	46228395	476279	99.366	98.954
Total		46523494	481314	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-665-RAC-ID.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-665-RAC-ID.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/2/2020 11:40:20 AM
Data Processed	: 1/2/2020 1:16:52 PM

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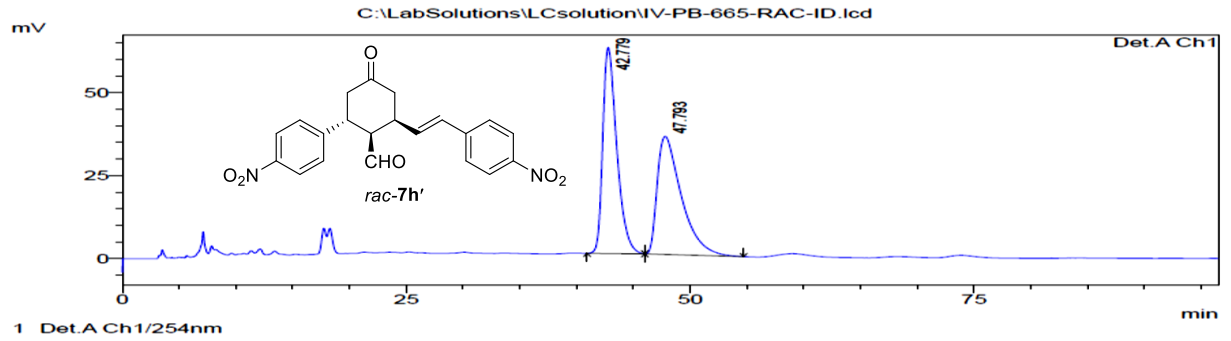

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	42.779	5322912	62081	50.311	63.564
2	47.793	5257135	35587	49.689	36.436
Total		10580047	97668	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-640.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-640.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/3/2020 12:24:25 PM
Data Processed	: 1/3/2020 1:59:39 PM

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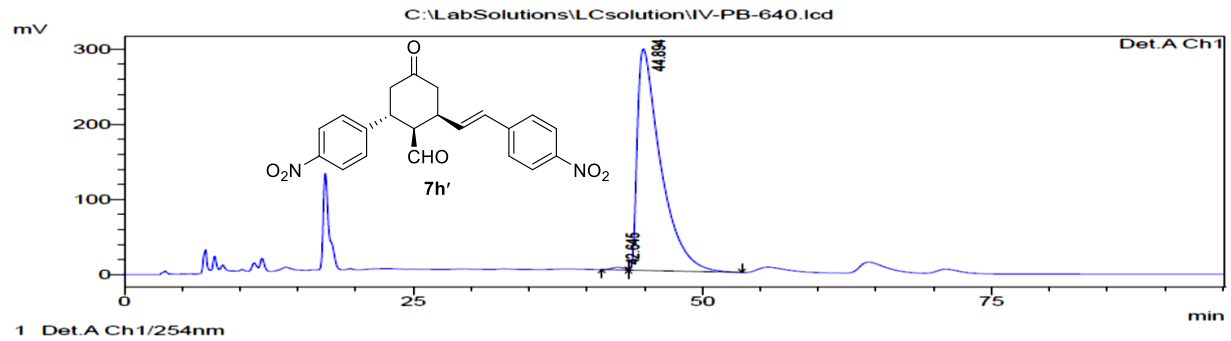

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	42.645	270415	3400	0.649	1.139
2	44.894	41417673	295181	99.351	98.861
Total		41688088	298581	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\MB-2-OMe-RAC-15%-0.7-IC-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
njection Volume	: 1 uL
Data File Name	: MB-2-OMe-RAC-15%-0.7-IC-1.lcd
Method File Name	: ChiralPak IC-15.0%-0.70 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 10/2/2019 3:10:12 PM
Data Processed	: 10/2/2019 4:07:26 PM

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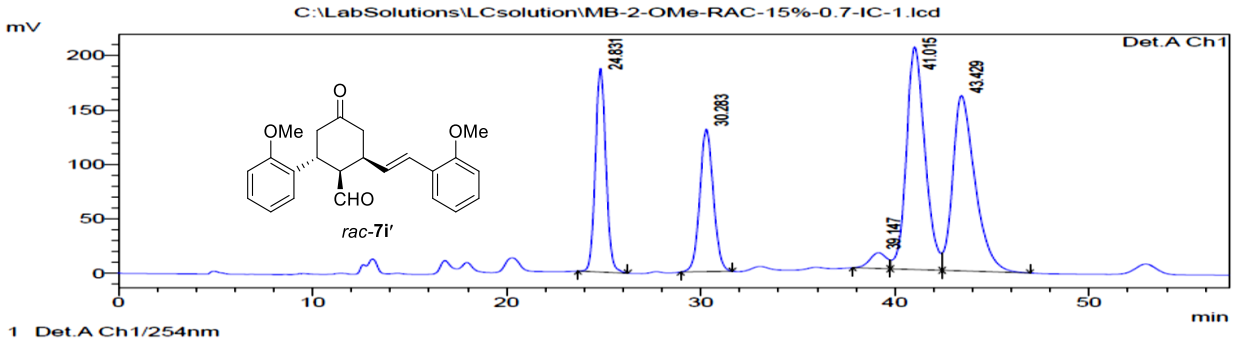

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	24.831	7067251	187150	17.318	26.817
2	30.283	6358099	130867	15.580	18.752
3	39.147	870193	14513	2.132	2.080
4	41.015	13657376	204365	33.466	29.284
5	43.429	12856505	160972	31.504	23.066
Total		40809425	697867	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-635.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-635.lcd
Method File Name	: ChiralPak IC-15.0%-0.70 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/14/2019 1:34:17 PM
Data Processed	: 12/14/2019 2:30:17 PM

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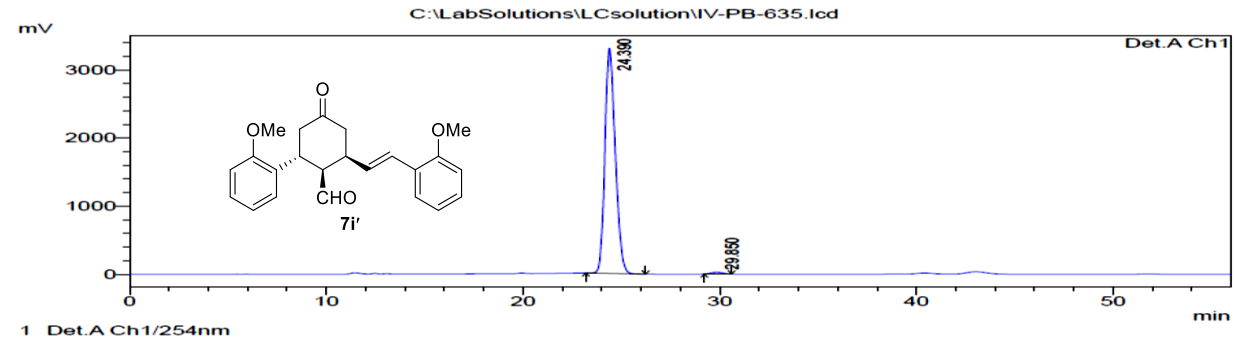


PeakTable

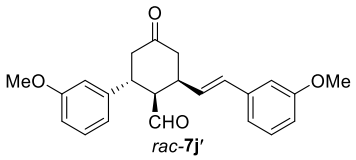
Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	24.390	121382784	3307879	99.071	99.175
2	29.850	1138433	27523	0.929	0.825
Total		122521217	3335402	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

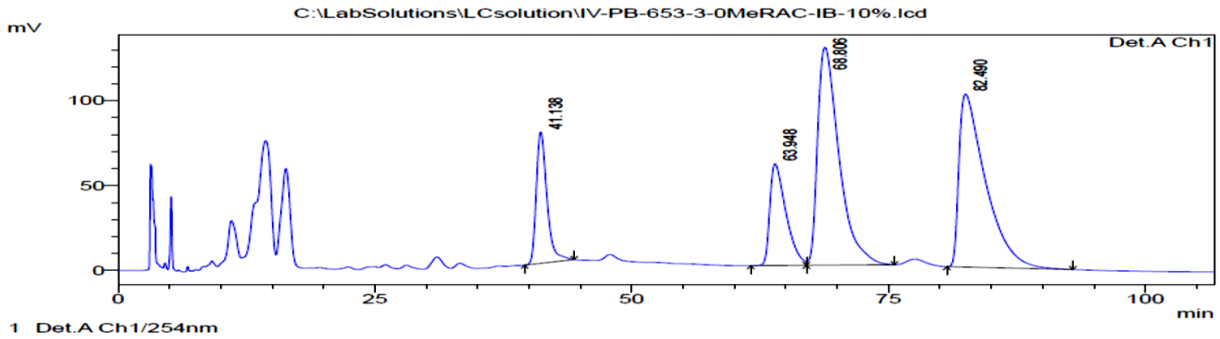
C:\LabSolutions\LCsolution\IV-PB-653-3-0MeRAC-IB-10%.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-653-3-0MeRAC-IB-10%.lcd
Method File Name	: ChiralPak IB-10%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/14/2020 10:42:04 AM
Data Processed	: 1/14/2020 12:28:46 PM



rac-**7j'**

<Chromatogram>



PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	41.138	5627367	77458	11.417	21.063
2	63.948	6536745	59980	13.262	16.311
3	68.806	18747203	128387	38.034	34.913
4	82.490	18379041	101914	37.287	27.714
Total		49290356	367739	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-661-3-0MeQDT.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-661-3-0MeQDT.lcd
Method File Name	: ChiralPak IB-10%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/14/2020 12:32:42 PM
Data Processed	: 1/14/2020 2:16:59 PM

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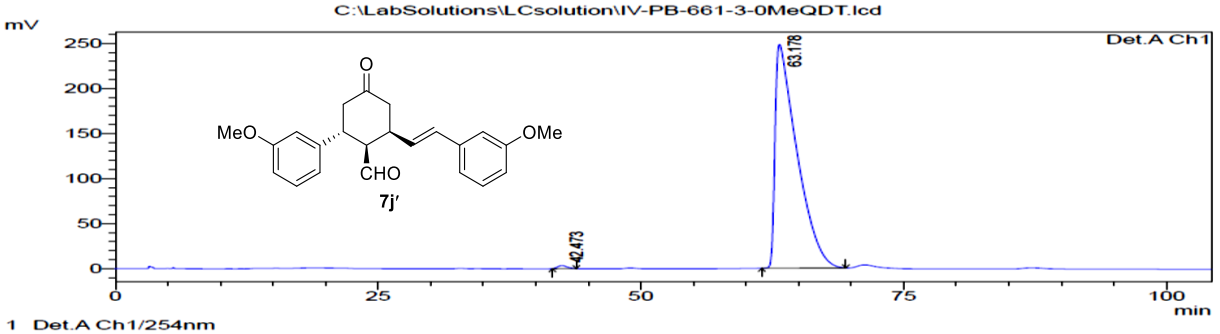


PeakTable

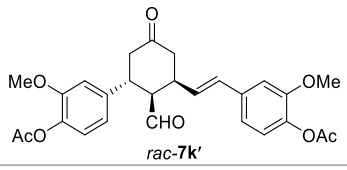
Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	42.473	217033	3515	0.600	1.397
2	63.178	35982514	248185	99.400	98.603
Total		36199547	251701	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

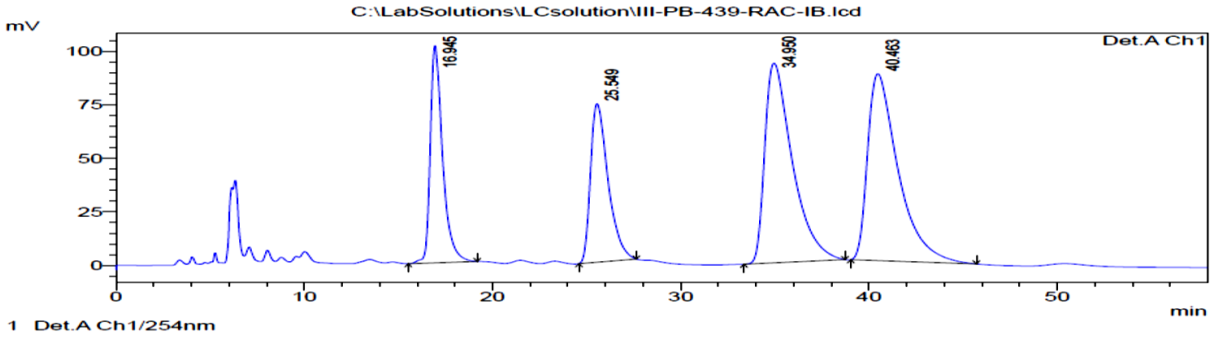
C:\LabSolutions\LCsolution\III-PB-439-RAC-IB.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: III-PB-439-RAC-IB.lcd
Method File Name	: ChiralPak IB-40%-1 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 10/4/2019 2:39:32 PM
Data Processed	: 10/4/2019 3:37:31 PM



rac-**7k′**

<Chromatogram>



PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.945	4642998	101609	16.088	28.491
2	25.549	4821022	74170	16.705	20.797
3	34.950	9529607	93441	33.020	26.201
4	40.463	9866874	87416	34.188	24.511
Total		28860501	356636	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-632.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-632.lcd
Method File Name	: ChiralPak IB-40%-1 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 12/12/2019 5:37:13 PM
Data Processed	: 12/12/2019 6:35:15 PM

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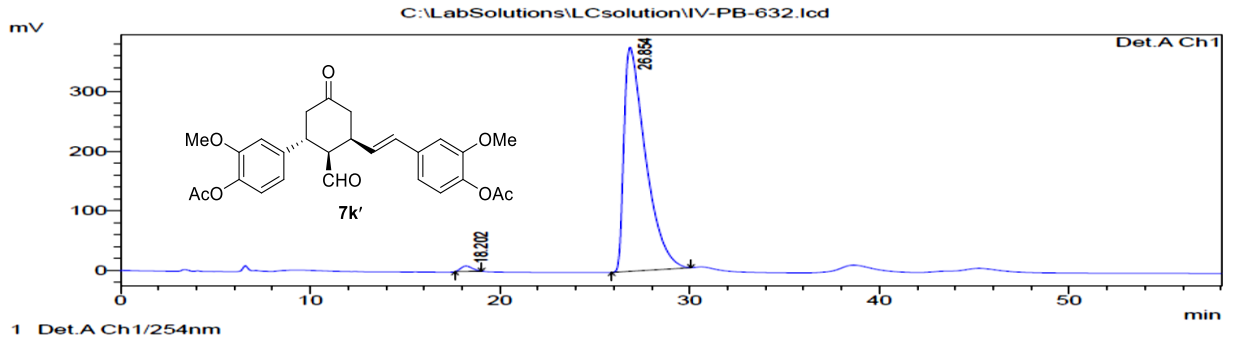

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	18.202	386513	9133	1.283	2.372
2	26.854	29750424	375935	98.717	97.628
Total		30136937	385068	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\I-NS-143 RACEMIC2.lcd

Acquired by	: Admin
Sample Name	: I-NS-143-IC
Sample ID	:
Vail #	:
Injection Volume	: 2 uL
Data File Name	: I-NS-143 RACEMIC2.lcd
Method File Name	: ChiralPak IC-20%-1.0 mL-220nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 4/3/2021 4:16:50 PM
Data Processed	: 4/3/2021 5:16:54 PM

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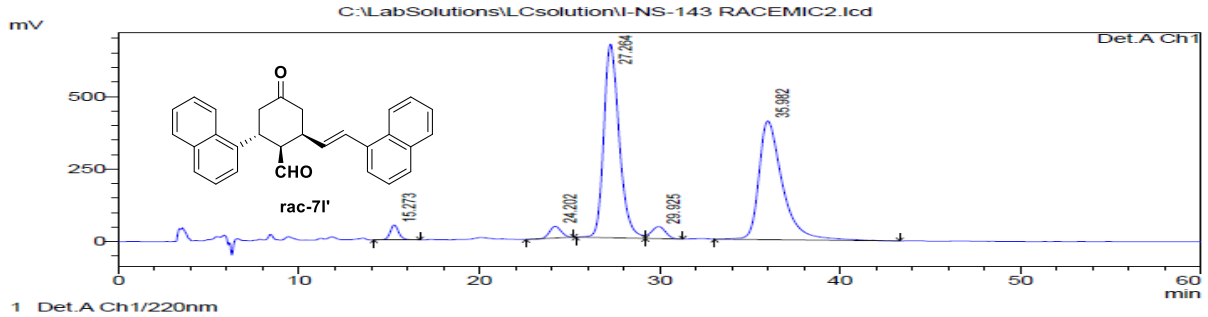

PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.273	1702491	51634	2.065	4.265
2	24.202	1755266	40448	2.129	3.341
3	27.264	39653049	667323	48.091	55.127
4	29.925	2278022	41951	2.763	3.466
5	35.982	37066172	409170	44.953	33.801
Total		82455000	1210526	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\I-NS-128NEW 2.lcd

Acquired by	: Admin
Sample Name	: I-NS-128-IC
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: I-NS-128NEW 2.lcd
Method File Name	: ChiralPak IC-20%-1.0 mL-220nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 4/3/2021 7:25:54 PM
Data Processed	: 4/5/2021 1:32:54 PM

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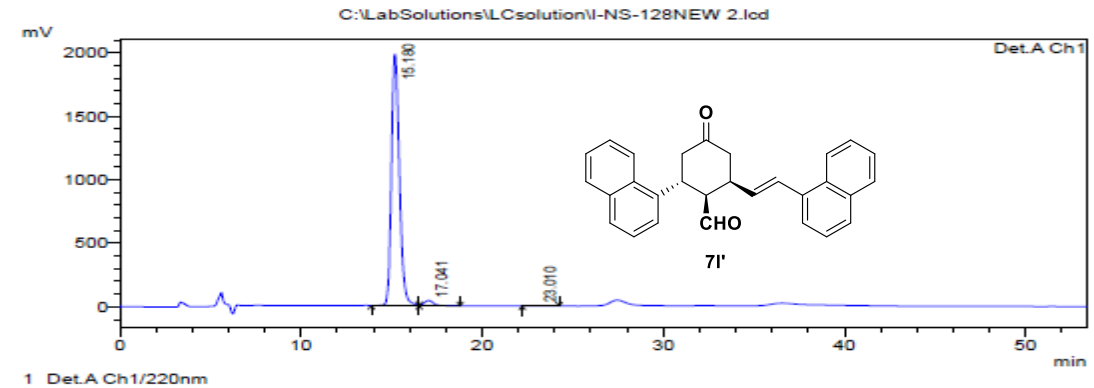

PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.180	60634009	1980050	97.593	97.957
2	17.041	1453558	40652	2.340	2.011
3	23.010	41789	636	0.067	0.031
Total		62129355	2021338	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1985-PURE-RM-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1985-PURE-RM-1.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/23/2020 1:04:46 PM
Data Processed	: 1/28/2020 2:22:16 PM

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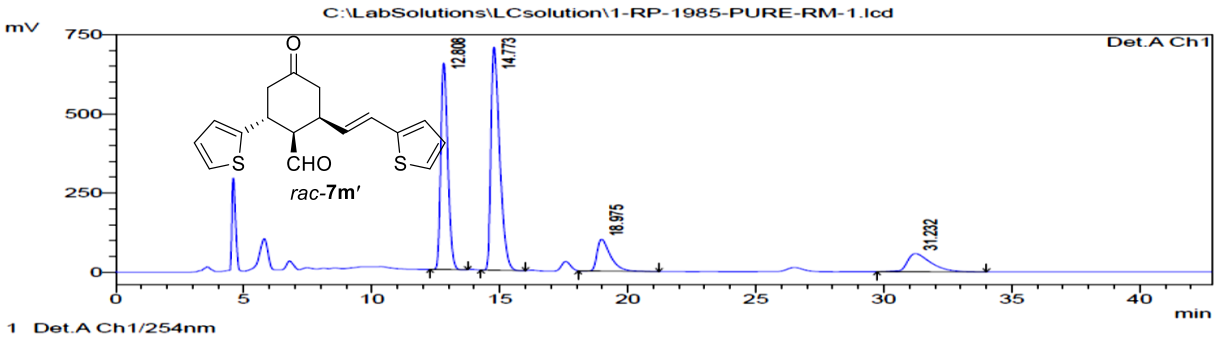

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.808	12465893	651609	34.159	43.028
2	14.773	16745782	704521	45.887	46.522
3	18.975	3586929	100665	9.829	6.647
4	31.232	3695106	57594	10.125	3.803
Total		36493710	1514389	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-RP-1977-PURE-CHIRAL.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-RP-1977-PURE-CHIRAL.lcd
Method File Name	: ChiralPak ID-20.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 1/23/2020 1:48:31 PM
Data Processed	: 1/23/2020 2:32:50 PM

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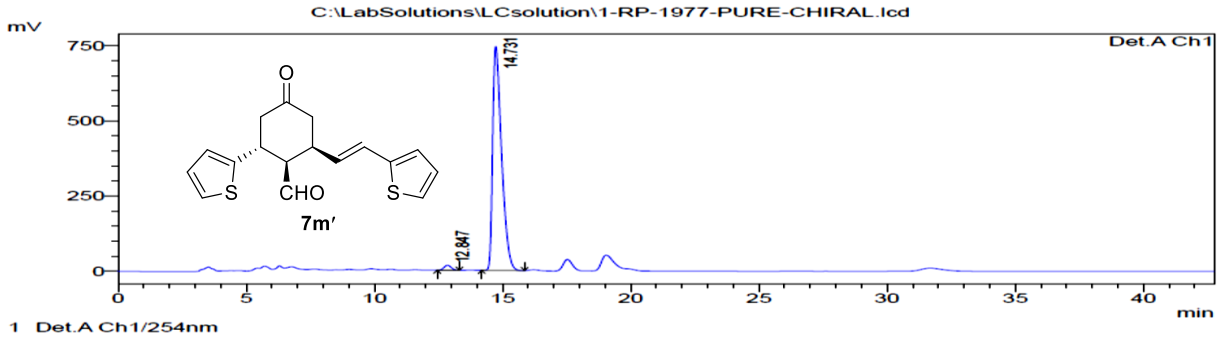

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.847	322493	16590	1.756	2.179
2	14.731	18045835	744610	98.244	97.821
Total		18368328	761200	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-712-RAC-IB-2.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-712-RAC-IB-2.lcd
Method File Name	: ChiralPak IB-15%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 2/4/2020 4:10:13 PM
Data Processed	: 2/4/2020 5:17:51 PM

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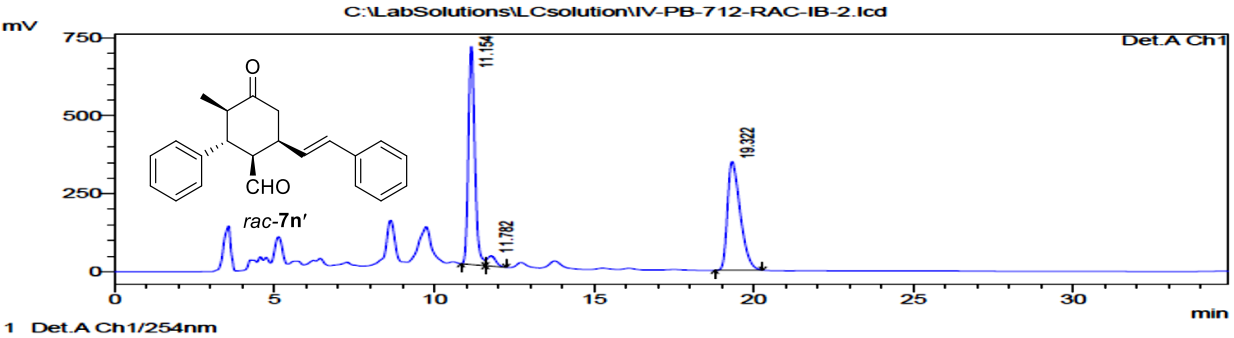

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.154	9825353	699599	48.762	64.656
2	11.782	612115	33619	3.038	3.107
3	19.322	9712159	348808	48.200	32.237
Total		20149627	1082025	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-712-up-4.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-712-up-4.lcd
Method File Name	: ChiralPak IB-15%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 2/5/2020 9:52:41 AM
Data Processed	: 2/5/2020 10:27:50 AM

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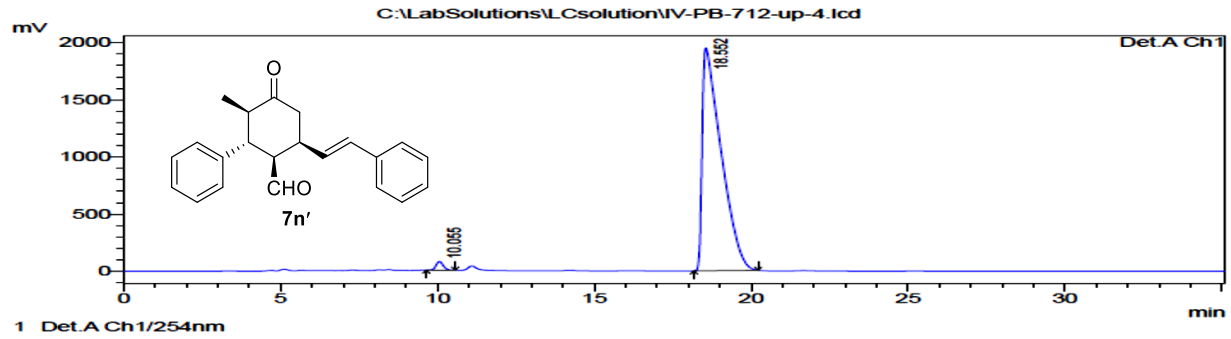

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.055	1184374	75174	1.427	3.714
2	18.552	81841272	1949107	98.573	96.286
Total		83025645	2024281	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-741-RAC.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-741-RAC.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 2/11/2020 11:48:36 AM
Data Processed	: 2/11/2020 12:38:31 PM

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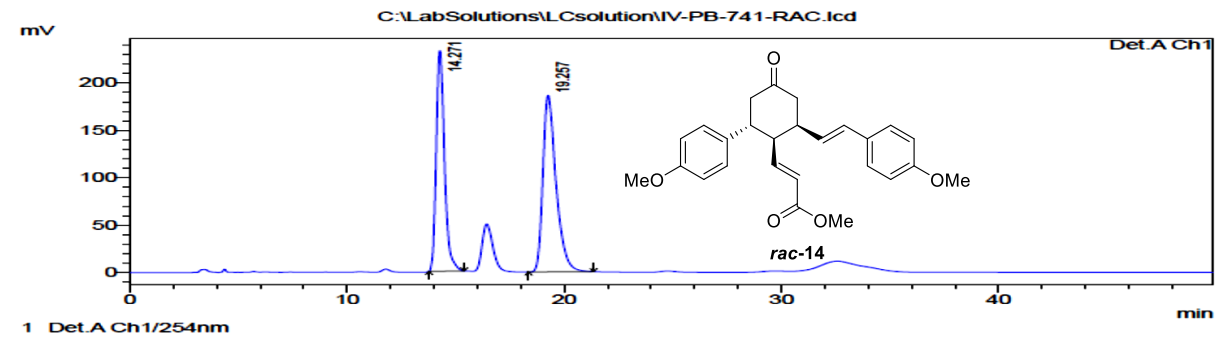

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.271	6158281	232661	43.942	55.556
2	19.257	7856238	186122	56.058	44.444
Total		14014519	418783	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\IV-PB-744-1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: IV-PB-744-1.lcd
Method File Name	: ChiralPak ID-30.0%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 2/11/2020 2:14:15 PM
Data Processed	: 2/11/2020 2:54:43 PM

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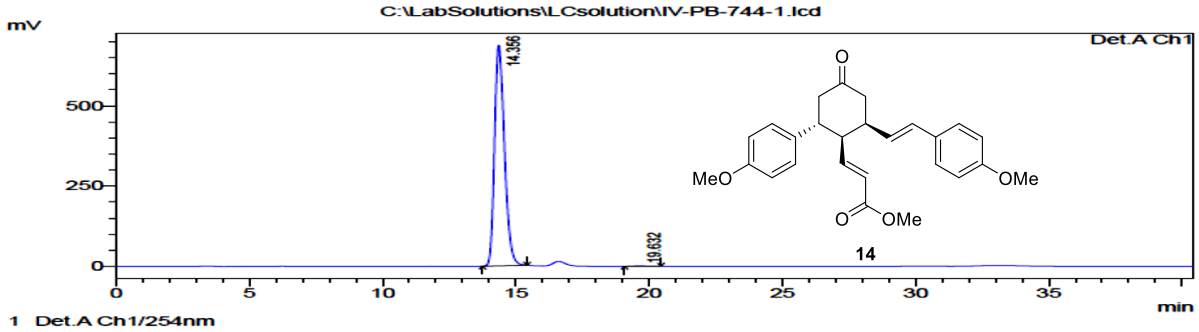


PeakTable

Detector A Ch1 254nm

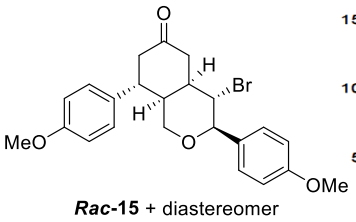
Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.356	17849654	687512	99.749	99.834
2	19.632	44918	1140	0.251	0.166
Total		17894572	688652	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

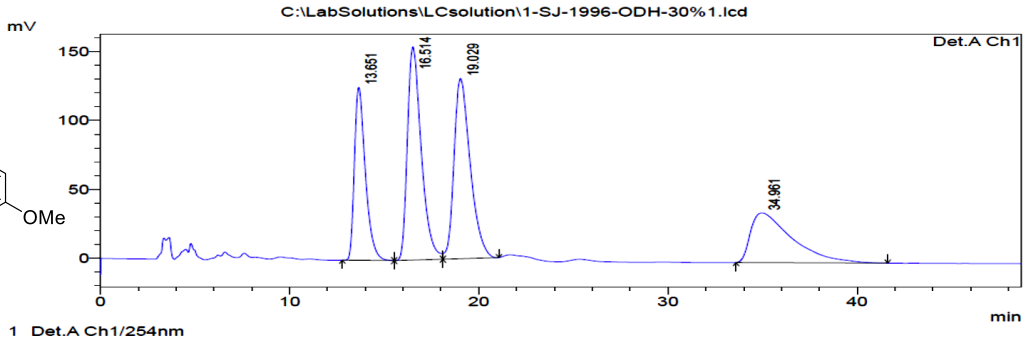
C:\LabSolutions\LCsolution\1-SJ-1996-ODH-30%1.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-SJ-1996-ODH-30%1.lcd
Method File Name	: ChiralPak OD-H-30%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 10/22/2020 10:12:31 AM
Data Processed	: 10/22/2020 11:01:55 AM

<Chromatogram>



***Rac*-15** + diastereomer



1 Det.A Ch1/254nm

PeakTable

Detector A Ch1 254nm

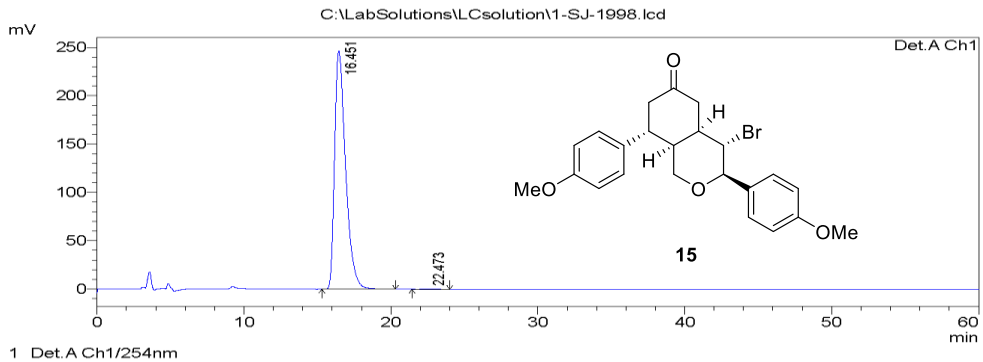
Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.651	5056610	125453	19.260	28.067
2	16.514	7905823	154661	30.113	34.602
3	19.029	7796640	130784	29.697	29.260
4	34.961	5494921	36080	20.930	8.072
Total		26253995	446978	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\1-SJ-1998.lcd

Acquired by	: Admin
Sample Name	:
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: 1-SJ-1998.lcd
Method File Name	: ChiralPak OD-H-30%-1.0 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 10/22/2020 10:17:25 AM
Data Processed	: 11/12/2020 10:41:20 AM

<Chromatogram>



1 Det.A Ch1/254nm

PeakTable

Detector A Ch1 254nm

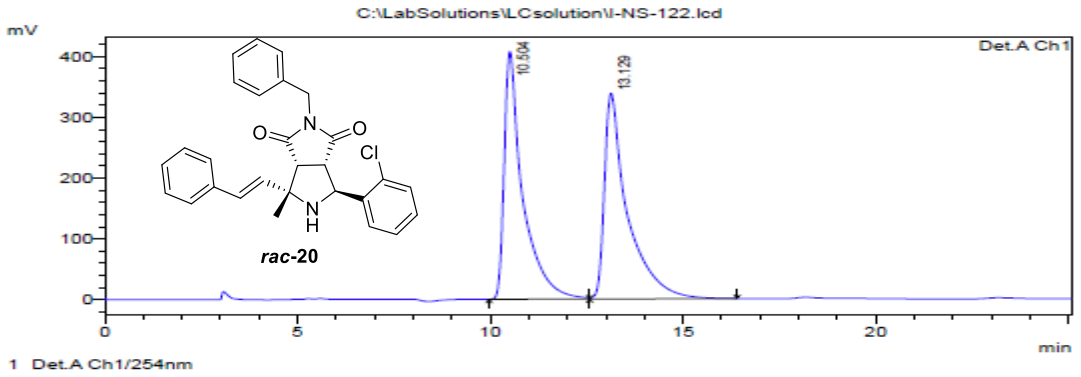
Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.451	12801081	246231	99.930	99.925
2	22.473	8970	186	0.070	0.075
Total		12810051	246417	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\I-NS-122.lcd

Acquired by	: Admin
Sample Name	: I-NS-122-AD-H
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: I-NS-122.lcd
Method File Name	: ChiralPak AD-H-10%-0.5 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 4/12/2021 1:37:05 PM
Data Processed	: 4/12/2021 2:02:12 PM

<Chromatogram>



PeakTable

Detector A Ch1 254nm

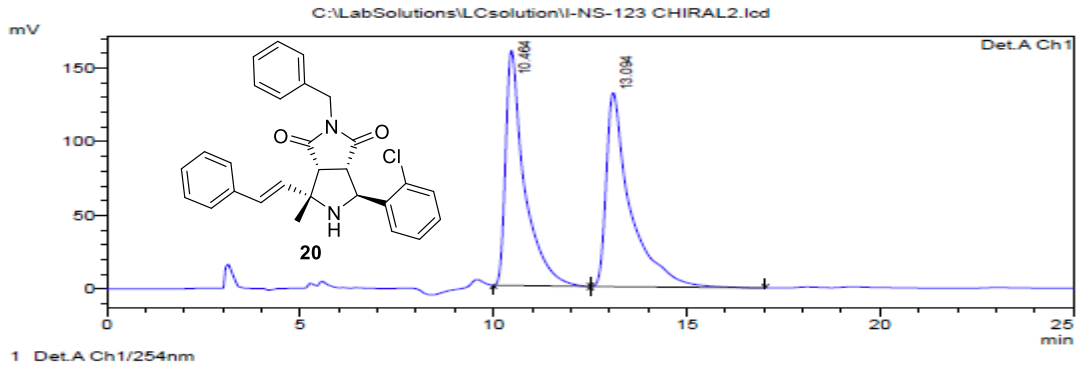
Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.504	13561243	407062	49.177	54.652
2	13.129	14015298	337759	50.823	45.348
Total		27576541	744821	100.000	100.000

==== Shimadzu LCsolution Analysis Report ====

C:\LabSolutions\LCsolution\I-NS-123 CHIRAL2.lcd

Acquired by	: Admin
Sample Name	: I-NS-123-AD-H
Sample ID	:
Vail #	:
Injection Volume	: 1 uL
Data File Name	: I-NS-123 CHIRAL2.lcd
Method File Name	: ChiralPak AD-H-10%-0.5 mL-254nm.lcm
Batch File Name	:
Report File Name	: Default.lcr
Data Acquired	: 4/12/2021 2:36:01 PM
Data Processed	: 4/12/2021 3:01:06 PM

<Chromatogram>



PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.464	5396098	159618	48.578	54.783
2	13.094	5711899	131744	51.422	45.217
Total		11107997	291361	100.000	100.000