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Journal:	*SYNLETT*
Manuscript ID:	Draft
Manuscript Type:	Letter
Date Submitted by the Author:	n/a
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Aqueous enantioselective aldol reaction of methyl- and phenylglyoxal organocatalyzed by *N*-Tosyl-(S_a)-binam-L-prolinamide.

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Received: The date will be inserted once the manuscript is accepted.

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Key words: methylglyoxal, organocatalysis, aldol, prolinamide, aqueous conditions.

Methylglyoxal (**1a**), an endogenous α-oxoaldehyde which is a potent protein modifier,[1] is a versatile reagent for the synthesis of heterocyclic compounds[2] using organocatalyzed methodologies.[3] However, it use as electrophile in related organocatalyzed enantioselective aldol processes[4] have been scarcely described,[5] although it would afford to synthetically important chiral γ-oxo-β-hydroxy carbonyl compounds. Probably, the reluctant use of this type of α-alkyl-α-oxo aldehydes as electrophiles is due to their facile hydratation and polymerization tendency. On the other hand, methylglyoxal is only commercially available as an aqueous solution (40%) and the use of water as a reaction media to carry out organocatalytic processes remains a challenge, due to the fact that water can interfere with the formation of hydrogen bonds and polar interactions between the organocatalysts and substrates.[6] Only some privileged organocatalytic systems such as prolinamide and diaryl prolinol derivatives among others, have shown their efficiency as organocatalysts in water or aqueous media.[7] Most of these systems are highly hydrophobic molecules that diminished the contact with bulk water and the transition states, with actually the process taking place in a highly concentrated organic phase.[8] Recently, we have shown that prolinamides derived from 1,1'-binaphthyl-2,2´-diamine (binam) **2**[9] and **3**[10] and their supported related binam derivatives (**4** and **5**),[11] led to excellent results in the inter- and intramolecular aldol reactions under several reaction conditions, even using challenging aqueous electrophiles such as glyoxylic acid[12] and 2,2-dimethoxyacetaldehyde.[13]

Based on these previous results, we thought of interest the study of the efficiency of binam-prolinamide derivatives as organocatalysts in the reaction between methyl- and phenylglyoxal with ketones[5a] and with aldehydes.[5b,c]

First, the optimization of the reaction parameters in the reaction between acetone (**6a**) and methylglyoxal (**1a**, 40% aqueous solution) was studied. This reaction gave the Henze´s ketol[14] (**7a**), which is involved in plants metabolism,[15] as a product.

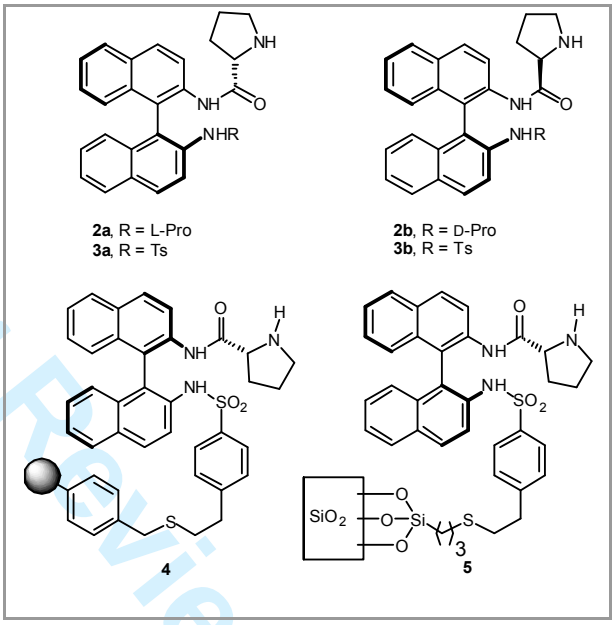

Figure 1 Binam-prolinamide derivatives as catalyst in the aldol reaction.

The efficiency of the two different binam-prolinamide derivatives **2** and **3**(20 mol%) was evaluated using 10 equiv. of acetone as nucleophile (Table1). Better enantioselectivity was achieved with catalysts **3** than with catalysts **2** (Table 1, entries 1-4).While catalysts **2a** and **3a** afforded compound **7a**, catalysts **2b** and **3b** gave its enantiomer (*ent*-**7a**) with lower enantioselectivity, showing that the configuration of the achieved aldol product was controlled by the chirality of the proline,[16] and that the match combination is (S_a)-binam and L-Pro. The results obtained with both catalysts were superior in terms of conversion, yields and enantioselectivities to the results achieved with L-proline (Table 1, compare entries 1-4 with entry 5), that gave product **7a** as a racemic mixture. As the best enantioselectivity for this process was achieved with the (S_a)-binamsulfo-L-Pro derivative (**3a**) as catalyst, the rest of the reaction

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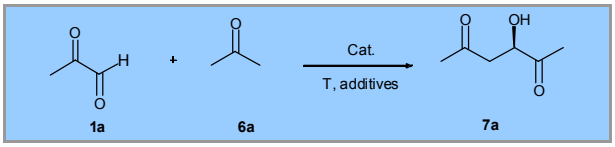
parameters, were done using this catalyst (Table 1, entry 3).

The effect of the amount of nucleophile was evaluated. While decreasing the amount of acetone (**6a**) from 10 to 5 equiv. led to similar results, using only 2 equiv. of acetone provoked a decrease in the reaction rate and enantioselectivity (Table 1, compare entry 3 with 6 and 7). Changing the catalyst loading to 10 and 5 mol%, led to similar results in terms of conversion but with slight lower selectivity being found when only 5 mol% of **3a** was used (Table 1, entries 8 and 9). Decreasing the temperature to 0 ºC in the presence of 10 mol% of **3a** and 5 equiv. of acetone, gave 88% ee but lower conversion and yield (Table 1, compare entries 3 and 10). Therefore, the effect of the addition of $PhCO_2H$ acid as co-catalyst was evaluated under these reaction conditions, but hardly any acceleration of the reaction was observed (Table 1, entry 12). Thus, under the best reaction conditions (10 mol% of **3a**, 5 equiv. of **6a** and 25ºC), the time required for the reaction completion was re-evaluated, finding that after 12h product **7a** was achieved in almost quantitative yield and 90% ee (Table 1, entry 12). These results are better to those previously reported using simple L-prolinamide or the dipeptide L-Pro-L-Leu under neat conditions.[5a] Finally, the use of the supported binam-derivatives **4** and **5** as catalysts in the reaction between acetone and methylglyoxal was tested, but the reaction failed (Table 1, entries 13 and 14).

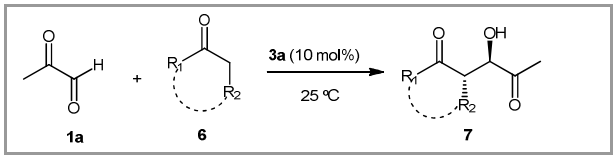
Table 1 Optimization of reaction conditions between acetone (**6a**) and methylglyoxal (**1**)[a]



Entry	Cat (mol%)	**6a** (equiv)	T (ºC)	t (h)	Conv.[b]	Yield (%)[c]	ee (%)[d]
1	**2a** (20)	10	25	24	100	-	80
2	**2b** (20)	10	25	24	100	-	-66
3	**3a** (20)	10	25	24	100	82	88
4	**3b** (20)	10	25	24	100	65	-68
5	L-Pro (20)	10	25	72	80	66	0
6	**3a** (20)	5	25	24	100	-	87
7	**3a** (20)	2	25	24	95	-	80
8	**3a** (10)	5	25	24	100	-	87
9	**3a** (5)	5	25	24	100	-	80
10	**3a** (10)	5	0	24	90	75	88
11[e]	**3a** (10)	5	0	24	93	84	88
12	**3a** (10)	5	25	12	100	94	90
13	**4** (20)	5	25	72	-	-	-
14	**5** (20)	5	25	168	-	-	-

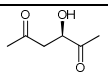
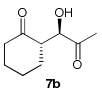
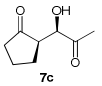
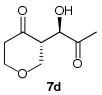
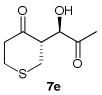
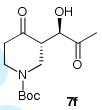
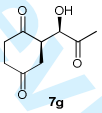
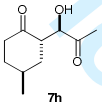
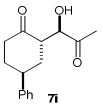
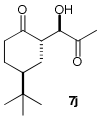
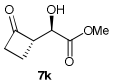
[a] Reaction conditions: **1a** (0.25 mmol, 40% aq. solution), **6a** and 10 mol% of catalysts, otherwise stated.[17b] Conversion based on the unreacted aldehyde. [c] After purification by column chromatography. [d] Determined by chiral-phase HPLC. [e] 5mol% of $PhCO_2H$ was added.

Once the best reaction conditions were established (Table 1, entry 12), the scope of the aldol reaction of methylglyoxal (40% aqueous solution) with different ketones was studied (Scheme1 and Table 2).[17]



Scheme 1 Aldol reaction of methylglyoxal with ketones.

Table 2 Aldol reaction of methylglyoxal with ketones[a]

Entry	Major product	Yield (%)[b]	Dr[c]	ee (%)[d]
1[e]	 **7a**	92	-	90
2	 **7b**	80	62:38	86
3	 **7c**	79	22:78	86
4	 **7d**	81	89:11	97
5	 **7e**	72	86:14	82
6[f]	 **7f**	77	93:7	95
7	 **7g**	70	40:60	34
8	 **7h**	78	87:7:4:2	92
9	 **7i**	67	68:29:2:1	87
10	 **7j**	74	54:32:10:4	91
11	 **7k**	42	63:37	90

[a] Reaction conditions: Methylglyoxal (0.25 mmol, 40% aq. solution), ketone (5 equiv), catalyst **3a** (10 mol%) at 25 ºC for 24 h, otherwise stated. [b] After purification by column chromatography. [c] Determined by the ^{1}H NMR of the crude product. [d] Determined by chiral-phase HPLC analysis for the major isomer. [e] Only 12h were required for reaction completion. [f] 30 h required for reaction completion.

In all cases, with the exception of cyclopentanone and 1,4-cyclohexadione (Table 2, entry 3 and 7, respectively), the major isomer achieved was the *anti*

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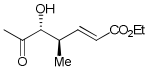
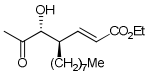
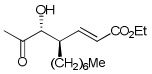
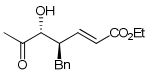
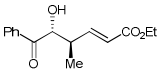
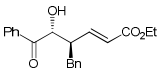
isomer **7**. The diastereoselectivities were rather moderate with the exception for cyclohexanone derivatives functionalized at the 4-position (products **7d-7f**, entries 4-6). Only product **7g**, achieved by reaction with 1,4-cyclohexadione, was obtained with low enantioselectivity (Table 2, entry 7), being the enantiomeric excesses for the rest of the examples higher that 82%. In the case of 4-substituted cyclohexanones, the major diastereoisomer formed was the expected *anti,anti*-aldol, being the diastereoselectivities highly dependent on the substituent at the 4-position (Table 1, entries 8-10). The relative configuration for compounds **7h-7j** was done comparing the chemical shifts and coupling constants to those previously reported for related glyoxylic acid and ethyl glyoxylate derivatives,[12] and confirmed by NOESY experiments. The reaction with cyclobutanone led to the *anti* expected product **7k** in good enantioselectivity but with low yield and diastereoselectivity (Table 2, entry 11). Attempts to extend the reaction to other ketones such as butanone orα-alkoxy ketones failed.

Once the scope of the reaction of aqueous methylglyoxal with ketones was accomplished, the cross aldol between methylglyoxal with enolizable aldehydes was studied under the same reaction conditions. This cross aldol reaction has been previously reported,[5b,c] showing that the corresponding γ-oxo-β-hydroxy aldehydes isomerized easily during purification procedures. Therefore, these aldol products were *in situ* allowed to react with Ph_3PCHCO_2Et to give the corresponding Wittig adducts. Following this one-pot two step procedure, products **10** were obtained(Scheme 2, Table 3).[18] As before, in all cases the *anti* isomer was the major isomer, being the stereochemistry of the product assigned based in previously reported results.[5b] The reaction of methylglyoxal (**1a**) with propanal led to product **10a** in moderate yield and diastereoselectivity but excellent enantioselectivity, comparable to the enantioselectivity achieved using diarylprolinol as catalyst (10 mol%) in THF[5b] (Table 3, entry 1). Better results were achieved in the reaction with octanal and heptanal and phenylpropanal, giving products **10b**, **10c** and **10d** in excellent diastereo- and enantioselectivity, respectively (Table 3, entries 2-4). The reaction between phenylglyoxal[19] (**1b**) and several aldehydes was also tested.[20] When propanal was used as nucleophile, moderate yield, diastereo- and enantioselectivity was obtained (Table 3, entry 5). Meanwhile, phenylpropanal led to lower diastereoselectivity but better enantioselectivity (Table 3, entry 6).

Table 3 Aldol reaction of glyoxals **1** with aldehydes followed by Wittig olefination[a]

Entry	Major product	Yield (%)[b]	Dr[c]	ee (%)[d]
1[e]	 **10a**	40	76:24	92
2	 **10b**	57	98:2	95
3	 **10c**	65	99:1	96
4	 **10d**	48	99:1	97
5	 **10e**	55	62:38	77
6[f]	 **10f**	48	55:45	86

[a] Reaction conditions: Methylglyoxal (0.25 mmol, 40% aq. solution)[18] or phenylglyoxal monohydrate (0.25 mmol),[20] aldehyde (2 equiv), catalyst **3a** (10 mol%) at 25 ºC for 24 h, otherwise stated. [b] Overall yield after purification by column chromatography. [c] Determined by the ^{1}H NMR of the crude product. [d] Determined by chiral-phase HPLC analysis for the major isomer.

In conclusion, *N*-tosyl-(S_a)-binam-L-prolinamide was an efficient catalysts to promote the aldol reaction between methylglyoxal under aqueous conditions or phenylglyoxal monohydrate with ketones or aldehydes, affording chiral γ-oxo-β-hydroxy carbonyl compounds and ε-oxo-δ-hydroxy α,β-unsaturated esters, respectively in good results in terms of yields, diastereo- and enantioselectivities.

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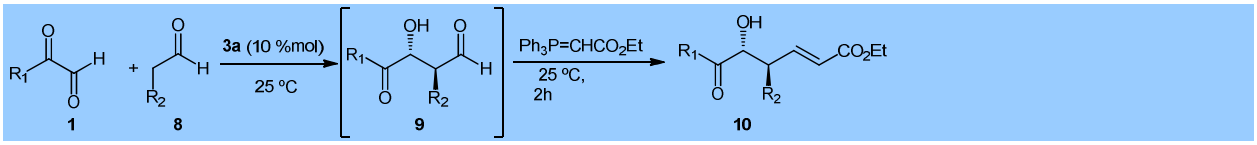

Scheme 2 Aldol reaction of glyoxals with aldehydes.

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Acknowledgment

This work was financially supported by the Ministerio de Economia y Competitividad (MINECO: Projects: CTQ2010-20387 and Consolider INGENIO CSD2007-0006), FEDER, the Generalitat Valenciana (Prometeo/2009/039, the University of Alicante and the EU (ORCA action CM0905). We thank to Dr. Rosa M. Ortiz for the synthesis of both enantiomers of [1,1'-binaphthalene]-2,2'-diamine.

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(16) Stereochemistry assigned by comparison of the optical rotation values of the literature, in reference 5a.

(17) To a mixture of the methylglyoxal (40% aqueous solution, 0.25 mmol, 0.038 mL) and catalyst (10 mol%) at the indicated temperature was added the corresponding ketone (1.25 mmol). The reaction was stirred until the methylglyoxal was consumed (monitored by TLC). The resulting residue was purified by chromatography (hexanes/AcOEt) to yield the pure aldol product. During purification aldols **7d-7f** undergo a slight epimerisation.

(18) To a mixture of the methylglyoxal (40% aqueous solution, 0.25 mmol, 0.038 mL) and catalyst (10 mol%) at the indicated temperature was added the corresponding aldehyde (0.5 mmol). The reaction was stirred until the methylglyoxal was consumed (monitored by TLC). Ph_3PCHCO_2Et (0.178 g, 0.5 mmol) was added and reaction mixture was stirred for 2 h. Upon completion, the reaction was quenched by passing through silica gel pad, and concentrated in vacuo. The resulting residue was purified by chromatography (hexanes/AcOEt) to yield the α,β-unsaturated ester.

(19) Arylglyoxals are important reagents for the synthesis of heterocyclic compounds. See, for instance: Eftekhari-Sis, B.; Zirak, M.; Akbari, A. *Chem. Rev.* **2013**, *113*, 2953.

(20) To a mixture of the phenylglyoxal monohydrate (0.25 mmol, 0.028 g) and catalyst (10 mol%) at the indicated temperature was added the corresponding aldehyde (0.5 mmol). The reaction was stirred until the phenylglyoxal was consumed (monitored by TLC). Ph_3PCHCO_2Et (0.178 g, 0.5 mmol) was added and reaction mixture was stirred for 2 h. Upon completion, the reaction was quenched by passing through silica gel pad, and concentrated in vacuo. The resulting residue was purified by chromatography (hexanes/AcOEt) to yield the α,β-unsaturated ester.

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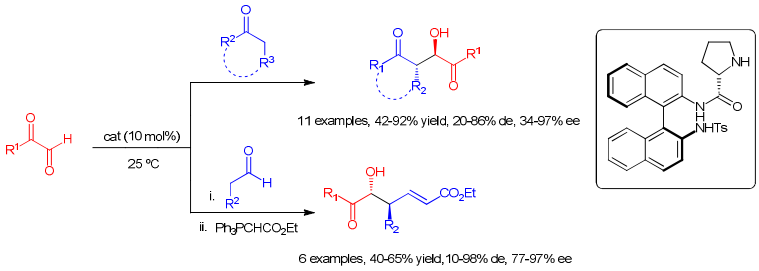
Binam-prolinamides catalyzed the aqueous aldol reaction of glyoxals.



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Supporting Information for:

Aqueous enantioselective aldol reaction of methyl- and phenylglyoxal organocatalyzed by *N*-Tosyl-(S_a)-binam-L-prolinamide.

Fernando J. N. Moles, Gabriela Guillena, Carmen Nájera**

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Table of Contents

1. General information: Catalysts **2** and **3** were prepared according to literature.[1] All the reagents were commercially available and used without further purification. ^{1}H NMR (300 MHz, 400 MHz) and ^{13}C NMR (75 MHz) spectra were obtained at 25 ºC using $CDCl_3$ as solvent and chemical shifts are reported as δ values relative to TMS as internal standard. IR spectra were obtained with Jasco 4100 LE (Pike Piracle ATR). High resolution mass spectra (HRMS-ESI) were obtained on a Waters LCT Premier XE apparatus equipped with a time of flight (TOF) analyzer and the samples were ionized by ESI techniques and introduced through an ultra-high pressure liquid chromatography (UPLC) model Waters ACQUITY H CLASS. Optical rotations were measured on a Jasco P-1030 Polarimeter with a 5 cm cell (c given in g/100 mL). HPLC analyses were performed on equipped with a chiral column and automatic injector, using mixtures of n-hexane/isopropyl alcohol (IPA) as mobile phase, at 25 ºC. Analytical TLC was performed on silica gel plates and the spots were visualized using $KMnO_4$ solution as revelator. For flash chromatography we employed silica gel 60 (0.040-0.063 mm).

2. General procedures for the aldol reaction

2.1 General procedure for the aldehyde-ketone aldol reaction using methylglyoxal 40% aqueous solution:

To a mixture of the methyl lyoxal 40% aqueous solution (0.25 mmol, 0.038 mL) and catalyst (10 mol%) at the indicated temperature was added the corresponding ketone (1.25 mmol). The reaction was stirred until the methylglyoxal was consumed (monitored by TLC). The resulting residue was purified by chromatography (hexanes/AcOEt) to yield the pure aldol product. During purification the aldols **7d**, **7e**and **7f** undergo an epimerisation and therefore the diastereoselectivities of the crude ^{1}H-RMN is different than the one showed in the ^{1}H NMR spectra.

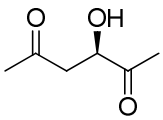
2.2 General procedure for the aldehyde-aldehyde aldol reaction using methylglyoxal 40% aqueous solution:

To a mixture of the methylglyoxal 40% aqueous solution (0.25 mmol, 0.038 mL) and catalyst (10 mol%) at the indicated temperature was added the corresponding aldehyde (0.5 mmol). The reaction was stirred until the methylglyoxal was consumed (monitored by TLC). Wittig Reagent (0.178 g, 0.5 mmol) was added and reaction mixture was stirred for 2 h. Upon completion, the Witting reaction was quenched by passing through silica gel pad, and concentrated in vacuo. The resulting residue was purified by chromatography (hexanes/AcOEt) to yield the □,□-unsaturated ester.

2.3 General procedure for the aldehyde-aldehyde aldol reaction using phenylglyoxal monohidrate:

To a mixture of the phenylglyoxal monohidrate (0.25 mmol, 0.028 g) and catalyst (10 mol%) at the indicated temperature was added the corresponding aldehyde (0.5 mmol). The reaction was stirred until the phenylglyoxal was consumed (monitored by TLC). Wittig Reagent (0.178 g, 0.5 mmol) was added and reaction mixture was stirred for 2 h. Upon completion, the Witting reaction was quenched by passing through silica gel pad, and concentrated in vacuo. The resulting residue was purified by chromatography (hexanes/AcOEt) to yield the □,□ -unsaturated ester.

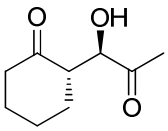
3. Spectra data of aldol products



7a

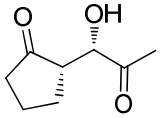
(*R*)-3-hydroxyhexane-2,5-dione (7a).[2] Yellow oil. (0.029 g, 90%); $[\alpha]^{26}_{D}$ = - 17 (*c*= 0.9; $CHCl_3$); R_f= 0.38 (Hex/EtOAc 1:1, revealed with $KMnO_4$). IR: ν 3423.0 (OH), 1721.6 (C=O), 1707.7 (C=O), 1357.6 (CH_2-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.36 (dd, *J* = 6.4, 3.8 Hz, 1 H,

CHOH), 3.00 (dd, *J* = 17.3, 3.8 Hz, 1 H, CH_aH_b-CHOH), 2.87 (dd, *J* = 17.3, 6.4 Hz, 1 H, CH_aH_b-CHOH), 2.28 (s, 3 H, CH_3), 2.24 (s, 3 H, CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 209.2 (C), 207.1 (C), 73.8 (CH), 46.1 (CH_2), 30.8 (CH_3), 25.4 (CH_3). MS (IE) m/z (%) for $C_6H_{10}O_3$: M^+ = 130 (2), 112 (3), 97 (6), 87 (100), 70 (10), 55 (11).



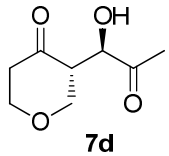
7b

(*S*)-2-((*R*)-1-hydroxy-2-oxopropyl)cyclohexanone (7b). Data for the isomer (2*S*,1'*R*). Yellow oil. (0.034 g, 80%); $[\alpha]^{26}_D$ = -29 (*c*= 0.5; $CHCl_3$); R_f= 0.43 (Hex/EtOAc 7:3, revealed with $KMnO_4$). IR: ν 3460.6 (OH), 1733.69 (C=O), 1703.8 (C=O), 1421.3 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.87 (dd, *J* = 7.9, 3.0 Hz, 1 H, CHOH), 3.56 (d, *J* = 7.9 Hz, 1 H, OH), 3.15 - 3.03 (m, 1 H, H_{cyclo}), 2.51 - 2.32 (m, 2 H, H_{cyclo}), 2.30 (s, 3 H, CH_3), 2.20 - 2.06 (m, 2 H, H_{cyclo}), 2.06 - 1.65 (m, 4 H, H_{cyclo}). ^{13}C NMR (75 MHz, $CDCl_3$): δ 212.3 (C), 210.0 (C), 77.9 (CH), 53.7 (CH), 42.0 (CH_2), 30.3 (CH_2), 26.9 (CH_2), 25.7 (CH_3), 24.8 (CH_2). HRMS calculated for $C_9H_{14}O_3$: 170.0943 found: 171.1020 (M^+ + H, calculated 171.1021).



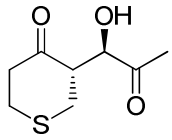
7c

(*S*)-2-((*S*)-1-hydroxy-2-oxopropyl)cyclopentanone (7c).[3] As a diastereoisomer mixture (22:78, *anti:syn*). Yellow oil. (0.031 g, 79%); $[\alpha]^{26}_D$ = -35 (*c*= 2 ; $CHCl_3$); R_f= 0.54 (Hex/EtOAc 1:1, revealed with $KMnO_4$). IR: ν 3455.8 (OH), 1733.7 (C=O), 1710.5 (C=O), 1402.9 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.71 (dd, *J* = 4.8, 2.3 Hz, 1 H, *syn*), 4.12 (dd, *J* = 3.6, 3.4 Hz, 1 H, *anti*), 3.87 (d, *J* = 3.6 Hz, 1 H, *anti*), 3.54 (d, *J* = 4.8 Hz, 1 H, *syn*), 2.81 - 2.71 (m, 1 H, H_{cyclo}, *anti*), 2.58 - 2.48 (m, 1 H, H_{cyclo}, *syn*), 2.27 (s, 3 H, CH_3, *anti*), 2.22 (s, 3 H, CH_3, *syn*), 2.20 - 1.98 (m, 6 H, H_{cyclo}), 1.90 - 1.67 (m, 6 H, H_{cyclo}). ^{13}C NMR (75 MHz, $CDCl_3$): δ 218.5 (C), 217.8 (C), 208.7 (C), 207.9 (C), 76.3 (CH), 75.5 (CH), 51.4 (CH), 50.6 (CH), 38.7 (CH_2), 38.3 (CH_2), 26.3 (CH_2), 25.3 (CH_3), 25.1 (CH_3), 21.7 (CH_2), 21.0 (CH_2), 20.6 (CH_2). MS (IE) m/z (%) for $C_8H_{12}O_4$: M^+ = 156 (2), 138 (3), 113 (100), 96 (30), 85 (40), 67 (84), 57 (28).



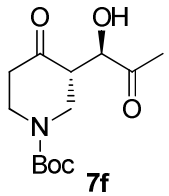
7d

(*S*)-3-((*R*)-1-hydroxy-2-oxopropyl)dihydro-2*H*-pyran-4(3*H*)-one (7d). As a diastereoisomer mixture (89:11, *anti:syn*). Yellow oil. (0.035 g, 81%); $[\alpha]^{26}_{D}$ = -38 (*c*= 1.5 ; $CHCl_3$); R_f= 0.26 (Hex/EtOAc; 1:1, revealed with $KMnO_4$). IR: ν 3449.1 (OH), 1769.6 (C=O), 1712.5 (C=O), 1373.1 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$, diastereomer mixture (1:1)): δ 4.70 (dd, *J* = 5.4, 3.1 Hz, 1 H, CHOH, *syn*), 4.35 (dd, *J* = 11.3, 6.8 Hz, 1 H, H_{cyclo}), 4.29 - 4.18 (m, 2 H, H_{cyclo}), 4.03 (dd, *J* = 11.3, 6.7 Hz, 1 H, H_{cyclo}), 3.90 - 3.65 (m, 6 H, H_{cyclo}), 3.43 (d, *J* = 5.5 Hz, 1 H, OH), 3.26 (ddd, *J* = 10.9, 6.8, 2.9 Hz, 1 H, H_{cyclo}), 3.02 (ddd, *J* = 10.7, 6.7, 3.1 Hz, 1 H, H_{cyclo}), 2.75 - 2.56 (m, 2 H, H_{cyclo}), 2.52 - 2.34 (m, 2 H, H_{cyclo}), 2.26 (s, 3 H, CH_3), 2.25 (s, 3 H, CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 209.3 (C), 207.8 (C), 206.4 (C), 206.1 (C), 74.6 (CH), 73.7 (CH), 70.0 (CH_2), 67.7 (CH_2), 67.6 (CH_2), 67.5 (CH_2), 53.6 (CH), 53.2 (CH), 42.3 (CH_2), 42.2 (CH_2), 26.1 (CH_3), 25.2 (CH_3). HRMS calculated for $C_8H_{12}O_4$: 172.0736 found: 173.0814 (M^+ + H, calculated 173.0814).



7e

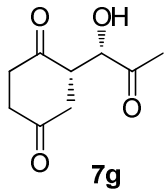
(*S*)-3-((*R*)-1-hydroxy-2-oxopropyl)dihydro-2*H*-thiopyran-4(3*H*)-one (7e). Colorless oil. Data for the isomer (2*S*,1'*R*). (0.034 g, 72%); $[\alpha]^{26}_{D}$ = -14 (*c*= 1 ; $CHCl_3$); R_f= 0.33 (Hex/EtOAc 1:1, revealed with $KMnO_4$); IR: ν 3413.4 (OH), 1715.5 (C=O), 1704.8 (C=O), 1419.3 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.93 (dd, *J* = 7.3, 2.8 Hz, 1 H, CHOH), 3.60 (d, *J* = 7.4 Hz, 1 H, OH), 3.46 - 3.36 (m, 1 H, H_{cyclo}), 3.29 - 2.75 (m, 6 H, H_{cyclo}), 2.29 (s, 3 H, CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 208.9 (C), 208.2 (C), 77.8 (CH), 55.8 (CH), 44.2 (CH_2), 32.5 (CH_2), 29.5 (CH_2), 25.4 (CH_3). HRMS calculated for $C_8H_{12}O_3S$: 188.0507 found: 189.0583 (M^+ + H, calculated 189.0585).



7f

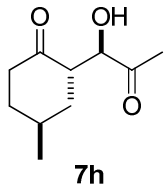
(*S*)- *tert*-butyl 3-((*R*)-1-hydroxy-2-oxopropyl)-4-oxopiperidine-1-carboxylate (7f). As a diastereomer mixture (93:7, *anti:syn*). Colorless oil. (0.064 g, 95%); $[\alpha]^{26}_{D}$ = -34 (*c*= 0.7 ; $CHCl_3$);

R_f= 0.55 (Hex/EtOAc; 1:1, revealed with $KMnO_4$). IR: ν 3390.2 (OH), 1791.6 (C=O), 1691.3 (C=O), 1419.3 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$, diastereoisomer mixture 1:1): δ 4.70 (dd, *J* = 4.9, 2.9 Hz, 1 H, CHOH, *syn*), 3.93 (dd, *J* = 6.2, 2.7 Hz, 1 H, CHOH, *anti*), 3.75 - 3.62 (m, 1 H, H_{cyclo}), 3.49 - 3.09 (m, 6 H, H_{cyclo}), 2.87 (ddd, *J* = 10.6, 6.2, 2.9 Hz, 1 H, H_{cyclo}), 2.63 - 2.38 (m, 6 H, H_{cyclo}), 2.30 (s, 3 H, CH_3, *anti*), 2.29 (s, 3 H, CH_3, *syn*), 1.52 (s, 9 H, $C(CH_3)_3$, *anti*), 1.50 (s, 9 H, $C(CH_3)_3$, *syn*). ^{13}C NMR (75 MHz, $CDCl_3$): δ 209.0 (C), 207.7 (C), 207.5 (C), 207.0 (C), 154.6 (C), 154.5 (C), 80.8 (2xC), 75.6 (CH), 74.6 (C), 52.4 (CH), 52.0 (CH), 45.3 (2xCH_2), 42.9 (CH_2), 42.7 (CH_2), 40.8 (2xCH_2), 28.3 (6xCH_3), 25.9 (CH_3), 25.2 (CH_3). HRMS calculated for $C_{13}H_{21}NO_5$: 271.1421 found: 294.1322 (M^+ + H, calculated 294.1317).



7g

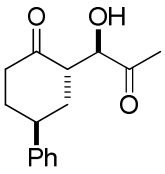
(*S*)-2-((*S*)-1-hydroxy-2-oxopropyl)cyclohexane-1,4-dione (7g). As a diastereoisomer mixture (40:60, *anti:syn*). Yellow oil. (0.032 g, 70%); $[\alpha]^{26}_D$ = -20 (*c*= 0.6 ; $CHCl_3$); R_f= 0.18 (Hex/EtOAc; 1:1, revealed with $KMnO_4$). IR: ν 3427.8 (OH), 1720.9 (C=O), 1703.8 (C=O), 1310.4 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.84 (dd, *J* = 4.8, 2.0 Hz, 1 H, CHOH, *syn*), 3.98 (dd, *J* = 4.3, 2.5 Hz, 1 H, CHOH, *anti*), 3.82 (d, *J* = 4.3 Hz, 1 H, OH, *anti*), 3.60 (d, *J* = 4.8 Hz, 1 H, OH, *syn*), 3.36 (ddd, *J* = 10.2, 6.4, 2.5 Hz, 1 H, H_{cyclo}), 3.16 - 3.03 (m, 2 H, H_{cyclo}), 2.91 - 2.61 (m, 11 H, H_{cyclo}), 2.35 (s, 3 H, CH_3, *anti*), 2.27 (s, 3 H, *syn*). ^{13}C NMR (75 MHz, $CDCl_3$): δ 208.1 (C), 207.9 (2xC), 207.3 (C), 207.0 (C), 206.5 (C), 77.7 (CH), 77.2 (CH), 48.9 (CH), 48.1 (CH), 41.3 (CH_2), 37.2 (CH_2), 37.1 (CH_2), 36.7 (CH_2), 35.9 (CH_2), 35.8 (CH_2), 25.4 (CH_3), 25.1 (CH_3). HRMS calculated for $C_9H_{12}O_4$: 184.0736 found: 185.0816 (M^+ + H, calculated 185.0814).



7h

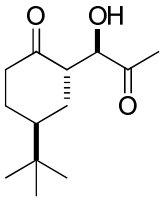
(2*S*,4*S*)-2-((*R*)-1-hydroxy-2-oxopropyl)-4-methylcyclohexanone (7h). As a diastereoisomer mixture (87:7:4:2). Colorless oil. (0029 g, 78%); $[\alpha]^{26}_D$ = -70 (*c*= 3.2 ; $CHCl_3$); R_f= 0.64 (Hex/EtOAc; 1:1, revealed with $KMnO_4$). IR: ν 3450.0 (OH), 1736.5 (C=O), 1708.6 (C=O), 1239.0 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.66 (dd, *J* = 4.8, 2.3 Hz, 1 H, CHOH, *syn*), 3.87 (dd, *J*

= 7.2, 3.1 Hz, 1 H, CHOH, *anti*), 3.58 (d, *J* = 7.2 Hz, 1 H, OH, *anti*), 3.27 (d, *J* = 4.8 Hz, 1 H, *syn*), 3.22 - 3.12 (m, 1 H, H_{cyclo}), 2.92 - 2.82 (m, 1 H, H_{cyclo}), 2.54 - 2.36 (m, 2 H, H_{cyclo}), 2.33 - 2.08 (m, 10 H, H_{cyclo}), 2.05 - 1.63 (m, 8 H, H_{cyclo}), 1.18 (d, *J* = 7.0 Hz, 3 H, $CHCH_3$, *anti*), 1.00 (d, *J* = 6.4 Hz, 3 H, $CHCH_3$, *syn*). ^{13}C NMR (75 MHz, $CDCl_3$): δ 212.6 (C), 211.6 (C), 210.4 (C), 209.6 (C), 78.5 (CH), 75.3 (CH), 52.1 (CH), 49.1 (CH), 41.2 (CH_2), 38.1 (CH_2), 36.1 (CH_2), 34.7 (CH_2), 34.3 (CH_2), 32.2 (CH_2), 31.3 (CH), 26.8 (CH), 26.4 (CH_3), 25.7 (CH_3), 21.3 (CH_3), 18.5 (CH_3). HRMS calculated for $C_{10}H_{16}O_3$: 184.1099 found: 185.1184 (M^+ + H, calculated 185.1178).



7i

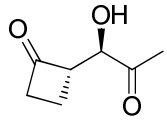
(2*S*,4*S*)-2-((*R*)-1-hydroxy-2-oxopropyl)-4-phenylcyclohexanone (7i). As a diastereoisomer mixture (68:29:2:1). Colorless oil. (0041 g, 67%); $[\alpha]^{26}_D$ = -19 (*c*= 2.3 ; $CHCl_3$); R_f= 0.61 (Hex/EtOAc; 1:1, revealed with $KMnO_4$). IR: ν 3439.4 (OH), 1710.1 (C=O), 1704.7 (C=O), 1102.1 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.41 - 7.21 (m, 5 H, ArH), 4.75 (dd, *J* = 4.8, 2.3 Hz, 1 H, CHOH, *syn*), 4.08 (dd, *J* = 5.8, 3.1 Hz, 1 H, CHOH, *anti*), 3.75 (d, *J* = 5.8 Hz, 1 H, OH, *anti*), 3.49 - 3.40 (m, 1 H, H_{cyclo}), 3.33 (d, *J* = 4.9 Hz, 1H, OH, *syn*), 3.21 - 3.03 (m, 2 H, H_{cyclo}), 2.67 - 2.38 (m, 5 H, H_{cyclo}), 2.36 - 1.79 (m, 14 H, H_{cyclo}). ^{13}C NMR (75 MHz, $CDCl_3$): δ 211.8 (C), 210.3 (C), 210.2 (C), 208.5 (C), 144.2 (C), 143.6 (C), 128.8 (CH), 128.7 (2xCH), 126.8 (CH), 126.7 (3xCH), 126.5 (C), 79.2 (CH), 75.4 (CH), 52.5 (CH), 49.9 (CH), 42.6 (CH), 41.5 (CH_2), 39.9 (CH_2), 37.2 (CH), 35.4 (CH_2), 33.9 (CH_2), 33.5 (CH_2), 30.6 (CH_2), 26.5 (CH_3), 25.6 (CH_3). HRMS calculated for $C_{15}H_{18}O_3$: 246.1256 found: 247.1342 (M^+ + H, calculated 247.1334).



7j

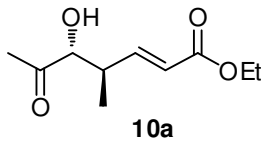
(2*S*,4*S*)-4-(*tert*-butyl)-2-((R)-1-hydroxy-2-oxopropyl)cyclohexanone (7j). As a diastereoisomer mixture (54:32:10:4). Colorless oil. (0041 g, 74%); $[\alpha]^{26}_D$ = -87 (*c*= 3.6 ; $CHCl_3$); R_f= 0.69 (Hex/EtOAc; 1:1, revealed with $KMnO_4$). IR: ν 3453.9 (OH), 1745.2 (C=O), 1708.6 (C=O), 1240.0 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.68 (dd, *J* = 4.9, 2.4 Hz, 1 H, CHOH, *syn*), 4.03 (dd, *J*

= 6.3, 3.4 Hz, 1 H, CHOH, *anti*), 3.67 (d, *J* = 6.3 Hz, 1 H, OH, *anti*), 3.31 (d, *J* = 4.9 Hz, 1 H, OH, *syn*), 3.06 (td, *J* = 7.9, 3.4 Hz, 1 H, H_{cyclo}), 2.51 - 2.38 (m, 2 H, H_{cyclo}), 2.30 (s, 3 H, CH_3, *anti*), 2.24 (s, 3 H, CH_3, *syn*), 2.13 - 1.47 (m, 11 H, H_{cyclo}), 0.93 (s, 9 H, $C(CH_3)_3$, *anti*), 0.90 (s, 9 H, $C(CH_3)_3$, *syn*). ^{13}C NMR (75 MHz, $CDCl_3$): □ 214.1 (C), 211.4 (C), 210.3 (C), 209.0 (C), 78.7 (CH), 75.6 (CH), 52.4 (CH), 49.7 (CH), 46.4 (CH), 42.6 (CH), 41.3 (CH_2), 40.1 (CH_2), 33.0 (C), 32.6 (C), 27.5 (3xCH_3), 27.4 (CH_2), 27.3 (CH_3), 27.0 (3xCH_3), 26.4 (CH_3), 25.7 (CH_3), 23.5 (2xCH_2). HRMS calculated for $C_{13}H_{22}O_3$: 226.1569 found: 227.1638 (M^+ + H, calculated 227.1647).



7k

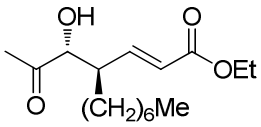
(*S*)-2-((*R*)-1-hydroxy-2-oxopropyl)cyclobutanone (7k).[4] As a diastereoisomer mixture (63:37, *anti:syn*). Colorless oil. (0.015 g, 42%); $[\alpha]^{26}_D$ = -20 (*c*= 1.2 ; $CHCl_3$); R_f= 0.46 (Hex/EtOAc 1:1, revealed with $KMnO_4$); IR: ν 3445.2 (OH), 1776.1 (C=O), 1711.5 (C=O), 1417.4 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$, diastereoisomer mixture 1:1): δ 4.62 (dd, *J* = 3.6, 3.2 Hz, 1 H, CHOH, *syn*), 4.21 (dd, *J* = 3.8, 3.4 Hz, 1 H, CHOH, *anti*), 3.88 - 3.62 (m, 4 H, H_{cyclo}), 3.15 2.94 (m, 4 H, H_{cyclo}), 2.29 (s, 3 H, CH_3, *anti*), 2.22 (s, 3 H, CH_3, *syn*), 1.97 (dd, *J* = 16.9, 8.5 Hz, 2 H, H_{cyclo}). ^{13}C NMR (75 MHz, $CDCl_3$): δ 208.1 (C), 207.5 (C), 207.1 (C), 206.5 (C), 75.2 (CH), 74.1 (CH), 61.3 (2xCH), 46.7 (CH_2), 46.1 (CH_2), 25.4 (CH_3), 25.0 (CH_3), 13.6 (CH_2), 10.6 (CH_2). MS (IE) m/z (%) for $C_7H_{10}O_3$: M^+ = 142 (2), 124 (10), 99 (34), 86 (24), 71 (80), 57 (100).



10a

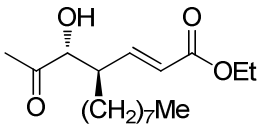
(4*R*,5*R*,*E*)-ethyl 5-hydroxy-4-methyl-6-oxohept-2enoato (10a).[5] As a diastereoisomer mixture (76:24, *anti:syn*). Colorless oil. (0.020 g, 40%); $[\alpha]^{26}_D$ = -15 (*c*= 0.6 ; $CHCl_3$); R_f= 0.20 (Hex/EtOAc; 85:15, revealed with $KMnO_4$). IR: ν 3326.6 (OH), 1715.4 (C=O), 1665.2 (C=O), 1226.5 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.06 (dd, *J* = 15.8, 7.1 Hz, 1 H, CH=CH, *syn*), 6.80 (dd, *J* = 15.8, 8.2 Hz, 1 H, CH=CH, *anti*), 5.93 (dd, *J* = 15.8, 1.4 Hz, 1 H, CH=CH, *syn*), 5.84 (dd, *J* = 15.8, 1.2 Hz, 1 H, CH=CH, *syn*), 4.27 (dd, *J* = 4.6, 2.8 Hz, 1 H, CHOH, *syn*), 4.24 - 4.12 (m, 5 H), 3.58 (d, *J* = 4.7 Hz, 1 H, OH, *anti*), 3.52 (d, *J* = 4.9 Hz, 1 H, OH, *syn*), 2.98 - 2.79 (m, 2 H), 2.25 (s, 3 H, CH_3, *syn*), 2.20 (s, 3 H, CH_3, *anti*), 1.32 - 1.24 (m, 9 H), 0.95 (d, *J* = 6.9 Hz, 3 H, $CHCH_3$, *syn*).^{13}C NMR (75 MHz, $CDCl_3$): δ 208.2 (C), 208.0 (C), 166.3 (C), 165.9 (C), 149.4 (CH),

146.6 (CH), 122.8 (CH), 121.9 (CH), 80.1 (CH), 79.0 (CH), 60.5 (CH_2), 60.4 (CH_2), 39.8 (CH), 39.2 (CH), 25.8 (CH_3), 25.6 (CH_3), 16.7 (CH_3), 14.2 (2xCH_3), 12.0 (CH_3). MS (IE) m/z (%) for $C_{10}H_{16}O_4$: M^+ = 200 (2), 182 (3), 157 (40), 128 (38), 111 (100), 100 (35), 83 (28), 55 (42).



10b

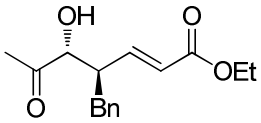
(*R*,*E*)-ethyl 4-((*R*)-1-hydroxy-2-oxopropyl)undec-2-enoate (10b). As a diastereoisomer mixture (99:1, *anti:syn*). Colorless oil. (0.046 g, 65%); $[\alpha]^{26}_D$ = -56 (*c*= 1.2 ; $CHCl_3$); R_f= 0.23 (Hex/EtOAc; 85:15, revealed with $KMnO_4$). IR: ν 3463.5 (OH), 1715.4 (C=O), 1653.7 (C=O), 1231.3 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.72 (dd, *J* = 15.8, 9.7 Hz, 1 H, CHCH), 5.81 (dd, *J* = 15.8, 0.7 Hz, 1 H, CHCH), 4.27 (dd, *J* = 4.5, 2.4 Hz, 1 H, CHOH), 4.18 (q, *J* = 7.1 Hz, 2 H, O$CH_2$$CH_3$), 3.55 (d, *J* = 4.5 Hz, 1 H, OH), 2.71 - 2.57 (m, 1 H), 2.20 (s, 3 H, CH_3), 1.79 - 1.62 (m, 2 H), 1.42 - 1.18 (m, 13 H), 0.90 (t, *J* = 6.7 Hz, 3 H, CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 208.0 (C), 165.7 (C), 145.7 (CH), 123.5 (C), 79.0 (CH), 60.5 (CH_2), 45.6 (CH), 31.8 (CH_2), 31.5 (CH_2), 29.4 (CH_2), 29.2 (CH_2), 27.3 (CH_2), 25.4 (CH_3), 22.6 (CH_2), 14.2 (CH_3), 14.1 (CH_3). HRMS calculated for $C_{16}H_{28}O_4$: 284.1988 found: 285.2072 (M^+ + H, calculated 285.2066).



10c

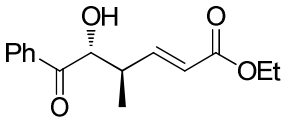
(*R*,*E*)-ethyl 4-((*R*)-1-hydroxy-2-oxopropyl)dodec-2-enoate (10c). As a diastereoisomer mixture (98:2, *anti:syn*). Colorless oil. (0.042 g, 57%); $[\alpha]^{26}_D$ = -50 (*c*= 1.4 ; $CHCl_3$); R_f= 0.22 (Hex/EtOAc; 85:15, revealed with $KMnO_4$). IR: ν 3463.5 (OH), 1713.4 (C=O), 1642.0 (C=O), 1367.3 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.72 (dd, *J* = 15.8, 9.7 Hz, 1 H, CHCH), 5.81 (dd, *J* = 15.8, 0.6 Hz, 1 H, CHCH), 4.27 (d, *J* = 2.4 Hz, 1 H, CHOH), 4.18 (q, *J* = 7.1 Hz, 2 H, O$CH_2$$CH_3$), 2.71 - 2.57 (m, 1 H), 2.20 (s, 3 H, CH_3), 1.78 - 1.56 (m, 2 H), 1.41 - 1.19 (m, 15 H), 0.90 (t, *J* = 6.7 Hz, 3 H, CH_3). ^{13}C NMR (75 MHz, $CDCl_3$, diastereoisomer mixture 1:1): δ 208.5 (C), 208.1 (C), 166.2 (C), 165.8 (C), 148.5 (CH), 145.8 (CH), 79.6 (CH), 79.0 (CH), 60.5 (2xCH_2), 45.6 (CH_3), 45.5 (CH_3), 33.9 (CH_2), 31.8 (2xCH_2), 31.4 (CH_2), 29.5 (CH_2), 29.4 (2xCH_2), 29.2 (2xCH_2), 29.1 (CH_2), 27.4 (CH_2), 27.3 (CH_2), 25.9 (CH_3), 25.4 (CH_3), 24.7 (CH_2), 22.6 (CH_2), 14.2 (CH_3),

14.1 (CH_3). HRMS calculated for $C_{17}H_{30}O_4$: 298.2144 found: 299.2243 (M^+ + H, calculated 299.2222).



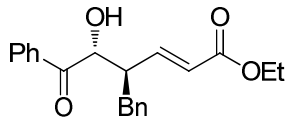
10d

(4*R*,5*R*,*E*)-ethyl 4-benzyl-5-hidroxy-6-oxohept-2-enoate (10d).[5] As a diastereoisomer mixture (99:1, *anti:syn*). Colorless oil. (0.033 g, 48%); $[\alpha]^{26}_D$ = -42 (*c*= 1.5 ; $CHCl_3$); R_f= 0.15 (Hex/EtOAc; 80:20, revealed with $KMnO_4$). IR: ν 3414.3 (OH), 1712.9 (C=O), 1709.6 (C=O), 1132.1 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.38 -7.22 (m, 5 H, ArH), 6.81 (dd, *J* = 15.8, 9.0 Hz, 1 H, CH=CH), 5.81 (d, *J* = 15.8 Hz, 1 H, CH=CH), 4.29 - 4.14 (m, 2 H), 4.11 (dd, *J* = 4.5, 2.0 Hz, 1 H, CHOH), 3.60 (d, *J* = 4.4 Hz, 1 H, OH), 3.14 - 2.68 (m, 3 H), 2.11 (s, 3 H, CH_3), 1.29 (t, *J* = 7.1 Hz, 3 H, CH_3). ^{13}C NMR (75 MHz, $CDCl_3$, diastereoisomer mixture (1:1)): δ 208.2 (2xC), 166.0 (C), 165.6 (C), 147.6 (CH), 144.8 (CH), 138.4 (2xC), 138.2 (2xC), 129.3 (CH), 128.7 (CH), 128.5 (2xCH), 128.3 (2xCH), 126.7 (2xCH), 126.4 (2xCH), 123.8 (CH), 123.1 (CH), 79.0 (CH), 77.2 (CH), 60.5 (2xCH_2), 47.3 (2xCH), 34.3 (CH_2), 30.6 (CH_2), 25.7 (CH_3), 25.2 (CH_3), 14.2 (CH_3), 14.1 (CH_3). MS (IE) m/z (%) for $C_{16}H_{20}O_4$: M^+ = 276 (2), 258 (8), 233 (16), 203 (28), 187 (27), 129 (37), 91 (100).



10e

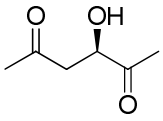
(4*R*,5*R*,*E*)-ethyl 5-hydroxy-4-methyl-6-oxo-6-phenylhex-2-enoate (10e). As a diastereoisomer mixture (61:39, *anti:syn*). Colorless oil. (0.035 g, 53%); $[\alpha]^{26}_D$ = -12 (*c*= 1.2 ; $CHCl_3$); R_f= 0.30 (Hex/EtOAc; 70:30, revealed with $KMnO_4$). IR: ν 3439.4 (OH), 1708.6 (C=O), 11692.2 (C=O), 1269.9 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.98 - 7.88 (m, 2 H, ArH), 7.73 - 7.50 (m, 3 H, ArH), 7.15 (dd, *J* = 15.7, 7.4 Hz, 1 H, CH=CH), 5.94 (dd, *J* = 15.7, 1.4 Hz, 1 H, CH=CH), 5.20 (dd, *J* = 6.4, 2.4 Hz, 1 H, CHOH), 4.22 (q, *J* = 7.1 Hz, 2 H, O$CH_2$$CH_3$), 3.78 (d, *J* = 6.4 Hz, 1 H, OH), 2.91 - 2.78 (m, 1 H), 1.32 (t, *J* = 7.1 Hz, 3 H, OCH_2CH3), 0.87 (d, *J* = 6.8 Hz, 3 H, CHCH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 200.6 (C), 166.3 (C), 149.8 (CH), 134.3 (CH), 133.5 (C), 129.1 (2xCH), 128.5 (2xCH), 121.7 (CH), 75.0 (CH), 60.4 (CH_2), 40.7 (CH), 14.3 (CH_3), 11.5 (CH_3). HRMS calculated for $C_{15}H_{18}O_4$: 262.1205 found: 285.1111 (M^+ + H, calculated 285.1103).



10f

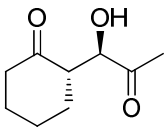
(4*R*,5*R*,*E*)-ethyl 4-benzyl-5-hydroxy-6-oxo-phenylhex-2-enoate (10f). As a diastereoisomer mixture (55:45, *anti:syn*). Colorless oil. (0.044 g, 52%); $[\alpha]^{26}_{D}$ = -18 (*c*= 0.4 ; $CHCl_3$); R_f= 0.35 (Hex/EtOAc; 70:30, revealed with $KMnO_4$). IR: ν 3452.8 (OH), 1711.5 (C=O), 1656.7 (C=O), 1249.1 (CH_3-C=O). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.65 - 7.28 (m, 10 H, ArH), 6.77 (dd, *J* = 15.8, 8.8 Hz, 1 H, CH=CH), 5.47 (dd, *J* = 15.8, 0.7 Hz, 1 H, CH=CH), 4.99 (dd, *J* = 6.0, 1.4 Hz, 1 H, CHOH), 4.14 (q, *J* = 7.1 Hz, 2 H, OCH_2CH_3), 3.72 (d, *J* = 6.1 Hz, 1 H, OH), 3.15 - 2.83 (m, 3 H), 1.26 (t, *J* = 7.1 Hz, 3 H, OCH_2CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 200.7 (C), 165.7 (C), 144.7 (CH), 138.6 (C), 134.1 (CH), 133.4 (C), 129.5 (2xCH), 128.9 (2xCH), 128.8 (2xCH), 128.3 (2xCH), 126.8 (CH), 123.8 (CH), 73.0 (CH), 60.5 (CH_2), 48.8 (CH), 37.7 (CH_2), 14.2 (CH_3). HRMS calculated for $C_{21}H_{22}O_4$: 338.1518 found: 339.1600 (M^+ + H, calculated 339.1596).

HPLC data for aldol products



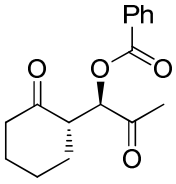
7a

The ee was determined by chiral GC analysis with a CP CHIRALSIL DEX CB column (80 ºC, 13.4 Psi), R_t = 34.6 min (major), R_t = 39.6 min (minor).



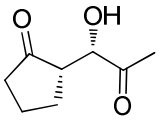
7b

The ee was determined as the benzoate ester.



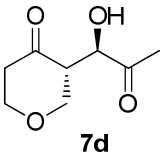
7b*

The ee was determined by chiral HPLC on Chiralpak OD-H column (99% hexane, 1% Pr^iOH, 25ºC, 1 mL/min, 230 nm, R_t= 12.8 min (minor *syn*), R_t = 14.9 min (major *syn*), R_t = 16.1 min (major *anti*), R_t = 22.3 min (minor *anti*).



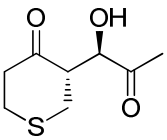
7c

The ee was determined by chiral GC analysis with a CP CHIRALSIL DEX CB column (120 ºC, 13.4 Psi), R_t = 21.3 min (major *anti*), R_t = 22.8 min (minor *anti*), R_t = 26.4 min (major *syn*), R_t = 31.8 min (minor *syn*).



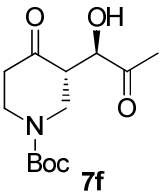
7d

The ee was determined by chiral GC analysis with a CP CHIRALSIL DEX CB column (150 ºC, 13.4 Psi), R_t = 8.8 min (major *anti*), R_t = 9.7 min (minor *anti*), R_t = 10.3 min (major *syn*), R_t = 11.0 min (minor *syn*).



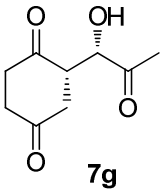
7e

The ee was determined by chiral GC analysis with a CP CHIRALSIL DEX CB column (130 ºC, 13.4 Psi), R_t = 67.0 min (major *anti*), R_t = 70.7 min (minor *anti*), R_t = 72.5 min (major *syn*), R_t = 79.2 min (minor *syn*).



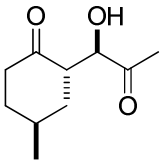
7f

The ee was determined by chiral HPLC on Chiralpak IA column (95% hexane, 5% Pr^{i}OH, 25ºC, 1 mL/min, 230 nm, R_t= 17.7 min (minor *syn*), R_t = 18.8 min (major *anti*), R_t = 20.3 min (minor *anti*), R_t = 22.1 min (minor *syn*).



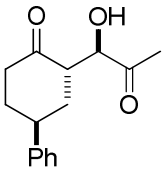
7g

The ee was determined by chiral GC analysis with a CP CHIRALSIL DEX CB column (140 ºC, 13.4 Psi), R_t = 60.2 min (major *syn*), R_t = 62.9 min (minor *syn*), R_t = 69.9 min (major *anti*), R_t = 71 min (minor *anti*).



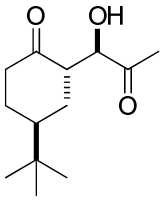
7h

The ee was determined by chiral GC analysis with a CYCLOHEXIL β column (130 ºC, 13.4 Psi), R_t = 42.9 min (major), R_t = 45.5 min (minor).



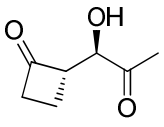
7i

The ee was determined by chiral HPLC on AD-H column (95% hexane, 5% Pr^{i}OH, 25ºC, 1 mL/min, 230 nm, R_t= 22.2 min (minor), R_t= 24.8 min (major).



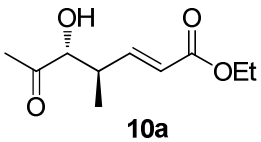
7j

The ee was determined by chiral GC analysis with a CYCLOHEXIL β column (165 ºC, 13.4 Psi), R_t = 27.8 min (major), R_t = 29.0 min (minor).



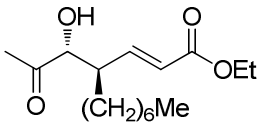
7k

The ee was determined by chiral GC analysis with a CP CHIRALSIL DEX CB column (130 ºC, 13.4 Psi), R_t = 9.1 min (major *anti*), R_t = 9.8 min (minor *anti*), R_t = 11.1 min (major *syn*), R_t = 12.9 min (minor *syn*).



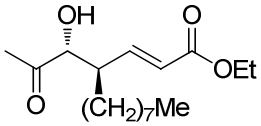
10a

The ee was determined by chiral GC analysis with a LIPODEX E column (145 ºC, 13.4 Psi), R_t = 47.6 min (minor *anti*), R_t = 50.0 min (major *anti*), R_t = 55.4 min (*syn*).



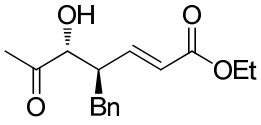
10b

The ee was determined by chiral HPLC on Chiralpak IA column (97% hexane, 3% Pr^{i}OH, 25ºC, 0.3 mL/min, 230 nm, R_t = 36.0 min (minor *syn*), R_t = 37.6 min (major *syn*), R_t = 39.6 min (major *anti*), R_t = 46.5 min (minor *anti*).



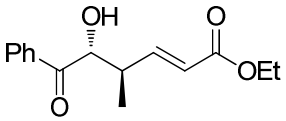
10c

The ee was determined by chiral HPLC on Chiralpak IA column (95% hexane, 5% Pr^{i}OH, 25ºC, 0.5 mL/min, 230 nm, R_t = 7.0 min (major *syn*), R_t = 7.3 min (minor *syn*), R_t = 7.7 min (major *anti*), R_t = 8.7 min (minor *anti*).



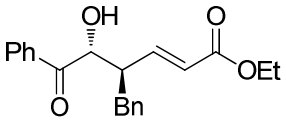
10d

The ee was determined by chiral HPLC on Chiralpak AD-H column (97% hexane, 3% Pr^{i}OH, 25ºC, 1 mL/min, 230 nm, R_t = 25.1 min (major *anti*), R_t = 27.9 min (minor *syn*), R_t = 29.6 min (major *syn*), R_t = 33.2 min (minor *anti*).



10e

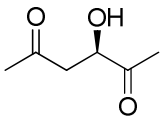
The ee was determined by chiral HPLC on Chiralpak IA column (95% hexane, 5% Pr^{i}OH, 25ºC, 1 mL/min, 230 nm, R_t = 16.4 min (major *syn*), R_t = 19.0 min (minor *anti*), R_t = 22.0 min (minor *syn*), R_t = 26.7 min (major *anti*).



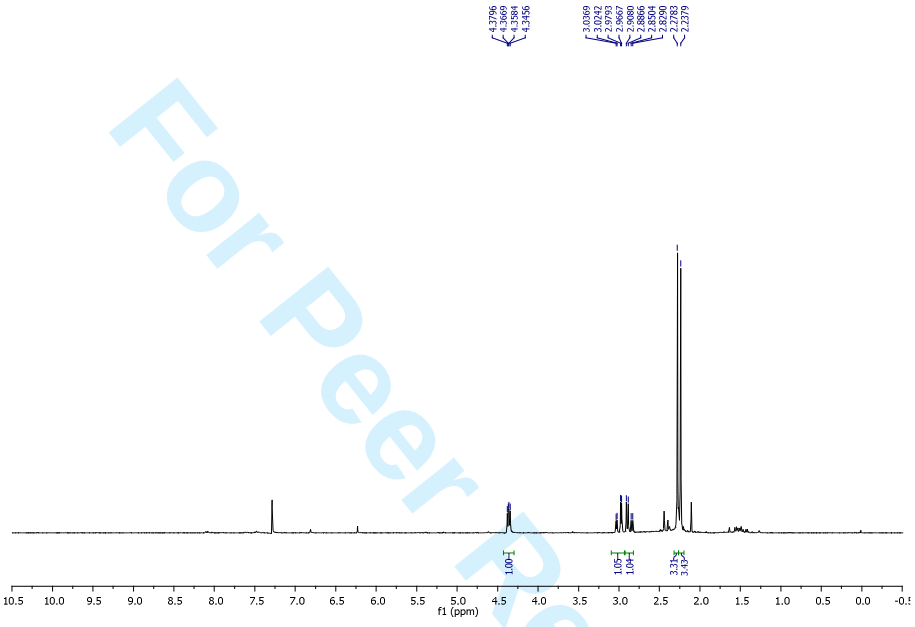
10f

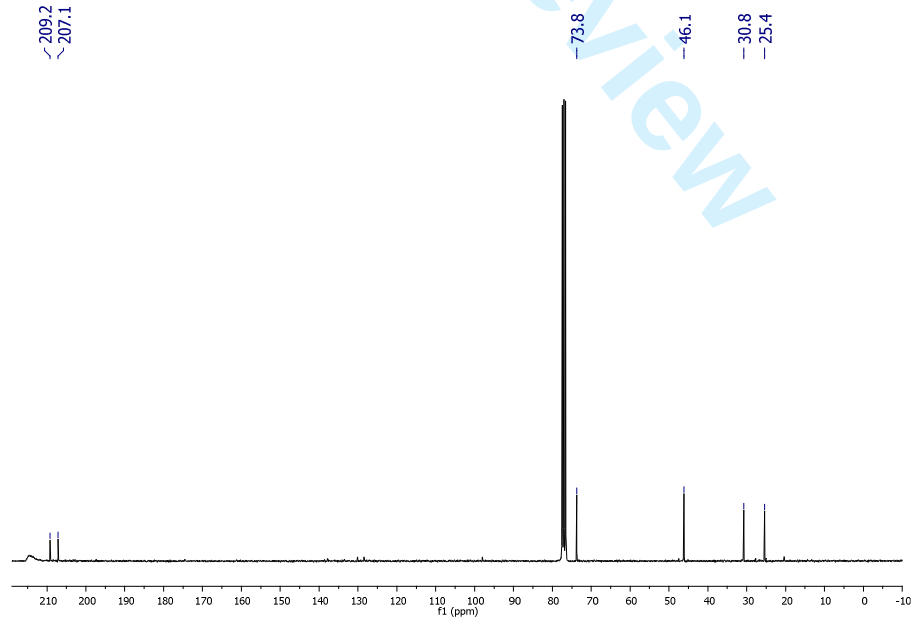
The ee was determined by chiral HPLC on Chiralpak IA column (98% hexane, 2% Pr^{i}OH, 25ºC, 1 mL/min, 230 nm, R_t = 27.8 min (major *anti*), R_t = 35.4 min (minor *anti*), R_t = 37.0 min (major *syn*), R_t = 39.9 min (minor *syn*).

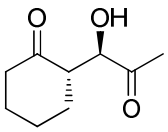
NMR spectra for aldol products



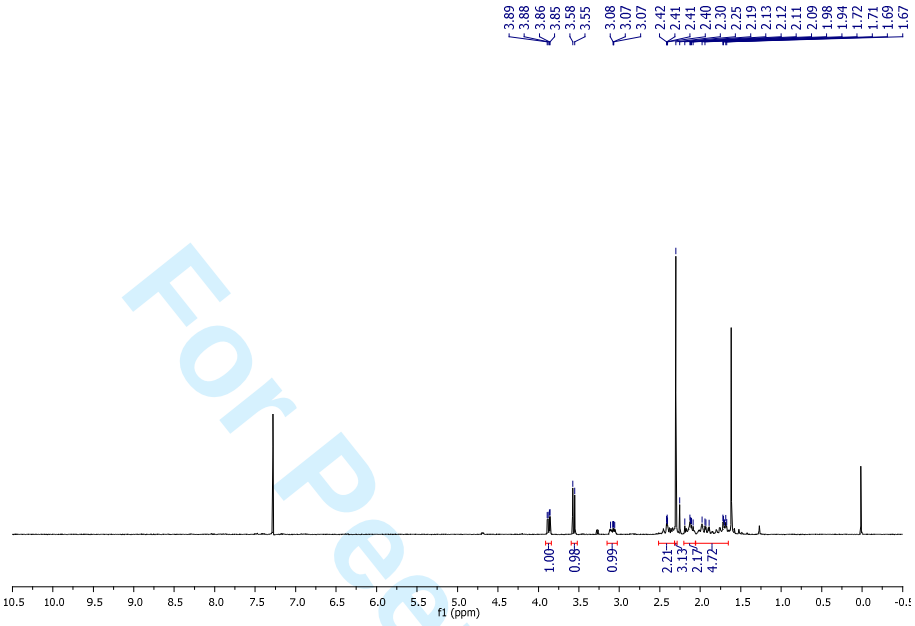
7a

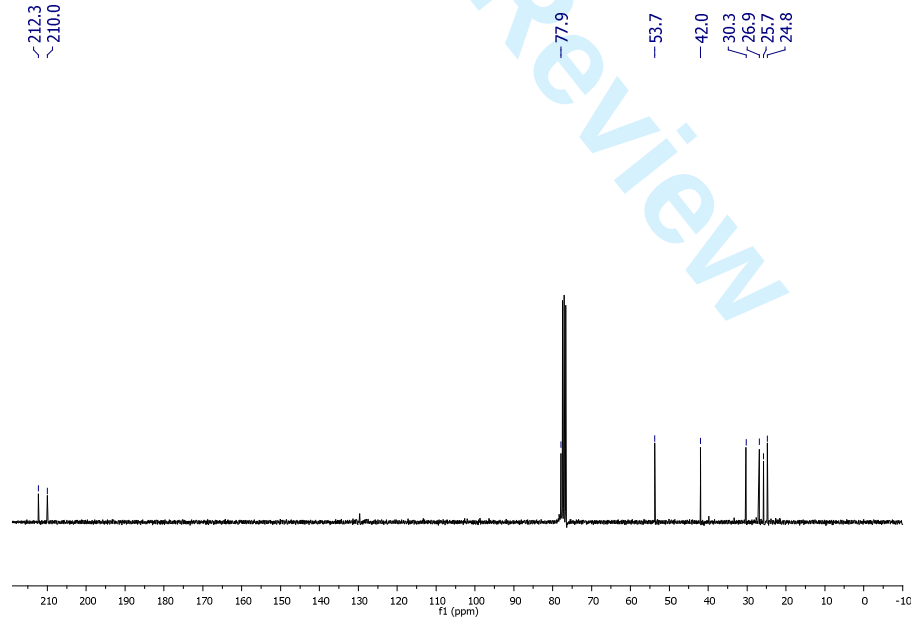


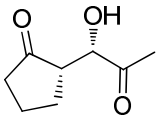




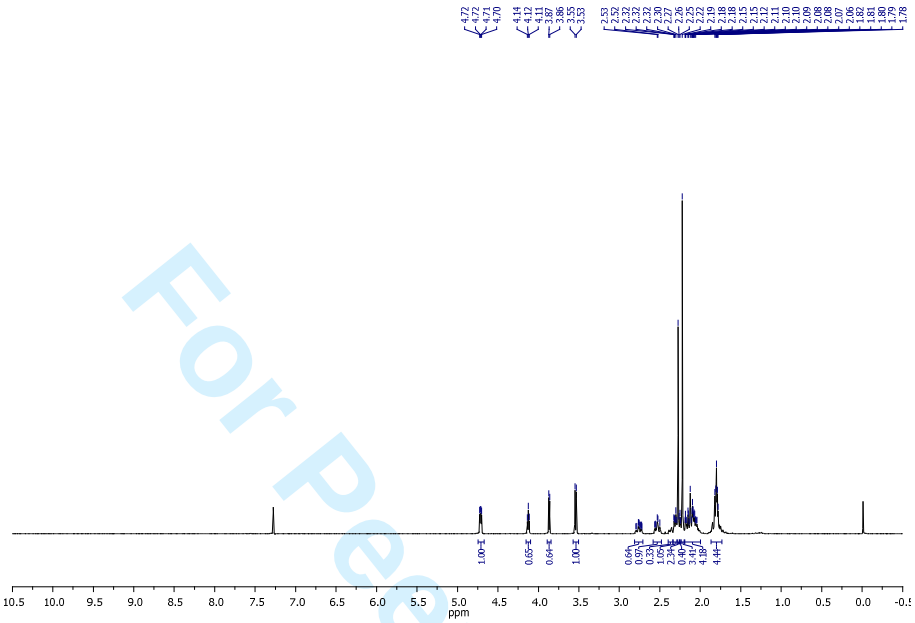
7b

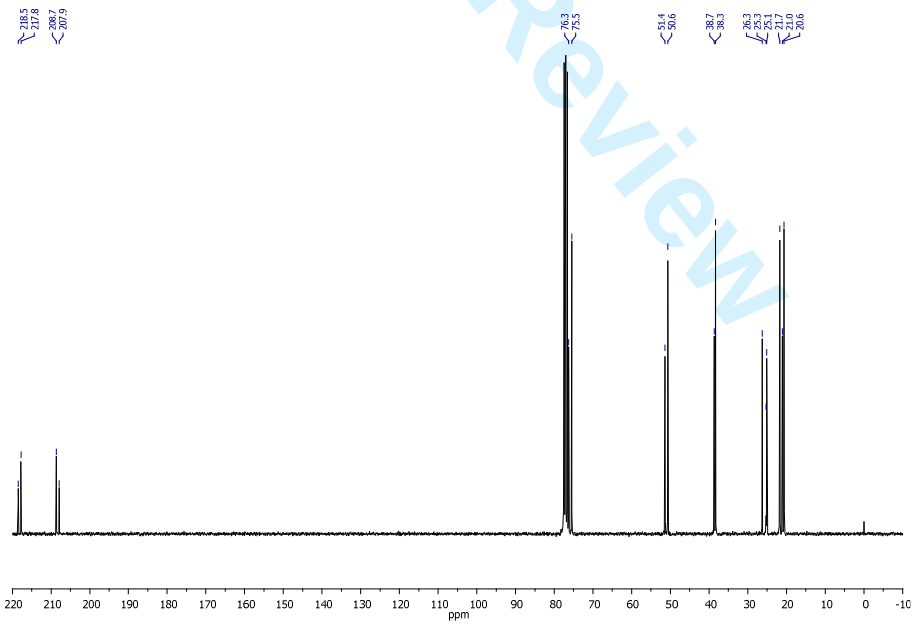


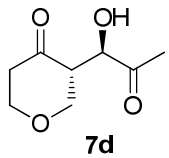




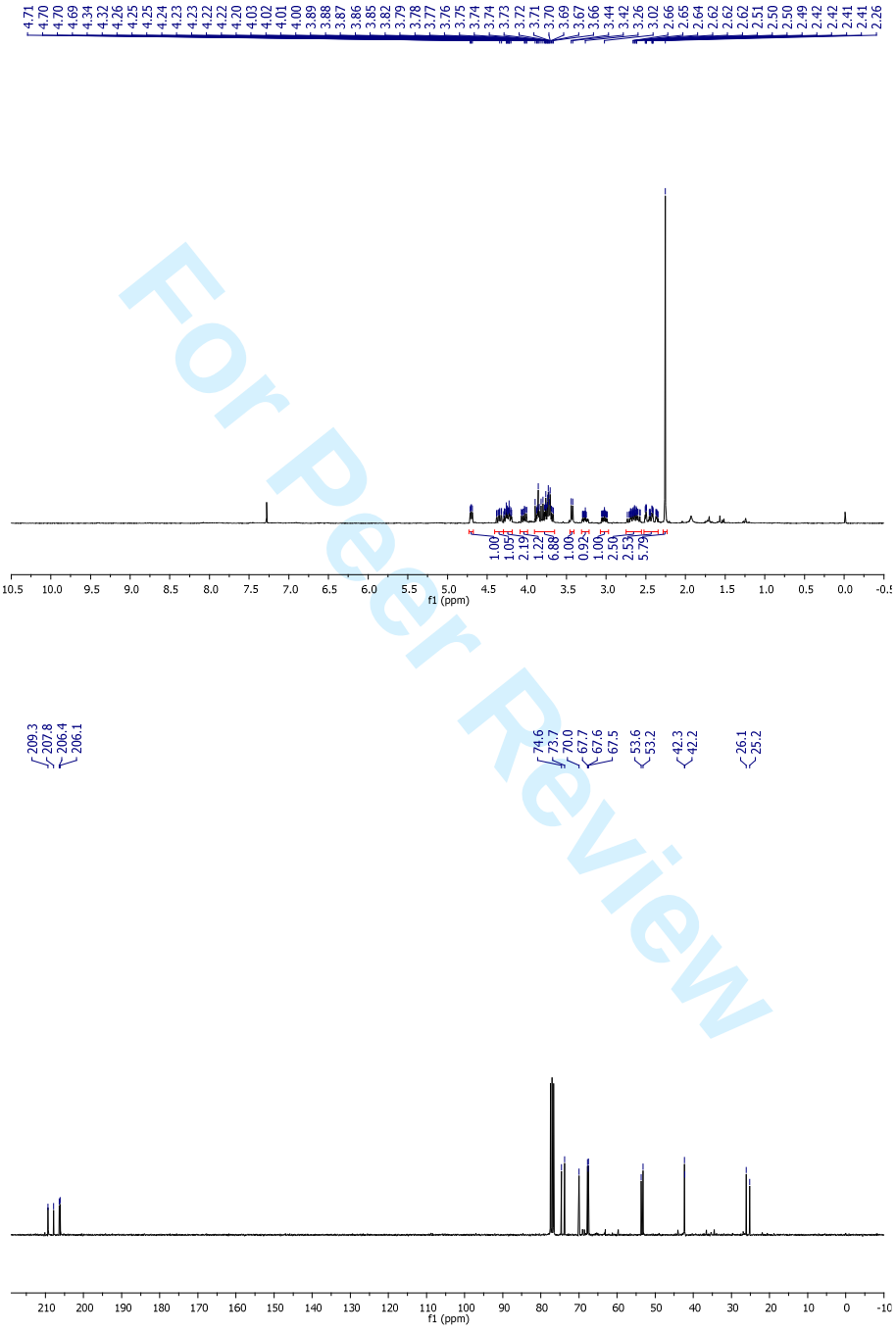
7c

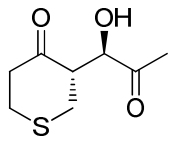




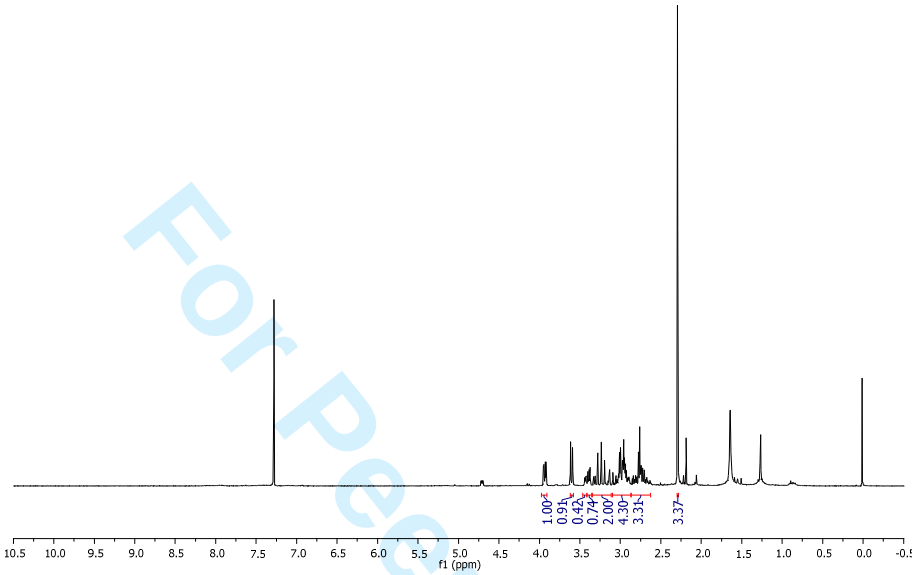


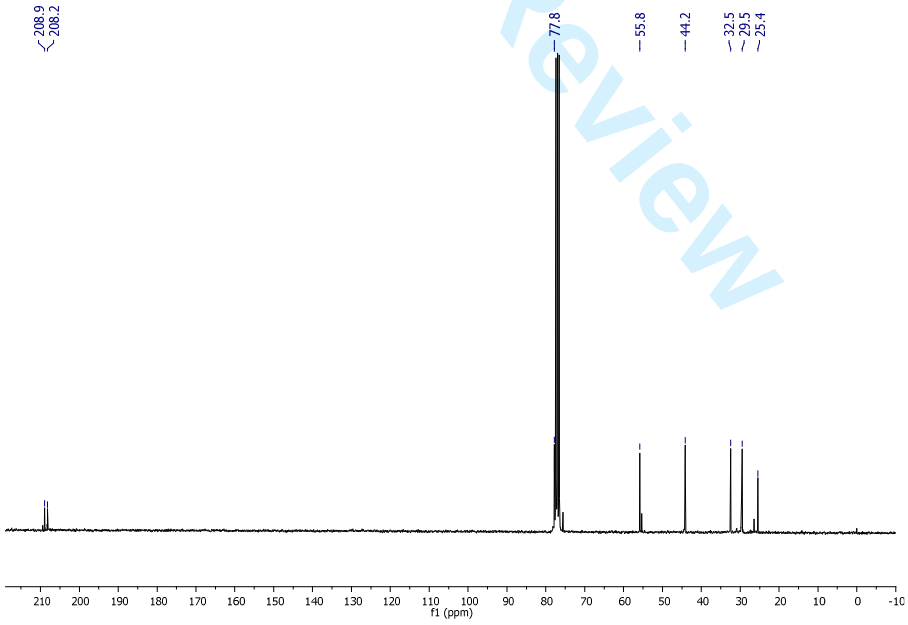
7d

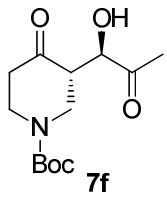




7e







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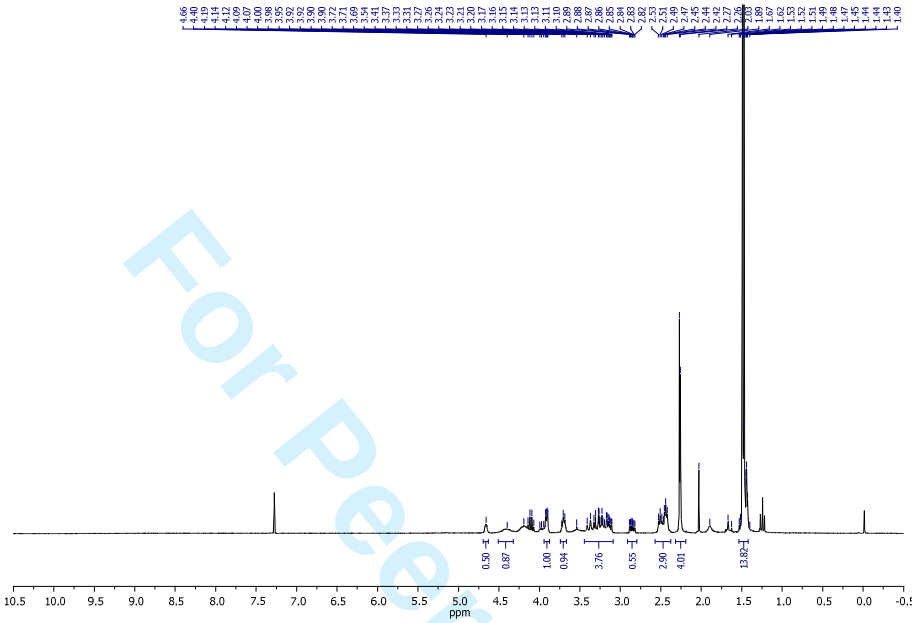
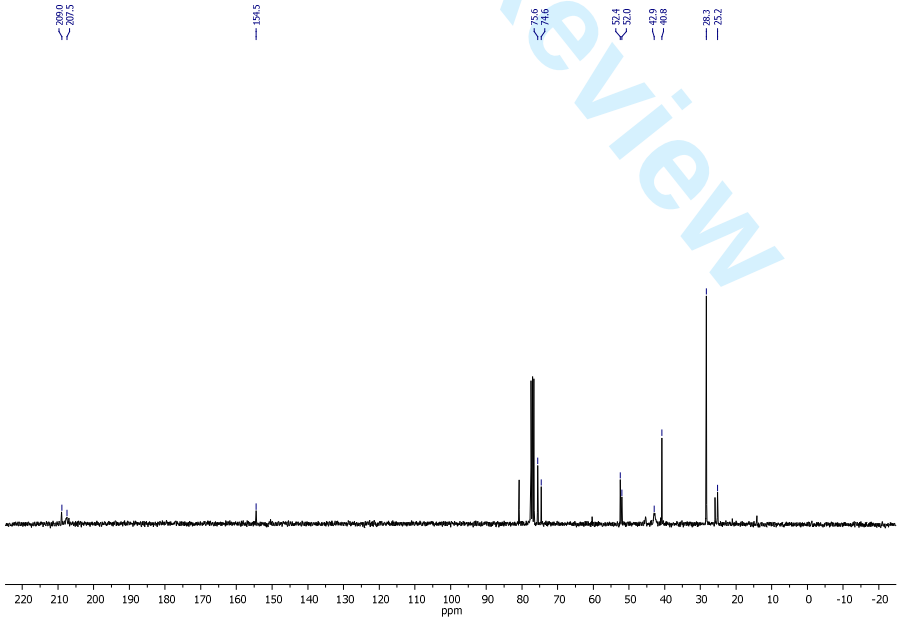
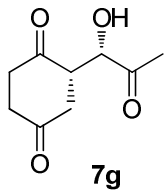
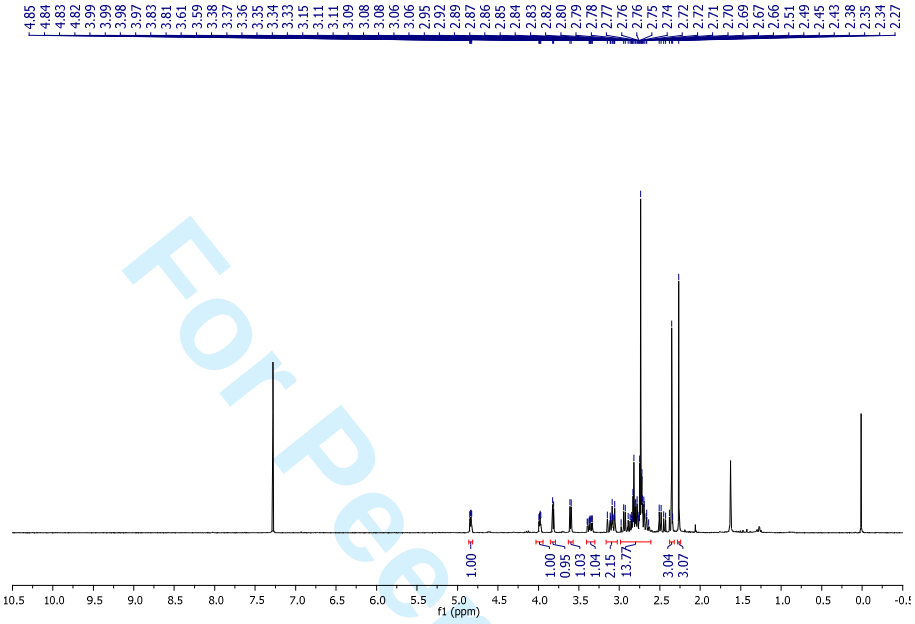
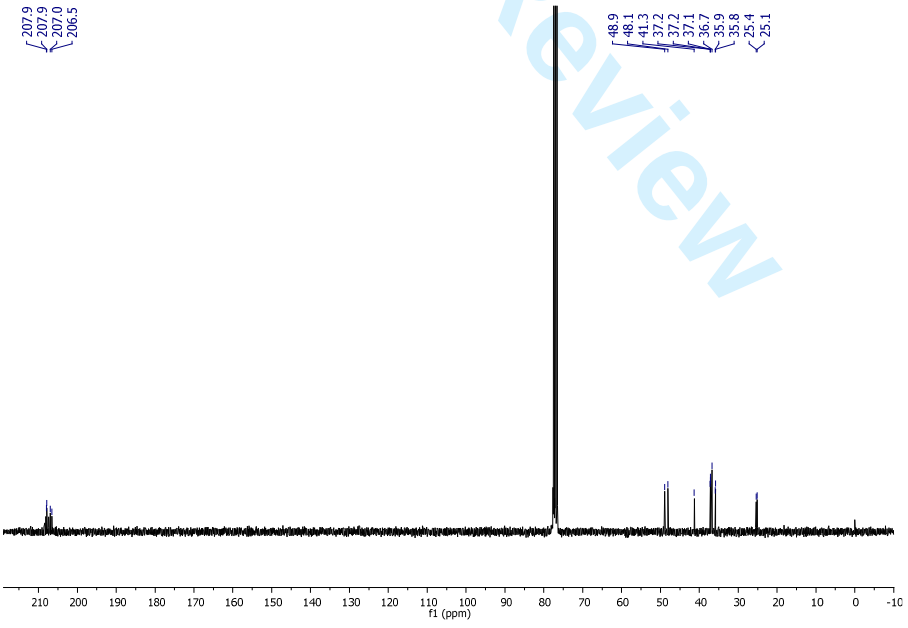


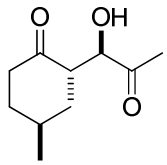




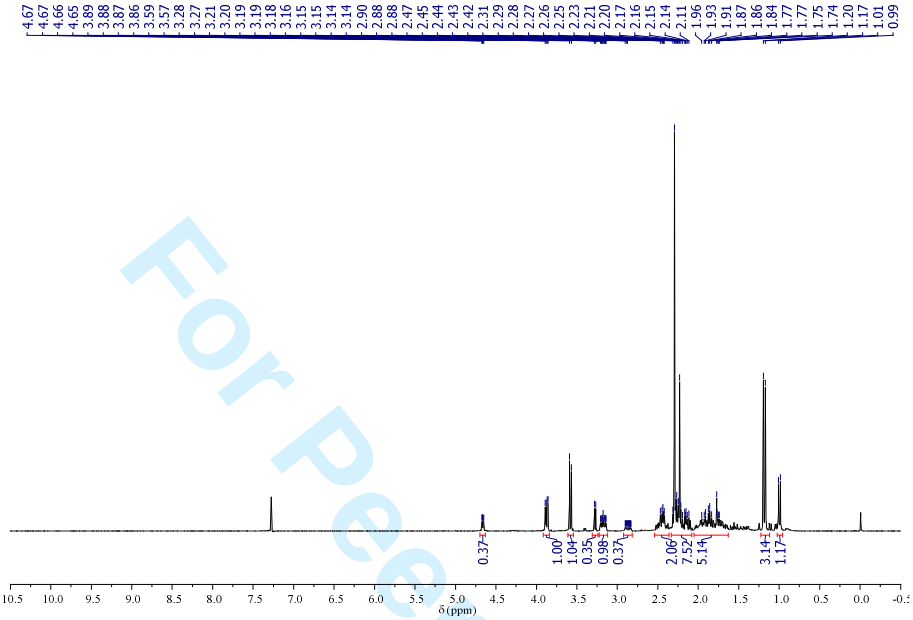
7g

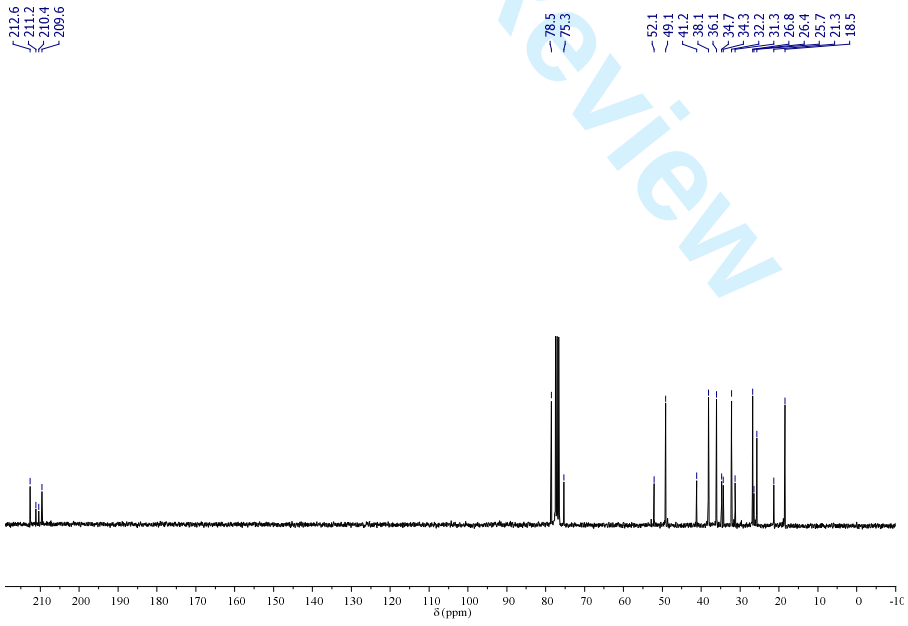


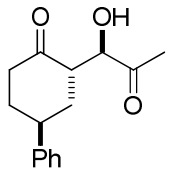




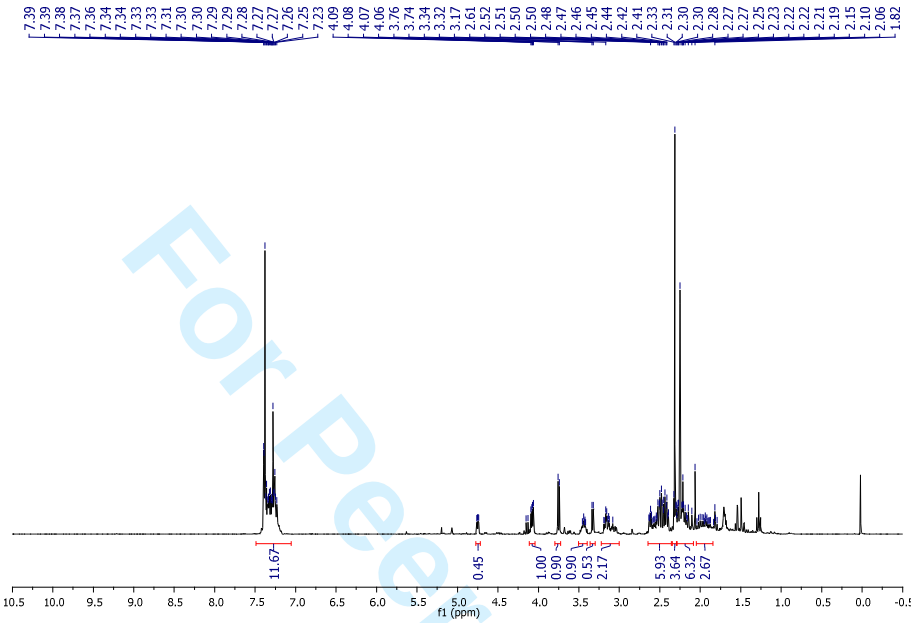
7h

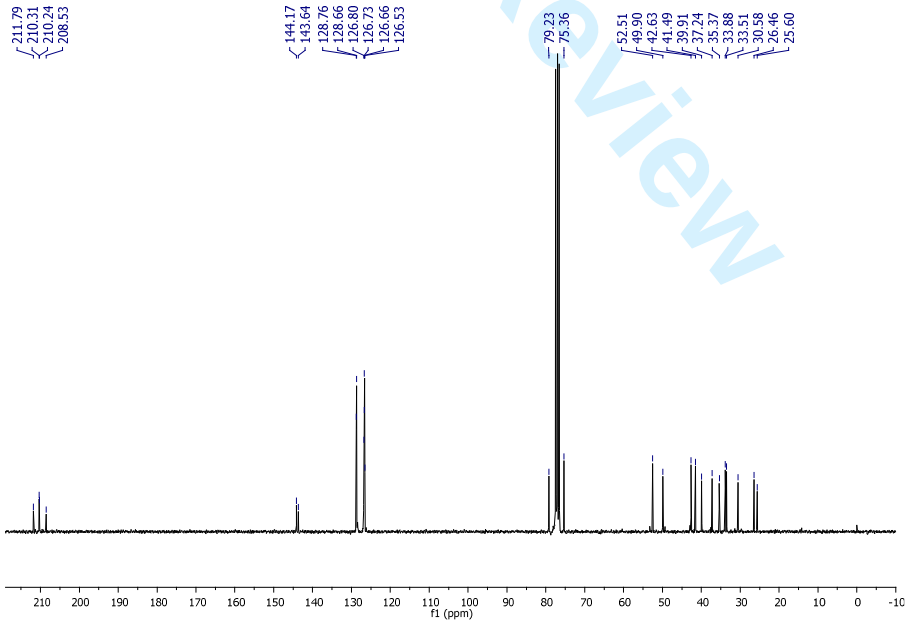


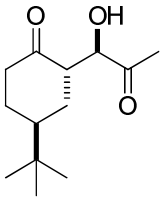




7i







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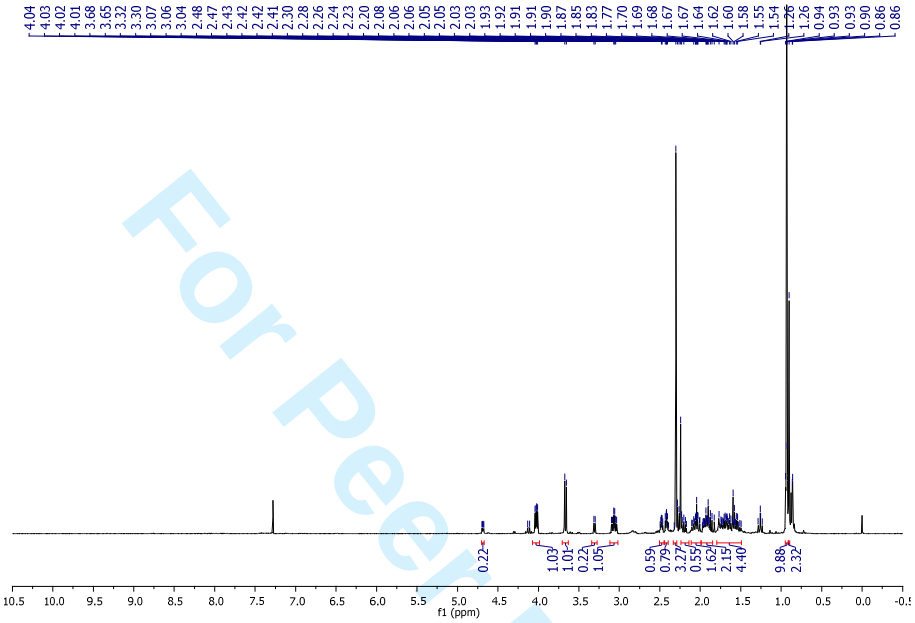
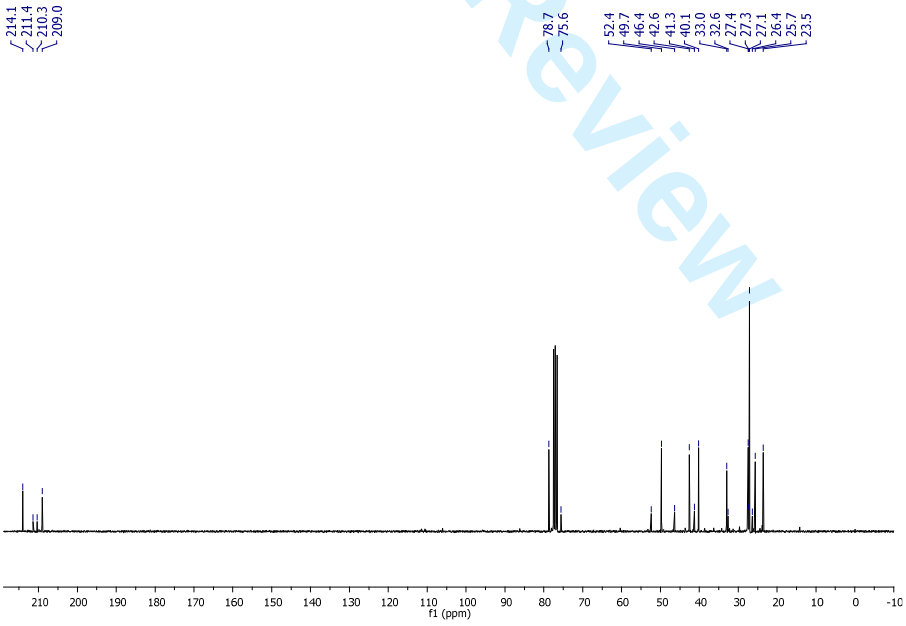
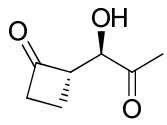
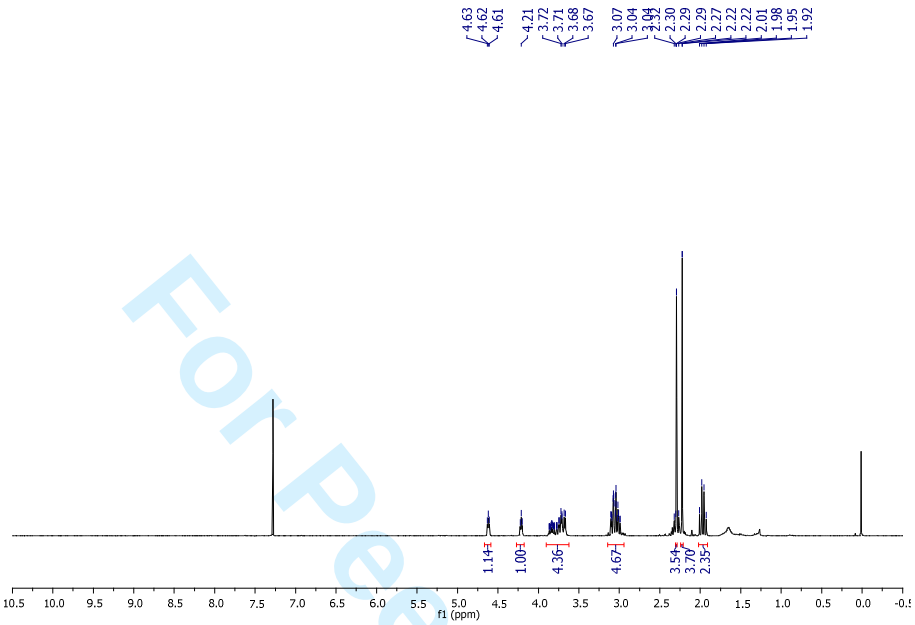
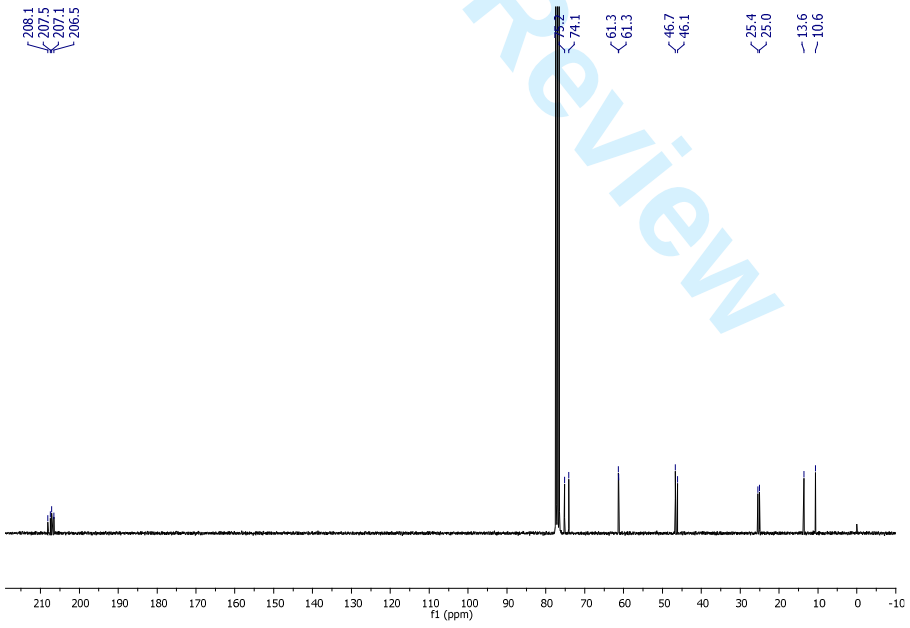


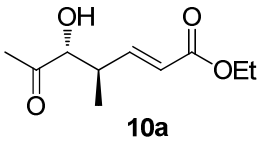




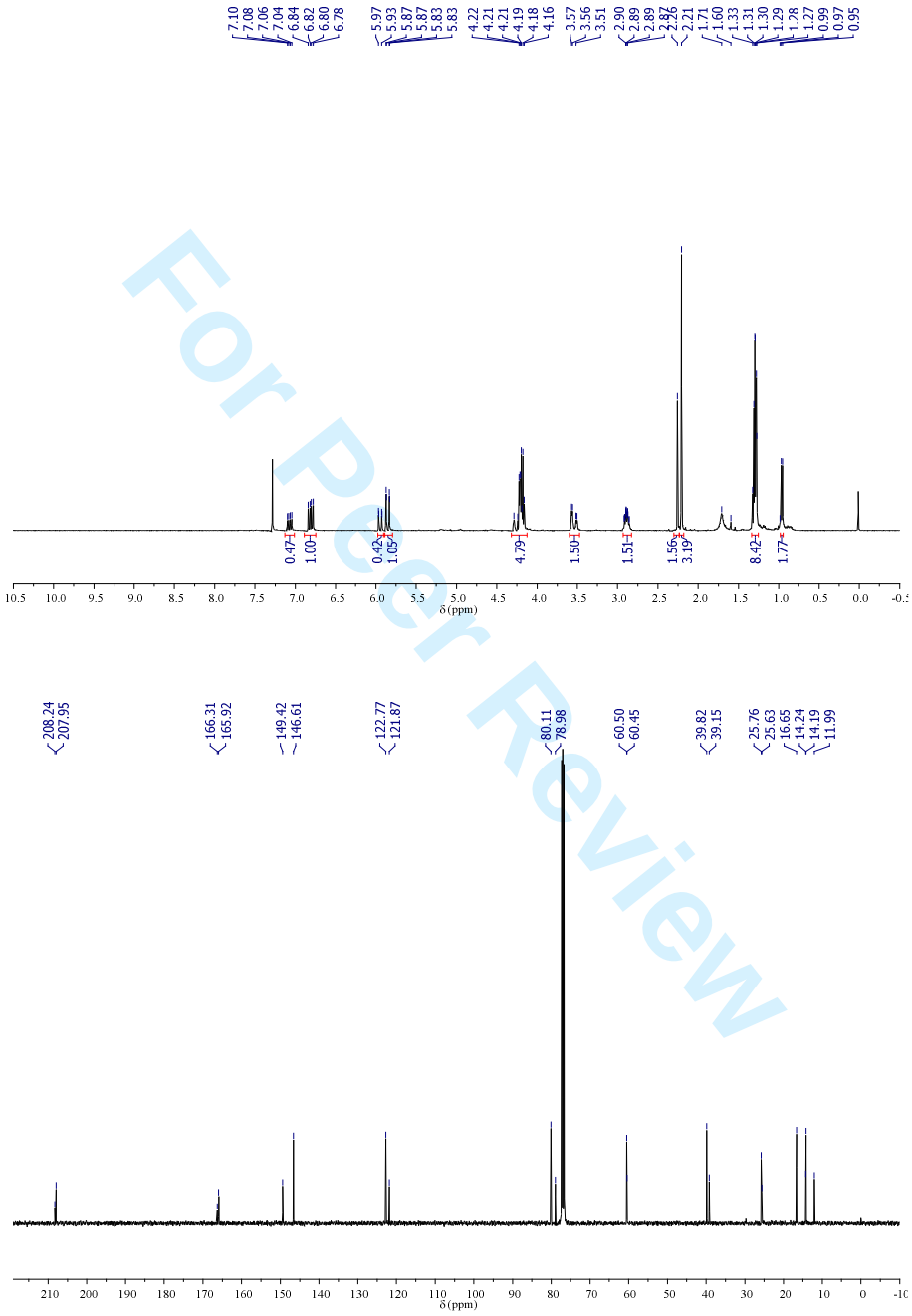
7k

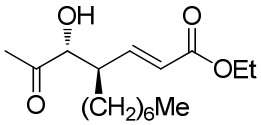






10a





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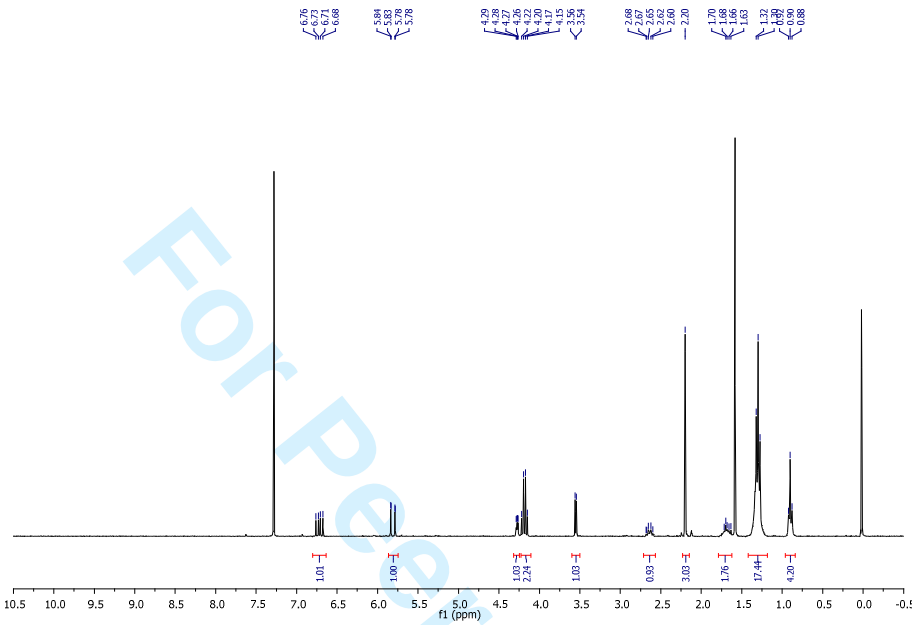

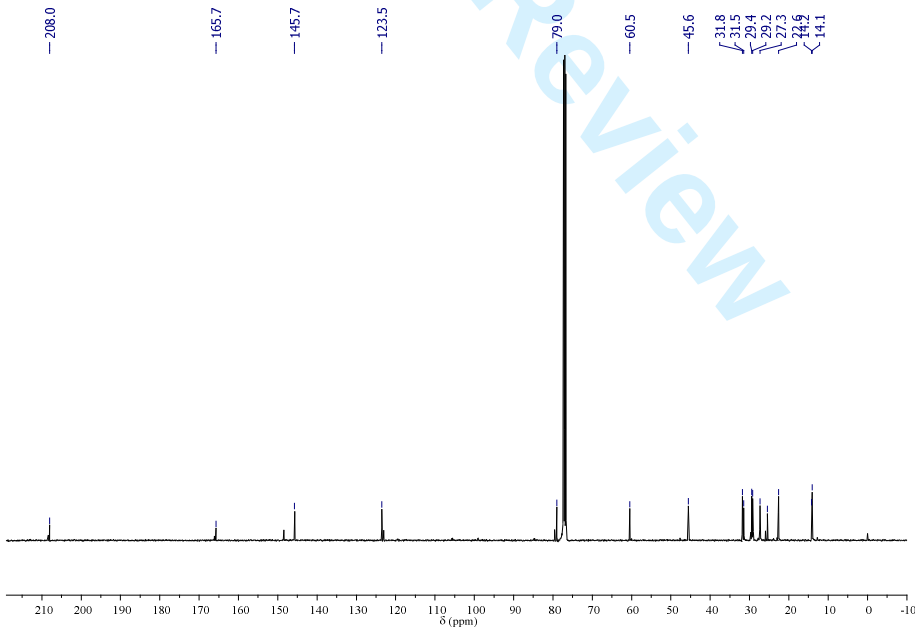

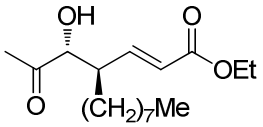

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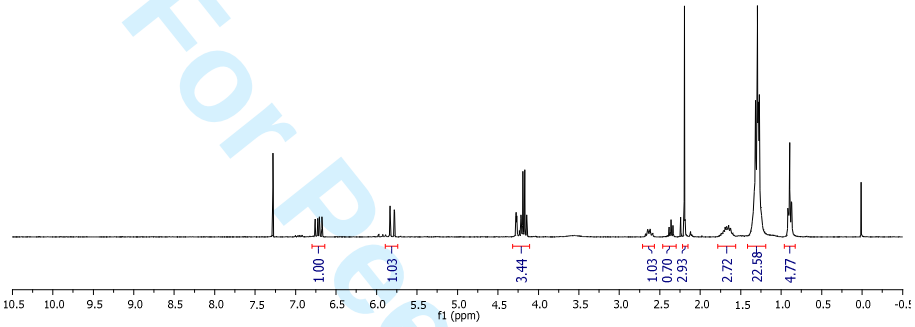

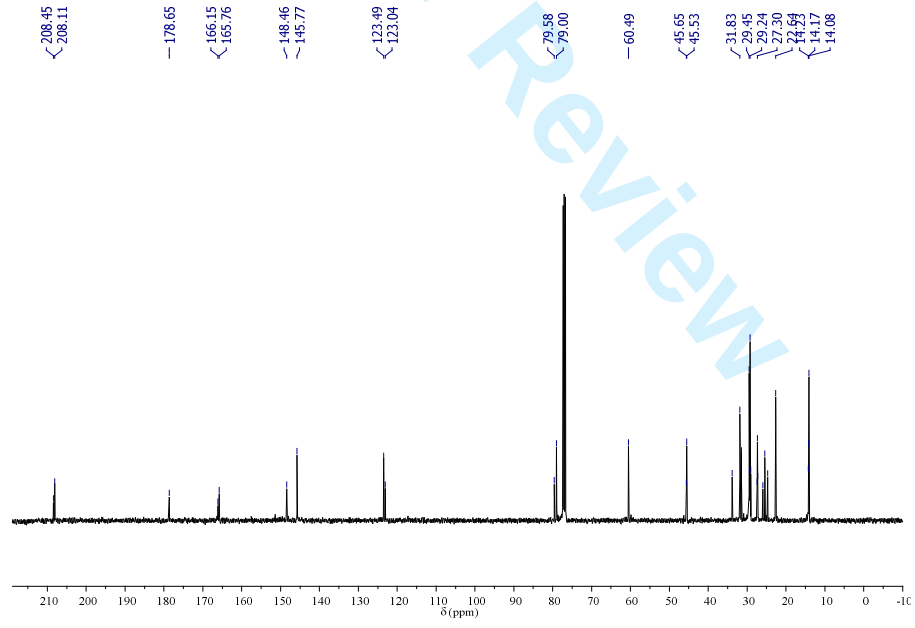

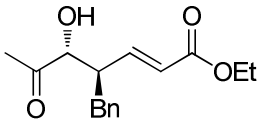

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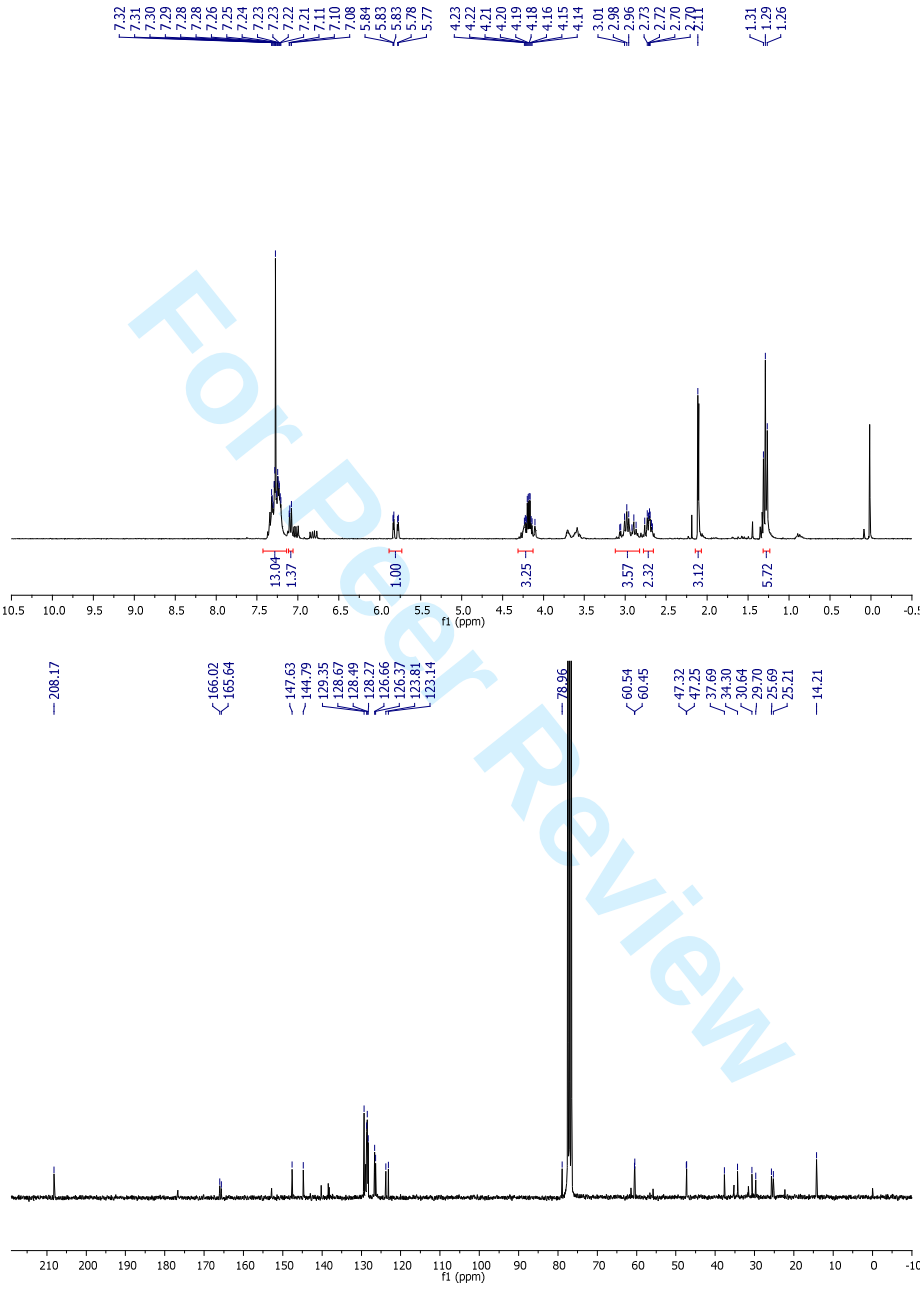
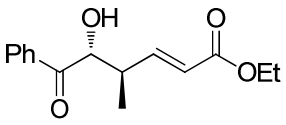
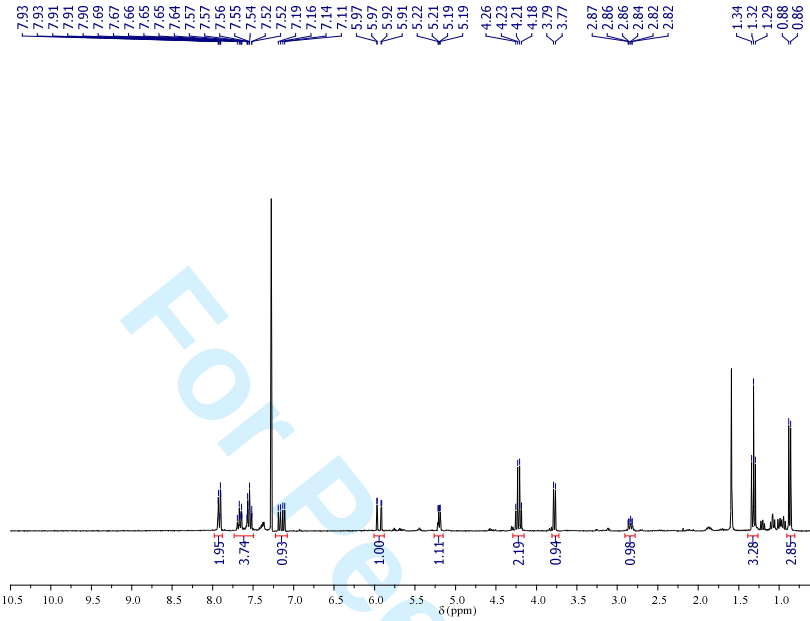
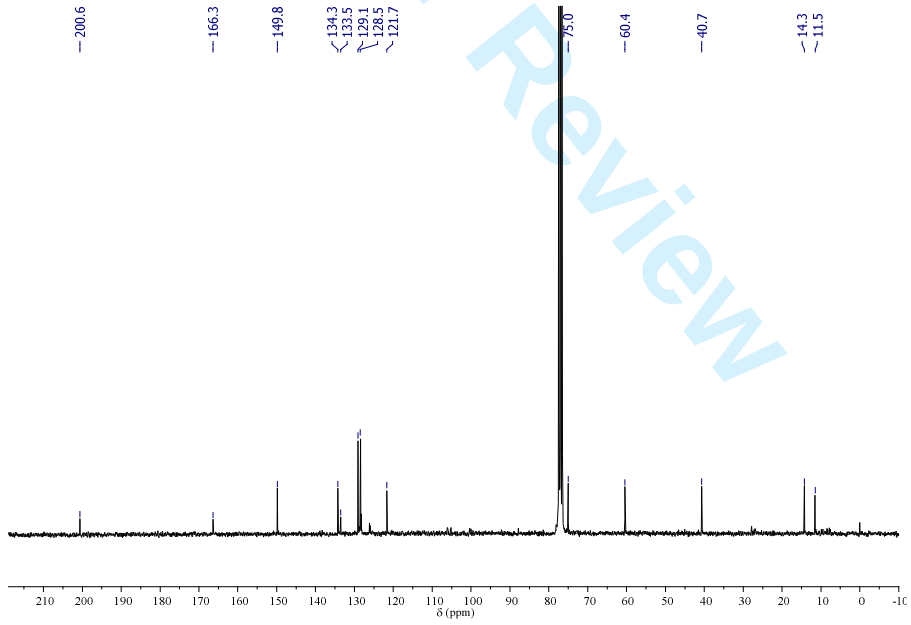
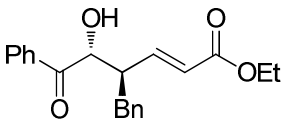




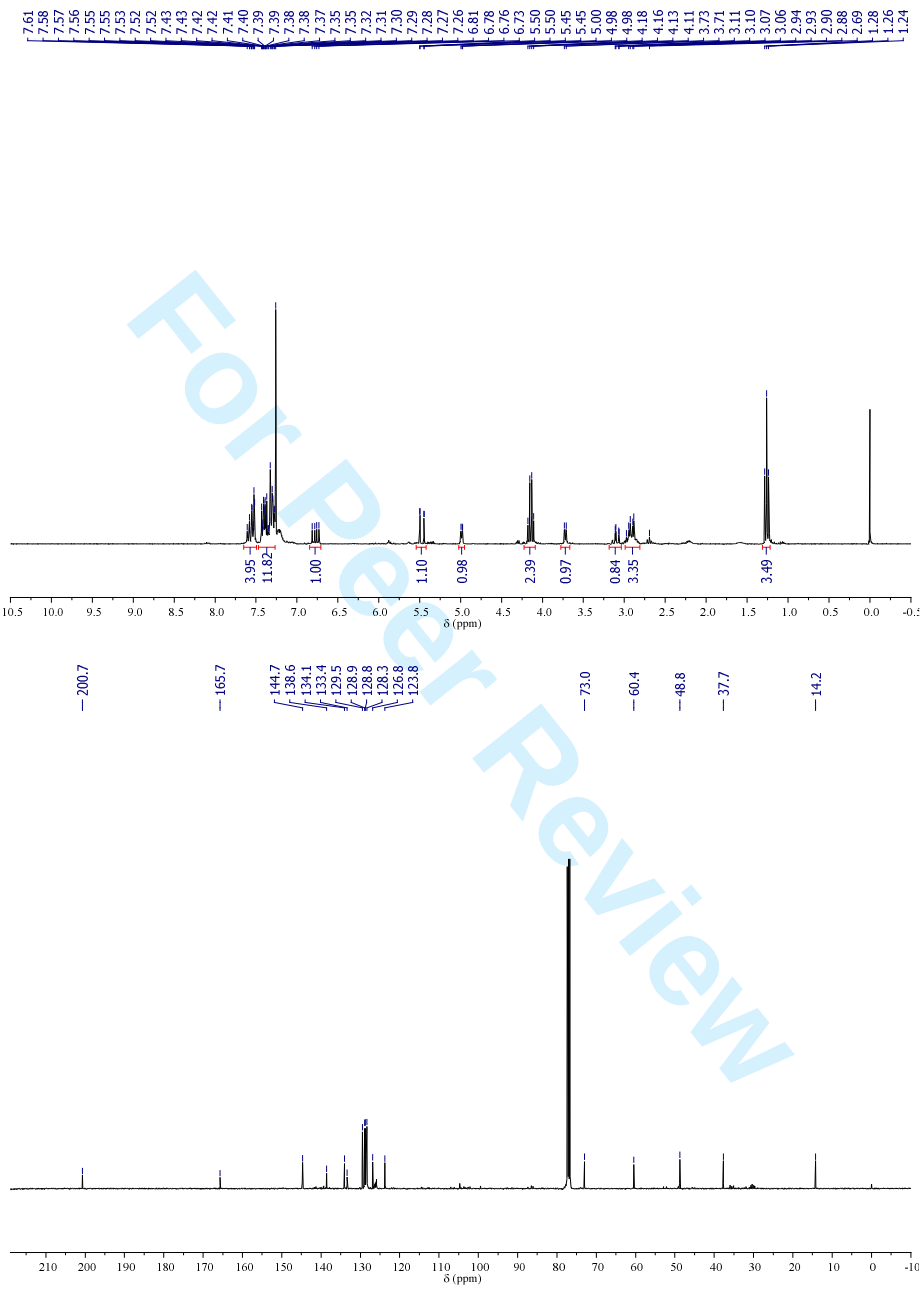
10e



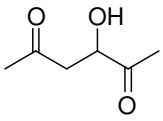




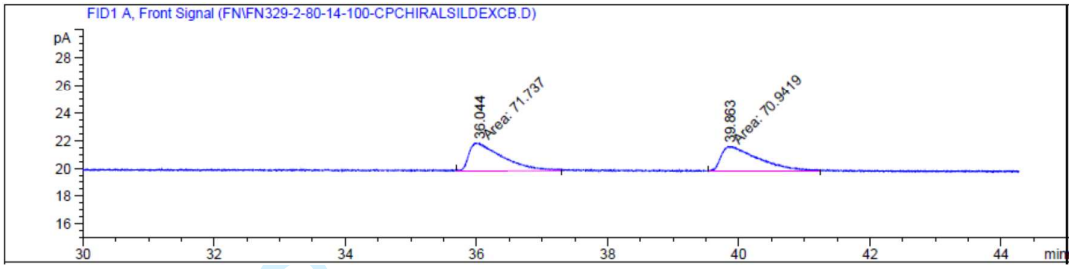
10f



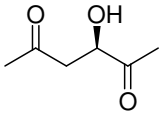
HPLC spectra for aldol products



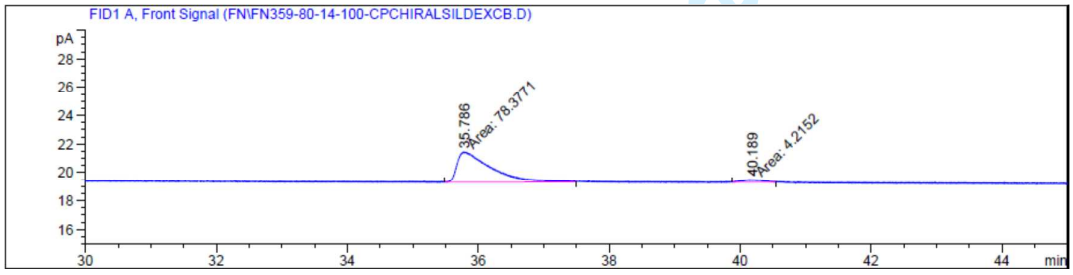
7a - *Rac*



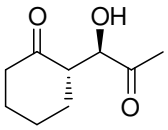
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	36.044	MM	0.5843	71.73704	2.04636	50.27865
2	39.863	MM	0.6651	70.94190	1.77784	49.72135



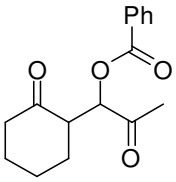
7a



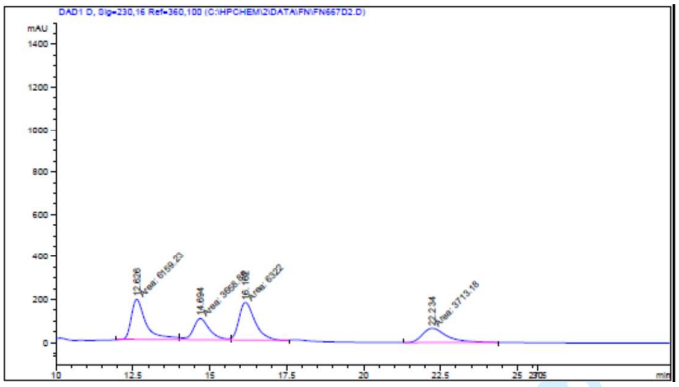
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	35.786	MM	0.6038	78.37714	2.16328	94.89638
2	40.189	MM	0.3498	4.21520	2.00823e-1	5.10362



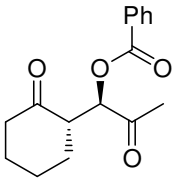
7b



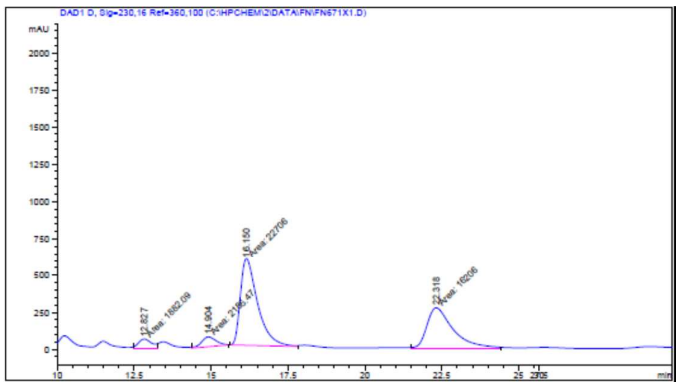
7b* - *Rac*



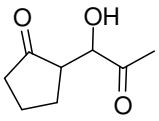
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.626	MM T	0.5528	6159.22656	185.70876	31.0237
2	14.694	MF T	0.6922	3658.89331	98.82606	18.4296
3	16.162	FM T	0.6022	6322.00098	174.97464	31.8436
4	22.234	MM T	1.0076	3713.18433	66.86020	18.7031



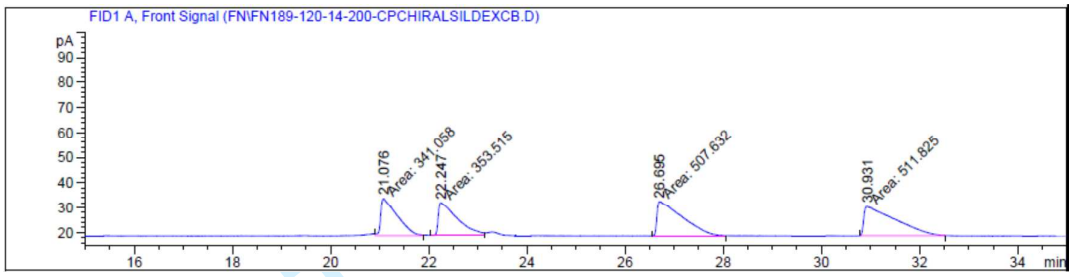
7b*



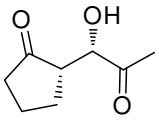
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.827	MM T	0.5003	1882.09229	62.69707	4.3790
2	14.904	MM T	0.6023	2185.47241	66.32415	5.0849
3	16.150	MM T	0.6479	2.27060e4	584.08606	52.8298
4	22.318	MM T	0.9913	1.62060e4	272.47745	37.7062



7c - *Rac*



Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	21.076	MM	0.3800	341.05814	14.96060	19.89804
2	22.247	MM	0.4453	353.51474	13.23264	20.62478
3	26.695	MM	0.6020	507.63150	14.05480	29.61627
4	30.931	MM	0.7330	511.82483	11.63817	29.86092



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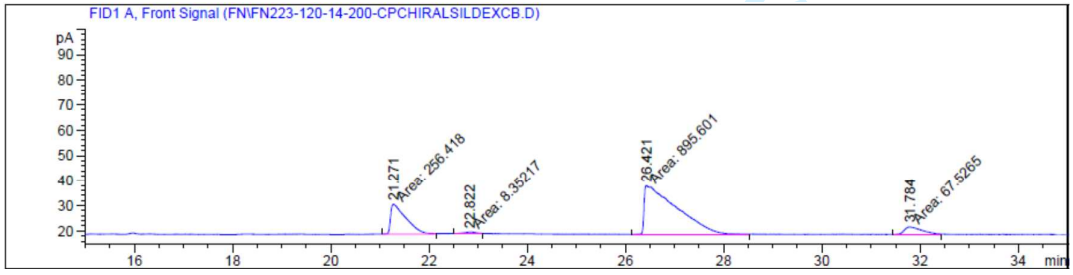
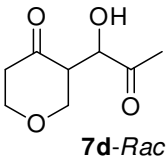
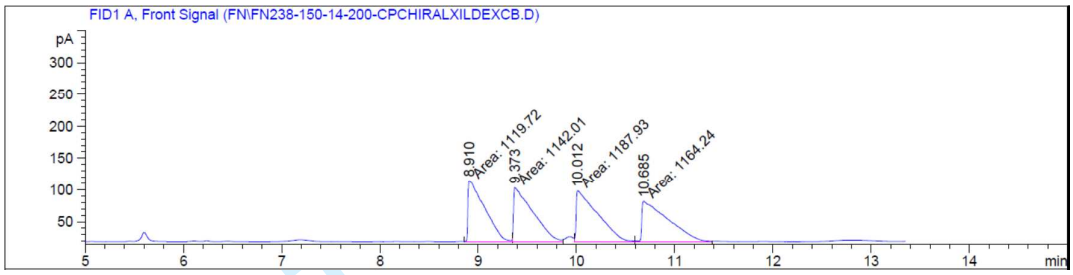


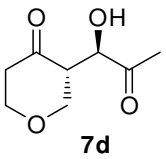
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	21.271	MM	0.3642	256.41824	11.73569	20.88270
2	22.822	MM	0.2436	8.35217	5.71418e-1	0.68020
3	26.421	MM	0.7746	895.60126	19.27095	72.93775
4	31.784	MM	0.3924	67.52645	2.86842	5.49935



7d-*Rac*



Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	8.910	MF	0.1960	1119.71643	95.22254	24.26834
2	9.373	FM	0.2269	1142.00781	83.90294	24.75148
3	10.012	MF	0.2503	1187.93152	79.09726	25.74681
4	10.685	FM	0.3089	1164.24207	62.80687	25.23337



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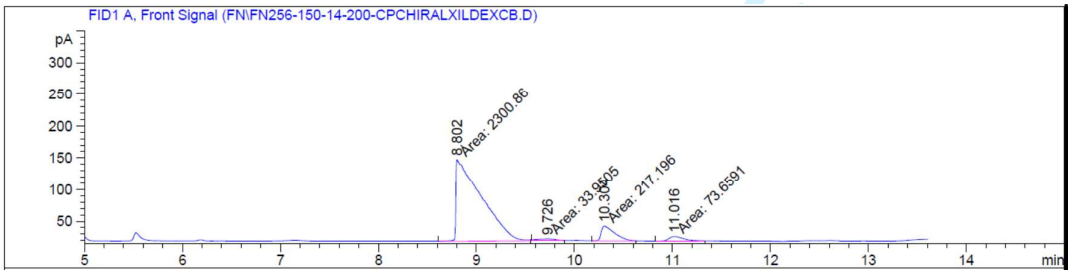
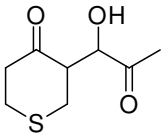
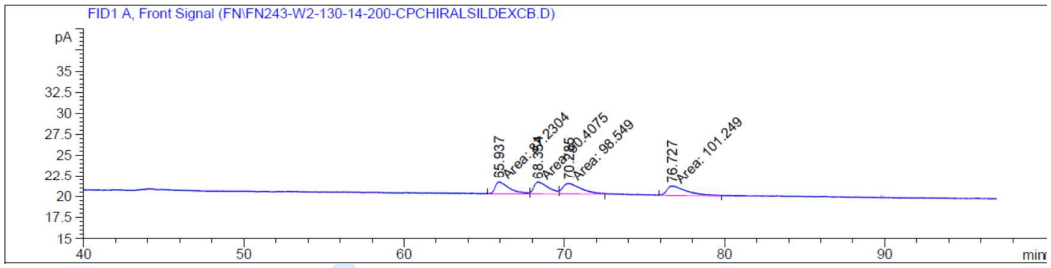


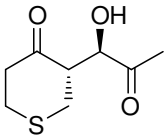
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	8.802	MM	0.2981	2300.85913	128.63562	87.62959
2	9.726	MM	0.2150	33.95055	2.63163	1.29303
3	10.304	MM	0.1569	217.19591	23.07042	8.27204
4	11.016	MM	0.1715	73.65915	7.15846	2.80535



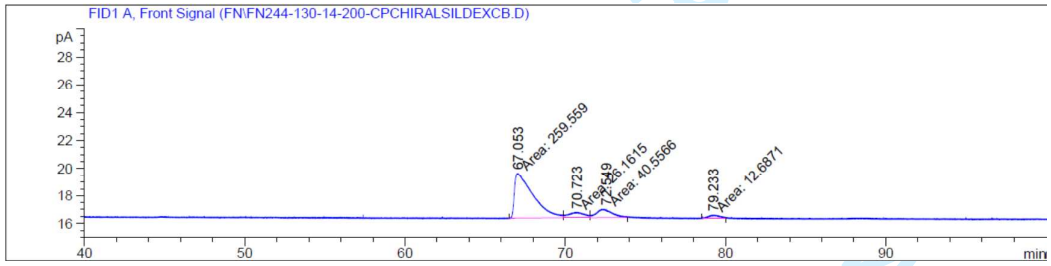
7e-*Rac*



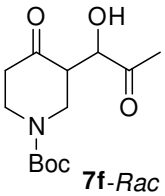
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	65.937	MF	1.0113	87.23039	1.43767	23.11133
2	68.354	MF	1.0445	90.40750	1.44255	23.95309
3	70.285	MM	1.2913	98.54900	1.27195	26.11014
4	76.727	MM	1.4663	101.24880	1.15087	26.82544



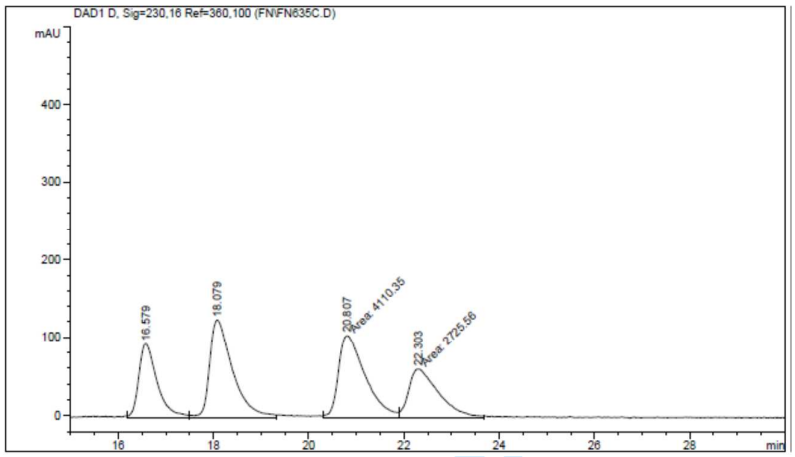
7e



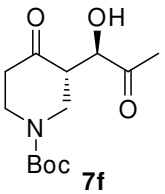
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	67.053	MF	1.3281	259.55905	3.25723	76.57417
2	70.723	MF	1.0739	26.16152	4.06014e-1	7.71808
3	72.549	FM	1.0761	40.55659	6.28127e-1	11.96486
4	79.233	MM	0.7708	12.68706	2.74316e-1	3.74289



7f-*Rac*



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.579	VV	0.3920	2522.59253	93.72870	18.5914
2	18.079	VV	0.4763	4210.12988	125.20703	31.0284
3	20.807	MF	0.6516	4110.35059	105.13191	30.2930
4	22.303	FM	0.7383	2725.55762	61.52640	20.0872



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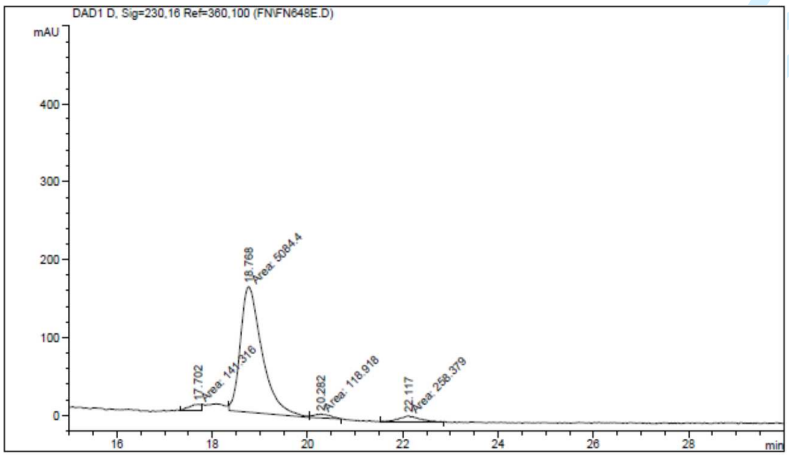
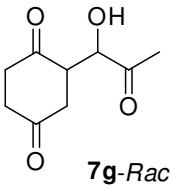
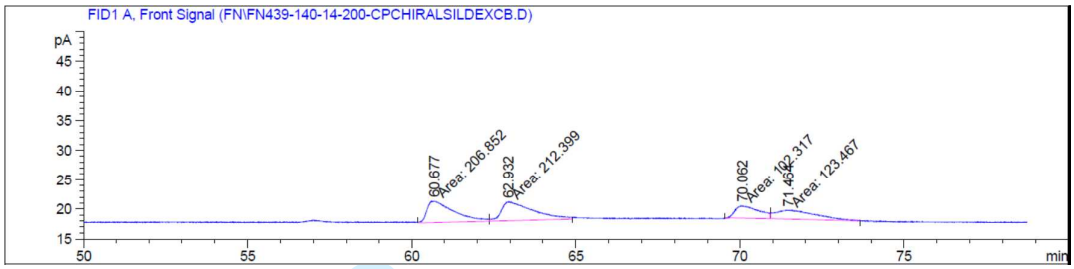


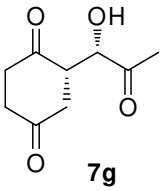
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.702	MM T	0.2954	141.31609	7.97360	2.5221
2	18.768	MM T	0.5259	5084.40479	161.12408	90.7440
3	20.282	MM T	0.3800	118.91827	5.21607	2.1224
4	22.117	MM	0.5273	258.37894	8.16640	4.6114



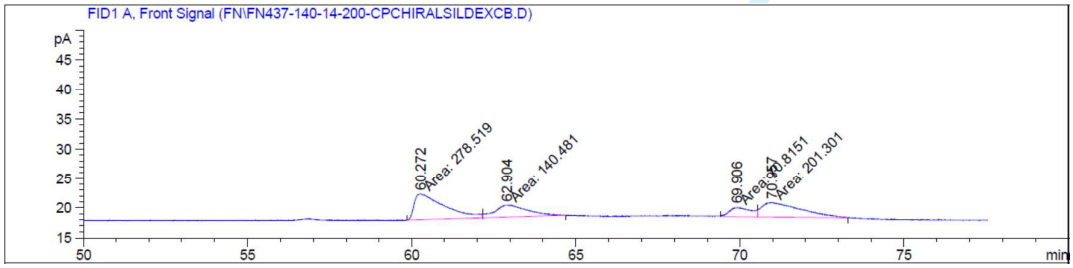
7g-*Rac*



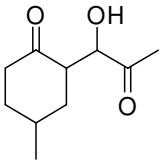
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	60.677	MF	0.9506	206.85226	3.62660	32.06832
2	62.932	FM	1.1193	212.39931	3.16280	32.92828
3	70.062	MF	0.8522	102.31743	2.00102	15.86228
4	71.464	FM	1.4103	123.46715	1.45908	19.14112



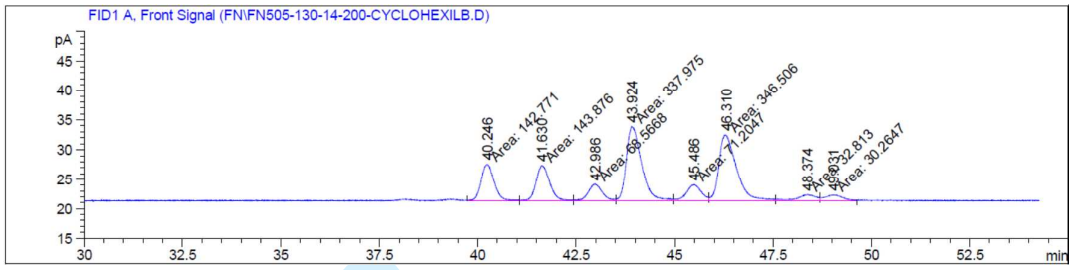
7g



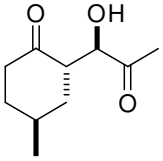
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	60.272	MF	1.0633	278.51883	4.36555	40.29986
2	62.904	FM	1.1537	140.48114	2.02949	20.32670
3	69.906	MF	0.7514	70.81514	1.57077	10.24649
4	70.957	FM	1.3743	201.30104	2.44132	29.12695



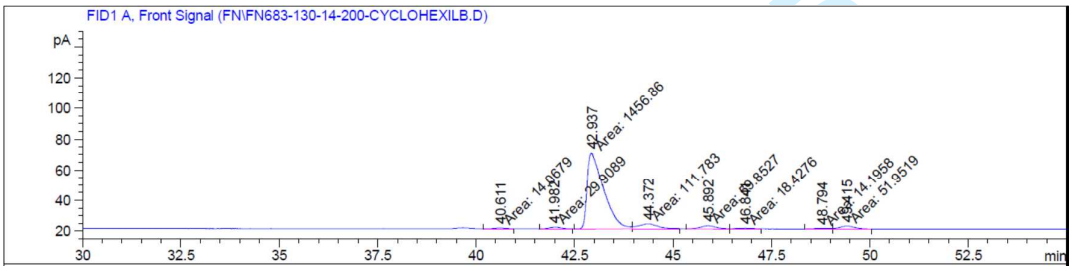
7h-*Rac*



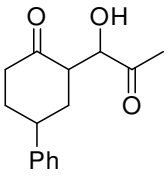
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	40.246	MF	0.3817	142.77107	6.23372	12.16131
2	41.630	MF	0.3983	143.87605	6.02115	12.25543
3	42.986	MF	0.4047	68.56679	2.82397	5.84055
4	43.924	MF	0.4499	337.97510	12.51968	28.78889
5	45.486	MF	0.4352	71.20470	2.72679	6.06525
6	46.310	MF	0.5189	346.50616	11.12988	29.51557
7	48.374	MF	0.5316	32.81301	1.02874	2.79503
8	49.031	FM	0.5232	30.26474	9.64123e-1	2.57797



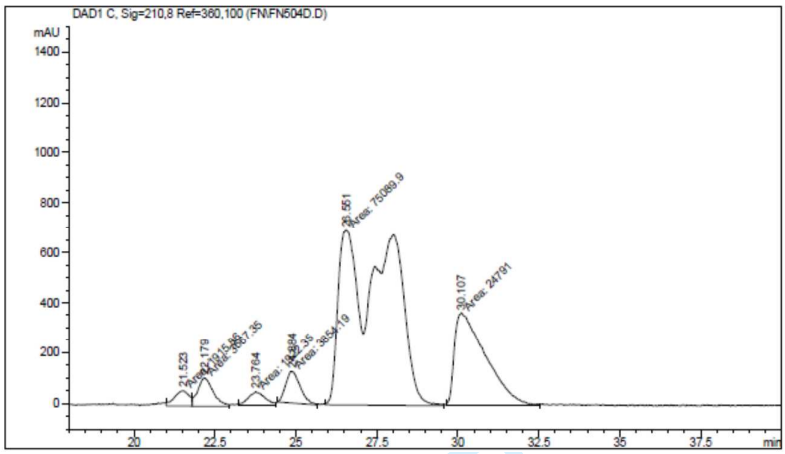
7h



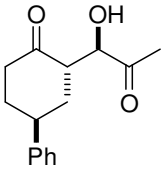
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	40.611	MM	0.3919	14.06788	5.98318e-1	0.80066
2	41.982	MM	0.3836	29.90887	1.29935	1.70223
3	42.937	MF	0.4870	1456.85510	49.85872	82.91518
4	44.372	FM	0.5822	111.78307	3.19989	6.36200
5	45.892	MF	0.4814	59.85265	2.07216	3.40644
6	46.841	FM	0.5046	18.42756	6.08637e-1	1.04878
7	48.794	MF	0.4111	14.19578	5.75525e-1	0.80794
8	49.415	FM	0.4556	51.95185	1.90058	2.95678



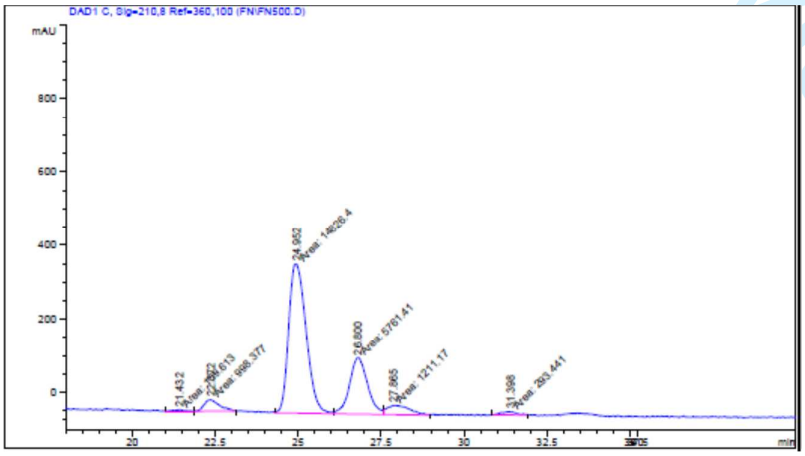
7i-*Rac*



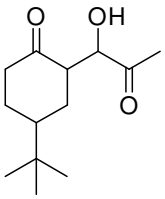
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.523	MF	0.5323	1915.86108	59.98716	1.7223
2	22.179	FM	0.5526	3667.35156	110.61553	3.2968
3	23.764	MM T	0.5909	1922.35437	52.90542	1.7281
4	24.884	MM	0.5205	3854.18628	123.41692	3.4647
5	26.551	MM T	1.4600	7.50899e4	694.66052	67.5022
6	30.107	MM T	1.1167	2.47910e4	370.00378	22.2859



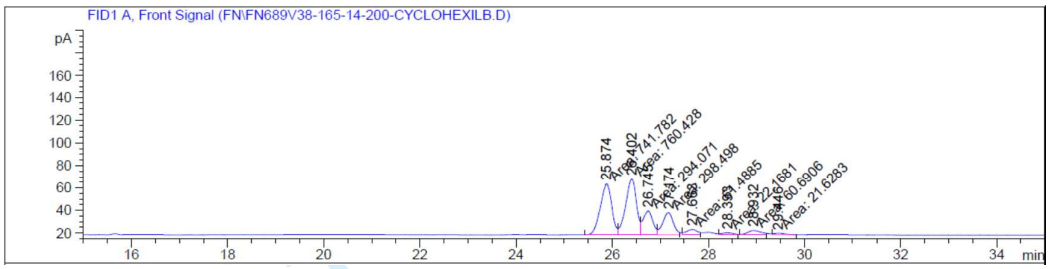
7i



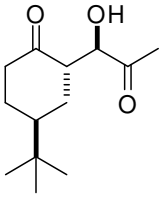
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.432	MM T	0.3912	109.61298	4.98924	0.4725
2	22.372	MM T	0.5396	998.37714	30.83524	4.3033
3	24.952	MF T	0.6105	1.48264e4	404.72870	63.9057
4	26.800	MF T	0.6282	5761.41455	152.86011	24.8333
5	27.865	FM T	0.8002	1211.16748	25.22749	5.2205
6	31.398	MM	0.5444	293.44104	8.98300	1.2648



7j-*Rac*



Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	25.874	MF	0.2747	741.78180	45.00652	32.81125
2	26.402	FM	0.2570	760.42810	49.30610	33.63603
3	26.745	FM	0.2320	294.07074	21.12223	13.00764
4	27.174	FM	0.2555	298.49817	19.47088	13.20348
5	27.663	MM	0.2535	61.48848	4.04272	2.71982
6	28.393	MM	0.2519	22.16809	1.46666	0.98056
7	28.932	MM	0.3001	60.69062	3.37099	2.68453
8	29.446	MM	0.2931	21.62832	1.23004	0.95669



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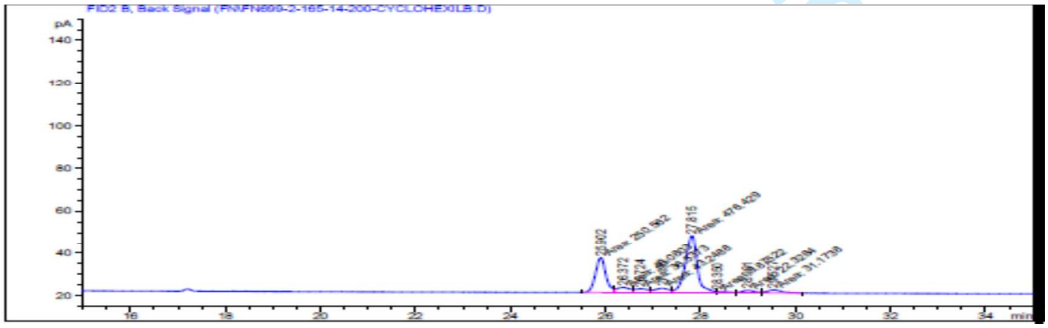
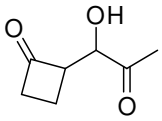
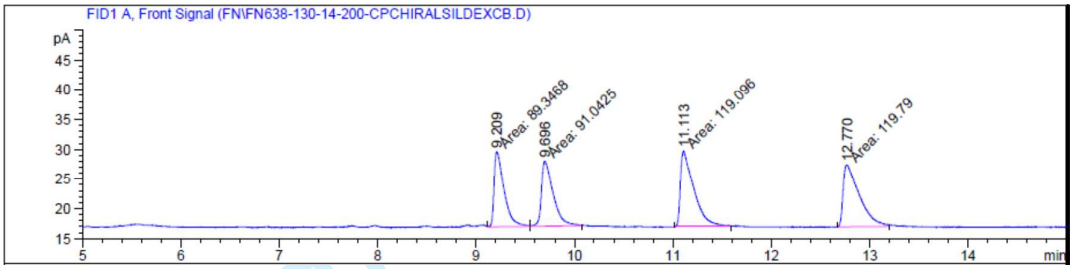


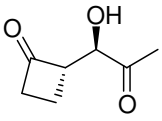
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	25.902	MF	0.2553	250.56163	16.35890	27.34689
2	26.372	FM	0.3114	46.08030	2.46622	5.02931
3	26.724	FM	0.3319	36.53725	1.83482	3.98776
4	27.192	FM	0.3424	43.24879	2.10526	4.72028
5	27.815	FM	0.2924	476.42914	27.15516	51.99860
6	28.350	MF	0.2719	9.87522	6.05371e-1	1.07780
7	28.991	MF	0.3065	22.32838	1.21433	2.43697
8	29.527	FM	0.3569	31.17376	1.45561	3.40238



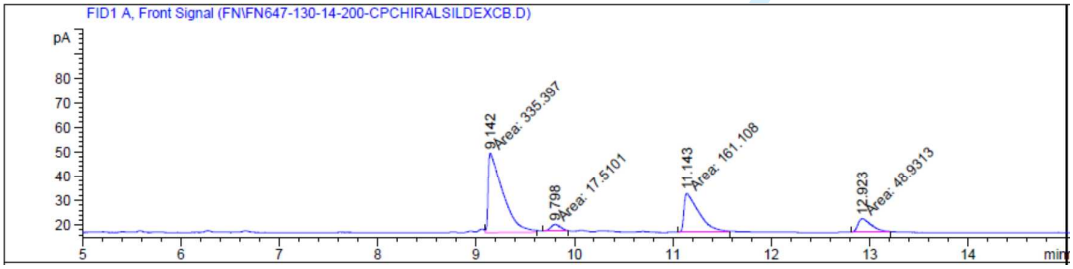
7k-*Rac*



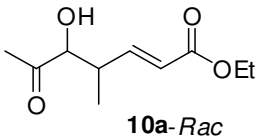
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	9.209	MF	0.1174	89.34682	12.68653	21.30984
2	9.696	FM	0.1380	91.04246	10.99381	21.71426
3	11.113	MM	0.1566	119.09615	12.67530	28.40526
4	12.770	MM	0.1910	119.78961	10.45437	28.57065



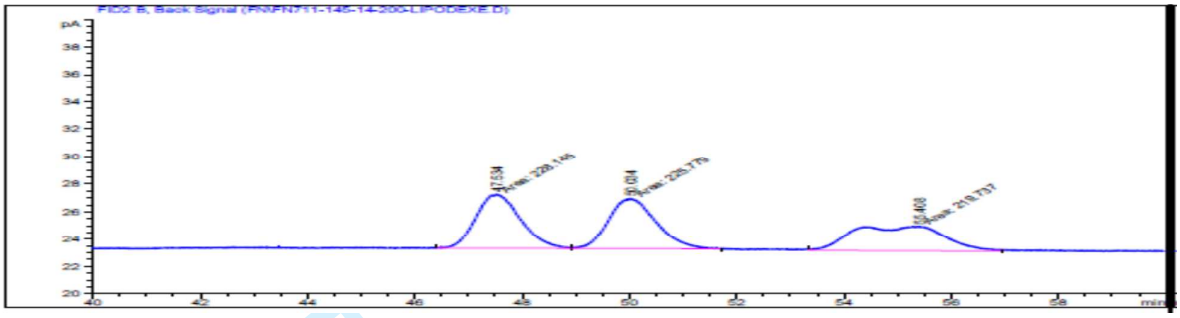
7k



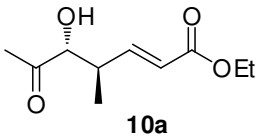
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	9.142	MM	0.1715	335.39655	32.58740	59.57887
2	9.798	MM	0.1127	17.51009	2.58992	3.11044
3	11.143	MM	0.1729	161.10751	15.53290	28.61867
4	12.923	MM	0.1547	48.93132	5.27145	8.69202



10a-*Rac*



Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	47.534	MF	0.9676	228.14508	3.92978	33.86649
2	50.034	FM	1.0276	225.77861	3.66183	33.51521
3	55.408	MM	2.0043	219.73653	1.82719	32.61830



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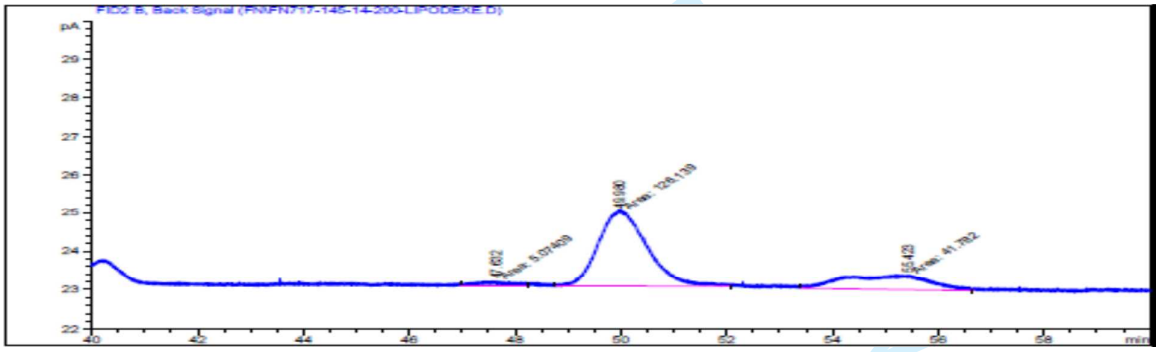
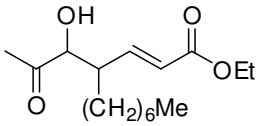
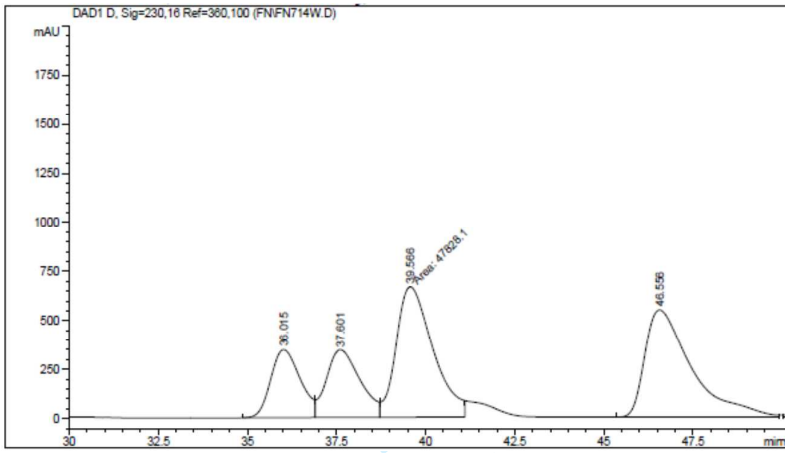


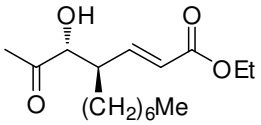
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	47.632	MM	0.6406	5.07409	1.32018e-1	2.93308
2	49.980	MM	1.0644	126.13940	1.97509	72.91486
3	55.423	MM	1.8025	41.78198	3.86335e-1	24.15207



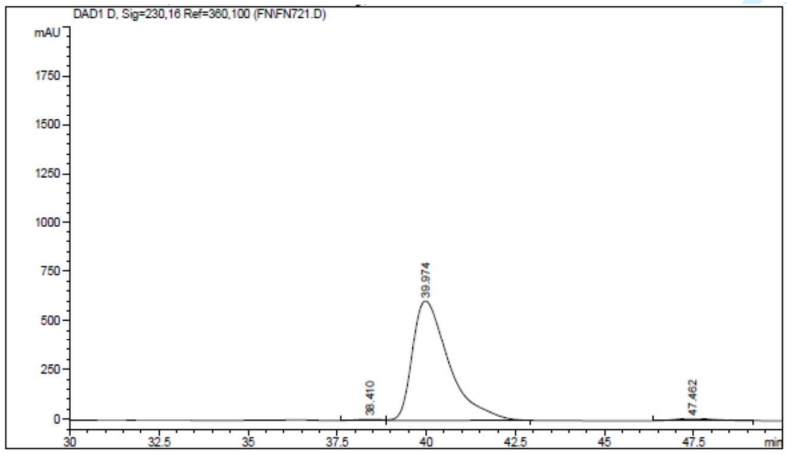
10b-*Rac*



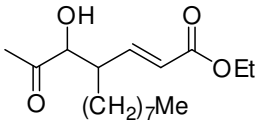
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	36.015	BV	0.8683	1.98764e4	345.93707	14.1926
2	37.601	VV	0.9898	2.25690e4	344.72467	16.1153
3	39.566	MF	1.1977	4.78281e4	665.57349	34.1514
4	46.556	BB	1.2701	4.97738e4	547.78198	35.5407



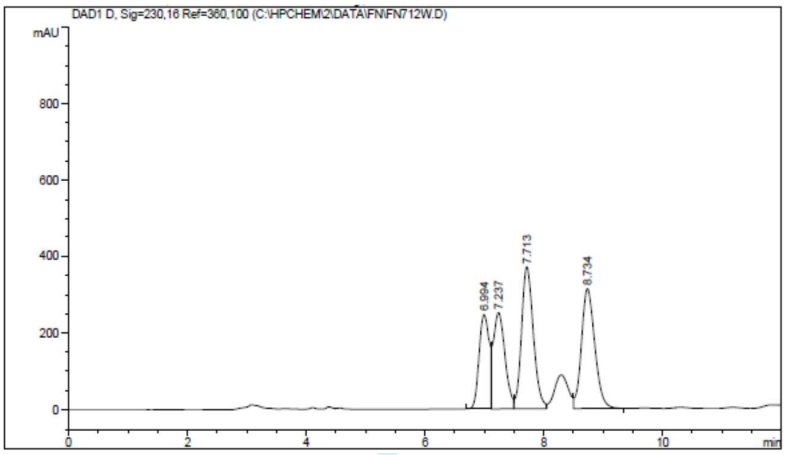
10b



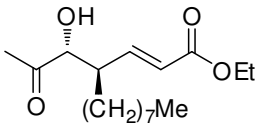
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	38.410	BV	0.6042	280.76089	5.74475	0.6255
2	39.974	VB	1.0269	4.31121e4	606.80841	96.0521
3	47.462	BB	0.8711	873.47980	12.00126	1.9461
4	51.311	BB	0.9613	617.74939	7.59209	1.3763



10c-*Rac*



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	6.994	BV	0.1816	2912.20703	246.83617	17.8318
2	7.237	VV	0.2053	3434.80664	251.53059	21.0318
3	7.713	VV	0.2137	5123.45557	369.63638	31.3716
4	8.734	VB	0.2414	4861.02783	312.69357	29.7647



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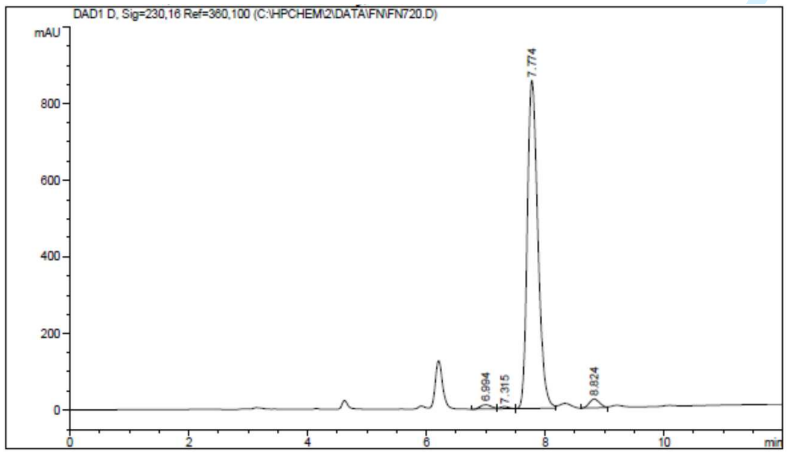
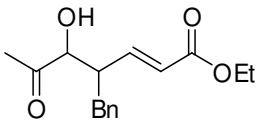
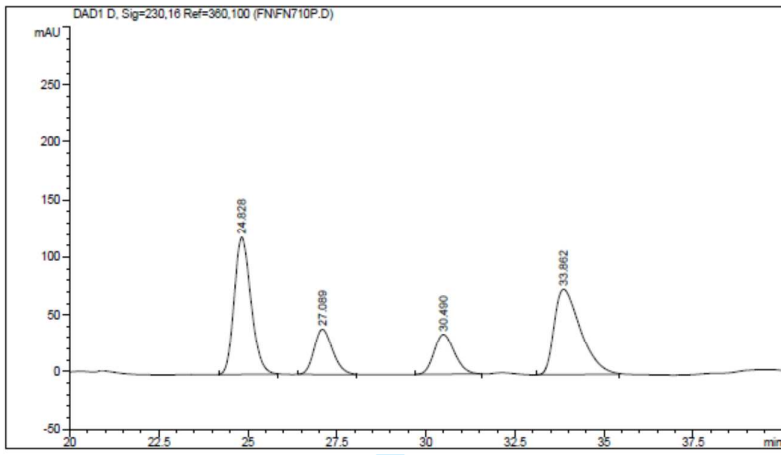


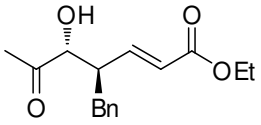
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	6.994	PV	0.2001	145.08846	11.42676	1.3073
2	7.315	VV	0.1664	62.20797	5.74388	0.5605
3	7.774	VV	0.1923	1.06135e4	857.90094	95.6284
4	8.824	VV	0.1914	277.89667	22.92982	2.5039



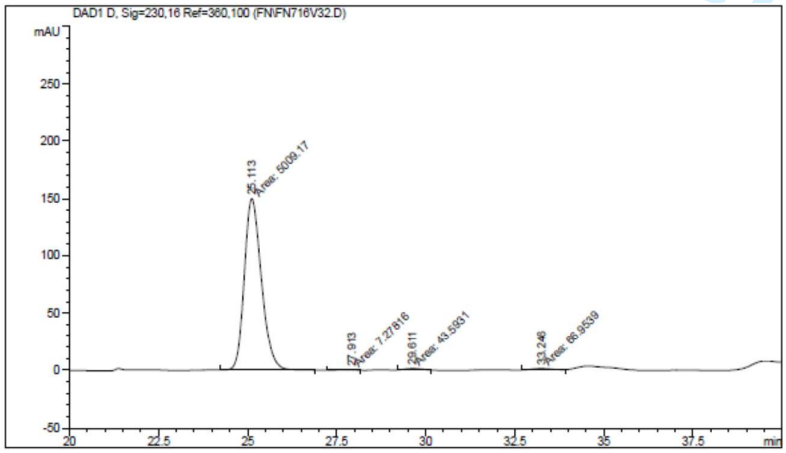
10d-*Rac*



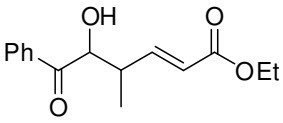
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.828	BB	0.5099	3967.47314	119.93842	36.9916
2	27.089	BB	0.5642	1458.02393	40.10164	13.5942
3	30.490	BB	0.6223	1414.68042	35.39716	13.1901
4	33.862	PB	0.7567	3885.15942	74.96174	36.2241



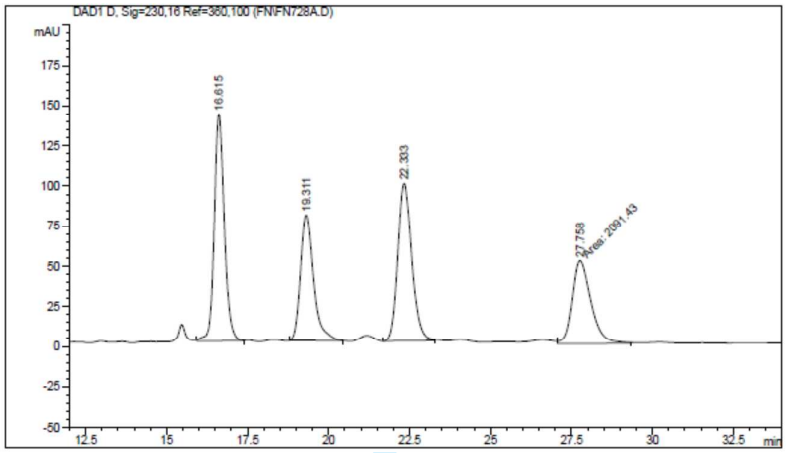
10d



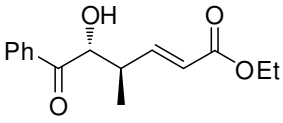
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	25.113	MM T	0.5554	5009.17139	150.30388	97.7019
2	27.913	MM T	0.4449	7.27816	2.72646e-1	0.1420
3	29.611	MM T	0.5454	43.59312	1.33217	0.8503
4	33.246	MM T	0.7397	66.95388	1.50849	1.3059



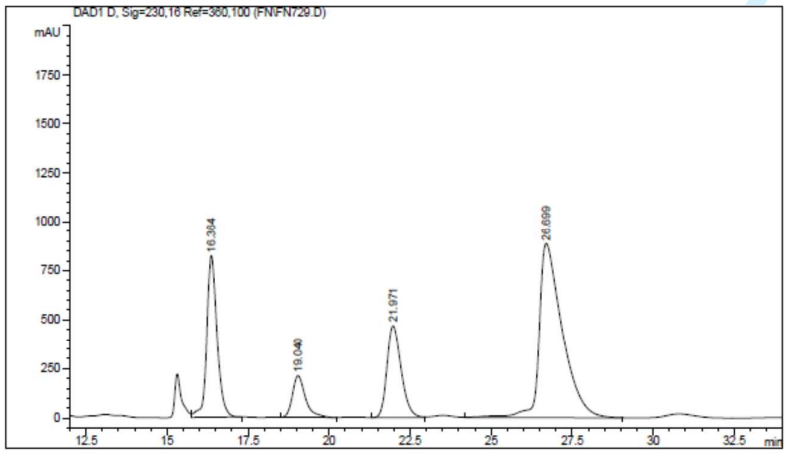
10e-*Rac*



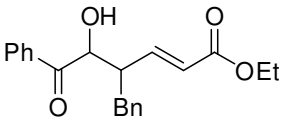
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.615	BB	0.3298	3080.44238	141.59848	29.8805
2	19.311	BB	0.4232	2184.10327	78.36445	21.1859
3	22.333	VB	0.4627	2953.24585	98.23289	28.6467
4	27.758	MM T	0.6738	2091.42651	51.72892	20.2870



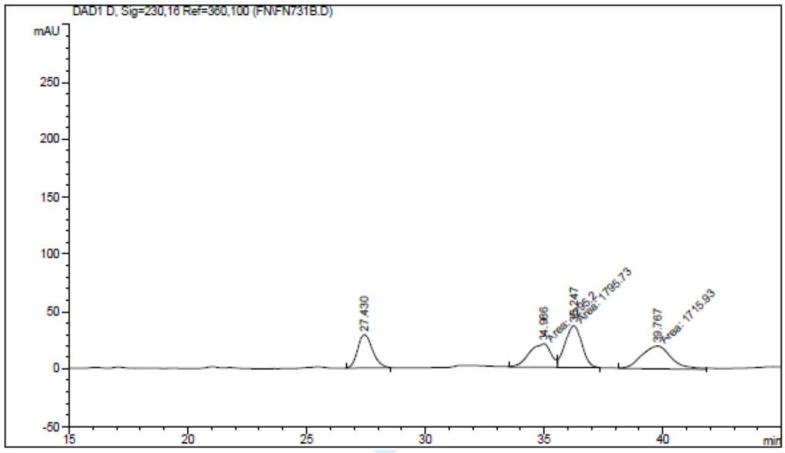
10e



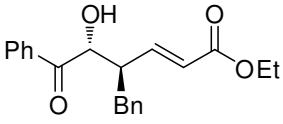
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.364	VB	0.3330	1.81085e4	822.00116	22.0523
2	19.040	BP	0.4183	5824.60400	209.52214	7.0931
3	21.971	VV	0.4635	1.41667e4	467.48294	17.2520
4	26.699	VB	0.7276	4.40164e4	886.06549	53.6026



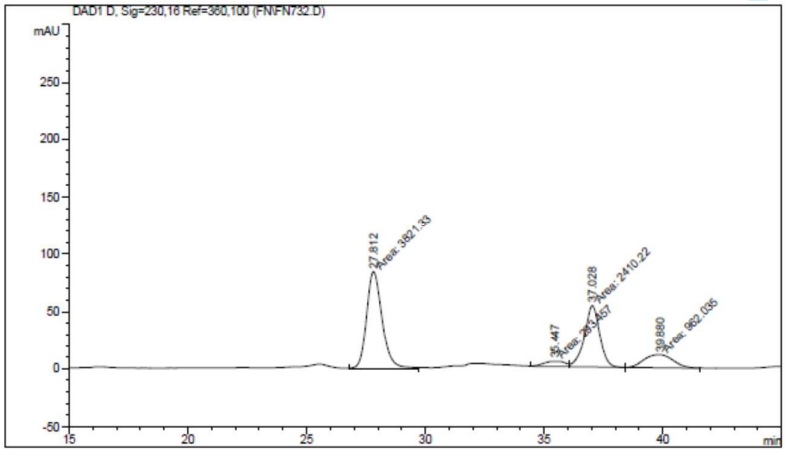
10f-*Rac*



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	27.430	BB	0.6520	1274.85278	29.86748	20.9621
2	34.986	MF T	1.0676	1295.20081	20.21909	21.2966
3	36.247	FM T	0.8093	1795.72839	36.98006	29.5267
4	39.767	MM T	1.4556	1715.93152	19.64767	28.2146



10f



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	27.812	MM T	0.7554	3821.32959	84.31599	51.0392
2	35.447	MF T	1.0690	293.45682	4.57515	3.9195
3	37.028	MF T	0.7427	2410.22290	54.08915	32.1919
4	39.880	FM T	1.4205	962.03522	11.28773	12.8493

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[1] a) G. Guillena, M. C. Hita, C. Nájera and S. F. Viozquez, *J. Org. Chem.* 2008, **73**, 5933. b) S. F. Viozquez, G. Guillena, C. Nájera, B. Bradshaw, G. Etxebarria-Jardi and J. Bonjoch, *Org. Synth.* 2011, **88**, 317.

[2] Alberg, D. G.; Poulsen, T. B.; Bertelsen, S.; Christensen, K. L.; Birkler, R. D.; Johannsen, M.; Jørgensen, K. A. *Bioorg. Med. Chem. Lett.* **2009**, *19*, 3888.

[3] Smith, III, A. B.; Liverton, N. J.; Hrib, N. J.; Sivaramakrishnan, H.; Winzenberg, K. *J. Am. Chem. Soc.* **1986**, *108*, 3040.

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[5] Hayashi, Y.; Yasui, Y.; Kojima, M. Kawamura, T., Ishikawa, H. *Chem. Commun.* **2012**, *48,* 4570.