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Enantioselective zinc-mediated conjugate alkynylation of saccharin-derived 1-*aza*-butadienes

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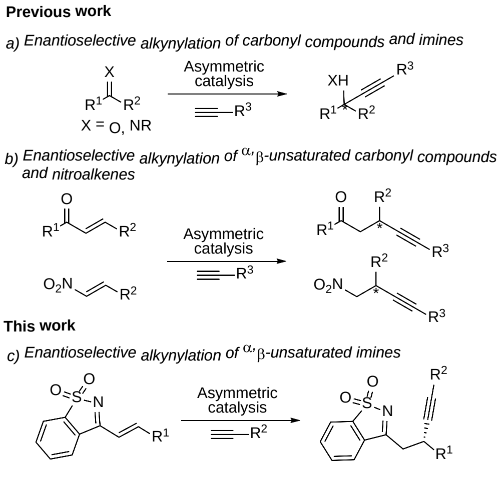
The enantioselective 1,4-alkynylation of conjugated imines derived from saccharin with aryl- and alkyl- substituted terminal alkynes has been achieved. The reaction mediated by diethylzinc in the presence of a catalytic amount of a bis(hydroxy)malonamide chiral ligand provides the corresponding imines bearing a propargylic stereocenter with moderate yields and fair to excellent enantioselectivities.

The C–C triple bond is present in the structures of many natural products and other organic compounds of interest in biochemistry and material science.[1] Furthermore, alkynes are versatile building blocks in synthetic organic chemistry that can undergo a broad range of transformation providing access to different functional groups and structural motifs.[2] Accordingly, the development of procedures to introduce a C–C triple bond in organic molecules is an important goal for many synthetic chemists. Among the different methodologies developed, those that exploit the acidic character of terminal alkynes are especially appealing. Thus, deprotonation of terminal alkynes with stoichiometric or catalytic amounts of base (in the presence of metal catalyst) provides nucleophilic metal alkynylides, which can react with carbon-based electrophiles to give internal alkynes with concomitant formation of a new C–C bond and, sometimes, of a new propargylic stereogenic center. In this context, considerable efforts have been devoted to the enantioselective alkynylation of carbonyl compounds[3] and imines[4] to give propargylic alcohols and amines, respectively (Scheme 1a). On the other hand, the enantioselective alkynylation of electrophilic C–C double bonds conjugated with electron-withdrawing groups has constituted a bigger challenge due to their lower electrophilicity and regioselectivity issues.[5] Nevertheless, considerable success has been obtained in the enantioselective alkynylation of conjugated carbonyl compounds[6] and nitroalkenes[7] under a variety of metal catalysis (Scheme 1b). However, despite these advances some limitations still remain. For instance, most of the reported procedures are appropriate for aryl- or trialkylsilyl- acetylenes but provide low enantioselectivities with alkyl-substituted alkynes.[5] Furthermore, developing conditions for the regio- and enantioselective alkynylation of other 1,4-acceptors, besides conjugated carbonyls and nitroalkenes, would be highly desirable.

Recently, α,β-unsaturated imines (1-*aza*-butadienes), the nitrogen analogues of enones, have been explored as Michael acceptors in enantioselective reactions.[8,9] However, although a synthesis of pyridines and pyrroles involving the copper-catalyzed conjugate addition of alkyl propiolates to *N*-sulfonyl *aza*-dienes has been reported,[10] there are no literature precedents on the enantioselective conjugate alkynylation of α,β-unsaturated imines to give chiral β-alkynyl imines bearing a propargylic stereocenter. Here, we describe our results on this elusive reaction (Scheme 1c), with special attention to the challenging aliphatic alkynes, affording chiral β-alkynyl imines



Scheme 1 Enantioselective addition of terminal alkynes

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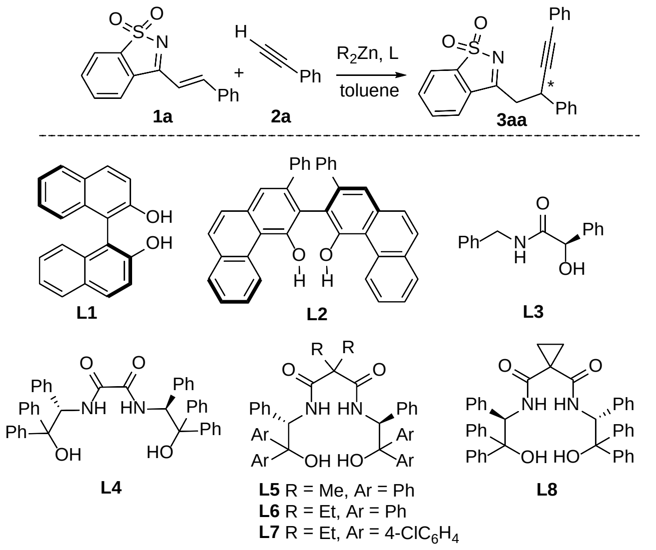
Electronic Supplementary Information (ESI) available: [details of any supplementary information available should be included here]. See DOI: 10.1039/x0xx00000x with excellent enantioselectivities.

Preliminary studies for the conjugate alkynylation of α,β-unsaturated imines were carried out using the addition of phenylacetylene to the *N*-tosylimine of chalcone mediated by zinc. However, although the applied conditions[11] led to the conjugate alkynylation product with fair levels of enantioselectivity, this was ineluctably obtained as an imine/enamine isomeric mixture (See SI). To avoid this drawback, saccharin-derived imines were chosen as substrates as we anticipated the preferential formation of the imine with the endocyclic double bond.[12] To begin with the optimization process, we studied the addition of phenylacetylene (**2a**) to saccharin-derived imine **1a** (Table 1).[11]

We initially tested the conditions developed in our group for the zinc-mediated conjugate alkynylation of unsaturated carbonyl compounds.[11] Under the initial conditions, the reactive system was prepared by heating a solution of ligand (20 mol%), alkyne **2a** (7.5 equiv.) and diethylzinc (2 equiv.) in toluene to 70 °C for 1 hour followed by addition of the imine **1a** after cooling to room temperature. Dihydroxybiaryl (**L1**, **L2**), mandelamide (**L3**), bis(hydroxy)oxamide (**L4**) and several bis(hydroxy)malonamide derivatives (**L5**-**L8**) were tested as chiral ligands. The most significative results are shown in Table 1 (see also SI). Ligands derived from 2,2-diethylmalonic acid and 1,1,2-triarylaminoethanol (**L6** and **L7**) provided the best results with similar performance for both ligands, compound **3aa** being obtained in ca 50% yield and 71% *ee* and 72% *ee*, respectively (Table 1, entries 6 and 7). Further optimization was performed with ligand **L7**. The effect of the catalyst load was examined. Increasing it to 30 mol% brought about a decrease of both yield and enantiomeric excess (Table 1, entry 9). On the other hand, only a slight decrease in the *ee* and yield was observed when the catalyst loading was reduced to 10 mol% (Table 1, entry 7 *vs* entry 10). Increasing the amount of diethylzinc from 2 to 4 equivalents in the presence of 10 mol% of **L7** allowed to improve the *ee* of the reaction up to 80% (Table 1, entry 11). Dimethylzinc was also tested but provided lower results than diethylzinc (Table 1, entry 12 *vs* 11). Finally, reducing the amount of alkyne **2a** to 5 equivalents increased the *ee* to 85%, while keeping the yield (Table 1, entry 13).

Table 1 Optimization of reaction conditions.[a]

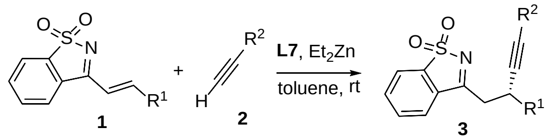


Entry	L (mol%)	2a (equiv.)	Et_2Zn (equiv.)	t (h)	Yield (%)	*ee* (%)[b]
1	**L1** (20)	7.5	2	3	22	0
2	**L2** (20)	7.5	2	3	48	-22
3	**L3** (20)	7.5	2	3	65	26
4	**L4** (20)	7.5	2	3	49	10
5	**L5** (20)	7.5	2	3	48	-65
6	**L6** (20)	7.5	2	3	50	-71
7	**L7** (20)	7.5	2	3	53	-72
8	**L8** (20)	7.5	2	3	54	30
9	**L7** (30)	7.5	2	3	27	-38
10	**L7** (10)	7.5	2	3	41	-67
11	**L7** (10)	7.5	4	3	53	-80
12[c]	**L7** (10)	7.5	4	3	50	-58
13	**L7** (10)	5	4	3	47	-85

[a] **1a** (0.125 mmol), **2a**, 1.5 M Et_2Zn in toluene, **L**, toluene (1.5 mL), rt. [b] Determined by HPLC with chiral stationary phases. Different sign indicates opposite enantiomers. [c] Me_2Zn was used instead of Et_2Zn.

Under the best conditions available (Table 1, entry 13) we studied the scope of the enantioselective conjugate alkynylation of imines **1** (Table 2). First, we performed the addition of arylacetylenes to imines **1**. The results of the reaction were highly dependent on both the substituent on the β position of the double bond in compounds **1** and on the aryl group of the alkyne **2**. In most of the cases the addition products **3** were obtained with fair yields[‡] and enantiomeric excesses (Table 2, entries 1-11). Interestingly, the addition of 4-phenyl-1-butyne (**2d**) to imine **1a** under the optimized conditions provided compound **3ad** with 90% *ee* together with some racemic ethylation product, which could be avoided by reducing

Table 2 Conjugate addition of aryl-substituted terminal acetylenes **2** to unsaturated imines **1**.[a]



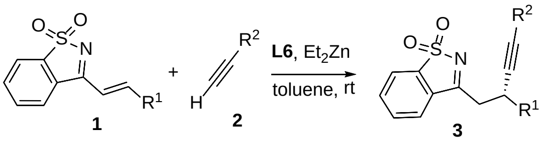
Entry	1	R^1	2	R^2	3	Yield (%)	*ee* (%)[b]
1	**a**	Ph	**a**	Ph	**3aa**	47	85
2	**b**	*p*-BrC_6H_4	**a**	Ph	**3ba**	59	69
3	**c**	*p*-$MeOC_6H_4$	**a**	Ph	**3ca**	40	33
4	**d**	*p*-MeC_6H_4	**a**	Ph	**3da**	33	58
5	**e**	*o*-MeC_6H_4	**a**	Ph	**3ea**	36	53
6	**f**	*m*-MeC_6H_4	**a**	Ph	**3fa**	35	71
7	**g**	2-naphthyl	**a**	Ph	**3ga**	35	83
8	**h**	2-thienyl	**a**	Ph	**3ha**	49	70
9	**i**	*tert*-butyl	**a**	Ph	**3ia**	84	35
10	**a**	Ph	**b**	*p*-ClC_6H_4	**3ab**	43	83
11	**a**	Ph	**c**	*p*-$MeOC_6H_4$	**3ac**	46	54
12[c]	**a**	Ph	**d**	$PhCH_2CH_2$	**3ad**	50	90

[a] **1** (0.125 mmol), **2** (0.625 mmol), 1.5 M Et_2Zn in toluene (0.50 mmol), **L7** (0.025 mmol), toluene (1.5 mL), rt, 3 h. [b] Determined by HPLC with chiral stationary phases. [c] Et_2Zn (0.25 mmol)

the amount of Et_2Zn to 2 equivalents (Table 2, entry 12). This is a remarkable result, since historically alkyl acetylenes tend to give lower enantioselectivities than aryl acetylenes.[5] In the view of these promising results, we decided to further investigate the addition of alkyl-substituted terminal acetylenes. The performance of ligands **L6** and **L7** was re-evaluated in the addition of 4-phenyl-1-butyne (**2d**) to imine **1a**. In this case **L6** gave better result, allowing to obtain compound **3ad** in 68% yield and 95% *ee* (Table 2, entry 12 *vs* Table 3, entry 1). With **L6**, we studied the addition of a number of alkyl-substituted terminal acetylenes to several imines (Table 3).

Besides 4-phenyl-1-butyne (**2d**), the reaction could be carried out with other alkynes bearing a fully alkyl chain such as 1-hexyne (**2e**), the functionalized 6-chloro-1-hexyne (**2f**), the challenging cyclopropylacetylene (**2g**), as well as other functionalized alkynes bearing ester, benzyl ether or aryl ether groups (**2h-j**). Regarding the conjugated imine partner, the aryl group attached to the β-carbon of the double bond was amenable to variation, allowing the presence of electron-withdrawing or electron-donating groups at either the *ortho*-, *metha*- or *para*-positions of the phenyl ring. In all the cases, the alkynylated imines were obtained with excellent enantioselectivities (82-97% *ee*), especially when a *para*-substituted aryl group was used (Table 3).

Table 3 Conjugate addition of alkyl-substituted terminal acetylenes **2** to unsaturated imines **1**.[a]



Entry	1	R¹	2	R²	3	Yield (%)	*ee* (%)[b]
1	**a**	Ph	**d**	$PhCH_2CH_2$	**3ad**	68	95
2	**b**	*p*-BrC_6H_4	**d**	$PhCH_2CH_2$	**3bd**	35	96
3	**a**	Ph	**e**	butyl	**3ae**	44	88
4	**b**	*p*-BrC_6H_4	**e**	butyl	**3be**	38	97
5	**d**	*p*-MeC_6H_4	**e**	butyl	**3de**	42	92
6	**a**	Ph	**f**	$Cl(CH_2)_4$	**3af**	48	96
7	**b**	*p*-BrC_6H_4	**f**	$Cl(CH_2)_4$	**3bf**	36	93
8	**d**	*p*-MeC_6H_4	**f**	$Cl(CH_2)_4$	**3df**	58	91
9	**a**	Ph	**g**	cyclopropyl	**3ag**	61	93
10	**b**	*p*-BrC_6H_4	**g**	cyclopropyl	**3bg**	45	96
11	**c**	*p*-$MeOC_6H_4$	**g**	cyclopropyl	**3cg**	69	93
12	**d**	*p*-MeC_6H_4	**g**	cyclopropyl	**3dg**	69	93
13	**e**	*o*-MeC_6H_4	**g**	cyclopropyl	**3eg**	55	85
14	**f**	*m*-MeC_6H_4	**g**	cyclopropyl	**3fg**	64	82
15	**a**	Ph	**h**	$PhCO_2CH_2$	**3ah**	63	93
16	**a**	Ph	**i**	*p*-$MeOC_6H_4O(CH_2)_4$	**3ai**	66	99
17	**a**	Ph	**j**	$PhCH_2OCH_2$	**3aj**	59	80
18[c]	**a**	Ph	**d**	$PHCH_2CH_2$	**3ad**	56	88

[a] **1** (0.125 mmol), **2** (0.625 mmol), 1.5 M Et_2Zn in toluene (0.17 mL, 0.25 mmol), **L6** (0.0125 mmol), toluene (1.5 mL), rt, 3 h. [b] Determined by HPLC with chiral stationary phases. [c] Reaction carried out with 1.25 mmol of **1a**.

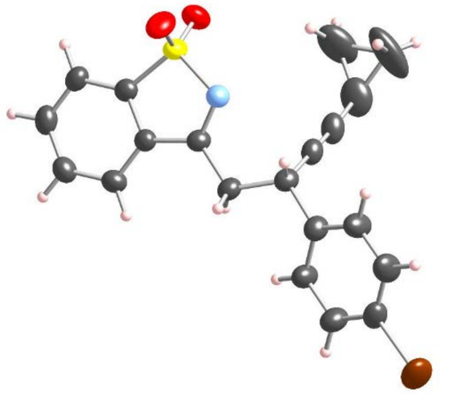
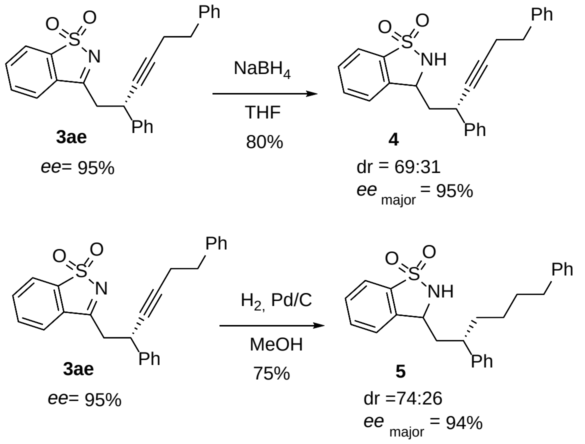


Figure 1 Ortep plot for the X-ray structure of compound **3bg**. The thermal ellipsoids are drawn at the 50% probability level. Flack parameter 0.017(6).

The conjugate alkynylation of **1a** with 4-phenyl-1-butyne (**2d**) was scaled up to 1.25 mmol of **1a** providing the expected product **3ad** with good yield and some erosion of enantioselectivity, but still with high 88% *ee* (Table 3, entry 18). Compound **3bg** (Table 3, entry 10) could be crystallized and subjected to X-ray analysis, what allowed to establish the configuration of the stereogenic center as *S* (Figure 1).[§] The absolute stereochemistry of all compounds **3** was assigned by analogy upon the assumption of a uniform stereochemical pathway.

Scheme 2 shows some transformations on compound **3ae** that show the potential application of compounds **3** in the synthesis of optically active benzosultams. Thus, selective reduction of the imine could be achieved by treatment with sodium borohydride in THF to give alkyne **4** in 80% yield as a 69:31 mixture of two diastereomers without erosion of the enantiomeric excess. On the other hand, compound **5** was obtained in 75% yield, as a 74:26 diastereomer mixture without loss of enantiomeric excess, after simultaneous reduction of the triple bond and the imine by catalytic hydrogenation on 10% Pd/C.



Scheme 2 Synthetic transformations of compound **3ae**.

In summary, we have reported the first example of enantioselective conjugate alkynylation of α.β-unsaturated imines (1-*aza*-butadienes). A reactive system formed by a terminal alkyne, diethylzinc and a chiral bis(hydroxy)malonamide allowed the enantioselective alkynylation of C–C double bonds conjugated with saccharin-derived imines to give the corresponding alkynylated imines bearing a propargylic stereocenter. The reaction can be performed with terminal alkynes of different characteristics and, remarkably, it is most convenient for alkyl-substituted alkynes. The results anticipated the potential application of this catalytic system to other unsaturated imines sucha as chalcone imines. Research with this regard is underway in our laboratory. This work was supported by the Agencia Estatal de Investigación and Fondo Europeo de Desarrollo Regional-EU (Grant CTQ2017-84900-P). We gratefully thank the access to NMR and MS facilities from the SCSIE-UV. C. V. thanks the Spanish Government for a Ramon y Cajal contract (RyC-2016-20187). A. S.-M. thanks the Generalitat Valenciana and FEDER-EU for a post-doctoral grant (APOST/2016/139) and the Spanish government for a Juan de la Cierva Contract (IJC2018-036682-I).

Conflicts of interest

There are no conflicts to declare

Notes and references

‡ In some cases we observed the formation of the conjugate ethylation product in some extent. This fact together with the low solubility showed by some of the products may account in part for the obtained fair yields. The mass balance in three representative entries (Table 2, entry 1 and Table 3, entries 16 and 17) can be found in the SI.

§ CCDC-1992564 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

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Enantioselective zinc-mediated conjugate alkynylation of saccharin-derived 1-*aza*-butadienes

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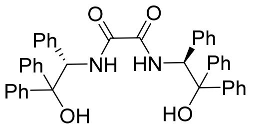
Supporting Information

Table of Contents:

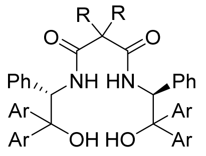
Preliminary experiments with chalcone *N*-tosyl imine (1j).

Preliminary studies for the conjugate alkynylation of α,β-unsaturated imines were carried out using the addition of phenylacetylene (**2a**) to the *N*-tosylimine of chalcone (**1j**). The conditions previously developed in our group for the zinc-mediated conjugate alkynylation of unsaturated carbonyl compounds were applied.[1] The reactive system was prepared by heating a solution of ligand (20 mol %), alkyne **2a** (7.5 equiv.) and diethylzinc (2 equiv.) in toluene to 70 °C for 1 hour followed by addition of the imine **1j** after cooling at room temperature. The reaction gave two compounds that could be separated and characterized as enamine (*Z*)-**3ja** and imine **3ja'**. Imine **3ja'** most probably results from quick isomerization of the (*E*)-enamine, initially formed, to avoid repulsion of the phenyl and phenylethynyl groups. The Z-enamine was stable for several days in the NMR tube while imine **3ja'** hydrolyzed almost completely after 24 hours in the NMR tube. Table S-1 shows the most representative results obtained with imine **1j.**

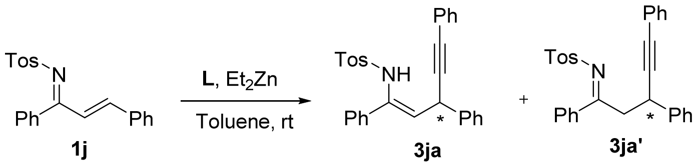
Table S1. Enantioselective reaction of phenylacetylene (**2a**) and the *N*-tosylimine of chalcone (**1j**). Short screening of catalysts.[a]



L4



L5 R = Me, Ar = Ph
L6 R = Et, Ar = Ph
L7 R = Et, Ar = 4-ClC_6H_4

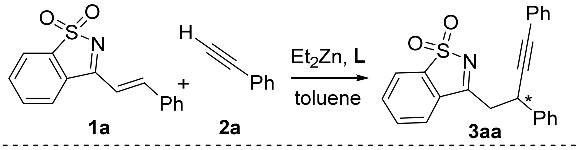


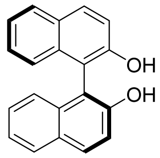
Entry	Ligand	yield (%)	**3ja:3ja'**[b]	*ee*$_{3ja}$ (%)[c]	*ee*$_{3ja'}$ (%)[c]
1	**L4**	31	40:60	24	33
2	**L5**	74	80:20	22	22
3	**L6**	52	76:24	43	34
4	**L7**	45	72:28	73	75

[a] **1** (0.125 mmol), **2a** (0.938 mmol), 1.5 M Et_2Zn in toluene (0.250 mmol), **L** (0.0250 mmol), toluene (1.5 mL), rt., 3 hours. [b] Determined by NMR. [c] Determined by HPLC with chiral stationary phases.

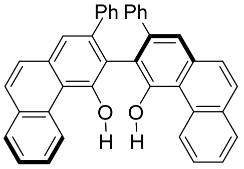
Additional Optimization Experiments with Imine 1a

Table S2. Enantioselective reaction between phenylacetylene (**2a**) and imine **1a**. Chiral ligand study.[a]

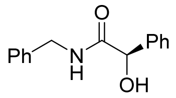




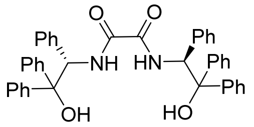
L1



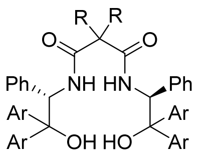
L2



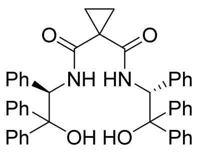
L3



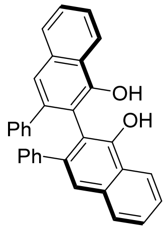
L4



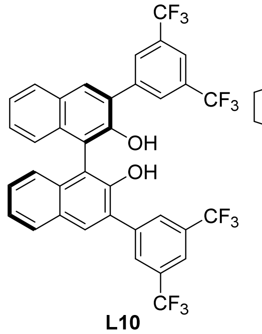
L5 R = Me, Ar = Ph
L6 R = Et, Ar = Ph
L7 R = Et, Ar = 4-ClC$_6$H$_4$



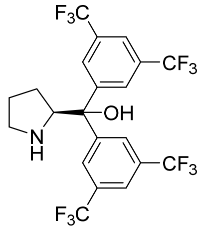
L8



L9



L10

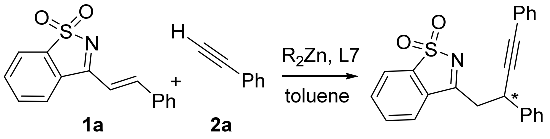


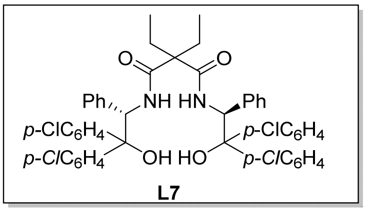
L11

entry	L	yield (%)	*ee* (%)[b]
1	**L1**	22	0
2	**L2**	48	-22
3	**L3**	65	26
4	**L4**	49	10
5	**L5**	48	-65
6	**L6**	50	-71
7	**L7**	53	-72
8	**L8**	54	30
9	**L9**	38	45
10	**L10**	22	0
11	**L11**	29	0

[a] **1a** (0.125 mmol), **2a** (0.938 mmol), 1.5 M Et$_2$Zn in toluene (0.50 mmol), **L7** (0.025 mmol), toluene (1.5 mL), rt, 3 hours. [b] Determined by HPLC with chiral stationary phases. Different sign indicates opposite enantiomers.

Table S3. Enantioselective reaction between phenylacetylene (**2a**) and imine **1a**. Effect of the number of equivalents of dialkylzinc reagent.[a]

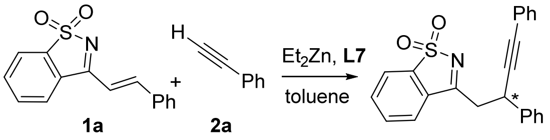


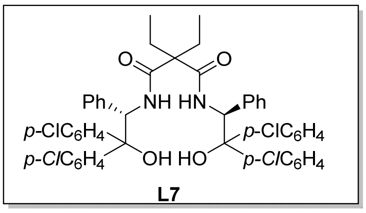


entry	Et_2Zn (equiv.)	yield (%)	*ee* (%)[b]
1	1.3	52	63
2	2	41	67
3	3	50	64
4	4	53	80
5	5	43	64
6[c]	4	50	58

[a] **1a** (0.125 mmol), **2a** (0.938 mmol), **L7** (0.0125 mmol), toluene (1.5 mL), rt, 3 hours. [b] Determined by HPLC with chiral stationary phases. [c] Me_2Zn was used instead of Et_2Zn.

Table S4. Enantioselective reaction between phenylacetylene (**2a**) and imine **1a**. Effect of the number of equivalents of alkyne.[a]

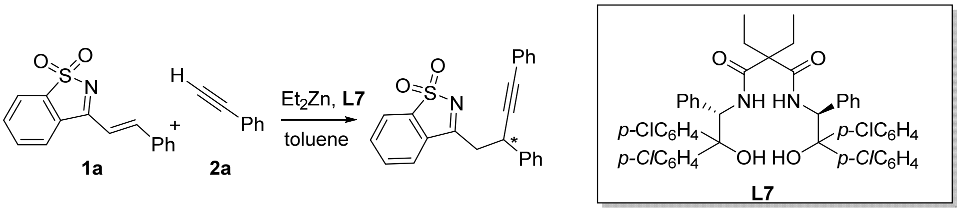




entry	**2a** (equiv.)	yield (%)	*ee* (%)[b]
1	4	38	57
2	5	47	85
3	7.5	53	80

[a] **1a** (0.125 mmol), **2a**, 1.5 M Et_2Zn in toluene (0.50 mmol), **L7** (0.0125 mmol), toluene (1,5 mL), rt, 3 hours. [b] Determined by HPLC with chiral stationary phases.

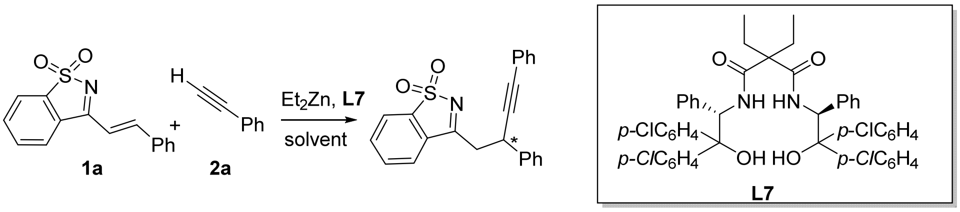
Table S5. Enantioselective reaction between phenylacetylene (**2a**) and imine **1a**. Effect of the concentration.[a]



Entry	[**1a**] (M)	yield (%)	*ee* (%)[b]
1	0.063	59	59
2	0.090	47	85
3	0.126	38	63

[a] **1a** (0.125 mmol), **2a** (0.625 mmol), 1.5 M Et_2Zn in toluene (0.50 mmol), **L7** (0.0125 mmol), toluene, rt, 3 hours. [b] Determined by HPLC with chiral stationary phases.

Table S6. Enantioselective reaction between phenylacetylene (**2a**) and imine **1a**. Effect of the solvent.[a]



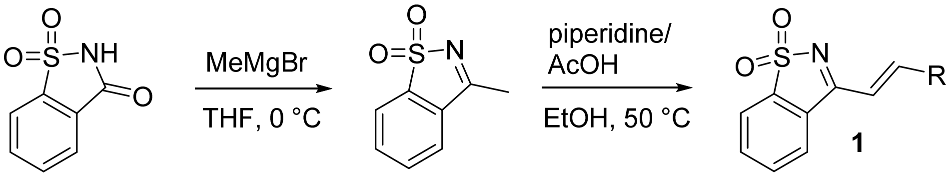
entry	solvent	yield (%)	*ee* (%)[b]
1	toluene	47	85
2	1,2-dichloroethane	46	41
3[c]	CH_2Cl_2	40	40
4[c]	THF	20	0

[a] **1a** (0.125 mmol), **2a** (0.625 mmol), 1.5 M Et_2Zn in toluene (0.50 mmol), **L7** (0.0125 mmol), solvent (1.5 mL), rt, 3 hours. [b] Determined by HPLC with chiral stationary phases. c **2a** (0.625 mmol), 1.5 M Et_2Zn in toluene (0.50 mmol) and **L7** (0.0125 mmol) in toluene (0.5 mL) at 70 ºC for 2 h and then **1a** (0.125 mmol) in solvent (1.o mL), rt, 3 hours.

Materials and methods

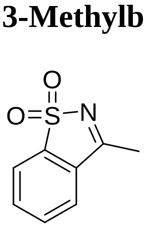
All reagents were purchased from commercial suppliers and used without further purification. All solvents employed in the reactions were distilled from appropriate drying agents prior to use. Toluene for the enantioselective reactions was freshly distilled from CaH_2 prior to use. Reactions were monitored by TLC analysis using Merck Silica Gel 60 F-254 thin layer plates. Flash column chromatography was performed on Merck silica gel 60, 0.040-0.063 mm. Melting points were determined in capillary tubes. NMR spectra were run at 300 MHz for ^1H and at 75 MHz for ^{13}C NMR using residual nondeuterated solvent as internal standard (δ 7.26 ppm for ^1H and 77.0 ppm for ^{13}C in $CDCl_3$, and δ 2.50 ppm for ^1H and 39.52 ppm for ^{13}C in DMSO-d_6, respectively). Chemical shifts are given in ppm. The carbon type was determined by DEPT experiments. High resolution mass spectra (ESI) were recorded on an AB SCIEX Triple TOF spectrometer equipped with an electrospray source with a capillary voltage of 4.5 kV. Specific optical rotations were measured using sodium light (D line 589 nm). Chiral HPLC analyses were performed in a chromatograph equipped with a UV diode-array detector using chiral stationary phase columns from Daicel or Phenomenex.

General procedure for the synthesis of saccharin-derived-1-*aza*-butadienes 1



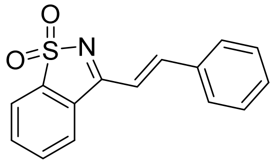
Compounds **1** were prepared following a modified literature procedure.[2,3] The synthesis of compound **1a** is illustrated.

3-Methylbenzo[d]isothiazole 1,1-dioxide[2]



A 3 M solution of MeMgBr in diethyl ether (21 mL, 62.8 mmol) was added dropwise to a solution of saccharin (5 g, 27.3 mmol) in dry THF (40 mL) a 0 °C under nitrogen. The reaction mixture was stirred overnight at room temperature and quenched with aqueous saturated NH_4Cl (50 mL). The aqueous layer was extracted with CH_2Cl_2 (3 × 50 mL) and the combined organic layers washed with brine (2 × 25 mL). After drying with $MgSO_4$ and evaporation of the solvent under reduced pressure, column chromatography eluting with hexane:EtOAc gave 3.96 g (80% yield) of the title compound. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.96–7.86 (m, 1H), 7.81–7.65 (m, 3H), 2.67 (s, 3H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.4 (C), 139.7 (C), 134.1 (CH), 133.7 (CH), 131.7 (C), 124.3 (CH), 122.5 (CH), 17.7 (CH_3).

(*E*)-3-Styrylbenzo[d]isothiazole 1,1-dioxide (1a)[3a]

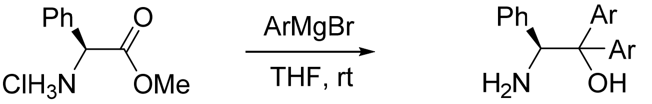


Benzaldehyde (0.98 mL, 9.6 mmol), piperidine (5 drops), and acetic acid (5 drops) were added in this order to a pre-heated solution of 3-methylbenzo[*d*]isothiazole 1,1-dioxide (0.78 g, 4.3 mmol) in absolute ethanol (15 mL) at 80 ºC. The mixture was stirred overnight and, then, cooled to 0 ºC and filtered. The solid was washed with cold ethanol (5 × 10 mL) and Et_2O (5 × 5 mL) to give 1.1 g (93% yield) of **1a**. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 8.32 (d, *J* = 15.6 Hz, 1H), 8.00–7.94 (m, 1H), 7.93–7.86 (m, 1H), 7.82–7.65 (m, 4H), 7.53–7.44 (m, 3H), 7.30 (d, *J* = 15.6 Hz, 1H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 167.2 (C), 148.0 (CH), 140.8 (C), 134.4 (C), 133.8 (CH), 133.7 (CH), 132.0 (CH), 131.7 (C), 129.4 (CH), 129.2 (CH), 123.9 (CH), 123.0 (CH), 113.7 (CH).

In some cases, compounds **1** were obtained contaminated with a by-product of unknown structure, which was not soluble in chloroform. In these cases, compounds **1** could be obtained pure by suspending the mixture in hot chloroform (100 mL), filtering and concentrating the filtrate.

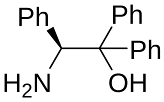
Synthesis of ligands L6 and L7

General procedure for the synthesis of 1,1,2-triaryl-2-aminoethanols



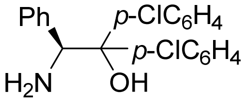
R = Ph or *p*-ClC$_6$H$_4$

(*S*)-2-Amino-1,1,2-triphenylethan-1-ol



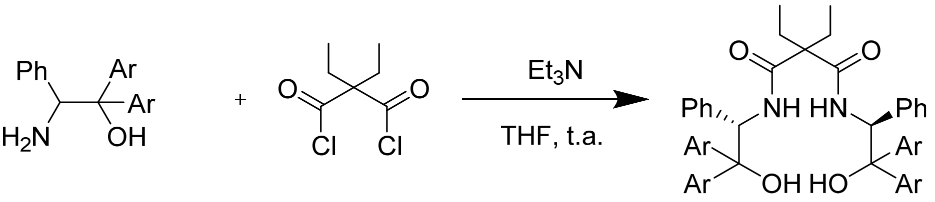
A commercially available 3 M solution of PhMgBr in dry diethyl ether (20 mL, 60 mmol) was introduced via syringe in a round bottom flask under nitrogen followed by diethyl ether (40 mL) and introduced in an ice bath. (*S*)-methyl phenylglycinate hydrochloride (1.65 g, 10 mmol) was added in two portions and the mixture stirred at room temperature for 6 hours. After this time, the mixture was poured into ice (ca. 35 g) and acidified with 6 M HCl (15 mL). The mixture was filtered and the solid washed with cold Et_2O (3 × 5 mL). The solid was treated with 2 M NaOH in MeOH (60 mL) and concentrated under reduced pressure. The resulting crude was stirred in a 1:1 mixture of water and dichloromethane (100 mL) for 10 min. The layers were separated and the organic layer was washed with water (3 × 25 mL), dried and concentrated under reduced pressure to give 1.85 g (65% yield) of the title compound. White solid, mp 140-142, $[\alpha]_D^{25}$ –195.8 (*c* 1.3, MeOH); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.78 (m, 2H), 7.44–7.39 (m, 2H), 7.31–7.26 (m, 1H), 7.15–7.11 (m, 7H), 7.08–7.02 (m,3H), 5.02 (s, 1H), 1.71 (br s, NH_2); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 146.5 (C), 143.9 (C), 140.0 (C), 128.6 (CH), 128.5 (2CH), 127.4 (CH), 127.3 (CH), 127.2 (CH), 127.0 (CH), 126.5 (CH), 126.2 (CH), 126.0 (CH), 79.5 (C), 61.8 (CH).

(*S*)-2-Amino-1,1-bis(4-chlorophenyl)-2-phenylethan-1-ol



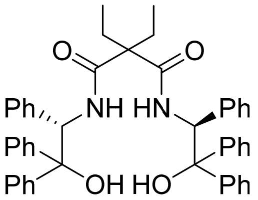
2.21 g (62%) were obtained. White solid; **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.70–7.67 (m, 2H), 7.42–7.39 (m, 2H), 7.19–7.13 (m, 5H), 7.04 (s, 4H), 4.95(s, 1H), 1.63 (br s, NH_2); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 144.7 (C), 142.1 (C), 139.4 (C), 133.2 (C), 132.3 (C), 128.7 (CH), 128.5 (CH), 127.9 (2CH), 127.7 (CH), 127.6 (CH), 127.5 (CH), 78.9 (C), 61.6 (CH).

***General procedure for the synthesis of bis-hydroxiamides*[1]**



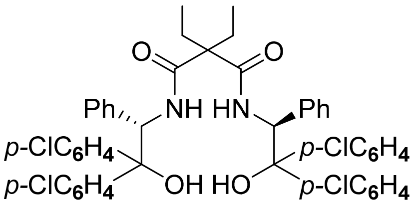
L6, Ar = Ph
L7, Ar = *p*-ClC_6H_4

***N,N'*-Bis[(1*S*)-1,2,2-triphenyl-2-hydroxyethyl]-2,2-diethylpropanodiamide (L6)**



Diethylmalonyl dichloride (141 μL, 0.82 mmol) was added dropwise to a solution of (*S*)-2-amino-1,1,2-triphenylethan-1-ol (472 mg, 1.63 mmol) and triethylamine (229 μL, 1.64 mmol) in THF (11 mL) at 0 ºC. The mixture was stirred at room temperature for 2 horas, filtered and the filtrate concentrated under reduced pressure to give 340 mg (58% yield) of ligand **L6**. White solid; mp 254-255 ºC; $[\alpha]_D^{25}$ –168 (*c* 0.06, MeOH); **^{1}H NMR** (300 MHz, DMSO-d_6) δ 9.02 (d, *J* = 8.4 Hz. 1H), 7.55 (d, *J* = 7.1 Hz, 2H), 7.29–7.21 (m, 5H), 7.11–7.00 (m, 8H), 6.17 (s, 1H), 5.86 (d, *J* = 8.4 Hz, 1H), 1.55–1.40 (m, 2H), –0.04 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** (75 MHz, DMSO-d_6) δ 171.8 (C), 146.1 (C), 145.0 (C), 139.4 (C), 129.2 (2CH), 127.7 (2CH), 127.2 (2CH), 126.6 (2CH), 126.4 (CH), 126.2 (3CH), 126.1 (3CH), 79.7 (C), 59.2 (CH), 57.0 (C), 30.7 (CH_2), 8.6 (CH_3).

N,N'-Bis[(*S*)-2,2-bis(4-chlorophenyl)-2-hydroxy-1-phenylethyl)-2,2-diethylmalonamide (L7)



The same procedure as for the synthesis of **L6** was followed. After the reaction was completed, the mixture was concentrated, suspended in EtOAc and filtered. The solid was dissolved in dichloromethane and washed with brine, dried over $MgSO_4$ and concentrated to give **L7** in 71% yield. White solid; mp 243-246 °C; $[\alpha]_D^{25}$ –175 (*c* 0.05, MeOH); **^{1}H NMR** (300 MHz, DMSO-d_6) δ 9.05 (d, *J* = 8.7 Hz, 2H), 7.59 (d, *J* = 8.7 Hz, 4H), 7.37 (d, *J* = 8.7 Hz, 4H), 7.28 (d, *J* = 8.7 Hz, 4H), 7.16 (d, *J* = 8.7 Hz, 4H), 7.04 (s, 10H), 6.37 (s, 2H), 5.84 (d, *J* = 8.7 Hz, 2H), 1.49 (tt, *J* = 15.3, 7.0 Hz, 4H), –0.10 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (75 MHz, DMSO-d_6) δ 171.9 (C), 144.8 (C), 143.5 (C), 139.0 (C), 131.5 (C), 131.1 (C), 129.2 (CH), 128.2 (CH), 128.1 (CH), 127.8 (CH), 127.4 (CH), 126.9 (CH), 126.6 (CH), 79.4 (C), 59.2 (CH), 57.1 (C), 30.8 (CH_2), 8.5 (CH_3).

Enantioselective conjugate alkynylation of imines 1 and characterization data for compounds 3

Enantioselective addition of terminal arylacetylenes 2 (R^2 = Aryl) to imines 1

A 1.5 M solution of Et_2Zn in toluene (0.34 mL, 0.5 mmol) was added dropwise to a solution of ligand **L7** (10.5 mg, 0.0125 mmol) and alkyne **2a-d** (0.625 mmol) in dry toluene (0.5 mL) at room temperature under nitrogen. The mixture was stirred at 70 ºC for 2 h. After cooling to room temperature, a solution of imine **1** (0.125 mmol) in toluene (1 mL) was added via syringe and the solution was stirred until the reaction was complete (TLC). The reaction was quenched with 20% aqueous NH_4Cl (1.0 mL), extracted with CH_2Cl_2 (3 × 15 mL), washed with brine (15 mL), dried over $MgSO_4$ and concentrated under reduced pressure. Purification by flash chromatography on silica gel eluting with hexane:Et_2O mixtures afforded compound **3**.

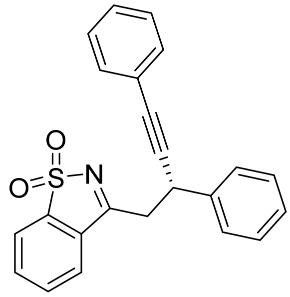
Racemic products **3** (R^2 = Aryl) were prepared following the same procedure but using *N*-benzil-2-hydroxy-2-phenylacetamide instead of **L7**.

Enantioselective addition of terminal alkylacetylenes 2 (R^2 = Alkyl) to imines 1

A 1.5 M solution of Et_2Zn in toluene (0.17 mL, 0.25 mmol) was added dropwise to a solution of ligand **L6** (9 mg, 0.0125 mmol) and alkyne **2e-h** (0.625 mmol) in dry toluene (0.5 mL) at room temperature under nitrogen. The mixture was introduced in a bath at 70 ºC for 2 hours and allowed to reach room temperature. Imine **1** (0.125 mmol) in dry toluene (1 mL) was added via syringe and the reaction mixture stirred until the reaction was complete (TLC). After this time, the reaction was quenched with 20% aqueous NH_4Cl (1.0 mL), diluted in CH_2Cl_2 (50 mL), washed with brine (10 mL), dried over $MgSO_4$. After filtration and concentration under reduced pressure, column chromatography eluting with hexane:Et_2O mixtures afforded compound **3**. In some cases we oserved the formation of the conjugate ethylation product **6**, which was not collected, except in some representative examples.

Near racemic compounds **3** (R^2 = Alkyl) were prepared by mixing enantiomeric compounds **3** obtained in separated reactions with **L6** or *ent*-**L6**

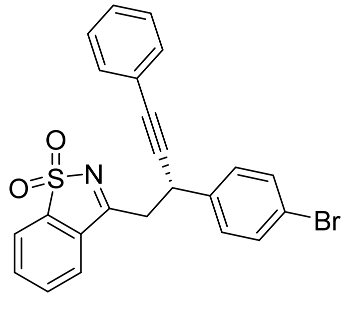
(*S*)-3-(2,4-diphenylbut-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3aa)



Obtained 21.8 mg (47%); ethylation product **6** (9.3 mg, 25%) was also isolated. The enantiomeric excess (85%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20 1 mL/min, major enantiomer: t_r = 29.1 min, minor enantiomer: t_r = 25.8 min.

Oil; $[\alpha]_D^{25}$ –2.5 (*c* 0.8, $CHCl_3$); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.96–7.86 (m, 1H), 7.76–7.58 (m, 2H), 7.57–7.49 (m, 2H), 7.43–7.26 (m, 8H), 4.65 (dd, *J* = 8.4, 6.3 Hz, 1H), 3.55 (dd, *J* = 15.3, 8.4 Hz, 1H), 3.41 (dd, *J* = 15.4, 6.3 Hz, 1H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.7 (C=N), 156.0 (C), 153.5 (C), 140.0 (C), 133.9 (CH), 133.7 (CH), 131.8 (CH), 131.4 (C), 129.1 (CH), 128.4 (CH), 127.9 (CH), 127.7 (CH), 124.3 (CH), 122.9 (CH), 122.7 (CH), 89.0 (C), 85.2 (C), 39.9 (CH_2), 36.1 (CH); HRMS (ESI) *m/z*: 372.4620 $[M+H]^+$, $C_{23}H_{18}NO_2S^+$ requires 372.4615.

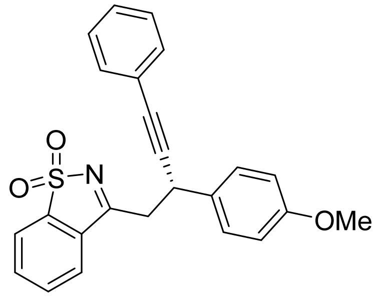
(*S*)-3-(2-(4-Bromophenyl)-4-phenylbut-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3ba)



Obtained 33.2 mg (59%). The enantiomeric excess (69%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20 1.5 mL/min, major enantiomer: t_r = 21.7 min, minor enantiomer: t_r = 35.1 min.

Yellow solid; mp 174-176 °C; $[\alpha]_D^{25}$ +1.3 (c 0.8, $CHCl_3$); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.87–7.81 (m, 1H), 7.71–7.53 (m, 3H), 7.46–7.39 (m, 2H), 7.39–7.33 (m, 2H), 7.31–7.24 (m, 2H), 7.25–7.18 (m, 3H), 4.57 (dd, *J* = 7.9, 6.5 Hz, 1H), 3.47 (dd, *J* = 15.8, 8.0 Hz, 1H), 3.32 (dd, *J* = 15.8, 6.5 Hz, 1H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.3 (C), 139.9 (C), 139.0 (C), 133.9 (CH), 133.8 (CH), 132.2 (CH), 131.8 (CH), 131.2 (C), 129.5 (CH), 128.5 (CH), 128.4 (CH), 124.2 (CH), 122.7 (CH), 122.6 (C), 121.8 (C), 88.5 (C), 85.3 (C), 39.6 (CH_2), 35.3 (CH); HRMS (ESI) m/z: 450.0160 $[M+H]^+$, $C_{23}H_{17}BrNO_2S^+$ requires 450.0158.

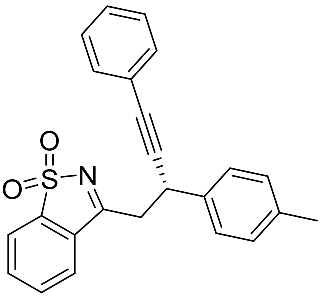
(*S*)-3-(2-(4-Methoxyphenyl)-4-phenylbut-3-yn-1-yl)benzo[*d*]isothiazole (3ca)



Obtained 20.1 mg (40%). The enantiomeric excess (33%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20 1.5 mL/min, major enantiomer: t_r = 25.5 min, minor enantiomer: t_r = 18.7 min.

Oil; $[\alpha]_D^{25}$ –27.5 (c 0.9, CHCl$_3$); **^{1}H NMR** (300 MHz, CDCl$_3$) δ 7.97–7.86 (m, 1H), 7.75–7.57 (m, 3H), 7.49–7.40 (m, 2H), 7.35–7.30 (m, 2H), 7.30–7.23 (m, 3H), 6.94–6.85 (m, 2H), 4.60 (dd, J = 8.1, 6.4 Hz, 1H), 3.79 (s, 3H), 3.52 (dd, J = 15.3, 8.2 Hz, 1H), 3.38 (dd, J = 15.3, 6.5 Hz, 1H); **^{13}C NMR** (75 MHz, CDCl$_3$) δ 173.7 (C), 159.1 (C), 139.8 (C), 133.8 (CH), 133.5 (CH), 131.9 (C), 131.7 (CH), 131.3 (C), 128.6 (CH), 128.2 (CH), 124.3 (CH), 122.8 (C), 122.5 (CH), 114.3 (CH), 89.3 (C), 84.8 (C), 55.4 (CH$_3$), 39.9 (CH$_2$), 35.2 (CH); HRMS (ESI) m/z: 402.1158 [M+H]$^+$, C$_{24}$H$_{20}$NO$_3$S requires 402.1158.

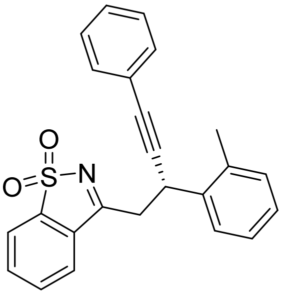
(*S*)-3-(2-(4-Methylphenyl)-4-phenylbut-3-yn-1-yl)benzo[*d*]isothiazole (3da)



Obtained 16.0 mg (33%). The enantiomeric excess (58%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20 1.5 mL/min, major enantiomer: t$_\mathrm{r}$ = 17.0 min, minor enantiomer: t$_\mathrm{r}$ = 13.4 min.

Yellow solid; mp 143-145 °C; $[\alpha]_D^{25}$ –5.3 (c 0.6, CHCl$_3$); **^{1}H NMR** (300 MHz, CDCl$_3$) δ 7.96–7.84 (m, 1H), 7.77–7.59 (m, 3H), 7.47–7.38 (m, 2H), 7.37–7.22 (m, 5H), 7.21–7.11 (m, 2H), 4.61 (dd, J = 8.4, 6.2 Hz, 1H), 3.52 (dd, J = 15.3, 8.4 Hz, 1H), 3.39 (dd, J = 15.3, 6.3 Hz, 1H), 2.34 (s, 3H); **^{13}C NMR** (75 MHz, CDCl$_3$) δ 173.7 (C), 139.9 (C), 137.5 (C), 137.0 (C), 133.8 (CH), 133.6 (CH), 131.7 (CH), 131.4 (C), 129.7 (CH), 128.3 (CH), 128.3 (CH), 127.5 (CH), 124.4 (CH), 123.0 (C), 122.6 (CH), 89.3 (C), 84.9 (C), 39.9 (CH$_2$), 35.7 (CH), 21.2 (CH$_3$); HRMS (ESI) m/z: 386.1208 [M+H]$^+$, C$_{24}$H$_{20}$NO$_2$S$^+$ requires 386.1209.

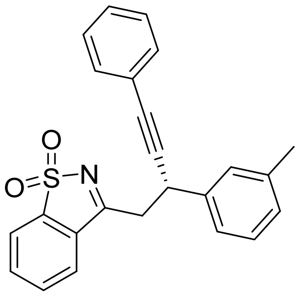
(*S*)-3-(2-(2-Methylphenyl)-4-phenylbut-3-yn-1-yl)benzo[*d*]isothiazole (3ea)



Obtained 17.3 mg (36%). The enantiomeric excess (53%) was determined by HPLC (Chiralpak AD-H), hexane:*i*PrOH 80:20 1 mL/min, major enantiomer: t$_\mathrm{r}$ = 11.9 min, minor enantiomer: t$_\mathrm{r}$ = 15.2 min.

Oil; $[\alpha]_D^{25}$ –11.6 (c 0.9, CHCl$_3$); **^{1}H NMR** (300 MHz, CDCl$_3$) δ 7.96–7.87 (m, 1H), 7.80–7.59 (m, 4H), 7.32–7.26 (m, 3H), 7.26–7.18 (m, 5H), 4.80 (dd, J = 9.2, 5.3 Hz, 1H), 3.51 (dd, J = 15.2, 9.2 Hz, 1H), 3.34 (dd, J = 15.2, 5.3 Hz, 1H), 2.49 (s, 3H); **^{13}C NMR** (75 MHz, CDCl$_3$) δ 173.9 (C), 139.9 (C), 138.2 (C), 135.3 (C), 133.9 (CH), 133.7 (CH), 131.7 (CH), 131.5 (C), 131.1 (CH), 128.3 (CH), 128.3 (CH), 127.8 (CH), 127.6 (CH), 126.9 (CH), 124.5 (CH), 122.9 (C), 122.7 (CH), 89.4 (C), 84.7 (C), 38.3 (CH$_2$), 32.9 (CH), 19.5 (CH$_3$); HRMS (ESI) m/z: 386.1213 [M+H]$^+$, C$_{24}$H$_{20}$NO$_2$S$^+$ requires 386.1209.

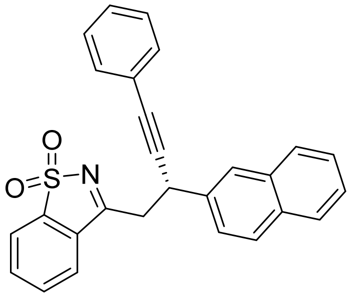
(*S*)-3-(2-(3-Methylphenyl)-4-phenylbut-3-yn-1-yl)benzo[*d*]isothiazole (3fa)



Obtained 16.8 mg (35%). The enantiomeric excess (71%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20 1 mL/min, major enantiomer: t_r = 20.9 min, minor enantiomer: t_r = 18.0 min.

Oil; $[\alpha]_D^{25}$ –5.1 (*c* 0.5, CHCl3); **^{1}H NMR** (300 MHz, CDCl3) δ 7.91 (dt, *J* = 7.5, 0.9 Hz, 1H), 7.76–7.58 (m, 3H), 7.36–7.30 (m, 4H), 7.29–7.22 (m, 4H), 7.09 (d, *J* = 7.6 Hz, 1H), 4.60 (dd, *J* = 8.5, 6.2 Hz, 1H), 3.53 (dd, *J* = 15.2, 8.6 Hz, 1H), 3.39 (dd, *J* = 15.2, 6.2 Hz, 1H); **^{13}C NMR** (75 MHz, CDCl3) δ 173.7 (C), 140.0 (C), 139.9 (C), 138.9 (C), 133.8 (CH), 133.6 (CH), 131.8 (CH), 131.5 (C), 129.0 (CH), 128.6 (CH), 128.4 (CH), 128.3 (CH), 124.6 (CH), 124.4 (CH), 123.0 (C), 122.7 (CH), 89.1 (C), 85.1 (C), 39.9 (CH2), 36.1 (CH), 21.6 (CH3); HRMS (ESI) m/z: 386.1214 [M+H]$^+$, $C_{24}H_{20}NO_2S^+$ requires 386.1209.

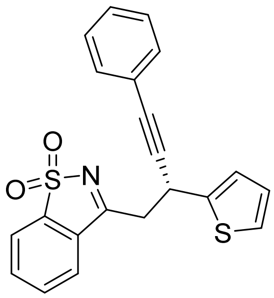
(*S*)-3-(2-(Naphthalen-2-yl)-4-phenylbut-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3ga)



Obtained 18.5 mg (35%). The enantiomeric excess (83%) was determined by HPLC (Chiralcel AS-H), hexane:*i*PrOH 80:20 1 mL/min, major enantiomer: t_r = 53.7 min, minor enantiomer: t_r = 60.9 min.

Oil; $[\alpha]_D^{25}$ +1.8 (c 0.5, CHCl3); **^{1}H NMR** (300 MHz, CDCl3) δ 8.01–7.96 (m, 1H), 7.93–7.78 (m, 4H), 7.74–7.58 (m, 4H), 7.52–7.45 (m, 2H), 7.40–7.33 (m, 2H), 7.28 (q, *J* = 3.1 Hz, 3H), 4.83 (dd, *J* = 8.4, 6.2 Hz, 1H), 3.63 (dd, *J* = 15.5, 8.4 Hz, 1H), 3.49 (dd, *J* = 15.4, 6.2 Hz, 1H); **^{13}C NMR** (75 MHz, CDCl3) δ 173.7 (C), 140.0 (C), 137.3 (C), 133.8 (CH), 133.7 (CH), 133.6 (C), 132.9 (CH), 131.8 (CH), 131.4 (C), 129.0 (CH), 128.4 (CH), 128.4 (CH), 128.1 (CH), 127.8 (CH), 126.6 (CH), 126.3 (CH), 125.5 (CH), 124.3 (CH), 122.9 (C), 122.8 (C), 122.7 (CH), 89.0 (C), 85.4 (C), 39.8 (CH2), 36.2 (CH); HRMS (ESI) m/z: 422.1209 [M+H]$^+$, $C_{27}H_{20}NO_2S^+$ requires 422.1209.

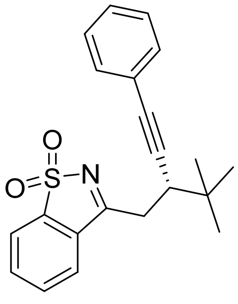
(*R*)-3-(4-Phenyl-2-(thiophen-2-yl)but-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3ha)



Obtained 23.1 mg (49%). The enantiomeric excess (70%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20 1 mL/min, major enantiomer: t_r = 31.9 min, minor enantiomer: t_r = 27.7 min.

Oil; $[\alpha]_D^{25}$ +3.5 (*c* 1.0, CHCl$_3$); **^{1}H NMR** (300 MHz, CDCl$_3$) δ 7.95–7.89 (m, 1H), 7.80–7.60 (m, 3H), 7.41–7.32 (m, 2H), 7.32–7.25 (m, 3H), 7.25–7.19 (m, 1H), 7.17–7.09 (m, 1H), 6.98–6.90 (m, 1H), 4.97 (dd, *J* = 7.5, 6.5 Hz, 1H), 3.62 (dd, *J* = 15.8, 7.7 Hz, 1H), 3.52 (dd, *J* = 15.8, 6.7 Hz, 1H); **^{13}C NMR** (75 MHz, CDCl$_3$) δ 173.2 (C), 143.2 (C), 139.9 (C), 134.0 (CH), 133.8 (CH), 131.8 (CH), 131.3 (C), 128.6 (CH), 128.4 (CH), 127.2 (CH), 125.7 (CH), 125.0 (CH), 124.3 (CH), 122.7 (CH), 122.6 (C), 88.5 (C), 84.6 (C), 40.1 (CH$_2$), 31.1 (CH); HRMS (ESI) m/z: 395.0880 [M+NH$_4$]$^+$, $C_{24}H_{19}N_2O_2S_2^+$ requires 395.0882.

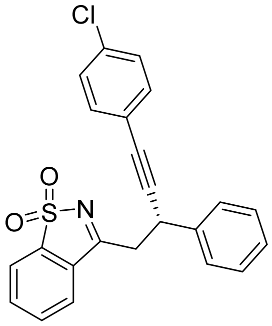
(*S*)-3-(2-(*tert*-Butyl)-4-phenylbut-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3ia)



Obtained 37.0 mg (84%). The enantiomeric excess (35%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20 1 mL/min, major enantiomer: t_r = 14.0 min, minor enantiomer: t_r = 9.0 min.

White solid; mp 90-93 °C; $[\alpha]_D^{25}$ –40.5 (*c* 1.0, CHCl$_3$); **^{1}H NMR** (300 MHz, CDCl$_3$) δ 7.95–7.88 (m, 1H), 7.81–7.59 (m, 3H), 7.24–7.14 (m, 5H), 3.24–3.06 (m, 3H), 1.18 (s, 9H); **^{13}C NMR** (75 MHz, CDCl$_3$) δ 175.8 (C), 140.0 (C), 133.8 (CH), 133.5 (CH), 131.7 (C), 131.6 (CH), 128.2 (CH), 128.0 (CH), 124.6 (CH), 123.2 (C), 122.6 (CH), 89.6 (C), 85.3 (C), 42.2 (CH), 34.4 (C), 32.1 (CH$_2$), 27.5 (CH$_3$); HRMS (ESI) m/z: 352.1370 [M+H]$^+$, $C_{21}H_{22}NO_2S^+$ requires 352.1366.

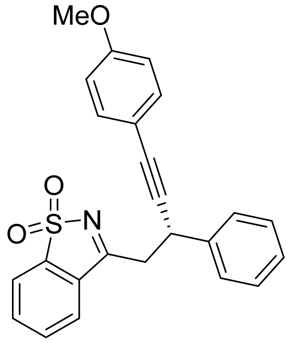
(*S*)-3-(4-(4-Chlorophenyl)-2-phenylbut-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3ab)



Obtained 21.8 mg (43%). The enantiomeric excess (83%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20 1 mL/min, major enantiomer: t_r = 26.9 min, minor enantiomer: t_r = 32.7 min.

Brown solid; mp 113-116 °C; $[\alpha]_D^{25}$ –1.9 (*c* 0.8, CHCl$_3$); **^{1}H NMR** (300 MHz, CDCl$_3$) δ 7.96–7.84 (m, 2H), 7.76–7.56 (m, 5H), 7.54−7.48 (m, 3H), 7.43−7.33 (m, 3H), 7.33−7.20 (m, 5H), 4.64 (dd, *J* = 8.5, 6.1 Hz, 1H), 3.53 (dd, *J* = 15.6, 8.5 Hz, 1H), 3.40 (dd, *J* = 15.5, 6.1 Hz, 1H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.5 (C), 139.9 (C), 139.8 (C), 134.4 (C), 133.9 (CH), 133.7 (CH), 133.0 (CH), 131.3 (C), 129.2 (CH), 128.7 (CH), 127.9 (CH), 127.6 (CH), 124.2 (CH), 122.7 (CH), 121.4 (C), 90.0 (C), 84.0 (CH), 39.7 (CH_2), 36.0 (CH); HRMS (ESI) m/z: 406.0662 $[M+H]^+$, $C_{23}H_{17}ClNO_2S^+$ requires 406.0663.

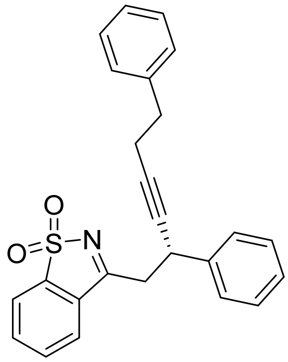
(*S*)-3-(4-(4-Methoxyphenyl)-2-phenylbut-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3ac)



Obtained 23.1 mg (46%). The enantiomeric excess (54%) was determined by HPLC (Chiralpak AD-H), hexane:*i*PrOH 80:20 1 mL/min, major enantiomer: t_r = 44.8 min, minor enantiomer: t_r = 28.8 min.

Oil; $[\alpha]_D^{25}$ −3.5 (*c* 0.9, $CHCl_3$); **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.94−7.86 (m, 1H), 7.74−7.65 (m, 1H), 7.65−7.58 (m, 2H), 7.56−7.50 (m, 2H), 7.42−7.32 (m, 3H), 7.27 (d, *J* = 9.0 Hz, 2H), 6.78 (d, *J* = 8.9 Hz, 2H), 4.62 (dd, *J* = 8.4, 6.2 Hz, 1H), 3.78 (s, 3H), 3.53 (dd, *J* = 15.2, 8.4 Hz, 1H), 3.39 (dd, *J* = 15.2, 6.2 Hz, 1H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.7 (C), 159.6 (C), 140.1 (C), 139.8 (C), 133.7 (CH), 133.5 (CH), 133.1 (CH), 131.3 (C), 129.0 (CH), 127.7 (CH), 127.5 (CH), 124.3 (CH), 122.5 (CH), 114.9 (C), 113.9 (CH), 87.4 (C), 85.0 (C), 55.3 (CH), 39.9 (CH_2), 36.1 (CH_3); HRMS (ESI) m/z: 419.1424 $[M+NH_4]^+$, $C_{24}H_{23}N_2O_3S^+$ requires 419.1424.

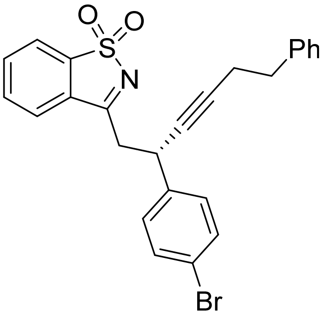
(*S*)-3-(2,6-Diphenylhex-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3ad)



Obtained 34.0 mg (68%). The enantiomeric excess (95%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 29.5 min, minor enantiomer t_r = 24.7 min.

Oil; $[\alpha]_D^{25}$ +6.2 (*c* 1.0, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.91−7.87 (m, 1H), 7.74−7.61 (m, 2H), 7.51−7.49 (m, 1H), 7.40−7.04 (m, 10H), 4.36 (ddt, *J* = 8.4, 6.2, 2.3 Hz, 1H), 3.40 (dd, *J* = 15.0, 8.6 Hz, 1H), 3.27 (dd, *J* = 15.0, 8.6 Hz, 1H), 2.74 (t, *J* = 7.4 Hz, 2H), 2.55−2.35 (m, 2H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.9 (C), 140.5 (C), 139.9 (C), 133.7 (CH), 133.6 (CH), 131.5 (C), 128.9 (CH), 128.7 (CH), 128.4 (CH), 127.6 (CH), 127.6 (CH), 126.3 (CH), 124.3 (CH), 122.6 (CH), 84.7 (C), 80.5 (C), 40.1 (CH_2), 35.6 (CH), 35.0 (CH_2), 21.0 (CH_2); HRMS (ESI) *m/z*: 400.1363, $[M+H]^+$, $C_{25}H_{22}NO_2S^+$ requires 400.1366.

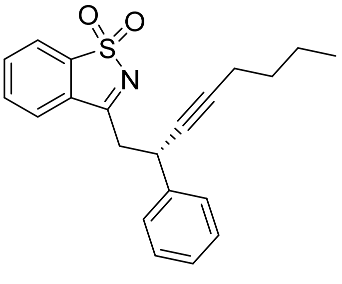
(*S*)-3-(2-(4-Bromophenyl)-6-phenylhex-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3bd)



Obtained 21.0 mg (35%). The enantiomeric excess (96%) was determined by HPLC (Chiralcel AD-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 18.6 min, minor enantiomer t_r = 21.8 min.

Oil; $[\alpha]_D^{25}$ +4.3 (*c* 1.0, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.92–7.90 (m, 1H), 7.73 (td, *J* = 7.4, 1.2 Hz, 1H), 7.66 (td, *J* = 7.5, 1.2 Hz, 1H), 7.53–7.50 (m, 1H), 7.44–7.40 (m, 2H), 7.28–7.15 (m, 7H), 4.34 (ddt, *J* = 8.4, 6.4, 2.2 Hz, 1H), 3.32 (dd, *J* = 15.7, 8.1 Hz, 1H), 3.20 (dd, *J* = 15.7, 8.1 Hz, 1H), 2.74 (t, *J* = 7.4 Hz, 2H), 2.48–2.42 (m, 2H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.3 (C), 140.5 (C), 139.7 (C), 139,4 (C), 133.6 (CH), 133.6 (CH), 131.8 (CH), 131.8 (C), 129.2 (CH), 128.5 (CH), 128.3 (CH), 126.2 (CH), 124.0 (CH), 122.6 (CH), 121.3 (C), 84.8 (C), 80.0 (C), 39.7 (CH_2), 34.8 (CH_2), 34.6 (CH), 20.7 (CH_2). HRMS (ESI) *m/z*: 478.0473, $[M+H]^+$, $C_{25}H_{21}BrNO_2S^+$ requires 478.0471.

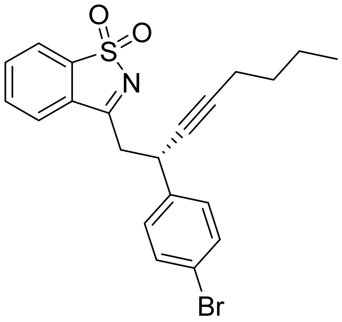
(*S*)-3-(2-Phenyloct-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3ae)



Obtained 19.3 mg (44%). The enantiomeric excess (88%) was determined by HPLC (Chiralpak IC), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 26.18 min, minor enantiomer t_r = 22.72 min.

Yellow solid; mp 91-93 ºC; $[\alpha]_D^{25}$ +4.7 (*c* 0.95, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.91–7.89 (m, 1H), 7.69 (dtd, *J* = 16.8, 7.3, 1.2 Hz, 2H), 7.60–7.57 (m, 1H), 7.47–7.43 (m, 2H), 7.36–7.30 (m, 2H), 7.27–7.22 (m, 1H), 4.39 (ddt, *J* = 8.5, 6.2, 2.3 Hz, 1H), 3.40 (dd, *J* = 15.0, 8.6 Hz, 1H), 3.27 (dd, *J* = 15.0, 6.2 Hz, 1H), 2.13 (td, *J* = 6.9, 2.2 Hz, 2H), 1.46–1.21 (m, 4H), 0.83 (t, *J* = 7.1 Hz, 3H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.8 (C), 140.6 (C), 139.8 (C), 133.6 (CH), 133.4 (CH), 131.5 (C), 128.8 (CH), 127.4 (CH), 127.4 (CH), 124.2 (CH), 122.5 (CH), 85.5 (C), 79.4 (C), 40.0 (CH_2), 35.6 (CH), 30.7 (CH_2), 21.9 (CH_2), 18.4 (CH_2), 13.5 (CH_3); HRMS (ESI) *m/z*: 352.1363, $[M+H]^+$, $C_{21}H_{22}NO_2S^+$ requires 352.1366.

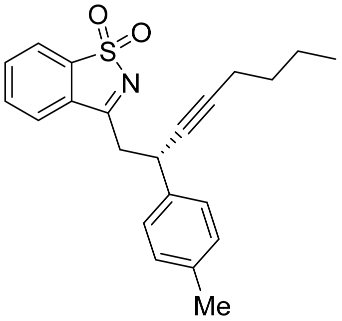
(*S*)-3-(2-(4-Bromophenyl)oct-3-yn-1-yl)benzo[*d*]isothiazole (3be)



Obtained 20.4 mg (38%). The enantiomeric excess (97%) was determined by HPLC (Chiralpak IC), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 26.56 min, minor enantiomer t_r = 24.13 min.

Yellow solid; mp 152-155 ºC; $[\alpha]_D^{25}$ +7.23 (*c* 0.98, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.92−7.89 (m, 1H), 7.71 (dtd, *J* = 16.1, 7.4, 1.3 Hz, 2H), 7.60−7.58 (m, 1H), 7.48−7.43 (m, 2H), 7.36−7.31 (m, 2H), 4.37 (ddt, *J* = 8.6, 6.4, 2.3 Hz, 1H), 3.38 (dd, *J* = 15.4, 8.1 Hz, 1H), 3.24 (dd, *J* = 15.4, 6.5 Hz, 1H), 2.13 (td, *J* = 6.9, 2.3 Hz, 2H), 1.43−1.23 (m, 4H), 0.84 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.6 (C), 139.9 (C), 139.8 (C), 133.8 (CH), 133.7 (CH), 132.0 (CH), 131.4 (C), 129.4 (C), 124.3 (CH), 122.7 (CH), 121.5 (C), 85.9 (C), 79.1 (C), 39.9 (CH_2), 35.0 (CH), 30.8 (CH_2), 22.0 (CH_2), 18.5 (CH_2), 13.7 (CH_3). HRMS (ESI) *m/z*: 430.0473, $[M+H]^+$, $C_{21}H_{21}BrNO_2S^+$ requires 430.0471.

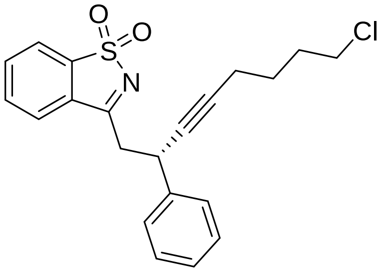
(*S*)-3-(2-(*p*-Tolyl)oct-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3de)



Obtained 19.2 mg (42%). The enantiomeric excess (92%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20, 0.7mL/min. Major enantiomer t_r = 18.32 min, minor enantiomer t_r = 16.35 min.

Yellow solid; mp 131-135 ºC; $[\alpha]_D^{25}$ +1.61 (*c* 0.99, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.91−7.88 (m, 1H), 7.69 (dtd, *J* = 16.0, 7.3, 1.3 Hz, 2H), 7.61−7.58 (m, 1H), 7.35−7.32 (m, 2H), 7.15−7.13 (m, 2H), 4.35 (ddt, *J* = 8.5, 6.1, 2.3 Hz, 1H), 3.38 (dd, *J* = 15.0, 8.6 Hz, 1H), 3.25 (dd, *J* = 15.0, 6.2 Hz, 1H), 2.32 (s, 3H), 2.11 (td, *J* = 6.9, 2.2 Hz, 2H), 1.42−1.23 (m, 4H), 0.83 (t, *J* = 7.1 Hz, 3H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 174.1 (C), 140.0 (C), 137.8 (C), 137.3 (C), 133.7 (CH), 133.5 (CH), 131.6 (C), 129.6 (CH), 127.4 (CH), 124.4 (CH), 122.6 (CH), 85.4 (C), 79.7 (C), 40.2 (CH_2), 35.4 (CH), 30.8 (CH_2), 22.0 (CH_2), 21.2 (CH_3), 18.5 (CH_2), 13.7 (CH_3). HRMS (ESI) *m/z*: 366.1523, $[M+H]^+$, $C_{22}H_{24}NO_2S^+$ requires 366.1522.

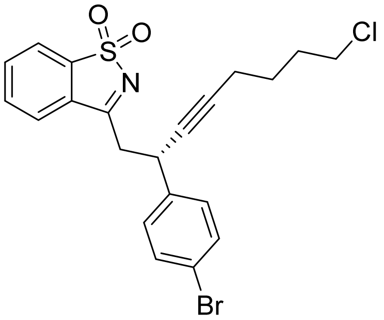
(*S*)-3-(8-Chloro-2-phenyloct-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3af)



Obtained 22.3 mg (48%). The enantiomeric excess (96%) was determined by HPLC (Chiralpak IC), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 34.72 min, minor enantiomer t_r = 32.14 min.

Oil; $[\alpha]_D^{25}$ –2.44 (*c* 0.98, CHCl3); **^{1}H NMR** (300 MHz,CDCl3) δ 7.92–7.90 (m, 1H), 7.70 (dtd, *J* = 16.8, 7.4, 1.3 Hz, 2H), 7.60–7.56 (m, 1H), 7.47–7.43 (m, 2H), 7.37–7.31 (m, 2H), 7.29–7.23 (m, 1H) 4.40 (ddt, *J* = 8.4, 5.3, 2.3 Hz, 1H), 3.50 (td, *J* = 6.5, 2.1 Hz, 2H) 3.40 (dd, *J* = 15.3, 8.9 Hz, 1H), 3.27 (dd, *J* = 15.3, 5.9 Hz, 1H), 2.19 (td, *J* = 6.8, 2.2 Hz, 2H), 1.83–1.74 (m, 2H), 1.61–1.51 (m, 2H); **^{13}C NMR** (75 MHz, CDCl3) δ 173.8 (C), 140.5 (C), 140.0 (C), 133.8 (CH), 133.7 (CH), 131.5 (C), 129.0 (CH), 127.7 (CH), 127.5 (CH), 124.3 (CH), 122.7 (CH), 84.7 (C), 80.3 (C), 44.8 (CH2), 40.1 (CH2), 35.6 (CH), 31.5 (CH2), 25.8 (CH2), 18.2 (CH2); HRMS (ESI), *m/z*: 386.0976, [M+H]$^+$, $C_{21}H_{21}ClNO_2S^+$ requires 386.0976.

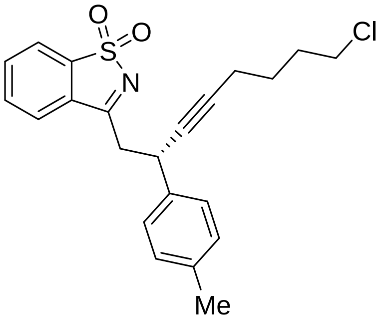
(*S*)-3-(2-(4-Bromophenyl)-8-chlorooct-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3bf)



Obtained 20.3 mg (36%). The enantiomeric excess (93%) was determined by HPLC (Chiralpak AD-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 21.33 min, minor enantiomer t_r = 17.69 min.

Yellow solid; mp 116-119 ºC; $[\alpha]_D^{25}$ +4.65 (*c* 1.0, CH3Cl); **^{1}H NMR** (300 MHz,CDCl3) δ 7.93–7.90 (m, 1H), 7.72 (dtd, *J* = 15.9, 7.4, 1.3 Hz, 2H), 7.61–7.57 (m, 1H), 7.49–7.44 (m, 2H), 7.36–7.31 (m, 2H), 4.38 (ddt, *J* = 8.4, 6.0, 2.3 Hz, 1H), 3.49 (td, *J* = 6.5, 1.8 Hz, 2H) 3.39 (dd, *J* = 15.7, 8.5 Hz, 1H), 3.25 (dd, *J* = 15.7, 6.2 Hz, 1H), 2.19 (td, *J* = 6.8, 2.2 Hz, 2H), 1.83–1.73 (m, 2H), 1.61–1.51 (m, 2H); **^{13}C NMR** (75 MHz, CDCl3) δ 173.5 (C), 139.9 (C), 139.6 (C), 133.9 (CH), 133.8 (CH), 132.1 (CH), 131.3 (C), 129.3 (CH), 124.2 (CH), 122.8 (CH), 121.6 (C), 84.9 (C), 79.9 (C), 44.7 (CH2), 39.8 (CH2), 34.9 (CH), 31.5 (CH2), 385.8 (CH2), 18.1 (CH2); HRMS (ESI), *m/z*: 464.0079, [M+H]$^+$, $C_{21}H_{20}BrClNO_2S^+$ requires 464.0081.

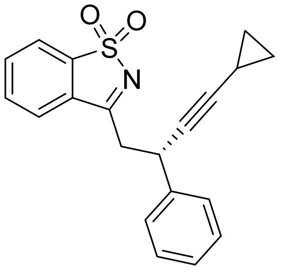
(*S*)-3-(8-Chloro-2-(p-tolyl)oct-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3df)



Obtained 28.0 mg (58%). The enantiomeric excess (91%) was determined by HPLC (Chiralpak AS-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 32.5 min, minor enantiomer t_r = 29.7 min.

Yellow solid; mp 85-89 ºC; $[\alpha]_D^{25}$ –3.50 (*c* 0.95, CH_3Cl); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.92–7.89 (m, 1H), 7.70 (dtd, *J* = 16.0, 7.4, 1.3 Hz, 2H), 7.61–7.58 (m, 1H), 7.35–7.31 (m, 2H), 7.17–7.13 (m, 2H), 4.36 (ddt, *J* = 8.5, 5.5, 2.4 Hz, 1H), 3.49 (td, *J* = 6.5, 2.2 Hz, 2H), 3.38 (dd, *J* = 15.3, 8.9 Hz, 1H), 3.25 (dd, *J* = 15.2, 5.9 Hz, 1H), 2.33 (s, 3H), 2.18 (td, *J* = 6.7, 1.9 Hz, 2H), 1.83–1.73 (m, 2H), 1.60–1.50 (m, 2H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.9 (C), 139.9 (C), 137.6 (C), 137.4 (C), 133.8 (CH), 133.6 (CH), 131.5 (C), 129.7 (CH), 127.4 (CH), 124.3 (CH), 122.7 (CH), 84.4 (C), 80.5 (C), 44.8 (CH_2), 40.1 (CH_2), 35.2 (CH), 31.5 (CH_2), 25.8 (CH_2), 21.2 (CH_3), 18.2 (CH_2); HRMS (ESI), *m/z*: 400.1132, $[M+H]^+$, $C_{22}H_{23}ClNO_2S^+$ requires 400.1133.

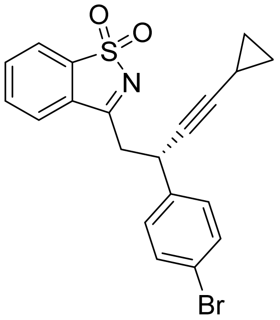
(*S*)-3-(4-Cyclopropyl-2-phenylbut-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3ag)



Obtained 25.6 mg (61%). The enantiomeric excess (93%) was determined by HPLC (Chiralpak AS-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 28.7 min, minor enantiomer t_r = 34.3 min.

Oil; $[\alpha]_D^{25}$ +6.56 (*c* 0.98, CH_3Cl); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.91–7.88 (m, 1H), 7.69 (dtd, *J* = 16.9, 7.4, 1.2 Hz, 2H), 7.59–7.56 (m, 1H), 7.45–7.41 (m, 2H), 7.36–7.29 (m, 2H), 7.27–7.22 (m, 1H), 4.34 (ddd, *J* = 8.3, 6.2, 1.8 Hz, 1H), 3.38 (dd, *J* = 14.9, 8.5 Hz, 1H), 3.26 (dd, *J* = 14.9, 6.3 Hz, 1H), 1.17 (ttd, *J* = 8.2, 5.0, 1.8, 1H), 0.70–0.61 (m, 2H), 0.60–0.47 (m, 2H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.9 (C), 140.6 (C), 139.9 (C), 133.7 (CH), 133.6 (CH), 131.5 (C), 128.9 (CH), 127.6 (CH), 127.5 (CH), 124.4 (CH), 122.6 (CH), 88.7 (C), 74.7 (C), 40.1 (CH_2), 35.7 (C), 8.2 (CH_2), 8.2 (CH_2), -0.4 (CH); HRMS (ESI), *m/z*: 336.1055, $[M+H]^+$, $C_{20}H_{18}NO_2S^+$ requires 336.1053.

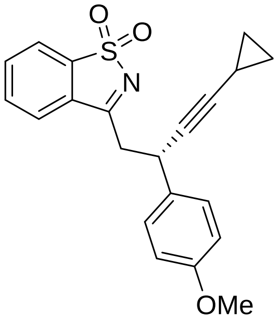
(*S*)-3-(2-(4-bromophenyl)-4-cyclopropylbut-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3bg)



Obtained 23.3 mg (45%). The enantiomeric excess (96%) was determined by HPLC (Chiralpak AD-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 20.01 min, minor enantiomer t_r = 16.73 min.

Yellow solid; mp 119-121 ºC; $[\alpha]_D^{25}$ +6.28 (*c* 1.0, CHCl$_3$); **^{1}H NMR** (300 MHz,CDCl$_3$) δ 7.92–7.89 (m, 1H), 7.71 (dtd, *J* = 16.1, 7.4, 1.2 Hz, 2H), 7.60–7.57 (m, 1H), 7.47–7.43 (m, 2H), 7.34–7.29 (m, 2H), 4.33 (ddd, *J* = 8.2, 6.5, 1.8 Hz, 1H), 3.36 (dd, *J* = 15.3, 8.2 Hz, 1H), 3.24 (dd, *J* = 15.3, 6.5 Hz, 1H), 1.17 (ttd, *J* = 8.2, 5.0, 1.8, 1H), 0.71–0.67 (m, 2H), 0.59–0.48 (m, 2H); **^{13}C NMR** (75 MHz, CDCl$_3$) δ 173.5 (C), 139.9 (C), 139.6 (C), 133.8 (CH), 133.7 (CH), 132.0 (CH), 131.4 (C), 129.4 (CH), 124.3 (CH), 122.7 (CH), 121.5 (C), 89.0 (C), 74.3 (C), 39.8 (CH$_2$), 35.0 (CH), 8.3 (CH$_2$), 8.2 (CH$_2$), –0.4 (CH); HRMS (ESI), *m/z*: 414.0154, [M+H]$^+$, C$_{20}$H$_{17}$BrNO$_2$S$^+$ requires 414.0158.

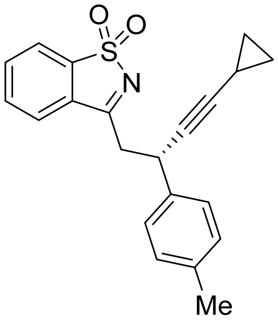
(*S*)-3-(4-Cyclopropyl-2-(4-methoxyphenyl)but-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3cg)



Obtained 31.5 mg (69%). The enantiomeric excess (92%) was determined by HPLC (Chiralpak AD-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 21.98 min, minor enantiomer t_r = 19.32 min.

Yellow solid; mp 112-115 ºC; $[\alpha]_D^{25}$ +7.46 (*c* 1.0, CHCl$_3$); **^{1}H NMR** (300 MHz,CDCl$_3$) δ 7.91–7.88 (m, 1H), 7.69 (dtd, *J* = 16.0, 7.4, 1.3 Hz, 2H), 7.59–7.56 (m, 1H), 7.37–7.32 (m, 2H), 6.87–6.82 (m, 2H), 4.30 (ddd, *J* = 8.2, 6.4, 1.8 Hz, 1H), 3.78 (s, 3H), 3.35 (dd, *J* = 14.9, 8.3 Hz, 1H), 3.24 (dd, *J* = 14.9, 6.5 Hz, 1H), 1.16 (ttd, *J* = 8.2, 5.0, 1.8, 1H), 0.69–0.62 (m, 2H), 0.59–0.46 (m, 2H); **^{13}C NMR** (75 MHz, CDCl$_3$) δ 174.0 (C), 159.1 (C), 139.9 (C), 133.7 (CH), 133.5 (CH), 132.7 (C), 131.6 (C), 128.6 (CH), 124.5 (CH), 122.6 (CH), 114.3 (CH), 88.5 (C), 75.1 (C), 55.5 (CH$_3$), 40.3 (CH$_2$), 35.0 (CH), 8.2 (CH$_2$), 8.2 (CH$_2$), -0.4 (CH); HRMS (ESI), *m/z*: 366.1159, [M+H]$^+$, C$_{21}$H$_{20}$NO$_3$S$^+$ requires 366.1158.

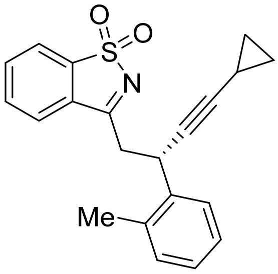
(*S*)-3-(4-Cyclopropyl-2-(p-tolyl)but-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3dg)



Obtained 31.0 mg (69%). The enantiomeric excess (93%) was determined by HPLC (Chiralcel OD-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 16.5 min, minor enantiomer t_r = 14.4 min.

Yellow solid; mp 104-107 ºC; $[\alpha]_D^{25}$ +1.32 (*c* 1.0, CHCl₃); **^{1}H NMR** (300 MHz,CDCl₃) δ 7.92–7.89 (m, 1H), 7.69 (dtd, *J* = 16.2, 7.3, 1.3 Hz, 2H), 7.60–7.57 (m, 1H), 7.34–7.30 (m, 2H), 7.15–7.12 (m, 2H), 4.30 (ddd, *J* = 8.3, 6.2, 1.7 Hz, 1H), 3.35 (dd, *J* = 14.9, 8.5 Hz, 1H), 3.24 (dd, *J* = 14.9, 6.3 Hz, 1H), 2.32 (s, 3H), 1.17 (ttd, *J* = 8.2, 5.0, 1.8, 1H), 0.70–0.61 (m, 2H), 0.58–0.45 (m, 2H); **^{13}C NMR** (75 MHz, CDCl₃) δ 174.0 (C), 139.9 (C), 137.6 (C), 137.3 (C), 133.7 (CH), 133.5 (CH), 131.6 (C), 129.6 (CH), 127.4 (CH), 124.5 (CH), 122.6 (CH), 88.5 (C), 74.9 (C), 40.2 (CH_2), 35.4 (CH), 21.2 (CH_3), 8.2 (CH_2), 8.2 (CH_2), -0.4 (CH); HRMS (ESI), *m/z*: 350.1212, $[M+H]^+$, $C_{21}H_{20}NO_2S^+$ requires 350.1209.

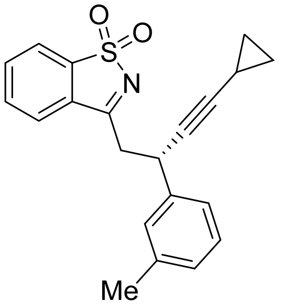
(*S*)-3-(4-Cyclopropyl-2-(*o*-tolyl)but-3-yn-1-yl)benzo[−]isothiazole 1,1-dioxide (3eg)



Obtained 24.0 mg (55%). The enantiomeric excess (85%) was determined by HPLC (Chiralpak AD-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 10.50 min, minor enantiomer t_r = 9.93 min.

Yellow solid; mp 143-146 ºC; $[\alpha]_D^{25}$ –17.8 (*c* 1.0, CHCl₃); **^{1}H NMR** (300 MHz,CDCl₃) δ 7.93–7.90 (m, 1H), 7.71 (dtd, *J* = 14.2, 7.3, 1.4 Hz, 2H), 7.65–7.61 (m, 1H), 7.59–7.56 (m, 1H), 7.25–7.14 (m, 3H), 4.50 (ddd, *J* = 9.3, 5.3, 1.8 Hz, 1H), 3.34 (dd, *J* = 14.7, 9.3 Hz, 1H), 3.19 (dd, *J* = 14.7, 5.3 Hz, 1H), 2.42 (s, 3H), 1.13 (ttd, *J* = 8.2, 5.0, 1.8, 1H), 0.67–0.58 (m, 2H), 0.56–0.42 (m, 2H); **^{13}C NMR** (75 MHz, CDCl₃) δ 174.1 (C), 140.0 (C), 138.8 (C), 135.1 (C), 133.7 (CH), 133.6 (CH), 131.6 (C), 131.0 (CH), 127.6 (CH), 127.5 (CH), 126.8 (CH), 124.6 (CH), 122.6 (CH), 88.2 (C), 75.0 (C), 38.6 (CH_2), 32.5 (CH), 19.4 (CH_3), 8.2 (CH_2), 8.1(CH_2), -0.4 (CH); HRMS (ESI), *m/z*: 350.1212, $[M+H]^+$, $C_{21}H_{20}NO_2S^+$ requires 350.1209.

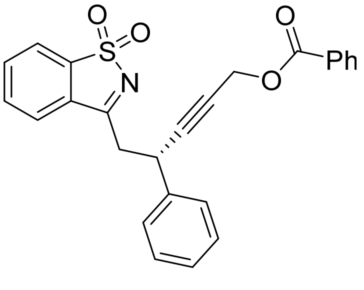
(*S*)-3-(4-Cyclopropyl-2-(*m*-tolyl)but-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3fg)



Obtained 28.0 mg (64%). The enantiomeric excess (82%) was determined by HPLC (Chiralpak AY-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 46.0 min, minor enantiomer t_r = 43.8 min.

Oil; $[\alpha]_D^{25}$ +11.2 (*c* 1.0, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.91–7.89 (m, 1H), 7.69 (dtd, *J* = 21.7, 7.4, 1.1 Hz, 2H), 7.60–7.57 (m, 1H), 7.23–7.21 (m, 3H), 7.07–7.04 (m, 1H), 4.29 (ddd, *J* = 8.5, 6.2, 1.8 Hz, 1H), 3.36 (dd, *J* = 14.8, 8.8 Hz, 1H), 3.25 (dd, *J* = 14.8, 6.1 Hz, 1H), 2.32 (s, 3H), 1.17 (ttd, *J* = 8.3, 5.0, 1.8, 1H), 0.69–0.64 (m, 2H), 0.58–0.47 (m, 2H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 174.0 (C), 140.5 (C), 139.9 (C), 138.7 (C), 133.7 (CH), 133.5 (CH), 131.6 (C), 128.9 (CH), 128.4 (CH), 128.3 (CH), 124.5 (CH), 124.4 (CH), 122.6 (CH), 88.7 (C), 74.8 (C), 40.1 (CH_2), 35.8 (CH), 21.5 (CH_3), 8.2 (CH_2), 8.2 (CH_2), -0.4 (CH); HRMS (ESI), *m/z*: 350.1211, $[M+H]^+$, $C_{21}H_{20}NO_2S^+$ requires 350.1209.

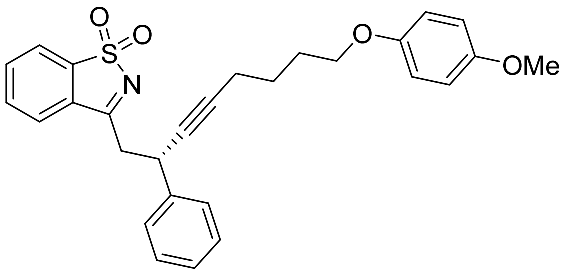
(*S*)-5-(1,1-Dioxidobenzo[d]isothiazol-3-yl)-4-phenylpent-2-yn-1-yl benzoate (3ah)



Obtained 34.0 mg (63%). The enantiomeric excess (93%) was determined by HPLC (Chiralpak IC), hexane:*i*PrOH 70:30, 1mL/min. Major enantiomer t_r = 56.5 min, minor enantiomer t_r = 46.8 min.

Oil; $[\alpha]_D^{25}$ +15.6 (*c* 1.0, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 8.04–8.02 (m, 2H), 7.86–7.83 (m, 1H), 7.66–7.55 (m, 4H), 7.47–7.41 (m, 4H), 7.36–7.23 (m, 3H), 4.90 (dd, *J* = 2.1, 1.5 Hz, 2H), 4.53–4.47 (m, 1H), 3.49 (dd, *J* = 15.7, 8.2 Hz, 1H), 3.33 (dd, *J* = 15.7, 6.4 Hz, 1H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.5 (C), 166.0 (C), 139.8 (C), 139.4 (C), 133.9 (CH), 133.7 (CH), 133.4 (CH), 131.3 (C), 130.0 (CH), 129.7 (C), 129.1 (CH), 128.5 (CH), 127.9 (CH), 127.6 (CH), 124.2 (CH), 122.6 (CH), 86.8 (C), 78.8 (C), 53.0 (CH_2), 39.5 (CH_2), 35.3 (CH); HRMS (ESI), *m/z*: 430.1104, $[M+H]^+$, $C_{25}H_{20}NO_4S^+$ requires 4301108.

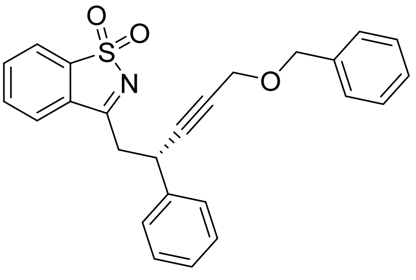
(*S*)-3-(8-(4-Methoxyphenoxy)-2-phenyloct-3-yn-1-yl)benzo[*d*]isothiazole 1,1-dioxide (3ai)



Obtained 39.3 mg (66%); the conjugate ethylation product **6** (12.3 mg, 33%). The enantiomeric excess (99%) was determined by HPLC (Chiralpak OD-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 38.7 min, minor enantiomer t_r = 48.1 min.

Oil; $[\alpha]_D^{25}$ +10.3 (c 0.96, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.89–7.86 (m, 1H), 7.68–7.64 (m, 2H), 7.58–7.56 (m, 1H), 7.47–7.44 (m, 2H), 7.36–7.31 (m, 2H), 7.28–7.22 (m, 1H), 6.81 (s, 4H), 4.40–4.37 (m, 1H) 3.86 (td, *J* = 6.3, 2.2 Hz, 2H), 3.76 (s, 3H), 3.39 (dd, *J* = 15.1, 8.7 Hz, 1H), 3.27 (dd, *J* = 15.1, 6.1 Hz, 1H), 2.21 (td, *J* = 7.1, 2.3 Hz, 2H), 1.79–1.71 (m, 2H), 1.63–1.55 (m, 4H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.1 (C), 153.8 (C), 153.3 (C), 140.6 (C), 139.9 (C), 133.8 (CH), 133.6 (CH), 131.5 (C), 129.9 (CH), 127.7 (CH), 127.5 (CH), 124.4 (CH), 122.6 (CH), 115.5 (CH), 114.8 (CH), 85.1 (C), 80.0 (C), 68.0 (CH_2), 55.9 (CH_3), 40.1 (CH_2), 35.7 (CH), 28.5 (CH_2), 25.3 (CH_2), 18.6 (CH_2); HRMS (ESI), *m/z*: 474.1732, $[M+H]^+$, $C_{28}H_{28}NO_4S^+$ requires 474.1734.

(*S*)-3-(5-(Benzyloxy)-2-phenylpent-3-yn-1-yl)benzo[d]isothiazole 1,1-dioxide (3aj)

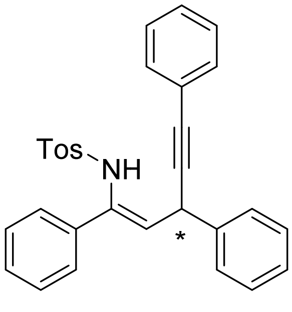


Obtained 30.7 mg (59%); the conjugate ethylation product **6** (5.3 mg, 14%). The enantiomeric excess (80%) was determined by HPLC (Chiralpak AD-H), hexane:*i*PrOH 80:20, 1mL/min. Major enantiomer t_r = 45.4 min, minor enantiomer t_r = 26.9 min.

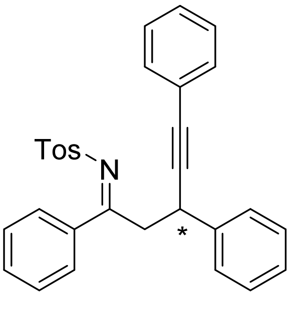
Oil; $[\alpha]_D^{25}$ +3.8 (c 0.65, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.89–7.86 (m, 1H), 7.72–7.61 (m, 2H), 7.58–7.55 (m, 1H), 7.49–7.45 (m, 2H), 7.37–7.27 (m, 8H), 4.52 (d, *J* = 1.9 Hz, 2H), 4.17 (d, *J* = 2.0 Hz, 2H), 3.48 (dd, *J* = 15.9, 8.5 Hz, 1H), 3.32 (dd, *J* = 15.8, 6.1 Hz, 1H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 173.5 (C), 139.9 (C), 139.8 (C), 137.6 (C), 133.9 (CH), 133.7 (CH), 131.3 (C), 129.1 (CH), 128.5 (CH), 128.2 (CH), 127.90 (CH), 127.85 (CH), 127.6 (CH), 124.2 (CH), 122.7 (CH), 86.3 (C), 80.7 (C), 71.6 (CH_2),

57.6 (CH$_3$), 39.7 (CH$_2$), 35.3 (CH); HRMS (ESI), *m/z*: 416.1312, [M+H]$^+$, $C_{25}H_{22}NO_3S^+$ requires 416.1315.

4-Methyl-*N*-(1,3,5-triphenylpent-1-en-4-yn-1-yl)benzenesulfonamide (3ja) and 4-Methyl-*N*-(1,3,5-triphenylpent-4-yn-1-ylidene)benzenesulfonamide (3ja')



3ja



3ja'

Obtained 24.5 mg (43%) as a mixture enamine **3ja**/imine **3ja'** (72/28).

Enamine **3ja**: The enantiomeric excess of enamine **3ja** (73%) was determined by HPLC (Chiralpak AD-H), hexane:*i*PrOH 90:10 1 mL/min, major enantiomer: t_r = 14.2 min, minor enantiomer: t_r = 17.5 min.

Brown solid; mp 45-50 °C; $[\alpha]_D^{25}$ +7.6 (*c* 1.0, CHCl$_3$, 73% *ee*); **^{1}H NMR** (300 MHz, CDCl$_3$) δ 7.56 (d, *J* = 8.3 Hz, 2H), 7.43–7.37 (m, 2H), 7.37–7.31 (m, 3H), 7.25–7.07 (m, 5H), 6.80 (s, 1H), 5.51 (dd, *J* = 8.1, 0.8 Hz, 1H), 4.35 (d, *J* = 8.1 Hz, 1H), 2.30 (s, 3H); **^{13}C NMR** (75 MHz, CDCl$_3$) δ 143.93 (C), 139.57 (C), 136.89 (C), 136.76 (C), 135.73 (C), 131.82 (CH), 129.66 (CH), 128.80 (CH), 128.42 (CH), 128.38 (CH), 128.08 (CH), 127.55 (CH), 127.47 (CH), 127.45 (CH), 127.36 (CH), 127.32 (CH), 124.19 (CH), 122.8 (C), 87.55 (C), 84.83 (C), 35.67 (CH), 21.56 (CH$_3$).

Imine **3ja':** The enantiomeric excess of imine **3ja'** (75%) was determined by HPLC (Chiralpak AD-H), hexane:*i*PrOH 90:10 1 mL/min, major enantiomer: t_r = 28.3 min, minor enantiomer: t_r = 22.9 min.

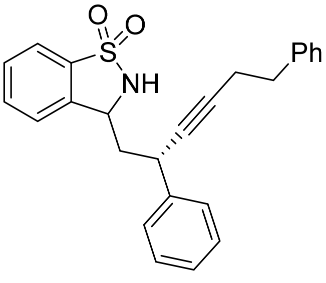
Oil; **^{1}H NMR** (300 MHz, CDCl$_3$) δ 7.94 (d, *J* = 8.1 Hz, 4H), 7.61 (bd, *J* = 7.4 Hz, 2H), 7.55–7.47 (m, 1H), 7.43–7.29 (m, 7H), 7.23–7.16 (m, 3H), 7.08 (bd, *J* = 6.5 Hz, 2H), 4.75 (s, 1H), 3.96 (s, 1H), 3.82 (s, 1H), 2.44 (s, 3H); **^{13}C NMR** (75 MHz, CDCl$_3$) δ 180.53 (C), 143.65 (C), 140.50 (C), 138.49 (C), 137.70 (C), 132.88 (CH), 131.54 (CH), 129.53 (CH), 129.14 (CH), 128.82 (CH), 128.51 (CH), 128.02 (CH), 127.96 (CH), 127.60 (CH), 127.44 (CH), 127.29 (CH), 123.04 (C), 89.15 (C), 85.86 (C), 41.38 (CH2), 37.32 (CH), 21.64 (CH$_3$).

Synthesis of compound 3ad at 1 mmol scale

Ligand **L6** (90 mg, 0.126 mmol) was introduced in a round bottom flask and purged with nitrogen. Dry toluene (5 mL), alkyne **2e** (6.3 mmol) and a 1.5 M solution of diethyzinc in toluene (1.7 mL, 2.52 mmol) were added in this order. The mixture was introduced in a bath at 70 ºC for 2 hours and allowed to reach room temperature. Imine **1a** (1.26 mmol) in dry toluene (10 mL) was injected ant the reaction mixture stirred until completion (TLC). After this time, the reaction was quenched with 20% aqueous NH_4Cl (5 mL), diluted in CH_2Cl_2 (100 mL), washed with brine (100 mL), dried over $MgSO_4$. After filtration and concentration under reduced pressure, column chromatography eluting with toluene:Et_2O (9:1) afforded compound **3ad** (280 mg, 56%, 88% *ee*).

Synthetic transformations of compound 3ad

3-((*S*)-2,6-Diphenylhex-3-yn-1-yl)-2,3-dihydrobenzo[d]isothiazole 1,1-dioxide (**4**)



$NaBH_4$ (8 mg, 0.2 mmol) was added to a solution of compound **3ad** (20 mg, 0.05 mmol) in THF (1 mL) at room temperature under nitrogen atmosphere. After 1 h, the reaction was quenched with 1M HCl and extracted with CH_2Cl_2, the organic layers were dried over $MgSO_4$, filtered and concentrated *in vacuo*. Purification by flash chromatography gave amine **4** (16 mg, 80%) as a 69:31 diastereomer mixture.

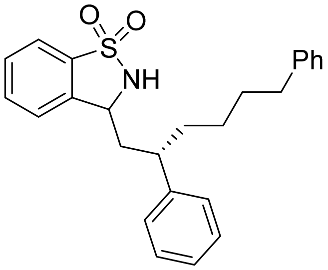
Major diastereomer: The enantiomeric excess (95%) was determined by HPLC (Lux Cellulose 4), hexane:iPrOH 80:20, 1 mL/min. Major enantiomer t_r = 36.5 min, minor enantiomer t_r = 24.1 min.

Oil; $[\alpha]_D^{25}$ +11.1 (*c* 0.7, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.78–7.75 (m, 1H), 7.59 (td, *J* = 7.5, 1.3 Hz, 1H), 7.52 (td, *J* = 7.4, 1.2 Hz, 1H), 7.35–7.19 (m, 11H), 4.80 (d, *J* = 4.6 Hz, 1H), 4.55 (dt, *J* = 9.4, 4.6 Hz, 1H), 3.90–3.85 (m, 1H), 2.86 (t, *J* = 7.3 Hz, 2H), 2.59 (td, *J* = 7.3, 2.2 Hz, 2H), 2.26–2.18 (m, 2H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 140.69 (C), 140.68 (C), 140.2 (C), 135.6 (C), 133.1 (CH), 129.5 (CH), 129.1 (2CH), 128.7 (2CH), 128.6 (2CH), 127.5 (2CH), 126.4 (CH), 124.6 (CH), 121.6 (CH), 84.9 (C), 81.5 (C), 56.3 (CH), 44.8 (CH_2), 35.8 (CH), 35.1 (CH_2), 20.9 (CH_2); HRMS (ESI), *m/z*: 402.1530, $[M+H]^+$, $C_{25}H_{24}NO_2S^+$ requires 402.1522.

Minor diastereomer: The enantiomeric excess (92%) was determined by HPLC (Chiralcel OD-H), hexane:iPrOH 80:20, 1mL/min. Major enantiomer t_r = 13.1 min, minor enantiomer t_r = 27.6 min

Oil; $[\alpha]_D^{25}$ −11.7 (c 0.3, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.78–7.75 (m, 1H), 7.58 (td, J = 7.5, 1.3 Hz, 1H), 7.53–7.48 (m, 1H), 7.32–7.15 (m, 11H), 4.77 (d, J = 6.0 Hz, 1H), 4.69–4.64 (m, 1H), 3.95–3.90 (m, 1H), 2.89 (t, J = 6.9 Hz, 2H), 2.66 (td, J = 7.0, 2.1 Hz, 2H), 2.03–1.97 (m, 2H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 141.0 (C), 140.8 (C), 140.6 (C), 136.7 (C), 133.1 (CH), 129.4 (CH), 128.8 (2CH), 128.7 (2CH), 128.6 (2CH), 127.4 (2CH), 127.2 (CH), 126.6 (CH), 124.3 (CH), 121.5 (CH), 85.3 (C), 80.8 (C), 56.5 (CH), 45.0 (CH_2), 35.6 (CH), 35.0 (CH_2), 20.7 (CH_2); HRMS (ESI), *m/z*: 402.1530, $[M+H]^+$, $C_{25}H_{24}NO_2S^+$ requires 402.1522.

3-((*S*)-2,6-Diphenylhexyl)-2,3-dihydrobenzo[d]isothiazole 1,1-dioxide (5)



A solution of **3ad** (20 mg, 0.05 mmol) in MeOH (1 mL) was stirred under hydrogen atmosphere in the presence of 10% Pd/C for 30 min. Then, the reaction mixture was filtered through celite® eluting with EtOAc and the solvent was removed under reduced pressure. Purification by flash chromatography gave compound **5** (15.3 mg, 75%) as a 74:26 diastereomeric mixture.

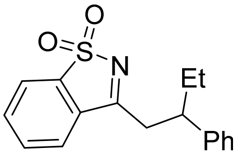
Major diastereomer: The enantiomeric excess (94%) was determined by HPLC (Lux Cellulose 4), hexane:iPrOH 80:20, 1mL/min. Major enantiomer t_r = 21.4 min, minor enantiomer t_r = 25.7 min

Oil; $[\alpha]_D^{25}$ –26.7 (c 0.8, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.74–7.71 (m, 1H), 7.54 (td, J = 7.5, 1.4 Hz, 1H), 7.47 (t, J = 7.1 Hz, 1H), 7.33–7.10 (m, 11H), 4.67–4.61 (m, 1H), 4.23 (d, J = 4.2 Hz, 1H), 2.88–2.78 (m, 1H), 2.56–2.50 (m, 2H), 2.29 (ddd, J = 14.4, 5.7, 4.2 Hz, 1H), 2.10 (dt, J = 14.6, 9.0 Hz, 1H), 1.74–1.54 (m, 4H), 1.29–1.18 (m, 2H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 144.0 (C), 142.6 (C), 140.4 (C), 135.4 (C), 133.0 (CH), 129.4 (CH), 129.1 (2CH), 128.5 (2CH), 128.4 (2CH), 127.8 (2CH), 127.1 (CH), 125.8 (CH), 124.4 (CH), 121.5 (CH), 57.1 (CH), 44.0 (CH), 43.6 (CH_2), 36.6 (CH_2), 35.9 (CH_2), 31.5 (CH_2), 27.0 (CH_2); HRMS (ESI), *m/z*: 406.1841, $[M+H]^+$, $C_{25}H_{28}NO_2S^+$ requires 406.1835.

Minor diastereomer: The enantiomeric excess (84%) was determined by HPLC (Lux Cellulose 4), hexane:iPrOH 80:20, 1mL/min. Major enantiomer t_r = 17.8 min, minor enantiomer t_r = 14.7 min.

Oil; $[\alpha]_D^{25}$ +41.3 (c 0.3, $CHCl_3$); **^{1}H NMR** (300 MHz,$CDCl_3$) δ 7.75–7.72 (m, 1H), 7.57 (td, J = 7.5, 1.3 Hz, 1H), 7.51–7.46 (m, 1H), 7.40–7.34 (m, 2H), 7.29–7.22 (m, 6H), 7.18–7.09 (m, 3H), 4.55 (d, J = 6.0 Hz, 1H), 4.22 (ddd, J = 11.1, 5.9, 3.0 Hz, 1H), 2.94–2.84 (m, 1H), 2.55–2.49 (m, 2H), 2.15–2.02 (m, 2H), 1.69–1.53 (m, 4H), 1.28–1.23 (m, 2H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 143.5 (C), 142.7 (C), 141.3 (C), 135.7 (C), 133.2 (CH), 129.3 (CH), 129.2 (2CH), 128.5 (2CH), 128.4 (2CH), 127.8 (2CH), 127.1 (CH), 125.8 (CH), 124.2 (CH), 121.5 (CH), 56.1 (CH), 43.6 (CH), 43.5 (CH_2), 37.3 (CH_2), 35.9 (CH_2), 31.5 (CH_2), 27.3 (CH_2); HRMS (ESI), *m/z*: 406.1841, $[M+H]^+$, $C_{25}H_{28}NO_2S^+$ requires 406.1835.

3-(2-Phenylbutyl)benzo[d]isothiazole 1,1-dioxide (6)



^{1}H NMR (300 MHz,$CDCl_3$) δ 7.88–7.84 (m, 1H), 7.68 (td, J = 7.4, 1.2 Hz, 1H), 7.61 (td, J = 7.5, 1.3 Hz, 1H), 7.49–7.46 (m, 1H), 7.31–7.25 (m, 2H), 7.23–7.15 (m, 3H), 3.27–3.16 (m, 3H), 1.98–1.91 (m,1H), 1.82–1.72 (m, 1H), 0.84 (t, J = 7.3 Hz, 3H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 175.4 (C), 143.3 (C), 139.8 (C), 133.8 (CH), 133.5 (CH), 131.6 (C), 128.8 (CH), 127.7 (CH), 127.0 (CH), 124.1 (CH), 122.5 (CH), 45.1 (CH_2), 38.5 (CH), 28.8 (CH_3), 12.2 (CH_2); HRMS (ESI), *m/z*: 300.1050, $[M+H]^+$, $C_{17}H_{18}NO_2S^+$ requires 300.1053.

References

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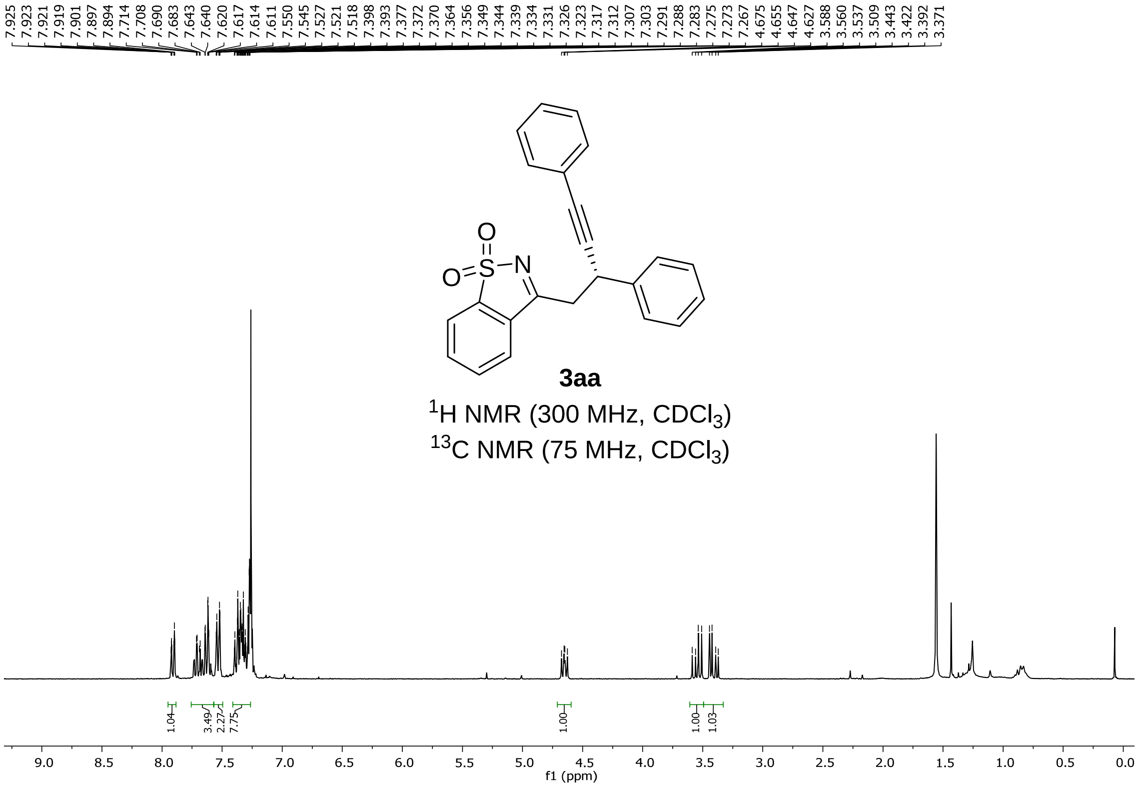
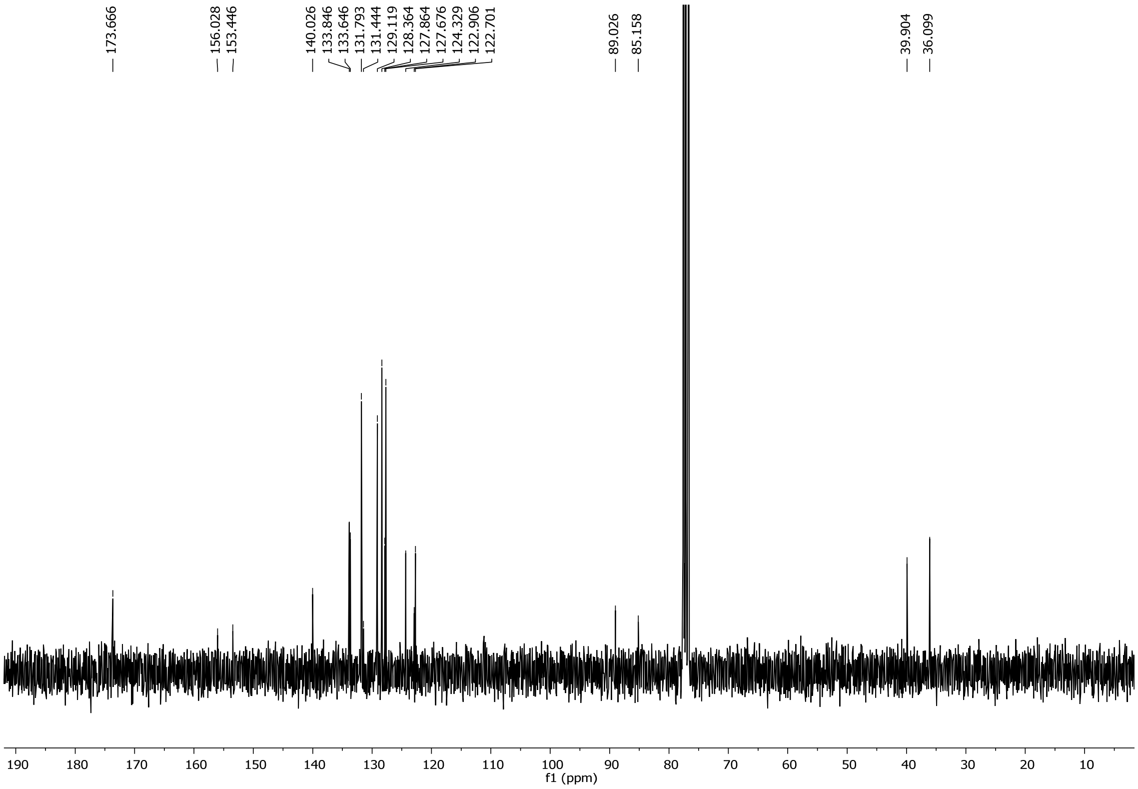
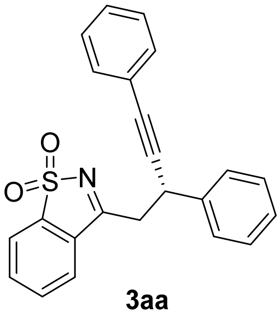


3aa

^{1}H NMR (300 MHz, CDCl$_3$)

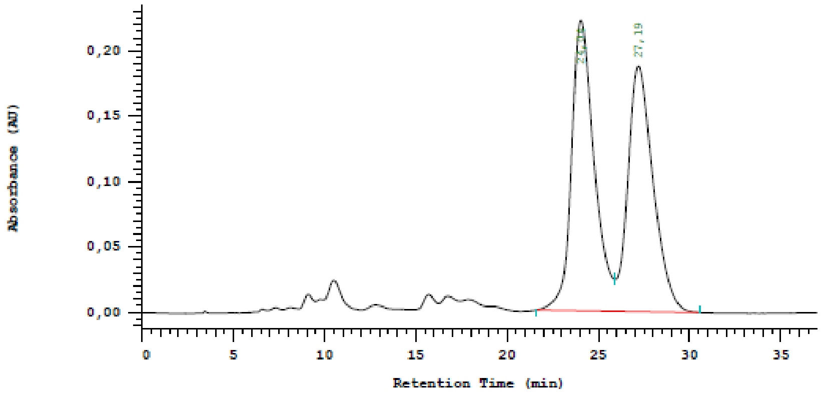
^{13}C NMR (75 MHz, CDCl$_3$)





3aa

Racemic or near racemic mixture:



No.	RT	Area	Area %	Name
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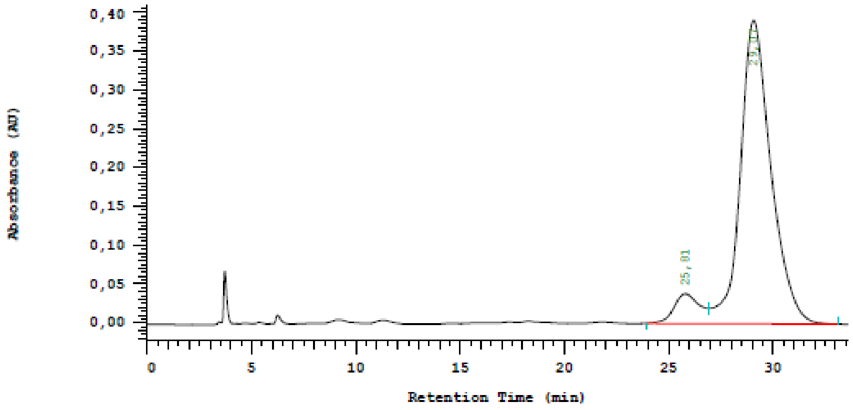
2	27,19	9090504	48,561	
		18719589	100,000	

Enantioselective reaction:



No.	RT	Area	Area %	Name
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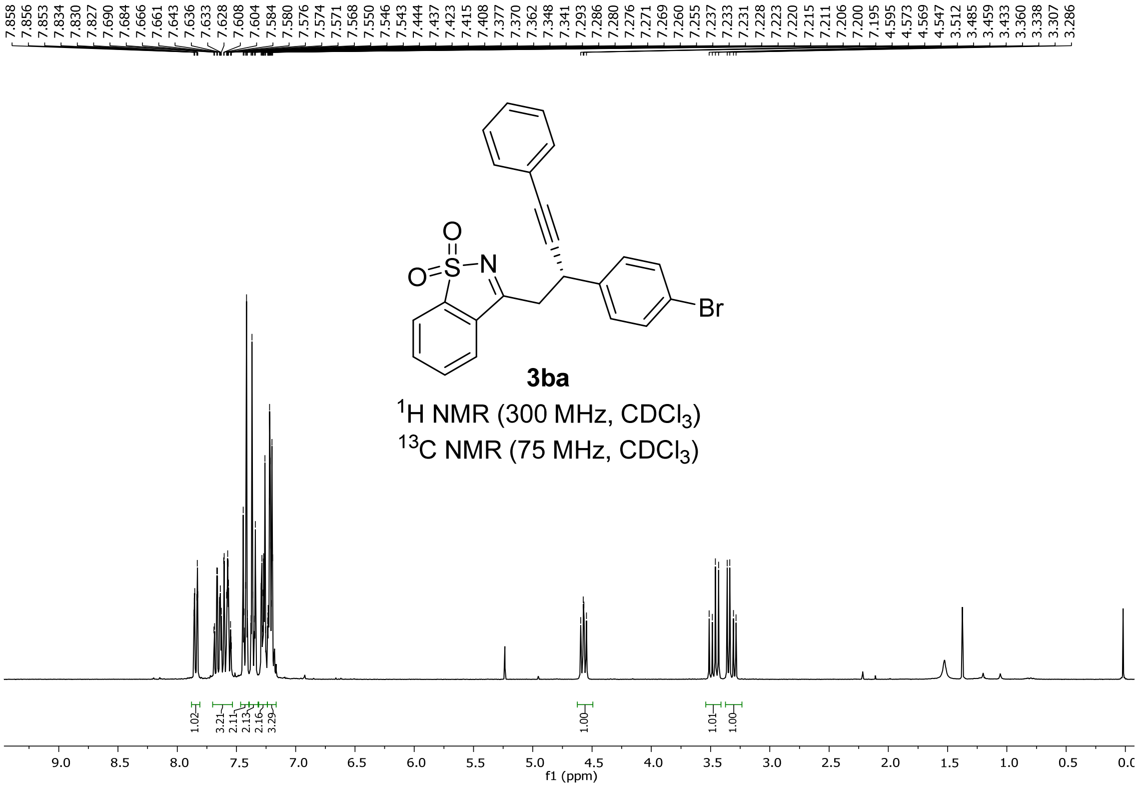
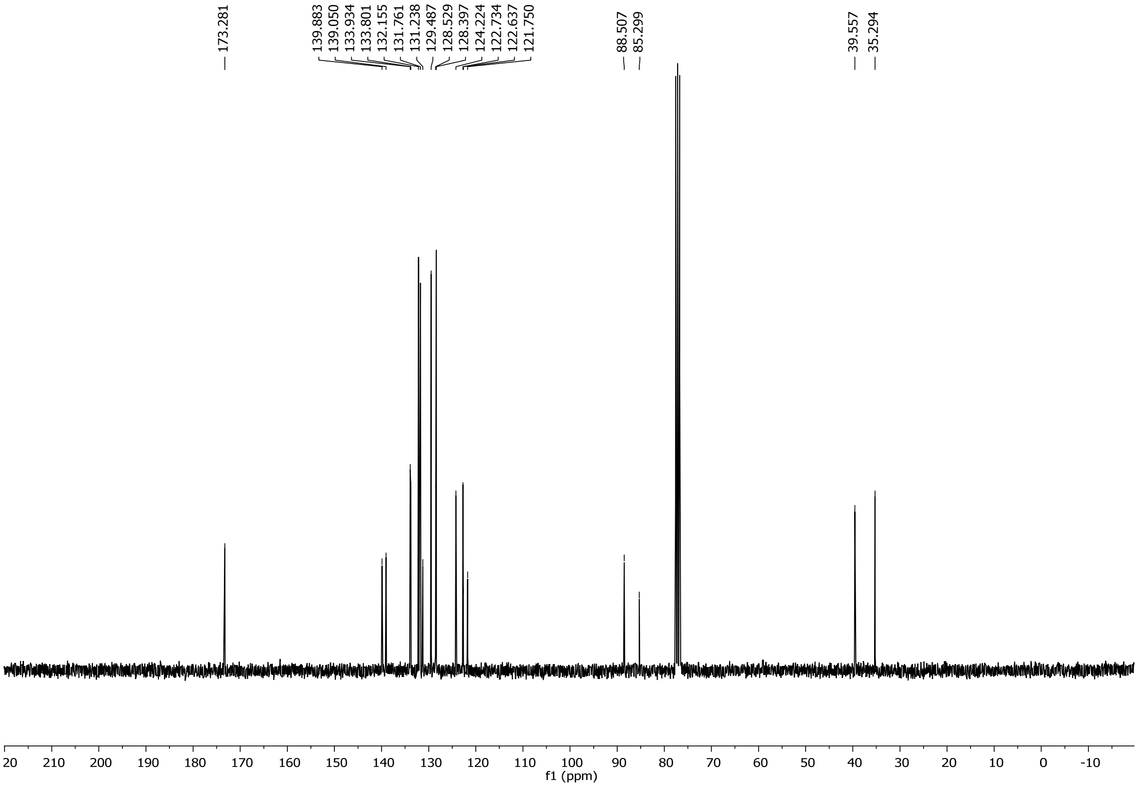
2	29,07	19905358	92,372	
		21549094	100,000	

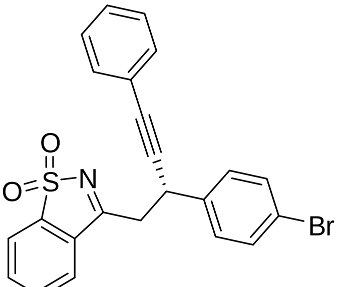


3ba

^{1}H NMR (300 MHz, CDCl$_3$)

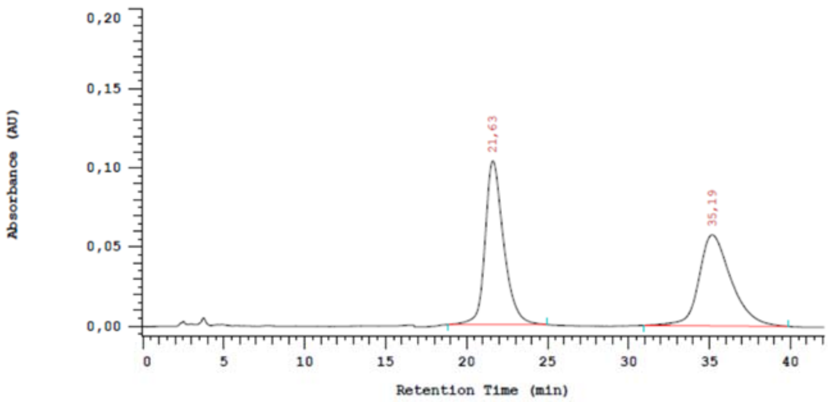
^{13}C NMR (75 MHz, CDCl$_3$)





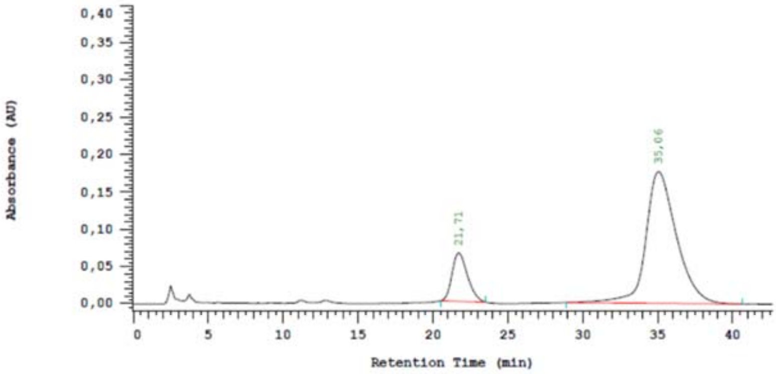
3ba

Racemic or near racemic mixture:

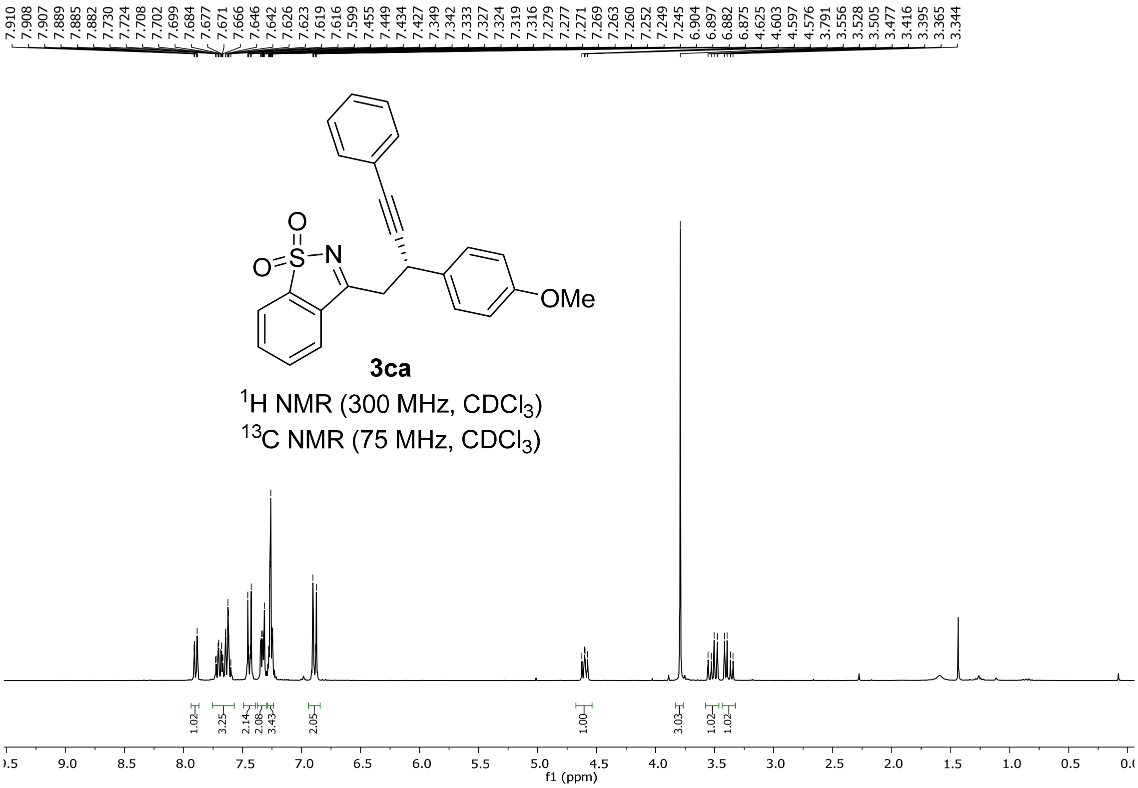


No.	RT	Area	Area %	Name
1	21,63	4093595	50,700	
2	35,19	3980515	49,300	
		8074110	100,000	

Enantioselective reaction:



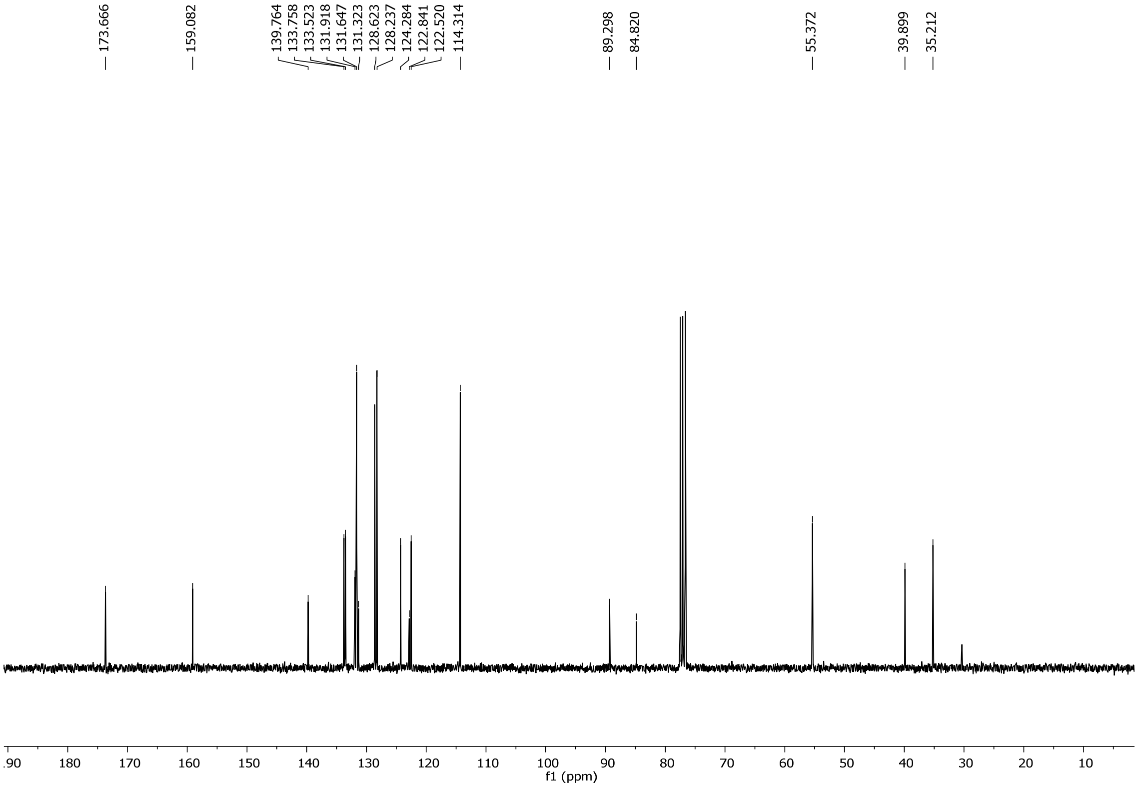
No.	RT	Area	Area %	Name
1	21,71	2334560	15,647	
2	35,06	12586035	84,353	
		14920595	100,000	

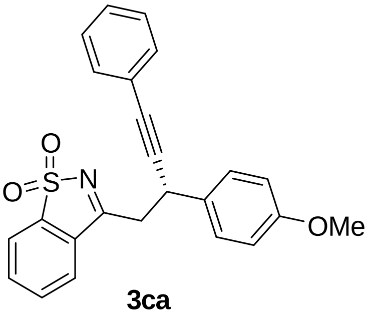


3ca

^{1}H NMR (300 MHz, CDCl$_3$)

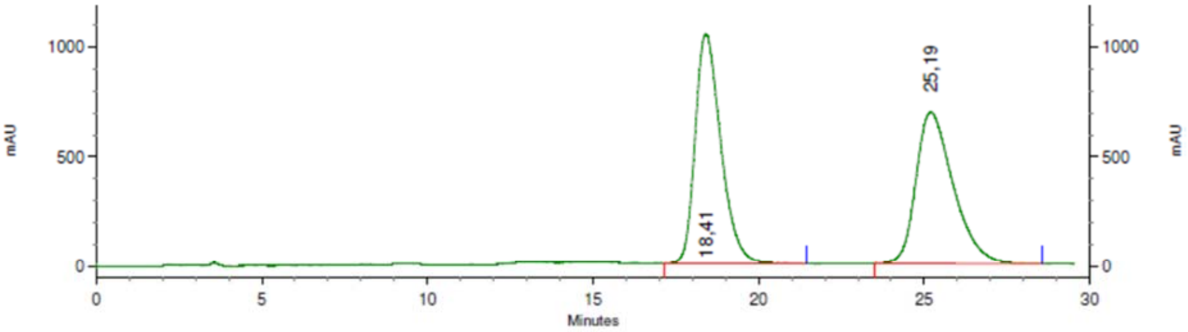
^{13}C NMR (75 MHz, CDCl$_3$)





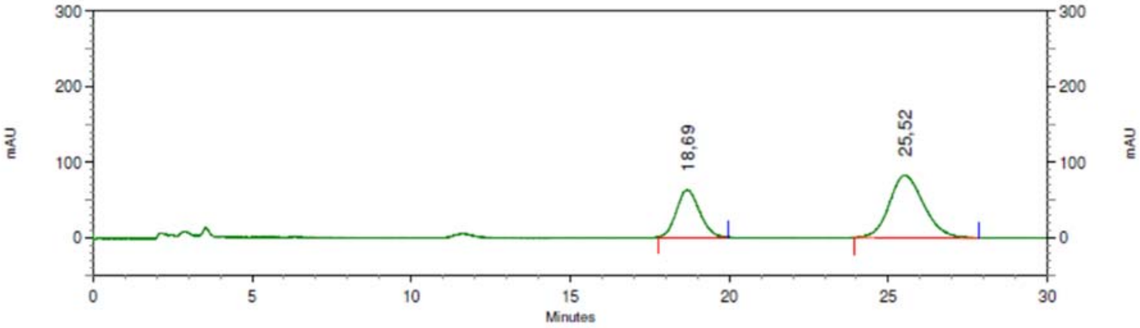
3ca

Racemic or near racemic mixture:

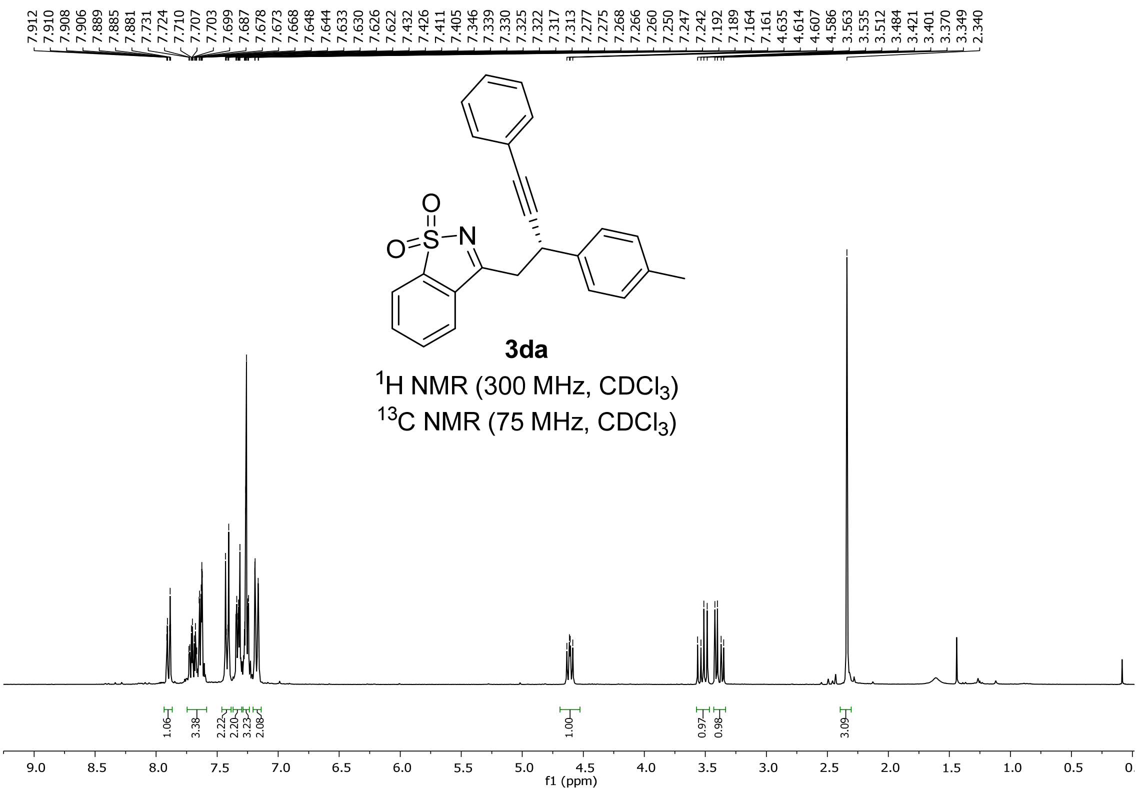


```
 9: 245 nm, 4 nm Results
           Retention Time                          Area                 Area Percent
                    18,41                     226501385                       51,117
                    25,19                     216600530                       48,883
```

Enantioselective reaction:



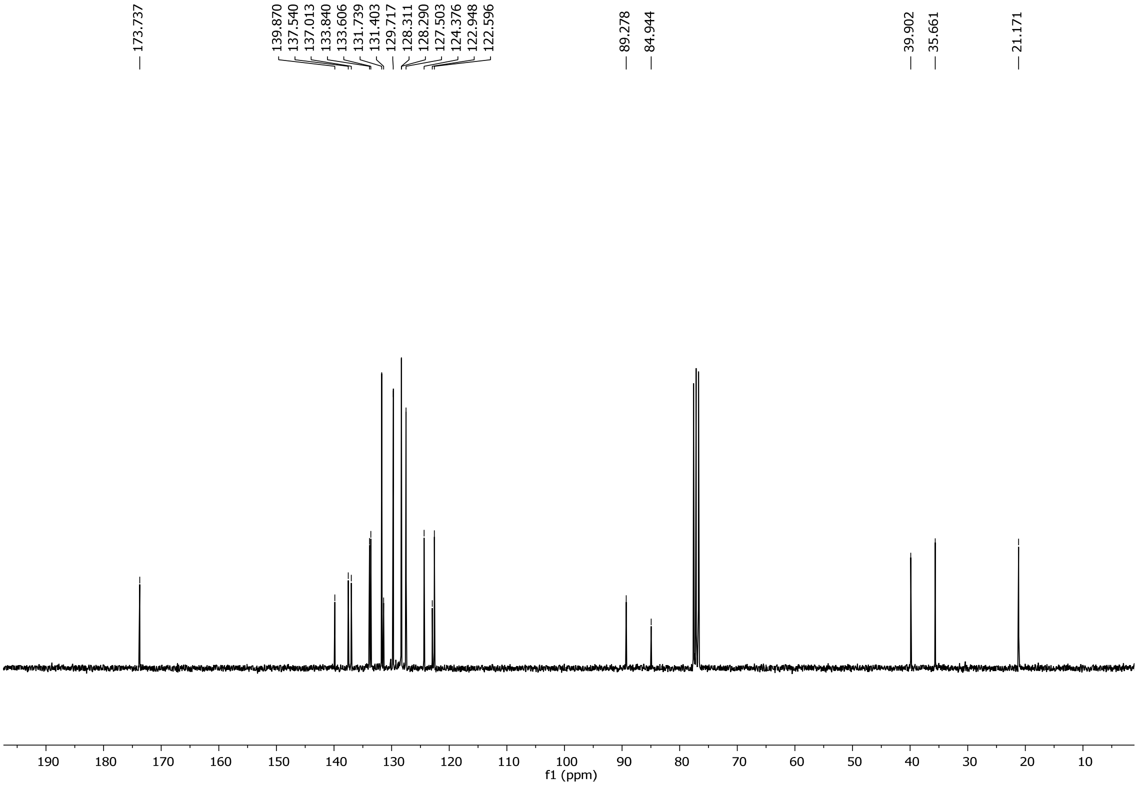
```
 9: 245 nm, 4 nm Results
           Retention Time                          Area                 Area Percent
                    18,69                      12734908                       33,621
                    25,52                      25142819                       66,379
```

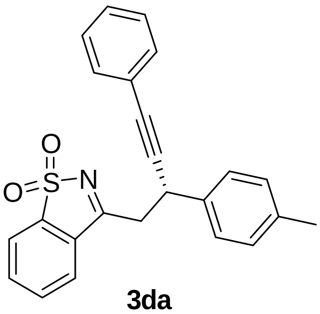


3da

^{1}H NMR (300 MHz, CDCl$_3$)

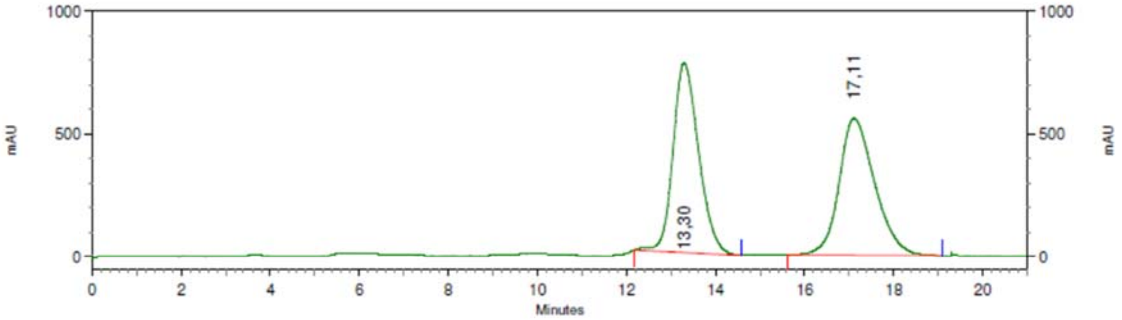
^{13}C NMR (75 MHz, CDCl$_3$)





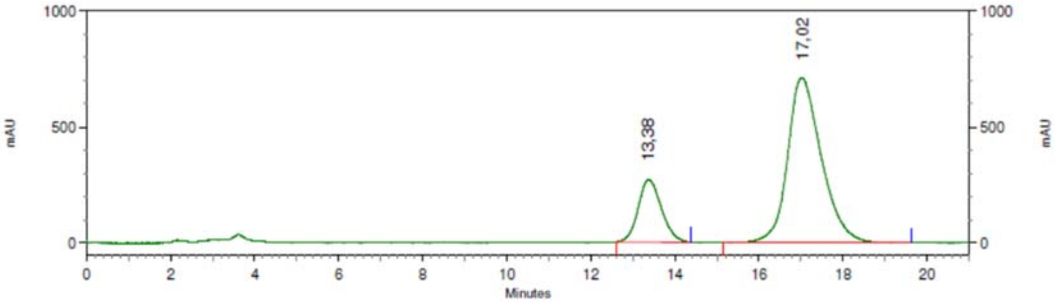
3da

Racemic or near racemic mixture:

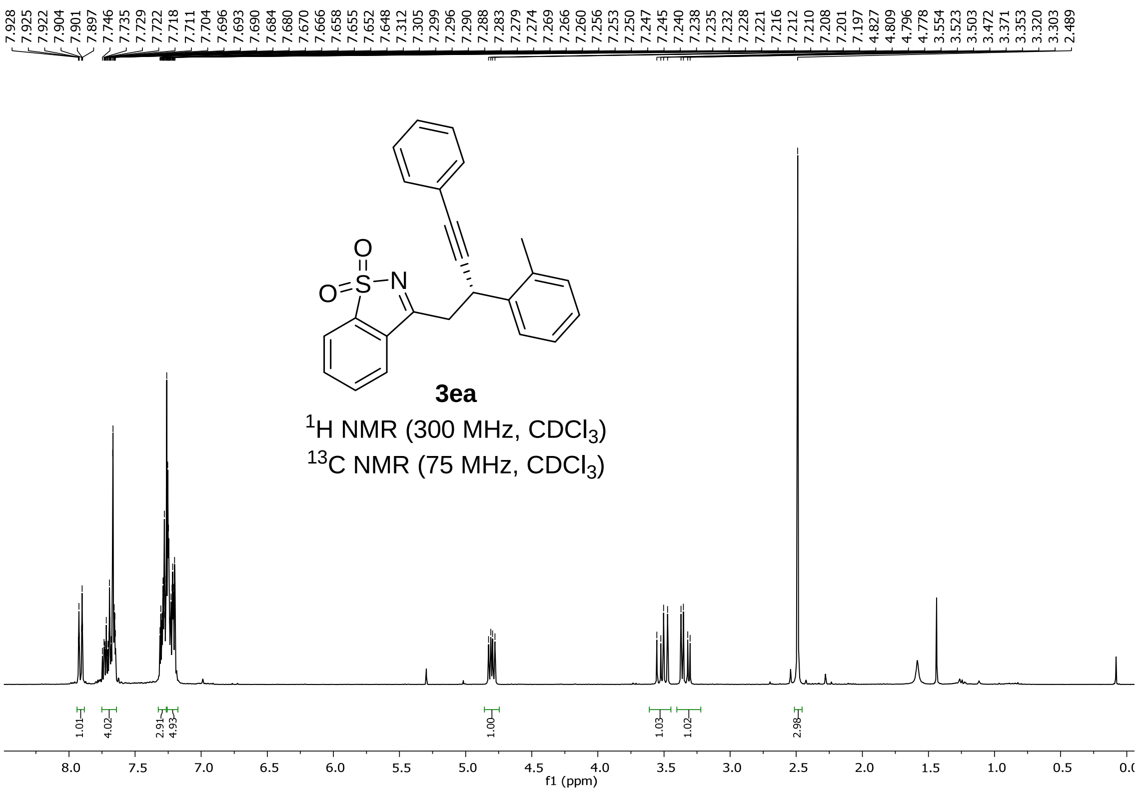


```
6: 242 nm, 4 nm Results
         Retention Time                    Area              Area Percent
                 13,30                123855977                    49,833
                 17,11                124683675                    50,167
```

Enantioselective reaction:



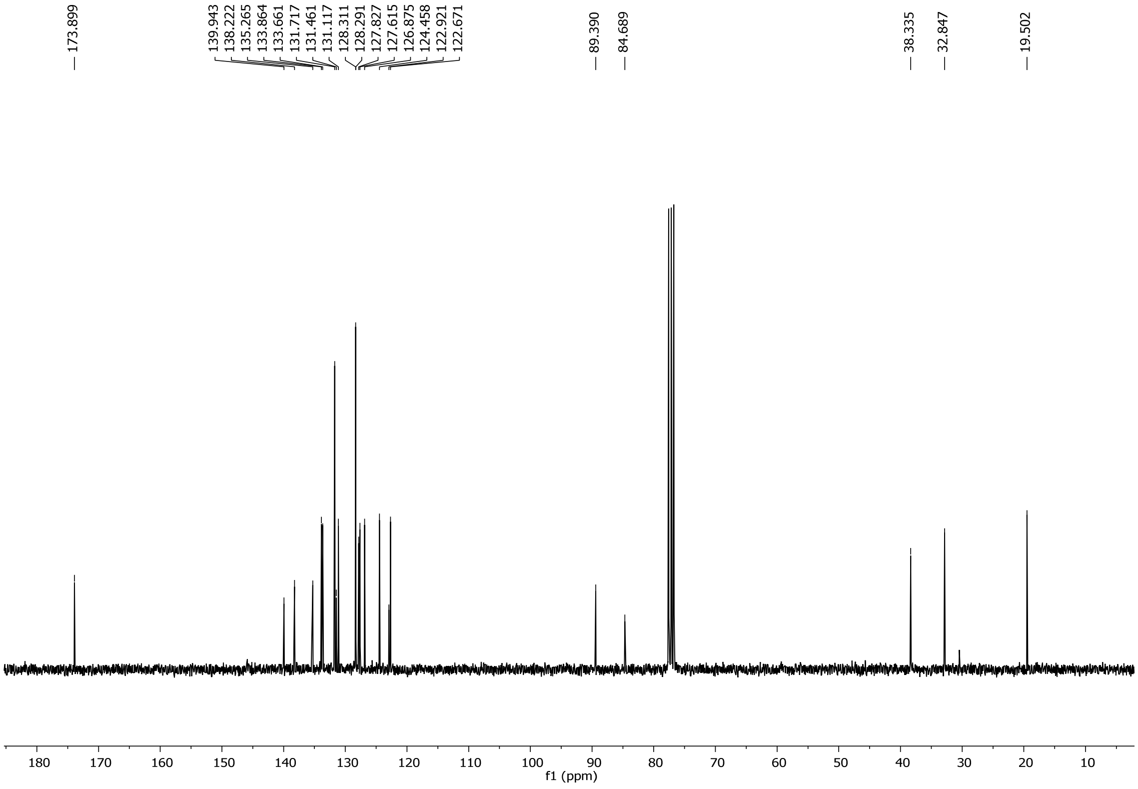
```
9: 245 nm, 4 nm Results
         Retention Time                    Area              Area Percent
                 13,38                 41865095                    20,701
                 17,02                160369460                    79,299
```

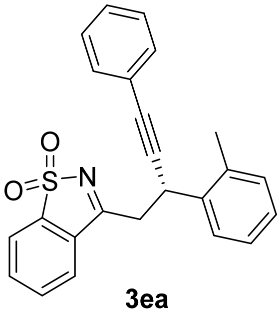


3ea

^{1}H NMR (300 MHz, $CDCl_3$)

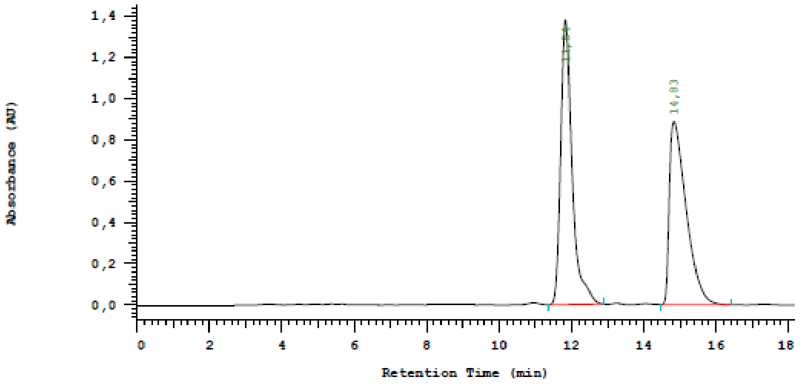
^{13}C NMR (75 MHz, $CDCl_3$)





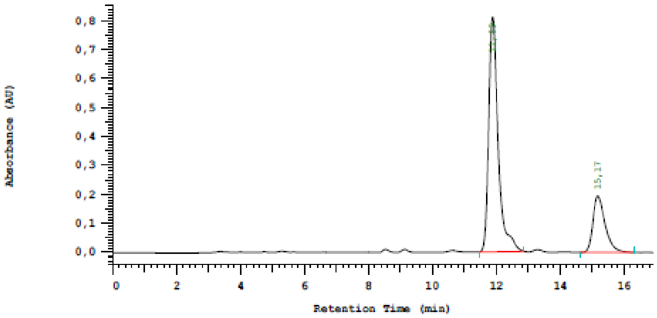
3ea

Racemic or near racemic mixture:

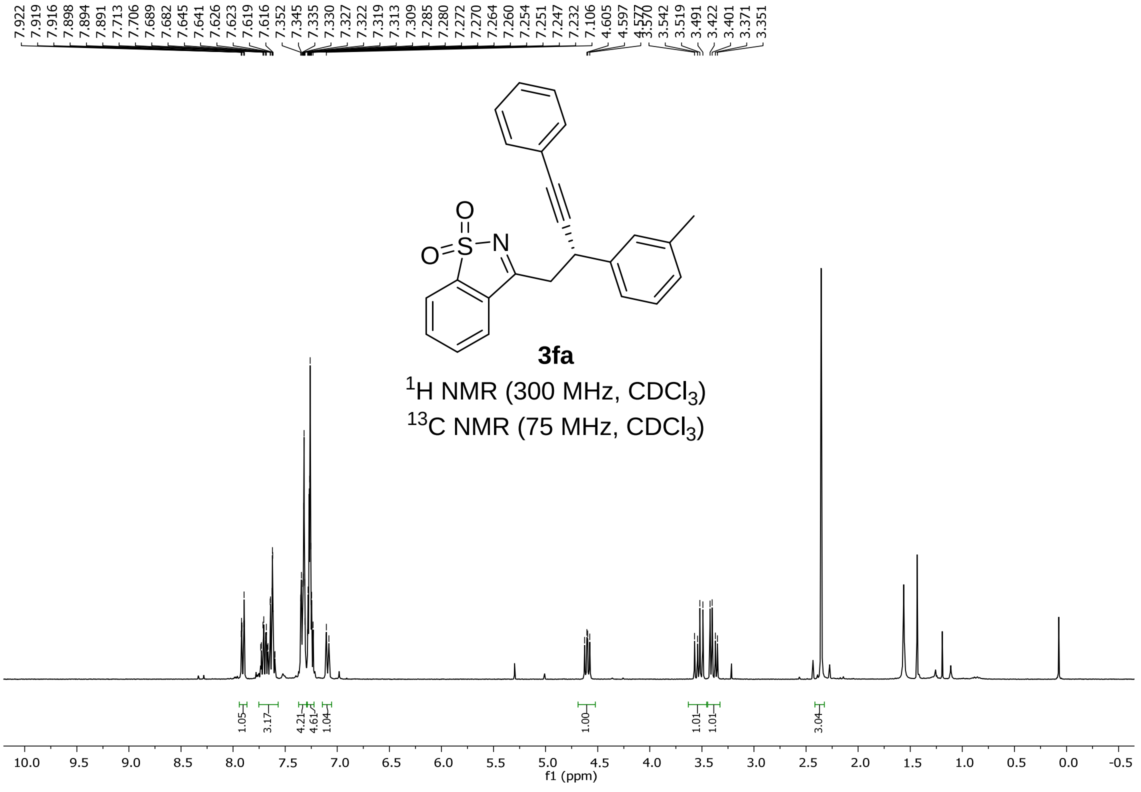


No.	RT	Area	Area %	Name
1	11,84	15064120	51,403	
2	14,83	14241760	48,597	
		29305880	100,000	

Enantioselective reaction:



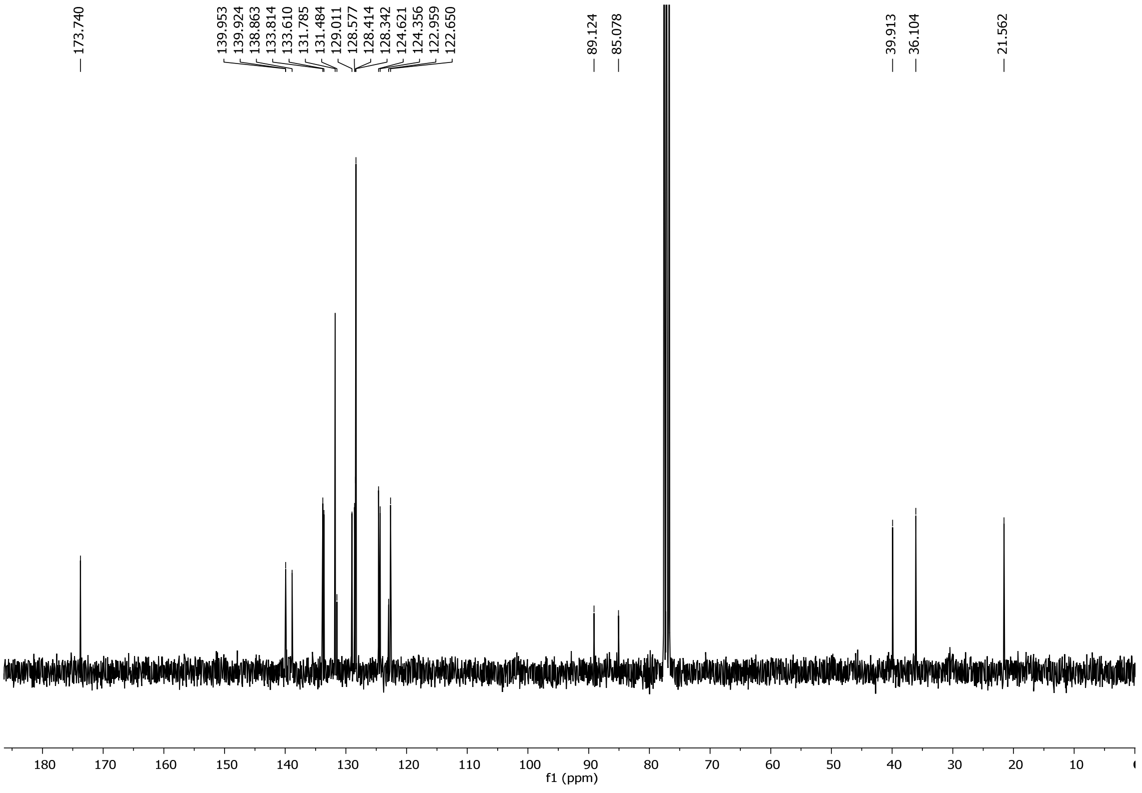
No.	RT	Area	Area %	Name
1	11,89	8333409	76,387	
2	15,17	2576065	23,613	
		10909474	100,000	

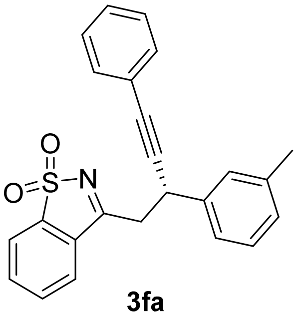


3fa

^{1}H NMR (300 MHz, CDCl$_3$)

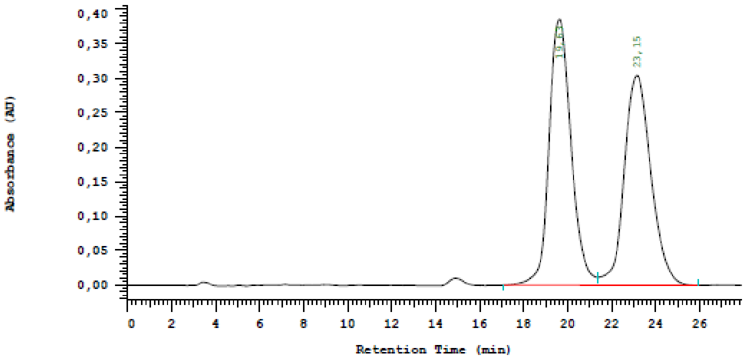
^{13}C NMR (75 MHz, CDCl$_3$)





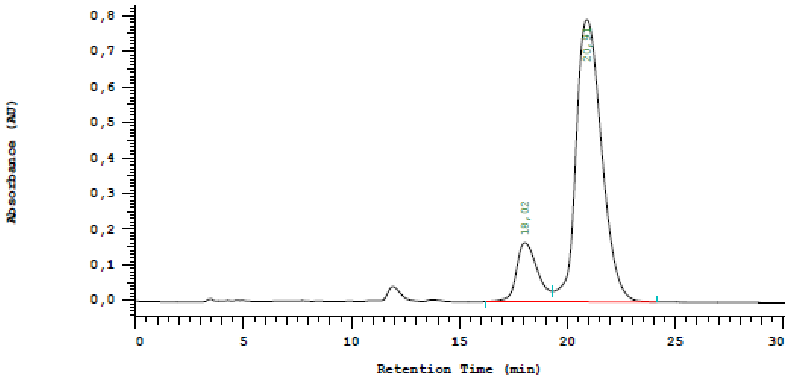
3fa

Racemic or near racemic mixture:

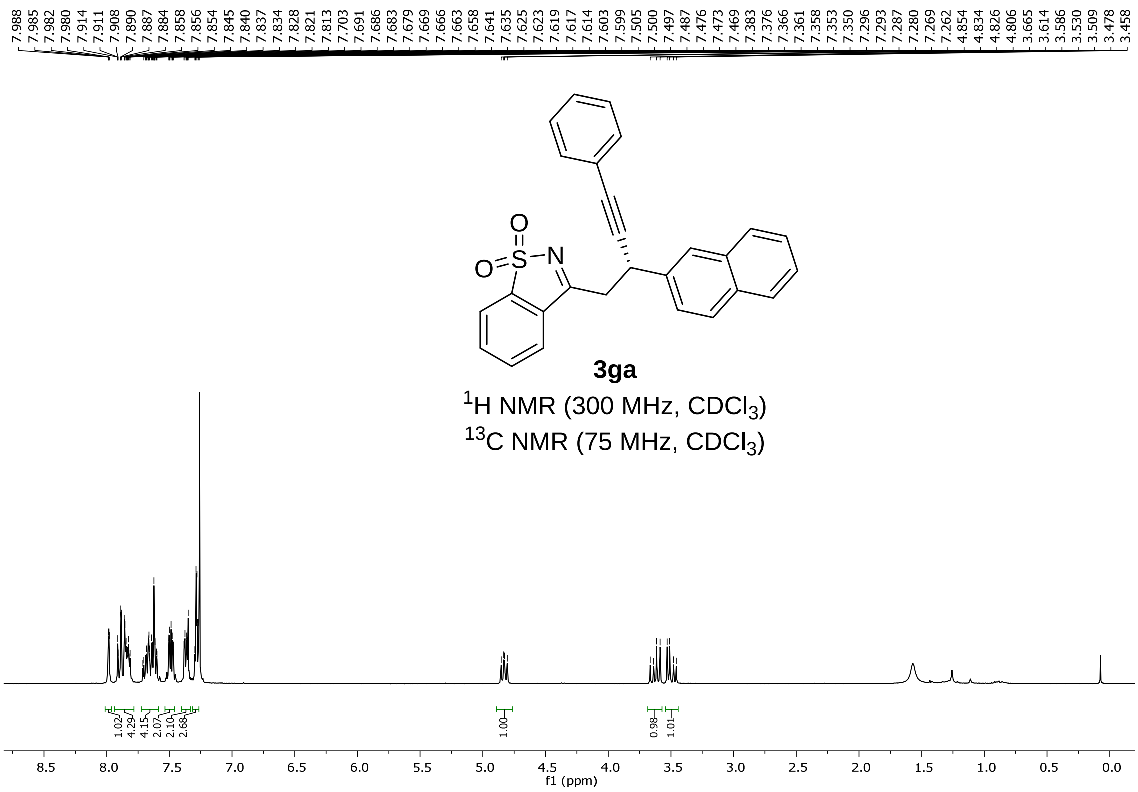


No.	RT	Area	Area %	Name
1	19,63	13434774	50,975	
2	23,15	12921004	49,025	
		26355778	100,000	

Enantioselective reaction:



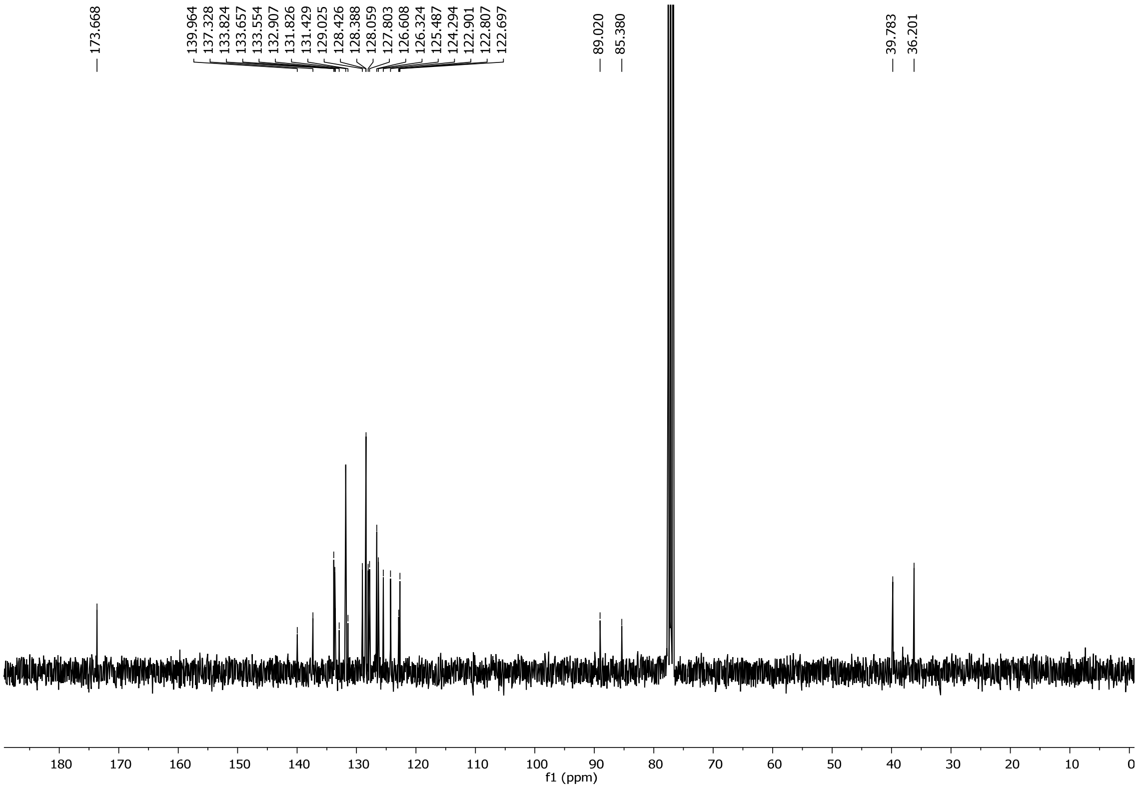
No.	RT	Area	Area %	Name
1	18,02	5525730	14,557	
2	20,91	32433190	85,443	
		37958920	100,000	

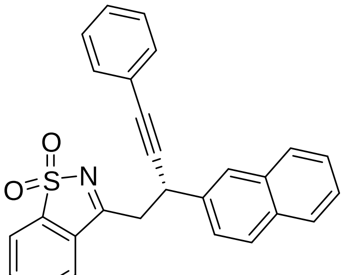


3ga

^{1}H NMR (300 MHz, CDCl$_3$)

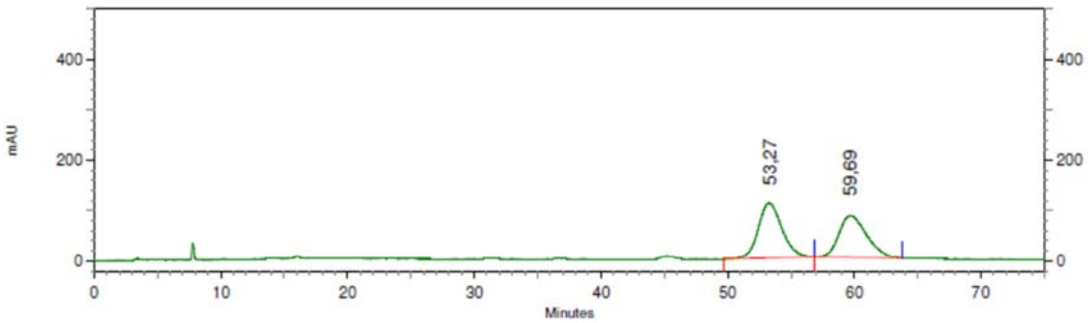
^{13}C NMR (75 MHz, CDCl$_3$)





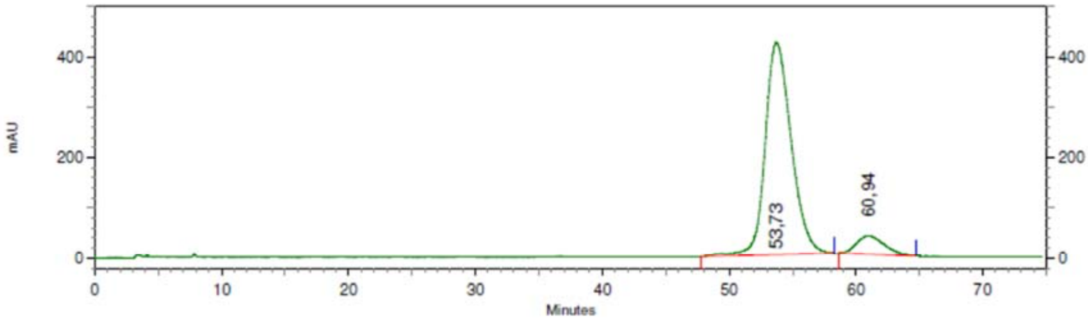
3ga

Racemic or near racemic mixture:

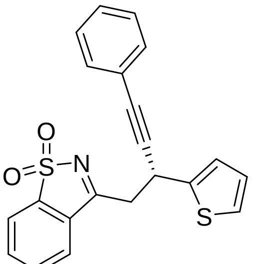


```
15: 245 nm, 4 nm
Results
          Retention Time                      Area          Area Percent
                   53,27                  56801629                53,042
                   59,69                  50285828                46,958
```

Enantioselective reaction:



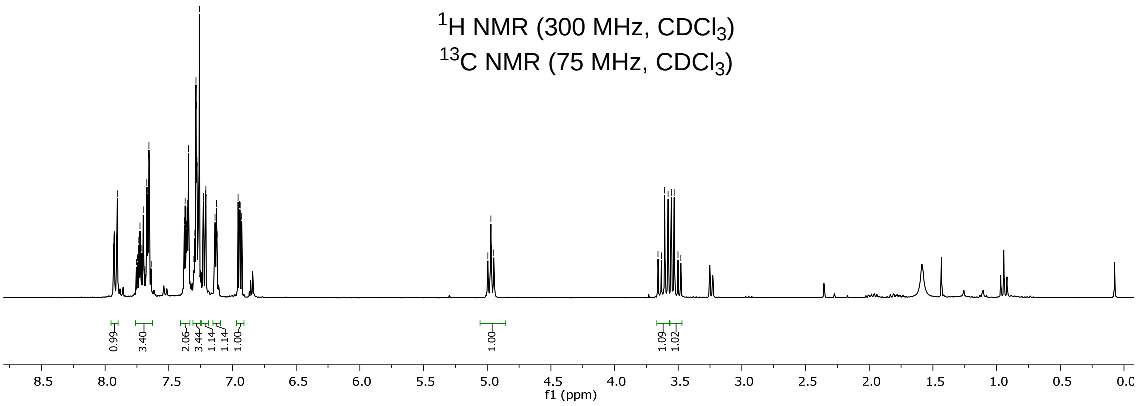
```
15: 245 nm, 4 nm
Results
          Retention Time                      Area          Area Percent
                   53,73                 241294007                91,489
                   60,94                  22446536                 8,511
```

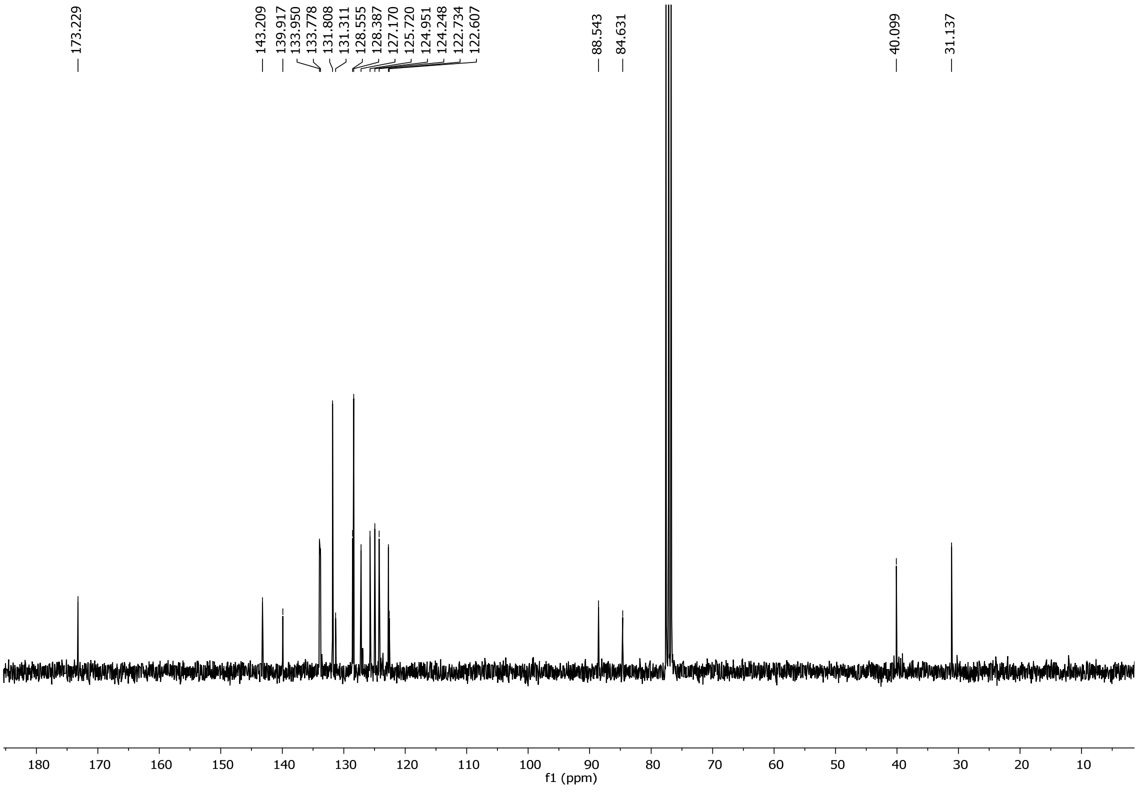


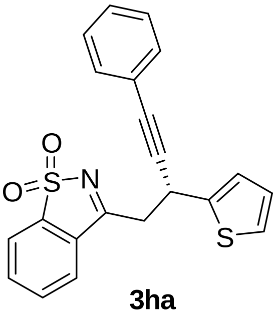
3ha

^{1}H NMR (300 MHz, CDCl$_3$)

^{13}C NMR (75 MHz, CDCl$_3$)

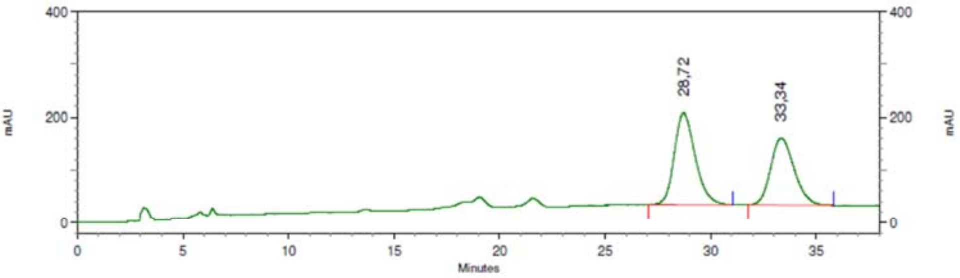






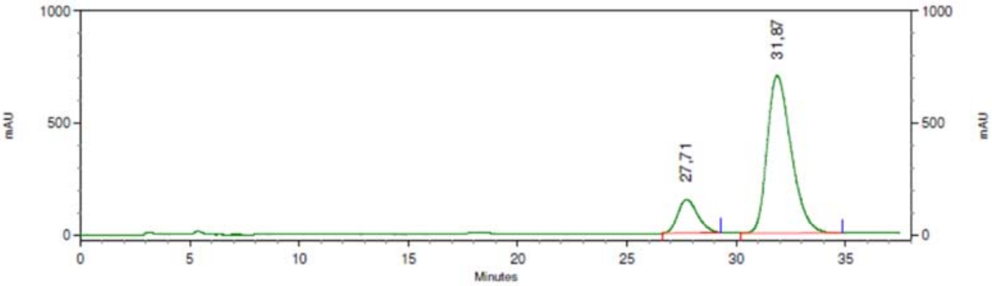
3ha

Racemic or near racemic mixture:

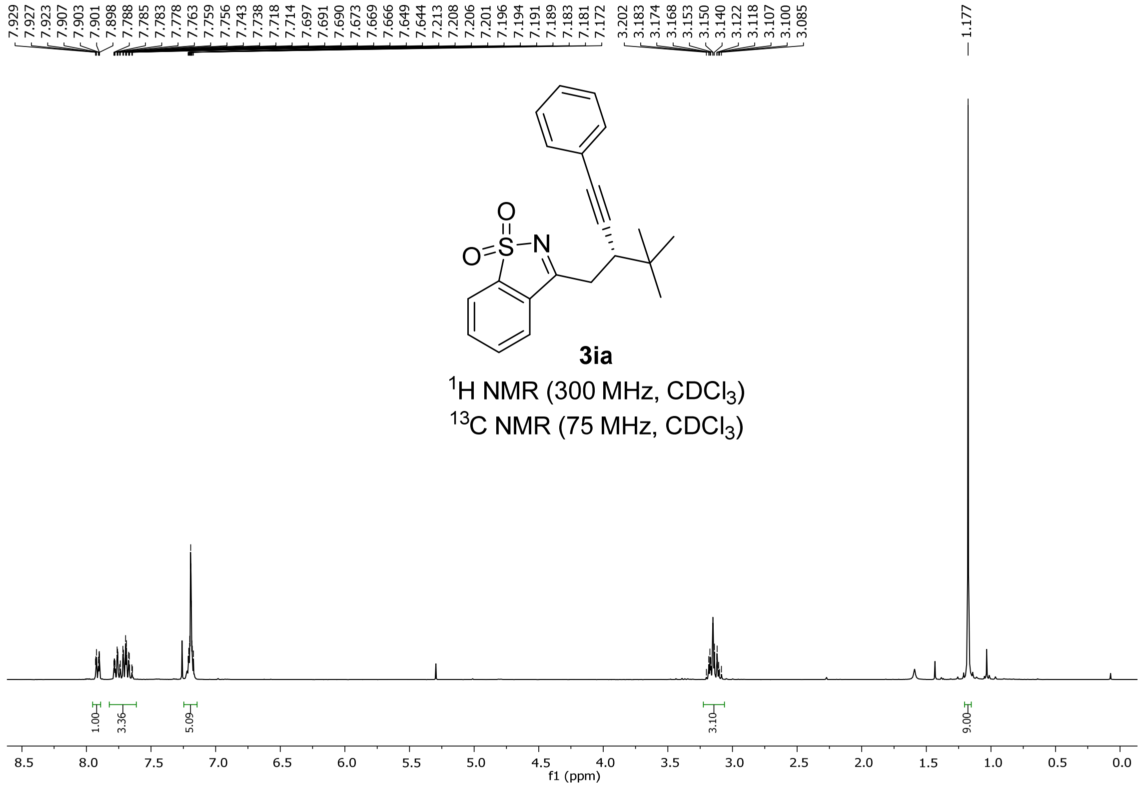


```
19: 221 nm, 4 nm
Results
            Retention Time                      Area              Area Percent
                     28,72                  48245961                    54,991
                     33,34                  39488857                    45,009
```

Enantioselective reaction:



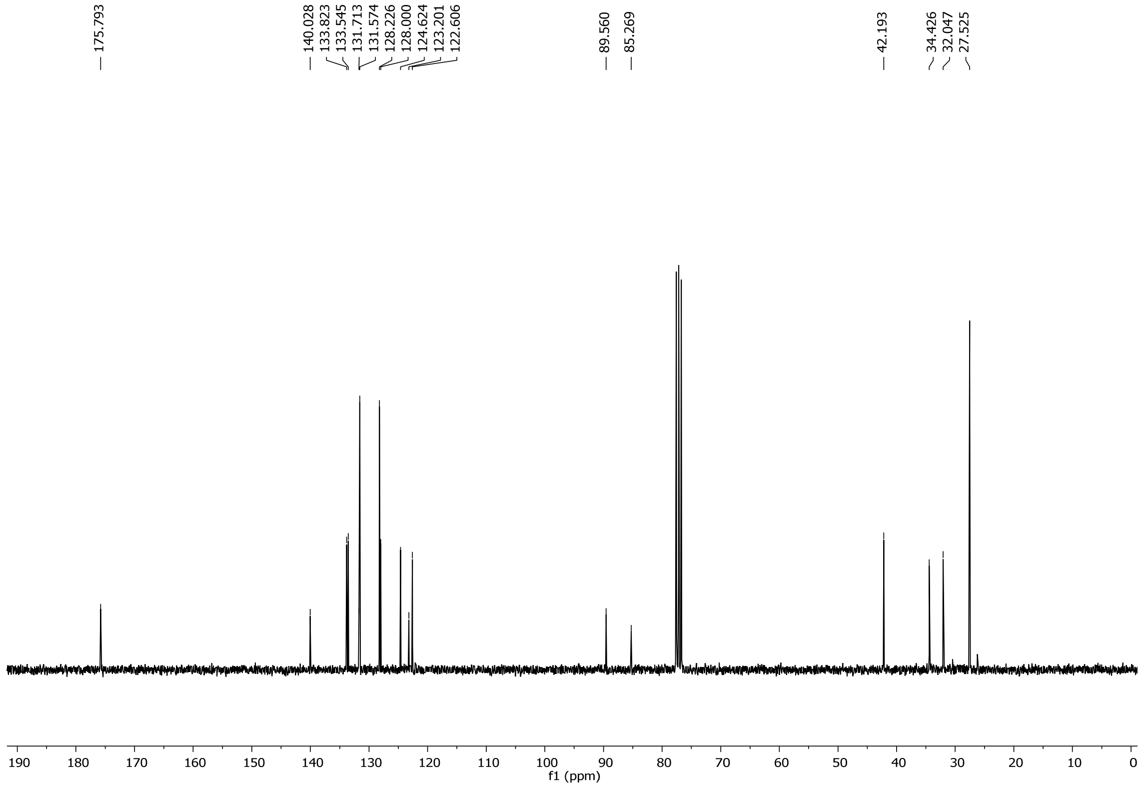
```
15: 245 nm, 4 nm
Results
            Retention Time                      Area                Area Percent
                     27,71                  38403186                      15,138
                     31,87                 215287629                      84,862
```

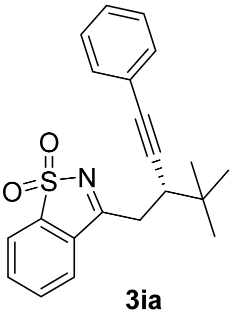


3ia

^{1}H NMR (300 MHz, $CDCl_3$)

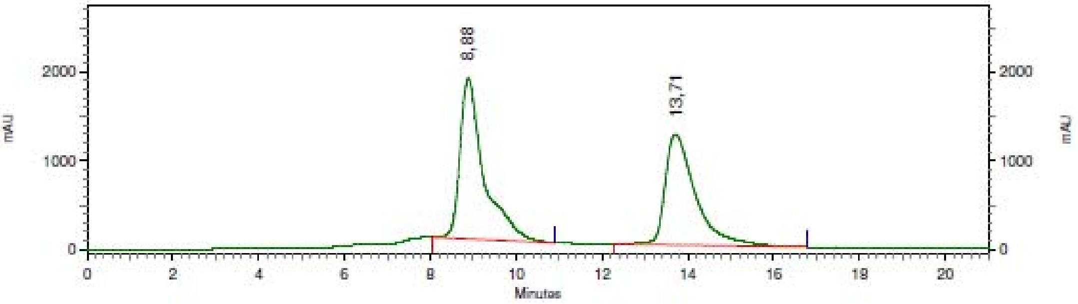
^{13}C NMR (75 MHz, $CDCl_3$)





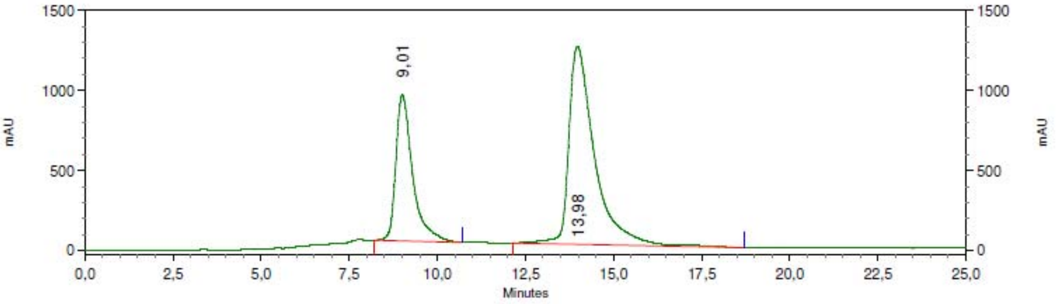
3ia

Racemic or near racemic mixture:

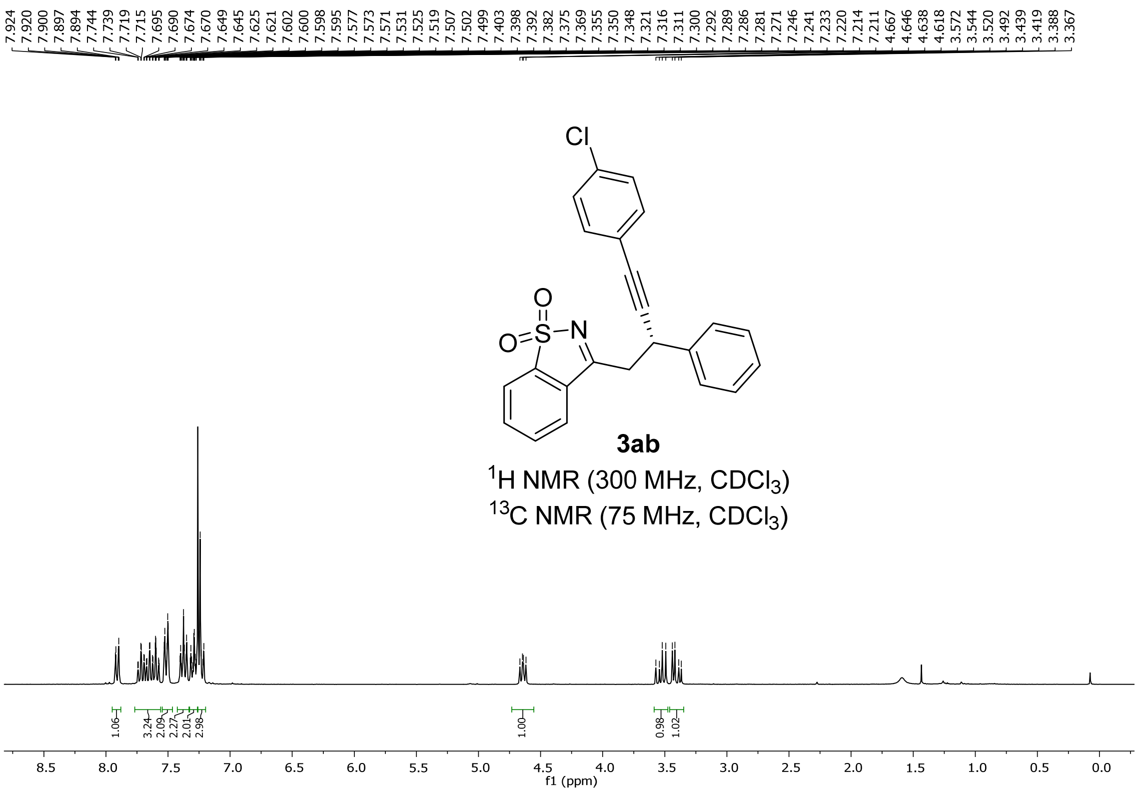


```
9: 243 nm, 4 nm Results
          Retention Time                          Area               Area Percent
                    8,88                     278579960                     53,092
                   13,71                     246131441                     46,908
```

Enantioselective reaction:



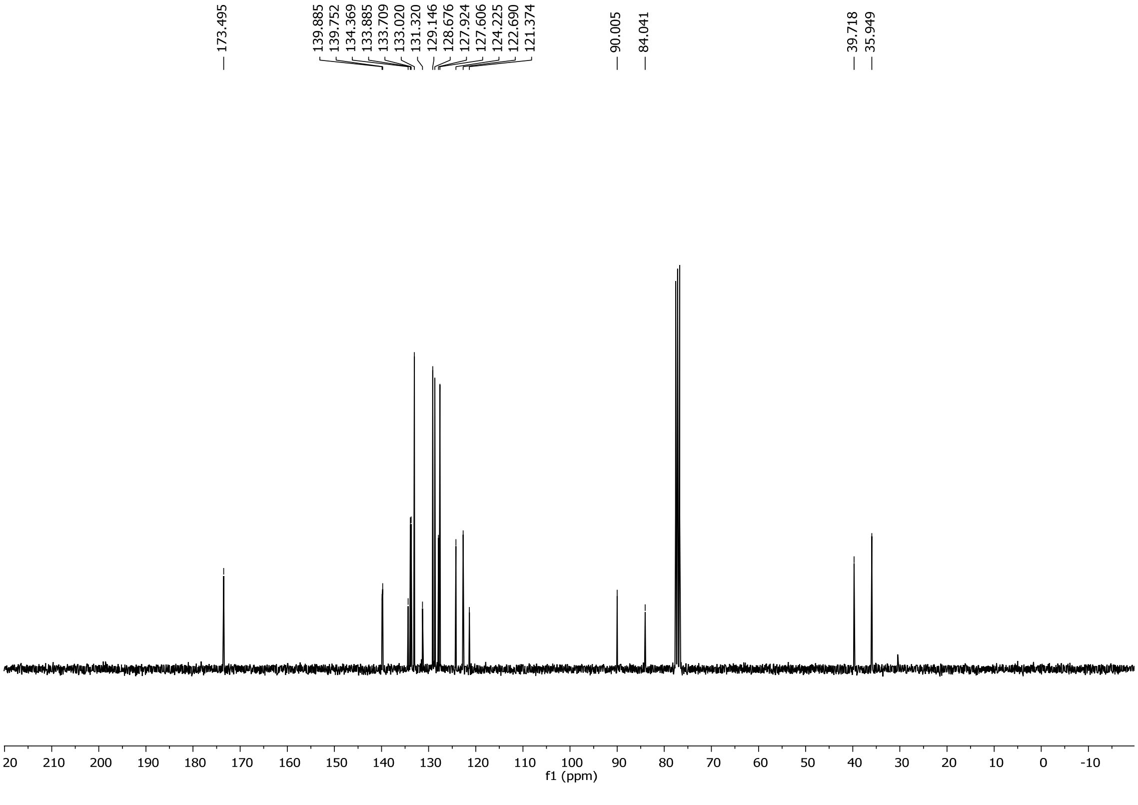
```
9: 250 nm, 4 nm Results
          Retention Time                          Area               Area Percent
                    9,01                     121004060                     32,470
                   13,98                     251664079                     67,530
```

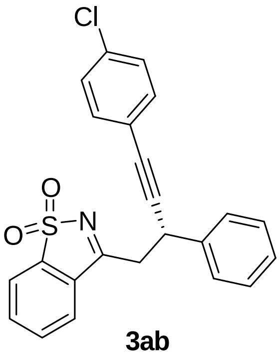


3ab

^{1}H NMR (300 MHz, $CDCl_3$)

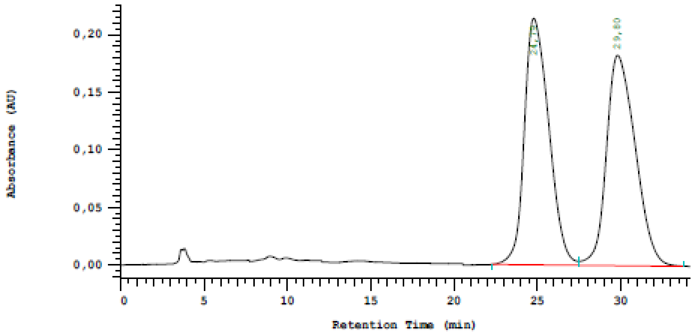
^{13}C NMR (75 MHz, $CDCl_3$)





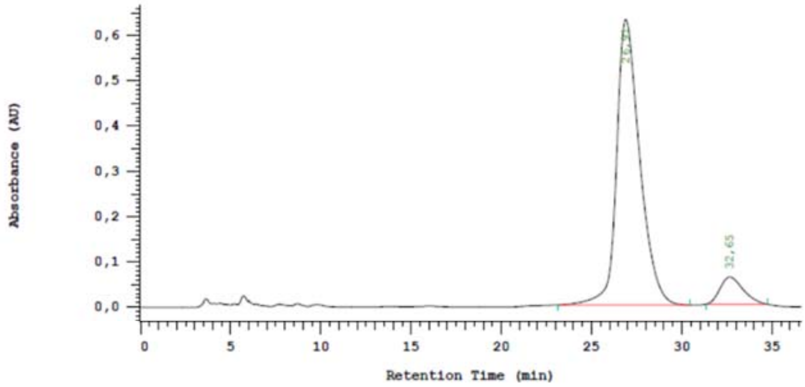
3ab

Racemic or near racemic mixture:

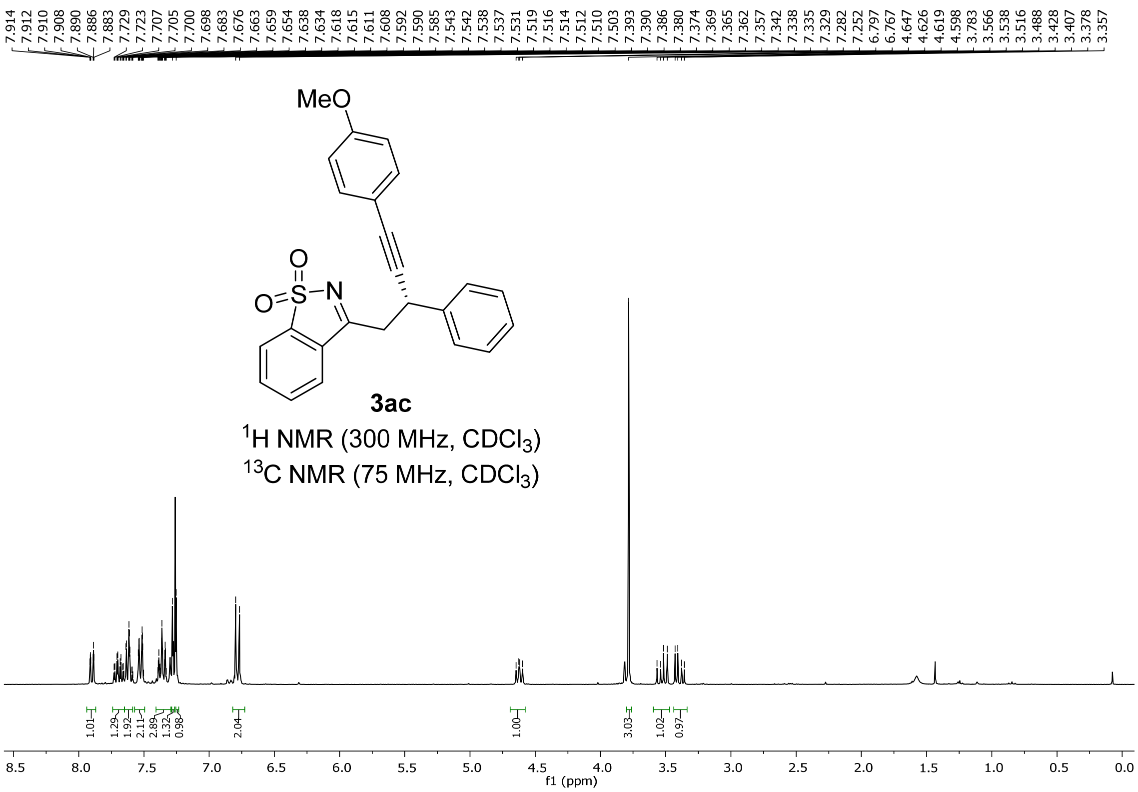


No.	RT	Area	Area %	Name
1	24,79	10927720	49,898	
2	29,80	10972194	50,102	
		21899914	100,000	

Enantioselective reaction:



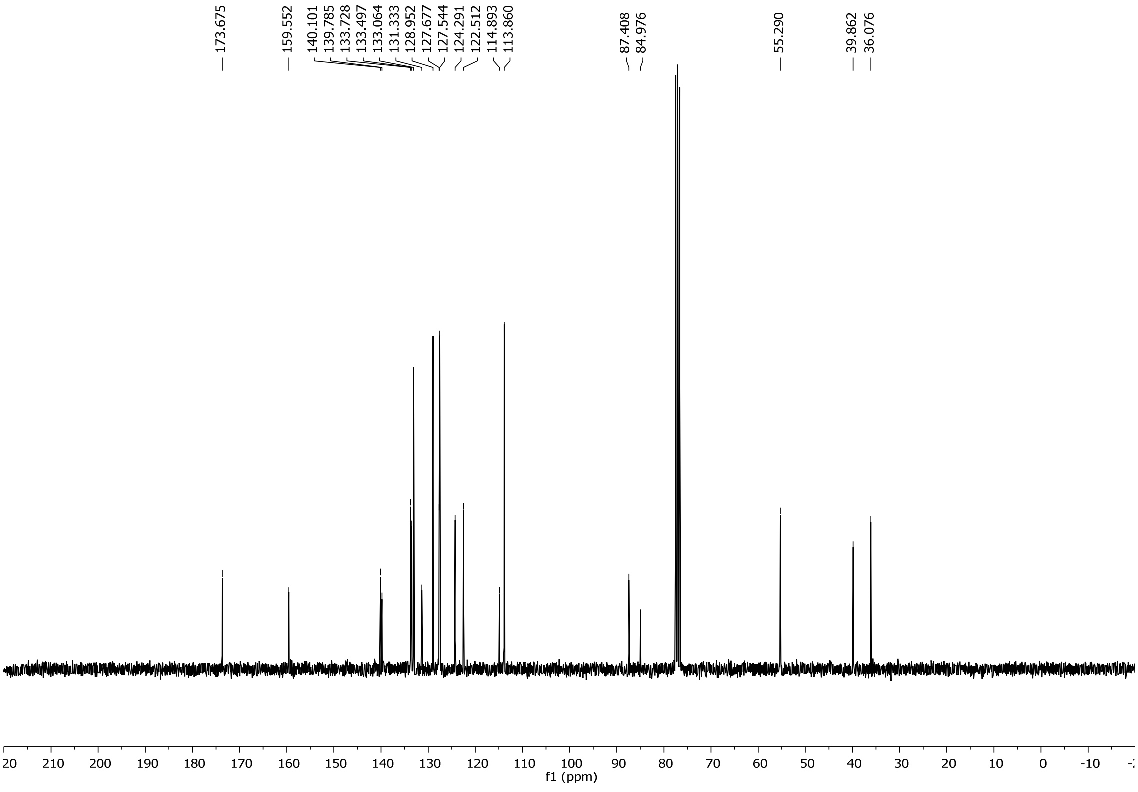
No.	RT	Area	Area %	Name
1	26,91	28149638	91,326	
2	32,65	2673610	8,674	
		30823248	100,000	

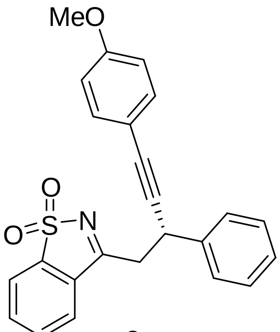


3ac

^{1}H NMR (300 MHz, CDCl$_3$)

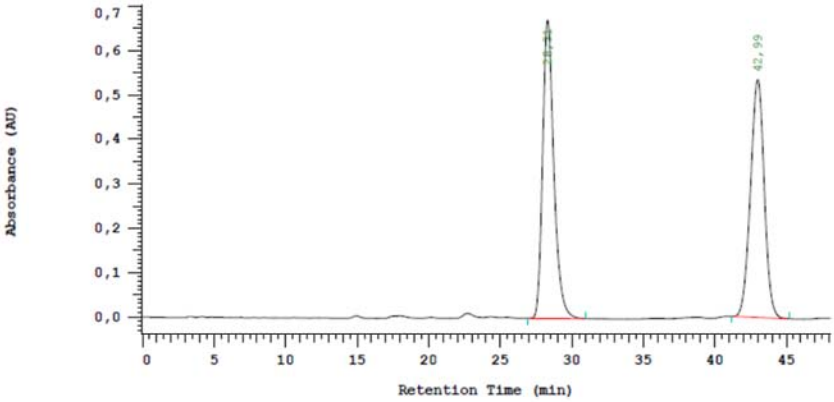
^{13}C NMR (75 MHz, CDCl$_3$)





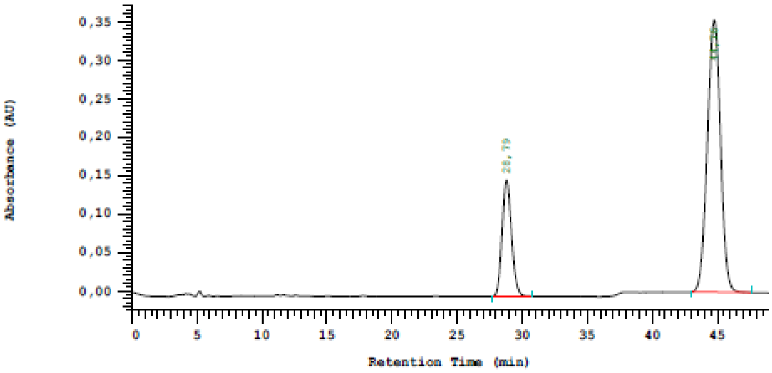
3ac

Racemic or near racemic mixture:

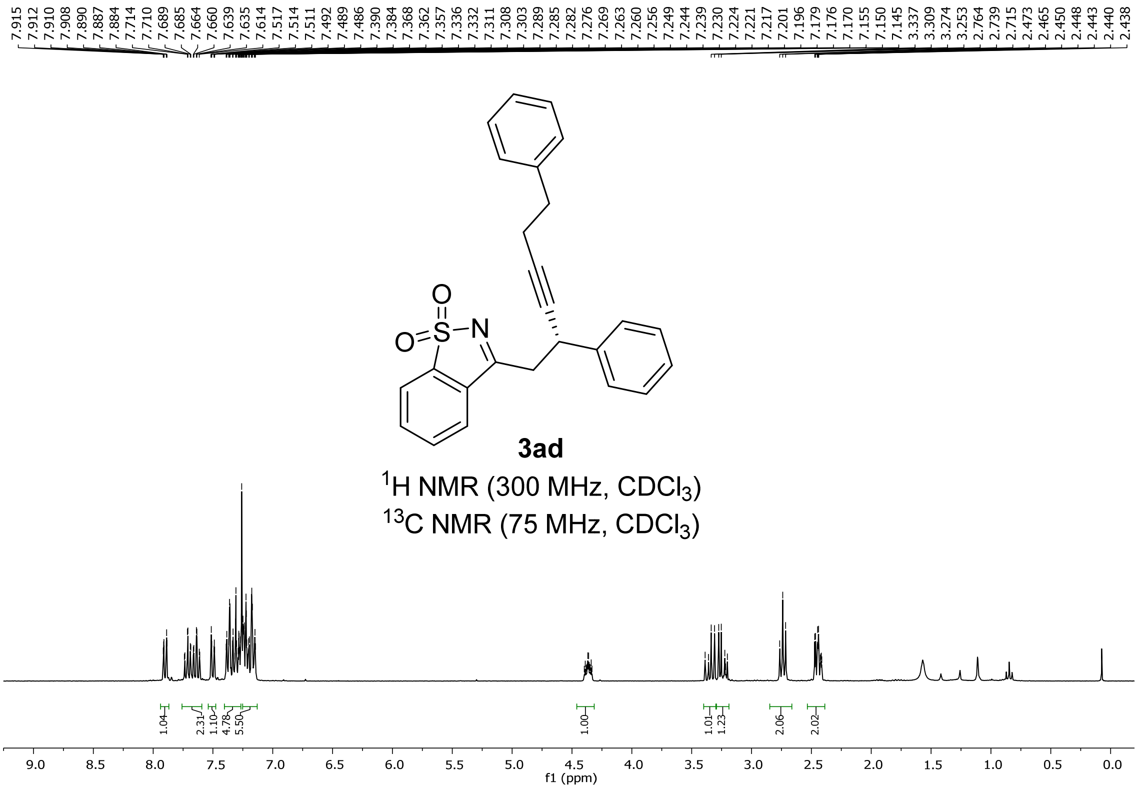


No.	RT	Area	Area %	Name
1	28,31	18141489	50,342	
2	42,99	17895059	49,658	
		36036548	100,000	

Enantioselective reaction:



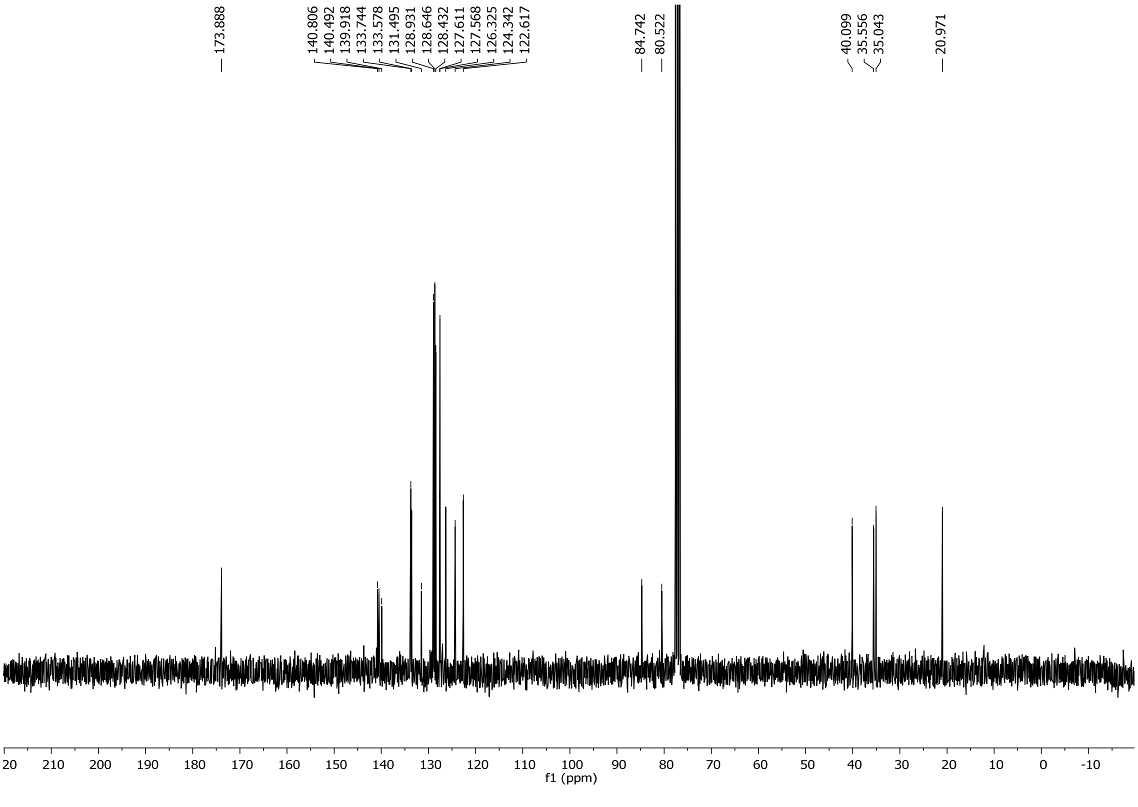
No.	RT	Area	Area %	Name
1	28,79	3738144	23,344	
2	44,76	12274864	76,656	
		16013008	100,000	

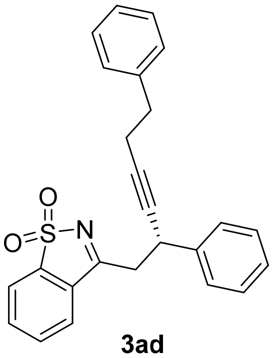


3ad

^{1}H NMR (300 MHz, $CDCl_3$)

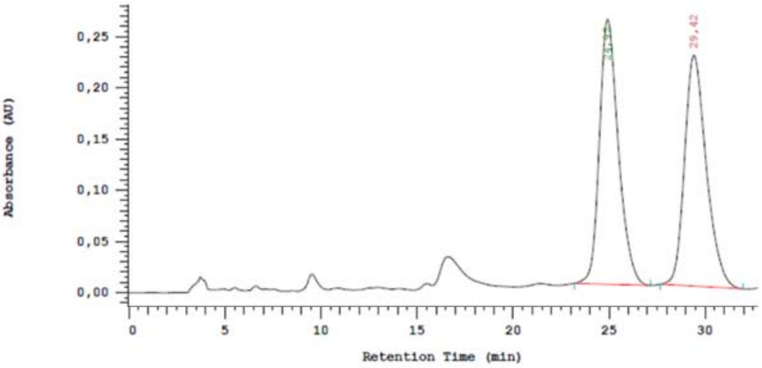
^{13}C NMR (75 MHz, $CDCl_3$)





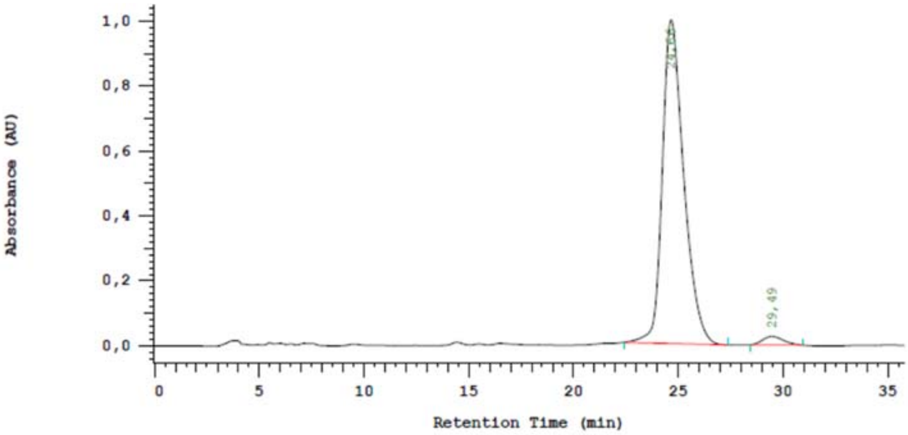
3ad

Racemic or near racemic mixture:

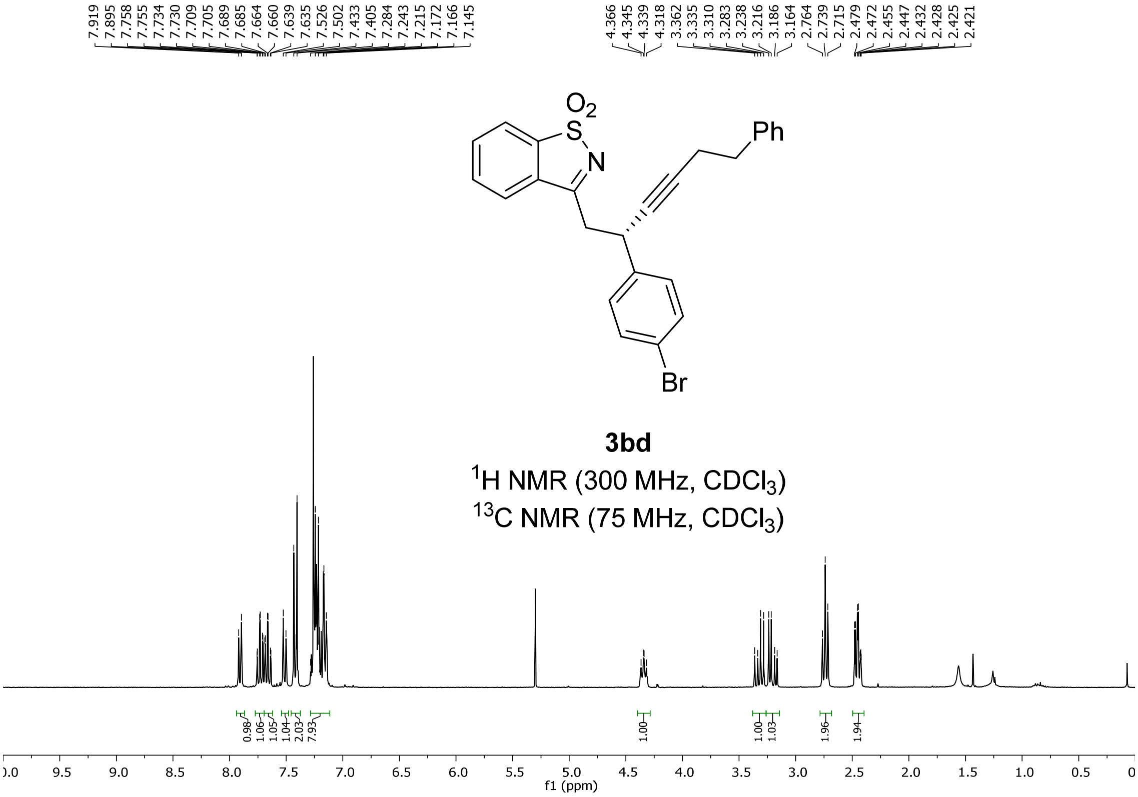


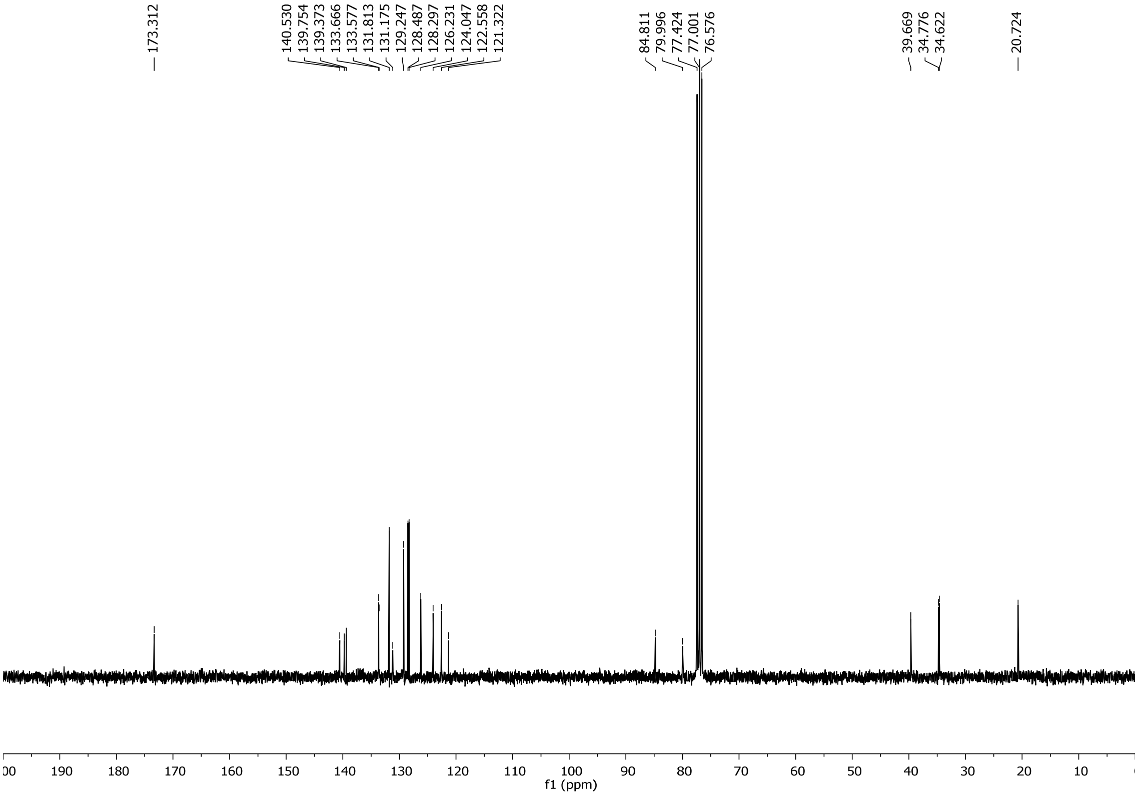
No.	RT	Area	Area %	Name
1	24,92	8841550	50,014	
2	29,42	8836630	49,986	
		17678180	100,000	

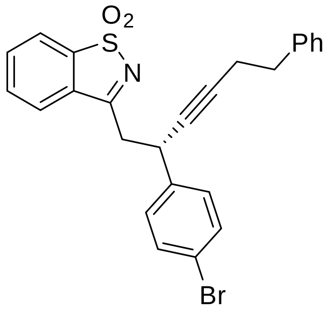
Enantioselective reaction:



No.	RT	Area	Area %	Name
1	24,66	35156310	97,459	
2	29,49	916560	2,541	
		36072870	100,000	

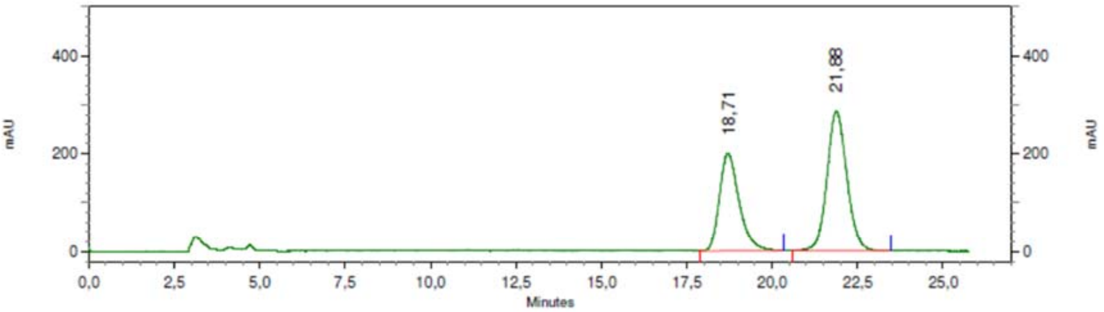

7.919
7.895
7.758
7.755
7.734
7.730
7.709
7.705
7.689
7.685
7.664
7.660
7.639
7.635
7.526
7.502
7.433
7.405
7.284
7.243
7.215
7.172
7.166
7.145
4.366
4.345
4.339
4.318
3.362
3.335
3.310
3.283
3.238
3.216
3.186
3.164
2.764
2.739
2.715
2.479
2.472
2.455
2.447
2.432
2.428
2.425
2.421
O2
S
N
Ph
Br
3bd
1H NMR (300 MHz, CDCl3)
13C NMR (75 MHz, CDCl3)
0.98
1.06
1.05
1.04
2.03
7.93
1.00
1.00
1.03
1.96
1.94
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


173.312
140.530
139.754
139.373
133.666
133.577
131.813
131.175
129.247
128.487
128.297
126.231
124.047
122.558
121.322
84.811
79.996
77.424
77.001
76.576
39.669
34.776
34.622
20.724
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)



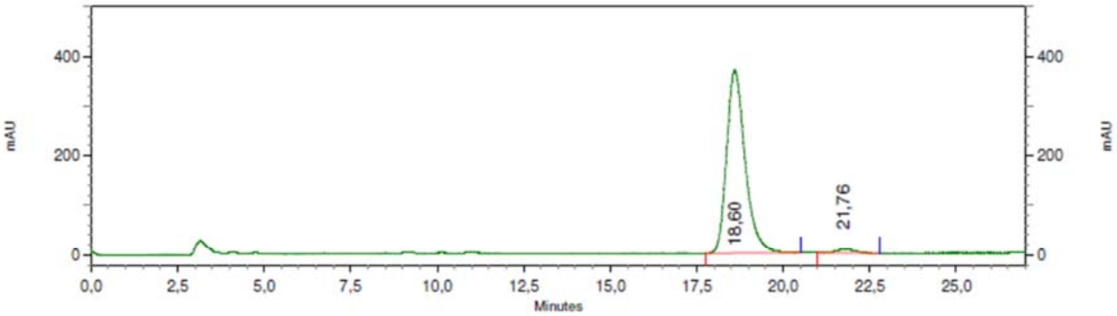
3bd

Racemic or near racemic mixture of enantiomers:

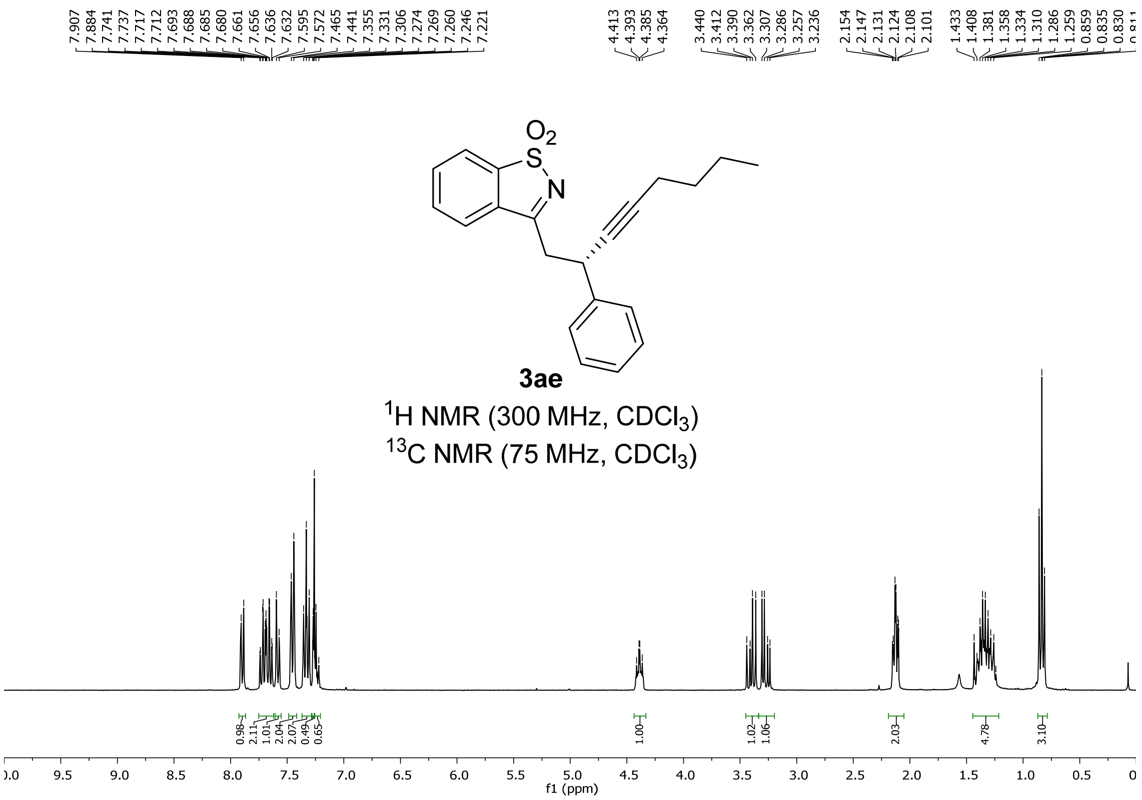


```
18: 220 nm, 4 nm
Results
          Retention Time                        Area                    Area Percent
                   18,71                    32020989                          40,880
                   21,88                    46308719                          59,120
```

Enantioselective reaction:



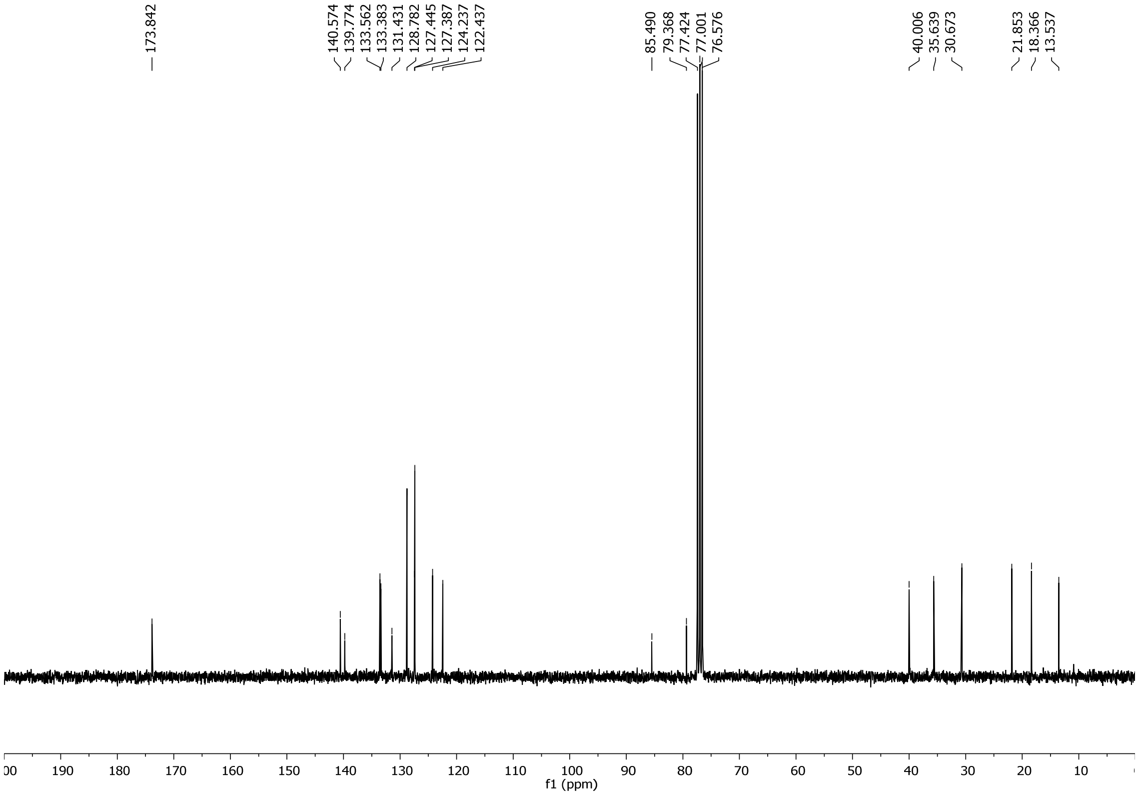
```
18: 220 nm, 4 nm
Results
          Retention Time                        Area                    Area Percent
                   18,60                    55020959                          97,752
                   21,76                     1265305                           2,248
```

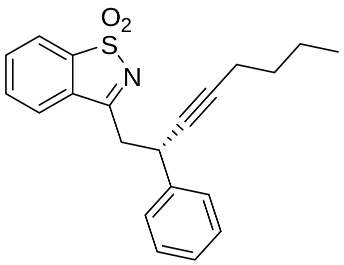


3ae

^{1}H NMR (300 MHz, CDCl$_3$)

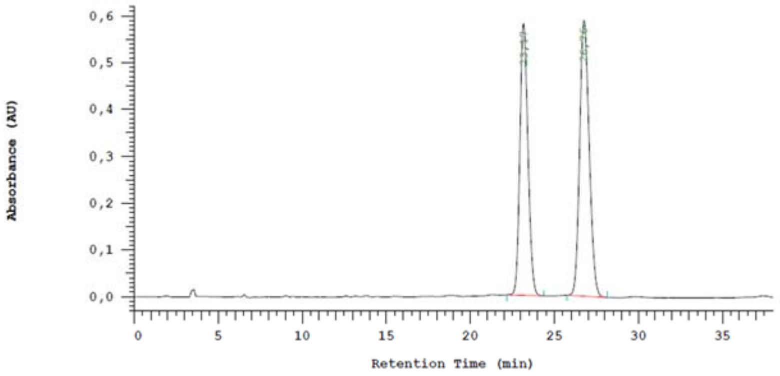
^{13}C NMR (75 MHz, CDCl$_3$)





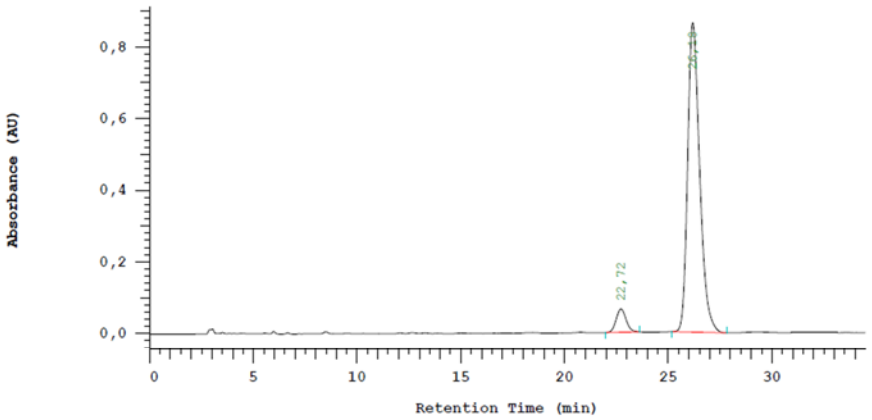
3ae

Racemic or near racemic mixture of enantiomers:

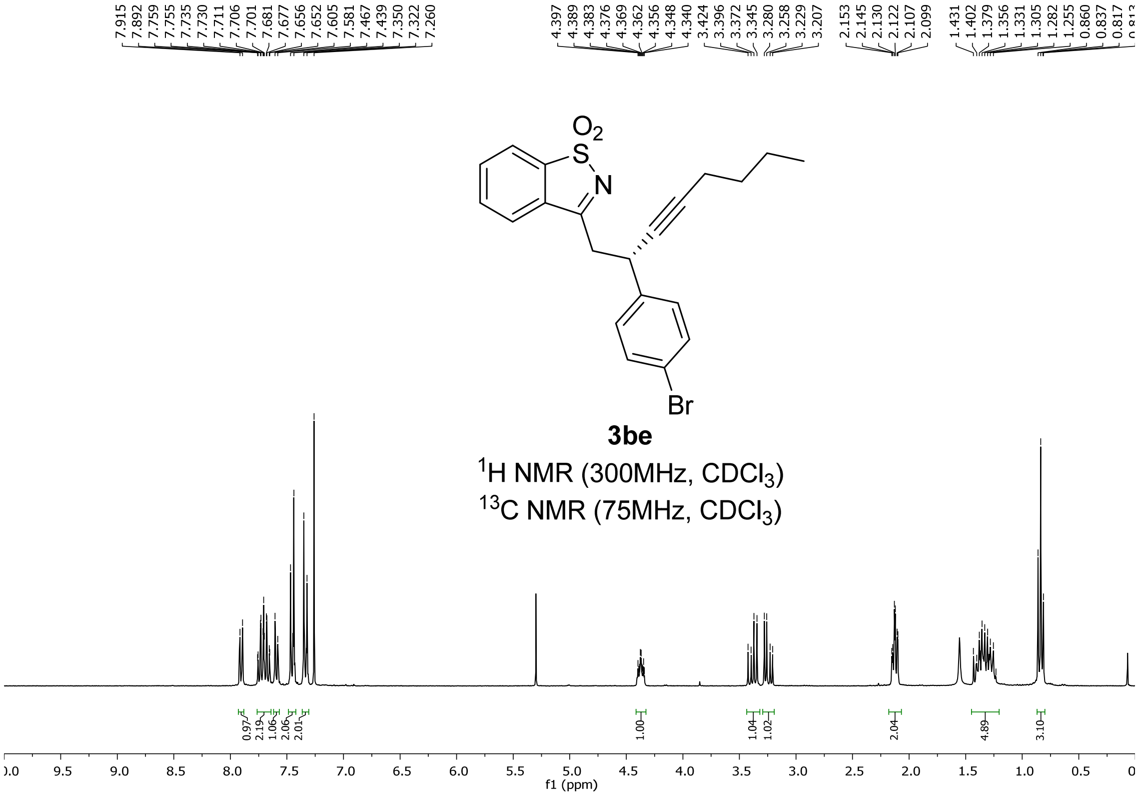


No.	RT	Area	Area %	Name
1	23,17	9625744	45,583	
2	26,76	11491329	54,417	
		21117073	100,000	

Enantioselective reaction:



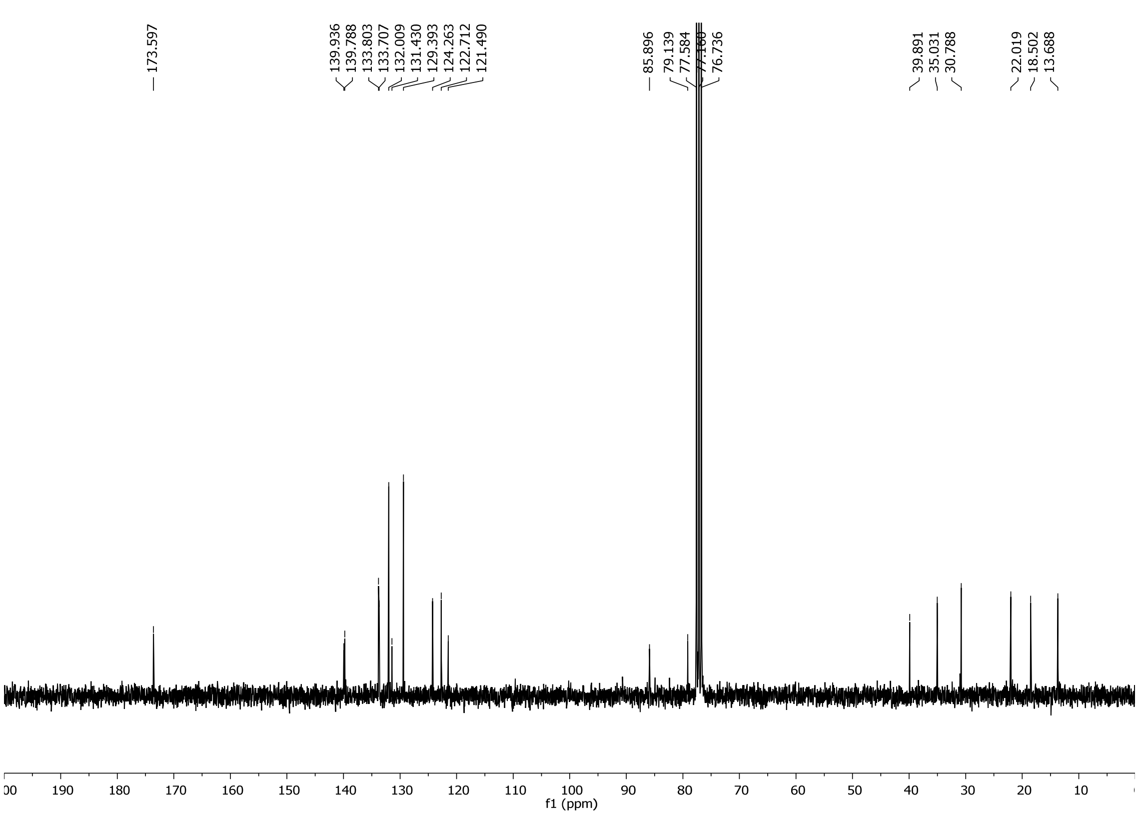
No.	RT	Area	Area %	Name
1	22,72	1081550	5,898	
2	26,18	17256240	94,102	
		18337790	100,000	

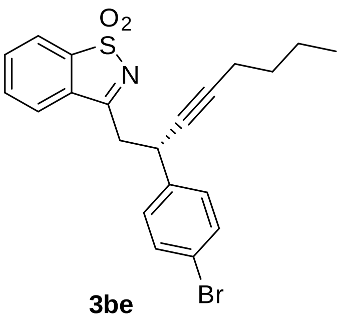


3be

^{1}H NMR (300MHz, $CDCl_3$)

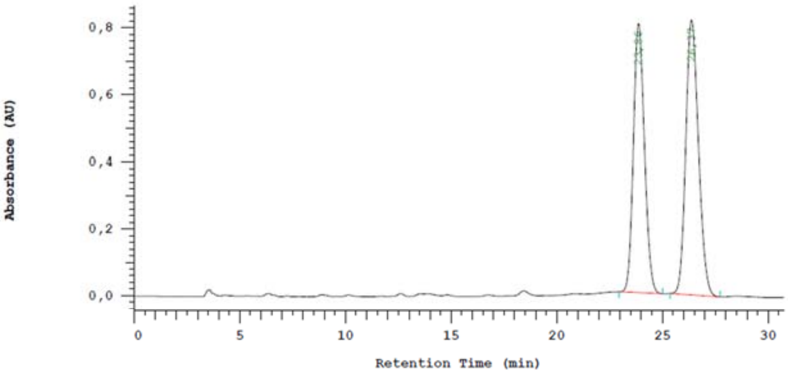
^{13}C NMR (75MHz, $CDCl_3$)





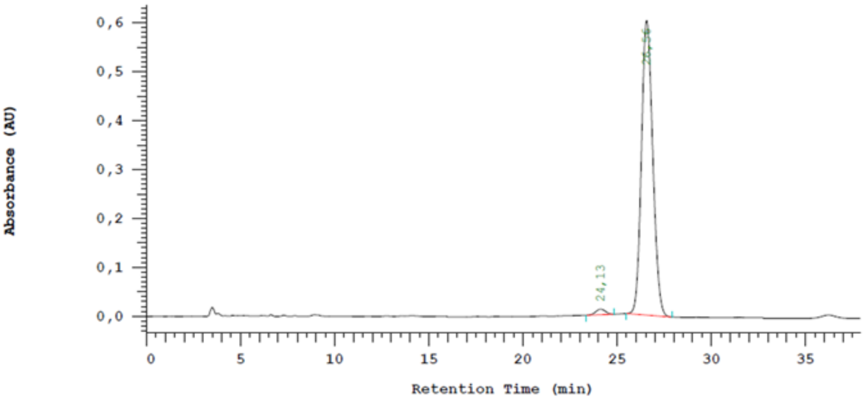
3be

Racemic or near racemic mixture of enantiomers:

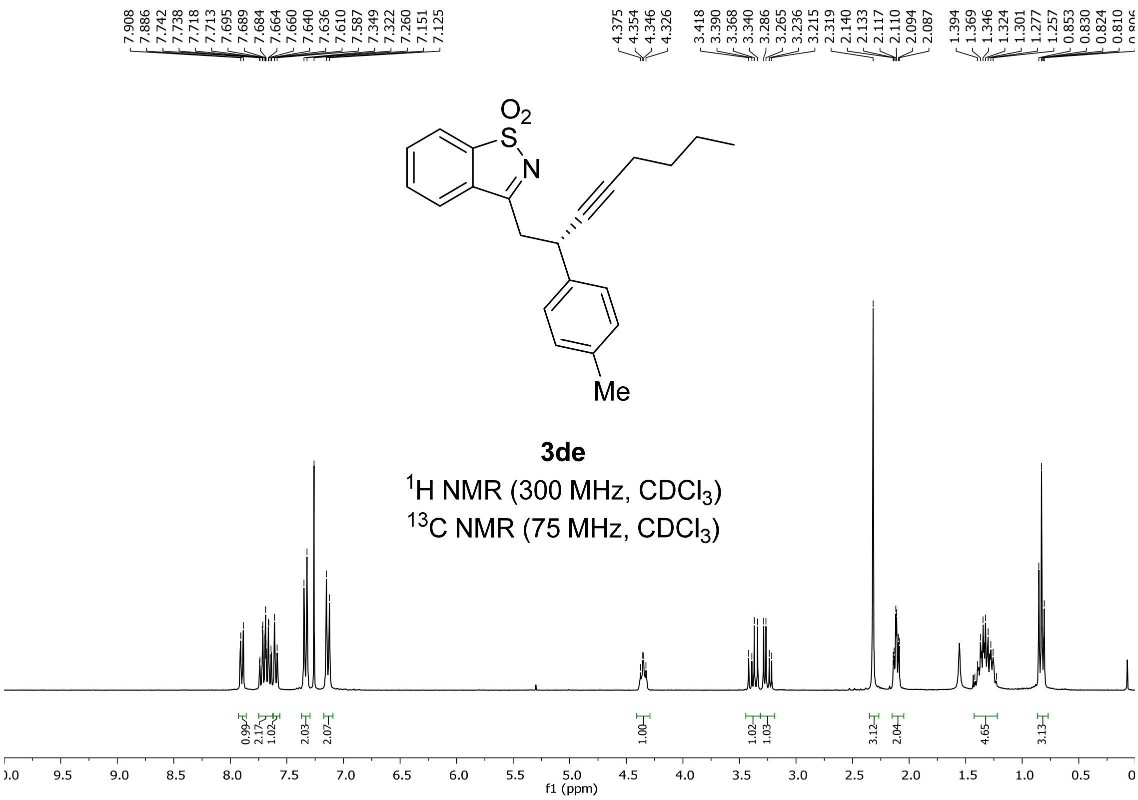


No.	RT	Area	Area %	Name
1	23,86	14572449	46,186	
2	26,37	16979510	53,814	
		31551959	100,000	

Enantioselective reaction:



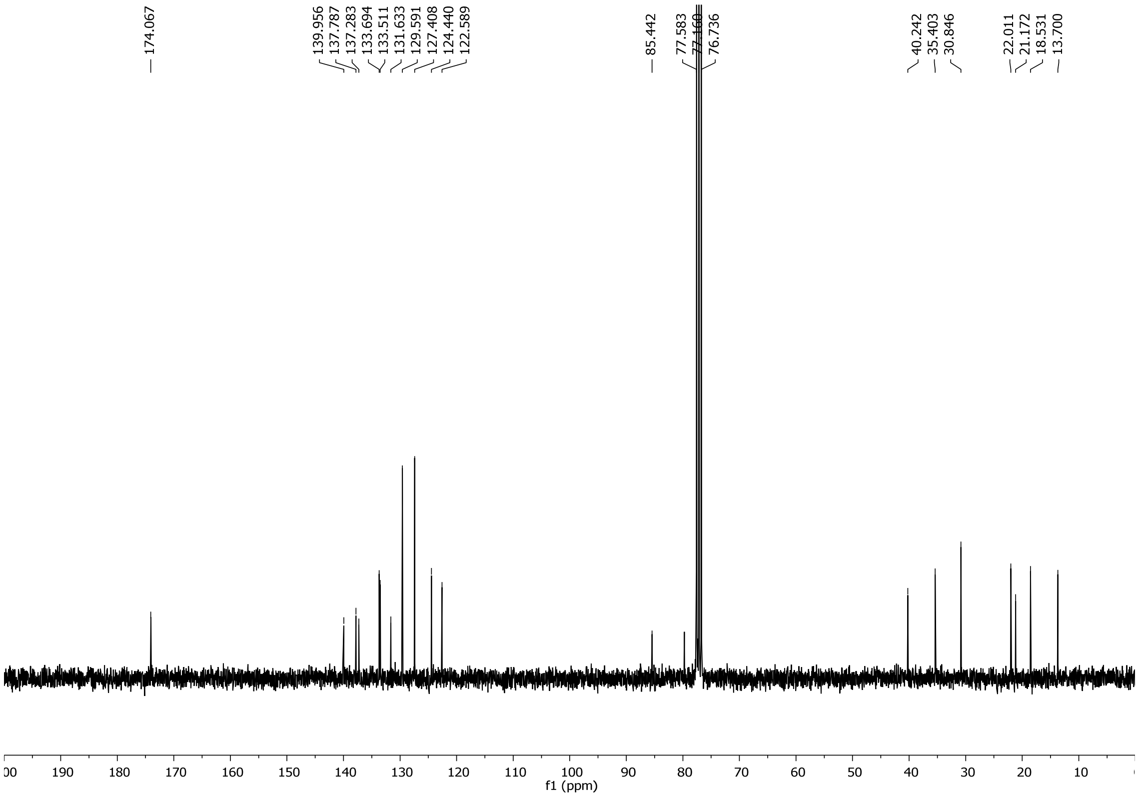
No.	RT	Area	Area %	Name
1	24,13	198690	1,570	
2	26,56	12454504	98,430	
		12653194	100,000	

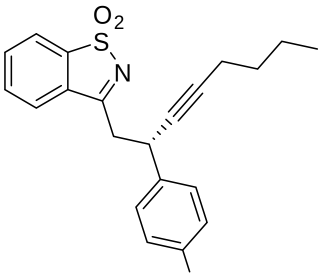


3de

^{1}H NMR (300 MHz, $CDCl_3$)

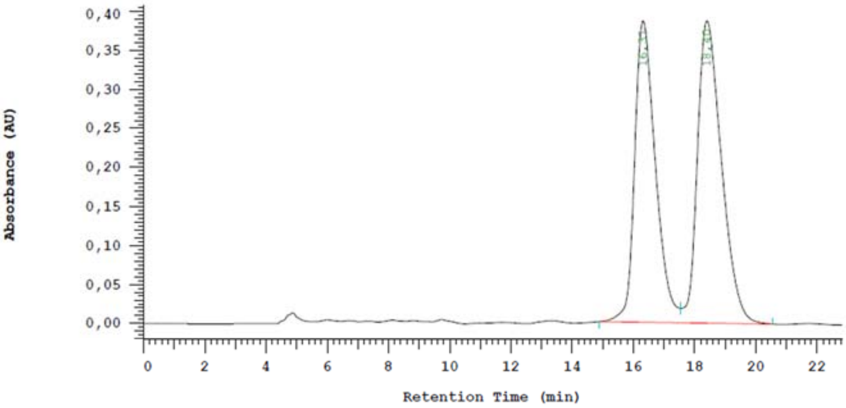
^{13}C NMR (75 MHz, $CDCl_3$)





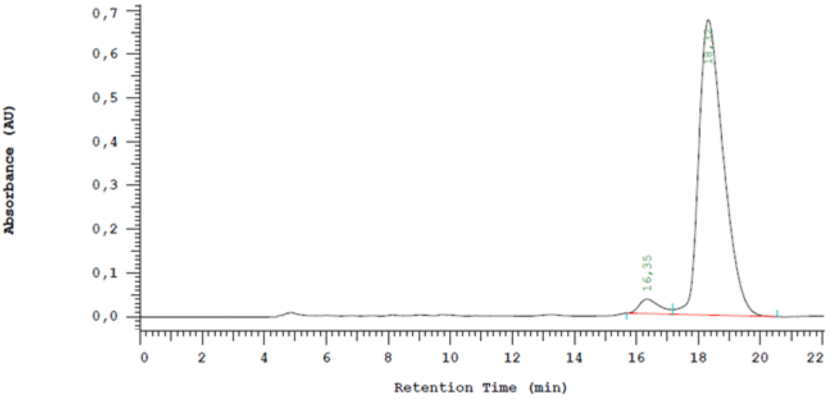
3de

Racemic or near racemic mixture of enantiomers:

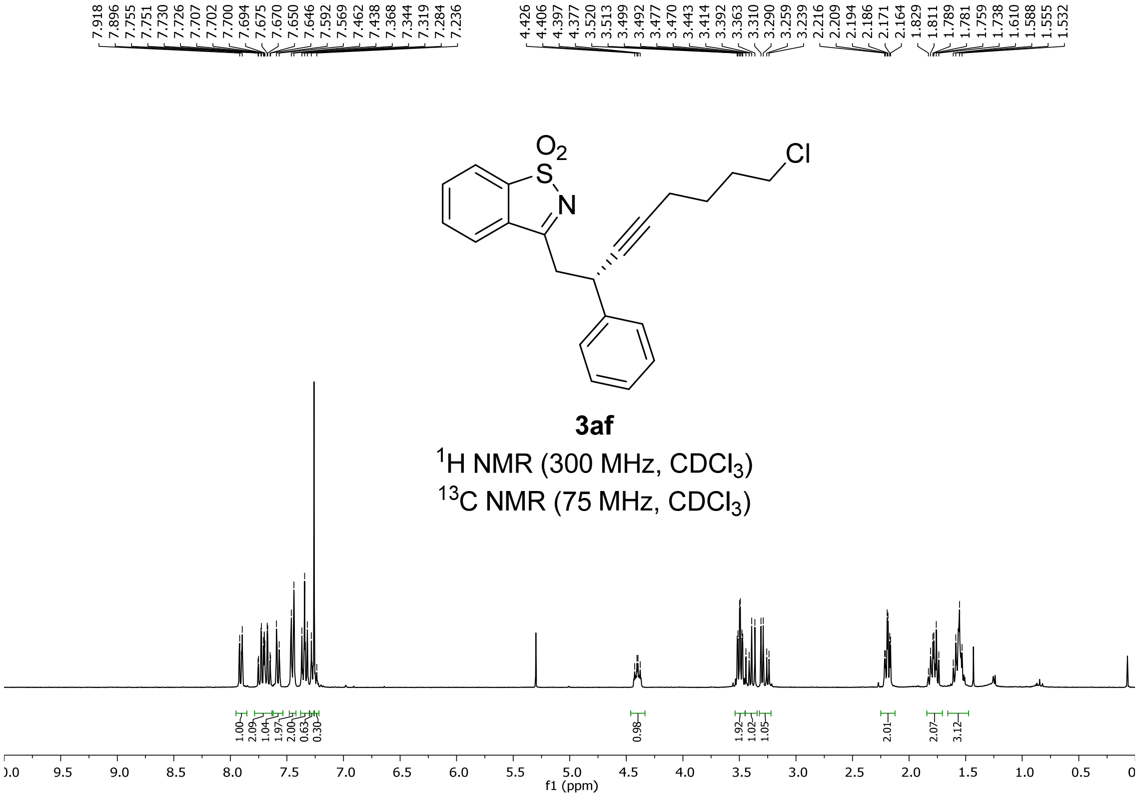


No.	RT	Area	Area %	Name
1	16,31	9140336	46,224	
2	18,40	10633608	53,776	
		19773944	100,000	

Enantioselective reaction:



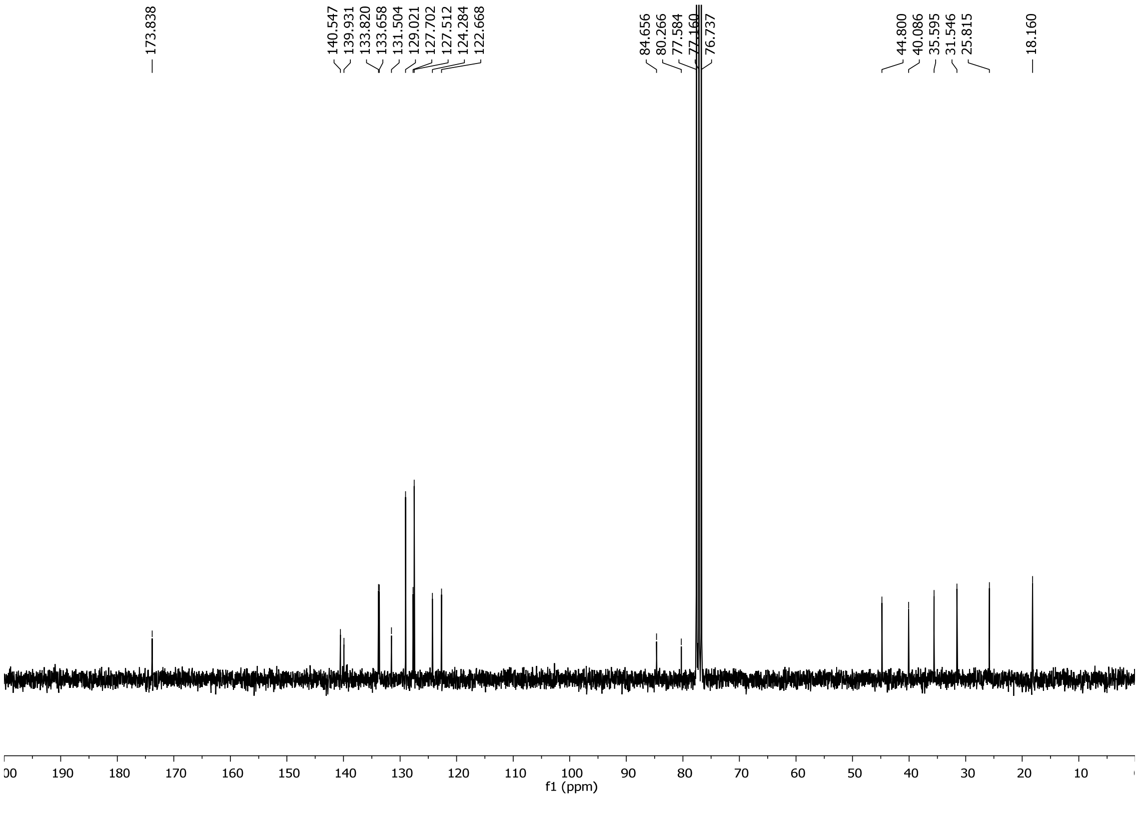
No.	RT	Area	Area %	Name
1	16,35	755407	3,894	
2	18,32	18645662	96,106	
		19401069	100,000	

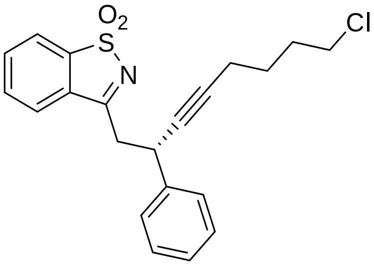


3af

^{1}H NMR (300 MHz, CDCl$_3$)

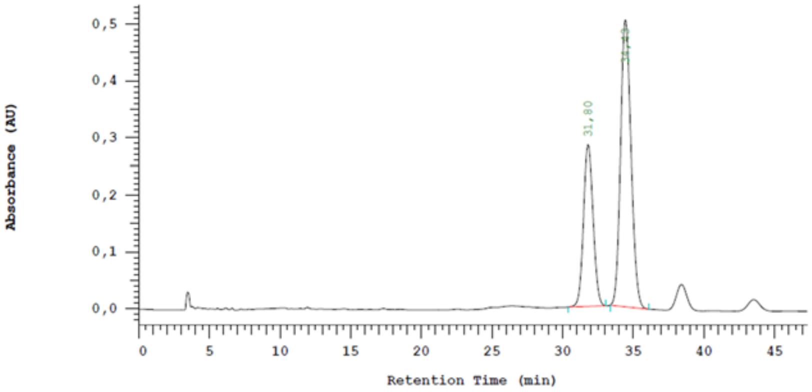
^{13}C NMR (75 MHz, CDCl$_3$)





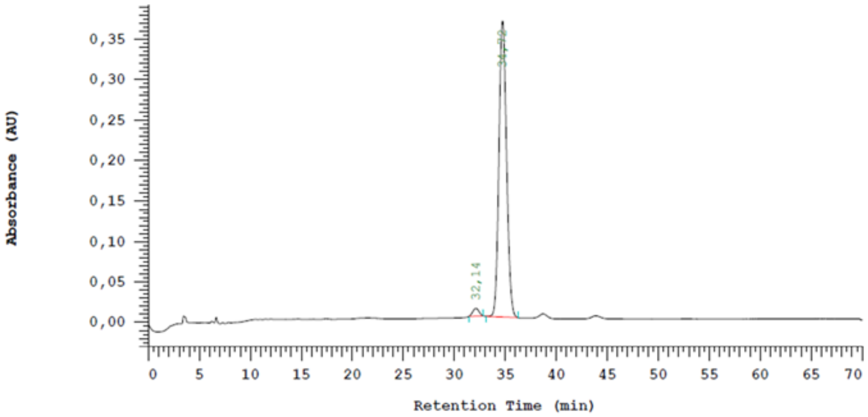
3af

Racemic or near racemic mixture of enantiomers:

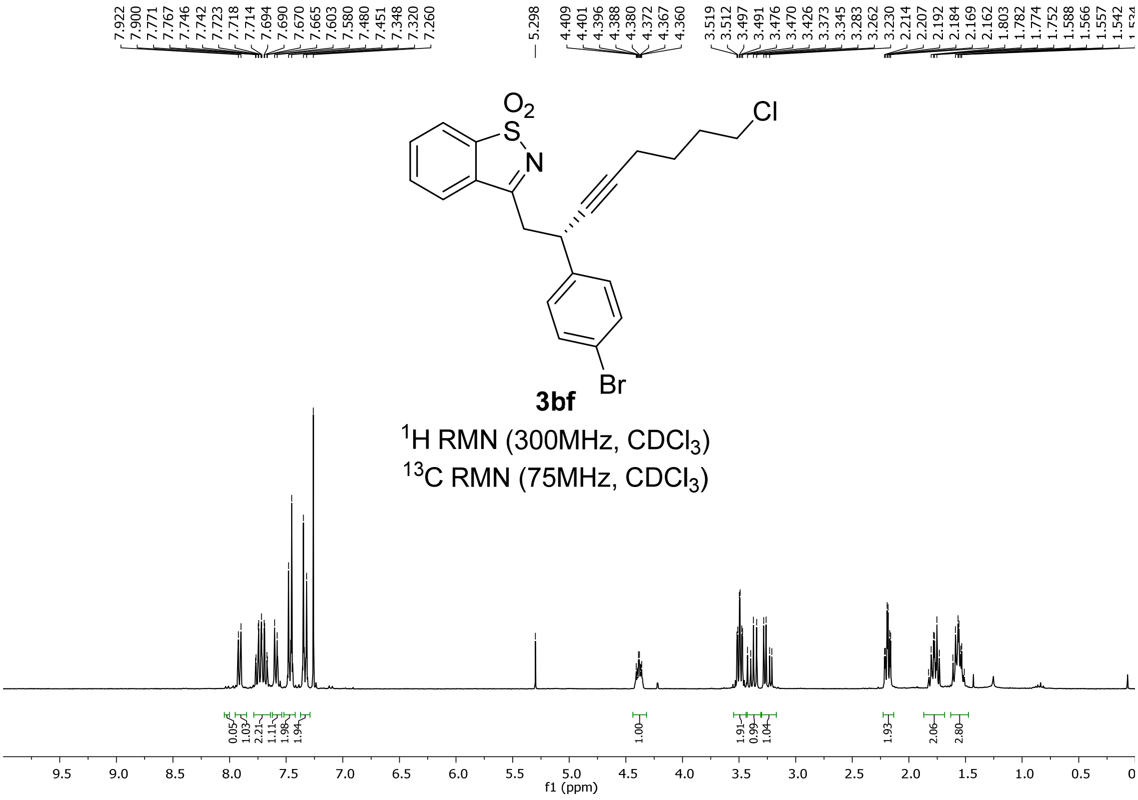


No.	RT	Area	Area %	Name
1	31,80	6645030	33,999	
2	34,43	12899800	66,001	
		19544830	100,000	

Enantioselective reaction:



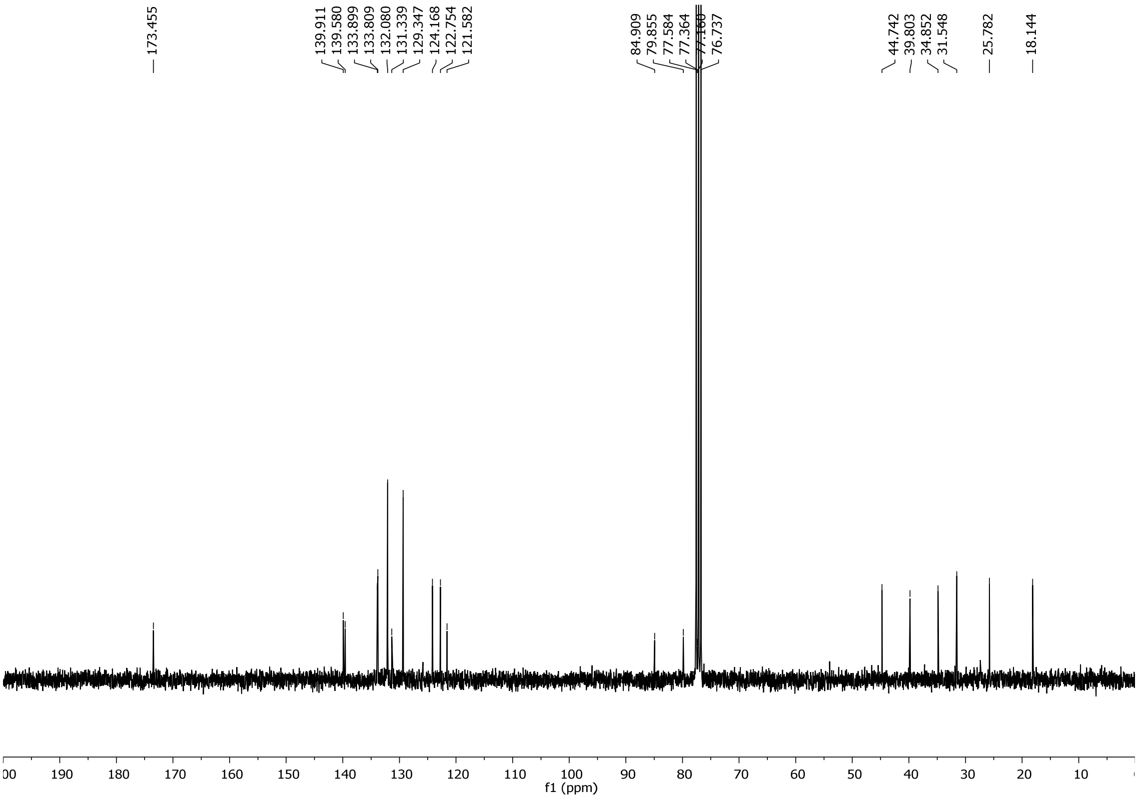
No.	RT	Area	Area %	Name
1	32,14	199995	2,079	
2	34,72	9417889	97,921	
		9617884	100,000	

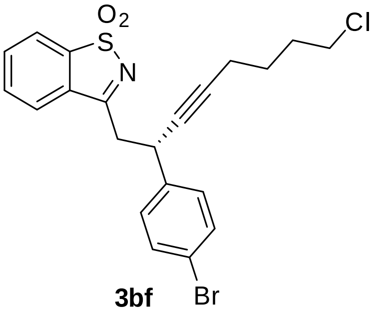


3bf

^{1}H RMN (300MHz, CDCl$_3$)

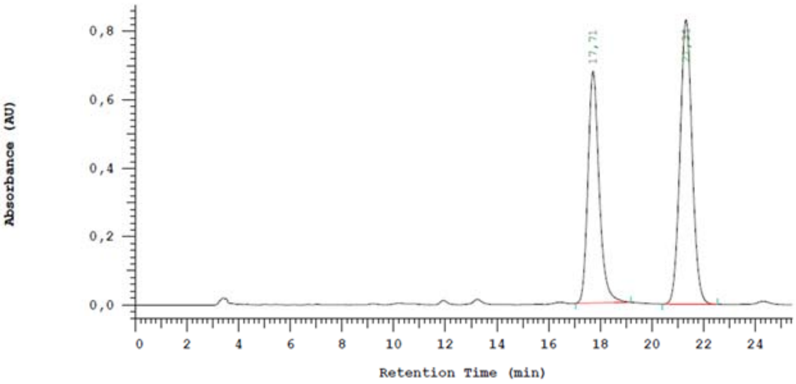
^{13}C RMN (75MHz, CDCl$_3$)





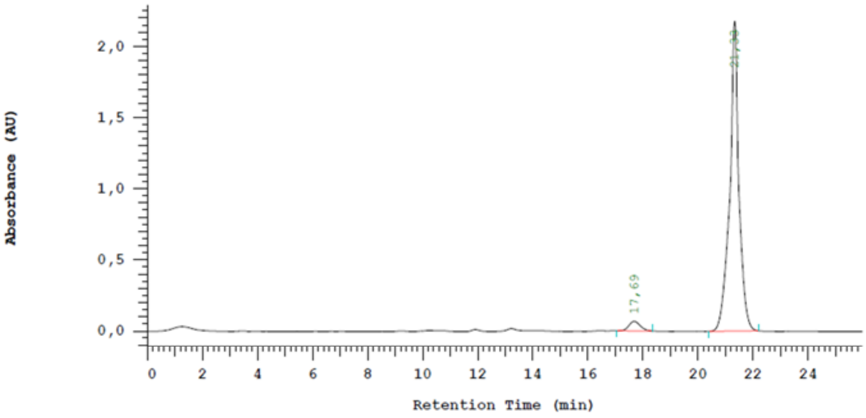
3bf

Racemic or near racemic mixture of enantiomers:

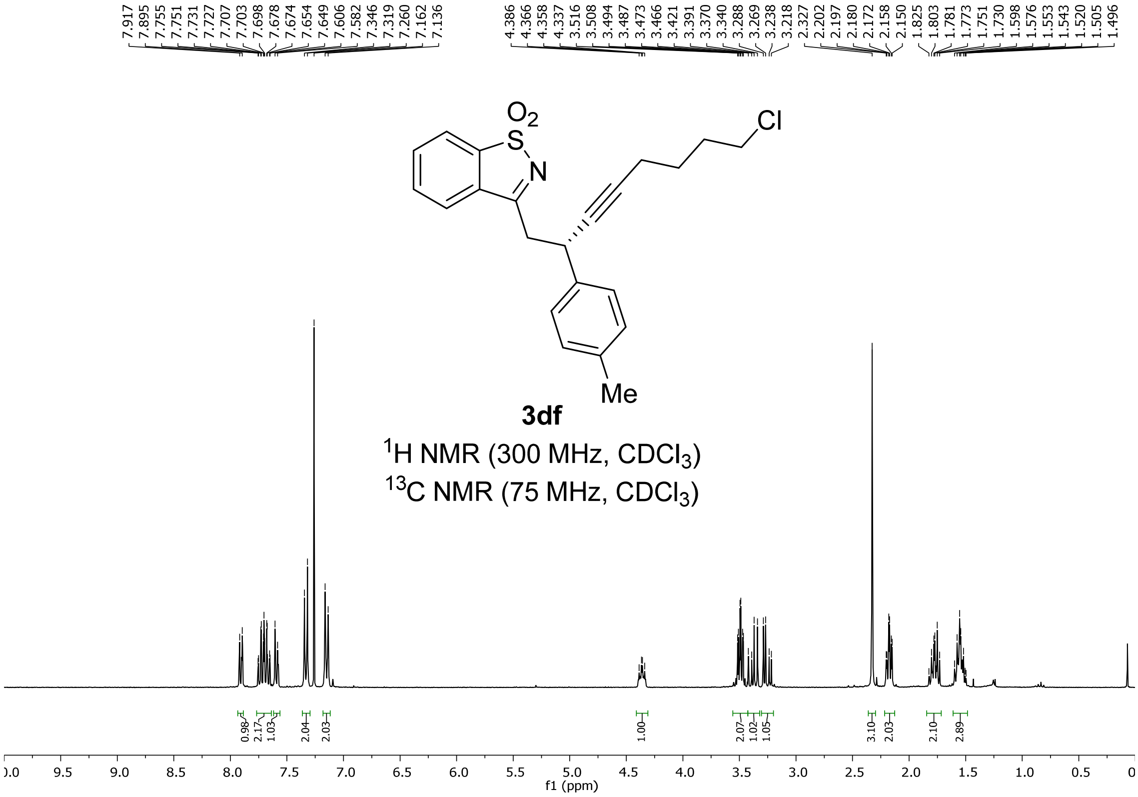


No.	RT	Area	Area %	Name
1	17,71	10183900	42,720	
2	21,31	13654979	57,280	
		23838879	100,000	

Enantioselective reaction:



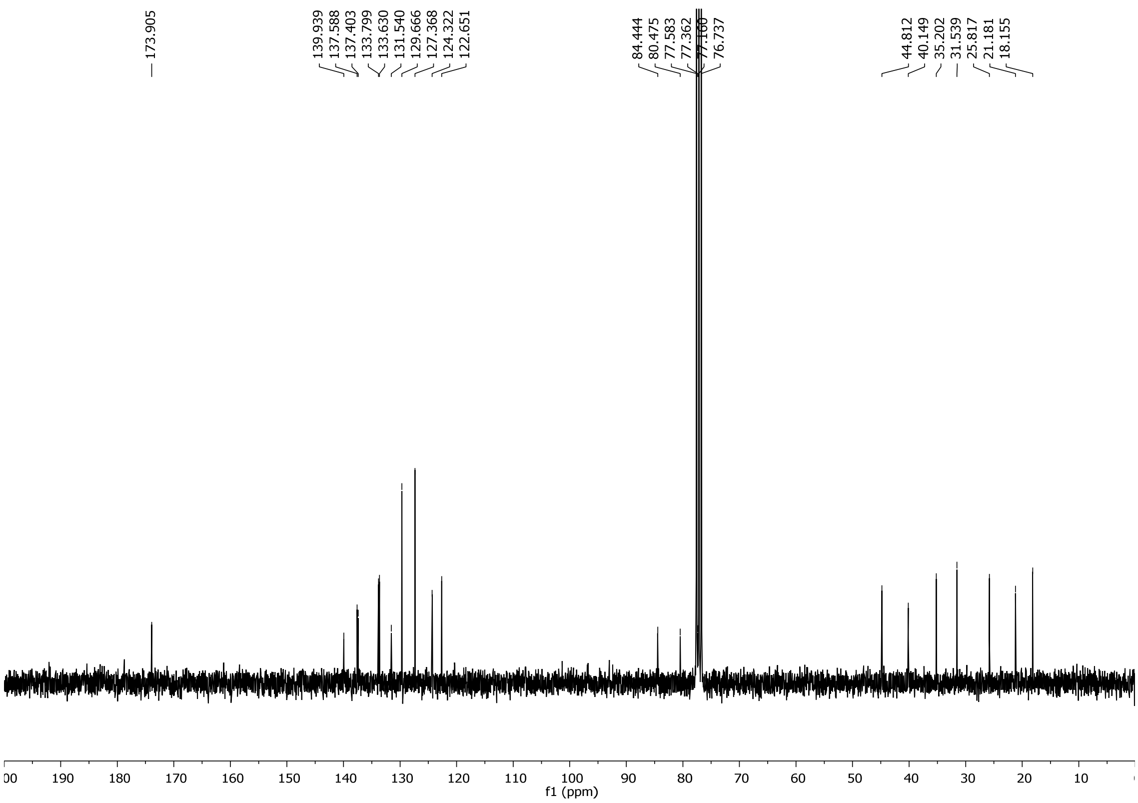
No.	RT	Area	Area %	Name
1	17,69	950905	3,611	
2	21,33	25385980	96,389	
		26336885	100,000	

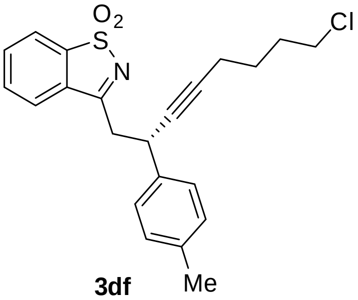


3df

^{1}H NMR (300 MHz, CDCl$_3$)

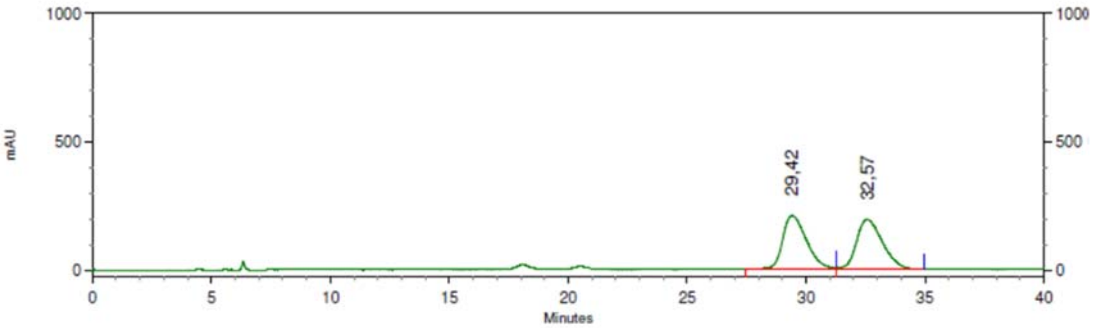
^{13}C NMR (75 MHz, CDCl$_3$)





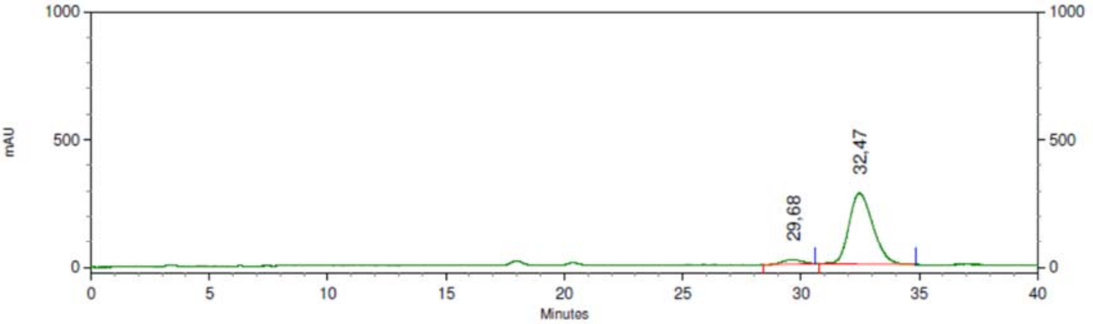
3df

Racemic or near racemic mixture of enantiomers:

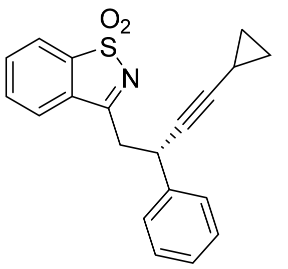


```
14: 259 nm, 4 nm
Results
          Retention Time                          Area                Area Percent
                   29,42                      58927730                      49,702
                   32,57                      59633840                      50,298
```

Enantioselective reaction:



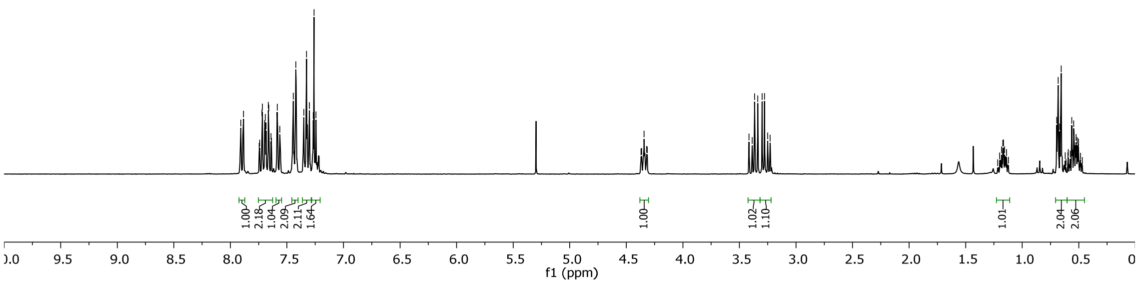
```
2: 229 nm, 4 nm Results
          Retention Time                          Area                Area Percent
                   29,68                       3881601                       4,738
                   32,47                      78050402                      95,262
```

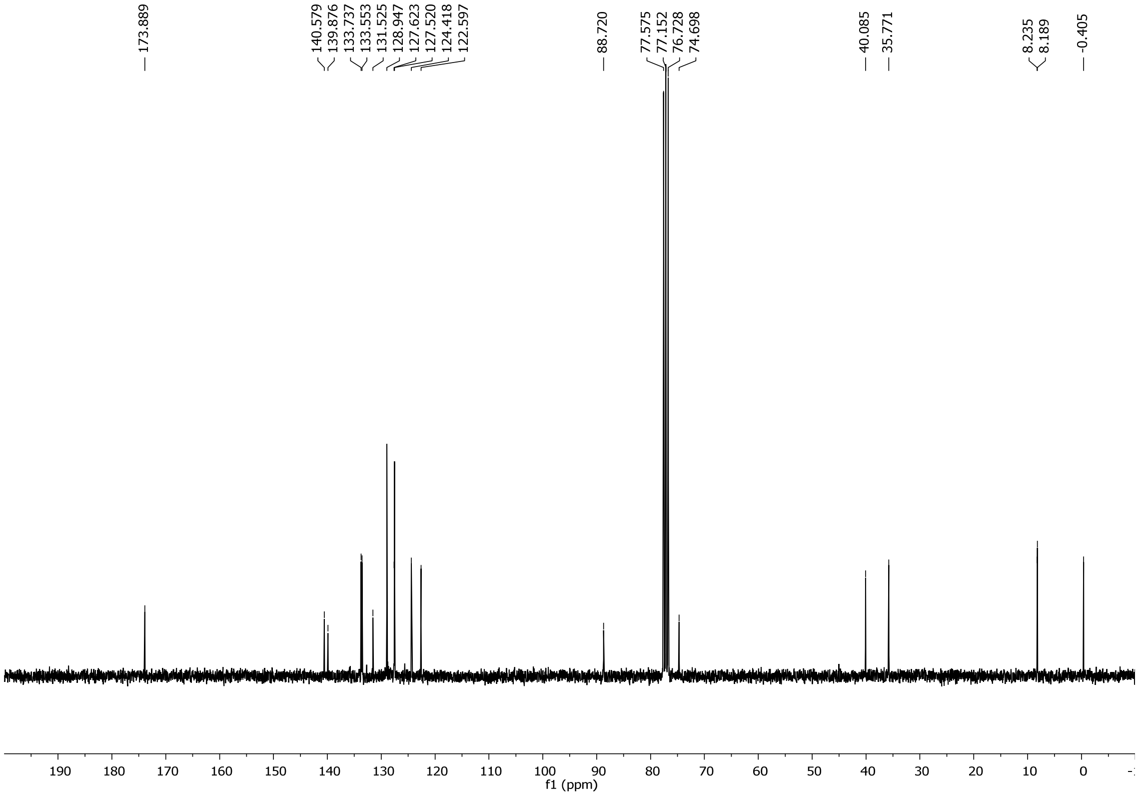


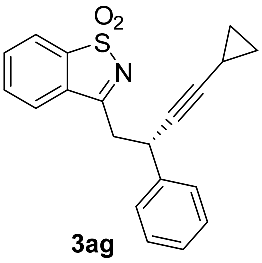
3ag

^{1}H NMR (300 MHz, CDCl$_3$)

^{13}C NMR (75 MHz, CDCl$_3$)

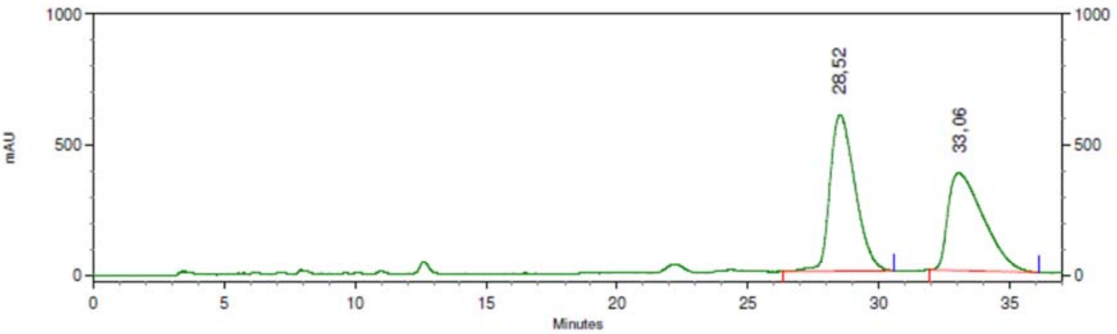






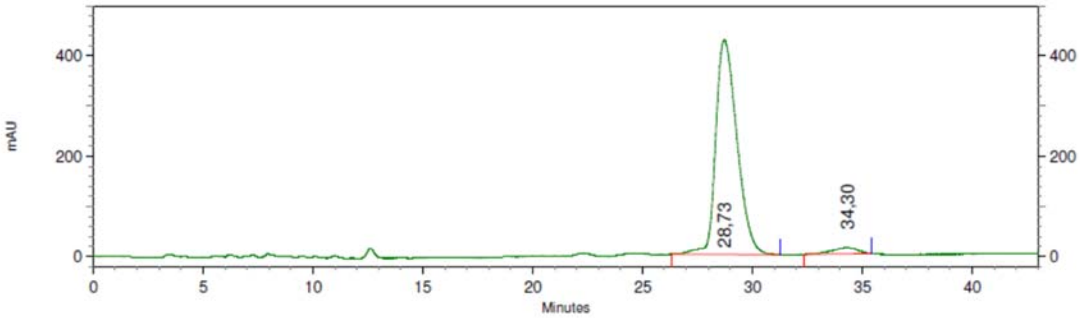
3ag

Racemic or near racemic mixture of enantiomers:

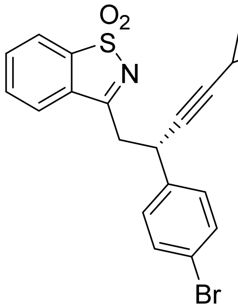


```
24: 242 nm, 4 nm
Results
          Retention Time                          Area              Area Percent
                   28,52                     160489802                    53,135
                   33,06                     141550470                    46,865
```

Enantioselective reaction:



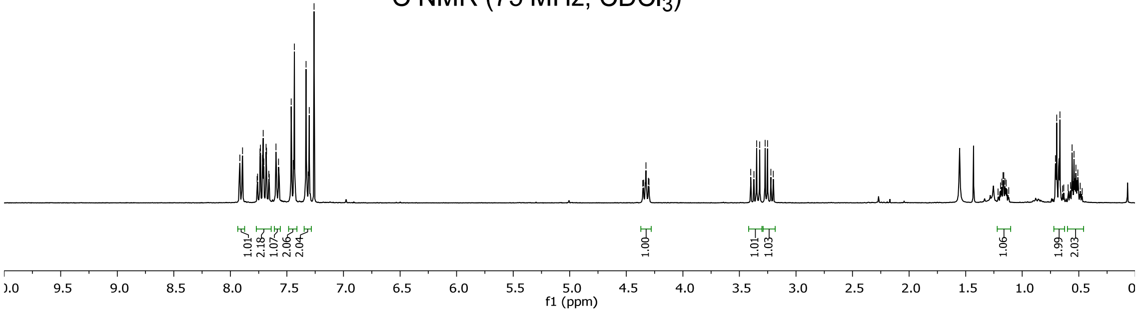
```
24: 242 nm, 4 nm
Results
          Retention Time                          Area              Area Percent
                   28,73                     115588387                    96,368
                   34,30                       4356850                     3,632
```

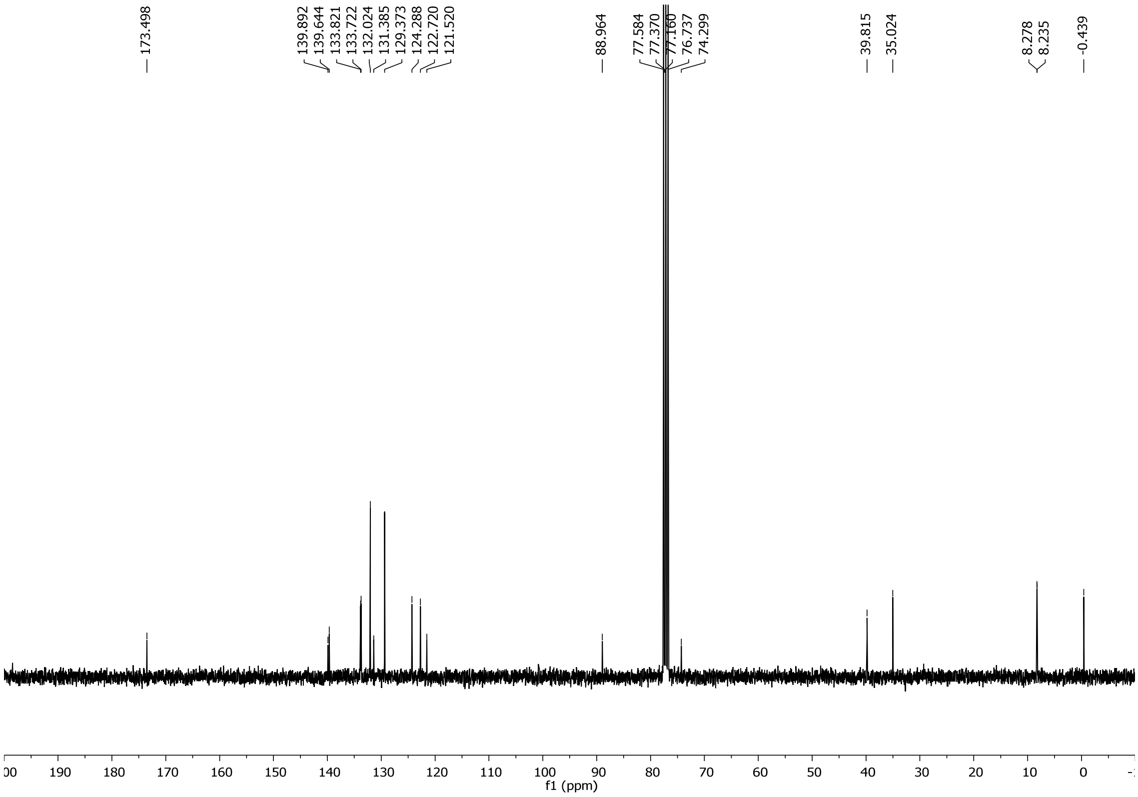


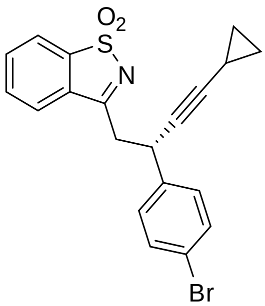
3bg

^{1}H NMR (300 MHz, $CDCl_3$)

^{13}C NMR (75 MHz, $CDCl_3$)

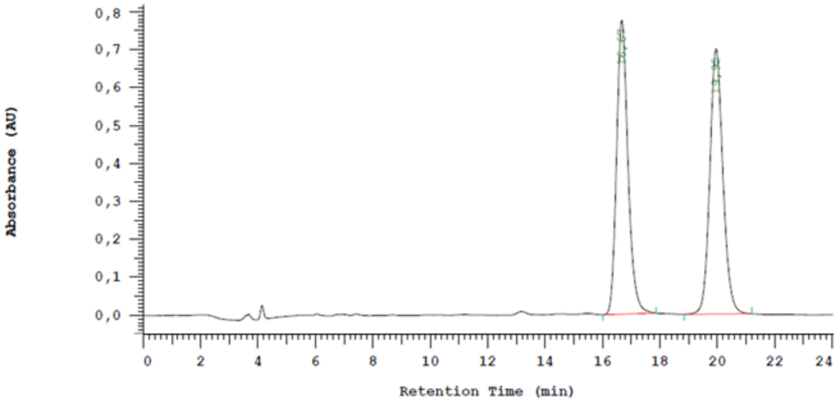






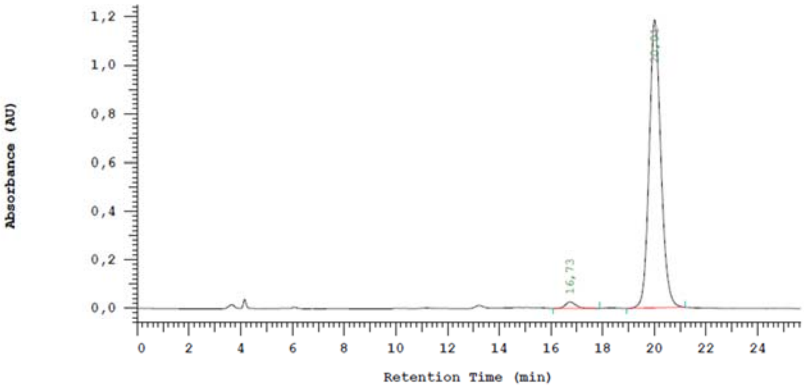
3bg

Racemic or near racemic mixture of enantiomers:

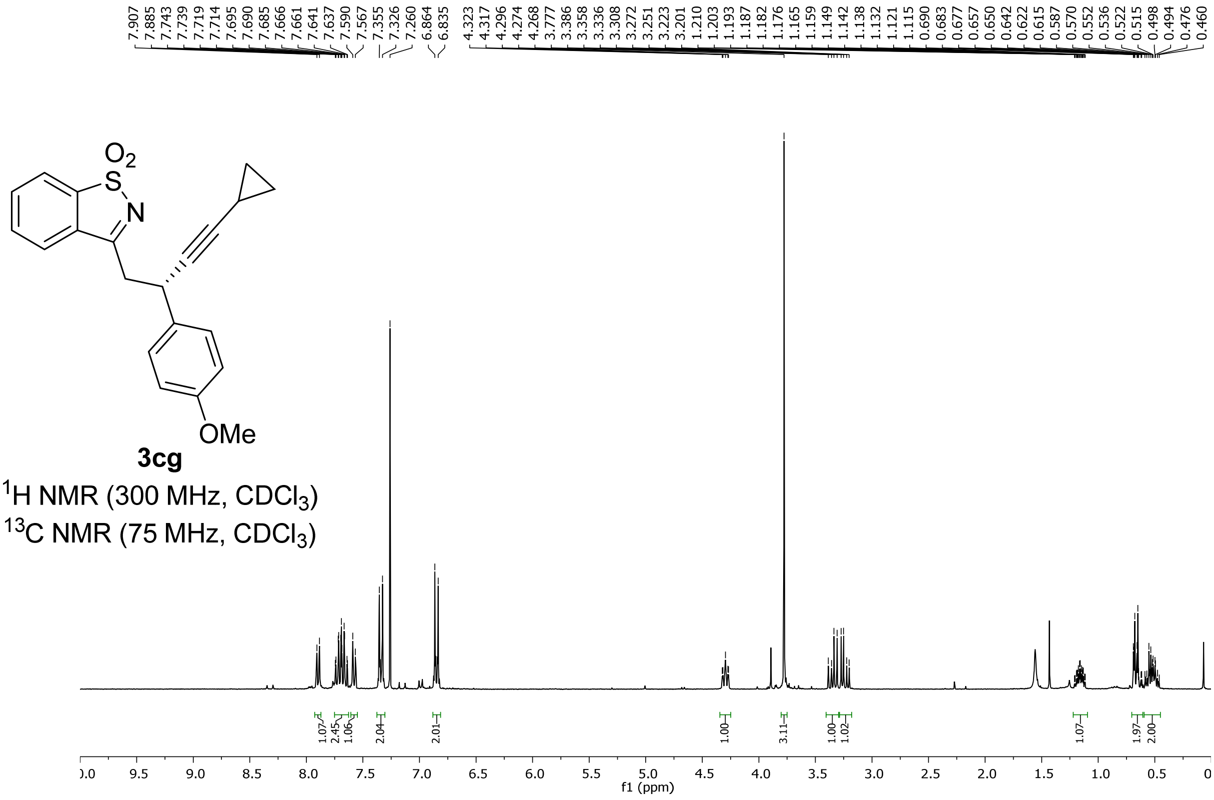


No.	RT	Area	Area %	Name
1	16,67	10639500	48,932	
2	19,95	11103820	51,068	
		21743320	100,000	

Enantioselective reaction:



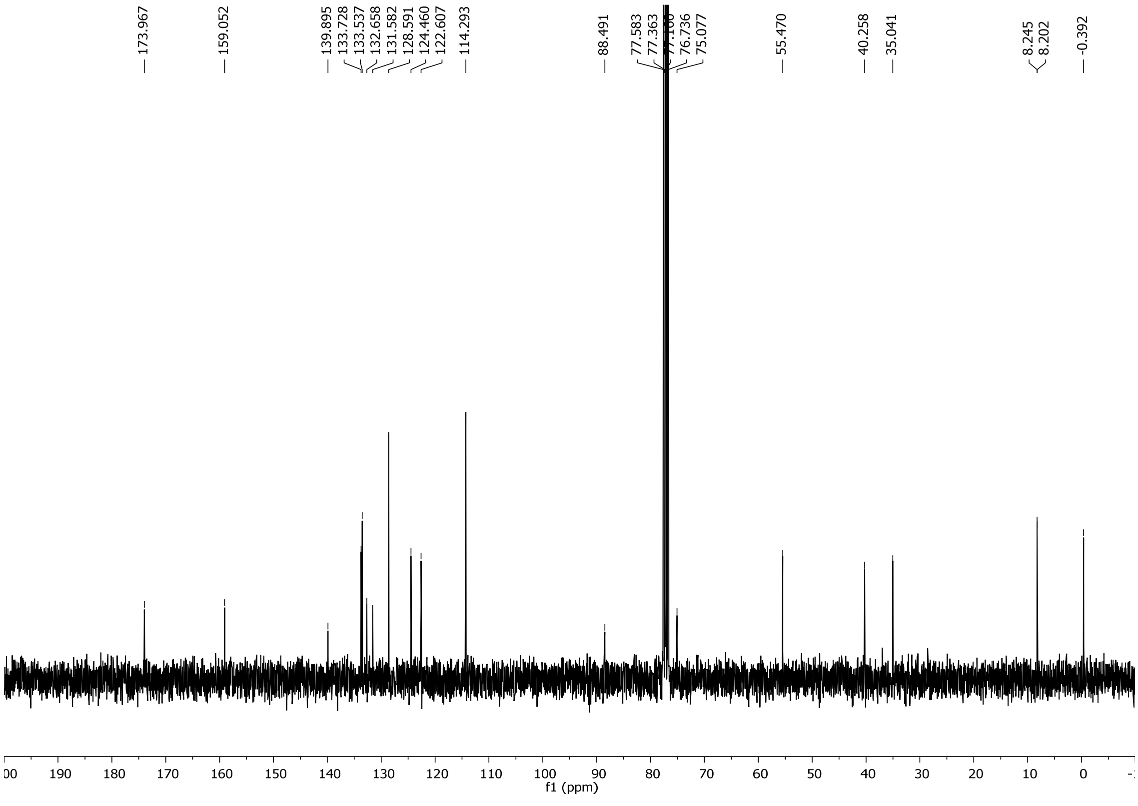
No.	RT	Area	Area %	Name
1	16,73	370170	1,940	
2	20,01	18711820	98,060	
		19081990	100,000	

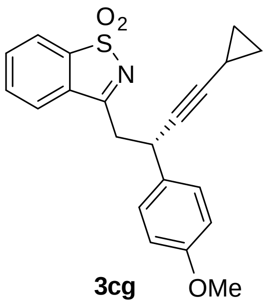


3cg

^{1}H NMR (300 MHz, $CDCl_3$)

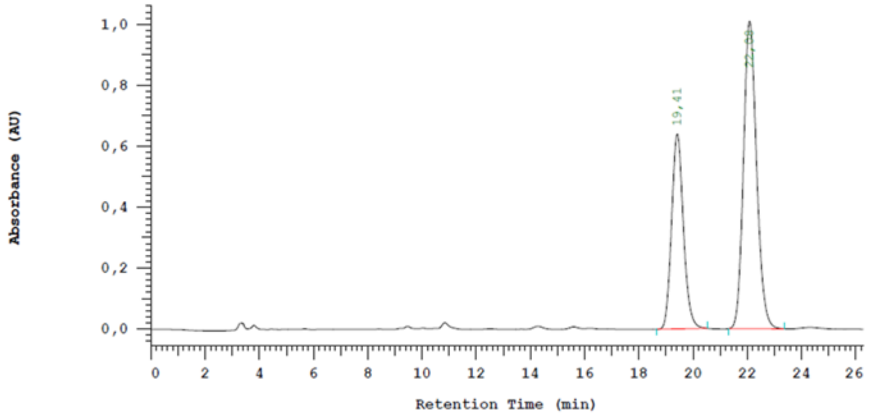
^{13}C NMR (75 MHz, $CDCl_3$)





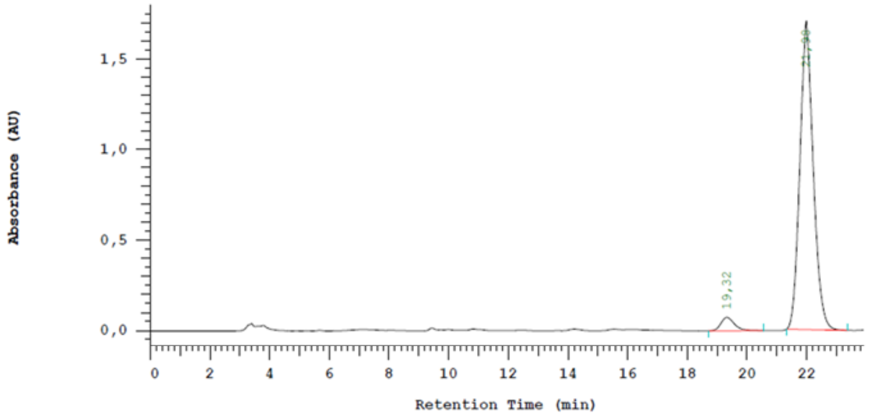
3cg

Racemic or near racemic mixture of enantiomers:

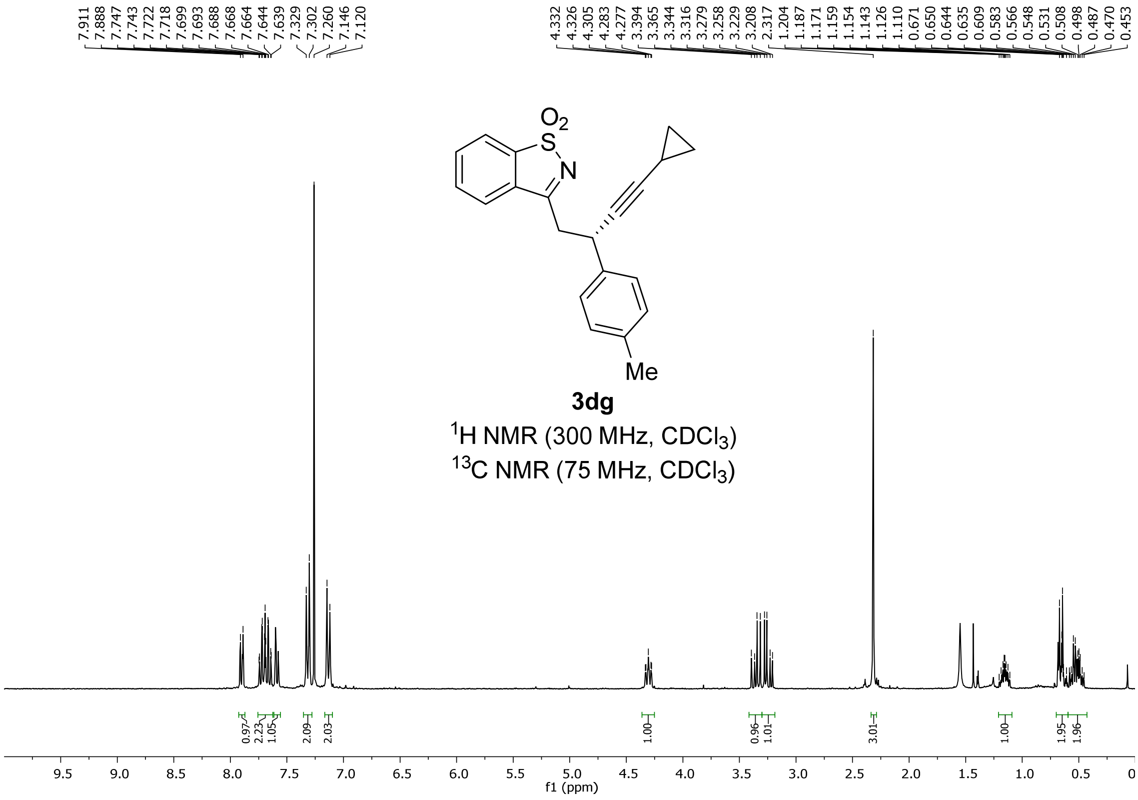


No.	RT	Area	Area %	Name
1	19,41	9640990	36,342	
2	22,08	16887315	63,658	
		26528305	100,000	

Enantioselective reaction:



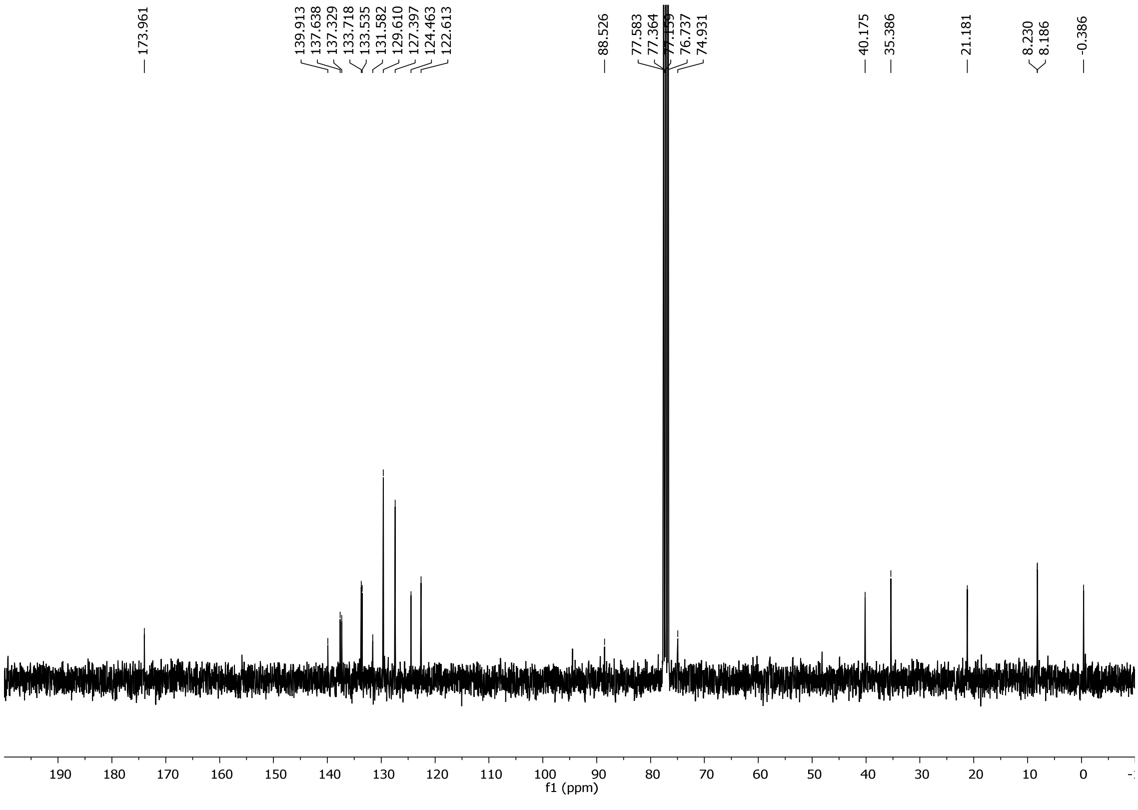
No.	RT	Area	Area %	Name
1	19,32	1135975	4,145	
2	21,98	26272099	95,855	
		27408074	100,000	

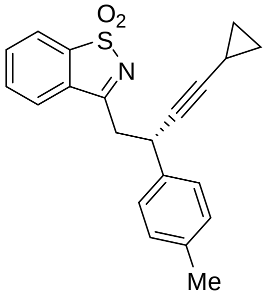


3dg

^{1}H NMR (300 MHz, CDCl$_3$)

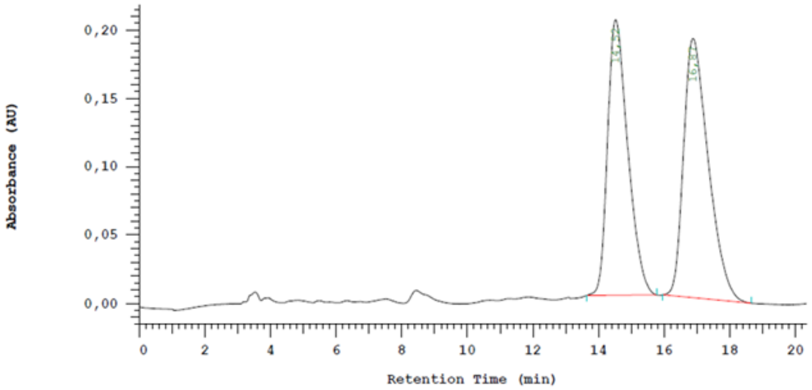
^{13}C NMR (75 MHz, CDCl$_3$)





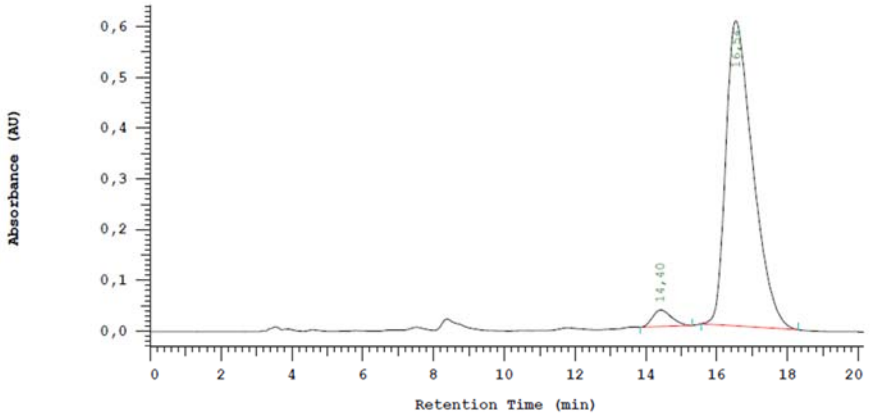
3dg

Racemic or near racemic mixture of enantiomers:

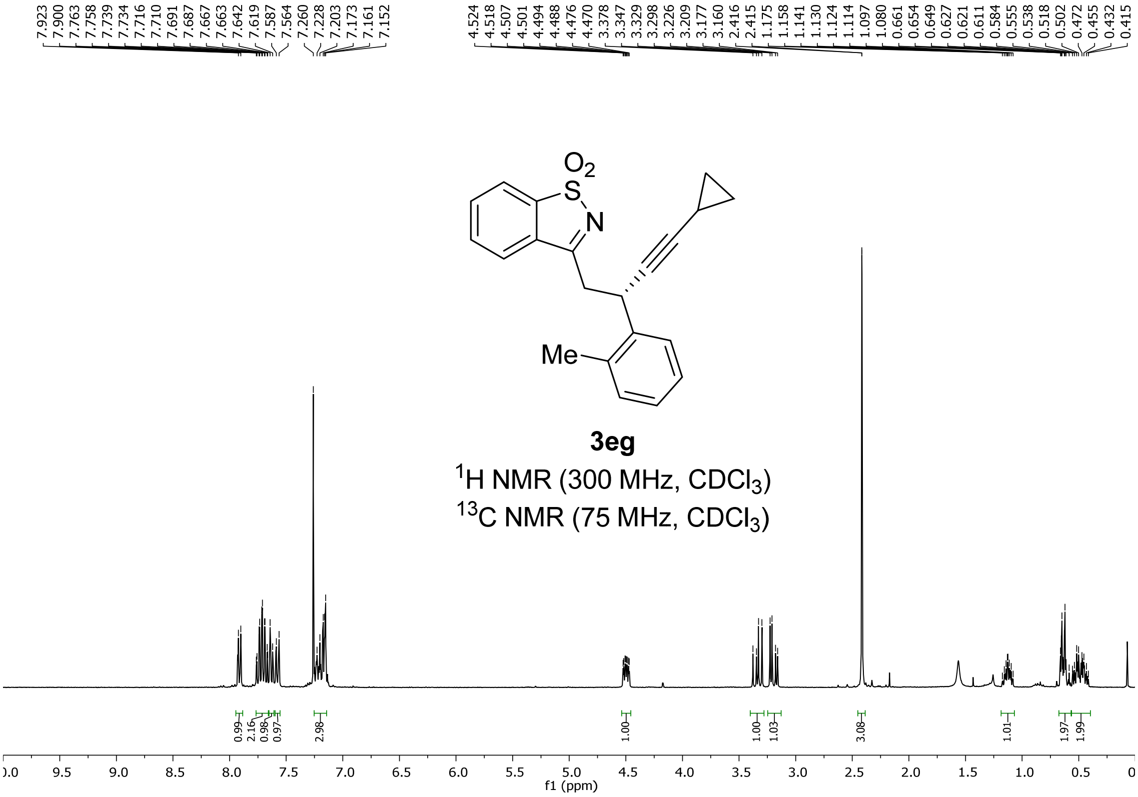


No.	RT	Area	Area %	Name
1	14,52	4322875	46,501	
2	16,87	4973360	53,499	
		9296235	100,000	

Enantioselective reaction:



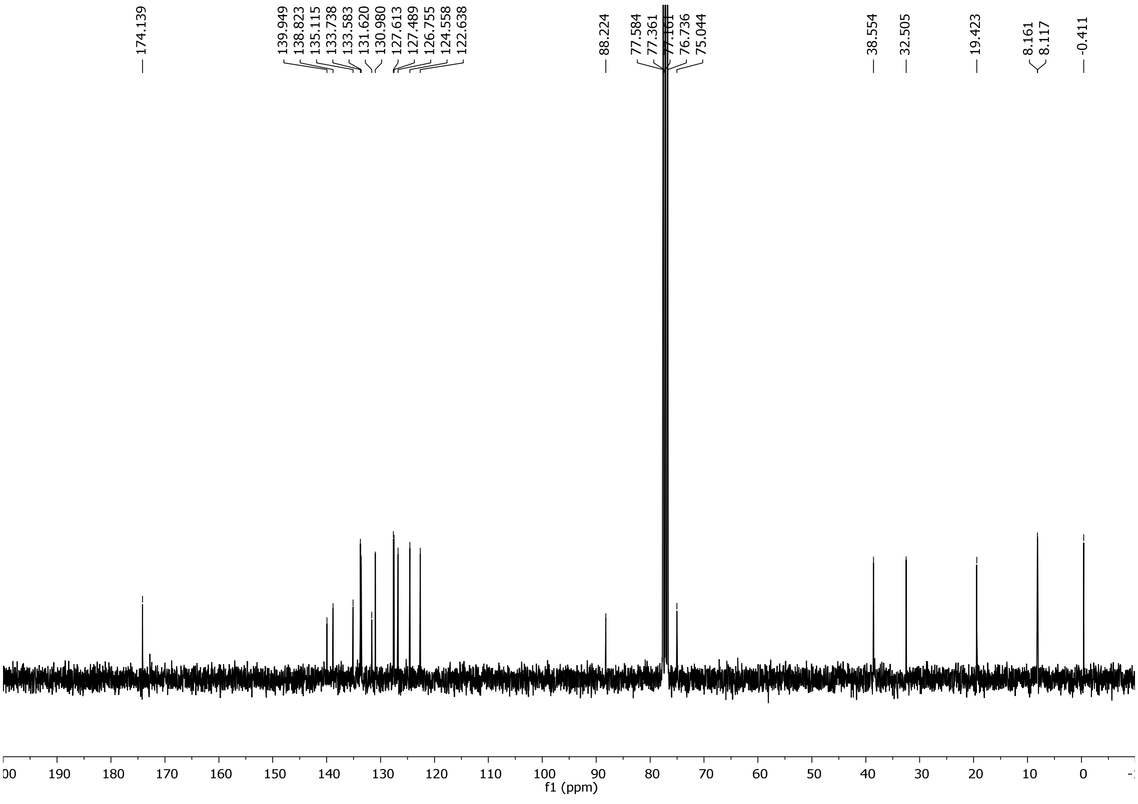
No.	RT	Area	Area %	Name
1	14,40	599085	3,616	
2	16,54	15966884	96,384	
		16565969	100,000	

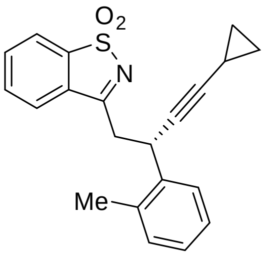


3eg

^{1}H NMR (300 MHz, CDCl$_3$)

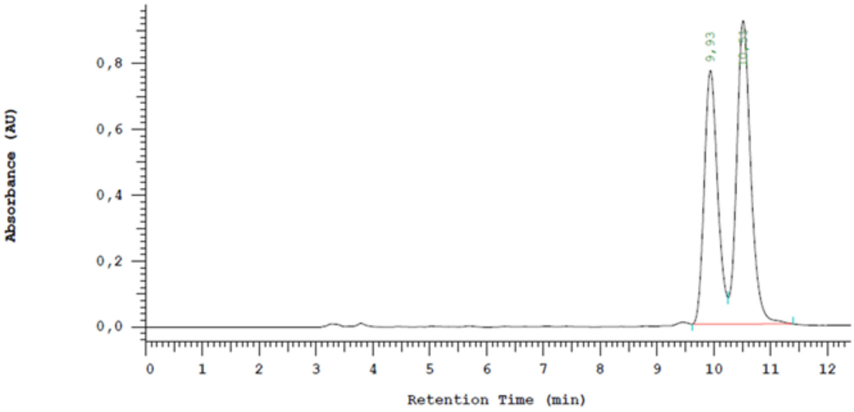
^{13}C NMR (75 MHz, CDCl$_3$)





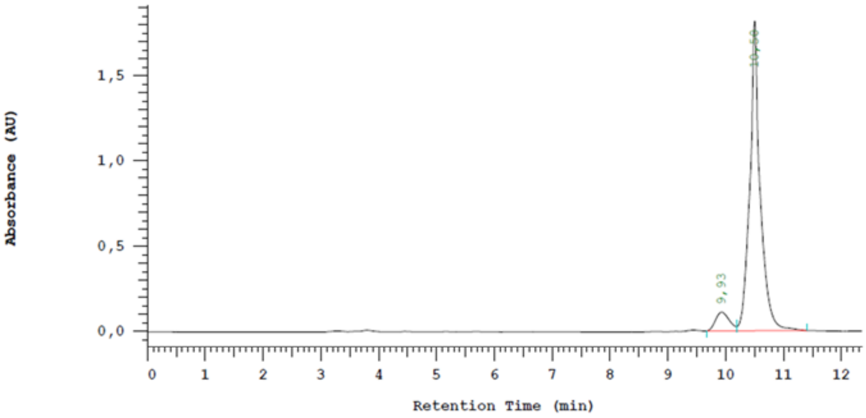
3eg

Racemic or near racemic mixture of enantiomers:

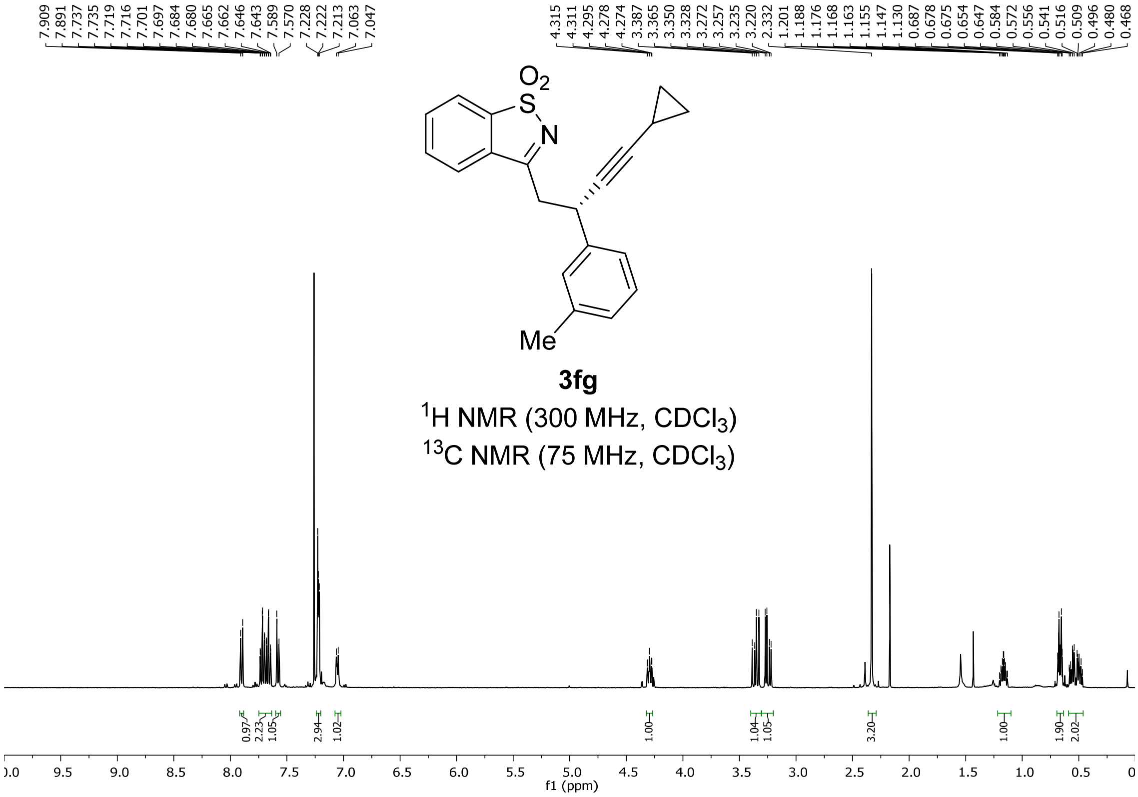


No.	RT	Area	Area %	Name
1	9,93	6282960	44,040	
2	10,51	7983640	55,960	
		14266600	100,000	

Enantioselective reaction:



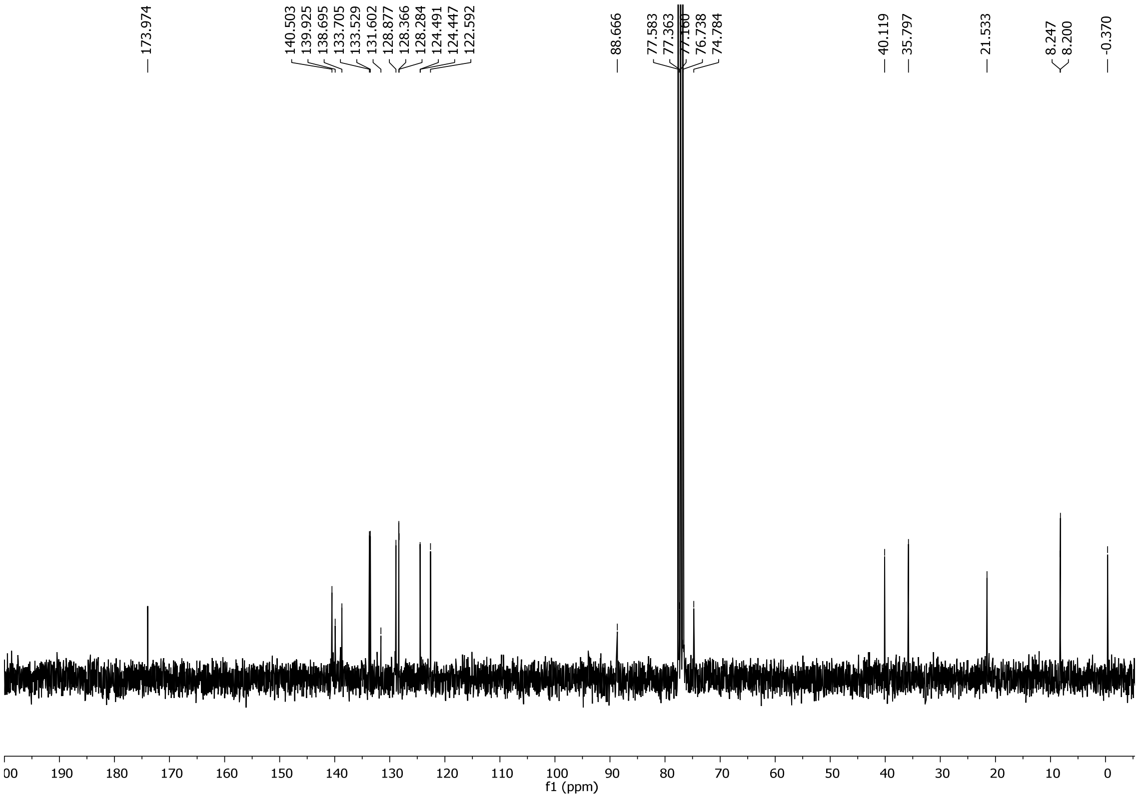
No.	RT	Area	Area %	Name
1	9,93	904102	7,378	
2	10,50	11350442	92,622	
		12254544	100,000	

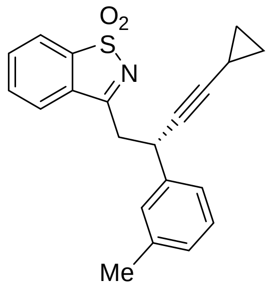


3fg

^{1}H NMR (300 MHz, $CDCl_3$)

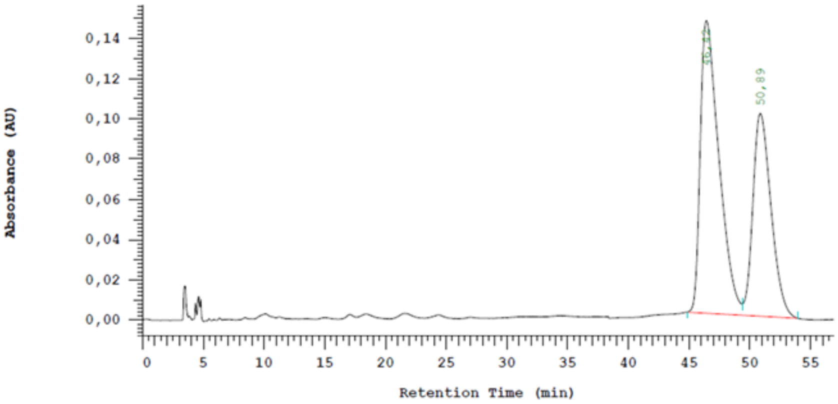
^{13}C NMR (75 MHz, $CDCl_3$)





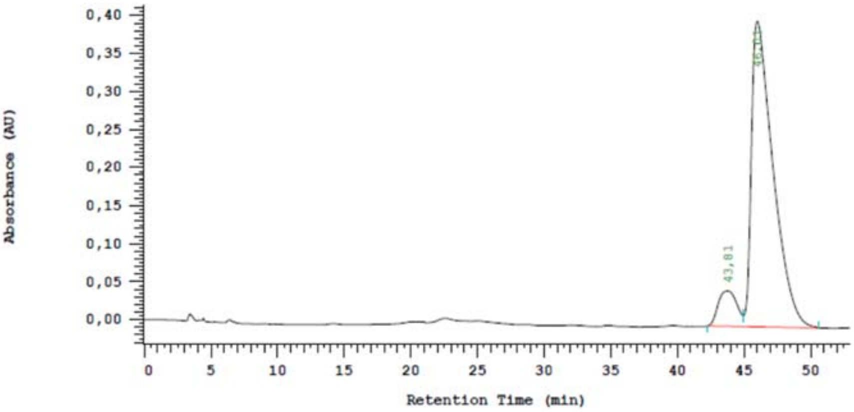
3fg

Racemic or near racemic mixture of enantiomers:

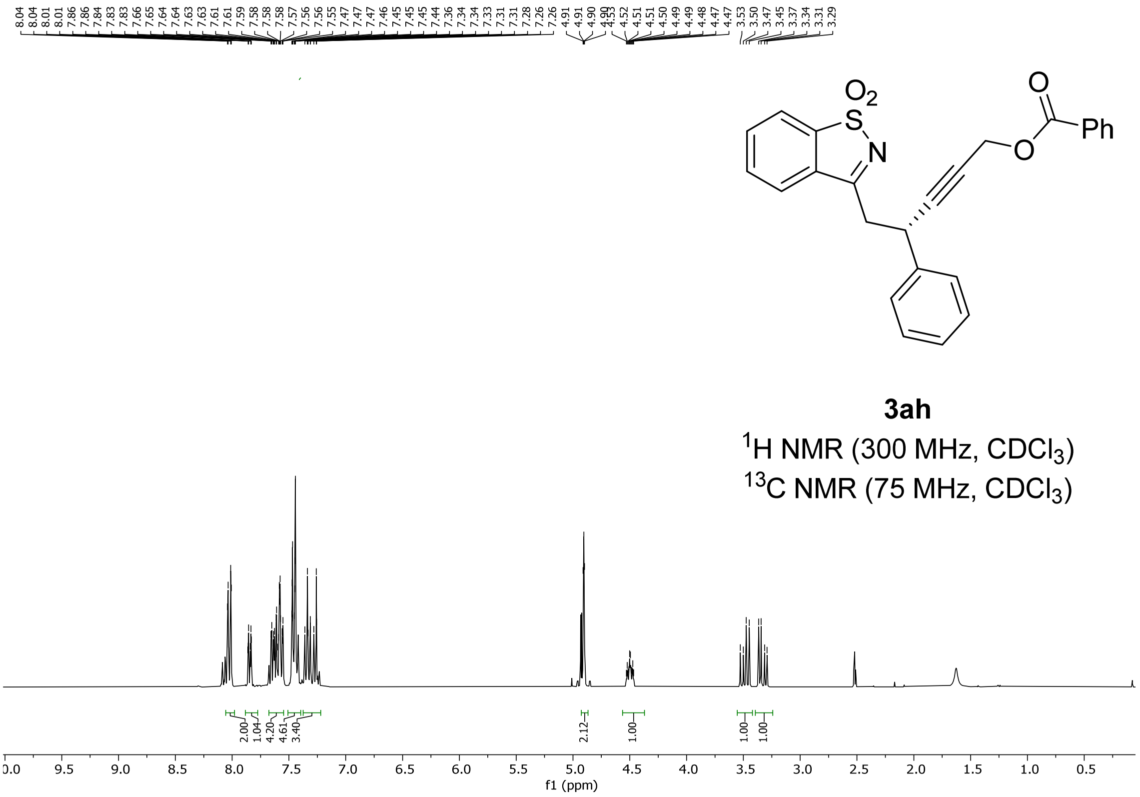


No.	RT	Area	Area %	Name
1	46,42	7748470	59,632	
2	50,89	5245439	40,368	
		12993909	100,000	

Enantioselective reaction:



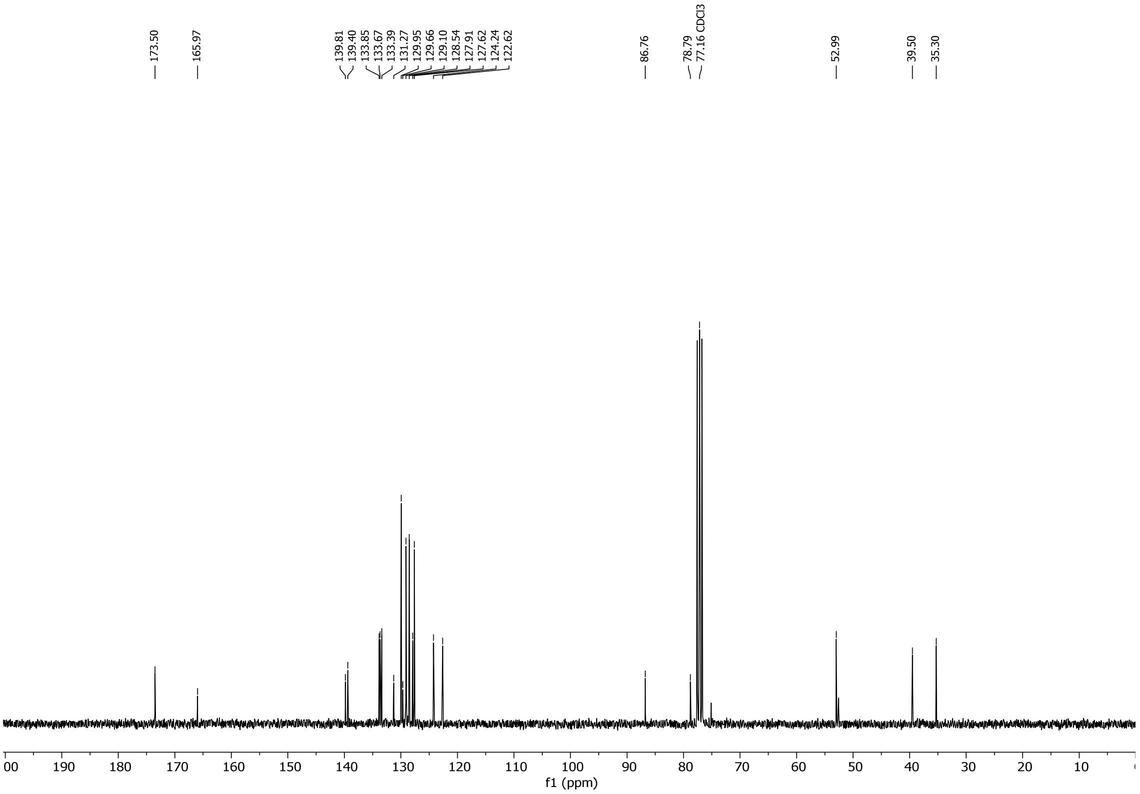
No.	RT	Area	Area %	Name
1	43,81	2270362	9,139	
2	46,01	22571467	90,861	
		24841829	100,000	

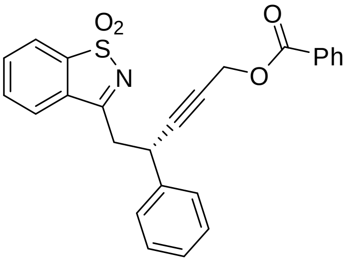


3ah

^{1}H NMR (300 MHz, $CDCl_3$)

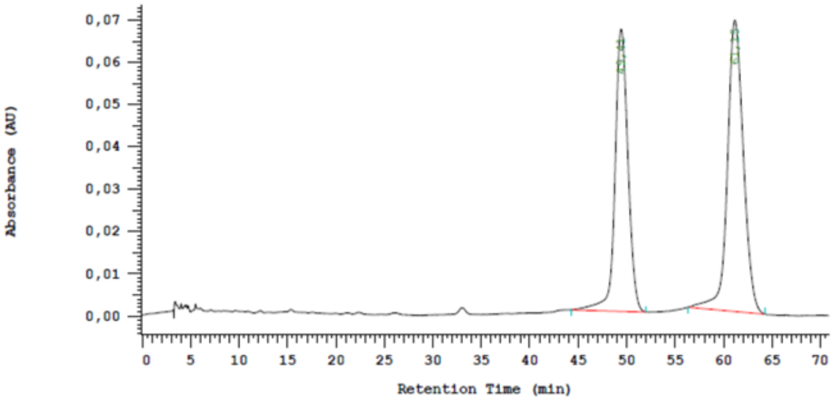
^{13}C NMR (75 MHz, $CDCl_3$)





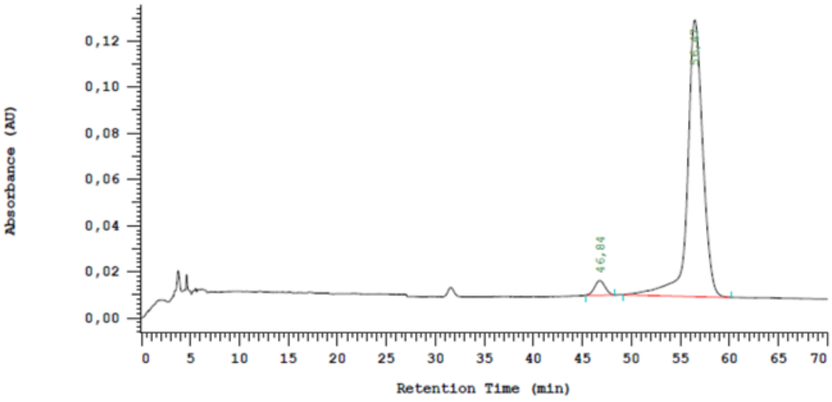
3ah

Racemic or near racemic mixture of enantiomers:

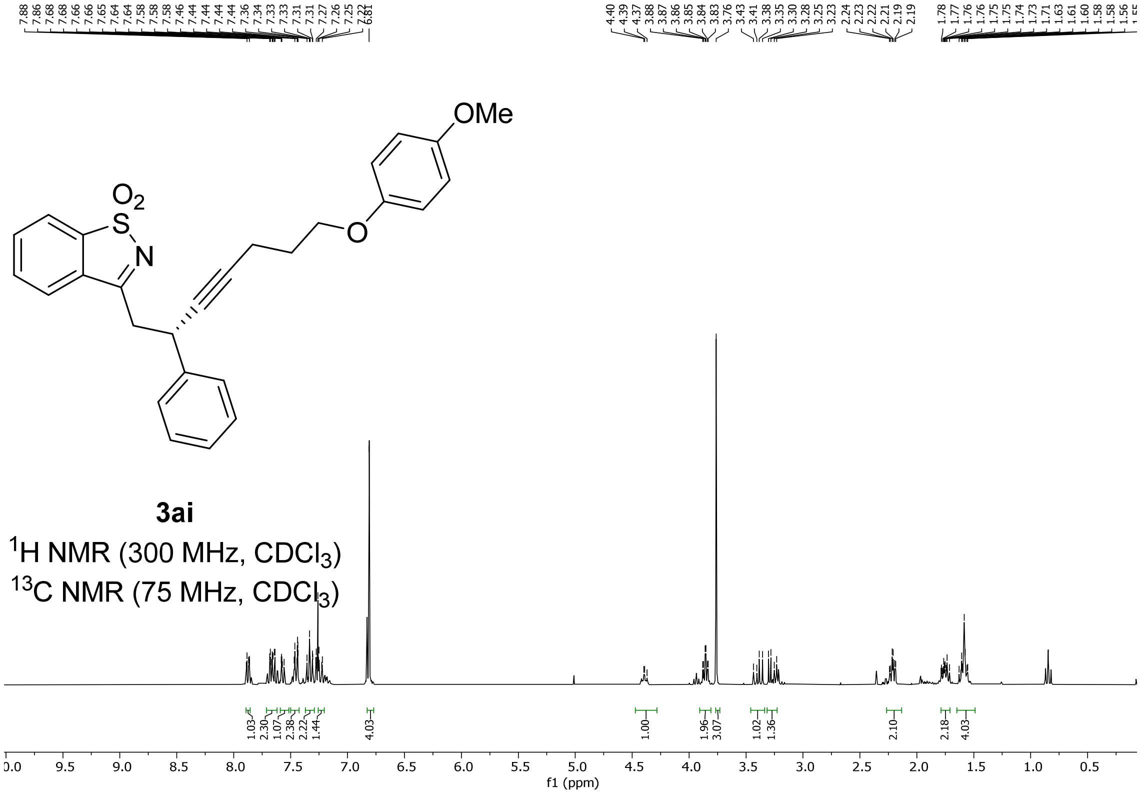


No.	RT	Area	Area %	Name
1	49,41	3065898	43,906	
2	61,15	3916918	56,094	
		6982816	100,000	

Enantioselective reaction:



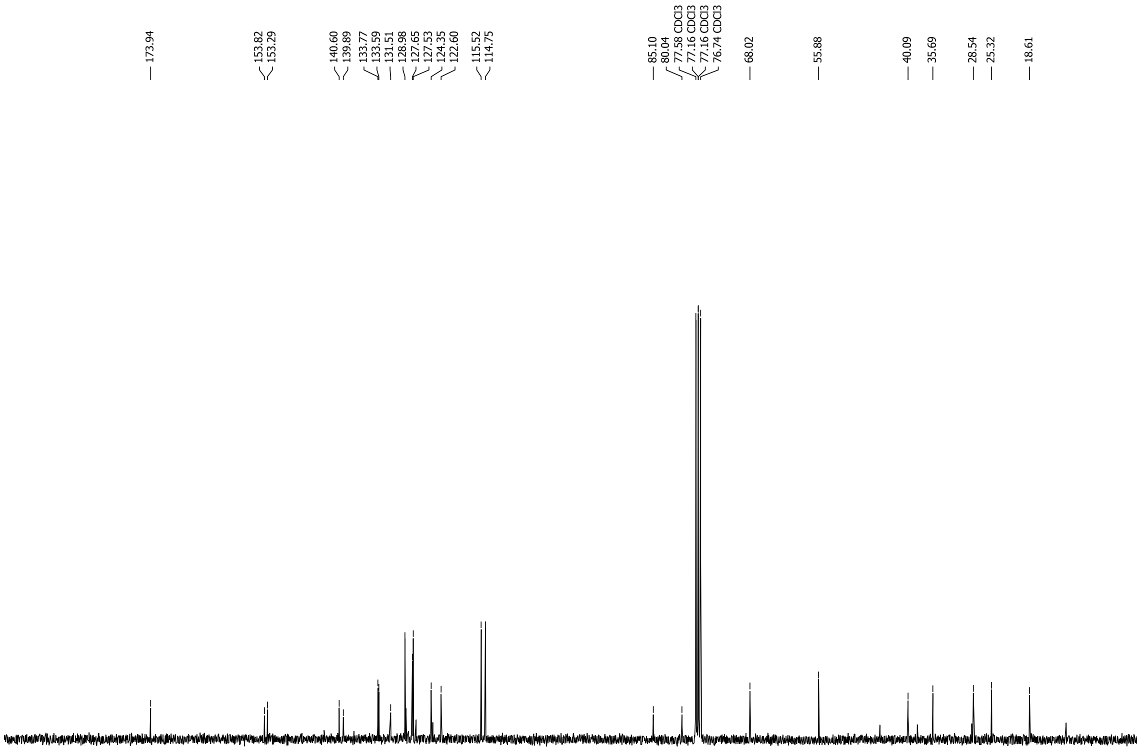
No.	RT	Area	Area %	Name
1	46,84	235995	3,513	
2	56,47	6481260	96,487	
		6717255	100,000	

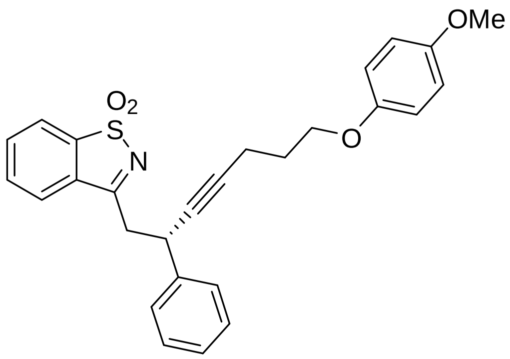


3ai

^{1}H NMR (300 MHz, CDCl$_3$)

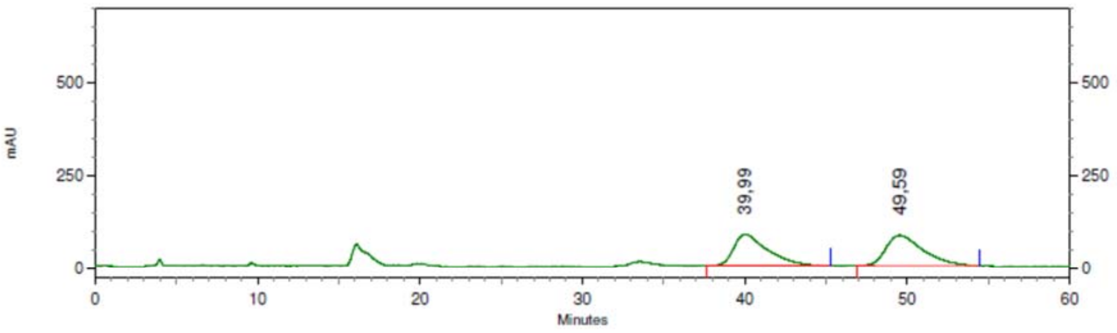
^{13}C NMR (75 MHz, CDCl$_3$)





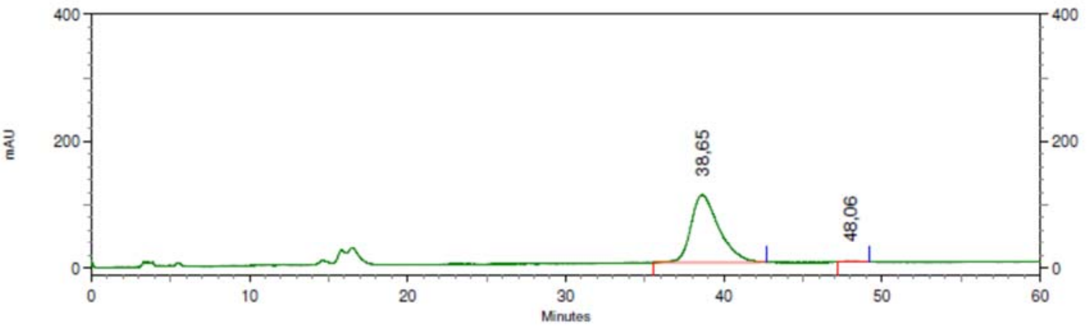
3ai

Racemic or near racemic mixture of enantiomers:

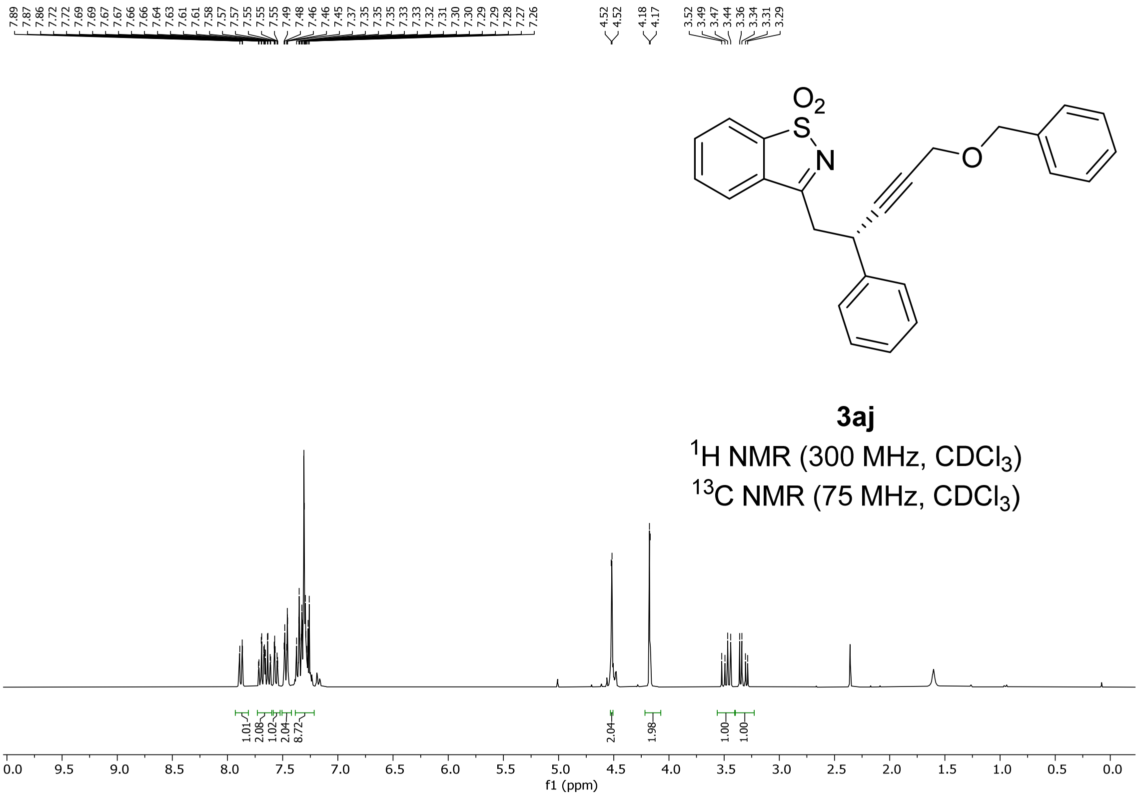


```
27: 236 nm, 4 nm
Results
          Retention Time                          Area                  Area Percent
                   39,99                      50050186                        48,478
                   49,59                      53193265                        51,522
```

Enantioselective reaction:



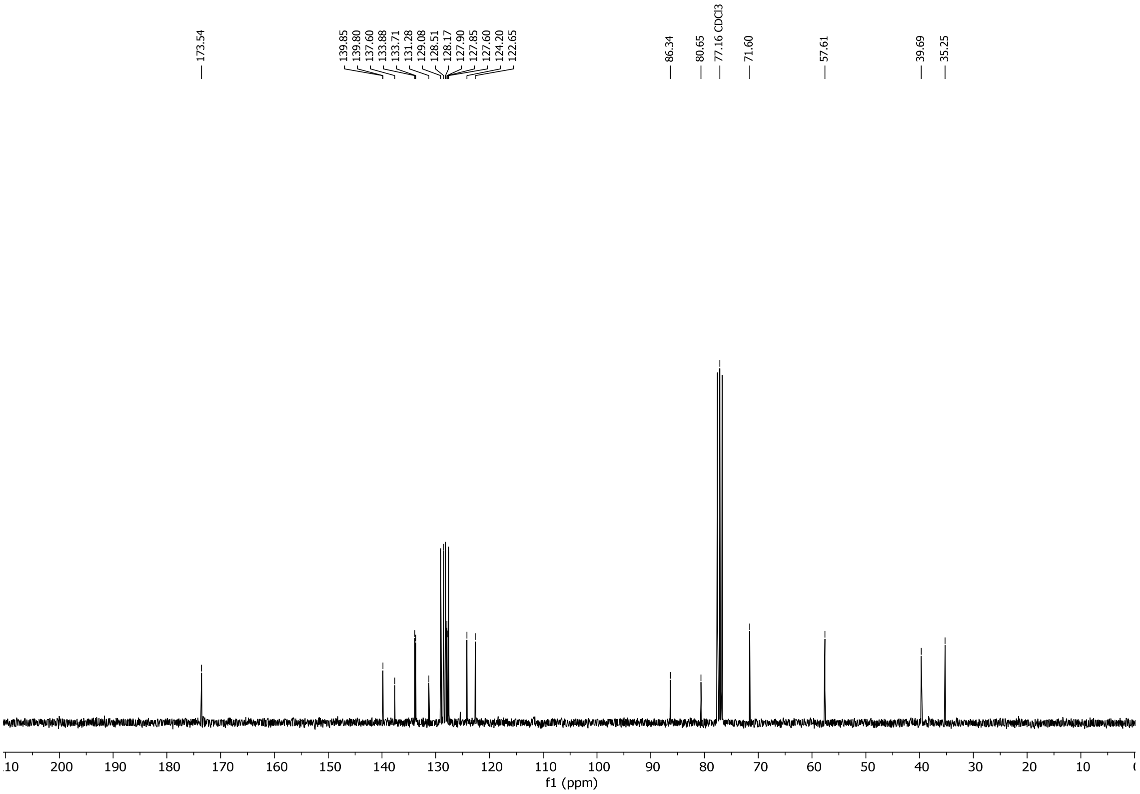
```
2: 229 nm, 4 nm Results
          Retention Time                          Area                  Area Percent
                   38,65                      52724926                        99,330
                   48,06                        355486                         0,670
```

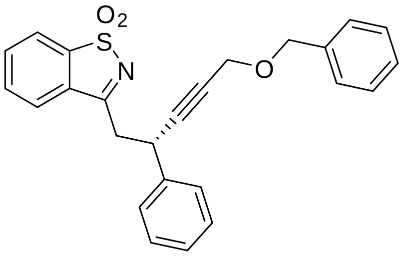


3aj

^{1}H NMR (300 MHz, $CDCl_3$)

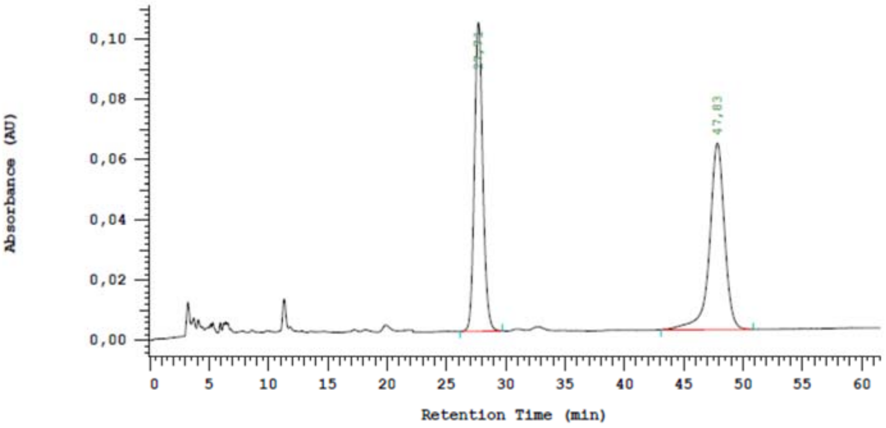
^{13}C NMR (75 MHz, $CDCl_3$)





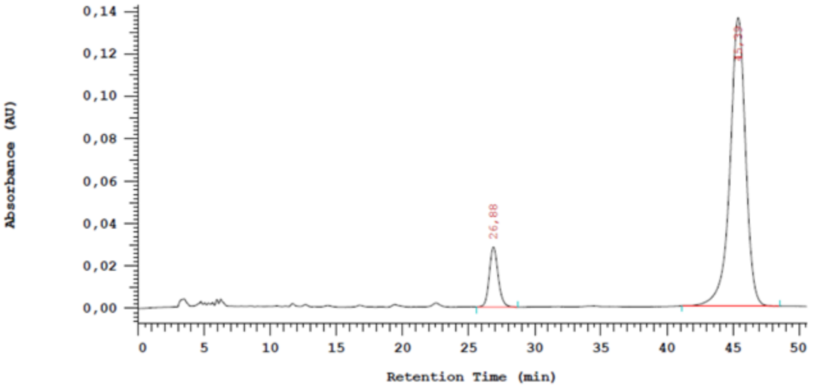
3aj

Racemic or near racemic mixture of enantiomers:

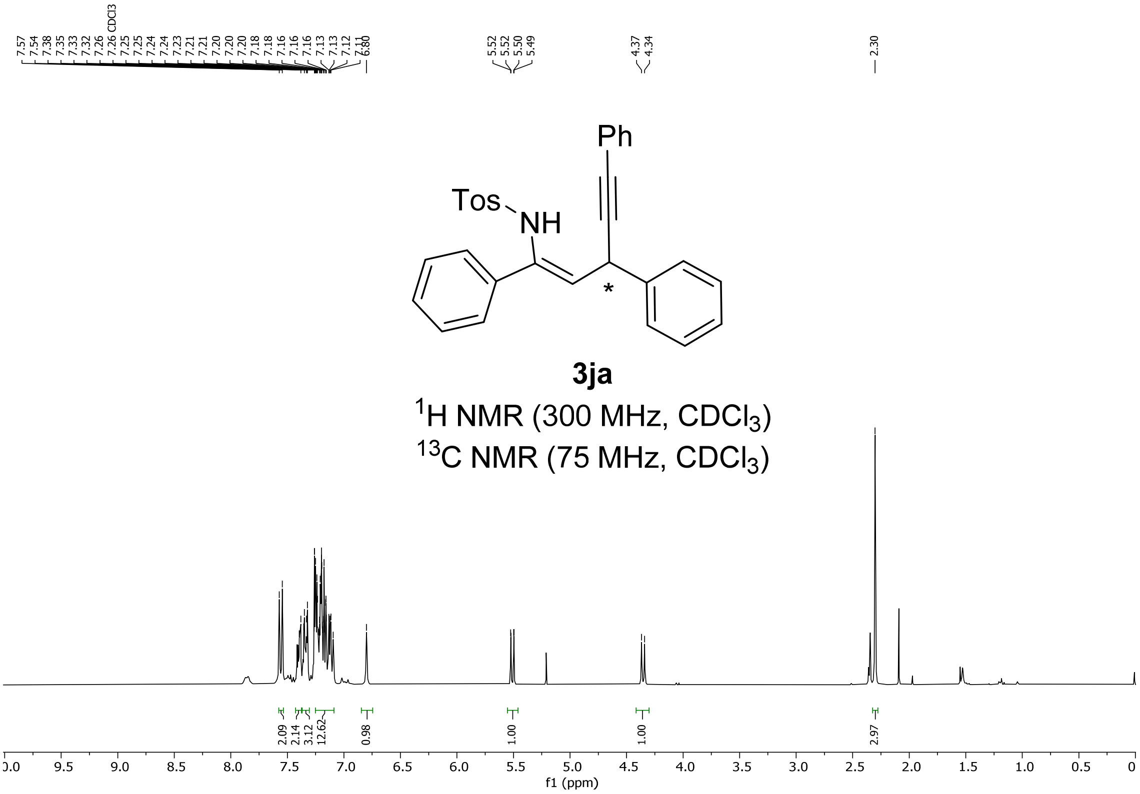


No.	RT	Area	Area %	Name
1	27,71	2482240	47,776	
2	47,83	2713290	52,224	
		5195530	100,000	

Enantioselective reaction:



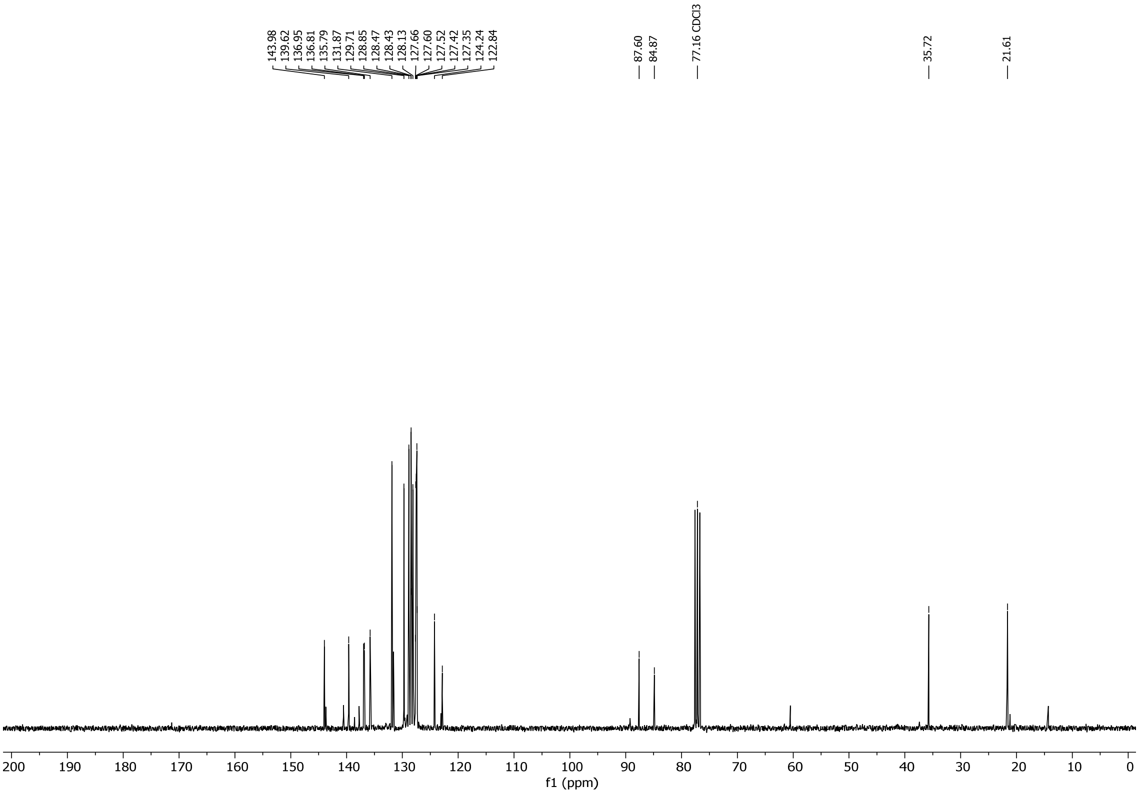
No.	RT	Area	Area %	Name
1	26,88	656695	10,549	
2	45,39	5568660	89,451	
		6225355	100,000	

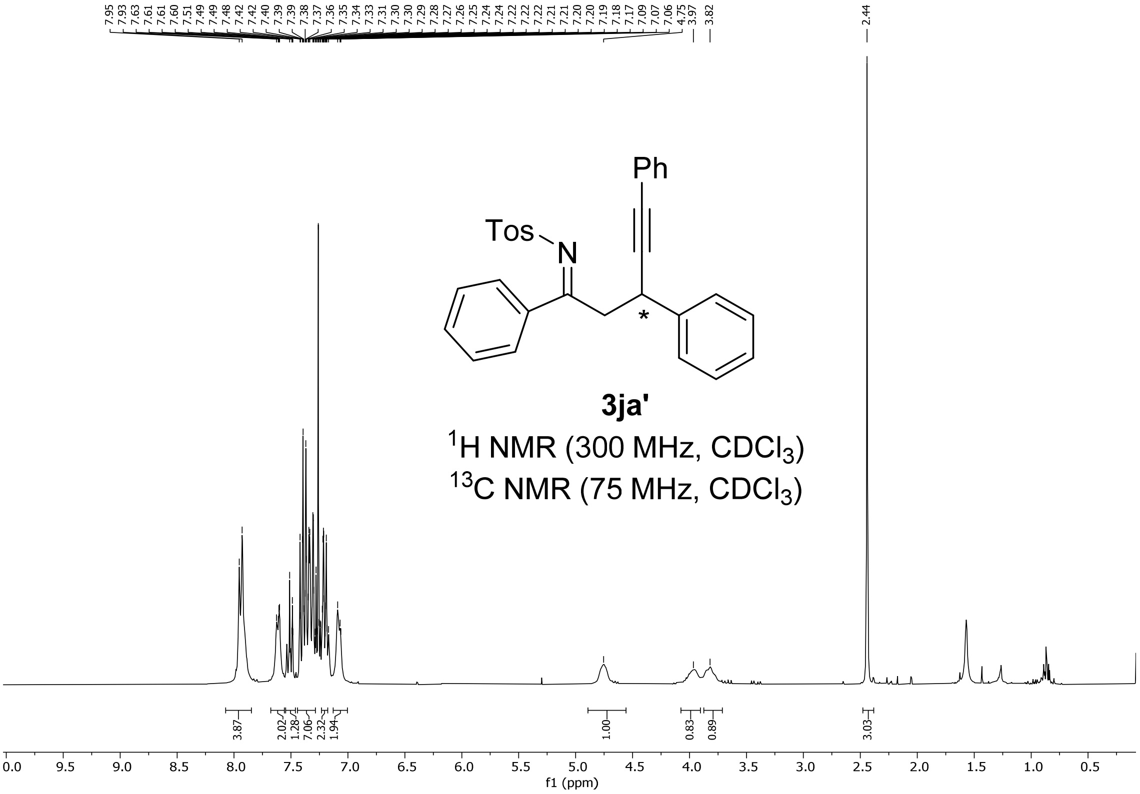


3ja

^{1}H NMR (300 MHz, CDCl$_3$)

^{13}C NMR (75 MHz, CDCl$_3$)

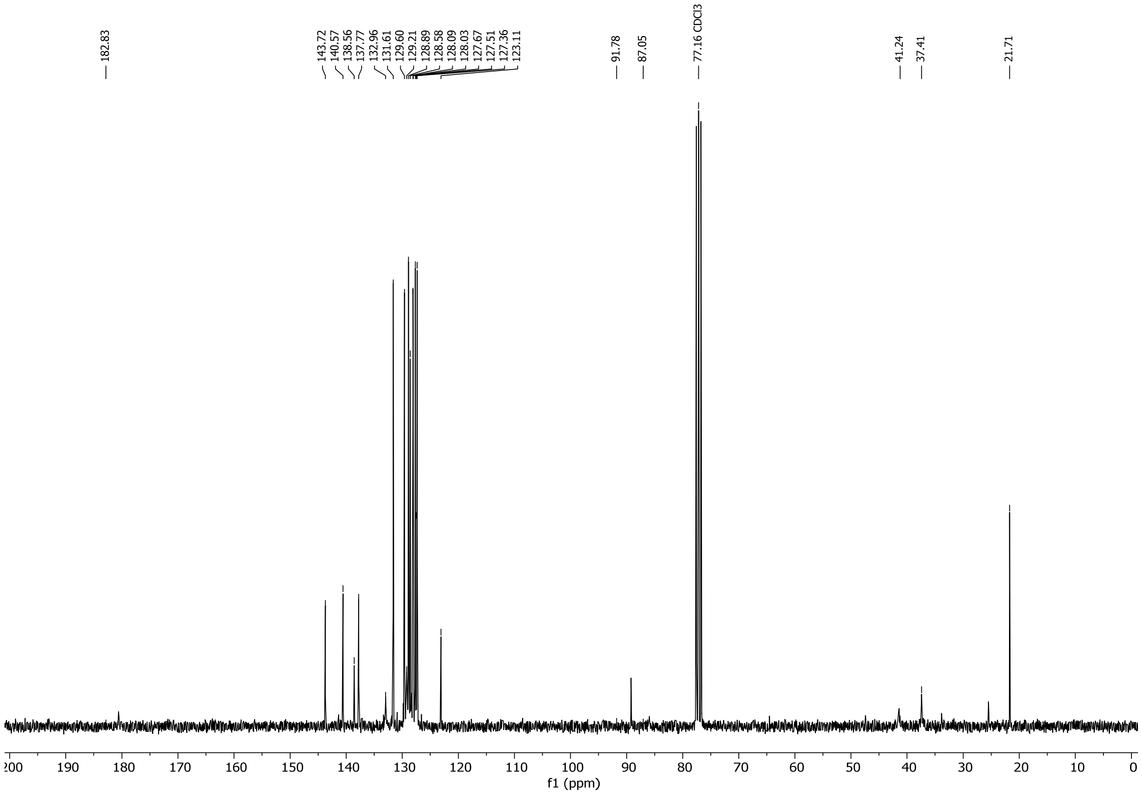


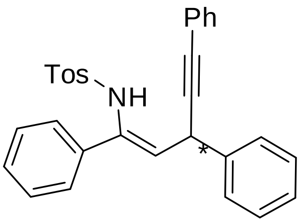


3ja'

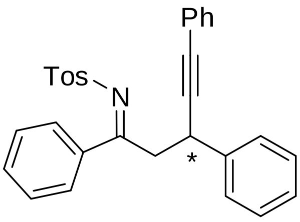
^{1}H NMR (300 MHz, $CDCl_3$)

^{13}C NMR (75 MHz, $CDCl_3$)



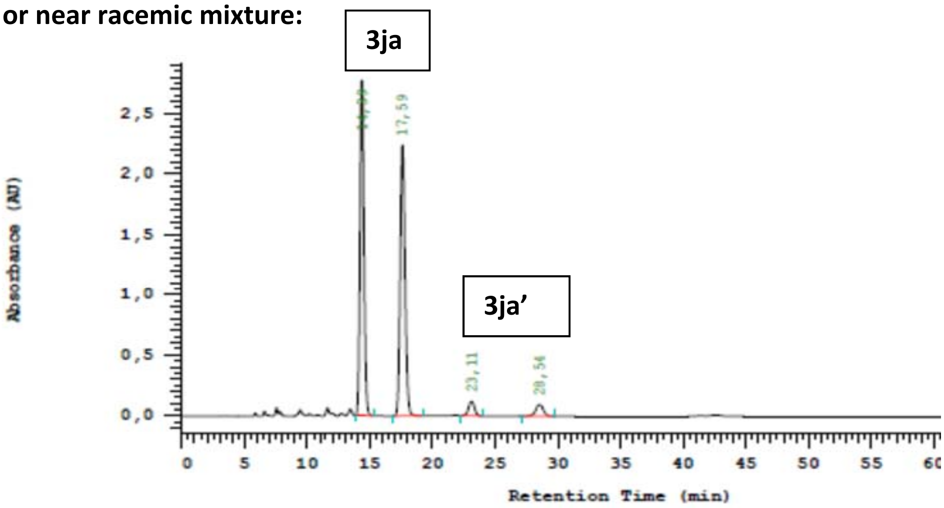


3ja



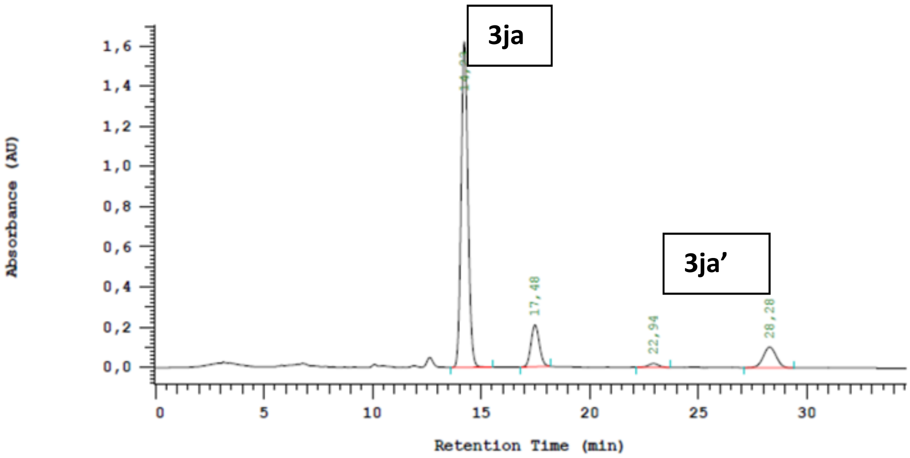
3ja'

Racemic or near racemic mixture:

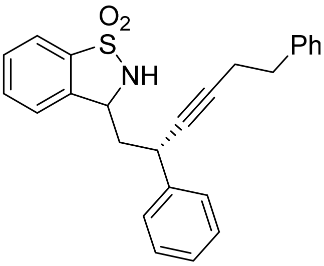


No.	RT	Area	Area %
1	14,39	28915600	46,944
2	17,59	28939929	46,984
3	23,11	1842060	2,991
4	28,54	1897840	3,081
		61595429	100,000

Enantioselective reaction:



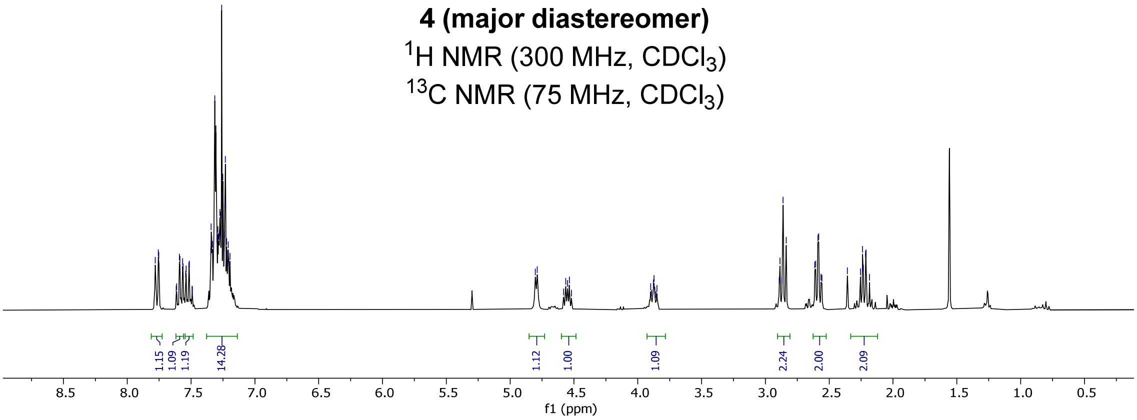
No.	RT	Area	Area %
1	14,23	17375590	77,056
2	17,48	2769410	12,282
3	22,94	303575	1,346
4	28,28	2100730	9,316
		22549305	100,000

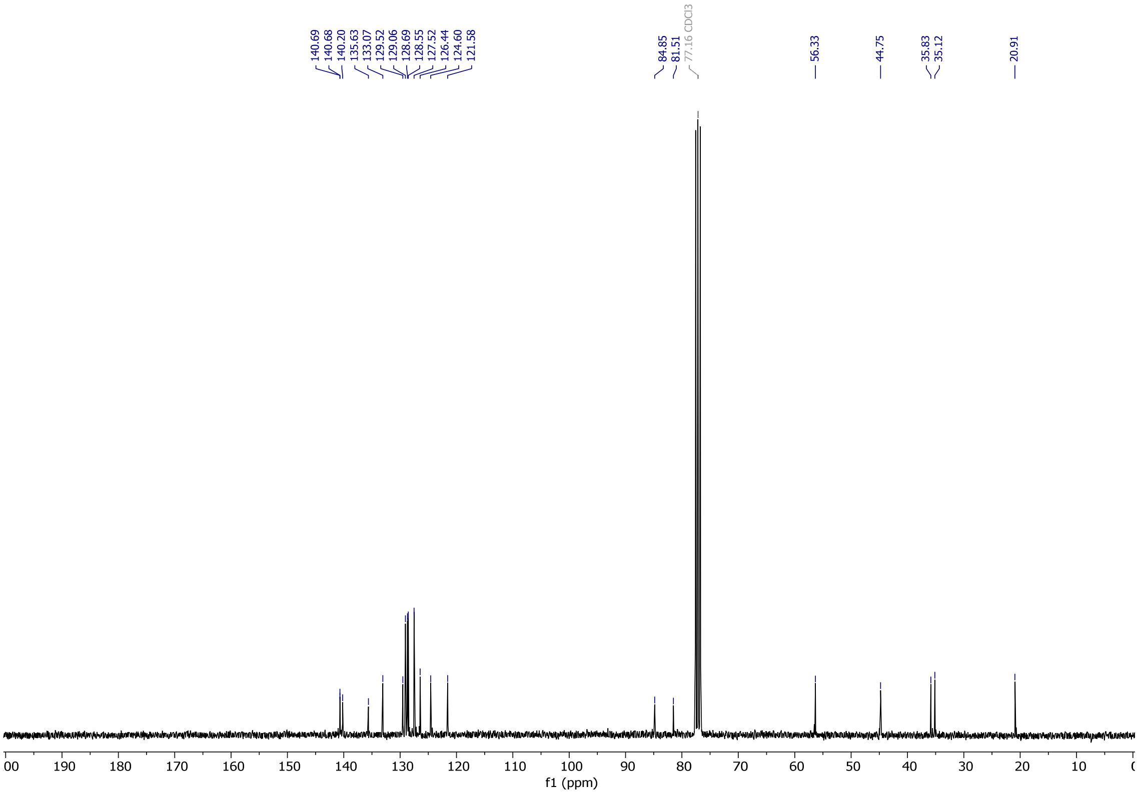


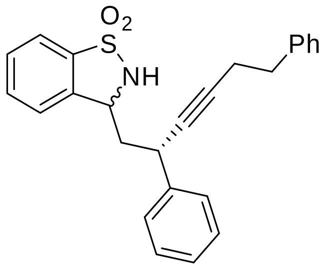
4 (major diastereomer)

^{1}H NMR (300 MHz, $CDCl_3$)

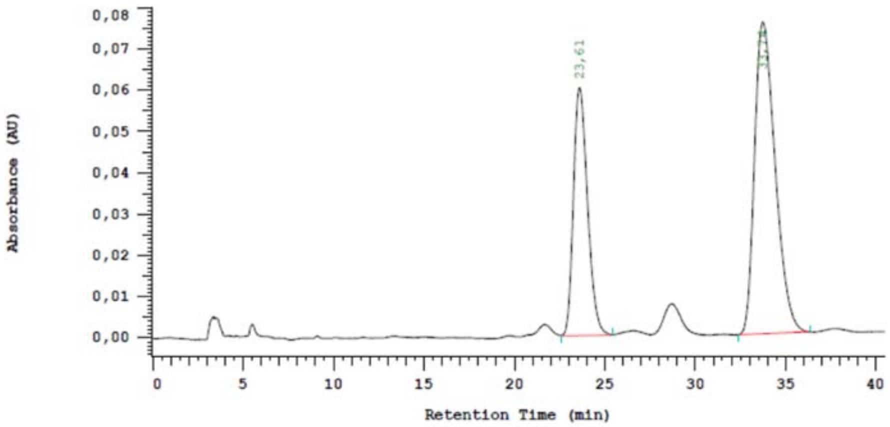
^{13}C NMR (75 MHz, $CDCl_3$)



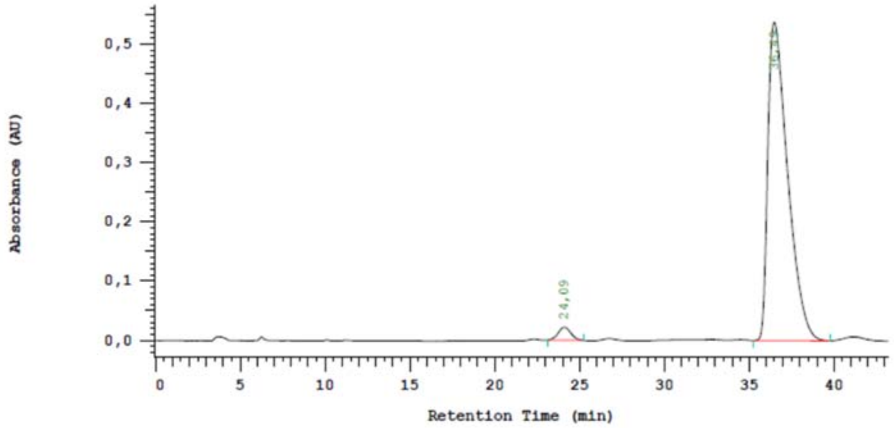




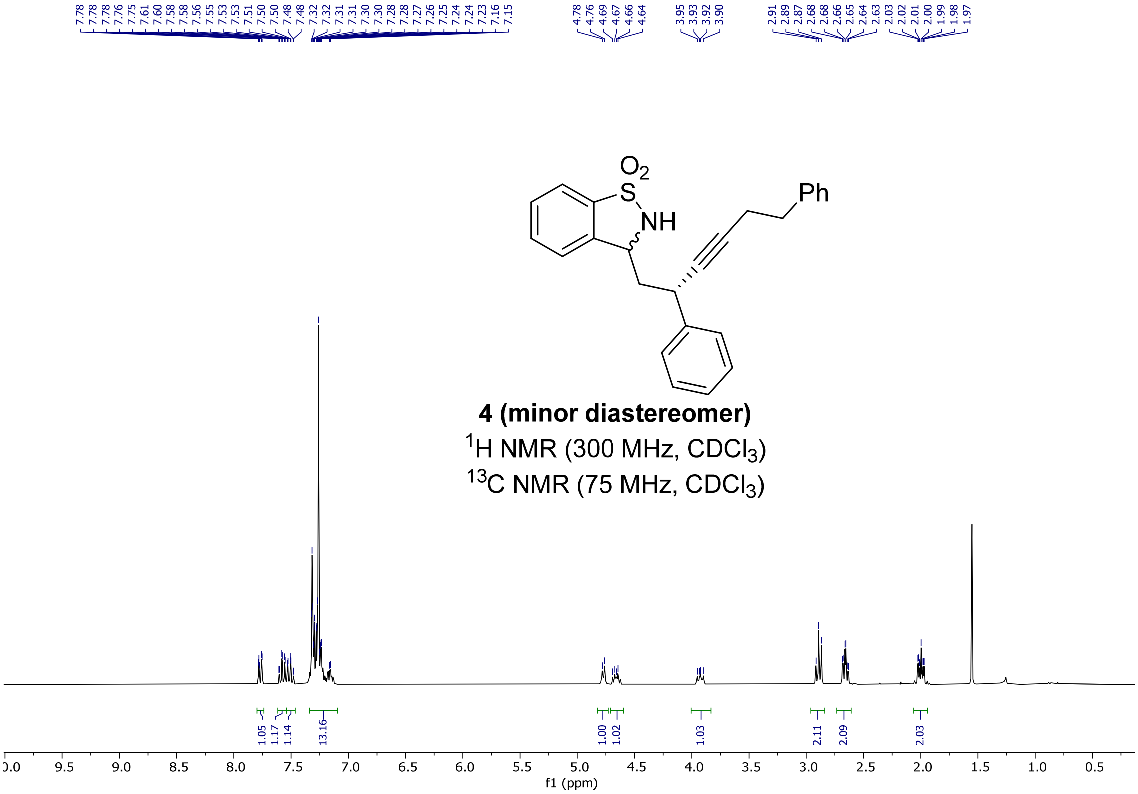
4 (major diastereomer)



No.	RT	Area	Area %	Name
1	23,61	1612960	35,086	
2	33,74	2984210	64,914	
		4597170	100,000	



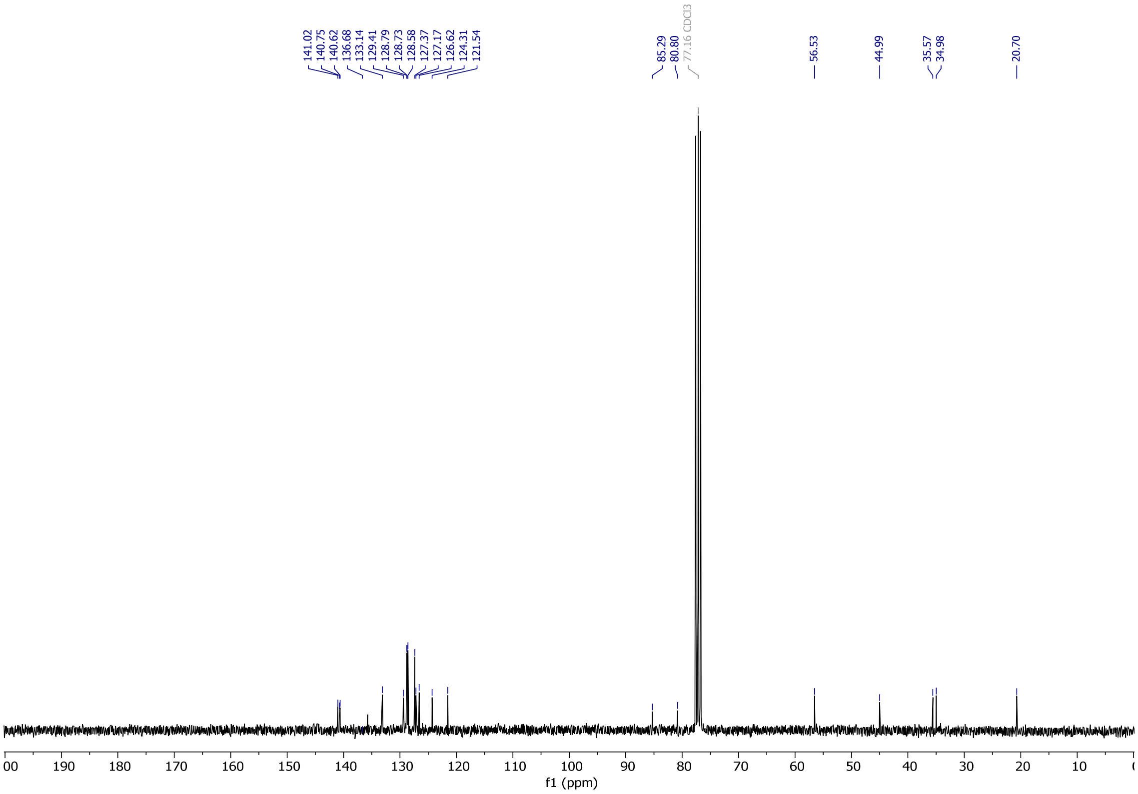
No.	RT	Area	Area %	Name
1	24,09	565220	2,549	
2	36,49	21606480	97,451	
		22171700	100,000	

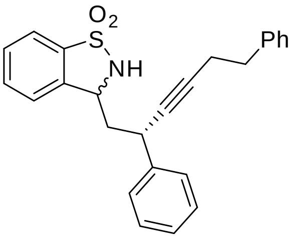


4 (minor diastereomer)

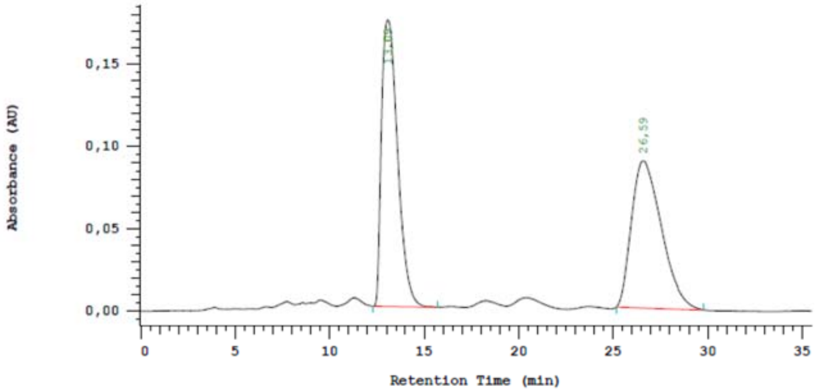
^{1}H NMR (300 MHz, $CDCl_3$)

^{13}C NMR (75 MHz, $CDCl_3$)

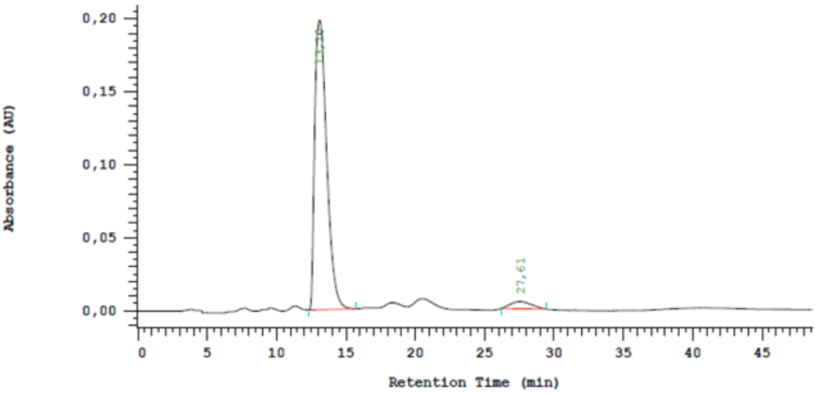




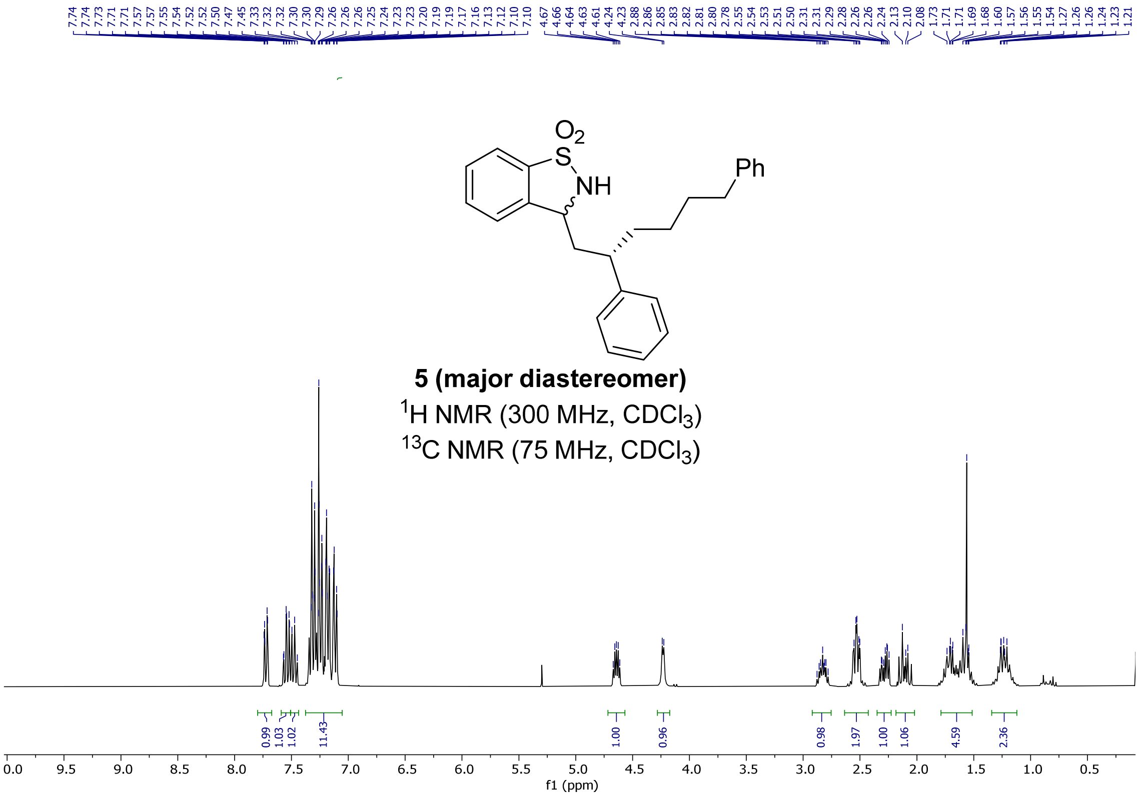
4 (minor diastereomer)



No.	RT	Area	Area %	Name
1	13,09	5131840	51,076	
2	26,59	4915550	48,924	enant. (+)
		10047390	100,000	



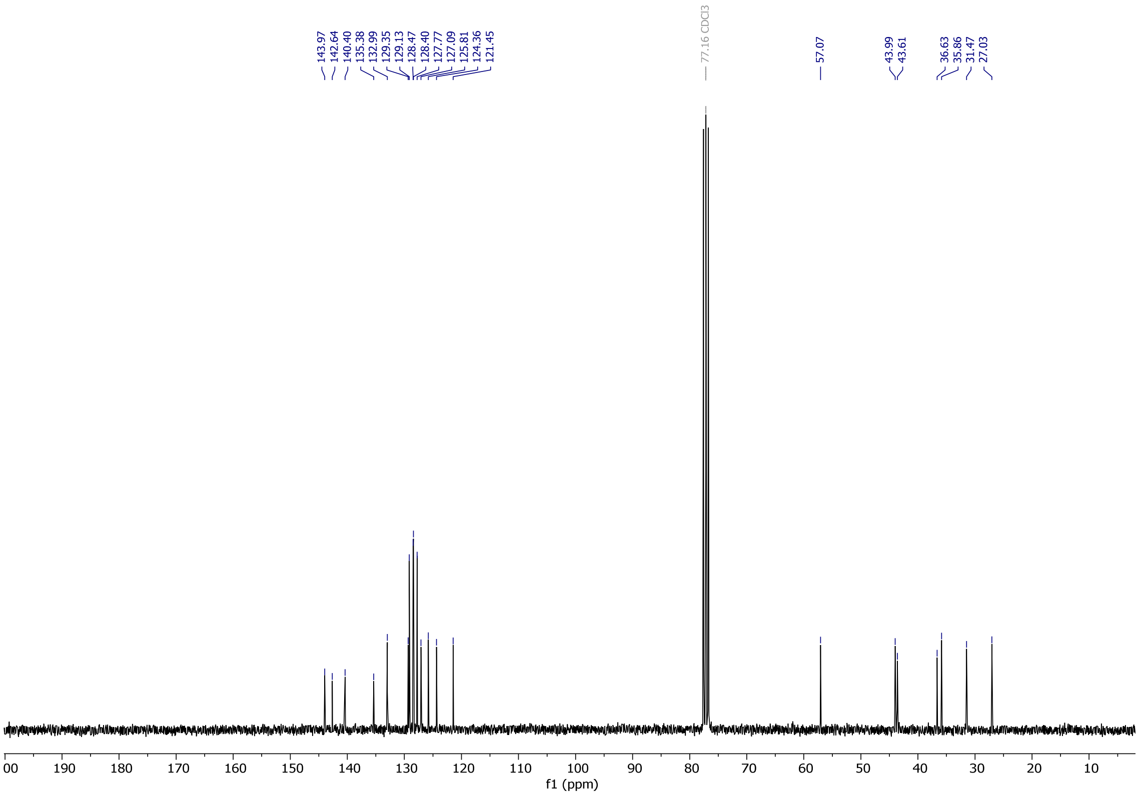
No.	RT	Area	Area %	Name
1	13,10	5936670	95,912	
2	27,61	253030	4,088	
		6189700	100,000	

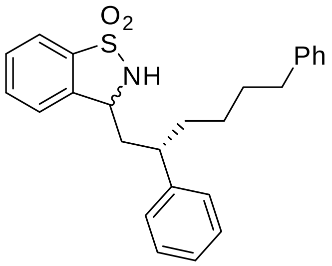


5 (major diastereomer)

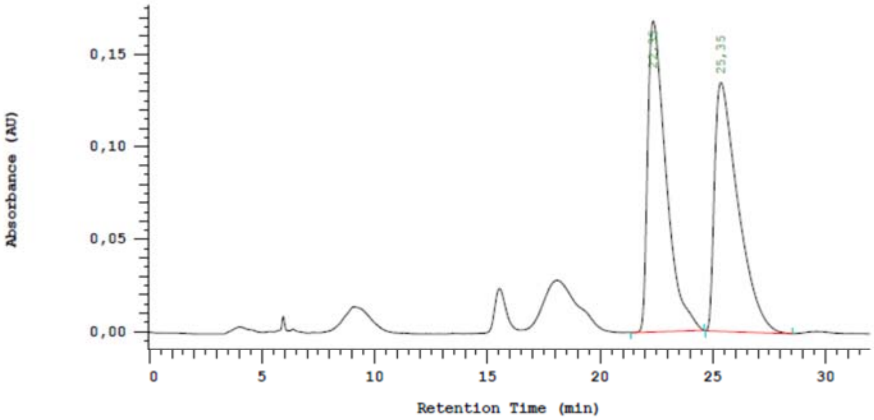
^{1}H NMR (300 MHz, CDCl$_3$)

^{13}C NMR (75 MHz, CDCl$_3$)

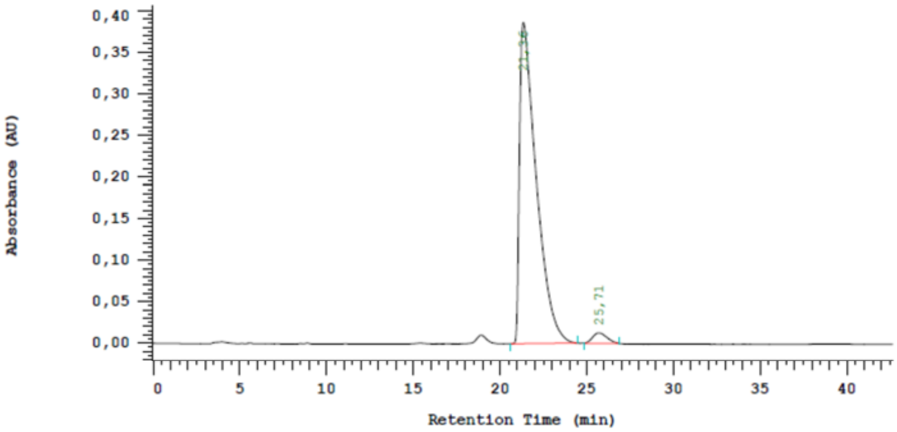




5 (major diastereomer)



No.	RT	Area	Area %	Name
1	22,35	4766030	49,562	
2	25,35	4850224	50,438	
		9616254	100,000	

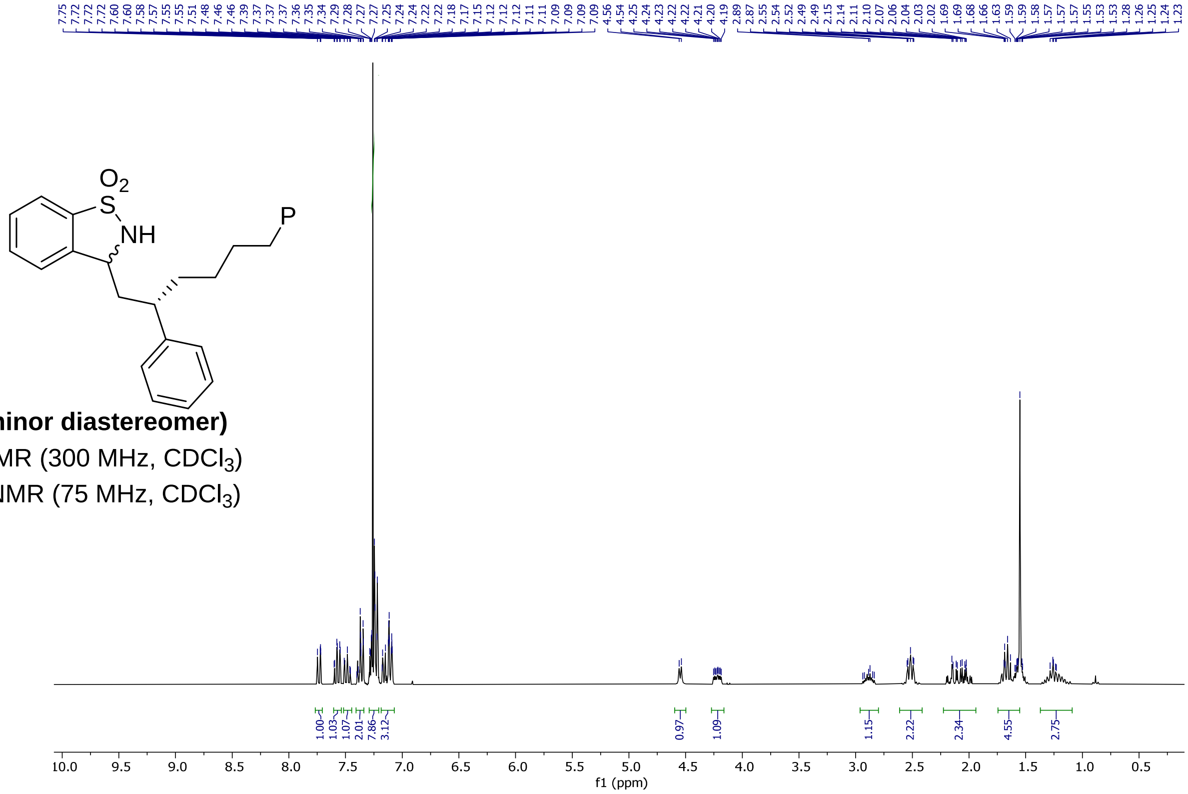


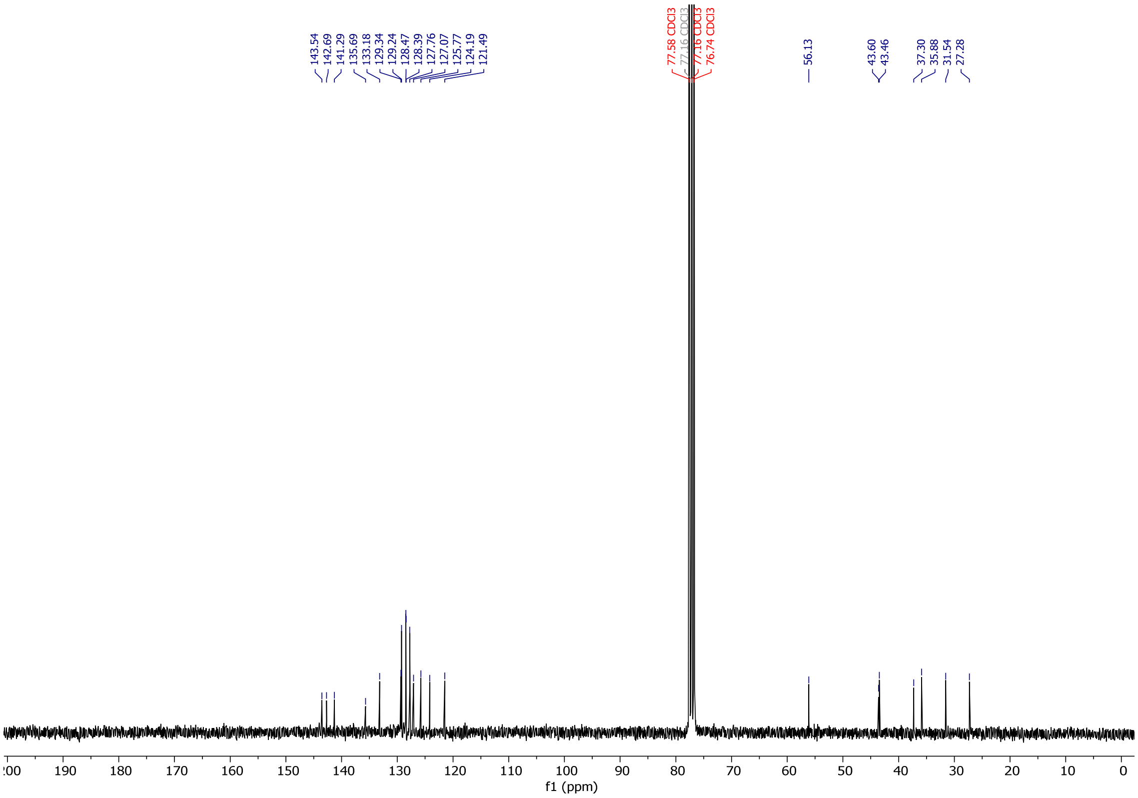
No.	RT	Area	Area %	Name
1	21,36	12941350	97,323	
2	25,71	355960	2,677	
		13297310	100,000	

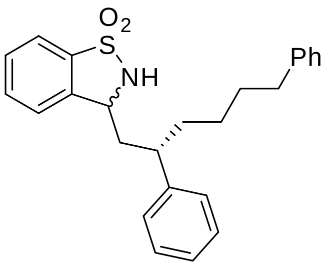
5 (minor diastereomer)

^{1}H NMR (300 MHz, $CDCl_3$)

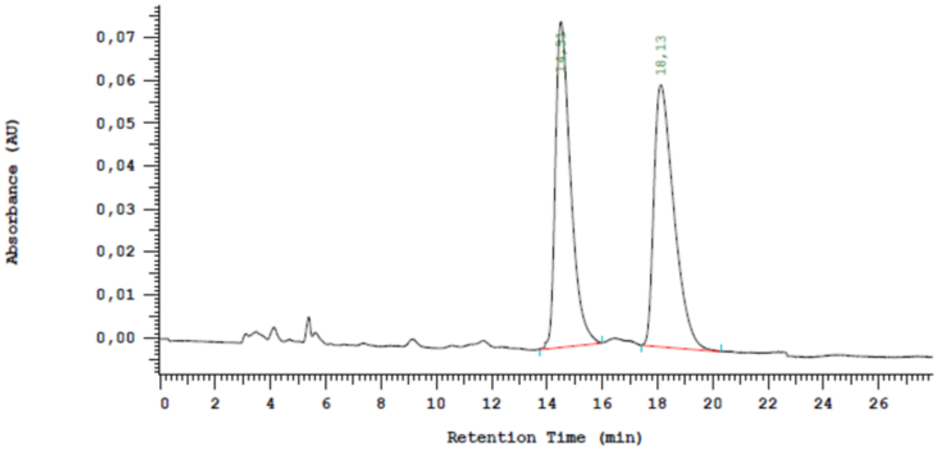
^{13}C NMR (75 MHz, $CDCl_3$)



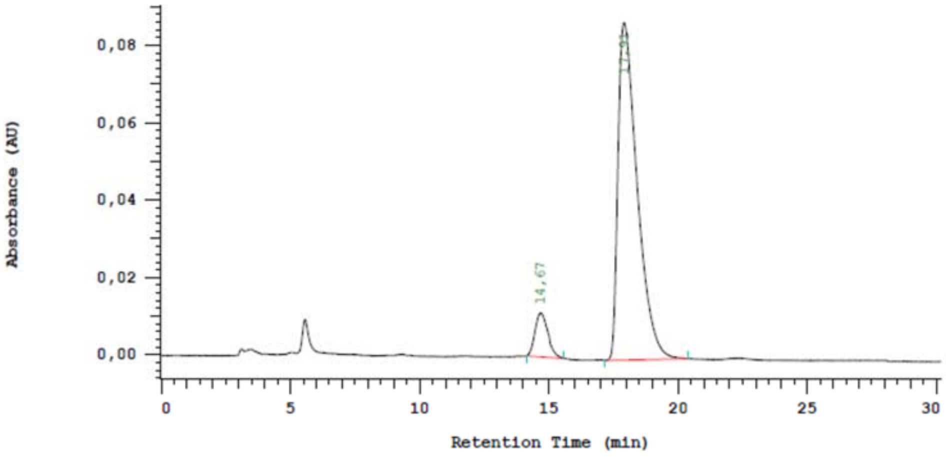




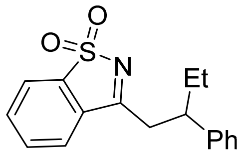
5 (minor diastereomer)



No.	RT	Area	Area %	Name
1	14,51	1451215	48,553	
2	18,13	1537740	51,447	
		2988955	100,000	



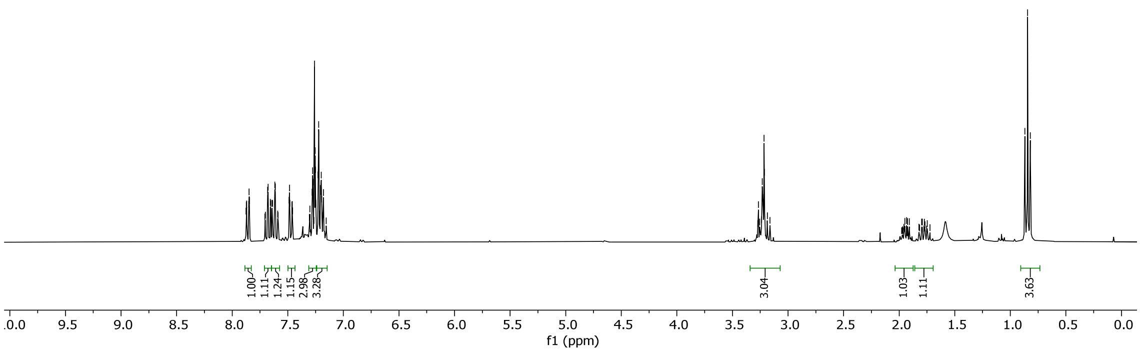
No.	RT	Area	Area %	Name
1	14,67	195100	8,005	
2	17,91	2242210	91,995	
		2437310	100,000	

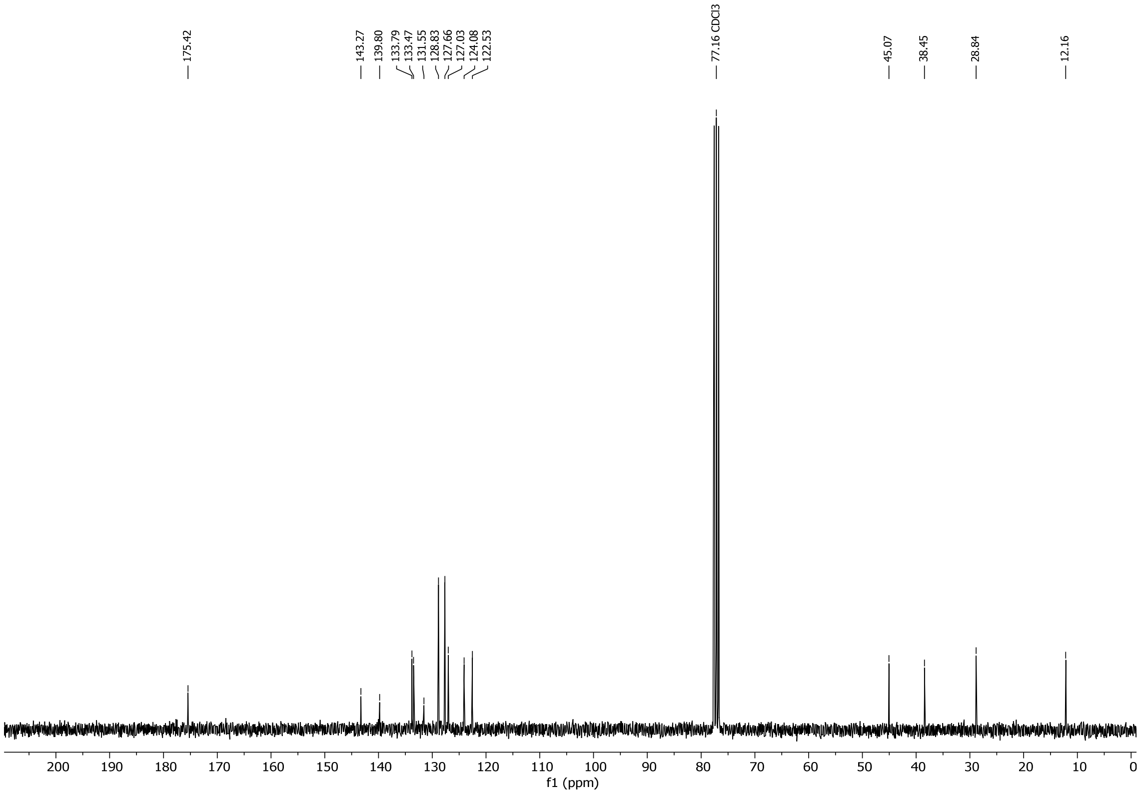


6

^{1}H NMR (300 MHz, $CDCl_3$)

^{13}C NMR (75 MHz, $CDCl_3$)





X-Ray Crystallography data for compound **3bg**: crystallized from hexane-EtOAc; $C_{20}H_{16}BrNO_2S$; Mr=414.31; monoclinic; space group=$P2_1$; a=7.4286(4), b=7.2641(3); c=17.1612(8) Å, β=96.473(2); V=929.15(8) Å^3; Z=2; ρ_{calcd}=1.495 Mg m^{-3}; μ=2.360 mm^{-1}; F(000)=420. A colorless crystal of 0.04x0.04x0.08 mm^3 was used; 3393 [R(int)=0.0504] independent reflections were collected on a Bruker S8 x-ray diffraction, equipped with a graphite monochromator and Mo Kα (λ = 0.71073 Å). The structure was solved by using direct methods with SHELXS-2014 and refined by using full matrix least squares on F^2 with SHELXL-2014. Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were refined isotropically. Final R(ωR) values were R=0.0451 (0.1152). CCDC-1992564 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

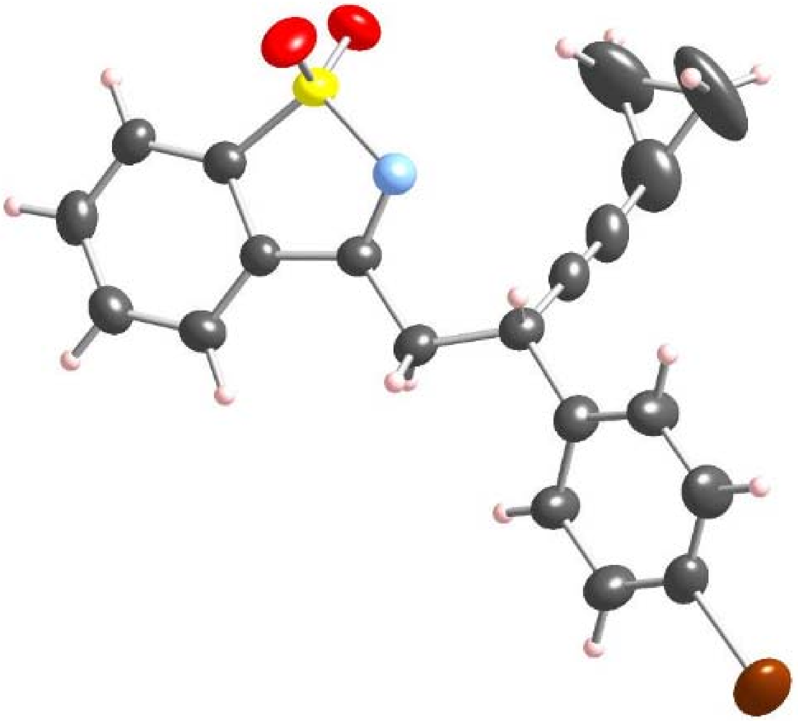


Figure S1. Ortep plot for the X-ray structure of compound **3bg**. The thermal ellipsoids are drawn at the 50% probability level. Flack parameter 0.017(6).