

Supplementary Material
for

**Synthesis of Both *Enantiomers* of Chiral Phenylalanine Derivatives
Catalyzed by Cinchona Alkaloid Quaternary Ammonium Salts as
Asymmetric Phase Transfer Catalysts**

Lei Jin, Shuai Zhao, Xin Chen*

School of Pharmaceutical & Life Sciences, Changzhou University, Changzhou, Jiangsu 213164, China;
15102307@smail.cczu.edu.cn (L.J.); 1138971580@qq.com (S.Z.)

* Correspondence: xinchen@cczu.edu.cn (X.C.); Tel.: +86-519-86334597; Fax: +86-519-86334598

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Abstract: A practical synthesis of both enantiomers of unnatural phenylalanine derivatives by using two pseudoenantiomeric phase transfer catalysts is described. Through asymmetric α -alkylation of glycine Schiff base with substituted benzyl bromides and 1-(bromomethyl)naphthalene under the catalysis of *O*-allyl-*N*-(9-anthracenmethyl) cinchoninium bromide (**1f**) and *O*-allyl-*N*-(9-anthracenmethyl) cinchonidium bromide (**1i**), respectively, a series of both (*R*)- and (*S*)-enantiomers of unnatural α -amino acid derivatives were obtained in excellent yields and enantioselectivity. The synthetic method is simple and scalable, and the stereochemistry of the products is fully predictable and controlled: the cinchonine-type phase transfer catalyst **1f** resulted in (*R*)- α -amino acid derivatives, and the cinchonidine-type phase transfer catalyst **1i** afforded (*S*)- α -amino acid derivatives,

Keywords: both enantiomers, unnatural α -amino acids derivatives, phase transfer catalysts, asymmetric α -alkylation, glycine Schiff base

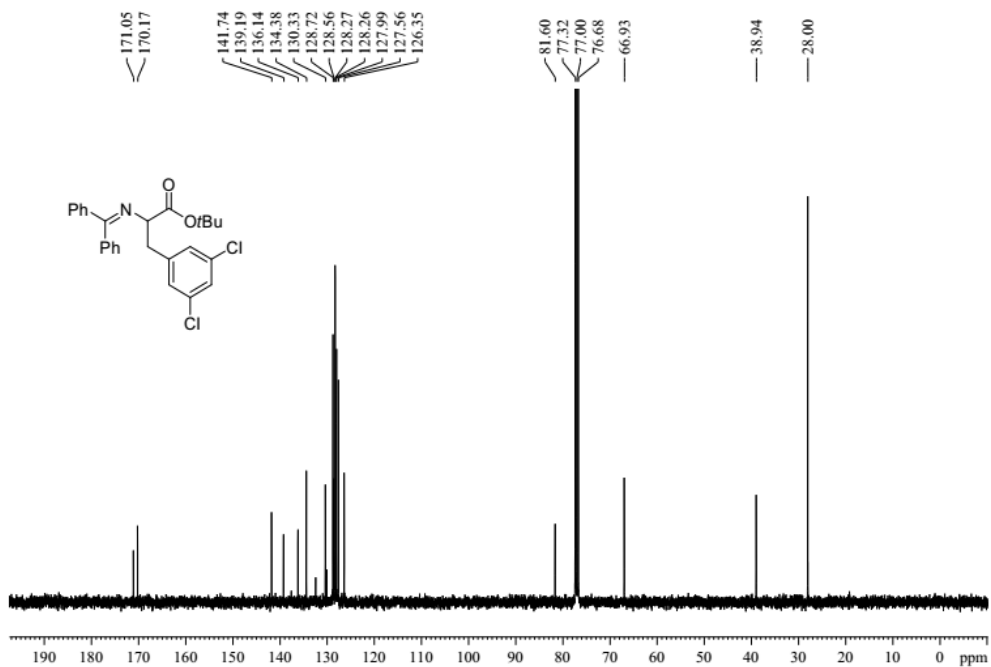
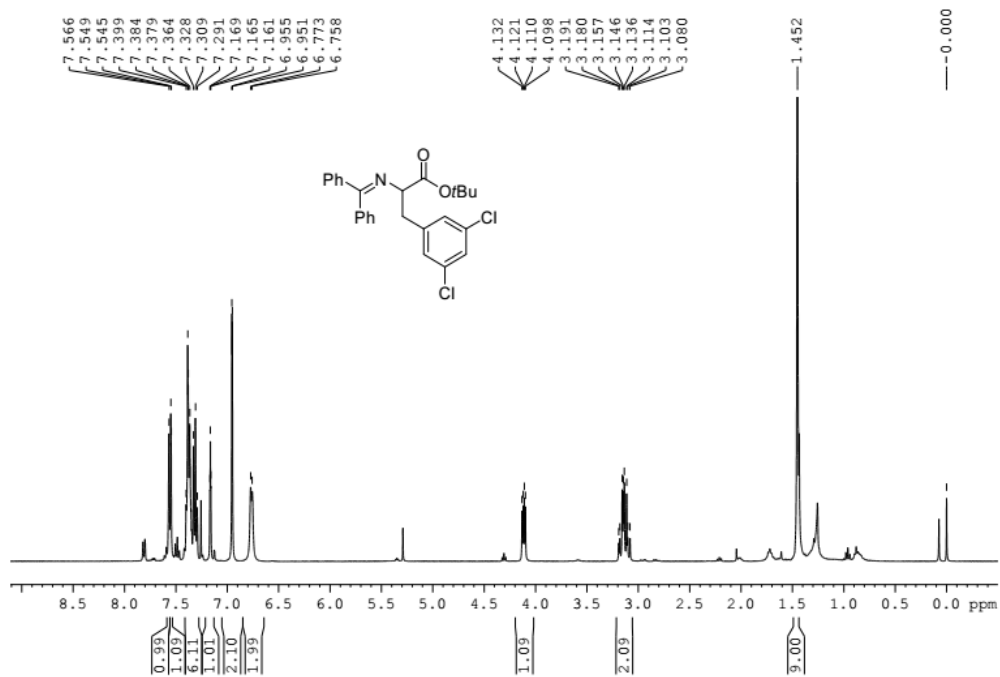
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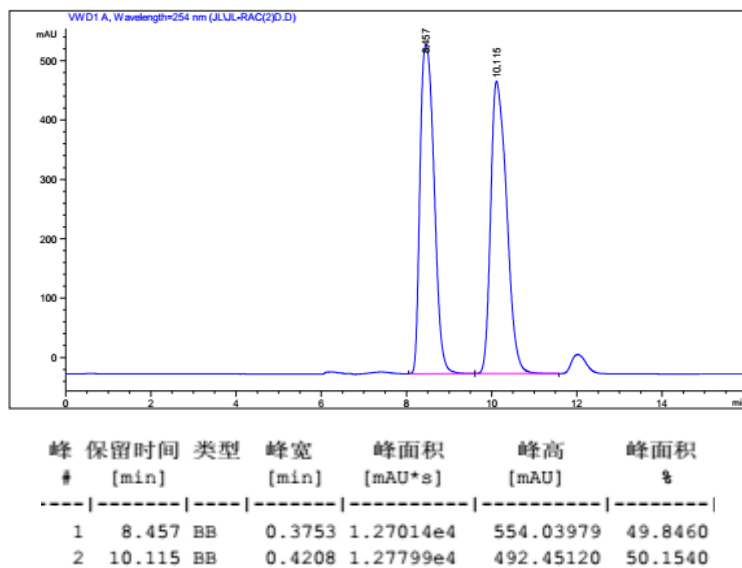
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NMR spectra and HPLC chromatogram of 4a and 4a'

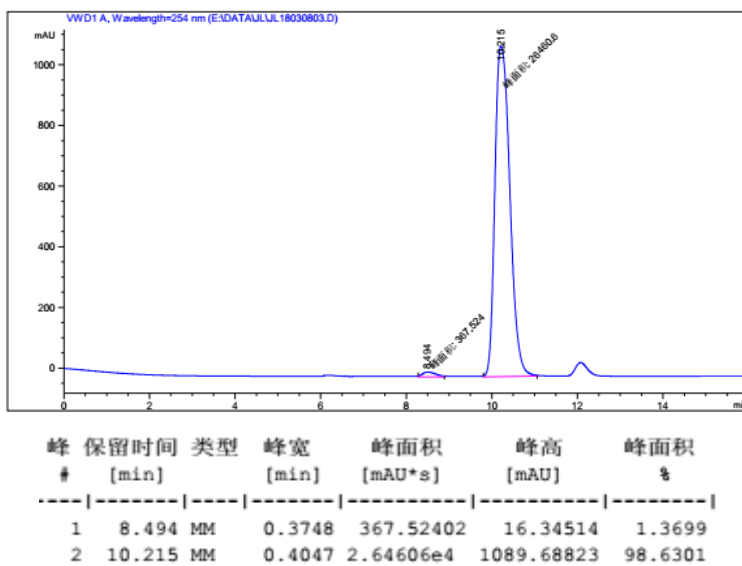
¹H and ¹³C NMR spectra of 4a and 4a'



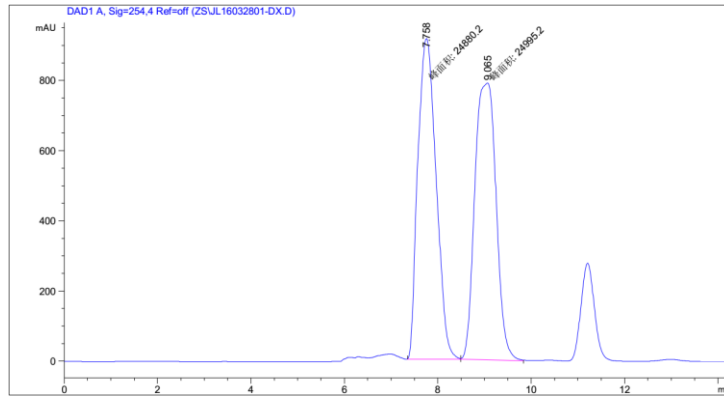
HPLC chromatogram of *rac-4a*



HPLC chromatogram of **4a**

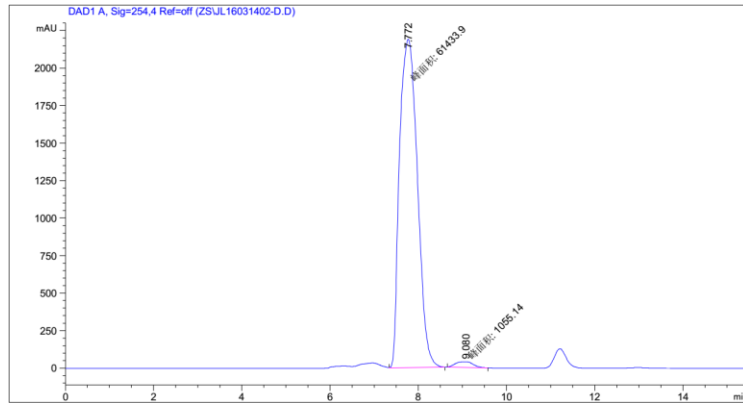


HPLC chromatogram of *rac-4a'*



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	7.758	MM	0.4536	2.48802e4	914.18732	49.8848
2	9.065	MM	0.5278	2.49952e4	789.28033	50.1152

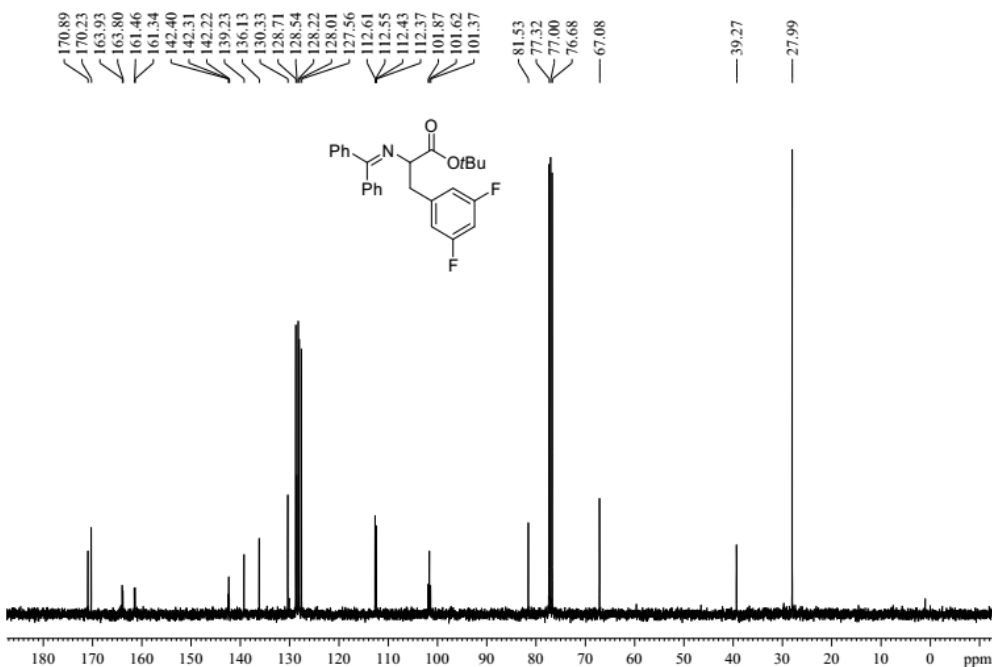
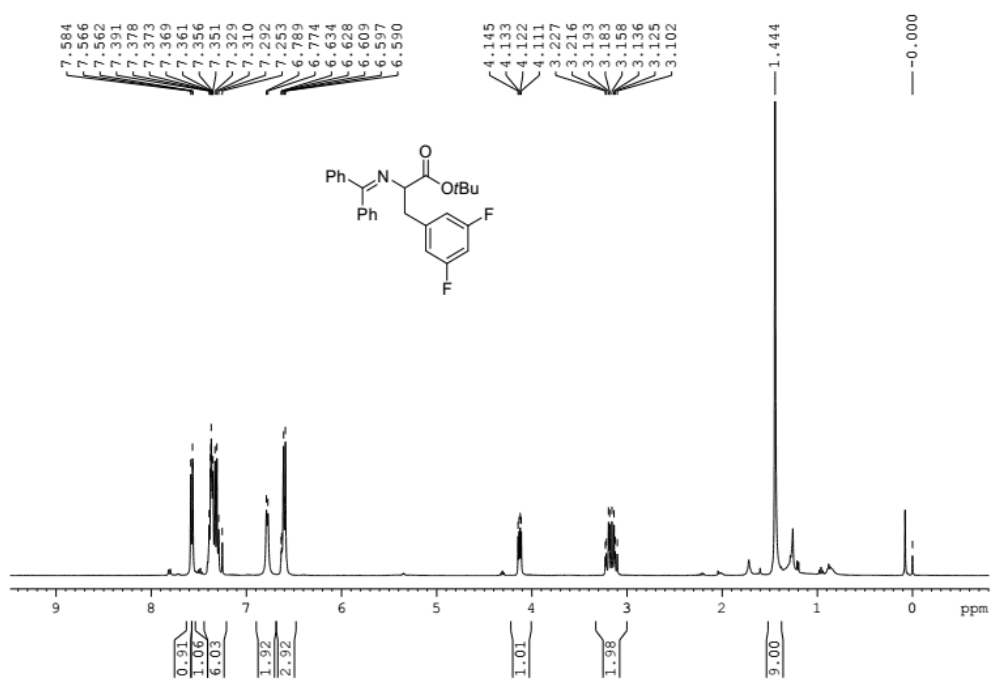
HPLC chromatogram of *4a'*



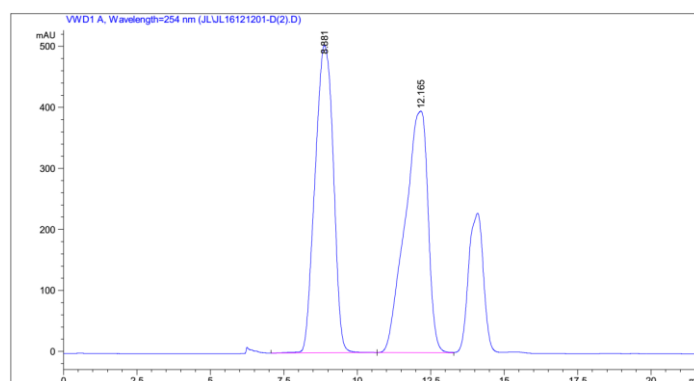
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1	7.772	MM	0.4677	6.14339e4	2189.04443	98.3115
2	9.080	MM	0.4618	1055.13892	38.08363	1.6885

NMR spectra and HPLC chromatogram of **4b** and **4b'**

^1H and ^{13}C NMR spectra of **4b** and **4b'**

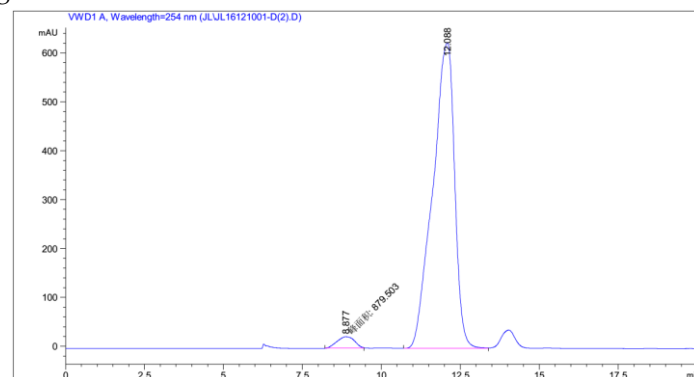


HPLC chromatogram of *rac-4b* (**4b'**)



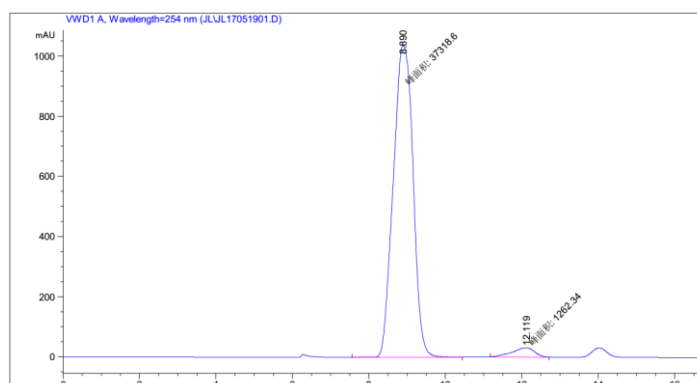
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.881	BB	0.7036	2.18291e4	503.69077	50.2237
2	12.165	BV	0.8019	2.16346e4	395.98453	49.7763

HPLC chromatogram of **4b'**



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.877	MM	0.6386	879.50299	22.95321	2.8481
2	12.088	BV	0.7042	3.00010e4	624.98010	97.1519

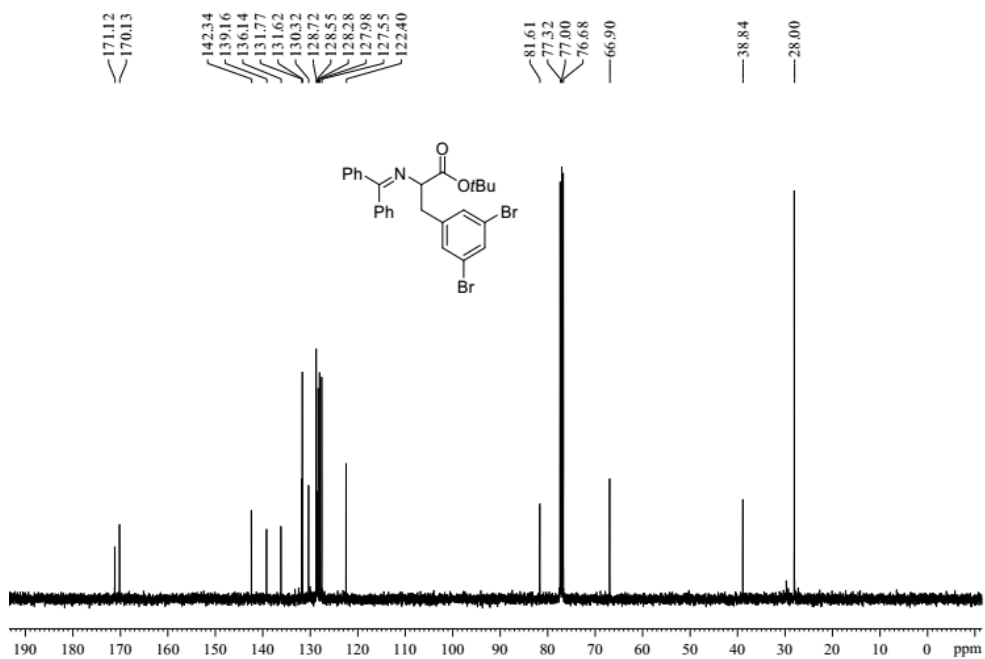
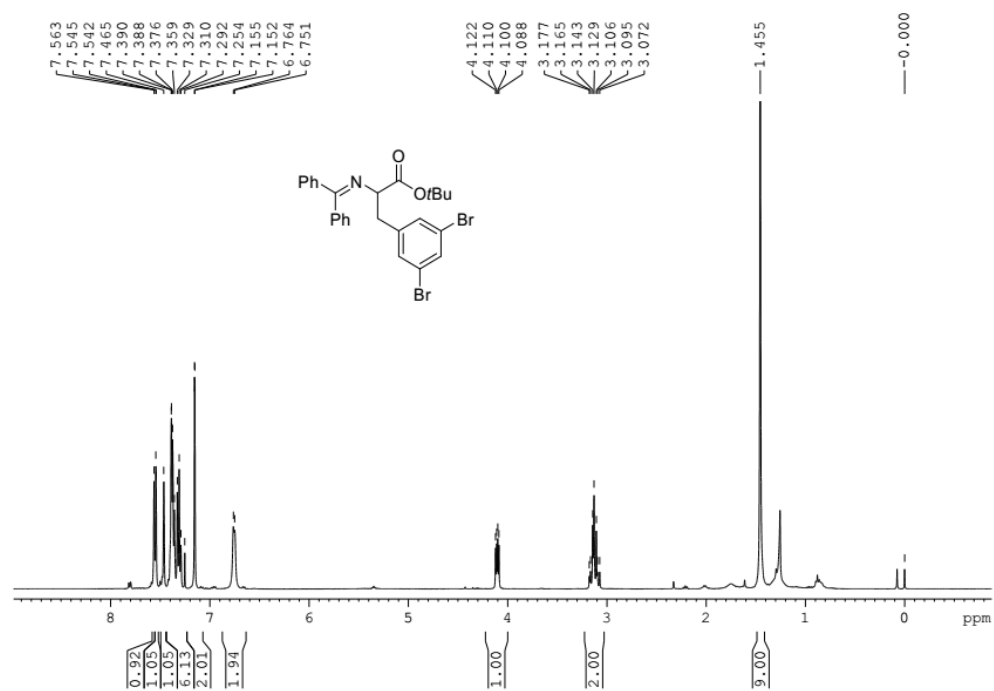
HPLC chromatogram of **4b**



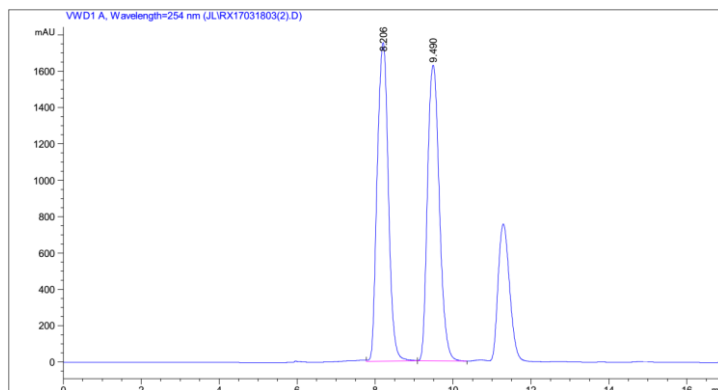
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.890	MM	0.5998	3.73186e4	1036.89526	96.7281
2	12.119	MM	0.6832	1262.34119	30.79416	3.2719

NMR spectra and HPLC chromatogram of **4c** and **4c'**

¹H and ¹³C NMR spectra of **4c** and **4c'**

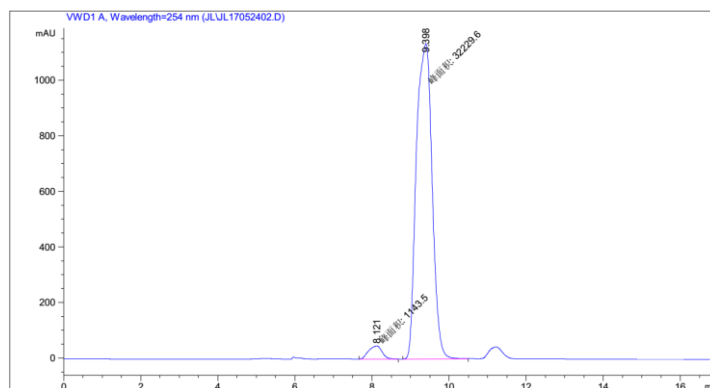


HPLC chromatogram of *rac*-4c



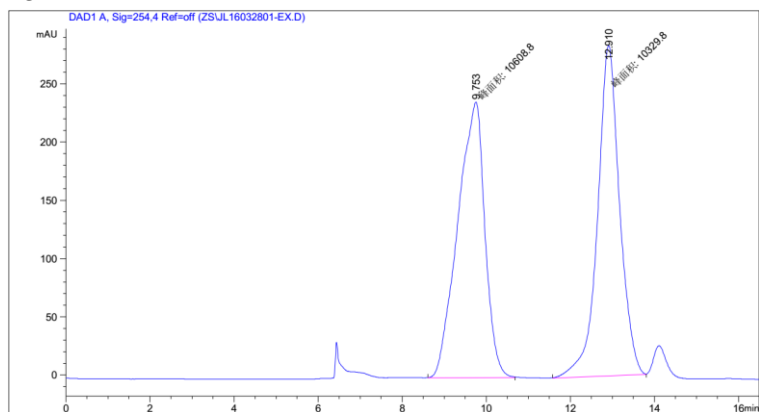
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.206	VB	0.3246	3.47315e4	1751.23987	50.3585
2	9.490	BB	0.3345	3.42369e4	1625.74329	49.6415

HPLC chromatogram of 4c



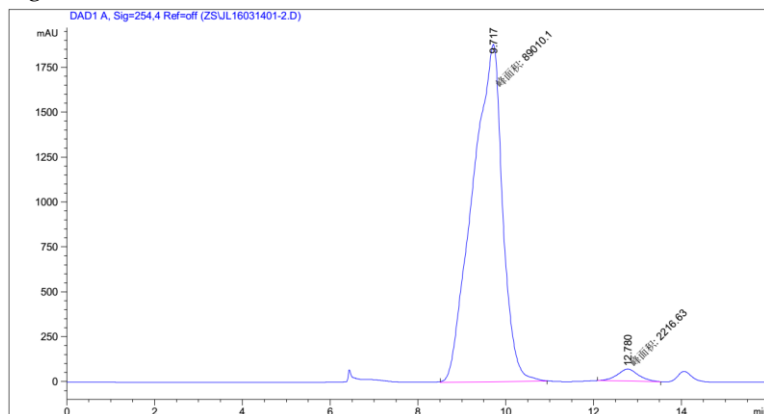
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1	8.121	MM	0.4046	1143.49902	47.10197	3.4264
2	9.398	MM	0.4735	3.22296e4	1134.37952	96.5736

HPLC chromatogram of *rac-4c'*



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.753	MM	0.7476	1.06088e4	236.51517	50.6663
2	12.910	MM	0.6068	1.03298e4	283.74463	49.3337

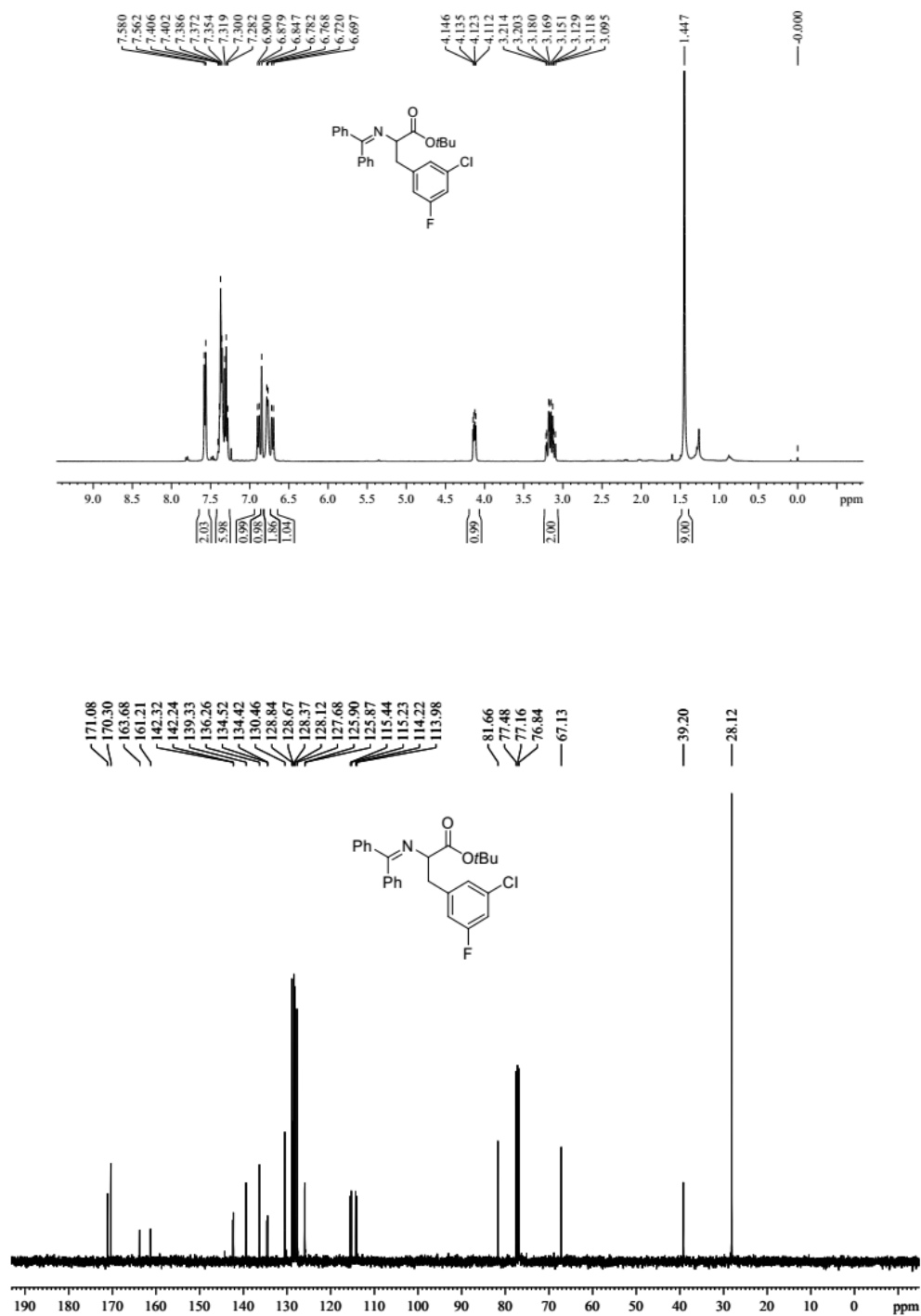
HPLC chromatogram of *4c'*



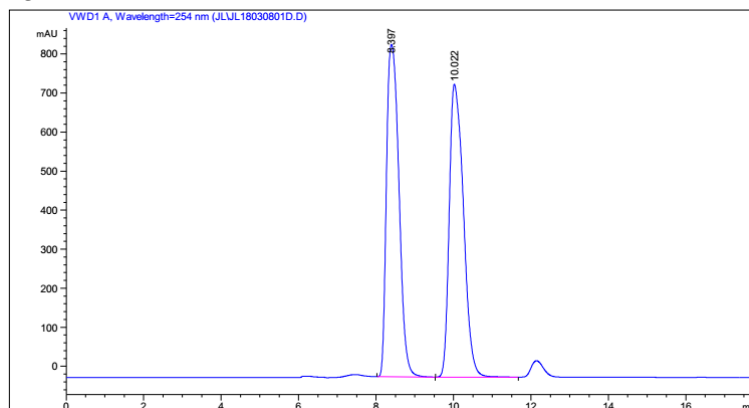
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1	9.717	MM	0.7898	8.90101e4	1878.31470	97.5702
2	12.780	MM	0.5531	2216.63037	66.79173	2.4298

NMR spectra and HPLC chromatogram of **4d** and **4d'**

^1H and ^{13}C NMR spectra of **4d** and **4d'**

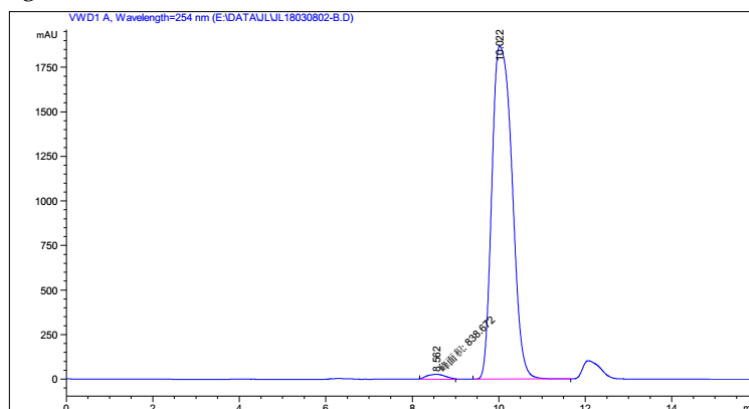


HPLC chromatogram of *rac*-4d (4d')



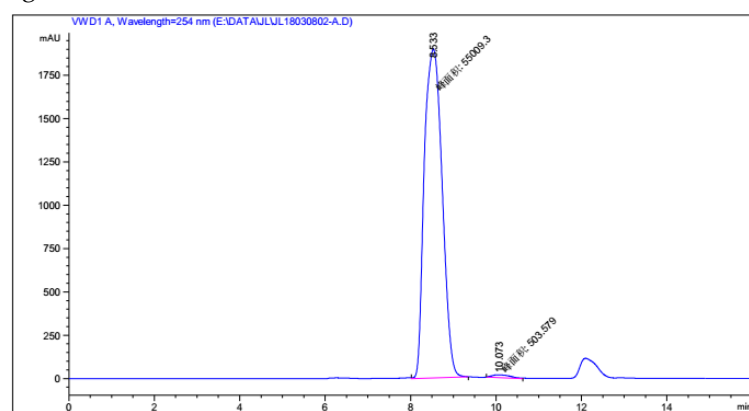
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.397	BB	0.3635	1.89676e4	851.13269	49.9479
2	10.022	BB	0.4092	1.90072e4	750.51227	50.0521

HPLC chromatogram of 4d



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.562	MM	0.5045	838.67169	27.70378	1.3681
2	10.022	BB	0.5247	6.04646e4	1868.60950	98.6319

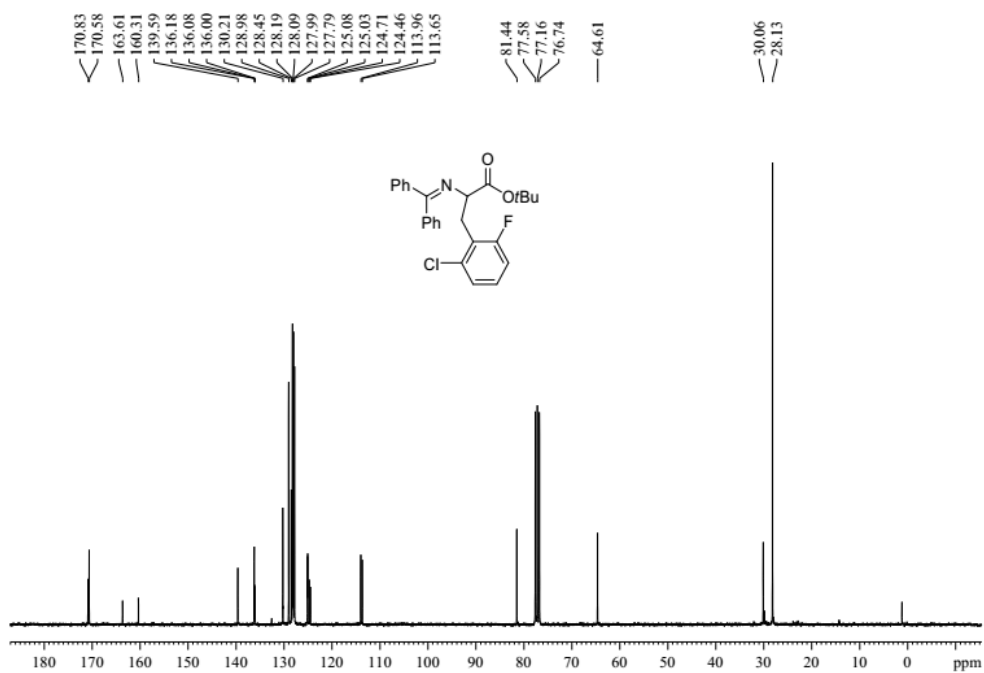
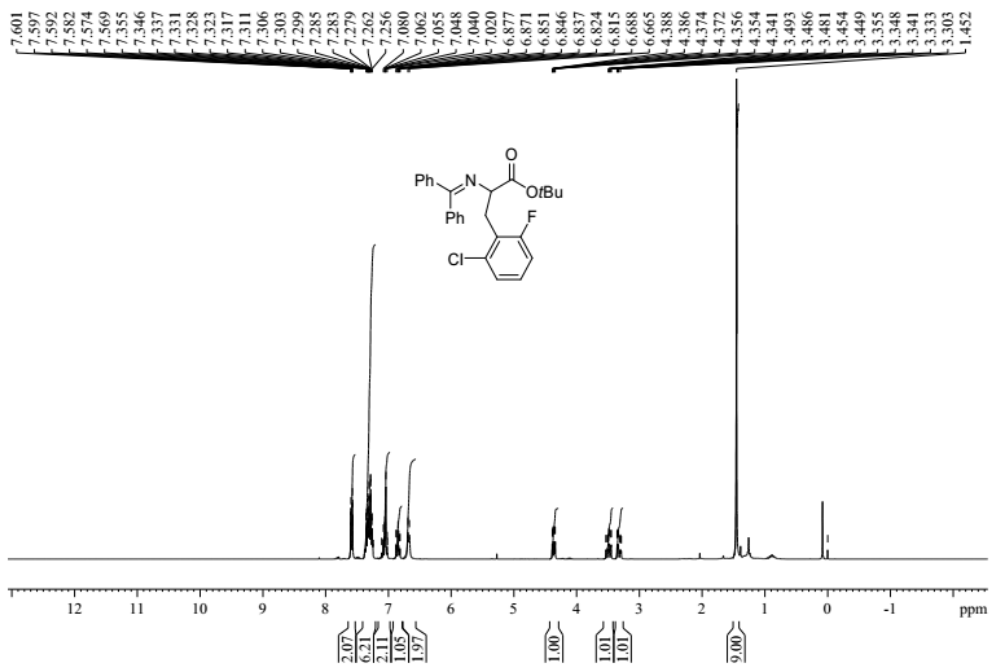
HPLC chromatogram of 4d'



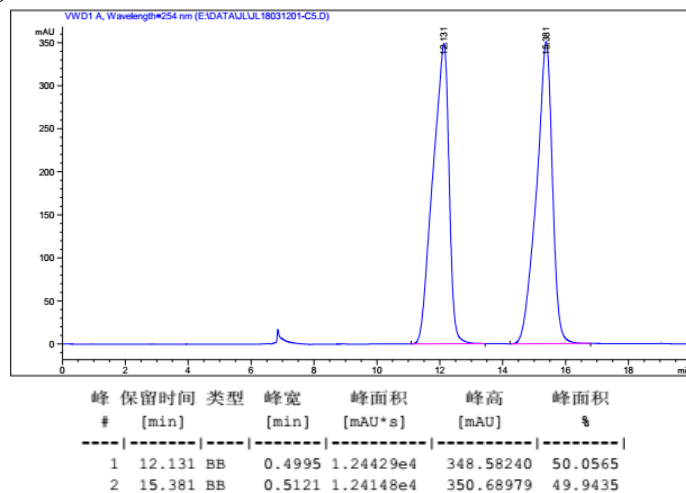
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1	8.533	MM	0.4831	5.50093e4	1897.59363	99.0929
2	10.073	MM	0.5107	503.57877	16.43492	0.9071

NMR spectra and HPLC chromatogram of 4e and 4e'

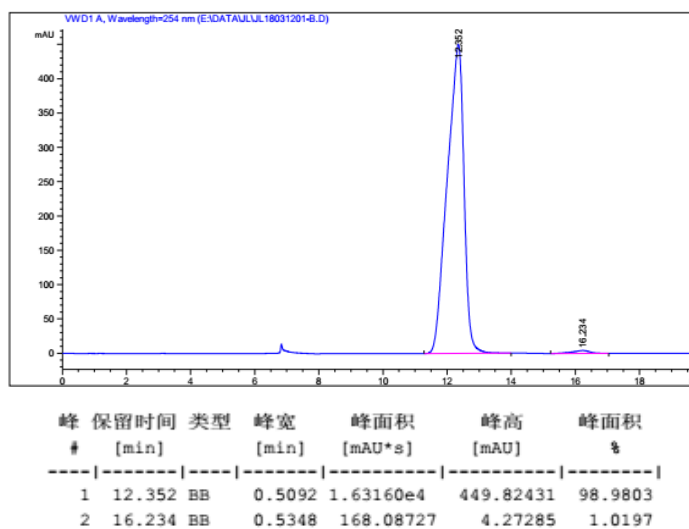
¹H and ¹³C NMR spectra of 4e and 4e'



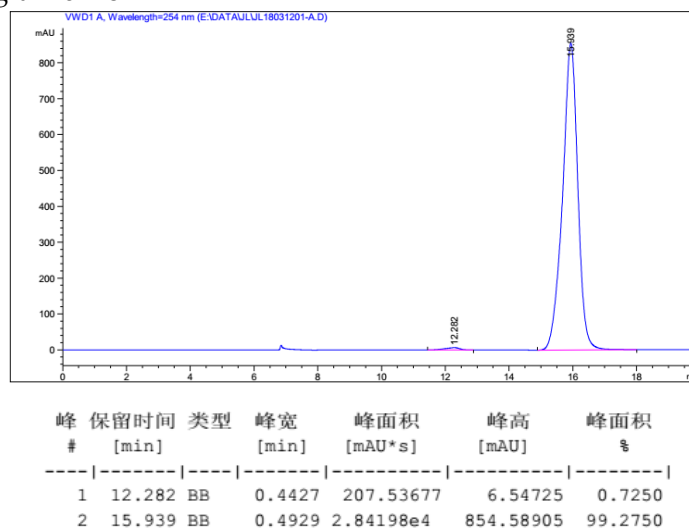
HPLC chromatogram of *rac*-**4e** (**4e'**)



HPLC chromatogram of **4e**

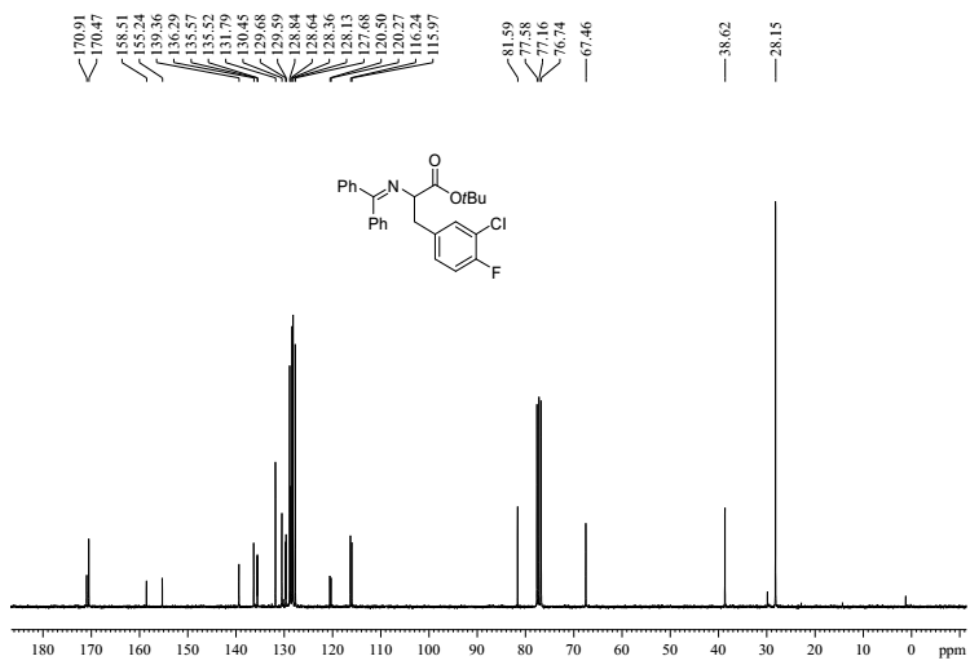
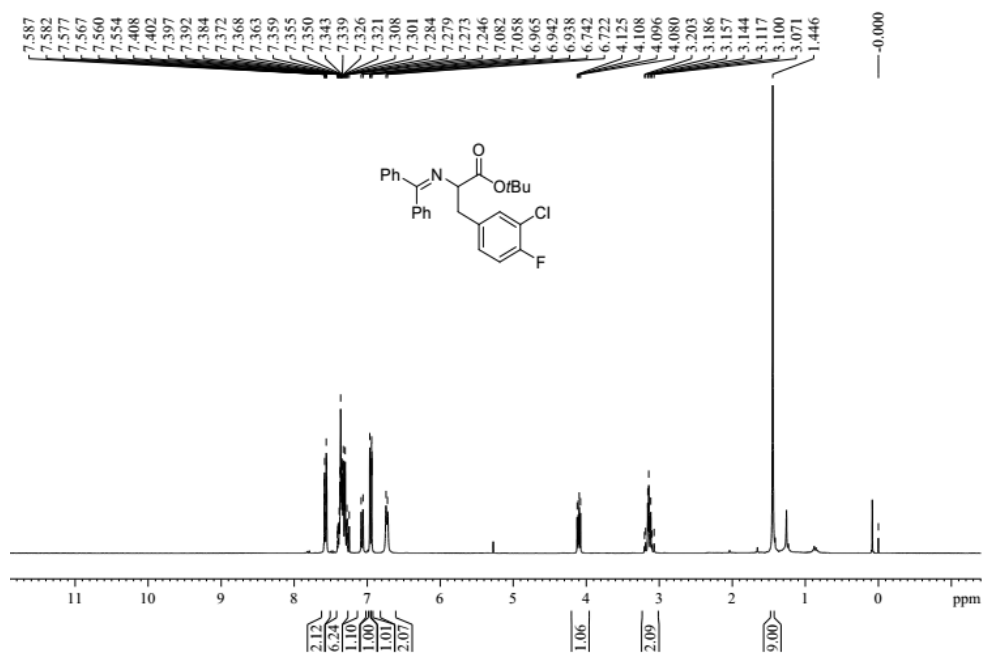


HPLC chromatogram of **4e'**

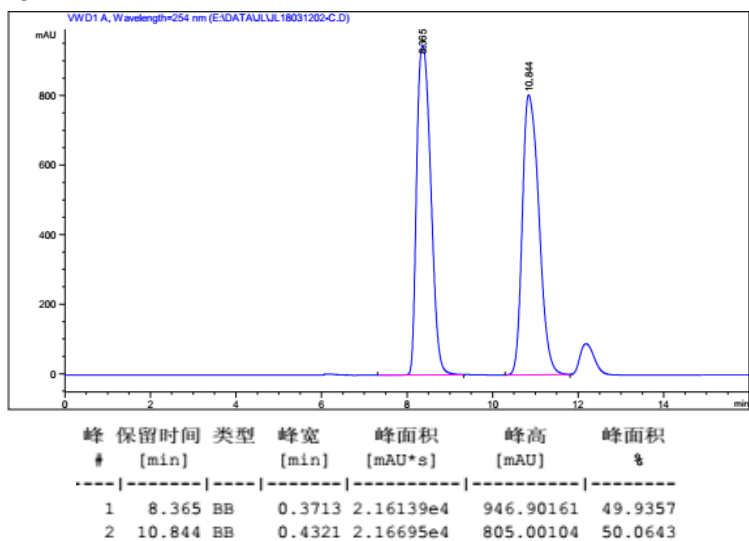


NMR spectra and HPLC chromatogram of 4f and 4f'

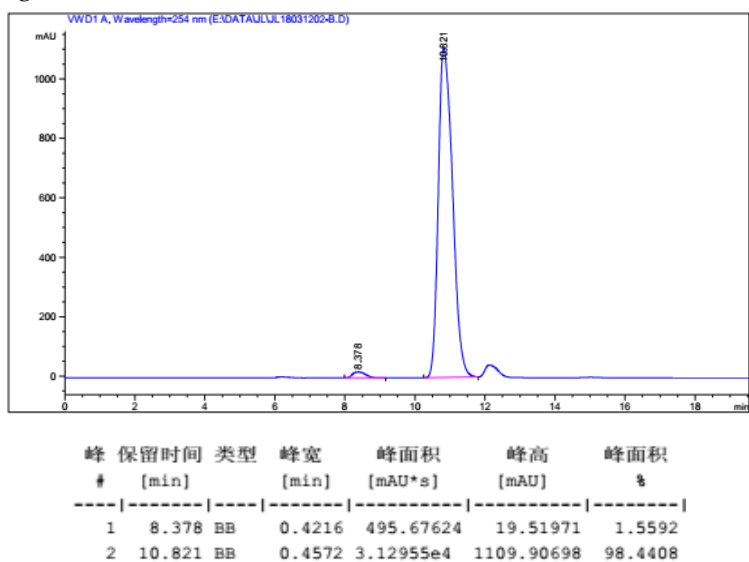
¹H and ¹³C NMR spectra of 4f and 4f'



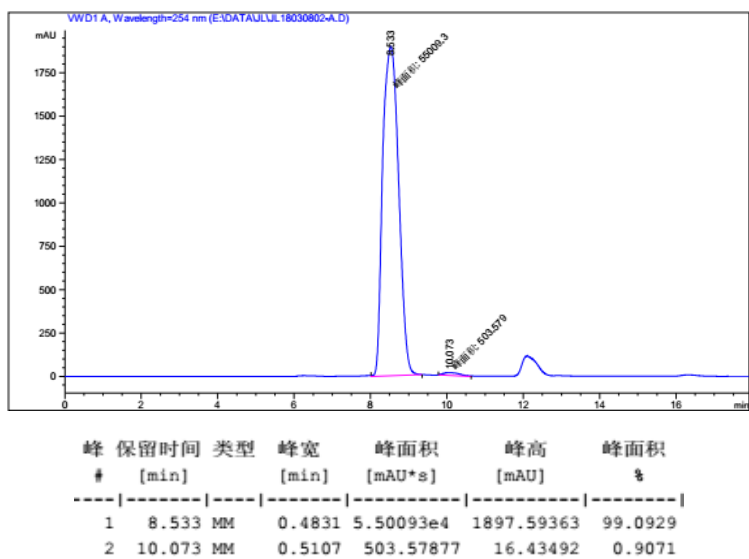
HPLC chromatogram of *rac*-4f (4f')



HPLC chromatogram of 4f

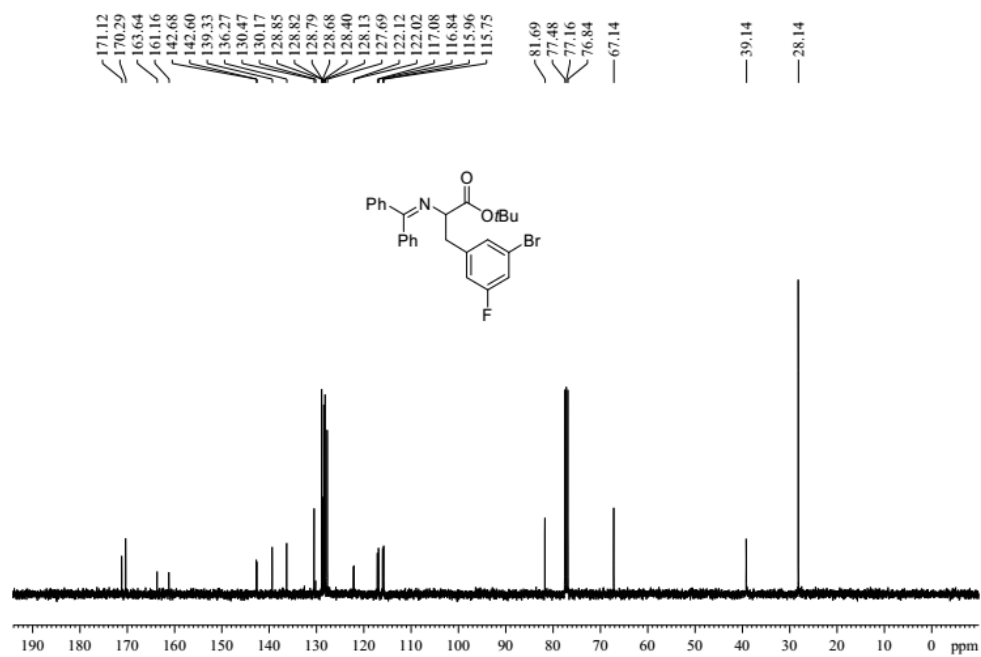
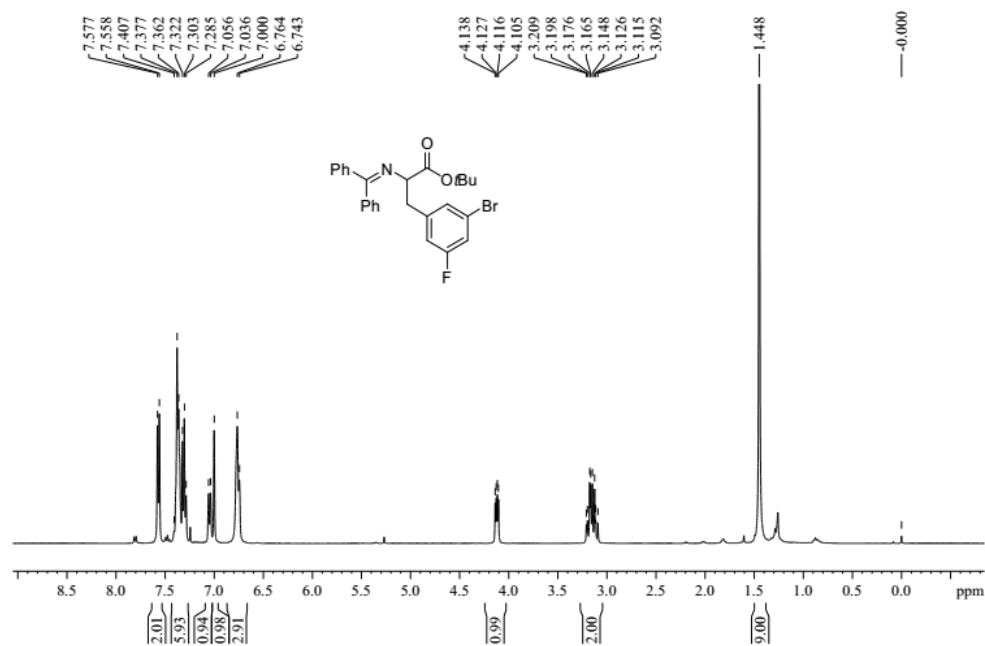


HPLC chromatogram of 4f'

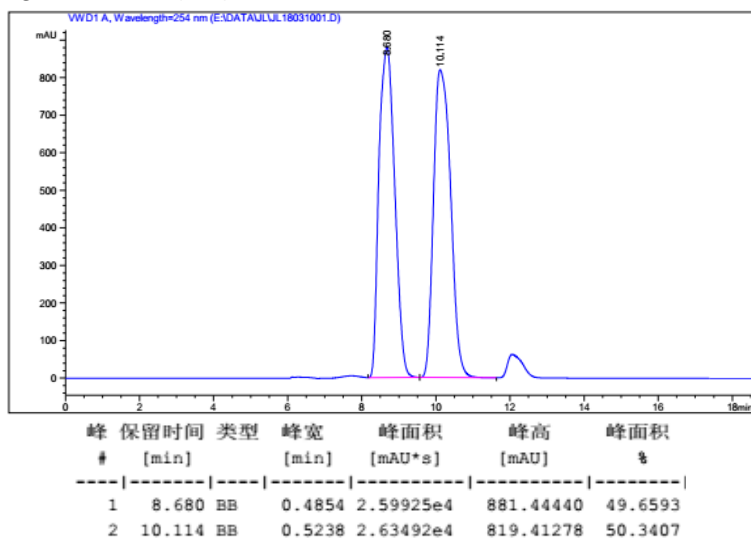


NMR spectra and HPLC chromatogram of **4g** and **4g'**

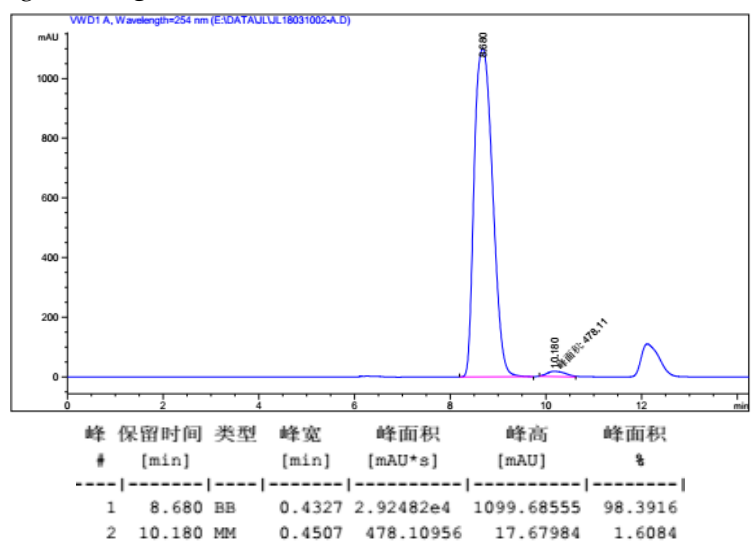
¹H and ¹³C NMR spectra of **4g** and **4g'**



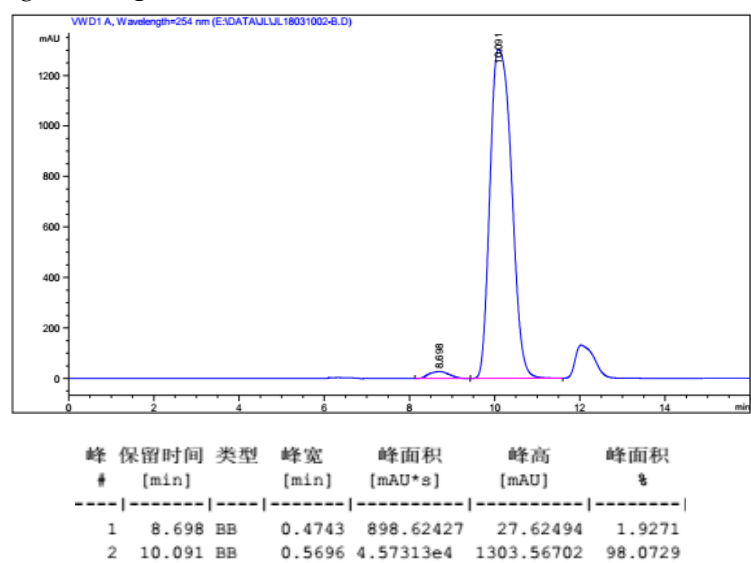
HPLC chromatogram of *rac-4g* (**4g'**)



HPLC chromatogram of **4g**

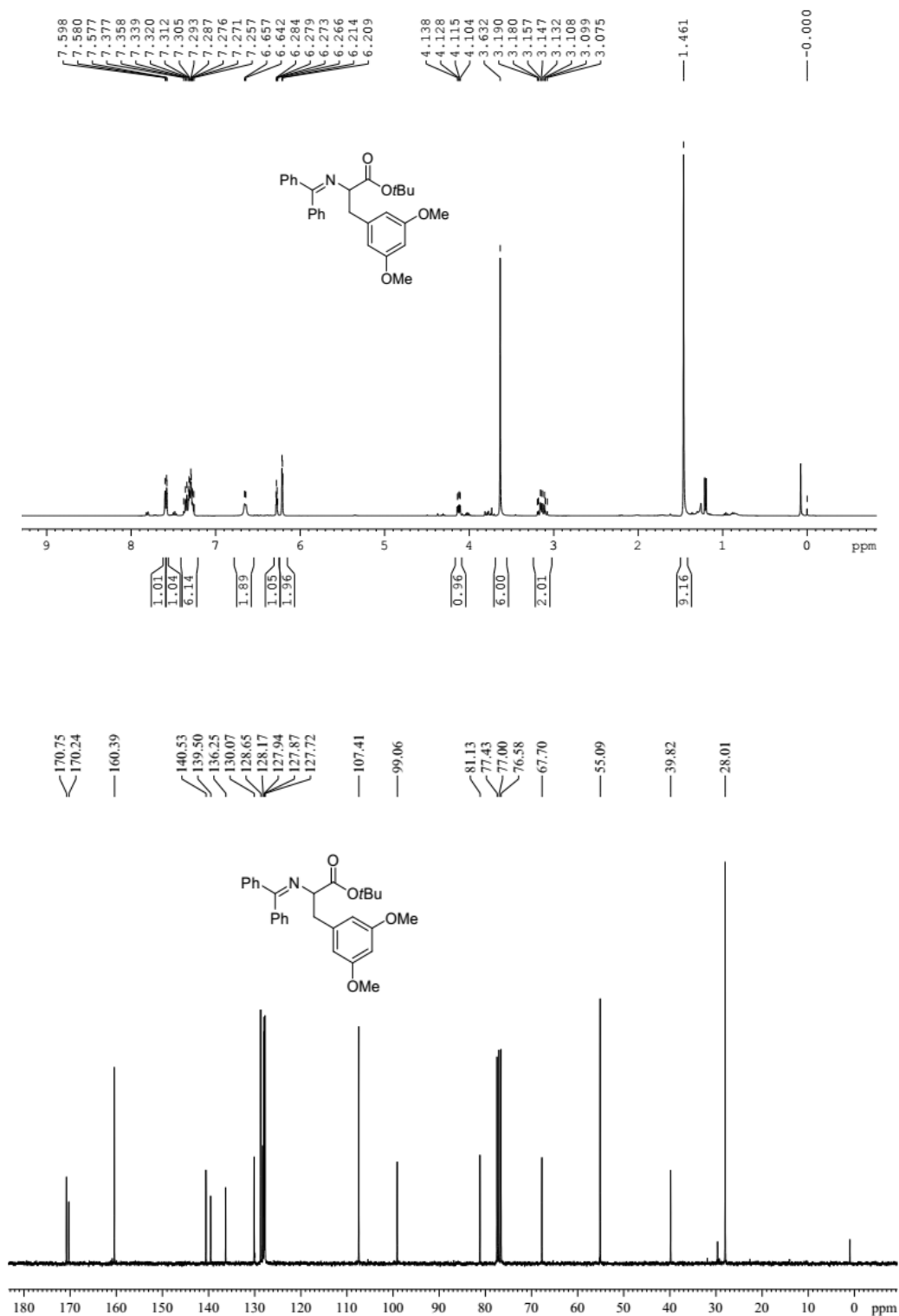


HPLC chromatogram of **4g'**

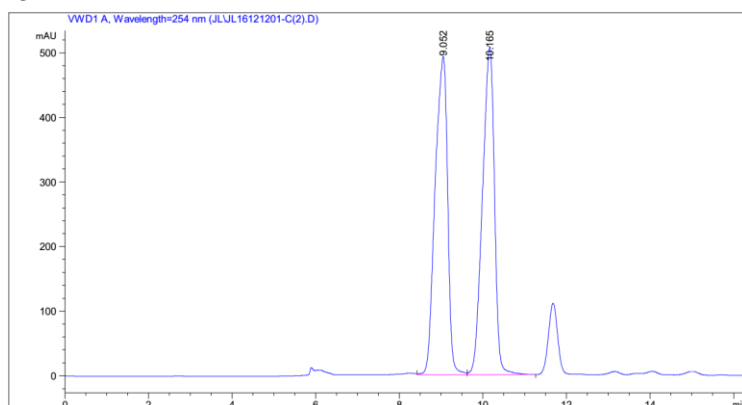


NMR spectra and HPLC chromatogram of **4h** and **4h'**

¹H and ¹³C NMR spectra of **4h** and **4h'**

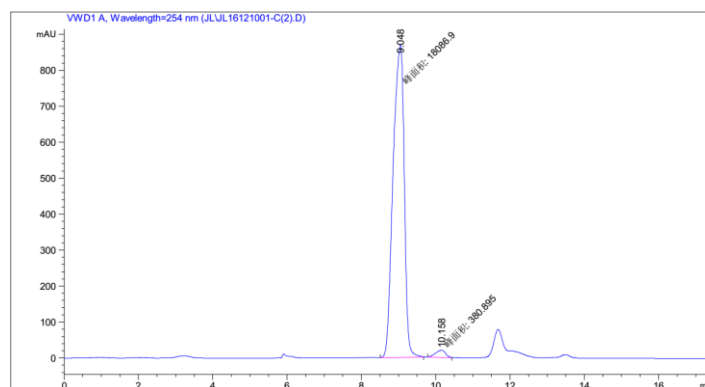


HPLC chromatogram of *rac*-4h (4h')



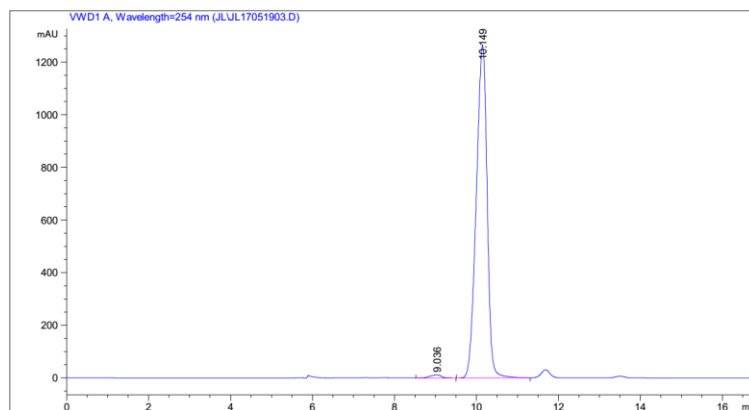
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1	9.052	VV	0.3466	1.02141e4	492.87582	50.2016
2	10.165	VB	0.3188	1.01321e4	507.64380	49.7984

HPLC chromatogram of 4h



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.048	MM	0.3465	1.80869e4	869.90308	97.9375
2	10.158	MM	0.3171	380.89493	20.02122	2.0625

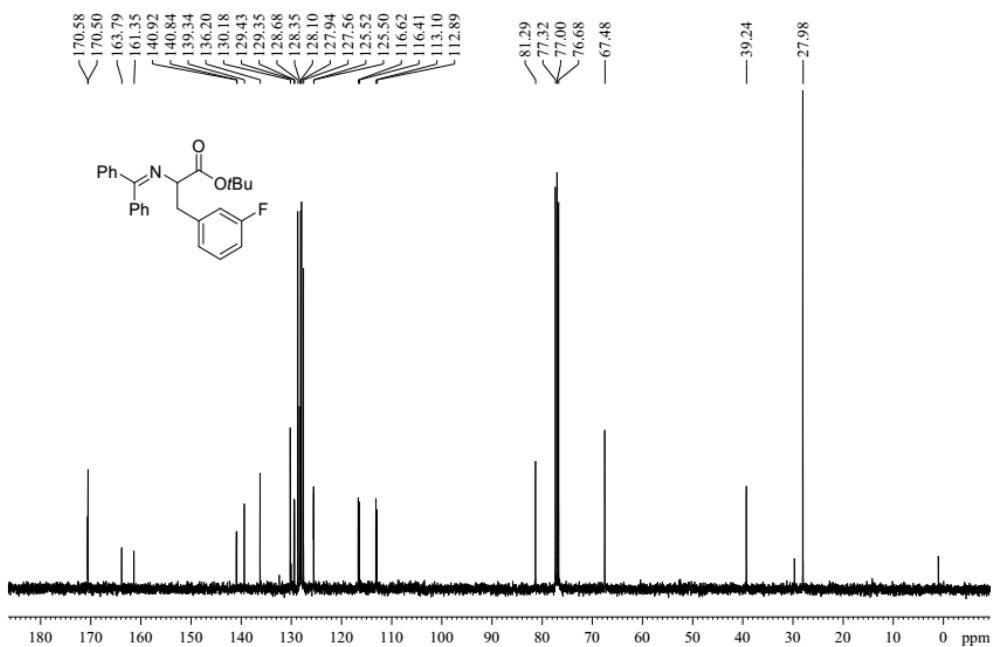
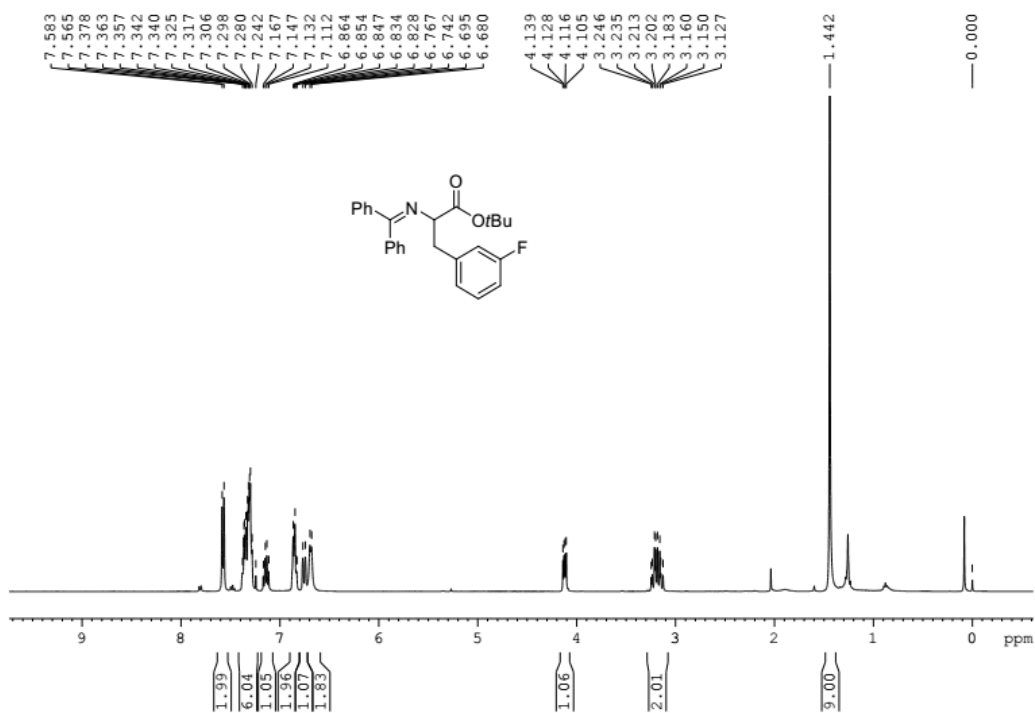
HPLC chromatogram of 4h'



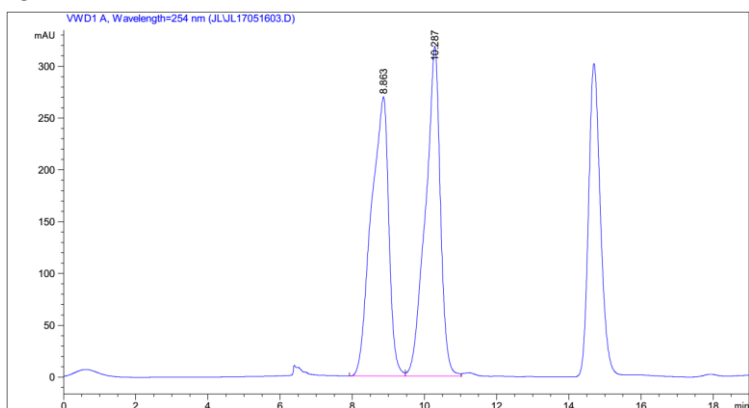
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.036	BB	0.3164	224.44653	11.65545	0.9551
2	10.149	BV	0.2889	2.32746e4	1264.93433	99.0449

NMR spectra and HPLC chromatogram of **4i** and **4i'**

¹H and ¹³C NMR spectra of **4i** and **4i'**

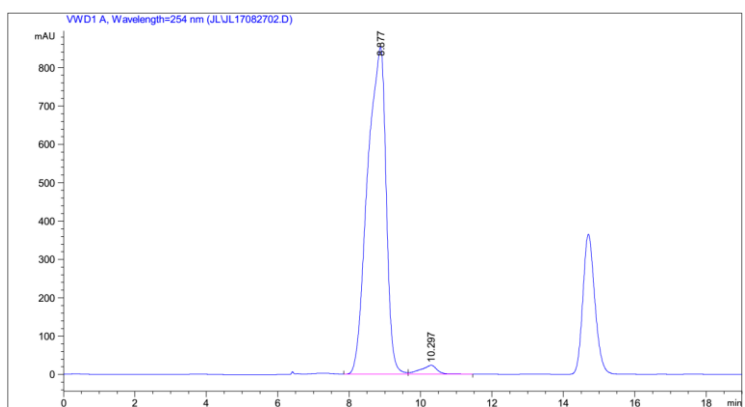


HPLC chromatogram of *rac*-**4i** (**4i'**)



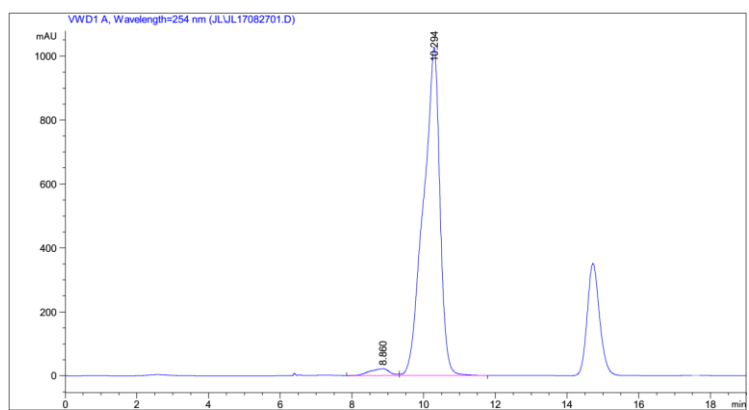
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1	8.863	BV	0.4611	9102.69434	269.42279	49.9121
2	10.287	VV	0.4004	9134.73828	318.25516	50.0879

HPLC chromatogram of **4i**



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.877	BV	0.4844	3.07185e4	852.67920	97.6025
2	10.297	VV	0.4454	754.58209	23.35627	2.3975

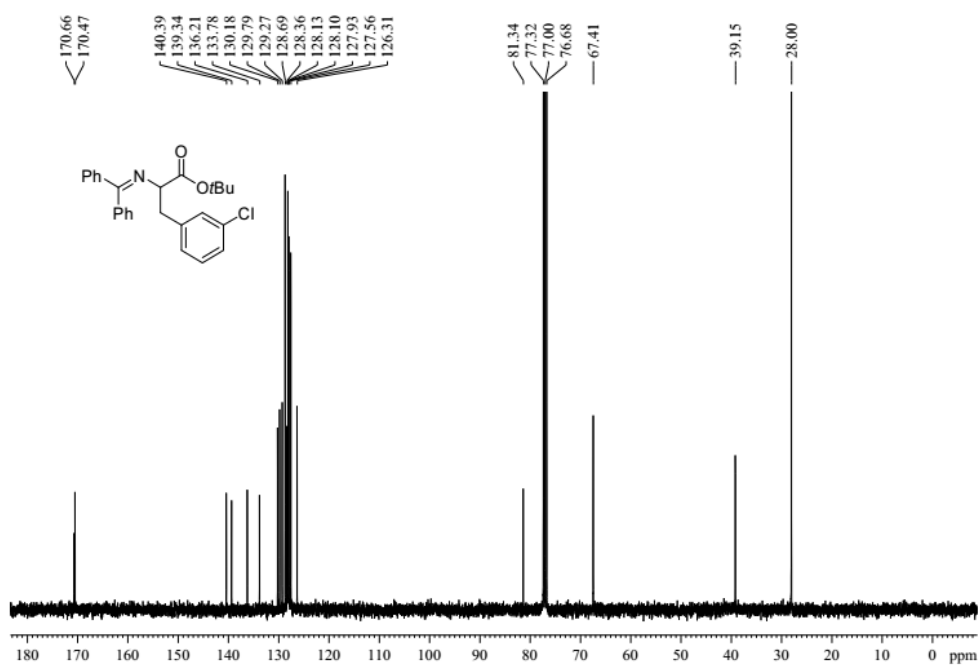
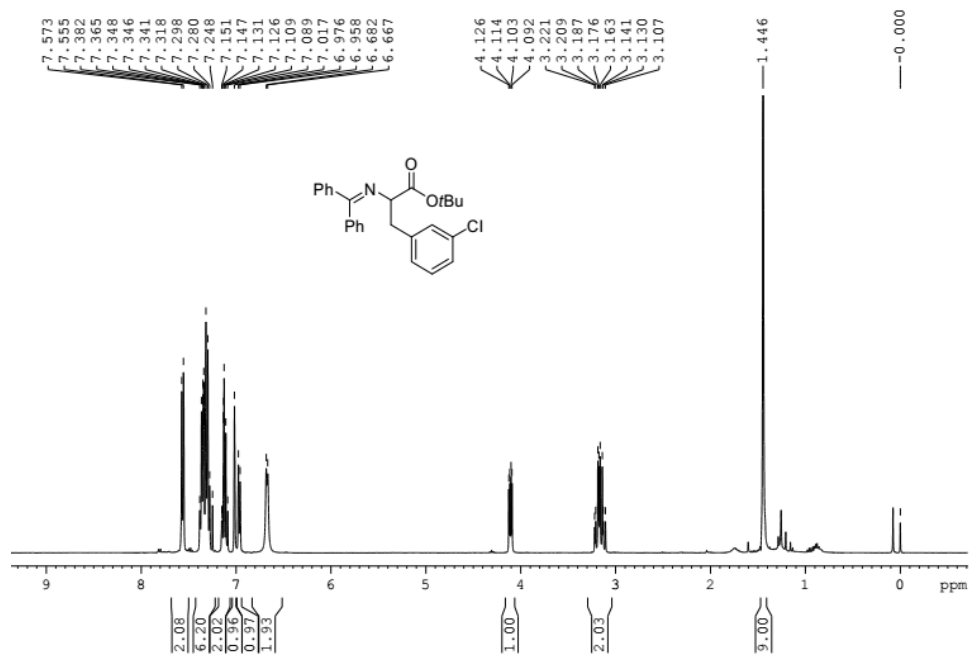
HPLC chromatogram of **4i'**



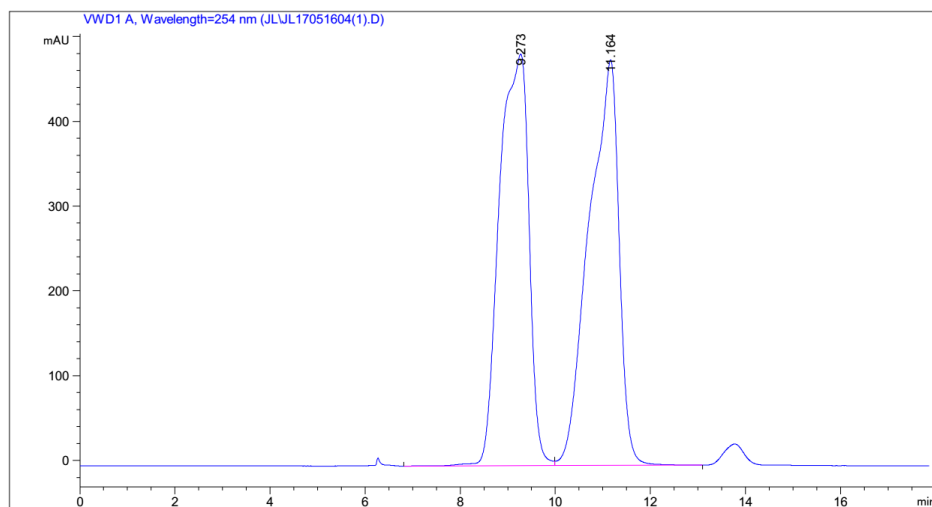
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1	8.860	BV	0.5257	838.35797	21.73728	2.4940
2	10.294	VB	0.4394	3.27762e4	1026.64282	97.5060

NMR spectra and HPLC chromatogram of 4j and 4j'

¹H and ¹³C NMR spectra of 4j and 4j'

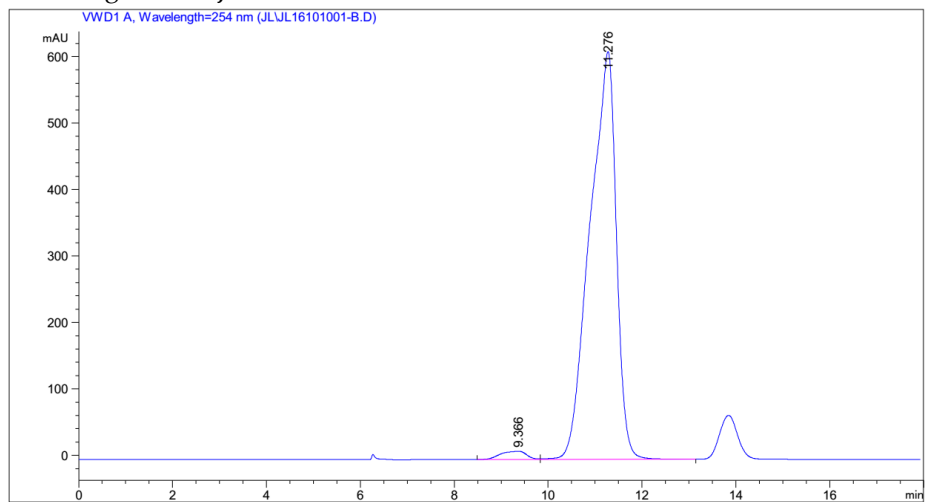


HPLC chromatogram of *rac-4j*



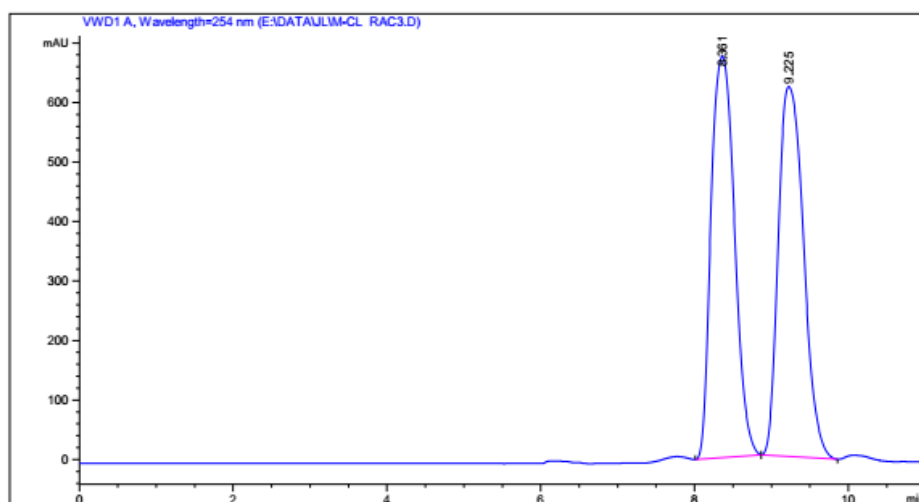
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1	9.273	BV	0.5766	2.09055e4	485.47672	49.9838
2	11.164	VB	0.5873	2.09190e4	478.37338	50.0162

HPLC chromatogram of **4j**



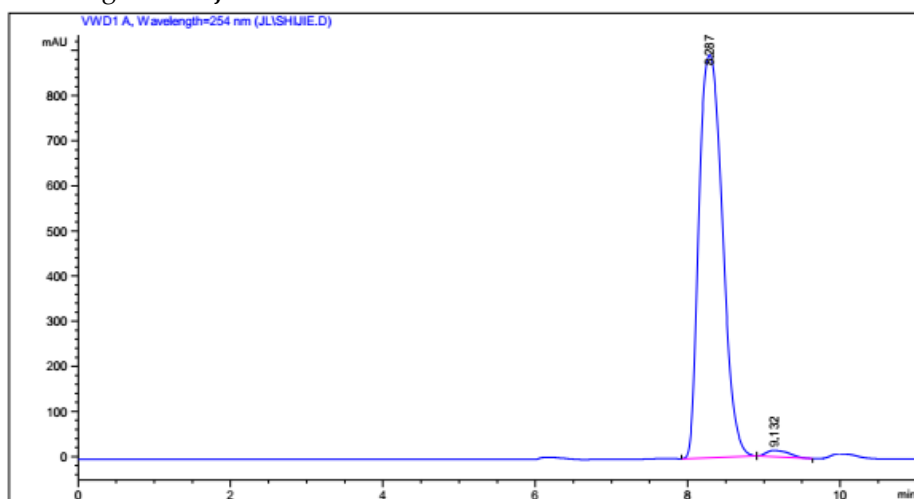
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1	9.366	BV	0.5233	467.99289	12.23717	1.9181
2	11.276	VB	0.5309	2.39302e4	613.37714	98.0819

HPLC chromatogram of *rac-4j'*



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.361	BB	0.3448	1.42203e4	675.20050	50.1295
2	9.225	BB	0.3661	1.41469e4	621.65082	49.8705

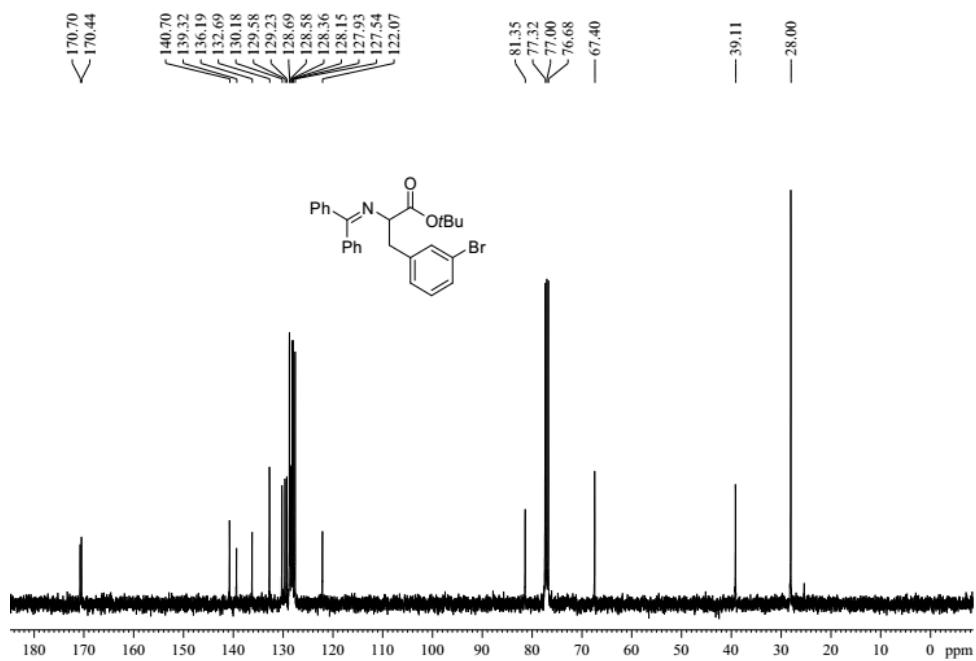
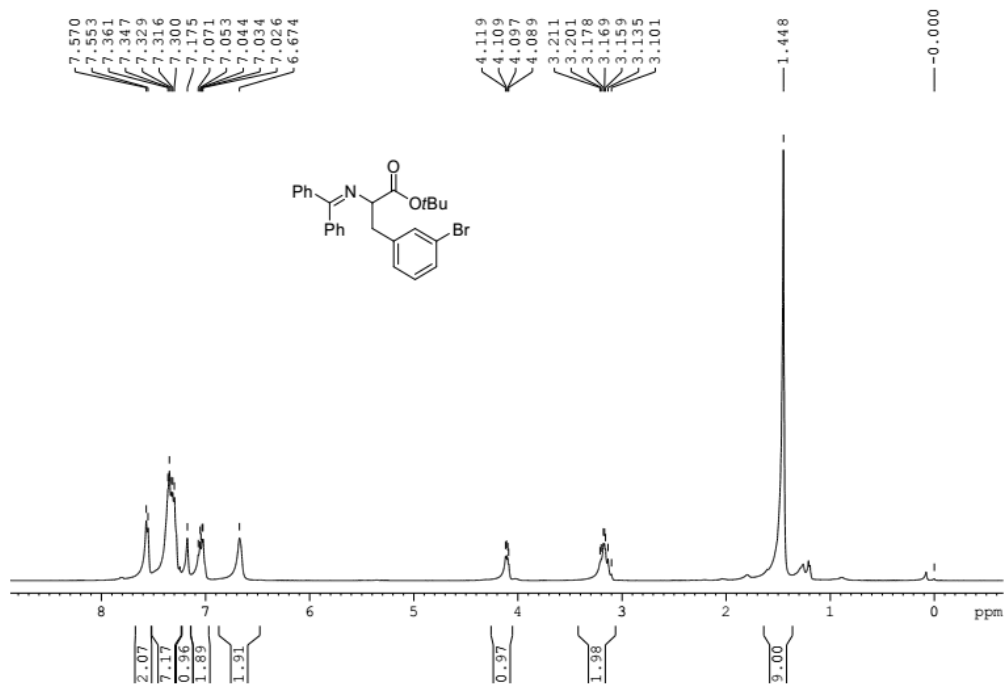
HPLC chromatogram of *4j'*



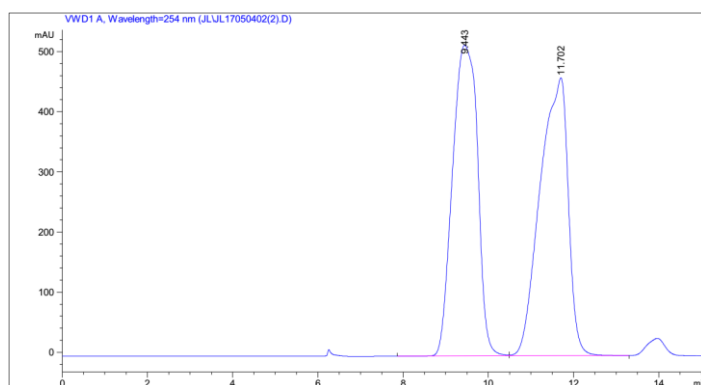
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.287	BB	0.3497	1.90647e4	892.75867	98.4652
2	9.132	BB	0.3496	297.15601	14.16903	1.5348

NMR spectra and HPLC chromatogram of **4k** and **4k'**

^1H and ^{13}C NMR spectra of **4k** and **4k'**

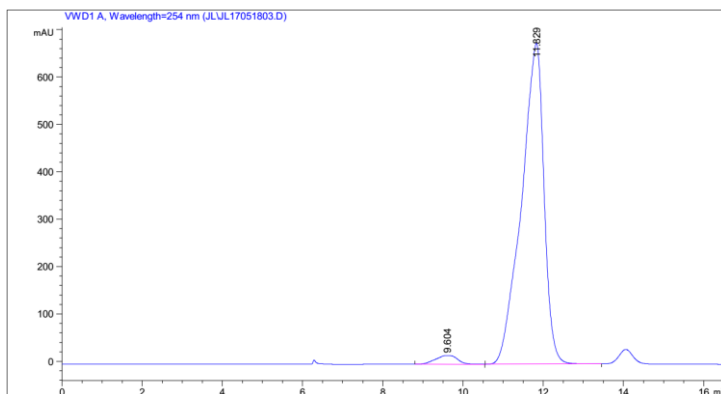


HPLC chromatogram of *rac*-4k (4k')



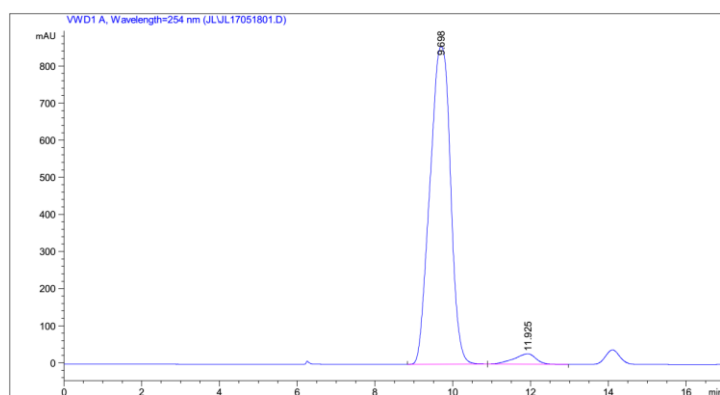
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.443	BV	0.6759	2.11636e4	516.67102	49.9899
2	11.702	VB	0.6028	2.11721e4	462.24307	50.0101

HPLC chromatogram of 4k



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.604	BB	0.5685	689.75122	18.45819	2.5488
2	11.829	BB	0.5854	2.63718e4	677.08789	97.4512

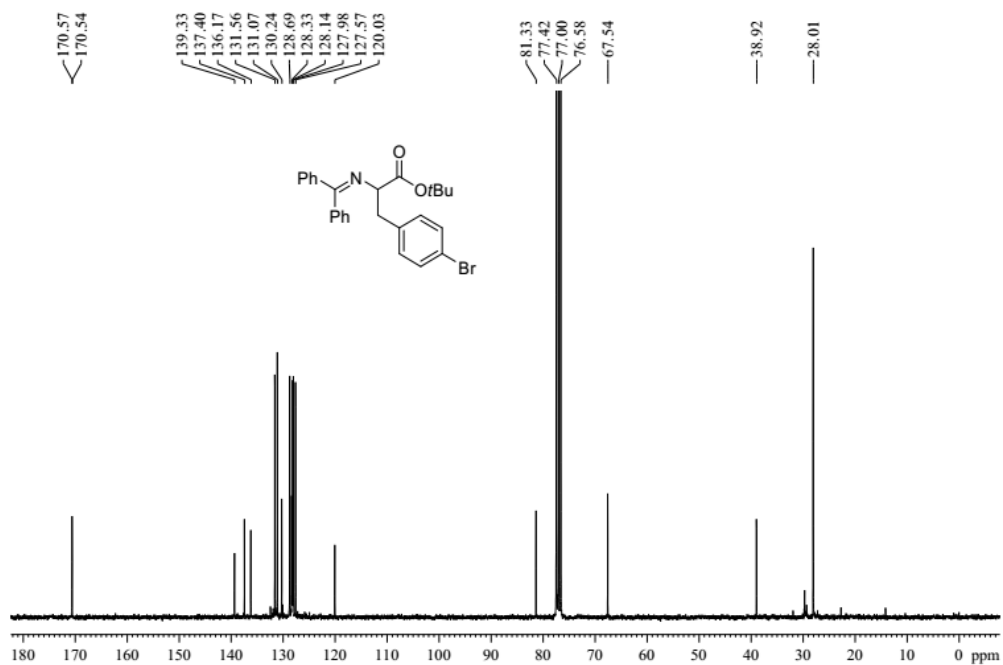
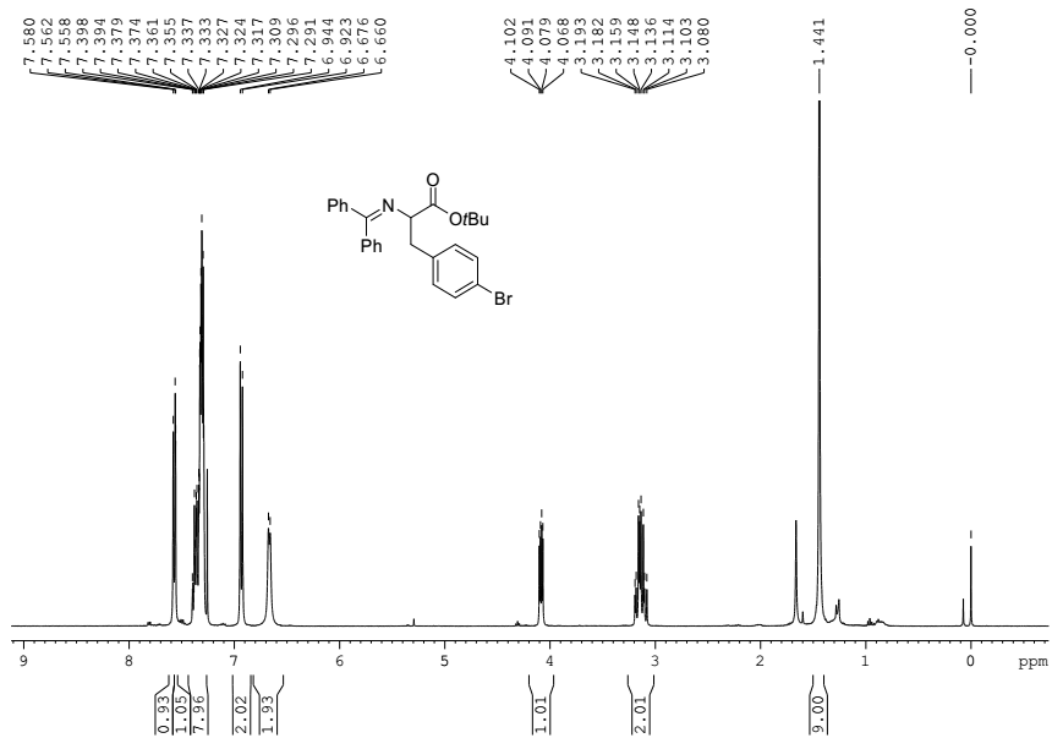
HPLC chromatogram of 4k'



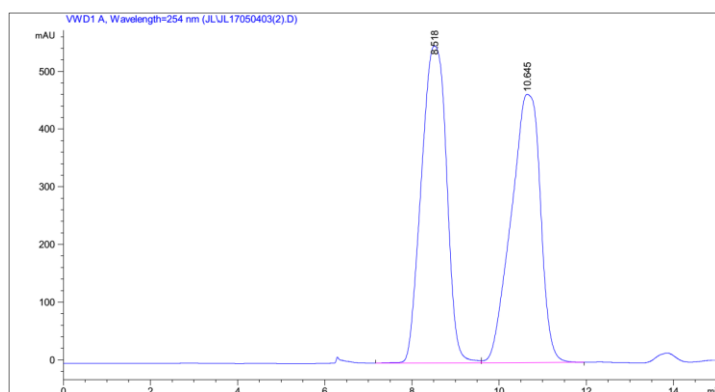
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.698	BB	0.5579	3.14106e4	855.63013	96.6341
2	11.925	BB	0.5824	1094.09119	27.83064	3.3659

NMR spectra and HPLC chromatogram of 4I and 4I'

¹H and ¹³C NMR spectra of 4I and 4I'

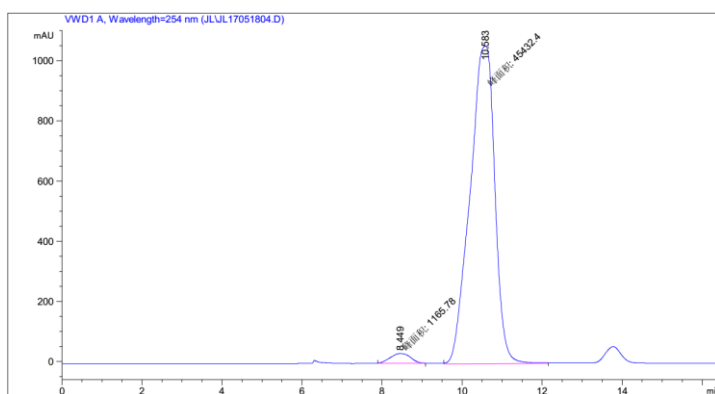


HPLC chromatogram of *rac*-**4I** (**4I'**)



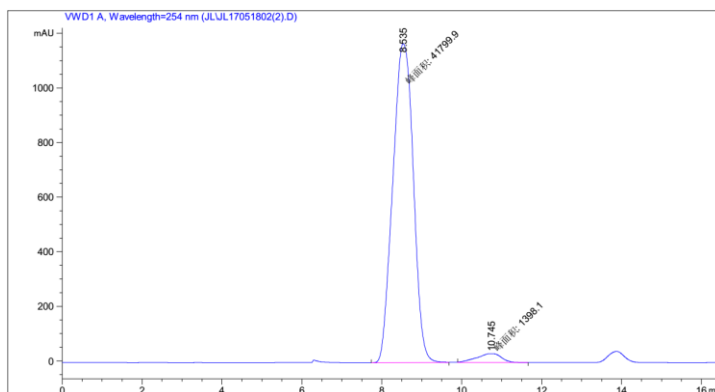
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.518	BV	0.6448	2.20682e4	549.42438	50.3824
2	10.645	VB	0.6936	2.17332e4	465.13022	49.6176

HPLC chromatogram of **4I**



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.449	MM	0.5908	1165.78491	32.88894	2.5018
2	10.583	MM	0.7173	4.54324e4	1055.66943	97.4982

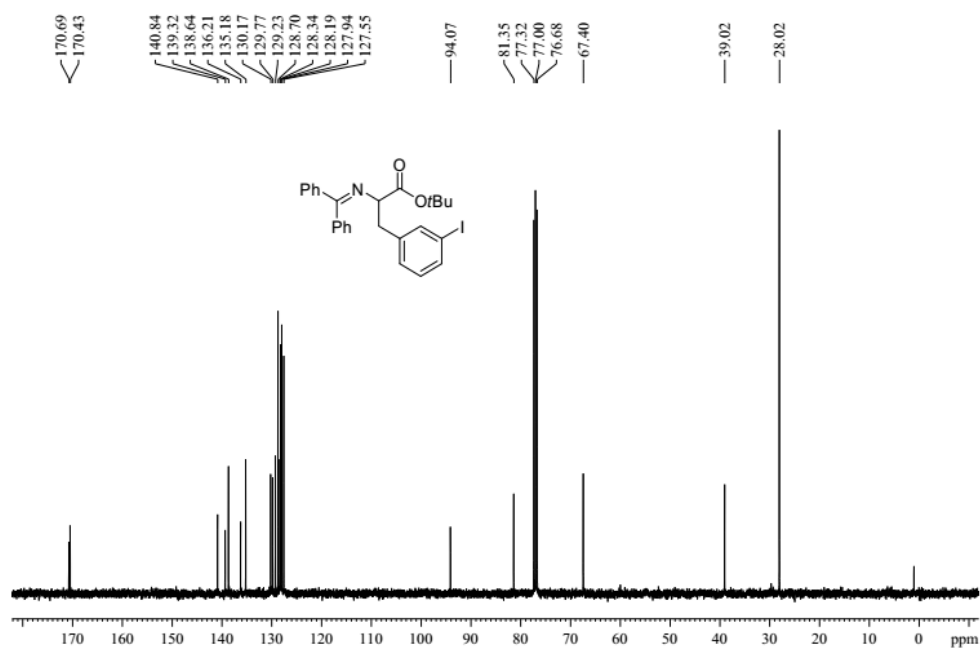
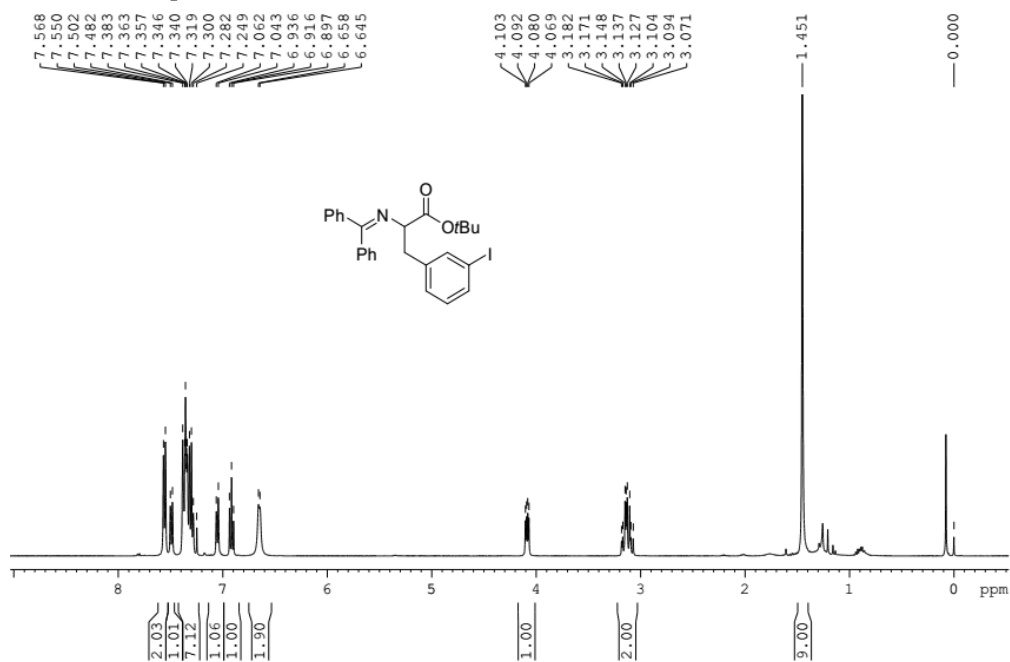
HPLC chromatogram of **4I'**



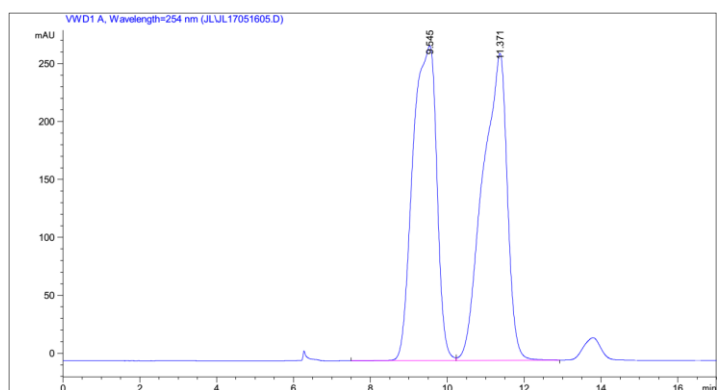
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	8.535	MM	0.5960	4.17999e4	1168.88110	96.7635
2	10.745	MM	0.7238	1398.09924	32.19222	3.2365

NMR spectra and HPLC chromatogram of **4m** and **4m'**

^1H and ^{13}C NMR spectra of **4m** and **4m'**

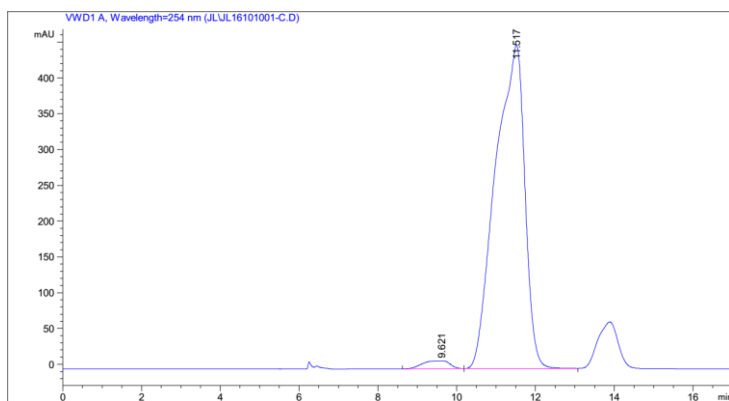


HPLC chromatogram of *rac*-4m (4m')



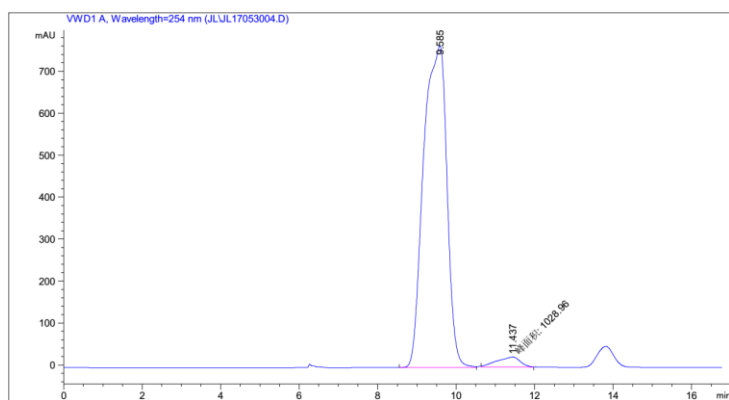
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.545	BV	0.5767	1.17008e4	271.68500	49.9704
2	11.371	VB	0.5974	1.17146e4	264.91830	50.0296

HPLC chromatogram of 4m



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.621	BV	0.6358	528.56335	11.15546	2.2168
2	11.517	VB	0.6909	2.33148e4	451.78198	97.7832

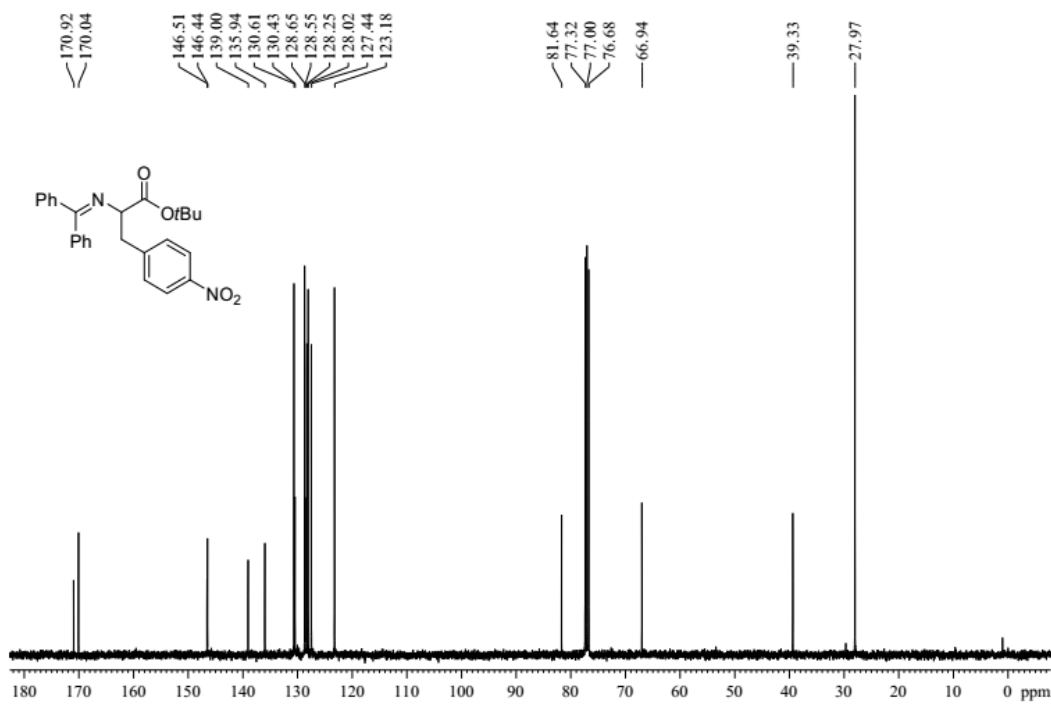
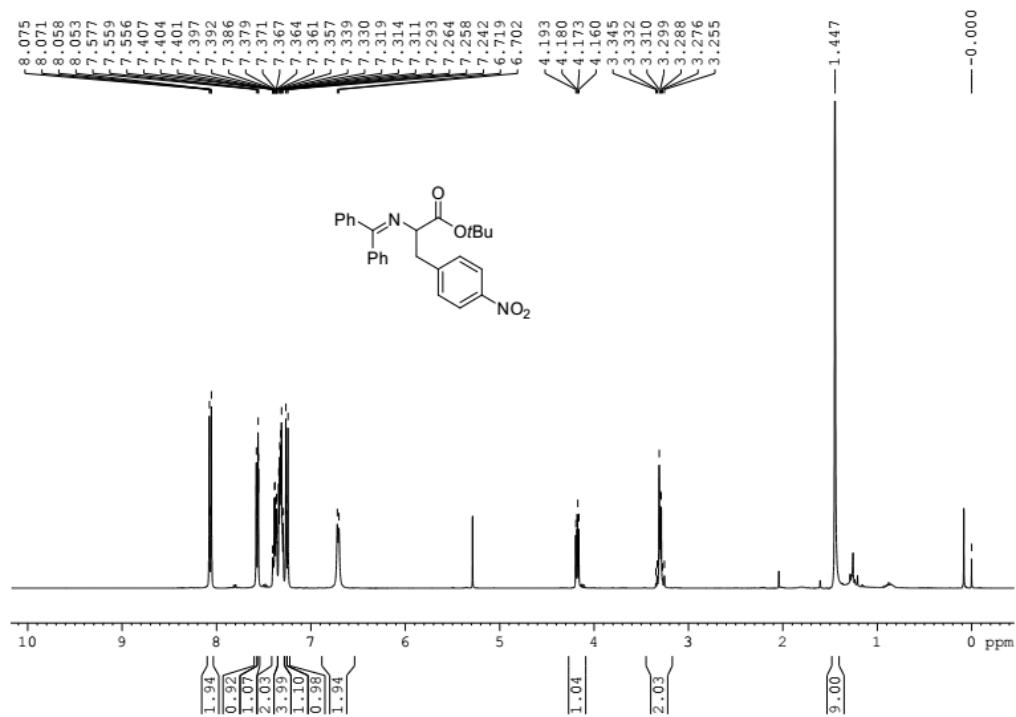
HPLC chromatogram of 4m'



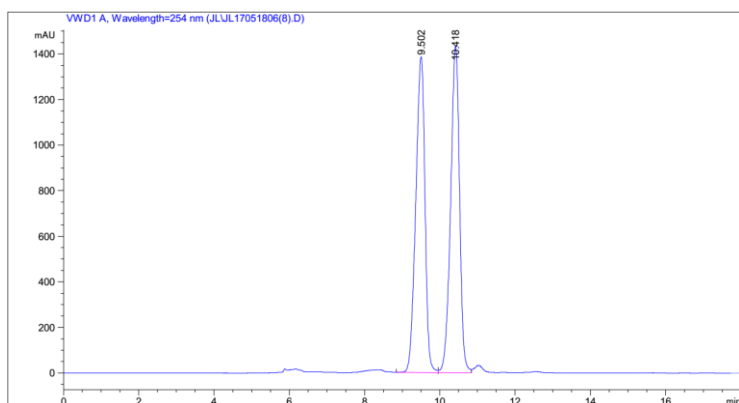
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.585	BV	0.5521	3.15561e4	765.85803	96.8422
2	11.437	MM	0.6992	1028.95996	24.52723	3.1578

NMR spectra and HPLC chromatogram of **4n** and **4n'**

^1H and ^{13}C NMR spectra of **4n** and **4n'**

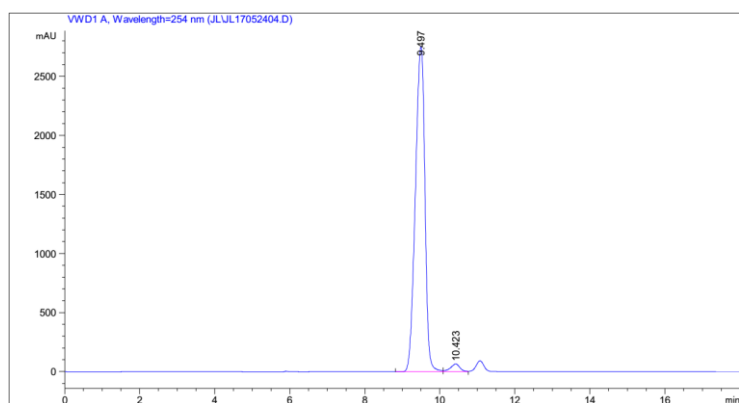


HPLC chromatogram of *rac*-4n (4n')



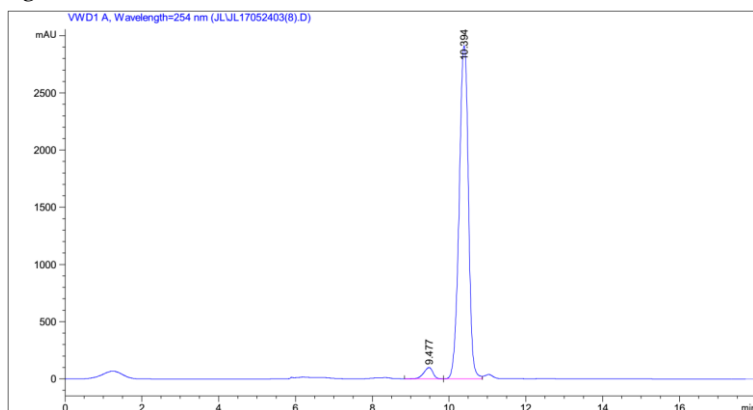
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.502	BV	0.2621	2.35259e4	1386.28088	49.9362
2	10.418	VV	0.2532	2.35860e4	1433.11316	50.0638

HPLC chromatogram of 4n



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.497	BV	0.2765	4.87463e4	2752.07056	97.6909
2	10.423	VV	0.2626	1152.19336	65.32389	2.3091

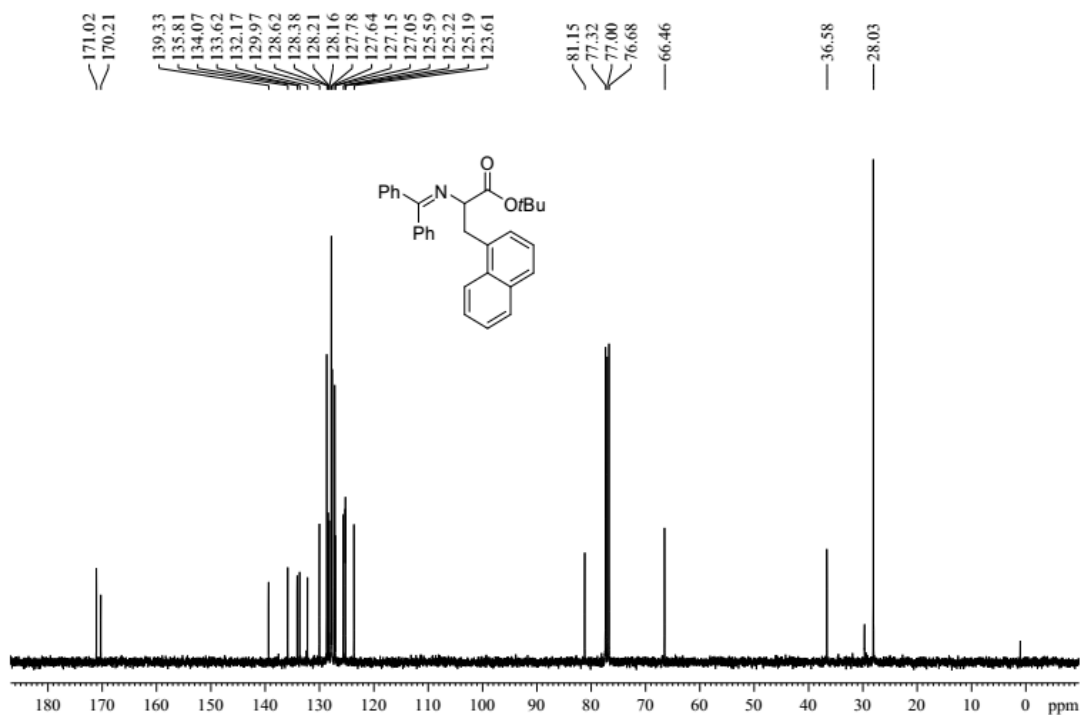
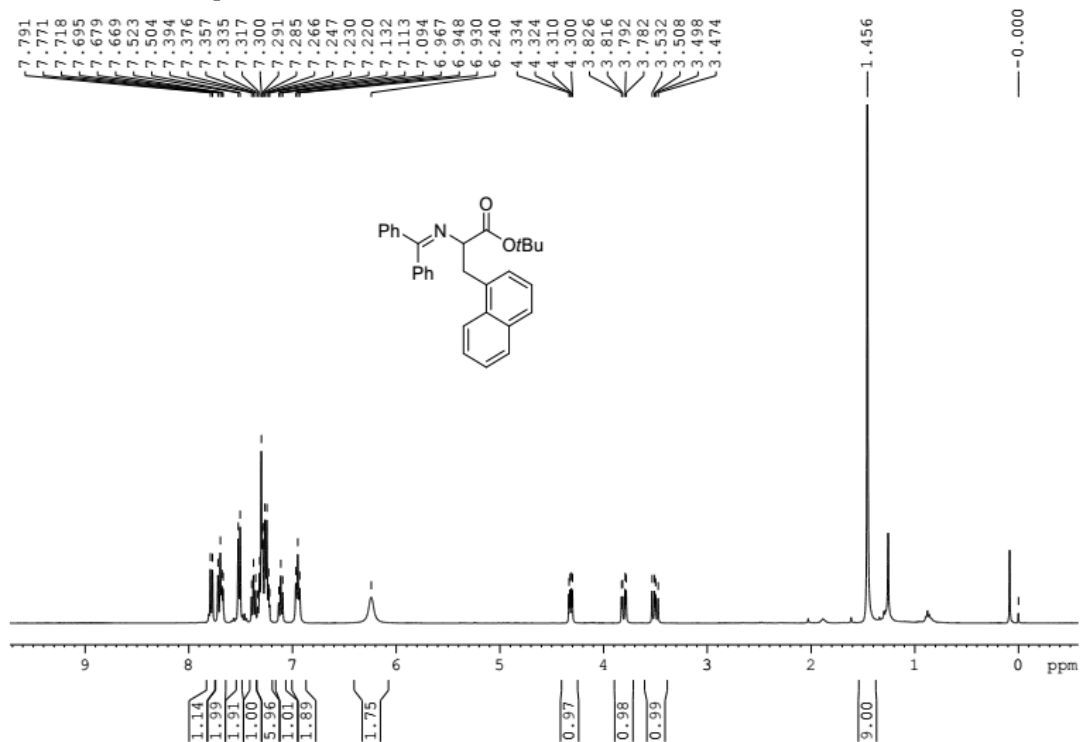
HPLC chromatogram of 4n'



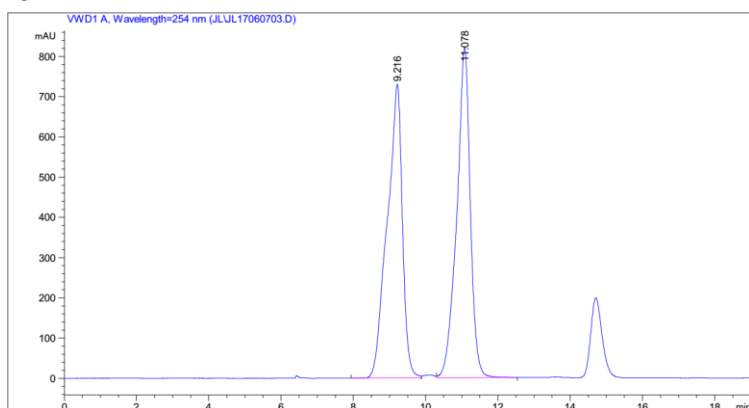
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.477	BB	0.2557	1626.01794	98.26515	3.2221
2	10.394	BV	0.2597	4.88388e4	2912.57715	96.7779

NMR spectra and HPLC chromatogram of **4o** and **4o'**

¹H and ¹³C NMR spectra of **4o** and **4o'**

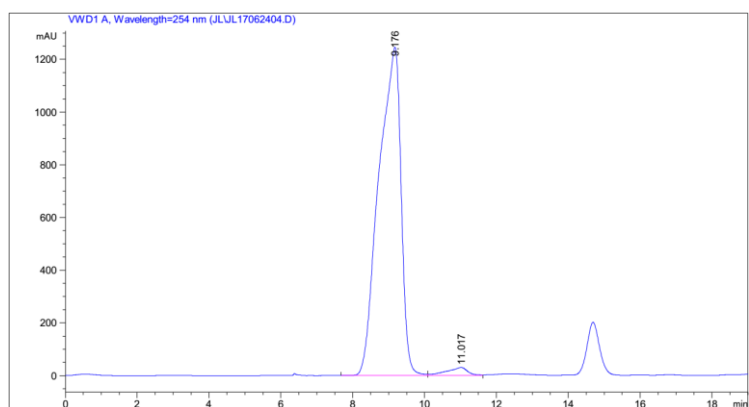


HPLC chromatogram of *rac*-4o (4o')



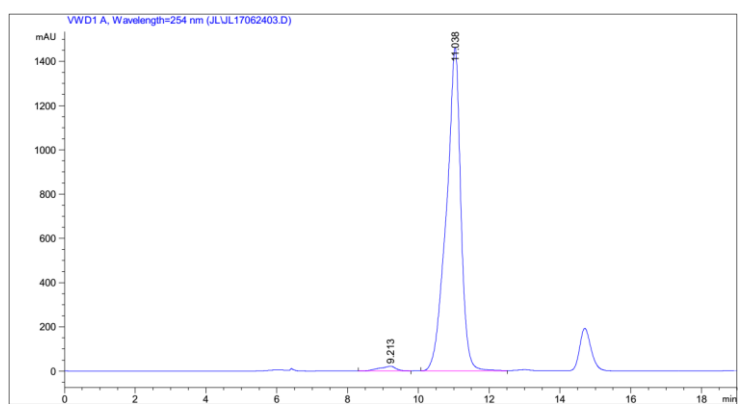
峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.216	BV	0.3994	2.12554e4	729.92163	49.8020
2	11.078	VB	0.3740	2.14245e4	821.79059	50.1980

HPLC chromatogram of 4o



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.176	BV	0.5754	5.33437e4	1245.51160	97.7920
2	11.017	VV	0.5371	1204.40552	30.16798	2.2080

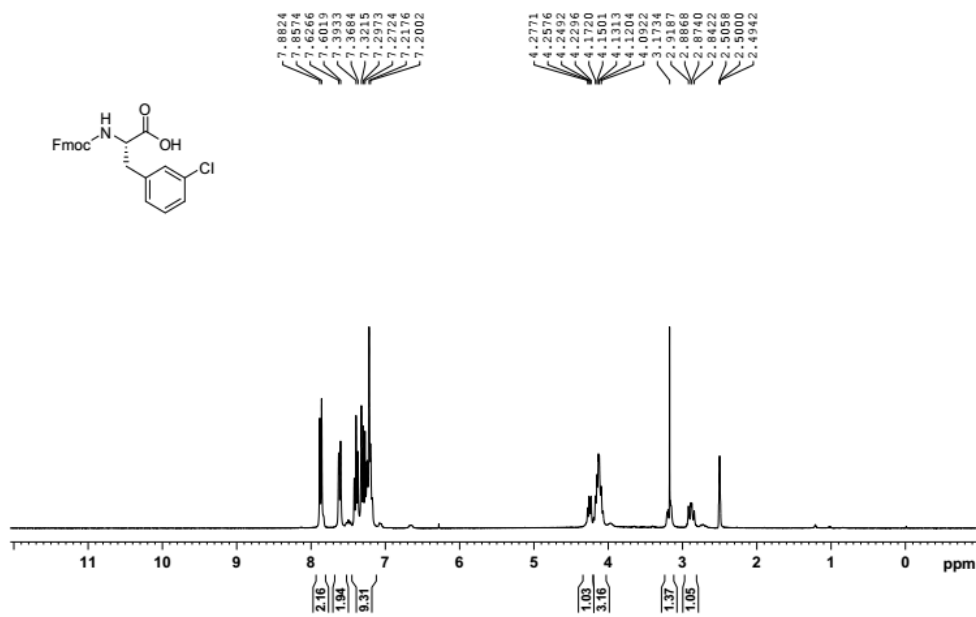
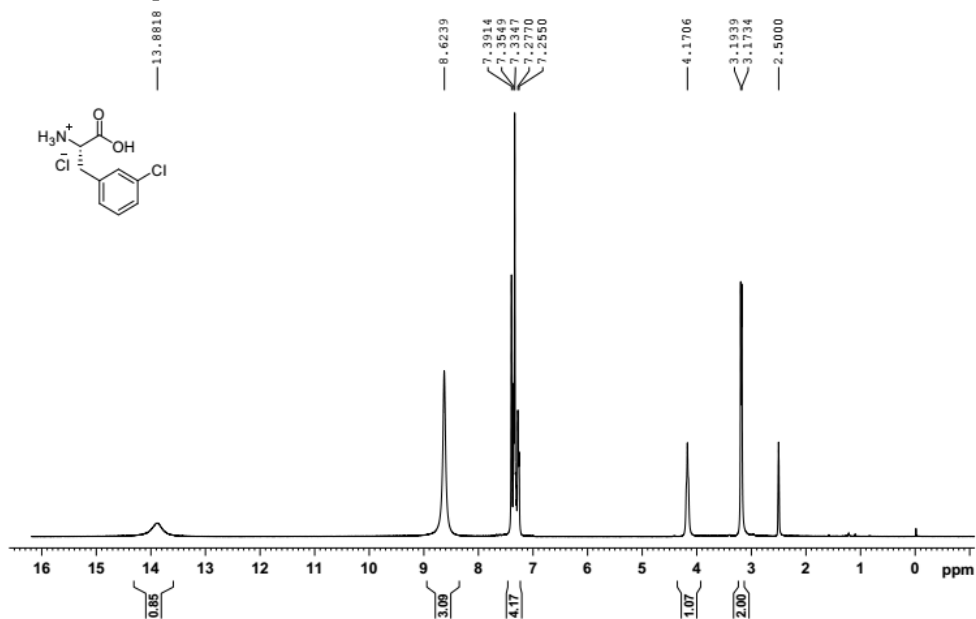
HPLC chromatogram of 4o;



峰 #	保留时间 [min]	类型	峰宽 [min]	峰面积 [mAU*s]	峰高 [mAU]	峰面积 %
1	9.213	BV	0.4411	708.93121	21.60378	1.6816
2	11.038	VV	0.3980	4.14482e4	1460.83630	98.3184

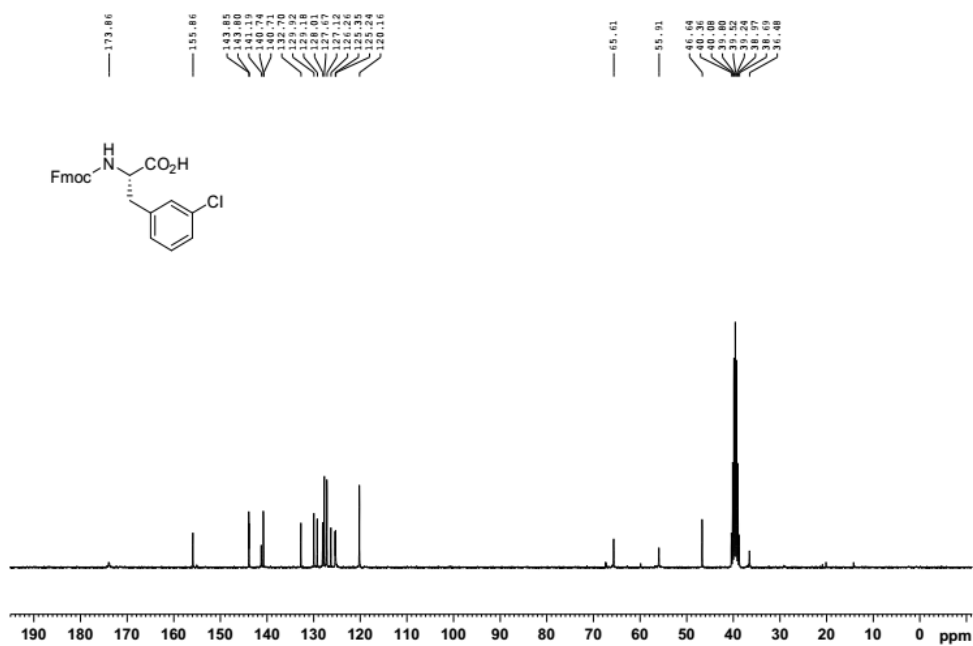
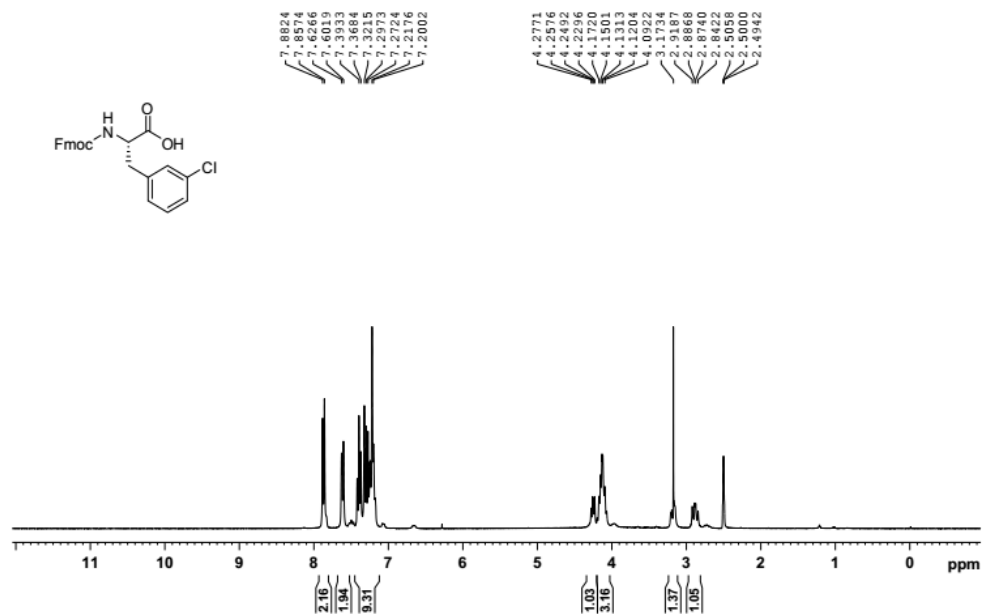
NMR spectra of 5

¹H and ¹³C NMR spectra of 5



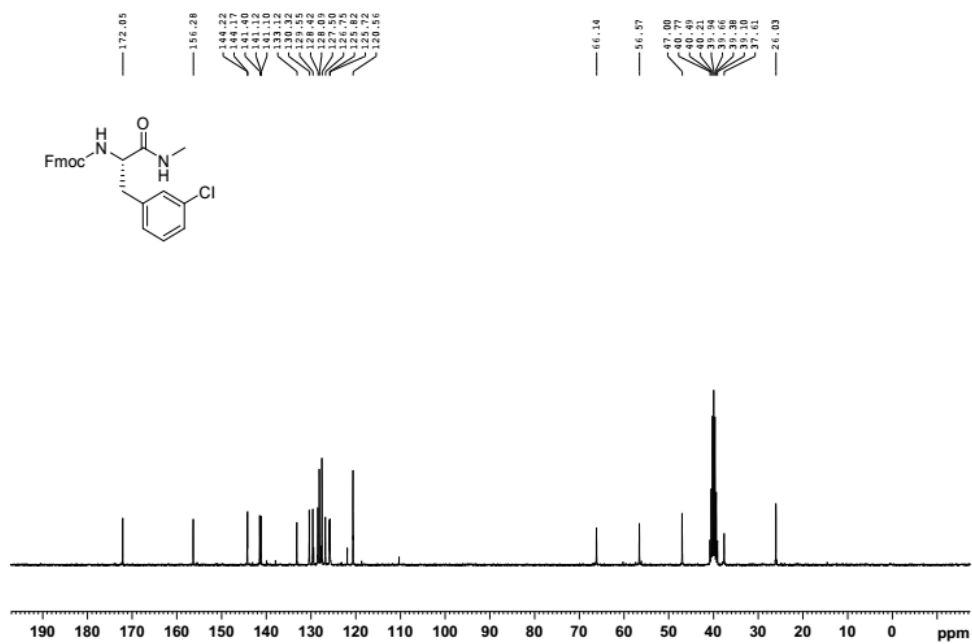
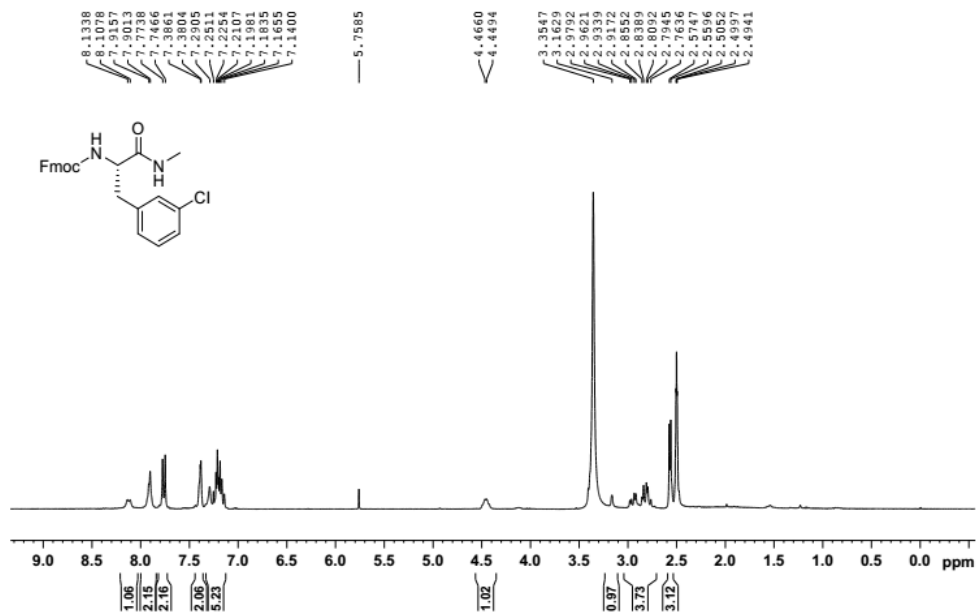
NMR spectra of **6**

¹H and ¹³C NMR spectra of **6**

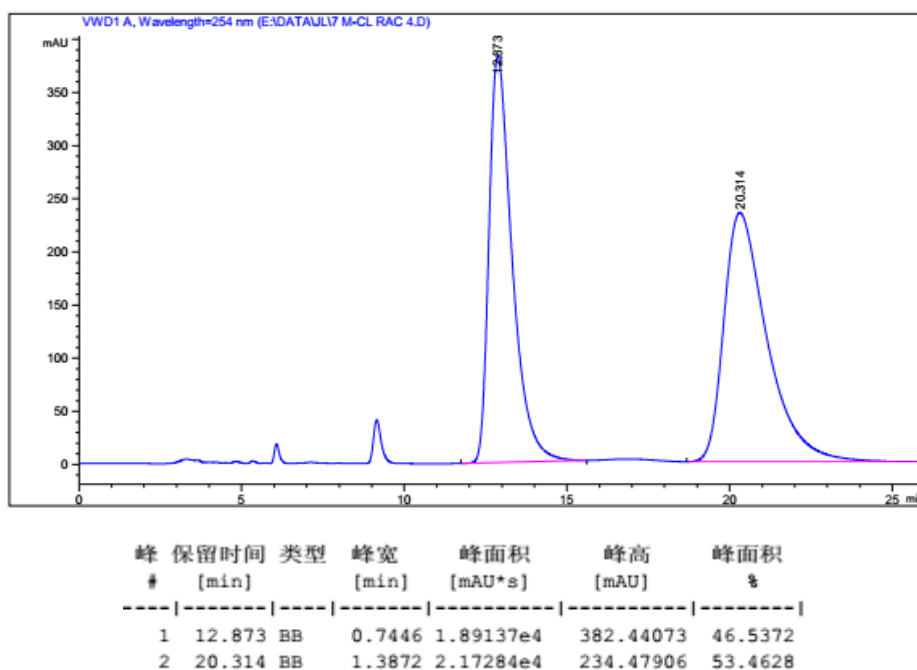


NMR spectra and HPLC chromatogram of 7

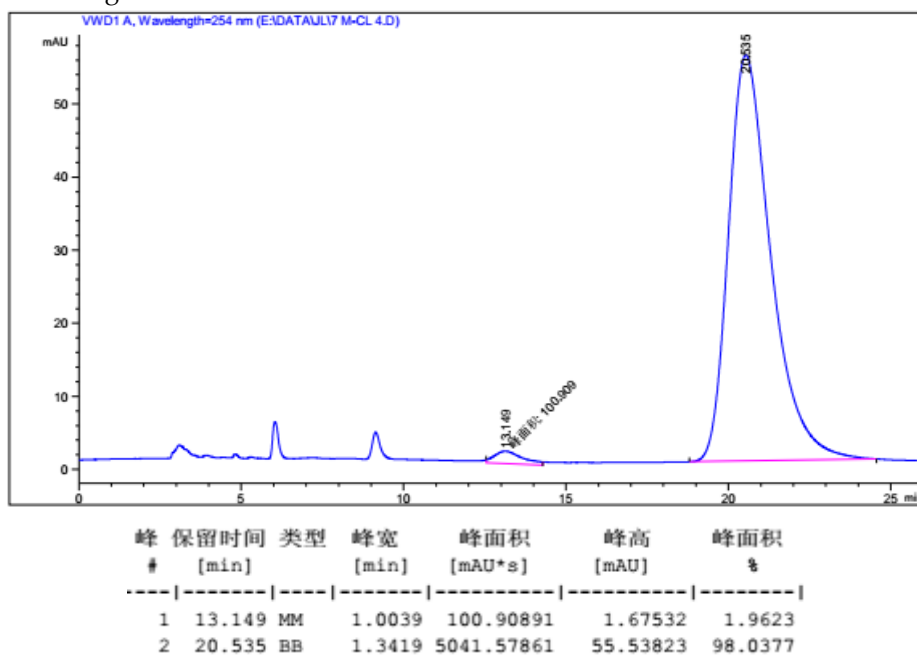
^1H and ^{13}C NMR spectra of 7



HPLC chromatogram of *rac-7*

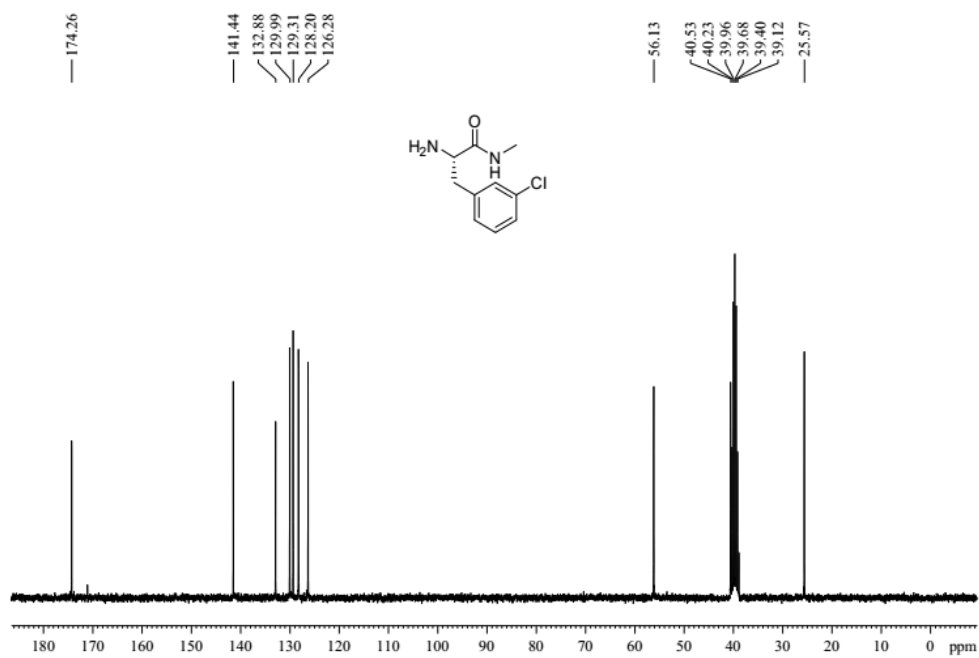
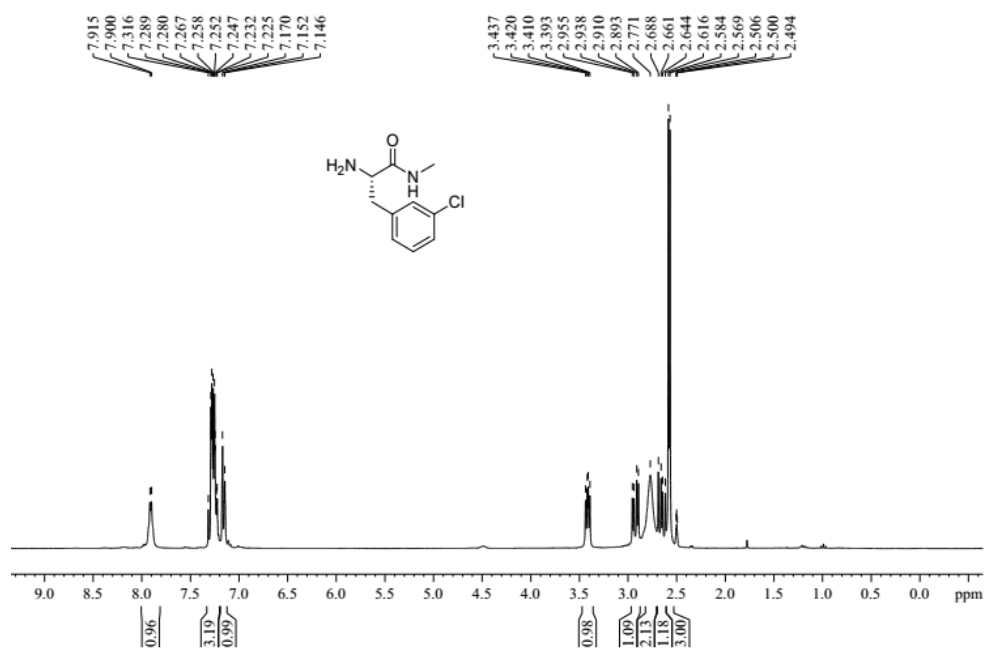


HPLC chromatogram of 7



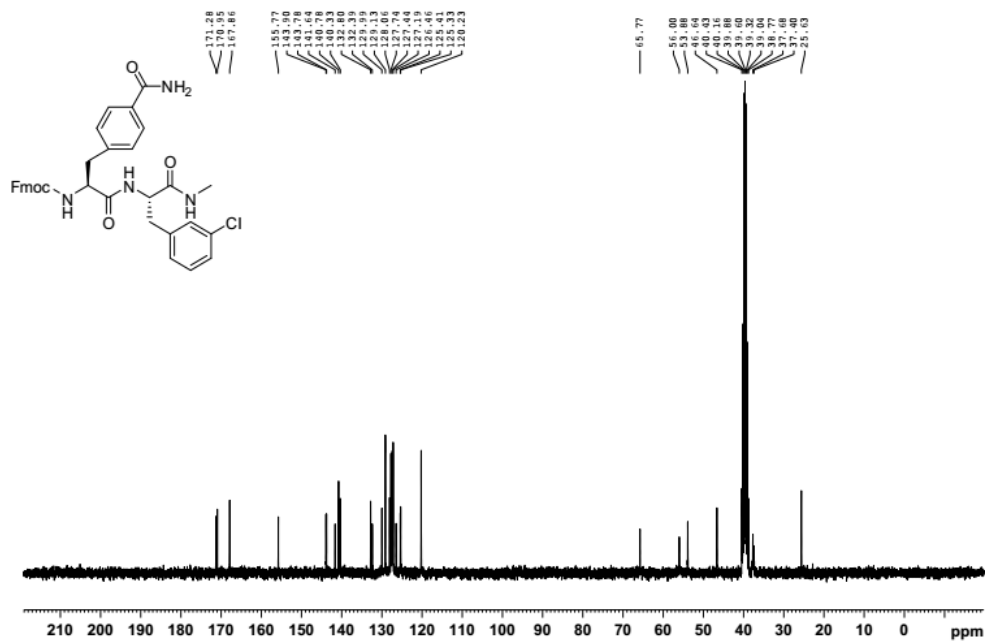
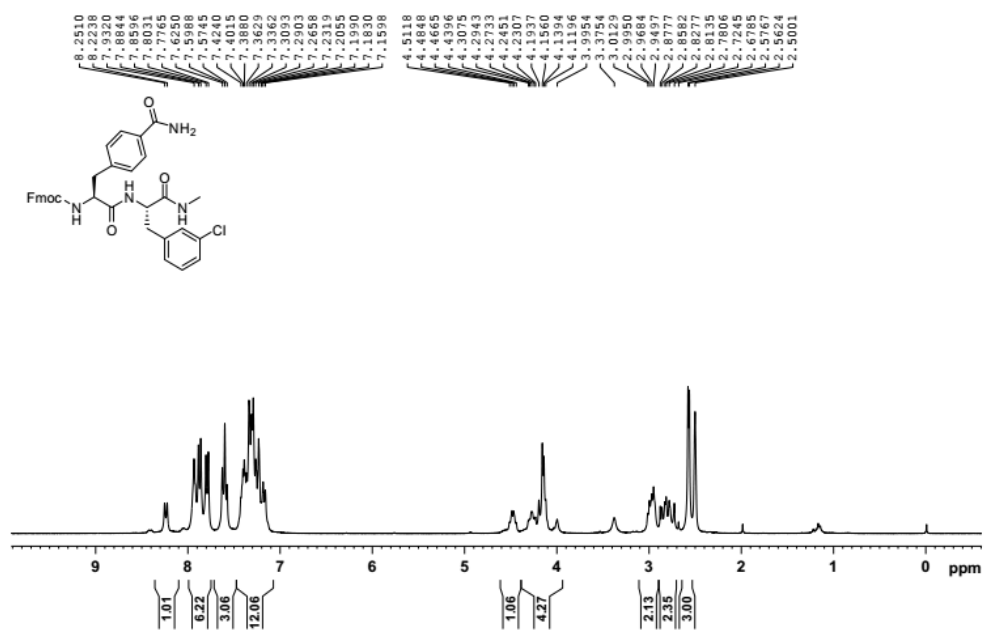
NMR spectra of 8

^1H and ^{13}C NMR spectra of 8



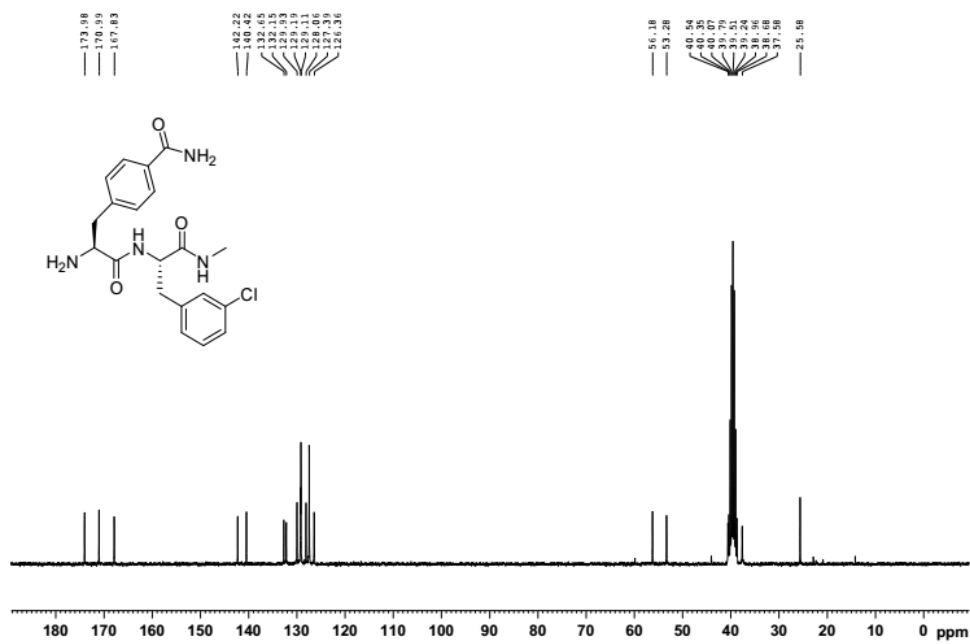
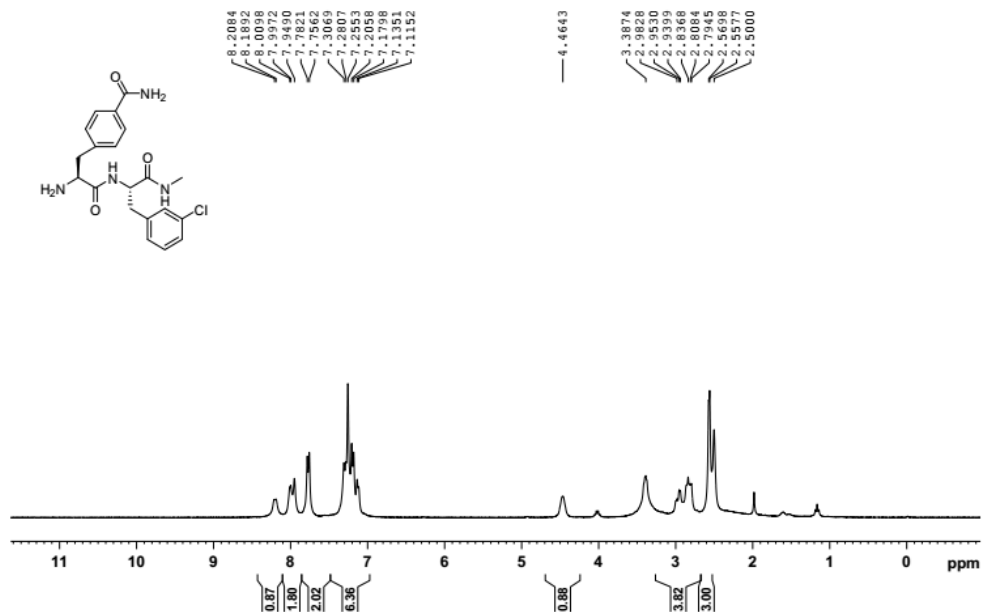
NMR spectra of 10

¹H and ¹³C NMR spectra of 10



NMR spectra of 11

¹H and ¹³C NMR spectra of 11



NMR spectra of 13

¹H and ¹³C NMR spectra of 13

