Supporting information

Efficient Chiral ^{1}H NMR Analysis of Indoloquinazoline Alkaloids Phaitanthrins A, Cephalanthrin-A and Their Analogues with A Chiral Phosphoric Acid

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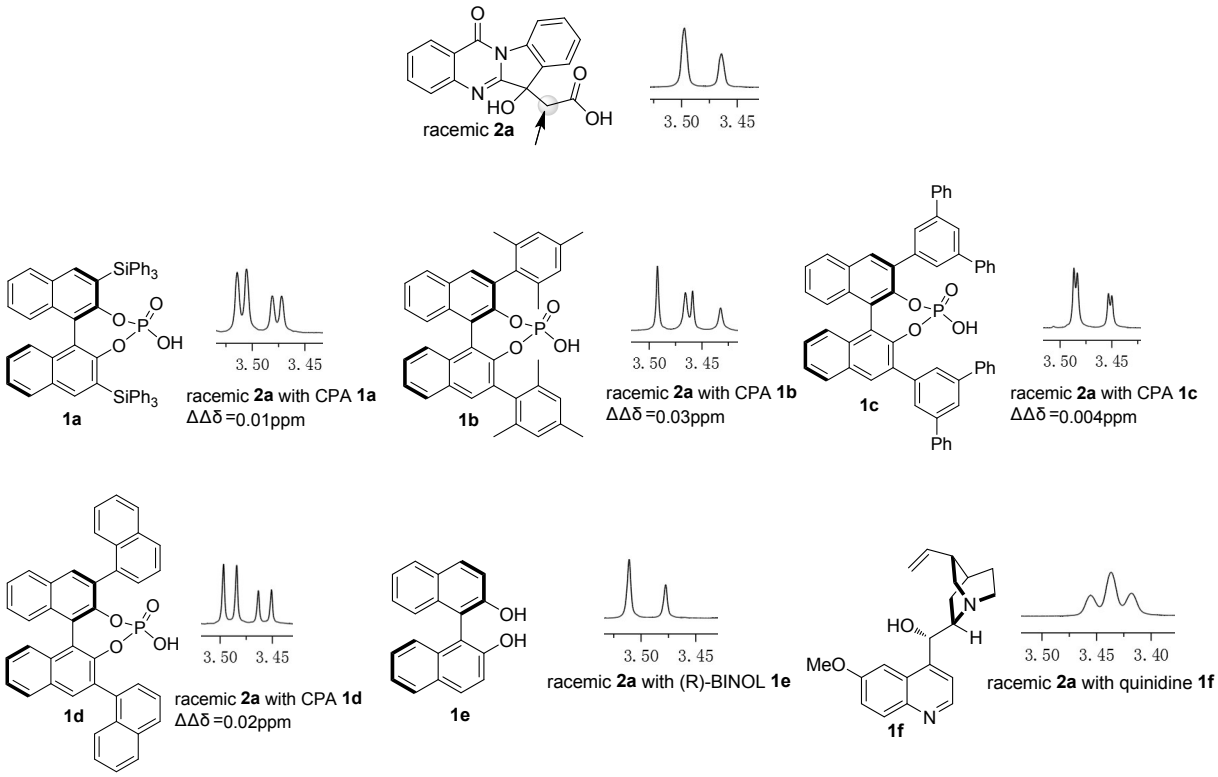
1. General information.

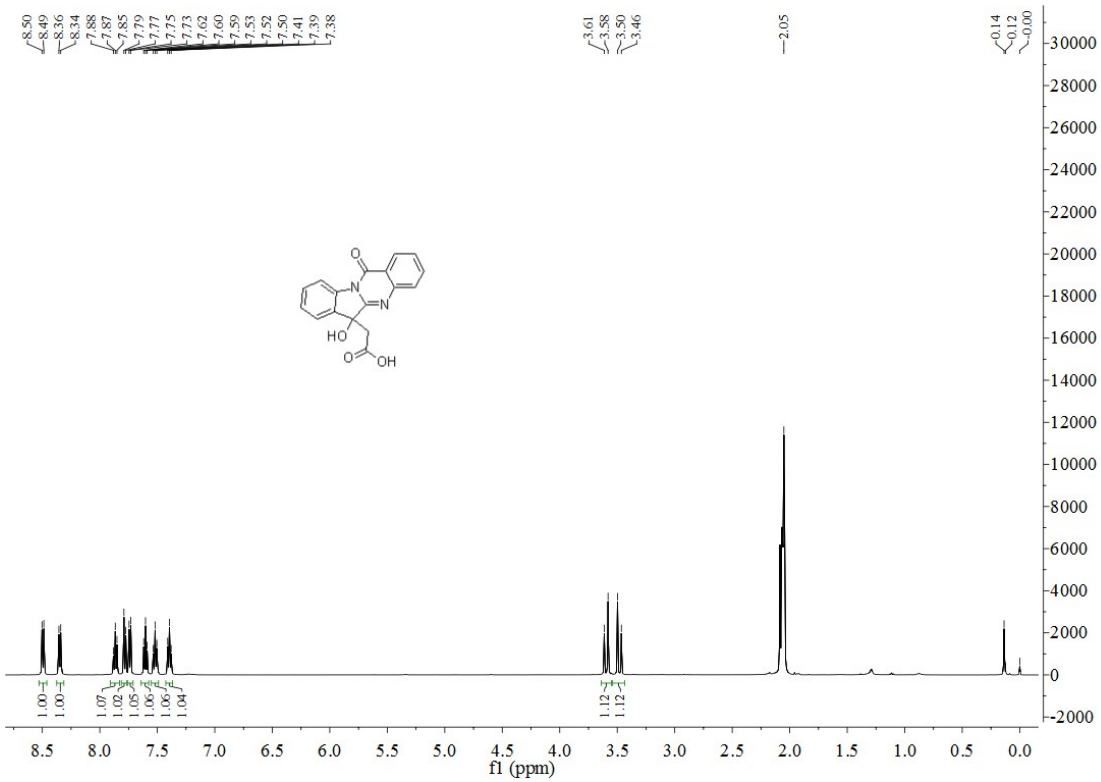
All commercial reagents were used as received without further purification unless otherwise stated. ^{1}H NMR (500 MHz) spectra were recorded in acetone-D_6 or $CDCl_3$ solutions using a 500 MHz spectrometer at 25 ^{o}C. Chemical shifts were reported in parts per million (ppm, δ) relative to residual TMS. **2q**, **2r**, **2s** were purchased from J&K Chemical Ltd. (Shanghai); **2a**-**2m** were synthesized according the procedures we developed previously (reference 7 in the main text); the chiral phosphoric acids were synthesized by known procedures (reference 11 in the main text).

2. Evaluating the chiral recognition abilities of chiral sensors 1a-1f (0.01 mmol) with 2a (0.01 mmol) in acetone-D_6 at 25 ^{o}C.

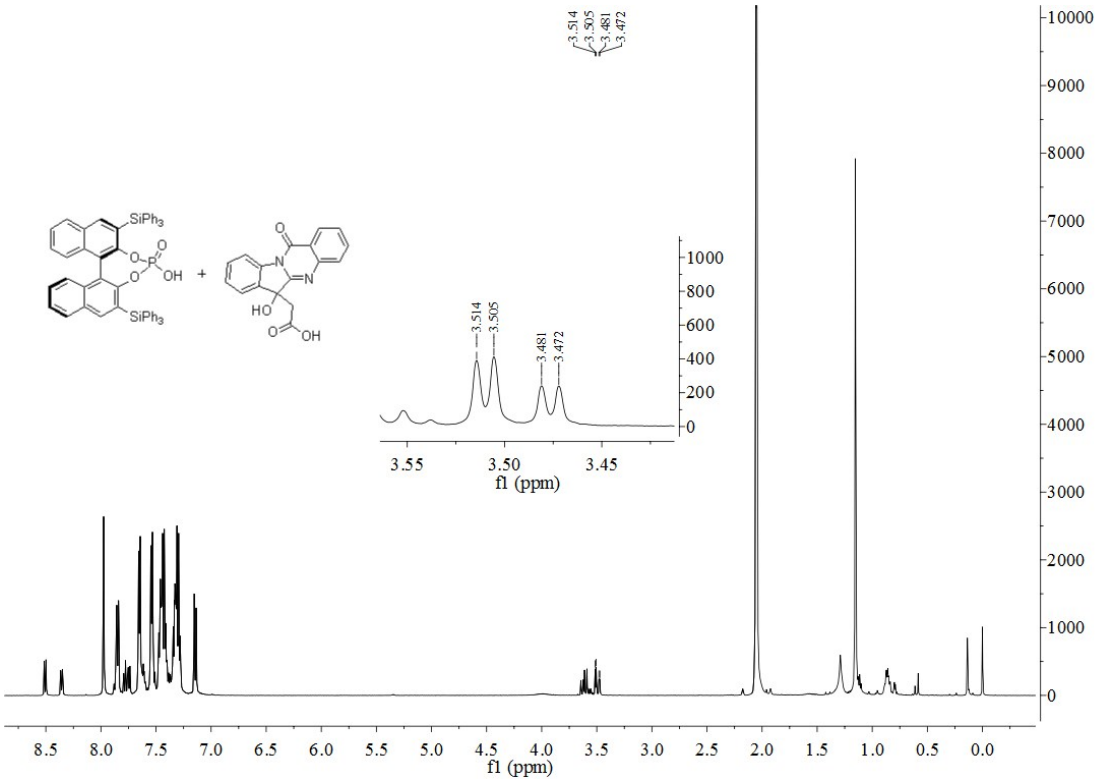


3. Copies of ^{1}H NMR spectra of chiral sensors 1a-1f (0.01 mmol, 1.0 equiv.) and racemic Cephalanthrin-A (0.01 mmol, 1.0 equiv.).

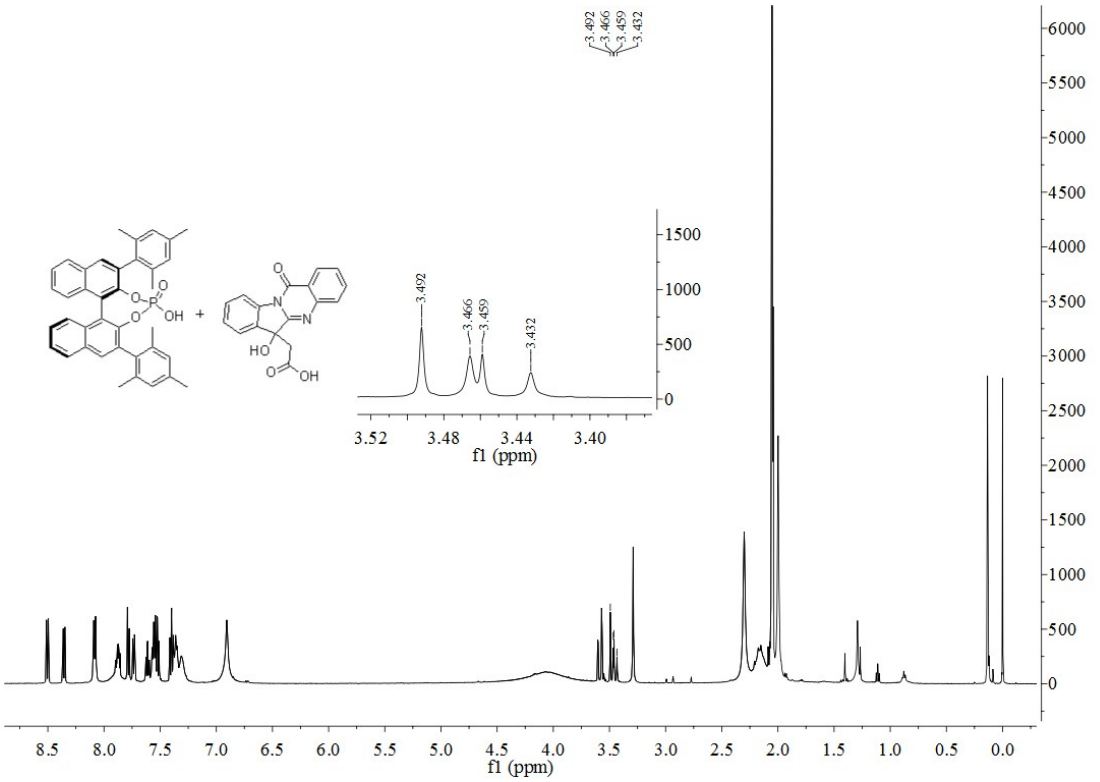
3.1. ^{1}H NMR (500 MHz, ACETONE-D_6) of racemic 2a.



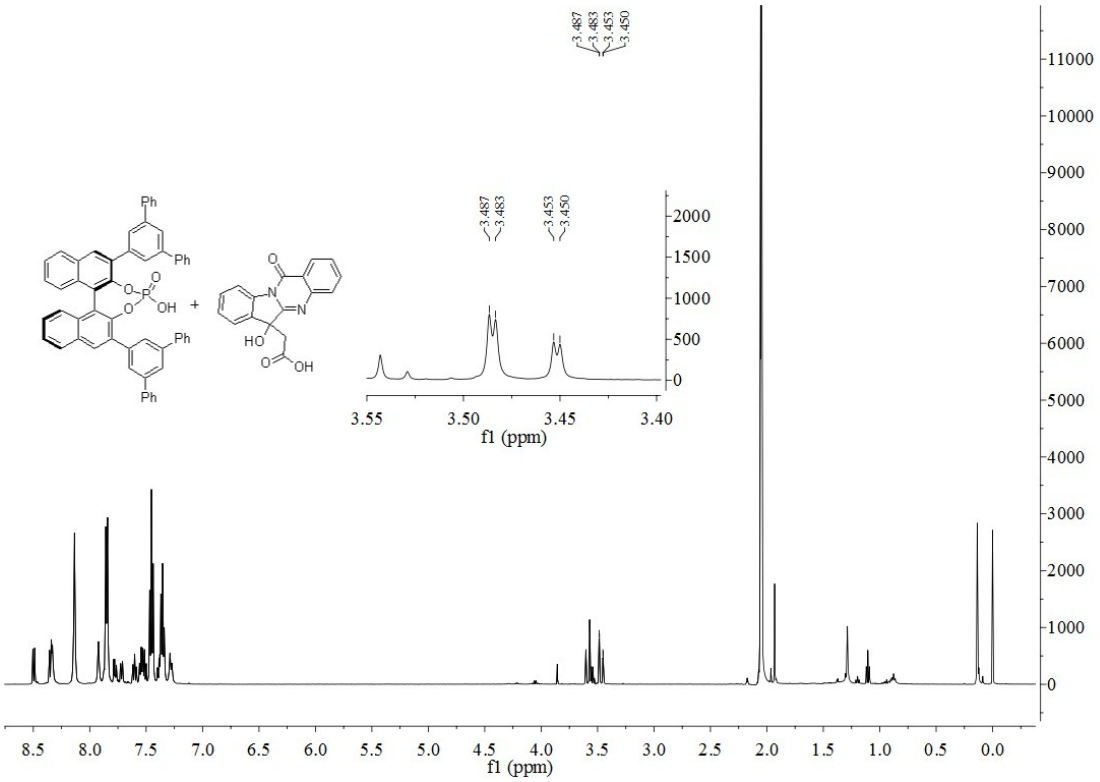
3.2. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1a and guest 2a.



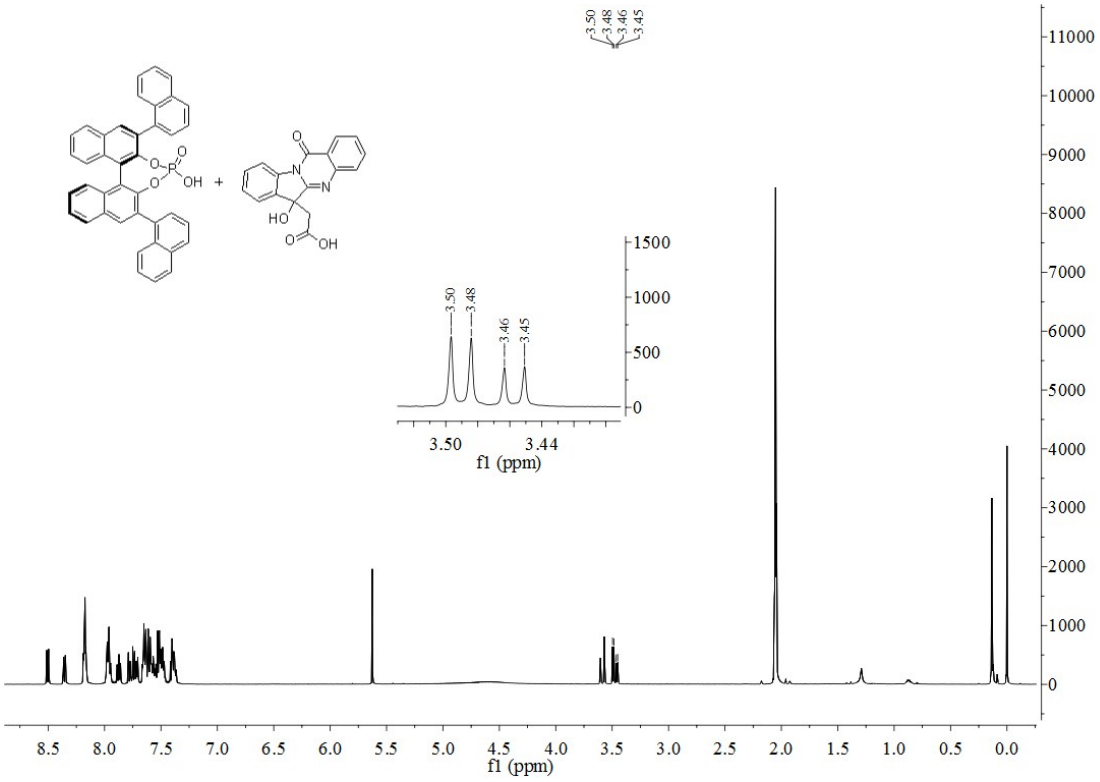
3.3. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1b and guest 2a.



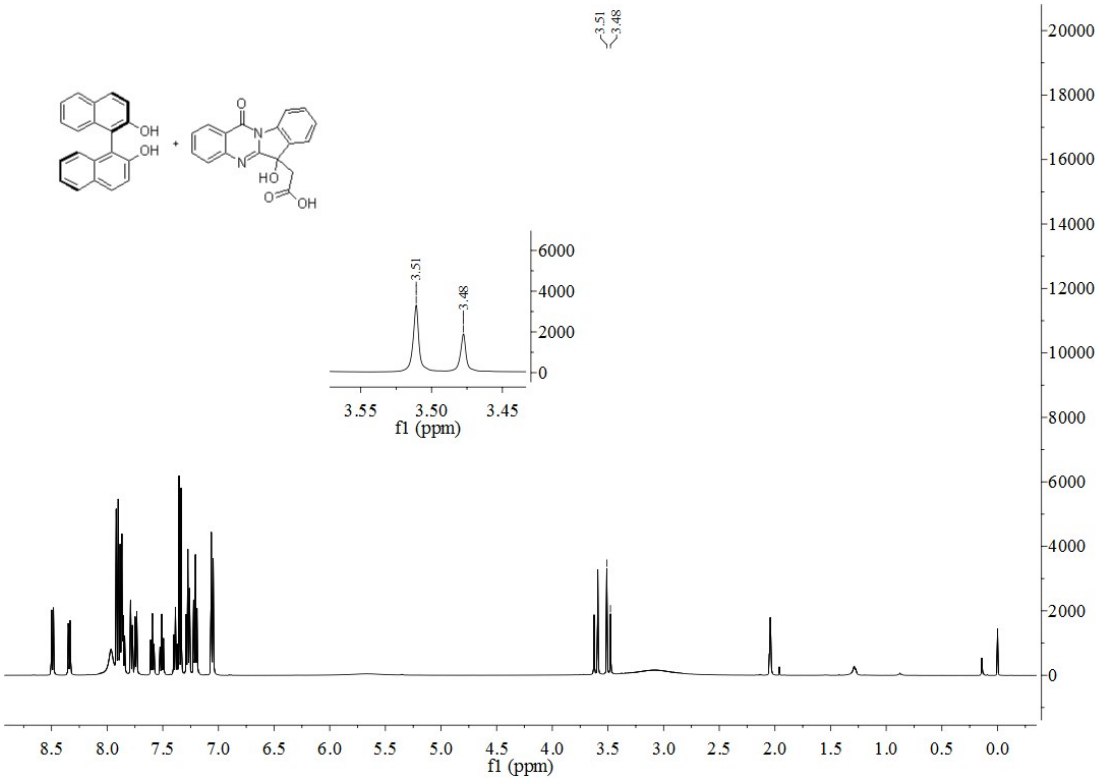
3.4. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1c and guest 2a.



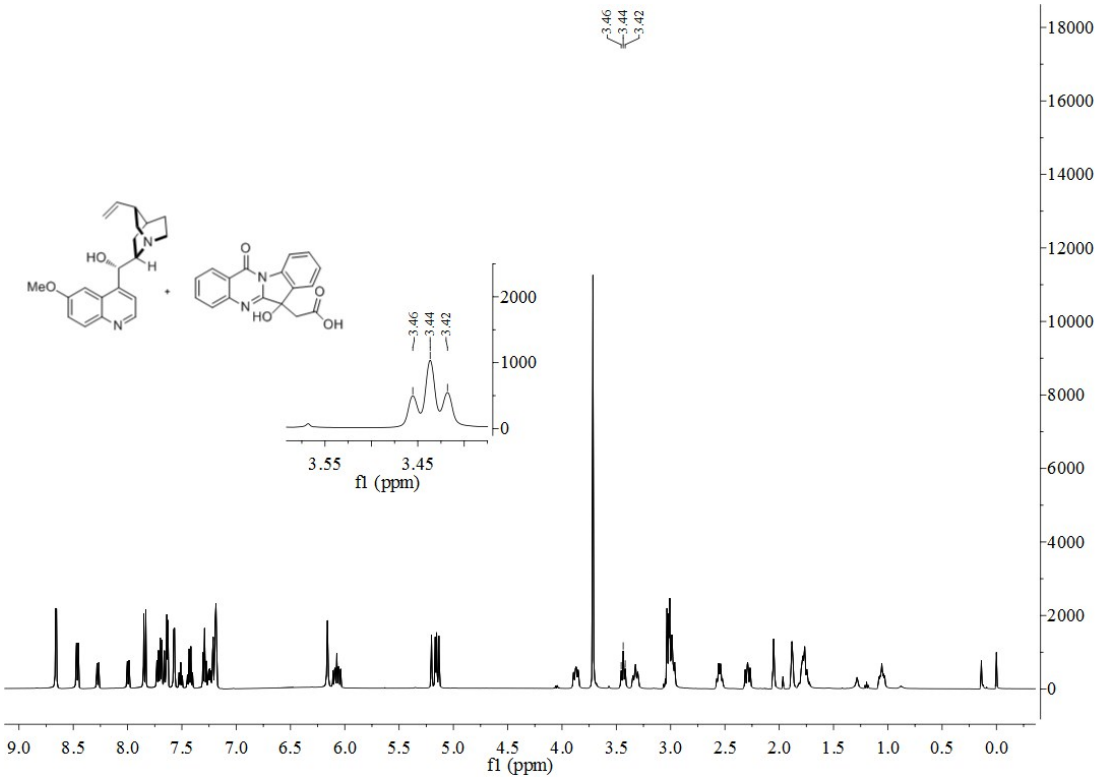
3.5. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2a.



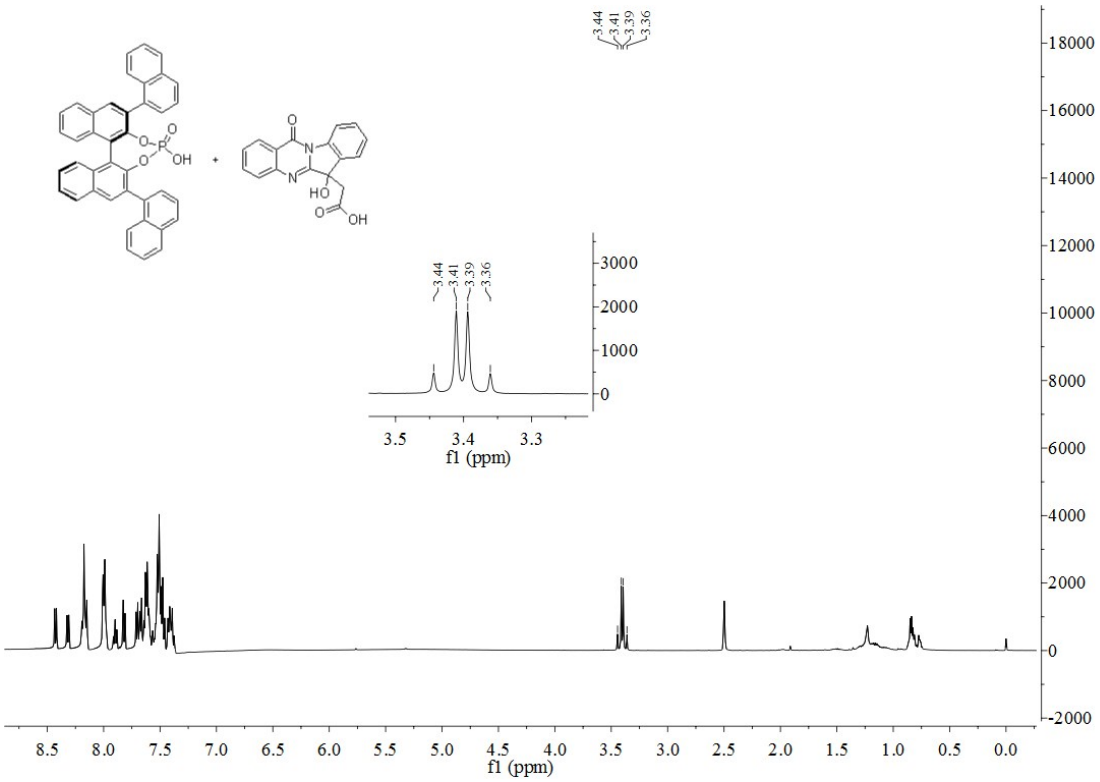
3.6. ^{1}H NMR (500 MHz, ACETONE-D_6) of (R)-BINOL 1e and guest 2a.



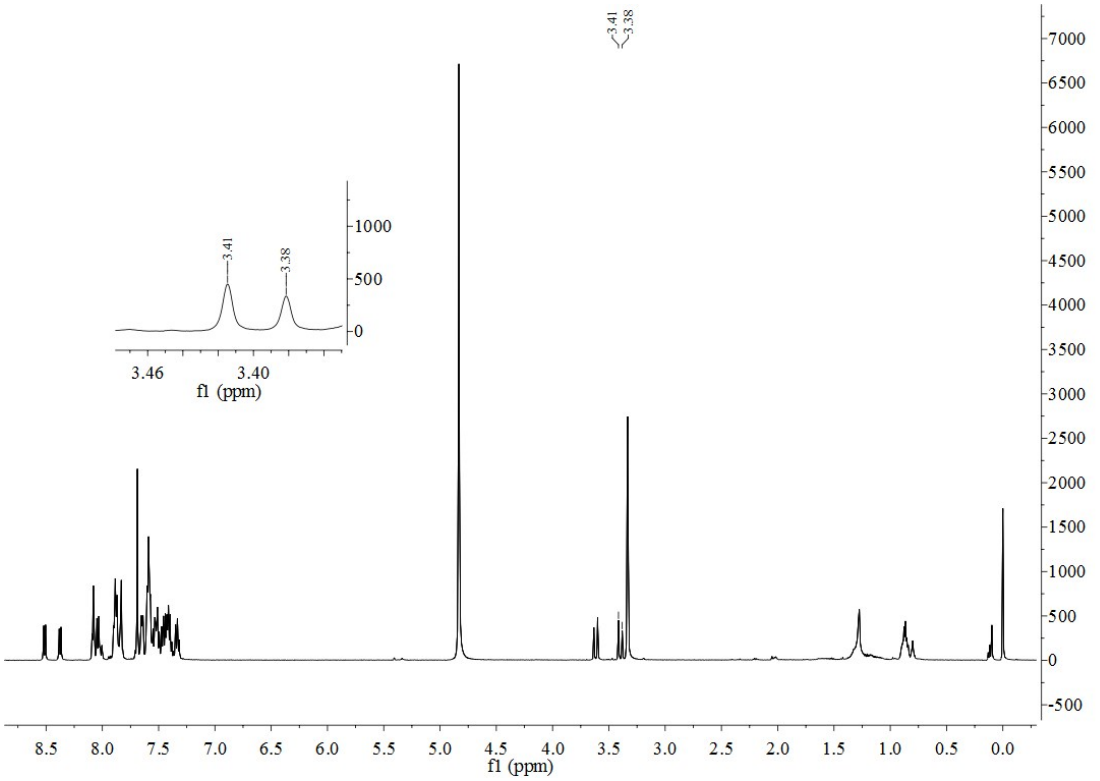
3.7. ^{1}H NMR (500 MHz, ACETONE-D_6) of quinidine 1f and guest 2a.



3.8. ^{1}H NMR (500 MHz, DMSO) of CPA 1d and guest 2a.

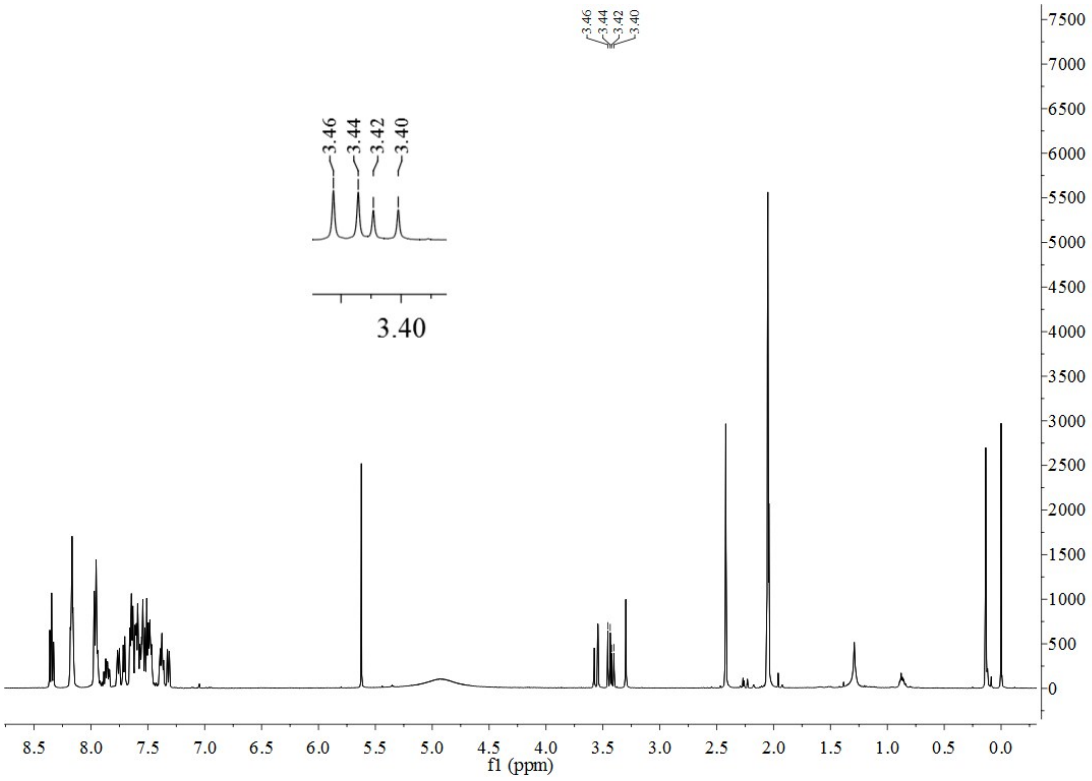


3.9. ^{1}H NMR (500 MHz, CD_3OD) of CPA 1d and guest 2a.

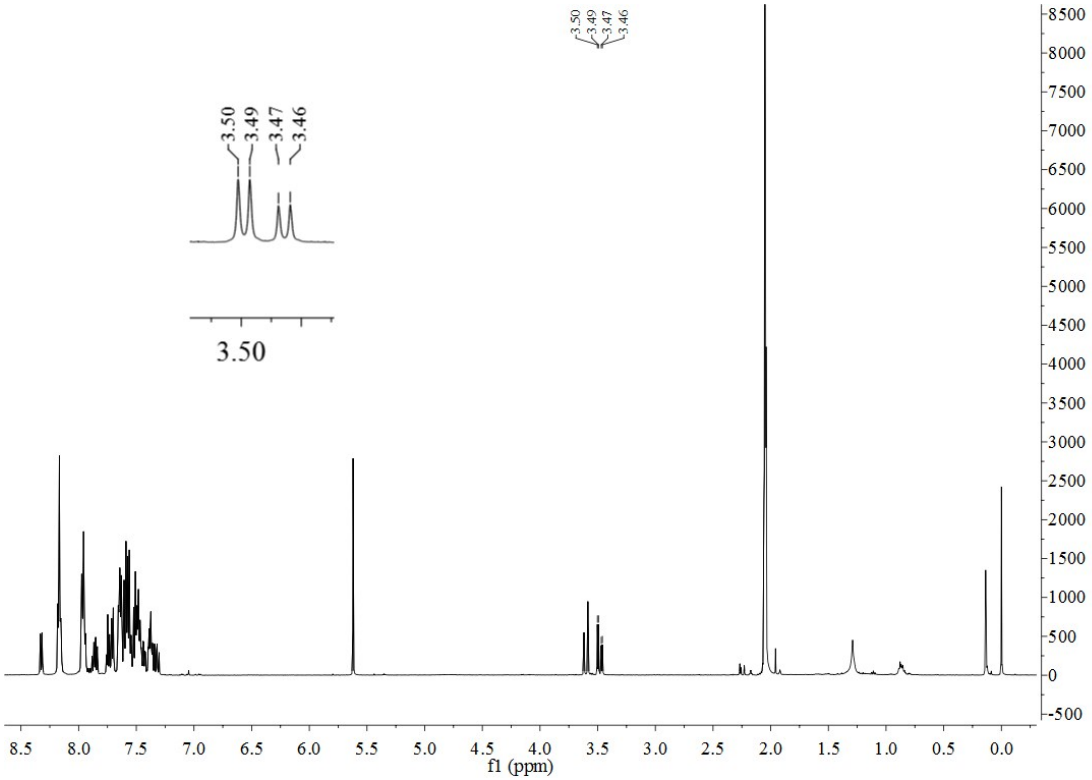


4. Copies of ^{1}H NMR spectra of 1d (0.01 mmol, 1.0 equiv.) and racemic 2 (0.01 mmol, 1.0 equiv.).

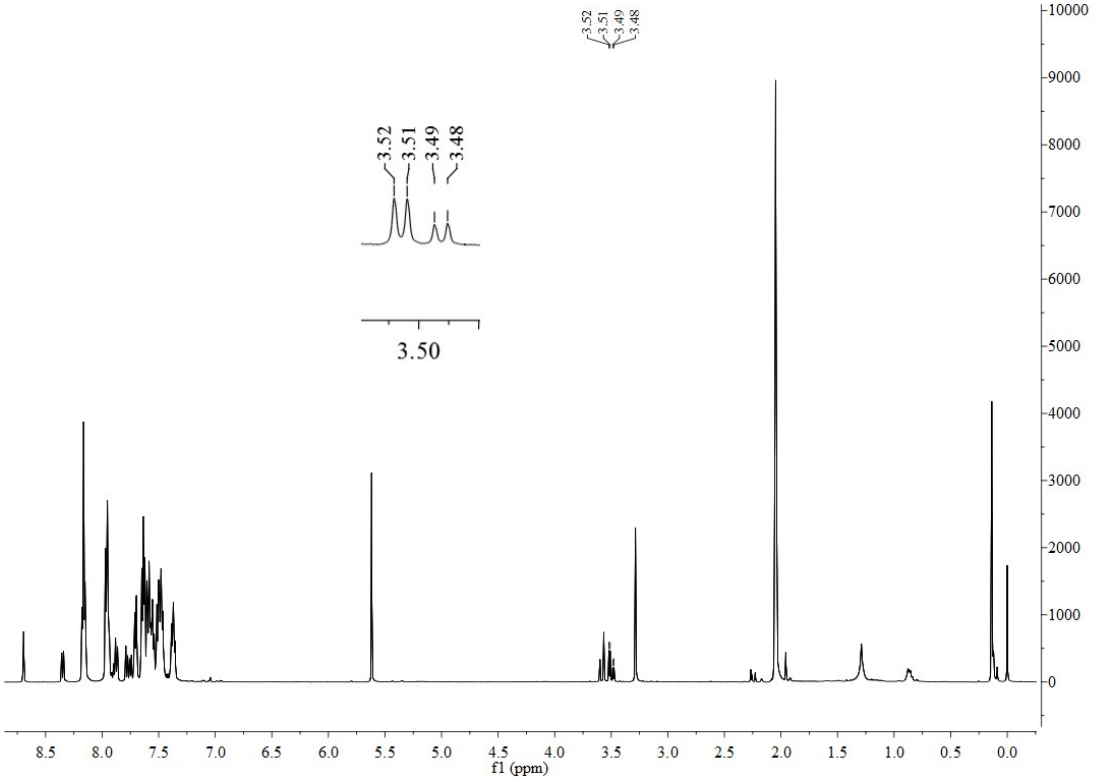
4.1. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2b.



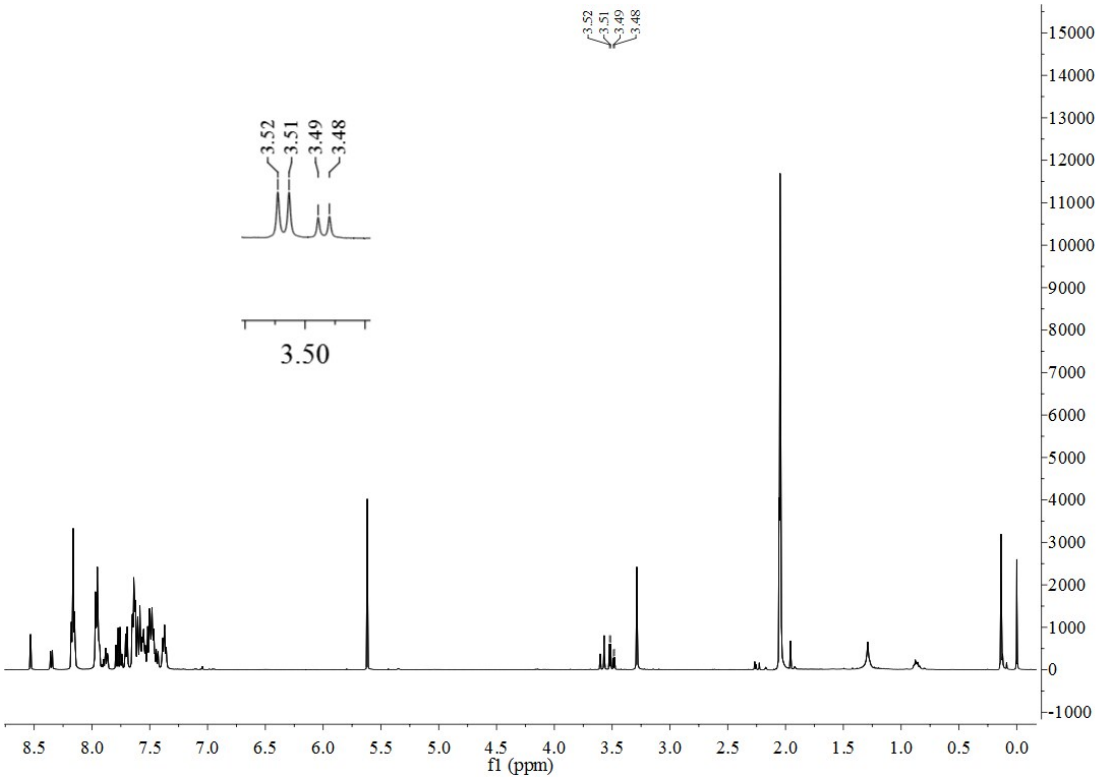
4.2. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2c.



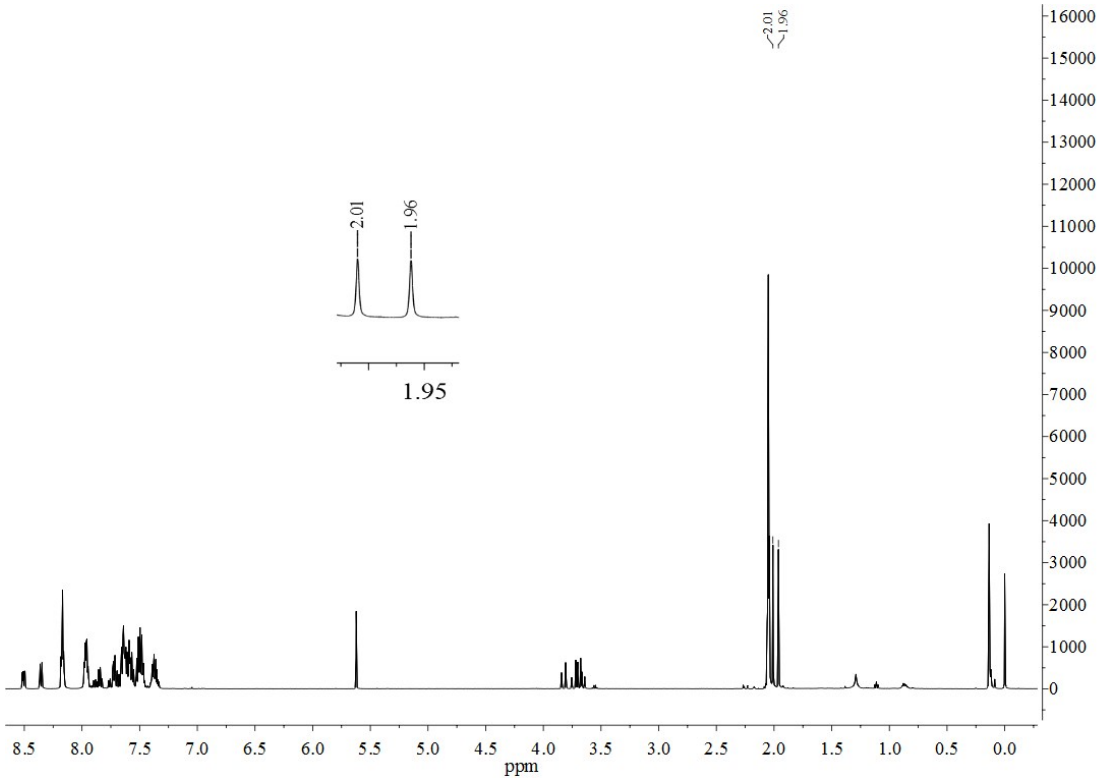
4.3. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2d.



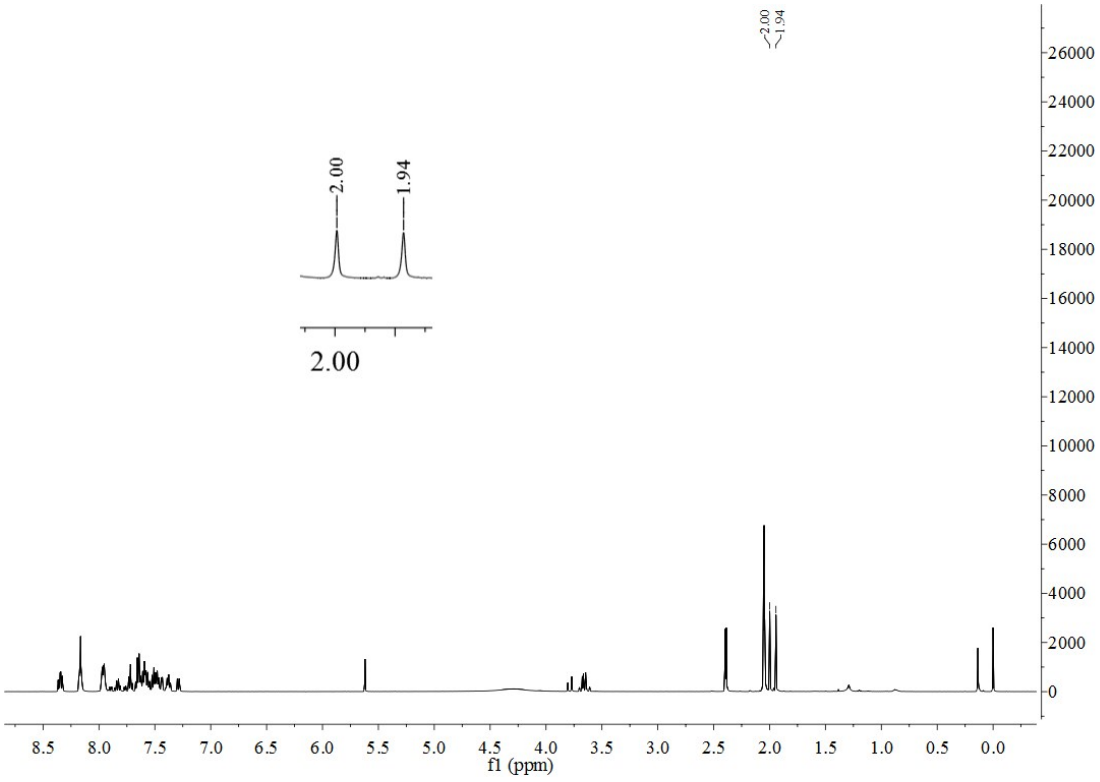
4.4. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2e.



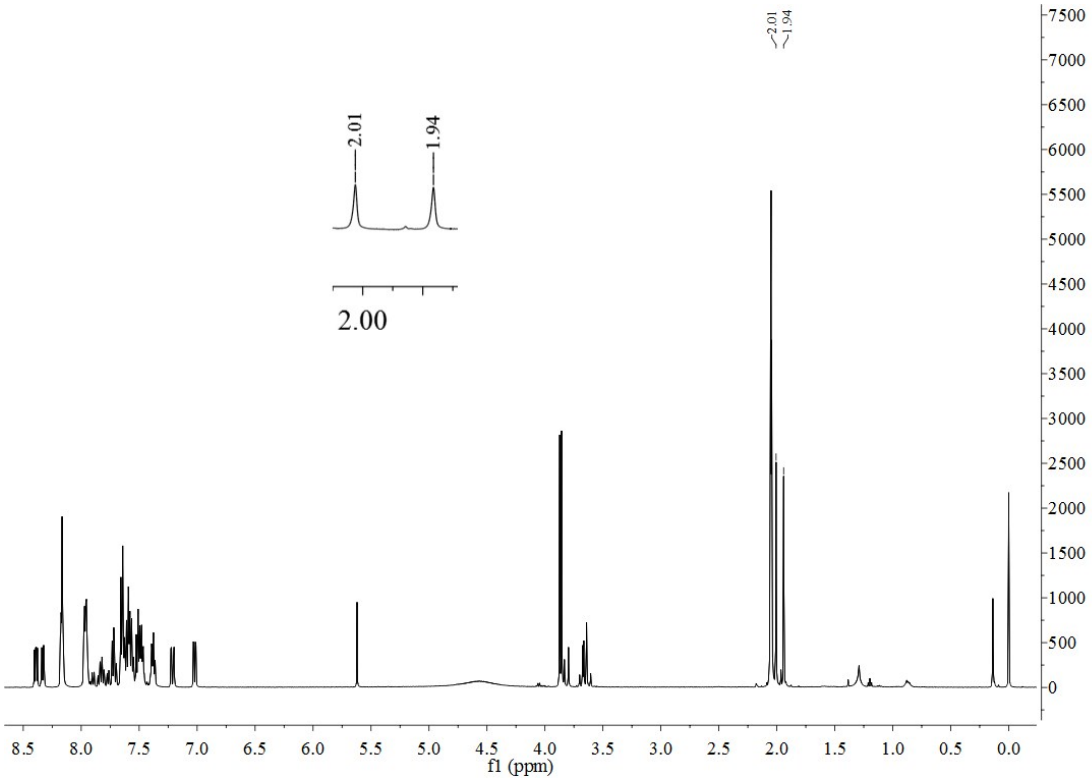
4.5. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2f.



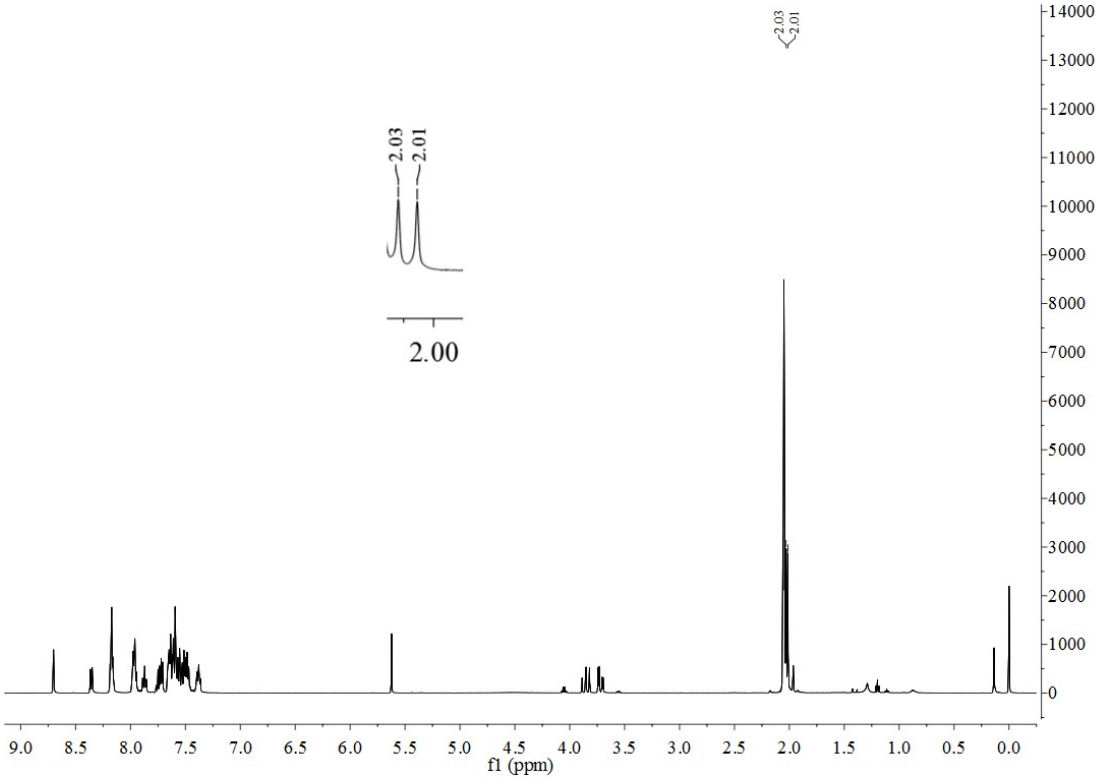
4.6. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2g.



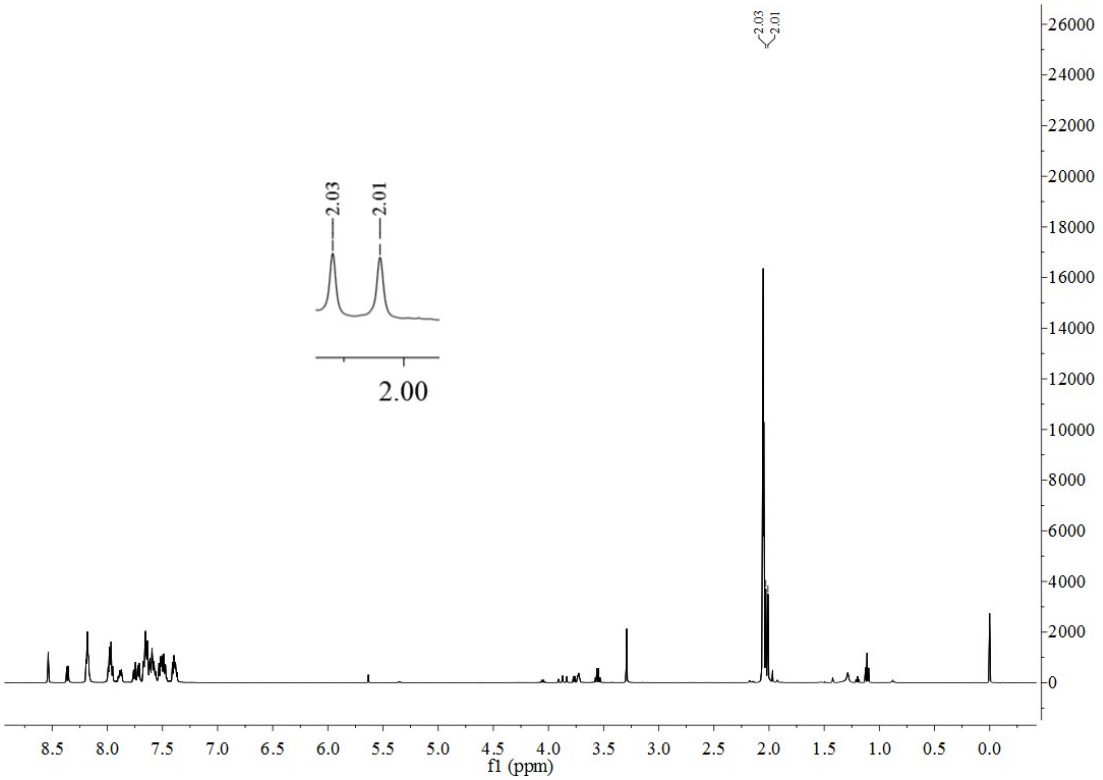
4.7. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2h.



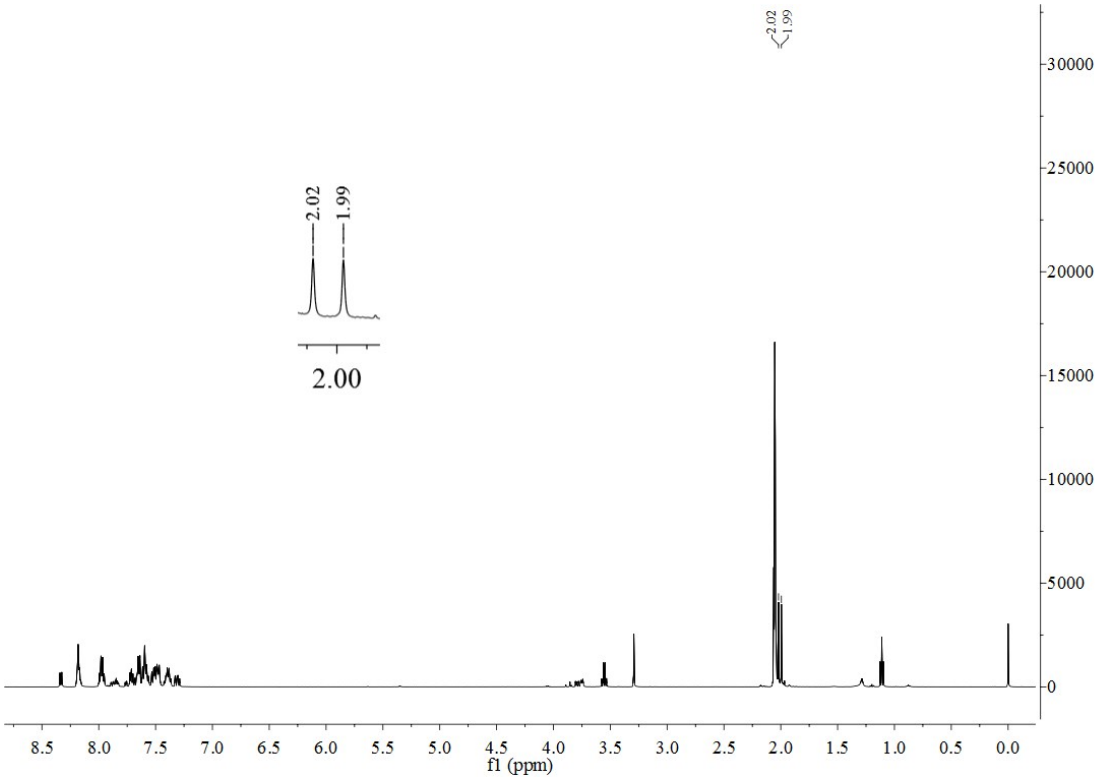
4.8. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2i.



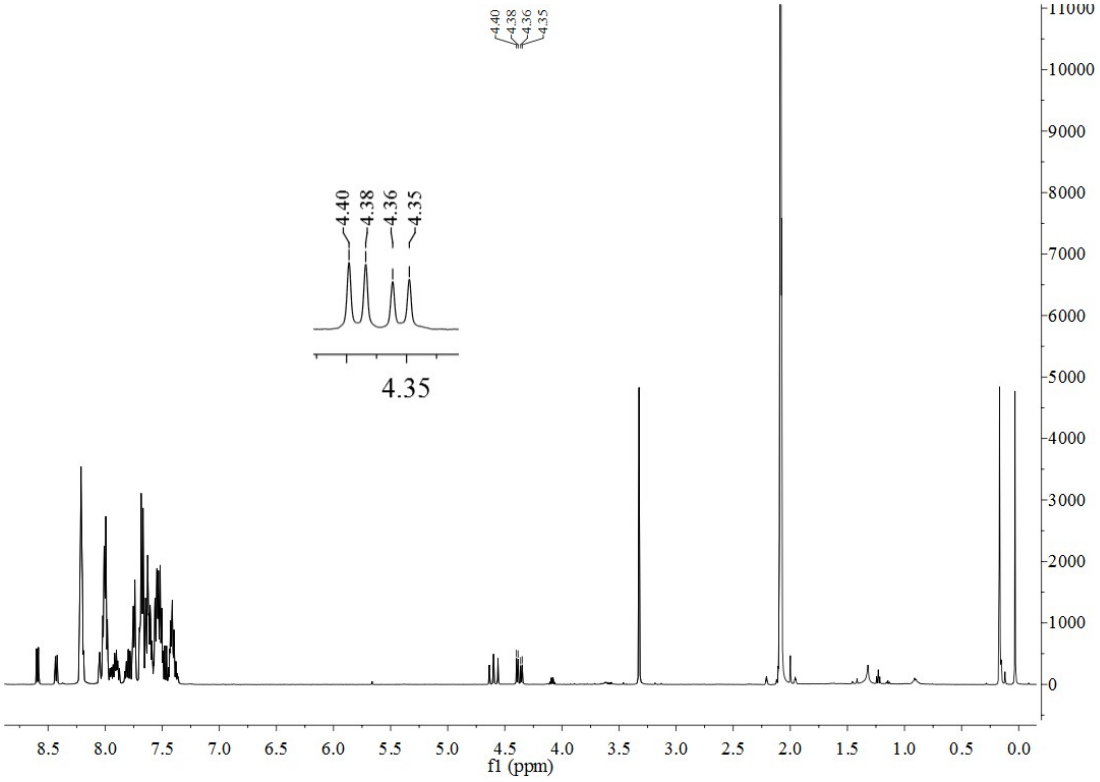
4.9. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2j.



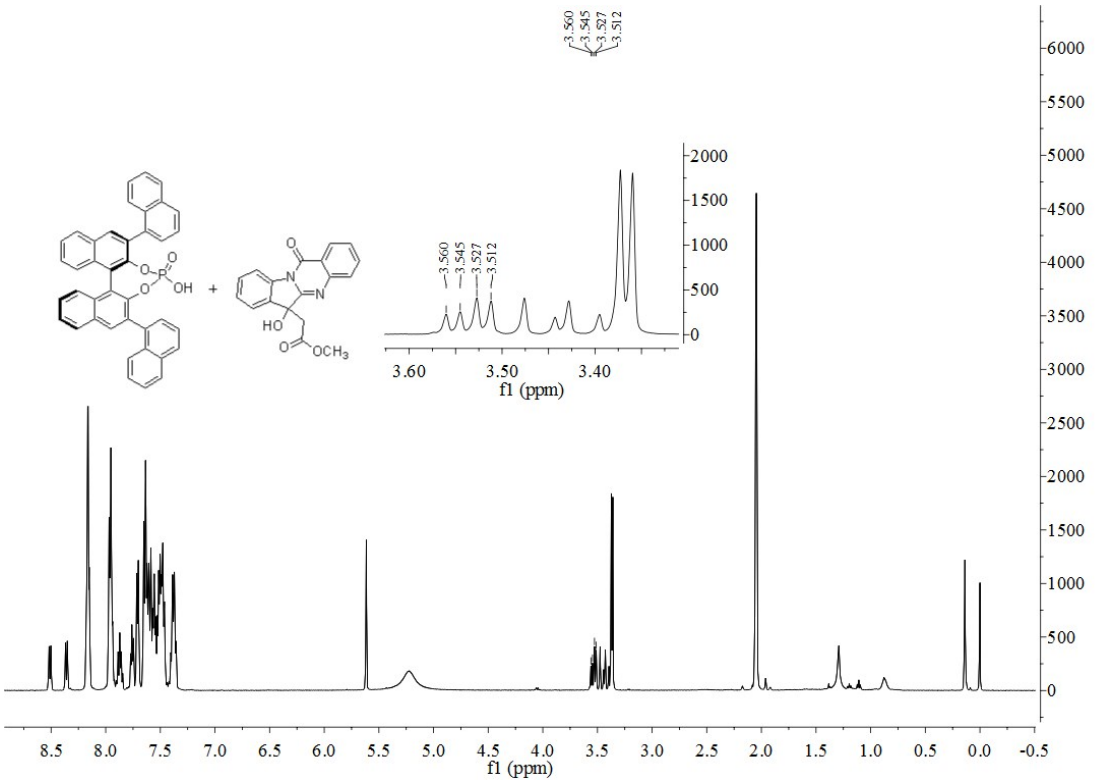
4.10. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2k.



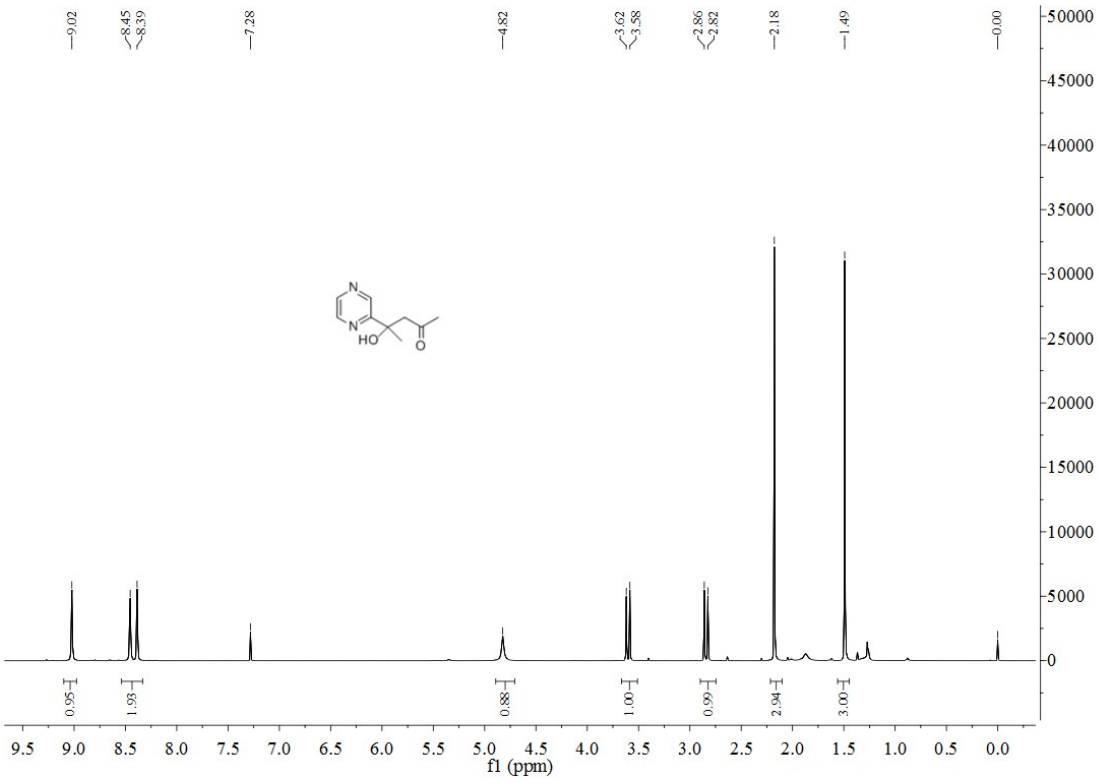
4.11. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and racemic guest 2l.



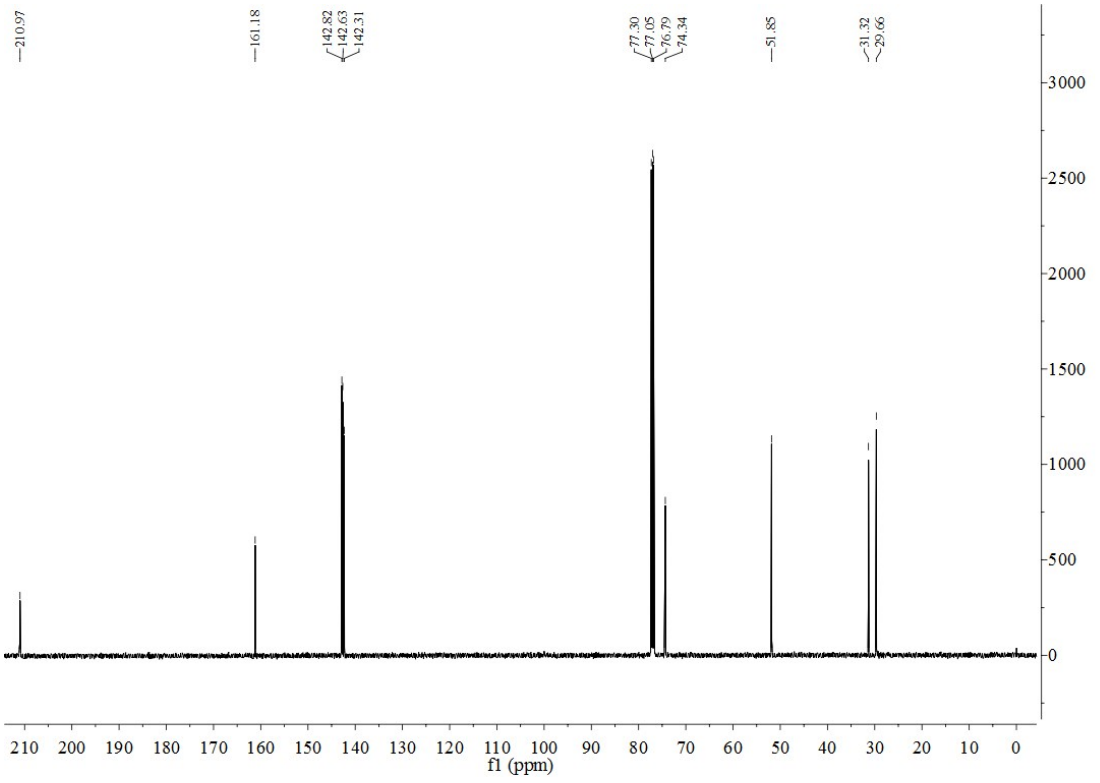
4.12. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d (0.015 mmol, 1.5 equiv.) and racemic guest 2m (0.01 mmol, 1.0 equiv.).



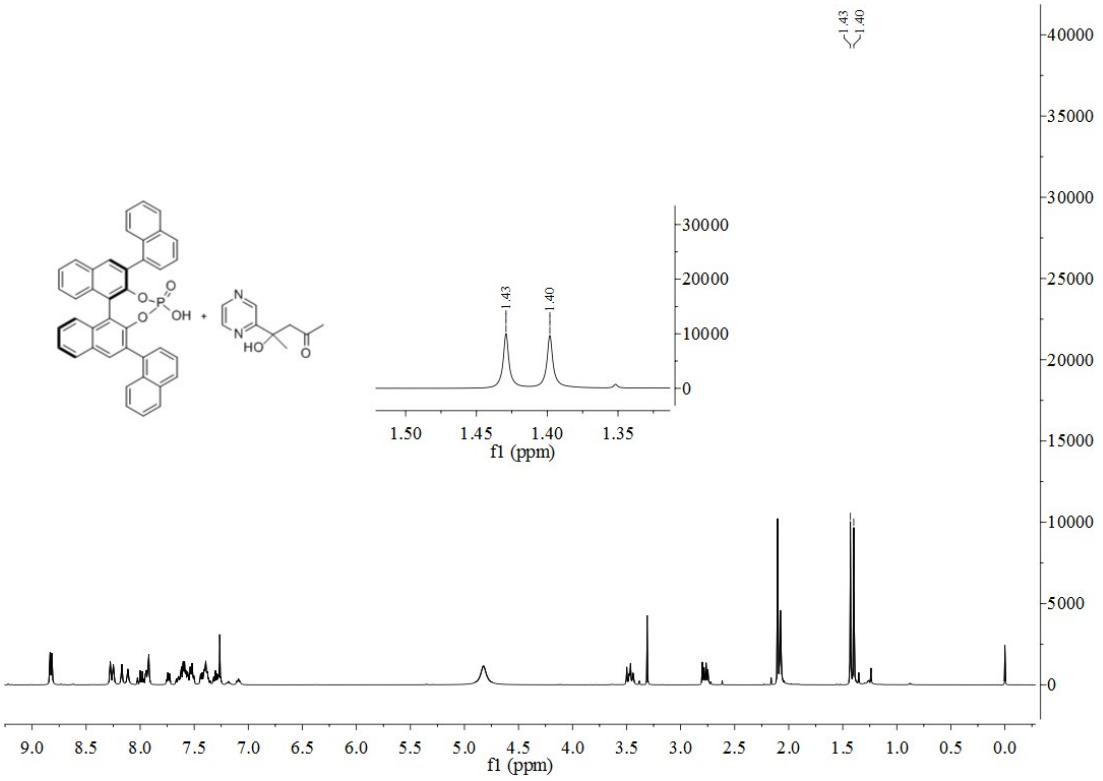
4.13. ^{1}H NMR (500 MHz, $CDCl_3$) of racemic 2n.



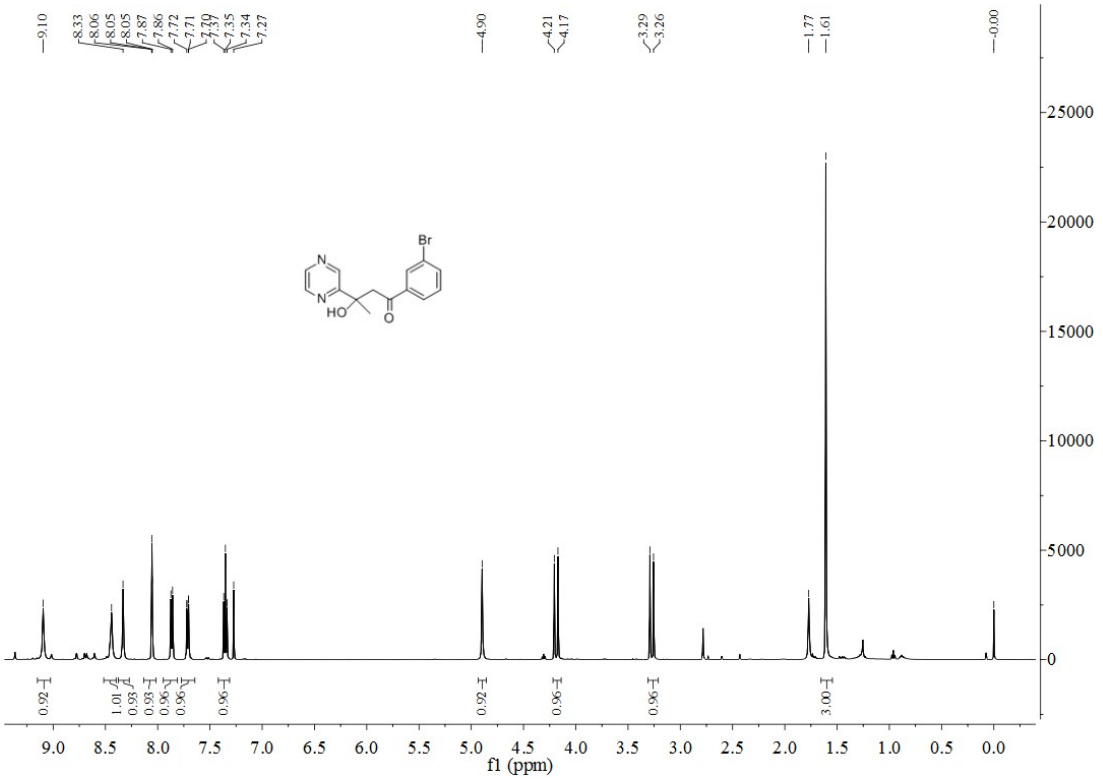
4.14. ^{13}C NMR (126 MHz, $CDCl_3$) of racemic 2n.



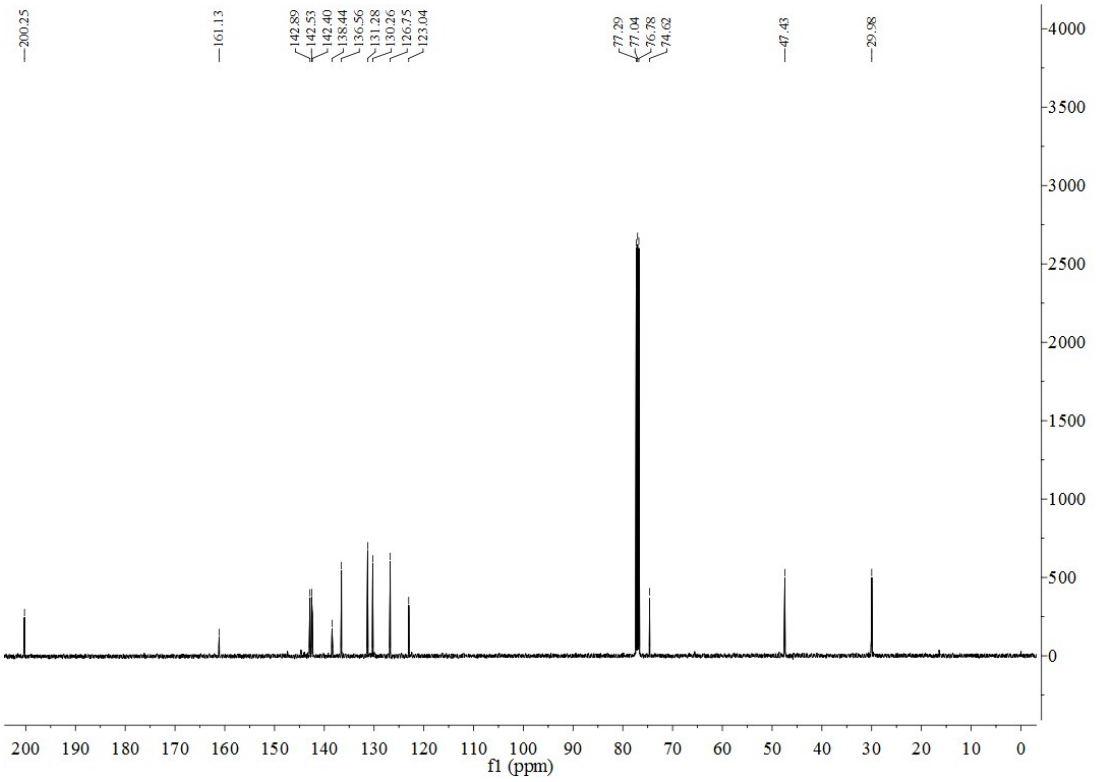
4.15. ^{1}H NMR (500 MHz, $CDCl_3$) of CPA 1d (0.01 mmol, 1.0 equiv.) and racemic guest 2n (0.02 mmol, 2.0 equiv.).



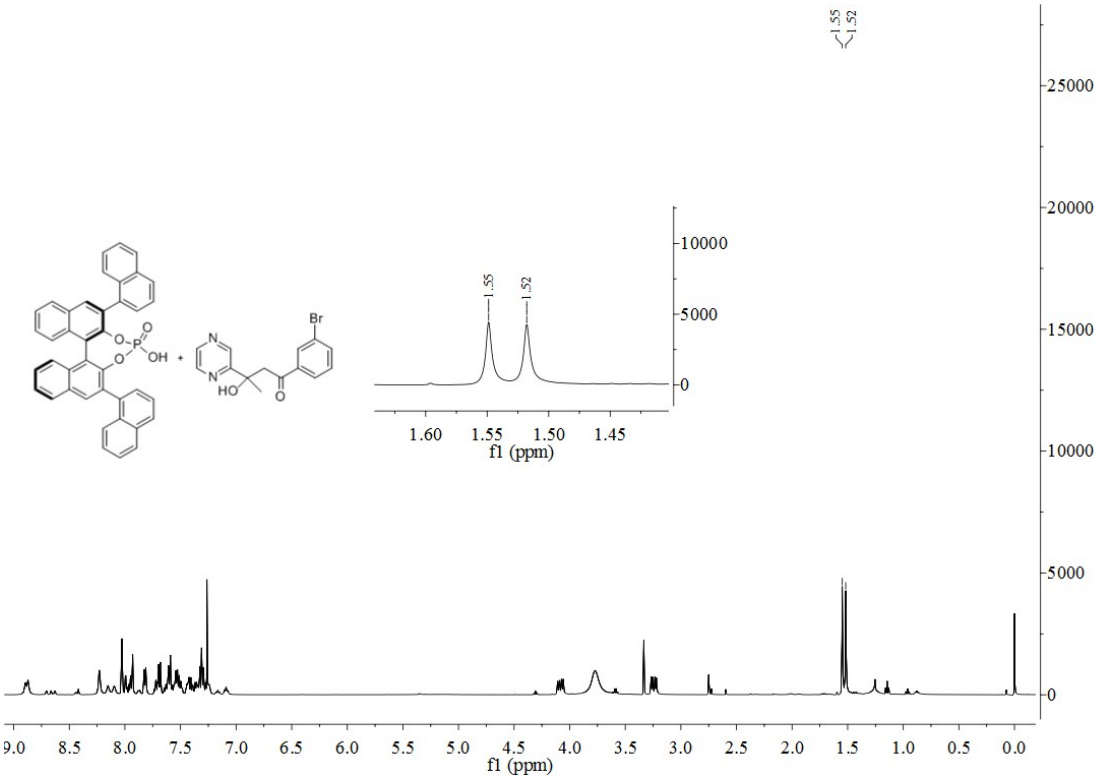
4.16. ^{1}H NMR (500 MHz, $CDCl_3$) of racemic 2o.



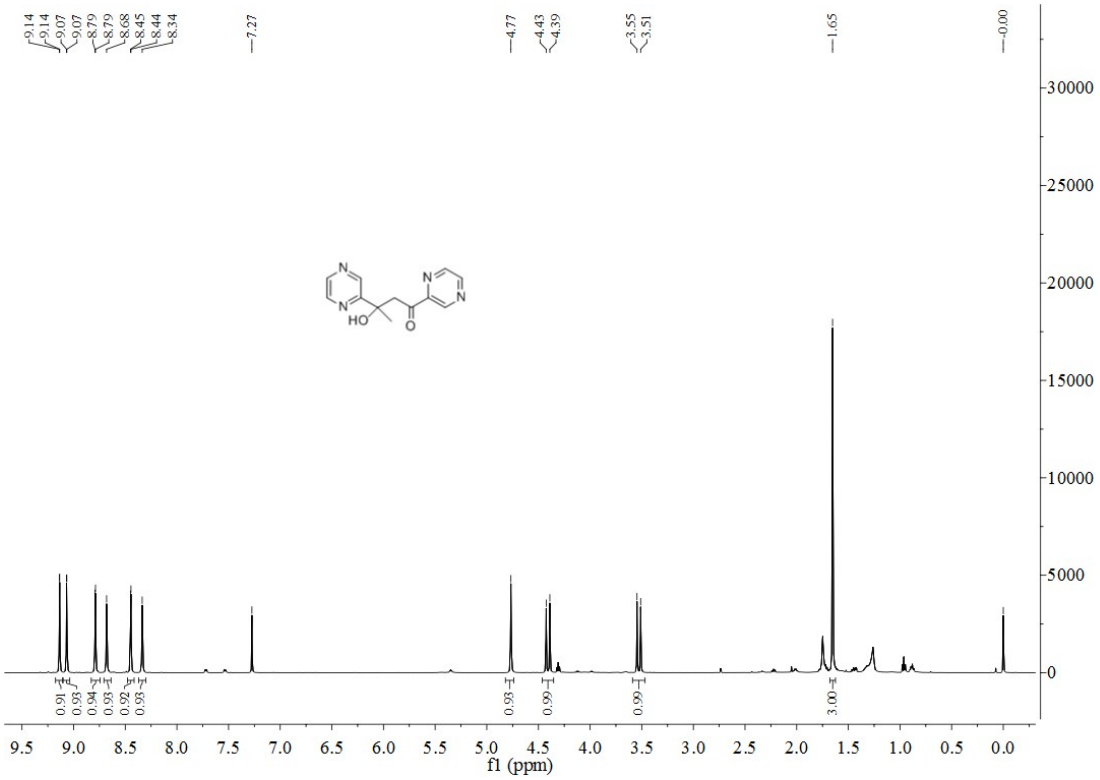
4.17. ^{13}C NMR (126 MHz, $CDCl_3$) of racemic 2o.



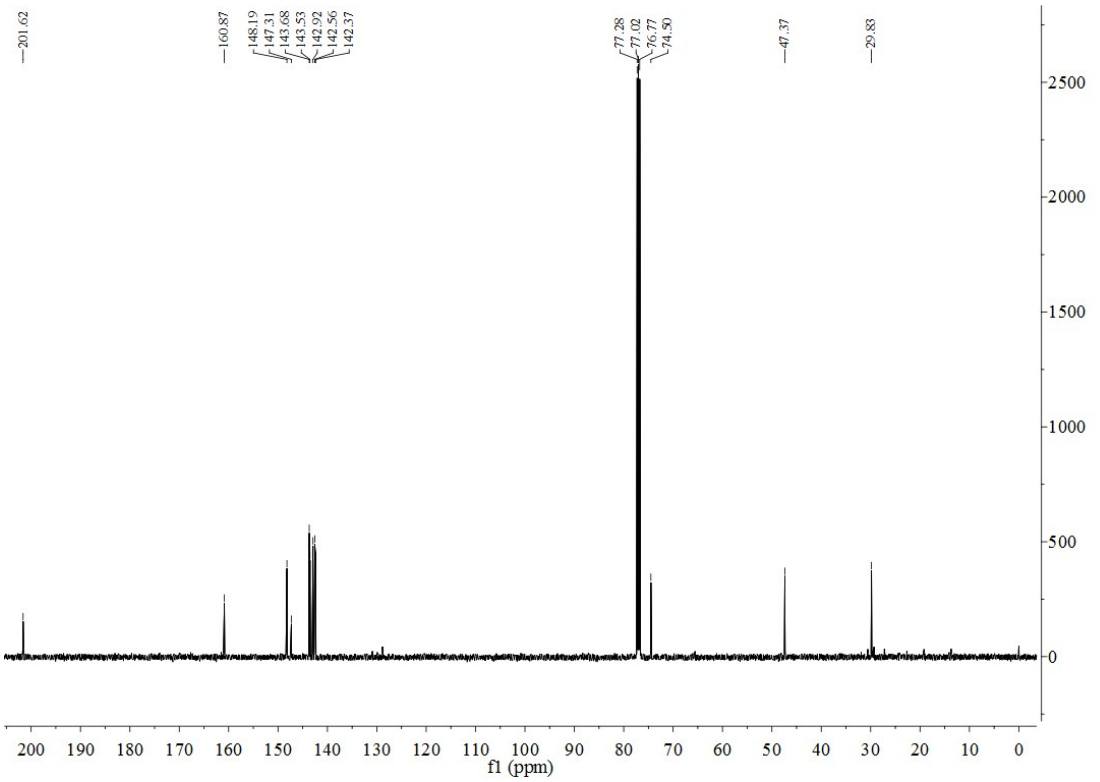
4.18. ^{1}H NMR (500 MHz, $CDCl_3$) of CPA 1d (0.01 mmol, 1.0 equiv.) and racemic guest 2o (0.01 mmol, 1.0 equiv.).



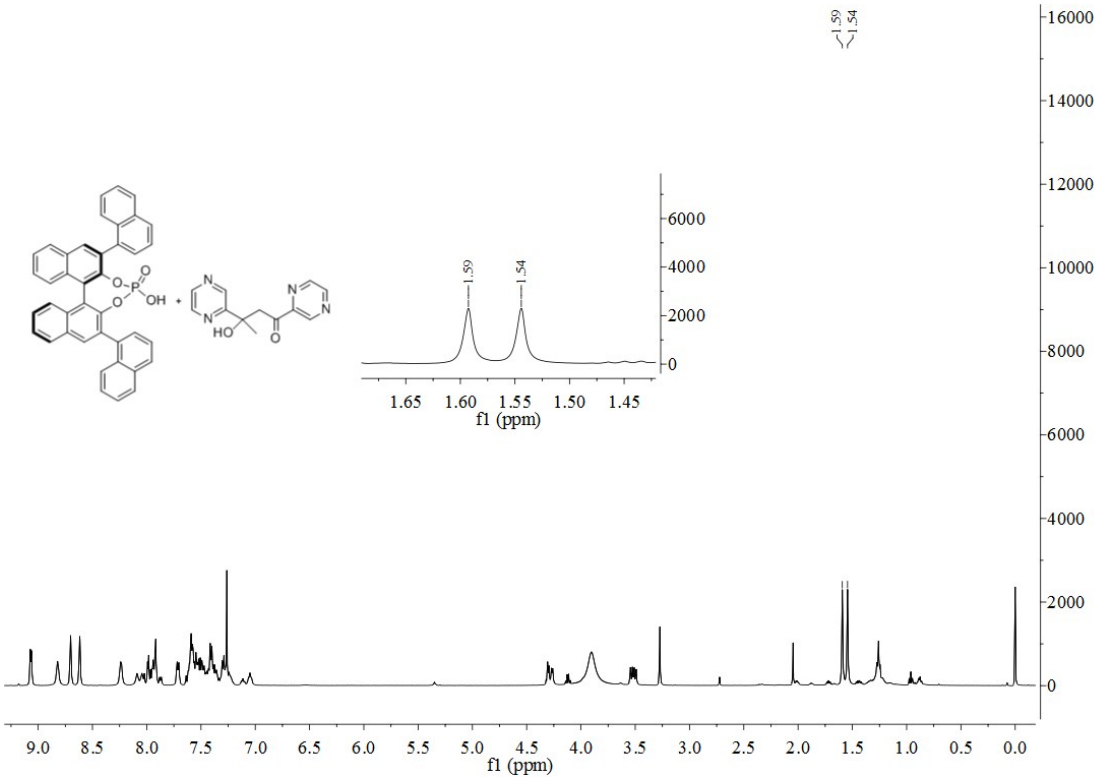
4.19. ^{1}H NMR (500 MHz, $CDCl_3$) of racemic 2p.



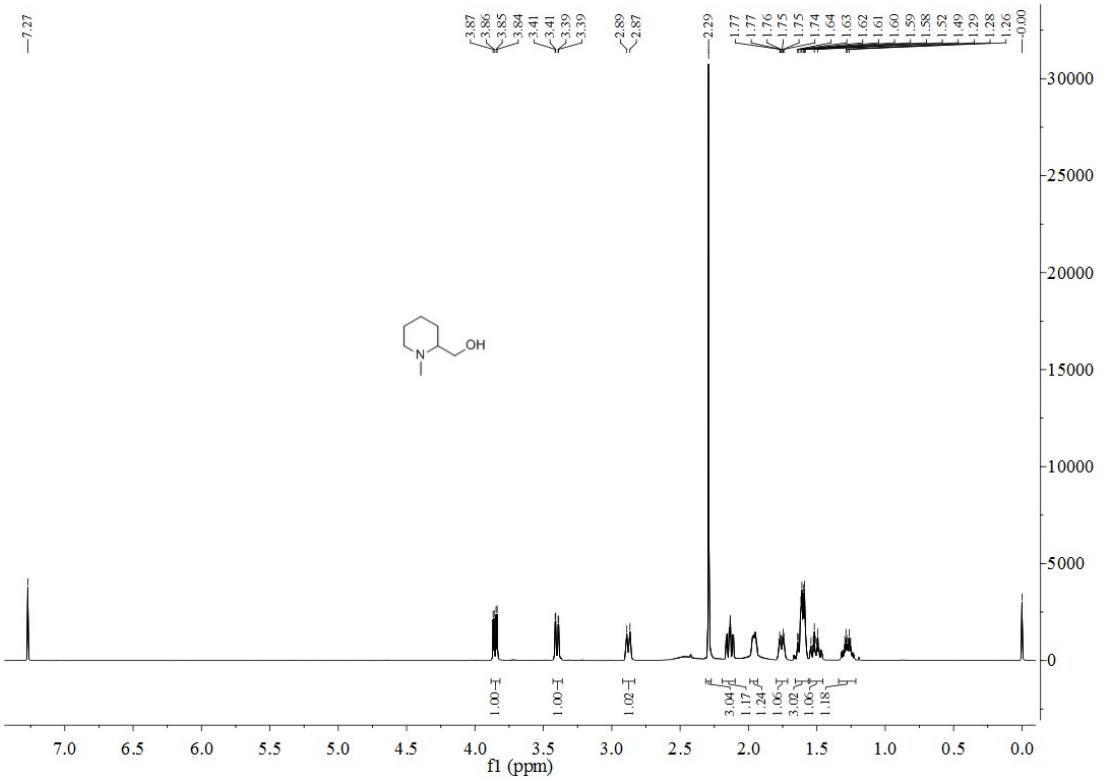
4.20. ^{13}C NMR (126 MHz, $CDCl_3$) of racemic 2p.



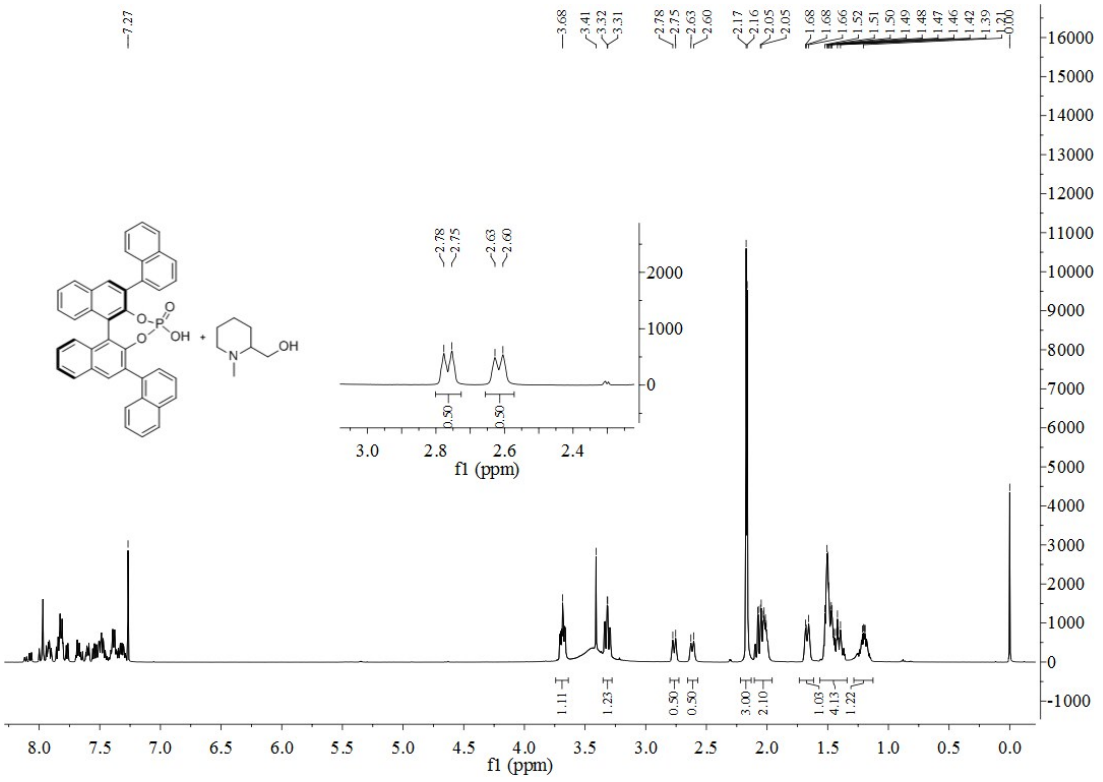
4.21. ^{1}H NMR (500 MHz, $CDCl_3$) of CPA 1d (0.01 mmol, 1.0 equiv.) and racemic guest 2p(0.01 mmol, 1.0 equiv.).



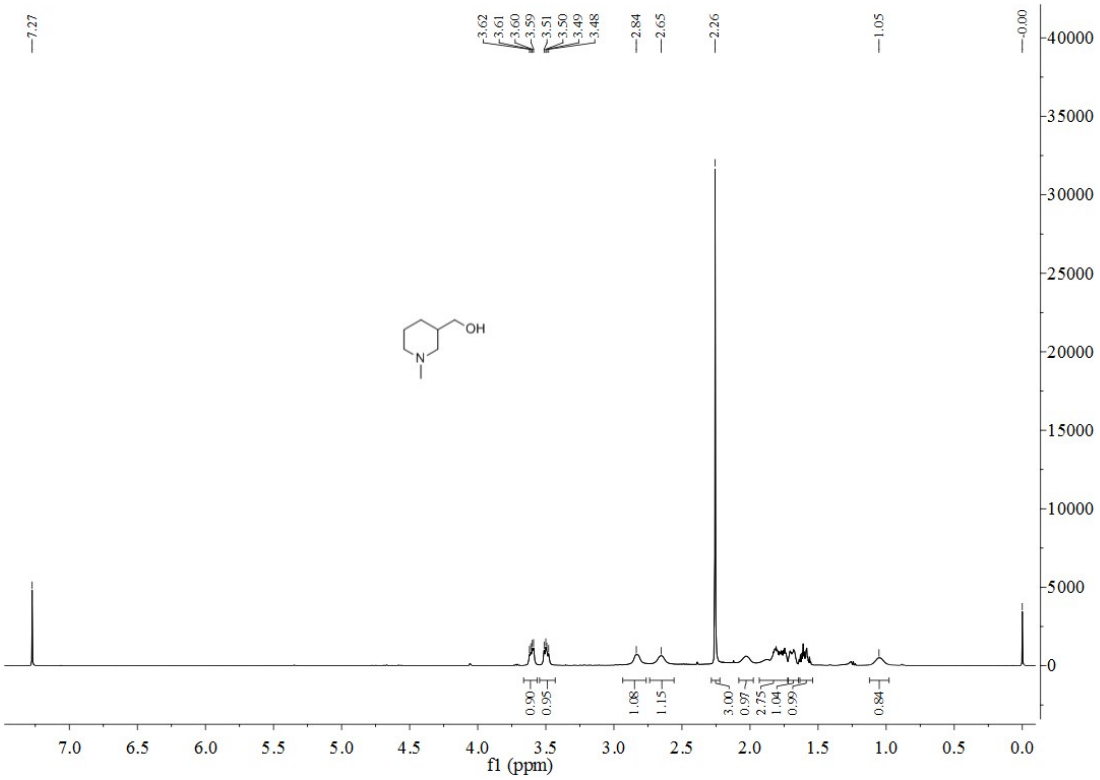
4.22. ^{1}H NMR (500 MHz, $CDCl_3$) of racemic 2q.



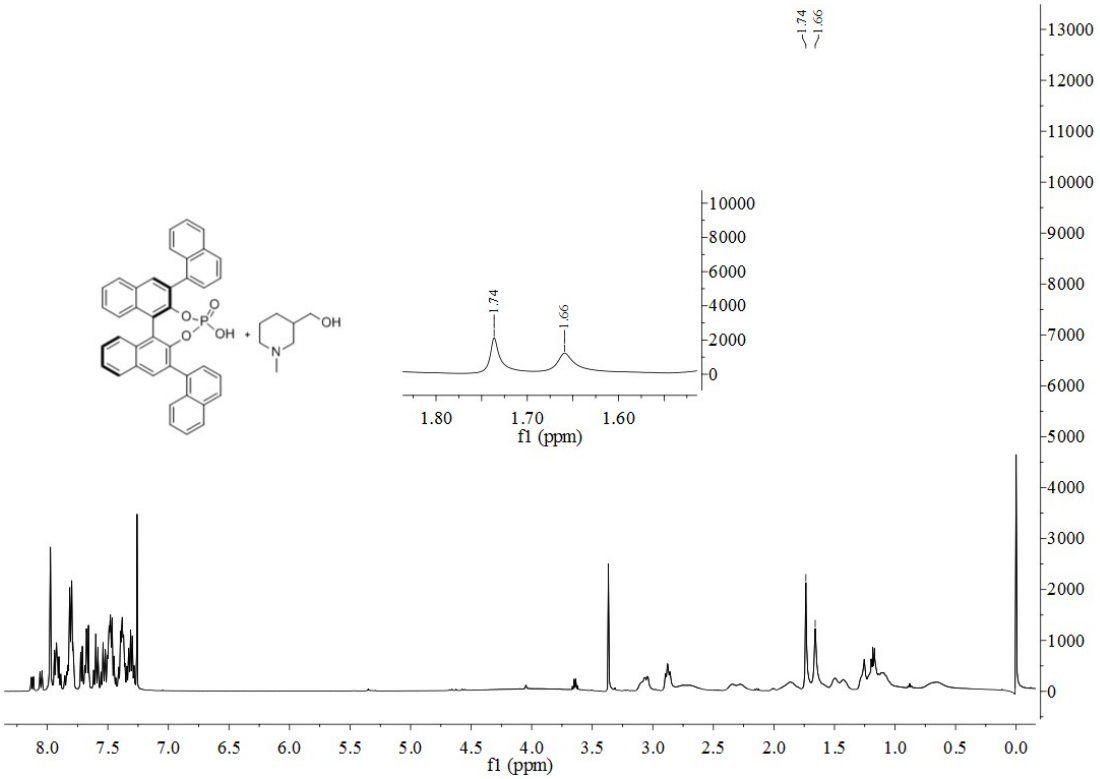
4.23. ^{1}H NMR (500 MHz, $CDCl_3$) of CPA 1d (0.01 mmol, 1.0 equiv.) and racemic guest 2q (0.02 mmol, 2.0 equiv.).



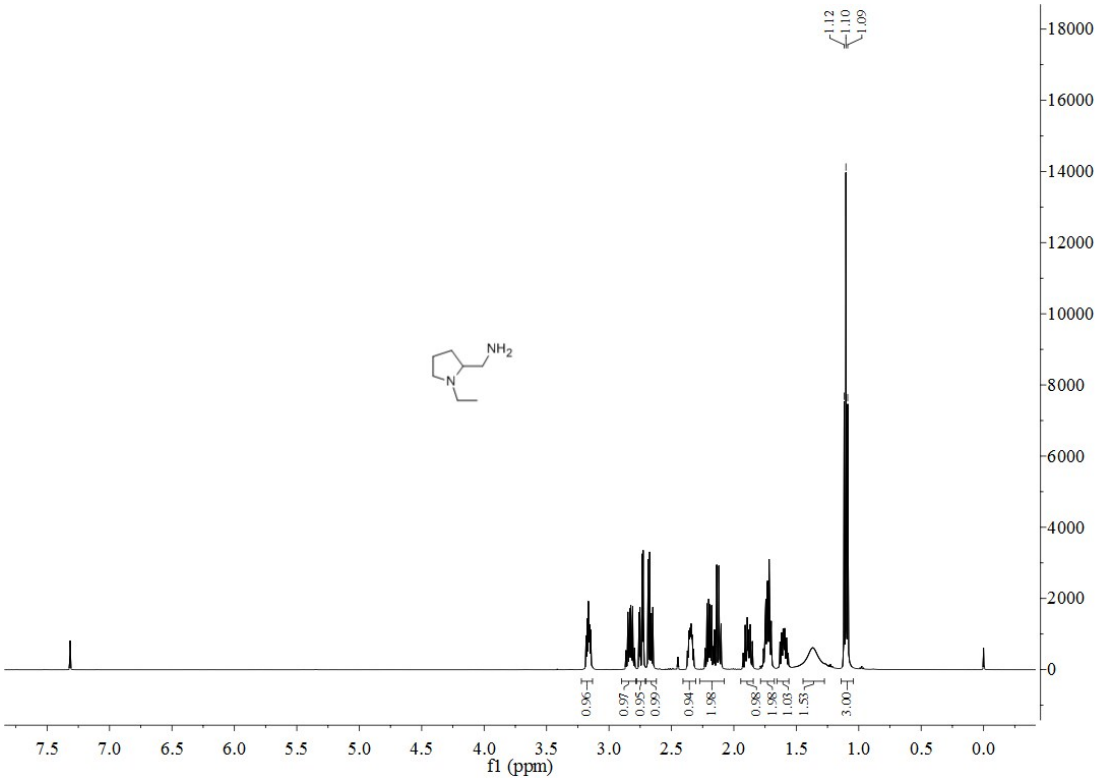
4.24. ^{1}H NMR (500 MHz, $CDCl_3$) of racemic 2r.



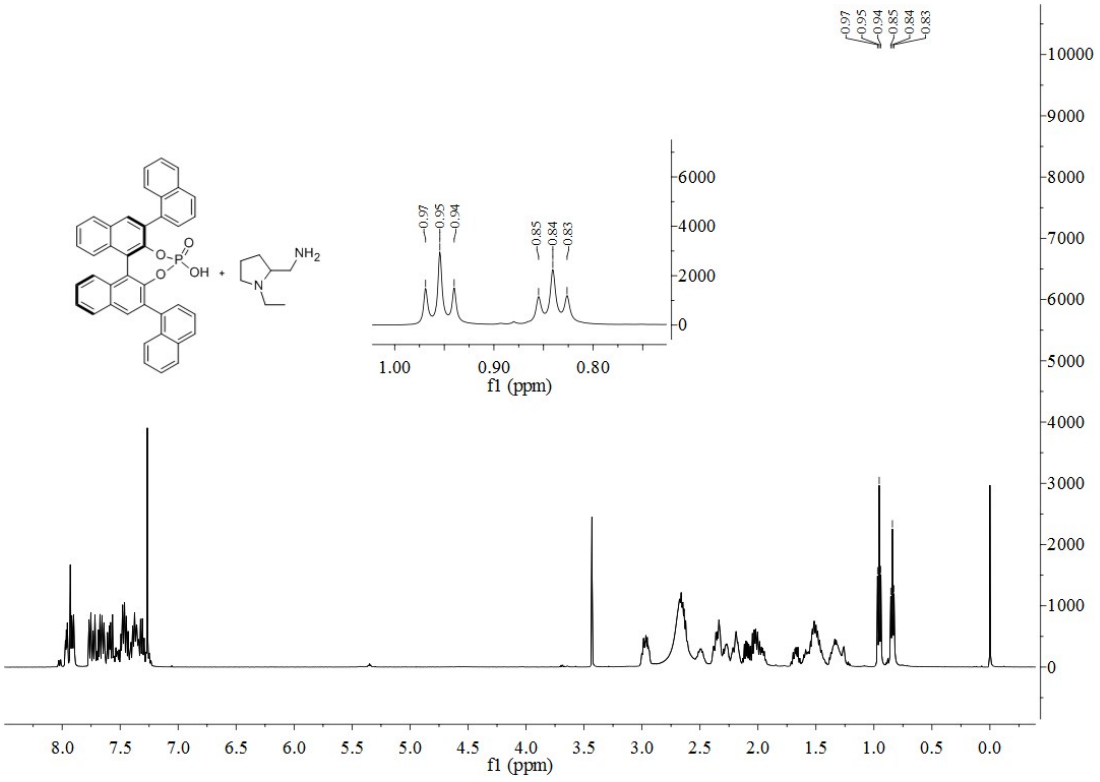
4.25. ^{1}H NMR (500 MHz, $CDCl_3$) of CPA 1d (0.01 mmol, 1.0 equiv.) and racemic guest 2r (0.015 mmol, 1.5 equiv.).



4.26. ^{1}H NMR (500 MHz, $CDCl_3$) of racemic 2s.

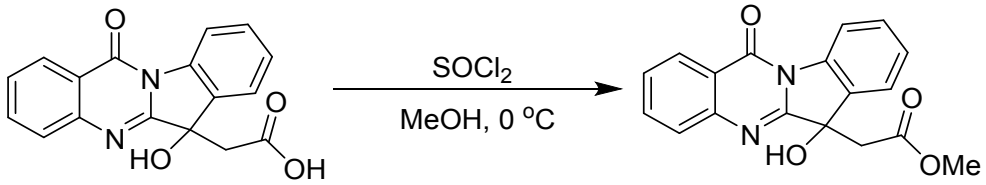


4.27. ^{1}H NMR (500 MHz, $CDCl_3$) of CPA 1d (0.01 mmol, 1.0 equiv.) and racemic guest 2s (0.02 mmol, 2.0 equiv.).



5. Copies of ^{1}H NMR spectra/HPLC data of 1d (0.01 mmol, 1.0 equiv.) and 2 (0.01 mmol, 1.0 equiv.) with different optical purities.

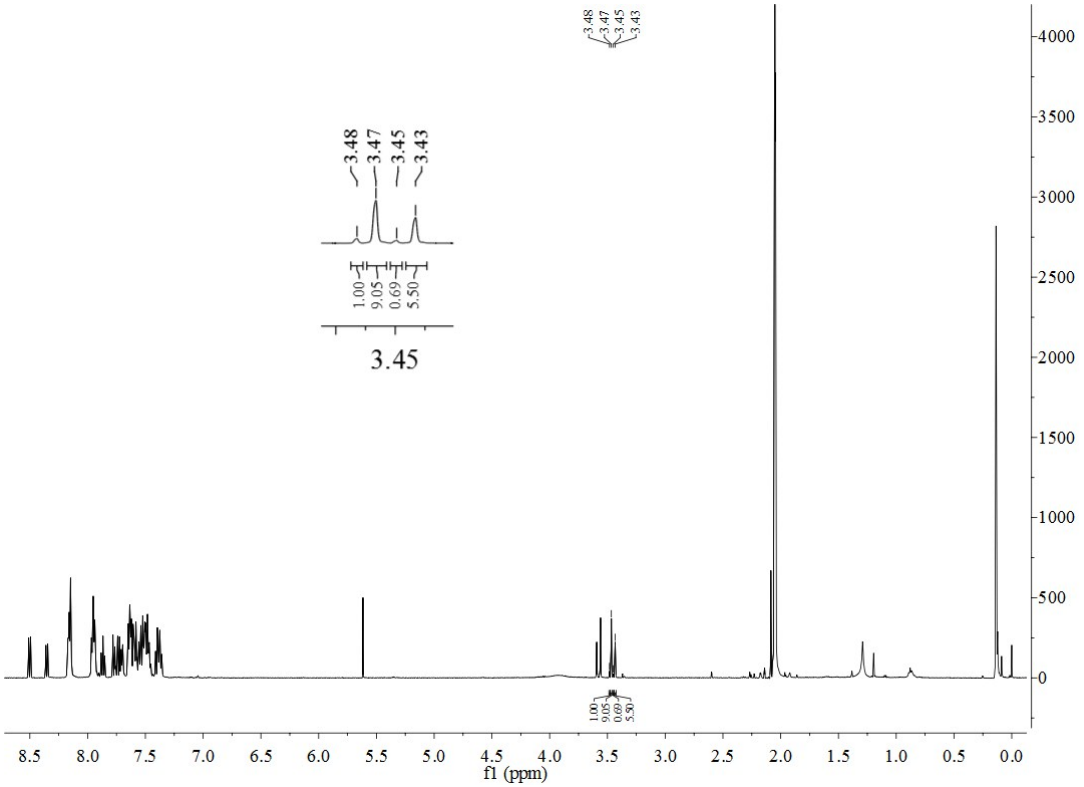
For chiral HPLC analysis, a wide range of nonracemic **2a** were converted into corresponding esters. The procedure is as follows:



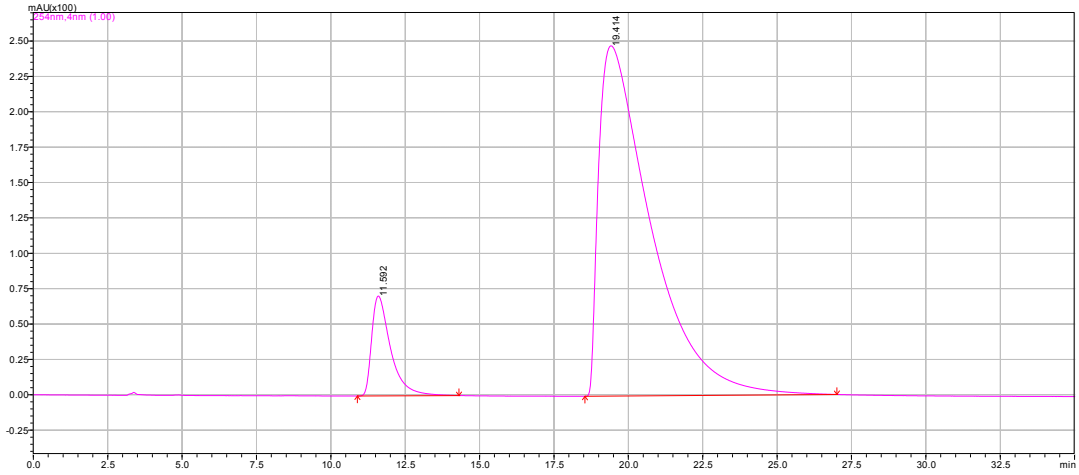
2a **2a'**

$SOCl_2$ (1.2 mL) was added slowly to a solution of **2a** in anhydrous CH_3OH (4.0 mL) at 0 °C, the resulting mixture was stirred at the same temperature for 4 hours followed by the addition of saturated aqueous $NaHCO_3$ solution (60 mL), and the reaction mixture was extracted with CH_2Cl_2 (4×10 mL). The combined organic phase was washed with brine (80 mL), and then dried over anhydrous Na_2SO_4, filtered and the solvent was removed in vacuo. The residue was purified through flash column chromatography on a silica gel (eluent: dichloromethane : ethyl acetate = 15/1-10/1) to yield **2a'**.

5.1. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2a (Sample 1, ee 79.2%).

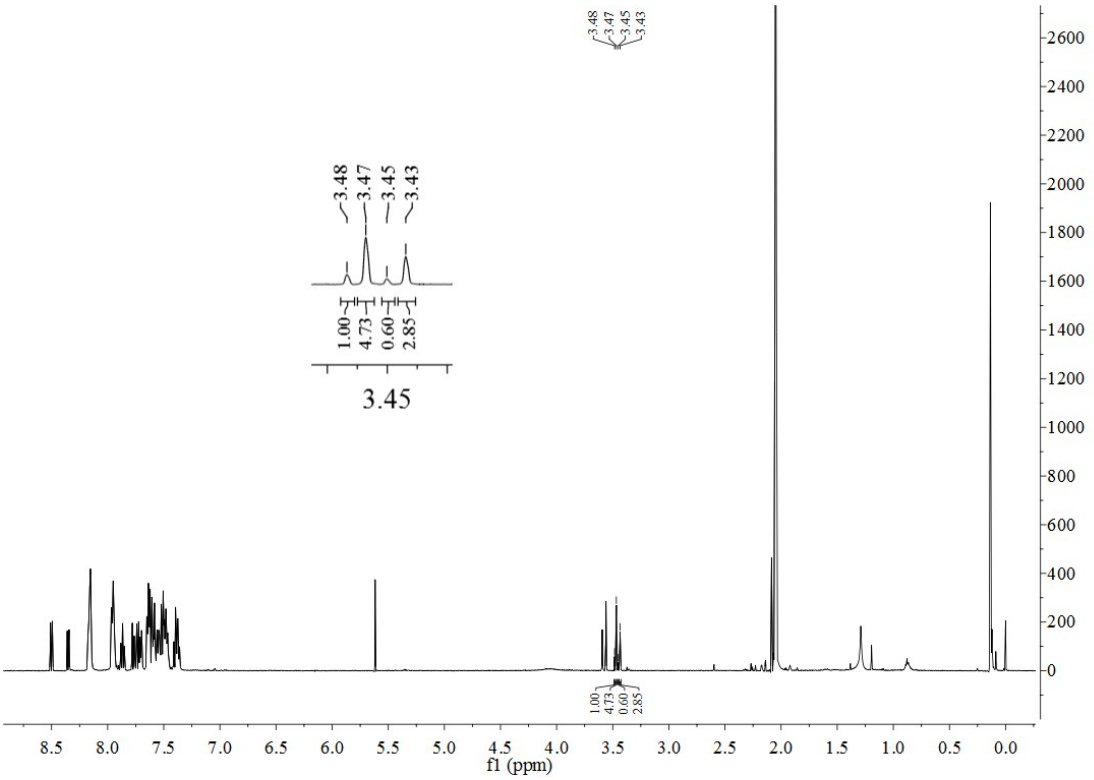


5.2. HPLC of guest 2a' (Sample 1, ee 81.2%).

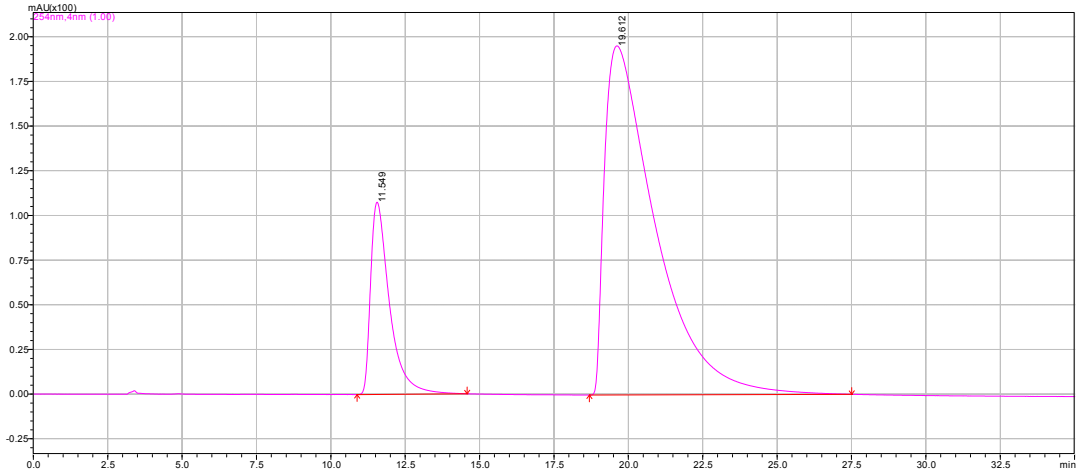


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	11.592	3137113	70627	10.891	14.304	9.4065
2	19.414	30213247	247556	18.539	27.008	90.5935

5.3. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2a (Sample 2, ee 65.1%).

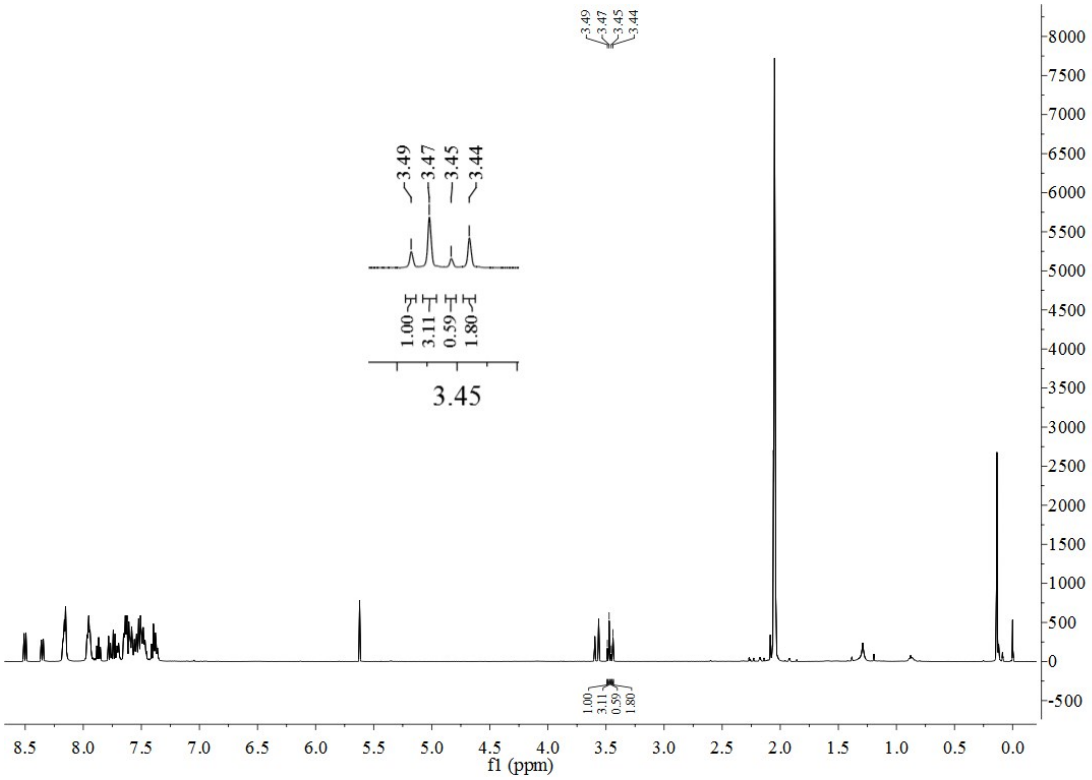


5.4. HPLC of guest 2a' (Sample 2, ee 66.1%).

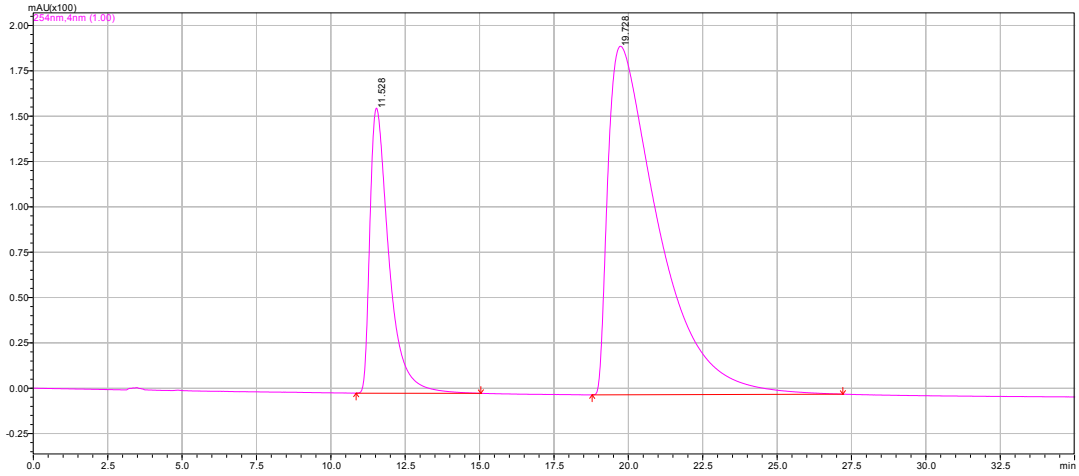


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	11.549	4761352	107576	10.880	14.581	16.9586
2	19.612	23314923	195381	18.688	27.509	83.0414

5.5. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2a (Sample 3, ee 51.1%).

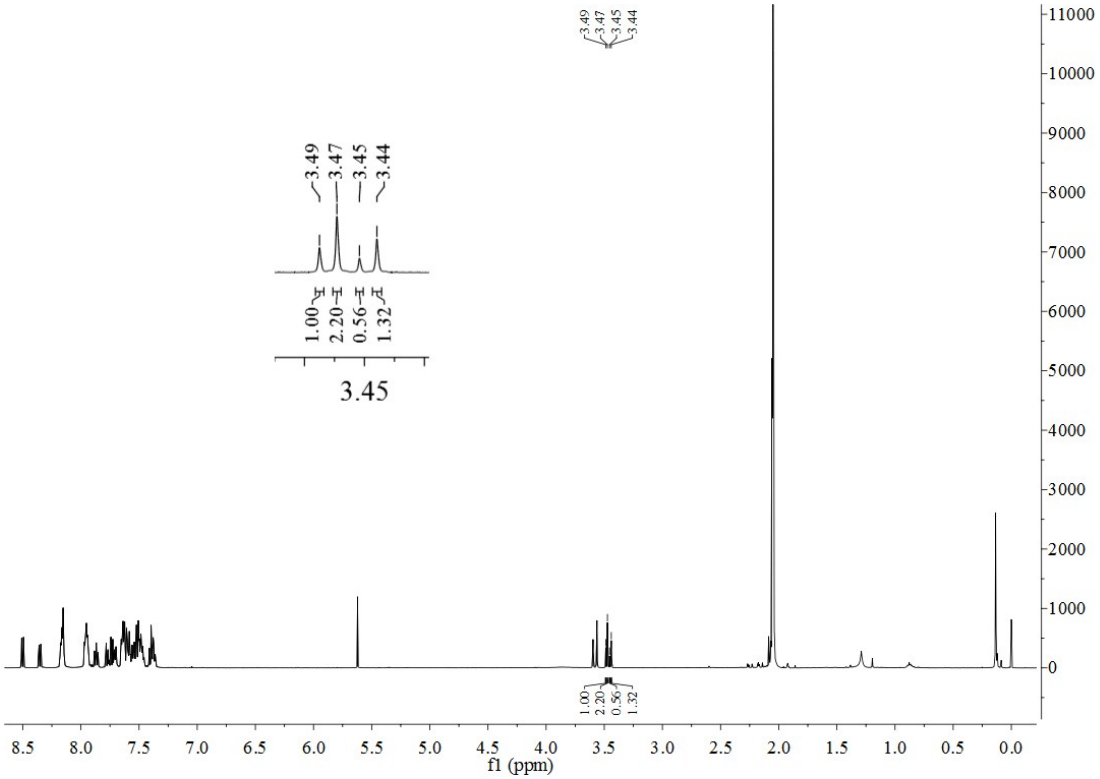


5.6. HPLC of guest 2a' (Sample 3, ee 52.7%).

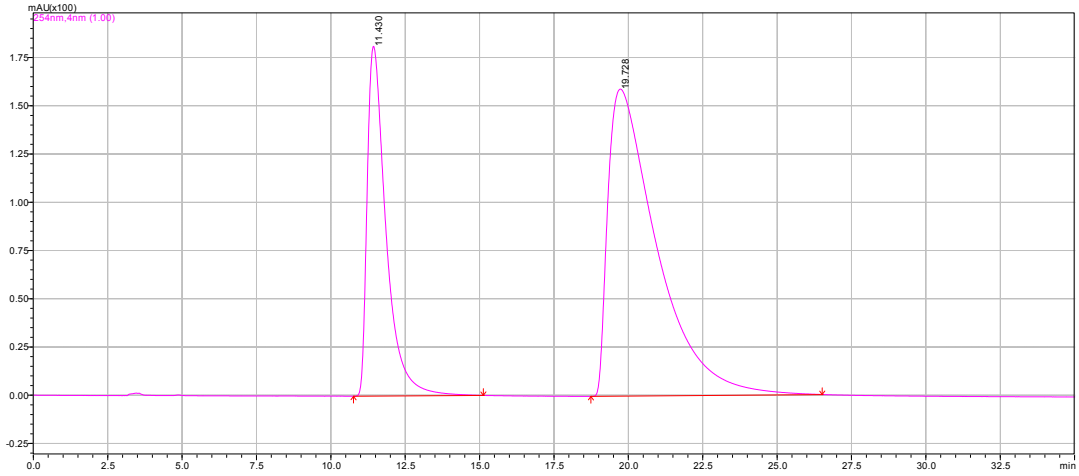


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	11.528	7030258	157159	10.848	15.040	23.6499
2	19.728	22696076	192142	18.784	27.211	76.3501

5.7. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2a (Sample 4, ee 38.6%).

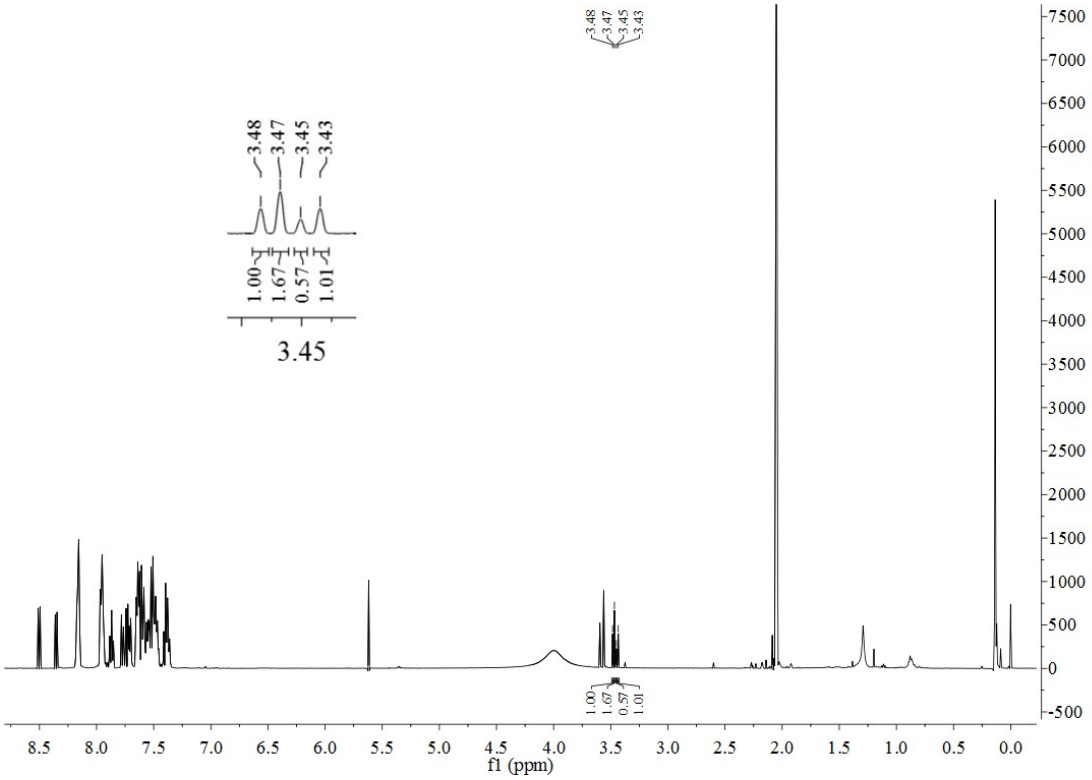


5.8. HPLC of guest 2a' (Sample 4, ee 38.9%).

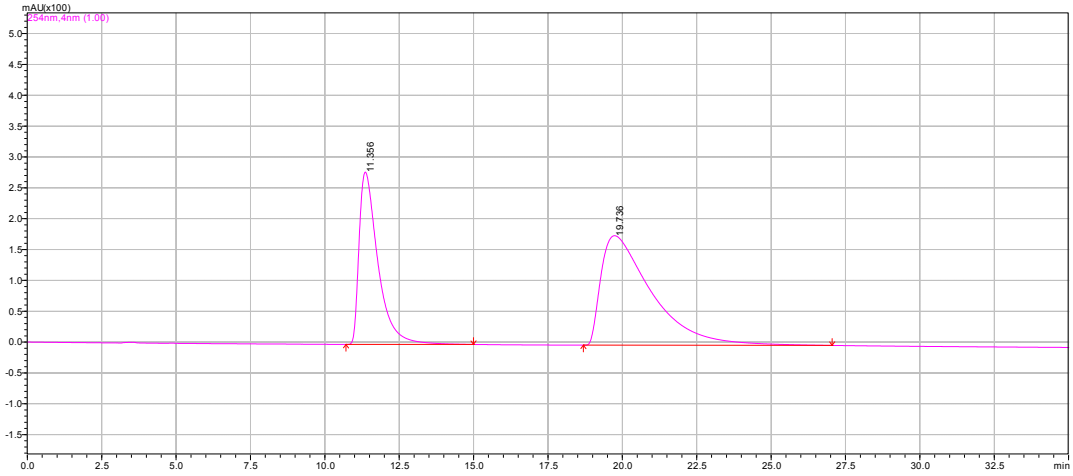


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	11.430	8015810	181334	10.763	15.125	30.5327
2	19.728	18237362	159155	18.741	26.517	69.4673

5.9. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2a (Sample 5, ee 26.1%).

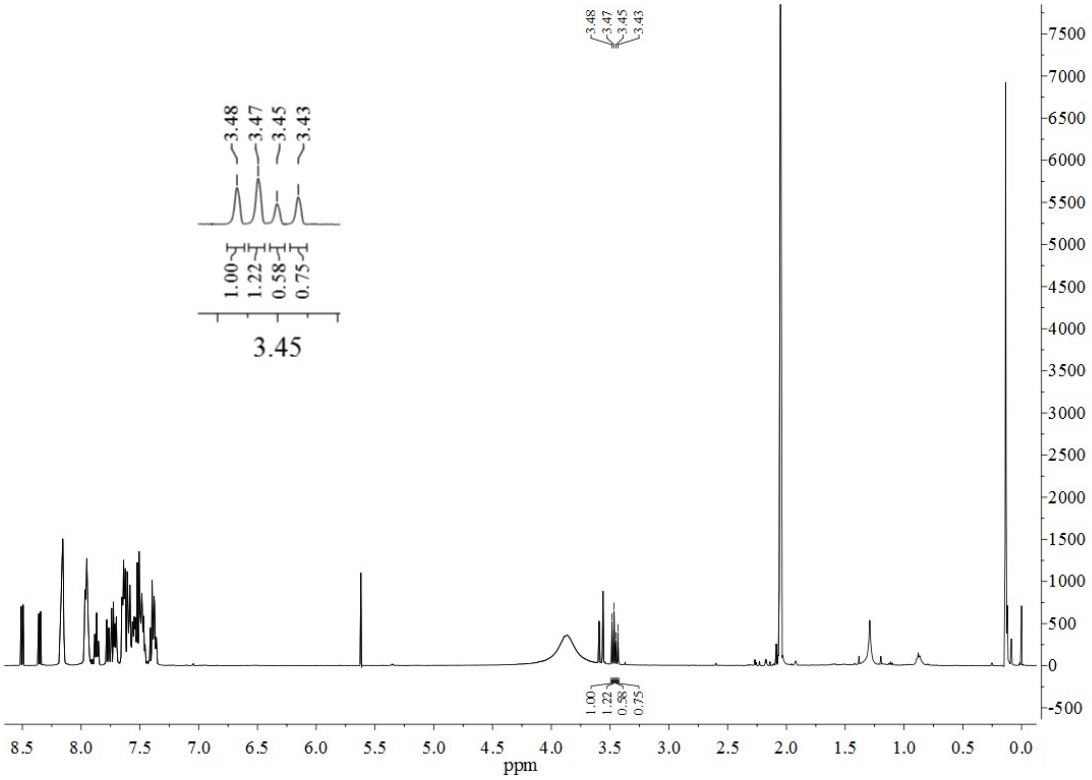


5.10. HPLC of guest 2a' (Sample 5, ee 26.0%).

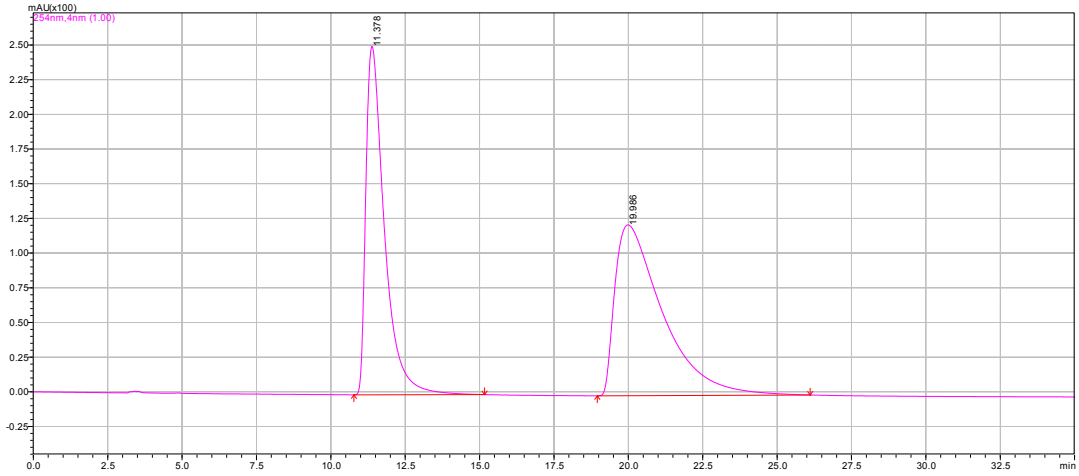


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	11.356	12345298	279349	10.709	14.997	36.9798
2	19.736	21038580	177489	18.688	27.051	63.0202

5.11. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2a (Sample 6, ee 11.0%).

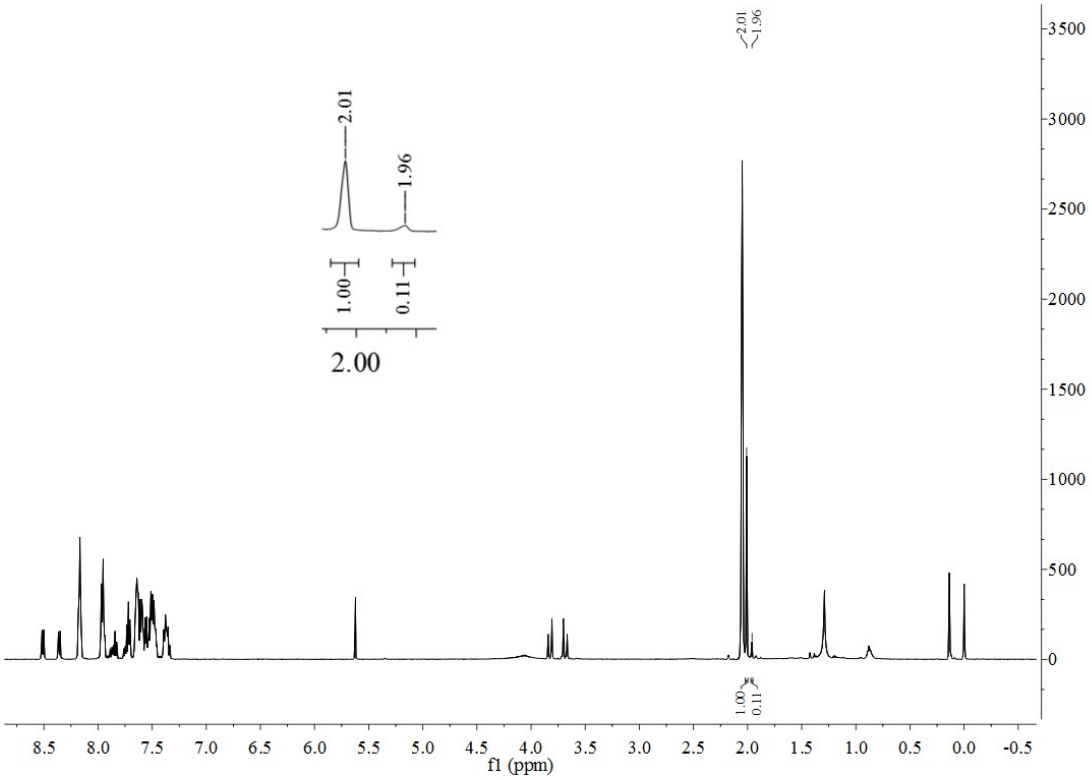


5.12. HPLC of guest 2a' (Sample 6, ee 11.4%).

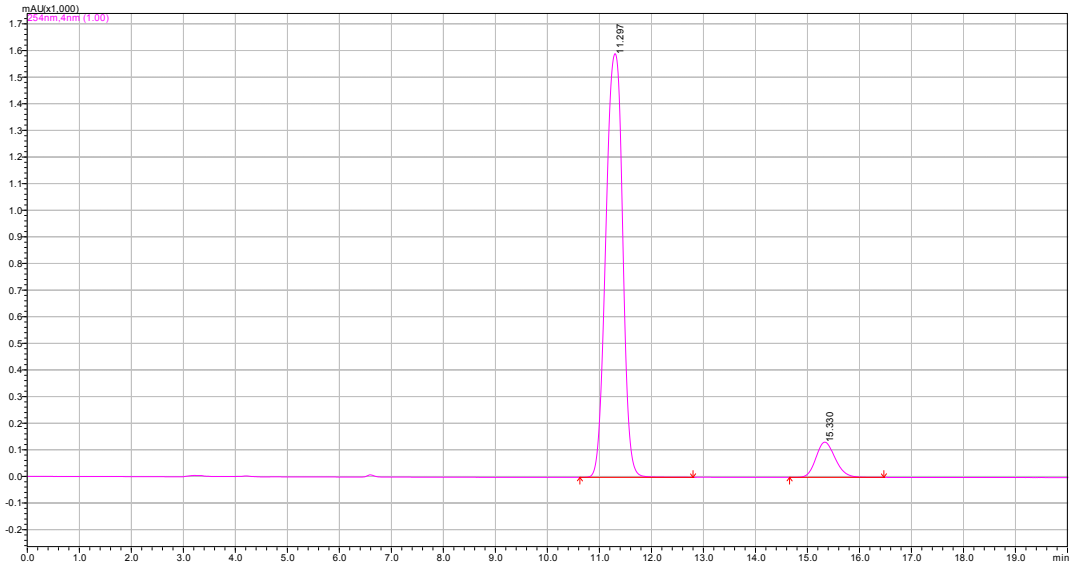


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	11.378	10945741	251330	10.773	15.168	44.3138
2	19.986	13754757	123222	18.955	26.112	55.6862

5.13. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2f (Sample 7, ee 80.2%).

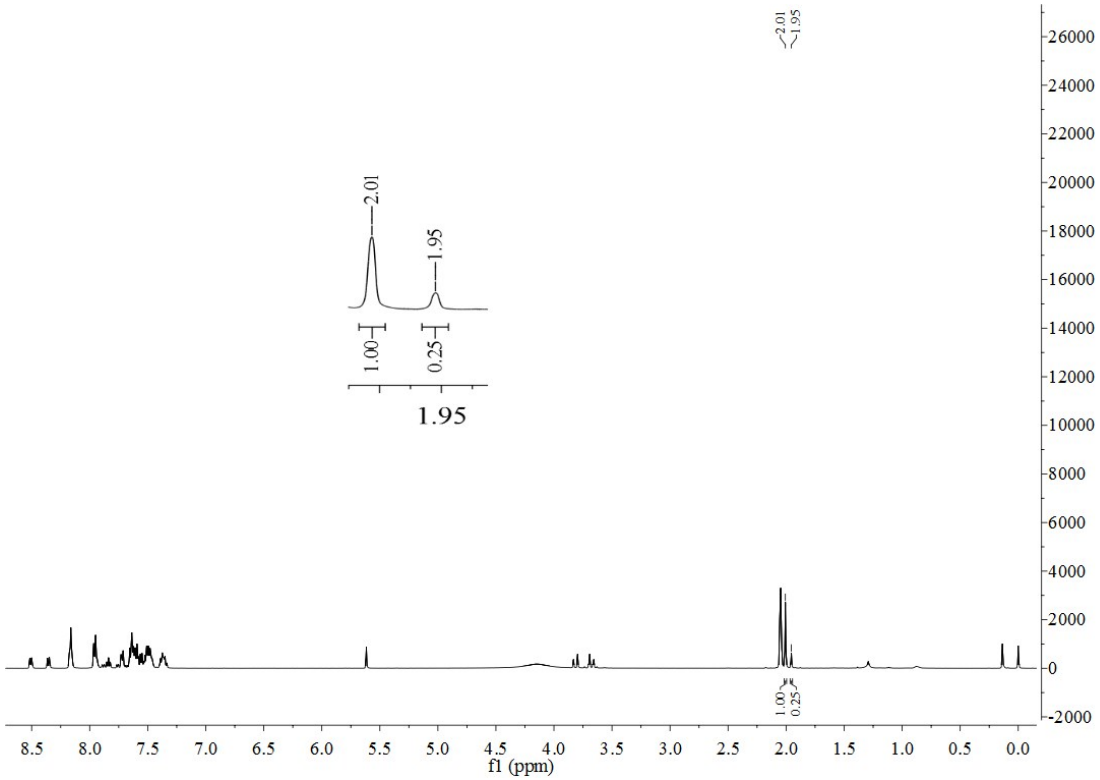


5.14. HPLC of guest 2f (Sample7, ee 82.5%).

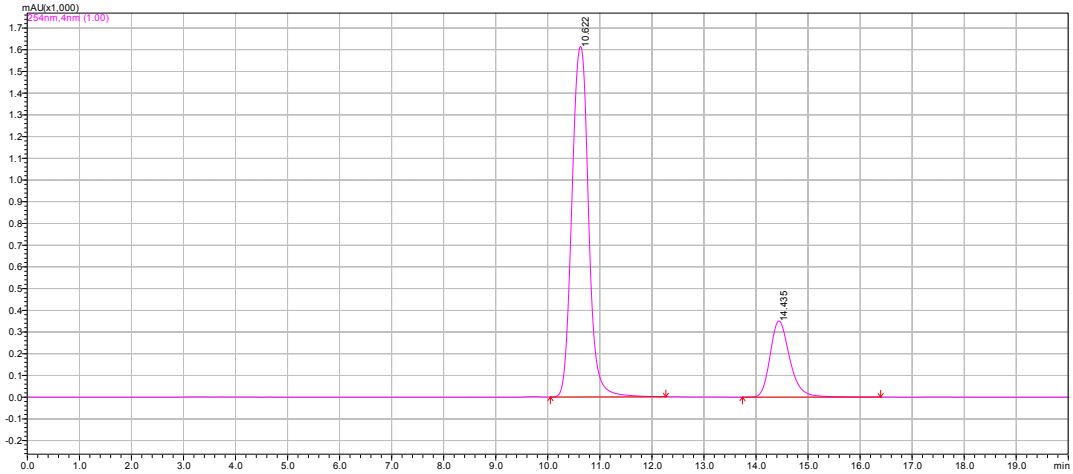


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	11.297	35709491	1591188	10.624	12.800	91.2619
2	15.330	3419074	132513	14.656	16.469	8.7381

5.15. ^{1}H NMR (500 MHz, ACETONE-D$_6$) of CPA 1d and guest 2f (Sample 8, ee 60.0%).

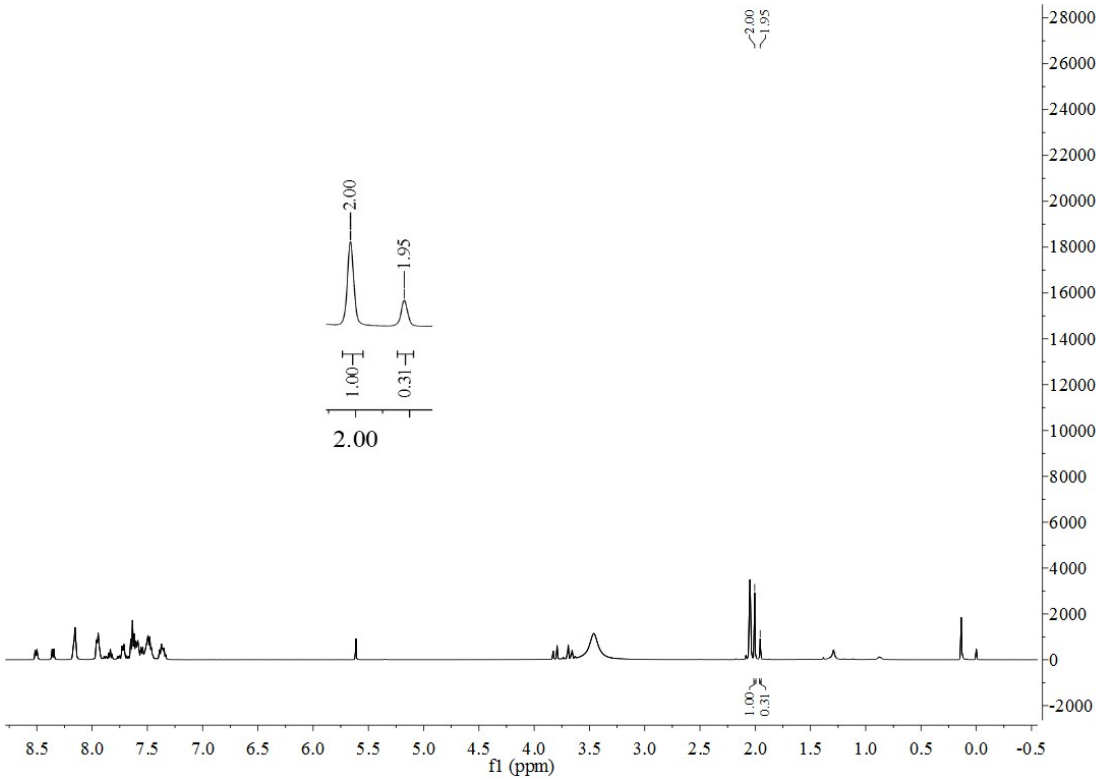


5.16. HPLC of guest 2f (Sample 8, ee 59.2%).

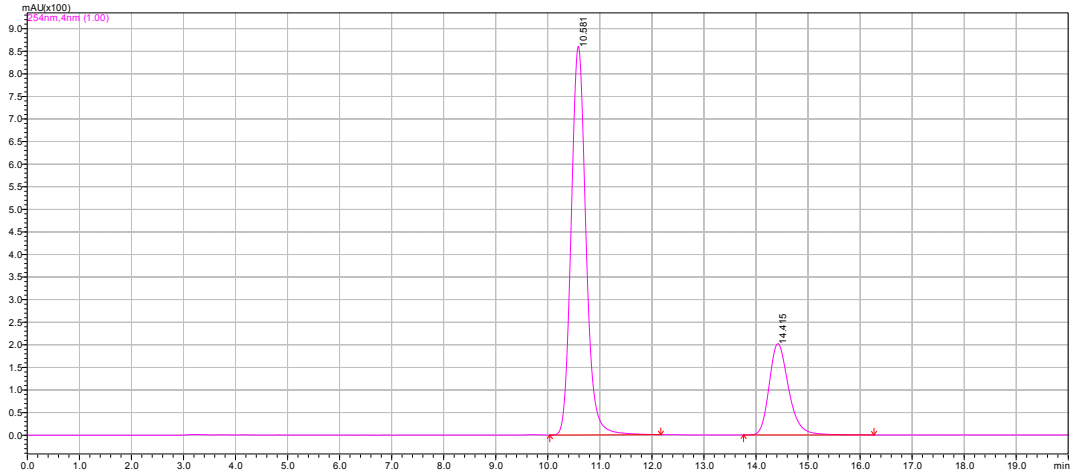


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.622	35890342	1614320	10.048	12.267	79.6094
2	14.435	9192717	350725	13.739	16.395	20.3906

5.17. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2f (Sample 9, ee 52.7%).

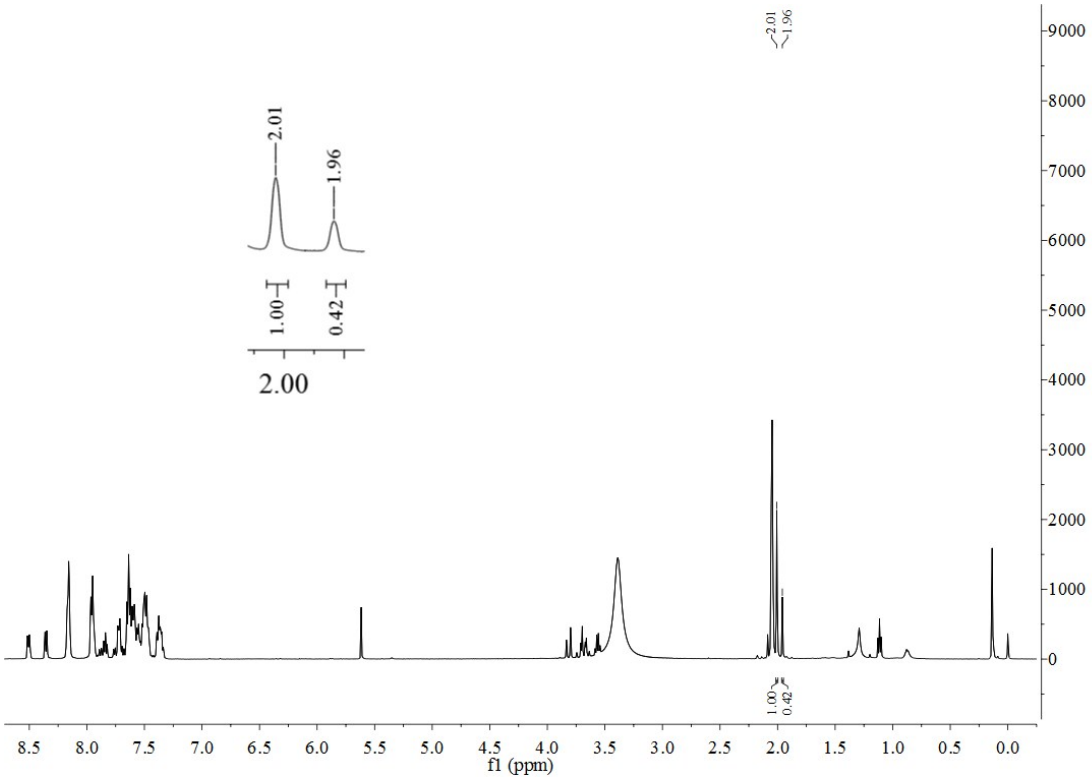


5.18. HPLC of guest 2f (Sample 9, ee 52.8%).

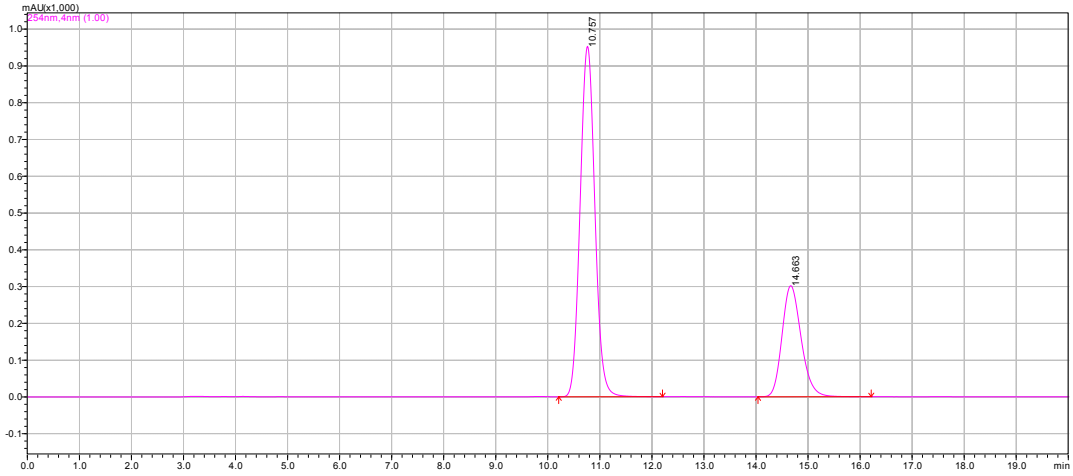


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.581	17042169	860334	10.037	12.171	76.4180
2	14.415	5259086	202128	13.760	16.267	23.5820

5.19. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2f (Sample 10, ee 40.8%).

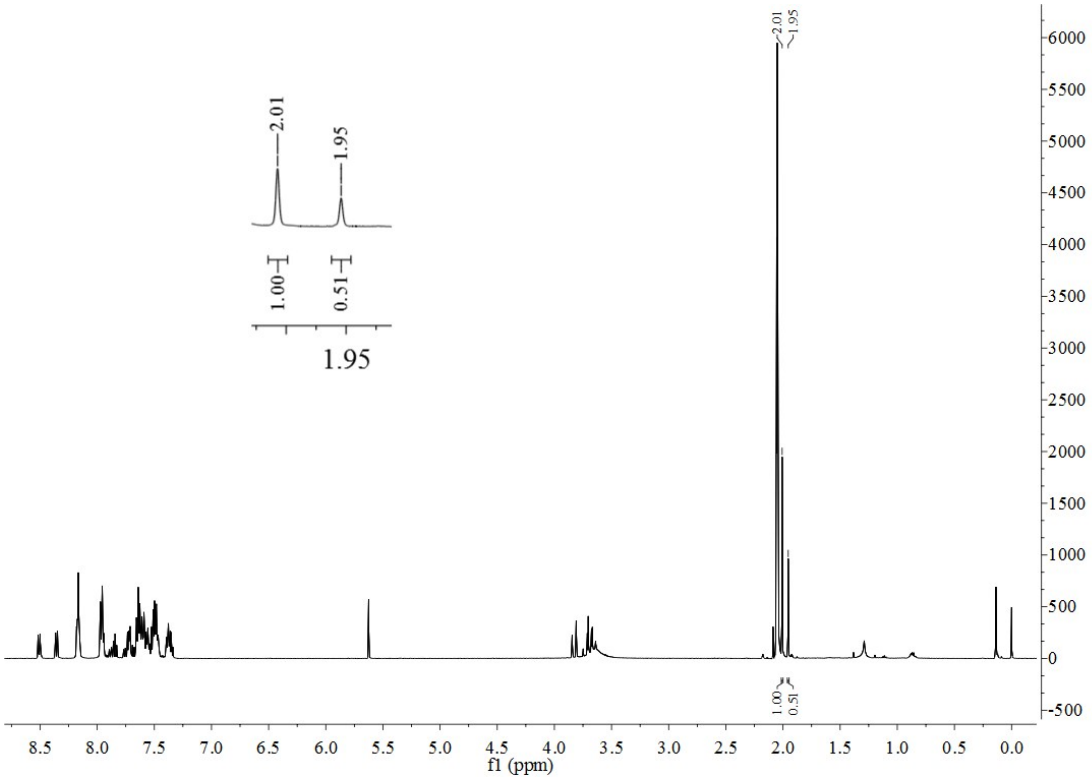


5.20. HPLC of guest 2f (Sample 10, ee 41.7%).

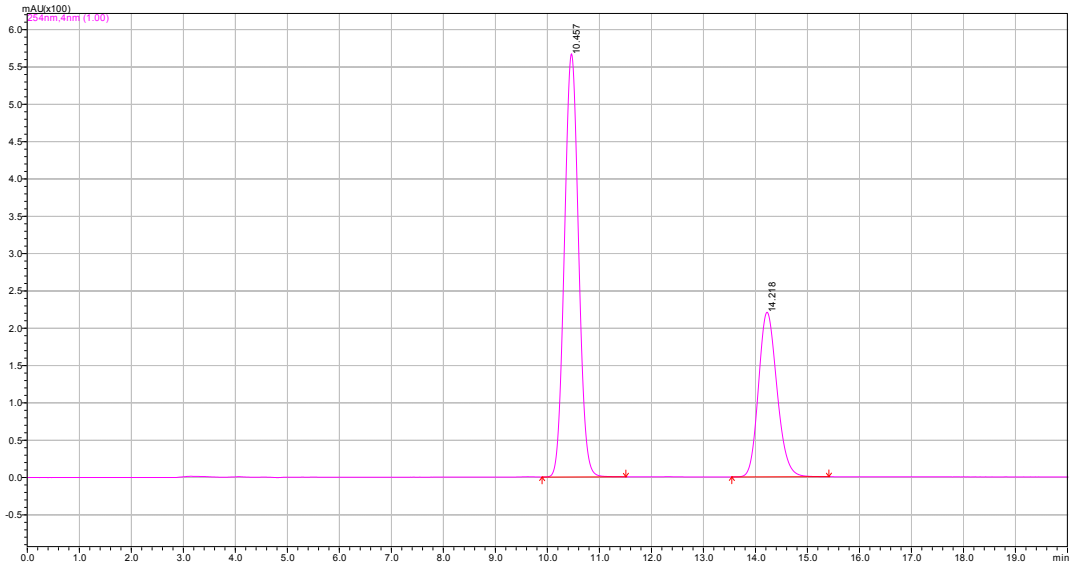


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.757	18745435	953030	10.208	12.203	70.8530
2	14.663	7711347	301972	14.037	16.213	29.1470

5.21. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2f (Sample 11, ee 32.5%).

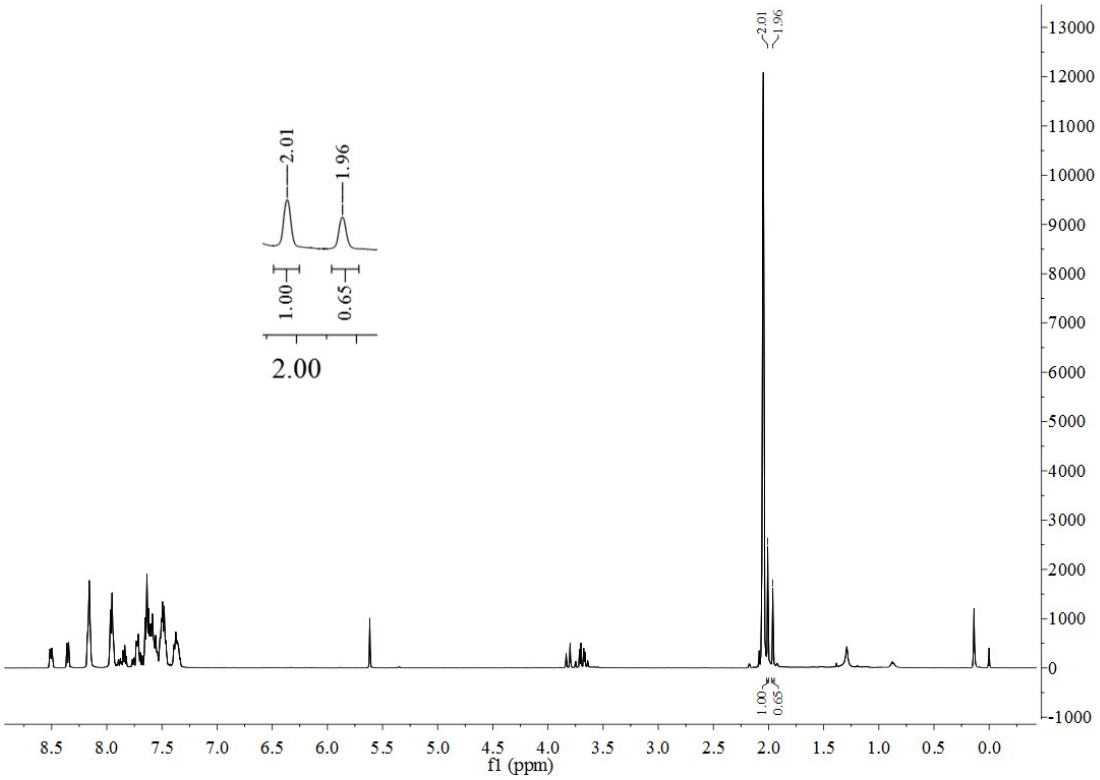


5.22. HPLC of guest 2f (Sample 11, ee 32.5%).

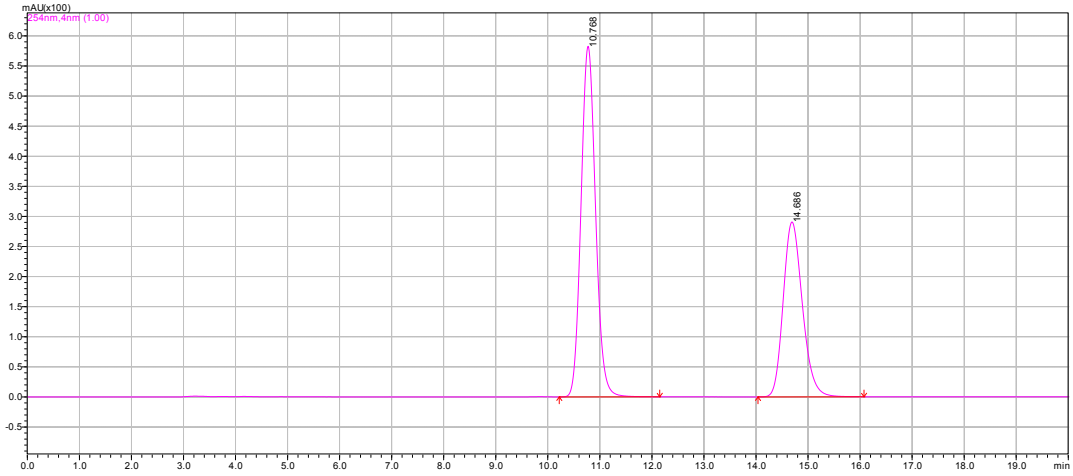


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.457	10705423	566954	9.899	11.509	66.2670
2	14.218	5449570	220488	13.547	15.413	33.7330

5.23. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2f (Sample 12, ee 21.2%).

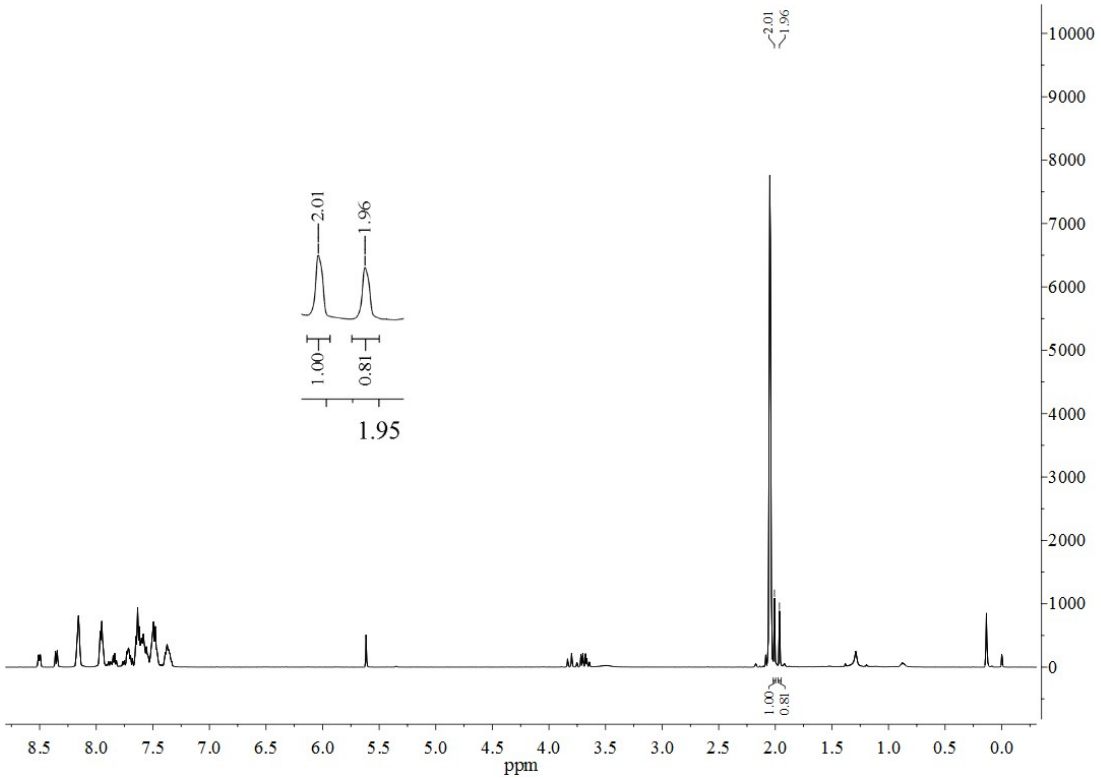


5.24. HPLC of guest 2f (Sample 12, ee 20.6%).

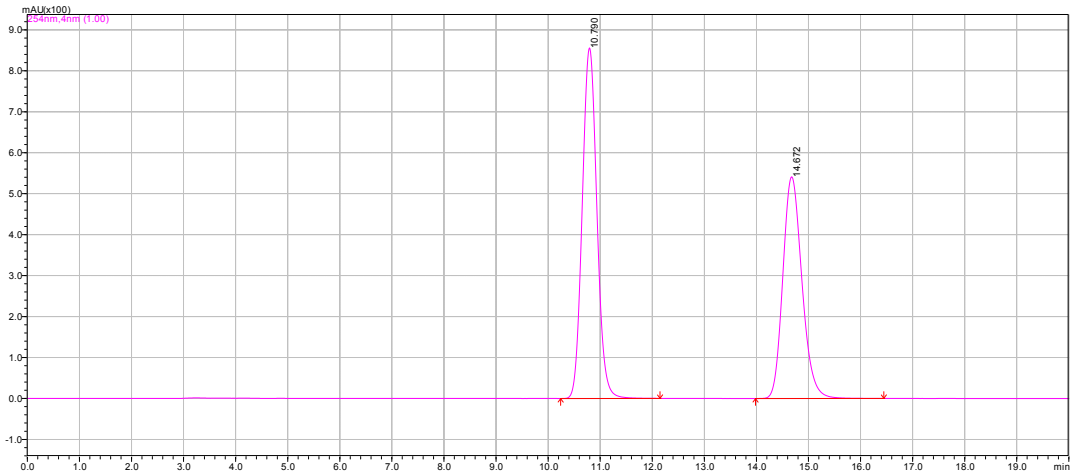


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.768	11302331	582636	10.219	12.149	60.2997
2	14.686	7441270	290554	14.037	16.075	39.7003

5.25. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2f (Sample 13, ee 10.5%).

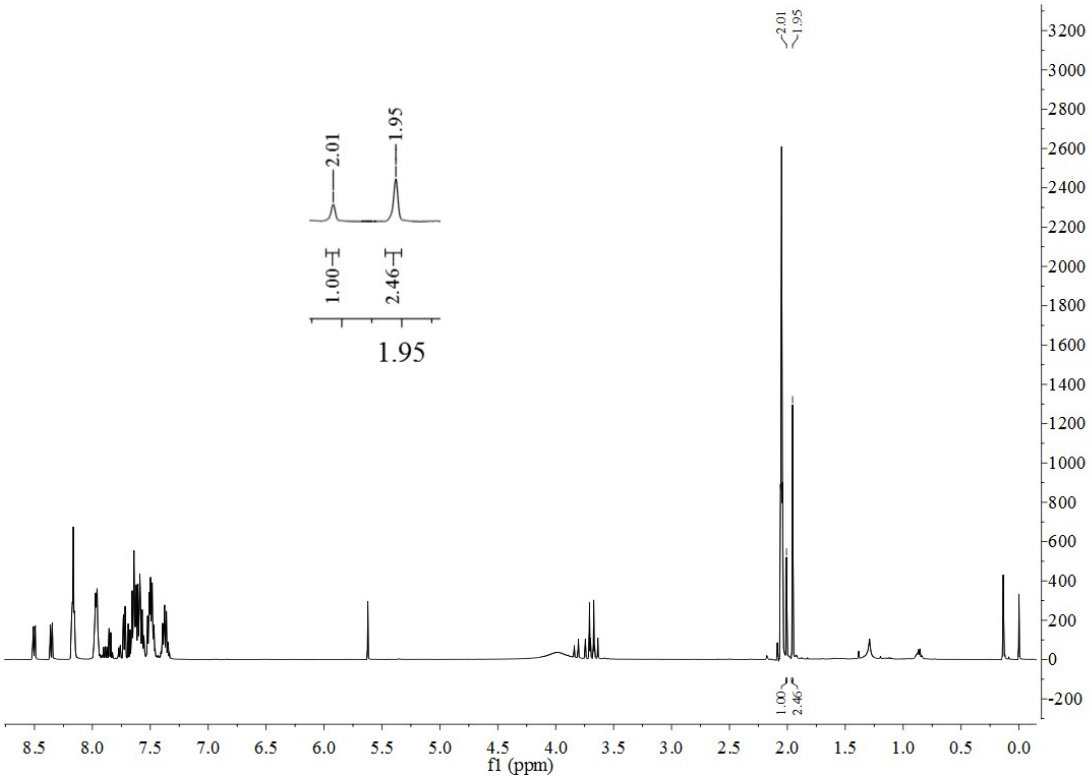


5.26. HPLC of guest 2f (Sample 13, ee 9.6%).

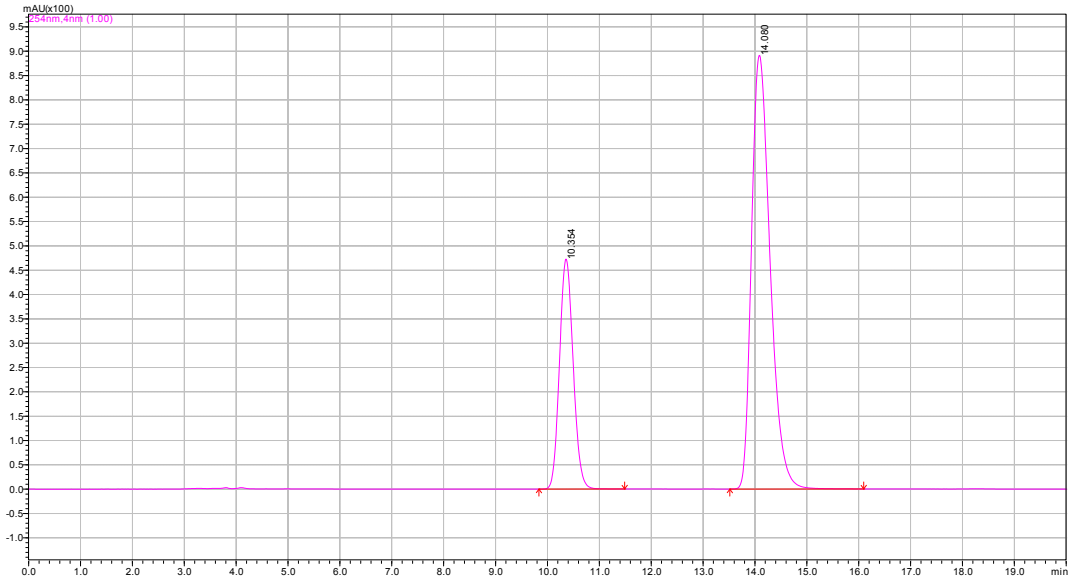


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.790	16737062	856071	10.240	12.149	54.7864
2	14.672	13812622	541397	13.984	16.448	45.2136

5.27. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2f (Sample 14, ee -42.2%).

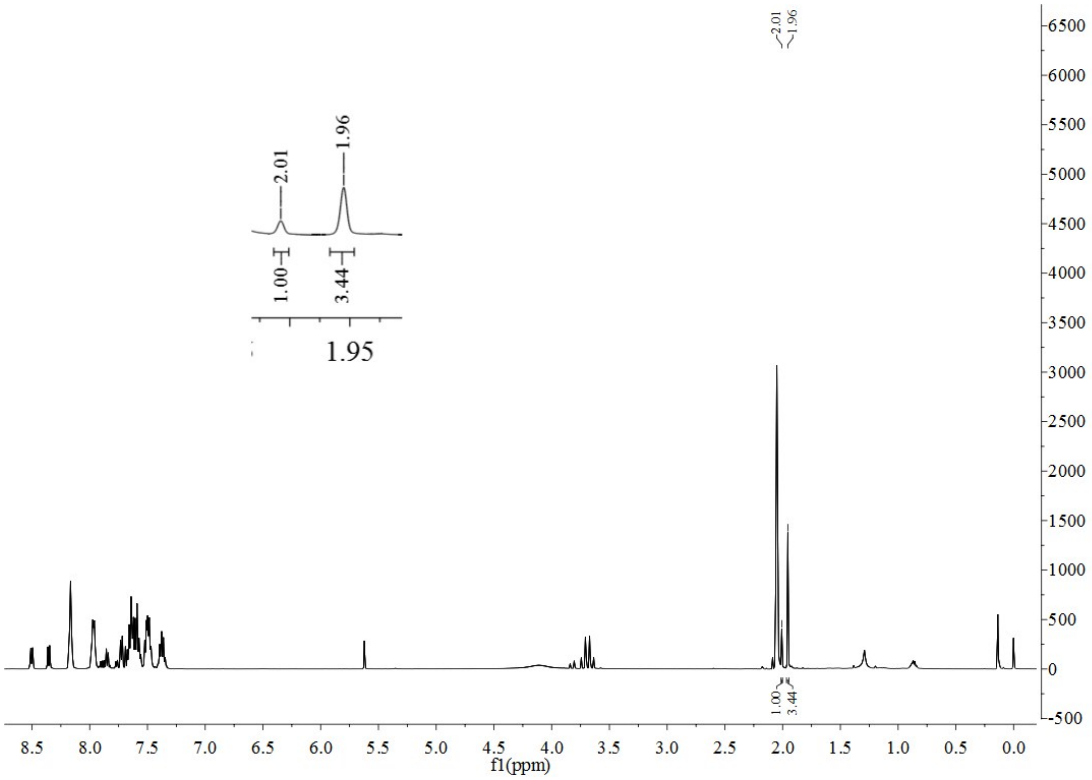


5.28. HPLC of guest 2f (Sample 14, ee -44.0%).

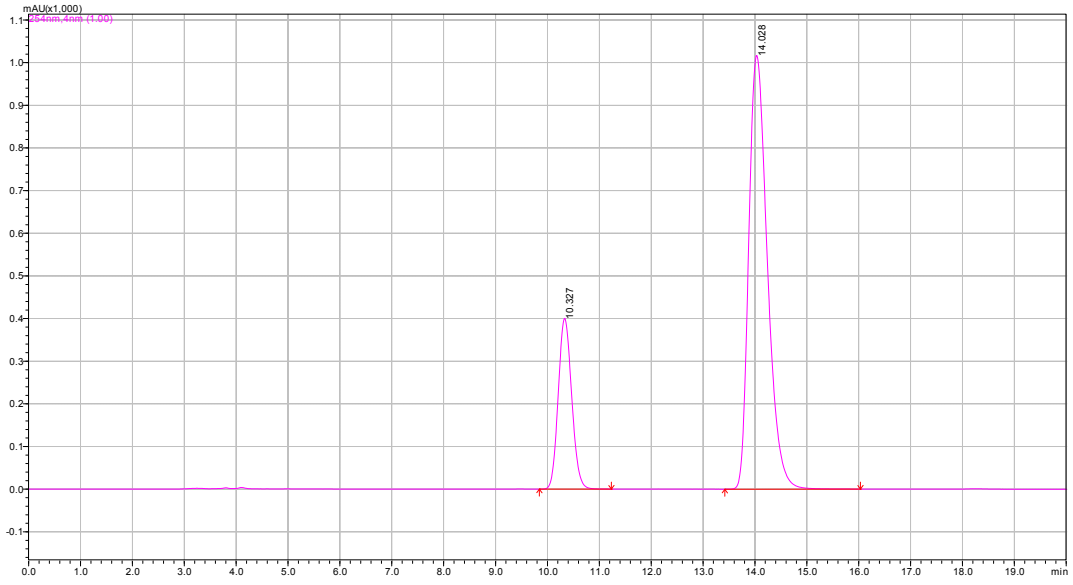


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.354	8648303	472606	9.835	11.488	28.0206
2	14.080	22215786	891115	13.515	16.096	71.9794

5.29. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d and guest 2f (Sample 15, ee -55.0%).



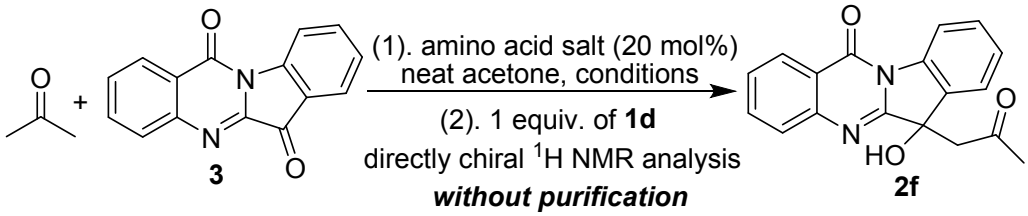
5.30. HPLC of guest 2f (Sample 15, ee -55.7%).

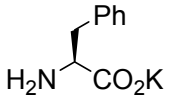
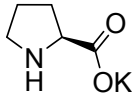
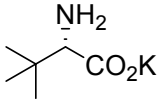
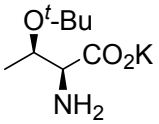
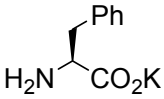


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.327	7208227	400148	9.845	11.232	22.1710
2	14.028	25303762	1016915	13.419	16.032	77.8290

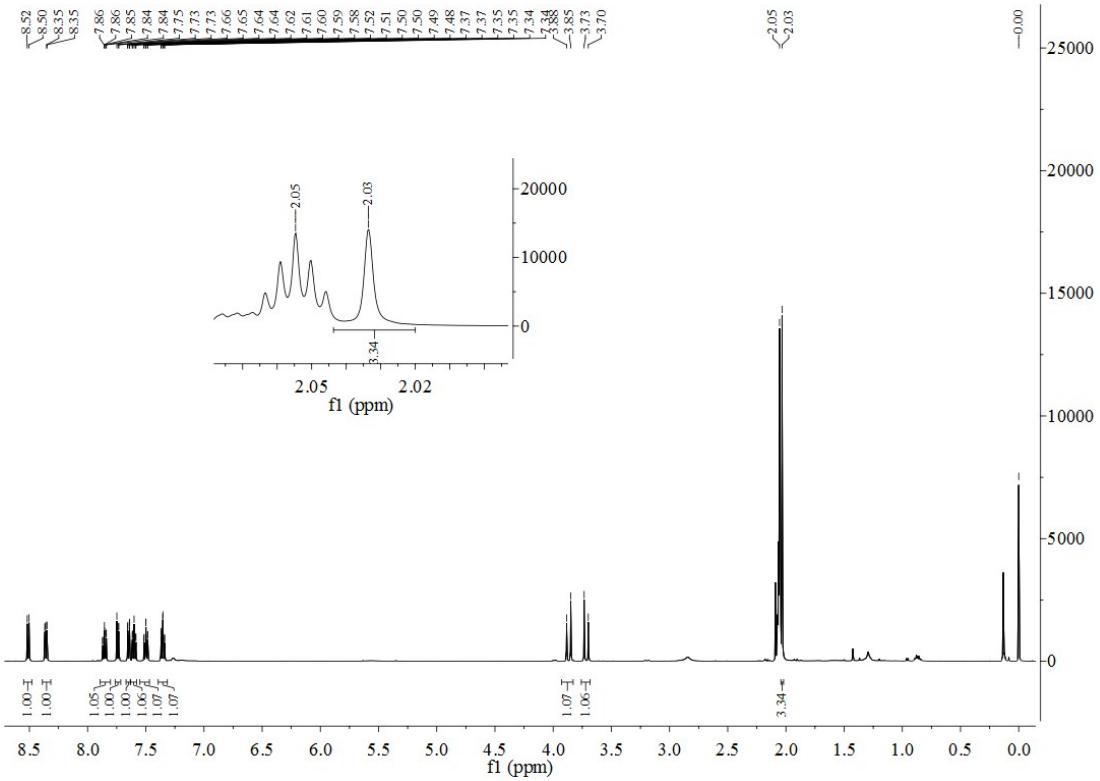
6. Copies of ^{1}H NMR spectra/HPLC data for the fast evaluation of reaction conditions in catalytic asymmetric aldol reaction between acetone and tryptanthrin.

General procedure: tryptanthrin (0.1 mmol) and catalyst (20 mmol %) were added to 0.8 mL of acetone and stirred under the specific temperature until the reaction was completed; then acetone was added to the reaction mixture until the volume of resulting solution reached 10 mL; 1.0 mL of the reaction mixture solution was subsequently removed to a flask and dried for ^{1}H NMR analysis in the presence of 0.01 mmol **1d**.

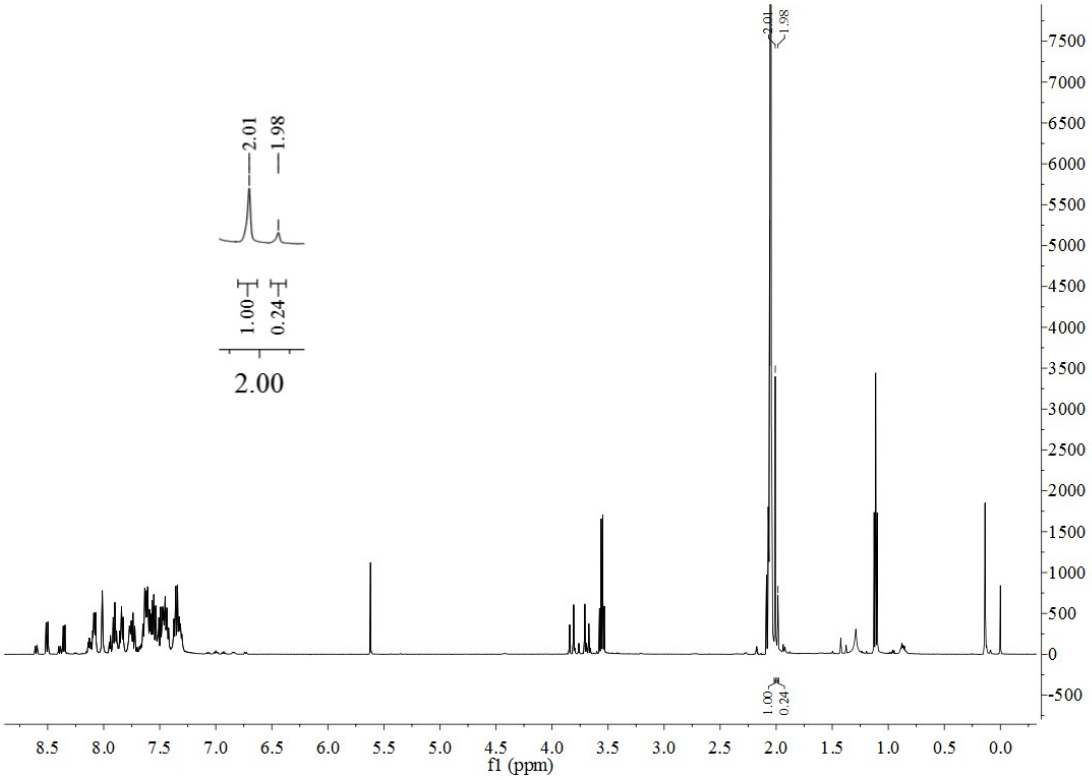


entry	cat.	temp.	*S*:*R* (by NMR)	*S*:*R* (by HPLC)	absolute error
1		0 °C	80.7 : 19.3	81.7 : 18.3	2.0
2		0 °C	51.8 : 48.2	50.6 : 49.4	2.4
3		0 °C	73.0 : 27.0	72.6 : 27.4	0.8
4		0 °C	75.8 : 24.2	76.3 : 23.7	1.0
5		-10 °C	87.7 : 12.3	88.6 : 11.4	1.8

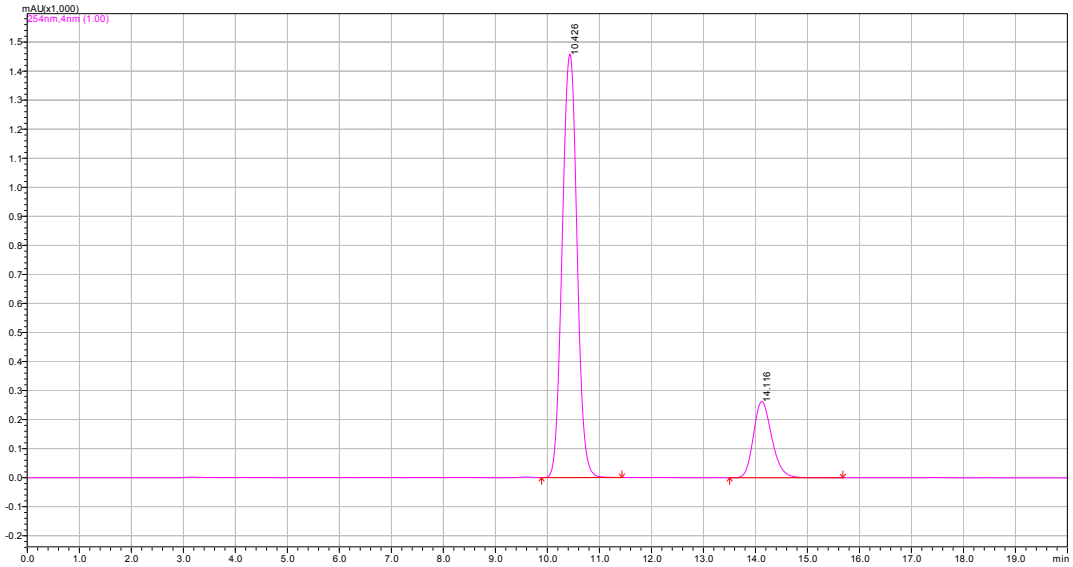
6.1. ^{1}H NMR (500 MHz, ACETONE-D_6) of reaction mixture without purification.



6.2. ^{1}H NMR (500 MHz, ACETONE-D_6) of entry 1, *S*:*R*= 80.7 : 19.3.

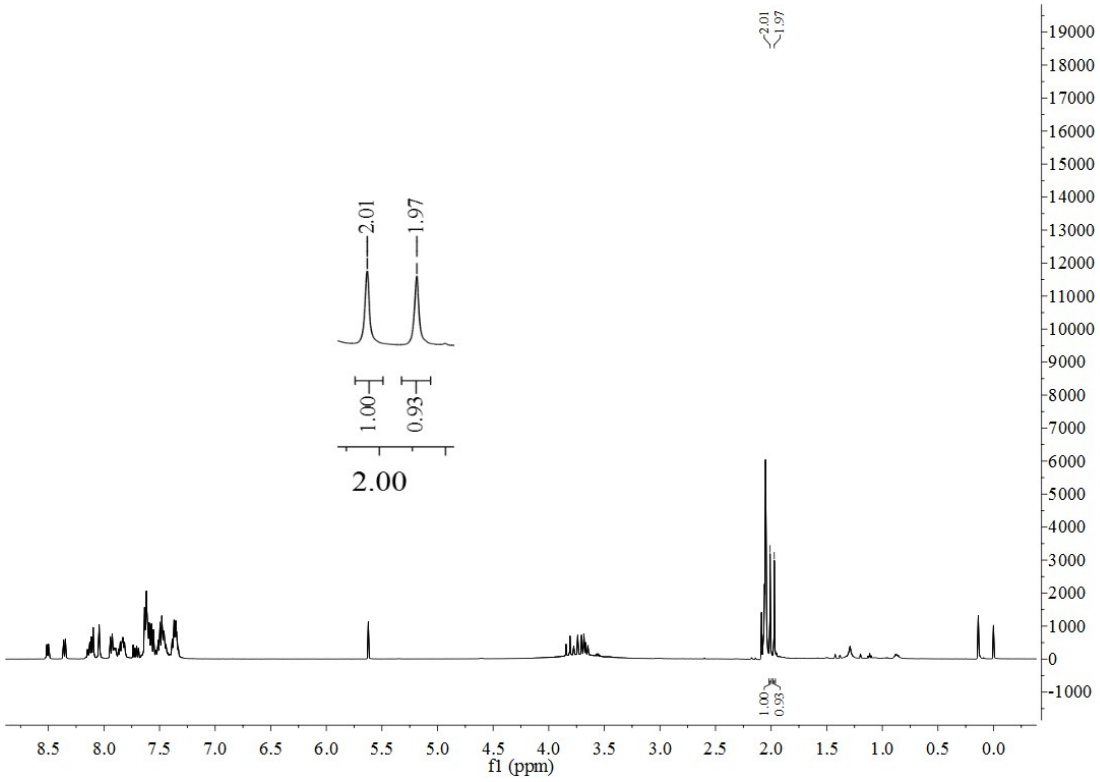


6.3. HPLC of entry 1, *S*:*R*= 81.7 : 18.3.

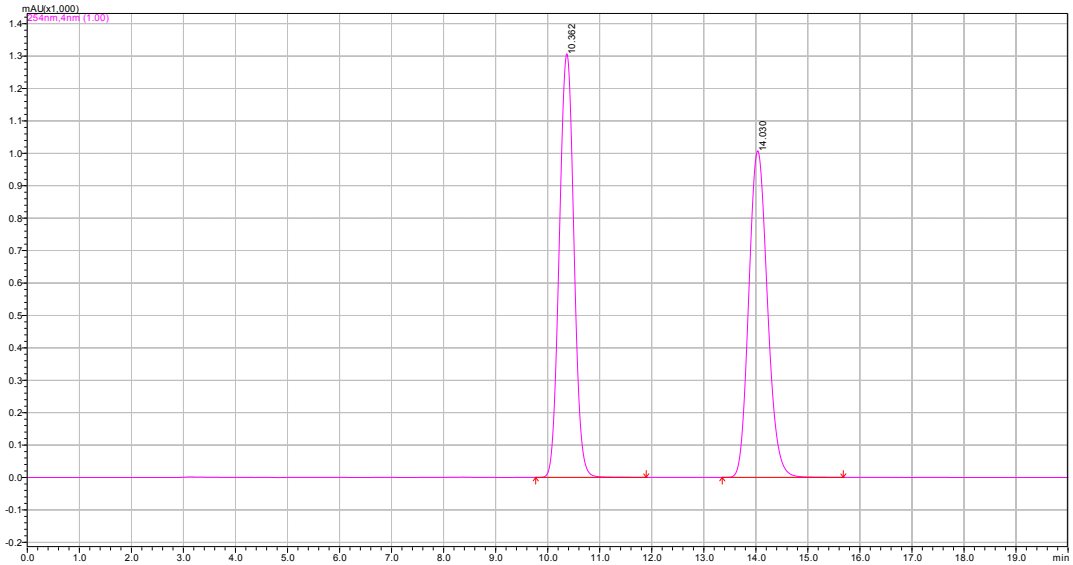


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.426	28837671	1458496	9.888	11.435	81.7277
2	14.116	6447409	262414	13.504	15.680	18.2723

6.4. ^{1}H NMR (500 MHz, ACETONE-D_6) of entry 2 , *S*:*R* = 51.8 : 48.2.

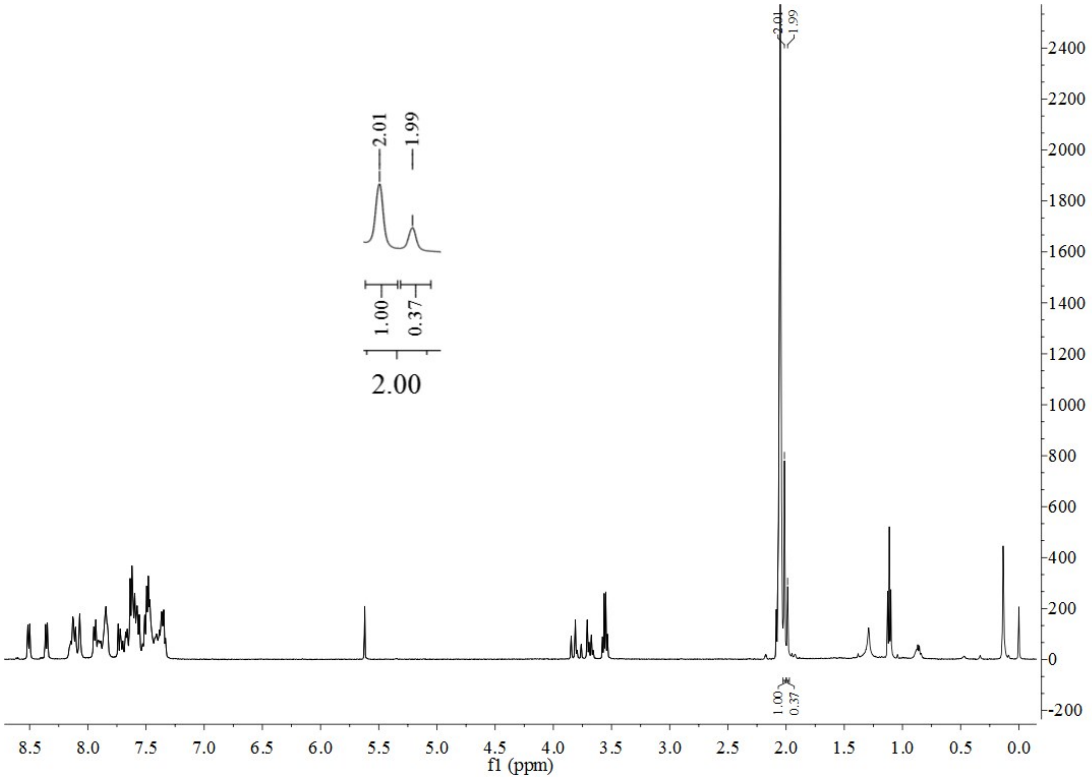


6.5. HPLC of entry 2 , *S*:*R* = 50.6 : 49.4.

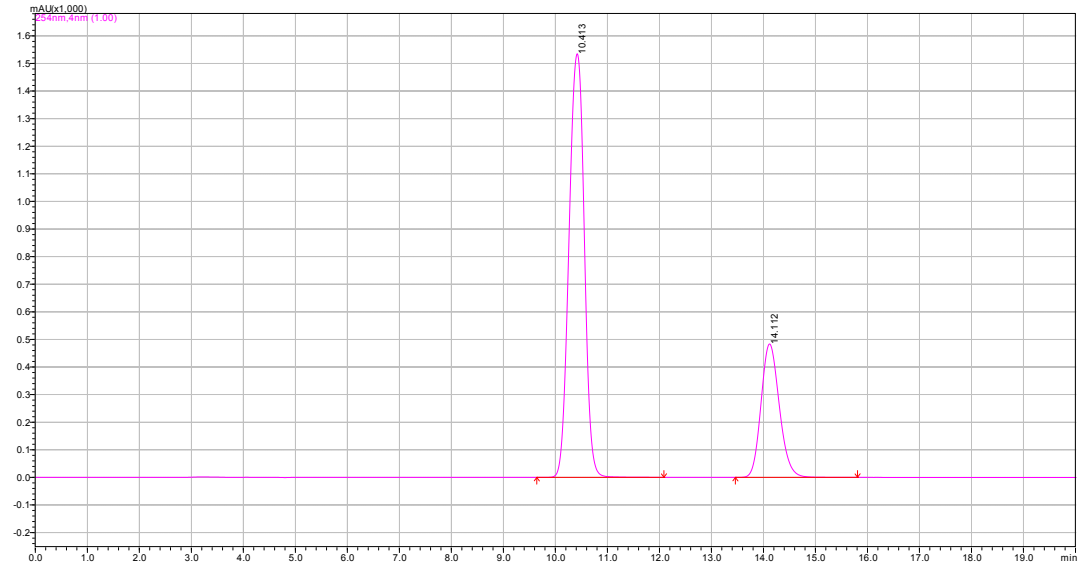


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.362	25539034	1307041	9.771	11.893	50.5573
2	14.030	24975980	1007753	13.355	15.680	49.4427

6.6. ^{1}H NMR (500 MHz, ACETONE-D_6) of entry 3, *S*:*R* =73.0 : 27.0.

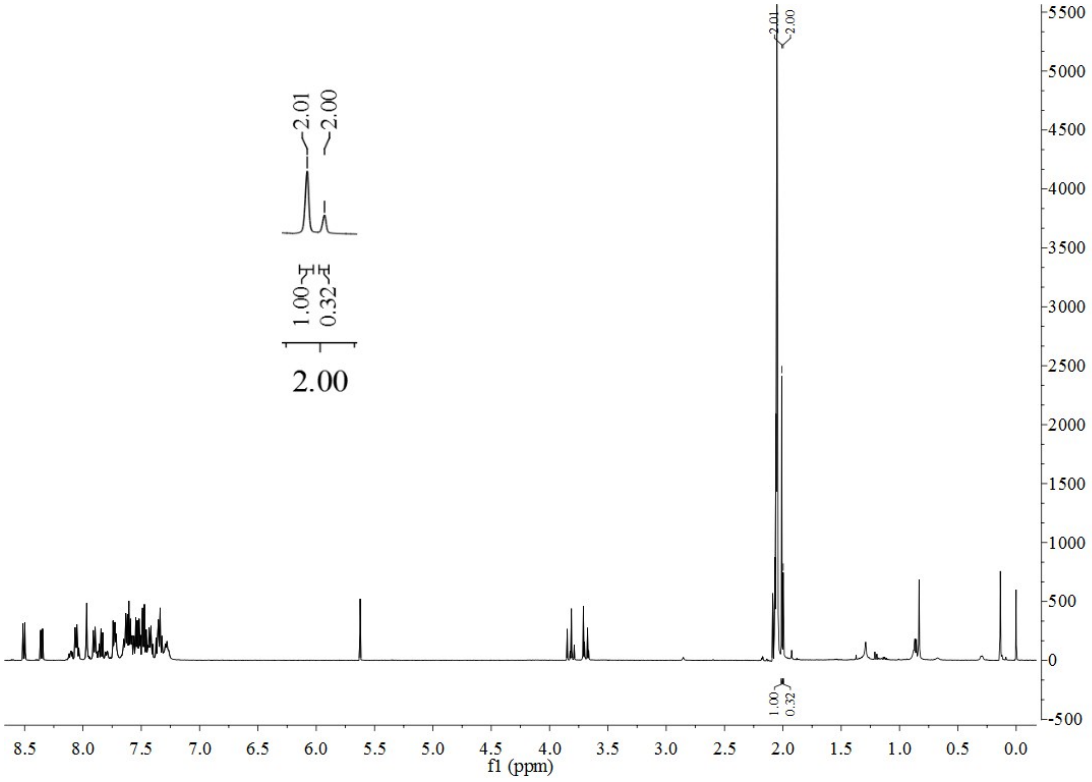


6.7. HPLC of entry 3, *S*:*R* =72.6 : 27.4.

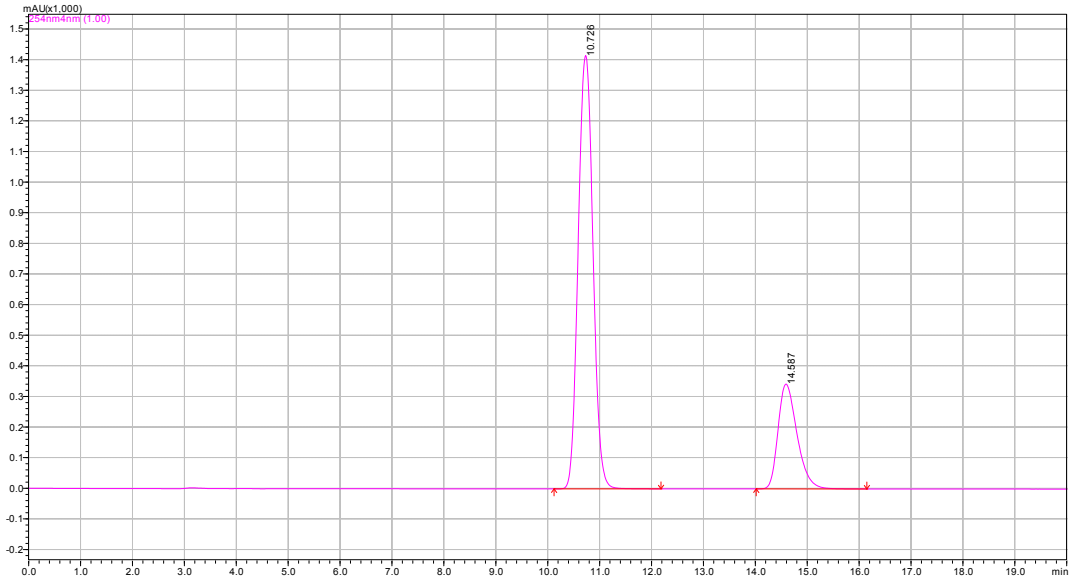


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.413	31340187	1535056	9.643	12.085	72.5607
2	14.112	11851517	483419	13.461	15.808	27.4393

6.8. ^{1}H NMR (500 MHz, ACETONE-D_6) of entry 4 , *S*:*R* =75.8 : 24.2.

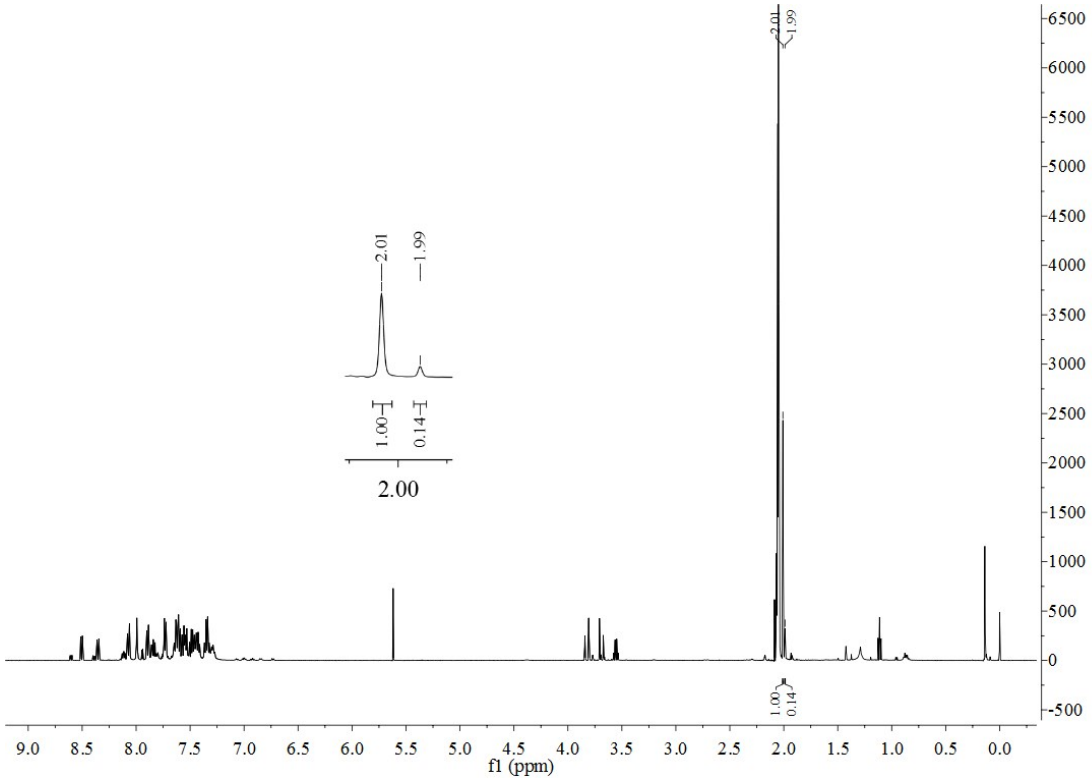


6.9. HPLC of entry 4, *S*:*R* =76.3 : 23.7.

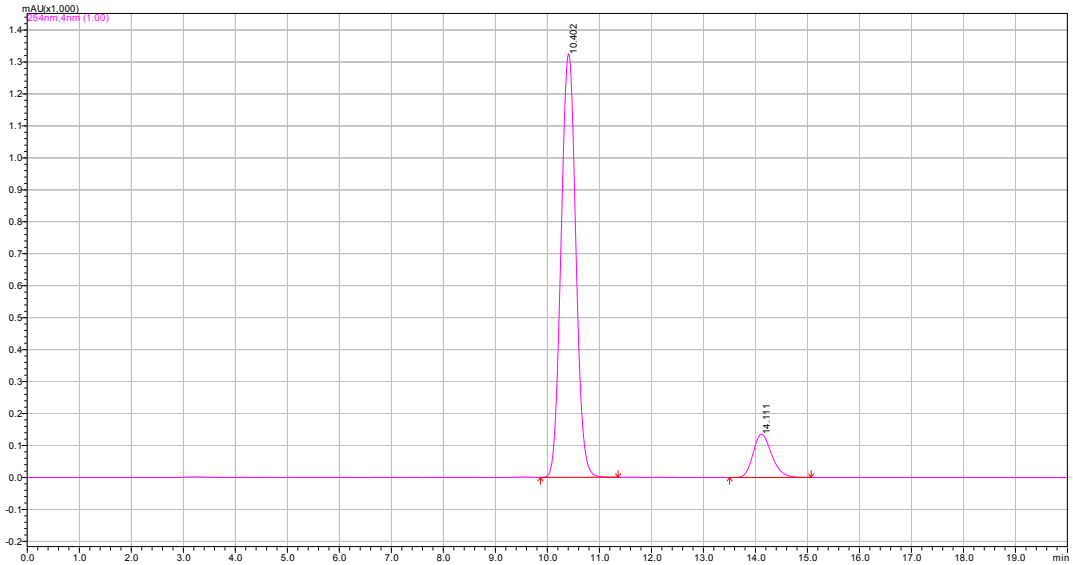


Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.726	28020828	1415441	10.123	12.181	76.2566
2	14.587	8724599	342495	14.016	16.149	23.7434

6.10. ^{1}H NMR (500 MHz, ACETONE-D_6) of entry 5, *S*:*R* =87.7 : 12.3.



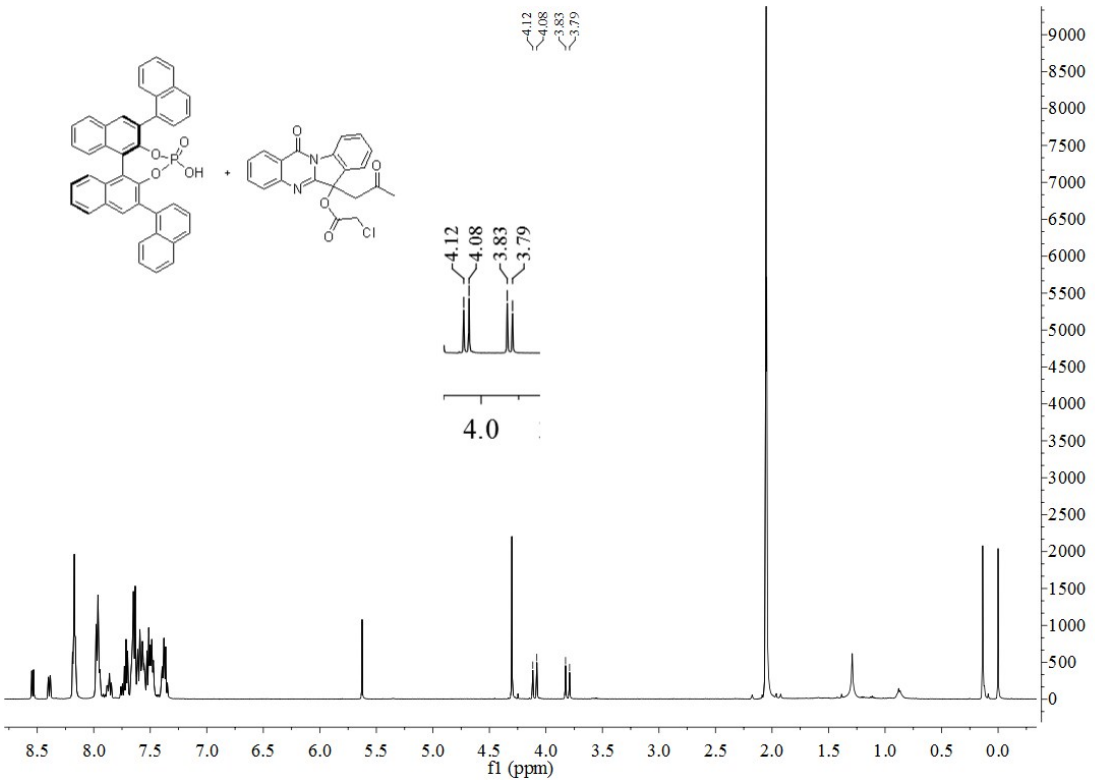
6.11. HPLC of entry 5, *S*:*R* = 88.6 : 11.4.



Peak	Ret. Time	Area	Height	Peak Start	Peak End	Area%
1	10.402	26160206	1325232	9.867	11.360	88.5749
2	14.111	3374347	135771	13.504	15.072	11.4251

7. Copies of ^{1}H NMR spectra of control experiments.

7.1. ^{1}H NMR (500 MHz, ACETONE-D_6) of CPA 1d (0.01 mmol, 1.0 equiv.) and guest 4 (0.01 mmol, 1.0 equiv.).



7.1. ^{1}H NMR (500 MHz, ACETONE-D6) of CPA 1d (0.01 mmol, 1.0 equiv.) and guest 5 (0.01 mmol, 1.0 equiv.).