Electronic Supplementary Information

for

Cinchona Alkaloid Derivatives modified Fe_3O_4 Nanoparticles for Enantioselective Ring Opening of *meso*- Cyclic Anhydrides

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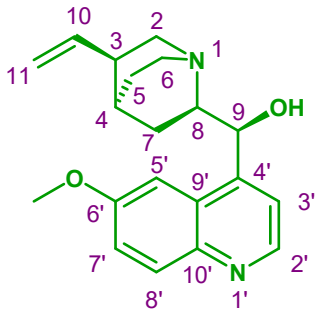


Fig. S1. Molecular frame-work of quinidine.

Table S1. BET surface characterization of as-synthesized Fe_3O_4@mQD NPs.

	Parametres	**Results**
1	BET surface area	57.55m^2/g
2	Adsorption average pore diameter (4V/A)	115.28Å
3	Adsorption average pore width (4V/Aby BET)	129.45Å
4	Volume in pores	0.0015cm^3/g
5	Total volume in pores	0.16 cm^3/g

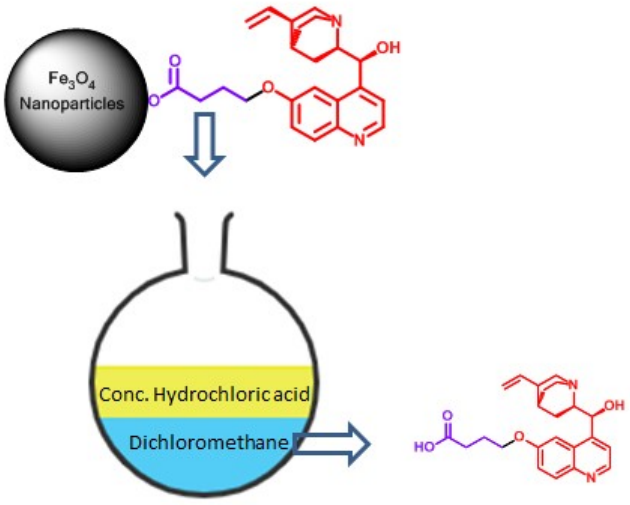


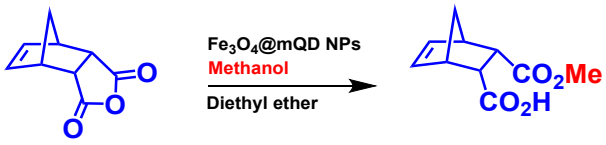
Fig. S2. Recovery process of mQD from Fe_3O_4@mQD NPs.

Table S2. Specific optical rotations (SOR) of pristine and recovered mQD.

Substrate	Specific optical rotation[a]
mQD acid (pristine)	130.40°
mQD acid (recovered)	128.03°

[a] $[\alpha]_D^{25}$ (C=1.0 Ethanol)

Table S3. Recycling of Fe_3O_4 @mQD NPs catalyst.[a]



Entry	Yield (%)	ee (%)	
1	91	**98**	**1st reaction**
2	90	**97**	**3rd cycle**
3	93	**94**	**5th cycle**

[a] The reaction was performed by treatment of the cyclic anhydride (1.0 mmol) with methanol (10 mmol) in the presence of Fe_3O_4@mQD (100 mg) at -45°C in diethylether (5.0 mL). During the recycling of the catalyst there was no loss in the quantity of the catalyst observed so there was no requirement of top-up of additional catalyst.

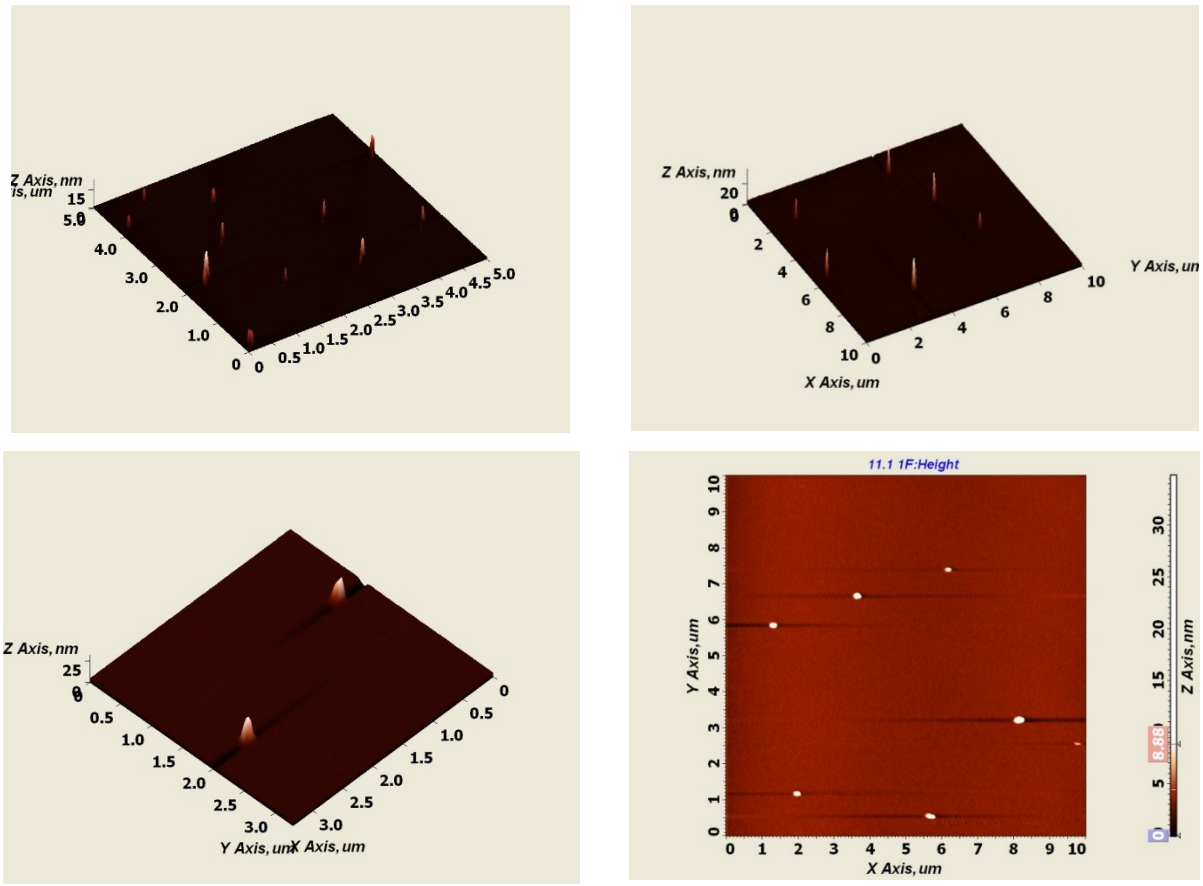


Fig. S3. AFM images of the Fe_3O_4 @ester-QD NPs at various magnifications.

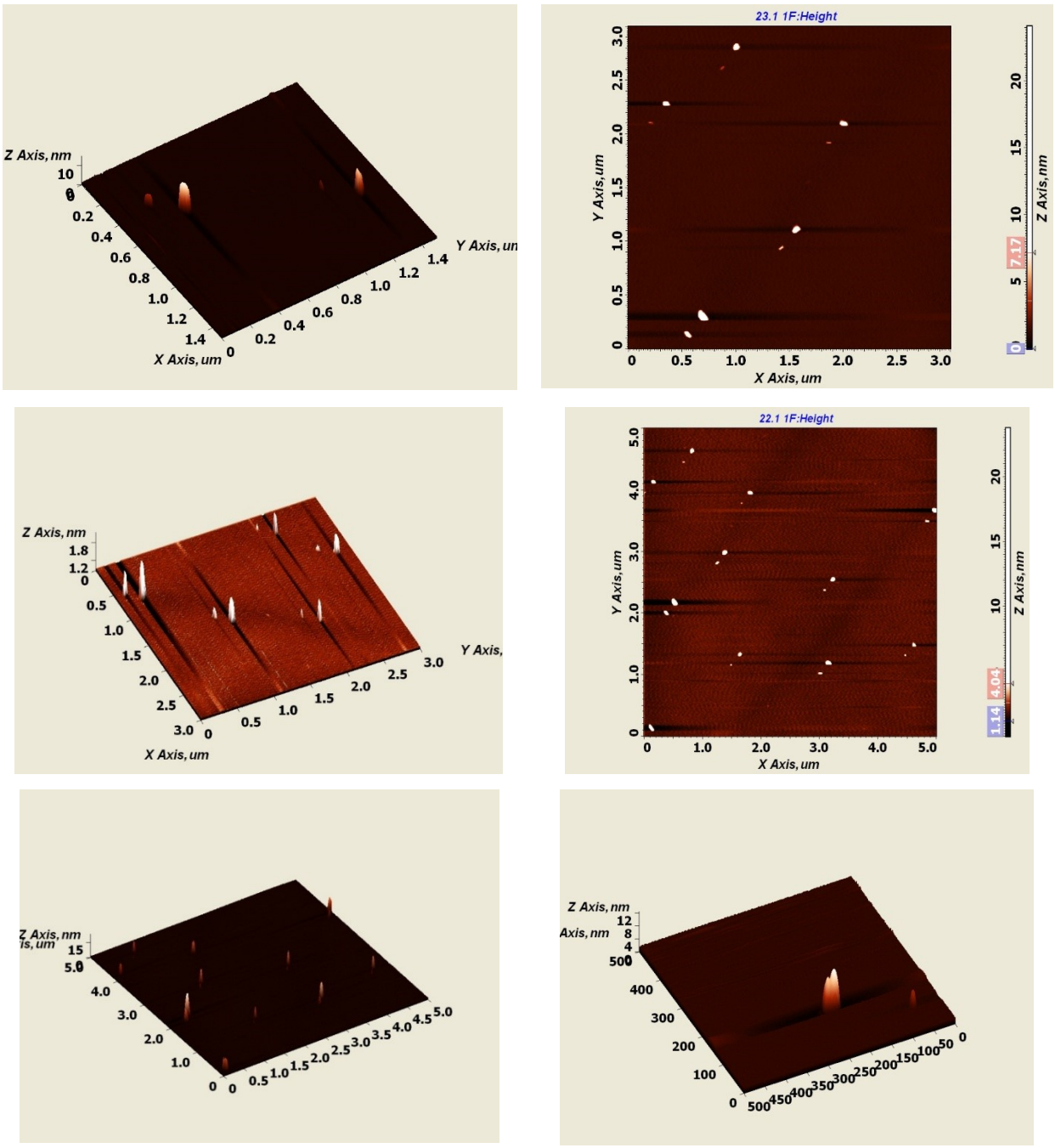


Fig. S4. AFM images of the Fe_3O_4@mQD NPs at various magnifications.

Experimental section

(a) **(b)**

Fig. S5. (a) Reaction mixture of Anhydride, Methanol and Fe_3O_4@mQD NPs under stirring with magnetic bar (**b)** reaction mixture when magnetic stirring is stopped and the catalyst sticks to the magnetic needle.

NMR spectra and HPLC chromatograms of the products and mQD intermediates:

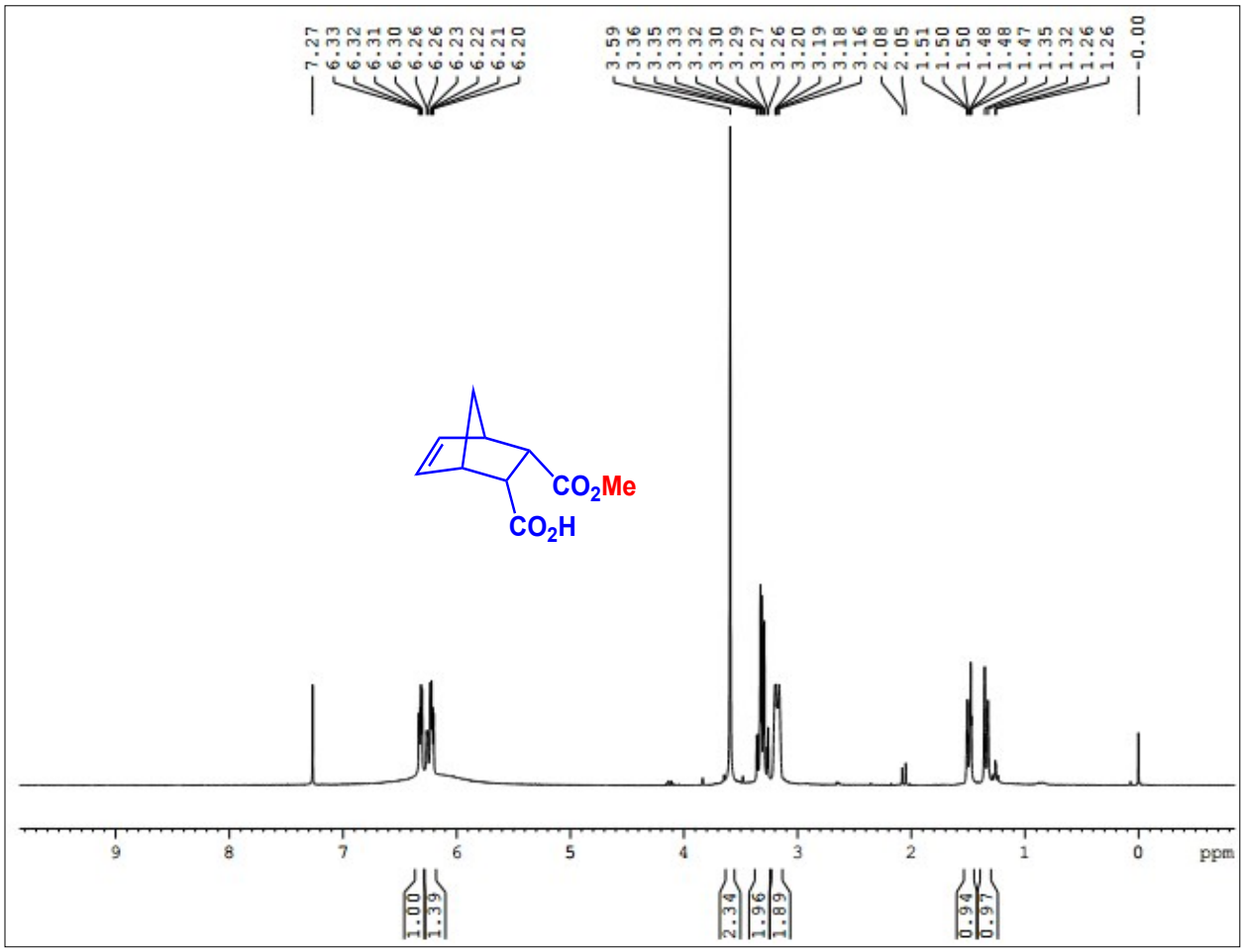


Fig. S6. ^{1}H NMR of (2*R*, 3*S*)-3-*endo*-methoxycarbonyl-bicyclo[2.2.1]hept-5-ene-2-*endo*-carboxylic acid (**22**).

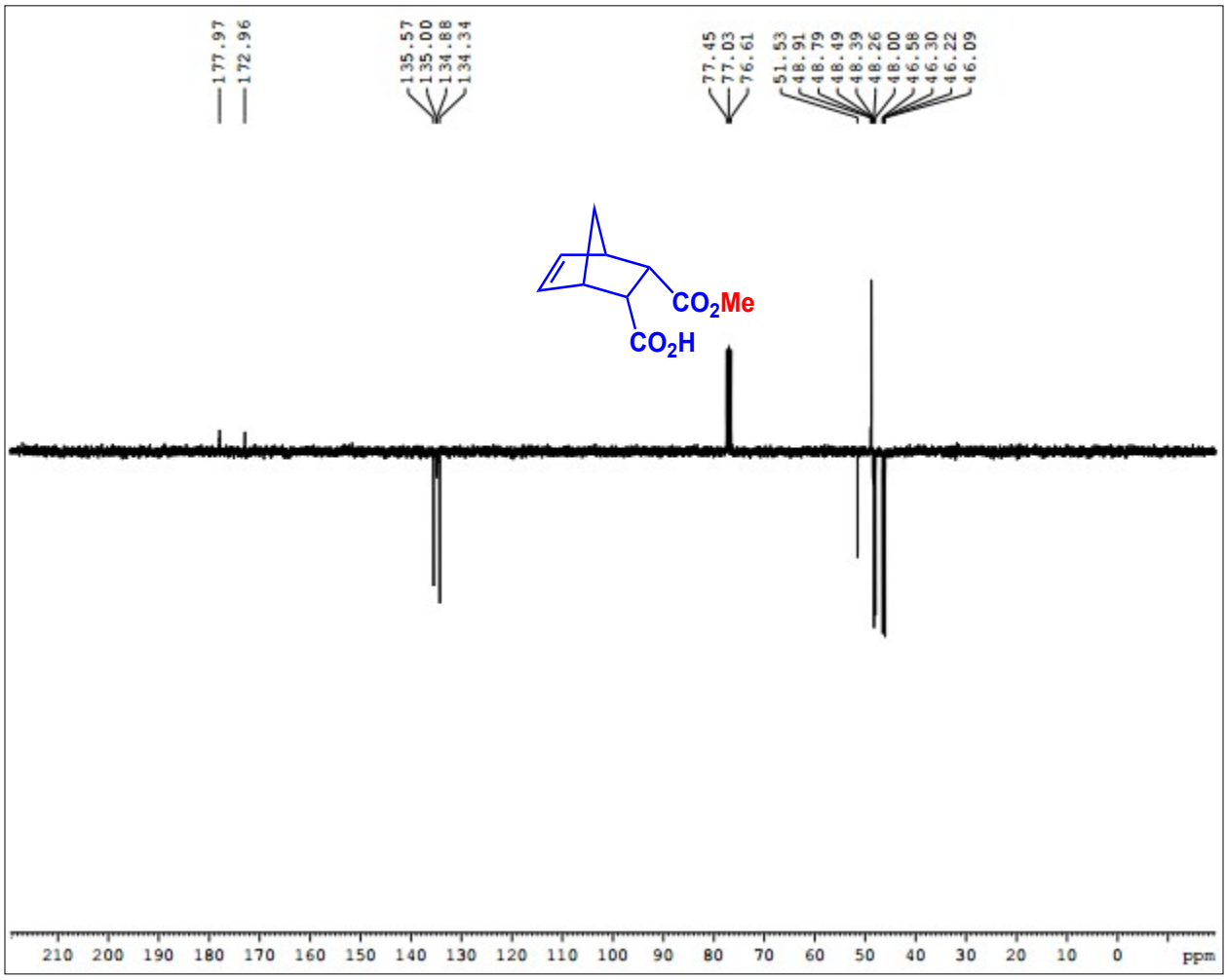
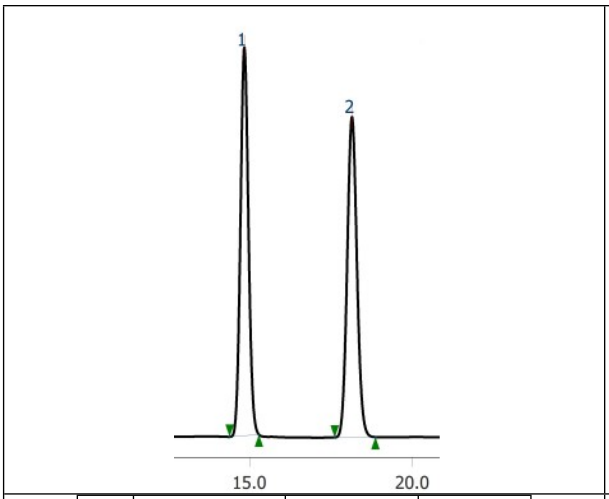
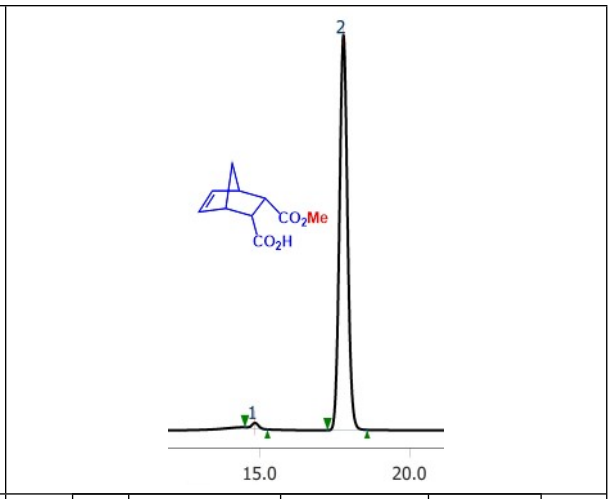


Fig. S7. ^{13}C NMR of (2*R*, 3*S*)-3-*endo*-methoxycarbonyl-bicyclo[2.2.1]hept-5-ene-2-*endo*-carboxylic acid (**22**).



	Retention time	Area	Area %
1	14.837	9732165	49.816
2	18.140	9804210	50.184



	Retention time	Area	Area %
1	14.819	142127	1.125
2	18.098	12491520	98.875

Fig. S8. HPLC chromatograms of racemic and (2*R*, 3*S*)-3-*endo*-methoxycarbonyl-bicyclo[2.2.1]hept-5-ene-2-*endo*-carboxylic acid **(22).**

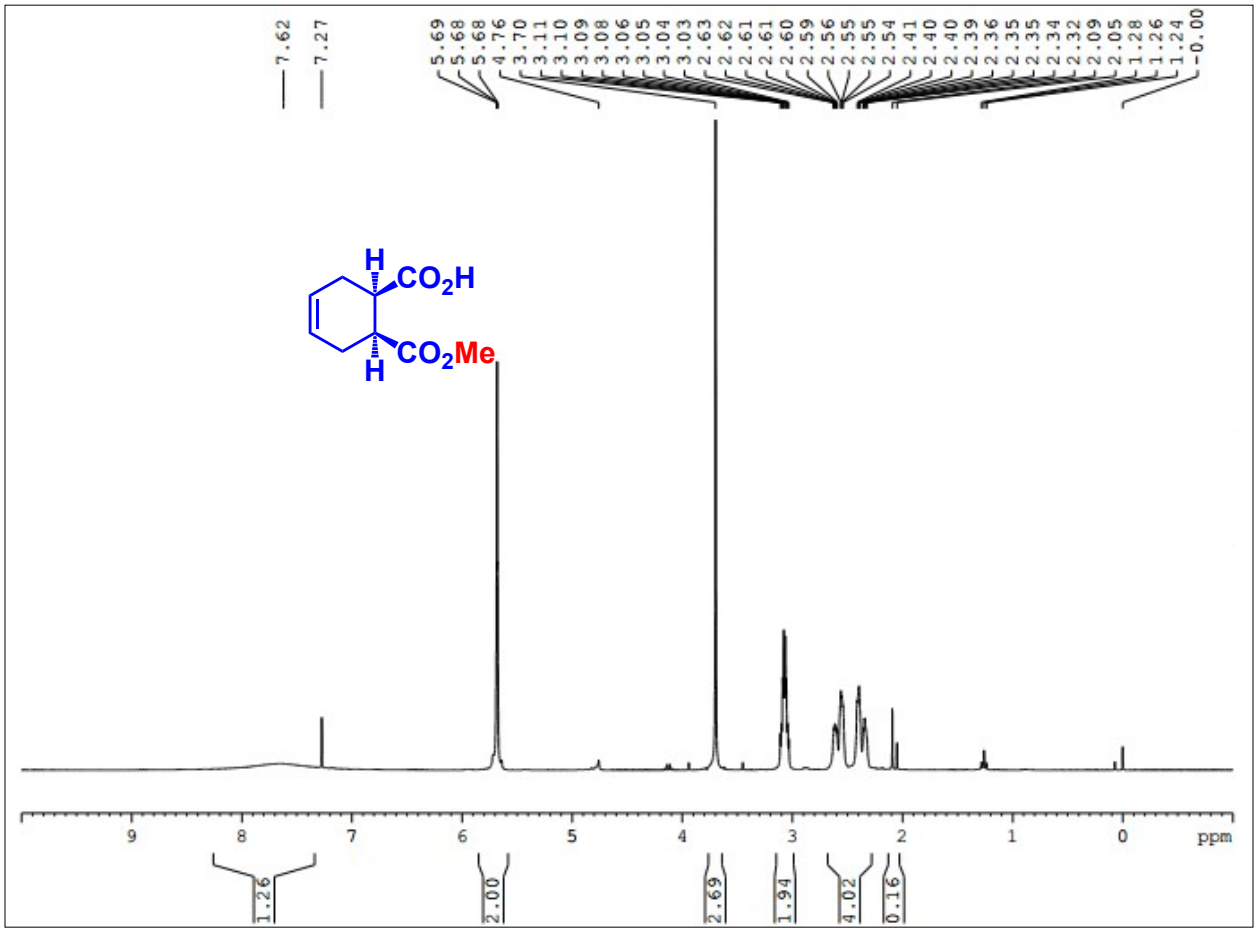


Fig. S9. ^{1}H NMR of (1*R*,2*S*)-*cis*-2-methoxycarbonyl-cyclohex-4-ene-1-carboxylic acid **(24).**

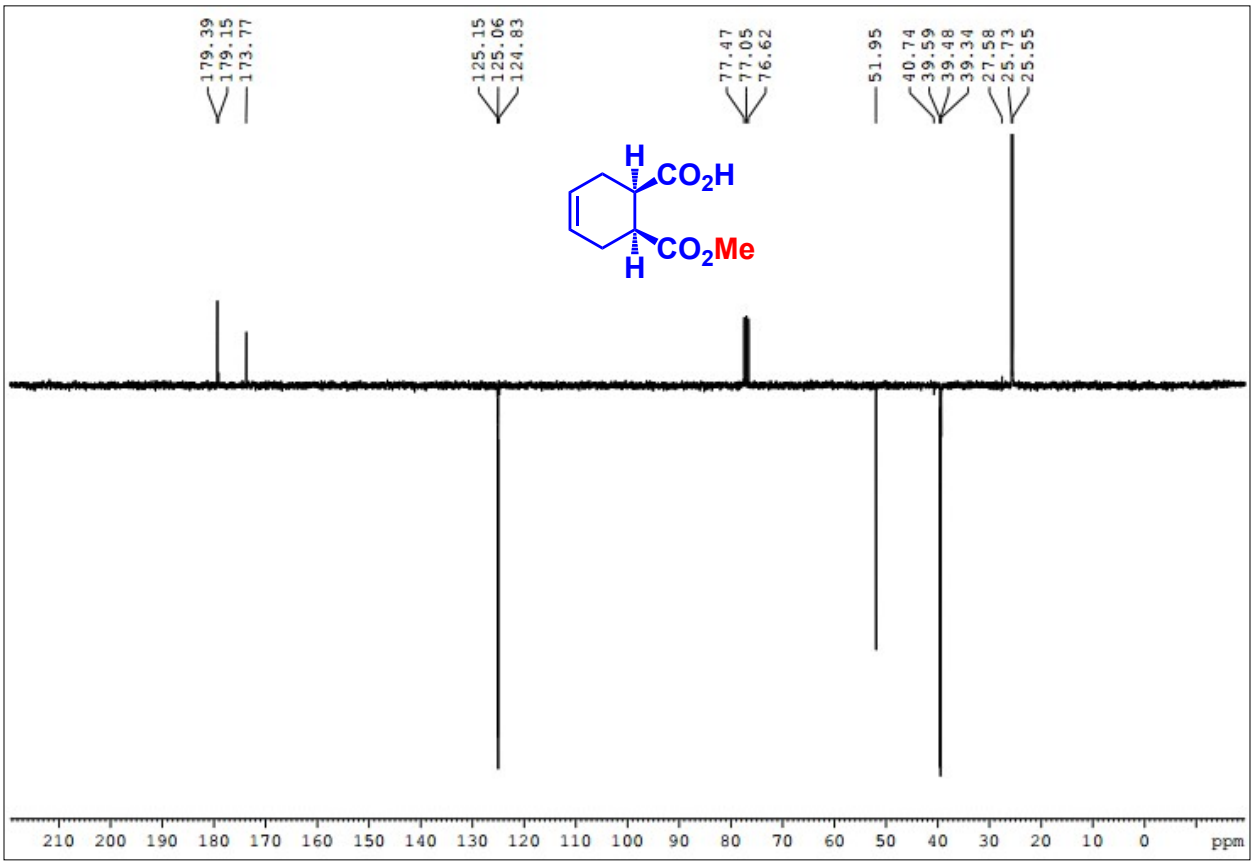
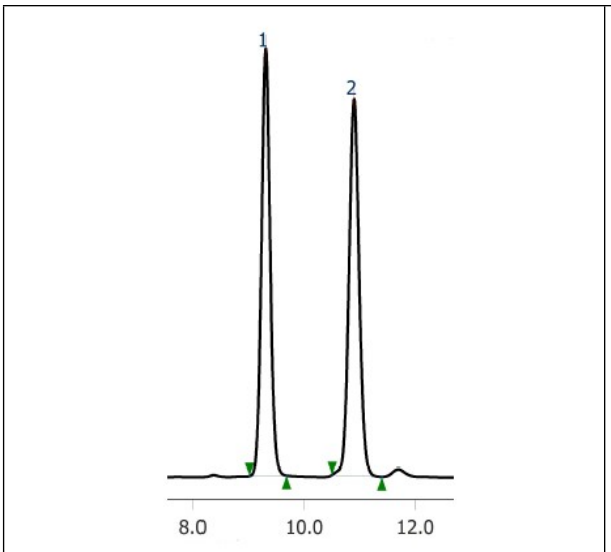
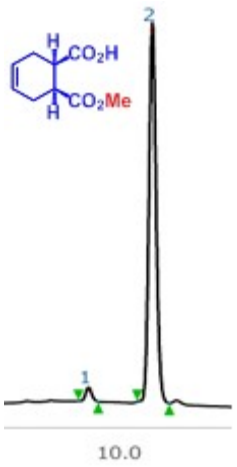


Fig. S10. ^{13}C NMR of (1*R*, 2*S*)-*cis*-2-methoxycarbonyl-cyclohex-4-ene-1-carboxylic acid **(24).**



	Retention time	Area	Area %
1	9.297	12616616	49.118
2	10.890	13069550	50.882



	Retention time	Area	Area %
1	9.233	230010	1.872
2	10.830	12056858	98.128

Fig. S11. HPLC chromatographs of racemic and (1*R*, 2*S*) *cis*-2-methoxycarbonyl-cyclohex-4-ene-1-carboxylic acid **(24).**

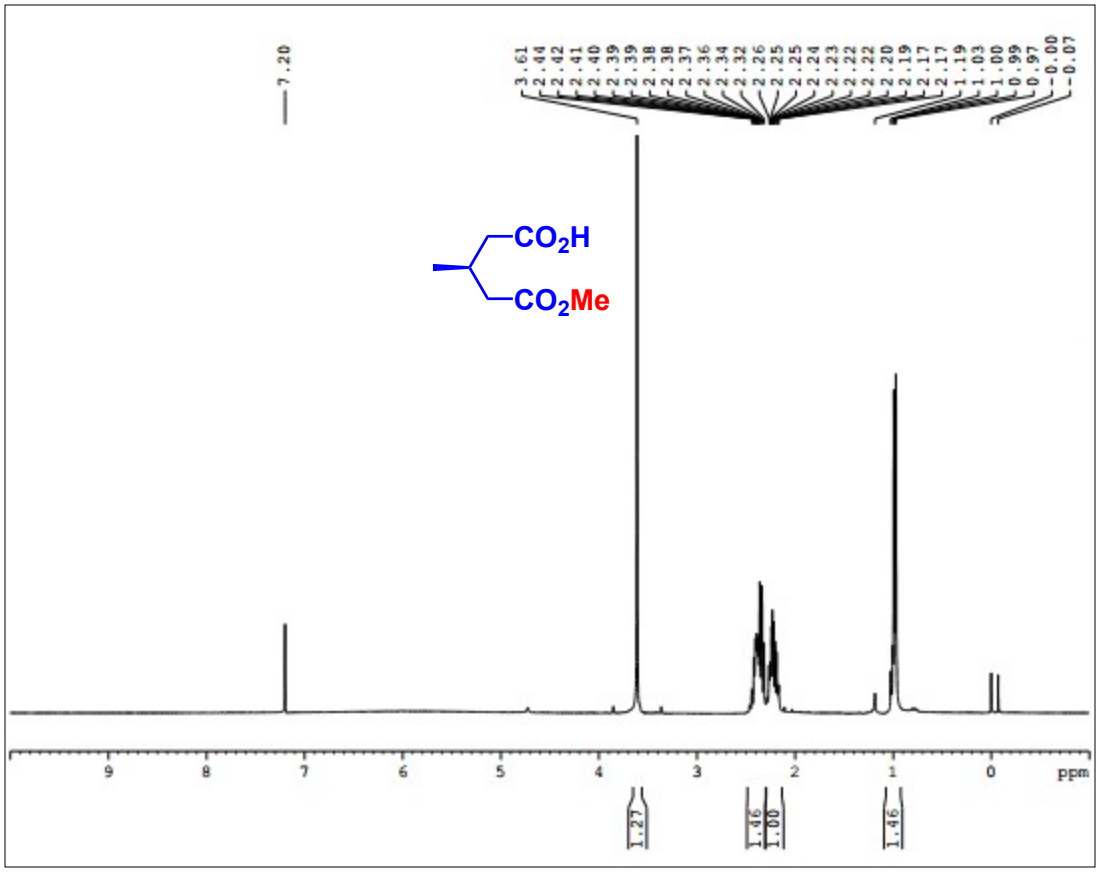


Fig. S12. ^{1}H NMR of (3R)-5-methoxy-3-methyl-5-oxopentanoic acid **(26).**

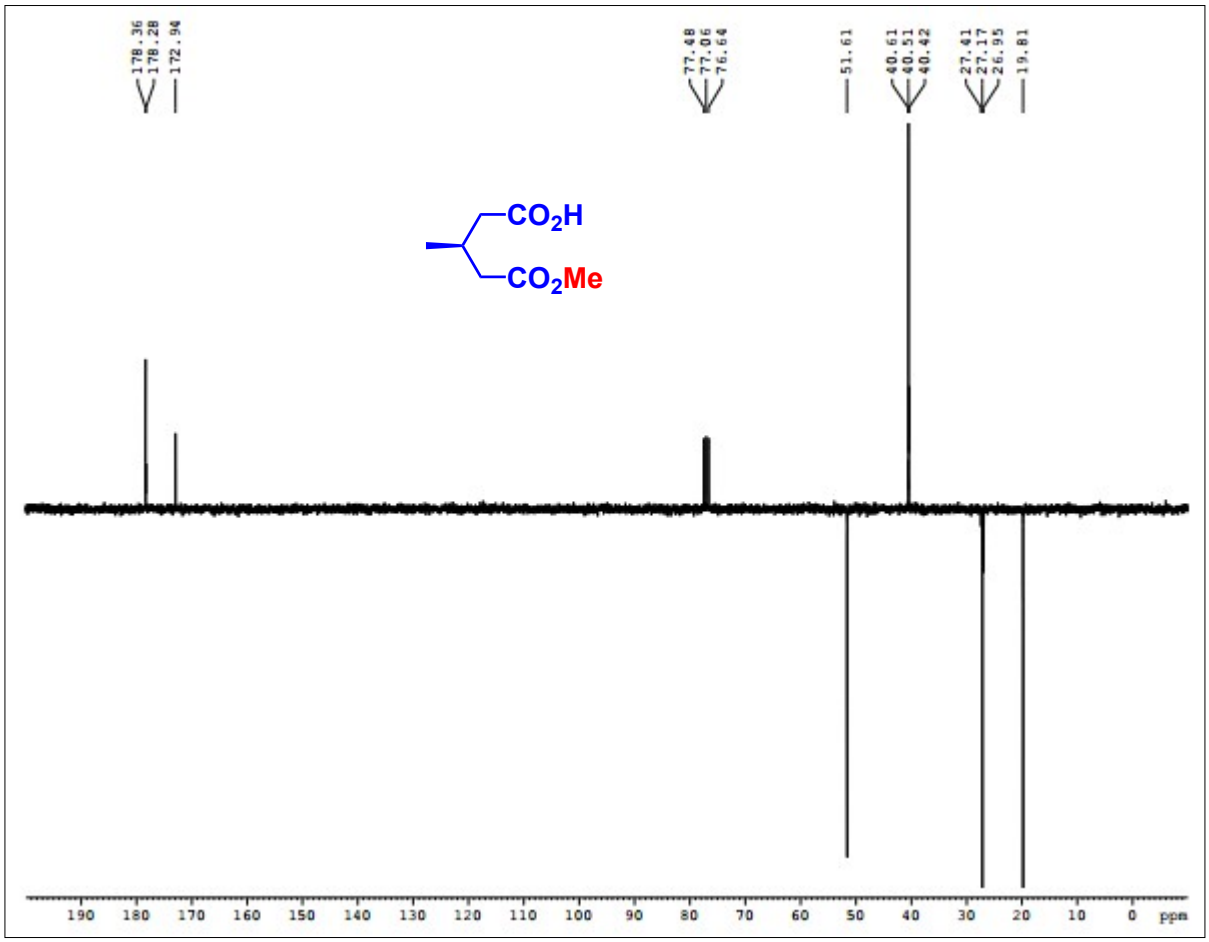
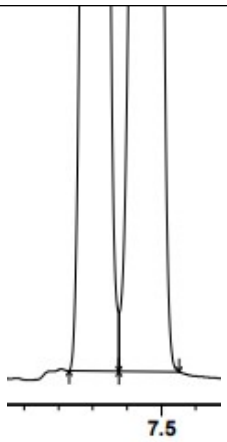
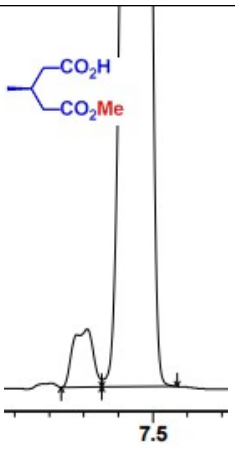


Fig. S13. ^{13}C NMR of (3R)-5-methoxy-3-methyl-5-oxopentanoic acid **(26).**



	Retention time	Area	Area %
1	6.631	7946040	49.274
2	7.406	8180067	50.726



	Retention time	Area	Area %
1	6.647	558829	3.600
2	7.459	14965172	96.400

Fig. S14. HPLC chromatograms of racemic and (3R)-5-methoxy-3-methyl-5-oxopentanoic acid **(26).**

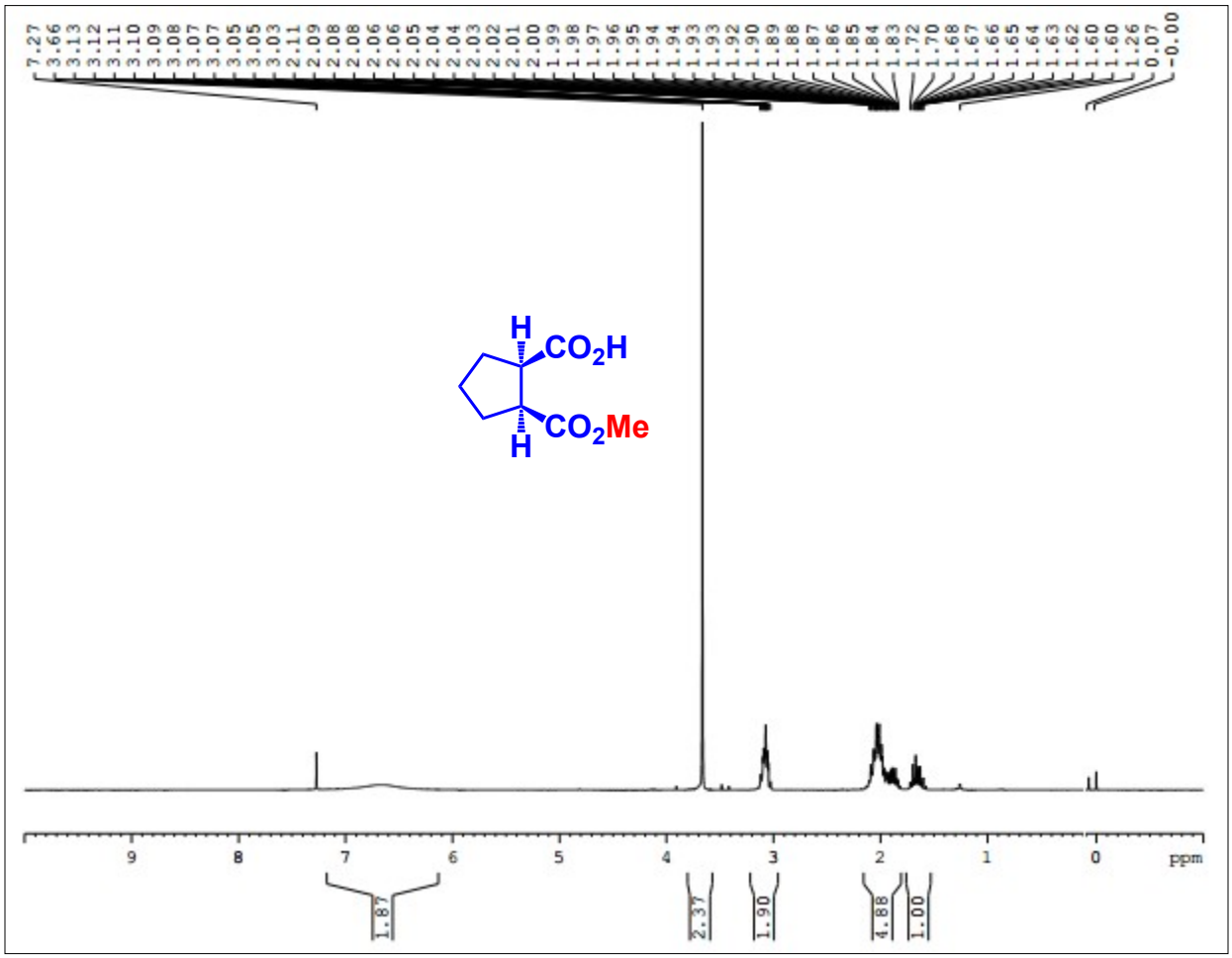


Fig. S15. ^{1}H NMR of (1*R*,2*S*)-*cis*-2-Methoxycarbonyl-cyclopentane-1-carboxylic acid **(28).**

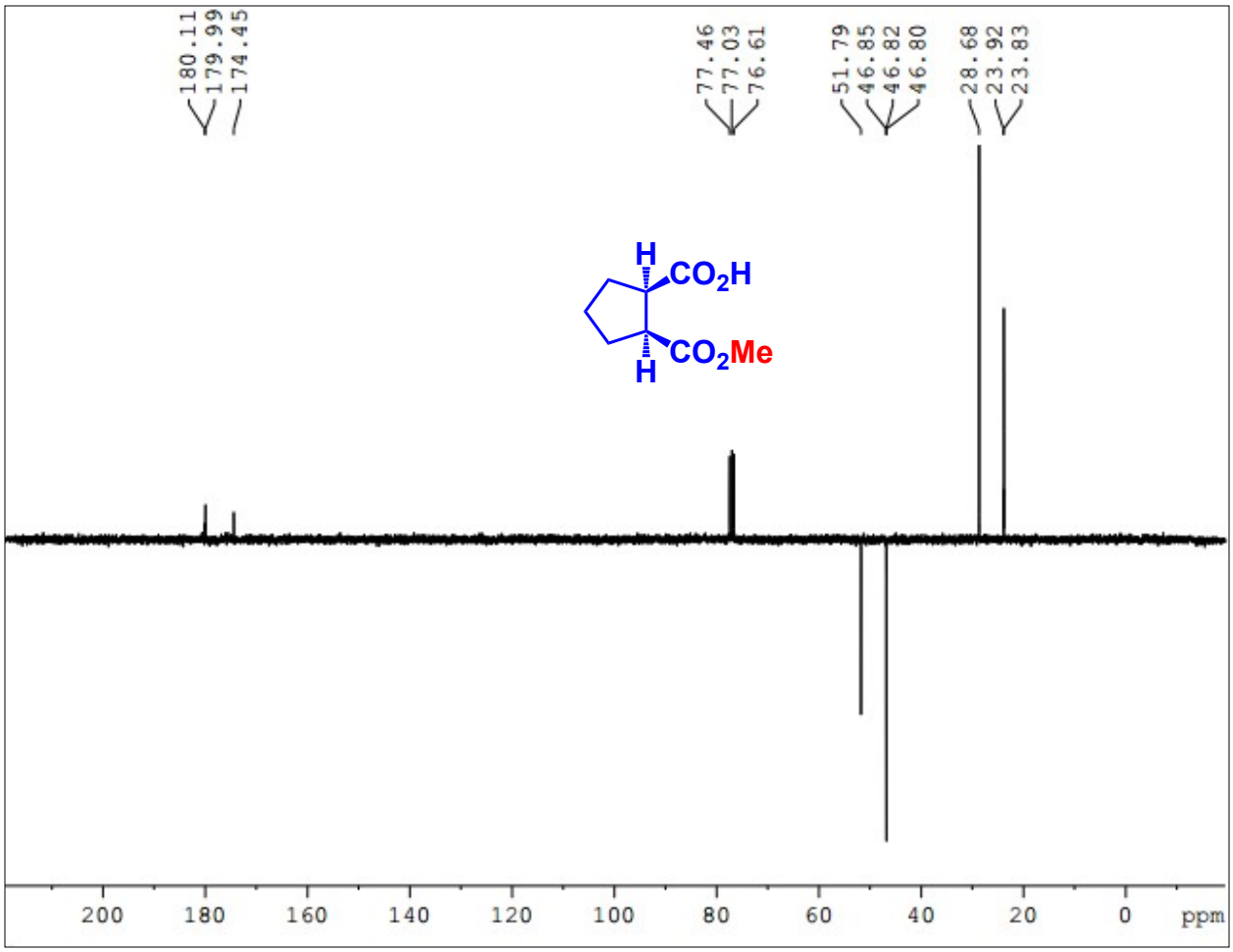
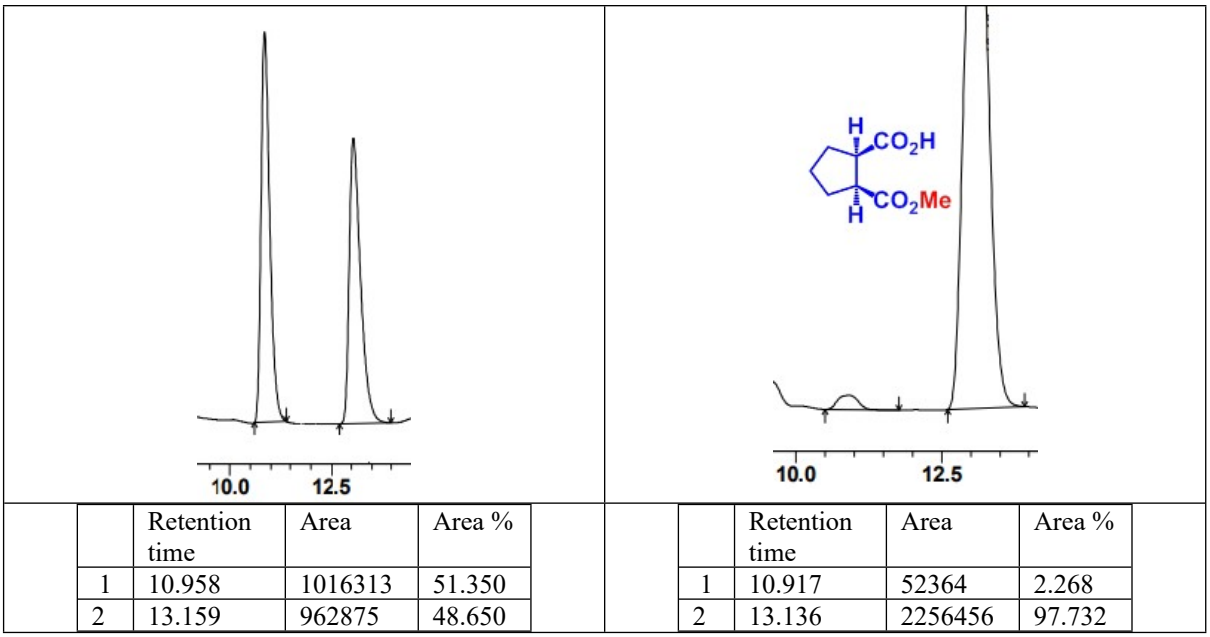


Fig. S16. ^{13}C NMR of (1*R*, 2*S*)-*cis*-2-Methoxycarbonyl-cyclopentane-1-carboxylic acid (28).



	Retention time	Area	Area %
1	10.958	1016313	51.350
2	13.159	962875	48.650

	Retention time	Area	Area %
1	10.917	52364	2.268
2	13.136	2256456	97.732

Fig. S17. HPLC chromatograms of racemic and (1*R*, 2*S*)-*cis*-2-Methoxycarbonyl-cyclopentane-1-carboxylic acid **(28).**

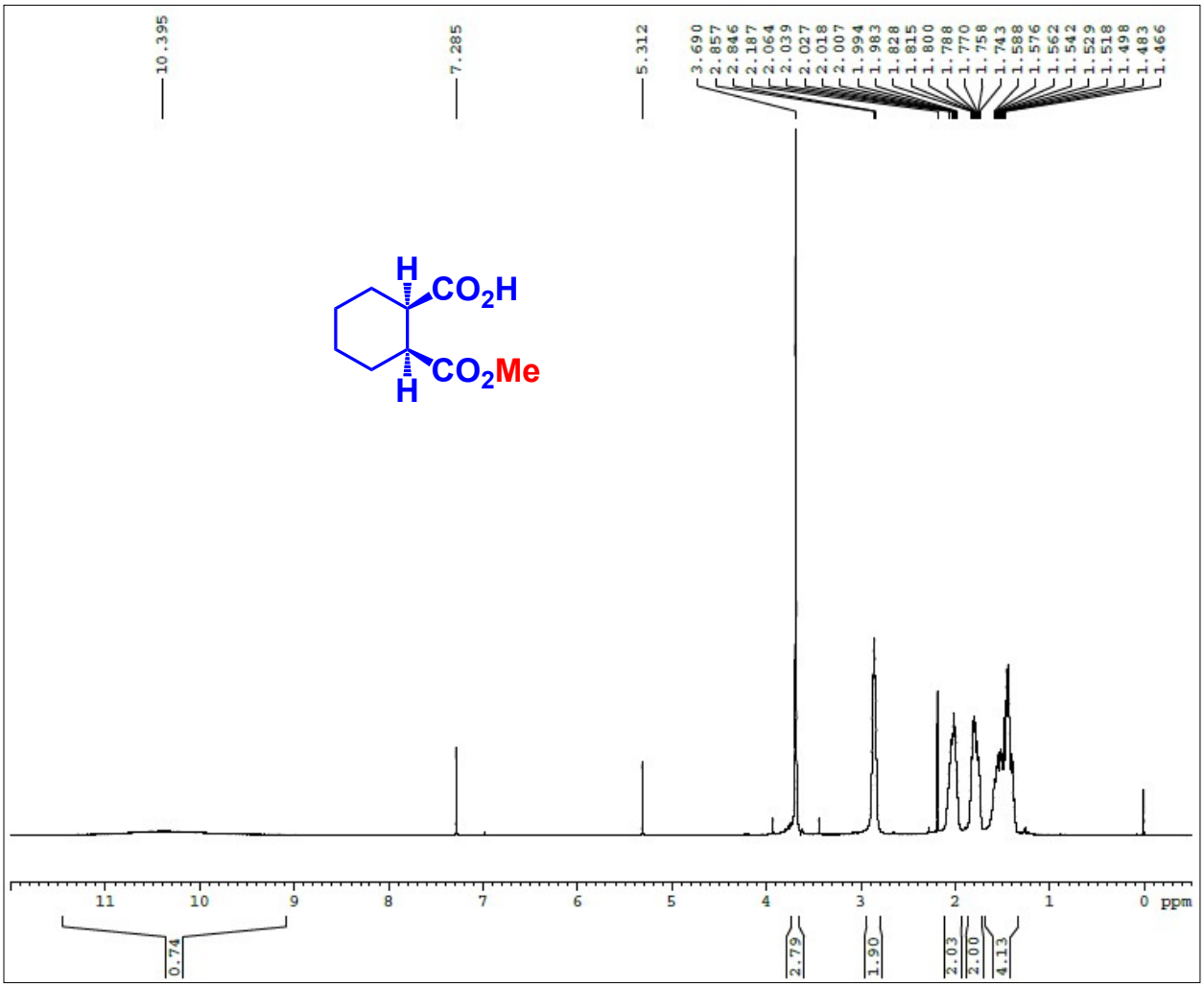


Fig. S18. ^{1}H NMR of (1R, 2S)-2-(methoxycarbonyl)-cyclohexane-1-carboxylic acid **(30).**

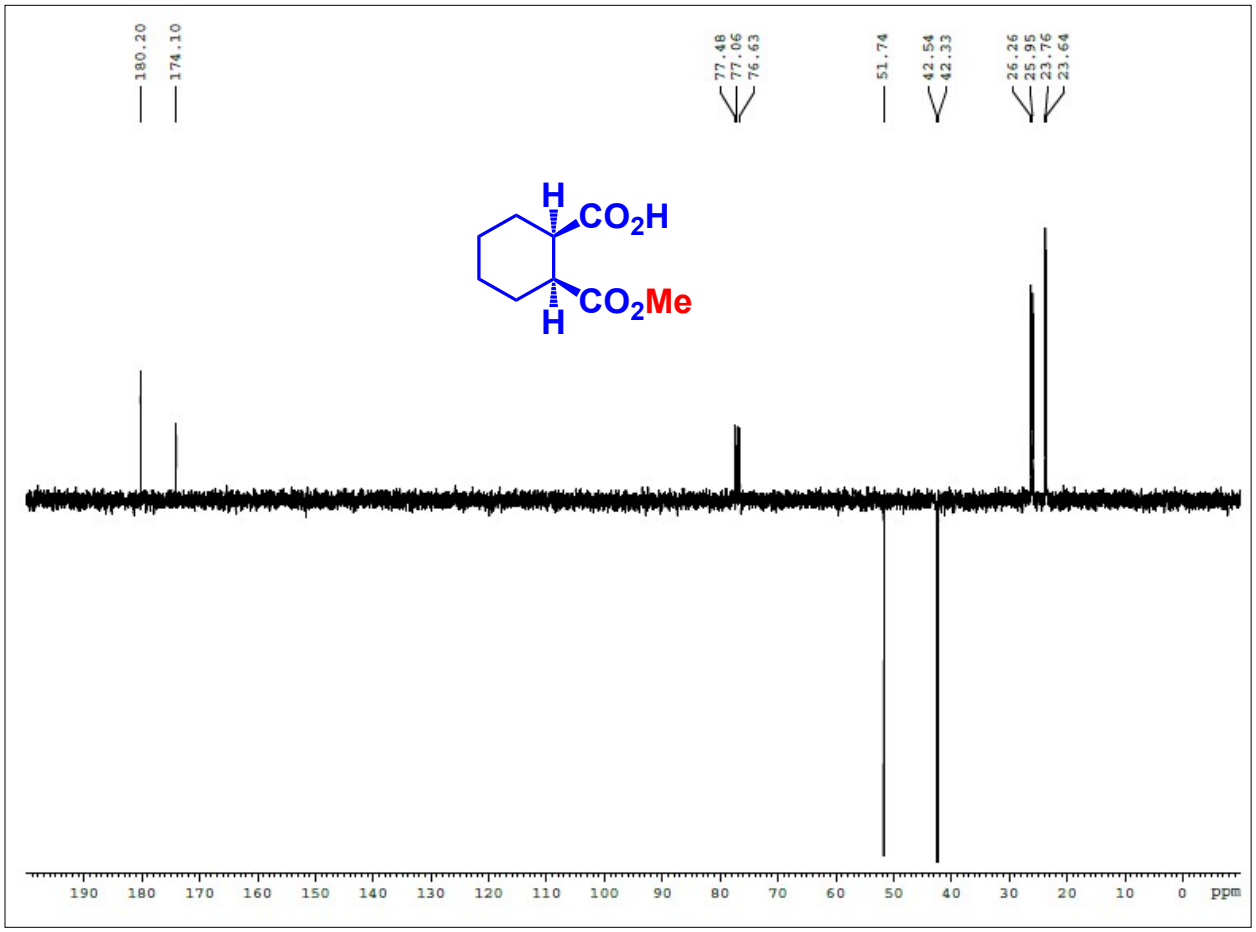
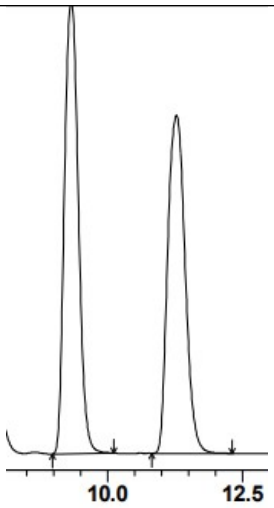
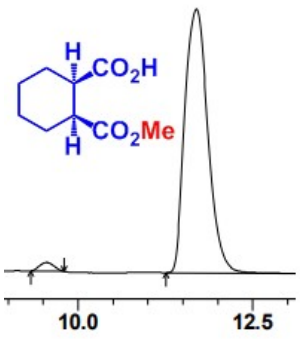


Fig. S19. ^{13}C NMR of (1R, 2S)-2-(methoxycarbonyl)-cyclohexane-1-carboxylic acid **(30).**



	Retention time	Area	Area %
1	9.326	995491	51.684
2	11.376	930633	48.316



	Retention time	Area	Area %
1	9.337	389282	3.112
2	11.382	12056858	96.385

Fig. S20. HPLC chromatograms of racemic and (1R, 2S)-2-(methoxycarbonyl)cyclohexane-1-carboxylic acid **(30).**

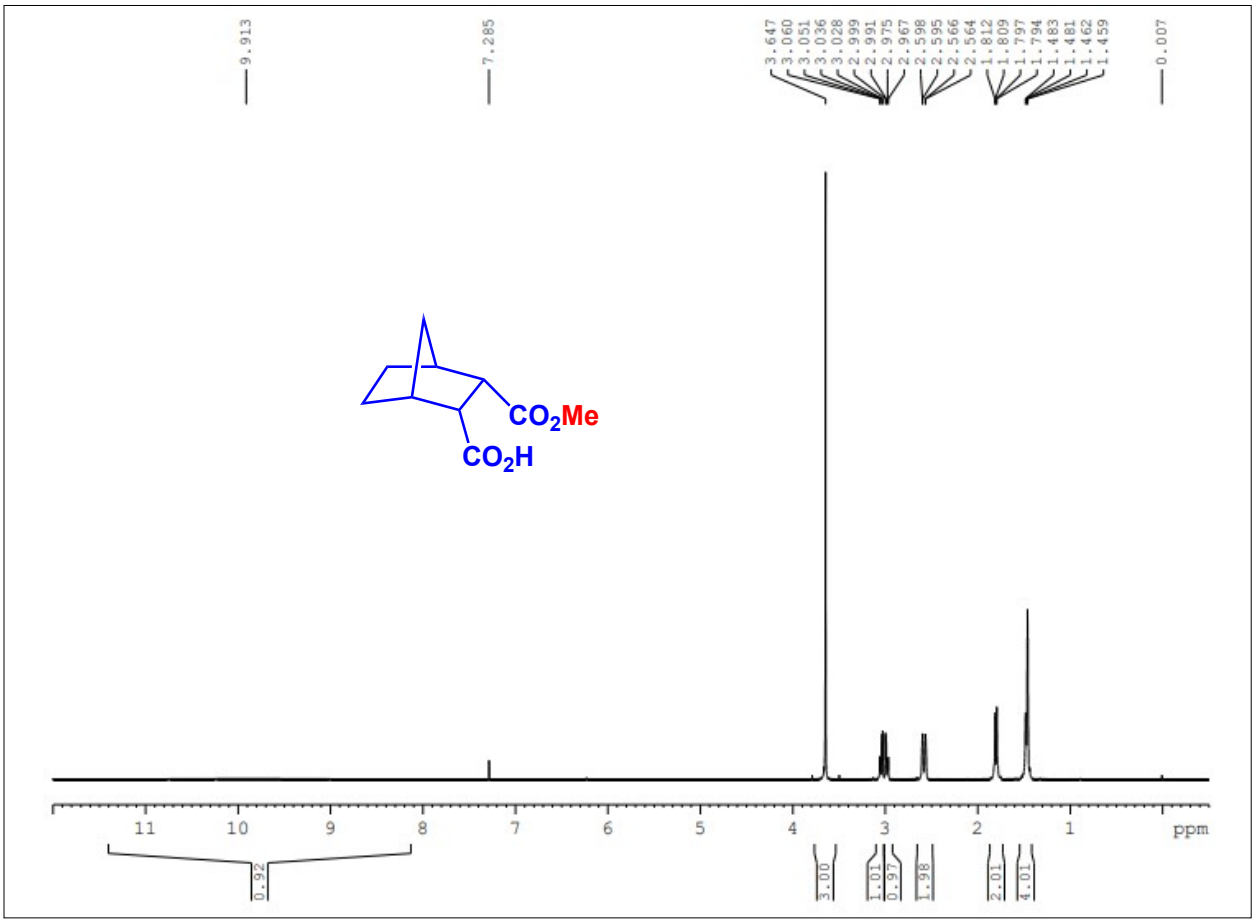


Fig. S21. ^{1}H NMR of (1R,2R,3S,4S)-3-(methoxycarbonyl)bicyclo[2.2.1]heptane-2-carboxylic acid (32).

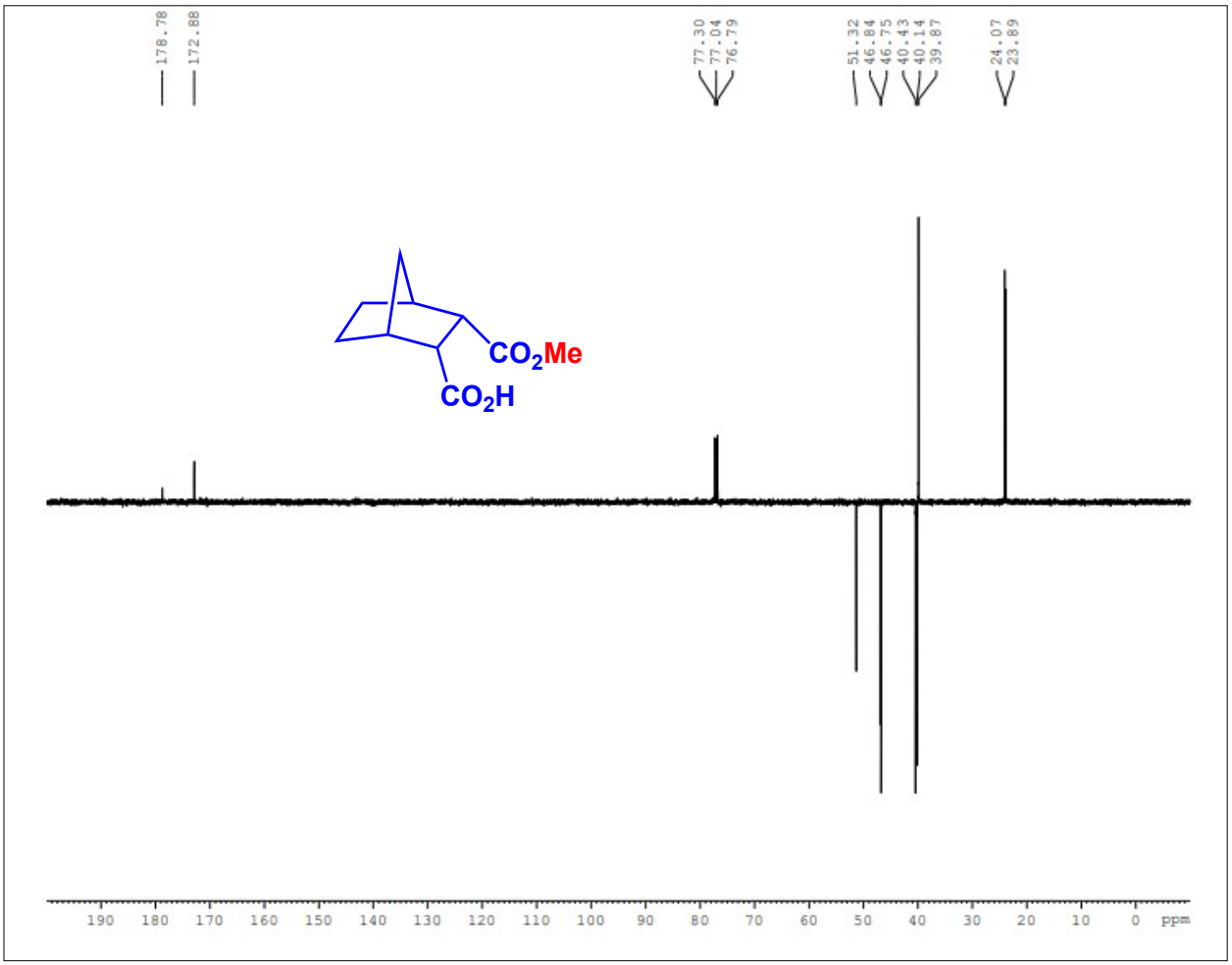
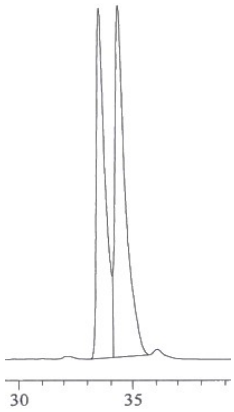
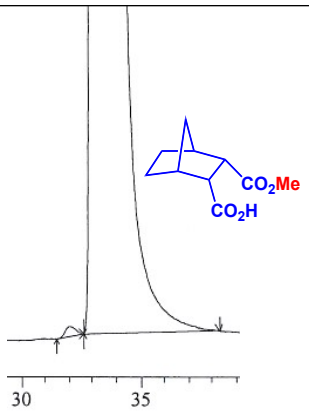


Fig. S22. ^{13}C NMR of (1R,2R,3S,4S)-3-(methoxycarbonyl)bicyclo[2.2.1]heptane-2-carboxylic acid (32).



	Retention time	Area	Area %
1	33.365	570264	49.3
2	34.184	586458	50.7



	Retention time	Area	Area %
1	32.016	13337	2.0
2	33.691	653523	98.0

Fig. S23. HPLC chromatograms of racemic and (1R,2R,3S,4S)-3(methoxycarbonyl)bicyclo-[2.2.1]heptane-2-carboxylic acid (32).

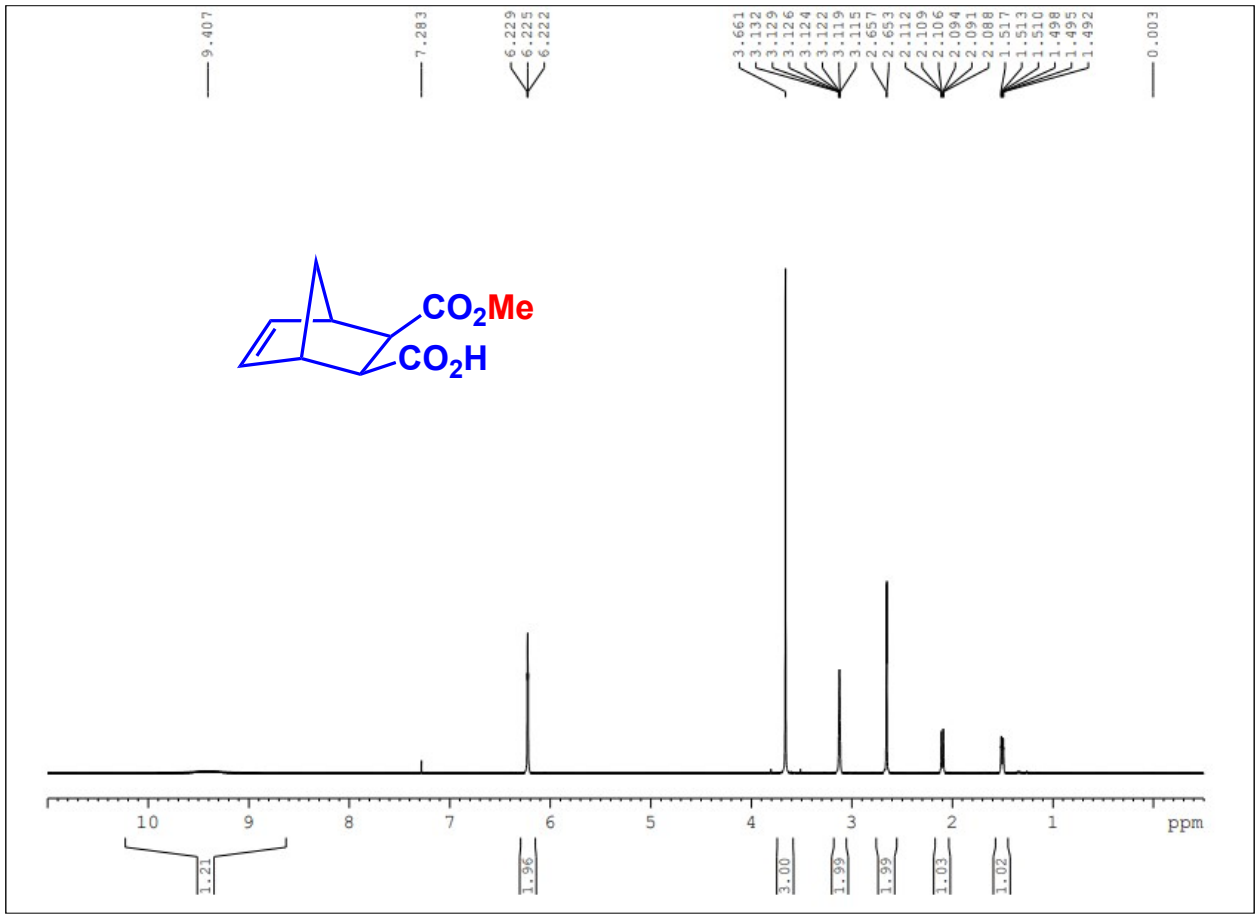


Fig. S24. ^{1}H NMR of (1R,2R,3S,4S)-3-(methoxycarbonyl)bicyclo[2.2.1]heptane-2-carboxylic acid (34).

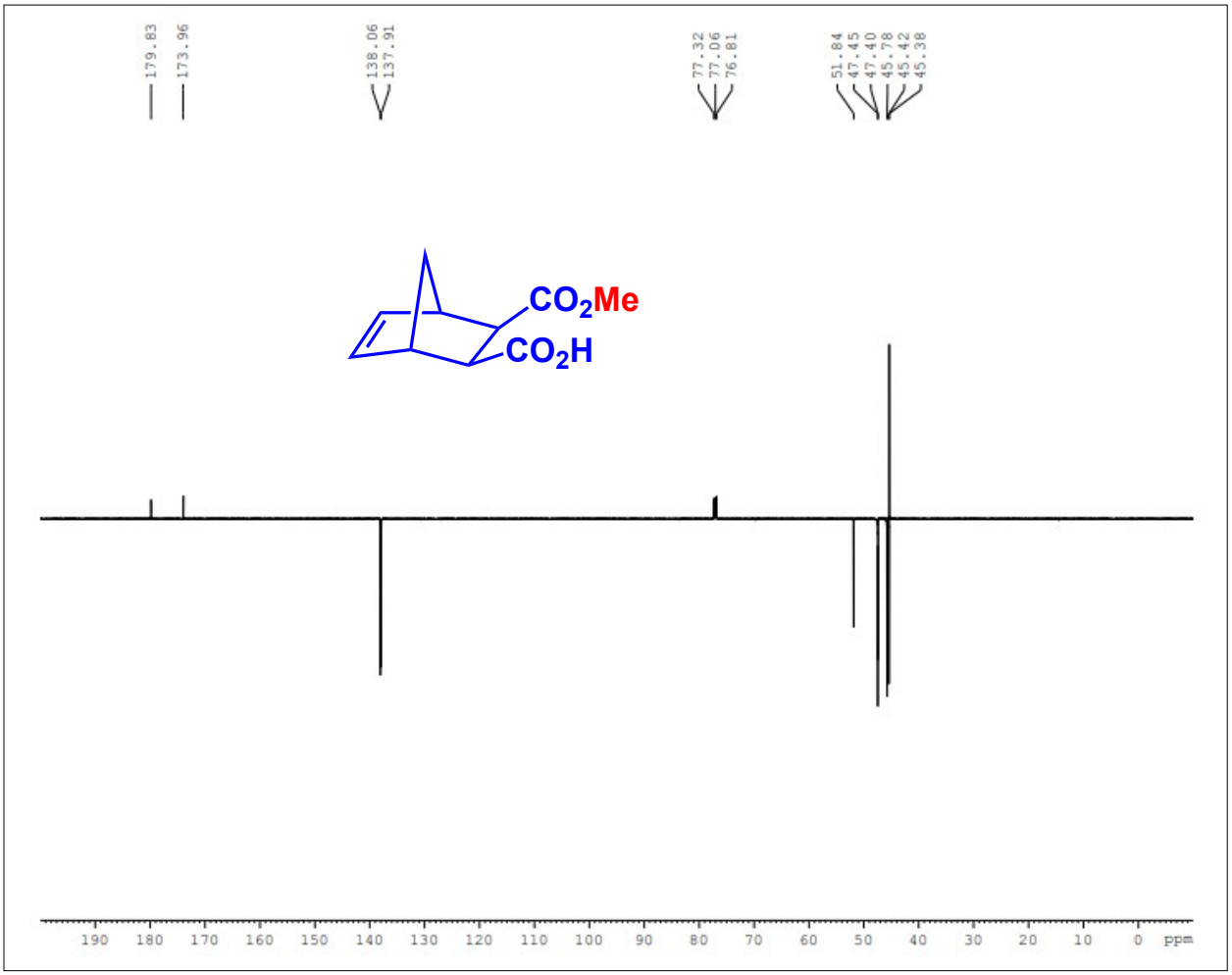
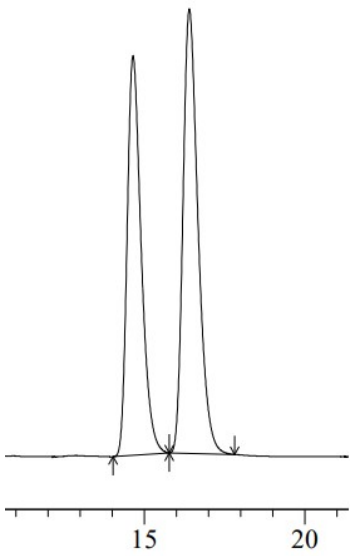
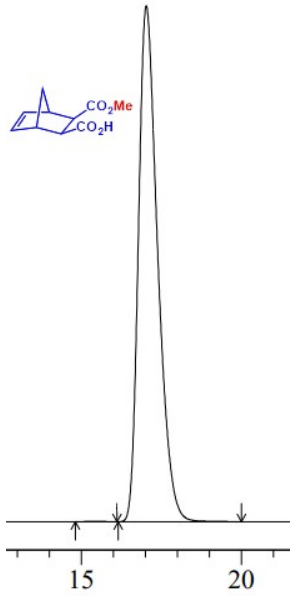


Fig. S25. ^{13}C NMR of (1R,2R,3S,4S)-3-(methoxycarbonyl)bicyclo[2.2.1]heptane-2-carboxylic acid (34).



	Retention time	Area	Area %
1	14.656	285236	48.3
2	16.452	305315	51.7



	Retention time	Area	Area %
1	15.482	8250	0.9
2	17.063	908368	99.1

Fig. S26. HPLC chromatograms of racemic and (1R,2R,3S,4S)-3-(methoxycarbonyl) bicyclo- [2.2.1]heptane-2-carboxylic acid (34).

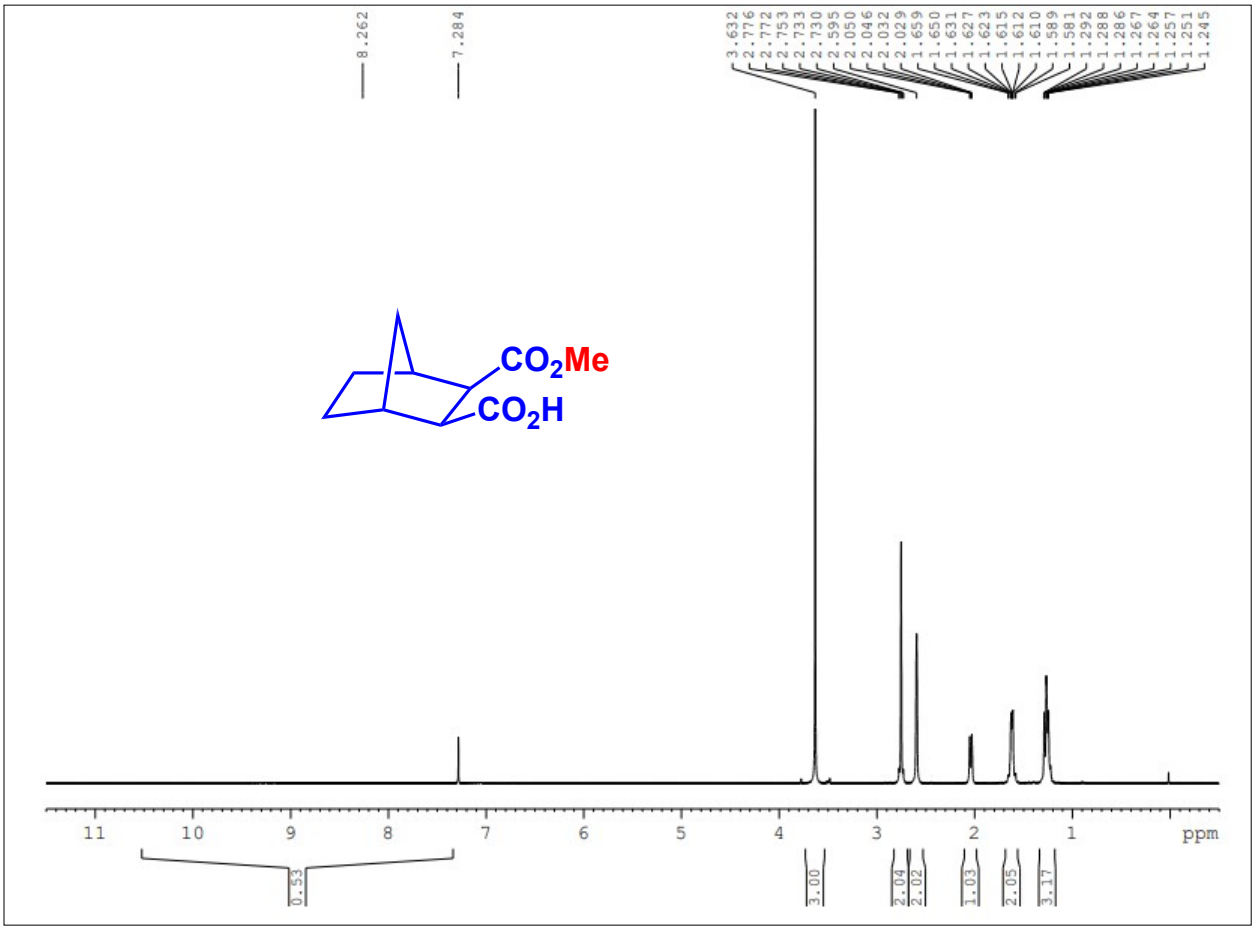


Fig. S27. ^{1}H NMR of (1R,2R,3S,4S)-3-(methoxycarbonyl)bicyclo[2.2.1]heptane-2-carboxylic acid (36).

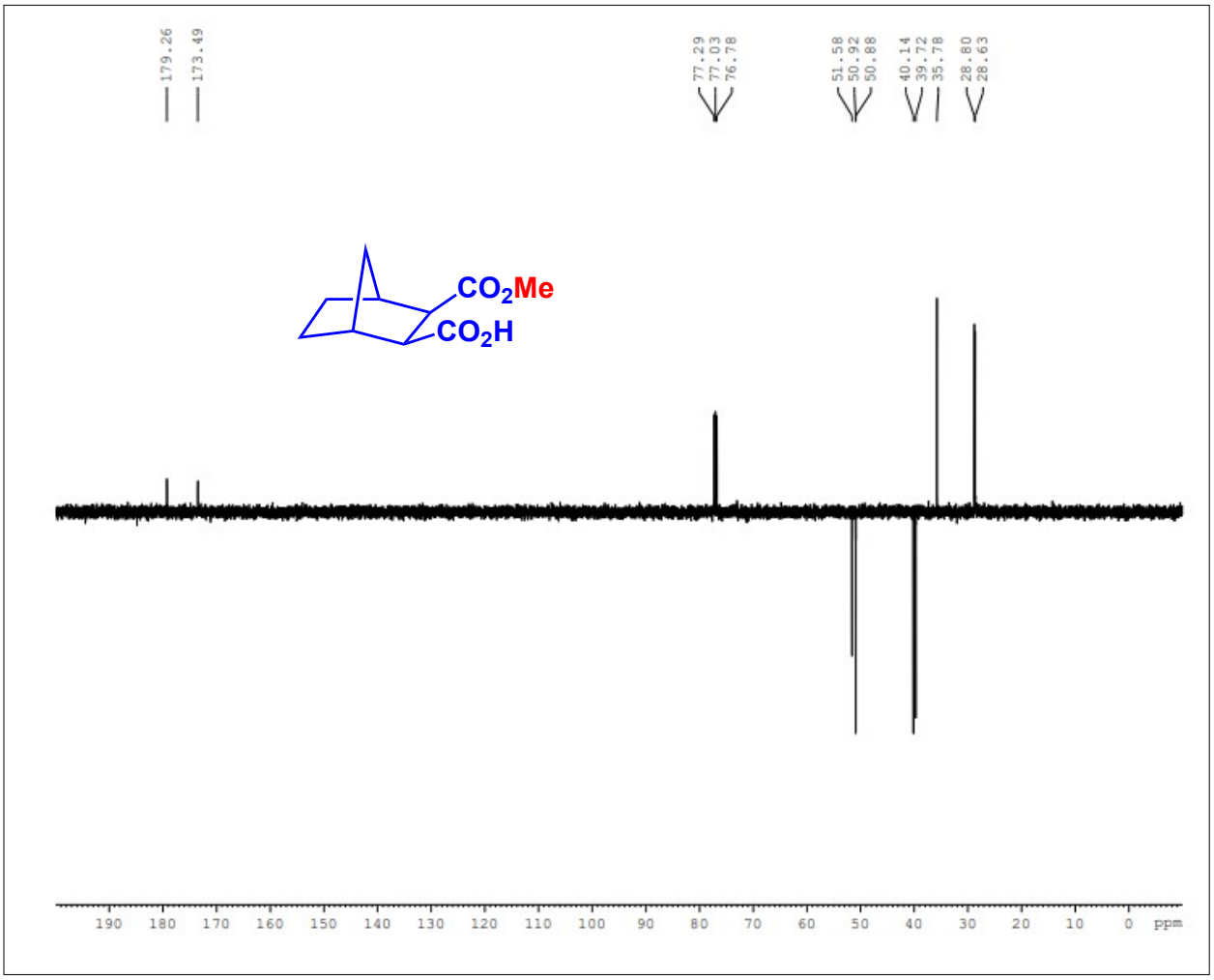
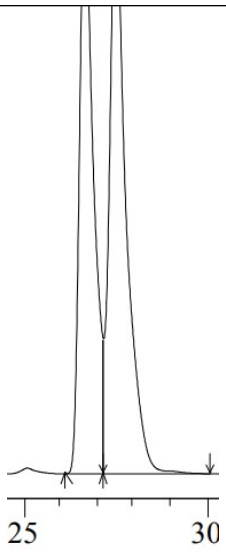
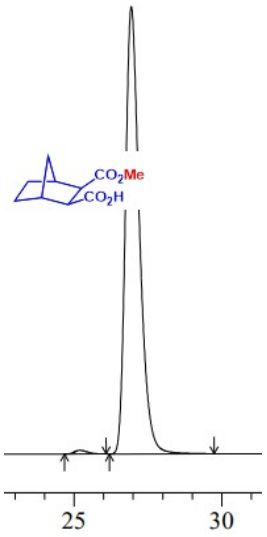


Fig. S28. ^{13}C NMR of (1R,2R,3S,4S)-3-(methoxycarbonyl)bicyclo[2.2.1]heptane-2-carboxylic acid (36).



	Retention time	Area	Area %
1	26.768	663542	49.2
2	27.673	685121	50.8



	Retention time	Area	Area %
1	25.264	7921	1.8
2	26.952	432156	98.2

Fig. S29. HPLC chromatograms of racemic and (1R,2R,3S,4S)-3-(methoxycarbonyl) bicyclo[2.2.1]heptane-2-carboxylic acid (36).

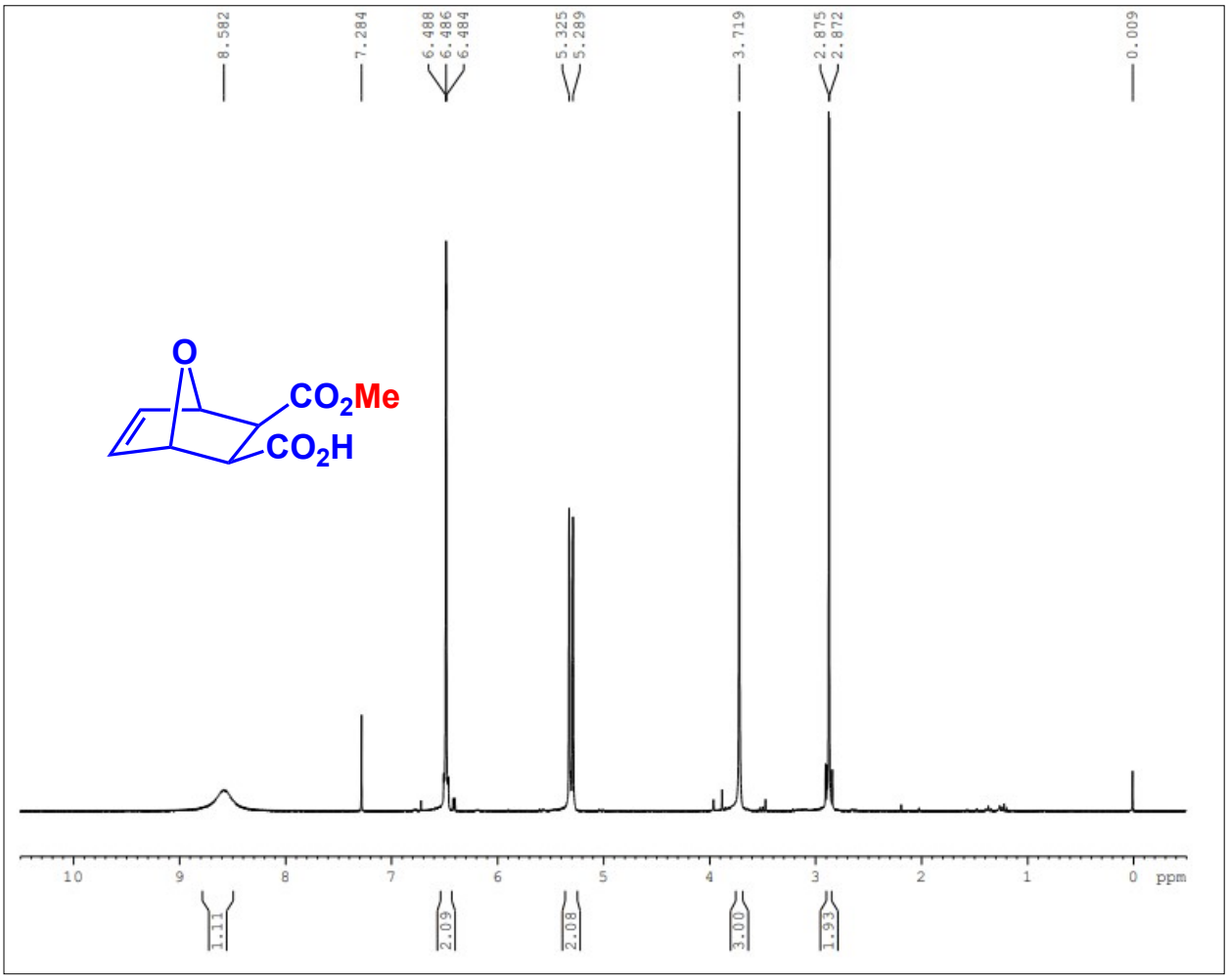


Fig. S30. ^{1}H NMR of (1S,2R,4R)-3-(methoxycarbonyl)-7-oxabicyclo[2.2.1]hept-5-ene-2-carboxylic acid (38).

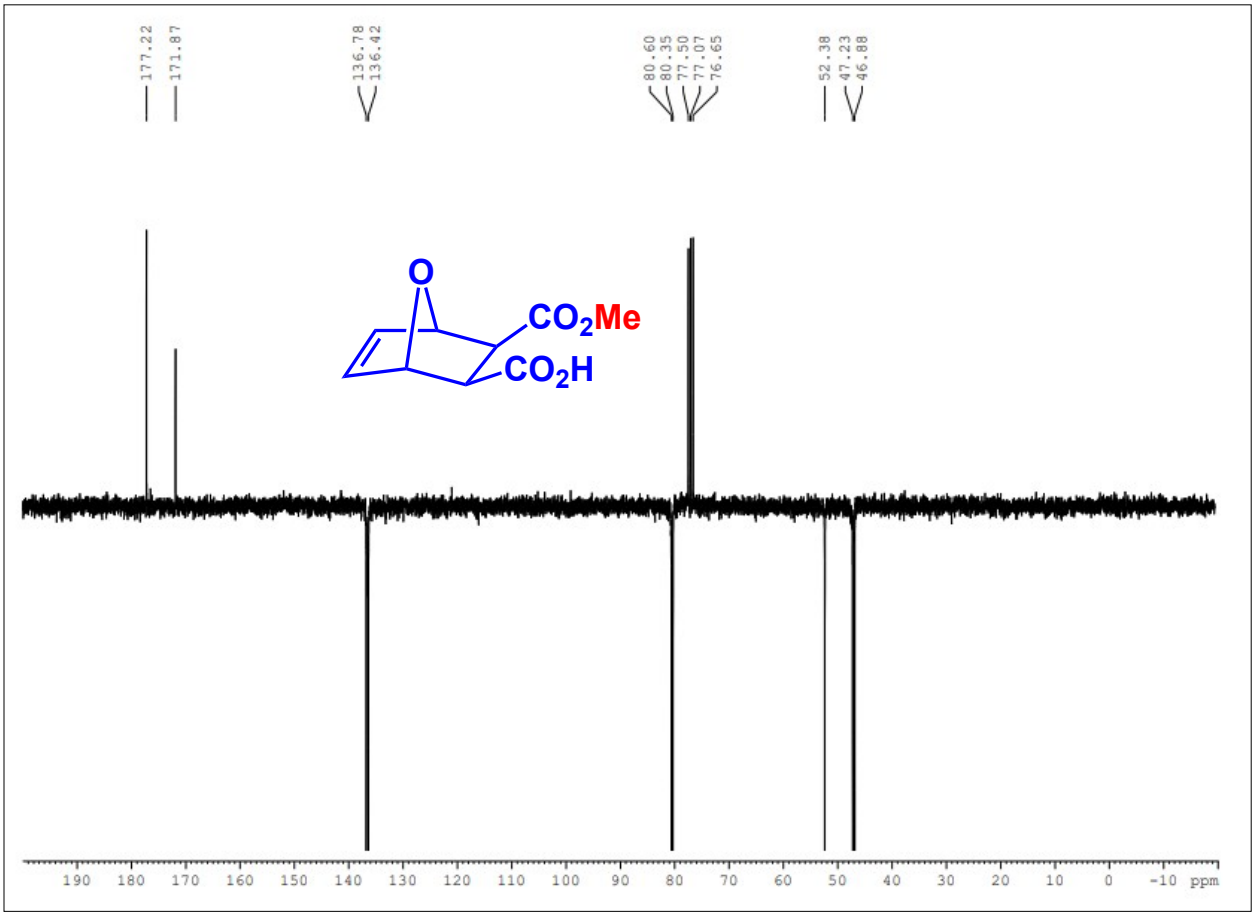
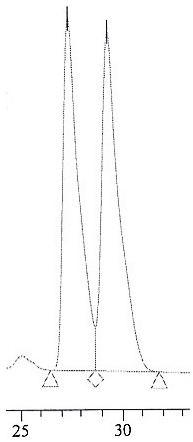
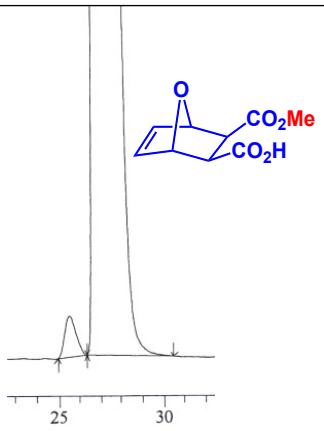


Fig. S31. ^{13}C NMR of (1S,2R,4R)-3-(methoxycarbonyl)-7-oxabicyclo[2.2.1]hept-5-ene-2-carboxylic acid (38).



	Retention time	Area	Area %
1	27.36	817426	48.6
2	29.15	864521	51.4



	Retention time	Area	Area %
1	25.52	9438	1.36
2	27.18	684561	98.64

Fig. S32. HPLC chromatograms of racemic and (1S,2R,4R)-3-(methoxycarbonyl)-7-oxabicyclo[2.2.1]hept-5-ene-2-carboxylic acid (38).

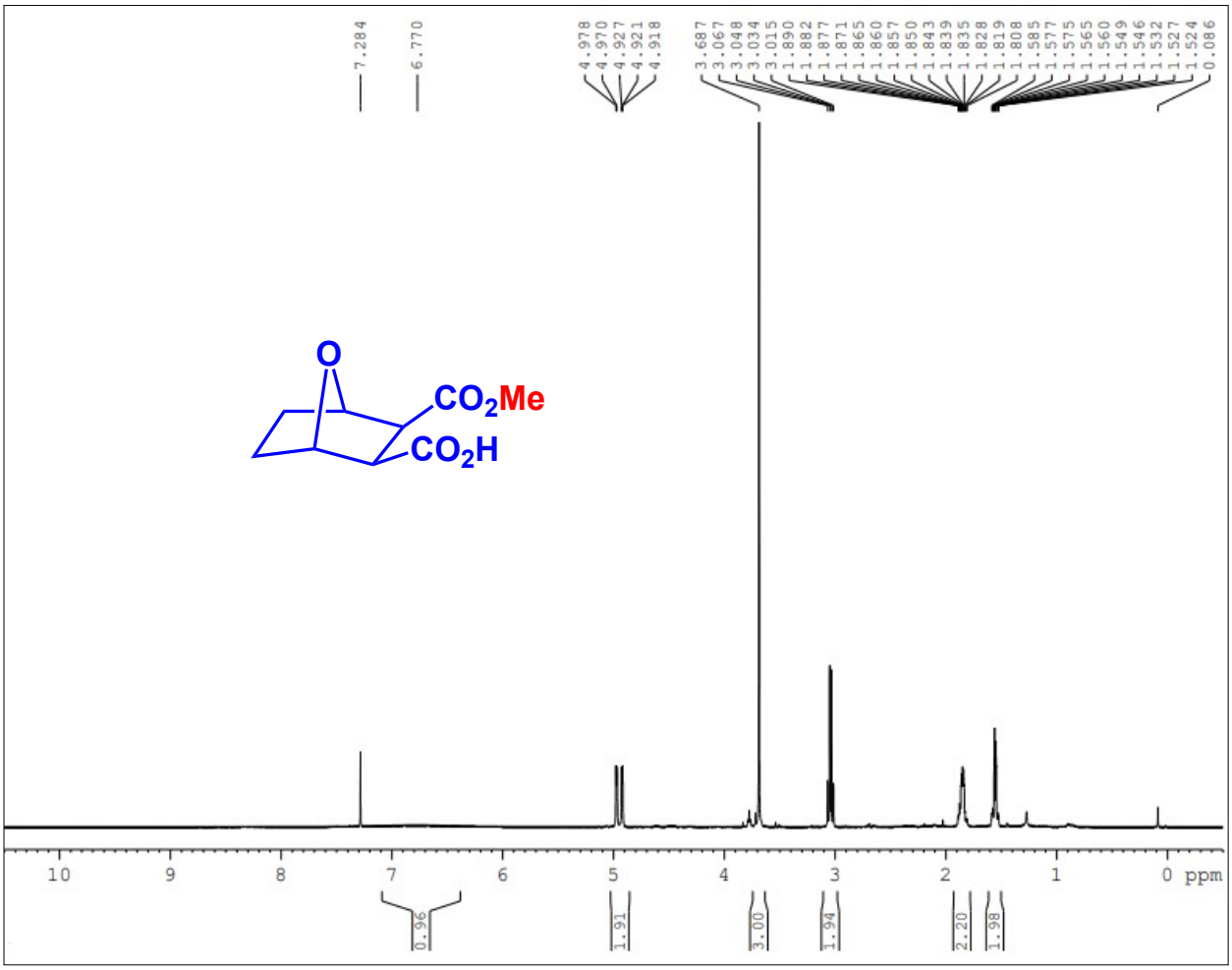


Fig. S33. ^{1}H NMR of (1S,2R,4R)-3-(methoxycarbonyl)-7-oxabicyclo[2.2.1]heptane-2-carboxylic acid (40).

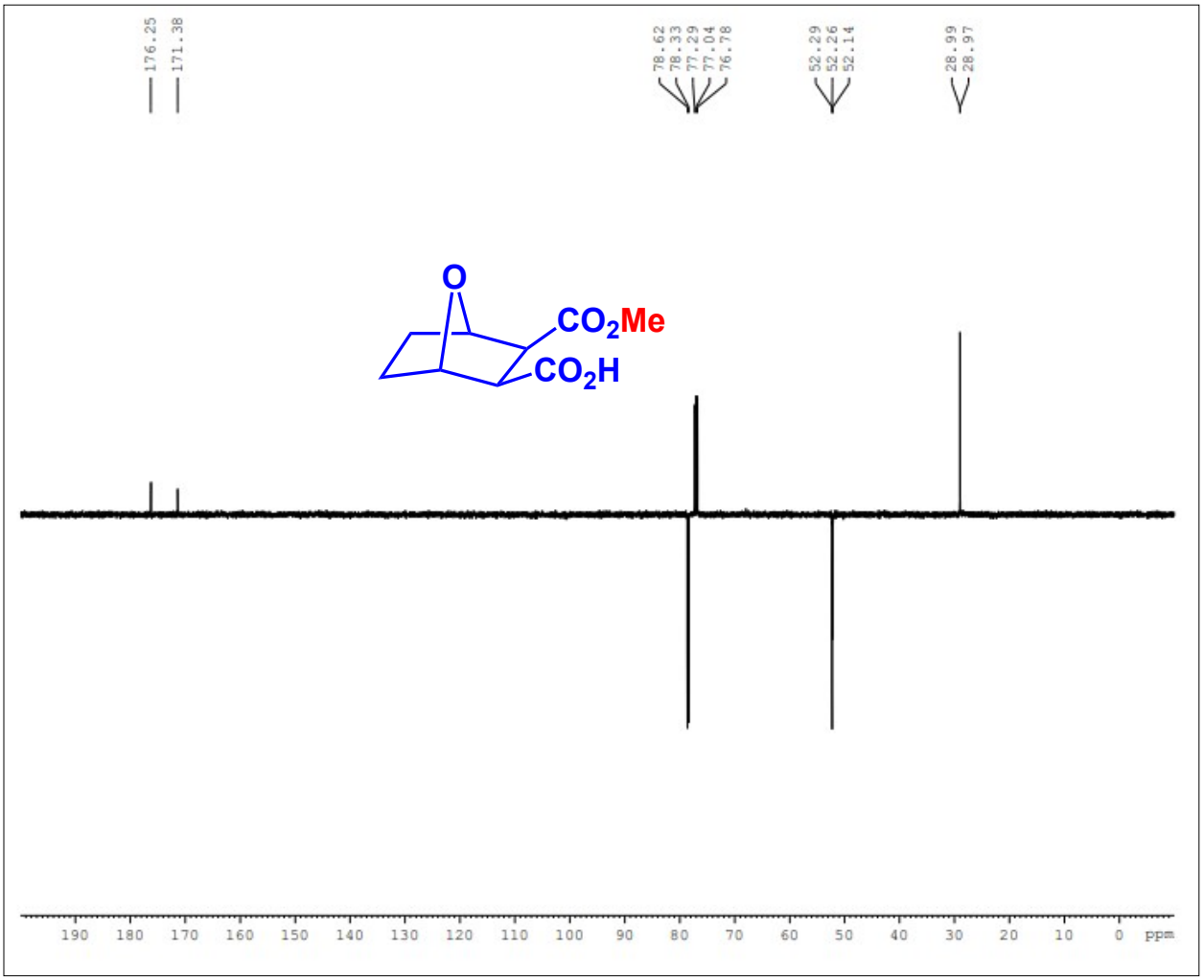
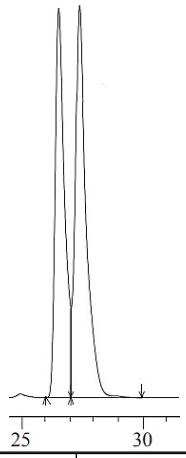
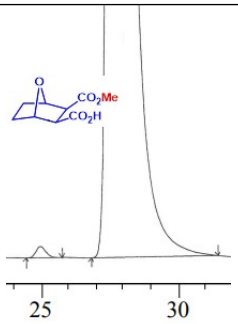


Fig. S34. ^{13}C NMR of (1S,2R,4R)-3-(methoxycarbonyl)-7-oxabicyclo[2.2.1]heptane-2-carboxylic acid (40).



	Retention time	Area	Area %
1	26.630	458643	49.8
2	27.482	462327	50.2



	Retention time	Area	Area %
1	26.002	5343	1.48
2	26.835	355654	98.52

Fig. S35. HPLC chromatograms of racemic and (1S,2R,4R)-3-(methoxycarbonyl)-7-oxabicyclo[2.2.1]heptane-2-carboxylic acid (40).

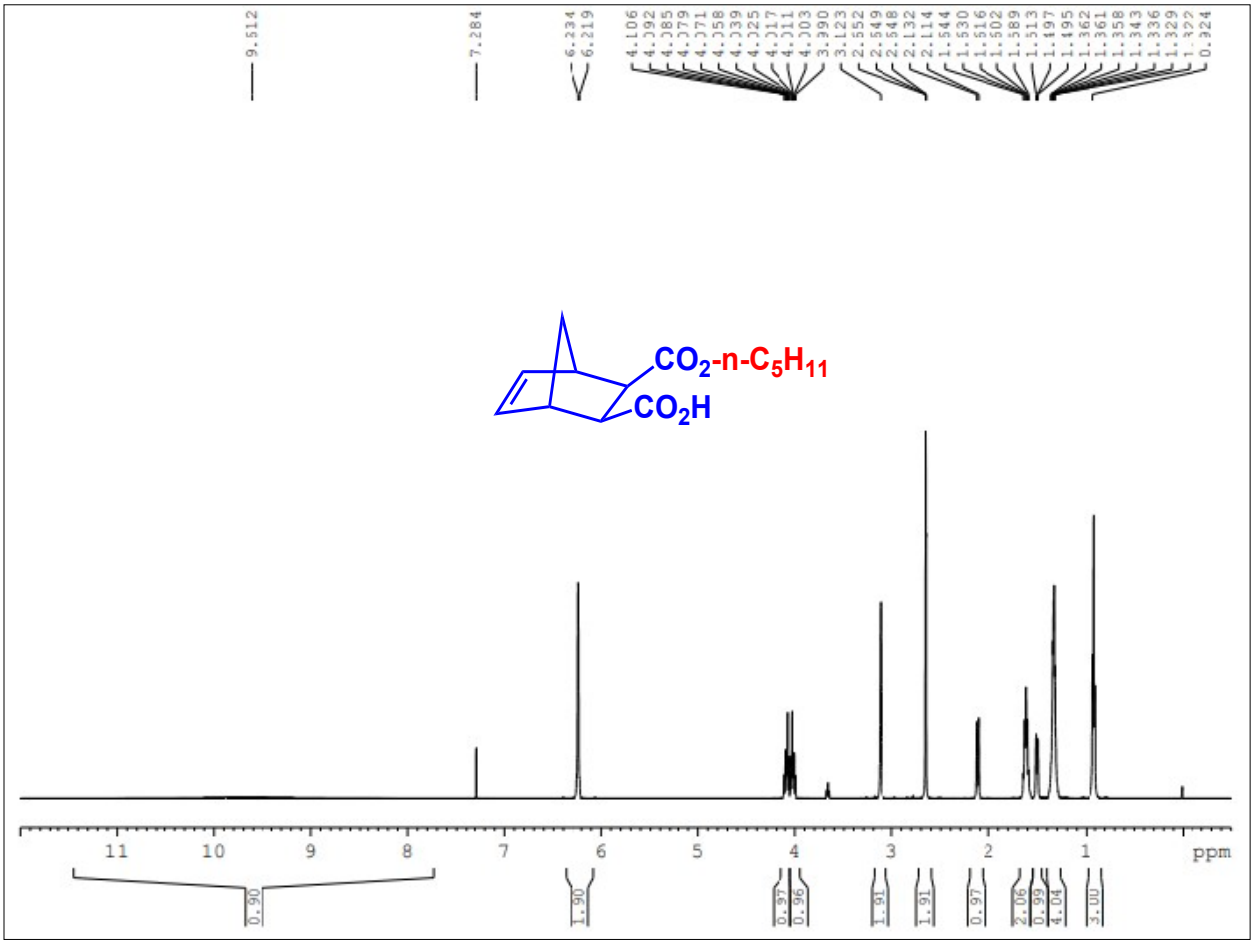


Fig. S36. ^{1}H NMR of (1S, 2S, 4R)-3-((pentyloxy)carbonyl)bicyclo[2.2.1]hept-5-ene-2-carboxylic acid (41).

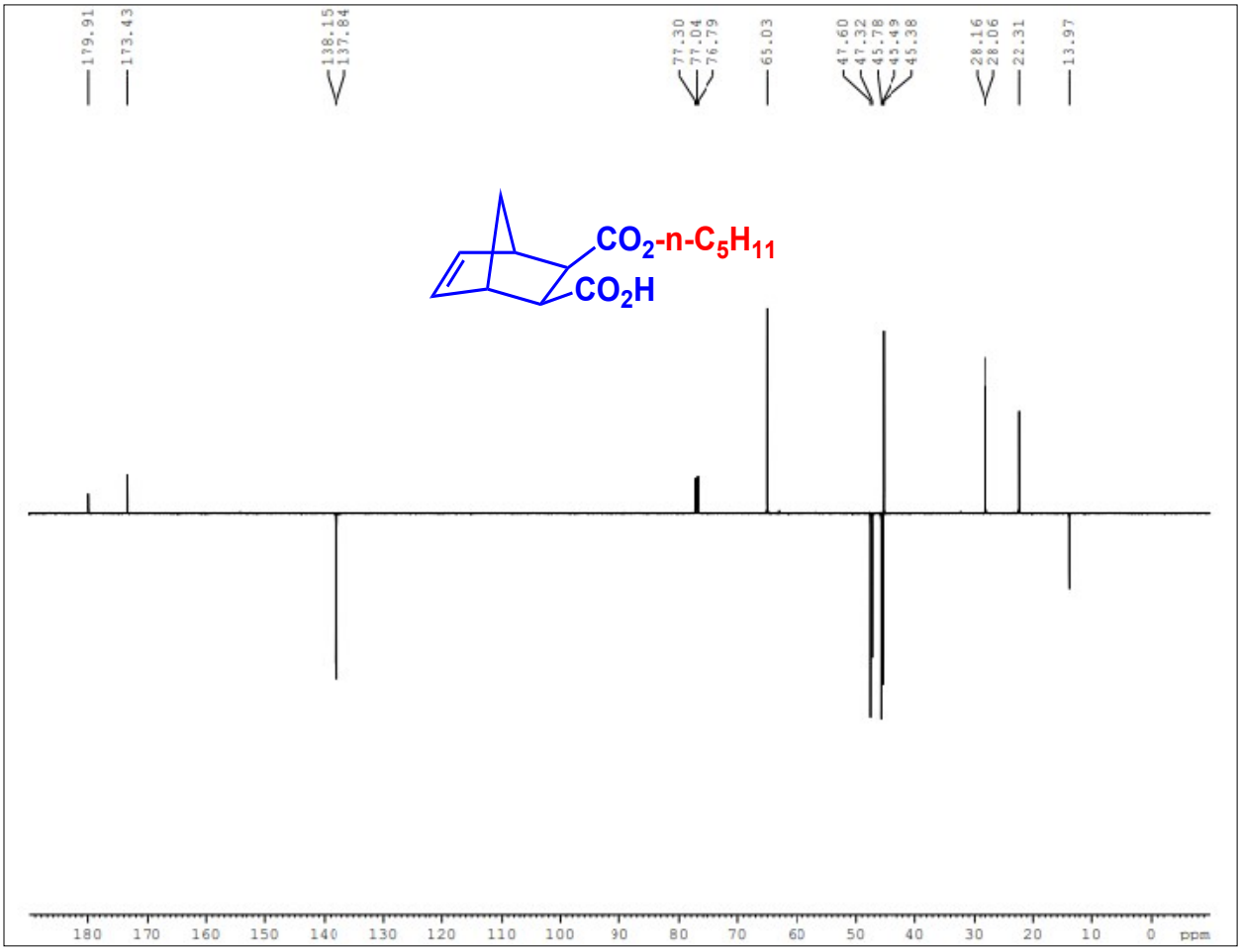
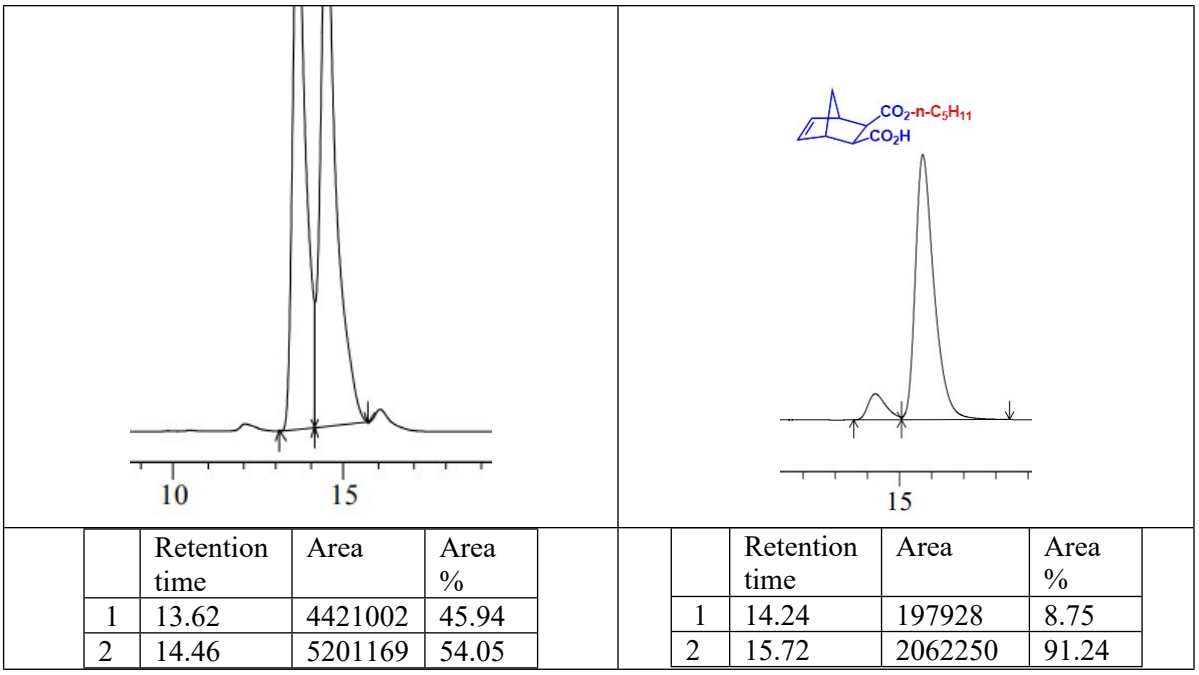


Fig. S37. ^{13}C NMR of (1S, 2S, 4R)-3-((pentyloxy)carbonyl)bicyclo[2.2.1]hept-5-ene-2-carboxylic acid (41).



	Retention time	Area	Area %
1	13.62	4421002	45.94
2	14.46	5201169	54.05

	Retention time	Area	Area %
1	14.24	197928	8.75
2	15.72	2062250	91.24

Fig. S38. HPLC chromatographs of racemic and (1S, 2S, 4R)-3-((pentyloxy) carbonyl) bicyclo [2.2.1]hept-5-ene-2-carboxylic acid (41).

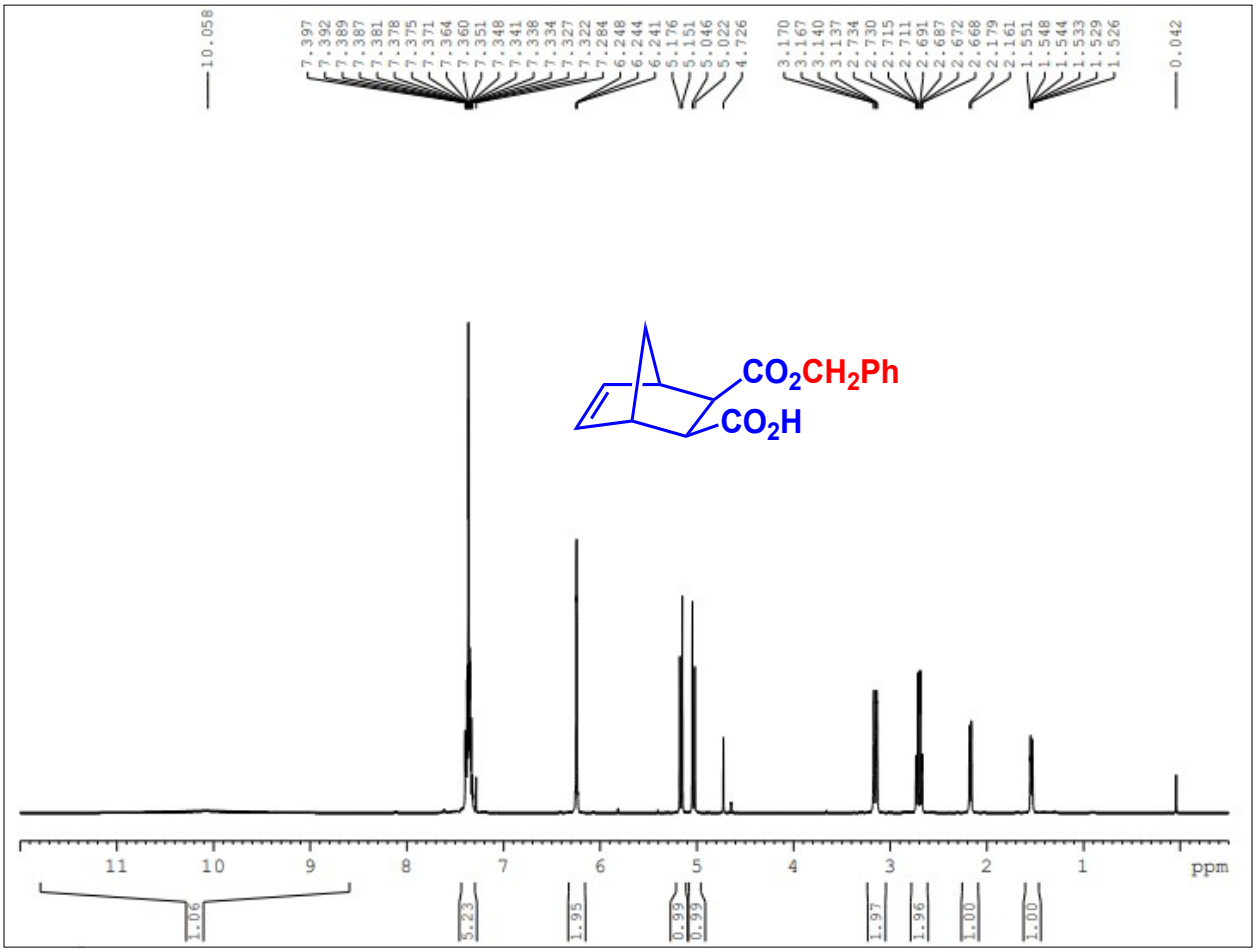


Fig. S39. ^{1}H NMR of (1S, 2S, 4R)-3-((benzyloxy)carbonyl)bicyclo[2.2.1]hept-5-ene-2-carboxylic acid (43).

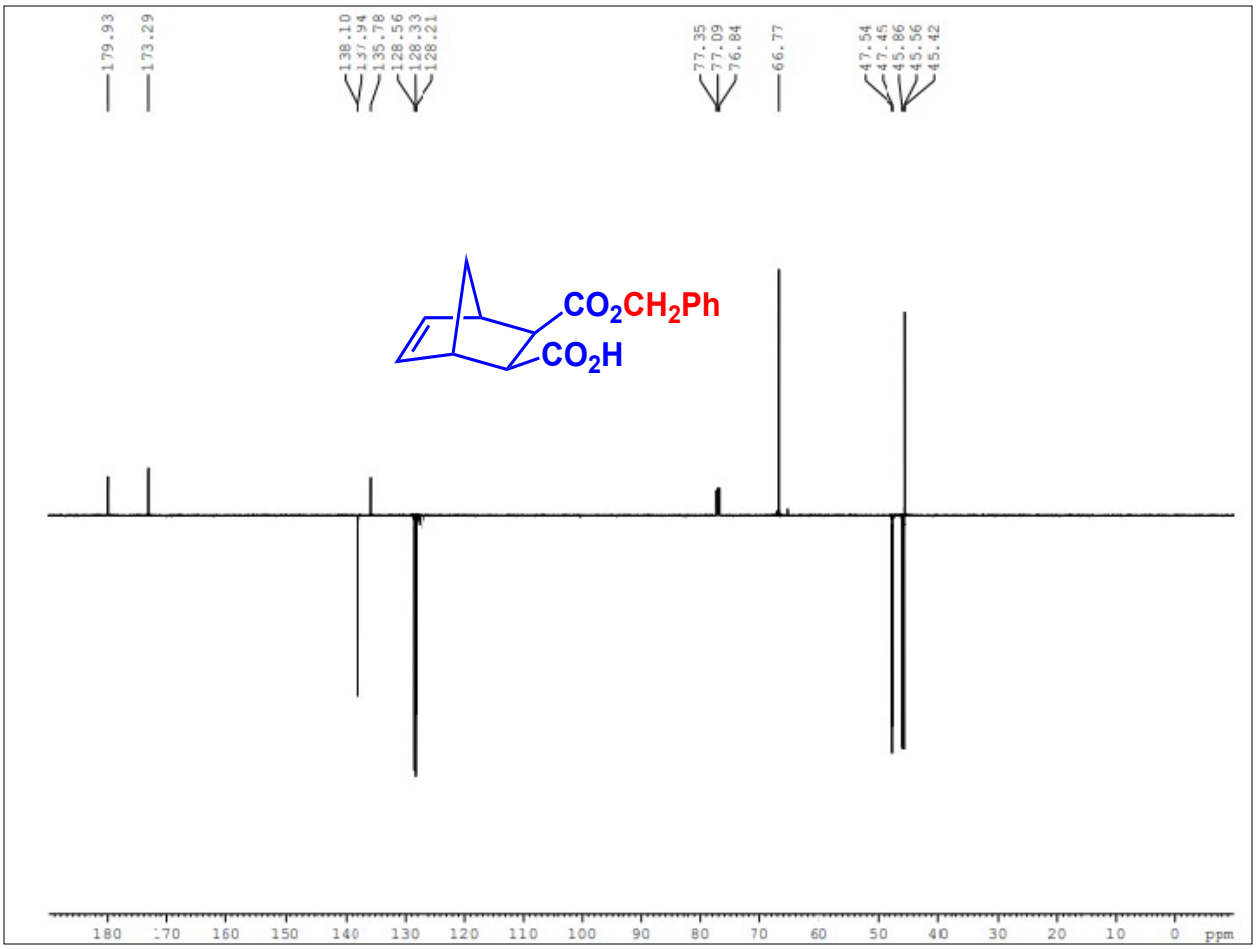
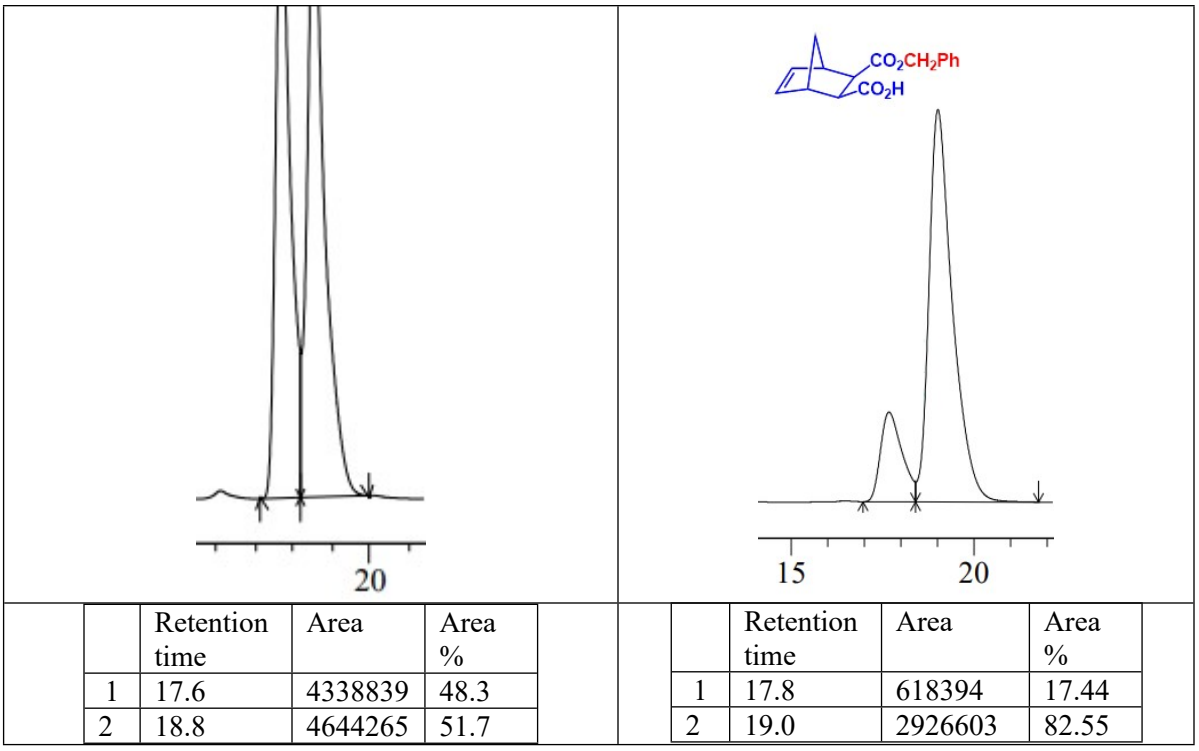


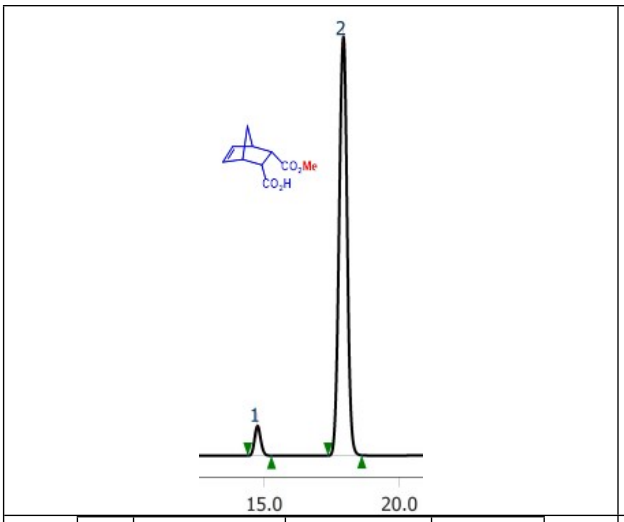
Fig. S40. ^{13}C NMR of (1S, 2S, 4R)-3-((benzyloxy)carbonyl)bicyclo[2.2.1]hept-5-ene-2-carboxylic acid (43).



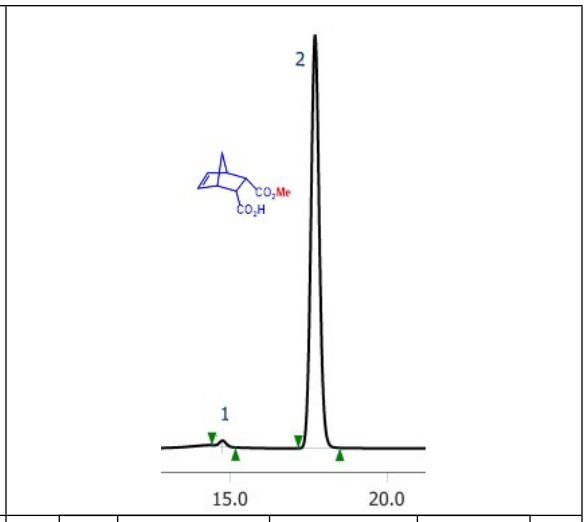
	Retention time	Area	Area %
1	17.6	4338839	48.3
2	18.8	4644265	51.7

	Retention time	Area	Area %
1	17.8	618394	17.44
2	19.0	2926603	82.55

Fig. S41. HPLC chromatographs of racemic and (1S, 2S, 4R)-3-((benzyloxy)carbonyl) bicyclo[2.2.1]hept-5-ene-2-carboxylic acid (43).

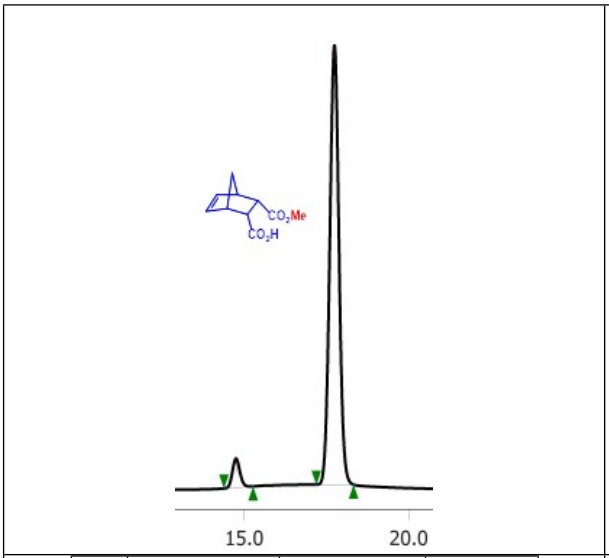


	Retention time	Area	Area %
1	14.843	1346183	3.244
2	18.113	40148959	96.756

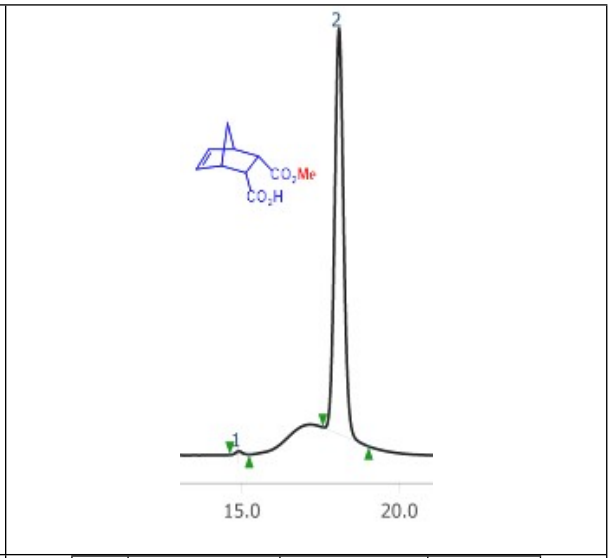


	Retention time	Area	Area %
1	14.883	271208	2.125
2	18.133	12491520	97.875

Fig. S42. HPLC chromatograms of racemic and (2*R*, 3*S*)-3-*endo*-Methoxycarbonyl-bicyclo[2.2.1]hept-5-ene-2-*endo*-carboxylic acid synthesized at 25 and 0°C.



	Retention time	Area	Area %
1	14.887	855445	3.157
2	18.173	26241343	96.843



	Retention time	Area	Area %
1	14.850	292011	1.28
2	18.168	22521377	98.72

Fig. S43. HPLC chromatograms of racemic and (2*R*, 3*S*)-3-*endo*-Methoxycarbonyl-bicyclo[2.2.1]hept-5-ene-2-*endo*-carboxylic acid synthesized after using the catalyst 10 and 5 cycles.

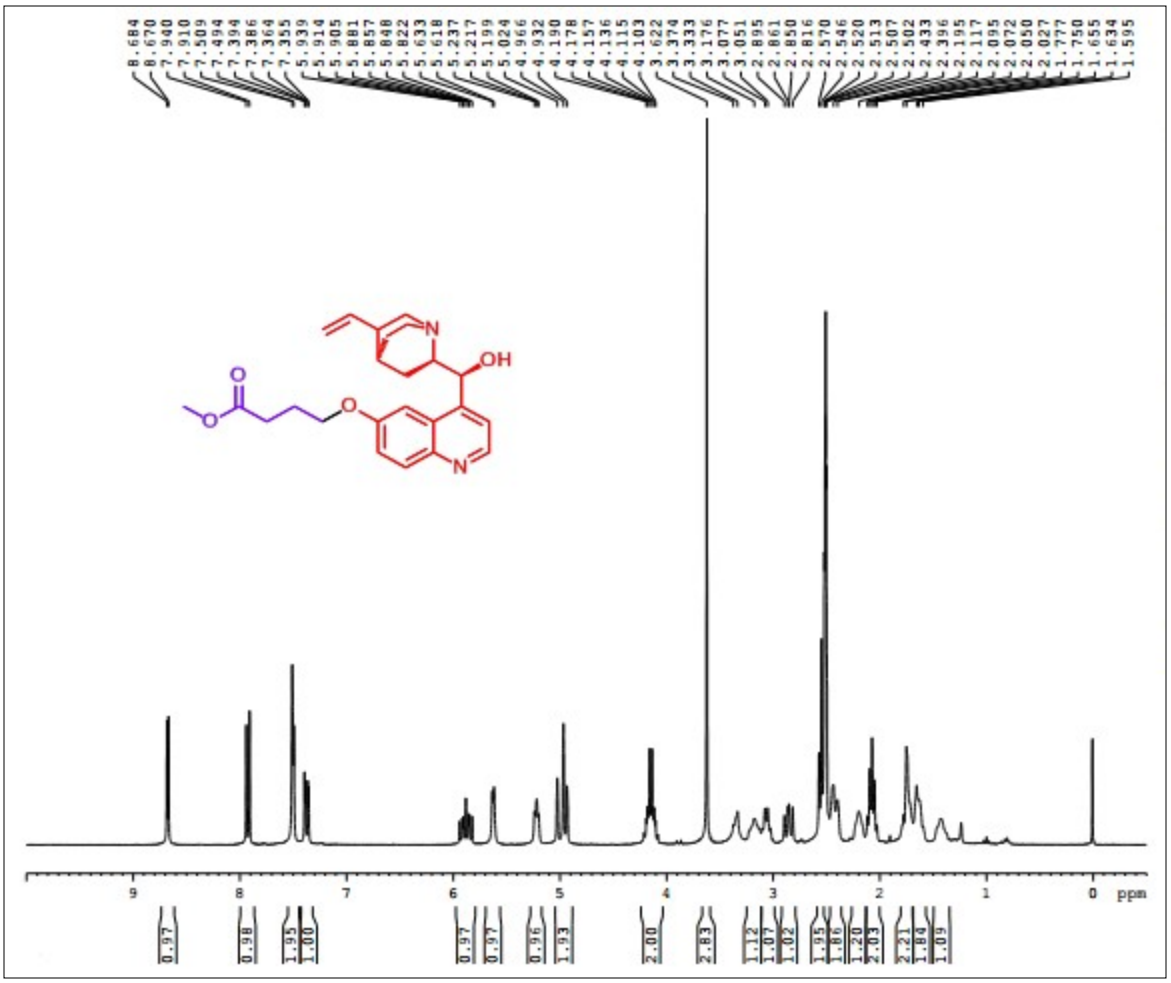


Fig. S44. ^{1}H NMR of 4-((4-((1S)-hydroxy((2R,4S,5R)-5-vinylquinuclidin-2-yl)methyl) quinolin-6-yl)oxy) butanoic acid methyl ester (18).

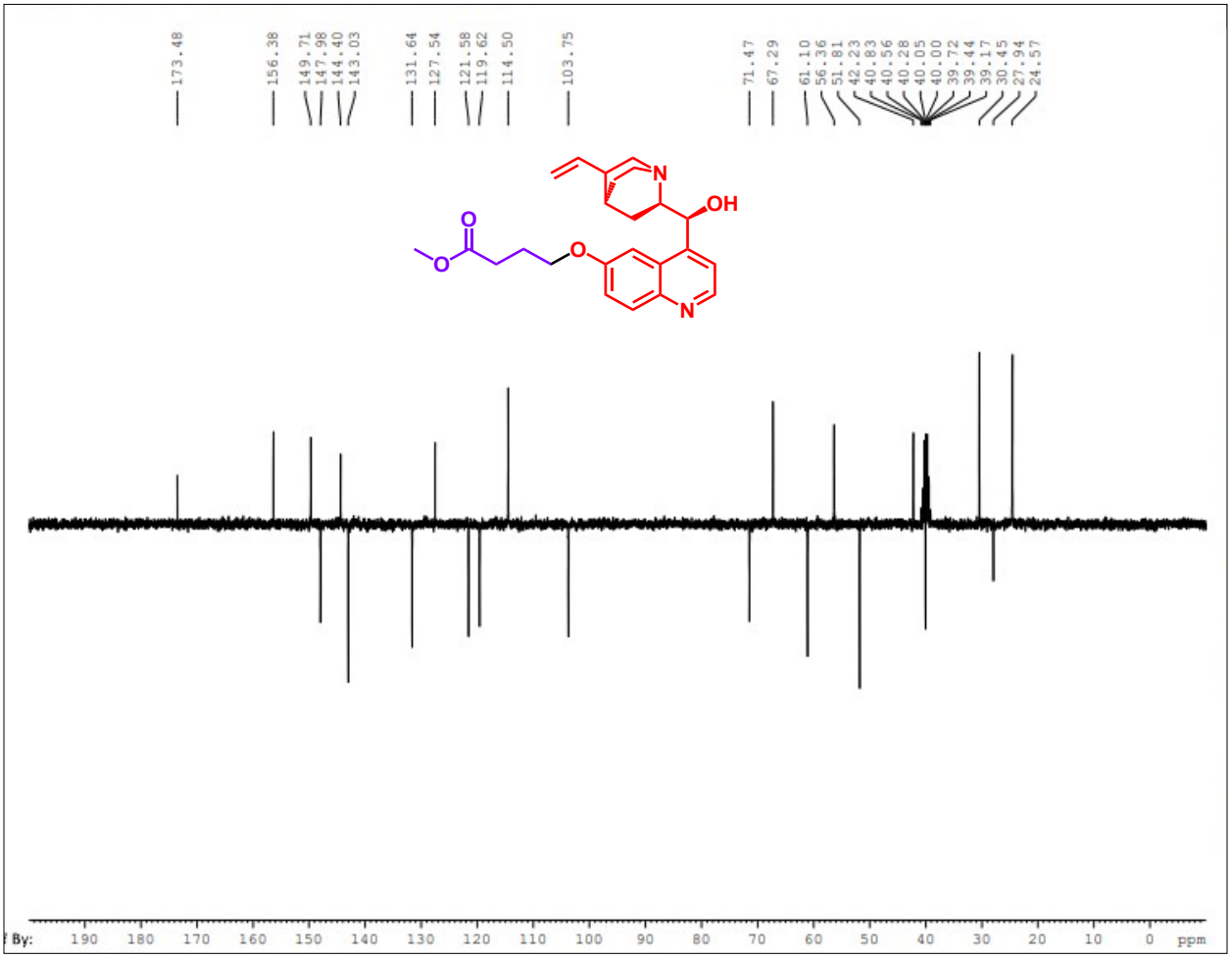


Fig. S45. ^{13}C NMR of 4-((4-((1S)-hydroxy((2R,4S,5R)-5-vinylquinuclidin-2-yl)methyl) quinolin-6-yl)oxy)butanoic acid methyl ester (18).

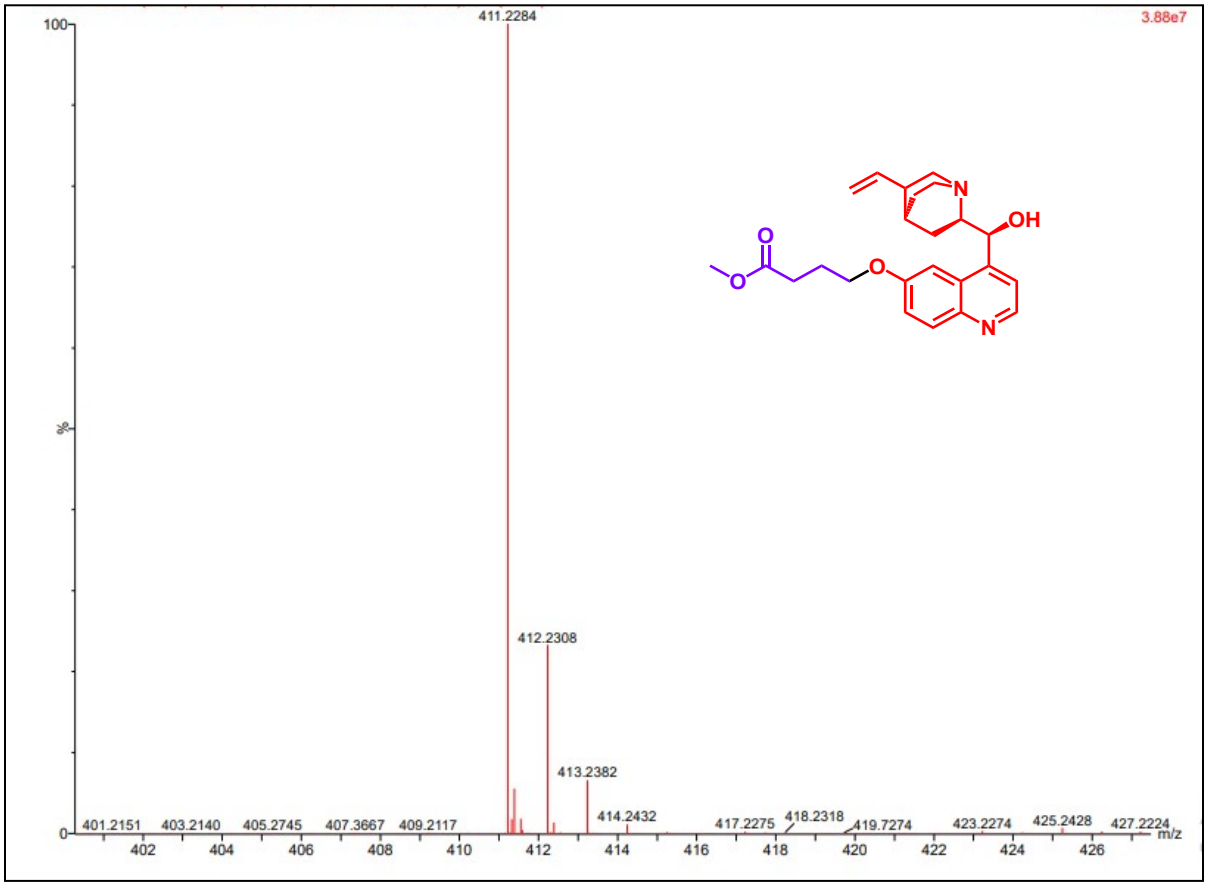


Fig. S46. HRMS of 4-((4-((1S)-hydroxy((2R,4S,5R)-5-vinylquinuclidin-2-yl)methyl) quinolin-6-yl)oxy)butanoic acid methyl ester (18).

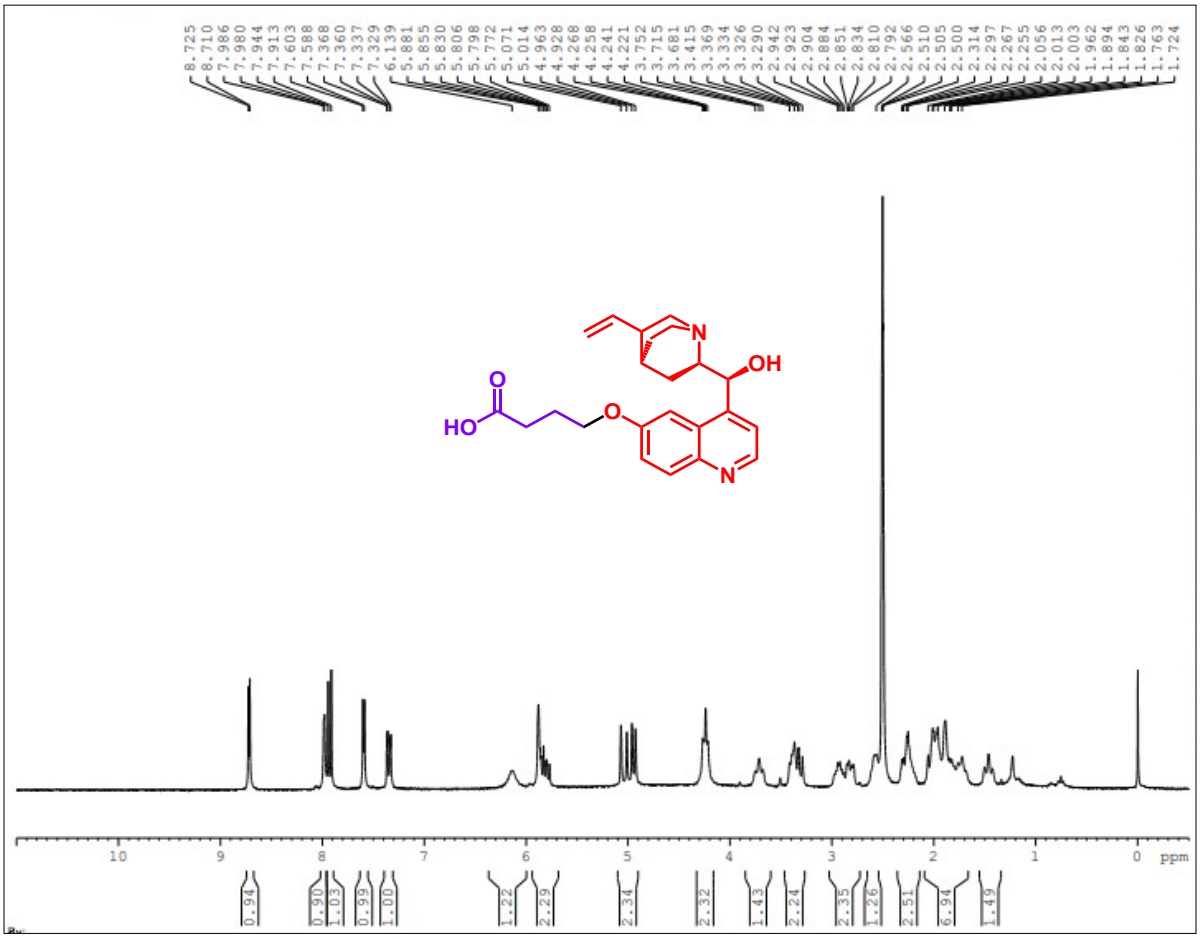


Fig. S47. ^{1}H NMR of 4-((4-((1S)-hydroxy((2R,4S,5R)-5-vinylquinuclidin-2-yl)methyl) quinolin-6-yl)oxy)butanoic acid (19).

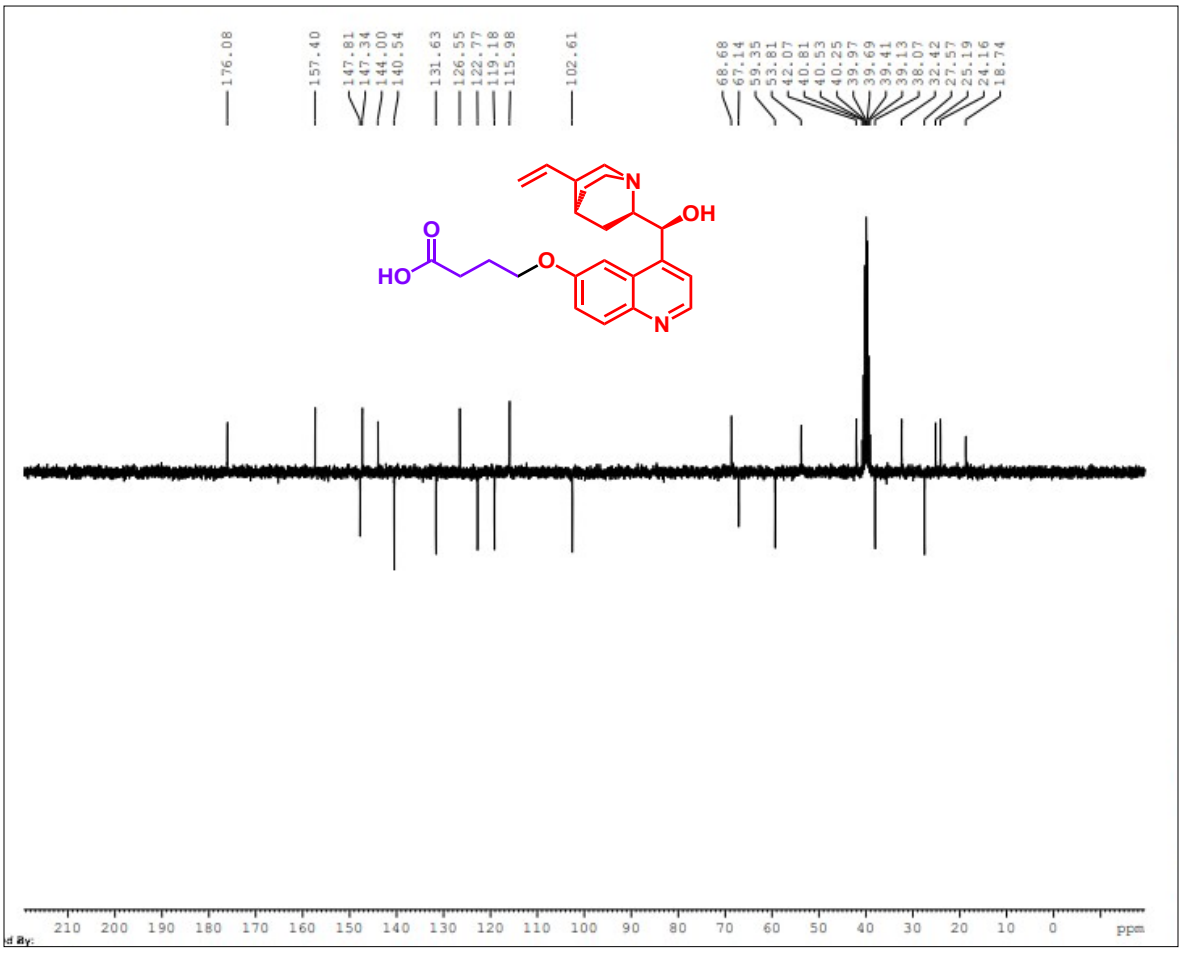


Fig. S48. ^{13}C NMR of 4-((4-((1S)-hydroxy((2R,4S,5R)-5-vinylquinuclidin-2-yl)methyl) quinolin-6-yl)oxy)butanoic acid (19).

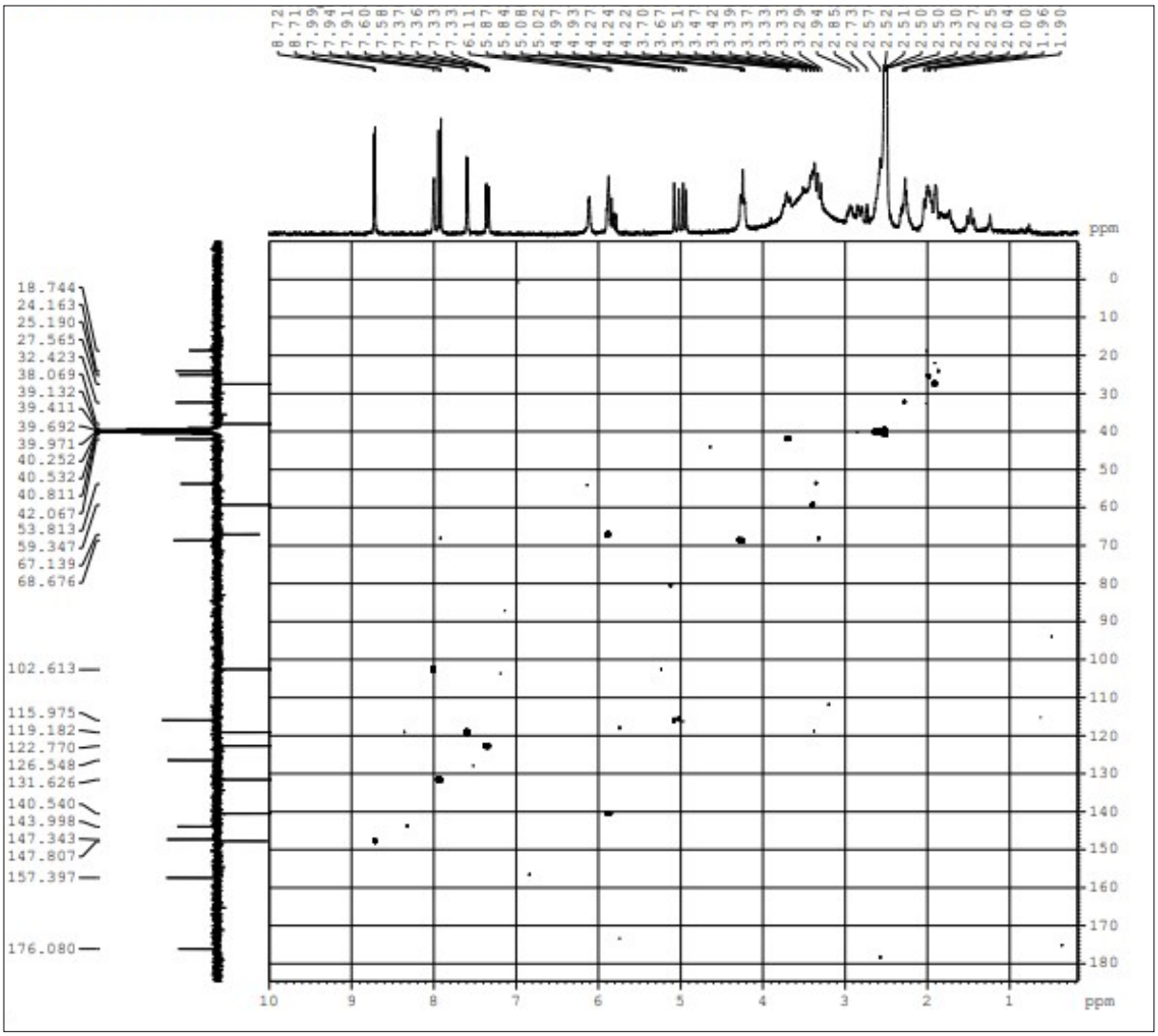


Fig. S49. HSQC of 4-((4-((1S)-hydroxy((2R,4S,5R)-5-vinylquinuclidin-2-yl)methyl)quinolin-6-yl)oxy)butanoic acid (19).

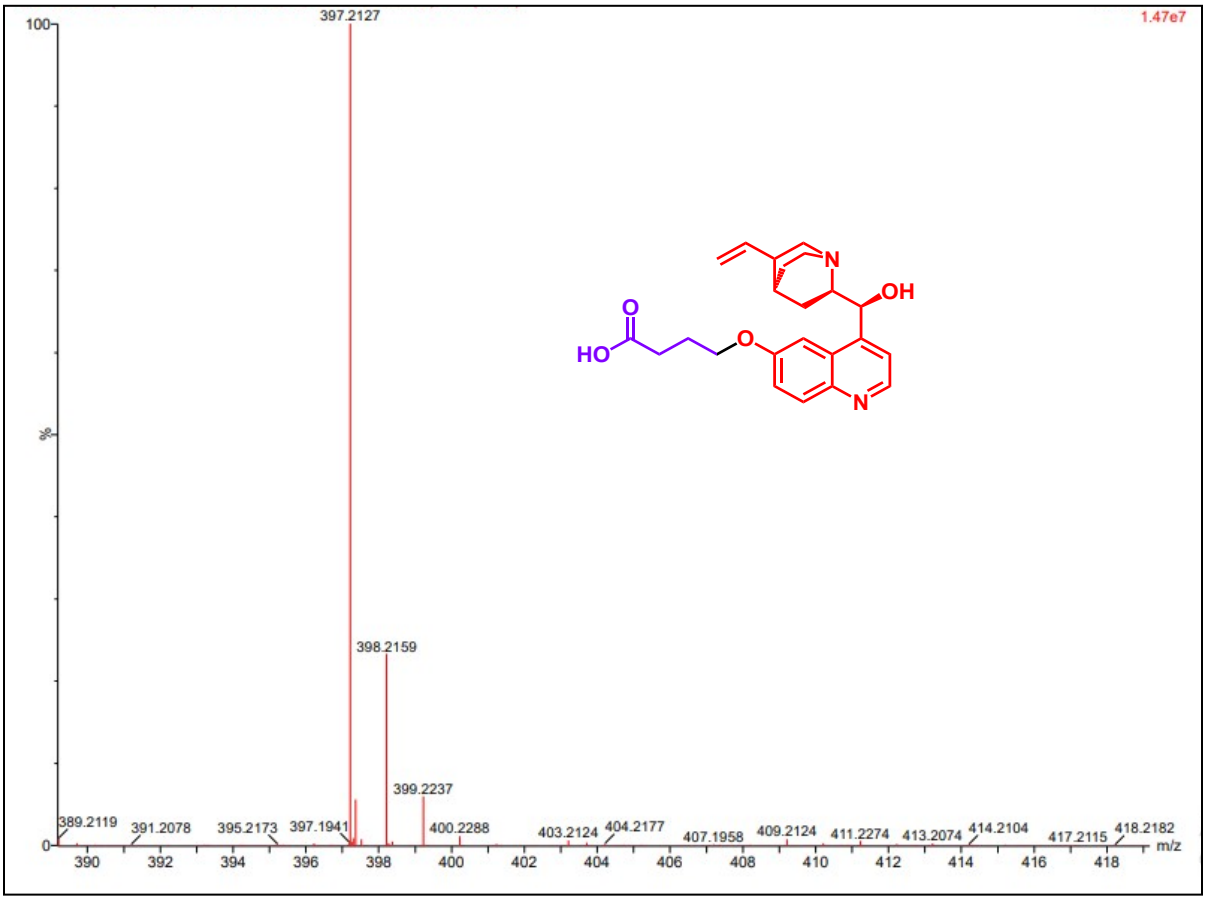


Fig. S50. HRMS of 4-((4-((1S)-hydroxy((2R,4S,5R)-5-vinylquinuclidin-2-l)methyl)quinolin-6-yl) oxy)butanoic acid (19).