Selective "One-Pot" Synthesis of Functionalized Cyclopentenones

Teresa Varea*,[§] Ana Alcalde,[§] Carolina López de Dicastillo,[§] Carmen Ramírez de Arellano,[§] Fernando P. Cossío,[‡] and Gregorio Asensio[§]

[§]Departamento de Química Orgánica Universidad de Valencia, 46100 Burjassot, Valencia, Spain.[‡]Departamento de Química Orgánica I, Universidad del País Vasco-Euskal Herriko Unibertsitatea (UPV-EHU), Facultad de Química, 20018 San Sebastián-Donostia, Spain

Email varea@uv.es

Supporting Information

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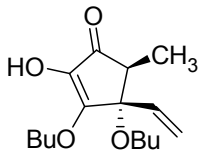
Experimental Section

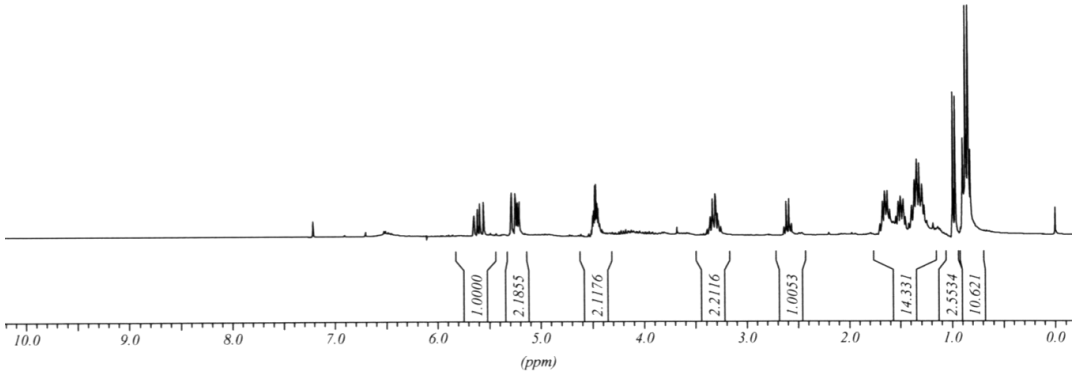
General Methods.

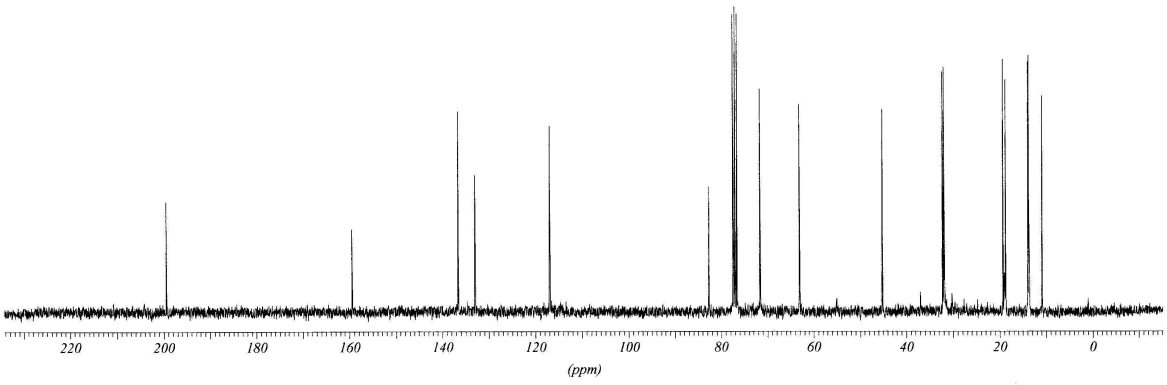
All reactions were carried out under an inert atmosphere of N_2. Jacketed glassware (flask and addition funnel) was oven-dried or flame-dried *in vacuo* and purged with N_2. Tetrahydrofuran and diethyl ether were distilled from sodium-benzophenone ketyl immediately prior to use. Vinyl magnesium bromide was initially purchased from Aldrich® as a 1M solution in THF but better results were obtained with the 1M solution in THF purchased from TCI®. Solutions of this Grignard reagent were titred following the method described by Love.[1] Squarates **1a-c** were used as received and stored in a N_2 atmosphere in order to avoid their hydrolysis. Reactions were monitored by analytical thin-layer chromatography using commercial aluminium sheets that had been pre-coated (0.2 mm layer thickness) with silica gel 60 F_{254}. Product purification by flash chromatography was performed using E. Merck Silica Gel (230-400 mesh). When indicated calcined silica gel was used (550^{0}C for 5h). ^{1}H and ^{13}C spectra were recorded on a AC-300 spectrometer in $CDCl_3$. Chemical shifts are reported in δ ppm relative to the $CHCl_3$ peak at 7.27 ppm (^{1}H) or $CDCl_3$ peak at 77.0 ppm (^{13}C). High Resolution Mass Spectra were determined on a double-focusing spectrometer equipped with a magnetic sector analyzer. Melting points are uncorrected. GC chromatograms were initially recorded with a capillary column 25QC2/BPX5 (0.25 μM) and/or with a capillary column 19091S-4331 (30m length, I.D. 0.25 mm, film thickness 0.25 μm) and a MS-GC interface. Oven profile: 60ºC (5 min)–10ºC/min–300ºC(10 min).

[1] Love, B.E.; Jones, E.G. *J. Org. Chem.* **1999**, *64*, 3755.

(*4S,5S)-dibutoxy-2-hydroxy-5-methyl-4-vinylcyclopent-2-en-1-one (8a)*







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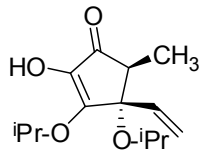

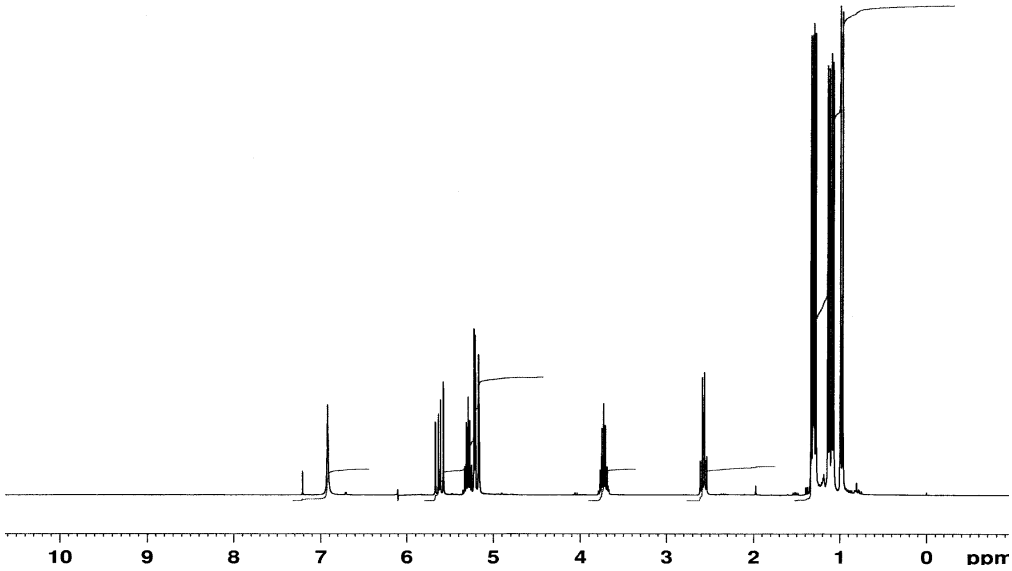

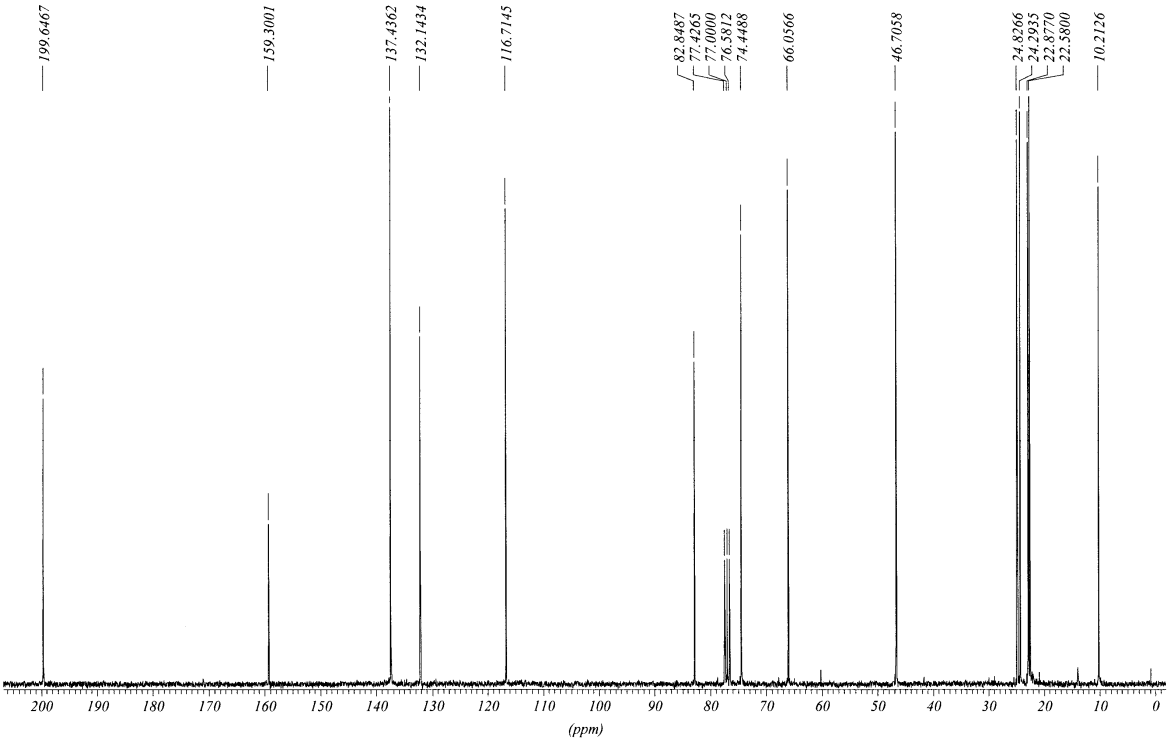

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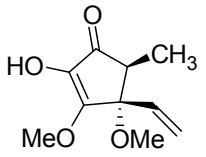
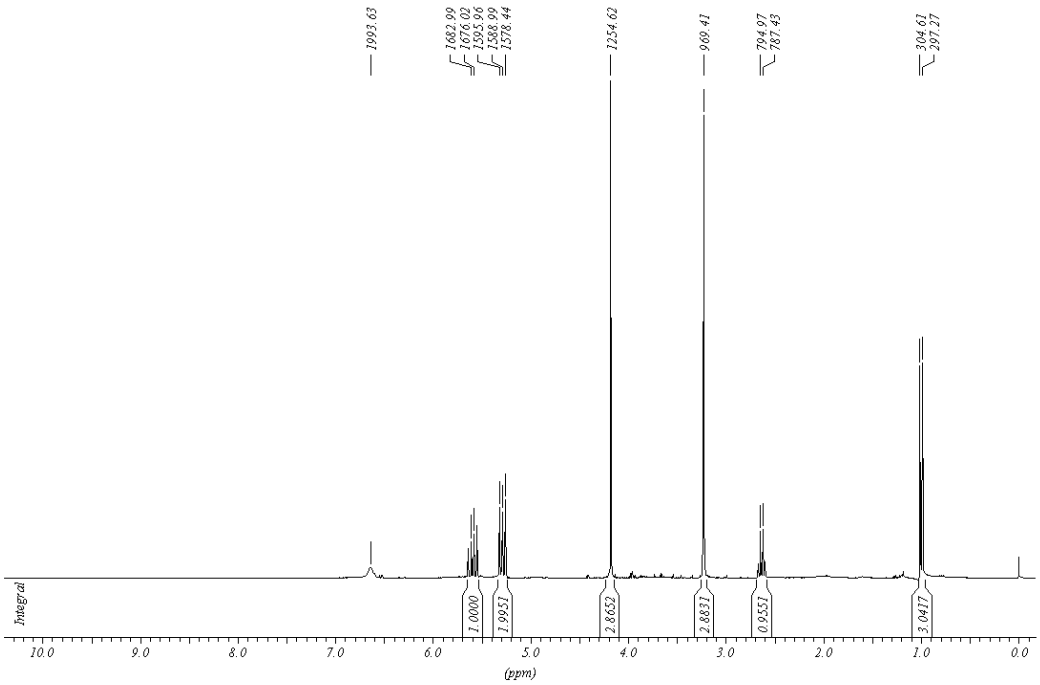
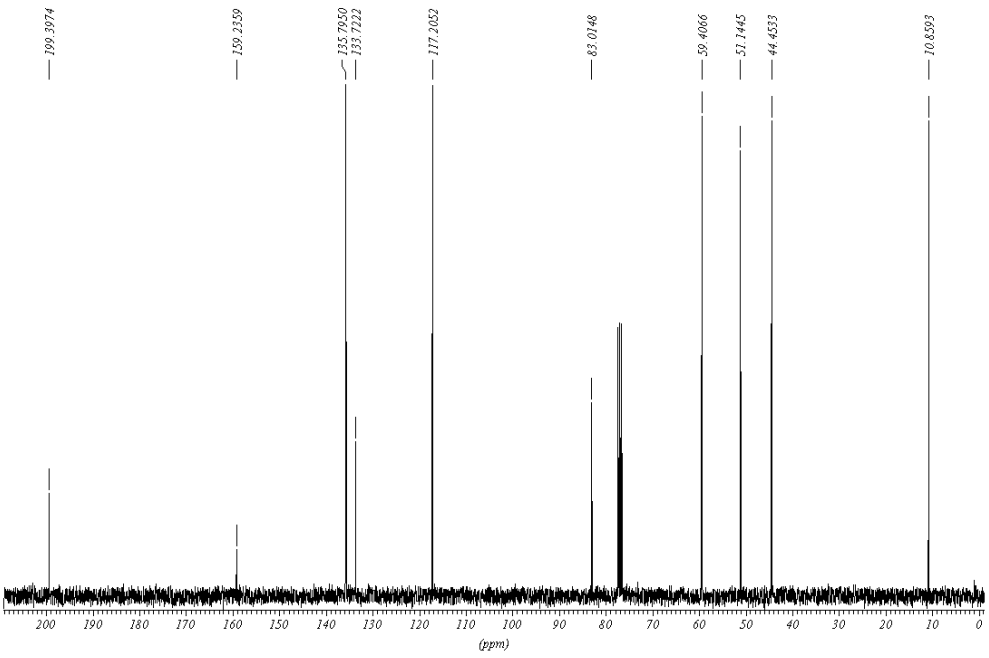
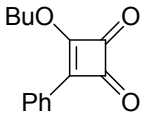




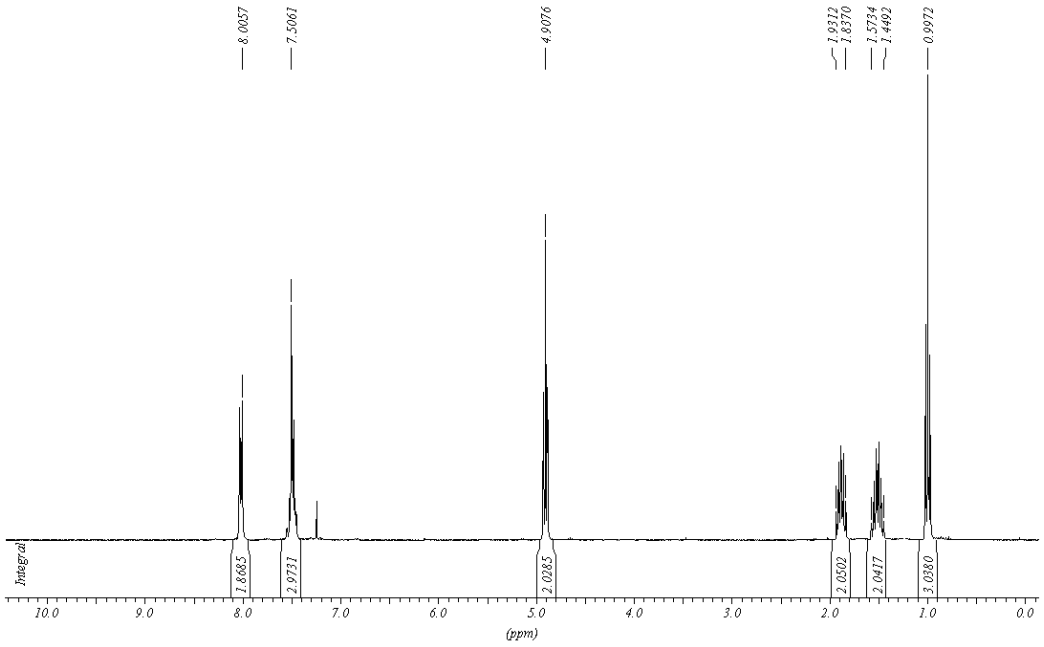
^{13}C



3-butoxy-4-phenylcyclobut-3-en-1,2-dione (12a)



^{1}H



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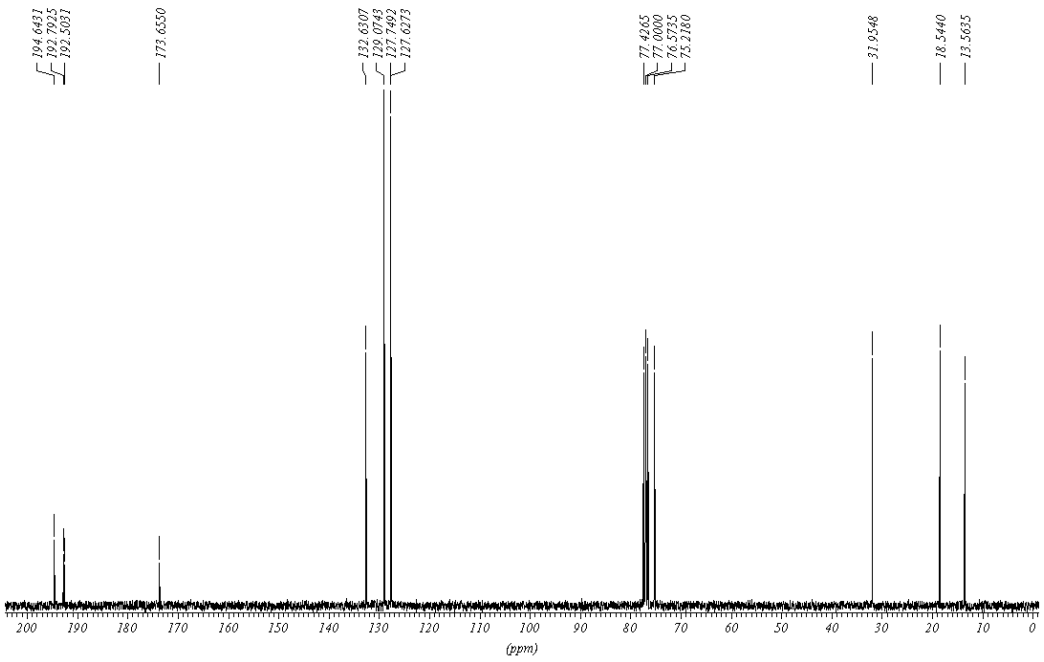

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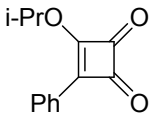

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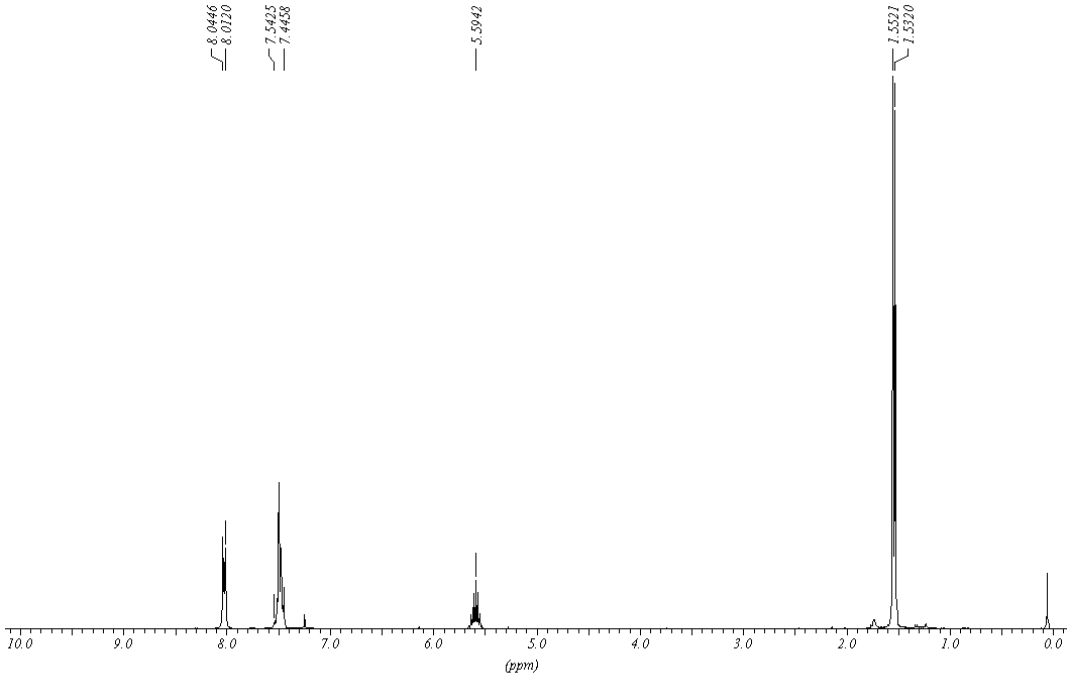

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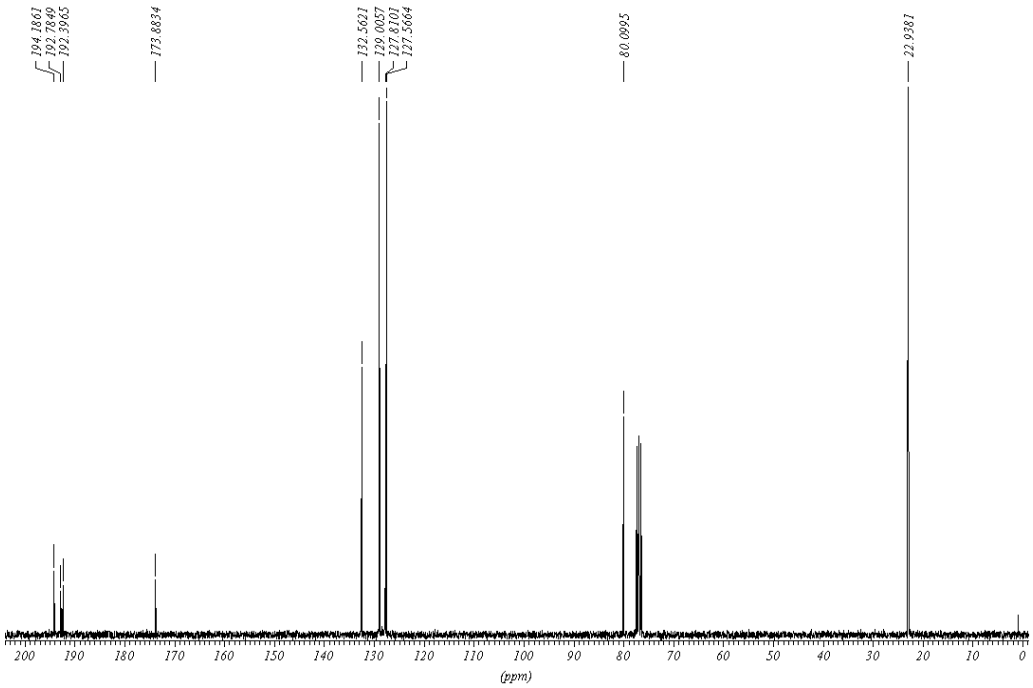

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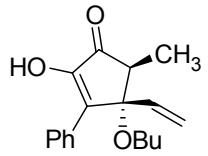
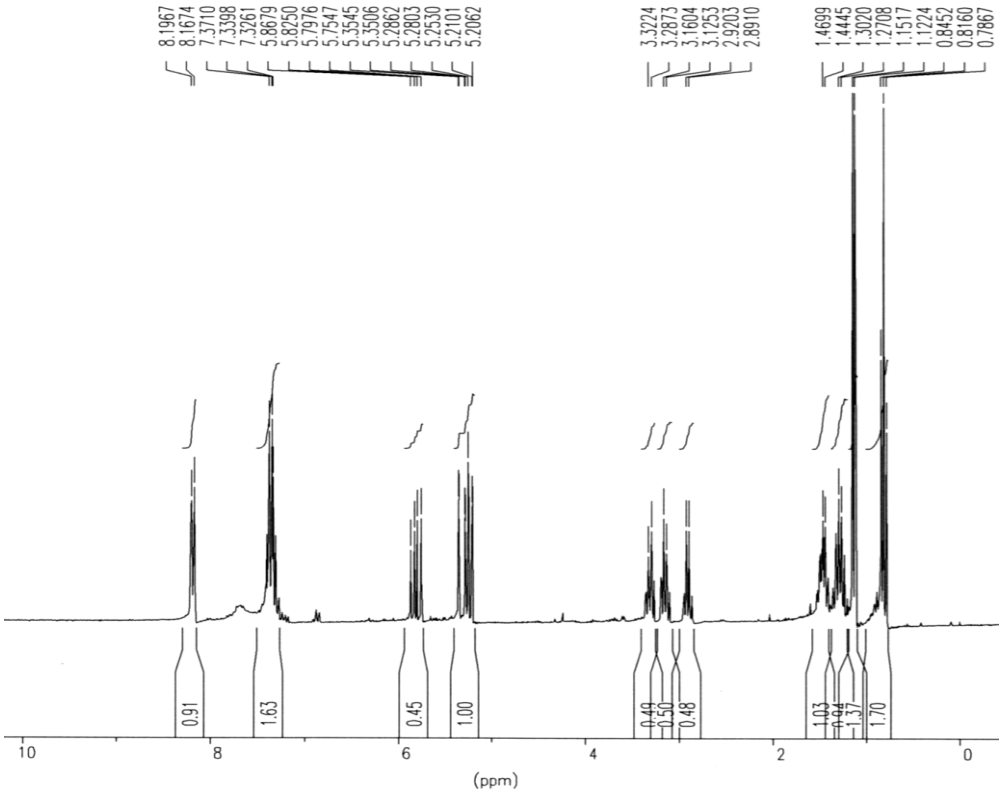
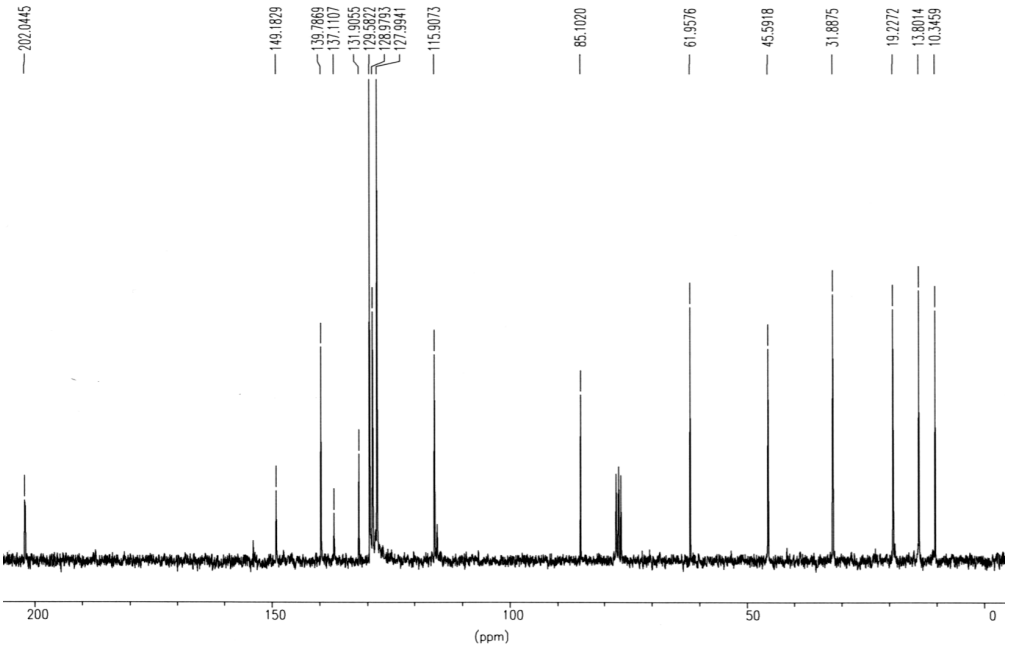


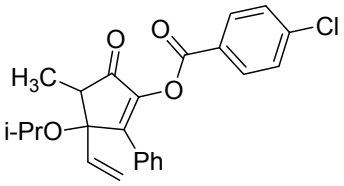
1H



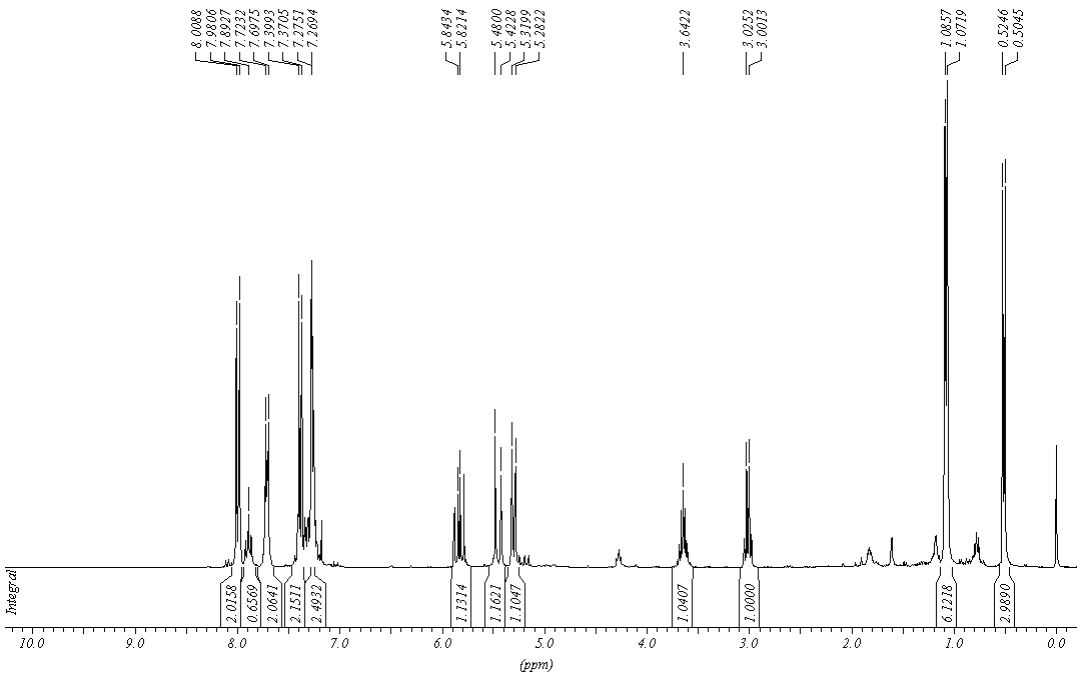
13C



(3S,4S)-3-isopropoxy-4-methyl-5-oxo-2-phenyl-3-vinylcyclopent-1-enyl 4-chlorobenzoate (14b)



1H



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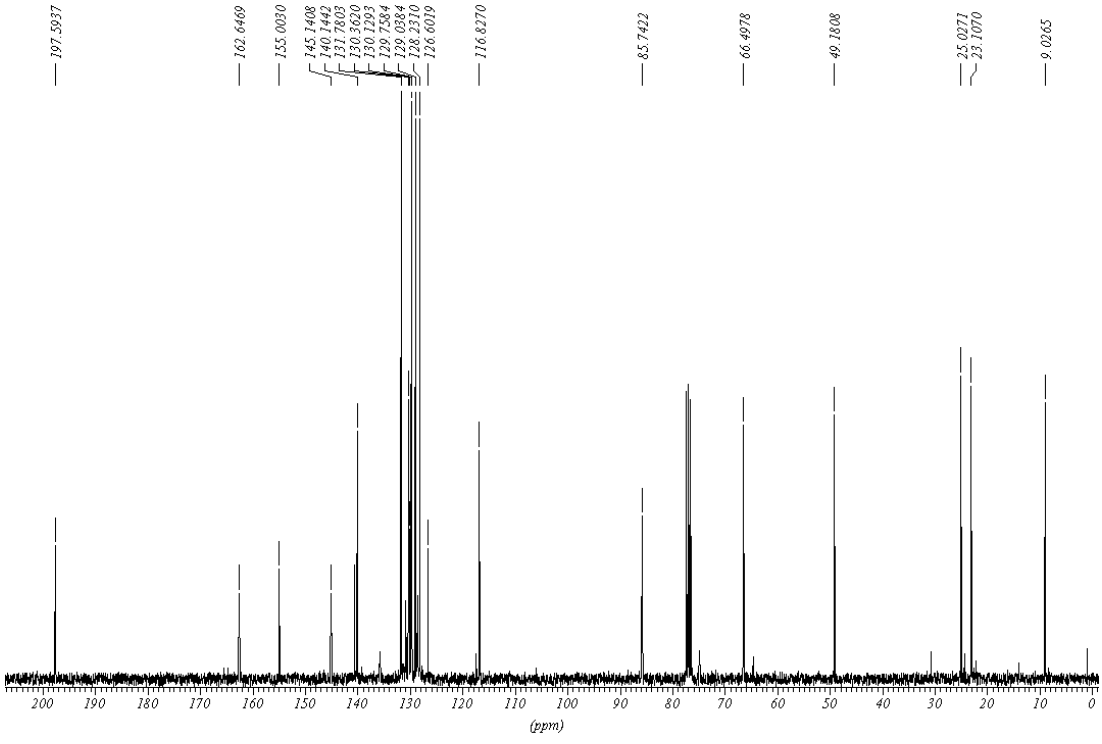
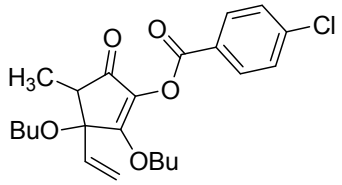
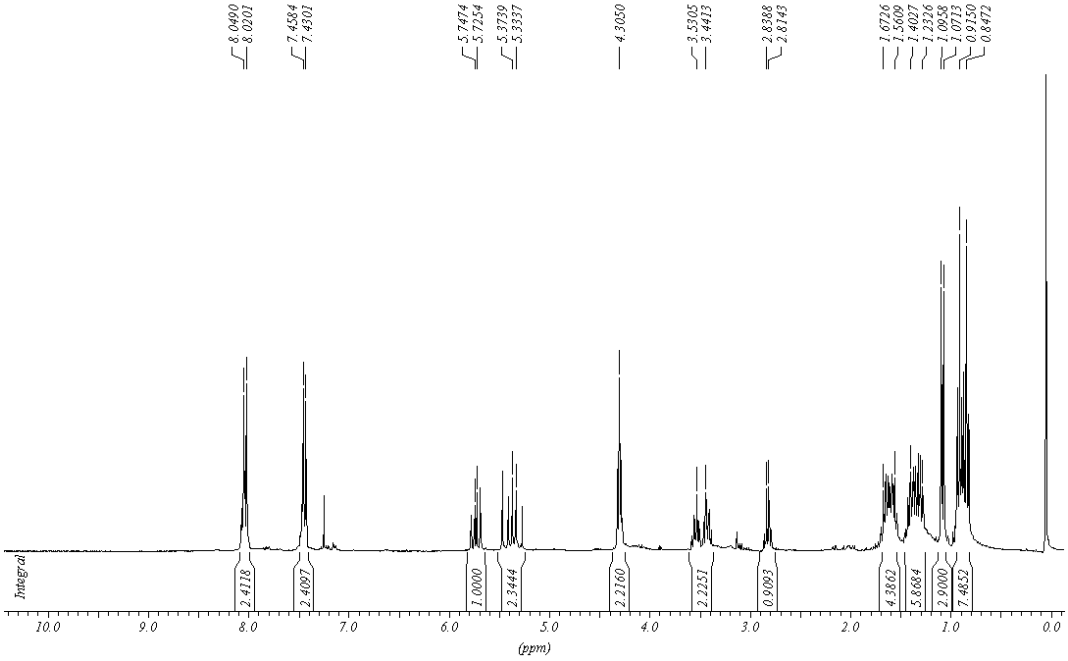


(3S,4S)-2,3-dibutoxy-4-methyl-5-oxo-3-vinylcyclopent-1-enyl 4-chlorobenzoate (15a)



^{1}H



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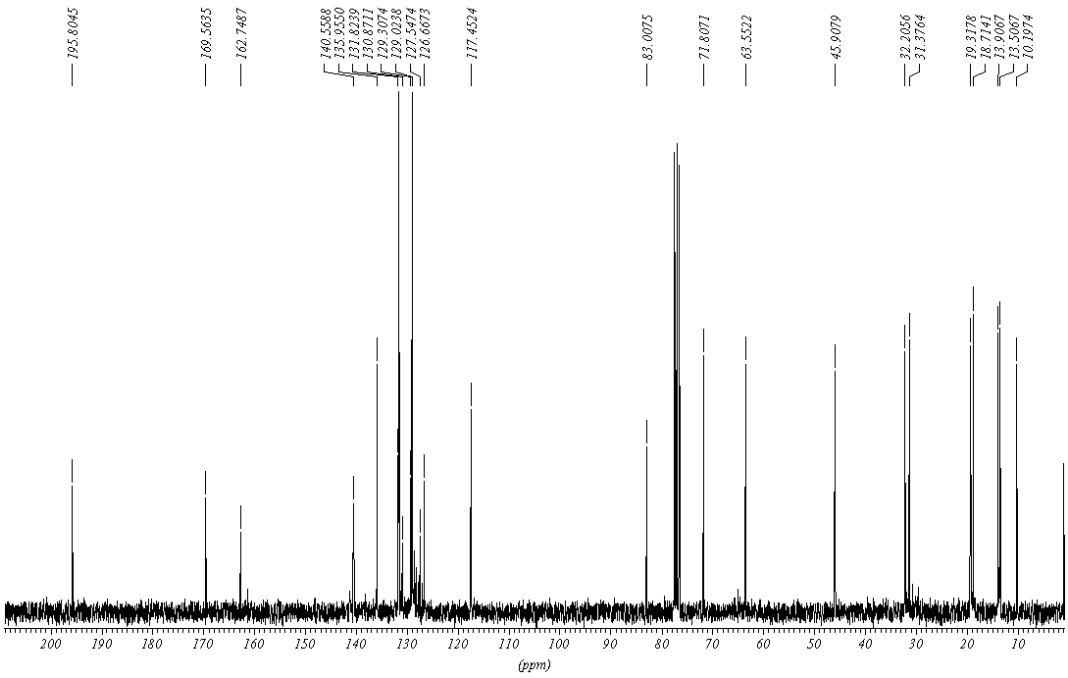
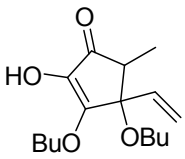
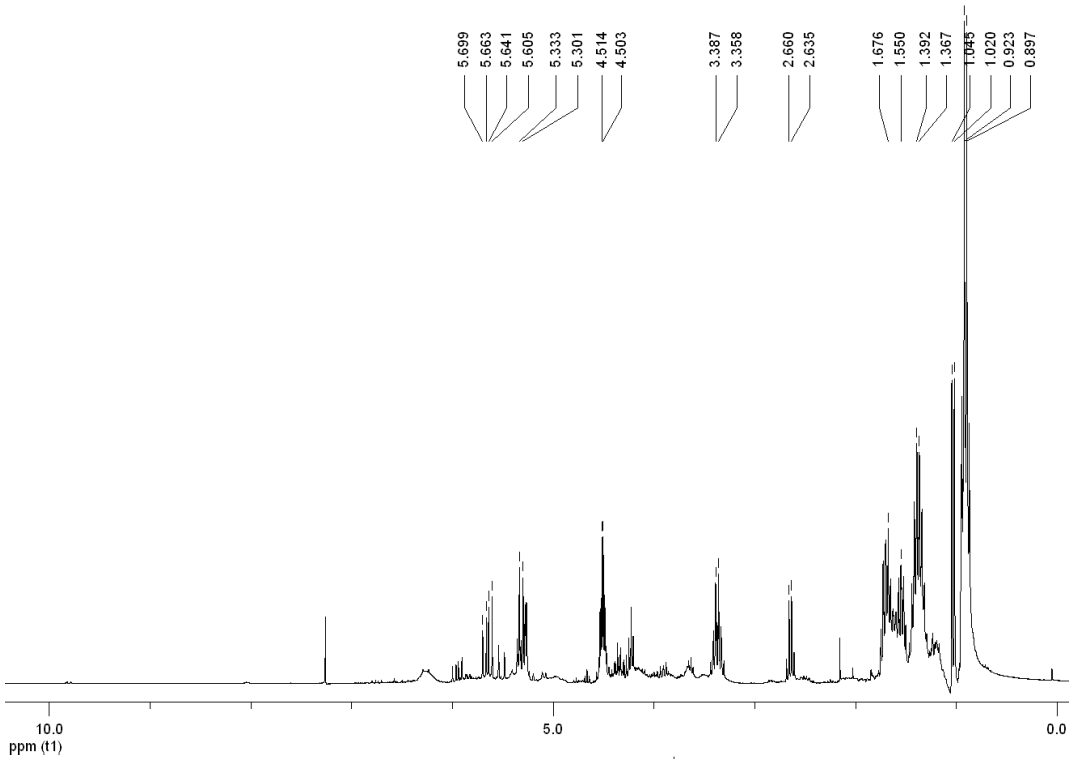
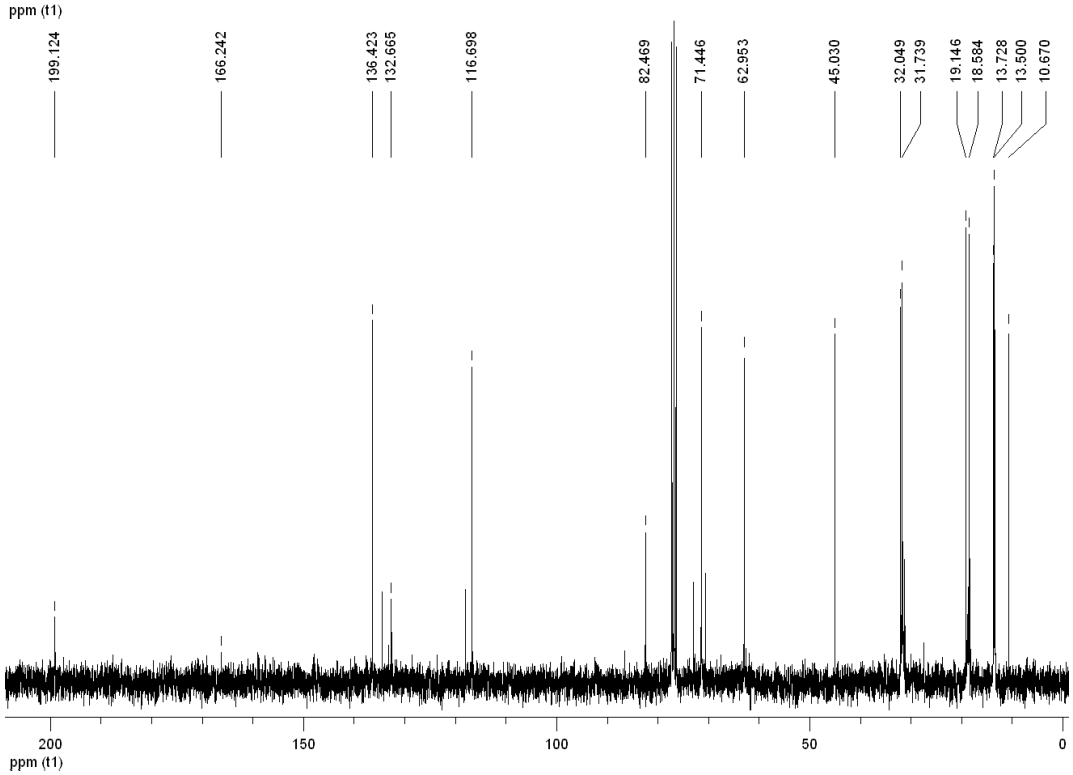
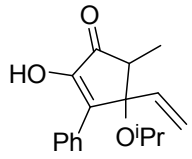




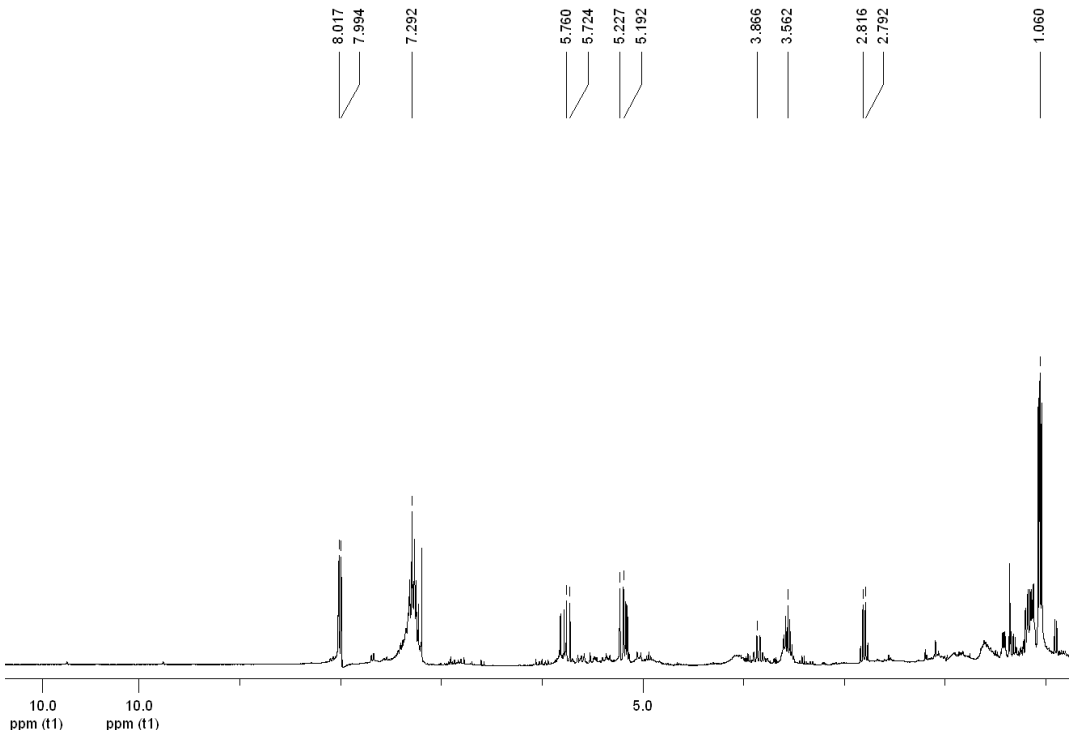
NMR spectra of the crude corresponding to the obtention of compound **8a (table 1, entry 4)**

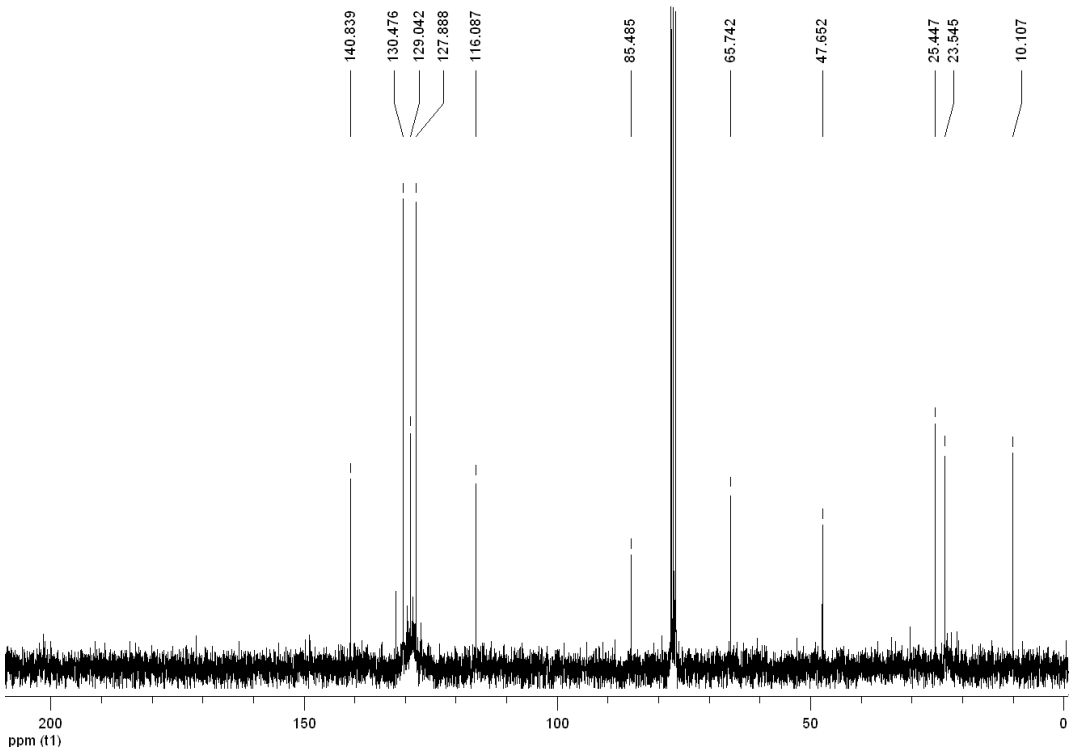






NMR spectra of the crude corresponding to the obtention of compound **13b**





X-Ray diffraction data of compound 8b: $C_{14}H_{22}O_4$, M_r = 254.32, 0.32 x 0.20 x 0.08 mm size, Triclinic, Pī, a = 8.4511(17), b = 9.7010(19), c = 9.863(2) Å, α = 65.48(3)°, β = 86.54(3)°, γ = 75.41(3)°, V = 711.1(3) Å^3, Z = 2, ρ_{calcd} = 1.188 gcm^{-3}, μ = 0.086, Mo Kα, λ = 0.71073 Å, T = 150(2) K, $2\theta_{max}$ = 60.07, 7972/3182 reflns. collected/independent (R_{int} = 0.0218), direct primary solution and refinement on F^2 (SHELXS-97 and SHELXL-97, G.M. Sheldrick, University of Göttingen, 1997), 169 parameters, hydrogen atoms refined as *rigid* hydroxyl and methyl groups, others *riding*, $R_1[I > 2\sigma(I)]$ = 0.0394, wR_2(all data) = 0.1009, $\Delta\rho_{max}$ = 0.34 eÅ^{-3}.

a) b)

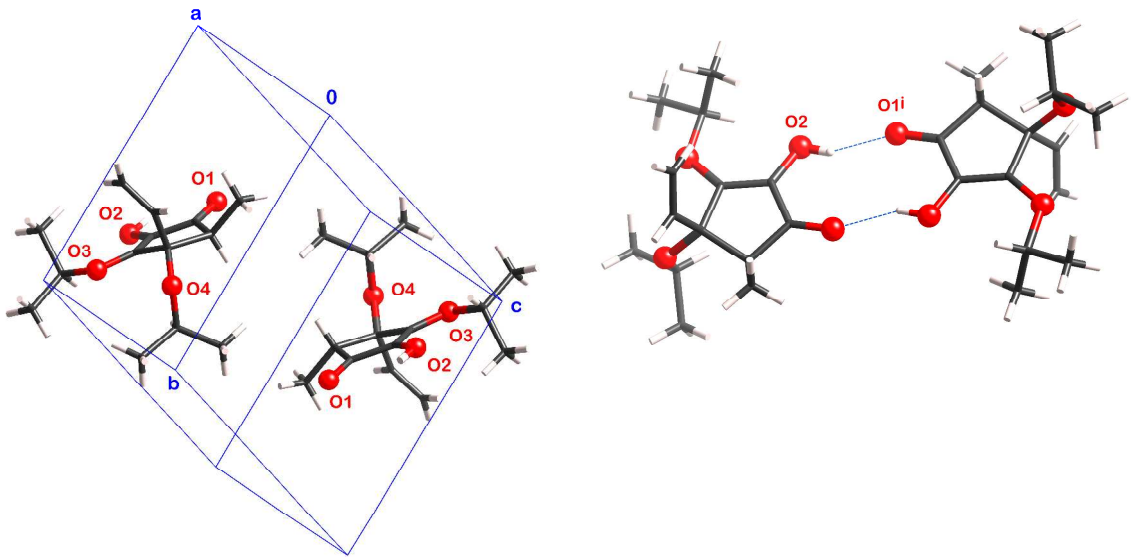


Figure 1. a) Single crystal X-ray plot of **8b** unit cell showing inversion related molecules (red oxygen, grey carbon and white hydrogen atoms). b) Packing view of compound **8b** showing the dimers formed through O-H···O=C hydrogen bonds [O(2)··· O(1)i (i: -x+1, -y+1, -z+2) 2.6757(12) Å, H(2)...O(1)i 1.90 Å, O(2)-H(2)...O(1)i 153.8] (A).

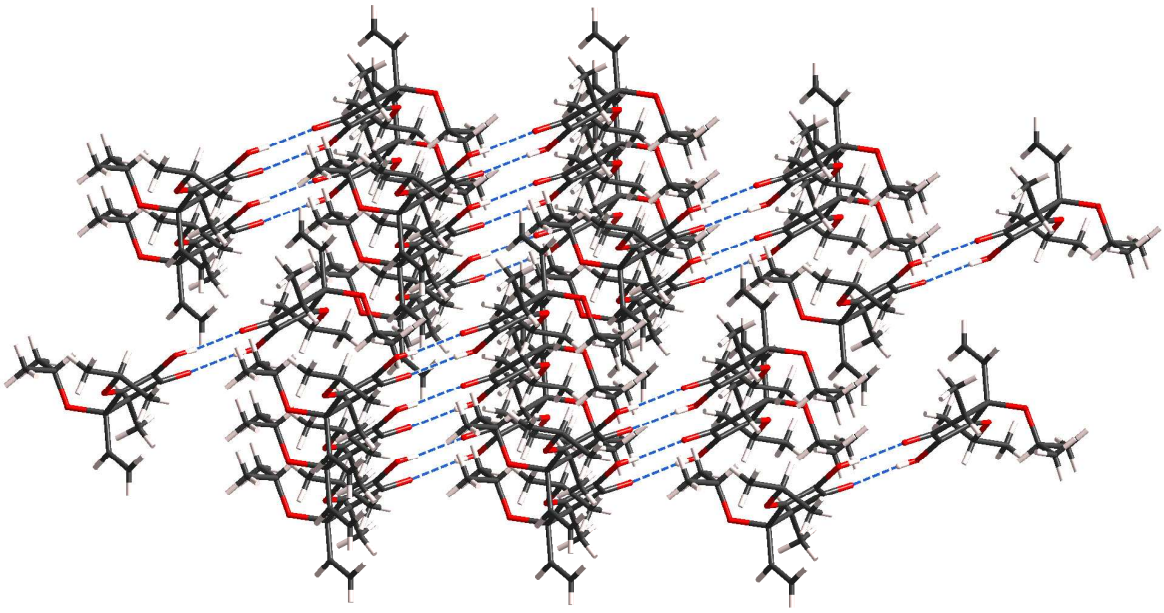


Figure 2. Crystal packing view of compound **8b**

Energies, imaginary frequencies and Cartesian geometries of stationary points discussed in the main text.

TS1

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Sum of electronic and zero-point Energies=          -3616.402981
Sum of electronic and thermal Energies=             -3616.379080
Sum of electronic and thermal Enthalpies=           -3616.378136
Sum of electronic and thermal Free Energies=        -3616.458417
```

Center Number	Atomic Number	Atomic Type	Coordinates (Angstroms) X	Y	Z
1	6	0	-0.758394	1.044758	-0.048237
2	6	0	-1.893423	1.872076	-0.101005
3	6	0	-3.137187	-0.048797	0.552794
4	6	0	-2.236501	-0.825869	-0.265136
5	6	0	-0.920267	-0.371127	-0.396861
6	8	0	0.408009	1.420106	0.379669
7	8	0	0.134725	-1.079566	-0.679218
8	12	0	1.699821	-0.048816	-0.018080
9	6	0	-1.919118	3.193469	0.605271
10	6	0	-2.920452	0.215528	1.985490
11	6	0	-2.025306	-0.413957	2.757536
12	8	0	-2.739250	-1.992524	-0.769805
13	6	0	-2.164395	-2.470266	-1.993736
14	8	0	-4.455103	0.028071	0.265622
15	6	0	-4.899945	-0.150358	-1.081833
16	35	0	3.552110	-0.893618	1.241123
17	8	0	2.662106	0.858569	-1.650782
18	6	0	3.720498	0.142911	-2.304046
19	6	0	2.940162	2.259355	-1.494581
20	1	0	-2.594893	1.736551	-0.913450
21	1	0	-1.463026	3.983283	-0.010799
22	1	0	-2.947674	3.507103	0.818658
23	1	0	-1.355126	3.150128	1.541928
24	1	0	-3.599255	0.950018	2.414373
25	1	0	-1.927911	-0.163977	3.809504
26	1	0	-1.368708	-1.186589	2.369714
27	1	0	-1.106666	-2.705164	-1.862059
28	1	0	-2.272468	-1.719360	-2.787895
29	1	0	-2.730000	-3.366850	-2.254894
30	1	0	-5.861923	0.361363	-1.148352
31	1	0	-5.014828	-1.212334	-1.307275
32	1	0	-4.189805	0.292919	-1.789857
33	1	0	3.402536	-0.898411	-2.377547
34	1	0	4.642295	0.199637	-1.716064
35	1	0	3.875644	0.557153	-3.307286
36	1	0	3.083063	2.717767	-2.480122
37	1	0	3.838073	2.403591	-0.881291
38	1	0	2.071068	2.692008	-0.997444

TS2

NIMAG=1 (-228.8111 cm-1)
Sum of electronic and zero-point Energies= -3616.391051
Sum of electronic and thermal Energies= -3616.367628
Sum of electronic and thermal Enthalpies= -3616.366684
Sum of electronic and thermal Free Energies= -3616.445101

Center Number	Atomic Number	Atomic Type	Coordinates (Angstroms) X	Y	Z
1	1	0	1.678008	1.350645	-2.630067
2	6	0	1.801312	1.293765	-1.545830
3	6	0	0.702475	0.706726	-0.892798
4	8	0	-0.468055	0.559143	-1.438571
5	12	0	-1.739144	-0.025592	-0.021960
6	8	0	-2.636618	1.843538	0.302309
7	6	0	-2.977684	2.573000	-0.887335
8	6	0	0.889494	0.066354	0.417296
9	8	0	-0.147253	-0.163189	1.166496
10	6	0	2.195650	-0.386456	0.640238
11	8	0	2.686375	-0.832298	1.837751
12	6	0	2.200074	-0.185745	3.021135
13	6	0	3.061446	-0.547417	-0.499977
14	8	0	4.392969	-0.357313	-0.420702
15	6	0	4.997187	0.297391	0.703463
16	6	0	2.748441	-1.400970	-1.658165
17	6	0	1.799695	-2.346571	-1.680713
18	35	0	-3.631625	-1.488992	-0.063615
19	6	0	-3.614501	1.971990	1.343927
20	6	0	2.759914	2.310525	-0.988162
21	1	0	3.407996	-1.261400	-2.512079
22	1	0	1.638756	-2.947034	-2.570558
23	1	0	1.161510	-2.548547	-0.826147
24	1	0	1.124582	-0.334753	3.132109
25	1	0	2.417270	0.890724	2.988925
26	1	0	2.740659	-0.644452	3.851434
27	1	0	5.959929	0.663731	0.342717
28	1	0	5.139709	-0.417828	1.515579
29	1	0	4.387527	1.132414	1.056362
30	1	0	-3.264691	1.370922	2.184985
31	1	0	-4.586927	1.596006	1.009054
32	1	0	-3.692250	3.023758	1.643871
33	1	0	-3.070738	3.639435	-0.650778
34	1	0	-3.919672	2.198542	-1.306201
35	1	0	-2.160377	2.411850	-1.591474
36	1	0	2.483481	3.312720	-1.348284
37	1	0	2.739493	2.338143	0.103961
38	1	0	3.791960	2.132339	-1.320126

6c

NIMAG=O
Sum of electronic and zero-point Energies= -3615.851181
Sum of electronic and thermal Energies= -3615.827045
Sum of electronic and thermal Enthalpies= -3615.826100
Sum of electronic and thermal Free Energies= -3615.907300

Center Number	Atomic Number	Atomic Type	Coordinates (Angstroms) X	Y	Z
1	6	0	0.350954	-0.659793	1.266208
2	6	0	1.222515	-0.942074	2.403284
3	6	0	2.557993	-0.956717	2.430712
4	6	0	2.184855	2.402378	1.048056
5	6	0	2.428342	2.128347	-0.228984
6	6	0	2.840382	0.796302	-0.698422
7	6	0	2.094296	-0.331142	-0.582974
8	6	0	0.701097	-0.358357	-0.036839
9	8	0	4.058431	0.768026	-1.386868
10	6	0	5.162976	1.086896	-0.571577
11	8	0	2.461090	-1.572866	-1.092076
12	6	0	3.711882	-2.071400	-0.679781
13	8	0	-0.248211	-0.089171	-0.930410
14	8	0	-0.960029	-0.688085	1.584308
15	12	0	-1.791861	-0.266983	0.024226
16	35	0	-3.477287	1.490282	-0.043508
17	8	0	-2.570985	-1.868804	-0.568857
18	6	0	-3.613277	-1.918136	0.398529
19	6	0	-2.971716	-1.397204	-1.850366
20	1	0	0.688951	-1.150332	3.343542
21	1	0	3.109677	-1.165414	3.341266
22	1	0	3.195099	-0.777255	1.564833
23	1	0	1.866953	3.384471	1.382762
24	1	0	2.238467	1.647660	1.832432
25	1	0	2.336594	2.889610	-1.013250
26	1	0	6.007227	1.045858	-1.263843
27	1	0	5.296931	0.350756	0.231379
28	1	0	5.080712	2.088539	-0.133240
29	1	0	3.605832	-3.151660	-0.809193
30	1	0	3.937306	-1.834172	0.372176
31	1	0	4.523412	-1.703636	-1.318505
32	1	0	-4.284856	-2.761097	0.191495
33	1	0	-4.180011	-0.973423	0.453812
34	1	0	-3.057977	-2.072431	1.331352
35	1	0	-3.537729	-0.452122	-1.791871
36	1	0	-3.554540	-2.165927	-2.373584
37	1	0	-2.008826	-1.222907	-2.345362