SUPPLEMENTARY INFORMATION

Amine-grafted heterogeneous catalysts from waste for diols conversion into cyclic carbonates

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Table S1. Two-step functionalization yields for chars and amine-grafted chars obtained from fir sawdust (FSD), pristine cellulose (PC), post-use starch-based bags (SBPB), potato starch (PS), post-use cigarette filter (PUCF), and cellulose acetate (CA).

Reaction Step	**Starting Material**					
	FSD	PC	SBPB	PS	PUCF	CA
1 – Pyrolysis (%)	25	22.5	18	21	22	20
2 – Amination (%)	110	112	102	108	113	107

[a] Yields of step 2 are higher than 100% due to addiction of functional groups (1,6 DH) that increases char weight.

Table S2. XPS quantitative analysis and BE value of AC-PS

Name	Peak BE	FWHM eV	Area (P) CPS.eV	Atomic %	Assignment
C1s - 1	285.0	2.47	113452.83	58.5	C – C; C=C
C1s - 2	287.2	2.47	26362.38	13.6	C = O; C-O; C-N
C1s - 3	289.7	2.47	5962.88	3.1	-COOH(R); -N-C=O
N1s - 1	399.8	3.07	12234.51	3.5	C-N (amine/amide)
N1s - 2	402.6	3.07	2642.29	0.8	(N – O); ammonium
O1s - 1	532.0	3.37	32458.94	5.8	C – O, C =O
O1s - 2	533.9	3.37	58769.62	10.6	O=C-O- /H_2O
Si2p3 - 1	104.8	2.83	3558.07	3.3	SiO_2
Si2p3 - 2	102.6	2.83	887.26	0.8	Silicates

Table S3. XPS quantitative analysis and BE value of AC-FSD

Name	Peak BE	FWHM eV	Area (P) CPS.eV	Atomic %	Assignment
C1s - 1	285.0	2.40	163375.30	57.5	C – C; C=C
C1s - 2	287.2	2.40	44305.70	15.6	C = O; C-O; C-N
C1s - 3	289.8	2.40	10114.72	3.6	-COOH(R); -N-C=O
N1s - 1	399.9	3.00	19662.92	3.9	C-N (amine/amide)
N1s - 2	402.7	3.00	4105.78	0.8	(N – O); ammonium
O1s - 1	532.0	3.19	56631.09	7.0	C – O, C =O
O1s - 2	534.0	3.19	73027.60	9.0	O=C-O- /H_2O
Si2p3 - 1	104.9	2.71	3765.81	2.4	SiO_2
Si2p3 - 2	102.0	2.71	433.79	0.3	Silicates

Table S4. XPS quantitative analysis and BE value of AC-PUCF

Name	Peak BE	FWHM eV	Area (P) CPS.eV	Atomic %	Assignment
C1s - 1	285.0	2.54	114593.52	55.1	C – C; C=C
C1s - 2	287.3	2.54	28562.37	13.7	C = O; C-O; C-N
C1s - 3	290.0	2.54	6266.99	3.0	-COOH(R); -N-C=O
N1s - 1	399.9	3.37	15463.62	4.2	C-N (amine/amide)
N1s - 2	403.7	3.37	3177.56	0.9	(N – O); ammonium
O1s - 1	532.0	3.35	36483.39	6.1	C – O, C =O

O1s - 2	534.1	3.35	70848.48	11.9	O=C-O- /H_2O
Si2p3	104.8	3.06	5891.49	5.2	SiO_2

Table S5. XPS quantitative analysis and BE value of AC-PC

Name	Peak BE	FWHM eV	Area (P) CPS.eV	Atomic %	Assignment
C1s - 1	285.0	2.42	118768.87	47.7	C – C; C=C
C1s - 2	287.2	2.42	36382.89	14.6	C = O; C-O; C-N
C1s - 3	289.6	2.43	7977.33	3.2	-COOH(R); -N-C=O
N1s - 1	400.0	3.18	15046.85	3.4	C-N (amine/amide)
N1s - 2	403.2	3.18	4002.62	0.9	(N – O); ammonium
O1s - 1	531.8	3.11	37670.92	5.3	C – O, C =O
O1s - 2	534.2	3.10	118854.82	16.7	O=C-O- /H_2O
Si2p3	104.8	2.97	11296.16	8.3	SiO_2

Table S6. XPS quantitative analysis and BE value of AC-SBP

Name	Peak BE	FWHM eV	Area (P) CPS.eV	Atomic %	Assignment
C1s - 1	285.0	2.50	118612.55	46.2	C – C; C=C
C1s - 2	287.0	2.50	38659.98	15.1	C = O; C-O; C-N
C1s - 3	289.7	2.50	8996.38	3.5	-COOH(R); -N-C=O
Ca2p3	348.8	2.64	21616.51	2.5	Ca^{+2}
N1s - 1	400.2	3.37	7408.52	1.6	C-N (amine/amide)
N1s - 2	403.4	3.37	3187.49	0.7	(N – O); ammonium
O1s - 1	532.2	3.37	32435.10	4.4	C – O, C =O
O1s - 2	533.8	3.37	130915.05	17.8	O=C-O- /H_2O
Si2p3 - 1	104.1	3.35	11560.10	8.2	SiO_2

Table S7. XPS quantitative analysis and BE value of AC-CA

Name	Peak BE	FWHM eV	Area (P) CPS.eV	Atomic %	Assignment
C1s - 1	285.0	2.47	113452.83	58.5	C – C; C=C
C1s - 2	287.2	2.47	26362.38	13.6	C = O; C-O; C-N
C1s - 3	289.7	2.47	5962.88	3.1	-COOH(R); -N-C=O
N1s - 1	399.7	3.07	12234.51	3.5	C-N (amine/amide))
N1s - 2	402.6	3.07	2642.29	0.8	(N – O); ammonium
O1s - 1	532.0	3.37	32458.94	5.8	C – O, C = O
O1s - 2	533.8	3.37	58769.62	10.6	O=C-O- /H_2O
Si2p3 - 1	104.7	2.83	3558.07	3.3	SiO_2
Si2p3 - 2	102.5	2.83	887.26	0.8	Silicates

Table S8. XPS quantitative analysis and BE value of recycled AC-PS (AC-PS_r)

Name	Peak BE	FWHM eV	Area (P) CPS.eV	Atomic %	Assignment
C1s - 1	285.0	2.43	110484.48	50.7	C – C; C=C

C1s - 2	286.9	2.43	34282.27	15.7	C = O; C-O; C-N
C1s - 3	289.1	2.43	9308.23	4.3	-COOH(R); -N-C=O
F1s - 1	689.6	2.28	2405.61	0.3	C – F
F1s - 2	691.6	2.28	1984.08	0.3	$-CF_2$
N1s - 1	400.1	3.02	8773.97	2.5	C-N (amine/amide)
N1s - 2	403.1	3.02	2262.13	0.6	N – O; ammonium
O1s - 1	532.3	3.16	62687.29	10.6	C – O, C =O
O1s - 2	533.3	3.16	56284.31	9.5	O=C-O- /H_2O
O1s - 3	536.0	3.16	3561.08	0.6	/
Si2p3 - 1	102.2	2.30	4731.24	3.5	Silicates
Si2p3 - 2	104.2	2.30	1835.39	1.4	SiO_2

Table S9. XPS quantitative analysis and BE value of recycled AC-FSD (AC-FSD$_r$)

Name	Peak BE	FWHM eV	Area (P) CPS.eV	Atomic %	Assignment
C1s - 1	285.0	2.40	125062.35	53.8	C – C; C=C
C1s - 2	287.2	2.40	37230.96	16.0	C = O; C-O; C-N
C1s - 3	289.7	2.40	10137.86	4.4	-COOH(R); -N-C=O
N1s - 1	400.2	2.93	8386.08	2.2	C-N (amine/amide)
N1s - 2	403.1	2.93	1853.49	0.5	N – O; ammonium
O1s - 1	532.8	3.37	115778.80	18.4	C – O, C =O, O=C-O-
O1s - 2	535.2	3.37	5914.80	0.9	/
Si2p3 - 1	102.3	2.27	4400.06	3.1	Silicates
Si2p3 - 2	104.5	2.27	1170.25	0.8	SiO_2

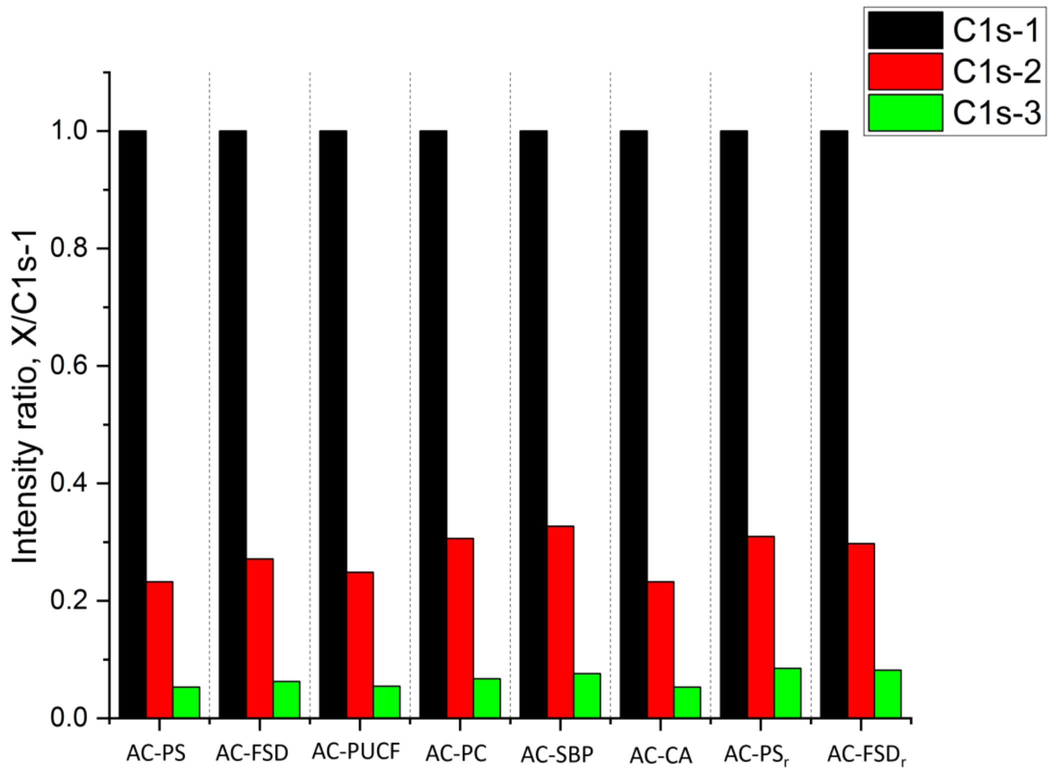


Figure S1. Comparison of the intensity of C 1s peaks: 1. aliphatic carbon; 2. C=O/C-N bonds; 3. carboxylic/amide groups.

S2. ^{1}H and ^{13}C-NMR characterization of CIR products (compounds **1-11b**)

1b. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 4.68 (qd, *J* = 7.5, 5.4 Hz, 1H), 4.50 (t, *J* = 8.1 Hz, 1H), 4.05 (dd, *J* = 8.4, 7.2 Hz, 1H), 1.79 (dddd, *J* = 14.1, 10.3, 7.4, 4.8 Hz, 1H), 1.72 – 1.62 (m, 1H), 1.49 – 1.28 (m, 4H), 0.91 (t, *J* = 7.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.04, 77.01, 69.36, 33.54, 26.41, 22.23, 13.76.

2b. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 4.90 – 4.76 (m, 1H), 4.52 (dd, *J* = 8.4, 7.6 Hz, 1H), 4.00 (dd, *J* = 8.4, 7.2 Hz, 1H), 1.46 (d, *J* = 6.3 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 154.95, 73.46, 70.60, 19.39.

3b. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 4.68 (qd, *J* = 7.5, 5.5 Hz, 1H), 4.50 (t, *J* = 8.4 Hz, 1H), 4.04 (dd, *J* = 8.3, 7.3 Hz, 1H), 1.87 – 1.60 (m, 2H), 1.52 – 1.18 (m, 16H), 0.86 (t, *J* = 6.9 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.00, 76.99, 69.33, 33.85, 31.82, 29.48, 29.40, 29.29, 29.23, 29.10, 24.32, 22.61, 14.04.

4b. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.47 – 7.38 (m, 3H), 7.35 (dt, *J* = 5.1, 4.4 Hz, 2H), 5.66 (t, *J* = 8.0 Hz, 1H), 4.78 (t, *J* = 8.4 Hz, 1H), 4.33 (t, *J* = 8.2 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 154.75, 135.76, 129.71, 129.21, 125.82, 77.95, 71.12.

5b. **^{1}H NMR** (400 MHz, $CDCl_3$) **cis**: δ 4.84 – 4.77 (m, 2H), 1.35 – 1.31 (m, 6H); **trans**: δ 4.30 (qd, *J* = 4.3, 1.5 Hz, 2H), 1.43 – 1.42 (m, 6H). **^{13}C NMR** (100 MHz, $CDCl_3$) **cis**: δ 154.54, 75.96, 14.32; **trans**: δ 154.44, 79.85, 18.34.

6b. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 4.74 – 4.54 (m, 2H), 1.88 (dd, *J* = 10.9, 5.4 Hz, 4H), 1.61 (dddd, *J* = 14.0, 7.8, 5.2, 3.5 Hz, 2H), 1.40 (dtt, *J* = 7.4, 6.2, 3.7 Hz, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.25, 75.66, 26.72, 19.10.

7b. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.20 – 7.04 (m, 6H), 6.93 (dd, *J* = 7.7, 1.8 Hz, 4H), 5.97 (s, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 154.82, 132.75, 128.76, 128.18, 126.05, 82.06.

8b. **^{1}H NMR** (400 MHz, $CDCl_3$) diagnostic signals: 4.78 (ddt, *J* = 8.4, 6.6, 3.3 Hz, 1H), 3.95 (dd, *J* = 12.8, 3.1 Hz, 1H), 3.69 (dd, *J* = 12.8, 3.5 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.15, 76.42, 66.00, 61.70.

8d. **^{1}H NMR** (400 MHz, $CDCl_3$) diagnostic signals: δ 4.96 – 4.89 (m, 1H), 3.80 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.08, 154.20, 73.42, 65.76, 65.68, 55.42.

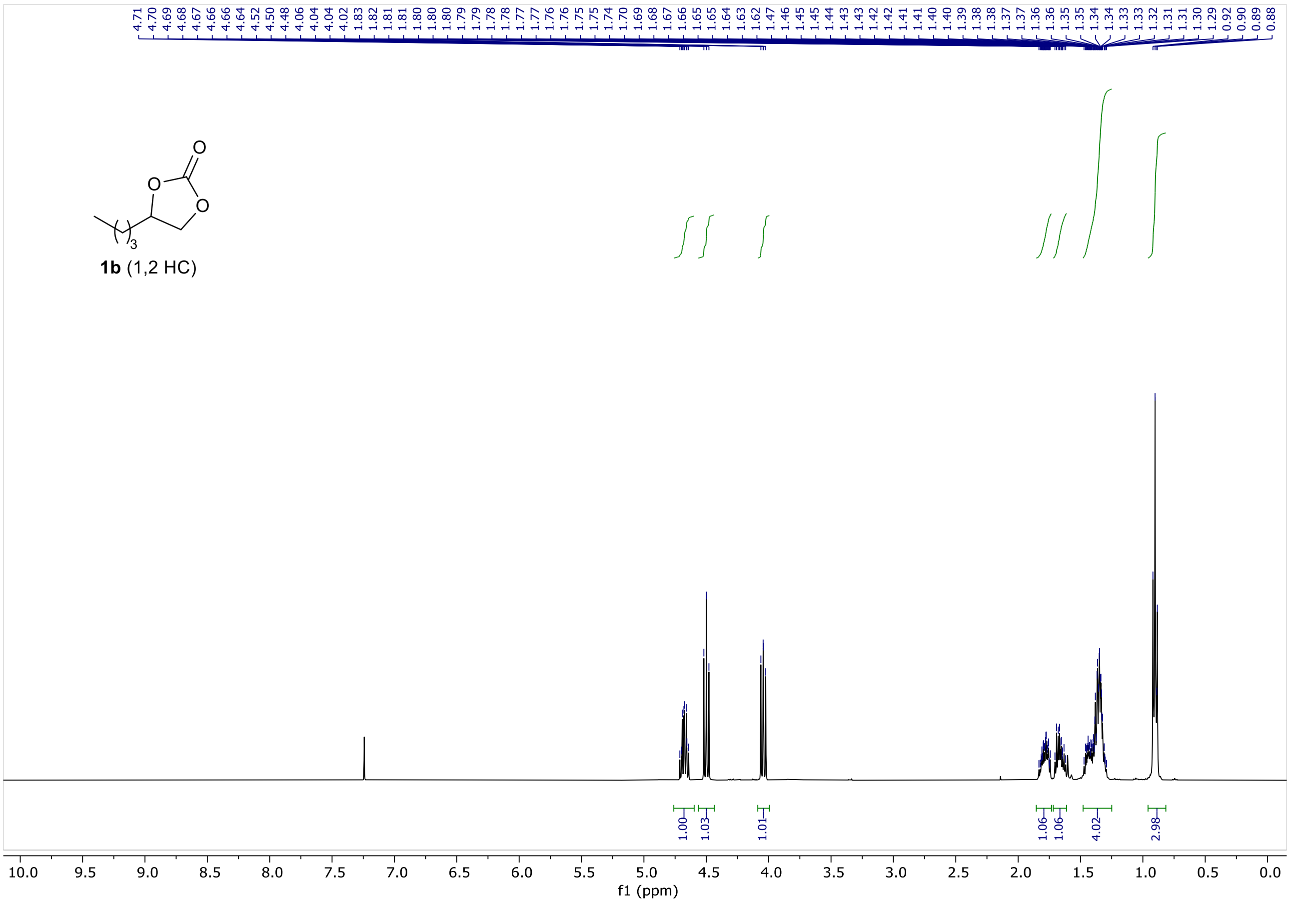
9c. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 4.28 (t, *J* = 6.2 Hz, 2H), 3.76 (s, 3H), 3.71 (q, *J* = 6.2 Hz, 2H), 1.89 (p, *J* = 6.2 Hz, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 156.02, 66.82, 64.99, 58.98, 31.64.

9e. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 4.22 (t, *J* = 6.3 Hz, 4H), 3.76 (s, 6H), 2.02 (p, *J* = 6.3 Hz, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.59, 64.25, 54.75, 31.64.

10c. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 4.39 – 4.30 (m, 1H), 4.28 – 4.12 (m, 1H), 3.96 – 3.85 (m, 1H), 3.76 (s, 3H), 1.84 – 1.66 (m, 2H), 1.21 (d, *J* = 6.2 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.98, 65.29, 64.67, 54.74, 37.92, 23.55.

10e. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 4.92 – 4.79 (m, 1H), 4.19 (t, 2H), 3.75 (s, 3H), 3.74 (s, 3H), 2.04 – 1.88 (m, 2H), 1.30 (d, *J* = 6.3 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.62, 155.18, 71.96, 64.18, 54.73, 54.57, 34.81, 19.99.

11b. **^{1}H NMR** (400 MHz, $CDCl_3$)) δ 4.60 (dqd, *J* = 12.4, 6.2, 3.1 Hz, 1H), 1.92 (dd, *J* = 14.2, 3.1 Hz, 1H), 1.73 (dd, *J* = 14.2, 11.9 Hz, 1H), 1.43 (s, 6H), 1.38 (d, *J* = 6.2 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 149.44, 80.77, 72.21, 40.51, 29.85, 26.51, 21.09.



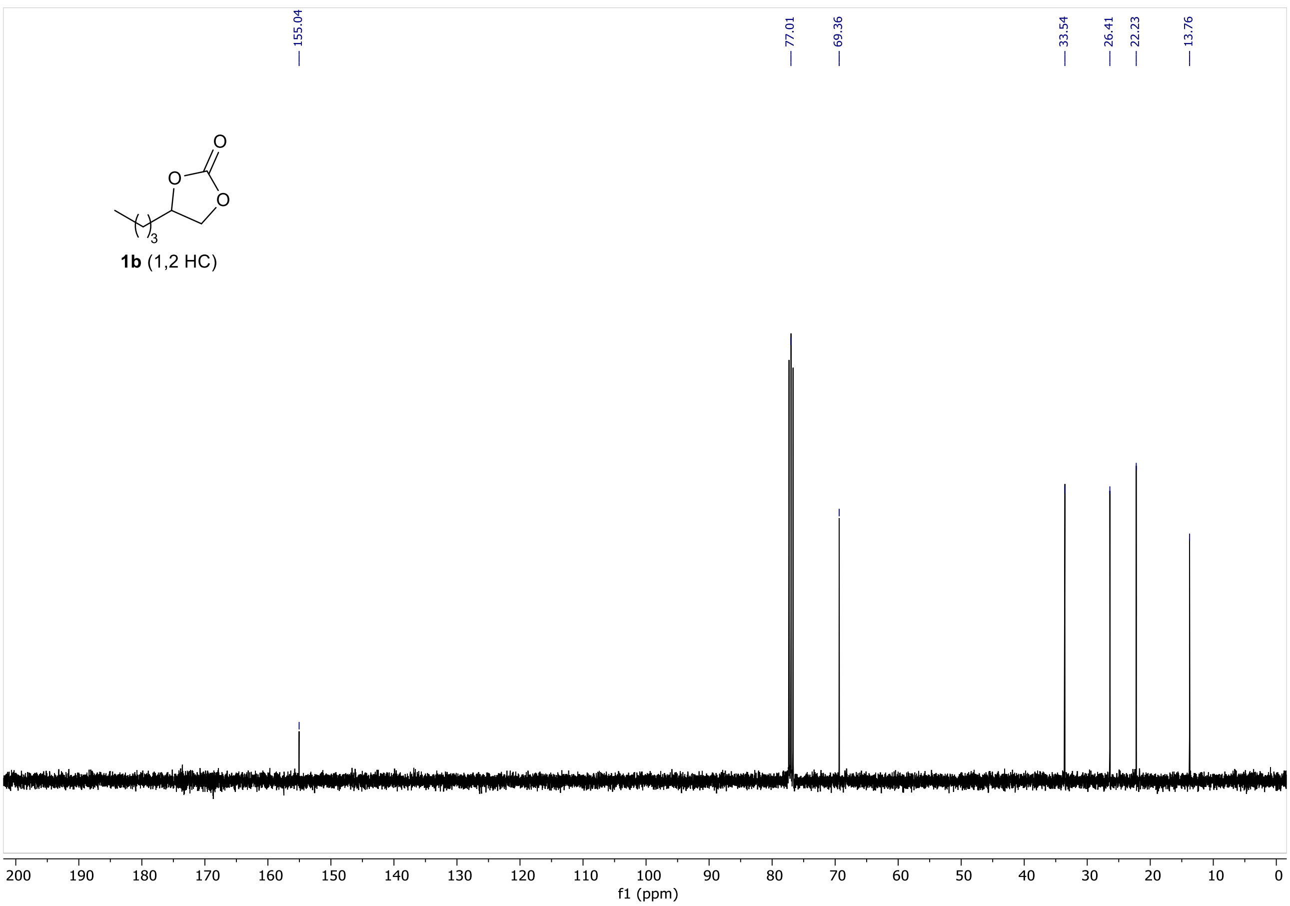
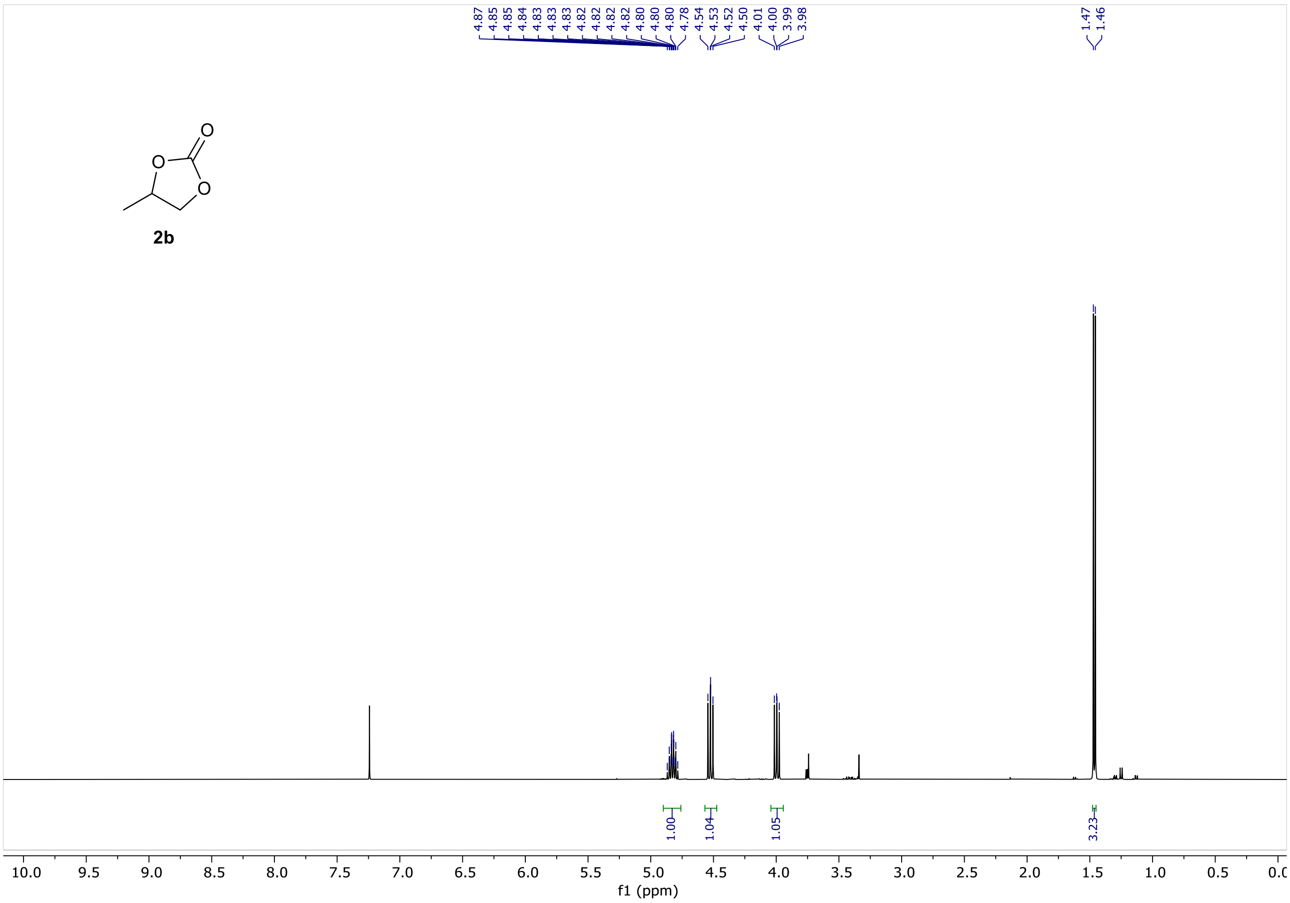


Figure S2. ^{1}H and ^{13}C-NMR for compound **1b**



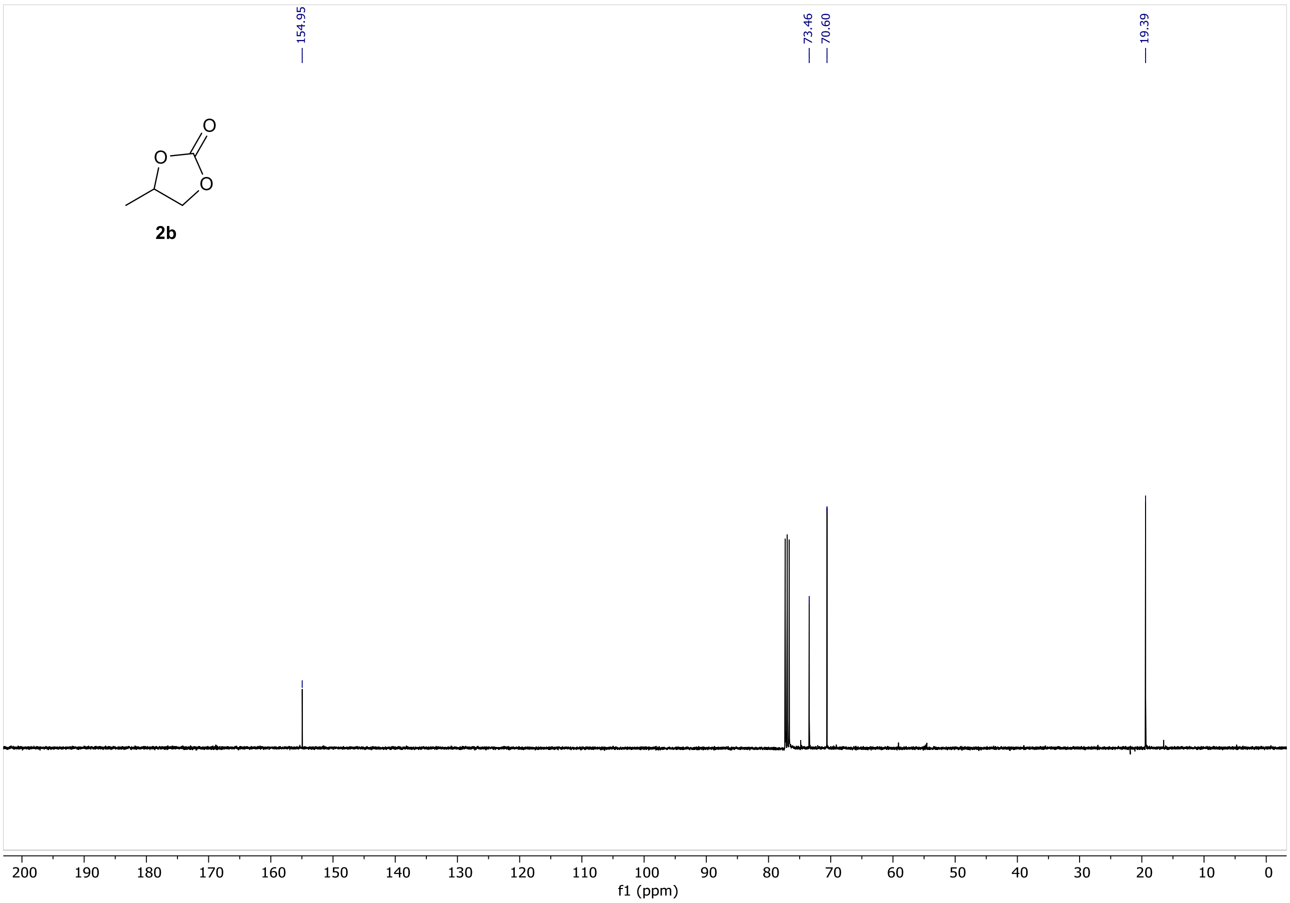
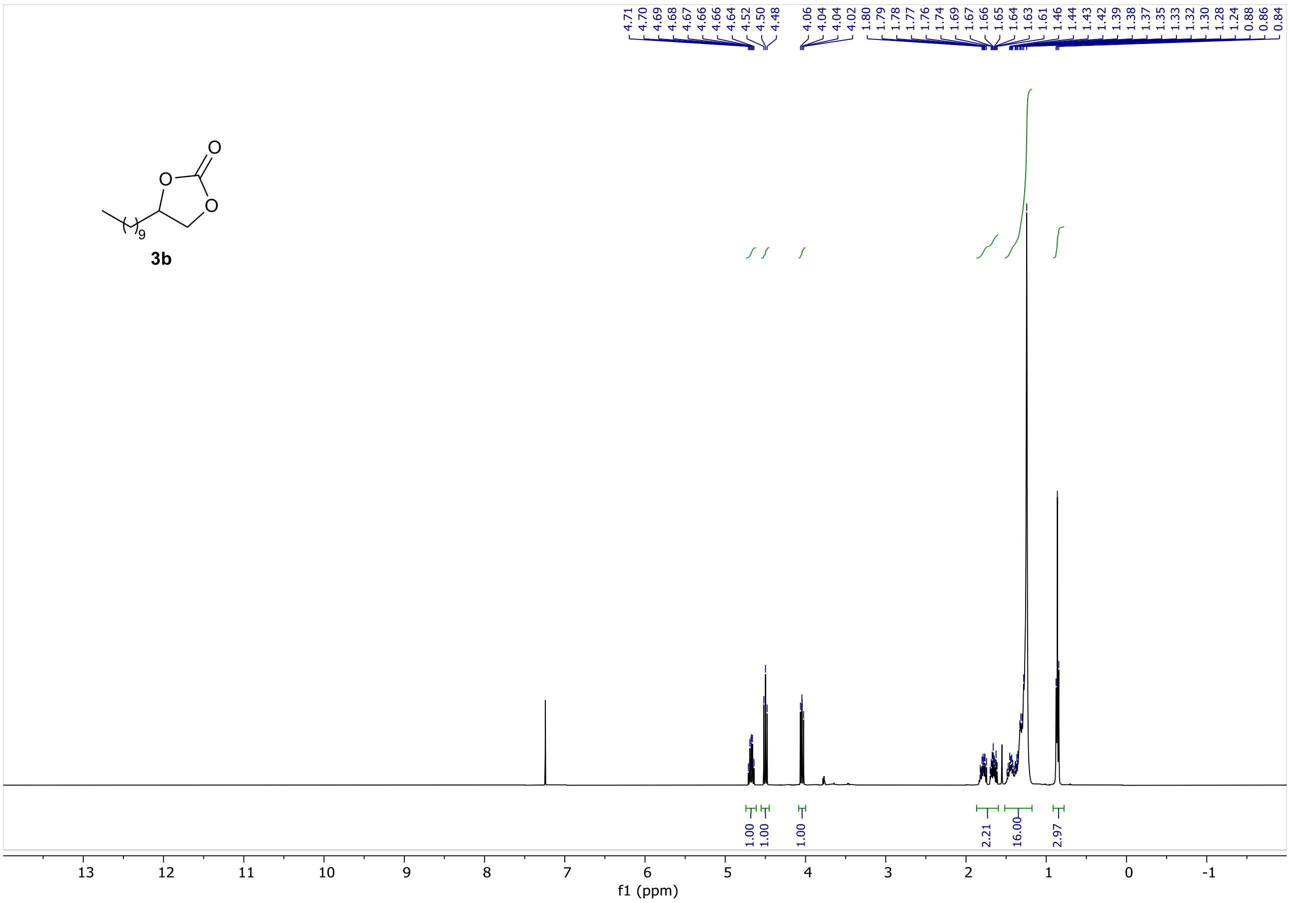


Figure S3. ^{1}H and ^{13}C-NMR for compound **2b**



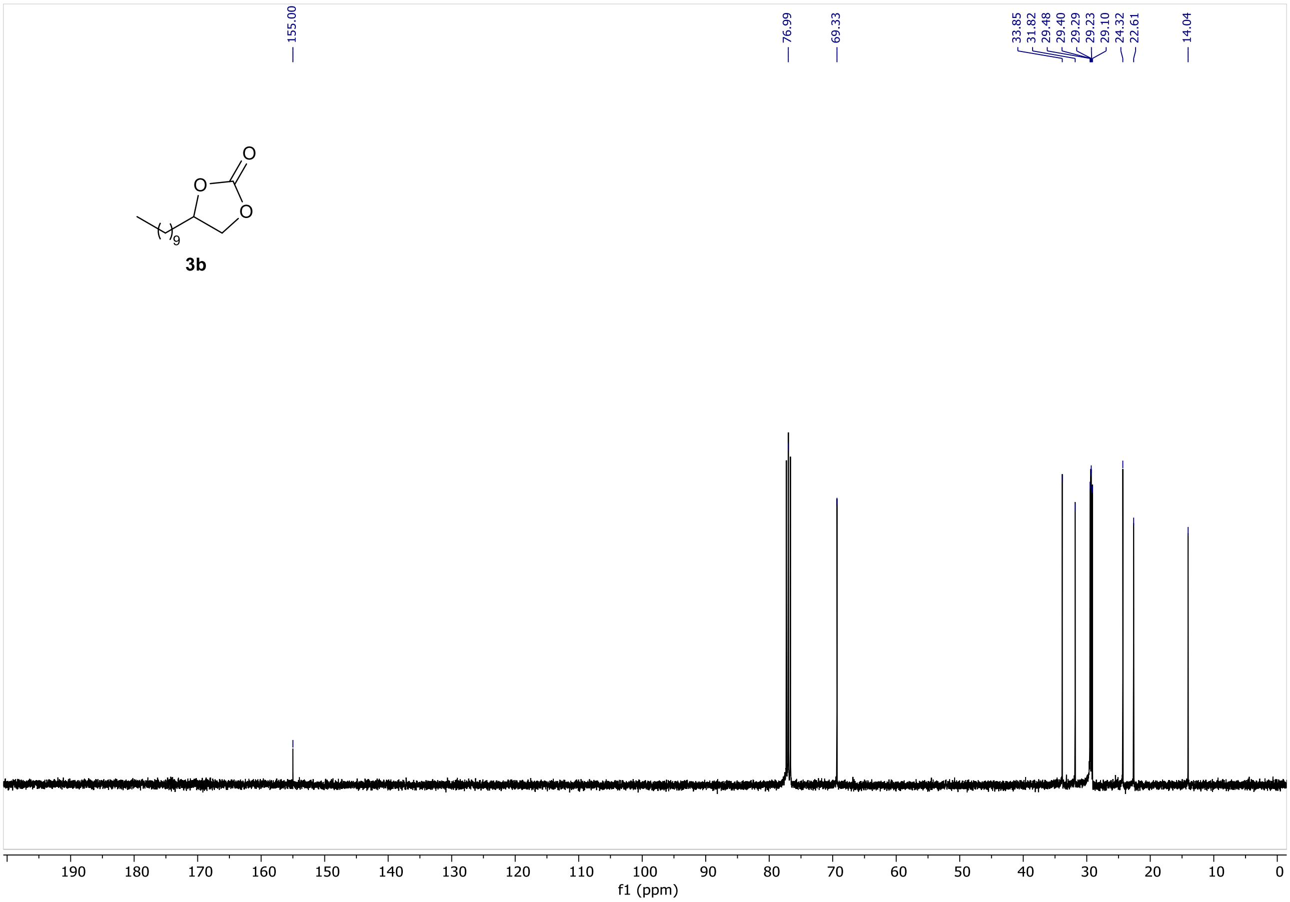
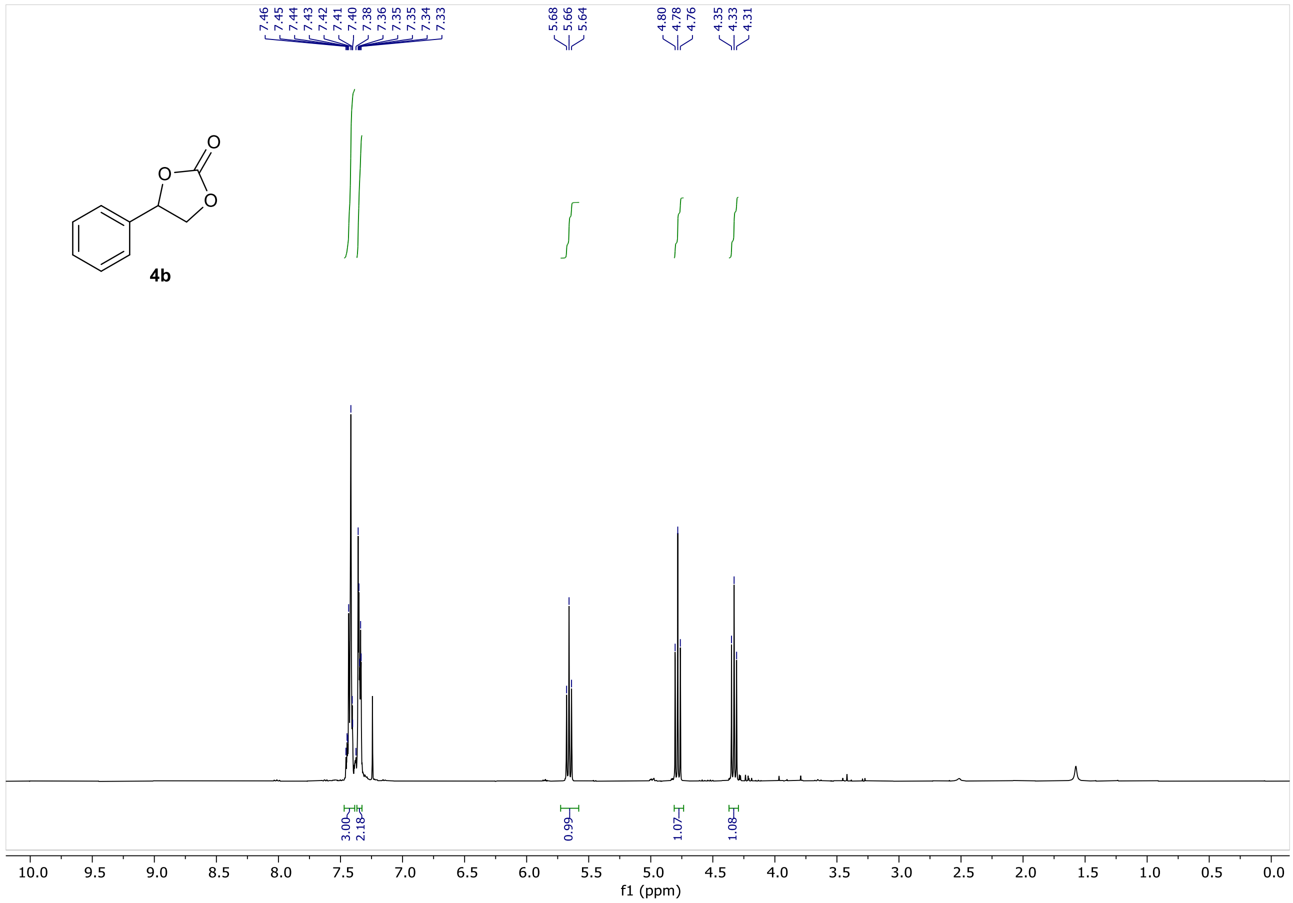


Figure S4. ^{1}H and ^{13}C-NMR for compound **3b**



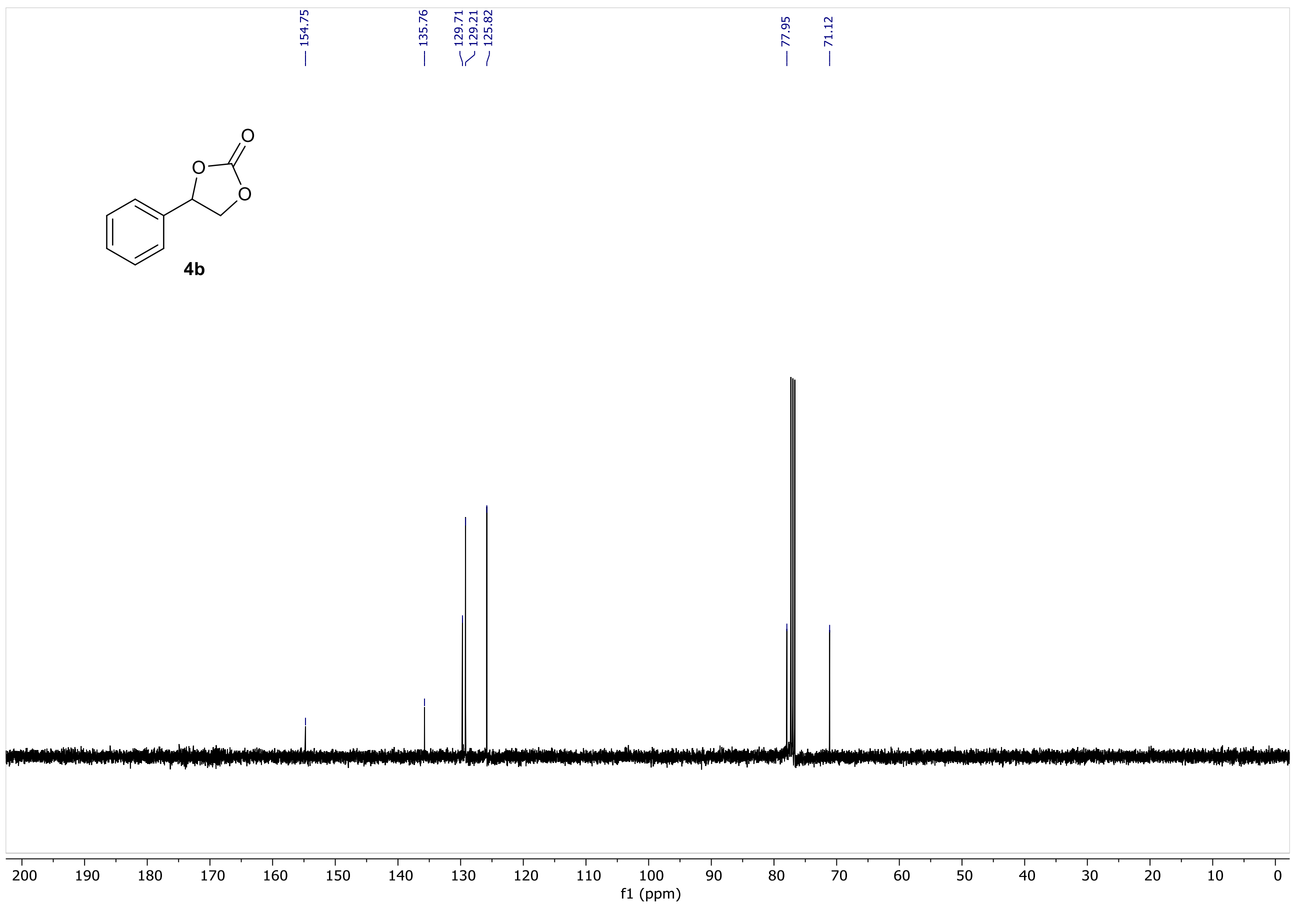
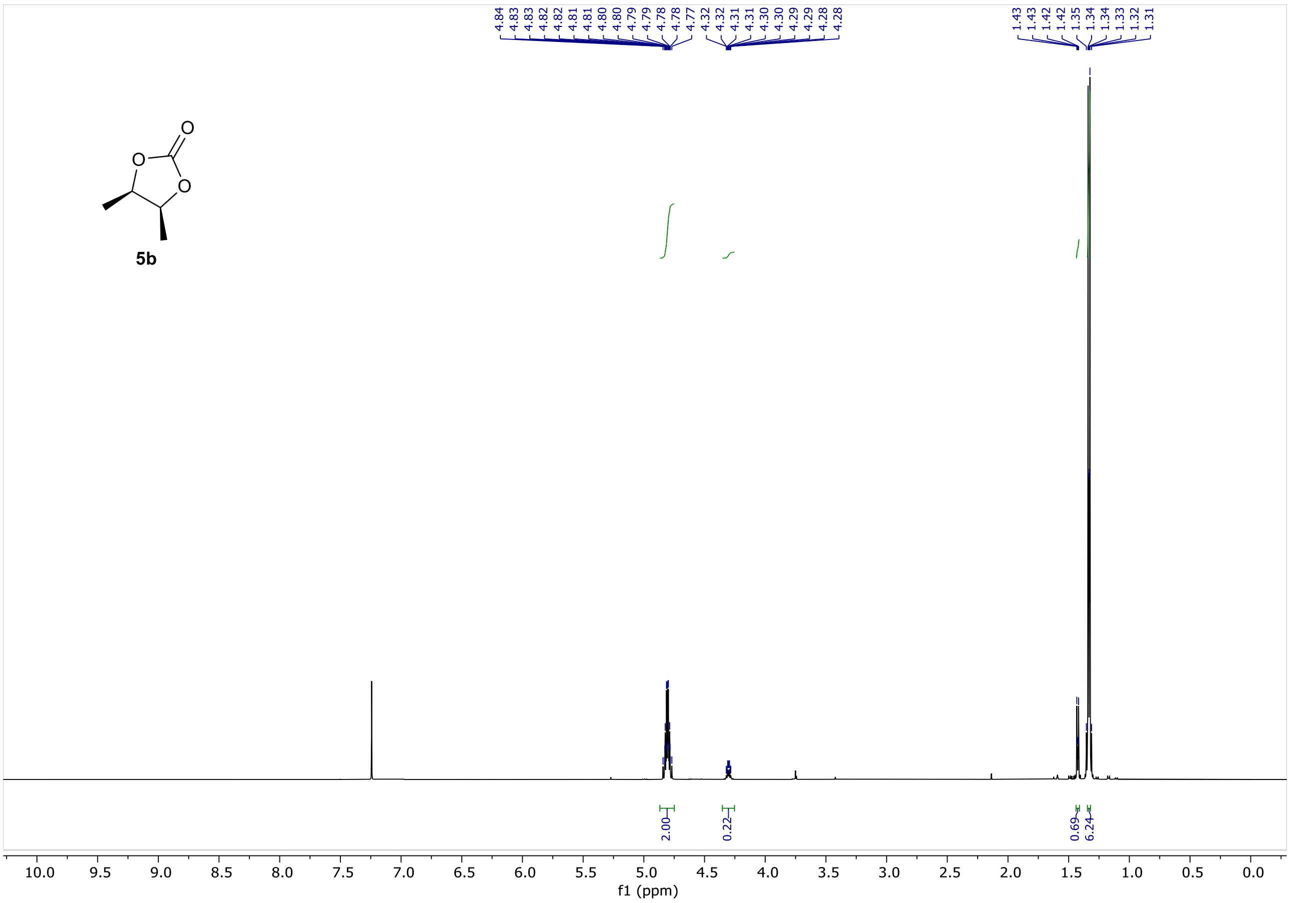


Figure S5. ^{1}H and ^{13}C-NMR for compound **4b**



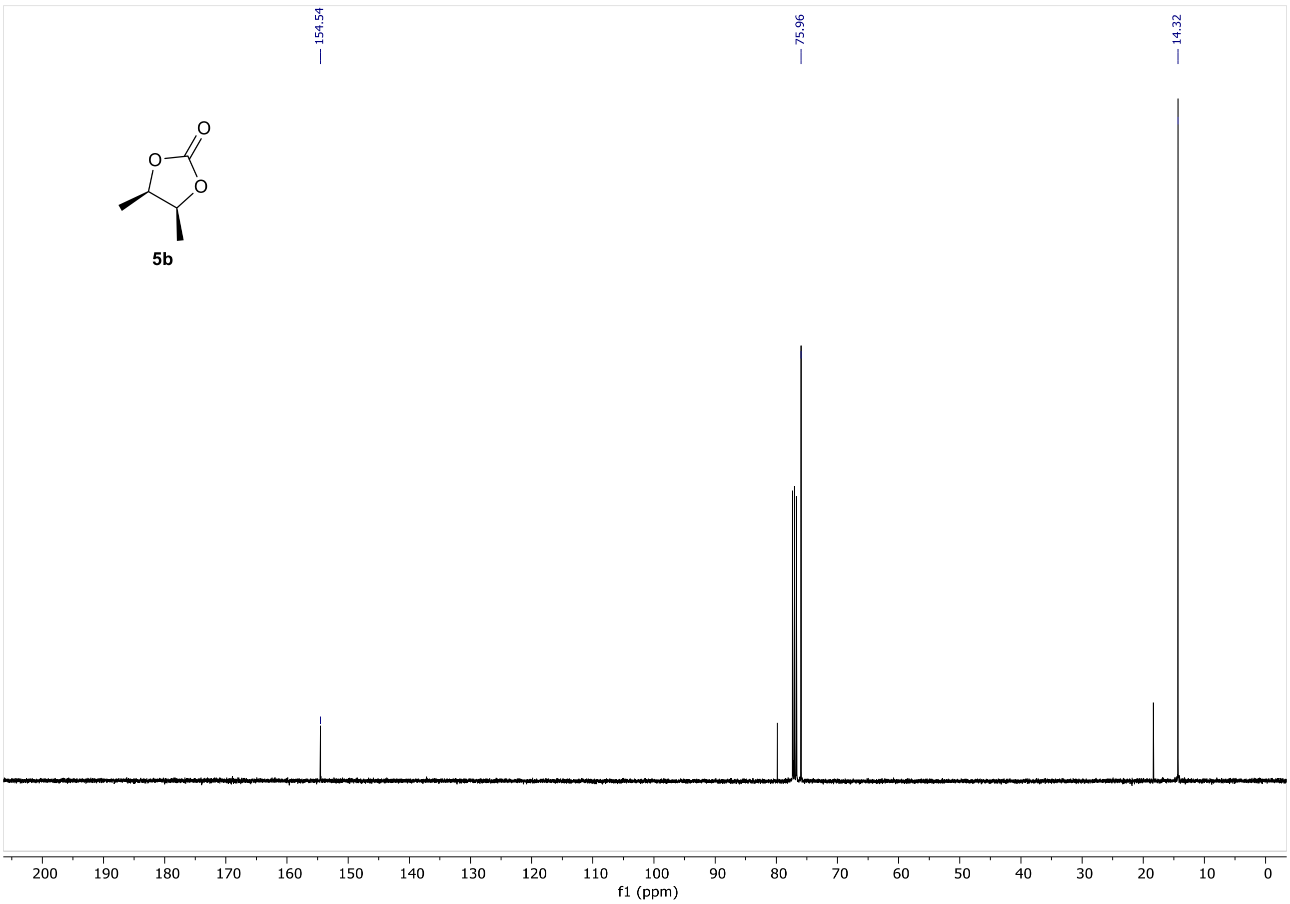
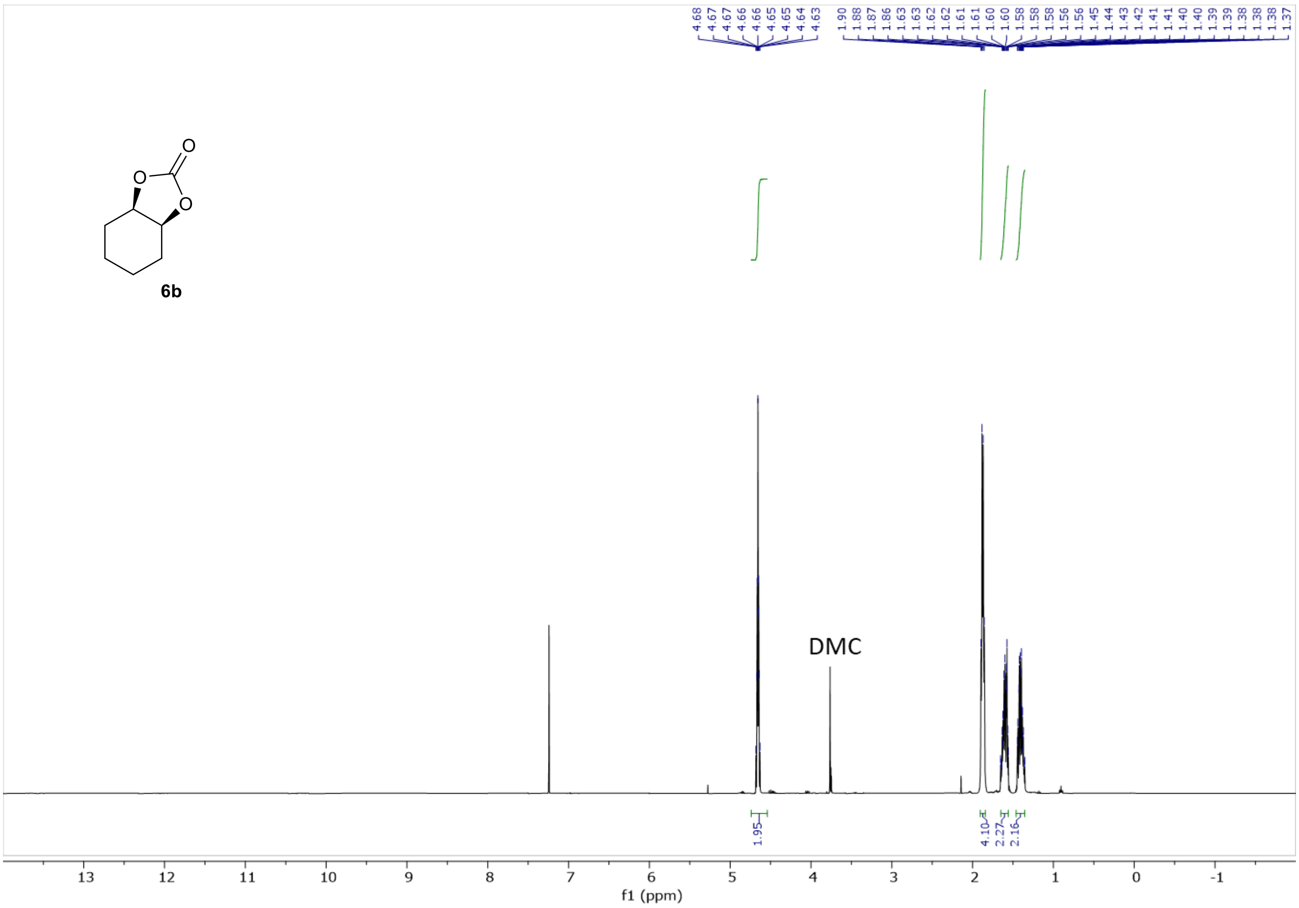


Figure S6. ^{1}H and ^{13}C-NMR for compound **5b**



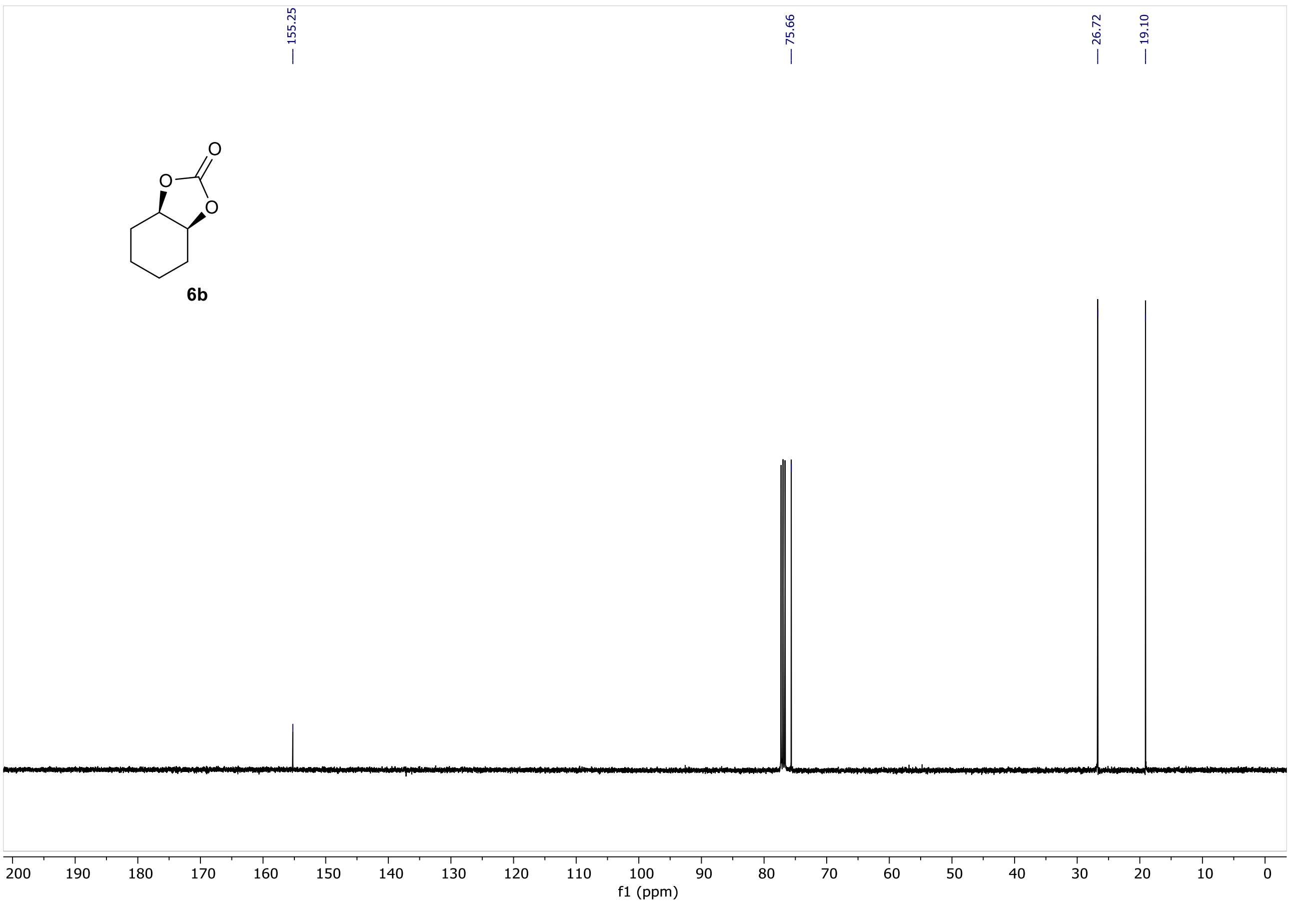
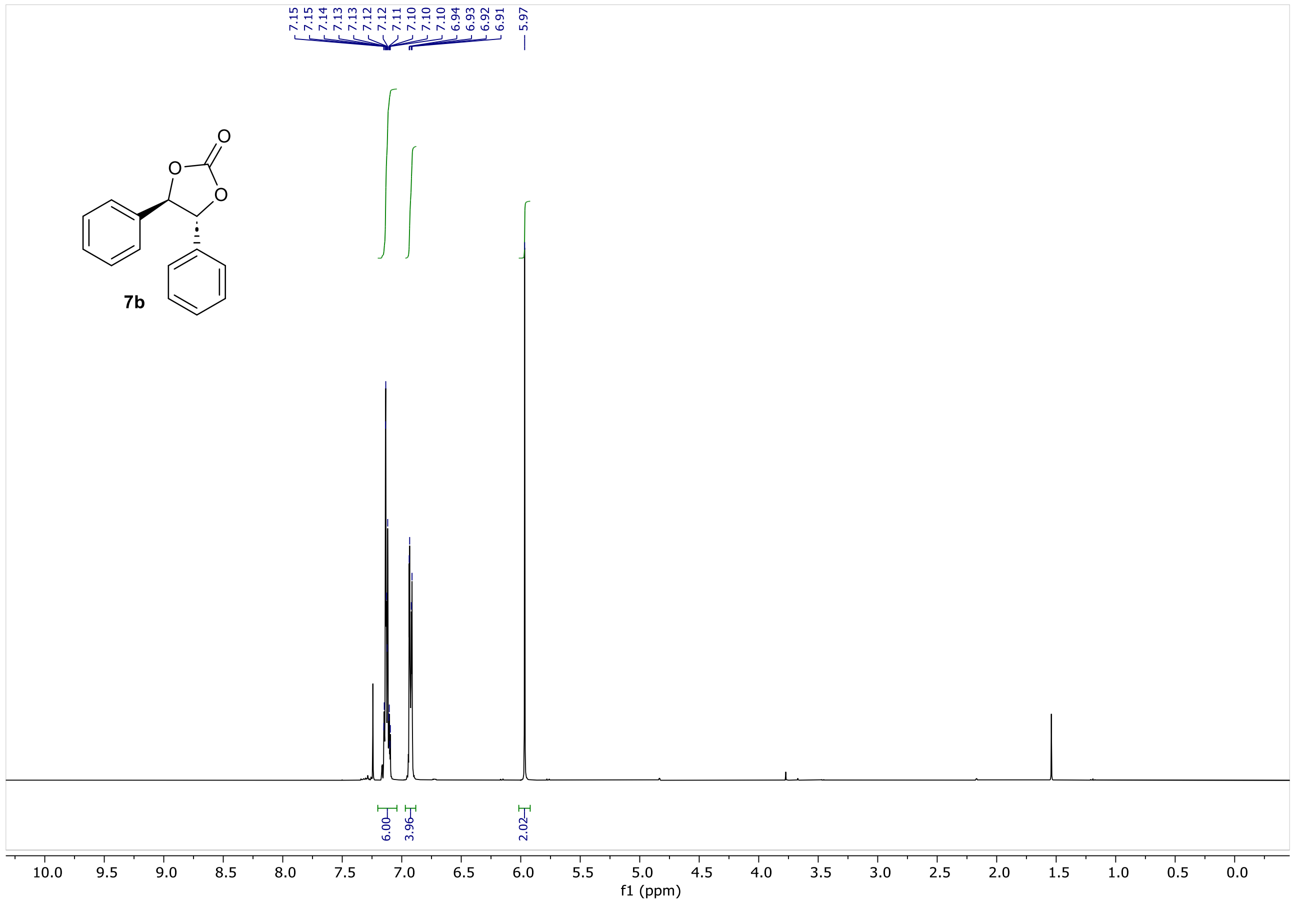


Figure S7. ^{1}H and ^{13}C-NMR for compound **6b**



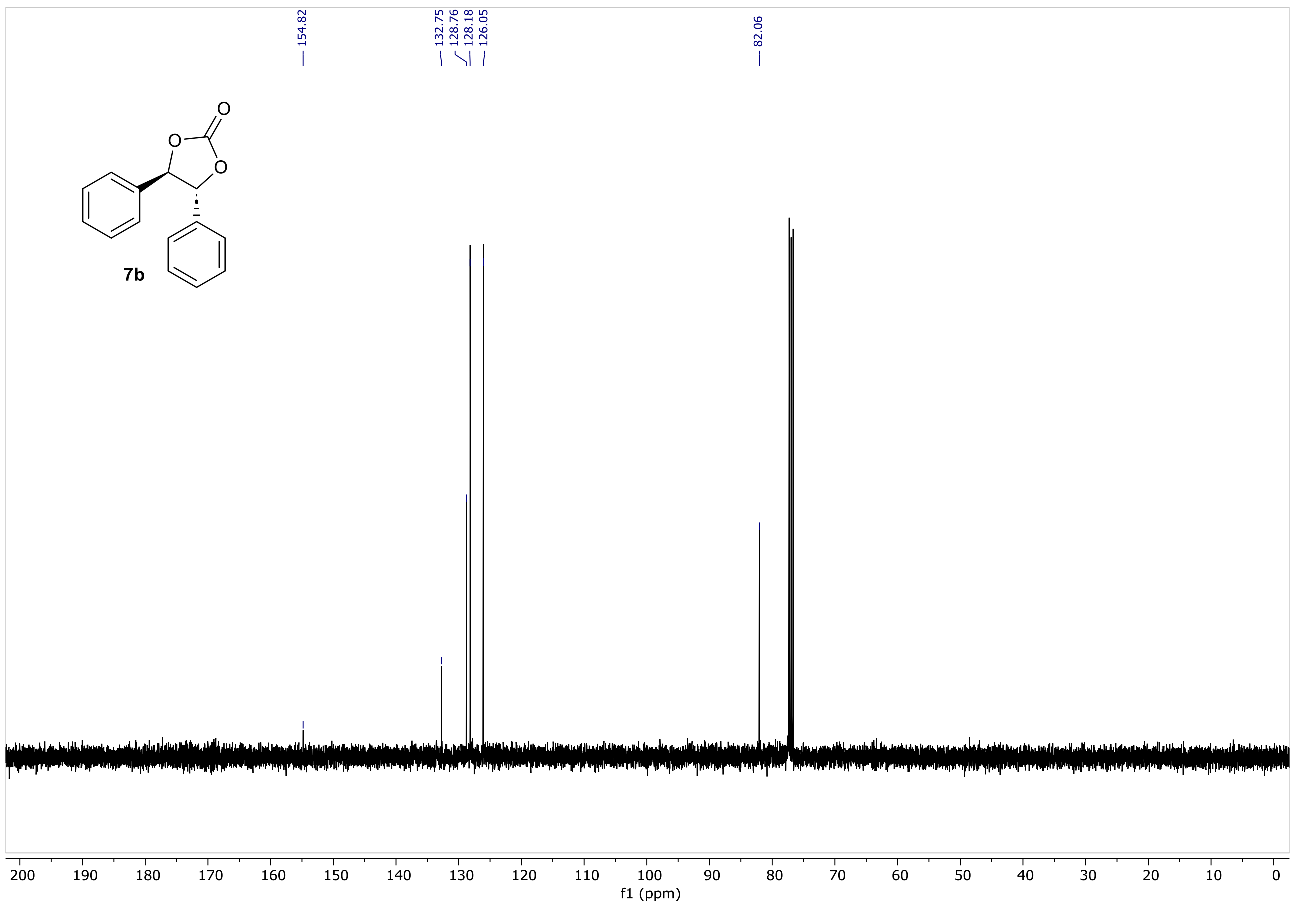


Figure S8. ^{1}H and ^{13}C-NMR for compound **7b**

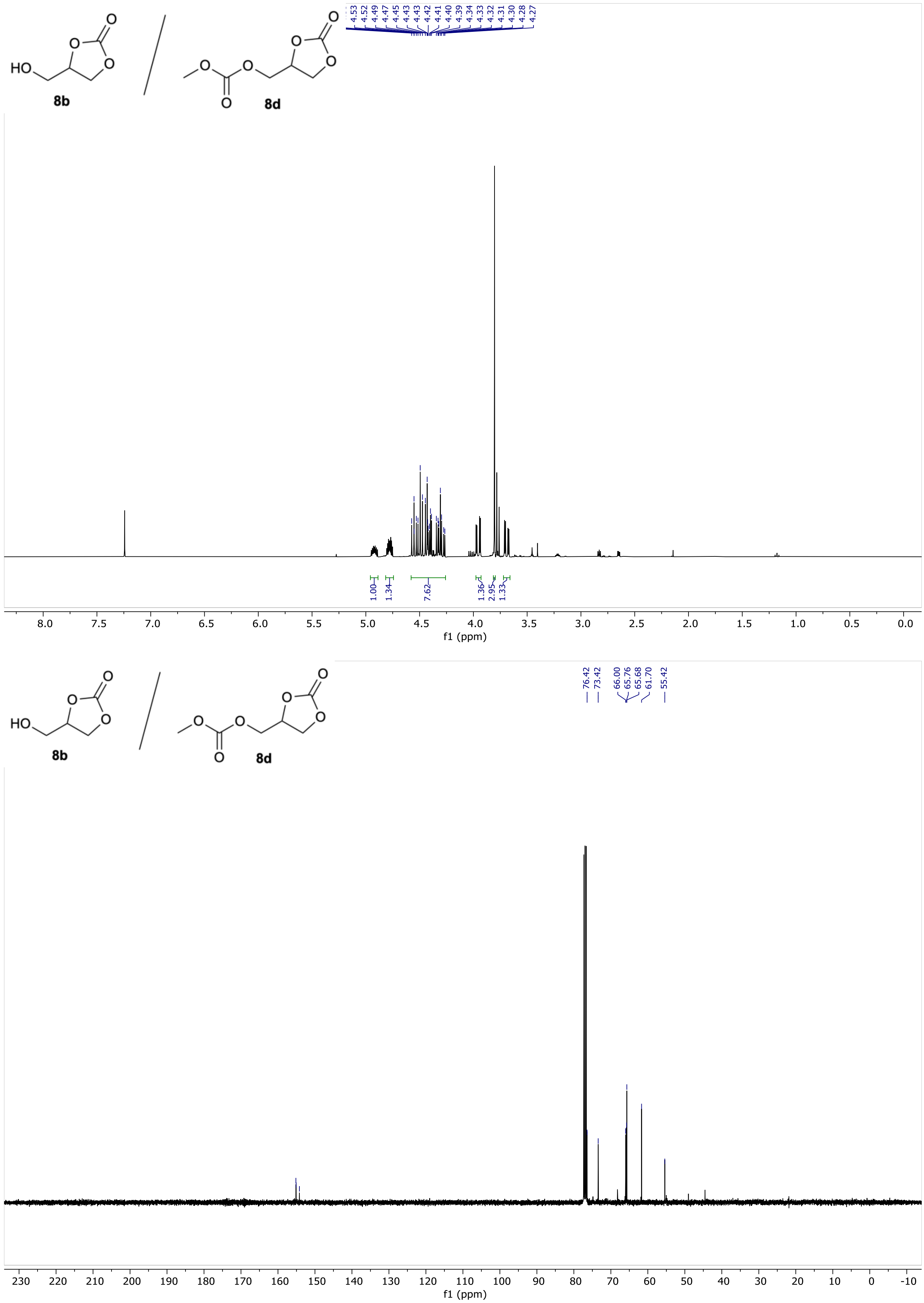
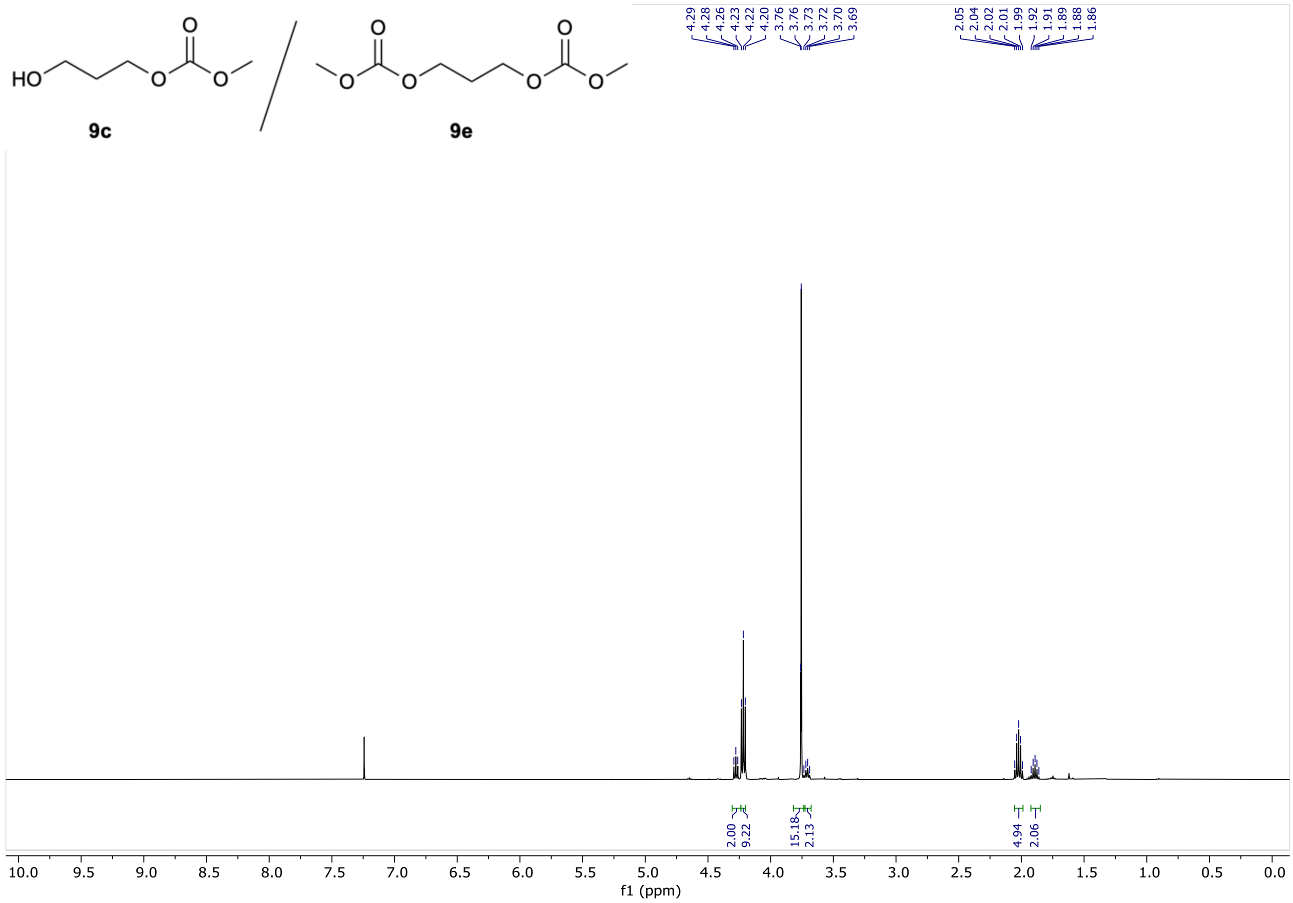


Figure S9. ^{1}H and ^{13}C-NMR for compounds **8b/8d**



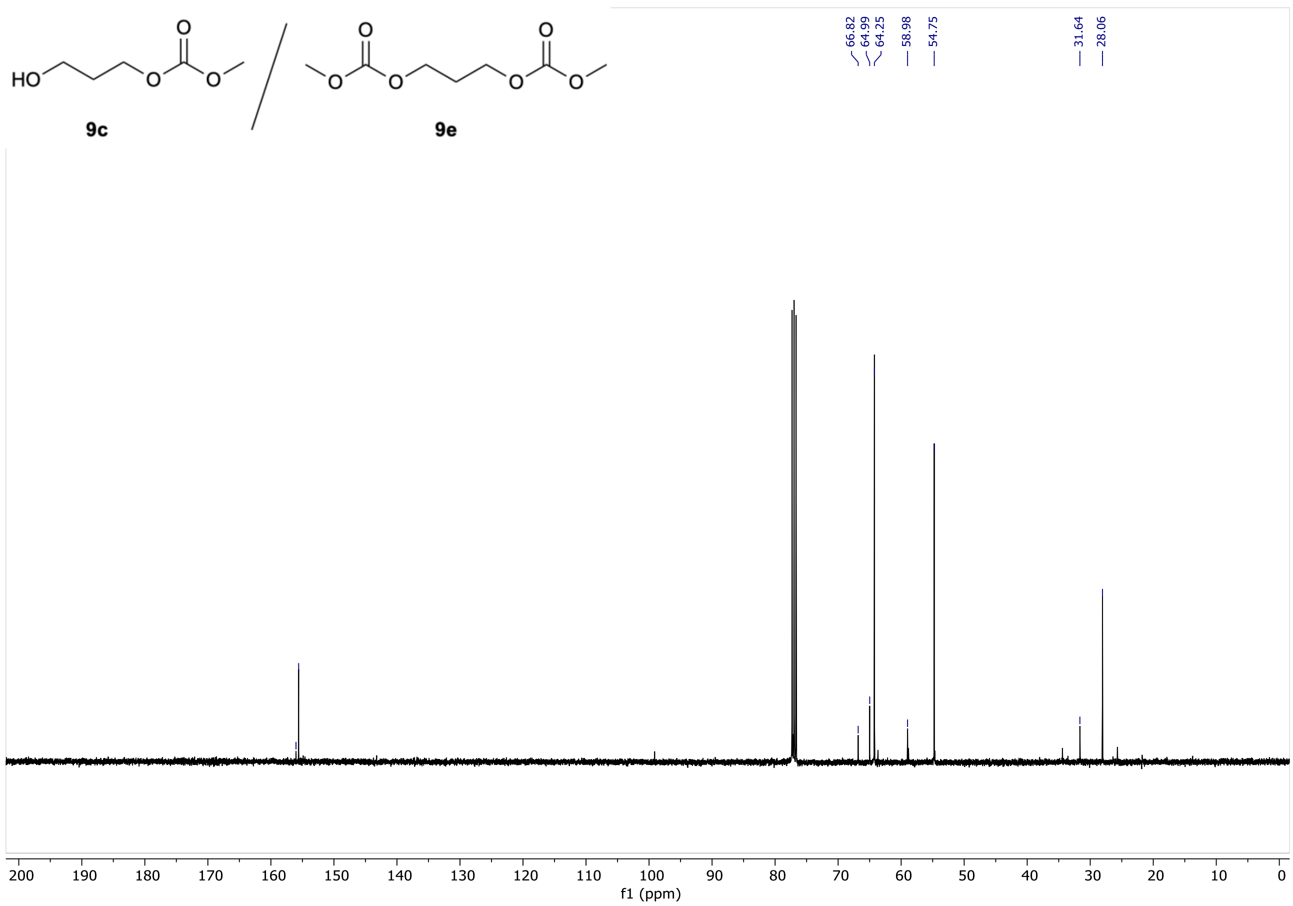
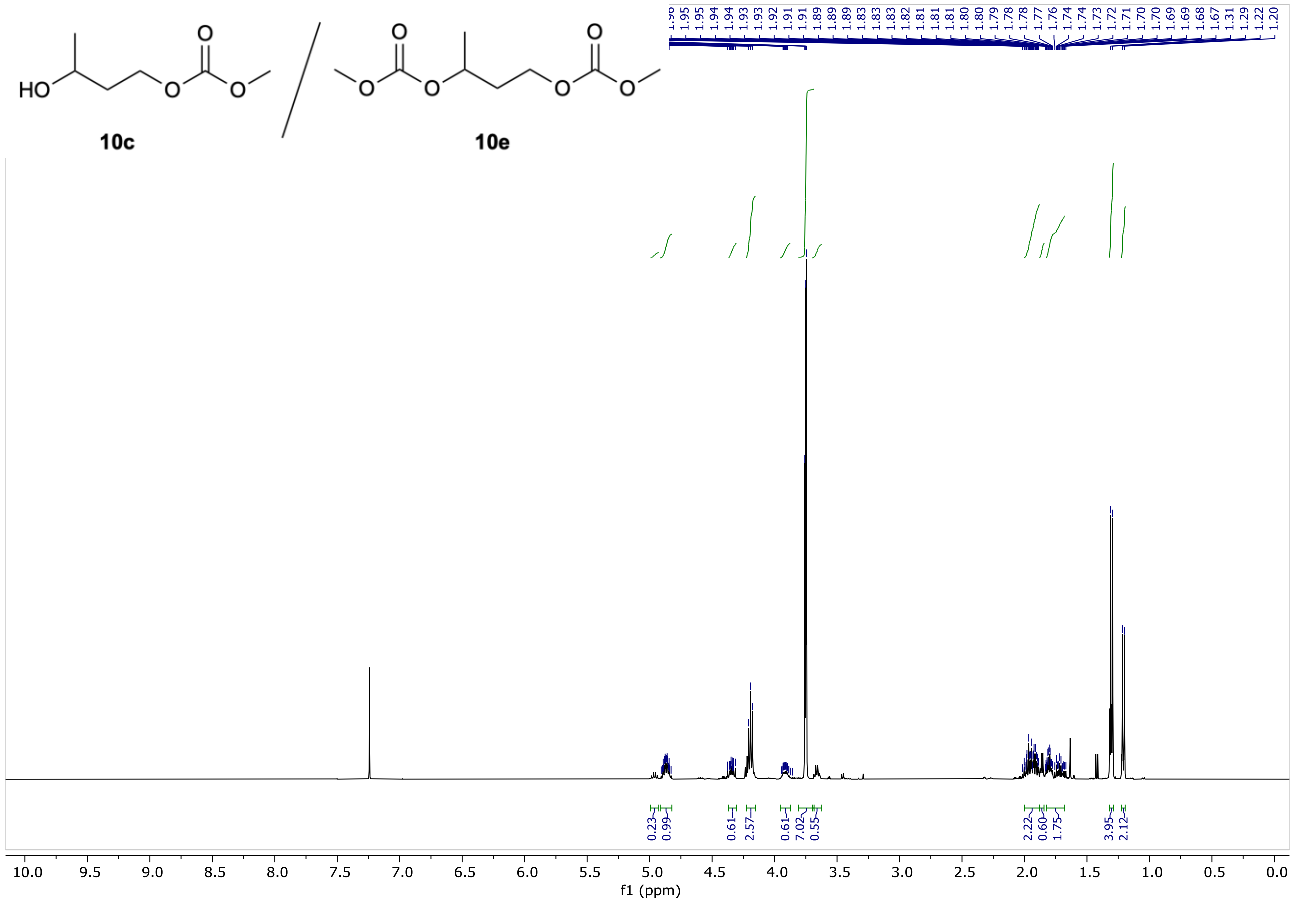


Figure S10. ^{1}H and ^{13}C-NMR for compounds **9**



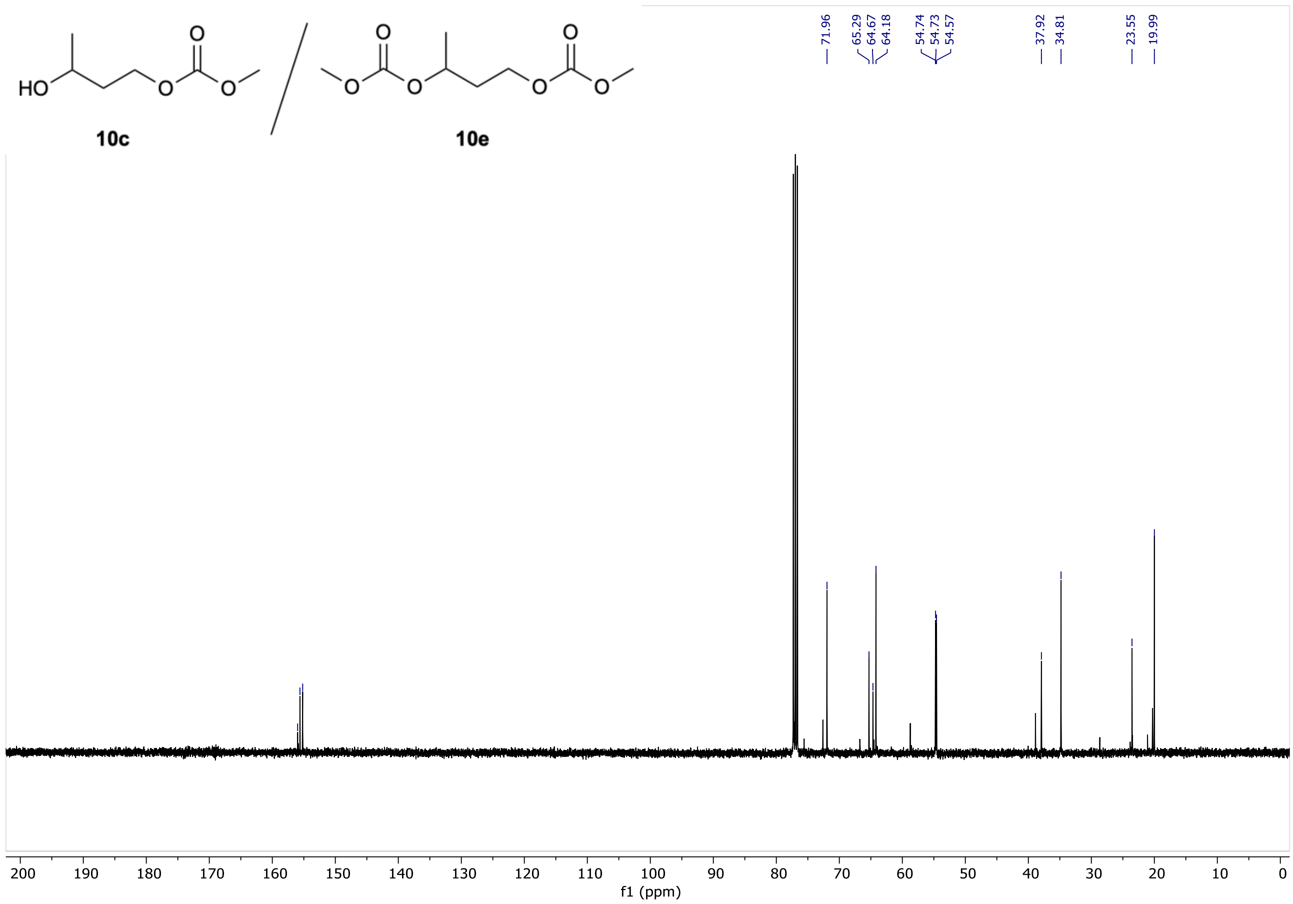


Figure S11. ^{1}H and ^{13}C-NMR for compounds **10**

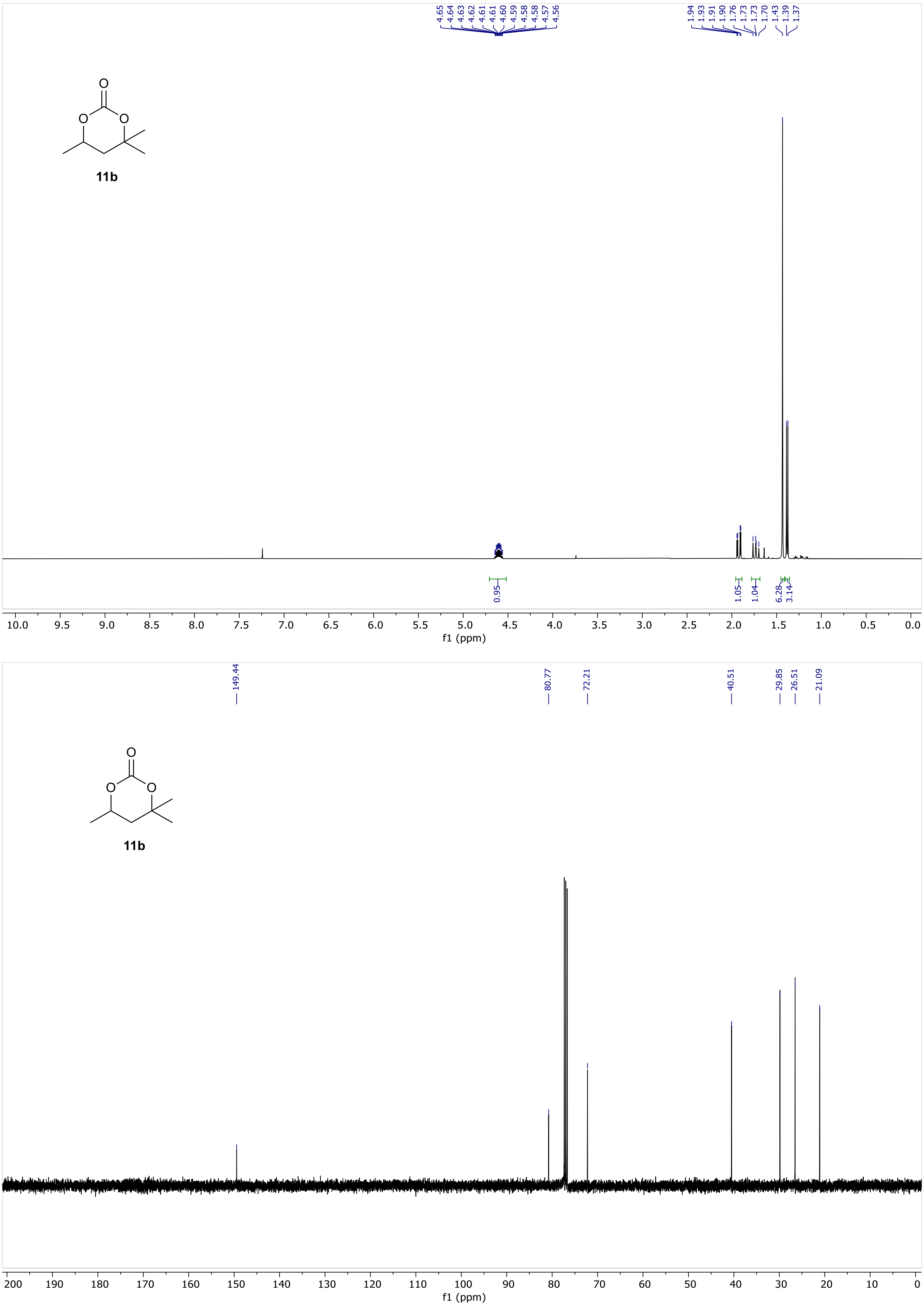


Figure S12. ^{1}H and ^{13}C-NMR for compound **11b**