

Supporting Informations

**“A Convenient Synthesis of 2-Tetrahydrofuranyl Ethers by
Rachid Baati, Alain Valleix, Charles Mioskowski,
D. K. Barma and J. R. Falck”**

Experimental Section

CrCl₂ (95%) was purchased from Lancaster and used without further purification. All reactions were performed under argon, and anhydrous solvents were dried and distilled before use.

General procedure for the tetrahydrofuranylation of alcohols. To a stirred suspension of chromium(II) chloride (2.5 mmol, 2.5 eq.) in THF (15ml) was added a THF (5ml) solution containing the alcohol (1mmol, 1 eq.) and CCl₄ (2.5 mmol, 2.5 eq.). The reaction mixture was stirred at room temperature until total conversion of the alcohol. The reddish reaction mixture was quenched with sat. aqueous NH₄Cl and extracted twice with diethyl ether. The combined organic extracts were washed with water and brine, dried over MgSO₄ and concentrated in vacuo to give the crude tetrahydrofuranyl ether as an oil. Purification by column on silica gel (hexane/diethyl ether 98/2) afforded analytically pure compounds.

2-Phenethyloxy-tetrahydro-furan 2: 24μl (0.20mmol) of 2-phenylethanol, 48μl (0.50mmol) CCl₄, 61.5mg (0.50mmol) of CrCl₂; yield: 42.6mg (90%); NMR ¹H (CDCl₃, 300 MHz): 1.50-2.10 (m, 4H), 2.92 (t, *J*=8Hz, 2H), 3.50-4.10 (m, 4H), 5.15 (m, 1H), 7.10-7.40 (m, 5H). ¹³C NMR (CDCl₃, 300 MHz): 23.4, 32.3, 36.4, 66.9, 67.8, 103.8, 126.1, 128.3, 128.9, 139.1. IR (neat, cm⁻¹): 3021, 2987, 1620, 926. MS (DCI/NH₃) *m/z* (MNH₄⁺) = 210.

2-(2-Isopropyl-5-methyl-cyclohexyloxy)-tetrahydro-furan 4: 33mg (0.21mmol) of L-menthol, 51μl (0.53mmol) CCl₄, 65.2mg (0.53mmol) of CrCl₂; yield: 56mg (85%); **Mixture of stereoisomers 50/50:** NMR ¹H (CDCl₃, 300 MHz): 0.71-2.32 (m, 21H), 3.20-3.60 (m, 1H), 3.70-4.10 (m, 2H), 5.15-5.33 (m, 1H). ¹³C NMR (CDCl₃, 300 MHz): 15.5, 16.3,

21.1, 21.2, 22.3, 22.4, 23.1, 23.3, 23.5, 23.6, 25.4, 25.6, 31.4, 31.7, 32.5, 32.6, 34.4, 34.6, 40.0, 43.4, 48.1, 48.7, 66.5, 66.7, 73.5, 78.7, 99.4, 105.4. IR (neat, cm^{-1}): 2998, 929. MS (DCI/ NH_3) m/z (MNH_4^+)= 244.

2-(3-Phenyl-allyloxy)-tetrahydro-furan 6: 40 μl (0.31mmol) of cinnamyl alcohol, 74 μl (0.77mmol) CCl_4 , 95mg (0.77mmol) of CrCl_2 ; yield: 69mg (92%); NMR ^1H (CDCl_3 , 300 MHz): 1.70-2.20 (m, 4H), 3.80-4.05 (m, 2H), 4.13 (ddd, $J=13$, $J=7$, $J=1$, 1H), 4.35 (ddd, $J=13$, $J=7$, $J=1$, 1H), 5.24 (m, 1H), 6.29 (ddd, $J=16$, $J=7$, $J=6$, 1H), 6.63 (d, $J=16$, 1H); 7.10-7.50 (m, 5H). ^{13}C NMR (CDCl_3 , 300 MHz): 23.5, 32.4, 67.1, 67.6, 103.2, 126.1, 126.5, 127.6, 128.5, 132.3, 136.8. IR (neat, cm^{-1}): 3050, 2980, 1590, 926. MS (DCI/ NH_3) m/z (MNH_4^+)= 222.

2- Benzyloxy-tetrahydro-furan 8: 22 μl (0.21mmol) of benzylic alcohol, 50 μl (0.53mmol) CCl_4 , 65mg (0.53mmol) of CrCl_2 ; yield: 40mg (95%); NMR ^1H (CDCl_3 , 300 MHz): 1.70-2.20 (m, 4H), 3.84-4.04 (m, 2H), 4.49 (d, $J=12\text{Hz}$, 1H), 4.73 (d, $J=12\text{Hz}$, 1H), 5.23 (m, 1H), 7.18-7.50 (m, 5H). ^{13}C NMR (CDCl_3 , 300 MHz): 23.5, 32.3, 67.1, 68.8, 103.1, 127.5, 127.9, 128.4, 138.4. IR (neat, cm^{-1}): 3012, 2995, 1610, 932. MS (DCI/ NH_3) m/z (MNH_4^+)= 196.

2-(Tetrahydro-furan-2-yloxymethyl)-furan 10: 26 μl (0.30mmol) of furfuryl alcohol, 72 μl (0.75mmol) CCl_4 , 93mg (0.75mmol) of CrCl_2 ; yield: 46mg (91%); NMR ^1H (CDCl_3 , 300 MHz): 1.70-2.20 (m, 4H), 3.80-4.05 (m, 2H), 4.46 (d, $J=13$, 1H), 4.62 (d, $J=13$, 1H), 5.22 (m, 1H), 6.33 (s, 2H), 7.41 (s, 1H). ^{13}C NMR (CDCl_3 , 300 MHz): 23.4, 32.3, 60.6, 67.1, 102.7, 109.2, 110.2, 142.8, 151.5. IR (neat, cm^{-1}): 3080, 2987, 1610, 990, 930. MS (DCI/ NH_3) m/z (MNH_4^+)= 186.

2-Phenoxy-tetrahydro-furan 12: 27mg (0.28mmol) of phenol, 69 μ l (0.72mmol) CCl₄, 89mg (0.72mmol) of CrCl₂; yield: 27mg (58%); NMR ¹H (CDCl₃, 300 MHz): 1.70-2.50 (m, 4H), 3.60-4.30 (m, 2H), 5.60-6.50 (m, 1H), 6.70-7.60 (m, 5H). ¹³C NMR (CDCl₃, 300 MHz): 23.4, 32.7, 68.1, 102.3, 116.5, 121.5, 129.4, 157.1. IR (neat, cm⁻¹): 3095, 1653, 926. MS (DCI/NH₃) m/z (MNH₄⁺) = 182.

2-(1-Methyl-1-phenyl-ethoxy)-tetrahydro-furan 14: 40 μ l (0.27mmol) of dimethyl phenyl carbinol, 79 μ l (0.82mmol) CCl₄, 101mg (0.82mmol) of CrCl₂; yield: 26.1mg (47%); NMR ¹H (CDCl₃, 300 MHz): 1.52 (s, 3H), 1.67 (s, 1H), 1.70-2.10 (m, 4H), 3.60-4.10 (m, 2H), 5.11 (dd, J=3, 1H), 7.10-7.40 (m, 5H). ¹³C NMR (CDCl₃, 300 MHz): 23.3, 28.7, 32.9, 67.1, 77.3; 103.6, 125.3, 126.5, 129.6, 144.1. IR (neat, cm⁻¹): 3101, 1615, 935. MS (DCI/NH₃) m/z (MNH₄⁺) = 224.

2-(4-Methoxy-benzyloxy)-tetrahydro-furan 16: 65mg (0.47mmol) of 4-methoxybenzyl alcohol, 106 μ l (1.1mmol) CCl₄, 135mg (1.1mmol) of CrCl₂; yield: 93mg (95%); NMR ¹H (CDCl₃, 300 MHz): 1.70-2.10 (m, 4H), 3.81 (s, 3H), 3.92 (m, 2H), 4.41 (d, J=12, 1H), 4.65 (d, J=12, 1H), 5.21 (t, J=3, 1H), 6.88 (d, J=9, 2H), 7.28 (d, J=9, 2H). ¹³C NMR (CDCl₃, 300 MHz): 23.5, 32.3, 55.3, 66.9, 68.5, 102.9, 113.8, 129.5, 130.5, 158.9. IR (neat, cm⁻¹): 3031, 2986, 1619, 889. MS (DCI/NH₃) m/z (MNH₄⁺) = 226.

4-(Tetrahydro-furan-2-yloxymethyl)-benzoic acid methyl ester 18: 80mg (0.48mmol) of 4-hydroxymethyl-benzoic acid methyl ester, 115 μ l (1.2mmol) CCl₄, 148mg (1.2mmol) of CrCl₂; yield: 103mg (91%); NMR ¹H (CDCl₃, 300 MHz): 1.70-2.20 (m, 4H), 3.70-4.10 (m, 5H), 4.54 (d, J=13Hz, 1H), 4.77 (d, J=13Hz, 1H), 5.23 (m, 1H), 7.41 (d, J=8Hz, 2H), 8.01 (d, J= 8Hz, 2H). ¹³C NMR (CDCl₃, 300 MHz): 23.4, 32.4, 52.1, 67.1, 68.1, 103.4,

127.3, 129.2, 129.7, 143.8, 166.9. IR (neat, cm^{-1}): 2995, 1730, 1643, 932. MS (DCI/ NH_3) m/z (MNH_4^+) = 254.

5-(Tetrahydro-furan-2-yloxymethyl)-benzo (1,3)dioxole 20: 76mg (0.50mmol) of 3,4-methylenedioxybenzyl alcohol, 120 μl (1.25mmol) CCl_4 , 154mg (1.25mmol) of CrCl_2 ; yield: 93mg (84%); NMR ^1H (CDCl_3 , 300 MHz): 1.70-2.10 (m, 4H), 3.80-4.10 (m, 2H), 4.38 (d, $J=12$, 1H), 4.61 (d, $J=12$, 1H), 5.21 (t, $J=4$, 1H), 5.95 (s, 2H), 6.70-7.05 (m, 3H). ^{13}C NMR (CDCl_3 , 300 MHz): 23.5, 32.3, 66.9, 68.6, 100.9, 102.8, 108.1, 108.7, 121.4, 132.1, 146.9, 147.6. IR (neat, cm^{-1}): 3029, 2999, 887, 925. MS (DCI/ NH_3) m/z (MNH_4^+) = 240.

2-(2-chloro-2-phenyl-ethoxy)-tetrahydro-furan 22: 40mg (0.26mmol) of 2-chloro-2-phenyl ethanol, 63 μl (0.65mmol) CCl_4 , 80mg (0.65mmol) of CrCl_2 ; yield: 47mg (82%); NMR ^1H (CDCl_3 , 300 MHz): *Mixture of stereoisomer 50/50*: NMR ^1H (CDCl_3 , 300 MHz): 1.70-2.10 (m, 8H), 3.65-3.95 (m, 6H), 4.00-4.20 (m, 2H), 5.02 (m, 2H), 5.11 (m, 1H), 5.21 (m, 1H), 7.39 (m, 10H). ^{13}C NMR (CDCl_3 , 300 MHz): 23.3, 32.4, 61.0, 61.8, 67.1, 71.5, 71.9, 103.9, 104.3, 127.5, 127.6, 128.5, 138.8. IR (neat, cm^{-1}): 3052, 2996, 1612, 932. MS (DCI/ NH_3) m/z (MNH_4^+) = 244.

2-(2,2,2-Trichloro-Ethoxy)-tetrahydro-furan 24: 55 μl (0.55mmol) of trichloro ethanol, 135 μl (1.4mmol) CCl_4 , 169mg (1.4mmol) of CrCl_2 ; yield: 104mg (87%); NMR ^1H (CDCl_3 , 300 MHz): 1.70-2.30 (m, 4H), 3.95 (m, 2H), 4.10 (d, $J=11\text{Hz}$, 1H), 4.25 (d, $J=11\text{Hz}$, 1H), 5.39 (d, $J=7\text{Hz}$, 1H). ^{13}C NMR (CDCl_3 , 300 MHz): 23.1, 32.3, 67.6, 78.7, 97.2, 104.4. IR (neat, cm^{-1}): 2987, 920. MS (DCI/ NH_3) m/z (MNH_4^+) = 236.

2-(2-chloro-1H-inden-1-yloxy)-tetrahydro-furan 26: : 50mg (0.30mmol) of 2-chloro-1H-inden-1-ol, 72 μ l (0.75mmol) CCl₄ , 93mg (0.75mmol) of CrCl₂; yield: 64mg (90%). **The less polar isomer:** NMR ¹H (CDCl₃, 300 MHz): 1.70-2.20 (m, 4H), 4.10-4.30 (m, 2H), 5.06 (s, 1H), 5.54 (d, *J*=3, 1H), 6.61 (s, 1H), 7.20-7.55 (m, 5H). ¹³C NMR (CDCl₃, 300 MHz): 23.3, 32.6, 67.6, 81.3, 104.3, 120.7, 124.2, 125.9, 128.3, 128.7, 140.2, 140.9, 141.7. **The more polar isomer:** NMR ¹H (CDCl₃, 300 MHz): 1.65-2.35 (m, 4H), 3.90-4.20 (m, 2H), 5.14 (s, 1H), 5.53 (m, 1H), 6.67 (s, 1H), 7.10-7.50 (m, 5H). ¹³C NMR (CDCl₃, 300 MHz): 23.1, 32.9, 67.4, 79.5, 102.7, 120.8, 123.6, 125.8, 128.6, 129.3, 140.75, 142.5. IR (neat, cm⁻¹): 3102, 2986, 1623, 990, 929. MS (DCI/NH₃) *m/z* (MNH₄⁺)= 254.

2.0368
2.0038
1.9359
1.9188
1.9072
1.8871
1.8364
1.6219

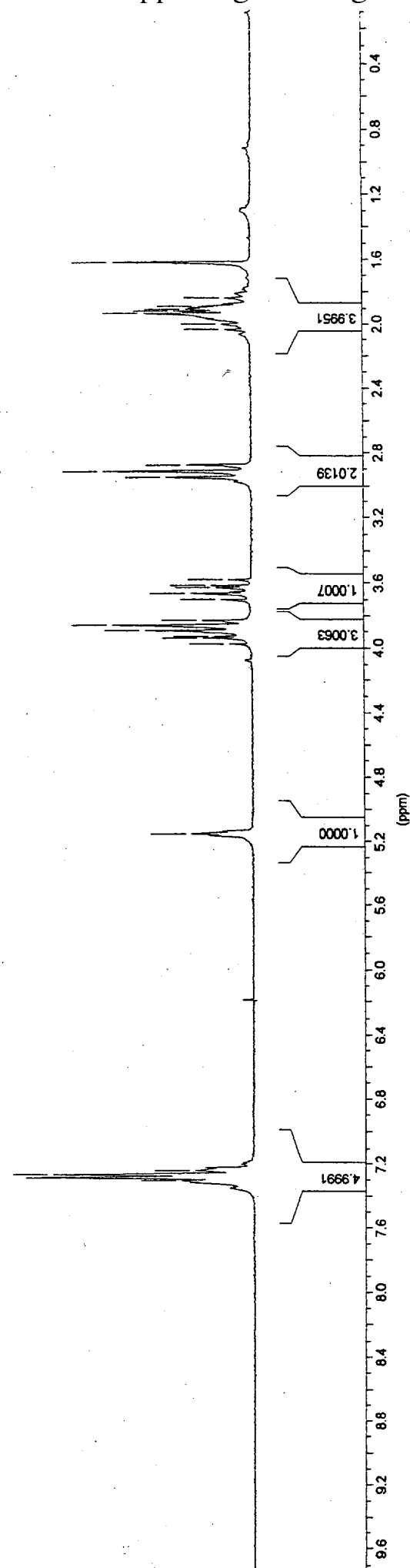
2.9483
2.9122
2.8756

3.9777
3.9416
3.9294
3.8940
3.8598
3.8274
3.7003
3.6643
3.6282
3.6166
3.5800

5.1568

7.3109
7.2920
7.2889
7.2700
7.2437

2



23.4253

32.3209

36.3395

66.6440

67.0652

76.3607

77.0000

77.8210

103.7599

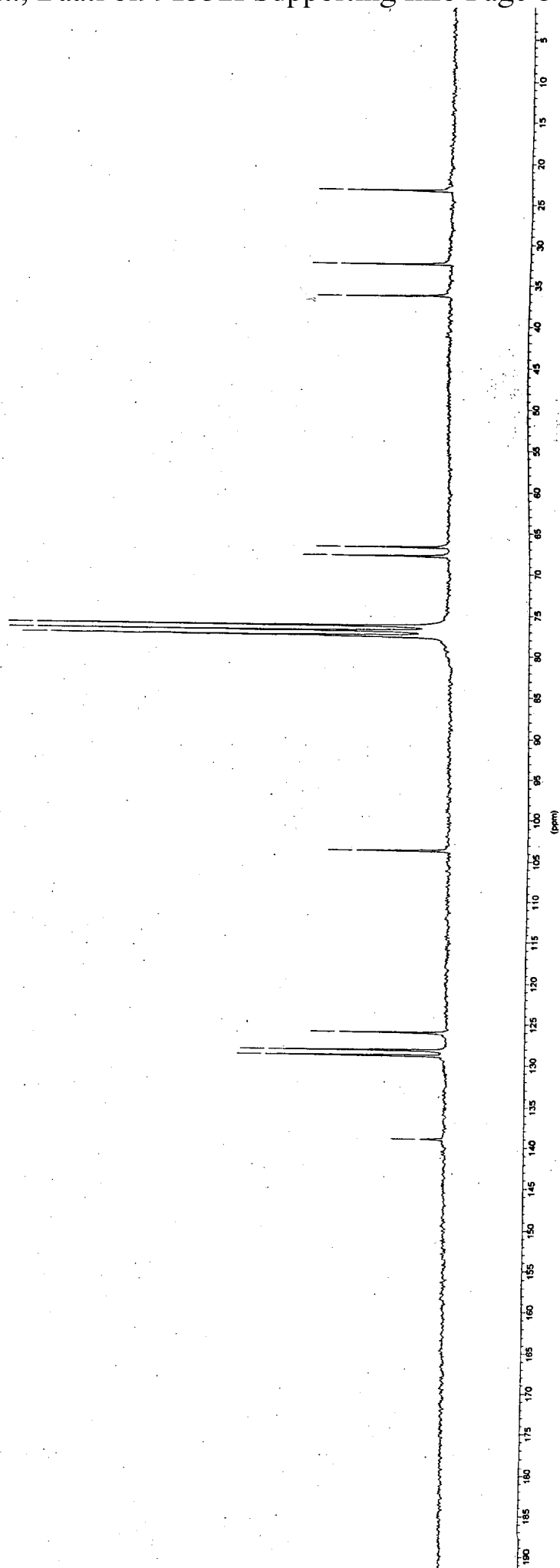
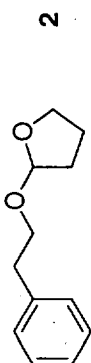
126.0612

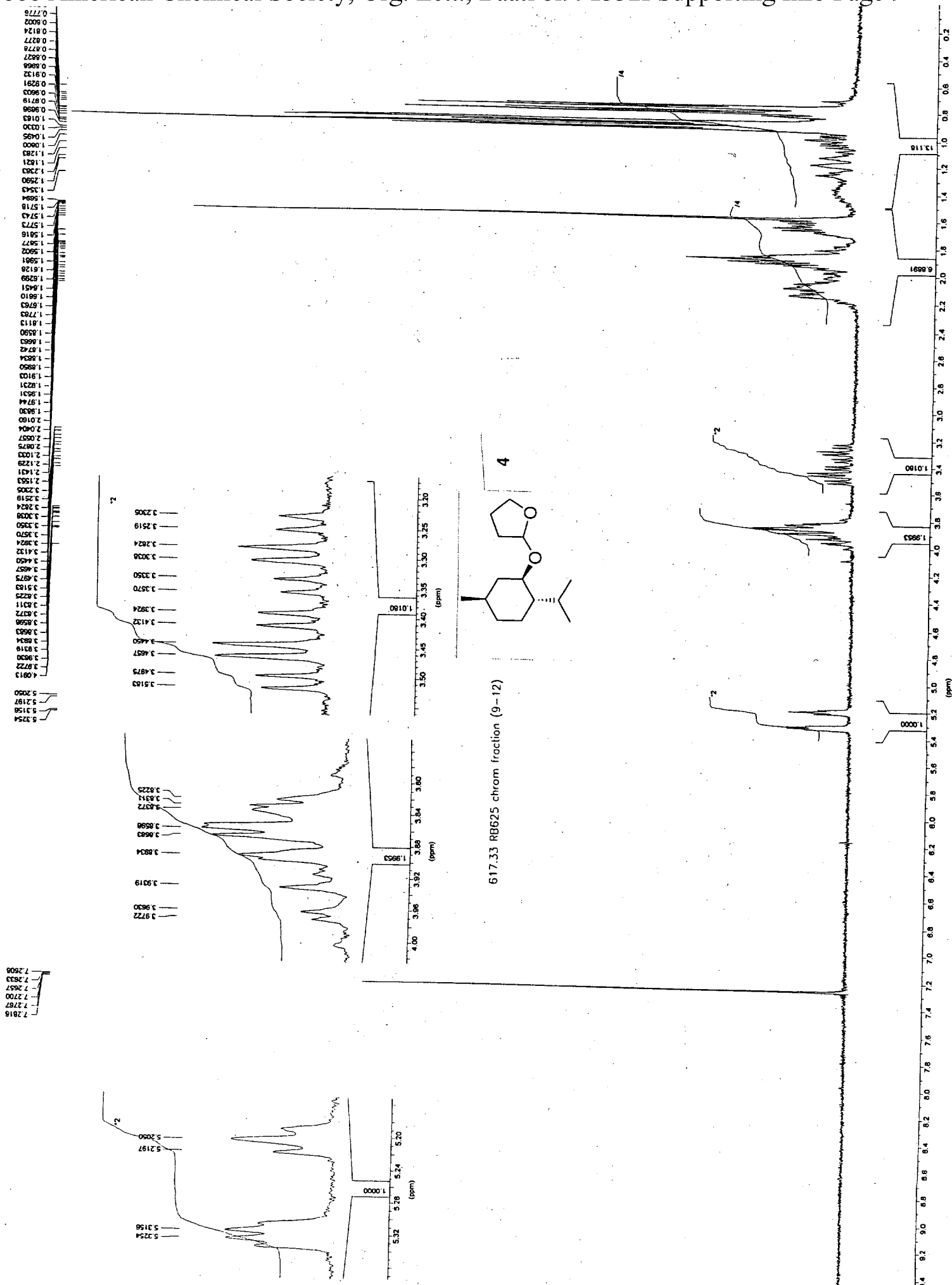
128.2366

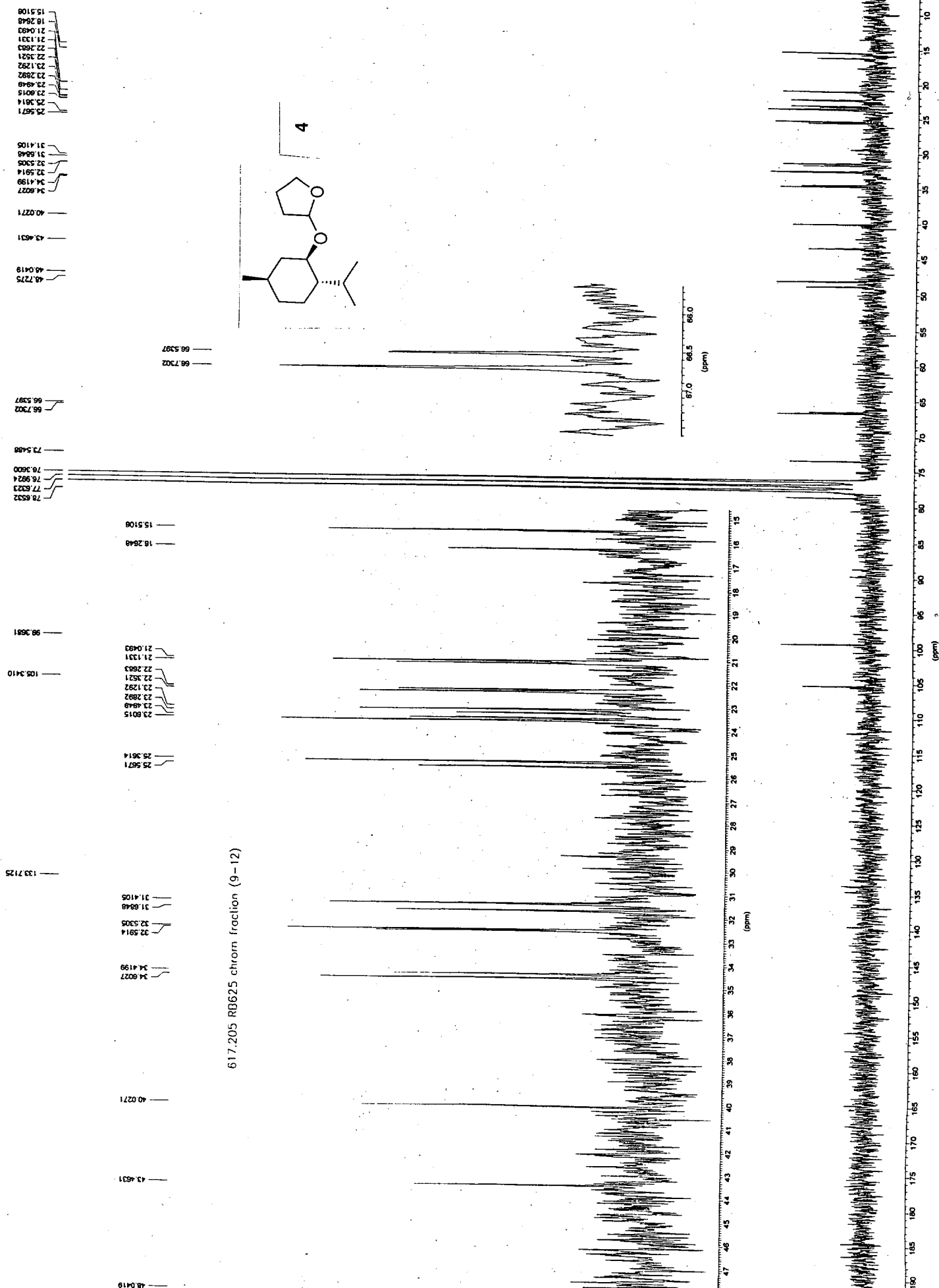
128.8942

139.0667

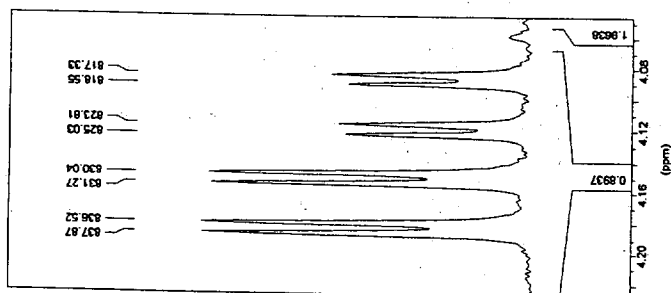
616.30 RB618 chrom fraction (11-14)



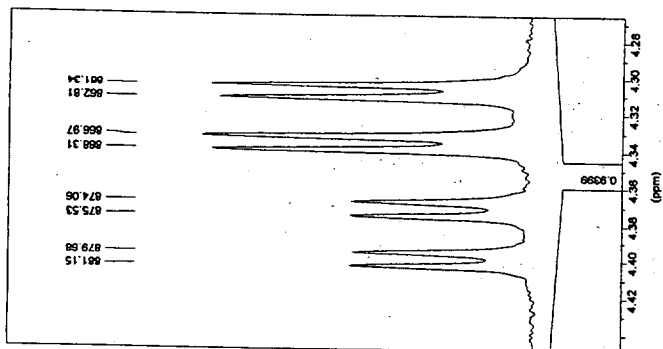




1.6012
1.5950
1.5904
1.5850
1.5782
1.5736
1.5647
1.5781
1.5805
1.5809
2.0166
2.0251
2.0520
2.0613
2.1107

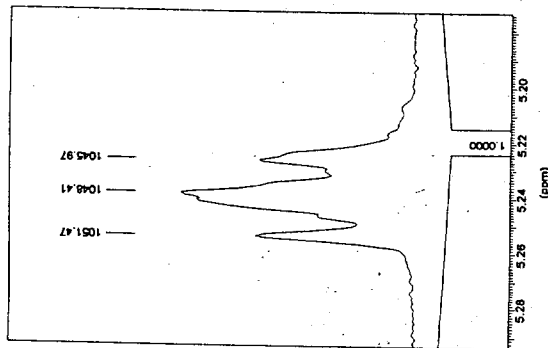


3.8789
3.8679
3.9172
3.9037
3.9502
3.9832
4.0840
4.0901
4.1164
4.1225
4.1475
4.1536
4.1789
4.1868
4.3039
4.3113
4.3320
4.3387
4.3675
4.3749
4.3956
4.4029



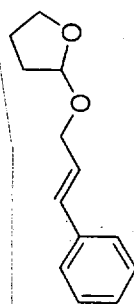
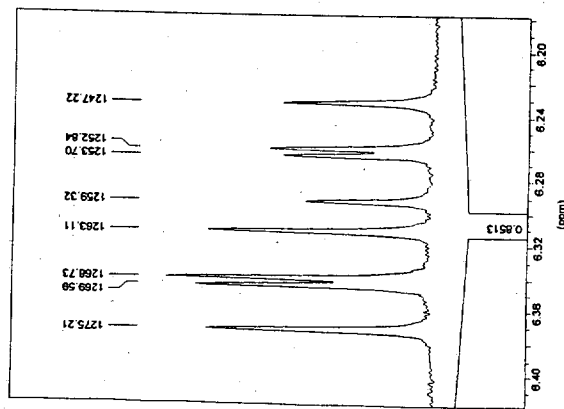
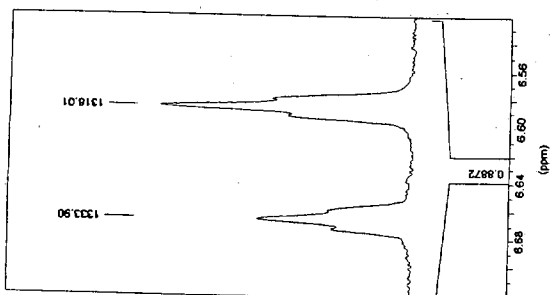
5.2264
5.2386
5.2539

617 RB chrom fraction (13-20)



6.2220
6.2601
6.2644
6.2825
6.3114
6.3385
6.3436
6.3719
6.3856
6.4052

7.0643
7.2004
7.2156
7.2348
7.2498
7.2580
7.2689
7.2700
7.2731
7.2786
7.2808
7.2908
7.2956
7.3232
7.3305
7.3409
7.3519
7.3604
7.3715
7.3849
7.4176
7.4276



6

4.5459
1.9838
0.8937
0.8939
1.0000
0.8513
0.8672
5.5356

0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
7.2
7.4
7.6
7.8
8.0
8.2
8.4
8.6
8.8
9.0
9.2
9.4

23.4796

32.3629

67.0121
67.5756

76.3677
77.0000
77.6400

103.1621

126.0254
126.4673
127.5720
128.4662

132.3031
136.7678

617.201 RB624 chrom fraction (14-20)

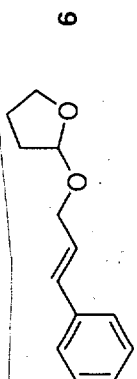
67.0121
67.5756

126.0254

126.4673

127.5720

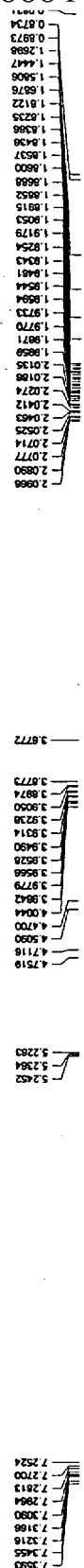
128.4662



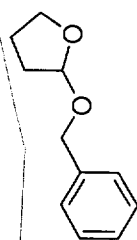
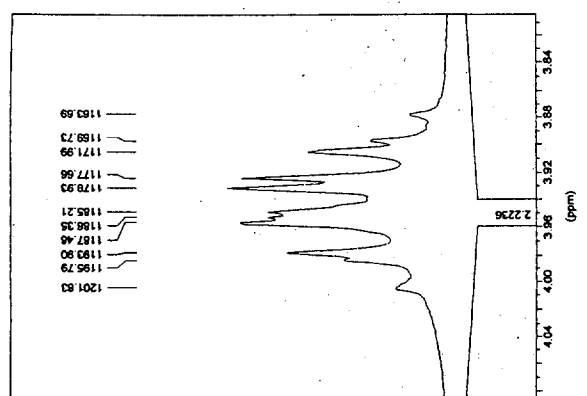
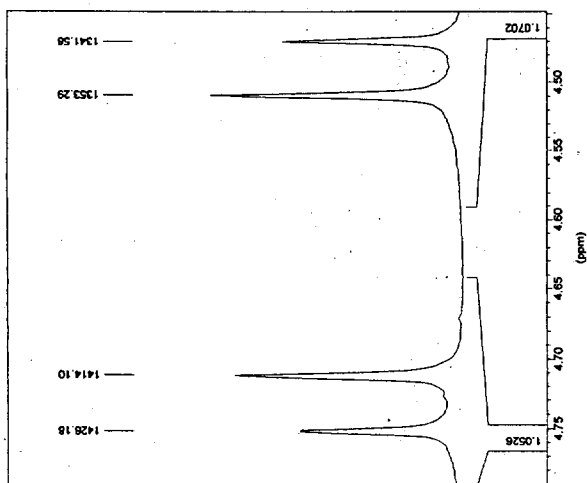
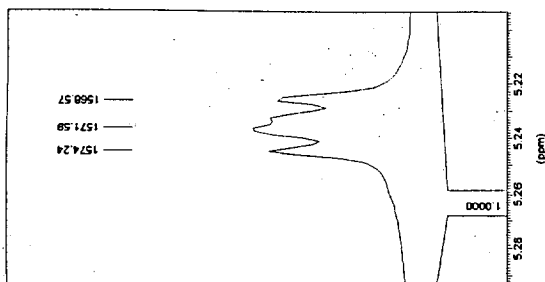
68.0 67.6 67.2 66.8 66.4 (ppm)

129.4 129.2 129.0 128.8 128.6 128.4 128.2 128.0 127.8 127.6 127.4 127.2 127.0 126.8 126.6 126.4 126.2 126.0 125.8 125.6 125.4 (ppm)

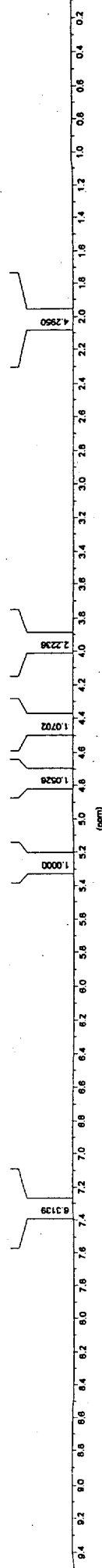
30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 (ppm)

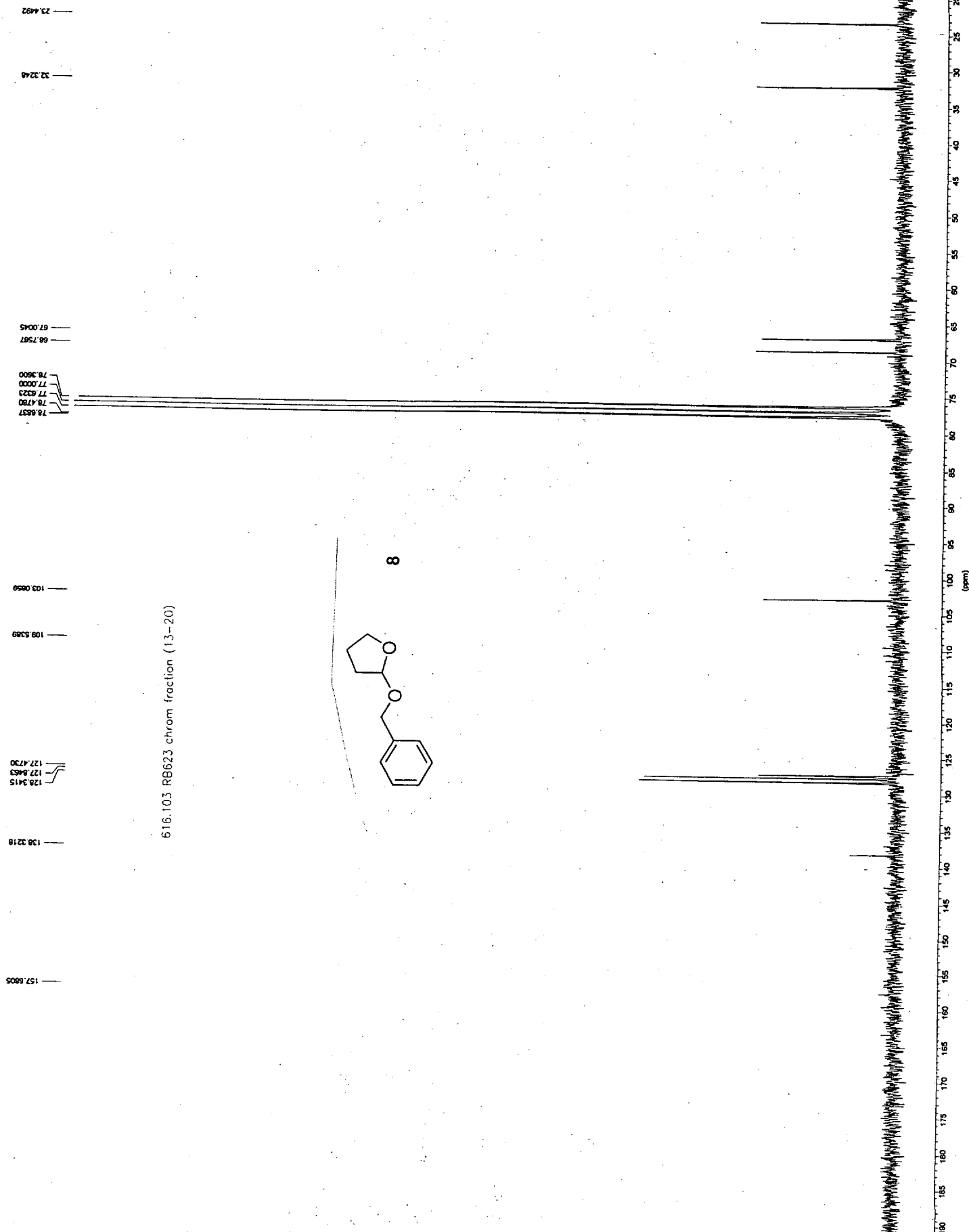


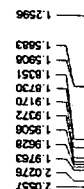
318.9RB023chromfraction(13-20)



8

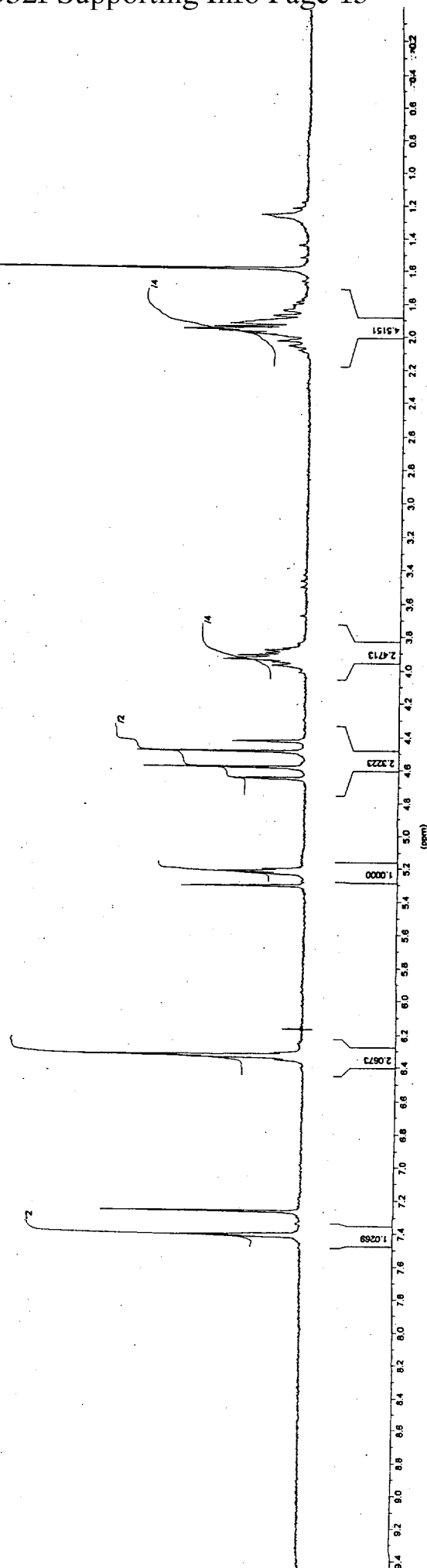
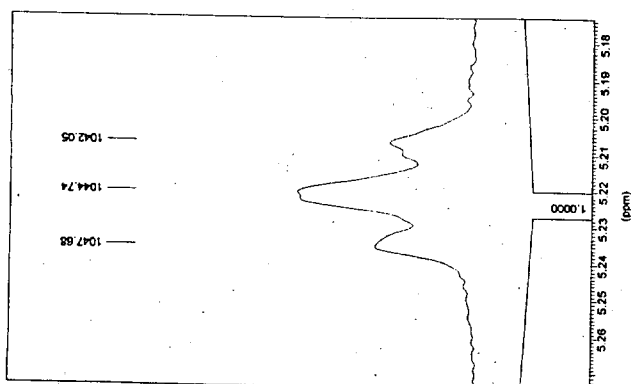
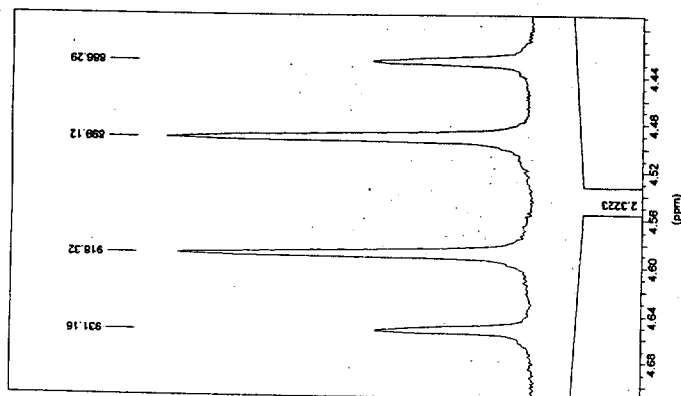
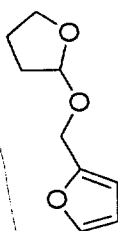


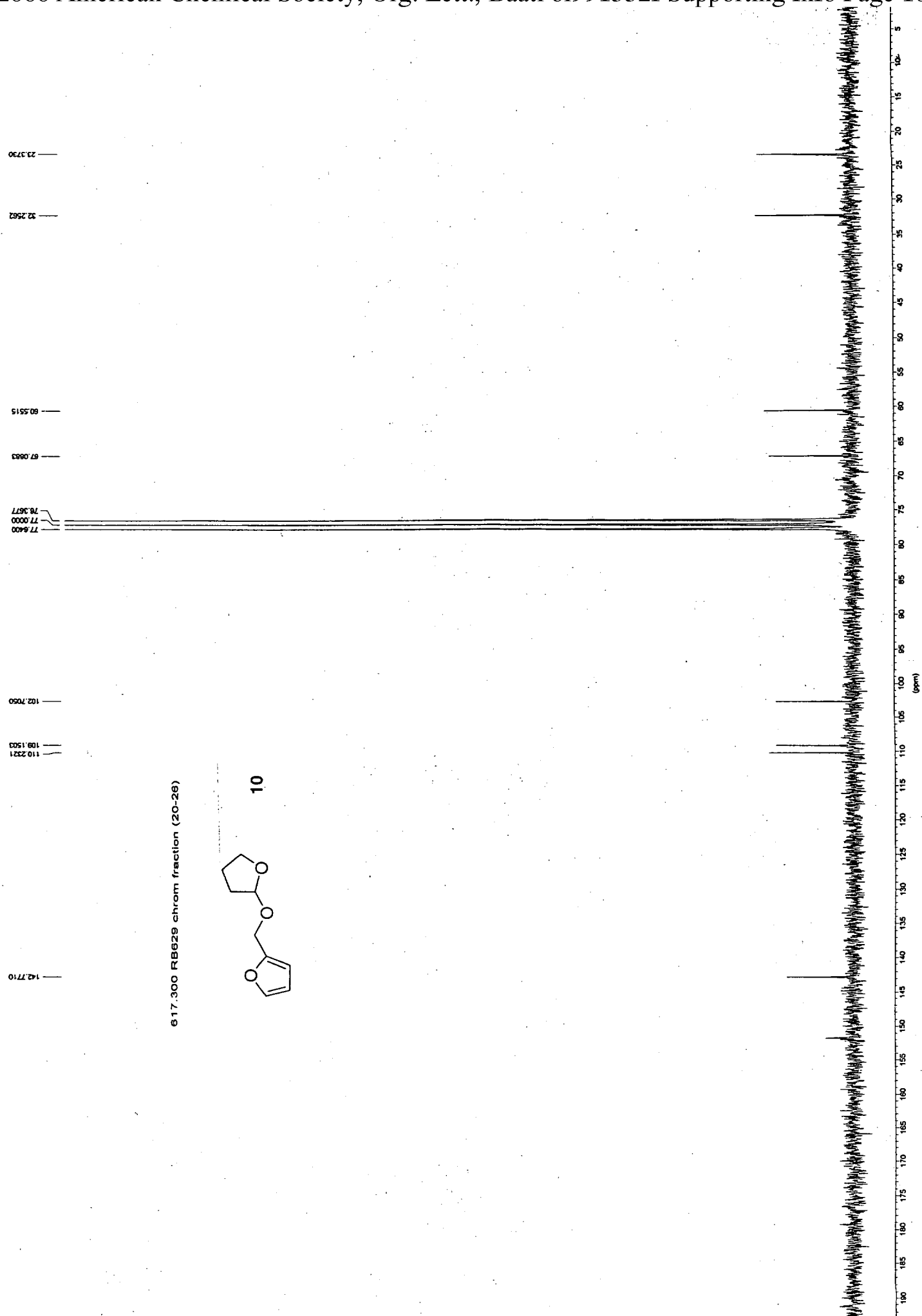




617.41 RB629 chrom fraction (20-28)

10





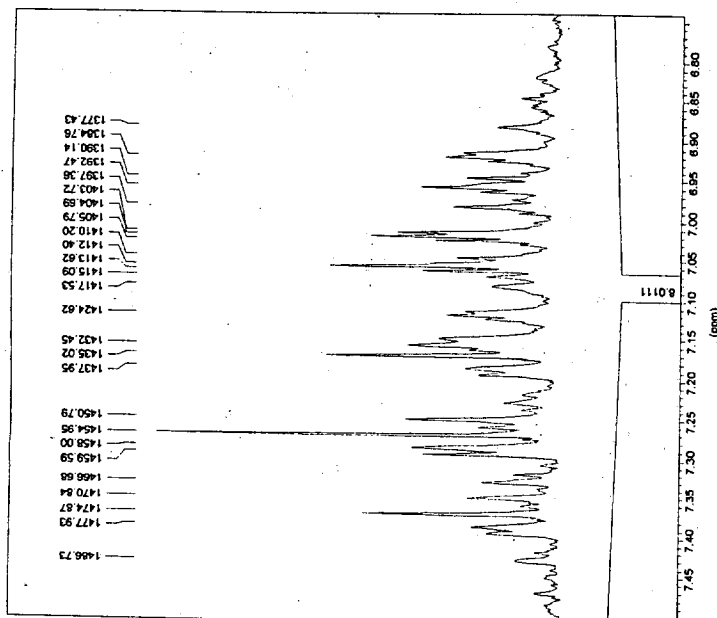
2.2728
2.2457
2.1724
2.1683
2.1481
2.0759

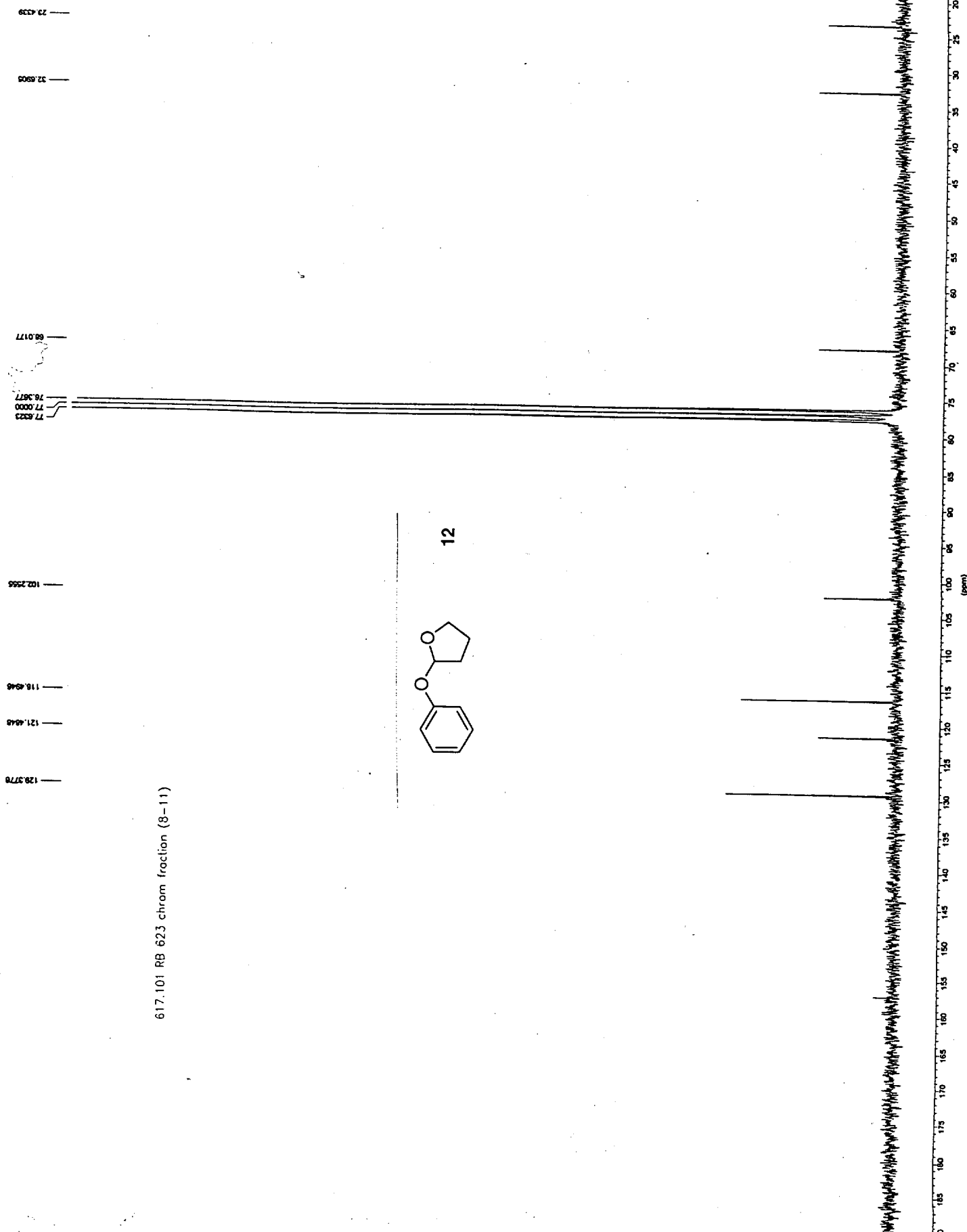
4.0534
4.0101
3.9532

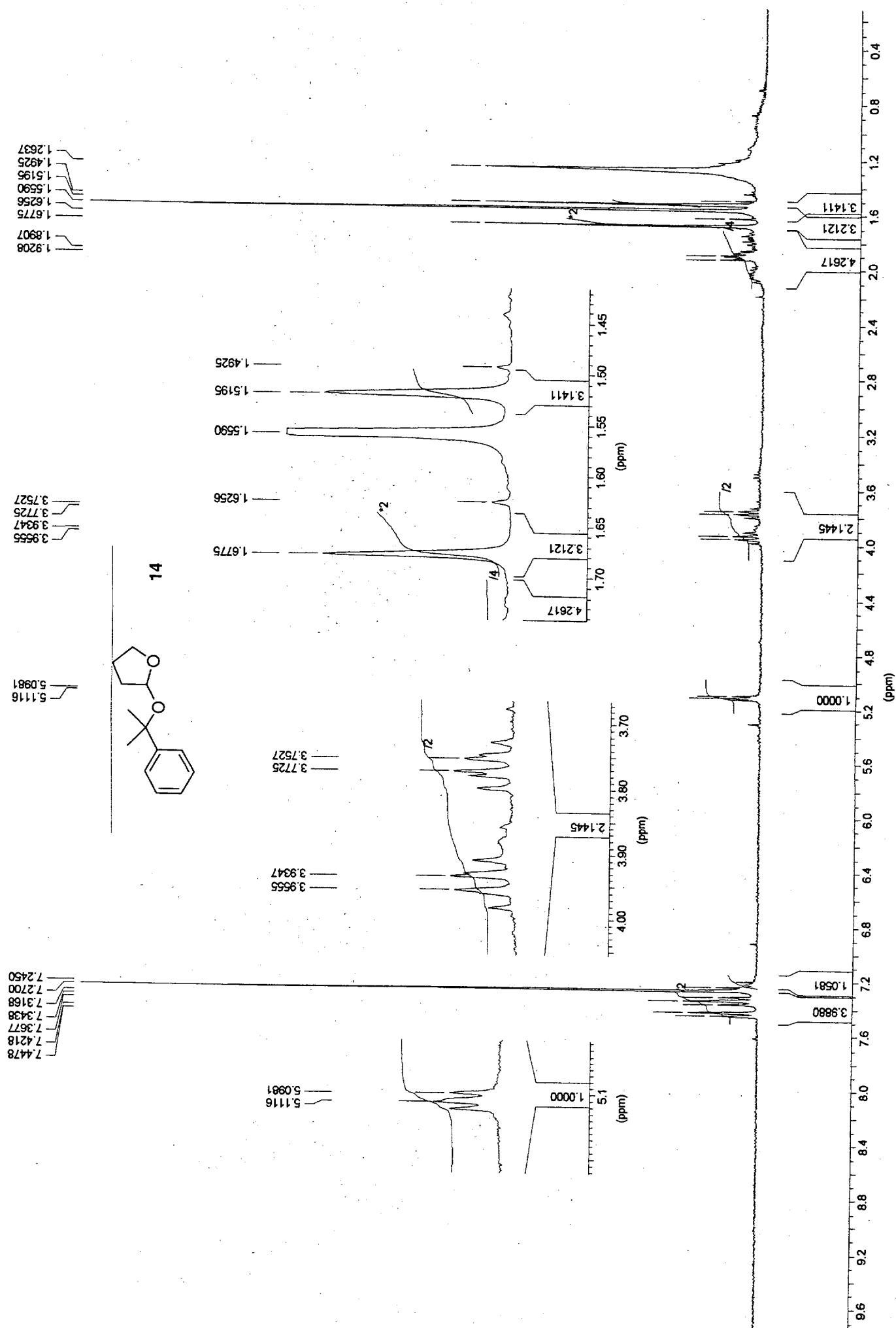
5.9101
5.8374
5.8099
5.7103

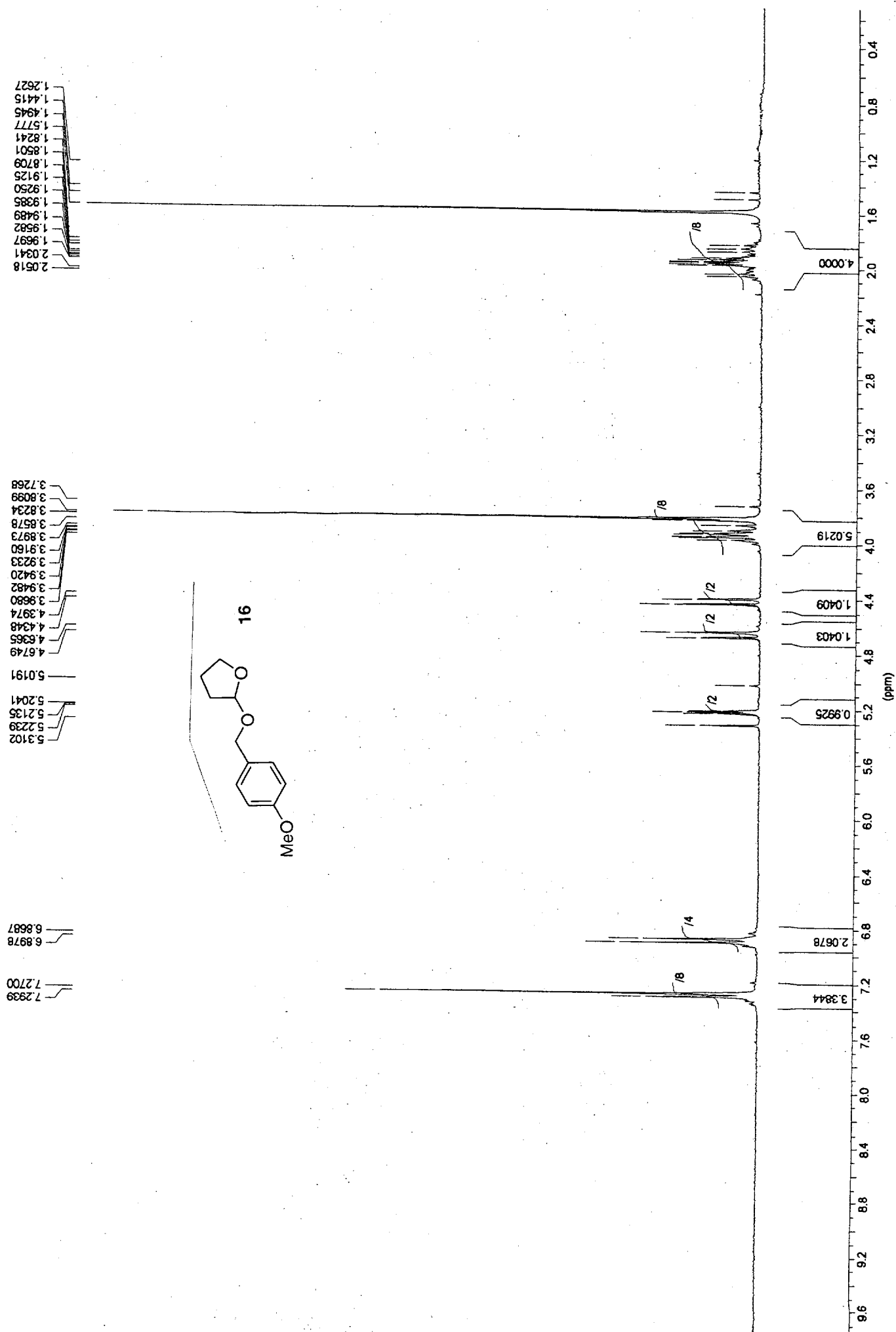
7.4269
7.3649
7.3636
7.3494
7.3266
7.2932
7.2853
7.2700
7.2492
7.1851
7.1704
7.1576
7.1185
7.0831
7.0706
7.0574
7.0454
7.0244
7.0140
6.9576
6.9462
6.9193
6.8827

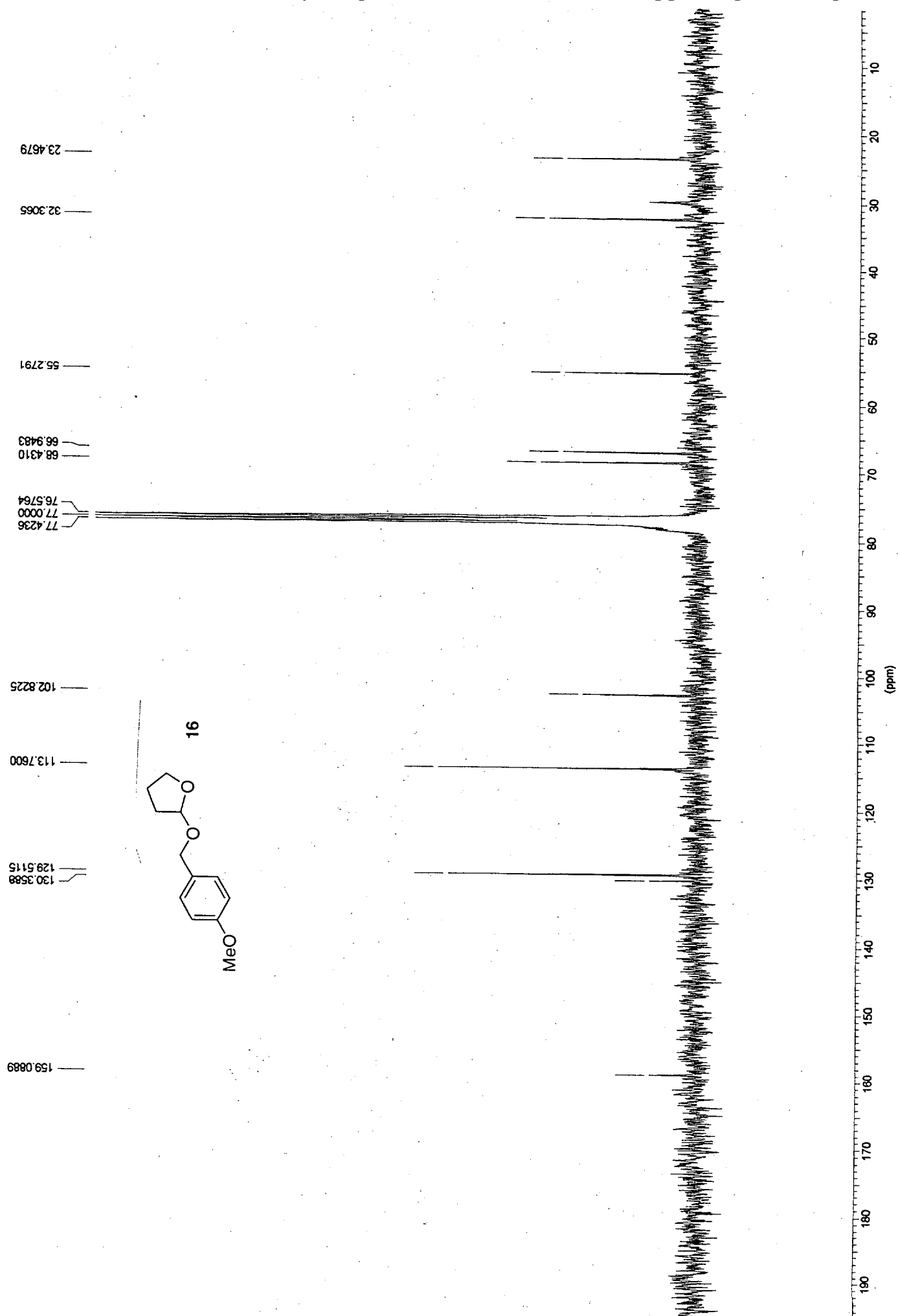
817.2 RB CHROM FRACTION (8-11)

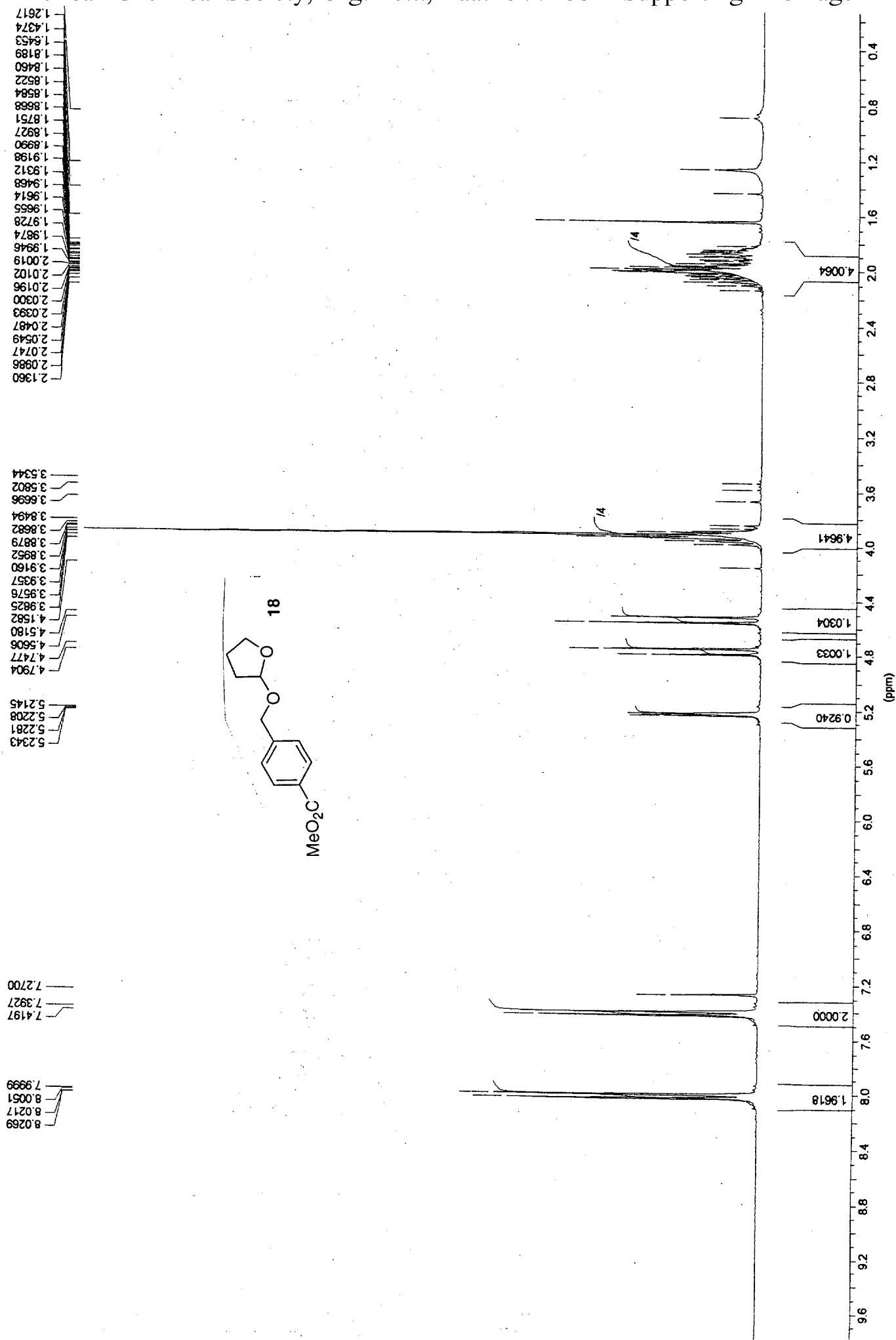


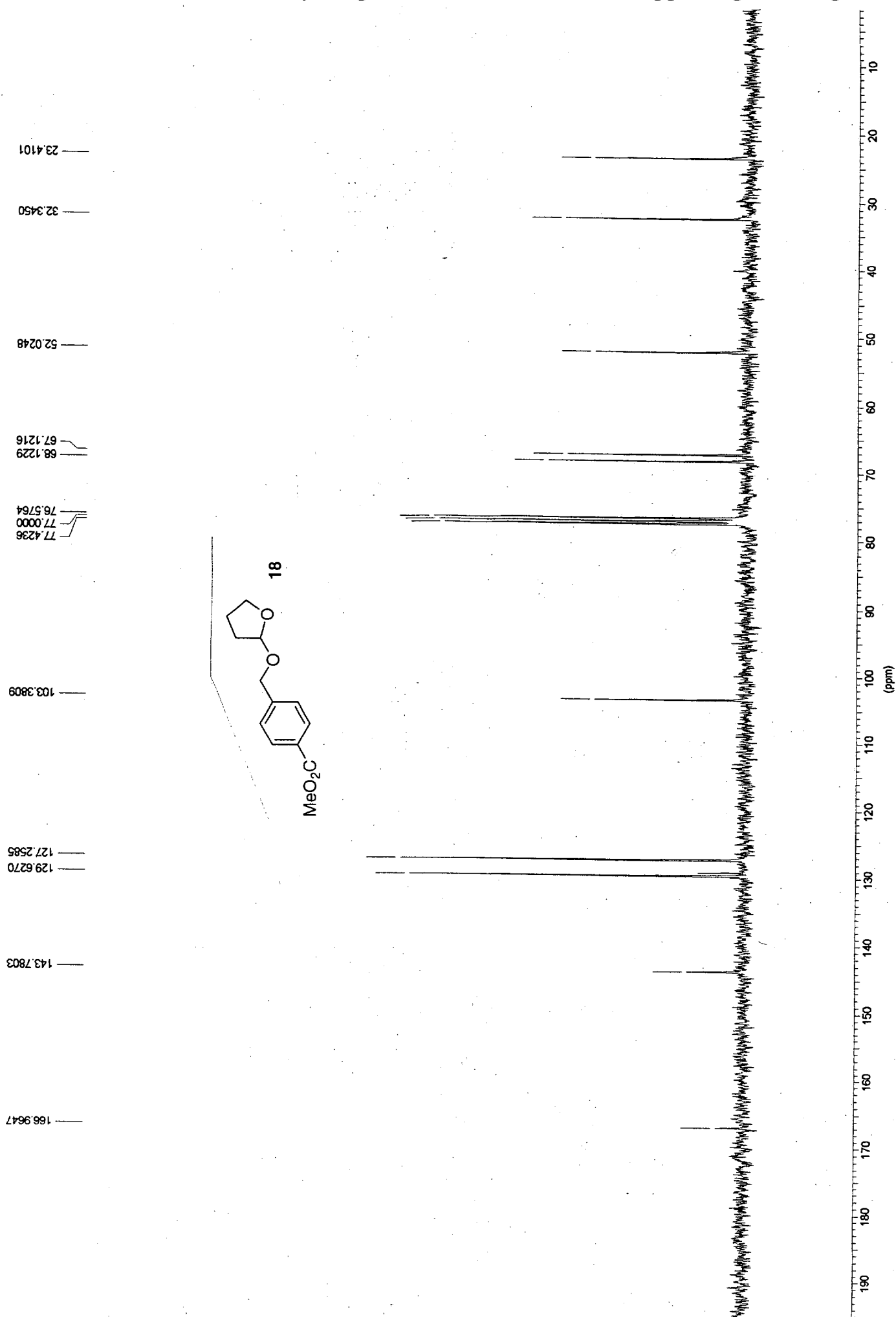












1.9728
1.9624
1.9520
1.9416
1.9271
1.9156
1.6599

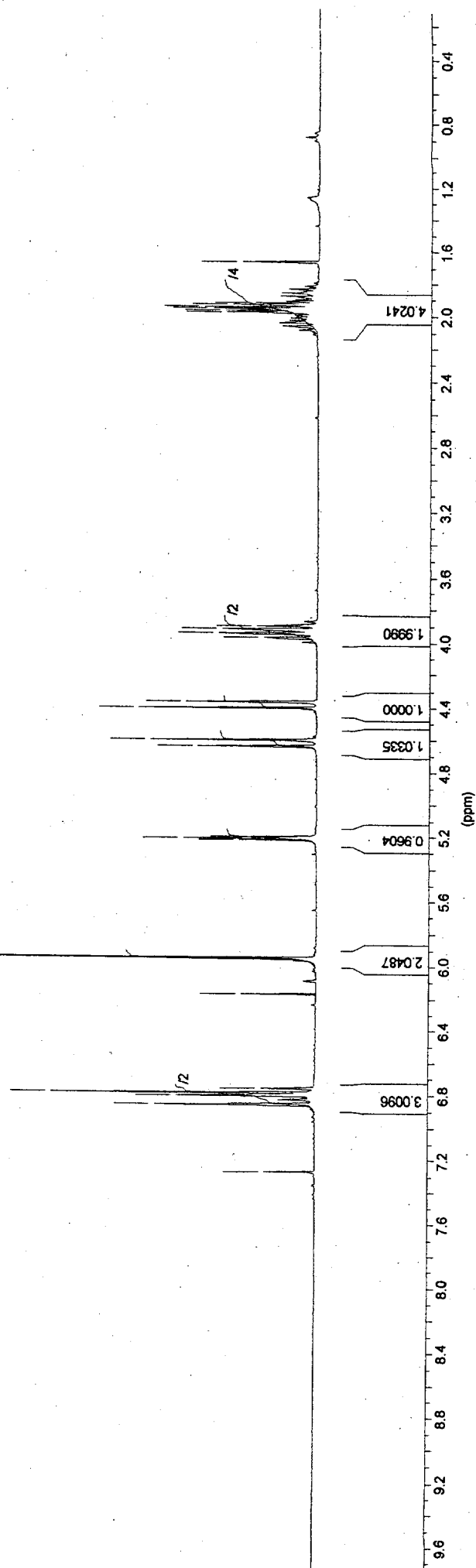
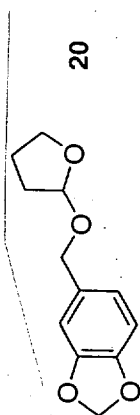
3.9638
3.9388
3.9139
3.8952

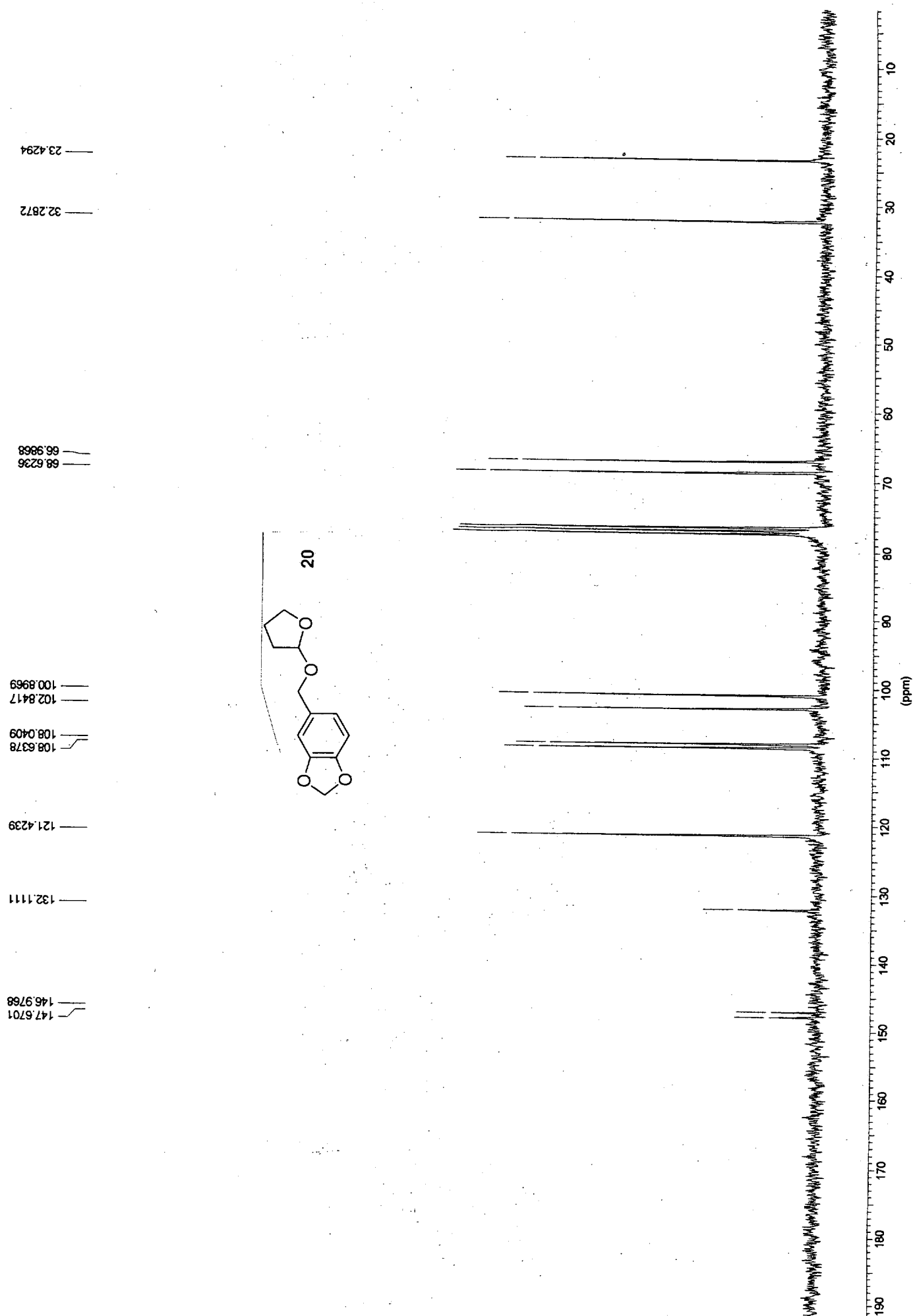
4.6354
4.5970
4.3984
4.3599

5.2145
5.2041
5.1948

5.9454
6.1659

7.2700
6.8510
6.7980
6.7824
6.7564





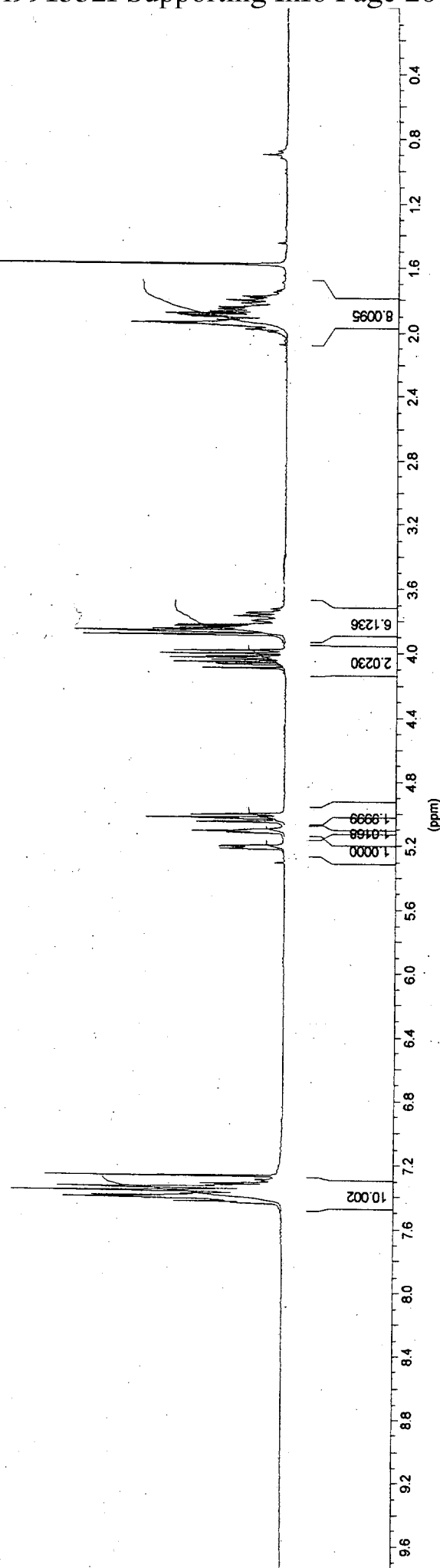
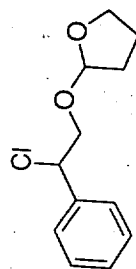
1.9364
1.8927
1.8824
1.5767

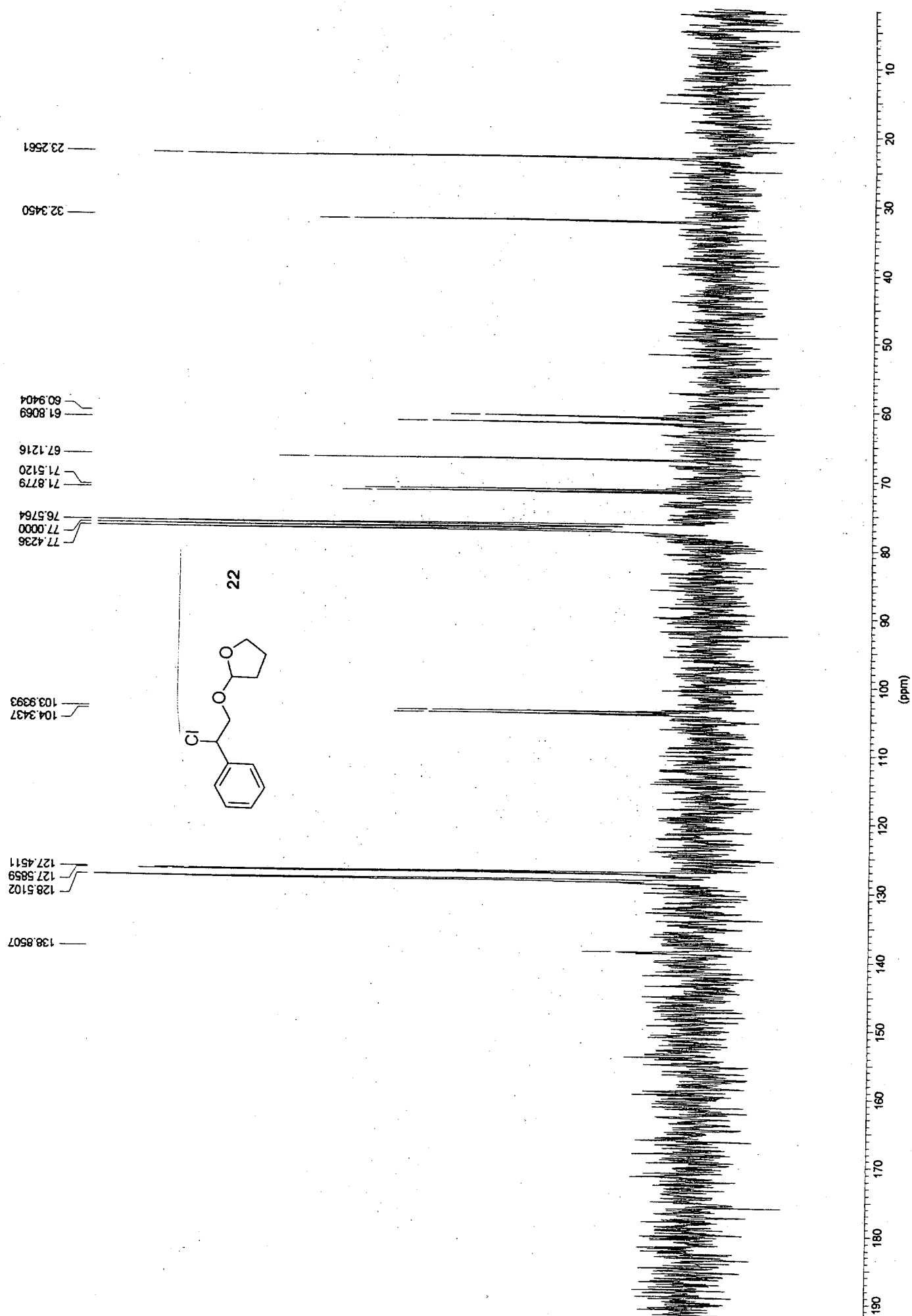
4.0927
4.0563
4.0324
4.0241
4.0054
3.9867
3.8858
3.8588
3.8484
3.8297
3.8214

5.2062
5.1075
5.0492
5.0243
5.0045

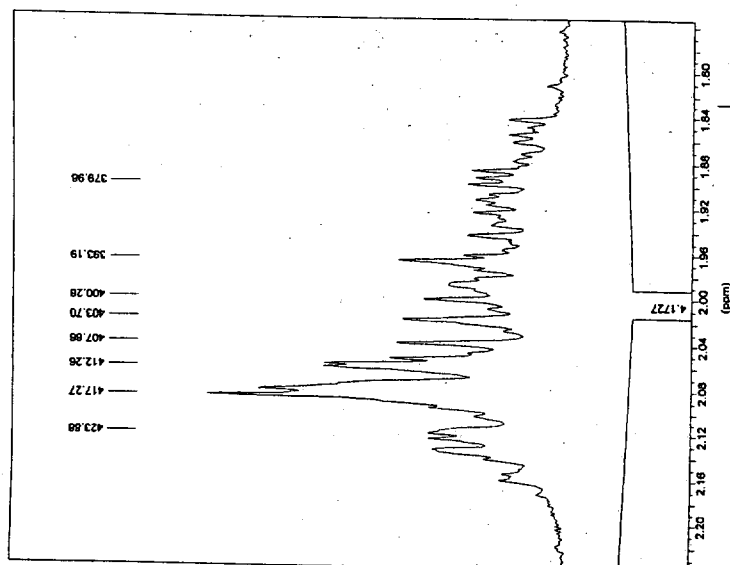
7.4062
7.3968
7.3657
7.3386
7.2700

22

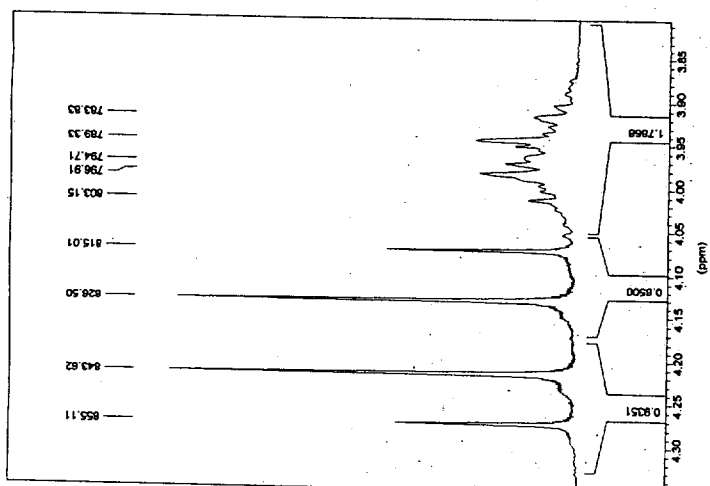




2.1160
2.0850
2.0600
2.0380
2.0172
2.0001
1.9847
1.9687
1.5767
1.2580
0.8894

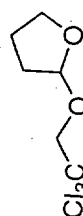
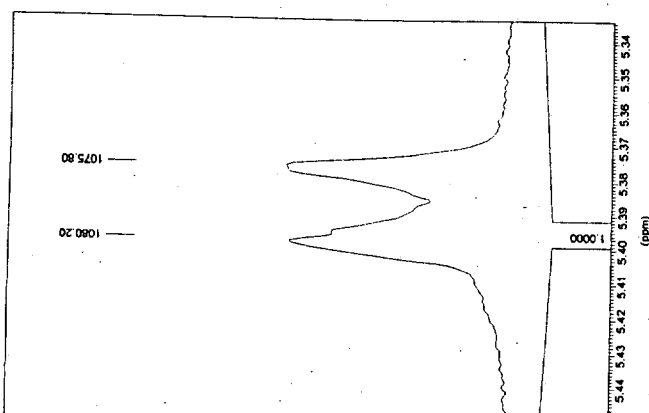


4.2728
4.2153
4.1788
4.0724
4.0131
3.9820
3.9710
3.9441
3.8168

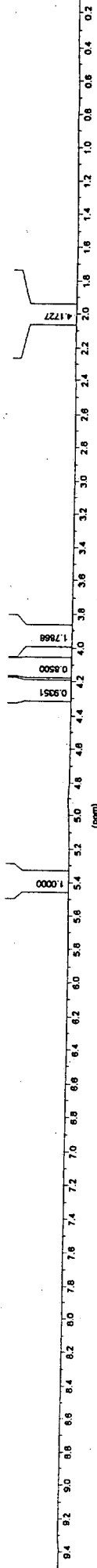


5.3975
5.3755

616.34 RB 628 chrom fraction (9-12)

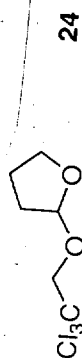


24



23.0635
 32.3172
 67.6215
 76.3800
 77.0000
 77.6323
 78.6913
 87.1892
 104.3508

617.207 RB628 chrom fraction (9-12)



(ppm)

