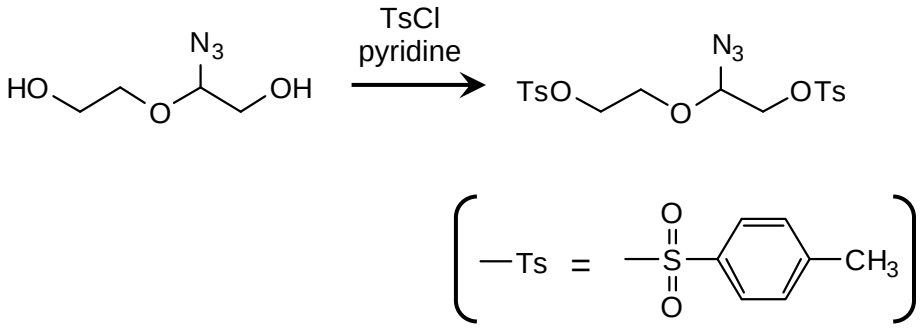
Chemistry 4361/8361 Fall 2012

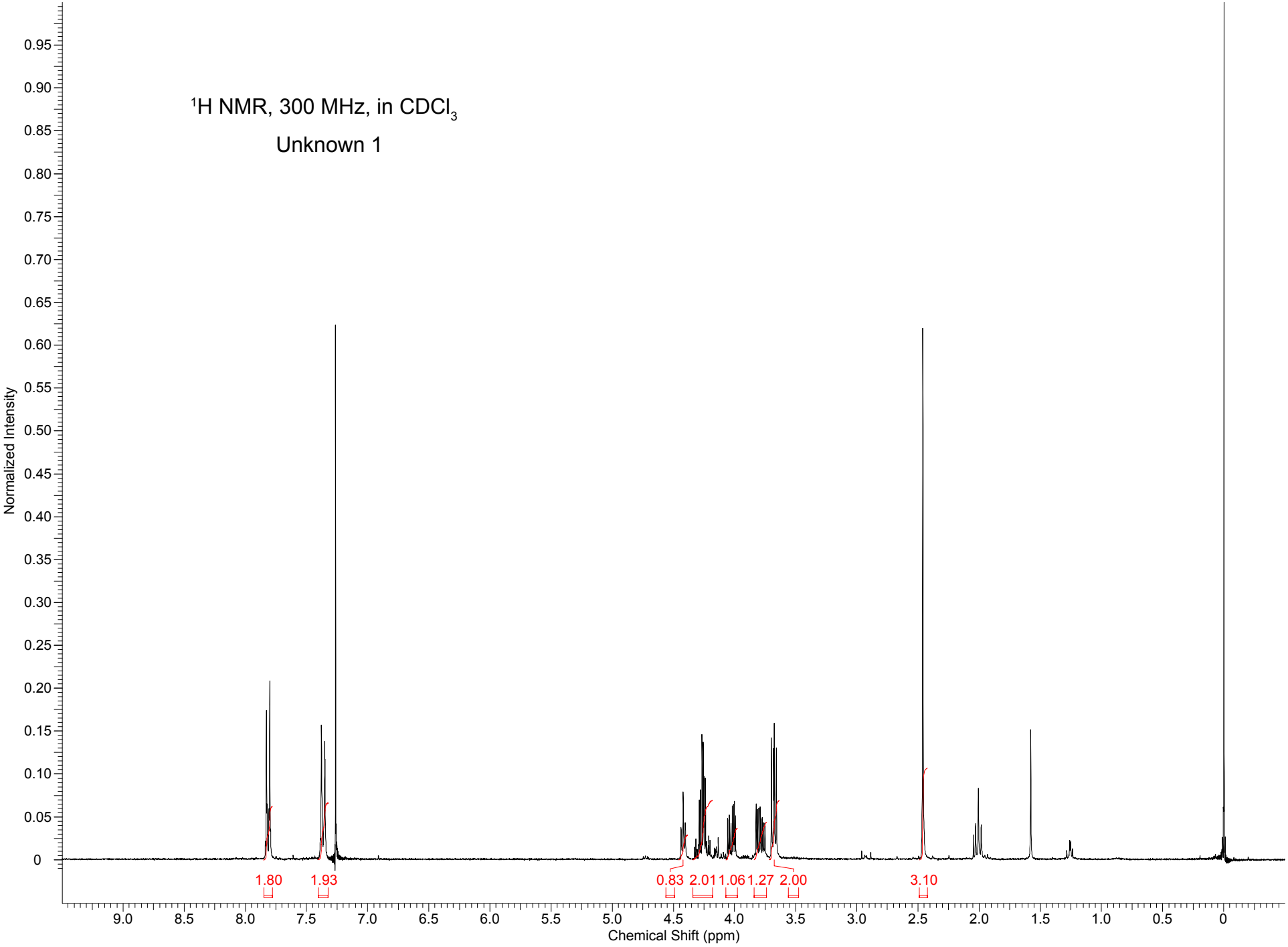
Problem Set 2
Advanced 1D NMR Interpretation
Due: Wednesday, September 26

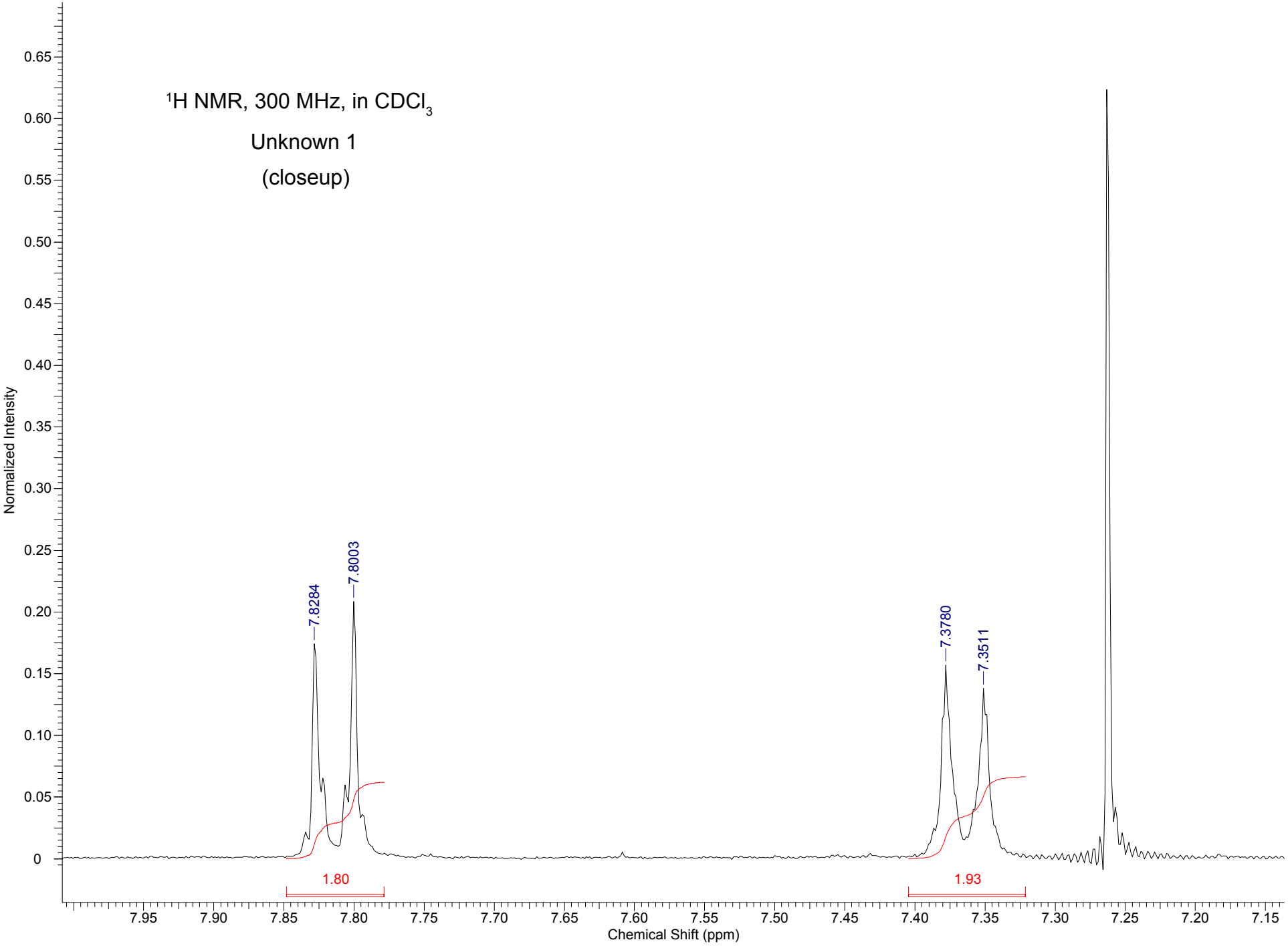
1. Chandru Ramasubramanian (Taton group) attempted the tosylation reaction shown below. Unfortunately, he did not isolate the expected ditosylate product from this reaction, but he did isolate two other products after column chromatography. ^{1}H NMR spectra (300 MHz, in $CDCl_3$) of the two molecules are shown on the following pages.

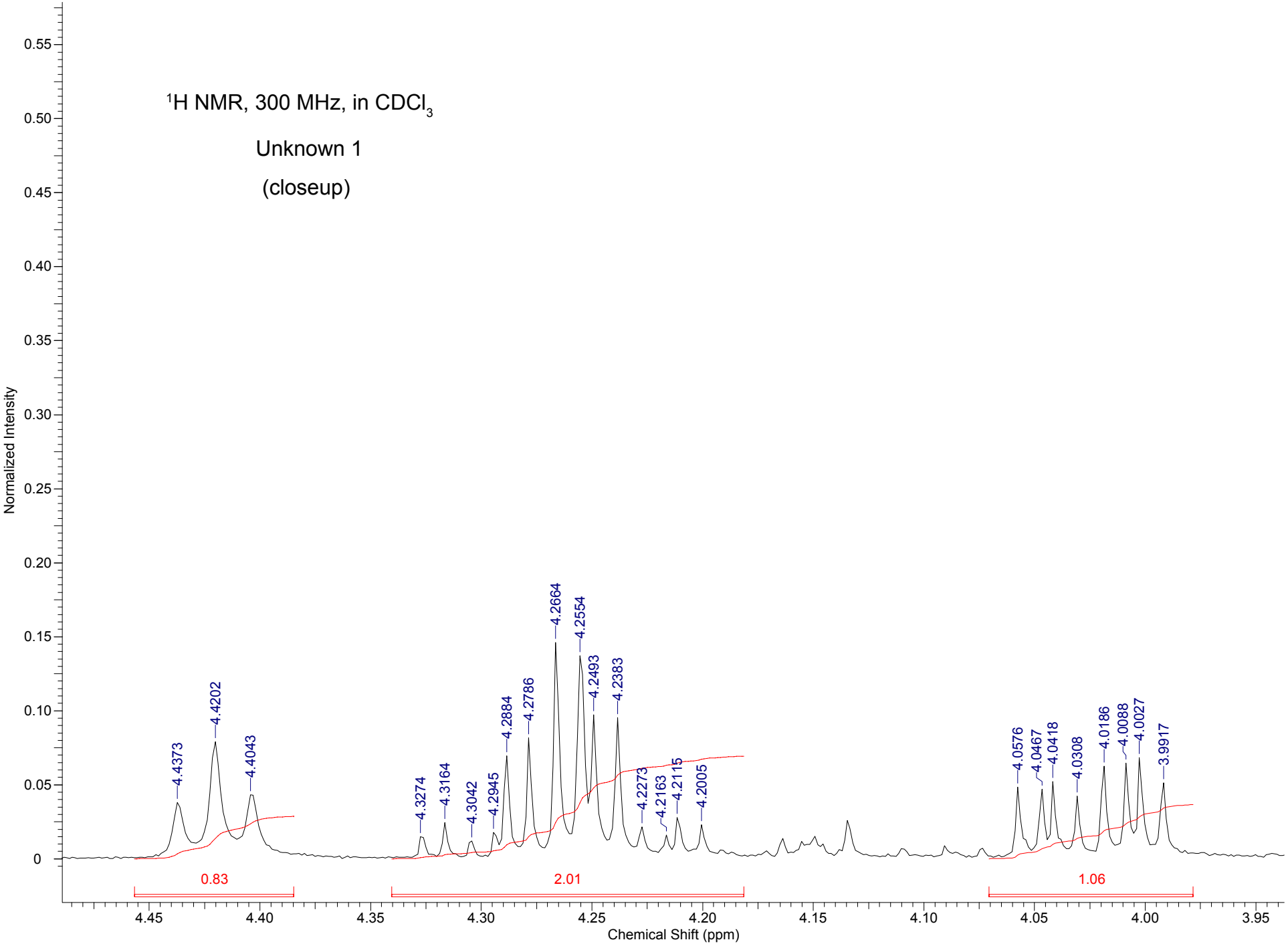


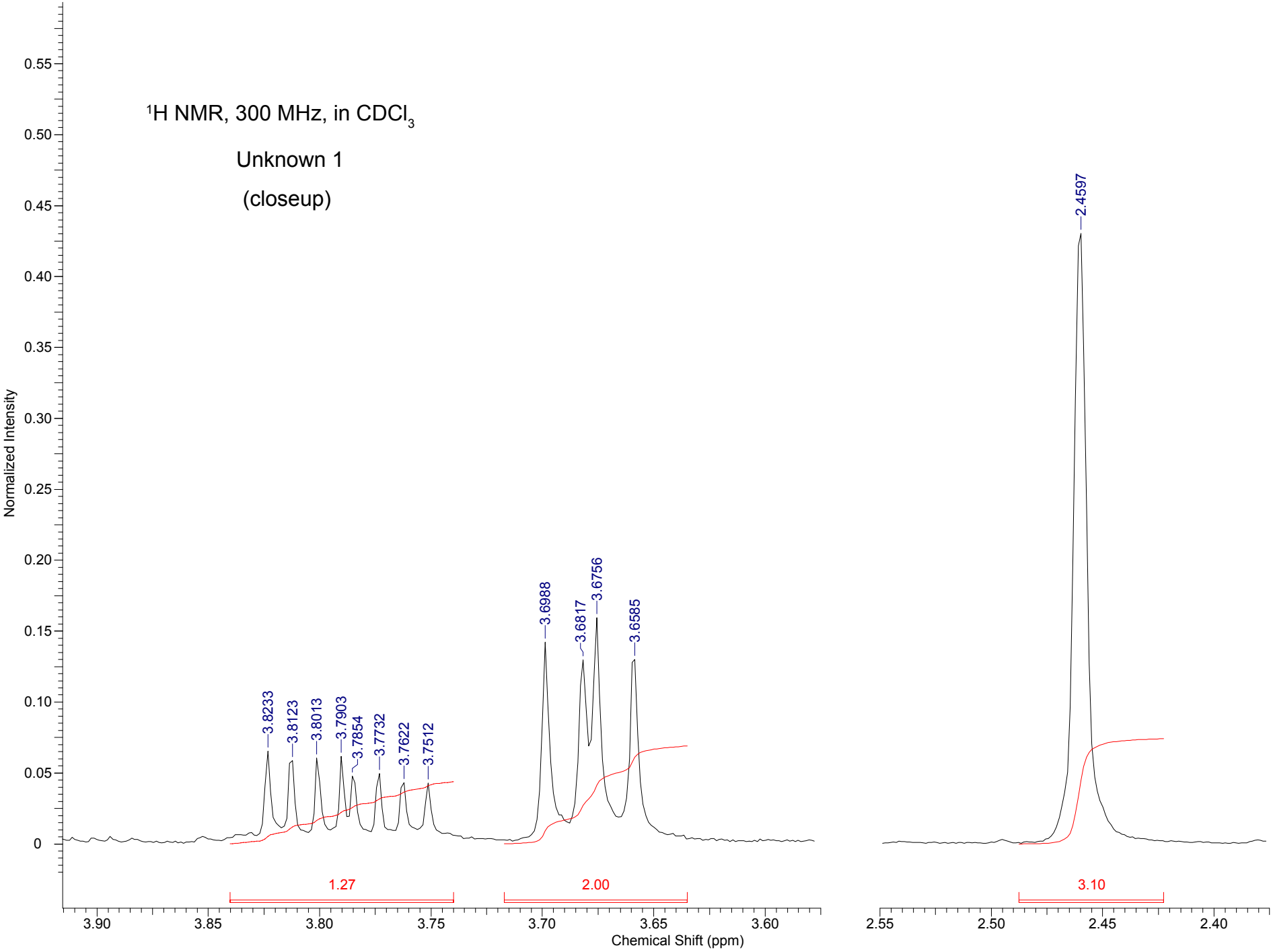
   a. What are the structures of the two side products?

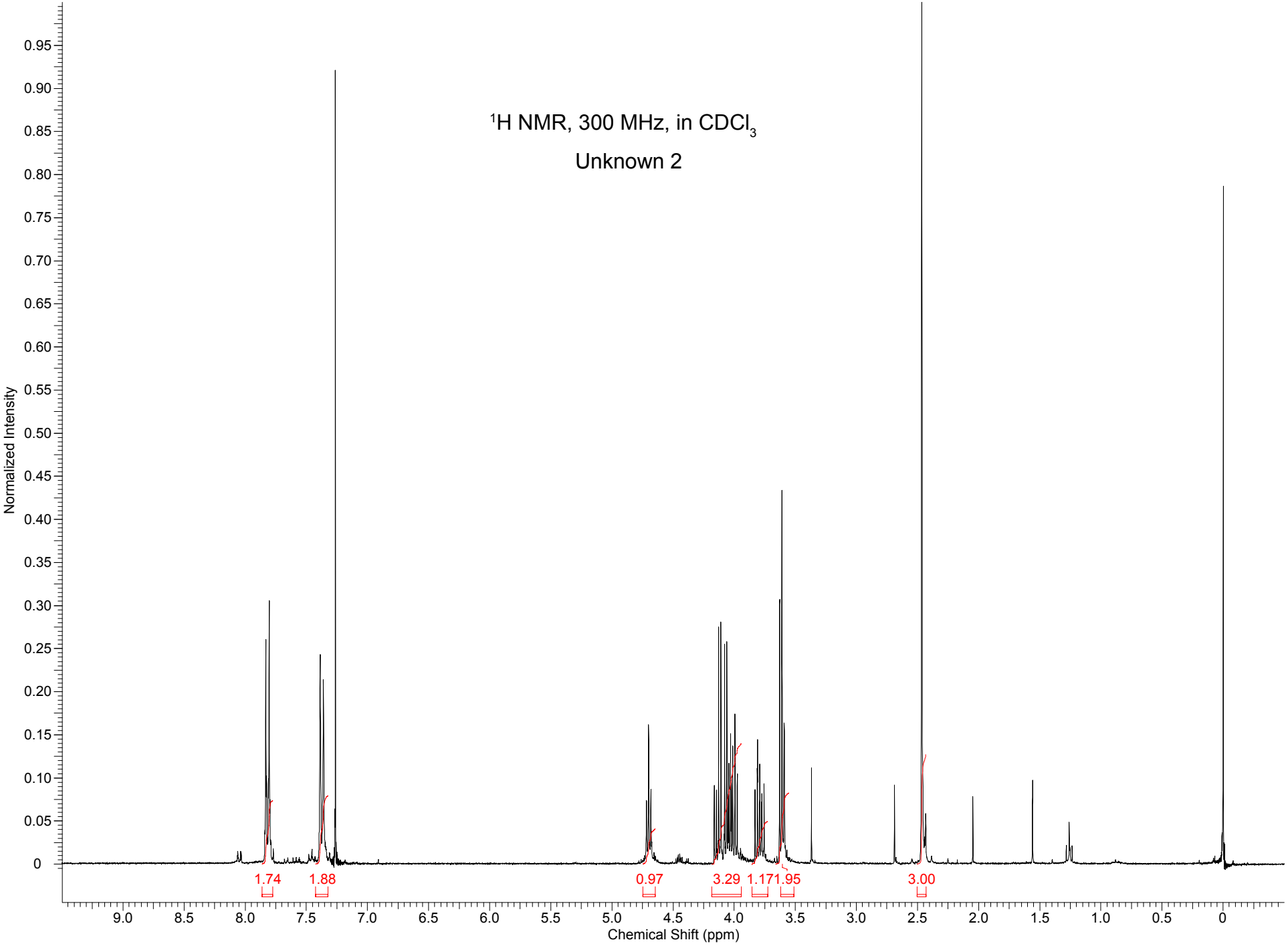
   b. Assign chemical shifts to each proton, as best you can, in your two structures. You do not have to report coupling constants in this problem, though you might find it useful to determine them.

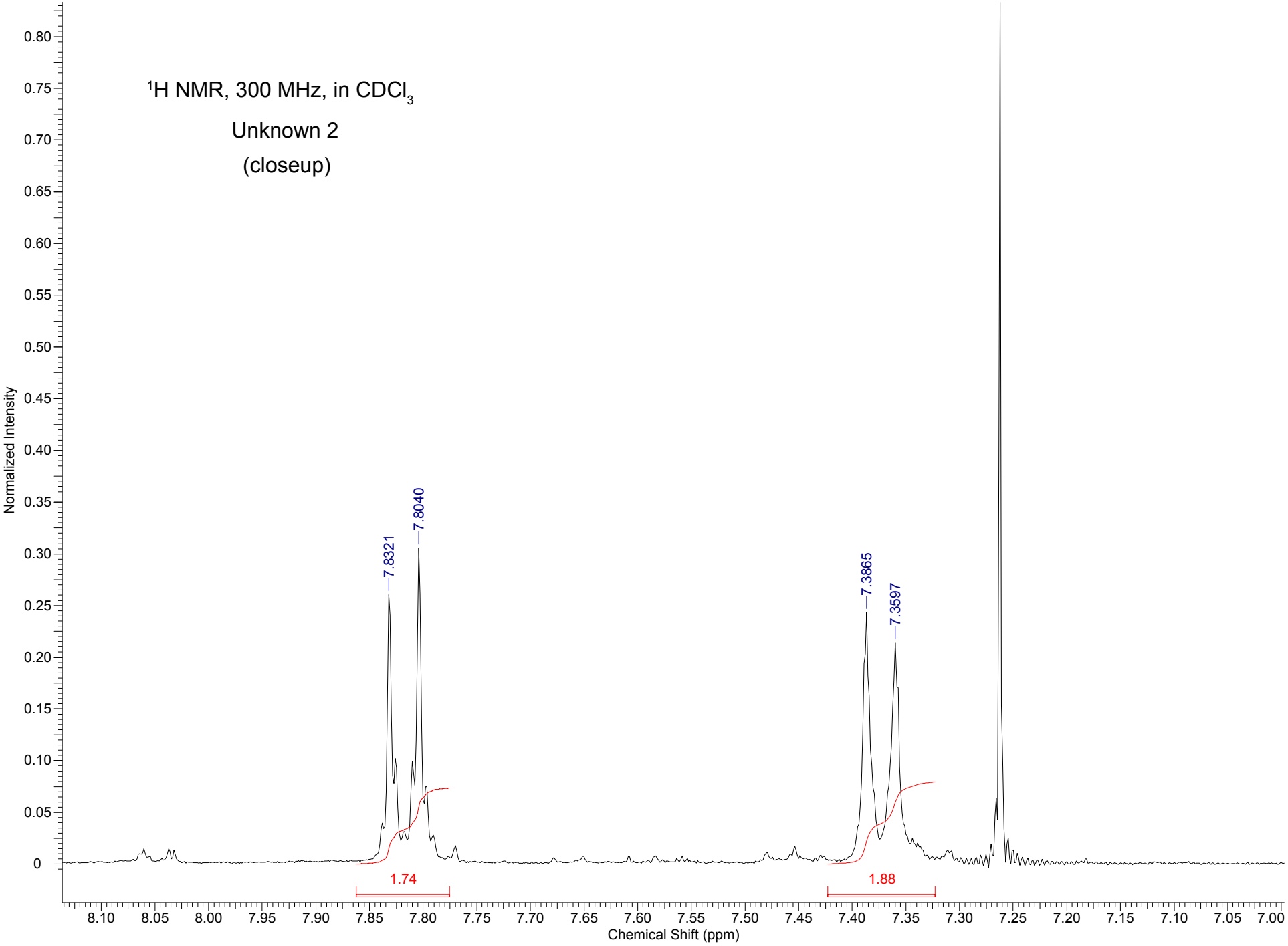

^{1}H NMR, 300 MHz, in $CDCl_3$
Unknown 1
Normalized Intensity
Chemical Shift (ppm)
1.80
1.93
0.83
2.01
1.06
1.27
2.00
3.10

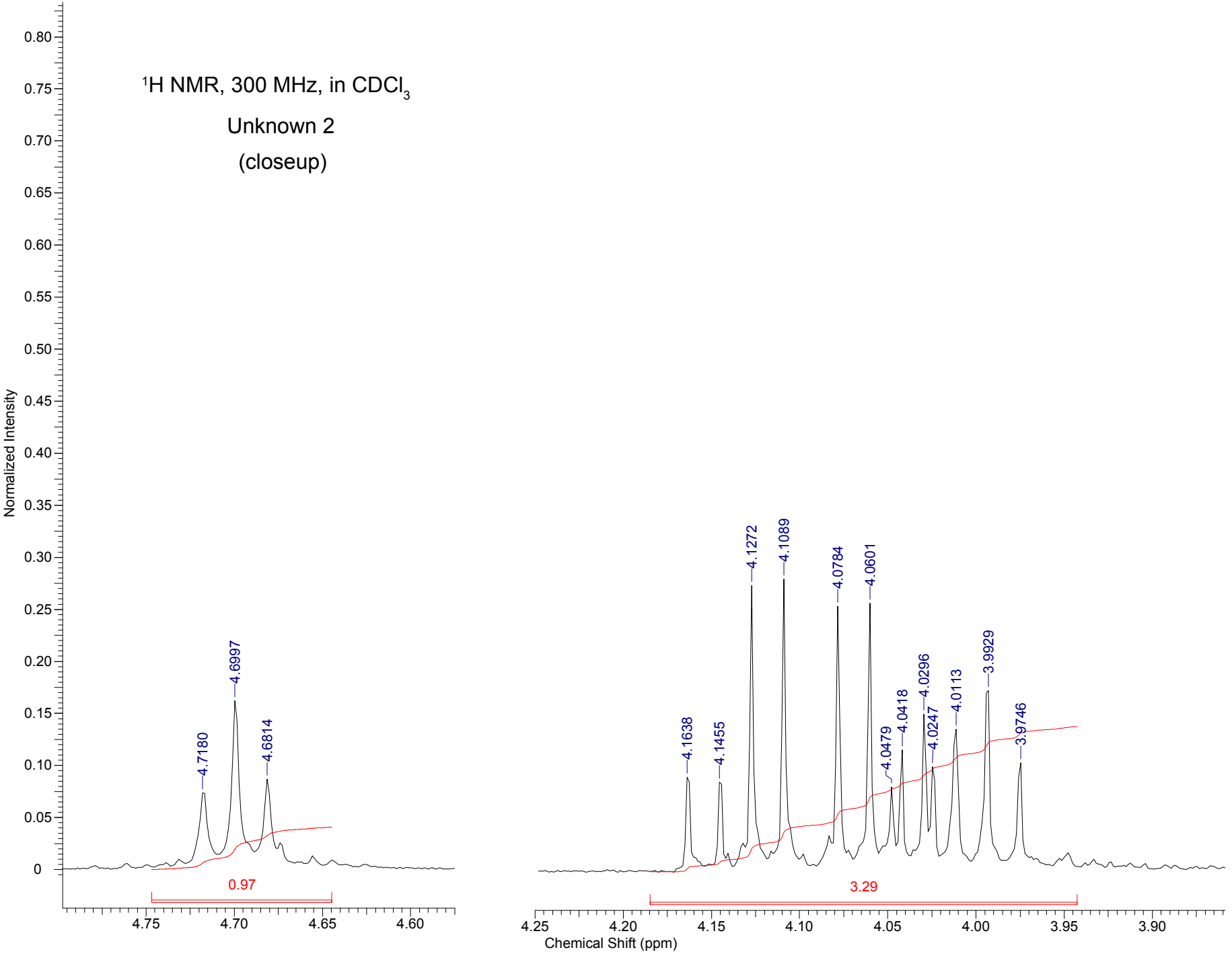

^{1}H NMR, 300 MHz, in $CDCl_3$
Unknown 1
(closeup)
Normalized Intensity
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
7.8284
7.8003
7.3780
7.3511
1.80
1.93
7.95
7.90
7.85
7.80
7.75
7.70
7.65
7.60
7.55
7.50
7.45
7.40
7.35
7.30
7.25
7.20
7.15
Chemical Shift (ppm)

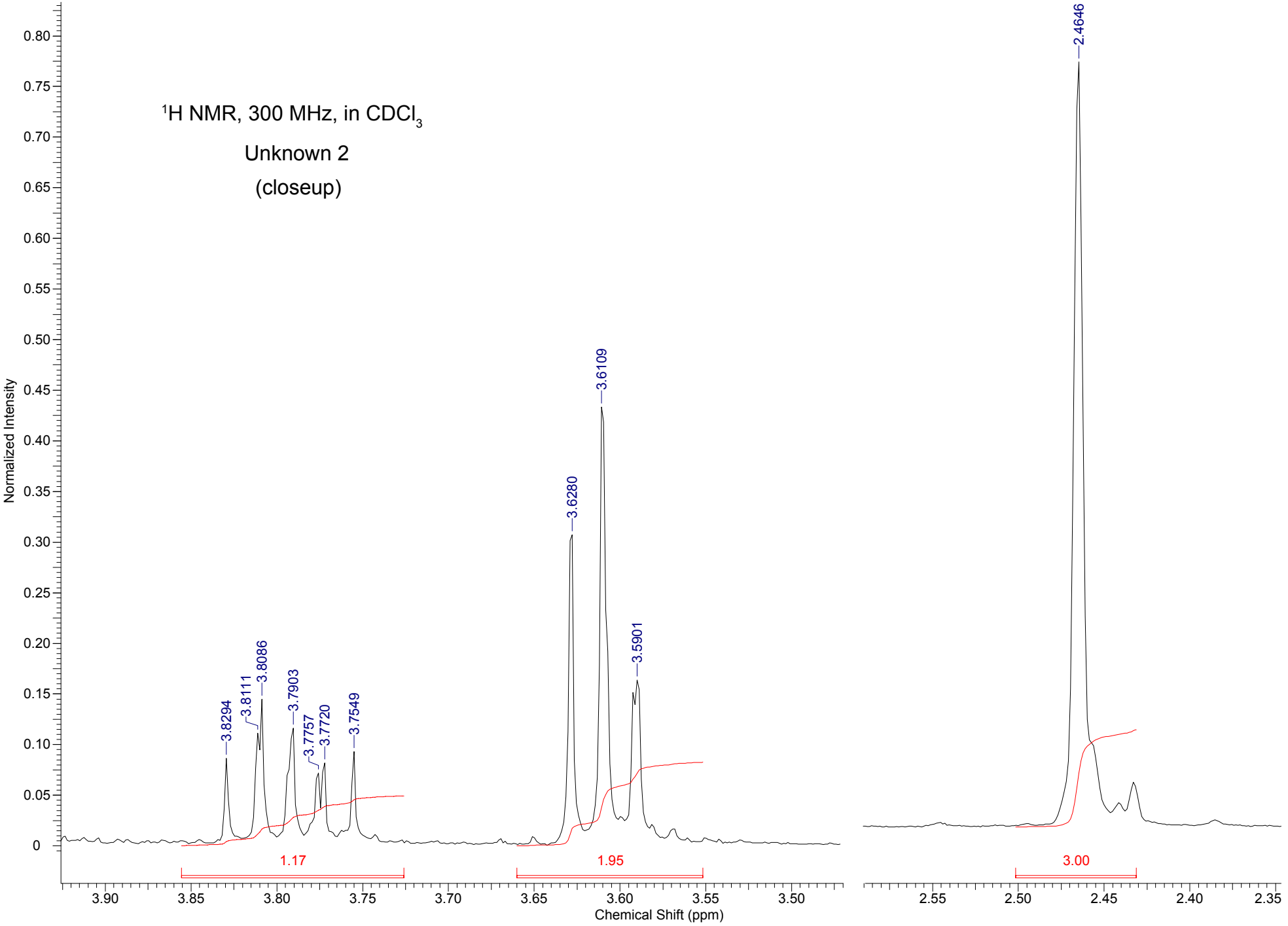

^{1}H NMR, 300 MHz, in $CDCl_3$
Unknown 1
(closeup)
Normalized Intensity
Chemical Shift (ppm)
4.4373
4.4202
4.4043
4.3274
4.3164
4.3042
4.2945
4.2884
4.2786
4.2664
4.2554
4.2493
4.2383
4.2273
4.2163
4.2115
4.2005
4.0576
4.0467
4.0418
4.0308
4.0186
4.0088
4.0027
3.9917
0.83
2.01
1.06


^{1}H NMR, 300 MHz, in $CDCl_3$
Unknown 1
(closeup)
Normalized Intensity
Chemical Shift (ppm)
3.8233
3.8123
3.8013
3.7903
3.7854
3.7732
3.7622
3.7512
3.6988
3.6817
3.6756
3.6585
2.4597
1.27
2.00
3.10

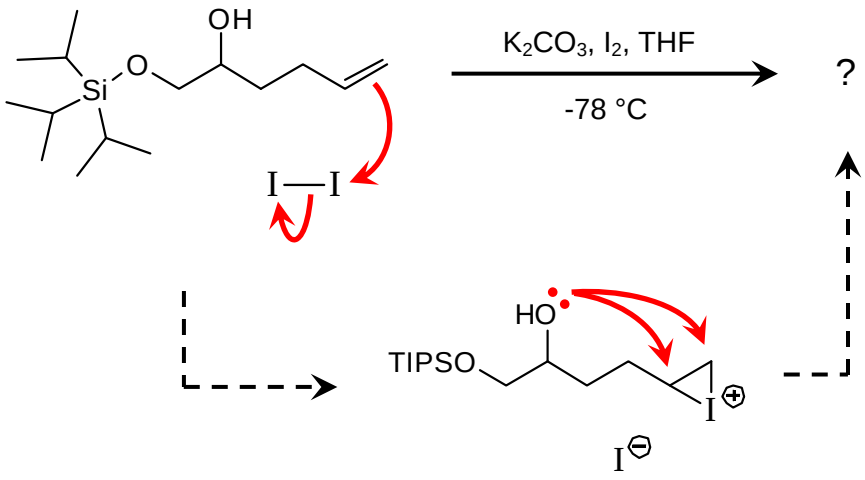

^{1}H NMR, 300 MHz, in $CDCl_3$
Unknown 2
Normalized Intensity
Chemical Shift (ppm)
1.74
1.88
0.97
3.29
1.17
1.95
3.00


^{1}H NMR, 300 MHz, in $CDCl_3$
Unknown 2
(closeup)
Normalized Intensity
Chemical Shift (ppm)
7.8321
7.8040
7.3865
7.3597
1.74
1.88


^{1}H NMR, 300 MHz, in $CDCl_3$
Unknown 2
(closeup)
Normalized Intensity
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
4.7180
4.6997
4.6814
0.97
4.75
4.70
4.65
4.60
4.1638
4.1455
4.1272
4.1089
4.0784
4.0601
4.0479
4.0418
4.0296
4.0247
4.0113
3.9929
3.9746
3.29
4.25
4.20
4.15
4.10
4.05
4.00
3.95
3.90
Chemical Shift (ppm)

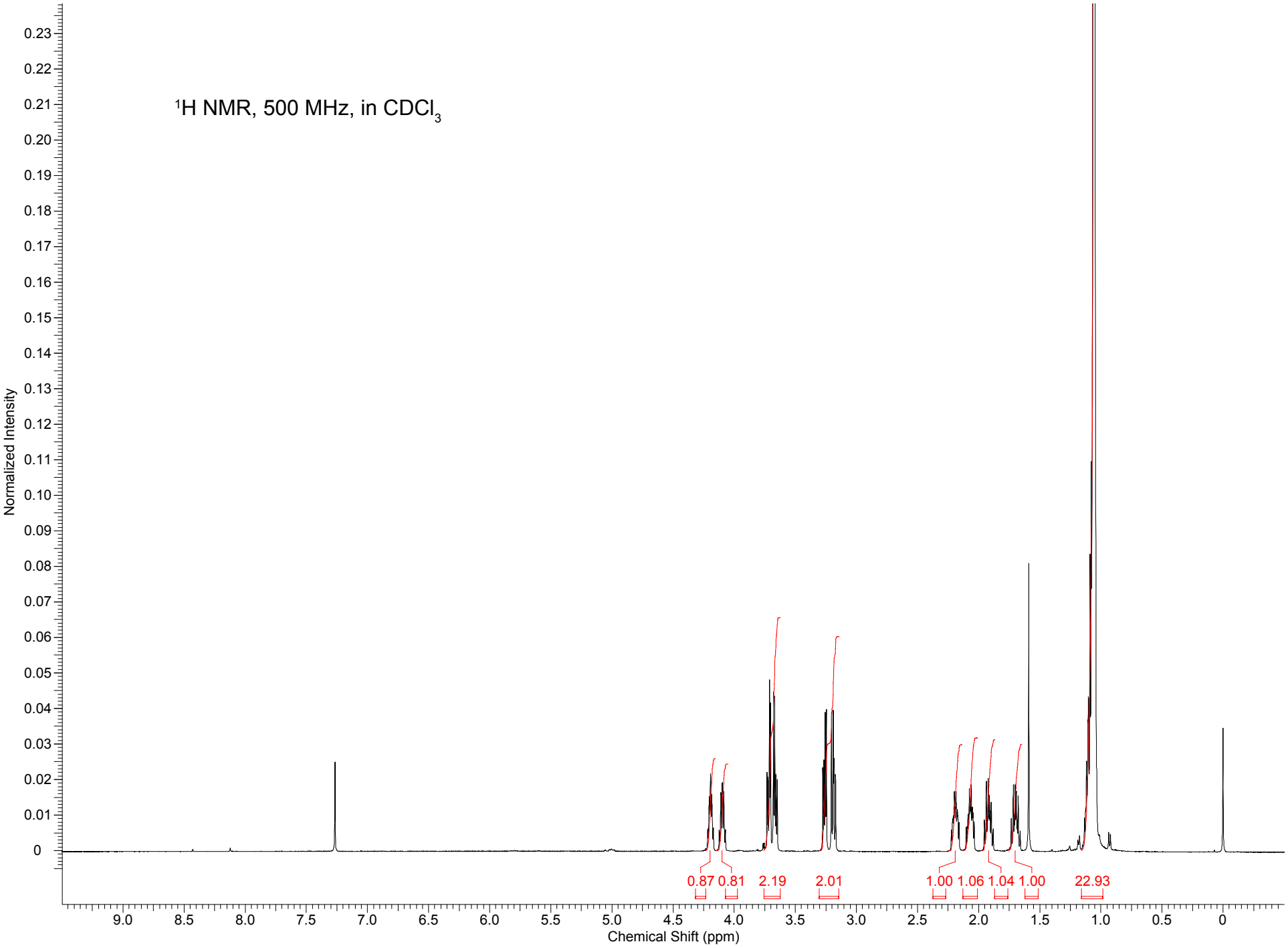

^{1}H NMR, 300 MHz, in $CDCl_3$
Unknown 2
(closeup)
Normalized Intensity
Chemical Shift (ppm)
3.8294
3.8111
3.8086
3.7903
3.7757
3.7720
3.7549
3.6280
3.6109
3.5901
2.4646
1.17
1.95
3.00

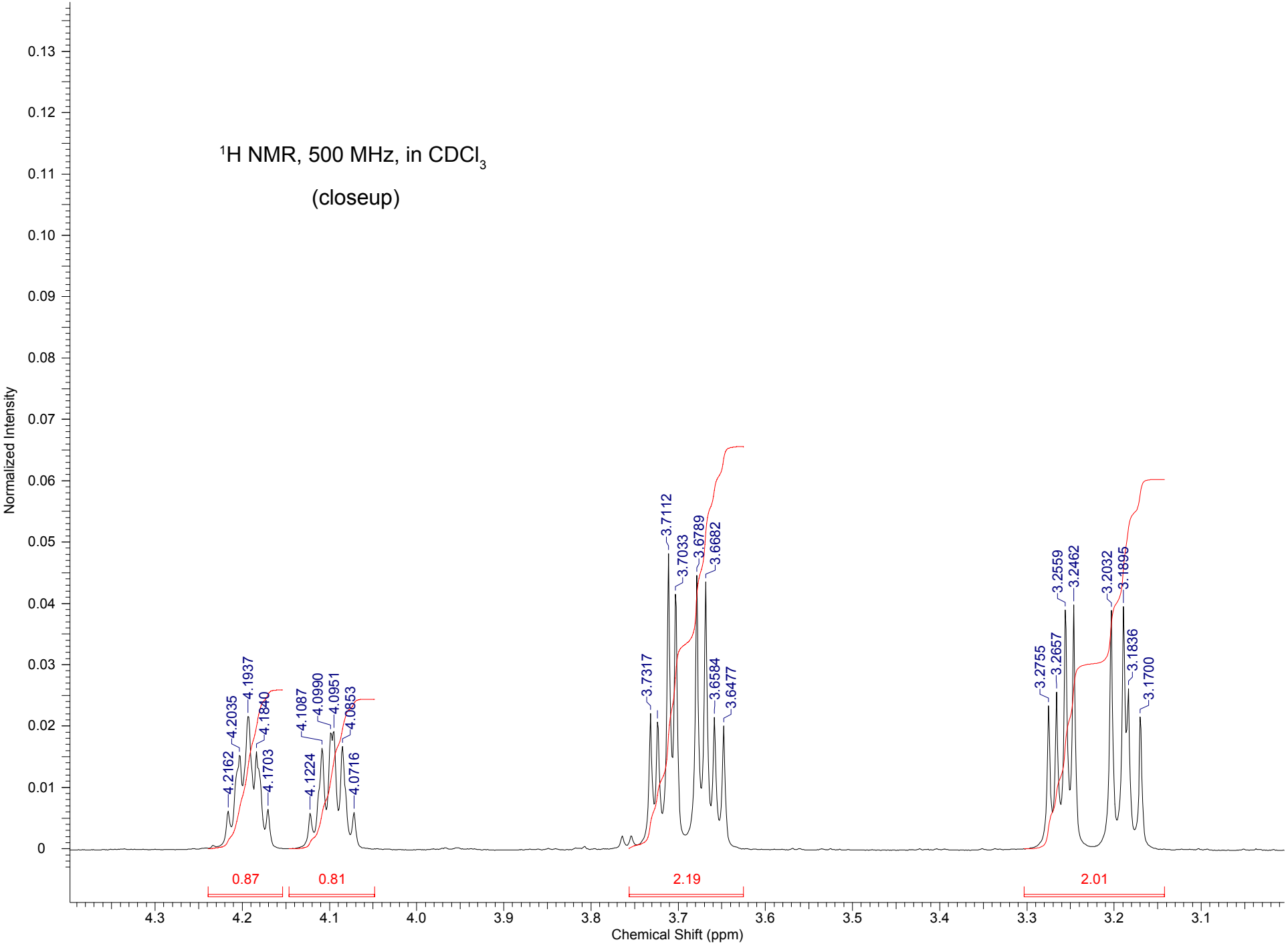
2. Brian Eklov (Hoye group) subjected a triisopropylsilyl (TIPS)-protected 5-hexene-1,2-diol to the iodination conditions below. The result was a single cyclic ether, which presumably formed via intramolecular attack of the free alcohol on an iodonium intermediate. But attack at which carbon?

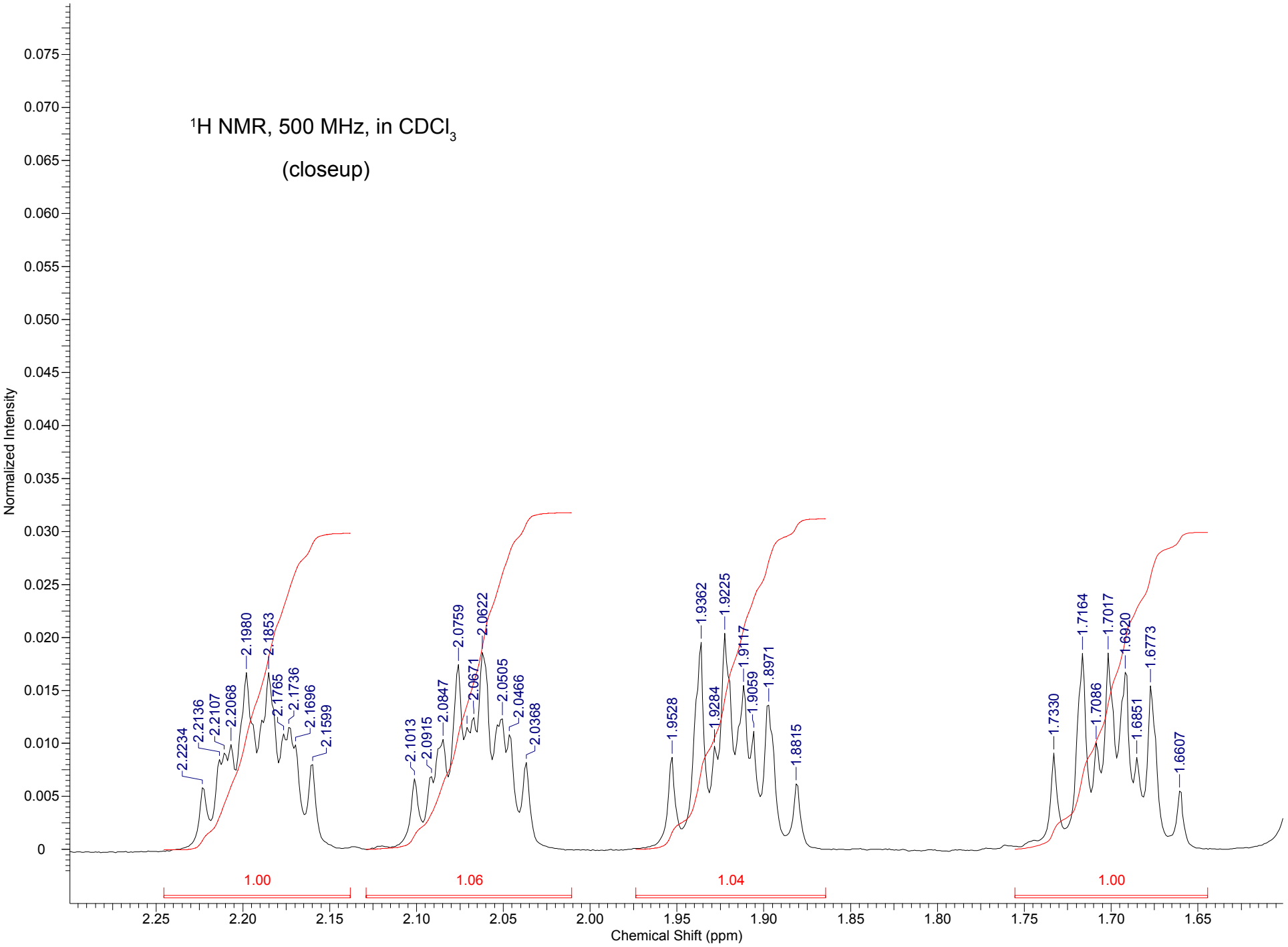


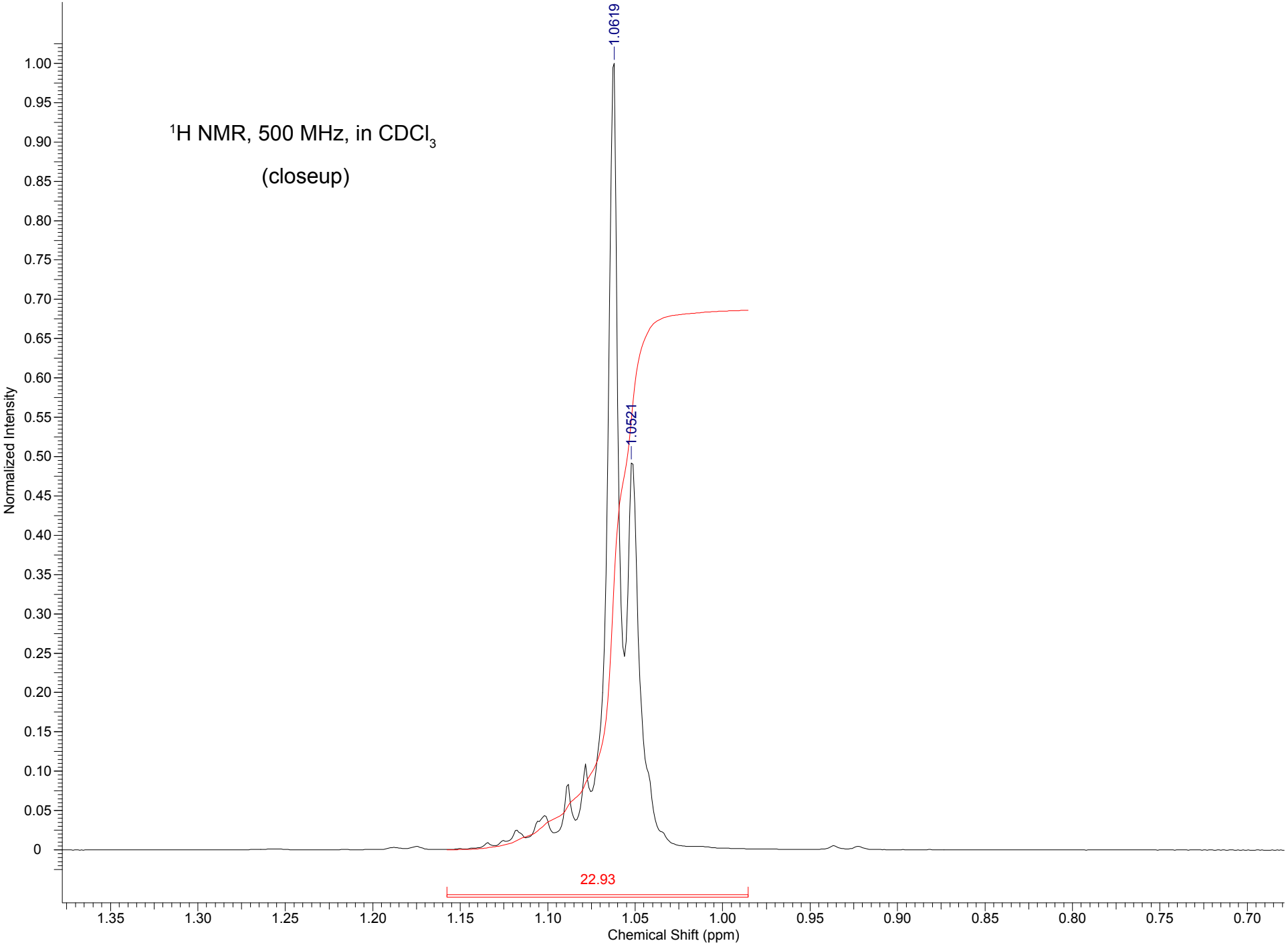
a. Use the attached ^{1}H NMR spectrum (500 MHz, in $CDCl_3$) to determine the regiochemistry of the attack and the identity of the product.

b. I have not drawn any stereochemistry in the molecules above, but the product would contain multiple chiral centers. Does the NMR data tell you anything about relative stereochemistry in the product?

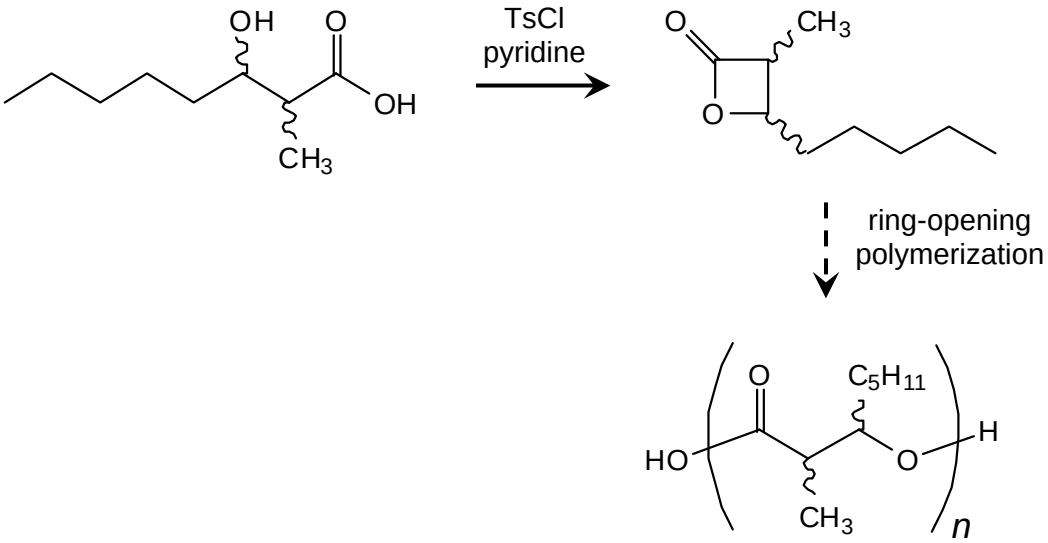

^{1}H NMR, 500 MHz, in $CDCl_3$
Normalized Intensity
Chemical Shift (ppm)
0.87 0.81 2.19 2.01 1.00 1.06 1.04 1.00 22.93


^{1}H NMR, 500 MHz, in $CDCl_3$
(closeup)
Normalized Intensity
Chemical Shift (ppm)
4.2162
4.2035
4.1937
4.1840
4.1703
4.1224
4.1087
4.0990
4.0951
4.0853
4.0716
3.7317
3.7112
3.7033
3.6789
3.6682
3.6584
3.6477
3.2755
3.2657
3.2559
3.2462
3.2032
3.1895
3.1836
3.1700
0.87
0.81
2.19
2.01


^{1}H NMR, 500 MHz, in $CDCl_3$
(closeup)
Normalized Intensity
0.075
0.070
0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0
2.2234
2.2136
2.2107
2.2068
2.1980
2.1853
2.1765
2.1736
2.1696
2.1599
2.1013
2.0915
2.0847
2.0759
2.0671
2.0622
2.0505
2.0466
2.0368
1.9528
1.9362
1.9284
1.9225
1.9117
1.9059
1.8971
1.8815
1.7330
1.7164
1.7086
1.7017
1.6920
1.6851
1.6773
1.6607
1.00
1.06
1.04
1.00
2.25
2.20
2.15
2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
Chemical Shift (ppm)


^{1}H NMR, 500 MHz, in $CDCl_3$
(closeup)
1.0619
1.0521
22.93
Normalized Intensity
Chemical Shift (ppm)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70

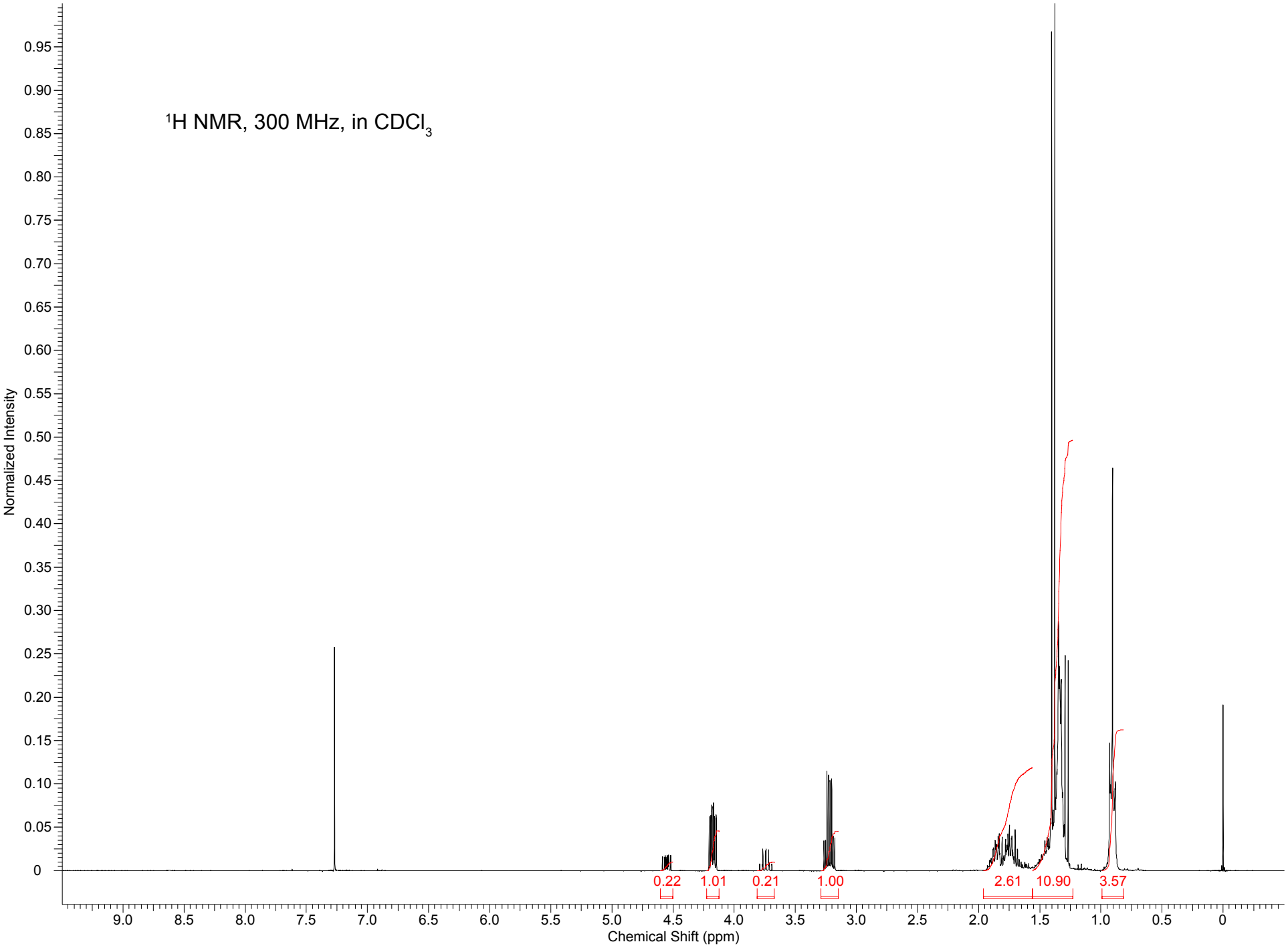
3. Kathleen Schreck (Hillmyer group) performed an intramolecular lactonization reaction on a diastereomeric mixture of β-hydroxy acids to generate a mixture four-membered lactones (cyclic esters) that could be polymerized to polyesters via ring-opening polymerization. One β-hydroxy acid lactonized much more efficiently that the other, leading to diastereomeric excess in the product.

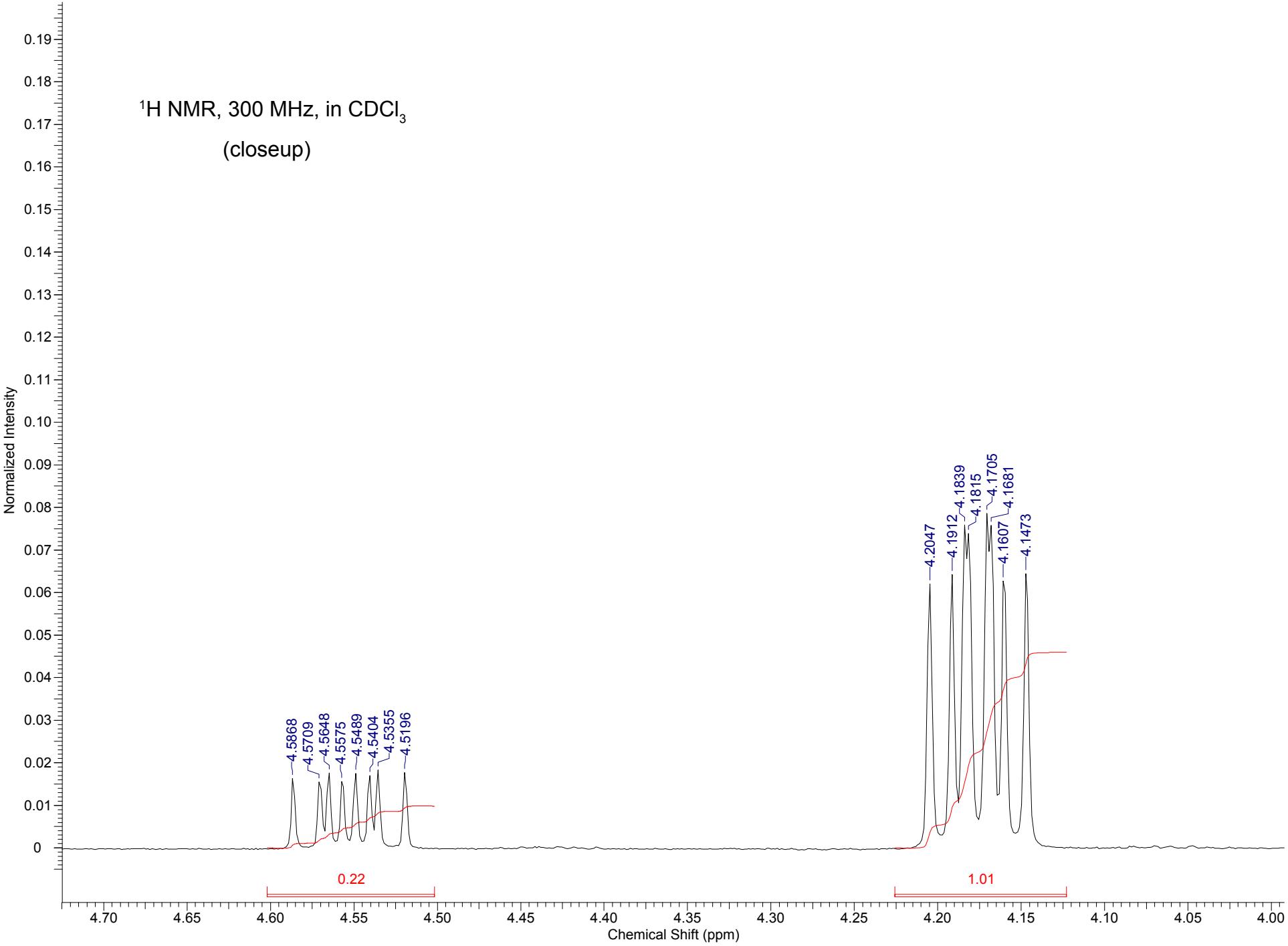


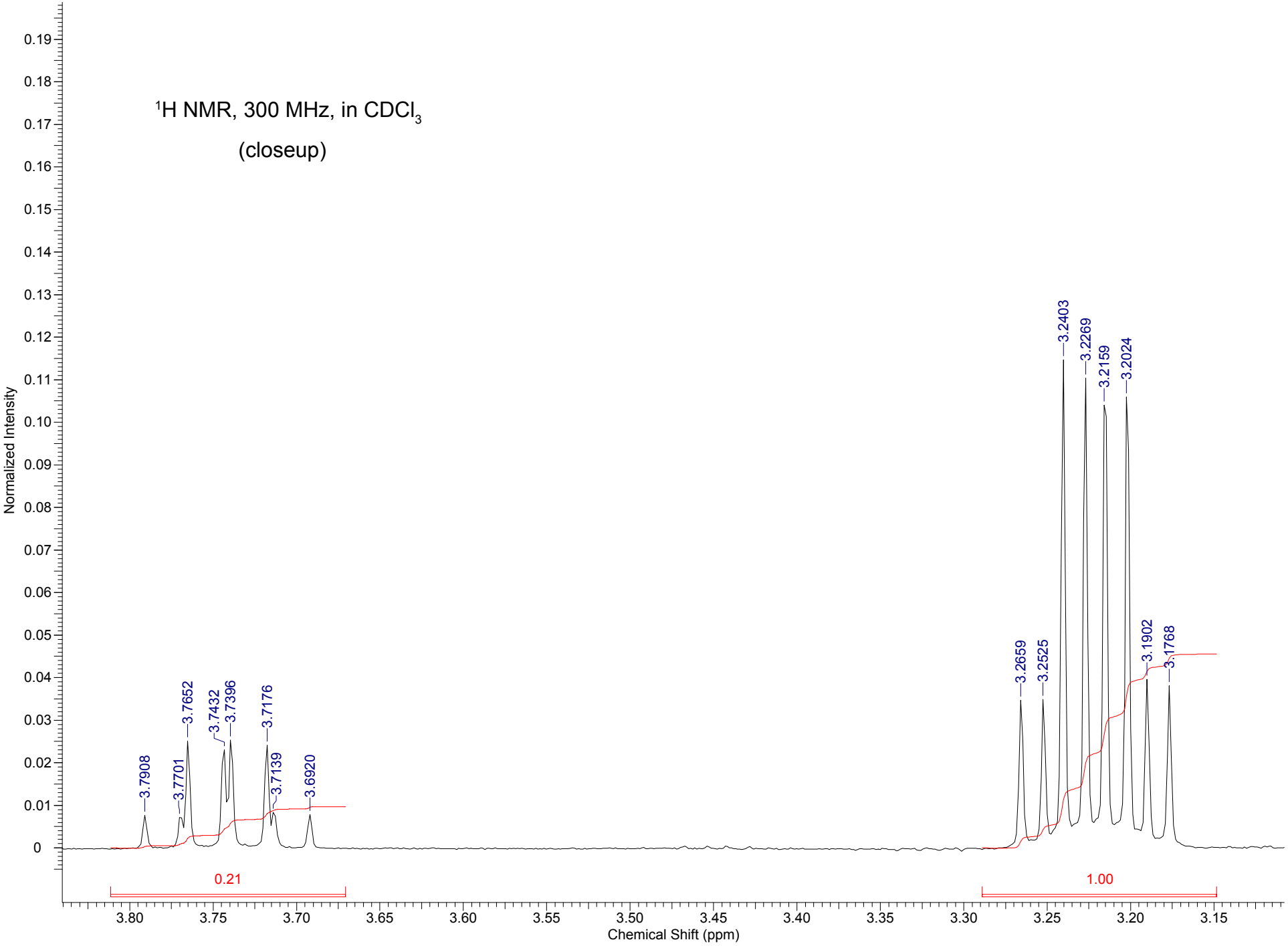
a. Kathleen wasn't able to separate the mixture of diastereomeric lactone products. As a result, the ^{1}H NMR spectrum (300 MHz, in $CDCl_3$) of the mixture shows peaks from both diastereomers. Which resonances go with which diastereomer? How did you make this determination from the NMR spectrum?

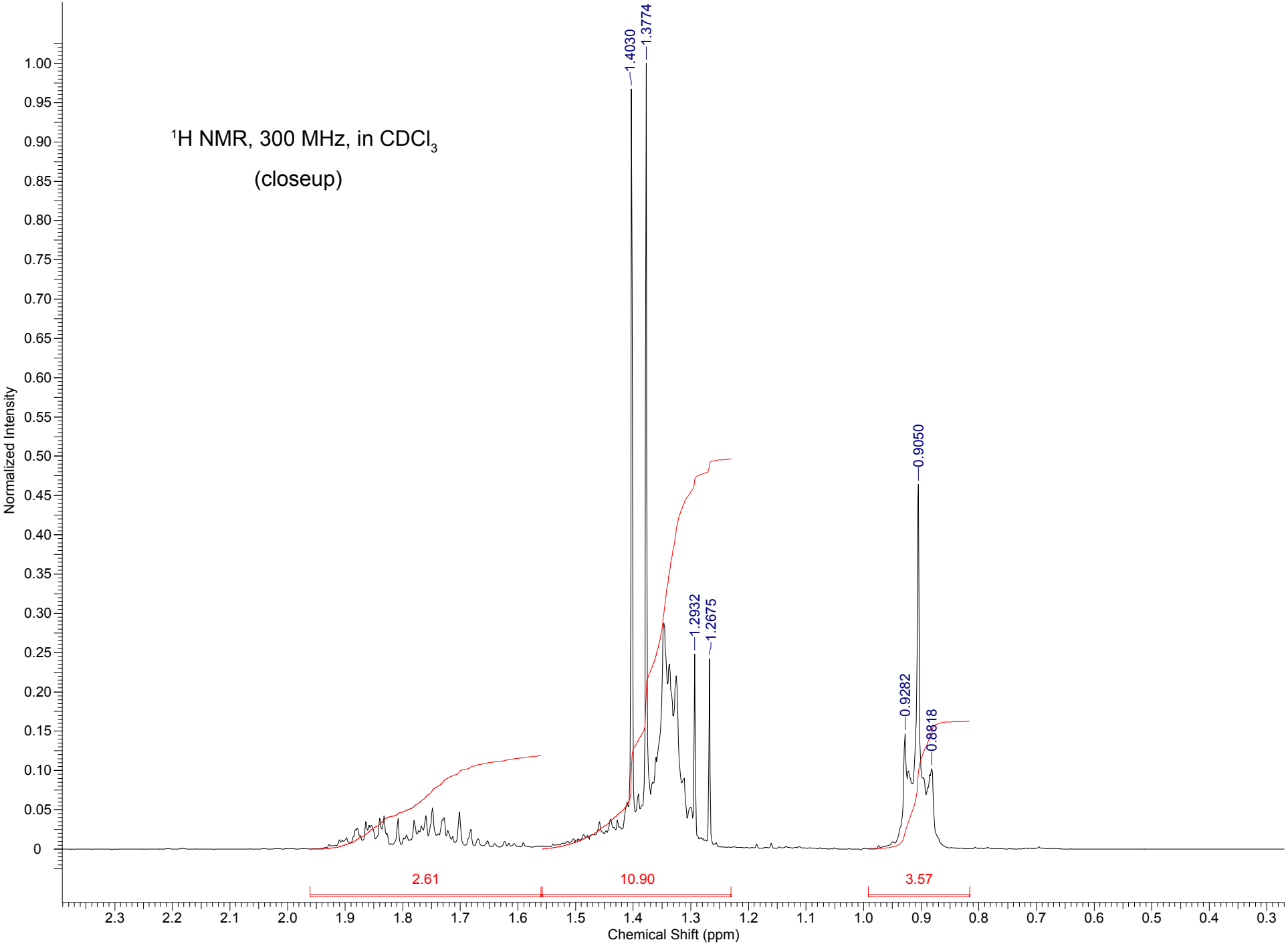
b. What was the diastereomeric excess (%*de*)? The common calculation for this is

%*de* = 2(% dominating stereoisomer) - 100%

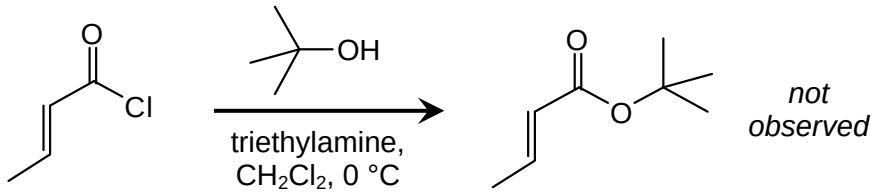

^{1}H NMR, 300 MHz, in $CDCl_3$
Normalized Intensity
Chemical Shift (ppm)
0.22
1.01
0.21
1.00
2.61
10.90
3.57


^{1}H NMR, 300 MHz, in $CDCl_3$
(closeup)
Normalized Intensity
Chemical Shift (ppm)
4.5868
4.5709
4.5648
4.5575
4.5489
4.5404
4.5355
4.5196
4.2047
4.1912
4.1839
4.1815
4.1705
4.1681
4.1607
4.1473
0.22
1.01


^{1}H NMR, 300 MHz, in $CDCl_3$
(closeup)
Normalized Intensity
Chemical Shift (ppm)
3.7908
3.7701
3.7652
3.7432
3.7396
3.7176
3.7139
3.6920
3.2659
3.2525
3.2403
3.2269
3.2159
3.2024
3.1902
3.1768
0.21
1.00


^{1}H NMR, 300 MHz, in $CDCl_3$
(closeup)
1.4030
1.3774
1.2932
1.2675
0.9050
0.9282
0.8818
2.61
10.90
3.57
Normalized Intensity
Chemical Shift (ppm)

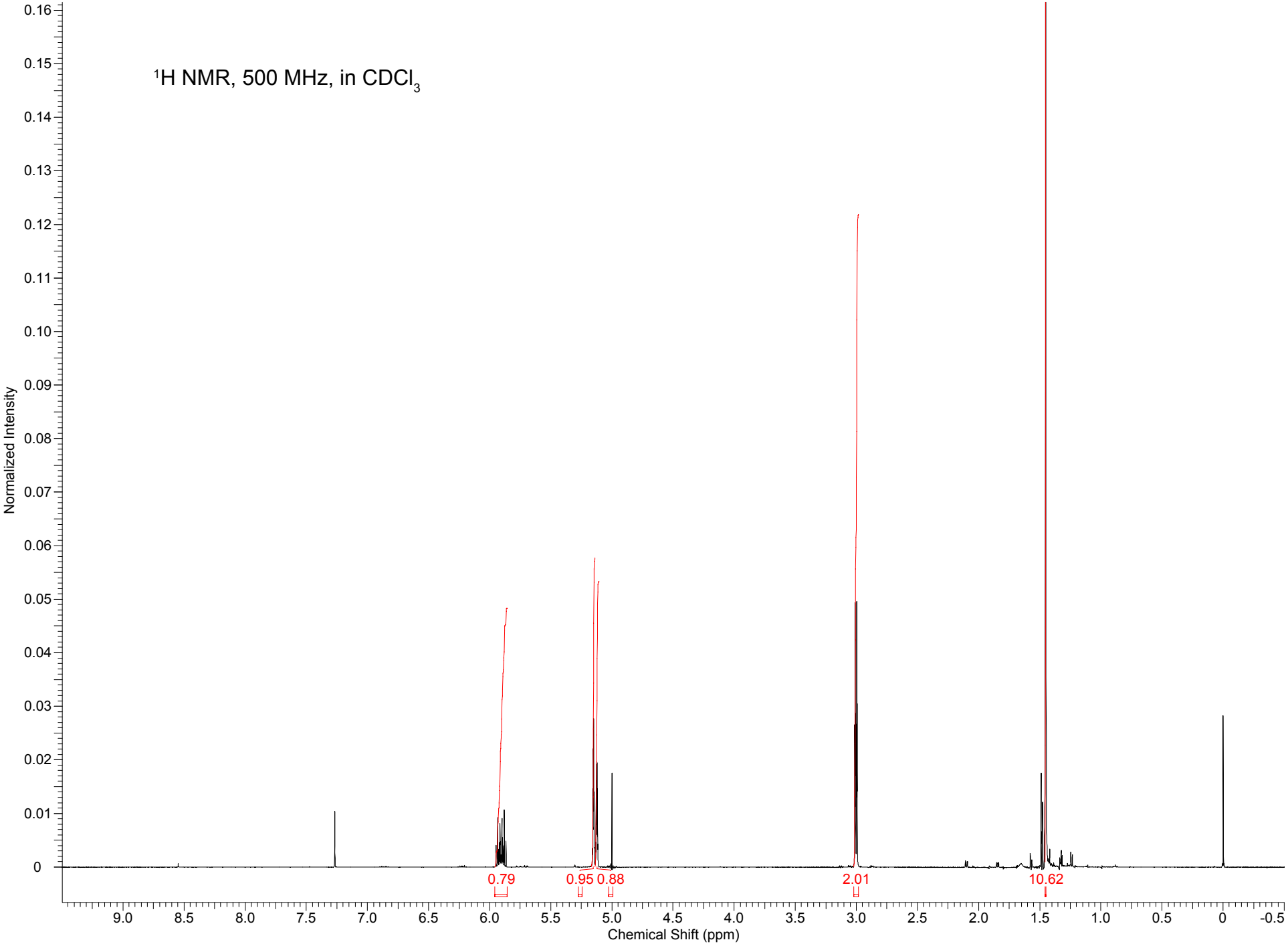
4. Chris Jeffrey (Hoye group) attempted to synthesize *t*-butyl crotonate by condensing crotonyl chloride with *t*-butanol. Chris made something, but it wasn't the product he expected.

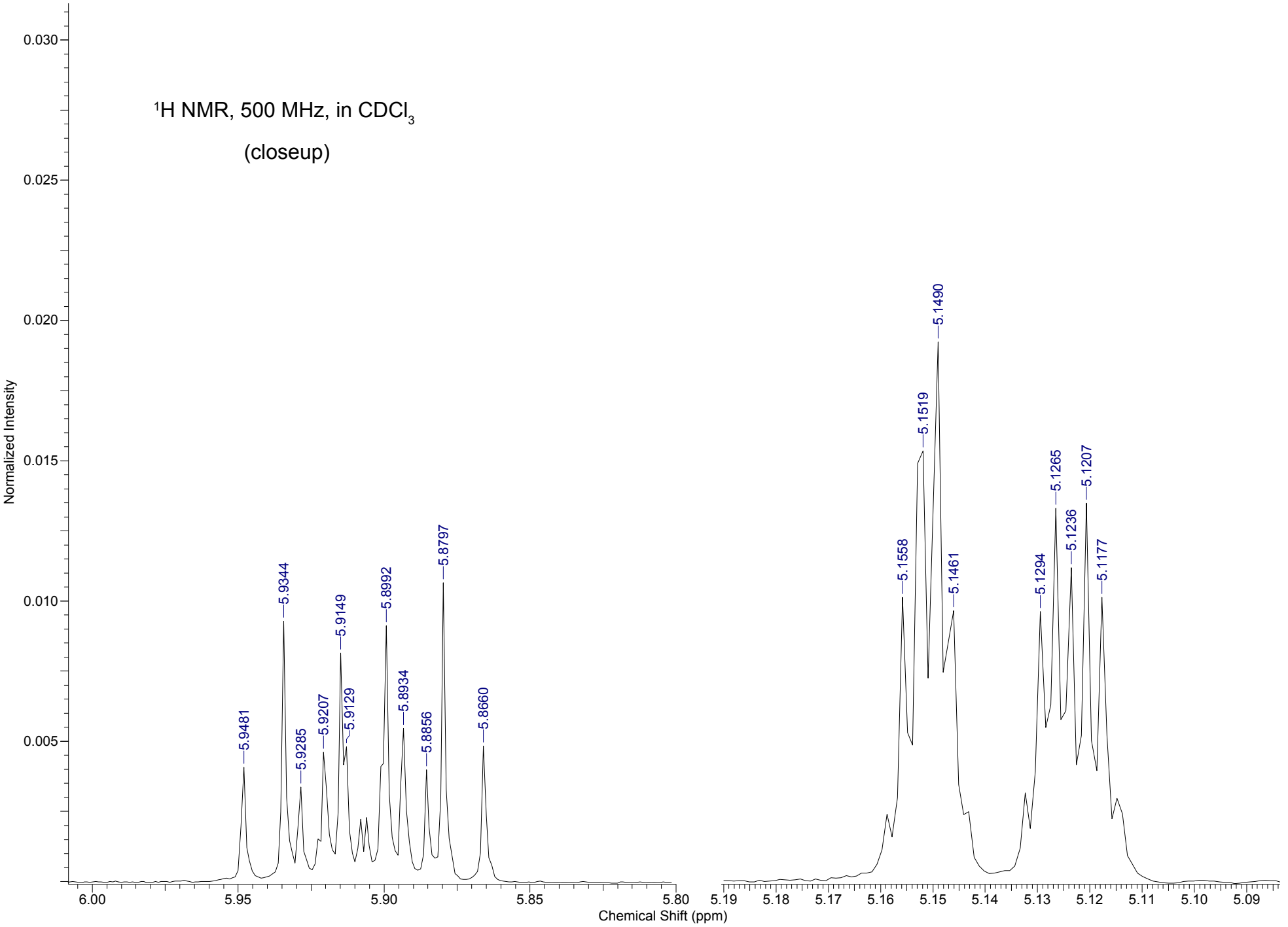


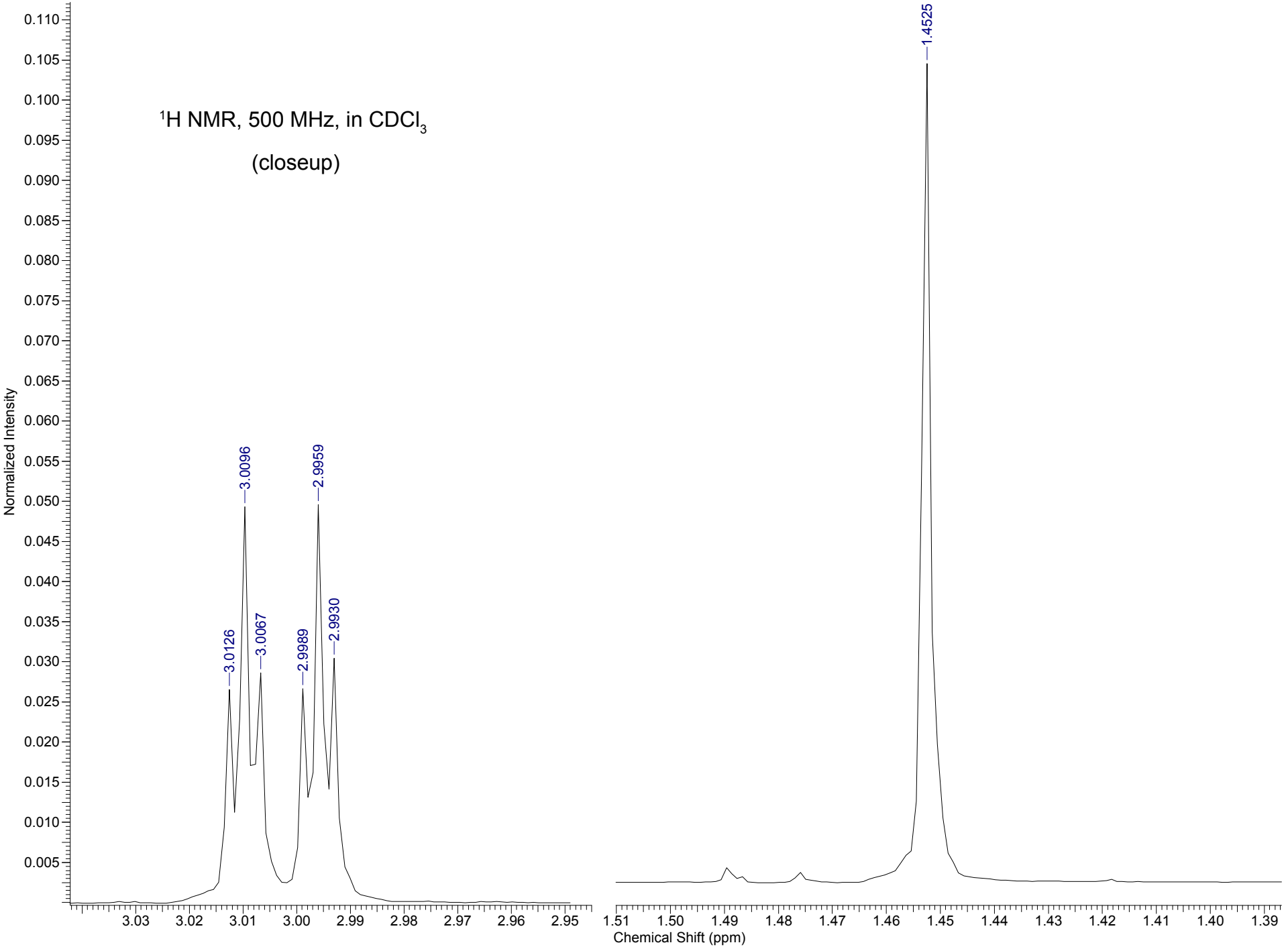
a. Based on the attached ^{1}H (500 MHz, in $CDCl_3$) and ^{13}C (126 MHz, also in $CDCl_3$) NMR spectra, what product did Chris make?

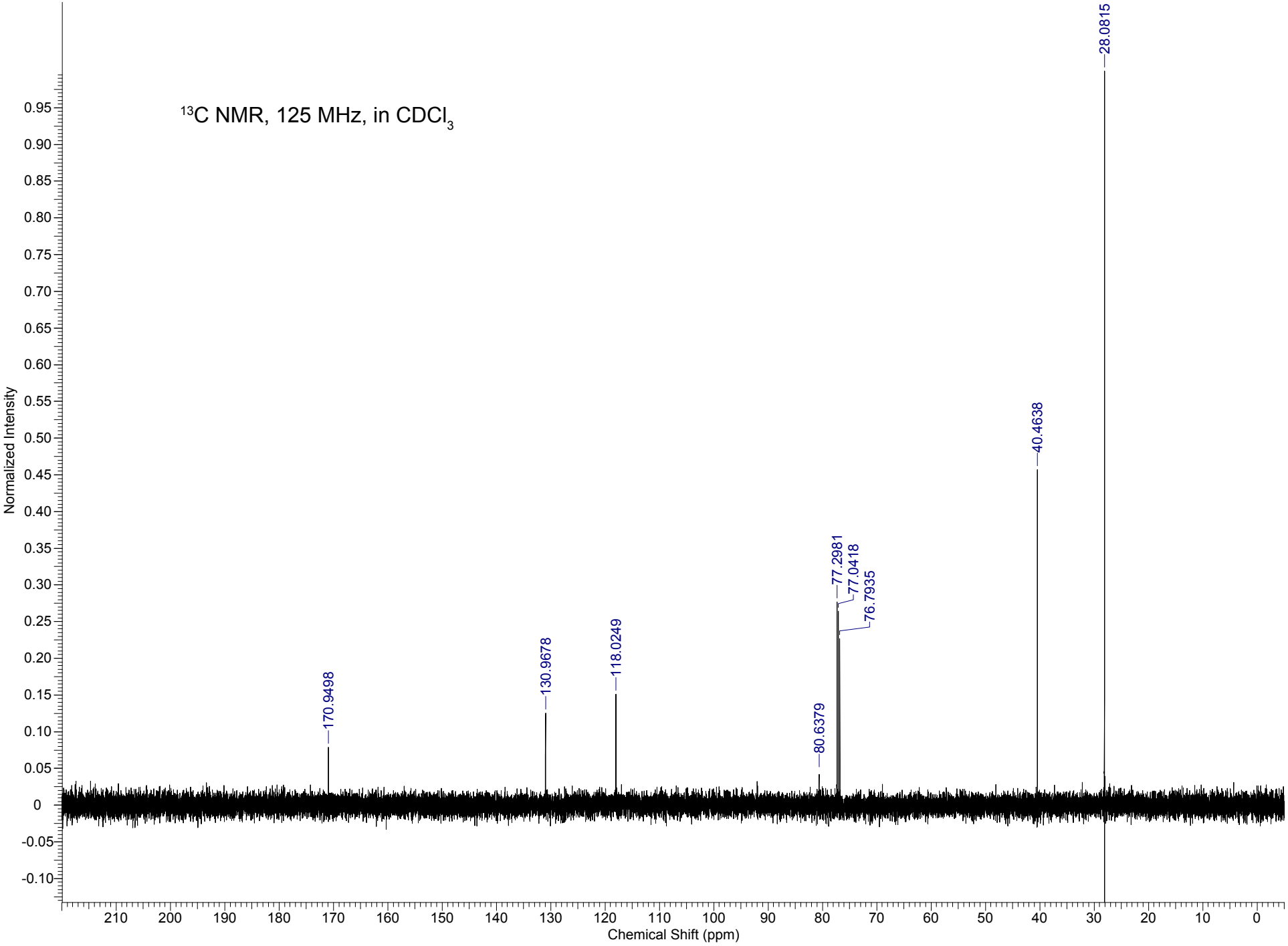
b. The extremely low intensity of the ^{13}C peak at δ = 80.6 ppm initially tripped Chris up—he originally mistook it for noise, and that made it difficult to reconcile the ^{13}C NMR spectrum with the ^{1}H spectrum. Experimentally, what could Chris have done to make that peak stand out? Give as many solutions as you can think of.

c. Why are there three peaks at δ = 77 MHz in the ^{13}C spectrum?


^{1}H NMR, 500 MHz, in $CDCl_3$
Normalized Intensity
Chemical Shift (ppm)
0.79
0.95
0.88
2.01
10.62


^{1}H NMR, 500 MHz, in $CDCl_3$
(closeup)
Normalized Intensity
0.030
0.025
0.020
0.015
0.010
0.005
5.9481
5.9344
5.9285
5.9207
5.9149
5.9129
5.8992
5.8934
5.8856
5.8797
5.8660
5.1558
5.1519
5.1490
5.1461
5.1294
5.1265
5.1236
5.1207
5.1177
6.00
5.95
5.90
5.85
5.80
5.19
5.18
5.17
5.16
5.15
5.14
5.13
5.12
5.11
5.10
5.09
Chemical Shift (ppm)


^{1}H NMR, 500 MHz, in $CDCl_3$
(closeup)
Normalized Intensity
0.110
0.105
0.100
0.095
0.090
0.085
0.080
0.075
0.070
0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
3.0126
3.0096
3.0067
2.9989
2.9959
2.9930
1.4525
3.03
3.02
3.01
3.00
2.99
2.98
2.97
2.96
2.95
1.51
1.50
1.49
1.48
1.47
1.46
1.45
1.44
1.43
1.42
1.41
1.40
1.39
Chemical Shift (ppm)


^{13}C NMR, 125 MHz, in $CDCl_3$
Normalized Intensity
Chemical Shift (ppm)
28.0815
40.4638
77.2981
77.0418
76.7935
80.6379
118.0249
130.9678
170.9498