Supporting Information

Synthesis of novel 1,2,3-triazolyl derivatives of pregnane, androstane and D-homoandrostane. Tandem "Click" reaction/Cu-catalyzed D-homo rearrangement

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3β-hydroxy-16β-chloro-17α-hydroxypregn-5-en-20-one (17a):

A solution of 3β-hydroxy-16α,17α-epoxypregn-5-en-20-one (200.0 mg, 0.605 mmol) in a mixture of acetone (12 mL) and conc. HCl (2.0 mL) was stirred under reflux for 6 h. The solution was diluted with CH_2Cl_2 (30 mL), washed with satd. Na_2CO_3 (30 mL), water (30 mL), dried with anhydrous Na_2SO_4, and evaporated in vacuum. The residue was purified by column chromatography (eluent: hexanes–EtOAc = 2:1). Yield 154.2 mg (69 %). White solid; mp 222–224 °C (lit.[1] 208–212 °C); ^{1}H NMR (400 MHz, $CDCl_3$–CD_3OD) δ 5.32 (d, J = 4.6 Hz, 1H, 6-CH), 4.12 (m, 1H, 16-CHCl), 3.89 (br s, 2H, OH), 3.45 (m, 1H, 3-C*H*OH), 2.60–2.52 (m, 1H), 2.30 (s, 3H, 21-CH_3), 2.29–2.16 (m, 2H), 2.00–1.91 (m, 1H), 1.87–1.76 (m, 2H), 1.69–1.41 (m, 9H), 1.19 (s, 3H, 18-CH_3), 1.10–0.90 (m, 2H), 1.01 (s, 3H, 19-CH_3); ^{13}C NMR (100.6 MHz, $CDCl_3$–CD_3OD) δ 206.4 [C(20)=O], 140.8 (5-C), 120.7 (6-CH), 89.5 (17-C), 71.0 (3-CHOH), 62.6 (16-CHCl), 49.4, 48.9, 46.6 (quat.), 41.6, 37.7, 37.0, 36.3 (quat.), 31.5, 30.9 (2C), 30.8, 27.7, 19.7, 19.1, 14.8.

16β-(phenylthio)-3β,17α-dihydroxypregn-5-en-20-one (17b):

A mixture of 3β-hydroxy-16α,17α-epoxypregn-5-en-20-one (220.0 mg, 0.666 mmol), thiophenol (0.20 mL, 1.94 mmol) and anhydrous K_2CO_3 (84.0 mg, 0.608 mmol) in acetone (2.0 mL) was stirred under reflux for 2 days. The solution was diluted with CH_2Cl_2 (25 mL), washed with satd. Na_2CO_3 (25 mL), water (25 mL), dried with anhydrous Na_2SO_4, and evaporated in vacuum. The residue was purified by column chromatography (eluent: CH_2Cl_2–MeOH = 100:1). Yield 255.0 mg (87 %). White solid; mp 175–177 °C (lit.[2] 178–180 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26–7.20 [m, 2H, 3,5-CH(Ph)], 7.19–7.15 [m, 2H, 2,6-CH(Ph)], 7.14–7.09 [m, 1H, 4-CH(Ph)], 5.33 (d, J = 5.1 Hz, 1H, 6-CH), 3.70 (t, J = 8.6 Hz, 1H, 16-C*H*SPh), 3.51 (tt, J = 11.3, 4.6 Hz, 1H, 3-C*H*OH), 2.44 (ddd, J = 14.7, 8.4, 6.3 Hz, 1H), 2.33 (s, 3H, 21-CH_3), 2.32–2.17 (m, 2H), 2.05–1.94 (m, 1H), 1.87–1.37 (m, 11H), 1.29–1.22 (m, 2H), 1.11–0.94 (m, 2H), 1.07 (s, 3H, 18-CH_3), 1.01 (s, 3H, 19-CH_3); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 209.9 [C(20)=O], 140.7 (5-C), 137.5 [1-C(Ph)], 129.0 [2C, CH(Ph)], 127.7 [2C, CH(Ph)], 125.7 [4-C(Ph)], 121.1 (6-CH), 90.8 (17-C), 71.6 (3-CHOH), 53.6 (16-*C*HSPh), 49.6, 49.4, 49.2 (quat.), 42.2, 37.2, 36.5 (quat.), 35.5, 31.9, 31.5, 31.2, 30.6, 30.0, 20.1, 19.4, 16.2.

3β,16β-diacetoxy-17α-hydroxypregn-5-en-20-one (18a):

A solution of 3β-acetoxy-16α,17α-epoxypregn-5-en-20-one (360.0 mg, 0.966 mmol) in a mixture of acetic acid (13.4 mL) and conc. H_2SO_4 (0.67 mL) was stirred at rt for 6 h. The solution was diluted with CH_2Cl_2 (50 mL), washed with water (50 mL), satd. Na_2CO_3 (2 × 50 mL), dried with anhydrous Na_2SO_4, and evaporated in vacuum. The residue was purified by

column chromatography (eluent: hexanes–EtOAc = 4:1). Yield 140.6 mg (34 %). White solid; mp 170–172 °C (lit.[3] 168–170 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.36 (d, J = 4.2 Hz, 1H, 6-CH), 4.81 (t, J = 7.3 Hz, 1H, 16-C*H*OAc), 4.59 (m, 1H, 3-C*H*OAc), 3.42 (s, 1H, OH), 2.37–2.36 (m, 3H), 2.22 (s, 3H, 21-CH_3), 2.05 [s, 3H, OC(O)CH_3], 2.02 [s, 3H, OC(O)CH_3], 2.02–1.94 (m, 1H), 1.90–1.81 (m, 2H), 1.75–1.35 (m, 9H), 1.19–0.96 (m, 2H), 1.02 (s, 3H, 19-CH_3), 0.93 (s, 3H, 18-CH_3); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 208.7 [C(20)=O], 171.2 [O*C*(O)CH_3], 170.5 [O*C*(O)CH_3], 139.7 (5-C), 122.0 (6-CH), 88.0 (17-C), 83.4 (16-*C*HOAc), 73.7 (3-*C*HOAc), 49.4, 47.7, 47.3 (quat.), 38.0, 36.9, 36.6 (quat.), 33.1, 31.8, 31.1, 30.7, 29.1, 27.7, 21.4, 21.2, 20.2, 19.3, 15.1.

16β-thiocyanato-17α-hydroxypregn-4-ene-3,20-dione (19c):

A mixture of 16α,17α-epoxypregn-4-ene-3,20-dione (227.9 mg, 0.694 mmol) and KSCN (900 mg, 9.26 mmol) in acetic acid (5.0 mL) was stirred at 100 °C for 5 h. The mixture was diluted with CH_2Cl_2 (30 mL), washed with water (30 mL), satd. Na_2CO_3 (2 × 30 mL), dried with anhydrous Na_2SO_4, and evaporated in vacuum. The residue was purified by column chromatography (eluent: CH_2Cl_2–MeOH = 50:1). Yield 102.0 mg (38 %). White solid; mp 236–238 °C (dec.) (lit.[4] 237–239 °C); ^{1}H NMR (400 MHz, $CDCl_3$–CD_3OD) δ 5.68 (s, 1H, 4-CH), 3.59–3.52 (m, 1H, 16-CHSCN), 2.78 (br s, 1H, OH), 2.63–2.55 (m, 2H), 2.43–2.20 (m, 3H), 2.15 (s, 3H, 21-CH_3), 2.02–1.55 (m, 8H), 1.47–1.30 (m, 2H), 1.21–0.90 (m, 2H), 1.13 (s, 3H, 19-CH_3), 0.70 (s, 3H, 18-CH_3); ^{13}C NMR (100.6 MHz, $CDCl_3$–CD_3OD) δ 211.7 [C(20)=O], 200.3 [C(3)=O], 171.7 (5-C), 123.6 (4-CH), 115.4 (SCN), 88.7 (17-C), 53.8, 52.8, 48.3, 48.1 (quat.), 38.4 (quat.), 37.4, 35.3, 35.0, 33.6, 32.5, 31.7, 30.9, 27.4, 20.4, 17.1, 15.1.

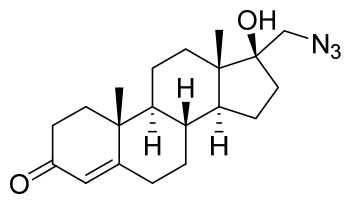
Deacetylation of 12a:

3β,17α-dihydroxy-16β-(4-phenyl-1H-1,2,3-triazol-1-yl)-17β-methyl-D-homoandrost-5-en-17a-one (S1):

A suspension of **12a** (15.9 mg, 30.7 μmol) and K_2CO_3 (8.6 mg, 62 μmol) in the mixture of MeOH (1 mL), THF (0.3 mL) and water (0.1 mL) was heated under reflux for 20 min. The solution was diluted with CH_2Cl_2 (20 mL), washed with water (2 × 20 mL), dried with anhydrous Na_2SO_4, and evaporated in vacuum. The residue was subjected to column chromatography (eluent: CH_2Cl_2–MeOH = 30:1) to afford the pure product. Yield 12.9 mg (88 %). White solid; mp 291–293 °C; ^{1}H NMR (400 MHz, CD_2Cl_2–CD_3OD) δ 7.97 [s, 1H, CH(triazole)], 7.78–7.73 [m, 2H, 2,6-CH(Ph)], 7.39–7.32 [m, 2H, 3,5-CH(Ph)], 7.26 [tt, J = 7.4, 1.7 Hz, 1H, 4-CH(Ph)], 5.27 (m, 1H, 6-CH), 4.39 (dd, J = 12.8, 4.3 Hz, 1H, 16-CH), 3.37 (tt, J = 11.1, 4.7 Hz, 1H, 3-C*H*OH), 2.54 (q, J = 13.3 Hz, 1H, 15β-CH), 2.45–2.33 (m, 3H, 15α-CH + 2

OH), 2.26–2.08 (m, 3H), 1.93 (m, 1H), 1.84–1.62 (m, 4H), 1.59–1.34 (m, 4H), 1.26 (ddd, *J* = 13.0, 10.5, 2.8 Hz, 1H), 1.17 (s, 3H, 17-CCH3), 1.05–0.91 (m, 2H), 1.02 (s, 3H, 18-CH3), 0.97 (s, 3H, 19-CH3); ^{13}C NMR (100.6 MHz, CD_2Cl_2–CD_3OD) δ 215.7 [C(17a)=O], 147.5 [C(triazole)], 141.5 (5-C), 131.2 [1-C(Ph)], 129.4 [2C, CH(Ph)], 128.7 [4-CH(Ph)], 126.2 [2C, CH(Ph)], 122.3 [6-CH or CH(triazole)], 120.9 [6-CH or CH(triazole)], 79.0 (17-COH), 71.7 (3-CHOH), 69.5 (16-CH), 49.7, 48.5, 47.4 (quat.), 42.3, 37.41, 37.37 (quat.), 33.4, 32.2, 31.9, 31.4, 26.3, 23.3, 19.9, 19.7, 16.4; HRMS (MALDI-TOF) calcd for $C_{29}H_{38}N_3O_3$ [M+H]+ 476.2913; found 476.2911.

1. V. Schwarz and K. Syhora, *Collect. Czech. Chem. Commun.*, 1963, **28**, 637.
2. N. Bischofberger and K. A. M. Walker, *J. Org. Chem.*, 1985, **50**, 3604.
3. A. A. Akhrem, V. A. Dubrovskii, A. V. Kamernitskii and A. V. Skorova, *Bull. Acad. Sci. USSR, Div. Chem. Sci. (Engl. Transl.)*, 1969, **18**, 2620.
4. T. Komeno, *Chem. Pharm. Bull.*, 1960, **8**, 680.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H
H
O

4

7.25
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3.50
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2.37
2.35
2.35
2.29
2.27
2.03
2.02
2.01
1.69
1.69
1.66
1.65
1.62
1.61
1.60
1.48
1.43
1.38
1.17
1.14
0.93
0.92
0.89
0.05 - HMD
0.92
1.01
1.00
4.08
5.26
5.29
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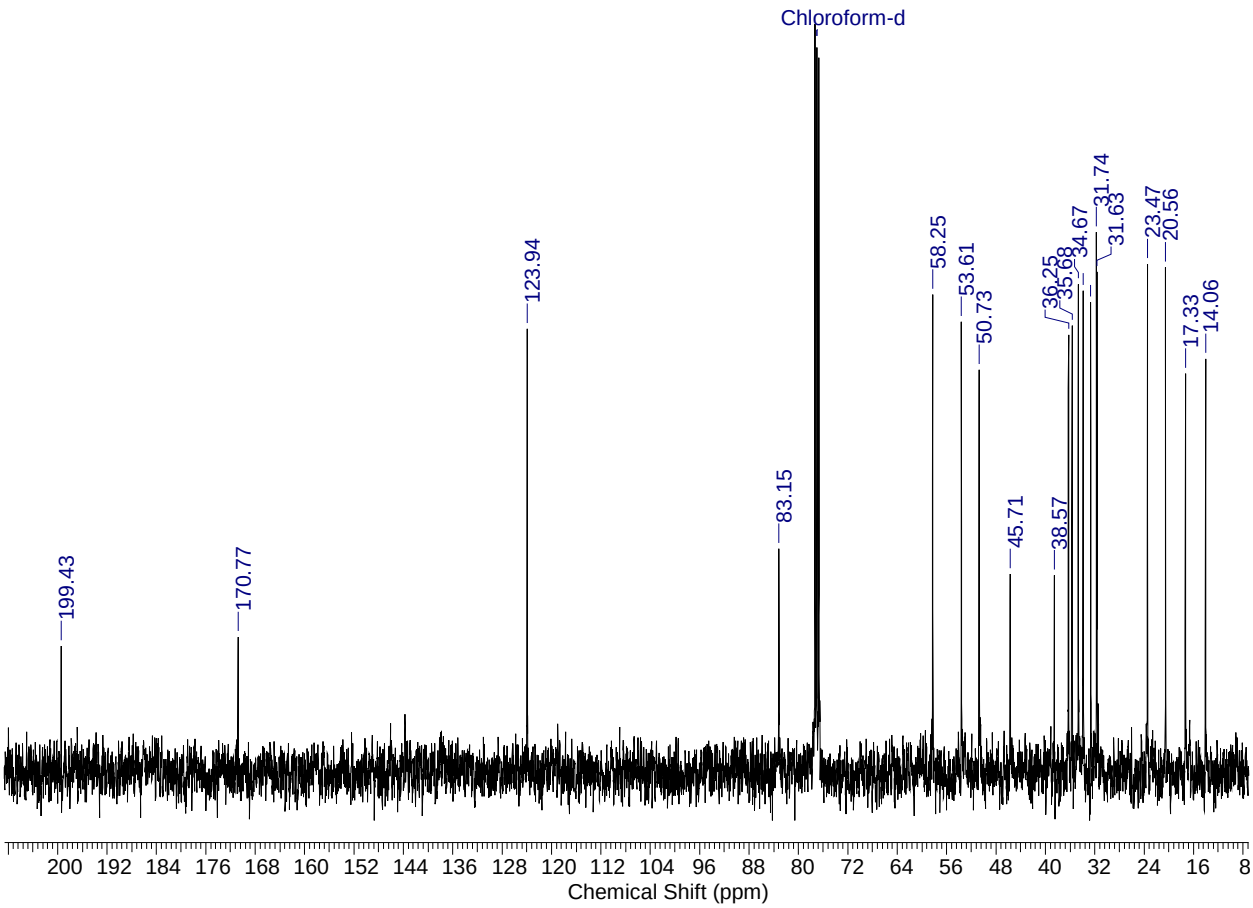
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31.74
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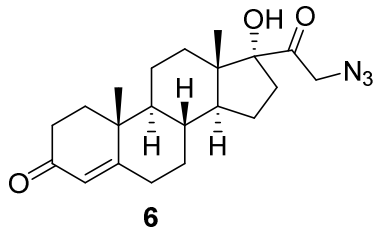
Chemical Shift (ppm)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H
H
O

6

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4.22
2.70
2.67
2.64
2.44
2.41
2.40
2.37
2.32
2.29
2.01
1.88
1.85
1.79
1.69
1.62
1.59
1.53
1.42
1.40
1.38
1.24
1.10
0.97
0.95
0.05-HMDS
1.00
1.17
1.02
1.19
1.05
4.33
1.12
2.92
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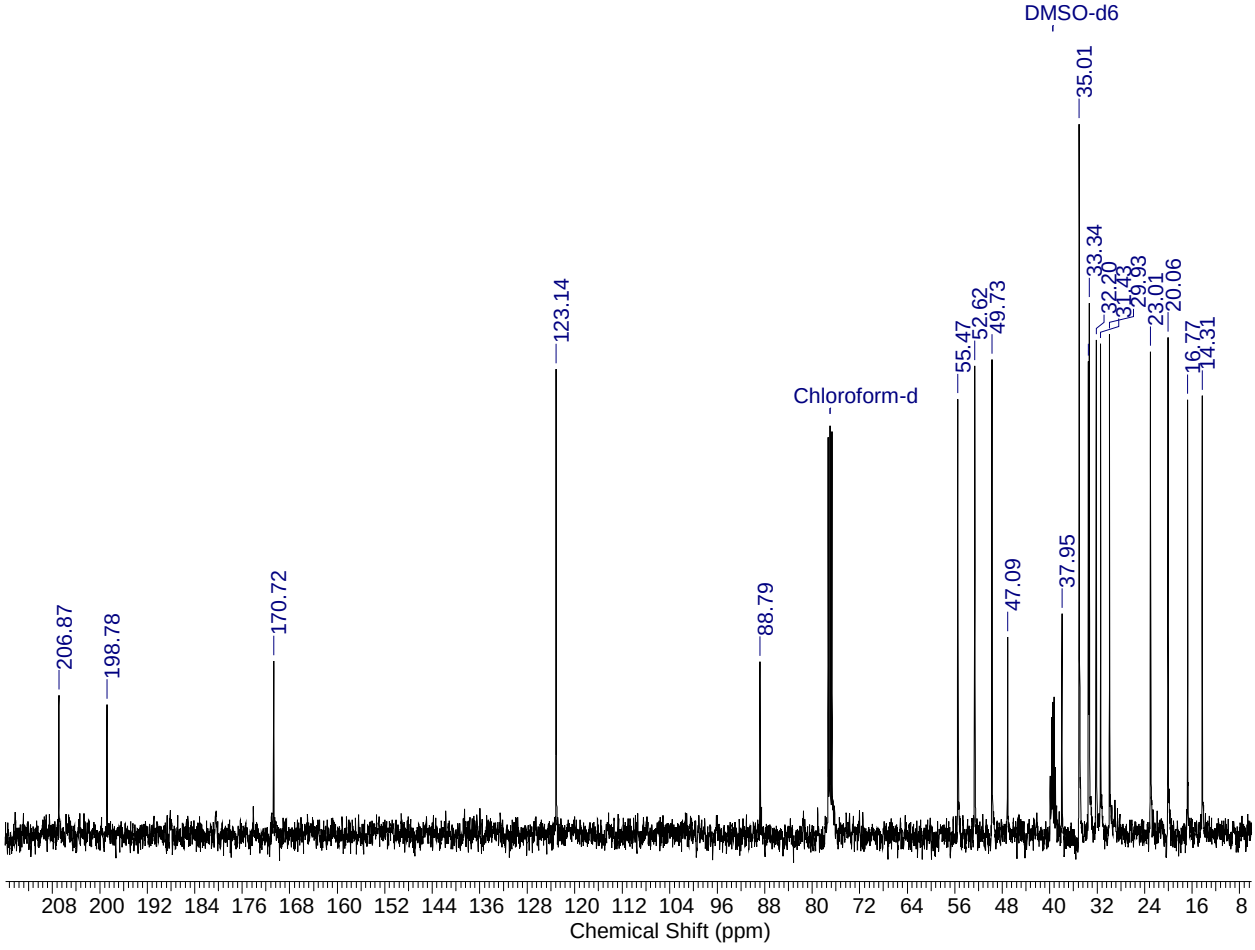
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23.01
20.06
16.77
14.31
206.87
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37.95
47.09
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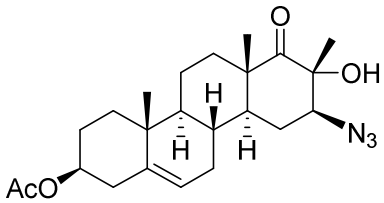
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H
H
H
N3
AcO

8

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5.36
4.58
3.54
3.53
3.51
3.50
2.38
2.36
2.34
2.33
2.31
2.17
1.96
1.88
1.85
1.65
1.61
1.59
1.57
1.53
1.24
1.15
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0.99
0.97
1.00
3.15
3.43
3.08
3.31
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6.5
6.0
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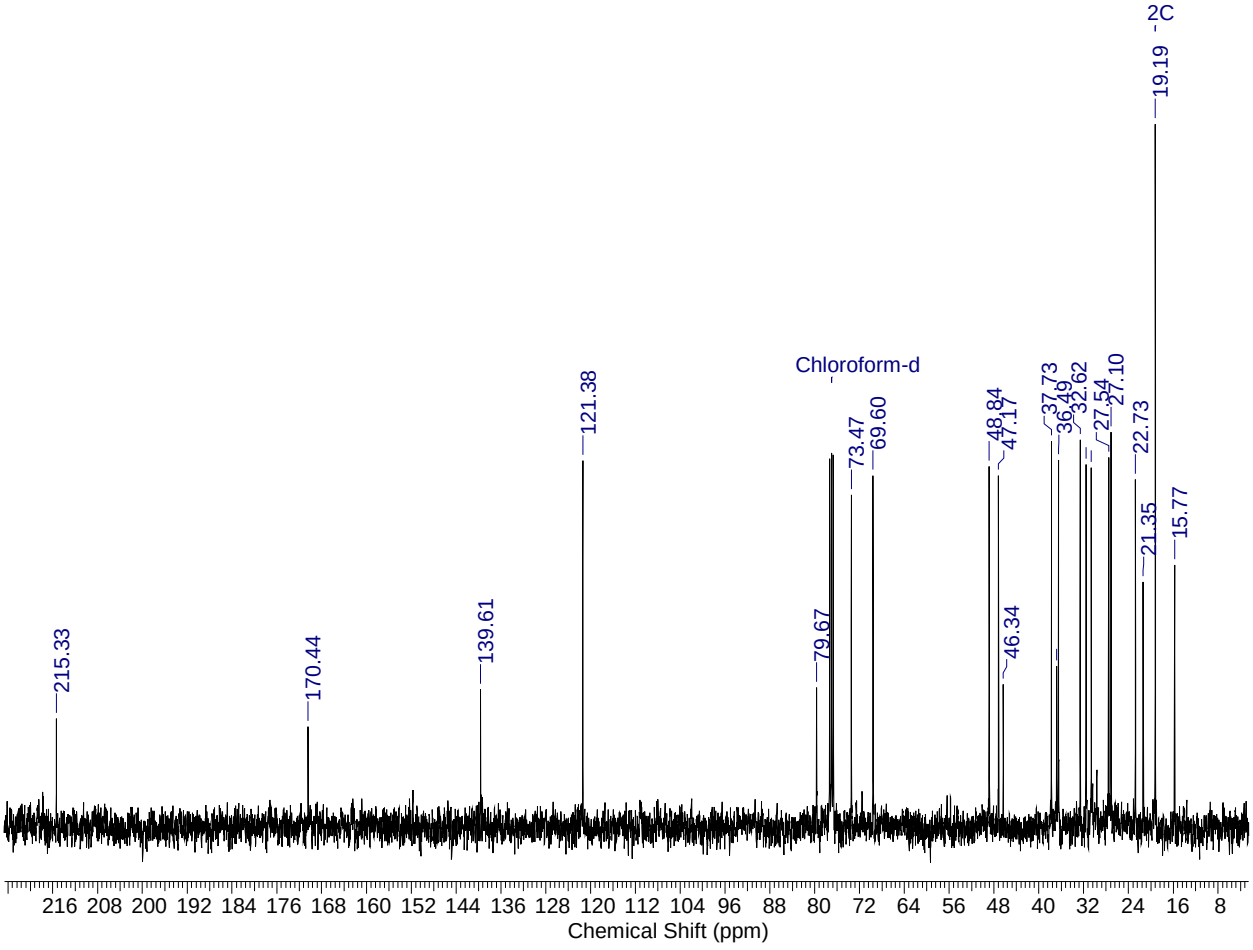
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21.35
15.77
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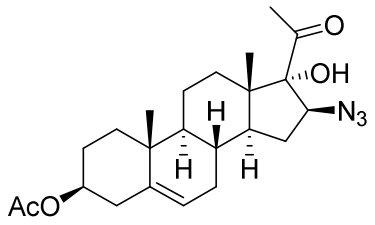
Chemical Shift (ppm)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H
H
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9

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2.30
1.86
1.83
1.64
1.62
1.48
1.46
1.40
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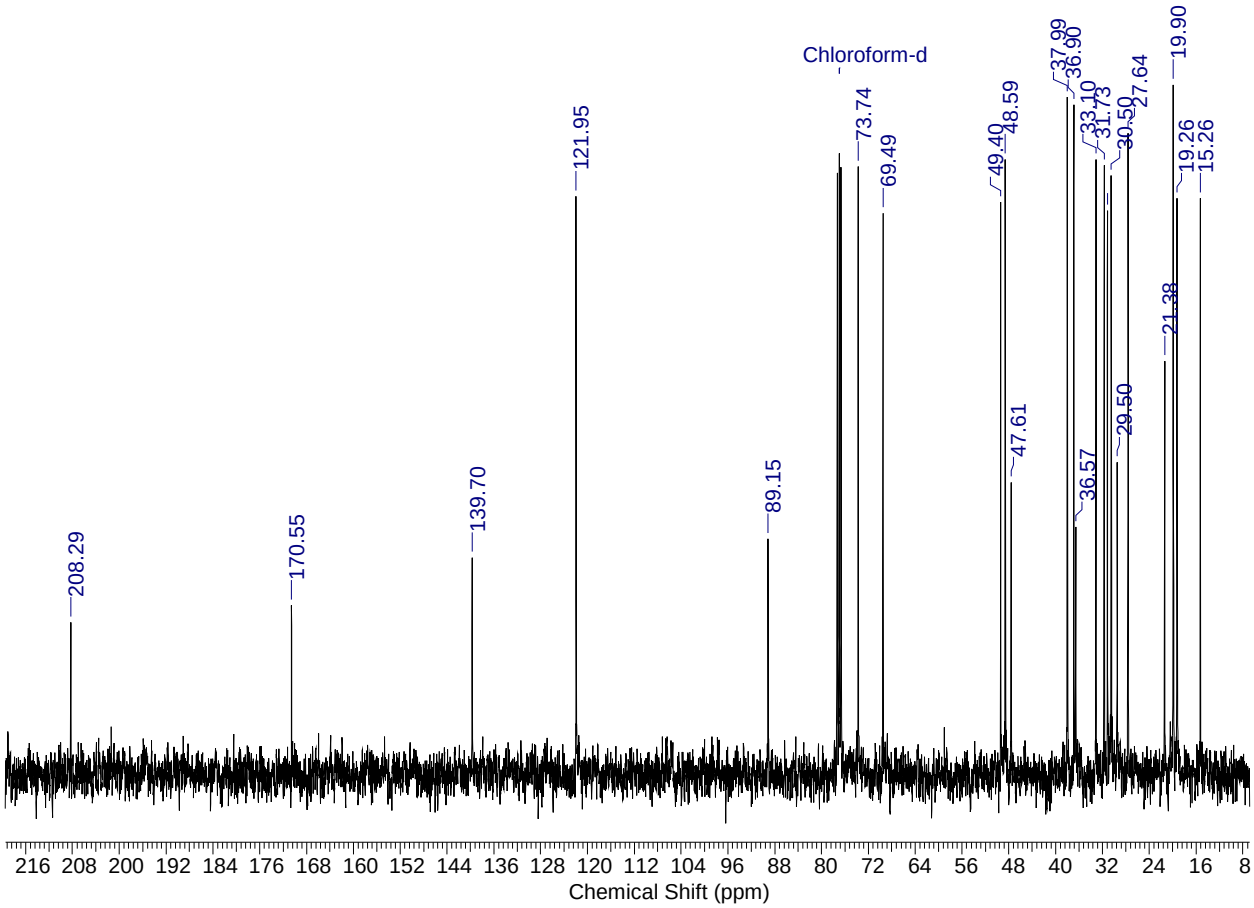
Chemical Shift (ppm)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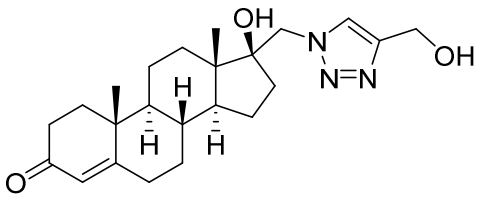
15.26
Chemical Shift (ppm)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OH
H
H
H
O

10a

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5.44
Et2O
MeOH
DMSO
H2O
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7.82
5.00
4.46
4.43
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2.02
1.89
1.86
1.70
1.69
1.65
1.62
1.58
1.34
1.31
1.15
1.14
0.97
0.05 - HM
0.05
1.00
1.00
0.97
3.15
1.07
2.05
4.27
1.08
3.06
3.33
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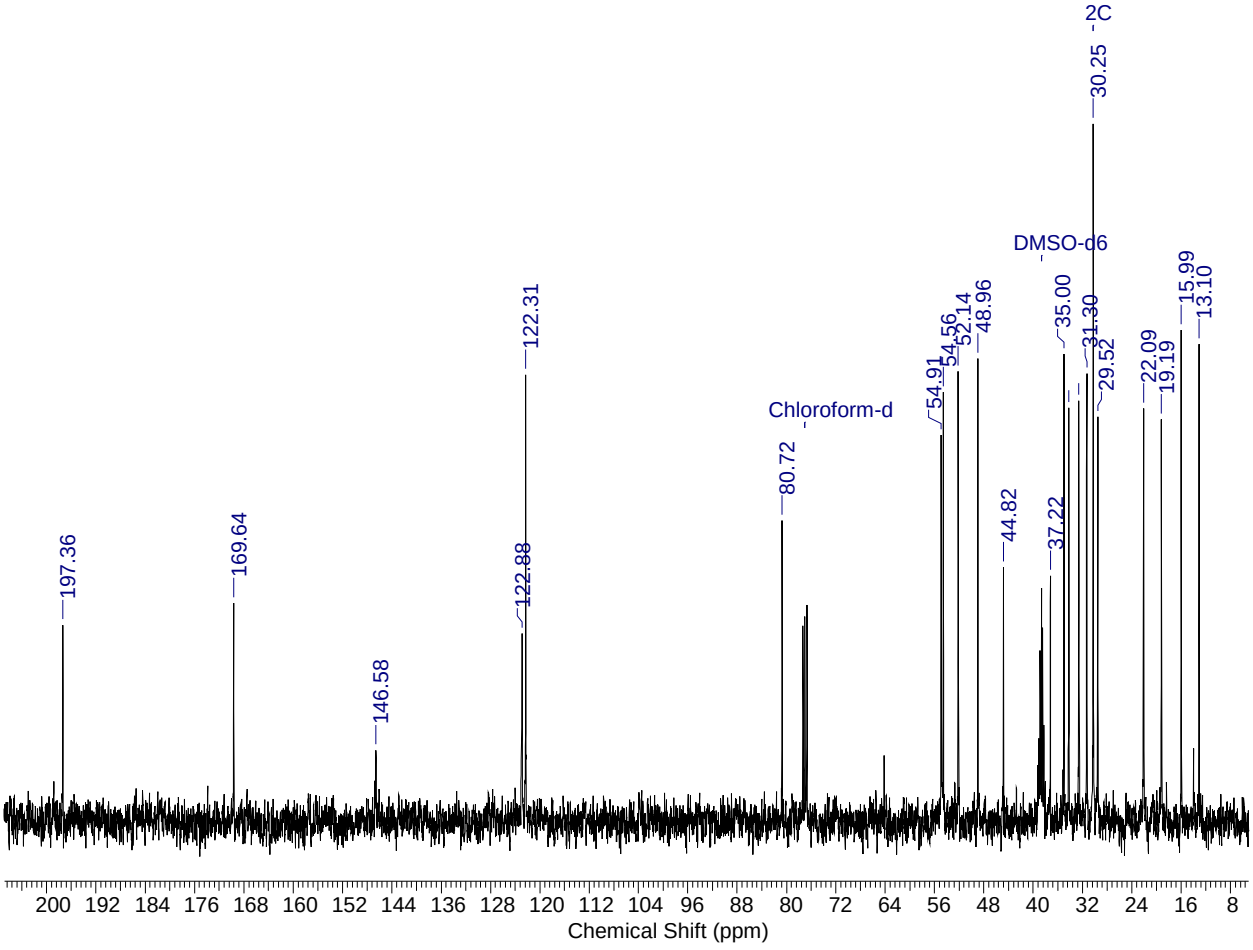
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Chloroform-d
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52.14
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35.00
31.30
29.52
22.09
19.19
15.99
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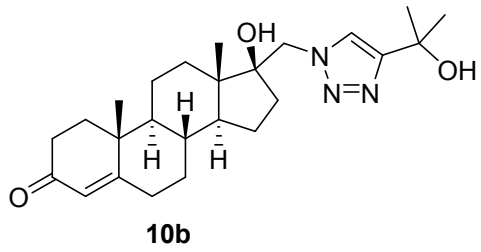
Chemical Shift (ppm)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OH
H
H
H
O

10b

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4.80
4.62
4.37
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4.15
4.12
3.80
MeOH
3.18
3.06
MeOH
aqua
DMSO-d6
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2.38
2.34
2.28
2.20
2.02
1.99
1.83
1.69
1.67
1.64
1.46
1.44
1.33
1.30
1.25
1.19
1.07
1.03
1.00
0.88
0.99
0.95
1.00
0.99
1.00
1.03
4.22
1.15
6.58
2.82
2.96
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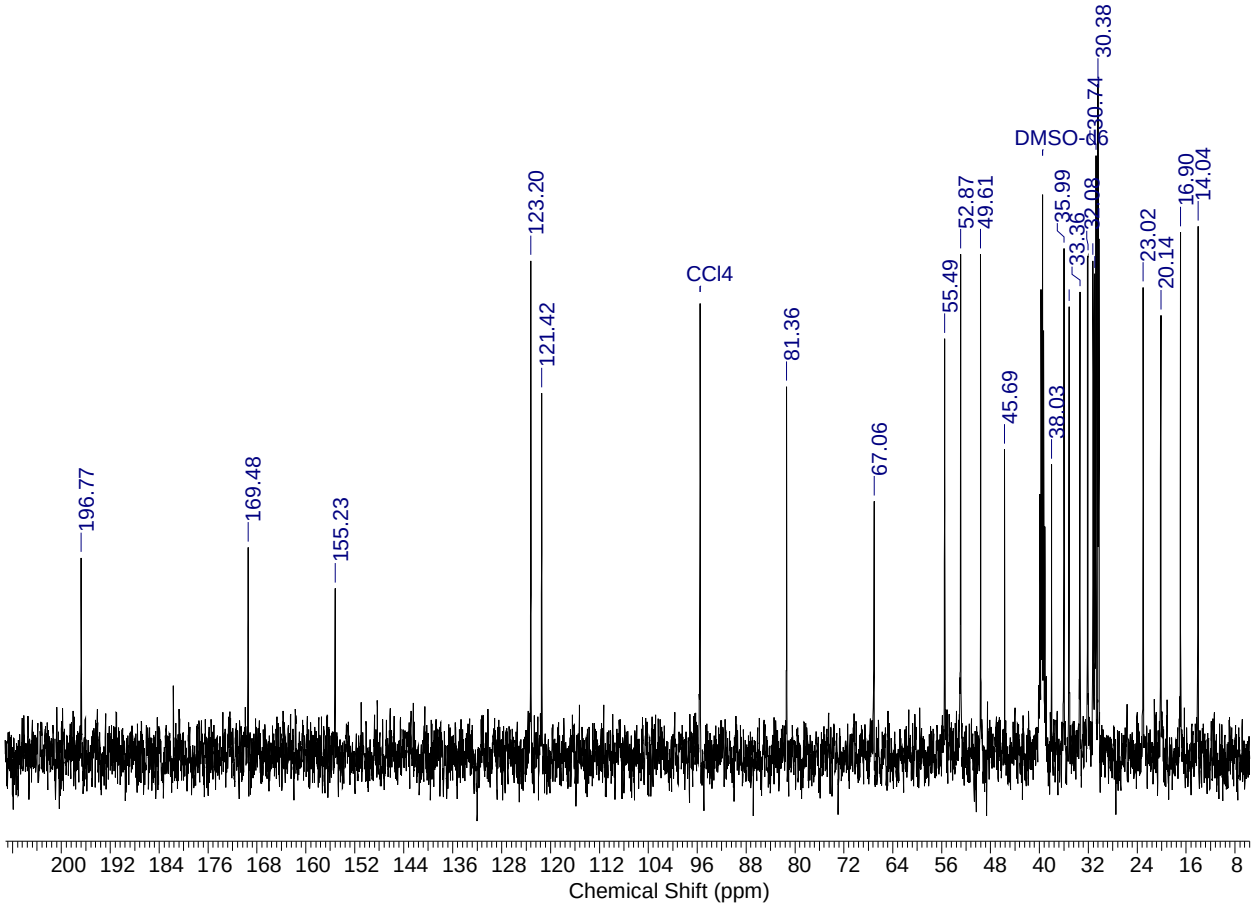
Chemical Shift (ppm)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52.87
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38.03
35.99
33.36
32.08
30.74
30.38
DMSO-d6
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14.04
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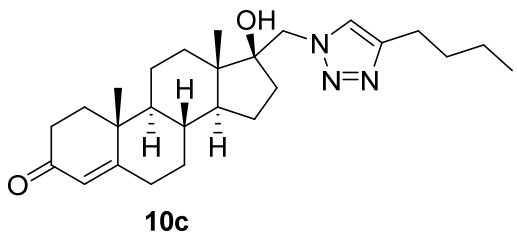
Chemical Shift (ppm)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H
H
H
O

10c

7.58
7.31
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4.44
4.40
4.33
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2.71
2.69
2.67
1.72
1.70
1.65
1.63
1.61
1.40
1.35
1.20
1.19
1.17
1.00
0.91
0.89
0.05 - HMD
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1.00
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1.03
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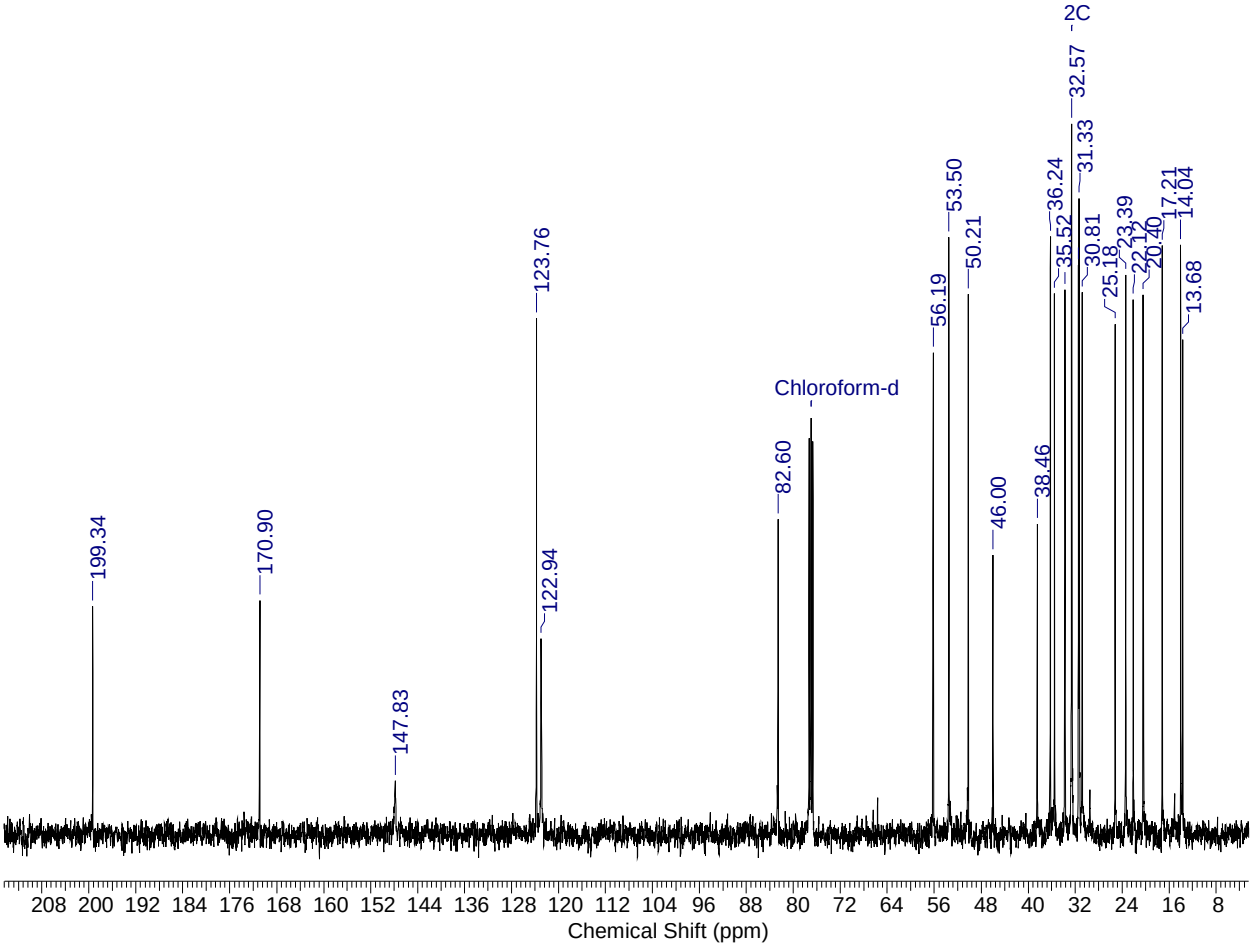
1.19
2.99
3.37
Chemical Shift (ppm)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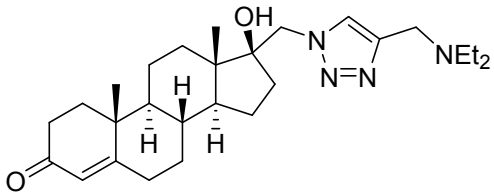
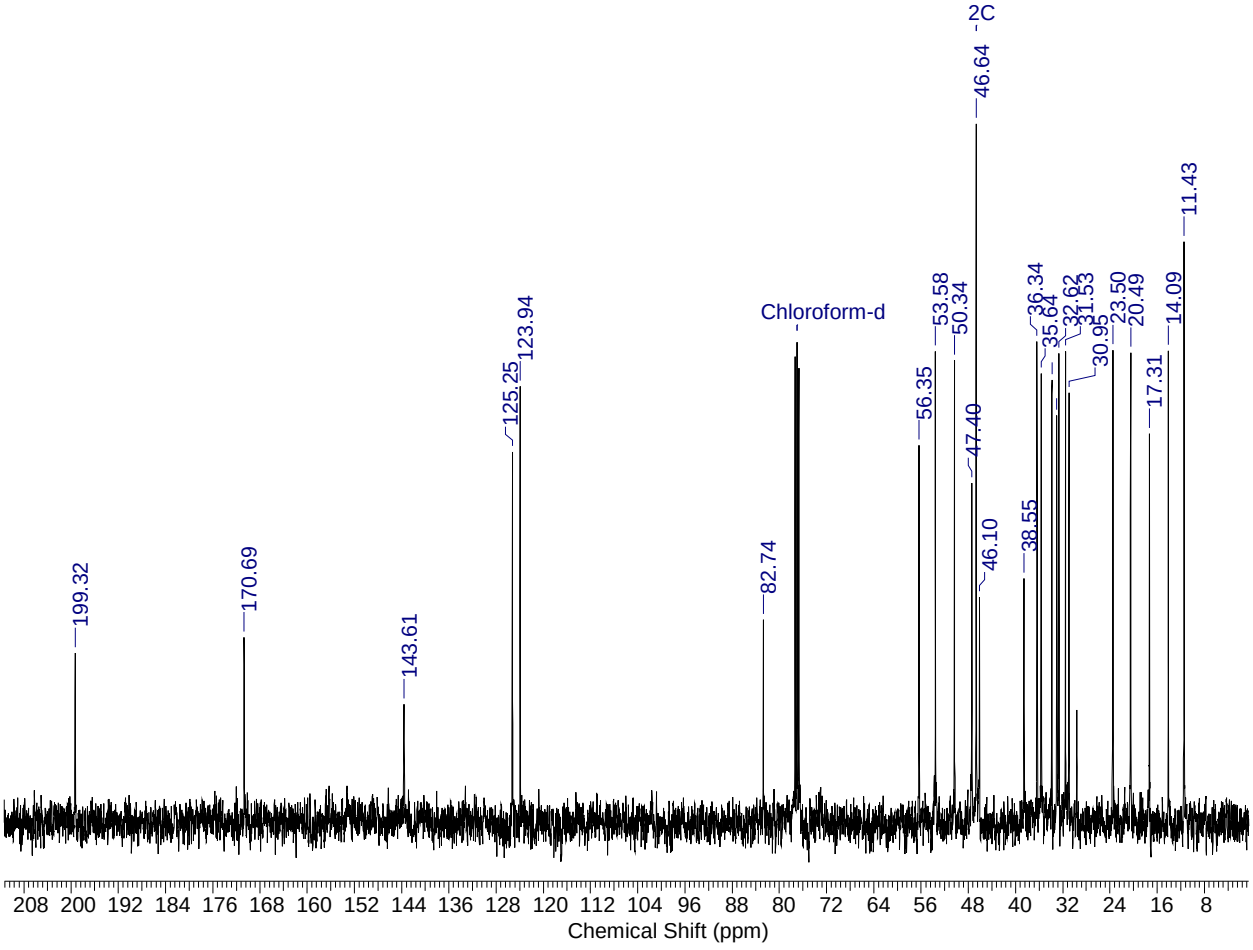
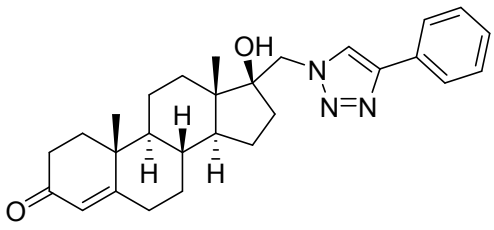
199.34
170.90
147.83
123.76
122.94
82.60
Chloroform-d
56.19
53.50
50.21
46.00
38.46
36.24
35.52
32.57
31.33
30.81
25.18
23.39
22.12
20.40
17.21
14.04
13.68
Chemical Shift (ppm)


OH
N
N=N
NEt2
H
H
H
O

10d

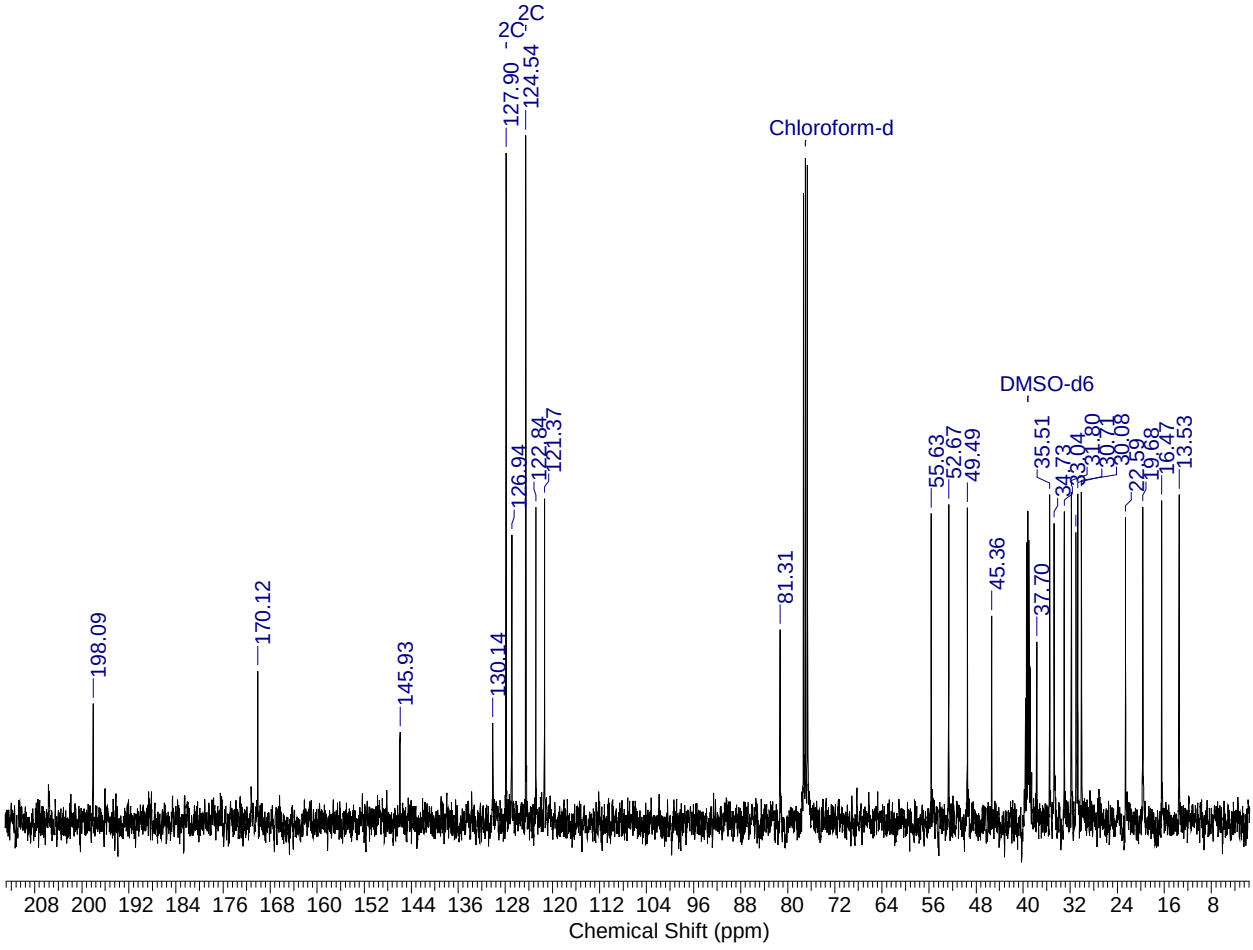
7.80
7.28
5.73
CH2Cl2
5.29
4.45
4.41
4.35
4.31
3.84
3.20
2.62
2.60
2.58
2.57
2.39
2.36
2.35
2.30
2.17
2.12
1.88
1.70
1.69
1.65
1.62
1.42
1.33
1.27
1.24
1.20
1.10
0.98
0.97
0.95
0.83
0.05 - HMDS
0.05
1.07
1.00
2.27
2.47
0.79
4.52
4.64
1.14
7.00
Chemical Shift (ppm)

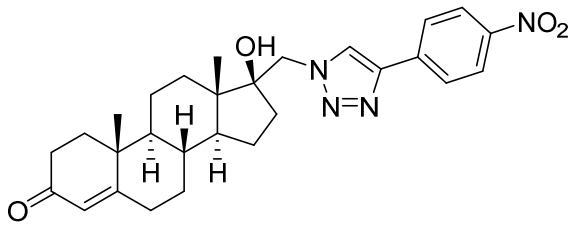

2C
46.64
199.32
170.69
143.61
125.25
123.94
82.74
Chloroform-d
77.32
77.00
76.68
56.35
53.58
50.34
47.40
46.10
38.55
36.34
35.64
32.62
31.53
30.95
23.50
20.49
17.31
14.09
11.43
Chemical Shift (ppm)


OH
N
N=N
H
H
H
O

10e

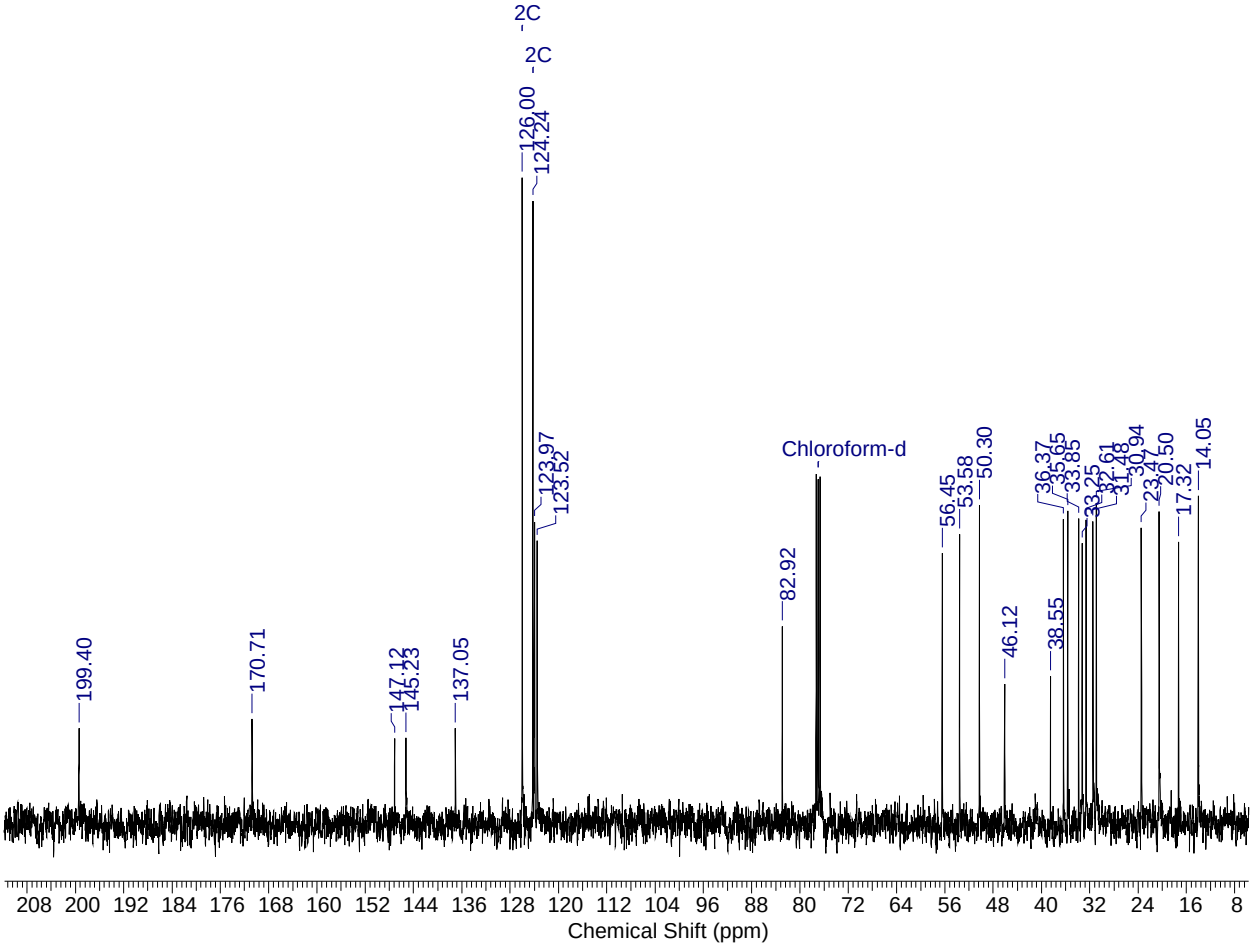
8.19
7.82
7.80
7.40
7.62
7.29
5.69
CH2Cl2
5.37
4.56
4.49
4.34
4.31
aqua
3.01
DMSO-d6
2.56
2.44
2.38
2.30
2.05
2.02
1.74
1.71
1.66
1.53
1.37
1.32
1.24
1.07
1.00
0.97
1.21
0.05 - HMDS
0.05
1.03
2.08
2.09
1.00
2.01
2.05
4.22
1.12
6.37
2.98
3.56
Chemical Shift (ppm)

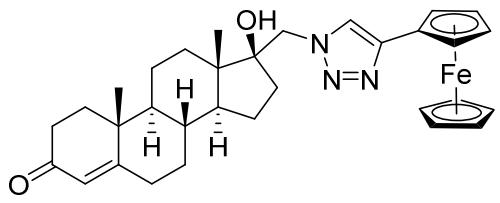

2C
2C
127.90
124.54
Chloroform-d
DMSO-d6
126.94
122.84
121.37
55.63
52.67
49.49
35.51
34.73
33.04
31.80
30.91
30.08
29.59
22.98
19.68
16.47
13.53
45.36
37.70
81.31
198.09
170.12
145.93
130.14
Chemical Shift (ppm)


OH
N
N=N
NO2
H
H
H
O

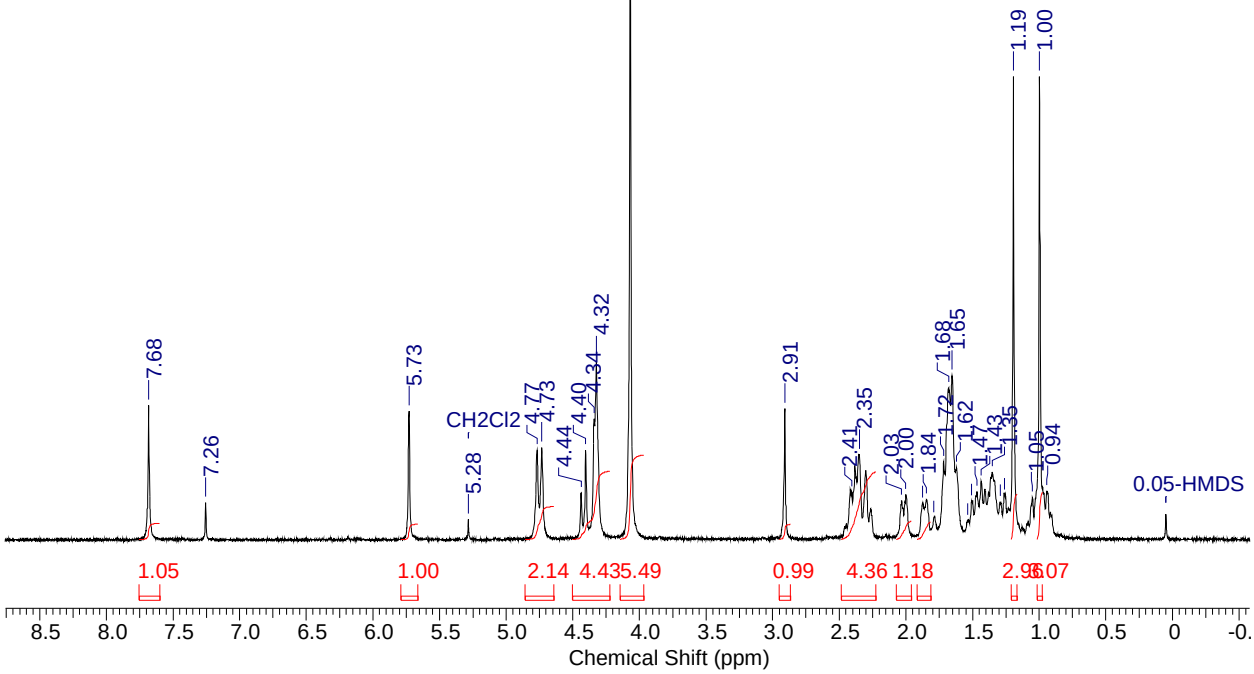
10f

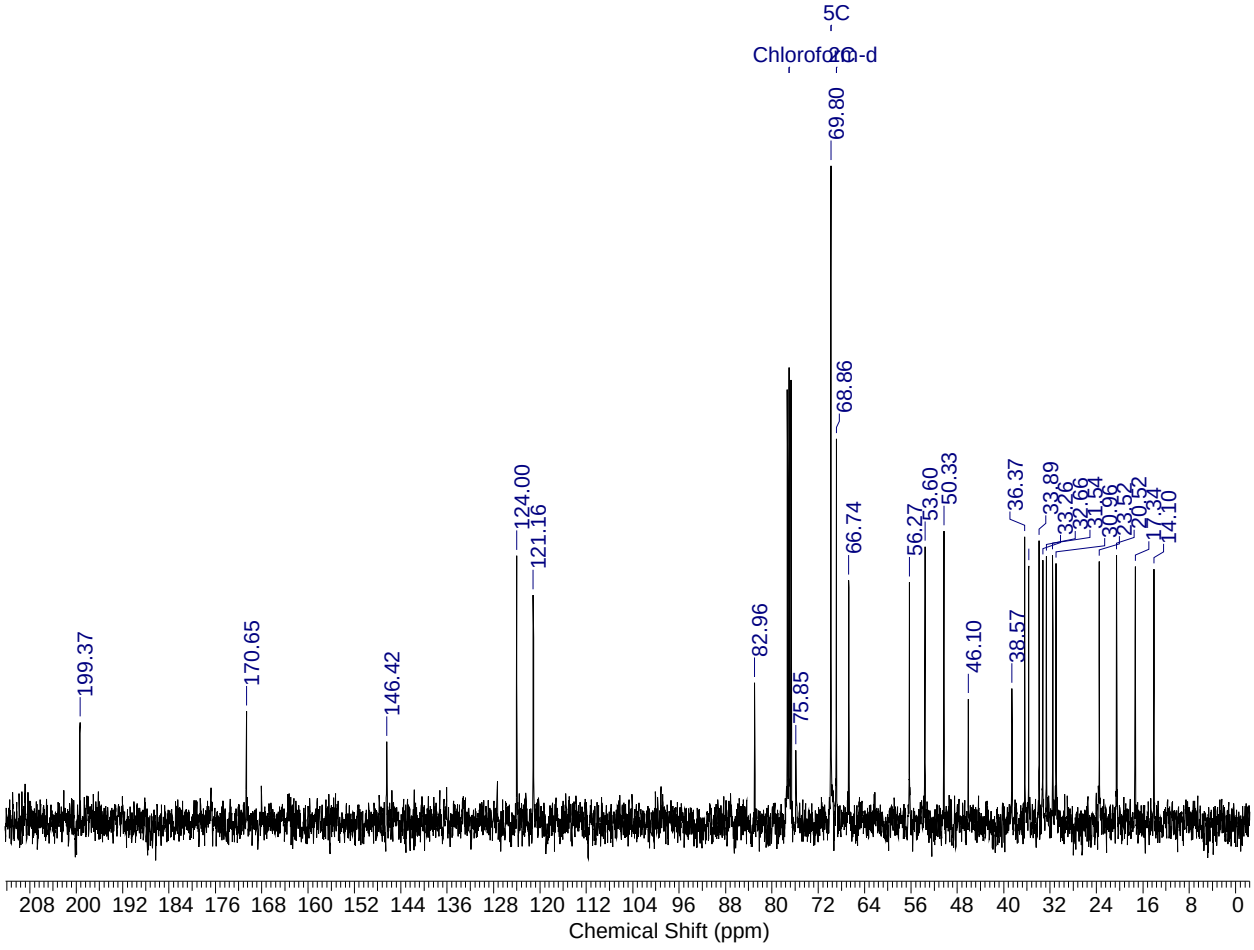
8.27
8.25
8.22
8.01
7.98
7.26
5.72
4.58
4.54
4.41
4.37
MeOH
3.47
2.60
2.41
2.40
2.38
2.36
2.35
2.04
1.78
1.76
1.75
1.73
1.72
1.69
1.68
1.52
1.39
1.36
1.20
1.01
0.99
0.98
0.96
0.05 - HMDS
0.05
3.12
2.09
1.00
1.05
1.04
4.23
1.17
3.08
8.29
Chemical Shift (ppm)

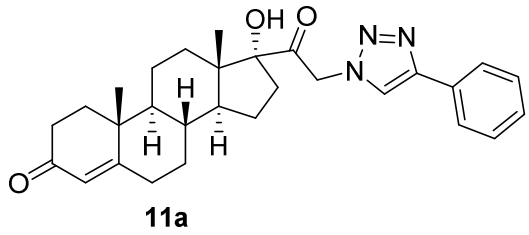

2C
2C
126.00
124.24
123.97
123.52
199.40
170.71
147.12
145.23
137.05
82.92
Chloroform-d
56.45
53.58
50.30
46.12
38.55
36.37
35.65
33.85
33.25
31.61
31.48
30.94
23.41
20.50
17.32
14.05
Chemical Shift (ppm)


OH
N
N=N
Fe
H
H
H
O

10g

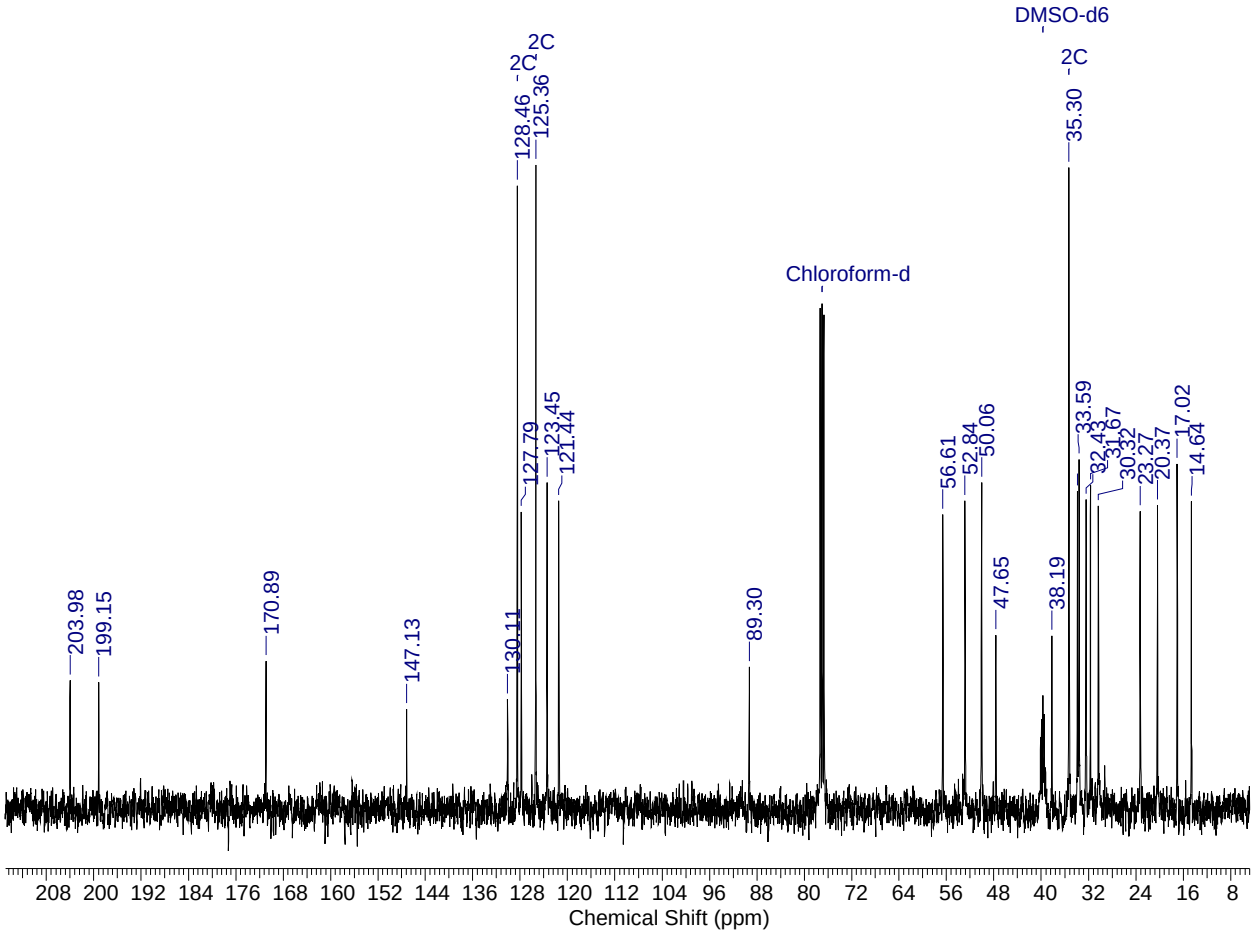

7.68
7.26
5.73
CH2Cl2
5.28
4.77
4.73
4.44
4.40
4.34
4.32
4.07
2.91
2.41
2.35
2.03
2.00
1.84
1.72
1.68
1.65
1.62
1.47
1.43
1.35
1.19
1.05
1.00
0.94
0.05-HMDS
1.05
1.00
2.14
4.43
5.49
0.99
4.36
1.18
2.96
6.07
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0 -0.
Chemical Shift (ppm)

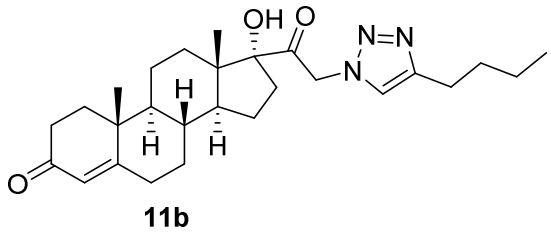

5C
Chloroform-d
69.80
68.86
66.74
56.27
53.60
50.33
46.10
38.57
36.37
33.89
33.26
31.54
30.96
23.52
20.52
17.34
14.10
199.37
170.65
146.42
124.00
121.16
82.96
75.85
208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8 0
Chemical Shift (ppm)


OH
O
N=N
N
H
H
H
O

11a

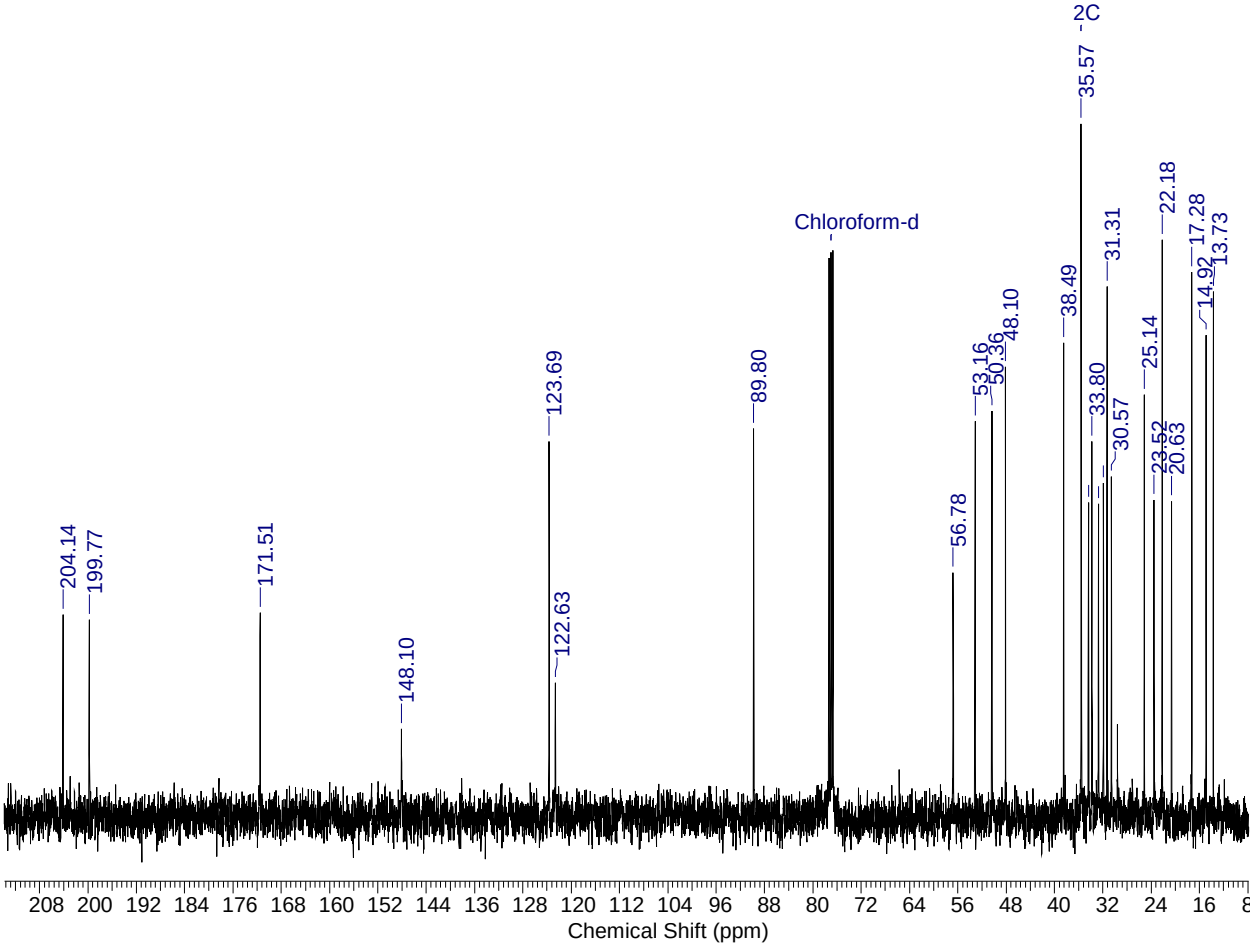
7.89
7.82
7.41
7.39
7.43
7.32
5.76
5.71
5.40
5.36
5.31
CH2Cl2
4.57
2.68
2.41
2.29
2.03
1.86
1.74
1.66
1.46
1.18
1.00
0.82
0.66
0.05 - HMDS
0.05
3.02
3.23
2.00
0.98
1.16
1.08
2.98
2.89
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0 -0.5
Chemical Shift (ppm)

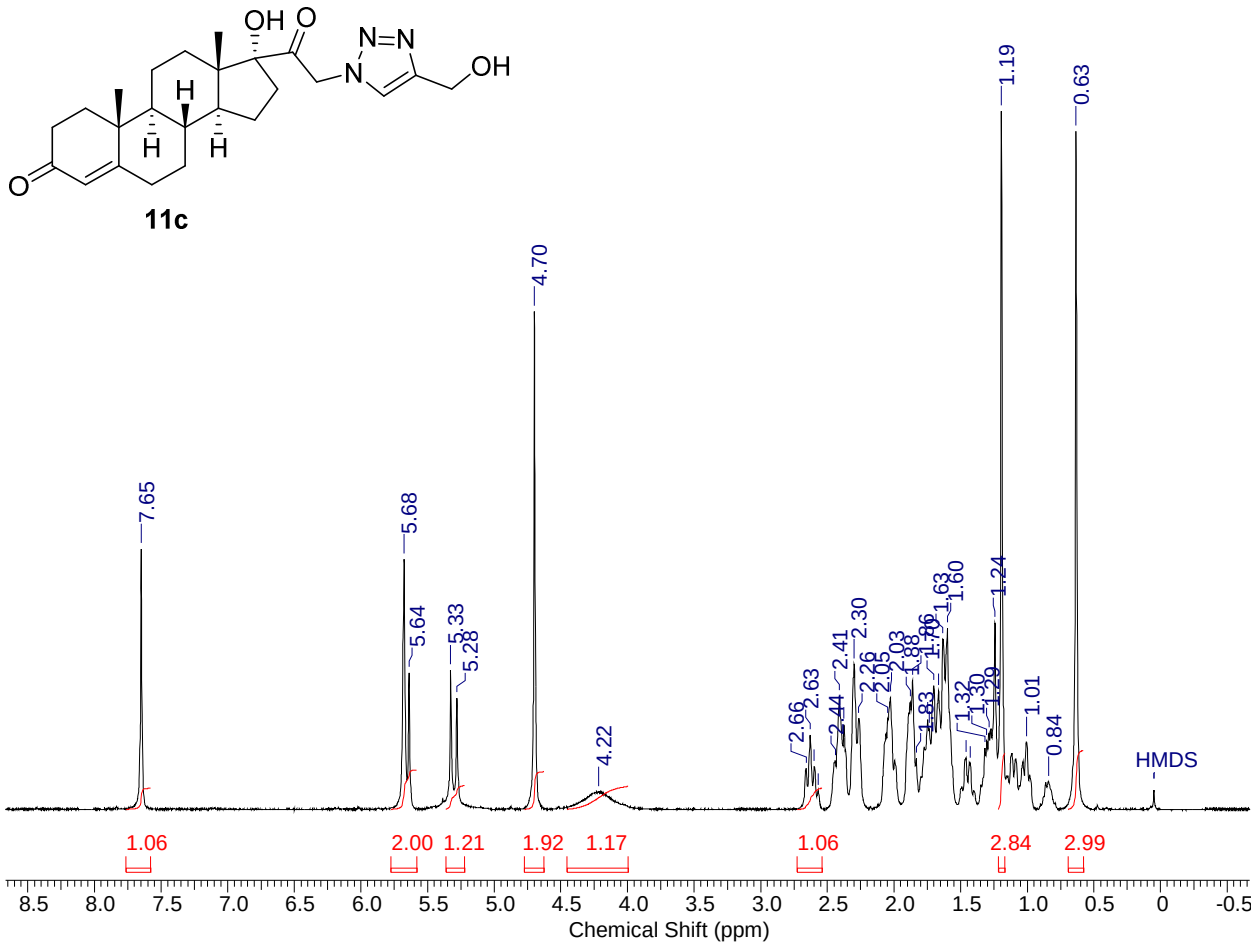

DMSO-d6
2C
2C
2C
128.46
125.36
35.30
Chloroform-d
203.98
199.15
170.89
147.13
130.11
127.79
123.45
121.44
89.30
56.61
52.84
50.06
47.65
38.19
33.59
32.43
31.67
30.32
23.27
20.37
17.02
14.64
208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8
Chemical Shift (ppm)

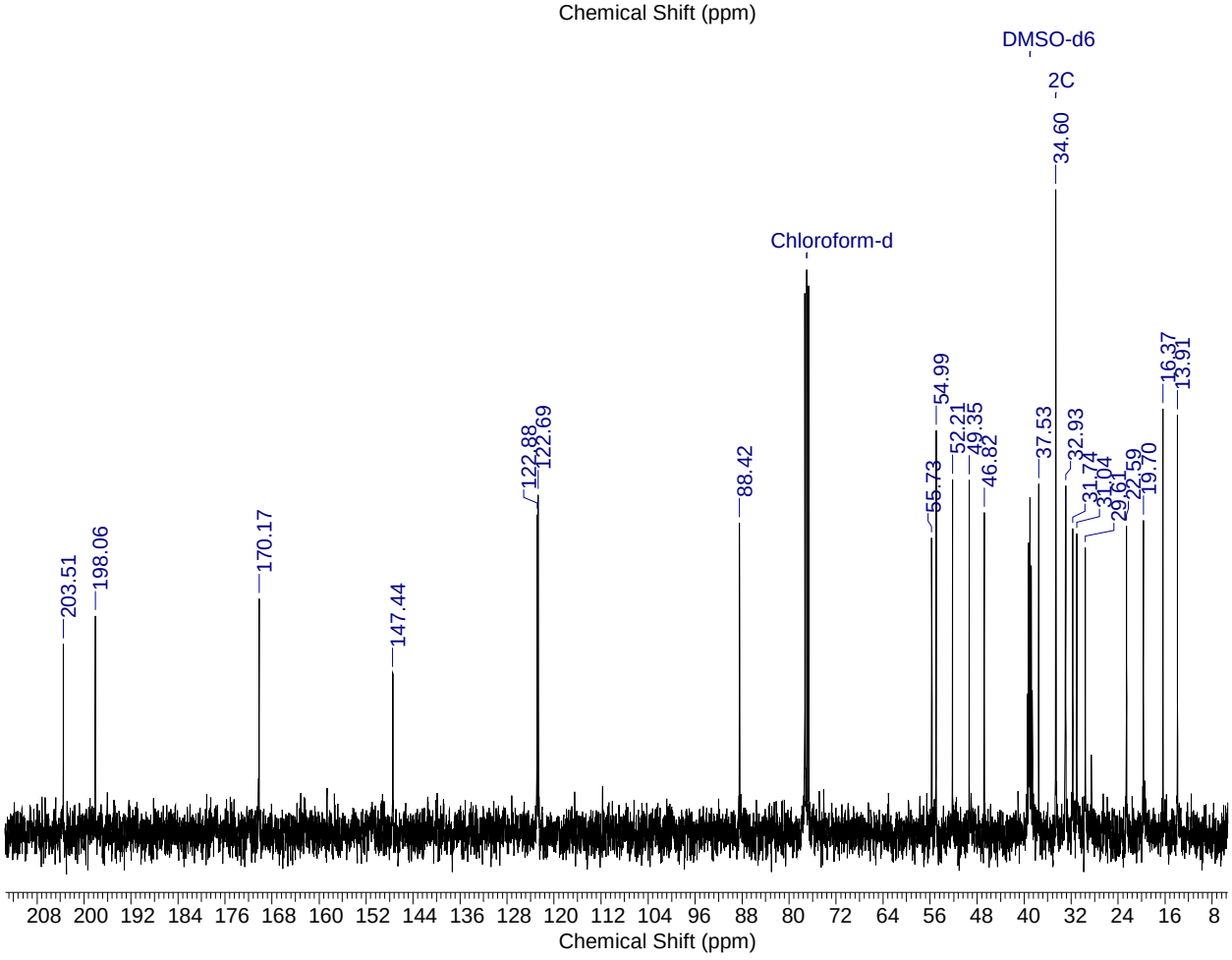

OH
O
N=N
N
H
H
H
O

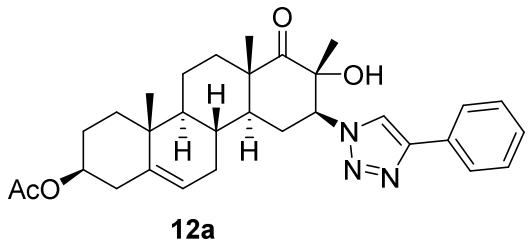
11b

7.32
7.29
5.72
5.74
5.69
5.32
5.27
4.62
Et2O
2.72
2.70
2.68
2.41
2.37
2.36
2.35
2.02
1.88
1.86
1.85
1.79
1.69
1.66
1.64
1.63
1.61
1.42
1.40
1.38
1.36
1.34
1.33
1.19
1.18
1.17
1.12
1.00
0.93
0.91
0.90
0.66
0.05 - HMDS
0.90
2.03
1.00
0.78
3.05
4.39
2.16
3.34
3.12
2.91
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)


2C
35.57
Chloroform-d
77.16
77.00
76.84
204.14
199.77
171.51
148.10
123.69
122.63
89.80
56.78
53.16
50.36
48.10
38.49
33.80
31.31
30.57
25.14
23.52
22.18
20.63
17.28
14.92
13.73
208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8
Chemical Shift (ppm)

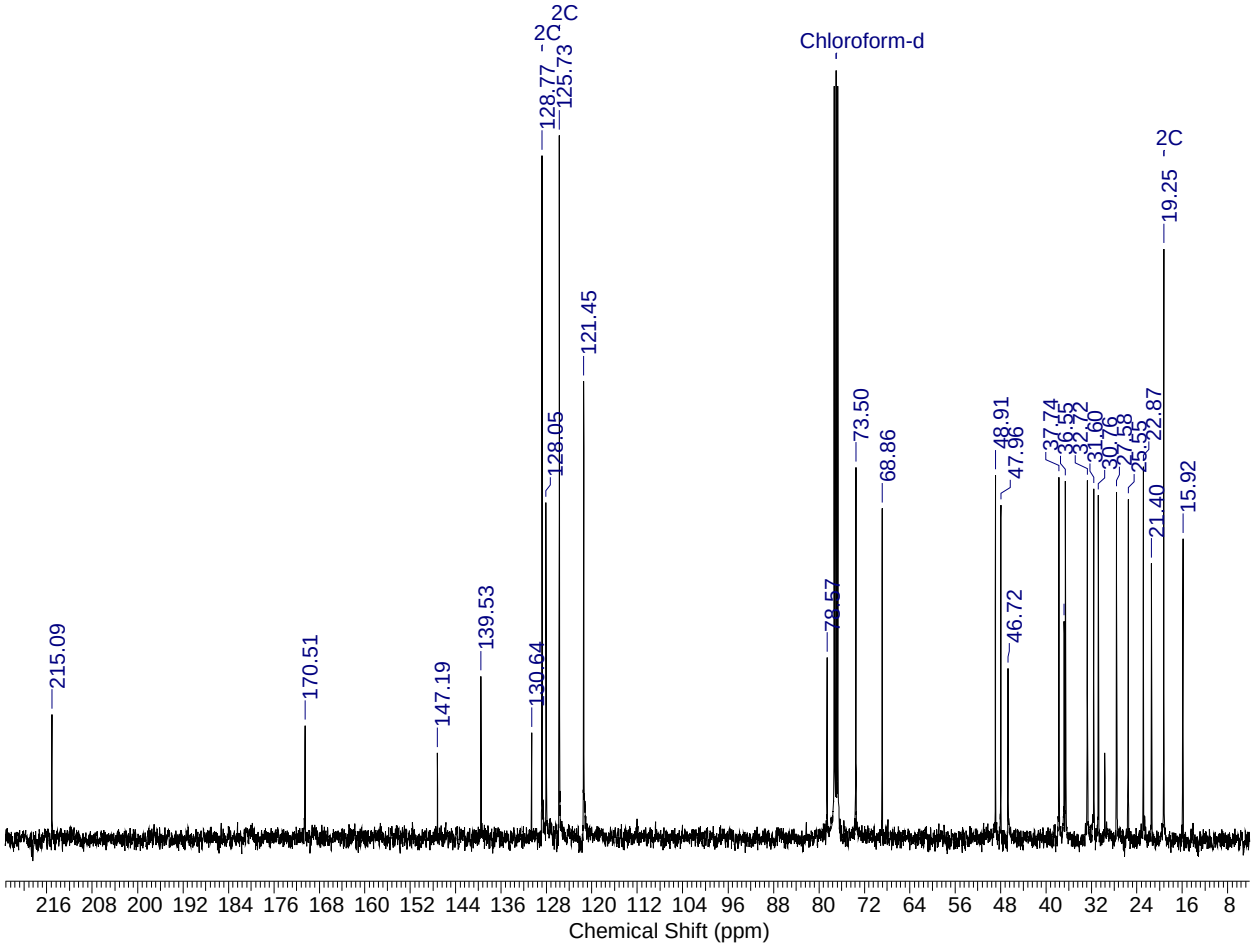

OH
O
N=N
N
OH
H
H
H
O
11c
7.65
5.68
5.64
5.33
5.28
4.70
4.22
2.66
2.63
2.44
2.41
2.30
2.26
2.05
2.03
1.88
1.86
1.83
1.79
1.63
1.60
1.32
1.30
1.29
1.24
1.19
1.01
0.84
0.63
HMDS
1.06
2.00
1.21
1.92
1.17
1.06
2.84
2.99
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0 -0.5
Chemical Shift (ppm)

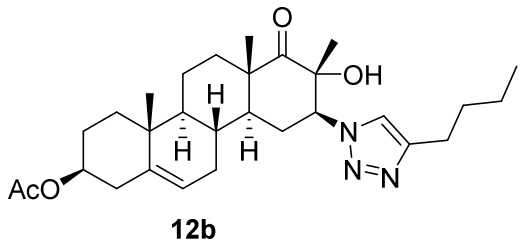

DMSO-d6
2C
34.60
Chloroform-d
203.51
198.06
170.17
147.44
122.88
122.69
88.42
55.73
54.99
52.21
49.35
46.82
37.53
32.93
31.74
31.04
29.61
22.59
19.70
16.37
13.91
208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8
Chemical Shift (ppm)


O
OH
H
H
H
N
N=N
AcO

12a

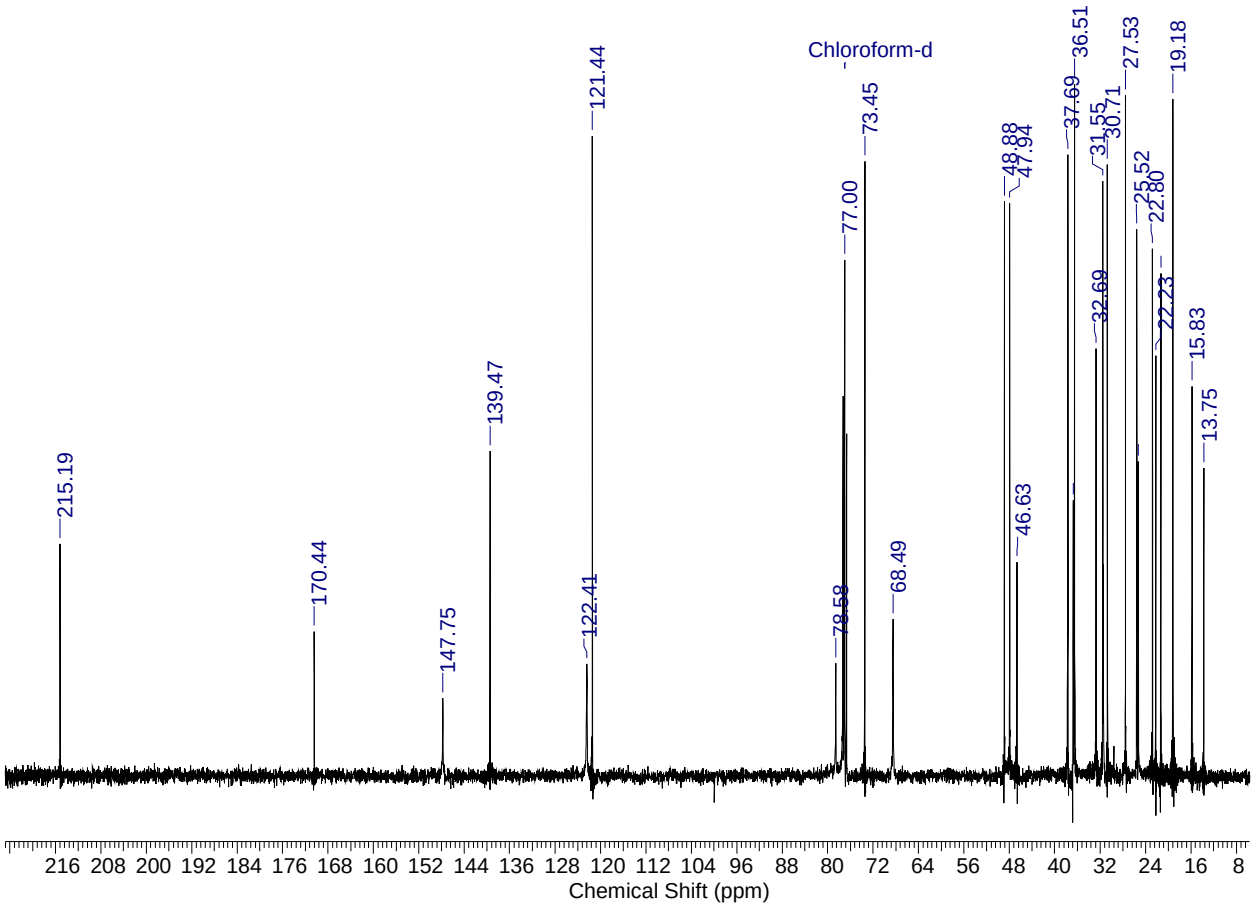
7.99
7.86
7.85
7.41
7.43
7.39
7.33
7.31
7.25
CH2Cl2
5.36
5.28
4.59
4.43
4.42
4.40
4.31
2.70
2.67
2.63
2.53
2.49
2.33
2.30
2.02
1.90
1.87
1.74
1.72
1.71
1.50
1.31
1.23
1.12
1.08
1.05
0.86
HMDS
0.05
1.82
1.91
0.96
1.03
3.01
3.77
Chemical Shift (ppm)

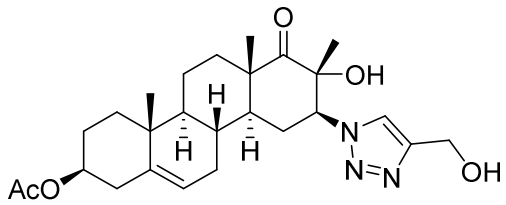

2C
2C
128.77
125.73
Chloroform-d
2C
19.25
121.45
128.05
73.50
68.86
48.91
47.96
37.74
22.87
15.92
215.09
170.51
147.19
139.53
130.64
79.57
46.72
21.40
Chemical Shift (ppm)


O
OH
H
H
H
N
N=N
AcO

12b

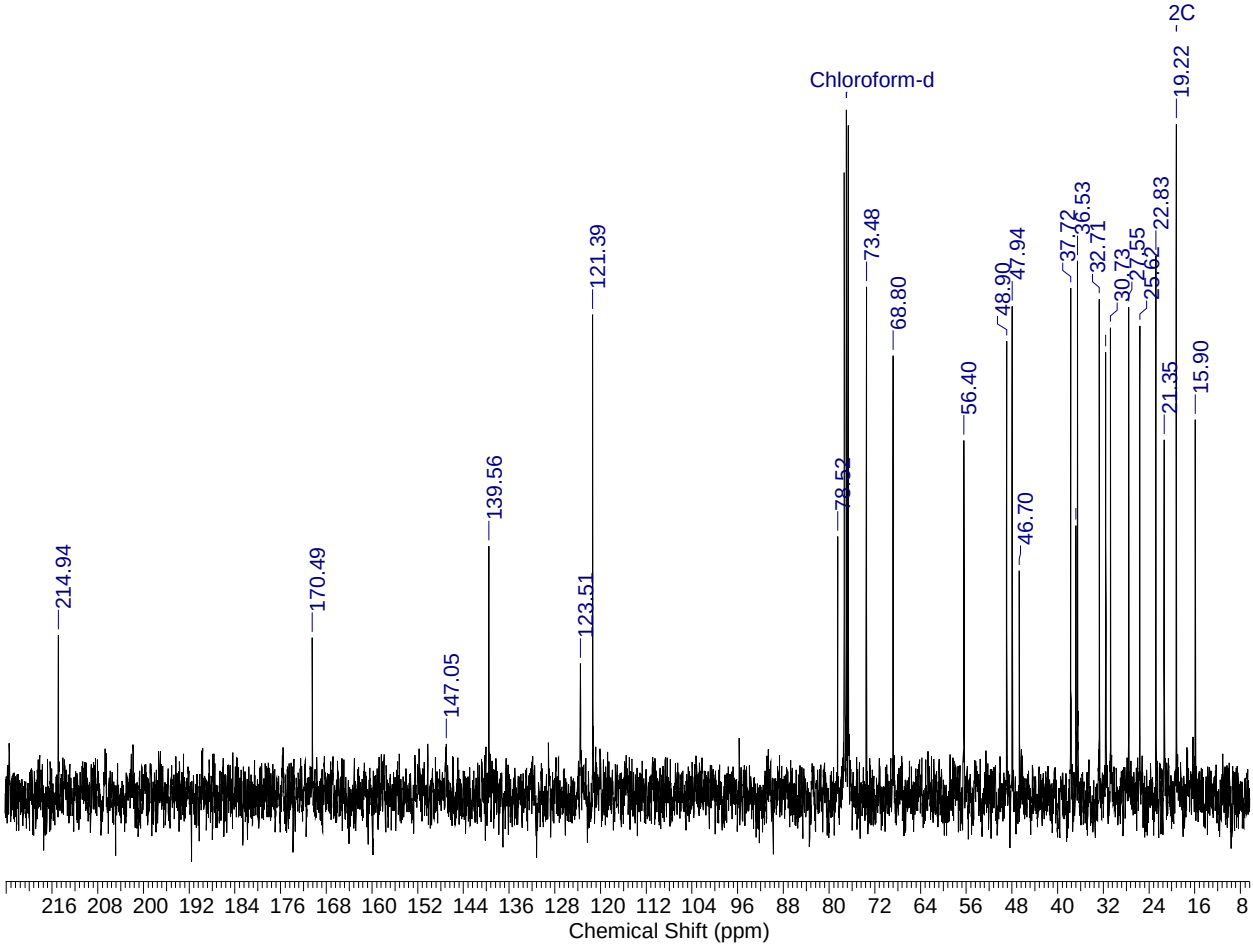
2.02
1.22
1.04
1.03
0.92
0.94
0.90
4.29
7.48
7.26
5.35
5.35
4.59
4.58
4.34
4.33
4.31
2.73
2.72
2.70
2.62
2.59
2.47
2.34
2.33
2.29
1.89
1.87
1.67
1.65
1.63
1.49
1.38
1.36
1.33
1.13
HMDS
0.05
0.96
1.00
1.02
1.97
1.95
3.06
4.03
2.86
1.59
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)

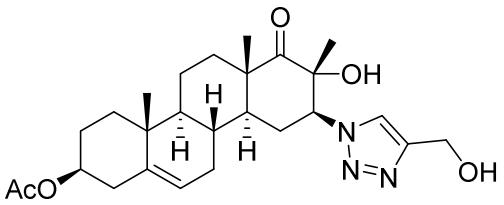

Chloroform-d
121.44
73.45
36.51
27.53
19.18
77.00
48.88
47.94
37.69
31.55
30.71
25.52
22.80
22.23
32.69
15.83
13.75
215.19
139.47
170.44
147.75
122.41
78.58
68.49
46.63
216 208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8
Chemical Shift (ppm)



12c

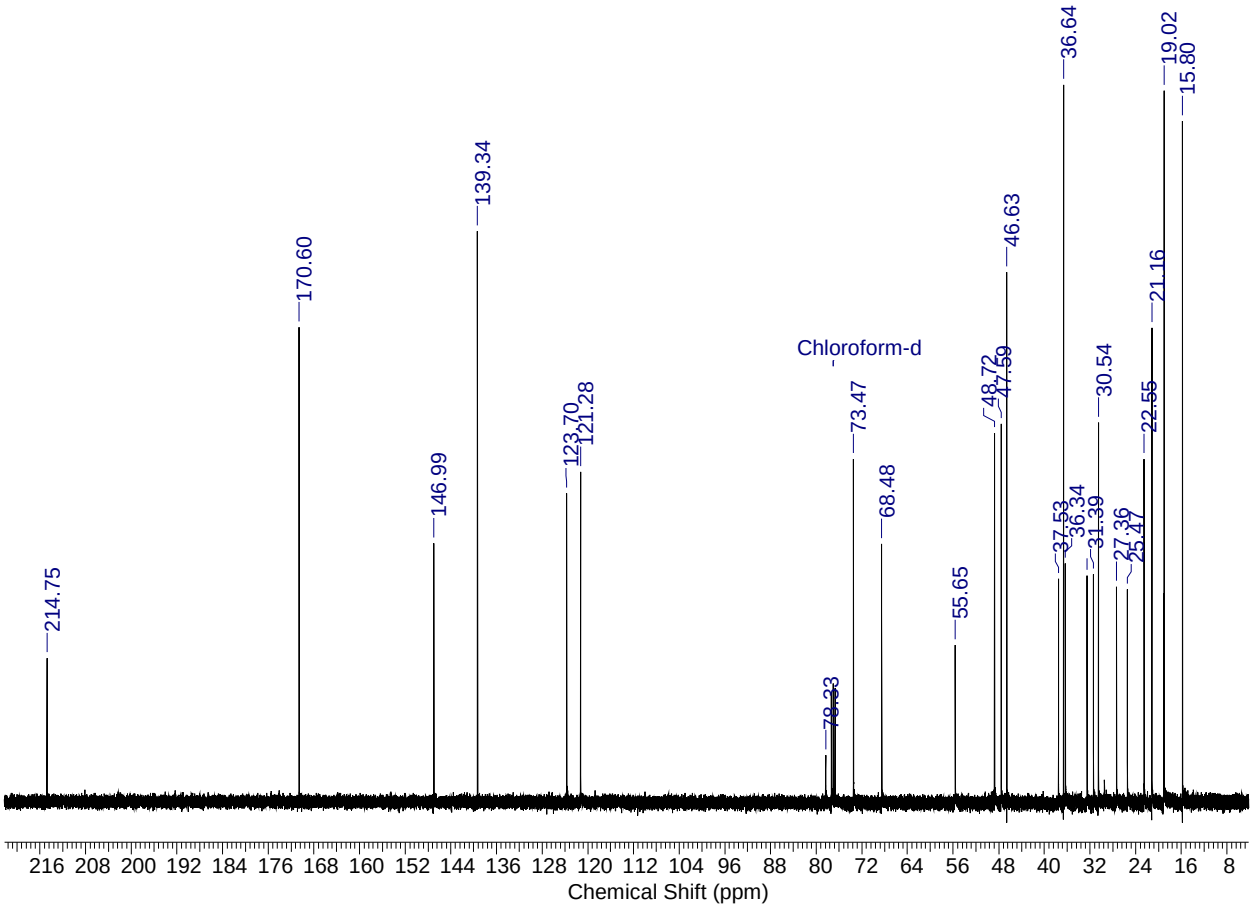
solvent: $CDCl_3$

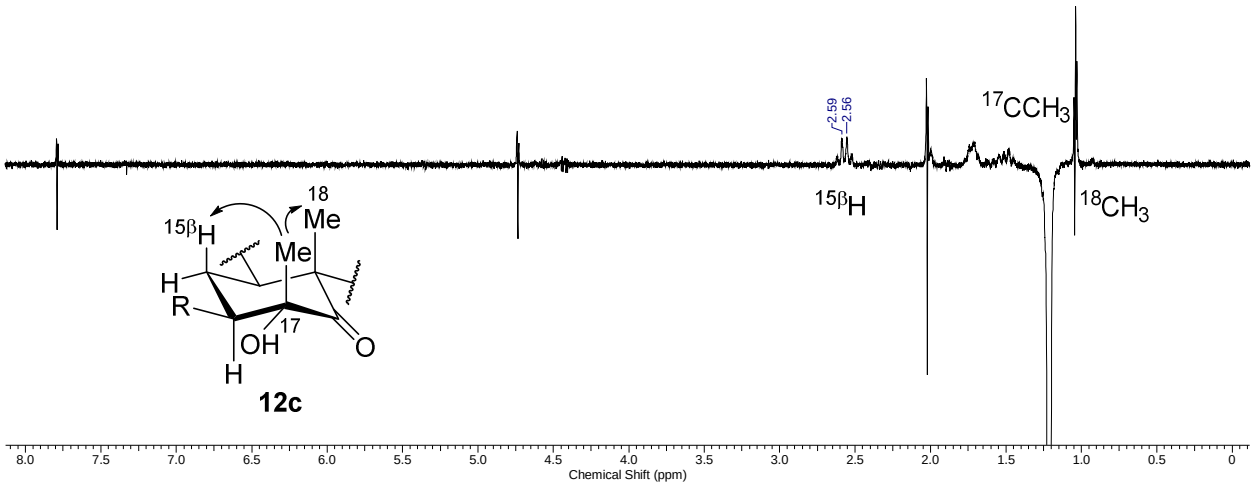


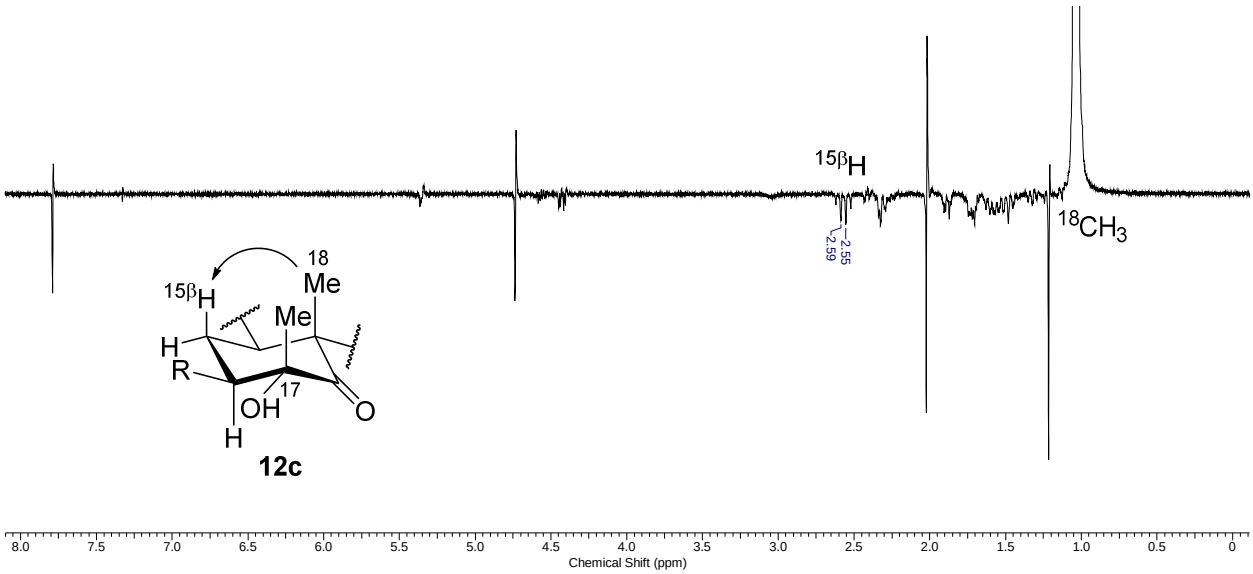


12c

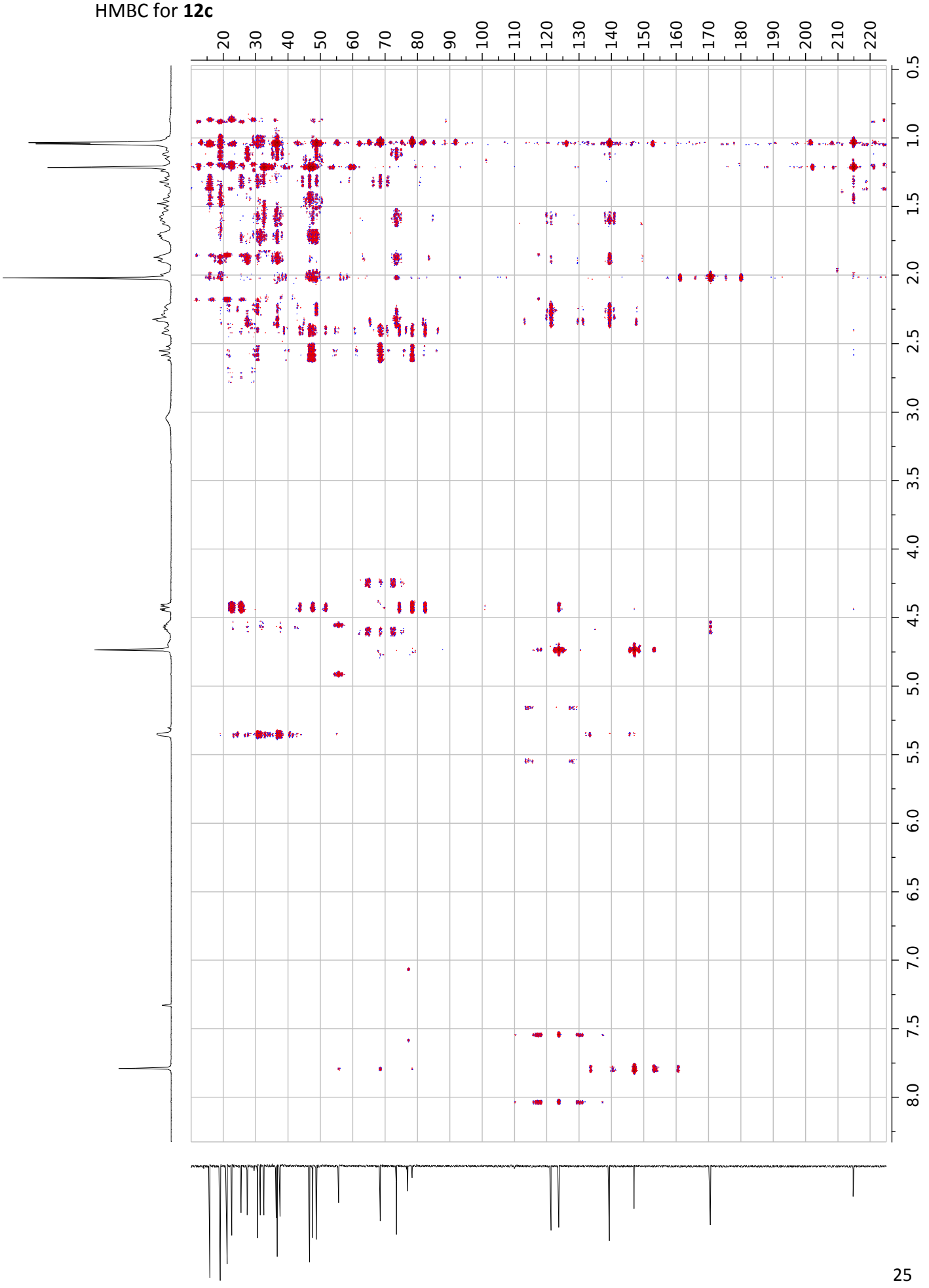
solvent: $CDCl_3$-CD_3OD



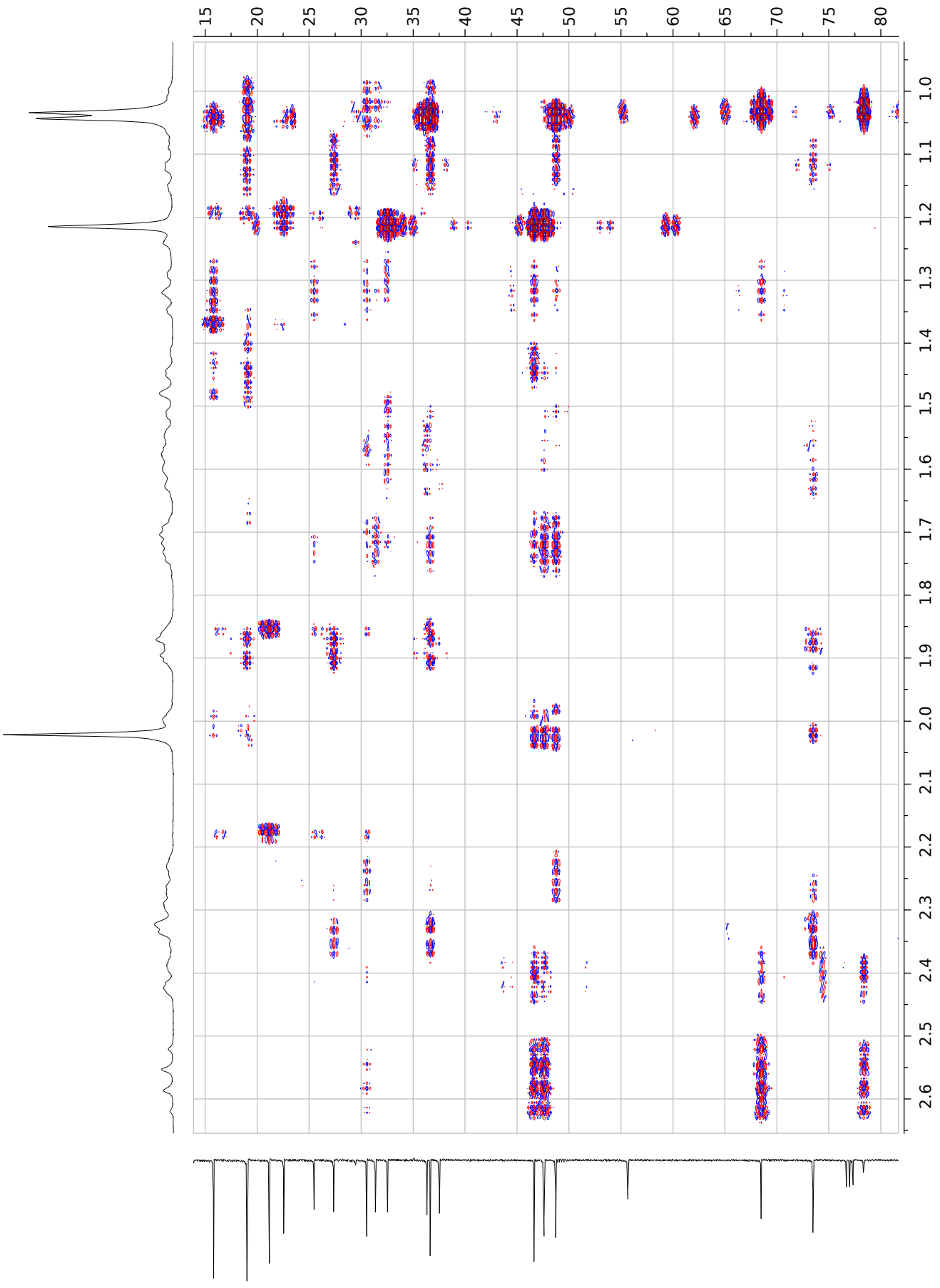

2.59
2.56
17CCH3
15βH
18CH3
18
Me
15βH
Me
H
R
17
OH
O
H
12c
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Chemical Shift (ppm)


15βH
2.69
2.55
18CH3
18
Me
15βH
Me
H
R
17
OH
O
H
12c
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Chemical Shift (ppm)

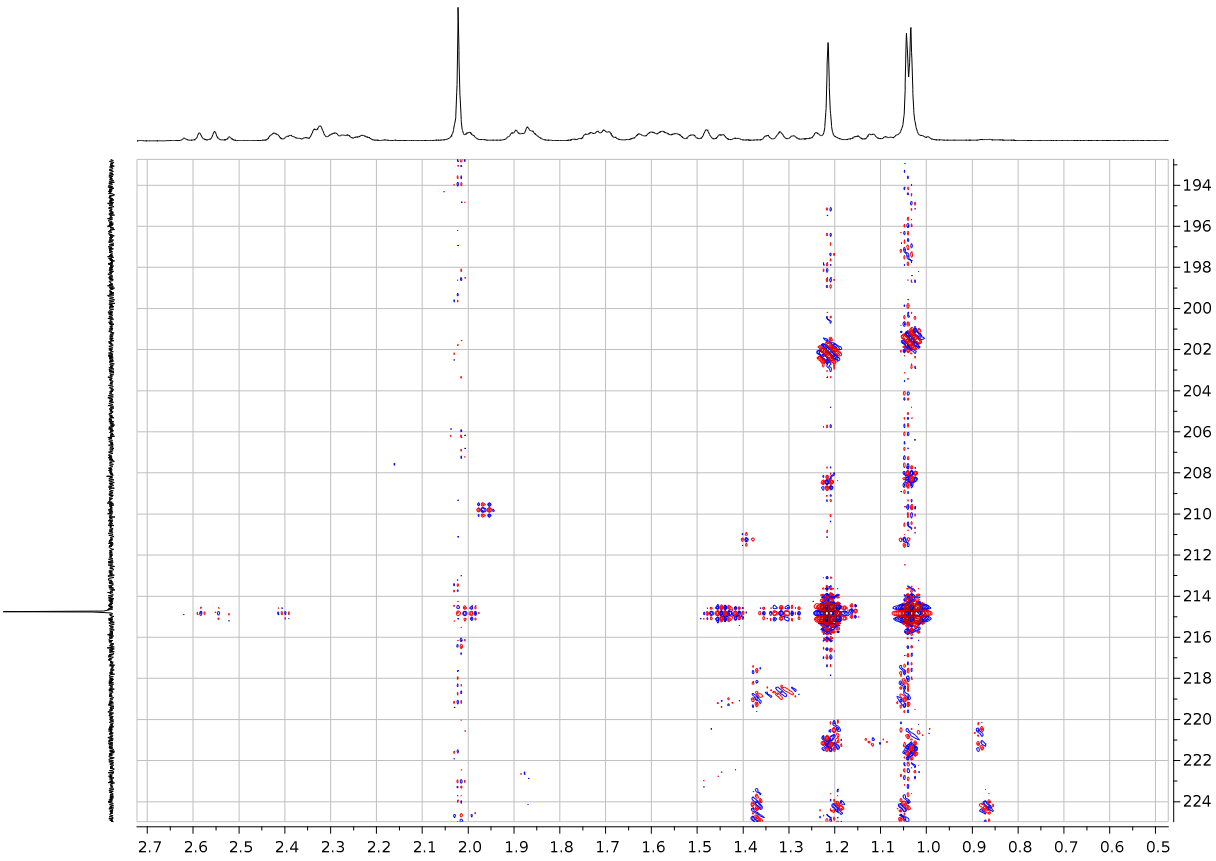
HMBC for **12c**

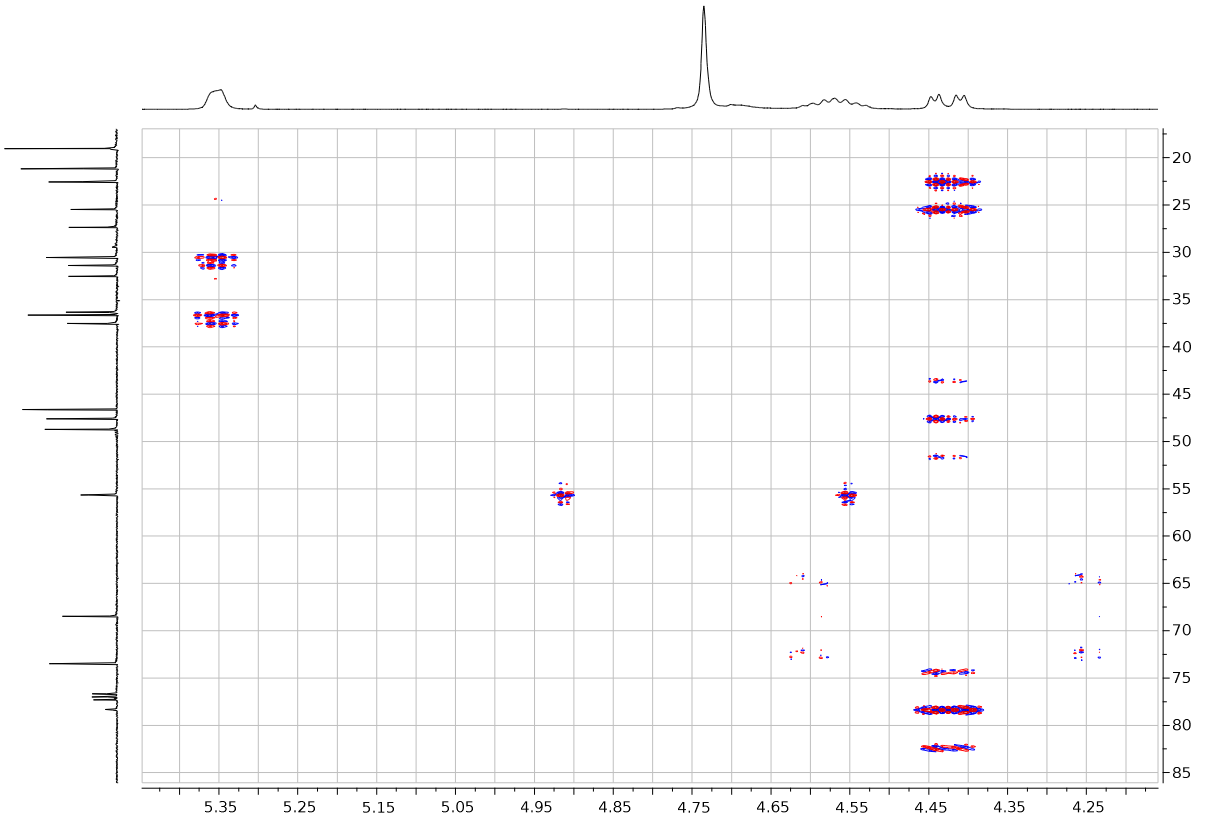

20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0

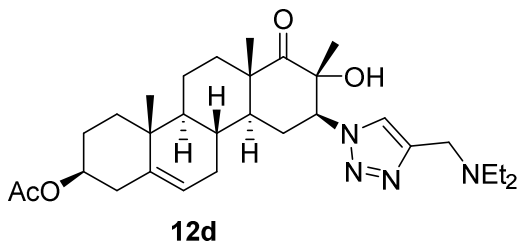
HMBC for **12c**


15
20
25
30
35
40
45
50
55
60
65
70
75
80
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6

HMBC for **12c**

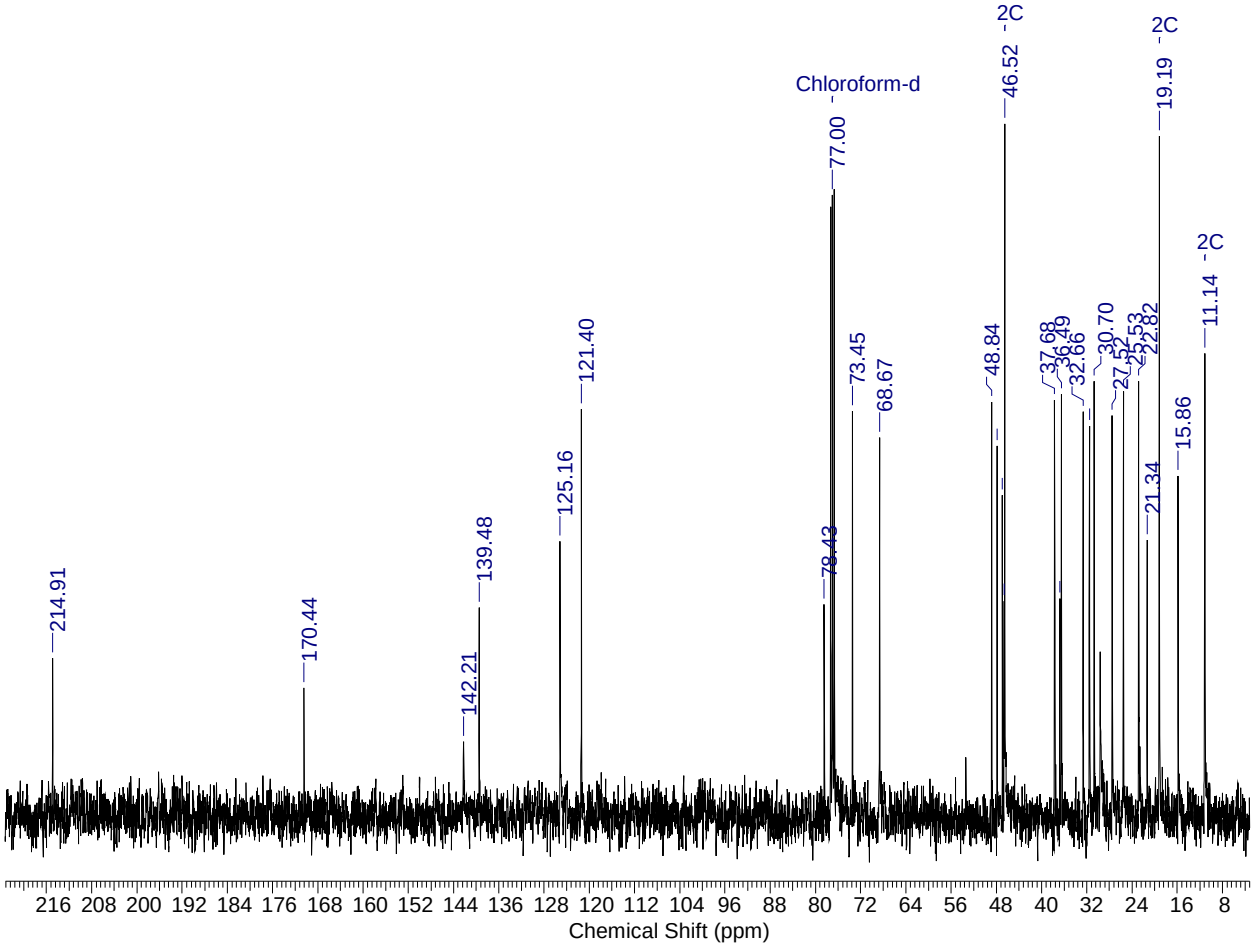

194
196
198
200
202
204
206
208
210
212
214
216
218
220
222
224
2.7 2.6 2.5 2.4 2.3 2.2 2.1 2.0 1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1 1.0 0.9 0.8 0.7 0.6 0.5

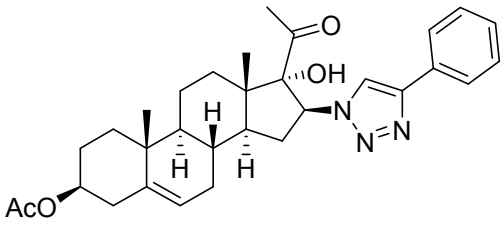

20
25
30
35
40
45
50
55
60
65
70
75
80
85
5.35 5.25 5.15 5.05 4.95 4.85 4.75 4.65 4.55 4.45 4.35 4.25


O
OH
H
H
H
N
N=N
NEt2
AcO

12d

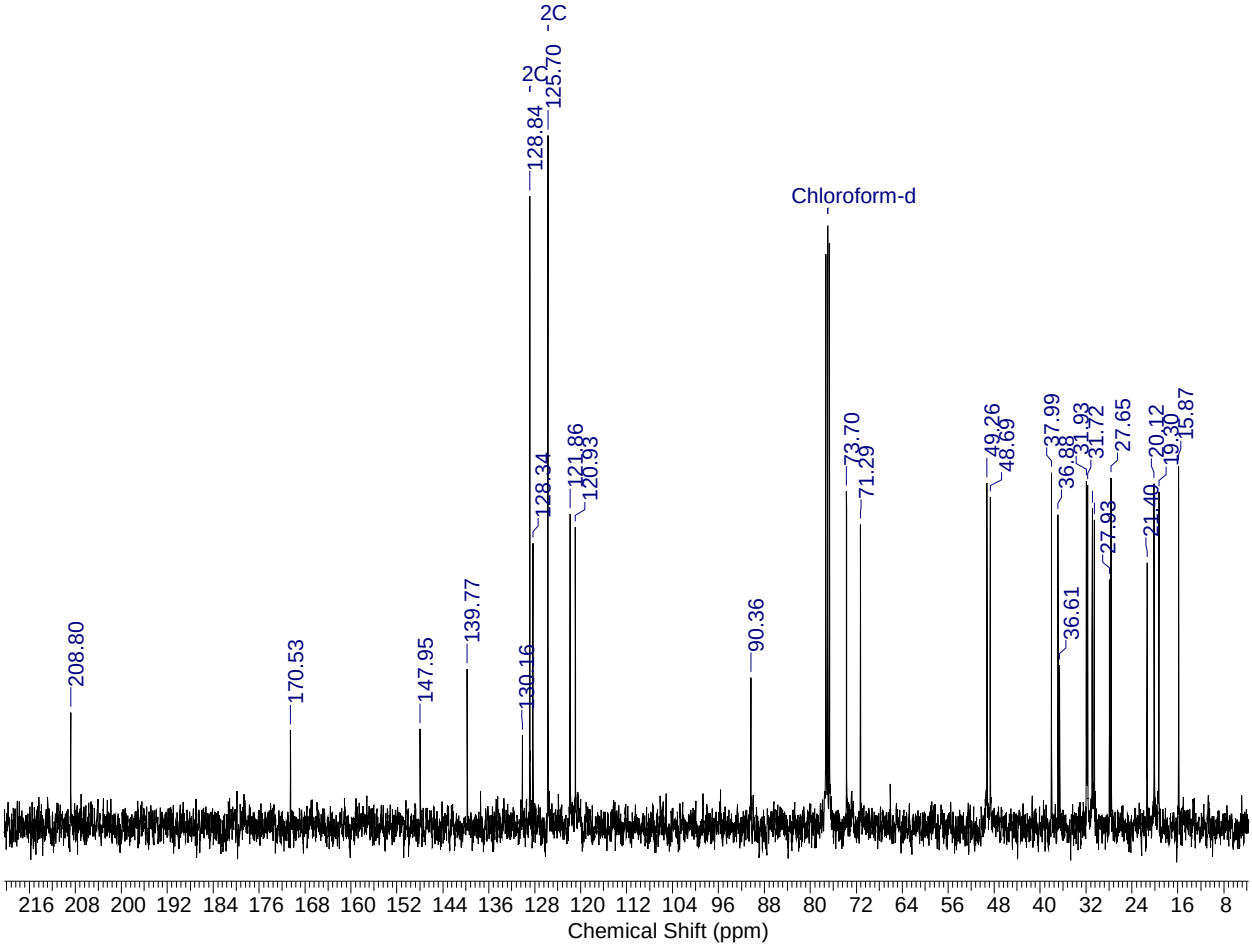
2.02
1.22
1.04
1.03
1.17
1.24
1.16
0.05-hmds
7.85
7.26
5.35
4.61
4.58
4.40
4.39
4.00
3.96
3.94
3.90
2.68
2.67
2.60
2.57
2.46
2.33
1.87
1.71
1.60
1.59
1.51
1.49
1.26
0.86
0.85
0.84
0.91
1.00
1.06
6.11
2.09
4.94
3.14
3.93
2.66
6.78
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)

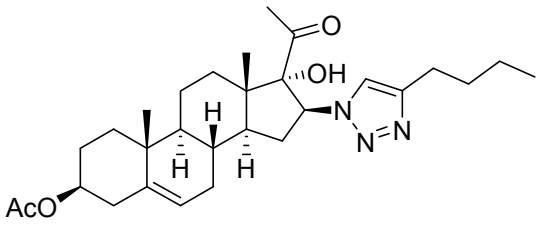

2C
2C
2C
Chloroform-d
46.52
19.19
11.14
77.00
214.91
170.44
142.21
139.48
125.16
121.40
78.43
73.45
68.67
48.84
37.68
36.49
32.66
30.70
27.52
27.53
22.82
21.34
15.86
216 208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8
Chemical Shift (ppm)


O
OH
H
H
H
N
N
N
AcO

13a

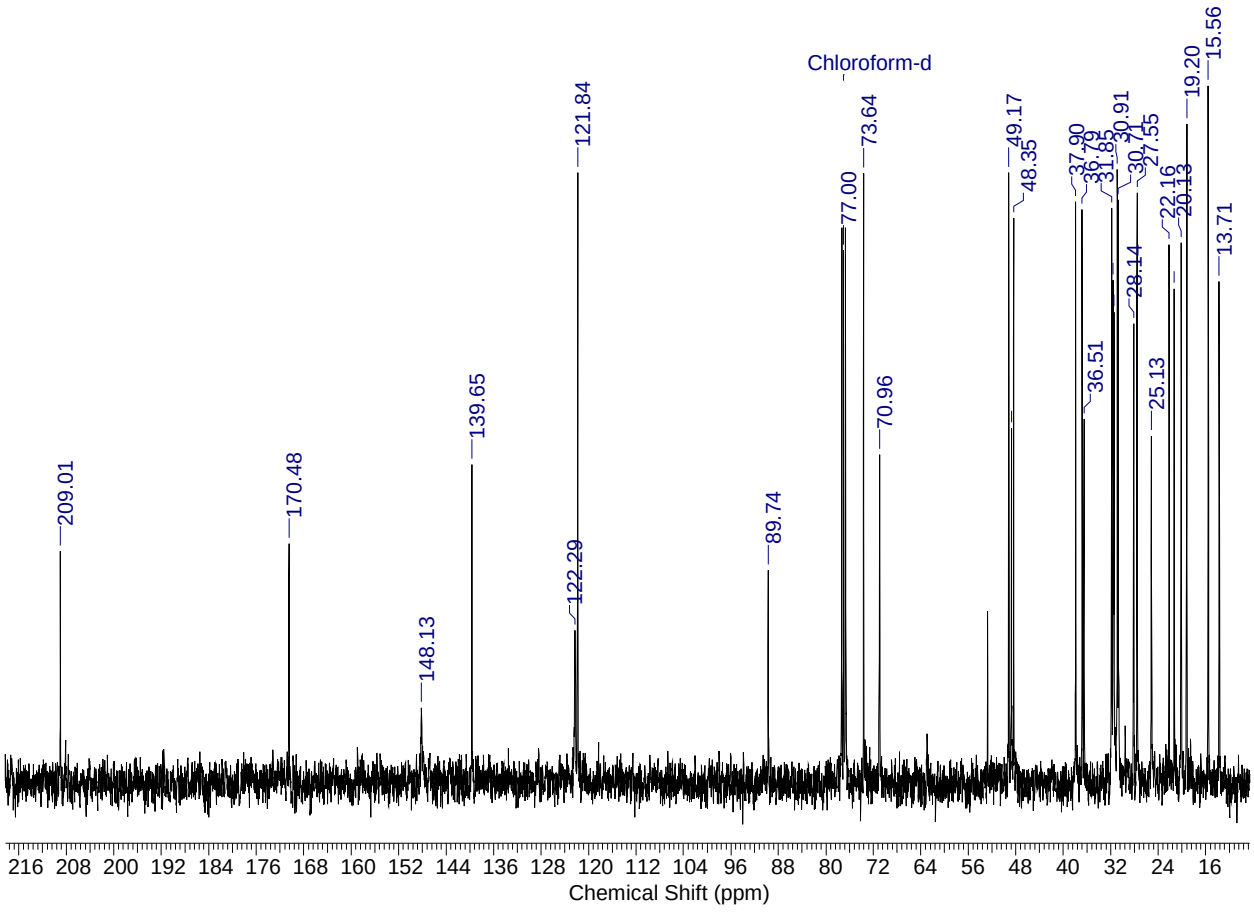
7.79
7.82
7.80
7.41
7.42
7.39
7.34
7.32
7.30
7.25
5.40
5.38
4.99
4.97
4.94
4.61
4.50
2.66
2.63
2.60
2.57
2.50
2.48
2.34
2.10
2.06
1.88
1.86
1.78
1.64
1.51
1.30
1.27
1.14
1.06
2.03
1.67
0.05 - HM
0.05
2.83
1.97
1.00
0.96
1.00
0.99
2.09
4.04
3.28
3.38
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Chemical Shift (ppm)

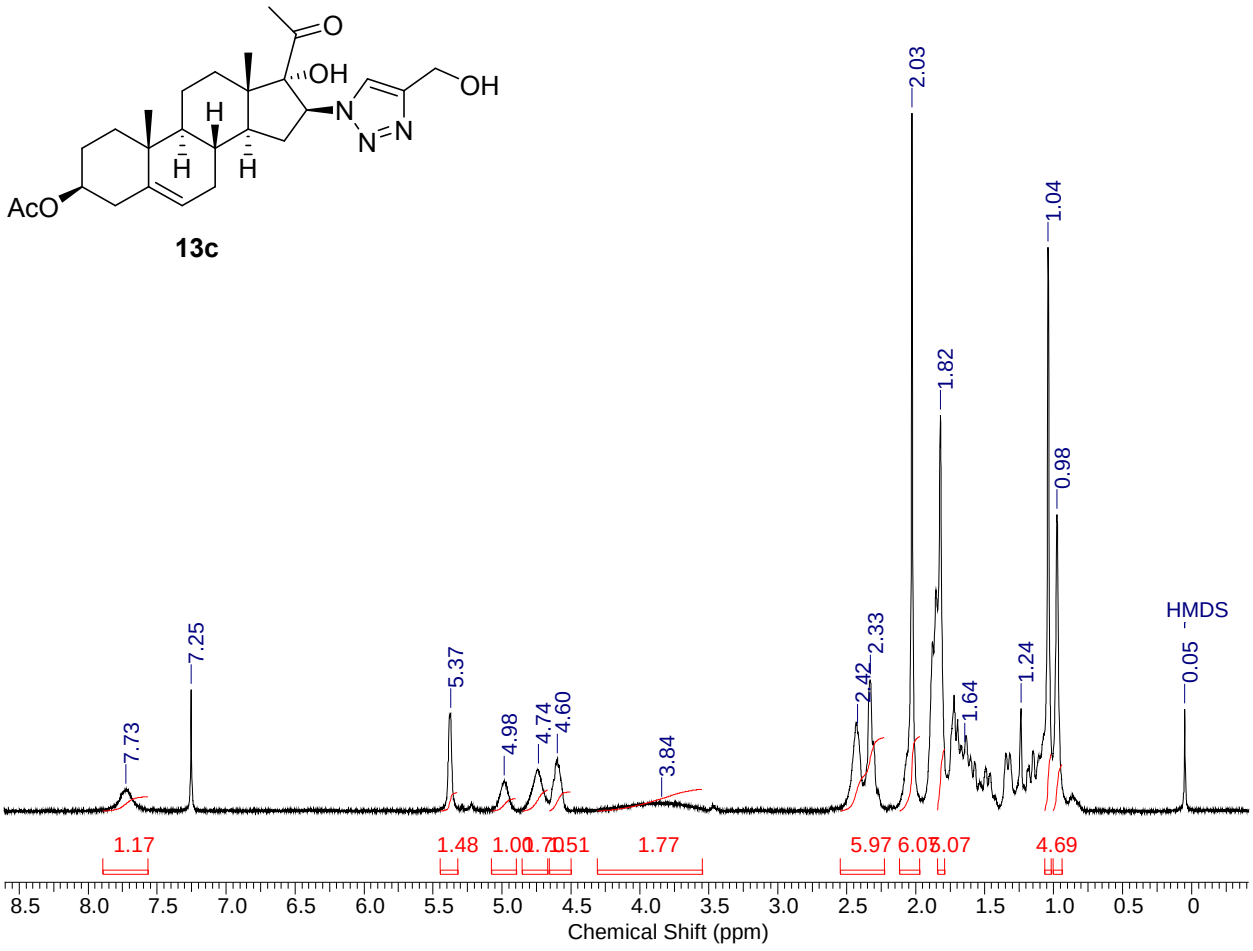

2C
2C
128.84
125.70
Chloroform-d
128.34
121.86
120.93
208.80
170.53
147.95
139.77
130.16
90.36
73.70
71.29
49.26
48.69
37.99
36.88
36.61
31.93
31.72
27.93
27.65
21.49
20.12
19.30
15.87
216
208
200
192
184
176
168
160
152
144
136
128
120
112
104
96
88
80
72
64
56
48
40
32
24
16
8
Chemical Shift (ppm)

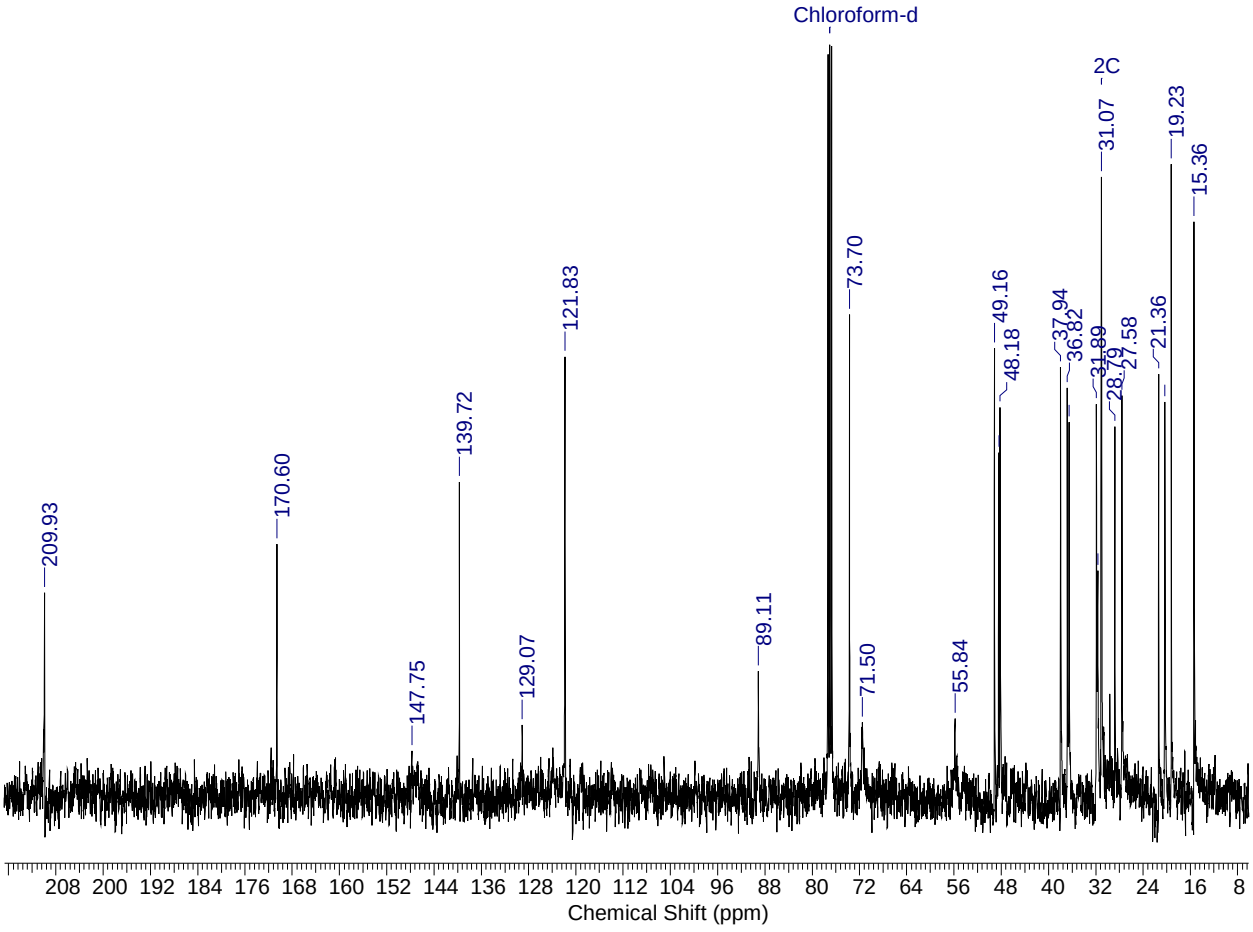

O
OH
H
H
H
N
N
N
AcO

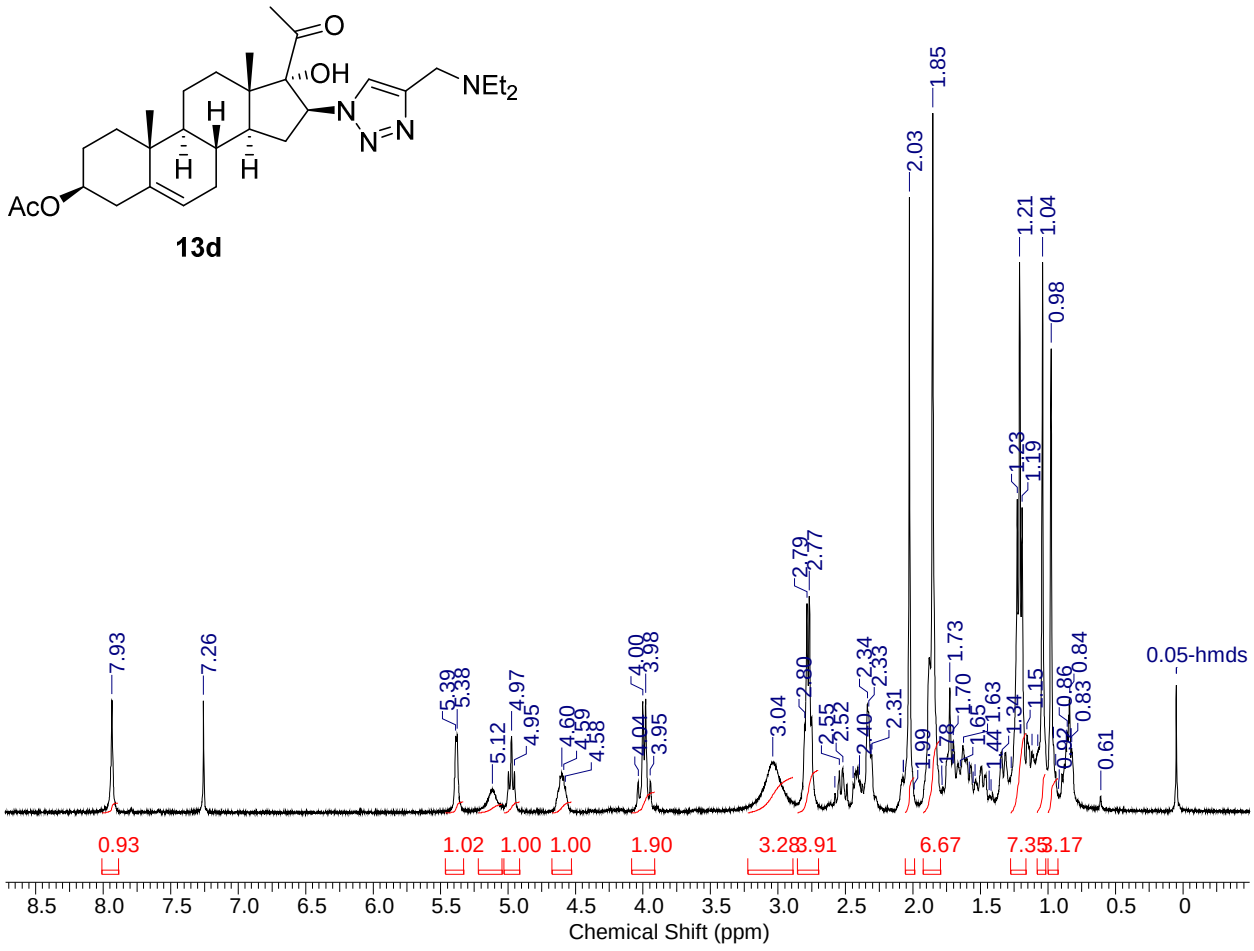
13b

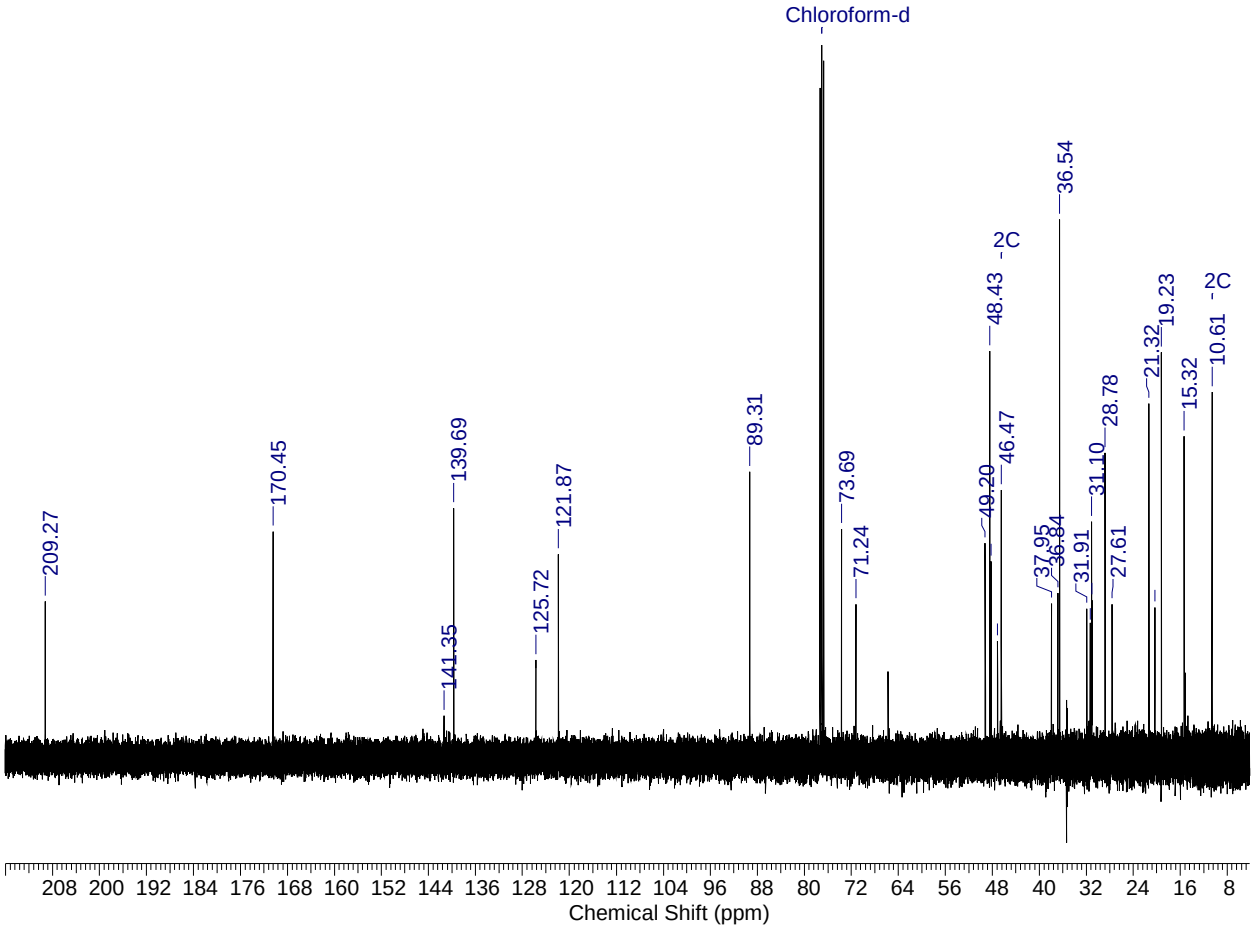
2.03
1.62
1.05
1.10
0.91
0.93
0.90
HMDS
0.05
2.71
2.72
2.69
2.33
1.85
1.74
1.65
1.37
1.24
1.39
1.33
1.15
1.49
2.31
2.08
2.61
2.59
2.47
1.80
7.42
7.25
5.38
4.94
4.92
4.90
4.60
0.92
1.00
0.91
1.23
1.97
4.29
4.89
2.41
3.60
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)

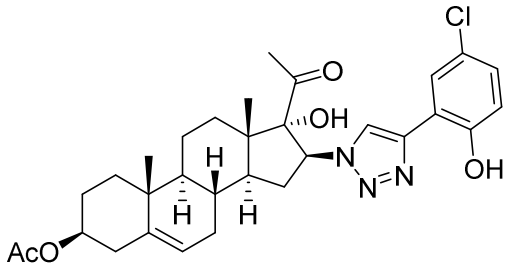

Chloroform-d
15.56
19.20
13.71
20.13
22.16
27.55
30.91
28.14
25.13
36.51
37.90
48.35
49.17
73.64
77.00
70.96
89.74
121.84
122.29
139.65
148.13
170.48
209.01
216 208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16
Chemical Shift (ppm)


O
OH
OH
N
N
N
H
H
H
AcO
13c
2.03
1.04
1.82
0.98
HMDS
7.25
5.37
2.33
2.42
1.64
1.24
0.05
7.73
4.98
4.74
4.60
3.84
1.17
1.48
1.77
5.97
6.07
5.07
4.69
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)


Chloroform-d
2C
31.07
19.23
15.36
73.70
49.16
37.94
36.82
31.89
28.79
27.58
21.36
48.18
121.83
139.72
170.60
209.93
89.11
71.50
55.84
147.75
129.07
208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8
Chemical Shift (ppm)

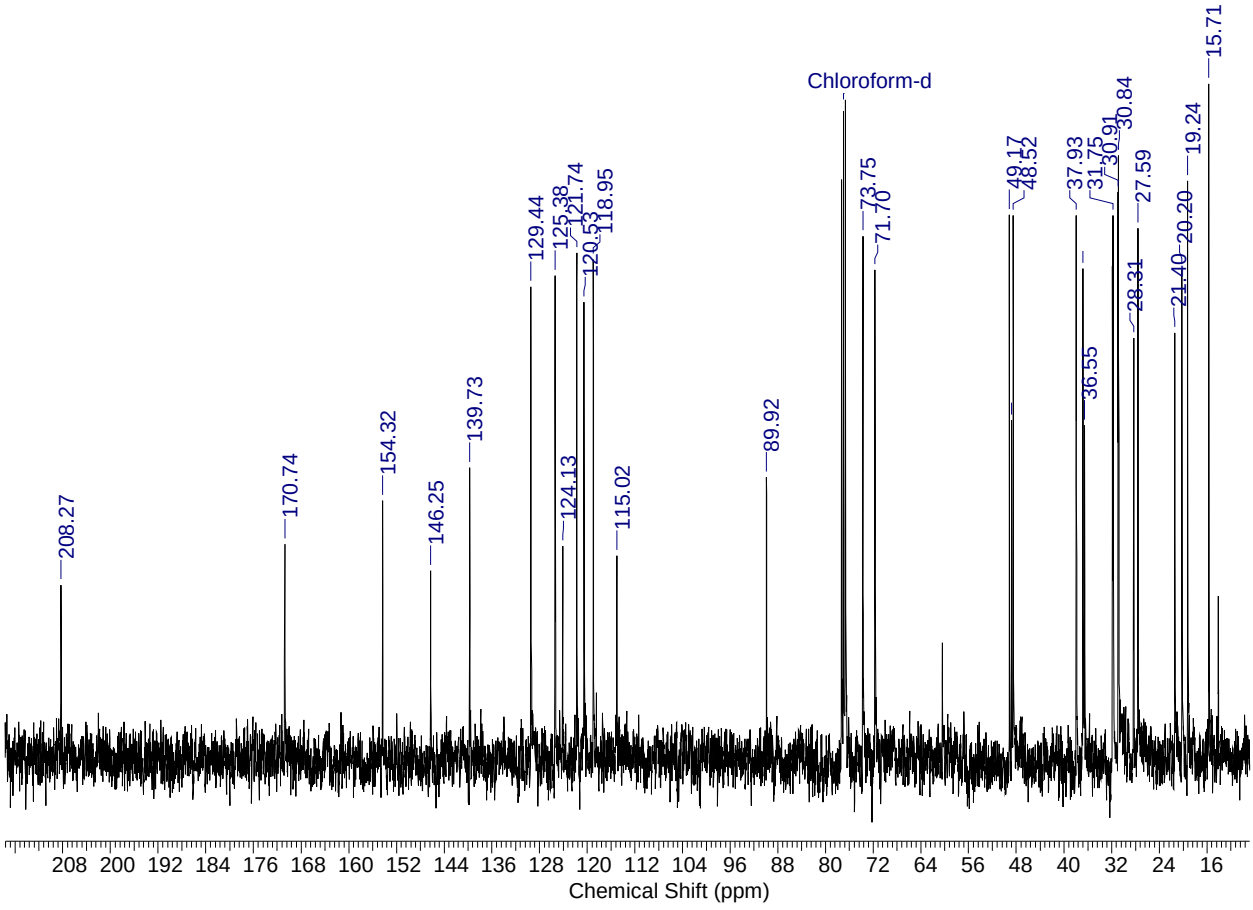

O
OH
NEt2
N
N
N
H
H
H
AcO
13d
7.93
7.26
5.39
5.38
4.97
4.95
5.12
4.60
4.59
4.58
4.00
3.98
4.04
3.95
3.04
2.79
2.77
2.80
2.55
2.52
2.40
2.34
2.33
2.31
1.99
1.78
1.85
2.03
1.73
1.70
1.65
1.63
1.44
1.34
1.23
1.21
1.19
1.15
1.04
0.98
0.92
0.86
0.84
0.83
0.61
0.05-hmds
0.93
1.02
1.00
1.00
1.90
3.28
3.91
6.67
7.35
5.17
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)

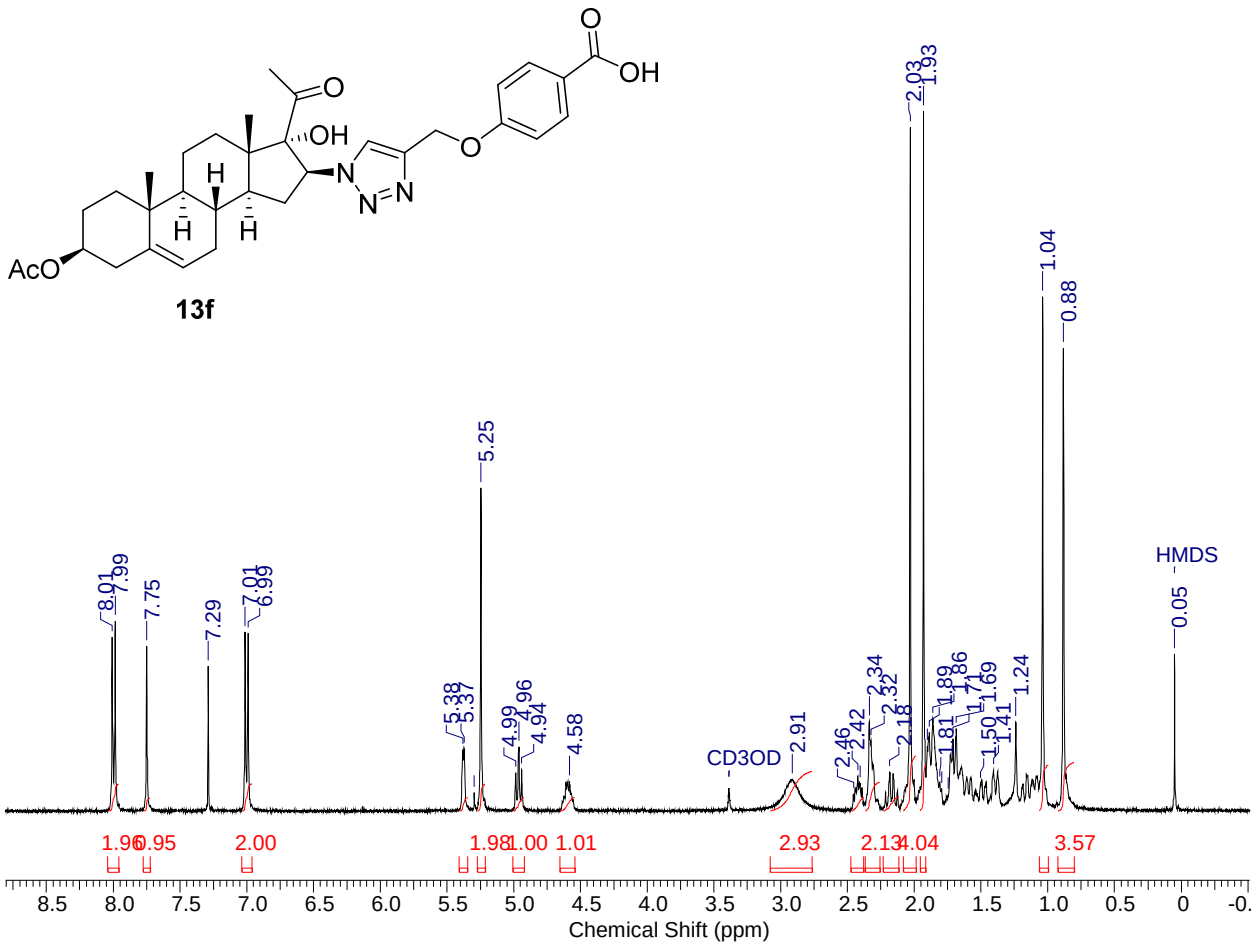

Chloroform-d
209.27
170.45
141.35
139.69
125.72
121.87
89.31
73.69
71.24
48.43
2C
49.20
46.47
36.54
37.95
36.84
31.91
31.10
28.78
27.61
21.32
19.23
15.32
10.61
2C
208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8
Chemical Shift (ppm)

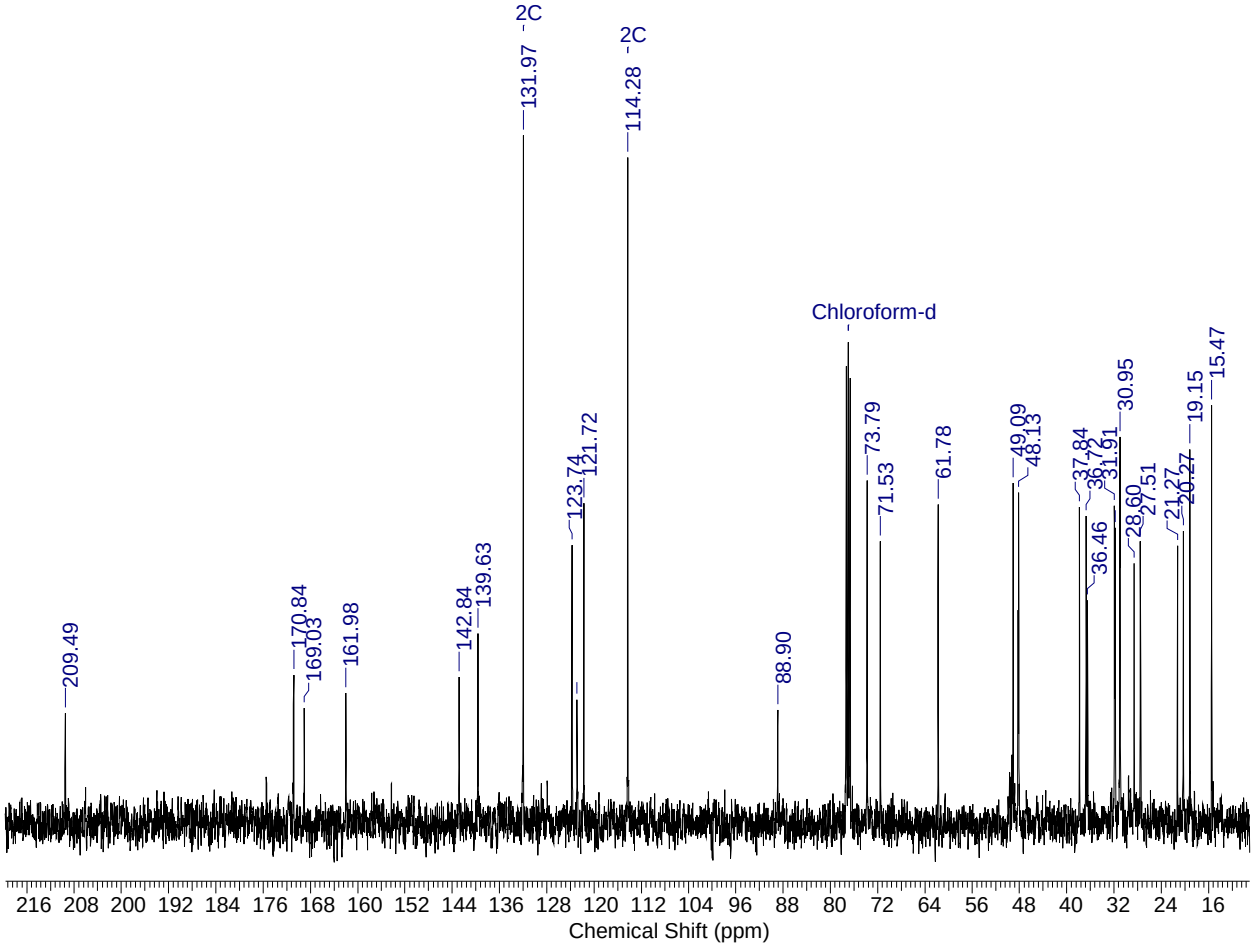

Cl
O
OH
H
H
N
N=N
OH
AcO

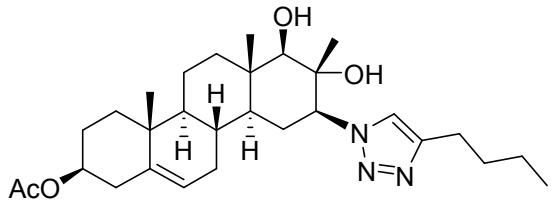
13e

10.70
7.88
7.37
7.25
7.16
6.98
6.96
5.39
5.00
4.61
4.24
2.51
2.34
2.16
1.61
1.36
2.04
1.76
1.06
HMDS
0.05
0.76
0.96
0.98
0.93
1.00
1.00
1.03
0.96
Chemical Shift (ppm)


208.27
170.74
154.32
146.25
139.73
129.44
125.38
124.13
120.53
118.95
115.02
89.92
Chloroform-d
73.75
71.70
49.17
48.52
37.93
36.55
31.75
30.91
30.84
28.31
27.59
21.40
20.20
19.24
15.71
Chemical Shift (ppm)

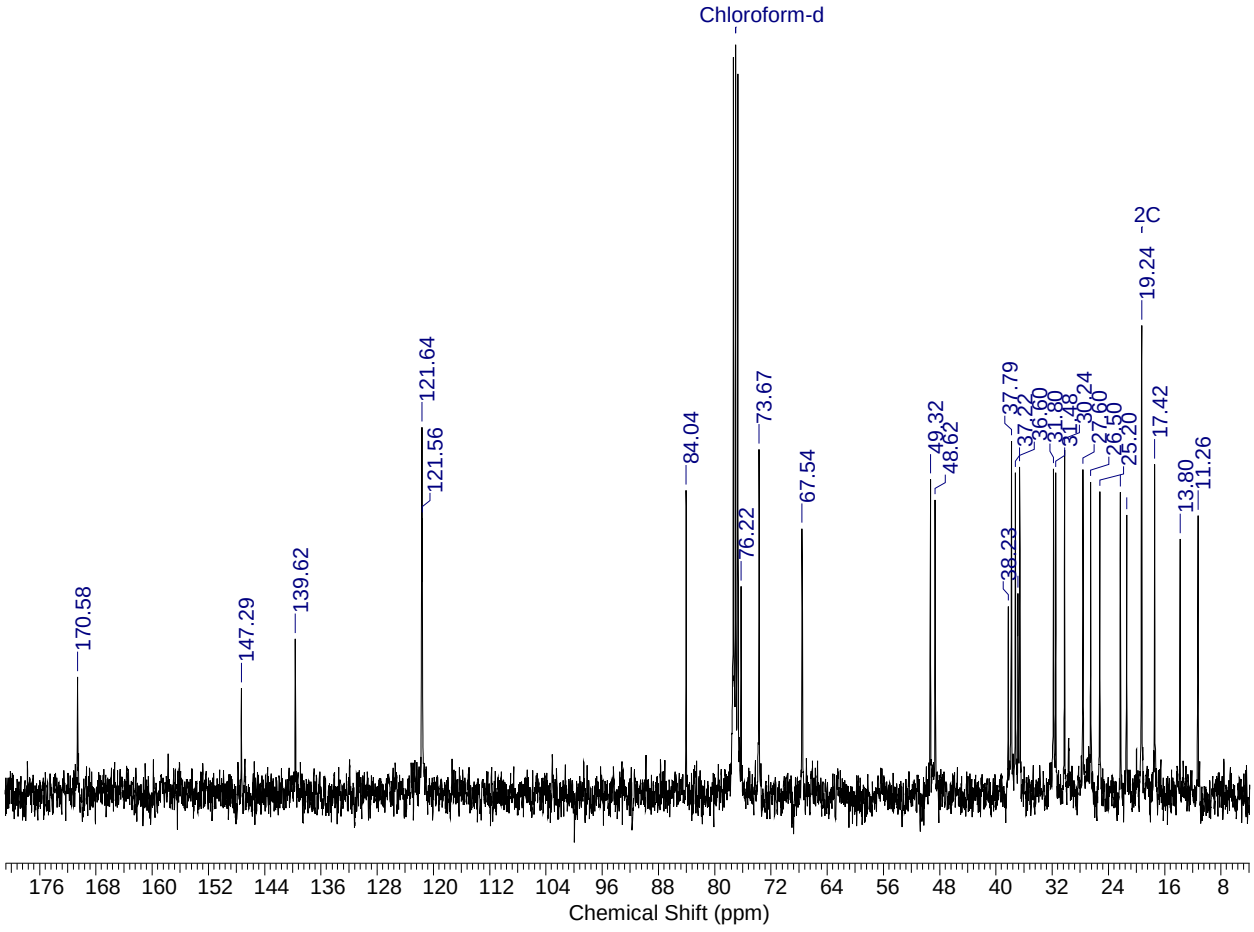

O
OH
O
OH
H
H
H
N
N=N
AcO
13f
8.01
7.99
7.75
7.29
7.01
6.99
5.38
5.37
5.25
4.99
4.96
4.94
4.58
CD3OD
2.91
2.46
2.42
2.34
2.32
2.18
2.03
1.93
1.89
1.86
1.81
1.71
1.69
1.59
1.41
1.24
1.04
0.88
HMDS
0.05
1.96
0.95
2.00
1.98
1.00
1.01
2.93
2.13
4.04
3.57
Chemical Shift (ppm)

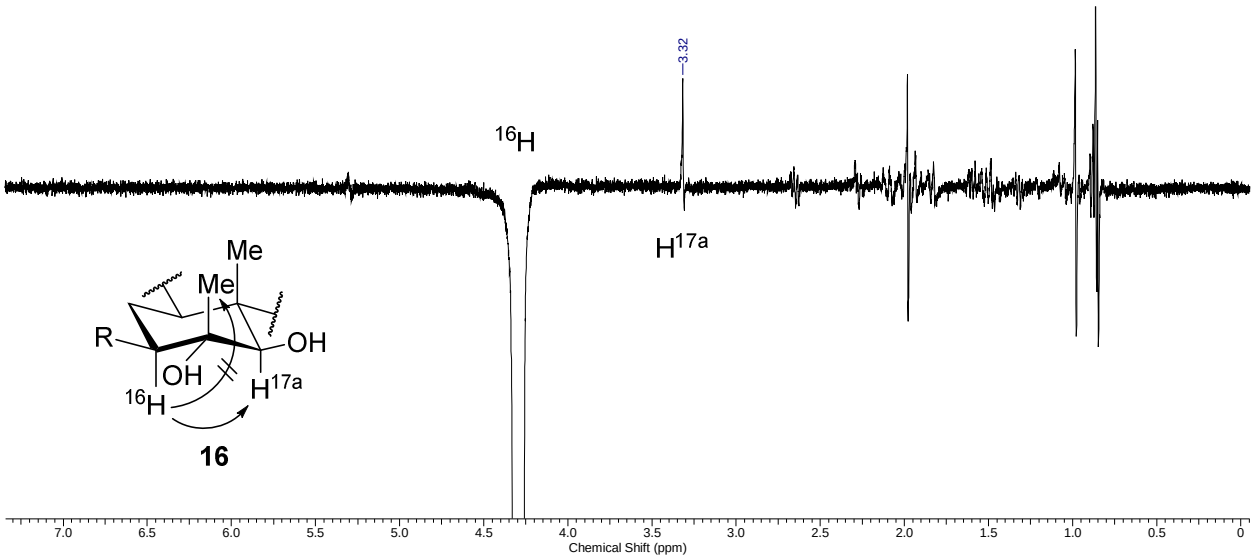

2C
131.97
2C
114.28
Chloroform-d
209.49
170.84
169.03
161.98
142.84
139.63
123.74
121.72
88.90
73.79
71.53
61.78
49.09
48.13
37.84
36.46
31.91
30.95
28.60
27.51
21.27
20.27
19.15
15.47
Chemical Shift (ppm)

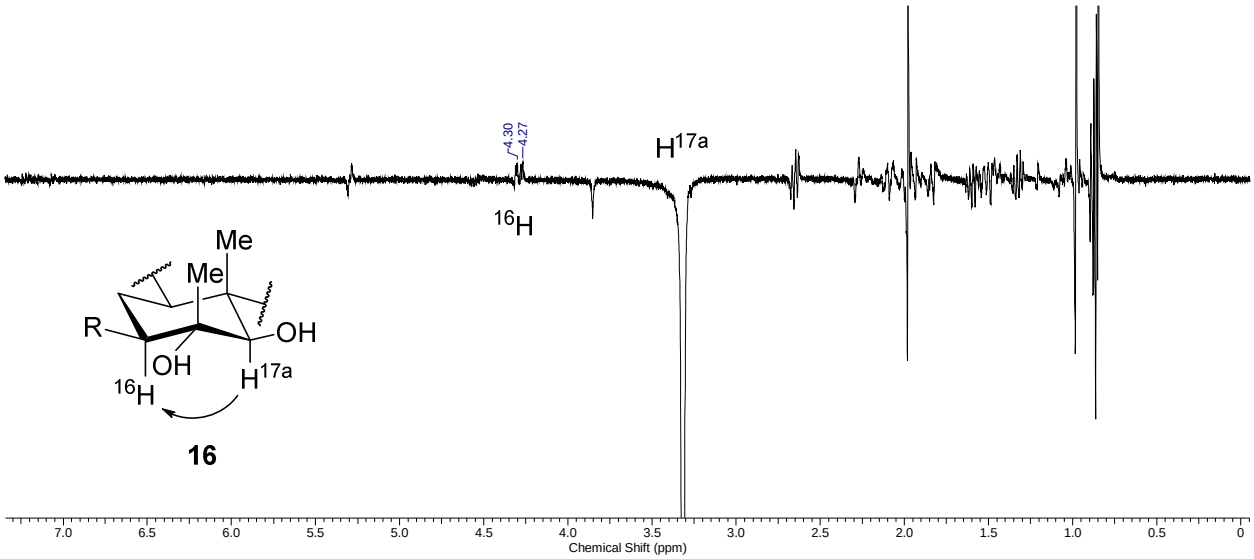

OH
OH
H
H
H
N
N=N
AcO

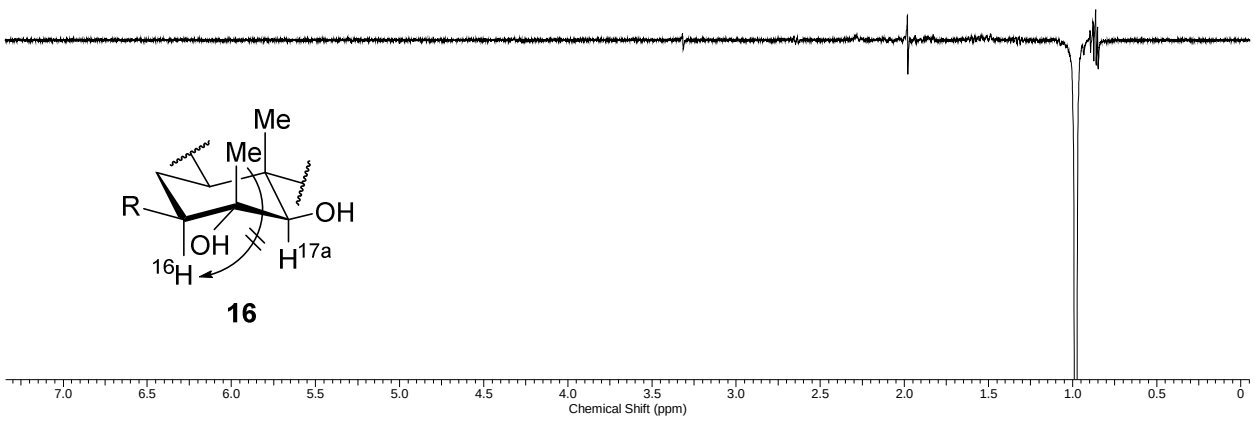
16

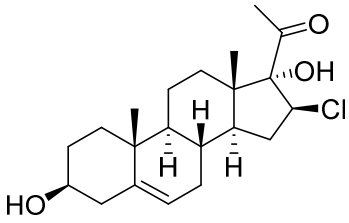
2.02
0.89
1.02
0.92
7.44
7.26
5.34
5.33
4.59
4.58
4.57
4.35
4.32
3.36
3.06
2.73
2.71
2.69
2.31
2.15
2.04
1.86
1.66
1.64
1.62
1.57
1.37
1.36
1.24
1.11
1.49
0.86
0.05 - HMD
1.01
0.99
1.00
0.85
0.89
1.61
1.98
2.00
3.16
2.29
8.24
Chemical Shift (ppm)


Chloroform-d
2C
19.24
121.64
121.56
84.04
73.67
76.22
67.54
49.32
48.62
37.79
38.23
17.42
13.80
11.26
170.58
147.29
139.62
Chemical Shift (ppm)


3.32
16H
H17a
Me
Me
R
OH
OH
16H
H17a
16
7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)

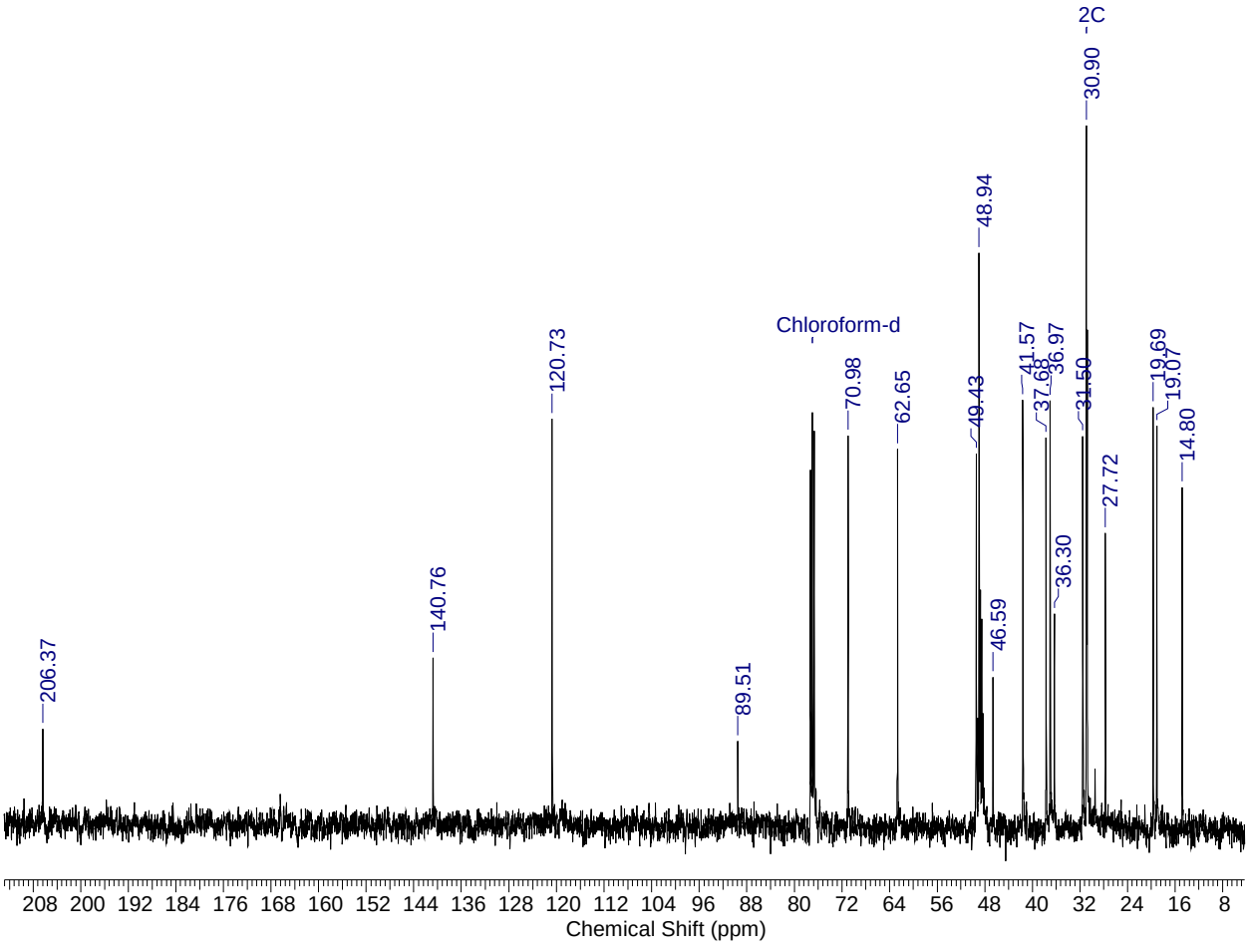

4.30
4.27
H17a
16H
Me
Me
R
OH
OH
16H
H17a
16
7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)

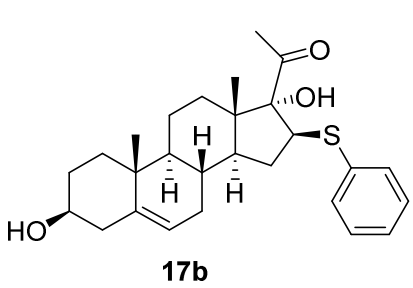

Me
Me
R
OH
OH
16H
H17a
16
7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)


O
OH
Cl
H
H
H
HO

17a

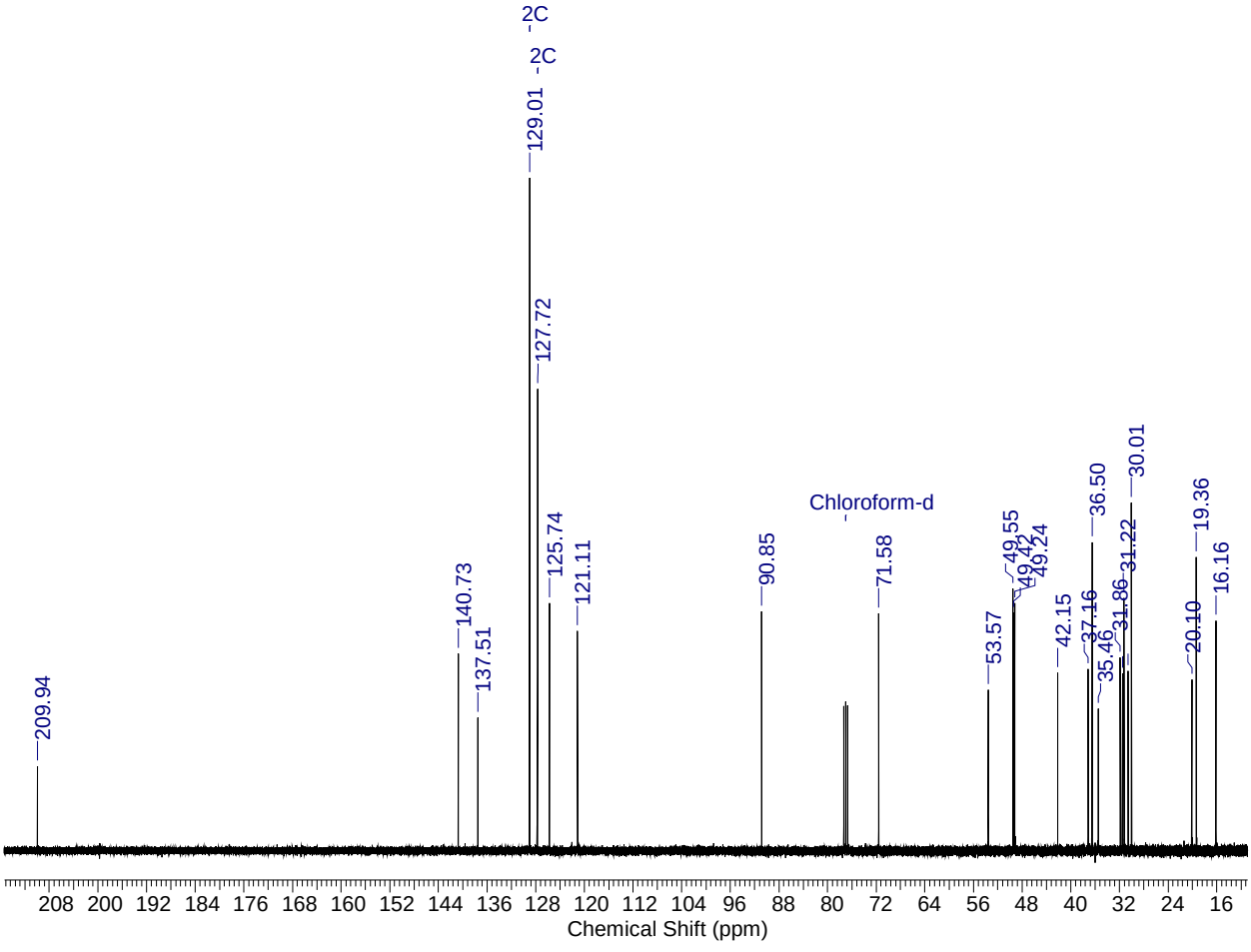
7.36
5.33
5.32
4.14
4.13
4.12
4.11
3.89
3.47
3.45
3.44
3.43
3.35
CD3OD
2.58
2.56
2.30
2.24
2.20
2.04
1.86
1.82
1.63
1.61
1.56
1.50
1.47
1.44
1.24
1.19
1.05
1.01
0.05-HMI
1.00
0.99
2.83
1.00
1.02
5.22
2.34
9.70
3.17
5.92
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)

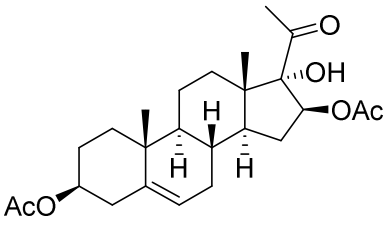

2C
30.90
206.37
140.76
120.73
89.51
Chloroform-d
70.98
62.65
48.94
49.43
46.59
41.57
37.68
36.97
36.30
31.50
27.72
19.69
19.07
14.80
208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8
Chemical Shift (ppm)


O
OH
H
S
H
H
HO

17b

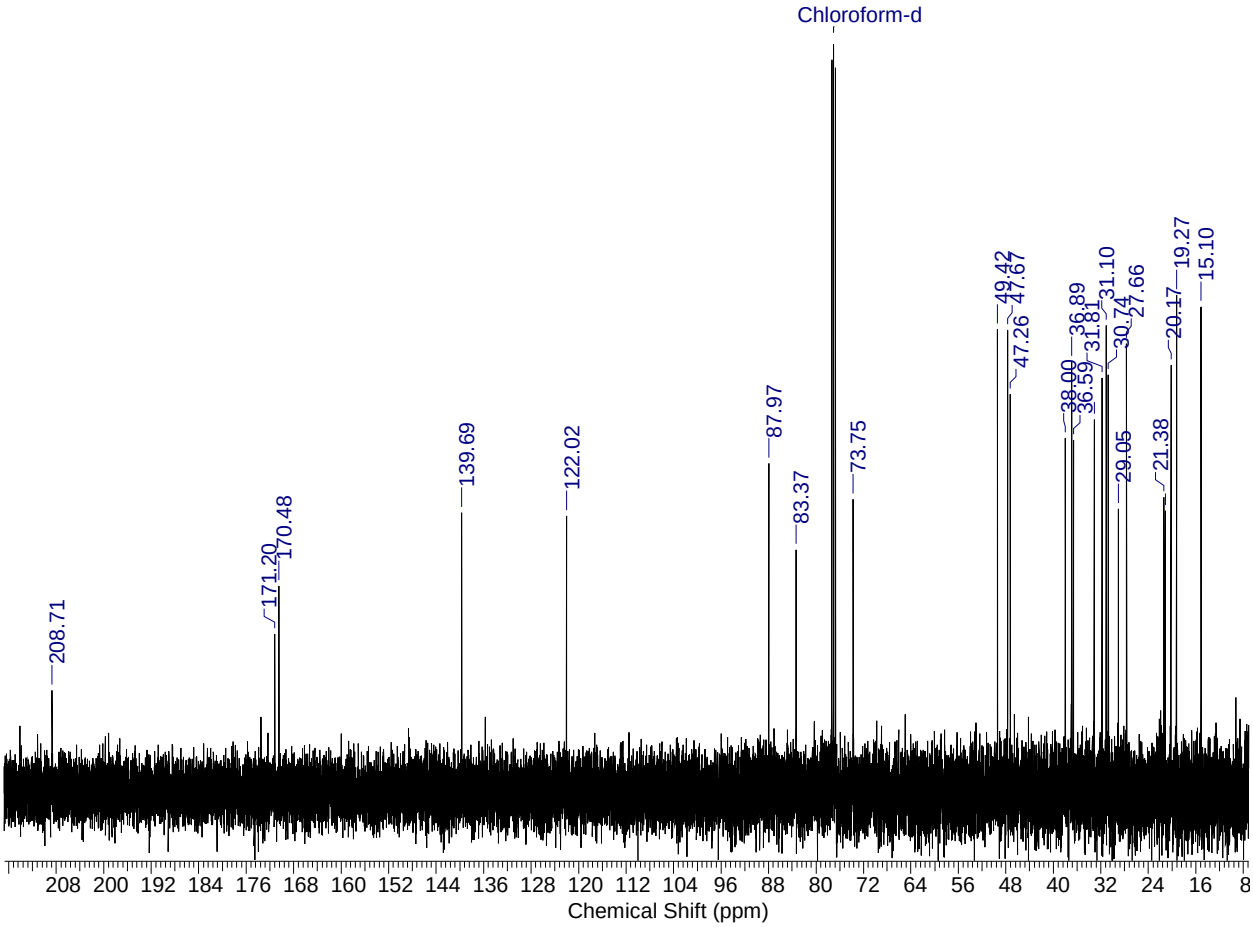
2.33
1.07
1.01
7.23
7.21
7.18
7.16
7.13
7.12
7.25
5.34
5.32
3.72
3.70
3.68
3.51
2.43
2.28
2.27
2.01
1.84
1.81
1.65
1.62
1.60
1.58
1.50
1.48
1.47
0.99
0.98
0.05-H
3.93
0.91
1.00
1.06
2.10
1.31
2.77
7.24
1.16
6.60
7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)

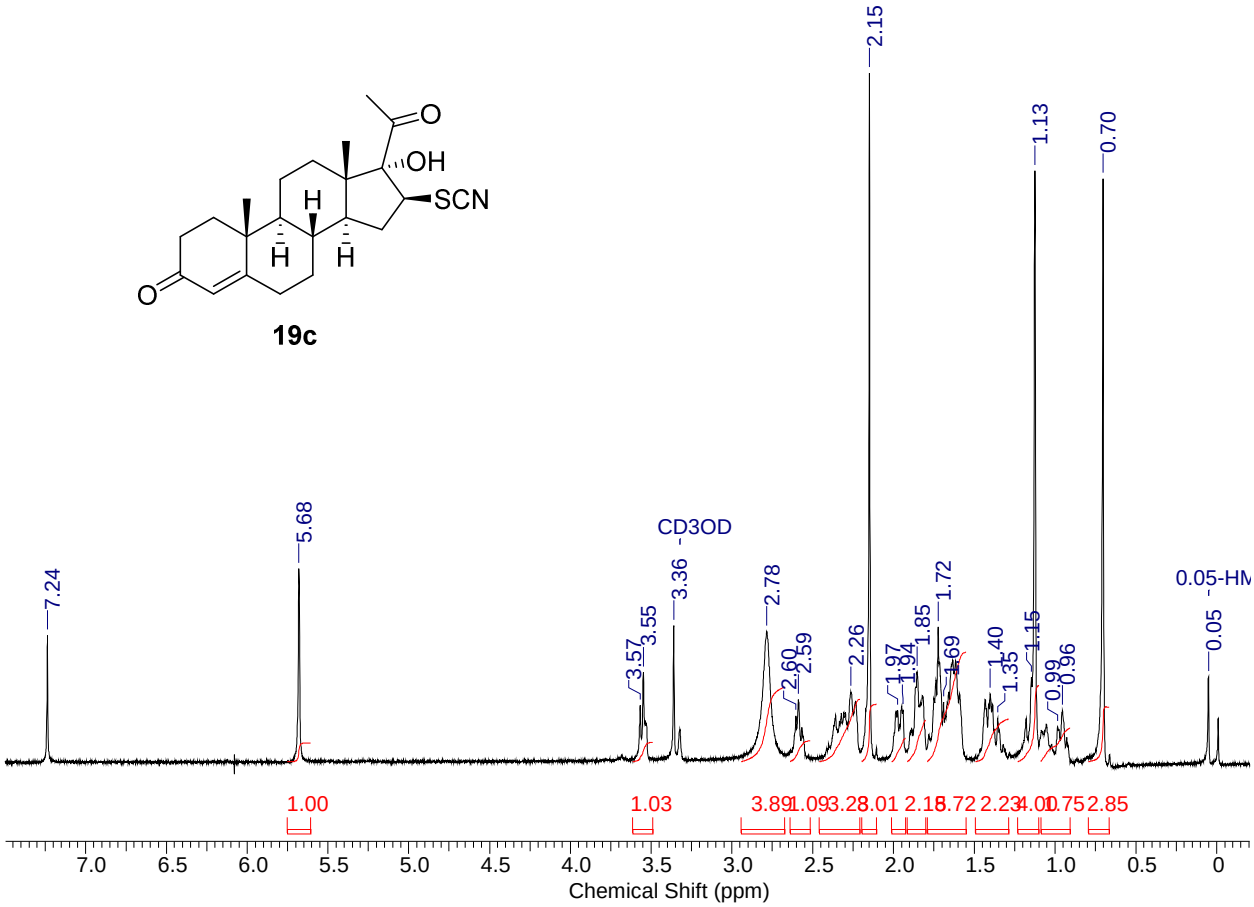

2C
2C
129.01
127.72
125.74
121.11
140.73
137.51
209.94
90.85
Chloroform-d
71.58
53.57
49.55
49.42
49.24
42.15
37.16
36.50
35.46
31.86
31.22
30.01
20.10
19.36
16.16
208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16
Chemical Shift (ppm)

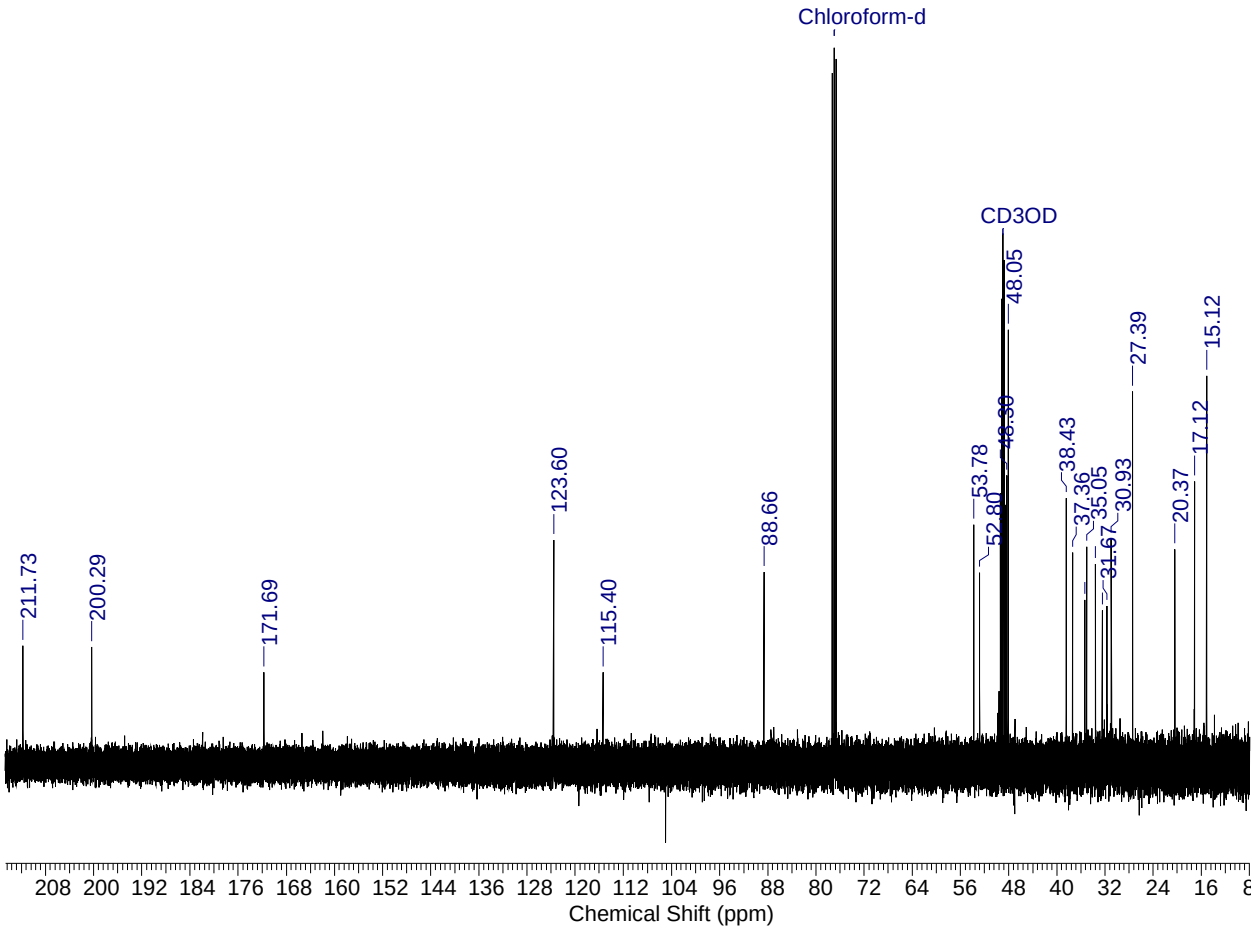

O
OH
OAc
H
H
H
AcO

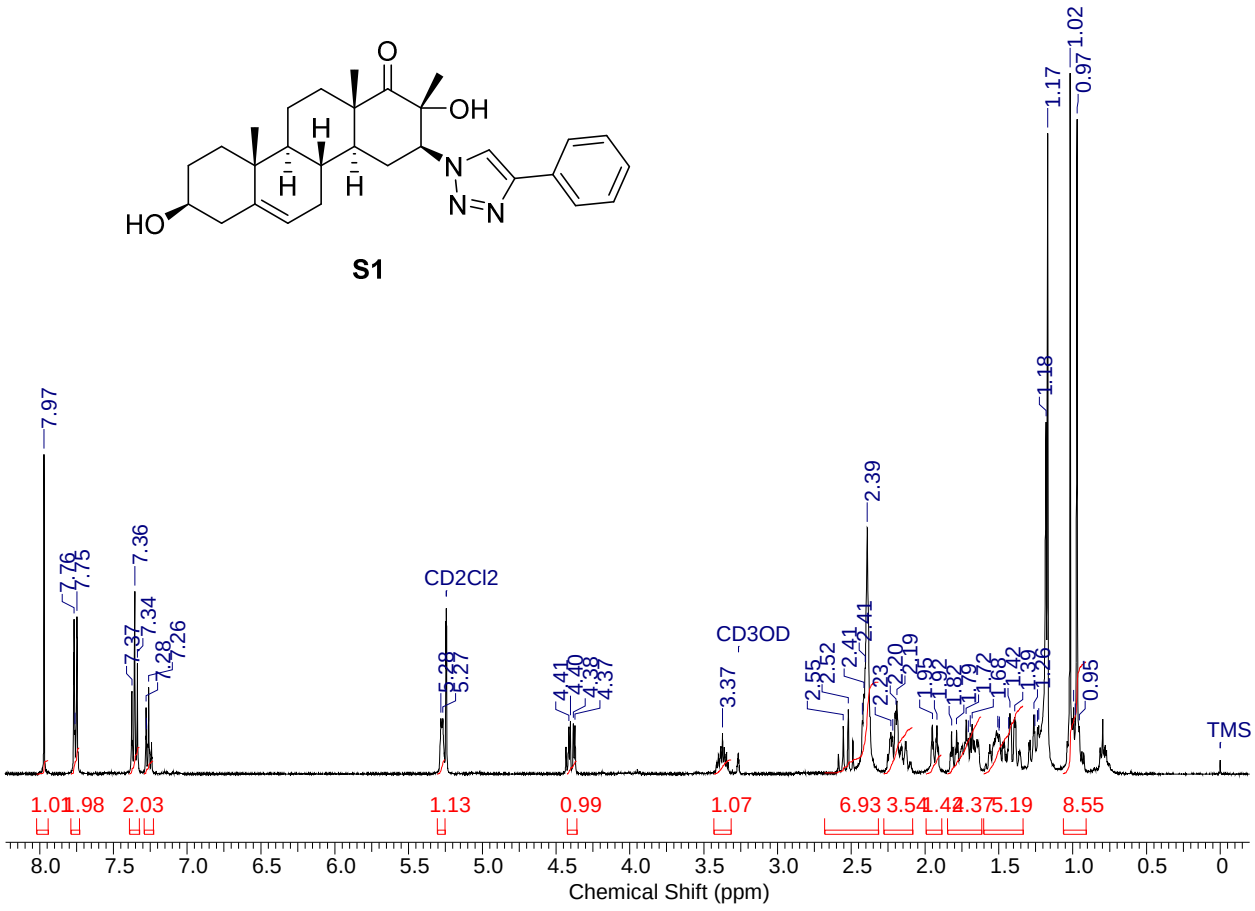
18a

2.22
2.05
2.02
1.02
0.93
3.42
2.32
1.61
1.84
1.24
CH2Cl2
5.37
5.36
4.83
4.81
4.79
4.59
5.29
7.26
1.70
1.45
1.43
1.42
0.05-HMDS
0.05
1.02
1.00
1.02
0.98
3.16
7.39
9.94
3.98
Chemical Shift (ppm)

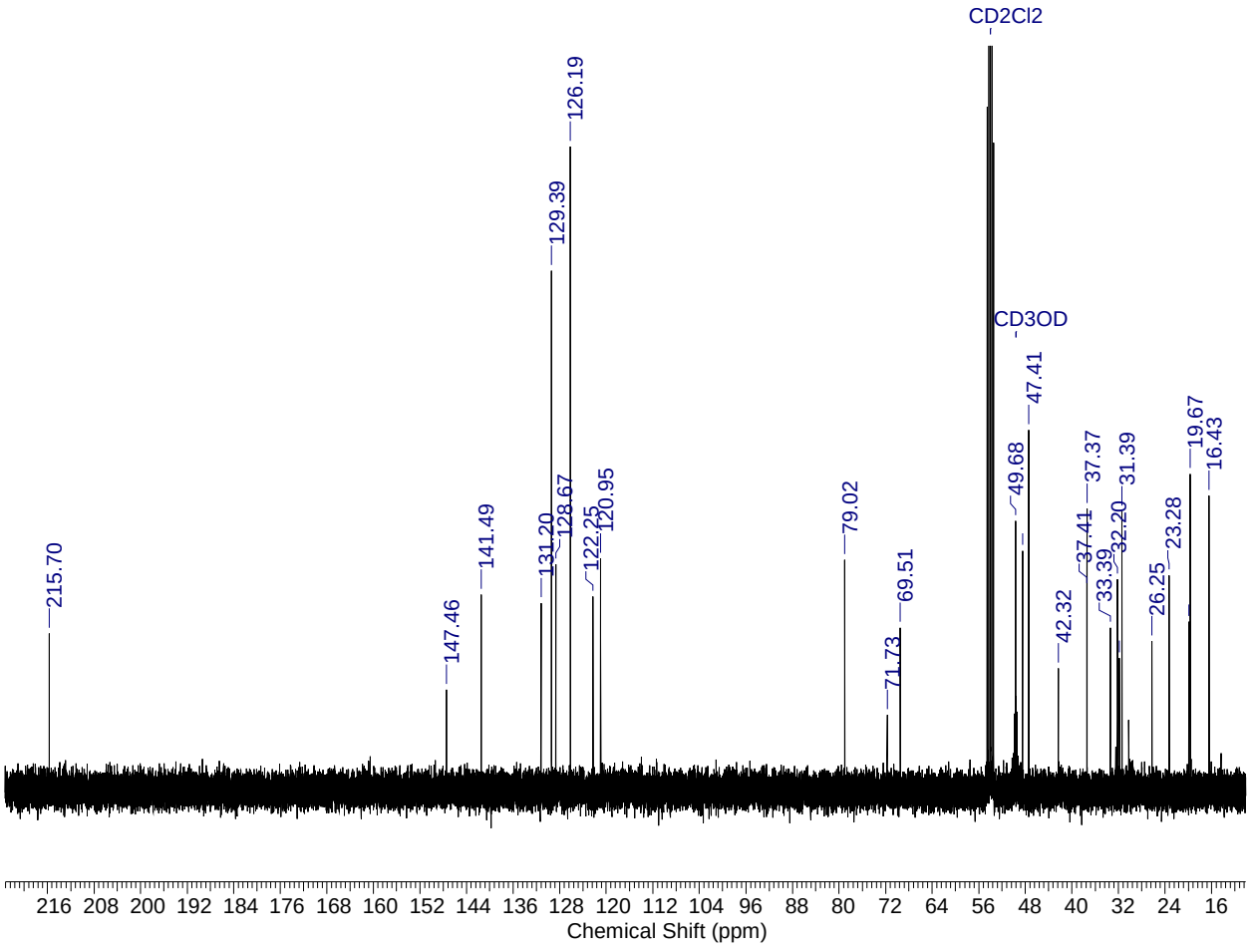

Chloroform-d
208.71
171.20
170.48
139.69
122.02
87.97
83.37
73.75
49.42
47.67
47.26
38.00
36.89
36.59
31.81
31.10
30.74
27.66
29.05
21.38
20.17
19.27
15.10
Chemical Shift (ppm)


O
OH
SCN
H
H
H
O
19c
7.24
5.68
CD3OD
3.36
3.57
3.55
2.78
2.60
2.59
2.26
2.15
1.97
1.94
1.85
1.72
1.69
1.40
1.35
1.15
1.13
0.99
0.96
0.70
0.05-HM
0.05
1.00
1.03
3.89
1.09
3.28
8.01
2.18
6.72
2.23
4.00
0.75
2.85
7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)


Chloroform-d
CD3OD
211.73
200.29
171.69
123.60
115.40
88.66
53.78
52.80
48.05
46.30
38.43
37.36
35.05
31.67
30.93
27.39
20.37
17.12
15.12
208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16
Chemical Shift (ppm)


O
OH
H
H
H
HO
N
N
N
CD2Cl2
CD3OD
TMS
Chemical Shift (ppm)

S1


CD2Cl2
CD3OD
Chemical Shift (ppm)