Tetrahedron Letters No. 42, pp 3635 - 3638, 1975. Pergamon Press. Printed in Great Britain.

^{13}C NMR SPECTRA OF SAPOGENINS

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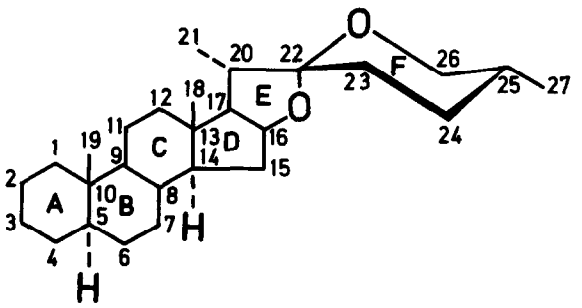
(Received in UK 2nd September 1975; accepted for publication 4th September 1975)

In connection with our continuing study of ^{13}C NMR spectra of steroids,[1-3] we needed for reference purposes the complete assignment of the ^{13}C NMR spectrum of the steroid sapogenin (spirostan) framework. Steroidal sapogenins are not only of great commercial utility as starting materials in the synthesis of a variety of steroid hormones, but new ones are still being isolated from plant sources. We wish to report briefly on our results with a series of sapogenins differing both with respect to substitution and skeletal stereochemistry.

All the spectra were obtained in $CDCl_3$ solution by the FT mode with proton noise decoupling. The sapogenins examined (see Table) include compounds varying with respect to configurations at C-5 (A/B cis and trans) and at C-25. For deoxytigogenin (A) the assignment of the resonances arising from carbon atoms in the (25R)-spiroketal sidechain was accomplished by comparison with spectra of deuterium labeled analogs. Thus, the spectra of three deoxytigogenins, Specifically labeled[4] (23-d_1, 20,23,23-d_3, 15,15,17-d_3) provided unambiguous assignment for all deuterated carbon atoms, 15, 17, 20, and 23 as well as neighboring carbon atoms. The latter were generally shifted upfield 0.1-0.2 ppm by the deuterium substitution,[1] which allowed the resonances for carbon atoms 13, 14, 16, 17, 21, 22, 24 to be identified. The assignment for the remaining carbon atoms in the spiroketal sidechain, C-25, 26, and 27, is straight-forward by using chemical shift considerations. The assignments were confirmed by comparing with the spectrum of the 25β hydroxyl substituted derivative, C, taking advantage of the known substituents effects of an axial hydroxyl group.[2,5] A comparison of the chemical shifts for carbon atoms 1-12 and 19 in A with the corresponding



(25R)-5α-Spirostane

A: (25R)-5α-spirostane (deoxytigogenin)

B: (25R)-5α-spirostan-3β-ol (tigogenin)

C: (25S)-5α-spirostan-25-ol

D: Δ^2-(25R)-5α-spirosten-15β-ol

E: Δ^5-(25R)-5α-spirosten-3β-ol (diosgenin)

F: 3β-hydroxy-(25R)-5α-spirostan-12-one (hecogenin)

G: (25R)-5β-spirostan-3β-ol (smilagenin)

H: (25S)-5β-spirostan-3β-ol (sarsasapogenin)

chemical shifts in cholestane[1] was sufficient to allow assignment of these carbon atom resonances; all shifts were found to be essentially the same in the two compounds. The assignment for C-18 follows by exclusion.

Once all carbon resonances were assigned to deoxytigogenin (A), the spectra of compounds B, D, E, and F were easily assigned, since the effects of the various substituents on the chemical shifts have been established in other steroid series.[1-3,6] Assignment of the spectra of the two 5β-sapogenins, G and H, followed by comparison with the data for 5β-cholestane,[7] the chemical shifts of ring A in digitoxigenin,[8] together with the assigned spectrum of desoxytigogenin. Compound H differs from G and all the other sapogenins in this study by having an

TABLE

^{13}C Chemical Shifts of Sapogenins.[a]

Carbon atom	A	B	C	D	E	F	G	H
1	38.7	37.0	38.6	39.7	37.2	36.5	29.9	29.9
2	22.2	31.5	22.2	125.7	31.6	31.2	27.8	27.8
3	26.8	71.2	26.8	125.5	71.5	70.7	67.0	67.0
4	29.0	38.2	29.0	28.7	42.2	37.8	33.6	33.6
5	47.1	44.9	47.0	41.6	140.8	44.6	36.6	36.5
6	29.0	28.6	29.0	30.3*	121.3	28.3	26.5	26.6
7	32.4	32.3	32.4	31.4°	32.0	31.4*	26.5	26.6
8	35.2	35.2	35.2	31.2°	31.4	34.4	35.3	35.3
9	54.8	54.4	54.8	54.6	50.1	55.5	40.3	40.3
10	36.3	35.6	36.4	34.9	36.6	36.0	35.3	35.3
11	20.7	21.1	20.6	21.0	20.9	37.8	20.9	20.9
12	40.2	40.1	40.1	42.6	39.8	213.0	39.9	39.9
13	40.6	40.6	40.6	40.7	40.2	55.0	40.7	40.6
14	56.5	56.3	56.5	61.3Δ	56.5	55.8	56.5	56.4
15	31.8	31.8	31.7	69.6	31.8	31.5*	31.8	31.7
16	80.8	80.7	81.3	82.1	80.7	79.1	80.9	80.9
17	62.3	62.2	62.0	60.7Δ	62.1	53.5	62.4	62.1
18	16.5	16.5	16.5	19.1	16.3	16.0	16.4	16.5
19	12.3	12.4	12.3	11.7	19.4	12.0	23.8	23.9
20	41.6	41.6	41.5	42.6	41.6	42.2	41.6	42.1
21	14.5	14.5	14.4	14.2	14.5	13.2	14.4	14.3
22	109.0	109.0	108.8	109.9	109.1	109.0	109.1	109.5
23	31.4	31.4	24.7	31.4	31.4	31.2	31.4	27.1
24	28.9	28.8	32.7	28.6	28.8	28.8	28.8	25.8*
25	30.3	30.3	66.6	30.2*	30.3	30.2	30.3	26.0*
26	66.7	66.7	68.9	67.1	66.7	66.8	66.8	65.0
27	17.1	17.1	27.0	17.1	17.1	17.1	17.1	16.1

[a] In ppm relative to TMS. Closelying peaks marked with *, o, or Δ may be reversed

axial C-25 methyl group rather than an equatorial one; the expected stereochemical dependence of the ring F chemical shifts[9,10] is found when comparing e.g. the spectra of G and H.

The three deuterated deoxytigogenins employed were only partially labeled, but this was found advantageous in the assignment. The isotope effects observed at neighboring carbon atoms are reflected in that the corresponding peaks appear as doublets and are thus recognized more reliably in this way than by comparison of spectra of labeled and unlabeled analogs. Furthermore, for purpose of comparison, the spectra of the labeled and unlabeled compounds must be obtained under identical experimental conditions - including the same concentration - which is inconvenient since the deuterated material frequently is available only in very small quantities.

Acknowledgements: We thank NATO (Grant RG 939) and the National Institutes of Health (Grant AM 17896) for partial financial support and Mr. C. L. VanAntwerp for recording some of the spectra.

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