SHORT PAPER

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Main NMR characteristics of synthetic (25r)-5α-furostanes†

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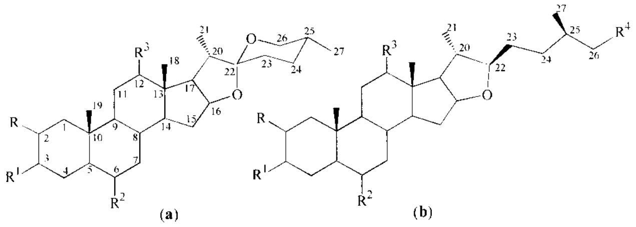
The assignment of ^{13}C signals of synthetic (25R)-5α-furostanes together with the main ^{1}H characteristics of the furostane side chain are presented. The main effects on chemical shifts due to conversion of ring F into an open chain are briefly discussed.

Keywords: synthetic (25R)-5α-furostanes

Furostanes are unusual compounds in both the natural and the synthetic domains. In the course of our synthetic program we have prepared a number of these compounds as possible bioactive analogues of several naturally occurring brassinosteroids.[1–3] As part of this investigation we have been able to form some conclusions about the main NMR characteristics of this family of compounds. We now offer spectroscopic data on eight synthetic furostanes which bear different functionality in rings A, B and C (see Fig. 1).



1a, 1b	$R = H, R^1 = \beta OH, R^2 = R^3 = R^4 = H$
2a, 2b	$R = R^1 = \alpha OH, R^2 = R^3 = R^4 = H$
3a, 3b	$R = H, R^1 = R^2 = \beta OH, R^3 = R^4 = H$
4a, 4b	$R = H, R^1 = \beta OH, R^2 = {=}O, R^3 = R^4 = H$
5a, 5b	$R = H, R^1 = R^2 = {=}O, R^3 = R^4 = H$
6a, 6b	$R = H, R^1 = R^2 = \beta OAc, R^3 = R^4 = H$
7a, 7b	$R = H, R^1 = \beta OAc, R^2 = H, R^3 = \beta OAc, R^4 = OAc$
8a, 8b	$R = R^1 = \alpha OAc, R^2 = \beta OAc, R^3 = H, R^4 = OAc$

Fig. 1 Compounds studied.

Results and discussion

Synthetic procedures for the preparation of spirostanes **2a**–**8a** have been previously described.[1–3] Furostanol **1b** was prepared by mixed hydride reduction[4] of tigogenin (**1a**), while **2b**, **3b**, **6b**, **7b** and **8b** were obtained by hydrogenation of the parent spirostane over PtO_2 in acetic acid/perchloric acid[5]. Both reduction techniques produced the same R configuration at the new C-22 stereogenic centre. Furostanones **4b** and **5b** are products of oxidation of **3b** with NBS.[6]

^{13}C-NMR[7] chemical shifts of the carbon atoms of rings A, B and C are in good agreement with the shielding data available for equivalent substitution patterns.[8,9] As expected, conversion of the F ring into a an open chain produces only minor modifications of the shielding of the ^{13}C nuclei of the steroid skeleton. Table 1 shows the chemical shifts of furostanes **1b**–**8b**. For comparison, the corresponding chemical shifts of the parent spirostanes **1a**–**8a** are presented.

Conversion of the F ring into an open chain produces the loss of a number of gauche and 1,3 diaxial shielding interactions and this results in significant deshielding of C-16, C-17, C-21, C-24, C-25 and C-26. Shielding at C-22 is associated with the conversion from cyclic ketal into cyclic ether, while shielding at C-20 and C-23 could be rationalised on the basis that free rotation of the C-22/C-23 bond (only possible in structure **b**) allows the gauche interaction between C-24 and H-21, which results in significant shielding of C-20 and minor shielding of C-23. (see Table 2).

Table 3 shows the main ^{1}H chemical shifts associated with the furostane side chain.[11] For comparison, the corresponding

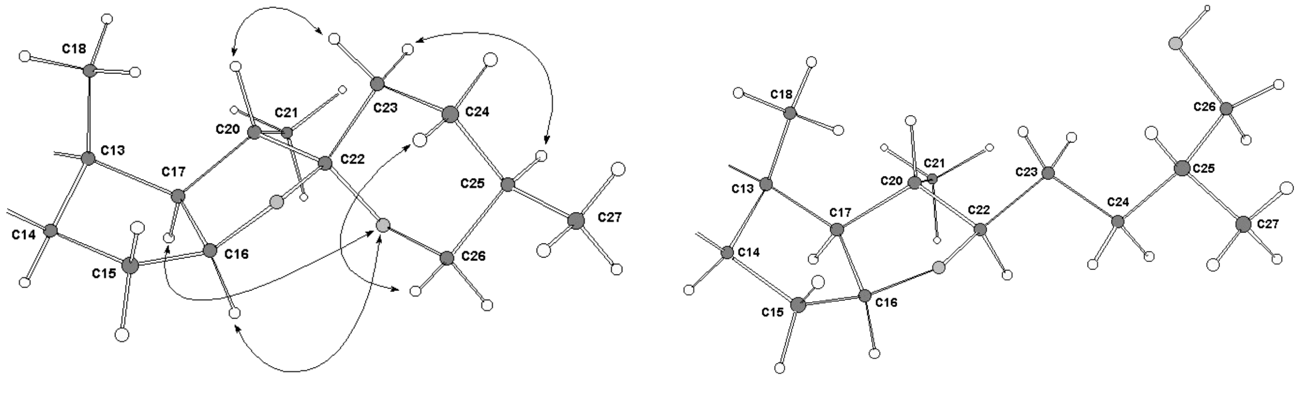


Fig. 2 Molecular graphics[10] for the spirostane and furostane side chains.

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† This is a Short Paper, there is therefore no corresponding material in *J Chem. Research (M).*

Table 1 ^{13}C chemical shifts (δ ppm) for compounds **1a** to **8b**

C	1a	2a	3a	4a	5a	6a	7a	8a	1b	2b	3b	4b	5b	6b	7b	8b
1	37.0	40.4	38.6	36.6	37.8	37.9	36.5	39.2	37.0	40.6	38.5	36.7	38.1	37.5	36.4	39.1
2	31.5	68.8	31.2	30.6	37.2	27.2	27.3	69.2	31.4	68.8	31.3	30.7	37.4	26.7	27.2	69.2
3	71.2	69.0	71.4	70.5	210.7	73.2	73.4	68.5	71.2	69.0	71.4	70.6	211.2	72.8	73.2	68.5
4	38.2	34.2	35.0	30.0	36.8	30.8	33.8	29.2	38.1	34.2	35.2	30.1	37.0	31.3	33.7	29.1
5	44.9	38.5	47.6	56.8	57.2	46.0	44.5	41.0	44.9	38.5	47.5	57.0	57.5	45.6	44.3	40.9
6	28.6	27.5	71.5	210.6	208.5	72.9	28.3	71.9	28.6	27.5	71.5	210.4	208.6	72.5	28.2	71.9
7	32.3	31.9	39.6	46.7	46.4	36.4	31.1	36.0	32.2	31.9	39.7	46.7	46.6	35.9	31.4	36.0
8	35.2	34.4	30.1	37.3	37.2	30.5	34.1	29.7	35.3	34.5	30.2	37.5	37.6	30.2	34.1	29.8
9	54.4	54.1	54.4	53.9	53.2	53.7	52.6	53.4	54.4	54.2	54.3	54.0	53.5	53.3	52.6	53.4
10	35.8	36.8	35.6	40.9	41.0	35.5	35.6	36.7	35.6	36.9	35.5	40.9	41.4	35.0	35.4	36.7
11	21.1	20.6	21.0	21.3	21.3	20.6	26.7	20.3	20.9	20.5	20.7	21.2	21.3	20.0	26.6	20.0
12	41.1	39.8	40.1	39.5	39.2	39.7	81.6	39.4	39.7	39.5	39.7	39.2	39.9	38.9	82.7	39.0
13	40.6	40.4	40.7	40.9	40.8	40.5	44.6	40.3	41.0	40.9	41.1	41.4	41.2	40.5	44.7	40.7
14	56.3	56.1	56.2	56.5	56.1	55.7	54.7	55.5	56.8	56.6	56.2	56.8	56.8	55.7	55.1	55.8
15	31.8	31.5	31.7	31.5	31.2	31.6	31.6	31.4	32.1	32.0	32.1	32.0	32.0	31.2	31.4	31.8
16	80.7	80.8	81.0	80.4	80.2	80.5	80.5	80.3	83.2	83.2	83.3	82.9	82.8	82.5	81.3	82.7
17	62.2	62.0	62.2	62.0	61.9	62.0	61.2	61.9	65.2	65.0	65.2	65.1	65.0	64.6	63.9	64.8
18	16.5	16.3	16.6	16.4	16.2	16.4	11.6	16.2	16.6	16.3	16.7	16.6	16.6	16.1	11.6	16.3
19	12.4	12.3	15.6	13.2	12.4	15.0	12.1	15.2	12.4	12.4	15.7	13.2	12.6	14.6	12.0	15.2
20	41.5	41.5	41.7	41.6	41.4	41.5	42.1	41.3	37.8	37.8	37.9	37.9	38.0	37.3	38.5	37.5
21	14.5	14.3	14.5	14.4	14.3	14.4	13.6	14.2	18.9	18.8	18.9	18.9	18.9	18.5	17.9	18.7
22	109.0	109.2	109.6	109.3	109.1	109.0	109.2	108.8	90.2	90.2	90.4	90.3	90.3	89.7	89.9	89.7
23	31.4	31.2	31.4	31.3	31.4	31.3	31.4	31.1	30.0	29.7	29.8	30.1	30.1	29.9	30.2	30.0
24	28.9	28.6	28.8	28.7	28.6	28.7	28.8	28.5	30.3	30.1	30.1	30.5	30.5	30.3	30.6	30.4
25	30.3	31.1	30.0	30.2	30.1	30.2	30.2	30.0	35.6	32.6	35.6	35.7	35.7	35.1	32.6	32.4
26	66.7	66.7	67.0	66.8	66.7	66.6	66.8	66.5	67.9	69.1	67.6	68.1	68.0	66.9	69.1	69.0
27	17.1	17.0	17.1	17.1	17.1	17.0	17.1	16.9	16.6	16.6	16.5	16.6	16.5	16.1	16.6	16.4

Table 2 Effects of the F ring opening

	C-16	C-17	C-18	C-20	C-21	C-22	C-23	C-24	C-25	C-26	C-27
Δ	+2.3	+2.8	+0.4	-3.7	+4.4	-18.7	-1.5	+1.3	+5.3	+1.4	-0.5

Table 3 ^{1}H chemical shifts associated to the furostane side chain

	H-16	H-18	H-20	H-21	H-22	H-26	H-27
3a	4.38 m	0.80 s	1.85 q	0.96 d	–	3.35 dd /3.46 t	0.78 d
3b	4.30 m	0.80 s	1.77 m	0.99 d	3.34 m	3.45 ABX	0.90 d

chemical shift of a parent spirostane is given. Significant changes occurs only in the signals of H-16, H-20, H-26 and H-27. The change of multiplicity of H-20 and H-26 also characterised the opening of the F ring. Irradiation of the signal of H-21 produced NOE enhancement on the signal corresponding to H-22 in a differential-NOE experiment and indicates spatial proximity of H-21 and H-22. This, and the unaltered ^{1}H and ^{13}C signals of CH_3-18 indicate α orientation for both C-21 and H-22 (see Fig. 2) resulting in the *R* configuration at C-22.

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