171. Substituent Increments for the ^{1}H-NMR. Chemical Shifts of the 18- and 19-Methyl Protons of Steroids. Part II: 9α,10β(Normal)-Steroids

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Dedicated to Professor *Pl. A. Plattner* on his 70th birthday

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Summary. In Part II of this series we report 292 substituent increments for the ^{1}H-NMR. chemical shifts (solvent: $CDCl_3$) of the 18- and 19-methyl protons of 9α,10β(normal)-steroids relative to 5α,9α,10β,-androstane. The increments were calculated by a least-squares procedure from 988 spectra of 681 different steroids.

1. Introduction. – In the preceding paper [1] we presented the additive contributions of 261 substituents to the chemical shifts of the 18- and 19-methyl protons of 9β,10α-steroids. In continuation of this work we have calculated the shift increments of 292 substituents within the class of 9α,10β-steroids, *i.e.* of compounds with 'normal' configuration. As previously, the shift increments were calculated with the aid of a standard least-squares computer program by minimizing the sum of the squared deviations between calculated and experimental chemical shifts of the angular methyl protons. All compounds were measured in $CDCl_3$ in concentrations between 0.05 and 0.5 M depending on the sample quantity available.

Since our first calculations started with an extension of the experimental data given in *Zürcher*'s basic papers [2] [3], our input data contained also chemical shifts from 139 compounds taken from [3]. Compounds with double bonds $\Delta^{8(9)}$ and $\Delta^{8(14)}$ as well as epoxides were excluded from our calculations since deviations from additivity due to alteration of the basic ring skeleton were to be expected. In contrast to the preceding paper [1] part of the compounds investigated here were of commercial origin from different sources. Microanalyses and spectroscopic data were found consistent with the chemical structures.

Concerning all further experimental and theoretical details we refer to [1] [2] and [3] as well as to a recent review [4].

2. Results. – In Table 1 the results of our computations are compiled. Tabulated are 292 additive substituent contributions (in ppm; solvent: $CDCl_3$) relative to the chemical shift of the 18- and 19-methyl protons of the unsubstituted basic compound 5α,9α,10β,-androstane. Its chemical shifts were taken from the average value of several measurements as 0.688 ppm (18-methyl protons) and 0.787 ppm (19-methyl protons) in good agreement with *Zürcher*'s values of 0.692 and 0.792 [3]. Some notations and abbreviations used in Table 1 are explained in Table 2.

The accuracy of predicted chemical shifts calculated from these increments will depend, to some extent, on the chemical structure of the compounds: *i.e.* whether or not deviations from additivity due to steric and electronic interactions of the

Table 1. *Substituent Increments* (in ppm; Solvent: $CDCl_3$) *for the Chemical Shifts of the 18- and 19-Methyl Protons of 9α,10β(Normal)-Steroids* (Plus Sign Represents a Downfield Shift)

No.	Substituent	Quantity	18-Methyl Protons	19-Methyl Protons
–	5α,9α,10β,-androstane		0.688	0.787
1	1α-OH	11	−0.002	0.005
2	1β-OH	1	0.003	0.049
3	1α-O-ac	5	−0.011	0.070
4	1α-ethynyl	2	0.003	0.049
5	1-oxo	2	0.006	0.375
6	1-CH_3 (at Δ^1)	1	0.021	0.024
7	1-OC_2H_5 (at Δ^1)	2	−0.013	0.123
8	Δ^2	9	0.018	−0.023
9	Δ^2+3-O-ac	1	0.012	0.049
10	2α-OH	1	0.004	0.087
11	2β-OH	2	0.009	0.242
12	2α-O-ac	2	−0.003	0.091
13	2β-O-ac	7	−0.004	0.138
14	2β-O-ac+3-oxo+$\Delta^{4,6}$	1	0.116	0.431
15	2α-Cl	3	0.008	0.094
16	2β-Cl	1	0.007	0.197
17	2α-Br	5	0.001	0.075
18	2α-CH_2OH	1	−0.004	0.037
19	2-oxo	2	0.008	−0.024
20	2-OH (at Δ^1)	2	0.000	0.014
21	2-O-ac (at Δ^1)	1	0.004	0.074
22	2-Br (at Δ^1)	1	0.002	0.048
23	$\Delta^{3,5}$	6	0.057	0.173
24	3α-OH	5	0.001	−0.011
25	3β-OH	35	0.004	0.036
26	3β-OCHO	1	0.013	0.098
27	3α-O-ac	4	0.012	0.030
28	3β-O-ac	88	0.005	0.054
29	3β-OCH_3	3	0.002	0.020
30	3β-$OC(CH_3)_3$	2	0.005	0.038
31	3β-O-$COC_{11}H_{23}$(n)	1	0.001	0.038
32	3β-OSO_2CH_3	2	0.014	0.062
33	3α-OH+Δ^4	2	0.037	0.160
34	3β-OH+Δ^4	5	0.028	0.271
35	3α-OH+$\Delta^{4,6}$	1	0.086	0.139
36	3β-OH+$\Delta^{4,6}$	3	0.081	0.214
37	3α-OH+Δ^5	2	0.041	0.225
38	3β-OH+Δ^5	79	0.034	0.232
39	3α-OH+Δ^5+7-oxo	3	0.061	0.410
40	3β-OH+Δ^5+7-oxo	1	0.031	0.416
41	3β-OH+$\Delta^{5,7}$	13	−0.026	0.166
42	3-O-ac+$\Delta^{3,5}$	9	0.060	0.223
43	3-O-ac+$\Delta^{3,5,7}$	5	−0.016	0.205
44	3α-O-ac+Δ^4	1	0.045	0.221
45	3β-O-ac+Δ^4	2	0.040	0.292
46	3β-O-ac+$\Delta^{4,6}$	5	0.082	0.226
47	3β-O-ac+Δ^4+6-oxo	2	0.053	0.254
48	3β-O-ac+Δ^5	103	0.035	0.244
49	3β-O-ac+$\Delta^{5,7}$	12	−0.017	0.175

Table 1. (continued)

No.	Substituent	Quantity	18-Methyl Protons	19-Methyl Protons
–	5α,9α,10β,-androstane		0.688	0.787
50	3-OCH_3+$\Delta^{3,5}$	7	0.052	0.193
51	3β-OCH_3+Δ^5	6	0.036	0.223
52	3β-OC_2H_5+Δ^5	1	0.030	0.226
53	3-OC_2H_5+$\Delta^{3,5}$	4	0.052	0.200
54	3β-OCH_2OCH_3+Δ^5	4	0.033	0.234
55	3β-$OC(CH_3)_3$+Δ^5	6	0.027	0.214
56	3-O-$Si(CH_3)_3$+$\Delta^{1,3,5}$	1	0.065	0.334
57	3-O-$Si(CH_3)_3$+$\Delta^{3,5}$	4	0.054	0.183
58	3β-O-thp+Δ^5	1	0.032	0.242
59	3β-O-benzyl+Δ^5	1	0.026	0.233
60	3-pyrrolidinyl+$\Delta^{3,5}$	2	0.056	0.232
61	3β-$OCOC(CH_3)_3$+Δ^5	1	0.035	0.255
62	3β-$OCOCH_2$-ac+Δ^5	1	0.045	0.248
63	3β-$OCOC_3H_7$(n)+$\Delta^{5,7}$	1	−0.024	0.179
64	3β-$OCOC_6H_{13}$(n)+Δ^5	1	0.034	0.249
65	3β-OCOCH=C(O-ac)CH_3+Δ^5	2	0.044	0.238
66	3β-$OCOC_8H_{17}$(n)+Δ^5	1	0.030	0.241
67	3β-$OCOC_{17}H_{35}$(n)+Δ^5	1	0.043	0.248
68	3β-OCOO-oleyl+Δ^5	1	0.029	0.231
69	3β-$OCOC_6H_5$+Δ^5	9	0.044	0.292
70	3β-$OCOC_6H_5$+$\Delta^{5,7}$	1	−0.015	0.224
71	3β-OCO-benzyl+Δ^5	1	0.023	0.226
72	3β-O-dnb+Δ^5	2	0.058	0.327
73	3β-O-dnb+$\Delta^{5,7}$	1	−0.007	0.251
74	3β-O-dnb+Δ^5+7-oxo	1	0.041	0.401
75	3β-Cl+Δ^5	5	0.028	0.250
76	3-Cl+$\Delta^{3,5}$	1	0.060	0.187
77	3β-Br+Δ^5	2	0.033	0.263
78	3β-I+Δ^5	2	0.039	0.267
79	3-oxo	38	0.039	0.237
80	3-oxo+Δ^1	6	0.063	0.252
81	3-oxo+$\Delta^{1,4}$	30	0.098	0.448
82	3-oxo+$\Delta^{1,4,6}$	27	0.145	0.419
83	3-oxo+$\Delta^{1,5}$	2	0.089	0.454
84	3-oxo+Δ^4	252	0.068	0.406
85	3-oxo+$\Delta^{4,6}$	70	0.116	0.337
86	3-oxo+Δ^4+6-oxo	6	0.083	0.390
87	3-oxo+Δ^4+6-=CH_2	4	0.059	0.310
88	3-oxo+Δ^5	8	0.067	0.408
89	3,3-di-OCH_3	1	0.009	0.011
90	3,3-ethylenedioxy+Δ^4	2	0.036	0.252
91	3,3-ethylenedioxy+$\Delta^{4,6}$	2	0.076	0.190
92	3,3-ethylenedioxy+Δ^5	14	0.039	0.247
93	3,3-ethylenedioxy+$\Delta^{5,7}$	14	−0.022	0.179
94	$\Delta^{4,6}$	1	0.118	0.201
95	4β-OH	1	0.003	0.260
96	4β-O-ac	1	−0.007	0.220
97	4-oxo	2	0.008	−0.036
98	4-CH_3 (at $\Delta^{1,4,6}$ or $\Delta^{4,6}$)	2	0.006	−0.045
99	4-CH_3 (at $\Delta^{1,4}$, Δ^4 or $\Delta^{3,5}$)	3	0.001	−0.014

Table 1. (continued)

No.	Substituent	Quantity	18-Methyl Protons	19-Methyl Protons
–	5α,9α,10β,-androstane		0.688	0.787
100	4-C_2H_5 (at Δ^4)	1	0.006	−0.003
101	4-(1-me-prop-2-ynyl)(at Δ^4)	1	0.005	0.000
102	4-Cl (at Δ^4)	9	0.000	0.037
103	4-Br (at Δ^4)	1	0.010	0.022
104	4,4-di-CH_3	1	−0.026	−0.327
105	4,4-di-C_2H_5	1	−0.039	−0.310
106	Δ^5	3	0.032	0.223
107	$\Delta^{5,7}$ [a]	2	−0.026	0.125
108	5α-OH	6	−0.007	0.146
109	5α-Cl	22	−0.007	0.272
110	5α-Br	9	−0.002	0.282
111	5α-OH + 6-oxo	6	−0.008	−0.016
112	Δ^6	2	0.052	−0.085
113	$\Delta^{6,8(14)}$	2	0.203	0.296
114	6α-OH	1	−0.006	−0.007
115	6β-OH	25	0.033	0.202
116	6β-OH + 6α-CH_3	2	0.026	0.184
117	6β-O-ac	10	0.039	0.174
118	6β-O-ac (from 3-oxo + Δ^4)	3	0.046	0.107
119	6β-O-ac + 6α-Cl [b]	1	−0.006	0.111
120	6α-CH_3	4	0.004	0.006
121	6β-CH_3	1	0.022	0.073
122	6α-CH_2OCH_3	1	−0.012	−0.007
123	6α-CH_2OH	1	0.001	0.011
124	6β-CH_2OH	6	0.004	0.016
125	6β-CH_2O-ac	1	0.014	0.035
126	6α-F	3	0.016	0.025
127	6β-F	1	−0.008	0.093
128	6α-Cl	4	0.003	0.035
129	6β-Cl	23	0.061	0.281
130	6β-Br	9	0.060	0.358
131	6-oxo	24	0.014	−0.050
132	6-oxo + $\Delta^{4,7}$	1	−0.035	0.317
133	6-oxo + Δ^7	17	−0.052	0.054
134	6-CH_3 (at Δ^5 or Δ^6)	16	−0.005	−0.029
135	6-Cl (at Δ^6)	23	−0.005	0.027
136	6-NO_2 (at Δ^5)	3	0.008	0.110
137	Δ^7	13	−0.117	−0.011
138	$\Delta^{7,9(11)}$	3	−0.134	0.102
139	7α-OH	9	0.000	−0.007
140	7β-OH	11	0.022	0.024
141	7α-O-ac	1	−0.008	−0.008
142	7α-OCH_3	1	−0.011	−0.016
143	7α-OC_2H_5	2	−0.014	−0.025
144	7β-OC_2H_5	1	0.005	0.031
145	7α-Cl	2	0.009	−0.002

[a] Tentatively calculated from compounds with 3β-OH and 3β-O-ac.
[b] Configuration tentative.

Table 1. (continued)

No.	Substituent	Quantity	18-Methyl Protons	19-Methyl Protons
–	5α,9α,10β,-androstane		0.688	0.787
146	7α-Br	5	0.023	0.003
147	7-Br (at Δ^6)	1	−0.002	0.041
148	7-oxo	4	0.007	0.270
149	7-oxo+$\Delta^{3,5}$	4	0.070	0.350
150	7-oxo+Δ^5	6	0.039	0.388
151	$\Delta^{8(14)}$	5	0.178	−0.132
152	$\Delta^{9(11)}$	2	−0.074	0.115
153	$\Delta^{9(11)}$ (from Δ^1)	2	−0.027	0.204
154	$\Delta^{9(11)}$ (from 3-oxo+Δ^4)	17	−0.043	0.157
155	$\Delta^{9(11)}$ (from 3-oxo+$\Delta^{4,6}$)	3	−0.024	0.193
156	Δ^{11}	3	0.078	−0.039
157	11α-OH	18	0.021	0.124
158	11β-OH	24	0.242	0.254
159	11β-OCHO	4	0.130	0.091
160	11α-O-ac	37	0.067	0.094
161	11β-O-ac	20	0.132	0.075
162	11α-OSO_2CH_3	5	0.079	0.192
163	11α-O-ts	2	−0.027	0.165
164	11α-$OCOC_6H_5$	1	0.139	0.124
165	11α-Cl	2	0.038	0.154
166	11β-Cl	2	0.301	0.325
167	11-oxo	18	−0.040	0.206
168	11-oxo+Δ^8	1	0.039	0.284
169	12α-O-ac	1	0.071	−0.012
170	Δ^{14}	7	0.242	0.031
171	14α-OH	2	0.090	0.015
172	14α-OH (from Δ^7)	5	0.076	−0.014
173	Δ^{15}	6	0.051	0.017
174	Δ^{15}+17,17-ethylenedioxy	4	0.217	0.036
175	15α-OH	2	0.018	0.007
176	15α-Br	1	0.044	0.004
177	15β-Br	5	0.340	0.040
178	15α,16α-isopropylidenedioxy	8	0.109	0.012
179	Δ^{16}	1	0.080	0.049
180	Δ^{16}+17-ac	46	0.192	0.032
181	Δ^{16}+17-me-dioxolanyl	4	0.265	0.039
182	Δ^{16}+17-CN	3	0.221	0.044
183	Δ^{16}+17-COOH	1	0.210	0.045
184	Δ^{16}+17-$COCH_2OH$	2	0.230	0.031
185	Δ^{16}+17-$C(CH_3)$=CH-O-ac	1	0.227	0.025
186	16β-O-ac	2	0.234	0.027
187	16α-OCH_3	8	0.009	−0.002
188	16β-OCH_3	2	0.181	0.003
189	16α-Cl	10	−0.012	−0.006
190	16α-Br	5	0.044	−0.007
191	16β-Br	3	0.562	0.010

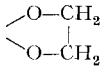
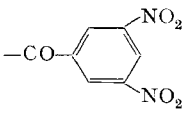
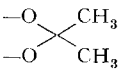
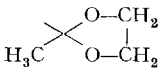
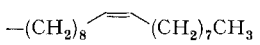
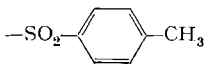
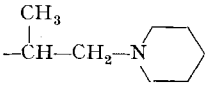
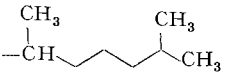
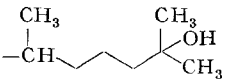
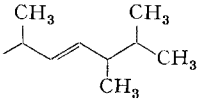
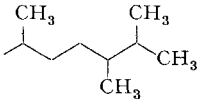
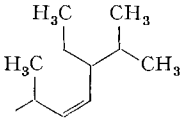
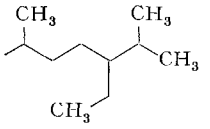
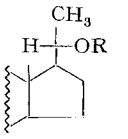
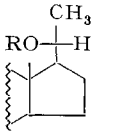
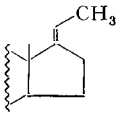
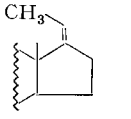
Table 1. (continued)

No.	Substituent	Quantity	18-Methyl Protons	19-Methyl Protons
–	5α,9α,10β,-androstane		0.688	0.787
192	16α-CN	3	−0.049	−0.012
193	16α-S-C_2H_5	1	0.014	0.001
194	16α-CH_3	10	0.047	−0.012
195	16β-CH_3	2	0.335	0.000
196	16-oxo	2	0.162	0.055
197	16-=CH_2	3	0.051	0.022
198	16-CH_3 (at Δ^{16})	3	0.072	−0.010
199	16-Cl (at Δ^{15})	1	0.052	0.004
200	16α-OH + 17α-OH + 17β-ac	1	−0.053	−0.016
201	16α,17α-isopropylidenedioxy + 17β-ac	3	−0.112	0.000
202	17α-OH	1	−0.041	0.007
203	17β-OH	38	0.042	0.006
204	17β-OCHO	1	0.107	−0.003
205	17β-O-ac	55	0.086	0.004
206	17α-O-ac	1	0.047	0.007
207	17β-$OCOC_2H_5$	4	0.095	0.009
208	17β-$OCOC_6H_{11}$	2	0.088	0.001
209	17β-$OCOC_6H_5$	3	0.244	0.019
210	17β-O-ts	1	0.089	−0.026
211	17β-$OP(O)(OCH_3)_2$	1	0.107	−0.006
212	17β-OCH_3	1	0.044	−0.001
213	17β-OCH_2OCH_3	3	0.080	0.013
214	17β-$OC(CH_3)_3$	6	0.007	−0.002
215	17β-O-$Si(CH_3)_3$	8	−0.004	−0.006
216	17β-O-thp	2	0.065	−0.004
217	17α-NH_2	1	−0.014	0.000
218	17β-NH_2	1	−0.068	0.000
219	17α-Cl	1	0.097	−0.002
220	17α-I	3	0.122	0.004
221	17β-OH + Δ^{15}	1	0.119	0.026
222	17-oxo	114	0.171	0.026
223	17-oxo + Δ^{15}	8	0.367	0.069
224	17-=CH-CH_3 (*cis*)	5	0.182	0.016
225	17-=CH-CH_3 (*trans*)	3	0.038	0.015
226	17-=$C(CH_3)$CHO	2	0.421	0.047
227	17-=$C(CH_3)$O-ac	2	0.062	0.001
228	17β-vinyl	1	−0.111	−0.002
229	17β-C_2H_5	3	−0.136	−0.005
230	17β-$C_8H_{16}N$	1	−0.018	−0.016
231	17β-C_8H_{17}	159	−0.040	−0.008
232	17β-$C_8H_{17}O$(25-OH)	3	−0.044	0.000
233	17β-C_9H_{17}	22	−0.025	−0.007
234	17β-C_9H_{19}	3	−0.030	−0.004
235	17β-$C_{10}H_{19}$	3	−0.018	−0.001
236	17β-$C_{10}H_{21}$	1	−0.039	−0.002
237	17α-ac	3	0.189	−0.013
238	17β-ac	135	−0.080	0.000
239	17β-ac-oxime	2	−0.080	−0.009
240	17β-$C(CH_3)$=NNHCONH$_2$	1	−0.128	−0.012
241	17β-me-dioxolanyl	19	0.061	0.000

Table 1. (continued)

No.	Substituent	Quantity	18-Methyl Protons	19-Methyl Protons
–	5α,9α,10β,-androstane		0.688	0.787
242	17β-COOH	3	0.033	0.004
243	17α-$COOCH_3$	1	0.165	−0.012
244	17β-$COOCH_3$	6	−0.040	0.000
245	17β-$COCH_2OH$	2	−0.057	0.001
246	17β-$COCH_2$O-ac	2	−0.045	0.006
247	17β-$COCH_2Cl$	1	−0.043	0.007
248	17β-$COCH_2OCOCH_2Br$	1	−0.075	−0.044
249	17β-$COCH_2OCOC_5H_{11}$(n)	1	−0.089	−0.072
250	17β-$CH(OH)CH_3$ (α)	10	−0.032	−0.007
251	17β-$CH(OH)CH_3$ (β)	26	0.052	0.003
252	17β-$CH(O\text{-ac})CH_3$ (α)	6	−0.029	−0.006
253	17β-$CH(O\text{-ac})CH_3$ (β)	35	−0.073	−0.008
254	17β-$CH(COOH)CH_3$ (α)	2	−0.012	−0.008
255	17β-$CH(COOCH_3)CH_3$ (α)	1	−0.021	0.002
256	17β-$CH(OCH_2OCH_3)CH_3$ (α)	1	−0.043	−0.010
257	17β-$CH(OCH_2OCH_3)CH_3$ (β)	6	0.001	−0.005
258	17β-$CH(CH_2CH_2COOCH_3)CH_3$ (α)	2	−0.039	−0.010
259	17β-$CH(OC(CH_3)_3)CH_3$ (β)	9	−0.014	−0.008
260	17β-$CH(OCOCOOCH_3)CH_3$ (β)	2	−0.055	−0.019
261	17β-$CH(OCOC_{17}H_{35}(n))CH_3$ (β)	1	−0.075	−0.014
262	17β-$CH(OCOC_6H_5)CH_3$ (β)	2	−0.023	−0.054
263	17β-$CH(O\text{-ts})CH_3$ (β)	1	0.017	−0.008
264	17β-$CH(OCOC_6H_4Br(p))CH_3$ (β)	1	−0.049	−0.058
265	17,17-ethylenedioxy	24	0.135	−0.008
266	17β-$CH(OH)CH_3$ (α) + 17α-OH	1	−0.027	0.070
267	17β-$CH(OH)CH_3$ (β) + 17α-OH	1	0.041	0.070
268	17β-me-dioxolanyl + 17α-OH	1	0.109	−0.080
269	17β-OH + 17α-CH_3	26	0.155	0.014
270	17β-OH + 17α-ethynyl	7	0.147	0.007
271	17β-OH + 17α-vinyl	2	0.205	−0.001
272	17β-OH + 17α-C_2H_5	1	0.176	0.012
273	17β-OH + 17α-(1-me-allyl)	2	0.185	0.003
274	17β-OH + 17α-(2-me-allyl)	1	0.191	0.024
275	17β-OH + 17α-(1-me-prop-2-ynyl)	5	0.199	0.004
276	17β-OH + 17α-$CH(OH)CH_2$O-ac (α)	2	0.066	−0.007
277	17β-O-ac + 17α-CH_3	9	0.134	0.020
278	17β-O-ac + 17α-ethynyl	10	0.154	0.017
279	17β-O-ac + 17α-(1,2-dichlorovinyl)	1	0.287	−0.009
280	17β-O-ac + 17α-ac	2	0.259	0.000
281	17β-O-$Si(CH_3)_3$ + 17α-CH_3	1	0.066	0.008
282	17β-Br + 17α-ac	1	0.429	0.003
283	17β-ac + 17α-OH	7	0.007	−0.004
284	17β-ac + 17α-O-ac	29	−0.070	0.010
285	17β-ac + 17α-OC_2H_5	2	−0.148	−0.033
286	17β-ac + 17α-CH_3	5	−0.041	−0.003
287	17β-ac + 17α-Br	9	0.067	0.007
288	17β-$COCH_2OH$ + 17α-OH	5	−0.040	−0.004
289	17β-$COCH_2$O-ac + 17α-OH	12	−0.046	−0.014
290	17β-$COCHBr_2$ + 17α-Br	3	0.217	0.015
291	17β-$COCBr_3$ + 17α-Br	1	0.826	0.032
292	17β-$COOCH_3$ + 17α-OH	1	−0.003	0.015

Table 2. *Abbreviations and Notations used in Table 1*

me	$-CH_3$
ac	$-COCH_3$
ac-oxime	$-C(CH_3)=NOH$
ethynyl	$-C\equiv CH$
vinyl	$-CH=CH_2$
1-me-allyl	$-CH(CH_3)-CH=CH_2$
2-me-allyl	$-CH_2-C(CH_3)=CH_2$
1-me-prop-2-ynyl	$-CH(CH_3)-C\equiv CH$
ethylenedioxy	
dnb	
isopropylidenedioxy	
me-dioxolanyl	
oleyl	
pyrrolidinyl	
thp	
ts	
C_6H_{11}	
$C_8H_{16}N$	
C_8H_{17}	
$C_8H_{17}O$(25-OH)	
C_9H_{17}	
C_9H_{19}	
$C_{10}H_{19}$	
$C_{10}H_{21}$	
configuration at 20-C:	
(α)	
(β)	
17-=CH—CH_3 (*trans*)	
17-=CH—CH_3 (*cis*)	

substituents or alterations of the conformations in the ring system may occur upon introduction of two or more substituents. However, in cases where these effects can be neglected predicted chemical shifts should, in general, deviate less than 0.01 ppm from the experimental shifts. This can be derived from the observation that the average deviation between observed and calculated shifts for the 988 spectra were 0.004 and 0.005 ppm for 18- and 19-methyl proton shifts, respectively.

The scattering is characterized by the fact that 90% of the deviations for 18- and 85% of the deviations for the 19-methyl protons were ≤ 0.01 ppm. In judging these figures one should, however, take into account that 94 of the 292 substituents occurred only once in the data and therefore all deviations of the chemical shifts of compounds containing these substituents were necessarily zero.

A further test of some of the reported shift increments is possible by comparison with those found for *retro*-steroids [1]. Since the shift increments should mainly depend on the relative geometry of substituent and angular methyl group, it is evident from an inspection of molecular models that substituents in positions 11 to 17 in rings C and D in 9α,10β-steroids should contribute practically the same increments to the shift of the 18-methyl protons as in 9β,10α-steroids. That this is indeed the case, is found by a comparison of Table 1 here and in our previous paper [1]. It is seen, therefore, that although the reported chemical shift increments of the 18- and 19-methyl protons arising from the introduction of substituents are, in general, different from one basic skeleton to the other, there can be cases with substituents in geometrically equivalent positions. This means that the reported shift increments may also be helpful in other classes of steroids for the confirmation or deduction of the structure of unknown products.

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172. Selektive Synthesen mit Organometallen I. Konfigurativ einheitliche Folgeprodukte aus Alkenylkalium-Zwischenstufen

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(16. V. 74)

Summary. Methyl groups in positions adjacent to an olefinic double bond can be metalated without *cis*/*trans* isomerisation. On the other hand configurational changes can be brought about via metalotropy; under equilibrium conditions the *Z* isomers (metal *cis* to an alkyl in β position) predominate overwhelmingly. This behaviour opens new stereoselective routes of high preparative utility.