# $^1$H and $^{13}$C NMR spectra of some drimanic sesquiterpenoids

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One-and two-dimensional homo- and heteronuclear correlation proton, carbon, proton—proton, and proton—carbon NMR spectra of fifteen drimanic sesquiterpenoids: 11,12-dibromodrima-5,8-dien-7-one, drim-8-en-7-one, 11-hydroxydrim-8-en-7-one, 11,12-dihydroxydrim-8-en-7-one, 11β-hydroxy-11,12-epoxydrim-8-en-7-one, 11α-hydroxy-11,12-epoxydrim-8-en-7-one, 8α,9α-epoxydriman-7-one, 8α,9α-epoxydriman-7β-ol, 11,12-diacetoxydrim-8-en-7β-ol, drimane-7α,8α,11-triol, 7α,8α-isopropylidenedioxydriman-11-al, 9α,11-dihydroxydrim-7-en-6-one, drimane-7β,8β,9α-triol, drimane-7β,8β,11-triol, and drim-8-ene-7β,11,12-triol were studied. The proton and carbon chemical shifts were assigned.

**Key words:** proton and carbon NMR spectra, chemical shifts, coupling constants, drimanic sesquiterpenoids.

Drimanic sesquiterpenoids are widely distributed in nature, many of these presenting practical interest due to their high and diverse biological activities.[1] The practically valuable properties of drimanes and their low contents in natural sources stimulate works aimed at their synthesis.[2]

This study is devoted to analysis of the $^1$H and $^{13}$C NMR spectra of a series of drimanic sesquiterpenoids using advanced multipulse NMR techniques, which allow unambiguous assignment of the chemical shifts of magnetic nuclei.

## Experimental

One-dimensional (1D) proton and carbon, two-dimensional (2D) homo- ($^1$H/$^1$H COSY-45) and heteronuclear ($^1$H/$^{13}$C HMQC and HMBC) correlation NMR spectra were recorded on a Varian AVANCE DRX-400 spectrometer operating at 400 and 100 MHz for protons and carbon nuclei, respectively at 25 °C for 5% solutions in $CDCl_3$. For determining the number of protons at carbon atoms, the carbon 1D spectra were recorded in CPD, DEPT 135°, and DEPT 90° pulse modes with complete broad-band proton decoupling. The chemical shifts for all compounds were assigned with allowance for the degree of protonation of carbon atoms, analysis of proton—proton (COSY) and carbon—proton (through carbon—proton coupling constants) coupling maps: direct carbon—proton constants in the 2D HMQC spectra, geminal and vicinal carbon—proton coupling constants in the 2D HMBC spectra. In analysis of the proton spectra, the PANIC iteration program was used. The chemical shifts are given in the δ scale with respect to internal $Me_4Si$.

## Results and Discussion

The carbon chemical shifts for fifteen drimanic sesquiterpenoids (**1—15**) are summarized in Table 1. The synthesis of compounds **1—15** has been reported previously.[3—7] For the convenience of discussion of some features of the carbon spectra of sesquiterpenoids **1—15**, most of them were divided conventionally into three groups. Compounds of the first group **1—7** all contain an oxo group in ring *B* at the C(7) atom and a double bond between the C(8) and C(9) atoms. Compound **1** is distinguished among this group, as its molecule contains one more double bond between the C(5) and C(6) atoms. The second group comprises compounds **8**, **9**, and **15** devoid of the oxo group at C(7) and with one double bond at C(8) and C(9) or an epoxy group between these carbon atoms, which is equivalent to the presence of a double bond. The third group includes sesquiterpenoids **10**, **11**, **13**, and **14**. A common feature of compounds of the first and second groups is the double bond between C(8) and C(9). Molecules of the third group are devoid of double bonds.

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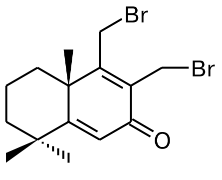
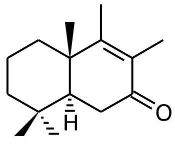
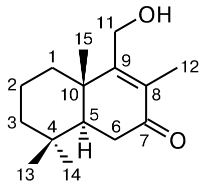


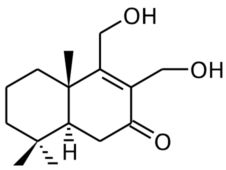
11,12-Dibromodrim-5,8-dien-7-one (**1**)



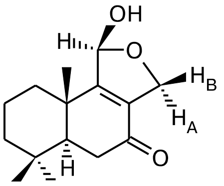
Drim-8-en-7-one (**2**)



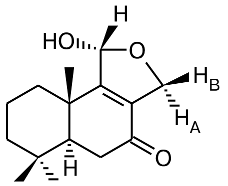
11-Hydroxydrim-8-en-7-one (**3**)



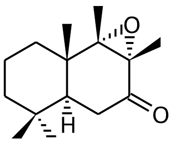
11,12-Hydroxydrim-8-en-7-one (**4**)



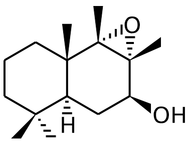
11β-Hydroxy-11,12-epoxydrim-8-en-7-one (**5**)



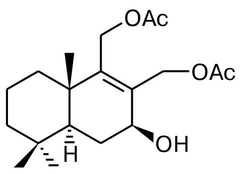
11α-Hydroxy-11,12-epoxydrim-8-en-7-one (**6**)



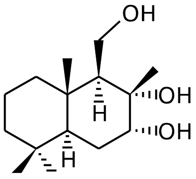
8α,9α-Epoxydriman-7-one (**7**)



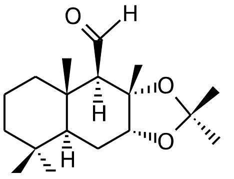
8α,9α-Epoxydriman-7β-ol (**8**)



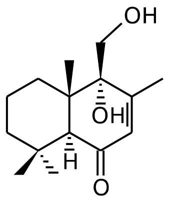
11,12-Diacetoxydrim-8-en-7β-ol (**9**)



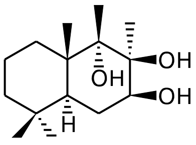
Drimane-7α,8α,11-triol (**10**)



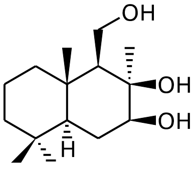
7α,8α-Isopropylidenedioxydrimane (**11**)



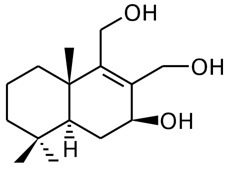
9α,11-Dihydroxydrim-7-en-6-one (**12**)



Drimane-7β,8β,9α-triol (**13**)



Drimane-7β,8β,11-triol (**14**)



Drim-8-en-7β,11,12-triol (**15**)

Computer analysis of conformations by the CS Chem 3D Pro, version 5, and HyperChem, version 6, software (using MM2 and MM+ methods, respectively) shows that ring *A* has a chair conformation in all compounds, rings *B* of compounds **2—9**, **12**, and **15** have five carbon atoms lying in one plane and only the C(6) atom deviating from this plane. In dibromide **1**, ring *B* is nearly planar. In third-group compounds, ring *B* has a chair shape.

Analysis of the data presented in Table 1 together with published data[8—11] shows that the influence of the C(8)=C(9) and C(5)=C(6) double bonds is mainly reduced to the substantial (~4—7 ppm) upfield shift of the signal from C(1). The chemical shifts of the C(1)—C(4) and C(12)—C(15) atoms in compounds of the first and second groups do not depend essentially on the nature and the spatial orientation of substituents in ring *B*, while the chemical shifts of the bridgehead carbon atoms of rings *A* and *B*, C(5) and C(10), largely depend on the nature of substituents. For example, the presence of an α-epoxide group between the C(8) and C(9) atoms results

**Table 1.** $^{13}$C NMR chemical shifts (100 MHz; 1D: CPD-BBI, DEPT BBI; 2D $^1$H/$^{13}$C: HMQC, HMBC) for compounds **1—15**

| C atom | $n^a$ | δ | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 1 | 2 | 34.87 | 36.18 | 35.49 | 34.93 | 34.59 | 35.40 | 35.11 |
| 2 | 2 | 18.04 | 18.65 | 18.46 | 18.65 | 18.07 | 18.07 | 18.51 |
| 3 | 2 | 40.07 | 41.2 | 41.14 | 40.99 | 41.11 | 41.17 | 41.13 |
| 4 | 0 | 37.50 | 33.04 | 33.01 | 33.06 | 33.09 | 33.18 | 33.24 |
| 5 | 1 | 137.07[d] | 50.03 | 50.21 | 49.98 | 52.60 | 52.54 | 41.72 |
| 6 | 2 | 123.90[e] | 35.22 | 35.25 | 35.01 | 36.06 | 36.01 | 35.89 |
| 7 | 0 | 183.75 | 199.88 | 201.19 | 200.94 | 197.34 | 197.39 | 209.43 |
| 8 | 0 | 135.47 | 129.30 | 132.41 | 134.70 | 134.16 | 134.16 | 65.84 |
| 9 | 0 | 161.13 | 165.26 | 162.84 | 169.45 | 165.41 | 165.41 | 72.36 |
| 10 | 0 | 44.53 | 40.36 | 39.92 | 40.20 | 36.84 | 36.84 | 37.89 |
| 11 | [f] | 24.45 (2) | 14.91 (3) | 58.50 (2) | 58.14 (2) | 103.16[e] | 101.90[e] | 12.34 (3) |
| 12 | [f] | 21.83 (2) | 11.93 (3) | 11.30 (3) | 56.45 (2) | 71.46(2) | 70.72 (2) | 12.34 (3) |
| 13 | 3 | 28.83 | 21.2 | 21.15 | 21.12 | 21.24 | 21.15 | 20.61 |
| 14 | 3 | 32.39 | 32.46 | 32.47 | 32.41 | 32.83 | 32.68 | 32.41 |
| 15 | 3 | 25.84 | 17.48 | 18.34 | 17.94 | 18.57 | 19.17 | 16.99 |

| C atom | $n^a$ | **8** | **9**[b] | **10** | **11**[c] | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 34.58 | 35.55 | 39.62 | 38.90 | 31.62 | 32.90 | 40.08 | |
| 2 | 2 | 18.51 | 18.46 | 18.59 | 18.06 | 17.99 | 18.32 | 18.35 | 18.55 |
| 3 | 2 | 41.99 | 41.07 | 40.79 | 41.80 | 42.55 | 41.51 | 41.74 | 41.21 |
| 4 | 0 | 32.69 | 32.92 | 32.70 | 32.67 | 32.24 | 33.17 | 33.18 | 32.82 |
| 5 | 1 | 39.99 | 42.24 | 45.08 | 46.47 | 55.71 | 43.66 | 52.41 | 49.55 |
| 6 | 2 | 28.62 | 28.58 | 25.70 | 23.00 | 200.21[c] | 27.70 | 27.72 | 29.44 |
| 7 | 0 | 70.15[e] | 69.70[e] | 24.03 | 80.41 | 129.18 | 73.53 | 76.59 | 75.14 |
| 8 | 0 | 64.82 | 15.26 | 75.28 | 77.23 | 154.92 | 77.33 | 75.71 | 136.37 |
| 9 | 0 | 71.04 | 145.04 | 54.41[e] | 68.64[e] | 74.74 | 78.91 | 57.78[e] | 150.47 |
| 10 | 0 | 37.90 | 39.39 | 36.99 | 37.14 | 44.95 | 42.17 | 38.07 | 39.32 |
| 11 | [f] | 13.90 (3) | 59.22 (2) | 60.76 (2) | 205.10 (0) | 61.79 (2) | 17.75 (3) | 59.82 (2) | 57.94 (2) |
| 12 | [f] | 16.79 (3) | 61.23 (2) | 23.07 (3) | 23.13 (3) | 19.99 (3) | 21.77 (3) | 25.83 (3) | 61.13 (2) |
| 13 | 3 | 21.15 | 21.50 | 21.60 | 21.37 | 21.80 | 21.81 | 21.64 | 21.50 |
| 14 | 3 | 33.46 | 32.92 | 32.31 | 33.07 | 33.71 | 33.63 | 33.57 | 33.01 |
| 15 | 3 | 17.71 | 20.40 | 15.64 | 15.74 | 17.68 | 17.14 | 16.74 | 19.96 |

[a] The number of protons at the carbon atom

[b] δ: 170.78 ($\underline{C}$(O)=C(16)); 21.06 (=C(17) and C(19)); 171.44 ($\underline{C}$(O)=C(18)).

[c] δ: 108.05 (quaternary =C(16)); 28.45 (primary); 27.12 (primary =C(17) and C(18)).

[d] Quaternary carbon atoms.

[e] Tertiary carbon atoms.

[f] The number of protons at carbon atoms is indicated in parentheses.

in an upfield shift (~10 ppm) of the C(5) signal (compounds **7** and **8**). In compounds of the first group (7-ketodrimane sesquiterpenoids), the C(6) atom is less shielded than that in the second- and third-group compounds. The carbonyl group in position 7 is an α-substituent with respect to the C(6) atom. The α-increment caused by the oxo group in hydrocarbons is ~22 ppm. The OR group attached to the C(7) atom is also an α-substituent with respect to C(6) but the increment corresponding to this group is 10 ppm. In addition, the carbonyl group forms an anisotropic local field and the C(6) nucleus might get into the deshielding part of the local magnetic field. These two reasons are responsible for different chemical shifts of C(6) in the spectra of these compounds. The possible reason for the upfield shift of the signal for C(1) of compounds **12** and **13** will be considered below in the discussion of proton spectra.

The chemical shifts and the coupling constants for the proton spectra of compounds **1—15**, derived from analysis of the 1D and 2D spectra with construction of the simulation (and, whenever possible, iteration) spectra by the PANIC program are listed in Table 2.

The six protons of ring *A* of most of compounds **1—15** form six-spin systems high coupling in which is accom-

**Table 2.** Proton chemical shifts of compounds **1—15** (400 MHz, 1D-$^1$H, 2D-$^1$H/$^1$H COSY-45, $^1$H/$^{13}$C-HMQC and HMBC)

| Proton | δ | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6**[a] | **7** |
| $1_{ax}$ | 1.70 (td, $^2J = 14.2$, $^3J_{ax,ax} = 14.1$, $^3J_{ax,eq} = 4.0$) | 1.248 (td, $^2J = 13.4$, $^3J_{ax,ax} = 13.2$, $^3J_{ax,eq} = 4.0$) | 1.478 (td, $^2J = 13.3$, $^3J_{ax,ax} = 13.3$, $^3J_{ax,eq} = 4.0$) | 1.48 (td, $^2J = 13.1$, $^3J_{ax,ax} = 13.0$ $^3J_{ax,eq} = 4.2$) | 1.393 (td, $^2J = 13.1$, $^3J_{ax,ax} = 13.0$, $^3J_{ax,eq} = 3.9$) | 1.393 (td) | 1.456 (td, $^2J = 13.1$, $^3J_{ax,ax} = 13.2$, $^3J_{ax,eq} = 5.1$) |
| $1_{eq}$ | 2.11 (dtd, $^2J = 14.2$, $^3J_{ax,eq} = 3.7$, $^3J_{eq,eq} = 3.6$, $^4J = 0.8$) | 1.875 (dtd, $^2J = 13.4$, $^3J_{ax,eq} = 3.7$, $^3J_{eq,eq} = 3.6$, $^4J = 1.4$) | 1.997 (dt, $^2J = 13.3$, $^3J_{ax,eq} = 3.7$, $^3J_{eq,eq} = 3.6$) | 1.982 (dt, $^2J = 13.1$, $^3J_{ax,eq} = 3.7$, $^3J_{eq,eq} = 3.7$) | 2.018 (dtd, $^2J = 13.1$, $^3J_{ax,eq} = 3.7$, $^3J_{eq,eq} = 3.6$, $^4J = 1.3$) | 2.018 (dtd) | 1.703 (dtd, $^2J = 13.1$, $^3J_{ax,eq} = 3.8$, $^3J_{eq,eq} = 3.8$) |
| $2_{ax}$ | 1.93 (qt, $^2J = 13.5$, $^3J_{ax,ax} = 14.1$, $^3J_{ax,ax} = 13.3$, $^3J_{eq,ax} =$ $^3J_{eq,ax} = 3.7$) | 1.685 (qt, $^2J = 13.7$, $^3J_{ax,ax} = 13.2$, $^3J_{ax,ax} = 13.5$, $^3J_{eq,ax} =$ $^3J_{ea} = 3.7$) | 1.717 (qt, $^2J = 14.3$, $^3J_{ax,ax} = 13.7$, $^3J_{ax,ax} = 13.3$, $^3J_{eq,ax} =$ $^3J_{eq,ax} = 3.7$) | 1.728 (qt, $^2J = 14.0$, $^3J_{ax,ax,} = 13.2$, $^3J_{ax,ax} = 13.4$, $^3J_{eq,ax} =$ $^3J_{eq,ax} = 3.7$) | 1.758 (qt, $^2J = 13.7$, $^3J_{ax,ax} = 13.0$, $^3J_{ax,ax} = 13.4$, $^3J_{eq,ax} =$ $^3J_{eq,ax} = 3.7$) | 1.758 (qt) | 1.61 (m, $^2J = 13.4$, $^3J_{ax,ax} = 14.1$, $^3J_{ax,ax} = 13.3$, $^3J_{eq,ax} =$ $^3J_{eq,ax} = 3.7$) |
| $2_{eq}$ | 1.750 (d.quint, $^2J = 13.5$, $^3J_{ax,eq} = 4.0$, $^3J_{eq,ax} = 3.5$, $^3J_{eq,eq} = 3.6$, $^3J_{eq,eq} = 3.6$) | 1.568 (d.quint, $^2J = 13.7$, $^3J_{ax,eq} = 4.0$, $^3J_{eq,ax} = 4.1$, $^3J_{eq,eq} = 3.6$, $^3J_{eq,eq} = 3.6$) | 1.607 (d.quint, $^2J = 14.3$, $^3J_{ax,eq} = 4.2$, $^3J_{eq,ax} = 4.0$, $^3J_{eq,eq} = 3.7$, $^3J_{eq,eq} = 3.7$) | 1.622 (d.quint, $^2J = 14.0$, $^3J_{ax,eq} = 4.2$, $^3J_{eq,ax} = 4.0$, $^3J_{eq,eq} = 3.7$, $^3J_{eq,eq} = 3.7$) | 1.597 (d.quint, $^2J = 13.7$, $^3J_{ax,eq} = 3.9$, $^3J_{eq,ax} = 4.0$, $^3J_{eq,eq} = 3.6$, $^3J_{eq,eq} = 3.6$) | 1.597 (d.quint) | 1.580 (d.quint, $^2J = 13.4$, $^3J_{ax,eq} = 5.1$, $^3J_{eq,ax} = 5.5$, $^3J_{eq,eq} = 3.8$, $^3J_{eq,eq} = 3.8$) |
| $3_{ax}$ | 1.413 (td, $^2J = 13.5$, $^3J_{ax,ax} = 13.3$, $^3J_{ax,eq} = 4.0$) | 1.207 (td, $^2J = 13.2$, $^3J_{ax,ax} = 13.5$, $^3J_{ax,eq} = 4.1$) | 1.243 (td, $^2J = 13.1$, $^3J_{ax,ax} = 13.7$, $^3J_{ax,eq} = 4.0$) | 1.247 (td, $^2J = 13.2$, $^3J_{ax,ax} = 13.7$, $^3J_{ax,eq} = 4.0$) | 1.245 (td, $^2J = 13.3$, $^3J_{ax,ax} = 13.4$, $^3J_{ax,eq} = 4.0$) | 1.245 (td) | 1.210 (td, $^2J = 13.0$, $^3J_{ax,ax} = 13.3$, $^3J_{ax,eq} = 5.5$) |
| $3_{eq}$ | 1.67 (dtd, $^2J = 13.5$, $^3J_{ax,eq} = 3.6$, $^3J_{eq,eq} = 3.6$, $^4J = 0.8$) | 1.463 (dtd, $^2J = 13.2$, $^3J_{ax,eq} = 3.6$, $^3J_{eq,eq} = 3.6$, $^4J = 1.4$) | 1.486 (dt, $^2J = 13.1$, $^3J_{ax,eq} = 3.6$, $^3J_{eq,eq} = 3.6$) | 1.489 (dt, $^2J = 13.2$, $^3J_{ax,eq} = 3.7$, $^3J_{eq,eq} = 3.6$) | 1.520 (dtd, $^2J = 13.3$, $^3J_{ax,eq} = 3.6$, $^3J_{eq,eq} = 3.6$, $^4J = 1.3$) | 1.520 (dtd) | 1.434 (dt, $^2J = 13.0$, $^3J_{ax,eq} = 3.7$, $^3J_{eq,eq} = 3.8$) |
| $5_{ax}$ | — | 1.690 (m) | 1.746 (m) | 1.770 (m) | 1.798 (m) | 1.951 (m) | 2.089 (m) |
| $6_{ax}$ | — | 2.353 (m) | 2.399 (m) | 2.413 (m) | 2.495 (m) | 2.436 (m) | 2.162 (m) |
| $6_{eq}$ | — | 2.488 (m) | 2.524 (m) | 2.538 (m) | 2.512 (m) | 2.551 (m) | 2.443 (m) |
| 7 | — | — | — | — | — | — | — |
| 11 | $\delta_A = 4.203$, $\delta_B = 4.423$ ($J_{AB} = 10.4$) | 1.836 | $\delta_A = 4.323$, $\delta_B = 4.371$ ($J_{AB} = 11.6$) | $\delta_A = 4.343$, $\delta_B = 4.307$ ($J_{AB} = 12.4$) | 6.222 | 6.154 | 1.323 |
| 12 | $\delta_A = 4.455$, $\delta_B = 4.591$ ($J_{AB} = 9.8$) | 1.736 | 1.870 | $\delta_A = 4.354$, $\delta_B = 4.528$ ($J_{AB} = 12.4$) | $\delta_A = 4.628$, $\delta_B = 4.877$ ($J_{AB} = 12.0$) | $\delta_A = 4.615$, $\delta_B = 4.836$ ($J_{AB} = 13.2$) | 1.411 |
| 13 | 1.307 | 0.921 | 0.928 | 0.938 | 0.970 | 0.961 | 0.847 |
| 14 | 1.231 | 0.882 | 0.891 | 0.905 | 0.910 | 0.917 | 0.839 |
| 15 | 1.416 | 1.08 | 1.270 | 1.174 | 1.347 | 1.364 | 0.897 |

[a] The $^1$H NMR spectra were recorded for epimer mixtures. Presumably, the spectral parameters of the protons of ring *A* in compound **6** are similar to those for compound **5**.

[b] The proton chemical shifts of ring *A* were determined from HMQC.

[c] δ 2.053 and 2.083 (C(O)—$CH_3$).

plished only through geminal protons at C(2) in the spectra recorded on a spectrometer operating at 400 MHz.

The $\Delta\delta_{AB}$ value for these protons in molecules **2—5**, **12**, and **14** is 29—102 Hz (for protons, at C(2)), 74—113 Hz

| **8**$^{b}$ | **9**$^{c}$ | **10** | **11** | **12** | **13** | **14** | **15***|
|---|---|---|---|---|---|---|---|
| 1.208 (m) | 1.207 (m, $^{2}J = 13.1$, $^{3}J_{\mathrm{ax,ax}} = 13.0$, $^{3}J_{\mathrm{ax,eq}} = 4.0$) | 1.124 (td, $^{2}J = 12.5$, $^{3}J_{\mathrm{ax,ax}} = 12.9$, $^{3}J_{\mathrm{ax,eq}} =3.7$) | 1.017 (td, $^{2}J = 12.6$, $^{3}J_{\mathrm{ax,ax}} = 13.2$, $^{3}J_{\mathrm{ax,eq}} = 3.2$) | 1.962 (td, $^{2}J = 13.2$, $^{3}J_{\mathrm{ax,ax}} = 12.5$, $^{3}J_{\mathrm{ax,eq}} = 4.2$) | 1.63 (m) | 0.834 (td, $^{2}J = 12.8$, $^{3}J_{\mathrm{ax,ax}} = 13.0$, $^{3}J_{\mathrm{ax,eq}} = 4.0$) | 1.159 (td, $^{2}J = 12.4$, $^{3}J_{\mathrm{ax,ax}} = 12.6$, $^{3}J_{\mathrm{ax,eq}} = 4.0$) |
| 1.699 (m) | 1.711 (dt, $^{2}J = 13.1$, $^{3}J_{\mathrm{ax,eq}} = 3.7$, $^{3}J_{\mathrm{eq,eq}} = 3.6$) | 1.698 (dtd, $^{2}J = 12.5$, $^{3}J_{\mathrm{ax,eq}} = 3.5$, $^{3}J_{\mathrm{eq,eq}} = 3.2$, $^{4}J = 1.3$) | 1.912 (dt, $^{2}J = 12.6$, $^{3}J_{\mathrm{ax,eq}} = 3.2$, $^{3}J_{\mathrm{eq,eq}} = 3.0$) | 1.353 (dtd, $^{2}J = 13.2$, $^{3}J_{\mathrm{ax,eq}} = 3.5$, $^{3}J_{\mathrm{eq,eq}} = 3.2$, $^{4}J = 1.4$) | 1.420 (m) | 1.832 (dt, $^{2}J = 12.8$, $^{3}J_{\mathrm{ax,eq}} = 3.7$, $^{3}J_{\mathrm{eq,eq}} = 3.4$) | 1.816 (dt, $^{2}J = 12.4$, $^{3}J_{\mathrm{ax,eq}} = 3.7$, $^{3}J_{\mathrm{eq,eq}} = 3.6$, $^{4}J = 0.8$) |
| 1.55 (m) | 1.628 (qt, $^{2}J = 13.8$, $^{3}J_{\mathrm{ax,ax}} = 13.1$, $^{3}J_{\mathrm{ax,ax}} = 13.7$, $^{3}J_{\mathrm{eq,ax}} =$ $^{3}J_{\mathrm{eq,ax}} = 3.7$) | 1.580 (qt, $^{2}J = 14.0$, $^{3}J_{\mathrm{ax,ax}} = 13.6$, $^{3}J_{\mathrm{ax,ax}} = 13.6$, $^{3}J_{\mathrm{eq,ax}} =$ $^{3}J_{\mathrm{eq,ax}} = 3.5$) | 1.670 (qt, $^{2}J = 11.6$, $^{3}J_{\mathrm{ax,ax}} = 13.2$, $^{3}J_{\mathrm{ax,ax}} = 13.0$, $^{3}J_{\mathrm{eq,ax}} = 3.2$, $^{3}J_{\mathrm{eq,ax}} = 3.5$) | 1.597 (qt, $^{2}J = 13.6$, $^{3}J_{\mathrm{ax,ax}} = 12.8$, $^{3}J_{\mathrm{ax,ax}} = 12.8$, $^{3}J_{\mathrm{eq,ax}} =$ $^{3}J_{\mathrm{eq,ax}} = 3.5$) | 1.470 (m) | 1.670 (qt, $^{2}J = 13.6$, $^{3}J_{\mathrm{ax,ax}} = 13.0$, $^{3}J_{\mathrm{ax,ax}} = 13.1$, $^{3}J_{\mathrm{eq,ax}} =$ $^{3}J_{\mathrm{eq,ax}} = 3.7$) | 1.660 (m) |
| 1.510 (m) | 1.502 (d.quint, $^{2}J = 13.8$, $^{3}J_{\mathrm{ax,eq}} = 4.0$, $^{3}J_{\mathrm{eq,ax}} = 4.0$, $^{3}J_{\mathrm{eq,eq}} = 3.6$, $^{3}J_{\mathrm{eq,eq}} = 3.6$) | 1.458 (d.quint, $^{2}J = 14.0$, $^{3}J_{\mathrm{ax,eq}} = 3.5$, $^{3}J_{\mathrm{eq,ax}} = 3.5$, $^{3}J_{\mathrm{eq,eq}} = 3.2$, $^{3}J_{\mathrm{eq,eq}} = 3.2$) | 1.423 (d.quint, $^{2}J = 11.6$, $^{3}J_{\mathrm{ax,eq}} = 3.2$, $^{3}J_{\mathrm{eq,ax}} = 3.6$, $^{3}J_{\mathrm{eq,eq}} = 3.0$, $^{3}J_{\mathrm{eq,eq}} = 3.2$) | 1.525 (d.quint, $^{2}J = 13.6$, $^{3}J_{\mathrm{ax,eq}} = 3.8$, $^{3}J_{\mathrm{eq,ax}} = 4.2$, $^{3}J_{\mathrm{eq,eq}} = 3.2$, $^{3}J_{\mathrm{eq,eq}} = 3.2$) | 1.400 (m) | 1.459 (d.quint, $^{2}J = 13.6$, $^{3}J_{\mathrm{ax,eq}} = 4.0$, $^{3}J_{\mathrm{eq,ax}} = 3.9$, $^{3}J_{\mathrm{eq,eq}} = 3.4$, $^{3}J_{\mathrm{eq,eq}} = 3.2$ | 1.520 (m) |
| 1.16 (m) | 1.176 (td, $^{2}J = 13.5$, $^{3}J_{\mathrm{ax,ax}} = 13.7$, $^{3}J_{\mathrm{ax,eq}} = 4.0$) | 1.223 (td, $^{2}J = 13.6$, $^{3}J_{\mathrm{ax,ax}} = 13.6$, $^{3}J_{\mathrm{ax,eq}} = 3.5$) | 1.219 (td, $^{2}J = 12.4$, $^{3}J_{\mathrm{ax,ax}} = 13.0$, $^{3}J_{\mathrm{ax,eq}} = 3.6$) | 1.200 (td, $^{2}J = 13.2$, $^{3}J_{\mathrm{ax,ax}} = 12.9$, $^{3}J_{\mathrm{ax,eq}} = 3.8$) | 1.150 (m) | 1.136 (td, $^{2}J = 12.2$, $^{3}J_{\mathrm{ax,ax}} = 13.1$, $^{3}J_{\mathrm{ax,eq}} = 3.9$) | 1.100 (m) |
| 1.390 (m) | 1.400 (dt, $^{2}J = 13.5$, $^{3}J_{\mathrm{ax,eq}} = 3.7$, $^{3}J_{\mathrm{eq,eq}} = 3.6$) | 1.389 (dtd, $^{2}J = 13.6$, $^{3}J_{\mathrm{ax,eq}} = 3.5$, $^{3}J_{\mathrm{eq,eq}} = 3.2$, $^{4}J = 1.3$) | 1.404 (dt, $^{2}J = 12.4$, $^{3}J_{\mathrm{ax,eq}} = 3.6$, $^{3}J_{\mathrm{eq,eq}} = 3.2$) | 1.483 (dtd, $^{2}J = 13.2$, $^{3}J_{\mathrm{ax,eq}} = 3.5$, $^{3}J_{\mathrm{eq,eq}} = 3.2$, $^{4}J = 1.4$) | 1.386 (m) | 1.436 (dt, $^{2}J = 13.2$, $^{3}J_{\mathrm{ax,eq}} = 3.7$, $^{3}J_{\mathrm{eq,eq}} = 3.2$) | 1.469 (m) |
| 1.400 (m) | 1.233 (m) | 1.571 (m, $J_{\mathrm{ax,ax}} = 11.0$) | 1.330 (m, $J_{\mathrm{ax,ax}} = 13.2$) | 2.774 (s) | 1.555 (m) | 1.136 (m, $J_{\mathrm{ax,ax}} = 12.4$) | 1.149 (m, $J_{\mathrm{ax,ax}} = 14.8$) |
| 1.164 (m) | 1.520 (m) | 1.532 (m, $J_{\mathrm{ax,ax}} = 13.2$) | 1.706 (m, $J_{\mathrm{ax,ax}} = 13.2$) | | 1.528 (m) | 1.627 (m, $J_{\mathrm{ax,ax}} = 12.4$) | 1.492 (m, $J_{\mathrm{ax,ax}} = 14.8$) |
| 1.924 (m) | 2.141 (m) | 1.857 (m) | 2.079 (m) | | 1.71 (m) | 1.777 (m) | 2.100 (m) |
| 3.886 (m) | 4.283 (m) | 3.666 ($J_{\mathrm{ax,eq}} = 3.6$) | 3.976 ($J_{\mathrm{ax,eq}} = 2.2$) | 5.721 (m) | 3.715 (m) | 3.331 ($J_{\mathrm{ax,ax}} = 11.5$) | 4.380 ($J_{\mathrm{ax,ax}} = 11.9$) |
| 1.220 | 4.585 | $\delta_A = 3.953$, $\delta_B = 3.987$ ($J = 11.6$) | 9.913 ($J = 2.2$) | $\delta_A = 3.750$, $\delta_B = 3.872$ ($J = 11.2$) | 17.35 | | $\delta_A = 4.220$, $\delta_B = 4.301$ ($J = 10.2$) |
| 1.360 | $\delta_A = 4.671$, $\delta_B = 4.920$ ($J_{AB} = 12.4$) | 1.33 (s) | 1.429 (s) | 2.003 (s) | 1.322 (s) | 1.478 (s) | 4.191 (s) |
| 0.826 | 0.875 | 0.900 (s) | 0.834 (s) | 0.939 (s) | 0.865(s) | 0.873 (s) | 0.873 (s) |
| 0.856 | 0.911 | 0.885 (s) | 0.899 (s) | 1.159 (s) | 0.912 (s) | 0.897 (s) | 0.898 (s) |
| | 1.076 | 0.790 (s) | 1.100 (s) | 1.181 (s) | 1.121 (s) | 1.213 (s) | 1.128 (s) |

(for protons at C(3)) and 200—560 Hz (for protons at C(1)). The difference between the chemical shifts of the coupled axial protons, $H(1)_{ax}$—$H(2)_{ax}$ and $H(2)_{ax}$—$H(3)_{ax}$, is larger by an order of magnitude almost in all cases than the vicinal coupling constants of these axial protons. Meanwhile, the vicinal ${}^3J_{\mathrm{ax,eq}}$ and ${}^3J_{\mathrm{eq,eq}}$ constants (5.1—3.2 Hz) are approximately 3—4 times lower than the ${}^3J_{\mathrm{ax,ax}}$ values. In addition, the geminal (${}^2J$) and vicinal (${}^3J_{\mathrm{ax,ax}}$) spin-spin coupling constants are approximately equal (${}^2J \approx {}^3J_{\mathrm{ax,ax}} = 13$—14.6 Hz). These facts markedly simplify the analysis of the miltiplets formed by these six-spin systems.

Analysis of the proton spectra from ring *A* shows that the axial protons at C(1) and C(3) have each two large constants approximately equal in magnitude (${}^2J$ and ${}^3J_{\mathrm{ax,ax}}$) and one small vicinal constant (${}^3J_{\mathrm{ax,eq}}$ or ${}^3J_{\mathrm{eq,ax}}$ ~5.1—3.6 Hz); the equatorial protons at these carbon atoms are characterized by one large ${}^2J$ and two small coupling constants (vicinal constants, ${}^3J_{\mathrm{ax,eq}}$ and ${}^3J_{\mathrm{eq,eq}}$, approximately equal in magnitude). The axial proton at C(2) has three large coupling constants (${}^2J$, ${}^3J_{1_{\mathrm{ax}},2_{\mathrm{ax}}}$, and ${}^3J_{2_{\mathrm{ax}},3_{\mathrm{ax}}}$) and two small vicinal constants (${}^3J_{1_{\mathrm{eq}},2_{\mathrm{ax}}}$ and ${}^3J_{2_{\mathrm{ax}},3_{\mathrm{eq}}}$); the equatorial proton at C(2) has one large geminal and four small vicinal constants (${}^3J_{\mathrm{ax,eq}}$, ${}^3J_{\mathrm{eq,ax}}$ and two ${}^3J_{\mathrm{eq,eq}}$ ~ 3.1—3.7 Hz). In the proton spectra recorded at a spectrometer frequency of 400 MHz with individual line width of ~0.4—0.6 Hz, the multiplets of the axial protons at C(1) and C(3) are manifested as triplets of doublets, those at C(2) as a quartet of triplets. The multiplets of the equatorial protons at C(1) and C(3) look as doublet of triplets; in the presence of a long-range constant, ${}^4J_{1_{\mathrm{eq}},3_{\mathrm{eq}}} > 1$ Hz, as doublets of triplets of doublets, while the multiplet of the equatorial proton at C(2) is a doublet of quintets.

Analysis of the data of Table 2 shows that in all compounds, the $\mathrm{H(2)_{ax}}$ axial proton resonates in a lower field than the $\mathrm{H(2)_{eq}}$ equatorial proton. In addition, in compounds **12** and **13**, the $\mathrm{H(1)_{ax}}$ axial proton resonates in a lower field than the equatorial $\mathrm{H(1)_{eq}}$ proton. For other compounds, the signals from the $\mathrm{H(1)_{ax}}$ and $\mathrm{H(3)_{ax}}$ protons occur in a higher field than the signals from $\mathrm{H(1)_{eq}}$ and $\mathrm{H(3)_{eq}}$. The same mechanism can interpret the abnormal chemical shifts of the $\mathrm{H(2)_{ax}}$ protons in the spectra of all drimanic sesquiterpenoids, the abnormal chemical shifts of the $\mathrm{H(1)_{ax}}$ axial proton, and the upfield shift of the signal for C(1) in the spectra of compounds **12** and **13**. As shown above,[12—14] the high-field position of the carbon signals from the $\mathrm{C(19)H_3}$ and $\mathrm{C(20)H_3}$ methyl groups (in drimanic compounds **1—15**, the $\mathrm{C(13)H_3}$ and $\mathrm{C(15)H_3}$ methyl groups) with respect to the signal from C(18) (in compounds **1—15**, the $\mathrm{C(14)H_3}$ group) in the spectra of diterpene compounds can be attributed to a strong van der Waals interaction between the protons of the 1,3-*cis*-diaxial methyl groups. For the same reason, the signal from C(2) occurs in a higher field than the signals from C(1) and C(3). In this case, $\mathrm{H(2)_{ax}}$ and the protons of the axial methyl groups, $\mathrm{C(19)H_3}$ and $\mathrm{C(20)H_3}$, are involved in a 1,3-*cis*-diaxial van der Waals interaction. Apparently, these 1,3-diaxial van der Waals interactions deshield the axial $\mathrm{H(2)_{ax}}$ proton, thus shifting its signal downfield compared to that of $\mathrm{H(2)_{eq}}$. The molecular models of compounds **1—15** indicate that the distance between the coupled protons of the 1,3-diaxial methyl groups is 2.05—2.35 Å. A similar situation is observed for compounds **12** and **13**. This suggests that the axial positions and the small distances between the interacting groups are sufficient for the existence of strong van der Waals interactions in the molecule. Note that the vicinal spin-spin coupling constants were determined from analysis of the proton spectra of the $\mathrm{H(5)_{ax}}$—$\mathrm{H(6)_{ax}}$—$\mathrm{H(6)_{eq}}$—H(7) four-spin systems; $J_{6_{\mathrm{ax}},7_{\mathrm{ax}}}$ and $J_{6_{\mathrm{eq}},7_{\mathrm{ax}}}$ are 9.3—11.5 Hz (for compounds **8**, **9**, **14**) and 8.4—6.9 Hz (**15**), and $J_{6_{\mathrm{ax}},7_{\mathrm{eq}}}$ and $J_{6_{\mathrm{eq}},7_{\mathrm{eq}}}$ are 4.8—2.2 Hz (**10**) and 3.2—0.6 Hz (**11**). The H(7) proton has a β-orientation in molecules **8**, **9**, **14**, and **15** and α-orientation in molecules **10** and **11**.

Thus, one can conclude that, if the axial proton of the cyclohexane fragment is involved in the 1,3-diaxial van der Waals interaction with the methyl or hydroxy group, this shields the carbon atom bearing this proton and deshields the axially oriented $\mathrm{H_{ax}}$ proton.

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