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LONG-RANGE COUPLING IN THE NOVEL KHUSENATE AND ISOKHUSENATE SERIES

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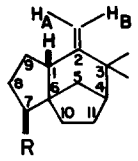
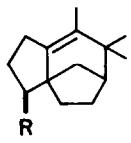
Two novel tricyclic sesquiterpene skeletons, khusenate (I) and isokhusenate (II), have been characterized recently in compounds isolated from Oil of Vetiver: Ia, Ib, IIa, IIb, IIc (1) and Ic, III (2). We now wish to report on the nature of the long-range coupling seen in the NMR spectra of these two classes of compounds.



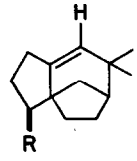
I

a: R = CO_2CH_3
b: R = CH_2OH
c: R = CH_3



II

a: R = CO_2CH_3
b: R = CO_2H
c: R = H



III

R = CH_3 or CO_2CH_3

IV

The vinylic protons of methyl khusenate (Ia) (4.77 and 4.63δ) and of khusenol (Ib) (4.75 and 4.62 δ) show a triplet-like form as illustrated in Fig. 1 for khusenol. Kido et al. (2) have also reported a triplet pattern for the vinylic protons (4.68 and 4.53δ, CCl_4) of Ic. By anology with camphene (IV), which shows two vinylic singlets (4.74 and 4.53δ; CCl_4 (3), we might expect the vinylic protons in the khusenate series, in the absence of long-range coupling, to appear as two singlets.

Spin decoupling experiments (Varian HA-100 spectrometer) performed on khusenol (Ib) demonstrated the presence of allylic and geminal coupling with the exo-methylene protons. On irradiation of the C-1 bridge-head proton located at 2.5δ*, the double triplet pattern

*This chemical shift is in excellent agreement with that (2.69δ, CCl_4)(3) found for the corresponding proton at C-4 in camphene (IV).

for the exo-methylene protons (Fig. 1) was reduced to two sets of doublets showing the removal of allylic coupling and the retention of geminal coupling (J_{gem}= 1.5 ± 0.1 Hz). When one band from the exo-methylene protons was irradiated the other band appeared as a somewhat broadened doublet indicating the removal of geminal coupling and the retention of allylic coupling (J_{al}= 1.9 ± 0.1 Hz). The magnitude of J_{al} appears reasonable for the khusenate structure in which the angle (θ) between the allyl hydrogen and the plane of the double bond is approximately 110°. The known range for J_{al} is 1.3-3.1 Hz for θ = 60-110° (4). The apparent absence of allylic coupling in camphene (IV) may be accounted for by the fact that J_{al} is very small (<0.5 Hz) when θ < 20° (4). The magnitude of J_{gem} is intermediate for the range (J_{gem}= 0-3 Hz)(5) found for terminal methylene protons of non-bridged olefins.

Examples of allylic and geminal coupling involving exo-methylene protons in fused ring systems are rare. Although much work has been done in the synthesis of 2- and 3- (6a), 6-(6b), 7-(6c), and 11-methylene steroids (6d), no NMR data is available for these compounds. An exo-methylene group is found in methyl angolensate, a ring-B-seco tetranor-tetracyclic triterpene, which is reported (7) to show two singlets for the vinylic protons at 5.12 and 4.97δ ($CDCl_3$). The apparent absence of allylic coupling in this compound may also be attributed to the small angle θ; however, as in camphene, it is puzzling why geminal coupling should appear to be absent or negligibly small. The geminal coupling from the exo-methylene protons observed in the khusenate molecule therefore appears to be novel for bridged systems so far examined.

We would assign the high field triplet of the vinylic pattern to proton H_b directed towards the C-3 gem-dimethyl group on the basis that (i) the differences in chemical shift values here are expected to be due largely to differences in the diamagnetic anisotropies of the adjacent vinylic C-C bonds (8) and (ii) the C_2-C_3 bond of I, being terminated by gem-dimethyl groups, should show greater anisotropic shielding than the C_1-C_2 bond. Recent calculations on long-range effects of methyl groups on the anisotropies of C-C bonds (9) of some bicyclic structures lend support to this proposal (e.g. shielding of an exomethine proton to the extent of 0.14 ppm is found by comparison of examples 16 and 18, loc cit.). Similarly we would assign the low-field singlet (4.74δ)(3) from camphene (IV) to the vinylic proton remote from the gem-dimethyl group and the high-field singlet (4.53δ) to the vinylic proton proximate to the gem-dimethyl group. This assignment is consistent with

that made by Claisse and Davies (8) for the C-1 proton of camphene (IV) at 1.88δ (CCl_4), the C-4 proton being found at 2.69δ (CCl_4)(3).

We have also observed triplet character for the C-2 methyl peak of methyl isokhusenate (IIa), Fig. 2 which we attribute to homoallylic coupling (10) with the methylene protons at C-9 (J ≃ 1.0 Hz). Kido et al. (2) have reported that the C-2 vinylic proton of III (R = CH_3 or CO_2CH_3) appears as a quartet (4.81 and 4.84δ respectively, CCl_4)(no J value cited). For Kido's system we would propose cisoid and transoid allylic coupling (10) by the C-9 methylene protons of III to account for the quartet seen for the vinylic protons.

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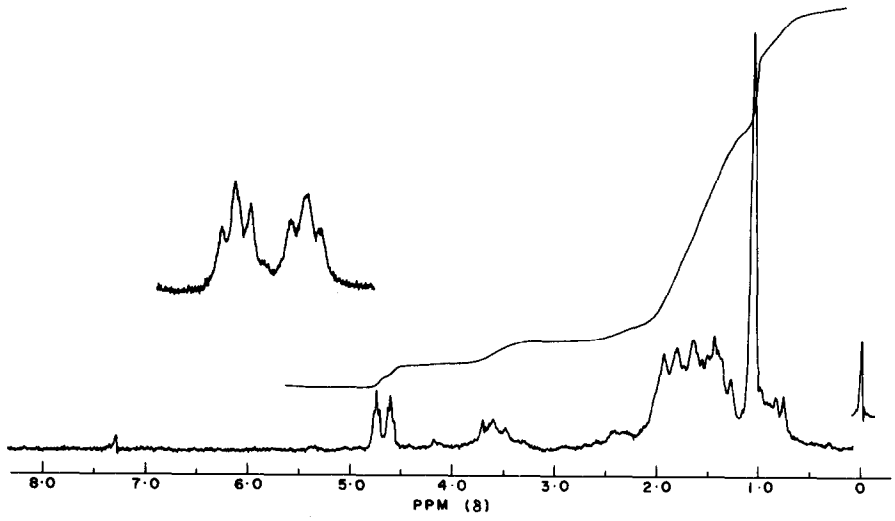

Fig. 1. NMR spectrum (Varian A-60A) of khusenol (Ib) in $CDCl_3$. Chemical shifts (δ) are reported downfield from TMS internal reference.

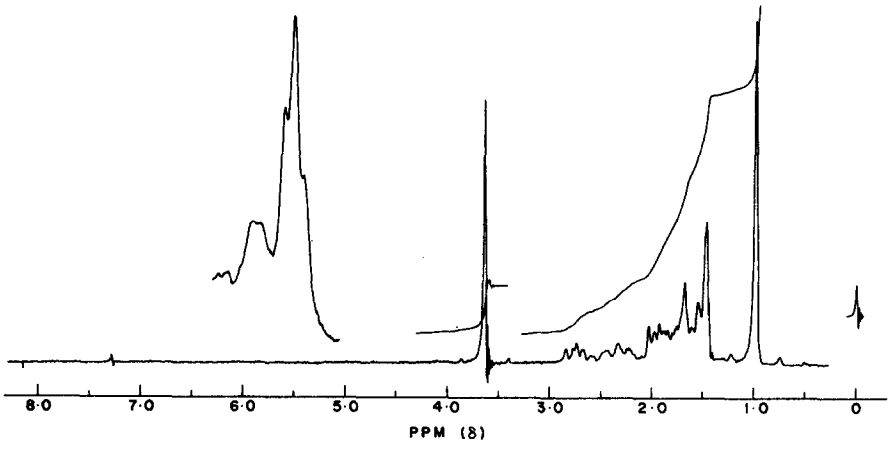

Fig. 2. NMR spectrum (Varian A-60A) of methyl isokhusenate (IIa) in $CDCl_3$. Chemical shifts (δ) are reported downfield from TMS internal reference.