Tetrahedron Letters No. 5, pp 425 - 428, 1978. Pergamon Press. Printed in Great Britain.

CARBON-13 NMR ANALYSIS OF NATURALLY OCCURRING 9,10-DIHYDROPHENANTHRENES AND THEIR DERIVATIVES

S. William Pelletier*, Naresh V. Mody, and J. Bhattacharyya
Institute for Natural Products Research and The Department of Chemistry,
University of Georgia, Athens, Georgia 30602, U.S.A.

and

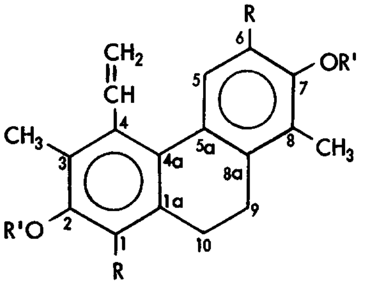
D. Howard Miles
Department of Chemistry, Mississippi State University
Mississippi State, Mississippi 39762, U.S.A.

(Received in USA 27 September 1977; received in UK for publication 6 December 1977)

To date, about twenty 9,10-dihydrophenanthrene derivatives have been isolated from nature. Although 9,10-dihydrophenanthrenes have been known[1] for over a decade, most of the members of this group of compounds have been isolated[2-5] in recent years. Many of these compounds are phytoalexins[6] and one of them, juncusol (1), is highly cytotoxic.[4] These important biological properties along with their widespread occurrence in nature make them an interesting subject of study. Although 9,10-dihydrophenanthrenes are relatively simple, their structure determination requires extensive chemical and spectral manipulations. In several cases, structures have been elucidated only after long and tedious syntheses.[7] The application of ^{13}C NMR spectroscopy to the structure elucidation of this class of compounds has, so far, been ignored. In this communication, we report the ^{13}C NMR spectra of juncusol[4] (1), juncunol[5] (7), and several of their derivatives which represent compounds having all the variety of substituents encountered in naturally occurring 9,10-dihydrophenanthrenes. These data will prove very useful for the structure elucidation of newly discovered 9,10-dihydrophenanthrenes.

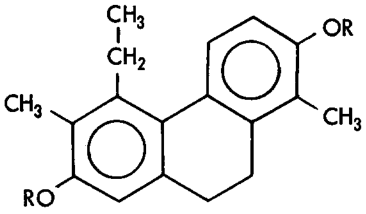
The chemical shifts of juncusol (1), juncunol (7), and their derivatives are presented in Table 1. These assignments of the chemical shifts of the various carbons in these compounds were made with the aid of deuterium exchange, acetylation of OH functions, direct analysis of non-protonated carbon centers, and complete and partial decoupled spectra. The spectrum of juncusol (1) shows 18 signals for 18 carbons in the molecule. The single frequency off-resonance decoupled (SFORD) spectrum of juncusol shows 9 singlets, 4 doublets, 3 triplets, and 2 quartets. Between the two quartets at 11.8 and 13.2 ppm, the former is assigned to the CH_3 group at C-8 by comparison with the corresponding shift of the CH_3 group at C-8 in juncunol (11.7 ppm). However, the CH_3 group at C-3 in juncunol (7) appears at 21.1 ppm. The large upfield shift of the CH_3 group at C-3 in juncusol ($\Delta\delta = 7.9$ ppm) must be attributed to the steric compression of the vinyl group at C-4 and the OH group at C-2 along with other anisotropic effects, with the former definitely predominating. In dihydrojuncusol (2), the CH_3 group at C-3 shifts further upfield to 11.8 ppm. By contrast, the position of the

CH_3 group at C-3 is practically unchanged in the spectra of juncunol and all its derivatives (7-10).



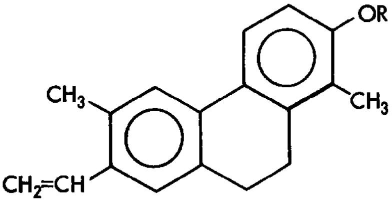
1 R = R' = H   4 R = D; R' = Ac

3 R = H; R' = Ac   6 R = H; R' = CH_3



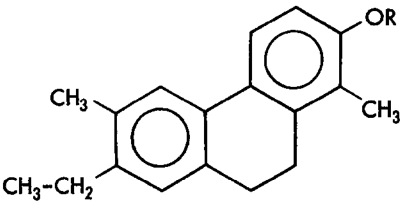
2 R = H

5 R = Ac



7 R = H

8 R = Ac



9 R = H

10 R = Ac

The triplet at 119.9 ppm and the doublet at 137.8 ppm may be definitely assigned to the vinyl group in juncusol because these signals disappeared in the spectrum of dihydrojuncusol. The unusual downfield shift of the $=CH_2$ in juncusol in comparison with that of styrene (113.2 ppm)[8] appears to be caused by the ring current effect on $=CH_2$ in juncusol induced by the restricted rotation of the vinyl group and not because of any anisotropic effect. The vinyl group at C-4 in juncusol is sterically hindered by the C-3 methyl group and the C-5 proton, and is held in a position where the plane of the double bond is perpendicular to the plane of the 9,10-dihydrophenathrene ring system, as shown by the X-ray structure.[4] This is substantiated by the ^1H NMR chemical shifts of the protons of the vinyl group in juncusol[4] which are significantly different from those of styrene. In juncunol,[5] the vinyl group has free rotation and, therefore, the chemical shifts of the vinyl carbons as well as the vinyl protons are very similar to those of styrene.

The triplets at 25.7 and 30.3 ppm are assigned to the methylene groups at C-9 and C-10, respectively, in juncusol by comparison with the chemical shifts of the corresponding carbons of 9,10-dihydrophenanthrene (29.2 ppm).[9] The considerable upfield shift of C-9 in juncusol ($\Delta\delta = 3.5$ ppm) as well as in juncunol ($\Delta\delta = 3.6$ ppm) must be attributed to the steric compression of the CH_3 group at C-8.

The lowfield doublets at 111.1 and 112.8 ppm are assigned to C-6 and C-1, respectively, in juncusol. These peaks collapse in the corresponding spectrum of the dideuteriated compound (4) because of

Table 1. Carbon-13 Chemical Shift Assignments of some 9,10-Dihydrophenanthrene Derivatives[a, b]

Carbon	1[c]	2	3	4	5	6	7	8	9	10
1	112.8	111.5	119.5	-	118.4	106.9	128.1	127.7	129.3	129.2
2	153.4[d]	153.3[d]	147.7[d]	147.7[d]	147.8[d]	156.3[d]	135.9[d]	139.0	140.1	140.6
3	120.6	120.2	126.1	125.9	125.7	122.7	135.2[d]	135.5	135.6	136.4
4	139.9	139.1	139.5	139.6	140.3	139.5	127.9	127.7	125.7	125.8
5	128.6	124.9	128.1	128.4	127.3	128.4	127.5	127.3	126.3	126.2
6	111.1	111.5	118.1	-	118.4	108.9	112.1	118.6	111.8	118.6
7	153.2[d]	153.4[d]	147.9[d]	147.6[d]	148.0[d]	156.6[d]	152.9	148.1	152.2	147.9
8	120.2	121.0	126.6	126.6	126.4	123.6	121.0	126.6	120.5	126.5
9	25.7	25.7	25.1	25.4	25.5	25.8	25.6	25.5	25.8	25.8
10	30.3	30.8	29.5	29.7	30.2	30.9	30.0	29.7	30.7	30.4
1a	137.1	136.7	136.8	137.0	137.7	137.0	135.9	136.6	139.0	139.4
4a	127.7[e]	126.3	131.3[e]	131.7[e]	132.0	127.3[e]	131.6	132.0	131.8	132.7
5a	127.9[e]	126.3	131.1[e]	131.5[e]	132.0	127.7[e]	126.9	130.7	127.7	131.4
8a	137.9	139.1	137.2	137.2	140.1	138.0	140.2	139.7	140.3	140.2
CO	-	-	168.6 168.6	168.9 168.9	168.6 168.6	-	-	169.5	-	169.5
CH_3	-	-	20.7 20.7	20.8 20.8	20.6 20.6	-	-	20.9	-	20.9
3-CH_3	13.2	11.8	13.8	13.9	12.2	13.4	21.1	21.1	21.0	21.1
8-CH_3	11.8	11.8	12.4	12.6	12.5	11.7	11.7	12.5	11.7	12.7
CH_2	-	23.7	-	-	23.9	-	-	-	26.9	26.8
CH_3	-	15.1	-	-	14.9	-	-	-	16.1	16.1
CH	137.8	-	136.4	136.5	-	137.5	139.3	138.8	-	-
CH_2	119.9	-	120.0	120.0		119.7	113.9	114.2	-	-
3-OCH_3	-	-	-	-	-	55.5	-	-	-	-
7-OCH_3	-	-	-	-	-	55.7	-	-	-	-

[a] Chemical shifts in ppm downfield from TMS. The solvent is deuterochloroform unless otherwise mentioned.

[b] Carbon-13 NMR spectra were taken at 25.03 MHz and at 15.03 MHz in the Fourier mode using a JEOL-PFT-100 spectrometer and a JEOL FX-60 spectrometer.

[c] A few drops of Acetone-d_6 were added.

[d, e] These assignments may be interchanged in any vertical column.

deuterium exchange in those positions. The doublet at 112.8 ppm is assigned to C-1 because, in the spectrum of dihydrojuncusol (2), this signal shifts upfield and appears in the same position (111.5 ppm) with C-6, which remains practically unchanged. The doublet at 128.6 ppm is assigned to C-5 which shifts to 124.9 ppm in the spectrum of dihydrojuncusol (2), possibly because of the steric compression of the C_2H_5 group at C-4.

The singlets at 120.6 and 120.2 ppm are assigned to C-3 and C-8, respectively, in juncusol, which shift to 126.1 and 126.6 ppm in the spectrum of the diacetate (3) and to 125.7 and 126.4 ppm in the dihydrodriacetate (5), as expected. The singlets at 153.4 and 153.2 ppm are assigned to C-2 and C-7 in juncusol. The singlet at 139.9 ppm is assigned to C-4 which does not appreciably shift in the spectrum of dihydrojuncusol (2) as expected. Of the remaining four singlets, the ones at 127.7 and 127.9 ppm are assigned to the ring junction carbons at C-4a and C-5a in juncusol because these signals shift to 131.3 and 131.1 ppm in the spectrum of juncusol diacetate (3) and to 132.0 ppm in the spectrum of dihydrojuncusol diacetate (5), showing the usual effect of acetylation of the phenolic OH function at the para position. The remaining two singlets at 137.1 and 137.9 ppm in juncusol are assigned to C-1a and C-8a respectively.

The spectrum of juncunol (7) exhibits eighteen signals corresponding to eighteen carbons in the molecule. The pattern of carbon-13 chemical shifts in juncunol is similar to that of juncusol (1). However, comparison of the spectrum of 7 with that of juncusol reveals the absence of a chemical shift due to the phenolic OH group in ring A and changes in chemical shifts of the ring-A carbons in juncunol. The chemical shifts of juncunol are in agreement with its assigned structure 7.[5]

The aromatic substitution additivity rule[10] seems to hold reasonably well for these 9,10-dihydrophenanthrene derivatives.

Acknowledgment: The authors gratefully acknowledge a matching grant from the National Science Foundation to the Department of Chemistry, University of Georgia, for purchase of the carbon-13 NMR spectrometer. We thank Mr. C. Pape for technical assistance in this work.

REFERENCES

1. E. Hardegger, M. Schellenbaum and H. Corrodi, Helv. Chim. Acta, 46, 1171 (1963) and references cited therein.
2. R. M. Letcher and L.R.M. Nhamo, J. Chem. Soc. Perkin I, 2941 (1972) and references cited therein.
3. M. A. DeAlvarenga and O. R. Gottlieb, Phytochemistry, 13, 1283 (1974).
4. D. H. Miles, J. Bhattacharyya, N. V. Mody, J. L. Atwood, S. Black, and P. A. Hedin, J. Am. Chem. Soc., 99, 618 (1977).
5. J. Bhattacharyya and D. H. Miles, Tetrahedron Letters, 2749 (1977).
6. M. H. Fisch, B. H. Flick, and J. Arditti, Phytochemistry, 12, 437 (1973), and references cited therein.
7. R. M. Letcher and L.R.M. Nhamo, J. Chem. Soc. Perkin I, 1263 (1973).
8. K. S. Dhami and J. B. Stothers, Can. J. Chem., 43, 510 (1965).
9. H. L. Retcofsky and R. A. Friedel in Spectrometry of Fuels , Ed. R. A. Friedel, Pleum Press, New York (1970), p. 90.
10. J. B. Stothers, Carbon-13 NMR Spectroscopy , Academic Press, New York (1972).

4