

R. Erra-Balsells

Departamento de Química Orgánica, Facultad de Ciencias Exactas y Naturales,
Universidad de Buenos Aires, Pabellón 2, 3°, Ciudad Universitaria,
1428-Buenos Aires, Argentina
Received October 13, 1987

The ¹³C nmr spectra of a series of methyl- and/or nitro-2,3-diphenylindole derivatives are reported. The dependence of a) ¹H and ¹³C methyl group shieldings on molecular geometry and b) the possibility that ¹³C nmr might be a useful tool in determining photochemical reactivity are discussed briefly.

J. Heterocyclic Chem., **25**, 1059 (1988).

In the present work ¹³C nmr assignments for several 2,3-diphenylindole derivatives in DMSO solution were determined. The ¹H nmr data for these indoles in DMSO solution were previously described [1] and the comparison between both series of nmr data affords interesting substituent effect conclusions and structural conclusions.

In the course of studies of the photochemical reactions of 2,3-diphenylindoles [1,2], the photocyclodehydrogenation of some stilbene analogues was observed (Table I, **1-5**, **11** and **12**, [1]) and several systems studied were found which did not photocyclise (Table I, **6-10**, [1]). Sometime ago some rules governing photocyclisation of stilbene analogues were summarised [3] and in a recent study on mass spectral fragmentation patterns of 2,3-diphenylindoles [4] we have discussed one of these rules. Timmons [3] has correlated the effect of the uv irradiation with the effect of electronic impact (in the mass spectrometer) and with the electron availability at the two *ortho*-positions between which the new bond would be expected to form. The calculated values of free-valence indices have also been used to predict the probable reaction sites in many aromatic compounds (stilbene analogues [5]). Mallory [6] suggested that the electronic distribution in the excited state may be such that there is sufficient electron availability at the two *ortho*-positions between which the new bond would be expected to form, the calculated values of free-valence indices [3] have been used to predict the probable reaction sites in many aromatic compounds (stilbene analogues) but some exceptions were found. This method is only a rough approximation even though it gives results which sometimes are in accord with experimental results.

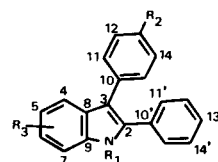
¹³C nmr spectroscopy is a useful tool to distinguish differences in electron density. Thus, we now wish to examine the possibility that ¹³C nmr chemical shifts may be useful in correlating photochemical behavior.

Results.

The 2,3-diphenylindoles studied are listed in Table I and the corresponding ¹³C chemical shifts in Table II and the corresponding ¹H chemical shifts elsewhere [1].

The assignments of the carbon resonances were based

Table I
2,3-Diphenylindole Derivatives



	R ₁	R ₂	R ₃	Photocyclisation [a]
1	H	H	H	+
2	H	H	5-Me	+
3	H	H	6-Me	+
4	H	H	7-Me	+
5	H	H	4,7-diMe	+
6	H	H	6-NO ₂	-
7	H	NO ₂	H	-
8	H	NO ₂	5-NO ₂	-
9	H	H	5-NO ₂ 6-Me	-
10	H	NO ₂	5-NO ₂ 6-Me	-
11	Me	H	H	+
12	Ph	H	H	+

[a] See reference [1].

on chemical shift correlations, data reported for methylindole derivatives [7-13] and for 2- and 3-phenylindoles [13,14], signal intensities in the partially relaxed spectra and multiplicities in some proton coupled spectra. In all cases, comparison with calculated chemical shifts obtained by semi-empirical rules and known substituent-induced shifts for monosubstituted benzenes [15] and pyrrole [16] were made. For compounds **6** and **8** the assignments of the chemical shifts of C-4, C-5, C-7 and C-4, C-6, C-7 respectively were confirmed using the off resonance C-[H] spin decoupling method of assigning ¹³C absorptions by connecting the residual splitting (Jr) with the proton frequency signals from directly bonded protons of known assign-

ment [15]. The ^1H nmr unambiguous assignments had been previously made [1] taking into account the chemical shifts and multiplicities.

Discussion.

In recent studies the ^{13}C resonance assignments of phenyl carbons of 2- and 3-phenylindole have been discussed [13,14]. In these *mono*-phenylindoles it has been observed that C-10' chemical shift values are lower than C-10 chemical shift values and that C-13' chemical shift

values are higher than C-13 chemical shift values, in general.

The above results, the known total net atomic electron densities of indole [17] and the ^{13}C nmr chemical shifts of anilines and their corresponding 2,4,6-trimethylpyridinium salt [18] helped the 2,3-diphenylindole ^{13}C nmr spectrum assignment (**1**, Table II). This assignment was confirmed later since by careful contrasting of the ^{13}C nmr spectrum of compounds **1** and **7** it is observed that C-10 to C-15 (Table II) are more shifted than C-10' to C-15'. Calculated

Table II

^{13}C Chemical Shifts of the 2,3-Diphenylindoles Studied (ppm relative to internal TMS in DMSO-d_6 solution) [a]

Compound	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9
1	135.0	113.1	119.4	118.3	121.7	111.2	127.7	135.9
2	134.3 (134.8)	112.0 (112.5)	117.9 (121.8)	125.7 (124.8)	123.4 (122.2)	111.0 (110.7)	128.0 (128.0)	135.3 (135.0)
3	134.3 (134.1)	112.9 (112.7)	118.5 (118.8)	120.5 (120.7)	131.7 (131.5)	111.2 (111.0)	125.7 (125.5)	137.2 (137.1)
4	134.6	113.4	117.0	118.7	121.7	120.3	127.3	137.2
5	135.1	114.0	126.3	120.9	122.0	118.3	126.9	137.3
6	137.0 (136.9)	113.2 (113.0)	117.9 (117.7)	112.5 (112.3)	141.4 (141.1)	107.3 (107.1)	130.5 (130.4)	139.3 (139.0)
7	135.9	118.1	120.2	118.4	122.3	111.7	127.9	136.0
8	139.7 (139.0)	119.0 (118.9)	115.4 (115.2)	138.0 (137.5)	116.7 (116.6)	111.1 (110.8)	125.6 (125.4)	139.1 (138.9)
9	138.2	116.0	113.8	138.6	127.2	112.0	124.9	142.9
10	138.4	116.1	114.0	138.6	127.1	112.0	124.6	142.7
11	131.8	112.0	119.3	117.9	121.2	109.0	127.0	134.5
12	135.1	113.0	119.2	118.2	121.5	111.1	127.8	135.8

Compound	C-10	C-11 C-15	C-12 C-14	C-13	C-10'	C-11' C-15'	C-12' C-14'	C-13'	Me
1	133.8	127.9	128.3	125.7	132.2	128.1	129.5	127.4	-
2	133.9	127.9	128.3	125.7	134.2	128.2	129.6	127.1	21.2
3	133.9	127.9	128.4	125.6	134.3	128.2	129.5	127.3	21.4
4	133.8	127.9	128.3	125.7	132.3	128.1	129.6	127.4	16.8
5	133.9	127.8	131.5	126.6	132.6	127.5	128.2	127.5	19.8 (MeC-4) 16.9 (MeC-7)
6	134.0	127.9	128.4	125.8	132.8	128.2	129.6	127.5	-
7	140.5 (139.8)	128.5 (128.7)	123.6 (123.0)	145.0 (145.3)	132.2	128.2	129.5	127.0	-
8	140.1	128.6	123.2	145.4	132.2	128.3	129.6	127.4	-
9	133.9	128.0	128.5	125.9	132.6	128.3	129.7	127.6	20.6
10	141.1	128.5	123.6	145.1	130.5	128.4	129.7	127.2	20.9
11	133.4	127.5	128.4	125.9	132.0	128.0	129.7	127.2	38.3
12	[134.5, 133.7, 133.5, 129.7, 129.6, 128.5, 128.4, 128.3, 128.0, 127.7, 127.5 and 126.0] [b]								

[a] Calculated values are in parentheses. [b] These signals could not be assigned (C-10 to C-15, Ph-C-3; C-10' to C-15', Ph-C-2 and Ph-N).

lated ^{13}C chemical shift values for C-10 to C-15 taking **1** as model compound are indicated in parentheses in Table II. In the indole ring system C-3 is the most shifted (Table II).

The nitro-substituent effect on the aromatic carbons (C-10 to C-15, Table II) was fairly constant for **7**, **8** and **10** and comparable to those reported for mono-substituted benzenes [5]. The nitro effect on the carbons of the indole ring system (C-2 to C-9, Table II) for **6** and **8-10** was comparable to those we previously observed for 5- and 6-nitro-2,3-dimethylindole [14].

The chemical shift values of C-2 to C-9 for **9** and **10** were also calculated taking **1** and **7** respectively as model compounds, by adding the known substituent chemical shifts of the 6-methyl substituent in the indole ring system [10] and those of the nitro substituent in the *ortho*-nitrotoluene [19]. These calculated chemical shifts were not as good as those calculated by adding the 5-nitro substituent chemical shifts above mentioned [14].

By comparison of the ^1H [1] and ^{13}C (Table II) chemical shift values of the methyl groups in **5** ($\text{CH}_3\text{C-4}$ 1.96, $\text{CH}_3\text{C-7}$ 2.53, $\text{CH}_3\text{C-4}$ 19.8, $\text{CH}_3\text{C-7}$ 16.9) with those for compounds **4** ($\text{CH}_3\text{C-7}$ 2.61, $\text{CH}_3\text{C-7}$ 16.8), 4-methylindole ($\text{CH}_3\text{C-4}$ 21.6) [10] and 7-methylindole ($\text{CH}_3\text{C-7}$ 16.6) [10] it can be observed that the 4-methyl group experience the shielding effect of the 3-phenyl group and both the ^1H and the ^{13}C signals are shifted to higher fields. This electronic effect of the 3-phenyl group on the 4-methyl group would explain the considerable shielding of the latter and the deshielding of the former (C-12/C-14 and C-13, Table II). It is interesting to mention that this shielding effect on the methyl group has not been observed neither in 2-phenyl-3-methylindole nor in 2-methyl-3-phenylindole ^{13}C nmr spectra [14].

Finally, it can be observed that the 5-nitro causes a considerable perturbation on 6-methyl substituent in **9** and **10** (**3**, **9** and **10**, Table II). This shielding effect is similar to that observed on the methyl group in the *ortho*-nitrotoluene [20] and in the *ortho*-chlorotoluene [20]. By comparison of the ^1H chemical shift of the 6-methyl group in compound **3** (2.45) [1] with those of compounds **9** (2.71) and **10** (2.70) [1] it can be observed that the methyl protons experience the electron-withdrawal effect of the nitro group and the ^1H signals are shifted to lower fields. This ^1H nmr downfield position is typical of a deshielding hydrogen-bonded conformation. It is interesting to note that this spatial interaction has been observed in the mass spectrum of **9** and **10** [(M—HO) ion, relative abundance 76 and 75% respectively] [4]. The preceding results show the importance of the steric interaction between methyl and nitro group in vicinal positions. When both groups are not in vicinal positions the spatial interaction between them causes a different effect on ^1H and ^{13}C chemical shift of the methyl group as we have observed [14] (spatial inter-

action between 3-methyl and 4-nitro group in 2,3-dimethyl-4-nitroindole). It is interesting to mention that a quantitative relationship between ^{17}O chemical shift data and the torsion angle of nitro groups in aromatic nitro compounds has recently been shown [21]. The described high nitrogen-oxygen double bond character of the respective nitro groups in *ortho*-nitro substituted aromatic compounds [21] could explain the shielding effect observed on 6-methyl substituent in **9** and **10** (Table II).

Conclusions.

As it was reported by our laboratory [1,2] under uv irradiation 2,3-diphenylindoles **1-5**, **11** and **12** undergo dehydrocyclisation with formation of dibenzo[*a,c*]carbazoles while **6-10** fail to undergo photocyclisation to the corresponding dibenzo[*a,c*]carbazoles. The possibility that ^{13}C nmr spectroscopy might prove to be a useful tool in determining photochemical reactivity of these compounds led us to investigate the possibility of distinguishing between compounds which photocyclise and those which do not. A gross examination between C-11/C-15, C-11'/C-15', C-2 and C-3 (Table II) ^{13}C chemical shifts of compounds **1-12** reveals that C-2 and C-3 experience the electron-withdrawal effect of the nitro group present at any position (stilbene moiety and/or indole ring system) while C-11/C-15 and C-11'/C-15' are less sensitive. Then, we think we should take into account the electronic density at all the positions involved in the photocyclisation and not only at the two *ortho*-positions. In this series we observed that when the electronic density at the olefinic carbons (C-2 and C-3) is lower than that in compound **1** (shift to lower field ≥ 2 ppm) the photocyclisation to phenanthrene analogue (dibenzo[*a,c*]carbazole derivatives) does not occur. On the other hand the low electronic density at C-2 and C-3 in compounds **6-10** would account for the photooxygenation of both carbons and the cleavage of the $\text{C}_2\text{-C}_3$ bond to yield the corresponding benzophenone [1].

EXPERIMENTAL

The ^{13}C nmr spectra were obtained at 25.2 MHz on a Varian XL-100-15 nmr spectrometer operating in the FT mode using a 620L-100 computer interfaced to a Sykes 7000 dual disk drive. Samples were spun in 5 mm tubes at ca 27°. Spectra were measured as 0.2-0.4M solutions in DMSO-d_6 , with TMS as internal standard, over a spectral width of 5400 Hz using 45° pulses and a pulse repetition rate of 0.75 s. An 8 K data table was used providing, after Fourier transformation, spectra with a digital resolution of 1.41 Hz per point.

Totally proton decoupled spectra are the results of 10000 pulses, and were obtained by irradiation of the ^1H spectrum at the central frequency of 4.5 ppm, with the irradiation frequency modulated by an external swept square-wave modulator. Single-frequency off-resonance ^1H decoupled spectra are the result of 25000 pulses, and were obtained by irradiating the ^1H spectrum with a CW frequency at ca 0 ppm. Selectively decoupled spectra were obtained as above, but irradiating the desired ^1H resonance with a low-power CW frequency. Lines were artificially broadened by ca 1 Hz by exponential weighting of the FID.

Compounds **1-12** were synthesized as described elsewhere [1]. All com-

pounds gave mp and spectral data [(ir, uv, ^1H nmr) [1] and ms [4]] in accord with their structures. These spectral data have been described elsewhere [1,4].

Acknowledgements.

The author thanks UMYMFOR (CONICET-FCEyN-UBA) and lic. Darío Doller, for generous technical support, and Universidad de Buenos Aires for financial support.

REFERENCES AND NOTES

- [1] C. A. Mudry and A. R. Frasca, *Tetrahedron*, **30**, 2983 (1974).
- [2] R. Erra-Balsells and A. R. Frasca, *An. Asoc. Quim. Argentina*, **75**, 453 (1987).
- [3] E. V. Blackburn and C. J. Timmons, *J. Chem. Soc. (C)*, 172 (1970).
- [4] R. Erra-Balsells, *J. Heterocyclic Chem.*, **25**, 221 (1988).
- [5] W. H. Laarkoven, Th. J. R. M. Cuppen and R. J. F. Nivard, *Rec. Trav. Chim.*, **87**, 687 (1968).
- [6] F. B. Mallory, C. S. Wood and J. T. Gordon, *J. Am. Chem. Soc.*, **86**, 3094 (1964).
- [7] G. W. Gribble, R. B. Nelson, J. L. Johnson and G. C. Levy, *J. Org. Chem.*, **40**, 3720 (1975).
- [8] E. Rosenberg, K. L. Williamson and J. D. Roberts, *Org. Magn. Reson.*, **8**, 117 (1976).
- [9] M. Shamma and D. M. Hindenlang, "Carbon-13 NMR Shift Assignments of Amines and Alkaloids", Plenum Press, New York, 1979.
- [10] R. G. Parker and J. D. Roberts, *J. Org. Chem.*, **35**, 996 (1970).
- [11] C. Carter, K. R. Freter, R. W. Kriwacki, S. F. Leonard and T. P. Pitner, *J. Heterocyclic Chem.*, **24**, 387 (1987).
- [12] G. Burton, A. A. Ghini and E. G. Gros, *Magn. Reson. Chem.*, **24**, 829 (1986).
- [13] M. S. Morales-Ríos, J. Espiñeira and P. Joseph-Nathan, *Magn. Reson. Chem.*, **25**, 377 (1987).
- [14] R. Erra-Balsells and A. R. Frasca, " ^{13}C NMR Studies of Substituted 2- and/or 3-Methylindoles. Nitro and Phenyl Derivatives", unpublished results.
- [15] J. B. Stothers, "Carbon 13 NMR Spectroscopy", Academic Press, New York, 1972.
- [16] E. Breitmeier, G. Hass and W. Voelter, " ^{13}C NMR Data", Heyden, 1979.
- [17] R. J. Sundberg, "The Chemistry of Indoles", Academic Press, 1970.
- [18] A. T. Balaban, A. Dinculescu, J. Elguero and R. Faure, *Magn. Reson. Chem.*, **23**, 553 (1985).
- [19] " ^{13}C Data Bank", Bruker, 1976.
- [20] L. F. Johnson and W. C. Jankowski, "Carbon-13 NMR Spectra", John Wiley and Sons, 1972.
- [21] P. Balakrishnan and D. W. Boykin, *J. Org. Chem.*, **50**, 3661 (1985).