

Naphthopyrones, Part I

Proton Magnetic Resonance Spectral Studies of Some Methylnaphthopyran-2-one and Methylnaphthopyran-4-one Derivatives

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The 220 MHz $^1\text{H-NMR}$ spectra of four methylnaphthopyrone derivatives are presented and discussed. The chemical shift changes which occur upon protonation in trifluoroacetic acid solution are much more significant for the benzochromones than for the benzocoumarins. The particularly large effects at the methyl (0.6 ppm) and at the residual pyrone ring proton (1.2 ppm) provide a useful technique for differentiation between the two series of compounds.

(Keywords: $^1\text{H-NMR}$; Naphthopyrones; Benzocoumarin; Benzochromone; Solvent shifts)

Naphthopyrone, I. Mitt.:

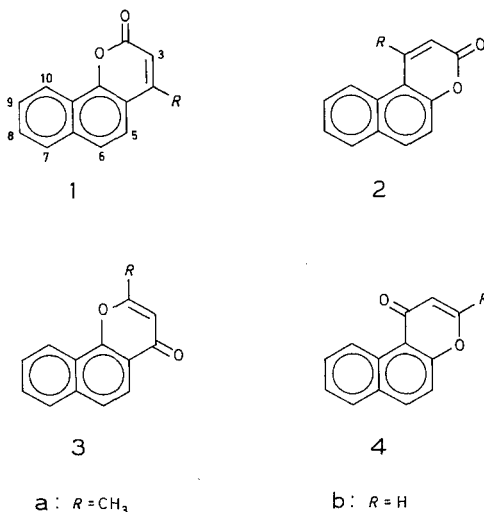
$^1\text{H-NMR}$ einiger Methylnaphthopyran-2-one und Methylnaphthopyran-4-one

Es werden die 220 MHz $^1\text{H-NMR}$ -Spektren von vier Methylnaphthopyronen diskutiert. Die Änderungen der chemischen Verschiebungen, die sich mit Trifluoressigsäure als Lösungsmittel ergeben, sind für die Benzochromone bedeutend signifikanter als für Benzocoumarine. Die besonders großen Effekte für Methyl (0,6 ppm) und das verbleibende Pyronringproton (1,2 ppm) stellen eine brauchbare Methode für die Unterscheidung der beiden Reihen dar.

Introduction

The 60 MHz $^1\text{H-NMR}$ spectra of the methylbenzocoumarin (methylnaphthopyran-2-one) derivatives **1 a** and **2 a** were first reported in 1970 by Jain et al.¹ Their spectral analyses were, however, very incomplete. Although the methyl and pyrone ring proton resonances were definitively identified, the aromatic signals were regarded as multiplets at 7.27–8.43 δ for **1 a** and at 7.40–7.91 for **2 a**. The spectra have also been included in the Sadtler reference collection², wherein

certain additional assignments (H-10 for **1 a**; H-5 and H-10 for **2 a**) were made. However, inspection of the integration² for **2 a** reveals that the low field signals are in the ratio of 5:1 for the *seven* protons, which suggests that the signal for one proton was not detected.



During the course of the identification of the "dimethyldicoumarin" first isolated by *Hantzsch* and *Zürcher*³, the spectra of **1 a** and **2 a** were re-examined at higher magnetic fields⁴. A complete assignment of all proton signals, including that initially missed^{1,2}, was made. In the present paper these spectral analyses have been discussed in greater detail, and the investigation extended to include the appropriate methylbenzochromone (methylnaphthopyran-4-one) derivatives **3 a** and **4 a** for which spectral data are very scarce. The earlier reports appear to be limited to studies of the parent compounds **3 b** and **4 b** examined by *Martin* et al.⁵ during the course of their extensive investigations of the spectra of polycyclic hydrocarbons. The spectrum of **4 a**, one of the products isolated from the *Pechmann* reaction with β -naphthol, has been measured in pyridine-*d*₅ solution by *Rangaswami* and co-workers⁶. The *six* aromatic protons were reported as a multiplet at 7.41–8.12 δ which would appear to be rather suspect since *Martin* et al.⁵ had previously found that the H-10 signal of **4 b** was very strongly deshielded and absorbed at 10.03 in CDCl₃ solution.

The spectral data obtained in the present paper should provide reliable information for the characterisation and identification of naphthopyrone derivatives.

Results and Discussion

The ¹H-NMR spectra of the compounds were measured in CDCl₃ solution at 220 MHz, and at 400 MHz for the more closely coupled **1 a**. The results obtained are given in Tables 1 and 2.

The assignments of the methyl and of the pyrone ring protons (H-2/H-3) were readily performed. The methyl signals of **1 a**, **3 a** and **4 a** all absorbed in the 2.3–2.5 δ region whilst that for **2 a** appeared at 2.88, due to a *peri*-proximity effect. The value of this characteristic deshielding effect for the differentiation between *linear* and *angular* isomers has already been propounded⁴. The H-2/H-3 resonances were all close to 6.3 δ, in accordance with earlier work^{1,2,5,6}, the signals appeared as fine

Table 1. 220 MHz ¹H-NMR chemical shifts in CDCl₃ (δ, ppm)

	1 a ^a	2 a	2 b	3 a	4 a
H-2/H-3	6.36	6.38	6.50	6.38	6.31
H-5	7.56	7.45	7.37	8.18	7.44
H-6	7.67	7.97	7.91	7.78	8.02
H-7	7.85	7.93	7.85	7.96	7.86
H-8	7.64	7.59	7.52	7.75	7.60
H-9	7.62	7.64	7.63	7.70	7.75
H-10	8.53	8.59	8.14	8.52	10.04
CH ₃	2.47	2.88	^b	2.52	2.36

^a At 400 MHz.

^b H-1: 8.39 δ.

Table 2. ¹H-NMR coupling constants in CDCl₃ (Hz)

	1 a	2 a	2 b ^a	3 a	4 a
J_{2-CH_3} or J_{3-CH_3}	1.2	1.2	—	0.7	0.7
J_{56}	8.8	8.8	9.0	8.5	9.1
J_{78}	^b	7.8	7.8	7.0	7.9
J_{79}	^b	1.8	1.6	2.0	1.6
J_{89}	^b	6.8	6.9	^b	7.0
$J_{8,10}$	^b	1.3	1.2	^b	1.3
$J_{9,10}$	^b	8.6	8.3	^b	8.5
$J_{6,10}$	^c	^c	^c	^c	0.7

^a $J_{12} = 9.8$ Hz, J_{15} not resolved.

^b Couplings not analysed.

^c Couplings not resolved.

quartets as a result of allylic coupling to the methyl signals which were correspondingly split into fine doublets. The stronger coupling (1.2 Hz) for **1a** and **2a** was readily discernible, even at 60 MHz², whilst the weaker coupling (0.7 Hz) for **3a** and **4a** required much higher spectral resolution. The respective magnitudes of the allylic couplings were found to correlate well with the appropriate *vicinal ortho* coupling constants^{7,8} *viz*:

$$\frac{J_{23}(\text{chromone})}{J_{34}(\text{coumarin})} = \frac{6.05}{9.58} = 0.63$$

$$\frac{J_{\text{CH}_3,3}(\text{chromone})}{J_{\text{CH}_3,3}(\text{coumarin})} = \frac{0.7}{1.2} = 0.58$$

These characteristic small differences in allylic couplings could prove to be of diagnostic value.

The assignments of the aromatic protons were performed by the same basic technique for each of **1a** to **4a**. Previous workers generally measured their spectra at 60 MHz which resulted in considerable overlap of signals; with the higher magnetic fields used in the present study the peaks were much better resolved. Accordingly the AB system for H-5 and H-6 was readily evident, although in the case of **1a** it was only clearly resolved at 400 MHz. The signals were readily distinguished since in each case the H-6 doublet was broadened, and of consequent lower intensity, due to long range ⁵J “zig-zag” coupling to H-10. Such long range inter-ring interactions occur in many polycyclic aromatic and heteroaromatic systems^{9a}, such as J_{48} in coumarin⁷. The assignment of H-6 was confirmed by irradiation at H-10 which then rendered the AB doublets of similar intensity.

The remaining aromatic protons formed an ABCD system, with the H-10 proton always appearing at lowest field due to characteristic deshielding effects (see later discussion). The other signals appeared as a “doublet”, assigned to H-7, and as two “triplets” due to H-8 and H-9. Differentiation between the latter two resonances was readily achieved through use of a spin decoupling experiment. Irradiation of the well separated H-10 signal collapsed the H-9 signal, whilst at H-8 the fine *meta* coupling was removed to leave a clear doublet of doublets for the two remaining dissimilar *ortho* couplings.

The particular features of interest in the spectra of **1a** to **4a** are discussed below, together with some revisions to certain of the earlier assignments.

The H-10 “bay” proton was considerably deshielded in all of the compounds studied. This low field signal was not detected at all in certain of the earlier measurements^{1,2,6}. In **1a** and **3a** H-10 was

deshielded by a *peri*-effect^{9b} due to the cyclic oxygen atom, the effect was of comparable magnitude for both compounds and similar to that experienced by *Martin* et al.⁵ for **3 b**. In **2 a** the deshielding was similar to that found for H-5 in 4-methylphenanthrene^{10,11}. The deshielding was particularly pronounced in **4 a**, the absorption being below 10 δ . *Martin* et al.⁵ have reported H-10 at 10.03 δ in **4 b**; the bay proton of tetrahydrophenanthrone was also similarly deshielded¹². The additional contribution from the anisotropic effect resulted in the deshielding effect by the carbonyl group in **4 a** being much more significant than that by the methyl group in **2 a**.

The shieldings of H-6, H-7, H-8 and H-9 in **1 a** and **3 a** were generally very similar, since the structural differences present are very distant; a similar situation pertains to H-5, H-6, H-7, H-8 and H-9 in **2 a** and **4 a**. The signal for H-5 in **2 a** and **4 a** was shielded by the *ortho* effect of the cyclic oxygen atom whilst in **1 a** and **3 a** it was deshielded by the *peri* substituent; again the effect caused by the carbonyl function was greater than that by the methyl group as noted previously at H-10.

The ABCD systems in **3 a** and **4 a** have been analysed by a first order treatment which allowed a study of the couplings in the naphthopyrone series (see Table 2). The *ortho* couplings across the 7,8- and 9,10-bonds were larger than that across the 8,9-bond in accordance with the known^{9c} relationship of these interactions to π -bond orders in alternant hydrocarbons. The strongest *ortho* coupling, J_{56} , was of a similar magnitude for each of **1 a-4 a**. The couplings have been found to correlate very well with those reported by *Barille* and *Smith*¹⁰ for phenanthrene derivatives, even to the extent that $J_{9,10} > J_{78}$ and $J_{79} > J_{8,10}$, as shown in Fig. 1. The $J_{6,10}$ long range "zig-zag" coupling^{9a}, although not generally resolved, was nevertheless of particular value to confirm the assignments of H-5 and H-6. The coupling (0.7 Hz) was only discernible at H-10 in **4 a**. Due to the minimal shift separations between H-8 and H-9 in **1 a** and **2 a** (0.02 and 0.05 ppm respectively) their ABCD systems exhibited considerable second order character which have not been thoroughly analysed in the present work.

Following the assignments made in this investigation certain of the earlier spectral analyses are in need of correction. In the initial study of **2 a** by *Jain* et al.¹ the H-10 signal was overlooked, the signal likewise remained undetected on the spectrum obtained by the *Sadtler* Research Laboratories². Although H-10 was correctly considered as the most downfield signal it was then assigned as 7.91 δ , the most deshielded signal observed, clearly this requires alteration. *Rangaswami* and co-workers⁶ have determined the spectrum of **2 a** using pyridine- d_5 as solvent and successfully detected the low field H-10 signal, however, no specific aromatic proton assignments were given. This measurement has

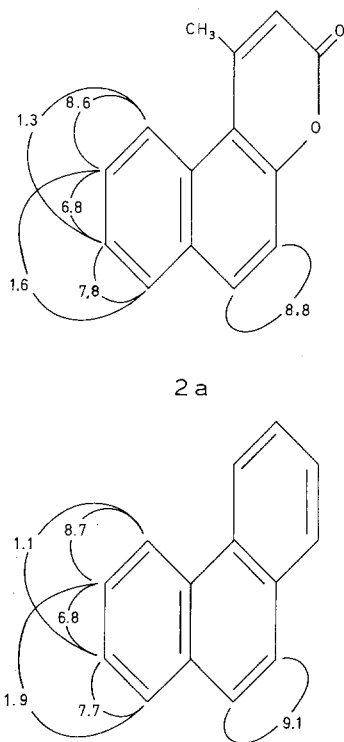


Fig. 1. Comparison of coupling constants (values in Hz) in the naphthopyrone and phenanthrene¹⁰ series

been repeated as part of the present investigation and the results are given in Table 3.

The present study has also been extended to include an examination of the NMR spectrum of **2b**. The results obtained are shown in Tables 1 and 2, these are in general agreement with the earlier studies^{13,14} in which only the pyrone ring proton shifts were assigned. In this compound both the H-1 and H-10 "bay" protons would be expected to be deshielded. The lowest field signal in this case was therefore not H-10, as found with **1a-4a**, but H-1; which appeared as a doublet ($J_{12} = 9.8$ Hz) slightly broadened by a long range "zig-zag" coupling (J_{15}).

Rangaswami and co-workers⁶ also measured the spectrum of **4a** in pyridine-*d*₅ solution, the aromatic multiplet was reported at 7.41–8.12 δ which suggests that the signal for H-10 was overlooked. The spectrum

Table 3. $^1\text{H-NMR}$ spectral studies in pyridine- d_5 ; chemical shift (δ , ppm)

Compound	H-2	H-5	H-6	H-7	H-8	H-9	H-10	CH_3	Ref.
2 a	6.39	←—————		7.35–8.45		—————→		2.65	⁶
	6.49	7.48	8.03	8.01	7.62	7.71	8.62	2.71	—
4 a	6.36	←—————		7.41–8.12		—————→		2.15	⁶
	6.46	7.52	8.14	8.01	7.66	7.81	10.51	2.18	—

Table 4. 220 MHz $^1\text{H-NMR}$ chemical shifts in $\text{CF}_3\text{CO}_2\text{H}$ (δ , ppm)

	1 a	2 a	3 a	4 a
H-2/H-3	6.74	6.76	7.58	7.61
H-5	7.76	7.55	8.32	7.98
H-6	7.90	8.18	8.24	8.67
H-7	7.99	8.06	8.24	8.26
H-8	7.81	7.75	8.12	7.99
H-9	7.75	7.84	8.04	8.09
H-10	8.45	8.73	8.90	9.57
CH_3	2.70	3.07	3.10	2.99

has therefore been re-examined in this study and the results are shown in Table 3. The H-10 signal appeared very far downfield at 10.51 δ . The choice of pyridine- d_5 as solvent for the original measurement⁶ would appear to have been rather unwise since the solvent residual must have contributed to the misleading integral value obtained.

Many condensed pyrone derivatives have only limited solubility in chloroform and hence an alternative solvent may sometimes be necessary. For the measurements upon *Hantzsch* and *Zürchers* "dimethyldicoumarin", trifluoroacetic acid (*TFA*) was found to be most satisfactory⁴. Accordingly, the spectra of **1 a–4 a** have also been measured in this solvent, the results obtained are shown in Tables 4 and 5. The chemical shift changes that occurred upon protonation in *TFA*, designated by Δ , are given in Table 6. For the benzocoumarin derivatives **1 a** and **2 a** the effects were generally quite small, ca. 0.4 ppm at H-2/H-3 and less than 0.25 ppm for the remaining signals. The situation with the benzochromone derivatives **3 a** and **4 a** was, however, very different. Characteristic large downfield shifts occurred at the methyl groups (0.58–0.63 ppm) and also at the pyrone ring protons (1.20–1.30 ppm). A search of the literature revealed that no other studies

Table 5. $^1\text{H-NMR}$ coupling constants in $\text{CF}_3\text{CO}_2\text{H}$ (Hz)

	1 a	2 a	3 a	4 a
$J_{2\text{-CH}_3}$ or $J_{3\text{-CH}_3}$	1.1	1.0	a	a
J_{56}	9.0	9.0	8.8	9.0
J_{78}	b	8.0	8.2	8.0
J_{79}	b	1.5	1.5	1.5
J_{89}	b	7.0	7.0	7.0
$J_{8,10}$	b	1.2	1.5	1.3
$J_{9,10}$	b	8.5	8.2	8.5
$J_{6,10}$	a	a	0.8	a

^a Couplings not resolved.

^b Couplings not analysed.

Table 6. Chemical shift changes on protonation; Δ (ppm) = $\delta_{\text{CF}_3\text{CO}_2\text{H}} - \delta_{\text{CDCl}_3}$

	Benzocoumarins		Benzochromones	
	1 a	2 a	3 a	4 a
H-2/H-3	0.38	0.38	1.20	1.30
H-5	0.20	0.10	0.14	0.54
H-6	0.23	0.21	0.46	0.65
H-7	0.14	0.13	0.28	0.40
H-8	0.17	0.16	0.37	0.39
H-9	0.13	0.20	0.34	0.34
H-10	-0.08	0.14	0.38	-0.47
CH_3	0.23	0.19	0.58	0.63

of the chromone system in *TFA* appear to have been undertaken, but it did uncover the work of *Brown* and *Bladon*¹⁵ upon solvent effects in the 4-pyrone series. Their results for the 2,6-dimethyl derivative (CH_3 : $\Delta = 1.06$ ppm, H-3/H-5: $\Delta = 0.46$ ppm) are in good agreement with the present investigation which suggests that such shifts would appear to be quite general.

The chemical shift changes on protonation at the other positions in **3 a** and **4 a** may now be considered. The shifts at H-6, H-7, H-8 and H-9 were all quite similar, in the range 0.28–0.65 ppm, with the effect at H-6 being the largest in each case. Protons *ortho* or *peri* to the ring oxygen (H-10 in **3 a**, H-5 in **4 a**) showed similar shifts to the other ring protons whilst the protons *ortho* or *peri* to a carbonyl group exhibited either smaller downfield shifts (H-5 in **3 a**) or upfield shifts (H-10 in **4 a**).

The above characteristic solvent effects observed in the benzochromone series therefore serves as a convenient means of differentiation from the benzocoumarin series by means of ¹H-NMR spectroscopy. It is suggested that the effects at the H-2/H-3 ring proton and at the methyl group would be of most use, these being large enough to be of diagnostic value even if low field instrumentation only is available.

The coupling constants for both series showed only minor variations in *TFA* solution (see Table 5), the most significant effect being an increase in the value of J_{56} to ca. 9 Hz.

Much of the previous work on the naphthopyrone series has involved very incomplete spectral analyses; aromatic resonances which occurred over an extended region being regarded as multiplets. If such partial analyses from low field spectra are to be of value for structural identification, then it is essential that a low field sweep and an accurate integration, with reliable proton ratios to any well separated signals, be obtained. If these procedures are carefully performed then no signals should remain undetected.

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Experimental

¹H-NMR spectra were recorded at 220 MHz (Perkin-Elmer R34 at P.C.M.U., Harwell) and at 400 MHz (Bruker WH-400 at University of Sheffield). Chemical shifts are reported as ppm (δ) downfield from internal *TMS* standard. Samples were recorded as dilute solutions in $CDCl_3$ or in *TFA* as indicated in the Tables.

4-Methyl-2*H*-naphtho[1,2-*b*]pyran-2-one (**1a**) was synthesised by the procedure of *Robertson et al.*¹⁶, m.p. 170–171°, lit.¹⁶ m.p. 170°.

1-Methyl-3*H*-naphtho[2,1-*b*]pyran-3-one (**2a**) was synthesised by the procedure of *Murty et al.*¹⁷, m.p. 181–182°, lit.¹⁷ m.p. 183°.

2-Methyl-4*H*-naphtho[1,2-*b*]pyran-4-one (**3a**) was synthesised by the procedure of *Van Allan et al.*¹⁸, m.p. 178–179°, lit.¹⁸ m.p. 181°.

3-Methyl-1*H*-naphtho[2,1-*b*]pyran-1-one (**4a**) was synthesised by the procedure of *Dey and Lakshminarayanan*¹⁹, m.p. 168–169°, lit.¹⁹ m.p. 168°.

3*H*-naphtho[2,1-*b*]pyran-3-one (**2b**) was synthesised by the general procedure of *Dey et al.*²⁰ except that potassium acetate was used in place of sodium acetate and the reaction conducted by boiling under reflux for 3 h, m.p. 118–119°, lit.²⁰ m.p. 118°.

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