

STUDY OF 5-NO₂-2-FURALDEHYDE DERIVATIVES, I. U. V., I. R. AND ¹H NMR SPECTRAL INVESTIGATIONS OF SCHIFF BASE COMPOUNDS

By

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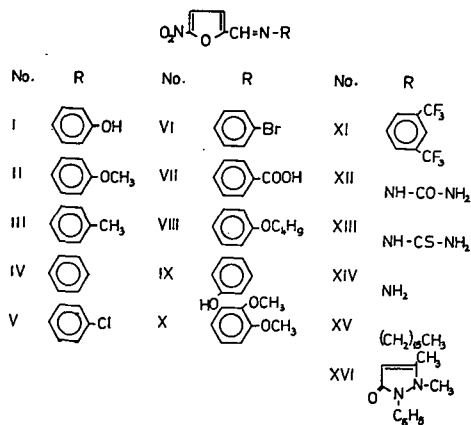
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Schiff base derivatives of 5-NO₂-2-furaldehyde were prepared and their u.v., i.r. and ¹H NMR spectra were examined.

Several investigations have been reported on the bacteriological properties of certain furan compounds [1—3]. DODD and STILLMAN [4] stated that the presence of a NO₂ group in position 5 of the furan ring conferred appreciable bacteriostatic action. Thus, the 5-NO₂-furan derivatives generally exhibited considerable antibacterial activity, primarily *in vitro* against gram-negative and gram-positive organisms. Some compounds of this type, e.g. Nitrofurazol, Nitrofurantoin and Furazolidon, are applied therapeutically in the treatment of bacterial infections of the urinary tract. TANAKA and USUI [5—8] described in several papers the preparation and antibacterial activity of 2-derivatives of 5-NO₂-furan, while MASSARINI et al. [9, 10], SZARVAS [11] and SPENCER et al. [12] investigated a number of Schiff base derivatives of 5-NO₂-2-furaldehyde (NFA).

As a continuation of our previous investigations on the spectral behaviour of aromatic Schiff bases [13], we have prepared and studied several Schiff base derivatives of NFA; in this paper we report on the spectral behaviour of the following Schiff bases.



Experimental

The Schiff bases were prepared by the following general procedure. A methanolic solution of 0.01 mol NFA was treated with an alcoholic solution of 0.01 mol of the appropriate amine. The mixtures were acidified with 0.001 mol cc. H_2SO_4 . The crystalline products separated immediately or after removal of half of the solvent. The products were recrystallized from an ethanol/benzene mixture. The compositions were checked *via* the m.p.s and C and H analysis; these data are given in Table I.

The u.v. spectra were measured on a SPECORD UV—VIS spectrophotometer, in spectroscopically pure solvents at room temperature; the records were begun 2.5 min after dissolution. The 1H NMR spectra were obtained in $CDCl_3$ -DMSO- d_6 solution with a JEOL 60 MHz spectrometer, and the chemical shifts in ppm were determined using TMS as internal standard. The i.r. spectra were taken on a ZEISS UR—10 spectrophotometer, in KBr discs.

The disappearance of Schiff bases was followed spectrophotometrically at 298 K in unbuffered 50% aqueous methanol solution. All kinetic runs were carried out in the time interval between $t=0$ and $t=360$ min. The preliminary rate constants were calculated by the GUGGENHEIM method.

Table I
Analytical data on Schiff bases

| No. | M. p. | C% | | H% | |
|------|--------|--------|-------|--------|-------|
| | | Calcd. | Found | Calcd. | Found |
| I | 181—4 | 56.85 | 56.78 | 3.47 | 3.39 |
| II | 124—6 | 58.48 | 58.45 | 4.01 | 5.01 |
| III | 130—3 | 62.54 | 62.44 | 4.38 | 4.31 |
| IV | 125—8 | 61.34 | 61.24 | 3.28 | 3.16 |
| V | 155—8 | 52.67 | 52.63 | 2.82 | 2.75 |
| VI | 156—7 | 44.73 | 44.70 | 2.39 | 2.34 |
| VII | 145* | 55.39 | 55.28 | 3.10 | 3.12 |
| VIII | 137—40 | 62.49 | 62.41 | 5.59 | 5.47 |
| IX | 145* | 56.85 | 56.74 | 3.47 | 3.52 |
| X | 126—8 | 56.52 | 56.48 | 4.38 | 4.35 |
| XI | 104—6 | 44.34 | 44.28 | 1.72 | 1.70 |
| XII | 239—42 | 36.34 | 36.19 | 3.05 | 3.11 |
| XIII | 250* | 33.61 | 33.54 | 2.82 | 2.75 |
| XIV | 251—2 | 38.68 | 38.61 | 3.25 | 3.21 |
| XV | 170—1 | 69.20 | 69.17 | 9.96 | 9.90 |
| XVI | 265—9 | 58.84 | 58.80 | 4.32 | 4.27 |

* decomposed

Results and discussion

U.v. spectra. The spectral data on the Schiff bases in methanol and benzene are presented in Table II; several spectra are shown in Fig. 1.

The NO_2 group exhibits two bands in the u.v. range, at 210 ($\epsilon=15\ 850$) and 270 nm ($\epsilon=20$); both bands are assigned as $\pi^* \leftarrow \pi$ bands [14]. The characteristic

Table II
U.v. spectral data on the Schiff bases studied

| No. | Solvent | Band maxima (nm and ϵ) | | |
|-------|-------------------------------|----------------------------------|-------------|--------------|
| NFA | MeOH | 225 (3 800) | 308(11 220) | |
| | C ₆ H ₆ | | 303 (9 770) | |
| I | MeOH | 222(15 490) | 294(15 130) | 397(22 900) |
| | C ₆ H ₆ | | 294(10 000) | 396(16 600) |
| II | MeOH | 222(14 800) | 290(15 130) | 390(20 900) |
| | C ₆ H ₆ | | 296(15 130) | 400 (25120) |
| III | MeOH | 213(17 780) | 284(15 130) | 360(23 990) |
| | C ₆ H ₆ | | 287(12 880) | 380(20 890) |
| IV | MeOH | | 279(12 020) | 357(19 050) |
| | C ₆ H ₆ | | 283(10 000) | 364(15 850) |
| V | MeOH | 232(14 800) | 282(14 450) | 360(23 990) |
| | C ₆ H ₆ | | 287(10 230) | 371(16 600) |
| VI | MeOH | 232(11 480) | 283(11 480) | 361(18 620) |
| | C ₆ H ₆ | | 284(11 220) | 370 (18 200) |
| VII* | MeOH | 219 (9 550) | 289(17 380) | |
| VIII | MeOH | 223(14 450) | 294(14 790) | 394(21 880) |
| | C ₆ H ₆ | | 298(14 120) | 402(23 440) |
| IX | MeOH | 217(19 050) | 300(15 850) | 394(17 780) |
| | C ₆ H ₆ | | 304(11 480) | 404(19 050) |
| X* | MeOH | 207(19 950) | 300(14 790) | 402(15 850) |
| XI | MeOH | 233(17 380) | ~280 | 340(25 120) |
| | C ₆ H ₆ | | | 346(19 050) |
| XII* | MeOH | ~238 | 264(14 450) | 364(22 910) |
| XIII* | MeOH | 240 (7 940) | 288(11 480) | 382(19 500) |
| XIV | MeOH | 233 (4 470) | | 373(16 600) |
| | C ₆ H ₆ | | 282 (6 920) | 373(26 300) |
| XV | MeOH | 225(13 490) | 324(15 850) | |
| | C ₆ H ₆ | | 239(16 980) | |
| XVI | MeOH | 234(12 590) | 291(13 180) | 404(18 620) |
| | C ₆ H ₆ | | 294(14 790) | 408(18 200) |

* practically insoluble in benzene

bands of furan, 2-furaldehyde and NFA are found at 250 nm ($\epsilon=6400$), at 230 and 275 nm ($\epsilon=3500$ and 13 750) and at 225 and 310 nm ($\epsilon=8250$ and 11 600) [15, 16], respectively. The longwave band of NFA, which is a superposition of the absorption of furaldehyde and that of the nitro group, shows a bathochromic shift of ca. 30 nm, and the intensity of this band is decreased, relative to the situation for 2-furaldehyde.

Both Fig. 1 and Table II show that the u.v. spectra of the Schiff bases studied are very similar to one another. In general, three well-defined bands can be found, at 210–240, 280–310 and 350–400 nm, respectively; these bands can be assigned in all

likelihood to $\pi^* \leftarrow \pi$ transitions. The structure of the spectra and the band positions show no appreciable differences in polar and in apolar solvents. It is interesting that for the 4-X-aniline derivatives the energy of the second band is the highest (279 nm) for the compound with $X=H$, while for the other derivatives — independently of the electron-repelling or — attracting effect of X — this band is shifted towards lower energy; a plot of λ_{\max} vs. σ_p gives a minimum curve (Fig. 2). The interpretation of this result is difficult at present.

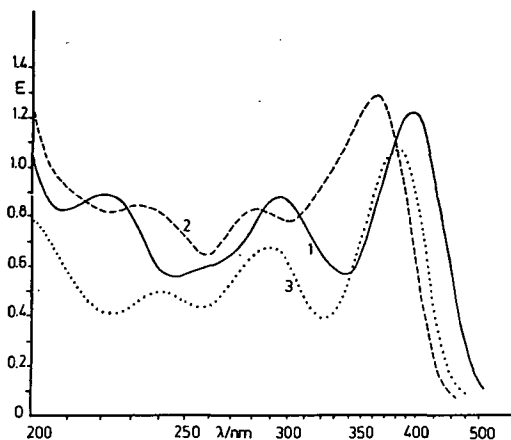


Fig. 1. U.v. spectra of I (curve 1), V (2) and XIII (3) in methanol. $c = 5 \cdot 10^{-4}$ mol dm $^{-3}$; $d = 0.1$ cm

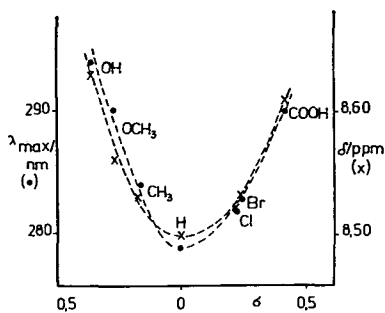


Fig. 2. Plots of λ_{\max} and δ/ppm vs. σ_p for the 4-X-aniline derivatives

The u.v. spectra seem relatively simple. However, if we take into account that these Schiff bases include three, or perhaps four chromophores, the unambiguous assignment of the bands is at least problematic. It can be unquestionably established that the spectra of the Schiff bases do not consist only of the absorption of aldehyde and amine moieties; in the range 360—400 nm a new high-intensity band appears due (probably) to the azomethine group formed and to the increased conjugated system, too.

All the spectra show considerable change with time, in particular in the presence of water; a set of curves is given in Fig. 3. Five isosbestic points can be seen, at ca. 206, 226, 246, 295 and 320 nm, which indicates that there is no accumulation of intermediates. Our preliminary investigations suggest that first-order or pseudo-first-order kinetics can be proposed on the basis of the initial rates. There is a linear relationship between $t_{1/2}$ and the σ_p value of X ; the reaction rate is higher for electron-donating substituents and it seems that the basicity of the parent amine also plays an important role.

It may be suggested that the transformation takes place *via* the carbinolamine intermediate, the decomposition of which results in aldehyde and the corresponding amine. The limiting curve is identical with the calculated one, as can be seen in Fig. 4. We have observed that the solvolysis rate in non-aqueous solvent is at least 100—500 times lower than in water-containing solvent, so the influence of methanolysis can be

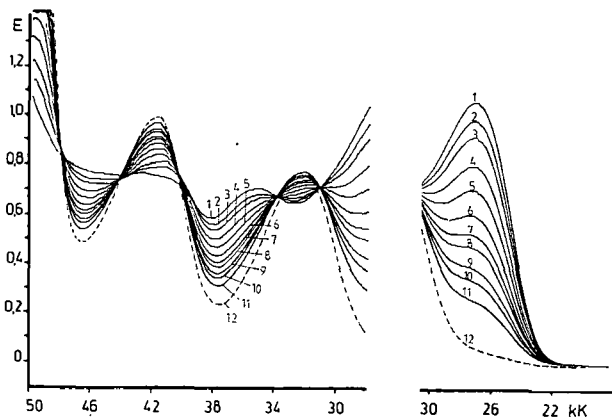


Fig. 3. Spectral change of CH₃OH/H₂O 1:1 solution of V with time at 298 K. $c = 6.4 \cdot 10^{-4}$ mol dm⁻³; $d = 0.1$ cm. Times from above downwards: 0, 10, 20, 40, 60, 90, 120, 150, 210, 270 and 390 min and 24 hours

neglected in our systems [see also *e.g.* 17]. The interpretation of the mechanism requires still further detailed experiments.

I. r. spectra. The main frequencies and the assignments are presented in Table III. The very intense C=N stretching can be found at 1570–1630 cm⁻¹. The <1600 cm⁻¹ values for X, XII, XIII and XVI are noteworthy; these are interpreted by the completely different structures of the molecular moieties bound to the azomethine nitrogen. The ν_{as} NO₂ and ν_s NO₂ frequencies appear with very high intensities at around 1500–1540 and 1340–1360 cm⁻¹, respectively. For the 4-X-aniline derivatives the above two frequencies lie closer to each other; the wave-number differences are approximately linearly correlated with σ_p . In spite of the fact that the

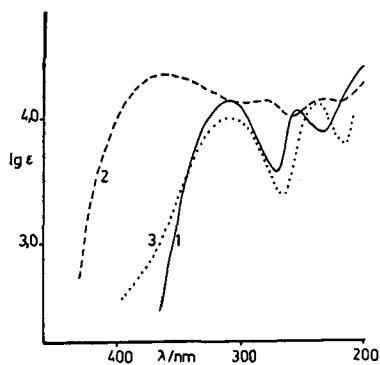


Fig. 4. Spectra of V. 1: calculated curve; 2: curve measured in methanol; 3: curve measured in methanol/water mixture after 24 hours.

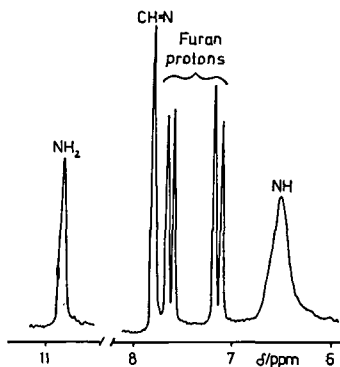


Fig. 5. A part of the ¹H NMR spectrum of XII

4-X-phenyl ring is far from the NO_2 group, it still seems that it forms a unified electron system; due to the effect of X , the O-N-O angle decreases gradually with increasing σ_p .

The different skeletal vibrations of the furan ring can be found among the other frequencies in the ranges 1300—1500 and 1000—1070 cm^{-1} .

Table III
Main i.r. frequencies for the Schiff bases

| No. | $\nu_{\text{C=N}}$ | $\nu_{\text{as NO}_2}$ | $\nu_{\text{s NO}_2}$ | $\nu_{\text{C-N}}$ | $\gamma=\text{CH}$ | |
|------|--------------------|------------------------|-----------------------|--------------------|--------------------|--------|
| I | 1621 m | 1506 s | 1350 s | 1170 s | 817 s | 1015 m |
| II | 1614 m | 1505 s | 1352 s | 1180 m | 805 m | 1010 m |
| III | 1621 m | 1504 s | 1357 s | 1179 m | 817 m | 1026 m |
| IV | 1617 s | 1499 s | 1359 s | 1181 m | 735 m | 1021 m |
| V | 1614 m | 1490 s | 1357 s | 1180 s | 810 m | 1021 m |
| VI | 1614 m | 1487 s | 1359 s | 1177 s | 810 m | 1022 m |
| VII | 1618 s | 1508 s | 1353 s | 1178 m | 855 m | 1020 m |
| VIII | 1617 s | 1507 s | 1358 s | 1177 m | 820 m | 1017 m |
| IX | 1624 m | 1527 s | 1355 s | 1150 m | 760 m | 1020 m |
| X | 1585 m | 1510 s | 1347 s | 1130 m | 846* m | 1020 m |
| XI | 1621 m | 1511 s | 1355 s | 1178 s | 827 m | 1020 m |
| XII | 1577 m | 1508 s | 1347 s | 1195 s | | 1016 m |
| XIII | 1595 s | 1534 s | 1355 s | 1186 m | | 1027 m |
| XIV | 1634 m | 1534 s | 1350 s | 1167 m | | 1027 m |
| XV | 1612 s | 1510 s | 1350 s | 1167 m | 820 m | 1020 m |
| XVI | 1575 m | 1500 s | 1390 s | 1183 m | | 1016 m |

* complex band; s: strong; m: medium-intensity band

Table IV
 $^1\text{H NMR data}^*$ (δ/ppm) on the Schiff bases**

| No. | δOH | δNH_2 | $\delta\text{CH=N}$ | δNH | δOCH_3 | δCH_3 | δCH_2 | |
|------|-------------------|---------------------|---------------------|-------------------|----------------------|---------------------|---------------------|------|
| I | 14.56 | | 8.63 | | 3.83 | 2.38 | | |
| II | | | 8.56 | | | | | |
| III | | | 8.53 | | | | | |
| IV | | | 8.50 | | | | | |
| V | | | 8.53 | | | | | |
| VI | | | 8.51 | | | | | |
| VII | | | 8.61 | | | | | |
| VIII | | | 8.36 | | | | 3.92 | 0.98 |
| IX | ? | | 8.83 | | 3.79 | | 1.66 | |
| X | | | 8.41 | | | | | |
| XI | | | 8.41 | | | | | |
| XII | | | 10.89 | 7.84 | | 6.56 | | |
| XIII | | | 11.92 | 8.06 | | 7.92 | | |
| XIV | | ? | 8.79 | | | | | |
| XV | | | 8.20 | | | 3.61 | 1.25 | |

* in $\text{CDCl}_3 + \text{DMSO}$ 1:1 mixture

** XVI is practically insoluble in the solvent used

¹H NMR spectra. The main resonance frequencies of the Schiff bases are reported in Table IV. It seems that the different proton signals are generally well distinguishable, except for XVI, where then ppm values are uncertain because of the low solubility. In the spectra of I—VI, IX, X and XVI a very complicated band system can be found between 6 and 7.5 ppm, which is the superposition of the proton signals of the furan and those of the substituted phenyl ring. The characteristic two doublets of the furan protons in the spectra of XII—XIV (see e.g. Fig. 5) appear at 7.10—7.30 and 7.40—7.70 ppm. The ring proton signals shift systematically toward higher ppm values in the sequence XII—XIII—XIV, while at the same time the distance between the doublets decreases. The positions of the azomethine proton signals depend on the character of the substituent X in I—VI; the plot of $\delta_{\text{CH}} = N$ vs. σ_p is totally analogous to the λ_{max} vs. σ_p relationship (Fig. 2).

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ИССЛЕДОВАНИЕ ПРОИЗВОДНЫХ 5-NO₂-2-ФУРАЛЬДЕГИДА, I. УФ—ИК— И ¹Н ЯМР-СПЕКТРОСКОПИЧЕСКОЕ ИЗУЧЕНИЕ СОЕДИНЕНИЙ ТИПА ОСНОВАНИЙ ШИФА

Й. Часар

Синтезированы основания Шифа производные 5-NO₂-2-фуральдегида и изучены их ультрафиолетовые, инфракрасные и протонно ядерно-магнитно резонансные спектры.