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Original scientific paper

¹³C- and ¹H-NMR substituent-induced chemical shifts in *N*(1)-(4-substituted phenyl)-3-cyano-4,6-dimethyl-2-pyridones

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Abstract: The ¹³C- and ¹H-NMR chemical shifts of thirteen *N*(1)-(4-substituted phenyl)-3-cyano-4,6-dimethyl-2-pyridones were measured in deuterated dimethyl sulfoxide (DMSO-*d*₆). The correlation analysis for the substituent-induced chemical shifts (*SCS*) with σ_p , inductive (σ_I) and different scale of resonance (σ_R) parameters were performed using the *SSP* (single substituent parameter), *DSP* (dual substituent parameter) and *DSP*-NLR (dual substituent parameter–non-linear resonance) methods. The results of the calculations concerning the polar and resonance effects satisfactorily describe the substituent effects at the carbon atoms of interest. The mode of transmission of the substituent effects, both inductive and resonance, in relation to the geometry of the investigated pyridones is discussed.

Keywords: ¹³C-NMR substituent chemical shifts; linear free energy relationships; *N*(1)-(4-substituted phenyl)-3-cyano-4,6-dimethyl-2-pyridones.

INTRODUCTION

N(1)-(4-Substituted phenyl)-3-cyano-4,6-dimethyl-2-pyridones are not only important intermediates in the synthesis of dyes, pigments, fuels and oil additives, but also in the development of medicinal products having a broad spectrum of biological activities depending on the derivative. It is worth mentioning their analgesic and antihypertensive, anti-anaphylactic, diuretic and sodiodiuretic, anti-oxidant, antiviral and antimicrobial properties.¹ Biologically degradable agrochemical products, plant growth regulators, pesticides, and herbicides are also synthesized from pyridone derivatives.^{2–4}

Chemical shifts in ¹³C- and ¹H-NMR spectra are frequently used for the study of the transmission of electronic effects of substituents in organic molecu-

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les. Analysis of the ^{13}C - and ^1H -NMR substituent chemical shifts (*SCS*) is based on the principles of linear free energy relationships (LFER) using the Equation for single substituent parameter (*SSP*) or dual substituent parameter (*DSP*) in the forms:

$$SCS = \rho\sigma + h \quad (1)$$

$$SCS = \rho_I\sigma_I + \rho_R\sigma_R + h \quad (2)$$

where ρ is a proportionality constant reflecting the sensitivity of the ^{13}C - and ^1H -NMR chemical shifts to substituent effects, σ is the corresponding substituent constant and h is the intercept.

Eq. (1) attributes the observed substituent effects to an additive blend of polar and π -delocalization effects, given as the corresponding σ_p values. In the *DSP*, Eq. (2), the *SCS* are correlated by a linear combination of the inductive (σ_I) and various resonance scales (σ_R° , σ_R , σ_R^+ and σ_R^-), depending on the electronic demand of the atom under examination. The calculated values ρ_I and ρ_R are relative measures of the transmission of inductive and resonance effects, respectively, through the investigated system.

Dual substituent parameter–non-linear resonance (*DSP*–*NLR*) analysis⁵ is a successful method in the modeling of long-range substituent effects to the ^{13}C -NMR substituent chemical shifts (in substituted aromatic systems^{5–7}), which shows deviations from Hammett-type correlations. The requirement for different σ_R scales can be better accommodated by the use of the (*DSP*–*NLR*) method developed by Bromilow *et al.*,⁵ which allows the resonance scale to vary with the electron demand of the site. This was achieved by the use of the parameter ε , characteristic of the group attached to the site, and Eq. (3):

$$SCS = \rho_I\sigma_I + \rho_R\sigma_R^\circ/(1 - \varepsilon\sigma_R^\circ) + h \quad (3)$$

This gave the best correlation of *para*-*SCS* in *p*-disubstituted benzenes,⁵ as well as in eight β -substituted styrenes,⁶ 3-phenyl and 3-thienyl-2-cyanoacrylamides⁷ and *N*-1-*p*-substituted phenyl-5-methyl-4-carboxy uracils.⁸

In this study, linear free energy relationships (LFER) were applied to the ^{13}C - and ^1H -NMR chemical shifts in *N*(1)-(4-substituted phenyl)-3-cyano-4,6-dimethyl-2-pyridones, with the aim of obtaining insight into the factors determining the chemical shifts in the investigated compounds. The transmission of polar and resonance electronic effects in the investigated compounds (Fig. 1), from the substituent (*X*) in the phenyl group to the carbon atoms of the pyridone and phenyl ring, as well as to the 5-H hydrogen, were studied using Eqs. (1), (2) and (3).

EXPERIMENTAL

All the *N*(1)-(4-substituted phenyl)-3-cyano-4,6-dimethyl-2-pyridone derivatives were synthesized as described in the literature.⁹

The structures of the studied compounds were determined using UV, IR, ^{13}C - and ^1H -NMR and MS data. The IR spectra were recorded on a Bomem MB 100 FTIR spectrophotometer in

the form of KBr pellets.⁹ The ¹³C- and ¹H-NMR spectral measurements were performed on a Bruker AC 250 spectrometer at 200 MHz. The spectra were recorded at room temperature in deuterated dimethyl sulfoxide (DMSO-*d*₆). The chemical shifts are expressed in ppm, referenced to the residual solvent signal at 39.5 ppm. The chemical shifts were assigned by the complementary use of DEPT, two-dimensional ¹H-¹³C correlation HETCOR and by selective INEPT long-range experiments. All mass spectra were recorded on a Thermo Finnigan Polaris Q ion trap mass spectrometer, including a TraceGC 2000 (ThermoFinnigan Corp., Austin, TX, USA) integrated GC-MS/MS system.

Geometry optimization

The reported conformation of the molecular forms were obtained by the semi-empirical MO PM6 method,^{10a,b} with implicit DMSO solvation (COSMO) (Keywords: EF, GNORM = 0.01, EPS = 48) using the MOPAC 2007 program package. A VEGA ZZ 2.2.0 was used as the graphical user interface (GUI).¹¹

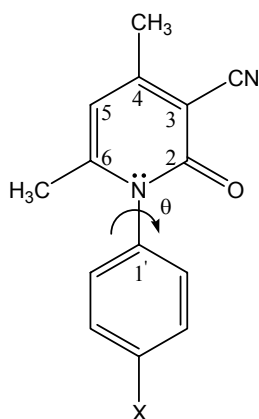


Fig. 1. General formula of the *N*(1)-(4-substituted phenyl)-3-cyano-4,6-dimethyl-2-pyridones, where (X) is H, NMe₂, OH, OMe, Me, Et, F, Cl, Br, I, NO₂, COCH₃ and COOH.

RESULTS AND DISCUSSION

The chemical shifts of the corresponding pyridone ring carbon atoms and the hydrogen at 5-position of the pyridone ring, as well as the *para*-carbon in the phenyl ring (C(1'-Ph)) for investigated compounds are given in Table I in terms of the substituent chemical shifts (*SCS*) relative to the parent compound.

The values of the *SCS* in Table I indicate that the substituent at the phenyl ring has a relatively small influence on the electron density at all the pyridone ring carbon atoms but is considerable for the C(1'-Ph) carbon of the phenyl ring. The chemical shifts of the C(4-Pyr), having small differences in the chemical shifts, are of no statistical values for analysis.

The aromatic ring electron-donor substituents cause a decrease of the electron density at the C(6-Pyr) carbon atom (downfield shift, including the F substituent), indicating that a reverse substituent effect operates at the C(6-Pyr) carbon. The opposite is true for electron-acceptor substituents. Electron-donor substituents increase the electron density at the other carbon atoms and H(5-Pyr) (upfield shifts), including halogens for C(5-Pyr) and C(1'-Ph) carbons. From the

comparison of the *SCS* values for the pyridone carbon atoms, it could be concluded that the C(5-Pyr) and C(3-Pyr) atoms are better shielded than the others, which probably could be attributed to their position in the conjugated system of the pyridone ring. According to the data in Table I, it could be proposed that the geometry of the investigated pyridones plays an important role, probably arising from the out-of-plane rotation of the phenyl rings for a certain torsion angle θ (Fig. 1). Thus, a definite molecular geometry is created, which is a consequence of the transmission modes of the substituent electronic effects (n,π - or π,π -conjugation).^{12,13} An aromaticity study by the NMR technique indicated that 2-pyridones have approx. 35 % of the aromatic character of benzene,¹⁴ as defined by the ability to sustain an induced ring current. This fact also indicates to the possibility of a definite non-planarity of the 2-pyridone moiety.

TABLE I. *SCS* values of H(5-Pyr), C(1'-Ph) and pyridone carbon atoms of *N*(1)-(4-substituted phenyl)-3-cyano-4,6-dimethyl-2-pyridones in DMSO-*d*₆^a

X	H(5-Pyr)	C(2-Pyr)	C(6-Pyr)	C(3-Pyr)	C(5-Pyr)	C(1'-Ph)
H ^b	6.459	159.845	152.434	109.085	100.164	137.614
NMe ₂	-0.051	-0.41	1.852	-0.195	-0.214	-9.351
OH	-0.05	-0.31	0.747	-0.164	-0.164	-9.012
OMe	-0.018	-0.137	0.628	-0.068	-0.105	-7.494
Me	-0.011	-0.082	0.246	-0.031	-0.164	-2.577
Et	-0.011	-0.082	0.246	-0.031	-0.068	-2.395
F	0.003	0.155	0.191	0.115	-0.032	-3.834
Cl	0.008	0.182	-0.217	0.109	-0.022	-1.183
Br	0.006	0.182	-0.218	0.109	-0.020	-0.728
I	0.002	0.191	-0.227	0.133	-0.014	-0.247
NO ₂	0.058	0.646	-0.701	0.424	0.150	5.616
COCH ₃	0.042	0.355	-0.428	0.224	0.106	3.959
COOH	0.022	0.327	-0.455	0.237	0.091	3.769

^a¹³C-Chemical shifts (in ppm) expressed relative to the unsubstituted compound; ^bchemical shifts of the unsubstituted compound relative to TMS (1H) and residual solvent signal at 39.5 ppm (¹³C)

To explain this observation, LFER analysis was applied using the *SSP* equation (Eq. (1)) and σ_p values from literature.¹⁵ The obtained results are given in Table II.

TABLE II. Correlations of the *SCS* values for the investigated compounds with the *SSP* equation

<i>SCS</i> type	ρ	h	r^a	s^b	F^c	n^d
<i>SCS</i> _{H(5-Pyr)}	0.070 (± 0.006)	-0.004 (± 0.002)	0.959	0.009	127	13
<i>SCS</i> _{C(2-Pyr)}	0.671 (± 0.040)	0.045 (± 0.016)	0.981	0.059	278	13
<i>SCS</i> _{C(6-Pyr)}	-1.53 (± 0.132)	0.203 (± 0.054)	0.961	0.193	133	13
<i>SCS</i> _{C(3-Pyr)}	0.395 (± 0.032)	0.047 (± 0.013)	0.966	0.046	155	13
<i>SCS</i> _{C(5-Pyr)}	0.247 (± 0.024)	-0.047 (± 0.010)	0.950	0.036	102	13
<i>SCS</i> _{C(1'-Ph)}	10.57 (± 1.243)	-2.33 (± 0.506)	0.932	1.810	72	13

^aCorrelation coefficient; ^bstandard error of estimate; ^cF-test for the significance of the regression; ^dnumber of points

Based on the sign of the constants ρ in correlations from Table II, it can be concluded that the effect of substituents on the phenyl ring have the same direction at all the carbon atoms, with the exception of C(6-Pyr), where it was the opposite. Much better results of the correlation coefficients (r), standard deviation (s) and F for H(5-Pyr) atom were obtained if the hydroxy group was assigned the σ_p^+ value, while the almost unchanged value of ρ is 0.062 ($r = 0.978$; $s = 0.006$; $F = 243$; $n = 6$). Separate correlations were performed for the C(3-Pyr) carbon: $\rho = 0.239$ ($r = 0.997$; $s = 0.006$; $F = 713$; $n = 5$) for the electron-donors (OH excluded) and $\rho = 0.517$ ($r = 0.984$; $s = 0.026$; $F = 155$; $n = 7$) for the electron-acceptors (F excluded). Electron-acceptor substituents exert larger electronic effects at the C(3-Pyr) carbon due to the opposing electron accepting effect of the cyano group and for these substituents, the value of ρ is significantly higher. The correlation for the C(6-Pyr) carbon is also significantly improved if σ_p^+ values are assigned to N(Me)₂, OH, OCH₃ and F ($\rho = -0.981$; $r = 0.990$; $s = 0.101$; $F = 509$; $n = 13$), thus showing that electron-donor substituents achieved better resonance interactions with this carbon. The substituent showed the highest influence at the C(1'-Ph) carbon but the correlation coefficients were only moderate. Two separate correlations, first for NMe₂, Me, Et, H, COOH and COCH₃, the gave the results: $\rho = 10.130$; $r = 0.997$; $s = 0.434$; $F = 646$; $n = 6$ and second for OH, OCH₃, F, Cl, Br and NO₂, which gave: $\rho = 12.860$; $r = 0.990$; $s = 0.745$; $F = 256$; $n = 7$, show well the complex influence of substituents and the pyridone ring on the chemical shifts of this carbon.

Although the *SSP* analysis uses an additive blend of inductive and resonance parameters of substituents given as σ_p values, it presented a satisfactory description of the transmission of substituent effects through the investigated systems.

To measure the separate contributions of the inductive and resonance effects of a substituent (X), regression analyses according to the *DSP* equation (Eq. (2)) with σ_R° , σ_R , σ_R^+ substituent constants^{16,17} were carried out, and results of the best fit are given in Table III.

The results of the correlation analysis from Table III indicate that the *SCS* values of the C(6-Pyr) carbon correlate better with the σ_R^+ and the *SCS* values of H(5-Pyr) with the σ_R substituent constants, while for the other carbon atoms acceptable results were obtained with the σ_R° values. The better correlation of the *SCS* values for the C(6-Pyr) with the σ_R^+ values indicates a somewhat higher contribution of extended resonance interaction for this carbon. Reversely, the better correlations of the *SCS* of the other carbons with the σ_R° values indicate a definite attenuation effect of the transmission of electronic substituent effects to these carbons. The ρ_I values in Table III show the dependence of the inductive effects on the molecular geometry of the investigated compounds. The ρ_R values depend on the σ scale used, which proves that the demand of the carbon atoms of investigated compounds for electrons is significantly different.

TABLE III. Correlation of the SCS values for investigated compounds with DSP equation

	Scale ^a	ρ_I	ρ_R	h	r	s	F	n	f^b
$SCS_{H(5-Pyr)}$	σ_R°	0.066 (± 0.016)	0.093 (± 0.014)	-0.004 (± 0.006)	0.931	0.012	33	13	-
	σ_R	0.061 (± 0.013)	0.076 (± 0.009)	-0.004 (± 0.005)	0.957	0.009	55	13	-
	σ_R^+	0.055 (± 0.017)	0.042 (± 0.006)	0.002 (± 0.006)	0.926	0.012	31	13	-
$SCS_{C(2-Pyr)}$	σ_R°	0.803 (± 0.030)	0.827 (± 0.032)	0.057 (± 0.012)	0.997	0.022	780	11 ^c	0.078
	σ_R	0.770 (± 0.049)	0.594 (± 0.038)	0.011 (± 0.020)	0.993	0.036	292	11 ^c	0.128
	σ_R^+	0.712 (± 0.110)	0.352 (± 0.043)	0.027 (± 0.044)	0.966	0.081	70	13	0.282
$SCS_{C(6-Pyr)}$	σ_R°	-1.300 (± 0.416)	-2.000 (± 0.365)	0.193 (± 0.157)	0.904	0.311	23	13	0.475
	σ_R	-1.171 (± 0.254)	-1.740 (± 0.175)	0.058 (± 0.100)	0.966	0.189	70	13	0.289
	σ_R^+	-1.016 (± 0.122)	-1.052 (± 0.048)	-0.022 (± 0.046)	0.995	0.083	361	11 ^d	0.122
$SCS_{C(3-Pyr)}$	σ_R°	0.482 (± 0.026)	0.478 (± 0.028)	0.017 (± 0.011)	0.994	0.020	352	11 ^c	0.113
	σ_R	0.464 (± 0.048)	0.335 (± 0.037)	0.018 (± 0.020)	0.981	0.036	103	11 ^c	0.208
	σ_R^+	0.439 (± 0.073)	0.174 (± 0.031)	0.022 (± 0.030)	0.957	0.053	44	11 ^c	0.312
$SCS_{C(5-Pyr)}$	σ_R°	0.225 (± 0.044)	0.332 (± 0.031)	-0.046 (± 0.018)	0.979	0.025	92	11 ^e	0.231
	σ_R	0.164 (± 0.047)	0.276 (± 0.027)	-0.010 (± 0.020)	0.978	0.026	87	11 ^e	0.236
	σ_R^+	0.131 (± 0.073)	0.155 (± 0.024)	0.020 (± 0.033)	0.950	0.040	37	11 ^e	0.354
$SCS_{C(1'-Ph)}$	σ_R°	5.890 (± 0.692)	17.932 (± 0.750)	-0.362 (± 0.283)	0.994	0.518	349	11 ^c	0.116
	σ_R	5.142 (± 0.957)	12.927 (± 0.748)	-0.228 (± 0.393)	0.989	0.717	183	11 ^c	0.159
	σ_R^+	4.125 (± 2.179)	6.788 (± 0.934)	-0.049 (± 0.910)	0.944	1.559	33	11 ^c	0.357

^a σ_I , σ_R° , σ_R and σ_R^+ are from Ref. 13 and 14; ^bTaft f value, $f = s/r.m.s.$; ^cwithout COOH and OH; ^dwithout OCH₃ and F; ^ewithout CH₃ and H

The correlations of the SCS values for the pyridone derivatives was performed according to a literature method of reference⁵ to determine the electronic demand of the carbon atoms, applying DSP-NLR analysis. The results are given in Table IV.

The results given in Table IV show the correlations of the SCS of all carbon atoms obtained using the DSP-NLR Equation (Eq. (3)) were as good, or much

better. Generally, based on the above results, it can be concluded that two opposing effects, *i.e.*, substituent electronic effects in the phenyl ring and electronic interactions in the pyridone part of the molecules are balanced, giving an overall effect on the chemical shifts of all the carbon atoms. The two separate π -polarizable systems, *i.e.*, the substituted phenyl and the pyridone rings, are defined by MO PM6 calculations. The optimized structures show the unambiguous perpendicular orientation of these rings for all the investigated compounds, except for the NO₂ substituted molecule, which is twisted by 72° from the plane of the pyridone ring. Transmission of the resonance effect from the substituted phenyl ring is efficiently suppressed in this way and the optimized structure is presented in Fig. 2 for the parent compound.

TABLE IV. Correlations of the *SCS* values for the investigated compounds with the *DSP*-NLR equation

	ρ_I	ρ_R	h	ε	r	s	F	n	f
$SCS_{C(2-Pyr)}$	0.805 (± 0.027)	0.775 (± 0.028)	0.007 (± 0.01)	-0.18	0.998	0.020	935	11 ^a	0.071
$SCS_{C(6-Pyr)}$	-1.134 (± 0.080)	-0.802 (± 0.024)	0.065 (± 0.030)	-1.50	0.998	0.056	819	11 ^b	0.081
$SCS_{C(3-Pyr)}$	0.480 (± 0.025)	0.510 (± 0.029)	0.016 (± 0.010)	0.20	0.995	0.018	384	11 ^a	0.108
$SCS_{C(5-Pyr)}$	0.215 (± 0.040)	0.312 (± 0.027)	-0.038 (± 0.017)	-0.24	0.982	0.023	110	11 ^c	0.213
$SCS_{C(1'-Ph)}$	5.942 (± 0.573)	16.133 (± 0.558)	-0.313 (± 0.235)	-0.28	0.996	0.430	510	11 ^a	0.095

^aWithout OH and COOH; ^bwithout OCH₃ and F; ^cwithout CH₃ and H

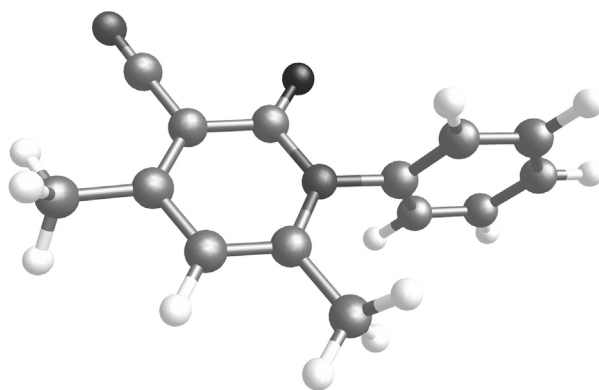


Fig. 2. Conformation of *N*(1)-phenyl-3-cyano-4,6-dimethyl-2-pyridone optimized by the MO semi-empirical PM6 method and implicit DMSO solvation (COSMO) using MOPAC 2007.

The calculated ρ_I and ρ_R values from Table IV indicate a prevalent polar (inductive/field) effect on the C(2-Pyr) and C(6-Pyr) carbon atoms of the pyridone ring. It can be noted that ρ_I and ρ_R are negative for the C(6-Pyr) carbon atom, while those for the other carbon atoms are positive. A negative sign of ρ_I is indicative of a reverse *SCS* effect, *i.e.*, inductive electron-acceptor substituents cause

an upfield shift, which is considered to be due to π -polarization.¹⁸ A similar effect has been observed in other systems, *i.e.*, in 3-aryl-2-cyanoacrylamides,⁷ *N*-benzylideneanilines,¹⁹ 2-substituted-5-(dimethylamino)phenyl dimethylcarbamates,²⁰ and in other systems containing a conjugated side chain.

As is cited in the literature, π -polarization of a distant π -system by a substituent dipole need not be transmitted *via* an intervening π -system,¹⁸ and theoretical results have demonstrated that a substituent dipole acts mainly in polarizing each of the π -units individually.²¹ This is defined as localized polarization. On the other hand, the terminal atoms of a conjugated π -system show some additional polarization of the whole π -network. This component is termed extended polarization.

Transmission of substituent electronic effects could be presented by mesomeric structures of the investigated pyridones and the contribution of π -polarization (Fig. 3).

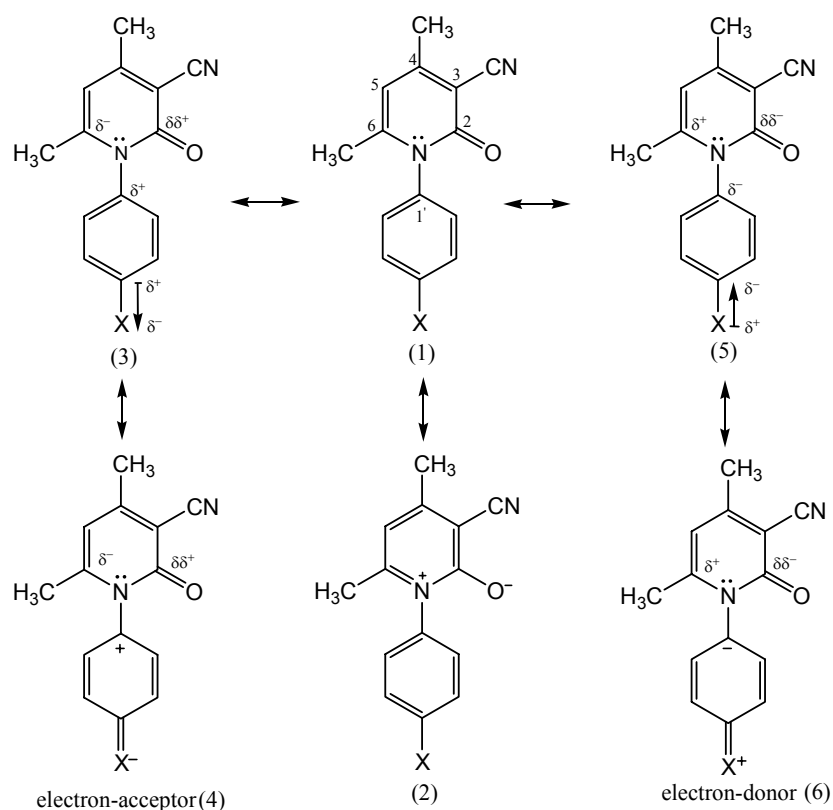


Fig. 3. Mesomeric structures with the contribution of π -polarization.

In structure (1), if X is an electron-acceptor substituent, a dipole on X (or near the C–X bond) is induced (structure (3)) and interaction of this dipole through

the space of the molecule results in polarization of the individual π -units (localized polarization). The reverse is true for electron-donor substituted compounds (structure (5)). The polarization mechanism of small localized π -units, presented by structures (3) and (5), is very important as well as polarization of the entire conjugated system of the investigated compounds (extended polarization). Resonance interaction in the extended conjugated system of the pyridone ring (structure (2)) has an opposing effect to the polarization caused by an electron-acceptor substituent (structure (4)). The net result is that the electron-acceptor substituents increase the electron density about the C(6-Pyr) carbon, hence, the increased shielding caused an upfield shift. Reversely, electron-donor substituents support the resonance interaction in the pyridone unit, which could be attributed to a potential delocalization of the electron lone pair at the N(1) nitrogen.

The correlation between the *SCS* values of the C(1'-Ph) atom and the substituent parameters using the *DSP-NLR* method ($r = 0.996$ and $f = 0.095$) shows that the demand for electrons of this atom is $\varepsilon = -0.28$. Sign and value of the parameter ε show that the pyridone ring, according to literature data for the COOEt group of -0.48 ,⁵ attached to the C(1'-Ph) atom has a moderate electron-acceptor character. This fact probably could be explained by a small contribution of the mesomeric structure (2), which has a higher electron-accepting power.

A somewhat lower demand for electrons ($\varepsilon = -0.18$) was observed for the C(2-Pyr) atom of the pyridone ring. The low polarizability of the π -carbonyl electrons is influenced by the vicinity of an electron-accepting oxygen, which contributes to a lower sensitivity.

The C(6-Pyr) carbon has the highest demand for an electron ($\varepsilon = -1.50$). Electron-acceptors cause an increased electron density at this carbon (structures (3) and (4)), opposing the conjugation present in the pyridone unit, while electron donors have the opposite effect (structures (5) and (6)). The C(3-Pyr) carbon has an ε value of 0.20, the higher electron density being the result of the neighboring cyano group, which increases the electron density at this carbon. A similar literature value⁵ of ε for an NMe₂ group (0.25) proves that the electron density of the pyridone ring is shifted to the carbonyl group. The electron demand for the C(5-Pyr) carbon is -0.24 , which indicates a significantly lower deficiency of electron density than the C(6-Pyr) carbon.

The contribution of the individual electronic effects of substituents on the phenyl ring to the carbon atoms of the pyridone ring and the C(1'-Ph) of the phenyl ring can be analyzed based on the ratio $\lambda = \rho_R/\rho_I$. Using the values of ρ_R and ρ_I from Table IV, the calculated values λ for the C(2-Pyr), C(6-Pyr), C(3-Pyr), C(5-Pyr) and C(1'-Ph) atoms are: 0.96, 0.71, 1.06, 1.45 and 2.72, respectively. *DSP* analysis and calculation of the λ parameter (for the same set of carbon atoms) gave the following results: 1.03, 1.04, 0.99, 1.48 and 3.04, respectively. Comparison of the values of λ from *DSP* (Eq. (2)) with those from *DSP-NLR* (Eq. (3))

indicates a significant decrease only for the C(6-Pyr) carbon atom, which has the highest electron demand ($\varepsilon = -1.50$), which probably suggests that the localized π -polarization effect is dominant in this part of the molecule.

The contributions of resonance and inductive substituent effects at the C(3-Pyr) and C(2-Pyr) atoms are balanced, while the resonance effect is dominant at the C(5-Pyr) atom. According to their position in the pyridone conjugated system and the influence of substituent electronic effects, the C(5-Pyr) carbon atom is more susceptible to the net π electron shifts caused by a substituent.

The electronic substituent effects are transmitted through the phenyl ring by resonance and inductive/field interaction toward the C(1'-Ph) carbon by developing different charges at the phenyl carbon atoms. The electron density, according to MO calculation, is localized at the C(2'-Ph)-C(3'-Ph) and C(5'-Ph)-C(6'-Ph) carbons for all compounds investigated. The large attenuation effect of the electronic substituent effects transmission to N(1) atom is influenced by the geometry of two perpendicular rings. Electron-donor substituents develop a negative charge at the C(1'-Ph) carbon (Fig. 3, structure (6)), while the opposite is true for electron-acceptors (Fig. 3, structure (4)). Only in the compound with the NO₂ group, which has strong negative inductive and resonance effects, did a decrease in the torsion angle occur and thus, the n,π -conjugation was increased.

The net electronic effect from substituents to the π -electron of pyridone system is transmitted mainly by inductive/field effects. Repulsion between π -electrons of the carbonyl group and the electron rich phenyl ring in electron-donor substituted compounds cause a somewhat higher interaction with the electron of the C(6-Pyr)-C(5-Pyr) double bond through space, thus the deshielding of the C(6-Pyr) carbon is higher. The opposite is true for electron-acceptor substituted compounds. According to the MO calculation, the electron density of the π -pyridone system is localized at the C(6-Pyr)-C(5-Pyr) and C(3-Pyr)-C(2-Pyr) carbons for all the investigated compounds. Thus, the substituent electronic effects are mainly reflected in the polarization of small π -polarizable units of the pyridone ring.

CONCLUSIONS

In summary, it can be concluded that the *DSP*-NLR analysis of the obtained results revealed that the applied method was successful for the correlation of the *SCS* values of the investigated compounds. All correlations were of good precision, indicating that the substituent effects on the ¹³C-NMR chemical shifts in this series are due to electron transfer. The inductive/field effect is the dominant factor for some of the observed carbon atoms of the pyridone ring. The resonance effect is the most prominent on the C(1'-Ph) carbon, while the reverse substituent effect was observed at the C(6-Pyr) atom, as a consequence of π -polarization.

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ИЗВОД

СУПСТИТУЕНТИМА ИЗАЗВАНА ^{13}C - И ^1H -NMR ХЕМИЈСКА ПОМЕРАЊА
N(1)-(4-СУПСТИТУИСАНИ ФЕНИЛ)-3-ЦИЈАНО-4,6-ДИМЕТИЛ-2-ПИРИДОНААЛЕКСАНДАР Д. МАРИНКОВИЋ, НАТАША В. ВАЛЕНТИЋ, ДУШАН Ж. МИЈИЋ,
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^{13}C - и ^1H -NMR хемијска померања тринаест N(1)-(4-супституисани фенил)-3-цијано-4,6-диметил-2-пиридона су одређена у деутерисаном диметилсулфоксиду (DMSO- d_6). Корелациона анализа хемијских померања појединих угљеникових атома испитиваних једињења изазвана присутним супституентима (SCS) са σ_p , индуктивним (σ_I) и различитим резонанционим (σ_R) константама је извршена коришћењем SSP (монопараметарска), DSP (двопараметарска) и DSP-NLR (двопараметарска нелинеарна) метода. Резултати корелационих анализа на задовољавајући начин описују ефекте супституената за посматране угљеникове атоме. Дискутован је начин преношења ефеката супституената, индуктивних и резонанционих, у односу на геометрију испитиваних молекула.

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