A STUDY OF TRANSMISSION EFFECTS OF SULFONYL AND CARBONYL GROUPS

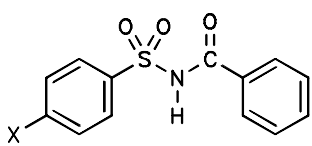
Miroslav LUDWIG, Patrik PARIK and Jiri KULHANEK

Department of Organic Chemistry,
University of Pardubice, 532 10 Pardubice, The Czech Republic

Received December 23, 1994
Accepted February 15, 1995

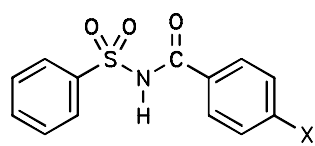
Seventeen *p*-substituted *N*-phenylsulfonylbenzamides of general formulas $XC_6H_4SO_2NHCOC_6H_5$ and $C_6H_5SO_2NHCOC_6H_4X$ have been synthesized and their structure has been confirmed by elemental analysis and ^{1}H NMR spectra. The dissociation constants of all the compounds have been measured by potentiometric titration in methanol, acetonitrile, dimethylformamide, dimethyl sulfoxide, and pyridine. The obtained pK_{HA} values have been correlated with three sets of Hammett substituent constants using simple or double linear regression. The solvent and substituent effects are discussed on the basis of experimental results, and the difference between the substituent effects from sulfonamide and benzamide sections is evaluated. It has been found that due to the extensive delocalization of negative charge in the conjugated base the transmission effects of carbonyl and sulfonyl groups on the transmission of substituent effect are roughly the same. The experimental data have been interpreted by the methods with latent variables: the principal component analysis (PCA), the conjugated deviation analysis (CDA), and the method of projection to latent structures (PLS). The results obtained by these procedures were similar.

The basic model process used by Hammett[1] in his studies of substituent effects in benzene nucleus was dissociation of substituted benzoic acids in water. Obviously, the substituent and solvent effects upon dissociation can be studied with other types of substrates such as various aromatic O-, N-, and C-acids and with other media. Such a substrate is, e.g., *N*-phenylsulfonylbenzamide with substituents at *para* position of benzenesulfonamide ring (type *A*) or at *para* position of benzamide ring (type *B*).



A

X = $(CH_3)_2N$, NH_2, OCH_3, CH_3, H, F, Cl, Br, CN, NO_2



B

X = $(CH_3)_2N$, OCH_3, CH_3, H, F, Cl, CN

These compounds offer a model for studying two types of substituent effects. In one case the reaction centre is affected by the substituent through aromatic ring and sulfonyl group, and in the other case through aromatic system and carbonyl group. The substitution at *para* position was chosen because the substituent effect from this position is more complex than that from the nonalternating *meta* position[2].

The dissociation of *N*-phenylsulfonylbenzamides has been studied several times experimentally, however, mostly within the framework of another reaction series. These studies involve the determination of dissociation constants of acylated benzenesulfonamides $C_6H_5SO_2NHR$ (R = $COCH_3$, $COCH_2Cl$, $COCHCl_2$, CONHCN, CH_2COOH, COC_6H_5, CSC_6H_5, COC_6H_4Cl, and $CONHC_6H_5$) in acetone and cyclohexanone[3], in anisole, butyl acetate, tributyl phosphate, and dibutyl ether–anisole mixture[4], and finally in 1-butanol, isobutyl alcohol, tert-butyl alcohol, cyclohexanol, acetone, and anisole[5]. A series of five *N*-phenylsulfonylbenzamides *p*-$XC_6H_4CONHSO_2C_6H_5$ (X = NH_2, H, CH_3, OCH_3, and NO_2) was measured[6] in 60% aqueous dioxane. The largest data set was provided by measurements[7] of dissociation constants of *p*-substituted *N*-phenylsulfonylbenzamides *p*-$XC_6H_4SO_2NHCOC_6H_4Y$-*p* (X = H, Cl, CH_3, NO_2, NH_2, Br, and Y = NO_2, Cl, Br).

The chief aims of the present work are to compare the substituent effects from the two nuclei of model substrates upon the value of dissociation constants, to study the transmission of substituent effects through the sulfonyl and carbonyl groups on the imide nitrogen atom and, as the case may be, the substituent effect upon the massive delocalization of negative charge in the conjugated base, and to discuss the solvent effect upon the effects mentioned. The paper forms a continuation of former contributions dealing with dissociation of various sulfonamides[8–11].

EXPERIMENTAL

The ^{1}H NMR spectra of the model compounds prepared were measured on a Bruker AMX 360 apparatus using their 5% solutions in $(CD_3)_2SO$ and the chemical shifts were referenced to the solvent signal. The pK_{HA} values of the imides type *A* and *B* were determined in methanol (MeOH), acetonitrile (AN), *N*,*N*-dimethylformamide (DMF), dimethyl sulfoxide (DMSO), and pyridine (Py) using potentiometric titration on an automatic titrator Radiometer RTS-622 using the same electrode arrangement and titration reagent as those in earlier papers[8–11]. The solvents used were purified in standard way.

Synthesis of *p*-Substituted *N*-Phenylsulfonylbenzamides

The synthesis of model substrates was carried out by procedures analogous to those given in literature: alkaline fusion of corresponding benzenesulfonamides with phenyl benzoates[12] or, in the case of preparation of *N*-benzoyl-*p*-toluenesulfonamide, reaction of *p*-toluenesulfonamide with benzoyl chloride[13]. The starting phenyl benzoates were prepared by reaction of substituted benzoyl chlorides with phenoxide[14] or by reaction[15] of substituted benzoic acids with phenol and $POCl_3$. The substituted benzoyl chlorides were prepared from corresponding benzoic acids by a reaction with

$SOCl_2$ catalyzed with DMF (ref.[16]). The benzoic acids and benzenesulfonamides used were prepared by known procedures.

Alkali Fusion of Benzenesulfonamides with Phenyl Benzoates (modified ref.[12])

A 100 ml flask equipped with reflux condenser was charged with a mixture of 0.02 mol respective benzenesulfonamide, 0.02 mol respective phenyl benzoate, and potassium carbonate (1.2 g, 0.12 mol), and the content was fused on a wire gauze 15 – 20 min. After cooling, the reaction mixture was dissolved in 5% aqueous sodium carbonate (200 ml), filtered, and extracted with benzene (2 × 100 ml). The alkaline solution was acidified with diluted hydrochloric acid (100 ml) to pH 1 (to pH 2 for *N*-benzenesulfonyl-*p*-dimethylaminobenzamide solution) and the separated solid was collected by filtration. If much contaminated, the imide was reprecipitated from carbonate solution by adding dilute hydrochloric acid. Finally, the product was recrystallized from ethanol or toluene until constant melting point. Table I presents the starting materials, melting points and yields of the products synthesized. The elemental analyses carried out for the known compounds agreed with the calculated values.

RESULTS AND DISCUSSION

Table II presents the chemical shifts of all the model derivatives of *N*-benzenesulfonylbenzamides prepared. The chemical shifts of acidic proton are not given since their signals were mostly very broad. The values of dissociation constants of the individual model substrates in individual solvents are given as average values $\overline{pK}_{HA}$ (with standard deviations) in Table III. The solvents were selected with the aim of covering the main types of solvents commonly used for titrations: amphiprotic methanol, dipolar aprotic protophobic acetonitrile, dipolar aprotic protophilic *N*,*N*-dimethylformamide, dimethyl sulfoxide, and pyridine. The substituents chosen can be classified as ones without any distinct mesomeric effect (CH_3, H, Cl, Br), those with positive mesomeric effects (NH_2, $N(CH_3)_2$, OCH_3, F), and those with negative mesomeric effects (CN, NO_2). The experimental results obtained were treated by several mathematical-statistical methods. For the treatment of results by simple and double linear regression analysis we always used all the experimental points found (each experiment was repeated four times). For the methods working with latent variables – the principal component analysis (PCA, ref.[20]), conjugated deviations analysis (CDA, ref.[21]), and projection of latent structures (PLS, ref.[22]) we used the average $\overline{pK}_{HA}$ values.

The classical treatment of results according to the original Hammett relation involved ten regressions, i.e. five linear regressions for the *A* series and the same number for *B*. The calculations were carried out with application of three sets of substituent constants, viz. σ_p (ref.[23]), σ_{P6}, and σ_{F6} (ref.[24]). A closer fit is obtained with the σ_{P6} and σ_{F6} constants, which can be due to the fact that these constants were defined on the basis of data describing the dissociation of benzoic acid in nonaqueous media. However, from the definition of the Hammett relation it follows that the pK_0 values should be the same for the two series *A*, *B*, in a given solvent. The result of testing the hypotheses of

TABLE I

Starting materials, melting points, and yields of syntheses of substituted *N*-benzenesulfonylbenzamides type *A* (4-X-$C_6H_4SO_2NHCOC_6H_5$) and type *B* (4-X-$C_6H_4CONHSO_2C_6H_5$)

N-(4-X-Benzoyl)benzenesulfonamide type *A*				*N*-Benzoyl-(4-X-benzenesulfonamide) type *B*		
X	starting compound	M.p., °C (M.p., °C, refs[12,16])	Yield %	starting compound	M.p., °C (M.p., °C, refs[17–19])	Yield %
$(CH_3)_2N$	sulfanilamide	206 – 208 [a]	12	4-*N*,*N*-dimethylaminobenzoic acid	204 – 206 [d]	19
NH_2	sulfanilamide	179 – 180 (181)	35			
OCH_3	4-methoxybenzenesulfonamide	145.5 – 147 (146 – 147)	23	4-methoxybenzoic acid	135 – 137 (135 – 135.5)	20
CH_3	4-toluenesulfonamide	146 – 147 (147)	42	*p*-toluic acid	129 – 132 (127 – 129)	25
H	benzenesulfonamide	144 – 146 (146)	15	benzenesulfonamide	144 – 146 (146)	15
F	4-fluorobenzenesulfonamide	174 – 177 [b]	16	4-toluidine	152 – 156 (152)	39
Cl	4-chlorobenzenesulfonamide	182 – 183.5 (183)	17	4-chlorobenzoic acid	199 – 201 (197 – 198)	17
Br	4-bromobenzenesulfonamide	176 – 177 (177)	24			
CN	sulfanilamide	174 – 178 [c]	5	4-aminobenzoic acid	155 – 159	16
NO_2	4-nitrobenzenesulfonamide	197 – 201 (201)	8			

[a] For $C_{15}H_{16}N_2O_3S$ (304.4) calculated: 59.19% C, 5.30% H, 9.20% N, 10.35% S; found: 58.73% C, 5.69% H, 9.03% N, 10.53% S. [b] For $C_{13}H_{10}FN_3OS$ (279.3) calculated: 55.91% C, 3.61% H, 5.02% N, 11.48% S; found: 55.71% C, 3.52% H, 5.26% N, 11.32% S. [c] For $C_{14}H_{10}N_2O_3S$ (286.3) calculated: 58.73% C, 3.52% H, 9.78% N, 11.20% S; found: 58.87% C, 3.52% H, 10.00% N, 10.92% S. [d] For $C_{15}H_{16}N_2O_3S$ (304.4) calculated: 59.19% C, 5.30% H, 9.20% N, 10.35% S; found: 59.04% C, 5.31% H, 9.19% N, 10.63% S.

TABLE II

^{1}H NMR chemical shifts of protons (δ, ppm) in model substrates series *A* and *B*

X	*A* Series	*B* Series
$(CH_3)_2N$	3.04 s, 6 H (H-7); 6.83 m and 7.82 m, 2 × 2 H (H-3,5 and H-2,6); 7.51 m, 2 H (H-3′,5′); 7.64 m, 1 H (H-4′); 7.89 m, 2 H (H-2′,6′)	3.01 s, 6 H (H-7′); 6.72 m and 7.79 m, 2 × 2 H (H-3′,5′ and H-2′,6′); 7.66 m, 2 H (H-3,5); 7.73 m, 1 H (H-4); 8.04 m, 2 H (H-2,6)
NH_2	3.41 s, 2 H (H-7); 6.66 m and 7.68 m, 2 × 2 H (H-3,5 and H-2,6); 7.51 m, 2 H (H-3′,5′); 7.63 m, 1 H (H-4′); 7.88 m, 2 H (H-2′,6′)	
OCH_3	3.90 s, 3 H (H-7); 7.20 m and 7.99 m, 2 × 2 H (H-3,5 and H-2,6); 7.53 m, 2 H (H-3′,5′); 7.66 m, 1 H (H-4′); 7.90 m, 2 H (H-2′,6′)	3.86 s, 3 H (H-7′); 7.06 and 7.92 m, 2 × 2 H (H-3′,5′ and H-2′,6′); 7.68 m, 2 H (H-3,5); 7.76 m, 1 H (H-4); 8.05 m, 2 H (H-2,6)
CH_3	2.44 s, 3 H (H-7); 7.49 m and 7.94 m, 2 × 2 H (H-3,5 and H-2,6); 7.53 m, 2 H (H-3′,5′); 7.66 m, 1 H (H-4′); 7.90 m, 2 H (H-2′,6′)	2.38 s, 3 H (H-7′); 7.33 m and 7.83 m, 2 × 2 H (H-3′,5′ and H-2′,6′); 7.69 m, 2 H (H-3,5); 7.76 m, 1 H (H-4); 8.05 m, 2 H (H-2,6)
H	7.54m, 2 H (H-3′,5′); 7.67 m, 3 H (H-3,4,5); 7.77 m, 1 H (H-4′); 7.91 m, 2 H (H-2′,6′); 8.06 m, 2 H (H-2,6)	7.54 m, 2 H (H-3′,5′); 7.67 m, 3 H (H-3,4,5); 7.77 m, 1 H (H-4′); 7.91 m, 2 H (H-2′,6′); 8.06 m, 2 H (H-2,6)
F	7.54 m, 4 H (H-3,5,3′,5′); 7.67 m, 1 H (H-4′); 7.91 m, 2 H (H-2′,6′); 8.13 m, 2 H (H-2,6), ^4J(H,F) = 5.14 Hz	7.37 m, 2 H (H-3′5′), ^3J(H,F) = 8.85 Hz; 7.70 m, 2 H (H-3,5); 7.77 m, 1 H (H-4); 7.99 m, 2 H (H-2′,6′), ^4J(H,F) = 5.42 Hz; 8.05 m, H (H-2,6)
Cl	7.54 m, 2 H (H-3′,5′); 7.67 m, 1 H (H-4′); 7.77 m and 8.07 m, 2 × 2 H (H-3,5 and H-2,6); 7.92 m, 2 H (H-2′,6′)	7.61 m and 7.93 m, 2 × 2 H (H-3′,5′ and H-2′,6′); 7.70 m, 2 H (H-3,5); 7.78 m, 1 H (H-4); 8.05 m, 2 H (H-2,6)
Br	7.54 m, 2 H (H-3′,5′); 7.68 m, 1 H (H-4′); 7.92 m, 4 H (H-3,5,2′,6′); 7.99 m, 2 H (H-2,6)	
CN	7.55 m, 2 H (H-3′,5′); 7.69 m, 1 H (H-4′); 7.92 m, 2 H (H-2′,6′); 8.20 m, 4 H (H-2,3,5,6)	7.69 m, 2 H (H-3,5); 7.76 m, 1 H (H-4); 8.03 m, 6 H (H-2,6,2′,3′,5′,6′)
NO_2	7.54 m, 2 H (H-3′,5′); 7.68 m, 1 H (H-4′); 7.92 m, 2 H (H-2′,6′); 8.29 m and 8.50 m, 2 × 2 H (H-3,5 and H-2,6)	

TABLE III
Average $p\overline{K}_{HA}$ values of model substrates of *A* and *B* series in five solvents

X	Sulfonamides *A* pK_{HA}/s_{pK}					Sulfonamides *B* pK_{HA}/s_{pK}				
	MeOH	AN	DMF	DMSO	Py	MeOH	AN	DMF	DMSO	Py
$(CH_3)_2N$	9.38	19.21	9.77	8.06	6.35	9.34	19.15	9.71	7.86	6.32
	0.06	0.06	0.06	0.20	0.07	0.02	0.06	0.01	0.15	0.03
NH_2	9.38	19.03	9.98	8.18	6.74	–	–	–	–	–
	0.02	0.03	0.03	0.10	0.06	–	–	–	–	–
OCH_3	8.72	18.07	8.82	7.32	5.44	8.63	18.03	8.81	7.10	5.27
	0.05	0.05	0.05	0.10	0.06	0.02	0.03	0.08	0.12	0.07
CH_3	8.45	17.87	8.60	6.62	5.21	8.48	17.82	8.58	6.77	5.05
	0.05	0.04	0.04	0.10	0.06	0.05	0.07	0.09	0.11	0.05
H	8.22	17.58	8.35	6.43	4.80	8.22	17.58	8.35	6.43	4.80
	0.04	0.07	0.04	0.10	0.06	0.04	0.07	0.04	0.10	0.06
F	8.06	17.20	7.94	6.25	4.44	7.96	17.15	7.95	6.17	4.48
	0.06	0.05	0.04	0.07	0.04	0.02	0.07	0.04	0.08	0.05
Cl	7.83	16.87	7.78	5.72	4.27	7.79	16.85	7.70	5.56	4.16
	0.04	0.07	0.06	0.06	0.08	0.03	0.02	0.03	0.09	0.02
Br	7.82	16.89	7.71	5.58	4.27	–	–	–	–	–
	0.04	0.07	0.07	0.09	0.08	–	–	–	–	–
CN	7.20	16.10	6.94	4.36	3.71	7.12	16.02	7.04	4.95	3.76
	0.09	0.04	0.05	0.05	0.09	0.04	0.08	0.06	0.18	0.09
NO_2	7.09	15.71	6.71	4.21	3.79	–	–	–	–	–
	0.09	0.07	0.09	0.13	0.05	–	–	–	–	–

equality of pK_0 values of the series *A* and *B* in a given solvent depends on the scale used for substituent constants. As the pK_0 values should be identical for the two series, it is more appropriate to describe the experimental data in the individual solvents by Eq. (*1*):

$$pK_{HA} = pK_0 + \rho_{SO_2}\sigma_A + \rho_{CO}\sigma_B \quad , \qquad (1)$$

where σ_A and σ_B are the substituent constants for *p*-substituents in the benzenesulfonamide and benzamide nuclei, respectively, and ρ_{SO_2} and ρ_{CO} are the reaction constants of the series *A* and *B*, respectively. From the calculation of double linear regression we obtain the pK_0 value valid for both series and the two reaction constants. The results of this method are given in Table IV (where the σ_{P6} constants have been used). The discussion of pK_0 values in the individual media is distorted by the fact that there is no universal pH scale for all solvents. The relatively low pK_0 value for pyridine is obviously due to its basicity. The pK_0 values found can be compared with the formerly published pK_0 values for substituted benzenesulfonamides[8–11]. The lowest differences are observed with methanol (6.1) and acetonitrile (7.0), while the values for other solvents vary about 8.8. It can generally be stated that the relatively distinct difference in all solvents is due to the strong electrophilic influence of the attached benzoyl group. A smaller difference with methanol follows from the relatively good solvation of conjugated bases by this solvent, which decreases the share of substrate in this stabilization. The smaller difference found for acetonitrile, as compared with the other dipolar aprotic solvents, cannot be interpreted in this way. Generally high pK_{HA} values in acetonitrile indicate a low ability to solvate charged particles on the dissociated side of equilibrium. Since a small difference is also found in the case of comparison of benzenesulfonamides or the imides described in the present paper with

TABLE IV
Parameters of double linear regression of pK_{HA} vs σ_{P6} (by Eq. (*1*))

Parameter	MeOH	AN	DMF	DMSO	Py
pK_0	8.21	17.47	8.27	6.32	4.87
(*s*)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
ρ_{SO_2}	1.70	2.44	2.32	2.92	2.17
(*s*)	(0.02)	(0.04)	(0.03)	(0.07)	(0.07)
ρ_{CO}	1.81	2.54	2.20	2.50	2.11
(*s*)	(0.03)	(0.06)	(0.04)	(0.01)	(0.10)
s	0.063	0.107	0.079	0.183	0.195
(*R*)	(0.997)	(0.995)	(0.997)	(0.989)	(0.979)

benzoic acids[25], the phenomenon is probably more general, being specific for this solvent type.

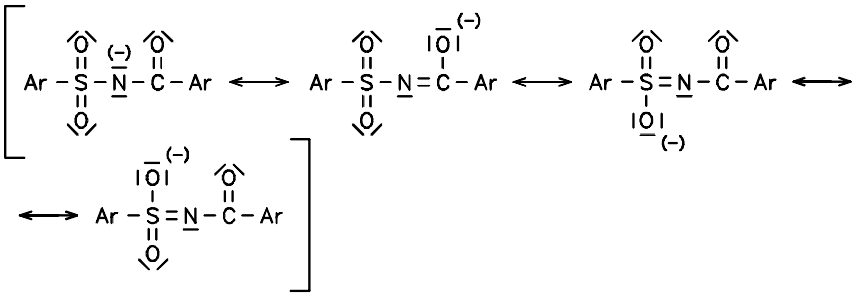
The comparison of reaction constants ρ_{SO_2} (Table IV) for individual media gives (like with the ρ_{CO} constants) the following order: methanol < pyridine < dimethylformamide < acetonitrile < dimethyl sulfoxide. The lowest value found for methanol follows from its amphiprotic character and its ability to solvate polar particles well. The other solvents solvate the conjugated base weakly thereby increasing the share of substituents in its stabilization and hence also increasing the reaction constant value. Among these solvents pyridine exhibits the lowest value, which agrees with the results published for both substituted benzenesulfonamides[10] and substituted benzoic acids[26,27]. If the values of reaction constants of the substrates discussed are compared with some results published by us earlier, it is possible to state – irrespective of solvent – the folowing rough increasing order: benzenesulfonamides[8–10], benzoic acids[25–27], *N*-benzenesulfonylbenzamides, *N*-benzenesulfonamides (the substiutuent is in the nucleus attached to N)[11]. It is interesting to compare the ρ_{SO_2} values with ρ values of benzenesulfonamides since in both the cases the substituent effects are transmitted through the same section of molecular skeleton. In all the solvents *N*-benzenesulfonylbenzamides are more sensitive to substituents. This comparison is somewhat surprising because in the case of the substrates studied in this paper the negative charge is delocalized to a larger area (from oxygen atoms of sulfonyl group to carbonyl oxygen), hence it could be anticipated to be less affected by substituents.

If the values of reaction constants ρ_{SO_2} and ρ_{CO} calculated for the individual media are compared with one another, very similar values are found (except for dimethyl sulfoxide). The values for methanol, dimethylformamide, and acetonitrile are identical within experimental error (the accuracy of determination of p*K* by potentiometric titration in nonaqueous media is about 0.1 pH unit). In the case of dimethyl sulfoxide the values differ (ρ_{SO_2} = 2.92, ρ_{CO} = 2.50). Hence the substituent effect is more intensive in the sulfonamide system. If the transmission effect is compared for the first four solvents, the equality of both reaction constants (ρ_{SO_2} and ρ_{CO}) can be interpreted by the above-mentioned strong delocalization of negative charge of the conjugated base. The dominating effect of this delocalization is the strong negative mesomeric effect of the two groups studied. The delocalization can be expressed by Scheme 1 wherefrom follows preferable delocalization to the oxygen atoms present in the two groups. The negatively charged region delimited by these groups will then be affected similarly from both aromatic rings. In the case of dimethyl sulfoxide the reason can lie in different solvation of carbonyl and sulfonyl groups. From the experimental findings obtained it can be deduced that this solvent solvates more effectively the charge transferred to the softer sulfonyl group: this shift of electrons somewhat increases the substituent effect in the sulfonamide section of the molecule. The small differences found for the other solvents in this case indicate an approximately equal solvation of

harder carbonyl and softer sulfonyl groups by the solvents discussed (methanol and acetonitrile exhibit a little higher ρ_{CO} value, the other solvents exhibit a higher ρ_{SO_2} value).

The comparison of results of transmission effects of the two groups discussed with literature data can be carried out only very approximately since there are not enough data published. The ratio of reaction constants for dissociation of substituted phenols[28] and benzoic acids[26] in dimethyl sulfoxide is 2.3, and that for anilines[28] and benzenesulfonamides[9] is 3.0. Although the transmission effects compared correspond to acids of different types, it can be roughly stated that the effect of sulfonyl group should be about 30% higher than that of carbonyl group. In the present type of substrate this is not the case due to the above-discussed strong electron delocalization in the conjugated base.

The analysis of experimental data by the methods using latent variables adopted matrices of three types: ***A*** matrix with 5 columns and 10 rows (solvents and substituents, respectively) containing $\overline{pK}_{HA}$ values for the *A* series only (PCA, CDA calculation), ***B*** matrix of 5×7 dimensions containing $\overline{pK}_{HA}$ values for the *B* series only (PCA, CDA calculation), and ***AB*** matrix of 10×10 dimensions (PCA, CDA, and PLS calculations). The methods working with the independent variables only (PCA and CDA) found the first principal component describing (in all cases: ***A***, ***B***, ***AB***) 99% of variability of the source data. The second principal component is near the limit of statistical significance, describing ca 0.6% of the variability in all the types of matrices. From the point of view of the substituents, the latter is particularly significant for the substituents with positive (dimethylamino, amino) or negative (nitro, cyano substituents) mesomeric effect. All these substituents exhibit a somewhat lower acidity as compared with the linear dependence of the Hammett type. This phenomenon is the most significant statistically in the case of dimethyl sulfoxide. Substituents with +M effect release electrons slightly more in this solvent in contrast to substituents with −M effect which attract electrons slightly less. This is probably connected with the existence of conjugated neighbourhood of the reaction centre. The PCA and CDA



SCHEME 1

calculations on the combined matrix ***AB*** showed no significant difference between the columns describing the series *A* and *B* which can be treated as a single series. The PLS calculation in both directions gave analogous results. The first principal component describes 99.8% of variability of matrix of independent variables in both types of calculations, which confirms the same inner structure of variability of data coming from the series *A* and *B*.

The described research was supported by the Grant Agency of the Czech Republic, Grant No. 203 94 0122.

REFERENCES

1. Hammett L. P.: *Physical Organic Chemistry*, 2nd ed. McGraw–Hill, New York 1970.
2. Ludwig M., Exner O., Wold S.: Acta Chem. Scand. *46*, 549 (1992).
3. Dulova V. I., Gordienko N. S., Dubina V. L.: Zh. Fiz. Khim. *1970*, 2640.
4. Gordienko N. S., Dulova V. I., Dubina V. L.: Izv. Vyssh. Ucheb. Zaved., Khim. Khim. Tekhnol. *1970*, 1220.
5. Gordienko N. S., Dulova V. I., Dubina V. L.: Izv. Vyssh. Ucheb. Zaved., Khim. Khim. Tekhnol. *1972*, 1535.
6. Chernykh V., Makurina V.: Org. React. (Tartu) *1977*, 101.
7. Plotnikova M. T., Kremlev M. M., Yurko D. G.: Vopr. Khim. Khim. Tekhnol. *1974*, 20; Chem. Abstr. *82*, 139564 (1975).
8. Ludwig M., Pytela O., Kalfus K., Vecera M.: Collect. Czech. Chem. Commun. *49*, 1182 (1984).
9. Ludwig M., Pytela O., Vecera M.: Collect. Czech. Chem. Commun. *49*, 2593 (1984).
10. Ludwig M., Pytela O., Vecera M.: Collect. Czech. Chem. Commun. *51*, 1984 (1986).
11. Ludwig M., Pytela O., Javurkova H., Vecera M.: Collect. Czech. Chem. Commun. *52*, 2900 (1987).
12. Takatori K.: J. Pharm. Soc. Jpn. *73*, 810 (1954); Chem. Abstr. *48*, 8750 (1954).
13. Kemp A. D., Stephen H.: J. Chem. Soc. *1948*, 110.
14. Furniss B. S., Hannaford A. J., Rogers V., Smith P. W. G., Tatchell A. R.: *Vogel's Textbook of Practical Organic Chemistry*. Longman, London 1978.
15. Titherley A. W., Stubbs L.: J. Chem. Soc. *105*, 304 (1914).
16. Becker H.: *Organikum*. VEB Deutscher Verlag der Wissenschaften, Berlin 1970.
17. Kretov A. E., Schevchenko V. I.: Ukr. Khim. Zh. *23*, 493 (1957); Chem. Abstr. *52*, 6241 (1958).
18. Kremlev M. M., Dolyuk V. G.: Zh. Org. Khim. *1977*, 144.
19. Kremlev M. M., Plotnikova M. T.: Zh. Org. Khim. *1969*, 279.
20. Wold S., Esbensen K., Geladi P.: Chemom. Intell. Lab. Syst. *2*, 37 (1987).
21. Pytela O.: Collect. Czech. Chem. Commun. *55*, 42 (1990).
22. Geladi P., Kowalski B. R.: Anal. Chim. Acta *185*, 1 (1986).
23. Exner O.: *Correlation Analysis of Chemical Data*. Plenum, New York 1988.
24. Pytela O., Ludwig M., Vecera M.: Collect. Czech. Chem. Commun. *51*, 2143 (1986).
25. Ludwig M., Baron V., Kalfus K., Vecera M.: Collect. Czech. Chem. Commun. *51*, 2135 (1986).
26. Pytela O., Kulhanek J., Ludwig M., Riha V.: Collect. Czech. Chem. Commun. *59*, 627 (1994).
27. Pytela O., Kulhanek J., Ludwig M.: Collect. Czech. Chem. Commun. *59*, 1637 (1994).
28. Bordwell F. G., McCallum R. J., Olmstead W. N.: J. Org. Chem. *49*, 1424 (1984).