

## TRANSMISSION OF SUBSTITUENT EFFECT ACROSS THE BENZOTHAZOLE SYSTEM

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Wavenumbers of symmetric and asymmetric N—H stretching vibrations of the  $\text{NH}_2$  group in twelve 6-substituted 2-benzothiazolamines in tetrachloromethane were determined. Analogous data for sixty four 3- and 4-substituted anilines were taken from the literature and the wavenumbers in both series of compounds were correlated with the Hammett  $\sigma$  and the nucleophilic  $\sigma^-$  substituent constants. It was proved that in the benzothiazole system the electronic effects are transmitted to the amino group mainly *via* ring nitrogen. The transmission factor for the benzothiazole system was calculated according to Charton and its value was compared with values obtained from other physico-chemical data.

Although the transmission of electronic substituent effects across the benzothiazole system was studied previously<sup>1,2</sup>, the value of the transmission factor for this system was not determined. Many authors studied linear relationships between wavenumbers of the N—H stretching vibration and substituent constants in various series of substituted anilines<sup>3-7</sup>. This paper compares wavenumbers of the symmetric and asymmetric N—H vibrations of the  $\text{NH}_2$  group in the series of 6-substituted 2-benzothiazolamines *I* with analogous data, obtained for a series of substituted anilines *II*. The aim of our study was to determine the transmission factor for benzothiazole system.

### EXPERIMENTAL

The 6-substituted 2-benzothiazolamines *I*,  $\text{X} = \text{H}$ ,  $\text{N}(\text{CH}_3)_2$ ,  $\text{SCN}$ , and  $\text{COOC}_2\text{H}_5$ , were prepared according to the procedures described in the literature<sup>8-11</sup>. The compounds *I*,  $\text{X} = \text{CN}$ ,  $\text{COCH}_3$ , were synthesized by the method reported in ref.<sup>11</sup> and the compounds *I*,  $\text{X} = \text{Cl}$ ,  $\text{Br}$ ,  $\text{CH}_3$ ,  $\text{NO}_2$ ,  $\text{OCH}_3$ , were obtained according to ref.<sup>12</sup>. The compound *I*,  $\text{X} = \text{NH}_2$ , was prepared by reduction of the corresponding nitro derivative with 57% hydriodic acid. The melting points and analytical constants of the prepared compounds agreed with those reported in the literature.

The wavenumbers of the N—H stretching vibrations were measured in 1–10 cm cells in tetrachloromethane on a Zeiss UR-20 spectrophotometer. The concentration was chosen so that the maximum absorption would be 70–75%. The accuracy was  $\pm 0.5 \text{ cm}^{-1}$ . The linear correlations between the wavenumbers and substituent constants were calculated on a Hewlett Packard 9100B computer, using the standard program.

## RESULTS AND DISCUSSION

Dilute solutions of 6-substituted 2-benzothiazolamines *I* in tetrachloromethane exhibit in the region 3300–3600  $\text{cm}^{-1}$  two absorption bands corresponding to the symmetric and asymmetric N—H stretching vibration of the free  $\text{NH}_2$  group. The wavenumbers of these bands are listed in Table I.

TABLE I

Wavenumbers of the N—H Stretching Vibrations (in  $\text{cm}^{-1}$ ) and the Corresponding Substituent Constants for the 6-Substituted 2-Benzothiazolamines *I*

Substituent X	$\nu_s$	$\nu_{as}$	$\sigma_p$	$\sigma_p^-$
$\text{N}(\text{CH}_3)_2$	3 397	3 495	-0.83	-0.83
$\text{NH}_2$	3 397.5	3 494.5	-0.66	-0.66
$\text{OCH}_3$	3 399.5	3 498.5	-0.27	-0.27
$\text{CH}_3$	3 401.5	3 501.5	-0.17	-0.17
H	3 403	3 503	0	0
Cl	3 404	3 505.5	0.23	0.23
Br	3 404.5	3 506	0.23	0.23
SCN	3 406.5	3 510.5	0.70	—
$\text{COCH}_3$	3 407	3 510	0.50	0.87
$\text{COOC}_2\text{H}_5$	3 407	3 510.5	0.45	0.68
CN	3 408	3 513	0.63	1.00
$\text{NO}_2$	3 408.5	3 514	0.78	1.27

TABLE II

Statistical Parameters of the Linear Correlations of Wavenumbers of N—H Stretching Vibrations with Substituent Constants for the Series of Compounds *I* and *II*

$n$  Number of points in the correlation,  $r$  correlation coefficient,  $q$  slope,  $s_q$  standard deviation of  $q$ ,  $q$  intercept on the axis of wavenumbers,  $s_q$  standard deviation of  $q$ ,  $S$  residual sum of squares.

Series	Correlation	$n$	$r$	$q$	$s_q$	$q$	$s_q$	$S$
<i>I</i>	$\nu_s - \sigma_p$	12	0.984	7.50	0.43	3 402.7	0.20	0.75
<i>I</i>	$\nu_{as} - \sigma_p$	12	0.984	12.56	0.72	3 503.5	0.33	1.27
<i>I</i>	$\nu_s - \sigma_p^-$	11	0.982	5.92	0.37	3 402.1	0.27	0.81
<i>I</i>	$\nu_{as} - \sigma_p^-$	11	0.988	9.91	0.52	3 502.6	0.37	1.13
<i>II</i>	$\nu_s - \sigma$	63	0.936	22.42	1.08	3 395.3	1.92	3.46
<i>II</i>	$\nu_{as} - \sigma$	63	0.933	32.28	1.59	3 479.3	2.83	5.08
<i>II</i>	$\nu_s - \sigma^-$	59	0.946	18.40	0.83	3 394.9	1.86	3.26
<i>II</i>	$\nu_{as} - \sigma^-$	59	0.945	26.48	1.21	3 478.7	2.69	4.72

TABLE III

Wavenumbers of N—H Stretching Vibrations (in  $\text{cm}^{-1}$ , taken in  $\text{CCl}_4$ ) for Substituted Anilines and the Corresponding Substituent Constants

Substituent X—Y	$\nu_s$	$\nu_{as}$	$\sigma^a$	$\sigma^{-a}$	Ref. <sup>b</sup>
4-NH <sub>2</sub>	3 377	3 453	-0.66	-0.66	4
4-N(CH <sub>3</sub> ) <sub>2</sub>	3 379.5	3 456.5	-0.83	-0.83	4
4-OH	3 380	3 459	-0.36	-0.36	16
4-N(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub>	3 381	3 458	-0.92	-0.90	6
4-OC <sub>2</sub> H <sub>5</sub>	3 381	3 459	-0.25	-0.25	4
4-OCH <sub>3</sub>	3 381.5	3 459	-0.27	-0.27	4, 17
3,4-(CH <sub>3</sub> ) <sub>2</sub>	3 387	3 468	-0.24	-0.24	3, 4
4-CH <sub>3</sub>	3 389.5	3 471	-0.17	-0.17	4
4-C <sub>2</sub> H <sub>5</sub>	3 390	3 469.5	-0.15	-0.15	17, 18
4-C(CH <sub>3</sub> ) <sub>3</sub>	3 391.5	3 474	-0.20	-0.20	4
4-CH(CH <sub>3</sub> ) <sub>2</sub>	3 392.5	3 474	-0.15	-0.15	4
4-F	3 393	3 473.5	0.06	0.06	4, 17
3-CH <sub>3</sub>	3 393.5	3 479.5	-0.07	-0.07	5, 17
3-C(CH <sub>3</sub> ) <sub>3</sub>	3 394	3 477	-0.12	-0.12	5
3-CH(CH <sub>3</sub> ) <sub>2</sub>	3 395	3 480	-0.07	-0.07	5
3-C <sub>2</sub> H <sub>5</sub>	3 395	3 479	-0.07	-0.07	5
3,5-(CH <sub>3</sub> ) <sub>2</sub>	3 395	3 480	-0.14	-0.14	5
3-NH <sub>2</sub>	3 395.5	3 479.5	-0.16	-0.16	5, 18
H	3 395.5	3 481	0	0	4
3,4-(CH) <sub>4</sub>	3 396	3 481	0.04	—	4
3-OH	3 398	3 482	0.12	0.12	17
4-OCHF <sub>2</sub>	3 398	3 482	0.18	0.11	6
4-Br	3 398	3 483.7	0.23	0.23	4, 17, 18
4-Cl	3 398.5	3 482.3	0.23	0.23	4, 6, 17
3-OC <sub>2</sub> H <sub>5</sub>	3 398.5	3 482.5	0.15	0.15	4, 5
3-OCH <sub>3</sub>	3 399	3 483.5	0.12	0.12	4, 5, 17
4-SCH <sub>3</sub>	3 399	3 485.5	-0.05	-0.05	16
4-C <sub>6</sub> H <sub>5</sub>	3 399	3 485.5	-0.01	-0.01	4
3-COOCH <sub>3</sub>	3 400	3 487	0.32	0.32	5, 17
3-COCH <sub>3</sub>	3 400.5	3 487.5	0.38	0.38	4, 5
4-SH	3 400.5	3 488	0.15	—	16
4-CH <sub>2</sub> CN	3 401	3 487	0.07	—	4
4-OCF <sub>3</sub>	3 401	3 487	0.35	0.25	6
3-I	3 401	3 487	0.35	0.35	17
4-I	3 402	3 490	0.28	0.18	4
3,5-(OCH <sub>3</sub> ) <sub>2</sub>	3 402	3 487	0.23	0.23	5
3-Cl	3 402	3 490	0.37	0.37	4, 5, 18
3-Br	3 404	3 492.5	0.39	0.39	4
3-CF <sub>3</sub>	3 404	3 492	0.42	0.42	4
3-F	3 404.5	3 491	0.34	0.34	4, 5, 17
3-Cl, 5-OCH <sub>3</sub>	3 405	3 494	0.49	0.49	5

TABLE III  
 (Continued)

Substituent X—Y	$\nu_s$	$\nu_{as}$	$\sigma^a$	$\sigma^-^a$	Ref. <sup>b</sup>
3-CN	3 406	3 494·7	0·56	0·56	4, 5, 17
3-SO <sub>2</sub> CHF <sub>2</sub>	3 406	3 495	0·75	0·87	6
4-N=N—C <sub>6</sub> H <sub>5</sub>	3 406	3 498	0·64	—	4
4-CH=CHCF <sub>3</sub>	3 406	3 496	0·27	0·34	6
3-NO <sub>2</sub>	3 407	3 496	0·71	0·71	4, 5, 17, 18
4-COOCH <sub>3</sub>	3 408	3 495	0·45	0·64	17
4-COOC <sub>2</sub> H <sub>5</sub>	3 408	3 497	0·45	0·68	4, 17
4-OSO <sub>2</sub> CF <sub>3</sub>	3 408	3 496	0·53	0·49	6
4-SeCF <sub>3</sub>	3 408	3 497	0·38	0·53	6
4-CHF <sub>2</sub>	3 408	3 497	—	0·48	6
3,5-Br <sub>2</sub>	3 408	3 498	0·78	0·78	5
3-OCH <sub>3</sub> , 5-NO <sub>2</sub>	3 410	3 499	0·83	0·83	5
4-CF <sub>3</sub>	3 410	3 499	0·54	0·61	6
4-SCN	3 410	3 500	0·70	—	4
4-CF=CFCF <sub>3</sub>	3 410	3 501	0·46	0·66	6
4-COCH <sub>3</sub>	3 410	3 501·5	0·50	0·87	4, 18
4-SOCHF <sub>2</sub>	3 411	3 502	0·58	0·93	6
4-SOCF <sub>3</sub>	3 412	3 504	0·69	1·05	6
4-CN	3 412·5	3 504·5	0·63	1·00	4, 17
4-CH=CHSO <sub>2</sub> CF <sub>3</sub>	3 413	3 506	0·59	0·83	6
4-NO <sub>2</sub>	3 415·5	3 508	0·78	1·27	4, 17, 18
4-SO <sub>2</sub> CHF <sub>2</sub>	3 418	3 511	0·86	1·44	6
4-SO <sub>2</sub> CF <sub>3</sub>	3 420	3 516	0·93	1·65	6

<sup>a</sup> Values  $\sigma$  and  $\sigma^-$  are taken from ref.<sup>6,13-15</sup>; <sup>b</sup> references for the values  $\nu$ .

The wavenumbers of symmetric as well as asymmetric N—H stretching vibration of the compounds *I* afforded statistically significant correlations with the Hammett  $\sigma_p$  and the nucleophilic  $\sigma_p^-$  substituent constants. Statistical parameters of these correlations are given in Table II. When  $\sigma_m$  constants or arithmetic means of  $\sigma_p$  and  $\sigma_m$  constants are used in these correlations, statistical significance of the obtained linear relationships was substantially lower. The good correlation of the symmetric and asymmetric N—H stretching vibrations with  $\sigma_p$  or  $\sigma_p^-$  constants shows that in the series of the compounds *I* the electronic substituent effects are transmitted predominantly *via* the nitrogen hetero atom. The same results were obtained also by other authors<sup>1,2</sup>.

The transmission factor across the benzothiazole system can be calculated using substituted anilines as a reference series. Since for substituted anilines the litera-

ture<sup>4,6,7</sup> reports different relationships between wavenumbers of the N—H stretching vibrations and substituent constants, we gathered all available values of these wavenumbers in order to obtain a statistically significant series containing as great as possible number of experimental data. These values are given in Table III, together with the corresponding substituent constants. In cases where for a given compound *II* more wavenumber values were reported (within the range of 3 cm<sup>-1</sup>), we calculated their arithmetic means, except in the case of values measured under conditions of high resolution<sup>4</sup> which were taken directly.

It is seen from Table II that the correlations of symmetric as well as asymmetric N—H stretching vibrations of the compounds *II* with  $\sigma^-$  substituent constants are statistically more significant than the analogous correlations with the Hammett  $\sigma$  constants. This fact is also in accord with the results of Andrianov and collaborators<sup>7</sup> who, however, used a substantially smaller number of compounds for their correlations. The better correlations with the  $\sigma^-$  constants in the series of substituted anilines are due to the strong electron-donating mesomeric interaction of the amino group which is bonded directly to the benzene ring.

According to the definition of Charton<sup>19</sup>, the transmission factor  $\gamma(\text{BT})$  for the benzothiazole system can be calculated from the slopes of the linear correlations for the series of compounds *I* and *II*:  $\gamma(\text{BT}) = \rho(I)/\rho(II)$ . Table IV shows the values of the transmission factors  $\gamma(\text{BT})$  calculated in this way from the correlations based on the N—H stretching vibrations, given in this paper, as well as from correlations

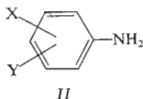
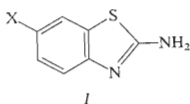


TABLE IV

Transmission Factors for the Benzothiazole System, Calculated on the Basis of Various Correlations

Correlation	$\nu_s-\sigma$	$\nu_{as}-\sigma$	$\nu_s-\sigma^-$	$\nu_{as}-\sigma^-$	$\delta-\sigma^a$	$\text{p}K_a-\sigma^b$
$\gamma(\text{BT})$	0.33	0.39	0.32	0.37	0.57	0.40

<sup>a</sup> Correlation of chemical shifts,  $\delta(\text{CH}_3)$ , for a series of seven 5- and 6-substituted 2-methylbenzothiazoles<sup>20</sup> and for a series of twenty two 3- and 4-substituted toluenes<sup>21</sup> with  $\sigma$  substituent constants; <sup>b</sup> correlations of  $\text{p}K_a$  values (50% ethanol, 25°C) with  $\sigma$  substituent constants for a series of six 5- and 6-substituted 2-benzothiazolecarboxylic acids<sup>1</sup> and for a series of nine 3- and 4-substituted benzoic acids<sup>22</sup>.

of other physico-chemical quantities, taken from the literature. The values of the transmission factors  $\gamma(\text{BT})$ , obtained from four different correlations of wavenumbers of the N—H stretching vibrations, are in good agreement. The mean value of the transmission factor, calculated from these data,  $\gamma(\text{BT}) = 0.35$ , compares well with the value of  $\gamma(\text{BT})$  calculated from the correlations of pKa values of the corresponding carboxylic acids.

## REFERENCES

1. Todesco P. E.: *Boll. Sci. Fac. Chim. Ind. Bologna* 23, 107 (1965).
2. Attanasi O., Bartoli G., Todesco P. E.: *Tetrahedron* 32, 399 (1976).
3. Krueger P. J., Thompson H. W.: *Proc. Roy. Soc. A* 243, 143 (1957).
4. Krueger P. J.: *Can. J. Chem.* 40, 2300 (1962).
5. Bryson A.: *J. Amer. Chem. Soc.* 82, 4858 (1960).
6. Titov E. V., Rybachenko V. I., Korzhenevskaya N. G., Yagupolskii L. M.: *Teor. Eksp. Khim.* 9, 642 (1973).
7. Andrianov V. F., Kaminsky A. Ya., Ivanov A. V., Ghitis S. S., Udris N. V., Gluzmann S. S., Buga S. I.: *Reakts. Sposobnost Org. Soedin*, 11, 477 (1974).
8. Wagner-Jaureg T., Helmert E.: *Ber. Deut. Chem. Ges.* 75, 935 (1942).
9. Heller G.: *J. Prakt. Chem.* 108, 257 (1924).
10. Straley J. M., Sagal J.: *U.S. 2 822 359 Chem. Abstr.* 52, 8570 (1958).
11. Kaye I. A., Roberts I.M.: *J. Amer. Chem. Soc.* 73, 4762 (1951).
12. Brewster R. Q., Danis F. B.: *J. Amer. Chem. Soc.* 58, 1364 (1936).
13. Hansch C., Leo A., Unger S. H., Ki Hwan Kim, Nikaitani D., Lien E. J.: *J. Med. Chem.* 16, 1207 (1973).
14. Tomasik P.: *Prace Naukowe Instytutu Chemii i Technologii Nafty i Wegla Politechniki Wroclawskiej*, Nr 19, Seria: Monografie Nr 5 (1974).
15. Titov E. V., Korzhenevskaya N. G., Kaplan L. M., Sedova L. N., Gandel'sman L. Z., Fialkov Yu. A., Yagupolskii L. M.: *Zh. Org. Khim.* 7, 2552 (1971).
16. Krueger P. J.: *Tetrahedron* 26, 4753 (1970).
17. Courville A., Peltier D.: *Bull. Soc. Chim. Fr.* 1967, 2164.
18. Califano S., Moccia R.: *Gazz. Chim. Ital.* 86, 1014 (1956).
19. Charton M.: *J. Org. Chem.* 26, 735 (1961).
20. Di Modica G., Barni E., Gasco A.: *J. Heterocycl. Chem.* 2, 457 (1965).
21. Marcus S. H., Reynolds W. F., Miller S. I.: *J. Org. Chem.* 31, 1872 (1966).
22. Jaffe H. H.: *Chem. Rev.* 53, 191 (1953).

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