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Abstract

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ESTIMATION OF THE RELATIVE ELECTRONEGATIVITY OF SUBSTITUENTS IN AROMATIC HETEROCYCLIC SYSTEMS BY POTENTIOMETRY

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In estimating the influence of substituents on an aromatic nucleus, the Lucas method (^{1}) is most often used; Lucas proposed measuring the strength (pK) of substituted benzoic acids in the para position and, on this basis, judging the degree of electropositivity or electronegativity of the substituent. The Lucas method, based on Lewis' s views (^{2}), was subsequently widely applied, especially by Ingold and his school. However, it is not easy for every substituent to synthesize the corresponding para-substituted benzoic acid. Moreover, the acid strength depends not only on the interaction of the substituent with the benzene ring, but is also, to some extent, determined by an additional interaction of the ring with the carboxyl group, by intermolecular interaction of groups, etc.

In studying the properties of pyrazoles, we found that the basicity of the pyrazole ring is directly dependent on the nature of the substituent attached to this ring.

Since the basicity of pyrazole is determined by the degree of basicity of the nitrogen atoms included in the pyrazole cycle, in this case we have the possibility of directly estimating the density of the electron cloud formed by the 6π electrons of the aromatic ring (or, in any case, that part of it concentrated on the nitrogen atoms). Pyrazoles are weak bases (close in basicity to dialkylanilines); therefore, in practice, it proved most convenient to measure not the basicity of the pyrazoles themselves, but the acidity of their sulfates. These sulfates are partially hydrolyzed, and the degree of their hydrolysis—and, correspondingly, the pH established in solution—characterizes the basicity of the compound. By choosing such conditions, we practically eliminated the influence of hydrogen bonds, which are strongly expressed in pyrazoles unsubstituted at nitrogen; to a considerable extent removed the influence of association of molecules and the intermolecular interaction of functions; although, of course, we introduced an additional interaction of sulfuric acid with the substituent. For most substituents, however, this interaction practically does not affect the general picture of the distribution of electron density.

For the work, an LP-58 vacuum-tube potentiometer with glass and calomel electrodes was used (adjustment was carried out with a buffer solution of pH 7). A weighed sample of 0.005 mole of the substance under investigation was weighed to an accuracy of two units in the fourth decimal place, dissolved in 25 ml of absolute methanol, 1 ml of 4.9732 N sulfuric acid was added from a microburet, and the pH was measured. Special experiments showed that an error in weighing of $±$0.0005 g and possible errors in measuring the methanol and acid practically do not change the pH value*. Under these conditions sulfuric acid itself showed pH 0.42. Upon introduction of the sample, the pH value increased, but not above 3.5. The potentiometer used by us, usually gives an accuracy of ±0.05 pH unit, but in comparative determinations and with daily adjustment of the potentiometer against a buffer solution, the difference in measurements did not exceed 0.02 pH unit. The pH values given below for 4-substituted solutions of dimethylpyrazoles and 5-substituted 1-phenyl-3-methylpyrazoles are averages of three measurements.

The pH values for solutions of 4-substituted 3,5-dimethylpyrazoles: for CH_3 3.47; H 3.12; $C_6H_5CH_2$ 3.02; J 1.27; Br 1.12; Cl 1.10; CH_3CO 0.92; NO 0.58; NO_2 0.47.

The pH values for solutions of 4-substituted 1-phenyl-3,5-dimethylpyrazoles: for CH_3 1.58; H 1.36; $C_6H_5CH_2$ 1.28; Br 0.77.

The pH values for solutions of 4-substituted 1-heptyl-3,5-dimethylpyrazoles: for CH_3 2.79; C_2H_5 2.73; C_3H_7 2.69; C_4H_9 2.68; H 2.35; $C_6H_5CH_2$ 2.28; Pyr CH_2* 1.78; CH_3CONH 1.37; C_6H_5CONH 0.97; CHO 0.93; J 0.85; Br 0.74; Cl 0.71; CH_3CO 0.66; C_6H_5CO 0.60; C_2H_5OCO 0.58; NO 0.57; NO_2 0.50.

The pH values for solutions of 5-substituted 1-phenyl-3-methylpyrazoles: for CH_3 1.36; CH_3S 1.25; C_2H_5O 1.22; H 0.63; α-furyl 0.61; Br 0.58; Cl 0.55; C_6H_5CO 0.54.

In the potentiometric determination by the indicated method of a series of 4-substituted 3,5-dimethylpyrazoles, it was found that the substances are arranged in a series fully corresponding to the Lucas series with respect to the degree of electronegativity of the substituent:

$$NO_2 > NO > CH_3CO > Cl \geq Br > J > C_6H_5CH_2 > H > CH_3$$

When the nitrogen of the ring is substituted by a phenyl group, the overall basicity of the compounds naturally decreases, but the series found is retained:

$$Br > C_6H_5CH_2 > H > CH_3$$

Conversely, when the nitrogen is substituted by an alkyl radical (a sufficiently large one—heptyl—was chosen), the overall basicity of the substances correspondingly increases (in comparison with the *N*-phenyl-substituted ones), without

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* Laboratory assistant T. A. Ivanova took part in the work.

disturbing the previously found sequence of influence of substituents located in position 4:

$$
\begin{aligned}
&NO_2 > NO > C_2H_5OOC > C_6H_5CO > CH_3CO > Cl \geq Br > J > \\
&> CHO > C_6H_5CONH > CH_3CONH > \text{Pyr } CH_2 > \\
&> C_6H_5CH_2 > H > C_4H_9 \geq C_3H_7 \geq C_2H_5 > CH_3.
\end{aligned}
$$

If the substituents are in another position, for example in 5-substituted 1-phenyl-3-methylpyrazoles, then here too the dependence found is preserved:

$$C_6H_5CO > Cl > Br > \alpha\text{-furyl} > H > C_2H_5O > CH_3S > CH_3$$

Thus, summarizing and comparing the data obtained, one can establish the following series, in which all members of the series preceding hydrogen impoverish the aromatic ring in electron charge (as compared with hydrogen), while those following hydrogen enrich the ring' s electron charge:

$$
\begin{aligned}
&NO_2 > NO > C_2H_5OOC > C_6H_5CO > CH_3CO > Cl \geq Br > J > CH_2O > \\
&> C_6H_5CONH > CH_3CONH > \alpha\text{-furyl?} > C_6H_5CH_2 > H > \\
&> C_2H_5O? > CH_3S? > C_4H_9 \geq C_3H_7 \geq C_2H_5 > CH_3
\end{aligned}
$$

The position in this series of the furyl residue, as well as of the groups C_2H_5O and CH_3S, requires additional clarification. Owing to the weak basicity of pyrazoles, in cases where an electron-acceptor substituent is located in position 4, pyrazole systems bind protons so weakly that the pH values of the mixture become close to the pH of a solution of sulfuric acid alone in methanol. Thus the scale of measurements, and consequently of the differences in pH values, is not the same for the beginning and the end of the series.

Thus, the difference between the basicity values of solutions of 4-nitroso- and 4-nitropyrazoles is 0.04 pH unit; whereas when 4-methyl- and 4-bu-

* Bis-(1-heptyl-3,5-dimethylpyrazolyl-4)-methane.

for thallipyrazoles the pH differs by 0.14; however, from this it cannot be concluded that the difference in basicity of the first pair of pyrazoles is smaller than the difference in basicity of the second pair.

The evaluation we propose of the influence of various functional groups on an aromatic nucleus, for which the basicity or acidity can be measured by potentiometry, can evidently also be extended to other heterocyclic systems.

The value of the method will be considerably greater when potentiometers with higher measurement accuracy are used. In this case our method, in which the influence of a substituent in a heterocyclic nucleus on the basicity (acidity) of the nucleus itself is evaluated, should reveal more subtle differences in structural changes than methods in which the influence of one substituent in an aromatic nucleus on another is evaluated. In our case, the length of the conjugated chain along which the influence is transmitted is shorter, and the mutual influence of the substituent and the nucleus should manifest itself more distinctly. Indeed, for example, we find a difference in the influence between iodine, bromine, and chlorine, which is not observed when evaluated by the method of two substituents.

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REFERENCES

[1] Lucas, J. Am. Chem. Soc., **48**, 1827 (1926). [2] Lewis, *Valence and the Structure of Atoms and Moleculs.* The Chemical Catalog Co., N. Y., 1923, p. 85, 139.

Note: Figure translations are in progress. See original paper for figures.