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SYNDONES AND SYNDONEIMINES. THE ALKALINE SPLITTING REACTION WITH 3- AND 3,4-SUBSTITUTED SYNDONEIMINES

L. E. Kholodov and V. G. Yashunskii

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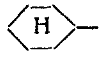
Alkaline splitting reaction equilibrium constants are determined polarographically for a series of 3-and 3,4-substituted syndoneimines. The stability of these heterocyclic compounds increases with decrease in electronegativity and increase in volume of substituents at positions 3 and 4. The steric effect is explained by a "broadening" of substituents at N_3 and C_4. Equilibrium constants for 3-substituted syndoneimines are correlated with Taft inductive and steric effects constants. The data obtained made it possible to determine the value of the energy of non-polar conjugation between the syndoneimine ring and the 4-phenyl ring, and it was found to be of the order of 2 kcal.

The literature [1-5] contains repeated statements regarding the unusual lability of the heterocyclic ring in syndoneimines. They cannot exist as bases, for when their salts (I) are neutralized, the syndoneimine ring opens to give N-nitroso derivatives of N-substituted α-aminonitriles (II). The present authors have previously investigated the kinetics and equilibrium state of this reaction for 3-isopropyl- [4] and 3-aryl- [5] derivatives, and in the case of the latter, the inductive nature of the effect of substituents on syndoneimine ring stability was demonstrated.

The present paper is concerned with a polarographic study of the equilibrium of syndoneimines with various substituents at positions 3 and 4. The logarithms of the reciprocals of the equilibrium constants (pK) are given in the table.

Expt. no.	R	R^1	i_{init}, ma	i_{equil}, ma	pH	pK	Average pK	σ* for R	E^c_s, for R	pK as calculated by Eq. 1
1	CH_3	H	1.75 1,74	1.29 0.91	6.20 6.55	6.65 6,60	6.65	0,00	0,00	6,63
2	C_2H_5	H	1,79 1,75	0.64 0.50	7.25 7.50	7.00 7,10	7.05	−0.10	−0.38	7.05
3	i-C_3H_7	H	1.74 1,72	0.91 0.57	7.55 7.90	7.60 7,60	7,60*	−0.19	−1.08	7.49
4	i-C_3H_7	CH_3	1.54 1.52	0.70 0.47	10.30 10.60	10.20 10.25	10,20	—	—	—
5	i-C_3H_7	CH_2Cl	1.64 1.64	0.55 0.43	9.05 9.30	8.75 8.85	8.80	—	—	—
6	n-C_4H_9	H	1,82 1.79	0.76 0,36	7.50 7.90	7.35 7.30	7.30	−0.13	−0.70	7.27
7		H	1.70 1.63	0,61 0.27	7.90 8.40	7.65 7.70	7.70	−0.15	−1.40	7.64
8	$ClCH_2CH_2$	H	1.68 1.65	1.03 0.56	6.10 6.55	6.30 6.25	6.30	+0.385	−1.21	6.25
9	$C_6H_5CH_2$	H	1.68 1.61	1.06 0.62	6.10 6.55	6.40 6.35	6.40	+0.215	−0.69	6.42
10	C_6H_5	H	1.91 2.01	0.45 0.91	6.70 6.30	6.20 6.20	6.20	+0,60	+0.25**	5,00
11	C_6H_5	CH_3	1.64 1.58	1.10 0.80	8.85 9.30	9.15 9.30	9.25	—	—	—
12	C_6H_5	C_6H_5	1.72 1.64	1.34 1.21	7.30 7.50	7.85 7.90	7.90	—	—	—

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*Reference [4] gives pK = 7.47, found spectrophotometrically for this compound.

**From [5].

It was shown that 4-substituted syndoneimines having non-aryl substituents at position 3 have equilibrium constants which do not obey the Taft equation when using the inductive constant σ^* (Fig. 1). If, then, the steric effect of substituents is taken into account as well as their inductive effect, and the constants σ^* and the steric constants E^c_s both simultaneously correlated with the found values of log K, the latter are found to be quite satisfactorily given by the equation (s = 0.04):

$$\lg K = -6.63 + 2.44\sigma^* + 0.46\, E^c_s. \qquad (1)$$

In other words, the stability of the syndoneimine ring falls with increase in electronegativity and decrease in volume of the substituent at position 3.

It is possible to show this graphically by linear relationships between the inductive component, vis., difference ($\log K - 0.46\, E^c_s$) and inductive constants σ^*, and correspondingly between the steric component ($\log K - 2.44\, \sigma^*$) and steric constants E^c_s (Figs. 1, 2).

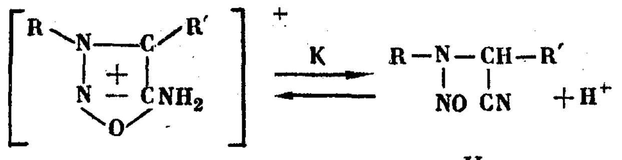
The values of E^c_s [6] differ from the Taft steric constants E_s by an amount equal to the correction for the hyperconjugation effect which Taft did not allow for in the standard reaction series, and

$$E^c_s = E_s + 0.306\ (n - 3),$$

where n is the number of α-hydrogen atoms in the substituent.

Because of the limited number of compounds with the same substituent at position 3 and a different one at position 4, it was not possible to evaluate quantitatively the effect of the substituent at position 4. However steric hindrance is also in evidence here. Thus substitution of hydrogen at position 4 in 3-isopropylsyndoneimine by the more electropositive methyl group, and by the more electronegative chloromethyl group gives increased ring stability, this being due to the undoubtedly greater volume of these two substituents as compared with hydrogen.

Steric hindrance caused by substituents at N_3 and C_4, can in all probability be ascribed to "broadening" of the substituents at N_3 and C_4, these having a planar configuration in the syndoneimine cation (hybridization, approximating to sp^2), acquiring a trigonal (p^3) and tetragonal (sp^3) configuration respectively in the nitrosonitrile II.



I

II

As the present authors have previously mentioned [5], a 3-phenyl substituent raises ring stability, as compared with a saturated substituent of the same volume and electronegativity, by 1.20 logarithmic units, equivalent to a non-polar conjugation energy of 1.6 kcal because of non-polar conjugation with the syndoneimine ring.

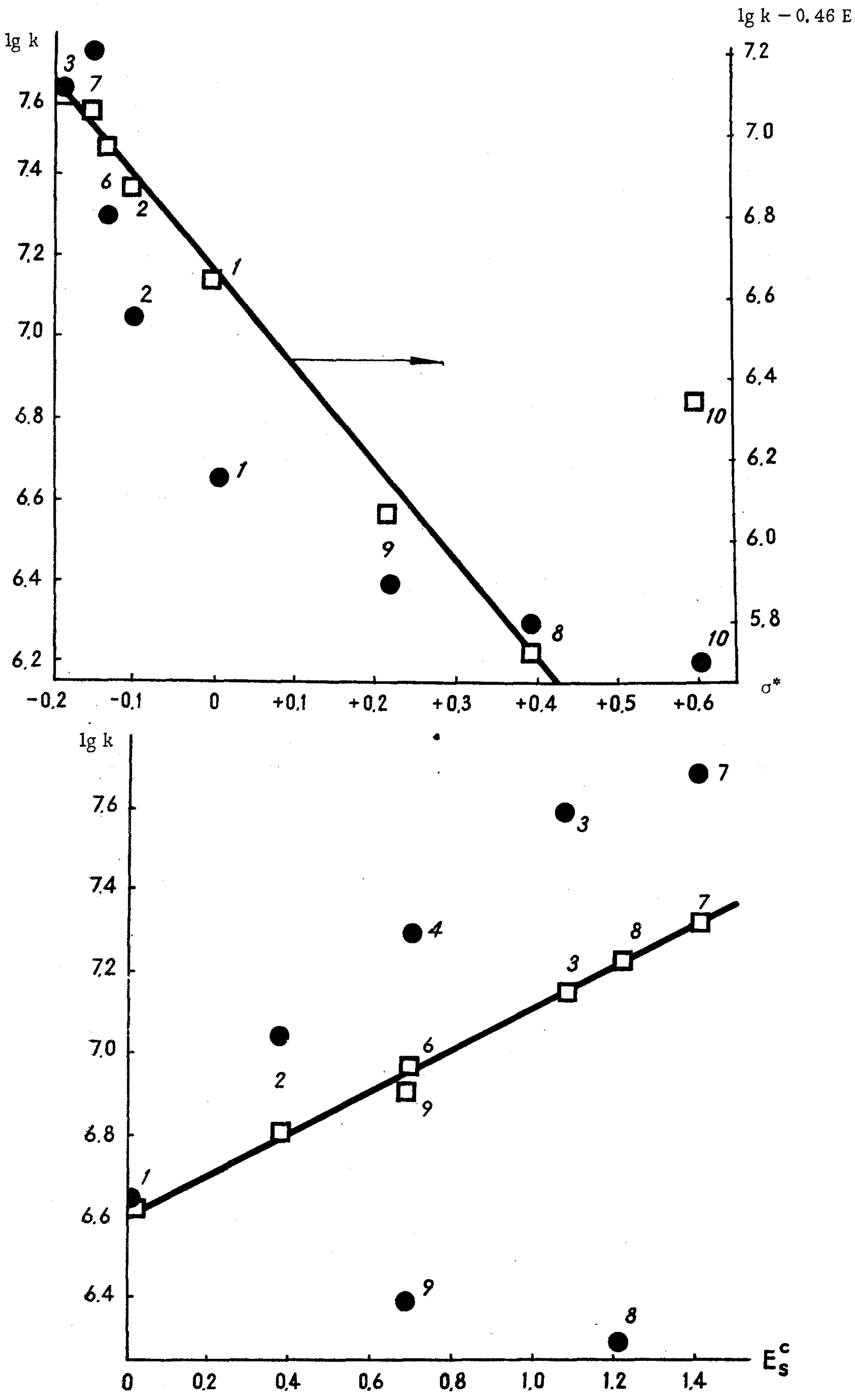
By comparing the equilibrium constants for 3-phenylsyndoneimine (Ia) and 3,4-diphenylsyndoneimine (Ib), it is possible to obtain an idea of the value for the 4-phenyl substituent. This is possible because the steric constants for phenyl and hydrogen substituents are about the same [5, 7], and differ little from the inductive constants: +0.60 and +0.49 respectively. Hence the increased strength of the ring of Ib as compared with that of Ia must be basically determined by the non-polar conjugation

$$\psi \cong \lg K_{Ib} - \lg K_{Ia} = -1.50$$

corresponding to an energy $E = 2.3\, RT,\ \psi \cong -2.0$ kcal. Hence the energy of non-polar conjugation of the 4- and 3-phenyl rings with the syndoneimine ring was shown to be of the same order of 1.6 to 2.0 kcal.

Experimental

Determinations were carried out using a PE-312 electronic polarograph, made by TsLA (Central Automation Laboratory). The cells were thermostatted at 25 ± 0.2°. A calomel electrode was used for comparison. The



Figs. 1 and 2. Experimentally determined equilibrium constants for alkaline splitting of syndoneimine hydrochlorides; E_s^c – steric constant, σ^* – inductive constant of a substituent, following Taft. ● – not allowing for, and □ – allowing for, steric (Fig. 1) and inductive (Fig. 2) effect. The number in Figs. 1 and 2 are those of the compounds given in the table.

parameters of the dropping mercury electrode were (in distilled water, broken circuit) t = 2.46 sec, m = 4.76 mg/sec (height 60 cm). Polarograms were read on specimens of a mixture of 2 ml of syndoneimine hydrochloride solution (10^{-3} mole/ml) with 25 ml of Britton-Robinson* universal buffer, with pH values calculated from previous experiments.

Height of the i_{init} wave. The solution was kept in the dark ** at 20° ± 1°C until equilibrium was established (5-15 days). Checks were made by periodically polarographing samples. Measurements at two pH values were made for each compound. After equilibrium had been reached, the polarogram of a solution comprised two waves (except Ia, see [9] (the first i_{equil} was the limiting current) with the more positive value of $E_{1/2}$, corresponding to the syndoneimine cation [8, 9], while the second corresponds to the nitrosonitrile II [9].

In the case of the polarographically hitherto uncharacterized 3-β-chloroethyl substituted compound, the values of $E_{1/2}$ found (relative to a saturated calomel electrode, pH 7.4) were: for cation I, 0.81 V (calculated according to [8]: 0.79 V), for nitrosonitrile II, 1.01 V (calculated according to [9]: 1.00 V).

Constants were calculated using formula

$$pK = pH + \lg \left(\frac{i_{equil}}{i_{init} - i_{equil}} \right).$$

It has previously been shown that the values of the limiting currents of reduction waves of cations I under selected conditions are directly proportional to the concentration of cation I.

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Ordzhonikidze All-Union Chemical-Pharmaceutical
Scientific Research Institute, Moscow

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* Potassium chloride (0.3 mole/l) was used for maintaining the ionic strength of the buffer solutions.

** In the case of 3-phenylsyndoneimine hydrochloride (Ia), it was shown that storing an aqueous solution (10^{-3} M) for 30 days in the light led to 70% of the compound decomposing, while a like solution kept in the dark remained practically unchanged.