

Polarographic study of the hydrolysis of 3-anil-(*p*-amino)isatin in alkaline medium

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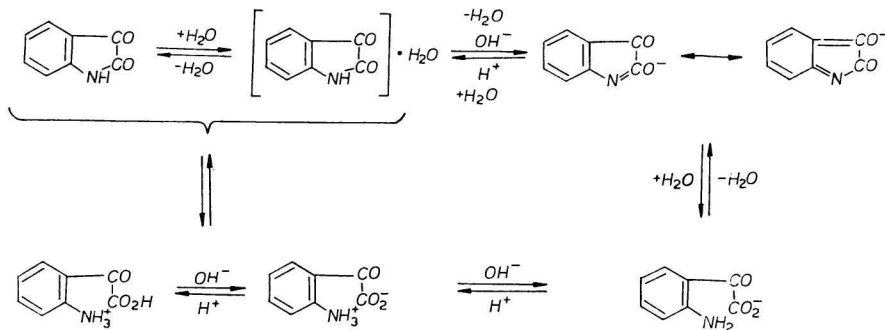
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The kinetics of hydrolysis of the α -anil-(*p*-amino)isatic acid anion in alkaline medium was investigated and the activation parameters of this reaction were determined. It has been found that there are two parallel processes taking place in the course of that hydrolysis. These processes are controlled by general base catalysis. On the basis of these results a general view of the mechanism of the reaction under investigation is presented.

It is well known that isatin in solutions exists in different tautomeric forms the occurrence of which is controlled by the acidity of solution [1]. The formation of these forms may be explained by the Scheme 1.



Scheme 1

These forms have been proved by polarographic as well as spectral methods [2]. The increase in the alkalinity of isatin solutions to pH 13 results in the quantitative transformation of this substance into the last form of above scheme, which is the anion of isatic acid.

The base hydrolysis of isatin substituted in position 3 is often applied in the syntheses of isatin and its derivatives [3–8].

The aim of this study is to elucidate the kinetics of hydrolysis of the α -anil-(*p*-amino)isatic acid anion in an alkaline aqueous solution containing 20 volume % of *n*-propyl alcohol. The resulting products of this reaction are *p*-phenylenediamine and isatic acid.

Experimental

3-Anil-(*p*-amino)isatin was prepared according to [9]. The substance prepared was characterized by melting point (240–242°C), infrared and ultraviolet spectra. The chemical grade chemicals used were purified by crystallization or distillation.

The kinetic measurements were carried out by means of a polarograph LP 60 equipped with an electron-tube recorder EZ 2. A Kalousek thermostatted vessel with separated calomel electrode was used. During measurements a constant temperature was held by means of a Hoespler ultrathermostat. Oxygen was removed from reaction system by bubbling through nitrogen. The hydrolysis was studied at ionic strength $\mu = 1$ in alkaline aqueous medium containing 20 volume % of *n*-propyl alcohol, which has a sufficiently high boiling point, is miscible with water and increases the solubility of the substance. The ionic strength was held constant by means of KCl additions. The kinetic measurements were performed by recording the polarographic waves at regular time intervals as well as by recording continuously the decrease in wave heights. Numerical values of reaction rate constant were established graphically from the limiting current values. The reactions were followed in time intervals exceeding their half completion.

The values of rate constants found are an average of 4–5 measurements. The calculation of activation energy and frequency factor was made by the method of least squares. The numerical value of frequency factor was used for the estimation of activation entropy. It was found graphically that the experimental values of rate constant are in accordance with the Arrhenius equation accurate to $\pm 3.5\%$. The calculations were carried out by means of an automatic computer Odra 1013.

In order to examine the reaction, the hydrolysis products were isolated. 3-Anil-(*p*-amino)isatin (1.5 g) was dissolved in 1 M solution of NaOH (400 ml). The mixture of water (50%) and ethyl alcohol (50%) was used as solvent. Ethyl alcohol was chosen instead of *n*-propyl alcohol because it can be distilled off after hydrolysis more easily than *n*-propyl alcohol. The solution thus prepared was heated on a water bath at 60°C. The course of hydrolysis was followed polarographically. After hydrolysis (90 minutes) alcohol was distilled off *in vacuo*. *p*-Phenylenediamine was extracted from aqueous solution with benzene. After separation and concentration of the benzene solution, the crystals of *p*-phenylenediamine were obtained. Yield 0.63 g of *p*-phenylenediamine, *i.e.* approximately 90% of theoretical amount.

The aqueous layer was neutralized with hydrochloric acid and acidified gently up to pH 5. Subsequently isatin separated from the solution. It was isolated, dissolved in 50% ethyl alcohol from which it crystallized after concentration. Yield 0.37 g of isatin, *i.e.* about 40% of theoretical amount. The reduced yield of isatin may be explained on the basis of results reported by Hofmann [10].

Results and discussion

Fig. 1 illustrates the polarographic examination of temporal course of the hydrolysis of α -anil-(*p*-amino)isatin acid in alkaline medium. Since it is known that the reduction of carbonyl group usually takes place at half-wave potentials more negative than the reduction of $>C=N-$ bond [11], it may be assumed that the wave at more positive potentials belongs to cathodic reduction of double bond between carbon and nitrogen whereas the wave at more negative potentials belongs to hydrolytically freed isatin which occurs in the form of isatin acid anion [2] in alkaline medium. The sum of heights of both waves continues to decrease during the hydrolysis of α -anil-(*p*-amino)isatin acid

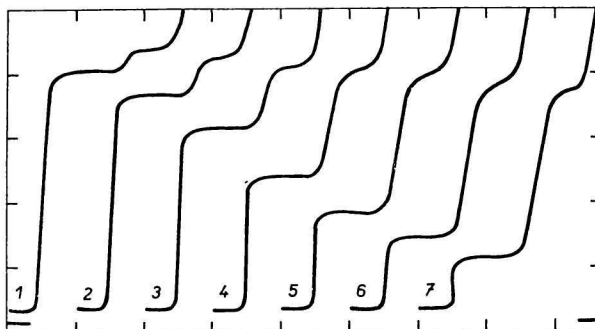


Fig. 1. Temporal course of the hydrolysis of α -anil-(*p*-amino)isatic acid.

10^{-3} M solution of this substance in 80% water, 20% *n*-propyl alcohol, and 1 M-NaOH; $t = 60^\circ\text{C}$, ionic strength $\mu = 1$.

Half-wave potentials measured against SCE from -500 mV, abscissa 200 mV, sensitivity 20 mA for full deflection.

1. 1 min; 2. 5 min; 3. 10 min; 4. 20 min; 5. 30 min; 6. 40 min; 7. 50 min.

what confirms the results of paper [10] because the products of subsequent decomposition of isatic acid *i.e.* aniline and oxalic acid are in the solutions investigated non-reducible.

It follows from the variation of $\log i_0/i$ with time for the first wave that this hydrolysis in the medium consisting of 1 M-NaOH and a mixture of water (80%) and *n*-propyl alcohol (20%) has the character of first-order reaction. A compilation of the average experimental values of rate constants as well as the values calculated from the Arrhenius equation by the least-square method is given in Table 1.

The corresponding activation parameters are: activation energy $E = 17.3 \pm 0.6$ kcal mol $^{-1}$, frequency factor $A = (1.2 \pm 0.25) \times 10^8$ s $^{-1}$, and activation entropy $\Delta S = 23.8 \pm 1.9$ cal K $^{-1}$ mol $^{-1}$.

The study of the influence of alkalinity on the numerical values of rate constants showed that these values increased linearly with the concentration of hydroxyl ions

Table 1

Average measured and calculated values of the overall rate constants for the hydrolysis of α -anil-(*p*-amino)isatic acid anion at varying temperatures 1 M-NaOH, 20% *n*-propyl alcohol, ionic strength $\mu = 1$

t [$^\circ\text{C}$]	$10^2 \cdot k_{\text{exp}}$ [min $^{-1}$]	$10^2 \cdot k_{\text{calc}}$ [min $^{-1}$]
40	0.63	0.61
45	0.91	0.94
50	1.41	1.44
55	2.20	2.17
60	3.23	3.22
65	4.91	4.75
70	6.90	6.91

(Fig. 2). The graphical analysis of this relationship which may be expressed by an equation of straight line $k = k_1 + k_2 c_{\text{NaOH}}$ enabled us to determine the catalytic coefficient k_2 and constant k_1 (Table 2).

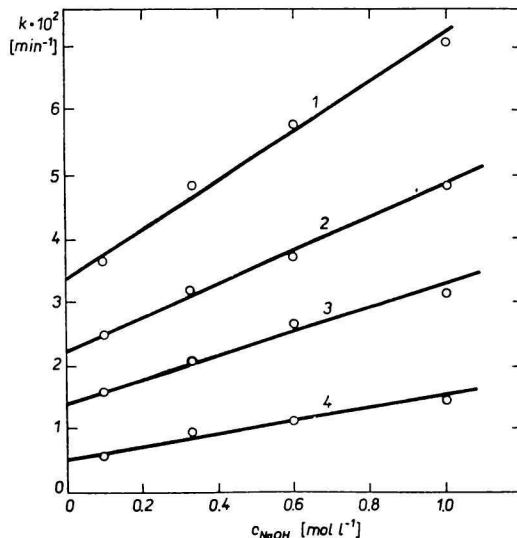


Fig. 2. Relationship between the measured rate constant and the OH^- ion concentration. 10^{-3} M solution of α -anil-(*p*-amino)isatic acid in 80% water and 20% *n*-propyl alcohol, ionic strength $\mu = 1$.

1. $t = 70^\circ\text{C}$; 2. $t = 65^\circ\text{C}$; 3. $t = 60^\circ\text{C}$; 4. $t = 50^\circ\text{C}$.

Since the rate constant depended relatively slightly on the ionic strength, which was held constant, it may be assumed that k_2 expresses only the effect of OH^- ions on the reaction rate while k_1 expresses the rate constant in pure water. For this reason the hydrolysis of 3-anil-(*p*-amino)isatin in alkaline medium takes place in two parallel processes. In the first case an immediate reaction between a molecule of reactant and

Table 2

Rate constant k_1 and catalytic coefficient k_2 for the hydrolysis of α -anil-(*p*-amino)isatic acid anion at varying temperatures
1 M-NaOH, 20% *n*-propyl alcohol, ionic strength $\mu = 1$

t [$^\circ\text{C}$]	$k_1 \cdot 10^2$ [min^{-1}]	$k_2 \cdot 10^2$ [$\text{min}^{-1} \text{mol}^{-1} \text{l}$]
50	0.5	0.9
60	1.4	1.6
65	2.3	2.2
70	3.4	3.3

a molecule of water proceeds, while in the second case the reaction is catalyzed by OH^- ions. As OH^- ions as well as water molecules are of nucleophilic character it may be supposed that in either case the first step involves bonding of the corresponding particles on electron deficiency of α -carbon in α -anil-(*p*-amino)isatic acid. The decay of the intermediate thus formed proceeds immediately in non-catalyzed reaction while it requires an interaction with another water molecule in the case of catalyzed reaction.

References

1. Sumpter, W. C. and Miller, F. M., *Heterocyclic Compounds with Indole and Carbazole Systems*, p. 115. Interscience, New York, 1954.
Sumpter, W. C., Williams, J. I., Wilken, P. H., and Willoughby, B. L., *J. Org. Chem.* **14**, 713 (1949).
- Stollé, R., Bergdol, R., Luther, M., Auerhahn, A., and Waker, W., *J. Prakt. Chem.* **118**, 1 (1928).
4. Giovannini, E. and Portmann, J., *Helv. Chim. Acta* **31**, 1375 (1948).
5. Martinet, J., *C. R. Acad. Sci. (Paris)* **166**, 851, 998 (1918).
6. Bonnefoy, J. and Martinet, J., *C. R. Acad. Sci. (Paris)* **172**, 220 (1921).
7. Möhlau, R. and Litter, H., *J. Prakt. Chem.* **73**, 469 (1906).
8. Engelhardt, A., *J. Prakt. Chem.* **65**, 260 (1902).
9. Binz, A. and Heuter, R., *Ber.* **48**, 1038 (1915).
10. Hofmann, A. W., *Justus Liebigs Ann. Chem.* **53**, 11 (1845).
11. Zuman, P., *Chem. Listy* **48**, 94 (1954).

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