

**HYDROLYSIS KINETICS AND MECHANISM
OF 3-N,N-DIETHYLAMINOPHENYL N'-METHYLCARBAMATE
AND 3-(N'-METHYLCARBAMOYLOXY)-N-METHYL-
-N,N-DIETHYLANILINIUM IODIDE***

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Hydrolysis of 3-N,N-diethylaminophenyl N'-methylcarbamate and 3-(N'-methylcarbamoyloxy)-N-methyl-N,N-diethylanilinium iodide has been followed in the range H_0 -3 to 0 and pH 0 to 14. The latter carbamate is hydrolyzed according to the described mechanisms and the pH profile of the hydrolysis has a similar course as the dependences measured earlier. On the contrary, the former carbamate shows a change in the pH region of spontaneous solvolysis, which is ascribed to protonation of the diethylamino group. The measurements results support the mechanism of spontaneous solvolysis suggested earlier.

The earlier papers¹⁻³ give the hydrolysis mechanisms and rate constants of N-alkyl and/or N-arylcarbamates. The hydrolysis rate constants at various pH values were determined for a number of substituted N-methylphenylcarbamates^{2,4,5}. In all the mentioned cases the derivatives studied contained substituents the character of which did not change with pH of the medium.

In this work we have dealt with the hydrolysis of 3-N,N-diethylaminophenyl N-methylcarbamate (I) whose diethylamino group is protonated in acid medium, which affects the hydrolysis rate of its carbamoyl group. For comparison we have further followed the hydrolysis of the analogous 3-N,N-diethylaminophenyl derivative II whose substituent does not undergo protonation. The dependence of the hydrolysis rate constant on the dielectric constant of medium has been followed to support the mechanism of alkaline hydrolysis of carbamates.

EXPERIMENTAL

Reagents

3-N,N-Diethylaminophenyl N'-methylcarbamate (I). 16.4 g 3-N,N-diethylaminophenol was dissolved in 20 ml tetrahydrofuran, and 10 ml methyl isocyanate was added to the solution. The reaction was catalyzed with 2 ml triethylamine⁶. After one day standing the precipitated crystals

* Part VI in the series Carbamates; Part V: This Journal 39, 281 (1974).

were collected by suction and purified by crystallization from a mixture benzene — n-heptane; m.p. 83–86°C. For $C_{12}H_{18}N_2O_2$ (222.3) calculated: 64.84% C, 8.16% H, 12.60% N; found: 64.92% C, 8.14% H, 12.57% N.

3-(*N'*-Methylcarbamoyloxy)-*N*-methyl-*N,N*-diethylanilinium iodide (II). 5 g carbamate I was dissolved in 100 ml benzene and treated with 20 ml methyl iodide. The mixture was heated under reflux one day, and the product was precipitated by addition of 100 ml n-hexane. Crystallization and purification was carried out from the mixture chloroform–n-hexane; m.p. 152–153.5°C. For $C_{13}H_{21}N_2O_2$ (364.2) calculated: 42.87% C, 5.81% H, 7.69% N; found: 42.55% C, 5.51% H, 7.83% N.

Kinetic Measurements

These measurements were described in our previous papers^{1,3} and the rate constants were transformed to the temperature 25°C graphically⁷ using Eq. (1), where k , E_a and T stand for the rate constant in s^{-1} , activation energy in kJ/mol, and absolute temperature in K, respectively.

$$\log k = \log k_0 - E_a / (19 \cdot 147 \cdot T) \quad (1)$$

Dissociation constants of 3-*N,N*-diethylaminophenol were obtained by the spectrophotometric method⁸. The wavelength 255 nm was chosen from spectral data and used for measurements of the both dissociation constants: $pK_1 = 6.36 \pm 0.12$; $pK_2 = 10.32 \pm 0.04$.

RESULTS AND DISCUSSION

Hydrolysis of the Carbamates I and II in Alkaline Medium

Dependence of the hydrolysis rate constants of these carbamates on pH (H_0) is given in Fig. 1. In the region pH 8 to 12 the both carbamates show linear dependence on OH^- ion activity, the slope of $\log k$ vs pH being unity. In this region the studied compounds behave as the carbamates described earlier^{2,9}, i.e. the hydrolysis goes

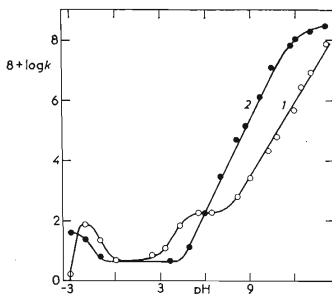
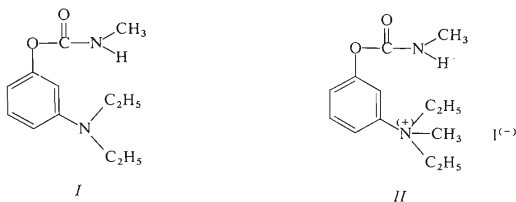


FIG. 1

Dependence of the Logarithm of Solvolysis Rate Constants of the Carbamates I (1) and II (2) on pH at 25°C

via ElcB mechanism. This mechanism is confirmed also by the behaviour of the carbamate *II* in the pH region 12 to 14, where the slope of the dependence $\log k$ vs pH approaches zero in accordance with the substrate being fully ionized and the overall reaction rate being determined by decomposition of the anion. This decomposition is independent of pH.



The mechanism of the carbamate hydrolysis follows indirectly also from the dependence $\log k$ vs dielectric constant of the medium, which was determined for the solvolysis of the carbamate *I* and 4-nitrophenyl acetate. The values obtained are given in Table I. The dependence found is linear, and the difference between the slopes (-0.55 and -1.49 for 4-nitrophenyl acetate and carbamate *I*, respectively) indicates different reaction mechanisms: the greater influence of dielectric constant of medium in the case of carbamate *I* agrees with the polarity of medium affecting both the pre-

TABLE I

Ethanolysis Rate Constants of 4-Nitrophenyl Acetate (k in s^{-1}) and Carbamate *I* (k' in s^{-1}) at pH 10.77 at 25°C

The ionic strength was not adjusted.

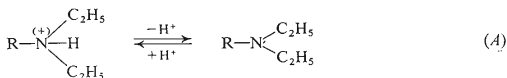
| $[C_2H_5OH]$ | $100/\epsilon$ | $[CO_3^{2-}] \cdot 10^3$ | $k \cdot 10^3, ^a$ | $k' \cdot 10^4, ^b$ |
|--------------|----------------|--------------------------|--------------------|---------------------|
| 0.00 | 1.26 | 19.2 | 23.92 | 14.46 |
| 1.81 | 1.35 | 17.3 | 15.51 | 7.59 |
| 4.05 | 1.44 | 15.4 | 14.60 | 4.68 |
| 6.75 | 1.55 | 13.4 | 11.80 | 1.66 |
| 10.20 | 1.66 | 11.5 | 7.71 | — |
| 14.70 | 1.81 | 9.6 | 5.95 | — |
| 21.50 | 2.00 | 7.7 | 3.62 | — |

^a Concentration of 4-nitrophenyl acetate was $1 \cdot 10^{-4}$ mol l^{-1} ; ^b concentration of the carbamate *I* was $1.67 \cdot 10^{-4}$ mol l^{-1} .

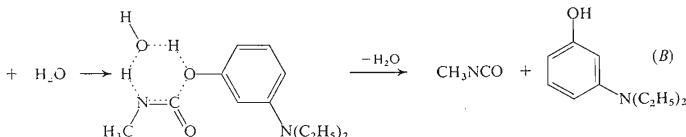
-equilibrium and the decomposition of the conjugated base. In this region the both carbamates fit in their log k values the formerly measured series of 3- and 4-substituted carbamates having the reaction constant values $\rho = 2.8$ (120°C; ref.²), $\rho = 2.5$ (25°C; ref.⁵). At pH 10.5 the difference in log k values of the carbamates *I* and *II* is 2.5, and from the known substituent constant values ($\sigma_{3-\text{N}(\text{CH}_3)_2} = 0.88$; $\sigma_{3-\text{N}(\text{CH}_3)_2} = -0.21$; ref.¹⁰) it is possible to estimate the reaction constant value $\rho = 2.3$, which quite agrees with the abovementioned values and highly exceeds the reaction constant values given for hydrolysis of *N,N*-dimethylphenyl carbamates going via $B_{Ac}2$ mechanism ($\rho = 1.00$; ref.¹¹).

Hydrolysis of the Carbamates *I* and *II* in pH Region 0 to 8

The dependence log k vs pH shows different behaviour of the two carbamates in this pH region. The carbamate *II* profile fits the set of pH profiles of the carbamates studied earlier, the hydrolysis rate being pH independent in the pH region 0 to 5. In this respect the carbamate *II* behaves as the 3-nitro derivative. On the contrary, the carbamate *I* shows two pH-independent sections in the abovementioned region (pH 0 to 2 and 5 to 7) separated by an ascending section and differing in the rate constant values by a factor of about 30. This different behaviour is ascribed to protonation of 3-diethylamino group, so that the protonated and the non-protonated forms of the carbamate *I* are hydrolyzed at pH 0–2 and 5–7, respectively. The acceleration of the spontaneous hydrolysis in the pH region 2 to 5 is due to increasing concentration of the non-protonated form of the substrate (Eq. (A)). The non-



-protonated diethylamino group polar effect affects favourably the electron situation in the intermediate suggested¹⁰ for the spontaneous solvolysis (Eq. (B)) and facilitates



its decomposition to the products. The proposed mechanism is also supported by good relation between the determined p*K* value of 3-*N,N*-diethylaminophenol

($pK_A = 6.36$) and pK value of the carbamate *I* ($pK_A = 4.6$) obtained from kinetic data. The difference between these experimental values is 1.76. On the basis of the calculation carried out according to the Hammett equation it can be expected that pK of the carbamate *I* will be lower than that of the phenol by 1.78 units. For this calculation we have used the following values: $\rho = 2.5$ (ref.⁵); $\sigma_{3-OH} = 0.01$; $\sigma_{3-OCNHCH_3} = 0.71$ (ref.¹²).

Hydrolysis of the Carbamates I and II in Acid Medium

This reaction follows the $A_{Ac}2$ mechanism¹, which is confirmed by the slope of the dependence $\log k$ vs H_0 being equal to unity. In the region above $H_0 - 2$ the two substrates behave differently. The carbamate *I* is completely protonated at this H_0 at the methylcarbamoyl group, and its decomposition rate reaches maximum. Towards higher H_0 values its decomposition rate abruptly decreases. This decrease is explained by decreased water activity in the reaction mixture². On the contrary, with the carbamate *II* the maximum value of the reaction rate in acid region is reached at $H_0 - 3$. With respect to possible decomposition of the compounds *I* and *II*, the measurements were not carried out at higher H_0 values.

REFERENCES

1. Vontor T., Socha J., Večeřa M.: This Journal 37, 2183 (1972).
2. Vontor T., Večeřa M.: This Journal 38, 516 (1973).
3. Vontor T., Večeřa M.: This Journal 38, 3139 (1973).
4. Hegarty A. F., Frost L. N.: J. Chem. Soc. Perkin II, 1973 1719.
5. Dittert L. W.: Thesis. University of Wisconsin 1961; Diss. Abstr. 22, 1837 (1961).
6. Baker J. W., Holdsworth J. B.: J. Chem. Soc. 1947, 713.
7. Jungers J. C.: *Chemická kinetika*, p. 142. Published by Nakladatelství ČSAV, Prague 1963.
8. Albert A., Serjeant E. P.: *Ionisation Constants*, p. 9. Wiley, London 1962.
8. Christenson I.: Acta Chem. Scand. 18, 904 (1964).
10. Cohen S. G., Streitwieser A., Taft R. W.: *Progress in Physical Organic Chemistry*, p. 506. Izd. Mir, Moscow 1967.
11. Vontor T., Drobilič M., Socha J., Večeřa M.: This Journal 39, 281 (1974).
12. Štohandl J., Večeřa M.: This Journal, in press.

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