REACTION OF 4-CHLOROBENZENEDIAZONIUM CHLORIDE WITH L-PROLINE, SARCOSINE, AND DL-ALANINE

Viktor MEJSTŘÍK, Petr GRYGA and Miroslav MATRKA

Section of Toxicology,
Research Institute of Organic Syntheses, 532 18 Pardubice - Rybitví

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The rates of reactions of substituted phenyldiazonium salts with the title amino acids were estimated in the pH range 6·5—10·5. The reaction product of 4-chlorobenzenediazonium chloride and L-proline was isolated and its triazene structure was shown.

Considerable attention has been paid to reactions of arenediazonium salts with primary or secondary amines or with ammonia. The products formed – triazenes (diazoamino compounds) – were of commercial interest as one of the components in wool dyeing. That is why preparation of these compounds and kinetics of the respective reactions were dealt with in a number of papers[1–6]. Only recently, however, industrial production of these compounds was stopped, as it was found that triazenes are biologically active compounds causing tumour formation in nervous centres and brain[7]. Some types of triazenes are used as cytostatics nowadays[8].

Similarly, aminocarboxylic acids can react to give triazenes, too. Eagle and Vickers[9] were the first authors who dealt with this reaction predominantly from preparative point of view (the reaction studied was that of 4-sulfobenzenediazonium chloride with a number of aminocarboxylic acids). Results of this and other studies can be summarized by a statement that the reaction produces triazene as the main product besides a certain amount of the respective pentazadiene and, according to the reaction conditions, decomposition products of the arenediazonium salt[10,11]. The reaction can be expressed by the following equation:

$$\mathrm{ArN_2^{(+)}} + \mathrm{NH_2CHRCOO^{(-)}} \rightarrow \mathrm{Ar{-}N{=}N{-}\overset{(+)}{N}H_2CHRCOO^{(-)}} \rightarrow$$

$$\rightarrow \mathrm{Ar{-}N{=}N{-}NHRCOOH}\,.$$

Much less attention was paid to kinetics of this reaction[12]. The aim of the present communication is to verify and complete the available data.

EXPERIMENTAL

The amines used were purified by crystallization or distillation and titrated with sodium nitrite solution. The amines were converted into the corresponding arenediazonium salts by usual methods. The reactions were carried out in aqueous Britton–Robinson buffers of specified ionic strength.

The reactions were followed in a Specord UV VIS spectrophotometer with a temperated cell compartment as follows: the 2 cm cell was filled with 6 ml buffer, and 10 µl $5 . 10^{-1}$ mol l^{-1} aminocarboxylic acid was injected thereto by a microdoser. The solution was temperated for about 15 min, and 20 µl $1 . 10^{-2}$ arenediazonium salt solution was injected. After mixing the solution, the recorder was started. pH of each sample was measured after kinetic measurements. This procedure was repeated at least three times with each sample, and average value of the rate constant was used for evaluation.

The rate constants (k, min^{-1}) were calculated from the equation of pseudomonomolecular reaction.

Reaction of 4-chlorobenzenediazonium chloride with L-proline. 4-Chloroaniline (1·276 g, 0·01 mol) was dissolved in warm concentrated hydrochloric acid (2·72 ml, 0·03 mol), the solution was cooled and diazotized by addition of sodium nitrite (0·69 g, 0·01 mol). Excess nitrous acid was removed by addition of amidosulphuric acid. Solution of 1·151 g (0·01 mol) L-proline in 20 ml water was treated with 28 ml 2·5 mol l^{-1} sodium carbonate, and the arenediazonium salt solution was added drop by drop at about 3°C with stirring (the presence of diazonium salt was checked by reaction with 1-amino-8-hydroxynaphthalene-3,6-disulphonic acid). After the reaction was completed, 15 g sodium chloride was added, and the separated solid was collected by suction, washed with little diethyl ether, mixed with about 40 ml acetone, again collected by suction, and dissolved in 30 ml methanol. The solvent was partially evaporated by bubbling through air, the separated crystals were washed with diethyl ether and collected by suction. A second portion of the product was obtained from the mother liquor by cooling in ice. The overall yield was 85%. For $C_{11}H_{11}N_3NaO_3$ (275·3) calculated: 47·94% C, 4·02% H, 15·25% N; found: 47·15% C, 4·30% H, 15·15% N. Structure of the product was verified by ^1H NMR spectrum. Qualitative test: a sample was dissolved in little hydrochloric acid (1 mol l^{-1}) and treated with 1-phenylaminonaphthalene-8-sulphonic acid (about 1% solution in about 2 mol l^{-1} acetic acid) to give a blue-violet colouration.

The chromatography was carried out on Silufol UV 254 in ethanol–water (3 : 2), detection with 0·5% solution of 1-phenylaminonaphthalene-8-sulphonic acid in 1 : 1 mixture of methanol and 1 mol l^{-1} hydrochloric acid.

RESULTS AND DISCUSSION

This study of reactions of arenediazonium salts with aminocarboxylic acids was directed primarily to determination of influence of pH. The measurements were carried out up to the pH region corresponding to conversion of arenediazonium ion into unreactive arenediazotate, *i.e.* in the pH range in which the reaction rate increases with increasing hydroxonium ion concentration. Results of the measurements are given in Table I for 4-chlorobenzenediazonium chloride and sarcosine, glycine and DL-alanine, in Table II for benzenediazoniumchloride and L-proline, wherefrom a considerable effect of substituent in arenediazonium salt on the reaction rate can be seen: The reaction is accelerated by electronegative substituents (Fig. 1).

From Table II and Fig. 2 it follows that the reaction rates of 4- and 3-chlorobenzenediazonium chlorides with L-proline increase linearly with increasing pH. Hence it can be presumed that the aminocarboxylic acid with non-protonated amino group is the reactive species in this region, concentration of this form being increased with increasing pH. This finding is supported also by comparison of the reaction rates of sarcosine, glycine and alanine with 4-chlorobenzenediazonium chloride;

TABLE I

pH Dependence of rate constants (log k) of reactions of 4-chlorobenzenediazonium chloride with some aminocarboxylic acids at 20°C at ionic strength $I = 0{\cdot}1$

Amino-carboxylic acid	7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5
Sarcosine	0·657	1·066	1·545	1·920	2·067	2·158	2·678	—
Glycine	—	—	0·726	1·214	1·430	1·885	2·428	2·621
DL-Alanine	—	—	—	0·760	1·266	1·758	2·059	2·336

TABLE II

pH Dependence of rate constants (log k) of reactions of substituted benzenediazonium chlorides with L-proline at 20°C at ionic strength $I = 0{\cdot}1$

Substituent	6·5	7·0	7·5	8·0	8·5	9·0	9·5	10·0
4-Cl	—	0·565	0·814	1·311	1·509	1·852	2·252	2·634
3-Cl	—	0·750	1·098	1·491	1·918	2·281	2·680	3·098
4-OCH$_3$	—	—	—	—	0·400	0·994	1·526	1·931
3-OCH$_3$	—	—	0·458	0·890	1·347	1·653	1·810	2·261
4-CH$_3$	—	—	—	—	0·888	1·175	1·620	2·085
3-CH$_3$	—	—	—	0·482	0·963	1·481	1·921	2·405
4-COCH$_3$	0·814	1·354	1·701	2·193	2·602	3·039	3·508	—
3-COCH$_3$	0·583	1·108	1·462	1·717	2·261	2·638	3·032	—
4-SO$_3$H	—	0·698	1·043	1·568	2·124	2·376	2·995	3·252
3-SO$_3$H	—	0·495	0·982	1·488	1·968	2·348	2·759	3·205
4-NO$_2$	1·553	1·978	2·378	2·723	3·141	—	—	—
3-NO$_2$	1·498	1·972	2·250	2·524	2·925	3·211	—	—
H	—	—	0·551	1·045	1·313	1·737	2·180	2·720
4-COOH	—	—	—	0·997	1·510	2·011	2·438	2·912
3-COOH	—	—	—	0·714	1·350	1·811	2·257	2·704

TABLE III

Temperature dependence of rate constant of reaction of 4-chlorobenzenediazonium chloride with L-proline at pH 9·0 at ionic strength $I = 0·1$ ($\Delta t_{\max} = 0·3°$)

T, K	280·65	285·25	288·15	290·15	293·15
log k	1·419	1·583	1·645	1·761	1·852

TABLE IV

Dependence of rate constant of reaction of 4-chlorobenzenediazonium chloride with L-proline on ionic strength of solution at 20°C at pH 9·2 (log $k_0 = 2·245$)

I	0·05	0·10	0·20	0·50	1·00
log k	2·081	1·961	1·890	1·703	1·504

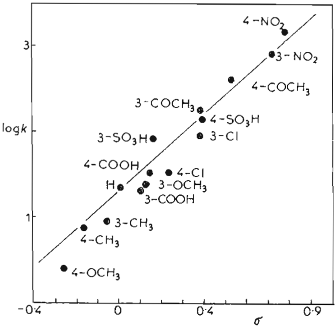

FIG. 1

Hammett correlation of rate constants of reaction of L-proline with substituted benzenediazonium chlorides. $n = 15$, $r = 0·964$, $\varrho = 2·20$, pH $= 8·5$, $t = 20°C$, $I = 0·1$

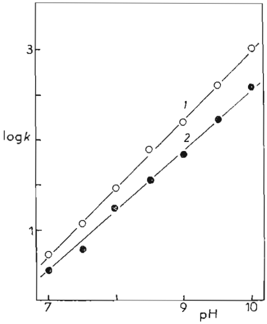

FIG. 2

pH Dependence of rate constants of reactions of 3-chloro- *1* and 4-chlorobenzenediazonium *2* chlorides with L-proline at 20°C at ionic strength $I = 0·1$

the rate obviously decreases with increasing p*K* value of the amino group (Table I). The temperature dependence of the reaction rate was followed in a considerably narrow temperature interval due to instability of the arenediazonium salts. The temperature increase by 10° accelerates the reaction three times. The activation energy calculated from the values given in Table III is 23 kJ mol^{-1}. Investigation of influence of ionic strength of the medium on the reaction rate revealed a primary negative salt effect (Table IV).

The reaction product of 4-chlorobenzenediazonium chloride and L-proline was isolated, and its elemental analysis indicates triazene structure. The latter was supported by ^{1}H NMR spectra and qualitative chemical test: hydrolysis of the compound produces the arenediazonium compound detectable by its reaction with suitable amine to give the respective azo dyestuff. At the pH values 7, 8·5, and 10 it was proved by TLC in ethanol–water that the product formed is identical with that synthetized ($R_F = 0{\cdot}79$). Both the synthetized compound and sample of the reaction mixture show two main maxima in UV spectrum (223 and 321 nm).

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