HYDROLYSIS OF ESTERS OF CERTAIN SUBSTITUTES OF 1,3,5-TRIAZINE

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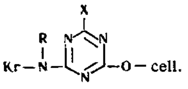
Khimiya Geterotsiklicheskikh Soedinenii, Vol. 4, No. 6, pp. 1119–1123, 1968

UDC 547.491.8:542.938

The mechanism of hydrolysis of esters of triazine substitutes was studied. It was shown that hydrolysis of *l*-menthyl esters in both alkaline and acid media at 80–120° C takes place with cleavage of the bond between the oxygen and carbon of triazine. The bond between the oxygen and carbon of alcohol is broken at 180–200° C in acid medium. The kinetics of alkaline hydrolysis of triazine esters was studied, and it was established that the stability of the latter increases in relation to the influence of the substitute in triazine in the order: $C_6H_5 < NHC_6H_5 < NHC_2H_5 < N(C_2H_5)_2$. A number of new C-substitutes of triazine was synthesized.

Among the numerous derivatives of triazine obtained on the basis of cyanurochloride [1], the active chlorotriazine dyes have acquired great practical importance over the past years [2,3]. When cellulose is dyed by these compounds, under certain conditions, esters of the type of compound I are formed, because in many cases, the dyes are sufficiently resistant to wet treatments including the action of aqueous solutions of alkalis and acids.

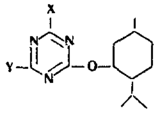


I

Kr, chromogenic portion of the dye; R, hydrogen or alkyl; Cell, cellulose residue; X, normally "nonchromogenic" substitute characterized by a λ_{max} at 300 nm.

The object of this study was to determine the site of cleavage of compounds I during the action of acids and alkalies, and to study the influence of the "nonchromogenic" substitute on the stability of these compounds toward hydrolytic cleavage. Due to the complexity of the compounds formed between the chlorotriazine dyes and cellulose, the study was conducted on standards.

In order to determine the first problem, compounds IIa and IIb were studied as standard compounds, in which the chromogen, cellulose, and compound IIb were replaced by diethylamine, *l*-menthol, and the trimenthyl ester of cyanuric acid, respectively.



IIa $X = Y = N(C_2H_5)_2$,
IIb $X = N(C_2H_5)_2$, $Y = OC_{10}H_{19}$,
IIc $X = Y = OC_{10}H_{19}$

As a result of the alkaline hydrolysis of compound II at 80–200° C and acid hydrolysis at 80–120° C, in addition to the oxyderivatives of triazine, only *l*-menthol is formed without change in optical activity. Thus, cleavage of the compounds studied under the given conditions takes place according to the site of the bond between oxygen and carbon of triazine (i.e., without affecting the asymmetrical carbon atom of the alcohol, analogous to the hydrolysis of esters of carboxylic acids [4]).

Saponification of compound II in acid medium at 180–200° C proceeds by another pathway. In addition to the oxyderivatives of triazine and *l*-menthol (+)-p-menthene was found among the products of the reaction. The latter was formed on rupture of the bond between oxygen and carbon of menthol in compound II [4], as *l*-menthol and compound II are stable under the conditions of the experiments.

The main theories suggest that (+)-p-menthene is formed as a result of the decomposition of the carbonium ion, which is formed at an intermediate stage

Table 1

Characteristics of Compounds Obtained[1*]

Compound	mp • C	Bp • C (pressure, mm)	$[\alpha^*]_D^{20}$, (c)	Empirical formula	Found, %			Calc., %			Yield, %
					C	H	N	C	H	N	
IIa	61—61.5	191—193 (1)	−66 (0.245)	$C_{21}H_{39}N_5O$	66.77	10.47	18.32	66.80	10.40	18.55	78.2
IIb	151—151.5	—	−108 (0.657)	$C_{27}H_{48}N_4O_2$	70.37	10.62	12.40	70.39	10.50	12.11	26.9
IIc	186—186.5	—	−116 (0.125)	$C_{33}H_{57}N_3O_3$	72.59	10.76	7.76	72.88	10.50	7.72	97.9
III	—	190—191 (1)	—	$C_{17}H_{25}N_5O$	65.07	7.90	22.53	64.73	7.93	22.25	51.0
IV	137—137.5	218—219 (1)	—	$C_{15}H_{21}N_5O$	62.40	7.50	24.59	62.67	7.31	24.37	53.5
V	102—103	257—259 (0.5)	—	$C_{19}H_{21}N_5O$	68.19	6.43	21.04	68.05	6.25	20.88	54.6
VI	44—45	218—219 (2)	—	$C_{19}H_{20}N_4O$	71.11	7.12	17.25	71.22	6.25	17.49	43.0
VII	180—181	—	—	$C_{11}H_{21}N_5O$	54.91	8.75	29.92	55.20	8.80	29.27	—
VIII	150—151	—	—	$C_7H_{12}N_4O_2$	45.23	6.75	30.09	45.68	6.52	30.42	—
IX	54—54.8	178—179 (1)	—	$C_{13}H_{15}N_4Cl$[2*]	59.69	5.82	—	59.43	5.71	—	71.0
X	26.7—27	143—144 (1)	—	$C_{11}H_{20}N_5Cl$[3*]	51.01	8.15	—	51.25	7.77	—	85.3

Measurements were conducted in a tube with $l = 1$ in ethyl alcohol for compounsd IIa and IIb, and in acetone for compound IIc. [2]Found, %: Cl, 13.59. Calculated, %: Cl, 13.50. [3*]Found, %: Cl, 13.81. Calculated, %: Cl, 13.76.

during hydrolytic rupture of the alkyl-oxygen bond, protonated at the oxygen of the ester II. If it is assumed [5,6] that, during acid hydrolysis, an intermediate active complex is formed in which the hydroxyl group of water occupies an axial position in relation to the ring of cyclohexane [7], neomenthol is probably formed on disruption of this complex with rupture of the alkyl-oxygen bond. It is well-known that neomenthol slightly dehydrates with the formation of Δ^3- or Δ^2-p-menthene [8,9].

Characteristics of the triazine esters on hydrolysis are in agreement with the ability of the alkoxysubstitutes of triazine to alkylate amines at 175–185° C [10], which does not occur at a lower temperature. In addition, the aryl-oxy substitutes of triazine do not arylate amines at high temperatures.

It was possible to select the latter as standards for studying the effect of the "nonchromogenic" substitute on the stability of the ester bond in I, the phenyl esters of derivatives of cyanuric acid. In this case, a study of the kinetics of hydrolysis is more convenient, as the phenoxy group in triazines is more mobile and is more easily determined quantitatively than the alkoxyl group.

The following compounds were studied: 2,4-bis-(diethylamino)-6-phenoxytriazine (III), 2-ethylamino-4-diethylamino-6-phenoxytriazine (IV), 2-anilino-4-diethylamino-6-phenoxytriazine (V), and 2-phenyl-4-diethylamino-6-phenoxytriazine (VI). The esters were saponified at 90–91° C in a medium of aqueous ethyl alcohol and a large excess of alkali, so that it was possible to describe the course of hydrolysis by a reaction kinetics equation of the first order. Rate of the reaction was determined according to the quantity of phenol which separated within various intervals of time. The phenol was back-titrated by the bromometric method. From the data obtained which are presented in Table 2, it is possible to arrange the studied substitutes according to the strength of their influence on the hydrolytic cleavage of triazine esters in an order corresponding to their electron donor-acceptor nature: $C_6H_5 > NHC_6H_5 > NHC_2H_5 > N(C_2H_5)_2$.

The mode of action of the substitutes on the stability of the oxygen-carbon bond of triazine is as follows. The electron density of the triazine ring in compound VI is less than that in compounds III–V, which facilitates the attack by nucleophilic reagents on the carbon atom of triazine associated with the phenoxy group. The substituted amino group, being an electron donor substitute, has the opposite action, and is greater the higher the basicity of the corresponding amine.

On the basis of the obtained data, it is possible to suggest that coloration of cellulose by monochlorotriazine dyes must be more resistant to hydrolysis the stronger the electron donor properties of the "nonchromogenic" substitute.

EXPERIMENTAL

1-2,4-Bis(diethylamino)-6-menthoxytriazine (IIa). A 25.8 g (0.1 mole) quantity of 2,4-bis-(diethylamino)-6-chlorotriazine (compound X, synthesized from cyanurochloride and diethylamine under conditions analogous to those previously described [11]), was added to a solution of sodium *l*-mentholate, obtained from 15.6 g (0.1 mole) *l*-menthol (mp 42.0–42.5° C, $[\alpha]_D^{20} = -48.5°$ C) and 2.3 g (0.1 g-at) metallic sodium in 60 ml dioxane, and the mixture was boiled with stirring for 10 hr. After addition of water, extraction with sulfuric ether, and removal of solvents, the residue was distilled under vacuum. A 12.8 g quantity of compound **IIa** was obtained.

Table 2

Constants of the Rate of Hydrolysis of Esters

Compound	K, sec^{-1}
III	$1.5 \cdot 10^{-5}$
IV	$4.8 \cdot 10^{-4}$
V	$8.5 \cdot 10^{-4}$
VI	$10.2 \cdot 10^{-4}$

Characteristics of compound IIa and other initially synthesized compounds are given in Table 1.

1-2-Diethylamino-4,6-bis(menthoxy)triazine (IIb). A 26 g quantity (0.146 mole) of sodium *l*-mentholate and 11 g (0.05 mole) of 2-diethylamino-4,6-dichlorotriazine [11] were boiled for 5 hr in 90 ml dioxane, and the solvents were removed from the ethereal extract by distillation. The residue was treated with heptane and recrystallized from ethyl alcohol. A 6.2 g quantity of compound **IIb** was obtained.

1-Trimethyl ester of cyanuric acid (IIc). Over the course of 1 hr at 55–60° C, 3.2 g (17 mM) cyanurochloride was added to a stirred solution of 8.9 g (0.05 mole) sodium *l*-mentholate in 12 ml toluene. After completion of the reaction, extraction with ether, and removal of the solvents from the extract, the residue was recrystallized from n-propyl alcohol. A 9.15 g quantity of compound IIc was obtained.

Alkaline hydrolysis of the esters. Hydrolysis of compound IIa. A mixture of 0.3776 g (1 mM) compound IIa, 0.168 g (3 mM) KOH, and 10 ml of 95% aqueous ethyl alcohol was heated in a sealed tube at 180–200° C for 10 hr. The cooled solution was mixed with water, neutralized with a 0.1 N HCl until the disappearance of the color of phenolphthalein, the volatile substances were removed by distillation with steam, and the distillate was extracted with sulfuric ether. After evaporation of the latter and sublimation of the residue, 0.085 g of *l*-menthol was separated, mp of the S-benzylthiuronic derivatives [12], 149.5–149.9° C. On cooling, the solution which remained after the volatile compounds had been removed by distillation, 0.1723 g of a substance was isolated with a mp of 61–62° C and $[\alpha]_D^{20} = -64.85°$ C (acetone, c = 1.33; *l* = 1). A mixture of this compound and compound **IIa** melts without depression. On partial evaporation of the solution which remained after separation of compound **IIa**, 0.1263 g of a substance was extracted with a mp of 180–181° C. A mixture of this compound and 2,4-bis(diethylamino)-6-oxytriazine (**VII**), obtained by hydrolysis of 2,4-bis(diethylamino)-6-chlorotriazine X) melts without depression.

Hydrolysis of compound IIb was conducted at 140–150° C in 5 hr under stable conditions, analogous to those previously described. A 0.2785 g quantity of *l*-menthol and 0.1778 g of a substance with a mp of 150–151° C, colorless needles were isolated. A mixed sample with 2,4-dioxy-6-diethylaminotriazine (VIII), obtained by hydrolysis of the corresponding dichlorotriazine, melts without depression.

Hydrolysis of compound IIc. A mixture of 1 g (1.8 mM) compound IIc, 0.785 g (14 mM) KOH, and 8 ml of 95% aqueous ethyl alcohol was heated in a sealed tube at 80° C for 2 hr and treated in an analogous manner to that described above. A 0.815 g quantity of *l*-menthol was extracted. After evaporation, extraction of the residue with sulfuric ether in a Soxhlet apparatus, and removal of ether, 0.22 g of a compound, possessing the properties of cyanuric acid, was obtained from the aqueous solution. As in the case of the latter compound, the copper ammonium complex consists of violet crystals. Found, %: C, 20.81; H, 2.96; N, 31.66; Cu, 18.38. Calculated for $C_6H_4N_6O_6Cu \cdot 2NH_3$, %: C, 20.37; H, 2.85; N, 31.68; Cu, 17.97.

Acid hydrolysis of esters at 80–120° C. Hydrolysis of compound IIa. A mixture of 3.776 g (0.01 mole) compound **IIa**, 1.8 ml (0.02 mole) HCl (d, 1.173) and 30 ml of 95% aqueous ethyl alcohol was heated in a sealed tube at 115–120° C for 8 hr and the solution was subsequently treated in an analogous manner to that described for alkaline hydrolysis of compound **IIa.** Approximately 1 g *l*-menthol, 1.1 g compound **IIa**, and 1.67 g compound **VII** were extracted.

Hydrolysis of compound IIc. After heating 1 g (1.8 mM) compound **IIc**, 0.5 ml (5.5 mM) HCl (d, 1.173) and 10 ml of 95% ethyl alcohol in a sealed tube at 80° C for 4 hr, the resulting solution was treated by the usual method. Approximately 0.8 g *l*-menthol and 0.2 g cyanuric acid were isolated.

Acid hydrolysis of esters at 180–200° C. Hydrolysis of compound IIa. A mixture of 3.7756 g (0.01 mole) compound **IIa**, 1.8 ml HCl (d, 1.173) and 35 ml of 95% aqueous ethyl alcohol were heated for 5 hr, the solution was neutralized, the volatile compounds were removed by steam distillation, the distillate was extracted with sulfuric ether, the latter was evaporated, and at 63–65° C (20 mm) 1.3 g of a compound with $[\alpha]_D^{20} = +29.15°$ C (ethyl alcohol, c = 1.065, *l* = 1) was removed by distillation. During the action of ethyl nitrite on the compound under previously described conditions [13], the nitrosyl chloride of menthene was obtained, mp 118–118.5° C. Found, %: C, 58.85; H, 9.16; N, 6.88. Calculated for $C_{10}H_{18}ClNO$, %: C, 58.95; H, 8.80; N, 6.87.

After removal of (+)-menthene, *l*-menthol was found in the residue.

Hydrolysis of compound IIb. A mixture of 2.3034 g (5 mM) compound **IIb**, 1.4 ml (15 mM) HCl (d, 1.173) and 20 ml of 95% alcohol was heated for 3 hr, and subsequent treatments were conducted in an analogous manner to those previously described. At 63–64° C (20 mm) 1.02 g (+)-menthene with $[\alpha]_D^{20} = +28.97°$ C (ethyl alcohol, c = 0.987, *l* = 1), 0.22 g *l*-menthol, and 0.86 g compound **VIII** were collected.

Hydrolysis of compound IIc. After 4 hr hydrolysis of compound **IIc** (+)-menthene with $[\alpha]_D^{20} = +36.5°$ C (ethyl alcohol, c = 0.98, *l* = 1), *l*-menthol and cyanuric acid were isolated.

Stability of *l*-menthol under experimental conditions. A mixture of 1.56 g *l*-menthol, 1.8 ml HCl (d, 1.173), and 20 ml of 95% ethyl alcohol was heated at 195–200° C for 6 hr and the solution was treated in an analogous manner to that described above. A 1.47 g quantity of *l*-menthol was isolated.

Thermal stability of esters II. After heating 1 mM compound II in 20 ml of 95% ethyl alcohol for 6–10 hr at 195–200° C, the qualitative reaction in the presence of menthene and menthol was negative. The original esters were separated almost quantitatively.

2,4-Bis(diethylamino)-6-phenoxytriazine (III). A 51.5 g quantity (0.2 mole) of 2,4-bis(diethylamino)-6-chlorotriazine was gradually added with mixing to 27.8 g (0.24 mole) sodium phenate in 50 ml toluene. The mixture was boiled for 4 hr, after which the toluene was removed by distillation and the remaining oil was extracted with ether. After removal of ether the residue was twice distilled under vacuum. A 32 g quantity of compound III was obtained.

2-Diethylamino-4-ethylamino-6-phenoxytriazine (IV). To a stirred mixture of 21.7 g (0.09 mole) 2,4-dichloro-6-phenoxytriazine [14] (112.8–113.5° C) and 25 ml acetone was gradually added 25 ml of an 18% aqueous solution of ethylamine (9.6 mM) at 20–25° C. A 10.2 ml (9.6 mM) quantity of diethylamine in 20 ml of acetone was added, increasing the temperature to 50–55° C. A 7.9 g (0.198 mole) quantity of NaOH in 30 ml water was then introduced, and the mixture was maintained for 2 hr. After extraction with sulfuric ether and removal of the solvents from the extract, the residue was distilled under vacuum.

2-Anilino-4-diethylamino-6-phenoxytriazine (V). At first 8.44 g (9.6 mM) aniline in 20 ml acetone and then 7.02 g (9.6 mM) diethylamine in 20 ml acetone were added to a suspension of 21.7 g (0.09 mole) 2,4-dichloro-6-phenoxytriazine in 40 ml acetone with stirring at 20–25° C. After heating to 30–35° C, 8 g NaOH in 30 ml water was added to the mixture. After maintaining for 2 hr the reaction mixture was treated with ether and distilled under vacuum.

2-Diethylamino-4-phenyl-6-chlorotriazine (IX). A 1.424 g (1.9 mM) quantity of diethylamine, and then 0.76 g 90.5% (1.9 mM) NaOH in 10 ml water were added gradually to a solution of 4.3 g (1.9 mM) 2,4-dichloro-6-phenyltriazine [15] in 20 ml n-hexane at 40° C, with stirring. The mixture was maintained for 2 hr and extracted with ether. After removal of the solvents the residue was distilled under vacuum.

2-Diethylamino-4-phenyl-6-phenoxytriazine (VI). A mixture of 5.2 g (1.9 mM) of compound **IX**, 4.6 g (0.04 mole) sodium phenate, and 30 ml anhydrous toluene was boiled for 8 hr, extracted with ether, the extract was washed with a solution of alkali and water for removal of phenol, the solvents were removed by distillation, and the residue was distilled under vacuum.

Hydrolysis of phenyl esters. A 0.5 mM quantity of esters III–VI, 5 mM KOH, and 8 ml of 95% aqueous ethyl alcohol, placed in identical ampuls, were heated in a thermostat at 90–91° C. After a particular time interval (from 5 min to 1 hr) the ampuls were removed and plunged into the chilled mixture at −10° C. The contents of the ampuls were quantitatively transferred with 2 ml ethyl alcohol and distilled water into a flask for bromination. The volume was adjusted to 150 ml and the content of the separated phenol was determined potentiometrically, back-titrating (by means of an automatic titrometer) with iodine hyposulfite, separated from potassium iodide during the action of excess bromide-bromate. The esters III–VI and the oxyderivatives of triazine formed during the hydrolysis under the experimental conditions were not brominated.

The constants for the rate of hydrolysis of esters (K) are presented in Table 2.

The values of K were calculated on the basis of not less than 20 determinations made within 8–10 different time intervals.

We thank Prof. A. I. Korolev for the proposal, and the attention he gave to this work.

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18 July 1966

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