

Chlorinated Long-chain Fatty Acids. Their Properties and Reactions. IX. The Kinetics and Stereochemical Course of the Neutral and the Base-promoted Dehydrochlorination of Sodium *erythro*- and *threo*-9(10)-Chloro-10(9)-hydroxyoctadecanoates

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The base-promoted and neutral dehydrochlorination of sodium *erythro*- and *threo*-9(10)-chloro-10(9)-hydroxyoctadecanoates in water has been studied. The appreciable contribution of the neutral reaction was taken into account by determining the rate coefficients for this and for the base-catalysed reaction simultaneously. The observation that the different reaction rates of the diastereoisomers are mainly due to the differences in the ground state energies of their *anti* conformations [$k_{\text{erythro}}/k_{\text{threo}} = 4.3 \pm 0.6$ (k_{OH}) and 2.3 ± 0.7 (k_0) and 4.5 (est.) at 298 K] confirmed the postulation that the reaction is stereochemically a *trans* process.

Ketola pointed out recently¹ that in alkaline water solution sodium *erythro*- and *threo*-9(10)-hydroxyoctadecanoates undergo a dehydrochlorination reaction which is promoted both by water and the base. The rate equation in his report was very approximate and hence both rate coefficients (k_0 and k_{OH}) may be estimated more accurately using the method described by Salomaa² and Euranto.³ Moreover, Ketola's earlier results for the *erythro* isomer were not accurate enough¹ that we ought to redetermine them whereas his original results¹ were used to recalculate the rate coefficients for the *threo* isomer.

The different reaction rates in the base-catalyzed removal of the first chlorine atom of sodium *erythro*- and *threo*-9,10-dichlorooctade-

canoates were mainly due to the differences in the ground state energies of their reactive conformations.⁴ Since the present reactions are also *trans* processes¹ it was worth trying to correlate the reaction rates of the isomers with their ground state energies.

EXPERIMENTAL

erythro-9(10)-Chloro-10(9)-hydroxyoctadecanoic acid was synthesized from elaidic acid by the method of Swern.^{1,5} The product which was a mixture of the two positional isomers melted at 326–331 K (lit.^{1,5,7} 326–327, 331.0–331.8, 325–330 K) and had a chlorine content of 10.39 ± 0.13 % (calc. 10.59 %). The *threo* isomer was not prepared but the original experimental results of Ketola¹ were used to recalculate the values of the rate constants.

Kinetic experiments. The alkaline dehydrochlorination of *erythro*-9(10)-chloro-10(9)-hydroxyoctadecanoic acid was studied at four temperatures at 4 to 5 different base concentrations (Table 1). The reaction solutions were prepared by pouring a weighed amount of the standard base (NaOH) solution into a mixture of weighed amounts of substrate and distilled water. The acid dissolved at once and the initial base concentration had to be corrected accordingly. Before mixing both components were thermostated for half an hour. The removal of the chlorine atom was followed by titrating the chloride ions formed with 0.01 N Hg(NO₃)₂ in 80 % (v/v) aqueous methanol. Otherwise the kinetic measurements were accomplished as reported earlier.^{1,7,8}

Calculation of the rate coefficients. In alkaline water solution the dehydrochlorination reactions of sodium *erythro*- and *threo*-9(10)-chloro-

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Table 1. The values of the rate coefficients for the neutral (k_0) and base-catalyzed (k_{OH}) dehydrochlorination of sodium *erythro*-9(10)-chloro-10(9)-hydroxyoctadecanoate at different temperatures. For the definition of $[S]$, $[OH^-]$, \bar{k}_t and \bar{c}_t see the text.

Temp. K	$10^3[S]/$ mol kg ⁻¹	$10^3[OH^-]/$ mol kg ⁻¹	$10^3\bar{k}_t/$ min ⁻¹	$10^3\bar{c}_t/$ mol kg ⁻¹	$10^4k_0/$ s ⁻¹	$10^3k_{OH}/$ kg mol ⁻¹ s ⁻¹
288	10.08	19.31	5.35	14.87	4.24 ± 0.24^a	31.80 ± 0.95^a
	9.82	24.96	6.52	21.04		
	10.13	29.79	7.51	25.48		
	10.04	39.66	9.37	36.02		
293	9.93	15.73	6.60	11.71	5.69 ± 0.34	46.78 ± 1.34
	9.86	20.59	8.30	16.78		
	9.96	30.40	10.84	26.83		
	10.32	41.86	14.10	37.99		
298	9.96	15.90	9.63	11.86	7.70 ± 0.44	72.69 ± 2.19
	9.99	17.92	10.98	14.40		
	9.89	23.48	13.21	19.62		
	10.09	25.25	14.09	21.27		
	9.78	32.59	16.99	28.66		
303	9.94	12.76	10.30	8.51	9.39 ± 1.61	101.77 ± 12.55
	10.19	14.27	12.17	10.07		
	10.14	16.97	13.79	12.82		
	10.35	22.17	16.40	18.01		

^a Standard deviation.

Table 2. The values of the rate coefficients for the neutral (k_0) and base-catalyzed (k_{OH}) dehydrochlorination of sodium *threo*-9(10)-chloro-10(9)-hydroxyoctadecanoate at different temperatures. For the definition of $[S]$, $[OH^-]$, \bar{k}_t and \bar{c}_t see the text.

Temp. K	$10^3[S]/$ mol kg ⁻¹	$10^3[OH^-]/$ mol kg ⁻¹	$10^3\bar{k}_t/$ min ⁻¹	$10^3\bar{c}_t/$ mol kg ⁻¹	$10^4k_0/$ s ⁻¹	$10^3k_{OH}/$ kg mol ⁻¹ s ⁻¹
293	20.72	20.52	2.51	14.84	2.32 ± 0.60^a	10.50 ± 1.21^a
	20.71	40.40	3.27	33.89		
	20.00	82.41	6.32	76.89		
298	20.68	21.68	3.87	15.96	3.32 ± 0.85	16.87 ± 1.74
	20.71	40.25	4.99	33.21		
	20.00	82.00	9.84	76.48		
303	20.95	38.33	8.27	32.42	5.24 ± 2.30	28.08 ± 4.03
	20.93	59.06	12.70	53.02		
	19.98	82.28	15.84	77.07		

^a Standard deviation

10(9)-hydroxyoctadecanoates follow the rate law:^{1,9}

$$\frac{dx}{dt} = (k_0 + k_{OH}[OH^-])[S] \quad (1)$$

where k_0 is the rate coefficient for the neutral and k_{OH} for the base-promoted reaction and $[OH^-]$ and $[S]$ the base and substrate concen-

trations. The reaction was carried out at several base concentrations (Tables 1 and 2) to obtain the values of k_0 and k_{OH} from the equation

$$\bar{k}_t = k_0 + k_{OH}\bar{c}_t \quad (2)$$

The average base concentrations \bar{c}_t for each run were calculated using a program written

Table 3. Values of thermodynamic functions of activation at 298 K for the neutral (A) and alkaline (B) dehydrochlorination of the *erythro* (I) and *threo* (II) acids.

Compound	Reaction	ΔH^\ddagger / kJ mol ⁻¹	ΔS^\ddagger / J mol ⁻¹ K ⁻¹	ΔG^\ddagger / kJ mol ⁻¹
I	A	36.6 ± 2.2 ^a	-182.2 ± 7.5 ^a	90.9 ± 0.04 ^a
I	B	54.6 ± 1.7	-83.7 ± 5.8	79.6 ± 0.04
II	A	57.6 ± 4.8	-118.1 ± 16.1	92.8 ± 0.07
II	B	70.2 ± 2.2	-43.4 ± 7.4	83.1 ± 0.03

^a Standard deviation

for an IBM 1130 computer with the aid of the trapezoidal rule.^{2,3}

$$\bar{c}_i = c_0 - \frac{1}{2t} \sum_{j=1}^i (x_j + x_{j-1}) (t_j - t_{j-1}) \quad (1)$$

where x_j is the amount of the chloride ion formed in time t_j . The average rate coefficients for each run were obtained from the normal first-order rate equation involved in the above program.

The values of k_0 and k_{OH} obtained from the above equation by the method of least squares ($r=0.995-0.999$) are shown in Tables 1 and 2. The values for sodium *threo*-9(10)-chloro-10(9)-hydroxyoctadecanoate have been recalculated from the experimental results of Ketola.¹ The values of thermodynamic functions of activation (Table 3) for the neutral and alkaline dehydrochlorination of sodium *erythro*- and *threo*-9(10)-chloro-10(9)-hydroxyoctadecanoates were obtained from the values of k_0 and k_{OH} (Tables 1 and 2) by the method of least squares.

RESULTS AND DISCUSSION

The values obtained in this work for the rate coefficients (k_0) of the neutral reaction of sodium *erythro*-9(10)-chloro-10(9)-hydroxyoctadecanoate do not differ appreciably from those of Ketola¹ whereas our values for k_{OH} are 2–3 times higher than his original ones. This is due to the different computational methods and the improved quality of the sample used for kinetic experiments. In the case of the *threo* isomer the recalculated values of k_0 remained practically equal to the earlier results¹ whereas those of k_{OH} increased by 16 to 48 %.

If we compare the rate coefficients determined for the neutral and base-catalysed dehydrochlorination of the studied octadecanoates with those of 2-chloroethanol^{1,9,10} we observe that the substitution increases the rate of both reactions but more that of the neutral reaction.

Kinetics and mechanisms of dehydrochlorination. The product analyses¹ and a stereochemical treatment (see below) confirm that the dehydrochlorination reaction is principally a *trans* process. The rate-determining step in the base-catalysed reaction is an intramolecular substitution reaction (S_N1)^{1,10} where an inversion occurs at the α -carbon during the ring closure. In the neutral reaction the primary product may well be a diol¹¹ though in the case of some reactive chlorohydrins the epoxide may still be an intermediate.¹²

The values of thermodynamic functions of activation for the neutral and base-catalysed reactions are close to those for the reactions of 2-chloroethanol.^{1,10} The values let us suppose that the mechanisms are the same for the compounds studied here and for 2-chloroethanol though the results for the neutral reaction reveal the need of a thorough study to clarify the detailed course of this reaction.¹²

Stereochemistry of the dehydrochlorination

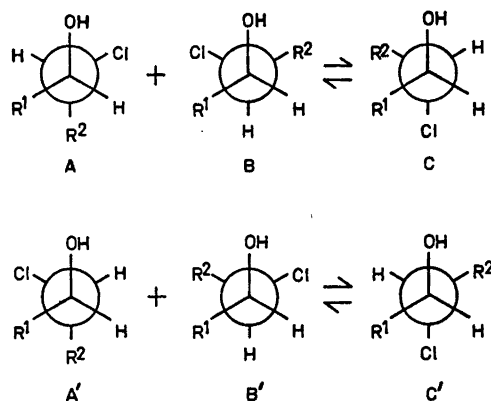


Fig. 1. The minimum energy conformations of sodium *threo* (A–C) and *erythro*-9(10)-chloro-10(9)-hydroxyoctadecanoates (A'–C').

reaction. It has been pointed out¹ that *threo* and *erythro* isomers produce *cis*- and *trans*-9,10-epoxyoctadecanoic acids, respectively. A stereochemical requirement for these products is that the reacting groups (OH and Cl) have an *anti*-arrangement.⁵

Both sodium *threo*- and *erythro*-9(10)-chloro-10(9)-hydroxyoctadecanoates have three minimum energy conformations (Fig. 1) from which only C and C' can undergo a *trans* process. The total rate coefficient of a given reaction of a conformationally heterogeneous system may be presented by the relation

$$k = \sum x_i k_i \quad (4)$$

where x_i is the mol fraction and k_i the rate coefficient of the reaction studied for the i th conformation. Since the studied reaction¹ has been postulated to be a *trans* process the total rates for the dehydrochlorination of sodium *threo*- (k_t) and *erythro*-9(10)-chloro-10(9)-hydroxyoctadecanoates (k_e) may be written

$$k_t = x_C k_C \quad (5)$$

$$k_e = x_{C'} k_{C'} \quad (6)$$

Consequently, if we assume that $k_C \sim k_{C'}$

$$k_e/k_t = x_{C'}/x_C \quad (7)$$

In other words if the reaction really occurs almost exclusively through the *anti* conformations C and C' (Fig. 1) the relative rates should be determined by the ground state energies and hence by the relative populations of the reactive conformations. If we use the following values (in kJ mol⁻¹) for the various *gauche* interactions^{4,13} at 298 K: R¹-R² +2.7, R¹-Cl or R²-Cl -0.2, R¹-OH or R²-OH 0.8, and Cl-OH -4.0 the estimated interaction energies for the different conformations (Fig. 1) are then

<i>threo</i>	A	-1.3	B	-3.4	C	+3.3
<i>erythro</i>	A'	-1.5	B'	-0.5	C'	+0.6

from which we obtain $x_C = 0.045$ and $x_{C'} = 0.204$. Accordingly, $k_e/k_t = 0.204/0.045 = 4.5$ in fair agreements with the experimental findings 4.3 ± 0.6 for the base-promoted reaction and 2.3 ± 0.7 for the neutral reaction at 298 K.

Finally, we like to emphasize that no attention has been paid to the possible difference in the dehydrochlorination rates of, e.g., sodium *erythro*-9-chloro-10-hydroxy- and *erythro*-10-chloro-9-hydroxyoctadecanoates. The influence

of the rather remote carboxylate group is likely to be very small¹⁴ and sometimes even an α -carboxylate group has practically no neighbouring group effect on the halide ion release.¹⁵

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