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CONCERTED FRAGMENTATION AND ANCHIMERICALLY ASSISTED ELIMINATION IN THE SOLVOLYSIS OF 3-CHLOROPROPANTHIOLS

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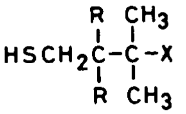
In contrast to 3-chloropropanols $HO{-}\underset{|}{\overset{|}{C}}{-}\underset{|}{\overset{|}{C}}{-}\underset{|}{\overset{|}{C}}{-}Cl$, the solvolytic reactions of which have been well studied [1], little is known about the sulfur analogues $HS{-}\underset{|}{\overset{|}{C}}{-}\underset{|}{\overset{|}{C}}{-}\underset{|}{\overset{|}{C}}{-}Cl$, particularly with respect to their ability to undergo olefinforming fragmentation [2].

The products and rates of 3-chloro-3-methylbutanthiol (1a) and 3-chloro-2,2,3-trimethylbutanthiol (2a) [3] in 80 % ethanol, in the presence and absence of NaOH, show that the corresponding anions undergo anchimerically assisted elimination to the $\Delta^{3,4}$ thiols 4a and 4b, respectively. Only when this novel reaction is excluded for steric reasons, as in the case of 3-chloroadamantanthiol (3a), does fragmentation occur. Under neutral conditions, however, all three 3-chlorothiols undergo conventional substitution and elimination reactions by the unimolecular S_N1 and E1 mechanisms.



$HSCH_2\underset{R}{\overset{R}{C}}{-}\underset{CH_3}{\overset{CH_3}{C}}{-}X$

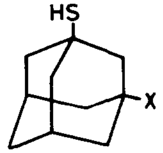
1 R = H

2 R = CH_3

a) X = Cl

b) X = OH

c) X = OEt



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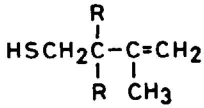
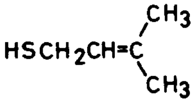


$HSCH_2\underset{R}{\overset{R}{C}}{-}\underset{CH_3}{C}{=}CH_2$

4a R = H

4b R = CH_3



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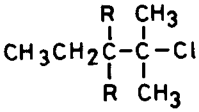


$CH_3CH_2\underset{R}{\overset{R}{C}}{-}\underset{CH_3}{\overset{CH_3}{C}}{-}Cl$

6a R = H

6b R = CH_3

Thus, reaction of 1a, 2a and 3a in neutral 80 % ethanol yields the corresponding alcohols 1b, 2b, 3b and ethyl ethers 1c, 2c and 3c, respectively [4]. In addition, both olefins 4a and 5 are formed from 1a, but only 4b from 2a. Due to the electron withdrawing effect of sulfur, 1a reacts 0.125 times, 2a 0.11 times as fast as the corresponding homomorph 6a and 6b, respectively, at 25°C. Furthermore, at 120° 3a reacts 0.02 times as fast as 1-chloroadamantane (3a, H instead of SH). Rate determining ionization to a tertiary carbocation is therefore indicated in these cases.

Table. Dependence of the first order rate constants for 1a and 3a (0.005 M) on NaOH concentration in 80 vol. % ethanol.

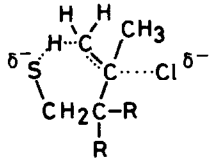
compound	temp. °C	[NaOH] M/l	$k(s^{-1})$	k_{rel}
1a	0.0	0	4.49×10^{-8} a)	1.04×10^{4}
		0.05	3.95×10^{-4} b)	
		0.075	3.81×10^{-4}	
		0.150	3.49×10^{-4}	
		0.260	3.15×10^{-4}	
		0.500	2.70×10^{-4}	
3a	40.0	0	1.55×10^{-9} a)	7.8×10^{4}
		0.099	9.30×10^{-5} c)	
		0.207	8.31×10^{-5}	
		0.402	7.12×10^{-5}	

a) extrapolated from measurements at higher temperatures. b) extrapolated to zero ionic strength: 4.73×10^{-4}. c) extrapolated to zero ionic strength: 12.2×10^{-5}

In the presence of ten or more equivalents of NaOH the rate constants for 1a and 2a increase by several orders of magnitude and only the $\Delta^{3,4}$ thiols 4a and 4b are formed. At higher NaOH concentrations the rate constants clearly decrease again, as shown for 1a in the Table. The rate depressions are due to a negative salt effect, since they are also brought about by the addition of sodium nitrate. In fact a plot of the logarithm of the observed rate constant against the square root of the ionic strength gives a straight line fitting the equation:

$$\log k = \log k_o - 0.345\sqrt{[\mathrm{NaOH}]}.$$

Extrapolation to zero ionic strength leads to k_o, the corrected rate constant for the anion of 1a, namely 4.73 x 10^{-4} at 0°C. The ratio of k_o and the rate constant k for 1a in the absence of base gives k_{rel}, which measures the assistance to ionization due to the negatively charged sulfur atom. For 1a k_{rel} is approximately 10^4 (Table), for 2a 10^7. These large values indicate that the elimination of HCl is anchimerically assisted [5] and that it involves a dispersal of negative charge in the transition state 7. The very high value of k_{rel} for the anion of 2a, i.e. 10^7, can be attributed to the geminal methyl groups at C(2), which would be expected to increase the population of conformation 8 (R = CH_3), a prerequisite for intramolecular base-induced elimination. A mechanism involving cyclization of 1a and 2a and subsequent ring opening of the intermediate thietanes 9 can be excluded, since the latter are stable under the reaction conditions.



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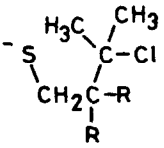

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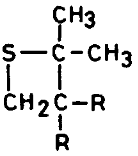

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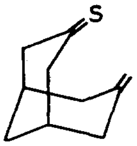
On the other hand 3a fragments to 3-methylene-bicyclo[3.3.1]nonanthione (10) when treated with ten equivalents of sodium ethoxide in dry ethanol at 100°. The unstable thione 10 is trapped as the benzyl thioether 11a of its enthiol tautomer 11b when benzyl chloride is added to the reaction mixture. When the same reaction sequence is carried out in 1 M aqueous NaOH only 28 % of the thioether 11a beside 72 % of 3-benzylthioadamantanol 12a are obtained. In 6.0 M NaOH the yield of 11a increases to 73 %. This shows that at lower base concentrations cyclization of the thione 10 to 3-mercaptoadamantanol 12b is faster than its conversion to the enthiol 11b or to the corresponding enthiolate ion.



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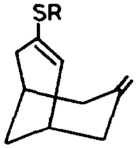

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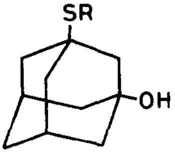
a) R = $CH_2C_6H_5$
b) R = H



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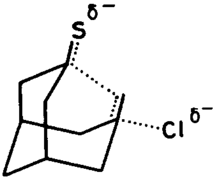
The rate constants for 3a increase strongly with the NaOH concentration. However, they decrease again slightly after 20 equivalents of base have been added (Table) due to a negative salt effect. Extrapolation to zero ionic strength, as shown above, leads to a rate constant of 12.2×10^{-5} at 40.0°C, from which a k_{rel} value of 7.8×10^{4} is obtained (Table). These results indicate a concerted fragmentation mechanism involving a dispersal of negative charge in the transition state 13.



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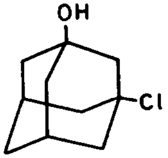

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A comparison of the k_{rel} values for the anions of 3-chloroadamantanthiol (3a) and 3-chloroadamantantanol (14) [1], i.e. 7.8×10^{4} and 1.2×10^{6}, respectively, shows that negative oxygen is 15 times as effective as negative sulfur in promoting concerted fragmentation. This larger frangomeric effect [6] is probably due to the greater tendency for carbon to form a C=O bond as compared to a C=S bond.

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3) The structures of all new compounds are supported by elemental and spectroscopic analyses.

4) As determined by g.l. chromatography.

5) This elimination mechanism was originally proposed to explain the fragmentation-elimination reactions of certain 3-chloroamines; see A.M. Braun, C.E. Ebner, C.A. Grob & F.A. Jenny, Tetrahedron Letters 1965, 4733.

6) C.A. Grob, Angew. Chemie, internat. edit. 8, 535 (1969).