# 157. Inductive, Hyperconjugative and Frangomeric Effects in the Solvolysis of 1-Substituted 3-Bromoadamantanes

**Polar Effects IV**

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*Summary*

Three kinds of polar substituent effects are observable in the solvolyses of 1-R-substituted 3-bromoadamantanes (VI). This follows from the relationship between products, rate constants $k$ in 80% ethanol, and the inductive substituent constants $\sigma_I^q$ of the substituent R. Alkyl groups and electron-attracting substituents at C(1) control the rate by their inductive effects alone, since $\log k$ correlates closely with $\sigma_I^q$. However, rates are higher than predicted on the basis of the respective $\sigma_I^q$ values when conjugating ($+M$)-substituents or electrofugal groups are attached to C(1). These exalted substituent effects are attributed to CC-hyperconjugative relay of positive charge from the cationic center at C(3) to the substituent at C(1). When the substituent is a strong electron donor (*e.g.* $O^-$ and $S^-$), accelerated substitution gives way to heterolytic fragmentation, rates and products then being controlled by the frangomeric effect.

**Introduction.** – In theory a $\gamma$-substituent R can affect the rate of ionization of a tertiary alkyl halide I in three conceptually distinctive ways *(Scheme 1):* a) by its inductive effect which acts on the cationic center in the incipient ion pair II; b) by a hyperconjugative effect which transfers positive charge from C($\alpha$) to C($\gamma$) (CC-hyperconjugation) and is superposed on the inductive effect as in III, and c) by a frangomeric effect [1] which operates as in b) except that the positive charge generated at C($\alpha$) is completely transfered to an electrofugal fragment IV [2] with concomitant cleavage of the C($\beta$)–C($\gamma$) bond[2]). While reactions a) and b) lead to the substitution and elimination products typical of $S_N1$ and E1 mechanisms [4], process c) leads to olefin-forming fragmentation [2] [5].

As in concerted fragmentation c), CC-hyperconjugation b) should become observable when R represents an electron donor. In fact the transition states are

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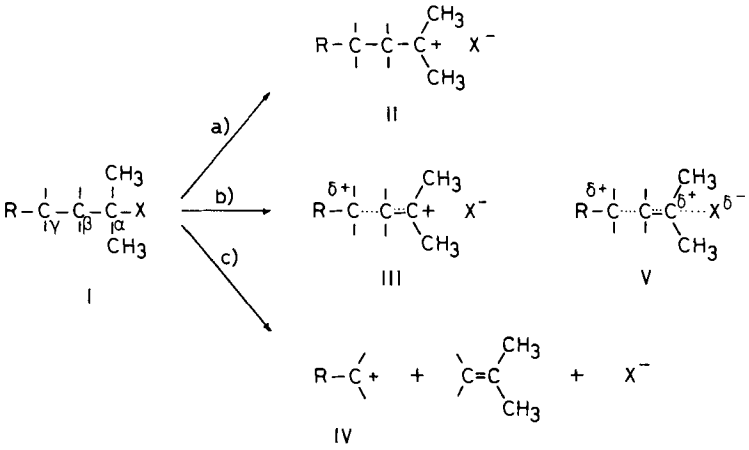
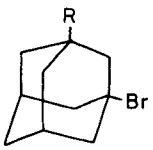
[2]) In acyclic molecules such as I a nucleophilic substituent R might also assist ionization by an anchimeric effect [3]. The latter would be expected to be weak because of steric hindrance to attack at a tertiary carbon atom.

*Scheme 1*



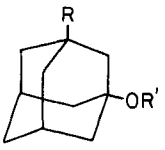
similar in both cases and resemble V, the essential difference being the degree of attenuation of the C($\beta$)–C($\gamma$) bond. Thus, a continuous range of interactions of R can be envisaged as its polar nature is varied.

While the mechanisms of olefin-forming fragmentation reactions have been studied in detail [1] [5], no systematic investigation of inductive and CC-hyperconjugative effects in solvolysis reactions has been recorded to our knowledge. Earlier studies of the solvolysis rates and products of bromoadamantane (VI, R = H) and its alkyl derivatives VI (R = $CH_3$, $C_2H_5$, *iso*-$C_3H_7$ and *t*-$C_4H_9$) in our laboratory [6] and by *Schleyer et al.* [7] failed to produce evidence for CC-hyperconjugation or for fragmentation. In fact only substitution products, *i.e.* alcohols VIIa and ethyl ethers VIIb, were obtained from reaction in 80% ethanol. Other unstrained $\gamma$-branched alkyl and cycloalkyl derivatives behaved likewise [6], and when a rate increase was observable it was traced to a steric effect. On the other hand when strong electron donors R, such as $NH_2$, $N(CH_3)_2$ [8], $O^-$ [9] and $S^-$ [10a] were present at C(1) of (VI) 3-bromoadamantane[3]), concerted fragmentation to 7-methylidenebicyclo-[3.3.1]nonane derivatives VIIIa–d took place.



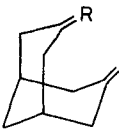
VI

**1–30**



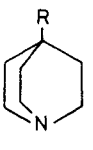
VII

R' = a) H
b) $C_2H_5$



VIII

R = a) $^+NH_2Br^-$
b) $^+N(CH_3)_2Br^-$
c) O
d) S



IX

[3]) For convenience all derivatives of bromoadamantane, *i.e.* **1–30**, are numbered such that the Br-atom is at C(3). All other adamantane derivatives are numbered according to the IUPAC rules.

Table 1. *First order rate constants for 1-R-3-bromoadamantanes in 80 vol.-% ethanol, and activation parameters*

| Nr. | R | T [°] | $k$ [$s^{-1}$] | $H^{\ddagger}$ [kcal/mol] | $S^{\ddagger}$ [cal/mol · degree] |
|---|---|---|---|---|---|
| **1** | H | 70.0 | $7.16 \cdot 10^{-5}$ a) | | |
| **2** | $CH_3$ | 70.0 | $5.31 \cdot 10^{-5}$ a) | | |
| **3** | $C_2H_5$ | 70.0 | $7.28 \cdot 10^{-5}$ a) | | |
| **4** | *iso*-$C_3H_7$ | 70.0 | $1.09 \cdot 10^{-4}$ a) | | |
| **5** | *t*-$C_4H_9$ | 70.0 | $1.66 \cdot 10^{-4}$ b) | 23.46 | − 7.74 |
| | | 80.0 | $4.58 \cdot 10^{-4}$ | | |
| | | 90.0 | $1.16 \cdot 10^{-3}$ | | |
| **6** | $CH_2Br$ | 70.0 | $3.50 \cdot 10^{-6}$ c) | 23.11 | − 16.43 |
| | | 110.0 | $1.34 \cdot 10^{-4}$ d) | | |
| | | 120.0 | $3.11 \cdot 10^{-4}$ | | |
| | | 130.0 | $6.33 \cdot 10^{-4}$ | | |
| **7** | COOH | 70.0 | $7.59 \cdot 10^{-7}$ c) | 26.09 | − 10.78 |
| | | 120.0 | $1.11 \cdot 10^{-4}$ e) | | |
| | | 130.0 | $2.74 \cdot 10^{-4}$ | | |
| | | 140.0 | $5.87 \cdot 10^{-4}$ | | |
| **8** | Br | 70.0 | $8.41 \cdot 10^{-8}$ c) | 25.32 | − 17.4 |
| | | 140.0 | $5.57 \cdot 10^{-5}$ d) | | |
| | | 150.0 | $1.20 \cdot 10^{-4}$ | | |
| | | 160.0 | $2.43 \cdot 10^{-4}$ | | |
| **9** | CN | 70.0 | $3.06 \cdot 10^{-8}$ c) | 24.70 | − 21.2 |
| | | 135.0 | $1.17 \cdot 10^{-5}$ f) | | |
| | | 155.0 | $5.08 \cdot 10^{-5}$ | | |
| **10** | $NO_2$ | 70.0 | $4.93 \cdot 10^{-9}$ c) | 24.6 | − 25.15 |
| | | 150.0 | $5.56 \cdot 10^{-6}$ f) | | |
| | | 180.0 | $4.13 \cdot 10^{-5}$ | | |
| **11** | $CH_2=C(CH_3)$ | 70.0 | $2.59 \cdot 10^{-5}$ a) | 23.85 | − 10.32 |
| | | 90.0 | $1.84 \cdot 10^{-4}$ b) | | |
| | | 100.0 | $4.91 \cdot 10^{-4}$ | | |
| | | 110.0 | $1.09 \cdot 10^{-3}$ | | |
| **12** | $C_6H_5$ | 70.0 | $1.57 \cdot 10^{-5}$ c) | 23.90 | − 11.14 |
| | | 100.0 | $2.88 \cdot 10^{-4}$ b) | | |
| | | 110.0 | $6.73 \cdot 10^{-4}$ | | |
| | | 120.0 | $1.57 \cdot 10^{-3}$ | | |
| **13** | $SCH_3$ | 70.0 | $2.94 \cdot 10^{-6}$ c) | 23.40 | − 15.9 |
| | | 100.0 | $5.04 \cdot 10^{-5}$ b) | | |
| | | 110.0 | $1.18 \cdot 10^{-4}$ | | |
| | | 120.0 | $2.64 \cdot 10^{-4}$ | | |
| **14** | $OCH_3$ | 70.0 | $9.74 \cdot 10^{-6}$ g) | | |
| **15** | OH | 70.0 | $3.37 \cdot 10^{-5}$ d) g) | 24.37 | − 8.27 |
| | | 90.0 | $2.51 \cdot 10^{-4}$ | | |
| | | 100.0 | $6.51 \cdot 10^{-4}$ | | |
| **16** | $CH_2NH_2$ | 70.0 | $4.89 \cdot 10^{-5}$ c) | 23.53 | − 9.97 |
| | | 90.0 | $3.46 \cdot 10^{-4}$ b) | | |
| | | 100.0 | $8.65 \cdot 10^{-4}$ | | |
| | | 110.0 | $1.99 \cdot 10^{-3}$ | | |
| **17** | $CONH_2$ | 70.0 | $1.58 \cdot 10^{-6}$ c) | 25.05 | − 12.36 |
| | | 110.0 | $8.17 \cdot 10^{-5}$ b) | | |
| | | 120.0 | $1.94 \cdot 10^{-4}$ | | |
| | | 130.0 | $4.40 \cdot 10^{-4}$ | | |
| **18** | $CH_2OH$ | 70.0 | $4.26 \cdot 10^{-5}$ c) | 23.81 | − 9.42 |
| | | 90.0 | $3.11 \cdot 10^{-4}$ b) h) | | |
| | | 100.0 | $7.84 \cdot 10^{-4}$ | | |
| | | 110.0 | $1.83 \cdot 10^{-3}$ | | |

Table 1 continued

| Nr. | R | T [°] | $k$ [$s^{-1}$] | $H^{\ddagger}$ [kcal/mol] | $S^{\ddagger}$ [cal/mol · degree] |
|---|---|---|---|---|---|
| **19** | $COO^-$ | 60.0 | $4.71 \cdot 10^{-5}$ [h][i] | 27.43 | 3.78 |
| | | 70.0 | $1.61 \cdot 10^{-4}$ | | |
| | | 80.0 | $5.22 \cdot 10^{-4}$ | | |
| **20** | $Sn(CH_3)_3$ | 70.0 | $4.18 \cdot 10^{-3}$ [j] | 21.90 | − 5.89 |
| | | 40.0 | $1.75 \cdot 10^{-4}$ | | |
| | | 50.0 | $5.47 \cdot 10^{-4}$ | | |
| | | 60.0 | $1.54 \cdot 10^{-3}$ | | |
| **21** | $NH_2$ | 70.0 | $2.67 \cdot 10^{-3}$ [k] | 22.98 | − 3.58 |
| **22** | $N(CH_3)_2$ | 70.0 | $8.50 \cdot 10^{-2}$ [k] | 22.86 | − 2.96 |
| **23** | SH | 70.0 | $1.58 \cdot 10^{-6}$ [c] | 21.17 | − 23.66 |
| | | 110.0 | $4.52 \cdot 10^{-5}$ [d] | | |
| | | 120.0 | $9.43 \cdot 10^{-5}$ | | |
| | | 130.0 | $1.89 \cdot 10^{-4}$ | | |
| **24** | *p*-$HOC_6H_4$ | 70.0 | $3.23 \cdot 10^{-5}$ [c] | 23.67 | − 10.39 |
| | | 90.0 | $2.32 \cdot 10^{-4}$ [l] | | |
| | | 100.0 | $5.78 \cdot 10^{-4}$ | | |
| | | 110.0 | $1.36 \cdot 10^{-3}$ | | |
| **25** | *p*-$CH_3OC_6H_4$ | 70.0 | $2.48 \cdot 10^{-5}$ [c] | 22.94 | − 13.04 |
| | | 90.0 | $1.68 \cdot 10^{-4}$ [b] | | |
| | | 100.0 | $3.99 \cdot 10^{-4}$ | | |
| | | 110.0 | $9.33 \cdot 10^{-4}$ | | |
| **26** | *p*-$H_2NC_6H_4$ | 70.0 | $4.50 \cdot 10^{-5}$ [c] | 23.70 | − 9.65 |
| | | 80.0 | $1.24 \cdot 10^{-4}$ [b][i] | | |
| | | 90.0 | $3.20 \cdot 10^{-4}$ | | |
| | | 100.0 | $8.02 \cdot 10^{-4}$ | | |
| **27** | *p*-$(CH_3)_2NC_6H_4$ | 70.0 | $5.06 \cdot 10^{-5}$ [c] | 23.69 | − 9.44 |
| | | 80.0 | $1.39 \cdot 10^{-4}$ [b] | | |
| | | 90.0 | $3.65 \cdot 10^{-4}$ | | |
| | | 100.0 | $8.95 \cdot 10^{-4}$ | | |
| **28** | *p*-$NO_2C_6H_4$ | 70.0 | $2.99 \cdot 10^{-6}$ [c] | 24.66 | − 12.24 |
| | | 110.0 | $1.45 \cdot 10^{-4}$ [b] | | |
| | | 120.0 | $3.42 \cdot 10^{-4}$ | | |
| | | 130.0 | $7.61 \cdot 10^{-4}$ | | |
| **29** | $CH_3\overset{\frown}{C}-CH_2-\overset{\frown}{C}H_2$ | 70.0 | $8.35 \cdot 10^{-5}$ [c] | 23.61 | − 8.67 |
| | | 80.0 | $2.29 \cdot 10^{-4}$ [b] | | |
| | | 90.0 | $5.96 \cdot 10^{-4}$ | | |
| | | 100.0 | $1.47 \cdot 10^{-3}$ | | |
| **30** | $^+N(CH_3)_3$ | 70.0 | $4.90 \cdot 10^{-9}$ [c] | 29.30 | − 11.47 |
| | | 135.0 | $4.45 \cdot 10^{-6}$ [h] | | |
| | | 155.0 | $3.09 \cdot 10^{-5}$ | | |

[a] [6].
[b] With 2 equiv. of triethylamine.
[c] Extrapolated.
[d] With 2–3 equiv. of glycine.
[e] With 1 equiv. of $^+N(CH_3)_3CH_2COO^-$ and 1 equiv. of $^+N(CH_3)_3CH_2COOH\ ClO_4^-$.
[f] With 2 equiv. of NaOH.
[g] With or without 2–4 equiv. of triethylamine.
[h] With 5 equiv. of NaOH.
[i] With 3 equiv. of NaOH.
[j] Without base.
[k] [8].
[l] With 2 equiv. of HBr.

Adamantane derivatives VI were chosen for these studies because of the locked antiplanar orientation of the C(1)–C(2) and C(3)–Br bonds[3]), a precondition for facile concerted fragmentation and, by inference, also for CC-hyperconjugation. However, a much wider range of substituents had to be studied in order to detect interactions of the kind outlined in *Scheme 1*. Furthermore, a reliable method to measure the inductive effect of substituents was needed in order to detect whether further interactions are superposed.

Meanwhile a new set of inductive substituent constants $\sigma_I^q$ has been derived from the thermodynamic $pK_a$ values of a large number of 4-substituted quinuclidines (IX) [11]. A linear correlation of the logarithms of the rate constants ($\log k$) for the solvolysis of 1-R-substituted 3-bromoadamantanes (VI) with the $\sigma_I^q$ values of R would indicate control by the inductive effect alone[4]). A deviation from a linear correlation would point to an additional interaction such as CC-hyperconjugation.

In this paper the first order rate constants $k$ for the reaction of the 1-substituted bromoadamantanes **1**–**30**[3]) in 80 vol.-% ethanol are reported *(Tab. 1)*. Their logarithms ($\log k$) were correlated with the corresponding $\sigma_I^q$ values when these were known. Reaction products were determined in the same solvent or in aqueous dioxane, special attention being paid to the occurrence of fragmentation besides substitution.

**Results**[5]). – The syntheses of the 1-substituted 3-bromoadamantanes **1**–**30** were reported earlier [8] [15], except those of the cyano (**9**), nitro (**10**), trimethyltin (**20**) and trimethylammonio derivatives (**30**). The latter compounds and the as yet unknown 4-substituted quinuclidines IX with R = $CH_2NH_2$, $(CH_3)_3N^+$ and $(CH_3)_3Sn$, which were needed for the determination of the corresponding $\sigma_I^q$ values, are described in the experimental part.

First order rate constantes in 80 vol.-% ethanol were measured conductometrically, or by bromide ion titration when temperatures above *ca.* 130° were required. These constants are listed in *Table 1* together with the activation parameters. In the kinetic and preparative runs triethylamine or glycine was added to buffer the hydrobromic acid generated. With the exceptions noted below, only substitution products, *i.e.* adamantanols VIIa and ethyl ethers VIIb[6]), were obtained from the solvolyses in 80% ethanol, in aqueous dioxane only the former. Products were determined quantitatively by GLC. and identified after isolation by comparison with authentic samples.

3-Bromo-1-adamantanol (**15**) deserves special mention, because its reaction products, but not its rate varied with the amount of added triethylamine. In 80% ethanol and in the absence of base, *i.e.* under weakly acidic conditions, the diol Xa and the monoethyl ether Xb were the only products. However, when 1–4 equiv. of triethylamine were added, up to 69% of 7-methylidenebicyclo[3.3.1]nonan-3-one (VIIIc) were formed at the expense of Xa and b.

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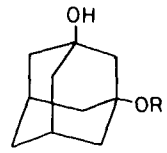
[4]) This has recently been demonstrated in the *N*-alkylation of 4-substituted quinuclidines (IX) [12].

[5]) For preliminary reports s. [13] [14].

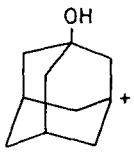
[6]) The ratio of alcohol VIIa to ether VIIb was approximately 3:2. The preponderance of alcohol has recently been discussed by *Pross* [16] and by *Ando & Tsukamoto* [17].



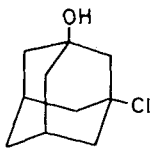

X

R = a) H

b) $C_2H_5$




XI




XII

On the other hand, when equivalent amounts of the bromide **15** and the unsaturated ketone VIIIc were reacted in 70% dioxane at 100° in the presence of two equiv. of glycine, the bromide was quantitatively converted to the diol Xa whereas the concentration of VIIIc was not noticeably changed (±2%). In the absence of the buffer, however, *ca.* 40% of the added VIIIc were cyclized to the diol Xa[7]). The conclusion is, that the bromide **15** ionizes to the 3-hydroxy-1-adamantyl cation XI which, under neutral or acidic conditions, reacts with solvent to yield the diol Xa and/or the ether Xb. In the presence of triethylamine fragmentation of the cation XI to VIIIc competes with diol and ether formation.

When two equiv. of NaOH were added to the solution of 3-bromo-1-adamantanol (**15**) in 80% ethanol the reaction was too fast to be followed even at 0°, and fragmentation to the unsaturated ketone VIIIc was the only observable reaction. The rate of the less reactive chloride XII was therefore measured as a function of NaOH concentration. *Table 2* shows that the observed first order rate constant at 0° increases by a factor of $4.86 \cdot 10^5$ as the NaOH concentration is increased to 1.34M. The estimated acceleration is *ca.* $10^6$ after allowance is made for the negative salt effect of the base, which is also observed in the fragmentation of other 3-chloro-alcohols [9].

Table 2. *Dependence on the NaOH concentration of the first order rate constants for the solvolysis of 3-chloro-1-adamantol (XII) in 80 vol.-% ethanol*

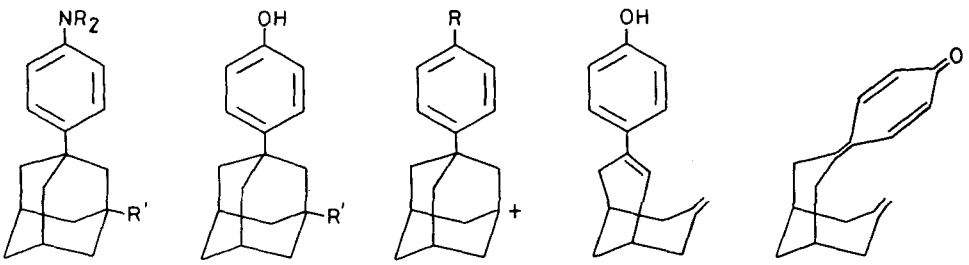
| Initial concentration [mol/l] | | T | $k$ |
|---|---|---|---|
| Chloride | NaOH | [°] | [$s^{-1}$] |
| 0.005 | – | 0.00 | $2.43 \cdot 10^{-10}$ a) |
| 0.005 | – | 56.00 | $3.47 \cdot 10^{-7}$ a) |
| 0.005 | – | 100.00 | $2.54 \cdot 10^{-5}$ b) |
| 0.005 | – | 110.00 | $5.84 \cdot 10^{-5}$ b) c) |
| 0.005 | – | 120.00 | $1.27 \cdot 10^{-4}$ b) |
| 0.01 | 0.05 | 0.00 | $1.57 \cdot 10^{-5}$ b) |
| 0.01 | 0.09 | 0.00 | $2.30 \cdot 10^{-5}$ b) |
| 0.005 | 0.31 | 0.00 | $6.20 \cdot 10^{-5}$ d) |
| 0.005 | 0.58 | 0.00 | $9.43 \cdot 10^{-5}$ d) |
| 0.005 | 1.00 | 0.00 | $1.13 \cdot 10^{-4}$ d) |
| 0.005 | 1.34 | 0.00 | $1.18 \cdot 10^{-4}$ d) |

a) Extrapolated.
b) By conductivity.
c) The rate constant for chloroadamantane (0.005M) at 110° is $1.30 \cdot 10^{-4}$ [10].
d) Titrimetric.

7) This is in agreement with the known tendency of VIIIc to cyclize under acidic conditions [15] [18].

These results show that the conjugate bases of 3-bromo- and 3-chloro-1-adamantanol (**15** and XII, respectively) undergo concerted fragmentation to the unsaturated ketone VIIIc. On the other hand, when the chloride XII was reacted in 80% ethanol buffered with glycine, only the diol Xa and the ether Xb were formed in 58 and 42% yield, respectively.

Solvolysis of the 1-(*p*-R-phenyl)-3-bromoadamantanes **24–28** in 80% ethanol yielded adamantanols and ethers only. When the *p*-aminophenyl derivatives **26** and **27** were reacted in 1M NaOH in 80% ethanol, which was saturated with sodium borohydride, reduction to the adamantanes XIIIc (R=H and $CH_3$, respectively) took place in 35 and 27% yield, respectively. This result strongly implicates the cations XV, R=$NH_2$ or $N(CH_3)_2$, as intermediates.




XIII XIV XV XVI XVII

R' = a) OH b) $OC_2H_5$ c) H

In 0.2M NaOH in 80% ethanol the *p*-hydroxyphenyl derivative **24** underwent substitution to XIVa and XIVb accompanied by 49% fragmentation to the bicyclo-[3.3.1]nonene derivative XVI *(Tab. 3)*. In 8M NaOH the yield of XVI increased to 90%. In a solution saturated with sodium borohydride and 1M in NaOH a 37% yield of the reduction product XIVc was obtained, while the yield of the fragmentation product XVI dropped from 56 to 18% *(Tab. 3)*. This indicates that the latter, as well as the substitution products XIVa, XIVb and XIVc, are formed *via* the zwitterion XV, R=$O^-$. If not trapped by solvent or hydride ion, the zwitterion fragments to the trienone XVII, which undergoes base-catalyzed enolisation to the phenol XVI.

Table 3. *Dependence on the NaOH concentration of the products from 0.05M p-(3-bromo-1-adamantyl)phenol* (**24**) *in 80 vol.-% ethanol at 100°*

| NaOH [mol/l] | Fragmentation (→XVI) [%] | Substitution [%] | Alcohol XIVa [%] | Ether XIVb [%] |
|---|---|---|---|---|
| 0.2 | 49 | 51 | 31 | 20 |
| 1.0[a]) | 56 | 44 | 24 | 20 |
| 5.0 | 79 | 21 | 9 | 12 |
| 8.0 | 90 | 10 | 6 | 4 |

[a]) Saturation of 1M NaOH with $NaBH_4$ at 70° led to 18% XVI, 24% XIVa, 21% XIVb and 37% *p*-(1-adamantyl)phenol (XIVc).

Table 4. *Dependence on the NaOH concentration of the first order rate constants for 0.005M p-(3-bromo-1-adamantyl)phenol* (**24**) *in 80 vol.-% ethanol at 70°*

| NaOH [mol/l] | Added salt [mol/l] | $k \cdot 10^4$ [$s^{-1}$] | NaOH [mol/l] | Added salt [mol/l] | $k \cdot 10^4$ [$s^{-1}$] |
|---|---|---|---|---|---|
| – | – | 0.323 | 0.10 | 0.35 $NaNO_3$ | 2.85 |
| 0.020 | – | 3.00[a]) | 0.10 | 1.27 $NaNO_3$ | 2.48 |
| 0.057 | – | 2.98 | 0.10 | 0.90 $NaClO_4$ | 5.02 |
| 0.10 | – | 2.97 | 0.10 | 1.7 $NaClO_4$ | 6.23 |
| 0.540 | – | 1.77 | | | |
| 1.05 | – | 0.941[a]) | | | |

[a]) $k = 3.24 \cdot 10^{-4}$ when extrapolated to zero NaOH concentration.

The latter was formed quantitatively when the bromide **24** was heated with potassium *t*-butoxide in *t*-butyl alcohol. Once formed, XVI is stable towards sodium borohydride. In aqueous acid at pH 1, however, it is immediately cyclized to the adamantanol XIVa, presumably *via* the protonated forms of XVII and XVI.

Addition of NaOH to a solution of the bromide **24** was accompanied by an increase in the solvolysis-fragmentation rate which reached a maximum at 0.02M NaOH and was reduced to *ca.* one third as the base concentration was increased to 1M *(Tab. 4)*. In *Figure 1* the logarithms of the observed first order rate constants at 70.0° are plotted against NaOH concentration. Extrapolation of the negative slope

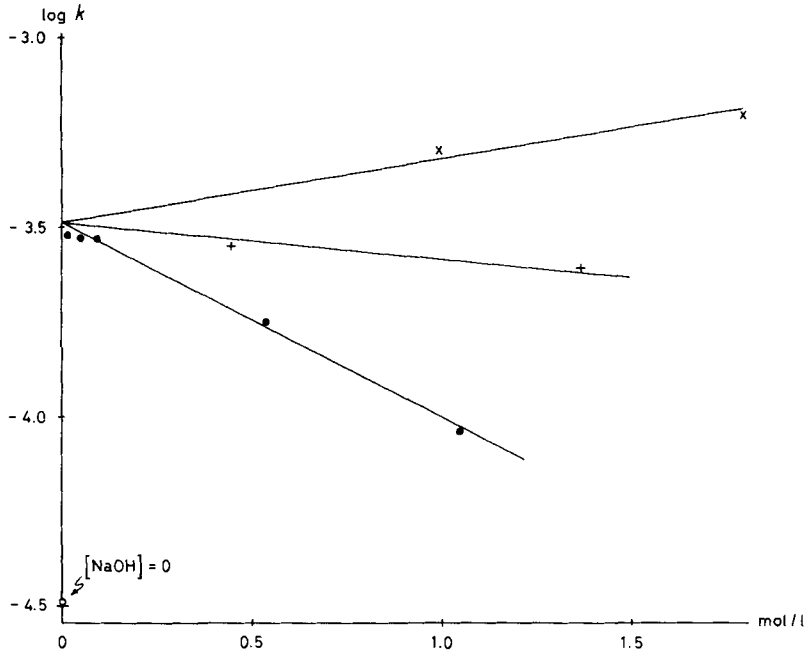
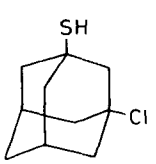


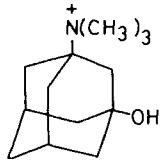

Fig. 1. *Plot of log* k *for the reaction of p-(3-bromo-1-adamantyl)phenol* (**24**) *against total electrolyte concentration in 80 vol.-% ethanol.* ● NaOH only; + 0.1M NaOH and $NaNO_3$; × 0.1M NaOH and $NaClO_4$

to zero concentration leads to an estimated rate constant of $3.24 \cdot 10^{-4}$ for the phenolate anion. This is ten times as large as that for the bromide **24** itself and reflects the influence of the negative charge of the phenolate anion. As *Table 4* and *Figure 1* show, addition of sodium nitrate to a solution of **24** in 80% ethanol, 0.1 M in NaOH, led to a far smaller negative salt effect, whereas sodium perchlorate produced a rate increase.

The reaction of 3-bromo-1-adamantanethiol (**23**) in 80% ethanol buffered with glycine yielded the substitution products VIIa and VIIb, R = SH, only. Addition of NaOH produced the anion of **23** which underwent rapid and quantitative fragmentation to 7-methylidenebicyclo[3.3.1]nonane-3-thione (VIIId). As discussed previously in the case of the 3-chloro analogue XVIII [10a] the thiolate anion reacts *ca.* $10^5$ times as fast as the thiol itself, *i.e.* with strong frangomeric acceleration.



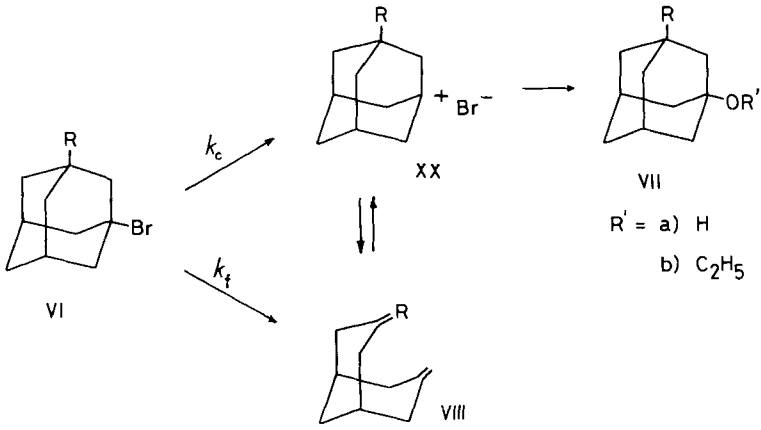

XVIII




XIX

When the trimethylammonio derivate **30** was reacted for four days in 0.1 N aqueous sodium hydroxide at 100° the unsaturated ketone VIIIc was the only detectable product. Evidently (3-hydroxy-1-adamantyl)trimethylammonium ion (XIX) is first formed and fragments subsequently to VIIIc.

*Scheme 2*



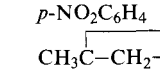

**Discussion.** – With the exception of the 1-amino (**21**) and 1-dimethylamino (**22**) derivatives, which undergo concerted fragmentation by the $k_f$ route *(Scheme 2)*, the bromides **1**–**30** are solvolyzed to adamantanols VIIa or their ethyl ethers VIIb by the $k_c$[8]) route. In the presence of NaOH the 1-hydroxy (**15**) and 1-mercapto (**23**)

[8]) Nucleophilically unassisted ionization rate constants were previously designated as $k_i$ [1] [5].

derivatives are converted to their conjugate bases **15a** and **23a**, respectively, which subsequently fragment to VIIIc and VIIId, respectively [9] [10a]. Thus, two processes have to be considered when discussing the relationship between reaction rates and inductive substituent constants $\sigma_I^q$ [11]. The relative rate constants for the bromides and, where available, the corresponding $\sigma_I^q$ values are listed in *Table 5*. The relationship between the log*k* and $\sigma_I^q$ values is shown in *Figure 2*.

It is evident from *Figure 2* that more than half of the log*k* values do not correlate with $\sigma_I^q$ within a limit of error of at least 60%. However, an excellent linear correlation (r = 0.998) is obtained for the ten bromides connected by the regression line. These, namely 1-bromoadamantane (**1**) and its derivatives **2**–**10**, contain practically neutral

Table 5. *Relative rate constants for 1-R-substituted 3-bromoadamantanes in 80 vol.% ethanol (70.0°), inductive substituent constants* $\sigma_I^q$ *and accelerations derived from the plot in* Figure 2

| Nr. | R | $k_{rel}$ | $\sigma_I^q$ | Acceleration |
|---|---|---|---|---|
| **1** | H | 1 | 0 | |
| **2** | $CH_3$ | 0.74 | 0.11 | |
| **3** | $C_2H_5$ | 1.02 | 0.03 | |
| **4** | iso-$C_3H_7$ | 1.52 | −0.08 | |
| **5** | *t*-$C_4H_9$ | 2.32 | −0.15 | |
| **6** | $CH_2Br$ | 0.049 | 1.07[d]) | |
| **7** | COOH | 0.01 | 1.70[e]) | |
| **8** | Br | 0.0012 | 2.65 | |
| **9** | CN | 0.00043 | 3.04 | |
| **10** | $NO_2$ | 0.000069 | 3.48 | |
| **11** | $CH_2=C(CH_3)$ | 0.36 | 0.60 | 1.7 |
| **12** | $C_6H_5$ | 0.22 | 0.94 | 2.5 |
| **13** | $SCH_3$ | 0.0410 | 1.66 | 3 |
| **14** | $OCH_3$ | 0.136 | 1.81 | 15 |
| **15** | OH[a]) | 0.471 | 1.74[d]) | 44 |
| **16** | $CH_2NH_2$ | 0.683 | 0.52[f]) | 2.5 |
| **17** | $CONH_2$ | 0.022 | 1.82[d]) | 2.6 |
| **18** | $CH_2OH$ | 0.598 | 0.66 | 3.1 |
| **19** | $COO^-$ | 2.19 | 0.58 | 9.3 |
| **20** | $Sn(CH_3)_3$ | 58.0 | −0.26[f]) | 26 |
| **21** | $NH_2$ | 37.4 | 0.98 | 470 |
| **22** | $N(CH_3)_2$ | 1196 | 0.97 | 15000 |
| **23** | SH[b]) | 0.022 | | |
| **24** | *p*-$HOC_6H_4$[c]) | 0.45 | | |
| **25** | *p*-$CH_3OC_6H_4$ | 0.35 | | |
| **26** | *p*-$H_2NC_6H_4$ | 0.62 | | |
| **27** | *p*-$(CH_3)_2NC_6H_4$ | 0.71 | | |
| **28** | *p*-$NO_2C_6H_4$ | 0.041 | | |
| **29** |  | 1.17 | | |
| **30** | $(CH_3)_3N^+$ | 0.000068 | 4.15[f]) | |

[a]) **15a**, R = $O^-$; $k_{rel}$ *ca.* $10^6$.
[b]) **23a**, R = $S^-$; $k_{rel}$ *ca.* $10^5$.
[c]) **24a**, R = *p*-$^-OC_6H_4$; $k_{rel}$ *ca.* 5.
[d]) Derived from the revised $pK_a$ of the corresponding quinuclidinium perchlorate [11].
[e]) $\sigma_I^q$ for the methyl ester [11].
[f]) New $\sigma_I^q$ value.

substituents, such as alkyl, or electron acceptors, such as COOH, Br, CN and $NO_2$. In these cases ionization rates are determined by the inductive effect of R alone. The reaction constant $\rho$ of $-1.14$ indicates that ionization rates respond only slightly more to the substituents than do the $pK_a$ values of the corresponding quinuclidines (IX)[9]. The negative sign of $\rho$ is in agreement with the rate determining ionization $k_c$ to ion pairs XX[10]).

In contrast the bromides **11–20** react 2–44 times faster than expected on the basis of the corresponding $\sigma_I^q$ values. This follows from the deviation of the points from the regression line *(Fig. 2* and *Tab. 5)*. These accelerations could be explained by assuming that the bromides undergo concerted fragmentation to 7-methylidenebicyclo-[3.3.1]nonane derivatives VIII ($k_f$ route in *Scheme 2*) which subsequently recyclize to adamantyl cations XX, the precursors of the substitution products VII.

It is well established, that concerted fragmentation is associated with frangomeric acceleration [1] [5], since $k_f$ is usually considerably larger than $k_c$. This is illustrated by the amines **21** and **22**, which, respectively, fragment 470 and 15,000 times faster than calculated from the regression line in *Figure 2 (Tab. 5)*. Frangomeric effects $k_f/k_c$ cannot be calculated with such a precision for the conjugate bases **15a** and **23a** of the hydroxy and mercapto derivatives **15** and **23**, respectively, because the $\sigma_I^q$ values

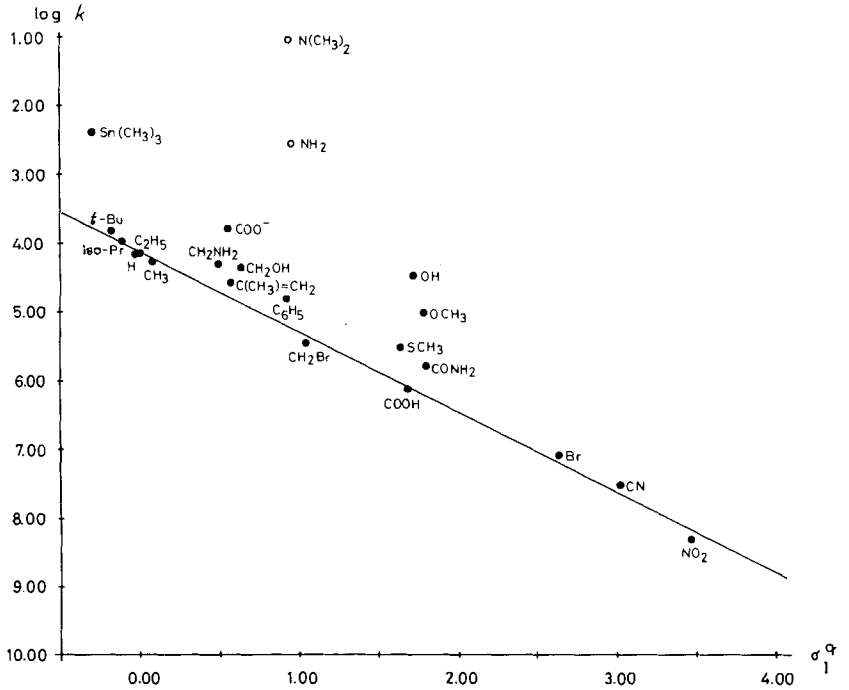



Fig. 2. *Relationship between log* k *for the reaction of 1-substituted 3-bromoadamantanes in 80 vol.-% ethanol and inductive substituent constants* $\sigma_I^q$. • substitution; o fragmentation

[9]) In this case $\rho = 1$ by definition [11].

[10]) The excellent correlation suggests that hidden return to VI is either negligible or constant.

for $O^-$ and $S^-$ as well as the equilibrium constants of **15** and **23** with NaOH and the above-mentioned salt effects are not known. However, taking the rate constant for bromoadamantane (**1**) as a measure for the $k_c$ process, frangomeric accelerations of at least $10^6$ and $10^5$, respectively, can be estimated[11]).

Nevertheless, the fragmentation-recyclization route VI → VIII → XX → VII is unlikely for the bromides **11**–**20** for two reasons. First, no fragmentation products were detectable under conditions in which the fragmentation products VIIIa–d and XVI are readily isolable from **21** and **22** and from the conjugate bases **15a**, **23a** and **24a**. Thus, the hypothetical fragmentation product VIIIc is not formed from the highly reactive hydroxy derivative **15** (acceleration 44) and if admixed, does not cyclize under the conditions of the rate measurements, *i.e.* in 80% ethanol buffered with glycine.

Second, log*k* for the solvolysis of 1-phenyl-3-bromoadamantane (**12**) and its *p*-substituted derivatives **24**–**28** should correlate with *Brown*'s substituent constants $\sigma^+$ and lead to a strongly negative reaction constant $\rho$ [19] if ring-opened conjugated carbenium ions XXI were formed in the transition state. In fact, log*k* for the aryl substituted bromides correlate better with accepted $\sigma_p$ constants [20] *(Fig. 3)* and $\rho$ equals $-0.84$, in accordance with the formation of an unconjugated and more remote cationic center. The point for *p*-$(CH_3)_2N$ lies well below the regression line when its accepted $\sigma_p$ value of 0.83 [20] is used. In this case through-resonance [21] weakens the standard acid, *i.e. p*-dimethylamino-benzoic acid, used to derive $\sigma_p$, and

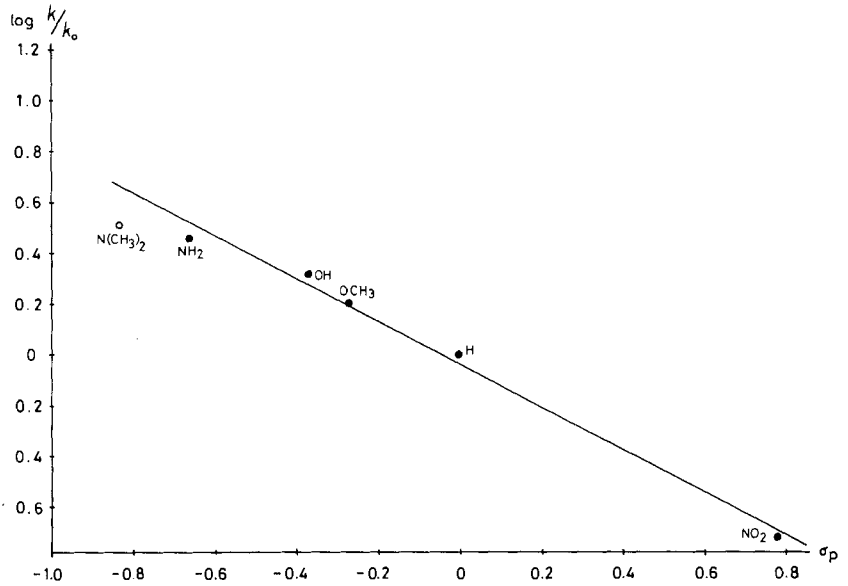
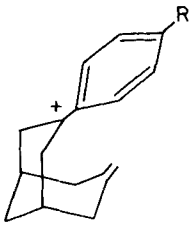
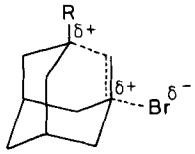



Fig. 3. *Plot of log* k *for the reaction of* p*-substituted 1-aryl-3-bromoadamantanes* **12** *and* **24**–**28** *in 80 vol.-% ethanol against substituent constants* $\sigma_p$ [20] (value for *p*-$(CH_3)_2N$ omitted from the regression line)

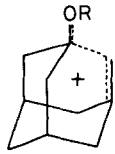
[11]) S. footnotes a) and b) in *Table 5.*




XXI




XXII




XXIII

R = a) $CH_3$
b) H

causes the latter to shift to a more negative value[12]). The low $\rho$ value of $-0.84$ reflects the small effect of the substituents. Thus, the *p*-substituted phenyl derivatives **24–27** react only 1.6–3.3 times faster, the nitro derivative **28** five times slower than the *p*-unsubstituted compound **12** *(Tab. 5)*.

A satisfactory explanation for the enhanced solvolysis rates of the bromides **11–20** involves hyperconjugation, as outlined in the introduction *(Scheme 1)*. It is conceivable that in the transition state XXII the electrons forming the C(1)–C(2) bond are progressively delocalized towards the incipient cationic center at C(3) as the ability of the substituent to donate electrons at C(1) increases. Positive charge is thus transferred from C(3) to C(1).

This process will be favored by substituents R with adjacent $\pi$-electrons as in **11** and **12**, or unshared electron pairs as in **13–15**. It is significant that the 1-methoxy group in **14** accelerates five times more than does the 1-methylthio group in **13** *(Tab. 5)* despite the larger $(-I)$-effect of the former, as evidenced by its higher $\sigma_I^9$ value. This points to a substancial electron deficieny at C(1) in the cation XXIIIa which an adjacent methoxy group can better stabilize because of its larger conjugative effect [23][13]). Furthermore, the hydroxy group in **15** accelerates three times more than the methoxy group in **14**. The resulting cation XXIIIb is very sensitive to base, for in the presence of two equiv. of triethylamine fragmentation to VIIIc competes with substitution to Xa and Xb. When the stronger base NaOH is added a mechanistic borderline is reached and concerted fragmentation $k_f$ supersedes the two-step process $k_c$ *(Scheme 2)*.

It is more difficult to rationalize the accelerations of 2.5 to 9 due to $CH_2NH_2$, $CONH_2$, $CH_2OH$ and $COO^-$ in the bromides **16–19**, since these substituents would be expected to exert a $(-I)$-effect rather than a conjugative effect. A common feature – also shared by the trimethyltin group in **20** (acceleration 26) – is, that they are potentially electrofugal, *i.e.* they can be eliminated as $a–b$ without the bonding electron pair in solvolytic fragmentations [2] [5] of the type: $a–b–c–d–X \rightarrow a–b + c{=}d + :X$. If these groups release electrons in the above reaction they should also act as weak donors to the electron deficient carbon atom in the hyperconjugated cation XXIV.

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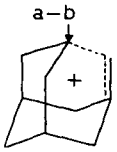
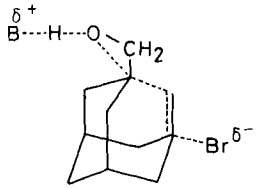
[12]) See the recent discussion by *Hammett* [22].

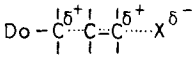
[13]) Since the effect is activated in the transition state, *Ingold's* term electromeric effect [4] would be appropriate.




XXIV




XXV




XXVI

An alternative explanation involves anchimeric assistance of hyperconjugation by the nucleophilic oxygen or nitrogen atom in the substituent at C(1), as illustrated in XXV for the hydroxymethyl derivative **18**. This, however, is unlikely because the trimethyltin substituent of **20**, which causes the largest acceleration (26) in this series of compounds, lacks a nucleophilic center. Furthermore, addition of ten equiv. of NaOH has no effect on the rate and products of the bromide **18**[14]).

The rate enhancing effect of the substituents in the bromides **11–20** thus appears to stem from their ability to promote the transfer of positive charge from C(3) to C(1) by hyperconjugation of the C(1)–C(2) bond, as illustrated in XXVI. Being a polarizability effect, CC-hyperconjugation acts in such a way as to facilitate ionization. In contrast, electron attracting or neutral substituents exert an inductive effect only. When the electron-donating power of the substituent lies between those of the OH and $NH_2$ groups, hyperconjugative electron displacement merges with concerted fragmentation[15]), which then appears as an extreme case of the former. It is also conceivable that fragmentation, though thermodynamically possible, is not completed because CC-hyperconjugation offers a kinetically more favorable reaction path such as substitution or elimination.

As the $k_{rel}$ values in *Table 5* show, the bromides **11–18** react more slowly than bromoadamantane (**1**) in spite of hyperconjugative acceleration, which therefore does not fully compensate the rate-retarding ($-I$)-effect. The only exception is the bromide **19** ($R = COO^-$) which reacts 2.2 times as fast as **1**, although the group has a net ($-I$)-effect ($\sigma_I^q = 0.58$). The $(CH_3)_3Sn$ derivative **20** which has the highest $k_{rel}$ of 58 also exerts the strongest ($+I$)-effect ($\sigma_I^q = -0.26$).

The alkyl derivatives **2–5**, which correlate well with $\sigma_I^q$, follow the usual inductive reactivity order $CH_3 < C_2H_5 < iso\text{-}C_3H_7 < t\text{-}C_4H_9$. However, the methyl group in **2** decreases the ionization rate slightly ($k_{rel} = 0.74$). This could mean that a methyl group at a $sp^3$ carbon atom is inherently electron withdrawing relative to hydrogen [11] or that steric hindrance to solvation in the 3-alkyl-1-adamantyl cations is sufficiently rate-depressing to overcome a weak ($+I$)-effect of the methyl group.

The methylcyclopropyl derivative **29** reacts only slightly faster ($k_{rel}$ 1.17) than bromoadamantane (**1**). However, since the cyclopropyl group is weakly electron-withdrawing by induction[16]) it must exert a net electron-releasing effect in the

[14]) Addition of base should enhance the nucleophilicity of the hydroxyl group by proton abstraction, as in XXV and thus facilitate hyperconjugation.

[15]) Possibly the borderline could be determined by weakening the conjugative effect of the amino group with suitable substituents.

[16]) For lit. pertaining to the polar effects of the cyclopropyl group s. [24].

solvolysis of **29**. On the other hand, the small acceleration of 1.17 clearly indicates that the positive charge generated at C(1) in the transition state from **29** is far smaller than the one generated in reactions leading to carbocations. The latter, as is well known, are strongly stabilized by an adjacent cyclopropyl group[16]).

In conclusion, polar substituent effects in saturated compounds are not independent of the reaction type, as is tacitly assumed when applying linear free energy relationships of the *Hammett* type, *i.e.* $\log k = \rho\sigma + \log k_o$. In fact hyperconjugative and frangomeric effects can modify the inductive effect, and their contributions to the total polar effect appear to vary continuously.

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## Experimental Part

Melting points (m.p.) were determined on a *Kofler*-Block and are corrected to ± 1°. IR. spectra in $cm^{-1}$. NMR. spectra in δ-values (ppm), coupling constants *J* in Hz.

**Syntheses.** – *3-Bromoadamantane-1-carbonitril* (**9**) is mentioned in the literature [7b] without comment. To 243 mg (0.94 mmol) of 3-bromoadamantane-1-carboxylic acid (**7**) [25] in 2 ml of abs. methylene chloride were added 156 mg (1.1 mmol) of chlorosulfonyl isocyanate [26] in 2 ml of the same solvent. After heating under reflux for 3 h 106 mg (1.05 mmol) of triethylamine were added [27] and heating was continued for 5 h. After washing of the $CH_2Cl_2$ solution with aqueous 2N $NaHCO_3$, 0.5N HCl, and water, it was dried with $K_2CO_3$ and evaporated. Sublimation of the solid residue at 60°/0.01 Torr (decomp. begins above 60°) yielded 170 mg (76%) **9**, m.p. 118–121° (decomp., in a capillary tube). – IR. ($CCl_4$): 2253, 2233 (CN).

$C_{11}H_{14}BrN$ (240.14) Calc. C 55.01 H 5.87 N 5.83% Found C 55.09 H 6.02 N 5.81%

*3-Bromo-1-nitro-adamantane* (**10**). 11.5 g (72.8 mmol) of finely powdered $KMnO_4$ were added in small portions to a stirred solution of 1.66 g (7.21 mmol) of 1-amino-3-bromoadamontane (**21**) [8] during 6 days at 25°. After evaporation the residue was suspended in ether, filtered and washed with ether. The combined extracts were dried over $Na_2SO_4$ and evaporated. From hexane 1.14 g (61%) **10**, m.p. 128° (decomp. above 90°). – IR. ($CCl_4$): 1538*s*, 1360*m* ($NO_2$).

$C_{10}H_{14}BrNO_2$ (260.13) Calc. C 46.17 H 5.42 N 5.38% Found C 46.36 H 5.55 N 5.40%

*(3-Bromo-1-adamantyl)trimethyltin* (**20**). A solution of 8.83 g (30 mmol) of 1,3-dibromoadamantane (**8**) in 50 ml of abs. ether was dropped to a stirred suspension of 486 mg (70 mmol) of finely cut lithium in abs. ether and in an argon atmosphere. After heating under reflux for 18 h 5.98 g (30 mmol) of trimethyltin chloride *(Fluka)* in 15 ml of abs. ether were added during 1 h. The mixture was heated under reflux for 3 h and then filtered. Evaporation of the filtrate yielded 9.24 g (82%) of **20** after distillation at 92–94°/0.03 Torr. From pentane at −78°, m.p. 34–35°. – NMR. ($CCl_4$): 0.01 (*s*, 9 H, $Sn(CH_3)_3$); 1.6–2.7 (*m*, 14 H).

$C_{13}H_{23}BrSn$ (377.92) Calc. C 41.31 H 6.13 Br 21.15% Found C 41.47 H 6.37 Br 21.41%

*(3-Bromo-1-adamantyl) trimethylammonium iodide* (**30**). 50 mg (0,161 mmol) of 3-Bromo-1-(dimethylamino)adamontane hydrobromide (**22**·HBr) [8] were heated with saturated aqueous $K_2CO_3$ and the free base was extracted with ether. The dried extract was partially evaporated to 5 ml, 400 mg (2.82 mmol) of methyl iodide were added and the mixture was heated under reflux for 48 h. Evaporation and crystallization from methanol/ether yielded 40 mg (62%) of **30**, m.p. 265° (decomp.).

$C_{13}H_{23}BrIN$ (400.14) Calc. C 39.03 H 5.79 N 3.50% Found C 39.05 H 5.89 N 3.41%

The iodide was converted to the *perchlorate* (used in the rate measurements) by adding the calculated amount of silver perchlorate in methanol and filtering off the silver iodide. The filtrate was

concentrated and ether was added until the perchlorate crystallized. Drying at 60°/0.02 Torr gave 16.1 mg (89%), m.p. 301–302° (decomp.).

$C_{13}H_{23}BrClNO_4$ (372.69) Calc. C 41.89 H 6.22 N 3.75% Found C 41.80 H 6.28 N 3.57%

*4-Aminomethyl-quinuclidine bishydrochloride* (IX · 2 HCl, $R = CH_2NH_2$)[17]. 0.4 g (2.6 mmol) of quinuclidine-4-carboxamide (IX, $R = CONH_2$) [28] in 5 ml of abs. tetrahydrofuran (THF) were slowly dropped into a stirred suspension of 0.2 g (5.27 mmol) of $LiAlH_4$ in 10 ml of THF. After 15 h at 25° and 2 h at 40° 0.8 ml of 0.1N NaOH were slowly added with external cooling. The white precipitate was filtered off and washed with THF. The filtrates were dried over $K_2CO_3$ and filtered, 5 ml of 5N HCl in ether were added and the mixture was evaporated to dryness. The white residue was crystallized from methanol/ether yielding 420 mg (76%) of microcrystals, decomp. above 300°. – IR. (KBr): 2683, 2602, 2043 ($NH^+$). – NMR. ($D_2O$): 1.8–2.07 (*m*, 6 H, 3 $CH_2$); 3.05 (*s*, 2 H, $CH_2NH_3^+$); 3.31–3.58 (*m*, 6 H, 3 $CH_2$).

$C_8H_{18}Cl_2N_2$ (213.152) Calc. C 45.08 H 8.51 Cl 33.27% Found C 45.09 H 8.42 Cl 33.11%

The *bishydroperchlorate* was prepared from the bishydrochloride with $AgClO_4$ in methanol. From 2-propanol fine needles, decomp. above 270°. The *thermodynamic* $pK_a$ values for the bishydroperchlorate were determined as described [11]: $pK_a^T(CH_2NH_3^+) = 8.90$; $pK_a^T(N(1)) = 10.60 \pm 0.01$.

$C_{18}H_{18}Cl_2N_2O_8$ (341.144) Calc. C 28.16 H 5.31 N 8.21% Found C 28.31 H 5.51 N 8.44%

*(4-Quinuclidinyl) trimethyltin* (IX, $R = Sn(CH_3)_3$). 11.97 g (60 mmol) of trimethyltin chloride *(Fluka)* in 50 ml of abs. THF were dropped into a stirred suspension of 1.665 g (240 mmol) of finely cut lithium held at 25° under argon. After further 2 h at 25° the green solution was filtered under argon pressure and cooled to 0°. 2.86 g (15 mmol) of 4-bromoquinuclidine [29] were then added, the mixture was stirred at 0° for 3 h and at 25° for 18 h and evaporated to dryness *in vacuo*. The residue was partitioned between ether and 1N aqueous HCl, the acidic extracts were made alkaline with 2N $K_2CO_3$ and then extracted thoroughly with ether. The combined extracts were dried over $K_2CO_3$ and evaporated to dryness. Sublimation of the residue at 70°/0.01 Torr yielded 1.95 g (47%), m.p. 107–107.5°. – NMR. ($CCl_4$): −0.11 (*s*, 9 H, $Sn(CH_3)_3$); 1,58 (*m*, 6 H, 3 $CH_2$); 2,69 (*m*, 6 H, 3 $CH_2$).

*Hydroperchlorate IX · $HClO_4$*, $R = Sn(CH_3)_3$. An ether extract of 60% perchloric acid was slowly added to the base until precipitation ceased. From 2-propanol m.p. 267–272° (decomp.). $pK_a^T = 11.38$.

$C_{10}H_{22}ClNO_4Sn$ (374.43) Calc. C 32.07 H 5.92 N 3.74% Found C 31.96 H 6.12 N 3.66%

*Hydroperchlorate of (4-quinuclidinyl) trimethylammonium perchlorate* (IX · $HClO_4$, $R = (CH_3)_3N^+ClO_4^-$). 113 mg (0.66 mmol) of benzylbromide in 6 ml of abs. ether were added with stirring to 100.7 mg (0.653 mmol) of 4-dimethylamino-quinuclidine [30] in 10 ml of abs. ether at 0°. After 3 h at 0° and 2 h of heating under reflux the solvent was evaporated and the crystalline residue of 1-benzyl-4-dimethylamino-quinuclidinium bromide dried *in vacuo:* 208 mg (98%). 194 mg (0.597 mmol) of this material were dissolved in 852 mg (6 mmol) of methyl iodide and 10 ml of dry acetonitrile. After standing for 15 h at 25° the solvent was evaporated, the residue dissolved in 8 ml of water and 5 ml of methanol and the solution potentiometrically titrated with 0.1N silver perchlorate. After filtration, evaporation and drying 279 mg of crude *1-benzyl-4-trimethylammonio-quinuclidinium diperchlorate* were obtained. – NMR. ($D_2O$): 2.25–2.68 (*m*, 6 H, 3 $CH_2$); 3.11 (*s*, 9H, $(CH_3)_3N^+$); 3.55–3.93 (*m*, 6 H, 3 $CH_2$); 4,50 (*s*, 2 H, $CH_2C_6H_5$); 7.56 (*s*, 5 H, $C_6H_5$).

This material was dissolved in 15 ml of water/methanol 2:1 and hydrogenated over 150 mg of 10% Pd/C at 25°. Filtration and evaporation of the solvent yielded 162 mg (73%) IX · $HClO_4$, m.p. 285–294° (decomp.) after crystallization from methanol/ether, $pK_a^T = 6.97$. – NMR. ($D_2O$): 2.18–2.65 (*m*, 6 H, 3 $CH_2$); 3.12 (*s*, 9 H, $(CH_3)_3N^+$); 3.40–3.79 (*m*, 6 H, 3 $CH_2$).

$C_{10}H_{22}Cl_2N_2O_8$ (369.20) Calc. C 32.53 H 6.00 N 7.62% Found C 32.67 H 6.21 N 7.38%

p-*(1-Adamantyl)phenol* (XIVc). 3.51 g (14.5 mmol) of *p*-(1-adamantyl)anisol [15] were heated in a solution of 30 ml of 40% HBr in glacial acetic acid for 3 h at 100° and 20 min at 110°. The mixture was

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[17]) This preparation was carried out by Dr. *M. G. Schlageter.*

poured into ice water, the precipitate filtered off, washed with water and dried[18]). After crystallization from $CH_2Cl_2$ and sublimation at 140°/12 Torr m.p. 179–181.5°. – NMR. ($CDCl_3$): 1.65–2.20 (*m*, 15 H, 6 $CH_2$, 3 CH); 4.62 (*s*, 1 H, HO); 6.72, 7.16 ($A_2B_2$, $J$ = 8, 4 H, $C_6H_4$).

$C_{16}H_{20}O$ (228.34) Calc. C 84.16 H 8.83% Found C 84.41 H 9.08%

p-*(7-Methylidenebicyclo[3.3.1]non-2-en-3-yl)phenol* (XVI). 400 mg (1.3 mmol) of *p*-(3-bromo-1-adamantyl)phenol (**24**) and 15 ml of a 1N solution of potassium *t*-butoxide in *t*-butyl alcohol were heated in a sealed tube to 170° for 3 days. The mixture was concentrated to 10 ml *in vacuo*, diluted with 50 ml of water, neutralized with conc. aqueous $NH_4Cl$ solution and extracted with ether. The extracts were dried with $Na_2SO_4$ and evaporated, the residue was sublimed at 110°/0.01 Torr and crystallized from hexane. Yield 280 mg (95%), m.p. 155–158°. – IR. ($CCl_4$): 3610, 1250 (Ar-OH); 3070, 1638 and 885 (C=$CH_2$); 3025, 1605 and 1504 (arom.). – NMR. ($CCl_4$/$(CD_3)_2SO$ 1:1): 1.0–2.8 (*m*, 10 H, 4 $CH_2$, 2 CH); 4.53 (*d*, $J$ = 12, 2 H, $H_2C$=C(7)); 5.76 (*d*, $J$ = 6, 1 H, H–C(2)); 6.53–7.14 ($A_2B_2$, $J$ = 9, 4 H, $C_6H_4$); 9.80 (br. *s*, 1 H, HO).

$C_{16}H_{18}O$ (226.319) Calc. C 84.91 H 8.02% Found C 85.16 H 8.29%

*3-(p-Hydroxyphenyl)-1-adamantanol* (XIVa). 400 mg (1.3 mmol) of the bromide **24** were heated with 10 ml of 2N aqueous NaOH to 100° for 15 min. The solution was diluted with 20 ml of water, acidified to pH 1 with 2N $H_2SO_4$ and extracted with ether after standing at 25° for 1 h. The extracts were dried over $Na_2SO_4$ and evaporated, yielding after sublimation at 140°/0.01 Torr 286 mg (90%) of XIVa, m.p. 221–222° (XIVa is extremely sensitive to oxygen). – NMR. ($(CD_3)_2SO$): 1.3–2.6 (*m*, 14 H, 6 $CH_2$, 2 CH); 4.43 (*s*, 1 H, HO); 6.65–7.23 ($A_2B_2$, $J$ = 9, 4 H, *p*-subst. $C_6H_4$); 9.12 (*s*, 1 H, ArOH).

$C_{16}H_{20}O_2$ (244.335) Calc. C 78.65 H 8.25% Found C 78.84 H 8.39%

p-*(3-Ethoxy-1-adamantyl)phenol* (XIVb). 400 mg (1.3 mmol) of the bromide **24** and a solution of 92 mg (4 mmol) of sodium in 10 ml of abs. ethanol were heated to 170° for 3 days. After dilution with 10 ml of abs. ethanol 0.5 ml of conc. $H_2SO_4$ were added gradually and the mixture was kept at 25° for 24 h. 30 ml of water were added, the pH was adjusted to 8 with 2N $Na_2CO_3$ and the solution was concentrated *in vacuo* to 20 ml. After dilution with 30 ml of water the mixture was extracted with ether. The extracts were dried and evaporated. The residue was sublimed at 110–130°/0.005 Torr to yield 330 mg (93%) of XIVb, m.p. 177–180° (XIVb is sensitive to oxygen). – NMR. ($CCl_4$/$(CD_3)_2SO$ 1:1): 1.07–2.40 (*m*, 14 H, 6 $CH_2$, 2 CH); 1.07 (*t*, $J$ = 7, 3 H, $CH_3CH_2O$); 3.42 (*q*, $J$ = 7, 2 H, $CH_3CH_2O$); 6.51–7.10 ($A_2B_2$, $J$ = 9, 4 H, $C_6H_4$); 8.49 (*s*, 1 H, $C_6H_4OH$).

$C_{18}H_{24}O_2$ (272.389) Calc. C 79.37 H 8.88% Found C 79.39 H 9.03%

p-*(1-Adamantyl)aniline* (XIIIc, R' = H) was prepared by hydrogenation of 1-(*p*-nitrophenyl)adamantane [15] with 10% Pd/C in ethyl acetate. The crude reaction product was dissolved in ether and extracted with 2N HCl, the extract was made alkaline with 2N NaOH and extracted with ether. After sublimation at 80°/0.005 Torr the amine (87%) melted at 107–108° ([31] m.p. 109°).

$C_{16}H_{21}N$ (227.35) Calc. C 84.53 H 9.31% Found C 84.38 H 9.40%

*3-Chloro-1-adamantanol* (XII) was prepared from 7-methylidenebicyclo[3.3.1]nonan-3-one (VIIIc) by shaking with conc. hydrochloric acid for 2 days at 25°, according to the procedure of *Stetter et al.* [18]. From petroleum ether m.p. 205–205.5°, yield 80% ([18]: m.p. 205.5°, 71%).

**Solvolyses of 1-substituted 3-bromoadamantanes** (VI). – *General procedure.* Unless stated otherwise 0.05M solutions of the bromide in 80 vol.-% ethanol or 70% dioxane, 0.1M in triethylamine, were reacted for ten half lives at the temp. indicated in *Table 1*. The product ratios were determined by GLC. (2.5% silicon oil SE-52 on *chromosorb* G at 200°, $N_2$, *Varian* CDS 111 integrator). The reaction solutions were then evaporated to dryness *in vacuo*, the residues were partitioned between ether and water (2N NaOH in the case of **27**), the ether extracts were dried over $Na_2SO_4$ and evaporated. The residues were crystallized or separated by chromatography on silica gel, if mixtures were obtained.

*Bromides* **1–5** were reacted as described previously [6] [7].

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[18]) The phenol is insoluble in 1N NaOH.

*Bromide* **6** (R = $CH_2Br$) [15] was reacted in 70% dioxane, with 3 equiv. of glycine, to yield pure *3-(bromomethyl)-1-adamantanol* (VIIa, R = $CH_2Br$). After sublimation at 70°/0.01 Torr m.p. 87–88° (in capillary tube), yield 92%. – NMR. ($CCl_4$): 1.3–1.55 (*m*, 12 H); 1.83 (*s*, 1 H, HO); 2.2 (*s*, 2 H, 2 CH); 3.15 (*s*, 2 H, $CH_2Br$).

$C_{11}H_{17}BrO$ (245.17) Calc. C 53.89 H 6.99 Br 32.54% Found C 54.10 H 6.86 Br 32.44%

*Bromide* **7** (R = COOH) reacted in 70% dioxane, with 1 equiv. of betaine and 1 equiv. of betaine hydroperchlorate, to yield *3-hydroxyadamantane-1-carboxylic acid* (VIIa, R = COOH), m.p. 206–208° ([25]: m.p. 202–203°), yield 90%.

*Bromide* **8** (R = Br) reacted in 70% dioxane, with 3 equiv. of glycine, to *1,3-adamantanediol* (VIIa, R = OH) (*via* 3-bromo-1-adamantanol). M.p. 310–315°, yield 86% ([31]; m.p. 315°). – NMR. ($(CD_3)_2SO$): 1.2–1.6 (*m*, 12 H, 6 $CH_2$); 2.08 (br. *s*, 2 H, 2 CH); 4.34 (*s*, 2 H, 2 HO).

*Bromide* **9** (R = CN) reacted in 50% dioxane to *3-hydroxy-adamantane-1-carbonitrile* (VIIa, R = CN). After sublimation m.p. 195–211° (decomp). – IR. ($CCl_4$): 3610 (*t*, OH), 2240 (CN).

$C_{11}H_{15}NO$ (177.25) Calc. C 74.54 H 8.53 N 7.90% Found C 77.44 H 8.81 N 7.36%

*Bromide* **10** (R = $NO_2$) reacted in 70% dioxane, with 1.5 equiv. of NaOH, to *3-nitro-1-adamantanol* (VIIa, R = $NO_2$). After sublimation at 115°/0.001 Torr and crystallization from ether m.p. 196–202°. – IR. (KBr): 3280*s* and 1113*s* (*t*, OH); 1540*s* and 1362*s* ($NO_2$).

$C_{10}H_{15}NO_3$ (197.24) Calc. C 60.89 H 7.67 N 7.10% Found C 60.79 H 7.75 N 6.94%

*Bromide* **11** (R = $CH_2$=$C(CH_3)$) reacted in 80% ethanol to a 3:2 mixture of the corresponding alcohol and the ethyl ether. Chromatography on silica gel with ether/petroleum ether 1:1 yielded a first fraction of *1-ethoxy-3-isopropenyladamantane* (VIIb, R = $CH_2$=$C(CH_3)$), b.p. 110–120°/10 Torr (bulb tube). – IR. ($CCl_4$): 3090, 1635 and 890 (C=$CH_2$); 1110 (C–OEt). – NMR. ($CCl_4$): 1.18 (*t*, *J* = 7, 3 H, $CH_3CH_2O$); 1.73 (*s*, 3 H, $H_3C$–C=C); 3.49 (*q*, *J* = 7, 2 H, $CH_3CH_2O$); 4.70 (*s*, 2 H, $H_2C$=C).

$C_{15}H_{24}O$ (220.356) Calc. C 81.76 H 10.98% Found C 81.58 H 11.20%

The second fraction consisted of *3-isopropenyl-1-adamantanol* (VIIa, R = $CH_2$=$C(CH_3)$). After sublimation at 70–80°/12 Torr m.p. 82.5°. – IR. ($CCl_4$): 3610 (*t*, OH); 3090, 1634 and 892 (C=$CH_2$). – NMR. ($CDCl_3$): 1.47 (*s*, 1 H, HO); 1.5–1.9 (*m*, 12 H, 6 $CH_2$); 1.72 (*m*, 3 H, $H_3C$–C=C); 2.22 (*m*, 2 H, 2 CH); 4.67 (*m*, 2 H, $H_2C$=C).

*Bromide* **12** (R = $C_6H_5$) reacted in 80% ethanol to a 3:2 mixture of the corresponding alcohol and ether. Chromatography with ether yielded *1-ethoxy-3-phenyladamantane* (VIIb, R = $C_6H_5$), b.p. 80–100°/0.005 Torr (bulb tube). – NMR. ($CDCl_3$): 1.17 (*t*, *J* = 3.6, 3 H, $CH_3CH_2O$); 1.50–2.0 (*m*, 12 H, 6 $CH_2$); 2.25 (*m*, 2 H, 2 CH); 3.51 (*q*, *J* = 6, 2 H, $CH_3CH_2O$); 7.30 (*m*, 5 H, $C_6H_5$).

$C_{18}H_{24}O$ (256.39) Calc. C 84.32 H 9.44% Found C 84.57 H 9.63%

The second fraction consisted of *3-phenyl-1-adamantanol* (VIIa, R = $C_6H_5$), m.p. 100–101°, which was identical with an authentic sample [15].

*Bromide* **13** (R = $SCH_3$) reacted in 70% dioxane to *3-methylthio-1-adamantanol* (VIIa, R = $SCH_3$), m.p. 72–73°, yield 92%, which was identical with an authentic sample [15].

*Bromide* **14** (R = $OCH_3$) reacted in 70% dioxane to *3-methoxy-1-adamantanol* (VIIa, R = $OCH_3$), m.p. 68–69°, yield 90%, identical with an authentic sample [15].

*Bromide* **15** (R = OH) reacted in 80% ethanol (without base) at 100° for 3 h to yield 48% of *1,3-adamantanediol* (VIIa, R = OH) and 46% of *3-ethoxy-1-adamantanol* (VIIb, R = OH), which were separated by prep. GLC., and identified with authentic samples prepared according to [18]. In the presence of 1 equiv. of triethylamine 63% of 7-methylidenebicyclo[3.3.1]nonan-3-one (VIIIc) were formed besides 20% of VIIa and 16% of VIIb. Reaction of the bromide **15** in 70% dioxane at 100° for 3 h afforded VIIa in quantitative yield, also in the presence of 2 equiv. of glycine. Added ketone VIIIc was not significantly cyclized under these conditions.

*Bromide* **16** · *HBr* (R = $CH_2NH_2$) reacted in 70% dioxane, with 3 equiv. of triethylamine, to *3-(aminomethyl)-1-adamantanol* (VIIa, R = $CH_2NH_2$) which was isolated as the picrate, m.p. 232–234°, yield 97%. – NMR. ($(CD_3)_2SO$): 1.36–1.54 (*m*, 14 H, 6 $CH_2$, 2 CH); 2.09–2.18 (br. *s*, 2 H, $CH_2N^+$); 4.49 (*s*, 1 H, HO, exchanges with $D_2O$); 8.58 (*s*, 2 H, arom. $C_6H_2$).

$C_{17}H_{22}N_4O_8$ (410.378) Calc. C 49.75 H 5.40 N 13.65% Found C 50.04 H 5.45 N 13.89%

*Bromide* **17** (R = $CONH_2$) reacted in 70% dioxane to *3-hydroxyadamantane-1-carboxamide* (VIIa, R = $CONH_2$), from acetone/ether m.p. 136°, yield 94%. – NMR. ($(CD_3)_2SO$): 1.48–1.59 (*m*, 12 H, 6 $CH_2$); 2.08–2.11 (*m*, 2 H, 2 CH); 4.41 (*s*, 1 H, HO, exchangeable with $D_2O$); 6.64–6.93 (br. *s*, 2 H, $CONH_2$).

$C_{11}H_{17}NO_2$ (195.254) Calc. C 67.66 H 8.77 N 7.17% Found C 67.39 H 8.74 N 7.15%

*Bromide* **18** (R = $CH_2OH$) reacted in 70% dioxane, with or without 2 equiv. of triethylamine or with 10 equiv. of NaOH, to *3-(hydroxymethyl)-1-adamantanol* (VIIa, R = $CH_2OH$); from cyclohexane m.p. 160–161°, yield 95%. – NMR. ($(CD_3)_2SO$): 1.1–1.7 (*m*, 12 H, 6 $CH_2$); 2.14 (br. *s*, 2 H, 2 CH); 3.08 (*d*, 2 H, $CH_2OH$); 4.2 (*m*, 2 H, 2 HO, disappears with $D_2O$).

$C_{11}H_{18}O_2$ (182.26) Calc. C 72.49 H 9.95% Found C 72.55 H 10.05%

*Bromide* **19** (R = COONa) reacted in water, with 3 equiv. of NaOH, to *3-hydroxyadamantane-1-carboxylic acid* (VIIa, R = COOH; 90%), identical with the product from bromide **7**.

*Bromide* **20** (R = $(CH_3)_3Sn$) reacted in 80% dioxane at 70° for 10 h (after 8 h 1.5 equiv. of triethylamine were added to neutralize HBr) to *(3-hydroxy-1-adamantyl)trimethyltin* (VIIa, R = $(CH_3)_3Sn$); from pentane and after sublimation at 50°/0.01 Torr m.p. 111–113°, yield 60%. – NMR. ($CDCl_3$): −0.02 (*s*, 9 H, $Sn(CH_3)_3$); 1.5–2.7 (*m*, 15 H, 6 $CH_2$, 2 CH, HO).

$C_{13}H_{24}OSn$ (315.02) Calc. C 49.56 H 7.67% Found C 49.36 H 7.91%

*Bromides* **21** (R = $NH_2$) and **22** (R = $(CH_3)_2N$) underwent quantitative fragmentation as described [8].

*Bromide* **23** (R = SH) reacted in 80% ethanol, with 2 equiv. of glycine, to a mixture of 58% alcohol and 42% monoether, which were separated by chromatography on silica gel. The alcohol was identified as *3-mercapto-1-adamantanol* (VIIa, R = SH) [15]. From petroleum ether m.p. 149–151°. – IR. ($CCl_4$): 3610 (OH); 2575 (SH). – NMR. ($CCl_4$): 1.4–1.9 (*m*, 14 H, 6 $CH_2$, 2 CH); 2.0–2.4 (*m*, 2 H, HO, HS).

$C_{10}H_{16}OS$ (184.30) Calc. C 65.17 H 8.75 S 17.40% Found C 65.09 H 8.84 S 17.57%

The ether was identified as *3-ethylthio-1-adamantanol* (VIIa, R = SEt)[19], m.p. 43–44° ([18]: m.p. 37–39°). – IR. ($CCl_4$): 3605 (OH). – NMR. ($CCl_4$): 1.4–1.9 (*m*, 12 H); 2.0–2.4 (*m*, 2 H, 2 CH); 2.49 (*q*, $J$ = 7.5, 2 H, $CH_3CH_2S$); 3.06 (*s*, 1 H, HO).

$C_{12}H_{20}OS$ (212.36) Calc. C 67.87 H 9.49 S 15.10% Found C 68.11 H 9.55 S 15.07%

*Bromide* **24** (R = *p*-$HOC_6H_4$) reacted in 80% ethanol (without base) to a 1:1 mixture of the alcohol XIVa and the ether XIVb, as shown by GLC. with authentic samples. To 0.05M solutions of **24** in 80% ethanol were added increasing amounts of NaOH *(Tab. 3)*. After reaction at 100° water was added, the mixture neutralized with conc. aqueous $NH_4Cl$ solution and extracted with ether. The dried extracts were evaporated and the residues analyzed by GLC. The amounts of XVI, XIVa and XIVb are listed in *Table 3*.

Reaction of the bromide **24** at 70° in 1N aqueous NaOH, to which $NaBH_4$ was continuously added until saturated, led to 18% XVI, 24% XIVa, 21% XIVb and 37% XIVc, as determined by GLC.

*Bromide* **25** (R = *p*-$CH_3OC_6H_4$) reacted in 80% ethanol to a 3:2 mixture of *3-(p-methoxyphenyl)-1-adamantanol* (VIIa, R = *p*-$CH_3OC_6H_4$) [15] and *1-ethoxy-3-(p-methoxyphenyl)adamantane* (VIIb, R = *p*-$CH_3OC_6H_4$). The oily mixture was isolated by chromatography on silica gel and bulb-tube distilled at 100°/0.005 Torr. – NMR. ($CDCl_3$): 1.20 (*t*, $J$ = 6, 3 H, $CH_3CH_2O$); 1.70–2.0 (*m*, 12 H, 6 $CH_2$); 2.35 (*m*, 2 H, 2 CH); 3.52 (*q*, $J$ = 6, 2 H, $CH_3CH_2O$); 3.80 (*s*, 3 H, $CH_3O$); 6.84 and 7.28 ($A_2B_2$, $J$ = 10, 4 H, $C_6H_4$).

$C_{19}H_{26}O_2$ (286.42) Calc. C 79.68 H 9.15% Found C 79.75 H 9.28%

*Bromide* **26** (R = *p*-$H_2NC_6H_4$) reacted in 80% ethanol to a 1.65:1 mixture of the alcohol XIIIa (R = H) and the ether XIIIb (R = H). The mixture was isolated and acetylated with excess acetic anhydride at 0° for 30 min. Usual work-up yielded a mixture of *N*-acetyl derivatives which were separated on silica gel with ethyl acetate. The first fraction consisted of *1-(p-acetylamino-phenyl)-3-*

[19]) The synthesis will be described in a forthcoming paper.

*ethoxyadamantane* (XIIIb, R = H and $CH_3CO$); from methylene chloride/pentane m.p. 151–152°. – NMR. ($CDCl_3$): 1.19 (*t*, *J* = 7, 3 H, $CH_3CH_2O$); 1.7–2.0, 2.35 (2 *m*, 12 H and 2 H, 2 CH, 6 $CH_2$); 2.17 (*s*, 3 H, $CH_3CO$); 3.49 (*q*, *J* = 7, 2 H, $CH_3CH_2O$); 7.29, 7.43 ($A_2B_2$, *J* = 8, 4 H, $C_6H_4$).

$C_{20}H_{27}NO_2$ (313.44) Calc. C 76.64 H 8.68 N 4.47% Found C 76.65 H 8.83 N 4.71%

The second fraction consisted of *3-(*p*-acetylamino-phenyl)-1-adamantanol* (XIIIa, R = H and $CH_3CO$): from methylene chloride m.p. 210–211°. – NMR. ($(CD_3)_2CO$/$(CD_3)_2SO$): 1.5–2.0, 2.30 (2 *m*, 12 H and 2 H, 6 $CH_2$, 2 CH); 3.22 (*s*, 4 H, $CH_3CO$, HO).

$C_{18}H_{23}NO_3$ (285.39) Calc. C 75.76 H 8.12 N 4.91% Found C 75.50 H 8.34 N 4.87%

Reaction of **26** in 80% ethanol at 70°, to which $NaBH_4$ was added until saturated led to 35% of p-*(1-adamantyl)-anilin* (XIIIc, R = H) besides the alcohol XIIIa (R = H; 33%) and the ether XIIIb (R = H; 32%), as determined by GLC. and comparison with authentic samples.

*Bromide* **27** (R = *p*-$(CH_3)_2NC_6H_4$) reacted in 80% ethanol to a 3:2 mixture of the alcohol XIIIa (R = $CH_3$) and the ether XIIIb (R = $CH_3$) which was separated by chromatography on silica gel. The first fraction consisted of p-*(3-ethoxy-1-adamantyl)*-N,N-*dimethylaniline* (XIIIb, R = $CH_3$); after sublimation at 80°/0.005 Torr, m.p. 67–73°. – NMR. ($CDCl_3$): 1.19 (*t*, *J* = 3, 3 H, $CH_3CH_2O$); 1.50–2.0 (*m*, 12 H, 6 $CH_2$); 2.32 (*m*, 2 H, 2 CH); 2.93 (*s*, 6 H, $(CH_3)_2N$); 3.53 (*q*, *J* = 3, 2 H, $CH_3CH_2O$); 6.72, 7.22 ($A_2B_2$, 4 H, $C_6H_4$).

$C_{20}H_{29}NO$ (299.46) Calc. C 80.22 H 9.76% Found C 80.13 H 9.74%

The second fraction consisted of *3-(*p*-dimethylaminophenyl)-1-adamantanol* (XIIIa, R = $CH_3$); from ether/pentane after sublimation m.p. 133–134°. – NMR. ($CDCl_3$): 1.75 (br. *s*, 1H, OH); 1.75 (*m*, 12 H, 6 $CH_2$); 2.35 (*m*, 2 H, 2 CH); 2.93 (*s*, 6 H, $(CH_3)_2N$); 6.70, 7.21 ($A_2B_2$, *J* = 10, 4 H, $C_6H_4$).

$C_{18}H_{25}NO$ (271.40) Calc. C 79.66 H 9.29 N 5.16% Found C 79.47 H 9.21 N 5.17%

Reaction of the bromide **27** in 80% ethanol saturated with $NaBH_4$ led to 31% of XIIIb and 42% of XIIIa besides 27% of a third product, which could not be completely separated by GLC. The IR. and NMR. spectra of this impure compound indicated the presence of p-*(1-adamantyl)*-N,N-*dimethylaniline* (XIIIc, R = $CH_3$).

*Bromide* **28** (R = *p*-$NO_2C_6H_4$) reacted in 80% ethanol to a 1.85:1 mixture of alcohol XIIIa and ether XIIIb which was separated by chromatography on silica gel to yield *1-ethoxy-3-(*p*-nitrophenyl)adamantane* (XIIIb, R = O); m.p. 104–105° after sublimation at 100°/0.005 Torr and crystallization from ether/petroleum ether. – NMR. ($CDCl_3$): 1.20 (*t*, *J* = 7, 3 H, $CH_3CH_2O$); 1.7–2.0 (*m*, 12 H, 6 $CH_2$); 2.39 (*m*, 2 H, 2 CH); 3.52 (*q*, *J* = 7, 2 H, $CH_3CH_2O$); 7.49, 8.18 ($A_2B_2$, *J* = 10, 4 H, $C_6H_4$).

$C_{18}H_{23}NO_3$ (301.39) Calc. C 71.73 H 7.69 N 4.65% Found C 71.44 H 7.83 N 4.71%

The second fraction consisted of *3-(*p*-nitrophenyl)-1-adamantanol* (XIIIa, R = O); m.p. 148°. – IR. ($CHCl_3$): 3595 (OH); 1510 and 1340 ($NO_2$). – NMR. ($CCl_4$): 1.59 (*s*, 1H, HO); 1.5–2.0 (*m*, 12 H, 6 $CH_2$); 2.35 (*m*, 2 H, 2 CH); 7.51, 8.19 ($A_2B_2$, *J* = 9, 4 H, $C_6H_4$).

$C_{16}H_{19}NO_3$ (273.33) Calc. C 70.31 H 7.01 N 5.12% Found C 70.50 H 7.20 N 5.11%

*Bromide* **29** (R = $CH_3\overline{C-CH_2-CH_2}$) reacted in 80% ethanol to yield a 3:2 mixture of alcohol VIIa and ether VIIb which was separated by chromatography on silica gel. The first fraction consisted of *1-ethoxy-3-(1'-methyl-1'-cyclopropyl)adamantane* (VIIb, R = $CH_3\overline{C-CH_2-CH_2}$), which was distilled at 130–135°/10 Torr (bulb tube). – IR. ($CCl_4$): 3075 and 3005 (cyclopropyl). – NMR. ($CCl_4$): 0.03, 0.66 (2 *m*, 2 H each, 2 H–C(2')–C(3')); 0.95 (*s*, 3 H, $H_3C$–C(1')); 1.08 (*t*, *J* = 7, 3 H, $CH_3CH_2O$); 1.25–1.75 (*m*, 12 H, 6 $CH_2$); 2.16 (*m*, 2 H, 2 CH); 3.36 (*q*, *J* = 7, 2 H, $CH_3CH_2O$).

$C_{16}H_{26}O$ (234.383) Calc. C 81.99 H 11.18% Found C 82.24 H 11.44%

The second fraction consisted of *3-(1'-methyl-1'-cyclopropyl)-1-adamantanol;* after crystallization from ether/pentane and sublimation at 80°/12 Torr, m.p. 116.5–118°. – NMR. ($CDCl_3$): 0.49, 0.02 (2 *m*, 2 H each, 2 H–C(2')–C(3')); 0.94 (*s*, 3 H, $H_3C$–C(1')); 1.3–1.7 (*m*, 12 H, 6 $CH_2$); 1.5 (*m*, 1H, HO); 2.18 (*m*, 2 H, 2 CH).

$C_{14}H_{22}O$ (206.329) Calc. C 81.50 H 10.75% Found C 81.34 H 10.76%

*Rate measurements.* The reactions of the bromides in 80 vol.-% ethanol were followed by conductivity by the method previously described [32], with the exception of the bromides **6–10**, **19**, **24a** and **30** which were followed by titrating bromide ion with aqueous silver nitrate. In the latter case 13 *ca.* 5.5 ml portions of a 0.005M solution of the bromide were sealed into ampoules. Each measurement was repeated at least once. The added bases or buffers are listed in *Table 1.*

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