

Amines as Dehalogenating Agents. IV [1]

## Hydrocarbons, N-Bornyl- and N-Isobornylaniline Formation in the Reaction between 3-Bromocamphor and N-Methylaniline

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### Amine als Dehalogenierungsreagenzien. IV. Kohlenwasserstoff-, N-Bornyl- und N-Isobornylanilinbildung bei der Reaktion zwischen 3-Bromocamphor und N-Methylanilin

Inhaltsübersicht. N-Methylanilin (4) reagiert bei 200°C im Vergleich zu N,N-Dimethylanilin entweder mit 3-Bromocamphor (2) oder Camphor (3) zu den Kohlenwasserstoffen, Camphen 5 und Tricyclen 6 und N-Bornylanilin (exo-endo-Isomers 7). Bei der Reaktion mit 3 ist Säurekatalyse notwendig. Untersuchungen zum Mechanismus erlauben es, anzunehmen, daß Camphoranil 8 ein gemeinsames Zwischenprodukt für alle Produkte und 4 der H-Donator in den Reduktionsstufen ist, auf der Grundlage von kinetischen und stereochemischen Beweisen und unabhängigen chemischen Experimenten.

N,N-Dimethylaniline (1) was found to be an efficient debrominating agent of 3-bromocamphor (2), which was reduced to camphor (3) [1]. We now find that the very similar N-methylaniline (4) behaved in quite a different fashion, yielding products of further reduction, i.e., the two hydrocarbons camphene (5) and tricyclene (6) and N-bornylaniline (7) in almost quantitative yields for longer reaction times near reflux temperature. That, on the other hand, camphor (3) and camphor anil (8) were reaction intermediates was suggested by their presence at shorter reaction durations (Table 1).

Table 1 Products of the Reaction between 3-Bromocamphor (2) and N-Methylaniline (4) as a Function of the Reaction Time at 200°C<sup>a</sup>

Time (h)	2 (%)	3 (%)	8 (%)	7 (%)	5 (%)	6 (%)	exo/endo
10	35	52	8	1	0	0	1:0.5
20	12	38	32	10	1	1	1:0.7
30	0	2	25	41	10	3	1:1.5
40	0	0	0.5	56	23	5	1:2

<sup>a</sup>) Molar ratio 4/2:9.

Camphor anil (8) originated from the acid catalyzed, reversible reaction between 3 and aniline (9) [2], which was in turn produced from 4 by group redistribution [3]. The build up of aniline (9) in the latter process as a function of time is shown in Table 2.

Table 2 Kinetics of Formation of Aniline (9) in the Reaction between N-Methylaniline (4) and N-Methylanilinium Bromide (10) at 200°C<sup>a)</sup>

Time (h)	1	2	3	4	5
9 (%)	9.5	21	24.5	28	29.5

<sup>a)</sup> Molar ratio 4/10: 10.

N-Methylaniline (4) appeared to perform the reduction of 3 to 5, 6 and 7. A separate experiment confirmed that camphor (3) and N-methylaniline (4) in presence, but not in absence, of N-methylanilinium bromide (10) gave the same products, namely, 5, 6 and 7 in comparable yields. N-Bornylaniline (7), in particular, was produced in both cases as the exo-endo pair<sup>1)</sup>. The relative amount of the two isomers of 7 depended on the reaction time; longer times produced mainly the endo isomer both in the reduction of 2 and that of 3 by 4.

If camphor (3) were directly reduced by 4 after the known and expected stage of debromination of 2, the reaction intermediate had to be borneol (11). This compound was searched for, but never detected in the reaction mixture. The presence of 11 as intermediate was conclusively ruled out on the basis of the results of the reaction of 11 with 4 and 10. In fact, although 5, 6 and 7 were actually produced, the disappearance of borneol was not so fast as to justify its complete absence in the reaction mixtures obtained from 2 plus 4 and 3 plus 4 plus 10. The stereochemical outcome of the borneol reaction was different, as only the exo isomer formed.

Thus, intermediate camphor (3), unable to be reduced directly by 4 in presence of acids, had to be reduced at a different stage or by some other compound. A suggestive hypothesis was that camphor anil (8) could be reduced under the reaction conditions to 7, which could break down to aniline (9) and the hydrocarbons 5 and 6 [4]. Separate experiments did show that 8 could be reduced at a reasonable rate by 4 — in presence, but not in absence of its hydrobromide 10, to 7 with a final exo-endo ratio 1/3. Kinetic data relative to this reaction are summarized in Table 3.

Table 3 Products of the Reaction between Camphor Anil (8), N-Methylaniline (4) and N-Methylanilinium Bromide (10) as a Function of Time at 200°C<sup>a)</sup>

Time (h)	8 (%)	7 (%)	5 (%)	6 (%)
2	76.5	19	5.5	0.5
4	54.5	26	7.5	1
6	44.5	33	11	1.5
8	39.5	39.5	12	3
10	28.5	48	14	3
29	0	74	20	5

<sup>a)</sup> Molar ratio 8/4/10: 1/10/1.

We feel that this is a definitive evidence for the mechanistic route of the formation of 7, which is depicted in Scheme 1.

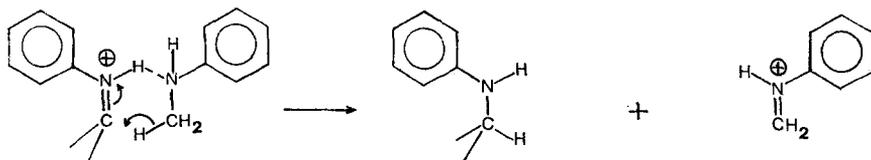
<sup>1)</sup> The exo-isomer corresponds to the isobornylaniline, the endo-isomer is called bornylaniline. Each of the isomers exist in two enantiomeric forms.



It is now interesting to notice that in the establishment of the equilibrium [4a]  $7 \rightleftharpoons 5 + 6 + 9$ , the incursion of *N*-methylaniline (**4**) to yield *N*-methyl-*N*-bornylaniline (**12**) did not materialize. Apparently, *N*-methylaniline (**4**) is unable to compete with aniline (**9**) for non-classical carbonium ion intermediate due to steric hindrance.

Although it was reasonable to think that the reaction **1** and **2** stopped with **3** because of the unfavourable kinetics leading to camphor anil (**8**) in this system, we also found that **8** in presence of **1** and its hydrobromide **13** was unable to give any product. Steric hindrance might be the explanation for this unexpected unreactivity. If this rationale is correct, it can be suggested that the reduction of **8**, or more probably its conjugated acid **14**, is more likely to occur via a preliminary hydride transfer, than an electron transfer, whose efficiency should be much less influenced by steric effects. The very inability of aniline (**9**) to reduce **8** must be taken as an evidence against a preliminary electron transfer. A hydride transfer requires a close approach to **14** by **4**, possibly favoured by a preliminary hydrogen bond between **14** and the amine **4**. This mechanism would be the nitrogen analog of the Meerwein-Ponndorf-Verley [5] reaction (Scheme 2).

SCHEMA II



The fate of **4** was found to be similar to that of **1** in the reduction of **2** [1]. Gas-chromatographic separation of the amine oxidation products, followed by mass spectrometric analysis, allowed the identification of 14 variously *N,N'*-methylated *o,o'*-, *o,p'*- and *p,p'*-diaminodiphenylmethanes. Their formation from the ion *N*-phenylmethyleneiminium (**15**) may be rationalized in terms of a sequence of alkylations and rearrangements [1].

This work was supported in part by a grant from the Italian National Research Council (CNR-to AGG).

## Experimental

Equipment and Materials. — Camphor anil (**8**) [2], borneol (**11**) (exo-/endo-ratio 9 to 1) [6] and *N*-bornylaniline (**7**) **4a** were prepared according to described methods. Camphene (**5**) was purchased from Merck; it contained less than 1% tricyclene (**6**, GC).

Infrared spectra were recorded with a Perkin Elmer infrared spectrophotometer 710 B. The spectra were recorded on neat liquids and with the KBr pellet technique for solids. Band calibration was made by the use of a polystyrene film. Proton n.m.r. spectra were recorded with a Perkin Elmer NMR spectrometer R 12 B; peak locations are given in  $\delta$  values (ppm) using tetramethylsilane as internal standard.

Gaschromatograms were obtained with a Perkin Elmer 900 Gaschromatograph using nitrogen as carrier gas and a flame ionization detector.

Mass spectra were recorded with an LKB 9000 Gaschromatograph-Mass Spectrometer (electron impact, positive ions) both using the direct inlet system and the GC inlet for the introduction of the samples into the ion source working at an ionization energy of 70 eV. The reported spectra have both ion source and GC backgrounds subtracted.

**3-Bromocamphor (2) and N-methylaniline (4).** Four identical mixtures, made up by **2** (3.9 mmol) and **4** (35 mmol) and kept in small flasks equipped with reflux condenser, were maintained on an oil bath (200°C) for different times (10, 20, 30, 40 h). Each mixture was extracted with 15 % cold hydrochloric acid and ether. The ether layer containing neutral material (NES) was washed with sodium carbonate aqueous solution and dried over sodium sulfate. The aqueous acidic layer from the treatment with acid was made strongly basic with aqueous sodium hydroxide, extracted with ether and the ether solution dried over sodium sulfate (AES). The results of the analyses of the four couples of AES and NES referred to compounds containing a bornyl related moiety are collected in Table 1.

The above reaction was repeated on a larger scale (1.35 mol of **4** and 153 mmol of **2**, 40 h). The NES gave upon evaporation of the solvent a solid made up mainly of **5** and **6**, as shown by i.r. and GC-MS. Crystallization from ethanol gave pure camphene (**5**). Vacuum distillation of the AES gave a first fraction (boiling range 115–120°C, 15 Torr) containing aniline (**9**), N-methylaniline (**4**) and N,N-dimethylaniline (**1**) and a second one (135–152°C, 0.2 Torr) beside a tarry residue. Redistillation of the second fraction gave two fractions. The second fraction exhibited five ill separated peaks by GC. MS of these peaks revealed the molecular ions of at least fourteen compounds related to several N,N'-methylated diaminodiphenylmethane structures. GC analysis of the first fraction revealed the presence of two not completely separated compounds (with a 1 m by 0.25 mm column filled with Carbowax 20 M 3% - KOH 5% on Chromosorb P 80–100 mesh; 170°C), identified as the exo and endo isomers of N-bornylaniline (**7**) on the basis of the following spectral data; MS (m/e, relative intensity; the two isomers, recorded via the GC inlet were identical): 95 (100), 93 (91), 106 (88), 119 (80), 158 (78), 77 (60), 41 (58), 229 (M<sup>+</sup>, 55), 55 (30) and 67 (28), metastable peaks at 37.5 and 61.8; i.r. (neat): 3300w, 2900s, 2870m, 3020w, 1580s, 1430m, 1400w, 1370w, 1350w, 1290m, 1250w, 1230w, 720s cm<sup>-1</sup>; n.m.r. (CCl<sub>4</sub>): 0.90 (m, 9H), 1.30 (m, 2H), 1.70 (m, 3H), 2.75 (m, 1H), 3.55 (m, 3H) and 6.75 (n, 5H). The identification was confirmed from comparison of these data with those obtained from the two isomers (ratio exo to endo 3:1) produced by the reduction of camphor anil with LiAlH<sub>4</sub> [7].

Camphor (**3**) and camphor anil (**8**) were separated and identified in the reaction mixture via GC-MS. Under these experimental conditions 81% of the bromine of **2** could be recovered from the final aqueous solution (provided all previous acid treatments were performed with sulphuric acid and all basic treatments with halogen free sodium hydroxide) made acidic with nitric acid by precipitation with silver nitrate.

**Camphor (3), N-methylaniline (4) and N-methylanilinium bromide (10).** The ketone (**3**, 87 mmol), N-methylaniline (**4**, 766 mmol) and its hydrobromide (**10**, 25.5 mmol) were refluxed during 16 h with continuous water removal. Acid base separation gave a NES and an AES. The reaction produced 22% camphene (**5**), 5% tricyclene (**6**) and 55% N-bornylaniline (**7**, exo/endo 1:3). The overall yield of oxidized products of **4**, i.e., the diaminodiphenylmethanes, whose nature and composition was practically the same as in the reduction of **2**, amounted to 78%.

**Borneol (11), N-methylaniline (4) and N-methylanilinium bromide (10).** The alcohol **8**, (5.9 mmol), prepared according to a described method [6], the amine (**4**, 75 mmol) and its hydrobromide, (**10**, 1.8 mmol) were refluxed during 4 h with continuous water removal. The resulting reaction mixture contained camphene (**5**, 24%), tricyclene (**6**, 10%), unreacted **11** (28%), N-bornylaniline (**7**, 28% exo-isomer only), aniline (**9**) and N,N-dimethylaniline (**1**).

**Camphor anil (8), N-methylaniline (4) and N-methylanilinium bromide (10).** The imine (**8**, 10 mmol), the amine (**4**, 100 mmol), its hydrobromide (**10**, 5.1 mmol) and n-hexadecane (**15**), added as internal standard, were heated on an oil bath at 200°C. Samples were withdrawn until the 29th

hour and analyzed by GC for camphor anil (8), N-bornylaniline (7), camphene (5) and tricyclene (6) content. The results are shown in Table 3. The nature and the relative amounts of the oxidation products of 4 were the same observed for the reduction of 2.

**Camphor (3) and N-methylaniline (4).** The ketone (3, 10 mmol) and the amine (4, 100 mmol) were refluxed during 11 h. No reaction.

**Camphor anil (8) and N-methylaniline (4).** The imine (8, 10 mmol) and the amine (4, 100 mmol) were refluxed during 11 h. No reaction.

**Camphene (5), aniline (9) and anilinium bromide (16).** The hydrocarbon (5, 10 mmol), the amine (4, 100 mmol), its salt (16, 5 mmol) and n-tetradecane (17) used as internal standard, were refluxed during 8 h. The reaction mixture contained, beside unreacted aniline (9) and camphene (5, 19%), tricyclene (6, 16%), N-bornylaniline (7, exo-isomer only) and diphenylamine (18, 1%, calculated on initial 9). At 4 h the yield of 7 amounted to 51%.

**N-Methylaniline (4) and N-methylanilinium bromide (10).** The amine (4, 100 mmol), its salt (10, 10 mol) and n-tetradecane (19, internal standard) were refluxed during 5 h. Samples were withdrawn at intervals and analyzed for aniline content. The results are collected in Table 2.

**Camphor anil (8), N,N-dimethylaniline (1) and N,N-dimethylanilinium bromide (13).** The imine (8, 10 mmol), the amine (1, 100 mmol), its salt (13, 5 mmol) and n-hexadecane (15), used as internal standard, were refluxed during 10 h. Samples were withdrawn at intervals and analyzed for N-bornylaniline (7), camphor anil (8), camphene (5) and tricyclene (6) content. 5, 6 and 7 were not produced.

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Bei der Redaktion eingegangen am 18. April bzw. 28. September 1979.

Ansch. d. Verf.: Prof. Dr. ANGELO G. GIUMANINI, MARCO M. MUSIANI, Istituto Chimico G. Ciamician and Centro di Gascromatografia-Spettrometria di Massa, Università di Bologna, I-40126 Bologna, Italy