UDC 542.953.4

STRUCTURE AND REACTIVITY OF THE CONDENSATION PRODUCTS OF AROMATIC AMINES WITH ALIPHATIC ALDEHYDES

VII. Synthesis and Structure of Bis-propylidenearylamines*

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A number of previously undescribed propylidenearylamine dimers have been synthesized by the interaction of propionaldehyde with a series of para-substituted anilines (R = H, CH_3, OCH_3, F, Cl, Br, I) and with α-naphthylamine. The structure of the bis-propylidenearylamines has been established by a study of their IR and UV spectra. It has been shown that all the bis-propylidenearylamines, except for bis(propylidene-p-fluoroaniline), have the structure of 2-ethyl-3-methyl-4-arylamino-1,2,3,4-tetrahydroquinolines. The dipole moments of the bis(propylidene-p-R-anilines) have been determined. Comparison of the values obtained with the calculated values indicates that the most favorable molecular conformation of the bis-propylidenearylamines is a tetrahydroquinoline half-chain with quasi-equatorial positions for the 4-NHAr and NH groups and an equatorial 3-CH_3 group. In contrast to the bis-ethylideneanilines, we did not succeed in finding other stable conformers for the bis-propylidene derivatives. It has been established that bis (propylidene-p-fluoroaniline) has the 1,3-bis (p-fluorophenylamino)-2-ethyl-1-hexene structure.

We have previously shown [1,2] that the alkylidenearylamine dimers formed on condensation of higher aliphatic aldehydes (beginning with n-butyric) with aromatic amines exist in the noncyclic enamine form (I), while the condensation products with acetaldehyde (bis-ethylidenearylamines) have the cyclic tetrahydroquinoline structure (II) [3,4].

It appeared interesting to discover which of these two possible structures (I or II) applies to the propylidenearylamine dimers, which we synthesized by the interaction of propionaldehyde with aniline and with a series of its p-substitution products under conditions analogous to those described in [1,5]. A detailed characterization of the resulting bis-propylidenearylamines is given in Table 1. The only compound of this type whose synthesis had previously been accomplished [6] is the product from the reaction of propionaldehyde with aniline in neutral medium. The azomethine structure III was ascribed to this product.

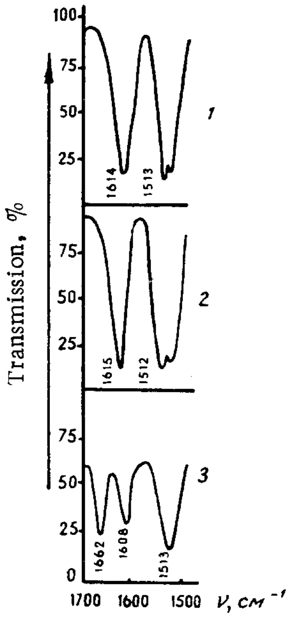
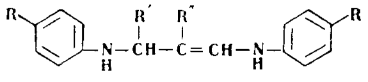
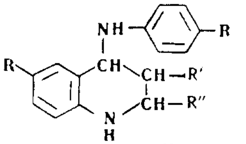


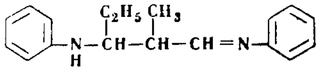
Fig. 1. IR spectra: 1) bis-ethylideneaniline (isomer having mp 126° C); 2) bis-propylideneaniline; 3) bis(propylidene-p-fluoroaniline).



I

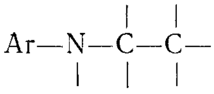


II



III

The choice among structures I-III was made on the basis of the UV and IR spectra. In contrast to structure I, the intense band of the C=C bond stretching vibration, which is characteristic of enamines [7] and appears in the 1640-1670 cm^{-1} region in compounds of type I [1,2], is absent from the IR spectra of the bis-propylideneanilines. If the structure III, which is tautomeric with I, existed, the $\nu_{C=N}$ band [8] would have to lie in the same region, or at even shorter wavelengths. At the same time, the spectra of the bis-propylidenearylamines are completely analogous to the spectra of the corresponding cyclic bis-ethylidenearylamines [5] (Fig. 1). The intense band found in the 1600-1618 cm^{-1} interval in the various bis-propylidenearylamines belongs to a vibration of the molecular fragment



$$Ar-\underset{|}{N}-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-.$$

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*For communication VI, see [1].

as has already been shown [5].

The UV spectra are no less indicative. As can be seen from Fig. 2, the UV spectrum of bis-propylideneaniline almost coincides with the spectrum of II, but differs substantially from the spectrum of the enamine I ($R' = C_3H_7$, $R'' = C_2H_5$). The absorption curves of the bis-propylideneaniline derivatives, some of which are shown in Fig. 3, appear similar to the spectrum of the parent compound. All this enables us to ascribe the tetrahydroquinoline structure II ($R' = C_2H_5$, $R'' = CH_3$), to the bis-propylidenearylamines.

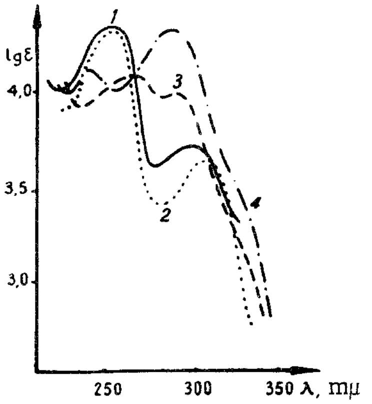


Fig. 2. UV spectra: 1) bis-ethylideneaniline (isomer having mp 126° C); 2) bis-propylideneaniline; 3) bisbutylideneaniline (I, $R' = n\text{-}C_3H_7$, $R'' = C_2H_5$); 4) bis(propylidene-p-fluoroaniline).

The only exception is the UV spectrum of bis(propylidene-p-fluoroaniline), which corresponds to the enamine structure I, as follows from a comparison with the spectrum of I (Fig. 2). This structure is also confirmed by the IR spectrum (Fig. 1), in which the $\nu_{C=C}$ band at 1662 cm^{-1} can be distinctly traced.

This peculiarity of the structure of bis(propylidene-p-fluoroaniline), which distinguishes it from the remaining propylidenearylamine dimers, is connected neither with the method of synthesis, which was the same for all the dimers, nor (as was established by special experiments) with possible fluctuations in the acidity of the reaction medium, which sometimes exert a substantial influence on the course of similar reactions [9]. The probable cause for the blockage of the transformation of structure I into II is the low nucleophilicity of the meta (relative to fluorine) carbon atom, at which position the electrophilic closure of the tetrahydroquinoline ring takes place. Actually, since the effect of a para substituent in the aniline nucleus on the magnitude of the effective charge at the meta position (relative to the substituent) is exerted mainly through its I-effect, one may expect that fluorine, which possesses the most powerful —I-effect of all the substituents studied, will create the greatest difficulties for cyclization into structure II.

The tetrahydroquinoline structure of the bis-propylidenearylamine dimers implies the possibility of their existence in the form of several conformers, differing primarily in the type of half-chair conformation of the piperidine ring. Thus, in the case of bis-ethylideneaniline four such conformers have been successfully isolated [4]. However, we have not succeeded in detecting appreciable quantities of isomers for any of the bis-propylidenearylamines which we have synthesized (Table 1). All the products, in contrast to those obtained during the synthesis of the bis-ethylideneanilines [3, 4], were chromatographically homogeneous.

Determination of the dipole moments of some of the bis-propylidenearylamines permits progress toward the establishment of their most favorable molecular conformation. The moment of compounds of type II can be represented as the sum of the moments of the corresponding 6-substituted tetrahydroquinoline (the alkyl groups in positions 2 and 3 have no effect on the dipole moment values) and the arylamine residue in position 4 of the the tetrahydroquinoline ring. We have computed the tetrahydroquinoline moments μ_T from the diagram (Fig. 4), taking account of the fact that, in the half-chair conformation of the piperidine ring of tetrahydroquinoline, a quasi-equatorial configuration of the NH group is the most favorable [10]. The results of the calculations are contained in Table 2.

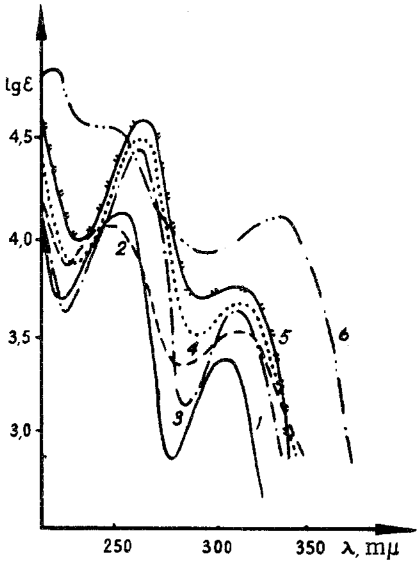
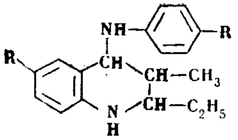


Fig. 3. UV spectra: 1) bis(propylidene-p-toluidine); 2) bis(propylidene-p-anisidine); 3) bis (propylidene-p-chloroaniline); 4) bis(propylidene-p-bromoaniline); 5) bis(propylidene-p-iodoaniline); 6) bis(propylidene-α-naphthylamine).

The results of our calculations of the dipole moments of the bis-propylidenearylamines, on the assumption of free rotation of the arylamine group around the C—N bond, are given in the $\mu_{free\ rot}$ column. Comparison with the experimental values μ_{exp} shows that the latter markedly exceed $\mu_{free\ rot}$. Actually, the free rotation hypothesis, which was permissible in analyzing the dipole moment values of the bis-ethylideneanilines, collapses when the dipole moments of the bis-propylidenearylamines are considered, since, in this case, free rotation will be hindered by the appearance of

Table 1

Dimers of Substituted Propylidenearylamines



R	Method of preparation	mp, °C (recrystallization solvent)	Formula	Found				Calc.				Yield, %
				C, %	H, %	N, %	M	C, %	H, %	N, %	M	
H	a	102 (ethanol)	$C_{18}H_{22}N_2$	81.08; 81.11	8.16; 8.20	10.71; 10.40	255	81.16	8.32	10.52	266.4	42
CH_3	a	104 (methanol)	$C_{20}H_{26}N_2$	81.48; 81.41	8.90; 9.01	9.70; 9.61	283	81.58	8.90	9.52	294.4	25
OCH_3	a	114 (methanol)	$C_{20}H_{26}N_2O_2$	73.40; 73.31	7.90; 7.91	8.60; 8.56	308	73.59	8.03	8.58	326.4	18
F*	b	119 (methanol)	$C_{18}H_{20}N_2F_2$	71.40; 71.52	6.64; 6.71	9.51; 9.39	291	71.50	6.67	9.26	302.4	24
Cl	a	142 (methanol)	$C_{18}H_{20}N_2Cl_2$	64.60; 64.44	5.92; 6.14	8.52; 8.31	326	64.48	6.01	8.36	335.3	28
Br	a	148 (methanol)	$C_{18}H_{20}N_2Br_2$	50.91; 51.16	4.60; 4.65	6.82; 6.61	399	50.97	4.75	6.60	424.2	30
I	a	174 (benzene + hexane)	$C_{18}H_{20}N_2J_2$	41.52; 41.59	3.76; 3.60	5.55; 5.37	489	41.72	3.89	5.41	518.2	65
2.3-C_6H_4**	b	147 (propanol)	$C_{26}H_{26}N_2$	84.93; 84.99	7.21; 7.13	7.80; 7.61	338	85.21	7.15	7.64	366.5	85

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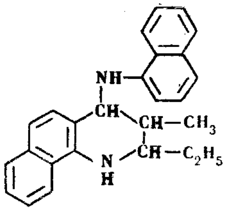
*This compound has structure I, R = F, R' = CH_3, R" = C_2H_5.

**This compound is a α-naphthylamine derivative and has the structure



of the quasi-equatorial methyl group in position 3 of the tetrahydroquinoline ring. The value of μ_{exp}, however, closely approximates the value obtained by summing the moments of the corresponding tetrahydroquinoline and arylamine (except for R = CH_3). This corresponds to a parallel mutual orientation of the dipole moment vectors of the tetrahydroquinoline and arylamine moieties. Knowing the vector of the former (Table 2) and the orientation of the vector of the latter relative to the N-Ar axis [12], one can establish the position of the arylamino group relative to the tetrahydroquinoline skeleton, and can represent the actual molecular conformation of the bis-propylidenearylamines in the form IV (see Fig. 4). The conformation IV corresponds to a piperidine half-chair with a quasi-equatorial position of the 4-NHAr and NH groups. Rotation around the C–N axis is restricted in the region of that configuration of the aryl nucleus in which the plane of the latter is roughly perpendicular to the plane of the aromatic nucleus of the tetrahydroquinoline moiety.

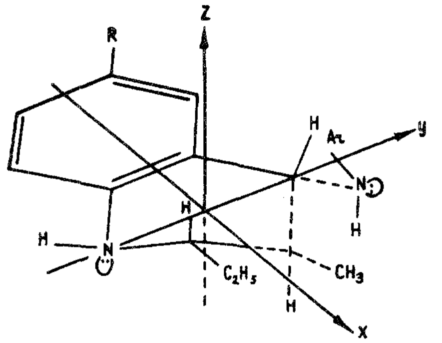
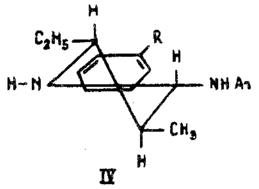


Fig. 4. Stable molecular conformation of the Compounds IV.

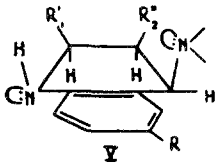
Zalukaev and Spitsina [12], basing their conclusions exclusively on an analysis of the preparative data, have recently expressed objections to the ascription of this conformation to the most stable α-isomer of bis-ethylideneaniline. Of these objections, the fundamental one is their citation of the establishment of an intramolecular hydrogen bond (IHB) with the cyclic NH group as the proton donor and the exocyclic NHAr as the acceptor. In the opinion of these authors, this leads to an increase in the stability of the conformation with quasi-axial configurations of the NH and 4-NHAr groups and, evidently, to a change of the geometry of the ring into a half-boat. However, neither this conformation nor any other meets the conditions for the formation of an IHB, since, first, the NH...N groups are not collinear, which, at the large N...N distance of about 3 Å, either excludes the possibility of an IHB or reduces its energy to a minimum; and, second, as has been shown [14], the low basicity of the electron pair of the amino group in aryl amines, in conjunction with the low acidity of the NH group, leads to the absence of an NH...N hydrogen bond in anilines, even when the geometry is favorable. To this it must be added that a conformation of type V is energetically roughly 2.7 kcal/mole less favorable than the half-chair IV, while the quasi-equatorial position of the electron pair of the cyclic nitrogen is unfavorable because of the partial loss of its energy of conjugation with the π-electrons of the benzene ring in comparison with the quasi-axial configuration.

It is interesting to note that the dipole moments of the cyclic structures II, especially the halogenated derivatives, are considerably higher than those of their enamine analogs I [1, 16]. This provides one more test for checking whether bis-alkylidenearylamines belong to the cyclic or enamine forms. Thus, the dipole moment measured in the present work for bis(butylidene-p-iodaniline), which exists in the cyclic form (type II), as has been shown [2] on the basis of UV and IR spectral data, equals 4.51 D, while the moments of its fluorine and chlorine analogs I R' = C_3H_7, R" = C_2H_5 amount to 3.21 [1] and 3.63 D [16], respectively.



IV

Fig. 5.



V

Fig. 6.

Table 2

Calculated and Experimental Dipole Moments of Compounds of Structure IV, D

R	m_x	m_y	m_z	μ_T	$\mu_{free\ rot}$	μ_{ar} [11]	$\mu_T + \mu_{ar}$	μ_{exp}
H	−1.25	−0.55	−1.28	1.86	2.54	1.55	3.41	2.96
CH_3	−1.05	−0.89	−1.28	1.88	2.29	1.32	3.20	1.93
Cl	−2.05	+0.83	−1.28	2.55	3.98	3.00	5.55	5.85
Br	−2.03	+0.81	−1.28	2.53	3.95	3.01	5.54	5.69
I	−1.96	+0.68	−1.28	2.43	3.75	2.82	5.25	5.46

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* Note: The position of the coordinate axes is shown in Fig. 4.

Table 3

Polarization and Refraction of the Compounds II

R	N, mole frac	P_∞, cm^3	R_D, cm^3
H	0.002784—0.011963	262.6	83.3
CH_3	0.002834—0.007053	169.0	92.6
Cl	0.002006—0.007690	892	93.0
Br	0.001708—0.007022	761	98.8
I	0.001604—0.006026	718	109.2
II*	0.001325—0.002868	534	118.5

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* Bis(butylidene-p-iodaniline), $\mu_{exp} = 4.51$ D.

Experimental

The bis-propylidenearylamines were obtained by one of the following procedures.

a) By keeping methanolic solutions of equimolar quantities of freshly redistilled propionaldehyde and the appropriate aryl amine, acidified with 1-2 drops of glacial acetic acid, for 2-4 days at room temperature;

b) by melting the reagents together with subsequent storage of the reaction mass in the refrigerator for 2-3 days. The solidified reaction product was filtered off, washed with petroleum ether, and recrystallized several times from an appropriate solvent (Table 1). All the bis-propylidenearylamines are colorless, well-formed crystals.

The IR absorption spectra were taken in chloroform solution (concentration 1:400, layer thickness 0.116 mm) on a UR-10 instrument with a NaCl prism. The UV spectra were obtained on an SF-4 spectrophotometer in methanolic solutions at concentrations of 10^{-4}–10^{-5} M.

The procedure for measuring the dipole moments has been described in [17, 18]. The measurements were made in benzene solutions at 25°± 0.05° C. The polarization at infinite dilution P_∞ was obtained by graphical extrapolation to zero concentration; the molecular refraction was computed as the sum of bond refractions; the atomic polarization was disregarded. The results are presented in Table 3.

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