THE CONFIGURATION OF C-ARYL C,N-DIALKYL AZOMETHINES. A DIPOLE MOMENT STUDY

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Dipole moments of azomethines *I—XII* were measured in benzene solution and compared with those calculated from bond moments for the *E* and *Z* configurations, respectively. The independent assignment of configuration is possible if a polar substituent is present and if the proportions of the two stereoisomers are sufficiently different (compounds *V—X*); the results agreed with other methods. In the remaining cases the expected dipole moments were computed for the *E—Z* isomer distribution as determined from ^{1}H-NMR spectra; the agreement with experiment is then satisfactory but a direct assignment is not possible on the basis of dipole moment data alone.

Although the stereochemistry of azomethines has been studied extensively with essentially concordant results[1], there are relatively few independent assignments of configuration, many arguments being based on mere analogy. From this point of view the configuration of ketimines, with a variable equilibrium, is less firmly established than the configuration of aldimines which are generally present in the *E* form[1], exceptionally as a mixture with the *E* form prevailing[2]. For diaryl ketimines the assignment depends mainly on the empirical correlation[3–5] of the IR absorption frequency at $690-700 \text{ cm}^{-1}$, and on the empirical comparison of UV spectra[3]. For particular diaryl ketimine structures more reliable assignments were possible, based on an intramolecular H-bond[6] or on the comparison with structurally related oximes[7]. Dialkyl ketimines[8] and alkyl aryl ketimines[5] have been studied mainly by ^{1}H-NMR spectroscopy with more attention being directed toward the equilibrium constants. The most compelling evidence for the configuration was the shift of the equilibrium with the steric demands of the alkyl groups. An additional evidence was provided by the shielding effect of the aryl ring on the N-methyl hydrogens[5]. Although these arguments may be convincing taken by themselves, we considered an independent assignment to be of use and report in this paper the solution dipole moments of alkyl aryl ketimines and diaryl ketimines of the general formulae:

E Z
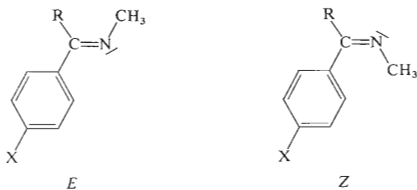
While the substituent R was varied, the N-methyl group was kept constant (Table I). Our additional aim was the comparison with aldimines whose dipole moments have been studied extensively[9–12] and represent hitherto the most direct proof of the configuration in solution.

The main merit of the dipole moment approach is found in the independence on model compounds and on empirical correlations, but is combined with a low sensitivity to the less abundant isomers; this is, however, in our case not important since the isomer distribution is known from the ^{1}H-NMR data[5]. Another limitation is the necessary presence of a polar group; in particular the configuration of aromatic compounds has been often deduced from their *para* derivatives. In our set of compounds we made use of 4-Cl and 4-NO$_2$ substituents to this purpose.

EXPERIMENTAL AND RESULTS

Materials: Most of the compounds were described previously[5], the remaining ones were prepared by the same method[5]:

N-(α-*Isopropyl-4-chlorobenzylidene*)*methylamine* (VII), m.p. 38—40°C (pentane), b.p. 60°C/ /0·2 Torr; for $C_{11}H_{14}ClN$ (195·7) calculated: 67·52% C, 7·21% H, 7·16% N; found: 67·55% C, 7·10% H, 7·00% N; ^{1}H-NMR in CDCl$_3$ (δ): 3·40 (s, NCH$_3$-*E*), 3·00 (s, NCH$_3$-*Z*).

N-(α-*Tert-butyl-4-chlorobenzylidene*)*methylamine* (VIII), m.p. 44—45°C, b.p. 56—60°C/ /0·1 Torr; for $C_{12}H_{16}ClN$ (209·7) calculated: 68·73% C, 7·69% H, 6·69% N; found: 68·65% C, 7·70% H, 6·80% N; ^{1}H-NMR in CDCl$_3$ (δ): 2·86 (s, NCH$_3$-*Z*).

Physical measurements: Dielectric constants and densities of benzene solutions were determined at 25°C, usually at five concentrations within the range 0·02—0·05M. A heterodyne apparatus with frequency 1·2 MHz was used. The results were processed according to Halverstadt and Kumler[13]. Molar refractions were calculated from Vogel's increments[14], valid for 20°C, and from the increment of 8·11 cm^3 for the C=N group bound on a benzene nucleus[15]. Corection for the atomic polarization, 5% or 15% of the R_D value, was applied. The results are listed in Table I. According to the previous experience[5] all the compounds were at equilibrium under the conditions of measurement. We were unable to confirm the configuration of crystalline compounds by measurements of fresh solutions since the procedure is insufficiently rapid; in addition the solutions appeared unstable and some compounds gave results of lowered accuracy (see Notes

to Table I). The ^{1}H-NMR spectra were recorded on a HA-100 instrument and the ratio of stereo-isomers evaluated as previously[5]. The results are included in Table I, last column.

TABLE I

Polarization Data and Dipole Moments of Aromatic N-Methyl Ketimines 4-XC$_6$H$_4$C(R)=NCH$_3$ (benzene, 25°C)

Com-pound	R	X	α^a β^a	P_2^0 cm^3	R_D^{20b} cm^3	$\mu(5)^c$, D $\mu(15)^c$, D	μ_{calc}^d D	% E^e
I	CH$_3$	H	2·98 −0·093	116·3	44·8	1·84 1·78	1·80 (1·69)	94
II	CH$_5$	H	2·78 −0·083	123·6	49·5	1·87 1·80	1·74 (1·60)	74
III	i-C$_3$H$_7$	H	2·25 −0·092	118·9	54·1	1·74 1·66	1·55 (1·80)	5
IV	t-C$_4$H$_9$	H	2·12 −0·086	125·1	58·8	1·76 1·68	1·53 (1·81)	0
V	CH$_3$	Cl	4·68 −0·246	192·3	49·7	2·61 2·56	2·38 (1·34)	95
VI	C$_2$H$_5$	Cl	3·0^f −0·251	151^f	54·4	2·18^f 2·11^f	2·19 (1·63)	75
VII	i-C$_3$H$_7$	Cl	0·430 −0·183	92·5	59·0	1·22 1·10	1·34 (2·38)	5^g
VIII	t-C$_4$H$_9$	Cl	1·19 −0·171	107·8	63·7	1·41 1·34	1·26 (2·42)	0^g
IX	CH$_3$	NO$_2$	13·72 −0·294	504·0	51·2	4·69 4·66	4·64 (3·43)	97
X	C$_2$H$_5$	NO$_2$	10·72 −0·290	440·5	55·8	4·32 4·29	4·45 (3·66)	81
XI	C$_6$H$_5$	Cl	1·5^f −0·274	124^f	69·4	1·58^f 1·47^f	1·75 (1·55)	59^h
XII	C$_6$H$_5$	Br	1·8^f −0·417	156^f	72·3	1·97^f 1·89^f	1·71 (1·56)	57^h

^{a} Slopes of the Halverstadt–Kumler[13] plots, ε_{12} vs w_2 and d_{12}^{-1} vs w_2, respectively; ^{b} calculated from increments, see Experimental; ^{c} correction for the atomic polarization 5% or 15% of the R_D values respectively; ^{d} calculated for the abundance of stereoisomers as given in the last column, the values in parentheses for the same numerical ratio with reversed assignment; ^{e} determined in CDCl$_3$ at room temperature by multiple ^{1}H-NMR integration[5]; ^{f} the plots ε_{12} vs w_2 were curved, the slopes given apply to the region of lower concentrations 0·002−0·008M and all the resulting values are less dependable; ^{g} new determinations; ^{h} in C$_6$D$_6$ solution.

DISCUSSION

The first task of the analysis is calculation of dipole moments expected for the E and Z configurations of compounds $I-XII$. We used the simple bond moment scheme with the standard values[16]: H—C_{al} 0·3 D, H—C_{ar} 0 D, C—N 0·45 D, C=N 1·8 D, C_{ar}—Cl 1·60 D, C_{ar}—Br 1·57 D. The most critical of them, the C=N bond moment, has been reexamined recently[15,17]. For the aromatic nitro group the group moment of 4·3 D was used, including the conjugation (and/or inductive interaction) with the C=N bond[11,15]. The bond angles of 120° were adopted[11] both at C and at N since the crystallographic data[18] do not reveal significant deviations from this value. Our set of parameters agrees well with more direct determinations on similar compounds: for N-benzylidenemethylamine we calculate $\mu = 1\cdot55$ D at the angle of 84° to the C_{ar}—C_{al} bond, experimentally determined from derivatives[10,11] 1·43 D (90°) or 1·41 D (84°); for N-benzylideneaniline we calculate $\mu = 1\cdot62$ D (74°), found[12] 1·61 D (70°).

Interpretation of our results in terms of the configuration is possible on either of two different level: a) without any additional information, b) utilizing the ^{1}H-NMR data as an estimate of the isomer distribution. In principle both the assignment and the equilibrium distribution can be obtained from the dipole moments alone but a high precision of experimental as well as of the calculated values is reqired, in addition the latter must be sufficiently different. This is rarely met in practice. If one isomer strongly predominates, a configurational assignment can be made but the equilibrium constant cannot be given any significant value (compounds V, $VII-IX$). If the isomer distribution is nearly equal, the assignment is not possible (XI, XII). The unsubstituted compounds $I-IV$ can be assigned only by analogy with their derivatives.

More definite results may be obtained by the graphical method[19] which makes use of several substituted compounds together with the firm assumption that substitution in the *para* position is without effect on the equilibrium. This assumption, itself plausible, is substantiated in our case by the equilibrium distribution of compounds $I-IV$ compared to $V-VIII$ (Table I, last column). In Fig. 1 the calculated values of μ^2 are plotted against each other for the E and Z configuration, respectively; in one plot the unsubstituted compounds $I-IV$ (x-axis) against the 4-chloro derivatives $V-VIII$ (y-axis), in the second plot the 4-nitro derivatives IX, X (x-axis) against the same 4-chloro derivatives (y-axis). These are compared with the experimental values (hatched circles). The figure reveals that the combined error of calculation and experiment, expressed by the size of circles, is considerable compared to the difference between stereoisomers. Nevertheless, the conclusion that the methyl derivatives I, V, IX are almost exclusively in the E-configuration, while isopropyl (III, VII) and tert-butyl (IV, $VIII$) derivatives exist mainly in the Z-configuration, may reasonably be drawn. With the ethyl derivatives II, VI, X the E-configuration

prevails and its abundance may be estimated to $70 \pm 10\%$ from the connecting line in Fig. 1 since the μ^2 values behave additively. Hence the agreement with the ^{1}H-NMR data is very good. The assignment is based essentially on the chloro and nitro derivatives, the unsubstituted compounds are not relevant, since the calculated values hardly differ (Fig. 1). Their configuration is in fact based on the analogy. Within the framework of the bond moment scheme the calculated values are the same for compounds $I-IV$, or for $V-VIII$. This approximation need not apply well to the tert-butyl derivatives IV and $VIII$ due to changes of bond angles or even induced dipoles in the bulky group. For these reasons the order of the isopropyl and tert--butyl derivatives in Fig. 1 is reversed but the assignment is not invalidated.

When the equilibrium distribution is known from the ^{1}H-NMR spectra, the second approach is possible, *viz.* relying on these data and referring to dipole moments only for the assignment. We started from the distribution as determined[5] either in $CDCl_3$ or C_6D_6 solutions, since the results were not significantly different. The expected dipole moments were then calculated for the assumed assignment as well as for the reversed one and compared with the experimental figures (Table I). The comparison confirms clearly the assumed configuration of the compounds $V-X$; that of the unsubstituted compounds $I-IV$ cannot be deduced with any reliability but at least the expected trend in the experimental dipole moments is observed.*
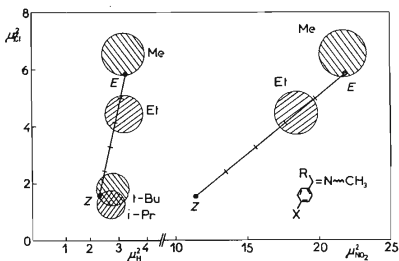

FIG. 1

Graphical Comparison of Squared Dipole Moments of Phenyl Alkyl N-Methyl Ketimines $I-IV$ and Their Chloro ($V-VIII$) and Nitro (IX, X) Derivatives

Calculated values for the E and Z configurations (full points) and experimental values (hatched circles) are shown.

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*   The reliability of the assignment for different compounds may be visualized in terms of the probability calculus[20]. For example, for compounds I, V and IX the probability that the prevailing isomer has the E configuration is 0·5, 0·99 and 0·995, respectively (with $\sigma = 0.4$ D). If we pressume that these three compounds must have the same configuration, the probability of E attains the enormous value of 0·99994.

In the case of the diaryl ketimines *XI* and *XII* the agreement of calculated and experimental moments confirms the fact that the distribution is near to 50% but individual assignments are not possible.

In conclusion we may state that the previously determined configurations[5] have been confirmed reliably and independently for all substituted alkyl aryl ketimines *V—X*, those of unsubstituted compounds *I—IV* were deduced indirectly but are also reliable and agree with previous determinations. The configuration of diaryl ketimines *XI* and *XII* depends still on the IR method[3-5]. The dipole moments of ketimines themselves agreed with expectation, in particular the same bond moments were applicable as for aldimines[10-12]; also the interactions with substituents are similar.

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