MASS SPECTRA AND STRUCTURE OF IMINES OF 2-AROYLBENZAMIDES

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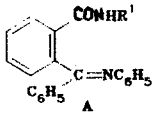
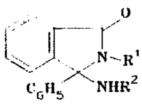
The electron impact mass spectra and DADI spectra of anils of N-alkyl-2-benzoylbenzamides and 2-alkyl-3-arylamino-3-phenylisoindolinones isomeric to them, as well as certain 2-substituted 3-alkyl(aryl)amino-3-phenylisoindolinones, were studied. The main direction of the decomposition were described. It was established that transition from 2-aroylbenzamides to their imines leads to a substantial stabilization of the cyclic isomeric form. A stabilization of the cyclic form with increasing steric volume of the alkyl substituent at the azomethine nitrogen atom was noted. The presence of a phenyl substituent at the nitrogen atom of the amide group destabilizes the cyclic form. A mechanism of isomerization explaining these phenomena is proposed.

Continuing our study of the mass spectra and study of 2-aroylbenzamides [1], we studied the electron impact (EI) mass spectra and the DADI spectra of imines of 2-aroylbenzamides, calculated on the basis of two isomers: anils of N-alkyl-2-benzoylbenzamides (A) and 2-substituted 3-alkyl(aryl)amino-3-phenylisoindolinones (B) [2].



A

I–IV



V–XIX

An analysis of the mass spectra obtained (Table 2) permitted us to draw conclusions on the structure of compounds I-XIX under conditions of ionization by electron impact.

According to the observed fragmentation, compounds V-VIII, which exist in the crystalline state in cyclic form B, decompose chiefly from this form. The main pathways of decomposition of compounds V-VIII can be represented by Scheme 1, in which the indicated fragmentation sequence was established by the DADI method.

In the spectra V-VIII, the peaks of the fragments Φ_1 or Φ_2 are a maximum (Table 2), with the exception of the spectrum of compound VI, where the introduction of a benzyl group as the substituent R^1 leads to the appearance of an intense peak of the ions $C_6H_5CH_2^+$ (91). In the spectrum of compound VIII, which has a voluminous tert-butyl group as the substituent R^1, the peak of the ion $[M-NHR^1]^+$ (Φ_5), characteristic of the decomposition of the open form (Scheme 2), appears with intensity $J_{rel} \sim 10\%$. This is an indication of partial isomerization of compound VIII to an open form under the conditions of the mass spectrometric experiment. In the spectra of compounds V-VII, in which the substituent R^1 has a smaller volume, the intensity of the peaks of the ion Φ_5 does not exceed 2%.

The spectra of compounds I-IV, which have an open structure A in the crystalline state and are isomers of compounds V-VIII, evidently represent a superposition of the spectra of the open and cyclic forms. This is indicated by the presence of the peaks of the ions Φ_5-Φ_8, characteristic of the decomposition of the open form, the maximum intensity among which is possessed by the peak of the ion Φ_5 (Scheme 2). Together with the peaks of the fragments presented in Scheme 2, the spectra of compounds I-IV contain intense peaks of the ions Φ_1, which can be interpreted only as decomposition products of the isomeric form B.

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TABLE 1. Ratio of the Intensities of the Peaks of the Ions Φ_1 and Φ_5 in the Spectra of Compounds I-XIX*

Compound	R¹	R²	I_{Φ_1}	I_{Φ_5}	I_{Φ_1}/I_{Φ_5}
I	n-C_3H_7	—	100	7	14,3
II	$CH_2C_6H_5$	—	77	14	5,0
III	i-C_3H_7	—	58	20	2,9
IV	t-C_4H_9	—	8	68	0,18
V	n-C_3H_7	C_6H_5	100	2	50
VI	$CH_2C_6H_5$	C_6H_5	100	2	50
VII	i-C_3H_7	C_6H_5	48	2	24
VIII	t-C_4H_9	C_6H_5	20	10	2
IX	i-C_3H_7	H	7	—†	—†
X	i-C_3H_7	t-C_4H_9	100	0,5	200
XI	i-C_3H_7	$C_6H_4NO_2$-p	100	5	20
XII	i-C_3H_7	2-Py	100	3	33
XIII	i-C_3H_7	$C_6H_4OCH_3$-p	96	5	19
XIV	C_6H_5	H	2	100	0,05
XV	C_6H_5	n-C_3H_7	17	100	0,17
XVI	C_6H_5	i-C_3H_7	30	100	0,3
XVII	C_6H_5	t-C_4H_9	43	100	0,4
XVIII	C_6H_5	$C_6H_4NO_2$-p	100	8	12,5
XIX	C_6H_5	$C_6H_4OCH_3$-p	100	8	12,5

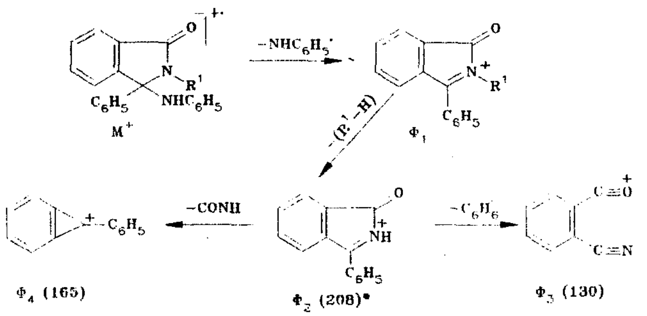
*The initial form of compounds I-IV is open, for V-XIX cyclic.
†For the compound IX the value m/z of the ion Φ_5 coincides with m/z of the ion Φ_2 formed in the decomposition of the cyclic form.

TABLE 2. Mass Spectra of Compounds I-XIX*

Compound	Value of m/z (intensity of the peaks of the ions in % of the maximum)
I	342 (5), 285 (7), 284 (7), 256 (5), 251 (12), 250 (100), 209 (4), 208 (27), 180 (3), 165 (3), 130 (16), 102 (4), 77 (6)
II	390 (1), 299 (19), 298 (77), 285 (12), 284 (4), 256 (4), 208 (1), 180 (2), 106 (6), 91 (100), 77 (7), 65 (9)
III	342 (9), 285 (17), 284 (20), 257 (9), 256 (17), 254 (4), 251 (14) 250 (58), 209 (15), 208 (76), 180 (24), 178 (11), 165 (45), 152 (14), 151 (9), 130 (100), 105 (8), 104 (4), 103 (3), 102 (21), 93 (6), 77 (35), 58 (12)
IV	357 (7), 356 (28), 299 (3), 285 (20), 284 (68), 264 (8), 256 (11), 255 (9), 223 (8), 209 (24), 208 (100), 180 (24), 178 (9), 165 (8), 152 (9), 151 (5), 130 (34), 102 (7), 93 (11), 77 (38), 58 (9).
V	342 (0,2), 285 (1), 284 (2), 251 (18), 250 (100), 208 (46), 180 (2), 165 (4), 130 (29)
VI	390 (0,3), 299 (25), 298 (100), 285 (1,4), 284 (1,5), 256 (1), 165 (2), 92 (7), 91 (66), 65 (5)
VII	342 (0,3), 285 (1), 284 (2), 256 (2), 251 (10), 250 (48), 209 (17), 208 (100), 180 (4), 165 (6), 130 (27)
VIII	356 (3), 285 (3), 284 (10), 264 (20), 209 (16), 208 (100), 180 (2), 165 (2), 130 (18), 77 (7)
IX	266 (7), 250 (7), 249 (6), 209 (47), 208 (100), 189 (37), 180 (34), 165 (6), 162 (10), 152 (13), 147 (2), 130 (74), 102 (21), 77 (21), 58 (13)
X	322 (1), 307 (8), 251 (19), 250 (100), 248 (18), 223 (20), 209 (16), 208 (91), 170 (5), 165 (4), 130 (23)
XI	387 (1), 330 (2), 329 (5), 251 (18), 250 (100), 209 (13), 208 (78), 165 (2), 130 (18)
XII	343 (1), 286 (1), 285 (3), 251 (19), 250 (100), 209 (16), 208 (100), 165 (3), 130 (44), 103 (5), 78 (6), 40 (6)
XIII	372 (8), 315 (3), 314 (5), 251 (19), 250 (96), 209 (16), 208 (100), 170 (5), 165 (5), 130 (4), 122 (5), 108 (5), 102 (8), 77 (6)
XIV	300 (2), 284 (2), 209 (57), 208 (100), 180 (4), 153 (7), 152 (12), 130 (34), 102 (7), 93 (21), 77 (24), 65 (5), 51 (6)
XV	342 (2), 285 (5), 284 (17), 251 (19), 250 (100), 208 (23), 180 (5), 165 (5), 130 (7)
XVI	342 (0,2), 285 (9), 284 (30), 251 (18), 250 (100), 209 (14), 208 (72), 170 (15), 165 (17), 152 (7), 104 (10), 102 (6), 77 (13)
XVII	356 (3), 285 (10), 284 (3), 264 (19), 209 (17), 208 (100), 130 (19), 93 (9), 77 (8)
XVIII	421 (1), 329 (8), 285 (32), 284 (100), 254 (11), 209 (7), 208 (9), 180 (8), 178 (7), 165 (6), 152 (7), 130 (7), 77 (16), 65 (5)
XIX	466 (1), 315 (2), 314 (8), 285 (26), 284 (100), 254 (4), 208 (1), 178 (2), 165 (2), 130 (3), 123 (4), 77 (4)

*Peaks of the ions M^+, Φ_1-Φ_6, as well as peaks of the ions with intensity ⩾3%, are cited.

Scheme 1



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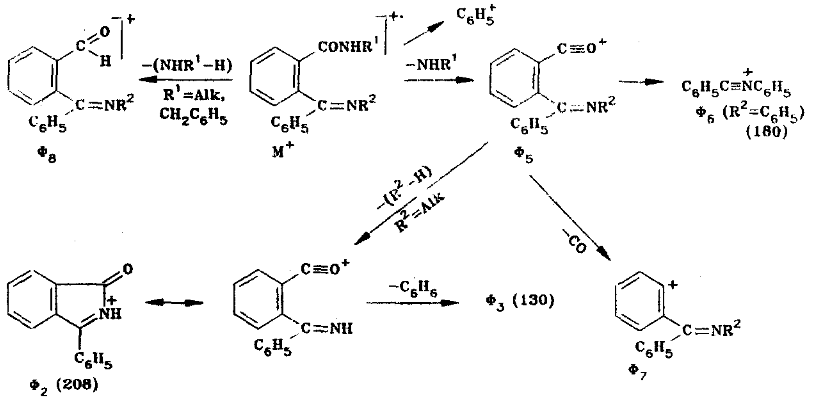
*Here and henceforth the numbers characterizing the ion define the value of m/z.

Scheme 2



The relative intensities of the peaks of the most characteristic fragments Φ_1 and Φ_5 in the spectra of the compounds studied are cited in Table 1. An examination of these data shows that with increasing volume of the substituent R^1 in the series of compounds I-IV, the intensity of the peak of the ions Φ_5, corresponding to decomposition of the open form A, falls monotonically from 68 (R^1 = t-C_4H_9) to 7% (R^1 = n-C_3H_7); moreover, an increase in the intensity of the peak of the ion Φ_1, due to decomposition of the form B, is observed. A similar nature of the intensities of the peaks is also observed for other fragment ions formed in the decomposition of open or cyclic forms. The value of the intensity ratio I_{Φ_1}/I_{Φ_5} (Table 1) shows that in the case R^1 = t-C_4H_9, the spectrum corresponds chiefly to decomposition of the initial open form, while for R^1 = n-C_3H_7 the greatest intensity is possessed by the peaks of the ions due to decomposition of the cyclic form.

These data indicate a transition of compounds I-IV to an isomeric cyclic form before their decomposition; moreover, the ease of conversion increases with increasing volume of the substituent R^1. Earlier the results of an investigation of the IR spectra of compounds I-IV were published [2, 3], indicating an easy conversion of the anils of N-alkyl-2-benzoylbenzamides to their isomeric 2-alkyl-3-phenylamino-3-phenylisoindolinones when ethanol solutions of them are heated. A comparison of these data and the data of the mass spectra permits us to conclude that such isomerization occurs when the investigated samples are heated and when these substances pass into the gas phase.

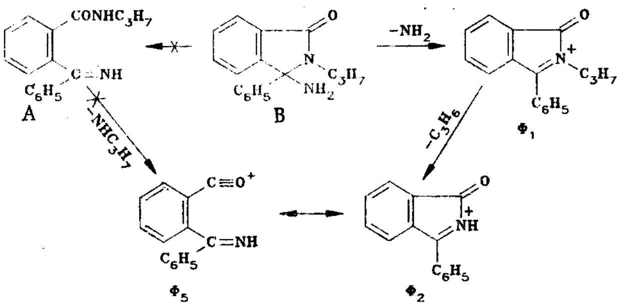
Thus, the behavior of cyclic isomers of imines differs substantially from the previously studied cyclic isomers of the 2-aroylbenzamides themselves, for which the existence of a virtually complete transition to the open form before decomposition of the molecular ion was demonstrated on the basis of mass spectral data [1] in cases when R^1 = i-C_3H_7, t-C_4H_9, $C_6H_5CH_2$. The presence of a significant amount of the cyclic form was noted only in the case of R^1-unsubstituted and methyl-substituted derivatives.

The results obtained indicate a substantial increase in the stability of the cyclic form as we go from the aroyl compounds to their N-arylimines.

The introduction of alkyl substituents and aromatic substituents $4\text{-}NO_2C_6H_4$, $4\text{-}CH_3OC_6H_4$, 2-Py into compounds X-XIII as the substituent R^2 instead of the phenyl group does not lead to any significant opening of the ring. As can be seen from the data of Table 1, the intensity of the peak of the ion Φ_5 for these compounds does not exceed 5%, i.e., the spectra of compounds X-XIII are virtually entirely due to decomposition from the cyclic form B of the molecular ion.

The indeterminacy in the interpretation of the spectrum of compound IX, where the peak of maximum intensity 208 might be attributed to decomposition both of the cyclic form (ion Φ_2) and of an open form (ion Φ_5), was established in an investigation of the spectra of the daughter ions DADI. According to these data, the formation of an ion with mass number 208 is associated with a stepwise elimination of NH_2 and C_3H_6 particles from structure B, as shown in Scheme 3. The stripping of a NHC_3H_7 radical from the molecular ion A was not detected. Thus, the molecular ion of compound IX also retains a cyclic form.

Scheme 3



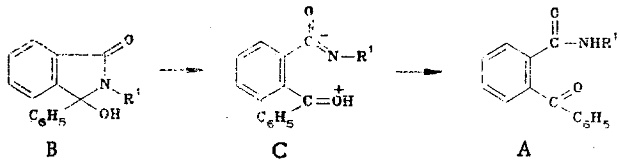
On the basis of the results obtained it can be assumed that the determining factor in the stabilization of the cyclic form in the transition from 2-aroylbenzamides to their imines is precisely replacement of the CO group by a $C{=}NR^2$ group. In this case stabilization of the cyclic form on account of conjugation of the p-electrons of the nitrogen atom with the π-electrons of the aromatic ring (see [4]) when a phenyl group is introduced as the substituent R^2 is evidently a supplementary effect and, as it follows from a comparison of the values of I_{Φ_1}/I_{Φ_5} for compounds V-XIII (Table 1), it is not noticeably manifested mass spectrometrically.

Interesting results were obtained in a study of compounds XIV-XIX ($R^1{=}C_6H_5$). According to the data of the IR spectra, in the crystalline state these compounds are in a cyclic form. An examination of their mass spectra shows that decomposition from the cyclic form basically corresponds to fragmentation only of compounds XVIII and XIX. The peaks of maximum intensity in the spectra of these compounds correspond to the ion Φ_1, characteristic of the decomposition of the cyclic form. At the same time, in these spectra with intensity $I_{rel} \sim 8\%$, the peaks of the fragment Φ_5, corresponding to breakdown of the open form, are observed. In the transition to compounds XIV and XVII, possessing R^2 = H or an alkyl radical, the relative intensity of the peak of the ion Φ_5 increases greatly; moreover, this increase is accompanied by the appearance of an intense peak of the fragment Φ_2, which is formed according to the data of the DADI spectra for compounds XVII by elimination of a $(R^2{-}H)$ group from the Φ_5 ion. Further breakdown of the fragment Φ_2 with elimination of the molecule C_6H_6 leads to the formation of the ion Φ_3 (Scheme 2).

An analysis of the spectra shows that compounds XIV-XVII break down substantially from the open form. From a comparison of the values of I_{Φ_1}/I_{Φ_5} of compounds IX-XIII and XIV-XIX, respectively (Table 1), it follows that the introduction of a phenyl radical instead of an alkyl radical as the substituent R^1 leads to a substantial destabilization of the cyclic form. The result obtained is in good agreement with the literature data [4]. The conservation of a certain amount of the cyclic form in the case of compounds XVIII and XIX can be explained by a competing stabilizing influence on the cyclic form of the $4\text{-}NO_2C_6H_4$ and $4\text{-}CH_3OC_6H_4$ groups as the substituent R^2.

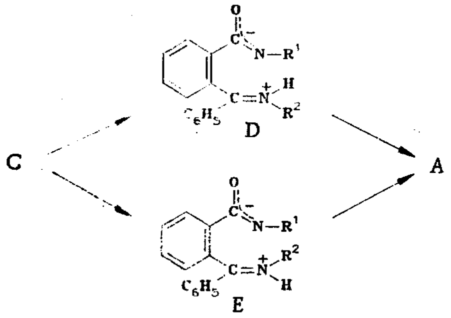
We should make special note of the previously unobserved (see [4]) facilitation of the opening of the ring with decreasing volume of the alkyl substituent R^2 in the compounds XIV-XVII. Actually, as can be seen from data of Table 1, the relative intensity of the peak of the ion Φ_5 increases sharply with increasing volume of the substituent R^2; moreover, this increase is accompanied by a drop in the intensity of the peak due to decomposition of the cyclic form. This phenomenon, as well as the above-noted differences between aroylbenzamidines and their imines can be explained by assuming that the isomerization B → A for these compounds proceeds through a bipolar transition state C (Scheme 4).

Scheme 4



For the corresponding imines, two sterically isomeric (cis-trans) transition states, D and E, are observed (Scheme 5).

Scheme 5



An examination of Scheme 5 shows that in structure E intramolecular migration of a proton with the formation of form A will be substantially hindered in comparison with structure D.

Evidently, the presence of a phenyl group at the carbon next to the nitrogen atom promotes a trans-orientation of the voluminous substituents, i.e., the formation of structure E in the transition state. As a result of this, in imines isomerization of the cyclic form to an open form should have been more hindered than in the corresponding oxoderivatives, as is actually observed experimentally.

Naturally an increase in the volume of the substituent R^2 makes a trans-orientation of it more profitable, i.e., hinders transition to an open form. And on the contrary, a decrease in the volume of R^2 will promote the formation of a transitional structure D, i.e., an open ring, as was noted for compounds XIV-XIX.

It is important that in a consideration of the profitability of the formation of transition structures D and E in the case of the imines studied, not only steric hindrances between the C-phenyl and NR^2 groups but also those between the NR^2 and NR^1 groups must be considered. The decrease in the volume of the substituent R^1 in the presence of a C-phenyl group will increase the fraction of the structure E, i.e., increase the stability of the cyclic form, while an increase in the volume of the substituent R^1 should be a factor promoting the formation of structure D, i.e., stability of the open form, as is observed for compounds I-XIII.

It can be assumed that the steric factor is one of the causes of the destabilizing influence of the phenyl group as the substituent R^1 in the case of compounds XIV-XIX. Another factor is evidently the decrease in the negative charge on the amide nitrogen atom in the transition state E on account of conjugation with the π-electrons of the aromatic ring. Such a drawing off of electron density should also hinder the intramolecular migration of protons with the formation of an open isomer A.

EXPERIMENTAL

The EI mass spectra and DADI spectra were obtained on a Varian MAT-112 mass spectrometer with direct introduction of the sample into the source. Temperature of the ionization chamber 180°C. Energy of ionizing electrons 70 eV.

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