BENZENOID-QUINONE TAUTOMERISM IN AZOMETHINES AND THEIR STRUCTURAL ANALOGS.
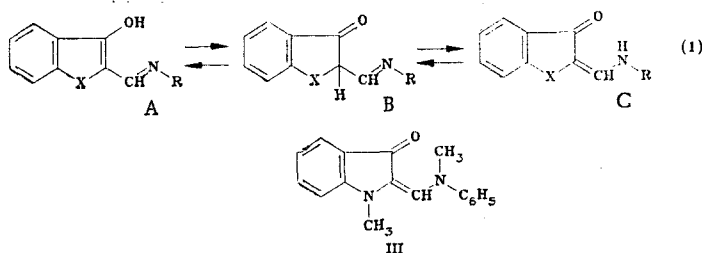
34.* 3-HYDROXY-1-METHYLINDOLE-2-CARBALDEHYDE IMINES

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N-aryl- and N-alkylimines of 3-hydroxy-1-methylindolecarbaldehyde have been synthesized, and have been assigned ketoenamino structures based on their UV, IR, and PMR spectra. The fluorescent properties of these materials have also been examined.

Imine derivatives of benzo[b]annelated five-membered ring 3-hydroxy-2-aldehydes of type I exist in the stable ketoenamino form C both in the crystalline state as well as in solution. The prototropic equilibrium depicted in (1), although possible, is shifted almost entirely toward this form [2].

In order to determine the effect of the heteroatom X on the structure and spectral properties of type I imines, it was of interest to us to study system II compounds, containing the highly electron-donating X = N—CH₃ group within the ring.

$$X = N\text{---}CH_3$$

I X=O, S, Se, CH₂; II X=N—CH₃; R=Ar, Alk

3-Hydroxy-1-methylindole-2-carbaldehyde (V), which has not been described previously, was synthesized as a precursor of both azomethines II (Table 1), as well as of compound III, in which the ketoenamino form is fixed:
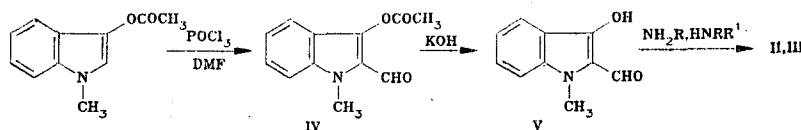
The IR spectrum of compound V in CCl₄ solution contains bands at 1635 and 3200 cm⁻¹, corresponding to the stretching vibrations of the aldehyde and hydroxyl groups, respectively. The PMR spectrum contains a singlet for the aldehyde proton at δ 9.8 ppm, as well as a broadened signal for the hydroxyl group proton at δ 9.4 ppm; the latter signal disappears upon deuteration of the sample. The existence of aldehyde V in the hydroxyaldehyde form was also confirmed by comparison of its UV spectrum with that of the hydroxyaldehyde tautomer of 3-hydroxybenzo[b]thiophene-2-aldehyde [3].

The electronic spectral bands of type II azomethines are relatively insensitive to changes in solvent polarity as well as to changes in the substituent R (Table 2). The absorption bands of type II compounds exhibit quite a pronounced bathochromic shift in com-

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*For communication No. 33, see [1].

TABLE 1. Azomethines II

Com-pound	R	mp, °C	Found, %		Molecular formula	Calcd., %		Yield, %
			C	H		C	H	
IIa	C_6H_5	114—115	76,8	5,6	$C_{16}H_{14}N_2O$	76,8	5,6	70
IIb	$p\text{-}NO_2C_6H_4$	250	64,8	4,5	$C_{16}H_{13}N_3O_3$	68,1	4,4	33
IIc	$p\text{-}CH_3OC_6H_4$	139—140	72,6	5,7	$C_{17}H_{16}N_2O_2$	72,8	5,7	80
IId	$p\text{-}ClC_6H_4$	170	67,4	4,8	$C_{16}H_{13}ClN_2O$	67,5	4,6	78
IIe	$p\text{-}(CH_3)_2NC_6H_4$	182	73,5	6,5	$C_{18}H_{19}N_3O$	73,7	6,5	45
IIf	$C_6H_5CH_2$	158	77,0	6,0	$C_{17}H_{16}N_2O$	77,3	6,1	62
IIg	C_6H_{11}	105—106	74,7	7,9	$C_{16}H_{20}N_2O$	75,0	7,9	55
IIh	$CH(CH_3)_2$	Oil	72,4	7,2	$C_{13}H_{16}N_2O$	72,2	7,4	18

TABLE 2. Spectral Characteristics of the Azomethines IIa-h

Com-pound	Solvent	UV spectrum, λ_{max}, nm $(\varepsilon \cdot 10^{-3})$	IR spectrum, ν, cm^{-1} (Vaseline mulls)
IIa	Hexane	265 (26,3), 308 (22,8), 370 (31,1), 510 (25,1)	1605, 1625, 1675
	2-Propanol	260 (19,0), 308 (17,7), 370 (31,4), 520 (25,4)	
	DMSO	315 (22,2), 365 (28,6), 520 (23,8)	
IIb	2-Propanol	285 (10,4), 392 (30,4), 535 (24,8)	1595, 1630, 1680
IIc	2-Propanol	258 (25,4), 308 (21,8), 375 (31,3), 518 (31,4)	1580, 1620, 1670
IId	2-Propanol	312 (22,4), 366 (27,7), 505 (20,6)	1600, 1625, 1675
IIe	Hexane	300 (14,7), 370 (11,2), 500 (20,1)	1585, 1620, 1675
	DMSO	308 (21,3), 390 (12,1), 520 (19,2)	
IIf	Benzene	312 (31,8), 330 (34,5), 480 (17,0)	1615, 1665, 3200
	2-Propanol	305 (20,8), 343 (34,6), 470 (16,7)	
IIg	2-Propanol	300 (6,3), 343 (34,6), 470 (16,7)	1610, 1660, 3265
IIh	2-Propanol	304, 334, 478	1580, 1620, 1675

parison with the absorption bands of the type I heterocyclic aminovinylketones [2]; this may be explained in terms of the greater electron-donating properties of the N—CH₃ group relative to the heteroatoms O, S, Se, and CH_2.

The IR spectra of azomethines II (Table 2) contain bands at 1620 and 1670 cm^{-1}, corresponding to the stretching vibrations of the C=C and ring carbonyl group, respectively. Compound III, which serves as the model compound for the ketoenamino structure, also contains an analogous carbonyl group absorption band. The $\nu C=O$ and $\nu N-H$ frequencies for the azomethines II are independent of concentration, which demonstrates that they exist primarily in the form of the E-isomers, which are stabilized by the presence of intramolecular hydrogen bonds.

The ketoenamino structure IIC was verified by PMR spectroscopy. Just as was shown in the case of the previously identified aminovinylketones I, the spectrum contains a broad N—H proton signal at δ ~ 10 ppm, which disappears upon deuteration; the CH group proton signal is hidden underneath the multiplet due to the aromatic protons.

The only significant difference between the type II imines and the previously studied analogs I is found in a comparison study of their luminescent properties.

Type I compounds exhibit a low-intensity fluorescence at room temperature; this effect is due exclusively to anion formation [4, 5] resulting from proton abstraction in the excited state. Type I compounds which do not contain an active proton on the imine nitrogen are not luminescent in solution at room temperature.

In contrast, type II azomethines display a very intense luminescence at room temperature, with conventional values of the Stokes' shift. As can be seen in Fig. 1, the fluorescence spectra of type II compounds are similar to those of the model compounds III, in which the ketoenamino form is fixed. The relatively low Stokes' shift values are consistent with the absence of molecular rearrangement during the lifetime of the excited state.

This comparative study of the spectral and luminescent properties of compounds I and II reveals, first of all, that type II compounds are much less reactive to ionization than I, even in the excited state and, second, that they exhibit a significantly higher fluorescence
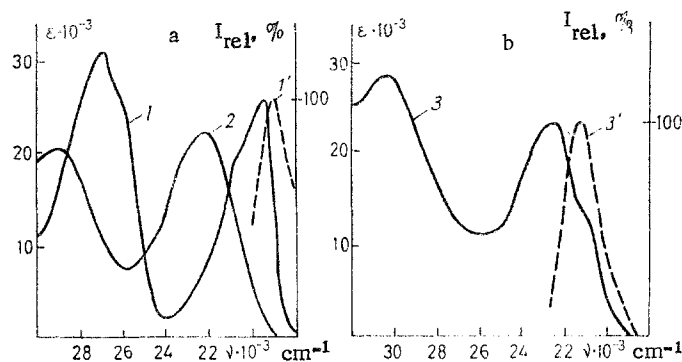
Fig. 1. Absorbance and fluorescence spectra: a) in 2-propanol: absorbance (1) and fluorescence (1') spectra of 3-oxo-1-methyl-2-phenylaminomethyleneindole (IIa); absorbance spectrum of the sodium salt of azomethine IIa (2); b) in hexane: absorbance (3) and fluorescence (3') spectra of 3-oxo-1-methyl-2-(N-methyl-N-phenylaminomethylene)indole (III).

yield for the ketoenamine structure under investigation. Both of these effects, as well as the previously examined bathochromic shifts of the absorption bands, may be explained in terms of the greater electron-donating characteristics of the N—CH₃ group in comparison with the other heteroatoms X which are found in the rings of the type I compounds.

Simultaneous introduction of a second highly electron-donating substituent exerts a marked long-wavelength shift of the ππ* transition band, as well as a smaller short-wavelength shift (or no shift) of the nπ* transition band. By comparing the type I and II systems with the xanthone and acridone systems which were studied earlier [6], and also by taking into account the fact that the positions of the nπ* transitions are roughly equivalent (about 26,000 cm⁻¹) in these different systems, we conclude that the absence of fluorescence in type I ketoenamino compounds is associated with the proximity of the lower excited ππ* singlet state and the nπ* level which, although it is not manifested spectroscopically, apparently facilitates an efficient nonradiative deactivation of the energy. The pronounced lowering of the $S_{\pi\pi^*}$ level which occurs in both type II compounds and in acridones leads to the appearance of an intense fluorescent response.

Substitution of the heteroatom X with a strongly electron-donating N—CH₃ group thus does not affect the position of the IIA ⇄ IIC equilibrium, which remains shifted in favor of the ketoenamino form IIC, but does exert a very strong effect on the fluorescent properties of the compounds under investigation.

EXPERIMENTAL

Electronic absorbance spectra were obtained on a Specord UV–vis spectrophotometer, whereas luminescence spectra were recorded on a "Fotolyum" apparatus (TsKB AMN SSSR). IR spectra were recorded on a Specord IR-71 spectrophotometer and PMR spectra were obtained on a Tesla BS-407-C spectrometer at 80 MHz versus HMDS as internal standard.

3-Acetoxy-1-methylindole-2-carbaldehyde (IV). A mixture of 6 ml of phosphorus oxychloride and 18 ml of DMF was prepared at 10–15°C, and a solution of 10 g (50 mmole) of 3-acetoxy-1-methylindole [7] in 18 ml of DMF was added with stirring at 25–30°C. The mixture was maintained at this temperature for 0.5 h, and then heated at 60°C for 2 h. The mixture was cooled and poured onto a slurry of 120 g of ice and 120 g of water. The resulting solution was neutralized with 20% KOH to pH 6. The resulting precipitate was removed by filtration and dried under vacuum. The material was crystallized from alcohol after the addition of activated carbon, and then recrystallized from octane. Yield 20–30%. Small yellow crystals, mp 137°C. IR spectrum (Vaseline mull): 1620, 1670, and 1760 cm⁻¹. PMR spectrum (in CH₂Cl₂): 2.35 (C—CH₃), 3.95 (N—CH₃), 9.9 (CHO) ppm. UV spectrum (in 2-propanol): λ_{max} ($\varepsilon \cdot 10^{-3}$): 240 (20.0), 315 nm (25.7). Found, %: C 66.1, H 5.2. $C_{12}H_{11}NO_3$. Calculated, %: C 66.35, H 5.1.

3-Hydroxy-1-methylindole-2-carbaldehyde (V). A solution of 50 ml of 20% KOH was cooled to 0°C and treated with stirring with portions of 8.8 g (50 mmole) of the acetoxy derivative IV and 10 ml of methanol under an argon atmosphere; the mixture was stirred until all of the precipitate had dissolved. Water (100 ml) was added and the solution was saturated with carbon dioxide at 0°C until the hydroxyaldehyde had completely precipitated. The precipitate was removed by filtration, washed with water, and dried under vacuum. The material was recrystallized from toluene. Light yellow crystals. Yield 2.7 g (38%), mp 132-133°C. IR spectrum (Vaseline mull): 1610, 1635 cm^{-1}. PMR spectrum (in CH_2Cl_2): 3.8 (N—CH$_3$), 9.4 (OH), 9.8 ppm (CHO). UV spectrum (in 2-propanol), λ_{max} ($\varepsilon \cdot 10^{-3}$): 243 (17.7), 322 (23.3), 370 nm (7.2). Found, %: C 68.4, H 5.3. $C_{10}H_9NO_2$. Calculated, %: C 68.3, H 5.5%.

Azomethines II. These were prepared by condensation of equimolar amounts of aldehyde V and aromatic or aliphatic amines in either 2-propanol or absolute benzene. Reaction times: 0.5-4 h for arylamines, 1-6 h for alkylamines. In the latter cases the reactions are accompanied by a significant amount of resin formation; the reaction products were therefore purified by chromatography. Compounds were crystallized from hexane, octane, or alcohol.

3-Oxo-1-methyl-2-(isopropylaminomethylene)indole (IIh). A solution of 0.18 g (1 mmole) of aldehyde V and 0.074 g (1.2 mmole) of isopropylamine in benzene was refluxed for 6 h. The completion of the reaction was followed chromatographically by the disappearance of aldehyde (Silufol UV-254, CHCl$_3$). The solvent was removed almost entirely by evaporation under vacuum. Pentane was added and a green oil was formed. The product was purified by column chromatography (Al$_2$O$_3$, CHCl$_3$). The yellow-colored product fraction was collected, and the chloroform diluent was evaporated under vacuum. Yield 0.036 g of a yellow oil.

3-Oxo-1-methyl-2-(N-methyl-N-phenylaminomethylene)indole (III). A solution of 0.54 g (3 mmole) of aldehyde V and 0.33 g (3 mmole) of N-methylaniline in 8 ml of absolute ethanol was heated at 60°C for 18 h. The solvent was partially removed under vacuum, and the unreacted aldehyde was removed by filtration. The solution was evaporated to dryness under vacuum. The product was purified by column chromatography (Silokhrom S-120, benzene). Well-defined separation of the various fractions was obtained, and the orange-colored fraction was excised and washed with ether. The solvent was removed under vacuum, and the product crystallized upon trituration with alcohol. Yield 0.16 g (20%). Red crystals which oiled upon storage were obtained, mp 159-162°C. IR spectrum (in CCl$_4$), $\nu_{C=O}$ 1685 cm^{-1}. UV spectrum (in 2-propanol), λ_{max} 364, 467 nm. Found, %: C 77.0, H 6.0. $C_{17}H_{16}N_2O$. Calculated, %: C 77.3, H 6.1.

LITERATURE CITED

1. V. A. Bren', V. P. Ribalkin, V. I. Minkin, S. M. Aldoshin, and L. O. Atovmyan, Zh. Org. Khim., 20, 1485 (1984).
2. V. A. Bren' and V. I. Minkin, Izv. Vyssh. Uchebn. Zaved., Khim. i Khim. Tekhnol., 25, 663 (1982).
3. V. A. Bren', V. I. Usacheva, and V. I. Minkin, Khim. Geterotsikl. Khim., No. 7, 920 (1972).
4. M. B. Stryukov, M. I. Knyazhanskii, V. A. Bren', V. I. Minkin, and Zh. V. Bren', Opt. i Spektro., 35, 1051 (1973).
5. M. B. Stryukov, M. I. Knyazhanskii, V. A. Bren', V. I. Minkin, B. Ya. Simkin, and V. I. Usacheva, Teor. Eksp. Khim., 10, 520 (1974).
6. R. N. Nurmukhametov, Absorbance and Luminescence Spectra of Aromatic Compounds [in Russian], Khimiya, Moscow (1971), p. 173.
7. N. V. Fakeeva and V. V. Zhidkova, Methods for the Preparation of Chemical Reagents and Materials [in Russian], No. 20, 134 (1969).