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RESEARCHES ON BENZ- AND NAPHTHAZOLES

XVI. Alkylation of Benzimidazole Formazans*

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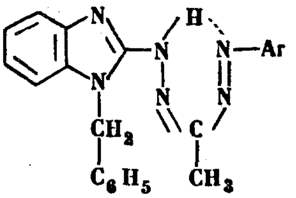
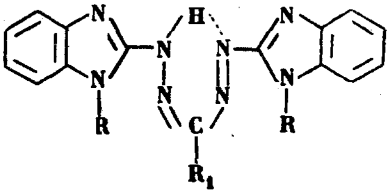
Unsymmetric 1-benzimidazolyl-5-aryl-3-methylformazans are formed when their monomethyl derivatives are methylated. On alkylation 1, 5-dibenzimidazolylformazans give 1, 5-dibenzimidazolyltetraazapentamethinecyanines. For the first time examples of benzimidazole azacyanine dyes are described.

It is known that 1, 5-diarylformazans can be methylated to give 1-methyl derivatives [1-3]. It was of interest to investigate the alkylation of the previously described [4, 5] unsymmetric 1-benzimidazolyl-5-arylformazans (I-IV) and symmetric 1, 5-dibenzimidazolylformazans (V-IX).



I Ar=p-$C_6H_4CH_3$
II Ar=p-C_6H_4Cl
III Ar=p-$C_6H_4NO_2$
IV Ar=o-C_6H_4COOH

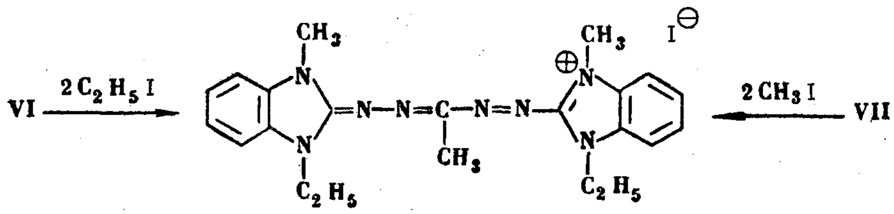


V R=$CH_2C_6H_5$
VI R=CH_3
VII R=C_2H_5
VIII R=H
} $R_1=CH_3$
IX R=$CH_2C_6H_5$ R_1=H

Refluxing unsymmetric 1-(1'-benzylbenzimidazolyl-2')-3-methyl-5-arylformazans with methyl iodide in ethanolic alkali gave monomethyl substituted derivatives (Table 1). So far the position of the methyl group has not been established (at the nitrogen atom) at position 1 or 5, or in the benzimidazole ring). The methyl derivatives obtained have absorption spectra in the visible region resembling the spectra of the starting formazans. Unlike the latter, the methyl derivatives do not form complexes with metals, and ethanol solutions do not change in color when made alkaline. Exceptions are formazan IV and its methyl derivative XIII, ethanol solutions of which on rendering alkaline become more colored due to salt formation at the carboxyl. Like the starting formazans, the methyl derivatives are unstable in acid solution, and decompose irreversibly with decolorization of the solution. Compounds with electron-accepting groups in the aryl portion are more stable.

Symmetric 1,5-di(1'-alkylbenzimidazolyl-2') formazans (V-IX) give other alkylation products. Elementary analytical data showed that these compounds were alkiodides of alkyl derivatives, and their visible region absorption spectra differed sharply from those of the starting formazans, and were reminiscent of the spectra of the hydrochlorides of the formazans (appearance of two peaks, and bathochromic shift, Table 2). All this gave reason for believing that the methylation products were azacyanines XIV-XVIII.

That the products of alkylation of symmetric dibenzimidazolylformazans are cyanines is shown by a retrosynthesis of one of these dyes:



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* For Part XV see [8].

Table 1

Methylation Products of 1-(1'-Benzylbenzimidazolyl-2')-3-methyl-5-arylformazans

Compound number	Aryl	Mp, (ex EtOH) °C	Appearance and shape of crystals	λ_{max}, mμ	$\varepsilon \cdot 10^{-4}$	Formula	Found, %			Calculated, %			Yield, %
							C	H	N	C	H	N	
X	p-$C_6H_4CH_3$	167—168	Brownish-orange needles	456	3.68	$C_{24}H_{24}N_6$	72.59	6.08	21.35	72.62	6.10	21.19	93
XI	p-C_6H_4Cl	122—123	Clusters of orange needles	470	3.85	$C_{23}H_{21}ClN_6 \cdot H_2O$	63.13	5.33	19.71	63.51	5.33	19.32	94
XII	p-$C_6H_4NO_2$	218—219	Red needles with a green reflex	526	4.01	$C_{23}H_{21}N_7O_2$	64.16	5.09	22.77	64.62	4.95	22.93	51
XIII	o-C_6H_4COOH	188—192	Red needles	528	5.39	$C_{24}H_{22}N_6O_2 \cdot H_2O$	64.93	5.27	19.17	64.85	5.44	18.90	66

Starting formazans, λ_{max}, mμ ($\varepsilon \cdot 10^{-4}$) I, 452 (3.47); II 468 (4.19); III 522 (3.96); IV 530 (5.75).
Starting formazans in ethanolic alkali, λ_{max} mμ ($\varepsilon \cdot 10^{-4}$): I 525 (5.15); II, 538 (6.34); III, 620 (7.16); IV, 518 (4.78).

The resultant dyes had identical melting points (undepressed mixed melting points) and identical spectra, but one of them contained one molecule of water of crystallization.

Alkylation of the formazan VIII unsubstituted in the benzimidazole rings takes place stepwise. First the hydrogen atom at the alkyl group (CH_3, C_2H_5) in the benzimidazole rings exchanges, and crystalline sodium salts of formazans VI or VII separate out. The corresponding cyanines XVa or XVIa are formed by further alkylation.

Azacyanines, like the starting formazans, can retain a component of crystallization (usually water).

Unlike formazans, they do not form complexes with metal ions and are readily decomposed, with decolorization, in solutions of alkalies.

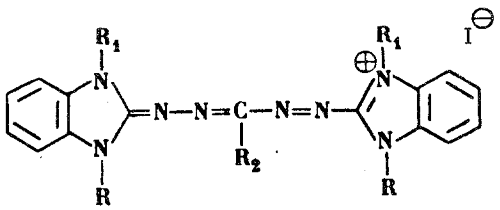
Reviewing the spectra of the azacyanines prepared, regularities are found which confirm that the dyes are cyanines. Thus comparing the spectra of dyes XIV and XVIII, it can be seen that introduction of a methyl group into the azamethine chain gives rise to a hypsochromic effect. The donor methyl group, when introduced into the chain of polymethine cyanines, has a like effect, as the researches of A. I. Kiprianov and coworkers shows [6]. If the cyanines which we have prepared are compared with the benzothiazole tetraazapentamethine dyes prepared by oxidative azo-coupling [7], the resemblance of the spectra of these similarly constituted dyes become evident.

Experimental

Methylation of unsymmetric formazans.

0.001 mole 1-(1'-benzylbenzimidazolyl-2')-3-methyl-5-p-tolylformazan (I) in 20 ml EtOH, with 2 ml 30% NaOH and 1 ml MeI were refluxed together for 1 hr, till the bright raspberry red color (formazan Na salt) changed to brownish-orange. The reaction products were evaporated to dryness, and the residue recrystallized from EtOH, to give minute brownish-orange needles of the methyl derivative X, readily soluble in EtOH, $CHCl_3$, benzene, Me_2CO, and dimethylformamide.

The following were prepared similarly to X: methyl derivative XI from 1-(1'-benzylbenzimidazolyl-2')-3-methyl-5-p-chlorophenylformazan (II); methyl derivative XII from 1-(1'-benzylbenzimidazolyl-2')-3-methyl-5-p-nitrophenylformazan (III), and methyl derivative XIII from 1-(1'-benzylbenzimidazolyl-2')-3-methyl-5-o-carboxyphenylformazan (IV).



XIV—XVIII

Table 2

1, 5-Di(1', 3'-dialkylbenzimidazolyl-2') tetraazapentamethinecyanines

Compound number	R	R_1	R_2	Synthetic method	Mp, ° C	Color and shape of crystals	λ_{max_1}, mμ ($\varepsilon_1 \cdot 10^{-4}$)	λ_{min}, mμ ($\varepsilon_1 \cdot 10^{-4}$)	λ_{max_2}, mμ ($\varepsilon_2 \cdot 10^{-4}$)	Formula	Found, %			Calculated, %			Yield, %
											C	H	N	C	H	N	
XIV	$CH_2C_6H_5$	CH_3	CH_3	Methylation V	215—216	Dark violet prisms with yellowish green reflex	586(7.19)	594(7.15)	618(7.89)	$C_{32}H_{31}IN_8$	58.16	4.85	16.84	58.71	4.77	17.12	80
XV	CH_3	CH_3	CH_3	Methylation VI	225—226	Bluish-violet needles with green reflex	580(7.99)	592(7.82)	612(8.48)	$C_{20}H_{23}IN_8$* · · $(CH_3)_2NCHO$ · · $3H_2O$	43.97	4.98	20.18	43.88	5.76	20.02	60
XVa	CH_3	CH_3	CH_3	Methylation of Na salt of VI	223—224	Blackish-blue needles	580(6.72)	590(6.63)	612(7.58)	$C_{20}H_{23}IN_8$	47.41	4.74	22.59	47.81	4.61	22.37	50—60
XVI	C_2H_5		CH_3	Ethylation VII	220—222	Violet plates with with greenish reflex	580(7.50)	591(7.33)	614(8.40)	$C_{24}H_{31}IN_8 \cdot {}^1/_2H_2O$	50.96	5.70	19.88	50.78	5.70	19.74	60
XVIa	C_2H_5	C_2H_5	CH_3	Ethylation of Na salt of VII	220—222		—	—	—	$C_{24}H_{31}IN_8 \cdot {}^1/_2H_2O$	50.76	5.83	19.26	50.78	5.70	19.74	50—60
XVII	C_2H_5	CH_3	CH_3	Methylation VII	226—227	Violet rhombs with yellow reflex	582(7.74)	590(7.66)	612(8.48)	$C_{22}H_{27}IN_8 \cdot H_2O$	48.71	5.12	20.44	48.16	5.33	20.43	87
XVIIa	C_2H_5	CH_3	CH_3	Ethylation VI	226—227	"	580(6.99)	588(6.95)	612(7.64)	$C_{22}H_{27}IN_8$	50.20	5.35	21.08	49.81	5.13	21.12	80
XVIII	$CH_2C_6H_5$	CH_3	H	Methylation IX	182—183	Violet needles with green rlex	592(6.92)	610(6.63)	626(6.80)	$C_{31}H_{29}IN_8 \cdot HI$ · · H_2O	47.36	4.02	14.04	47.34	4.11	14.24	60

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* With compound XV the weight loss on drying at 180-200° was 21.31%. Calculated: 20.19% (dimethylformanide and water).

Alkylation of symmetric formazans.

1, 5-Di(1'-benzyl-3'-methylbenzimidazolyl-2')-3-methyltetraazapentamethinecyanine (XIV). 0.002 mole 1, 5-di(1'-benzylbenzimidazolyl-2')-3-methylformazan (V), 10 ml dimethylformamide, and 3 ml MeI were refluxed together on a water bath for half an hour, then left overnight. The crystals of compound XIV which separated were filtered off and washed with EtOH; soluble in EtOH, Me_2CO, $CHCl_3$, dimethylformamide, insoluble in benzene and EtOAc. Solutions were bluish violet, addition of strong alkali led to decolorization in a few minutes, and subsequent acidification did not lead to the color's being restored. There was no change of color when dye solutions were treated with dissolved copper or nickel salts, and no complexing.

Methylation of formazans VI, VII, and IX gave, similarly to the preparation of compound XIV, compounds XV, XVI, and XVIII.

1, 5-Di(1'-diethylbenzimidazolyl-2') 3-methyltetraazapentamethinecyanine (XVII). 0.001 mole formazan VII, 4 ml dimethylformamide, 2 ml EtI, were refluxed together for 1 hr, then left overnight. The crystals of XVII which separated were filtered off, and washed with EtOH.

Similarly ethylation of formazan VI gave the azacyanine XVIIa. The azacyanines from formazans VI and VII are more soluble in organic solvents than are those from formazans V and IX.

The sodium salts of formazans VI and VII were methylated and ethylated in dimethylformamide in a way similar to that described above.

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