

[CONTRIBUTION FROM THE CANCER RESEARCH LABORATORY, UNIVERSITY OF FLORIDA]

Physical Properties of the Aminoazobenzene Dyes. IX. Absorption Spectra in Alcohol and Acid Solution of Disazobenzene Dyes¹

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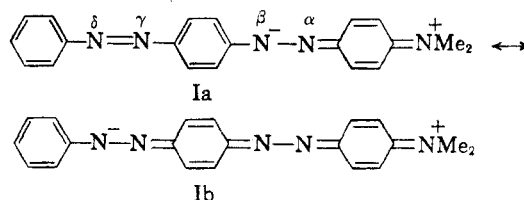
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The position of proton addition and the absorption spectra in various solvents of 4-dimethylamino-*p*-disazobenzene dyes has been investigated. Spectral evidence has been presented which indicates that the first proton adds to the β -azo nitrogen and the second proton to the δ -azo nitrogen. The tautomerism of these salts has also been investigated.

In previous papers the *beta* and amino nitrogens of a large number of 4-aminoazobenzene derivatives³⁻⁶ were shown to be of the same order of basicity. For example, the basicity of the amino nitrogen relative to the β -nitrogen is increased by the following substitutions in 4-dimethylaminoazobenzene: (a) replacement of one or both methyl groups by ethyl groups; (b) a methyl,⁶ fluoro,⁷ or methoxy⁸ group in the 3-position; (c) alkyl, methoxy, chloro, or nitro groups in the 2'-position;⁶ (d) electron donor groups in the 4'-position.⁶ The basicity of the β -nitrogen relative to the amino nitrogen in dyes such as 4-dimethylaminoazobenzene is increased by (a) substitution in the 2-position by an alkyl⁶ or fluoro⁷ group; (b) the presence of a 2'-carboxy group;⁶ (c) 4'-substitution by electron-attracting groups;⁶ (d) replacement of an *N*-methyl group by a base-weakening phenyl, benzyl, or β -chloroethyl⁸ group. As the amino and β -nitrogens are of the same order of basicity, the 4-aminoazobenzene dyes tend to form a mixture of monocationic tautomers in acid solution consisting of the C tautomer involving proton addition to the β -nitrogen and the A tautomer involving proton addition to the amino nitrogen. With C_ϵ equivalent to the molar extinction coefficient of the long wave length band of the C tautomer and A_ϵ equivalent to the molar extinction coefficient of the long wave length band of the A tautomer, the C_ϵ/A_ϵ ratio has been shown to give a crude indication of what one would expect for the relative tauto-

meric equilibria on the basis of structural modifications and *pK*'s.

Knowing the effect of the position of a methyl group on the C_ϵ/A_ϵ ratio of 4-dimethylaminoazobenzene, it was believed that the position of proton addition in 4-dimethylamino-*p*-disazobenzene (I) should be capable of determination. 4-Dimethylaminoazobenzene has a C_ϵ/A_ϵ ratio of 3.6 in 50% alcoholic 1.2*N* hydrochloric acid, its 2'-methyl derivative has a C_ϵ/A_ϵ ratio of 0.29, while the 3'-, 4'-, and 2-methyl isomers have C_ϵ/A_ϵ ratios of 4.1, 2.6, and 10.0, respectively.⁶ In the 4-dimethylamino-*p*-disazobenzene dyes a much more complicated situation is present. There are five nitrogens at which salt formation can take place. If we consider zwitterionic resonance structures such as Ia and Ib as contributors to the over-all structure of



these dyes, then the β - and δ -azo nitrogens have a greater electron density than the α - or γ -azo nitrogens which cannot act as a negative resonance terminal. As Ia involves one *p*-benzoquinonic ring and Ib involves two such rings and also a greater separation of charge, Ib is probably of higher energy and the β -nitrogen would consequently have a higher electron density than the δ -nitrogen. Consequently in a competition for the first proton, the amino and β -nitrogens would probably be the chief competitors. In the derivatives under study the only methyl groups that appear to definitely affect the C_ϵ/A_ϵ ratio of I, C_ϵ/A_ϵ 3.5, are those that would be expected to affect the electron density of the β -azo nitrogen. For example, 2', 2''-dimethyl-I has a C_ϵ/A_ϵ ratio of 0.28. Just as in 2'-methyl-4-dimethylaminoazobenzene the 2'-methyl group has strongly decreased the C_ϵ/A_ϵ ratio. In 3',4''-dimethyl-I the C_ϵ/A_ϵ ratio is practically the same as in I, Table I. These methyl groups would not be expected to have a strong electronic effect on the β -nitrogen, but would be expected to increase the

(1) This investigation was supported by research grant C-1308 from the National Cancer Institute of the National Institutes of Health, U. S. Public Health Service. Paper VIII, E. Sawicki, *J. Org. Chem.*, **22**, 1084 (1957).

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(3) E. Sawicki and F. Ray, *J. Org. Chem.*, **19**, 1686 (1954).

(4) E. Sawicki and D. Gerber, *J. Org. Chem.*, **21**, 410 (1956).

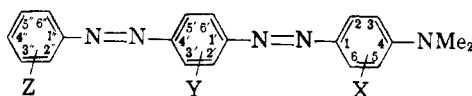
(5) E. Sawicki, *J. Org. Chem.*, **21**, 605 (1956).

(6) E. Sawicki, *J. Org. Chem.*, **22**, 621 (1957).

(7) G. Cilento, E. Miller, and J. Miller, *J. Am. Chem. Soc.*, **78**, 1718 (1956).

(8) This is a prediction based on the results of W. Ross and G. Warwick, *J. Chem. Soc.*, 1719 (1956), who showed that in the acid spectra of some thirty 4-di(2-chloroethyl)aminoazobenzene dyes only the 3-methoxy-4'-carboxy derivative had an A band. They pointed out that the 3-methoxy derivative increased the basicity of the amino nitrogen.

TABLE I

ABSORPTION SPECTRA OF 4-DIMETHYLAMINO-*p*-DISAZOBENZENE DYES IN ALCOHOL AND ACID SOLUTION^a

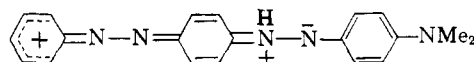
X	Y	Z	λ_{\max} ($\epsilon \times 10^{-3}$)		Solvent ^b	$\frac{C_{\epsilon}}{A_{\epsilon}}$
H	H	H	330 (16.0)	476 (35.8)	A	3.5
			355 (17.1)	548 (59.6)	B	
				635 (106.3)	C	
				490 ^d (39.7)	D	
				470 (34.6)	A	
H	2'-CH ₃	2''-CH ₃	335 (14.2)	470 (34.6)	A	0.28
			370 (35.8)	534 (9.80)	B	
				630 (73.2)	E	
				540 (46.4)	D	
				475 (38.0)	A	
H	3'-CH ₃	4''-CH ₃	340 (14.6)	475 (38.0)	A	3.4
			360 (17.1)	558 (58.7)	B	
			428 (7.08)	647 (110.0)	C ^e	
				545 (51.4)	D	
				475 (37.4); 490 (36.4)	A	
2-CH ₃	3'-CH ₃	4''-CH ₃	344 (14.2)	475 (37.4); 490 (36.4)	A	5.6
			360 (12.3)	550 (69.0)	B	
			425 (6.02)	645 (108.0)	C ^e	
				540 (46.4)	D	

^a Spectral data for the 320–800 $m\mu$ region. ^b A = 95% ethanol containing 0.25% dioxane; B = 50% alcoholic 1.2N HCl; C = 50% alcoholic 50% sulfuric acid; D = 95% sulfuric acid; E = 50% alcoholic, 40% sulfuric acid. ^c This ratio gives a crude idea of the tautomeric equilibrium. C_{ϵ} is the molecular extinction coefficient at the wave length maximum of the C band ($\sim 540 m\mu$); A_{ϵ} is the molecular coefficient at the wave length maximum of the A band ($\sim 360 m\mu$). ^d Also a shoulder at 620 $m\mu$, $\log \epsilon$ 3.97 due to the presence of some dicationic salt. ^e Spectrum in 50% alcoholic 6N HCl very closely similar.

electron density of the δ -nitrogen. This would be mainly due to the 3'-methyl group. As the $C_{\epsilon}/A_{\epsilon}$ ratio shows no change, this must mean that the first proton adds to the β -azo nitrogen. This is substantiated by the $C_{\epsilon}/A_{\epsilon}$ ratio of 2,3',4''-trimethyl-I, $C_{\epsilon}/A_{\epsilon}$ 5.6. The 2-methyl group has increased the electron density of the β -nitrogen. The increased $C_{\epsilon}/A_{\epsilon}$ ratio must mean that the first proton adds at the β -nitrogen. The definite effect of the 2- and 2'-methyl groups on the spectra and the tautomeric equilibrium of the 4-dimethylamino-*p*-disazobenzene dyes are shown in Fig. 1. The band at approximately 360 $m\mu$ is the A band of the A tautomer which is iso- π -electronic to *p*-disazobenzene, $\lambda_{\max}^{\text{EtOH}}$ 359, ϵ 80600.⁹

Substitution of a phenylazo group into the 4'-position of 4-dimethylaminoazobenzene, $\lambda_{\max}^{\text{EtOH}}$ 408, $\log \epsilon$ 4.44 shifts the values to $\lambda_{\max}^{\text{EtOH}}$ 476, $\log \epsilon$ 4.55. In this respect the phenylazo group is approximately equivalent to a nitro group for 4'-nitro-4-dimethylaminoazobenzene has $\lambda_{\max}^{\text{EtOH}}$ 478, $\log \epsilon$ 4.52.⁶

In 50% alcoholic 1.2N hydrochloric acid the long wave length band of the C tautomer of 4-dimethylamino-*p*-disazobenzene, λ_{\max} 548, absorbs at a longer wave length than the long wave length band of the C tautomer of 4-dimethylaminoazobenzene, λ_{\max} 516. This absorption is probably due to the contribution of extraconjugative structures such as



to the excited state of the molecule. Essentially this type of conjugation could cause a net stabilization of the excited state. This, of course, has a

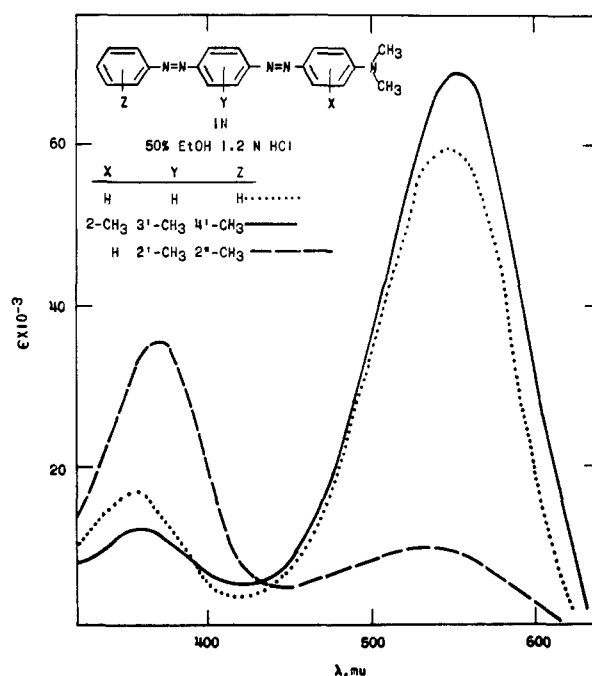


Fig. 1. Absorption spectra in 50% alcoholic 1.2N HCl: 4-dimethylamino-*p*-disazobenzene (.....); 2',2''-dimethyl-4-dimethylamino-*p*-disazobenzene (—); and 2,3',4''-trimethyl-4-dimethylaminoazobenzene (—)

(9) H. Dahn and H. Castelmur, *Helv. Chim. Acta*, **36**, 638 (1953).

bathochromic and hyperchromic effect on the long wave length band. This same type of extraconjugative effect is shown by phenyl- or benzo-substituents in the prime ring of 4-dimethylaminoazobenzene, Table II. While electron acceptor groups (e.g., the nitro group) in the 4'-position of 4-dimethylaminoazobenzene cause an increase in the C_e/A_e ratio,⁶ the interposition of another benzene ring between the nitro group and the prime ring (as in the nitrofluorene derivative, Table II) destroys this effect. As was mentioned previously many types of 2'-substituents in the 4-dialkylaminoazobenzene dyes cause a strong decrease in the C_e/A_e ratio. This same type of effect is seen in the 1-naphthyl dye as compared to its 2-isomer, Table II.

TABLE II
THE C_e/A_e RATIO OF SOME POLYNUCLEAR AZO DYES

Ar	$\lambda_{\max} (\epsilon \times 10^{-3})$		Normality	
	C band	A band	HCl ^a	C_e/A_e
<i>p</i> -Biphenyl-	544 (39.5)	350 (13.4)	1.2	3.0
2-Fluorenyl-	565 (36.9)	370 (15.5)	1.2	2.4
2-(7-Nitrofluorenyl)-	545 (42.3)	368 (19.4)	1.2	2.2
2-Naphthyl-	545 (35.9)	325 (14.1)	1.2	2.6
1-Naphthyl	540 (3.20)	380 (11.9)	1.2	0.27
	540 (8.08)	380 (10.1)	6.0	0.8

^a In 50% ethanol.

The addition of a second proton causes another strong bathochromic and hyperchromic effect to an approximate λ_{\max} 640, $\log \epsilon$ 5.0, Fig. 2. These data

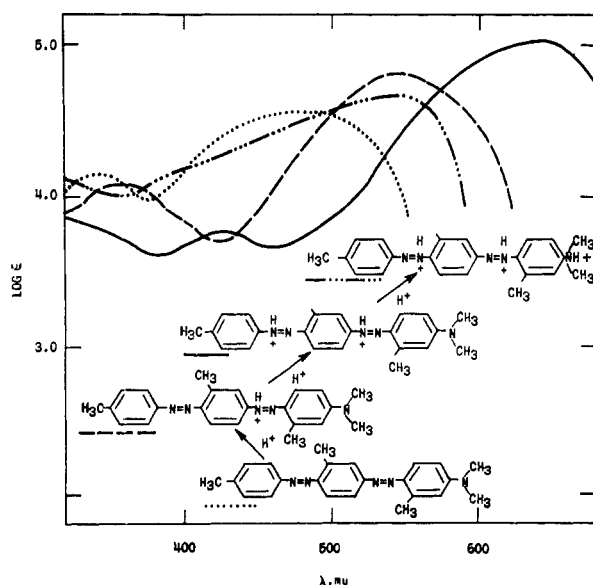
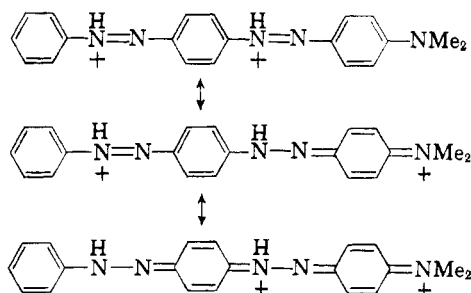


Fig. 2. Absorption spectra of 2,3,4'-trimethyl-4-dimethylamino-*p*-disazobenzene in 95% ethanol containing 0.25% dioxane (.....); in 50% alcoholic 1.2*N* HCl (—); in 50% alcoholic 50% sulfuric acid (— — —); and in 95% sulfuric acid (— · — · —)

strongly indicate that the second proton has added to the δ azo nitrogen. The spectral data show that the dicationic tautomer involving salt formation at the β - and δ -nitrogens is present to a very large extent in 50% alcoholic 50% sulfuric acid, Table I, Fig. 2. The dicationic dye is apparently also formed in pure trifluoroacetic acid for solutions of all the 4-dimethylamino-*p*-disazobenzene dyes in this acid are brilliant blue. In these dicationic dyes the absorption at such a long wavelength is apparently due to the increased length of conjugation involved in the cationic resonance structures contributing to the ground and excited states of the molecule.



The third proton possibly adds to these dyes with a protropic shift as shown in Fig. 2. The presence of other tautomers is also possible. The main structure for the tricationic salt is based on the fact that *p*-disazobenzene, $\lambda_{\max}^{\text{H}_2\text{SO}_4}$ 502, $\log \epsilon$ 4.74,⁹ is spectrally similar to 4-dimethylamino-*p*-disazobenzene, $\lambda_{\max}^{\text{H}_2\text{SO}_4}$ 490, $\log \epsilon$ 4.60.

EXPERIMENTAL¹⁰

4-Dimethylamino-p-disazobenzene. To a stirred solution of 19.6 g. of 4-aminoazobenzene in 12 ml. of *N,N*-dimethylformamide was added a mixture of 100 g. of ice and 20 ml. of concentrated hydrochloric acid. A solution of 7.4 g. of sodium nitrite in 20 ml. of water was added slowly with stirring at 0–5°. Five grams of urea were added gradually followed by a 10-min. stirring period. Then 12.1 g. of dimethylaniline in 18 ml. of acetic acid followed by 40 g. of potassium acetate in 100 ml. of water were gradually added to the stirred solution at 0–5°. The mixture was stirred an additional hour, filtered cold, and then washed thoroughly with water. Crystallization from dimethylformamide followed by two crystallizations from Methyl Cellosolve (β -methoxyethanol) gave an approximately 60–70% yield of glistening brown-red micro crystals, m.p. 198–199°. Lit. m.p. 190°.¹¹

Anal. Calcd. for $C_{20}H_{19}N_5$: N, 21.3. Found: N, 21.0.

2',2''-Dimethyl-4-dimethylamino-p-disazobenzene. The same procedure was used for this compound. Three crystallizations from Methyl Cellosolve gave an approximately 50–60% yield of gleaming brown-red crystals, m.p. 139–140°.

Anal. Calcd. for $C_{22}H_{23}N_5$: N, 19.6. Found: N, 19.9.

3',4''-Dimethyl-4-dimethylamino-p-disazobenzene. Several crystallizations of the crude product prepared by the standard procedure from Methyl Cellosolve gave an approximately 50–60% yield of brown-red crystals, m.p. 187–189°.

Anal. Calcd. for $C_{22}H_{23}N_5$: N, 19.6. Found: N, 19.5.

2,3',4''-Trimethyl-4-dimethylamino-p-disazobenzene. Sev-

(10) All melting points are uncorrected. Analyses are by the Peninsular ChemResearch, Inc., Gainesville, Fla.

(11) J. Hewitt and F. Thole, *J. Chem. Soc.*, **95**, 1393 (1909).

eral crystallizations of the crude product, prepared by the standard procedure, from Methyl Cellosolve gave an approximately 50–60% yield of gleaming red plates, m.p. 177–179°.

Anal. Calcd. for C₂₂H₂₆N₂: N, 18.9. Found: N, 18.6.

Preparation of the remainder of the dyes. 4'-Phenyl-4-dimethylaminoazobenzene,¹² m.p. 219–220° (1. xylene, 2. kerosene, 3. Methyl Cellosolve); 2-(4'-dimethylaminophenylazo)fluorene,¹³ m.p. 227° (1, 2. Methyl Cellosolve, 3. ace-

tone); 1-(4'-dimethylaminobenzeneazo)naphthalene,¹⁴ m.p. 134–135° (1. heptane, 2,3. Methyl Cellosolve); 2-(4'-dimethylaminobenzeneazo)naphthalene,¹⁵ m.p. 174° (1,2. heptane); and 2-(4'-dimethylaminophenylazo)-7-nitrofluorene, m.p. 270–271° (1,2. nitrobenzene) were prepared by the procedure used for the preparation of 4-dimethylaminop-diazobenzene.

Ultraviolet-visible absorption spectra. The absorption spectra were determined with a Beckman Model DU Quartz spectrophotometer in the range of 325–800 m μ .

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(12) W. Brode, J. Gould, and G. Wyman, *J. Am. Chem. Soc.*, **74**, 4641 (1952).

(13) A. Korczynski, G. Karlowska, and L. Kierzik, *Bull. soc. chim. France*, [4] **41**, 65 (1927).

(14) C. Bischoff, *Ber.*, **23**, 1908 (1890).

(15) H. Goldschmidt and B. Bardach, *Ber.*, **25**, 1347 (1892).

[CONTRIBUTION NO. 813 FROM THE CHEMISTRY LABORATORY OF INDIANA UNIVERSITY]

Reduction of Schiff Bases. II. Benzhydrylamines and Structurally Related Compounds^{1a,b}

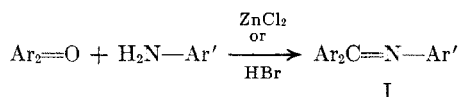
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A new method has been developed for the preparation of secondary amines of the *N*-aryl substituted benzhydryl type and structurally related compounds by reduction of the corresponding Schiff bases with lithium aluminum hydride. In connection with this study, a series of Schiff bases has been prepared by a modification of procedures previously described. In preliminary studies, the optimum ratio of the lithium aluminum hydride to the Schiff bases has been found to be one hundred percent excess above the theoretical amount. The chlorine atoms present in the *N*-aryl group of the Schiff bases were not removed by the hydride. Acetyl and phenylurea derivatives and hydrochloride salts of the secondary amines were prepared. The *N*-aryl substituted anthrylideneimine failed to give the corresponding anthrylamines by this method. An explanation has been offered.

The present investigation was concerned with a new method for the preparation of secondary amines of the benzhydryl type, having the general formula Ar₂CH-NHAr' (II). The Ar₂ represents aryl groups which may be the same or different, or the aryl groups in fluorene and xanthene. Ar' represents an aryl group.

Schiff bases, in general, form with little difficulty. However, those that were needed for the present work had to be made by an extension of the procedure of Reddelien^{2,3} in which a catalyst such as fused zinc chloride or 48% hydrobromic acid was used.



The two catalysts worked equally well but the Schiff bases prepared through the use of hydrobromic acid were easier to purify. In the experiments where 2,4-dichloroaniline was used the yield of Schiff base was lower than in other cases. 2,4,6-Trichloroaniline failed to react with the correspond-

ing ketones probably due to excessive steric hindrance and the decreased basicity of the amine. The Schiff bases that were prepared are listed in Table I.

A survey of the literature showed that only a limited number of secondary amines of the aforementioned type (II) have been synthesized. In most instances the methods of preparation were rather inconvenient and gave poor yields or the author failed to report yields. At the time this work was started, no information had been published on the catalytic hydrogenation of these compounds. However, during the course of the investigation it was reported⁴ that *N*-phenylbenzhydrylideneimine could be reduced catalytically but since no other compounds of this type were reduced it is impossible to draw any conclusions as to how general the procedure may be. Since none of the literature references gave evidence of a general preparative method for complex amines of the type under investigation, it was decided to try lithium aluminum hydride as the reducing agent which has been shown previously to reduce simpler Schiff bases.⁵

(4) I. H. Kaye, I. C. Kogon and C. L. Parris, *J. Am. Chem. Soc.*, **74**, 403 (1952).

(1a) Taken in part from the Ph.D. thesis of Kwang M. Tai, Indiana University, 1953. (b) J. H. Billman and A. C. Diesing, *J. Org. Chem.*, **22**, 1068 (1957).

(2) G. Reddelien, *Ber.*, **43**, 2476 (1910).

(3) G. Reddelien, *Ber.*, **46**, 2718 (1913).

(5) R. F. Nystrom and W. G. Brown, *J. Am. Chem. Soc.*, **70**, 3738 (1948). E. D. Bergmann, D. Lavie, and S. Pinchas, *J. Am. Chem. Soc.*, **73**, 5662 (1951). W. Stühmer and G. Messwarb, *Arch. Pharm.*, **286**, 19 (1953). R. N. Castle, D. L. Aldous, and M. Hall, *J. Am. Pharm. Assoc.*, **42**, 435