The Reaction of 12H-Benzo[*a*]phenothiazine and 12H-Benzo[*b*]phenoxazine with Certain Heterocyclic Azides

J. A. VanAllan, G. A. Reynolds, and D. P. Maier

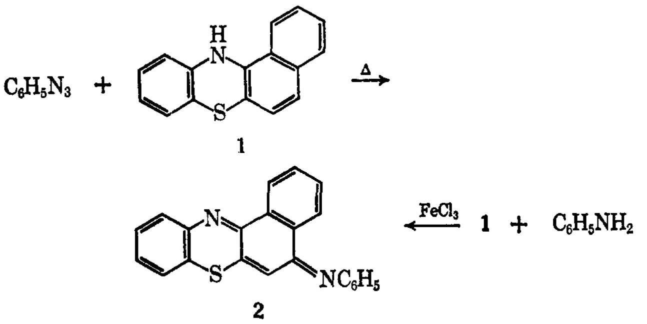
Research Laboratories, Eastman Kodak Company, Rochester, New York 14650

Received October 1, 1968

12H-Benzo[*a*]phenothiazine (1) reacts with certain heterocyclic azides under the influence of heat or light to give azomethine dyes in which the coupling occurs at the 5 position of 1. 12H-Benzo[*b*]phenoxazine under the same conditions yields a dimer of the azacarbon, and in the case of one class of heterocyclic azides, azomethine dyes derived from the dimer are obtained.

The formation of nitrene intermediates by the thermal or photochemical elimination of nitrogen from aryl azides is well known.[1] Aryl nitrenes undergo a variety of reactions including insertion into a C–H bond.[2] The present paper describes an intermolecular insertion reaction of heterocyclic nitrenes into benzo[*a*]-phenothiazine to give azomethine dyes, and the dimerization of benzo[*b*]phenoxazine by these nitrenes.

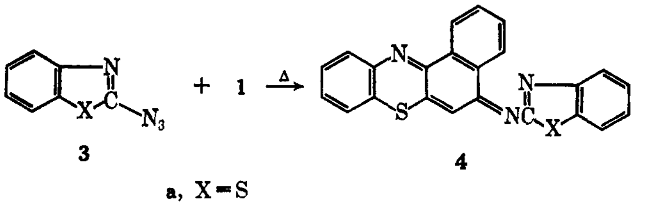
Phenyl azide was thermally decomposed in the presence of 12H-benzo[*a*]phenothiazine (1) in 1,2,4-trichlorobenzene to give dye 2, which has been prepared previously by the oxidative coupling of aniline with 1.[3]



This reaction has been extended to a wide variety of heteroxyclic azides with phenothiazine, phenazine, and phenoxazine derivative, but only a few representative examples will be included in this paper.

The heterocyclic azides **3a–3d**[4] were thermally decomposed in 1,2,4-trichlorobenzene in the presence of **1** to give dyes **4a–4d** (Scheme I). We were unable to obtain satisfactory elemental analyses for **4b** prepared by thermal decomposition, so the dye **4d** was saponified with methanolic potassium hydroxide to give a sample of **4b**, for which we did obtain a correct analysis.

Scheme I



a, X = S
b, X = NH
c, X = O
d, X = $NCONHCH_2CO_2C_4H_9$

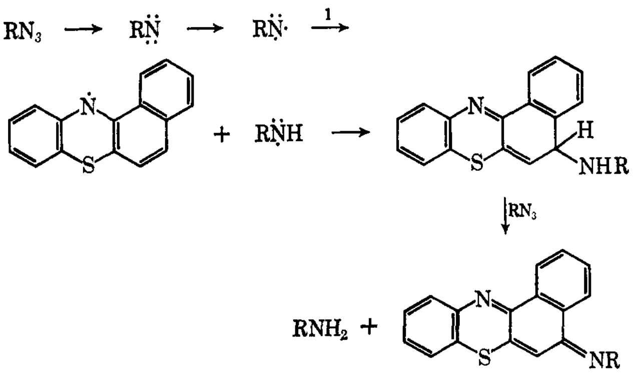
The thermolysis procedure, in the case of **3d**, gave a mixture of **4b** and **4d**. Dye **4d** was prepared by the reaction of **3d** with **1** at room temperature with cupric acetate in acetone or tetrahydrofuran. Copper salts are effective catalysts for dye formation only with N-carbonyl-substituted azides, such as **3d**.

Dyes **4a–4d** are the same as those produced by the photolysis of the corresponding azide and **1**,[5] as shown by comparison of their electronic spectra.

The reaction of a nitrene with **1** to give dyes **4a–4d** requires that an oxidation take place. For the investigation of this facet of the reaction, equal molar quantities of **3a** and **1** were heated in trichlorobenzene in a nitrogen atmosphere. Dye **4a** was isolated in 47% yield. A similar run was made bubbling air through the solution and **4a** was obtained in the same yield. The reaction was then carried out with 2 equiv of azide per mol of **1**, resulting in a quantitative yield of **4a**.

A plausible reaction sequence which leads to dye formation is shown in Scheme II. This mechanism is similar to that proposed for the formation of N-alkylamines from phenyl azide and alkanes.[2]

Scheme II



The dye **4c**, on mass spectrometric analysis, gives a molecular ion at *m/e* 379 for the proposed structure and a peak at 381 corresponding to a dihydro derivative of **4c**. The relative intensity of the peak at *m/e* 381 was approximately half that observed at *m/e* 379. This ratio is subject to a number of variables, in addition to differences in the actual amount of each component which may be present. The variables include different yields of the molecular ion under electron impact for

---

[1] L. Horner and A. Christmann, *Angew. Chem. Intern. Ed. Engl.*, **2**, 599 (1963).

[2] J. H. Hall, J. W. Hill, and J. M. Fargher, *J. Amer. Chem. Soc.*, **90**, 5313 (1968).

[3] F. Kehrmann, *Ann.*, **322**, 45 (1902).

[4] It has been shown [G. A. Reynolds, J. A. VanAllan, and J. F. Tinker, *J. Org. Chem.*, **24**, 1205 (1959)] that **3b** is a tetrazole. We have used the azide structure in the present paper for convenience and because it is probably the representative structure in heated solutions.

[5] J. J. Sagura and J. A. VanAllan, U. S. Patent 3,282, 693 (1966).

different structures, and differences in volatility of two components at a given temperature. The mass spectrum of **4d** does not show the intact molecule (molecular weight 535) but does show two peaks at 378 and 380. These may be rationalized on the basis of a thermal decomposition of the parent compound to compounds **4b** and its dihydro derivative, with the loss of $CONHCH_2COOC_4H_9$. This type of thermal reaction also occurs with **3d**, which decomposes to **3b** (*m/e* 159), 2-aminobenzimidazole (*m/e* 133), and $(C_4H_9O_2CCH_2NH)_2CO$ (*m/e* 288). In the case of **4d**, the ratio observed for mass spectral peaks at *m/e* 378 and *m/e* 380 varied from 1:2 to 2:1 from one analysis to another. Since the samples were examined in the direct inlet probe with the temperature programmed from 200 to 230°, this variation might be connected with the actual temperature at the time the paricular peaks were recorded. Since it is possible that the dihydro derivatives may be formed in the heated inlet of the mass spectrometer, compound **2**, which is of known structure, was examined under the same conditions as **4b**, **4c** and **4d** (*i.e.*, in a direct inlet system but at temperatures of 140–160° rather than from 200 to 230°) and produced only a very small amount (<5%) of the dihydro compound. The spectra on this known showed that the intensity of the *m/e* 340 peak, relative to the molecular ion at *m/e* 338, was greatest at 140° (where it was about 20%) and that it decreased to about 5% at 160°, where the volatility of the *m/e* 338 material was about 80 times as great. From this evidence, we believe that a dihydro form of **4a–4d** may be present in the original samples and that the dihydro form and the dye may occur as a molecular complex, possibly of a quinhydrone type.[6]

The reaction of heterocyclic azides has been extended to 12H-benzo[*b*]phenoxazine (**5**), yielding products that were more complicated than those from the corresponding reactions with **1**. The thermal decomposition of 1 equiv of **3a–3d** in the presence of 1 eqiv of **5** gave a dimer of **5** (parent peak *m/e* 464) to which we have assigned the structure **6**. It was found that **5** dimerizes with a variety of oxidizing agents, such as cupric acetate, hydrogen peroxide, benzoquinone, cobaltic acetate and potassium permanganate. A convenient method for the preparation of **6** in 75–80% yield consists in aerating a solution of **5** in pyridine in the presence of a catalytic amount of cupric acetate at room temperature. In a similar fashion, 2-phenyl-12H-benzo[*b*]phenoxazine (**7**), 3-pentadecyl-12H-benzo[*b*]phenoxazine (**8**), and 12H-benzo[*b*]phenothiazine (**9**) give dimers **10, 11,** and **12**, respectively. Phenoxazine, 12H-benzo[*a*]phenothiazine, 7H-benzo[*c*]phenoxazine, and phenothiazine give oxidation products but no dimer by this procedure, and 12-methylbenzo-[*b*]phenoxazine was recovered unchanged. From these data it appears that the essential requirements for dimer formation under these conditions are the presence of at least four linear fused rings in an azacarbon containing an NH group.

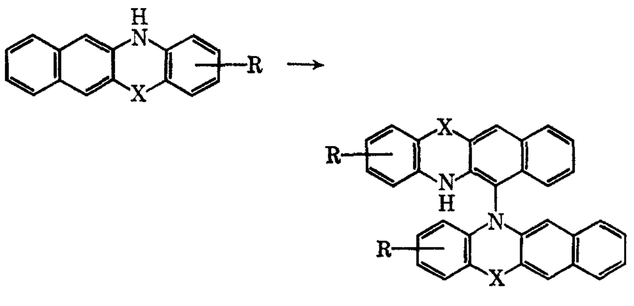
It seems reasonable to assume that the dimers are not bonded through a 2 or 3 position, since **7** and **8** give dimers. We have shown previously[7] that the 6 and 11 positions of **5** have enhanced reactivity in a variety of reactions, and we have assigned the 11 position as the point of fusion of one of the benzophenoxazine moieties of the dimer. There is precedent for the choice of this position since Musso[8] has shown that phenoxazine gives dimers and polymers in which some of the coupling occurs in a position adjacent to a heteronitrogen atom.

The infrared spectra of the dimers show a well-defined absorption at 3380 cm^{-1} for the NH group. The intensity of this NH absorption for the dimers is approximately one-half the intensity of the corresponding absorption for the monomers, which is evidence that one of the fusion points in the dimers is a nitrogen atom. We were unable to prepare an acetyl derivative of **6**, but this is probably the result of steric hindrance. The nmr spectrum of **6** could not be determined because of solubility difficulties.

The electronic spectra of **5** and its dimer **6** are almost identical with respect to the position of peak absorptions, and the extinction coefficients are higher by a factor of 2 for the dimers. This is consistent with the postulate that the two monomeric units are not in the same plane, and the π systems do not interact.

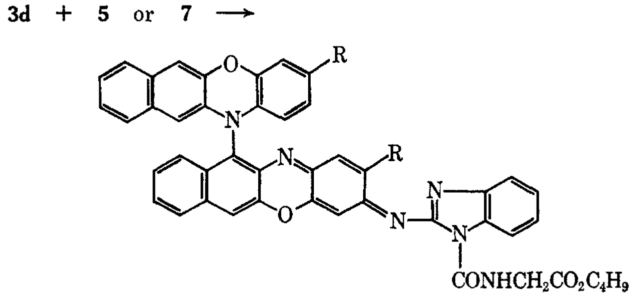
More rigorous conditions of oxidation of **5**, for instance, heating **5** in pyridine at 95–100° for 16 hr in the presence of cupric acetate, give a trimer of **5** (parent peak *m/e* 923) and other higher "mers" which are not volatile in the mass spectrometer.

The reaction of excess **3d** with **5** or **7** and cupric acetate in acetone or tetrahydrofuran gives the dyes **13** and **14**. The dimer **6** also reacts with **3d** under similar conditions (pyridine was used as solvent because of the limited solubility of **6**) to give **13**. Other azides of the same type as **3d** have also given dyes derived from the dimer. It appears that for the dye formation, the



5, X = O; R = H
7, X = O; R = 2-phenyl
8, X = O; R = 3-pentadecyl
9, X = S; R = H

6, X = O; R = H
10, X = O; R = 2-phenyl
11, X = O; R = 3-pentadecyl
12, X = S; R = H



13, R = H
14, R = phenyl

---

[6] Heterocyclic compounds such as phenazines are known to form quinhydrones. See G. Swan and D. Felton, "The Chemistry of Heterocyclic Compounds," Vol. 11, Interscience Publishers, New York, N. Y., 1957, p 48.

[7] J. A. VanAllan, G. A. Reynolds, and R. E. Adel, *J. Org. Chem.*, **27**, 1659, 2873 (1962); **28**, 520 (1963).

[8] H. Musso, *Chem. Ber.*, **92**, 2862, 2873 (1959).

TABLE I
PHYSICAL CONSTANTS OF COMPOUNDS

Compd no.	Mp, °C	Empirical formula	Calcd, %			Found, %			Method of prepn	Yield, %	Solvent of recrystn	Absorption spectra λ_{max} mμ ($\times 10^{-3}$)		Solvent
			C	H	N	C	H	N						
2	178–179	$C_{22}H_{14}N_2S$	78.3	3.9	8.3	78.2	4.2	8.1	A	45	Chlorobenzene	230 (27.6) 268 (23.6) 318 (19.7)	360 (11.3) 470 (11.3)	Acetonitrile
4a	230–231	$C_{23}H_{13}N_3S_2$	69.9	3.3	10.6	70.0	3.6	10.3	A	96	*o*-Dichlorobenzene	218 (23.7) 263 (11.9) 340 (9.2)	370 (8.5) 519 (9.4)	Dimethylformamide
4b	330–332	$C_{23}H_{14}N_4S$	73.0	3.7	14.8	72.9	3.4	14.7		62	Pyridine	283 (20.4) 348 (15.0)	374 (16.7) 535 (19.5)	Dimethylformamide
4c	229–230	$C_{23}H_{13}N_3OS$	72.8	3.5	11.1	73.2	3.2	11.2	A	91	*o*-Dichlorobenzene	280 (10.5) 365 (6.0)	560 (10.0)	Dimethylformamide
4d	208–209	$C_{30}H_{25}N_5O_3S$	67.3	4.7	13.1	67.3	4.8	12.7	B	66	Tetrahydrofuran + methyl alcohol	240 (28.2) 277 (18.8) 355 (14.0)	388 (14.5) 560 (18.7)	Chloroform
6	356–357	$C_{32}H_{20}N_2O_2$	82.7	4.3	6.0	82.4	4.5	5.8	C	78	Dimethylformamide	236 (79.5) 260 (55.4)	310 (19.8) 368 (19.4)	Acetonitrile
10	327–329	$C_{44}H_{28}N_2O_2$	85.7	4.6	4.5	85.3	4.7	4.5	C	68	Dimethylformamide			
11	155–156	$C_{62}H_{80}N_2O_2$	84.1	9.1	3.2	84.1	9.4	3.3	C	48	Tetrahydrofuran + methyl alcohol			
12	140–142	$C_{32}H_{20}N_2S_2$ $+C_4H_8O$	76.0	5.0	4.9	76.1	4.9	4.8	C	52	Tetrahydrofuran			
13	226–228	$C_{46}H_{34}N_6O_5$	73.6	4.6	11.2	73.6	4.8	10.9	D	93	Tetrahydrofuran	460 (20.4) 548 (28.0)	597 (27.6) 650 (16.0)	Chloroform
14	219–220	$C_{58}H_{42}N_6O_5$	77.1	4.7	9.3	76.8	4.8	9.3	D	83	Tetrahydrofuran	279 (88.5) 310 (25.2) 478 (22.8)	540 (32.2) 580 (26.4) 630 (15.0)	Chloroform

initial step is the dimerization of **5** followed by the reaction of the dimer with azide. The mechanism outlined in Scheme II is also applicable in this case if it is assumed that the benzophenoxazine radical dimerizes more rapidly than it couples with RNH. The 100-mμ shift in the absorption spectrum of **13**, compared with that of the dyes derived from **1**, suggests that the benzimidazole substituent enters a position which permits increased conjugation, and this condition is satisfied by placing this substituent in a position *para* to the heteronitrogen atom. Compound **7** reacts with **3d** to give dye **14**, whereas **8**, on reaction with **3d**, gives a dimer of **8**, and not the expected dye.

Experimental Section

The methods of preparation for most of the compounds described in this paper are recorded as general procedures and the physical constants and analytical data are collected in Table I.

12H-Benzo[*a*]phenothiazine (**1**) was prepared as previously described.[7]

Azides **3a**–**3d** were prepared as previously described.[9]

12H-Benzo[*b*]phenoxazine (**5**).—A mixture of 165 g of 2,3-dihydroxynaphthalene and 113 g of *o*-aminophenol was heated overnight at 200°. The temperature was reduced to 160–170° and 430 ml of acetic anhydride was added. Heating was then continued until a clear solution formed (about 2 hr). The reaction mixture was cooled to 15° and the precipitate was collected and washed first with acetic acid and then with alcohol. The yield of the N-acetyl derivative of **5** was 163 g (59%), mp 140–144°. This material was dissolved in 600 ml of hot ethoxyethanol, followed by slow addition of 140 ml of concentrated hydrochloric acid. A vigorous reaction ensued, and the reaction mixture solidified. The solid was collected and washed with methyl alcohol to give 118 g (51%) of white **5**: mp 298°; absorption spectrum in acetonitrile, λ_{max} mμ ($\epsilon \times 10^{-3}$) 237 (33.2), 262 (30.8), 315 (9.9), 360 (8.5).

Phenoxazines **7** (mp 284–285°) and **8** (mp 194–195°) were prepared in a similar manner from the appropriate *o*-aminophenol derivative.

General Procedure A.—A mixture of 0.02 mol of the azide, 0.01 mol of **1** and 10 ml of 1,2,4-trichlorobenzene was heated under reflux for 10 min, cooled, and the solid was collected and recrystallized.

General Procedure B.—A suspension of 0.01 mol of **1**, 0.011 mol of the azide, 0.5 g of cupric acetate hydrate, and 50 ml of acetone was stirred for 2 hr at room temperature and then heated under reflux for 5 min. The solid was collected and recrystallized.

General Procedure C.—A mixture of 0.01 mol of **5**, **7**, **8** or **9** and 0.01 mol of azides **3a**–**3d** in 100 ml of 2-ethoxyethanol or toluene was refluxed for 1 hr, cooled, and the gray solid was collected.

General Procedure D.—The preparations were carried out as in procedure B, with 3 equiv of **3d** and 1 equiv of **5**.

5-(2-Benzimidazolylimino)-5H-benzo[*a*]phenothiazine (**4b**).—A suspension of 2 g of **4d** in 12 ml of pyridine was heated on the steam bath, 12 ml of 10% methanolic potassium hydroxide was added, and heating was continued for 2 hr. The reaction mixture was filtered, the filtrate diluted with water, and the precipitate collected and washed with alcohol.

11-(Benzo[*b*]phenoxazinyl-12)-12H-benzo[*b*]phenoxazine (**6**).—In addition to procedure C, the following methods were used to prepare **6**.

(1) A fast stream of air was passed through a solution of 22 g of **5** and 0.5 g of cupric acetate monohydrate in 450 ml of pyridine for 7 hr. The dimer began to precipitate during the first half-hour. The solid was collected, washed with methyl alcohol, and recrystallized, yield 17 g.

(2) A suspension of 3 g of **5** and 3 g of potassium permanganate in 100 ml of acetone was stirred for 3 hr, decolorized with aqueous sodium bisulfite, and the precipitated solid was collected and recrystallized, yield 2.1 g.

(3) A solution of 75 g of **5** in 1.5 l. of 1,2,3-trichloropropane was heated on a steam bath and 22.5 ml of 30% hydrogen peroxide was added with stirring. The mixture was cooled and the solid was collected, yield 65 g.

(4) A solution of 2.3 g of **5** and 1 g of benzoquinone in 25 ml of chlorobenzene was refluxed 1 hr and cooled, yield 1.6 g of solid.

(5) A solution of 3 g of **5** and 0.5 g of cobaltic acetate in 50 ml of 1,2,3-trichloropropane was heated to reflux while air was bubbled in. The solution was cooled and 2.1 g of **6** was collected.

Dimers **10**–**12** were also prepared by these procedures.

Trimer from Benzo[*b*]phenoxazine.—A solution of 10 g of **5** and 0.25 g of cupric acetate in 400 ml of pyridine was aerated for 16 hr, the temperature being kept at 90–95°. The solution was diluted with water, chilled, and the solid was collected. The solid was boiled with 150 ml of toluene and the insoluble material collected, yield 5 g, mp >400°.

Registry No.—**1**, 225-83-2; **2**, 19359-56-9; **4a**, 19359-57-0; **4b**, 19359-58-1; **4c**, 19359-06-9; **4d**, 19359-07-0; **5**, 258-04-8; **6**, 19359-09-2; **10**, 19359-10-5; **11**, 19359-11-6; **12**, 19359-12-7; **13**, 19359-13-8; **14**, 19588-11-5.

---

[9] J. A. VanAllan and G. A. Reynolds, *J. Heterocycl. Chem.*, **5**, 471 (1968).