152–153° (760 mm.), yield 67.8%, n^{20}_D 1.4670. *Anal.* Calcd. for $C_6H_{14}N_2$: N, 24.52. Found: N, 24.75.

The dimaleate salt of the above base was prepared in ethanol in 98% yield, m.p. 140°. A mixed melting point with the dimaleate salt of VI showed no depression. *Anal.* Calcd. for $C_{14}H_{22}N_2O_8$: N, 8.08; neut. equiv., 86.55. Found: N, 7.95; neut. equiv., 86.41.

The dipicrate salt of the above base was prepared in ethanol in 96% yield, m.p. 192.5°. A mixed melting point with the dipicrate salt of VI showed no depression. *Anal.* Calcd. for $C_{18}H_{20}N_8O_{14}$: N, 19.56. Found: N, 19.46.

N-Methyl-3-aminopiperidine.—An alcoholic solution containing 96.0 g. (0.50 mole) of 3-aminopyridine methobromide was reduced with Raney nickel catalyst (five teaspoonfuls) at 2,000 p.s.i. of hydrogen and 175° in a steel bomb. The catalyst was removed by filtration and the filtrate concentrated to one-third its original volume. The residue was treated with the calculated amount of sodium methoxide and the sodium bromide removed by filtration. The filtrate was subjected to a fractional distillation and the product collected at 163–165°, yield 27.7 g. (48.6%), n^{20}_D 1.4699. *Anal.* Calcd. for $C_6H_{14}N_2$: N, 24.56. Found: N, 24.13. The dimaleate salt melted at 154–155°, mixed m.p. with IV dimaleate gave no depression.

N-(β-Dimethylaminoethyl)-N'-(1-Methyl-3-piperidyl)-hydrazine.—To 23.5 g. (0.23 mole) of β-dimethylaminoethylhydrazine in 75 cc. of methanol was added 25.7 g. (0.23 mole) of freshly distilled N-methyl-3-piperidone in 25 cc. of methanol. The solution was refluxed for 10 minutes and the methanol removed by distillation. The residue was dissolved in 25 cc. of tetrahydrofuran and reduced with 8.62 g. (0.23 mole) of lithium aluminum hydride, dissolved in 150 cc. of tetrahydrofuran. The mixture was refluxed with stirring for 3 hours and the complex decomposed by the addition of 15% aqueous potassium hydroxide to the cold reaction mixture. The inorganic salts were removed by filtration and the filtrate dried with potassium carbonate. The product was collected by distillation *in vacuo*, b.p. 81–84° (0.03 mm.), yield 32 g. (70%).

MILWAUKEE, WISC.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF CINCINNATI]

The Mesomorphic State: The Mesomorphic 4,4'-Di(n)alkoxybenzalazines

BY WILFRID G. SHAW[1] AND GLENN H. BROWN

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A homologous series of azines of *p-n*-alkoxybenzaldehydes and related benzalazine compounds were synthesized and their mesomorphism analyzed. Mesomorphism of these compounds in terms of even and odd series, pairing of transition points, and bonding forces is discussed in relationship to transition temperature *versus* alkoxy chain length. X-Ray diffraction patterns were obtained for the nematic and liquid structures for anisaldazine and several of its dialkoxy homologs. The small differences found between the mesomorphic and liquid diffraction patterns are discussed. Several additional substituted alkoxybenzalazines were synthesized only one of which exhibited mesomorphism.

It is well known that a large number of organic compounds exhibit the mesomorphic state. An extensive review of the structure and the properties of the mesomorphic state may be found in a recent article.[2] It can be generally stated that compounds exhibiting mesomorphism have molecules that are elongated, and in some cases flattened as well, and which possess one or more polar groups. This shape of the molecules favors a parallel alignment to one another, like a bundle of pencils. In the crystalline state of a mesomorphic substance, the molecules lie parallel to one another and are held together by attraction through the polar groups as well as by the unspecific van der Waals attraction. When the solid is heated, the weaker bonds break first, leaving the solid with some degree of relative movement before sufficient thermal energy has been acquired to overcome in any great degree the tendency for them to set themselves parallel to one another. Thus, the system becomes fluid but remains birefringent because of the preferred orientation of some of the molecules.

On the basis of the swarm hypothesis, first proposed by Bose,[3,4] the molecules in the nematic structure are not oriented in the same direction throughout the whole medium but are grouped in aggregates or swarms. The molecules in the swarm lie parallel or approximately so, but in a direction that is random to the molecules of other swarms in the medium. From this point of view the nematic structure resembles a mass of small crystals rather than a single crystal, but with this difference, owing to the mobility of the molecules, the swarms do not remain static but are continually exchanging molecules with one another and with the optically isotropic liquid; the arrangement of the swarms is not a rigid one and is subject to mechanical deformation.

Almost all of the compounds that form the mesomorphic state can be classified as forming the smectic or nematic structure. The smectic structure is stratified, the molecules being arranged in layers with their long axes approximately normal to the planes of the layers. In the nematic structure the only restriction on the arrangement of the molecules is that the molecules preserve a parallel or nearly parallel orientation.

The lower homologs of the 4,4'-di(*n*)alkoxybenzalazines show only the nematic structure while the higher homologs exhibit both the smectic and the nematic structures. These structural modifications are exhibited by homologous series of other compounds. For example, investigations of the homologous series of *p*-substituted mono- or di- alkyl-(and alkoxy) compounds, *e.g.*, the azoxy-, azo- and azomethine-phenol ethers,[5,6] have shown that the lowest members of the series have only a nematic structure, and as the chain length increases the smectic structure appears, while at still

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[1] This paper was abstracted from a portion of the Ph.D. thesis of Wilfrid G. Shaw, University of Cincinnati, 1957; Dreyer Foundation Fellow 1955–1956; present address: Standard Oil Co. (Ohio) Research Laboratory, Warrensville Heights, Ohio.

[2] G. H. Brown and W. G. Shaw, *Chem. Revs.*, **57**, 1049 (1957).

[3] E. Bose, *Physik. Z.*, **10**, 32 (1909).

[4] E. Bose, *ibid.*, **10**, 230 (1909).

[5] C. Weygand and R. Gabler, *Ber.*, **71B**, 2399 (1938).

[6] C. Weygand and R. Gabler, *J. prakt. Chem.*, **155**, 332 (1940).

greater chain lengths only the smectic structure exists.

The nomenclature for transition temperatures used for the equilibrium between structures is designated as follows: the crystalline to smectic structure transition is designated the C–S point, crystalline to nematic the C–N point, smectic to nematic the S–N point, and nematic to liquid the N–L point. A more complete nomenclature system may be found in the review on the mesomorphic state by Brown and Shaw.[2]

Discussion of Transition Temperatures

The transition temperatures for the 4,4'-di(*n*)-alkoxybenzalazines are given in Table I. It can be seen that the nematic structure is shown by all the dialkoxybenzalazines while the smectic structure doesn't occur until the seventh member, 4,4'-diheptoxybenzalazine. If a plot is made of the transition temperatures of crystalline to mesomorphic structure *versus* the number of carbon atoms in the alkoxy chain, the curve will show an abrupt break between the sixth and seventh members as the transition change from crystalline–nematic is replaced by the crystalline–smectic change. Such a plot is found in Fig. 1 along with other transition temperatures *versus* carbon atoms in the alkoxy chain.

TABLE I

TRANSITION TEMPERATURES FOR THE 4,4'-DI(*n*)ALKOXYBENZALAZINES

Alkoxy group	Crystal-smectic point	Crystal-nematic point	Smectic-nematic point	Nematic-liquid point	Phase length of Smectic structure	Nematic structure
Methoxy	..	169°	..	182°	..	13°
Ethoxy	..	173°	..	197°	..	24°
Propoxy	..	148°	..	154°	..	6°
Butoxy	..	148°	..	171°	..	23°
Pentoxy	..	127°	..	152°	..	25°
Hexoxy	..	127°	..	153°	..	25°
Heptoxy	82°	..	132°	144°	51°	12°
Octoxy	97°	..	132°	144°	35°	12°
Nonoxy	81°	..	126°	139°	45°	13°
Decoxy	83°	..	126°	136°	43°	10°

It is apparent, if one considers the first four points of the N–L plot of this series, that the stability relationship can be considered to be governed by the rule of even and odd carbon atoms in a homologous series, *e.g.*, C_2 and C_4 belong close together morphologically as do the forms C_1 and C_3 of the series. There appear to be very few conclusions drawn to the contrary for homologous series that possess mesomorphism. A curve joining the N–L points of the compounds having an even number of carbons in the alkoxy chain, and a second joining those containing an odd number in the alkoxy group, lie approximately on smooth curves as has been found for other systems.[7] The C–N points for these compounds could also be considered to lie on smooth curves.

In the case of the three transition point groups, C–N, S–N and C–S of the dialkoxybenzalazines, however, an apparent "pairing" of points between chains of an odd number of carbon atoms and the next even member of the series can be inferred from the data. The six points on the C–N point curve illustrate this relationship quite well. When the crystalline form of a mesomorphic compound is converted to the nematic structure, the thermal energy has overcome the bonding forces in two directions. Data on the C–N and S–N points for the dialkoxybenzalazines, given in Table I and Fig. 1, indicate that immediate neighbors (*e.g.*, 1, 2 and 3,4, etc.) rather than the successive even and successive odd members show far greater similarities with respect to these bonding forces. For these compounds it would appear that there is not a great difference in the energies of associations in two of the directions of bonding in the crystal between immediate members of the odd–even pair.

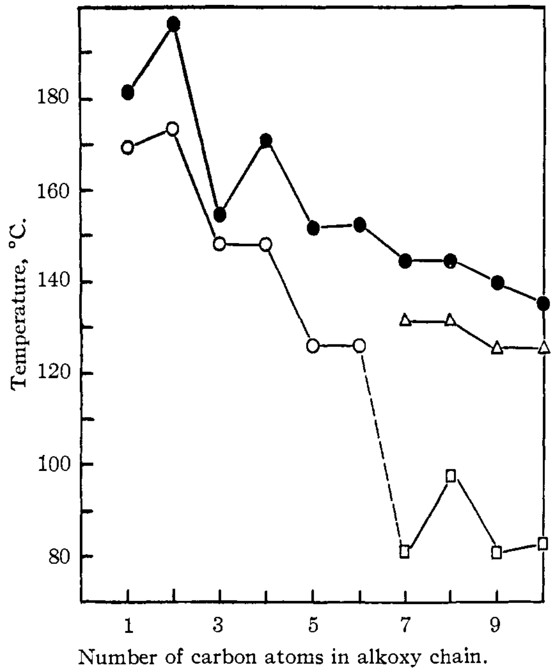

Fig. 1.—Structure transitions for the 4,4'-di(*n*)alkoxybenzalazines; solid points, N–L; open points. C–N; triangles, S–N; squares, C–S.

Malkin[8] proposed that the alternation in physical constants with odd and even numbered carbon atoms in the chain occurs only in reference to the solid state. In work on the esters of fatty acids, Malkin interpreted the difference in bonding energy as due to tilted chains. The even numbered chains are separated by similar closely packed planes whereas the odd are separated by alternate loosely and closely packed planes. The crystalline structure of the odd members are therefore less stable and the even numbered chains have a higher melting point than the preceding and succeeding odd members. With mesomorphic 4,4'-di(*n*)alkoxybenzalazines the transition points from solid to a given mesomorphic structure do not follow the alternation rule.

Most other mesomorphic systems with a different central dipole (group) but the same 4,4'-dialkoxy- or 4,4'-dialkyl- groups do not show this apparent pairing of transition points of immediate neighbors. However, the series reported here is

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(7) G. W. Gray and B. Jones, *J. Chem. Soc.*, 2556 (1954).

(8) T. Malkin, *Nature*, **127**, 126 (1931); *J. Chem. Soc.*, 2796 (1931).

not unique; the azomethine ether series[6] exhibits a somewhat analogous behavior. Although no conclusions of a general nature can be drawn from these limited data, it does point out the need for caution in discussing the alternation of physical constants from odd to even number of carbon atoms in a homologous series of mesomorphic substances.

It can be observed in Fig. 1 that the apparent slope of the line joining the S–N points of the homologs is negative, or perhaps zero, but certainly not a positive slope as seems characteristic for most other 4,4′-dialkoxy- or dialkyl-substituted homologous series. The positive slope also seems characteristic of monosubstituted series such as *p*-*n*-alkoxybenzoic acids[9] and compounds of the same general type. It has most logically been concluded[10] that neither the range of existence of a phase nor the C–N point, determines the degree of mesomorphism—but the N–L transition points; it is at the N–L point that the linear orientation of the mesophase is being destroyed. Also, in the case of the S–N points, it can be seen that the greatest smectic character for the dialkoxybenzalazines is to be found with the molecules that first exhibit the structure rather than the higher homologs; the zero or negative slope of the S–N line means that the highest S–N point (132°) should be associated with the first two members of the series to exhibit smectic structures, the 4,4′-diheptoxy- and dioctoxy-benzalazines. Of course, considering the mesomorphic character of the series regardless of mesomorphic structure type, the most mesomorphic member is 4,4′-diethoxybenzalazine which exhibits nematic character up to 197°, and the mesomorphism of the other members decreases as the chain lengths of the homologous series increases. Therefore, in the dialkoxybenzalazine series, both the smectic and the nematic character decreases as the length of the *n*-alkoxy group increases. Without additional data it cannot be said with certainty that the range of existence of both structures will also decrease together. More likely, as is found for other series after the appearance of the smectic structure, the range of the nematic phase decreases gradually, until finally, for some higher homolog in the series, only a smectic structure is observed.

It is interesting to note that the phenylhydrazones of the *p*-*n*-alkoxybenzaldehydes exhibit a very narrow nematic structure in the order of 1–2° or so. However, the mesomorphic character of these compounds is real for it was found to persist even after several recrystallizations. Apparently with only one end of the molecule substituted in the *p*-position the dipole character of the molecule is such that the intermolecular attraction of the molecules toward parallel alignment is greatly reduced resulting in a small thermal stability of the mesophase. With so small a mesomorphic tendency it is surprising that the mesomorphism persists as the paraffinic character of the *p*-substituent increases.

X-Ray Studies. Observations.—A comparison of the nematic structure and the liquid state of *p*-azoxyanisole by means of X-ray analysis has been made by several workers[11–13]; it was reported by the earlier workers that X-ray diffraction patterns for the two structures were similar. More recently definite small differences in X-ray patterns of the nematic and liquid structures of this compound have been reported.[14–17]

Examination of the X-ray patterns of the mesomorphic and liquid states of anisaldazine shows that the diffraction patterns of the nematic and liquid states are quite similar in regard to shape but that the diffraction intensity showing up at the principal maximum in a microphotometer trace of the diffraction pattern is a few per cent. greater for the nematic structure than for the liquid state. The nematic diffraction intensity shows a slight displacement relative to the liquid and its principal peak in the microphotometer trace is defined more clearly than in the liquid phase. The greater sharpness found for the principal peak of the nematic structure, as well as its steeper inner slope, indicate more regularity of structure in the mesomorphic state than in the liquid.

In addition to the comparison of diffraction patterns of anisaldazine in the mesomorphic and liquid states, the X-ray diffraction patterns of the same two states of its dialkoxybenzalazine homologs, 4,4′-diethoxy-, 4,4′-dipentoxy-, and 4,4′-dihexoxybenzalazine, were obtained and compared. These diffraction patterns gave results comparable to those for anisaldazine. If the X-ray diffraction patterns of the nematic structure are considered for the different members of the series, however, a small shift of the principal maximum (first peak in the microphotometer traces of the film) to a smaller diffraction angle, θ, occurs as the length of the *p*-substituents increase from anisaldazine to 4,4′-dihexoxybenzalazine. A definite difference is also obtained in the location of the minor peak in the vicinity of $(\sin \theta)/\lambda = 0.420$ (using MoK α radiation). There is a definite shift to a greater angle from that for anisaldazine, $2\theta = 34.5°$, to about $2\theta = 35.5°$ (both uncorrected for identical glass container) for the 4,4′-dihexoxybenzalazine.

As mentioned above, the X-ray diffraction patterns of the nematic and liquid structures for anisaldazine and the other three homologous compounds tested show small differences. These small differences may be ascribed to one or more of the following factors: (1) the swarms are small and consequently there are not enough intraswarm repeat distances that can show up and give a large difference in the patterns; (2) the interswarm spacings are highly irregular or are greater than 9 or 10 Å.; (3) the number of molecules in swarms in the mesomorphic state is small in comparison to the total number of molecules in the system; (4) a significant preferred relationship of molecules exists in the isotropic liquid. Further research in X-ray studies will provide additional information

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(9) G. W. Gray and B. Jones, *J. Chem. Soc.*, 4179 (1953).

(10) G. W. Gray and B. Jones, *ibid.*, 683 (1954).

(11) E. Hückel, *Physik. Z.*, **22**, 561 (1921).

(12) W. Kast, *Naturwissenschaften*, **21**, 737 (1933).

(13) J. R. Katz, *ibid.*, **16**, 758 (1928).

(14) P. W. Glamann, K. Herrmann and A. H. Krummacher, *Z. Krist.*, **74**, 73 (1930).

(15) G. W. Stewart, *Phys. Rev.*, **38**, 931 (1931).

(16) H. R. Letner and G. W. Stewart, *ibid.*, **47**, 332 (1935).

(17) G. W. Stewart, *J. Chem. Phys.*, **4**, 231 (1936).

on the structural differences between the nematic and liquid structures.

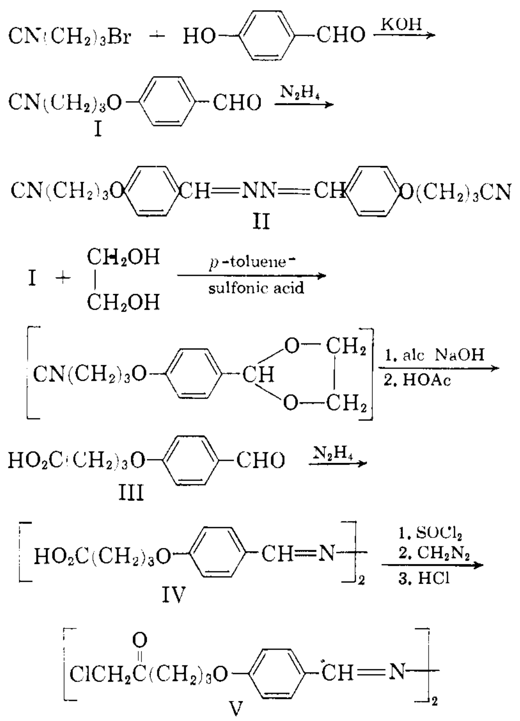
Camera Design.—The basic camera design used in these studies was similar to those described in the literature[18] which permit variable sample-to-film distances. However, instead of placing the sample holder over the end of the collimator, the sample holder containing the heating element and terminals for an electric field (if so desired) was attached to a brass collar insulated with asbestos. The sample holder can slide in the tube up to the collimator. This permits a high local heating of the sample to the desired temperature without heating any other parts of the camera. All electrical leads were introduced into the camera through Kovar seals.

The heating element was constructed by winding two helixes of number 26 Nichrome wire near the top and the bottom of a thin asbestos insulated brass bar. The heater was then surrounded by asbestos sheeting and the whole assembly covered with "Sauereisen" to incase the unit. A 2.3-mm. hole was drilled into the top of the brass support and extended three quarters of the length of the unit; the capillary sample tube is inserted in this hole and held in this manner. A 3.2-mm. hole extended through the center of the heating unit, perpendicular to the sample tube, and permitted passage of the X-ray beam through the sample tube near the center. The temperature was regulated with a Variac and a constant voltage regulator and measured by an iron–constantan thermocouple with its junction at a point close to the sample.

Each sample was placed in a Pyrex glass capillary tube while in the liquid state, allowed to solidify and both ends of the tube sealed while under partial vacuum. The uniform tubes had a 0.23 mm. inner radius and 0.024 mm. wall thickness. Exposures of 24 hours and 12 or 37 hours at 35 kv. and 15 ma. were made using MoK_α radiation filtered through zirconium foil. The samples were held approximately 10° above the C–N point and above the N–L point to get the mesomorphic and liquid patterns, namely, 175° and 190° for anisaldazine, 182° and 208° for 4,4'-diethoxybenzalazine, 137° and 162° for 4,4'-dipentoxybenzalazine, and 137° and 162° for 4,4'-dihexoxybenzalazine, respectively. The diffracted radiation was recorded photographically and microphotometered on a Leeds and Northrup recording microphotometer, and film densities used as a measure of relative intensity.

Halogen Derivatives.—Although hundreds of compounds are known to exhibit a mesomorphic structure, only a few compounds containing chlorine and bromine attached to a benzene ring exhibit a mesomorphic phase; even fewer containing an iodine atom show the property of mesomorphism (*e.g.*, see references 7, 19). The compound 4,4'-diiodobenzalazine had been found to decompose at 231°[20] while the corresponding dichloro- and dibromo-compounds give sharp melting points. Some halogen-containing compounds of the dialkoxybenzalazine series were synthesized in this study but none were found to exhibit mesomorphism. One such synthesis is described below.

It was thought that there would be a possibility of mesomorphism if the molecules had halogens situated in a *p*-substituent which contained a group capable of hydrogen bonding. When *p*-hydroxybenzaldehyde was allowed to react with γ-bromobutyronitrile in a basic solution, *p*-(γ-cyanopropoxy)-benzaldehyde (I) was obtained. Attempts at reaction of *p*-hydroxybenzaldehyde or 4,4'-dihydroxybenzalazine with *p*-bromo-α-iodoacetophenone to form a *p*-substituted ether were unsuccessful. Reaction of I with hydrazine gave 4,4'-bis(γ-cyanopropoxy)-benzalazine (II). Upon heating, the purified light yellow crystals softened to a smectic structure at 164°, to the nematic structure at 168° and to a liquid at 176°. The spherulite formation exhibited many brilliant colors in all drops (as observed under a polarizing microscope) at 174–176°. Other mesomorphic compounds containing nitrile groups previously reported seemed to have much wider mesomorphic ranges, but these contained nitrile groups attached directly to benzene rings. Obviously the mesomorphic character of the molecule is weakened by positioning the nitrile groups at the extremities of the molecule in the alkoxy chain rather than on the aromatic nucleus.



Protection of the aldehyde group of I was achieved by reaction with ethylene glycol in the presence of *p*-toluenesulfonic acid. The cyclic ethylene glycol acetal was treated with alcoholic sodium hydroxide to form *p*-(γ-carboxypropoxy)-benzaldehyde ethylene glycol acetal after neutralization with dilute hydrochloric acid. The material obtained was an acid, but could not be crystallized. Treatment with acetic acid gave a

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[18] H. L. Ritter and L. C. Erich, *Anal. Chem.*, **20**, 665 (1948).

[19] G. W. Gray and B. Jones, *Nature*, **170**, 451 (1952).

[20] C. Willgerodt and R. Rieke, *Ber.*, **38**, 1478 (1905).

non-crystalline material *p*-(γ-carboxypropoxy)-benzaldehyde (III) Treatment of III with hydrazine gave non mesomorphic 4,4′-bis-(γ-carboxypropoxy)-benzalazine (IV). Mesomorphic compounds containing only one carboxylic acid group have been reported, but based on observations of Bernal and Crowfoot[21] that only one strongly polar group can be present in a molecule in order to obtain mesomorphism, it was not surprising that IV exhibited no mesophase.

An Arndt–Eistert type reaction of IV with highly purified thionyl chloride, and then with diazomethane, gave a bis-diazomethyl ketone; treatment with hydrogen chloride gave a main product of 4,4′-bis-(δ-keto ε-chloropentoxy)-benzalazine which exhibited no mesomorphism. Apparently a combination of the steric hindrance of the keto and chloro groups at both ends of the molecule together with polar characteristics of these substituents prevented close molecular packing and thus the realization of the mesomorphic structure. It appears that one halogen atom in a long chain *para* group, especially with a hydrogen bonding group close by, would have greater chance to achieve the desired mesophase than a compound with halogens at the extreme ends of both *p*-substituents. However, such a compound was not prepared in this work.

Experimental[22]

Determination of Transition Temperatures.—The transitions were determined on a hot-stage fitted with a microscope and are uncorrected. A thin sample was placed between the glass slide and a cover slip and inserted in the slide slot. The temperature in the vicinity of each transition was raised at less than 1°/minute; the transitions were also determined by slowly lowering the temperature through the phase changes.

***p*-*n*-Alkoxybenzaldehydes.**—The experimental procedure described by Hildesheimer[23] was employed for the preparation of the *p*-*n*-alkoxybenzaldehydes.[6,23,24]

4,4′-Di(*n*)alkoxybenzalazines.—Anisaldazine and its 4,4′-di(*n*)alkoxybenzalazine homologs were prepared and purified by the procedure used by Curtius[25] for anisaldazine, modified only by (1) the necessity of continuous shaking of the reagents instead of occasional shaking used for anisaldazine and (2) recrystallization of 4,4′-dipropoxybenzalazine and the higher homologs from ethanol instead of benzene. Besides anisaldazine, 4,4′-diethoxybenzalazine was the only other dialkoxybenzalazine reported previously. Pertinent analytical data on this series are given in Table II. The transition point data may be found in Table I.

TABLE II

4,4′-DI(*n*)ALKOXYBENZALAZINES

Alkoxy group	Formula	Analyses, % Calcd. C	H	N	Found C	H	N
Propoxy	$C_{20}H_{24}N_2O_2$	74.04	7.46	8.64	74.00	7.52	8.48
Butoxy	$C_{22}H_{28}N_2O_2$	74.96	8.01	7.95	74.67	7.98	7.92
Pentoxy	$C_{24}H_{32}N_2O_2$	75.75	8.48	7.37	75.53	8.40	7.53
Hexoxy	$C_{26}H_{36}N_2O_2$	76.43	8.88	6.86	76.25	8.82	6.95
Heptoxy	$C_{28}H_{40}N_2O_2$	77.02	9.24	6.42	77.20	9.26	6.67
Octoxy	$C_{30}H_{44}N_2O_2$	77.54	9.54	6.03	77.26	9.50	5.88
Nonoxy	$C_{32}H_{48}N_2O_2$	77.98	9.82	5.69	77.90	9.76	5.52
Decoxy	$C_{34}H_{52}N_2O_2$	78.40	10.07	5.38	78.06	10.08	5.15

Phenylhydrazones of *p*-*n*-Alkoxybenzaldehydes.—Phenylhydrazones were prepared by the method of Shriner and Fuson.[26] Characteristics of some of the phenylhydrazones are given below. All exhibited birefringence in the nematic state. Besides possessed mesomorphism, *p*-nonoxy- and *p*-decoxybenzalphenylhydrazones exhibit phototropism. The phototropic property of these compounds is described elsewhere.[27]

***p*-Pentoxybenzalphenylhydrazone.**—Light yellow needles and plates were obtained after a second recrystallization from ethanol, C–N point 97–98°, N–L point 99–100°.

Anal. Calcd. for $C_{18}H_{22}N_2O$: C, 76.56; H. 7.85. Found: C, 76.67; H, 7.87.

***p*-Heptoxybenzalphenylhydrazone**: light yellow needles after one recrystallization, C–N point 122–123°, N–L point at 127–128°. No change in transition points was obtained after a second or third recrystallization. The product decomposed when dried under reduced pressure.

Anal. Calcd. for $C_{20}H_{26}N_2O$: C, 77.38; H, 8.44. Found: C, 76.18; H, 8.84.

***p*-Octoxybenzalphenylhydrazone**: light yellow needles after the first recrystallization, C–N point 129–130°, N–L point 131–132°.

Anal. Calcd. for $C_{21}H_{28}N_2O$: C, 77.74; H, 8.70. Found: C, 77.66; H, 8.43.

***p*-Nonoxybenzalphenylhydrazone**: white flakes after several recrystallizations, turning pink upon standing, C–N point 94–95°, N–L point 97–98°.

Anal. Calcd. for $C_{22}H_{30}N_2O$: C, 78.06; H, 8.93. Found: C. 77.86; H, 8.72.

***p*-Decoxybenzalphenylhydrazone**: white flakes turning a light pink upon standing, C–N point 91–92°, N–L point 93–94°.

Anal. Calcd. for $C_{23}H_{32}N_2O$: C, 78.36; H, 9.15. Found: C, 78.11; H, 9.02.

***p*-(γ-Cyanopropoxy)-benzaldehyde (I).**—A solution of 24.4 g. (0.2 mole) of *p*-hydroxybenzaldehyde in 100 ml. of methanol containing 11.2 g. (0.2 mole) of potassium hydroxide was added to 34.6 g. (0.24 mole) of γ-bromobutyronitrile in 30 ml. of methanol. The solution was refluxed for 20 hours, cooled, and 200 ml. of ether added. The ethereal solution was washed with two 50-ml. portions of water, twice with 50 ml. of dilute hydrochloric acid, twice with 50 ml. of 5% sodium hydrogen carbonate solution, and once with 50 ml. of water. The ethereal solution was dried over sodium sulfate. and distillation yielded 28.2 g. (74%) of a light yellow oil which boiled at 108–110° (3 mm.); the yellow oil solidified at atmospheric pressure and melted at 45°.

Anal. Calcd. for $C_{11}H_{11}NO_2$: C, 69.82; H, 5.86. Found: C, 69.47; H. 6.15.

4,4′-Bis-(γ-cyanopropoxy)-benzalazine (II).—Reaction of 9.5 g. (0.05 mole) of I with 3.5 g. (0.027 mole) of hydrazine sulfate gave 8.2 g. (88%) of a light yellow solid. Recrystallized from benzene it gave the following transitions: C–S point 164°, S–N point 168° and N–L point at 176°. Spherulite formation was noted in all drops at 174° until clearing (176°).

Anal. Calcd. for $C_{22}H_{22}N_4O_2$: C, 70.56; H, 5.92; N, 14.97. Found: C, 70.51; H, 6.09; N, 14.63.

***p*-(γ-Carboxypropoxy)-benzaldehyde (III).**—To a mixture of 9.5 g. (0.05 mole) of I and 3.4 g. (0.056 mole) of ethylene glycol was added a few small crystals of *p*-toluenesulfonic acid and 25 ml. of benzene. The mixture was refluxed until no further trace of water distilled over with the benzene, a few drops of alcoholic sodium hydroxide was added, and the volume reduced until traces of a solid were obtained. The solid gave a negative aldehyde test.

To the mixture was then added 9.0 g. of sodium hydroxide in 75 ml. of water and the solution refluxed until no further test for ammonia was obtained (a long time—36 hours). The solution was cooled, acidified carefully with hydrochloric acid, and 11 g. of a white precipitate giving a negative aldehyde test was collected. The precipitate was not recrystallizable. Approximately 6.5 g. of this ethylene glycol acetal of *p*-(γ-carboxypropoxy)-benzaldehyde was added to 20 ml. of ethanol, 15 ml. of glacial acetic acid and 10 ml. of water. The mixture was refluxed gently for 15 hours, fil-

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(21) J. D. Bernal and D. Crowfoot, *Trans. Faraday Soc.*, **29**, 1032 (1933).

(22) Carbon, hydrogen and nitrogen analyses were performed by The Mikroanalytisches Laboratorium im Max-Planck-Institut, Mulheim, Germany.

(23) A. Hildesheimer, *Monatsh. Chem.*, **22**, 497 (1901).

(24) R. Stoermer and F. Wodarg, *Ber.*, **61B**, 2323 (1928).

(25) T. Curtius, *J. prakt. Chem.*, **85**, 437 (1912).

(26) R. L. Shriner and R. C. Fuson, "The Systematic Identification of Organic Compounds," 3rd ed., John Wiley and Sons, Inc., New York, N. Y., 1948, p. 116.

(27) G. H. Brown and W. G. Shaw, *J. Org. Chem.*, **24**, 132 (1959).

tered, neutralized, washed and dried; the yield was 5.1 g. (95%). Over-all yield for the above three steps was approximately 70%. The product was not crystallizable; from ethyl acetate the non-crystalline material gave a m.p. 245–246°.

Anal. Calcd. for $C_{11}H_{12}O_4$: C, 63.45; H, 5.81. Found: C, 61.27; H, 5.76.

4,4′-Bis-(γ-carboxypropoxy)-benzalazine (IV).—When 4.2 g. (0.02 mole) of III was treated with 1.8 g. (0.014 mole) of hydrazine sulfate, 3.7 g. (90%) of a yellow precipitate was obtained which could not be obtained in crystalline form; from ethyl acetate, m.p. 240–241°; neut. equiv. calcd. 206, found 208 (average of three).

Anal. Calcd. for $C_{22}H_{24}O_6N_2$: C, 64.06; H, 5.87. Found: C, 64.70; H, 6.44.

4,4′-Bis-(δ-keto-ε-chloropentoxy)-benzalazine (V).—To an iced mixture of 1.55 g. (0.0037 mole) of IV and 30 ml. of anhydrous benzene was added dropwise 3.38 g. (2.13 ml., 0.028 mole) of highly purified thionyl chloride. The mixture was gently refluxed until the evolution of sulfur dioxide and hydrogen chloride ceased, and excess thionyl chloride removed. Anhydrous benzene was added and the solution distilled to remove all traces of thionyl chloride. Approximately 150 ml. of dried dioxane was added to the solution and the mixture was added dropwise to freshly prepared cold, dried, ethereal diazomethane (4.3 g., 0.02 mole, of N-methyl-N-nitroso-*p*-toluenesulfonamide was used). After the solution remained chilled for 10 hours, the excess diazomethane and ether were removed under reduced pressure. To the solution of this diazomethylketone partially dissolved in dioxane was added an ether–chloroform mixture until a solution was achieved. Hydrogen chloride was added, the color of the solution lightened, and a small amount of semicrystalline material separated; more of the material was obtained as the solvent was removed under reduced pressure. Recrystallization from a benzene–acetone mixture gave 0.5 g. of light brown needles, m.p. 179–180°.

Anal. Calcd. for $C_{24}H_{26}N_2O_4Cl_2$: Cl, 14.85. Found: Cl, 14.99.

***p*-Bromo-α-iodoacetophenone.**—On refluxing 8.34 g. (0.03 mole) of *p*,α-dibromoacetophenone with 4.50 g. (0.03 mole) of sodium iodide in 150 ml. of anhydrous acetone, sodium bromide precipitated. Addition of excess water caused the product to precipitate and it was removed by filtration. The product was washed with water, dried, and recrystallized from ethanol giving white needles, m.p. 95°, yield 8.2 g. (86%); it formed a 2,4-dinitrophenylhydrazone, red needles, m.p. 194–195°.

Anal. Calcd. for C_8H_6OBrI: C, 29.57; H, 1.86. Found: C, 29.85; H, 1.92.

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[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

A Synthesis of 6-Hydroxy-4-quinolizones

BY ROGER ADAMS AND WALTER REIFSCHNEIDER

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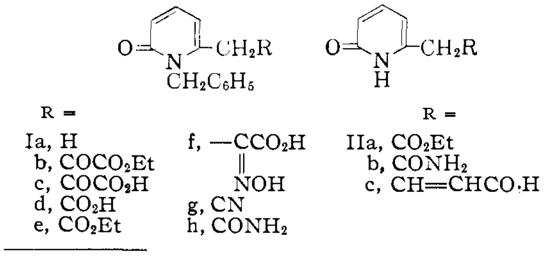
Ethyl 2-pyridone-6-acetate (IIa) and ethyl 2-ethoxy-6-pyridylacetate (IVe) were prepared from 1-benzyl-6-methyl-2-pyridone and 2-ethoxy-6-methylpyridine 1-oxide, respectively. Ethyl 2-pyridone-6-acetate but not ethyl 2-ethoxy-6-pyridylacetate condenses with diethyl ethoxymethylenemalonate to form 1,3-dicarbethoxy-6-hydroxy-4-quinolizone (VIa).

The possibility of building the condensed ring system found in cytisine[1] from either ethyl 2-pyridone-6-acetate (IIa) or ethyl 2-ethoxy-6-pyridylacetate (IVe) as the starting material stimulated a study of the syntheses and some of the reactions of these two compounds. The results are described in this Communication. Compound IIa has been synthesized by the following steps: (1) 1-benzyl-6-methyl-2-pyridone (Ia) with ethyl oxalate to ethyl 1-benzyl-2-pyridone-6-pyruvate (Ib); (2) hydrolysis of compound Ib to the corresponding acid Ic; (3) alkaline peroxide oxidation of compound Ic to 1-benzyl-2-pyridone-6-acetic acid (Id); esterification of compound Id to the ethyl ester Ie. This is a more satisfactory procedure than the one previously described[2] which combined steps 2 and 3 into one operation. An alternative procedure for synthesis of compound Ie consisted in pyrolysis of the 1-benzyl-2-pyridone-6-pyruvic acid oxime (If) to 1-benzyl-2-pyridone-6-acetonitrile (Ig). With ethanol and hydrogen chloride, the nitrile was converted to the ester Ie. Debenzylation of compound Ie was effected with sodium and liquid ammonia to give ethyl 2-pyridone-6-acetate (IIa).



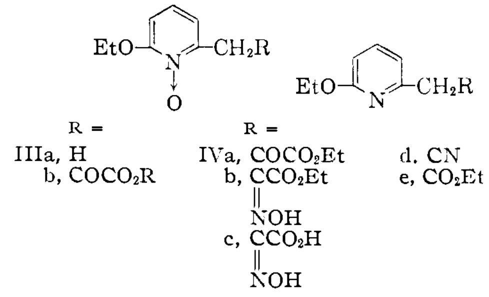
R =

Ia, H
b, $COCO_2Et$
c, $COCO_2H$
d, CO_2H
e, CO_2Et
f, $\underset{\substack{\| \\ \text{NOH}}}{\text{—CCO}_2\text{H}}$
g, CN
h, $CONH_2$

R =

IIa, CO_2Et
b, $CONH_2$
c, $CH{=}CHCO_2H$

Ethyl 2-ethoxy-6-pyridylacetate (IVe) was derived from 2-ethoxy-6-methylpyridine 1-oxide (IIIa), formed either by the action of sodium ethoxide in ethanol on 2-bromo-6-methylpyridine 1-oxide or by the action of peracetic acid upon 2-ethoxy-6-methylpyridine. Condensation of the compound IIIa with ethyl oxalate gave ethyl 2-ethoxy-6-pyridylpyruvate 1-oxide (IIIb). Attempts to hydrolyze compound IIIb to the corresponding acid



R =

IIIa, H
b, $COCO_2R$

R =

IVa, $COCO_2Et$
b, $\underset{\substack{\| \\ \text{NOH}}}{\text{CCO}_2\text{Et}}$
c, $\underset{\substack{\| \\ \text{NOH}}}{\text{CCO}_2\text{H}}$
d, CN
e, CO_2Et

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(2) R. Adams and S. Miyano, THIS JOURNAL, **76**, 3168 (1954).