# TRICARBOCYANINES WITH DIHYDROPYRAN, DIHYDROTHIAPYRAN, AND N-METHYLTETRAHYDROPYRIDINE RINGS IN THE CHROMOPHORE

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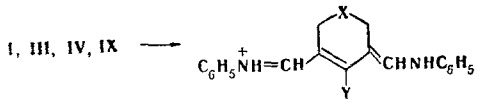
UDC 547.812.823:77.021

Glutaconic dialdehyde dianil salts, the α,α'-carbon atoms of which are included in dihydropyran, dihydrothiapyran, or N-methyltetrahydropyridine rings, were synthesized. Tricarbocyanine dyes with epoxydimethylene, epithiodimethylene, or N-methylepiminodimethylene groupings were synthesized by condensation of the dianil salts with a 2-methylbenzothiazole quaternary salt. The color of the dyes is discussed.

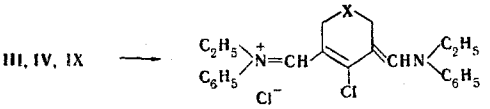
We have recently developed the synthesis of tricarbocyanine dyes in which the three central methylidyne groups of the chromophore are closed by a trimethylene grouping [1, 2]. In the present research we set out to accomplish the synthesis and investigate the spectral properties of similar dyes containing dihydropyran, dihydrothiapyran, or N-methyltetrahydropyridine rings in the chromophore chain. For this we studied the aminoformylation of 3-formyl-5,6-dihydro-2H-pyran (I), tetrahydro-γ-pyrone (III), tetrahydro-1-thio-γ-pyrone (IV), and 1-methyl-4-piperidone (IX). Dihydropyran I was aminoformylated with a dimethylformamide (DMF) complex with phosphorus oxychloride, and the substituted vinylog of formamide obtained after saponification was treated, without isolation, with aniline hydrochloride, as in the aminoformylation of 1-formylcyclohexene [1]. When the diethylacetal (Ia) of aldehyde I is used in place of I in this reaction, as in [3], the yield of dianil salt II can be raised; the free anil (IIa) is isolated when the salt is treated with triethylamine.



I, III, IV, IX → II, VII, VIII, X

I, II, III, VII X = O; IV, VIII X = S; IX, X X = NCH$_3$; I, II Y = H; III–X Y = Cl

The aminoformylation of pyrone III and thiopyrone IV was carried out with complexes of phosphorus oxychloride with ethylformanilide or N-formyltetrahydroquinoline. It was found that the resulting dianil salts that contain secondary amino groups, for example, V and VI, are extremely unstable and cannot be isolated. The reaction mass was therefore treated with aniline hydrochloride and methanol. In contrast to V and VI, the analogs of glutaconic dialdehyde dianil hydrochloride (VII and VIII) were completely stable.

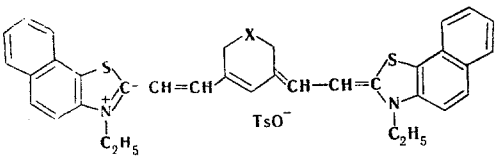


III, IV, IX → V, VI

Dianil hydrochloride X is formed by aminoformylation of 1-methyl-4-piperidone (IX) under conditions similar to those used in the synthesis of II. Measurement of the electronic absorption spectrum shows that in solution this compound exists almost completely in the form of a salt involving the heterocyclic nitrogen atom.

Institute of Organic Chemistry, Academy of Sciences of the Ukrainian SSR, Kiev. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 2, pp. 175-178, February, 1976. Original article submitted January 3, 1974; revision submitted February 24, 1975.

The thiatricarbocyanines (XIII-XVI) presented in Table 1 were synthesized by condensation of II, VII, VIII, and X with 2-methyl-3-ethylbenzothiazolium toluenesulfonate; in addition, thiatricarbocyanine XIX was obtained from dianil IIa and the quaternary salt of 2-methylnaphtho[2,1-d]thiazole.



XIX, XX

XIX X=O, $\lambda_{max}$ 796 nm; XX X=$CH_2$, $\lambda_{max}$ 800 nm

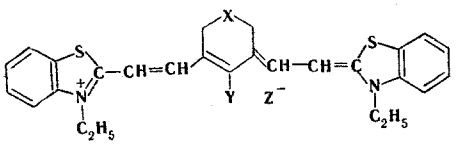
Measurements of the absorption spectra of alcohol solutions showed that the dianil salts are in equilibrium with the free dianils, which absorb at about 415 nm.

Replacement of the central methylene group in the trimethylene bridge of the dianil salts (Table 1) by sulfur atoms, oxygen atoms, or the $\overset{+}{N}HCH_3$ group leads to a hypsochromic shift of the absorption bands (compare II with XI; and VII, VIII, and X with XII); a similar regularity is also observed in a number of tricarbocyanines (compare XIII with XVII, XIV-XVI with XVIII, and XIX with XX). This phenomenon is evidently due to the negative inductive effect of the indicated substituents (the $\overset{+}{N}HCH_3$ group, for which the —I effect is a maximum, causes the greatest hypsochromic shift of the absorption maximum both in the case of dianil salts X and in the series of tricarbocyanines XVIa). Because of their electron-donor character, alkyl substituents in the examined positions of the chromophore of both dianil salts and thiatricarbocyanines should, according to the Dewar—Knott rule [4, 5], cause a bathochromic shift of the absorption maximum, and this is confirmed by a comparison of the spectra of dianil salt XI and thiatricarbocyanines XVII with the spectra of their analogs that do not contain substituents in the chromophore (the $\lambda_{max}$ values of which are, respectively, 492 and 758 nm). Thus, X groups that have an —I effect reduce the effect of methylene substituents attached to the chromophore, and this, in accordance with the same rule, leads to an increase in the coloration.

## EXPERIMENTAL

3-Formyl-5,6-dihydro-2H-pyran Diethylacetal (Ia). A hot solution of 0.7 g of ammonium nitrate in 18 ml of absolute alcohol was added to 15 g (0.13 mole) of pyran I [6] and 22.5 g (0.15 mole) of ethyl orthoformate, and the mixture was allowed to stand for 48 h, after which 45 ml of water and 15 drops of piperidine were added. The liberated oil was extracted with

TABLE 1. Absorption Maxima of Dianil Salts and Thiatricarbocyanine Dyes



XIII-XVIII

| Compound | X | Y | $\lambda_{max}$, nm* | Compound | X | Y | Z⁻ | $\lambda_{max}$, nm† | ε · 10⁻⁴ |
|---|---|---|---|---|---|---|---|---|---|
| II | O | H | 501 | XIII | O | H | I | 764 | 27,00 |
| VII | O | Cl | 523 | XIV | O | Cl | I | 784 | 26,25 |
| VIII | S | Cl | 524 | XV | S | Cl | Br | 780 | 24,70 |
| X | $NCH_3$ | Cl | 506 | XVI | $NCH_3$ | Cl | Br | 790 | 16,00 |
| XI | $CH_2$ | H | 503 | XVIa | $\overset{+}{N}HCH_3$ | Cl | Br | 765 | — |
| XII | $CH_2$ | Cl | 528 | XVII | $CH_2$ | H | I | 766 | 30,00 |
| | | | | XVIII | $CH_2$ | Cl | I | 794 | 26,80 |

*In $CH_3COOH$.

†In $CH_3OH$; in the case of XVIa, in the presence of HCl.

ether, and the ether extract was washed with water and dried over sodium sulfate. The ether was removed by distillation, and the residue was vacuum distilled. Two distillations gave 15.8 g (62%) of a product with bp 124° (27 mm) and $n_D^{20}$ 1.4510. The purity of the acetal was verified by gas–liquid chromatography (GLC). Found, %: Cl 64.5; H 9.5. $C_{16}H_{18}O_3$. Calculated, %: C 64.5; H 9.7.

α,α'-(Epoxydimethylene)glutaconic Dialdehyde Dianil Hydrochloride (II). A) A total of 31.5 ml (0.78 mole) of absolute methanol was added dropwise at −10° to the complex obtained from 195 ml of DMF and 70 ml (0.78 mole) of phosphorus oxychloride, after which 43.6 g (0.39 mole) of I was added dropwise at the same temperature in the course of 30 min. The mixture was then heated to 45° for 1 h, and the resulting solution was heated at this temperature for 3 h. It was then poured over 300 g of crushed ice, and the aqueous mixture was made alkaline to pH 8-9 with 10% alkali solution. The alkaline mixture was stirred, 150 g (1.16 mole) of aniline hydrochloride was added, and the mixture was then heated to 50° and cooled to room temperature. After 12 h, the resulting precipitate was removed by filtration, washed with water and ether, air dried, and triturated with 50 ml of acetone. The solid material was removed by filtration and washed with 10 ml of acetone and 10 ml of ether. The yield was 16.6 g (13%). Crystallization from alcohol with the addition of aniline hydrochloride gave a product with mp 206-207°. Found, %: Cl 10.9. $C_{19}H_{18}N_2O \cdot HCl$. Calculated, %: Cl 10.9.

B) A 15.3-g (0.1 mole) sample of phosphorus oxychloride was added slowly at 0-5° to 25 ml of DMF, after which the mixture was heated to 20° for 30 min. A 9.3-g (0.05 mole) sample of diethylacetal Ia was then added, and the mixture was allowed to stand at room temperature for 1.5 h and at 40° for 2 h. It was then poured over crushed ice, and the aqueous mixture was made alkaline to pH 9 with 10% alkali solution. A 19-g (0.15 mole) sample of aniline hydrochloride was added, and the mixture was heated to 50°. After 12 h, the precipitate was removed by filtration and washed successively with water, 30 ml of dioxane, 20 ml of acetone, and ether to give 7.6 g (47%) of a product with mp 201-203°.

In order to isolate the base of dianil IIa, 0.6 g (6 mmole) of triethylamine was added to a suspension of 0.65 g (2 mmole) of salt II in 25 ml of dry benzene, and the mixture was shaken for 15 min. The triethylamine hydrochloride was removed by filtration, the benzene was removed by vacuum distillation, and the residue was heated with 5 ml of heptane. The solid material was removed by filtration to give an almost quantitative yield of orange crystals with mp 174° (from alcohol). Found, %: N 9.7. $C_{19}H_{18}N_2O$. Calculated, %: N 9.6.

β-Chloro-α,α'-(epoxydimethylene)glutaconic Dialdehyde Dianil Hydrochloride (VII). A solution of 5 g (0.05 mole) of pyranone III [8] in 10 ml of chloroform was added slowly at room temperature to the complex obtained from 24.2 g (0.15 mole) of N-formyltetrahydroquinoline [7] and 23 g (0.15 mole) of phosphorus oxychloride in 30 ml of dry chloroform, after which the mixture was allowed to stand at room temperature for 1 h and at 45° for 3 h. It was then treated with 19 g (0.15 mole) of aniline hydrochloride, and 75 ml of methanol was added carefully with stirring. The mixture was refluxed until hydrogen chloride liberation ceased, after which it was evaporated to half its initial volume, and 50 ml of 5% hydrochloric acid was added. The resulting precipitate was removed by filtration and washed with water and alcohol to give 2.4 g (13.5%) of dark-red crystals with mp 222-223° (from glacial acetic acid). Found, %: Cl 19.3. $C_{19}H_{17}ClN_2O \cdot HCl$. Calculated, %: Cl 19.7.

β-Chloro-α,α'-(epithiodimethylene)glutaconic Dialdehyde Dianil Hydrochloride (VIII). The method used to obtain VII was used to prepare this compound by aminoformylation of 5.8 g (0.05 mole) of pyranone IV [9] by means of the complex obtained from 23 g (0.15 mole) of phosphorus oxychloride and 22.4 g (0.15 mole) of ethyl formanilide. The yield of dark-red crystals of VIII with mp 227-227.5° (from glacial acetic acid) was 2 g (10.5%). Found, %: S 8.5. $C_{19}H_{17}ClN_2S \cdot HCl$. Calculated, %: S 8.5.

1-Methyl-3-formyl-4-chloro-5-dimethylaminomethylene-1,2,5,6-tetrahydropyridine. A 5.6-g (0.05 mole) sample of 1-methyl-4-piperidone [10] was added at 20° in the course of 15 min to the complex obtained from 11 g (0.15 mole) of DMF and 23 g (0.15 mole) of phosphorus oxychloride in 50 ml of chloroform, after which the mixture was allowed to stand at 20° for 30 min and at 40° for 30 min. It was then cooled, a saturated aqueous solution of potassium carbonate was added, and the chloroform layer was separated. The aqueous layer was extracted with chloroform, the combined extracts were dried with potassium carbonate, and the solvent was removed by distillation. The residue was crystallized from acetone to give 3.3 g (31%)

of yellow prisms with mp 107°. Found, %: C 16.6; N 13.1. $C_{10}H_{15}ClN_2O$. Calculated, %: Cl 16.5; N 13.0.

β-Chloro-α,α'-(N-methylepiminodimethylene)glutaconic Dialdehyde Dianil Hydrochloride (X). A solution of 0.43 g (2 mmole) of the aminomethylene derivative and 0.52 g (4 mmole) of aniline hydrochloride in 12 ml of methanol was refluxed for 3 min, and the resulting precipitate was removed by filtration and washed with methanol and ether to give 0.46 g (62%) of dark-red needles with mp 184° (from methanol). Found, %: Cl 19.2. $C_{20}H_{20}ClN_3 \cdot HCl$. Calculated, %: Cl 19.0.

2-[7-(3-Ethylbenzo-2-thiazolinylidene)-3,5-(epi-X-dimethylene)-1,3,5-heptatrien-1-yl]-3-ethylbenzothiazolium Halides (XIII-XVIII). A solution of 0.77 g (2.2 mmole) of 2-methyl-3-ethylbenzothiazolium toluenesulfonate, 1 mmole of the appropriate analog of glutaconic dialdehyde dianil hydrochloride (II, VII, VIII, or X), and 2.5 mmole of anhydrous sodium acetate (or triethylamine) in 10 ml of absolute alcohol was refluxed for 15 min. Dyes XIII and XIV were converted to the iodides by addition of sodium iodide to the reaction mixture, whereas dyes XV and XVI were converted to the bromides by the addition of tetraethylammonium bromide. The reaction mixture was cooled, and the dye was removed by filtration and washed with alcohol and water. Dye XIII, with mp 261° (decomp., from alcohol—nitromethane), was obtained in 66% yield. Found, %: S 21.4. $C_{27}H_{27}IN_2OS_2$. Calculated, %: S 21.8. Dye XIV, with mp 238° (decomp., from nitromethane), was obtained in 34% yield. Found, %: I 20.1. $C_{27}H_{26} \cdot ClIN_2OS_2$. Calculated, %: I 20.4. Dye XV, with mp 230° (decomp., from alcohol), was obtained in 73% yield. Found, %: S 16.1. $C_{27}H_{26}BrClN_2S_3$. Calculated, %: S 16.3. Dye XVI, with mp 245° (decomp., from methanol), was obtained in 75% yield. Found, %: S 10.8. $C_{28}H_{29}BrClN_3S_2$. Calculated, %: S 10.9.

2-{7-(3-Ethylnaphtho[2,1-d]-2-thiazolinylidene)-3,5-(epoxydimethylene)-1,3,5-heptatrien-1-yl}-3-ethylnaphtho[2,1-d]thiazolium Toluene Sulfonate (XIX). A solution of 0.9 g (2.2 mmole) of 2-methyl-3-ethylnaphtho[2,1-d]-thiazolium toluenesulfonate, 0.29 g (1 mmole) of dianil IIa, and 0.3 ml (2.2 mmole) of triethylamine in 8 ml of pyridine was refluxed for 3 min, after which the dye was removed by filtration and washed with alcohol to give 0.57 g (78%) of a product with mp 231° (decomp., from methanol—nitromethane). Found, %: S 13.1. $C_{42}H_{38}N_2O_4S_3$. Calculated, %: S 13.2.

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