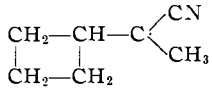
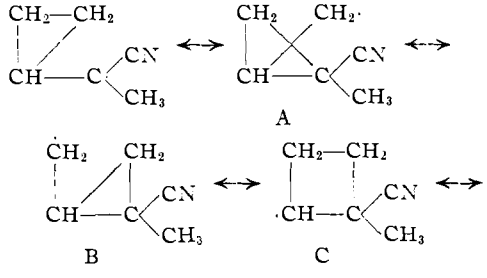
ruled out at that time. The fact that the azo nitrile from methyl cyclobutyl ketone did not show this enhancement of rate strongly supports the suggestion that this is a true case of hyperconjugation and not back strain—no other simple conclusion can be drawn from the evidence. The evidence indicates that the formation of radical I is not ac-



I

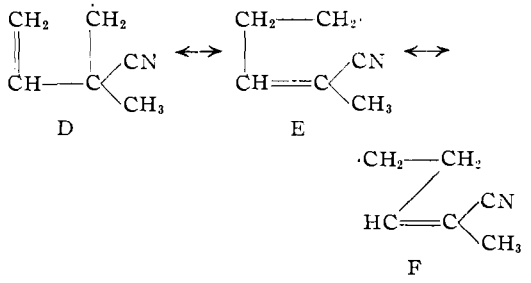
companied by stabilization involving delocalization of the carbon–carbon bonds of the cyclobutyl ring. The cyclopropyl case is similar in principle to the solvolysis of cyclopropylcarbinyl chloride where it has been demonstrated that extensive stabilization of the cyclopropylcarbinylcarbonium ion is responsible for the high reactivity of the chloride. There is undoubtedly a difference of degree in the radical case and there remains a question whether electron distributions such as A, B, C and D contribute more or less than types indicated by E and F. It is not possible at present to assess the relative contribution of a distribution such as C, and thus whether any increase in the decomposition rate of the cyclopropyl compound is due to a driving force of a rearrangement to products resulting from structure C.



A



B C



D E F

The distributions depicted by A, B, C and D represent structures formally similar to those suggested for the symmetrical cyclopropylcarbinylcarbonium ion for which considerable evidence was amassed.[12]

Roberts and Mazur[12] in discussing the symmetrical cyclopropylcarbinylcarbonium ion point out that the three extra $Sp^3$ orbitals of each of the methylene groups are positioned so that they do overlap and can form one stable molecular orbital holding two electrons and two vacant considerably less stable orbitals. In the corresponding radical form there is an excess electron which could necessarily go into a less stable orbital. Thus, distributions such as A, B and C may contribute very little since they are less probable. They reported no interconversion to cyclopropyl derivatives when cyclobutane was chlorinated in the light in the vapor phase to give cyclobutyl chloride.

It is noteworthy that Mariella and Raube[9] in a study of the ultraviolet absorption spectra of cycloalkyl methyl ketones have concluded that some interaction of the carbonyl group with the ring may occur in some excited states with cycloalkyl groups higher than cyclopropyl.

(12) J. D. Roberts and R. H. Mazur, THIS JOURNAL, **73**, 2509 (1951); **73**, 3542 (1951).

BROOKLYN, NEW YORK

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[CONTRIBUTION FROM THE RESEARCH DEPARTMENT, CALCO CHEMICAL DIVISION, AMERICAN CYANAMID COMPANY]

# Optical Bleaching Agents. I. Derivatives of Dichlorodiaminostilbenedisulfonic Acid

BY D. W. HEIN AND ELLIOT S. PIERCE

RECEIVED OCTOBER 22, 1953

Two new dye intermediates, 5,5-dichloro- (III) and 6,6′-dichloro-4,4′-diaminostilbene-2,2′-disulfonic acid (IV) were prepared, and several new optical bleaching agents were prepared from them, mainly by acylation with substituted benzoyl chlorides. The fluorescent properties and ultraviolet absorbency characteristics of the products were compared with those of the corresponding acyl derivatives of 4,4′-diaminostilbene-2,2′-disulfonic acid.

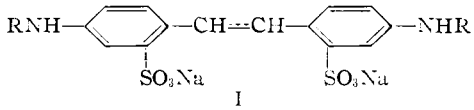
The use of fluorescent colorless dyes in laundry soaps to counteract the gray or yellow tinges of white fabrics and to brighten colored fabrics is well established.[1] Previously, it was general practice to neutralize the yellow tinge of white fabrics by the use of a blue dye ("bluing"). Unless a careful balance was struck between the relative amounts of blue and yellow colors, there was always a residual blue or yellow tinge depending upon which was in excess. Even when a careful balance was struck between the blue and yellow components, there was always some graying or dulling since the total amount of light reflected from the surface of the cloth was less than when no "bluing" was used. This was due to the fact that the blue dye absorbed some of the impinging light.

Optical bleaches are fluorescent colorless dyes which operate by absorbing ultraviolet light and re-emitting this energy as blue light. By their use, the natural yellow tinge of the fabric is neutralized by resupplying the blue light absorbed by the yellow substance. Since the total amount of light coming from the surface of the fabric is greater than when the optical bleach is absent, a true

(1) T. F. Cooke, H. E. Millson and E. I. Stearns, *Soap Sanit. Chemicals*, **XXVI**, No. 3, 37 (1950); *ibid.*, **XXVI**, No. 4, 48 (1950).

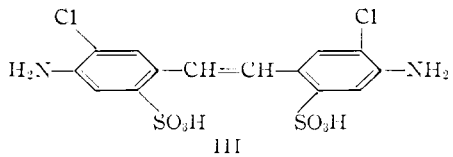
"brightening" effect is achieved. Even colored fabrics are brightened to some extent by this increased apparent "reflectance" and by the improved contrast if white is also present.

The original discovery of this whitening action was due to P. Krais[2] who demonstrated the effect by the use of the fluorescent compound aesculin. After this discovery it remained for the industry to develop fluorescent colorless dyes which were substantive, or possessed affinity, for the various fibers. Substantivity, or affinity, is required since the optical bleach must attach itself to the fabric during the washing operation. A number of products which have both the desired fluorescence and affinity have been reported. Of these, the optical bleaches in common use for the whitening of cellulosic fabrics are mostly derivatives I of 4,4′-diaminostilbene-2,2′-disulfonic acid (DAS, II), where R = substituted benzoyl, 2,4-disubstituted-1,3,5-triazinyl, or phenylcarbamyl.

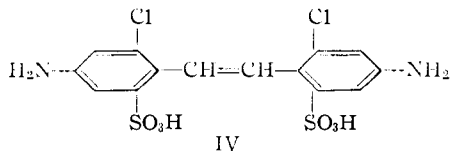


I

It was considered of interest to investigate the corresponding derivatives of 5,5′-dichloro- (III) and 6,6′-dichloro-4,4′-diaminostilbene-2,2′-disulfonic acid (IV) to determine if they possessed improved hypochlorite (laundry bleach) resistance and to determine the effect of chlorine substitution on such properties as fluorescent intensity and shade, and affinity. III was made in the usual



III



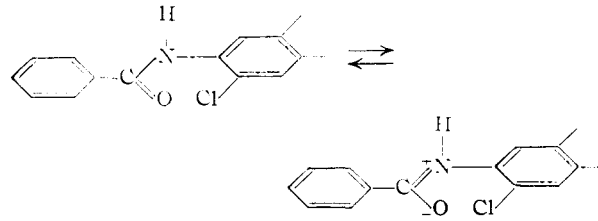
IV

manner[3] by the aqueous alkaline hypochlorite condensation of sodium 5-chloro-4-nitrotoluene-2-sulfonate to form sodium 5,5′-dichloro-4,4′-dinitrostilbene-2,2′-disulfonate, followed by reduction by the Béchamp method. Comparison of the ultraviolet absorption curves of DAS (II) and 5,5′-dichloro-DAS (III) with that of *trans*-4,4′-diaminostilbene shows that both are obviously also *trans*. We were unable to prepare IV in this way, since the aqueous alkaline hypochlorite condensation of sodium 6-chloro-4-nitrotoluene-2-sulfonate to the desired stilbene failed under the conditions tried. The failure of this stilbene condensation was probably due to the steric hindrance of the *o*-chloro- and -sulfonic acid groups. IV was finally prepared by condensing 2 moles of phenyl 6-chloro-4-nitrotoluene-2-sulfonate in methanolic potassium hydroxide solution in the presence of oxygen to form potassium 6,6′-dichloro-4,4′-dinitrostilbene-2,2′-disulfonate (precipitated as the cyclohexylammonium salt), followed by reduction by the Béchamp method. III and IV were benzoylated quantitatively with the substituted benzoyl chlorides in boiling pyridine.

The optical bleaches prepared from 5,5′-dichloro-DAS (III) and 6,6′-dichloro-DAS (IV), and the corresponding 4,4′-diaminostilbene-2,2′-disulfonic acid (DAS) analogs are tabulated in Table I together with their ultraviolet absorption data.[4]

The 5,5-dichloro-DAS derivatives were unusually resistant to attack by hypochlorite (laundry bleach), being almost unaffected by contact with it in aqueous solution or on the fiber. They also have the property of whitening soaps and detergents while the corresponding DAS derivatives usually cause some yellowing. The 5,5′-dichloro-DAS derivatives, with the exception of X and XIII, were about equal to the corresponding DAS analogs in fluorescence dyeing strength on a molar basis and thus were somewhat weaker on a weight basis; X and XIII were stronger (*ca.* 25%) than the DAS analogs, IX and XII. The fluorescence hue or shade of X and XIII was slightly redder (more violet) than that of IX and XII. The 6,6′-dichloro-DAS derivatives XI and XIV possessed low fluorescence dyeing strengths on cotton due to low affinity for the fiber or low fluorescence strength or both.

In general the relationship between the ultraviolet absorption curves of the corresponding 5,5′-dichloro-DAS and the DAS derivatives was the same. The curves clearly showed that the 5,5′-dichloro-DAS derivative generally gave a hypsochromic shift in absorption maximum, a decreased molar absorptivity, and a broadening of the absorption band with respect to the unchlorinated DAS derivative. The hypsochromic shifts in absorption maxima brought about by 5,5′-dichlorination are no doubt due to steric inhibition of the amide resonance



The importance of this amide resonance is well demonstrated by the lowering of carbonyl stretching frequency in amides (1670 cm.$^{-1}$) compared to ketones (1700 cm.$^{-1}$).[5] Only to the extent that amide resonance occurs can conjugation between the benzoyl and stilbene residues occur. That this type of conjugation is important is shown by comparison of the shifts in the long wave length band of aniline produced by acetylation and benzoylation

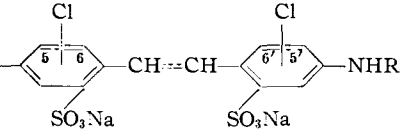
(2) P. Krais, *Melliand Textilber.*, **10**, 468 (1929).

(3) A. Green and A. Wahl, *Ber.*, **30**, 3109 (1897).

(4) The spectra referred to in this article have been deposited as Document number 4185 with the ADI Auxiliary Publications Project, Photoduplication Service, Library of Congress, Washington 25, D. C. A copy may be secured by citing the Document number and by remitting in advance $2.50 for photoprints, or $1.75 for 35 mm. microfilm by check or money order payable to: Chief, Photoduplication Service, Library of Congress.

(5) R. B. Barnes, R. C. Gore, J. Liddel and V. Z. Williams, "Infrared Spectroscopy," Reinhold Publ. Corp., New York, N. Y., 1944, pp. 21, 89.

TABLE I

EFFECT OF Cl ON WAVE LENGTH AND MOLAR ABSORPTIVITY, RNH—  —NHR

| Compound | R | Cl position | $\lambda_{max}$, mμ | ε | Formula | Microanalyses, % Calculated C | H | N | Cl | S | Found C | H | N | Cl | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| II | H | None | 338 | 18,420 | | | | | | | | | | | |
| III | H | 5,5′ | 340 | 20,200 | $C_{14}H_8O_{10}N_2Cl_2S_2 \cdot H_2O$ | 32.5 | 1.94 | 5.42 | ... | 12.4 | 32.3, 32.3 | 2.36, 2.27 | 5.82 | ... | 12.4 |
| V | Benzoyl | None | 335 | 48,750 | $C_{28}H_{20}O_8N_2Na_2S_2 \cdot 3H_2O$ | 49.8 | 3.86 | 4.13 | ... | 9.47 | 50.4 | 4.59 | 4.07 | ... | 9.55 |
| VI | Benzoyl | 5,5′ | 322 | 44,950 | $C_{28}H_{20}O_8N_2Cl_2Na_2S_2 \cdot 2^1/_2H_2O$ | 45.5 | 3.12 | 3.79 | ... | 8.67 | 45.5 | 3.60 | 4.09 | ... | 8.50 |
| VII | Anisoyl | None | 338 | 54,810 | $C_{30}H_{24}O_{10}N_2Na_2S_2 \cdot H_2O$ | 51.3 | 3.71 | 4.00 | ... | 9.13 | 51.2, 51.5 | 3.68, 3.60 | 3.96 | ... | 9.03 |
| VIII | Anisoyl | 5,5′ | 322 | 45,690 | $C_{30}H_{22}O_{10}N_2Cl_2Na_2S_2 \cdot 6H_2O$ | 44.2 | 4.42 | 3.44 | 8.70 | ... | 43.4 | 4.54 | 3.56 | 8.62 | .. |
| IX | *o*-Ethoxybenzoyl | None | 341 | 50,840 | $C_{32}H_{28}O_{10}N_2Na_2S_2 \cdot H_2O$ | 52.7 | 4.12 | 3.84 | ... | 8.78 | 53.0 | 3.87 | 3.79 | ... | 9.01 |
| X | *o*-Ethoxybenzoyl | 5,5′ | 381 | 58,110 | $C_{32}H_{26}O_{10}N_2Cl_2Na_2S_2 \cdot 4H_2O$ | 45.2 | 4.00 | 3.30 | ... | 7.53 | 45.3 | 4.23 | 3.23 | ... | 7.34 |
| XI | *o*-Ethoxybenzoyl | 6,6′ | 322 | 30,690 | $C_{32}H_{26}O_{10}N_2Cl_2Na_2S_2 \cdot 2H_2O$ | 47.1 | 3.68 | 3.45 | 8.70 | 7.87 | 46.8 | 3.60 | 3.45 | 8.95 | 7.76 |
| XII | 2,4-Dimethoxybenzoyl | None | 345 | 57,290 | $C_{32}H_{28}O_{12}N_2Na_2S_2 \cdot 3H_2O$ | 48.2 | 4.27 | 3.52 | ... | 8.04 | 48.1 | 4.10 | 3.61 | ... | 8.16 |
| XIII | 2,4-Dimethoxybenzoyl | 5,5′ | 387 | 72,830 | $C_{32}H_{28}O_{12}N_2Cl_2Na_2S_2 \cdot 4H_2O$ | 43.5 | 3.85 | 3.17 | 8.05 | 7.26 | 43.7 | 4.04 | 3.15 | 8.54 | 7.26 |
| XIV | 2,4-Dimethoxybenzoyl | 6,6′ | 320 | 40,150 | $C_{32}H_{26}O_{12}N_2Cl_2Na_2S_2 \cdot 2H_2O$ | 45.3 | 3.54 | 3.30 | ... | 7.56 | 45.5 | 3.39 | 3.30 | ... | 7.51 |
| XV | Furoyl | None | 345 | 46,270 | $C_{24}H_{16}O_{10}N_2Na_2S_2 \cdot 2H_2O$ | 45.2 | 3.14 | 4.39 | ... | 10.0 | 45.2 | 3.81 | 4.52 | ... | 9.71 |
| XVI | Furoyl | 5,5′ | 326 | 42,030 | $C_{24}H_{14}O_{10}N_2Cl_2Na_2S_2$ | 42.9 | 2.10 | 4.17 | 10.56 | 9.55 | 43.0 | 2.21 | 4.16 | 10.5 | 9.51 |
| XVII | Phenoxyacetyl | None | 330 | 32,970 | $C_{30}H_{24}O_{10}N_2Na_2S_2 \cdot 2^1/_2H_2O$ | 49.6 | 3.99 | 3.85 | ... | 8.83 | 49.6 | 3.76 | 3.87 | ... | 8.98 |
| XVIII | Phenoxyacetyl | 5,5′ | 317 | 35,920 | $C_{30}H_{22}O_{10}N_2Cl_2Na_2S_2 \cdot 3H_2O$ | 44.7 | 3.48 | 3.48 | 8.80 | 7.96 | 45.3 | 3.55 | 3.62 | 8.44 | 7.37 |
| XIX | Phenylcarbamyl | None | 335 | .... | | | | | | | | | | | |
| XX | Phenylcarbamyl | 5,5′ | 334 | 65,220 | $C_{28}H_{20}O_8N_4Cl_2Na_2S_2 \cdot 5H_2O$ | 41.4 | 3.70 | 6.90 | 8.74 | 7.90 | 41.5, 41.8 | 3.55, 3.43 | 6.87 | 8.27 | 7.61 |
| XXI | *o*-Phenoxybenzoyl | None | 350 | 37,520 | $C_{40}H_{28}O_{10}N_2Na_2S_2 \cdot 1^1/_2H_2O$ | 57.7 | 3.73 | 3.36 | ... | 7.70 | 57.8 | 3.55 | 3.04 | ... | 7.25 |
| XXII | *o*-Phenoxybenzoyl | 5,5′ | 331 | 37,830 | $C_{40}H_{26}O_{10}N_2Cl_2Na_2S_2 \cdot 3H_2O$ | 51.6 | 3.44 | 3.02 | 7.63 | 6.90 | 52.0 | 3.59 | 3.02 | 7.89 | 6.40 |
| XXIII | 2,4-Dianilino-1,3,5-triazinyl | None | 353 | 60,450 | $C_{44}H_{34}O_6N_{12}Na_2S_2 \cdot 9H_2O$ | 48.1 | 4.74 | 15.3 | ... | 5.84 | 47.9 | 5.72 | 15.1 | ... | 5.94 |
| XXIV | 2,4-Dianilino-1,3,5-triazinyl | 5,5′ | 346 | 46,400 | *Cf.* Experimental | | | | | | | | | | |
| XXV | β-Naphthoyl | None | 343 | 49,640 | $C_{36}H_{24}O_8N_2Na_2S_2 \cdot 5H_2O$ | 53.3 | 4.18 | 3.45 | ... | 7.89 | 53.3 | 3.90 | 3.56 | ... | 7.73 |
| XXVI | β-Naphthoyl | 5,5′ | 340 | 40,950 | $C_{36}H_{22}O_8N_2Cl_2Na_2S_2 \cdot 6H_2O$ | 47.9 | 3.78 | 3.11 | 7.89 | 7.12 | 51.1, 51.0 | 3.60, 3.77 | 3.12 | 7.88 | 7.11 |
| XXVII | 4-Chlorobenzoyl | 5,5′ | ...[a] | .... | $C_{28}H_{16}O_8N_2Cl_4Na_2S_2 \cdot 6H_2O$ | 38.7 | 3.23 | 3.23 | ... | 7.39 | 38.6, 38.7 | 3.08 | 3.00 | ... | 7.00 |
| XXVIII | Sorboyl | 5,5′ | ...[a] | .... | $C_{26}H_{22}O_8N_2Cl_2Na_2S_2 \cdot 4H_2O$ | 42.0 | 4.03 | 3.76 | ... | 8.62 | 42.3, 42.2 | 4.05 | 3.71 | ... | 8.45 |
| XXIX | 4-Diethylaminobenzoyl | 5,5′ | ...[a] | .... | $C_{36}H_{36}O_8N_4Cl_2Na_2S_2 \cdot 2H_2O$ | 49.6 | 4.60 | 6.44 | ... | 7.37 | 49.6 | 4.98 | 6.42 | ... | 6.18, 6.35 |

[a] The fluorescent dyeing strength of these compounds was so low that they were of no further interest, and thus these data were not obtained.

(41 and 7 mμ hypsochromic shifts, respectively). The amide and therefore the conjugation resonances are interfered with by loss of planarity[6] due to steric hindrance between the oxygen and the chlorine atoms, as shown by models. This hindrance would seem at first to be removed by simple rotation of the benzamido group through 180°. But even then a small interference occurs between the oxygen and the *ortho* hydrogen atoms. What the chlorine atom causes, then, is not the introduction of steric interference, but a large increase in already-present interference. It must be assumed that the benzamido group rotates through all possible attitudes, though absorbing at the long wave lengths only when approximating the planar configuration. The decreased probability of planarity causes both the decrease in molar absorptivity and the hypsochromic shift. (Planarity is less important to the ground state than to the excited state.[7,8]) This sort of behavior also has been reported for 1,4-di-(*o*-tolyl)-butadiene.[9]

The hypochromic and hypsochromic shifts observed in the 6,6′-dichloro-DAS derivatives, XI and XIV, are quite evidently caused by steric interference with the planarity necessary for conjugation resonance.[5] All four positions *ortho* to the stilbene vinyl group are occupied by bulky substituents, two chloro- and two sulfonic acid groups, which collide with the vinyl group and force it 30° out of planarity (in models). This would be expected to lower both the fluorescence intensity and substantivity of the compounds.

There was found to be a notable correlation between the ultraviolet absorbency data and the fluorescence intensity of these compounds when dyed on cotton. X and XIII, the only two compounds which showed bathochromic shifts in absorption maxima and appreciably higher molar absorptivities, also showed a much stronger fluorescence intensity by dye test on cotton (*ca.* 25%) than the corresponding DAS derivatives, IX and XII. The fluorescence intensity on cloth depends on the absolute fluorescence intensity of the compound and its affinity for the fiber. In the cases of X and XIII, it was not established which of these factors was responsible for the increased fluorescence intensity on the fiber. Increased affinity could be responsible because the percentage of dye exhausted from the dye bath in the case of DAS analogs, IX and XII, is less than 100%[9a] but an increase of this magnitude in affinity would hardly be expected based on available evidence. Increased fluorescence intensity on the fiber due to an increased fluorescence intensity of the compound, would be somewhat surprising in the case of compounds X and XIII, since it has been pointed out[10] that the introduction of a nitro- or chloro-substituent into the resonant part of a fluorescent structure can be expected to diminish the fluorescence of the system. It will be seen below, however, that in X and XIII special effects occur involving the chlorine atoms; it is, therefore, not surprising that these two compounds do not conform to that general observation.

The effect of the combination of chlorine in the 5,5′-positions with alkoxy groups in the *ortho*-positions of the acyl radicals (compounds X and XIII) seems at first paradoxical. In these two cases acylation caused large hyperchromic shifts and bathochromic shifts of 41 and 47 mμ, respectively, whereas similar acylation of DAS caused bathochromic shifts of only 3 and 7 mμ (compounds IX and XII). Moreover the introduction into benzoylated DAS of 5,5′-chlorines alone shifts the absorption maximum hypsochromically by 13 mμ. Since the combination (in compound VIII) of methoxy in the *para*-positions and chlorine in the 5,5′-positions causes the usual hypsochromic shift it is evident that this is not a simple resonance effect but an ortho effect,[11] the nature of which is discussed below.

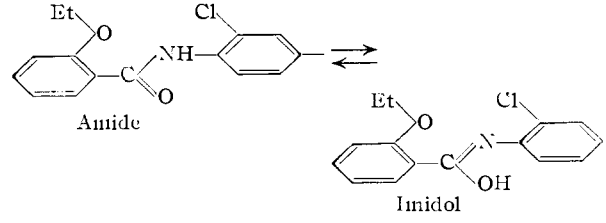
To determine whether this effect may be general, we studied the ultraviolet absorption spectra of the model compounds benzanilide (XXX), *o*-benzamidochlorobenzene (XXXI) and *o*-(2-ethoxybenzamido)-chlorobenzene (XXXII). Table II shows that in this simple series the same order of an hypsochromic and then a bathochromic shift is observed, although of different relative magnitudes.

TABLE II

SPECTRAL EFFECTS OF Cl AND ETHOXY IN DAS AND BENZANILIDE DERIVATIVES

| Compound | λmax mμ | Molar absorptivity |
|---|---|---|
| V | 337 | 48,750 |
| VI | 322 | 44,950 |
| X | 381 | 58,110 |
| Benzanilide | 277 | 13,000 |
| *o*-Benzamidochlorobenzene | 255 | 9,560 |
| *o*-(2-Ethoxybenzamido)-chlorobenzene | 271 (300 shoulder) | 13,930 |

The most satisfactory explanation envisages actual tautomerism, with its resulting full conjugation. There is some evidence, in both infrared and ultraviolet absorptions, for this tautomeric equilibrium in X




In the infrared spectrum of this compound an —OH band appears, and the carbonyl band at 1670 cm.$^{-1}$ is weak compared to that of benzanilide and related amides. The ultraviolet curve has a shoulder at 365 mμ, perhaps attributable to the keto form in low concentration. Estimation of the relative amounts of tautomers present is not justifiable with presently available experimental data. The

(6) L. W. Pickett, G. F. Walter and H. France, THIS JOURNAL, **58**, 2296 (1936).

(7) R. N. Beale and E. M. F. Roe, *ibid.*, **74**, 2302 (1952).

(8) C. A. Coulson and J. Jacobs, *J. Chem. Soc.*, 1983 (1949).

(9) Y. Hirschberg, E. Bergmann and F. Bergmann, THIS JOURNAL, **72**, 5120 (1950).

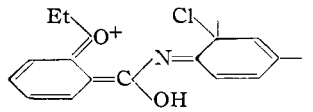
(9a) S. M. Davis, private communication.

(10) G. N. Lewis and M. Calvin, *Chem. Revs.*, **25**, 273 (1939).

(11) G. E. K. Branch and M. Calvin, "Theory of Organic Chemistry," Prentice-Hall, Inc., New York, N. Y., 1945, p. 258.

imidol forms of X and XIII thus seem much stabler, relative to their keto forms, than do the imidol forms of all the other acylated DAS compounds.

It was seen above that the explanation for this cannot rest on resonance alone, but must include a proximal effect of ethoxy and chlorine. Those molecules which will tautomerize must therefore have the chlorine and ethoxy on the same side. Steric factors place the carbonyl oxygen on the opposite side, and the N–hydrogen on the same side, as the chlorine and ethoxy. Molecular models show no crowding of the hydrogen by chlorine or ethoxy. It thus seems that a resonance–electrostatic effect is responsible: the net negative charge on chlorine and the net positive charge on oxygen,[12] mutually enhanced both capacitor fashion and resonance-wise, give increased importance to the polar structure

(B) 


Since conjugation is full in the imidol but only partial in the amide, the polar imidol contributor (B) has more importance than the analogous polar amide contributor; hence the imidol is favored by its much larger resonance stabilization involving the polar structure. Also the chlorine and oxygen charges, by exerting a combined push–pull on the N–hydrogen, may encourage imidol formation by rendering the N-position relatively untenable to the proton.

We can now understand also the failure of X and XIII to adhere to the loose bolt theory,[11] in that they exhibit not diminished but enhanced fluorescence. The chlorine atom, in being electrostatically attracted by the neighboring oxygen, is no longer so free to vibrate and dissipate the energy of the excited state, but is instead an improved energy reservoir in its capacitor action with the oxygen.

## Experimental

**Sodium 5-Chloro-4-nitrotoluene-2-sulfonate.**—This compound was first prepared from *m*-chlorotoluene by the method of Wynne[13]; cyclohexylamine salt, m.p. 245.5–247.0° (cor.). Later a more convenient synthesis from *m*-toluidine was developed by Dr. S. M. Tsang of this Laboratory. It is outlined below.

**5-Aminotoluene-2-sulfonic Acid.**—The procedure used was similar to that reported previously.[14] However, since the reference is not readily available in many libraries and since the procedure has to be adapted to laboratory apparatus, it is described briefly here.

*m*-Toluidine (214.0 g., 2 moles) was added with stirring to 203 g. (2 moles) of 96.5% sulfuric acid at about 100°. Vigorous stirring was continued while the reaction mixture was heated to 225°. After about 15 minutes at this temperature, the mixture became very thick and stirring was stopped. Heating was continued for 2.5 hours at 230–235°. The solid cake which resulted was dissolved with dilute sodium hydroxide solution, and this solution was then clarified with Darco and acidified to congo red with sulfuric acid to precipitate the product; yield 324 g. (88%). Titration with sodium nitrite indicated a purity of 100%.

**5-Chlorotoluene-2-sulfonic Acid.**—A slurry of 34.8 g. (0.186 mole) of 5-aminotoluene-2-sulfonic acid in 100 cc. of water and 60 cc. (0.6 mole) of 10 *N* hydrochloric acid was diazotized at 8–10° with 24.8 cc. (0.186 mole) of 7.5 *N* sodium nitrite solution. The slurry which resulted was added in 45 minutes to a solution of 0.18 mole of cuprous chloride in 100 cc. of 12 *N* hydrochloric acid, adding ice internally as needed to maintain the temperature at 5–8°. The cuprous chloride was prepared from 90 g. (0.36 mole) of copper sulfate by sulfite reduction.[15] The reaction mixture was allowed to stir to room temperature overnight and the product was isolated as the sodium salt by the addition of sodium chloride, filtration and washing with sodium chloride solution. It formed shiny, colorless plates; yield 37.1 g. (87%). It was purified for analysis by precipitation from absolute ethyl alcohol with petroleum ether.

*Anal.* Calcd. for $C_7H_6ClO_3NaS$: C, 36.8; H, 2.65; Cl, 15.5; S, 14.0. Found: C, 36.7; H, 2.64; Cl, 15.0; S, 14.3.

**5-Chloro-4-nitrotoluene-2-sulfonic Acid.**—A solution of 22.9 g. (0.1 mole) of sodium 5-chlorotoluene-2-sulfonate in 50 g. of 96.9% sulfuric acid and 10.0 g. (0.127 mole) of 80% nitric acid was prepared at 5°, then warmed slowly to 50° during one hour and finally held at 50° for ten minutes. The reaction mixture was poured into ice-water, neutralized with sodium hydroxide, and filtered. The product crystallized from 80 cc. of water as cream colored needles; yield 22.3 g. (82%). For identification, it was converted to the cyclohexylamine salt, m.p. and mixed m.p. 249–250° (cor.).

**Sodium 5,5′-Dichloro-4,4′-dinitrostilbene-2,2′-disulfonate.**—Sodium 5-chloro-4-nitrotoluene-2-sulfonate (22.8 g., 0.084 mole) was dissolved in 400 cc. of water at 60° and 40 cc. of 30% sodium hydroxide solution was added. Sodium hypochlorite solution, 100 cc. (7% by weight active chlorine), was added dropwise over a period of 20 to 40 minutes at 60° with stirring; it is essential to maintain a positive starch–iodide paper test at all times. It was stirred an additional 10 to 30 minutes until the starch–iodide test became very faint. Salt (120 g.) was added and the slurry was cooled to 20°, filtered, and the cake was washed with five 10-cc. portions of 20% salt solution. After drying at 60°, there was obtained 7.8 to 9.5 g. (26–32%) of bright yellow needles, which titrated about 77% pure by 0.1 *N* potassium permanganate titration. The *o*-toluidine salt was obtained in the form of uniform needles after recrystallization from Pentasol, decomposition point above 360°.

*Anal.* Calcd. for $C_{28}H_{26}O_{10}N_4Cl_2S_2$: C, 47.1; H, 3.67. Found: C, 46.9; H, 3.69.

The barium salt precipitated from an aqueous solution of the sodium salt in the form of uniform, golden yellow, boat-shaped crystals.

**5,5′-Dichloro-4,4′-dinitrostilbene-2,2′-disulfonic Acid.**—A slurry of 23.2 g. of barium 5,5′-dichloro-4,4′-dinitrostilbene-2,2′-disulfonate in 300 cc. of water and 17 cc. of 5 *N* sulfuric acid was boiled for a few minutes, filtered hot, cooled and added to 600 cc. of concentrated hydrochloric acid. The slurry was cooled, filtered, and the cake was washed with 60 cc. of 1:2 water:concentrated hydrochloric acid solution and dried at 60° to give 18.6 g. (93%) of uniform yellow needles, decomposition point 260°. Recrystallization from glacial acetic acid did not improve the decomposition point nor the crystalline form. The material was very hygroscopic and lost 20% water content on drying at 100° and 2 mm. pressure.

*Anal.* Calcd. for $C_{14}H_8O_{10}N_2Cl_2S_2 \cdot H_2O$: C, 32.5; H, 1.94; N, 5.42; S, 12.4. Found: C, 32.3, 32.3; H, 2.36, 2.27; N, 5.82; S, 12.4.

**5,5′-Dichloro-4,4′-diaminostilbene-2,2′-disulfonic Acid.**—A solution of 17.6 g. (0.035 mole) of 5,5′-dichloro-4,4′-dinitrostilbene-2,2′-disulfonic acid in 100 cc. of water was added dropwise over a period of 50 minutes to a vigorously stirred mixture of 100 g. (1.8 moles) of powdered iron (Master Builder's iron, Grade D), 200 cc. of water and 2 cc. of glacial acetic acid at the boiling point. The mixture was heated under reflux for an additional 1.5 hours, cooled somewhat, made basic with solid sodium carbonate, filtered, and the iron sludge was washed with water. The filtrate was cooled, acidified with hydrochloric acid, filtered, and the solid was washed with 25 cc. of ice-water and dried at 100° *in vacuo*. There was obtained 15.2 g. (93%) of cream-colored uniform needles.

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*Anal.* Calcd. for $C_{14}H_{12}O_6N_2Cl_2S_2 \cdot H_2O$: C, 36.8; H, 3.08; N, 6.13; S, 14.0. Found: C, 36.5; H, 3.97; N, 5.95; S, 13.7.

**Acylation of 5,5'-Dichloro-4,4'-diaminostilbene-2,2'-disulfonic Acid.**—All the benzoylations with substituted benzoyl chlorides were carried out in essentially the same way. The substituted benzoyl chloride, 0.03 to 0.06 mole, was added dropwise slowly to a slurry of 4.4 g. (0.01 mole) of 5,5'-dichloro-4,4'-diaminostilbene-2,2'-disulfonic acid in 150 cc. of dry, redistilled pyridine at the boiling point. The free amine test usually became negative within a few minutes; the test was made by diazotizing a test portion in the inverse manner and spotting *vs.* an alkaline solution of 2-naphthol-3,6-disulfonic acid (R-salt). The mixture was drowned in 150 cc. of water and made basic by the addition of 10% sodium carbonate solution. The pyridine was removed by steam distillation and the residual slurry, or solution, in the flask was cooled, or salted, to induce crystallization. It was filtered, the cake was washed with 2% salt solution, dried at 100° *in vacuo*, and recrystallized from water or aqueous alcohol solution, if necessary, for purification.

**Sodium 4,4'-Bis-(phenylcarbamylamino)-5,5'-dichlorostilbene-2,2'-disulfonate.**—5,5'-Dichloro-4,4'-diaminostilbene-2,2'-disulfonic acid (4.4 g., 0.01 mole) was dissolved in 100 cc. of water by the addition of sufficient 10% sodium carbonate solution to give a weakly basic test. Phenyl isocyanate (4.8 g., 0.04 mole) was added dropwise and the mixture was stirred at 40° for 24 hours. It was cooled to 20°, filtered, and the cake was washed with four 25-cc. portions of 2% salt solution and dried at 100° *in vacuo*. There was obtained 5.5 g. of a white solid which gave a negative free amine test. It was purified by solution in water, filtration and precipitation with salt.

*Anal.* Calcd. for $C_{28}H_{20}O_8N_4Cl_2Na_2S_2 \cdot 5H_2O$: C, 41.4; H, 3.70; N, 6.90; Cl, 8.74; S, 7.90. Found: C, 41.8, 41.5; H, 3.55, 3.43; N, 6.87; Cl, 8.27; S, 7.61.

**Sodium 4,4'-Bis-(4,6-dianilino-1,3,5-triazinylamino)-5,5'-dichlorostilbene-2,2'-disulfonate.**—5,5'-Dichloro-4,4'-diaminostilbene-2,2'-disulfonic acid (4.4 g., 0.01 mole) was dissolved in 90 cc. of water by adding sufficient 10% sodium carbonate solution to give a weakly basic test. The solution was cooled to 0° and a solution of 3.7 g. (0.02 mole) of cyanuric chloride (recrystallized from carbon tetrachloride, m.p. 144–145°) in 80 cc. of acetone was added dropwise at such a rate that the temperature did not rise above 0°. The acidity was adjusted periodically to negative to congo red paper and positive to methyl red yellow paper by the addition of sodium carbonate solution (total usage 8.6 cc. of 10 g./100 cc. solution). The free amine test was negative within ten minutes after the cyanuric chloride addition was complete. Aniline (18.6 g., 0.2 mole) was added and solvent was distilled until the boiling point rose to 99°, water (100 cc.) being added dropwise simultaneously to maintain constant volume. Aniline (18.6 g., 0.2 mole) was added and the mixture was heated under reflux for 45 minutes. It was made basic by the addition of 10% sodium carbonate solution, and the excess aniline was removed by steam distillation. The slurry was cooled, filtered, and the cake was washed with four 25-cc. portions of 2% salt solution and dried at 100° *in vacuo*. There was obtained 10.4 g. of a light tan solid. It was stirred with 1000 cc. of hot 40% by volume aqueous alcohol, filtered, and the alcohol was removed from the filtrate by steam distillation. The residual suspension, *ca.* 750 cc., was cooled, salted with 15 g. of salt, filtered and dried at 100° *in vacuo*. There was obtained 7.2 g. of a light tan solid which contained salt and water of hydration but which gave the correct C/N and C/S ratios on analysis.

*Anal.* Calcd. for $C_{44}H_{32}O_6N_{12}Cl_2Na_2S_2$: C, 52.6; H, 3.18; N, 16.8; Cl, 7.05; S, 6.38. Found: C, 40.7; H, 2.85; N, 13.0; Cl (total), 16.7, 16.4; S, 4.75. Calcd. C/N, 3.66; C/S, 22. Found: C/N, 3.66; C/S, 22.8.

**Acyl Derivatives of 4,4'-Diaminostilbene-2,2'-disulfonic Acid.**—The corresponding acyl derivatives of 4,4'-diaminostilbene-2,2'-disulfonic acid were made in the same way as those from 5,5'-dichloro-4,4'-diaminostilbene-2,2'-disulfonic acid.

**2-Chloro-4-nitrotoluene.**—This compound was prepared substantially by the method of Ullmann and Wagner.[16]

**Sodium 2-Chloro-4-nitrotoluene-6-sulfonate.**—A solution of 155 g. (0.9 mole) of 2-chloro-4-nitrotoluene in 610 g. of 30% oleum (2.3 moles of sulfur trioxide) was stirred at 75° for two hours and then allowed to stand overnight without further heating. It was drowned in 2720 g. of ice, Super-Cel was added, and the mixture was filtered. Salt, 680 g., was dissolved in the filtrate, the slurry was filtered, and the cake was washed with five 100-cc. portions of 20% salt solution. It was dried at 100° *in vacuo*. There was obtained 273.3 g. of a light brown solid. The *o*-toluidine salt was obtained in the form of prisms, decomposition point 271°, after recrystallization from 50% by volume aqueous alcohol solution.

*Anal.* Calcd. for $C_{14}H_{15}O_5N_2SCl$: C, 46.9; H, 4.21. Found: C, 47.0; H, 4.29.

**2-Chloro-4-nitrotoluene-6-sulfonyl Chloride.**—Sodium 2-chloro-4-nitrotoluene-6-sulfonate, (150 g. crude), 150 g. (0.72 mole) of phosphorus pentachloride and 150 cc. of phosphorus oxychloride were stirred and heated under reflux for one hour, cooled, drowned in 3 l. of ice and water, filtered, and the cake was thoroughly washed with water. After drying *in vacuo*, there was obtained 92.8 g. (69%, two steps) of a brown solid.

**Phenyl 2-Chloro-4-nitrotoluene-6-sulfonate.**—Phenol (65 g., 0.7 mole) was dissolved in 110 g. (1.4 moles) of redistilled pyridine and 92.8 g. (0.34 mole) of 2-chloro-4-nitrotoluene-6-sulfonyl chloride was added portionwise below 20° with good stirring. The mixture was stirred for three hours without further cooling. It was drowned in ice and water containing excess sodium hydroxide solution. The organic material was extracted with 1 liter of benzene and the benzene solution was washed successively with two 500-cc. portions of 0.5 *N* sodium hydroxide, two 500-cc. portions of 1 *N* hydrochloric acid, and two 500-cc. portions of water. The benzene was removed by evaporation and the solid was dried at 50° *in vacuo*. There was obtained 53.7 g. (57%) of a tan solid. Recrystallization from 400 cc. of Pentasol, including a treatment with 6 g. of Darco G-60, gave 47.1 g. (50%) of uniform white needles, m.p. 92°.

*Anal.* Calcd. for $C_{13}H_{10}O_5NClS$: C, 47.6; H, 3.08; N, 4.27; Cl, 10.8; S, 9.80. Found: C, 47.3; H, 3.12; N, 4.42; Cl, 10.9; S, 9.90.

**Cyclohexylammonium 6,6'-Dichloro-4,4'-dinitrostilbene-2,2'-disulfonate.**—Phenyl 2-chloro-4-nitrotoluene-6-sulfonate, 5.0 g. (0.015 mole), was dissolved in 300 cc. of methanol. A rapid stream of oxygen was passed through the solution and rapid stirring was commenced. Potassium hydroxide solution (30 cc. of 50% aqueous solution) was added, and the stirring and oxygen stream was continued for five minutes. The solution became a deep blue-green, then an orange-yellow, and considerable solid separated, most of which passed back into solution. The solid was removed by filtration, washed with methanol, and dried at 60°. It amounted to 0.8 g. and was apparently the diphenyl ester of the desired stilbene. The methanolic filtrate was acidified with 35 cc. of concentrated hydrochloric acid and the potassium chloride formed was removed by filtration. The filtrate was evaporated to dryness. The residue amounted to 7.2 g. The phenol was removed by steam distillation. The residual solution, *ca.* 150 cc., was cooled to room temperature and 30 cc. of 1 *N* cyclohexylamine hydrochloride solution was added with stirring. The slurry was allowed to stand an hour, was filtered, and the cake was washed with a little water and dried at 60°. There was obtained 2.0 g. of a light yellow solid. Attempts to recrystallize the product from water, water–alcohol, or water–acetone mixtures failed so it was used without purification.

**6,6'-Dichloro-4,4'-diaminostilbene-2,2'-disulfonic Acid.**—A mixture of 4.4 g. (0.006 mole) of cyclohexylammonium 6,6'-dichloro-4,4'-dinitrostilbene-2,2'-disulfonate in 50 cc. of water and 11 cc. of 10% sodium carbonate solution (10 g./100 cc. solution) was subjected to steam distillation until no further cyclohexylamine came over. The residual solution, about 100 cc., was added dropwise over a period of 45 minutes to a vigorously stirred mixture of 20 g. (0.36 mole) of powdered iron (Master Builder's iron, Grade D), 100 cc. of water and 2 cc. of concentrated hydrochloric acid at the boiling point. The mixture was stirred and heated under reflux for an additional hour, made alkaline with sodium carbonate, filtered, and the iron sludge was washed with a little water. The filtrate was acidified with concentrated hydrochloric acid, cooled, filtered, and the cake was washed

(16) F. Ullmann and C. Wagner, *Ann.*, **355**, 360 (1907).

with a little water and dried at 100° *in vacuo*. There was obtained 1.5 g. of an orange-yellow solid. It gave a reddish blue color when tetrazotized and coupled with alkaline 2-naphthol-3,6-disulfonic acid (R-salt).

**Acylation of 6,6'-Dichloro-4,4'-diaminostilbene-2,2'-disulfonic Acid.**—The acylation of this compound with 2,4-dimethoxybenzoyl chloride and with *o*-ethoxybenzoyl chloride was done in same way as in the case of the 5,5'-dichloro analog.

**2-Ethoxy-2'-chlorobenzanilide.**—Mrs. Nancy Buckwalter prepared this compound for us by the Schotten–Baumann reaction and recrystallized it twice from alcohol; m.p. 75°.

*Anal.* Calcd. for $C_{15}H_{14}O_2NCl$: C, 65.3; H, 5.12; N, 5.08; Cl, 12.9. Found: C, 65.2; H, 5.13; N, 5.21; Cl, 12.8.

**Ultraviolet Absorption Data. A. Nomenclature.**—The spectra are plotted as $\log_{10}$ molar absorptivities *vs.* wave length in mμ.

**B. Preparation of Solutions.**—About 0.250 g. of each dye was weighed and dissolved in 400 ml. of distilled water by boiling for two minutes. The solution was then cooled to room temperature and diluted to 500 ml.. A 6.25-ml. aliquot was pipetted into a 250-ml. low actinic volumetric flask containing 200 ml. of water buffered to pH 9.0 ± 0.3. The solution was then diluted to the mark with distilled water. Benzanilide and its two derivatives were dissolved in and diluted with 95% ethanol in similar fashion.

All operations of dissolving and diluting the samples were performed in dim light and low actinic (red) flasks were used for making dilutions and storing. Extreme precaution was also used when filling the Beckman cells in order to minimize the light admitted to the sample. Direct sunlight and strong indirect lighting were avoided.

The spectra were determined on a Beckman Model DU quartz spectrophotometer over the range 210–400 mμ, in 1.000 ± 0.003 cm. cells, at 25–28°.

**Acknowledgment.**—The authors wish to thank Miss M. R. O'Rourke for the absorption data and other observations, Dr. S. M. Davis for valuable suggestions based on infrared observations, Miss Alice Kantor for certain preparations, and Mr. O. E. Sundberg and his associates for the microanalyses.

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[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE STATE UNIVERSITY OF IOWA]

# The Synthesis of Substituted β-Thienyl- and β-Furylglutaric Acids

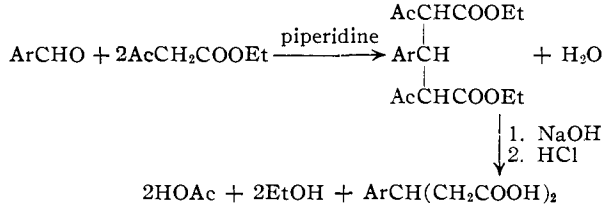
BY WALTER T. SMITH, JR.,[1] AND ROBERT W. SHELTON

RECEIVED JANUARY 6, 1954

Heterocyclic aldehydes have been condensed with ethyl acetoacetate in the presence of piperidine to give ethyl bis-acetoacetates. These products were cleaved with alkali to give β-substituted glutaric acids. Eleven new ethyl bis-acetoacetates and ten new β-substituted glutaric acids are reported.

β-Alkylglutaric acids often have been prepared by treating the appropriate aldehyde with malonic acid,[2] malonic ester[2–4] or cyanoacetamide,[5,6] followed by hydrolysis and decarboxylation. This method usually affords good yields and is readily adapted to the preparation of various substituted glutaric acids but has the disadvantage of being rather long. A less versatile method is that employing the condensation of ethyl sodiomalonate[7–9] or ethyl sodiocyanoacetate,[10,11] with substituted ethyl crotonates, and ethyl sodiocyanoacetate has also been treated with ethyl β-hydroxybutyrate.[12] Other limited methods include the permanganate oxidation of 4-alkylcyclopentenes[13,14] and the hypochlorite oxidation of 5-alkyl-1,3-cyclohexanediones.[15]

For the preparation of β-aryl glutaric acids, a convenient method was used by Knoevenagel[16] and later developed by Smith and Kort.[17] This method involved the piperidine-catalyzed condensation of an aromatic aldehyde with two moles of ethyl acetoacetate to give an ethyl benzal-bis-acetoacetate, which upon hydrolysis with concentrated alkali solution and subsequent acidification gave the corresponding β-arylglutaric acid.




It was the purpose of the present work to determine whether this synthetic method could be extended to include the preparation of glutaric acids having heterocyclic residues in the β-position.

Twelve heterocyclic aldehydes were successfully condensed with ethyl acetoacetate to give the corresponding ethyl bis-acetoacetates in yields of 24–77%. The data for these products are summarized in Table I. Condensation attempts with 2-quinolinecarboxaldehyde, 3-indolecarboxaldehyde, 3-thianaphthenecarboxaldehyde and 5-nitro-2-furaldehyde were unsuccessful.

Hydrolysis of the bis-esters with concentrated alkali resulted in the formation of ten new β-substituted glutaric acids in yields of 52–73%. These

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