PART - III

DYES

(STRUCTURE-SPECTRA CORRELATION.)
INTRODUCTION

Compared to many other heterocyclic systems, relatively little is known about the chemical reactivity of imidazo-[1,2-a] pyridine and pyrrolo pyridine. A recent review by Mosby\textsuperscript{2} and an older review by Kickhoffen\textsuperscript{1} expertly summarise material published on this heterocyclic system while some publication dealing mainly with preparative methods have appeared since this area was reviewed. Azapyrrocoline is known to be as basic as 2-amino pyridine ($pK_a = 6.7$)\textsuperscript{3}.

The frontier-electron densities and the calculation of total $\pi$ electron suggest that electrophilic substitution of imidazo [1,2-a] pyridines should occur at C-3. While the total $\pi$-electron densities predict almost equally probable substitution at several other positions, the frontier-electron distribution suggests quite strongly that the most preferred position of substitution is position -3.

Mosby\textsuperscript{2} states that the most important resonance contributing structures of imidazo [1,2-a] pyridine (I) are Ia and Ib.
On this basis, electrophilic attack occurs most readily at position-3. One can easily write the contribution of structure Ic, which would predict electrophilic substitution at position-2. There are very few known examples of electrophilic substitution in the imidazo [1,2-a] pyridine ring. Some of these are given in scheme-1.

It is noteworthy that in the study of electrophilic substitution reactions of imidazo [1,2-a] pyridine in each instance a single monosubstituted product was obtained with apparently no significant amount of contaminating isomer. Indeed this compound falls to the category of Hückel aromatic nucleus with considerable delocalisation of π electrons.

Since both pyrrocoline and aza pyrrocoline possess a
built-in carbanion system, it has been considered worthwhile to study more about these molecules by preparing benzylidene type of dyes, and from their absorption spectra, to know position of electrophilicity by the application of FE model.
Section - 2

APPLICATION OF FE MODEL TO CALCULATE THE VALUE OF $\lambda_{\text{max}}$.

The simplest delocalised orbitals that can be constructed are the free particle orbitals for particles in boxes. The conjugated chains can be thought of as 'boxes' in which the $\pi$ electrons behave as free particles in a potential well presenting likeness to that of the (CT) core. The wave function and the orbital energies of a particle in a one dimensional box is given by equation (1) and (2) respectively.

$$\psi_j = \sqrt{\frac{2}{L}} \sin \frac{j \pi x}{L}$$

$$\epsilon_j = \frac{\hbar^2 j^2}{8mL^2}$$

[Even chain $L=Nx1$, odd chain $L=(N+1)l$.]

where $L =$ length of the well.

The energy of the lowest transition ($\psi_n \longrightarrow \psi_{n+1}$) is

$$\epsilon_g - \epsilon_f = \frac{(n+1)^2 \hbar^2}{8mL^2} - \frac{n^2 \hbar^2}{8mL^2}$$

$$= \frac{(2n+1) \hbar^2}{8mL^2}$$

(2)

This method has also been applied successfully to calculate the absorption maximum in cyanine dyes. For cyanine dyes with two terminal nitrogens, it has also been suggested that only $2n$ of the $2n+2$ electrons are truly free.

The long wave length transition in a conjugated system has been calculated by employing the equation (2), which can be
written as (3) and (4).

\[ \lambda = \frac{hc}{\Delta E} = \frac{8mL^2c}{(2n+1)h} \quad \ldots (3) \]

\[ = \frac{33L^2}{(2n+1)} \quad \ldots (4) \]

where \( m = 9.1 \times 10^{-23} \text{ g} \), \( c = 3.0 \times 10^{10} \text{ cm} \), \( h = 6.6 \times 10^{-27} \text{ g cm}^{-2} \text{ sec}^{-1} \).

For an acyclic analogue of the cyanine dye, \((\text{Me})_2N^+ = \text{CH}-(\text{CH}=\text{CH})_r-N(\text{Me})_2\), Simpson transformed the equation (4) to the following equation (5).

\[ \lambda = \frac{8mL^2c}{(2r+5)h} = \frac{33L^2}{(2r+5)} \quad \ldots (5) \]

The average length of the chromophore is considered to be 2.48 \( \text{Å} \) and the additive term to allow for the length of the bonds outside this group is 5.04 \( \text{Å} \). So a value of \((2.48r + 5.04) \text{Å}\) has been used for \( L \), the length of the potential box.

The benzylidene type of dyes prepared from 2-phenyl pyrrocoline and dimethylamino benzaldehyde can have the following structures II and III depending on the electrophilic property of position 1 or 3.

The values of \( \lambda_{\text{max}} \) calculated with the help of the equation (5) are 467.25 m\( \mu \) (\( n=3 \), structure II) and 574.2 m\( \mu \) for structure III. The experimentally obtained value of \( \lambda_{\text{max}} \) is 605.0 m\( \mu \), which agrees with the calculated value for structure III. This, therefore, is another evidence for the greater electrophilicity of position 3.
APPLICATION OF FE MODEL TO EXPLAIN THE INFLUENCE OF REPLACEMENT OF -CH = by -N =.

Influence of heteroatom:

Consider, for instance, the odd atom polyene anion \( \text{C}_5\text{H}_7^- \) with six \( \pi \) electrons. The doubly filled non bonding orbital is given by equation (6).

\[
3 = \frac{1}{\sqrt{3}} (\phi_1 + \phi_3 + \phi_5) \quad \ldots \ldots (6)
\]

Let the central -CH = group be replaced by -N = atom to form the \((\text{CH}_2 = \text{CH-N = CH-CH}_2)^-\) skeleton. The replacement is like a small perturbation "H" causing a change \( \Delta \alpha = \alpha_N - \alpha_C \) of the coulomb integral for the central atom in the original chain. The change in energy is given by equation (7) and (8) respectively for the filled \( f \) and empty \( g \) orbital.

\[
\begin{align*}
\Delta (\varepsilon_f) &= \int \psi_f^* H' \psi_f \, d\tau = q_3^{(f)} \Delta \alpha = \frac{1}{3} \Delta \alpha \quad \ldots \ldots (7) \\
\Delta (\varepsilon_g) &= \int \psi_g^* H' \psi_g \, d\tau = q_3^{(g)} \Delta \alpha = 0 \quad \ldots \ldots (8)
\end{align*}
\]

where \( q_3^{(f)} \) and \( q_3^{(g)} \) are the partial charge densities at the atom 3. The change in transition energy is therefore given by equation (9).

\[
\Delta (\varepsilon_g - \varepsilon_f) = - \frac{1}{3} \Delta \alpha > 0 \quad \ldots \ldots (9)
\]

So this substitution causes a shift towards higher frequencies i.e. a blue shift with systems of \( 4n' + 1 \) atoms. But with systems
of $4n' + 3$ atoms this causes a red shift. Hence the general rule can be stated as "aza substitution at a terminal atom or any atom separated from it by an even number of bonds is at an antinode of the f orbital and should give blue shifts; at the other atoms it is at a node of the f orbital and should give red shifts".

In order to verify this generalised statement, 2-phenyl pyrrocoline and 1-aza 2-phenyl pyrrocoline have been synthesised by the scheme given below (scheme-2).

![Scheme-2]

Each was separately condensed with DAB and NDA (structure-IV). The following table (Table 1) shows the experimentally obtained results.

IV

$Y = -CH$ when $X = \equiv CH \equiv$ and $\equiv N \equiv$

$Y = -N$ when $X = \equiv CH \equiv$ and $\equiv N \equiv$
Table 1

Values of $\lambda_{\text{max}}$ in m$\mu$ for the dyes derived from 2-phenyl pyrrocoline and 1-aza 2-phenyl pyrrocoline.

<table>
<thead>
<tr>
<th>Basic nuclei</th>
<th>Condensed with</th>
<th>$\lambda_{\text{max}}$ in m$\mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-phenyl-pyrrocoline</td>
<td>DAB</td>
<td>605</td>
</tr>
<tr>
<td></td>
<td>NDA</td>
<td>695</td>
</tr>
<tr>
<td>1-Aza 2-phenyl-pyrrocoline</td>
<td>DAB</td>
<td>580</td>
</tr>
<tr>
<td></td>
<td>NDA</td>
<td>680</td>
</tr>
</tbody>
</table>

In this molecule the replacement of $-\text{CH} = -\text{N} =$ at position 1, results in a blue shift. This atom is separated from the terminal atom by even number of bonds and hence is at the antinode of the 'f' orbital (according to nomenclature of Platt$^6$) and should give blue shift, which is found to be true whereas because the $-\text{N} =$ atom of the chain is separated by odd number of bonds from the terminals, such a replacement should result in a red shift, which is also found to be true. The shift in absorption frequency due to a replacement at position 1 is by 15-25 m$\mu$ whereas that due to a replacement at the benzylic carbon is by 90-100 m$\mu$. This can be explained as follows.

Replacement in the chain (Replacement at a point separated from odd number of bonds from the terminal).
The characteristic charge in the structure (V ↔ Va) is +C- or +N-. Since +C- is more stable than +N-, the contribution of the structure Va is more in the ground state with +C- than with +N-. Therefore due to the replacement, of the ground state is relatively destabilised and hence the value of $\Delta E$ decreases; therefore a bathochromic shift results according to Foster's rule.

Replacement in the ring (Replacement at a point separated by even number of bonds from the terminals).

The characteristic charge in this dye is +N-. Since +N- is more stable than +C-, the same argument as above can be advanced for the hypsochromic shift due to replacement.

If the relative contribution of structures Va and Via is judged, then it can be seen that the contribution of Va is very much more significant than that due to Via and therefore bathochromic shift is greater than hypsochromic shift. The value of $\lambda_{\text{max}}$ for the diaza compound can be calculated as follows:

$$\lambda_{\text{max}}(\text{diaza}) = \lambda_{\text{max}}(\text{structure IV, } Y=\text{-CH}=) + \text{Bathochromic shift (IV, } Y=\text{-CH}=, X=\text{-N}=) - \text{Hypsochromic shift (IV, } X=\text{-N}=, X=\text{-CH}=)$$

$$= (605 + 90 - 25) \text{ m}\mu = 670 \text{ m}\mu .$$

The experimentally obtained value = 680 m$\mu$. This type of observation has also been made by Rout et al.
Section - 4

SYNTHESIS OF 2-PHENYL PYRROCOLINE AND 1-AZA 2-PHENYL PYRROCOLINE.

Synthesis of N-phenacyl 2-picolinium bromide:—

2-Picoline (9.3 gms, 1 mole) and phenacyl bromide (19.9 gms, 1 mole) were refluxed in benzene over water bath for three hours. The salt was separated out which was filtered, washed with ether and air dried. (m.p. 185-86°C, yield 80%, Found Br, 27.30; C_{14}H_{14}NOBr requires 27.39% Br.)

Synthesis of 2-phenyl pyrrocoline:—

N-phenacyl picolinium bromide (2.02 gms, 1 mole) was dissolved in absolute alcohol (10 ml). Sodium hydroxide (2N, 10 ml) was added to it and stirred for half an hour. The precipitate was filtered and was crystallised from absolute alcohol (m.p. 120°C, yield 70%; Found C, 86.92; H, 5.68; N, 7.0; C_{14}H_{11}N requires C, 87.04; H, 5.699; N, 7.23%).

Synthesis of 2-phenyl pyrrocolinium perchlorate:—

2-Phenyl pyrrocoline (1.93 gm, 1 mole) was reacted with 70% perchloric acid (1.5 ml) and 10 c.c. of water was added to it. The mixture was heated slowly to dissolve the salt, thus formed. After chilling the solution for 2-3 hours needle shaped crystals separated out. (m.p. 150°C, yield 90%).

Synthesis of 1-aza 2-phenyl pyrrocoline (3-phenyl imidazo [1,2-a] pyridine):—

To a solution of 2-amino pyridine (0.92 gm, 1 mole) in 95% ethanol was added an ethanolic solution of phenacyl bromide
(1.99 gm, 1 mole). After the addition of two mole equivalent of sodium bicarbonate, the stirred mixture was refluxed for 14-22 hours. The dark brown reaction mixture was filtered and the filtrate was basified with 5% sodium hydroxide solution. The aqueous solution was extracted with chloroform several times. The combined extract was dried with anhydrous MgSO₄ and filtered. The chloroform was then removed under reduced pressure and residual solid was recrystallised from absolute alcohol (m.p. 14°C, yield 70%; Found C, 80.37; H, 4.93; N, 14.20; C₁₃H₁₀N₂ requires C, 80.41; H, 5.15; N, 14.43%).

1-Aza 2-phenyl pyrrocoline perchlorate:-
This salt was prepared by the method given earlier for the preparation of pyrrocolinium perchlorate.
SYNTHESIS OF THE BENZYLIDENE TYPE OF DYES AND THEIR AZA ANALOGUES FROM 2-PHENYL PYRROCOLINE AND 1-AZA 2-PHENYL PYRROCOLINE.

I. Synthesis of 3-(p-dimethyl amino benzylidene)2-phenyl pyrrocolinium perchlorate (Structure IV, X- = CH-, Y—CH=).

Pyrrocolinium perchlorate (0.29 gm, 1 mole) was dissolved in acetic anhydride (5 ml) was added to N:N-dimethyl amino benzaldehyde (0.149 gm, 1 mole) in acetic anhydride. The solution was heated over water bath for one hour. The acetic anhydride was removed under reduced pressure and the residue was treated with dry ether. The precipitate was filtered and washed with ether and dried in a vacuum desiccator.

II. Synthesis of 3-(p-dimethyl amino phenyl imino)2-phenyl pyrrocolinium perchlorate (Structure IV, X- =N-, Y—CH=)

Pyrrocolinium perchlorate (0.29 gm, 1 mole) was dissolved in acetic anhydride (5 ml) and to it p-nitros N:N-dimethyl aniline (0.148 gm, 1 mole) in acetic anhydride was added. The solution was heated over water bath for one hour. Acetic anhydride was removed under reduced pressure and the residue was treated with dry ether several times and was dried in the vacuum desiccator.

III. Synthesis of 3-(p-dimethyl amino benzylidene)1-aza 2-phenyl pyrrocolinium perchlorate (Structure IV, X- =CH-, Y—N=) and 3-(p-dimethyl amino phenyl imino)1-aza 2-phenyl pyrrocolinium perchlorate (Structure IV, X- =N-, Y—N=) were
prepared by condensing 1-aza pyrrocolinium perchlorate with p-dimethyl amino benzaldehyde and p-nitroso N:N-dimethyl aniline respectively in acetic anhydride by following the above procedure.

The m.p. etc. of all these dyes have been presented in table-2.

Table - 2
Melting point and analytical data of the dyes derived from 2-phenyl pyrrocoline and 1-aza 2-phenyl pyrrocoline.

<table>
<thead>
<tr>
<th>No. of X</th>
<th>Nature of Y</th>
<th>m.p. in °C</th>
<th>yield in %</th>
<th>λ_{max} in μ</th>
<th>% Carbon</th>
<th>% Hydrogen</th>
<th>% Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>=CH- -CH=</td>
<td>160</td>
<td>50</td>
<td>605</td>
<td>64.97</td>
<td>65.01</td>
<td>4.30</td>
</tr>
<tr>
<td>II</td>
<td>=N- -CH=</td>
<td>&gt;250</td>
<td>45</td>
<td>695</td>
<td>61.89</td>
<td>62.04</td>
<td>4.66</td>
</tr>
<tr>
<td>III</td>
<td>=CH- -N=</td>
<td>&gt;300</td>
<td>45</td>
<td>580</td>
<td>61.97</td>
<td>62.04</td>
<td>4.67</td>
</tr>
<tr>
<td>IV</td>
<td>=N- -N=</td>
<td>hygroscopic</td>
<td>40</td>
<td>680</td>
<td>58.96</td>
<td>59.09</td>
<td>4.38</td>
</tr>
</tbody>
</table>

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