

Syntheses, Structure, Properties and Chemistry of 1,1-Di(pyrrolyl)ethenes

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Reaction of a 2-unsubstituted pyrrole with acetic anhydride and stannic chloride unexpectedly promotes self-condensation to give symmetrical di(pyrrolyl)ethene as a side-product in 6–10% yield, but overall yields of these 1,1-di(pyrrolyl)ethenes can be improved to 66% using a rational alternate route; structure and chemistry of 1,1-di(pyrrolyl)ethenes **2** are discussed.

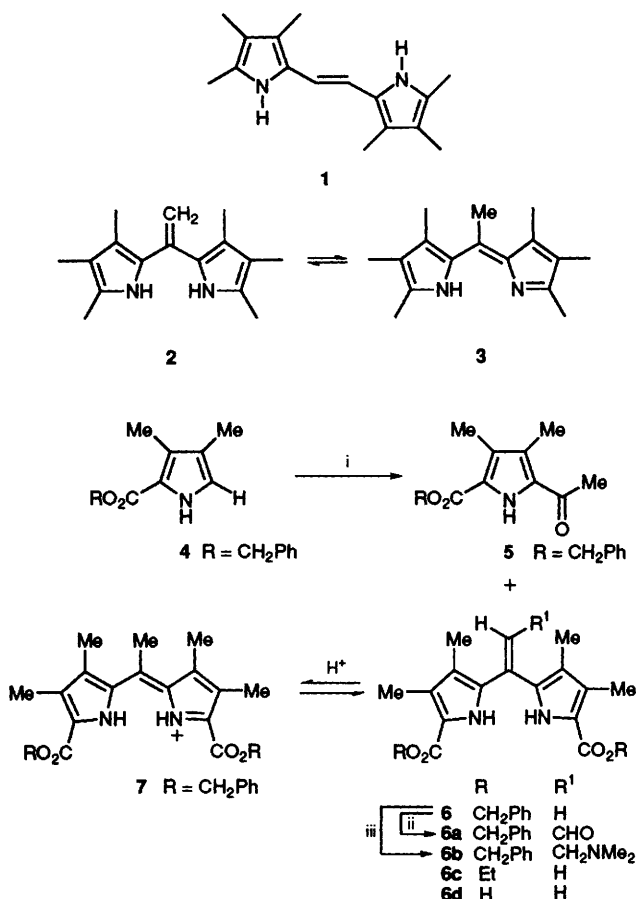
The synthesis, chemistry and spectroscopy of 1,2-di(pyrrolyl)ethenes **1** were discussed, in detail, by Hayes *et al.*¹ in 1965. Though BF₂ complexes have been reported,² the isomeric 1,1-di(pyrrolyl)ethenes **2**, have never been described, even though an intriguing tautomeric equilibrium with 5-methyldipyrromethene **3** is possible.

Attempted Friedel–Crafts acylation of benzyl 3,4-dimethylpyrrole-2-carboxylate **4** using acetic anhydride and tin(IV) chloride afforded the expected 2-acetylpyrrole **5** (86% yield), along with a minor, less polar product (6–12% yield).[†] ¹H, ¹³C NMR, mass spectrometry, elemental analyses, and single crystal X-ray‡ (Fig. 1) studies showed the minor product to be 1,1-di(pyrrolyl)ethene **6**. Fig. 1 shows that **6** is not completely planar (the two pyrrole rings are twisted against each other by 54.9°), providing a rationale for the absence of the (coloured) 5-methyldipyrromethene tautomer **3**.

When colourless **6**, in CH₂Cl₂, was treated with an excess of TFA in CH₂Cl₂ a pronounced red shift from 303 (ε 35 100) to 522 nm (ε 71 600) was observed for the salt **7** (Fig. 2). Also apparent in **7** was a three proton peak in the NMR spectrum, at δ 3.05, corresponding to the 5-methyl. When CF₃CO₂D was used, rapid disappearance of the 5-methyl group at δ 3.05 was observed in the proton NMR spectrum, indicating participa-

tion of the acid–base equilibrium **6** ⇌ **7**. Attempts to isolate **7** have so far failed. Upon treatment with protic solvents such as methanol or water, dipyrromethene **7** immediately reverted to the **6** as indicated by the disappearance of the red colour and by ¹H NMR spectroscopy. Presumably, the increased steric interactions experienced by the *meso*-substituted **7** are relieved by the formation of the nonplanar (Fig. 1), thermodynamically stable **6** (Scheme 1).

Yields in the synthesis of 1,1-di(pyrrolyl)ethenes were improved as follows. Acid catalysed condensation of 2-unsubstituted pyrrole **4** with chloroacetaldehyde diethyl acetal (Aldrich) using an excess of Montmorillonite K-10 clay and 15 equiv. of TFA in CH₂Cl₂ gave the desired 5-(chloromethyl)-



Scheme 1 Reagents and conditions: i, Ac₂O, SnCl₄; ii, POCl₃, DMF then hydrolysis; iii, CH₂=NMe₂+I⁻

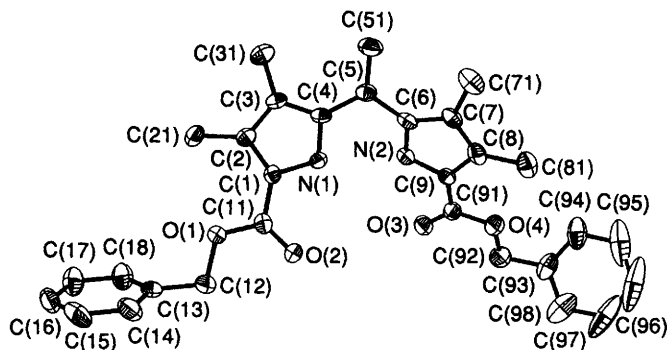


Fig. 1 X-Ray structure of **6**. Important bond length (Å) and angles (°): C(5)–C(51) 1.333(6); C(4)–C(5)–C(6) 118.0(3), C(4)–C(5)–C(51) 122.2(4), C(51)–C(5)–C(6) 119.8(4)

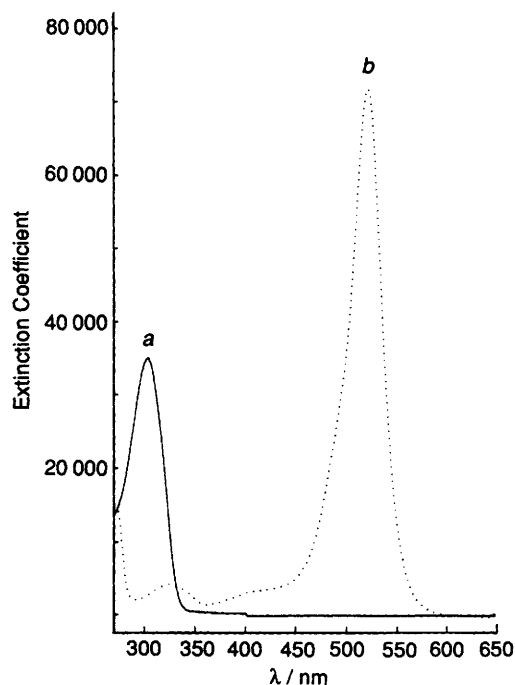
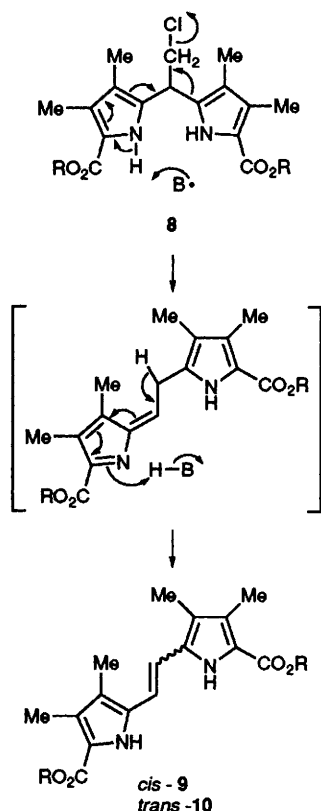


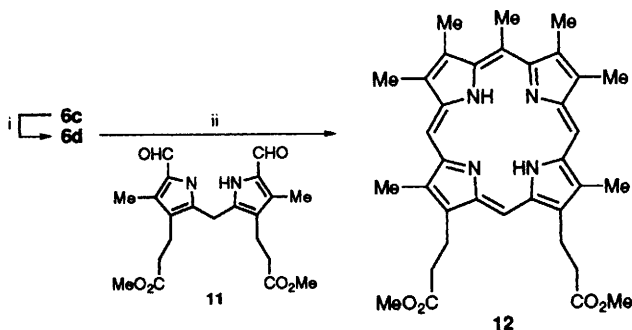
Fig. 2 Optical spectra, in CH₂Cl₂ of **6** (a) under neutral conditions (b) in presence of TFA (*i.e.* structure **7**)

dipyrrromethane **8** in 75–91% yields. Treatment of **8** with 1.3 equiv. of DBU in CH_2Cl_2 yielded the desired **6** in 66% yield after purification. Regardless of the conditions employed in the elimination reaction to form **6**, two minor fluorescent byproducts were always formed, and these were characterized by ^1H NMR spectroscopy and HRMS as the *cis*- and *trans*-1,2-di(pyrrolyl)ethenes **9** and **10**, respectively.¹ A proposed mechanism for their formation is shown in Scheme 2. Use of large excesses of base (*e.g.* up to 10 equiv.) for the elimination caused **9** and **10** to become major products. No ethylene dimers were ever formed in acidic media.

The vinyl group at the 5-position of dipyrrromethanes



Scheme 2 Proposed mechanism for the formation of 1,2-di(pyrrolyl)ethenes **9** and **10** during base catalysed elimination from **8**



appears to be highly reactive. For example, treatment of **6** with the Vilsmeier reagent from POCl_3 in DMF yielded the di(pyrrolyl)acrolein **6a** in 90% yield after intermediate imine hydrolysis.⁴ When **6** was treated with a large excess of dimethyl(methylene)ammonium iodide,^{5,6} 90–95% yields of the corresponding 1,1-di(pyrrolyl)-3-(dimethylamino)propane product **6b** were obtained.

1,1-Di(pyrrolyl)ethenes are also useful intermediates for the synthesis of *meso*-substituted porphyrins. For example, condensation of the 5-methylidene-dipyrromethane-1,9-dicarboxylic acid **6d** (obtained by saponification of the diethyl-1,9-dicarboxylate, **6c**) with the 1,9-diformyldipyrromethane **11** under modified⁷ MacDonald conditions⁸ gave the *meso*-methylporphyrin **12** in 13% yield, compared with a 28% yield using the corresponding 5-methylidipyrromethane (obtained by catalytic hydrogenation of **6**).

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Footnotes

† A similar acylation reaction in the indole series has also been observed³ to afford rosindoles existing in the methyl-methene (not 1,1-ethene disubstituted) form.

‡ *Crystal data for 6*: Yellow blocks; $\text{C}_{30}\text{H}_{30}\text{N}_2\text{O}_4$, monoclinic $P2_1/c$; $Z = 4$; $T = 130\text{ K}$, $\text{Mo-K}\alpha$, $a = 13.690(7)$, $b = 12.209(5)$, $c = 14.952(6)$ Å, $\beta = 91.14(4)^\circ$, $V = 2499(2)$ Å³; 2719 observed reflections with $F > 5.0 \sigma(F)$; all non-hydrogen atoms refined with anisotropic thermal parameters; $R = 0.063$. Atomic coordinates, bond lengths and angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre. See Information for Authors, Issue No. 1.

References

- 1 A. Hayes, A. H. Jackson, J. M. Judge and G. W. Kenner, *J. Chem. Soc.*, 1965, 4385.
- 2 A. Treibers and F.-H. Kreuzer, *Justus Liebigs Ann. Chem.*, 1968, 718, 208.
- 3 W. Borsche and H. Groth, *Justus Liebigs Ann. Chem.*, 1941, 549, 238.
- 4 A. W. Nichol, *J. Chem. Soc., C*, 1970, 903, K. M. Smith, G. M. F. Bisset and M. J. Bushell, *J. Org. Chem.*, 1980, 45, 2218.
- 5 J. Schreiber, H. Maag, N. Hashimoto and A. Eschenmoser, *Angew. Chem., Int. Ed. Engl.*, 1971, 10, 330.
- 6 R. K. Pandey, F.-Y. Shiau, N. W. Smith, T. J. Dougherty and K. M. Smith, *Tetrahedron*, 1992, 48, 7591.
- 7 J. A. S. Cavaleiro, A. M. d' A. Rocha Gonsalves, G. W. Kenner and K. M. Smith, *J. Chem. Soc., Perkin Trans. 1*, 1974, 1771.
- 8 G. P. Arsenault, E. Bullock and S. F. MacDonald, *J. Am. Chem. Soc.*, 1960, 82, 4384.