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

Hong Xie, David A. Lee, Mathias O. Senge and Kevin M. Smith*

Department of Chemistry, University of California, Davis, CA 95616, USA

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 BF_2 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, ^{13}C 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 CH_2Cl_2, was treated with an excess of TFA in CH_2Cl_2 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 CF_3CO_2D was used, rapid disappearance of the 5-methyl group at δ 3.05 was observed in the proton NMR spectrum, indicating participation 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 CH_2Cl_2 gave the desired 5-(chloromethyl)-

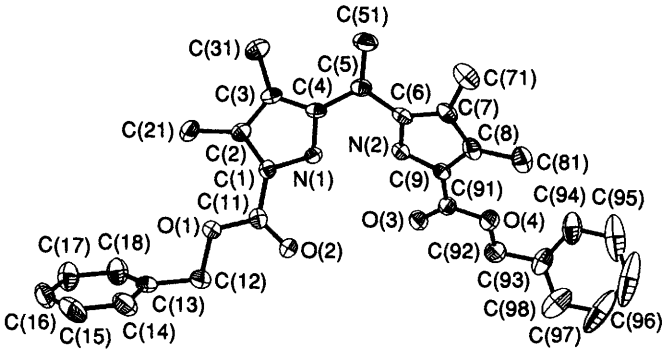
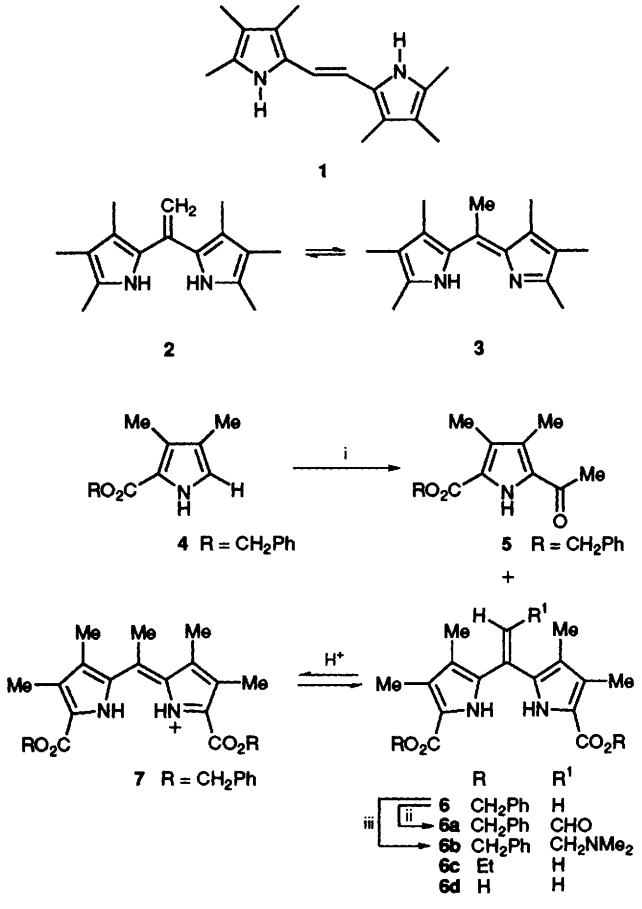


Fig. 1 X-Ray structure of **6**. Important bond length (Å) and angles (°): C(5)–C(51) 1.333(6); C(4)–C(5)–C(6) 118.0(3), C(4)–C(5)–C(51) 122.2(4), C(51)–C(5)–C(6) 119.8(4)



Scheme 1 *Reagents and conditions*: i, Ac_2O, $SnCl_4$; ii, $POCl_3$, DMF then hydrolysis; iii, $CH_2{=}NMe_2{}^+I^-$

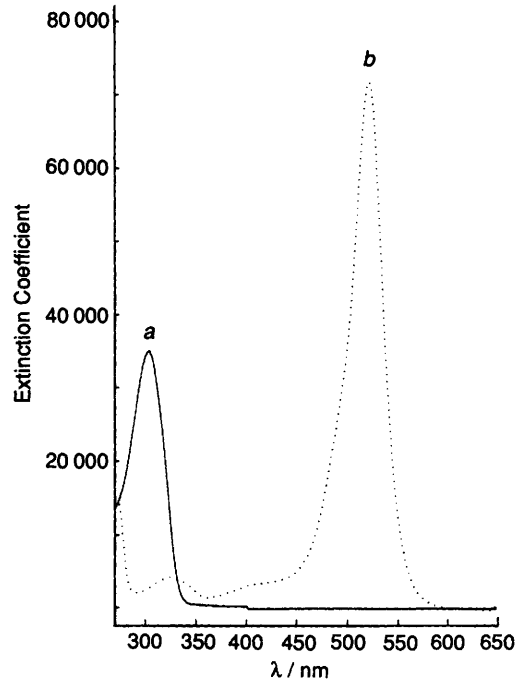
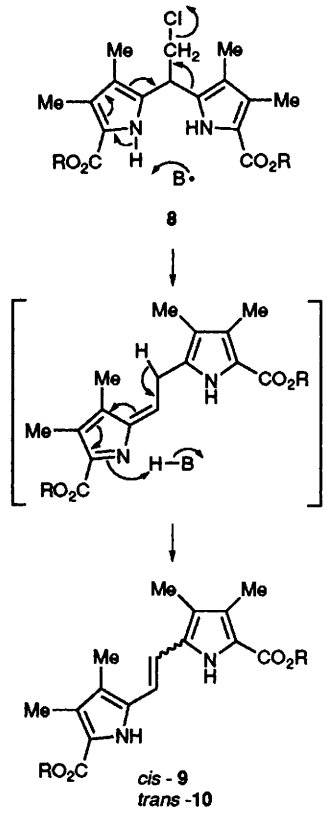


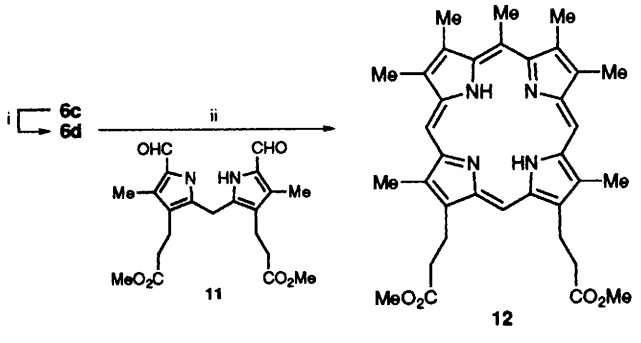
Fig. 2 Optical spectra, in CH_2Cl_2 of **6** (*a*) under neutral conditions (*b*) in presence of TFA (*i.e.* structure **7**)

dipyrromethane **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 dipyrromethanes



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 modified[7] MacDonald conditions[8] gave the *meso*-methylporphyrin **12** in 13% yield, compared with a 28% yield using the corresponding 5-methyldipyrromethane (obtained by catalytic hydrogenation of **6**).

This research was supported by grants from the National Institutes of Health (HL 22252) and the Deutsche Forschungsgemeinschaft (Se 54311-1). Mass spectrometric analyses were performed by the UCSF Mass Spectrometry Facility (A. L. Burlingame, Director) supported by the Biomedical Research Technology Programme of the National Center for Research Resources, NIH NCRR BRTP 01614.

Received, 12th November 1993; Com. 3/06791B

Footnotes

† A similar acylation reaction in the indole series has also been observed[3] to afford rosindoles existing in the methyl-methene (not 1,1-ethene disubstituted) form.

‡ *Crystal data* for **6**: Yellow blocks; $C_{30}H_{30}N_2O_4$, monoclinic *P2/c*; $Z = 4$; $T = 130$ K, Mo-Kα, $a = 13.690(7)$, $b = 12.209(5)$, $c = 14.952(6)$ Å, $\beta = 91.14(4)°$, $V = 2499(2)$ Å^3; 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. Treibs 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.