

One-flask synthesis of porphyrin metal complexes

Amaravathi Manda^{a*}, Mohan Babu Maradolla^a, Chandramouli Garimella^a and Giribabu Lingamallu^b

^aDepartment of Chemistry, National Institute of Technology Warangal (AP)-506004, India

^bNanomaterials Laboratory, Inorganic and Physical Chemistry Division, Indian Institute of Chemical Technology, Hyderabad (AP)-500 007, India

One-flask synthesis of metallo porphyrins by condensation of aromatic aldehydes with pyrrole in refluxing propionic acid in presence of corresponding metal acetates is described. The yields are better when compared to Rothmund and Adler–Longo methods.

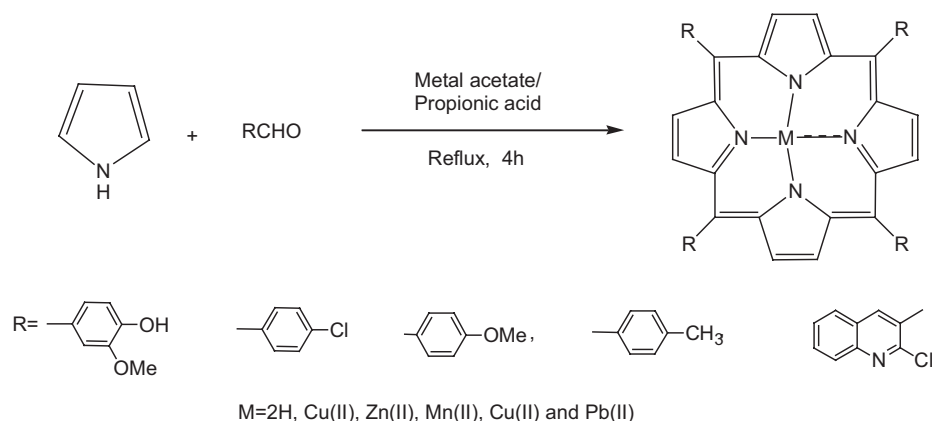
Keywords: metal acetates, propionic acid, pyrrole, vaniline

The chemistry of porphyrins and their metallo-derivatives has been an attractive subject for investigation over the past few decades because of its relevance to applications such as biomimetic photosynthesis, molecular electronics, supramolecular catalysis, organic synthesis, magnetic resonance imaging, photodynamic therapy, cytochrome P-450 function, *etc.*¹ Numerous research groups have developed model systems for these biological processes.²⁻⁴ A constant theme among these diverse areas is the creation of structured assemblies containing porphyrins and their metallo-derivatives located in well-defined chemical environments. The precise sculpturing of the porphyrin environment required the synthesis of porphyrin derivatives carrying functional groups attached at the periphery of the macrocycle. The meso-tetraphenyl-porphyrins and their metallo- derivatives offer attractive features in the context and have been used in a wide variety of model studies.

Rothmund first reported the synthesis of tetraphenyl porphyrin more than 50 years ago, by condensation of benzaldehyde and pyrrole in pyridine as solvent in a sealed bomb at 150°C for 24 h.⁵ Yields were low and the conditions so severe that few substituted benzaldehydes could be converted to the corresponding porphyrin. Adler–Longo modified the Rothmund reaction by allowing benzaldehyde and pyrrole to react for 30 min. in refluxing propionic acid (141°C) open to the air.⁶ These comparatively milder reaction conditions have allowed a wider selection of substituted benzaldehydes to be converted to the corresponding porphyrins in yields up to 20%. Later, Lindsey modified the synthetic methodology for improving yields of porphyrins. He allowed the aldehyde and pyrrole to react in chloroform at room temperature under anaerobic conditions in presence of an oxidising agent.⁷

By adopting this method, a variety of alkyl and aromatic aldehydes undergo the porphyrin reaction in up to 45% yield. Recently, Lindsey has also reported direct synthesis of palladium porphyrins from acyldipyrromethanes.⁸ All these methods involve the synthesis of free-base porphyrins only. There are no reports in the literature for synthesis of metallo-porphyrins in one step by condensation of aldehydes and pyrrole to our knowledge.

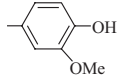
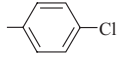
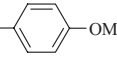
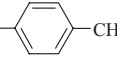
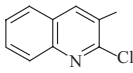
During the course of our work, we realised the formation of metallo-porphyrins in a single step when aromatic aldehydes and pyrrole were refluxed in propionic acid in presence of metal acetate (Scheme 1). In a typical reaction, a mixture of aromatic aldehyde (0.02M), pyrrole (0.02M) and metal acetate (0.01M) in freshly distilled propionic acid (60 ml) was refluxed for four hours in open air. The excess propionic acid was distilled under vacuum and neutralised with saturated sodium bicarbonate solution. The black coloured precipitate was filtered and purified by passing through a flash column using a mixture of chloroform:methanol (98:2) as eluent to give pure metallo-porphyrin. We have taken five different aromatic aldehydes, four different metal acetates and the results are presented in Table 1. The reactions were conducted with and without metal acetates and these results are also given in Table 1. The by-products formed in our reaction are less in quantity when compared to the Rothmund and Adler–Longo methods and hence purification is easy. It is clear from Table 1 that porphyrin metal complexes were obtained in greater yields in presence of the corresponding metal acetates. Moreover, the yields are greater in case of Cu(OAc)₂ and Zn(OAc)₂. We have observed two different porphyrins in the case of Mn(OAc)₂ and Pb(OAc)₂, one is the corresponding metallo-porphyrin and other one is free-base porphyrin.



Scheme 1

* Correspondent. E-mail: ammi_reddy@hotmail.com

Table 1 Yields of various metallo-porphyrins

Species no.	R	Mn(OAc) ₂	Cu(OAc) ₂	Zn(OAc) ₂	Pb(OAc) ₂	In absence of metal acetate ^a
1		8% ^c	28%	24%	11% ^d	21%
2			25%	24%		21%
3			28%	25%		22%
4			25%	26%		22%
5			15%	14%		12% ^b

^aFrom ref.9^bFrom ref.10.^c8% is the Mn(II) porphyrin and remaining 12% is corresponding free-base porphyrin. ^d11% is the Pb(II) porphyrin and remaining 10% is the corresponding free-base porphyrin.

In conclusion, we have developed a one-flask synthesis of metallo-porphyrins in good yields when compared to the Rothmund and Adler–Longo methods for the synthesis of porphyrins.

General procedure

A mixture of vaniline (3.04 g, 0.02M), pyrrole (1.34 g, 0.02M) and zinc acetate (2.2 g, 0.01M) in freshly distilled propionic acid (60 ml) was refluxed for four hours in open air. The excess of propionic acid was distilled under vacuum and the residue was neutralised with sodium bicarbonate solution. The black coloured precipitate obtained was filtered and dried. The residue was purified by passage through a flash column using chloroform:methanol (98:2) as solvent to get a dark red coloured compound [meso-tetrakis(3-methoxy-4-hydroxyphenyl)porphyrinato]zinc(II) (1.04 g, 24%). M.p. > 300°C. Anal. calcd. for C₄₈H₃₆N₄O₈Zn: C, 67.05; H, 4.2; N, 6.5. Found: C, 67.5; H, 4.2; N, 6.5%. FAB-MS *m/z* 861 (M + 1)⁺, requires 860. UV: λ_{max} nm (CHCl₃) (log ε): 428(5.218), 550 (4.19). ¹H NMR (CDCl₃ + d₆-DMSO) δ ppm: 8.92 (m, 8H, pyrrole β-protons), 7.74 (d, 4H, Ar-H), 7.59 (s, 4H, Ar-H), 7.25, 7.22 (d, 4H, Ar-H), 3.94 (s, 12H, 4x O-CH₃). IR (KBr) cm⁻¹: 3492–2500 (s, broad, O-H stretch), 1595, 1508, 1461, 1416 (m, aromatic C=C, C=N ring stretch), 928 (s, porphyrin macrocyclic bend), 803, 776 (m, aromatic C=C-H out-of plane bend). E_{1/2}: -1.05; 0.80, 1.00, 1.22 V vs. SCE

Synthesis of [meso-tetrakis(2-chloroquinolin-3-yl)porphyrinato]copper(II) (5Cu-II): A mixture of 2-chloro-6-methoxyquinoline-3-carboxaldehyde (**1b**), (443 mg, 2 mmol) freshly distilled pyrrole (134 mg, 2 mmol) and copper acetate (200 mg) was dissolved in propionic acid (50 ml) and refluxed for 4 h with stirring. After usual workup, the compound is obtained 15% yield. Anal. calcd. for C₅₆H₂₈N₈Cl₄Cu: C, 66.1; H, 2.75; N, 11.0. Found: C, 66.0; H, 2.8; N, 11.0%. FAB-MS *m/z* 1018 (M + 1)⁺ requires 1017. UV: λ_{max} nm (CHCl₃) (log ε): 425 (5.76), 545 (4.91).

Synthesis of [meso-tetrakis(2-chloroquinolin-3-yl)porphyrinato]zinc(II) (5Zn-II): A mixture of 2-chloro-6-methoxyquinoline-3-carboxaldehyde (**1b**) (443 mg, 2 mmol), freshly distilled pyrrole (134 mg, 2 mmol) and zinc acetate (220 mg) was dissolved in propionic acid (50 ml) and refluxed for 4 h with stirring. After usual workup, the compound was obtained 14% yield. Anal. calcd. for C₅₆H₂₈N₈Cl₄Zn: C, 66.0; H, 2.75; N, 11.0. Found: C, 66.0; H, 2.7; N, 11.0%. FAB-MS *m/z* 1019 (M + 1)⁺ requires 1018. UV: λ_{max} nm (CHCl₃) (log ε): 435 (5.54), 5.60 (4.67). ¹H NMR (CDCl₃ + DMSO- d₆) δ ppm: 9.06 (m, 8H, pyrrole β-protons), 8.65 (s, 4H, quinoline C₄-H), 8.06 (m, 8H, quinoline C₅ & C₈-H), 7.82 (m, 4H, quinoline C₆-H), 7.60 (m, 4H, quinoline C₇-H), -2.63 (s, 2H, porphyrin N-H).

M. Amaravathi is very grateful to DST for sanctioning the project Women Scientist Scheme-A and L. Giribabu is thankful to ICT for providing infrastructural facilities.

Received 8 May 2007; accepted 10 July 2007

Paper 07/4637 doi: 10.3184/030823407X228227

References

- K.M. Kadish, K.M. Smith and R. Guilard (eds), *The Porphyrin Handbook*: Academic Press, Boston, 2000.
- Y. Nakamura, N. Aratani and A. Osuka, *Chem. Soc. Rev.*, 2007 (0000).
- E. Iengo, E. Zangrando and E. Alessio, *Acc. Chem. Res.*, 2006, **39**, 841.
- M.R. Wasielewski, *J. Org. Chem.*, 2006, **71**, 5051.
- P. Rothmund, *J. Am. Chem. Soc.*, 1935, **57**, 2010.
- A.D. Adler, F.R. Longo, J.D. Finarelli, J. Goldmacher, J. Assour and L. Korsakoff, *J. Org. Chem.* 1966, **32**, 476.
- J.S. Lindsey, I.C. Schreiman, H.C. Hsu, P.C. Kearney and A.M. Marguerettaz, *J. Org. Chem.*, **52**, 827.
- D.S. Sharada, A.Z. Muresan, K. Muthukukaran and J.S. Lindsey, *J. Org. Chem.*, 2005, **70**, 3500.
- J.H. Fuhrop and K.M. Smith, In *Porphyrins and Metalloporphyrins*; K. Smith (ed.), Elsevier: Amsterdam, 1975, p 769.
- M. Amaravathi, M.M. Babu and G. Chandramouli. *ARKIVOC*, 2007, 148.