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Hetero-Diels–Alder reactions of β-imino-*meso*-tetraphenylporphyrin derivatives: a new approach to pyrido[2,3-*b*]porphyrins

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Abstract—The title compounds were prepared from hetero-Diels–Alder reactions of β-imino-*meso*-tetraphenylporphyrin derivatives with 3,4-dihydro-2*H*-pyran or 2,3-dihydrofuran catalysed by lanthanum triflate. © 2001 Elsevier Science Ltd. All rights reserved.

The use of β-vinyl and β,β′-divinyl porphyrins in Diels–Alder reactions with electron-deficient dienophiles[1] and heterodienophiles[2] is well described in the literature. In these cases the porphyrin macrocycle acts as diene. Recently we have shown that porphyrins with buta-1,3-dien-2-yl groups in β-positions can also be used as dienes in Diels–Alder reactions.[3] We have also shown, for the first time, that the porphyrin macrocycle can also be used as a dienophile in Diels–Alder reactions.[4]

Despite all the research in this area, as far as we know, there are no studies on the use of porphyrins as heterodienes in Diels–Alder reactions. This fact, and our interests concerning pericyclic reactions of porphyrins,[5] prompted us to investigate the reactivity of β-imino derivatives of *meso*-tetraphenylporphyrin **1a** and **1b** as heterodienes.

The Lewis acid catalysed [4+2] cycloaddition of *N*-arylaldimines to electron-rich alkenes has been the subject of many studies. Different types of catalysts have been used;[6,7] usually high yields of the quinoline derivatives are obtained. In our work we have used lanthanum triflate as catalyst and 3,4-dihydro-2*H*-pyran and 2,3-dihydrofuran as dienophiles.

The β-iminoporphyrins **1** were obtained from the reaction of the nickel complex of β-amino-*meso*-tetraphenylporphyrin with benzaldehydes in the presence of La(OTf)$_3$. Both compounds were synthesised in refluxing toluene and were used in the next step without purification. The reaction mixtures were allowed to cool to room temperature and a large excess of dienophile was added. The resulting mixtures were stirred at room temperature during 4 days. Then they were diluted with dichloromethane, washed with water and dried (Na$_2$SO$_4$). Evaporation of the solvent and purification by preparative TLC afforded the new compounds which were fully characterized by NMR [1D: ^{1}H, ^{13}C, and DEPT; 2D: COSY, HETCOR, HMBC and NOESY], MS and UV–Vis spectroscopic techniques.

In the reaction of imines **1** with 3,4-dihydro-2*H*-pyran the products with higher R_f were identified as the expected tetrahydropyridine-fused[8] derivatives **2a**[9] (35%) and **2b** (25%) while the other compounds were identified as the pyridoporphyrins **3a**[10] (37%) and **3b** (28%) (Scheme 1). The *trans* configuration of compounds **2a** and **2b** was confirmed by NOE studies: (i) close proximity is observed between H-2^2 and NH, adjacent H-*o*-Ph and one of the two H-2^4; (ii) there is a close proximity between H-2^{2a} and H-2^{6a} but not with H-2^2.

A probable pathway leading to the formation of compounds **3** is outlined in Scheme 1: the aromatization of the pyridine ring, with the opening of the pyranyl ring, can give rise to intermediates **4**; addition of another molecule of 3,4-dihydro-2*H*-pyran to **4** yields the final products **3**. In support of this mechanism we have seen that derivative **2b**, when stirred with 3,4-dihydro-2*H*-pyran in the presence of La(OTf)$_3$, is converted into

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Keywords: porphyrins and analogues; Diels–Alder reactions; cycloadditions.

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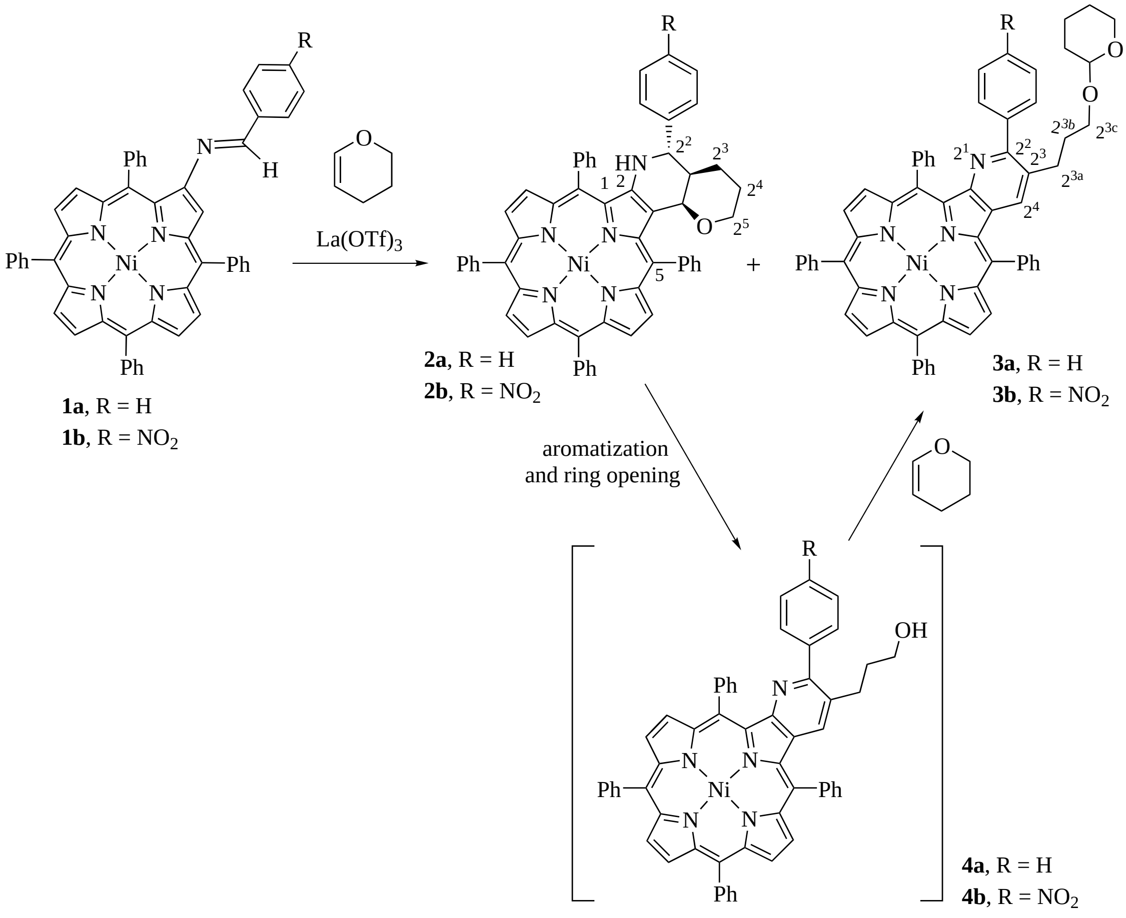
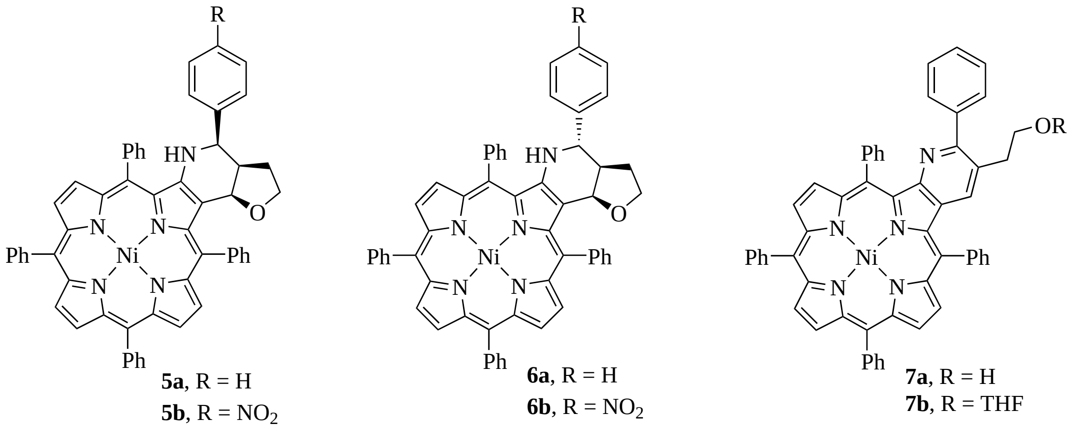


Scheme 1.

compound **3b**. We also verified that compounds **3**, when treated with aqueous trifluoroacetic acid, afford the metal free derivatives of **4**.

Imines **1** also react with 2,3-dihydrofuran, in the conditions described above, to yield the corresponding tetrahydropyridine-fused derivatives in ca. 70%. However, contrary to the reaction with 3,4-dihydro-2*H*-pyran, which gives only *trans*-tetrahydropyridine-fused derivatives **2**, in this case mixtures of *cis* (**5**) and *trans* (**6**) products are obtained, the *cis* isomers being the main products. With imine **1a** minor amounts of the alcohol **7a** and the corresponding tetrahydrofuranyl derivative **7b** were also obtained (Scheme 2). In the case of imine **1b** the very minor fractions, probably corresponding to products of type **7**, have not yet been considered.

This work is currently being extended to other iminoporphyrin derivatives and to other dienophiles.



Scheme 2.

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9. Spectroscopic data for **2a**: ^{1}H NMR (CDCl$_3$): δ (ppm) 1.15–1.28 (m, 1H, H-2^4), 1.42–1.45 (m, 2H, H-2^3), 1.79–1.86 (m, 1H, H-2^4); 2.05–2.08 (m, 1H, H-2^{2a}), 2.86 (dd, 1H, H-2^5, *J* 11.2 and 10.3 Hz), 3.84 (dd, 1H, H-2^5, *J* 4.3 and 11.2 Hz), 4.03 (d, 1H, H-2^{6a}, *J* 2.2 Hz); 4.19 (s, 1H, NH), 4.84 (d, 1H, H-2^2, *J* 11.5 Hz), 7.21–7.25 (m, 2H, H-*o*-Ph-2^2), 7.32–7.34 (m, 3H, H-*m,p*-Ph-2^2), 7.52–7.65 (m, 12H, H-*m,p*-Ph), 7.95–7.98 (m, 6H, H-*o*-Ph), 8.04 (d, 2H, *J* 6.7 Hz, H-*o*-Ph), 8.46 (d, 1H, *J* 4.8 Hz, H-β), 8.57 (d, 1H, *J* 5.2 Hz, H-β), 8.59 (d, 1H, *J* 4.8 Hz, H-β), 8.60 (s, 2H, H-12, 13), 8.62 (d, 1H, *J* 5.2 Hz, H-β); ^{13}C NMR (CDCl$_3$): δ (ppm) 21.6 (C-2^4), 24.6 (C-2^3), 38.9 (C-2^{2a}), 55.3 (C-2^2), 68.5 (C-2^5), 70.2 (C-2^{6a}), 113.6, 114.8 (C-3), 115.6, 118.0, 120.0, 126.2, 126.8, 126.9, 127.4, 127.5, 127.6, 127.7, 128.1, 128.2, 129.5 (C-β), 130.4, 130.8 (C-β), 131.3 (C-β), 131.4 (C-β), 131.5, 132.1 (C-β), 132.37 (C-β), 132.40 (C-*o*-Ph), 133.5 (C-*o*-Ph), 133.6 (C-*o*-Ph), 139.4, 140.2, 140.8, 140.9, 141.25, 141.34, 141.7, 142.3, 142.6, 144.2, 152.6 (C-2); UV–Vis (CHCl$_3$) $\lambda_{\text{max/nm}}$ (log ε) 415 (5.16), 537 (3.94), 579 (3.90); HRMS (FAB) *m*/*z* calcd for $C_{56}H_{42}N_5NiO$ (M+H)$^+$ 858.2743, found 858.2760.
10. Spectroscopic data for **3a**: ^{1}H NMR (CDCl$_3$): δ (ppm) 1.52–1.76 (m, 8H, H-2^{3b}, 2^{3f}, 2^{3g}, 2^{3h}), 2.86–2.98 (m, 2H, H-2^{3a}), 3.28–3.35 and 3.63–3.70 (2m, 2H, H-2^{3c}), 3.44–3.48 and 3.74–3.81 (2m, 2H, H-2^{3i}), 4.50–4.52 (m, 1H, H-2^{3e}), 7.12 (s, 1H, H-2^4), 7.35–7.37 and 7.42–7.45 (2m, 5H, H-NPh), 7.56–7.60, 7.64–7.68 and 7.76–7.81 (3m, 12H, H-*m,p*-Ph), 7.87 (dd, 2H, *J* 7.8 and 1.8 Hz, H-*o*-Ph), 7.96–8.01 (2m, 6H, H-*o*-Ph), 8.66 (s, 2H, H-12, 13), 8.64–8.75 (m, 4H, H-7.8, 17, 18); UV–Vis (CHCl$_3$) $\lambda_{\text{max/nm}}$ (log ε) 427 (5.41), 541 (4.22), 579 (3.99); HRMS (FAB) *m*/*z* calcd for $C_{61}H_{48}N_5NiO_2$ (M+H)$^+$ 940.3161, found 940.3118.