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Preparation of monohydroxyphthalocyanines and their use in the synthesis of heteronuclear complexes

Alexander Yu. Tolbin[a,b] and Larisa G. Tomilova*[a,b]

[a] *Department of Chemistry, M. V. Lomonosov Moscow State University, 119991 Moscow, Russian Federation. Fax: +7 495 939 0290; e-mail: tom@org.chem.msu.ru*
[b] *Institute of Physiologically Active Compounds, Russian Academy of Sciences, 142432 Chernogolovka, Moscow Region, Russian Federation. Fax: +7 495 785 7024*

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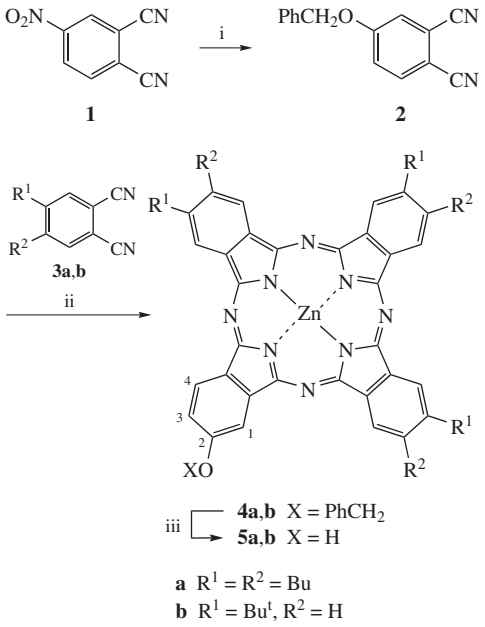
A directed synthesis of monohydroxyphthalocyanines has been developed; using the phthalocyanine–O-subphthalocyanine complex as an example, it has been shown that they can be used as building blocks in syntheses of heteronuclear complexes.

In the past decade, special interest of scientists was focused on nonsymmetrically substituted phthalocyanines containing various substituents at the macrocycle.[1] Such phthalocyanines have interesting properties that enable their use as new technical materials, for instance in non-linear optics,[2,3] as well as photosensitizers in the photodynamic therapy of cancer.[4]

Structural modification of substituents is increasingly used in syntheses of new nonsymmetrically substituted monophthalocyanines.[5] We believe that, from a preparative point of view, monohydroxyphthalocyanines are very promising compounds of the monophthalocyanine series. These compounds are convenient building blocks owing to the availability of the free OH group.[6–8]

Previously, it was found in the syntheses of tetrahydroxyphthalocyanines that 4-hydroxyphthalodinitrile does not undergo self-cyclisation.[9] In view of this, hydrolysis of ether bonds in the corresponding alkoxy-substituted complexes is the only method to synthesise hydroxyphthalocyanines.[8–10] Leznoff and Greenberg[11] used binuclear *clamshell*-type phthalocyanines as starting compounds to synthesise monohydroxyphthalocyanines. Treatment of the former with BBr_3 gave the target nonsymmetrically substituted monophthalocyanines in 0.7–4.8% overall yields. However, we consider this approach to be quite laborious as it requires binuclear phthalocyanines to be synthesised first.

We have developed a directed synthesis of nonsymmetrically substituted monophthalocyanines containing an OH group at the 2-position (Scheme 1). First, starting from 4-nitrophthalodinitrile **1** and benzyl alcohol, we synthesised 4-benzyloxyphthalodinitrile **2**.† Mixed cyclisation of the latter‡ with 4,5-dibutylphthalodinitrile **3a** or 4-*tert*-butylphthalodinitrile **3b** in the presence of zinc acetate gave monobenzyloxyphthalocyanines **4a**,**b**. However, as shown by TLC data, these products and zinc



Scheme 1 *Reagents and conditions*: i, $PhCH_2OH$, NaH, DMF; ii, $Zn(OAc)_2{\cdot}2H_2O$, *N*,*N*-dimethylaminoethanol; iii, H_2SO_4, 5 min, H_2O.

phthalocyanines formed as by-products have similar R_f values; in view of this, we carried out stage (iii) without preliminary isolation of compounds **4a**,**b**. The mass spectra (MALDI-TOF) of the reaction mixtures formed in stage (ii) revealed molecular ion peaks of compounds **4a**,**b** with *m*/*z* 1020 and 852, respec-

† *Synthesis of* **2**. NaH (145 mg, 6.0 mmol) was added to a solution of benzyl alcohol (0.5 ml, 4.8 mmol) in DMF (2 ml). After the reaction was completed, a solution of compound **1** (0.8 g, 4.6 mmol) in DMF (2 ml) was added with cooling (+5 °C) and vigorous stirring to the reaction mixture; the mixture was allowed to reach room temperature, and stirring was continued for another 30 min. Once the reaction was completed, the reaction mixture was treated with water. The flaky precipitate formed was filtered off, washed with water (3×50 ml) and dried at 60 °C. The target product was purified on silica gel using $CHCl_3$ as the eluent. The yield of product **2** was 776 mg (69%). IR (KBr, ν/cm^{-1}): 2229 (w, CN). ^{1}H NMR ($CDCl_3$) δ: 5.30 (s, 2H), 7.20–7.65 (m, 8H). MS, *m*/*z*: 234 $[M]^{+\cdot}$, 91 $[M - C_8H_3N_2O]^{+\cdot}$. Found (%): C, 76.86; H, 4.34; N, 11.89. Calc. for $C_{15}H_{10}N_2O$ (%): C, 76.91; H, 4.30; N, 11.96.

‡ *Synthesis of* **5a**. $Zn(OAc)_2{\cdot}2H_2O$ (250 mg, 1.14 mmol) was added to a solution of compounds **2** (90 mg, 0.38 mmol) and **3a** (548 mg, 2.28 mmol) in DMAE (35 ml). The mixture was stirred for 5 h and then treated with water. The phthalocyanine products were filtered off, washed with MeOH (3×50 ml), dried at 50 °C, dissolved in conc. H_2SO_4 and kept for 15 min, then poured onto ice. The phthalocyanine complexes that precipitated were filtered off, repeatedly washed with water to a neutral pH, and chromatographed on silica gel ($CHCl_3$–THF, 50:1) to isolate 39 mg (18%) of complex **5a**. IR (KBr, ν/cm^{-1}): 3210–3500 (OH). ^{1}H NMR ($[^2H_8]$THF) δ: 1.14 (t, 18H), 1.55–1.68 (m, 12H), 1.85–2.10 (m, 12H), 3.90 (t, 12H), 8.78–9.30 (m, 9H). UV-VIS ($CHCl_3$, λ_{max}/nm): 350, 614, 685. MS, *m*/*z*: 930 $[MH]^+$, 1858 2×$[M - H]^+$.

5b: yield 22%. IR (KBr, ν/cm^{-1}): 3200–3460 (OH). ^{1}H NMR ($[^2H_8]$THF) δ: 1.66 (s, 27H), 9.11–9.58 (m, 12H). UV-VIS ($CHCl_3$, λ_{max}/nm): 349, 612, 679. MS, *m*/*z*: 760 $[MH]^+$, 1522 2×$[M + H]^+$.

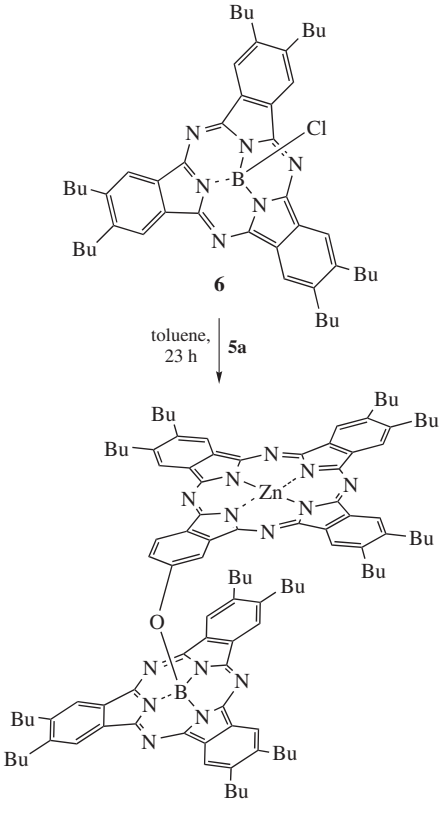
tively. Monohydroxyphthalocyanines **5a**,**b** obtained by acidic treatment differ considerably from symmetric by-products in chromatographic mobility, which simplified the isolation of these compounds.

The IR spectra of complexes **5a**,**b** were found to contain characteristic absorption bands in the range 3200–3500 cm^{-1} (OH group). The signals of aliphatic and aromatic protons in the ^{1}H NMR spectra (Bruker WM-250, [$^2H_8$]THF) are observed in the ranges of δ 1.14–3.90 and 8.78–9.30, respectively. The mass spectra (MALDI-TOF) of compounds **5a**,**b** were found to contain molecular ion peaks ([M]$^{+\cdot}$) with *m*/*z* 930 and 762, respectively. The character of electronic absorption spectra of complexes **5a**,**b** and the positions of the main bands are identical to those for symmetrically substituted analogues, which suggests that the OH group makes no contribution to the chromophore system.

Note that we were the first to perform the cleavage of benzyl ethers (iii) on treatment with concentrated sulfuric acid in the case of phthalocyanines. The overall yields of complexes **5a**,**b** were 18–22%, which exceeded considerably the yields of related compounds obtained by Leznoff's method.[11]

We have previously found that nonsymmetrically substituted monophthalocyanines containing a benzyl-type OH group in the peripheral substituent can react with subphthalocyanines[12] to give heteronuclear complexes.[10] We have now shown for phthalocyanine **5a**[13] as an example that a phenol-type OH group can undergo a similar reaction. The reaction of compound **5a** with boron 2,3,9,10,16,17-hexabutylsubphthalocyanine **6** resulted in a new heteronuclear complex, 'phthalocyanine-O-subphthalocyanine' **7** (Scheme 2).[§]

It was found that the decrease in the distance between the macrocycles in compound **7** creates certain steric hindrance that primarily results in a considerable increase in the reaction time in comparison with the related heterodimer that we obtained previously.[13]



Scheme 2

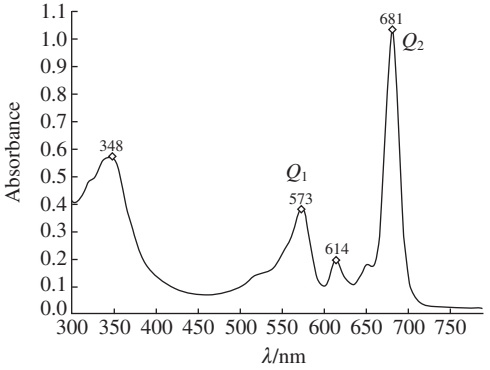


Figure 1 Electronic absorption spectrum of heteronuclear complex **7** (THF).

The mass spectrum (MALDI-TOF) of heteronuclear complex **7** contained peaks of the molecular ion (*m*/*z* 1659, M$^+$) and the characteristic fragment ion (*m*/*z* 731, M$^+$ – $C_{56}H_{63}N_8OZn$) formed by cleavage of the ether bond. In the ^{1}H NMR spectrum ($CDCl_3$ + [$^2H_5$]pyridine) of complex **7**, the singlet of aromatic protons of the subphthalocyanine macrocycle (6H) is shifted downfield by 0.03–0.04 ppm with respect to the original subphthalocyanine **6**.[13] The multiplet of the phthalocyanine ring protons and the signals of aliphatic protons are observed in the regions of δ 8.85–9.24 (9H) and 1.05–3.45 (108H), respectively. The ^{11}B NMR spectrum of compound **7** was found to contain a singlet at δ –15.21 that is somewhat shifted upfield in comparison with compound **6**.[13]

Heteronuclear complex **7** is also characterised by the electronic absorption spectrum (Figure 1). As a result of combining two macrocycles in one molecule, we observed the bands of both macrocycles. Unlike of initial compounds mechanical mixture, in the case of complex **7**, the specific ratio of *Q*-bands is revealed (Q_1:Q_2 = 1:2.7). Moreover, the extinction coefficient of subphthalocyanine band (Q_1) in **7** (log ε = 4.42) is lower than that in corresponding free subphthalocyanine **6** (log ε = 4.76).[13]

Heteronuclear complex **7** is stable and well-soluble in the majority of organic solvents; however, cleavage of the B–O bond occurs almost instantly in the presence of acids, even at room temperature. Compound **7** is also unstable on absorption carriers, so we isolated it on a Bio-Beads cross-linked polymer.

Thus, we have elaborated a directed method for synthesising monohydroxyphthalocyanines. A new heteronuclear complex, phthalocyanine-O-subphthalocyanine **7**, has been obtained from complex **5a**.

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§ *Synthesis of* **7**. Compound **5a** (5 mg, 0.005 mmol) was added to a solution of compound **6** (4 mg, 0.005 mmol) in toluene (5 ml). The mixture was refluxed for 23 h and then concentrated *in vacuo*. Target product **7** was isolated by chromatography on BioBeads SX1. The yield of compound **7** was 7 mg (89%). ^{1}H NMR ($CDCl_3$ + [$^2H_5$]pyridine) δ: 1.10–3.45 (m, 108H), 8.55 (s, 6H), 8.75–9.20 (m, 9H). ^{11}B NMR ($CDCl_3$) δ: –15.21 (s, B). UV-VIS [THF, λ_{max}/nm (log ε)]: 348 (4.59), 573 (4.42), 614 (4.14), 681 (4.85). MS, *m*/*z*: 1659 [M – H]$^+$, 731 [M – $C_{56}H_{62}N_8OZn$]$^{+\cdot}$.

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