A NEW SYNTHESIS OF BENZOPORPHYRINS USING 4,7-DIHYDRO-4,7-ETHANO-*2H*-ISOINDOLE AS AN ISOINDOLE EQUIVALENT

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Dedicated to Professor Teruaki Mukaiyama on the occasion of his 73rd birthday.

Abstract- Various benzoporphyrins and their metal complexes were obtained in 100% yield by heating porphyrins fused with bicyclo[2.2.2]octadiene at 200 °C. This thermal (retro Diels-Alder) reaction proceeds very cleanly to give pure benzoporphyrins without further purification.

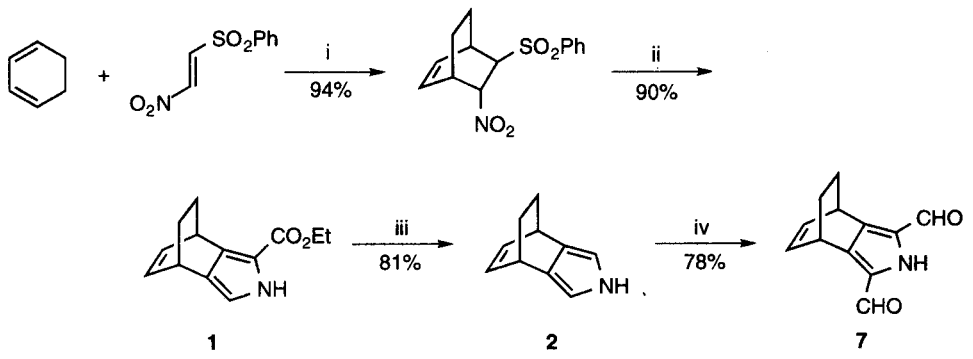
Tetrabenzoporphyrin having similar skeletons to phthalocyanines is known to exhibit very interesting physical, chemical and biochemical properties.[1] Their derivatives have been used as photosensitizers for photodynamic therapy of cancer tissues on *in vivo* studies.[2] However, tetrabenzoporphyrin derivatives have not been well studied due to the difficulty of the preparation in spite of their importance. Isoindole, a building unit of tetrabenzoporphyrin, is generally so unstable at rt, especially in the presence of air and under acidic conditions.[3] In addition, purification of tetrabenzoporphyrin and its metal complexes is very

difficult because they are insoluble in most organic solvents.[4] Thus, pure tetrabenzoporphyrin and its metal complexes are very difficult to be prepared.

In the literature, *meso*-tetraphenyltetrabenzoporphyrin has been prepared by two routes. Namely, *meso*-tetraphenyltetrabenzoporphyrin has been prepared either by the reaction of isoindole with benzaldehyde,[5a] or the tetramerzation of 3-benzylidenephthalimidine[5b] in the presence of excess zinc acetate. However, these methods always yield a mixture of mono-, di-, tri-, and tetraphenyltetrabenzoporphyrin zinc complexes and give *meso*-tetraphenyltetrabenzoporphyrin in only *ca.* 0.4% yield.[5c]

Our laboratory has developed a synthesis of isoindoles *via* Barton-Zard pyrrole synthesis using aromatic nitro compounds and ethyl isocyanoacetate, from which polypyrroles and porphyrins fused with various aromatic rings have been prepared. However, this method is not applicable to the synthesis of unsubstituted isoindole because nitrobenzene does not react with ethyl isocyanoacetate.[6]

Recently, we have reported a new general method for the preparation of pyrroles fused with bicyclo[2.2.2]octadiene[7] (4,7-dihydro-4,7-ethano-2*H*-isoindole (**2**)) which is constructed on the basis of the Diels-Alder reaction of β-(phenylsulfonyl)nitroethylene[8] as a nitroacetylene equivalent with cyclohexadiene and the subsequent Barton-Zard pyrrole synthesis.[9] The retro-Diels-Alder reaction of pyrroles (**1**, **2** or **7**) may give the corresponding isoindoles *via* thermal elimination of ethylene.[10] In a previous communication, we have reported a convenient synthesis of tetrabenzoporphyrins and their metal complexes using 4,7-dihydro-4,7-ethano-2*H*-isoindole (**2**) as an isoindole synthon.[11] In this paper we report details of synthesis of benzoporphyrins based on this strategy.

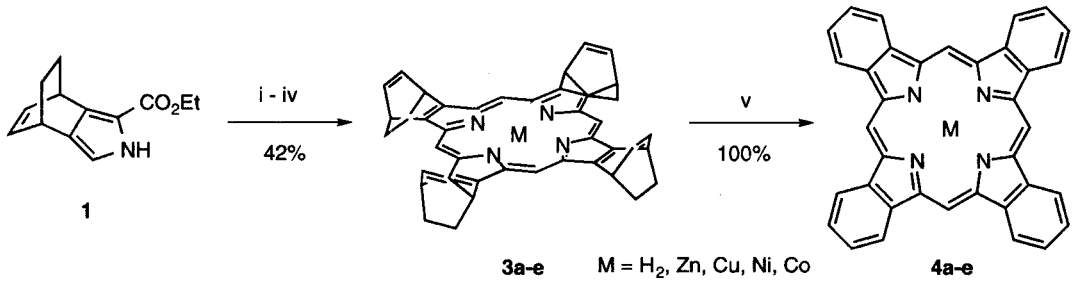


Scheme 1. Reagents and Conditions:
i) $CHCl_3$, reflux, 3 h; ii) $CNCH_2CO_2Et$, DBU, rt, 8 h; iii) KOH, $HOCH_2CH_2OH$, 160 °C, 2 h; iv) $CH(OMe)_3$, CF_3CO_2H, rt, 2 h.

Ethyl 4,7-dihydro-4,7-ethano-2*H*-isoindole-1-carboxylate (**1**) was prepared by the Diels-Alder reaction of 1,3-cyclohexadiene with β-(phenylsulfonyl)nitroethylene followed by treatment with ethyl isocyanoacetate

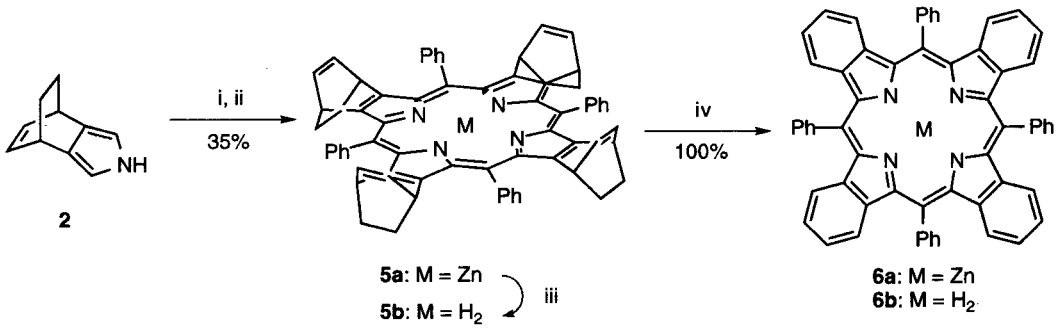
(1.1 equiv) in the presence of DBU (2.4 equiv) to give 85% yield for 2 steps. The ester group of **1** was removed by heating with KOH in ethylene glycol at 160 °C to give 4,7-dihydro-4,7-ethano-*2H*-isoindole (**2**) in 81% yield. The pyrrole (**2**) was converted to 4,7-dihydro-4,7-ethano-*2H*-isoindole-2,5-dicarbaldehyde (**7**) in 78% yield by treatment with trimethyl orthoformate in trifluoroacetic acid . (Scheme. 1)

Porphyrin (**3a**) was prepared from the pyrrole (**1**) by reduction with $LiAlH_4$ at 0 °C followed by subsequent tetramerization and oxidation with chloranil in 42% yield as maroon crystals.[12] Various metal complexes (Zn, Cu, Ni, Co) (**3b-e**) were readily prepared by the reaction with metal acetate in almost quantitative yield. Heating **3** for 10 min at 200 °C under vacuum (10 mmHg) gave the corresponding tetraphenyltetrabenzoporphyrins (**4a-e**) in 100% yield. Color of the crystals changed from maroon-purple to deep green. The absorption spectra of tetrabenzoporphyrin (**4a**) and metal complexes (**4b-e**) are in good agreement with those reported.[4] Direct introduction of metal atoms into tetrabenzoporphyrin is very difficult because tetrabenzoporphyrin (**4a**) is insoluble in most organic solvents. As the porphyrin fused with bicyclo[2.2.2]octadiene (**3a**) is soluble in CH_2Cl_2 and $CHCl_3$, various metals can be readily introduced to porphyrin (**3a**) by stirring a mixture of **3a** and metal acetates in CH_2Cl_2-MeOH. Furthermore, they can be purified easily either by column chromatography (alumina) or recrystallization from $CHCl_3$-MeOH. (Scheme 2)



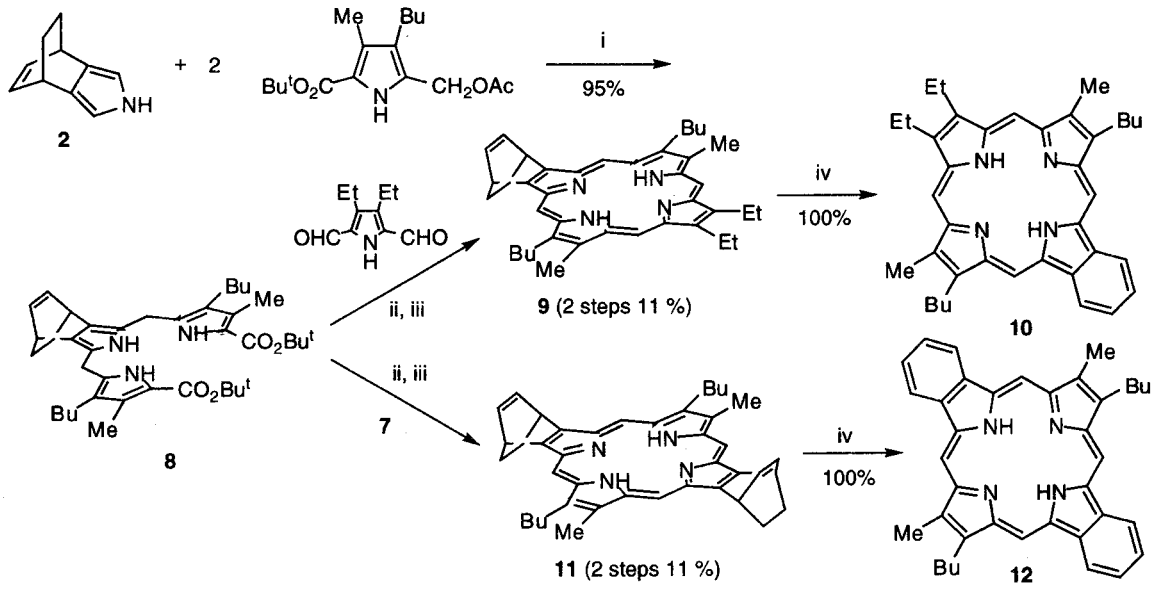
Scheme 2. Reagents and Conditions:
i) $LiAlH_4$, THF, 0 °C, 2 h; ii) *p*-TsOH, $CHCl_3$, 24 h; iii) *p*-chloranil, 48 h; iv) $(AcO)_2M$, $CHCl_3$, rt; v) 200 °C, 10 min.

meso-Tetraphenylporphyrin zinc complex (**5a**) was obtained in 35% yield as a purple red powder by tetramerization of pyrrole (**2**) with benzaldehyde in the presence of boron trifluoride etherate as Lewis acid and zinc(II) acetate as a template, followed by oxidation with *p*-chloranil. Demetallation by treatment of a suspension of **5a** in acetic acid at rt gave free base porphyrin (**5b**) in 90% yield. Heating **5a** and **5b** at 200 °C for 10 min under vacuum (10 mmHg) gave the corresponding *meso*-tetraphenyltetrabenzoporphyrins (**6a** and **6b**) in 100% yield. (Scheme 3)



Scheme 3. Reagents and Conditions:
i) PhCHO, BF_3·OEt_2, $(AcO)_2Zn$, $CHCl_3$, 8 h; ii) *p*-chloranil, 1.5 h; iii) AcOH, 2 h;
iv) 200 °C, 10 min.

Mono- and dibenzoporphyrin can be prepared *via* a [3 + 1] approach[13] as shown in Scheme 4. Reaction of crude 2,5-bis-(5-*tert*-butyloxycarbonyl-3-methyl-4-butyl-2-pyrrolylmethyl)-4,7-dihydro-4,7-ethano-2*H*-isoindole (**8**) with 3,4-diethylpyrrole-2,5-dicarbaldehyde and 4,7-dihydro-4,7-ethano-2*H*-isoindole-2,5-dicarboxyaldehyde (**7**) followed by oxidation with dichlorodicyano-*p*-benzoquinone (DDQ) gave the corresponding porphyrins (**9** and **11**) in both 11% yields. The requisite tripyrrane (**8**) was readily prepared by the reaction of **2** with 2 equiv of *tert*-butyl 5-acetoxymethyl-4-butyl-3-methyl-1*H*-pyrrole-2-carboxylate. Tripyrrane (**8**) was used for the preparation of porphyrins (**9** and **11**) without additional purification because it was too soluble for most organic solvents (methanol, hexane, chloroform, etc.) to obtain as a pure form by recrystallization. Monobenzoporphyrin (**10**) and dibenzoporphyrin (**12**) were also prepared quantitatively by heating **9** and **11** at 200 °C for 10 min, respectively. (Scheme 4)



Scheme 4. Reagents and Conditions:
i) AcOH-EtOH, reflux, 16 h; ii) CF_3CO_2H, rt, 2 h; iii) DDQ, $CHCl_3$, rt, 1 h; iv) 200 °C, 10 min.

The UV-VIS spectra of **9** [λ_{max}/nm (log ε): 398 (5.21), 497 (4.15), 529 (3.89), 566 (3.73), 619 (3.54)] and **11** [λ_{max}/nm (log ε): 400 (5.19), 495 (4.00), 540 (3.37), 567 (3.59), 621 (3.60) nm] were changed to those of **10** [λ_{max}/nm (log ε): 404 (5.48), 504 (4.12), 541 (4.40), 574 (3.91), 629 (3.54)] and **12** [λ_{max}/nm (log ε): 410 (5.73), 514 (3.69), 548 (4.56), 584 (3.73), 642 (4.42)]. Their absorption pattern of Q band was changed from etio-type (IV>III>II>I) to rhodo-type (III>I>IV>II) and the magnitude of absorption strength (ε) increased, which are typical spectra for mono- and dibenzoporphyrins.[14]

Purity of porphyrins (**3**, **4**, **5**, **6**, **9**, **10**, **11** and **12**) was confirmed by elemental analysis as shown in Table 1. If pure porphyrins fused with bicyclo[2.2.2]octadiene (**3**, **5**, **9** and **11**) are used, pure benzoporphyrins are obtained by just heating. Purification processes such as chromatography or recrystallization are not necessary for preparation of any benzoporphyrins.

Table 1. Elemental analysis data of porphyrins fused with bicyclo[2.2.2]octadiene and benzoporphyrins.

Porphyrin	Formula	Elemental analysis (%)[a]			Benzoporphyrin	Formula	Elemental analysis (%)[a]		
		C	H	N			C	H	N
3a	$C_{44}H_{38}N_4$	82.94 (82.54)	6.03 (6.46)	8.74 (8.55)	**4a**	$C_{36}H_{22}N_4$	84.64 (84.69)	4.49 (4.34)	10.81 (10.97)
3b	$C_{44}H_{36}N_4Zn{\cdot}MeOH$	75.67 (75.25)	5.39 (5.61)	7.76 (7.80)	**4b**	$C_{36}H_{20}N_4Zn{\cdot}1/2MeOH$	74.42 (74.30)	3.73 (3.76)	9.28 (9.50)
3c	$C_{44}H_{36}N_4Cu{\cdot}MeOH$	72.15 (71.84)	5.11 (4.75)	7.52 (7.53)	**4c**	$C_{36}H_{20}N_4Cu{\cdot}1/2H_2O$	74.34 (77.40)	3.77 (3.64)	9.41 (9.64)
3d	$C_{44}H_{36}N_4Ni{\cdot}CHCl_3$	66.57 (67.66)	4.64 (4.67)	7.02 (7.01)	**4d**	$C_{36}H_{20}N_4Ni$	76.08 (76.22)	3.71 (3.55)	9.87 (9.88)
3e	$C_{44}H_{36}N_4Co{\cdot}2H_2O$	73.56 (73.83)	5.29 (5.63)	7.70 (7.83)	**4e**	$C_{36}H_{20}N_4Co{\cdot}2MeOH$	72.55 (72.26)	4.60 (4.47)	8.29 (8.87)
5a	$C_{68}H_{52}N_4Zn{\cdot}2CHCl_3$	68.44 (68.39)	4.58 (4.43)	4.34 (4.56)	**6a**	$C_{60}H_{36}N_4Zn$	82.08 (82.05)	4.26 (4.13)	6.22 (6.38)
5b	$C_{68}H_{54}N_4{\cdot}1/2H_2O$	87.00 (87.24)	5.99 (5.92)	5.81 (5.98)	**6b**	$C_{60}H_{38}N_4{\cdot}2H_2O$	84.40 (84.68)	5.05 (4.97)	6.12 (6.58)
9	$C_{40}H_{48}N_4{\cdot}1/2H_2O$	80.89 (80.90)	8.24 (8.31)	9.29 (9.43)	**10**	$C_{38}H_{44}N_4$	81.91 (81.97)	7.93 (7.96)	9.90 (10.06)
11	$C_{42}H_{46}N_4{\cdot}1/2MeOH$	81.86 (81.95)	7.62 (7.77)	8.96 (8.99)	**12**	$C_{38}H_{38}N_4{\cdot}1/2MeOH$	81.86 (81.59)	7.06 (7.11)	9.74 (9.88)

[a] Calculated values in parentheses.

Thus, the present method provides a very useful tool for the preparation of the various kinds of tetrabenzoporphyrin metal complexes, which are difficult to be handled due to their insolubility in most solvents.

In summary, various benzoporphyrins are easily prepared by elimination of ethylene moiety of porphyrins fused with the bicyclo[2.2.2]octadiene skeleton. This process proceeds very cleanly to give pure benzoporphyrins in 100% yield without purification, if precursor porphyrins fused with bicyclo[2.2.2]octadiene are pure. Thus, porphyrins (**3**, **5**, **9** and **11**) can be regarded as soluble

equivalents of the corresponding benzoporphyrins. This method may provide a new strategy for the preparation of metal benzoporphyrins, which are difficult to be prepared by the conventional methods. Application of such porphyrin to material science is now in progress in our laboratory.

EXPERIMENTAL

Mps were measured with a Yanagimoto BY-1 melting point apparatus. ^1H and ^{13}C NMR spectra were recorded on a JEOL-JNM-GSX 270 or JNM-EX 400 spectrometer using tetramethylsilane as an internal standard. IR and UV-visible spectra were obtained with a Hitachi 270-30 and a Shimazu UV-2200 spectrophotometer, respectively. MS spectra were measured with a Hitachi M80B spectrometer. FAB MS spectra of porphyrins were measured with a JEOL JMS-DX 300 or JMS-LX 2000 spectrometer; samples were dissolved in *m*-nitrobenzyl alcohol was used as a matrix. Elemental analysis was performed with a Yanako MT-5 corder.

Preparation of 4,7-dihydro-4,7-ethano-*2H*-isoindole (2)

A stirring mixture of **1** (2.264 g, 10.34 mmol) and KOH (1.0 g, 18.0 mmol) in ethylene glycol (30 mL) was heated at 160 °C under Ar for 3.5 h. The reaction mixture was poured into water (150 mL) and extracted with $CHCl_3$ (100 mL x 3). The organic layer was washed with water (300 mL x 2) and brine (10 mL), and dried over anhydrous Na_2SO_4. After evaporation, crude **2** was purified by column chromatography (silica gel, $CHCl_3$), followed by sublimation (150 °C) to give pure **2** as a white needle (1.226 g, 81%): mp 130-131 °C; ^1H NMR ($CDCl_3$) δ 1.54 (4 H, m), 3.85 (2 H, m), 6.45 (2 H, d, J = 2.1), 6.50 (1 H, d, J = 4.3), 6.52 (1 H, d, J = 4.3), 7.53 (1 H, NH); ^{13}C NMR ($CDCl_3$) δ 27.59, 33.16, 108.01, 129.34, 136.30; IR (KBr)/cm^{-1} 3380 (NH), 2938, 1048, 790, 686, 530; m/z (EI) 145 (M^+, 7%), 117 (100); Anal. Calcd for $C_{10}H_{11}N$: C, 82.72; H, 7.63; N, 9.65. Found: C, 82.67; H, 7.72; N, 9.55.

Preparation of porphyrin (3a)

To a stirred mixture of **1** (0.109 g, 0.50 mmol) in THF (15 mL) was added $LiAlH_4$ powder (0.144 g, 3.79 mmol) at 0 °C. The reaction mixture was stirred for 2 h at this temperature, then poured into water (25 mL), and extracted with $CHCl_3$ (50 mL x 3). To the combined extracts was added *p*-TsOH (0.010 g), the resulting solution was stirred for 12 h at rt, and then *p*-chloranil (0.150 g, 0.61 mmol) was added. The

mixture was stirred for 12 h at rt, and washed with saturated aqueous $NaHCO_3$ (250 mL x 5), water (250 mL) and brine (100 mL), and dried over anhydrous Na_2SO_4. After evaporation, the residue was purified by column chromatography (alumina, $CHCl_3$) followed by recrystallization from $CHCl_3$-MeOH to give pure **3a** (0.094 g, 42%) as purple needles: mp > 200 °C (decomp); ^1H NMR ($CDCl_3$) δ -4.80 (2H, br s, NH), 2.24 (8H, m), 5.81 (8H, m), 7.20 (8H, m), 10.40 (4H, m, *meso*-H); UV-VIS ($CHCl_3$) λmax ($\log_{10}$ ε) 386 (5.13), 494 (4.12), 525 (3.70), 562 (3.59), 614 (3.09) nm; m/z (FAB) 623 (M^++1).

Preparation of porphyrin zinc complex (3b)

A solution of **3a** (0.020 g, 0.032 mmol) and $Zn(MeCO_2)_2 \cdot 2H_2O$ (0.100 g, 0.54 mmol) in $CHCl_3$ (30 mL) and MeOH (3 mL) was stirred for 3 h at rt. The solution was washed with water (100 mL x 2) and brine (40 mL), and dried over anhydrous Na_2SO_4. After evaporation, the purple-red powder was purified by recrystallization from $CHCl_3$-MeOH to give pure **3b** (0.022 g, quantitative yield) as a purple-red needle: mp > 200 °C (decomp); ^1H NMR ($CDCl_3$) δ 2.25 (8H, m), 5.83 (8H, m), 7.20 (8H, m), 10.40 (4H, m, *meso*-H); UV-VIS ($CHCl_3$) λmax ($\log_{10}$ ε) 400 (5.40), 534 (4.09), 561 (4.91) nm.

Preparation of porphyrin copper complex (3c)

A solution of **3a** (0.020 g, 0.032 mmol) and $Cu(MeCO_2)_2 \cdot 2H_2O$ (0.100 g, 0.55 mmol) in $CHCl_3$ (30 mL) and MeOH (3 mL) was stirred for 3 h at rt. The solution was washed with water (100 mL x 2) and brine (40 mL) and dried with anhydrous Na_2SO_4. After evaporation, the purple-red powder was purified by recrystallization from $CHCl_3$-MeOH to give pure **3c** (0.022 g, quantitative yield) as a purple-red powder: mp > 200 °C (decomp); UV-VIS (in $CDCl_3$) λmax ($\log_{10}$ ε) 397 (5.50), 519 (4.04), 555 (4.21); m/z (FAB) 685 (M^++2).

Preparation of porphyrin nickel complex (3d)

A solution of **3a** (0.020 g, 0.032 mmol) and $Ni(MeCO_2)_2 \cdot 2H_2O$ (0.100 g, 0.56 mmol) in $CHCl_3$ (30 mL) and MeOH (3 mL) was refluxed for 3 h. The solution was washed with water (100 mL x 2) and brine (40 mL), and dried over anhydrous Na_2SO_4. After evaporation, the purple-red powder was purified by recrystallization from $CHCl_3$-MeOH to give pure **3d** (0.022 g, quantitative yield) as a purple-red needle: mp > 200 °C (decomp); UV-VIS ($CHCl_3$) λmax ($\log_{10}$ ε) 393 (5.34), 512 (3.79), 546 (4.23); m/z (FAB) 680 (M^++2).

Preparation of porphyrin cobalt complex (3e)

A solution of **3a** (0.020 g, 0.032 mmol) and $Co(MeCO_2)_2 \cdot 2H_2O$ (0.100 g, 0.56 mmol) in $CHCl_3$ (30 mL) and MeOH (3 mL) was refluxed for 3 h. The solution was washed with water (100 mL x 2) and brine (40 mL), and dried over anhydrous Na_2SO_4. After evaporation, the purple-red powder was purified by recrystallization from $CHCl_3$-MeOH to give pure **3e** (0.022 g, quantitative yield) as purple-red crystals: mp > 200 °C (decomp); UV-VIS ($CHCl_3$) λmax 392 (5.27), 515 (4.02), 546 (4.20); m/z (FAB) 681 (M^++2).

Preparation of tetrabenzoporphyrin (4a-d)

Porphyrin (**3a-e**) (0.020 mmol) was heated in sample tube under vacuum (10 mmHg) at 200 °C for 10 min to give Tetrabenzoporphyrin (**4a-e**) (100 % yield without purification.

Tetrabenzoporphyrin (**4a**): a green powder; mp > 250 °C; UV-VIS ($CHCl_3$+CF_3CO_2H) λmax 431, 605, 660 nm1: Tetrabenzoporphyrin zinc complex (**4b**): a green powder; mp > 250 °C; UV-VIS (THF-pyridine) λmax 425, 622 nm: Tetrabenzoporphyrin copper complex (**4c**): a green powder; mp > 250 °C; UV-VIS (pyridine) λ max 427, 621 nm: Tetrabenzoporphyrin nickel complex (**4d**): a green powder; mp > 250 °C; UV-VIS ($CHCl_3$+pyridine) λ max 435, 620 nm: Tetrabenzoporphyrin cobalt complex (**4e**): a green powder; mp > 250 °C; UV-VIS ($CHCl_3$+pyridine) λ max 431, 612 nm.

Preparation of *meso*-tetraphenylporphyrin zinc complex (5a)

A solution of pyrrole (**2**) (0.145 g, 1.00 mmol), benzaldehyde (0.110 g, 1.04 mmol) and $Zn(MeCO_2)_2 \cdot 2H_2O$ (0.500 g, 2.73 mmol) in $CHCl_3$ (300 mL) was stirred for 5 min at rt and then $BF_3 \cdot OEt_2$ (0.014 g, 1.00 mmol) was added. The resulting solution was stirred at rt for 12 h, and then *p*-chloranil (0.050 g, 0.20 mmol) was added. The mixture was stirred for 3 h at rt, and washed with saturated aqueous $NaHCO_3$ (300 mL x 3), water (300 mL) and brine (100 mL). MeOH (4 mL) and $Zn(MeCO_2)_2 \cdot 2H_2O$ (0.500 g, 2.73 mmol) were added and the organic layer was stirred for 3 h at rt. The mixture was washed with water (100 mL x 2), and dried over anhydrous Na_2SO_4. After evaporation, the residue was purified by column chromatography (alumina, $CHCl_3$), followed by recrystallization from $CHCl_3$-MeOH to give pure **5a** (0.053 g, 31%) as purple-red needles: mp > 200 °C (decomp); ^{1}H NMR ($CDCl_3$) δ 1.44 (16 H, m), 3.39 (8 H, m), 6.45 (8 H, m), 7.78 (12 H, m), 8.24 (8 H, m); UV-VIS ($CHCl_3$) λmax ($\log_{10} \varepsilon$) 425 (5.43), 495 (4.15) nm.

Preparation of *meso*-tetraphenylporphyrin (5b)

5a (0.020 g, 0.020 mmol) was treated with acetic acid (10 mL) at rt. After stirring for 30 min, the mixture was poured into water (100 mL), then saturated aqueous $NaHCO_3$ was added until pH of the solution became neutral. The solution was extracted with $CHCl_3$ (50 mL), and the organic layer was washed with water (100 mL x 2) and dried over anhydrous Na_2SO_4. After evaporation, the purple powder was linsed with MeOH, recovered by filtration, and dried under vacuum to give the porphyrin (**5b**) as a purple powder (0.017 g, 90%): mp > 200 °C (decomp); ^{1}H NMR ($CDCl_3$) δ -3.45 (2 H, br s, NH), 1.23-1.48 (16 H, m), 3.38 (8 H, m), 6.26-6.57 (8 H, m), 7.85 (12 H, m), 8.31 (8 H, m); UV-VIS ($CHCl_3$) λmax ($\log_{10}$ ε) 433 (5.33), 527 (4.07), 568 (2.36), 597 (3.30), 661(3.30) nm.

Preparation of *meso*-tetraphenyltetrabenzoporphyrin (6a and 6b)

Porphyrin (**5a-b**) (20 mg, 0.020 mmol) was heated in a sample tube under vacuum (10 mmHg) at 200 °C for 10 min to give *meso*-tetraphenyltetrabenzoporphyrin (**6a-b**) (18 mg, 100 %).

meso-Tetraphenyltetrabenzoporphyrin zinc complex (**6a**): a blue plate; mp > 250 °C; ^{1}H NMR ($CDCl_3$) δ 7.17 (8 H, m), 7.28 (8 H, m), 7.87 (8 H, m), 7.95 (4 H, t, m), 8.30 (8 H, d, m); ^{13}C NMR ($CDCl_3$) 117.30, 124.45, 125.30, 128.82, 129.00, 134.13, 138.67, 145.17, 143.34; UV-VIS ($CHCl_3$/Et_3N) λmax ($\log_{10}$ ε) 463 (5.44), 609 (4.09), 652 (4.68) nm; m/z (FAB) 876 (M^+ +1): *meso*-Tetraphenyltetrabenzoporphyrin (**6b**): a green-blue powder; mp > 250 °C; ^{1}H NMR ($CDCl_3$) δ -1.16 (2 H, br s, NH), 6.98-7.44 (16 H, br), 7.85 (8 H, t, J = 6.84), 7.93 (4 H, t, J = 7.33), 8.36 (8 H, d, J = 6.84); ^{13}C NMR ($CDCl_3$) δ 115.72, 124.29, 125.87, 128.97, 134,55, 141.99 (Singnals of three carbons of the porphyrin ring could not be assigned at rt.); UV-VIS ($CHCl_3$) λmax ($\log_{10}$ ε) 464 (5.53), 549 (2.96), 591 (3.67), 638 (4.50), 696 (3.94) nm.

Preparation of 4,7-dihydro-4,7-ethano-*2H*-isoindole-2,5-dicarboxyaldehyde (7)

4,7-Dihydro-4,7-ethano-*2H*-isoindole (**2**) (0.680 g, 4.69 mmol) was dissolved in CF_3CO_2H (8.5 mL) under N_2 and protection from light. The mixture was stirred at 0 °C for 5 min before freshly distilled trimethyl orthoformate (8.5 mL) was slowly added. The stirring mixture was kept at 0 °C for 1 h, and then mixture was poured into water (4 mL). 20% NaOH was then added until the pH was neutral. The solution was extracted with $CHCl_3$ (100 mL). The extract was washed with water (200 mL x 2) and dried over anhydrous Na_2SO_4. After evaporation, the residue was purified by column chromatography (silica gel, Hexane:EtOAc=1:1), followed by recrystallization from EtOH to give pure **7** as a white plate (0.507 g, 78% yield): mp 164-166 °C; ^{1}H NMR ($CDCl_3$) δ 1.53 (2 H, m), 1.69 (2 H, m), 4.34 (2 H, m), 6.55 (2

H, m), 9.47 (1 H, br s, NH), 9.85 (2 H, s); ^{13}C NMR ($CDCl_3$) δ 26.28, 32.66, 126.68, 135.02, 140.31, 179.53; IR (KBr)/cm^{-1} 3346 (NH), 2957, 2838, 1670 (CHO), 1649, 1455, 1203, 850; m/z (EI) 201 (M^+ 8%), 173 (100); Anal. Calcd for $C_{12}H_{11}NO_2$: C, 71.63; H, 5.51; N, 6.96; Found. C, 71.42; H, 5.61; N, 6.79.

2,5-Bis-(5-*tert*-butyloxycarbonyl-3-ethyl-4-*n*-butyl-2-pyrrolylmethyl)-4,7-dihydro-4,7-ethano-*2H*-isoindole (8)

A solution of **2** (0.073 g, 0.503 mmol) and *tert*-butyl 5-acetoxymethyl-4-butyl-3-methyl-*1H*-pyrrole-2-carboxylate (0.309 g, 1.000 mmol) in isopropyl alcohol (10 mL) and acetic acid (10 mL) was refluxed under nitrogen for 16 h, then the mixture was poured into water (40 mL), and saturated aqueous $NaHCO_3$ was added to the solution until the pH of that was neutral. The solution was extracted with $CHCl_3$ (200 mL), and the extract was washed with water (300 mL x 2), brine (100 mL) and dried with anhydrous Na_2SO_4. After evaporation, the crude tripyrrane (**8**) was obtained (0.305 g, 95 % yield). This material was used for the preparation of porphyrins (**9** and **11**) without additional purification.

Preparation of porphyrin (9)

A solution of crude **8** (0.643 g, *ca.* 1.0 mmol) in CF_3CO_2H (1 mL) was stirred under N_2 at rt for 10 min. The mixture was diluted with $CHCl_3$ (20 mL) followed by the addition of **7** (0.186 g, 1.000 mmol), and the resulting mixture was stirred for 2 h under N_2. After Et_3N was added to the solution until the pH of that was neutral, 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (0.240 g, 1.05 mmol) was added and the mixture was stirred at rt for 1 h. The solution was washed with water (100 mL x 2) and brine (50 mL), and dried over anhydrous Na_2SO_4. After evaporation, the residue was purified by column chromatography (alumina, $CHCl_3$) followed by recrystallization from $CHCl_3$-MeOH to give pure **9** as maroon needles (0.067 g, 11% yield for 2 steps): mp > 200 °C (decomp); ^1H NMR ($CDCl_3$) δ -3.99 (2 H, s), 1.18 (6 H, t, J = 7.3), 1.48 (6 H, s), 1.79 (6 H, t, J = 7.3), 2.1-2.3 (8 H, m), 4.07 (4 H, t, J = 7.3), 4.13 (4 H, q, J = 7.3), 5.72 (2 H, s), 7.20 (2 H, m), 10.12 (2 H, s), 10.17 (2 H, s); ^{13}C NMR ($CDCl_3$) 11.93, 14.23, 14.35, 18.43, 18.54, 19.75, 23.17, 26.41, 27.99, 35.36, 36.02, 36.21, 96.07, 97.00, 128.74, 136.82, 140.66, 141.92, 147.08; UV-VIS ($CHCl_3$) λmax ($\log_{10}\varepsilon$) 398.0 (5.21), 497 (4.15), 529.5 (3.89), 566.0 (3.73), 619.5 (3.54) nm; m/z(FAB) 585 (M^++1).

Preparation of 7,18-di-*n*-butyl-12,13-diethyl-8,17-dimethylbenzo[*b*]porphyrin (10)

Porphyrin **9** (20 mg, 0.020 mmol) was heated in a sample tube under vacuum (10 mmHg) at 200 °C for 10 min to give tetraphenyltetrabenzoporphyrin (**10**) as a purple powder (20 mg, 100 %): mp > 250 °C; ^{1}H NMR($CDCl_3$) δ -3.64 (2 H, m), 1.14 (6 H, t, *J* = 7.3), 1.52 (6 H, s), 1.80 (4 H, m), 1.89 (6 H, t, *J* = 7.3), 2.30 (4 H, m), 4.02 (4 H, q, *J* = 7.3), 4.16 (4 H, t, *J* = 7.3), 8.08 (2 H, dd, m), 9.34 (2 H, m). 10.08 (2 H, s), 10.39 (2 H, s); ^{13}C NMR ($CDCl_3$) 11.63, 14.23, 18.71, 19.88, 23.12, 26.16, 35.16, 94.24, 97.19, 120.66,126.95, 133.12, 135.64, 136.11, 137.39, 141.69, 144.22, 149.25, 152.23; UV-VIS ($CHCl_3$) λmax ($\log_{10}$ ε) 403.5 (5.48), 503.5 (4.12), 541.0 (4.40), 574.0 (3.91), 628.5 (4.17) nm; m/z (FAB) 557 (M^++1).

Preparation of porphyrin (11)

A solution of crude **8** (0.643 g, *ca.* 1.0 mmol) in CF_3CO_2H (1 mL) was stirred under N_2 at rt for 10 min. The mixture was diluted with $CHCl_3$ (20 mL) and 4,7-dihydro-4,7-ethano-2*H*-isoindole-1,3-dicarboxyaldehyde (**7**) (0.201 g, 1.000 mmol) was added. The resulting mixture was stirred for 2 h under N_2. After Et_3N was added to the solution until the pH of that was neutral, 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (0.240 g, 1.05 mmol) was added and the mixture was stirred at rt for 1 h. The solution was washed with water (100 mL x 2) and brine (50 mL), and dried over anhydrous Na_2SO_4. After evaporation, the residue was purified by column chromatography (alumina, $CHCl_3$) followed by recrystallization from MeOH to give **11** as a maroon powder (0.070g, 11% yield for 2 steps): mp > 200 °C; ^{1}H NMR δ -4.29 (2 H, br, NH), 1.15 (6 H, m), 1.81 (4 H, m), 1.8-2.0 (4 H, m), 2.26 (4 H, m), 2.31 (4 H, m), 3.62 (3 H, s), 4.05 (4 H, m), 5.77 (4 H, m), 7.17 (4 H, m), 10.20 (2 H, s), 10.23 (2 H, s); UV-VIS ($CHCl_3$) λmax ($\log_{10}$ ε) 400 (5.19), 495 (4.00), 540 (3.37), 567 (3.59), 621 (3.60); m/z (FAB) 608 (M^++2).

Preparation of 7,18-dibutyl-8,17-dimethyldibenzo[*b,l*]porphyrin (12)

Porphyrin (**11**) (20 mg, 0.020 mmol) was heated in a sample tube under vacuum (10 mmHg) at 200 °C for 10 min to give the title porphyrin (**12**) as a violet powder (20 mg, 100 %): mp > 250 °C; ^{1}H NMR ($CDCl_3$) δ -3.75 (2 H, br s, NH), 1.16 (6 H, t, *J* = 7.3), 1.80 (4 H, m), 2.31 (4 H, m), 3.71 (6 H, s), 4.15 (4 H, t, *J* = 7.3), 8.09 (4 H, m), 9.33 (4 H, m), 10.33 (2 H, s), 10.35 (2 H, s); ^{13}C NMR ($CDCl_3$) 11.49, 14.21, 23.11, 26.03, 35.11, 94.69, 120.51, 120.51, 126.78, 126.78, 132.30, 135.23, 135.60, 137.51, 141.45, 141.45, 148.65; UV-VIS ($CHCl_3$) λmax ($\log_{10}$ ε) 410 (5.73), 514 (3.69), 548 (4.56), 584 (3.73), 642 (4.42); m/z (FAB) 552 (M^++2).

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