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Synthesis of New Cationic π-Extended *meso*-Arylporphyrin Dimer via Sonogashira Cross-Coupling

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In honor of the 90th anniversary of Professor A. F. Mironov

This work proposes an approach for the preparation of a cationic dimer of meso-arylporphyrin. The Sonogashira cross-coupling reaction was chosen as the synthetic strategy. The obtained conjugate was characterized by a number of modern analytical methods. The resulting dimer exhibits enhanced absorption in the NIR range, which enables deep light penetration into tissues.

Keywords: Synthesis, porphyrin dimer, π-extended porphyrins, Sonogashira cross coupling.

Синтез нового катионного димера *мезо*-арилпорфирина с расширенной π-системой с использованием реакции кросс-сочетания Соногаширы

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В честь 90-летия со дня рождения профессора А. Ф. Миронова

В работе предложен подход к получению катионного димера мезо-арилпорфирина. В качестве синтетической стратегии выбрана реакция кросс-сочетания Соногаширы. Полученный конъюгат был охарактеризован рядом современных методов анализа. Полученный димер обладает увеличенным поглощением в БИК-диапазоне, что обеспечивает глубокое проникновение света в ткани.

Ключевые слова: Синтез, порфириновый димер, π-расширенные порфирины, реакция кросс-сочетания Соногаширы.

Introduction

Improving the efficacy of cancer therapy remains a critical challenge in modern medicine.[1] In this context, considerable attention has been directed toward the development of alternative therapeutic modalities, among which photodynamic therapy (PDT) has emerged as a particularly promising approach.[2-4] PDT relies on the use of photosensitizers (PSs) that, upon photoexcitation, generate reactive oxygen species (ROS), leading to selective destruction of malignant cells while sparing surrounding healthy tissue. Elaboration of PSs plays a key role to improve the efficiency of PDT.[5-6] A diverse set of stringent and frequently incompatible demands is placed on modern photosensitizers. An ideal PS must meet the following requirements: (a) purity and established chemical properties; (b) have a high quantum yield of singlet oxygen (Φ_Δ); (c) possess strong absorption with a high extinction coefficient in the

600–800 nm range; (d) accumulate efficiently in tumor tissue and exhibit low toxicity under dark conditions; (e) be stable and soluble in the physiological conditions; (f) be readily eliminated from the body after the completion of therapy. Consequently, identifying a single dye that satisfies all of these criteria simultaneously is an exceptionally complex and, to date, elusive goal.

Among the clinically approved PSs, porphyrins and their derivatives, chlorins, and bacteriochlorins have found the widest application.[7-10] Porphyrins represent one of the most thoroughly investigated classes of photosensitizers, owing to their high photoactivity, their propensity to accumulate in neoplastic and infected tissues, and their relatively low dark toxicity.[11] Nevertheless, their clinical utility is hampered by weak absorption within the near-infrared (NIR) region (650–900 nm), the spectral range where light achieves its maximal tissue penetration. To overcome this limitation, a promising approach is the expansion of the 18π-electron porphyrin system through the introduction of additional conjugated fragments, which leads to a red shift of the absorption band and enhances the effectiveness of PDT for deep-seated tumors.[12-14]

Covalently-linked porphyrin dimers were proposed since they have unique molecular architecture and properties.[15-16] Chemical synthesis of such dimers involves the functionalization of the *meso*- or β-positions as well as the introduction of functional bridging groups. Thus, various types of dimers have been synthesized ethynyl,[15,17] phenylethynyl,[18] diazo-conjugated,[13] cofacial,[19] *meso-meso*-[16] and β,β-substituted molecules.[20] Previously, the most part of synthesized dimers possessed bulky hydrophobic substituents for implementation in dye-sensitized solar cells (DSSC). Dimers bearing hydrophilic groups for biological applications are rarely reported in the literature;[15] furthermore, dimers with positively charged substituents have not been synthesized.

Among synthetic routes to the *meso-meso*-bridged dimers a palladium-catalyzed reactions are one of the most convenient and widely described in the literature.[21-22] In our work we have implemented Sonogashira cross-coupling reaction to synthesize *meso-meso*-ethynyl bridged porphyrin with the cationic pyridyl groups. Synthesized dimer has a wide absorption in the red region at 630–700 nm with high extinction coefficient (~80 000 $M^{-1}cm^{-1}$). The received spectral characteristics make these dimers promising agents for PDT.

Experimental

General

Commercial chemicals were of analytical grade and were used without further purification Sigma-Aldrich, ABCR, Merck. The individuality of the compounds was confirmed by TLC on Merck TLC Silicagel 60 F254 plates. The solvents was purified according to the standard procedures. NMR spectra (^{1}H and ^{13}C) were registered on spectrometer q-ONE AS400 Quatntum I Plus, using frequencies 399.879 and 100.549 MHz consequently, with deuterium internal stabilization. Measurements were reported on the δ scale using tetramethylsilane (TMS) as an external standard or boron trifluoride etherate ($BF_3{\cdot}OEt_2$) as an internal standard. The spectra were recorded in $CDCl_3$, DMSO-d_6, or THF-d_8 as solvents, depending on the solubility of the compounds. Mass spectra were recorded using a matrix-activated laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrometer (Bruker Daltonics Inc., Bremen, Germany), for which the matrix used was 3,5-dihydroxybenzoic acid. Electronic absorption spectra were recorded either using Shimadzu UV-1800 (Japan) spectrophotometer at room temperature in quartz cells with an optical path length of 10 mm and a resolution of 1 nm. Stationary emission spectra were recorded using a Perkin Elmer LS-50 luminescence spectrometer (USA) under similar conditions.

Synthesis

*5,15-Bis(4-(6-bromohexyloxy)-3-methoxyphenyl)porphyrin (**1**).* 0.219 g (1.5 mmol mol) of dipyrrolylmethane and 0.473 g (1.5 mmol mol) of 6-bromohexyloxybenzaldehyde were dissolved in 100 mL of CH_2Cl_2. The reaction mixture was stirred for 15 min under argon, after which trifluoroacetic acid (112 μL, 1.5 mmol) was added. The process was carried out for 1 h 40 min at room temperature in an inert atmosphere in the dark, then DDQ (341 mg, 1.5 mmol) was added and stirring was continued for 3 h. The reaction mixture was concentrated under vacuum, extracted with a methylene chloride/water system with the addition of an aqueous ammonia solution. The target product was purified by column chromatography on silica gel G 60 (CH_2Cl_2). Yield: 0.187 g (35%). UV-Vis ($CHCl_3$) λ_{max} nm (lgε): 411 (5.27), 505 (3.95), 542 (3.65), 578 (2.52), 634 (2.95). ^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm: 10.34 (2H, s, meso-10,20), 9.42 (4H, d, *J*=4.6 Hz, βPyr), 9.18 (4H, d, *J*=4.6 Hz, βPyr), 7.88 (2H, s, Ar-H), 7.81 (2H, d, *J* = 8.2 Hz, Ar-H), 7.32 (2H, d, *J*=8.2 Hz, Ar-H), 4.39 (4H, t, J_1=J_2=6.6 Hz, OCH_2), 4.05 (6H, s, OCH_3), 3.55 (4H, t, J_1=J_2=6.64 Hz, CH_2Br), 2.13 (4H, m, OCH_2CH_2), 2.06 (4H, m, CH_2CH_2Br), 1.71 (4H, m, $O(CH_2)_2CH_2$), 1.56 (4H, m, $CH_2(CH_2)_2Br$), –3.04 (2H, m, NH). ^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm: 191.22, 154.42, 150.15, 148.76, 147.60, 145.04, 134.76, 132.20, 130.48, 129.65, 127.90, 126.75, 118.51, 110.81, 108.82, 104.52, 69.50, 64.63, 55.81, 33.80, 32.69, 29.53, 28.98, 26.38, 25.00, 1.62. MALDI-TOF *m/z*: calculated for $C_{46}H_{48}Br_2N_4O_4$ 880.204, found $[M-H]^+$ 879.874.

*5,15-Bis(4-(6-bromohexyloxy)-3-methoxyphenyl)-10-bromoporphyrin (**2**).* 100 mg (0.114 mmol) of compound **1** was dissolved in 16 mL of chloroform, 20.3 mg (0.114 mmol) of NBS was added, and the mixture was stirred for 1 h. The resulting mixture was concentrated under vacuum and then purified by column chromatography using a methylene chloride:hexane (2:1) solvent system. Yield: 35 mg (35%). UV-Vis (CH_2Cl_2) λ_{max} nm (lgε): 419 (5.51), 514 (4.26), 551 (3.94), 591 (3.82), 647 (3.55). ^{1}H NMR (300 MHz, $CDCl_3$) δ_H ppm: 10.13 (1H, s, *meso*-5-H), 9.74 (2H, d, *J*=4.8 Hz, βPyr), 9.26 (2H, d, *J*=4.7 Hz, βPyr), 9.01 (4H, dd, J_1=4.8, J_2=1.6 Hz, βPyr), 7.78 (2H, d, *J* = 2.0 Hz, 2-ArH), 7.71 (2H, dd, J_1=8.1, J_2 =2.0 Hz, 6-ArH), 7.29–7.20 (4H, m, 5-ArH), 4.32 (4H, t, J_1=J_2=6.6 Hz, OCH_2), 4.00 (6H, s, OCH_3), 3.52 (4H, t, J_1=J_2=6.7 Hz, CH_2Br), 2.11–1.96 (8H ,m, $CH_2(CH_2)_2CH_2$), 1.72–1.64 (8H, m, $O(CH_2)_2CH_2CH_2(CH_2)_2Br$), –2.94 (2H, s, NH). ^{13}C NMR (75 MHz, $CDCl_3$) δ_C ppm: 148.78, 147.91, 134.17, 132.55, 132.16, 131.91, 131.64, 127.80, 120.26, 119.10, 111.49, 105.65, 103.73, 69.28, 56.43, 33.95, 32.94, 29.85, 29.40, 28.22, 25.60. MALDI-TOF *m/z*: calculated for $C_{46}H_{47}Br_3N_4O_4$ 958.110, found $[M+H]^+$ 959.780.

*5,15-Bis(4-(6-bromohexyloxy)-3-methoxyphenyl)-10-trimethylsilylethynylporhynatozinc (**3**).* 50 mg (0.05 mmol) of compound **2** was dissolved in a $CHCl_3/CH_3OH$ mixture (1:1), and 10 equiv. of zinc acetate dihydrate was added. The reaction was carried out at room temperature, extracted with methylene chloride, and concentrated under vacuum. The product was then dissolved in 3 mL of freshly distilled THF, and 2 mg (0.05 mmol) of copper(I) iodide, 4 mg (0.05 mmol) of $Pd[P(C_6H_5)_3]_2Cl_2$, and 500 μL of dry triethylamine were added. The reaction mixture was stirred at room temperature for 10 minutes under an argon atmosphere. Then, 68.75 mg (0.5 mmol) of TMSA was added, and the mixture was stirred for about 8 hours at room temperature. The resulting

mixture was concentrated under vacuum, extracted with methylene chloride and water, passing the organic layer through a filter with sodium sulfate. The product was purified by column chromatography in chloroform. Yield: 38 mg (77%). UV-Vis (CH_2Cl_2) λ_{max} nm (lgε): 484 (3.72), 601 (3.88), 635 (3.24). ^{1}H NMR (300 MHz, $CDCl_3$) δ_H ppm: 10.08 (1H, d, *J*=3.0 Hz, 20-*meso*-H), 9.80 (2H, dd, *J*=4.7, 0.7 Hz, βPyr), 9.26 (2H, dd, J_1=4.6, J_2=2.6 Hz, βPyr), 9.09 (2H, dd, *J*=4.7, J_2=1.0 Hz, βPyr), 9.04 (2H, dd, J_1=4.5, J_2=2.2 Hz, βPyr), 7.73 (2H, d, *J*=1.9 Hz, 2-ArH), 7.69 (2H, dd, J_1=8.1, J_2=2.0 Hz, 6-ArH), 7.20 (2H, d, *J*=8.1 Hz, 5-ArH), 4.27 (4H, t, J_1=J_2=6.6 Hz, OCH_2), 3.95 (6H, d, *J*=1.8 Hz, OCH_3), 3.52 (4H, t, J_1=J_2=6.8 Hz, CH_2Br), 2.12–1.95 (8H, m, $OCH_2CH_2(CH_2)_2CH_2CH_2Br$), 1.70–1.62 (8H, m, $OCH_2CH_2(CH_2)_2CH_2CH_2Br$), 0.64 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$) δ_C ppm: 152.20, 150.77, 150.20, 149.44, 148.28, 147.54, 135.03, 132.83, 132.45, 131.82, 131.01, 127.44, 121.20, 118.92, 111.30, 107.77, 107.47, 101.34, 100.05, 69.15, 56.24, 33.82, 32.80, 29.70, 29.25, 28.08, 25.44, 0.43. MALDI-TOF *m/z*: calculated for $C_{51}H_{54}Br_2N_4O_4SiZn$ 1040.157, found $[M]^+$ 1040.110.

Dimer ***4***. To a solution of **3** in THF, a 1 M solution of tetrabutylammonium fluoride (0.03 mL, 0.13 mmol) in THF was slowly added to remove the trimethylsilyl group. The reaction was stirred at room temperature for 30 minutes. The resulting mixture was concentrated under vacuum, then extracted with methylene chloride and water, and dried over anhydrous Na_2SO_4. The obtained product was dissolved in 4 mL of THF and mixed with 2 mg (0.05 mmol) of copper(I) iodide, 4 mg (0.05 mmol) of dichlorobis(triphenylphosphine)palladium(II), and 500 μL of dry triethylamine under an argon atmosphere. The reaction mixture was stirred at room temperature for 12 hours, then extracted with methylene chloride and water. The organic phase was passed through anhydrous Na_2SO_4. Product **4** was purified by column chromatography in methylene chloride and concentrated under vacuum.Yield: 35 mg (70%). UV-Vis (DMSO-d_6) λ_{max} nm (lgε): 447 (5.46), 478 (5.35), 562 (4.41), 630 (4.56), 673 (4.78). ^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm: 10.12 (2H, s, 20-*meso*-H), 10.03 (4H, d, *J*=4.6 Hz, βPyr), 9.30 (4H, d, *J*=4.5 Hz, βPyr), 9.17 (4H, d, *J*=4.6 Hz, βPyr), 9.03 (4H, d, *J*=4.4 Hz, βPyr), 7.85 (4H, s, 2-ArH), 7.76 (4H, d, *J*=8.0 Hz, 6-ArH), 7.22 (4H, m, 5-ArH), 4.32 (8H, m, OCH_2), 4.04 (12H, s, OCH_3), 3.52 (8H, t, J_1=J_2=6.8 Hz, CH_2Br), 4.35–4.25 (8H, m, OCH_2), 4.02 (12H, s, OCH_3), 3.50 (6H, t, J_1=J_2=6.8 Hz, CH_2Br), 2.14–1.96 (16H, m, $(CH_2)_4$), 1.74–1.62 (16H, m, $(CH_2)_4$). ^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm: 153.10, 151.03, 149.94, 149.46, 148.28, 147.52, 143.32, 135.80, 135.56, 133.05, 132.21, 131.76, 130.58, 127.69, 122.27, 121.46, 119.10, 111.20, 108.13, 98.03, 88.35, 85.21, 83.03, 82.00, 69.17, 56.34, 33.82, 32.80, 30.58, 30.33, 29.29, 28.08, 25.91, 25.45, 25.21. MALDI-TOF *m/z*: calculated for $C_{96}H_{90}Br_4N_8O_8Zn_2$ 1933.220, found $[M]^+$ 1933.730.

Dimer ***5***. 50 mg (0.026 mmol) of compound **4** was dissolved in 3 mL of dry pyridine. The reaction mixture was refluxed at 115 °C with stirring. The target product **5** was concentrated under vacuum and washed with diethyl ether to remove pyridine residues. Yield: 47 mg (95%). UV-Vis (DMSO-d_6) λ_{max} nm (lgε): 445 (5.60), 476 (5.45), 565 (4.47), 630 (4.70), 679 (4.90). ^{1}H NMR (400 MHz, DMSO-d_6) δ_H ppm: 10.37 (2H, s, 20-*meso*-H), 9.99 (4H, d, *J* = 4.6 Hz, βPyr), 9.49 (4H, d, *J*=4.7 Hz, βPyr), 9.25 (8H, d, *J* = 5.9 Hz, αPy), 9.14 (4H, d, *J*=4.6 Hz, βPyr), 8.96 (4H, d, *J* = 4.2 Hz, βPyr), 8.68 (4H, t, J_1=J_2=7.9 Hz, 4-H Py), 8.25 (8H, m, βPy), 7.88 (4H, s, 2ArH), 7.75 (4H, s, 6-ArH), 7.41 (4H, m, 5-ArH), 4.74 (6H, t, J_1=J_2=7.6 Hz, CH_2Py), 4.28 (8H, m, OCH_2), 3.97 (12H, s, OCH_3), 2.18–1.85 (16H, m, $OCH_2CH_2(CH_2)_2CH_2CH_2NC_5H_5$), 1.76–1.44 (16H, m, $OCH_2CH_2(CH_2)_2CH_2CH_2NC_5H_5$). ^{13}C NMR (101 MHz, DMSO-d_6) δ_C ppm: 152.51, 151.04, 149.69, 148.49, 147.59, 146.00, 145.31, 136.72, 134.95, 133.70, 133.16, 132.56, 130.63, 130.04, 128.61, 127.86, 124.38, 121.96, 119.24, 111.70, 109.55, 96.78, 88.83, 85.16, 83.55, 81.72, 68.67, 61.26, 56.34, 49.08, 31.26, 30.46, 30.27, 29.37, 29.22, 25.89, 25.79, 25.67, 25.11, 25.06). HPLC-MS *m/z*: calculated for $C_{116}H_{110}N_{12}O_8Zn_2$ $[M]^{4+}$ 482.430, found 482.700 $[M]^{4+}$.

Partition coefficients

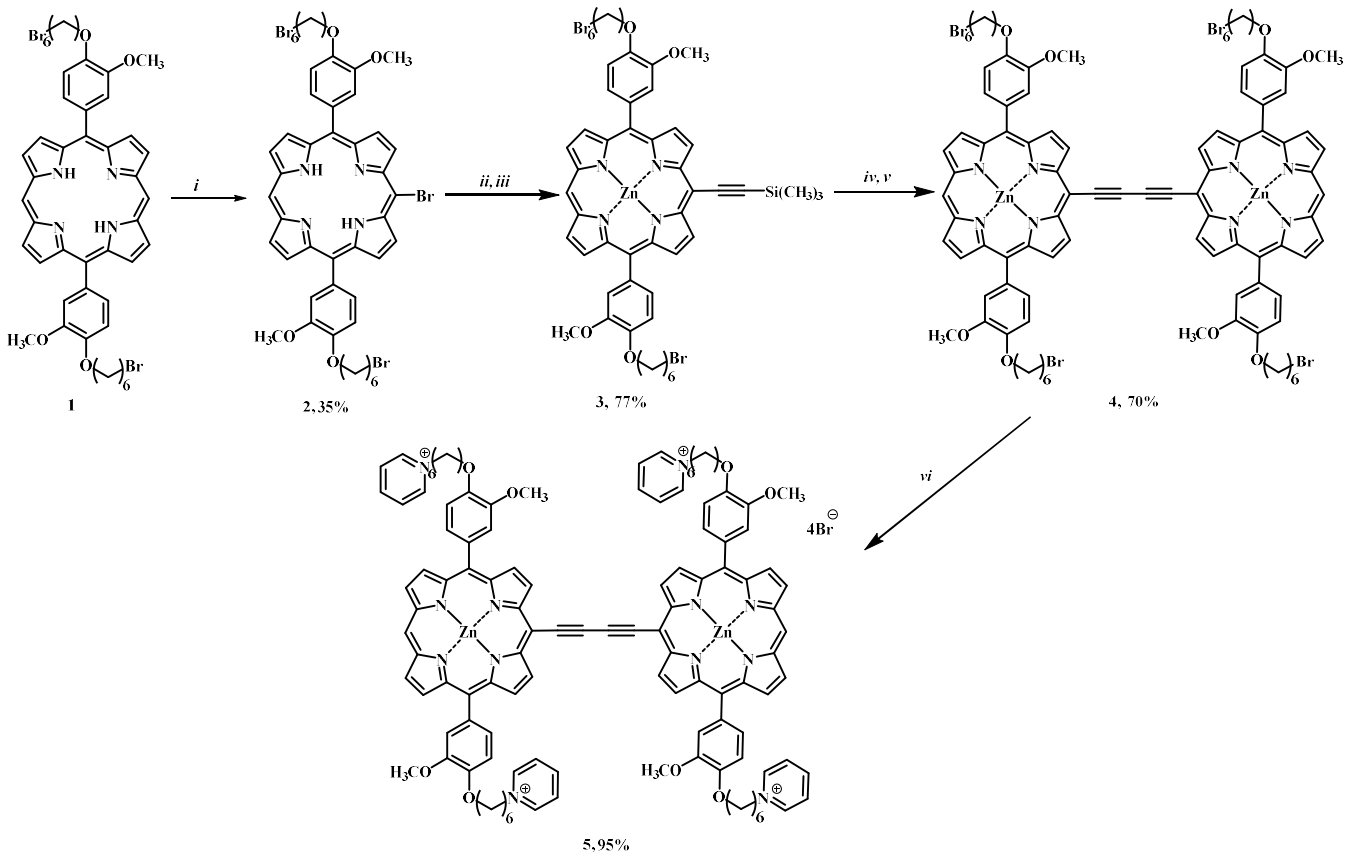
Partition coefficient of compound **5** was measured using 1-octanol and aqueous phosphate-buffered saline (PBS) by the described method.[23] Porphyrins (1.0–1.5 mg) were dissolved in 3 mL of 1-octanol, previously saturated with a PBS solution. The same volume of PBS saturated with 1-octanol was added, sonicated for 30 min and stirred at room temperature for 30 min. The organic and aqueous phases were separated by centrifugation. The distribution coefficients were calculated as the ratio between the absorption of the Soret band of photosensitizers in the organic (A(org)) and aqueous phases (A(aq)) and the dilution coefficients for the organic (d(org)) and aqueous (d(aq)) layers in accordance within the above way:

$$P = \frac{A(org) * d(org)}{A(aq) * d(aq)}$$

Results and Discussion

The synthesis of the target compound was accomplished via a strategy involving the preparation of a meso-ethynyl-substituted porphyrin followed by its dimerization through a cross-coupling reaction. The starting porphyrin **1** was synthesized according to a previously reported procedure (Scheme 1).[15] Bromination of porphyrin 1 with one equivalent of N-bromosuccinimide afforded compound **2** in 35% yield. Subsequently, the corresponding zinc(II) complex was prepared using an excess of zinc salt (10 eq.) to protect the macrocyclic cavity. For the introduction of the ethynyl moiety, the Zn(II) complex was dissolved in a mixture of freshly distilled THF and triethylamine. The Sonogashira coupling with trimethylsilylacetylene (TMSA) was carried out in the presence of copper(I) iodide and bis(triphenylphosphine)palladium(II) dichloride as catalysts.[24] The reaction mixture was stirred under an argon atmosphere for 10 minutes prior to the addition of TMSA, after which stirring was continued for 12 hours. Removal of the trimethylsilyl protecting group was achieved using standard conditions with TBAF in THF. The resulting product was extracted, dried, and redissolved in THF. A second reaction of Sonogashira cross-coupling was performed by adding copper(I) iodide and bis(triphenylphosphine)palladium(II) dichloride in the presence of triethylamine under an inert atmosphere. The reaction mixture was stirred at ambient temperature for 12 hours. The desired product 4 was purified by column chromatography on silica gel using methylene chloride as the eluent and concentrated under reduced pressure, yielding 70% of the product. In the aromatic region of ^{1}H NMR spectra doubling of signals of porphyrin's proton is observed. In the ^{1}H NMR spectrum of product **4** the following signals can be seen: a signal form two meso-protons at 10.02 ppm, four doublets form β-pyrrolic protons at 10.03, 9.30, 9.17, 9.02 ppm, respectively; aromatic protons of aryl groups are at 7.85, 7.76 and 7.22 ppm. ^{13}C NMR spectrum shows four signals for the C–C triple bond at 88.19, 84.93, 83.03 and 82.00 ppm, which is absent in the spectrum of porphyrin monomer **1**. The target cationic dimer **5** was obtained by refluxing the bromo-substituted dimer **4** in anhydrous pyridine. The reaction was conducted at 115°C with continuous stirring, and its progress was monitored by TLC. Upon completion, the reaction mixture was concentrated in vacuum,

and the residue was washed with diethyl ether to remove residual pyridine. The target compound **5** was isolated in 95% yield, its structure was confirmed by spectral analysis (^{1}H NMR, ^{13}C NMR, ESI-MS). In the aromatic region of ^{1}H NMR spectrum of the target dimer signals are similar to the its precursor **4** except of additional signals of the pyridine groups at 9.25, 9.14 and 8.25 ppm. The presence of the C–C triple bond signal are observed in the ^{13}C NMR spectrum at 88.81, 85.58, 83.91 and 81.70 ppm. In the ESI mass-spectrum of the final dimer strong peak at *m/z* 482.700, which corresponds to the quadruply charged ion $[M]^{4+}$ (Figure 1).



Scheme 1. Reagents and reaction conditions: i) NBS; CH_2Cl_2; ii) $Zn(OAc)_2$, CH_2Cl_2/CH_3OH; iii) TMSA, $Pd(PPh_3)_2Cl_2$, CuI, Et_3N, THF, rt; iv) TBAF, THF, rt; v) $Pd(PPh_3)_2Cl_2$, CuI, Et_3N, THF, rt; vi) Pyridine, 115 °C.

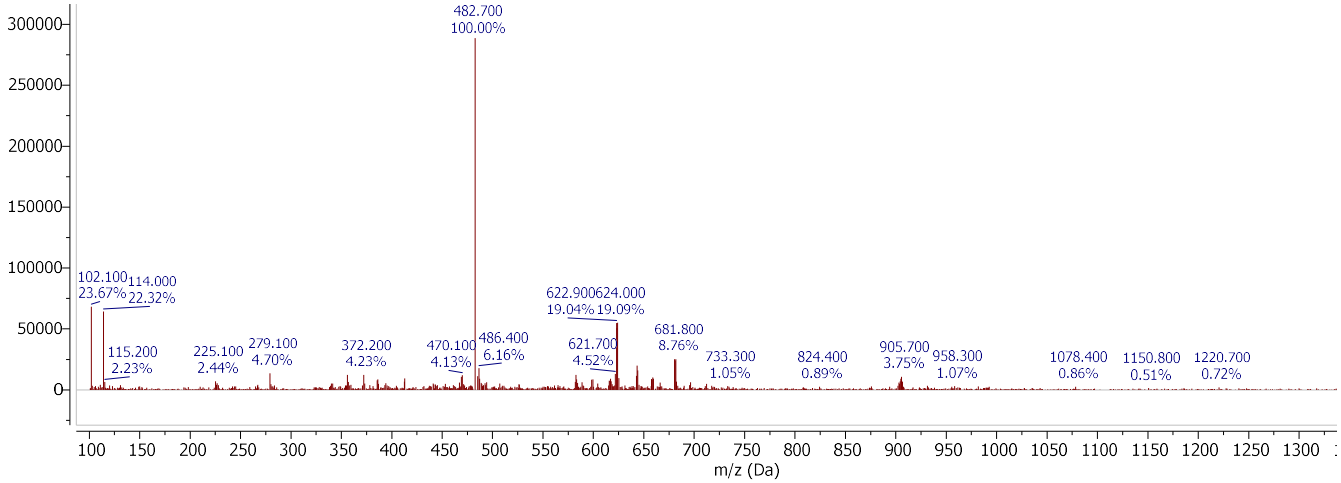


Figure 1. ESI-MS spectrum of the target dimer **5** (*m/z*= 482.700 corresponds to the ion $[M]^{4+}$).

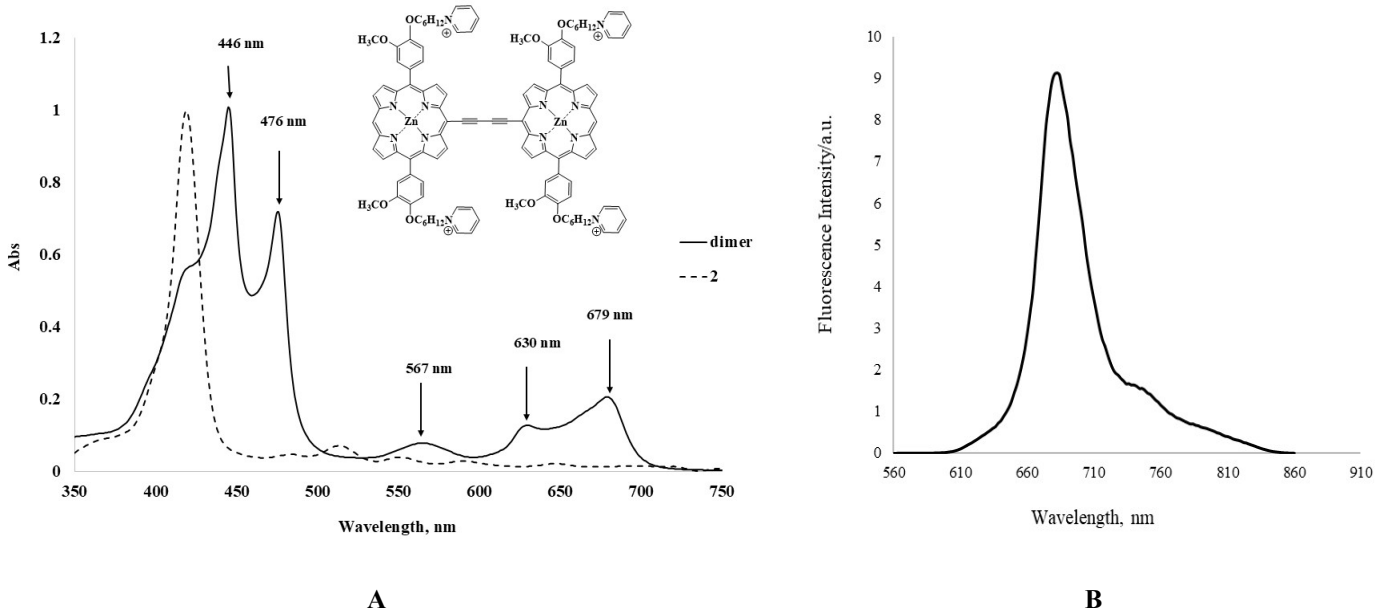


Figure 2. A) Normalized absorption spectra of solutions of dimer (solid line) and porphyrin monomer (dashed line) in DMF; B) Fluorescence spectrum of dimer in DMF solution (C*porph*=1 μM) (λ_{ex}=445 nm).

Table 1. Absorption characteristics of initial porphyrin **1** and dimer **5** in DMF.

Compound	Soret bands				Q bands								Log*P*
	λ_1	ε	λ_2	ε	λ_1	ε	λ_2	ε	λ_3	ε	λ_4	ε	
1	411	5.27	-	-	505	3.95	542	3.65	578	2.52	634	2.95	-
Dimer 5	446	5.60	476	5.45	567	4.47	630	4.70	679	4.90	-	-	0.49

In the UV-Vis spectrum of the dimer molecule in DMF a significant red shift and broadening both of Soret and Q-bands are observed due to larger delocalized system (Figure 2A). Summarized data on the absorption spectra for monomer **1** and dimer **5** are presented in Table 1. Soret band of dimer are splitted with the peaks at 446 and 476 nm with high extinction coefficients (ε) 400 000 and 282 000 $M^{-1}cm^{-1}$, consequently. Such behavior was also demonstrated in works.[15,16] Q-bands of dimer **5** exhibit three peaks at 567, 630 and 679 nm, the last band has the highest ε value among Q-bands 80 000 $M^{-1}cm^{-1}$. In contrast to the zinc complexes of conventional monomeric porphyrins, the zinc complexes of the dimer have three Q-bands. It can be attributed to the loss of symmetry of a porphyrin chromophore upon conjugation along the inter-macrocycle axis (arbitrarily indicated as x).[15,16] Upon excitation at 445 nm one emission band at 685 nm is observed, which corresponds to a planar conformation and, consequently, to a single fluorescence band (Figure 2B).[15] This band is also red-shifted compared to a porphyrin monomer.

Octanol-PBS partition coefficient (Log*P*) is important parameter to estimate molecule amphiphilicity and possible biological activity of compounds. Log*P* was estimated according to the literature procedure in 1-octanol and phosphate buffer saline (PBS) at wavelength 446 nm. The final dimer possesses amphiphilic characteristics (logP = 0.49) and thus can be used in a future biological experiments as PS for PDT.

Conclusions

In this work, a new π-extended cationic porphyrin dimer was successfully synthesized via a stepwise strategy employing Sonogashira cross-coupling reactions. The target compound and all intermediates were characterized by a set of physicochemical methods ^{1}H, ^{13}C NMR, UV-Vis absorption and fluorescence spectroscopy, and mass spectrometry (MALDI-TOF or ESI-MS). The resulting compound exhibits a significant red shift and broadening of both Soret and Q-bands compared to the monomeric porphyrin, indicating an effective expansion of the π-conjugated system. Notably, the Q-band region displays three distinct bands, with the longest-wavelength band at 679 nm showing a high extinction coefficient (up to 80 000 $M^{-1}cm^{-1}$). The determined 1-octanol/PBS partition coefficient indicates that the synthesized compound possesses amphiphilic properties. The enhanced absorption in the near-infrared (NIR) region, combined with its amphiphilic nature, makes the obtained cationic porphyrin dimer a promising candidate for further biological evaluation as a PS for photodynamic therapy (PDT).

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