



SAKARYA ÜNİVERSİTESİ

FEN BİLİMLERİ ENSTİTÜSÜ DERGİSİ

Sakarya University Journal of Science
SAUJS

ISSN 1301-4048 e-ISSN 2147-835X Period Bimonthly Founded 1997 Publisher Sakarya University
<http://www.saujs.sakarya.edu.tr/>

Title: Synthesis and Characterization of Novel Water-Soluble Tetra-Substituted Zn(II)
Phthalocyanine Containing Triazole and Galactose Moieties

Authors: Yasemin BAYĞU

Received: 2022-10-28 00:00:00

Accepted: 2023-02-23 00:00:00

Article Type: Research Article

Volume: 27

Issue: 4

Month: August

Year: 2023

Pages: 744-756

How to cite

Yasemin BAYĞU; (2023), Synthesis and Characterization of Novel Water-Soluble
Tetra-Substituted Zn(II) Phthalocyanine Containing Triazole and Galactose
Moieties. Sakarya University Journal of Science, 27(4), 744-756, DOI:
10.16984/saufenbilder.1266799

Access link

<https://dergipark.org.tr/en/pub/saufenbilder/issue/79486/1266799>

New submission to SAUJS

<http://dergipark.gov.tr/journal/1115/submission/start>

Synthesis and Characterization of Novel Water-Soluble Tetra-Substituted Zn(II) Phthalocyanine Containing Triazole and Galactose Moieties

Yasemin BAYĞU*¹ 

Abstract

In this study, new water-soluble non-peripheral tetra-substituted zinc complex of phthalocyanine which is contain galactose moieties was synthesized. ZnPc-I was prepared from the galactose substituted dicyano compound by the cyclotetramerization reaction. This dicyano compound was synthesized by Click reaction between 3-(pent-4-yn-1-yloxy)phthalonitrile and 6-azido-6-deoxy-1,2:3,4-di-O-isopropylidene- α -D-galactopyranose. ZnPc-II was obtained by hydrolysis of the protected isopropylidene groups in ZnPc-I in TFA and water mixture. The galactose linked Zn(II) phthalocyanine was achieved to dissolve in common polar solvents and water. All of the new compounds were characterized by elemental analysis, ¹H NMR, ¹³C NMR, IR, UV-vis and MS spectral data.

Keywords: Zinc(II) phthalocyanine, galactose, click reaction, water soluble phthalocyanine

1. INTRODUCTION

Phthalocyanine (Pc) compound having 18 π -electron systems contains four nitrogen atoms in the central cavity and it is known as blue-green-coloured [1]. Phthalocyanines and their metal complexes are widely used a wide range of areas for a long time because of their matchless electronic properties of the phthalocyanine core, high degree of aromaticity and the ability to be added different substituents. Their applications such as non-linear optical devices [2], sensors [3], liquid crystals [4], dye-sensitized solar cells (DSSCs) [5], Langmuir-Blodgett films [6], and photodynamic therapy [7] can be showed as example. Phthalocyanines are generally soluble in commonly used organic solvents

due to substituents such as alkyl, alkoxy, crown ethers.

Photodynamic therapy (PDT) is a clinical treatment method that depended on the use of light to treat a number of cancers such as early gastrointesti, oesophageal, lung and skin cancer [8]. A non-toxic, photosensitizing drug known as a photosensitizer (PS) is used in this treatment method. The photosensitizer causes the formation of reactive oxygen species, which is known as singlet oxygen, from molecular oxygen by using light of the appropriate wavelength. Phthalocyanines are used as second generation photosensitizers [9] because they have photophysical and photochemical properties such as no dark toxicity, strong absorption at long wavelengths, high singlet oxygen production

* Corresponding author: ybaygu@pau.edu.tr (Y. BAYĞU)

¹ Pamukkale University

ORCID: <https://orcid.org/0000-0003-3776-9633>



efficiency, chemical stability and penetration into deep tissues [10, 11]. Phthalocyanine compounds must be water-soluble for to be used as photodynamic therapy agents. For this reason, substituents such as carboxylate, sulfonate and quaternized amino groups can be added to their peripheral, non-peripheral or axial positions. However anionic sulfonated phthalocyanines tend to aggregate in water [12]. In conclusion their photosensitizing ability is lost for their use in PDT. Therefore galactosylated or glucosylated substituted phthalocyanines have prepared in literature [13, 14]. Moreover, carbohydrate moieties such as galactose suggests the specific affinity for tumour tissues for application as photosensitizers in PDT, because the cancer cell gets its energy from carbohydrate. [15-17].

Click Chemistry which was called by Sharpless is used to connect various functional groups together [18]. Click reactions that are selective, cheap and easy are obtained by using copper(I) catalyst between azide and alkyne compounds with high yield [19]. Thanks to these characteristics, Click reactions are commonly used in the synthesis of carbohydrate-containing porphyrins derivatives [20, 21].

In this study, the synthesis and characterization of zinc(II) phthalocyanines, whose galactose derivatives are protected by acetyl units and galactose derivatives contain hydroxyl groups, were reported. A new water-soluble zinc(II) phthalocyanine containing alkyl-linked triazole units and tetra-substituted galactose groups was synthesized. This new compound exhibited the partially-aggregated behavior in aqueous media. The structures of all new compounds were confirmed by using elemental analysis, ^1H and ^{13}C NMR, FT-IR, UV-vis, and MS spectral techniques.

2. EXPERIMENTAL

2.1. General

All chemicals which were used for synthesis of reactions were purchased from commercial suppliers and n-pentanol was dried according to the procedure [22]. FT-IR spectra were recorded on Perkin-Elmer UATR Two spectrometer. ^1H and ^{13}C NMR spectra were measured by Agilent-vnmrs 400/54 and Varian Mercury plus 300 MHz spectrometers. Mass spectra were determined on a Micromass Quattro Ultima LC-MS/MS and on a Bruker Daltonics Microflex LT MALDI-TOF spectrometers. The UV-vis absorption spectra were measured on a Shimadzu UV-1601 spectrophotometer by using double-beamed in 1 mL quartz cuvette. Elemental analyses were determined on a Costech ECS 4010 instrument. Melting points were measured on an electro thermal melting point apparatus in a sealed tube.

2.2. Synthetic Procedures and Spectral Data

2.2.1. Preparation of 3-(3-(1-(((3aR,5R,5aS,8aS,8bR)-2,2,7,7-tetramethyltetrahydro-5H-bis([1,3]dioxolo)[4,5-b:4',5'-d]pyran-5-yl)methyl)-1H-1,2,3-triazol-4-yl)propoxy)phthalonitrile (3):

A suspension of copper(II) acetate monohydrate (0.2 g, 0.98 mmol) and sodium-L-ascorbate (0.4 g, 2.01 mmol) in water (35 mL) was added to the mixture of compound 1 (1.05 g, 5 mmol) and compound 2 (2.15 g, 7.5 mmol) in *tert*-butanol (35 mL). Then, the mixture was stirred under argon atmosphere at room temperature for overnight. The end of this period, the reaction mixture was poured into water (70 mL) and stirred and then extracted with dichloromethane (3x25 mL). The collected organic extracts was washed brine solution (50 mL) and dried over anhydrous MgSO_4 . The product was stirred with diethyl ether and filtered off. Then dried in vacuo to give cream coloured solid. Yield:

1.93 g (77.82%), m.p: 150-152 °C. ¹H NMR (300 MHz, CDCl₃), (δ: ppm): 7.63 (s, 1H, HC=C), 7.53-7.30 (s, 3H, C-H)_{arom}, 5.45 (s, 1H, -OCH), 4.62-4.30 (m, 4H, -OCH), 4.17 (m, 2H, -OCH₂), 4.15 (d, 2H, -NCH₂), 2.93 (m, 2H, -CCH₂), 2.25 (m, 2H, -CH₂CH₂), 1.46-1.24 (s, 12H, CH₃). ¹³C NMR (75 MHz, CDCl₃), (δ: ppm): 161.51, 134.90, 134.83, 125.26, 125.20, 117.21, 115.6, 113.30, 110.08, 109.20, 105.02, 96.40, 71.42, 71.35, 70.89, 68.89, 67.48, 50.65, 28.40, 26.18, 26.11, 25.10, 24.61, 21.81. FT-IR (ATR, cm⁻¹): 3151 (triazole), 3087 (C-H)_{arom}, 2995-2903 (C-H)_{aliph}, 2234 (C≡N), 1299, 1070, 1007. MS (m/z): 496.03 [M+H]⁺, 518.01 [M+Na]⁺, 597.05 [M+2K+Na]⁺. Anal. cald. for C₂₅H₂₉N₅O₆: C, 60.60; H, 5.90; N, 14.13. Found: C, 60.76; H, 5.94; N, 14.20.

2.2.2. Preparation of ZnPc-I:

Non-peripheral substitue dinitrile compound (**3**) (0.25 g, 0.5 mmol), anhydrous zinc(II) acetate (33 mg, 0.18 mmol) and 5 drops of DBU in dry pentanol (3.5 mL) were heated and stirred at 155 °C under argon atmosphere for 24 h in a Schlenck system.. After cooling to room temperature, the reaction mixture was poured into hexane (20 mL) and then centrifuged. Purification of the crude product was carried out by column chromatography on silica gel using dichlorometane/ethanol (98:3) to give green solid. Yield: 66 mg (26.4%), m.p> 300 °C. ¹H NMR (400 MHz, CDCl₃), (δ: ppm): 9.20 (s, 4H, HC=C), 8.09-7.51 (s, 12H, C-H)_{arom}, 5.44 (s, 4H, -OCH), 4.58-4.28 (m, 16H, -OCH), 4.21 (m, 8H, OCH₂), 4.14 (m, 8H, -NCH₂), 2.97 (s, 8H, -CCH₂), 2.57 (m, 8H, -CH₂CH₂), 1.45-1.16 (s, 48H, CH₃). ¹³C NMR (100 MHz, CDCl₃), (δ: ppm): 156.17, 153.60, 141.62, 136.25, 134.55, 125.73, 122.46, 115.44, 109.76, 109.69, 108.89, 96.06, 71.04, 70.62, 70.19, 67.97, 67.11, 50.26, 29.12, 25.88-24.32, 21.93. UV-vis (CHCl₃): λ_{max} (log ε): 705 (5.26), 637 (4.51), 322 (4.65). FT-IR (ATR, cm⁻¹): 3149 (triazole), 3048 (C-H)_{arom}, 2933-2856 (C-H)_{aliph}, 1627 (C=N), 1451, 1324, 1152. MS (m/z): 2045.68 [M]⁺. Anal. cald. for C₁₀₀H₁₁₆N₂₀O₂₄Zn: C, 58.66; H,

5.71; N, 13.68; Zn, 3.19. Found: C, 58.78; H, 5.85; N, 13.76; Zn, 3.32.

2.2.3. Preparation of ZnPc-II:

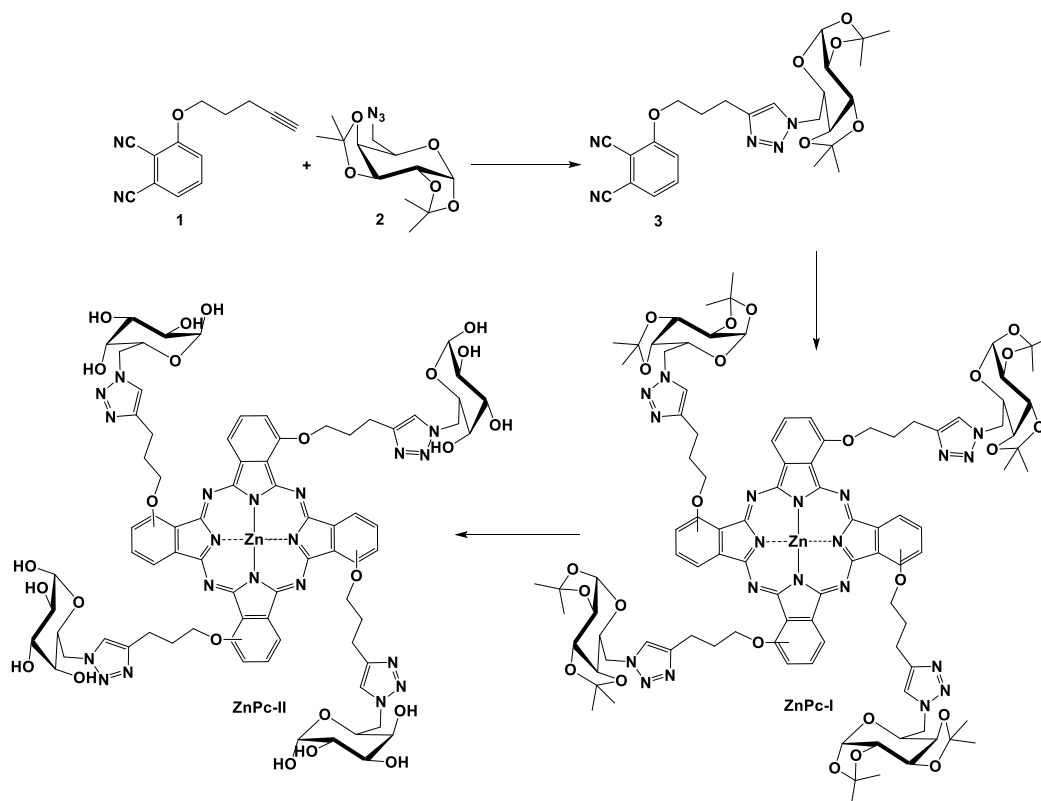
ZnPc-I (61.35 mg, 0.03 mmol) was stirred in trifluoro acetic acid water mixture [(9:1) (1.5 mL)] at room temperature for 35 minute. Diethyl ether (6 mL) was added to the solution at the end of this period and the product precipitated. The green solid was filtered off, washed with diethyl ether and then dried under vacuo. Yield: 46.09 mg, (89.06%), m.p> 300 °C. ¹H NMR (400 MHz, DMSO-d₆), (δ: ppm): 8.59 (s, 4H, HC=C), 8.07-7.57 (s, 12H, C-H)_{arom}, 4.96-3.53 (m, 52 Gal-H and -OH), 3.14 (s, 8H, -CCH₂), 2.57 (m, 8H, -CH₂CH₂). ¹³C NMR (100 MHz, CDCl₃), (δ: ppm): 156.17, 146.98, 146.31, 140.03, 136.35, 123.24, 119.58, 115.19, 102.25, 97.91, 76.42, 72.07, 70.01, 69.26, 68.78, 51.31, 29.60, 21.92. UV-vis λ_{max} (log ε): 708 (5.31), 638 (4.58), 327 (4.62) in DMSO, 682 (4.64), 319 (4.47) in H₂O. FT-IR (ATR, cm⁻¹): 3269 (OH), 3153 (triazole), 2924-2882 (C-H)_{aliph}, 1673 (C=N), 1268, 1198, 1058. MS (m/z): 1725.95 [M]⁺. Anal. cald. for C₇₆H₈₄N₂₀O₂₄Zn: C, 52.86; H, 4.90; N, 16.22; Zn, 3.79. Found: C, 53.03; H, 5.02; N, 16.39; Zn, 3.93.

3. RESULTS AND DISCUSSION

The synthetic routes were described to prepare Zn(II) phthalocyanines in Scheme 1. The precursor compound **3** was synthesized via Husgein 1,3-dipolar cycloaddition reaction between 3-(pent-4-yn-1-yloxy)phthalonitrile [23] and 6-azido-6-deoxy-1,2:3,4-di-O-isopropylidene-α-D-galactopyranose [24] in the presence of copper(II) acetate monohydrate and sodium-L-ascorbate in water/tert-butanol mixture (1:1) at room temperature in high yield (77.82%). FT-IR spectrum of this compound was showed characteristic vibrations at 3151 cm⁻¹ for triazole and at 2234 cm⁻¹ for C≡N moieties (Figure 1). In the ESI mass spectra of compound **3** at m/z = 496.03, 518.01, 597.05 signals should be concerned [M+H]⁺,

$[M+Na]^+$ and $[M+2K+Na+H]^+$ ion peaks respectively (Figure 2). These mass spectra were confirmed the structure. The characteristic triazole resonances at $\delta = 7.63$

ppm in 1H NMR spectra and $\delta = 134.9$ and 125.20 ppm in ^{13}C NMR spectra were confirmed the formation of compound 3 (Figure 3 and Figure 4).



Scheme 1 The synthesis procedure of ZnPc-II

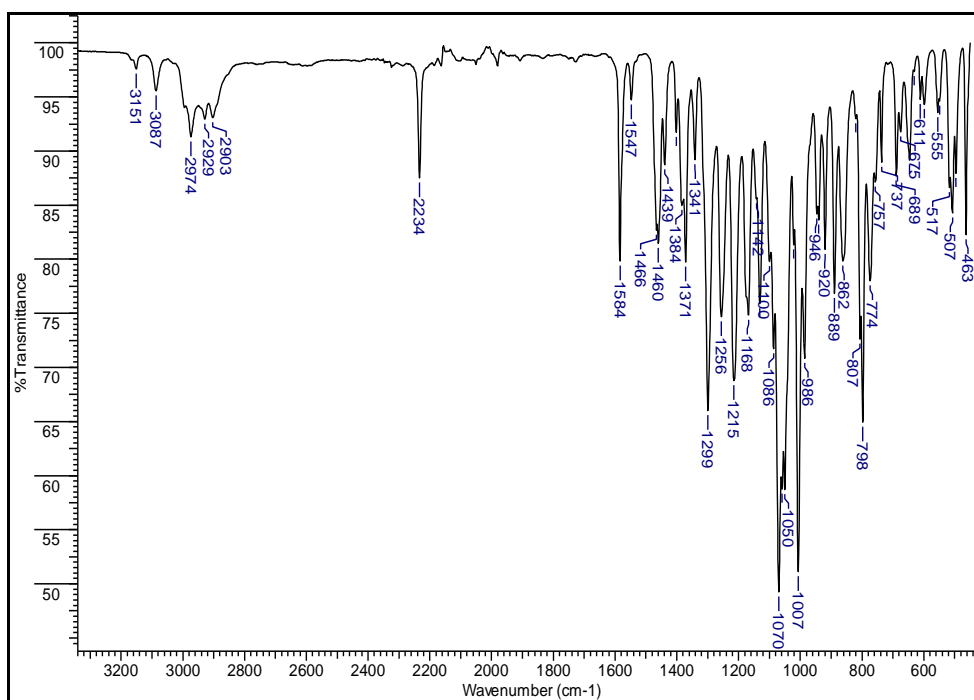
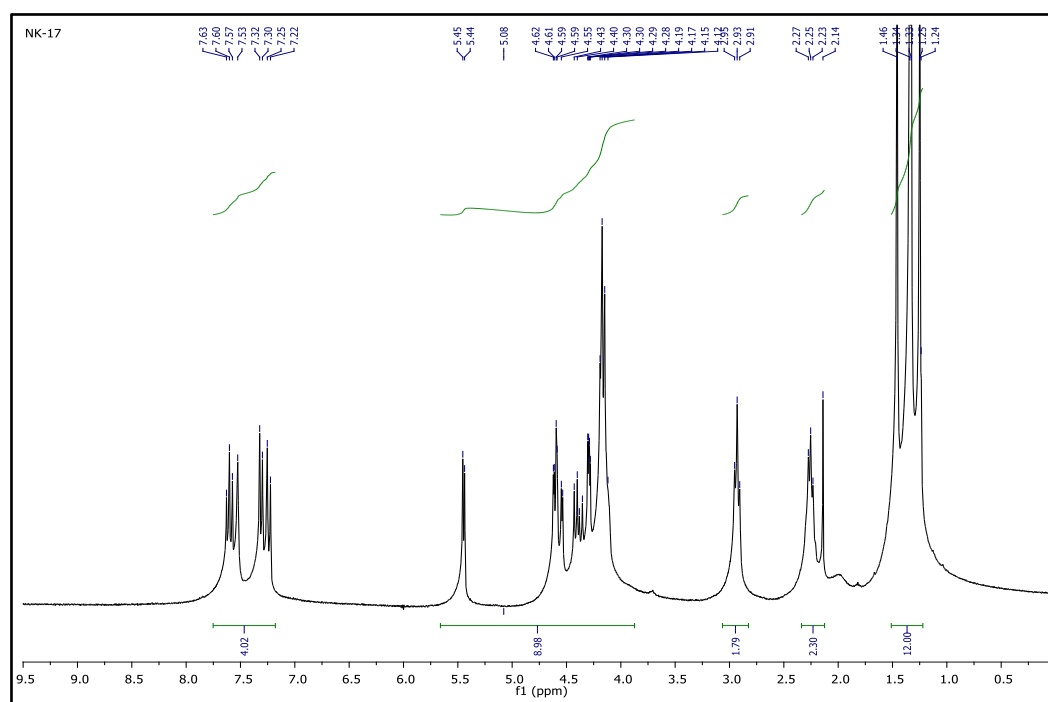
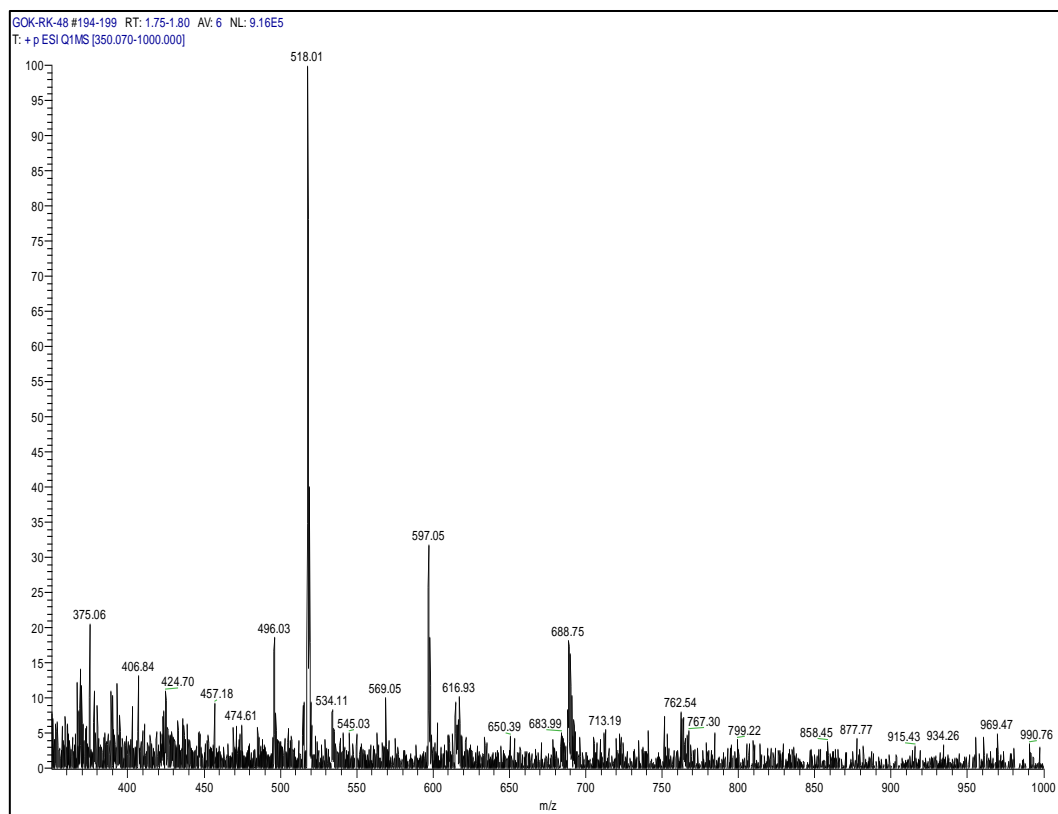
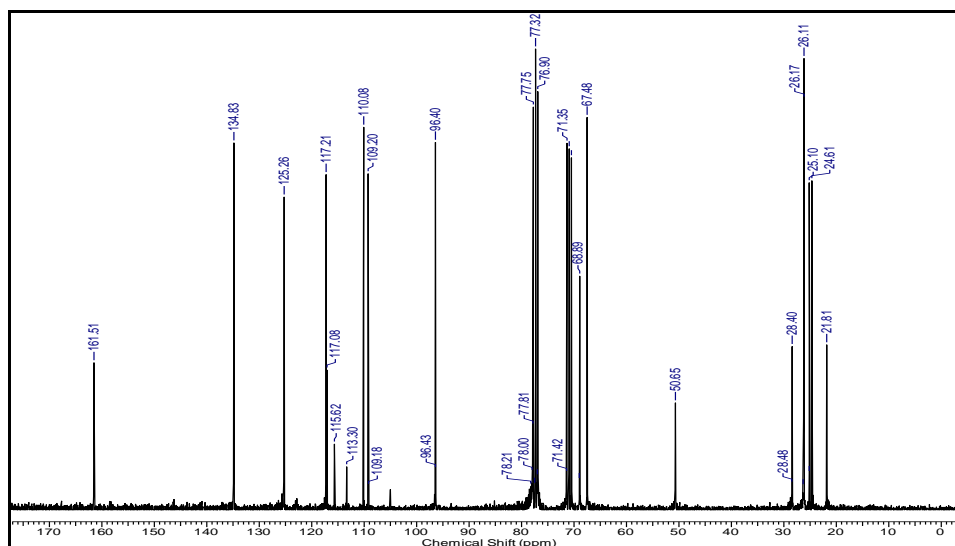


Figure 1 IR spectrum of compound 3



Figure 4 ^{13}C -NMR Spectrum of compound 3

Zn(II) phthalocyanine (ZnPc-I) was prepared from compound 3 by the template reaction with anhydrous Zn(II) acetate and a few drop of DBU in dry n-pentanol under reflux in inert atmosphere. Purification of the ZnPc-I by column chromatography on silica gel using dichlorometane/ethanol (98:3) gave a blue-green solid in yield 26.4%. The phthalocyanine formations was supported by disappearance of characteristic $\text{C}\equiv\text{N}$ stretching vibration at 2234 cm^{-1} in the precursor compound 3 in the FT-IR spectra. In addition to that, the novel signal at 1627 cm^{-1} concerning $\text{C}=\text{N}$ moieties also supported the phthalocyanine formation (Figure 5). The

molecular ion peak at $m/z = 2045.68\text{ [M]}^+$ confirmed the proposed structure in the MALDI-TOF mass spectrum of ZnPc-I, (Figure 6). A proton belonging to triazole groups was observed at $\delta = 9.20$ and the other aromatic ring protons were observed at $\delta = 8.09\text{--}7.51\text{ ppm}$ in the ^1H NMR spectrum of ZnPc-I (Figure 7). In the ^{13}C NMR spectrum of ZnPc-I, the disappearance of characteristic $\text{C}\equiv\text{N}$ signal belonging to the precursor compound 3 at $\delta = 113.30\text{ ppm}$ and the appearance of the novel signals at $\delta = 141.62\text{ ppm}$ concerning $\text{C}=\text{N}$ moieties was indicated the phthalocyanine formation (Figure 8).

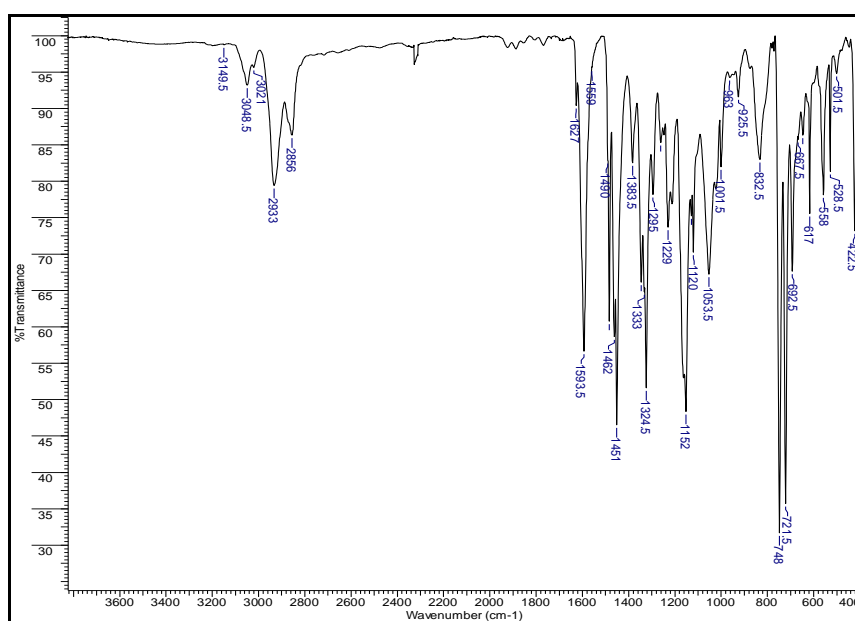


Figure 5 IR spectrum of ZnPc-I

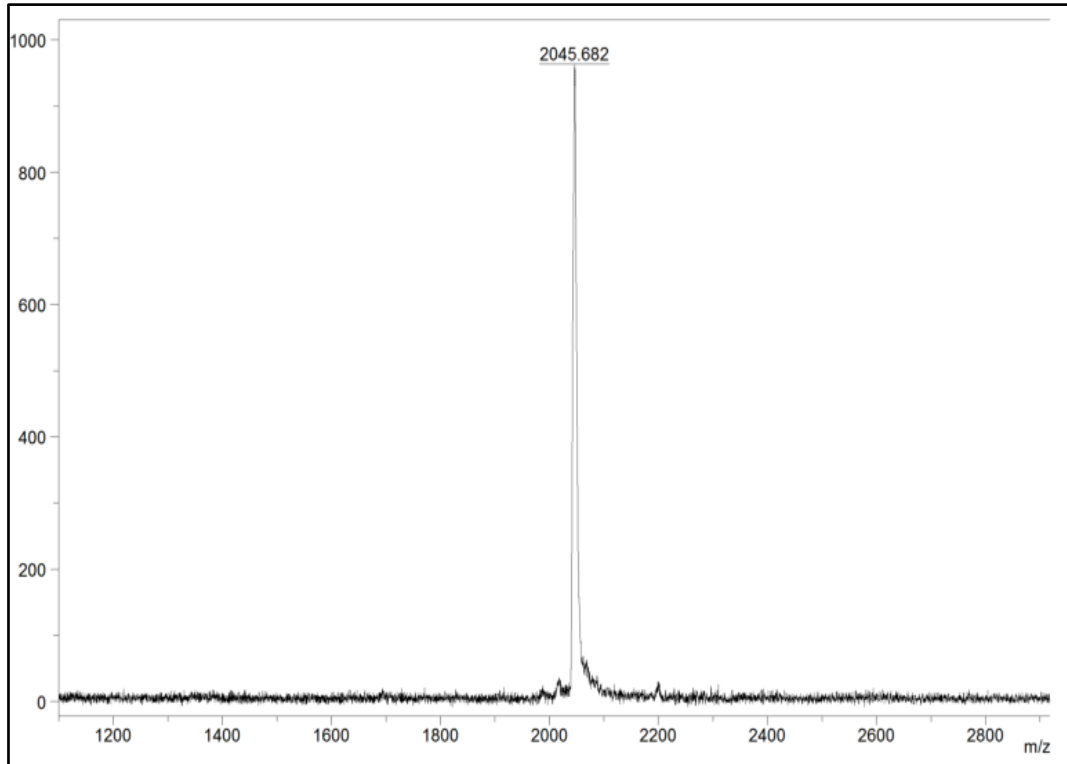


Figure 6 Mass spectrum of ZnPc-I

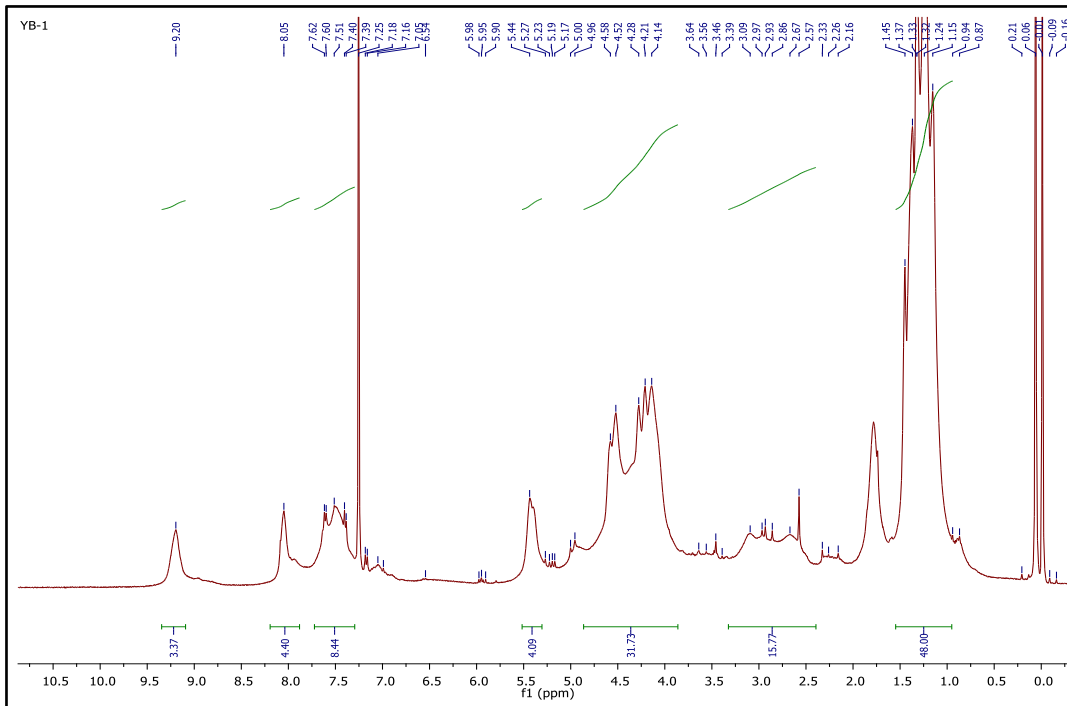
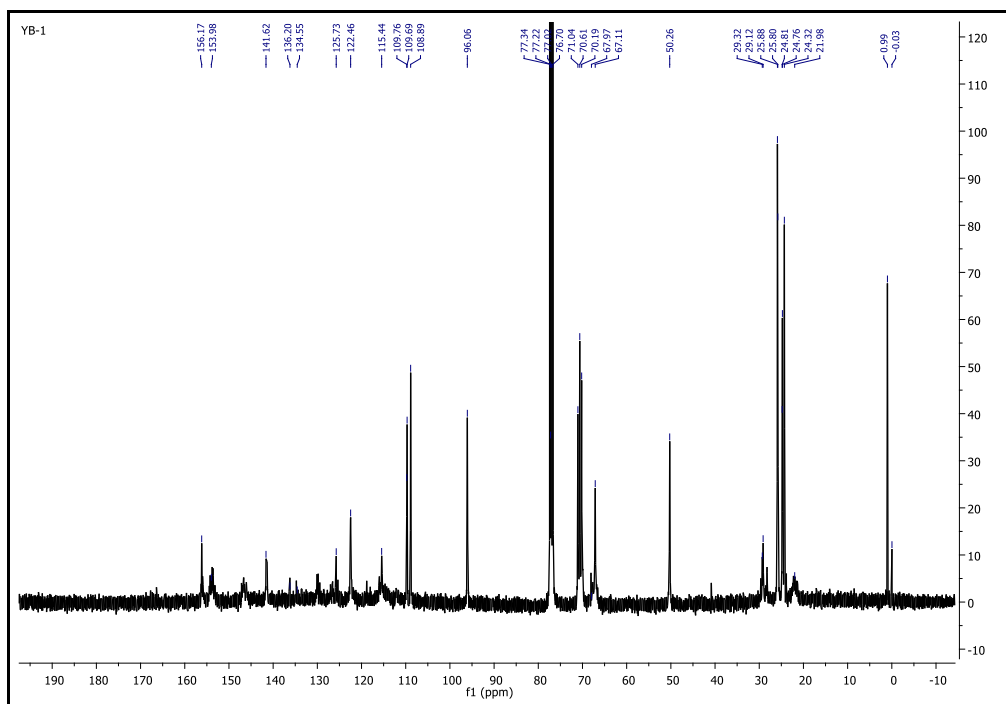


Figure 7 ¹H NMR spectrum of ZnPc-I

Figure 8 ^{13}C NMR spectrum of ZnPc-I

ZnPc-I was stirred in a mixture of trifluoroacetic acid and water (9:1) at room temperature for 35 minute. As a result of this process, the isopropylidene groups of ZnPc-I were deprotected and ZnPc-II was obtained in very high yield (89.07%). This compound dissolved in water due to galactose units. The presence of O—H stretching vibrations at 3269 cm^{-1} in FT-IR spectrum of this compound supported the removal of the protecting groups (Figure 9). The molecular

ion peak being at $m/z = 1725.95 [\text{M}]^+$ was confirmed the structure in the MALDI-TOF mass spectrum of ZnPc-II (Figure 10). The chemical shifts at $\delta = 1.45\text{--}1.16\text{ ppm}$ should be indicated the disappearance of isopropylidene group of ZnPc-II (Figure 11). The observed novel moieties at $\delta = 25.88\text{--}24.32\text{ ppm}$ in the ^{13}C NMR spectrum of ZnPc-II also showed the formation of ZnPc-II (Figure 12).

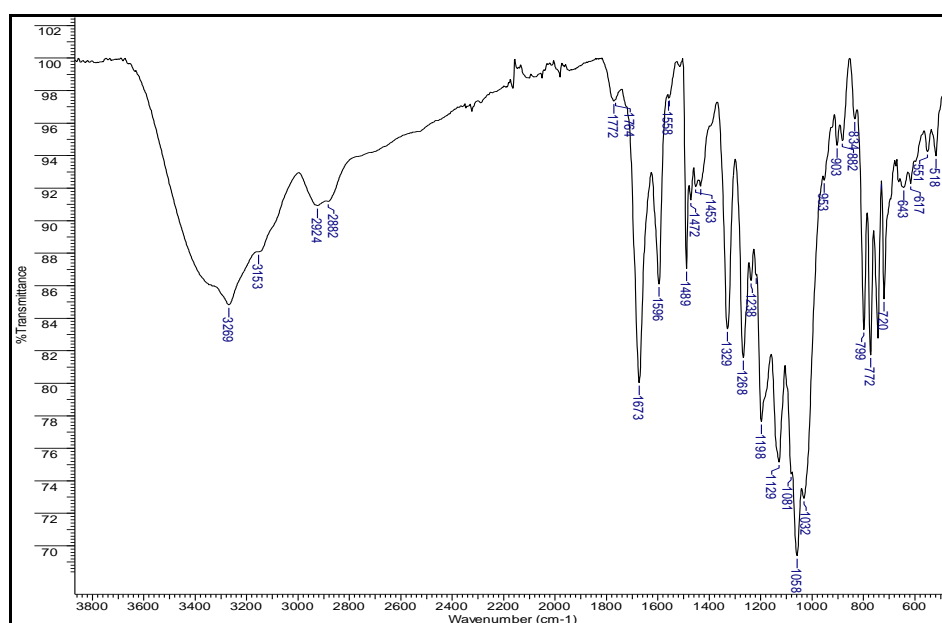


Figure 9 IR spectrum of ZnPc-II

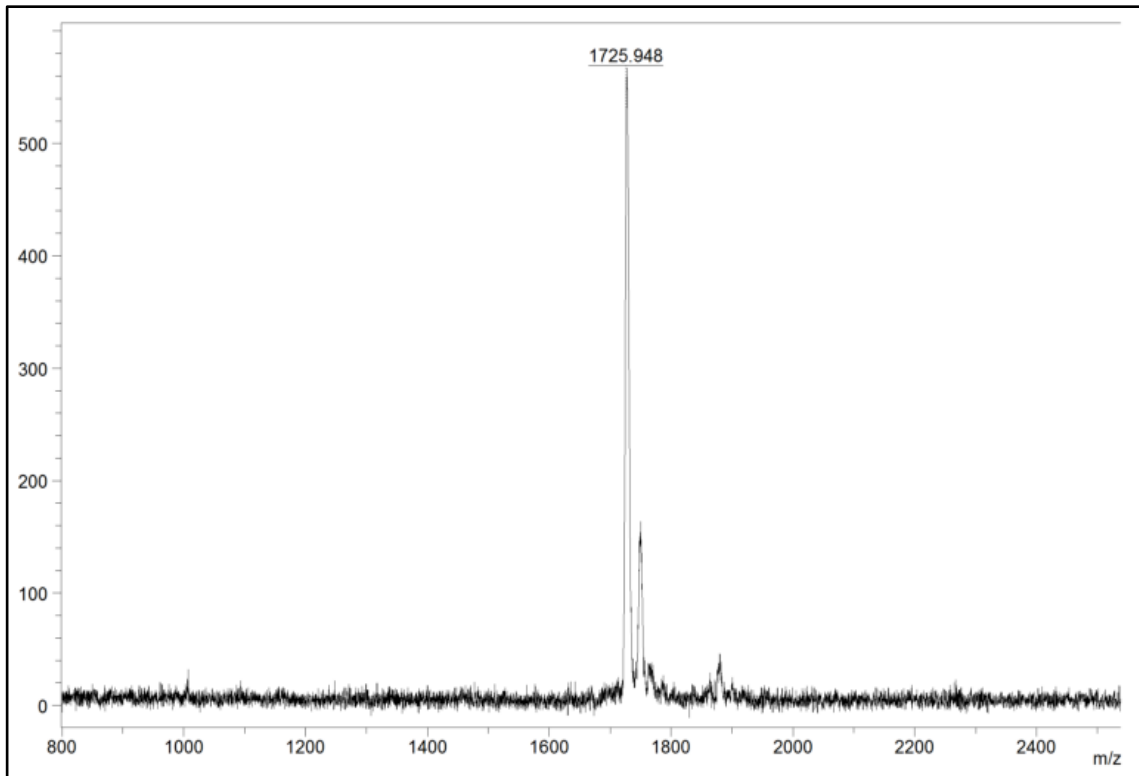


Figure 10 Mass spectrum of ZnPc-II

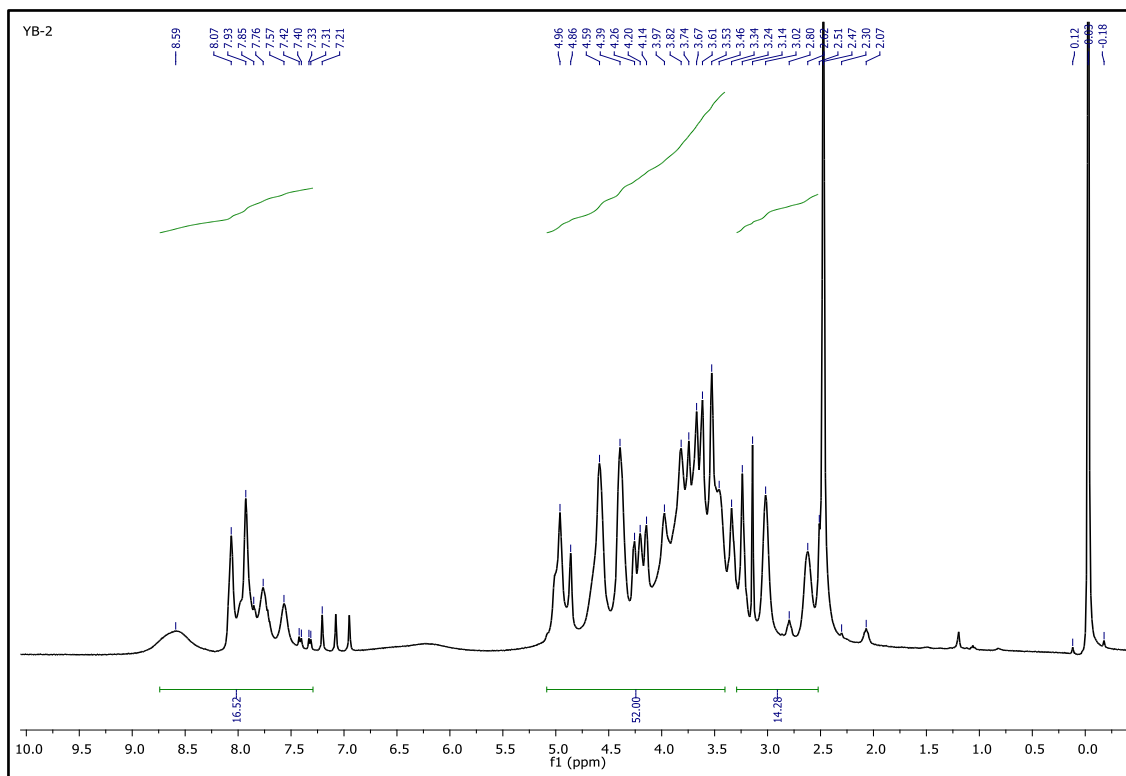
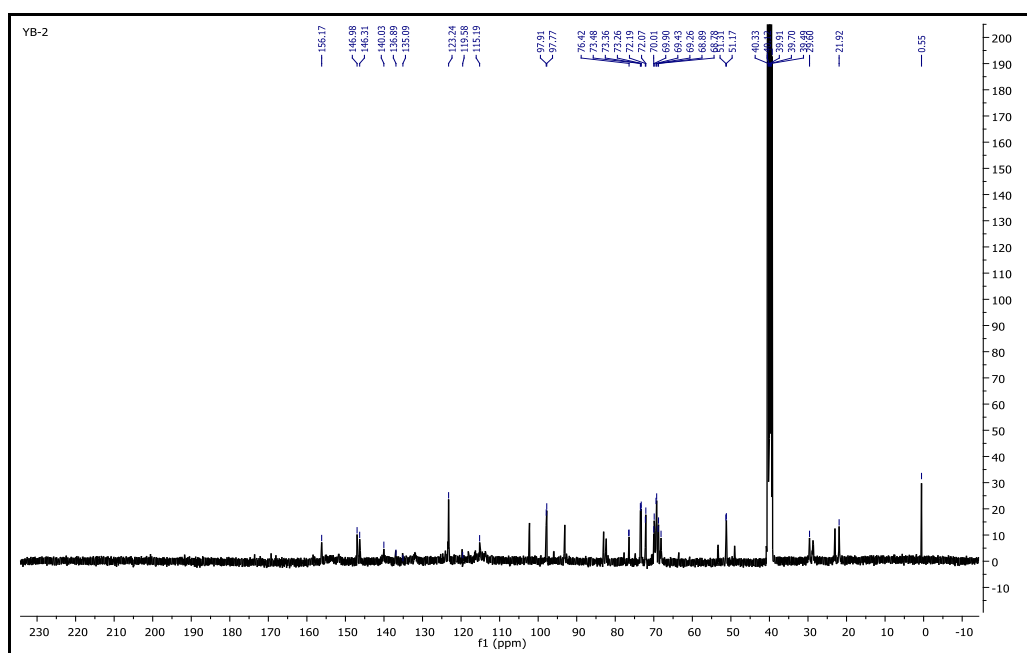
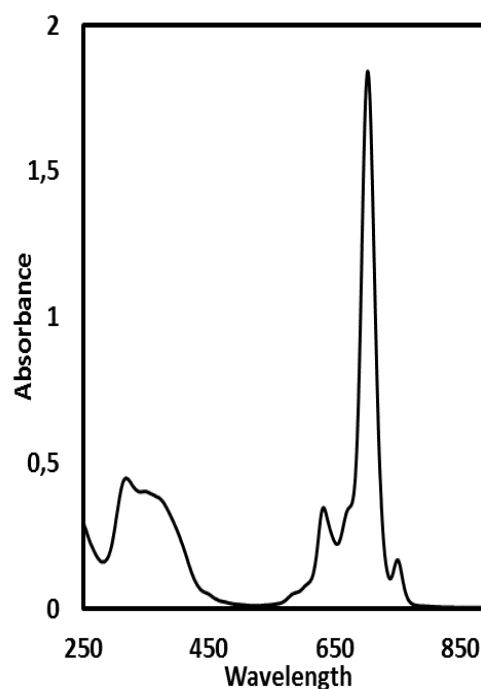


Figure 11 ¹H NMR spectrum of ZnPc-II

Figure 12 ^{13}C NMR spectrum of ZnPc-II

The synthesized novel zinc(II) phthalocyanines ZnPc-I and ZnPc-II exhibited in the ground state typical electronic absorption having with the characteristic $\pi \rightarrow \pi^*$ transitions of the phthalocyanine core in Q band region. These absorptions were observed at $\lambda = 705$ nm in chloroform for ZnPc-I and 708 nm in DMSO, 682 nm in water for ZnPc-II respectively. These single and narrow transitions in Q band region of UV-vis spectra where are shown in Figure 13 and Figure 14 indicated the monomeric and non-aggregated behaviors of ZnPc-I in chloroform and ZnPc-II in DMSO. The UV-vis spectra of ZnPc-II showed that the intensity of Q band is much lower in water than in DMSO. This situation can be comment as showing aggregated behaviors of ZnPc-II. However this aggregation is much lower than according to in a similar study [25]. Alkyl groups linked by triazole rings in ZnPc-I and ZnPc-II compounds may have prevented aggregation.

Figure 13 UV-vis Spectrum of ZnPc-I (10^{-5} M in chloroform)

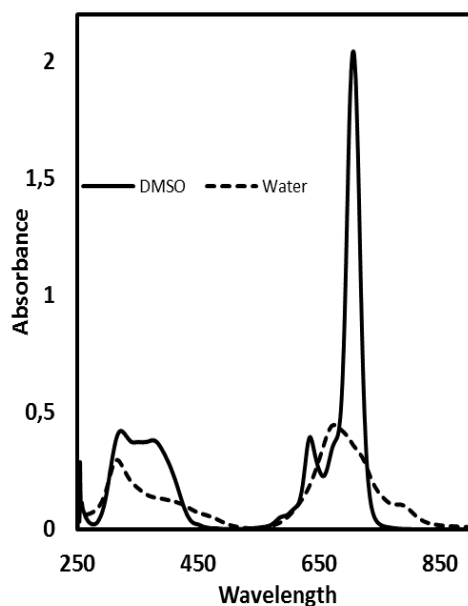


Figure 14 UV-vis Spectrum of ZnPc-II (10^{-5} M in water and DMSO)

4. CONCLUSION

In summary, compound 3 was synthesized using Husein 1,3-dipolar cycloaddition reaction between 3-(pent-4-yn-1-yloxy)phthalonitrile (1) and azido of galactose compound (2). ZnPc-I was obtained from tetramerization of compound 3. ZnPc-II was prepared with hydrolysis of ZnPc-I. All of novel compounds was characterized by various spectral data. Thus water soluble and partially aggregated phthalocyanine containing four D-galactose units was obtained. This new water soluble compound due to carbohydrate moieties can be used for the potential application as photosensitizers in PDT.

Funding

The author has no received any financial support for the research, authorship or publication of this study.

Authors' Contribution

The author designed this study, carried out all experiments and wrote the manuscript.

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

REFERENCES

- [1] C. C. Leznoff, A. B. P. Lever (Eds.), "Phthalocyanines—Properties and Applications," Vols. 1–4, VCH, New York, 1989.
- [2] N. Farajzadeh, G. Kösoğlu, M. Erdem, G. Eryürek, M. Burkut Koçak, "Nonlinear optical properties of peripheral symmetrically and non-symmetrically 4-(trifluoromethoxy)phenoxy substituted zinc phthalocyanines," *Synthetic Metals*, vol. 266, pp. 116440, 2020.
- [3] Y. Baygu, R. Capan, M. Erdogan, C. Ozkaya, Acikbas, Kabay, Y. Gok, "Synthesis, characterization and chemical sensor properties of a novel Zn(II) phthalocyanine containing 15-membered dioxo-dithia macrocycle moiety," *Synthetic Metals*, vol. 280, pp. 116870, 2021.
- [4] A. J. Duro, G. de la Torre, J. Barbera, J. L. Serrano, T. Torres, "Synthesis and Liquid-Crystal Behavior of Metal-Free and Metal-Containing Phthalocyanines Substituted with Long-Chain Amide Groups," *Chemistry of Materials*, vol. 8, no. 5, pp. 1061, 1996.
- [5] B. Yıldız, B. S. Arslan, E. Güzel, M. Nebioglu, N. Menges, I. Sisman, M. K.

- Sener, “Non-aggregating zinc phthalocyanine sensitizer with bulky diphenylphenoxy donor groups and pyrazole-3-carboxylic acid anchoring group for coadsorbent-free dye-sensitized solar cells,” *Solar Energy*, vol. 226, pp. 173–179, 2021.
- [6] L. Valli, “Phthalocyanine-based Langmuir–Blodgett films as chemical sensors,” *Advances in Colloid and Interface Science*, vol. 116, no. 1-3, pp. 13-44, 2005.
- [7] T. Nyokong, V. Ahsen (Eds.), “Photosensitizers in Medicine, Environment and Security,” Springer, Dordrecht Heidelberg London New York, 2012.
- [8] C. Hopper, “Photodynamic therapy: a clinical reality in the treatment of cancer,” *The Lancet Oncology*, vol. 1, pp. 212-219, 2000.
- [9] Y. Uruma, L. Sivasamy, P. M. Y. Yoong, K. Onuma, Y. Omura, M. Doe, M. Osaki, F. Okada, “Synthesis and biological evaluation of glucose conjugated phthalocyanine as a second-generation photosensitizer,” *Bioorganic & Medicinal Chemistry*, vol. 27, no. 15, pp. 3279-3284, 2019.
- [10] H. T., Akçay, M. Piskin, Ü. Demirbas, R. Bayrak, M. Durmus, E. Menteşe, H. Kantekin, “Novel triazole bearing zinc(II) and magnesium(II) metallo-phthalocyanines: Synthesis, characterization, photophysical and photochemical properties,” *Journal of Organometallic Chemistry*, vol. 745-746, pp. 379-386, 2013.
- [11] G. Reddy, E. D. Enrico Della Gaspera, L. A. Jones, L. Giribabu, “Self-assembly of a symmetrical dimethoxyphenyl substituted Zn(II) phthalocyanine into nanoparticles with enhanced NIR absorbance for singlet oxygen generation,” *Journal of Photochemistry & Photobiology, A: Chemistry*, vol. 408, pp. 113123, 2021.
- [12] A. Ogunsipe, T. Nyokong, “Photophysical and photochemical studies of sulphonated non-transition metal phthalocyanines in aqueous and non-aqueous media,” *Journal of Photochemistry & Photobiology, A: Chemistry*, vol. 173, no. 2, pp. 211, 2005.
- [13] Z. Iqbal, M. Hanack, T. Ziegler, “Synthesis of an octasubstituted galactose zinc(II) phthalocyanine,” *Tetrahedron Letters*, vol. 50, no. 8, pp. 873–875, 2009.
- [14] A. O. Ribeiro, J. P. C. Tomé, M. G. P. M. S. Neves, A. C. Tomé, J. A. S. Cavaleiro, Y. Iamamoto, T. Torres, “[1,2,3,4-Tetrakis(α/β -d-galactopyranos-6-yl)phthalocyaninato]zinc(II): a water-soluble phthalocyanine,” *Tetrahedron Letters*, vol. 47, no. 52, pp. 9177–9180, 2006.
- [15] T. K. Horne, M. J. Cronjé, “Novel carbohydrate-substituted metallo-porphyrazine comparison for cancer tissue-type specificity during PDT,” *Journal of Photochemistry and Photobiology B: Biology*, vol. 173, pp. 412-422, 2017.
- [16] A. M. Otto, “Warburg effect(s)—a biographical sketch of Otto Warburg and his impacts on tumor metabolism,” *Cancer and Metabolism*, vol. 4, no. 5, pp. 1-8, 2016.
- [17] M. V. Liberti, J. W. Locasale, “The Warburg effect: how does it benefit cancer cells?,” *Trends in Biochemical Sciences*, vol. 41, no. 3, pp. 211–218, 2016.

- [18] R. Huisgen, "1,3-Dipolar Cycloadditions Past and Future," *Angewandte Chemie International Edition*, vol. 2, pp. 565-598, 1963.
- [19] H. C. Kolb, M. G. Finn, K. B. Shapless, "Click Chemistry: Diverse Chemical Function from a Few Good Reactions," *Angewandte Chemie International Edition*, vol. 40, pp. 2004-2021, 2001.
- [20] Y. Baygu, B. Yıldız, N. Kabay, Y. Gök, "Novel magnesium and zinc porphyrazines containing galactose moieties: synthesis via click reaction and characterization," *Inorganic Chemistry Communications*, vol. 71, pp. 35-40, 2016.
- [21] F. Bächle, N. Siemens, T. Ziegler, "Glycoconjugated Phthalocyanines as Photosensitizers for PDT – Overcoming Aggregation in Solution," *European Journal of Organic Chemistry*, vol. 2019, pp. 7089-7116, 2019.
- [22] D. D. Perin, W. L. F. Armarego, D. R. Perin, "Purification of Laboratory Chemicals," 2nd ed., Pergamon Press, New York, 1985.
- [23] Z. Kanat, H. Dinçer, "The synthesis and characterization of nonperipherally tetra terminal alkynyl substituted phthalocyanines and glycoconjugation via the click reaction," *Dalton Transactions*, vol. 43, pp. 8654–8663, 2014.
- [24] J. A. F. Joosten, B. Evers, R. P. van Summeren, J. P. Kamerling, J. F. G. Vliegthart, "Synthesis of β -D-Galp-(1 \rightarrow 4)- β -D-GlcpNAc-(1 \rightarrow 2)- α -D-Manp-(1 \rightarrow O)(CH₂)₇CH₃ Mimics to Explore the Substrate Specificity of Sialyltransferases and trans-Sialidases," *European Journal of Organic Chemistry*, vol. 18, no. 6, pp. 3569-3586, 2003.
- [25] A. R. M. Soares, J. P. C., Tomé, M. G. P. M. S. Neves, A. C. Tomé, J. A. S. Cavaleiro, T. Torres, "Synthesis of water-soluble phthalocyanines bearing four or eight D-galactose units," *Carbohydrate Research*, vol. 344, no. 4, pp. 507–510, 2009.