

Mono-ring phthalocyanine complexes of large ions Lu³⁺ and Sn⁴⁺: synthesis and comparison of photophysical properties

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Dedicated to Acad. Ivan Juchnovski on the occasion of his 80th birthday

Phthalocyanine complexes have been extensively studied during last years as photosensitizers for photodynamic therapy (PDT). The advantages of metal phthalocyanine complexes (MPcs) of far red absorption and high levels of singlet oxygen generation have been featured some MPcs for clinical PDT. Presently only a few phthalocyanines are approved for clinical PDT. These are ZnPc-liposomes (Italy), differently sulfonated AlPcS₁₋₄, (Photosense, Russia) and a silicon complex (Pc4, USA). The unique absorption properties such as two order higher extinction coefficient at the far red region (670-740 nm) in comparison to the firstly approved porphyrins (~ 630 nm) make MPcs efficiently excitable through disordered tissue. The development of new generation MPcs with favourable physicochemical properties includes complexes of large metal ions such as lutetium and tin, which are actual ions for MPcs within the PDT. The complexes can participate in the intersystem crossing transition to the triplet state which facilitates the further photocatalytic reactions to produce the highly reactive singlet oxygen. The study presents the effective synthesis strategy to prepare large ions phthalocyanines (Sn⁴⁺Pc and Lu³⁺Pc) as mono-ring complexes for advance of PDT efficacy. The effects of the coordinated ions on the photophysical properties of Sn⁴⁺Pc and Lu³⁺Pc were studied in comparison to the metal-free phthalocyanine (H₂Pc).

Key words: phthalocyanine complexes; lutetium, tin; photophysical properties; photodynamic therapy

INTRODUCTION

Phthalocyanines are well known as second generation photosensitizers for biomedical applications, especially the metallated derivatives with ions coordinated in the cavity of the macrocycle [1-5]. The chemical classification of metallophthalocyanines (MPcs) is heterocyclic organic semiconductor molecules with metal ion Mⁿ⁺ of oxidation state $1 \leq n \leq 6$ which can coordinate one or two negatively charged tetraisoindoles ligands yielding in mono - or diphthalocyaninato, i.e. double-decker, complexes [6]. The unique optical and electronic properties of the MPcs besides their high chemical and thermal stability are the key factors for their usage as photosensitizers for photodynamic therapy (PDT) of cancer [1-5] and for optical limiting devices [7, 8]. MPcs have a much higher extinction coefficient ($\epsilon > 10^5 \text{ M}^{-1} \text{ cm}^{-1}$) of the Q band, as approx. in the 650 - 720 nm spectra which makes them efficiently excitable directly through living tissue. MPcs have been widely thought to be ideal photosensitizers for

PDT due to their far-red and high intensity absorption, red shifted fluorescence and high level of singlet oxygen quantum yields [9]. However, as large planar molecules because of strong interactions between the macrocycles, these Pcs readily form stacked aggregates and are poorly soluble which depresses their photoactivity and restrains further studies on their photophysicochemical properties and photodynamic activity [10].

The reducing of the aggregation potential and improving the solubility of the MPcs are currently of an active research interests. The efforts in development of soluble phthalocyanine photosensitizers for PDT applications have been made in order to obtain complexes with favorable photophysical and photochemical characteristics *via* molecular design that facilitates the uptake and selectivity for a high PDT efficiency. Pcs` macrocyclic system is very flexible to modifications of the structure and their photophysical properties can be tuned by altering the substituents on the Pc ring and on the axial position at the coordinated different central metal ions [11, 12]. Phthalocyanines are able to form

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complexes with a wide range of metals as the role of the central metal is not only to alter their photo-physicochemical properties but most importantly is to prevent the aggregation. The bigger in size encompassed atoms in the central cavity of the Pcs ensures the monomeric state of MPcs molecules in solutions [13,14].

Among the new generation phthalocyanine complexes, lanthanide (III) phthalocyanines are of a high interest, especially the lutetium phthalocyanines (LuPcs) that have been studied due to their rich electrochromic and gas-sensing properties and the ability of the Lu^{3+} for coordination of two or more Pc-molecules per one lutetium ion [15, 16]. The known LuPcs have an optimal singlet oxygen quantum yields (> 0.3) and that property is an indication of the potential of these complexes as photosensitizers for PDT [17, 18]. The first lutetium complex studied for PDT was Lu-texaphyrine which is a porphyrin derivative. Presently this compound is clinically approved for USA as a photosensitizer for PDT in oncology with the commercial name **Lutrin®**. Chemically, Lutrin is a water-soluble compound with high tumor selectivity and it has an intensive absorption maximum at 732 nm but with low efficiency of singlet oxygen quantum yield (~ 0.11) in comparison to other photosensitizers [19-21]. The usage of lutetium ion in phthalocyanine complexes as mono-ring molecule was explored in our recent works suggesting that two newly synthesized methylpyridyloxy- substituted LuPcs have high efficiency for PDT applications [16, 22].

The second metal ion for formation of MPc complex, which is explored in the present study, is tin ($\text{Sn}^{2+/4+}$). Tin characterizes with different oxidation states so that the phthalocyanine Sn^{2+} and Sn^{4+} complexes can be synthesized in dependence on the rations between the ligand and metal salt. Moreover, the tin ion has a size which is not allowing the coordination within the cavity of the Pc ring. This structure facilitates the existence of molecules in monomeric state due to the steric hindrance which is of importance for the effectiveness of photosensitizers in solution. Similar to Lu, Sn ions tends to form double – decker structures. The monomolecular SnPcs complexes showed relatively long wavelength absorbance (> 690 nm) and high photochemical potential for cancer PDT application [23-25]. Presently Sn^{4+} etiopurpurin (SnET2 , **Purlytin™**) is accepted as a drug for macular degeneration treatment with PDT. The in vitro studies showed stronger influence of the nature of the coordinated

tin ion on the uptake and the photocytotoxicity as compared to the non-coordinated photosensitizers [19, 26].

The macrocyclic molecule of phthalocyanine appears a ligand able to coordinate the most of the metal and semimetal ions in the periodic table. The synthesis of phthalocyanines (Pcs) involves a routine pathway which is based on the reaction of tetracyclomerization starting from the non- or different substituted dinitriles. The addition of metal salts can facilitate the formation of macrocycle and leads to the high yield product of phthalocyanine complex which are further accessible for proper functionalization.

The study presents the synthesis of phthalocyanine complexes coordinated with large ions of Lu^{3+} and Sn^{4+} starting from a metal-free phthalocyanine by using the suitable metal salts and high boiling point solvent. Both complexes were chemically characterized by the means of ^1H NMR, MS, IR and UV-vis spectroscopy. The absorption and fluorescence properties of LuPc and SnPc were investigated in solutions of dimethylformamide in comparison to the metal-free phthalocyanine used as a ligand molecule.

EXPERIMENTAL

General

All reagents and solvents were of reagent-grade quality obtained from commercial suppliers. All solvents used for synthesis such as dimethylformamide (DMF) and quinoline were dried or distilled and stored over molecular sieves (3 Å) before experiments. The used metal salts: $\text{Lu}(\text{OAc})_3$ and SnCl_2 were dried in Glass oven over P_2O_5 . The purity of the products were tested by using thin layer chromatography (TLC). All reactions were carried out under dry nitrogen atmosphere. The spectrophotometric experiments were carried out in diluted solutions ($< 10^{-5}$ M) of dimethylformamide (DMF) of spectroscopic grade.

Instruments and equipment

FT-IR spectra were recorded on a Bruker Tensor 27 apparatus. UV-visible spectra were recorded with a Perkin Elmer Lambda 25 UV/Vis Spectrometer. Fluorescence spectra were recorded with a Perkin Elmer LS 55 Luminescence Spectrometer. ^1H NMR spectra were recorded on Bruker 600 MHz spectrometer in DMSO-d_6 solution. Mass spectrometer (Q-TOF

MS/MS) in ESI mode was used for evidence of both complexes.

Synthesis

The synthesis of metal free phthalocyanine (H_2Pc) was carried out by using the commercially available dilithium phthalocyanine (Sigma-Aldrich). The product was used after extraction on Soxhlet apparatus with methanol and was additionally purified with acetone. The reaction of demetallation of Li_2Pc was carried out according to the well know procedure [15–17]. The phthalocyanine complexes of Lu^{3+} and Sn^{4+} (LuPc and SnPc) were prepared by using the metal – free phthalocyanine, the proper metal salt by using the equal equivalency (1:1) of the molecules of H_2Pc and metal salt was used. The reaction was carried out by using a high boiling point solvent such as quinoline ($> 200\text{ }^\circ\text{C}$) under inert nitrogen atmosphere (Scheme 1). The change of color from dark blue to soft bluish was observed in synthesis of LuPc and the color changes to green for SnPc . The lack of absorption band approx. at 800 nm confirms that both complexes are monomolecular without non-desirable double-decker molecules. As the coordination number of rare-earth metals is above 8, but the obtained Lu^{3+}Pc has 3, we assume that the others are saturated with the solvents molecules.

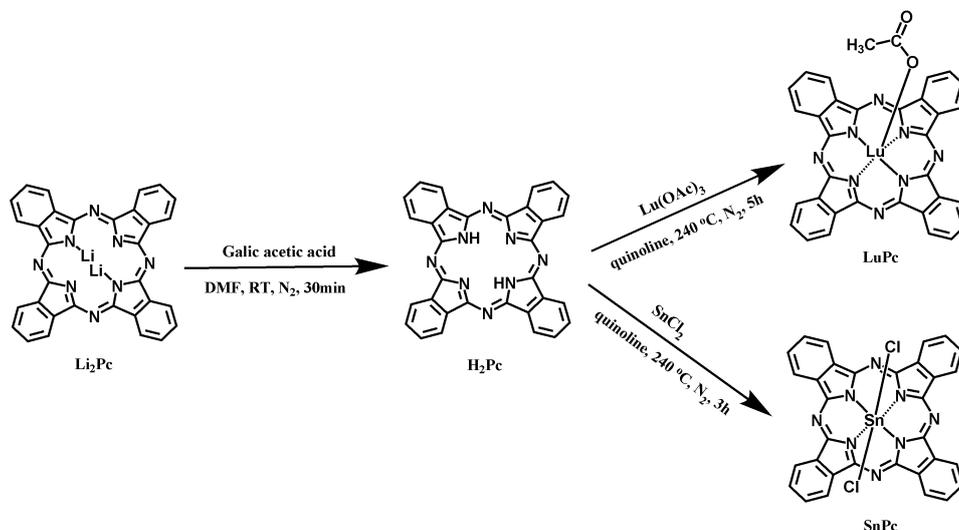
Synthesis of metal free phthalocyanine (H_2Pc)*dy*

The mixture of 0.1 g (0.190 mmol) of dilithium phthalocyanine was dissolved in 10 mL DMF and 10 mL (0.175 mmol) galic acetic acid and stirred under nitrogen atmosphere at room temperature for

30 minutes. After the reaction finished the mixture was precipitated in isopropyl ether and then in water, filtrated out and washed several times with excess of distilled water. Yield: 80 mg (80%). Molecular Formula: $\text{C}_{32}\text{H}_{18}\text{N}_8$, Molecular Weight: 514.54 g/mol. FT-IR [$\nu_{\text{max}}/\text{cm}^{-1}$]: 3272, 1500, 1436, 1333, 1321, 1117, 1093, 1001, 779, 750, 728, 718. UV-Vis (DMF) λ_{max} , nm (log ϵ): 689 (3.82). ^1H NMR (d_6 -DMSO), δ , ppm: 8.47-8.40 (m, 6H, CH Ar), 8.35-8.29 (m, 6H, CH Ar), 7.96-7.90 (m, 4H, CH Ar), 7.73-7.53 (m, 10H, CH arom), 7.33-7.30 (d, 2H, CH arom).

Synthesis of Lu^{3+} - phthalocyanine (LuPc)

A solution of 0.1 g (0.194 mmol) metal free phthalocyanine and 0.082 g (0.195 mmol) $\text{Lu}(\text{OAc})_3$ in dry quinoline was heated while stirring at $240\text{ }^\circ\text{C}$ under nitrogen atmosphere for 5 hours. The reaction was monitored with TLC. Then reaction mixture was cooled to room temperature and precipitated in hexane, filtrated and washed with hexane and an excess of water. Yield: 60 mg (60%). Molecular Formula: $\text{C}_{34}\text{H}_{19}\text{LuN}_8\text{O}_2$, Molecular Weight: 746.53 g/mol. FT-IR [$\nu_{\text{max}}/\text{cm}^{-1}$]: 3049 (Aromatic CH), 2919, 2849 (Aliphatic CH), 1569, 1487, 1454 (ArC=C), 1330, 1283, 1162, 1115, 1078, 887, 805, 779, 733. UV-Vis (DMF) λ_{max} , nm (log ϵ): 669 (4.01). ^1H NMR (d_6 -DMSO), δ , ppm: 9.43-9.42 (m, 4H, CH Ar), 8.92-8.91 (m, 1H, CH Ar), 8.38-8.37 (dd, $J=8.35, 8.29$, 1H, CH Ar), 8.23-8.22 (m, 4H, CH Ar), 8.18-8.16 (m, 1H, CH Ar), 8.04-8.02 (dd, $J=8.55, 8.47$, 1H, CH Ar), 8.00-7.98 (dd, $J=8.08, 8.10$, 1H, CH Ar), 7.79-7.76 (m, 1H, CH Ar), 7.63-7.61 (m, 1H, CH Ar), 7.55-7.53 (m, 1H, CH Ar), 1.66 (s, 3H, CH_3). MS (ESI): m/z 785 [$\text{M} + \text{K}$] $^+$.



Scheme 1. Reaction conditions to obtain phthalocyanine complexes of LuPc and SnPc .

Synthesis of Sn^{4+} -phthalocyanine (**SnPc**)

A solution of 0.1 g (0.194 mmol) metal free phthalocyanine and 0.037 g (0.195 mmol) SnCl_2 in dry quinoline was heated while stirring at 240 °C under nitrogen atmosphere for 3 hours. The reaction was monitored with TLC. Then reaction mixture was cooled to room temperature and precipitated in hexane, filtrated and washed with excess of water. Yield: 38 mg (38%). Molecular Formula: $\text{C}_{32}\text{H}_{16}\text{Cl}_2\text{N}_8\text{Sn}$, Molecular Weight: 702.14 g/mol. FT-IR [$\nu_{\text{max}}/\text{cm}^{-1}$]: 3051 (Aromatic CH), 1487, 1468 (ArC=C), 1335, 1284, 1118, 1075, 1060, 887, 745, 723. UV-Vis (DMF) λ_{max} , nm (log ϵ): 691 (3.87). ^1H NMR (d_6 -DMSO), δ , ppm: 8.92-8.91 (m, 2H, CH Ar), 8.38-8.37 (br, 2H, CH Ar), 8.03-8.02 (d, $J=8.34$, 2H, CH Ar), 8.00-7.99 (d, $J=8.40$, 2h, CH Ar), 7.79-7.76 (m, 3H, CH Ar), 7.64-7.61 (m, 3H, CH Ar), 7.55-7.53 (m, 2H, CH Ar). MS (ESI): m/z 720.5 [$\text{M}+\text{H}_2\text{O}$] $^+$

Absorption and fluorescence study

The obtained complexes of Lu^{3+} and Sn^{4+} phthalocyanines were photophysical studied in DMF solutions. The stock solutions of both complexes and the starting metal-free phthalocyanine were freshly prepared on the basis on the molecular weights with a concentration of 1 mM. The studies were carried out by the several dilutions. The spectra were recorded at room temperature. The dilutions were made in order to prevent the formation of aggregated molecules (dimers or higher associates) in the studied concentration range. Five different concentrations were used for study the absorption characteristics. The fluorescent spectra were recorded in comparison at excitation 610 nm following the same experimental protocol and equipment details for the studied phthalocyanine complexes **LuPc** and **SnPc** versus **H₂Pc**.

RESULTS AND DISCUSSION

Synthesis

Two unsubstituted metal phthalocyanine complexes of Lu^{3+} (**LuPc**) and Sn^{4+} (**SnPc**) were synthesized (Scheme 1) by slight modifications of the known synthetical procedure for preparation of complexes which involves a reaction from metal free phthalocyanine (**H₂Pc**) boiling with the proper metal salt. The high energy is required for formation of these complexes due to the large in

size atoms chosen for coordination with Pc ligand. The synthesis was carried out in 1-pentanol firstly at 140 °C but it was not successful. A high boiling point solvent such as quinoline (> 200 °C) was used for the coordination of both ions and the reactions were performed by preheating of the starting compound to allow the high yielded coordination reactions. The obtained products were precipitated in hexane and washed several times with hexane and excess of distilled water. The formation of the fine sediments was proving the success of reaction with central ions exchange.

The complexes were characterized by various spectroscopic methods. The ^1H NMR spectra (Fig. 1) showed the numbers of protons which are consistent with the predicted structures. Due to low solubility the metal-free **H₂Pc** showed very low intensive ^1H NMR signals. The spectrum appears as inappropriate for presentation vs. the spectra of **LuPc** and **SnPc**.

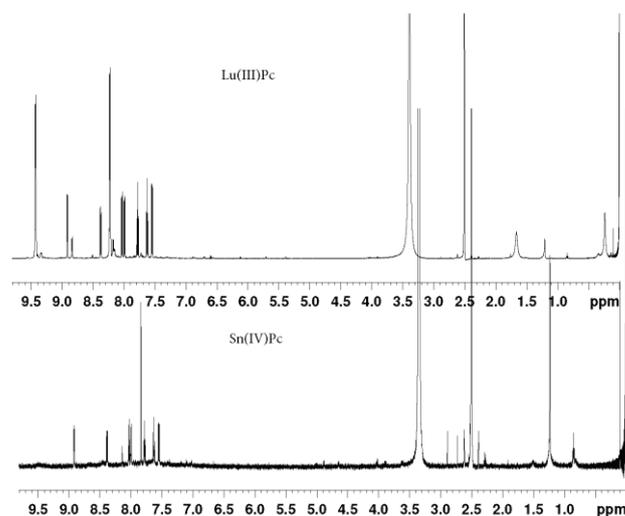


Fig. 1. ^1H NMR spectra

The ESI mass spectra of complexes showed the protonated molecular ion signal as the base peak, of which the isotopic distribution was in good agreement with the simulated pattern as is described in the Experimental part. The main ring structure was proven by the mass of the studied complexes and the basic ligand molecule. FT-IR spectra of the unsubstituted phthalocyanine confirmed the coordination of the ions in the ring molecule of the phthalocyanine (Fig. 2). In order to verify the metallization process the most distinctive feature in the FT-IR spectra for metal-free **H₂Pc** is

a signal for the N–H vibration mode at 3291 cm^{-1} which is not observed for the metallated compounds (**LuPc** and **SnPc**).

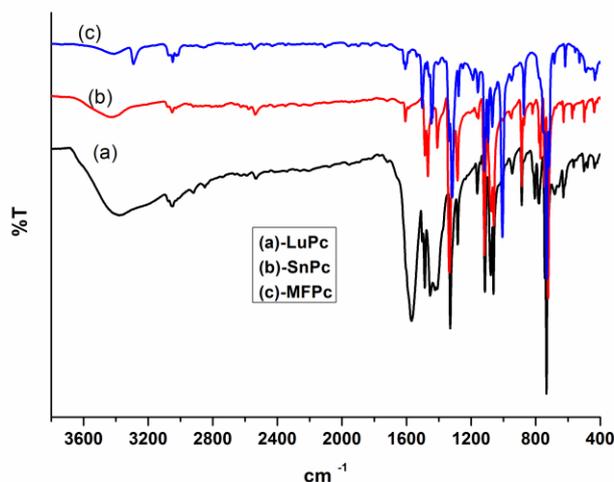


Fig. 2. FT-IR spectra

The electronic absorption spectra of the studied Lu^{3+} and Sn^{4+} phthalocyanines (**LuPc** and **SnPc**) were recorded in organic solution of dimethylformamide (Fig. 3). The spectra showed characteristic absorption bands in the visible red region with absorption maximum of Q-band at 669 nm for **LuPc** and 691 nm for **SnPc**, respectively. In the UV region the characteristic second B bands at 336 nm for **LuPc** and 354 nm for **SnPc** were recorded. The largest atom of Lu contributes to the red absorption of phthalocyanine with 669 nm. The second metal (Sn) allows much more red shifted absorbance for the complex **SnPc** (691 nm) as compare to **H₂Pc** (splitters at 665, 689 nm). The single, narrow Q band was recorded for both metallated phthalocyanine complexes for a wide concentration range of the studied MPCs. The spectra evidenced the photoactive monomeric molecules in organic solutions which are photoactive and can participate in the photosensitization reactions.

Fluorescence emission spectra of **LuPc** and **SnPc** were recorded at excitation 610 nm for the diluted solutions in DMF (Fig. 4). The fluorescence emission maxima are red shifted as compared to the absorption maxima, which are at 688 nm with a shift of 19 nm for **LuPc** and 696 nm (5 nm shift) for **SnPc** as compared to the absorbance band.

The intensity of fluorescence spectra suggested a relatively good fluorescence quantum yield of **SnPc** as its fluorescence intensity is higher than the signal intensity of the starting **H₂Pc**. In case of **LuPc** the intensity of the fluorescence band is twice lower

than the intensity of the fluorescence of **H₂Pc** which is maybe due to the high atomic number of lutetium that facilitates the intersystem crossing (high quantum yields of triplet state) after excitation.

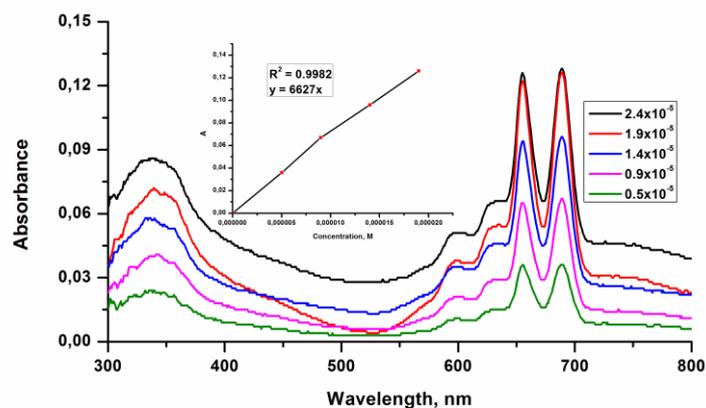
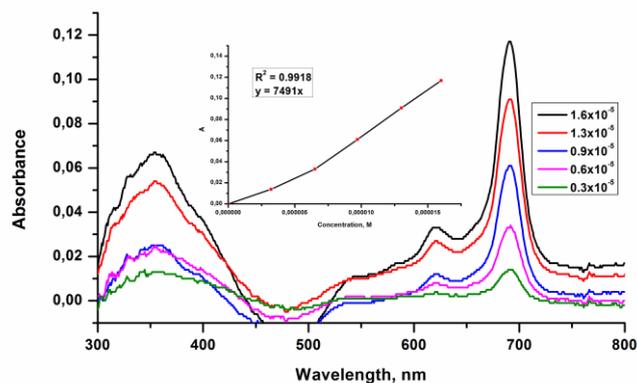
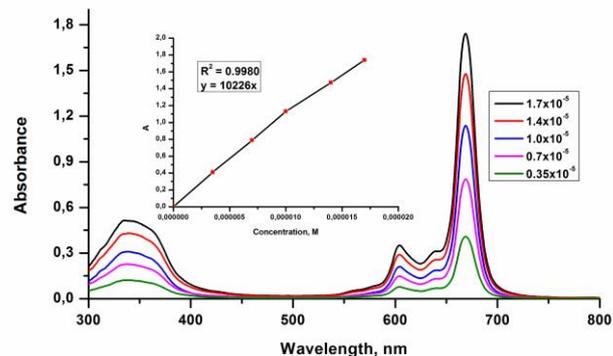


Fig. 3. Absorption spectra of **LuPc** (a), **SnPc** (b) and metal-free **H₂Pc** (c) in DMF for a concentration range.

The both synthesized complexes are more soluble than the H_2Pc which is also an advantage for their further studies as photosensitizers for biomedical applications

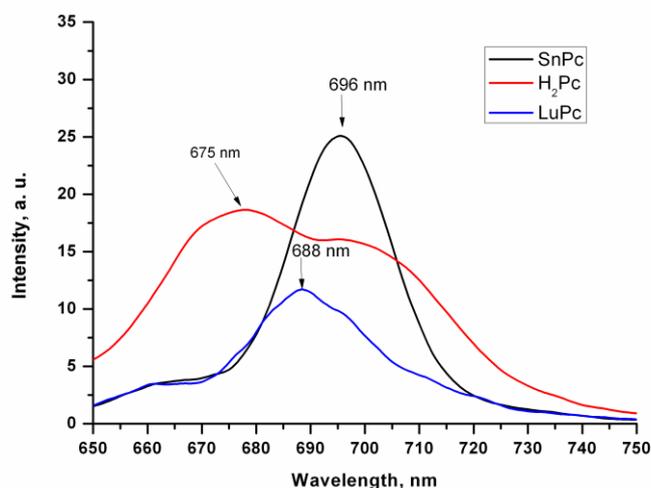


Fig. 4. Fluorescence spectra of **LuPc**, **SnPc** and metal-free **H₂Pc** recorded at excitation 610 nm in DMF.

The model studies of both complexes **LuPc** and **SnPc** and metal-free **H₂Pc** are in progress. The susceptibility of pathogenic bacteria and fungi with antibiotics resistance are under investigation for efficiency of the both complexes.

CONCLUSION

Two unsubstituted complexes of acetated Lu^{3+} and dichloride Sn^{4+} phthalocyanines were synthesized and characterized. The modification of the known synthetic procedure was successful to prepare the large ions phthalocyanine complexes. The pathway involves a reaction between a metal free phthalocyanine and the respective metal salt at high temperature reaction conditions ($> 200^\circ \text{C}$). The obtained compounds were chemically characterized by the means of general spectroscopic techniques such as FT-IR, UV-Vis and ^1H NMR. The absorption spectra of both metal complexes showed monomeric behavior of molecules in solutions, as it was evidenced by a single, narrow Q band in the far red region. The fluorescence spectra suggested a relatively good fluorescence quantum yield of **SnPc** as its fluorescence intensity is higher than the intensity of the fluorescence of the starting **H₂Pc**. Both synthesized metal complexes showed better solubility in organic solutions than the metal-free analogue **H₂Pc** which is an advantage for the further studies of the complexes as photosensitizers for biomedical applications.

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REFERENCES

1. M. S. Wesley, E. V. Johan, M. A. Cynthia, *Adv. Drug Deliv. Rev.*, **56**, 53 (2004).
2. D. Aydın Tekdaş, U. Kumru, A. G. Gürek, M. Durmuş, V. Ahsen, F. Dumoulin, *Tetrahedron Lett.*, **53**, 5227 (2012).
3. N. Sekkat, H. van den Bergh, T. Nyokong, N. Lange, *Molecules*, **17**, 98 (2012).
4. G. Jori, C. Fabris, S. Soncin, S. Ferro, O. Coppellotti, D. Dei, L. Fantetti, G. Chiti, G. Roncucci, *Lasers Surg. Med.*, **38**, 468 (2006).
5. T. G. S. Denis, T. Dai, A. Izikson, C. Astrakas, R. R. Anderson, M. R. Hamblin, G. P. Tegos, *Virulence*, **2**, 1 (2011).
6. R. Kubiak, J. Janczak, *Cryst. Res. Technol.*, **36**, 1095 (2001).
7. D. Dini, M. J. F. Calvete, M. Hanack, *Chem. Rev.*, **116** (22), 13043 (2016).
8. G. M. Mikheev, I. P. Angelov, V. N. Mantareva, T. N. Mogileva, K. G. Mikheev, *Tech. Phys. Lett.*, **39**, 7, 664 (2013).
9. S. L. Manoto, P. R. Sekhejane, N. N. Houreld, H. Abrahamse, *Photodiagn Photodyn Ther.* **9**, 52 (2012)
10. A. Erdoğan, S. Moeno, C. Litwinskia, T. Nyokong, *J. Photochem. Photobiol. A: Chem.*, **210**, 200 (2010).
11. P. Muthukumar, H. S. Kim, J. W. Jeong, Y. A. Son, *J. Molec. Struct.* **1119**, 325 (2016).
12. J. Chen, Q. Gan, S. Li, F. Gong, Q. Wang, Z. Yang, S. Wang, H. Xu, J. S. Ma, G. Yang, *J. Photochem. Photobiol. A: Chem.*, **207**, 58 (2009).
13. V. Mantareva, V. Kussovski, I. Angelov, D. Wöhrle, R. Dimitrov, E. Popova, S. Dimitrov, *Photochem. Photobiol. Sci.*, **10**, 92 (2011).
14. V. Mantareva, V. Kussovski, I. Angelov, E. Borisova, L. Avramov, G. Schnurpfeil, D. Wöhrle, *Bioorg. Med. Chem.*, **15**, 4829 (2007).
15. C. Bozoğlu, M. Arıcı, A. L. Uğur, A. Erdoğan, A. Koca, *Synth. Metals*, **190**, 56 (2014).
16. V. Mantareva, M. Durmuş, M. Aliosman, I. Stoineva, I. Angelov, *Photodiagn Photodyn Ther.*, **14**, 98 (2016).
17. R. Zügler, T. Nyokong, *J. of Molec. Cal. A: Chem.*, **358**, 49 (2012).
18. M. Durmuş, S. Yeşilot, B. Çoşut, A. G. Gürek, A. Klımiç, V. Ahsen, *Synth. Metals*, **160**, 436 (2010).
19. S. Yano, S. Hirohara, M. Obata, Y. Hagiya, S. Ogura, A. Ikeda, H. Kataoka, M. Tanaka, T. Joh, *J. Photochem. Photobiol. C: Photochem. Rew.*, **12**, 46 (2011).
20. S. H. van Rij, P. J. Sadler, *Drug Disc. Today* **Vol. 14**, **23**, 1089 (2009).

21. M. R. Detty, C. L. Gibson, S. J. Wagner, *J. Med. Chem.*, **47**, 3897 (2004).
22. V. Mantareva, V. Kussovski, M. Durmus, E. Borissova, I. Angelov, *Lasers Med Sci.*, **31**, 1591 (2016).
23. S. Khene, A. N. Cammidge, M. J. Cook, T. Nyokong, *J. Porphy. Phthalocy.*, **11**, 761 (2007).
24. M. Idowu, T. Nyokong, *J. Photochem. Photobiol. A: Chem.*, **199**, 282 (2008).
25. J. Alzeer, P. J. C. Roth, N. W. Luedtke, *Chem. Comm.*, **15**, 1970 (2009).
26. Z. Odabas, A. Altindalb, M. Buluta, *Synth. Metals*, **161**, 1742 (2011).

МОНО-ПРЪСТЕННИ ФТАЛОЦИАНИНОВИ КОМПЛЕКСИ С ЙОНИ НА Lu³⁺ и Sn⁴⁺: СИНТЕЗ И СРАВНИТЕЛНИ ИЗСЛЕДВАНИЯ НА ФОТОФИЗИЧНИТЕ СВОЙСТВА

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(Резюме)

През последните години, фталоцианиновите комплекси се изследват интензивно като фотосенсибилизатори за фотодинамична терапия (ФДТ) поради уникалните им фотофизични свойства. Метал-координираните фталоцианини (МФц) имат свойства, които ги доближават до идеалните за фотосенсибилизатори за ФДТ. Така например висок екстинционен коефициент на ивицата в червената област (680 - 720 nm), която е на 3 порядъка по интензивна в сравнение с тази при порфиринови производни. Фотофизичните свойства на МФц-ни са благоприятни за ефективното им възбуждане директно в тъкани и клетки, като мишена. Понастоящем, ограничен брой МФц-ни с М: Al³⁺, Zn²⁺ и Si⁴⁺ са клинично одобрени за метода ФДТ и се прилагат в терапията на тумори. За нуждите на ФДТ, активно се разработват и изследват ново поколение МФц-ни с различни координиращи метали с висока атомна маса, което ги определя като обемни метални йони. Известно е, че Фц, координирани с подходящ метал, са по - ефективни като фотосенсибилизатори, благодарение на подобрения процес на вътрешносистемен пренос на енергия от синглетно към триплетно възбудено състояние на молекулата. Обещаващ подход с цел подобряване на фотосенсибилизиращата способност на фталоцианините е синтез, включващ комплексобразуване с метали с голям атомен номер като калай (Sn⁴⁺) и лутеций (Lu³⁺). Настоящото изследване представя ефективен синтетичен подход за координиране на фталоцианини с йони с голям атомен номер, като Sn⁴⁺ и Lu³⁺. Бяха изследвани ефектите на използваните метали върху фотофизичните свойства на получените комплекси SnPc и LuPc в сравнение с фталоцианиновия лиганд.