

Interaction between creatinine and sulfonated derivatives of cobalt phthalocyanine

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Macrocycle synthesis:

Cobalt tetrasulfophthalocyaninate (CoTSPcI): the sample of 99.9 % purity (Sigma Aldrich) was used.

Cobalt 2,9,16,23-tetrakis(6-sulfonaphthalen-2-yloxy)phthalocyaninate (CoTSPcII) was synthesized from nitrile [V. P. Kulinich, G. P. Shaposhnikov, R. A. Badaukaite, *Macroheterocycles*, 2010, **3**, 23; S. A. Znoiko, A. S. Kambolova, V. E. Maizlish, G. P. Shaposhnikov, I. G. Abramov, S. I. Filimonov, *Russ. J. Gen. Chem.*, 2009, **79**, 1735]. Found (%): C 58.42; H 2.70; N 7.62; S 8.80. $C_{72}H_{40}N_8S_8O_{16}Co$. Calculated (%): C 59.22; H 2.74; N 7.68; S 8.80. IR (KBr), ν/cm^{-1} : 1045 (-S=O), 1103 (-S=O), 1205 (Ar-O-Ar).

Cobalt 2,9,16,23-tetrakis(6,8-disulfonaphthalen-2-yloxy)phthalocyaninate (CoTSPcIII) was obtained according to the method similar to **CoTSPcII** using dipotassium salt of 4-[(6',8'-disulfo-2'-naphthyl)oxy]phthalonitrile. Found (%): C 48.32; H 2.20; N 6.23; S 14.43. $C_{72}H_{40}N_8S_8O_{28}Co$. Calculated (%): C 48.57; H 2.25; N 6.30; S 14.39. IR (KBr), ν/cm^{-1} : 1039 (-S=O), 1103 (-S=O), 1210 (Ar-O-Ar).

Cobalt 2,9,16,23-tetrakis(benzotriazol-1-yl)-3,10,17,24-tetrakis(4-sulfonaphthalen-1-yloxy)phthalocyaninate (CoTSPcIV) was synthesized according to the method described in [K. Sakamoto, E. Ohno-Okumura, *Materials*, 2009, **2**, 1127; A. Vashurin, A. Filippova, S. Znoyko, A. Voronina, O. Lefedova, I. Kuzmin, V. Maizlish, O. Koifman, *J. Porphyrins Phthalocyanines*, 2015, **19**, 983] by sulfonation of initial phthalonitrile. Found (%): C 52.00; H 4.05; N 12.43; S 5.36. $C_{98}H_{52}N_{20}S_4O_{16}Co \times 16H_2O$. Calculated (%): C 52.01; H 3.82; N 12.64; S 5.78. IR (KBr), ν/cm^{-1} : 745 (C-N), 1045 (N=N), 1230 (Ar-O-Ar), 1060 (C-S), 1150-1190 (S=O or SO₃H). MALDI-TOF m/z : 1932.71 [M+4H]⁺. NMR ¹H (DMSO-*d*₆) δ /ppm: 7.45 (Ar-5H), 7.94 (Ar-4H), 8.07 (Ar-6H), 8.29 (Ar-3H) – triazole group, 7.64 (Ar-8H), 7.73 (Ar-7H), 7.85 (Ar-11H), 8.18 (Ar-10H), 8.53 (Ar-9H), 8.85 (Ar-12H) – naphthoxy group, 8.97 (SO₃H).

Cobalt 2,9,16,23-tetrakis(benzotriazol-1-yl)-3,10,17,24-tetrakis(1,6-disulfonaphthalen-2-yloxy)phthalocyaninate (CoTSPcV) was synthesized according to the method similar to **CoTSPcIV**. Cobalt 2,9,16,23-tetrakis(benzotriazol-1-yl)-3,10,17,24-tetrakis(2-naphthoxy)phthalocyaninate was used as the starting material for sulfonation. Found (%): C 42.29; H 4.42; N 9.73; S 9.36. $C_{96}H_{52}N_{20}S_8O_{28}Co \times 32H_2O$. Calculated (%): C 42.29; H 4.14; N 9.91; S 9.08. IR (KBr), ν/cm^{-1} : 741 (C-N), 1049 (N=N), 1262 (Ar-O-Ar), 1091 (C-S), 1158 (S=O or SO₃H). MALDI-TOF m/z : 2248.82 [M]⁺. NMR ¹H (DMSO-*d*₆) δ /ppm: 7.48(Ar-5H), 7.75 (Ar-4H), 7.94 (Ar-6,7H), 8.14 (Ar-3H) – triazole group, 8.33 (Ar-2H) – macrocycle 8.72 (Ar-8,9,11H) – naphthoxy groups, 8.83, 8.81 (SO₃H).

Commercial creatinine (Sigma Aldrich) of not less than 99.9 % purity was used without additional purification.

Stability constant calculation for molecular complex was done based on the change in absorption density of the solution in range of macrocycle Q-band. Research was done under condition of ligand excess compared to metal phthalocyanine. Therefore, equilibrium concentration of the ligand was considered to be equal to its initial concentration, which simplifies the procedure of K_y calculation:

$$K_y = \frac{(A_0 - A_p)}{(A_0 - A_k) \cdot c_L^0}$$

Equipment

Electronic absorption spectrum (UV-Vis spectra) were registered by the Unico 2800 (USA) spectrophotometer in spectral range of 200-1000 nm. Solutions for UV-Vis registration were placed in quartz cuvettes of 2, 5 or 10 mm thickness and then in thermostat. Elemental analysis was carried out by chromatographic analyzer Flash HCNS-OEA 1112 (Germany). The rate of helium feed is 140 ml/min; reactor temperature is 1173 K, the rate of the oxygen feed is 250 ml/min, exposure time is 12 seconds. IR spectra were recorded in the Fourier transform mode by spectrophotometer Avatar 360 (USA) in frequency range of 400 – 4000 cm^{-1} . NMR-spectra were obtained by spectrometer Bruker AVANCE-500 (Germany) of 500 MHz operating frequency. Inner standard is TMS. Mass spectrum was obtained by Axima MALDI-TOF mass spectrometer (Shimadzu, Japan).

Table S1 Energies of the creatinine tautomeric transformations.

parameter	HF/3-21G	HF/6-31G
G_1 , a.u.	-391.4362	-393.4523
G_2 , a.u.	-391.4701	-393.4852
G_3 , a.u.	-391.4642	-393.4823
ΔG_{1-2} , kJ/mol	88.9677	86.2844
ΔG_{2-3} , kJ/mol	15.49045	7.61395
ΔG_{1-3} , kJ/mol	73.4772	78.6705
K_1	0.9648	0.9658
K_2	0.9937	0.9969
K_{1+2}	0.9587	0.9681

Table S2 The content of creatinine tautomers in equilibrium transitions.

method	2 \leftrightarrow 3		2 \leftrightarrow 1		3 \leftrightarrow 1	
	$[X_2]$	$[X_3]$	$[X_1]$	$[X_2]$	$[X_1]$	$[X_3]$
HF/3-21G	0.501563	0.498437	0.508976	0.491024	0.510539	0.489461
HF/6-31G	0.500768	0.499232	0.508705	0.491295	0.509473	0.490527
B3LYP/6-31G**	0.500927	0.499073	0.505794	0.494206	0.506721	0.493279
PBE0/6-31G**	0.501033	0.498967	0.505967	0.494033	0.507	0.493

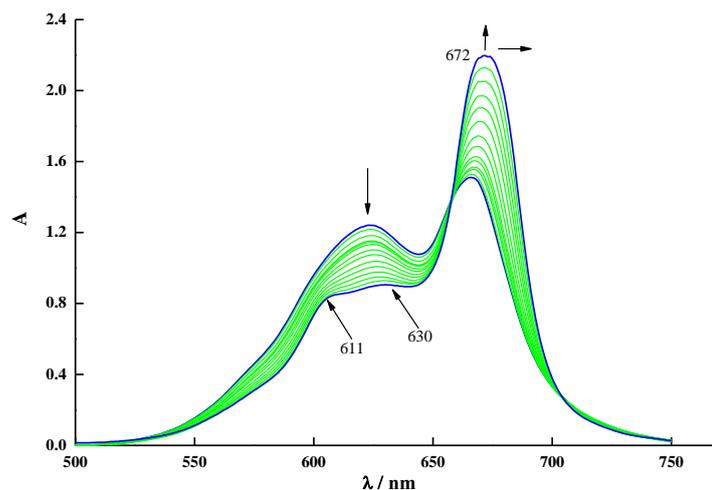


Figure S1 UV-Vis spectra changes under titration of CoPcI water solution (pH 7.4) (c 7.58×10^{-5} M) by creatinine up to $n_{\text{CoPcI}}:n_{\text{Crt}}$ 1:200 molar ration under 298.15 K.

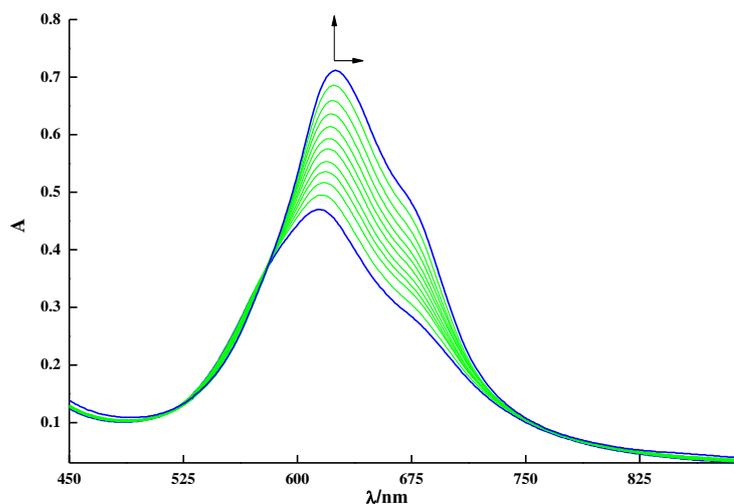


Figure S2 UV-Vis spectra changes under titration of CoTSPcII water solution (pH 7.2) (c 1.21×10^{-4} M) by creatinine under 298.15 K, c_L $0 \div 5 \times 10^{-3}$ M.

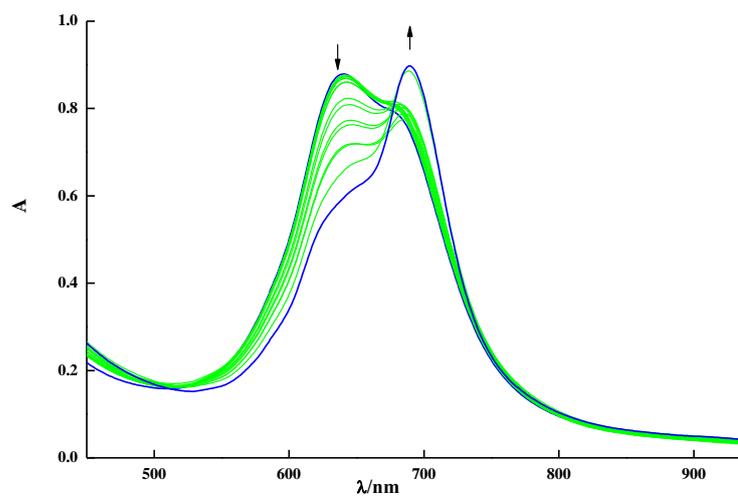


Figure S3 UV-Vis spectra changes under titration of CoTSPcIV water solution (pH 7.9) ($c = 7.1 \times 10^{-5}$ M) by creatinine up to $n_{\text{CoTSPcIV}}:n_{\text{Crt}}$ 1:200 molar ration under 298.15 K.

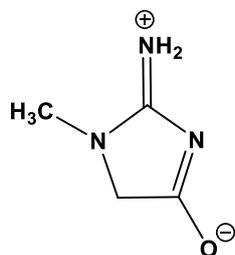


Figure S4 Creatinine zwitterion.

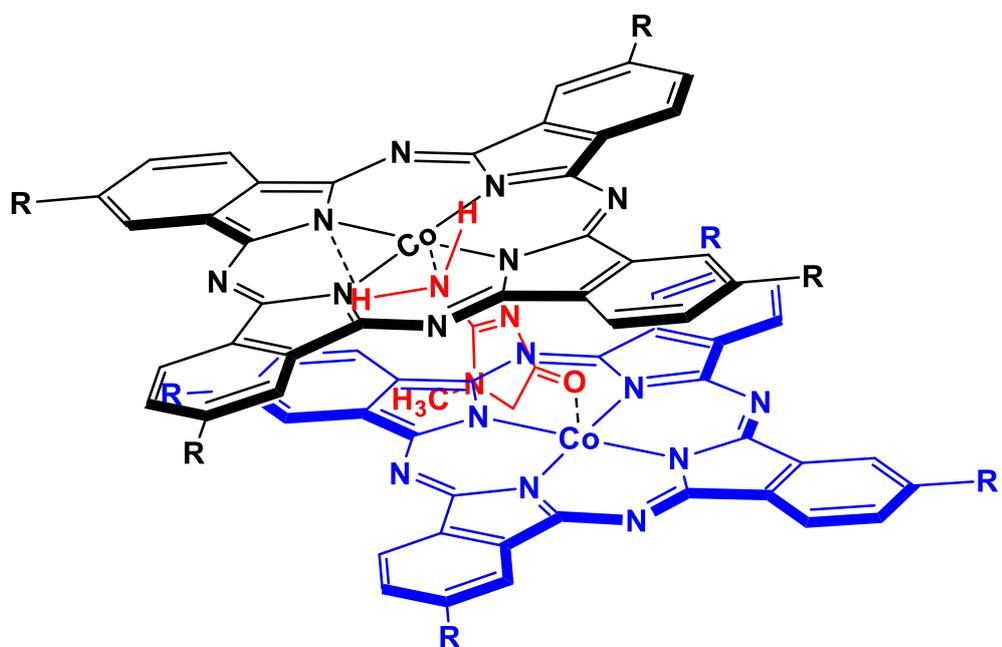


Figure S5 Scheme of sandwich complex of CoPc with creatinine.