

THE EFFECT OF DIMETHYLSULFOXIDE ON THE FLUORESCENCE PROPERTIES OF SOME 4-HYDROXYQUINOLINES

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Fluorescence properties of 4-hydroxy-2-methylquinoline (**1**) and 2-(5-mercapto-1,3,4-oxadiazol-2-yl)-6-methylquinoline-4-ol (**2**) were studied in dimethylsulfoxide (DMSO) aqueous solutions. The fluorescence properties of **1** and **2** exhibit substantial dependence on the DMSO concentration. The fluorescence quantum yield (Φ_f) of **1** decreases upon adding DMSO due to the shift in the keto-enol (E) tautomeric equilibrium toward E form. On the contrary **2** demonstrates a tendency of increase of Φ_f upon adding DMSO due to intermolecular charge transfer from DMSO to the aromatic ring of quinoline, which increases the electron density on the ring and hence the fluorescence efficiency.

<https://doi.org/10.46991/PYSU:B/2021.55.2.112>

Keywords: 4-hydroxy-2-methylquinoline, 2-(5-mercapto-1,3,4-oxadiazol-2-yl)-6-methylquinoline-4-ol, fluorescence quantum yield, dimethylsulfoxide.

Introduction. Recently, the detection and imaging of biological molecules via fluorescent tags, also known as fluorescent labels or fluorescent probes, is widely used in biomedical studies. The sensitivity of fluorescent tag directly depends on the fluorescence quantum yield of the fluorophore, which is defined by the competition of radiative and non-radiative decay channels [1]. Quinoline based fluorescent tags exhibit high selectivity and sensitivity to a variety of metal ions detection under physiological conditions in living cells [2, 3]. Quinoline derivatives, such as 4-hydroxyquinolines, 8-hydroxyquinolines and 8-aminoquinoline as well exhibit such properties [4, 5]. As it was shown in [6], UV irradiation of 4-hydroxyquinoline aqueous solutions brings to the formation of the triplet states with the quantum yields of 30, 35, and 7.5% in acidic, neutral, and basic solutions, respectively. In neutral solutions, the keto (K) form is the major tautomeric structure for the ground, excited singlet and triplet states of 4-hydroxyquinoline. The fluorescence and photochemical properties of hydroxyquinolines can be changed due to the equilibrium shift between

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K and enol (E) tautomeric and also protonated and deprotonated forms in solution [6].

Dimethylsulfoxide (DMSO) is a polar aprotic solvent ($\epsilon = 47$) that is miscible with organic solvents as well as water. It dramatically changes the physicochemical characteristics (dielectric constant, refractive index, electrical conductivity, density, viscosity etc.) of binary solvents [7, 8], thus affecting the fluorescence decay processes [9, 10]. It can promote the formation of more rigid, conjugated molecular structures thus affecting the fluorescence quantum yield (Φ_f) of chromophore. The aim of this study is to evaluate the effect of DMSO on the fluorescence properties of 4-hydroxy-2-methylquinoline (**1**) and 2-(5-mercapto-1,3,4-oxadiazol-2-yl)-6-methylquinoline-4-ol (**2**) (Fig. 1).

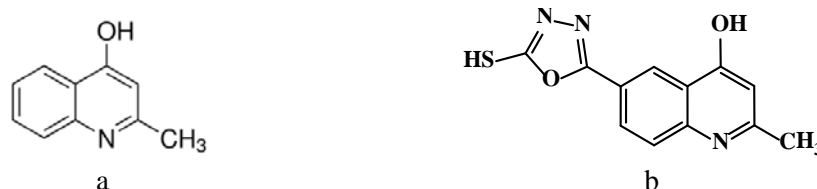


Fig. 1. Molecular structure of compounds **1** (a) and **2** (b).

Materials and Methods. Compounds **1** and **2** were synthesized and characterized according to [11]. Stock solutions of **1** and **2** were prepared in DMSO, concentrations were $1.6 \cdot 10^{-5} \text{ mol} \cdot \text{L}^{-1}$. DMSO, 2-aminopyridine and quinine sulfate were purchased from “Sigma-Aldrich”. The molar fraction of DMSO in aqueous solution was varied from 0 to 1. Bidistilled water was used for the preparation of solutions. UV/Vis absorption spectra were recorded on a SPECORD 50 spectrophotometer (Germany) in the 200–500 nm wavelength range. The fluorescence spectra were recorded on a Varian Cary Eclipse spectrophotometer (Australia) in the 335–600 nm wavelength range. For the measurements 1.0 cm quartz cells were used. The excitation and emission slits were set at 5 nm. The graphs and diagrams were constructed and analyzed using the ORIGIN 8.5 software.

Calculation of Relative Φ_f . The fluorescence quantum yield Φ_f of **1** and **2** were calculated relative to a 0.1 N H_2SO_4 aqueous solution of 2-aminopyridine ($\Phi_f=0.60$) and quinine sulfate ($\Phi_f=0.557$), respectively [12]. All measurements were performed at room temperature.

The Φ_f were determined according to the equation:

$$\Phi_f = \Phi_{ST} \frac{I_X}{I_{ST}} \cdot \frac{A_{ST}}{A_X} \cdot \frac{n_X^2}{n_{ST}^2},$$

where the subscripts *ST* and *X* denote standard and test, respectively; *I* is the area under the emission peak; *A* is the absorbance at the excitation wavelength; *n* is the refractive index of the solvent [12].

Results and Discussion. The fluorescence spectra of the compounds **1** and **2** in DMSO– H_2O binary solvents are depicted in Fig. 2.

The fluorescence spectrum of **2** in an aqueous solution is described by a broad, featureless emission band at $\lambda=404\text{ nm}$ (peak 1). Upon adding and increasing DMSO concentration in a binary solvent, the fluorescence intensity of the peak 1 increases and a new peak (peak 2) appears at $\lambda=523\text{ nm}$. Peak 1 and peak 2 demonstrate a blue shift from 404 to 397 and from 523 to 454 nm respectively. The appearance of two emitting bands could be a result of the existence of different emitting species presented in Fig. 3.

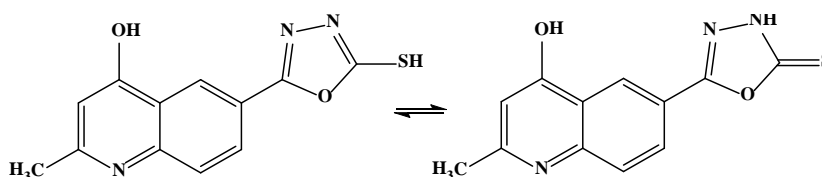


Fig. 3. Possible structures of compound **2** in DMSO–H₂O binary solvents.

The values of the fluorescence quantum yield of compound **2**, listed in Table, demonstrate an increase with increasing DMSO content in binary solvent. Determined quantum yields are a result of the effect of the solvent polarity and the intermolecular charge transfer (ICT) phenomena. Since, when an increase in the polarity of the solvent leads to a decrease in the intensity of the fluorescence spectra, a red shift of the fluorescence spectrum also occurs. ICT from DMSO to the aromatic ring of quinoline increases the electron density on the ring and hence the fluorescence efficiency.

Conclusion. The studies of the effect of DMSO on the fluorescence properties of compounds **1** and **2** showed that the solvent properties affect differently on the fluorescence properties of **1** and **2**. Φ_f of compound **1** decreases upon adding DMSO due to the tautomeric equilibrium shift from K to E form, which negatively affects the quantum yield of **1**. The relatively high quantum yield of compound **2** in a polar aprotic solvent DMSO is the indication of the electron donating effect of the solvent. Due to its fluorescence properties, compound **2** in DMSO solutions could be used as fluorescence tag for various biomolecules, such as proteins, living cells and small cellular metabolites.

This work was supported by Science Committee of the MESCS RA, in the frame of protection financing of Basic Laboratory of the Chair of Physical Chemistry of YSU and research project No. 18RF-020.

Received 11.06.2021

Reviewed 02.07.2021

Accepted 16.07.2021

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Չ. Լ. ԳՐԻԳՈՐՅԱՆ, Լ. Պ. ՀԱՄԲԱՐԶՈՒՄՅԱՆ

ԳԻՄԵՌԻԼՍՈՒԼՖՕՔՍԻԴԻ ԱԶԳԵՑՈՒԹՅՈՒՆԸ ՈՐՈՇ
4-ՀԻԴՐՕՔՍԻԽԻՆՈԼԻՆՆԵՐԻ ՖԼՈՒՈՐԵՍԿԵՆՏԱՑԻՆ
ՀԱՏԿՈՒԹՅՈՒՆՆԵՐԻ ՎՐԱ

Ուսումնասիրվել է 4-հիդրօքսի-2-մեթիլխինոլինի (**1**) և 2-(5-մերկապտո-1,3,4-օքսադիազոլ-2-իլ)-6-մեթիլխինոլին-4-ոլի (**2**) ֆլուորեսցենսային հատկությունները դիմեթիլսուլֆօքսիդի (ԴՄՍՕ) ջրային լուծույթներում: **1**-ի և **2**-ի ֆլուորեսցենսային հատկությունները զգալիորեն կախված են ԴՄՍՕ-ի

կոնցենտրացիայից: **1**-ի ֆլուորեսցենսային քվանտային ելքը (Φ_f) փոքրանում է ԴՄՍՕ-ի կոնցենտրացիայի մեծացումից կետո-ենոլային տաուտոմերիայի հավասարակշռության դեպի ենոլային ձևի կողմը տեղաշարժվելու հետևանքով: Ի տարբերություն, **2**-ը ԴՄՍՕ ավելացնելիս ցուցաբերում է Φ_f -ի աճի միտում՝ ի շնորհիվ ԴՄՍՕ-ից խինոլինի արոմատիկ օղակին լիցքի փոխանցման, ինչը մեծացնում է օղակի էլեկտրոնային խտությունը և, հետևաբար, ֆլուորեսցենցիայի արդյունավետությունը:

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ВЛИЯНИЕ ДИМЕТИЛСУЛЬФОКСИДА НА ФЛУОРЕСЦЕНТНЫЕ СВОЙСТВА НЕКОТОРЫХ 4-ГИДРОКСИХИНОЛИНОВ

Изучены флуоресцентные свойства 4-гидрокси-2-метилхинолина (**1**) и 2-(5-меркапто-1,3,4-оксадиазол-2-ил)-6-метилхинолин-4-ола (**2**) в водных растворах диметилсульфоксида (ДМСО). Флуоресцентные свойства **1** и **2** существенно зависят от концентрации ДМСО. Флуоресцентный квантовый выход (Φ_f) **1** уменьшается по мере увеличения концентрации ДМСО, так как кето-енольное таутомерное равновесие **1** смещается в сторону енольной формы. При этом **2** показывает тенденцию увеличения Φ_f при добавлении ДМСО из-за переноса заряда от ДМСО на ароматическое кольцо хинолина, что увеличивает электронную плотность кольца и, следовательно, эффективность флуоресценции.