

Novel combinatorial approach to the synthesis of dihydropyridine (quinoline) based merocyanine dyes

Alexander Y. Rudenko,^{*,a,b} Andrey A. Zubarev,^c Ratislav M. Ozhiganov,^d Sofia S. Mariasina,^b Lyudmila A. Rodinovskaya,^c Ivan Sanin Sprague,^c Konstantin A. Lyssenko,^a and Anatoliy M. Shestopalov^c

^a Department of Chemistry, Lomonosov Moscow State University, Leninskie Gory 1/3, Moscow, 119991, Russian Federation

^b Laboratory of Magnetic Tomography and Spectroscopy, Faculty of Fundamental Medicine, M.V. Lomonosov Moscow State University, 119991 Moscow, Russian Federation

^c N. D. Zelinsky Institute of Organic Chemistry, Russian Academy of Sciences, 119991 Moscow, Russian Federation

^d Mendeleev University of Chemical Technology, 125190 Moscow, Russian Federation
Email: RudAlex1303@gmail.com

Received mm-dd-yyyy

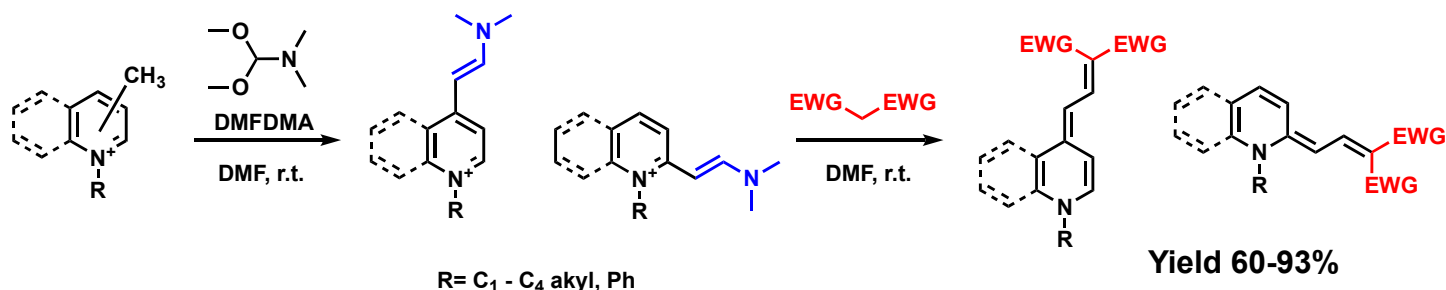
Accepted Manuscript mm-dd-yyyy

Published on line mm-dd-yyyy

Dates to be inserted by editorial office

Abstract

A novel, efficient, two-step approach to the synthesis of merocyanine dyes was developed. Initially, N-substituted picolinium salts were formylated with *N,N*-dimethylformamide dimethyl acetal to produce enamine derivatives. Then a series of merocyanine dyes were obtained by the high-yield reaction between the enamines and various active methylene compounds. The described reactions, carried out in mild conditions, provide access to the synthesis of a wide range of dyes. This innovative method enabled the synthesis of a number of new merocyanine dyes and increased the yields of the known compounds.



Keywords: Merocyanines; azinium salts; enamines; protonation

Cite as *Arkivoc* 2023 (vii) 202311994

DOI: <https://doi.org/10.24820/ark.5550190.p011.994>

Page 1 of 16

©AUTHOR(S)

Introduction

Merocyanines are important class of dyes. Both theoretical studies and practical applications of merocyanines are well illustrated in reviews.¹⁻⁵ In spite of significant attention to merocyanine dyes, based on azoheterocycles, such as pyridine and quinoline, these compounds have not been studied as well as other classes. The most common structure of merocyanine dyes includes an electron-withdrawing group linked to a cyclic electron-donor fragment via two methine groups. The major approach to the synthesis of these merocyanine systems involves the interaction between a methyl group of *N*-alkylazinium salts and the acetaldehyde derivatives (EWG)₂CHCHO and their analogs.⁶⁻¹⁷ The disubstituted acetaldehyde derivatives can be obtained by the formylation of methylene active compounds. According to this synthetic protocol, the selected heterocyclic substrate generally reacts with a set of methylene active compounds, each of which must be previously formylated. Following this synthetic protocol we synthesized a series of dyes^{18,19} utilizing 2- and 4-picoline as substrates. The products were purified by column chromatography. Despite the fact that this approach is quite simple and provides good yields, this method requires time-consuming purification techniques, making it inefficient for the synthesis of large dye libraries. An interesting variation of this method is formylation of an active methylene compound by DMF/Ac₂O mixture with heating and condensation with azinium salt (2 examples in 54 – 60% yield) without isolation of intermediate.²⁰ Thus, there are gaps in the published data for pyridine- or quinoline-containing merocyanine dyes.

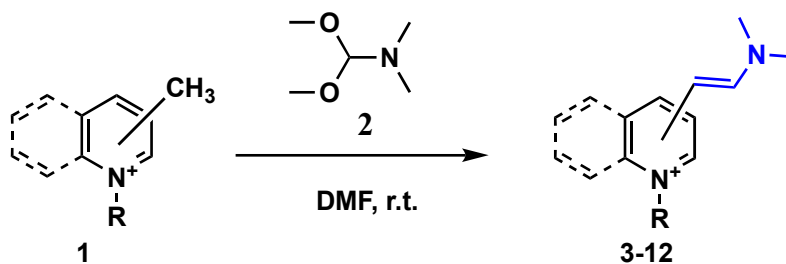
Another synthetic approach appears to be more practical. A methyl group from an azinium salt is formylated to produce (*N*-phenyl-*N*-acetyl)enamines.²¹⁻²⁴ Next, the enamine derivatives react with active methylene compounds to form cyanine cationic dyes. However, this approach is less common for the synthesis of merocyanine dyes because enamine formation requires extreme conditions and the yields of the reaction are small.

In this paper we describe a novel and facile approach to the synthesis of merocyanine dyes. The reactions are based on mild formylation of a methyl group in the heterocyclic substrate by *N,N*-dimethylformamide dimethyl acetal (DMFDMA). This leads to the formation of enamine derivatives with high yields. The obtained enamines can be reacted with a series of readily accessible active methylene compounds, providing the capacity to quickly create compound libraries containing a wide range of desired merocyanine dyes.

Results and Discussion

As starting materials we chose quaternary azinium salts **1** (R C₁ – C₄ alkyl, Ph) prepared from picolines and methyl quinolines according to previously described procedures.²⁵⁻²⁸

In the first step, the condensation reaction between the salts **1** and DMFDMA (**2**) was carried out in mild conditions in DMF at room temperature and without any catalyst. This resulted in the formation of enamines **3-12** with high yields (Scheme 1, Table 1, Figure 1).



Scheme 1. Synthesis of enamines 3-12

Table 1. Enamines 3-12

Entry	Product	R	Ring structure	Yield, (*) %
1	3	Me	lepidine	95
2	4	Me	4-picoline	98 (34) ^{29,30}
3	5	Et	4-picoline	99 (78) ²⁹
4	6	<i>n</i> -Pr	4-picoline	96
5	7	<i>n</i> -Bu	4-picoline	97
6	8	Ph	4-picoline	93
7	9	Me	quinaldine	93 (60) ³¹
8	10	Me	2-picoline	98 (82) ²⁹
9	11	Et	2-picoline	98 (62) ²⁹
10	12	<i>n</i> -Pr	2-picoline	96

* the yield reported in the literature

In the second step, enamines **3-12** reacted in DMF with a series of commercially available methylene active compounds **13-18** (Figure 2) to form merocyanine dyes **19-45**. This approach can be efficiently applied to the synthesis of dyes **19-45** based on the enamine derivatives of 4-methylazines (Scheme 2, Table 2), as well as the 2-methylazines (Scheme 3, Table 3).

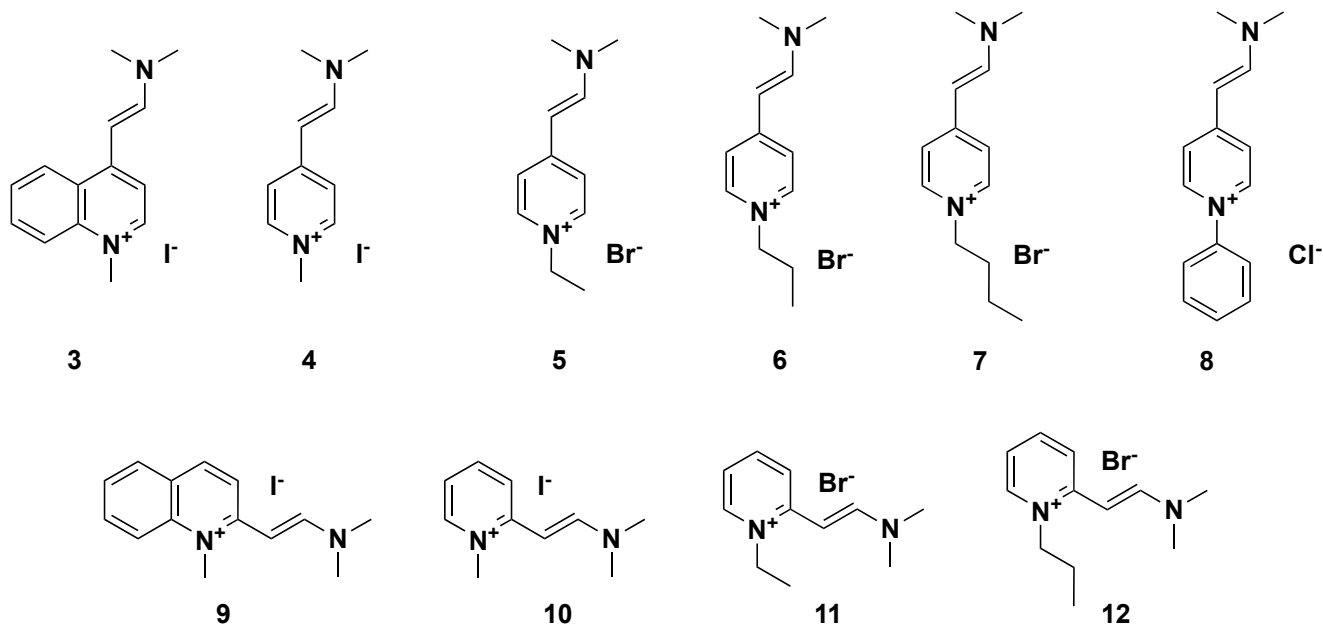
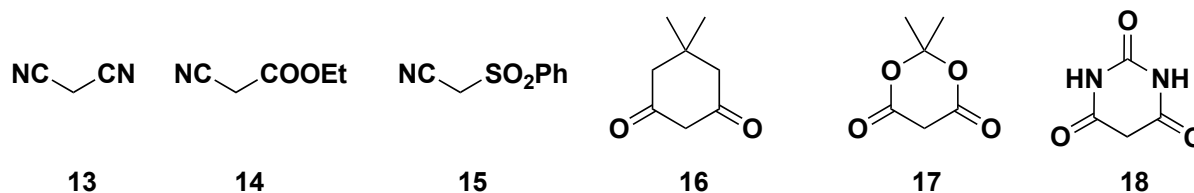
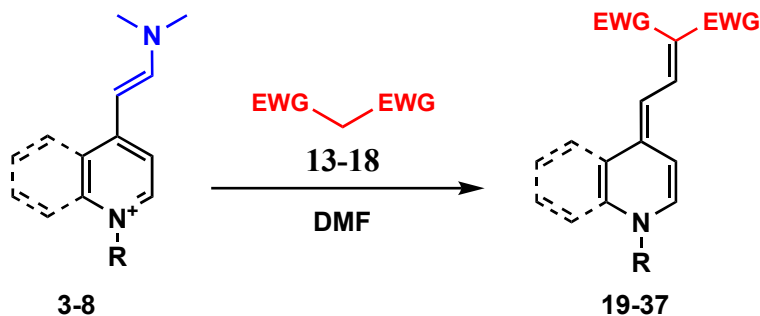


Figure 1. Range of enamines **3-12****Figure 2.** Range of active methylene compounds **13-18**

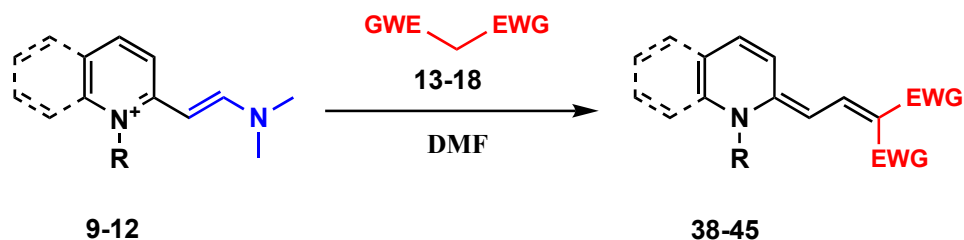
For dye syntheses based on methylene components **13**, **17**, **18** the reaction mixture was simply kept at room temperature for 12 h. For the other methylene components used, the best results were achieved by heating reaction mixtures at 60 °C for 5 hours in the presence of sodium acetate. In both cases the products were isolated by diluting reaction mixtures with water followed by filtration after 12 hours (see the Supporting Information for general procedure). The resulting dyes **19-45** were obtained in moderate to high yields. Unlike the previously described method,^{18, 19} no further purification was needed.

**Scheme 2.** Synthesis the dyes **19-37****Table 2.** Synthesis of merocyanine dyes **19-37**

Entry	Product	Ring structure	R	EWG	Yield, (*) %
1	19	lepidine	Me	NC-CH ₂ -COOEt	75
2	20	lepidine	Me	NC-CH ₂ -SO ₂ Ph	86
3	21	lepidine	Me	Meldrum's acid	93 (55) ³²
4	22	4-picoline	Me	NC-CH ₂ -SO ₂ Ph	66
5	23	4-picoline	Me	Meldrum's acid	62
6	24	4-picoline	Et	NC-CH ₂ -CN	57 (23) ³³
7	25	4-picoline	Et	NC-CH ₂ -COOEt	48 (53) ³³
8	26	4-picoline	Et	NC-CH ₂ -SO ₂ Ph	66
9	27	4-picoline	Et	dimedone	47
10	28	4-picoline	Et	Meldrum's acid	66
11	29	4-picoline	Et	barbituric acid	65
12	30	4-picoline	Pr	Meldrum's acid	74
13	31	4-picoline	Bu	NC-CH ₂ -SO ₂ Ph	73
14	32	4-picoline	Bu	dimedone	76
15	33	4-picoline	Bu	Meldrum's acid	85

16	34	4-picoline	Ph	NC-CH ₂ -COOEt	91 (62) ³⁴
17	35	4-picoline	Ph	dimedone	79
18	36	4-picoline	Ph	Meldrum's acid	78
19	37	4-picoline	Ph	barbituric acid	89

* the yield reported in the literature



Scheme 3. Synthesis of the dyes **38-45**

Table 3. Synthesis of merocyanine dyes **38-45**

Entry	Product	Ring structure	R	EWG	Yield, (*) %
20	38	quinaldine	Me	dimedone	91
21	39	2-picoline	Me	barbituric acid	68 (81) ³⁵
22	40	2-picoline	Et	NC-CH ₂ -CN	75
23	41	2-picoline	Et	NC-CH ₂ -SO ₂ Ph	70
24	42	2-picoline	Et	barbituric acid	87 (52) ³⁵
25	43	2-picoline	Pr	NC-CH ₂ -CN	58
26	44	2-picoline	Pr	NC-CH ₂ -COOEt	63
27	45	2-picoline	Pr	barbituric acid	77

* the yield reported in the literature

The proposed two-step approach will significantly facilitate the practical production of a wide-range merocyanine dyes based on methyl-substituted quaternary azinium salts. For the synthesis of the known merocyanines **21** and **34**, a 30-40% yield increase was achieved in comparison to previously reported methods.³²⁻³⁵ All other dyes were synthesized by us for the first time.

UV/Vis absorption spectra of all the synthesized dyes **19-45** were recorded in acetone solution. The combined data for the maximum absorption wavelength and the extinction coefficient for each compound are shown in Table 4. Analysis of the UV/Vis absorption spectra of the merocyanines **24-29** with various electron withdrawing groups (Figure 2) shows that the variation of an acceptor group smoothly shifts the absorption maximum within 25 nm.

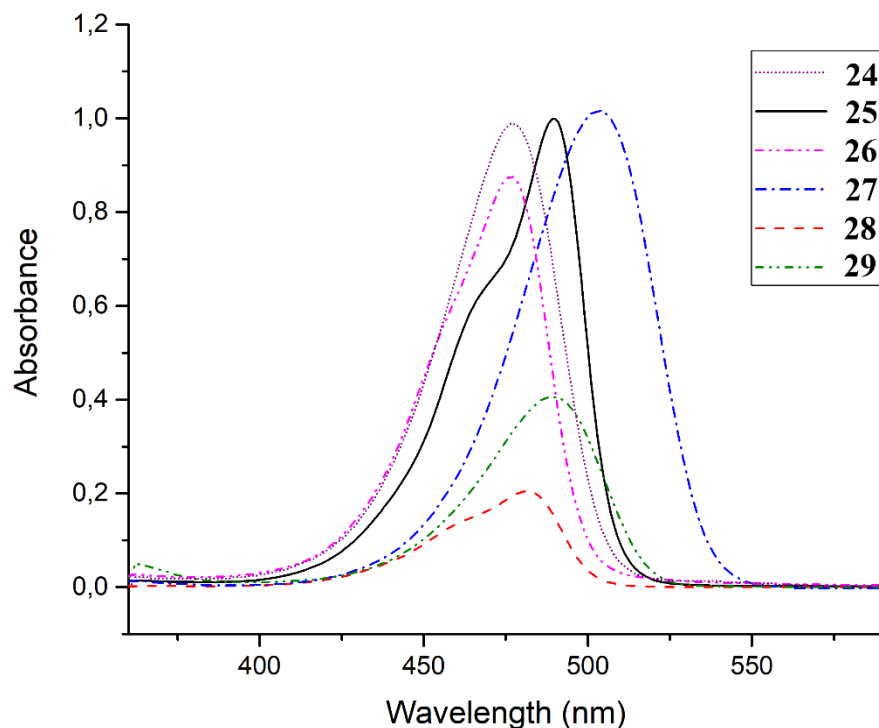


Figure 3. UV/Vis spectra of the merocyanines **24-29**, arranged according to substituent types

Table 4. Absorption spectra of the merocyanine dyes in acetone

Compound	λ_{\max} [nm]	$\epsilon_{\max} \times 10^{-4}$ [$M^{-1} \times cm^{-1}$]	Compound	λ_{\max} [nm]	$\epsilon_{\max} \times 10^{-4}$ [$M^{-1} \times cm^{-1}$]
19	542	7.95	33	476	7.90
20	531	6.54	34	503	8.12
21	542	7.29	35	523	4.92
22	474	2.71	36	495	9.11
23	474	6.54	37	511	3.39
24	479	9.88	38	574	6.30
25	488	10.00	39	457	2.67
26	475	8.73	40	450	6.30
27	501	10.24	41	448	5.00
28	475	1.93	42	464	2.37
29	487	4.03	43	452	3.42
30	476	8.24	44	456	4.11
31	476	7.99	45	463	9.43
32	507	3.65			

Dissolving the synthesized dyes in trifluoroacetic acids had interesting results. We previously showed¹⁸ that in trifluoroacetic acid the α -carbon of the polyene chain in dye **25** becomes protonated which, according to ¹H NMR data, disrupts the conjugation. This is fully in line with the dye structure, approaching the cyanine limit. This process also occurs in the case of protonation of compound **25** (Figure 4). On the other hand, the

protonation of dye **39** occurs without affecting the polyene system. The oxygen atom in the barbituric acid residue is apparently involved in the protonation. This possibly indicates that compound **39** is strongly polarized and that its structure is close to that of a betaine. The X-ray data for **39** (see the Supporting Information for X-ray data) (Figure 5) supports this hypothesis: the values of the determined bond lengths between C(9) – C(8) 1.436Å, C(8) – C(7) 1.358Å and C(7) – C(4) 1.422Å demonstrate that single and double bonds are altered in this molecule, which is consistent with its betaine nature.

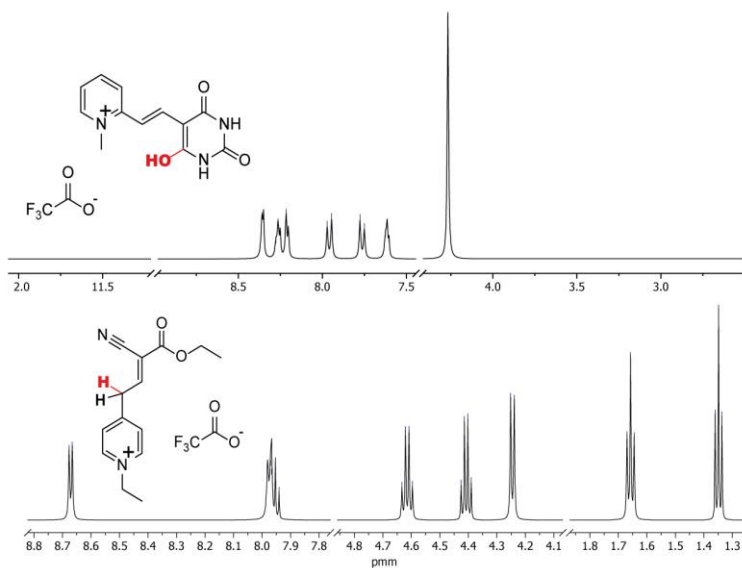


Figure 4. Comparison of ^1H NMR spectra for compounds **39** and **25**, protonated by trifluoroacetic acid.

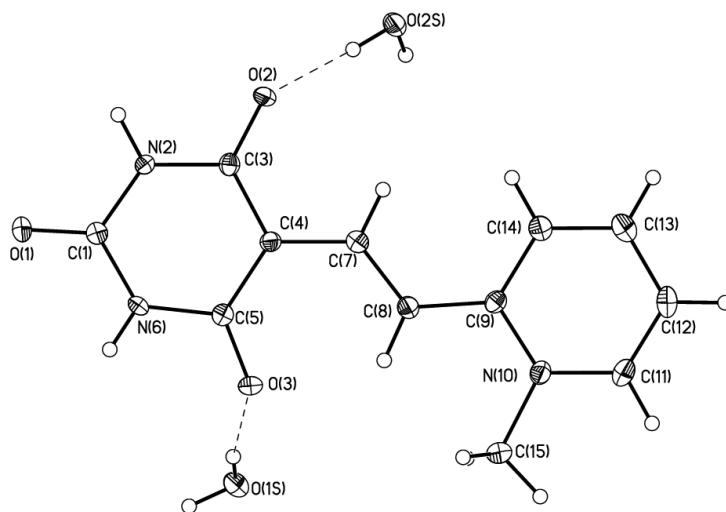


Figure 5. General view of **39** in a crystal, non-hydrogen atoms are represented by probability ellipsoids of atomic displacements ($p=50\%$).

Conclusions

In conclusion, we have reported a new facile approach to the combinatorial synthesis of merocyanine dyes based on readily available starting materials. This promising method for the synthesis of merocyanine dye libraries does not require additional purification of the final products.

Experimental Section

General. ^1H NMR spectra were recorded on a Bruker AVANCE 600 spectrometer (600.13 MHz). Chemical shifts are given in ppm relative to SiMe_4 . The IR spectra recorded on a “Bruker Alpha” in KBr pellets. Melting points were measured on Kofler bench. UV spectra were recorded on a Shimadzu UV-2600 instrument in quartz cells with a light pathlength of 1 cm with the concentration of the substance $C_M 10^{-5}$ [M] (solvent acetone). Reactions were monitored by thin layer chromatography (TLC).

Synthesis of salts 3-12. General Experimental Procedure.

Dimethylformamide dimethyl acetal (5.36 g, 45.0 mmol) was added to a solution of the corresponding picolinium or quinolinium salt **1** (30.0 mmol) in DMF (25 mL), the resulting mixture was stirred at rt for 16 h. The solution was evaporated to near dryness in vacuo. The crude product was purified by precipitation from boiling methanol–diethyl ether to obtain a grey solid **3-12** which was filtered off, washed with diethyl ether and dried.

Synthesis of dyes 23, 24, 28, 29, 30, 33, 36, 37, 39, 40, 42, 43, 45. General Experimental Procedure.

Compounds **13, 17, 18** (1.36 mmol) were added to the solution of the corresponding salts **3-12** (1.46 mmol) in DMF (5-6 mL), the resulting mixture was stirred at rt for 12 h. The reaction mixture was diluted with water (50 mL) and left to stand at room temperature for 12 h. The precipitated product was filtered off, washed with water and air-dried. The products were obtained in good yields without further purification.

Synthesis of dyes 19, 20, 21, 22, 25, 26, 27, 31, 32, 34, 35, 38 41, 44. General Experimental Procedure.

Compounds **14, 15, 16** (1.36 mmol) and NaOAc (1.36 mmol) were added to the solution of the corresponding salts **3-12** (1.46 mmol) in DMF (5-6 mL), the resulting mixture was heated at 60 °C for 5 h and then cooled to rt. The reaction mixture was diluted with water (50 mL). The resulting precipitate was filtered off, washed with water and air-dried. The products were obtained in good yields without further purification.

4-(2-(Dimethylamino)vinyl)-1-methylquinolin-1-ium iodide (3).: Yield: 95% ^1H NMR: (600 MHz, $\text{DMSO}-d_6$) δ 8.66 (d, J 8.4 Hz, 1H), 8.56 (d, J 12.3 Hz, 1H), 8.41 (d, J 7.3 Hz, 1H), 8.04 – 7.99 (m, 2H), 7.75 – 7.71 (m, 1H), 7.62 (d, J 7.3 Hz, 1H), 6.27 (d, J 12.3 Hz, 1H), 4.14 (s, 3H), 3.44 (s, 3H), 3.28 (s, 3H). ^{13}C NMR: (151 MHz, $\text{DMSO}-d_6$) δ 154.6, 153.4, 142.4, 137.9, 132.8, 125.6, 125.2, 122.3, 117.2, 105.8, 90.0, 45.1, 41.2, 37.3. *Anal. calcd* for $\text{C}_{14}\text{H}_{17}\text{IN}_2$ (340,21): C, 49.43; H, 5.04; N, 8.23 Found: C, 49.27; H, 4.93; N, 7.99.

4-(2-(Dimethylamine)vinyl)-1-methylpyridin-1-ium iodide (4). Yield: 98% ^1H NMR: (600 MHz, $\text{DMSO}-d_6$) δ 8.12 – 8.00 (m, 3H), 7.67 – 7.02 (s, 2H), 5.31 (d, J 13.0 Hz, 1H), 3.88 (s, 3H), 3.20 (s, 3H), 2.93 (s, 3H). ^{13}C NMR: (151 MHz, $\text{DMSO}-d_6$) δ 155.0, 152.2, 141.7, 127.9, 92.1, 44.7, 44.5, 37.0. *Anal. calcd* for $\text{C}_{10}\text{H}_{15}\text{IN}_2$ (290,15): C, 41.40; H, 5.21; N, 9.66 Found: C, 41.18; H, 5.02; N, 9.51; Spectral data in according with previously described.^{29,30}

4-(2-(Dimethylamino)vinyl)-1-ethylpyridin-1-ium bromide (5). Yield: 99% ^1H NMR: (600 MHz, $\text{DMSO}-d_6$) δ 8.19 (d, J 6.9 Hz, 2H), 8.15 (d, J 13.0 Hz, 1H), 7.67 – 7.10 (m, 2H), 5.31 (d, J 13.0 Hz, 1H), 4.16 (q, J 7.4 Hz, 2H), 3.21 (s, 3H), 2.94 (s, 3H), 1.38 (t, J 7.4 Hz, 3H). ^{13}C NMR: (151 MHz, $\text{DMSO}-d_6$) δ 155.2, 152.4, 140.6, 92.2, 52.5, 44.6, 36.9, 34.2, 16.0. *Anal. calcd* for $\text{C}_{11}\text{H}_{17}\text{BrN}_2$ (257,18): C, 51.37; H, 6.66; N, 10.89; Found: C, 51.12; H, 6.49; N, 10.63; Spectral data in according with previously described.²⁹

4-(2-(dimethylamino)vinyl)-1-propylpyridin-1-ium bromide (6). Yield: 96% $^1\text{H NMR}$: (600 MHz, DMSO- d_6) δ 8.32 – 8.23 (m, 3H), 7.47 (s, 2H), 5.41 (d, J 12.9 Hz, 1H), 4.19 (t, J 7.3 Hz, 2H), 3.29 (s, 3H), 3.01 (s, 3H), 1.85 (q, J 7.3 Hz, 2H), 0.90 (t, J 7.3 Hz, 3H). $^{13}\text{C NMR}$: (151 MHz, DMSO- d_6) δ 154.7, 152.0, 140.3, 115.5, 91.7, 57.8, 44.1, 36.4, 23.1, 9.7. *Anal. calcd* for $\text{C}_{12}\text{H}_{19}\text{BrN}_2$ (271,02): C, 53.15; H, 7.06; N, 10.34 Found: C, 52.92; H, 6.98; N, 9.96;

1-butyl-4-(2-(dimethylamino)vinyl)pyridin-1-ium bromide (7): Yield: 97% $^1\text{H NMR}$: (600 MHz, DMSO- d_6) δ 8.16 (d, J 7.0 Hz, 2H), 8.11 (d, J 12.9 Hz, 1H), 7.35 (s, 1H), 5.31 (d, J 12.9 Hz, 1H), 4.11 (t, J 7.3 Hz, 2H), 3.20 (s, 3H), 2.94 (s, 3H), 1.74 (p, J 7.4 Hz, 2H), 1.26 (hept, J 7.4 Hz, 2H), 0.89 (t, J 7.4 Hz, 3H). $^{13}\text{C NMR}$: (151 MHz, DMSO- d_6) δ 155.2, 152.5, 140.9, 92.2, 56.9, 44.7, 36.9, 34.2, 32.2, 18.7, 13.3. *Anal. calcd* for $\text{C}_{13}\text{H}_{21}\text{BrN}_2$ (285,23): C, 54.74; H, 7.42; N, 9.82; Found: C, 54.5; H, 7.28; N, 9.53.

4-(2-(dimethylamino)vinyl)-1-phenylpyridin-1-ium chloride (8): Yield: 93% $^1\text{H NMR}$: (600 MHz, DMSO- d_6) δ 8.59 (d, J 12.8 Hz, 1H), 8.44 (d, J 7.4 Hz, 2H), 8.03 – 7.83 (m, 1H), 7.78 (d, J 7.8 Hz, 2H), 7.68 (t, J 7.8 Hz, 2H), 7.61 (t, J 7.3 Hz, 1H), 7.46 – 7.03 (m, 1H), 5.59 (d, J 12.8 Hz, 1H), 3.37 (s, 3H), 3.08 (s, 3H). $^{13}\text{C NMR}$: (151 MHz, DMSO- d_6) δ 154.8, 153.8, 141.5, 139.1, 138.6, 129.5, 128.5, 122.4, 118.7, 113.3, 92.8, 44.6, 36.7. *Anal. calcd* for $\text{C}_{15}\text{H}_{17}\text{ClN}_2$ (260,77): C, 69.09; H, 6.57; N, 10.74 Found: C, 68.95; H, 6.46; N, 10.46.

2-(2-(dimethylamino)vinyl)-1-methylquinolin-1-ium iodide (9): Yield: 93% $^1\text{H NMR}$: (600 MHz, DMSO- d_6) δ 8.50 (d, J 12.2 Hz, 1H), 8.13 (d, J 9.5 Hz, 1H), 7.99 (d, J 8.8 Hz, 1H), 7.96 (d, J 9.6 Hz, 1H), 7.89 (d, J 7.8 Hz, 1H), 7.78 (t, J 7.9 Hz, 1H), 7.51 (t, J 7.4 Hz, 1H), 5.56 (d, J 12.2 Hz, 1H), 3.94 (s, 3H), 3.37 (s, 3H), 3.18 (s, 3H). $^{13}\text{C NMR}$: (151 MHz, DMSO- d_6) δ 156.9, 156.2, 139.1, 137.1, 132.4, 129.1, 125.2, 123.9, 118.1, 117.0, 89.1, 54.4, 45.8, 38.0, 36.86. *Anal. calcd* for $\text{C}_{14}\text{H}_{17}\text{IN}_2$ (340,21): C, 49.43; H, 5.04; N, 8.23 Found: C, 49.22; H, 4.91; N, 8.03; Spectral data in according with previously described.³¹

2-(2-(dimethylamino)vinyl)-1-methylpyridin-1-ium iodide (10): Yield: 98% $^1\text{H NMR}$: (600 MHz, DMSO- d_6) δ 8.21 (d, J 6.5 Hz, 1H), 8.18 (d, J 12.6 Hz, 1H), 7.94 (d, J 8.9 Hz, 1H), 7.79 (t, J 7.9 Hz, 1H), 6.99 (t, J 6.8 Hz, 1H), 5.13 (d, J 12.6 Hz, 1H), 3.86 (s, 3H), 3.25 (s, 3H), 3.02 (s, 3H). $^{13}\text{C NMR}$: (151 MHz, DMSO- d_6) δ 155.1, 153.31, 142.6, 139.2, 119.2, 115.7, 84.8, 54.4, 54.4, 54.4, 45.0, 44.2, 37.4. *Anal. calcd* for $\text{C}_{10}\text{H}_{15}\text{IN}_2$ (290,15): C, 41.40; H, 5.21; N, 9.66 Found: C, 41.22; H, 5.04; N, 9.53; Spectral data in according with previously described.²⁹

2-(2-(dimethylamino)vinyl)-1-ethylpyridin-1-ium bromide (11): Yield: 98% $^1\text{H NMR}$: (600 MHz, DMSO- d_6) δ 8.30 – 8.21 (m, 2H), 8.00 (d, J 8.9 Hz, 1H), 7.78 (t, J 7.8 Hz, 1H), 7.03 (t, J 6.7 Hz, 1H), 5.21 (d, J 12.5 Hz, 1H), 4.35 (q, J 7.1 Hz, 2H), 3.26 (s, 3H), 3.03 (s, 3H), 1.33 (t, J 7.1 Hz, 3H) $^{13}\text{C NMR}$: (151 MHz, DMSO- d_6) δ 154.2, 153.6, 141.7, 139.2, 119.8, 116.3, 84.4, 50.7, 44.9, 37.3, 13.6. *Anal. calcd* for $\text{C}_{11}\text{H}_{17}\text{BrN}_2$ (257,18): C, 51.37; H, 6.66; N, 10.89 Found: C, 51.18; H, 6.46; N, 10.69; Spectral data in according with previously described.²⁹

2-(2-(dimethylamino)vinyl)-1-propylpyridin-1-ium bromide (12): Yield: 96% $^1\text{H NMR}$: (600 MHz, DMSO- d_6) δ 8.29 – 8.24 (m, 2H), 8.02 (d, J 8.8 Hz, 1H), 7.78 (t, J 7.9 Hz, 1H), 7.01 (td, J 6.9, 1.2 Hz, 1H), 5.19 (d, J 12.5 Hz, 1H), 4.30 (t, J 7.4 Hz, 2H), 3.25 (s, 3H), 3.02 (s, 3H), 1.78 – 1.71 (m, 2H), 0.90 (t, J 7.4 Hz, 3H). $^{13}\text{C NMR}$: (151 MHz, DMSO- d_6) δ 154.4, 153.5, 142.3, 139.2, 119.9, 115.9, 84.6, 56.5, 44.9, 37.3, 20.9, 10.4. *Anal. calcd* for $\text{C}_{12}\text{H}_{19}\text{BrN}_2$ (271,02): C, 53.15; H, 7.06; N, 10.33 Found: C, 52.96; H, 6.9; N, 10.06.

Ethyl 2-cyano-4-(1-methylquinolin-4(1H)-ylidene)but-2-enoate (19): Yield: 75% *mp*: 209–211°C $^1\text{H NMR}$: (600 MHz, DMSO- d_6) δ 8.38 (d, J 13.6 Hz, 1H), 8.24 (d, J 8.1 Hz, 1H), 7.99 (d, J 7.3 Hz, 1H), 7.90 (t, J 7.8 Hz, 1H), 7.83 (d, J 8.6 Hz, 1H), 7.63 (t, J 7.6 Hz, 1H), 7.24 (d, J 7.4 Hz, 1H), 6.52 (d, J 13.6 Hz, 1H), 4.23 (q, J 7.1 Hz, 2H), 3.98 (s, 3H), 1.31 (t, J 7.1 Hz, 3H). $^{13}\text{C NMR}$: (151 MHz, DMSO- d_6) δ 164.7, 148.9, 147.2, 140.6, 138.2, 132.0, 125.1, 123.7, 122.1, 118.4, 116.7, 105.6, 98.6, 81.3, 59.1, 40.5, 13.9. *Anal. calcd* for $\text{C}_{17}\text{H}_{16}\text{N}_2\text{O}_2$ (280,12): C, 72.84; H, 5.75; N, 9.99; Found: C, 72.65; H, 5.63; N, 9.82; λ_{max} [nm] (acetone): 542 $\epsilon_{\text{max}} \times 10^{-4}$ [$\text{M}^{-1} \times \text{cm}^{-1}$]: 7.95

4-(1-methylquinolin-4(1H)-ylidene)-2-(phenylsulfonyl)but-2-enitrile (20): Yield: 86% *mp*: 253–255 °C *IR* (KBr), ν , cm^{-1} : 3449, 2188, 1621, 1522, 1370, 1276, 1227, 1137, 1081, 1029, 823, 757, 717, 694, 608, 573, 528. $^1\text{H NMR}$: (600 MHz, DMSO- d_6) δ 8.27 (d, J 8.4 Hz, 1H), 8.24 (d, J 13.6 Hz, 1H), 8.17 (d, J 7.2 Hz, 1H), 7.99 – 7.89

(m, 4H), 7.73 – 7.64 (m, 4H), 7.45 (d, *J* 7.3 Hz, 1H), 6.40 (d, *J* 13.6 Hz, 1H), 4.07 (s, 3H) ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 150.3, 144.6, 142.6, 141.5, 138.1, 132.3, 132.0, 128.9, 125.6, 125.5, 124.0, 122.1, 117.0, 116.3, 106.5, 97.5, 88.8, 40.9. *Anal. calcd* for C₂₀H₁₆N₂O₂S (348,09): C, 68.94; H, 4.63; N, 8.04; Found: C, 68.70; H, 4.43; N, 7.91; λ_{max} [nm] (acetone):531 ε_{max} ×10⁻⁴ [M⁻¹ ×cm⁻¹]: 6.54

(E)-2,2-Dimethyl-5-(2-(1-methylquinolin-4(1H)-ylidene)ethylidene)-1,3-dioxane-4,6-dione (21). Yield: 93% *mp*: 234-237 °C *IR* (KBr),v, cm⁻¹: 3532, 3471, 1629, 1556, 1519, 1426, 1369, 1360, 1323, 1267, 1220, 1160, 1111, 976, 929. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.32 (d, *J* 7.1 Hz, 1H), 8.30 (d, *J* 14.6 Hz, 1H), 8.25 (d, *J* 8.4 Hz, 1H), 7.99 – 7.93 (m, 2H), 7.91 (d, *J* 14.6 Hz, 1H), 7.71 (t, *J* 6.3 Hz, 1H), 7.55 (d, *J* 7.1 Hz, 1H), 4.10 (s, 3H), 1.59 (s, 6H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 153.9, 144.7, 143.4, 138.7, 133.3, 126.8, 124.7, 123.8, 118.0, 108.2, 104.3, 101.6, 89.5, 42.1, 26.5. The signal of C(4) is overlapped with CH(beta). *Anal. calcd* for C₁₈H₁₇NO₄ (311,12): C, 69.44; H, 5.50; N, 4.50; Found: C, 69.26; H, 5.30; N, 4.25; λ_{max} [nm] (acetone):542,00 ε_{max} ×10⁻⁴ [M⁻¹ ×cm⁻¹]: 7.29; Spectral data in according with previously described.³²

4-(1-Methylpyridin-4(1H)-ylidene)-2-(phenylsulfonyl)but-2-enenitrile (22). Yield: 66% *mp*: 277-280 °C *IR* (KBr),v, cm⁻¹: 3423, 2170, 1646, 1548, 1480, 1387, 1311, 1269, 1198, 1135, 1088, 1037, 852, 753, 603. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.02 (d, *J* 6.8 Hz, 2H), 7.90 – 7.80 (m, 3H), 7.64 (d, *J* 7.4 Hz, 3H), 7.55 – 7.09 (s, 2H), 5.63 (d, *J* 14.4 Hz, 1H), 3.91 (s, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 152.6, 144.1, 142.2, 141.3, 131.2, 128.6, 125.0, 117.7, 100.3, 80.8, 43.6. The signal of C(CN) is overlapped with hetaryl. *Anal. calcd* for C₁₆H₁₄N₂O₂S (298,08): C, 64.41; H, 4.73; N, 9.39; Found: C, 64.24; H, 4.55; N, 9.21; λ_{max} [nm] (acetone):474 ε_{max} ×10⁻⁴ [M⁻¹ ×cm⁻¹]: 2.71

2,2-Dimethyl-5-(2-(1-methylpyridin-4(1H)-ylidene)ethylidene)-1,3-dioxane-4,6-dione (23). Yield: 62% *mp*: 281-283 °C *IR* (KBr),v, cm⁻¹: 3440, 1682, 1638, 1558, 1539, 1479, 1402, 1344, 1263, 1185, 1124 ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.12 (d, *J* 7.0 Hz, 2H), 7.93 (d, *J* 15.2 Hz, 1H), 7.44 (d, *J* 5.9 Hz, 2H), 7.01 (d, *J* 15.2 Hz, 1H), 3.93 (s, 3H), 1.53 (s, 6H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 155.6, 142.2, 141.6, 118.4, 108.3, 100.9, 85.1, 44.8, 26.3. The signal of C(4) is overlapped with hetaryl. *Anal. calcd* for C₁₄H₁₅NO₄ (261,10): C, 64.36; H, 5.79; N, 5.36; Found: C, 64.12; H, 5.60; N, 5.07; λ_{max} [nm] (acetone):474 ε_{max} ×10⁻⁴ [M⁻¹ ×cm⁻¹]: 6.54

2-(2-(1-Ethylpyridin-4(1H)-ylidene)ethylidene)malononitrile (24). Yield: 57% *mp*: 183-185 °C *IR* (KBr),v, cm⁻¹: ¹H NMR: (600 MHz, DMSO-*d*₆) δ 7.98 (d, *J* 7.3 Hz, 2H), 7.73 (d, *J* 14.2 Hz, 1H), 7.69 – 6.65 (m, 2H), 5.65 (d, *J* 14.2 Hz, 1H), 4.07 (q, *J* 7.2 Hz, 2H), 1.35 (t, *J* 7.3 Hz, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 152.6, 147.5, 140.5 (br), 121.2, 119.0, 102.1, 52.2, 47.4, 15.9. *Anal. calcd* for C₁₂H₁₁N₃ (197,10): C, 73.07; H, 5.62; N, 21.30 Found: C, 72.94; H, 5.46; N, 21.17; λ_{max} [nm] (acetone):479 ε_{max} ×10⁻⁴ [M⁻¹ ×cm⁻¹]: 9,88; Spectral data in according with previously described.³³

Ethyl-2-cyano-4-(1-ethylpyridin-4(1H)-ylidene)-but-2-enoate (25). Yield: 48% *mp*: 163-166 °C *IR* (KBr),v, cm⁻¹: 3445, 2186, 1664, 1648, 1542, 1485, 1415, 1326, 1248, 1223, 1180, 1094, 1029, 945 ¹H NMR: (600 MHz, DMSO-*d*₆) δ 7.96 (d, *J* 14.4 Hz, 1H), 7.89 (d, *J* 7.1 Hz, 2H), 7.44 – 6.79 (m, 2H), 5.63 (d, *J* 14.4 Hz, 1H), 4.21 – 3.89 (m, 4H), 1.34 (t, *J* 7.2 Hz, 3H), 1.19 (t, *J* 7.1 Hz, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 166.2, 152.8, 145.7, 139.7(br), 120.4, 101.4, 74.1, 58.8, 51.9, 15.9, 14.6. *Anal. calcd* for C₁₄H₁₆N₂O₂ (244,12): C, 68.83; H, 6.60; N, 11.47; Found: C, 68.61; H, 6.46; N, 11.24; λ_{max} [nm] (acetone):488 ε_{max} ×10⁻⁴ [M⁻¹ ×cm⁻¹]: 10,00; Spectral data in according with previously described.³³

4-(1-Ethylpyridin-4(1H)-ylidene)-2-(phenylsulfonyl)but-2-enenitrile (26). Yield: 66% *mp*: 231-234 °C *IR* (KBr),v, cm⁻¹: 3459, 2172, 1644, 1553, 1478, 1445, 1387, 1311, 1271, 1185, 1134, 1085, 1034, 604, 578 ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.02 (d, *J* 7.1 Hz, 2H), 7.84 – 7.72 (m, 3H), 7.64 – 7.47 (m, 3H), 7.44 – 7.04 (m, 2H), 5.56 (d, *J* 14.4 Hz, 1H), 4.10 (q, *J* 7.2 Hz, 2H), 1.36 (t, *J* 7.2 Hz, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 153.4, 144.6, 142.9, 140.2, 131.8, 129.2, 125.5, 118.2, 107,7, 100.9, 81.6, 52.3, 16.0. *Anal. calcd* for C₁₇H₁₆N₂O₂S

(312,09): C, 65.36; H, 5.16; N, 8.97; Found: C, 65.11; H, 4.99; N, 8.74; λ_{max} [nm] (acetone):475 $\epsilon_{max} \times 10^{-4}$ [$M^{-1} \times cm^{-1}$]: 8.73

2-(2-(1-Ethylpyridin-4(1H)-ylidene)ethylidene)-5,5-dimethylcyclohexane-1,3-dione (27). Yield: 47% *mp*: >300 °C *IR* (KBr), ν, cm^{-1} : 3443, 2958, 1644, 1635, 1548, 1531, 1508, 1478, 1396, 1354, 1264, 1174, 1120, 989, 886 1H NMR: (600 MHz, DMSO- d_6) δ 8.14 (d, *J* 7.0 Hz, 2H), 8.01 (d, *J* 15.1 Hz, 1H), 7.46 (d, *J* 15.1 Hz, 1H), 7.37 (d, *J* 5.4 Hz, 2H), 4.17 (q, *J* 7.2 Hz, 2H), 2.15 (s, 4H), 1.39 (t, *J* 7.2 Hz, 3H), 0.94 (s, 6H). ^{13}C NMR: (151 MHz, DMSO- d_6) δ 193.5, 157.0, 140.7, 139.9, 118.3, 111.5, 108.8, 52.6, 51.9, 30.5, 28.4, 16.0. *Anal. calcd* for $C_{17}H_{21}NO_2$ (271,16): C, 75.25; H, 7.80; N, 5.16; Found: C, 75.04; H, 7.60; N, 4.98; λ_{max} [nm] (acetone):501 $\epsilon_{max} \times 10^{-4}$ [$M^{-1} \times cm^{-1}$]: 10.24

5-(2-(1-Ethylpyridin-4(1H)-ylidene)ethylidene)-2,2-dimethyl-1,3-dioxane-4,6-dione (28). Yield: 66% *mp*: 258-261 °C *IR* (KBr), ν, cm^{-1} : 3460, 3052, 2988, 1681, 1642, 1548, 1531, 1476, 1397, 1347, 1261, 1201, 1167, 989, 935, 892, 772. 1H NMR: (600 MHz, DMSO- d_6) δ 8.22 (d, *J* 7.0 Hz, 2H), 7.95 (d, *J* 15.2 Hz, 1H), 7.45 (d, *J* 5.1 Hz, 2H), 7.02 (d, *J* 15.2 Hz, 1H), 4.21 (q, *J* 7.2 Hz, 2H), 1.53 (s, 6H), 1.40 (t, *J* 7.2 Hz, 3H). ^{13}C NMR: (151 MHz, DMSO- d_6) δ 155.8, 141.8, 141.1, 118.6, 108.3, 101.0, 85.2, 52.9, 26.3, 16.0. The signal of C(4) is overlapped with hetaryl. *Anal. calcd* for $C_{15}H_{17}NO_4$ (275,12): C, 65.44; H, 6.22; N, 5.09; Found: C, 65.22; H, 6.06; N, 4.92; λ_{max} [nm] (acetone):475 $\epsilon_{max} \times 10^{-4}$ [$M^{-1} \times cm^{-1}$]: 1.93

5-(2-(1-Ethylpyridin-4(1H)-ylidene)ethylidene)pyrimidine-2,4,6(1H,3H,5H)-trione hydrate (29). Yield: 65% *mp*: >300 °C *IR* (KBr), ν, cm^{-1} : 3164, 3065, 1718, 1697, 1644, 1601, 1559, 1426, 1333, 1310, 1273, 1170, 1038, 979, 528. 1H NMR: (600 MHz, DMSO- d_6) δ 9.95 – 9.84 (m, 2H), 8.19 (d, *J* 7.1 Hz, 2H), 8.00 (d, *J* 15.2 Hz, 1H), 7.44 (d, *J* 5.7 Hz, 2H), 7.29 (d, *J* 15.2 Hz, 1H), 4.19 (q, *J* 7.3 Hz, 2H), 1.40 (t, *J* 7.3 Hz, 3H). ^{13}C NMR: (151 MHz, DMSO- d_6) δ 168.7, 155.9, 151.1, 140.9, 140.8, 118.4, 108.3, 92.8, 52.8, 16.0. *Anal. calcd* for $C_{13}H_{15}N_3O_4$ (277,11): C, 56.31; H, 5.45; N, 15.15; Found: C, 56.16; H, 5.31; N, 14.97; λ_{max} [nm] (acetone):487 $\epsilon_{max} \times 10^{-4}$ [$M^{-1} \times cm^{-1}$]: 4,03

2,2-Dimethyl-5-(2-(1-propylpyridin-4(1H)-ylidene)ethylidene)-1,3-dioxane-4,6-dione (30). Yield: 74% *mp*: 245-247 °C *IR* (KBr), ν, cm^{-1} : 3564, 3491, 3075, 2979, 1687, 1679, 1645, 1632, 1553, 1538, 1409, 1349, 1270, 1181. 1H NMR: (600 MHz, DMSO- d_6) δ 8.20 (d, *J* 6.9 Hz, 2H), 7.95 (d, *J* 15.2 Hz, 1H), 7.46 (d, *J* 6.5 Hz, 2H), 7.02 (d, *J* 15.2 Hz, 1H), 4.14 (t, *J* 7.3 Hz, 2H), 1.80 (q, *J* 7.3 Hz, 2H), 1.53 (s, 6H), 0.85 (t, *J* 7.3 Hz, 3H). ^{13}C NMR: (151 MHz, DMSO- d_6) δ 155.8, 141.9, 141.3, 118.5, 108.3, 100.9, 85.4, 58.9, 40.0, 26.3, 23.7, 10.3. *Anal. calcd* for $C_{16}H_{19}NO_4$ (289,33): C, 66.42; H, 6.62; N, 4.84; Found: C, 66.21; H, 6.5; N, 4.65; λ_{max} [nm] (acetone):476 $\epsilon_{max} \times 10^{-4}$ [$M^{-1} \times cm^{-1}$]: 8.24

4-(1-Butylpyridin-4(1H)-ylidene)-2-(phenylsulfonyl)but-2-enenitrile (31). Yield: 73% *mp*: 176-178 °C *IR* (KBr), ν, cm^{-1} : 3436, 2172, 1642, 1545, 1539, 1508, 1478, 1390, 1314, 1267, 1181, 1134, 1082, 1029, 843, 759, 713, 607. 1H NMR: (600 MHz, DMSO- d_6) δ 8.01 (d, *J* 7.1 Hz, 2H), 7.84 – 7.71 (m, 3H), 7.61 – 7.50 (m, 3H), 7.45 – 6.83 (m, 2H), 5.56 (d, *J* 14.4 Hz, 1H), 4.07 (t, *J* 7.2 Hz, 2H), 1.78 – 1.64 (m, 2H), 1.28 – 1.20 (m, 2H), 0.89 (t, *J* 7.3 Hz, 3H). ^{13}C NMR: (151 MHz, DMSO- d_6) δ 153.4, 144.6, 143.0, 140.5, 131.8, 129.2, 125.5, 118.2, 100.9, 81.8, 56.7, 32.3, 18.7, 13.3. The signal of C(CN) is overlapped with hetaryl. *Anal. calcd* for $C_{19}H_{20}N_2O_2S$ (340,12): C, 67.03; H, 5.92; N, 8.23; Found: C, 66.80; H, 5.75; N, 8.08; λ_{max} [nm] (acetone):476 $\epsilon_{max} \times 10^{-4}$ [$M^{-1} \times cm^{-1}$]: 7.99

2-(2-(1-Butylpyridin-4(1H)-ylidene)ethylidene)-5,5-dimethylcyclohexane-1,3-dione (32). Yield: 76% *mp*: >300 °C *IR* (KBr), ν, cm^{-1} : 3425, 2955, 1645, 1625, 1555, 1470, 1405, 1359, 1277, 1185, 975, 872. 1H NMR: (600 MHz, DMSO- d_6) δ 8.12 (d, *J* 7.1 Hz, 2H), 8.00 (d, *J* 15.1 Hz, 1H), 7.46 (d, *J* 15.1 Hz, 1H), 7.40 – 7.33 (m, 2H), 4.14 (t, *J* 7.3 Hz, 2H), 2.15 (s, 4H), 1.78 – 1.72 (m, 2H), 1.30 – 1.23 (m, 2H), 0.94 (s, 6H), 0.90 (t, *J* 7.4 Hz, 3H). ^{13}C NMR: (151 MHz, DMSO- d_6) δ 193.5, 157.0, 140.9, 139.9, 111.5, 108.9, 57.0, 51.9, 40.4, 32.3, 30.5, 28.4, 18.8, 13.3.

Anal. calcd for C₁₉H₂₅NO₂ (299,19): C, 76.22; H, 8.42; N, 4.68; Found: C, 76.02; H, 8.22; N, 4.53; λ_{max} [nm] (acetone):507 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 3.65

5-(2-(1-Butylpyridin-4(1H)-ylidene)ethylidene)-2,2-dimethyl-1,3-dioxane-4,6-dione (33). Yield: 85% *mp*: 262-265 °C *IR* (KBr),v, cm⁻¹: 3433, 3067, 2958, 1705, 1649, 1566, 1542, 1479, 1416, 1352, 1277, 1206, 1188, 966, 936, 863. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.20 (d, *J* 7.0 Hz, 2H), 7.95 (d, *J* 15.2 Hz, 1H), 7.45 (d, *J* 5.6 Hz, 2H), 7.02 (d, *J* 15.2 Hz, 1H), 4.17 (t, *J* 7.2 Hz, 2H), 1.80 – 1.72 (m, 2H), 1.53 (s, 6H), 1.30 – 1.21 (m, 2H), 0.89 (t, *J* 7.4 Hz, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 155.8, 141.9, 141.3, 118.5, 108.3, 101.0, 85.4, 57.3, 32.3, 26.3, 18.8, 13.3. The signal of C(4) is overlapped with hetaryl. *Anal. calcd* for C₁₇H₂₁NO₄ (303,15): C, 67.31; H, 6.98; N, 4.62; Found: C, 67.18; H, 6.85; N, 4.44; λ_{max} [nm] (acetone):476 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 7.90

Ethyl 2-cyano-4-(1-phenylpyridin-4(1H)-ylidene)but-2-enoate (34). Yield: 91% *mp*: 205-208 °C *IR* (KBr),v, cm⁻¹: 3449, 2186, 1671, 1646, 1536, 1505, 1480, 1420, 1246, 1190, 1173, 1087. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.10 (d, *J* 14.1 Hz, 1H), 8.04 (d, *J* 16.7 Hz, 2H), 7.63 (d, *J* 7.5 Hz, 3H), 7.59 (t, *J* 7.8 Hz, 2H), 7.50 (t, *J* 7.2 Hz, 1H), 7.41 – 7.30 (s, 1H), 7.02 – 6.91 (s, 1H), 5.78 (d, *J* 14.1 Hz, 1H), 4.11 (q, *J* 7.1 Hz, 2H), 1.21 (t, *J* 7.1 Hz, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 165.6, 151.7, 147.1, 142.2, 138.4, 137.7, 130.0, 128.6, 122.6, 119.4, 118.5, 113.2, 102.3, 78.7, 59.3, 14.5. *Anal. calcd* for C₁₈H₁₆N₂O₂ (292,12): C, 73.95; H, 5.52; N, 9.58; Found: C, 73.82; H, 5.37; N, 9.35; λ_{max} [nm] (acetone):503 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 8.12; Spectral data in according with previously described.³⁴

5,5-Dimethyl-2-(2-(1-phenylpyridin-4(1H)-ylidene)ethylidene)cyclohexane-1,3-dione (35). Yield: 79% *mp*: >300 °C *IR* (KBr),v, cm⁻¹: 3423, 3045, 2954, 1642, 1634, 1561, 1528, 1475, 1400, 1354, 1254, 1184, 1165, 976. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.28 (d, *J* 7.3 Hz, 2H), 8.12 (d, *J* 14.9 Hz, 1H), 7.70 (d, *J* 7.6 Hz, 2H), 7.63 (t, *J* 7.8 Hz, 2H), 7.56 (t, *J* 7.3 Hz, 1H), 7.51 (d, *J* 14.9 Hz, 1H), 7.47 – 7.29 (m, 2H), 2.21 (s, 4H), 0.96 (s, 6H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 194.4, 156.7, 142.2, 141.4, 139.4, 130.1, 129.2, 123.1, 113.3, 108.7, 40.0, 30.4, 28.4, 27.9. *Anal. calcd* for C₂₁H₂₁NO₂ (319,16): C, 78.97; H, 6.63; N, 4.39; Found: C, 78.74; H, 6.45; N, 4.16; λ_{max} [nm] (acetone):523 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 4.92; Spectral data in according with previously described.²⁹

2,2-Dimethyl-5-(2-(1-phenylpyridin-4(1H)-ylidene)ethylidene)-1,3-dioxane-4,6-dione (36). Yield: 78% *mp*: 272-274 °C *IR* (KBr),v, cm⁻¹: 3443, 3051, 1698, 1649, 1541, 1525, 1509, 1478, 1409, 1349, 1253, 1180, 1125, 931, 762, 511. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.46 (d, *J* 7.4 Hz, 2H), 8.18 (d, *J* 15.0 Hz, 1H), 7.80 (d, *J* 8.1 Hz, 2H), 7.71 (t, *J* 7.8 Hz, 2H), 7.65 (t, *J* 7.4 Hz, 1H), 7.63 – 7.51 (s, 2H), 7.19 (d, *J* 15.0 Hz, 1H), 1.64 (s, 6H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 155.2, 143.2, 141.6, 139.5, 129.5, 128.8, 122.7, 122.7, 107.7, 100.8, 87.2, 25.9. The signal of C(4) is overlapped with hetaryl. *Anal. calcd* for C₁₉H₁₇NO₄ (323,12): C, 70.58; H, 5.30; N, 4.33; Found: C, 70.39; H, 5.13; N, 4.08; λ_{max} [nm] (acetone): 495 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 9.11

5-(2-(1-Phenylpyridin-4(1H)-ylidene)ethylidene)pyrimidine-2,4,6(1H,3H,5H)-trione (37). Yield: 89% *mp*: >300 °C *IR* (KBr),v, cm⁻¹: 3433, 2361, 2342, 1699, 1639, 1605, 1542, 1510, 1475, 1423, 1323, 1260, 1227, 1175, 975, 858, 606, 518. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 10.27 – 10.04 (m, 2H), 8.41 (d, *J* 7.2 Hz, 2H), 8.22 (d, *J* 14.9 Hz, 1H), 7.79 (d, *J* 7.9 Hz, 2H), 7.71 (t, *J* 7.7 Hz, 2H), 7.65 (t, *J* 7.4 Hz, 1H), 7.60 – 7.48 (s, 2H), 7.44 (d, *J* 14.9 Hz, 1H). ¹³C NMR: (151 MHz, DMSO-*d*₆) 155.2, 150.4, 142.2, 141.6, 139.2, 129.5, 129.5, 128.7, 122.6, 122.6, 107.6, 94.6. *Anal. calcd* for C₁₇H₁₃N₃O₃ (307,10): C, 66.44; H, 4.26; N, 13.67; Found: C, 66.28; H, 4.13; N, 13.43; λ_{max} [nm] (acetone):511 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 3.39

5,5-Dimethyl-2-(2-(1-methylquinolin-2(1H)-ylidene)ethylidene)cyclohexane-1,3-dione (38). Yield: 91% *mp*: 257-259 °C *IR* (KBr),v, cm⁻¹: 3473, 3385, 2951, 2865, 1619, 1541, 1508, 1366, 1269, 1240, 1234, 1224, 966. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.37 (d, *J* 14.4 Hz, 1H), 8.29 (d, *J* 14.3 Hz, 1H), 8.22 (d, *J* 8.3 Hz, 1H), 8.17 (d, *J* 7.1 Hz, 1H), 7.94 – 7.78 (m, 2H), 7.70 – 7.59 (m, 1H), 7.44 (d, *J* 7.3 Hz, 1H), 4.02 (s, 3H), 2.27 (s, 4H), 0.97 (s, 6H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 195.0, 154.7, 142.5, 142.0, 138.7, 133.0, 126.3, 124.6, 124.1, 117.8, 114.6, 107.7,

105.0, 53.4 – 50.2, 41.8, 30.4, 28.3. *Anal. calcd* for C₂₀H₂₁NO₂ (307,39): C, 78.15; H, 6.89; N, 4.56; Found: C, 77.90; H, 6.77; N, 4.37; λ_{max} [nm] (acetone):574 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 6.3

5-(2-(1-Methylpyridin-2(1H)-ylidene)ethylidene)pyrimidine-2,4,6(1H,3H,5H)-trione dihydrate (39). Yield: 68% *mp*: >300 °C *IR* (KBr),v, cm⁻¹: 3391, 3185, 2793, 1691, 1648, 1607, 1543, 1427, 1397, 1343, 1271, 1165, 1038, 848, 770, 515. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 10.18 – 9.86 (m, 2H), 8.28 (d, *J* 6.2 Hz, 1H), 8.07 (d, *J* 14.7 Hz, 1H), 7.96 (d, *J* 8.7 Hz, 1H), 7.84 (t, *J* 7.8 Hz, 1H), 7.46 (d, *J* 14.7 Hz, 1H), 7.09 (t, *J* 6.7 Hz, 1H), 3.88 (s, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 164.6 (br), 155.8, 151.1, 143.1, 142.1, 139.8, 120.3, 117.1, 100.1, 93.4, 44.1. *Anal. calcd* for C₁₂H₁₅N₃O₅ (281,27): C, 51.24; H, 5.38; N, 14.94; Found: C, 51.04; H, 5.19; N, 14.76; λ_{max} [nm] (acetone):457 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 2.67; Spectral data in according with previously described.³⁵

2-(2-(1-Ethylpyridin-2(1H)-ylidene)ethylidene)malononitrile (40). Yield: 75% ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.08 (d, *J* 6.4 Hz, 1H), 7.92 (d, *J* 8.9 Hz, 1H), 7.88 (d, *J* 13.8 Hz, 1H), 7.63 (t, *J* 7.9 Hz, 1H), 6.93 – 6.83 (m, 1H), 5.57 (d, *J* 13.8 Hz, 1H), 4.17 (q, *J* 7.1 Hz, 2H), 1.33 (t, *J* 7.2 Hz, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 152.2, 149.0, 141.1, 138.2, 120.7, 120.7, 118.6, 115.3, 92.9, 50.4, 48.4, 13.4. *Anal. calcd* for C₁₂H₁₁N₃ (197,10): C, 73.07; H, 5.62; N, 21.30 Found: C, 72.84; H, 5.49; N, 21.16; λ_{max} [nm] (acetone):450 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 6.30

4-(1-Ethylpyridin-2(1H)-ylidene)-2-(phenylsulfonyl)but-2-enenitrile (41). Yield: 70% *mp*: 184-186 °C *IR* (KBr),v, cm⁻¹: 3442, 2172, 1634, 1526, 1440, 1397, 1316, 1300, 1273, 1223, 1140, 1085, 1032, 621, 601, 577. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.12 (t, *J* 6.6 Hz, 1H), 7.94 – 7.86 (m, 2H), 7.84 – 7.79 (m, 2H), 7.72 – 7.67 (m, 1H), 7.60 – 7.54 (m, 3H), 6.95 (t, *J* 6.8 Hz, 1H), 5.48 (d, *J* 14.0 Hz, 1H), 4.18 (q, *J* 7.2 Hz, 2H), 1.31 (t, *J* 7.2 Hz, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 152.8, 144.4, 144.3, 141.4, 138.7, 131.9, 129.2, 125.7, 120.7, 117.8, 115.8, 91.7, 82.7, 50.4, 13.5. *Anal. calcd* for C₁₇H₁₆N₂O₂S (312,09): C, 65.36; H, 5.16; N, 8.97; Found: C, 65.11; H, 4.98; N, 8.75; λ_{max} [nm] (acetone):448 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 5.00

5-(2-(1-Ethylpyridin-2(1H)-ylidene)ethylidene)pyrimidine-2,4,6(1H,3H,5H)-trione hydrate (42). Yield: 87% *mp*: >300 °C *IR* (KBr),v, cm⁻¹: 3450, 3141, 1689, 1636, 1606, 1542, 1433, 1405, 1337, 1293, 1143, 762, 524 ¹H NMR: (600 MHz, DMSO-*d*₆) δ 10.16 – 9.82 (m, 2H), 8.31 (d, *J* 6.3 Hz, 1H), 8.08 (d, *J* 14.6 Hz, 1H), 7.99 (d, *J* 8.7 Hz, 1H), 7.85 (t, *J* 7.8 Hz, 1H), 7.60 (d, *J* 14.6 Hz, 1H), 7.14 (t, *J* 6.6 Hz, 1H), 4.29 (q, *J* 6.9 Hz, 2H), 1.41 (t, *J* 7.1 Hz, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 164.45 (br), 154.9, 151.1, 142.3, 142.1, 139.8, 120.9, 117.6, 99.7, 93.25, 51.2, 13.8. *Anal. calcd* for C₁₃H₁₅N₃O₄ (277,28): C, 56.31; H, 5.45; N, 15.15; Found: C, 56.06; H, 5.29; N, 15.01; λ_{max} [nm] (acetone):464 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 2,37; Spectral data in according with previously described.³⁵

2-(2-(1-Propylpyridin-2(1H)-ylidene)ethylidene)malononitrile (43). Yield: 58% *mp*: 147-149 °C *IR* (KBr),v, cm⁻¹: 3432, 2191, 1665, 1624, 1541, 1518, 1462, 1372, 1324, 1284, 1206, 1154, 1090, 825, 766. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.06 (d, *J* 6.2 Hz, 1H), 7.93 (d, *J* 8.9 Hz, 1H), 7.90 (d, *J* 13.8 Hz, 1H), 7.63 (t, *J* 7.7 Hz, 1H), 6.87 (t, *J* 6.4 Hz, 1H), 5.54 (d, *J* 13.8 Hz, 1H), 4.10 (t, *J* 7.0 Hz, 2H), 1.90 – 1.56 (m, 2H), 0.91 (t, *J* 7.2 Hz, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 152.3, 149.0, 141.6, 138.2, 120.7, 120.6, 118.5, 114.9, 93.1, 56.4, 48.5, 20.7, 10.4. *Anal. calcd* for C₁₃H₁₃N₃ (211,11): C, 73.91; H, 6.20; N, 19.89 Found: C, 73.76; H, 6.03; N, 19.63; λ_{max} [nm] (acetone):452 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 3.42

Ethyl 2-cyano-4-(1-propylpyridin-2(1H)-ylidene)but-2-enoate (44). Yield: 63% *mp*: 162-165 °C *IR* (KBr),v, cm⁻¹: 3450, 2969, 2182, 1669, 1635, 1532, 1449, 1412, 1310, 1241, 1217, 1155, 1100, 1078, 803, 757. ¹H NMR: (600 MHz, DMSO-*d*₆) δ 8.08 (d, *J* 14.0 Hz, 1H), 8.01 (d, *J* 6.4 Hz, 1H), 7.75 (d, *J* 9.0 Hz, 1H), 7.57 (t, *J* 7.9 Hz, 1H), 6.79 (t, *J* 6.6 Hz, 1H), 5.53 (d, *J* 14.0 Hz, 1H), 4.14 – 4.01 (m, 4H), 1.85 – 1.65 (m, 2H), 1.20 (t, *J* 7.1 Hz, 3H), 0.92 (t, *J* 7.4 Hz, 3H). ¹³C NMR: (151 MHz, DMSO-*d*₆) δ 165.9, 152.7, 146.9, 141.6, 137.8, 120.3, 120.0, 114.0, 92.2, 75.1, 58.9, 56.1, 20.6, 14.6, 10.4. *Anal. calcd* for C₁₅H₁₈N₂O₂ (258,14): C, 69.74; H, 7.02; N, 10.84; Found: C, 69.53; H, 6.88; N, 10.65; λ_{max} [nm] (acetone):456 $\epsilon_{max} \times 10^{-4}$ [M⁻¹ × cm⁻¹]: 4.11

5-(2-(1-Propylpyridin-2(1H)-ylidene)ethylidene)pyrimidine-2,4,6(1H,3H,5H)-trione hydrate (45). Yield: 77%
mp: >300 °C *IR* (KBr), ν , cm^{-1} : 3526, 3410, 3153, 1685, 1636, 1606, 1542, 1432, 1400, 1336, 1300, 1273, 1158, 755, 523. $^1\text{H NMR}$: (600 MHz, $\text{DMSO-}d_6$) δ 10.14 – 9.81 (m, 2H), 8.29 (d, J 6.2 Hz, 1H), 8.08 (d, J 14.6 Hz, 1H), 8.00 (d, J 8.7 Hz, 1H), 7.84 (t, J 7.7 Hz, 1H), 7.61 (d, J 14.6 Hz, 1H), 7.12 (t, J 6.6 Hz, 1H), 4.21 (t, J 7.2 Hz, 2H), 1.83 (q, J 7.3 Hz, 2H), 0.95 (t, J 7.3 Hz, 3H). $^{13}\text{C NMR}$: (151 MHz, $\text{DMSO-}d_6$) δ 164.5 (br), 155.0, 151.1, 142.5, 142.2, 139.8, 120.8, 117.2, 99.9, 93.3, 57.2, 21.2, 10.5. *Anal. calcd* for $\text{C}_{14}\text{H}_{17}\text{N}_3\text{O}_4$ (291,31): C, 57.72; H, 5.88; N, 14.42; Found: C, 57.3; H, 5.54; N, 13.93; λ_{max} [nm] (acetone):463 $\epsilon_{\text{max}} \times 10^{-4}$ [$\text{M}^{-1} \times \text{cm}^{-1}$]: 8.85

Acknowledgements

NMR spectroscopic measurements were carried out in the Laboratory of Magnetic Tomography and Spectroscopy, Faculty of Fundamental Medicine, Moscow State University.

Notes: The authors declare no competing financial interest.

Supplementary Material

The Supporting Information is available free of charge on the website.

Details of experimental, synthetic, and analytical procedures, along with spectroscopic data for synthesized compounds.

References

1. Kulinich, A. V.; Ishchenko, A. A. *Russ. Chem. Rev.* **2009**, *78*, 141.
<https://doi.org/10.1070/RC2009v078n02ABEH003900>.
2. Shirinian, V. Z.; Shimkin, A. A. *Heterocyclic Polymethine Dyes: Synthesis, Properties and Applications* **2008**, 75-105.
https://doi.org/10.1007/7081_2007_110
3. Shindy, H. A. *Dyes Pigments*, **2017**, *145*, 505-513.
<https://doi.org/10.1016/J.dyepig.2017.06.029>
4. Mustroph, H. *Phys. Sci. Rev.* **2021**, *7*, 143-158.
<https://doi.org/10.1515/psr-2020-0145>
5. Hamer, F. M. (Ed.). *The Cyanine Dyes and Related Compounds* **2009**, Volume 18, John Wiley & Sons.
6. Abuhaie, C.-M.; Ghinet, A.; Farce, A.; Dubois, J.; Gautret, P.; Rigo, B.; Belei, D.; Bîcu, E. *Eur. J. Med. Chem.* **2013**, *59*, 101–110.
<https://doi.org/10.1016/J.ejmech.2012.11.008>
7. Würthner, F.; Yao, S.; Debaerdemaeker, T.; Wortmann, R. *J. Am. Chem. Soc.* **2002**, *124*, 9431–9447.
<https://doi.org/10.1021/Ja020168f>
8. Wolfbeis, O. S.; Trummer, I. Knierzinger, A. *Liebigs Ann. Chem.* **1981**, *5*, 811–818.
<https://doi.org/10.1002/Jlac.198119810506>
9. Lohr, A.; Uemura, S.; Würthner, F. *Angew. Chemie* **2009**, *121*, 6281–6284.

- <https://doi.org/10.1002/ange.200902299> .
10. Kay, A. J.; Woolhouse, A. D.; Gainsford, G. J.; Haskell, T. G.; Barnes, T. H.; McKinnie, I. T.; Wyss, C. P. *J. Mater. Chem.* **2001**, *11*, 996–1002.
<https://doi.org/10.1039/b008316j>
 11. Nesterov, V. N.; Shestopalov, A. M.; Sharanin, Y. A.; Aitov, I. A.; Shklover, V. E.; Struchkov, Y. T.; Litvinov, V. P. *Bull. Acad. Sci. USSR Div. Chem. Sci.* **1991**, *40*, 795–800.
<https://doi.org/10.1007/BF00958576>
 12. Würthner, F. *Synthesis* **1999**, *1999*, 2103–2113.
<https://doi.org/10.1055/s-1999-3635>
 13. Henning, H.-G.; Thanh, L. H.; Laue, J.; Urban, B.; Reck, G. *Monatsh. Chem.* **1994**, *125*, 95–105.
<https://doi.org/10.1007/BF00811679>
 14. Barrois, S.; Wörner, S.; Wagenknecht, H.-A. *Photochem. Photobiol. Sci.* **2014**, *13*, 1126.
<https://doi.org/10.1039/C4PP00153B>
 15. Strell, M.; Braunbrück, W. B.; Reithmayr, L. *Justus Liebigs Ann. Chem.* **1954**, *587*, 195–206.
<https://doi.org/10.1002/jlac.19545870303>
 16. Kakehi, A.; Ito, S.; Matsubara, K. *Bull. Chem. Soc. Jpn.* **1995**, *68*, 2409–2415.
<https://doi.org/10.1246/bcsj.68.2409>
 17. Kakehi, A.; Ito, S.; Ohizumi, T.; Maeda, T. *J. Org. Chem.* **1982**, *47*, 369–371.
<https://doi.org/10.1021/Jo00341a042>
 18. Borisova, I. A.; Zubarev, A. A.; Rodinovskaya, L. A.; Shestopalov, A. M. *Arkivoc* **2017**, *iii*, 73–86.
<https://doi.org/10.24820/ark.5550190.p009.908>
 19. Borisova, I. A.; Zubarev, A. A.; Rodinovskaya, L. A.; Shestopalov, A. M. *Russ. Chem. Bull.* **2018**, *67*, 1868–1872.
<https://doi.org/10.1007/s11172-018-2300-7>
 20. Wuerthner, F. *Synthesis*, **1999**, 2103–2113.
<https://doi.org/10.1055/s-1999-3635>
 21. Miao, J.-T.; Wu, X.-Z.; Sun, R.; Song, Y.-L.; Ge, J.-F. *Dyes Pigment.* **2014**, *105*, 41–46.
<https://doi.org/10.1016/j.dyepig.2014.01.014>
 22. Abramenko, P. I.; Zhiryakov, V. G.; Ponomareva, T. K. *Chem. Heterocycl. Compd.* **1976**, *12*, 52–56.
<https://doi.org/10.1007/BF00473913>
 23. Jung, H. S.; Lee, J.-H.; Kim, K.; Koo, S.; Verwilt, P.; Sessler, J. L.; Kang, C.; Kim, J. S. A. *J. Am. Chem. Soc.* **2017**, *139*, 9972–9978.
<https://doi.org/10.1021/Jacs.7b04263>
 24. Ilina, K., & Henary, M. *Chem. Eur. J.* **2021**, *27*(13), 4230–4248.
<https://doi.org/10.1002/chem.202003697>
 25. Senthil, K.; Kalainathan, S.; Ruban Kumar, A. *CrystEngComm* **2014**, *16*, 9847–9856.
<https://doi.org/10.1039/C4CE01350F>
 26. Wróblewski, S.; Trzebiatowska, K.; Jędrzejewska, B.; Pietrzak, M.; Gawinecki, R.; Pączkowski, J. *J. Chem. Soc. Perkin Trans. 2* **1999**, No. 9, 1909–1917.
<https://doi.org/10.1039/a902904d>
 27. Coe, B. J.; Harris, J. A.; Asselberghs, I.; Persoons, A.; Jeffery, J. C.; Rees, L. H.; Gelbrich, T.; Hursthouse, M. B. *J. Chem. Soc. Dalton Trans.* **1999**, 3617–3625.
<https://doi.org/10.1039/a905652a>
 28. Das, P. J.; Das, J. J. *Mol. Liq.* **2015**, *209*, 94–98.

- <https://doi.org/10.1016/J.molliq.2015.05.028>
29. Stanovnik, B.; Tišler, M.; J. Heterocycl. Chem. **1996**, 33, 465-474.
<https://doi.org/10.1002/Jhet.5570330240>
30. Gawinecki, R.; Stanovnik, B.; Valkonen, A.; Kolehmainen, E.; Ośmiałowski, B.; Dobosz, R.; Zakrzewska, A. *Structural Chem.* **2009**, 20, 655-662.
<https://doi.org/10.1007/s11224-009-9457-5>
31. Meerwein, H.; Florian, W.; Schön, N.; & Stopp, G. *Ann. Chem.* **1961**, 641, 1-39.
<https://doi.org/10.1002/Jlac>
32. Henning, H.-G.; Thanh, L. H.; Laue, J.; Urban, B.; Reck, G. *Monatsh. Chem.* **1994**, 125, 95–105.
<https://doi.org/10.1007/BF00811679>
33. Wortmann, R.; Glania, C.; Krämer, P.; Lukaszuk, K.; Matschiner, R.; Twieg, R. J.; & You, F.; *Chem. Phys.* **1999**, 245, 107-120.
[https://doi.org/10.1016/S0301-0104\(99\)00087-7](https://doi.org/10.1016/S0301-0104(99)00087-7)
34. Borisova, I. A.; Zubarev, A. A.; Rodinovskaya, L. A.; Shestopalov, A. M. *Russ. Chem. Bull.* **2018**, 67, 1868–1872.
<https://doi.org/10.1007/s11172-018-2300-7>
35. Hisanao Zenno, *Studies on Cyanine Dyes. V*, YAKUGAKU ZASSHI, **1953**, Volume 73, Issue 3, Pages 301-303, Released on J-STAGE February 19, 2010, Online ISSN 1347-5231, Print ISSN 0031-6903,
https://doi.org/10.1248/yakushi1947.73.3_301

This paper is an open access article distributed under the terms of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>)