*ISSN 1070-3632, Russian Journal of General Chemistry, 2014, Vol. 84, No. 7, pp. 1353–1357. © Pleiades Publishing, Ltd., 2014.*
*Original Russian Text © A.A. Shkel', O.A. Mazhukina, O.V. Fedotova, N.V. Pchelintseva, 2014, published in Zhurnal Obshchei Khimii, 2014, Vol. 84, No. 7, pp. 1158–1162.*

# 3-(1,3-Dioxobutan-1-yl)-2*H*-chromen-2-one in Reactions with Electrophilic and Nucleophilic Reagents

**A. A. Shkel', O. A. Mazhukina, O. V. Fedotova, and N. V. Pchelintseva**

*Institute of Chemistry, Saratov State University, ul. Astrakhanskaya 83, Saratov, 410012 Russia*
*e-mail: ee1402@mail.ru*

Received November 5, 2013

**Abstract**—Reactions of 3-(1,3-dioxobut-1-yl)-2*H*-chromen-2-one with electrophilic (boron trifluoride diethyl etherate and phosphorus pentachloride) and nucleophilic (phosphorus pentasulfide and hydrogen sulfide) compounds have been studied. The reactions proceed mainly with the enol form of the substrate which is more stable both in polar and nonpolar solvents. The substrate ability to undergo aromatization into 4-oxopyranochromolium salts under action of electrophilic reagents and thionation at the oxo groups have been demonstrated. The suggested schemes of heterocyclization have been described. Possibility of in situ competitive formation of the hemiketal at the interaction with hydrogen sulfide in acidic medium has been found.

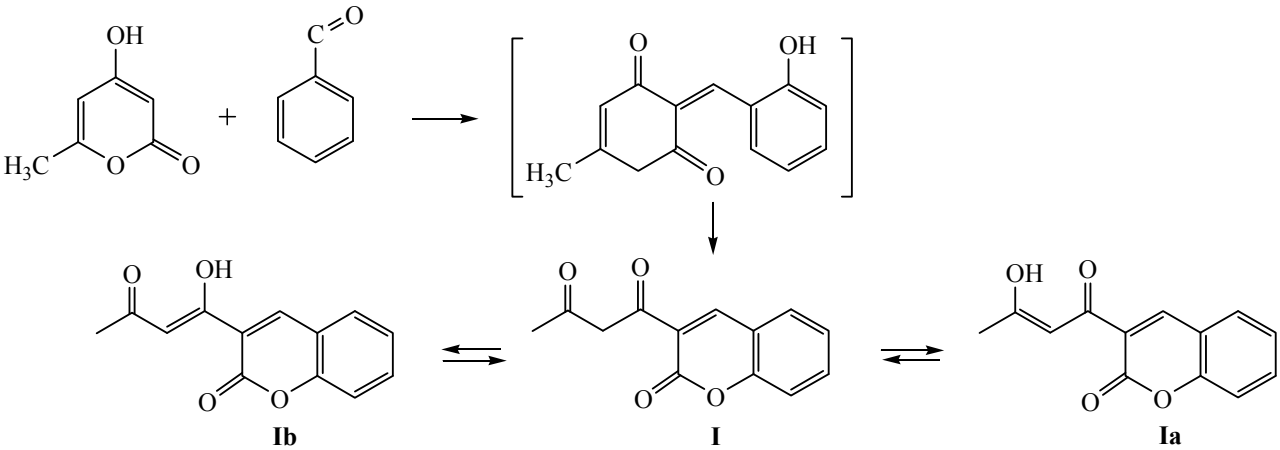
**Keywords:** 4-oxopyranochromilium salt, 4-oxopyranochromene, heterocyclization, keto-enol tautomerism, 2-oxo(thioxo)chromene

**DOI:** 10.1134/S1070363214070172

Previously we studied the interaction of 4-hydroxy-3-(3-oxo-1,3-diaryl)-2*H*-chromen-2-ones containing carbonyl groups of ketone and lactone types with *in situ* generated hydrogen sulfide in acidic medium, the products being 2,4-diaryl-4*H*-thiopyrano[1,2-*c*]-chromen-5-ones [1]. Reactions of 3-substituted 4-hydroxychromen-2-ones with electrophilic agents like boron trifluoride diethyl etherate and phosphorus pentachloride have been scarcely discussed [2], and the described reactions with phosphorus pentasulfide [3] have been limited to synthesis of 2*H*-chromen-2-thiones. In view of that, study of the mentioned reactions of 3-dioxobutanyl-substituted chromen-2-ones is important for understanding the chemistry of such compounds, related to natural flavonoids.

The starting 3-(1,3-dioxobut-1-yl)-2*H*-chromen-2-one **I** was prepared as described elsewhere [4] via the

**Scheme 1.**



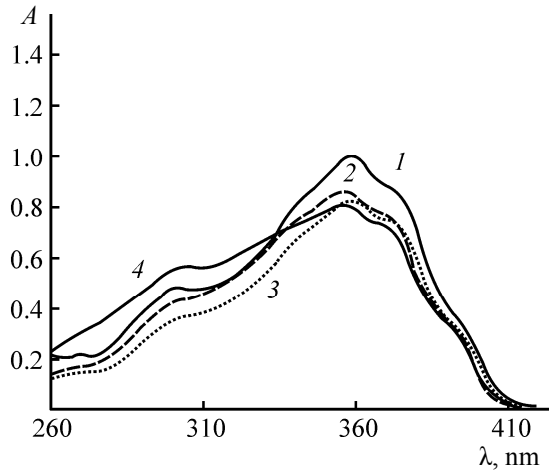



**Fig. 1** UV spectrum of compound **I** in (*1*) tetrachloromethane, (*2*) propan-2-ol, (*3*) acetic acid, and (*4*) ethanol ($c = 5\times10^{-5}$ mol/L).

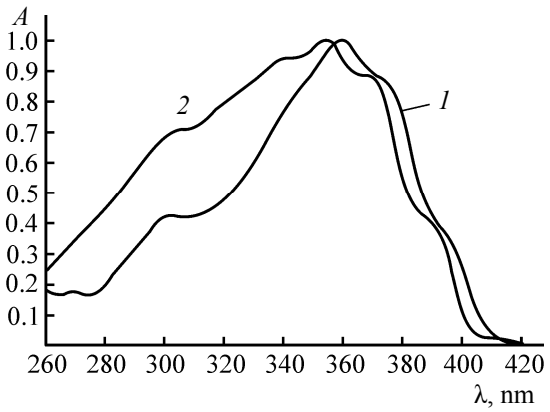



**Fig. 2.** Theoretical UV spectrum of a mixture of tautomeric forms of compound **I**: (*1*) keto form and (*2*) enol form.

condensation of 4-hydroxy-6-methyl-2*H*-pyran-2-one with 2-hydroxybenzaldehyde (Scheme 1).

Basing on UV spectroscopy data (Fig. 1) we found that compound **I** predominantly existed in the enol form in the solvents of various polarity.

Figure 2 demonstrates results of the resolution of spectra; evidently, two tautomeric forms of compound **I** were present: keto (*1*) and enol (*2*) ones. The forms fractions as determined in solvents of various polarity are shown in the Table. The forms fractions were calculated applying the independent components method as implemented in the MILCA algorithm [5, 6].

Existence of compound **I** in the enol form **Ib** in the crystalline state as well as in the solutions in DMSO-$d_6$, $CDCl_3$, and acetone-$d_6$ was confirmed by the HMBC spectroscopy (correlation between methyl protons and carbonyl carbon was found) [7, 8]. At the same time, formation of the hemiketal accompanying enol **Ib** formation was not excluded; we believe that this reaction is possible exclusively via enol **Ia** [7]. Furthermore, 3-(3-amino-1-oxo-2-butenyl)-7-diethylamino-2*H*-chromen-2-one was isolated as a product of reaction of ammonium acetate with chromen-2-one **I** in acetic acid [8], thus proving the higher activity of acetyl carbonyl in that medium. Accounting for the nature of the used media and the ability of compound **I** to form the hemiketal, enol **Ia** was the most likely option. That information was essential for elucidation of mechanism of the transformations of polyoxo compound **I** studied in this work.

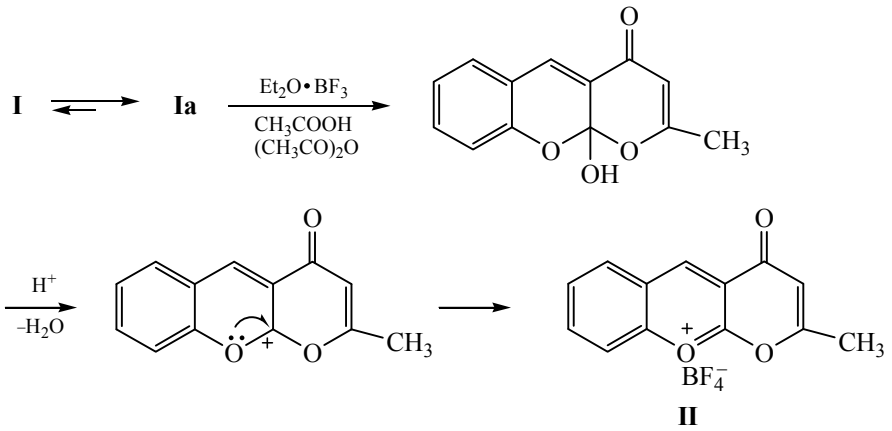
Ratio of the co-existing ketone and enol forms of compound **I**

| Solvent | Forms fraction, % | |
|---|---|---|
| | ketone | enol |
| Ethanol | 44 | 56 |
| Propan-2-ol | 37 | 63 |
| Acetic acid | 22 | 78 |
| Tetrachloromethane | 8 | 92 |

It was demonstrated that 3-substituted 2*H*-chromen-2-one **I** formed a new heterocyclic system in acetic acid medium in the presence of acetic anhydride and boron trifluoride diethyl etherate (aprotic acid) giving 2-methyl-4-oxo-4*H*-pyrano[2,3-*b*]chromen-10-ylium tetrafluoroborate (**II**) in an yield of 76%. The formation of the latter included likely the stage of heterocyclization at the enolized carbonyl of the aliphatic part of the substrate followed by the formation of the hemiketal, the dehydration via the interaction with acetic anhydride, and, finally, the aromatization of the chromene fragment (Scheme 2).

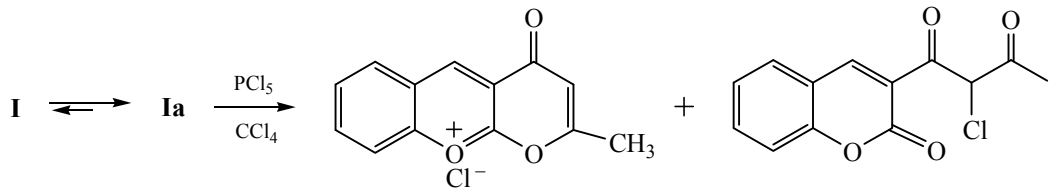
$^1$H NMR spectrum of compound **II** contained, along with the aromatic protons signals (7.26–7.78 ppm), the characteristic signals of the chromylium and the pyran-4-one vinyl fragments: singlets at 9.03 and 6.16 ppm, respectively.

**Scheme 2.**



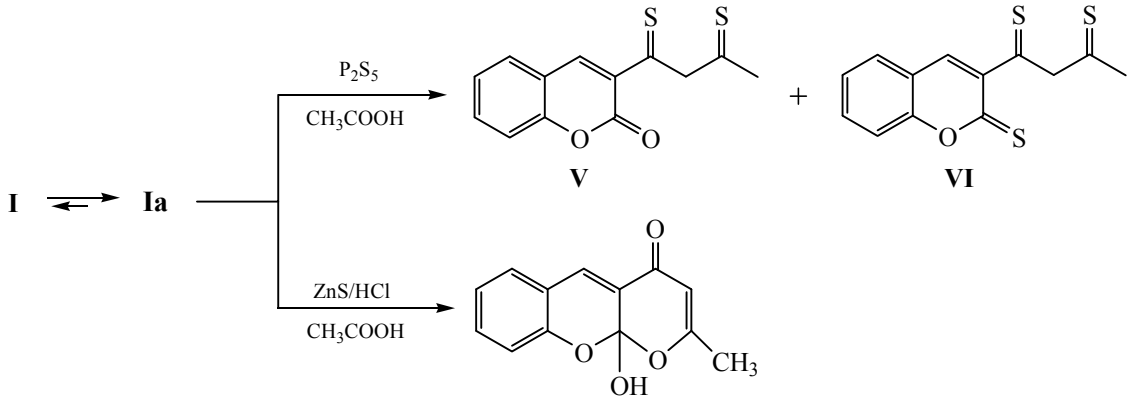

**II**

**Scheme 3.**




**III** **IV**

**Scheme 4.**




**V** **VI**

**VII**

The suggested pathway was additionally confirmed by the reaction of compound **I** with phosphorus pentachloride: along with the formation of 2-methyl-4-oxo-4*H*-pyrano-[2,3-*b*]chromen-10-ylium chloride (**III**) (21%), the characteristic halogen addition at the double bond of the aliphatic enol fragment occurred followed by the hydrogen chloride elimination to yield 2-chloro-1-(2-oxo-2*H*-chromen-3-yl)butan-1,3-dione (**IV**) (46%) (Scheme 3).

IR and $^1$H NMR spectral features of salt **III** were identical to those of its tetrafluoroborate analog **II**. $^1$H NMR spectrum of compound **IV** contained singlets of the methine and vinyl (chromene part) protons at 6.11 and 8.79 ppm, respectively. The aromatic protons multiplet was observed at 7.26–7.78 ppm; the methyl group singlet was found at 2.56 ppm.

Reaction of 2*H*-chromen-2-one **I** with phosphorus pentasulfide in acetic acid gave two products of nucleophilic substitution: at the carbonyl group in the aliphatic fragment [3-(3-thioxobutanthioyl)-2*H*-chromen-2-one (**V**)] and at the less active lactone carbonyl [1-(2-thioxo-2*H*-chromen-3-yl)butan-1,3-dithione (**VI**)] (Scheme 4).

The possibility of the hemiketal formation as an intermediate of substrate **I** electrophilic reactions was further confirmed by isolation of 10a-hydroxy-2-methylpyrano[2,3-*b*]chromen-4(10a*H*)-one (**VII**) as a product (72%) of interaction of **I** with the *in situ* generated hydrogen sulfide (ZnS/HCl) in acetic acid medium. The acidic medium favored formation of the hemiketal, whereas the hydrogen sulfide concentration was likely too low for inducing the nucleophilic substitution at the oxo groups. Preservation of the oxo group at $C^4$ of pyran fragment (in **VII**) and its thionation (in **V** and **VI**) indirectly confirmed participation of **Ia** enol form rather than **Ib** one in all discussed reactions.

In $^1$H NMR spectrum of compound **V** the signal of vinyl proton appeared in the range of aromatic protons signals (6.93–7.95 ppm), whereas in the case of compound **VI** this proton was found at 9.04 ppm. Singlet signals of $CH_2$ groups were observed at 4.22 (**V**) and 3.89 (**VI**) ppm; the aromatic protons multiplet was detected at 7.26–7.95 ppm in the case of compound **VI**.

$^1$H NMR spectrum of compound **VII** contained the following signals: singlets of two vinyl protons (5.92 and 8.66 ppm), singlet of methyl protons (1.88 ppm), broadened singlet of hydroxy group (2.35 ppm), and multiplet of aromatic protons (7.03–7.66 ppm).

To conclude, this work is the first to demonstrate that the 3-substituted chromen-2-one **I** can undergo heterocyclization into new condensed systems (including the previously unknown pyranochromylium salts) via enol form **Ia** or nucleophilic thionation at the oxo groups, depending on the reagents nature.

## EXPERIMENTAL

Elemental analysis was performed using the Elementar Vario Micro Cube analyzer. IR spectra (KBr) were recorded with the FSM 1201 Fourier spectrometer. $^1$H NMR spectra were obtained using the Varian 400 spectrometer (400 MHz, 25°C, TMS as internal reference). The reactions course and the products purity were monitored by TLC (Silufol UV-254 plates, hexane–diethyl ether–acetone 3 : 1 : 1 or hexane–ethyl acetate–acetone 2 : 2 : 1 as eluent, iodine vapor as developer). Electronic spectra of the studied solutions were registered with the Shimadzu-1800 spectrophotometer (optical path of 1 cm, scanning step of 1 nm, $c = 5\times10^{-5}$ mol/L). The solvents and the chemicals used were of "specially pure" grade.

**2-Methyl-4-oxo-4*H*-pyrano-[2,3-*b*]chromen-10-ylium tetrafluoroborate (II).** 1 g (2.4 mmol) of 3-(1,3-dioxobutan-1-yl)-2*H*-chromen-2-one (**I**) and then 0.34 mL (2.4 mmol) of boron trifluoride diethyl etherate were added to a mixture of 30 mL of glacial acetic acid and 10 mL of acetic anhydride at heating; the reaction mixture was refluxed during 5 h. The crystals precipitated upon cooling were filtered off and washed with diisopropyl ether. Yield 0.55 g (76%), mp 280–282°C. IR spectrum, ν, cm$^{-1}$: 1680 (C=O), 1068 ($BF_4^-$). $^1$H NMR spectrum ($CDCl_3$), δ, ppm: 9.03 s (1H, CH), 6.16 s (1H, =CH), 2.60 s (3H, $CH_3$), 7.26–7.78 m (4H, Ar). Found, %: C 52.24; H 3.50. $C_{13}H_9BF_4O_3$. Calculated, %: C 52.04; H 3.02.

**2-Methyl-4-oxo-4*H*-pyrano[2,3-*b*]chromen-10-ylium chloride (III) and 2-chloro-1-(2-oxo-2*H*-chromen-3-yl)butan-1,3-dione (IV).** 0.6 g (2.6 mmol) of compound **I** was dissolved in 20 mL of tetrachloromethane at heating, 0.54 g (2.6 mmol) of phosphorus pentachloride was then added, and the reaction mixture was refluxed during 1 h. The solvent was evaporated, and the mixture of crystalline compounds **III** and **IV** was washed with acetone. The insoluble part (crystals of compound **IV**) was dried in a vacuum. Yield 0.32 g (46%) of compound **IV**, mp. 145–147°C. IR spectrum, ν, cm$^{-1}$: 1724 (C=O, lactone), 1670 (C=O), 756 (C–Cl). $^1$H NMR spectrum ($CDCl_3$), δ, ppm: 8.79 s (1H, =CH), 6.11 s (1H, CH), 2.56 s (3H, $CH_3$), 7.26–7.78 m (4H, Ar). Found, %: C 59.37; H 3.77; Cl 12.93. $C_{13}H_9ClO_4$. Calculated, %: C 59.00; H 3.43; Cl 13.40.

Acetone evaporation from the solution yielded 0.13 g (21%) of compound **III**, mp. 269–270°C. IR spectrum, ν, cm$^{-1}$: 1680 (C=O). $^1$H NMR spectrum (DMSO-$d_6$), δ, ppm: 9.03 s (1H, CH), 6.26 s (1H, =CH), 2.66 s (3H, $CH_3$), 7.36–7.87 m (4H, Ar). Found, %: C 62.93; H 3.72; Cl 14.21. $C_{13}H_9ClO_3$. Calculated, %: C 62.79; H 3.65; Cl 14.26.

**3-(3-Thioxobutanthioyl)-2*H*-chromen-2-one (V) and 1-(2-thioxo-2*H*-chromen-3-yl)butan-1,3-dithione (VI).** A mixture of 1 g (4.3 mmol) of compound **I** and 20 mL of xylene was stirred at 70–80°C and cooled to 20–30°C; 0.96 g (4.3 mmol) of phosphorus pentasulfide was then added. The mixture was heated to 60–70°C. The precipitate was separated, and the solvent was evaporated from the filtrate. Yield 0.30 g (25%) of compound **VI**, mp 283–284°C. IR spectrum, ν, cm$^{-1}$: 1187 (C=S). $^1$H NMR spectrum ($CDCl_3$), δ, ppm: 3.89 s (1H, $CH_2$), 9.04 s (1H, =CH),

2.01 s (3H, $CH_3$), 7.26–7.95 m (4H, Ar; 1H, =CH). Found, %: C 56.13; H 3.67; S 34.16. $C_{13}H_{10}OS_3$. Calculated, %: C 56.08; H 3.62; S 34.55.

The precipitate was treated with chloroform, and the extract was evaporated to isolate 0.36 g (32%) of compound **V**, mp 164–165°C. IR spectrum, ν, $cm^{-1}$: (C=O, lactone), 1181 (C=S). $^1H$ NMR spectrum ($CDCl_3$), δ, ppm: 4.22 s (1H, $CH_2$), 2.20 s (3H, $CH_3$), 6.93–7.95 м (4H, Ar; 1H, =CH). Found, %: C 59.93; H 3.95; S 24.86. $C_{13}H_{10}O_2S_2$. Calculated, %: C 59.52; H 3.84; S 24.45.

**10a-Hydroxy-2-methylpyrano[2,3-*b*]chromen-4(10a*H*)-one (VII).** A mixture of 1 g (4.3 mmol) of compound **I** and 0.42 g (4.3 mmol) of zinc sulfide was added to 10 mL of acetic anhydride and 20 mL of glacial acetic acid, and the mixture was stirred at 70–80°C till the reagents dissolution. After that, the mixture was cooled to 20–30°C, and 6 mL (0.2 mmol) of hydrogen chloride ($d$ = 1.19 mg/mL) was added. The mixture was stirred during 72 h. The inorganic precipitate was separated, and the filtrate was diluted with water. The formed precipitate was filtered off and washed with water till neutral pH. Yield 0.73 g (72%), mp 169–170°C. IR spectrum, ν, $cm^{-1}$: 1716 (C=O, lactone). $^1H$ NMR spectrum ($CDCl_3$), δ, ppm: 5.92 s (1H, =CH), 8.66 s (1H, $COCHCCH_3$), 1.88 s (3H, $CH_3$), 7.03–7.66 m (4H, Ar), 2.35 s (1H, OH). Found, %: C 67.91; H 4.33. $C_{13}H_{10}O_4$. Calculated, %: C 67.82; H 4.38.

## REFERENCES


1. Shkel', A.A., Mazhukina, O.A., and Fedotova, O.V., *Chem. Heterocycl. Comp*., 2011, vol. 47, no. 5, p. 656. DOI: 10.1007/s10593-011-0816-y.
2. Shkel, A.A., Mazhukina, O.A., and Fedotova, O.V., *Am. Chem. Sci. J.,* 2013, vol. 3, no. 3, p. 356.
3. Kovalenko, S.M., Vlasov, S.V., Silin, O.V., and Chernykh, V.P., *J. Sulfur Chem*., 2009, vol. 30, no. 1, p. 53. DOI: 10.1080/ 17415990802455795.
4. March, P., Moreno-Manas, M., and Roca, J.L., *J. Heterocyclic. Chem*., 1984, vol. 21, no. 5, p. 1371. DOI: 10.1002/jhet. 5570210525.
5. Monakhova, Yu.B., Astakhov, S.A., and Mushtakova, S.P., *Russ. J. Anal. Chem*., 2009, vol. 64, no. 5, p. 479. DOI: 10.1134/S1061934809050098.
6. Mazhukina, O.A., Monakhova, Yu.B., Kolesnikova, S.S., Fedotova, O.V., and Mushtakova, S.P., *J. Mater. Sci. Eng.,* 2012, vol. 2, no. 10B, p. 505.
7. Xiang-Shan, W., Zhao-Sen, Z., Mei-Mei, Z., Da-Qing, S., and Shu-Jiang, T., *J. Chem. Res*., 2006, no. 9, p. 602.
8. Svetlik, J., Pranayova, N., and Hanus, V., *J. Heterocyclic Chem*., 2000, vol. 37, p. 395. DOI: 10.1002/ jhet.5570370227.