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SYNTHESIS AND FLUORESCENCE OF 6-(4-DIMETHYLAMINOPHENYL)- AND 6-[2-(4-*N,N*-DISUBSTITUTED AMINOPHENYL)VINYL]-4-METHYLTHIO-2-OXO-2*H*-PYRAN-3-CARBONITRILES IN SOLUTION AND IN THE SOLID STATES

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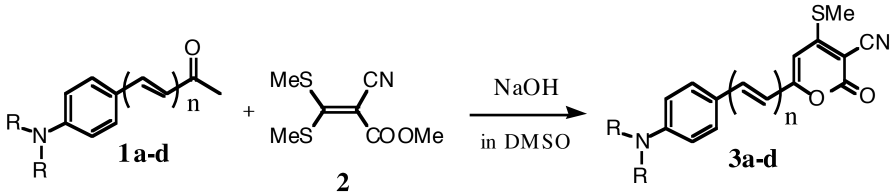
Abstract—Fluorescent dyes, 6-(4-dimethylaminophenyl)-4-methylthio- and 6-[2-(4-*N,N*-disubstituted aminophenyl)vinyl]-4-methylthio-2-oxo-2*H*-pyran-3-carbonitriles (**3a-d**) were synthesized by the reaction of 4-dimethylaminoacetophenone (**1a**) and 4-aminobenzalacetone derivatives (**1b-d**) with ketene dithioacetal (**2**) in the presence of sodium hydroxide in dimethylsulfoxide at room temperature. These 2-pyrone derivatives (**3a-d**) showed orange and red fluoresecence ($F_{\max}$: 607, 699, 705, 645 nm) in dichloromethane solution. The preparation and fluorescence 4-amino-2*H*-pyrone derivatives is also described.

Fluorecent dyes which show fluorescence in the solid state are useful as materials such as emitters for electro-luminescence (EL) devices for use in various fields.[1] Several 4*H*-pyran derivatives, for instance 4-(dicyanomethylene)-2-methyl-6-(4-dimethylaminostyryl)-4*H*-pyran (DCM), are interesting organic EL compounds.[2] This suggests that 2*H*-pyrans might also have useful EL, and may be red colored, one of the most important in the field of EL chemistry. Komatsu *et al.* reported fluorescence for 3,4,6-triphenyl-2-pyrone derivatives in which the phenyl group at position 6 is important for fluorescent expression.[3] Here, interest was first directed at 6-(4-dimethylaminophenyl)-2*H*-pyran-2-one (**3a**), which showed interesting fluorescence in the solid state, and it was hoped that 6-styryl-2*H*-pyran-2-ones (**3b-d**) would have superior red fluorescence. Fluorescence was not detected in the 2-pyrone derivatives due to the vulnerability of the fluorescence in solution as noted in previous study.[4] The synthesis and fluorescent properties of the novel functional fluorophores, 6-(4-dimethylaminophenyl)-4-methylthio- and 6-[2-(4-*N,N*-disubstituted aminophenyl)vinyl]-4-methylthio-2-oxo-2*H*-pyran-3-carbonitriles are reported here. The reaction of 4-dimethylaminoacetophenone (**1a**) with 2-cyano-3,3-bis(methylthio)acrylonitrile (**2**) was carried out in the presence of sodium hydroxide to give the desired product, 6-(4-dimethylaminophenyl)-4-methylthio-2-oxo-2*H*-pyran-

3-carbonitrile (**3a**)[6] in 43% yield, as described in Scheme 1. Benzalacetone derivatives, 4-(*N,N*-disubstituted aminophenyl)but-3-en-2-ones (**1b-d**), also reacted with **2** in a manner similar to that described for the preparation of **3a** giving the corresponding 6-[2-(4-*N,N*-disubstituted aminophenyl)vinyl]-4-methylthio-2-oxo-2*H*-pyran-3-carbonitriles (**3b-d**)[7-9] in 32, 26, and 29% yields, respectively.

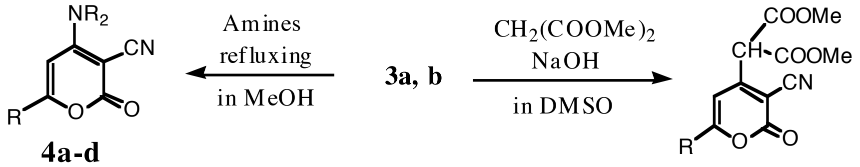


a: n=0, R=Me
b: n=1, R=Me
c: n=1, R=Et
d: n=1, R=Ph

a: n=0, R=Me
b: n=1, R=Me
c: n=1, R=Et
d: n=1, R=Ph

Scheme 1

4-Methylthio-2-oxo-2*H*-pyran-3-carbonitriles are very useful in the synthesis of 4-substituted 2*H*-pyran-2-ones and showed the activity toward amino compounds or active methylene compounds. The 4-amino-2-oxo-2*H*-pyrane-3-carbonitriles (**4a-d**)[10] were prepared in 24-64% yields by the reaction of **3a, b** with amines (dimethylamine, pyrrolidine, and morpholine) in refluxing methanol. The reaction of **3a, b** with dimethyl malonate in the presence of potassium carbonate in DMSO gave the corresponding desired products (**5a, b**)[10] in 77 and 84% yields, respectively.



4a-d

a: R=C_6H_4-NMe_2(4), NR_2=dimethylamino, Yield=64%
b: R=C_6H_4-NMe_2(4), NR_2=pyrrolidino, Yield=44%
c: R=C_6H_4-NMe_2(4), NR_2=morpholino, Yield=50%
d: R=CH=CH-C_6H_4-NMe_2(4), NR_2=morpholino, Yield=24%

5a, b

a: R=C_6H_4-NMe_2(4), Yield=77%
b: R=CH=CH-C_6H_4-NMe_2(4), Yield=84%

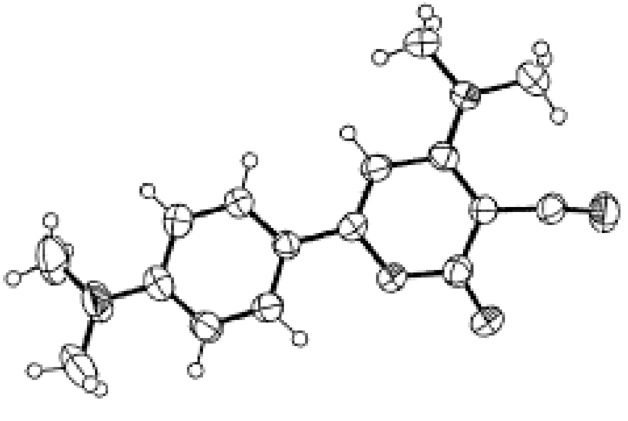
Scheme 2

DMC and AlQ_3[tris(8-hydroxyquinolinato)aluminum] were used as standards for absorption and fluorescence spectra. The measurements of both absorption and fluorescence spectra was carried out in dichloromethane solution at room temperature. The spectroscopic properties, absorption maxima (λ_{max}), molar absorptivities (ε), fluorescence maxima(Em_{max}), and relative fluorescent intensities (RI) are listed in Table 1. The aryl and styryl bearing *N,N*-disubstituted amino group at the position 6 of the 2-pyrone derivatives fulfils the important effect of fluorescent expression, and are much simpler to prepared than compounds produced following Komatsu's procedure.[3] Compounds (**3a-d**) showed longer wavelength shifts in comparison with the most basic 2-pyrone, 6-phenyl-4-methylthio-2-oxo-2*H*-pyran.[11] However, their relative fluorescence intensities have a tendency to decrease, while the ε values increases in the absorption spectra. On the other hand, 4-substituted compounds (**5a, b**) showed only a small bathochromic shift and fluorescence as compared to **3a** and **b**. In comparison with the 4-methylthio compounds (**3a, b**), the 4-amino compounds (**4a-d**) demonstrate hypsochromic shifts of the λmax and ε value in the absorption spectra. The fluorescent properties of these 2-pyrone derivatives show a dependence on solvent polarity. For example, the emission of **3a** (541 nm), **3b** (625 nm) and **4a** (515 nm) in ethanol shifts to longer wavelength with an increase in the polarity of the solvent. This behavior is indicative of polar character in the exited state, presumably associated with a contribution from the betaine form. Fluorescence in the solid state is very important for functional fluorescent materials. The fluorescence of these 2-pyrone derivatives in the solid state was not particularly strong except for **4a-c**. However, even compounds (**3a**, **b**, **5a**, and **b)** showed stronger fluorescence than DCM, which has a typical red-orange fluorescence in the solid state. The ΔF value, indicating the difference in Em from solid state to solution, varied widely from 25 nm for dye (**3d)** to 109 nm for dye (**4c)**. Only dye (**5b)** demonstrated a negative ΔF. The dimethylamino group at position 6 and the dimethylamino group at position 4 are almost plane due to their small torsion angles (15°). This phenomenon has caused strong molecular stacking which is one of the causes of solid state fluorescence from result of the X-Ray crystallographic analysis (See ORTEP Representation and Molecular Paking Diagram of **4a** showing in Figures 1 and 2).[10] The molecular packing diagram of **4a** clearly displays short intermolecular distances as shown in Figure 2. The interplane distance between molecules is ca 3.12 Å.

Table 1. UV and fluorescence spectra of 6-aryl- and 6-vinyl-2*H*-pyran-2-ones in solution and in the solid states

No.	Mp ℃	λmax (log ε)[a] nm	Ex (nm) (CH_2Cl_2)	Em (nm) CH_2Cl_2	SS[b]	RI[c]	Ex (nm) Solid	Em (nm) Solid	ΔF[d]	RI[e]
3a	249-251	465 (4.72)	466	531	66	8.54	301	607	76	0.15
3b	280-284	513 (4.67)	541	610	97	2.36	300	699	89	0.01>
3c	187-190	529 (4.69)	554	612	83	0.93	346	705	93	0.01>
3d	210-216	498 (3.78)	573	620	122	0.01>	349	645	25	0.01>
4a	265-267	399 (4.57)	391	465	93	5.57	294	517	32	9.90
4b	270-271	395 (4.60)	391	464	73	7.9	373	537	57	3.86
4c	272-274	412 (4.68)	407	497	85	2.69	322	606	109	1.08
4d	245-255	459 (4.58)	460	582	122	0.69	300	645	63	0.10
5a	194-198	484 (4.78)	493	542	58	4.95	296	610	68	0.70
5b	200-202	528 (4.47)	570	629	101	0.63	558	620	-9	0.40
DCM	217-219	466 (4.63)	480	577	111	1	342	645	68	0.01

[a] Measurement in CH_2Cl_2.
[b] Stoke's Shift, Em-Ex in solution.
[c] Relative intensity of fluorescence in the solution, using DCM as a standard compound.
[d] ΔF=Em(solid)-Em(solution).
[e] Relative intensity of fluorescence in the solid states, using AlQ_3 as a standard compound.



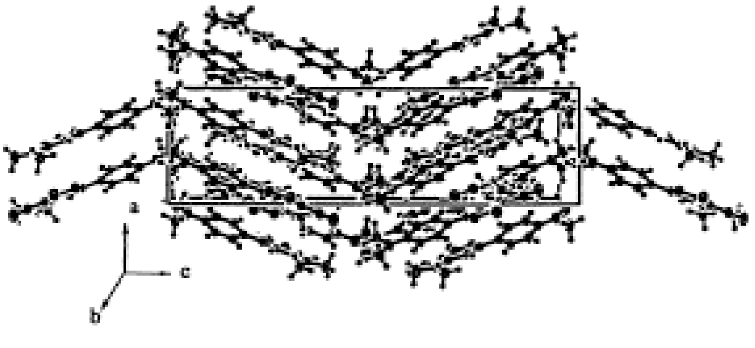


Figure 1. ORTEP of Asymmeteric Unit of 4a. **Figure 2. Molecular Packing Diadram of 4a.**

In conclusion, 6-aryl- and 6-styryl-2-oxo-2*H*-pyran-3-carbonitriles are valuable as new fluorescent chromophores having large ε_{max} values and long wavelength absorption and emission. The presence of an amino group at the *para*-position of the aryl group shifts the emission to longer wavelength. The 2-pyrone derivatives bearing an electron-donating group at the 4-position and an electron-withdrawing group at the 3-position of the 2-pyrone fluoresce in solution and in the solid state.

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5. **3a**: red prisms (MeOH-toluene). ^{1}H-NMR ($CDCl_3$)δ□2.66 (3H, s, SMe), 3.11 (6H, s, 2xNMe_2), 6.47 (1H, s, 5-H), 6.69(2H, d, *J*=9.0 Hz, 3', 4'-H), 7.75 (2H, d, *J*=9.0 Hz, 2', 6'-H).
6. **3b**: black violet leaflets(MeOH-toluene). ^{1}H-NMR($CDCl_3$) δ: 2.65(3H, s, SMe), 3.10(6H, s, 2xNMe_2), 12(1H, s, 6-H), 6.44 (1H, d, *J*=15.7 Hz, =CH), 6.72 (2H, *J*=9.1 Hz, 3', 5'-H), 7.48 (2H, d, *J*=9.1 Hz, 2', 6'-H), 7.68 (2H, d, *J*=15.7 Hz, =CH).
7. **3c**: black violet leaflets (MeOH-toluene). ^{1}H-NMR($CDCl_3$) δ: 1.21(6H, t, *J*=7.1 Hz, N-CH_2-$\underline{CH_3}$), 2.61(3H, s, SMe), 3.43 (4H, q , *J*=7.1 Hz, N-CH_2-), 6.07 (1H, s, 5-H), 6.37(1H, d, *J*=15.7 Hz, =CH), 6.65 (2H, d, *J*=9.1 Hz, 3', 5'-H), 7.42(2H, d, *J*=9.1 Hz, 2', 6'-H), 7.63 (1H, d, *J*=15.7 Hz, =CH).
8. **3d**: red brown leaflets (MeOH-toluene). ^{1}H-NMR($CDCl_3$) δ: 2.62(3H, s, SMe), 6.18(1H, s, 5-H), 6.48(1H, d, *J*=15.1 Hz, =CH), 6.75-7.40 (14H, m, phenyl-H), 7.61(1H, d, *J*=15.1 Hz, =CH).
9. **4a:** lemon yellow needles (MeOH). **4b**: lemon yellow needles (MeOH). **4c**: yellow needles (MeOH). **4d**: orange needles (MeOH). **5a**: orange needles (MeOH). **5b**: red needles (MeOH).
10. Crystal data of **4a**: lemon yellow needles ($C_{16}H_{17}N_3O_2$=283.33, 0.40 x 0.12 x 0.08 mm^3), orthorhombic, space group= $P2_12_12_1$, Z=8, a=7.5938 Å, b=14.0254 Å, c=27.4606 Å, V=2924.72 $Å^3$, $D_{(calcd)}$=1.28g/cm^3, μ(Mo-Kα)=0.90 cm^{-1}, F(000)=1200, Reflection=11603, Residuals=0.044(R1), 0.106(wR2).
11. In the 6-phenyl-2-pyrone derivatives, the fluorescent intensity in which the derivatives on the phenyl group with an electron donating group is stronger than other compounds was clarified.
12. These 2-oxo-2*H*-pyran-3-carbonitriles (**3a-d, 4a-d**) can use as a fluorescence reagent in an oxalate chemiluminscence system.