HETEROCYCLES, Vol. 78, No. 3, 2009, pp. 555 - 570. © The Japan Institute of Heterocyclic Chemistry
Received, 3rd September, 2008, Accepted, 4th November, 2008, Published online, 5th November, 2008
DOI: 10.3987/REV-08-642

DEVELOPMENT OF FLUORESCENT 2-PYRONE DERIVATIVES USING KETENE DITHIOACETALS FOR ORGANIC EL DEVICES

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Abstract – In recent years, organic electro luminescent (EL) materials have received considerable attention due to their potential application in next-generation display devices with high brightness levels, wide color ranges, and wide viewing angles. Fluorescent 2-pyrone derivatives have been synthesized using a convenient method involving ketene dithioacetals, which emit fluorescence (red, green, and blue) in both solution (dichloromethane and ethanol) and solid state. The structure-activity relationships of various 2-pyrone derivatives have been clarified.

1. INTRODUCTION

Pigment chemistry such as that of mauveine pigments from the United Kingdom and indigo pigments from Germany has contributed to modern chemistry.[1–4] Many heterocycles are examples of pigment compounds. The design of pigment compounds has become easier with the development of computational chemistry; however, not all compounds can be designed theoretically since practical and experimental pigment compounds possess large molecules.[5,6] Since pigment chemistry obviously involves the π electron system, it is important that the chemical structure should include a functional group such as a chromophore or auxochrome. In particular, utilizing the properties of hetero atoms such as nitrogen, oxygen, and sulfur is critical in the design of pigments with various functionalities.[2]

Recently, the properties of pigment compounds have been used to create materials with new functions, including information storage, display of information, and energy conversion, for devices that act in response to light, heat, pressure, and electric fields.[7–11] 4-(Dicyanomethylene)-2-methyl-6-(*p*-dimethylaminostyryl)-4*H*-pyran (DCM), a red laser dye, has the capability of enhancing luminous efficiency in electro luminescence (EL) and controlling the light spectrum by expressing the property of a small amount of dopant molecule that exhibits a high fluorescence quantum yield.[12] From the synthesis of heterocycles using ketene dithioacetals, we found that fluorescent 2-pyrone derivatives had remarkably similar properties to those of DCM. These compounds developed our interest in the organic EL materials. Herein, we describe our studies on the synthesis of organic EL materials expected to be used as next-generation display devices that will replace the widely used liquid crystal displays.

2. SYNTHESIS OF 4-METHYLSULFANYL-2-PYRONE DERIVATIVES

Ketene dithioacetals are readily prepared by the condensation of active methylene compounds with carbon disulfide in the presence of a base, followed by alkylation with suitable alkylating reagents. They are very important electrophilic reagents used in the synthesis of heterocycles having various substituents.

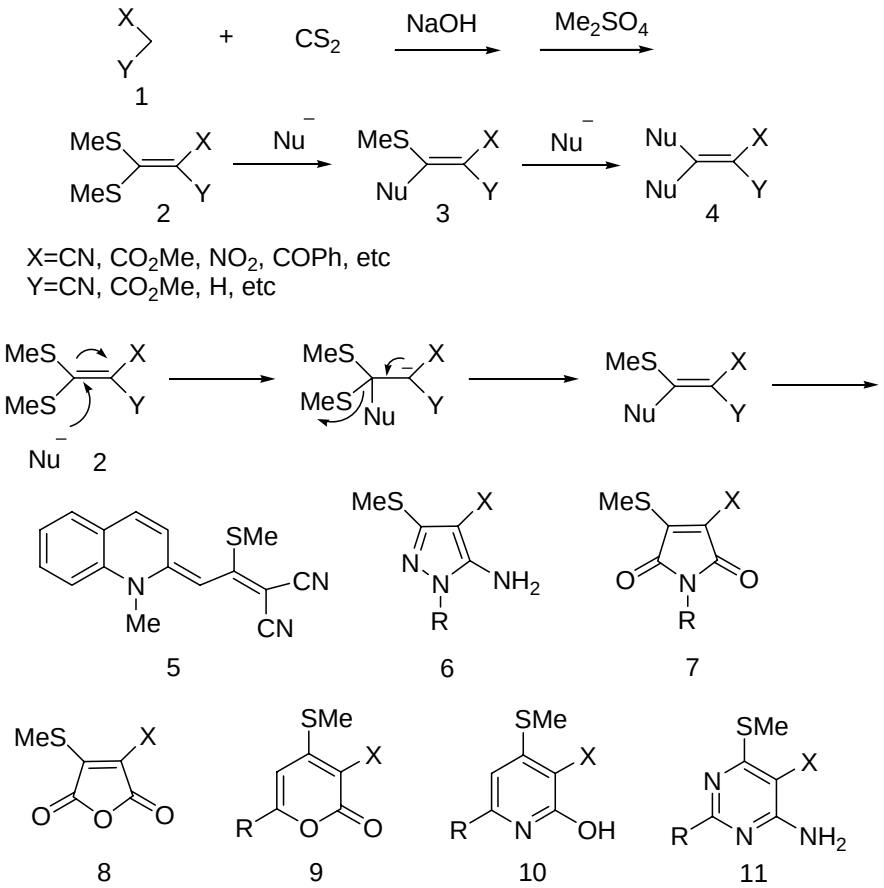
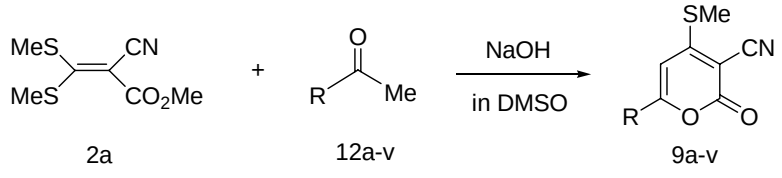


Figure 1. Ketene dithioacetals and heterocycles synthesized from ketene dithioacetals

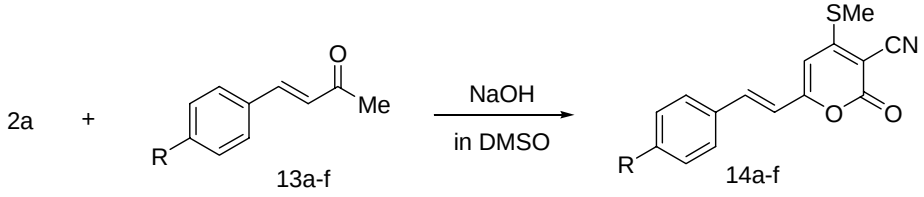
Since 1962, research on the use of this reagent in the synthesis of heterocyclic compounds has been greatly advanced by R. Gompper *et al.* in Germany and our group. As shown in Figure 1, these reactions proceed *via* an addition-elimination mechanism, which is initiated by a nucleophilic addition at the sp^2 sulfur-substituted carbon atom of ketene dithioacetal, followed by an elimination of the methylsulfanyl group to complete the substitution reaction. Further, the same substitution reaction occurs at the other methylsulfanyl group and produces various derivatives. Therefore, ketene dithioacetals enable the introduction of various functional groups. In particular, chromophores and auxochromes can be introduced into the pigment molecules.[13–19]

On the basis of the initial research on ketene dithioacetals, it has been suggested that their skeletons are significant in the construction of dye molecules such as merocyanine dyes and the styryl series. We began our studies on the synthesis of materials for information storage with absorption in the near infrared and luminol type chemical luminescence reagents as high-sensitive analytical reagents of enzymes and reactive oxygen. This research finding triggered the development of fluorescence 2*H*-pyrone derivatives.[20–26]



2a 12a-v 9a-v

R	Yield(%)	R	Yield(%)
9a: Me	50	l: C_6H_4-Cl(4)	44
b: C_6H_5	61	m: C_6H_4-Cl(2)	65
c: C_6H_4-OMe(4)	64	n: C_6H_4-Ph(4)	88
d: C_6H_4-OMe(2)	58	o: C_6H_4-CN(4)	66
e: C_6H_4-OMe(3)	53	p: 1-naphthyl	63
f: C_6H_3-$(OMe)_2$(3,4)	40	q: 2-naphthyl	75
g: C_6H_3-$(OMe)_2$(2,4)	33	r: 3-pyridyl	58
h: C_6H_3-$(OMe)_2$(2,5)	27	s: 2-thienyl	68
i: C_6H_2-$(OMe)_3$(3,4,5)	56	t: 2-benzothienyl	84
j: C_6H_4-NMe_2(4)	85	u: 2-furyl	30
k: C_6H_4-Br(4)	42	v: 2-furyl-Me(5)	44

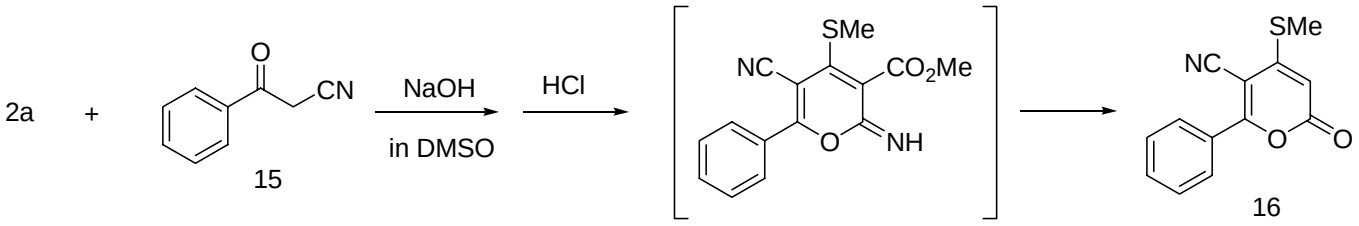


13a-f 14a-f

R	Yield(%)
14a: H	35
b: OMe	43
c: Cl	45
d: NMe_2	32
e: NEt_2	26
f: NPh_2	29

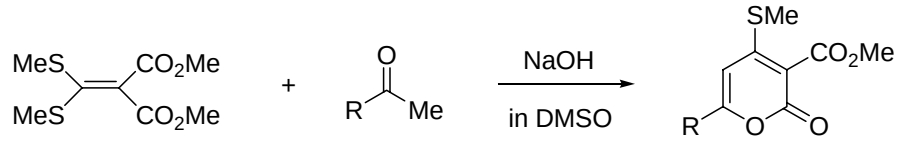
Scheme 1

The arrangement of suitable chromophores and auxochromes within the molecules both in the solution and solid states is necessary to confer fluorescent properties to a compound. In this respect, heterocycles synthesized using ketene dithioacetals have good substituents show fluorescence, due to ketene dithioacetals having strong electro-donating groups such as a methylsulfanyl group and strong electro-withdrawing groups such as cyano and ester groups. Therefore, many fluorescent materials are expected to be included under the category of heterocycles that we have previously synthesized. While in search of a solid fluorescent material, we found that 2*H*-pyrone derivatives exhibit strong fluorescence; this was first reported in 1977.[27] A variety of pyrone derivatives were obtained *via* the reactions of various active methylene compounds with ketene dithioacetals; however, not all these derivatives were found to be fluorescent compounds. Our research suggests that the substitution of an aryl group without electro-withdrawing group such as a phenyl group at position 6 and not position 5 of the pyrone ring was important for fluorescence to occur. For example, 6-methyl- (**9a)**, 6-(4-cyanophenyl)- (**9o**), 5-cyano- (**16)**, and 6-pyrid-3-yl-2*H*-pyrone (**9r)** do not show fluorescence (Schemes 1 and 2).



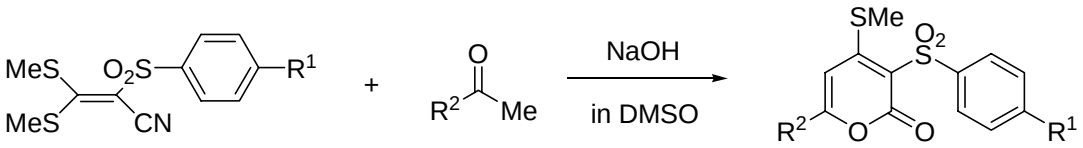
Scheme 2

In a similar manner to **9** and **14**, methyl ester compounds (**17a**–**m**) were synthesized *via* the reactions between arylacetyl compounds and ketene dithioacetal (**2b**), which was prepared from methyl malonate (**12**) (Scheme 3). In addition, reactions of methyl ketones with sulfonyl ketene dithioacetal (**2c**, **d**) afforded 3-phenylsulfonyl derivatives (**18a**−**d**) (Scheme 4).[28]



R	Yield(%)	R	Yield(%)
17a: C_6H_5	32	h: 2-pyridyl	48
b: C_6H_4-Br(4)	59	i: 1-methylpyrrol-2-yl	7
c: C_6H_4-OMe(4)	39	j: 2-thienyl	42
d: C_6H_3-$(OMe)_2$(3,4)	23	k: 2-furyl	25
e: C_6H_3-O-CH_2-O(3,4)	37	l: 4-MeO-C_6H_4-HC=CH-	15
f: C_6H_2-$(OMe)_3$(3,4,5)	41	m: 3,4-O-CH_2-O-C_6H_3-CH=CH-	17
g: 3-pyridyl	34		

Scheme 3



2c, d

12b, 12c

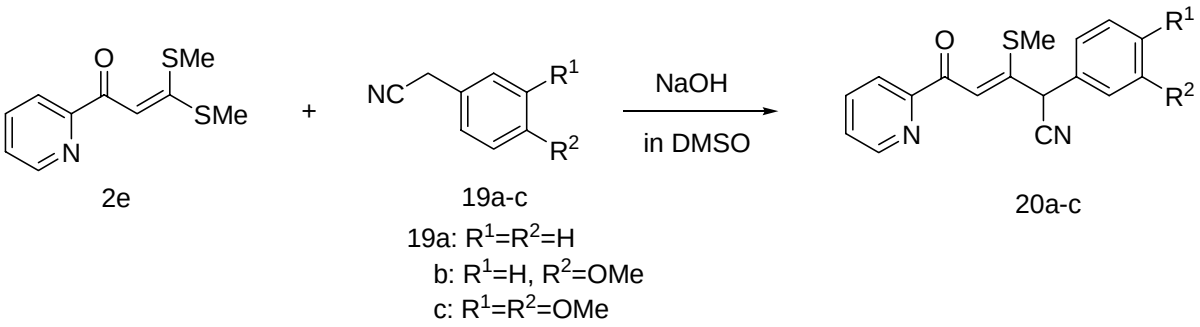
18a-d

2c: R^1=H
d: R^1=Me

	R^1	R^2	Yield(%)
18a:	H	C_6H_5	61
b:	H	C_6H_4-OMe(4)	58
c:	Me	C_6H_5	64
d:	Me	C_6H_4-OMe(4)	58

Scheme 4

The introduction of electro-withdrawing groups such as cyano, ester, and sulfonyl groups at position 3 of the pyrone ring was necessary for fluorescence to occur in 2-pyrone derivatives. The introduction of electron-rich aromatic compounds at position 6 of the pyrone ring increased the intensity of fluorescence. In the case of derivatives in which electron-poor compounds were introduced, such as pyridine or 4-cyanophenyl derivative (**9o**), no fluorescence emission was observed.[29] However, 6-pyridyl-3-phenyl-4-sulfanyl-2-pyrone derivatives (**21a**–**c**), especially 3′,4′-dimethoxyphenyl derivative (**21c**), exhibit strong fluorescence (Scheme 5).[30] These results suggest that derivatives with an electron-rich group and an electron-poor group at either position 3 or 6 of the pyrone ring, respectively, exhibit fluorescence. Compounds **21a**–**c** were obtained *via* the reactions of phenylacetonitrile (**19a**–**c**) with the ketene dithioacetal (**2e**) in the presence of sodium hydroxide as a base in DMSO followed by neutralization with hydrochloric acid.

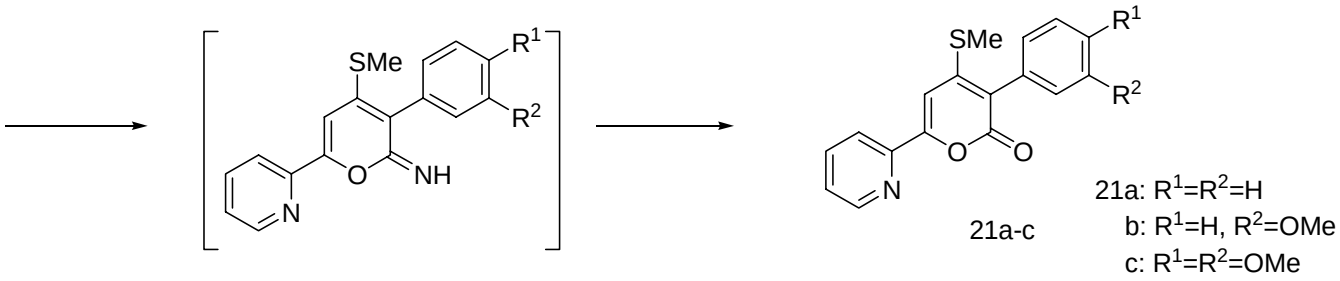


2e

19a-c

19a: R^1=R^2=H
b: R^1=H, R^2=OMe
c: R^1=R^2=OMe

20a-c



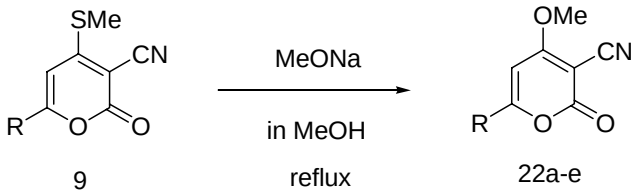
21a-c

21a: R^1=R^2=H
b: R^1=H, R^2=OMe
c: R^1=R^2=OMe

Scheme 5

3. SYNTHESIS OF 2-PYRONE DERIVATIVES VIA THE NUCLEOPHILIC-SUBSTITUTION REACTION OF 4-METHYLSULFANYL-2-PYRONES

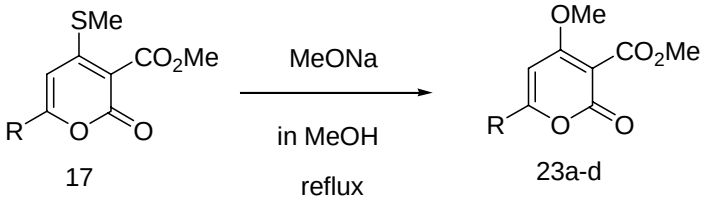
When 2-pyrone derivatives are synthesized using ketene dithioacetals, they have a methylsulfanyl group at position 4 of the pyrone ring, which can be easily substituted by other functional groups. The reactions of **9a**–**e** with methyl alkoxide afford 4-methoxy-2-pyrone derivatives (**22a**–**e**) (Scheme 6), and the reactions of ester compounds (**17a**–**d**) with methyl alkoxide produce 2-pyrone derivatives such as methoxyphenylcoumarin (**23a**)[31] and methoxyparakotoin (**23d**)[32] that are found in natural products, albeit



9 22a-e

22a: C_6H_5
b: C_6H_4-OMe(4)
c: C_6H_4-Cl(4)
d: -CH = CH-C_6H_4
e: -CH = CH-C_6H_4-OMe(4)

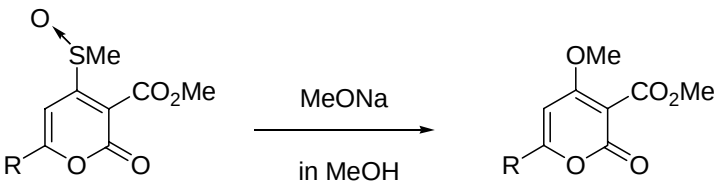
Scheme 6



17 23a-d

23a: C_6H_5
b: C_6H_4-OMe(4)
c: C_6H_3-$(OMe)_2$(3,4)
d: CH = CH- C_6H_3-O-CH_2-O-(3,4)

Scheme 7



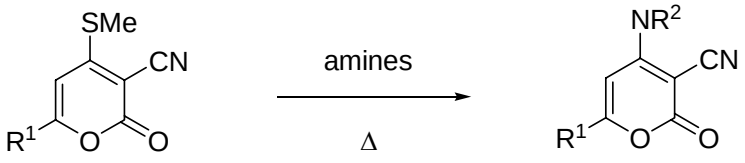
24 23a,b, 25a-c

23a: C_6H_5
b: C_6H_4-OMe(4)
25a: C_6H_3-O-CH_2-O(3,4)
b: C_6H_2-$(OMe)_3$(3,4,5)
c: CH = CH-C_6H_4-OMe(4)

Scheme 8

very weak intensities (Scheme 7). In order to avoid altering the ester group, the above reaction was performed and was then followed by conversion of the methylsulfanyl group to a sulfonyl group; this reaction was found to be effective (Scheme 8).[33]

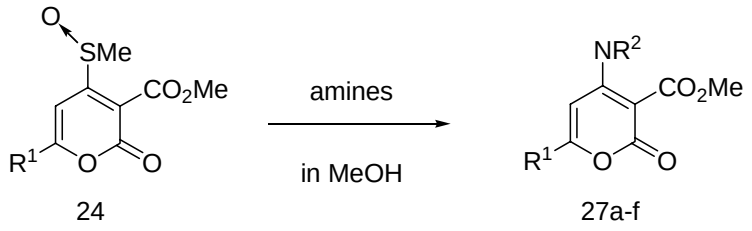
4-Amino-2-pyrone derivatives (**26a**–**y**, **27a**–**f**) were synthesized by reacting methylsulfanyl and methylsulfenyl derivatives (**9**, **24**) with amines (Schemes 9 and 10). Although only aliphatic amine derivatives are examined in this section, aromatic amine derivatives are of more interest from the viewpoint of fluorescence. These derivatives will be examined in the future. Amine derivatives are easily synthesized using an excess of amines in methanol; however, the reactions are slow. Without the presence of a solvent, **9** directly reacts with amines; however, this reaction is accompanied by the ring-opening reaction of the pyrone ring.[34] The resulting amine derivatives, in which the sulfur atom at position 4 of the pyrone ring is replaced by an oxygen or nitrogen atom, show relatively strong fluorescence, and the emitting regions showed an approximately 30–50 nm blue shift.



9 26a-y

R^1	NR^2	R^1	NR^2
26a: C_6H_5	dimethylamino	m: C_6H_4-NMe_2(4)	pyrolidino
b: C_6H_5	pyrolidino	o: C_6H_4-NMe_2(4)	morpholino
c: C_6H_5	morphorino	p: C_6H_4-NMe_2(4)	thiomorpholino
d: C_6H_4-OMe(3)	dimethylamino	q: C_6H_4-Br(4)	pyrrolidino
e: C_6H_4-OMe(4)	dimethylamino	r: C_6H_4-Cl(2)	morpholino
f: C_6H_4-OMe(4)	pyrolidino	s: C_6H_4-Cl(4)	pyrrolidino
g: C_6H_4-OMe(4)	morpholino	t: C_6H_4-C_6H_5(4)	pyrrolidino
h: C_6H_4-OMe(4)	thiomorpholino	u: 1-naphthyl	pyrrolidino
i: C_6H_4-OMe(4)	phenethylamino	v: 1-naphthyl	morpholino
j: C_6H_3-$(OMe)_2$(2,5)	morpholino	w: 2-thienyl	pyrrolidino
k: C_6H_3-$(OMe)_2$(3,4)	morpholino	x: 2-thienyl	morpholino
l: C_6H_4-NMe_2(4)	dimethylamino	y: 2-benzothienyl	piperidino

Scheme 9



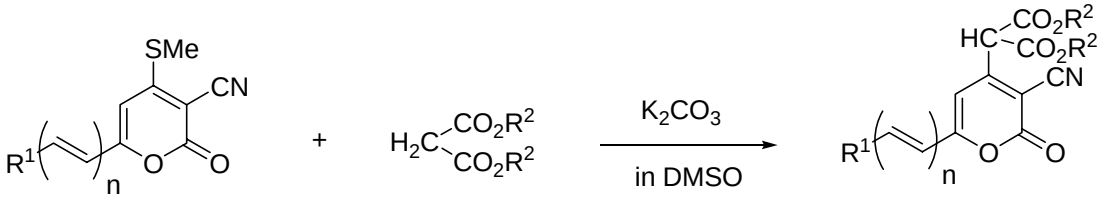
24 27a-f

	R^1	NR^2
27a:	C_6H_5	methylamino
b:	C_6H_5	benzylamino
c:	C_6H_5	dimethylamino
d:	C_6H_4-OMe(4)	methylamino
e:	C_6H_4-OMe(4)	dimethylamino
f:	C_6H_4-OMe(4)	pyrrolidino

Scheme 10

Malonate derivatives (**29a**–**h**, **30a**–**e**) are obtained in good yields *via* the reactions of malonates (**28a**, **b**) with 4-methylsulfany-2-pyrone derivatives (**9**, **14**, **17**) (Tables 1 and 2).[35] Using various active methylene compounds (**31**), pyranopyridine derivatives (**32a–h**) (Table 3) and pyranopyrone derivative (**33a–e**) (Table 4) have also been synthesized.[36,37] Among these compounds, **29h** is found to emit more red light than DCM (630 nm), which is known as a red fluorescent compound. In addition, pyranopyrone derivatives (**33a–e**) are also obtained *via* the reaction between the active methylene compound and **31** with no emission of fluorescence. In contrast, **32a–h** exhibit fluorescence due to an intramolecular

Table 1. Synthesis of dialkyl 3-cyano-6-phenyl-2-oxo-2*H*-pyran-4-ylmalonates

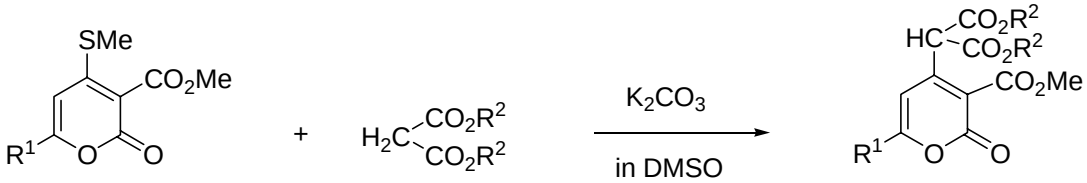


9b, 9c, 9j, 9s, 14d 28a, b 29a-h

No.	R^1	R^2	n	Yield (%)	mp (°C)	Appearance
29a	C_6H_5	Me	0	97	159-160	pale yellow needled
b	C_6H_5	Et	0	82	158-159	pale yellow needles
c	C_6H_4-OMe(4)	Me	0	81	182-183	yellow needled
d	C_6H_4-OMe(4)	Et	0	72	194-198	pale yellow needles
e	$C_6H_4NMe_2$(4)	Me	0	77	198-199	red needles
f	$C_6H_4NMe_2$(4)	Et	0	74	194-198	red needles
g	thienyl	Me	0	83	174-175	yellow needles
h	$C_6H_4NMe_2$(4)	Me	1	84	200-202	black red needles

H-bonded structure resulting between the proton of the hydroxyl group and the carbonyl group, which leads to a molecular flatness arising from electron delocalization.[35]

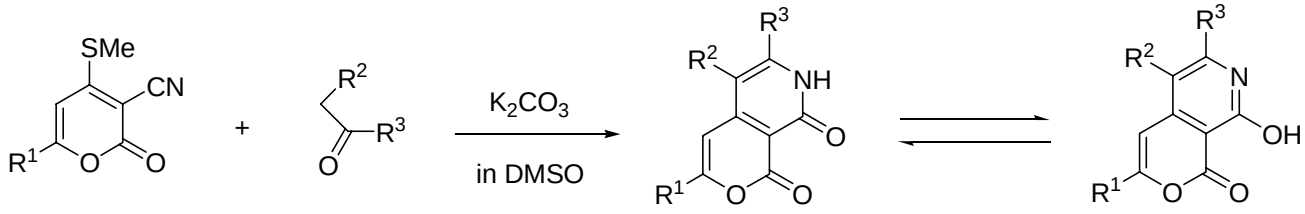
Table 2. Synthesis of dialkyl 3-methoxycarbonyl-6-phenyl-2-oxo-2*H*-pyran-4-ylmalonates



17a, c, e 28a, b 30a-e

No.	R^1	R^2	Yield(%)	mp(°C)	Appearance
30a	C_6H_5	Me	88	120-121	yellow needles
b	C_6H_5	Et	80	80-90	yellow needles
c	C_6H_4-OMe(4)	Me	90	120-121	yellow needles
d	C_6H_4-OMe(4)	Et	79	89-92	yellow needles
e	C_6H_3-O-CH_2-O(3,4)	Me	53	143-146	yellow needles

Table 3. Synthesis of 1*H*-pyrano[3,4-*c*]pyridines

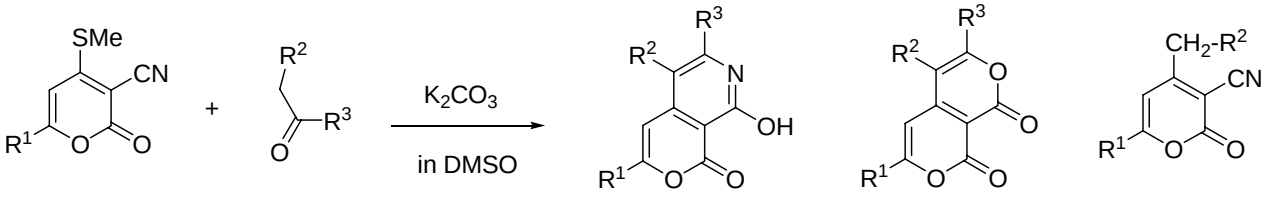


9b, 9c, 9f, 9g, 9j 31a-c 32a-h

31a: R^2 = CO_2Me, R^3 = Me
b: R^2 = CO_2Et, R^3 = Me
c: R^2 = SO_2-C_6H_4-Me(4), R^3 = Me

No.	R^1	R^2	R^3	Yield(%)	Mp(°C)
32a	C_6H_5	CO_2Me	Me	52	>300
b	C_6H_4-OMe(4)	CO_2Me	Me	30	296-297
c	C_6H_5	CO_2Et	Me	70	295-297
d	C_6H_4-OMe(4)	CO_2Et	Me	31	287-288
e	C_6H_3-OMe_2(2,4)	CO_2Et	Me	30	298-299
f	C_6H_3-OMe_2(3,4)	CO_2Et	Me	28	303-304
g	C_6H_4-NMe_2(4)	CO_2Et	Me	9	298-299
h	C_6H_4-OMe(4)	SO_2-C_6H_4-Me(4)	Me	22	260-270

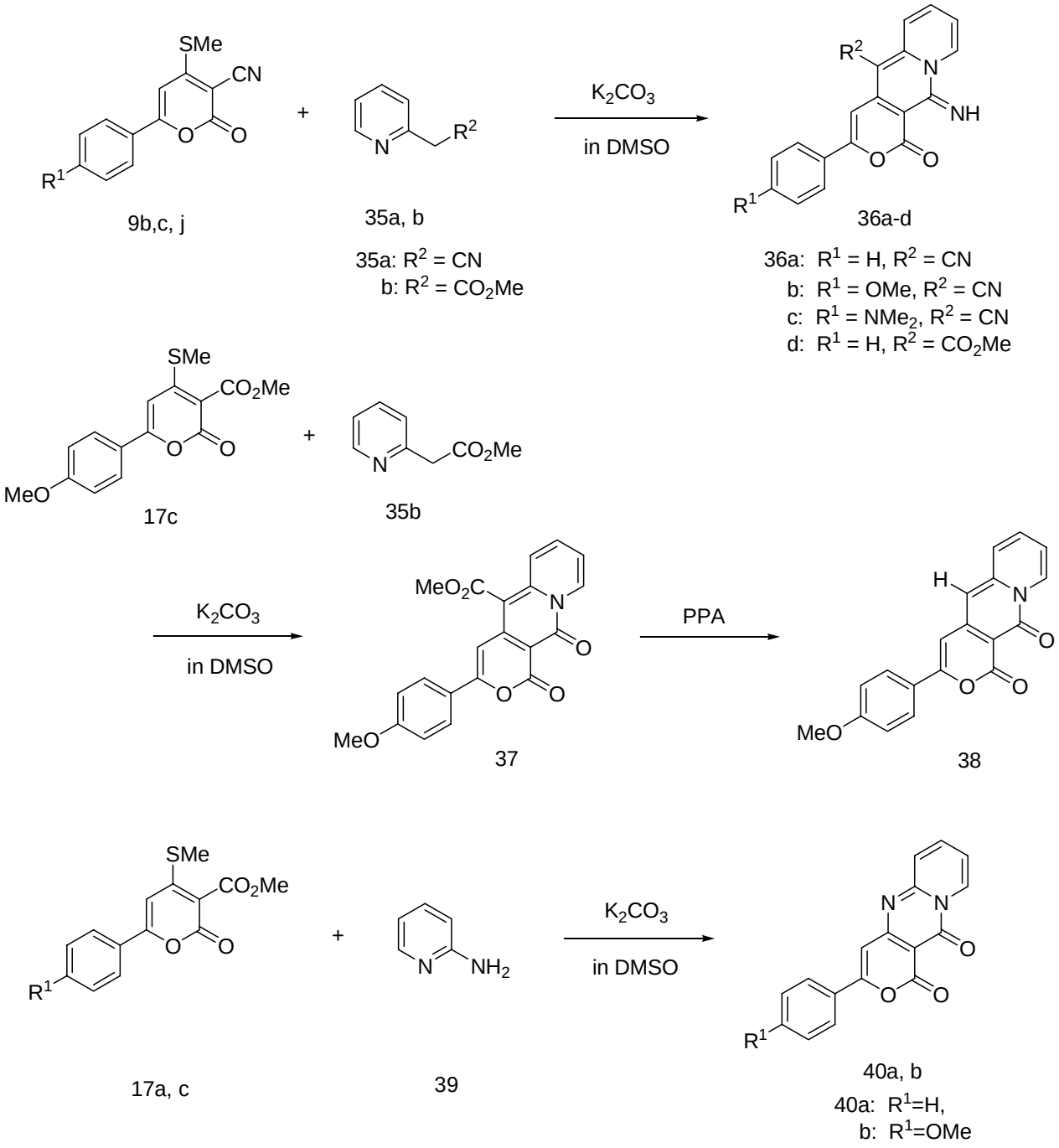
Table 4. Synthesis of 1*H*-pyrano[3,4-*c*]pyridines



9b, 9c, 9f, 9j | 31a-c | 32a, 32c, 32d, 32g, 32h | 33a-e | 34a-g

Entry	R^1	R^2	R^3	32 Yield(%)	33 Yield(%)	34 Yield(%)
1	C_6H_5	CO_2Me	Me	32a 10	-- --	34a 60
2	C_6H_5	CO_2Et	Me	32c 12	33a 11	34b 36
3	C_6H_4-OMe(4)	CO_2Et	Me	32d 30	33b 21	34c 22
4	C_6H_3-$(OMe)_2$(3,4)	CO_2Et	Me	-- --	33c 14	34d 45
5	C_6H_4-NMe_2(4)	CO_2Et	Me	32g 9	-- --	34e 2
6	C_6H_5	CO_2Et	Ph	-- --	33d 11	34b 69
7	C_6H_4-OMe(4)	CO_2Et	Ph	-- --	33e 14	34c 43
8	C_6H_5	SO_2-C_6H_4-Me(4)	Me	-- --	-- --	34f 66
9	C_6H_4-OMe(4)	SO_2-C_6H_4-Me(4)	Me	32h 22	-- --	34g 18

Coumarin derivatives, which are fused pyrone derivatives, are essential intramolecular excimer-forming fluorescence derivatization reagents required for high-sensitivity analysis. The fused pyrone derivatives (**33a**–**e**) obtained from ketene dithioacetal show weak or no fluorescence; however, the pyrano[4,3-*b*]quinolizine derivatives (**36a**–**d**) shown in Scheme 11 exhibit strong fluorescence. These derivatives are easily synthesized *via* the reactions of pyridine-2-acetonitriles (**35a**, **b**) (an active methylene compound) with 2-pyrone derivatives (**9b**, **c**, **j**) in the presence of potassium carbonate as the base in DMSO. The reaction of these compounds results in the formation of an intramolecular hydrogen bond as shown in **32a**–**h**. However, although the pyrano[4,3-*b*]quinolizine derivative (**37**) does not possess a hydrogen bond, it exhibits fluorescence when synthesized *via* the reaction of **35b** with **17c**. Moreover, its decarboxylated derivative (**38**) is easily obtained by treating **37** with polyphosphoric acid (PPA). This derivative shows fluorescence although it does not contain an electro-withdrawing group. These results suggest that fluorescence is determined by the presence of a quinolizine ring. For similar reasons, **40a** and **b** synthesized *via* the reaction of 2-aminopyridine (**39**) with **17a** and **c** exhibited yellow fluorescence. Thus, stretching the conjugated structures of 2-pyrone derivatives affords near-infrared fluorescent dyes.[38]

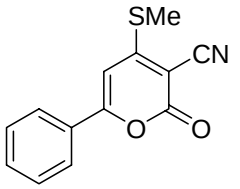


Scheme 11

3. FLUORESCENCE PROPERTY

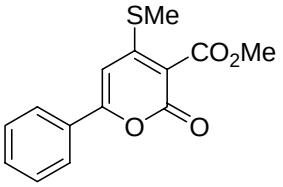
In 2-pyrone derivatives, the arrangement of the substitution groups in the pyrone ring is very important for fluorescence. In particular, aryl groups such as the phenyl group at position 6 have a significant effect on the fluorescent properties. Compounds possessing alkyl groups such as the methyl group at position 6 exhibit no fluorescence. Figure 2 shows representative fluorescent 2*H*-pyrone derivatives. An aryl group such as the phenyl group is absolutely necessary at position 6 in order for it to emit fluorescence. Further, electro-donating groups such as an amino or alkoxy group on the aryl group influence the fluorescence

emission and bathochromic shifts. The dimethylamino derivative (**9j**) emits at 608 nm and the 6-(4-dimethylamino)styryl derivative (**14d**) emits at 610 nm in dichloromethane; both these are red fluorescent compounds (Figure 3). Electro-withdrawing groups such as the cyano group are necessary at position 3 of the pyrone ring. Moreover, ester derivatives (**17a**, **18d**) exhibit stronger fluorescence than cyano derivatives. Detailed structural analysis using X-ray crystallography has revealed that the intramolecular nonbonded S…O (SMe…CO_2Me) distance is 2.735 Å, which is shorter than the sum of



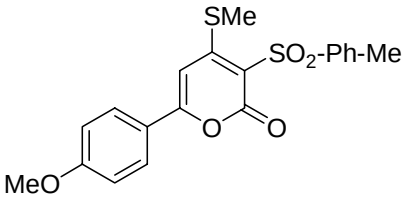
9b

Em max (solid) = 340 nm
R.I = 1.54



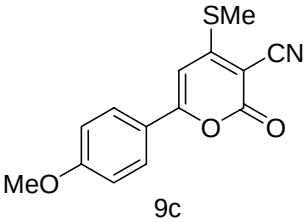
17a

Em max (solid) = 475 nm
R.I = 6.31



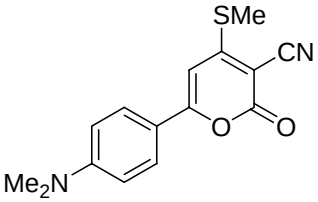
18d

Em max (solid) = 508 nm
R.I = 11.27



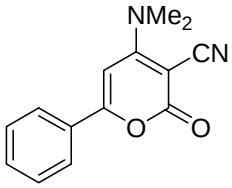
9c

Em max (solid) = 536 nm
R.I = 1.23



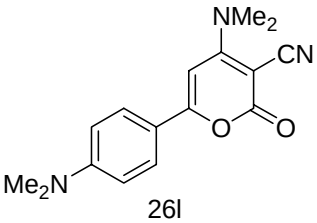
9j

Em max (CH_2Cl_2) = 531 nm
Em max (solid) = 608 nm
R.I = 0.15



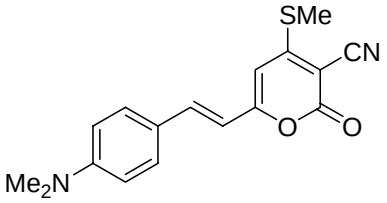
26a

Em max (EtOH) = 447 nm
Em max (solid) = 447 nm, R.I = 1.50



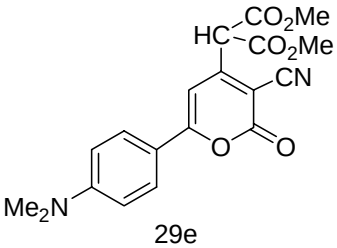
26l

Em max (EtOH) = 475 nm
Em max (solid) = 517 nm, R.I = 9.90



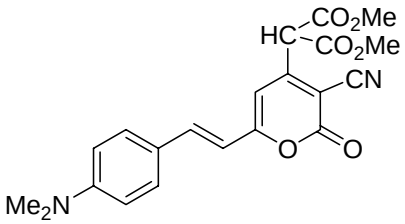
14d

Em max (CH_2Cl_2) = 610 nm
Em max (solid) = 699 nm, R.I = 0.01>



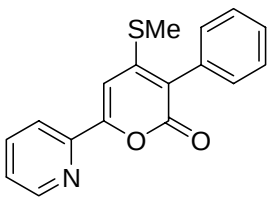
29e

Em max (CH_2Cl_2) = 547 nm
Em max (solid) = 610 nm, R.I = 0.70



29h

Em max (CH_2Cl_2) = 634 nm
Em max (solid) = 620 nm, R.I = 0.40



21a

Em max (EtOH) = 439 nm
Em max (solid) = 474 nm, R.I = 6.47

RI = relative intensity

Figure 2

the van der Waals distance for O and S (3.25 Å). This result suggests the presence of strong molecular stacking because of the planar nature of molecules, and this strong molecular stacking strongly influences the fluorescence properties. The same phenomenon is observed when compounds **32** and **33** are compared. Although compound **33** does not exhibit fluorescence in the solid state, compound **32,** which has an intramolecular H-bonded structure due to the C=O----H-O-C system, exhibits strong fluorescence. The reaction of 4-methylsulfanyl-2-pyrone derivatives with various nucleophilic reagents, as shown in Scheme 6–11 and Table 1–4, produces various derivatives by displacing the methylsulfanyl group at position 4 of the pyrone ring. Amino derivatives such as compounds **26a** and **26l** show stronger fluorescence; however, they also exhibit hypsochromic shifts. The malonate derivative (**29e**) exhibits a slight bathochromic shift and stronger fluorescence. In particular, the 6-(4-dimethylamino)styryl derivative (**29h**) emits at 620 nm, which is close to the ideal wavelength for red-fluorescent compounds used in EL devices. The derivatives not substituted at positions 5 have much greater fluorescence than compounds with an electro-withdrawing or electro-donating group at that position. This fact suggests that derivatives bridged at positions 5 and 6 exhibit no fluorescence. Our findings show that an electron-rich aryl group is necessary at position 6 of the pyrone ring for the emission of fluorescence, and derivatives containing electron-poor heterocycles such as the pyridyl group exhibit no fluorescence. However, the introduction of a phenyl group at position 3 of the 6-pyridyl-2-pyrone ring in **21a** affects the fluorescence expression. Consequently, in 2-pyrone derivatives, the introduction of various substituents at each position enables the control of the light-emission region and intensity, and also allows us to design pigments with various functionalities.[39]

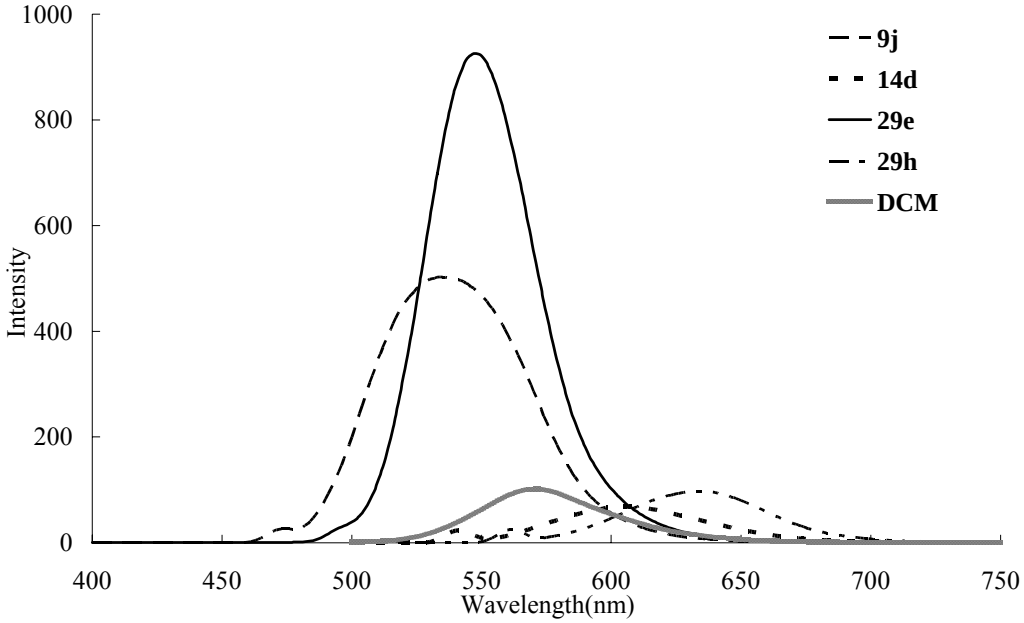


Figure 3. Comparison of fluorescent intensity of 2-pyrone derivatives **9j**, **14d**, **29e**, **29h** and DCM in dichloromethane.

4. CONCLUSION

Display devices using organic EL materials are making rapid progress in terms of practical use. Studies on novel organic EL compounds are underway, with particular focus on aromatic compounds. Heterocycles, in which a carbon atom in the aromatic ring is replaced by an oxygen or nitrogen atom, have also received considered attention due to their diversity. In fact, many fluorescent heterocycles have been reported as diagnostic reagents or intramolecular excimer-forming fluorescence derivatization reagents for use in biological samples and pharmaceuticals. These findings will contribute to the development of organic EL materials. In addition, fluorescent heterocycles will be applicable not only to the synthesis of optimal organic EL materials but also to the synthesis of exotic materials that support the progress in technology, such as laser dyes and chemical luminous materials. We expect that ketene dithioacetals will be the best starting materials for the synthesis of various useful dyes. For almost 5 decades, there has been research on these reagents; however, their application to the synthesis of merocyanine dyes and chemical luminescence reagents is only a recent development. Therefore, these reagents will be applied in the development of useful fluorescent dyes.

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