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A NEW APPROACH TO IMIDAZO[1,2-*a*]PYRIDINE DERIVATIVES AND THEIR APPLICATION TO THE SYNTHSES OF NOVEL 2*H*-PYRANO[2',3':4,5] IMIDAZO[1,2-*a*]PYRIDIN-2-ONE DERIVATIVES[1]

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Abstract – 3-[Bis(methylthio)methylene]-2(3*H*)-imidazo[1,2-*a*]pyridinones were prepared from the *S*-alkylation of pyridinium 1-[1-carbamoyl-1-[(methylthio) thiocarbonyl]]methylides with methyl iodide followed by the alkaline treatment of the resulting pyridinium salts. The reactions of these 3-methylene-2(3*H*)-imidazo[1,2-*a*]pyridinones with some ethyl cyano- or acyl-substituted acetates in the presence of a base did not afford the initially expected 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-2-one derivatives, but, instead of them, provided ethyl 3-[2-hydroxyimidazo[1,2-*a*]pyridin-3-yl]acrylates. The thermolyses of these acrylates without any solvent under reduced pressure gave the corresponding 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-2-one derivatives.

Imidazo[1,2-*a*]pyridine derivatives have a variety of biological activities and have attracted much attention as potential pharmaceutical and agricultural medicines.[2—8] Thus, various constructive routes for this skeleton have been developed,[3-5,7-13] but, the access by their methods to the suitably functionalized imidazo[1,2-*a*]pyridine derivatives which can readily lead to the fused one is usually difficult. In a continuation of our work on nitrogen-bridged heterocycles, we were interested in the preparation of such functionalized imidazo[1,2-*a*]pyridine derivatives, because we were familiar with the formation and the reaction of its 1-deaza analogue, indolizine derivative. For example, we have described that 2(3*H*)-indolizinones derivatives[14] were useful precursors for the syntheses of some

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Dedicated to Professor Akira Suzuki on his 80th birthday.

functionalized compounds such as 3-[bis(alkylthio)methylene]-2(3*H*)-indolizinones[15] and 3-vinylindolizines,[16] and which in turn were converted to the corresponding indolizine derivatives fused with a furan,[17] pyran,[15] and oxepine ring.[18,19] So, we planned the preparation of 3-[bis(alkylthio)methylene]-2(3*H*)-imidazo[1,2-*a*]pyridinone (**A**, see Figure 1) as a potential precursor for a novel heterocycle, 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-2-one. However, the brief survey of the literature[20] disclosed its inaccessibility from the potential precursor, 3-[mercapto(alkylthio)methylene]-2(3*H*)-imidazo[1,2-*a*]pyridine (**B**), because this molecule behaved as its enolic tautomer, alkyl 2-hydroxyimidazo[1,2-*a*]pyridine-3-dithiocarboxylate (**B'**), and afforded only the *O*-alkylated product (**C**). We next looked for an alternative method for the preparation of such molecules and developed a new one for them in which the higher acidity of the amide proton in 1-(1-carbmoylvinyl)pyridinium salt (**D**) was utilized for the construction of the imidazole ring. In this paper, we report the preparation of 3-[bis(methylthio)methylene]-2(3*H*)-imidazo[1,2-*a*]pyridinones and their reaction with activated ethyl acetates to provide novel pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine derivatives via the thermolyses of the resulting ethyl 3-(2-hydroxyimidazo[1,2-*a*]pyridin-3-yl)acrylates.

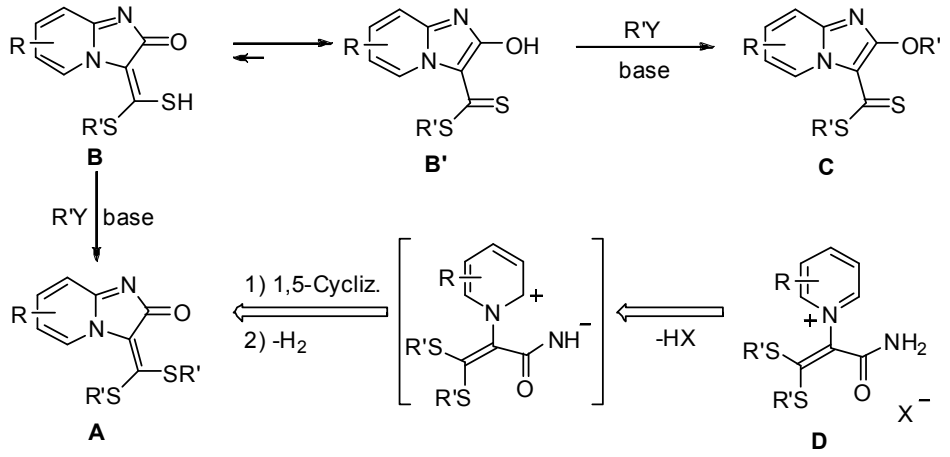
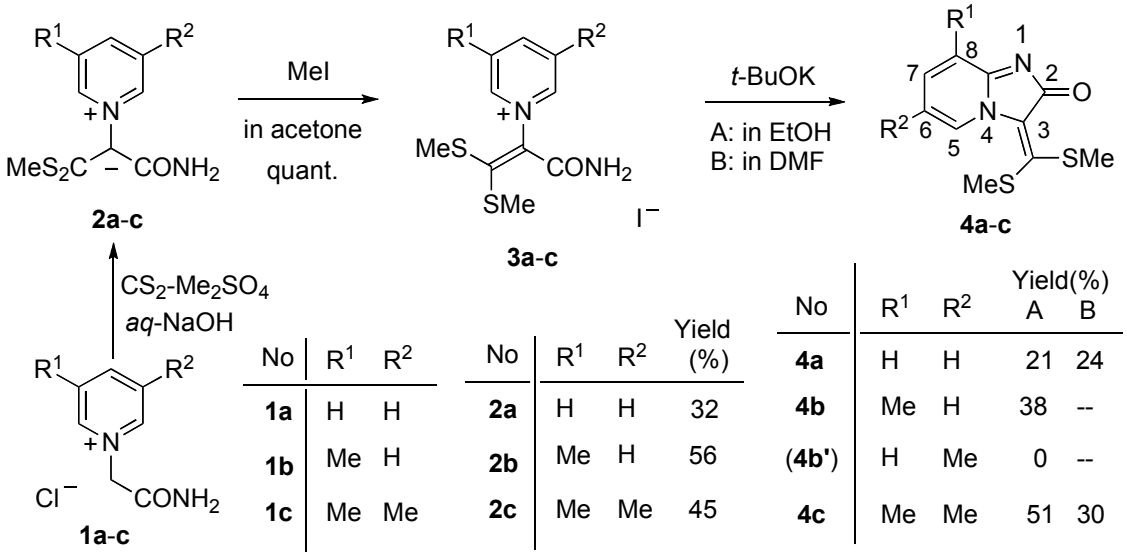


Figure 1

RESULTS AND DISCUSSION

Preparations of 3-methylene-2(3*H*)-imidazo[1,2-*a*]pyridinones (4). Since an amide proton has higher acidity than that of normal amino protons, we thought that the desired 3-methylene-2(3*H*)-imidazo[1,2-*a*]pyridinone derivatives such as **4** could be obtained by the deprotonation of the carbamoyl group in the corresponding 1-[1-carbamoylvinyl]pyridinium halides (**3**) with a base, followed by the attack of the resulting imide ion to the 2-position of the pyridine ring and the dehydrogenation of the primary bicycloadducts. In fact, although the treatment of the 1-[1-carbamoyl-2,2-bis(methylthio)-vinyl]pyridinium iodides (**3a—c**), readily obtainable from the reactions of pyridinium 1-[1-carbamoyl-1-[(methylthio)thiocarbonyl]]methylides (**2a—c**) with methyl iodide, with a comparatively weak base such

as DBU, triethylamine, or potassium carbonate did not afford the desired 3-[bis(methylthio)methylene]-2(3*H*)-imidazo[1,2-*a*]pyridinone derivatives (**4a—c**) at all, the use of a stronger base such as potassium *t*-butoxide in ethanol (method A) or in DMF (method B) gave the corresponding products **4a—c** in moderate yields (21—51%) as orange to reddish crystals. Interestingly, in the reaction of unsymmetrical 3-methylpyridinium iodide (**3b**) only the 8-methyl derivative **4b** was obtained, while the alternative 6-methyl one **4b'** was not. In general, it is well known that the attack at the 2-position of the pyridine ring in the cyclization and the cycloaddition reactions of the 3-substituted pyridinium ylides or salts in the ground state is preferred over that at the 6-position,[21-23] but the observation of the exclusive mode at the 2-position is rare. These results are shown in Scheme 1.



No	R^1	R^2
1a	H	H
1b	Me	H
1c	Me	Me

No	R^1	R^2	Yield (%)
2a	H	H	32
2b	Me	H	56
2c	Me	Me	45

No	R^1	R^2	Yield(%) A	B
4a	H	H	21	24
4b	Me	H	38	--
(**4b'**)	H	Me	0	--
4c	Me	Me	51	30

Scheme 1

The structural assignment of these compounds (**4a—c**) was accomplished mainly from physical and spectral means, and confirmed by the X-ray analysis of one compound **4c**. For example, elementary analyses of compound (**4a—c**) were in good accord with the compositions of our proposed structures. The IR spectra of these compounds showed a strong carbonyl absorption band near 1630 cm^{-1}, indicating the contribution of a similar polarized structure as observed in 3-methylene-2(3*H*)-indolizinones (near 1600 cm^{-1}). ^{1}H-NMR spectra of **4a—c** showed two

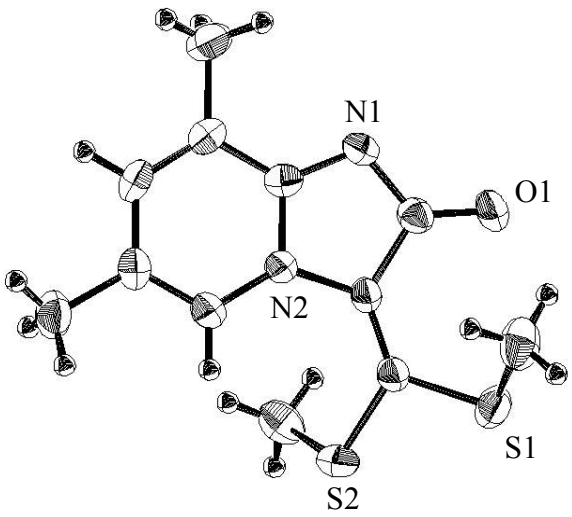


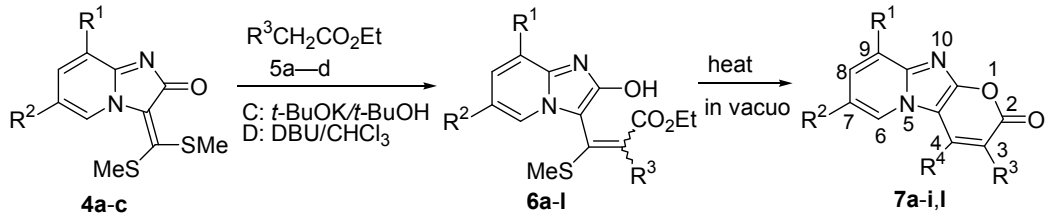
Figure 2. ORTEP drawing of **4c**

methylthio proton signals at separate positions (δ 2.47—2.50 and 2.67—2.69) as each singlet due to their magnetic nonequivalence. These values showed distinctly that both methyl groups are attached to the sulfur atom but not to the oxygen atom. Furthermore, that the product from the 3-methylpyridinium salt **3b** was the 8-methyl derivative **4b** was clearly showed by the presence of the vicinal ABC pattern signals in the ^{1}H-NMR spectra. The numbers for the sp^{2}- and sp^{3}-carbons in their ^{13}C-NMR spectra of **4a—c** were well in accord with those of our proposed structures. Finally, the X-ray analysis of one compound **4c** was carried out and the structure was confirmed. The ORTEP drawing[24] of **4c** is shown in Figure 2.

Preparation of ethyl 3-[2-hydroxyimidazo[1,2-*a*]pyridin-3-yl]acrylates (6) and their transformation to 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-2-ones (7). In imitation of our previous syntheses of pyrano[2,3-*b*]indolizines,[15] the reactions of **4a—c** with some activated ethyl acetates were investigated. However, these reactions of **4a—c** with ethyl cyanoacetate (**5a**), diethyl malonate (**5b**), ethyl benzoylacetate (**5c**), and ethyl acetoacetate (**5d**) under various conditions did not afford the expected 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridin-2-one derivatives (**7a—l**) at all. Instead of them, many of these reactions formed ethyl 3-[2-hydroxyimidazo[1,2-*a*]pyridin-3-yl]acrylates. For example, when the reactions of **4a—c** with **5a—c** were carried out in the presence of potassium *t*-butoxide in *t*-butanol (method C) at room temperature, the smooth evolution of methanethiol was observed and the corresponding acrylate derivatives **6a—i** were isolated in 55—98% yields from the reaction mixtures. On the other hand, similar reactions of **4a**,**b** and **5d** gave only complex mixtures and any significant products such as **6j**,**k** could not be isolated from them, though the reaction of **4c** with **5d** afforded the normal product **6l** in 75% yield. The same products **6c**,**l** were obtained from the reactions of **4c** with **5a**,**d** in the presence of DBU in chloroform (method D) at room temperature in 62 and 75% yields respectively, but the application of method D to the reactions of **4a**,**b** and **5d** did not give good results.

Since we failed to obtain directly 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridin-2-one derivatives (**7**) from the reactions of 2(3*H*)-imidazo[1,2-*a*]pyridinones (**4**) and acetates **5**, we next examined the elimination of ethanol from acrylates **6a—i,l** obtained. Heating of acrylates **6a—i,l** in various solvents or treatment with acetic acid or concentrated sulfuric acid did not provide the condensation products **7a—i,l**. However, when acrylates **6a—h** were heated without any solvent at reduced pressure (3 torr), the eliminations smoothly occurred to give the expected products **6a—h** in 21—73% yields. On the other hand, similar treatment of **6i**,**l** did not provide the corresponding products **7i**,**l**, but 4-unsubstituted **7i'** and 3-unsubstituted 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-2-one derivatives (**7l'**) were formed in 34 and 16% yields, respectively. These results are shown in Scheme 2.

The elementary analyses of compounds **6a—i**,**l** were in good accord with our postulated structures. The IR spectra of **6a—i**,**l** exhibited characteristic absorption bands at 3406—3447 cm^{-1} and at 1608—1651 cm^{-1} due to the presences of the 2-hydroxy and the 3-vinyl groups respectively. Each ^{1}H-NMR spectra



5a (R^3=CN), **5b** (R^3=CO_2Et), **5c** (R^3=COPh), **5d** (R^3=COMe)

No	R^1	R^2	R^3	Yield (%) C	D
6a	H	H	CN	68	--
6b	Me	H	CN	72	--
6c	Me	Me	CN	55	62
6d	H	H	CO_2Et	55	--
6e	Me	H	CO_2Et	74	--
6f	Me	Me	CO_2Et	84	--
6g	H	H	COPh	73	--
6h	Me	H	COPh	98	--
6i	Me	Me	COPh	78	--
6j	H	H	COMe	0[a]	0[a]
6k	Me	H	COMe	0[a]	0[a]
6l	Me	Me	COMe	69	75

No	R^1	R^2	R^3	R^4	Yield (%)
7a	H	H	CN	SMe	21
7b	Me	H	CN	SMe	50
7c	Me	Me	CN	SMe	42
7d	H	H	CO_2Et	SMe	59
7e	Me	H	CO_2Et	SMe	65
7f	Me	Me	CO_2Et	SMe	73
7g	H	H	COPh	SMe	59
7h	Me	H	COPh	SMe	66
7i	Me	Me	COPh	SMe	0
7i'	Me	Me	COPh	H	34
7l	Me	Me	COMe	SMe	0
7l'	Me	Me	H	SMe	16

a) Complex mixture.

Scheme 2

showed only one set of proton signals for **6a—i,l**. Similarly, any signals of mixture were not observed in the ^{13}C-NMR spectra of unsymmetrical acrylates **6g—i**. This fact suggested that compounds **6a—i**,**l** are the sole products, and not cis-trans mixtures in the relation of the 3-vinyl group, though we could not determined their *E/Z* configurations for **6a—c**,**g—i**,**l** because of the tetra-substituted mode. In addition, the presences of one methylthio signal at δ 1.94—2.58 (3H, s) and one or two ethoxycarbonyl signals at δ 0.95—1.27 (3H, t) and 3.86—4.18 (2H, q) in compounds **6a—i,l** were also indicated, together with protons and methyl group(s) on the pyridine ring. On the other hand, each proton signal for the 2-hydroxy group in **6a—i** was not shown, but this must be due to the broadening of the signal because one sp^3-carbon signal which should appear in its tautomeric 2(3*H*)-imidazo[1,2-*a*]pyridinone structure did not appear in the ^{13}C-NMR spectra. Judging from these data and their smooth transformation to subsequent elimination products **7a—h**,**i',l'**, we concluded **6a—i,l** to be ethyl 3-[2-hydroxyimidazo-[1,2-*a*]pyridin-3-yl]acrylates.

Similarly, compounds **7a—h** afforded satisfactory elemental analyses and their ^{1}H-NMR spectra demonstrated clearly the disappearance of an ethoxy group from the precursors **6a—h**. However, the analyses for **7i'**,**l'** exhibited formulas $C_{19}H_{14}N_2O_3$ and $C_{13}H_{12}N_2O_2S$ respectively and they were not in

accord with our initially expected compositions ($C_{20}H_{16}N_2O_3S$ and $C_{15}H_{14}N_2O_3S$). ^{1}H-NMR spectral analyses of **7i'**,**l'** provided a solution for the structural question, that is, the loss of a methylthio or an acetyl group from the initially formed **7i**,**l** and the appearance of a new olefinic proton at the 4- (**7i'**) or 3-position (**7l'**) were shown. These findings suggested that the cyclization products **7i**,**l** underwent a further elimination reaction under the conditions employed here to give the observed ones **7i'**,**l'**, though the detailed mechanisms for them is unclear. Finally, one (**7d**) of this type of compound was subjected to X-ray analysis and the skeleton was completely confirmed to be 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridin-2-one. The ORTEP drawing of **7d** is shown in Figure 3.[24]

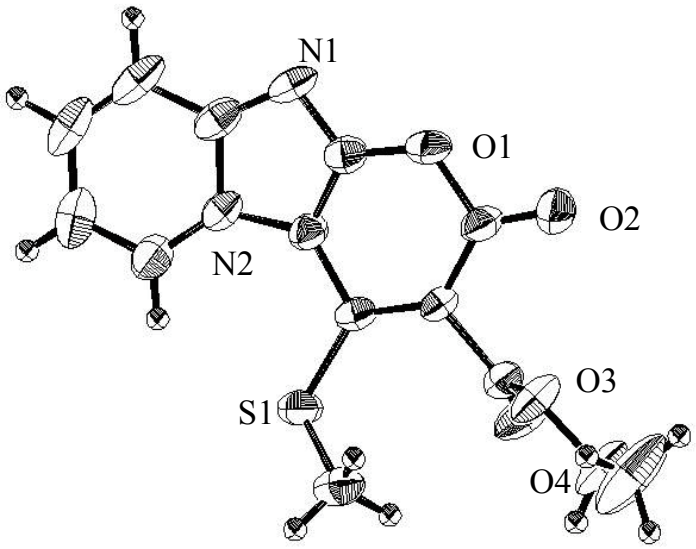
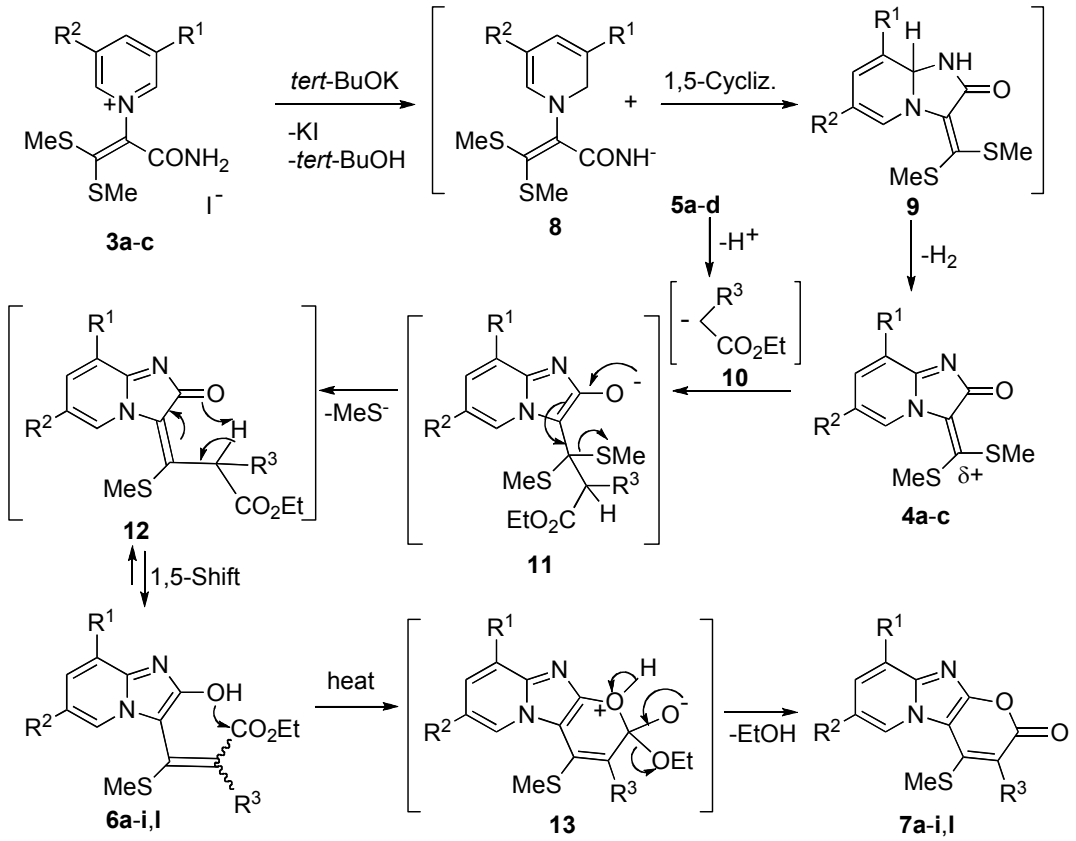


Figure 3. ORTEP drawing of **7d**.

Reaction Mechanisms. Possible mechanisms are shown in Scheme 3. As described above, 3-methylene-2(3*H*)-imidazo[1,2-*a*]pyridinones (**4a—c**) can be created by the intramolecular nucleophilic cyclization of the imide ion **8**, generated by the proton abstraction from the comparatively acidic carbamoyl group of pyridinium salts (**3a—c**), to the 2-position on the pyridine ring, followed by the dehydrogenation of the primary bicycloadducts **9**. The production of ethyl 3-[2-hydroxyimidazo-[1,2-*a*]pyridin-3-yl]acrylates (**6a—i**,**l**) can be explained by the nucleophilic attack of the carbanion **10**, produced in situ by the treatment of active methylene compounds **5a—d** with a base, to the electron-poor 3(1)-methylene carbon in **4a—c**, followed by the elimination of a methylthio anion from the resulting adduct **11** and the 1,5-shift of a hydrogen atom from the 3(2)-position to the 2-carbonyl oxygen in intermediates **12**. Although the reason why the transformation from **6a—i**,**l** to **7a—i**,**l** was ineffective on heating in a solvent or by treatment with an acid or a base is still uncertain, the route from **6a—i**,**l** to pyranoimidazopyridines (**7a—i**,**l**) should proceed via the nucleophilic addition of the lone pair electrons of the 2-hydroxy oxygen to the ester carbonyl carbon attached with the 3-vinyl group and subsequent elimination of a molecule of ethanol.

EXPERIMENTAL

Melting points were measured with a Yanagimoto micromelting point apparatus and were not corrected. Microanalyses were carried out on a Perkin-Elmer 2400 elemental analyzer. The ^{1}H-NMR and



Scheme 3

^{13}C-NMR spectra were determined with a JEOL JNM-LA400 (^{1}H: 400 MHz and ^{13}C: 100.4 MHz) spectrometer in deuteriochloroform[25] with tetramethylsilane used as the internal standard; the chemical shifts are expressed in δ values. The IR spectra were taken with JASCO FT/IR-5300 IR spectrophotometers.

Materials. 1-(Carbamoylmethyl)pyridinium chloride (**1a**—**c**) were prepared in good yields from the reaction of pyridine, 3-methylpyridine, and 3,5-dimethylpyridine with α-chloroacetamide in acetone according to the literature.[26] Some physical and spectral data for the new compound **1c** are as follows: 1-Carbamoylmethyl-3,5-dimethylpyridinium chloride (**1c**); 80%, colorless prisms, mp 250—253 °C (from $CHCl_3$-hexane), IR (KBr) ν 1682, 3086, 3244 cm^{-1}. ^{1}H-NMR δ: 2.59 (6H, s, 3- and 5-H), 5.68 (1H, br, NH), 5.82 (2H, s, NCH_2), 8.04 (1H, br s, 4-H), 8.95 (2H, br s, 2- and 6-H), 9.66 (1H, br, NH). *Anal.* Calcd for $C_9H_{13}ClN_2O$: C, 53.87; H, 6.53; N, 13.96. Found: C, 53.78; H, 6.43; N, 14.15.

Pyridinium 1-(1-carbamoyl)[1-methylthio(thiocarbonyl)]methylides **2a**—**c** were prepared from the treatment of a mixture of pyridinium salts **1a**—**c**, carbon disulfide, and dimethyl sulfate with aqueous sodium hydroxide, according to the procedure described by Tominaga *et al*.[27] Some data for new pyridinium methylides **2b**,**c** are as follows: 3-Methylpyridinium 1-(1-carbamoyl)-

[1-methylthio(thiocarbonyl)]methylide (**2b**), 56%, yellow prisms, mp 179—180 °C (from $CHCl_3$-hexane). IR (KBr): ν 1631, 3243, 3293 cm^{-1}. ^{1}H-NMR δ: 2.48 (3H, s, SMe), 2.58 (3H, s, 3-Me), 5.53 (1H, br, NH), 7.79 (1H, dd, *J*=8.0, 6.1 Hz, 5-H), 8.19 (1H, br d, *J*=8.0 Hz, 4-H), 8.29 (1H, br s, 2-H), 8.30 (1H, br d, *J*=6.1 Hz, 6-H), 10.69 (1H, br, NH). ^{13}C-NMR δ: 16.67, 18.62, 126.34, 126.41, 138.20, 145.06, 146.57, 148.89, 165.11, 178.18. *Anal.* Calcd for $C_{10}H_{12}N_2OS_2$: C, 49.97; H, 5.03; N, 11.66. Found: C, 49.73; H, 5.27; N, 11.66. 3,5-Dimethylpyridinium 1-(1-carbamoyl)[1-methylthio(thiocarbonyl)]methylide (**2c**), 45%, yellow prisms, mp 199—200 °C (from $CHCl_3$-hexane). IR (KBr): ν 1631, 3244, 3281 cm^{-1}. ^{1}H-NMR δ: 2.49 (3H, s, SMe), 2.53 (6H, s, 2-, 6-Me), 5.53 (1H, br, NH), 7.98 (1H, br s, 4-H), 8.49 (2H, br s, 2-, 6-H), 10.70 (1H, br, NH). ^{13}C-NMR δ: 16.68, 18.49, 126.36, 137.51, 145.82, 146.19, 165.22, 178.02. *Anal.* Calcd for $C_{11}H_{14}N_2OS_2$: C, 51.94; H, 5.55; N, 11.01. Found: C, 51.88; H, 5.59; N, 10.91.

Preparations of 3-[bis(methylthio)methylene]-2(3*H*)-imidazo[1,2-*a*]pyridinones (4a—c). General Method. The mixture of pyridinium methylide (**2**, 10 mmol) and methyl iodide (1.846 g, 13 mmol) in acetone (20 mL) was stirred at room temperature for 1 day. The precipitates of pyridinium salt **3** which separated were collected by suction and washed with acetone (20 mL). Without further purification, the salt **3** was treated with potassium *t*-butoxide (1.346 g, 12 mmol) in ethanol (25 mL, Method A) or DMF (25 mL, Method B) at room temperature and stirred for the time given in the description for each product. The resulting solution was concentrated under reduced pressure at a temperature below 30 °C. The residue was then separated by column chromatography on alumina using $CHCl_3$ as an eluent. The yellow to orange layers which eluted first were collected and the combined solution was concentrated under reduced pressure. The recrystallization from $CHCl_3$-Et_2O provided the corresponding product **4**.

In these reactions the use of other bases such as DBU, triethylamine, or potassium carbonate did not provide the desired 2(3*H*)-imidazo[1,2-*a*]pyridinone derivative (**4**) at all. Furthermore, the formation of an alternative 6-methyl derivative **4b'** in the alkaline treatment of unsymmetrical 3-methylpyridinium salt **3b** could not be detected.

3-[Bis(methylthio)methylene]-2(3*H*)-imidazo[1,2-*a*]pyridinones (4a): From **2a**, 21% (Method A, reaction time 5 h) or 24% (Method B, reaction time 5 h), orange prisms, mp 142—143 °C. IR (KBr): ν 1610 cm^{-1}. ^{1}H-NMR δ: 2.48 and 2.68 (each 3H, s, SMe), 6.64 (1H, ddd, *J*=7.0, 7.0, 1.4 Hz, 6-H), 7.14 (1H, br d, *J*=9.0 Hz, 8-H), 7.44 (1H, ddd, *J*=9.0, 7.0, 1.4 Hz, 7-H), 8.93 (1H, br d, *J*=7.0 Hz, 5-H). ^{13}C-NMR δ: 19.63, 20,72, 110.45, 116.04, 124.46, 130.19, 137.52, 152.34, 160.91, 170.84. *Anal.* Calcd for $C_{10}H_{10}N_2OS_2$: C, 50.39; H, 4.23; N, 11.75. Found: C, 50.17; H, 4.37; N, 12.01.

3-[Bis(methylthio)methylene]-8-methyl-2(3*H*)-imidazo[1,2-*a*]pyridinones (4b): From **2b**, 38% (Method A, reaction time 4 h), red prisms, mp 149—151 °C. IR (KBr): ν 1630 cm^{-1}. ^{1}H-NMR δ:

2.38 (3H, s, 8-Me), 2.50 and 2.69 (each 3H, s, SMe), 6.57 (1H, t, *J*=7.0, 6-H), 7.25 (1H, br d, *J*=7.0 Hz, 7-H), 8.79 (1H, br d, *J*=7.0 Hz, 5-H). ^{13}C-NMR δ: 17.13, 19.58, 20.66, 110.25, 124.88, 125.80, 127.46, 135.69, 151.72, 160.97, 170.85. *Anal.* Calcd for $C_{11}H_{12}N_2OS_2$: C, 52.35; H, 4.79; N, 11.10. Found: C, 52.40; H, 4.82; N, 11.03.

3-[Bis(methylthio)methylene]-6,8-dimethyl-2(3*H*)-imidazo[1,2-*a*]pyridinones (4c): From **2c**, 51% (Method A, reaction time 2 h) or 30% (Method B, reaction time 4 h), red prisms, mp 209—211 °C. IR (KBr): ν 1630 cm^{-1}. ^{1}H-NMR δ: 2.23 (3H, s, 6-Me), 2.37 (3H, s, 8-Me), 2.47 and 2.67 (each 3H, s, SMe), 7.13 (1H, br s, 7-H), 8.57 (1H, br s, 5-H). ^{13}C-NMR δ: 17.19, 18.07, 19.70, 21.02, 119.77, 125.19, 125.27, 125.54, 138.62, 151.25, 160.11, 171.04. *Anal.* Calcd for $C_{12}H_{14}N_2OS_2$: C, 51.94; H, 5.55; N, 11.01. Found: C, 51.88; H, 5.59; N, 10.91.

Preparations of ethyl 3-[2-hydroxy-2(3*H*)-imidazo[1,2-*a*]pyridin-3-yl]acrylates (6a—l). General method. A mixture of 3-[bis(methylthio)methylene]-2(3*H*)-imidazo[1,2-*a*]pyridinone (**4**, 1 mmol) and an active methylene compound (**5**, 1.2 mmol) was stirred with potassium *t*-butoxide (0.135 g, 1.2 mmol) in *t*-BuOH (30 mL) (method C) or with DBU (0.182 g, 1,2 mmol) in $CHCl_3$ (30 mL) (Method D) at room temperature for the time indicated in the description for each product. The solution was then concentrated under reduced pressure, and the residue was separated by column chromatography on alumina using $CHCl_3$-EtOH (9:1) as an eluent. The yellow layers were collected and the combined solution was concentrated under reduced pressure. Recrystallization of the crude product from EtOH afforded the corresponding ethyl 3-[2-hydroxyimidazo[1,2-*a*]pyridine-3-yl]-acrylates (**6a—i,l**).

The reactions of 2(3*H*)-imidazo[1,2-*a*]pyridinones **4a**,**b** with ethyl acetoacetate (**5d**) gave complex mixtures and the isolation of significant products such as **6j**,**k** from them was unsuccessful. Some physical and spectral data for these products **6a—i,l** are shown below.

Ethyl 2-cyano-3-(2-hydroxyimidazo[1,2-*a*]pyridin-3-yl)-3-(methylthio)acrylate (6a): From **4a** and ethyl cyanoacetate (**5a**), 68% (Method C, reaction time 6 h), yellow needles, mp 260—263 °C. IR (KBr): ν 1651, 1685, 2199, 3412 cm^{-1}. ^{1}H-NMR δ: 1.27 (3H, br, OCH_2CH_3), 2.52 (3H, br s, SMe), 4.17 (2H, br, OCH_2CH_3), 7.10 (1H, br t, *J*=6.8, 6.8 Hz, 6-H), 7.46 (1H, br d, *J*=8.5 Hz, 8-H), 7.53 (1H, br q, *J*=8.5, 6.8 Hz, 7-H), 8.03 (1H, br d, *J*=6.8 Hz, 5-H). *Anal.* Calcd for $C_{14}H_{13}N_3O_3S$: C, 55.43; H, 4.32; N, 13.85. Found: C, 55.46; H, 4.24; N, 13.91.

Ethyl 2-cyano-3-(2-hydroxy-8-methylimidazo[1,2-*a*]pyridin-3-yl)-3-(methylthio)acrylate (6b): From **4b** and **5a**, 72% (Method C, reaction time 3 h), yellow needles, mp 284—287 °C. IR (KBr): ν 1620, 1705, 2203, 3425 cm^{-1}. ^{1}H-NMR δ: 1.27 (3H, br, OCH_2CH_3), 2.50 (3H, br s, SMe), 2.58 (3H, br s, 8-Me), 4.18 (2H, br, OCH_2CH_3), 7.02 (1H, br t, *J*=6.8, 6.8 Hz, 6-H), 7.33 (1H, br d, *J*=6.8 Hz, 7-H), 7.99

(1H, br d, *J*=6.8 Hz, 5-H). *Anal.* Calcd for $C_{15}H_{15}N_3O_3S$+1/2C_2H_5OH: C, 56.46; H, 5.33; N, 12.34. Found: C, 56.64; H, 5.04; N, 12.59.

Ethyl 2-cyano-3-(2-hydroxy-6,8-dimethylimidazo[1,2-*a*]pyridin-3-yl)-3-(methylthio)acrylate (6c): From **4c** and **5a**, 55% (Method C, reaction time 15 h) or 62% (Method D, reaction time 15 h), yellow needles, mp 299—302 °C. IR (KBr): ν 1633, 1693, 2200, 3437 cm^{-1}. ^{1}H-NMR δ: 1.26 (3H, br, OCH_2CH_3), 2.33 (3H, br s, 6-Me), 2.50 (3H, br s, 8-Me), 2.53 (3H, br s, SMe), 4.18 (2H, br, OCH_2CH_3), 7.17 (1H, br s, 7-H), 7.75 (1H, br s, 5-H). *Anal.* Calcd for $C_{16}H_{17}N_3O_3S$: C, 57.99; H, 5.17; N, 12.68. Found: C, 57.99; H, 5.17; N, 12.69.

Diethyl [1-(2-hydroxyimidazo[1,2-*a*]pyridin-3-yl)-1-(methylthio)]methylene]malonate (6d): From **4a** and diethyl malonate (**5b**), 55% (Method C, reaction time 15 h) or 62% (Method D, reaction time 15 h), yellow needles, mp 64—66 °C. IR (KBr): ν 1616, 1651, 1718, 3404 cm^{-1}. ^{1}H-NMR δ: 1.18 (6H, t, *J*=7.1 Hz, 2×OCH_2CH_3), 2.16 (3H, s, SMe), 4.17 (4H, q, *J*=7.1 Hz, 2×OCH_2CH_3), 6.97 (1H, br t, *J*=6.8, 6.8 Hz, 6-H), 7.33 (1H, br q, *J*=8.8, 6.8 Hz, 7-H), 7.43 (1H, br d, *J*=8.8 Hz, 8-H), 8.05 (1H, br d, *J*=6.8 Hz, 5-H). ^{13}C-NMR δ: 13.97, 15.71, 60.99, 97.01, 109.87, 114.40, 120.04, 124.52, 127.26, 135.59, 146.83, 156.88, 164.34. *Anal.* Calcd for $C_{16}H_{18}N_2O_5S$: C, 54.84; H, 5.18; N, 7.99. Found: C, 54.54; H, 5.29; N, 8.28.

Diethyl [1-(2-hydroxy-8-methylimidazo[1,2-*a*]pyridin-3-yl)-1-(methylthio)methylene]malonate (6e): From **4b** and (**5b**), 55% (Method C, reaction time 15 h) or 62% (Method D, reaction time 15 h), yellow needles, mp 95—98 °C. IR (KBr): ν 1608, 1638, 1697, 3423 cm^{-1}. ^{1}H-NMR δ: 1.18 (6H, t, *J*=7.1 Hz, 2×OCH_2CH_3), 2.18 (3H, s, SMe), 2.57 (3H, s, 8-Me), 4.17 (4H, q, *J*=7.1 Hz, 2×OCH_2CH_3), 6.88 (1H, t, *J*=7.0, 7.0 Hz, 6-H), 7.13 (br d, *J*=7.0 Hz, 7-H), 7.96 (1H, br d, *J*=7.0 Hz, 5-H). ^{13}C-NMR δ: 14.05, 15.72, 16.38, 60.94, 97.57, 114.06, 119.58, 120.81, 122.54, 127.17, 136.47, 147.47, 157.29, 164.49. *Anal.* Calcd for $C_{17}H_{20}N_2O_5S$: C, 56.03; H, 5.53; N, 7.69. Found: C, 55.93; H, 5.71; N, 7.61.

Diethyl [1-(2-hydroxy-6,8-dimethylimidazo[1,2-*a*]pyridin-3-yl)-1-(methylthio)methylene]malonate (6f): From **4c** and (**5b**), 84% (Method C, reaction time 15 h) or 62% (Method D, reaction time 15 h), yellow needles, mp 182—185 °C. IR (KBr): ν 1610, 1705, 3447 cm^{-1}. ^{1}H-NMR δ: 1.17 (6H, t, *J*=7.1 Hz, 2×OCH_2CH_3), 2.17 (3H, s, SMe), 2.29 (3H, s, 6-Me), 2.51 (3H, s, 8-Me), 4.15 (4H, q, *J*=7.1 Hz, 2×OCH_2CH_3), 6.97 (1H, br s, 7-H), 7.75 (1H, br s, 6-Me). *Anal.* Calcd for $C_{18}H_{22}N_2O_5S$: C, 57.13; H, 5.86; N, 7.40. Found: C, 57.19; H, 5.87; N, 7.33.

Ethyl 2-benzoyl-3-(2-hydroxyimidazo[1,2-*a*]pyridin-3-yl)-3-(methylthio)acrylate (6g): From **4a** and ethyl benzoylacetate (**5c**), 73% (Method C, reaction time 3 h), red prisms, mp 260—263 °C. IR (KBr): ν 1624, 1653, 1701, 3406 cm^{-1}. ^{1}H-NMR δ: 1.07 (3H, t, *J*=7.1 Hz, OCH_2CH_3), 2.02 (3H, s, SMe), 4.12 (2H, q, *J*=7.1 Hz, OCH_2CH_3), 7.05 (1H, t, *J*=6.9, 6-H), 7.31—7.47 (5H, m, 7-, 8-H, Phenyl-H),

7.86—7.91 (2H, m, Phenyl-H), 8.29 (1H, br d, *J*=6.9 Hz, 5-H). ^{13}C-NMR δ: 14.09, 15.73, 60.78, 97.76, 109.86, 114.68, 124.46, 126.34, 127.39, 128.06, 128.53, 132.32, 135.70, 137.84, 145.49, 157.31, 164.24, 193.20. *Anal.* Calcd for $C_{20}H_{18}N_2O_4S$: C, 62.81; H, 4.74; N, 7.33. Found: C, 62.77; H, 5.04; N, 7.07.

Ethyl 2-benzoyl-3-(2-hydroxy-8-methylimidazo[1,2-*a*]pyridin-3-yl)-3-(methylthio)acrylate (6h): From **4b** and **5c**, 98% (Method C, reaction time 17 h), red prisms, mp 209—212 °C. IR (KBr): ν 1618, 1638, 1661, 1719, 3429 cm^{-1}. ^{1}H-NMR δ: 1.05 (3H, t, *J*=7.1 Hz, OCH_2CH_3), 1.94 (3H, s, SMe), 2.48 (3H, s, 8-Me), 4.10 (2H, q, *J*=7.0 Hz, OCH_2CH_3), 6.92 (1H, t, *J*=7.0, 6-H), 7.13 (1H, br d, *J*=7.0 Hz, 7-H), 7.31—7.37 (2H, m, Ph-H), 7.41—7.47 (1H, m, Ph-H), 7.99—8.04 (2H, m, Ph-H), 8.30 (1H, br d, *J*=6.8 Hz, 5-H). ^{13}C-NMR δ: 14.11, 15.51, 16.13, 60.63, 98.20, 114.65, 120.50, 122.35, 126.52, 127.40, 128.01, 128.87, 132.33, 135.95, 137.87, 144.02, 157.76, 164.25, 193.66. *Anal.* Calcd for $C_{21}H_{20}N_2O_4S$: C, 63.62; H, 5.08; N, 7.07. Found: C, 63.53; H, 5.16; N, 7.08.

Ethyl 2-benzoyl-3-(2-hydroxy-6,8-dimethylimidazo[1,2-*a*]pyridin-3-yl)-3-(methylthio)acrylate (6i): From **4c** and **5c**, 78% (Method C, reaction time 17 h), red prisms, mp 234—236 °C. IR (KBr): ν 1616, 1660, 1712, 3409 cm^{-1}. ^{1}H-NMR δ: 1.05 (3H, t, *J*=7.1 Hz, OCH_2CH_3), 1.95 (3H, s, SMe), 2.32 (3H, s, 6-Me), 2.41 (3H, s, 8-Me), 4.10 (2H, q, *J*=7.1 Hz, OCH_2CH_3), 7.15 (1H, br s, 7-H), 7.30—7.37 (2H, m, Ph-H), 7.39—7.47 (1H, m, Ph-H), 7.97—8.04 (2H, m, Ph-H), 8.09 (1H, br s, 5-H). ^{13}C-NMR δ: 14.11, 15.32, 15.50, 16.14, 60.62, 98.22, 114.62, 120.55, 122.35, 126.59, 127.35, 128.01, 128.90, 132.32, 136.04, 137.89, 144.00, 157.78, 164.24, 193.63. *Anal.* Calcd for $C_{22}H_{22}N_2O_4S$: C, 64.37; H, 5.40; N, 6.82. Found: C, 64.51; H, 5.42; N, 6.68.

Ethyl 2-acetyl-3-(2-hydroxy-6,8-dimethylimidazo[1,2-*a*]pyridin-3-yl)-3-(methylthio)acrylate (6l): From **4c** and **5c**, 78% (Method C, reaction time 17 h), red prisms, mp 234—236 °C. IR (KBr): ν 1616, 1660, 1712, 3409 cm^{-1}. ^{1}H-NMR δ (DMSO-d_6): 0.95 (3H, t, *J*=7.1 Hz, OCH_2CH_3), 2.08 (3H, s, SMe), 2.09 (3H, s, 6-Me), 2.22 (3H, s, 8-Me), 2.23 (3H, s, COMe), 4.10 (2H, q, *J*=7.1 Hz, OCH_2CH_3), 7.09 (1H, br s, 7-H), 8.17 (1H, br s, 5-H), 8.24 (1H, s, OH). *Anal.* Calcd for $C_{17}H_{20}N_2O_4S$: C, 64.37; H, 5.40; N, 6.82. Found: C, 64.51; H, 5.42; N, 6.68.

Preparation of 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-2-ones (7a-h,i',l'). General method. Ethyl 3-(2-hydroxyimidazo[1,2-*a*]pyridin-3-yl)-3-(methylthio)acrylate (**6**, 0.5 mmol) without any solvent was put in a test tube equipped with a vacuum system, and the tube was heated by an electronic furnace under reduced pressure (3 torr) at the reaction temperature and for the time described for each compound **7a—h,i',l'**. The resulting reaction mixture was dissolved in as small amount of $CHCl_3$ as possible and the solution was separated by column chromatography on silica gel using $CHCl_3$-EtOH (9:1). The yellow fractions which eluted first were combined and concentrated under reduced pressure. The

recrystallization of the residue from $CHCl_3$-Et_2O afforded the corresponding 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-2-one derivative (**7**).

First we examined the syntheses of these compounds **7a—i,l** by the reactions of ethyl 3-[2-hydroxyimidazo[1,2-*a*]pyridine-3-yl]acrylates (**6a—i,l**) under various reaction conditions (for example, heating at 80 °C in DMF in the presence of a base such as potassium *t*-butoxide, heating at 80 °C in acetic acid, and treatment with concentrated sulfuric acid at room temperature), but the expected 2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-2-ones (**7a—i,l**) could not be obtained at all.

Some physical and spectral data for these products **7a—h**,**i',l'** are shown below.

4-Methylthio-2-oxo-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-3-carbonitrile (7a): From **6a,** 21% (reaction temperature 75 °C, time 15 min), yellow needles, mp 266—270 °C. IR (KBr): ν 1715, 2216 cm^{-1}. ^{1}H-NMR δ: 3.11 (3H, s, SMe), 7.23 (1H, ddd, *J*=7.0, 7.0, 1.4 Hz, 7-H), 7.67 (1H, ddd, *J*=9.0, 7.0, 1.2 Hz, 8-H), 7.79 (1H, br d, *J*=9.0 Hz, 9-H), 9.17 (1H, br d, *J*=7.0 Hz, 6-H). *Anal.* Calcd for $C_{12}H_{17}N_3O_2S$: C, 56.02; H, 2.74; N, 16.33. Found: C, 56.20; H, 2.79; N, 16.11.

9-Methyl-4-methylthio-2-oxo-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-3-carbonitrile (7b): From **6b,** 50% (reaction temperature 150 °C, time 10 min), yellow needles, mp 287—291 °C. IR (KBr): ν 1705, 2214 cm^{-1}. ^{1}H-NMR δ: 2.65 (3H, s, 9-Me), 3.09 (3H, s, SMe), 7.12 (1H, t, *J*=7.0, 7-H), 7.46 (1H, br d, *J*=7.0 Hz, 8-H), 9.02 (1H, br d, *J*=7.0 Hz, 6-H). *Anal.* Calcd for $C_{13}H_9N_3O_2S$: C, 57.55; H, 3.34; N, 15.49. Found: C, 57.44; H, 3.26; N, 15.69.

7,9-Dimethyl-4-methylthio-2-oxo-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-3-carbonitrile (7c): From **6c,** 42% (reaction temperature 200 °C, time 20 min), yellow needles, mp >300 °C. IR (KBr): ν 1667, 2212 cm^{-1}. ^{1}H-NMR δ: 2.44 (3H, s, 7-Me), 2.61 (3H, s, 9-Me), 3.08 (3H, s, SMe), 7.32 (1H, s, 8-H), 8.80 (1H, br s, 6-H). *Anal.* Calcd for $C_{14}H_{11}N_3O_2S$: C, 58.93; H, 3.89; N, 14.73. Found: C, 58.63; H, 3.88; N, 15.01.

Ethyl 4-methylthio-2-oxo-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-3-carboxylate (7d): From **6d,** 59% (reaction temperature 100 °C, time 15 min), yellow needles, mp 172—175 °C. IR (KBr): ν 1703 cm^{-1}. ^{1}H-NMR δ: 1.42 (3H, t, *J*=7.2 Hz, $OCH_2\mathit{CH_3}$), 2.63 (3H, s, SMe), 4.43 (2H, q, *J*=7.2 Hz, $O\mathit{CH_2}CH_3$), 7.13 (1H, ddd, *J*=7.0, 7.0, 1.2 Hz, 7-H), 7.54 (1H, ddd, *J*=9.0, 7.0, 1.2 Hz, 8-H), 7.73 (1H, br d, *J*=9.0 Hz, 9-H), 9.17 (1H, br d, *J*=7.0 Hz, 6-H). ^{13}C-NMR δ: 14.01, 17.79, 62.31, 105.99, 112.06, 114.50, 117.71, 127.06, 129.49, 145.37, 145.83, 156.52, 157.42, 164.96. *Anal.* Calcd for $C_{14}H_{12}N_2O_4S$: C, 55.25; H, 3.97; N, 9.21. Found: C, 55.25; H, 4.07; N, 9.50.

Ethyl 9-methyl-4-methylthio-2-oxo-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-3-carboxylate (7e): From **6e,** 65% (reaction temperature 100 °C, time 20 min), yellow needles, mp 164—167 °C. IR (KBr): ν 1709 cm^{-1}. ^{1}H-NMR δ: 1.42 (3H, t, *J*=7.2 Hz, $OCH_2\mathit{CH_3}$), 2.61 (3H, s, 8-Me), 2.62 (3H, s, SMe), 4.43

(2H, q, *J*=7.2 Hz, O*CH*$_2$CH$_3$), 7.05 (1H, t, *J*=7.0, 7.0 Hz, 7-H), 7.35 (br d, *J*=7.0 Hz, 8-H), 9.01 (1H, br d, *J*=7.0 Hz, 6-H). ^{13}C-NMR δ: 14.12, 17.00, 17.91, 62.32, 106.41, 112.16, 114.41, 124.73, 128.05, 128.58, 145.31, 146.05, 156.33, 157.50, 164.85. *Anal.* Calcd for $C_{15}H_{14}N_2O_4S$: C, 56.59; H, 4.43; N, 8.80. Found: C, 56.52; H, 4.34; N, 8.97.

Ethyl 7,9-dimethyl-4-methylthio-2-oxo-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-3-carboxylate (7f): From **6f,** 73% (reaction temperature 100 °C, time 90 min), yellow needles, mp 181—184 °C. IR (KBr): ν 1693 cm^{-1}. ^{1}H-NMR δ: 1.42 (3H, t, *J*=7.1 Hz, OCH$_2$*CH$_3$*), 2.41 (3H, s, 7-Me), 2.60 (3H, s, 9-Me), 2.62 (3H, s, SMe), 4.43 (2H, q, *J*=7.1 Hz, O*CH*$_2$CH$_3$), 7.21 (1H, br s, 8-H), 8.81 (1H, br s, 6-Me). ^{13}C-NMR δ: 14.14, 16.89, 17.91, 18.61, 62.29, 106.33, 111,76, 122.71,124.37, 127.17, 131.63, 144.97, 145.37, 156.28, 157.58, 165.01. *Anal.* Calcd for $C_{16}H_{26}N_2O_4S$: C, 57.82; H, 4.85; N, 8.43. Found: C, 57.78; H, 4.78; N, 8.54.

3-Benzoyl-4-methylthio-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridin-2-one (7g): From **6g,** 59% (reaction temperature 50 °C, time 20 min), orange needles, mp 161—164 °C. IR (KBr): ν 1655, 1696 cm^{-1}. ^{1}H-NMR δ: 2.44 (3H, s, SMe), 7.14 (1H, ddd, *J*=7.0, 7.0, 1.4 Hz, 7-H), 7.46—7.52 (2H, m, Phenyl-H), 7.56 (1H, ddd, J=9.0, 7.0, 1.2 Hz, 8-H), 7.58—7.64 (1H, m, Phenyl-H), 7.86—7.91 (2H, m, Phenyl-H), 8.29 (1H, br d, *J*=7.0 Hz, 5-H). *Anal.* Calcd for $C_{18}H_{12}N_2O_3S$+H_2O: C, 61.01; H, 3.98; N, 7.91. Found: C, 60.87; H, 4.24; N, 7.79.

3-Benzoyl-9-methyl-4-methylthio-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridin-2-one (7h): From **6h,** 66% (reaction temperature 100 °C, time 15 min), orange needles, mp 193—196 °C. IR (KBr): ν 1697 cm^{-1}. ^{1}H-NMR δ: 2.42 (3H, s, SMe), 2.67 (3H, s, 9-Me), 7.04 (1H, t, *J*=7.0, 7.0 Hz, 7-H), 7.36 (1H, br d, *J*=7.0 Hz, 8-H), 7.44—7.51 (2H, m, Ph-H), 7.57—7.63 (1H, m, Ph-H), 7.95—8.00 (2H, m, Ph-H), 9.06 (1H, br d, *J*=7.0 Hz, 6-H). *Anal.* Calcd for $C_{19}H_{14}N_2O_3S$: C, 65.13; H, 4.03; N, 7.99. Found: C, 65.04; H, 3.97; N, 8.14.

3-Benzoyl-7,9-dimethyl-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridin-2-one (7i'): From **6i,** 34% (reaction temperature 100 °C, time 45 min), orange needles, mp 250—252 °C. IR (KBr): ν 1641, 1716 cm^{-1}. ^{1}H-NMR δ: 2.42 (3H, s, 7-Me), 2.62 (3H, s, 9-Me), 7.28 (1H, br s, 8-H), 7.41—7.48 (2H, m, Ph-H), 7.52—7.59 (1H, m, Ph-H), 7.76—7.82 (2H, m, Ph-H), 8.03 (1H, br s, 6-H), 8.56 (1H, s, 4-H). ^{13}C-NMR δ: 16.72, 18.21, 100.37, 107.97, 113.16, 120.74, 125.12, 127.65, 128.03, 128.97, 132.49, 133.11, 133.95, 137.67, 146.33, 159.12, 160.68, 192.40. *Anal.* Calcd for $C_{19}H_{14}N_2O_3$: C, 71.69; H, 4.43; N, 8.80. Found: C, 71.83; H, 4.33; N, 8.77.

7,9-Dimethyl-4-methylthio-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridin-2-one (7l'): From **6l,** 16% (reaction temperature 100 °C, time 30 min), yellow needles, mp 222—226 °C. IR (KBr): ν 1701 cm^{-1}.

^{1}H-NMR δ (DMSO-d_6): 2.38 (3H, s, 7-Me), 2.58 (3H, s, 9-Me), 2.64 (3H, s, SMe), 5.71 (1H, s, 3-H), 7.12 (1H, br s, 8-H), 8.35 (1H, br s, 6-H). *Anal.* Calcd for $C_{13}H_{12}N_2O_2S$: C, 59.98; H, 4.65; N, 10.76. Found: C, 60.27; H, 4.64; N, 10.48.

Crystallography of 3-[Bis(methylthio)methylene]-6,8-dimethyl-2(3*H*)-imidazo[1,2-*a*]pyridinone (4c) A red prismatic single crystal (0.82×0.28×0.24 mm) grown from $CHCl_3$-hexane was used for the unit-cell determinations and data was collected using a Rigaku AFC5S four-circle diffractometer with graphite-monochromated MoK_α radiation (λ=0.71069 Å). The crystal data of this compound are as follows: **4c**: $C_{12}H_{14}N_2OS_2$; M=266.38; monoclinic, space group $P2_1/n$ (#14), Z=4 with a=10.95(3) Å, b=10.388(14) Å, c=11.518(14) Å, β=105.97(14)°, V=1259.8(38) Å^3 and $D_{calc.}$=1.404 g/cm^3. All calculations were performed using CrystalStructure.[28] The structure was solved by a direct method (SIR).[29] The non-hydrogen atoms were refined anisotropically, and the hydrogen atoms were attached at the idealized position and not refined. The final R- and R_w-factors after full-matrix least-squares refinements were 0.048 and 0.039 respectively for 1897 (I>2.00σ(I)) observed reflections.

Crystallography of ethyl 4-methylthio-2-oxo-2*H*-pyrano[2',3':4,5]imidazo[1,2-*a*]pyridine-3-carboxylate (7d) A yellow prismatic single crystal (0.82×0.68×0.32 mm) grown from $CHCl_3$ was used for the unit-cell determinations and data was collected using a Rigaku AFC5S four-circle diffractometer with graphite-monochromated MoK_α radiation (λ=0.71069 Å). The crystal data of this compound are as follows: **3c**: $C_{14}H_{12}N_2O_4S$; M=304.32; triclinic, space group P-1(#2), Z=2 with a=7.959(13) Å, b=13.19(2) Å, c=7.116(13) Å, α=103.98(16)°, β=104.73(14)°, γ=75.74(13)°, V=687.2(19) Å^3 and $D_{calc.}$=1.471 g/cm^3. All calculations were performed using CrystalStructure.[28] The structure was solved by a direct method (SIR).[29] The non-hydrogen atoms were refined anisotropically, and the hydrogen atoms were attached at the idealized position and not refined. The final R- and R_w-factors after full-matrix least-squares refinements were 0.076 and 0.068 respectively for 2383 (I>2.00σ(I)) observed reflections.

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