Preparation of New Nitrogen-Bridged Heterocycles. 48.[1] Syntheses and Reactions of Ethyl 3-[2-(Methylthio)indolizin-3-yl]acrylate Derivatives

Akikazu KAKEHI,* Suketaka ITO, and Hoh SA

Department of Chemistry and Material Engineering, Faculty of Engineering, Shinshu University, Wakasato, Nagano 380–8553, Japan. Received June 21, 1999; accepted July 30, 1999

Title compounds were prepared in 20—72% yields from the *S*-aklylation of pyridinium 1- [3-ethoxycarbonyl-1-[(methylthio)thiocarbonyl]]allylides with some alkyl halides, followed by the treatment of the resulting pyridinium salts with a base and then a dehydrogenating agent. In part of these reactions novel heterocycles, ethyl 1-cyano-3-(methylthio)thieno[3,4-*b*]indolizine-9-carboxylates, were also formed. The oxidation of the title compounds with *m*-chloroperbenzoic acid gave the corresponding sulfoxides in moderate to good yields, which smoothly underwent Pummerer reactions on treatment with acetic anhydride. The bromination of the 3-vinyl group in the title compounds, followed by treatment of the resulting dibromo adducts with a base afforded ethyl 2-bromo-3-[2-(methylthio)indolizin-3-yl]acrylates, 3-[1-cyano-2-(methylthio)indolizin-3-yl]propiolates, and ethyl thieno[2,3-*b*]indolizine-2-carboxylate depending upon the substrate used.

Key words 3-vinylindolizine; oxidation; bromination; pyridinium methylide; cyclization; Pummerer reaction

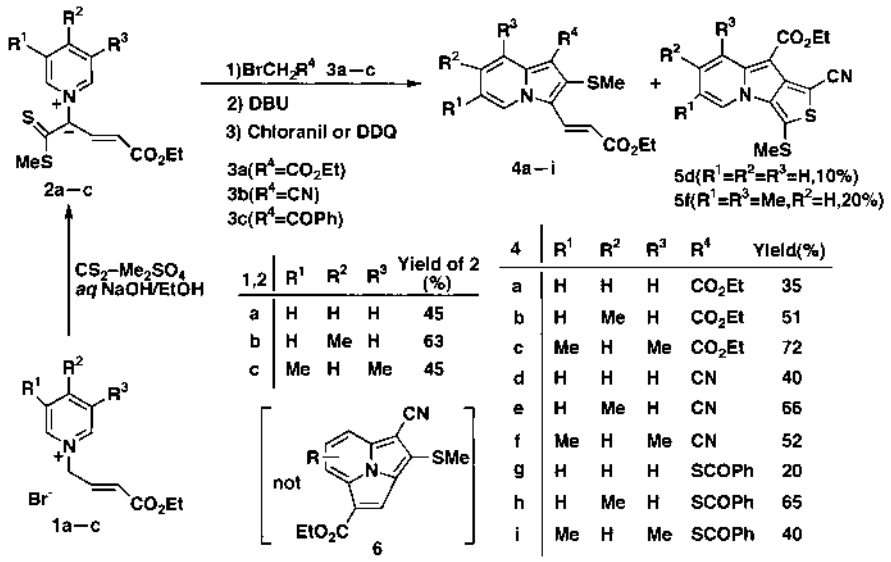
In recent papers from our laboratory we described the smooth syntheses of indolizines[2] and pyrido[1,2-*d*][1,4]thiazepines[3] starting from pyridinium methylides possessing a thiocarbonyl group at the anionic carbon. We also confirmed the usefulness of these products as precursors for some fused indolizines[1,4] and hetero-cage compounds.[5] The reactions of these pyridinium (1-thiocarbonyl)methylides were initiated by the attack of an electrophile on the sulfur atom of the thiocarbonyl group. On the other hand, other pyridinium methylides without a thiocarbonyl substituent on the ylidic carbanion are known to react exclusively with dipolarophiles at the carbanion and the 2-carbon to afford the corresponding indolizines.[6] Similarly, pyridinium allylides gave indolizines through their intramolecular 1,5-dipolar cyclizations.[6b] In a continuation of our studies on this series we are especially interested in the development of new pyridinium methylides, by which novel reactivities can be expected and the access to novel heterocycles is possible. In this paper we report the preparations and the reactions of pyridinium vinyl-substituted (thiocarbonyl)methylides, and some transformation reactions of the 2- and 3-substituents in 2-methylthio-3-vinylindolizine derivatives formed.

Results and Discussion

Preparations and Reactions of Pyridinium 1-[3-Ethoxycarbonyl-1-[methylthio(thiocarbonyl)]allylides These pyridinium 1-[3-ethoxycarbonyl-1-[methylthio(thiocarbonyl)]-allylides (**2a**—**c**) were formed in moderate yields from the reactions of the corresponding pyridinium salts **1a**—**c** with carbon disulfide and dimethyl sulfate in the presence of a base. Interestingly, these ylides **2a**—**c** are very stable compounds and did not show the tendency for the 1,5-dipolar cyclization at all as seen in pyridinium 1-allylides reported earlier.[6b] The *S*-alkylation of these pyridinium allylides (**2a**—**c**) with ethyl bromoacetate (**3a**), bromoacetonitrile (**3b**), and phenacyl bromide (**3c**), followed by the treatment of the resulting pyridinium salts with a base and then dehydrogenating agent afforded the expected ethyl 3-[1-ethoxycarbonyl-(**4a**—**c**), 3-[1-cyano-(**4d**—**f**), and 3-[1-benzoylthio-2-(methylthio)indolizin-3-yl]acrylates (**4g**—**i**) in 20—72% yields as yellow crystalline products. In the reactions of pyridinium allylides (**2a**, **c**) with **3b**, quite different types of products, ethyl 1-cyano-3-(methylthio)thieno[3,4-*b*]indolizine-9-carboxylates **5d**, **f**, were also formed in 10 and 20% yields, respectively, as strong fluorescent orange crystals. These results are shown in Chart 1.

The structures of pyridinium allylides **2a**—**c** were determined by physical and spectral means and by spectral comparison with other pyridinium (thiocarbonyl)methylides.[2,7] The vinyl protons in ^{1}H-NMR spectra of **2a**—**c** appeared as AB type signals coupled with 14.0 Hz at near δ 4.3 and 8.4. The upfield shift for one (near δ 4.3) of the vinyl protons showed the high electron density at the 1(3)-position, though the 1,5-dipolar cyclization was not observed. The IR spectra of 3-vinylindolizine derivatives **4a**—**i** showed characteristic absorption bands due to the ester carbonyl and the 3-vinyl groups at 1685—1703 and 1610—1618 cm^{-1}, respectively. The *trans* configuration of the 3-vinyl group was deduced from a large coupling constant (16.0 Hz) between two vinyl protons in their ^{1}H-NMR spectra. The elemental analyses of **4a**—**i** were also in good accord with the compositions of our proposed structures. Some physical and spectral data of compound **4d** coincided with those reported earlier by Kobayashi and his colleagues.[8] On the other hand, the structures for minor products **5d**, **f** were initially suspected to be cyclo[3.2.2]azine derivatives such as **6** owing to their strong fluorescence. However, this structure **6** was discarded by the presence of the signals {δ 6.84 (1H, br t, J=7.0, 7.0 Hz, 6-H), 7.49 (1H, br q, J=7.0, 9.0 H, 7-H), 8.44 (1H, br d, J=9.0 Hz, 8-H), 9.05 (1H, d, J=7.0 Hz, 5-H)} attributable to the 4 protons on the pyridine ring in ^{1}H-NMR spectrum of **5d** and by the involvement of two sulfur atoms in elemental analyses of **5d**, **f**. Furthermore, the chemical shift (δ 8.44) for the 8-H of **5d** was more suggestive of the structure: This is close to the value (δ 8.34) for the 8-H in ethyl 3-vinylindolizine-9-carboxylate (**4a**) but not to that (δ 7.70) in 3-vinylindolizine-9-carbonitrile (**4d**). The structures, ethyl 1-cyano-3-(methylthio)thieno[3,4-*b*]indolizine-9-carboxylates for **5d**, **f** were ultimately decided by examining these spectral data and their formation mechanisms in detail (see Mecha-

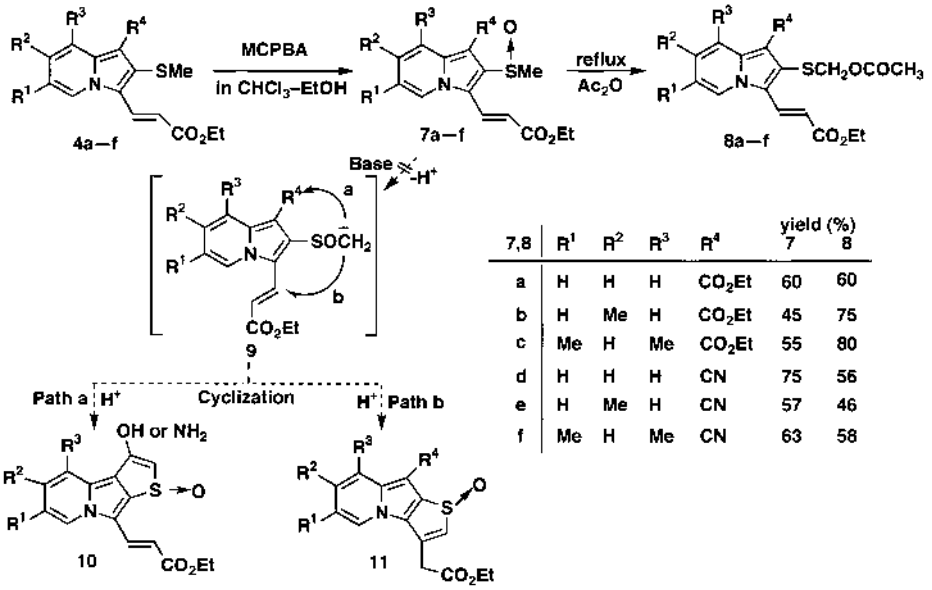
* To whom correspondence should be addressed.



1,2	R^1	R^2	R^3	Yield of 2 (%)
a	H	H	H	45
b	H	Me	H	63
c	Me	H	Me	45

4	R^1	R^2	R^3	R^4	Yield(%)
a	H	H	H	CO_2Et	35
b	H	Me	H	CO_2Et	51
c	Me	H	Me	CO_2Et	72
d	H	H	H	CN	40
e	H	Me	H	CN	66
f	Me	H	Me	CN	52
g	H	H	H	SCOPh	20
h	H	Me	H	SCOPh	65
i	Me	H	Me	SCOPh	40

Chart 1



7,8	R^1	R^2	R^3	R^4	yield (%) 7	8
a	H	H	H	CO_2Et	60	60
b	H	Me	H	CO_2Et	45	75
c	Me	H	Me	CO_2Et	55	80
d	H	H	H	CN	75	56
e	H	Me	H	CN	57	46
f	Me	H	Me	CN	63	58

Chart 2

nisms). In connection with the structural assignment for **5d**, **f**, we also investigated thermal transformation of these 3-vinylindolizines (**4a**—**f**) to cyclo[3.2.2]azines (**6**) in the absence or presence of dehydrogenating agent such as Pd/C, but we were unable to obtain good results.

Syntheses and Pummerer Reactions of 2-Methylsulfinyl-3-vinylindolizines We previously observed that the functionalization of 2-(alkylamino)indolizine derivatives having substituents at the 1- and 3-positions suffered severe steric interference.[4e] To investigate the reactivities of the 2-methylthio group in these 1,2,3-trisubstituted indolizines **4a**—**f** and to accomplish the functionalization of this group we examined their reactions with an oxidizing agent. When 2-methylthio-3-vinylindolizines (**4a**—**f**) were treated with *m*-chloroperbenzoic acid (MCPBA) in ethanol–chloroform at room temperature, the corresponding 2-methylsulfinyl-3-vinylindolizines (**7a**—**f**) were smoothly formed in 45—75% yields. In these reactions no attack of MCPBA to the 3-vinyl group could be detected. The high reactivity of the 2-methylthio group in **4a**—**f** in this oxidation may be owing to the reduction of the steric repulsion based upon its longer carbon-sulfur bond and/or to the small introducing atom (oxygen) derived from MCPBA.

Since the increase of the acidity of the methyl hydrogens in the 2-substituent through the transformation from sulfides **4a**—**f** to sulfoxides **7a**—**f** was expected, the alkaline treatment of **7a**—**f** was examined with the expectation of the formation of 2-unsubstituted thieno[3,2-*a*]- (**10**) and thieno[2,3-*b*]indolizine-1-oxides (**11**). The transformations from **7a**—**f** to **10** or **11** in the presence of a base such as 1,9-diazabicyclo[5.4.0]-7-undecene (DBU) or potassium *tert*-butoxide, however, could not be observed even under heating conditions. On the other hand, the reactions of **7a**—**f** with acetic anhydride in the presence of sodium acetate at the refluxing temperature provided the expected Pummerer reaction products, 2-acetoxymethylthio-3-vinylindolizine derivatives

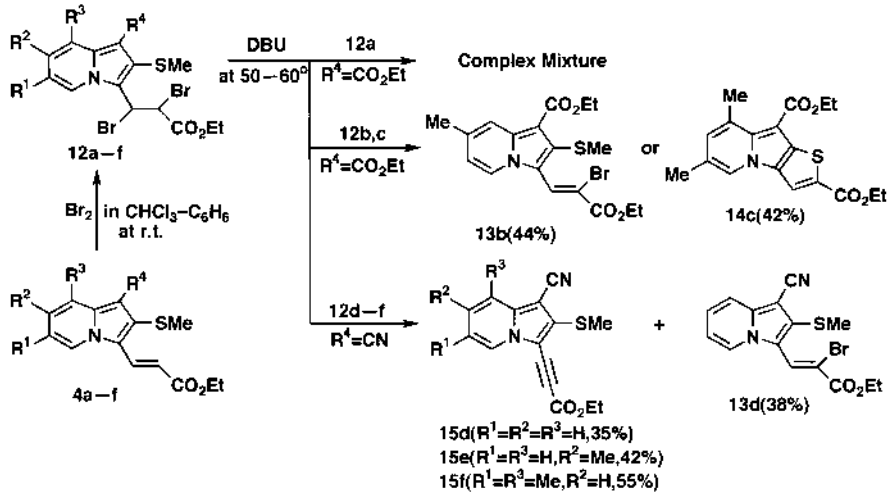


Chart 3

(**8a**—**f**), in 46—80% yields. These results are shown in Chart 2.

The structures of 2-methylsulfinyl-3-vinylindolizines (**7a**—**f**) and 2-(acetoxymethylthio)-3-vinylindolizines (**8a**—**f**) were principally determined by pursuing spectroscopically the structural change of the 2-substituent. For example, the IR spectra of 2-methylsulfinyl-3-vinylindolizines (**7a**—**f**) exhibited a sulfoxide absorption band at 1037—1053 cm^{-1}, and the chemical shifts and signal patterns in their ^{1}H-NMR spectra were similar to those of 2-methylthio-3-vinylindolizines (**4a**—**f**) except the 2-methylsulfinyl signal which appeared at considerably lower magnetic field (near δ 3.1). Similarly, the IR spectra of 2-(acetoxymethylthio)-3-vinylindolizines (**8a**—**f**) showed a new saturated carbonyl absorption band at 1734—1753 cm^{-1} due to an acetoxyl group, and their ^{1}H-NMR spectra provided acetyl and methylene proton signals at δ 2.02—2.12 and δ 5.33—5.50, respectively, with the disappearance of methylthio proton signal. The elemental analyses for products **7a**—**f** and **8a**—**f** coincided with the expected structures.

Brominations of 2-Methylthio-3-vinylindolizines and Alkaline Treatment of Their Adducts We next investigated the reactivity of the 3-vinyl group to a halogen. The reactions of 2-methylthio-3-vinylindolizines (**4a**—**f**) with bromine proceeded smoothly at room temperature, but the dibromo adducts **12a**—**f** were considerably unstable and their isolation and characterization were unsuccessful. This instability of dibromo adducts **12a**—**f** seemed to be due to the change from the electron-withdrawing 2-(ethoxycarbonyl)-vinyl group to the electron-releasing dihaloalkyl group as readily presumable by considering the resonance structures of indolizines. Therefore, dibromo adducts **12a**—**f**, without the isolation, were immediately treated with DBU at 50—60 °C. Although no significant products were isolated in the reaction of **12a** with a base, the reactions of **12b**, **c** with DBU gave 2-methylthio-3-(2-bromovinyl)indolizine (**13b**) and diethyl thieno[2,3-*b*]indolizine-2,9-dicarboxylate (**14c**) in 44 and 42% yields, respectively. Similar treatment of **12d**—**f** afforded methylthio-3-(2-bromovinyl)indolizine (**13d**) and 2-methylthio-3-ethynylindolizines (**15d**—**f**) in moderate yields. These results are shown in Chart 3.

The structures of single (**13b**, **d**) and double dehydrobromination products (**15d**—**f**) were decided by their elemental analyses and IR and ^{1}H-NMR spectral comparisons with those of starting indolizines (**4a**—**f**). The (*Z*)-configuration of the 2-bromo-2-(ethoxycarbonyl)vinyl group in **13b**, **d** was assigned by the lower chemical shifts (δ 8.67 or 8.47) of the remaining vinyl proton. Each characteristic absorption band for the carbon–carbon triple bond was indicated at 2185—2197 cm^{-1} in the IR spectra of compounds **15d**—**f**, though their intensities were very weak. The single crystal X-ray analysis of one compound **15f** was also carried out and its structure was finally confirmed. The ORTEP drawing[9] for **15f** is shown in Fig. 1. The bond length of the carbon–carbon triple bond is 1.178(6) Å and this value is much shorter than the bond length (1.203 or 1.205 Å) in acetylene[10] or cyanoacetylene.[11] Furthermore, this triple bond is more deformed toward the ethoxycarbonyl group [its C(11)–C(12)–C(13) angle is 173.0(5)°] rather than to 3-indolizinyl moiety [its C(3)–C(11)–C(12) angle is 177.8(5)°]. The structure of

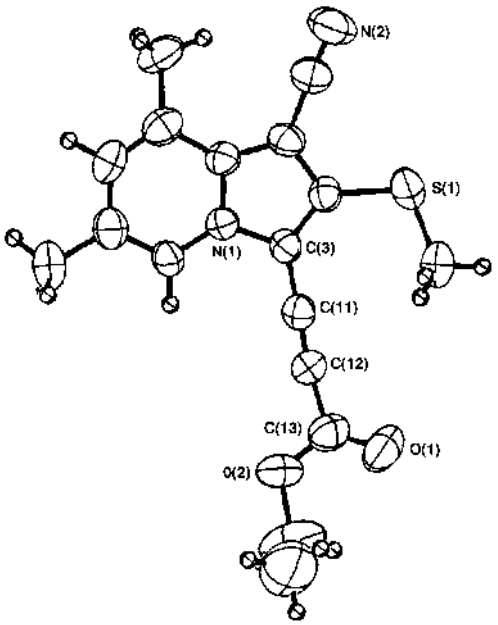


Fig. 1. ORTEP Drawing of Ethyl 3-[1-Cyano-6,8-dimethyl-2-(methylthio)-indolizin-3-yl]propiolate (**15f**)

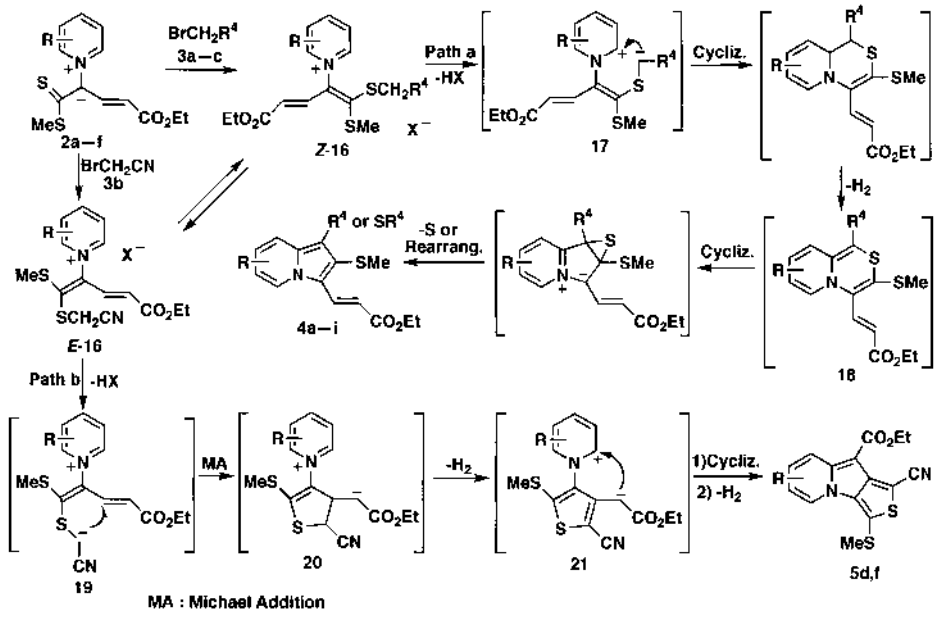


Chart 4

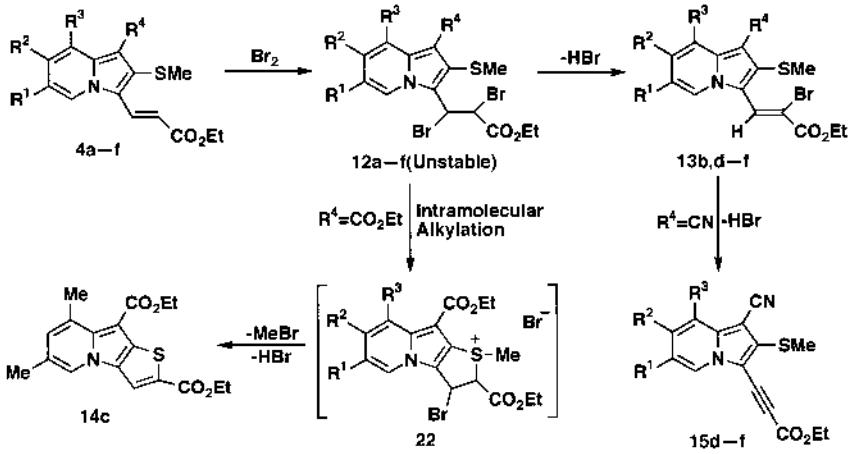


Chart 5

product **14c** was decided by the disappearance of the 2-methylthio signal in the ^{1}H-NMR spectrum and by the lack of involvement of any bromine in the molecule. The IR and ^{1}H-NMR spectral data of **14c** were closely similar to those of the thieno[2,3-*b*]indolizines prepared earlier by us.[4a—c)]

Reaction Mechanisms Possible formation mechanisms of 2-methylthio-3-vinylindolizines (**4a**—**i**) and ethyl 1-cyano-3-(methylthio)indolizine-9-carboxylates (**5d**, **f**) are shown in Chart 4. The route (path a) for the former is the same as that *via* pyrido[1,2-*d*][1,4]thiazine intermediates such as **18** we reported earlier.[2)] Path b for the latter compounds **5d**, **f** is composed of the *S*-alkylation of pyridinium 1-(thiocarbonyl)allylides **2a**, **c** with bromoacetonitrile (**3b**) providing E-16, followed by the intramolecular Michael addition of carbanions **19** generated under the basic conditions, the cyclization of 1,5-dipoles **21** after the dehydrogenation, and final aromatization. Although the reason why similar thieno[3,4-*b*]indolizines (**5**) could not be obtained when the other alkylating agents **3a**, **c** were used was unclear, a higher stabilizing effect toward the carbanion intermediates **19** of the cyano group and/or its less steric interaction may promote this intramolecular Michael addition process.

Possible reaction mechanisms for products **13b**, **d**, **14c**, and **15d**—**f** are indicated in Chart 5. The formations of **13b**, **d**, and **15d**—**f** are the results of single and double dehydrobrominations of the corresponding dibromo adducts **12b**, **d**—**f** in the presence of a base (DBU), respectively. The reason why second dehydrobromination of ethyl 2-bromo-3-[2-(methylthio)indolizin-3-yl]acrylate (**13b**) did not occur may be due to the increased crowd of the pyrrole moiety. In contrast, thieno[2,3-*b*]indolizine (**14c**) must be formed *via* the intramolecular *S*-alkylation of dibromo adduct **12c**, followed by the successive eliminations of methyl bromide and hydrogen bromide from the corresponding sulfonium salt **22**. Since both processes, the dehydrobromination (the regeneration of the conjugated system) and the intramolecular *S*-alkylation (the generation of the strong electron-withdrawing group) of dibromo adducts **12**, stabilize this indolizine ring system, it is not surprising to observe such reactions. However, the reason that no thieno[2,3-*b*]indolizines other than

14c were obtained is still unclear.

Experimental

Melting points were measured with a Yanagimoto micromelting point apparatus and are not corrected. Microanalyses were carried out on a Perkin-Elmer 2400 elemental analyzer. The ^{1}H-NMR spectra were determined with a Hitachi R-600 spectrometer (60 MHz) in deuteriochloroform with tetramethylsilane used as an internal standard; the chemical shifts are expressed in δ values. The IR were taken with a JASCO FT/IR-5300 IR spectrophotometer.

Preparation of Pyridinium 1-[3-Ethoxycarbonyl-1-[methylthio(thiocarbonyl)]allylides These pyridinium 1-[3-ethoxycarbonyl-1-[methylthio(thiocarbonyl)]allylides (**2a**—**c**) were prepared from the alkaline treatment of 1-(3-ethoxycarbonyl-2-propenyl)pyridinium bromides (**1a**—**c**), carbon disulfide, and dimethyl sulfate in ethanol according to the procedure described earlier.[2,7] Some data of compounds **2a**—**c** are as follows:

Pyridinium 1-[3-Ethoxycarbonyl-1-[(methylthio)thiocarbonyl]]allylide (**2a**): 45% (from **1a**), orange needles ($CHCl_3$–ether), mp 182—184 °C. IR (KBr) cm^{-1}: 1660, 1624. ^{1}H-NMR ($CDCl_3$) δ: 1.24 (3H, t, J=7.0 Hz), 2.69 (3H, s), 4.16 (2H, q, J=7.0 Hz), 4.32 (1H, d, J=14.0 Hz), 7.7—8.7 (5H, m), 8.43 (1H, d, J=14.0 Hz). *Anal*. Calcd for $C_{13}H_{15}NO_2S_2$: C, 55.49; H, 5.37; N, 4.98. Found: C, 55.56; H, 5.37; N, 4.91.

4-Methylpyridinium 1-[3-Ethoxycarbonyl-1-[(methylthio)thiocarbonyl]]-allylide (**2b**): 63% (from **1b**), orange needles ($CHCl_3$–ether), mp 188—190 °C. IR (KBr) cm^{-1}: 1685, 1631. ^{1}H-NMR ($CDCl_3$) 1.26 (3H, t, J=7.0 Hz), 2.72 (6H, s), 4.19 (2H, q, J=7.0 Hz), 4.38 (1H, d, J=14.0 Hz), 7.7—8.6 (4H, m), 8.52 (1H, d, J=14.0 Hz). *Anal*. Calcd for $C_{14}H_{17}NO_2S_2$: C, 56.92; H, 5.80; N, 4.74. Found: C, 57.01; H, 5.82; N, 4.83.

3,5-Dimethylpyridinium 1-[3-Ethoxycarbonyl-1-[(methylthio)thiocarbonyl]]allylide (**2c**): 45% (from **1c**), yellow needles ($CHCl_3$–ether), mp 206—207 °C. IR (KBr) cm^{-1}: 1666, 1620. ^{1}H-NMR ($CDCl_3$) 1.27 (3H, t, J=7.0 Hz), 2.55 (6H, s), 2.68 (3H, s), 4.16 (2H, q, J=7.0 Hz), 4.30 (1H, d, J=14.0 Hz), 8.05 (1H, br s), 8.10 (2H, br s), 8.41 (1H, d, J=14.0 Hz). *Anal*. Calcd for $C_{15}H_{19}NO_2S_2+H_2O$: C, 55.02; H, 6.46; N, 4.28. Found: C, 55.17; H, 6.47; N, 4.12.

Preparations of 2-Methylthio-3-vinylindolizine Derivatives. General Method A chloroform solution (20 ml) of pyridinium 1-[(methylthio)thiocarbonyl]methylide (**2**, 2 mmol) was treated with alkyl halide (**3**, 2.4 mmol) at room temperature for 1 d. Evaporation of the solvent from the reaction mixture, followed by the removal of the excess alkylating agent by washing three times with ether (20 ml) gave the corresponding pyridinium salt. The salt was again dissolved in chloroform (30 ml), and the resulting solution was treated with DBU and then chloranil or 2,3-dichloro-4,5-dicyano-*p*-benzoquinone (DDQ) under stirring at 0 °C. The reaction mixture was allowed to react for a further 4 h under the same reaction conditions. The mixture was concentrated under reduced pressure and the residue was separated by column chromatography on alumina using ether and then chloroform. The yellow chloroform layers were combined and concentrated under reduced pressure. Recrystallization from chloroform–hexane of crude products gave the corresponding 3-vinylindolizines **4a**—**i** as yellow needles.

Other types of products **5d**, **f** were also obtained as orange needles together with the expected 3-vinylindolizines **4d**, **f** in the reactions of **2a**, **c** with bromoacetonitrile (**3b**), respectively. Some data on compounds **4a**—**i** and **5d**, **f** are as follows:

Ethyl 3-[1-Ethoxycarbonyl-2-(methylthio)indolizin-3-yl]acrylate (**4a**): 35%, (from **2a** and **3a**), mp 112—114 °C. IR (KBr) cm^{-1}: 1685, 1616. ^{1}H-NMR ($CDCl_3$) δ: 1.36, 1.46 (each 3H, t, J=7.0 Hz), 2.49 (3H, s), 4.32, 4.45 (each 2H, q, J=7.0 Hz), 6.72 (1H, d, J=16.0 Hz), 6.93 (1H, br t, J=7.0, 7.0 Hz), 7.25 (1H, br q, J=7.0, 9.0 Hz), 8.20 (1H, d, J=16.0 Hz), 8.34 (1H, d, J=9.0 Hz), 8.37 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{17}H_{19}NO_4S$: C, 61.24; H, 5.74; N, 4.20. Found: C, 61.41; H, 5.73; N, 4.04.

Ethyl 3-[1-Ethoxycarbonyl-7-methyl-2-(methylthio)indolizin-3-yl]acrylate (**4b**): 51%, (from **2b** and **3a**), mp 103—105 °C. IR (KBr) cm^{-1}: 1689, 1618. ^{1}H-NMR ($CDCl_3$) δ: 1.36, 1.46 (each 3H, t, J=7.0 Hz), 2.41 (3H, s), 2.46 (3H, s), 4.31, 4.45 (each 2H, q, J=7.0 Hz), 6.64 (1H, d, J=16.0 Hz), 6.76 (1H, dd, J=7.0, 2.0 Hz), 8.08 (1H, br s), 8.12 (1H, d, J=7.0 Hz), 8.20 (1H, d, J=16.0 Hz). *Anal*. Calcd for $C_{18}H_{21}NO_4S$: C, 62.23; H, 6.09; N, 4.03. Found: C, 62.37; H, 6.13; N, 3.85.

Ethyl 3-[1-Ethoxycarbonyl-6,8-dimethyl-2-(methylthio)indolizin-3-yl]acrylate (**4c**): 72%, (from **2c** and **3a**), mp 95—97 °C. IR (KBr) cm^{-1}: 1691, 1685, 1618. ^{1}H-NMR ($CDCl_3$) δ: 1.38, 1.44 (each 3H, t, J=7.0 Hz), 2.30 (3H, s), 2.40 (3H, s), 2.44 (3H, s), 4.31, 4.44 (each 2H, q, J=7.0 Hz), 6.74 (1H, br s), 6.80 (1H, d, J=16.0 Hz), 7.99 (1H, br s), 8.12 (1H, d, J=16.0 Hz). *Anal*. Calcd for $C_{19}H_{23}NO_4S$: C, 63.14; H, 6.41; N, 3.88. Found: C, 63.07; H, 6.45; N, 3.66.

Ethyl 3-[1-Cyano-2-(methylthio)indolizin-3-yl]acrylate (**4d**): 40%, (from **2a** and **3b**), mp 142—143 °C (lit.[8] mp 145 °C). IR (KBr) cm^{-1}: 2218, 1695, 1616. ^{1}H-NMR ($CDCl_3$) δ: 1.38 (3H, t, J=7.0 Hz), 2.69 (3H, s), 4.33 (2H, q, J=7.0 Hz), 6.73 (1H, d, J=16.0 Hz), 6.98 (1H, br t, J=7.0, 7.0 Hz), 7.29 (1H, br q, J=7.0, 9.0 Hz), 7.70 (1H, d, J=9.0 Hz), 8.00 (1H, d, J=16.0 Hz), 8.36 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{15}H_{14}N_2O_2S$: C, 62.92; H, 4.93; N, 9.78. Found: C, 63.07; H, 4.84; N, 9.72.

Ethyl 3-[1-Cyano-7-methyl-2-(methylthio)indolizin-3-yl]acrylate (**4e**): 66%, (from **2b** and **3b**), mp 147—149 °C. IR (KBr) cm^{-1}: 2212, 1700, 1616. ^{1}H-NMR ($CDCl_3$) δ: 1.36 (3H, t, J=7.0 Hz), 2.44 (3H, s), 2.66 (3H, s), 4.31 (2H, q, J=7.0 Hz), 6.67 (1H, d, J=16.0 Hz), 6.80 (1H, dd, J=7.0, 2.0 Hz), 7.44 (1H, br s), 7.94 (1H, d, J=16.0 Hz), 8.24 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{16}H_{16}N_2O_2S$: C, 63.98; H, 5.37; N, 9.33. Found: C, 64.06; H, 5.43; N, 9.19.

Ethyl 3-[1-Cyano-6,8-dimethyl-2-(methylthio)indolizin-3-yl]acrylate (**4f**): 52%, (from **2c** and **3b**), mp 116—119 °C. IR (KBr) cm^{-1}: 2206, 1703, 1614. ^{1}H-NMR ($CDCl_3$) δ: 1.39 (3H, t, J=7.0 Hz), 2.35 (3H, s), 2.59 (3H, s), 2.72 (3H, s), 4.32 (2H, q, J=7.0 Hz), 6.78 (1H, d, J=16.0 Hz), 6.87 (1H, br s), 7.97 (1H, d, J=16.0 Hz), 8.00 (1H, br s). *Anal*. Calcd for $C_{17}H_{18}N_2O_2S$: C, 64.94; H, 5.77; N, 8.91. Found: C, 64.99; H, 5.90; N, 8.73.

Ethyl 3-[1-Benzoylthio-2-(methylthio)indolizin-3-yl]acrylate (**4g**): 20%, (from **2a** and **3c**), mp 149—152 °C. IR (KBr) cm^{-1}: 1693, 1670, 1610. ^{1}H-NMR ($CDCl_3$) δ: 1.38 (3H, t, J=7.0 Hz), 2.38 (3H, s), 4.31 (2H, q, J=7.0 Hz), 6.85 (1H, d, J=16.0 Hz), 6.88 (1H, br t, J=7.0, 7.0 Hz), 7.10 (1H, br q, J=7.0, 9.0 Hz), 7.4—8.3 (6H, m, 8-H), 8.20 (1H, d, J=16.0 Hz), 8.40 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{21}H_{19}NO_3S_2$: C, 63.45; H, 4.82; N, 3.52. Found: C, 63.63; H, 4.83; N, 3.33.

Ethyl 3-[1-Benzoylthio-7-methyl-2-(methylthio)indolizin-3-yl]acrylate (**4h**): 65%, (from **2b** and **3c**), mp 158—161 °C. IR (KBr) cm^{-1}: 1698, 1673, 1614. ^{1}H-NMR ($CDCl_3$) δ: 1.36 (3H, t, J=7.0 Hz), 2.37 (6H, s), 4.32 (2H, q, J=7.0 Hz), 6.71 (1H, dd, J=7.0, 2.0 Hz), 6.78 (1H, d, J=16.0 Hz), 7.30 (1H, br s), 7.4—8.3 (5H, m), 8.21 (1H, d, J=16.0 Hz), 8.29 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{22}H_{21}NO_3S_2$: C, 64.21; H, 5.14; N, 3.40. Found: C, 63.95; H, 5.15; N, 3.25.

Ethyl 3-[1-Benzoylthio-6,8-dimethyl-2-(methylthio)indolizin-3-yl]acrylate (**4i**): 40%, (from **2c** and **3c**), mp 156—158 °C. IR (KBr) 1702, 1691, 1678, 1614. ^{1}H-NMR ($CDCl_3$) δ: 1.37 (3H, t, J=7.0 Hz), 2.15 (3H, s), 2.20 (3H, s), 2.34 (3H, s), 4.32 (2H, q, J=7.0 Hz), 6.70 (1H, br s), 6.82 (1H, d, J=16.0 Hz), 7.4—8.3 (5H, m), 8.10 (1H, br s), 8.18 (1H, d, J=16.0 Hz). *Anal*. Calcd for $C_{23}H_{23}NO_3S_2$: C, 64.91; H, 5.45; N, 3.29. Found: C, 64.98; H, 5.48; N, 3.19.

Ethyl 1-Cyano-3-(methylthio)thieno[3,4-*b*]indolizin-9-carboxylate (**5d**): 10%, (from **2a** and **3b**), mp 203—205 °C ($CHCl_3$). IR (KBr) cm^{-1}: 2195, 1698. ^{1}H-NMR ($CDCl_3$) δ: 1.49 (3H, t, J=7.0 Hz), 2.69 (3H, s), 4.54 (2H, q, J=7.0 Hz), 6.84 (1H, br t, J=7.0, 7.0 Hz), 7.49 (1H, br q, J=7.0, 9.0 Hz), 8.44 (1H, br d, J=9.0 Hz), 9.05 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{15}H_{12}N_2O_2S_2$: C, 56.94; H, 3.82; N, 8.85. Found: C, 57.19; H, 3.76; N, 8.66.

Ethyl 1-Cyano-6,8-dimethyl-3-(methylthio)thieno[3,4-*b*]indolizin-9-carboxylate (**5f**): 20%, (from **2c** and **3b**), mp 235—237 °C ($CHCl_3$). IR (KBr) cm^{-1}: 2206, 1695. ^{1}H-NMR ($CDCl_3$) δ: 1.47 (3H, t, J=7.0 Hz), 2.32 (3H, s), 2.65 (3H, s), 2.75 (3H, s), 4.53 (2H, q, J=7.0 Hz), 7.10 (1H, br s), 8.81 (1H, br s). *Anal*. Calcd for $C_{17}H_{16}N_2O_2S_2$: C, 59.28; H, 4.68; N, 8.13. Found: C, 59.36; H, 4.66; N, 8.07.

Reactions of 2-Methylthio-3-vinylindolizines with MCPBA. General method A chloroform–ethanol solution (1 : 1, 10 ml) of 2-methylthio-3-vinylindolizine (**4**, 2 mmol) and MCPBA (2 mmol) was allowed to react under stirring at room temperature for 1 h. The separations of the reaction mixture by column chromatography on alumina using chloroform and recrystallization of the product from chloroform–hexane afforded the corresponding 2-methylsulfinyl-3-vinylindolizine derivative (**7a**—**f**).

Some data on compounds **7a**—**f** are as follows:

Ethyl 3-[1-Ethoxycarbonyl-2-(methylsulfinyl)indolizin-3-yl]acrylate (**7a**): 60% (from **4a**), yellow needles, mp 144—146 °C. IR (KBr) cm^{-1}: 1707, 1687, 1612, 1039. ^{1}H-NMR ($CDCl_3$) δ: 1.38, 1.46 (each 3H, t, J=7.0 Hz), 3.11 (3H, s), 4.35, 4.46 (each 2H, q, J=7.0 Hz), 6.53 (1H, d, J=16.0 Hz), 7.05 (1H, br t, J=7.0, 7.0 Hz), 7.37 (1H, br q, J=7.0, 9.0 Hz), 8.40 (1H, d, J=9.0 Hz), 8.68 (1H, d, J=7.0 Hz), 8.91 (1H, d, J=16.0 Hz). *Anal*. Calcd for $C_{17}H_{19}NO_5S$: C, 58.44; H, 5.48; N, 4.01. Found: C, 58.19; H, 5. 50; N, 3.91.

Ethyl 3-[1-Ethoxycarbonyl-7-methyl-2-(methylsulfinyl)indolizin-3-yl]-acrylate (**7b**): 45% (from **4b**), yellow needles, mp 130—133 °C. IR (KBr) cm^{-1}: 1712, 1684, 1614, 1037. ^{1}H-NMR ($CDCl_3$) δ: 1.37, 1.45 (each 3H, t, J=7.0 Hz), 2.48 (3H, s), 3.09 (3H, s), 4.34, 4.46 (each 2H, q, J=7.0 Hz),

6.46 (1H, d, J=16.0 Hz), 6.87 (1H, dd, J=7.0, 2.0 Hz), 8.14 (1H, br s), 8.54 (1H, d, J=7.0 Hz), 8.90 (1H, d, J=16.0 Hz). *Anal*. Calcd for $C_{18}H_{21}NO_5S$: C, 59.49; H, 5.82; N, 3.85. Found: C, 59.24; H, 5.85; N, 3.65.

Ethyl 3-[1-Ethoxycarbonyl-6,8-dimethyl-2-(methylsulfinyl)indolizin-3-yl]-acrylate (**7c**): 55% (from **4c**), orange needles, mp 124—126 °C. IR (KBr) cm^{-1}: 1714, 1691, 1616, 1053. ^{1}H-NMR ($CDCl_3$) δ: 1.37, 1.43 (each 3H, t, J=7.0 Hz), 2.34 (3H, s), 2.54 (3H, s), 3.09 (3H, s), 4.32, 4.44 (each 2H, q, J=7.0 Hz), 6.42 (1H, d, J=16.0 Hz), 6.85 (1H, br s), 8.10 (1H, br s), 8.41 (1H, d, J=16.0 Hz). *Anal*. Calcd for $C_{19}H_{23}NO_5S$: C, 60.46; H, 6.14; N, 3.71. Found: C, 60.33; H, 6.20; N, 3.60.

Ethyl 3-[1-Cyano-2-(methylsulfinyl)indolizin-3-yl]acrylate (**7d**): 75%, (from **4d**), yellow needles ($CHCl_3$–hexane), mp 145—147 °C. IR (KBr) cm^{-1}: 2208, 1695, 1622, 1043. ^{1}H-NMR ($CDCl_3$) δ: 1.38 (3H, t, J=7.0 Hz), 3.13 (3H, s), 4.35 (2H, q, J=7.0 Hz), 6.53 (1H, d, J=16.0 Hz), 7.11 (1H, br t, J=7.0, 7.0 Hz), 7.44 (1H, br q, J=7.0, 9.0 Hz), 7.88 (1H, d, J=9.0 Hz), 8.08 (1H, d, J=16.0 Hz), 8.42 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{15}H_{14}N_2O_3S$: C, 59.59; H, 4.67; N, 9.27. Found: C, 59.60; H, 4.96; N, 8.99.

Ethyl 3-[1-Cyano-7-methyl-2-(methylsulfinyl)indolizin-3-yl]acrylate (**7e**): 66% (from **4e**), yellow needles, mp 165—168 °C. IR (KBr) cm^{-1}: 2206, 1699, 1628, 1039. ^{1}H-NMR ($CDCl_3$) δ: 1.37 (3H, t, J=7.0 Hz), 2.51 (3H, s), 3.13 (3H, s), 4.36 (2H, q, J=7.0 Hz), 6.50 (1H, d, J=16.0 Hz), 6.98 (1H, dd, J=7.0, 2.0 Hz), 7.63 (1H, br s), 8.08 (1H, d, J=16.0 Hz), 8.36 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{16}H_{16}N_2O_3S$: C, 60.74; H, 5.10; N, 8.85. Found: C, 60.65; H, 5.19; N, 8.85.

Ethyl 3-[1-Cyano-6,8-dimethyl-2-(methylsulfinyl)indolizin-3-yl]acrylate (**7f**): 52%, (from **4f**), orange needles, mp 160—163 °C. IR (KBr) cm^{-1}: 2214, 1707, 1626, 1037. ^{1}H-NMR ($CDCl_3$) δ: 1.36 (3H, t, J=7.0 Hz), 2.37 (3H, s), 2.72 (3H, s), 3.10 (3H, s), 4.31 (2H, q, J=7.0 Hz), 6.49 (1H, d, J=16.0 Hz), 6.97 (1H, br s), 7.98 (1H, d, J=16.0 Hz), 8.04 (1H, br s). *Anal*. Calcd for $C_{17}H_{18}N_2O_3S$: C, 61.80; H, 5.49; N, 8.48. Found: C, 61.90; H, 5.50; N, 8.37.

Pummerer Reactions of 2-Methylsulfinyl-3-vinylindolizines. General Method To a solution of 2-methylsulfinyl-3-vinylindolizine (**7**, 1.5 mmol) in acetic anhydride (5 ml) was added a small amount of sodium acetate (0.1 g) as a catalyst. The resulting mixture was allowed to react under refluxing conditions for 4 h, and then cooled to room temperature. Benzene (6 ml) and hexane (4 ml) were added to the reaction solution, and the precipitates separated were filtered off by suction. The concentration of the filtrate, the separation of the residue by column chromatography on alumina using chloroform, and recrystallization from chloroform–hexane provided the corresponding 2-(acetoxymethylthio-3-vinylindolizine derivatives **8a**—**f** as yellow needles.

Some data on compounds **8a**—**f** are as follows:

Ethyl 3-[2-Acetoxymethylthio-1-ethoxycarbonylindolizin-3-yl]acrylate (**8a**): 60% (from **7a**), mp 144—146 °C. IR (KBr) cm^{-1}: 1734, 1687, 1620. ^{1}H-NMR ($CDCl_3$) δ: 1.38, 1.47 (each 3H, t, J=7.0 Hz), 2.02 (3H, s), 4.35, 4.46 (each 2H, q, J=7.0 Hz), 5.50 (2H, s), 6.31 (1H, d, J=16.0 Hz), 7.02 (1H, br t, J=7.0, 7.0 Hz), 7.35 (1H, br q, J=7.0, 9.0 Hz), 8.23 (1H, d, J=16.0 Hz), 8.40 (1H, d, J=9.0 Hz), 8.49 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{19}H_{21}NO_6S$: C, 58.30; H, 5.41; N, 3.58. Found: C, 58.09; H, 5.48; N, 3.42.

Ethyl 3-[2-Acetoxymethylthio-1-ethoxycarbonyl-7-methylindolizin-3-yl]-acrylate (**8b**): 75% (from **7b**), mp 119—121 °C. IR (KBr) cm^{-1}: 1741, 1693, 1614. ^{1}H-NMR ($CDCl_3$) δ: 1.38, 1.47 (each 3H, t, J=7.0 Hz), 2.02 (3H, s), 2.47 (3H, s), 4.34, 4.47 (each 2H, q, J=7.0 Hz), 5.49 (2H, s), 6.72 (1H, d, J=16.0 Hz), 6.83 (1H, dd, J=7.0, 2.0 Hz), 8.22 (1H, d, J=16.0 Hz), 8.29 (1H, br s), 8.38 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{20}H_{23}NO_6S$: C, 59.24; H, 5.72; N, 3.45. Found: C, 59.47; H, 5.77; N, 3.31.

Ethyl 3-[2-Acetoxymethylthio-1-ethoxycarbonyl-6,8-dimethyl-2-indolizin-3-yl]acrylate (**8c**): 80% (from **7c**), mp 95—97 °C, IR (KBr) 1753, 1724, 1709, 1616. ^{1}H-NMR ($CDCl_3$) δ: 1.34, 1.40 (each 3H, t, J=7.0 Hz), 2.03 (3H, s), 2.30 (3H, s), 2.44 (3H, s), 4.30, 4.43 (each 2H, q, J=7.0 Hz), 5.33 (2H, s), 6.78 (1H, d, J=16.0 Hz), 6.78 (1H, br s), 8.04 (1H, br s), 8.10 (1H, d, J=16.0 Hz). *Anal*. Calcd for $C_{21}H_{25}NO_6S$: C, 60.13; H, 6.01; N, 3.34. Found: C, 60.17; H, 6.06; N, 3.34.

Ethyl 3-[2-Acetoxymethylthio-1-cyanoindolizin-3-yl]acrylate (**8d**): 56%, (from **7d**), mp 125—128 °C. IR (KBr) cm^{-1}: 2206, 1747, 1697, 1614. ^{1}H-NMR ($CDCl_3$) δ: 1.36 (3H, t, J=7.0 Hz), 2.12 (3H, s), 4.35 (2H, q, J=7.0 Hz), 5.41 (2H, s), 6.84 (1H, d, J=16.0 Hz), 7.05 (1H, br t, J=7.0, 7.0 Hz), 7.34 (1H, br q, J=7.0, 9.0 Hz), 7.74 (1H, d, J=9.0 Hz), 8.06(1H, d, J=16.0 Hz), 8.40 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{17}H_{16}N_2O_4S$: C, 59.29; H, 4.68; N, 8.13. Found: C, 59.06; H, 4.63; N, 8.42.

Ethyl 3-[2-Acetoxymethylthio-1-cyano-7-methylindolizin-3-yl]acrylate (**8e**): 46% (from **7e**), mp 134—137 °C. IR (KBr) cm^{-1}: 2214, 1747, 1707, 1622. ^{1}H-NMR ($CDCl_3$) δ: 1.37 (3H, t, J=7.0 Hz), 2.11 (3H, s), 2.47 (3H, s), 4.34 (2H, q, J=7.0 Hz), 5.40 (2H, s), 6.81 (1H, d, J=16.0 Hz), 6.89 (1H, dd, J=7.0, 2.0 Hz), 7.50 (1H, br s), 8.04 (1H, d, J=16.0 Hz), 8.29 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{18}H_{18}N_2O_4S$: C, 60.32; H, 5.06; N, 7.82. Found: C, 60.02; H, 5.13; N, 8.11.

Ethyl 3-[2-Acetoxymethylthio-1-cyano-6,8-dimethyl-indolizin-3-yl]acrylate (**8f**): 58%, (from **7f**), mp 134—136 °C. IR (KBr) cm^{-1}: 2216, 1745, 1711, 1624. ^{1}H-NMR ($CDCl_3$) δ: 1.38 (3H, t, J=7.0 Hz), 2.10 (3H, s), 2.36 (3H, s), 2.74 (3H, s), 4.34 (2H, q, J=7.0 Hz), 5.34 (2H, s), 6.84 (1H, d, J=16.0 Hz), 6.90 (1H, br s), 8.00 (1H, d, J=16.0 Hz), 8.06 (1H, br s). *Anal*. Calcd for $C_{19}H_{20}N_2O_4S$: C, 61.27; H, 5.41; N, 7.52. Found: C, 61.10; H, 5.33; N, 7.31.

Bromination and Dehydrobromination of 2-Methylthio-3-vinylindolizines. General Method A chloroform–benzene solution (1 : 1, 10 ml) of 2-methylthio-3-vinylindolizine (**4**, 2 mmol) and bromine (2.4 mmol) was allowed to react under stirring at room temperature until the disappearance of material was confirmed by TLC monitoring (*ca*. 2 h). Excess DBU (4 mmol) was added to the reaction mixture and the resulting solution was allowed to react in a water bath (50—60 °C) for 3 h. Evaporation of the solvent from the reaction mixture and column chromatographic separation (alumina) of the residue gave the corresponding ethyl 2-bromo-3-[2-(methylthio)indolizin-3-yl]acrylates (**13b**, **d**), diethyl 6,8-dimethylthieno[2,3-*b*]indolizine-2,9-dicarboxylate (**14c**), and 3-[1-cyano-2-(methylthio)indolizin-3-yl]propiolates (**15d**—**f**).

The isolation and purification of the dibromo adducts (**12a**—**f**) were unsuccessful, however, because the removal of the solvent caused their smooth decomposition, and the alkaline treatment of **12a** gave a complex mixture and no significant product could be isolated.

Some data on compounds **13b**, **d**, **14c**, and **15d**—**f** are as follows:

Ethyl 2-Bromo-3-[1-ethoxycarbonyl-7-methyl-2-(methylthio)indolizin-3-yl]acrylate (**13b**): 44% (from **4b**), yellow needles (from $CHCl_3$–hexane), mp 138—140 °C. IR (KBr) cm^{-1}: 1747, 1697, 1606. ^{1}H-NMR ($CDCl_3$) δ: 1.43, 1.48 (each 3H, t, J=7.0 Hz), 2.48 (3H, s), 2.50 (3H, s), 4.44, 4.56 (each 2H, q, J=7.0 Hz), 6.79 (1H, dd, J=7.0, 2.0 Hz), 7.80 (1H, d, J=7.0 Hz), 8.17 (1H, br s), 8.67 (1H, s). *Anal*. Calcd for $C_{18}H_{20}BrNO_4S$: C, 50.71; H, 4.73; N, 3.29. Found: C, 50.70; H, 4.80; N, 3.23.

Ethyl 2-Bromo-3-[1-cyano-2-(methylthio)indolizin-3-yl]acrylate (**13d**): 38% (from **4d**), yellow needles (from $CHCl_3$–hexane), mp 135—137 °C. IR (KBr) cm^{-1}: 2212, 1712, 1612. ^{1}H-NMR ($CDCl_3$) δ: 1.42 (3H, t, J=7.0 Hz), 2.64 (3H, s), 4.44 (2H, q, J=7.0 Hz), 6.97 (1H, br t, J=7.0, 7.0 Hz), 7.30 (1H, br q, J=9.0, 7.0 Hz), 7.75 (1H, br d, J=9.0 Hz), 7.89 (1H, d, J=7.0 Hz), 8.47 (1H, s). *Anal*. Calcd for $C_{15}H_{13}BrN_2O_2S$: C, 49.33; H, 3.59; N, 7.67. Found: C, 49.53; H, 3.57; N, 7.49.

Diethyl 6,8-Dimethylthieno[2,3-*b*]indolizine-2,9-dicarboxylate (**14c**): 42% (from **4c**), orange needles (from $CHCl_3$–hexane), mp 95—97 °C. IR (KBr) cm^{-1}: 1753, 1724, 1709, 1616. ^{1}H-NMR ($CDCl_3$) δ: 1.40, 1.43 (each 3H, t, J=7.0 Hz), 2.32 (3H, s), 2.69 (3H, s), 4.41, 4.43 (each 2H, q, J=7.0 Hz), 6.97 (1H, br s), 7.82 (1H, br s), 7.96 (1H, s). *Anal*. Calcd for $C_{18}H_{19}NO_4S$: C, 62.59; H, 5.54; N, 4.06. Found: C, 62.67; H, 5.59; N, 3.94.

Ethyl 3-[1-Cyano-2-(methylthio)indolizin-3-yl]propiolate (**15d**): 35%, (from **7d**), colorless needles (from $CHCl_3$–hexane), mp 135—137 °C. IR (KBr) cm^{-1}: 2197, 2197, 1693. ^{1}H-NMR ($CDCl_3$) δ: 1.39 (3H, t, J=7.0 Hz), 2.78 (3H, s), 4.37 (2H, q, J=7.0 Hz), 6.84 (1H, d, J=16.0 Hz), 7.02 (1H, br t, J=7.0, 7.0 Hz), 7.37 (1H, br q, J=7.0, 9.0 Hz), 7.69 (1H, d, J=9.0 Hz), 8.42 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{15}H_{12}N_2O_2S$: C, 63.36; H, 4.25; N, 9.85. Found: C, 63.35; H, 4.40; N, 9.71.

Ethyl 3-[1-Cyano-7-methyl-2-(methylthio)indolizin-3-yl]propiolate (**15e**): 42% (from **4e**), colorless needles (from $CHCl_3$–hexane), mp 139—141 °C. IR (KBr) cm^{-1}: 2214, 2191, 1698. ^{1}H-NMR ($CDCl_3$) δ: 1.39 (3H, t, J=7.0 Hz), 2.44 (3H, s), 2.75 (3H, s), 4.36 (2H, q, J=7.0 Hz), 6.83 (1H, dd, J=7.0, 2.0 Hz), 7.43 (1H, br s), 8.26 (1H, d, J=7.0 Hz). *Anal*. Calcd for $C_{16}H_{14}N_2O_2S$: C, 64.41; H, 4.73; N, 9.39. Found: C, 64.33; H, 4.90; N, 9.31.

Ethyl 3-[1-Cyano-6,8-dimethyl-2-(methylthio)indolizin-3-yl]propiolate (**15f**): 55%, (from **4f**), colorless needles (from $CHCl_3$–hexane), mp 127—129 °C. IR (KBr) cm^{-1}: 2206, 2185, 16891, 1624. ^{1}H-NMR ($CDCl_3$) δ: 1.39 (3H, t, J=7.0 Hz), 2.35 (3H, s), 2.72 (6H, s), 4.38 (2H, q, J=7.0 Hz), 6.90 (1H, br s), 8.02 (1H, br s). *Anal*. Calcd for $C_{17}H_{16}N_2O_2S$: C, 65.36; H, 5.16; N, 8.97. Found: C, 65.33; H, 5.25; N, 8.91.

Crystallography of Ethyl 3-[1-Cyano-6,8-dimethyl-2-(methylthio)indolizin-3-yl]propiolate (15f) A single crystal (0.08×0.48×1.00 mm) grown from $CHCl_3$–hexane was used for the unit-cell determinations and the data collections of a Rigaku AFC5S four-circle diffractometer, with graphite-monochromated MoK_α radiation (λ=0.71069 Å). Crystal data of **15f**: $C_{17}H_{16}N_2O_2S$; M=312.39; triclinic, space group $P\bar{1}$ (#2), Z=2 with a=10.153(4) Å, b=10.948(4) Å, c=8.292(3) Å, α=99.26°(3), β=104.37°

(3), $\gamma=65.06°(2)$; $V=807.9(5)$ Å^3, and $D_{calc.}=1.284$ g/cm^3. All calculations were performed using the TEXSAN program.[12] The structure was solved by a direct method (SIR).[13] 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 0.082 and 0.097 for 2111 ($I>2.00\sigma(I)$), respectively, observed reflections.

References

1) For part 47 of this series, see Kakehi A., Ito S., Suga H., Takahashi H., Dobashi K., *Heterocycles*, in press.
2) Kakehi A., Ito S., Yonezu S., Maruta K., Yuito K., *Heterocycles*, **23**, 33—35 (1985); Kakehi A., Ito S., Yonezu S., Maruta K., Yuito K., Shiohara M., Adachi K., *Bull. Chem. Soc. Jpn*., **60**, 1867—1879 (1987); Kakehi A., Ito S., Kinoshita N., Abaka Y., *ibid*, **61**, 2055—2061 (1988); Kakehi A., Ito S., Yamada N., Yamaguchi K., *ibid*, **63**, 829—834 (1990).
3) Kakehi A., Ito S., Hakui J., *Chem. Lett*., **1992**, 777—780 (1986); *idem*, *Bull. Chem. Soc. Jpn*., **66**, 3475—3482 (1993).
4) *a*) Kakehi A., Ito S., Matsumoto S., Morimoto Y., *Chem. Lett*., **1987**, 2043—2046; *b*) Kakehi A., Ito S., Fujii T., Matsumoto S., Morimoto Y., Shiohara M., *Bull. Chem. Soc. Jpn*., **62**, 119—127 (1989); *c*) Kakehi A., Ito S., Yamada N., Yamaguchi K., *Chem. Pharm. Bull*., **38**, 1527—1535 (1990); *d*) Kakehi A., Ito S., Sakurai T., Urushido K., Isawa H., Enomoto M., *Bull. Chem. Soc. Jpn*., **64**, 3289—3295 (1991); *e*) Kakehi A., Ito S., Hayashi S., Fujii T., *ibid*, **68**, 3573—3580 (1995).
5) Kakehi A., Ito S., *Heterocycles*, **36**, 1195—1198 (1993); Kakehi A., Ito S., Mitani M., Kanaoka M., *Bull. Chem. Soc. Jpn*., **67**, 1646—1654 (1994); Kakehi A., Ito S., Fujita S., *ibid*, **68**, 1473—1483 (1995).
6) There are numerous papers for the 1,3-dipolar cycloaddition. See following reviews: *a*) Stuckwisch C. G., *Synthesis*, **1973**, 469—483; *b*) Uchida T., Matsumoto K., *ibid*, **1976**, 209—236.
7) Tominaga Y., Miyake Y., Fujito H., Matsuda Y., Kobayashi G., *Yakugaku Zasshi*, **97**, 927—932 (1977).
8) Maseda C., Sone M., Tominaga Y., Natsuki R., Matsuda Y., Kobayashi G., *Yakugaku Zasshi*, **94**, 839—843 (1974).
9) Johnson C. K., "ORTEP II, Report ORNL-5138," Oak Ridge National Laboratory, Oak Ridge, Tennessee (1976).
10) "Kagaku Binran," ed by Chem. Soc. Jpn., Maruzen, Chap. 15, p II-653.
11) "Kagaku Binran," ed by Chem. Soc. Jpn., Maruzen, Chap. 15, p II-655
12) "TEXSAN TEXRAY", Structure Analysis Package, Molecular Structure Corporation (1985).
13) Burla M. C., Camalli M., Cascarano G., Giacovazzo C., Polidoli G., Spagna R., Viterbo D., *J. Appl. Cryst*., **22**, 389—393 (1989).