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One Step Synthesis of Heteropolycycles, Indolizinoquinolizines by the Reaction of either Pyridylketene Dithioacetal with Pyridinium Salt or Pyridiniumketene Dithioacetal with Pyridylacetonitrile

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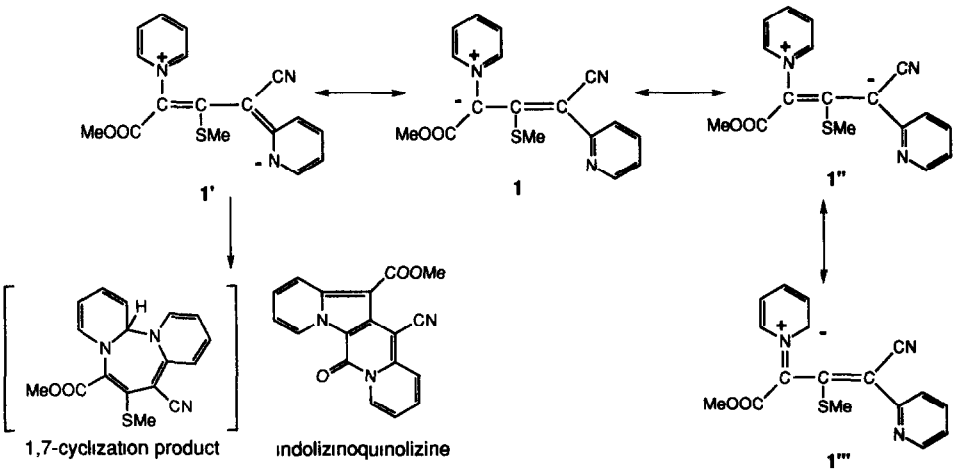
Abstract: The heteropolycycles, indolizinoquinolizines (**7**, **8**, **20**) were obtained by the reaction of either pyridylketene dithioacetal (**2**) with two molar equivalents of pyridinium salts (**4a-c**) or pyridiniumketene dithioacetal (**19**) with two molar equivalents of pyridylacetonitrile (**3**) in the presence of triethylamine

Scheme 1



Pyridinium *N*-allylides and *N*-vinylimino ylides which are prepared by the reaction of pyridinium salts with polarized olefins (ketene dithioacetals and ethoxymethylene compounds) in the presence of a base are well known to give thermal 1,5-dipolar cyclization products and thermal 1,6-cyclization products.[1-8] Ketene dithioacetals functionalized by a cyano, a methoxycarbonyl, a nitro, a sulfonyl, a pyridyl, and so on are versatile reagents which have been extensively utilized in heterocyclic synthesis.[9,10] As a part of our interest in ketene dithioacetal chemistry, we have been studying the reaction of heteroaromatic compounds with various ketene dithioacetals and their analogues.[11-15] One of the *N*-allylide molecule attached the pyridyl moiety at the 3-position of the allyl group is a resonance hybrid of the representative structures (**1**, **1'**, **1"**, **1'''**) shown in Scheme 1.

A number of the previous studies on the *N*-allylide (**1**) have mainly concerned the synthesis of bicyclic compounds with bridgehead nitrogen atom such as indolizine, azaindolizine, pyridotriaziniumide, etc. proceeding by 1,5-dipolar cyclization due to the resonance structure (**1"**) and by 1,6-cyclization due to the resonance structure (**1'"**). We have been taking advantage of an alternative *N*-allylide form according to the resonance structure (**1'**) to realize a novel reaction, 1,7-cyclization. However, our preliminary study on the reaction of the ketene dithioacetal, 3,3-bis(methylthio)-2-pyridylacryronitrile (**2**) with pyridinium salts (**4**) has led to a new heterocyclic ring closure proceeding by the interesting double cyclization to produce the heteropolycycles, indolizinoquinolizines (**7**, **8**).[16] The purpose of the present investigation is to study the extension of the double cyclization to the synthesis of heteropolycycles (**7**, **8**, **10**, **11**, **20**) and to elucidate the mechanism of the double cyclization.

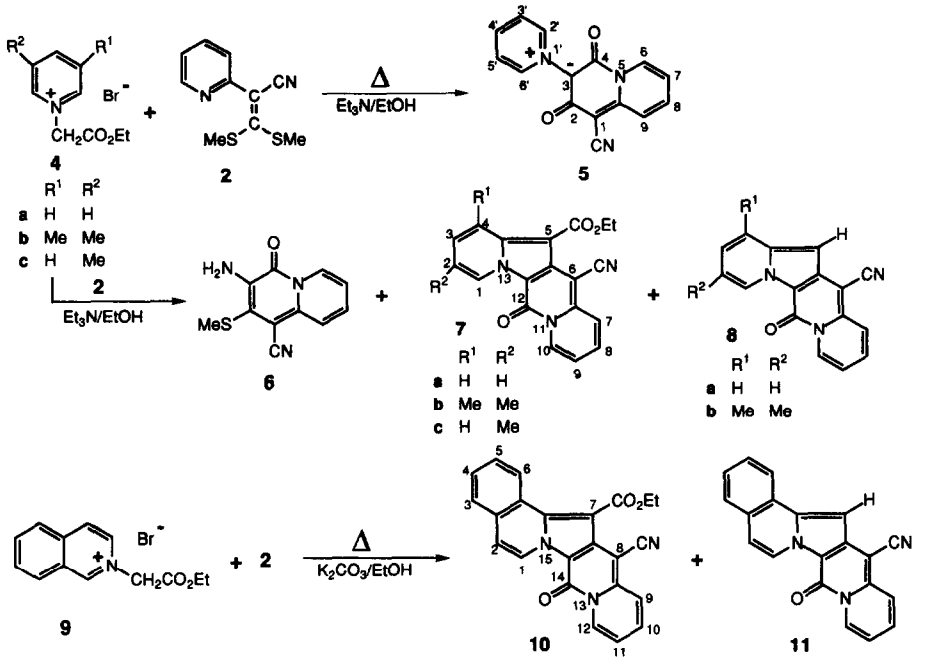
Results and Discussion

The starting pyridylketene dithioacetal (**2**) used in the present work was prepared by the condensation of pyridylacetonitrile (**3**) with carbon disulfide in the presence of sodium hydride in THF, followed by methylation with dimethyl sulfate.[17]

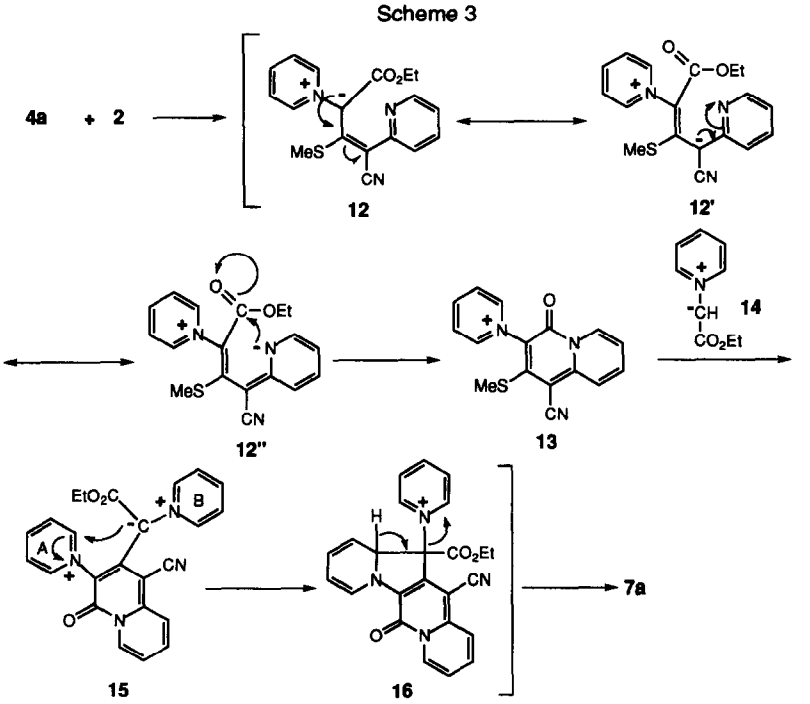
Our attempts to obtaine a 1,7-cyclization product from **2** and the pyridinium salt (**4a**) by the use of triethylamine-$CHCl_3$, K_2CO_3-$CHCl_3$, triethylamine-THF, or K_2CO_3-THF, etc., were failed. Thus, only unreacted and/or alternation or unknown decomposition products could be detected by ^{1}H-NMR spectroscopy and TLC, and these were therefore not further studied. After much investigation, we found that the reaction of **2** with **4a** in the presence of K_2CO_3 in acetonitrile for a week gave an unexpected product, indolizinoquinolizine (**7a**) in the poor yield. For the purpose to find the more suitable synthetic method of **7a**, we carried out following reactions. Heating of **2** and **4a** with triethylamine in refluxing EtOH gave the undesired *N*-ylide, dioxoquinolizine (**5**). It was observed that the reaction of **2** with two molar equivalents of **4a** could be effected smoothly with triethylamine in EtOH at room temperature for a weeek to give indolizinoquinolizines (**7a**, **8a**) together with aminoquinolizone (**6**) in moderate yield. The structure of **7a** was supported by a satisfactory elemental analysis, the presence of one cyano and two carbonyl absorptions in the IR spectrum, and the signals of four doublets ($C_{1,4,7,10}$-H) in the ^{1}H-NMR spectrum. Indolizinoquinolizines (**7b**, **8b**) were also obtained by the reaction of **2** with **4b**. In the reaction of **2** with **4c**, only 2-methylindolizinoquinolizine (**7c**) was obtained. This high regioselectivity may be accounted for by steric factors. As shown in Scheme 3, cyclization would be expected to be hindered as a result of non-bonded interaction between the 3-methyl group of pyridinium (A) moiety and the ethoxycarbonyl and pyridinium (B) groups in the final step (**15** $\longrightarrow$ **16**). Thus, as pointed out by Tamura[18], the production of **7c** may be considered to reflect the steric effect of the methyl group rather than the general tendency for preferential attack at C-2 of pyridinium (A) moiety owing to stabilzation by resonance[19]. Under the similar reaction condition abave for the reaction of **2** with **4**, treatment of **2** and isoquinolizinium salt (**9**) with triethylamine in EtOH could not give a desired product. The synthesis of benzindolizinoquinolizines (**10**, **11**) was achieved on reacting **2** with **9** in the presence of K_2CO_3 in refluxing EtOH for 10 h. (Scheme 2)

The formation of the compound (**7a**) may be rationalized as outlined in Scheme 3. Thus, *N*-allylide (**12**) does not undergo 1,5-dipolar cyclization due to the resonance structure (**12'**) to give an indolizine derivative but **12** cyclizes as a 1,6-dipole due to **12"** to give pyridinium oxoquinolizine (**13**), followed by the substitution of the methylthio group of **13** with the pyridinium *N*-ylide (**14**) to give the betaine (**15**) which leads to **7a** *via* the

Scheme 2

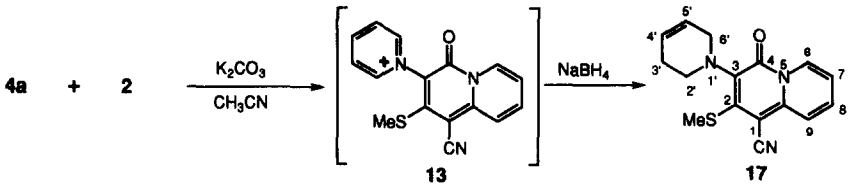


Scheme 3



intermediate (**16**). According to this mechanism, we presumed that dioxoquinolizine (**5**) was obtained by the hydrolysis of the methylthio group of the intermediate (**13**) and aminoquinolizone (**6**) was produced by the ring cleavage of the pyridinium moiety of **13**.

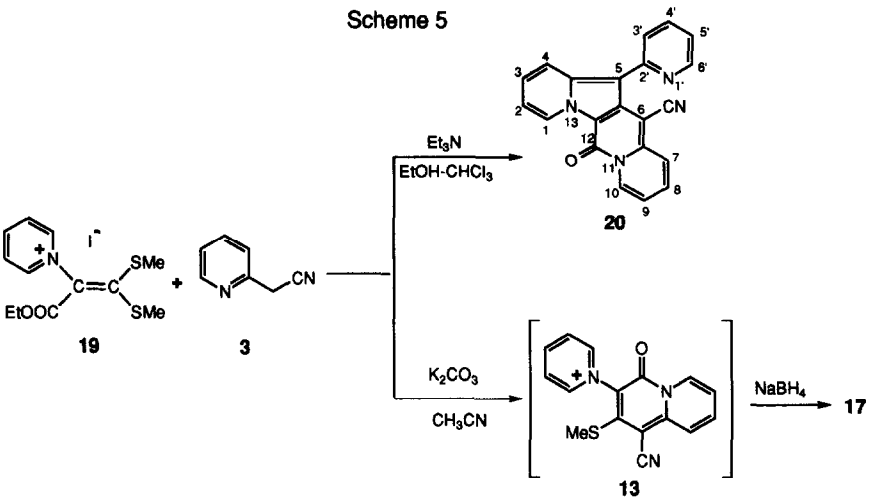
Scheme 4



13 17

In addition, the tetrahydro derivative (**17**) of the intermediate, pyridinium oxoquinolizine (**13**) was obtained by the reaction of **4a** with **2** in the presence of K_2CO_3 in acetonitrile for 4 h, followed by reduction with $NaBH_4$. (Scheme 4) The structure of **17** was supported by a satisfactory elemental analysis, the presence of one cyano and one carbonyl absorptions in its IR spectrum. Furthermore, the 1',2',3',6'-tetrahydropyridyl moiety of **17** was identified by comparison with ^{1}H-NMR spectrum of 1-methyl-1,2,3,6-tetrahydropyridine (**18**).[20] This result established that we regarded the isolation of **17** as evidence of the rationality of the reaction mechanism as shown in Scheme 3.

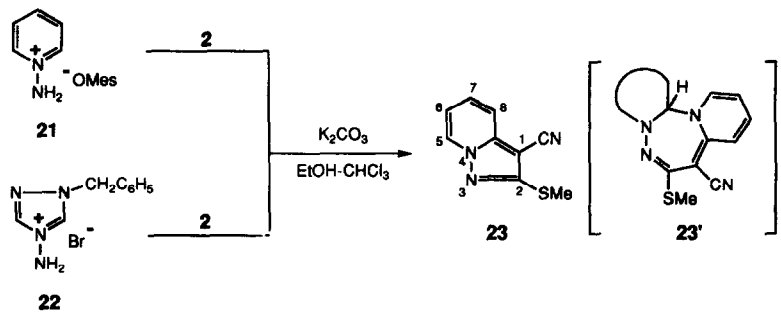
Scheme 5



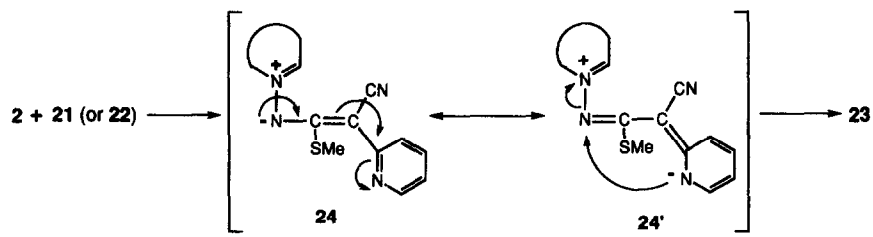
19 3 20 13

As an extension of our previous studies on the ketene dithioacetals, we reported the reaction of pyridiniumketene dithioacetal (**19**)[14, 21] as an interesting synthon. We suggested that replacement of one methylthio group in **19** by **3** could give the same intermediate (**13**). Thus, the reaction of **19** with two molar equivalents of **3** in the presence of triethylamine in EtOH-$CHCl_3$ for a week gave pyridylindolizinoquinolizine (**20**) in 28% yield. The tetahydropyridylquinolizine (**17**) was also obtained by the reaction of pyridiniumketene dithioacetal (**19**) with pyridylacetonitrile (**3**), followed by reduction of $NaBH_4$ under the similar reaction condition above for the reaction of **4a** with **2**. (Scheme 5) The formation of **20** may be rationalized by the course *via* the intermediate, pyridinium oxoquinolizine (**13**), followed by the substitution of its mehtylthio group with pyridylacetonitrile (**3**).

Scheme 6



Scheme 7



A further attempt to obtaine a 1,7-cyclization product (**23'**) by the reaction of **2** with the pyridinium *N*-amino salt (**21**)[22] was fruitless. However the mixture of **2** and **21** in the presence of K_2CO_3 in EtOH-$CHCl_3$ was stirred at room temperature for a week to give an unexpected product, pyrazolopyridine (**23**). Under the similar condition above, the reaction of **2** with the triazolium *N*-amino salt (**22**)[23] also produced **23** in 63% yield. (Scheme 6) The reaction mechanism for the synthesis of **23** may be rationalized as outlined in Scheme 7.

The synthesis of indolizines from pyridinium *N*-allylides involving 1,5-dipolar cyclization has been reported. However, the present result provides the first example of the one step synthesis of the heteropolycycles, indolizinoquinolizines (**7**, **8**, **20**) from the reaction of either pyridylketene dithioacetal (**2**) with the pyridinium salt (**4**) or pyridiniumketene dithioacetal (**19**) with pyridylacetonitrile (**3**).

Experimental Section

Melting points were determined with a Mitamura Mel-Temp and were uncorrected. Infrared (IR) spectra were recorded in KBr pellets on a JASCO IRA-2 spectrophotometer. Ultraviolet (UV) spectra were recorded on a Hitachi 322 spectrophotometer. Nuclear magnetic resonance (^{1}H-NMR) spectra were obtained on a JNM-FX-90Q spectrometer with tetramethylsilane as internal standard. Chemical shifts are reported in parts per million (δ). Elemental analyses (C,H,N) of all compounds described here were performed on a Yanagimoto MT-2 CHN recorder. Mass spectra (MS) were measured on a JMS-DX-303G spectrometer.

1-Cyano-2,4-oxo-2,4-dihydroquinolizin-3-yl-pyridinium *N*-ylide (5)

A mixture of **2** (4 mmol), **4a** (4 mmol), and triethylamine (5 mmol) in EtOH (50 mL) was refluxed for 12 h and the mixture was then evaporated under reduced pressure. To the residue was added ice-water (100 mL). The precipitate was filtered, washed with water, dried and recrystallized from $CHCl_3$-MeOH to give **5**.

Mp 356-359°C (64%); IR(KBr) 2100 (CN), 1650 (CO), 1630 (CO) cm^{-1}; UV(EtOH) λmax (log ε) 214(4.32), 230(4.52), 285(4.02), 375(3.84) nm; ^{1}H-NMR (DMSO-d_6) δ 6.88(1H, dt, *J*=1, 7 Hz, Ar-H), 7.35-7.71(2H, m, Ar-H), 8.00-8.20(2H, m, Ar-H), 8.56(1H, dt, *J*=1, 7 Hz, Ar-H), 8.77(1H, dd, *J*=1, 7 Hz, C_6-H), 8.92(2H, dd, *J*=1, 7 Hz, $C_{2'}$, $_{6'}$-H). *Anal.* Calcd for $C_{15}H_9N_3O_2$: C, 68.43; H, 3.45; N, 15.96. Found: C, 68.05; H, 3.63; N, 15.85.

Reaction of Pyridinium Salts (4a-b) with 2

Method A) A solution of **4a** (4.2 mmol), **2** (2 mmol), and K_2CO_3 (3 mmol) in acetonitrile (60 mL) was stirred at room temperature for a week and the solution was then evaporated under reduced pressure. To the residue was added ice-water (50 mL) and the mixture was extracted with $CHCl_3$ (4x30 mL). The combined extracts were washed with water (50 mL), dried (Na_2SO_4), and evaporated under reduced pressure. The residue was submitted to column chromatography on silica gel. From abenzene-$CHCl_3$ (3:1) fraction, **7a** (4%) was obtained.

Method B) A solution of **4a-b** (4.2 mmol), **2** (2 mmol), and triethylamine (5 mmol) in EtOH (60 mL) was stirred at room temperature for a week and the solution was then evaporated under reduced pressure. To the residue was added ice-water (50 mL) and the mixture was extracted with $CHCl_3$ (4x30 mL). The combined extracts were washed with water (50 mL), dried (Na_2SO_4), and evaporated under reduced pressure. The residue was submitted to column chromatography on silica gel. From a first benzene-$CHCl_3$ (3:1) fraction, **8a,b** were obtained. From a second benzene-$CHCl_3$ (3:1) fraction, **6** was obtained. From a third benzene-$CHCl_3$ (3:1) fraction, **7a-c** were obtained.

6: mp 271-273°C(25%); IR(KBr) 2100(CN), 1630(CO) cm^{-1}; UV(EtOH) λmax (log ε) 255(4.18), 281(4.26), 388(4.15) nm; ^{1}H-NMR ($CDCl_3$) δ 2.52(3H, s, SCH_3), 5.10-5.14(2H, br s, NH_2), 6.97(1H, dt, *J*=1, 7 Hz, C_7-H), 7.23(1H, ddd, *J*=1, 7, 9 Hz, C_8-H), 7.82(1H, dd, *J*=1, 9 Hz, C_9-H), 8.89(1H, dd, *J*=1, 7 Hz, C_6-H). *Anal.* Calcd for $C_{11}H_9N_3OS$: C, 57.13; H, 3.92; N, 18.17; S, 13.86. Found: C, 57.29; H, 3.96; N, 18.20; S, 14.16.

7a: mp 233-235°C(40%) (lit[16] mp 235°C).

7b: mp 233-235°C(25%) (lit[16] mp 233-235°C).

7c: mp 286-288°C(45%); IR(KBr) 2100(CN), 1680(CO), 1680(CO) cm^{-1}; UV(EtOH) λmax 219, 250, 262, 297, 321, 404, 426 nm; ^{1}H-NMR ($CDCl_3$) δ 1.52(3H, t, *J*=7 Hz, $CH_2\underline{CH_3}$), 2.48(3H, s, CH_3), 4.57(2H, q, *J*=7 Hz, $C\underline{H_2}CH_3$), 7.04(1H, dt, *J*=1, 7 Hz, Ar-H), 7.39-7.64(2H, m, Ar-H), 8.19(1H, dd, *J*=1, 9 Hz, Ar-H), 8.44(1H, d, *J*=9 Hz, Ar-H), 9.17(1H, dd, *J*=1, 7 Hz, C_{10}-H), 9.75(1H, s, C_1-H). *Anal.* Calcd for $C_{20}H_{15}N_3O_3$: C, 69.56; H, 4.38; N, 12.17. Found: C, 69.32; H, 4.53; N, 12.04.

8a: mp 271-273°C(5%) (lit[16] mp 271-273°C).

8b: mp 305-307°C(8%) (lit[16] mp 305-307°C).

Reaction of Isoquinolinium Salt (9) with 2

A mixture of **9** (4 mmol), **2** (2 mmol), and K_2CO_3 (5 mmol) in EtOH (50 mL) was refluxed for 10 h and the mixture was then evaporated under reduced pressure. To the residue was added ice-water (100 mL) and the mixture was extracted with $CHCl_3$ (4x30 mL). The combined extracts were washed with water (50 mL), dried (Na_2SO_4), and evaporated under reduced pressure. The residue was submitted to column chromatography on silica gel. From a first benzene-$CHCl_3$ (2:1) fraction, **11** was obtained. From a second benzene-$CHCl_3$ (2:1) fraction, **10** was obtained.

10: mp 214-318°C(12%); IR(KBr) 2100(CN), 1710(CO), 1680(CO) cm^{-1}; UV(EtOH) λmax 211, 256, 292, 318, 350, 382, 419, 443 nm; ^{1}H-NMR ($CDCl_3$) δ 1.53(3H, t, *J*=7 Hz, $CH_2\underline{CH_3}$), 4.69(2H, q, *J*=7 Hz, $\underline{CH_2}CH_3$), 7.03(1H, dt, *J*=1, 7 Hz, Ar-H), 7.21(1H, d, *J*=7 Hz, C_2-H), 7.43-7.78(4H, m, Ar-H), 8.11(1H, dd, *J*=1, 9 Hz, Ar-H), 8.86-8.97(1H, m, Ar-H), 9.21 (1H, dd, *J*=1, 7 Hz, C_{12}-H), 9.69(1H, d, *J*=7 Hz, C_1-H). HRMS ; *Anal.* Calcd for $C_{23}H_{15}N_3O_3$: 381.1113. Found: 381.1117. *Anal.* Calcd for $C_{23}H_{15}N_3O_3$: C, 72.43; H, 3.96; N, 11.02. Found: C, 72.24; H, 4.20; N, 10.90.

11: mp 341-344°C(8%); IR(KBr) 2100(CN), 1680(CO) cm^{-1}; UV(EtOH) λmax (log ε) 213(4.38), 219(4.39), 252(4.25), 293(4.65), 318(4.33), 348(4.29), 365(4.16), 386(4.27), 422 (3.83), 448(3.56) nm; ^{1}H-NMR ($CDCl_3$) δ 6.94(1H, dd, *J*=1, 7 Hz, Ar-H), 7.10(1H, d, *J*=7 Hz, C_2-H), 7.21-7.76(5H, m, Ar-H), 7.89(1H, dd, *J*=1, 9 Hz, Ar-H), 8.21-8.41(1H, m, Ar-H), 9.18 (1H, dd, *J*=1, 7 Hz, C_{12}-H), 9.43(1H, d, *J*=7 Hz, C_1-H). HRMS ; *Anal.* Calcd for $C_{20}H_{11}N_3O$: 309.0902. Found: 309.0904. *Anal.* Calcd for $C_{20}H_{11}N_3O$: C, 77.66; H, 3.58; N, 13.58. Found: C, 77.39; H, 3.86; N, 13.34.

1-Cyano-2-methylthio-3-(*N*-1',2',3',6'-tetrahydropyridyl)-4-oxo-4*H*-quinolizine (17)

A) A solution of **4a** (2 mmol), **2** (2 mmol), and K_2CO_3 (3 mmol) in CH_3CN (60 mL) was stirred at room temperature. After 4 h, to the solution was added $NaBH_4$ (4 mmol) and the mixture was stirred at room temperature for 30 min. And then to the solution was added 2-3 drops of AcOEt. To the solution was added ice-water (50 mL) and the mixture was extracted with $CHCl_3$ (4x30 mL). The combined extracts were washed with water (50 mL), dried (Na_2SO_4), and evaporated under reduced pressure. The residue was submitted to column chromatography on silica gel. From a benzene-$CHCl_3$ (2:1) fraction, **17** (5%) was obtained.

B) Compound **17** (5%) was also prepared by the reaction of **19** (2 mmol), **3** (2 mmol), K_2CO_3 (3 mmol), and $NaBH_4$ (4 mmol) in CH_3CN (60 mL) using procedure above for the method A.

Mp 151-154°C; IR(KBr) 2100(CN), 1650(CO), cm^{-1}; UV(EtOH) λmax 220, 266, 300, 325, 363, 383, 421, 445, 473 nm; ^{1}H-NMR ($CDCl_3$) δ 2.64-2.78(2H, m, $C_{3'}$-H), 2.78(3H, s, SCH_3), 3.30(2H, t, *J*=6Hz, $C_{2'}$-H), 3.56-3.72(2H, m, $C_{6'}$-H), 5.72-5.88(2H, m, $C_{4'}$,$_{5'}$-H), 7.15(1H, dt, *J*=1, 7 Hz, C_7-H), 7.62(1H, ddd, *J*=1, 7, 9 Hz, C_8-H), 7.86(1H, dd, *J*=1, 9 Hz, C_9-H), 9.11(1H, dd, *J*=1, 7 Hz, C_6-H). *Anal.* Calcd for $C_{16}H_{15}N_3OS$: C, 64.62; H, 5.08; N, 14.13; S, 10.78. Found: C, 64.41; H, 5.16; N, 14.15; S, 10.76.

5-(2'-Pyridyl)-6-cyano-12-oxo-12*H*-indolizino[2,3-*b*]quinolizine (20)

A solution of **19** (2 mmol), **3** (4 mmol), and triethylamine (5 mmol) in EtOH-$CHCl_3$ (1:1) (60 mL) was stirred at room temperature for a week and the solution was then evaporated under reduced pressure. To the residue was added ice-water (50 mL) and the mixture was extracted with $CHCl_3$ (4x30 mL). The combined extracts were washed with water (50 mL), dried (Na_2SO_4), and evaporated under reduced pressure. The residue was submitted to column chromatography on silica gel. From a $CHCl_3$ fraction, **20** (28%) was obtained.

Mp 266-269°C; IR(KBr) 2100(CN), 1690(CO), cm^{-1}; UV(EtOH) λmax 220, 266, 300, 325, 363, 383, 421, 445, 473 nm; ^{1}H-NMR ($CDCl_3$) δ 6.87-7.08(2H, m, Ar-H), 7.21-8.06(7H, m, Ar-H), 8.81(1H, dd, *J*=1, 6 Hz, $C_{6'}$-H), 9.19(1H, dd, *J*=1, 7 Hz, C_{10}-H), 9.85(1H, dd, *J*=1, 7 Hz, C_1-H). *Anal.* Calcd for $C_{21}H_{12}N_4O$: C, 74.99; H, 3.60; N, 16.66. Found: C, 74.61; H, 3.77; N, 16.50.

1-Cyano-2-methylthiopyrazolo[1,6-*a*]pyridine (23)

A) A solution of **21** (2 mmol), **2** (2 mmol), and K_2CO_3 (4 mmol) in EtOH-$CHCl_3$ (1:1) (60 mL) was stirred at room temperature for a week and the solution was then evaporated under reduced pressure. To the residue was added ice-water (50 mL) and the mixture was extracted with $CHCl_3$ (4x30 mL). The combined extracts were

washed with water (50 mL), dried (Na_2SO_4), and evaporated under reduced pressure. The residue was submitted to column chromatography on silica gel. From a benzene-$CHCl_3$ (2:1) fraction, **23** (55%) was obtained.

B) Compound **23** (63%) was also prepared by the reaction of **22** (2 mmol), **2** (2 mmol), and K_2CO_3 (4 mmol) in EtOH-$CHCl_3$ (1:1) (60 mL) using procedure above for the method A.

Mp 118-120°C; IR(KBr) 2100(CN) cm^{-1}; UV(EtOH) λmax (log ε) 213(4.68), 225(4.51)sh, 257(4.25)sh, 265(4.33), 293(4.40), 302(4.36)sh 339(4.06) nm; ^{1}H-NMR ($CDCl_3$) δ 2.69(3H, s, SCH_3), 6.86(1H, dt, *J*=1, 7 Hz, C_6-H), 7.15(1H, ddd, *J*= 1, 7, 9 Hz, C_7-H), 7.66(1H, dd, *J*=1, 9 Hz, C_8-H), 8.05(1H, dd, *J*=1, 7 Hz, C_5-H). *Anal.* Calcd for $C_9H_7N_3S$: C, 57.12; H, 3.73; N, 21.21. Found: C, 56.86; H, 3.84; N, 21.44.

REFERENCES

1. Matsumoto, K.; *Yuki Gosei Kagaku Kyokaishi*, **1974**, *32*, 731.
2. Uchida, T.; Matsumoto, K.; *Synthesis*, **1976**, 209.
3. Swinbourne, F. J.; Hunt, J. H.; Klinkert, G.; *Advances in Heterocyclic Chemistry*, Vol. **23**, ed. by Katritzky, A. R.; Boulton, A. J.; Academic Press, New York, 1978, p. 103.
4. Acheson, R. M.; Elmore, N. F.; *ibid.*, Vol. **23**, 1978, p. 263.
5. Tamura, Y.; Ikeda, M.; *ibid.*, Vol. **29**, 1981, p. 71.
6. Taylor, E. C.; Turchi, I. J.; *Chem Rev* , **1979**, *79*, 181.
7. Kakehi, A.; Ito, S.; Funahashi, T.; Ota, Y.; *J Org. Chem.*, **1976**, *41*, 1570.
8. Kakehi, A.; Ito, S.; Uchiyama, K.; Konno, Y.; Kondo, K.; *ibid.*, **1977**, *42*, 443.
9. Tominaga, Y.; Matsuda, Y.; *J. Heterocycl. Chem.*, **1985**, *22*, 937.
10. Kolb, M.; *Synthesis*, **1990**, 171.
11. Matsuda, Y.; Gotou, H.; Katou, K.; Matsumoto, H.; Yamashita, M.; Takahashi, K.; Ide, S.; *Heterocycles*, **1990**, *31*, 977.
12. Matsuda, Y.; Gotou, H.; Katou, K.; Matsumoto, H.; Yamashita, M.; Takahashi, K.; Ide, S.; Furuno, K.; Torisu, K.; *ibid*, **1991**, *32*, 2217.
13. Matsuda, Y.; Yamashita, M.; Takahashi, K.; Ide, S.; Torisu, K.; Furuno, K.; *ibid*, **1992**, *33*, 295.
14. Tominaga, Y.; Matsuda, Y.; *Yuki Gosei Kagaku Kyokaishi*, **1985**, *43*, 669.
15. Matsuda, Y.; Gotou, H.; *Heterocycles*, **1987**, *26*, 2757.
16. Matsuda, Y.; Yamashita, M.; Takahashi, K.; Ide, S.; Furuno, K.; Torisu, K.; Itou, T.; Motokawa, C.; *ibid*, **1992**, *34*, 899.
17. Kobayashi, G.; Furukawa, S.; Matsuda, Y.; Natsuki, R.; Matsunaga, S.;*Yakugaku Zasshi*, **1970**, *90*, 127.
18. Tamura, Y.; Sumida, Y.; Miki, Y.; Ikeda, M; *J Chem. Soc.*, **1975**, 406.
19. Bradlow, H. L.; Vanderwerf, C. A.; *J. Org. Chem.*, **1951**, *16*, 73.
20. *The Aldrich Library of NMR Spectra*, Edition II, Vol. **1**, ed. by Pouchert, C. J.; Aldrich Chemical Company, INC., Milwaukee, 1983, p. 350 Chart A.
21. Tominaga, Y.; Miyake, Y.; Fujito, H.; Matsuda, Y.; Kobayashi, G.; *Yakugaku Zasshi*, **1977**, *97*, 927.
22. Tamura, Y.; Minamikawa, J.; Sumoto, K.; Fujii, S.; Ikeda, M.; *J. Org Chem.*, **1973**, *38*, 1239.
23. Becker, H. G. O.; Nagel, D.; Timpe, H. J.; *J Prakt Chem.*, **1973**, *315*, 97.