Synthesis and Reaction of Methylbenzo[*a*]quinolizinium Salts [1]

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All isomers of (monomethyl)benzo[*a*]quinolizinium salts including five new monomethyl derivatives were prepared by photocyclization, sulfur extrusion, or cyclodehydration reaction, and their aldol-type condensation was examined. The 2- and 4-methyl derivatives **3b** and **3c** reacted with *p*-methoxybenzaldehyde in the presence of piperidine to yield *trans*-(*p*-methoxystyryl)benzo[*a*]quinolizinium salts **11**. The other methyl derivatives did not react with the aldehyde. The methyl group was reactive at the 2- and 4-positions, located *para* and *ortho* to the azonia ring nitrogen, respectively; however, it was unreactive at the 6-position located at another *ortho* position.

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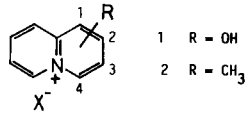
In our previous paper [2] we examined the acidity of four hydroxyquinolizinium salts **1** in order to investigate the electron-attracting character of the quaternary nitrogen of azonia aromatic compounds. We found that the compounds **1** were strong acids (p*K*a = 4-5) compared to naphthols (p*K*a = 9.2 and 9.5) and their p*K*a values correlated with the electron-attracting effect and the field effect of the azonia nitrogen. These results suggested that the methyl group attached to an azonia aromatic ring should be acidic. Among the four isomeric (monomethyl)quinolizinium salts **2**, both the 2- and 4-methyl derivatives have

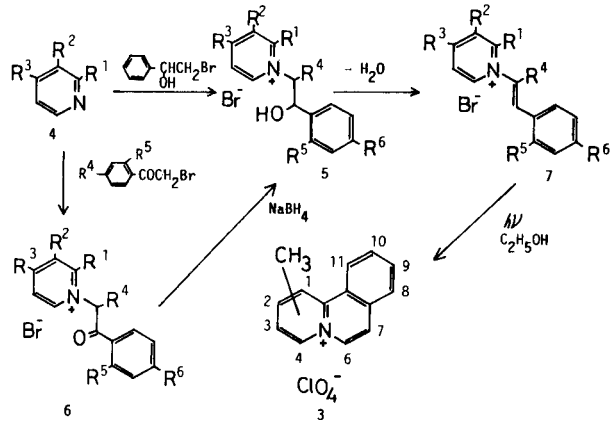


been reported to undergo base-catalyzed condensation with a benzaldehyde derivative [3]. Therefore, in the case of the (monomethyl)benzo[*a*]quinolizinium salts **3**, the 2-, 4-, and 6-methyl derivatives (which contain a methyl group located *ortho* or *para* to the azonia nitrogen) would also be expected to react with aldehydes. Among the ten possible (monomethyl)benzo[*a*]quinolizinium salts, however, the synthesis of the 1-, 2-, 3-, 4-, and 6-methyl derivatives has not yet been reported [4,5]. We report here the synthesis and the aldol-type condensation of the compounds **3**.

Synthesis of Methylbenzo[*a*]quinolizinium Perchlorates.

Doolittle and Bradsher used the process of stilbene photocyclization for the synthesis of a benzo[*a*]quinolizinium salt and its 8- and 10-methyl derivatives **3g** and **3i** [4]. Recently, we demonstrated that the photocyclization reaction provided a good and convenient route to the condensed polycyclic azonia aromatic compounds [6]. The syntheis of the new compounds **3a**, **3b**, **3c**, **3d**, and **3e** was attempted by this photocyclization method (Scheme 1). Pyridine **4a** and methylpyridines **4b-4d** were treated with 2-bromo-1-phenylethanol at 90° to afford the quaternary salts **5** in about 70% yield. The low yield (35%) of the reaction with compound **4b** was thought to be due to the steric hindrance of the methyl group. The same approach was applied to the synthesis of the quaternary salt **5e**. An attempt to react compound **4a** with 2-bromo-1-phenylpropanol, however, gave only unexpected pyridinium bromide in 45% yield. The preparation of the alcohol **5e** was achieved by the reduction of the corresponding ketone **6e**. The reaction of compound **4a** with 2-bromo-1-phenyl-1-propanone gave the pyridinium salt **6e** in 75% yield. The salt **6e** was reduced by sodium borohydride [7] to afford the desired alcohol **5e** in 50% yield. The methyl derivatives **5f** and **5g** were also prepared by this method.

Scheme 1



4 - 7

a: R^1 - R^6 = H
b: R^1 = CH_3, R^2 - R^6 = H
c: R^2 = CH_3, R^1 = R^3 - R^6 = H
d: R^3 = CH_3, R^1 = R^2 = R^4 - R^6 = H
e: R^4 = CH_3, R^1 - R^3 = R^5 = R^6 = H
f: R^5 = CH_3, R^1 - R^4 = R^6 = H
g: R^6 = CH_3, R^1 - R^5 = H

3

position of CH_3 group

a	b	c	d	e	f	g	h	i	j
1	2	3	4	6	7	8	9	10	11

The styryl derivatives **7a**, **7c**, **7f**, and **7g** were obtained by heating the corresponding alcohols **5a**, **5c**, **5f**, and **5g**, respectively, with benzoyl chloride [8]. The alcohols **5b**, **5d**, and **5e**, which possess a methyl group located *ortho* or *para* to the quaternary nitrogen atom, however, were not dehydrated by benzoyl chloride. Therefore, the dehydra-

tion of the secondary alcohols **5** was examined under various conditions (Table 1). The compound **7b** was obtained by the chlorination of the alcohol **5b** with thionyl chloride, followed by dehydrochlorination with ethanolic potassium hydroxide. Although the alcohols **5d** and **5e** were chlorinated by thionyl chloride, the dehydrochlorination gave many unidentified products. Ultimately, the styryl derivatives **7d** and **7e** were successfully prepared by the treatment of the alcohols **5d** and **5e** with phosphorus tribromide in 43 and 67% yields, respectively. It is worth noting that compounds **7a** and **7c** were obtained by all of the methods described above, while the dehydration of the compounds **5b**, **5d** and **5e**, whose methyl groups are located *ortho* or *para* to the quaternary nitrogen atom, required various reagents.

Table 1

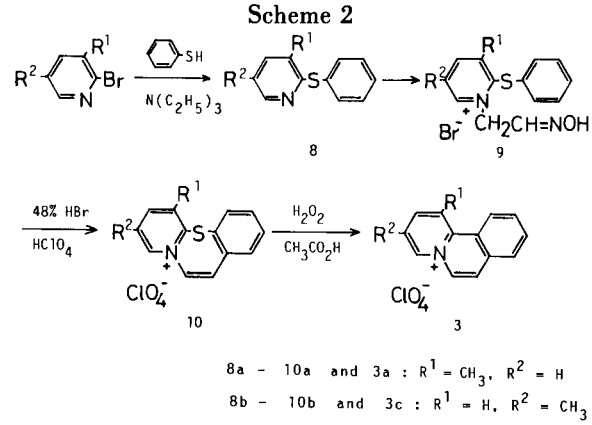
Dehydration of Alcohols **5**

Method	Yield (%) of Styryl Compound **7**						
	7a	**7b**	**7c**	**7d**	**7e**	**7f**	**7g**
A: PhCOCl	68	0	83	0	0	61	76
B: $SOCl_2$; KOH-EtOH	37	73	28	0	0	[a]	[a]
C: PBr_3	53	53	37	43	67	[a]	[a]

[a] The reactions were not attempted.

The *trans*-styryl derivatives **7a-7g** [9] were photocyclized to the benzo[*a*]quinolizinium salts **3b**, **3d**, **3e**, **3g**, and **3i** by the irradiation with a Pyrex-filtered light ($\lambda > 280$ nm) in ethanol in the presence of iodine. The desired new methyl derivatives **3b**, **3d**, and **3e**, whose methyl groups were located at an *ortho* or *para* position to the azonia nitrogen, were isolated as the perchlorate salts in good yields (79, 68, and 71%, respectively). In the ^1H nmr spectrum of the photocyclization product of compound **7c**, however, two methyl signals (2.65 and 3.25 ppm) were observed. A paper chromatogram (butan-1-ol-pyridine-water 3:1:1) of the product showed two spots. These results suggest the presence of two isomers **3a** and **3c** [5]. The isolation of these two isomers, however, was unsuccessful. In order to circumvent this problem, a sulfur extrusion reaction [10] was applied for the synthesis of the methyl derivatives **3a** and **3c** (Scheme 2). The isomeric 2-phenylthiopicolines **8** were prepared by the reaction of 2-bromopicolines with thiophenol in the presence of triethylamine. The reaction of compounds **8** with bromoacetaldehyde oxime in sulfolane afforded the quaternary salts **9**. The salts **9** were cyclized with 48% hydrobromic acid to yield the thiazepinium salts **10**, which underwent oxidative sulfur extrusion in the presence of 30% hydrogen peroxide in acetic acid to afford the desired methyl derivatives **3a** and **3c** in 14 and 12% yields from **8**, respectively.

Scheme 2



The 7-, 9-, and 11-methylbenzo[*a*]quinolizinium perchlorates **3f**, **3h**, and **3j** were prepared by cyclodehydration of 2-phenylpyridinium salts according to reported procedures [11,12].

Reaction of Methylbenzo[*a*]quinolizinium Perchlorates with *p*-Methoxybenzaldehyde.

The reactivity of (monomethyl)benzo[*a*]quinolizinium perchlorates for the aldol-type condensation is compared in Table 2. The methyl derivatives **3b** and **3d** underwent the condensation with *p*-methoxybenzaldehyde in the presence of piperidine in methanol to yield *trans*-(4-methoxystyryl)benzo[*a*]quinolizinium perchlorates **11** [9], which showed greenish yellow fluorescence in ultraviolet light (Scheme 3). The other methyl derivatives did not react with the aldehyde. In the Knoevenagel condensation of active methylene compound with benzaldehyde in the presence of piperidine, the adduct **12a** has been proposed to be an active intermediate (Scheme 4) [13]. In the case of the reaction of *p*-methoxybenzaldehyde with piperidine, the formation of adduct **12b** was also confirmed. The reaction of the 4-methyl derivative **3d** with the adduct **12b** increased remarkably the yield of the styryl derivative **11b** (Table 2). The methyl derivatives other than the derivatives **3b** and **3d**, however, did not yield the styryl derivatives **11** even in the reaction with the adduct **12b**. It is noteworthy that the 6-methyl derivative **3f**, whose methyl group is located at an *ortho* position to the azonia nitrogen, did not react with the aldehyde.

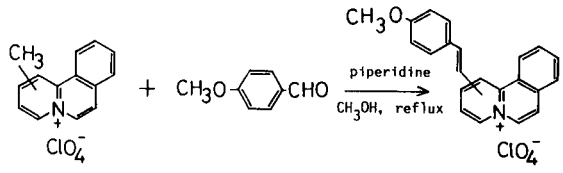
Further studies on the reactivities of methylsubstituted azonia aromatic compounds are in progress.

Table 2

Reaction of **3a-3j** with *p*-Methoxybenzaldehyde

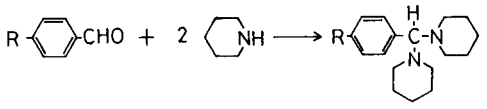
Compound	Yield (%) of **11** [*p*-Methoxybenzaldehyde adduct **12b**]	
3a	0	0
3b	99	99
3c	0	0
3d	46	90
3e	0	0
3f-3j	0	0

Scheme 3



3 11

Scheme 4



12a R = H

12b R = OCH_3

EXPERIMENTAL

The ^1H nmr spectra were measured with a Hitachi R-24 (60 MHz) or Jeol FX90Q (90 MHz) spectrometer in solutions of dimethyl sulfoxide-d_6 or trifluoroacetic acid using tetramethylsilane or sodium 3-trimethylsilylpropane-1-sulfonate as internal standards, respectively. Chemical shifts were reported in ppm downfield from the internal standard. The ir spectra were recorded with a JASCO IRA-1 spectrometer. The uv and visible spectra were obtained with either a Shimazu UV-200 or a Hitachi 220A spectrometer. Elemental analyses were performed by Mr. Hirokatsu Suzuki at Department of Chemistry, Tokyo Metropolitan University. Melting points, measured on a Yamato melting points apparatus MP-21, were uncorrected, whereas melting points determined by the capillary methods were corrected.

Procedure for the Preparation of the Pyridinium Salts **5a-5d**, *e.g.* Compound **5d**.

1-(2-Hydroxy-2-phenylethyl)-4-methylpyridinium Bromide (**5d**, X = Br).

A mixture of 2-bromo-1-phenylethanol [6] (70 g, 0.348 mole) and compound **4d** (68.6 g, 0.737 mole) was stirred for 14 hours at 90°. The resulting solid was filtered, washed with cold anhydrous acetone (2 x 50 ml), and recrystallized from ethanol (200 ml) to afford **5d** (X = Br) (78.8 g, 77%), mp 188° corr; ir (potassium bromide): 3240, 3030, 1640, 1170, 1060, 810, 770, and 700 cm^{-1}; ^1H nmr (60 HMz, trifluoroacetic acid): δ 2.63 (3H, s, CH_3), 4.8-5.6 (3H, m, $CH(OH)CH_2$), 7.45 (5H, m, ArH), 7.87 (2H, d, J = 7 Hz, pyridinium 3- and 5H), and 8.57 (2H, d, J = 7 Hz, pyridinium 2-and 6-H).

Anal. Calcd. for $C_{14}H_{16}NOBr$: C, 57.15; H, 5.48; N, 4.76. Found: C, 57.05; H, 5.56; N, 4.64.

1-(2-Hydroxy-2-phenylethyl)pyridinium Bromide (**5a**, X = Br).

The reaction between compound **4a** and 2-bromo-1-phenylethanol at 90° for 14 hours gave **5a** (X = Br) (70%), mp 234.9-236.8° corr (lit [8] 234-235°); ir (potassium bromide): 3240, 3045, 1625, 1485, 1172, 1058, 765, 658, and 675 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 5.04 (1H, d, J = 6 Hz, CH_AH_B), 5.06 (1H, d, J = 4 Hz, CH_AH_B), 5.60 (1H, dd, J = 4 and 6 Hz, CH(OH)), and 7.4-8.8 (10H, m, ArH).

Anal. Calcd. for $C_{13}H_{14}NOBr$: C, 55.73; H, 5.04; N, 4.99. Found: C, 55.79; H, 5.09; N, 4.72.

1-(2-Hydroxy-2-phenylethyl)-2-methylpyridinium Bromide (**5b**, X = Br).

The reaction between compound **4b** and 2-bromo-1-phenylethanol at 90° for 14 hours gave **5b** (X = Br) (35%), mp 228-229° corr; ir (potassium bromide): 3280, 3040, 1620, 1170, 1070, 785, and 705 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 2.73 (3H, s, CH_3), 4.95 (2H, d, J = 8 Hz, CH_2), 5.46 (1H, t, J = 8 Hz, CH), and 7.1-8.7 (9H, m, ArH).

Anal. Calcd. for $C_{14}H_{16}NOBr$: C, 57.15; H, 5.48; N, 4.76. Found: C, 57.08; H, 5.55; N, 4.72.

1-(2-Hydroxy-2-phenylethyl)-3-methylpyridinium Bromide (**5c**, X = Br).

The reaction between compound **4c** and 2-bromo-1-phenylethanol at 90° for 14 hours gave **5c**, (X = Br) (68%), mp 165-166° corr (lit [8] 165-166°); ir (potassium bromide): 3240, 3055, 1621, 1498, 1200, 1060, 798, 697 cm^{-1}; ^1H nmr (90 MHz, DMSO-d_6): δ 2.50 (3H, s, CH_3), 4.4-5.2 (3H, m, $CH_2CH(OH)$), and 7.3-9.1 (9H, m, ArH).

Anal. Calcd. for $C_{14}H_{16}NOBr$: C, 57.15; H, 5.48; N, 4.76. Found: C, 57.05; H, 5.53; N, 4.62.

Procedure for the Preparation of the Ketones **6e-6g**, *e.g.* Compound **6e**.

2-(1-Pyridinium)-1-phenylpropanone Bromide (**6e**, X = Br).

A methanol solution (20 ml) of 2-bromo-1-phenyl-1-propanone [14] (16.7 g, 78.4 mmoles) and compound **4a** (7g, 88.5 mmoles) was refluxed for 3.5 hours. The solvent was removed under reduced pressure and the residue was filtered, washed with diethyl ether, and dried to afford a yellow solid (17.2 g). Recrystallization from 2-propanol-acetone gave **6e** (X = Br) (14.0 g, 61%) as pale yellow crystals. The perchlorate **6e** (X = ClO_4) was obtained by the addition of 60% aqueous perchloric acid to an aqueous solution of **6e** (X = Br). A white powder resulted which was recrystallized from methanol, mp 143.6-144.2°; ir (potassium bromide): ν C=O 1682 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 2.12 (3H, d, J = 7.6 Hz, CH_3), 6.87 (1H, q, J = 7.6 Hz, CH), and 7.4-9.0 (10H, m, ArH).

Anal. Calcd. for $C_{14}H_{14}NO_5Cl$: C, 53.94; H, 4.53; N, 4.49. Found: C, 53.71; H, 4.59; N, 4.57.

2-(1-Pyridinium)-1-(*o*-tolyl)ethanone Salt **6f**.

The reaction between compound **4a** and 2-bromo-2'-methylacetophenone gave **6f** (X = Br) (61%). Compound **6f** (X = ClO_4) was obtained as white crystals from methanol, mp 152.2-152.8°; ir (potassium bromide): ν C=O 1685 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 2.51 (3H, s, CH_3), 6.32 (2H, s, CH_2), and 7.2-8.9 (10H, m, ArH).

Anal. Calcd. for $C_{14}H_{14}NClO_5$: C, 53.94; H, 4.53; N, 4.49. Found: C, 53.87; H, 4.50; N, 4.25.

2-(1-Pyridinium)-1-(*p*-tolyl)ethanone Salt **6g**.

The reaction between compound **4a** and 2-bromo-4'-methylacetophenone gave **6g** (X = Br) (50%). Compound **6g** (X = ClO_4) was obtained as white crystals from methanol, mp 190.7-191.8°; ir (potassium bromide): ν C=O 1690 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 2.42 (3H, s, CH_3), 6.38 (2H, s, CH_2), and 7.2-8.8 (9H, m, ArH).

Anal. Calcd. for $C_{14}H_{14}NClO_5$: C, 53.94; H, 4.50; N, 4.49. Found: C, 53.93; H, 4.63; N, 4.40.

Procedure for the Preparation of the Hydroxy Compounds **5e**, **5f**, and **5g**, *e.g.* Compound **5e**.

1-(3-Hydroxy-2-phenylpropyl)pyridinium Salt **5e**.

To the solution of the ketone **6e** (14.6 g, 50 mmoles) in water (100 ml) was added portionwise sodium borohydride (0.567 g, 15 mmoles) at room temperature. The mixture was stirred for 6 hours. The solvent was then removed under reduced pressure. The pale yellow residue was recrystallized from water-ethanol to afford **5e** (X = Br) (7.3 g, 50%) as pale yellow crystals. Compound **5e** (X = ClO_4) was obtained as white crystals from methanol, mp 168.5-169.5°; ir (potassium bromide): 3210, 1628, 1482, 1120, 985, 778, and 698 cm^{-1}; ^1H nmr (90 MHz, DMSO-d_6): δ 1.51 (3H, d, J = 6.7 Hz, C*H*$_3$), 4.9-5.3 (2H, m, C*H*(CH$_3$)C*H*(OH)), 7.34 (5H, s, Ph*H*), and 8.0-9.1 (5H, m, pyridinium).

Anal. Calcd. for $C_{14}H_{16}NClO_5$: C, 53.59; H, 5.14; N, 4.47. Found: C, 53.63; H, 5.17; N, 4.39.

1-(1-Hydroxy-2-*o*-tolylethyl)pyridinium Salt **5f**.

The reaction of the ketone **6f** with sodium borohydride gave **5f** (X = Br) (61%). Compound **5f** (X = ClO_4) was obtained as white crystals from methanol, mp 165-166°; ir (potassium bromide): 3270, 1627, 1485, 1120, 767, and 678 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 2.36 (3H, s, C*H*$_3$), 5.00 (2H, m, C*H*$_2$), 5.75 (1H, m, C*H*), and 7.0-8.6 (9H, m, ArH).

Anal. Calcd. for $C_{14}H_{16}NClO_5$: C, 53.59; H, 5.14; N, 4.47. Found: C, 53.57; H, 5.16; N, 4.24.

1-(1-Hydroxy-2-*p*-tolylethyl)pyridinium Salt **5g**.

The reaction of the ketone **6g** with sodium borohydride gave **5g** (X = Br) (48%). Compound **5g** (X = ClO_4) was obtained as white crystals from methanol, mp 149-150°; ir (potassium bromide): 3270, 1630, 1490, 1100, 805, 758, and 680 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 2.30 (3H, s, C*H*$_3$), 4.8-5.6 (3H, m, C*H*$_2$C*H*(OH)), and 7.0-8.7 (9H, m, ArH).

Anal. Calcd. for $C_{14}H_{16}NClO_5$: C, 53.59; H, 5.14; N, 4.47. Found: C, 53.28; H, 5.11; N, 4.38.

Typical Procedure for the Preparation of Compounds **7**, *e.g.* Compound **7a**.

1-Styrylpyridinium Salts **7a**.

Method A.

A mixture of **5a** (15 g, 53.5 mmoles) and benzoyl chloride (33.9 g, 0.24 mole) was stirred for 1 hour at 200°. After being cooled to room temperature, the resulting solid was filtered and washed with anhydrous acetone (50 ml) and diethyl ether (20 ml) to afford a yellow solid (12.1 g). Recrystallization from pentan-1-ol gave **7a** (X = Br) (9.5 g, 68%) as pale yellow crystals, mp 161.8-162.6° corr (lit [8] 154-156°); uv: λ max (ethanol) 232 (log ϵ 4.10) and 323 nm (4.15); ir (potassium bromide): 3050, 1625, 1615, 1605, 1475, 950, 770, and 690 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 7.3-8.9 (10H, m, ArH and C*H*=C*H*), and 9.16 (2H, d, J = 6 Hz, pyridinium 2- and 6-H).

Anal. Calcd. for $C_{13}H_{12}NBr$: C, 59.56; H, 4.62; N, 5.34. Found: C, 59.14; H, 4.52; N, 5.09.

The perchlorate **7a** (X = ClO_4) was obtained as white crystals from methanol, mp 171.5-172.3° corr (lit [8] 171-172°).

Method B.

A mixture of compound **5a** (3.00 g, 11 mmoles) and thionyl chloride (3 ml) was stirred at 60° for 5 minutes. After being cooled to room temperature, excess thionyl chloride was removed *in vacuo* and the residual solid was dissolved in acetone. Upon the addition of diethyl ether, a white solid (2.50 g) was precipitated. Recrystallization from ethanol-diethyl ether afforded 1-(2-chloro-2-phenylethyl)pyridinium bromide (1.76 g, 55%) as colorless crystals, mp 151.1° corr (lit [8] 153°). A 10% ethanolic potassium hydroxide solution was added to a solution of the chloro compound (1.0 g) in ethanol (30 ml) until a *p*H 9 was obtained. The color changed from yellow to violet. The solution was filtered and the filtrate was neutralized with hydrochloric acid. The solvent was removed *in vacuo* and the residual solid was washed with acetone. Recrystallization from pentan-1-ol afforded **7a** (X = Br) (0.58 g, 67%).

Method C.

The mixture of compound **5a** (1.70 g, 6 mmoles) and phosphorus tribromide (10 ml) was stirred at 150° for 3 hours. The excess phosphorus tribromide was removed under reduced pressure. The residual solid was washed with cold acetone and diethyl ether to give a yellow solid (1.50 g), which was recrystallized from pentan-1-ol to afford **7a** (X = Br) (0.85 g, 53%) as pale yellow crystals.

1-Styryl-2-methylpyridinium Salt **7b** (X = Br).

This was isolated as pale yellow crystals from butan-1-ol, mp 229° corr; uv: λ max (ethanol) 235 (log ϵ 4.05), 250 (sh), 280 (sh), and 305 nm (4.01); ir (potassium bromide): 3100, 1640, 1610, 1495, 1485, 990, 775, and 745 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 2.86 (3H, s, C*H*$_3$) and 7.1-8.9 [11H, m+d (7.25 and 7.78, J = 14 Hz), ArH and C*H*=C*H*].

Anal. Calcd. for $C_{14}H_{14}NBr$: C, 60.86; H, 5.11; N, 5.07. Found: C, 60.70; H, 4.96; N, 4.81.

Compound **7b** (X = ClO_4) was obtained as white crystals from methanol, mp 152.9-153.9° corr.

1-Styryl-3-methylpyridinium Salt **7c** (X = Br).

This formed pale yellow crystals from water, mp 186-187° corr (lit [8] 186-188°); uv: λ max (ethanol) 232 (log ϵ 4.12) and 322 nm (4.18); ir (potassium bromide): 3030, 1490, 1125, 958, 756, and 692 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 2.62 (3H, s, C*H*$_3$) and 7.3-8.9 (11H, m, ArH and C*H*=C*H*).

Anal. Calcd. for $C_{14}H_{14}NBr \cdot H_2O$: C, 57.10; H, 5.44; N, 4.76. Found: C, 57.07; H, 5.25; N, 4.55.

Compound **7c** (X = ClO_4) was obtained as white crystals from methanol, mp 151.3-151.8° corr (lit [8] 150-151°).

1-Styryl-4-methylpyridinium Salt **7d** (X = Br).

This formed pale yellow crystals from water, mp 253.0-254.4° corr; uv: λ max (ethanol) 235 (log ϵ 4.16), 322 nm (4.20); ir (potassium bromide): 3040, 1625, 1470, 1210, 948, 815, and 758 cm^{-1}; ^1H nmr (60 MHz, trifluoroacetic acid): δ 2.78 (3H, s, C*H*$_3$) and 7.4-9.1 (11H, m, ArH and C*H*=C*H*).

Anal. Calcd. for $C_{14}H_{14}NBr$: C, 60.86; H, 5.11; N, 5.07. Found: C, 60.83; H, 5.05; N, 4.93.

Compound **7d** (X = ClO_4) was obtained as white crystals from methanol, mp 147.3-148.3° corr.

1-[(1-Methyl-2-phenyl)ethenyl]pyridinium Salt **7e**.

The reaction of the alcohol **5e** with phosphorus tribromide gave **7e** (X = Br). Compound **7e** (X = ClO_4) was obtained as pale yellow crystals from methanol, mp 180-181°; uv: λ max (ethanol)

297 nm (log ε 3.73); ir (potassium bromide): 3065, 1616, 1468, 1100, 894, and 778 cm^{-1}; ^1H nmr (90 MHz, DMSO-d_6): δ 2.53 (3H, s, CH_3), 7.16 (1H, s, olefin), 7.50 (5H, s, Ph*H*), and 8.1-9.4 (5H, m, pyridinium)

Anal. Calcd. for $C_{14}H_{14}NClO_4$: C, 56.86; H, 4.77; N, 4.74. Found: C, 57.02; H, 4.51; N, 4.81.

1-[2-(2-Methyl)phenylethenyl]pyridinium Salt **7f**.

The reaction of the alcohol **5f** with benzoyl chloride gave **7f** (X = Br). The salt form of **7f** (X = ClO_4) was obtained as pale yellow crystals from methanol, mp 183-184°; uv: λ max (ethanol) 327 nm (log ε 4.09); ir (potassium bromide): 3065, 1616, 1474, 1100, 952, and 760 cm^{-1}; ^1H nmr (90 MHz, DMSO-d_6): δ 2.46 (3H, s, CH_3) and 7.3-9.5 (11H, m, ArH and C*H*=C*H*).

Anal. Calcd. for $C_{14}H_{14}NClO_4$: C, 56.86; H, 4.77; N, 4.74. Found: C, 56.97; H, 4.69; N, 4.68.

1-[2-(4-Methyl)phenylethenyl]pyridinium Salt **7g**.

The reaction of the alcohol **5g** with benzoyl chloride gave **7g** (X = Br) (pale yellow crystals from pentan-1-ol), mp 273-275°; (lit [4] 272-275°); uv: λ max (ethanol) 235 nm (log ε 4.14); ^1H nmr (60 MHz, trifluoroacetic acid): δ 2.34 (3H, s, CH_3) and 7.1-9.0 (11H, m, ArH and C*H*=C*H*).

Anal. Calcd. for $C_{14}H_{14}NBr$; C, 60.88; H, 5.11; N, 5.07. Found: C, 60.73; H, 5.26; N, 5.21.

A Typical Procedure for the Photocyclization of *trans*-1-Styrylpyridinium Salts **7**, *e.g.* Compound **3b**.

2-Methylbenzo[*a*]quinolizinium Perchlorate (**3b**).

An ethanol solution (400 ml) of **7d** (X = Br) (0.552 g, 2 mmoles) and iodine (32 mg) in a Pyrex vessel was irradiated with a 300W high-pressure mercury lamp (Eikosha) at room temperature. At regular time intervals, a sample solution was taken out and subjected to uv spectral measurements. After the irradiation was judged to be essentially complete, the solution was concentrated and the residue was dissolved in water (100 ml). An insoluble brown solid was filtered and 60% aqueous perchloric acid was added to the filtrate. The resulting white solid was filtered, washed with cold water, and recrystallized from methanol to afford **3b** (X = ClO_4) (464 mg, 79%) as white crystals, mp 254.0-254.5°; uv: λ max (ethanol) 322 (log ε 3.72), 337 (4.05), and 353 nm (4.16); ^1H nmr (90 MHz, DMSO-d_6): δ 2.80 (s, 3H, CH_3) and 8.0-9.4 (m, 9H, ArH).

Anal. Calcd. for $C_{14}H_{12}NClO_4$: C, 57.24; H, 4.13; N, 4.77. Found: C, 57.23; H, 3.94; N, 4.64.

4-Methylbenzo[*a*]quinolizinium Perchlorate (**3d**).

The photocyclization of **7b** gave **3d** in 68% yield, mp 239-240°; uv: λ max (ethanol) 328 (log ε 3.73), 343 (4.05), and 360 nm (4.18); ^1H nmr (90 MHz, DMSO-d_6): δ 3.12 (s, 3H, CH_3) and 8.0-9.6 (m, 9H, ArH).

Anal. Calcd. for $C_{14}H_{12}NClO_4$: C, 57.24; H, 4.13; N, 4.77. Found: C, 57.33; H, 4.24; N, 4.63.

6-Methylbenzo[*a*]quinolizinium Perchlorate (**3e**).

The photocyclization of **7e** gave **3e** in 71% yield, mp 241.5-242.5°; uv: λ max (ethanol) 330 (log ε 3.65), 345 (3.94), and 362 nm (4.06); ^1H nmr (90 MHz, DMSO-d_6): δ 3.00 (s, 3H, CH_3) and 7.9-9.6 (m, 9H, ArH).

Anal. Calcd. for $C_{14}H_{12}NClO_4$: C, 57.24; H, 4.13; N, 4.77. Found: C, 57.31; H, 3.87; N, 4.72.

8-Methylbenzo[*a*]quinolizinium Perchlorate (**3g**).

The photocyclization of **7f** gave **3g** in 63% yield, mp 248.3-249.4° (lit [4] 250-251°); uv: λ max (ethanol) 325 (log ε 3.73), 340 (3.94), and 357 nm (4.03): ^1H nmr (90 MHz, DMSO-d_6): δ 2.79 (s, 3H, CH_3) and 7.9-9.6 (m, 9H, ArH).

Anal. Calcd. for $C_{14}H_{12}NClO_4$: C, 57.24; H, 4.13; N, 4.77. Found: C, 56.99; H, 3.83; N, 4.66.

10-Methylbenzo[*a*]quinolizinium Perchlorate (**3i**).

The photocyclization of **7g** gave **3i** in 68% yield, mp 245.1-246.3° (lit [4] 247-248°); uv: λ max (ethanol) 328 (sh), 344 (log ε 3.96), and 360 nm (4.11); ^1H nmr (90 MHz, DMSO-d_6): δ 2.75 (s, 3H, CH_3) and 8.0-9.5 (m, 9H, ArH).

Anal. Calcd. for $C_{14}H_{12}NClO_4$: C, 57.24; H, 4.13; N, 4.77. Found: C, 57.46; H, 4.06; N, 4.92.

2-Phenylthio-5-methylpyridine (**8a**).

A mixture containing 2-bromo-5-methylpyridine (14.71 g, 85.5 mmoles), thiophenol (11.57 g, 105 mmoles) and triethylamine (15 ml) was heated at 100° for 2 days. The reaction mixture was made alkaline with aqueous sodium hydroxide and extracted with benzene. The benzene extract was washed with water, dried (magnesium sulfate), and concentrated. The residue was distilled under reduced pressure to afford **8a** (12.03 g, 70%), bp 146-148°/1 mm Hg (lit [15] 130-132°/0.4 mm Hg); ^1H nmr/(60 MHz, deuteriochloroform): δ 2.14 (3H, s, CH_3) and 7.0-8.2 (8H, m, ArH).

2-Phenylthio-3-methylpyridine (**8b**).

The reaction of 2-bromo-3-methylpyridine with thiophenol afforded **8b** (72%), bp 142-145°/1 mm Hg (lit [15] 130-132°/0.5 mm Hg); ^1H nmr (60 MHz; deuteriochloroform): δ 2.25 (3H, s, CH_3) and 7.0-8.1 (8H, m, ArH).

1-Methylbenzo[*a*]quinolizinium Perchlorate (**3a**).

A mixture of 2-phenylthio-5-methylpyridine **8a** (4.42 g, 22 mmoles) and bromoacetaldehyde oxime (4.76 g, 34 mmoles) in sulfolane (5 ml) was refrigerated (0-5°) for 2 months. To the resulting dark viscous oil was added 48% hydrobromic acid (20 ml) and the mixture was refluxed for 29 hours. After concentration of the mixture under reduced pressure, water (80 ml) was added. The resulting black solid was filtered and 60% aqueous perchloric acid was added to the filtrate to give the dark viscous perchlorate **10** (3.08 g). A solution of the compound **10**, 30% hydrogen peroxide (4 ml), and acetic acid (35 ml) was heated at 56° for 20 hours, then at 100° for 22 hours. The mixture was concentrated under reduced pressure. The residual oil was dissolved in methanol. Upon addition of diethyl ether, a pale yellow solid resulted. Recrystallization from methanol afforded **3a** (897 mg) in 14% yield from compound **3a** as colorless crystals, mp 201-202°; uv: λ max (ethanol) 331 (sh), 346 (log ε 4.00), and 362 nm (4.13); ^1H nmr (90 MHz, DMSO-d_6): δ 3.25 (s, 3H, CH_3) and 8.0-9.5 (m, 9H, ArH).

Anal. Calcd. for $C_{14}H_{12}NClO_4$: C, 57.24; H, 4.13; N, 4.77. Found: C, 57.40; H, 4.17; N, 4.91.

3-Methylbenzo[*a*]quinolizinium Perchlorate (**3c**).

The title compound **3c** (724 mg, 12%) was prepared from 2-phenylthio-5-methylpyridine (4.23 g, 21 mmoles) and bromoacetaldehyde oxime (4.76 g, 35 mmoles) in a similar way to that of compound **3a**, mp 204.0-204.5°; uv: λ max (ethanol) 323 (log ε 3.76), 338 (4.06), and 354 nm (4.19); ^1H nmr (90 MHz, DMSO-d_6):

δ 2.65 (s, 3H, CH_3) and 8.0-9.5 (m, 9H, ArH).

Anal. Calcd. for $C_{14}H_{12}NClO_4$: C, 57.24; H, 4.13; N, 4.77. Found: C, 57.32; H, 4.11; N, 4.80.

7-Methylbenzo[*a*]quinolizinium Perchlorate (**3f**).

The compound **3f** was obtained as white crystals (methanol), mp 255.6-256.5° (lit [10] 260-262°); uv: λ max (ethanol) 324 (log ε 3.77), 339 (4.04), and 356 nm (4.16); ^{1}H nmr (90 MHz, DMSO-d_6): δ 2.73 (s, 3H, CH_3) and 8.0-9.5 (m, 9H, ArH).

Anal. Calcd. for $C_{14}H_{12}NClO_4$: C, 57.24; H, 4.13; N, 4.77. Found: C, 57.42; H, 4.03; N, 4.61.

9-Methylbenzo[*a*]quinolizinium Perchlorate (**3h**).

The compound **3h** was obtained as white needles (methanol), mp 228.8-229.2° (lit [11] 227-229°); uv: λ max (ethanol) 323 (log ε 3.81), 338 (4.09), and 354 nm (4.23); ^{1}H nmr (90 MHz, DMSO-d_6): δ 2.61 (s, 3H, CH_3) and 7.8-9.5 (m, 9H, ArH).

Anal. Calcd. for $C_{14}H_{12}NClO_4$: C, 57.24; H, 4.13; N, 4.77. Found: C, 57.46; H, 4.06; N, 4.70.

11-Methylbenzo[*a*]quinolizinium Perchlorate (**3j**).

The compound **3j** was obtained as white crystals (methanol), mp 206-207° (lit [12] 209-210°); uv: λ max (ethanol) 340 (sh), 343 (log ε 3.89), and 359 nm (3.98); ^{1}H nmr (90 MHz, DMSO-d_6): δ 3.15 (s, 3H, CH_3) and 7.9-9.6 (m, 9H, ArH).

Anal. Calcd. for $C_{14}H_{12}NClO_4$: C, 57.24; H, 4.13; N, 4.77. Found: C, 57.04; H, 3.96; N, 4.72.

A Typical Procedure for the Reaction of Compound **3** with *p*-Methoxybenzaldehyde, *e.g.* Compound **11a**.

trans-2-(*p*-Methoxystyryl)benzo[*a*]quinolizinium Perchlorate (**11a**).

To a methanol (40 ml) solution of compound **3b** (294 mg, 1.0 mmole) and *p*-methoxybenzaldehyde (150 mg, 1.1 mmoles), three drops of piperidine were added. The mixture was stirred under reflux for 5 hours. After being cooled to room temperature, the resulting solid was filtered and washed with cold aqueous hydrochloric acid (*p*H 2). Addition of cold diethyl ether to the filtrate gave a second crop. The combined solid was recrystallized from diethyl ether-acetone to afford **11a** (407 mg, 99%) as orange crystals, mp 246-247°; uv: λ max (ethanol) 420 nm (log ε 4.68); ir (potassium bromide): 1620, 1600, 1518, 1482, 1258, 1178, 1125, 980, and 838 cm^{-1}; ^{1}H nmr (90 MHz; DMSO-d_6): δ 3.83 (3H, s, CH_3), 7.04 (2H, d, J = 8.8 Hz, ArH), 7.43 (1H, d, J = 16.1 Hz, CH=), 7.68 (2H, d, J = 8.8 Hz, ArH), and 7.9-9.4 (10H, m, ArH + CH=).

Anal. Calcd. for $C_{22}H_{16}NClO_5$: C, 64.16; H, 4.40; N, 3.40. Found: C, 64.25; H, 4.30; N, 3.23.

trans-4-(*p*-Methoxystyryl)benzo[*a*]quinolizinium Perchlorate (**11b**).

The reaction of compound **3d** with *p*-methoxybenzaldehyde gave **11b** (46%) (yellow crystals from methanol-acetone), mp 236.4-237.9°; uv: λ max (methanol) 399 nm (log ε 4.42); ir (potassium bromide): 3030, 1596, 1466, 1080, 965, and 798 cm^{-1}; ^{1}H nmr (90 MHz, acetonitrile-d_3): δ 3.87 (3H, s, CH_3) and 7.0-9.2 (15H, m, ArH and CH=CH).

Anal. Calcd. for $C_{22}H_{18}NClO_5$: C, 64.16; H, 4.40; N, 3.40. Found: C, 64.41; H, 4.30; N, 3.34.

Bis(1-piperidino)(*p*-methoxyphenyl)methane (**12b**).

A mixture of *p*-methoxybenzaldehyde (2.0 g, 14.7 mmoles) and piperidine (3.0 g, 35.3 mmoles) was stirred overnight at room temperature. Distillation using a Kugelrohr distillation apparatus at 200° (oven temperature)/1 mm Hg afforded the title compound **12b** (3.73 g, 91%); ir (sodium chloride): 2928, 1608, 1510, 1238, 1100, and 828 cm^{-1}; ^{1}H nmr (90 MHz, deuteriochloroform): δ 1.54 (12H, m, piperidine), 2.4-2.7 (8H, m, piperidine), 3.78 (3H, s, CH_3), 4.58 (1H, s, CH), 6.88 (2H, d, J = 8.8 Hz, ArH), and 7.26 (2H, d, J = 8.8 Hz, ArH).

Anal. Calcd. for $C_{18}H_{18}N_2O$: C, 77.67; H, 6.52; N, 10.07. Found: C, 77.40; H, 6.41; N, 10.34.

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