SYNTHESIS AND REACTIVITIES OF 1,3-DIMETHYL-2-(α-HYDROXYBENZYL)IMIDAZOLIUM AND 1,3-DIMETHYL-2-(α-HYDROXYBENZYL)BENZIMIDAZOLIUM IODIDES

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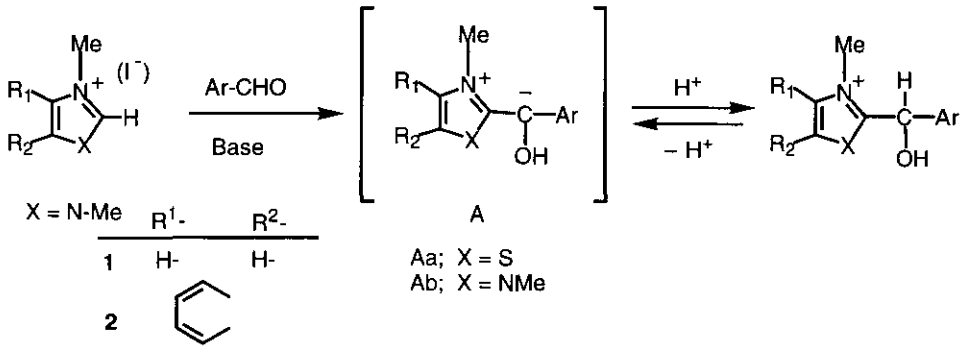
Abstract——1,3-Dimethyl-2-(α-hydroxybenzyl)benzimidazolium iodide (**3a**) was synthesized from 1-methylbenzimidazole (**10**) through two steps involving lithiation and quaternization. Treatment of **3a** with 4-chloro-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**6**) afforded 4-benzoyl-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**15a**). 4-Benzoylquinazoline (**14a**) and 7-benzoyl-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine (**16a**) were given by reaction of **3a** with 4-chloroquinazoline (**5**) and 7-chloro-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine (**7**). Treatment of **3a** with benzaldehyde (**9a**) gave benzoin (**8a**). Similar results were obtained in the reactions of 1,3-dimethyl-2-(α-hydroxybenzyl)imidazolium iodide (**4a**).

In the preceding papers,[1] we have reported that 1,3-dimethylimidazolium iodide (**1**) and 1,3-dimethylbenzimidazolium iodide (**2**) are effective catalysts for benzoin condensation and related reactions. Various aroylheteroarenes, such as 4-aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines (**15**) and 4-aroylquinazolines (**14**), and benzoins (**8**) have been obtained through such catalytic aroylations using arenecarbaldehydes. We proposed that the aroylations proceed through the formation of the intermediate A as a key step, as shown in Scheme 1. To clarify the reaction pathway, we synthesized 1,3-dimethyl-2-(α-hydroxybenzyl)benzimidazolium

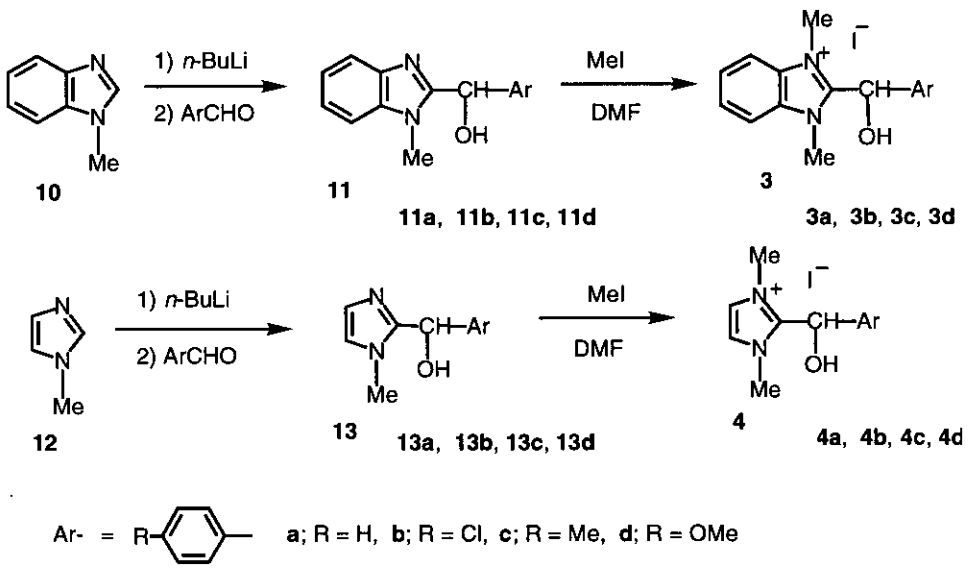


Scheme 1

iodides (**3**) and 1,3-dimethyl-2-(α-hydroxybenzyl)imidazolium iodides (**4**), and examined their reactivities. We considered that these quaternary salts (**3** and **4**) are precursors for the key intermediate A. In this paper, we wish to report the results in detail.

Breslow and McNelis reported that the anion (Aa) having a thiazolium moiety (X=S) is an important intermediate for benzoin condensation catalyzed by thiazolium salt.[2] They also suggested that the anion (Ab) having an imidazolium or a benzimidazolium moiety (X = N-Me) is the key intermediate for benzoin condensation and related reactions catalyzed by imidazolium or benzimidazolium salts.

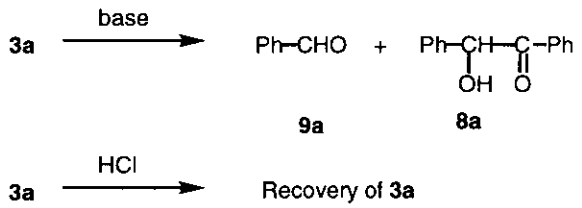
We synthesized 1,3-dimethyl-2-(α-hydroxybenzyl)benzimidazolium iodide (**3a**) from 1-methylbenzimidazole (**10**) in two steps. Lithiation of **10** followed by addition of benzaldehyde (**9a**) gave 1-methyl-2-(α-hydroxybenzyl)benzimidazole (**11a**),[3] which was led to **3a** by quaternization with methyl iodide, as shown in Scheme 2. Similar treatments of **10** with several arenecarbaldehydes (**9**) afforded the corresponding quaternary salts (**3**) having a benzimidazolium moiety in good yields. By use of 1-methylimidazole (**12**) as the starting compound, the quaternary salts (**4**) having an imidazolium moiety could be prepared.



Scheme 2

When the quaternary salt (**3a**) was treated with NaH in THF, benzaldehyde (**9a**) and benzoin (**8a**) were formed. However, treatment with triethylamine (TEA) gave only **9a**. Treatment of **3a** with hydrogen chloride resulted in recovery of the starting **3a**. These results indicate that **3a** decomposed under basic conditions. Ohta *et al.* [4] reported that imidazolium salts having an α-hydroxymethyl moiety at the 2-position decomposed under basic conditions to give carbonyl compounds and imidazolium ylide.

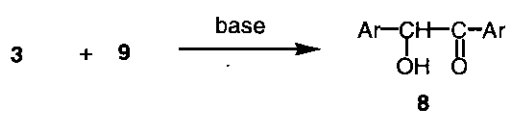
When the quaternary salt (**3a**) was treated with benzaldehyde (**9a**) under basic conditions, benzoin (**8a**) was obtained in good yield. As shown in Scheme 4, similar results were obtained by reaction of the quaternary salts (**3**) with arenecarbaldehydes (**9**). Thus, we have established that the anions of **3** are important intermediates in benzoin condensation and have synthesized benzoins (**8**)[5] by use of these quaternary salts (**3**).



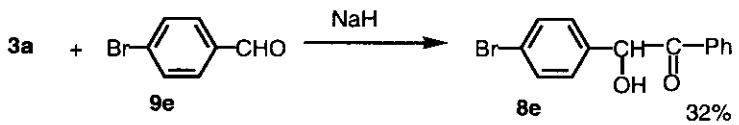
base	Products (%) 9a	8a
TEA	48	—
NaH	15	25

Scheme 3

The above results indicated that cross-benzoin-condensed product could be easily prepared by this procedure. As expected, the quaternary salt (**3a**) reacted with *p*-bromobenzaldehyde (**9e**) to give the cross-benzoin, 1-phenyl-2-(*p*-bromophenyl)-2-hydroxyethanone (**8e**),[6] in 32% yield.



3	9	8	Product, Yield (%) NaH	DBU
3a	**9a**	**8a**	52	86
3b	**9b**	**8b**	49	34
3c	**9c**	**8c**	40	58
3d	**9d**	**8d**	31	34

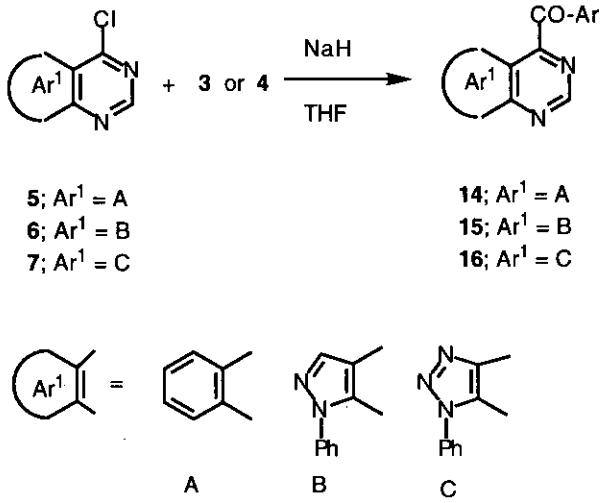


Scheme 4

By analogy with the benzoin condensation, we considered that the anions of **3** and **4** would also be important intermediates for the preparation of aroylheteroarenes. The expected 4-benzoyl-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**15a**) was obtained by treatment of **3a** with 4-chloro-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**6**)[7] under basic conditions. An attempt at aroylation of **6** with **3a** under neutral conditions failed to produce benzoylpyrazolopyrimidine (**15a**). The aroylations using quaternary salts (**3**) require base action for the purpose of formation of the carbanions.

Similar results could be obtained in the reactions of 4-chloroquinazoline (**5**) and 7-chloro-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine (**7**)[8] with **3a**. Namely, 4-benzoylquinazoline (**14a**) and 7-benzoyl-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine (**16a**) were obtained in moderate yields. In addition, the quaternary salts (**3** and **4**) reacted with **5**, **6**, and **7** to give the corresponding aroylheteroarenes (**14**, **15** and **16**)[2] in moderate to good yields, respectively. These results are summarized in Scheme 5.

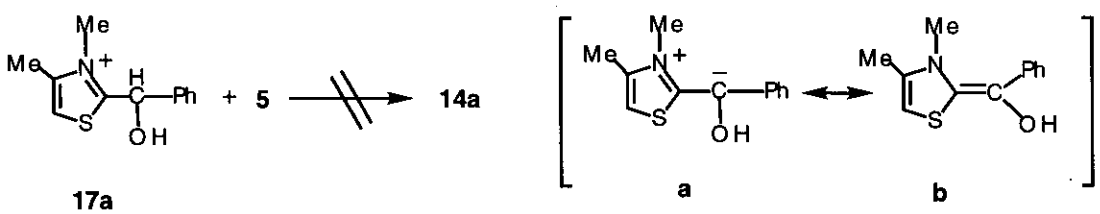
On the other hand, 4-benzoylquinazoline (**14a**) was not formed by the reaction of 4-chloroquinazoline (**5**) with the quaternary salt (**17a**) having a thiazolium moiety. Moreover, such aroylations were unsuccessful with



5-7	3-4	Product,	Yield (%)
5	3a	14a	80
5	3b	14b	77
5	3c	14c	81
5	3d	14d	98
6	3a	15a	79
6	3b	15b	60
6	3c	15c	61
6	3d	15d	72
7	3a	16a	34
7	3b	16b	53
7	3c	16c	73
7	3d	16d	45
5	4a	14a	57
5	4b	14b	39
5	4c	14c	59
5	4d	14d	49
6	4a	15a	62
6	4b	15b	72
6	4c	15c	86
6	4d	15d	63

Scheme 5

thiazolium salt as the catalyst.[9] To prepare aroylheteroarenes, sufficient nucleophilic reactivity of the anions derived from the quaternary salts (**3**, **4**, and **17**) is required. These results indicate that nucleophilic activity of the anion of the quaternary salt (**17a**) having the thiazolium moiety is lower than that in the case of the imidazolium or benzimidazolium moiety, because the electron-density of the α-carbon of the C-2 substituent on the thiazole is not sufficient. One of the reasons for the low activity of the anion of **17a** having the thiazolium moiety may be as follows. The anion of **17a** exists in two resonance structures (**a** and **b**). Because of the strong electron-withdrawing effect of the thiazolium moiety, the anion of **17a** might mainly exist in the **b** form. Aroylations require the **a** form.

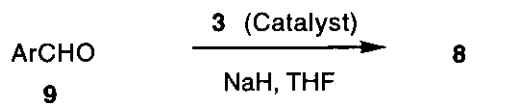


Scheme 6

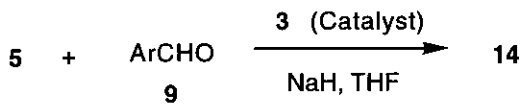
These results show that the anions of 1,3-dimethyl-2-(α-hydroxybenzyl)benzimidazolium iodides and 1,3-dimethyl-2-(α-hydroxybenzyl)imidazolium iodides (**3** and **4**) are important intermediates in catalytic aroylations such as the benzoin condensation and in the preparation of aroylheteroarenes. Nucleophilic introductions of

aroyl groups are achieved by use of these quaternary salts (**3** and **4**).

In this aroylation system using the quaternary salts (**3**) as the aroyl sources, the aroylated compounds are formed by expulsion of benzimidazolium ylide (**18**). The ylide (**18**) can be used as the catalyst provided that arenecarbaldehyde (**9**) exists in the reaction system. The aroylation pathway proposed by us led to use the active aldehydes (**3**) as the catalyst.[1] In the presence of a catalytic amount of the quaternary salts (**3**), aroylation of haloheteroarenes with arenecarbaldehydes (**9**) and self-condensation of arenecarbaldehyde (**9**) proceeded successfully. The results are shown in Scheme 7.



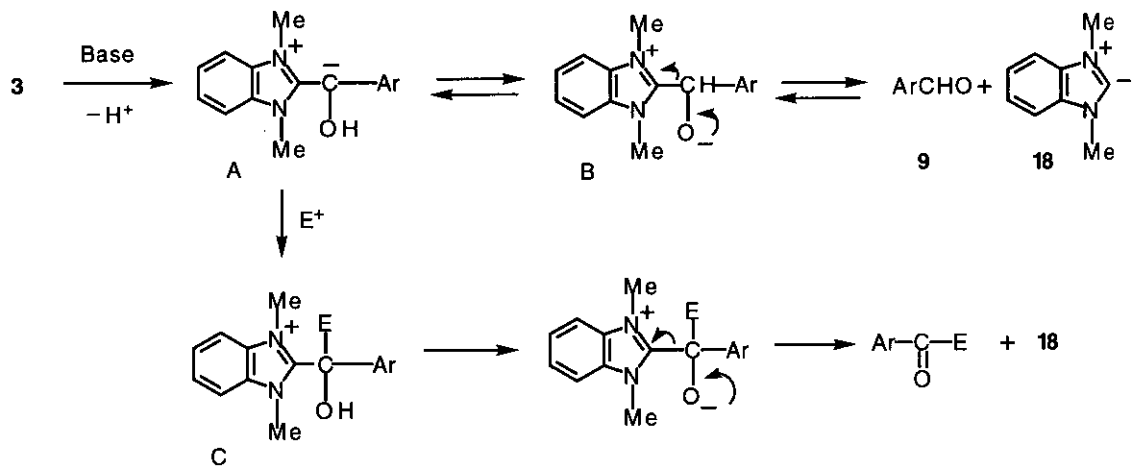
9	3	Product, Yield (%)	
9b	**3b**	**8b**	47
9c	**3c**	**8c**	40



9	3	Product, Yield (%)	
9a	**3a**	**14a**	60
9b	**3b**	**14b**	62
9c	**3c**	**14c**	70
9d	**3d**	**14d**	47

Scheme 7

The reaction pathway is summarized in Scheme 8. Namely, the anion derived from the quaternary salt (**3**) exists in two forms. One is the *O*-anion (B) and another is the carbanion (A). The carbanion (A) reacts with an electrophile, and decomposition of the intermediate (C) proceeds to achieve the aroylation. The *O*-anion (B) decomposes to afford the arenecarbaldehyde (**9**) and the ylide (**18**).



Scheme 8

The structures of the obtained ketones (**14**, **15**, and **16**)[1] and benzoins (**8**)[5] were determined by comparison of the spectral data with those of authentic samples.

In conclusion, we have shown that the anions of **3** and **4** are key intermediates for catalytic aroylations, *i. e.*,

benzoin condensation and preparation of aroylheteroarenes. The results also support the reaction pathway proposed by us for catalytic aroylations involving the catalytic action of azolium salts.[1]

EXPERIMENTAL

All melting points were obtained without correction. Ir spectra were recorded on a JASCO A-102 diffraction grating ir spectrophotometer. ^{1}H-Nmr spectra were measured at 60 MHz on a Hitachi high resolution NMR R-1100 spectrometer, and at 270 MHz on a JEOL JNM-GSX270 FT-NMR spectrometer. Chemical shifts are quoted in parts per million (ppm) with tetramethylsilane as an internal standard, and coupling constants are given in Hz.

Preparation of 1-Methyl-2-(α-hydroxybenzyl)benzimidazole (11); General Procedure To a stirred solution of TMEDA (9.5 ml, 63 mmol) in THF (25 ml) at –78 °C was added slowly *n*-BuLi (1.62 mol/l *n*-hexane solution, 37.5 ml, 60 mmol). A solution of 1-methylbenzimidazole (**10**, 6.6 g, 50 mmol) in 25 ml of THF was added to the resulting mixture below –60 °C with stirring, and the whole was stirred at –78 °C for 1 h. A solution of arenecarbaldehyde (**9**, 55 mmol) in 25 ml of THF was added dropwise during 30 min below –60°C, and the reaction mixture was stirred at –78 °C for 1 h. The cooling bath was removed, and the mixture was allowed to warm to room temperature with stirring. The solvent was removed under reduced pressure. Ice-H_2O was added to the residue, and the mixture was allowed to stand overnight. The separated solid was collected, washed with H_2O then *n*-hexane, and dried. The solid was recrystallized from MeOH to give 1-methyl-2-(α-hydroxybenzyl)benzimidazole (**11**).

1-Methyl-2-(α-hydroxybenzyl)benzimidazole (**11a**): Yield 78%. Colorless granules, mp 159-160 °C. *Anal.* Calcd for $C_{15}H_{14}N_2O$: C, 75.61; H, 5.92; N, 11.76. Found: C, 75.65; H, 5.91; N, 11.58. Ir (KBr) cm^{-1}: 2990-3490 (OH). ^{1}H-Nmr ($CDCl_3$): 3.45 (3H, s, Me), 6.13 (1H, s, CH or OH), 7.13-7.90 (10H, m, aromatic H).

1-Methyl-2-(α-hydroxy-4-chlorobenzyl)benzimidazole (**11b**): Yield 83%. Colorless granules, mp 187-189 °C. *Anal.* Calcd for $C_{15}H_{13}N_2OCl$: C, 66.06; H, 4.80; N, 10.27. Found: C, 65.70; H, 4.77; N, 10.15. Ir (KBr) cm^{-1}: 2975-3325 (OH). ^{1}H-Nmr ($CDCl_3$): 3.70 (3H, s, Me), 6.01 (1H, s, CH or OH), 6.59 (1H, s, CH or OH), 6.95-7.85 (8H, m, aromatic H).

1-Methyl-2-(α-hydroxy-4-methylbenzyl)benzimidazole (**11c**): Yield 69%. Colorless scales, mp 136-138 °C. *Anal* Calcd for $C_{16}H_{16}N_2O$: C, 76.17; H, 6.39; N, 11.10. Found: C, 75.76; H, 6.39; N, 11.05. Ir (KBr) cm^{-1}: 2960-3350 (OH). ^{1}H-Nmr (DMSO-d_6): 2.27 (3H, s, Me), 3.66 (3H, s, Me), 6.06 (1H, s, CH or OH), 7.00-7.76 (9H, m, aromatic H and OH or CH).

1-Methyl-2-(α-hydroxy-4-methoxybenzyl)benzimidazole (**11d**): Yield 97%. Colorless scales, mp 170-173 °C. *Anal.* Calcd for $C_{16}H_{16}N_2O_2$: C, 71.62; H, 6.01; N, 10.44. Found: C, 71.64; H, 6.03; N, 10.54. Ir (KBr) cm^{-1}: 3030-3330 (OH). ^{1}H-Nmr ($CDCl_3$): 3.46 (3H, s, Me), 3.77 (3H, s, OMe), 6.01 (1H, s, CH or OH), 6.74-8.15 (9H, m, aromatic H and CH).

Preparation of 1,3-Dimethyl-2-(α-hydroxybenzyl)benzimidazolium Iodide (3); General Procedure A solution of 1-methyl-2-(α-hydroxybenzyl)benzimidazole (**11**, 3 mmol) and methyl iodide (2 ml, 21 mmol) in DMF (2 ml) was refluxed for 3 h. Ether (20 ml) was added to the cooled mixture, and the solid

separated was collected. The solid was recrystallized from MeOH to give the quaternary salt (**3**).

1,3-Dimethyl-2-(α-hydroxybenzyl)benzimidazolium iodide (**3a**): Yield 95%. Colorless scales, mp 175-180 °C. *Anal* Calcd for $C_{16}H_{17}N_2OI$: C, 50.54; H, 4.51; N, 7.37. Found: C, 50.62; H, 4.53; N, 7.09. Ir (KBr) cm^{-1}: 3075-3400 (OH). ^{1}H-Nmr (DMSO-d_6): 4.13 (6H, s, Me x 2), 6.79 (1H, d, J = 4 Hz, CH or OH), 7.15 (1H, d, J = 4 Hz, OH or CH), 7.44-8.08 (9H, m, aromatic H).

1,3-Dimethyl-2-(α-hydroxy-4-chlorobenzyl)benzimidazolium iodide (**3b**): Yield 92%. Colorless granules, mp 181-184 °C. *Anal.* Calcd for $C_{16}H_{16}N_2OClI$: C, 46.34; H, 3.89; N, 6.76. Found: C, 46.31; H, 3.83; N, 6.81. Ir (KBr) cm^{-1}: 3075-3310 (OH). ^{1}H-Nmr (DMSO-d_6): 3.99 (6H, s, Me x 2), 6.67 (1H, d, J = 5 Hz, CH or OH), 7.21 (1H, d, J = 5 Hz, OH or CH), 7.87-8.04 (8H, m, aromatic H).

1,3-Dimethyl-2-(α-hydroxy-4-methylbenzyl)benzimidazolium iodide (**3c**): Yield 97%. Colorless granules, mp 153-155 °C. *Anal.* Calcd for $C_{17}H_{19}N_2OI$: C, 51.79; H, 4.86; N, 7.11. Found: C, 51.49; H, 4.82; N, 6.93. Ir (KBr) cm^{-1}: 3090-3370 (OH). ^{1}H-Nmr (DMSO-d_6): 2.34 (3H, s, Me), 4.10 (6H, s, Me x 2), 6.70 (1H, d, J = 4 Hz, CH or OH), 7.00 (1H, d, J = 4 Hz, OH or CH), 7.12-8.14 (8H, m, aromatic H).

1,3-Dimethyl-2-(α-hydroxy-4-methoxybenzyl)benzimidazolium iodide (**3d**): Yield 82%. Colorless columns, mp 158-160 °C. *Anal.* Calcd for $C_{17}H_{19}N_2O_2I$: C, 49.77; H, 4.67; N, 6.83. Found: C, 49.48; H, 4.52; N, 6.80. Ir (KBr) cm^{-1}: 3110-3350 (OH). ^{1}H-Nmr (DMSO-d_6): 3.75 (3H, s, OMe), 4.08 (6H, s, Me x 2), 6.59-8.53 (10H, m, aromatic H, CH, and OH).

Preparation of 1-Methyl-2-(α-hydroxybenzyl)imidazole (13); General Procedure To a stirred solution of TMEDA (2.0 ml, 13 mmol) in THF (5 ml) at –78°C was added slowly *n*-BuLi (1.62 mol/l *n*-hexane solution, 7.5 ml, 12 mmol). A solution of 1-methylbenzimidazole (**12**, 0.82 g, 10 mmol) in 5 ml of THF was added to the resulting mixture below –60 °C with stirring, and the whole was stirred at –78 °C for 1 h. A solution of arenecarbaldehyde (**9**, 11 mmol) in 5 ml of THF was added dropwise during 30 min below –60°C, and the mixture was stirred at –78 °C for 1 h. The cooling bath was removed, and the mixture was allowed to warm to room temperature with stirring. The solvent was removed under reduced pressure. Ice-H_2O was added to the residue, and the mixture was allowed to stand overnight. The solid separated was collected, washed with H_2O then *n*-hexane, and dried. The solid was recrystallized from MeOH to give 2-(α-benzyloxybenzyl)imidazole (**13**).

1-Methyl-2-(α-hydroxybenzyl)imidazole (**13a**): Yield 87%. Colorless granules, mp 113 °C. *Anal.* Calcd for $C_{11}H_{12}N_2O$: C, 69.96; H, 6.72; N, 14.75. Found: C, 70.19; H, 6.43; N, 14.88. Ir (KBr) cm^{-1}: 3230 (OH). ^{1}H-Nmr ($CDCl_3$): 3.33 (3H, s, Me), 5.89 (1H, s, CH or OH), 6.68 (1H, s), 6.82 (1H, s), 7.16-7.33 (5H, m, aromatic H).

1-Methyl-2-(α-hydroxy-4-chlorobenzyl)imidazole (**13b**): Yield 98%. Colorless granules, mp 133-134 °C. *Anal.* Calcd for $C_{11}H_{11}N_2OCl$: C, 59.33; H, 4.98; N, 12.58. Found: C, 59.50; H, 4.93; N, 12.45. Ir (KBr) cm^{-1}: 2960-3400 (OH). ^{1}H-Nmr ($CDCl_3$): 3.52 (3H, s, Me), 5.89 (1H, d, J = 5 Hz, CH or OH), 6.76 (1H, s,), 7.04 (1H, s), 7.33-7.40 (4H, m, aromatic H).

1-Methyl-2-(α-hydroxy-4-methylbenzyl)imidazole (**13c**): Yield 94%. Colorless prisms, mp 123-124 °C. *Anal.* Calcd. for $C_{12}H_{14}N_2O$: C, 71.26; H, 6.98; N, 13.85. Found: C, 71.10; H, 7.14; N, 13.95. Ir (KBr) cm^{-1}: 2960-3320 (OH). ^{1}H-Nmr ($CDCl_3$): 2.35 (3H, s, Me), 3.30 (3H, s, Me), 5.85 (1H, d, J = 5 Hz, CH or OH), 6.61 (1H, s), 6.77 (1H, s), 6.95-7.41 (4H, m, aromatic H and CH).

1-Methyl-2-(α-hydroxy-4-methoxybenzyl)imidazole (**13d**): Yield 74%. Colorless oil. *Anal.* Calcd for

$C_{12}H_{14}N_2O_2$: C, 66.04; H, 6.47; N, 12.84. Found: C, 65.99; H, 6.33; N, 12.85. Ir (KBr) cm^{-1}: 3030-3330 (OH). ^{1}H-Nmr ($CDCl_3$): 3.46 (3H, s, Me), 3.77 (3H, s, OMe), 6.01 (1H, s, CH or OH), 6.74-8.15 (9H, m, aromatic H and OH or CH).

Preparation of 1,3-Dimethyl-2-(α-hydroxybenzyl)imidazolium Iodide (4); General Procedure A solution of 1-methyl-2-(α-hydroxybenzyl)imidazole (**13**, 42 mmol) and methyl iodide (12 ml) in DMF (6 ml) was refluxed for 3 h. Acetone (6 ml) was added to the cooled mixture, and the solid separated was collected. The solid was recrystallized from MeOH-*n*-hexane to give the quaternary salt (**4**).

1,3-Dimethyl-2-(α-hydroxybenzyl)imidazolium iodide (**4a**): Yield 85%. Colorless prisms, mp 169-172 °C. *Anal.* Calcd for $C_{12}H_{15}N_2OI$: C, 44.09; H, 4.62; N, 8.43. Found: C, 43.65; H, 4.58; N, 8.49. IR (KBr) cm^{-1}: 3210 (OH). ^{1}H-Nmr (DMSO-d_6): 3.81 (6H, s, Me x 2), 6.47 (1H, d, J = 5 Hz, CH or OH), 7.00 (1H, d, J = 4 Hz, CH or OH), 7.34-7.47 (5H, m, aromatic H), 7.73 (2H, s).

1,3-Dimethyl-2-(α-hydroxy-4-chlorobenzyl)imidazolium iodide (**4b**): Yield 85%. Colorless granules, mp 143-146 °C. *Anal.* Calcd for $C_{12}H_{14}N_2OClI$: C, 39.53; H, 3.87; N, 7.68. Found: C, 39.81; H, 3.71; N, 7.64. Ir (KBr) cm^{-1}: 3270 (OH). ^{1}H-Nmr (DMSO-d_6): 3.82 (6H, s, Me x 2), 6.48 (1H, d, J = 4 Hz, CH or OH), 7.08 (1H, d, J = 4 Hz, CH or OH), 7.40-8.52 (6H, m, aromatic H).

1,3-Dimethyl-2-(α-hydroxy-4-methylbenzyl)imidazolium iodide (**4c**): Yield 84%. Colorless granules, mp 145-146 °C. *Anal.* Calcd for $C_{13}H_{17}N_2OI$: C, 45.37; H, 4.98; N, 8.14. Found: C, 45.49; H, 4.94; N, 8.07. Ir (KBr) cm^{-1}: 3090-3370 (OH). ^{1}H-Nmr (DMSO-d_6): 2.31 (3H, s, Me), 3.80 (6H, s, Me x 2), 6.40 (1H, s, J = 4 Hz, CH or OH), 6.86 (1H, s, J = 4 Hz, CH or OH), 7.18-7.21 (4H, m, aromatic H), 7.68 (2H, s).

1,3-Dimethyl-2-(α-hydroxy-4-methoxybenzyl)imidazolium iodide (**4d**): Yield 57%. Colorless columns, mp 142-144 °C. *Anal.* Calcd for $C_{13}H_{17}N_2O_2I$: C, 43.35; H, 4.76; N, 7.78. Found: C, 43.18; H, 4.92; N, 7.67. Ir (KBr) cm^{-1}: 3210 (OH). ^{1}H-Nmr (DMSO-d_6): 3.35 (3H, s, OMe), 3.80 (6H, s, Me x 2), 6.40 (1H, d, J = 4 Hz, CH or OH), 6.90 (1H, d, J = 4 Hz, CH or OH), 6.96-7.30 (4H, m, aromatic H), 7.71 (2H, s).

Decomposition of 1,3-Dimethyl-2-(α-hydroxybenzyl)benzimidazolium Iodide (3a) under Basic Conditions. A mixture of 1,3-dimethyl-2-(α-hydroxybenzyl)benzimidazolium iodide (**3a**, 762 mg, 2 mmol) and base (NaH: 60% in oil, 80 mg, 2 mmol, or triethylamine: 0.5 ml, 3.5 mmol) in 20 ml of THF was refluxed for 1 h. The reaction mixture was poured into ice-H_2O and the resulting mixture was extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene, then $CHCl_3$.

With TEA as the base, the fraction eluted with benzene gave benzaldehyde (**9a**, 102 mg, 48%).

With NaH as the base, the fraction eluted with benzene gave benzaldehyde (**9a**, 32 mg, 15%) and the fraction eluted with $CHCl_3$ gave benzoin (**8a**, 53 mg, 25%).

Synthesis of Benzoins by Reaction of 1,3-Dimethyl-2-(α-hydroxybenzyl)benzimidazolium Iodide (3) with Arenecarbaldehydes (9); General Procedure To a stirred mixture of the quaternary salt (**3**, 2 mmol) and an arenecarbaldehyde (**9**, 2 mmol) in 20 ml of THF was added NaH (60% in oil, 100 mg, 2.5 mmol), and the mixture was refluxed for 3 h. The reaction mixture was poured into ice-H_2O and the resulting mixture was extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene, then $CHCl_3$. The

fraction eluted with $CHCl_3$ gave benzoin (**8**).[5] Yields are shown in Scheme 4.

Synthesis of 2-(4-bromophenyl)-1-phenyl-2-hydroxyethanone (8e) To a mixture of an active aldehyde (**3a**, 2 mmol) and *p*-bromobenzaldehyde (**9e**, 370 mg, 2 mmol) in 10 ml of DMF was added NaH (60% in oil, 100 mg, 2.5 mmol), and the mixture was stirred at 80 °C for 1 h. The reaction mixture was poured into ice-H_2O and extracted with AcOEt. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene then $CHCl_3$. The fraction eluted with $CHCl_3$ gave benzoin (**8e**) in 32% (186 mg) yield, mp. 121-123 °C (lit.,[6] 125-126 °C).

Synthesis of Aroylheteroarenes by Reaction of Quaternary Salt (3 or 4) with Haloheteroarenes; General Procedure To a stirred mixture of a haloheteroarene (**5**, **6**, or **7**, 1 mmol) and the quaternary salt (**3** or **4**, 1 mmol) in 8 ml of THF was added NaH (60% in oil, 50 mg, 1.3 mmol), and the resulting mixture was refluxed for 1 h with stirring. The reaction mixture was poured into ice-H_2O, and the resulting mixture was extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene then $CHCl_3$. The fraction eluted with $CHCl_3$ gave aroylheteroarene (**14**, **15**, or **16**).[1] Yields are shown in Scheme 5.

Preparation of 4-Methyl-2-(α-hydroxybenzyl)thiazole To a stirred solution of TMEDA (19 ml, 125 mmol) in THF (60 ml) at –78°C was added slowly *n*-BuLi (1.62 mol/l *n*-hexane solution, 64 ml, 120 mmol). A solution of 4-methylthiazole (9.9 g, 100 mmol) in 60 ml of THF was added to the resulting mixture below –60 °C with stirring, and the mixture was stirred at –78°C for 1 h. A solution of benzaldehyde (**9a**, 10.6 g, 100 mmol) in 60 ml of THF was added dropwise to the mixture during 30 min below –60°C, and the whole was stirred at –78°C for 1 h. The cooling bath was removed, and the mixture was allowed to warm to room temperature with stirring. The solvent was removed under reduced pressure. Ether (200 ml) was added to the residue, and the solid separated was collected. The solid was dried and recrystallized from acetone to give 4-methyl-2-(α-hydroxybenzyl)thiazole (16.3 g, 79%). Colorless needles, mp 98-99 °C. *Anal.* Calcd for $C_{11}H_{11}NOS$: C, 64.36; H, 5.40; N, 6.82. Found: C, 64.38; H, 5.43; N, 6.75. Ir (KBr) cm^{-1}: 2950-3300 (OH). ^{1}H-Nmr ($CDCl_3$): 2.33 (3H, s, Me), 5.93 (1H, s, CH), 6.71 (1H, s, thiazole ring-H), 7.15-7.41 (5H, m, aromatic H).

Preparation of 3,4-Dimethyl-2-(α-hydroxybenzyl)thiazolium Iodide (17a) A solution of 4-methyl-2-(α-hydroxybenzyl)thiazole (2.05 g, 10 mmol) and methyl iodide (3.3 ml, 35 mmol) in DMF (3 ml) was refluxed for 3 h. Ether (6 ml) was added to the cooled mixture, and the solid separated was collected. The solid was recrystallized from MeOH to give the quaternary salt (**17a**).
3,4-Dimethyl-2-(α-hydroxybenzyl)thiazolium iodide (**3a**): Yield 91% (3.15 g). Colorless needles, mp 156-158 °C. *Anal.* Calcd for $C_{12}H_{14}NOIS$: C, 41.51; H, 4.06; N, 4.03. Found: C, 41.48; H, 3.86; N, 4.07.
Ir (KBr) cm^{-1}: 3190 (OH). ^{1}H-Nmr (DMSO-d_6): 2.48 (3H, s, Me), 3.27 (1H, br, OH), 3.78 (3H, s, NMe), 6.35 (1H, br, CH), 7.41 (5H, m), 7.94 (1H, s, thiazole ring-H).

Synthesis of Benzoins Catalyzed by Quaternary Salt (3); General Procedure. To a stirred mixture of an arenecarbaldehyde (**9**, 4 mmol) and the quaternary salt (**3**, 0.2 mmol) in 20 ml of THF was added NaH

(60% in oil, 100 mg, 2.5 mmol), and the mixture was refluxed for 3 h with stirring. The reaction mixture was poured into ice-H_2O and the resulting mixture was extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with $CHCl_3$. The fraction eluted with $CHCl_3$ gave benzoin (**8**). Yields are shown in Scheme 7.

Synthesis of Aroylheteroarenes Catalyzed by Quaternary Salt (3); General Procedure Sodium hydride (60% in oil, 120 mg, 3 mmol) was added to a stirred mixture of haloheteroarene (**5**, 2 mmol), arenecarbaldehyde (**9**, 2 mmol), and the quaternary salt (**3**, 0.2 mmol) in 20 ml of THF, and the mixture was refluxed for 1 h with stirring. The reaction mixture was poured into ice-H_2O and the resulting mixture was extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with $CHCl_3$. The fraction eluted with $CHCl_3$ gave aroylheteroarene (**14**). Yields are shown in Scheme 7.

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