THERMAL REACTION OF BENZIMIDAZOLIUM *N*-ALLYLIDES†

Yoshiro Matsuda*, Makoto Yamashita, Kimitoshi Takahashi, Shizuki Ide, Katsura Torisu, and Kazuki Furuno

School of Pharmaceutical Sciences, Nagasaki University, 1-14 Bunkyo-machi Nagasaki 852, Japan

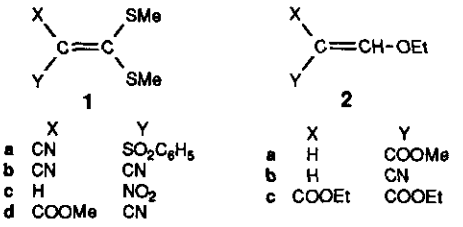
Abstract – The reaction of benzimidazolium salt (**3**) and polarized olefins (**1a,b,d** and **2c**) with K_2CO_3 in $CHCl_3$ gave the corresponding benzimidazolium *N*-allylides (**4a-d**). Thermolyses of *N*-allylides (**4a,b**) in refluxing xylene afforded the 1,5-dipolar cyclization product, benzopyrroloimidazole (**5a**), whereas heating of *N*-allylides (**4c,d**) resulted in back-donated 1,6-cyclization to give the mesomeric betaines, benzimidazopyridiniumides (**7a,b**). Treatment of **3** and **2a** with K_2CO_3 in $CHCl_3$ yielded directly benzopyrroloimidazole (**5b**), while similar treatment of **3** with **1c** or **2b** gave benzopyrrolopyrazines (**6a,b**).

1,5-Dipolar cyclization of *N*-allylides or *N*-vinylimino ylides, which were obtained by the reaction of *N*-ylides or *N*-imines with acetylenes and polarized olefins (ketene dithioacetals and ethoxymethylene compounds) is useful for the syntheses of heterocyclic compounds.[1-9] With regard to benzimidazolium *N*-ylides, 1,5-dipolar cyclization was observed for the reaction of benzimidazolium *N*-ylides with acetylenes, giving the corresponding benzopyrroloimidazoles or benzopyrrolo-

† Dedicated to Prof. Masatomo Hamana on the occasion of his 75th birthday.

pyrazines *via* benzimidazolium *N*-allylides.[9] However, the literature was devoid of the reaction of benzimidazolium *N*-ylides with polarized olefins. As part of our continuing interest in ylide chemistry, we briefly reported on the synthesis of the mesomeric betaine, benzimidazo[1,2-*a*]pyridiniumide (**7b**) which was obtained by the reaction of benzimidazolium salt (**3**) with diethyl ethoxymethylenemalonate (**2c**) in the presence of K_2CO_3 *via* a novel back-donated 1,6-cyclization.[10] The purpose of the present investigation is to see whether benzimidazolium *N*-allylides (**4**) undergo 1,5-dipolar cyclization to afford benzopyrrolo[1,2-*a*]imidazoles (**5**) or back-donated 1,6-cyclization to give the mesomeric betaines, 4-oxobenzimidazo[1,2-*a*]pyridiniumides (**7**). The polarized olefins (**1**,**2**) used in the present work were shown below. (Scheme 1)

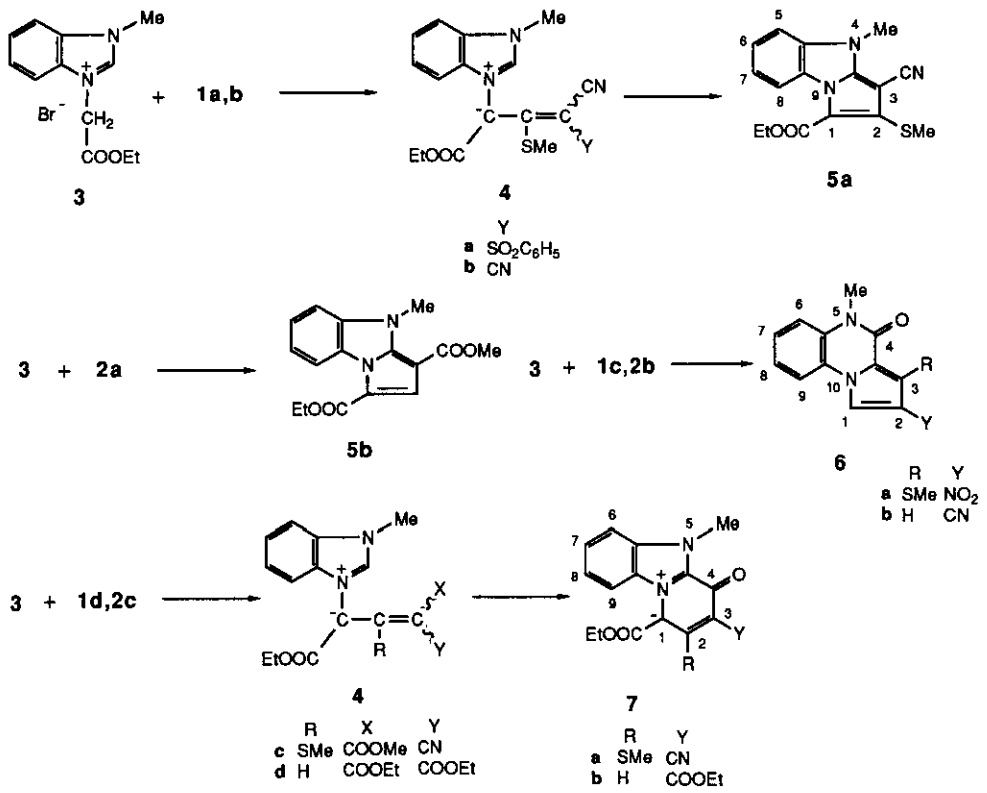
Scheme 1



The reaction of benzimidazolium salt (**3**) with polarized olefins (**1a**,**b**) in the presence of K_2CO_3 in $CHCl_3$ for three days gave benzimidazolium *N*-allylides (**4a**,**b**) in good yield. A solution of the *N*-allylide (**4a**) in xylene was refluxed for 24 h to afford benzopyrroloimidazole (**5a**), a 1,5-dipolar cyclization product in moderate yield. In our previous paper,[11] we reported that thermolysis of imidazolium *N*-(3,3-dicyano-1-ethoxycarbonyl-2-methylthio)allylide afforded the back-donated 1,6-cyclization product, 7-iminoimidazopyridiniumide derivative. However, heating of benzimidazolium *N*-allylide (**4b**) in refluxing xylene gave the 1,5-dipolar cyclization product (**5a**). Treatment of **3** with polarized olefin (**2a**) in $CHCl_3$ did not give *N*-allylide but afforded directly benzopyrroloimidazole (**5b**) in 25% yield. Interestingly, the reaction of **3** with **1c** or **2b** gave benzopyrrolo[1,2-*a*]pyrazine derivatives (**6a**,**b**). The reaction of **3** with **1d** in the presence of K_2CO_3 in $CHCl_3$ gave benzimidazolium *N*-allylide (**4c**). As reported in our previous paper,[10] when the salt (**3**) and **2c** were

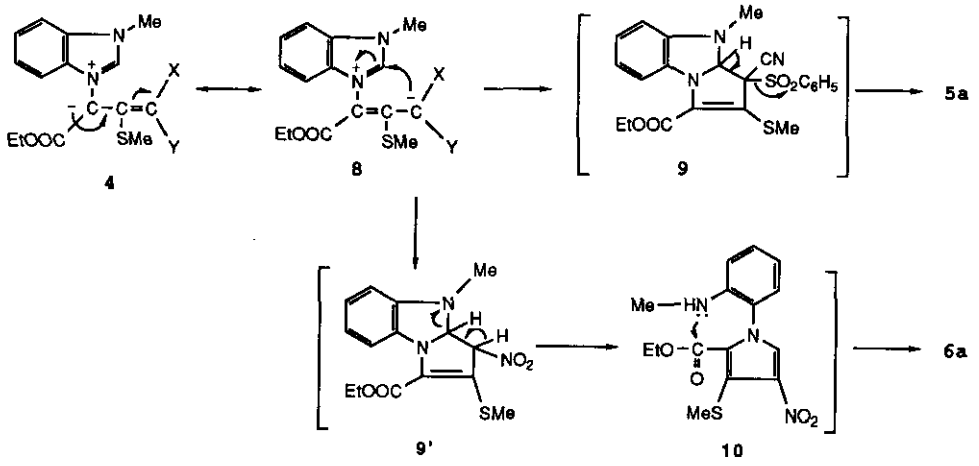
treated with K_2CO_3 in $CHCl_3$ for a week, the mesomeric betaine, benzimidazopyridiniumide (**7b**) was obtained in 16% yield. However, the mixture of **3** and **2c** with K_2CO_3 in $CHCl_3$ was stirred at room temperature for three days to give *N*-allylide (**4d**) in 68% yield. It should be noted that heating of **4c,d** in refluxing xylene resulted in the back-donated 1,6-cyclization giving rise to the mesomeric betaines (**7a,b**) in 87% and 64% yields, respectively. (Scheme 2)

Scheme 2

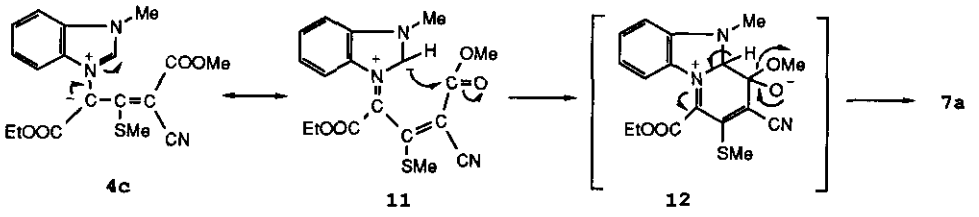


The formation of compounds (**5a,6a**) may be rationalized as outlined in Scheme 3. In the case of benzopyrroloimidazole (**5a**), as described in the previous papers,[1-10] the initial step may be 1,5-cyclization to give **9**. This step is then followed by elimination of the phenylsulfonyl group that leads to **5a**, whereas, as pointed out by Meth-Cohn,[9] the resonance structure (**8**) may cyclize to give benzopyrrolopyrazine (**6a**) *via* **9'**. The formation of benzimidazopyridiniumide (**7a**) may be clarified as described in our previous paper.[10] The resonance structure (**11**) may cyclize to give **7a** *via* **12**. (Scheme 4)

Scheme 3



Scheme 4



EXPERIMENTAL

Melting points were determined with a Mitamura Mel-Temp and are uncorrected. Ir spectra were recorded as KBr pellets on a JASCO IRA-2 spectrophotometer. Uv spectra were recorded on a Hitachi 323 spectrophotometer. ^{1}H-Nmr spectra were obtained on a JNM-FX-90Q (90 MHz) 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.

Benzimidazolium *N*-(1-ethoxycarbonyl)allylides (4a-d)

A mixture of **3** (1.20 g, 4 mmol), polarized olefins (**1a,b,d,2c**) (4 mmol) and K_2CO_3 (1.10 g, 8 mmol) in $CHCl_3$ (40 ml) was stirred at room temperature for three days 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 products (**4a-d**), respectively.

4a: mp 196°C; yield 1.44 g (79%); ir(KBr) νmax 2150(CN), 1660(CO) cm^{-1}; uv(EtOH) λmax (log ε) 243(4.06), 272(3.99), 279(3.99), 303(3.93), 381(4.27) nm; ^{1}H-nmr ($CDCl_3$) δ 1.24(3H, t, *J*=7 Hz, $CH_2C\underline{H}_3$), 2.72(3H, s, SCH_3), 4.08(3H, s, NCH_3), 4.11(2H, q, *J*=7 Hz, $C\underline{H}_2CH_3$), 7.25-7.78(9H, m, Ar-H), 9.57(1H, s, C_2-H). *Anal.* Calcd for $C_{22}H_{21}N_3O_4S_2$: C, 58.00; H, 4.65; N, 9.22. Found: C, 57.89; H, 4.68; N, 9.29.

4b: mp 180°C; yield 0.72 g (53%); ir(KBr) νmax 2190(CN), 2170(CN), 1660(CO) cm^{-1}; uv(EtOH) λmax (log ε) 242(3.65), 265(3.59), 272(3.65), 280(3.65), 302(3.55), 370(4.06) nm; ^{1}H-nmr ($CDCl_3$) δ 1.24(3H, t, *J*=7 Hz, $CH_2C\underline{H}_3$), 2.61(3H, s, SCH_3), 4.13(3H, s, NCH_3), 4.19(2H, q, *J*=7 Hz, $C\underline{H}_2CH_3$), 7.27-7.70(4H, m, Ar-H), 8.74(1H, s, C_2-H). *Anal.* Calcd for $C_{17}H_{16}N_4O_2S$: C, 59.98; H, 4.74; N, 16.46. Found: C, 59.88; H, 4.74; N, 16.37.

4c: mp 185°C; yield 1.38 g (93%); ir(KBr) νmax 2170(CN), 1680(CO), 1660(CO) cm^{-1}; uv(EtOH) λmax (log ε) 203(4.16), 235sh(3.84), 263(3.59), 276(3.59), 289(3.59) nm; ^{1}H-nmr ($CDCl_3$) δ 1.22(3H, t, *J*=7 Hz, $CH_2C\underline{H}_3$), 2.46(3H, s, SCH_3), 3.50(3H, s, OCH_3), 4.14 (2H, q, *J*=7 Hz, $C\underline{H}_2CH_3$), 7.40-7.72(4H, br s, Ar-H), 8.92(1H, s, C_2-H). *Anal.* Calcd for $C_{18}H_{19}N_3O_4S$: C, 57.90; H, 5.13; N, 11.25. Found: C, 57.87; H, 5.11; N, 11.14.

4d: mp 200°C; yield 1.06 g (68%); ir(KBr) νmax 1690(CO), 1660(CO), 1640(CO) cm^{-1}; uv(EtOH) λmax (log ε) 264(4.13), 270(4.13), 278(4.04), 344(4.56) nm; ^{1}H-nmr($CDCl_3$) δ 0.95(6H, t, *J*=7 Hz, 2x$CH_2C\underline{H}_3$), 1.28(3H, t, *J*=7 Hz, $CH_2C\underline{H}_3$), 3.73(4H, q, *J*=7 Hz, 2x$C\underline{H}_2CH_3$), 4.07(3H, s, NCH_3), 4.19(2H, q, *J*=7 Hz, $C\underline{H}_2CH_3$), 7.39-7.49(4H, m, Ar-H), 8.57(1H, s, C_2-H), 8.59(1H, s, $C_{2'}$-H). *Anal.* Calcd for $C_{20}H_{24}N_2O_6$: C, 61.85; H, 6.23; N, 7.21. Found: C, 61.84; H, 6.20; N, 7.24.

3-Cyano-1-ethoxycarbonyl-4-methyl-2-methylthio-4*H*-benzo[*b*]pyrrolo-[1,2-*a*]imidazole (5a)

A solution of **4a** or **4b** (2 mmol) in xylene (60 ml) was refluxed for 24 h and the solution was then evaporated under reduced pressure. To the residue was added ice-water (50 ml). The precipitate was filtered, washed with water, dried and recrystallized from EtOH to give **5a**.

5a: mp 180°C; yield 0.40 g (64%) from **4a** (0.91 g), 0.36 g (57%) from **4b** (0.68 g); ir(KBr) νmax 2200(CN), 1670(CO) cm^{-1}; uv(EtOH) λmax (log ε) 217(4.32), 245(4.54), 267(4.18), 282(4.37), 305(4.06), 331(4.21) nm; ^{1}H-nmr($CDCl_3$) δ 1.48(3H, t, *J*=7 Hz, $CH_2C\underline{H}_3$), 2.74(3H, s, SCH_3), 3.94(3H, s, NCH_3), 4.47(2H, q, *J*=7 Hz, $C\underline{H}_2CH_3$), 7.15-7.40(3H, m, Ar-H), 8.59-8.70(1H, m, C_8-H). *Anal.* Calcd for $C_{16}H_{15}N_3O_2S$: C, 61.32; H, 4.82; N, 13.41. Found: C, 61.53; H, 4.88; N, 13.33.

1-Ethoxycarbonyl-3-methoxycarbonyl-4-methyl-4*H*-benzo[*b*]pyrrolo-[1,2-*a*]imidazole (5b)

A mixture of **3** (1.20 g, 4 mmol), **2a** (0.52 g, 4 mmol), and K_2CO_3 (1.10 g, 8 mmol) in $CHCl_3$ (40 ml) was stirred at room temperature for 6 days and the mixture was added to ice-water (100 ml) and extracted with $CHCl_3$ (2x30 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-$CHCl_3$ (20:1) fraction, product (**5b**) was obtained.

5b: mp 138°C; yield 0.30 g (25%); ir(KBr) νmax 1700(CO), 1680(CO) cm^{-1}; uv(EtOH) λmax (log ε) 214(4.36), 248(4.47), 277(4.12), 293(4.37), 320(4.22), 330(4.34) nm; ^{1}H-nmr($CDCl_3$) δ 1.41(3H, t, *J*=7 Hz, $CH_2C\underline{H}_3$), 3.87(3H, s, OCH_3), 4.22(3H, s, NCH_3), 4.37(2H,

q, *J*=7 Hz, $C\underline{H}_2CH_3$), 7.19-7.46(3H, m, Ar-H), 7.67(1H, s, C_2-H), 8.75-8.86(1H, m, C_8-H). *Anal.* Calcd for $C_{16}H_{16}N_2O_4$: C, 63.99; H, 5.37; N, 9.33. Found: C, 63.83; H, 5.39; N, 9.23.

4,5-Dihydro-5-methyl-4-oxobenzo[*c*]pyrrolo[1,2-*a*]pyrazines (6a,b)

Benzopyrrolopyrazines (**6a,b**) were prepared by the reaction of **3** (1.20 g, 4 mmol) with polarized olefins (**1c,2b**) (4 mmol) in the presence of K_2CO_3 (1.10 g, 8 mmol) in $CHCl_3$ (40 ml) using procedure above for the synthesis of **5b**. From a benzene-$CHCl_3$ (20:1) fraction, products (**6a,b**) were obtained, respectively.

6a: mp 236°C; yield 1.08 g (93%); ir(KBr) νmax 1660(CO) cm^{-1}; uv(EtOH) λmax (log ε) 220(4.43), 245 (4.23), 275(4.20), 327(4.18), 340(4.08) nm; ^{1}H-nmr ($CDCl_3$) δ 2.61(3H, s, SCH_3), 3.67(3H, s, NCH_3), 7.20-7.78(4H, m, Ar-H), 8.45(1H, s, C_1-H). *Anal.* Calcd for $C_{13}H_{11}N_3O_3S$: C, 53.96; H, 3.80; N, 14.53. Found: C, 53.86; H, 3.90; N, 14.48.

6b: mp 292°C; yield 0.65 g (72%); ir(KBr) νmax 2220(CN), 1650(CO) cm^{-1}; uv(EtOH) λmax (log ε) 240(4.41), 260(3.83), 302(3.63), 313(3.79), 326(3.68) nm; ^{1}H-nmr($CDCl_3$) δ 3.68(3H, s, NCH_3), 7.26-8.05(6H, m, Ar-H). *Anal.* Calcd for $C_{13}H_9N_3O$: C, 69.95; H, 4.06; N, 18.82. Found: C, 70.22; H, 4.22; N, 18.62.

1,4-Dihydro-1-ethoxycarbonyl-5-methyl-4-oxobenz[*b*]imidazo[1,2-*a*]-pyridin-9b-ium-1-ides (7a,b)

Compound (**7a,b**) was obtained by heating of **4c,d** (2 mmol) using procedure above for the synthesis of **5a**.

7a: mp 247°C; yield 87%; ir(KBr) νmax 2200(CN), 1710(CO) cm^{-1}; uv(EtOH) λmax (log ε) 230(4.29), 263(4.27), 280(4.38), 364(3.93), 382(4.19), 404(4.23) nm; ^{1}H-nmr($CDCl_3$) δ 1.48(3H, t, *J*=7 Hz, $CH_2C\underline{H}_3$), 2.58(3H, s, SCH_3), 4.60(2H, q, *J*=7 Hz, $C\underline{H}_2CH_3$), 4.69(3H, s, NCH_3), 7.46-7.79(4H, m, Ar-H). *Anal.* Calcd for $C_{17}H_{15}N_3O_3S$: C, 59.81; H, 4.43; N, 12.31. Found: C, 59.77; H, 4.47; N, 12.31.

7b[1]: mp 278°C; yield 64%.

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