

SYNTHESIS OF DIPOLAR ETHYLENEIMIDAZOLIUM BENZIMIDAZOLATE INNER SALTS AND THEIR TRANSFORMATION TO 2-VINYLBENZIMIDAZOLES THROUGH A TYPE OF β -ELIMINATION REACTION¹

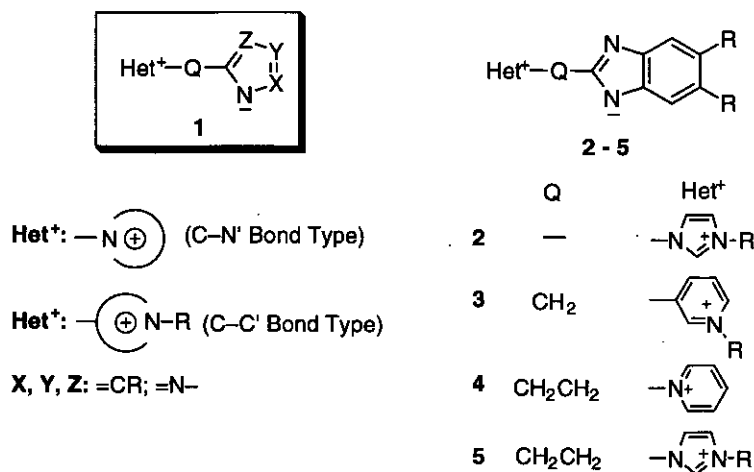
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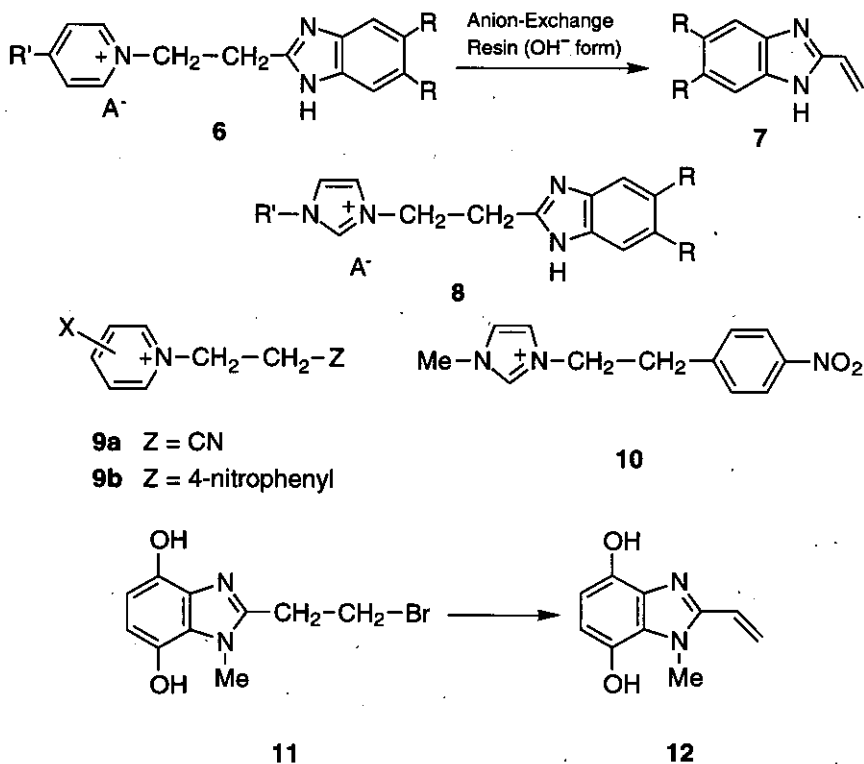
Abstract — The synthesis and spectroscopic properties of the fairly stable title inner salts (**5**) are reported. For several of the betaines (**5**), both the highly dipolar character due to the terminal rings and the nature of the spacer promoted a type of β -elimination reaction. Thus, formation of 2-vinylbenzimidazoles (**7**) from the corresponding betaines (**5**) proceeds in high yield under neutral and mild conditions. Following similar treatment, the 1-(2-benzimidazol-2-ylethyl)imidazolium salt (**8b**) undergo nucleophilic substitution reactions.

Heterocyclic betaines and compounds with a betaine character of general type (**1**) are ideal substrates for the study of chemical reactivity in both ground and excited states.¹ The singular dipolar nature of **1** is a powerful driving force and this, together with the C-N' and C-C' bond types and the nature and length of the interannular *linker*, generates a wide range of possibilities for the study of their reactivity. So far, the chemical reactivity of the inner salts (**2**,² **3**,³ **4**,^{4a} and **5**^{4b}) has been investigated (Figure 1).

Since several 1-(2-benzimidazol-2-ylethyl)pyridinium salts (**6**), potential precursors of betaines (**4**) (C-N' bond type), was reported to undergo a type of β -elimination to be transformed at room temperature into their corresponding 2-vinyl-1*H*-benzimidazoles (**7**)^{4a} using an anion-exchange resin (OH⁻ form),⁵ we have been prompted to investigate the chemical behaviour, in alkaline and neutral media, of

**Figure 1**

1-(2-benzimidazol-2-ylethyl)imidazolium salts (**8**),^{4b,6} (Figure 2) the immediate precursors of betaines (**5**) (C-N' bond type), and the results are discussed in the present report.

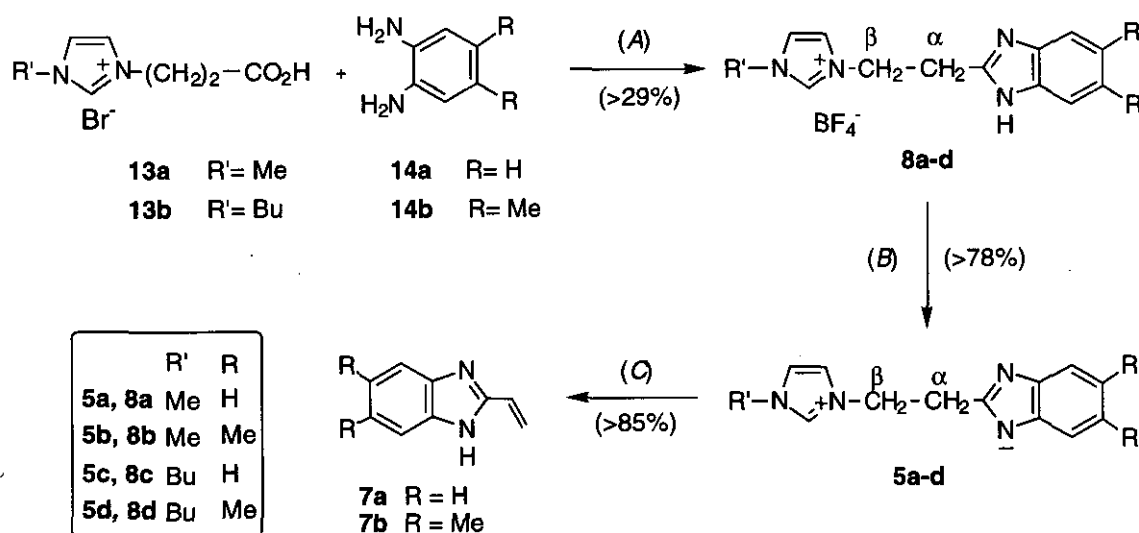
**Figure 2**

Among the different types of 1,2-elimination reactions,⁷ Bunting *et al.*⁸ have reported a detailed kinetic

and mechanistic study of *N*-(2-cyanoethyl)pyridinium cations (**9a**),^{8b} as well as several *N*-pyridinium cations (**9b**), and the imidazolium analogue (**10**) has also been investigated.^{8c} Furthermore, Boruah and Skibo⁹ have studied the 1,2-elimination mechanism of 2-(2-bromoethyl)benzimidazole (**11**), with the formation of 2-vinylbenzimidazole (**12**) (Figure 2).

RESULTS AND DISCUSSION

The Hein's benzimidazole synthesis^{4b,10} was applied to the preparation of 3-alkyl-1-[2-(1*H*-benzimidazol-2-yl)ethyl]imidazolium salts (**8a-d**). Then, they were transformed into their corresponding inner salts (**5a-d**) using a strong anion-exchange resin (OH⁻ form)⁵ (Scheme 1). Notwithstanding, betaines (**5a-d**) are fairly stable in comparison to betaines of type (**4**), but they should be handled with care due to their instability in solution at temperatures above 20 °C.



Scheme 1. Reagents and conditions: (A) method A; (i) In polyphosphoric acid, at 165-70 °C, 12 h to 60 h; (ii) the cooled mixture was poured into ice-water; (iii) Na₂CO₃ up to pH 8; (iv) 50% HBF₄-H₂O to pH 6. (B) method B; Anion-exchange Amberlite resin (OH⁻ form). (C) method C; 80% EtOH, at 80 °C, *ca.* 75 h.

The aforementioned ethyleneimidazolium benzimidazolate inner salts (**5a-d**) were transformed into the 2-vinylbenzimidazoles (**7a,b**) under neutral and mild conditions in remarkably good yields (Scheme 1; see also Table 1). It is noteworthy that the reaction temperature was of crucial importance, and best yields were found at 80 °C. For instance, at *ca.* 15 °C in ethanolic solution, the inner salt (**5b**) remained

unaltered for four days.

Table 1. Reaction Conditions for the Formation of 2-Vinyl-1*H*-benzimidazoles (**7a,b**) and Tetrahydrobisbenzimidazo-[1,5]diazocine (**15**)

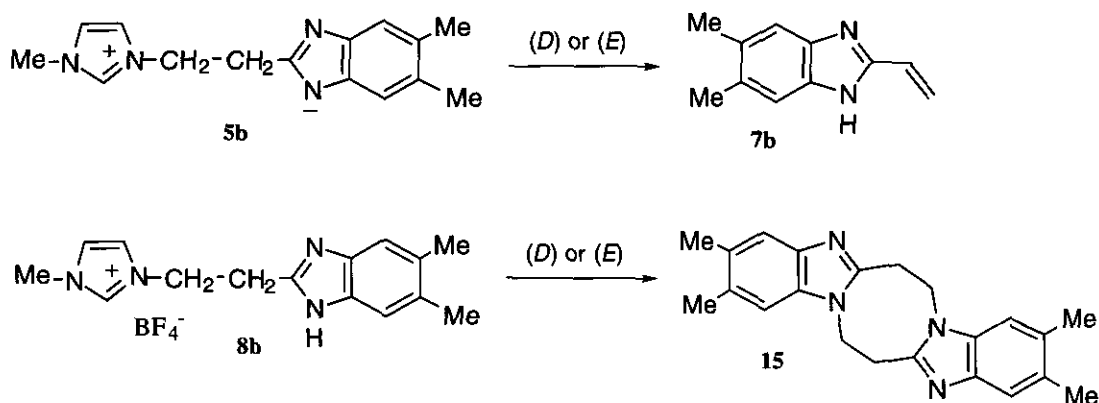
starting material	method ^a	reaction time (h)	product	yield(%) ^b
5a	C	75	7a	85
5b	C	50	7b	90
5c	C	80	7a	85
5d	C	75	7b	89
8b^c	C	72	7b	15
6a	C	72	7a	70
5b	D	24	7b	90
8b	D	40	15	68
5b	E	12	7b	95
8b	E	26	15	67

^a See Schemes 1 and 2 and Experimental Section. ^b Yields were not optimized. ^c For the influence of temperature on the β -elimination process in salts (**8b**) and (**6a**), see Table 2.

The susceptibility of the compound pairs (**5**) (*i.e.* **5b**) and (**8**) (*i.e.* **8b**) to undergo a type of β -elimination^{8c} is favoured by the betaine structure (**5**). The negative parts of dipoles (**5**) are strongly basic moieties, taking into account the pK_a values in the benzimidazole series.¹¹

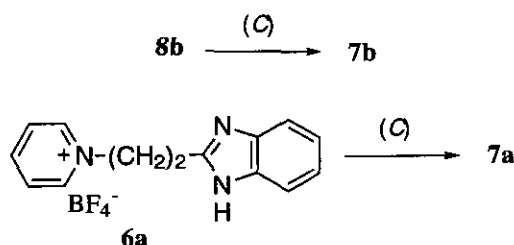
The model compound pair selected was **5b** and **8b**. Upon heating in refluxing acetonitrile or pyridine at 100 °C,^{12a} betaine (**5b**) underwent β -elimination to give 2-vinylbenzimidazole (**7b**), whereas its corresponding benzimidazolylethylimidazolium tetrafluoroborate (**8b**) was converted to 1,5-diazocine (**15**)¹² (Scheme 2 and Table 1). These results illustrate an example of the chemical behaviour of quaternary heteroaromatic salts as leaving group or nucleofuge in dipolar non-HBD solvents (β -elimination *versus* substitution).

Two correlated aspects were examined concerning the chemical behaviour of model compound pairs (**5**) and (**8**) together with **6** (Scheme 2). First, as mentioned above, the inner salts (**5a-5d**) were transformed



Scheme 2. Reagents and conditions: (D) method D; acetonitrile, reflux; (E) method E; pyridine, at 100 °C.

into the corresponding 2-vinylbenzimidazoles (**7a,b**) e.g. **5b** to **7b** by heating at 80°C in 80% ethanol (Table 1). Whereas under the same conditions, the benzimidazolylethylimidazolium tetrafluoroborate (**8b**) gave **7b** in rather low yield (Tables 1 and 2). Second, the propensity of the 1-(2-benzimidazol-2-ylethyl)pyridinium and imidazolium salts (**6**) and (**8**), (e.g. the tetrafluoroborates (**6a**) and (**8b**)) to undergo a type of β -elimination was explored in protic HBD solvents.¹³ Accordingly, the ethylimidazolium tetrafluoroborate (**8b**) was found to be fairly stable and the transformation to 2-vinylbenzimidazole (**7a**) occurred only slightly (*ca.* 15%), whereas the ethylpyridinium tetrafluoroborate (**6a**) was transformed into **7a** in a marked extent (Table 2). The cationic charged moiety modulates the β -elimination process depending on the leaving group ability.⁸



Scheme 3. Reagents and conditions: (C) method C; 80% EtOH, at 80 °C, 72 h.

Physical data of all new compounds described in this work (**5** and **8**) are listed in Table 3. The structures of the new inner salts (**5a-d**) and their immediate precursors (**8a-d**) were unambiguously characterized on the basis of their spectroscopic data.

Table 2. Influence of Temperature on the β -elimination Process in Tetrafluoroborates (**6a**) and (**8b**) in 80% EtOH Leading to **7a** and **7b**

experiment no.	t (°C)	reaction time (h)	(yield, %) 7a	(yield, %) 7b
1	room temperature	180	— ^a	— ^a
2	40	90	20	3
3	60	80	50	8
4	80	72	70	15

^a Starting compounds (**6a**) and (**8b**) are recovered in almost quantitative yield.

Table 3. Physical Data of Compounds (**5**) and (**8**)

compd	method ^a (yield, %)	mp (°C) [solvent] ^b	reaction time (h)	molecular formula	analysis(%)					
					calculated			observed		
					C	H	N	C	H	N
8a	A (40)	137-8 [i]	60	C ₁₃ H ₁₅ N ₄ BF ₄	49.7	4.8	17.8	49.8	4.8	17.8
8b	A (31)	157-8 [i]	12	C ₁₅ H ₁₉ N ₄ BF ₄	52.6	5.6	16.4	52.5	5.6	16.3
8c	A (56)	^c	24	C ₁₆ H ₂₁ N ₄ BF ₄ ·1/2H ₂ O	52.6	6.1	15.3	52.3	6.3	15.3
8d	A (29)	131-2	36	C ₁₈ H ₂₄ N ₄ BF ₄	56.3	6.6	14.6	56.2	6.7	14.6
5a	B (83)	116-8 [ii]	^d	C ₁₃ H ₁₄ N ₄ ·2H ₂ O	59.5	6.9	21.4	59.1	7.2	21.3
5b	B (90)	114-5 [iii]	^d	C ₁₅ H ₁₈ N ₄ ·2H ₂ O	62.0	7.6	19.3	61.9	7.6	19.3
5c	B (91)	70-2 [iv]	^d	C ₁₆ H ₂₀ N ₄ ·2H ₂ O	63.1	8.0	18.4	63.2	7.6	18.2
5d	B (78)	81-2 [iii]	^d	C ₁₈ H ₂₄ N ₄ ·3H ₂ O	61.6	8.6	16.0	61.2	8.2	15.6

^a Yields were not optimized. ^b Recrystallization solvent: (i) dichloromethane; (ii) acetonitrile-ether (9:1); (iii) 80% ethanol; (iv) acetonitrile-ether (1:9). ^c Oily compound. ^d See Experimental Section.

The ir spectra of compounds (**8a-d**) showed absorption in the range of 3500-3400 cm⁻¹ (ν NH) and 2800-2500 cm⁻¹ (hydrochlorides) or 1200-1000 cm⁻¹ (tetrafluoroborates). These bands were absent for the inner salts (**5a-d**). ¹H and ¹³C nmr chemical shifts of **5a-d** proved to be important for structural proof of their dipolar character, as they were for other types of heterocyclic betaine of general structure (**1**) (e.g. the *N*-ylides **22b**). ¹H and ¹³C nmr chemical shifts of betaines (**5a-d**) and their precursors (**8a-d**) are shown in Tables 4 and 5. Unambiguous assignments for compounds (**5**) and (**8**) were made by using

bidimensional HMQC^{14c} and HMBC^{14c} spectroscopic techniques with the selected pair (**5a**, **8a**).

Table 4. ¹H Nmr Data¹⁴ of Imidazolioethylbenzimidazolate Inner Salts (**5**) and their Corresponding Benzimidazolylethylimidazolium Salts (**8**)^a

Compd	H-2'	H-4'	H-5'	-CH ₂ -N ⁺ -	-CH ₂ -	H-4	H-5	H-6	H-7	R'	R ₁ (NH)	R _{5,6}
5a	9.13 ^b	7.58	7.73	4.63	3.21	7.20	6.65	6.65	7.20	3.77	---	---
8a	9.13	7.64	7.77	4.70	3.43	7.51	7.14	7.14	7.51	3.81	12.34	---
$\Delta\delta^c$	0	-0.06	-0.04	-0.07	-0.22	-0.31	-0.49	-0.49	-0.31	-0.04		
5b	9.09 ^b	7.56	7.67	4.60	3.16	6.97	---	---	6.97	3.76	---	2.18
8b	9.11	7.64	7.73	4.66	3.35	7.30 ^d	---	---	7.20 ^d	3.81	12.02	2.22
$\Delta\delta^c$	-0.02	-0.08	-0.06	-0.06	-0.19	-0.28 ^e			-0.28 ^e	-0.05		-0.04
5c	9.11	7.66	7.75	4.62	3.23	7.21	6.70	6.70	7.21	4.05 ^f	---	---
8c	9.15	7.73	7.82	4.68	3.42	7.45	7.14	7.14	7.45	4.11 ^f	12.39	---
$\Delta\delta^c$	-0.04	-0.07	-0.07	-0.06	-0.19	-0.24	-0.44	-0.44	-0.24	-0.06 ^f		
5d	9.09 ^b	7.66	7.71	4.60	3.18	7.00	---	---	7.00	4.06 ^f	---	2.19
8d	9.12	7.71	7.78	4.64	3.35	7.25 ^d	---	---	7.18 ^d	4.09 ^f	12.02	2.25
$\Delta\delta^c$	-0.03	-0.05	-0.07	-0.04	-0.17	-0.21 ^e			-0.21 ^e	-0.03 ^f		-0.06

^a In (CD₃)₂SO. ^b Weak signal. ^c $\Delta\delta$: observed chemical shifts difference between betaines and their corresponding salts. ^d Anisochronous signals of benzimidazole H-4 and H-7 protons were observed owing to slow proton exchange between N-1 and N-3. NH proton signal *ca.* 12.0 ppm. ^e From the mean values of δ H-4 and δ H-7 in compounds (**8b**) or (**8d**). ^f Only δ for the α -protons to nitrogen are listed.

Both the ¹H and the ¹³C nmr parameters^{14c-g} accord well with the nature of the π -excessive and π -deficient heteroaromatic rings and with data for related systems within dipolar molecules (**1**).^{5b} The chemical shifts of the CH protons in the benzimidazolate moiety move to lower frequencies with respect to their precursors (**8a-d**), manifesting the high electron density on the azolate ring, and they are consistent with the ¹H nmr chemical shifts for anionic species in the azole series.^{5b} Moreover, the δ values of carbon atoms (see Table 5) were in agreement with data reported for a variety of benzimidazolate anions. With regard to the quaternary imidazolium rings, both the ¹H and the ¹³C nmr chemical shifts accord with the data previously reported for betaines of imidazolium azolate (**2**).^{2b,5b} Concerning the chemical shift values for the ethylene interannular linkage,¹⁵ the corresponding parameters for the α -CH₂ are much more affected than those for the β -CH₂ counterpart (see Tables 4 and 5); thus, for betaines (**5a-d**) the chemical shifts of the α -CH protons move upfield (*ca.* 0.19 ppm), and the same methylenic carbon atoms shift downfield (*ca.* 2.8 ppm).

Table 5. Selected ^{13}C Nmr Data¹⁴ of Imidazolioethylbenzimidazolate Inner Salts (**5**) and Their Corresponding Benzimidazolyethylimidazolium Salts (**8**)^{a,b}

compd	C-2'	C-4'	C-5'	CH ₂ -N ⁺	CH ₂	C-2	C-4	C-5	C-6	C-7
5a	137.2	123.5	123.0	48.6	32.4	159.1	115.5	117.8	117.8	115.5
8a	137.5	124.0	123.0	46.8	29.2	151.4	115.0 ^c	122.1	122.1	115.0 ^c
$\Delta\delta^d$	-0.3	-0.5	0.0	+1.8	+3.2	+7.7	+0.5	-4.3	-4.3	+0.5
5b	136.5	122.8	122.3	47.9	31.6	156.6	115.1	124.0	124.0	115.1
8b	137.4	123.9	122.9	46.8	29.2	150.3	118.9 ^e	130.0 ^e	131.5 ^e	111.5 ^e
$\Delta\delta^d$	-0.9	-1.1	-0.6	+1.1	+2.4	+6.3	-0.1 ^f	-6.7 ^f	-6.7 ^f	-0.1 ^f
8c	137.1	123.0	122.8	47.0	29.0	151.4	115.1 ^c	122.1	122.1	115.1 ^c
8d	137.0	122.9	122.7	47.1	29.0	150.3	115.2 ^c	130.3	130.3	115.2 ^c

^a In $(\text{CD}_3)_2\text{SO}$. ^b ^{13}C Nmr for compounds (**5c**) and (**5d**) were not recorded due to their instability in $(\text{CD}_3)_2\text{SO}$. ^c Broad signal due to the annular prototopic tautomerism.

^d $\Delta\delta$: observed chemical shifts difference between betaines and their corresponding salts.

^e Anisochronous signals of benzimidazole C-4/C-7 and C-5/C-6 carbon atoms were observed owing to slow proton exchange between N-1 and N-3. ^f From the mean values of δ C-4/C-7 and δ C-5/C-6 in compound (**8b**).

As for electronic impact mass spectrometry,¹⁶ compounds (**5**) and (**8**) exhibit a common characteristic behaviour. In all the cases, the fragmentation pattern shows that the base peak never corresponds to the molecular ion, but to a fragment resulting from a β -elimination type reaction of molecules (**5**) and (**8**), *i.e.* to 2-vinylbenzimidazoles (**7a,b**); the other peak appearing with high relative abundance belongs to the nucleofuge moiety, *i.e.* an 1-alkylimidazole.¹⁷ This fragmentation pattern anticipates the major features of the chemical reactivity of compounds (**5**) and (**8**).

In conclusion, the alkene-forming elimination reactions displayed by the ethyleneimidazolium azolate inner salts (**5**) are predictable since the dipolar nature contained within the substrate is the driving force, as shown by the different reactivity exhibited by their precursors (**8**). Thus, the negative part of the dipole in (**5**) is a basic azolate nucleus, which favors an assisted proton transfer pathway which promotes a type of β -elimination under mild conditions, the cationic moiety being the nucleofugal species.

EXPERIMENTAL SECTION

General Methods. Melting point: CTP-MP 300 hot-plate apparatus with ASTM 2C thermometer (given in Table 3). Ir (KBr disks): Perkin Elmer 1430 spectrophotometer. ^1H Nmr: Varian Gemini 200 and

Varian Unity 300 spectrometers (200 MHz and 300 MHz). ^{13}C Nmr: Varian Gemini 200 spectrometer (50.3 MHz). HMQC and HMBC:^{14c} Varian VXR-500 spectrometer (500 MHz). Nmr spectra were determined in dimethyl- d_6 sulfoxide,^{14d} and chemical shifts are expressed in parts per million (δ) relative to the central peak of dimethyl- d_6 sulfoxide. EIMS: Hewlett-Packard HP-5988A. Tlc: Merck precoated silica gel 60 F254 plates; detection by UV light. For methods C and D, a column (0.5-in. diameter) was packed with anion-exchange resin IRA-401 (OH^- form)^{5b,15b} up to a height of 5 in. When a rotary evaporator was used, the bath temperature was 25 °C. In general, the compounds were dried overnight at 25 °C in a vacuum oven. Microanalyses (Table 3) were performed on a Carlo Erba 1106 analyzer.

Materials. 1-[2-(1*H*-Benzimidazol-2-yl)ethyl]pyridinium tetrafluoroborate (**6a**)^{4a} was prepared as described in the literature. *N*-Butyl- and *N*-methylimidazole, 1,2-diaminobenzene (**14a**) and 1,2-diamino-4,5-dimethylbenzene (**14b**) were purchased from commercial sources.

Preparation of 1-(2-Carboxyethyl)-3-methylimidazolium Bromide (13a) and 1-Butyl-3-(2-carboxyethyl)imidazolium Bromide (13b). A stirred solution of *N*-methylimidazole or *N*-butylimidazole (5.33 g or 8.06 g, 65.0 mmol) and 3-bromopropionic acid (9.95 g, 65.0 mmol) in anhydrous acetonitrile (50 ml) was refluxed under an atmosphere of nitrogen for 8 h or 15 h. After cooling, the solution was filtered to remove some insoluble materials and the filtrate was evaporated to dryness. The resulting brown oil consisted of a mixture of **13a**, 1-methylimidazolium hydrobromide and acrylic acid (8:1:1) or **13b**, 1-butylimidazolium hydrobromide and acrylic acid (12:1:1), as determined by ^1H nmr. The oil was washed in acetone (3 x 50 ml) for **13a** or (3 x 10 ml) for **13b**, and dried to give 12.4 g (91%) of **13a** or 16.2 g (90%) of **13b**, which purity was *ca.* 90%, as determined by ^1H nmr.

Compound (**13a**): ^1H Nmr (DMSO- d_6 , 200 MHz) δ 2.90 (t, J = 7.5 Hz, 2H, CH_2), 4.12 (s, 3H, CH_3), 4.30 (t, J = 7.5 Hz, 2H, CH_2N^+), 7.63 (s, 1H, H-4), 7.75 (s, 1H, H-5), 9.24 (s, 1H, H-2). ^{13}C Nmr (DMSO- d_6 , 50.3 MHz) δ 34.1 (CH_2), 36.0 (CH_3), 44.9 (CH_2N^+), 122.6 (C-4), 123.7 (C-5), 137.2 (C-2), 171.9 (CO).

Compound (**13b**): ^1H Nmr (DMSO- d_6 , 200 MHz) δ 0.85 (t, J = 4.5 Hz, 3H, CH_3), 1.20 (m, 2H, Me-CH_2), 1.73 (m, 2H, Et-CH_2), 2.92 (t, J = 6.5 Hz, 2H, CH_2), 4.20 (t, J = 7.0 Hz, 2H, Pr-CH_2), 4.35 (t, J = 6.5 Hz, 2H, CH_2N^+), 7.84 (s, 2H, H-4, 5), 9.36 (s, 1H, H-2). ^{13}C Nmr (DMSO- d_6 , 50.3 MHz)

δ 13.5 (CH₃), 18.9 (Me-CH₂), 31.6 (Et-CH₂), 34.0 (CH₂), 45.0 (Pr-CH₂), 48.7 (CH₂N⁺), 122.5 (C-4), 122.7 (C-5), 136.7 (C-2), 171.9 (CO).

Preparation of 2-[2-(3-Alkyl-1-imidazolium)ethyl]benzimidazolate Inner Salts (5a-d). Method A. A stirred suspension of *o*-arylenediamine (**14a**) or (**14b**) (1.49 g or 1.88 g, 13.8 mmol) and (2-carboxyethyl)imidazolium bromide (**13a**) or (**13b**) (3.62 g or 4.27 g, 15.4 mmol) in PPA (20 g) under an atmosphere of nitrogen was heated at 165-170 °C (bath temperature) for the time specified in Table 3. The cooled mixture was poured into ice-water (50-100 ml), and the resulting solution was treated with solid sodium carbonate to reach pH 5-6 and then with a saturated sodium carbonate solution to pH 8. This solution was filtered and then acidified with 50% HBF₄-H₂O to pH 5.

For compounds (**8a**) and (**8b**) the solution was washed in dichloromethane (3 x 50 ml) and the aqueous layer was concentrated in the rotavapor to a volume of 100-150 ml, and then subjected to continuous extraction for 24 or 72 h. The dichloromethane layer was dried with anhydrous sodium sulfate and the solvent was removed *in vacuo*. The resulting solid was washed in dichloromethane (3 x 15 ml), filtered and dried (Table 3).

For compounds (**8c**) and (**8d**) the solution was extracted with dichloromethane (4 x 100 ml). The organic layer was dried (Na₂SO₄), and the solvent was removed *in vacuo*. Compound (**8c**) was dissolved in water (400 ml) and washed in ether (5 x 100 ml). The aqueous solution was concentrated to dryness in the rotavapor, and dried (Table 3). Compound (**8d**) was washed in a solution of ether-acetonitrile (9:1) (30 ml) and the solid obtained was dissolved in acetone (5 ml) and precipitated with ether (2 ml). The white solid was filtered, washed in ether (2 x 3 ml) and dried (Table 3).

Method B. A solution of the benzimidazolylethylimidazolium tetrafluoroborates (**8a-8d**) (*ca.* 0.13 mmol) in 80% ethanol (40 ml) was passed through a column packed with anion-exchange Amberlite resin IRA-401, with a flow rate of *ca.* 10 mg/min (*ca.* 8 ml/min; total time *ca.* 5 min). The neutral eluates were evaporated to dryness at 25 °C to give the imidazolioethylbenzimidazolate inner salts (**5a-d**) as solids, which were then recrystallized in cold (Table 3).

Formation of 2-Vinyl-1H-benzimidazoles (7a,b) and Tetrahydrobisbenzimidazo[1,5]diazocine (15).

Method C. A solution of imidazolioethylbenzimidazolate inner salts (**5a-d**) (*ca.* 0.08 mmol) in 80 %

ethanol (30 ml) was heated in a bath at 80 °C for the time specified in Table 3. The cooled solution was evaporated to dryness. The solid obtained was then washed in ether (2 x 2 ml) and dried to yield the 2-vinylbenzimidazoles (**7a,b**) (Table 1). Compound (**7a**): mp 203 °C (lit.,^{4a} mp 203-204 °C). Compound (**7b**): mp 172 °C (lit.,^{4a} mp 174-175 °C).

Following the same procedure, the benzimidazolylethylimidazolium tetrafluoroborate (**8b**) afforded the 2-vinylbenzimidazole (**7b**) in 15% yield (Table 1; see also Table 2).

Under the same reaction conditions, the 1-(2-benzimidazol-2-ylethyl)pyridinium tetrafluoroborate (**6a**) gave the 2-vinylbenzimidazole (**7a**) in 70% yield (Table 1; see also Table 2).

Method D. A solution of imidazolioethylbenzimidazolate (**5b**) (50 mg, 0.2 mmol) in anhydrous acetonitrile (20 ml) was heated in a bath at 100 °C for the time specified in Table 1. After cooling the reaction mixture, the solid precipitated was filtered, washed in acetone (2 x 5 ml) and dried to give 33 mg (95%) of **7b**.

Following the same procedure, the benzimidazolylethylimidazolium tetrafluoroborate (**8b**) afforded the diazocine (**15**) in 68% yield (Table 1). Compound (**15**): mp 316-317 °C (lit.,^{12c} 311-314 °C).

Method E. A solution of imidazolioethylbenzimidazolate (**5b**) (45 mg, 0.18 mmol) in anhydrous pyridine (3 ml) was heated in a bath at 100 °C for the time specified in Table 1. After cooling, acetone was added (10 ml) and the precipitate was filtered, washed in acetone (2 x 5 ml) and dried to give 28 mg (90%) of **7b**.

Following the same procedure, the benzimidazolylethylimidazolium tetrafluoroborate (**8b**) afforded the diazocine (**15**) in 67% yield (Table 1).

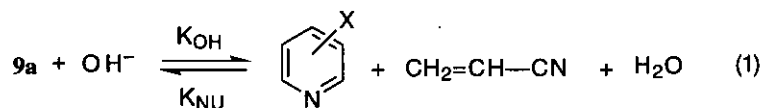
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2. (a) A preliminary study of the behaviour of imidazolium benzimidazolate betaine (**2**) (*C-N'* bond type) toward dipolarophiles has been reported,^{2b} and a new tetracyclic structure (1:1 adduct) has been isolated using equimolecular amounts of **2** and DMAD. (b) E. Alcalde and I. Dinarés, *J. Org. Chem.*, 1991, **56**, 4233, and references quoted therein.
3. (a) As for the 1-alkyl-3-pyridiniummethyl-3(5)-1,2,4-triazolate betaines (**3**) (*C-C'* bond type) with a captodative methylene center, they constitute the first stable examples within this system containing a *C-CH₂-C'* bond spacer.^{3b} (b) E. Alcalde, M. Gisbert, and L. Pérez-García, *J. Chem. Soc., Chem. Commun.*, 1994, 981.
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5. (a) An appropriate protocol used for the preparation of the *N*-ylides (**2**) and also applied to other homologues and analogous inner salts (**1**).^{5b} (b) E. Alcalde, *Adv. Heterocycl. Chem.*, 1994, **60**, 197.
6. The imidazolium quaternary moiety has proved to be stable in 3-alkyl-1-(1*H*-benzimidazol-2-yl)imidazolium salts and their homologues, as well as other analogous systems.^{5b}
7. (a) J. March, "Advanced Organic Chemistry", 4th ed., John Wiley & Sons, New York, 1992, Chapter 17. (b) A. Krebs and J. Swienty-Busch, "Comprehensive Organic Synthesis", Vol. 6, ed. by B.M. Trost and I. Fleming, Pergamon Press, Oxford, 1991, pp. 949-962. (c) F.M. Bickelhaupt, L.J. de Koning, and N.M.M. Nibbering, *J. Org. Chem.*, 1993, **58**, 2436. (d) A.R. Katritzky, C.H. Watson, Z. Dega-Szafran, and J.R. Eyler, *J. Am. Chem. Soc.*, 1990, **112**, 2479, and references quoted therein. (e) A.R. Katritzky and B.E. Brycki, *Chem. Soc. Rev.*, 1990, **19**, 83.
8. (a) The kinetic and mechanistic study for base catalyzed E1cB reactions of *N*-(2-cyanoethyl)pyridinium cations (**9a**) shown in eq. (1), together with the rates and equilibria for the Michael-type addition have been studied.^{8b}



Of particular interest in relation with the present study are the results with several *N*-pyridinium cations (**9b**) and the imidazolium analogue (**10**), with the same activating group, which have shown that for leaving groups of similar basicity, pyridine is a better nucleofuge than 1-methylimidazole.^{8c}

- Moreover, the kinetics and mechanism of the formation of *N*-vinylpyridinium cations in 1,2-elimination reaction in aqueous base have also been studied,^{8d} as well as the Hofmann-type elimination induced on *N*-(β -cyanoethyl)quaternary azolium salts by reaction with strong bases at room temperature.^{8e} (b) J.W. Bunting, A. Toth, C.K.M. Heo, and R.G. Moors, *J. Am. Chem. Soc.*, 1990, **112**, 8878. (c) J.W. Bunting and J.P. Kanter, *J. Am. Chem. Soc.*, 1991, **113**, 6950. (d) J.W. Bunting, A. Toth, and J.P. Kanter, *Can. J. Chem.*, 1992, **70**, 1195. (e) A. Horváth, *Synthesis*, 1995, 1183.
9. (a) Formation of 4,7-dihydroxy-1-methyl-2-vinylbenzimidazole (**12**)^{9b} from the corresponding 2-(2-haloethyl)benzimidazole (**11**) (Figure 2), was consistent with both the general base and the specific acid/general base-catalyzed 1,2-elimination of HX of "E2" type.^{7b} (b) R.C. Boruah and E.B. Skibo, *J. Org. Chem.*, 1993, **58**, 7797.
10. E. Alcalde, I. Dinarés, L. Pérez-García, and T. Roca, *Synthesis*, 1992, 395.
11. (a) The basicity of the benzimidazole anion is that of a classical benzimidazolate^{11b} perturbed by the substituent at position 2. (b) The basicity and acidity of azoles have been reviewed.^{11c} (c) J. Catalán, J.L.M. Abboud, and J. Elguero, *Adv. Heterocycl. Chem.*, 1987, **41**, 187.
12. (a) Following a similar protocol described by Katritzky and co-workers^{12b,c} for preparation of the 1,5-diazocine system (**15**). (b) As for quaternary salts (**6**), the authors reported that compound 1-[2-(5,6-dimethyl-1*H*-benzimidazol-2-yl)ethyl]-4-methylpyridinium bromide was converted into cyclic dimer (**15**), its structure being verified by X-ray diffraction of the 1,5-diazocine system unsubstituted in the 5,6 positions of the benzimidazole ring. It was pointed out that the 1,5-diazocine system had to be formed directly from the starting salts of type (**6**). (c) J. Elguero, A.R. Katritzky, and B.S. El-Osta, *J. Chem. Soc., Perkin Trans. 1*, 1976, 312.
13. (a) A solvent change^{13b} from dipolar non-HBD (*i.e.* acetonitrile, pyridine) to protic HBD (*i.e.* 80% aqueous ethanol) affected the propensity of the 1-(2-benzimidazol-2-ylethyl)pyridinium salts (**6**)^{12b} and imidazolium salts (**8**) (Scheme 2) to undergo a substitution *versus* a type of β -elimination. Subsequently, the product formation was whether the 1,5-diazocine system, *e.g.* **15**, or the corresponding 2-vinylbenzimidazoles (**7**) (Scheme 2). (b) C. Reichardt, "Solvents and Solvent Effects in Organic Chemistry", 2nd ed., VCH Publishers, Weinheim, 1988, Chapter 5.
14. (a) Unambiguous assignments have been made by DEPT,^{14b} heteronuclear multiple-quantum

- coherence (HMQC),^{14c} and heteronuclear-multiple bond correlation (HMBC)^{14c} techniques. (b) E. Breitmeier and W. Voelter, "Carbon-13 Nmr Spectroscopy", VHC, Weinheim, 1987, p.80. (c) M.F. Summers, L.G. Marzilli, and A. Bax, *J. Am. Chem. Soc.*, 1986, **108**, 4285. (d) (CD₃)₂SO was previously dried with an activated molecular sieve (3 Å) to reduce the presence of water in the solvent. (e) Although the ¹H nmr were also recorded in CD₃OD for compounds (**8a-d**) and Na⁺ CD₃O⁻ /CD₃OD for the inner salts (**5a-d**), (CD₃)₂SO was the solvent of choice to observe the dipolar nature of compounds (**5a-d**). (f) The ¹H Nmr spectrum of **5b** registered in CD₃CN with addition of TBAH (three fold excess) did not show any estimable change in its chemical shift values. (g) The instability of compounds (**5c**) and (**5d**) in solution of (CD₃)₂SO precluded recording their ¹³C nmr spectra.
15. (a) For coherence with previous work reported on heterocyclic betaines,^{5b,15b} for compounds (**5**) and (**8**) we quoted as α-CH₂ the methylene group directly attached to the azole/azolate moiety, and β-CH₂ the methylene group directly linked to the quaternary moiety. (b) E. Alcalde, I. Dinarés, J.-M. Pons, and T. Roca, *J. Org. Chem.*, 1994, **59**, 639, and references quoted therein.
 16. Katritzky *et al.*^{7d,e} have investigated the fragmentation pathways for collisionally activated dissociation (CAD) of *N*-alkylpyridinium cations to pyridinium cations and olefins in the gas phase, by laser desorption (LD) FTICR mass spectrometry.
 17. The characteristic fragmentation pattern exhibited by compounds (**5**) and (**8**) using EIms is shown in Figure 3 and Table 6.

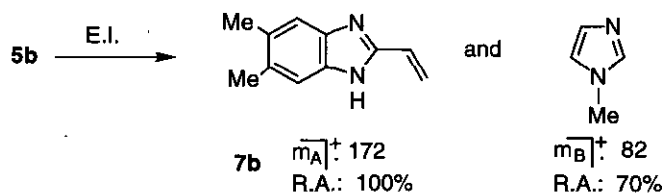


Figure 3

Table 6. EIms of Imidazolioethylbenzimidazolate Inner Salts (**5**) and Their Corresponding Benzimidazolylethylimidazolium Salts (**8**)

m/z (%)	5a	8a	5b	8b	5c	8c	5d	8d
mA	144 (100)	144 (100)	172 (100)	172 (100)	144 (100)	144 (100)	172 (100)	172 (100)
mB	82 (85)	82 (88)	82 (70)	82 (73)	82 (57)	82 (66)	81 (38)	81 (43)