SYNTHESIS OF DIPOLAR ETHYLENEIMIDAZOLIUM BENZIMIDAZOLATE INNER SALTS AND THEIR TRANSFORMATION TO 2-VINYLBENZIMIDAZOLES THROUGH A TYPE OF β-ELIMINATION REACTION[1]

Ermitas Alcalde,* Maria Gisbert, and Lluïsa Pérez-García

Laboratorio de Química Orgánica, Facultad de Farmacia, Universidad de Barcelona, E-08028 Barcelona, Spain

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

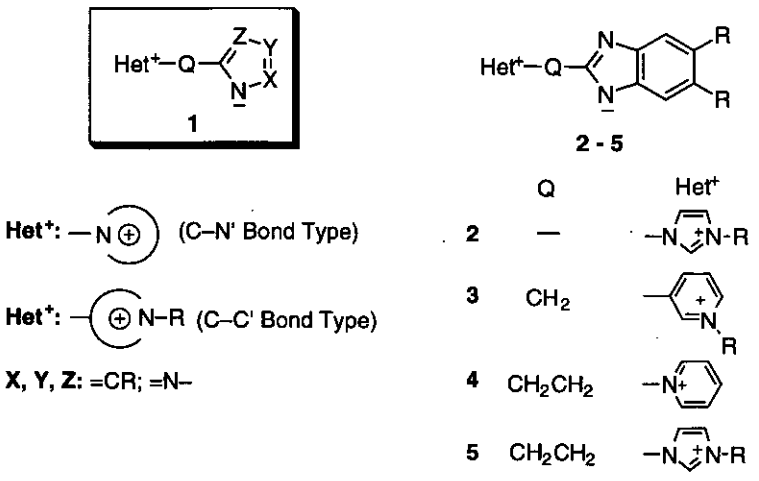


Figure 1

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.

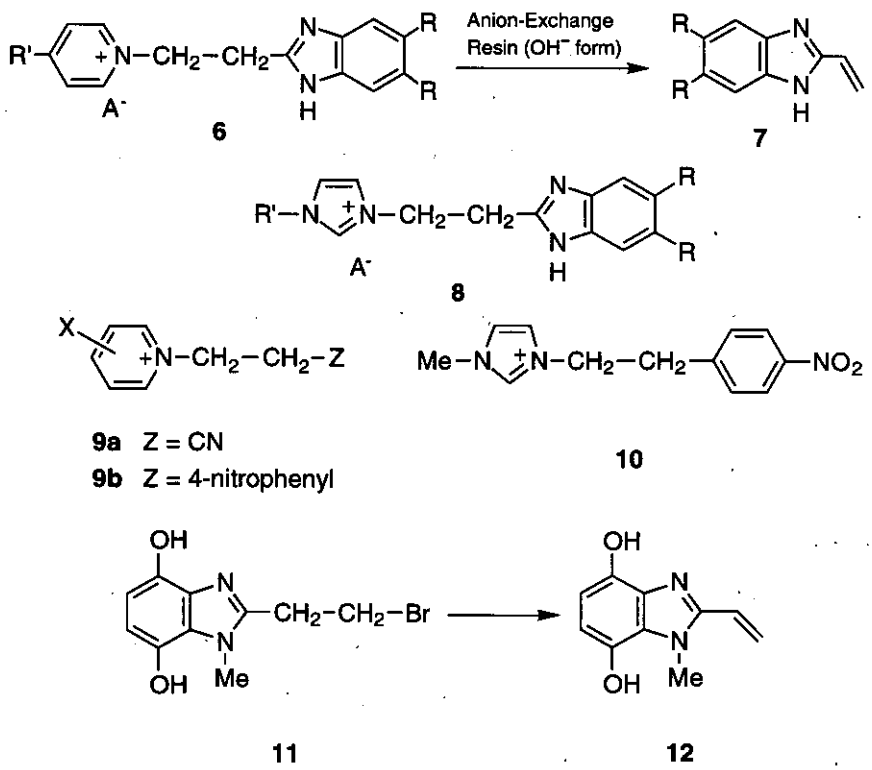


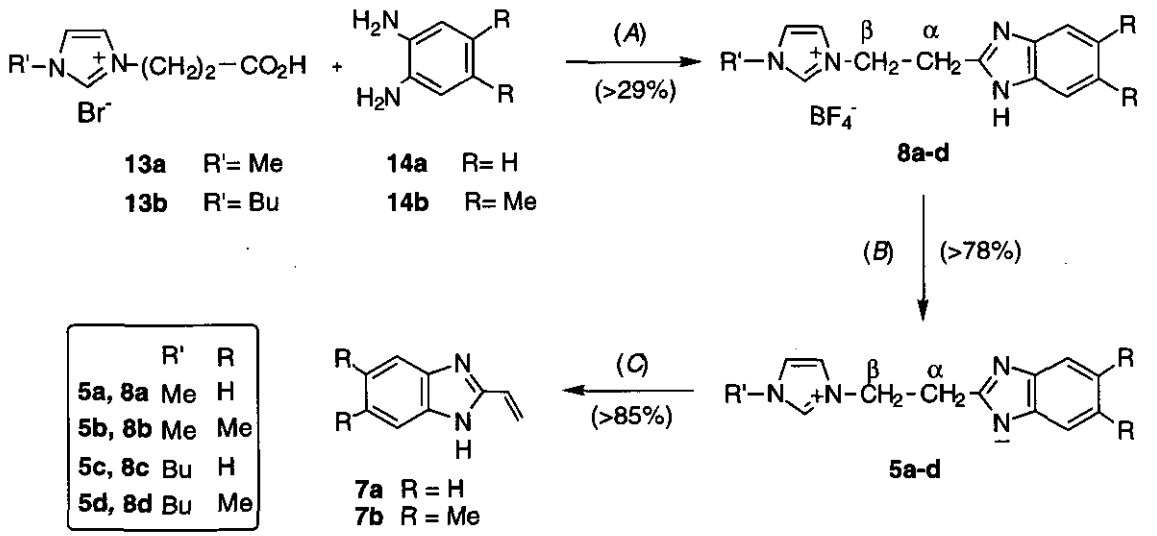
Figure 2

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 Skibo[9] 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) Na_2CO_3 up to pH 8; (iv) 50% HBF_4-H_2O 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

unalterated for four days.

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

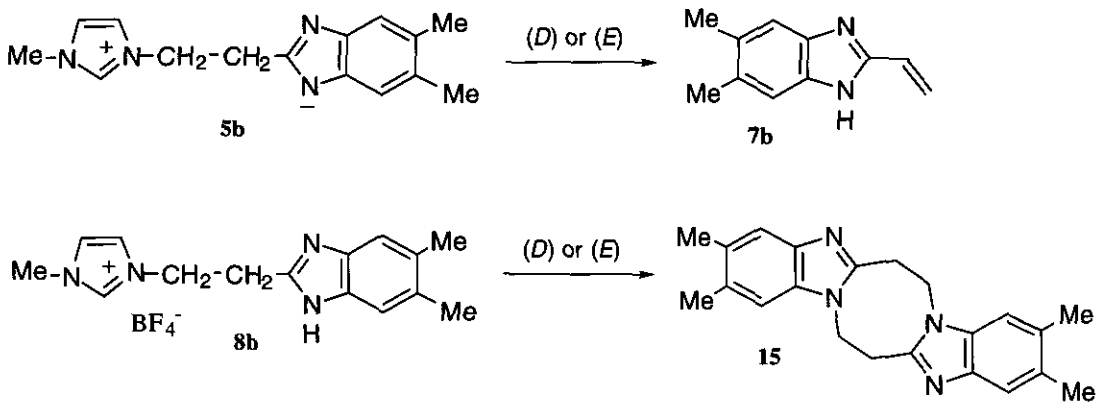
starting material	method[a]	reaction time (h)	product	yield(%)[b]
5a	C	75	**7a**	85
5b	C	50	**7b**	90
5c	C	80	**7a**	85
5d	C	75	**7b**	89
8b[c]	C	72	**7b**	15
6a	C	72	**7a**	70
5b	D	24	**7b**	90
8b	D	40	**15**	68
5b	E	12	**7b**	95
8b	E	26	**15**	67

[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]

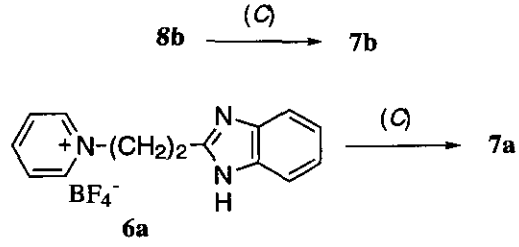
The model compound pair selected was **5b** and **8b**. Upon heating in refluxing acetonitrile or pyridine at 100 °C,[12a] betaine (**5b**) underwent β-elimination to give 2-vinylbenzimidazole (**7b**), whereas its corresponding benzimidazolylethylimidazolium tetrafluoroborate (**8b**) was converted 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 C	H	N	observed C	H	N
8a	A (40)	137-8 [i]	60	$C_{13}H_{15}N_4BF_4$	49.7	4.8	17.8	49.8	4.8	17.8
8b	A (31)	157-8 [i]	12	$C_{15}H_{19}N_4BF_4$	52.6	5.6	16.4	52.5	5.6	16.3
8c	A (56)	*c*	24	$C_{16}H_{21}N_4BF_4;1/2H_2O$	52.6	6.1	15.3	52.3	6.3	15.3
8d	A (29)	131-2	36	$C_{18}H_{24}N_4BF_4$	56.3	6.6	14.6	56.2	6.7	14.6
5a	B (83)	116-8 [ii]	*d*	$C_{13}H_{14}N_4;2H_2O$	59.5	6.9	21.4	59.1	7.2	21.3
5b	B (90)	114-5 [iii]	*d*	$C_{15}H_{18}N_4;2H_2O$	62.0	7.6	19.3	61.9	7.6	19.3
5c	B (91)	70-2 [iv]	*d*	$C_{16}H_{20}N_4;2H_2O$	63.1	8.0	18.4	63.2	7.6	18.2
5d	B (78)	81-2 [iii]	*d*	$C_{18}H_{24}N_4;3H_2O$	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 ^{13}C 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 **2**[2b]). ^1H and ^{13}C 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. ^{1}H Nmr Data[14] 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 $(CD_3)_2SO$. [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 ^{1}H and the ^{13}C nmr parameters[14e-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 ^{1}H 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 ^{1}H and the ^{13}C 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-CH_2 are much more affected than those for the β-CH_2 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 Data[14] of Imidazolioethylbenzimidazolate Inner Salts (**5**) and Their Corresponding Benzimidazolylethylimidazolium 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 $(CD_3)_2SO$. [b] ^{13}C Nmr for compounds (**5c**) and (**5d**) were not recorded due to their instability in $(CD_3)_2SO$. [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 shifs are expressed in parts per million (δ) relative to the central peak of dimethyl-d_6 sulfoxide. EIMS: Hewwlett-Packard HP-5988A. Tlc: Merck precoated silica gel *60* F_{254} 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-C<u>H</u>$_2$), 1.73 (m, 2H, Et-C<u>H</u>$_2$), 2.92 (t, *J*= 6.5 Hz, 2H, CH_2), 4.20 (t, *J*= 7.0 Hz, 2H, Pr-C<u>H</u>$_2$), 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 (CH_3), 18.9 (Me-$\underline{C}H_2$), 31.6 (Et-$\underline{C}H_2$), 34.0 (CH_2), 45.0 (Pr-$\underline{C}H_2$), 48.7 ($\underline{C}H_2N^+$), 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% HBF_4–H_2O 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 (Na_2SO_4), 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-1*H*-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).

ACKNOWLEDGEMENTS.

This work was supported by *DGICYT*, MEC-Spain through grant PB 92-0792. Thanks are also due to the *Comissionat per a Universitats i Recerca (Generalitat de Catalunya)* for a grant GRQ 94-1009 and BQUIFI fellowship to M.G. The authors thank Dr. Immaculada Dinarés for a sample of compound (**6a**).

REFERENCES AND NOTES

1. Heterocyclic Betaines. Part 25; Part 24: E. Alcalde, M. Alemany, L. Pérez-García, and M.L. Rodriguez, *J. Chem. Soc., Chem. Commun.*, 1995, 1239, and references cited therein.

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-pyridiniomethyl-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-CH*$_2$*-C'* bond spacer.[3b] (b) E. Alcalde, M. Gisbert, and L. Pérez-García, *J. Chem. Soc., Chem. Commun.*, 1994, 981.

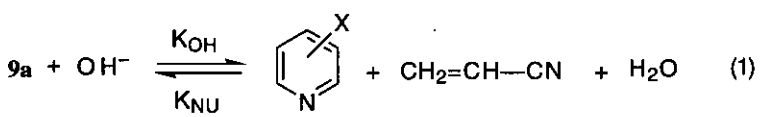
4. (a) E. Alcalde, L. Pérez-García, I. Dinarés, and J. Frigola, *J. Org. Chem.*, 1991, **56**, 6516, and references quoted therein. (b) E. Alcalde, M. Gisbert, and L. Pérez-García, *Chem. Lett.*, 1992, 2357.

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) $(CD_3)_2SO$ 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 CD_3OD for compounds (**8a-d**) and $Na^+ CD_3O^-$ /CD_3OD for the inner salts (**5a-d**), $(CD_3)_2SO$ was the solvent of choice to observe the dipolar nature of compounds (**5a-d**). (f) The ^1H Nmr spectrum of **5b** registered in CD_3CN 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 $(CD_3)_2SO$ precluded recording their ^{13}C nmr spectra.

15. (a) For coherence with previous work reported on heterocyclic betaines,[5b,15b] for compounds (**5**) and (**8**) we quoted as α-CH_2 the methylene group directly attached to the azole/azolate moiety, and β-CH_2 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.

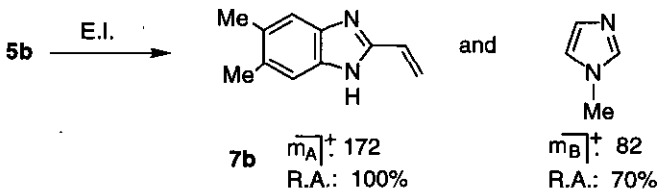


Figure 3

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

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

Received, 21st September, 1995