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Photosolvolysis reactions of 3-alkoxypyridinium tetrafluoroborate salts

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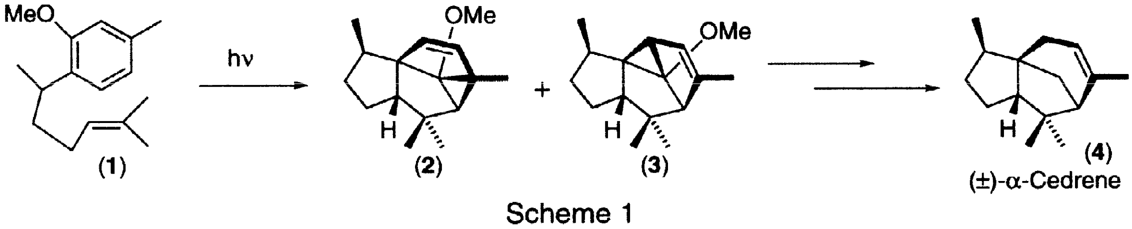
Abstract

Irradiation of a series of 3-alkoxypyridinium tetrafluoroborate salts in alcohol solution resulted in the formation of cyclopentenone ketals by diastereoselective incorporation of the alcohol solvent under the basic conditions of the photolysis reaction. In a second series of photochemical reactions, the same 3-alkoxypyridinium salts were irradiated in water to yield β-hydroxycyclopentanones stereoselectively. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Alkoxypyridinium; tetrafluoroborate; photochemistry; ketal formation; cyclopentanone; aziridines.

Introduction

One of the most interesting and important reactions in synthetic organic photochemistry is the metaphotocycloaddition reaction [1]. This reaction, discovered in 1966 [2], has been used (most notably by Wender) for the synthesis of some highly intricate natural products such as (±)-α-cedrene (4) [3] (Scheme 1) and (±)-modhephene [4].



Scheme 1

To our knowledge a heteroaromatic version of this all-carbon photoreaction has not been published, although an interesting related photohydration reaction of pyridinium salts was reported by Wilzbach, Kaplan and Pavlik in 1972 [5]. In this paper the diastereoselective

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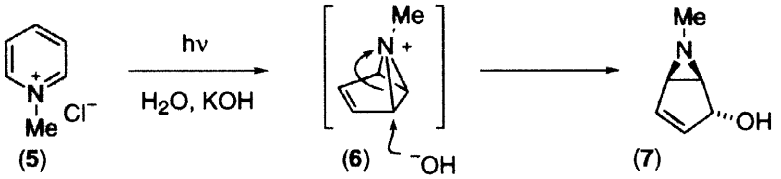
formation of a bicyclic aziridinyl alcohol (**7**) is described, which was the result of irradiating an alkaline solution of *N*-methylpyridinium chloride (**5**). In order to explain the high degree of stereoselectivity, the researchers proposed that the reaction proceeded *via* the intermediacy of an azabenzvalene cation (**6**) which was captured from the less hindered face (opposite to the newly formed aziridine) by water (Scheme 2).



Scheme 2

This reaction went relatively unnoticed until recently, when there was a resurgence of interest in it. Mariano investigated various ring opening reactions of aziridine photoproducts [6] and has used the reaction to form (+)-mannostatin [7]. Burger showed that the reaction could be used for β-lactam synthesis [8] and more recently has shown its use in the formation of polyhydroxylated aminocyclopentanes [9].

We wished to investigate the effect on this reaction of having an electron donating group on the pyridine ring. We chose to use a series of 3-alkoxypyridine derivatives, because although 3-hydroxypyridines can exist as zwitterions, they have only one tautomeric form. Hence the formation of 3-alkoxypyridinium ions is made easier by the absence of tautomeric problems. 2-Hydroxypyridines on the other hand are tautomeric with 2-pyridones, which have different photochemical properties [10]. 3-Alkoxypyridines also have the advantage that, after the initial photochemical step has taken place, the structurally reorganised cation will have an electron releasing group neighbouring the positive charge.

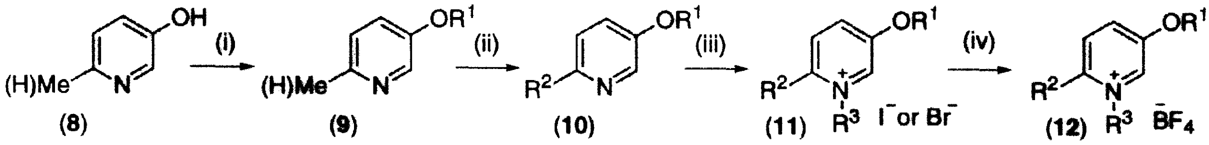
Two series of experiments were performed using either an alcohol or water as the solvent, and the results of this work are reported herein.

Results and discussion

The alcohol series

In order to test this hypothesis, a series of 3-alkoxypyridinium salts were prepared according to standard literature procedures [11,12], starting from either 3-hydroxypyridine or 3-hydroxy-6-methylpyridine (Scheme 3).

In previous photochemical studies, the halide or perchlorate salts of the pyridinium ions were used in the photochemical step. We chose to use tetrafluoroborate salts as they do not tend to undergo single electron transfer processes (like the halides) and were less likely to detonate than perchlorate salts.

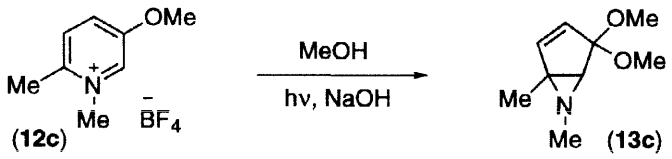


(i) R^{1}I or R^{1}Br, DMSO, KOH; (ii) LDA, MeI or EtBr; (iii) R^{3}I or R^{3}Br, Δ, sealed tube; (iv) Ag$_2$CO$_3$, HBF$_4$, acetone, MeOH.

Compound	10a	10b	10c	10d	10e	10f
R^1	Me	Me	Me	Me	^{n}Pr	^{n}Pr
R^2	H	Me	Et	^{n}Pr	H	Me

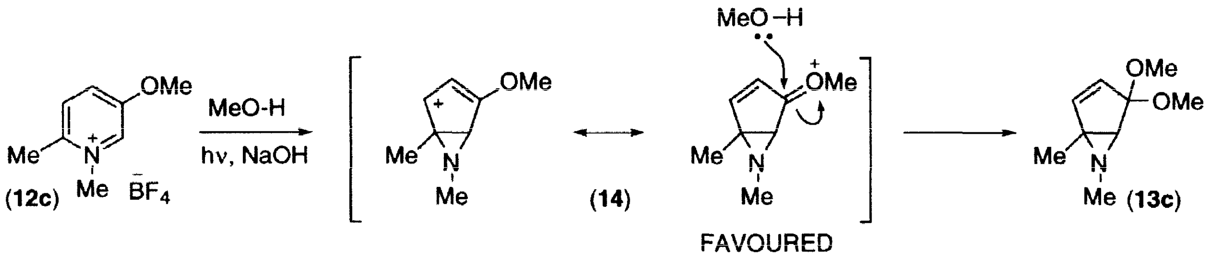
Scheme 3

Initial irradiation studies, using 5-methoxy-1,2-dimethylpyridinium tetrafluoroborate (**12c**) dissolved in a solution of sodium hydroxide in methanol, resulted in the formation of a cyclopentenone ketal derivative (**13c**) (Scheme 4).



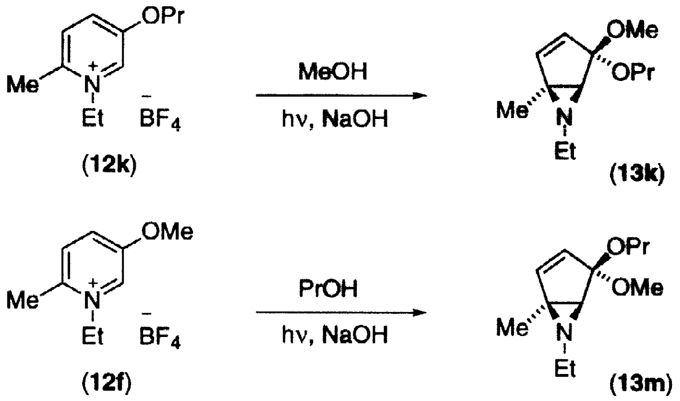
Scheme 4

This light-induced reaction caused the pyridinium salt to undergo a bond reorganisation, thereby forming a cyclopentenyl cation (**14**). This cation, being allylic, could potentially be trapped by the solvent at one of two positions, although it is the carbon adjacent to the methoxy group which is the favoured site for attack. Hence it is the ketal (**13c**) which is isolated as the product (Scheme 5).



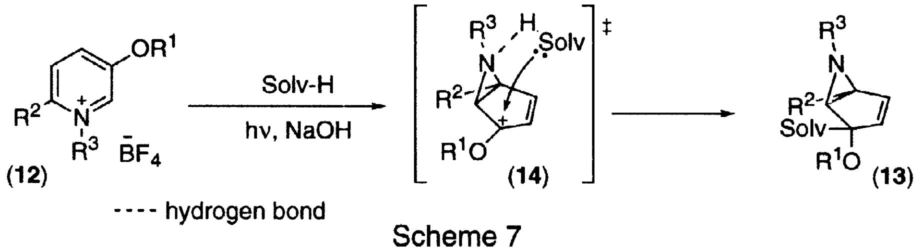
Scheme 5

Nearly all methods of ketal formation involve the use of acidic conditions, although in this instance a ketal was formed under basic conditions. This meant that the ketal products were not subject to equilibration with the solvent. In order to probe the reaction further, an alcohol solvent was used during irradiation different from that of the 3-alkoxy substituent on the pyridinium salt. This led to the isolation of a mixed ketal and a rather unexpected discovery (Scheme 6).



Scheme 6

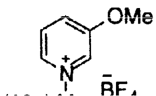
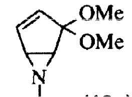
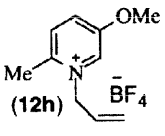
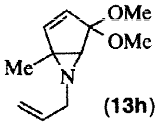
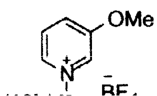
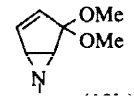
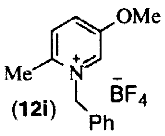
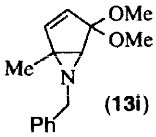
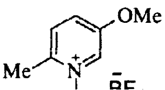
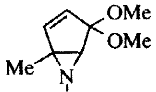
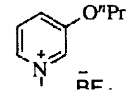
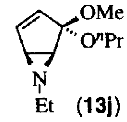
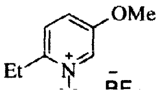
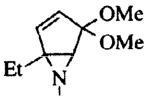
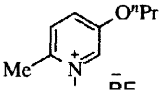
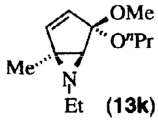
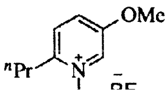
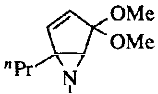
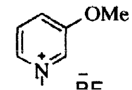
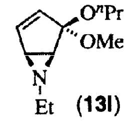
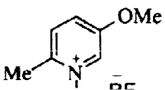
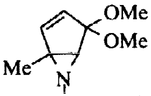
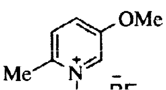
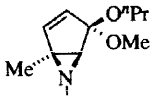
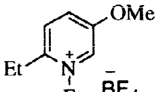
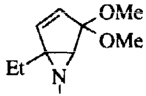
Analysis of the products [13] showed that the solvent was being introduced into the photoadduct from the same face as the aziridine, which was at odds with the previously observed result (Scheme 2). This would suggest that the azabenzvalene cation model is not applicable in this case and we assume this is due to the additional stability being conferred on the cation (**14**) by the alkoxy group. This made the neighbouring group participation of the aziridinyl nitrogen redundant and hence an azabenzvalene cation was not formed. The aziridinyl nitrogen was now free to hydrogen bond to the solvent and therefore lead the solvent in from the same face as the aziridine (Scheme 7). We ruled out steric hindrance as being a controlling factor, because the same stereochemistry of solvent addition was observed in the absence of an alkyl group (R^2) at the 2-position on the aromatic ring in compound (**13j**).



Scheme 7

In order to probe the effect of other alkyl substituents on the heteroaromatic ring, a series of other pyridinium salts were irradiated for four hours in either methanol or *n*-propanol using a pyrex filtered, medium pressure mercury vapour lamp. The results of this study are displayed in Table 1 and a few simple observations can be made from these data. The yield of the various photoproducts varies from poor to excellent and appears to depend on a number of factors. The yield of photoadduct is improved, when methanol is used as the solvent rather than *n*-propanol and the absence of an alkyl group at the 2-position of the pyridine ring gives rise to a poor or insignificant yield of photoadduct. Larger alkyl groups in either the 1- or 2-position and the oxygen appear to have a positive effect on the isolated yield of photoproduct. Entries 8 and 9 in Table 1 show that the photoreaction will take place when groups other than fully saturated alkyl chains are used in the formation of the pyridinium salt. It is interesting that the *N*-benzyl derivative (**12i**) did undergo the photosolvolysis reaction, as Mariano reported that the reaction did not occur in the case of an unsubstituted *N*-benzylpyridinium salt [6]. Mariano speculated that single electron transfer between the two aromatic rings inhibited the photoreaction in this case. The more electron rich nature of the alkoxy substituted pyridinium ring may reduce the significance of this process, although to obtain a reasonable yield of the photoproduct (**13i**) the photosubstrate (**12i**) needs to be irradiated for at least 15 hours.

Table 1. Photoreactions in alcohol.[a]

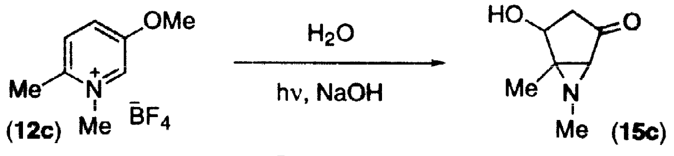
Entry	Substrate	Solvent	Product	Yield	Entry	Substrate	Solvent	Product	Yield
1	 (**12a**)	MeOH	 (**13a**)	6 %	8	 (**12h**)	MeOH	 (**13h**)	46 %
2	 (**12b**)	MeOH	 (**13b**)	17 %	9[b]	 (**12i**)	MeOH	 (**13i**)	22 %
3	 (**12c**)	MeOH	 (**13c**)	41 %	10	 (**12j**)	MeOH	 (**13j**)	50 %
4	 (**12d**)	MeOH	 (**13d**)	77 %	11	 (**12k**)	MeOH	 (**13k**)	81 %
5	 (**12e**)	MeOH	 (**13e**)	70 %	12	 (**12b**)	^{n}PrOH	 (**13l**)	0 %
6	 (**12f**)	MeOH	 (**13f**)	65 %	13	 (**12f**)	^{n}PrOH	 (**13m**)	42 %
7	 (**12g**)	MeOH	 (**13g**)	92 %					

[a] 3-Alkoxypyridinium salts (**12a-k**) were irradiated for 4 hours in basic methanol or *n*-propanol.

[b] When the benzyl derivative (**12i**) was irradiated for a further 11 hours, the yield of photoproduct (**13i**) was increased to 50 %.

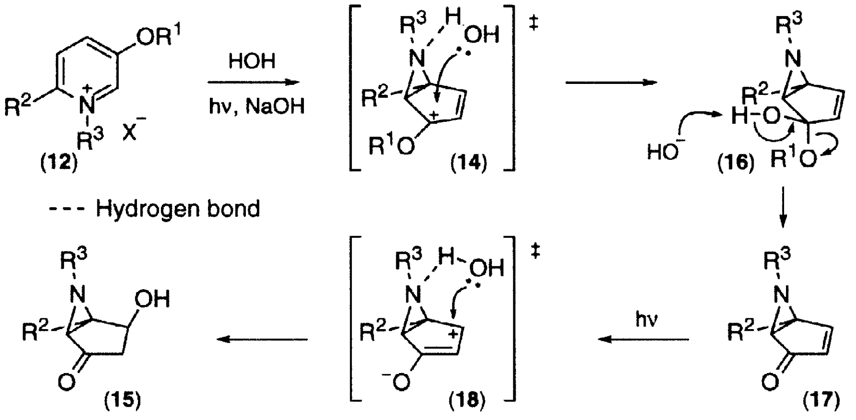
The water series

In a second series of photolysis experiments, the pyridinium salts (**12**) were irradiated in a solution of sodium hydroxide in water instead of an alcohol. In this case the products differed significantly from the alcohol series in that they were β-hydroxycyclopentanone derivatives (**15**) (Scheme 8).



Scheme 8

During the formation of the aqueous photolysis products, we believe the initially formed charged intermediate (**14**) is common in both water and alcohol solvents. The path leading to products then diversifies, depending on whether or not water or an alcohol was used as the solvent during the irradiation. For the aqueous reaction, the attacking nucleophile is water (or hydroxide) and the first intermediate to form is the hemi-ketal (**16**). Unlike a ketal, this can undergo a base catalysed elimination of an alcohol (R^1OH) to yield an enone (**17**). This enone has been reported to be unstable [14] and is readily attacked by water to form a β-hydroxyketone (**15**). This process may be photochemical in nature, as enones tend to have an absorption chromaphore coincident with the pyrex filtered irradiation source. Upon absorption of light, the enone (**17**) may form a charge transfer intermediate (**18**), which is captured by water to form the β-hydroxyketone (**15**) (Scheme 3).

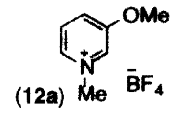
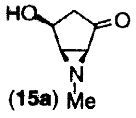
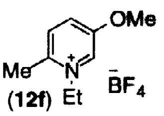
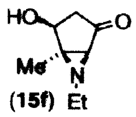
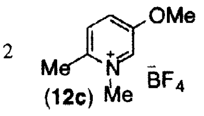
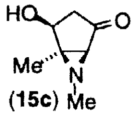
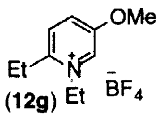
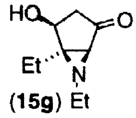
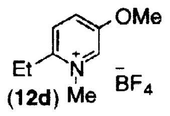
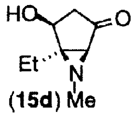
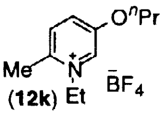
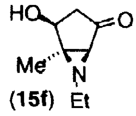
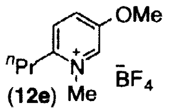
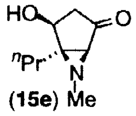


Scheme 9

The relative stereochemistry of the product has only been tentatively assigned [15] such that the hydroxyl group is delivered from the same face of the cyclopentenone ring as the aziridine. This again may be due to a hydrogen bonding interaction between the aziridinyl nitrogen and the solvent.

Many of the pyridinium salts which were used in the previous alcohol series were also irradiated in water and the results are displayed in Table 2.

Table 2. Photoreactions in water.[a]

Entry	Substrate	Solvent	Product	Yield	Entry	Substrate	Solvent	Product	Yield
1	 (12a)	H_2O	 (15a)	< 5 %	5	 (12f)	H_2O	 (15f)	34 %
2	 (12c)	H_2O	 (15c)	38 %	6	 (12g)	H_2O	 (15g)	35 %
3	 (12d)	H_2O	 (15d)	40 %	7	 (12k)	H_2O	 (15f)	24 %
4	 (12e)	H_2O	 (15e)	44 %					

[a] 3-Alkoxypyridinium salts (**12a**, **c-g**, **k**) were irradiated for 4 hours in alkaline aqueous solution.

The yields of photoadduct isolated from the water photolysis reactions were rather disappointing in comparison with the alcohol series. The aqueous photoadduct (**15g**) was only isolated in 35% yield from (**12g**), compared with a 92% yield of photoadduct (**13g**) when the same starting material was irradiated in methanol. This may have been due to a number of factors such as the relative instability of the β-hydroxycyclopentanones (**15**) compared with the cyclopentenone ketals (**13**) or the difficulty in extracting the hydroxyamines (**15**) from the aqueous solvent. However the large increase in molecular complexity, and the ability to define relative stereochemistry at three centres during one reaction, compensate for the moderate yield and we feel that the reaction may yet find use in synthesis.

Summary

In this paper we present the results of irradiating various 3-alkoxypyridinium salts in a variety of protic solvents. When an alcohol is used as the solvent, a cyclopentenone ketal is obtained as the photolysis product. The basic conditions of the reaction allowed the formation of mixed ketals, because equilibration with the solvent did not occur. When a similar reaction is conducted in water, the products are β-hydroxycyclopentanone derivatives. In comparing the two separate reactions, it was evident that the alcohol reaction was much more efficient than the water reaction.

Experimental

^{1}H-NMR spectra were recorded at 300 MHz on a Bruker Advance DPX-300 instrument or at 500 MHz on a Bruker AMX-500. Chemical shifts are reported in parts per million (ppm) relative to residual $CHCl_3$ (δ 7.27) or tetramethylsilane as the internal reference (δ 0.00). The following abbreviations are used to describe the multiplicity of a given signal: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad. Coupling constants *J* are given in Hertz. ^{13}C-NMR spectra were recorded at 75 MHz on the Bruker Advance DPX-300 instrument. Chemical shifts are reported in parts per million (ppm) relative to $CDCl_3$ (central line of triplet δ 77.00). Many of the photoproducts (**13a**) to (**13m**) exist as a mixture of invertomers and NMR data is quoted for the major invertomer. EI-MS and CI-MS were recorded on a VG Autospec instrument and at the EPSRC mass spectra service at the University of Swansea. FAB-MS were recorded on a Kratos MS80RF instrument. Infrared spectra were recorded on a Perkin-Elmer 1710 Fourier transform spectro-photometer as a thin film between NaCl plates or as solution cell. Melting points were uncorrected. Analytical TLC was performed on Merck glass backed thin layer chromatography plates pre-coated with a 0.25 mm layer of 60 F_{254} silica gel containing a fluorescent indicator. Visualisation was achieved by ultraviolet light (254 nm), iodine or by staining with alkaline potassium permanganate solution or anisaldehyde solution followed by heating. Column chromatography was carried out using Merck Kieselgel 60 silica gel (Merck art. no. 9385, 230-400 mesh, 0.04-0.063 nm). All solvents and reagents were obtained from commercial sources and used without further purification unless otherwise stated. Petrol refers to petroleum ether with the boiling range 40-60 °C. Dry diethyl ether and tetrahydrofuran were distilled from sodium / benzophenone under an atmosphere of nitrogen.

The quartz immersion well photoreactor, pyrex filter and 400 W medium pressure mercury vapour lamp were purchased from Photochemical Reactors Ltd, Sonning Common, Reading RG4 9PA, UK. The Ace Glass resealable pressure tube was purchased from Aldrich Chemical Company.

5-Methoxy-2-methylpyridine (10b). 5-Hydroxy-2-methylpyridine (2.0 g, 18.7 mmol) was added to a suspension of potassium hydroxide (4.2 g, 74.8 mmol) in DMSO (30 ml) and stirred for 1 h. Iodomethane (1.25 ml, 2.85 g, 20.1 mmol) was added and the reaction mixture was stirred for a further hour, then poured into water (100 ml) and extracted with ether (3 x 100 ml). The combined organic layers were dried ($MgSO_4$) and concentrated *in vacuo* to give the title product as an orange oil (1.77 g, 14.4 mmol, 77 %). δ_H(300 MHz): 2.49 (3H, s, $ArCH_3$), 3.83 (3H, s, OCH_3), 7.07 (1H, d, *J* 8.5 Hz, 3-H), 7.12 (1H, dd, *J* 8.5 Hz, 2.9 Hz, 4-H), 8.17 (1H, d, *J* 2.8 Hz, 6-H). δ_C(75.5 MHz): 21.90, 55.44, 121.18, 123.15, 136.04, 150.17, 153.52. ν_{max}/cm^{-1} (CHCl$_3$ solution): 2965, 2839, 1602, 1575, 1500, 1274, 1241, 1034, 832, 668. *m/z* (EI$^+$): 123 (M$^+$, 100%), 108 (90%), 80 (65%), 53 (60%). HRMS predicted for C_7H_9NO 123.0684, found 123.0686.

2-Ethyl-5-methoxy-pyridine (10c). To a solution of diisopropylamine (2.0 ml, 1.44 g, 14.2 mmol) in anhydrous THF (30 ml) cooled to 0 °C was added *n*-butyllithium (5.7 ml, 2.5 M solution in hexanes, 14.2 mmol) under a atmosphere of nitrogen. The solution was stirred at 0 °C for 30 min and then cooled to -78 °C. A solution of 5-methoxy-2-methylpyridine (**10b**) (1.5 g, 12.2 mmol) in THF (5 ml) was added dropwise over 15 min, during which time the solution turned deep red. After a further 15 min iodomethane (0.88 ml, 2.01 g, 14.1 mmol) was added and the reaction mixture was stirred for 2.5 h at -78 °C before being allowed to warm to room temperature. Concentrated aqueous ammonia (20 ml) was added and the reaction mixture was stirred for a further hour, before being poured into water (100 ml). The partitioned aqueous layer was extracted with ethyl acetate (3 x 100 ml) and the combined organic layers were dried (MgSO$_4$), and concentrated *in vacuo*. The residue was subjected to flash chromatography (SiO$_2$, petrol: ethyl acetate 4:1) to give the title compound (**10c**) as a yellow oil (655 mg, 4.74 mmol, 39%), as well as some recovered starting material (**10b**) (497 mg, 4.04 mmol, 33 %). δ_H(300 MHz): 1.20 (3H, t, *J* 7.6 Hz, $CH_2\underline{CH_3}$), 2.69 (2H, q, *J* 7.6 Hz, $ArC\underline{H_2}CH_3$), 3.76 (3H, s, $OC\underline{H_3}$), 7.00 (1H, d, *J* 8.5 Hz, 3-H), 7.05 (1H, dd, *J* 8.5 Hz, 2.8 Hz, 4-H), 8.15 (1H, d, *J* 2.7 Hz, 6-H). δ_C(75.5 MHz): 14.59, 30.75, 56.02, 121.31, 122.48, 136.60, 154.17, 156.03. ν_{max}/cm^{-1} (CHCl$_3$ solution): 2970, 2840, 1601, 1573, 1489, 1271, 1035, 910, 832, 666. *m/z* (EI$^+$): 137 (M$^+$, 100%), 136 (90%), 122 (60%), 95 (30%). HRMS predicted for $C_8H_{11}NO$ 137.0841, found 137.0831.

5-Methoxy-2-propylpyridine (10d). To a solution of diisopropylamine (2.0 ml, 1.44 g, 14.2 mmol) in anhydrous THF (30 ml) cooled to 0 °C was added *n*-butyllithium (6.3 ml, 2.5 M solution in hexanes, 15.8 mmol) under a atmosphere of nitrogen. The solution was stirred at 0 °C for 30 min and then cooled to -78 °C. A solution of 5-methoxy-2-methylpyridine (**10b**) (752 mg, 6.10 mmol) in THF (5 ml) was added dropwise over 15 min, during which time the solution turned deep red. After a further 15 min bromoethane (1.20 ml, 1.75 g, 16.1 mmol) was added. The reaction mixture was stirred for 2.5 h then allowed to warm to room temperature. Concentrated ammonia (20 ml) was added and the reaction mixture was stirred for a further hour, then poured into water (100 ml) and extracted with ethyl acetate (3 x 100 ml). The combined organic layers were dried (MgSO$_4$) and concentrated *in vacuo*. The residue was subjected to flash chromatography (SiO$_2$, petrol: ethyl acetate 4:1) to give the title product as a yellow oil (582 mg, 3.85 mmol, 63 %). δ_H(300 MHz): 0.86 (3H, t, *J* 7.4 Hz, $CH_2\underline{CH_3}$), 1.66 (2H, sextet, *J* 7.5 Hz, $ArCH_2\underline{CH_2}CH_3$), 2.62 (2H, t, *J* 7.6 Hz, $ArC\underline{H_2}CH_2$), 3.75 (3H, s, $OC\underline{H_3}$), 6.98 (1H, d, *J* 8.5 Hz, 3-H), 7.05 (1H, dd, *J* 8.5 Hz, 2.9 Hz, 4-H), 8.15 (1H, d, *J* 3.1 Hz, 6-H). δ_C(75.5 MHz): 13.71, 23.21, 39.27, 55.47, 121.08, 122.66, 136.22, 153.65, 154.29. ν_{max}/cm^{-1} ($CHCl_3$ solution): 2963, 2874, 1601, 1573, 1498, 1465, 1272, 1240, 1033, 824, 667. *m/z* (EI$^+$): 151 (M$^+$, 25%), 150 (30%), 136 (50%), 123 (100%), 108 (45%). HRMS predicted for $C_9H_{13}NO$ 151.0997, found 151.1008.

3-Propoxypyridine (10e). 3-Hydroxypyridine (1.50 g, 15.8 mmol) was added to a suspension of sodium hydroxide (700 mg, 17.5 mmol) in DMSO (20 ml) and stirred at room temperature for 30 min. 1-Bromopropane (1.50 ml, 2.03 g, 16.5 mmol) was added and the reaction mixture was stirred at room temperature for 3 h, then poured into 5% sodium hydroxide solution (100 ml) and extracted with ether (3 x 100 ml). The combined organic layers were washed with water (100 ml), dried ($MgSO_4$) and concentrated *in vacuo* to give the title compound as a pale yellow oil (1.40 g, 10.2 mmol, 65 %). δ_H(300 MHz): 0.96 (3H, t, *J* 7.4 Hz, $CH_2C\underline{H}_3$), 1.74 (2H, sextet, *J* 7.0 Hz, $CH_2C\underline{H}_2CH_3$), 3.87 (2H, t, *J* 6.5 Hz, $ArOC\underline{H}_2CH_2$), 7.11 (2H, m, Ar$\underline{H}$), 8.11 (1H, t, *J* 1.8 Hz, 6-H), 8.22 (1H, s, 2-H). δ_C(75.5 MHz): 10.32, 22.37, 69.62, 120.85, 123.67, 137.91, 141.73, 155.12. ν_{max}/cm^{-1} ($CHCl_3$ solution): 2970, 2880, 1576, 1474, 1427, 1392, 1268, 1189, 1067, 1051, 1013, 974, 798, 666, 600. *m/z* (EI$^+$): 137 (M$^+$, 40%), 95 (100%), 78 (10%). HRMS predicted for $C_8H_{11}NO$ 137.0841, found 137.0853.

2-Methyl-5-propoxypyridine (10f). 5-Hydroxy-2-methylpyridine (2.00 g, 18.3 mmol) was added to a suspension of potassium hydroxide (3.10 g, 55.3 mmol) in DMSO (30 ml) and stirred at room temperature for 30 min. 1-Bromopropane (1.67 ml, 2.26 g, 18.3 mmol) was added and the reaction mixture was stirred at room temperature for 3 h, then poured into 5% sodium hydroxide solution (100 ml) and extracted with ether (3 x 100 ml). The combined organic layers were washed with water (100 ml), dried ($MgSO_4$) and concentrated *in vacuo* to give the title compound as a pale yellow oil (1.40 g, 10.2 mmol, 65%). δ_H(300 MHz): 0.97 (3H, t, *J* 7.4 Hz, $CH_2C\underline{H}_3$), 1.77 (2H, sextet, *J* 7.1 Hz, $CH_2C\underline{H}_2CH_3$), 2.44 (3H, s, $ArC\underline{H}_3$), 3.88 (2H, t, *J* 6.6 Hz, $ArOC\underline{H}_2CH_2$), 7.01 (1H, d, *J* 8.5 Hz, 3-H), 7.06 (1H, dd, *J* 8.5 Hz, 2.8 Hz, 4-H), 8.14 (1H, d, *J* 2.7 Hz, 6-H). δ_C(75.5 MHz): 10.31, 22.42, 23.15, 69.80, 121.92, 123.20, 136.50, 149.94, 153.12. ν_{max}/cm^{-1} ($CHCl_3$ solution): 2969, 1601, 1573, 1499, 1387, 1225, 1067, 1048, 1022, 977, 830, 666. *m/z* (EI$^+$): 151 (M$^+$, 30%), 109 (100%), 80 (15%). HRMS predicted for $C_9H_{13}NO$ 151.0997, found 151.0989.

3-Methoxy-1-methylpyridinium tetrafluoroborate (12a). A solution of 3-methoxypyridine (602 mg, 5.52 mmol) in iodomethane (0.50 ml, 1.14 g, 8.0 mmol) and ether (3 ml) was heated at 70 °C in a sealed tube overnight. The solid was filtered off and washed with ether to give 3-methoxy-1-methylpyridinium iodide (858 mg, 3.42 mmol, 62%). This was dissolved in a 1:1 mixture of acetone and methanol (5 ml) and added dropwise to a solution of silver(I) carbonate (470 mg, 1.70 mmol) and fluoroboric acid (0.45 ml, 48% solution in water, 0.302 g, 3.44 mmol) in acetone (40 ml) and methanol (40 ml). The silver iodide precipitate was filtered and the filtrate was concentrated *in vacuo*. The crude product was purified by chromatography (basic alumina, acetone) to give the title compound as a colourless gum (722 g, 3.42 mmol, 62 % from 3-methoxypyridine). δ_H(300 MHz): 3.85 (3H, s, $OC\underline{H}_3$), 4.24 (3H, s, $NC\underline{H}_3$), 7.76 (1H, t, *J* 7.1 Hz, 5-H), 7.90 (1H, d, *J* 8.3 Hz, 4-H), 8.23 (1H, d, *J* 5.3 Hz, 6-H), 8.29 (1H, s, 2-H). δ_C(75.5 MHz): 48.33, 56.98, 128.30, 130.44, 132.45, 137.56, 158.40. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3093, 3040, 1632, 1591, 1532, 1326, 120, 1063, 850. *m/z* (FAB) 124 (100%, $[M - BF_4]^+$).

1-Ethyl-3-methoxypyridinium tetrafluoroborate (12b). 3-Methoxypyridine (1.10 g, 10.1 mmol) and bromoethane (1.15 ml, 1.68 g, 15.4 mmol) were heated to 60 °C in a sealed tube for 72 h. The brown precipitate was collected by filtration and washed with ether to give 1-ethyl-3-methoxypyridinium bromide (1.15 g, 5.26 mmol, 52%). This was dissolved in a mixture of acetone (2 ml) and methanol (2 ml) and added dropwise to a solution of silver(I) carbonate (800 mg, 2.90 mmol) and fluoroboric acid (0.75 ml, 48% solution in water, 0.504 g, 5.74 mmol) in acetone (10 ml) and methanol (10 ml). The silver bromide precipitate was filtered and the filtrate was concentrated *in vacuo*. The crude product was purified by chromatography (basic alumina, acetone) to give the title compound as a colourless gum (986 mg, 4.40 mmol, 44% from 3-methoxypyridine). δ_H(300 MHz): 1.45 (3H, t, *J* 7.0 Hz, $NCH_2C\underline{H}_3$), 3.78 (3H, s, $OC\underline{H}_3$), 4.42 (2H, q, *J* 7.2 Hz, $NC\underline{H}_2CH_3$), 7.60-7.85 (2H, m, $Ar\underline{H}$), 8.27 (1H, d, *J* 5.6 Hz, 6-H), 8.36 (1H, s, 2-H). δ_C(75.5 MHz): 16.09, 56.78, 57.17, 128.21, 130.35, 130.51, 136.00, 158.30. ν_{max}/cm^{-1} (liquid film): 3635, 3099, 2989, 2854, 1708, 1587, 1510, 1294, 1052, 882, 813, 726, 682, 624. *m/z* (FAB): 138 (100%, $[M - BF_4]^+$).

5-Methoxy-1,2-dimethylpyridinium tetrafluoroborate (12c). A solution of 5-methoxy-2-methylpyridine (**10b**) (2.00 g, 16.3 mmol) in iodomethane (1.50 ml, 3.42 g, 24.1 mmol) was heated to 60 °C for 18 h in a sealed tube. The precipitate was collected and washed with ether to give 5-methoxy-1,2-dimethylpyridinium iodide (3.76 g, 14.2 mmol, 87%). This was dissolved in a 1:1 mixture of acetone and methanol (20 ml) and added dropwise to a solution of silver(I) carbonate (2.34 g, 8.47 mmol) and fluoroboric acid (2.23 ml, 48% solution in water, 1.50 g, 1.71 mmol) in acetone (40 ml) and methanol (40 ml). The silver iodide precipitate was filtered and the filtrate was concentrated *in vacuo*. The crude product was purified by chromatography (basic alumina, acetone) to give the title compound as a colourless gum (3.19 g, 14.1 mmol, 86 %). δ_H(300 MHz): 2.55 (3H, s, 2-$C\underline{H}_3$), 3.80 (3H, s, $OC\underline{H}_3$), 4.08 (3H, s, 1-$C\underline{H}_3$), 7.58 (1H, d, *J* 9.0Hz, 3-H), 7.70 (1H, dd, *J* 9.0 Hz, 2.6 Hz, 4-H), 8.27 (1H, d, *J* 2.6 Hz, 6-H). δ_C(75.5 MHz): 18.77, 45.73, 56.72, 129.36, 131.36, 131.65, 141,40, 156.29. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3034, 1636, 1532, 1461, 1326, 1287, 1060, 841. *m/z* (FAB): 138 (100%, $[M - BF_4]^+$). *m/z* (EI^+): 138 ($[M - BF_4]^+$, 5%), 137 ($[M - HBF_4]^+$, 90%), 122 (100%), 94 (100%). HRMS predicted for $C_8H_{11}NO$ 137.0841, found 137.0841.

2-Ethyl-1-methyl-5-methoxypyridinium tetrafluoroborate (12d). A solution of 2-ethyl-5-methoxypyridine (**10c**) (536 mg, 3.91 mmol) and iodomethane (0.50 ml, 1.14 g, 8.0

mmol) in ether (2 ml) were heated to 80 °C in a sealed tube overnight. The precipitate was collected by filtration and washed with ether to give 2-ethyl-5-methoxy-1-methylpyridinium iodide (855 mg, 3.05 mmol, 78%). This was dissolved in methanol (5 ml) and acetone (5 ml) and added to a solution of silver(I) carbonate (460 mg, 1.67 mmol) and fluoroboric acid (0.45 ml, 48% solution in water, 630 mg, 3.4 mmol) in methanol (15 ml) and acetone (15 ml). The precipitate was removed by filtration and the filtrate concentrated *in vacuo*. The residue was subjected to column chromatography (basic alumina, acetone) to give the title compound as a yellow gum (690 mg, 2.90 mmol, 74 %). δ_H(300 MHz): 1.39 (3H, t, *J* 7.5 Hz, $CH_2C\underline{H}_3$), 3.03 (2H, q, *J* 7.2 Hz, $ArC\underline{H}_2CH_3$), 4.00 (3H, s, $OC\underline{H}_3$), 4.35 (3H, s, $NC\underline{H}_3$), 7.69 (1H, d, *J* 9.0 Hz, 3-H), 7.87 (1H, dd, *J* 9.0 Hz, 2.3 Hz, 4-H), 8.45 (1H, d, *J* 2.4 Hz, 2-H). δ_C(75.5 MHz): 11.29, 24.97, 45.55, 57.06, 127.84, 132.01, 132.07, 151.68, 156.51. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3035, 1633, 1532, 1464, 1319, 1063, 850. m/z (FAB): 152 (100%, $[M-BF_4]^+$). *m/z* (EI^+): 152 ($[M - BF_4]^+$, 25%), 152 ($[M - HBF_4]^+$, 100%), 151 ($[M - H_2BF_4]^+$, 70%), 136 (85%), 108 (70%). HRMS predicted for $C_9H_{13}NO$ 151.0993, found 151.1001.

5-Methoxy-1-methyl-2-propylpyridinium tetrafluoroborate (12e). A solution of 5-methoxy-2-propylpyridine (**10d**) (1.34 g, 8.87 mmol) and iodomethane (1.50 ml, 3.42 g, 24.1 mmol) in ether (2 ml) were heated to 70 °C in a sealed tube overnight. The precipitate was collected by filtration and washed with ether to give 5-methoxy-1-methyl-2-propylpyridinium iodide (2.47 g, 8.43 mmol, 95%). This was dissolved in methanol (5 ml) and acetone (5 ml) and added dropwise to a solution of silver(I) carbonate (1.40 g, 5.07 mmol) and fluoroboric acid (1.3 ml, 48% solution in water, 9.95 mmol) in methanol (25 ml) and acetone (25 ml). The precipitate was removed by filtration and the filtrate concentrated *in vacuo*. The residue was subjected to column chromatography (basic alumina, acetone) to give the title compound as a yellow powder (1.72 g, 6.80 mmol, 77 %); mp 47-49 °C. δ_H(300 MHz): 1.06 (3H, t, *J* 7.3 Hz, $CH_2CH_2C\underline{H}_3$), 1.73 (2H, sextet, *J* 7.6 Hz, $CH_2C\underline{H}_2CH_3$), 2.95 (2H, t, *J* 7.8 Hz, $ArC\underline{H}_2CH_2CH_3$), 3.98 (3H, s, $OC\underline{H}_3$), 4.30 (3H, s, $NC\underline{H}_3$), 7.67 (1H, d, *J* 9.0 Hz, 3-H), 7.86 (1H, dd, *J* 9.0 Hz, *J* 1.9 Hz, 4-H) 8.43 (1H, d, *J* 2.2 Hz, 6-H). δ_C(75.5 MHz): 13.48, 20.86, 33.62, 57.25, 128.30, 132.11, 132.22, 150.91, 156.66. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3033, 2976, 1674, 1613, 1532, 1465, 1379, 1319, 1062, 848. *m/z* (FAB): 166 (100%, $[M - BF_4]^+$). *m/z* (EI^+): 166 ($[M - BF_4]^+$, 10%), 165 ($[M - HBF_4]^+$, 50%), 150 (100%). HRMS predicted for $C_{10}H_{15}NO$ 165.1154, found 165.1154.

1-Ethyl-5-methoxy-2-methylpyridinium tetrafluoroborate (12f). A solution 5-methoxy-2-methylpyridine (**10b**) (4 g, 32.5 mmol) and bromoethane (3.6 ml, 5.26 g, 48.2 mmol) in ether (3 ml) was heated at 80 °C in a sealed tube for 3 days. The solid was collected by filtration and washed with ether to give 1-ethyl-5-methoxy-2-methylpyridinium bromide (6.00 g, 25.8 mmol, 80%). A portion of this (1.0 g, 4.31 mmol) was dissolved in a 1:1 mixture of methanol and acetone (5 ml) and added to a solution of silver (I) carbonate (590 mg, 2.14 mmol) and fluoroboric acid (0.56 ml, 48% solution in water, 376 mg, 4.32 mmol) in methanol (20 ml) and acetone (20 ml). The precipitate was removed by filtration and the filtrate concentrated *in vacuo* and purified by column chromatography (basic alumina, acetone) to give the title compound as a white powder (937 mg, 3.92 mmol, 73 %); mp 89-91 °C. δ_H(300 MHz) (D_2O): 1.55 (3H, t, *J* 7.5 Hz, $CH_2C\underline{H}_3$), 2.74 (3H, s, 2-$C\underline{H}_3$), 3.98 (3H, s, $OC\underline{H}_3$), 4.54 (2H, q, *J* 7.4 Hz, $NC\underline{H}_2CH_3$), 7.77 (1H, d, *J* 9.0 Hz, 3-H), 7.95 (1H, dd, *J* 9.0 Hz, 2.7 Hz, 4-H), 8.45 (1H, d, *J* 2.7 Hz, 6-H). δ_C(75.5 MHz): 14.58, 17.84, 53.30, 56.40, 129.81, 130.05, 131.05, 145.82, 156.36. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3093, 3036, 2990, 1635, 1578, 1532, 1447, 1322, 1168, 1061, 841. *m/z* (FAB): 152 (100%, $[M - BF_4]^+$). *m/z* (EI^+): 152 ($[M - BF_4]^+$, 10%), 151 ($[M - HBF_4]^+$, 60%), 123 (95%), 108 (100%). HRMS predicted for $C_9H_{13}NO$ 151.0997, found 151.0997.

1,2-Diethyl-5-methoxypyridinium tetrafluoroborate (12g). A solution of 2-ethyl-5-methoxypyridine (**10c**) (740 mg, 5.4 mmol) and iodoethane (0.65 ml, 1.28 g, 8.2 mmol) in ether (3 ml) were heated at 80 °C in a sealed tube for 2 days. The precipitate was collected by filtration and washed with ether to give 1,3-diethyl-5-methoxypyridinium iodide (1.52 g, 5.19 mmol, 96%). This was dissolved in methanol (5 ml) and acetone (5 ml) and added to a solution of silver(I) carbonate (715 mg, 2.59 mmol) and fluoroboric acid (0.70 ml, 48% solution in water, 470 mg, 5.4 mmol) in methanol (25 ml) and acetone (25 ml). The precipitate was removed by filtration and the filtrate concentrated *in vacuo*. The residue was subjected to column chromatography (basic alumina, acetone) to give the title compound as a yellow gum (1.26 g, 4.99 mmol, 92 %). δ_H(300 MHz): 1.18 (3H, t, *J* 7.5 Hz, $ArCH_2C\underline{H}_3$), 1.37 (3H, t, *J* 7.2 Hz, $NCH_2C\underline{H}_3$), 2.82 (2H, q, *J* 7.5 Hz, $ArC\underline{H}_2CH_3$), 3.78 (3H, s, OCH_3), 4.40 (2H, q, *J* 7.2 Hz, $NC\underline{H}_2CH_3$), 7.56 (1H, d, *J* 9.0 Hz, 3-H), 7.73 (1H, dd, *J* 9.0 Hz, 2.6 Hz, 4-H), 8.37 (1H, d, *J* 2.6 Hz). δ_C(75.5 MHz): 11.99, 15.64, 24.05, 53.02, 56.74, 127.89, 130.47, 131.63, 150.43, 156.51. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3034, 2988, 1633, 1532, 1462, 1293, 1061, 850. *m/z* (FAB): 166 (100%, $[M-BF_4]^+$). *m/z* (CI^+): 168 ($[M - BF_4 + H_2]^+$, 100%), 166 ($[M - BF_4]^+$, 25%), 138 (40%). HRMS predicted for $C_{10}H_{16}NO$ 166.1232, found 166.1224.

1-Allyl-5-methoxy-2-methylpyridinium tetrafluoroborate (12h). A solution of 5-methoxy-2-methylpyridine (**10b**) (1.00 g, 8.13 mmol) and allyl bromide (0.95 ml, 1.33 g, 11.0 mmol) in ether (3 ml) were heated at 80 °C in a sealed tube for 4 h. The precipitate was collected by filtration and washed with ether to give 1-allyl-5-methoxy-2-methylpyridinium bromide (1.68 g, 6.89 mmol, 85%). This was dissolved in methanol (5 ml) and acetone (5 ml) and added to a solution of silver(I) carbonate (1.14 g, 4.13 mmol) and fluoroboric acid (1.10 ml, 48% solution in water, 739 mg, 8.42 mmol) in methanol (20 ml) and acetone (20 ml). The precipitate was removed by filtration and the filtrate concentrated *in vacuo*. The residue was subjected to column chromatography (basic alumina, acetone) to give the title compound as a colourless gum (1.66 g, 6.61 mmol, 96 %). δ_H(300 MHz): 2.66 (3H, s, 2-CH_3), 3.91 (3H, s, OCH_3), 5.10-5.15 (3H, m, $NC\underline{H}_2CH{=}CHH$, $NCH_2CH{=}C\underline{H}H$), 5.35 (1H, d, *J* 10.4 Hz, $NCH_2CH{=}CH\underline{H}$), 5.88-6.01 (1H, m, $NCH_2C\underline{H}{=}CHH$), 7.68 (1H, d, *J* 8.9 Hz, 3-H), 7.82 (1H, dd, *J* 9.0 Hz, 2.5 Hz, 4-H), 8.30 (1H, d, *J* 2.4 Hz). δ_C(75.5 MHz): 18.94, 57.30, 60.63, 121.39, 129.28, 130.52, 131.00, 132.42, 147.50, 157.19. ν_{max}/cm^{-1} (liquid film): 3091, 2975, 1635, 1531, 1449, 1293, 1061, 850, 735. *m/z* (FAB) 164 (100%, [M - BF$_4$]$^+$). *m/z* (EI$^+$): 164 ([M - BF$_4$]$^+$, 5%), 163 ([M - HBF$_4$]$^+$, 50%), 162 ([M - H$_2$BF$_4$]$^+$, 45%), 148 (100%). HRMS predicted for $C_{10}H_{12}NO$ 162.0919, found 162.0919.

1-Benzyl-5-methoxy-2-methylpyridinium tetrafluoroborate (12i). A solution of 5-methoxy-2-methyl-pyridine (**10b**) (1.00 g, 8.13 mmol) and benzyl bromide (0.95 ml, 1.33 g, 11.0 mmol) in ether (3 ml) were heated at 80 °C in a sealed tube for 16 h. The precipitate was collected by filtration and washed with ether to give 1-benzyl-5-methoxy-2-methyl-pyridinium bromide (1.90 g, 6.48 mmol, 80%). This was dissolved in methanol (5 ml) and acetone (5 ml) and added to a solution of silver(I) carbonate (893 mg, 3.23 mmol) and fluoroboric acid (0.85 ml, 48% solution in water, 571 mg, 6.50 mmol) in methanol (20 ml) and acetone (20 ml). The precipitate was removed by filtration and the filtrate concentrated *in vacuo*. The residue was subjected to column chromatography (basic alumina, acetone) to give the title compound as a white powder (1.79 g, 5.96 mmol, 92 %); mp 141-144 °C. δ_H(300 MHz): 2.30 (3H, s, 2-CH$_3$), 3.63 (3H, s, OCH$_3$), 5.44 (2H, s, NC$\underline{H}_2$Ph), 6.77-6.80 (2H, m, ArH), 6.99-7.04 (3H, m, ArH), 7.41 (1H, d, *J* 8.9 Hz, 3-H), 7.59 (1H, dd, *J* 8.9 Hz, 2.7 Hz, 4-H), 8.39 (1H, d, *J* 2.7 Hz). δ_C(75.5 MHz): 18.55, 56.58, 60.89, 126.52, 128.51, 128.69, 130.07, 131.08, 131.24, 131.83, 146.74, 156.28. ν_{max}/cm^{-1} (CHCl$_3$ solution): 3033, 1635, 1580, 1532, 1461, 1322, 1288, 1062, 843. *m/z* (FAB): 214 (100%, [M - BF$_4$]$^+$). *m/z* (EI$^+$): 213 ([M - HBF$_4$]$^+$, 10%), 212 ([M - H$_2$BF$_4$]$^+$, 10%), 122 (50%), 91 (100%). HRMS predicted for $C_{14}H_{14}NO$ 212.1075, found 212.1076.

1-Ethyl-3-propoxypyridinium tetrafluoroborate (12j). A solution of 3-propoxy-pyridine (**10e**) (1.00 g, 7.29 mmol) and bromoethane (0.82 ml, 1.20 g, 11.0 mmol) were heated at 60 °C in a sealed tube for 24 h. The precipitate was collected by filtration and washed with ether to give 1-ethyl-3-methoxypyridinium bromide (1.67 g, 6.78 mmol, 93%). This was dissolved in a mixture of acetone (5 ml) and methanol (5 ml) and added dropwise to a solution of silver(I) carbonate (933 mg, 3.39 mmol) and fluoroboric acid (0.89 ml, 48% solution in water, 0.548 g, 6.81 mmol) in acetone (20 ml) and methanol (20 ml). The silver iodide precipitate was filtered and the filtrate was concentrated *in vacuo*. The crude product was purified by chromatography (basic alumina, acetone) to give the title product as a colourless gum (1.57 g, 6.21 mmol, 85 %). δ_H(300 MHz): 0.98 (3H, t, *J* 7.4 Hz, OCH$_2$CH$_2$C$\underline{H}_3$), 1.65 (3H, t, *J* 7.3 Hz, NCH$_2$C$\underline{H}_3$), 1.80 (2H, sextet, *J* 6.8 Hz, OCH$_2$C$\underline{H}_2$CH$_3$), 4.25 (2H, t, *J* 6.3 Hz, OC$\underline{H}_2$CH$_2$CH$_3$), 5.02 (2H, q, *J* 7.3 Hz, NC$\underline{H}_2$CH$_3$), 7.87-7.97 (2H, m, Ar$\underline{H}$), 9.03 (1H, d, *J* 5.6 Hz, Ar$\underline{H}$), 9.34 (1H, s, 2-H). δ_C(75.5 MHz): 9.53, 16.16, 21.33, 57.11, 71.29, 128.19, 130.54, 130.66, 135.80, 157.85 ν_{max}/cm^{-1} (liquid film): 3093, 2973, 1626, 1587, 1510, 1466, 1337, 1298, 1162, 1062, 814, 683. *m/z* (FAB): 166 (100%, [M - BF$_4$]$^+$). *m/z* (EI$^+$): 166 ([M - BF$_4$]$^+$, 100%), 95 (100%). HRMS predicted for $C_{10}H_{16}NO$ 166.1232, found 166.1231.

1-Ethyl-2-methyl-5-propoxypyridinium tetrafluoroborate (12k). A solution of 2-methyl-5-propoxypyridine (**10f**) (1.0 g, 6.62 mmol) and bromoethane (0.75 ml, 1.09 g, 10.0 mmol) in diethyl ether (2 ml) were heated to 80 °C in a sealed tube for 3 days. The precipitate was filtered and washed with ether to give 1-ethyl-2-methyl-5-propylpyridinium bromide (1.45 g, 5.57 mmol, 84%). This was dissolved in a mixture of acetone (5 ml) and methanol (5 ml) and added dropwise to a solution of silver(I) carbonate (920 mg, 3.34 mmol) and fluoroboric acid (0.90 ml, 48% solution in water, 0.605 g, 6.89 mmol) in acetone (25 ml) and methanol (25 ml). The silver bromide precipitate was filtered and the filtrate was concentrated *in vacuo*. The crude product was purified by chromatography (basic alumina, acetone) to give the title compound as a colourless gum (1.32 g, 4.77 mmol, 72 %). δ_H(300 MHz): 0.95 (3H, t, *J* 7.4 Hz, $OCH_2CH_2C\underline{H}_3$), 1.51 (3H, t, *J* 7.3 Hz, $NCH_2C\underline{H}_3$), 1.75 (2H, sextet, *J* 6.9 Hz, $OCH_2C\underline{H}_2CH_3$), 2.70 (3H, s, 2-$C\underline{H}_3$), 4.05 (2H, t, *J* 6.4 Hz, $OC\underline{H}_2CH_2CH_3$), 4.55 (2H, q, *J* 7.3 Hz, $NC\underline{H}_2CH_3$), 7.65 (1H, d, *J* 8.9 Hz, 3-H), 7.76 (1H, dd, *J* 8.9 Hz, 2.6 Hz, 4-H), 8.42 (1H, d, *J* 2.6 Hz, 6-H). δ_C(75.5 MHz): 9.94, 15.36, 18.68, 21.82, 54.10, 71.70, 130.23, 130.72, 132.10, 145.90, 156.76. ν_{max}/cm^{-1} (liquid film): 3091, 2973, 1635, 1577, 1532, 1461, 1294, 1061, 849. *m/z* (FAB): 180 (100%, $[M-BF_4]^+$. *m/z* (EI^+): 180 ($[M-BF_4]^+$, 5%), 179 ($[M - HBF_4]^+$, 30%), 151 ($[M - C_2H_5BF_4]^+$, 25%), 136 (40%), 109 (100%). HRMS predicted for $C_{11}H_{17}NO$ 179.1310, found 179.1313.

6-Aza-4,4-dimethoxy-6-methylbicyclo[3.1.0]hex-2-ene (13a). A solution of 3-methoxy-1-methylpyridinium tetrafluoroborate (**12a**) (343 mg, 1.62 mmol) and sodium hydroxide (165 mg, 4.12 mmol) in N_2-purged methanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered off and the filtrate concentrated and subjected to flash chromatography (SiO_2, EtOAc:MeOH:NH_3 100:10:1) to give the title compound as a red oil (16 mg, 0.10 mmol, 6 %). δ_H(300 MHz): 2.23 (1H, m, 5-H) 2.35 (4H, m, 1-H, NCH_3), 3.26 (3H, s, OCH_3), 3.40 (3H, s, OCH_3), 5.78 (1H, m, 3-H), 6.23 (1H, m, 2-H δ_C(75.5 MHz): 44.62, 45.37, 46.21, 49.39, 51.37, 109.14, 132.41, 134.43. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3003, 2956, 1656, 1602, 1456, 1363, 1261, 1154, 1106, 1064, 1049, 977, 909, 832. *m/z* (EI^+): 156 ($[M + H]^+$, 5%), 124 ($[M - OCH_3]^+$, 100%). Sample decomposed prior to accurate mass measurement.

6-Aza-6-ethyl-4,4-dimethoxybicyclo[3.1.0]hex-2-ene (13b). A solution of 1-ethyl-3-methoxypyridinium tetrafluoroborate (**12b**) (336 mg, 1.49 mmol) and sodium hydroxide (193 mg, 4.82 mmol) in N_2-purged methanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered off and the filtrate concentrated and subjected to flash chromatography (SiO_2, EtOAc:MeOH:NH_3 100:10:1) to give the title compound as a red oil (42 mg, 0.25 mmol, 17 %). δ_H(300 MHz): 1.11 (3H, t, *J* 7.1 Hz, $NCH_2C\underline{H}_3$), 2.20-2.35 (4H, m, 1-H, 5-H and $NC\underline{H}_2CH_3$), 3.27 (3H, s, $OC\underline{H}_3$), 3.37 (3H, s, OCH$_3$), 5.73 (1H, d, *J* 5.7 Hz, 3-H), 6.18 (1H, d, *J* 5.8 Hz, 2-H). δ_C(75.5 MHz): 14.30, 43.88, 44.75, 49.23, 51.01, 52.28, 109.92, 133.42, 135.41. ν_{max}/cm^{-1} (liquid film) 2937, 1735, 1655, 1605, 1384, 1365, 1202. *m/z* (EI$^+$): 138 ([M - OCH$_3$]$^+$, 100%), 110 (80%), 95 (60%) HRMS predicted for $C_8H_{12}NO$ 138.0919, found 138.0918.

6-Aza-4,4-dimethoxy-1,6-dimethylbicyclo[3.1.0]hex-2-ene (13c). A solution of 5-methoxy-1,2-dimethylpyridinium tetrafluoroborate (**12c**) (425 mg, 1.89 mmol) and sodium hydroxide (285 mg, 7.12 mmol) in N$_2$-purged methanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered off and the filtrate concentrated and subjected to flash chromatography (SiO$_2$, EtOAc: MeOH:NH$_3$ 100:4:1) to give the title compound as a yellow oil (131 mg, 0.77 mmol, 41 %). δ_H(300 MHz): 1.41 (3H, s, 1-CH$_3$), 1.93 (1H, d, *J* 1.3 Hz, 5-H), 2.35 (3H, s, NCH$_3$), 3.15 (3H, s, OCH$_3$), 3.34 (3H, s, OCH$_3$), 5.62 (1H, dd, *J* 5.8 Hz, 1.4 Hz, 3-H), 6.00 (1H, d, *J* 5.8 Hz, 2-H). δ_C(75.5 MHz): 9.27, 38.88, 48.21, 48.45, 50.10, 51.09, 110.31, 130.95, 141.06. ν_{max}/cm^{-1} (liquid film) 2940, 1676, 1609, 1452, 1400. *m/z* (EI$^+$): 138 ([M - OCH$_3$]$^+$, 100%), 122 (55%), 95 (30%) HRMS predicted for $C_8H_{12}NO$ 138.0919, found 138.0915.

6-Aza-4,4-dimethoxy-1-ethyl-6-methylbicyclo[3.1.0]hex-2-ene (13d). A solution of 2-ethyl-5-methoxy-1-methylpyridinium tetrafluoroborate (**12d**) (350 mg, 1.46 mmol) and sodium hydroxide (387 mg, 9.7 mmol) in N$_2$-purged methanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered off and the filtrate concentrated and subjected to flash chromatography (SiO$_2$, EtOAc: MeOH:NH$_3$ 100:10:1) to give the title compound as a yellow oil (205 mg, 1.12 mmol, 77 %). δ_H(300 MHz): 1.04 (3H, t, *J* 7.5 Hz, CH$_2$C$\underline{H}_3$), 1.76 (2H, qd, *J* 7.5 Hz, 3.3 Hz, 1-C$\underline{H}_2$CH$_3$), 1.99 (1H, d, *J* 1.5 Hz, 5-H), 2.41 (3H, s, NC$\underline{H}_3$), 3.26 (3H, s, OC$\underline{H}_3$), 3.38 (3H, s, OC$\underline{H}_3$), 5.66 (1H, dd *J* 5.8 Hz, 1.8 Hz, 3-H), 6.15 (1H, d, *J* 5.9 Hz, 2-H). δ_C(75.5 MHz): 11.35, 17.28, 38.83, 49.31, 49.71, 51.25, 54.01, 110.37, 131.73, 139.51. ν_{max}/cm^{-1} (liquid film): 2970, 2832, 1667, 1460, 1247, 1150, 1053, 979, 909, 828, 665. *m/z* (EI) 152 ([M - OCH$_3$]$^+$, 100%), 137 (50%), 122 (60%), 94 (30%). HRMS predicted for $C_9H_{14}NO$ 152.1075, found 152.1085.

6-Aza-4,4-dimethoxy-1-propyl-6-methylbicyclo[3.1.0]hex-2-ene (13e). A solution of 5-methoxy-1-methyl-2-propylpyridinium tetrafluoroborate (**12e**) (400 mg, 1.58 mmol) and sodium hydroxide (198 mg, 4.95 mmol) in N$_2$-purged methanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered off and the filtrate concentrated and subjected to flash chromatography (SiO$_2$, EtOAc: MeOH:NH$_3$ 100:10:1) to give the title compound as a yellow oil (218 mg, 1.11 mmol, 70 %). δ_H(300 MHz): 0.87 (3H, t, *J* 7.5 Hz, CH$_2$C$\underline{H}_3$), 1.43 (2H, sextet, *J* 7.7 Hz, CH$_2$C$\underline{H}_2$CH$_3$), 1.60

(2H, m, 1-C$\underline{H}_2$CH$_2$CH$_3$), 1.77 (1H, s, 5-H), 2.29 (3H, s, NC$\underline{H}_3$), 3.25 (3H, s, OC$\underline{H}_3$), 3.33 (3H, s, OC$\underline{H}_3$), 5.65 (1H, dd *J* 5.8 Hz, 1.7 Hz, 3-H), 6.10 (1H, d, *J* 5.9 Hz, 2-H). δ_C(75.5 MHz): 13.86, 20.33, 26.02, 38.89, 49.20, 49.77, 51.43, 52.79, 110.29, 131.57, 139.71. ν_{max}/cm^{-1} (liquid film): 3053, 2959, 1669, 1610, 1456, 1391, 1269, 1148, 1082, 981, 734. *m/z* (EI) 166 ([M - OCH$_3$]$^+$, 100%), 137 (35%), 122 (40%), 94 (15%). HRMS predicted for $C_{10}H_{16}NO$ 166.1232, found 166.1222.

6-Aza-4,4-dimethoxy-6-ethyl-1-methylbicyclo[3.1.0]hex-2-ene (13f). A solution of 1-ethyl-5-methoxy-2-methylpyridinium tetrafluoroborate (**12f**) (400 mg, 1.67 mmol) and sodium hydroxide (300 mg, 7.5 mmol) in N_2-purged methanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered off and the filtrate concentrated and subjected to flash chromatography (SiO_2, DCM:EtOH: NH_3 200:8:1) to give the title product as a red oil (197 mg, 1.08 mmol, 65 %). δ_H(300 MHz): 0.90 (3H, t, *J* 7.1 Hz, CH$_2$C$\underline{H}_3$), 1.43 (3H, s, 1-C$\underline{H}_3$), 1.95 (1H, d, *J* 1.3 Hz, 5-H), 2.32-2.48 (2H, m, NC$\underline{H}_2$CH$_3$), 3.26 (3H, s, OC$\underline{H}_3$), 3.35 (3H, s, OC$\underline{H}_3$), 5.65 (1H, dd, *J* 5.8 Hz, 1.7 Hz, 3-H), 6.03 (1H, d, *J* 5.8 Hz, 2-H). δ_C(75.5 MHz): 9.94, 14.98, 46.92, 48.58, 49.06, 49.32, 51.12, 110.49, 131.28, 141.56. ν_{max}/cm^{-1} (liquid film): 3054, 2964, 2831, 1610, 1449, 1263, 1146, 1057, 911, 729. *m/z* (EI$^+$) 152 (100%, [M - OCH$_3$]$^+$), 124 (40%), 109 (20%). HRMS predicted for $C_9H_{14}NO$ 152.1074, found 152.1077.

6-Aza-1,6-diethyl-4,4-dimethoxybicyclo[3.1.0]hex-2-ene (13g). A solution of 1,2-diethyl-5-methoxypyridinium tetrafluoroborate (**12g**) (416 mg, 1.64 mmol) and sodium hydroxide (201 mg, 5.0 mmol) in N_2-purged methanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered off and the filtrate concentrated and subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 100:10:1) to give the title compound as a yellow oil (296 mg, 1.50 mmol, 92 %). δ_H(300 MHz, 3:2 mixture of invertomers): 0.88 (1.2 H, t, *J* 7.1 Hz, NCH$_2$C$\underline{H}_3$), 0.93 (1.2 H, t, *J* 7.4 Hz, 1-CH$_2$C$\underline{H}_3$), 1.01 (1.8H, t, *J* 7.5 Hz, 1-CH$_2$C$\underline{H}_3$), 1.12 (1.8 Hz, *J* 7.2 Hz, NCH$_2$C$\underline{H}_3$), 1.59-1.82 (m, 2H, 1-C$\underline{H}_2$CH$_3$), 1.96 (0.6 H, d, *J* 1.2 Hz, 5-H), 2.30-2.60 (2.4 H, m, 5-H, NC$\underline{H}_2$CH$_3$), 3.25 (1.8 H, s, OCH$_3$), 3.26 (1.2 H, s, OCH$_3$), 3.31 (1.2 H, s, OCH$_3$), 3.35 (1.8 H, s, OCH$_3$), 5.67 (0.6 H, dd, *J* 5.9 Hz, 1.7 Hz, 3-H), 5.74 (0.4 H, d, *J* 5.9 Hz, 2-H), 5.91 (0.4 H, dd, *J* 5.9 Hz, 2.0 Hz, 3-H), 6.12 (0.6 H, d, *J* 6.12 Hz, 2-H). δ_C(75.5 MHz): 10.55, 11.58, 14.94, 15.21, 17.70, 26.63, 38.20, 44.62, 46.48, 47.88, 49.10, 49.29, 50.98, 51.83, 52.77, 53.30, 107.37, 110.39, 131.78, 131.85, 131.93, 139.81. ν_{max}/cm^{-1} (liquid film): 2967, 2830, 1663, 1610, 1463, 1352, 1260, 1059, 911, 831, 732. *m/z* (CI$^+$) 198 (70%, [MH]$^+$), 166 (75%), 138 (90%), 91 (100%). HRMS predicted for $C_{11}H_{20}NO_2$ 198.1494, found 198.1494.

6-Aza-6-allyl-4,4-dimethoxy-1-methylbicyclo[3.1.0]hex-2-ene (13h). A solution of 1-allyl-2-methyl-5-methoxypyridinium tetrafluoroborate (**12h**) (510 mg, 2.03 mmol) and sodium hydroxide (200 mg, 5.00 mmol) in N_2-purged methanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered and the filtrate concentrated and subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 100:8:1) to give the title product as a brown oil (182 mg, 0.93 mmol, 46 %). δ_H(300 MHz): 1.43 (3H, s, 1-CH_3), 2.00 (1H, d, *J* 1.0 Hz, 5-H), 2.88 (1H, dd, *J* 13.8 Hz, 6.7 Hz, $NC\underline{H}HCH{=}CH_2$), 3.18 (1H, m, $NCH\underline{H}CH{=}CH_2$), 3.26 (3H, s, OCH_3), 3.35 (3H, s, OCH_3), 5.04 (1H, dd, *J* 10.2 Hz, 1.3 Hz, $CH{=}C\underline{H}H$), 5.14 (1H, dd, *J* 17.2 Hz, 1.5 Hz, $CH{=}CH\underline{H}$), 5.66 (1H, dd, *J* 5.9 Hz, 1.8 Hz, 3-H), 5.89-6.01 (1H, m, $NCH_2C\underline{H}{=}CH_2$), 6.03 (1H, d, *J* 5.8 Hz, 2-H). δ_C(75.5 MHz): 10.16, 48.89, 49.77, 49.81, 51.78, 56.03, 110.44, 116.55, 131.53, 135.71, 141.25. ν_{max}/cm^{-1} ($CHCl_3$ solution): 2940, 2833, 1645, 1461, 1396, 1267, 1136, 1052, 980, 822, 665. *m/z* (EI) 164 ($[M - OCH_3]^+$, 100%), 148 (60%), 134 (60%). HRMS predicted for $C_{10}H_{14}NO$ 164.1075, found 164.1064.

6-Aza-6-benzyl-4,4-dimethoxy-1-methylbicyclo[3.1.0]hex-2-ene (13i). A solution of 1-benzyl-5-methoxy-2-methylpyridinium tetrafluoroborate (**12i**) (516 mg, 1.71 mmol) and sodium hydroxide (198 mg, 4.95 mmol) in N_2-purged methanol (350 ml) was irradiated for 15 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered and the filtrate concentrated and subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 100:8:1) to give the title product as a brown oil (210 mg, 0.94 mmol, 50 %). δ_H(300 MHz): 1.48 (3H, s, 1-CH_3), 2.11 (1H, d, *J* 1.1 Hz, 5-H), 3.21 (3H, s, OCH_3), 3.27 (3H, s, OCH_3) 3.35 (1H, d, *J* 13.3 Hz, $NC\underline{H}HPh$), 3.75 (1H, d, *J* 13.3 Hz, $NCH\underline{H}Ph$), 5.67 (1H, dd, *J* 5.8 Hz, 1.7 Hz, 3-H), 6.07 (1H, d, *J* 5.8 Hz, 2-H), 7.13-7.34 (5H, m, ArH). . δ_C(75.5 MHz): 10.29, 48.47, 48.62, 49.93, 50.87, 56.23, 110.31, 126.83, 127.54, 128.09, 128.34, 131.71, 138.73, 141.12. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3009, 2941, 2834, 1638, 1605, 1453, 1265, 1140, 1052, 980, 910. *m/z* (EI) 245 (M^+, 25%), 230 (25%), 214 (75%), 170 (15%), 91 (100%). HRMS predicted for $C_{15}H_{19}NO_2$ 245.1416, found 245.1427.

(±)-1S-4S-5S-6-Aza-6-ethyl-4-methoxy-4-propoxybicyclo[3.1.0]hex-2-ene (13j) [13]. A solution of 1-ethyl-3-propoxypyridinium tetrafluoroborate (**12j**) (512 mg, 2.06 mmol) and sodium hydroxide (194 mg, 4.85 mmol) in N_2-purged methanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered and the filtrate concentrated and subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 200:8:1) to give the title product as a brown oil (200 mg, 1.02 mmol, 50 %). δ_H(300 MHz): 0.87 (3H, t, *J* 7.4 Hz, $OCH_2CH_2C\underline{H}_3$), 1.09 (3H, t, *J* 7.1 Hz, $NCH_2C\underline{H}_3$), 1.59 (2H, sextet, *J* 7.1 Hz, $OCH_2C\underline{H}_2CH_3$), 2.18-2.35 (4H, m, $NC\underline{H}_2CH_3$, 1-H, 5-H), 3.27 (3H, s,

$OC\underline{H}_3$), 3.56 (2H, m, $OC\underline{H}_2CH_2CH_3$), 5.74 (1H, d, *J* 5.8 Hz, 3-H), 6.17 (1H, d, *J* 5.8 Hz, 2-H). Irradiation of the OCH_2 group produced an NOE of 3.8 % to the hydrogen at δ 2.2. Irradiation of the methoxy group produced an NOE of 0.8% to the same hydrogen. δ_C(75.5 MHz): 10.64, 14.29, 22.95, 44.11, 44.88, 49.21, 52.26, 65.34, 109.44, 133.71, 135.15. ν_{max}/cm^{-1} (liquid film): 2967, 1663, 1605, 1466, 1361, 729. *m/z* (EI) 166 ($[M - OCH_3]^+$, 95%), 138 ($[M - OC_3H_7]^+$, 100%), 124 (90%), 110 (50%), 96 (70%). HRMS predicted for $C_{10}H_{16}NO$ 166.1232, found 166.1232.

(±)-1S-4S-5S-6-Aza-6-ethyl-4-methoxy-1-methyl-4-propoxybicyclo[3.1.0]hex-2-ene (13k). A solution of 1-ethyl-2-methyl-5-propoxypyridinium tetrafluoroborate (**12k**) (447 mg, 1.61 mmol) and sodium hydroxide (230 mg, 5.75 mmol) in N_2-purged methanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered and the filtrate concentrated and subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 200:8:1) to give the title compound as a yellow oil (274 mg, 1.30 mmol, 81 %). δ_H(300 MHz): 0.87 (3H, t, *J* 7.4 Hz, $OCH_2CH_2C\underline{H}_3$), 1.11 (3H, t, *J* 6.9 Hz, $NCH_2C\underline{H}_3$), 1.41 (3H, s, 5-$C\underline{H}_3$), 1.55 (2H, sextet, *J* 7.2 Hz, $OCH_2C\underline{H}_2CH_3$), 1.97 (1H, d, *J* 1.1 Hz, 5-H), 2.29-2.53 (2H, m, $NC\underline{H}_2CH_3$), 3.31 (3H, s, $OC\underline{H}_3$), 3.56 (2H, m, $OC\underline{H}_2CH_2CH_3$), 5.68 (1H, dd, *J* 5.7, 1.7 Hz, 2-H), 6.06 (1H, d, *J* 5.8 Hz, 3-H). Irradiation of the OCH_2 group produced an NOE of 3.4% to the hydrogen at δ 1.97. Irradiation of the methoxy group produced an NOE of 0.5 % to the same hydrogen. δ_C(75.5 MHz): 9.66, 10.46, 14.75, 17.98, 22.95, 46.64, 48.58, 48.83, 65.13, 109.78, 131.72, 140.95. ν_{max}/cm^{-1} (liquid film): 2964, 1685, 1454, 1265, 1054, 731. *m/z* (EI) 180 ($[M - OCH_3]^+$, 100%), 152 ($[M - OC_3H_7]^+$, 100%), 138 (90%), 124 (70%), 110 (90%). HRMS predicted for $C_{11}H_{18}NO$ 180.1388, found 180.1390.

(±)-1S-4R-5S-6-Aza-6-ethyl-4-methoxy-1-methyl-4-propoxybicyclo[3.1.0]hex-2-ene (13m). A solution of 1-ethyl-5-methoxy-2-methylpyridinium tetrafluoroborate (**12f**) (300 mg, 1.26 mmol) and sodium hydroxide (200 mg, 5.0 mmol) in N_2-purged 1-propanol (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The solution was then concentrated *in vacuo* and the residue triturated with chloroform. The solid was filtered off and the filtrate concentrated and subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 200:8:1) to give the title compound as an orange oil (115 mg, 0.54 mmol, 42 %). δ_H(500 MHz): 0.93 (3H, t, *J* 7.4 Hz, $OCH_2CH_2C\underline{H}_3$), 1.20 (3H, t, *J* 7.2 Hz, $NCH_2C\underline{H}_3$), 1.49 (3H, s, 1-$C\underline{H}_3$), 1.60 (2H, sextet, *J* 7.2 Hz, $OCH_2C\underline{H}_2CH_3$), 2.05 (1H, d, *J* 1.8 Hz, 5-H), 2.43 (1H, dq, *J* 11.9 Hz, 7.2 Hz, $NC\underline{H}HCH_3$), 2.54 (1H, dq, *J* 11.9 Hz, 7.2 Hz, $NCH\underline{H}CH_3$), 3.43 (3H, s, $OC\underline{H}_3$), 3.46 (1H, dt, *J* 9.2 Hz, 6.4 Hz, $OC\underline{H}HCH_2CH_3$), 3.57 (1H, dt, *J* 9.2 Hz, 6.4 Hz, $OCH\underline{H}CH_2CH_3$), 5.68 (1H, dd *J* 5.8, 1.8 Hz, 3-H), 6.06 (1H, d, *J* 5.8 Hz, 2-H). Irradiation of the methoxy group produced an NOE of 3.5% to the hydrogen at δ 2.05. Irradiation of the OCH_2 group produced a minimal NOE to the same hydrogen (<0.5%).

δ_C(75.5 MHz): 9.75, 10.45, 14.93, 23.05, 46.76, 48.66, 48.94, 50.86, 63.07, 110.65, 131.87, 141.90. ν_{max}/cm^{-1} ($CHCl_3$ solution): 2966, 2937, 2877, 1669, 1609, 1455, 1398, 1378, 1260, 1138, 1118, 1038, 909, 855, 800. *m/z* (EI) 180 ([M - OCH_3]$^+$, 85%), 152 ([M - OC_3H_7]$^+$, 100%), 138 (80%), 124 (45%), 110 (50%). HRMS predicted for $C_{11}H_{18}NO$ 180.1388, found 180.1390.

(±)-1R-2S-5S-6-Aza-2-hydroxy-1,6-dimethylbicyclo[3.1.0]hexan-4-one (15c). A solution of 5-methoxy-1,2-dimethylpyridinium tetrafluoroborate (**12c**) (500 mg, 2.22 mmol) and sodium hydroxide (180 mg, 4.5 mmol) in N_2-purged water (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The reaction mixture was extracted with ethyl acetate (3 x 300 ml) and the combined organic layers were dried ($MgSO_4$) and concentrated *in vacuo* to give an orange oil. This was subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 150:8:1) to give the title compound as a yellow oil (125 mg, 0.83 mmol, 38 %). δ_H(300 MHz): 1.46 (3H, s, 1-C$\underline{H}_3$), 1.80 (1H, d, *J* 17.8 Hz, 3-H), 1.86 (1H, s, 5-H), 2.37 (3H, s, NC$\underline{H}_3$), 2.62 (1H, dd, *J* 18.0 Hz, 5.8 Hz, 3-H), 3.65 (1H, s, br, O$\underline{H}$), 4.25 (1H, d, *J* 5.8 Hz, 2-H). δ_C(75.5 MHz): 7.08, 38.38, 44.48, 53.14, 54.46, 71.56, 212.01. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3422, 3009, 2926, 1743, 1510, 1455, 1391, 1345, 1115, 1030, 668. *m/z* (EI) 141 (M$^+$, 45%), 124 (40%), 112 (60%), 96 (65%), 71 (80%), 56 (80%), 42 (100%). HRMS predicted for $C_7H_{11}NO_2$ 141.0790, found 141.0801.

(±)-1R-2S-5S-6-Aza-1-ethyl-2-hydroxy-6-methylbicyclo[3.1.0]hexan-4-one (15d). A solution of 2-ethyl-5-methoxy-1-methylpyridinium tetrafluoroborate (**12d**) (300 mg, 1.26 mmol) and sodium hydroxide (191 mg, 4.78 mmol) dissolved in N_2-purged water (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The reaction mixture was extracted with ethyl acetate (3 x 300 ml) and the combined organic layers were dried ($MgSO_4$) and concentrated *in vacuo* to give an orange oil. This was subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 200:8:1) to give the title product as an orange oil (84 mg, 0.54 mmol, 43 %). δ_H(300 MHz): 1.08 (3H, t, *J* 7.5 Hz, CH_2C$\underline{H}_3$), 1.60 (1H, q, *J* 7.3 Hz, 1-C$\underline{H}$HCH_3), 1.80 (1H, d, *J* 18.0 Hz, 3-H), 1.8 (1H, s, 5-H), 2.37 (1H, q, *J* 7.5 Hz, 1-CH$\underline{H}$CH_3), 2.43 (3H, s, NC$\underline{H}_3$), 2.64 (1H, dd, *J* 18.0 Hz, 5.7 Hz, 3-H), 4.40 (1H, d, *J* 5.7 Hz, 2-H). δ_C(75.5 MHz): 10.44, 14.50, 38.39, 44.91, 53.51, 58.84, 69.70, 212.54. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3422, 2977, 1742, 1460, 1384, 1115, 1042, 665. *m/z* (CI) 156 ([MH]$^+$, 100%). HRMS predicted for $C_8H_{14}NO_2$ 156.1025, found 156.1024.

(±)-1R-2S-5S-6-Aza-2-hydroxy-6-methyl-1-propylbicyclo[3.1.0]hexan-4-one (15e). A solution of 5-methoxy-1-methyl-2-propylpyridinium tetrafluoroborate (**12e**) (480 mg, 1.89 mmol) and sodium hydroxide (278 mg, 6.9 mmol) dissolved in N_2-purged water (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The reaction mixture was extracted with ethyl acetate (3 x 300 ml) and the combined organic layers were dried ($MgSO_4$) and concentrated *in vacuo* to give an orange oil. This was subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 100:8:1) to give the title compound as an yellow oil (139 mg, 0.82 mmol, 44 %). δ_H(300 MHz): 0.93 (3H, t, *J* 7.0 Hz, $-CH_2C\underline{H}_3$) 1.40 -1.62 (3H, m, $1\text{-}C\underline{H}HCH_2CH_3$ and $1\text{-}CHHC\underline{H}_2CH_3$), 1.78 (1H, d, *J* 18.0 Hz, 3-H), 1.85 (1H, s, 5-H), 2.25 (1H, m, $1\text{-}CH\underline{H}CH_2CH_3$), 2.41 (3H, s, $NC\underline{H}_3$), 2.60 (1H, dd, *J* 18.0 Hz, 5.8 Hz, 3-H), 4.32 (1H, d, *J* 5.7 Hz, 2-H). δ_C(75.5 MHz): 14.09, 19.01, 23.82, 38.02, 44.35, 52.75, 57.70, 69.65, 212.17. ν_{max}/cm^{-1} ($CHCl_3$ solution): 3424, 2983, 1712, 1605, 1511, 1470, 1225, 1116, 671. *m/z* (EI) 169 (M^+, 45%), 152 (25%), 140 (85%), 112 (50%), 99 (70%), 42 (100%). HRMS predicted for $C_9H_{15}NO_2$ 169.1103, found 169.1106.

(±)-1R-2S-5S-6-Aza-6-ethyl-2-hydroxy-1-methylbicyclo[3.1.0]hexan-4-one (15f) [15]. A solution of 1-ethyl-5-methoxy-2-methylpyridinium tetrafluoroborate (**12f**) (500 mg, 2.09 mmol) and sodium hydroxide (266 mg, 6.65 mmol) in N_2-purged water (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The reaction mixture was extracted with ethyl acetate (3 x 300 ml) and the combined organic layers were dried ($MgSO_4$) and concentrated *in vacuo* to give an orange oil. This was subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 150:8:1) to give the title product as a yellow oil (110 mg, 0.71 mmol, 34 %). δ_H(300 MHz): 1.11 (3H, t, *J* 7.1 Hz, $NCH_2C\underline{H}_3$), 1.55 (3H, s, $1\text{-}C\underline{H}_3$), 1.87 (1H, d, *J* 18.0 Hz, 3-H), 1.96 (1H, s, 5-H), 2.40 (1H, dq, *J* 12.0 Hz, 7.1 Hz, $NC\underline{H}HCH_3$), 2.45 (1H, br s, $O\underline{H}$), 2.53 (1H, dq, *J* 12.0 Hz, 7.1 Hz, $NCH\underline{H}CH_3$), 2.74 (1H, dd, *J* 18.0 Hz, 5.8 Hz, 3-H), 4.25 (1H, d, *J* 5.8 Hz, 2-H). δ_C(75.5 MHz): 7.36, 14.74, 44.61, 46.20, 51.66, 54.72, 71.81, 212.34. m/z (EI) 155 (M^+, 75%), 138 (40), 127 (40), 112 (80), 85 (85). ν_{max}/cm^{-1} (liquid film): 3424, 3053, 2975, 1741, 1447, 1391, 1121, 1083, 913, 732, 648. The peak at 3424 remained broad upon dilution in $CHCl_3$. *m/z* (EI) 155 (M^+, 65%), 138 (35%), 127 (35%), 112 (80%), 85 (80%). HRMS predicted for $C_8H_{13}NO_2$ 155.0946, found 155.0940.

(±)-1R-2S-5S-6-Aza-1,6-diethyl-2-hydroxybicyclo[3.1.0]hexan-4-one (15g). A solution of 1,2-diethyl-5-methoxypyridinium tetrafluoroborate (**12g**) (467 mg, 1.85 mmol) and sodium hydroxide (276 mg, 6.9 mmol) in N_2-purged water (350 ml) was irradiated for 4 h using a 400 W medium pressure mercury lamp with a pyrex filter. The reaction mixture was extracted with ethyl acetate (3 x 300 ml) and the combined organic layers were dried ($MgSO_4$) and concentrated *in vacuo* to give a yellow oil. This was subjected to flash chromatography (SiO_2, DCM:EtOH:NH_3 100:8:1) to give the title product as an yellow oil (107 mg, 0.63 mmol, 35 %). δ_H(300 MHz): 1.08 (3H, t *J* 7.5 Hz, $1\text{-}CH_2C\underline{H}_3$) 1.10 (3H, t, *J* 7.0 Hz, $N\text{-}CH_2C\underline{H}_3$), 1.62 (1H, q, *J* 7.4 Hz, $1\text{-}C\underline{H}HCH_3$), 1.80 (1H, d, *J* 18.0 Hz, 3-H), 1.89 (1H, s, 5-H), 2.20-2.35 (2H, m, $NC\underline{H}_2CH_3$), 2.67 (1H, dd, *J* 18.0 Hz, 5.7 Hz, 3-H), 2.78 (1H, q, *J* 6.9 Hz, $1\text{-}CH\underline{H}CH_3$), 3.40 (1H, br, $O\underline{H}$), 4.39 (1H, d, *J* 5.7 Hz, 2-H). δ_C(75.5 MHz): $\nu_{max.}$/cm^{-1} (liquid film): 3424, 2959, 1740. *m/z* (EI) 169 (M^+, 55%), 154 (45%), 126 (85%), 99 (70%). HRMS predicted for $C_9H_{15}NO_2$ 169.1103, found 169.1116.

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References

[1] (a) Wender PA, Siggel L, Nuss JM. Organic Photochemistry. Editor; Padwa A. New York: Marcel-Dekker, 1989; Vol. 10, Chapter 4. (b) Cornelisse J. Chem. Rev. 1993; 93: 615.

[2] (a) Wilzbach KE, Kaplan L, J. Am. Chem. Soc. 1966; 88: 2066. (b) Bryce-Smith D, Gilbert A, Orger BH. J. Chem. Soc., Chem. Commun. 1966: 512.

[3] Wender PA, Howbert JJ, J. Am. Chem. Soc. 1981; 103: 688.

[4] Wender PA, Dreyer GB, J. Am. Chem. Soc. 1982; 104: 5805.

[5] Kaplan L, Pavlik JW, Wilzbach KE. J. Am. Chem. Soc. 1972; 94: 3283.

[6] Ling R, Yoshida M, Mariano PS, J. Org. Chem. 1996; 61: 4439.

[7] Ling R, Mariano PS, J. Org. Chem. 1998; 63: 6072-6076.

[8] Glarner F, Thornton SR, Schärer D, Bernardinelli G, Burger U. Helv. Chim. Acta. 1997; 80: 121.

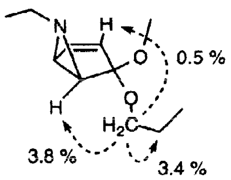
[9] Acar EA, Glarner F, Burger U. Helv. Chim. Acta. 1998; 81: 1095.

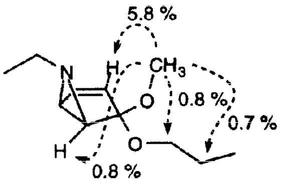
[10] Corey EJ, Streith J. J. Am. Chem. Soc. 1964; 86: 950.

[11] Kohl B, Sturm E, Senn-Bilfinger J, Simon WA, Krüger U, Schaefer H, Rainer G, Figala V, Klemm K. J. Med. Chem. 1992; 35: 1049.

[12] Osuch C, Levine R, J. Am. Chem. Soc. 1956; 78: 1723.

[13] NOE difference results for compound (**13j**);

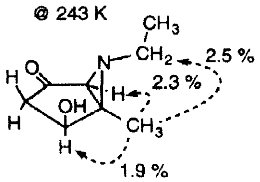


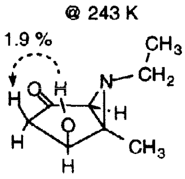


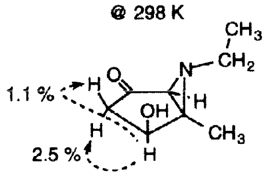
[14] Katritzky AR, Wilde H. J. Chem. Soc., Chem. Commun. 1975: 770.

[15] The stereochemistry of (**15f**) has been assigned on the basis of;

(a) NOE difference studies (done at 298 K and also at 243 K to freeze out the exchanging OH),







(The lack of an NOE enhancement between the C1-Me and the OH leads us to believe that the stereochemistry is as drawn).

(b) and the OH stretching band in the IR spectrum. This remained broad even after dilution indicating a significant degree of intramolecular hydrogen bonding between the hydroxyl group and the aziridinyl nitrogen.