One-Pot Synthesis of Dihydroimidazo- and Imidazophenanthridinium Salts

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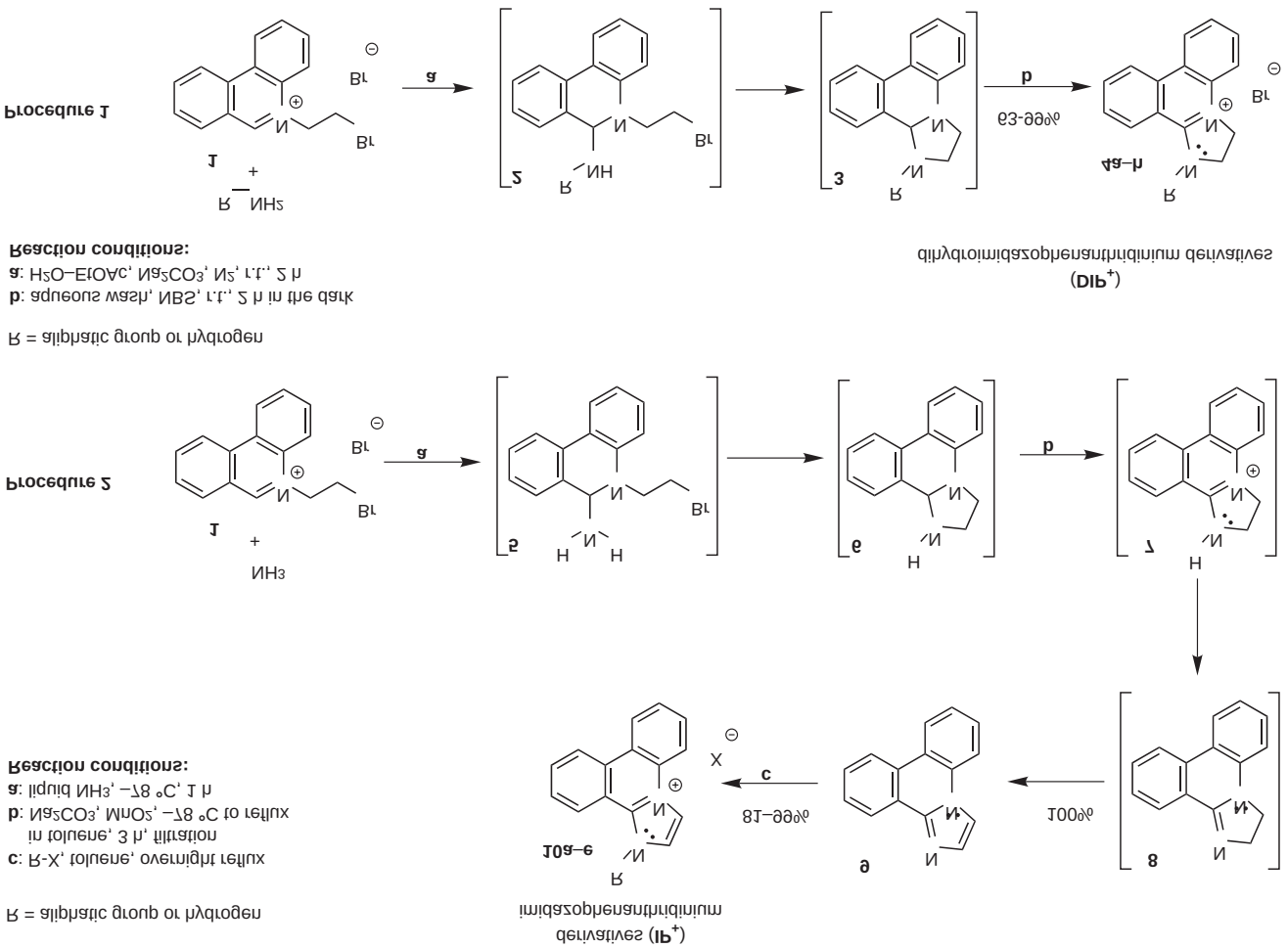
Received 15 February 2007

PSP No 108

Abstract: Two highly efficient and general one-pot annulation reactions are described for the synthesis of dihydroimidazo- and imidazophenanthridinium salts (**DIPs**$^+$ and **IPs**$^+$). These two methodologies exploit the difference in reactivity between primary amino-based or ammonia nucleophiles and the dielectrophilic starting material, 2-bromoethylphenanthridinium bromide.

Key words: annulation reaction, heterocycles, phenanthridinium derivatives, DNA intercalating agents, anticancer agents



Scheme 1 The 'one-pot' reaction methodologies leading to **DIPs**$^+$ (Procedure 1) and **IPs**$^+$ (Procedure 2)

Introduction

Improvements in screening methods in the pharmaceutical industry have encouraged the development of highly flexible synthetic procedures that could increase the structural complexity of a given target whilst decreasing the number of synthetic steps. Efficient syntheses leading to N-heteroaromatic cations are particularly appealing because they often have high affinity for DNA as a result of their planar structure and charged characteristics.[1] In this respect, molecules containing the phenanthridinium core are an important subset of heteroaromatic cations as they

SYNTHESIS 2008, No. 1, pp 0155–0160
Advanced online publication: 11.09.2007
DOI: 10.1055/s-2007-983895; Art ID: Z04007SS

have numerous applications as drugs,[2] DNA targeting agents,[3] dyes,[4] and DNA probes.[5] Recently, we have exploited the reactivity of the dielectrophile 2-bromoethylphenanthridinium in two annulation reactions that produce two new cationic heterocyclic frameworks based on the dihydroimidazo-[6] and imidazophenanthridinium[7] moieties. Both procedures have allowed the synthesis of a library of phenanthridinium derivatives with a range of interesting physical and chemical properties including resistance to hydrolysis,[8,9] excellent DNA affinity,[7,9,10] and cytotoxicity on cancerous cell lines A2780, A2780/cp70, and MCP1.[9,10b]

The dielectrophilic starting material **1** (Scheme 1), common in both procedures, is easily prepared by reacting phenanthridine with an excess of 1,2-dibromoethane (see experimental part). The reaction mechanisms of the following two procedures have been thoroughly studied and are now well understood: [6,7,11] In a water/ethyl acetate biphasic system, the **DIP**$^+$ synthesis (Procedure 1, Scheme 1) is initiated by a nucleophilic addition of a primary amine at the iminium moiety of **1** leading to intermediate **2**. The resulting secondary amine undertakes a rapid five-membered ring cyclisation to give the imidazolidine intermediate **3**, which can be extracted in the organic layer. Subsequent oxidation of intermediate **3** via addition of *N*-bromosuccinimide (NBS) leads to the formation of dihydroimidazophenanthridinium bromide (**DIP**$^+$) **4**, which precipitates from the solution and is recovered by filtration (Scheme 1 and Table 1).

Table 1 Some **DIP**$^+$ and **IP**$^+$ Derivatives Obtained via Procedures 1, 1′ and 2

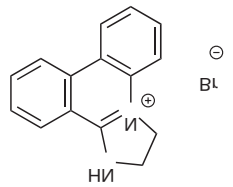
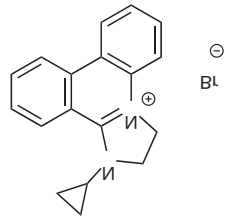
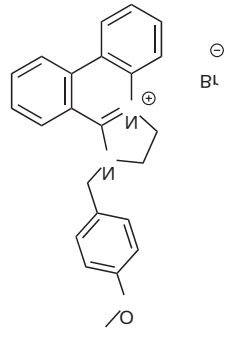
Entry	Structure	Yield (%)/ Procedure
4a		96/1
4b		91/1
4c		99/1

Table 1 Some **DIP**$^+$ and **IP**$^+$ Derivatives Obtained via Procedures 1, 1′ and 2 (continued)

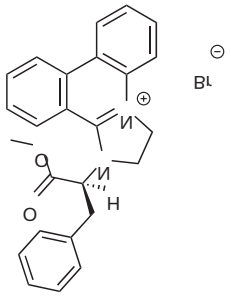
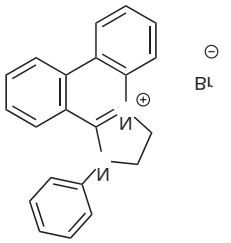
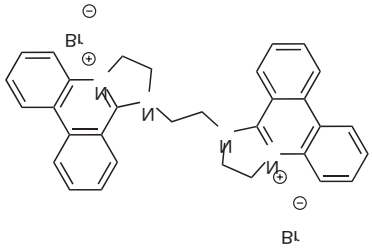
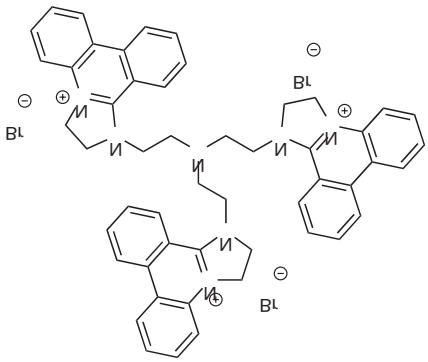
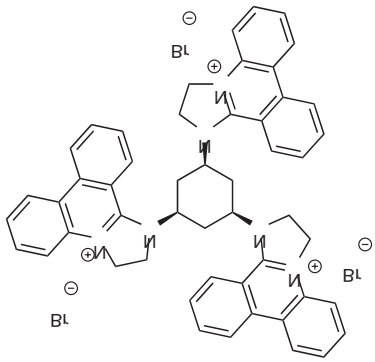
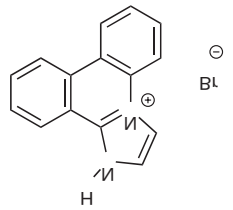
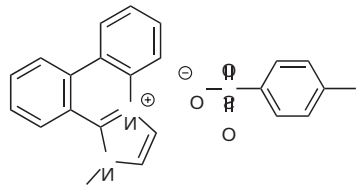
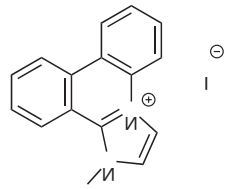
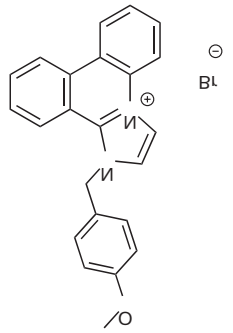
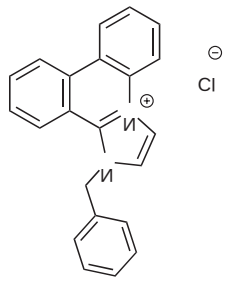
Entry	Structure	Yield (%)/ Procedure
4d		63/1
4e		73[a]/1′
4f		98[a]/1′
4g		95[a]/1′
4h		91[a]/1′

Table 1 Some **DIP**$^+$ and **IP**$^+$ Derivatives Obtained via Procedures 1, 1′ and 2 (continued)

Entry	Structure	Yield (%)/ Procedure
10a		85/2
10b		99/2
10c		95/2
10d		98/2
10e		81/2

[a] Yield based on the consumption of amine.

The first three steps of the synthesis of **IP**$^+$ derivatives are identical to those of **DIP**$^+$ discussed above: In liquid ammonia, starting material **1** undertakes an α-addition to form intermediate **5**, followed by a cyclisation to form imidazolidine intermediate **6** that is oxidised by MnO_2 to the acidic intermediate **7**. Deprotonation of dihydroimidazolium **7** takes place in the solution of ammonia, yielding the intermediate dihydroimidazole **8**. The final oxidation step leading to imidazophenanthridine **9** occurs at higher temperature after evaporation of ammonia and reflux in toluene. Compound **9** can be isolated in a quantitative yield after filtering off the residual inorganic reactants and side products. The desired imidazophenanthridinium salts (**IP**$^+$) **10a–e** are obtained by reacting compound **9** with a range of electrophiles, and recovered by filtration (Scheme 1 and Table 1).

Scope and Limitations

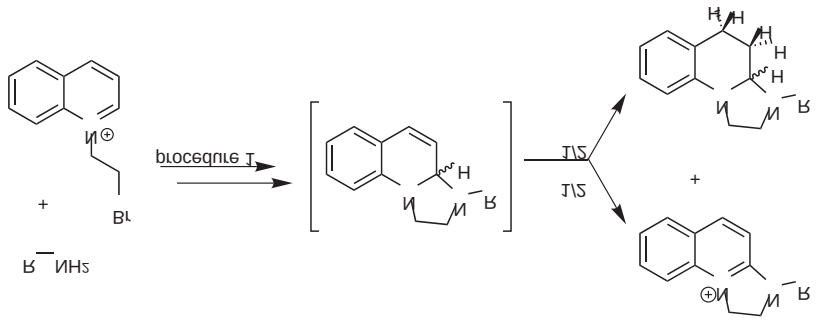
We have tested both Procedures 1 and 2 on N-heterocyclic systems other than phenanthridine and have encountered the following limitations: (1) None of the procedures are applicable to pyridine as the reactions invariably leads to ring-opening side reactions of the pyridine moiety upon nucleophilic attack of the iminium moiety;[12] (2) Procedure 1 leads to a disproportionation reaction that halves the yield when applied to quinoline derivatives (Scheme 2);[6] and (3) Procedure 2 also works on quinoline, isoquinoline, quinazoline and phthalazine derivatives but better results are obtained when a biphasic system (toluene/ammonia) is used in the first stage of the reaction: this partitions intermediate **6** in the organic phase, away from the ammonia phase containing starting material **1,** therefore avoiding unwanted redox side-reactions.[13]

Also, it is worth noting some limitations of Procedure 1 concerning the nature of the amines that can be used: (1) Polyamine derivatives, expected to lead to **poly-DIP**$^+$ derivatives with poly-DNA intercalation properties, could not be obtained via Procedure 1 for solubility reasons. This is because the corresponding intermediate **3**, bearing another amino-tail on its R group, is compartmented in the organic layer of the biphasic system, away from another equivalent of **1** that is necessary to perform a new reaction cycle; and (2) Also, Procedure 1 is not effective with aromatic amines due to a side reaction originating from the alpha addition of the more nucleophilic hydroxide ion formed in the aqueous layer. Note that the limitations concerning the nature of the amine can be overcome by changing the reaction conditions (Procedure 1′, Scheme 3). In a monophasic system in a solution of DMF, it is possible to use polyamines and aromatic amines as long as two equivalents of **1** are present: one equivalent used as an electrophile and another one as an oxidizing agent.[6]

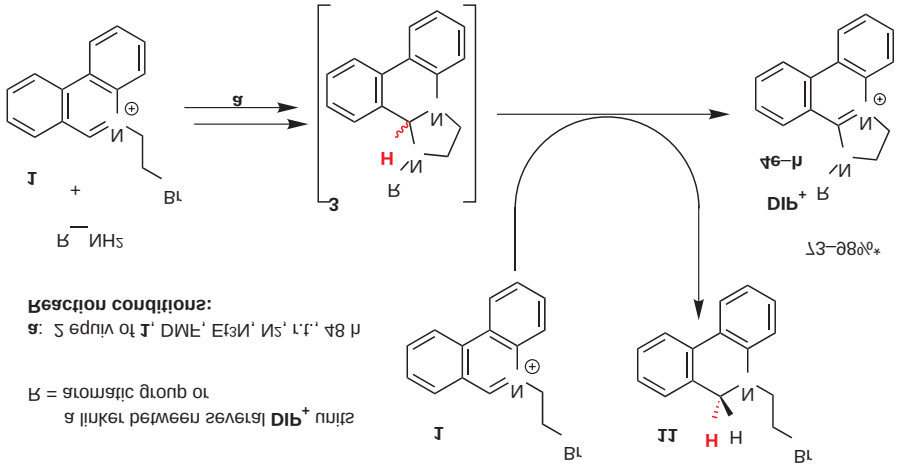
Note that molecule **11**, the reduced form of **1**, stays in solution while the final product **DIP**$^+$ **4e–h** is recovered after precipitation by addition of diethyl ether (Scheme 3 and Table 1). Using these modifications, **DIP**$^+$ derivatives functionalised with aromatic R groups could be obtained, as well as really large architectures of **Poly-DIP**$^+$ molecules containing 3 to 16 units.

Procedures

In this paper, we report the detailed protocols for **Procedures 1**, **1′** and **2**, along with the analytical data for some **DIP**$^+$ and **IP**$^+$ derivatives. The characterisation of the remaining molecules can be found in the published literature.[6,7]



Scheme 2 Disproportionation issue when applying Procedure 1 to quinolinium-based heterocycles



Scheme 3 Procedure 1′: Modification of Procedure 1 to accommodate the use of aromatic amines and polyamines; * yield based on the consumption of amine

All starting materials and solvents were commercially available (reagent grade) and used as supplied, from Aldrich Chemical Co., without further purification. ^{1}H NMR and ^{13}C NMR were recorded using a Bruker DPX 400 spectrometer operating at 400 and 100 MHz, respectively. Chemical shifts (δ) are given in ppm relative to residual solvent peak. Infra red spectral analyses were performed on a JASCO 410 spectrophotometer using a KBr disc; peaks are quoted in wave numbers (cm^{-1}) and their relative intensities are reported as follows: s = strong, m = medium, w = weak. Mass spectra were obtained using a JEOL JMS 700 spectrometer operating in FAB, EI, or CI mode. Microanalyses were performed on a CE-440 elemental analyser. Melting points were determined on a digital IA9000 series melting point apparatus, using capillary tubes.

2-Bromoethylphenanthridinium Bromide (1)

Phenanthridine (5.44 g, 30.4 mmol) was dissolved in 1,2-dibromoethane (114.2 g, 52 mL, 608 mmol) and stirred at 100 °C for 5 d . During that time, the precipitate that formed was filtered every day, rinsed with 1,2-dibromoethane (5 mL), and the mother liquor was returned to stir at 100 °C until the next filtration. The reaction was complete when no more precipitate formed. The precipitates were combined and washed thoroughly with acetone to give **1** (7.92g, 95%) as a beige powder; mp 234–235 °C (dec.).

IR (KBr): 2947 (w), 1620 (m), 763 (s), 717 cm^{-1} (m).

^{1}H NMR (D_2O, 400 MHz): δ = 9.81 (s, 1 H), 8.72 (d, *J* = 7.2 Hz, 1 H), 8.63 (d, *J* = 7.2 Hz, 1 H), 8.37 (d, *J* = 7.2 Hz, 1 H), 8.26 (d, *J* = 7.2 Hz, 1 H), 8.18 (t, *J* = 7.2 Hz, 1 H), 7.98 (t, *J* = 7.2 Hz, 1 H), 7.90 (m, 2 H), 5.37 (t, *J* = 5.8 Hz, 2 H), 4.05 (t, *J* = 5.8 Hz, 2 H).

^{13}C NMR (D_2O, 100 MHz): δ = 155.27 (CH), 139.03 (CH), 135.59 (C), 133.18 (CH), 132.78 (C), 132.58 (CH), 130.85 (CH), 130.72 (CH), 126.57 (C), 125.13 (CH), 123.32 (C), 123.00 (CH), 118.91 (CH), 58.87 (CH_2), 29.41 (CH_2).

MS (EI): *m/z* (%) = 288.1 (M – Br, 100), 206.2 (8).

Anal. Calcd for $C_{15}H_{13}Br_2N$: C, 49.32; H, 3.59; N, 3.84. Found: C, 49.15; H, 3.48; N, 3.76.

CAUTION: Product **1** was found to be an extreme irritant and allergenic material. Appropriate safety protection and utmost care are required while preparing and handling this compound.

Procedure 1: Monomeric DIP$^+$ Derivatives 4a–d from Aliphatic Amines

To a biphasic solution of 5% aq Na_2CO_3 (20 mL) and EtOAc (40 mL) was added the primary amine or its HCl salt (2.1 mmol) followed by 2-bromoethylphenanthridinium bromide (**1**; 700 mg, 1.9 mmol). The mixture was stirred under N_2 at r.t. for 2 h. The organic layer was separated, washed with H_2O (2 × 40 mL) and placed in a round-bottomed flask covered with aluminum foil. NBS (375 mg, 2.1 mmol) was added to the stirred solution at 0 °C, and the mixture left stirring at r.t. for 2 h in the dark. The precipitate was filtered and washed with Et_2O to yield the corresponding **DIP**$^+$ frameworks **4a–d**.

2,3-Dihydro-1*H*-imidazo[1,2-*f*]phenanthridin-4-ylium Bromide (4a)

Yield: 550 mg (96%); yellow powder; mp 392–394 °C (dec.).

IR (KBr): 3435 (s), 3028 (m), 2997 (m), 2950 (m), 2773 (w), 2684 (w), 2050 (w), 1626 (s), 1608 (s), 1585 (s), 1469 (m), 1454 (m), 1358 (m), 1294 (m), 1267 (w), 1169 (w), 1022 (w), 754 cm^{-1} (s).

^{1}H NMR (D_2O, 400 MHz): δ = 7.83 (d, *J* = 8.0 Hz, 1 H), 7.79 (d, *J* = 8.0 Hz, 1 H), 7.66 (t, *J* = 8.0 Hz, 1 H), 7.46 (m, 3 H), 7.28 (t, *J* = 8.0 Hz, 1 H), 6.93 (d, *J* = 8.0 Hz, 1 H), 4.13 (t, *J* = 10.8 Hz, 2 H), 3.91 (t, *J* = 10.8 Hz, 2 H).

^{13}C NMR (D_2O, 100 MHz): δ = 154.69 (C), 135.75 (CH), 133.18 (C), 131.65 (C), 129.56 (CH), 126.26 (CH), 125.65 (CH), 123.40 (CH), 123.01 (CH), 119.25 (C), 115.45 (CH), 113.64 (C), 47.62 (CH_2), 43.04 (CH_2).

MS (EI+): *m*/*z* (%) = 220 (M – Br, 10), 219.3 (12), 142.3 (8), 112.2 (5), 100.2 (15), 86.2 (100), 56.1 (50).

Anal. Calcd for $C_{15}H_{13}BrN_2$: C, 59.82; H, 4.35; N, 9.30. Found: C, 59.39; H, 4.23; N, 9.03.

1-(4-Methoxybenzyl)-2,3-dihydro-1*H*-imidazo[1,2-*f*]phenanthridin-4-ylium Bromide (4c)

Yield: 792 mg (99%); off-white powder; mp 245–246 °C (dec.).

IR (KBr): 3431 (s), 2924 (w), 2360 (w), 1612 (s), 1576 (s), 1514 (m), 1456 (m), 1304 (m), 1248 (m), 1026 (m), 814 (m), 754 cm^{-1} (m).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 8.52 (d, *J* = 8.2 Hz, 1 H), 8.36 (d, *J* = 8.2 Hz, 1 H), 8.21 (d, *J* = 8.2 Hz, 1 H), 7.93 (t, , *J* = 8.2 Hz, 1 H), 7.69 (t, *J* = 8.2 Hz, 1 H), 7.56 (t, *J* = 8.2 Hz, 1 H), 7.51 (m, 2 H), 7.32 (d, *J* = 8.2 Hz, 2 H), 6.91 (d, *J* = 8.2 Hz, 2 H), 5.41 (s, 2 H), 5.04 (t, *J* = 10.6 Hz, 2 H), 4.68 (t, , *J* = 10.6 Hz, 2 H), 3.76 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 160.26 (C), 154.91 (C), 136.30 (C), 135.79 (CH), 133.25 (C), 132.25 (CH), 129.49 (CH), 128.34 (CH), 127.94 (CH), 126.28 (CH), 125.29 (C), 124.42 (CH), 123.96 (CH), 120.93 (C), 116.38 (CH), 115.91 (C), 115.40 (CH), 55.81 (CH_3), 55.36 (CH_2), 52.54 (CH_2), 47.72 (CH_2).

MS (FAB): *m*/*z* (%) = 341.2 (M – Br, 35), 232 (10), 157.1 (56), 121.2 (13), 79.7 (100).

Anal. Calcd for $C_{23}H_{21}BrN_2O{\cdot}0.5H_2O$: C, 64.19; H, 5.15; N, 6.51. Found: C, 64.87; H, 5.47; N, 6.95.

Procedure 1′: Polymeric DIP$^+$ Derivatives or DIPs$^+$ 4e–h Derived from Aromatic Amines

To a solution of primary amine (0.95 mmol of amino group) and Et_3N (530 μL, 3.8 mmol) in DMF (20 mL) was added 2-bromoethylphenanthridinium bromide (**1**; 700 mg, 1.9 mmol). After stirring for 48 h at r.t. under N_2, the final product and the triethylamine hydrobromide were precipitated from the solution with Et_2O (100 mL) and recovered by filtration. The precipitate was washed thoroughly with Et_2O and triturated with a small amount of H_2O (3 × 1 mL) to remove the triethylamine hydrobromide salt, yielding after drying, the corresponding **DIP**$^+$ derivatives **4e**–**h**.

1-Phenyl-2,3-dihydro-1*H*-imidazo[1,2-*f*]phenanthridin-4-ylium Bromide (4e)

Yield: 260 mg (73%); yellow powder; mp 355–356 °C (dec.).

IR (KBr): 3434 (s), 3047 (w), 1612 (m), 1599 (m), 1575 (s), 1545 (s), 1485 (w), 1440 (m), 1309 (s), 1171 (w), 935 (w), 758 cm^{-1} (s).

^{1}H NMR (CD_3OD, 400 MHz): δ = 8.85 (d, *J* = 8.4 Hz, 1 H), 8.75 (d, *J* = 8.4 Hz, 1 H), 8.05 (t, *J* = 8.4 Hz, 1 H), 7.93 (t, *J* = 8.4 Hz, 1 H), 7.81 (d, *J* = 8.4 Hz, 1 H), 7.71 (m, 6 H), 7.45 (m, 2 H), 5.04 (t, *J* = 10.4 Hz, 2 H), 4.69 (t, *J* = 10.4 Hz, 2 H).

^{13}C NMR (CD_3OD, 100 MHz): δ = 154.87 (C), 144.05 (C), 141.02 (CH), 137.69 (CH), 137.07 (CH), 134.63 (C), 133.20 (CH), 132.60 (CH), 132.02 (CH), 129.94 (CH), 129.24 (CH), 128.47 (CH), 126.45 (CH), 125.76 (CH), 122.72 (C), 120.46 (C), 117.43 (CH), 117.00 (C), 56.19 (CH_2), 48.76 (CH_2);

MS (FAB): *m*/*z* (%) = 297 (M – Br, 100), 269 (2), 230 (8), 219 (4), 178 (4), 154 (6), 136 (5), 107.2 (1), 77.6 (2).

Anal. Calcd for $C_{21}H_{17}BrN_2{\cdot}0.5H_2O$: C, 65.30; H, 4.70; N, 7.25. Found: C, 65.71; H, 4.53; N, 7.11.

***cis*-1,3,5-Triaminocyclohexane DIP$^+$ Polymeric Derivative 4h**

Yield: 850 mg (91%); yellow powder; mp 360 °C.

IR (KBr): 3421 (s), 1610 (s), 1570 (s), 1533 (s), 1452 (m), 1386 (w), 1304 (s), 1263 (s), 1155 (m), 1122 (m), 783 (m), 754 (s), 717 (m), 669 cm^{-1} (m).

^{1}H NMR (DMSO-d_6, 400 MHz): δ = 9.11 (d, *J* = 8.4 Hz, 3 H), 8.91 (d, *J* = 8.4 Hz, 3 H), 8.73 (d, *J* = 8.0 Hz, 3 H), 8.18 (t, *J* = 5.1 Hz, 3 H), 8.04 (t, *J* = 5.1 Hz, 3 H), 7.86 (t, *J* = 5.1 Hz, 3 H), 7.70 (d, *J* = 8.0 Hz, 3 H), 7.64 (t, *J* = 5.1 Hz, 3 H), 5.93 (m, 3 H), 4.79 (t, *J* = 6.9 Hz, 6 H), 4.53 (t, *J* = 6.9 Hz, 6 H), 2.82 (q, *J* = 11.6 Hz, 3 H), 2.6 (d, *J* = 11.6 Hz, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ = 156.31 (CH), 135.53 (CH), 135.25 (C), 133.11 (CH), 131.82 (CH), 130.40 (CH), 129.17 (CH), 125.80 (C), 124.68 (CH), 124.23 (C), 120.41 (CH), 116.32 (C), 115.85 (CH), 52.66 (CH_2), 46.25 (CH_2), 45.54 (CH), 32.43 (CH_2).

MS (FAB): *m*/*z* (%) = 247.14 [(M – 3·Br)/3, 5), 232.1 (11), 219.11 (10), 214.08 (2), 157.1 (45), 79.7 (100).

Anal. Calcd for $C_{51}H_{45}Br_3N_6$: C, 62.40; H, 4.62; N, 8.56. Found: C, 62.30; H, 4.71; N, 8.64.

Procedure 2: IP$^+$ Derivatives 10a–e

To a stirred solution of ammonia (50 mL) at –78 °C on a dry ice/acetone bath was added 2-bromoethylphenanthridinium bromide (**1**; 700 mg; 1.9 mmol). The cooling bath was removed to allow the mixture to warm up to –30 °C, the boiling point of ammonia, and the reaction left stirring at that temperature for 1 h to yield the intermediate **6**. The reaction medium was returned to –78 °C before adding under stirring Na_2CO_3 (1 g, 9.4 mmol) followed by MnO_2 (1.65 g, 19 mmol), and the cooling bath was removed to allow the evaporation of ammonia (1–2 h), yielding intermediate **8** along with inorganic side products. The dry residue was suspended in toluene (20 mL) and refluxed for 3 h. The mixture was then filtered on glass frit No. 4 and the residue rinsed extensively with acetone. Finally, the mother liquor was concentrated to dryness to afford **9** (410 mg, quant.) as a light yellow powder; mp 77–78 °C; R_f = 0.3 (EtOAc).

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IR (KBr): 3432 (s), 1629 (m), 1532 (m), 1495 (w), 1463 (m), 1439 (m), 1316 (m), 1262 (s), 1104 (s), 803 (m), 719 cm^{-1} (s).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 8.79 (m, 1 H), 8.51 (dd, *J* = 8.0, 1.0 Hz, 1 H), 8.42 (m, 1 H), 8.05 (d, *J* = 1.2 Hz, 1 H), 7.93 (dd, *J* = 8.0, 1.0 Hz, 1 H), 7.7 (m, 3 H), 7.68 (d, *J* = 1.2 Hz, 1 H), 7.58 (td, *J* = 8.0, 1.0 Hz, 1 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ = 142.08 (C), 131.49 (C), 130.45 (C), 129.19 (CH), 129.06 (CH), 128.86 (CH), 127.68 (C), 125.53 (CH), 124.59 (CH), 124.29 (CH), 122.42 (CH), 121.91 (C), 115.94 (CH), 112.15 (CH).

MS (FAB): *m*/*z* (%) = 219.4 (M + 1, 100), 178.7 (3), 164.9 (2), 98.8 (5), 71.2 (7), 57.4 (10).

Anal. Calcd for $C_{15}H_{10}N_2$: C, 82.55; H, 4.62; N, 12.84. Found: C, 82.40; H, 4.65; N, 12.90.

Freshly made imidazophenanthridine **9** (410 mg, 1.9 mmol) was dissolved in toluene (20 mL) and the electrophilic agent RX (2–20 equiv)[14] was added. The reaction was stirred overnight under reflux.[15] The final product precipitates from the solution and is recovered by filtration. The residue was washed extensively with diethyl ether and dried to yield the corresponding imidazophenanthridinium framework **IP$^+$ 10a**–**g**.

1*H*-Imidazo[1,2-*f*]phenanthridinium Bromide (10a)
Yield: 483 mg (85%); white powder; mp 337–339 °C (dec.).

IR (KBr): 3030 (s), 2842 (s), 2669 (s), 1660 (w), 1628 (s), 1559 (s), 1533 (m), 1469 (m), 1446 (m), 1395 (m), 915 (w), 757 (s), 716 (s), 691 (m), 611 cm^{-1} (w).

^1H NMR (D_2O, 400 MHz): δ = 7.57 (d, *J* = 2.0 Hz, 1 H), 7.33 (d, *J* = 2.0 Hz, 1 H), 7.14 (m, 3 H), 7.07 (t, *J* = 7.4 Hz, 2 H), 6.97 (d, *J* = 7.4 Hz, 2 H), 6.92 (t, *J* = 7.4 Hz, 1 H).

^{13}C NMR (D_2O, 100 MHz): δ = 135.63 (C), 132.39 (CH), 130.34 (CH), 129.24 (CH), 127.87 (CH), 127.09 (C), 126.57 (C), 122.85 (CH), 122.41 (CH), 121.94 (CH), 120.66 (CH), 19.36 (C), 115.49 (CH), 114.12 (CH), 113.21 (C).

MS (FAB): *m*/*z* (%) = 219.4 (M – Br, 85), 188.6 (100), 187.6 (90), 95.8 (80), 78.0 (20), 59.3 (10), 48.4 (8).

Anal. Calcd for $C_{15}H_{11}BrN_2 \cdot 2H_2O$: C, 53.75; H, 3.51; N, 8.36. Found: C, 53.60; H, 3.48; N, 8.36.

1-Methyl-1*H*-imidazo[1,2-*f*]phenanthridinium Tosylate (10b)
Yield: 760 mg (99%); white powder; mp 115–116 °C.

IR (KBr): 3441 (m), 3113 (m), 3087 (m), 1706 (w), 1615 (w), 1561 (m), 1532 (m), 1472 (w), 1357 (w), 1215 (s), 1198 (s), 1119 (s), 1033 (s), 1010 (s), 817 (w), 755 (s), 680 (s), 567 cm^{-1} (s).

^1H NMR (D_2O, 400 MHz): δ = 7.91 (d, *J* = 2.4 Hz, 1 H), 7.77 (d, *J* = 8.0 Hz, 1 H), 7.67 (d, *J* = 2.4 Hz, 1 H), 7.64 (d, *J* = 8.0 Hz, 1 H), 7.55 (d, *J* = 8.0 Hz, 2 H), 7.45 (m, 3 H), 7.41 (t, *J* = 8.0 Hz, 1 H), 7.32 (t, *J* = 8.0 Hz, 1 H), 7.29 (t, *J* = 8.0 Hz, 1 H), 7.23 (t, *J* = 8.0 Hz, 1 H), 7.11 (d, *J* = 8.0 Hz, 2 H), 3.90 (s, 3 H), 2.16 (s, 3 H).

^{13}C NMR (D_2O, 100 MHz): δ = 142.17 (C), 139.41 (C), 134.57 (C), 132.17 (CH), 130.59 (CH), 129.35 (CH), 123.81 (CH), 123.01 (CH), 122.57 (CH), 119.70 (C), 115.51 (CH), 114.63 (C), 113.06 (CH), 39.11 (CH_3), 20.33 (CH_3).

MS (FAB): *m*/*z* (%) = 233.3 (M – Br, 100), 178.7 (3), 94.8 (1), 77.1 (1).

Anal. Calcd for $C_{24}H_{24}N_2O_3S$: C, 65.55; H, 4.75; N, 6.66. Found: C, 65.58; H, 4.53; N, 6.63.

1-(4-Methoxybenzyl)-1*H*-imidazo[1,2-*f*] phenanthridinium Bromide (10d)
Yield: 780 mg (98%); white powder; mp 169–170 °C.

IR (KBr): 3432 (m), 3032 (s), 1613 (s), 1556 (s), 1532 (s), 1516 (s), 1465 (s), 1249 (s), 1179 (s), 1029 (s), 803 (m), 758 cm^{-1} (s).

^1H NMR (DMSO-d_6, 400 MHz): δ = 9.33 (d, *J* = 2.4 Hz, 1 H), 9.00 (d, *J* = 8.4 Hz, 1 H), 8.97 (d, *J* = 8.0 Hz, 1 H), 8.71 (d, *J* = 8.0 Hz, 1 H), 8.53 (d, *J* = 8.0 Hz, 1 H), 8.40 (d, *J* = 2.4 Hz, 1 H), 8.01 (m, 2 H), 7.89 (t, *J* = 7.4 Hz, 1 H), 7.84 (t, *J* = 7.4 Hz, 1 H), 7.32 (d, *J* = 8.0 Hz, 2 H), 7.16 (m, 1 H), 7.12 (m, 1 H), 6.97 (d, *J* = 8.8 Hz, 2 H), 6.14 (s, 2 H), 3.74 (s, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ = 159.17 (C), 136.38 (C), 132.37 (CH), 130.88 (CH), 130.01 (C), 129.55 (C), 129.49 (CH), 128.40 (CH), 128.30 (CH), 126.91 (CH), 125.53 (C), 125.31 (CH), 124.80 (CH), 124.19 (CH), 121.69 (C), 117.40 (CH), 116.48 (C), 115.06 (CH), 114.46 (CH), 55.14 (CH_3), 53.48 (CH_2).

MS (FAB): *m*/*z* (%) = 339.3 (M – Br, 100), 231.3 (4), 219.4 (10), 155.0 (18), 122.4 (50), 90.9 (8), 79.0 (8).

Anal. Calcd for $C_{23}H_{19}BrN_2O$: C, 65.88; H, 4.57; N, 6.68; 3.82. Found: C, 65.96; H, 4.50; N, 6.53.

Acknowledgment

We thank the EPSRC, Scottish Enterprise, and the University of Glasgow for their financial support.

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(14) The quantity of electrophilic reactant added in excess depends on its physical properties: 20 equivalents were used with low boiling point inexpensive material, whereas only 2 equivalents were necessary with solid starting material.
(15) With the exception of the electrophile HBr, where r.t. conditions and only 1 min stirring were used on 1 mL of a 48% HBr aqueous solution.