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Dedicated to Prof. Dr. Roberto A. Rossi on the occasion of his 60th anniversary
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Abstract
New 2-chloromethyl-6-halogeno-imidazo[1,2-\(a\)]pyridines and 2-chloromethyl-6-halogeno-3-nitroimidazo[1,2-\(a\)]pyridines were prepared and reacted under experimental conditions of \(S_{RN1}\) reactions with different sulfur and carbon centered nucleophiles to give new 6-halogeno-2-substituted-imidazo[1,2-\(a\)]pyridines and 6-halogeno-3-nitro-2-substituted-imidazo[1,2-\(a\)]pyridines in good yields. Only the chloromethyl group was found to be reactive under these experimental conditions.

Keywords: Imidazo[1,2-\(a\)]pyridine, reductive alkylating agent, nitroheterocycles, \(S_{RN1}\)

Introduction

Substitution reactions at an sp\(^3\) carbon atom of the reductive alkylating agents, \(p\)-nitrobenzyl chloride or 2-halogeno-2-nitropropane, which proceed via a chain multi-stage sequence involving radical anions and free radicals as intermediates were first proposed independently by Kornblum\(^1\) and Russell\(^2\) in 1966. This pathway has been applied in 1970 to rationalize the substitution of unactivated aromatic halides and named \(S_{RN1}\) by Bunnett.\(^3\) The process has a considerably wide scope and synthetic capabilities. Recently, all the aspects of nucleophilic substitution reactions by electron transfer have been magnificently reviewed by Rossi, Pierini and Peñenory.\(^4\) Among the heterocyclic analogues of \(o\)-nitrobenzyl derivatives which react by \(S_{RN1}\) reactions, our group has reported the \(S_{RN1}\) reactions of nitronate anions with a series of imidazoles fused to a heterocyclic ring bearing the chloromethyl group ortho to the nitro group.
This system constitutes a powerful synthetic tool to obtain nitro heterocycles with potential pharmaceutical properties.\textsuperscript{5}

Imidazo[1,2-\textit{a}]pyridine derivatives are important compounds which are known for their useful pharmacological activities.\textsuperscript{6} For example, gastric antisecretory,\textsuperscript{7} local anesthetic,\textsuperscript{8} antiviral,\textsuperscript{9} hypnotic\textsuperscript{10} and antianxiety\textsuperscript{11} properties have been described. The nature and the position of the substituent on the pyridinic moiety influence these activities.\textsuperscript{9} Zolpidem (Stilnox®, Ambien®, Myslee®) sold by Sanofi-Synthélabo, is a non-benzodiazepine hypnotic of the imidazopyridine class, leader of the international market with a blockbuster status for the treatment of sleep disorders.

As part of our current interest on the synthesis by $S_{RN1}$ reactions of new imidazo[1,2-\textit{a}]pyridines, which can be used in different coupling reactions for the preparation of more complex structures of pharmacological interest, we have prepared new 2-chloromethyl-6-halogeno-imidazo[1,2-\textit{a}]pyridines 3\textit{a-b} and 2-chloromethyl-6-halogeno-3-nitroimidazo[1,2-\textit{a}]pyridines 4\textit{a-b} (Figure 1) and studied their reactivity with different nucleophiles under $S_{RN1}$ experimental conditions.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{2-Chloromethyl-6-halogeno-imidazo[1,2-\textit{a}]pyridines and 2-chloromethyl-6-halogeno-3-nitro-imidazo[1,2-\textit{a}]pyridines.}
\end{figure}

**Results and Discussion**

Herein we describe the synthesis of 3\textit{a} and 3\textit{b} (Scheme 1) starting respectively from the commercially available 2-amino-5-chloropyridine (1\textit{a}) or 2-amino-5-bromopyridine (1\textit{b}) by condensation with 1,3-dichloroacetone (2) and nitration to give 4\textit{a} and 4\textit{b} (Scheme 2) and their conversion to new 6-halogeno-2-substituted-imidazo[1,2-\textit{a}]pyridines 3\textit{c-d} by reaction with sodium benzenesulfinate (Scheme 1) and 6-halogeno-3-nitro-2-substituted-imidazo[1,2-\textit{a}]pyridines by $S_{RN1}$ reactions with lithium salt of 2-nitropropane 5\textit{a-b} (Scheme 2), sodium phenylthiolate 6\textit{a-b}, sodium benzenesulfinate 7\textit{a-b} and sodium salt of diethylmalonate 8\textit{a-b} (Scheme 3).

Although $S_{RN1}$ displacements of aromatic substrates by sulfur nucleophiles can be achieved in DMSO with different types of initiation,\textsuperscript{3} the PhSO$_2^-$ anion has not been reported to react. With photostimulation in DMSO in presence of 2 equivalents of the sodium salt of benzenesulfinic acid, 3\textit{a} and 3\textit{b} react probably following an $S_{N2}$ mechanism only at the
chloromethyl group with good yield, respectively 69 and 80%, to give the corresponding sulfones 3c and 3d. No substitution of chloride or bromide in position 6 has been observed under these experimental conditions. The sulfones 3c and 3d were also obtained with similar yields without photostimulation.

Scheme 1. Reagents and conditions: (i) ClCH₂COCH₂Cl (2), EtOH, reflux, 6 h; (ii) C₆H₅SO₂Na, DMSO, N₂, hν, 3 h.

The SRN1 displacements on the pyridine moiety of the imidazo[1,2-a]pyridine being more difficult than an SN2 on the chloromethyl group, we have prepared, new reductive alkylating agents, the nitro derivatives 4a and 4b and studied their conversion with different nucleophiles to the corresponding derivatives by SRN1 reactions at the sp³ carbon atom of the chloromethyl group.

Scheme 2. Reagents and conditions: (iii) H₂SO₄, HNO₃ 60%, 0 °C to RT 3 h. (iv) LiC(NO₂(CH₃))₂, DMSO, N₂, hν, 0.3 h.

The C-alkylation of 2-nitropropane anion, which is a classical example of an SRN1 reaction at sp³ carbon atom of an o- or p-nitrobenzyl chloride, gives with 4a and 4b (Scheme 2) the ethylenic derivatives 5a and 5b in 70% yields. 5a and 5b result of the consecutive C-alkylation of the 2-nitropropane anion and nitrous acid elimination from the C-alkylation product (Scheme 2). These reactions are strongly inhibited in presence of TEMPO, a classical free scavenger used in the mechanism studies of SRN1 reactions.12

With the phenylthiolate anion, 4a and 4b react to give the corresponding sulfides 6a and 6b in 80% yields. (Scheme 3). These reactions also are inhibited in presence of TEMPO.
With the phenylsulfinate anion, 4a and 4b react to give the corresponding sulfones 7a and 7b in 80% yields. These sulfones could be used for further \( S_{RN1} \) reactions with different electrophiles as recently shown in nitroimidazole series.\(^{13}\)

Finally, 4a and 4b react with diethyl malonate anion to give the corresponding diethyl malonates in 85% yields. Further functional group transformations could give lactams of pharmaceutical interest.\(^{14}\)

\[
\begin{align*}
\text{Scheme 3. Reagents and conditions: (v)} & \quad \text{NaH 60\%, HSC}_6\text{H}_5\text{, DMSO, 1 h and N}_2\text{, h}_2\text{, 0.5 h. (vi) C}_6\text{H}_5\text{SO}_2\text{Na, DMSO, N}_2\text{, 3 h, h}_2\text{. (vii) CH}_2(\text{CO}_2\text{CH}_2\text{CH}_3)_2\text{, DMSO, NaH 60\%, 0.5 h and N}_2\text{, h}_2\text{, 2 h.}}
\end{align*}
\]

In conclusion, the 2-chloromethyl-6-halogeno-imidazo[1,2-\( \alpha \)]pyridines 3a-b and 2-chloromethyl-6-halogeno-3-nitroimidazo[1,2-\( \alpha \)]pyridines 4a-b react with different sulfur or carbon centered anions only by substitution of the chloromethyl group. The reactions with 2-chloromethyl-6-halogeno-3-nitroimidazo[1,2-\( \alpha \)]pyridines 4a-b are very probably \( S_{RN1} \) reactions. These new 6-halogeno-imidazo[1,2-\( \alpha \)]pyridines could be used in different coupling reactions for the preparation of more complex structures of pharmacological interest. Work is in progress to prepare new derivatives by the Suzuki reaction and \( S_{RN1} \) reaction on the pyridine moiety.
Experimental Section

General Procedures. Melting points were determined with a B-540 Büchi melting point apparatus. 300 MHz $^1$H NMR and 75.4 MHz $^{13}$C NMR spectra were recorded on a Bruker Avance DPX 300 in CDCl$_3$ or DMSO-d$_6$ solution at the Centre Régional de RMN de la Faculté des Sciences et Techniques de Saint-Jérôme. $^1$H and $^{13}$C NMR chemical shifts ($\delta$) are reported in ppm with respect to CHCl$_3$ 7.26 ppm ($^1$H) and 77.16 ppm ($^{13}$C) or DMSO 2.62 ppm ($^1$H) and 40.6 ppm ($^{13}$C). The multiplicity of the signals is: s, singulet; d, doublet; t, triplet; q, quadruplet; m, multiplet. Elemental analyses were carried out at the Centre de Microanalyses de la Faculté des Sciences et Techniques de Saint-Jérôme.

6-Chloro-2-chloromethylimidazo[1,2-a]pyridine (3a). To a solution of 1,3-dichloroacetone (2) (2.17 g, 0.0171 mol, 1.1 eq) in absolute ethanol (24 mL) was added 2 g (0.0155 mol, 1 eq) of 2-amino-5-chloropyridine (1a). The mixture was stirred and heated under reflux for 6 h. The solvent was evaporated in vacuo and the residue was taken up in H$_2$O (50 mL) and basified with saturated aqueous solution of Na$_2$CO$_3$. The solution was extracted with CHCl$_3$ (3 x 80 mL). The combined organic phases were dried (MgSO$_4$), filtered and concentrated in vacuo. Flash column chromatography of the crude solid on silica gel (solvent Et$_2$O) yielded 3a (62%) as a light brown solid. The analytical sample of 3a was obtained as a light brown solid by crystallization (isopropanol), m.p. 127.4 °C. $^1$H NMR (CDCl$_3$) $\delta$ 4.74 (s, 2H, CH$_2$); 7.15 (dd, $J = 2.0$ Hz, $J = 9.6$ Hz, 1H, H$_7$); 7.50 (d, $J = 9.6$ Hz, 1H, H$_8$); 7.58 (s, 1H, H$_3$); 8.12 (dd, $J = 0.9$ Hz, $J = 2.0$ Hz, 1H, H$_5$). $^{13}$C NMR (CDCl$_3$) $\delta$ 39.3 (CH$_2$); 111.2 (CH); 118.1 (CH); 120.9 (C); 123.5 (CH); 126.6 (CH); 143.7 (C); 144.2 (C). Anal. Calcd. for C$_8$H$_6$Cl$_2$N$_2$: C, 47.79; H, 3.01; N, 13.93. Found: C, 47.69; H, 3.01; N, 14.05.

6-Bromo-2-chloromethylimidazo[1,2-a]pyridine (3b). Caution: this compound is a skin irritant. Following the procedure used for 3a. Flash column chromatography of the crude solid on silica gel (solvent CHCl$_3$/AcOEt 9:1) afforded 3b (58%) as a white solid from 1b and 2. The analytical sample of 3b was obtained as a white solid by crystallization (isopropanol), m.p. 127.7 °C. $^1$H NMR (CDCl$_3$) $\delta$ 4.73 (s, 2H, CH$_2$); 7.22 (dd, $J = 2.0$ Hz, $J = 9.5$ Hz, 1H, H$_7$); 7.45 (dd, $J = 9.5$ Hz, 1H, H$_8$); 7.57 (s, 1H, H$_3$); 8.22 (dd, $J = 1.0$ Hz, 1H, H$_5$). $^{13}$C NMR (CDCl$_3$) $\delta$ 39.3 (CH$_2$); 107.4 (C); 111.0 (CH); 118.3 (CH); 125.8 (CH); 128.7 (CH); 143.9 (C). The quaternary carbon atom bearing bromo group was not observed under these experimental conditions. Anal. Calcd. for C$_8$H$_6$BrClN$_2$: C, 39.14; H, 2.46; N, 11.41. Found: C, 39.13; H, 2.42; N, 11.36.

2-Benzensulfonylmethyl-6-chloroimidazo[1,2-a]pyridine (3c).$^{15}$ To a solution of sodium benzensulfinate (1.64 g, 10 mmol, 2 eq) in DMSO (40 mL) under an inert atmosphere (N$_2$) and irradiation with a tungsten 150W lamp was added 1 g (5.0 mmol, 1 eq) of 6-chloro-2-chloromethylimidazo[1,2-a]pyridine (3a). The mixture was stirred at room temperature for 3 h. After disappearance of 3a (monitored by TLC), the mixture was poured into an ice-water mixture and a solid precipitated. The white solid was collected by filtration and dried in the air to
give 3c in 69% yield. The analytical sample of 3c was obtained as a white solid by crystallization (isopropanol), m.p. 178.7 °C. 1H NMR (CDCl₃) δ 4.57 (s, 2H, CH₂); 7.11 (dd, J = 2.0 Hz, J = 9.6 Hz, 1H, H₂); 7.30-7.80 (m, 7H); 8.12 (dd, J = 0.5 Hz, J = 2.0 Hz, 1H, H₃). ¹³C NMR (CDCl₃) δ 56.3 (CH₂); 113.4 (CH); 117.9 (CH); 121.1 (C); 123.4 (CH); 126.4 (CH); 128.3 (CH*2); 129.1 (CH*2); 133.8 (CH); 135.0 (C); 138.6 (C); 143.3 (C). Anal. Calcd. for C₁₄H₁₁ClN₂O₂S: C, 54.81; H, 3.61; N, 9.13. Found: C, 54.85; H, 3.64; N, 9.21.

2-Benzensulfonylmethyl-6-bromoimidazo[1,2-a]pyridine (3d). Following the procedure used for 3c, the bromo derivative 3d was obtained as a white-grey solid in 80% yield from sodium benzenesulfinate and 3b. The analytical sample of 3d was obtained as a white-grey solid by crystallization (isopropanol), m.p. 216.4 °C. 1H NMR (DMSO-d₆) δ 4.83 (s, 2H, CH₂); 7.31-7.83 (m, 8H); 8.91 (s, 1H). ¹³C NMR (DMSO-d₆) δ 55.7 (CH₂); 114.1 (CH); 117.9 (CH); 127.1 (CH); 128.0 (CH); 128.1 (CH*2); 129.3 (CH*2); 134.0 (C); 135.0 (C); 139.0 (CH); 142.7 (C). Anal. Calcd. for C₁₄H₁₁BrN₂O₂S: C, 47.88; H, 3.16; N, 7.98. Found: C, 47.88; H, 3.24; N, 7.95.

6-Chloro-2-chloromethyl-3-nitroimidazo[1,2-a]pyridine (4a). To a solution of (3a) (1.40 g, 7 mmol, 1 eq) in concentrated sulfuric acid (14 mL, 25.8 g, 0.26 mol, 37 eq) cooled by an ice-water bath, nitric acid 65% (1.4 mL, 1.9 g, 0.02 mol, 2.9 eq) was added. The mixture was stirred and allowed to warm to room temperature and stirred at room temperature for 3 h. The mixture was poured into an ice-water mixture and a solid precipitated. The yellow solid was collected by filtration and dried in the air to give 4a in 70% yield. The analytical sample of 4a was obtained as a yellow solid by crystallization (isopropanol), m.p. 198.1 °C. ¹H RMN (CDCl₃) δ 5.10 (s, 2H, CH₂); 7.65 (dd, J = 2.0 Hz, J = 9.5 Hz, 1H, H₇); 7.80 (dd, J = 0.7 Hz, J = 9.5 Hz, 1H, H₈); 9.50 (dd, J = 0.7 Hz, J = 2.0 Hz, 1H, H₅). ¹³C NMR (CDCl₃) δ 38.6 (CH₂); 118.9 (CH); 125.7 (C); 125.9 (CH); 132.3 (CH); 143.0 (C); 147.9 (C). The quaternary carbon atom bearing nitro group was not observed under these experimental conditions. Anal. Calcd. for C₈H₅Cl₂N₃O₂: C, 39.05; H, 2.05; N, 17.08. Found: C, 39.18; H, 1.99; N, 17.12.

6-Bromo-2-chloromethyl-3-nitroimidazo[1,2-a]pyridine (4b). Following the procedure used for 4a, the bromo derivative 4b was obtained as a yellow solid in 100% yield from 3b. The analytical sample of 4b was obtained as a yellow solid by crystallization (isopropanol), m.p. 205.6 °C. ¹H NMR (DMSO-d₆) δ 5.12 (s, 2H, CH₂); 7.96 (dd, J = 0.8 Hz, J = 9.4 Hz, 1H, H₇); 8.03 (dd, J = 1.7 Hz, J = 9.4 Hz, 1H, H₈); 9.42 (dd, J = 0.8 Hz, J = 1.7 Hz, 1H, H₅). ¹³C NMR (CDCl₃) δ 38.6 (CH₂); 112.4 (C); 119.1 (CH); 127.7 (CH); 134.6 (CH); 143.1 (C); 147.7 (C). The quaternary carbon atom bearing nitro group was not observed under these experimental conditions. Anal. Calcd. for C₈H₅BrClN₃O₂: C, 33.08; H, 1.73; N, 14.66 Found: C, 33.14; H, 1.65; N, 14.54.

6-Chloro-2-(2-methylpropenyl)-3-nitroimidazo[1,2-a]pyridine (5a). To a solution of lithium salt of 2-nitropropane (0.465 g, 4.9 mmol, 3 eq) in DMSO (15 mL) under an inert atmosphere (N₂) and irradiation with a tungsten 150W lamp was added 0.4 g (1.63 mmol, 1 eq) of 6-chloro-2-chloromethyl-3-nitroimidazo[1,2-a]pyridine (4a). The mixture was stirred at room temperature for 20 minutes. After disappearance of 4a (monitored by TLC), the mixture was poured into an ice-water mixture and extracted with diethyl ether (3 x 80 mL). The combined organic phases
were dried (MgSO\(_4\)), filtered and concentrated \textit{in vacuo} to give \(5a\) as a orange solid. Purification by column chromatography (silica gel), eluting with a mixture of chloroform-diethyl ether (8/2) gave \(5a\) in 70% yield. The analytical sample of \(5a\) was obtained as a pale orange solid by crystallization (isopropanol), m.p. 133.8 °C. \(^1\)H NMR (CDCl\(_3\)) \(\delta\) 2.10 (d, \(J = 1.1\) Hz, 3H, CH\(_3\)); 2.33 (d, \(J = 1.1\) Hz, 3H, CH\(_3\)); 7.06 (septuplet, \(J = 1.1\) Hz, 1H, CH); 7.52 (dd, \(J = 1.8\) Hz, \(J = 9.4\) Hz, 1H, H\(_7\)); 7.68 (dd, \(J = 0.4\) Hz, \(J = 9.4\) Hz, 1H, H\(_8\)); 9.53 (dd, \(J = 0.4\) Hz, \(J = 1.8\) Hz, 1H, H\(_5\)). \(^{13}\)C NMR (CDCl\(_3\)) \(\delta\) 21.2 (CH\(_3\)); 28.3 (CH\(_3\)); 115.2 (CH); 117.9 (CH); 124.1 (C); 125.9 (CH); 131.8 (CH); 143.5 (C); 149.2 (C); 151.2 (C). Anal. Calcd. for C\(_{11}\)H\(_{10}\)ClN\(_3\)O\(_2\): C, 52.50; H, 4.01; N, 16.70. Found: C, 52.64; H, 4.00; N, 16.64.

\textbf{6-Benzoxo-2-(2-methylpropenyl)-3-nitroimidazo[1,2-\textit{a}]pyridine (5b).} Following the procedure used for \(5a\), the bromo derivative \(5b\) was obtained as a yellow solid in 70% yield from \(4b\). The analytical sample of \(5b\) was obtained as a yellow solid by crystallization (isopropanol), m.p. 132 °C. \(^1\)H NMR (CDCl\(_3\)) \(\delta\) 2.08 (d, \(J = 1.1\) Hz, 3H, CH\(_3\)); 2.32 (d, \(J = 1.1\) Hz, 3H, CH\(_3\)); 7.05 (septuplet, \(J = 1.1\) Hz, 1H, CH); 7.60 (dd, \(J = 0.9\) Hz, \(J = 9.4\) Hz, 1H, H\(_8\)); 7.66 (dd, \(J = 1.8\) Hz, \(J = 9.4\) Hz, 1H, H\(_7\)); 9.61 (dd, \(J = 0.9\) Hz, \(J = 1.8\) Hz, 1H, H\(_5\)). \(^{13}\)C NMR (CDCl\(_3\)) \(\delta\) 21.2 (CH\(_3\)); 28.3 (CH\(_3\)); 110.5 (C); 115.2 (CH); 118.1 (CH); 127.9 (CH); 134.0 (CH); 143.6 (C); 148.9 (C); 151.3 (C). Anal. Calcd. for C\(_{11}\)H\(_{10}\)BrN\(_3\)O\(_2\): C, 44.62; H, 3.40; N, 14.14. Found: C, 44.56; H, 3.46; N, 14.32.

\textbf{6-Chloro-3-nitro-2-phenylsulfanylmethylimidazo[1,2-\textit{a}]pyridine (6a).} Sodium hydride 60% (0.32 g, 13.6 mmol, 3.3 eq) and thiophenol (1.34 g, 12.2 mmol, 3 eq) under an inert atmosphere (N\(_2\)) were added to DMSO (50 mL). The mixture was stirred for 1 h and 1 g (4.08 mmol, 1 eq) of 6-chloro-2-chloromethyl-3-nitroimidazo[1,2-\textit{a}]pyridine (4a) was added. The mixture was stirred at room temperature for 30 minutes under irradiation with a tungsten 150W lamp. After disappearance of 4a (monitored by TLC), the mixture was poured into an ice-water mixture and a solid precipitated. The yellow solid was filtered and dried in the air to give \(6a\) in 80% yield. The analytical sample of \(6a\) was obtained as a yellow solid by crystallization (isopropanol), m.p. 172.9 °C. \(^1\)H NMR (CDCl\(_3\)) \(\delta\) 4.66 (s, 2H, CH\(_2\)); 7.19-7.52 (m, 5H); 7.60 (dd, \(J = 2.0\) Hz, \(J = 9.4\) Hz, 1H, H\(_7\)); 7.70 (dd, \(J = 0.8\) Hz, \(J = 9.4\) Hz, 1H, H\(_8\)); 9.49 (dd, \(J = 0.8\) Hz, \(J = 2.0\) Hz, 1H, H\(_5\)). \(^{13}\)C NMR (CDCl\(_3\)) \(\delta\) 33.2 (CH\(_2\)); 118.3 (CH); 125.1 (C); 125.7 (CH); 126.9 (CH); 128.9 (CH*2); 130.3 (CH*2); 132.0 (CH); 135.0 (C); 143.0 (C); 150.3 (C). Anal. Calcd. for C\(_{14}\)H\(_{10}\)ClN\(_3\)O\(_2\)S: C, 52.59; H, 3.15; N, 13.14. Found: C, 52.43; H, 3.14; N, 13.15.

\textbf{6-Bromo-3-nitro-2-phenylsulfanylmethylimidazo[1,2-\textit{a}]pyridine (6b).} Following the procedure used for \(6a\), the bromo derivative \(6b\) was obtained as a yellow solid in 80% yield from 4b. The analytical sample of \(6b\) was obtained as a yellow solid by crystallization (isopropanol), m.p. 173 °C. \(^1\)H NMR (CDCl\(_3\)) \(\delta\) 4.66 (s, 2H, CH\(_2\)); 7.19-7.70 (m, 7H); 9.58 (dd, \(J = 1.1\) Hz, \(J = 1.6\) Hz, 1H, H\(_5\)). \(^{13}\)C NMR (CDCl\(_3\)) \(\delta\) 33.3 (CH\(_2\)); 111.7 (C); 118.6 (CH); 126.9 (CH); 127.8 (CH); 128.9 (CH*2); 130.4 (CH*2); 134.2 (CH); 135.0 (C); 143.1 (C); 150.2 (C). The quaternary carbon atom bearing nitro group was not observed under these experimental conditions. Anal. Calcd. for C\(_{14}\)H\(_{10}\)BrN\(_3\)O\(_2\)S: C, 46.17; H, 2.77; N, 11.54. Found: C, 46.22; H, 2.61; N, 11.50.
2-Benzene sulfonylethyl-6-chloro-3-nitroimidazo[1,2-α]pyridine (7a). To a solution of 1.34 g (8.2 mmol, 2 eq) of sodium benzenesulfinate in DMSO (50 mL) under an inert atmosphere was added 1 g (4.1 mmol, 1 eq) of 6-chloro-2-chloromethyl-3-nitroimidazo[1,2-α]pyridine (4a). The mixture was stirred at room temperature for 3 h under irradiation with a tungsten 150W lamp. After disappearance of 4a (monitored by TLC), the mixture was poured into an ice-water mixture and a solid precipitated. The yellow solid was filtered and dried in the air to give 7a in 80% yield. The analytical sample of 7a was obtained as a pale beige solid by crystallization (isopropanol), m.p. 219.2 °C. 1H NMR (CDCl₃), δ 5.12 (s, 2H, CH₂); 7.50-7.90 (m, 7H); 9.43 (dd, J = 0.8 Hz, J = 1.9 Hz, 1H, H₅). 13C NMR (CDCl₃) δ 56.7 (CH₂); 118.9 (CH); 125.6 (CH); 125.9 (C); 128.3 (CH*2); 129.3 (CH*2); 132.3 (CH); 134.2 (CH); 139.1 (C); 139.7 (C); 143.2 (C). The quaternary carbon atom bearing nitro group was not observed under these experimental conditions. Anal. Calcd. for C₁₄H₁₀ClN₃O₄S: C, 47.80; H, 2.87; N, 11.95. Found: C, 47.75; H, 2.84; N, 12.01.

2-Benzene sulfonylethyl-6-bromo-3-nitroimidazo[1,2-α]pyridine (7b). Following the procedure used for 7a, the bromo derivative 7b was obtained as a yellow solid in 80% yield from 4b. The analytical sample of 7b was obtained as a yellow solid by crystallization (isopropanol), m.p. 237.7 °C. 1H NMR (CDCl₃), δ 5.14 (s, 2H, CH₂); 7.28-7.90 (m, 7H); 9.54 (s, 1H, H₅). 13C NMR (CDCl₃) δ 56.6 (CH₂); 112.5 (C); 119.1 (CH); 127.6 (CH); 128.3 (CH*2); 129.3 (CH*2); 134.3 (CH); 134.6 (CH); 139.0 (C); 139.5 (C); 143.3 (C). The quaternary carbon atom bearing nitro group was not observed under these experimental conditions. Anal. Calcd. for C₁₄H₁₀BrN₃O₄S: C, 42.44; H, 2.54; N, 10.61. Found: C, 42.58; H, 2.46; N, 10.55.

Diethyl 2-(6-chloro-3-nitroimidazo[1,2-α]pyridin-2-ylmethyl)malonate (8a). Sodium hydride (60%, 0.54 g, 13.5 mmol, 3.3 eq) and diethyl malonate (1.3 g, 12.2 mmol, 3 eq) under an inert atmosphere (N₂) were added to DMSO (20 mL). The mixture was stirred 0.5 h and 1 g (4.08 mmol, 1 eq) of 6-chloro-2-chloromethyl-3-nitroimidazo[1,2-α]pyridine (4a) was added. The mixture was stirred at room temperature for 2 h under irradiation with a tungsten 150W lamp. After disappearance of 4a (monitored by TLC), the mixture was poured into an ice-water mixture and a solid precipitated. The pale beige solid was collected by filtration and dried in the air to give 8a in 85% yield. The analytical sample of 8a was obtained as a pale beige solid by crystallization (isopropanol), m.p. 143 °C. 1H NMR (CDCl₃), δ 1.27 (t, J = 7.2 Hz, 6H, 2*CH₃); 3.83 (d, J = 7.2 Hz, 2H, CH₂); 3.57 (m, 5H, 2* CH₂, CH); 7.57 (dd, J = 2.0 Hz, J = 9.5 Hz, 1H, H₇); 7.66 (dd, J = 0.8 Hz, J = 9.5 Hz, 1H, H₅); 9.50 (dd, J = 0.8 Hz, J = 2.0 Hz, 1H, H₅). 13C NMR (CDCl₃) δ 14.0 (2*CH₃); 29.4 (CH₂); 49.3 (CH); 61.7 (2* CH₂); 118.2 (CH); 124.9 (C); 125.7 (CH); 131.8 (CH); 143.0 (C); 150.9 (C); 168.6 (C). Anal. Calcd. for C₁₅H₁₆ClN₃O₆: C, 48.72; H, 4.36; N, 11.36. Found: C, 48.76; H, 4.36; N, 11.36.

Diethyl 2-(6-bromo-3-nitroimidazo[1,2-α]pyridin-2-ylmethyl)malonate (8b). Following the procedure used for 8a, the bromo derivative 8b was obtained as a pink beige solid in 85% yield from 4b. The analytical sample of 8b was obtained as a pink beige solid by crystallization (isopropanol), m.p. 141 °C. 1H NMR (DMSO-d₆), δ 1.17 (t, J = 7.1 Hz, 6H, 2*CH₃); 3.66 (d, J = 7.4 Hz, 2H, CH₂); 4.15 (t, J = 7.4 Hz, 1H, CH); 4.15 (q, J = 7.1 Hz, 4H, 2*CH₂); 7.86 (dd, J =
9.4 Hz, 1H, H_8); 7.97 (dd, J = 1.8 Hz, J = 9.4 Hz, 1H, H_7); 9.42 (d, J = 1.0 Hz, 1H, H_3). ^13^C NMR (CDCl_3) \( \delta \) 14.0 (2*CH_3); 29.4 (CH_2); 49.4 (CH); 61.7 (2* CH_2); 111.4 (C); 118.4 (CH); 127.8 (CH); 134.0 (CH); 150.8 (C); 168.7 (C). Anal. Calcd. for C_{15}H_{16}BrN_3O_6: C, 43.50; H, 3.89; N, 10.14. Found: C, 43.39; H, 3.93; N, 10.26.

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References