C-Imidoylation of esters, sulfones, sulfoxides, amides and nitro compounds

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Abstract

C-Imidoylation of esters, sulfones, sulfoxides, amides, and nitro- compounds with *N*-imidoylbenzotriazoles **1a–g** gives β-enaminoesters **2a–d**, β-iminosulfones **6a–c**, β-enaminosulfoxides **7a–c**, β-iminoamides **9a–d**, and α-nitroenamines **10a–c** respectively in yields averaging 60%.

Keywords: Imidoylation, β-enaminoesters, β-iminosulfones, iminosulfoxides, β-iminoamides, α-nitroimines

Introduction

C-Acylations of activated CH groups are familiar reactions for many classes of compounds including alkanecarboxylic esters,[1a-b] alkyl sulfones[2a] and sulfoxides,[2b] and aliphatic nitro compounds.[3a-b] By contrast there are only limited reports of analogous C-imidoylation reactions although C-imidoylated products are useful for the preparation of natural products such as apo-β-erythroidine,[4a] and (+/–)-lupinine,[4b] terpenes,[4c] 2,2'-bis-imidazoles[4d] for receptors, supramolecular architectures, and seleno-imidates[4e] (Figure 1). Radical-mediated group-transfer imidoylation has been widely applied in synthetic and theoretical studies of organometallic compounds.[4g]

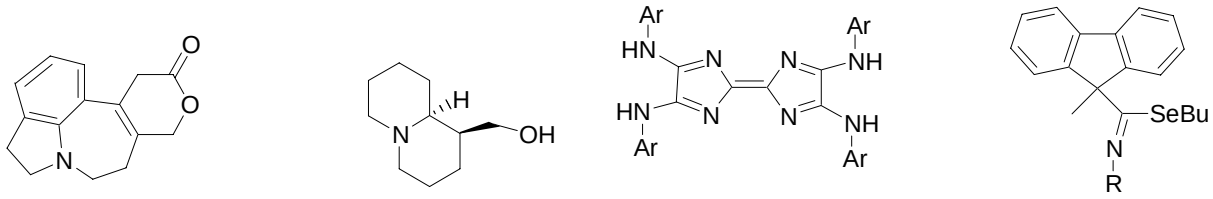
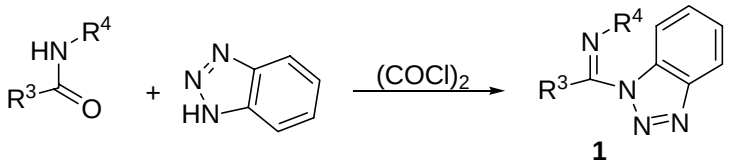


Figure 1. Apo-β-erythroidine, (+/–)-lupinine, 2,2'-biimidazoles, and selenoimidates.

We reasoned that *N*-imidoylbenzotriazoles could enable efficient C-imidoylation, by analogy with the many applications of *N*-acylbenzotriazoles[5a-b] in C-acylation.[2,5c-e] We now disclose simple procedures for the imidoylation at carbon of esters, sulfones, sulfoxides, amides, and nitro compounds via deprotonation in the presence of a strong base followed by treatment with imidoylbenzotriazoles **1a–g**.

The imidoylbenzotriazoles **1** are important stable alternatives to the corresponding imidoyl chlorides. Major synthetic strategies utilized for the preparation of the imidoylbenzotriazoles **1** include reaction of secondary amides with: (i) benzotriazole and $POCl_3$ in the presence of triethylamine;[6a] (ii) triphenylphosphine and 1-chlorobenzotriazole;[6b] or (iii) 1,1'-sulfinyldibenzotriazole.[6c] Imidoylbenzotriazoles **1a–g** were prepared in good yields (50–90%) from the reaction of a secondary amide (1 equiv.), oxalyl chloride (1 equiv.) and benzotriazole (2 equiv.) in the presence of pyridine[7a] (Scheme 1). The crude products were washed with aqueous sodium carbonate and were chromatographed on basic alumina (EtOAc/Hex.) to give pure imidoylbenzotriazoles **1a–g**.



1

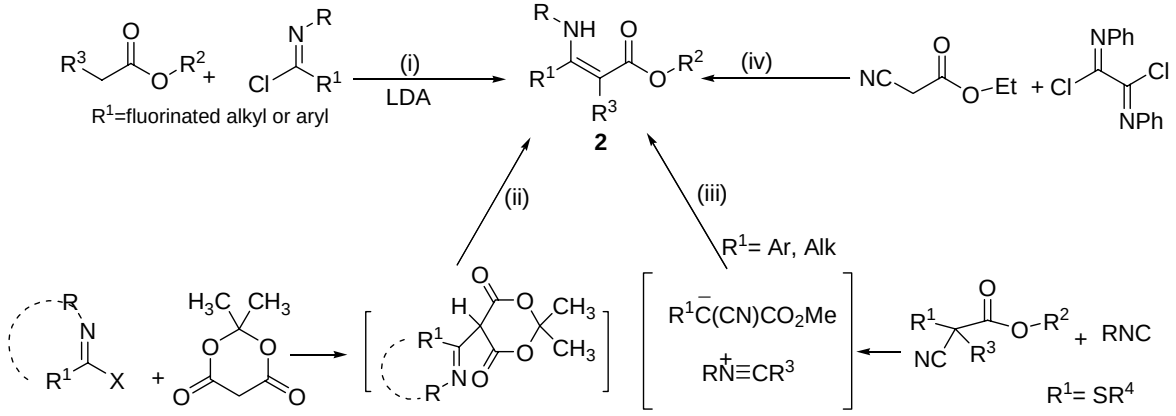
1a R^3= Me, R^4=*p*-Tol 67%, Mp 105-108 ^{0}C (Lit. 108 ^{0}C)[7b]
1b R^3= Me, R^4=*i*-Bu 50%, Mp 63-65 ^{0}C (Lit. 65 ^{0}C)[7a]
1c R^3= Bn, R^4=*p*-Tol 61%, Mp 122-124 ^{0}C (Lit. 123-125 ^{0}C)[7b]
1d R^3= Ph, R^4=*i*-Bu 60%, Mp 68-69 ^{0}C (Lit. 69 ^{0}C)[7b]
1e R^3= *p*-Tol , R^4=4-OMeC_6H_4 70%, Mp 69-71 ^{0}C (Lit. 71 ^{0}C)[7b]
1f R^3= Ph, R^4=Ph 90%, Mp 129-130 ^{0}C (Lit. 130-132 ^{0}C)[7a]
1g R^3= furyl, R^4=*p*-Tol 70%, Mp 118-120 ^{0}C (Lit. 120-123 ^{0}C)[7a]

Scheme 1

C-Imidoylation of esters

The β-Enaminoesters **2a–d** were prepared in 77–88% yield from the reaction of the corresponding ester enolate with imidoylbenzotriazoles **1** (Scheme 3, Table 1). Published C-imidoylations of esters **2** (Scheme 2) include; (i) efficient reactions with ester enolates, but these are limited to fluorinated imidoyl chlorides;[8a-c] (ii) reaction of malonic esters with alkyl carboximidates, alkyl carboximidothioates, or carboximidic chlorides,[9a] (iii) a single reaction of an isocyanide with a cyanoester sulfide;[9b] or, (iv), one example of the condensation of ethyl cyanoacetate with bis-(imidoyl)chloride.[9c] Alternative access to compounds **2** is given by amination of β-ketoesters (no yields are mentioned).[10]

Preparations of β-enaminoesters 2a–d from imidoylbenzotriazoles (1a,b). The imidoylbenzotriazoles **1a,b** were reacted with the enolates generated from the corresponding esters **3a–d** by treatment with potassium *tert*-butoxide at room temperature (Scheme 3). Treatment of 2 equiv. of the ester enolates **3a–d** with 2.5 equiv. of potassium *tert*-butoxide in THF at room temperature, followed by 1 equiv. of imidoylbenzotriazoles **1a,b**, afforded the β-enaminoesters **2a–d** in excellent yields (Table 1) with reduced times. If less potassium *tert*-butoxide was used the reaction was incomplete.



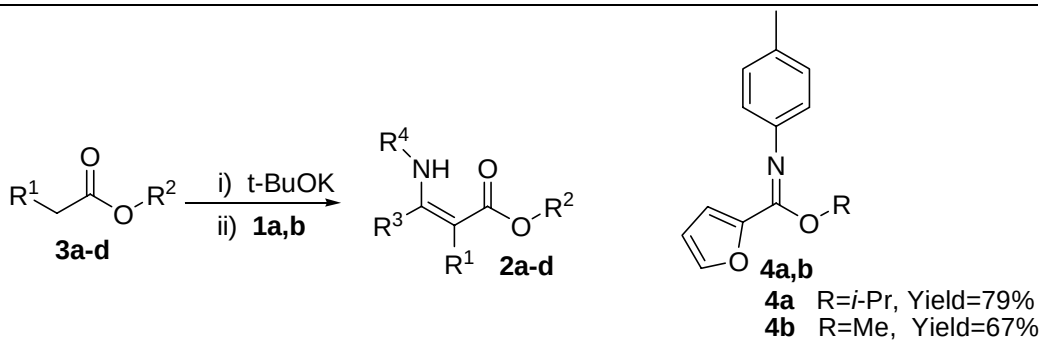
Scheme 2

Elemental analysis and NMR spectral data support the structural assignments of the novel products **2a–d**. The ^{1}H-NMR spectra of β-enaminoesters **2a–d** reveal a broad signal at 11.25–11.40 ppm which is assigned to the N-H proton. Thus, the structures of **2a–d** have a double bond between the ester and the imidoyl carbons (Scheme 3). Attempted C-imidoylation of esters **3c,d** using imidoylbenzotriazole **1g** gave only the imidoyl esters **4a,b** (73% average yield) (Scheme 3).

Table 1. Preparation of β-enaminoesters **2a–d**

3	R^1	R^2	R^3	R^4	Product	Yield%
3a	Ph	Me	Me	*p*-Tol	**2a**	88
3b	Naphthyl	Me	Me	*p*-Tol	**2b**	85

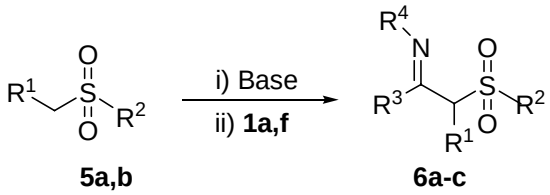
3c	H	*i*-Pr	Me	*p*-Tol	**2c**	82
3d	H	Me	Me	*i*-Bu	**2d**	77



Scheme 3

C-Imidoylation of sulfones

Previous successful imidoylations of sulfones by imidoyl chlorides are limited to fluorinated imidoyl chlorides and aryl methyl sulfones (R^1=H, R^3=Ar, Alk).[11a–b] Other reports of C-imidoylations of sulfones describe analytical and spectral data, but the products were not characterized fully.[11c–d] Other than forming a C–C bond between imidoyl chlorides and sulfones, compound **6** can be prepared by the reaction of linear β-ketoalkyl sulfones with simple amines.[11e] However, linear β-ketoalkyl sulfones are of limited stability, which dramatically affects the yields.[11e] We have now prepared the β-iminosulfones **6a–c** in 75–97 % yield by the reaction of imidoylbenzotriazoles **1a,f** with sulfones **5a,b** (Scheme 4, Table 2).



Scheme 4

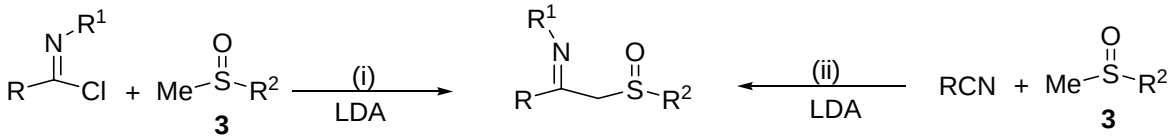
Preparations of β-iminosulfones 6a–c from imidoylbenzotriazoles (1a,f). Treatment of the sulfones **5a,b** (2 equiv.) with potassium *tert*-butoxide (2.5 equiv.) (**6a,c**) or *n*-BuLi (1.1 equiv.) (**6b**) in THF followed by an imidoylbenzotriazoles **1a,f** afforded the β-iminosulfones **6a–c** (Scheme 4). The progress of the reaction was monitored by TLC. Upon completion of the reaction, water was added and the organic layer was separated then chromatographed to give pure β-iminosulfones **6a–c** in 53–97% yields (Table 2). The novel β-iminosulfones **6a–c** were characterized by NMR and elemental analysis. In the ^{1}H-NMR spectra a signal in the region 4.30–5.16 is assigned to the proton attached to the carbon between the sulfone- and the imidoyl groups. In the case of **6c**, both the imine and the enamine tautomers formed in a 53:47 ratio.

Table 2. Preparation of β-iminosulfones **4a–c**

Reagent	R^1	R^2	R^3	R^4	Product	Yield%
1a	Ph	Ph	Me	*p*-Tol	**6a**	97
1g	Ph	Ph	Furyl	*p*-Tol	**6b**	53
1c	Ph	Ph	Bn	*p*-Tol	**6c**	65

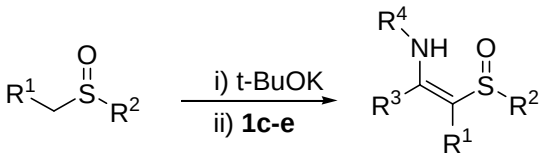
C-Imidoylation of sulfoxides

Reported imidoylations of the sulfoxides **3** include (i) reaction of fluorinated imidoyl chlorides with methylsulfinyl carbanion (but yields were greatly influenced by the nature of the methylsulfinyl carbanion),[12a–c] and (ii) reactions of unstable nitriles with methylsulfinyl carbanion (R^1=H) (Scheme 5).[13] We prepared the β-enaminosulfoxides **7a–c** in 48–78% yield from the reaction of imidoylbenzotriazoles **1e–g** with sulfoxides (Scheme 6, Table 3).



Scheme 5

Preparations of β-enaminosulfoxides 7a–c from imidoylbenzotriazoles (1e–g). Potassium *tert*-butoxide (2 equiv.) or *n*-BuLi (1.1 equiv.) (in the case of **7b**) was added to the sulfoxide (2 equiv.) in THF at room temperature followed by imidoylbenzotriazole (1 equiv.). Upon completion, the reaction mixture was hydrolyzed with water and extracted with chloroform. After workup, the residue was purified by flash column chromatography on silica to afford pure β-enaminosulfoxides **7a–c** (Scheme 6, Table 3)**.** Compound **7a**, isolated in good yield, existed only in a single tautomeric structure; the N-H proton could be observed at 7.2 ppm. However in the cases of both **7b** and **7c** the imine and the enamine tautomers (30:70 ratio) exist in equilibrium, with the N-H protons appearing at *ca* 7.6 ppm.



7a-c

Scheme 6

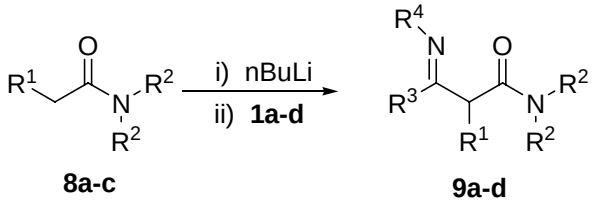
Table 3. Preparation of β-enaminosulfoxides **7a–c**

R^1	R^2	R^3	R^4	Product	Yield%
Ph	Ph	Ph	Ph	**7a**	78
H	Me	Furyl	*p*-Tol	**7b**	48
H	Me	*p*-Tol	4-$MeOC_6H_4$	**7c**	71

C-Imidoylation of amides

C-Imidoylation of amides is apparently unexplored: no report of the preparation of a β-iminoamide by C–C bond formation has been located. A single example of the preparation of an α-iminoamide by the reaction of an imidoyl chloride with a carbamoylsilane under palladium(0) catalysis was reported recently.[14] β-Iminoamides **9a–d** have now been prepared in 51–75% yield by the reaction of imidoylbenzotriazoles **1a,c,e,g** with amides **8a–c** (Scheme 7, Table 4).

Preparations of β-iminoamides 7a–d from imidoylbenzotriazoles (1a,c,e,g). Deprotonation of the amide was carried out using n-BuLi, after which imidoylbenzotriazole was added to the reaction mixture. The pure β-imino-amides **9a–d** (Scheme 7, Table 4) were obtained in 48–75 % yield. NMR data prove that we had obtained the imine tautomers of compounds **9a–d**. There was no evidence of the N-H proton, but a singlet assigned to the proton on the α- carbon was seen around 3.6 ppm. The two Et groups of **9a,c** showed different signals in the H-NMR, indicating restricted rotation around the Et_2N–CO bond. The structures of the novel compounds **9a–d** were supported by elemental analysis.



8a-c **9a-d**

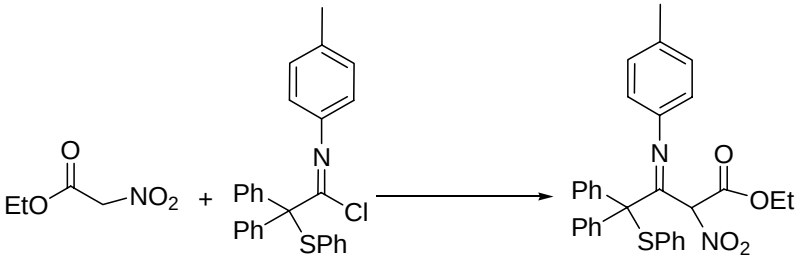
Scheme 7

Table 4. Preparation of β-iminoamides **9a–d**

R^1	R^2	R^3	R^4	Product	Yield %
Ph	Et	Me	*p*-Tol	**9a**	51
Ph	Et	Furyl	*p*-Tol	**9b**	48
Ph	Et	Bn	*p*-Tol	**9c**	75
Ph	Et	*p*-Tol	4-$MeOC_6H_4$	**9d**	69

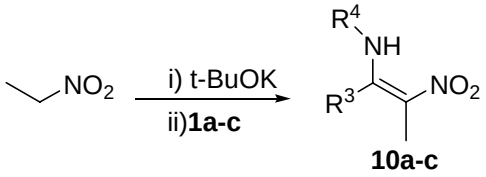
C-Imidoylation of nitro compounds

A single example of C-imidoylation of a nitro compound involved ethyl nitroacetate and an imidoyl chloride (Scheme 8).[15] So far, no general procedure for C-imidoylation of nitro compounds has been reported. It was suggested on infrared and NMR spectral evidence that the imidoylation product arose from the rearrangement of the *N*-nitroenamine shown (Scheme 8).[16] We have now prepared α-nitroenamines **10a–c** in 34–60% yield by the reaction of imidoylbenzotriazoles **1a,c,e** with nitroethane (Scheme 9, Table 5).



Scheme 8

Preparations of α-nitroenamines 10a–c from imidoylbenzotriazoles (1a,c,e). Potassium *tert*-butoxide was added to nitroethane at room temperature followed by imidoylbenzotriazoles **1a,c,e** in DMSO. Purification of the crude product gave pure α-nitroenamines **10a–c** (Scheme 9, Table 5). Compounds **10a–c** were isolated as the enamine tautomeric structure, as indicated by the N-H peak in the 7.2–7.7 region of the ^{1}H- NMR spectra. Elemental analysis was also used to further verify the identities of the novel **10a–c.**



Scheme 9

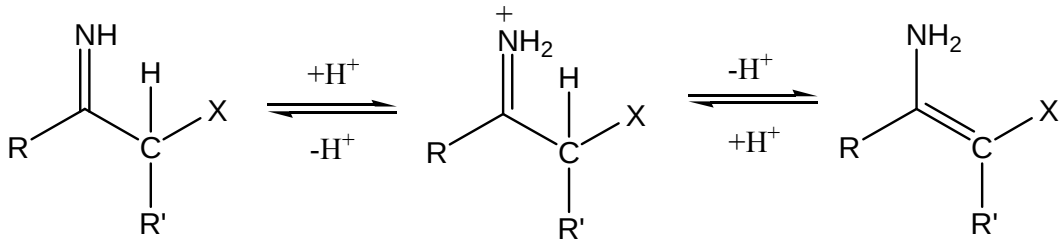
Table 5. Preparation of α-nitroenamines **10a–c**

R^3	R^4	Product	Yield%
Me	*p*-Tol	**10a**	60
p-Tol	4-OMeC$_6$H$_4$	**10b**	34
Bn	*p*-Tol	**10c**	50

Tautomeric structures of products

These imidoylation products are potentially tautomeric with alternative imine or enamine structures. Throughout this paper, compounds have been designated as the predominant form in solution; these forms are easily identified by NMR analysis. The enamine form predominates for the imidoylated products **2a–d** of esters**, 7a–c** of sulfoxides**,** and **10a–c** of nitro compounds**.** However, the imidoylated products **6a–c** of sulfones, and **9a–d** of amides exist in the imide form. We have located no previous discussion of the tautomerism of the products of imidoylation of esters, sulfones, sulfoxides, amides and nitro compounds in the literature. In the references cited in the present paper, some structures were represented in the imino-form[11a-b, 12a, 14] and others in the enamino-form[8a-c] evidence of the structure assignment was provided via NMR analysis.

In the present work, we utilized NMR to assign the precise tautomeric structure of each product. The position of tautomeric equilibrium is classified by consideration of the common cation **11** formed by the two forms **12** and **13**. Thus a strongly inductively electron-withdrawing substituent X in **11** is expected to increase the acidity of the α-proton; mesomeric electron withdrawal by contrast will increase the acidity of the NH_2 proton because of increased interaction in **13**. This helps to explain the preference of the enamine form for esters **2**, sulfoxides **7** and nitro compounds **10**, but of the imine form for sulfones **6** and amides **9**.



12 **11** **13**

Conclusions

A simple and straightforward method for the C-imidoylation of esters, sulfones, sulfoxides, amides, and nitro compounds was established using the imidoylbenzotriazoles **1a–i**. The imidoylated products **2a–d**, **6a–c**, **7a–c**, **9a–d**, and **10a–c** were easily isolated in 34–97%, average 80 %, yield.

Experimental Section

General Procedures. Melting points were determined on a hot-stage apparatus and are uncorrected. NMR spectra were recorded in $CDCl_3$, or DMSO-d_6 with TMS as the internal standard for ^{1}H- (300 MHz) or a solvent as the internal standard for ^{13}C- NMR (75 MHz).

Column chromatography was conducted on silica gel (200–425 mesh) or on basic alumina (60–325 mesh). Microwave heating was carried out with a single-mode cavity Discover Microwave Synthesizer (CEM Corporation, NC).

General procedure for the preparation of β-enaminoesters 2a–d

To a stirred solution of the corresponding ester (1.2 mmol) and potassium tert-butoxide (1.5 mmol) in THF (20 mL) was added (0.6 mmol) of **1.** The mixture was stirred at room temperature for 1–2 hours. Progress of the reaction was monitored by TLC. After the reaction was complete, water (20 mL) was added to the reaction mixture which was then extracted with dichloromethane (3x30 mL). The combined extracts were dried over anhydrous magnesium sulfate. The solvent was removed under reduced pressure and the remaining residue was purified by gradient column chromatography on silica gel (ethyl acetate/hexanes) to give pure β-enaminoesters **2a–d**.

Methyl 3-[(4-methylphenyl)imino]-2-phenylbutanoate (2a). Recrystallized from EtOAc–hexanes to give white microcrystals (88%), mp 94–95 °C; ^{1}H NMR δ 11.21 (br. s, 1H), 7.27–7.10 (m, 5H), 7.05 (d, *J* = 8.2 Hz, 2H), 6.93 (d, *J* = 8.2 Hz, 2H), 3.59 (s, 1H), 3.53 (s, 3H), 2.24 (s, 3H), 1.67 (s, 3H); ^{13}C NMR δ 170.4, 158.1, 138.3, 136.8, 134.8, 132.0, 129.6, 127.9, 126.2, 125.1, 50.8, 41.1, 20.8, 18.4. Anal. Calcd for $C_{18}H_{19}NO_2$: C, 76.84; H, 6.81; N, 4.98. Found: C, 76.62; H, 6.94; N, 4.81.

Methyl 2-(1-naphthyl)-3-(4-toluidino)-2-butenoate (2b). Recrystallized from EtOAc–hexanes to give white microcrystals (85%), mp 111–112 °C; ^{1}H NMR δ 11.25 (br. s, 1H), 7.85–7.82 (m, 1H), 7.78–7.75 (m, 1H), 7.72–7.69 (m, 1H), 7.41–7.35 (m, 3H), 7.28–7.25 (m, 1H), 7.05 (d, *J* = 8.2 Hz, 2H), 6.99 (d, *J* = 8.2 Hz, 2H), 3.42 (s, 3H), 2.24 (s, 3H), 1.53 (s, 3H) ; ^{13}C NMR δ 170.8, 158.8, 136.8, 135.8, 134.9, 133.8, 133.8, 129.6, 129.6, 128.3, 127.2, 125.8, 125.6, 125.5, 125.1, 95.9, 50.8, 50.8, 20.8, 18.0. Anal. Calcd for $C_{22}H_{21}NO_2$: C, 79.73; H, 6.39; N, 4.23. Found: C, 79.54; H, 6.50; N, 4.35.

Isopropyl 3-(4-toluidino)-2-butenoate (2c). Yellow oil (82%); ^{1}H NMR δ 11.32 (br. s, 1H), 7.08 (d, *J* = 8.1, 2H), 6.65 (d, *J* = 8.1 Hz, 2H), 5.18 (d, 1H), 2.30 (s, 3H), 1.78 (s, 3H), 1.30 (d, *J* = 6.2 Hz, 6H); ^{13}C NMR δ 160.4, 144.3, 131.8, 129.5, 120.9, 115.7, 67.4, 58.8, 37.9, 22.6, 20.8 . Anal. Calcd for $C_{14}H_{19}NO_2$: C, 72.07; H, 8.21; N, 6.00. Found: C, 72.57; H, 8.08; N, 9.04.

Methyl 3-isobutylamino-2-butenoate (2d).[17] Yellow oil (78%); ^{1}H NMR δ 11.40 (br. s, 1H), 5.42 (s, 1H), 3.00 (t, *J* = 6.3 Hz, 2H), 1.92 (s, 3H), 1.71–1.64 (m, 1H), 1.18 (s, 3H), 0.84 (d, *J* = 6.7 Hz, 6H); ^{13}C NMR δ 170.0, 155.9, 47.0, 31.9, 29.7, 28.4, 23.4, 20.1.

Isopropyl *N*-(4-methylphenyl)-2-furancarboximidoate (4a). Colorless oil (79%); ^{1}H NMR δ 7.32 (s, 1H), 7.09 (d, *J* = 8.0 Hz, 2H), 6.69 (d, *J* = 8.0 Hz, 2H), 6.23–6.21 (m, 1H), 5.97–5.96 (m, 1H), 5.35–5.31 (m, 1H), 2.33 (s, 3H), 1.42 (d, *J* = 6.2 Hz, 6H); ^{13}C NMR δ 148.6, 146.2, 143.2, 132.0, 129.7, 120.0, 116.1, 111.0, 103.3, 68.4, 21.8, 20.8. Anal. Calcd for $C_{15}H_{17}NO_2$: C, 74.05; H, 7.04; N, 5.76. Found: C, 74.26; H, 7.38; N, 5.78.

Methyl *N*-(4-methylphenyl)-2-furancarboximidoate (4b). Colorless oil (67%); ^{1}H NMR δ 7.33 (s, 1H), 7.10 (d, *J* = 8.1 Hz, 2H), 6.71 (d = 8.1 Hz, 2H), 6.24–6.23 (m, 1H), 5.96–5.95 (m, 1H), 3.96 (s, 3H), 2.33 (m, 3H); ^{13}C NMR δ 149.8, 145.8, 143.3, 143.2, 132.3, 129.7, 120.0,

116.2, 111.1, 53.6, 20.8, 14.1. Anal. Calcd for $C_{13}H_{13}NO_2$: C, 72.54; H, 6.09; N, 6.51. Found: C, 72.60; H, 6.24; N, 6.74.

General procedure for the preparation of β-iminosulfones 6a and 6c

To a stirred solution of the corresponding sulfone (1.2 mmol) and potassium tert-butoxide (1.5 mmol) in THF (20 mL) was added (0.6 mmol) of **1.** The mixture was stirred at room temperature for 7–10 hours. Progress of the reaction was monitored by TLC. After the reaction was complete, water (20 mL) was added to the reaction mixture which was then extracted with dichloromethane (3x30 mL). The combined extracts were dried over anhydrous magnesium sulfate. The solvent was removed under reduced pressure and the remaining residue was purified by gradient column chromatography on silica gel (ethyl acetate/hexanes) to give pure β-iminosulfones **6a and 6c**.

4-Methyl-*N*-[1-methyl-2-phenyl-2-(phenylsulfonyl)ethylidene]aniline (6a). Colorless oil (97%); ^{1}H NMR δ 7.50 (d, *J* = 7.8 Hz, 2H), 7.36–7.14 (m, 8H), 6.89 (d, *J* = 8.1 Hz, 2H), 6.54 (d, *J* = 8.1 Hz, 2H), 5.16 (s, 1H), 2.31 (s, 3H), 2.16 (s, 3H); ^{13}C NMR δ 156.4, 144.8, 135.4, 134.0, 132.6, 130.3, 129.8, 129.7, 128.7, 128.5, 127.0, 124.3, 115.2, 53.5, 41.9, 34.6. Anal. Calcd for $C_{22}H_{21}NO_2S$: C, 72.70; H, 5.82; N, 3.85. Found: C, 72.25; H, 5.87; N, 3.89.

***N*-[1-Benzyl-2-phenyl-2-(phenylsulfonyl)-1-ethenyl]-*N*-(4-methylphenyl)amine (6c).** Yellow oil (65%); ^{1}H NMR δ (mixture of tautomers) 9.66 (s, 0.61H), 7.71–7.682 (m, 1.54H), 7.61–7.51 (m, 2.78H), 7.44–7.33 (m, 5.38H), 7.29–7.17 (m, 5.48H), 7.14–7.05 (m, 6.51H), 7.00 (d, J = 8.1 Hz, 2.22H), 6.95 (d, J = 6.9 Hz, 2.22H), 6.86–6.84 (m, 2.70H), 6.74–6.72 (m, 1.9H), 6.63 (d, J = 8.1 Hz, 1.6H), 5.10 (s, 0.54H), 3.70–3.38 (m, 0.86H), 3.42 (s, 2H), 2.32 (s, 2.1H), 2.28 (s, 2.8H).; ^{13}C NMR δ 163.9, 154.4, 146.8, 142.5, 137.8, 137.0, 136.4, 135.7, 134.7, 133.7, 133.4, 133.2, 132.4, 130.9, 130.1, 129.7, 129.6, 129.5, 129.2, 129.1, 128.9, 128.5, 128.3, 128.1, 128.0, 127.9, 127.8, 127.0, 126.9, 126.1, 126.3, 118.7, 115.2, 107.4, 112.2, 74.1, 39.9, 35.9, 20.9, 20.8. HRMS (EI) Calcd for $C_{28}H_{25}NO_2S$ $(M+Na)^+$: 462.1498. Found: 462.1487.

Procedure for the preparation of 6b

To (0.50 mmol) of benzylphenylsulfone in 15 mL THF at -78 °C was added (0.55 mmol) n-BuLi dropwise over a period of 15 min. The mixture was warmed to -20 C, stirred for 1 h at this temperature and re-cooled to -78 °C. A solution of **1g** (0.5 mmol) in 10 mL THF was added to the mixture over a period of 15 min. The mixture was stirred for 1 h at -78 C, then warmed to room temperature and stirred overnight. The mixture was quenched with 20 mL saturated NH_4Cl then extracted with (3x25 mL) dichloromethane. The organic layer was dried over magnesium sulfate, concentrated and chromatographed on silica gel (EtOAc/hexanes gradient) to give **6b**.

***N*-[1-(2-Furyl)-2-phenyl-2-(phenylsulfonyl)ethylidene]-*N*-(4-methylphenyl)amine (6b).** Yellow gum (53%); ^{1}H NMR δ 7.58–7.52 (m,1 H), 7.39–7.33 (m, 4 H), 7.22–7.14 (m, 3H), 7.01–6.95 (m, 5H), 6.76 (d, J = 8.1 Hz, 2H), 6.35 (d, J = 7.8 Hz, 2H), 6.24 (s, 1H), 2.15 (s, 3H); ^{13}C NMR δ 144.3, 143.7, 139.5, 138.6, 136.7, 136.4, 134.4, 133.3, 130.9, 130.3, 129.4, 128.7, 128.6, 128.4, 128.2, 127.9, 118.6, 77.2, 20.6. Anal. Calcd for $C_{50}H_{44}N_2O_7S_2$.0.5 HCl: C, 69.23; H, 5.00; N, 3.23. Found: C, 68.84; H, 5.28; N, 2.95.

General procedure for the preparation of β-iminosulfoxides 7a and 7c

To a stirred solution of the corresponding sulfoxide (0.7 mmol) and THF (10 mL), t-BuOK (0.7 mmol) was added at room temperature and the reaction mixture was stirred for 15 min. A solution of **1** (0.35 mmol) in THF (2 mL) was added slowly by syringe, and the mixture was allowed to react for 1.5–3 h at room temperature (TLC control). The reaction mixture was hydrolyzed with water (10–15 mL) and extracted with chloroform. The aqueous phase was acidified to pH 6–7 by addition of hydrochloric acid and extracted with chloroform. Combined organic layers were dried over anhydrous magnesium sulfate, filtered and evaporated under vacuum. The residue was purified by flash column chromatography on silica using hexanes/EtOAc (9/1) as an eluent to give pure β-iminosulfoxides **7a and 7c**.

***N*-[1,2-Diphenyl-2-(phenylsulfinyl)ethylidene]aniline (7a).** Colorless oil (78%); ^{1}H NMR δ 7.84 (d, *J* = 7.3 Hz, 5H), 7.65 (d, *J* = 8.2 Hz, 4H), 7.55–7.44 (m, 5H), 7.37 (t, *J* = 7.8 Hz, 4H), 7.16 (t, *J* = 7.4 Hz, 2H), 4.30 (s, 1H); ^{13}C NMR δ 165.7, 148.8, 137.9, 135.0, 133.7, 132.6, 131.8, 130.8, 129.1, 128.8, 128.7, 128.6, 127.0, 124.6, 120.2, 62.8. Anal. Calcd for $C_{26}H_{21}NOS$: C, 78.95; H, 5.35; N, 3.54. Found: C, 79.24; H, 5.62; N, 6.08.

***N*-(4-Methoxyphenyl)-*N*-[1-(4-methylphenyl)-2-(methylsulfinyl)-1-ethenyl]amine (7c).** Recrystallized from EtOAc/Hexane to give white crystals (71%), mp 137–139 °C; ^{1}H NMR δ (mixture of isomers 57:43) 7.74 (d, *J* = 8.1 Hz, 2H), 7.58 (br. s, 1H), 7.51 (d, *J* = 8.7 Hz, 2H), 7.25 (d, *J* = 9.0 Hz, 2H), 7.15 (d, *J* = 8.1 Hz, 2H), 6.97 (d, *J* = 8.1 Hz, 2H), 6.90 (d, *J* = 9.0 Hz, 2H), 6.69 (d, *J* = 9.0 Hz, 2H), 6.57 (d, *J* = 8.7 Hz, 2H), 3.79 (s, 3H), 3.71 (s, 2.3H), 2.40 (s, 3H), 2.26 (s, 2.33H)., 1.61 (s, 6H), 1.41 (s, 1H), 1.27 (s, 1H).; ^{13}C NMR δ 166.0, 157.7, 156.5, 155.2, 142.2, 139.9, 139.1, 132.5, 132.0, 131.1, 129.5, 129.4, 128.5, 126.9, 122.3, 122.0, 114.2, 114.0, 80.5, 77.2, 55.5, 55.4, 28.3, 28.4, 21.5, 21.3. Anal. Calcd for $C_{17}H_{19}NO_2S$: C, 67.74; H, 6.35; N, 4.65. Found: C, 67.22; H, 6.69; N, 4.58.

Procedure for the preparation of 7b

To (0.40 mmol) dimethyl sulfoxide in 15 mL THF -78 °C was added (0.44 mmol) n-BuLi dropwise over a period of 15 min. The mixture was warmed to -20 C, stirred for 1 h at this temperature and cooled to -78 C. A solution of **1g** (0.40 mmol) in 10 mL THF was added to the mixture over a period of 15 min. The mixture was stirred for 1 h at -78 C, then warmed to room temperature and stirred overnight. The mixture was quenched with 20 mL saturated NH_4Cl then extracted with (3x25 mL) dichloromethane. The organic layer was dried over magnesium sulfate, concentrated, and chromatographed on silica gel (EtOAc/hexanes gradient) to give **7b**.

***N*-[1-(2-Furyl)-2-(methylsulfinyl)-1-ethenyl]-*N*-(4-methylphenyl)amine (7b).** (48%); ^{1}H NMR δ (mixture of isomers 60:40) 7.62–7.61 (m, 1H), 7.41–7.40 (m, 0.61H), 7.18–7.13 (m, 4.29H), 6.77 (d, *J* = 8.1 Hz, 2H), 6.64 (d, *J* = 8.1 Hz, 1.34H), 6.59–6.57 (m, 1H), 6.32–6.28 (m, 0.6H), 5.78 (d, *J* = 3.6 Hz, 0.59H), 4.53–3.99 (m, 2H), 2.82 (s, 1.86H), 2.50 (s, 3H), 2.36 (s, 1.96 H), 2.35 (s, 3H), ; ^{13}C NMR δ 152.2, 150.5, 149.5, 148.8, 146.8, 146.5, 145.6, 143.8, 134.2, 133.6, 130.3, 129.8, 120.0, 117.6, 117.1, 115.2, 112.4, 112.3, 61.1, 53.9, 39.4, 39.3, 21.0, 20.9. Anal. Calcd for $C_{28}H_{32}N_2O_5S_2$: C, 62.20; H, 5.97; N, 5.18. Found: C, 62.93; H, 6.07; N, 5.21.

General procedure for the preparation of β-iminoamides 9a–d

To (0.8 mmol) of the corresponding amide in 15 mL THF at -78 ˚C was added (0.88 mmol) n-BuLi dropwise over a period of 15 minutes. The mixture was warmed to -20 ˚C, stirred for 1 h at this temperature, and then re-cooled to -78 ˚C. A solution of **1** (0.8 mmol) in 10 mL THF was added to the mixture over a period of 15 min. The reaction mixture was stirred for 2 hrs at -78 ˚C, then warmed to room temperature overnight. The mixture was quenched with 20mL saturated NH_4Cl then extracted with (3x50mL) dichloromethane. The organic layer was dried over anhydrous magnesium sulfate, concentrated under vacuum, and chromatographed on silica gel (EtOAc/hexanes gradient) to give pure β-iminoamides **9a–d**.

***N,N*-Diethyl-3-[(4-methylphenyl)imino]-2-phenylbutanamide hydrochloride (9a).** Colorless oil (51%); ^{1}H NMR δ 7.31 (d, *J* = 8.4 Hz, 2H), 7.23–7.13 (m, 5H), 6.97 (d, *J* = 8.2 Hz, 2H), 3.61 (s, 1H), 3.30 (q, *J* = 7.1 Hz, 2H), 3.22 (q, *J* = 7.1 Hz, 2H), 2.19 (s, 3H), 1.98 (s, 3H), 1.06–0.98 (m, 6H) ; ^{13}C NMR δ 170.2, 168.8, 135.7, 135.2, 133.3, 129.1, 128.5, 126.6, 120.0, 119.7, 42.3, 40.6, 40.1, 24.0, 20.6, 14.0, 12.8. Anal. Calcd for $C_{42}H_{53}ClN_4O_2$: C, 74.04; H, 7.84; N, 8.22. Found: C, 73.82; H, 8.08; N, 8.46.

***N,N*-Diethyl-3-(2-furyl)-2-phenyl-3-(4-toluidino)-2-propenamide hydrochloride (9b).** Colorless oil (48%); ^{1}H NMR δ 7.65–7.62 (m, 2H), 7.42–7.40 (m, 3H), 7.30–7.26 (m, 1H), 7.09 (d, *J* = 8.1 Hz, 2H), 6.70 (d, *J* = 8.1 Hz, 2H), 6.52 (s, 1H), 6.23–6.21 (m, 2H), 3.41–3.35 (m, 4H), 2.33 (s, 3H), 1.15–1.05 (m, 6H).; ^{13}C NMR δ 167.8, 148.4, 145.5, 143.9, 135.4, 132.2, 129.6, 128.9, 128.8, 128.8, 128.7, 120.1, 116.7, 111.0, 74.4, 41.8, 40.9, 20.9, 13.7, 12.9. HRMS (EI) Calcd for $C_{24}H_{26}N_2O_2$: 375.2067. Found: 375.2063

***N,N*-Diethyl-3-[(4-methylphenyl)imino]-2,4-diphenylbutanamide hydrochloride (9c).** Colorless oil (75%); ^{1}H NMR δ 7.80 (br. s, 1H), 7.34–7.22 (m, 12H), 7.05 (d, *J* = 8.2 Hz, 1H), 3.71 (s, 3H), 3.67 (s, 1H), 3.40 (q, *J* = 7.1 Hz, 2H), 3.30 (q, *J* = 7.1 Hz, 2H), 2.27 (s, 2H), 1.15–1.07 (m, 6H) ; ^{13}C NMR δ 170.2, 169.2, 135.3, 134.7, 133.7, 129.8, 129.3, 129.2, 128.9, 128.5, 127.4, 127.2, 126.6, 119.9, 44.4, 42.3, 40.8, 40.1, 20.7, 14.1, 12.8. Anal. Calcd for $C_{27}H_{31}N_2OCl$: C, 74.55; H, 6.95; N, 6.44. Found: C, 74.49; H, 7.47; N, 5.80.

***N,N*-Diethyl-3-(4-methoxyanilino)-3-(4-methylphenyl)-2-phenyl-2-propenamide hydrochloride (9d).** Pale yellow solid (69%), mp 130–131 °C; ^{1}H NMR δ 7.64–7.61 (m, 2H), 7.43–7.32 (m, 5H), 6.99 (d, J = 8.1 Hz, 2H), 6.73–6.6 (m, 4H), 6.54 (s, 1H), 3.74 (s, 3H), 3.43–3.32(m, 4H), 2.26 (s, 3H), 1.14–1.06 (m, 6H).^{13}C NMR δ 168.2, 158.3, 155.2, 141.4, 140.0, 138.2, 135.7, 129.7, 128.7, 128.69, 128.5, 127.9, 122.3, 114.0, 74.4, 55.3, 41.8, 40.8, 21.4, 13.7, 12.9. Anal. Calcd for $C_{27}H_{30}N_2O_2.0.5HCl$: C, 74.93; H, 7.10; N, 6.47. Found: C, 74.82; H, 7.32; N, 6.23.

General procedure for the preparation of α-nitroimines 10a–c

To the corresponding nitro compound (1.2 mmol) was added potassium tert-butoxide (1.5 mmol) at room temperature followed by **1** (0.6 mmol) in DMSO (10 mL). The mixture was heated and stirred at 50 ˚C for 5 hours. Progress of the reaction was monitored by TLC. Upon the completion of the reaction, HCl or acetic acid was used to acidify the reaction mixture. The organic layer was then extracted with dichloromethane (3x30 mL). The combined extracts were

dried over anhydrous magnesium sulfate. The solvent was removed under reduced pressure and the remaining residue was purified by gradient column chromatography on silica gel (ethyl acetate/hexanes) to give pure α-nitroimines **10a–c**.

4-Methyl-*N*-[1-methyl-2-nitropropylidene]aniline (10a). Colorless oil (60%); ^{1}H NMR δ 7.71 (br. d, lH), 7.30 (d, *J* = 8.2 Hz, 2H), 7.01 (d, *J* = 8.1 Hz, 2H), 2.32 (s, 3H), 2.22 (s, 3H), 2.06 (s, 3H); ^{13}C NMR δ 168.6, 135.4, 133.7, 129.3, 120.0, 70.4, 24.3, 20.8, 16.3. Anal. Calcd for $C_{22}H_{30}N_4O_5$: C, 61.38; H, 7.02; N, 13.01. Found: C, 61.96; H, 7.28; N, 11.32.

***N*-(4-Methoxyphenyl)-*N*-[1-(4-methylphenyl)-2-nitro-1-propenyl]amine (10b).** Yellow oil (34%); ^{1}H NMR δ 7.14 (d. *J* = 8.1 Hz, 2H), 7.06 (d. *J* = 8.1 Hz, 2H), 6.72–6.62 (m, 5H), 3.71 (s, 3H), 2.35 (s, 3H), 1.98 (s, 3H); ^{13}C NMR δ 157.4, 152.8, 139.9, 129.8, 129.5, 129.2, 128.6, 125.6, 114.0, 55.3, 29.7, 21.4, 16.2. Anal. Calcd for $C_{34}H_{36}N_4O_7.0.5H_2O$: C, 66.43; H, 6.23; N, 9.11. Found: C, 66.84; H, 6.45; N, 9.69.

***N*-[(*Z*)-1-Benzyl-2-nitro-1-propenyl]-*N*-(4-methylphenyl)amine (10c).** Yellow oil (50%); ^{1}H NMR δ 7.37–7.26 (m, 8H), 7.07 (d, *J* = 8.4 Hz, 2H), 3.73 (s, 2H), 2.28 (s, 3H), 1.25 (s, 3H); ^{13}C NMR δ 168.9, 135.0, 134.5, 134.0, 129.7, 129.5, 129.3, 129.1, 127.5, 119.9, 44.7, 29.7, 20.8. Anal. Calcd for $C_{17}H_{18}N_2O_2$: C, 72.32; H, 6.43; N, 9.92. Found: C, 71.98; H, 6.62; N, 9.86.

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