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Synthesis of Chromeno[4,3-*b*]pyrrol-4(1*H*)-ones, from β-Nitroalkenes and 4-Phenylaminocoumarins, under Solvent–free Conditions

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A new approach toward chromeno[4,3-*b*]pyrrol-4(1*H*)-ones, by annulation of 4-phenylaminocoumarins with β-nitroalkenes, is reported and its conditions were optimized. The transformations under the fine-tuned conditions took place under promotion by $TsOH.H_2O$, in the absence of solvent. The scope and limitations of the process were explored, by systematic modification of two diversification points. A reaction mechanism, triggered by a Michael addition of the nitrogen moiety of the 4-phenylaminocoumarins to the β-nitroalkene, was also proposed. Further functionalization of a selected tricycle was performed; the photophysical (UV and fluorescence spectra; $^1O_2$ generation) and electrochemical (cyclic voltammetry) properties of some heterocycles were studied.

Introduction

2*H*-Chromen-2-one (coumarin) is a privileged heterocycle and many of its derivatives are relevant for their biological activity.[1] Not less important, substituted 2*H*-chromen-2-ones are also technologically useful for their photophysical properties, as fluorescent probes, laser dyes, sensors, diagnostic reagents and chemical switches, among others.[2]

*T*he chromeno[4,3-*b*]pyrrol-4(1*H*)-ones are still a rather rare kind of compounds, not observed in nature. Their potential as bioactive substances has been early recognized, but they were synthetically explored in relatively recent times.[3] This motif is now present (Figure 1) among natural product analogs (**A**),[3a] different bioactive compounds (**B**, **C**),[4] drug candidates (**D**),[5a] chemical sensors (**E**),[5b] and photoredox switches (**F**).[5c]

The handful of currently available approaches toward this heterocyclic scaffold usually start with 4-substituted coumarin derivatives (hydroxy,[6] chloro[5c,6d] or amino[7a–c]). They generally entail two-stage processes, where the initial reaction is followed by a cyclization (often taking place with concomitant dehydration) to afford the expected target. Many strategies have been designed to furnish more complex polycycles, such as azacoumestans, isoazacoumestans and others.[7d–f]

Variations of this approach include the cyclization of 3-substituted 4-phenylaminocoumarins,[8] coumarins carrying a tethered amino group on C-3,[9] the use of Knorr, Fischer-Fink or aldol condensation type sequences,[6d,10] and the Nenitzescu

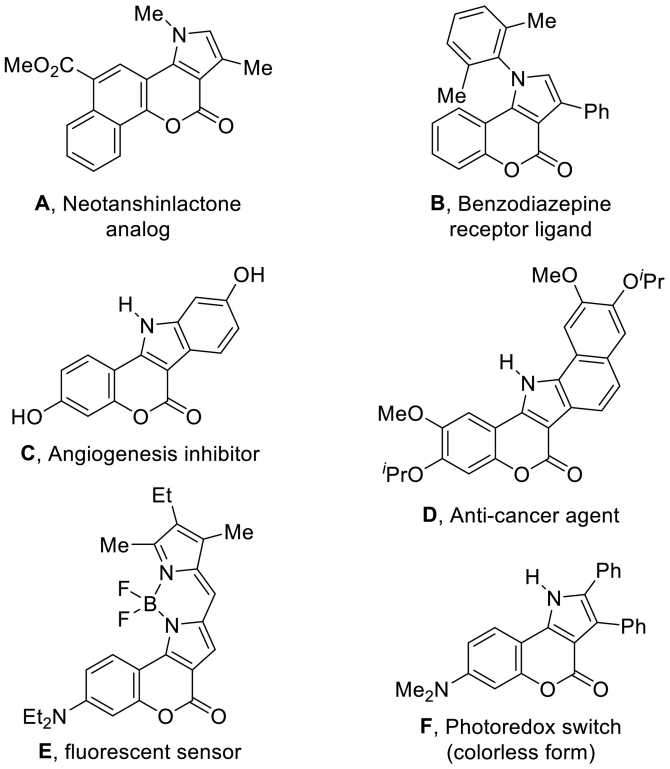

Figure 1. Selected examples of relevant chromeno[4,3-*b*]pyrrol-4(1*H*)-ones.

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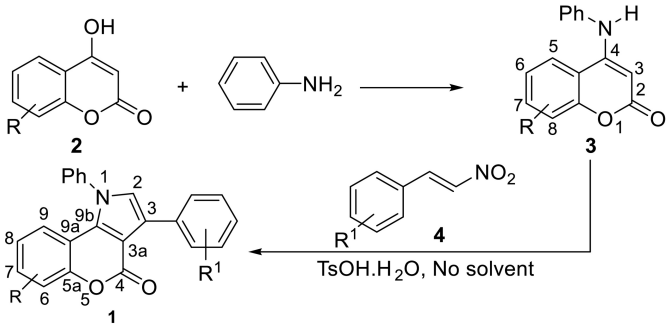
reaction.[11a] Acetylenes have also been frequently used as two-carbon atom sources, needed to form the pyrrole moiety.[6a,11b–d]

Other alternatives include the synthesis and further lactonization of 2-arylpyrrole derivatives,[4c,12] the Cadogan reaction,[13a] oxidative C–H/C–H coupling strategies,[13b] and the oxidation of precursors.[13c] Some of these methods have limitations such as substrate generality and availability of synthetic precursors, which may restrict their use. Hence, there is a need for new approaches toward these heterocycles.

On the other hand, the β-nitroalkenes are highly reactive and versatile intermediates, which can participate in various complex chemical transformations, acting as dienophiles, Michael acceptors and dipolarophiles, among others.[14]

We have recently reported a facile and modular synthesis of polysubstituted pyrroles based on a tri-component reaction which involves the in situ formation of β-enamino carbonyl intermediates between amines and 1,3-dicarbonyls, and their further cyclization with β-nitrostyrenes, under cerium(III) promotion.[15]

In pursuit of our interest in developing new and alternative routes for the synthesis of polyfunctionalized privileged heterocycles,[16] herein we wish to report a novel approach toward chromeno[4,3-*b*]pyrrol-4(1*H*)-ones (**1**), which entails the synthesis of 4-phenylaminocoumarins (**3**) from the corresponding 4-hydroxy-substituted coumarin precursors (**2**), and their further annulation with β-nitroalkenes (**4**) under TsOH.H_2O promotion and solvent-free conditions (Scheme 1).



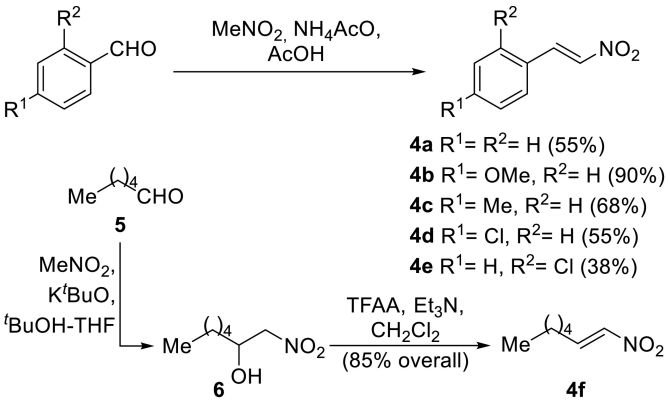
Scheme 1. Proposed reaction sequence toward chromeno[4,3-*b*]pyrrol-4(1*H*)-ones **1.**

The suitability of an aliphatic β-nitro-olefin as an annulation partner was also explored. In addition, the functionalization of a model tricycle was examined and some photophysical and electrochemical properties of selected heterocycles were determined.

Results and Discussion

The required 4-phenylaminocoumarin derivatives **3a–c** (R = H, 8Me, and 6Cl, respectively)[17a,b] were synthesized by reaction of aniline with the corresponding 4-hydroxycoumarins (**2a–c**, R = H, 8Me, and 6Cl, respectively),[17c–e] under microwave irradiation.

The β-nitrostyrenes **4a–e** were accessed (Scheme 2) by a Henry reaction of aromatic aldehydes with $MeNO_2$ in AcOH



Scheme 2. Syntheses of the β-nitrostyrenes **4a–e** and preparation of the two-step preparation of β-nitroalkene **4f** from hexanal (**5**).

containing some NH_4AcO, whereas the aliphatic β-nitroalkene **4f** was prepared by the K^{t}BuO-mediated nitroaldol reaction between hexanal (**5**) and $MeNO_2$ in ^{t}BuOH-THF, followed by dehydration (TFAA, Et_3N, CH_2Cl_2) of the nitroaldolic intermediate **6.**[18]

Taking into account our previous experience,[15] and in order to find the optimum reaction conditions, a systematic study of the annulation was undertaken with the 4-phenylamino coumarin derivative **3a** and the β-nitrostyrene **4a** as the prototypic reactants, modifying the reaction solvent, temperature, promoter and time. The most relevant results are detailed in Table 1.

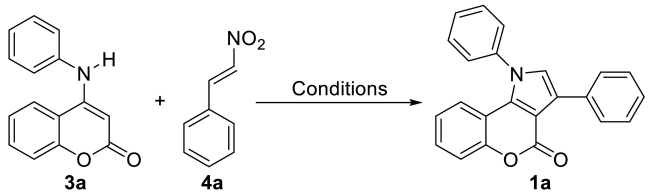
The solvent screen, performed in AcOH and with 20 mol% TsOH in PhMe, MeCN, DMF, DMSO, THF, dioxane, BMIM.BF_4, $MeNO_2$ and without solvent revealed that products were obtained in $MeNO_2$ (56%), PhMe (25%) and under solvent-free conditions (76%, entry 1), at 120 °C or refluxing overnight.

As TsOH.H_2O in PhMe did not afford an acceptable performance other sulfonic acid derivatives were explored.[19] CSA.H_2O (20 mol%) gave traces of product (entry 2), but the yield improved by increasing the amount of promoter up to 74% after running the reaction overnight (entry 4). Surprisingly, the transformation failed to take place with Amberlyst-15 (entry 5).

An analogous analysis was executed with regard to $MeNO_2$ as solvent (entries 6–11). The results unveiled that $CeCl_3.7H_2O$, L-proline, PPTS and Amberlyst-15 were inefficacious, whereas $FeCl_3.6H_2O$ gave low yields of **1a** even after 48 h (entries 9 and 10) and among the tests with sulfonic acids the best outcome (58% yield) was attained with 50 mol% TsOH.H_2O under reflux, after a 24 h reaction period (entry 7). This was a slight yield gain over the results of the solvent screen stage, at the expense of increasing the amount of promoter and the reaction time.

On the other side, when the reaction was performed under solvent-free conditions (entries 12–18), it was observed that the $CeCl_3.7H_2O$, $Ce(OTf)_3$ and PPTS failed to provide the expected product, whereas $FeCl_3.6H_2O$ afforded 58% of **1a** (entry 12) and

Table 1. Optimization of the synthesis of the chromeno[4,3-*b*]pyrrol-4(1*H*)-one **1a.**[a]



Entry No	Solvent	Promoter	Promoter (mol%)	Temp. (°C)	Time (h)[c]	Yield (%)[b]
1	-	$TsOH.H_2O$	20	120	ON	76
2	PhMe	$CSA.H_2O$	20	Reflux	ON	Traces
3	PhMe	$CSA.H_2O$	50	Reflux	48	57
4	PhMe	$CSA.H_2O$	100	Reflux	ON	74
5	PhMe	Amberlyst-15	20	Reflux	ON	-
6	$MeNO_2$	$TsOH.H_2O$	20	Reflux	72	47
7	$MeNO_2$	$TsOH.H_2O$	50	Reflux	24	58
8	$MeNO_2$	$CSA.H_2O$	20	Reflux	48	23
9	$MeNO_2$	$FeCl_3.6H_2O$	20	Reflux	ON	30
10	$MeNO_2$	$FeCl_3.6H_2O$	20	Reflux	48	24
11	$MeNO_2$	$Ce(OTf)_3$	20	100	24	15
12	-	$FeCl_3.6H_2O$	20	120	ON	58
13	-	Amberlyst-15	20	120	ON	28
14	-	$CSA.H_2O$	20	120	ON	67
15	-	$CSA.H_2O$	20	100	ON	50
16	-	$TsOH.H_2O$	20	100	ON	65
17	-	$TsOH.H_2O$	10	120	ON	48
18	-	$TsOH.H_2O$	30	120	ON	67

[a] *Standard reaction conditions:* 4-phenylaminocoumarin (0.5 mmol), β-nitrostyrene (0.75 mmol), solvent (1 mL).
[b] Isolated yields after column chromatography.
[c] ON: overnight.

Amberlyst-15 furnished a disappointing 28% yield (entry 13). Not unexpectedly, the yields improved with $CSA.H_2O$, being better at 120 °C than at 100 °C (entries 14 and 15).

Finally, examination of $TsOH.H_2O$ revealed a strong dependency of the yields from both, the reaction temperature and the amount of the promoter (entries 16–18). However, the performance attained under the conditions of entry 1 could not be surpassed; therefore, from the economic and environmental points of view, these were considered as the best ones.

Interestingly, additional experiments further demonstrated that quite similar results could be accomplished by running the transformation at 140 °C for a shorter period of time (2-4 h); therefore these were taken as alternative, more advantageous conditions, and chosen for further reactions.

Once both sets of optimal conditions were defined, they were used to explore the scope and limitations of the reaction, through the systematic synthesis of an array of chromeno[4,3-*b*] pyrrol-4(1*H*)-ones (Table 2). For the sake of comparison, the 4-phenylaminocoumarin **3a** was reacted with **4a–f** under the first set of conditions (entries 1–6). It was observed that, except for the aliphatic nitroalkene **4f** which exhibited a rather poor performance (28% yield, entry 6), and the electron-donating **4b**, which performed moderately (42% yield, entry 2), the remaining β-nitrostyrenes gave good product yields (68-77%).

An analogous pattern, with the best yields in the range 65–72%, was observed when the same transformations were carried out employing the alternate set of conditions, at 140 °C for 2–4 h (entries 7–12). However, compound **1f** was obtained in a meager 15% yield, as part of a complex mixture of products, which severely difficulted its purification from the reaction extract.

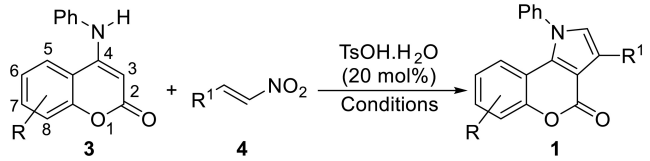
Quite similar results were recorded when the same set of β-nitroalkenes was reacted with the 8-methylcoumarin **3b** (entries 13–18). This derivative provided the expected products in 2–3 h (66-76% yield) at 140 °C, except for the β-nitrostyrenes **4b** and **4c**, which displayed a less satisfactory performance (30 and 44%, respectively, entries 14 and 15). Analogously, a problematic reaction was observed with the aliphatic nitroalkene **4f**, which decomposed upon heating. As a consequence, the expected compound **1l** could not be accessed in this way.

On the other hand, the 6-chlorocoumarin derivative **3c** reacted sluggishly even at 140 °C; its peak performance was at 160 °C, where most of the reactions were completed in 3–4 h (entries 19–24). However, the products were obtained only in moderate yields (39-61%), probably reflecting additional impacts of electronic effects on the reaction outcome. Not unexpectedly, only 6% of product **1r** could be isolated when the reaction was carried out overnight at 120 °C; furthermore, no product could be isolated from an experiment with **4f** carried out at 180 °C.

Interestingly, **1a, 1c** and **1d** have been synthesized and demonstrated to be good ligands of the benzodiazepine receptor, with efficacy and affinity similar to those of diazepam.[4b–d] The remaining chromeno[4,3-*b*]pyrrol-4(1*H*)-ones are novel and were fully characterized by NMR analysis (^1H and ^{13}C), and elemental analysis or HRMS. The diagnostic signals of the pyrrole (H2 and C2) appeared, respectively, as a singlet, at $\delta_H = 7.04 \pm 0.07$ ppm in the ^1H NMR spectra and as a C_{sp}^2–H carbon atom in the region of $\delta_C = 127 \pm 5$ ppm, in the ^{13}C NMR spectra. Their correlation was unequivocally observed in the HSQC spectra.

Although the reaction mechanism of the annulation is not clear, it can be drawn a rough picture of it (Scheme 3). In the proposed course, the annulation takes place through sequence where the β-enaminone moiety of **3**[20a] could trigger a Michael addition on the β-nitroalkene **4**,[20b] under tosic acid promotion, to afford the iminium-nitronate intermediate ***i.*** In turn, this iminium derivative could rearrange to the enaminone intermediate ***ii*** (imino-enamine tautomerization).

Table 2. Study of the scope of the reaction.[a]



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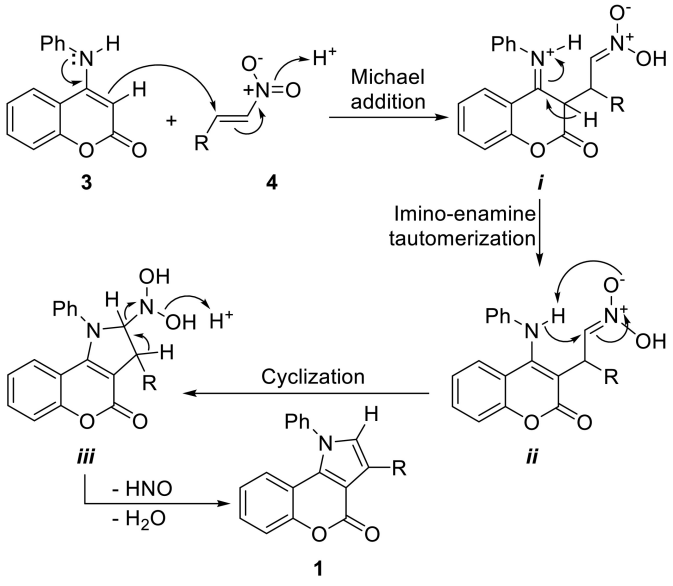
Entry No	β-Nitroalkene No	Coumarin No (R)	R_1	Temp. (°C)	Time (h)	Prod. No	Yield (%)[b]
1	**4a**	**3a** (H)	C_6H_5	120	ON	**1a**	76
2	**4b**	**3a** (H)	4MeO-C_6H_4	120	ON	**1b**	42
3	**4c**	**3a** (H)	4Me-C_6H_4	120	ON	**1c**	70
4	**4d**	**3a** (H)	4Cl-C_6H_4	120	ON	**1d**	77
5	**4e**	**3a** (H)	2Cl-C_6H_4	120	ON	**1e**	68
6	**4f**	**3a** (H)	$Me(CH_2)_4$	120	ON	**1f**	28
7	**4a**	**3a** (H)	C_6H_5	140	2	**1a**	72
8	**4b**	**3a** (H)	4MeO-C_6H_4	140	4	**1b**	45
9	**4c**	**3a** (H)	4Me-C_6H_4	140	3	**1c**	65
10	**4d**	**3a** (H)	4Cl-C_6H_4	140	2	**1d**	69
11	**4e**	**3a** (H)	2Cl-C_6H_4	140	3	**1e**	71
12	**4f**	**3a** (H)	$Me(CH_2)_4$	140	7	**1f**	15[c]
13	**4a**	**3b** (8Me)	C_6H_5	140	2	**1g**	66
14	**4b**	**3b** (8Me)	4MeO-C_6H_4	140	5	**1h**	30
15	**4c**	**3b** (8Me)	4Me-C_6H_4	140	3	**1i**	44
16	**4d**	**3b** (8Me)	4Cl-C_6H_4	140	3	**1j**	72
17	**4e**	**3b** (8Me)	2Cl-C_6H_4	140	3	**1k**	76
18	**4f**	**3b** (8Me)	$Me(CH_2)_4$	160	3.5	**1l**	–[d]
19	**4a**	**3c** (6Cl)	C_6H_5	160	3	**1m**	55
20	**4b**	**3c** (6Cl)	4MeO-C_6H_4	160	4	**1n**	30
21	**4c**	**3c** (6Cl)	4Me-C_6H_4	160	3	**1o**	45
22	**4d**	**3c** (6Cl)	4Cl-C_6H_4	160	3	**1p**	39
23	**4e**	**3c** (6Cl)	2Cl-C_6H_4	160	4	**1q**	61
24	**4f**	**3c** (6Cl)	$Me(CH_2)_4$	120	ON	**1r**	6[c]

[a] *Conditions:* 4-phenylaminocoumarin (0.5 mmol), β-nitroalkene (0.75 mmol).
[b] Isolated yields after column chromatography.
[c] Complex mixture of products, which were extremely difficult to purify. Yields are approximate.
[d] The expected product was not formed



Scheme 3. Proposed mechanism for the synthesis of the chromeno[4,3-*b*] pyrrol-4 (1*H*)-ones **1.**

This instance could enable the following intramolecular electrophilic cyclization, facilitated by activation of the nitrogen functionality, which would lead to intermediate ***iii.*** Final aromatization with concomitant dehydration and release of nitroxyl (HNO), which may dimerize to hyponitrous acid ($H_2N_2O_2$) and eventually end as nitric oxide,[21a] leading to the target **1**, should complete the sequence. Interestingly, analogous mechanisms have been proposed for similar multi-component reactions furnishing pyrrole derivatives.[21]

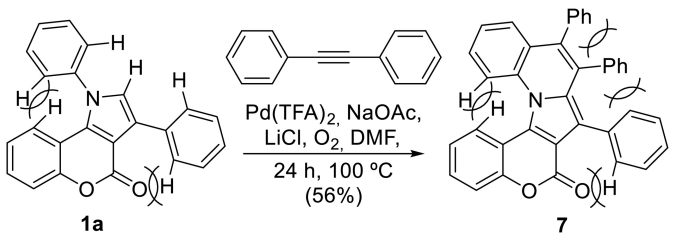
Luckily, the so synthesized chromeno[4,3-*b*]pyrrol-4(1*H*)-ones (**1**) proved to be suitable starting materials for further functionalization toward more complex polycyclic structures. For example, the oxidative cyclocondensation of **1a** with diphenylacetylene under 5 mol% $Pd(TFA)_2$ catalysis gave **7** in 38% yield, as shown in Scheme 4.[22] Interestingly, the yield increased to 56% by using 10 mol% of the catalyst.

The single crystal X-ray analysis of compound **7** (Figure 2) fully confirmed its structure[23] and revealed that that both, the coumarin (the dihedrals C1-C14b-C14a-C6a and C3-C4-C4a-O5 measure 160.31° and 175.38°, respectively) and the quinoline (C13-C13a-N14-C14a and C10-C9a-C9-C8 measure 150.59° and 164.79°, respectively) ring systems clearly deviate from planarity and that the whole structure is twisted like a propeller (the angle C1-C14-C13 is 63.21°).

Further, it also exhibited that the ring-oxygen atom has a sp^2 hybridization (the angle C4a-O5-C6 measures 123.12°), whereas none of the pendant aromatic rings is able to properly overlap with the π-system of the main chromophore in the ground state (Scheme 4).

Next, we turned our attention to examine the photophysical and electrochemical properties of the synthesized chromeno [4,3-*b*]pyrrol-4(1*H*)-ones, using **1a** and **7** as models. In their electronic excitation spectra, taken in dilute chloroformic solutions (Figure 3), it was observed that both heterocycles exhibited intense absorption in the region of 250 nm.

Compound **7** displayed maxima at 256 nm (with a shoulder at 320 nm) and 386 nm, while **1a** showed a single maximum at 322 nm, being its extinction coefficient higher than those of **7** (Table 3), Both lower energy maxima are red-shifted from the corresponding peak in 4-hydroxycoumarin (**2**, λ_{max} =



Scheme 4. Synthesis of the chromeno[4,3-b]pyrrol-4(1H)-one derivative **7**..

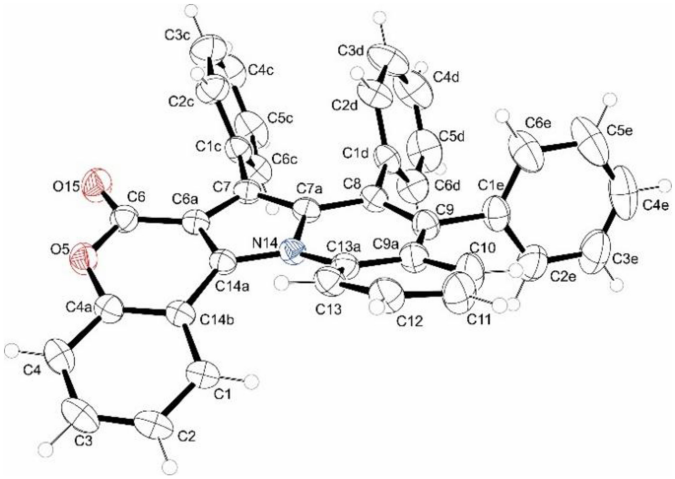


Figure 2. ORTEP projection of compound **7** (CCDC 1526530).

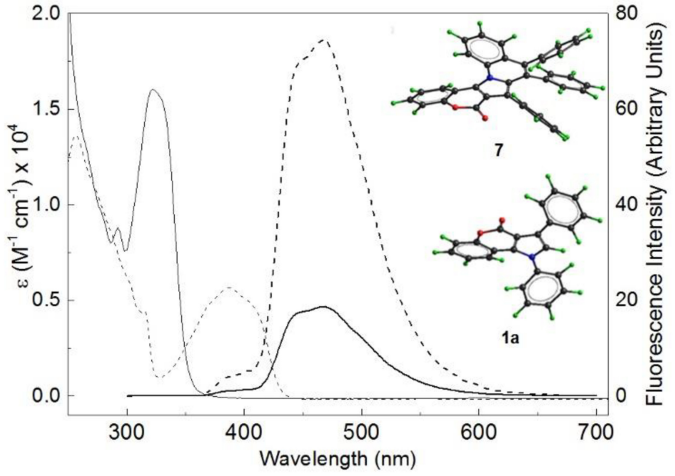


Figure 3. Normalized excitation (thin lines) an emission (thick lines) spectra of the chromeno[4,3-*b*]pyrrol-4(1*H*)-one derivatives **1 a**(—) and **7**(- - -) in oxygen free $CHCl_3$.

317 nm),[24a–c] or coumarin itself (λ_{max} = 310 nm), suggesting a certain contribution of a charged nitrogen tautomer to the structure of the heterocycles.[24d]

Modeling of both angularly fused molecules confirmed the previous observations on distorted coplanarity of the polycyclic core. This could contribute to explain the relative low values of

Table 3. Photophysical properties of compounds **1 a** and **7**.

Comp. No	λ_{max} (nm)	ε &λτ";+&γτ";($M^{-1}cm^{-1}$)	λ_{em} (nm)[a]	Φ_{fl}[b]	Δλ, Stokes Shift (nm)[c]	$\Delta E_{0\text{-}0}$ (eV)[d]
1 a	322	16040	467	0.040	145	3.333
7	256	13613	468	0.101	82	2.910
	386	5675				

[a] λ_{exc} = 250 nm, in $CHCl_3$ (slit width = 2 nm).
[b] 9,10-Diphenylanthracene as quantum yield standard (Φ_{fl} = 0.65).
[c] $\Delta\lambda = \lambda_{em} - \lambda_{max}$.[d] $\Delta E_{0\text{-}0} = 1240/\lambda_{int}$.

the observed extinction coefficients (ε) at the different λ_{max}, which according to their intensities should result from π→π* transitions.[24d]

In agreement with this report, we observed that the emission spectra of **1 a** and **7** were of rather low intensity, in the blue region, and exhibited essentially the same shape and position of their maxima (467/468 nm, with half band widths of 74 and 84 nm, respectively), suggesting that the different organic moieties in the coumarins did not play a fundamental role in the excited state of these compounds.[25] The low emission intensities are not fully unexpected; it has been recently noticed that pyrrole-fused coumarins show little fluorescence.[7c, 25b, c]

The substituent effect was maximized in the case of **1 a** which displayed a large Stokes shift(λ_{em} = 467 nm, Δλ = 145 nm), insinuating the presence of some charge separation, which can be assigned to an intramolecular charge transfer character in the excited state. For the sake of comparison, 4-hydroxycoumarin (**2 a**) exhibited λ_{em} = 390 nm and Δλ = 73 nm.[24a] In addition, despite the extent of the conjugation in **7** did not bring a greater spectral shift, it was reflected in a higher value of the quantum yield of the fluorescence (Φ_{fl} = 0.101).

However, although **7** was many times more powerful light emitter than coumarin itself (Φ_{fl} = 0.009),[24a] its efficiency was considered low when compared to the quantum yield of the fluorescence of the 9,10-diphenylanthracene standard (Φ_{fl} = 0.65).[26] The excitation and emission spectra of **1 a** and **7** intersected at λ_{int} = 272 nm and 426 nm, respectively, resulting in estimation of band gap energy ($\Delta E_{0\text{-}0}$) values of 3.333 and 2.910 eV, respectively.

On the other side, energy transfer between the triplet state of certain compounds, like some coumarins, and the ground state of O_2 causes generation of singlet oxygen ($^1O_2$). Currently, the production of $^1O_2$ is of high interest because of its importance in the photo-oxidation of biological systems; this is the basis of its potential use in photo-chemotherapy, where the coumarins can perform as relevant building blocks of structurally complex sensitizers.[27]

Therefore, the ability of the coumarin derivatives to act as triplet sensitizers for the generation of singlet oxygen ($^1O_2$) was also assessed in a specific test, where the $^1O_2$ produced by red light irradiation of the heterocycles in an aerobic condition

reacted in situ with 1,3-diphenylisobenzofuran (DPBF) to afford an oxidized species which does not absorb at 415 nm.

It was observed that both tested heterocycles behaved quite similarly (Figure 4), exhibiting a rather low photo-

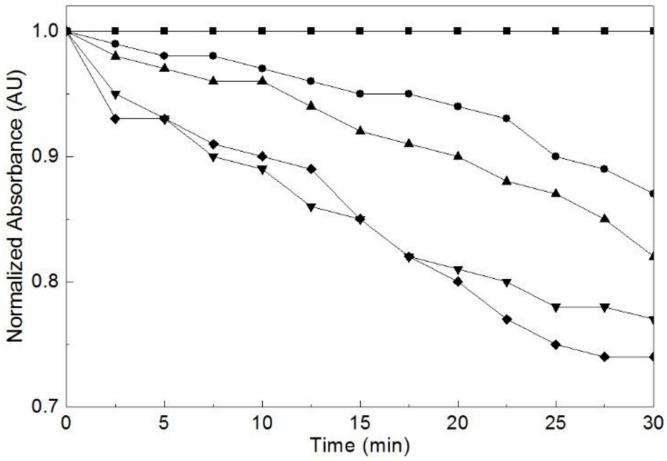


Figure 4. Photo-oxidation of DPBF in DMF without coumarin derivatives (■) and in the presence of 0.5 μM each of 4-hydroxycoumarin (●), 4-phenylaminocoumarin **8** (▲), **1 a** (▼) and **7** (◆), at 0.5 μM, after red light irradiation.

decomposition rate of the indicator (~25%/30 min). Nevertheless, the tested compounds were twice as efficient as their parent 4-hydroxycoumarin (**2**) and 4-aminocoumarin (**8**). A control experiment was performed utilizing identical reaction conditions, except for the absence of the coumarin derivative as sensitizer. Under these conditions, no variation was observed in the absorbance of DPBF.

The cyclic voltammograms of **1 a** and **7** in anhydrous CH_2Cl_2 under aerobic conditions (Figure 5) displayed oxidation peaks

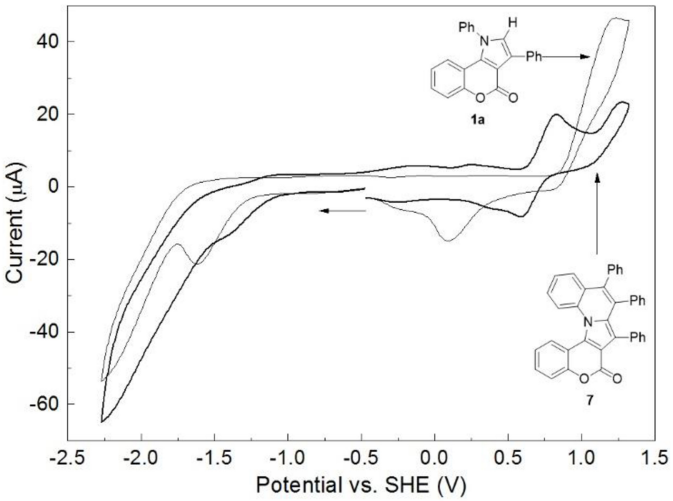


Figure 5. Cyclic voltammograms of compounds **1 a** (thin line) and **7** (thick line), in CH_2Cl_2 containing 0.1 M $Bu_4N^+PF_6^-$ as supporting electrolyte, at a scan rate of 100 mV/s.

between +0.7 and +1.25 V vs. SHE (Table 4), which can be associated to the formation of intermediates like radical

Table 4. Electrochemical properties of chromeno[4,3-*b*]pyrrol-4(1*H*)-ones **1 a** and **7**.

Comp. No	E_1 (V)	E_2 (V)	E_3 (V)	HOMO (eV)[d]	LUMO (eV)[e]	$\Delta E_{0\text{-}0}$ (eV)[f]
1 a	−1.612[a]	+0.089[b]	+1.205[b]	−6.005	−2.672	3.333
7	−1.391[a]	+0.711[c]	+1.256[b]	−5.511	−2.601	2.910

[a]Cathodic peak (E_{pc}); [b]Anodic peak (E_{pa}); [c]$E_{1/2}$; [d]E_{HOMO} (eV) = −[4.80 + E_{ox} (vs. SHE)]; [e]$E_{LUMO} = E_{HOMO} + \Delta E_{0\text{-}0}$; [f]$\Delta E_{0\text{-}0}$ values were taken from Table 3.

cationic species. In the reduction range, at −0.5 to −2.5 V, the derivatives exhibited one irreversible reduction wave in the reduction range (E_{pc}). The cathodic peak can be assigned to π-anion radical species in solution.[28] Interestingly, no meaningful variations either in the current or potential were observed after performing several cycles, discardeding polymerization events.

Conclusions

A facile synthesis of chromeno[4,3-*b*]pyrrol-4(1*H*)-ones was developed, by a solvent-free annulation of 4-phenylamino coumarins and β-nitroalkenes, under TsOH promotion. The reaction conditions were optimized, finally ensuring the efficient delivery of the products in short times. The scope and limitations of the transformation were assessed, and a mechanism was proposed. Electrochemical and photophysical properties of some heterocycles were also evaluated.

This approach provides a new and efficient access to diverse chromeno[4,3-*b*]pyrrol-4(1*H*)-ones, which cannot be easily prepared by other methods and can be used as scaffolds toward more complex heterocycles, as demonstrated through the synthesis of a pentacyclic ring system.

Attractive features of this protocol include operational simplicity, short reaction time, ease of product purification and the use of solvent-free conditions, which turn the procedure more economic and eco-friendly; hence, it can be foreseen that it will find use in modern synthetic organic chemistry.

Furthermore, in view of the bioactivity recorded for **1 a**, **1 c** and **1 d**, steps toward increasing knowledge in this regard are in progress and their relevant results will be disclosed at due time.

Supporting Information Summary

Detailed experimental procedures, full characterization data, ^1H and ^{13}C NMR spectra of the synthesized compounds. Single crystal X-ray diffraction data of compound 7.

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Conflict of Interest

The authors declare no conflict of interest.

Keywords: Chromeno[4,3-*b*]pyrrol-4(1*H*)-ones · Condensed heterocycles · Cyclization · β-Nitrostyrenes · TsOH-promoted solvent-free reaction

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