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REGIOSELECTIVITY IN THE 1,3-DIPOLAR CYCLOADDITION REACTIONS OF NITRILE OXIDES AND ORGANIC AZIDES WITH BROMOCARBAZOLE-1,4-DIONES

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Abstract – The effect exerted by the presence of a bromine atom in 2 or 3 position of a carbazole-1,4-dione on the regiocontrol of 1,3-dipolar cycloaddition reactions with nitrile oxides and organic azides was investigated. Comparison with the results obtained with 2,3-unsubstituted-carbazole-1,4-dione shows that bromine substituents on *para*-carbazolequinones effectively orient the 1,3-dipolar cycloadditions. The regiochemistry observed may be explained by the orienting effect of the bromine atom independently of the values of the orbital coefficients.

INTRODUCTION

As part of our investigations on the biological properties of aryl- and heteroaryl-condensed carbazolequinones, we have recently reported the synthesis of pyrido- and benzo-derivatives by Diels-Alder reaction of tricyclic carbazolediones with some azadienes[1-3] and carbodienes.[4] We have particularly studied the orienting effect of bromine atom in [4+2] cycloaddition of 2- or 3-bromocarbazole-1,4-dione with an azadiene. This reaction provided regioselectively the isomer in which the nitrogen atom of the azadiene was delivered at the brominated carbon of quinone. In continuation of this work, we planned to synthesize a series of isoxazolo- and triazolocarbazolequinone derivatives by the 1,3-dipolar cycloaddition reaction of carbazole-1,4-diones with nitrile oxides and azides respectively, and to investigate the orienting effect of bromine atom in this reaction. To date, few reports dealing with the 1,3-dipolar cycloaddition of quinones with nitrile oxides[5-12] and organic azides[13-18] have been reported in the literature and only one has described the regiocontrol effect of

bromine substituent on naphthoquinones in the reaction with nitrile oxides.[12] In this case, only the regioisomer in which the oxygen atom of nitrile oxide was linked to the brominated carbon of quinone was obtained.

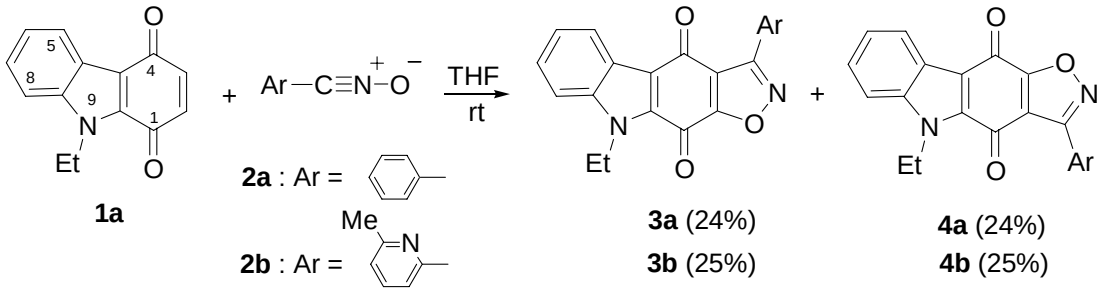
In this work, we wish to report our results from a related study of the 1,3-dipolar cycloaddition reactions of unbrominated carbazolequinone (**1a**) and bromocarbazolequinones (**1b**) and (**1c**) towards both nitrile oxides (**2a**) and (**2b**) and organic azides (**5a**) and (**5b**).

RESULTS AND DISCUSSION

Quinone (**1a**) was obtained starting from the commercially available 4-hydroxycarbazole by a chemoselective N-alkylation followed by oxidation with Frémy's salt. Bromoquinones (**1b**) and (**1c**) were prepared from the N-alkylated compound respectively by oxidation/bromination or by bromination/oxidation, according to the procedure which we have reported in a previous paper.[1] Nitrile oxides (**2a**) and (**2b**) were synthesized by dehydrogenation of the corresponding aldoximes with sodium hypochlorite.[19] Organic azides (**5a**) and (**5b**) can be prepared from the corresponding bromide or chloride by reaction with sodium azide in ethanol.[20]

Cycloaddition of carbazolequinones (1a), (1b) and (1c) with nitrile oxides (2a) and (2b):

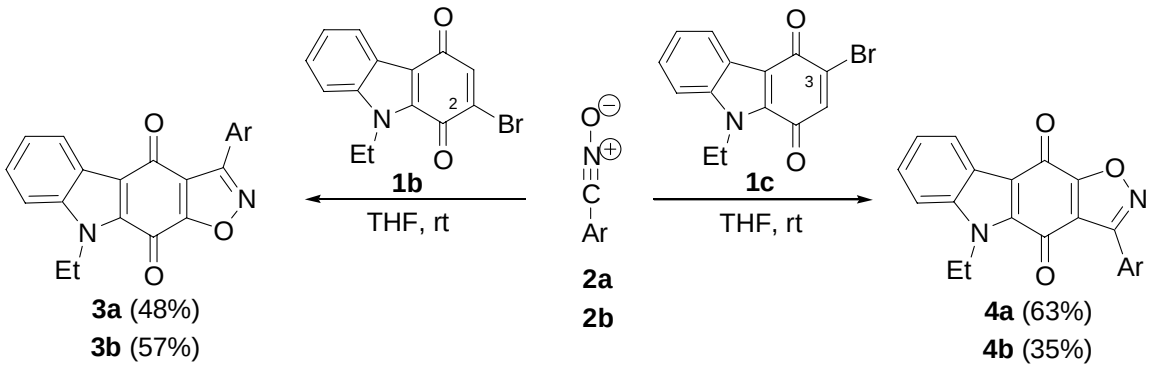
The reaction of quinone (**1a**) (Scheme 1) with nitrile oxide (**2a**) in THF at room temperature affords a 48% yield of a mixture of the regioisomeric adducts (**3a**) and (**4a**) in approximately equal proportions. In this case, the primary cycloadducts are not observed, certainly due to a rapid oxidation with **1a**. The reaction with nitrile oxide (**2b**) requires the presence of basic Al_2O_3 to give a 1:1 mixture of the regioisomeric compounds (**3b**) and (**4b**) in 50% overall yield. In absence of basic Al_2O_3, this reaction leads to a mixture of **3b** and **4b** plus the corresponding primary cycloadducts.



Scheme 1. Reaction of carbazolequinone (**1a**) with nitrile oxides (**2a**) and (**2b**).

In order to obtain the regioselective formation of the isoxazolocarbazolequinones (**3**) and (**4**), we turn our attention to the use of the 2- and 3- bromocarbazolequinones (**1b**) and (**1c**) in accordance with our study of the orienting effect of bromine in Diels-Alder cycloadditions (Scheme 2).

The reaction of **1b** with nitrile oxides (**2a**) and (**2b**) in THF at room temperature gave selectively **3a** and **3b** in 48 and 57% yields, respectively. In similar conditions, 3-bromocarbazolequinone (**1c**) reacted with **2a** and **2b** to give selectively **4a** and **4b** in 63 and 35% yields, respectively. The orienting effect of bromine atom in these reactions agrees with results reported by Behar and co-workers.[12]



Scheme 2. Reaction of bromocarbazolequinones (**1b**) and (**1c**) with nitrile oxides (**2a**) and (**2b**).

Concerning the reactive site of quinones in the 1,3-dipolar cycloaddition with nitrile oxides, it has been reported[6,7] that quinones have two kinds of potentially reactive sites. One is the carbon-oxygen double bond and the other is the carbon-carbon double bond. In our case, only the C=C cycloaddition reactions have been observed.

Proofs of the regiochemistry were made by ^{1}H-NMR NOE 1D experiments performed on isomers (**3b**) and (**4b**) (Figure 1). In the case of **3b**, an irradiation at 8.12 ppm (H-3') gives two responses: one on H-4' (7.81 ppm) and the other one on H-5 (8.36 ppm). Then, irradiation of the methyl signal at 1.52 ppm affords two responses: one on the CH_2 of the ethyl group (4.73 ppm) and the other one on H-8 (7.48 ppm). On the other hand, irradiation of the methyl signal (1.47 ppm) of compound (**4b**) gives four responses: one on H-6 (7.47 ppm), the second on the CH_2 of the ethyl group (4.70 ppm), the third one on H-3' (7.88 ppm) and the fourth one on the CH_3-6' (2.71 ppm).

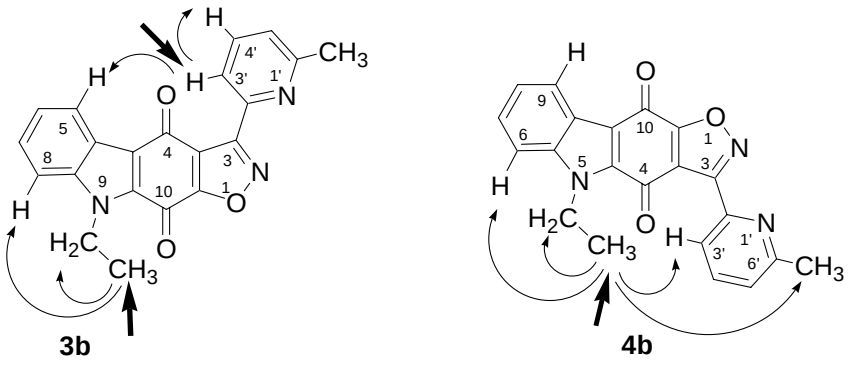


Figure 1. ^{1}H-NMR NOE 1D experiments

Moreover, IR spectra of the regioisomers (**3a**) and (**3b**) formed from the 2-bromocarbazolequinone (**1b**), show two absorption bands for the carbonyl groups while in the regioisomers (**4a**) and (**4b**) formed from the 3-bromocarbazolequinone (**1c**), the latter are not differentiated.

In order to better understand the regiochemistry of the [3+2] cycloaddition of quinones (**1a**), (**1b**) and (**1c**) towards nitrile oxides (**2a**) and (**2b**), we used Frontier Molecular Orbital theory and calculations of the respective LUMO and HOMO energy levels and orbital coefficients were carried out at the B3LYP theory level using the Gaussian 98 program.[21] Thus, the values given in Table 1 indicated that the energy difference between the LUMO of quinones and the HOMO of nitrile oxides is smaller than that between the HOMO of quinones and LUMO of nitrile oxides. This result suggests that the HOMO (nitrile oxide)-LUMO (quinone) interaction is the governing factor of this reaction. On the other hand, the values given in Table 2 indicated that the larger orbital coefficients were located at C-3 for quinones (**1a**), (**1b**) and (**1c)** while they are at the oxygen atom for the nitrile oxides (**2a**) and (**2b**).

Table 1. Energy levels [eV] of FMO of carbazolequinones (**1a-c**) and nitrile oxides (**2a,b**).

Carbazolequinones	HOMO	LUMO
1a	- 6.065	- 3.087
1b	- 6.201	- 3.299
1c	- 6.201	- 3.281
2a	- 6.338	- 1.313
2b	- 6.650	- 1.614

Table 2. Orbital coefficients of carbazolequinones (LUMO) and nitrile oxides (HOMO).

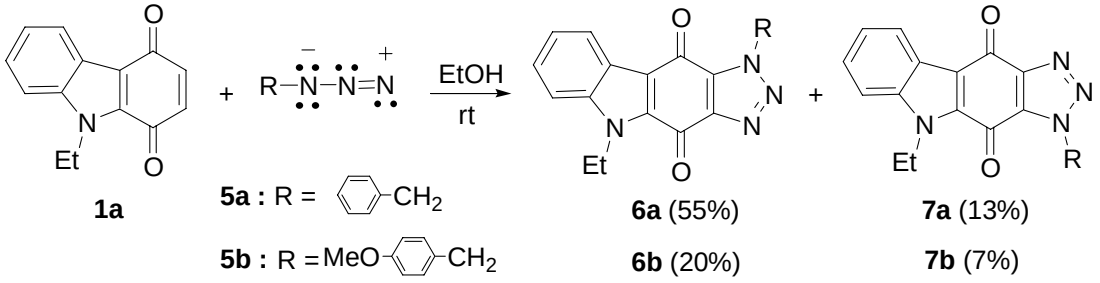
Carbazolequinones (LUMO)	C-2	C-3
1a	0.185	0.221
1b	0.194	0.216
1c	0.181	0.234
Nitrile oxides (HOMO)	Carbon atom	Oxygen atom
2a	0.272	0.419
2b	0.288	0.426

The regiochemistry observed in the cycloaddition between 2-bromoquinone (**1b**) and nitrile oxides (**2a**) and (**2b**) can not be explained by the values of the orbital coefficients but by the orienting effect of the bromine atom. Indeed the oxygen atom of nitrile oxides attacks preferentially at C-2 of **1b**. For 3-bromoquinone (**1c**), both the values of the orbital coefficients and the regiocontrol effect of the bromine

atom orientate the cycloaddition to the formation of regioisomers (**4a**) or (**4b**) in which the oxygen atom of nitrile oxides was linked to the brominated carbon of quinone (C-3).

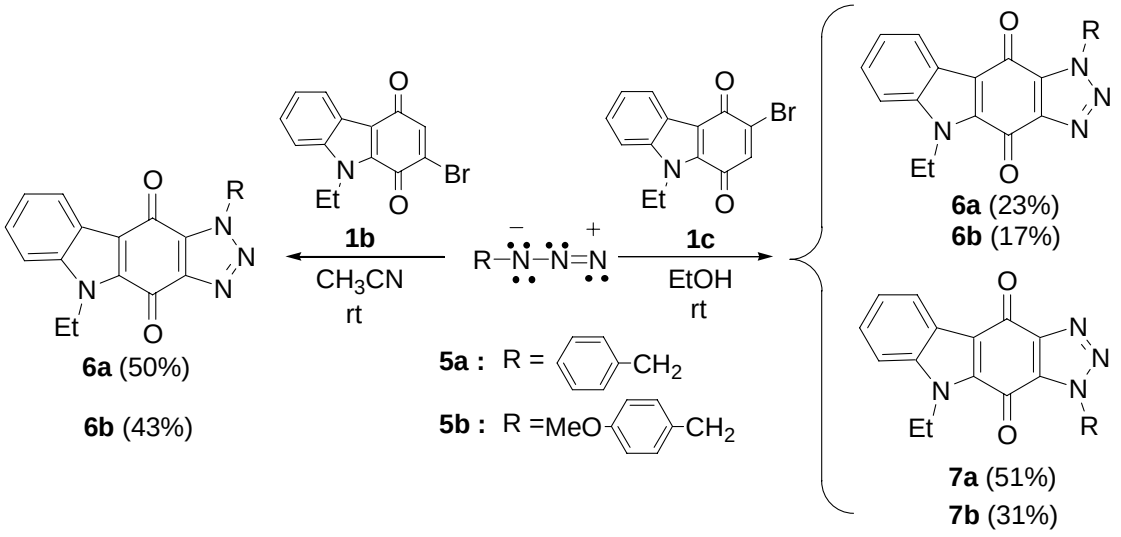
Cycloaddition of carbazolequinones (1a), (1b) and (1c) with organic azides (5a) and (5b):

The unbrominated carbazolequinone (**1a**) reacted with an excess of benzyl azide (**5a**) in ethanol at room temperature to afford a mixture of the two possible isomeric products (**6a**) and (**7a**) in 55 and 13% yield, respectively. On the other hand, treatment of **1a** with an excess of 4-methoxybenzyl azide (**5b**) in similar conditions, gave regioisomers (**6b**) and (**7b**) in 20 and 7% yield, respectively (Scheme 3).



Scheme 3. Reaction of carbazolequinone (**1a**) with azides (**5a**) and (**5b**).

When 2-bromocarbazolequinone (**1b**) was treated with azides (**5a**) or (**5b**) in acetonitrile at room temperature, we obtained the only regioisomers (**6a**) or (**6b**) in 50 and 43% yield, respectively. Alternatively, treatment of 3-bromocarbazolequinone (**1c**) with azides (**5a**) or (**5b**) in ethanol at room temperature gave a mixture of regioisomeric compounds (**6a**) (23%) and (**7a**) (51%) or (**6b**) (17%) and (**7b**) (31%) (Scheme 4).



Scheme 4. Reaction of bromocarbazolequinones (**1b**) and (**1c**) with azides (**5a**) and (**5b**).

For the regiochemistry assignment, we used the 2D ^{1}H-^{13}C HMBC correlations for **6b** and **7b** (Figure 2). In the case of **6b**, ^{4}J couplings were observed between C-4 and H of CH_2 of the ethyl group and between C-10 and H of CH_2 of the methoxybenzyl group. In the case of **7b**, both H of CH_2 of the ethyl group and H of CH_2 of the methoxybenzyl group had ^{4}J couplings with C-4.

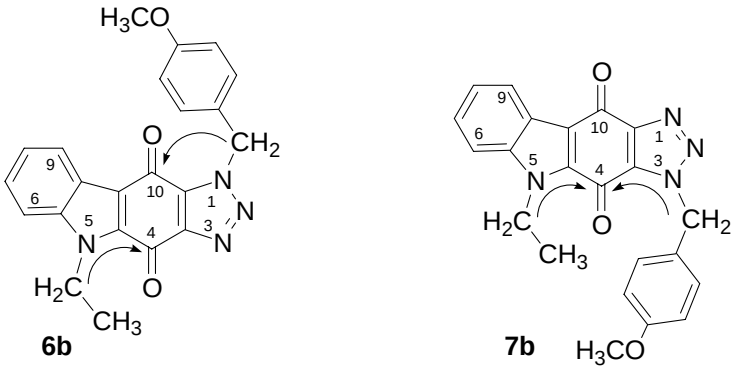


Figure 2. 2D ^{1}H-^{13}C HMBC correlations

Moreover, IR spectra of the regioisomers (**6a**) and (**6b**) formed from the 2-bromocarbazolequinone (**1b**), show two absorption bands for the carbonyl groups while in the regioisomers (**7a**) and (**7b**) formed in a majority from the 3-bromocarbazolequinone (**1c**), the latter are not differentiated.

The respective LUMO and HOMO energy levels of carbazolequinones (**1a**), (**1b**) and (**1c**) given in Table 1 and LUMO and HOMO energy levels of azides (**5a**) and (**5b**) given in Table 3 indicated that the HOMO (azide)-LUMO (quinone) interaction is the governing factor of this reaction. On the other hand, the values of the orbital coefficients of azides given in Table 4 indicated that the larger orbital coefficients were located at N-1 of **5a** and **5b**.

Table 3. Energy levels [eV] of FMO of azides (**5a**) and (**5b**).

Azides	HOMO	LUMO
5a	- 6.822	- 0.827
5b	- 6.058	- 0.724

Table 4. Orbital coefficients of azides (HOMO).

Azides (HOMO)	N-1[a]	N-3[a]
5a	0.393	0.327
5b	0.075	0.048

[a] $R-\overset{-}{N}-N=\overset{+}{N}$ (1, 3)

The regiochemistry observed in the cycloaddition of quinone (**1a)** and 2-bromoquinone (**1b)** with azides (**5a)** and (**5b)** agrees with the calculations. Indeed, N-1 of azides attacks at C-3 of quinones to give preferentially or exclusively regioisomers (**6a)** and (**6b)**. But, in the case of 3-bromoquinone (**1c)**, N-1 of azides adds preferentially to the unbrominated carbon C-2 of this quinone.

CONCLUSION

We have reported the regioselective synthesis of isoxazolocarbazolequinone and triazolocarbazolequinone derivatives by 1,3-dipolar cycloaddition reactions of bromocarbazolequinones respectively with nitrile oxides and azides. The regiochemistry observed in these reactions may be explained by the orienting effect of the bromine atom independently of the values of the orbital coefficients. Cycloadditions with nitrile oxides provide exclusively the regioisomers in which the oxygen atom was linked to the brominated carbon of the carbazolequinone. In the case of azides, we obtained preferentially or exclusively the regioisomers in which the N-1 atom was linked to the unbrominated carbon of the carbazolequinone. The regiochemistry obtained was unambiguously confirmed by ^{1}H-NMR NOE experiments and 2D ^{1}H-^{13}C HMBC correlations.

EXPERIMENTAL SECTION

1. General: Melting points were measured with a Büchi apparatus (capillary tube). The IR spectra were recorded with a Perkin-Elmer 1310 spectrophotometer. The NMR spectra were recorded with a Bruker AM 300 spectrometer (^{1}H-NMR: 300 MHz, ^{13}C-NMR: 75 MHz). Chemical shifts (δ) are reported in ppm using tetramethylsilane (TMS) as an internal reference. Coupling constant (*J*) values are given in Hz. Elemental analyses were performed at the Centre de Microanalyse du CNRS at Solaize, France. Calculations of the LUMO and HOMO energy and orbital coefficients were carried out at the B3LYP theory level using the Gaussian 98 program.

2. General procedure for the preparation of nitrile oxides (2a) and (2b) from aldoximes: A mixture of benzaldehyde oxime (539 mg, 4.45 mmol) or 6-methylpyridine carbaldehyde oxime (605 mg, 4.45 mmol) and 13% aqueous solution of sodium hypochlorite (6 mL) in THF (6 mL) was stirred for 15 minutes at room temperature and the resulting green solution of **2a** or **2b** was dried with Na_2SO_4.

3. [3+2]-Cycloadditions of nitrile oxides to carbazolequinones:

3.1. 9-Ethyl-3-phenylisoxazolo[5,4-*b*]carbazole-4,10(9*H*)-dione (3a): The solution of nitrile oxide (**2a)** prepared above was added dropwise to a stirred solution of 2-bromocarbazolequinone (**1b)** (152 mg, 0.5 mmol) in THF (10 mL). Stirring was maintained for 3 days at rt. The reaction mixture was evaporated to dryness in vacuum and the resultant product was taken up in Et_2O to give a red precipitate of **3a** which

was purified by column chromatography on silica gel with CH_2Cl_2/petroleum ether (1:1) as the eluent. It was obtained in 64% yield (110 mg). mp 244 °C. IR (KBr): 1673, 1658 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ ppm 1.52 (t, *J* = 7.2 Hz, 3H, CH_2CH_3), 4.74 (q, *J* = 7.2 Hz, 2H, CH_2CH_3), 7.39 (m, 1H, 6-H), 7.48 (m, 2H, 7-H and 8-H), 7.55 (m, 3H, Ar-H), 8.18 (m, 2H, Ar-H), 8.38 (d, *J* = 7.9 Hz, 1H, 5-H). ^{13}C NMR (75 MHz, $CDCl_3$): δ ppm 15.61, 40.92, 111.47, 119.42, 120.44, 124.19, 124.70, 125.72, 126.97, 128.41, 129.01 (2C), 129.98 (2C), 131.47, 132.92, 140.26, 161.15, 167.43, 168.20, 177.24. Anal. Calcd for $C_{21}H_{14}N_2O_3$. 0.5 H_2O (351.36): C 71.79, H 4.30, N 7.97. Found: C 71.64, H 4.20, N 7.86.

3.2. 5-Ethyl-3-phenylisoxazolo[4,5-*b*]carbazole-4,10(5*H*)-dione (4a): The solution of nitrile oxide (**2a)** prepared above was added dropwise to a stirred solution of 3-bromocarbazolequinone (**1c)** (152 mg, 0.5 mmol) in THF (10 mL). Stirring was maintained for 3 days at rt. The reaction mixture was evaporated to dryness in vacuum and the resultant product was taken up in Et_2O to give a red precipitate of **4a** which was purified by column chromatography on silica gel with EtOAc/petroleum ether (3:1) as the eluent. It was obtained in 69% yield (118 mg). mp 241 °C. IR (KBr): 1667 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ ppm 1.47 (t, *J* = 7.1 Hz, 3H, CH_2CH_3), 4.73 (q, *J* = 7.1 Hz, 2H, CH_2CH_3), 7.42 (m, 1H, 8-H), 7.48 (m, 2H, 6-H and 7-H), 7.56 (m, 3H, Ar-H), 8.09 (m, 2H, Ar-H), 8.37 (d, *J* = 7.1 Hz, 1H, 9-H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ ppm 15.50, 40.98, 111.66, 117.72, 118.00, 123.79, 124.100, 126.008, 126.90, 127.81, 129.02 (2C), 129.75 (2C), 131.50, 135.73, 139.57, 161.00, 168.724, 170.50, 175.01. Anal. Calcd for $C_{21}H_{14}N_2O_3$. 0.1 H_2O (344.15): C 73.29, H 4.16, N 8.14. Found: C 73.35, H 4.19, N 8.19.

3.3. 9-Ethyl-3-(6-methylpyridin-2-yl)isoxazolo[5,4-*b*]carbazole-4,10(9*H*)-dione (3b): The solution of nitrile oxide (**2b)** prepared above was added dropwise to a stirred solution of 2-bromocarbazolequinone (**1b)** (152 mg, 0.5 mmol) in THF (10 mL). Stirring was maintained for 3 days at rt. The reaction mixture was evaporated to dryness in vacuum and the resultant product was taken up in Et_2O to give a red precipitate of **3b** which was purified by column chromatography on silica gel with EtOAc/CH_2Cl_2 (1:1) as the eluent. It was obtained in 58% yield (103 mg). mp 224 °C. IR (KBr): 1673 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ ppm 1.52 (t, *J* = 7.2 Hz, 3H, CH_2CH_3), 2.71 (s, 3H, 6'-CH_3), 4.73 (q, *J* = 7.2 Hz, 2H, CH_2CH_3), 7.34 (d, *J* = 7.8 Hz, 1H, 5'-H), 7.38 (m, 1H, 6-H), 7.48 (m, 2H, 7-H and 8-H), 7.81 (t, *J* = 7.8 Hz, 1H, 4'-H), 8.12 (d, *J* = 7.8 Hz, 1H, 3'-H), 8.36 (d, *J* = 8.2 Hz, 1H, 5-H). ^{13}C NMR (75 MHz, $CDCl_3$): δ ppm 15.61, 25.09, 40.96, 111.51, 119.64, 120.43, 123.19, 124.18, 124.68, 125.56, 125.75, 128.45, 132.99, 137.35, 140.28, 146.04, 159.73, 160.55, 167.33, 168.07, 176.91. Anal. Calcd for $C_{21}H_{15}N_3O_3$. 0.1 H_2O (359.17): C 70.23, H 4.27, N 11.70. Found: C 70.24, H 4.30, N 11.66.

3.4. 5-Ethyl-3-(6-methylpyridin-2-yl)isoxazolo[4,5-*b*]carbazole-4,10(5*H*)-dione (4b): The solution of nitrile oxide (**2b)** prepared above was added dropwise to a stirred solution of 3-bromocarbazolequinone

(**1c)** (152 mg, 0.5 mmol) in THF (10 mL). Stirring was maintained for 3 days at rt. The reaction mixture was evaporated to dryness in vacuum and the resultant product was purified by column chromatography on silica gel with EtOAc/ petroleum ether (1:3) as the eluent. **4b** was obtained in 35% yield (64 mg). mp 221 °C. IR (KBr): 1673 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ ppm 1.47 (t, *J* = 7.2 Hz, 3H, CH_2CH_3), 2.71 (s, 3H, 6'-CH_3), 4.70 (q, *J* = 7.2 Hz, 2H, CH_2CH_3), 7.35 (d, *J* = 7.8 Hz, 1H, 5'-H), 7.42 (m, 1H, 8-H), 7.47 (m, 2H, 6-H and 7-H), 7.80 (t, *J* = 7.8 Hz, 1H, 4'-H), 7.88 (d, *J* = 7.8 Hz, 1H, 3'-H), 8.34 (d, *J* = 7.8 Hz, 1H, 9-H). ^{13}C NMR (75 MHz, $CDCl_3$): δ ppm 15.44, 25.05, 40.96, 111.68, 117.68, 118.35, 122.68, 123.74, 124.09, 125.52, 126.00, 127.79, 135.72, 137.35, 139.51, 146.07, 159.71, 160.47, 168.48, 170.30, 174.43. Anal. Calcd for $C_{21}H_{15}N_3O_3$. 0.3 H_2O (362.77): C 69.53, H 4.33, N 11.58. Found: C 69.68, H 4.37, N 11.49.

3.5. [3+2]-Cycloaddition of nitrile oxide (2a) to carbazolequinone (1a): The solution of nitrile oxide (**2a)** prepared above was added dropwise to a stirred solution of carbazolequinone (**1a)** (113 mg, 0.5 mmol) in THF (10 mL). Stirring was maintained for 3 days at rt. The reaction mixture was evaporated to dryness in vacuum to yield a mixture of regioisomeric compounds (**3a)** and (**4a)** which were separated by column chromatography on silica gel using, first CH_2Cl_2/ petroleum ether (1:1) and then, EtOAc/ petroleum ether (3:1) as the eluent. **3a** was obtained in 24% yield (41 mg) and **4a** in 24% yield (41 mg).

3.6. [3+2]-Cycloaddition of nitrile oxide (2b) to carbazolequinone (1a): The solution of nitrile oxide (**2b)** prepared above was added dropwise to a stirred solution of carbazolequinone (**1a)** (113 mg, 0.5 mmol) in THF (10 mL). Then, basic alumina (1g) was added. Stirring was maintained for 3 days at rt. After filtration, the solvent was evaporated to yield a mixture of regioisomeric compounds (**3b)** and (**4b)** which were separated by column chromatography on silica gel using, first EtOAc/ petroleum ether (1:3) and then, EtOAc/ CH_2Cl_2 (1:1) as the eluent. **3b** was obtained in 25% yield (45 mg) and **4b** in 25% yield (45 mg).

4 General procedure for the preparation of azides (5a) and (5b): To a solution of sodium azide (480 mg, 7.38 mmol) in EtOH (50 mL) was added benzyl bromide (1130 mg, 6.61 mmol) or 4-methoxybenzyl bromide (1330 mg, 6.61 mmol). The solution was heated at reflux for 24 h, cooled, diluted with water (40 mL) and extracted with Et_2O (3 × 30 mL). The combined organic solution was dried with Na_2SO_4 and concentrated to provide colourless viscous oil of benzyl or 4-methoxybenzyl azide which was used without further purification.

4.1. 1-Benzyl-5-ethyl[1,2,3]triazolo[4,5-*b*]carbazole-4,10(1*H*,5*H*)-dione (6a): The benzyl azide (**5a)** prepared above was added dropwise to a stirred solution of 2-bromocarbazolequinone (**1b)** (152 mg, 0.5 mmol) in MeCN (10 mL). Stirring was maintained for 4 days at rt. The orange reaction suspension was

concentrated in vacuum then filtered to yield compound (**6a)** as an orange solid which was purified by recristallization from EtOH. It was obtained in 50% yield (90 mg). mp 279 °C. IR (KBr): 1678, 1667, 1652 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ ppm 1.48 (t, *J* = 7.0 Hz, 3H, CH_2CH_3), 4.76 (q, *J* = 7.0 Hz, 2H, CH_2CH_3), 5.98 (s, 2H, CH_2), 7.35 (m, 3H), 7.46 (m, 3H), 7.53 (m, 2H), 8.33 (d, *J* = 7.2 Hz, 1H, 9-H). ^{13}C NMR (75 MHz, $CDCl_3$): δ ppm 15.51, 40.95, 53.72, 111.66, 118.00, 123.64, 124.37, 125.81, 127.72, 129.08 (2C), 129.27, 129.35 (2C), 134.65 (2C), 135.48, 139.47, 145.95, 172.67, 172.90. Anal. Calcd for $C_{21}H_{16}N_4O_2$. 0.4 H_2O (363.59): C 69.37, H 4.66, N 15.41. Found C 69.41, H 4.44, N 15.48.

4.2. 5-Ethyl-1-(4-methoxybenzyl)[1,2,3]triazolo[4,5-*b*]carbazole-4,10(1*H*,5*H*)-dione (6b): The 4-methoxybenzyl azide (**5b)** prepared above was added dropwise to a stirred solution of 2-bromocarbazolequinone (**1b)** (152 mg, 0.5 mmol) in acetonitrile (10 mL). Stirring was maintained for 3 days at rt. The orange reaction suspension was evaporated to dryness in vacuum and the resultant product was taken up in diethyl ether to give an orange precipitate of **6b** which was filtered and purified by column chromatography on silica gel with CH_2Cl_2/ petroleum ether (2:1) as the eluent. It was obtained in 43% yield (82 mg). mp 292 °C. IR (KBr): 1679, 1668, 1655 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ ppm 1.48 (t, *J* = 6.9 Hz, 3H, CH_2CH_3), 3.80 (s, 3H, OCH_3), 4.76 (q, *J* = 6.9 Hz, 2H, CH_2CH_3), 5.93 (s, 2H, CH_2), 6.90 (d, *J* = 8.52 Hz, 2H, Ar-H), 7.45 (m, 1H, 8-H), 7.49 (m, 2H, Ar-H), 7.52 (d, *J* = 8.2 Hz, 2H, Ar-H), 8.38 (d, *J* = 7.6 Hz, 1H, 9-H). ^{13}C NMR (75 MHz, $CDCl_3$): δ ppm 15.37, 40.86, 53.26, 55.65, 111.55, 114.74 (2C), 118.85, 123.67, 124.45, 125.67, 126.96, 127.60, 130.58 (2C), 134.56, 135.60, 139.52, 146.01, 160.51, 172.73, 172.86. Anal. Calcd for $C_{22}H_{18}N_4O_3$. 0.6 H_2O (397.22): C 66.52, H 4.87, N 14.10. Found: C 66.57, H 4.64, N 13.96.

4.3. [3+2]-Cycloadditions of benzyl azides (5a) to 3-bromocarbazolequinones (1c): The benzyl azide (**5a)** prepared above was added dropwise to a stirred solution of 3-bromocarbazolequinone (**1c)** (152 mg, 0.5 mmol) in EtOH (5 mL). Stirring was maintained for 2 weeks at rt. The orange reaction suspension was concentrated in vacuum then filtered to yield an orange solid of a mixture of regioisomeric compounds (**6a)** and (**7a)** which were separated by column chromatography on silica gel with CH_2Cl_2/ petroleum ether (1:1) as the eluent. **6a** was obtained in 23% yield (40 mg) and **7a** in 51% yield (90 mg).

3-Benzyl-5-ethyl[1,2,3]triazolo[4,5-*b*]carbazole-4,10(3*H*,5*H*)-dione (7a): mp 273 °C. IR (KBr): 1666 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ ppm 1.48 (t, *J* = 7.2 Hz, 3H, CH_2CH_3), 4.67 (q, *J* = 7.2 Hz, 2H, CH_2CH_3), 5.94 (s, 2H, CH_2), 7.51 (m, 2H, Ar-H), 7.60 (m, 6H, Ar-H), 8.40 (dd, *J* = 7.9 Hz and *J* = 1.1 Hz, 1H, 9-H). ^{13}C NMR (75 MHz, $CDCl_3$): δ ppm 15.56, 40.84, 53.93, 111.25, 119.97, 124.42 (2C), 125.57, 128.24, 128.96 (2C), 129.33, 129.38 (2C), 133.56, 133.95, 134.48, 139.96, 147.12, 170.41, 175.44. Anal. Calcd for $C_{21}H_{16}N_4O_2$. 0.2 H_2O (359.99): C 70.07, H 4.59, N 15.56. Found: C 70.10, H 4.42, N 15.55.

4.4. [3+2]-Cycloadditions of 4-methoxybenzyl azides (5b) to 3-bromocarbazolequinones (1c): The 4-methoxybenzyl azide (**5b)** prepared above was added dropwise to a stirred solution of 3-bromocarbazolequinone (**1c)** (152 mg, 0.5 mmol) in ethanol (5 mL). Stirring was maintained for 10 days at rt. The orange reaction mixture was evaporated to dryness in vacuum and the resultant product was taken up in Et_2O then filtered to give an orange precipitate of a mixture of regioisomeric compounds (**6b)** and (**7b)** which were separated by column chromatography on silica gel with CH_2Cl_2/ petroleum ether (2:1) as the eluent. **6b** was obtained in 17% yield (30 mg) and **7b** in 30% yield (53 mg).

5-Ethyl-3-(4-methoxybenzyl)[1,2,3]triazolo[4,5-*b*]carbazole-4,10(3*H*,5*H*)-dione (7b): mp 270 °C. IR (KBr): 1666 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ ppm 1.49 (t, *J* = 7.2 Hz, 3H, CH_2CH_3), 3.78 (s, 3H, CH_3), 4.69 (q, *J* = 7.2 Hz, 2H, CH_2CH_3), 5.88 (s, 2H, CH_2), 6.88 (d, *J* = 8.5 Hz, 2H, Ar-H), 7.35 (m, 1H, Ar-H), 7.42 (m, 2H, Ar-H), 7.46 (d, *J* = 8.5 Hz, 2H, Ar-H), 8.43 (d, *J* = 7.8 Hz, 1H, 9-H). ^{13}C NMR (75 MHz, $CDCl_3$): δ ppm 15.33, 40.58, 53.25, 55.46, 110.98, 114.42 (2C), 119.75, 124.21 (2C), 125.32, 126.40, 127.98, 130.31 (2C), 133.16, 133.75, 139.72, 146.92, 160.20, 170.26, 175.24. HRMS: calcd. for $C_{22}H_{18}N_4O_3$ 386.1379; found 386.13736.

4.5. [3+2]-Cycloaddition of azide (5a) to carbazolequinone (1a): The benzyl azide (**5a)** prepared above was added dropwise to a stirred solution of carbazolequinone (**1a)** (113 mg, 0.5 mmol) in EtOH (5 mL). Stirring was maintained for 2 weeks at rt. The orange reaction suspension was concentrated in vacuum then filtered to yield a mixture of regioisomeric compounds (**6a)** and (**7a)** which were separated by column chromatography on silica gel with CH_2Cl_2/ petroleum ether (1:1) as the eluent. **6a** was obtained in 55% yield (98 mg) and **7a** in 13% yield (23 mg).

4.6. [3+2]-Cycloaddition of azide (5b) to carbazolequinone (1a): The 4-methoxybenzyl azide (**5b)** prepared above was added dropwise to a stirred solution of carbazolequinone (**1a)** (113 mg, 0.5 mmol) in ethanol (5 mL). Stirring was maintained for 2 weeks at rt. The orange reaction mixture was evaporated to dryness in vacuum and the resultant product was taken up in Et_2O then filtered to give an orange precipitate of a mixture of regioisomeric compounds (**6b)** and (**7b)** which were separated by column chromatography on silica gel with CH_2Cl_2/ petroleum ether (2:1) as the eluent. **6b** was obtained in 20% yield (39 mg) and **7b** in 7% yield (14 mg).

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