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Substituent control in the diastereoselectivity of dipolar cycloadditions of nitrones and their Zn(II) complexes with *N*-arylmaleimides

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Abstract—The π–π stacking interactions between maleimide's and nitrone's aromatic rings during the 1,3-dipolar cycloaddition were assumed to control the *exo–endo* selectivity of the reaction. The *exo–endo* ratios change during the reactions until they reach a constant value, which depends on the substituent. Electron-withdrawing groups favour the *exo* adduct while electron-donating groups favour the *endo* adduct. The nitrone $ZnBr_2$ complexes react much more slowly than the free nitrone and the cycloaddition is *exo* selective in all cases independent of the substituents on the maleimide's aromatic ring. Thermal retrocycloaddition of the cycloadducts produce the corresponding nitrones. The ring opening in the presence of secondary amines did not induce imine formation. *endo* Adducts were shown for the first time to be the stable paramagnetic compounds.

1. Introduction

Intra- and intermolecular 1,3-dipolar cycloadditions are a straightforward way to prepare various five-membered heterocyclic compounds. Nitrones are an important class of dipoles largely used in cycloadditions with a variety of dipolarophiles.[1] The control of stereochemistry in dipolar cycloaddition reactions is an important target and can be achieved by either choosing the appropriate substrates or adding a metal complex to the reaction.[2]

The regio- and stereoselectivity of the cycloadditions of di- and tri-arylimidazolin-3-oxide[3] with a variety of dipolarophiles[4] was reported elsewhere. In our previous work, 1,3-dipolar cycloadditions of imidazolin-3-oxides were shown to proceed regio- and diastereoselectively and interesting reactions of these adducts under a variety of conditions especially the double cis elimination they undergo in the presence of dialkylamines were reported.[4d,e,5] The reaction of imidazolin-3-oxides with *N*-arylmaleimides in benzene and toluene was shown to proceed selectively to give the *endo* adducts as major products. The *exo–endo* ratio decreases when electron-donating groups are present at the aromatic ring of maleimides, and increases when the groups are electron-withdrawing.[6]

As a continuation of our interest in the synthesis of bicyclic isoxazolidines with potential biological activity and in the stereochemistry of dipolar cycloadditions of nitrones, a series of *N*-arylmaleimides **3** were reacted with acyclic nitrones **1** and with their corresponding $ZnBr_2$ complexes **2**. The adducts were then subjected to ring opening in the presence of secondary and tertiary amines[5] in order to assess the scope and limitations of the interesting deoxygenation we have recently reported.[6] In this work, we also investigated the effects of substituents on the *N*-aryl group of the maleimide on the reaction rate, yield and the *exo–endo* selectivity of the cycloaddition reaction with acyclic nitrones **1**. This could ensure an entry to the control of the stereochemistry of cycloaddition, where the π–π stacking interactions may play a crucial role. The problem of *exo–endo* selectivity in 1,3-dipolar cycloadditions has not been fully assessed yet, but some *exo–endo* selectivity of the cycloaddition of nitrones with different types of dipolarophiles has been reported.[7]

2. Results and discussion

2.1. Preparation of the zinc nitrone complexes

The reaction of an in situ-formed Reformatsky reagent from the reaction of ethyl 2-bromoacetate and zinc in refluxing THF with nitrones **1**, to our surprise, led to a product, which

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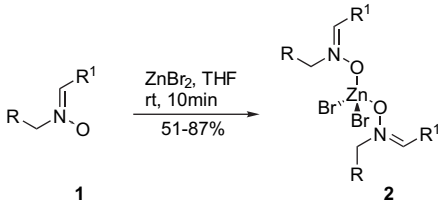
was characterised to be a zinc-nitrone complex **2**. When 1 mol of $ZnBr_2$ was stirred with 2 mol of nitrone **1** in THF for a short time at room temperature, the same zinc-nitrone complex **2** was also readily obtained, upon evaporation of the solvent and trituration of the residue with ether (Scheme 1). Although, the nitrones **1c**,**e**,**f** having electron-withdrawing nitro group on the C-aromatic ring (R^1) formed similar zinc complexes **2** (by observing the resonance shifts of the corresponding benzylic protons in the ^1H NMR spectra of the samples in $CDCl_3$), upon treatment of the residue with ether, the complexes decomposed to the corresponding free nitrones **1c**,**e**,**f**, which were recovered as pure compounds upon crystallisation from ether. This failure may be due to the low basicity of the nitrones **1c**,**e**,**f** caused by the electron-withdrawing groups at the *C*-aryl ring (R^1), which could hence lead to the low stability of the corresponding zinc-nitrone complexes **2c**,**e**,**f**. Therefore, in these cases, the complexes were preformed in benzene using $ZnBr_2$ and 2 equiv of the nitrone. On the other hand, nitrones **1d**,**g**,**h**, in which R^1 is either an alkenyl or aromatic ring with electron-donating groups, gave the corresponding complexes **2d**,**g**,**h** in high yields (78–87%). The resonance of the imine-carbon shifts from ca. 130 ppm in the nitrones to ca. 140 ppm in the complexes (downfield by ca. 10 ppm). On the other hand the *N*-methylenes' hydrogens appear at ca. 5.05 ppm in nitrones and ca. 5.35 ppm in the complexes (approximately 0.3 ppm downfield). A NOESY experiment revealed that the configuration of the ligand is *Z* as is in the starting nitrone.

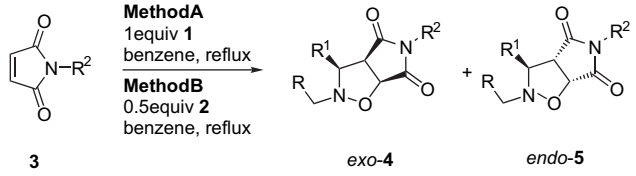


Scheme 1. Syntheses of $ZnBr_2$-nitrone complexes **2** from nitrones **1**. (a) R=R^1=Ph; (b) R=furfuryl, R^1=2-furyl; (c) R=Ph, R^1=2-$NO_2C_6H_4$; (d) R=Ph, R^1=2,3-$(MeO)_2C_6H_3$; (e) R=2,3-$(MeO)_2C_6H_3$, R^1=2-$NO_2C_6H_4$; (f) R=Ph, R^1=3-$NO_2C_6H_4$; (g) R=Ph, R^1=6,6-dimethylbicyclo[3.1.1]-hept-2-en-2-yl; (h) R=2,3-$(MeO)_2C_6H_3$, R^1=2,3-$(MeO)_2C_6H_3$.

2.2. Synthesis of dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-diones from the reaction of nitrones 1 and zinc nitrone complexes 2 with maleimides 3

In our recent work,[6] we have found that the reaction of imidazolin-3-oxides with *N*-arylmaleimides **3** (4 equiv) in solvents such as benzene and toluene proceeded quickly to give 1,4-diaryl- and 1,2,4-triaryl-imidazolin-3-oxides with *endo* selectivity. However, the reaction of nitrones **1a** with *N*-arylmaleimides **3**, under identical conditions, was even faster. The reaction was complete within 3 h, compared to the 10 h and 51 h reaction times for 1,4-diaryl- and 1,2,4-triaryl-imidazolin-3-oxide, respectively.

The cycloaddition of nitrone **1a** and its corresponding $ZnBr_2$ complex **2a** with *N*-arylmaleimides **3a–e** produced the corresponding *exo*-**4** and *endo*-**5** adducts, depending on the substituent effect. A second series of reactions were performed using different substituted nitrones **1f–i** and their corresponding $ZnBr_2$ complexes **2f–i** with *N*-arylmaleimide **3e** (Scheme 2). The yields as well as the *exo*-**4**/*endo*-**5** ratios are presented in Table 1.



Scheme 2. Synthesis of dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-diones.

Nitrone **1a** reacts with *N*-phenylmaleimide **3a** to give the corresponding *exo* and *endo* adducts in equal amounts. The same nitrone and arylmaleimides **3b**,**c** having electron-donating groups react *endo* selectively while with maleimides **3d**,**e** having electron-withdrawing groups gave the corresponding *exo* adducts, which are the predominating products of the cycloadditions (Table 1).

The selectivity in the case of cycloaddition of **1a** with **3a–e** prompted us to assume a π–π stacking complex formations

Table 1. Synthesis of *exo*-**4a–i** and *endo*-**5a–i** both from nitrones **1** and their complexes **2**

Starting nitrone	**3–5**	R	R^1	R^2	*Method*[a] *A*			*Method B*	
					exo-**4**	*endo*-**5**	**4**:**5**[b]	Total yield	**4**:**5**[c]
1a	**a**	Ph	Ph	Ph	**42**[d]	**42**	**1:1**	15[d]	1.3:1
1a	**b**	Ph	Ph	4-$MeOC_6H_4$	33	**54**	1:**1.6**	17	1.2:1
1a	**c**	Ph	Ph	4-MeC_6H_4	36	**50**	1:**1.4**	26	1.3:1
1a	**d**	Ph	Ph	4-ClC_6H_4	**51**	42	**1.2**:1	27	2.1:1
1a	**e**	Ph	Ph	4-$NO_2C_6H_4$	**57**	33	**1.8**:1	60	4.6:1
1b	**f**	2-Furyl	2-Furyl	4-$NO_2C_6H_4$	20	41	1:2.1	0	
1c	**g**	Ph	3-$NO_2C_6H_4$	4-$NO_2C_6H_4$	60	24	2.5:1	42	2:1
1d	**h**	Ph	2,3-$(MeO)_2C_6H_4$	4-$NO_2C_6H_4$	53	30	1.8:1	46	1.8:1
1e	**i**	2,3-$(MeO)_2C_6H_4$	2-$NO_2C_6H_4$	4-$NO_2C_6H_4$	50		5.2:1	45	5.5:1[e]

[a] All reactions were performed at 0.25 mmol scale in 5 mL of benzene.
[b] The ratio of the isolated adducts except for entry **i** where only **4i** was isolated.
[c] The yields and the *exo–endo* ratio were determined by ^1H NMR, as well as by isolation of the products in the case of entry **a**.
[d] The reaction time for entries **a–e**,**h** is 5.5 h and 7.5, 14, 13 h for **f**,**g**,**i**, respectively.
[e] After 3 h, 29%, *exo–endo* 11:1; after 8 h, 43%, *exo–endo* 8:1; after 28 h, 50%, *exo–endo* 3.9:1; and after 52 h, 60%, *exo–endo* 3.2:1.

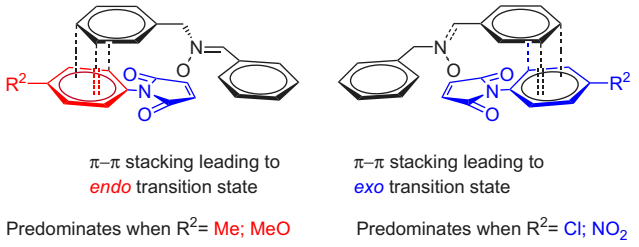


Figure 1. Pre-transition states π–π stacking complexes for *endo* and *exo* adducts.

as shown in Figure 1 where electron rich maleimides couple with the electron poor benzylic phenyl to give the *endo* adduct, while electron poor maleimide's aromatic ring couples with the relatively more electron rich C-aromatic ring to give the corresponding *exo* adducts. A model that considers the σ-framework and the π-electrons of the aromatic rings separately and demonstrates that net favourable π–π interactions are actually the result of π–σ attractions that overcome π–π repulsions is reported.[8a] However, attempts to quantify such interactions are scarcely reported.[8b] The stacking of aromatic rings is one of the most common noncovalent interaction motifs found in both natural and synthetic systems.[9]

To prove the role of π–π stacking in the dipolar cycloadditions, we have performed the cycloaddition of **1a** with **3c** in the presence of equivalent amount of anisole and surprisingly observed that the reaction proceeds nearly with half as fast than in the case without anisole. The *exo–endo* ratio was found to be inversed at the second hour to 1.1:1 and again approaching 1:1.2 after 4.5 h. Addition of 1 equiv of nitrobenzene to the reaction mixture of **1a** and **3a** resulted in the preferred *endo* adduct formation (*exo–endo* ratio was 1:1.2). The cycloadditions of the complexed nitrones proceed slower than the free nitrones. This is probably due to the steric and electronic reasons. The tetrahedral complexes **2** where the coordination is assumed only through the nitrone's oxygen have no sterically preferred side for the approach of the dipolarophile (Scheme 1). However, the experimental results show that the *exo* side is preferred. We assume that the coordination of the electronically poorer benzylic aromatic rings with the electronically enriched metal centre (Fig. 2) enhances the probability for the interaction leading to the *exo* adduct.

Hoping to affect the above mentioned coordination and thus to change the *exo–endo* selectivity of the cycloaddition, we have reacted complex **2a** with maleimide **3c** in the presence of 1 equiv (to the amount of the maleimide) of anisole. The reaction rate was slower than those without anisole, however, the *exo–endo* ratio was seen to decrease. This indicates that anisole stacks much more efficiently with R^1-ring,

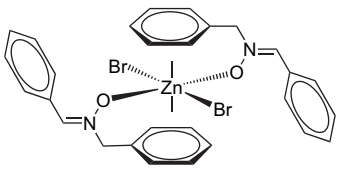


Figure 2. Probable coordination of nitrones **1** with $ZnBr_2$.

which is relatively more electron deficient than in its uncomplexed form to prevent the *exo* attack to some extend. It was clearly demonstrated that the electron-donating groups on R^2-ring decelerated the cycloaddition. It seems that there is an equilibrium interaction between the dipolarophile and the complexes **2** where the dipolarophile probably competes with the *R*-ring to give the corresponding mixed ligand complex, thus, in the cases of maleimides with electron-donating groups the complexes are probably much more stable than in the cases of those with electron-withdrawing groups thus giving rise to lower conversion rate. To prove this hypothesis, we have performed a cycloaddition between complex **2a** and **3c** in the presence of 0.5 equiv (to the amount of the nitrone complex) of $ZnBr_2$. No conversion to any product was observed after long time heating in benzene. This serves as an evidence for the strong coordination of the dipolarophile's and/or the nitrone's aromatic rings with Zn(II). Another type of coordination is expected to accelerate the HOMO–LUMO controlled cycloaddition rather than to decelerate it.

A comparison of the *exo–endo* selectivity of *methods A* and *B* is presented in Figure 3. Independent of the nature of the substituent in all cases the cycloaddition according to *method B* became *exo* selective. In the less effectively coordinating **3e** the *exo–endo* ratio is much higher than in the case of **3a–d**.

The reaction of 4-nitrophenylmaleimide with nitrone **1b** proceeded *endo* selectively, 2:1, while its complex **2b** produced no product after long time heating. Coordination of the *C*-2-furyl ring's oxygen with the metal centre probably hinders the dipole to the attack of the dipolarophile. Nitrone having electron-withdrawing nitro group at the R^1-ring reacted relatively more slowly than those with electron-donating methoxy groups (Table 1, entries g and h). However, the reactions were *exo* selective in both cases independent of the substituents. The *exo* selectivity remained in the same magnitude in the case of the cycloadditions of the complexes of these nitrones. The reaction rates were lowered in lesser degree in the cases of dipolarophiles with electron-withdrawing groups than those with electron-donating groups. The situations here and in the case of nitrone **1e** and complex **2e** (Table 1, entry **i**) seem to be more complicated and could not be explained directly by the interactions of electron rich and poor aromatic rings. The drastically pronounced *exo* selectivity in the latter case, where *o*-nitro

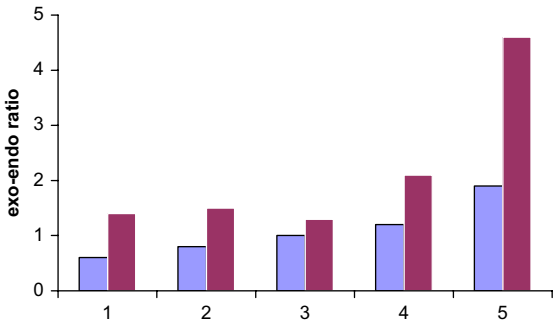


Figure 3. Comparison of the *exo–endo* selectivity in the reactions of **1a** (*method A*, blue) and **2a** (*method B*, red) with **3a–e** at 2 h; 1=MeO; 2=Me; 3=H; 4=Cl; 5=NO_2.

substituted R^1-ring seems to be more preferred than 2,3-dimethoxy substituted *R*-ring for coupling with the electronically poorer 4-nitro substituted R^2-ring of the maleimide, implies the presence of other types of interactions between the aromatic rings beside the generally considered face to face and face to edge (CH to π) ones.

2.3. Stereochemical elucidation of adducts 4 and 5

Some characteristic assignments for adducts **4** and **5** based on 1D and 2D NMR experiments are given in Table 2.

All discussions on the *exo–endo* selectivity of the cycloaddition reaction between nitrones **1** and maleimides **3** are based on the assumption that all of the nitrones **1** studied have *Z* configuration.[10]

The *exo* stereochemistry of adducts **4a–i** was based on the NOESY 1D experiments performed on compound **4f** (Fig. 4) as follows:

Irradiation of the proton on the C6a enhanced only the proton signal of C3a by 1.3%, whereas irradiation of the proton on C3a not only enhanced the proton signal of C6a, but also the proton signal of C3, by 3.8% and 4.4%, respectively. This clearly proves that the protons on C3, C3a and C6a are at the same side of the isoxazolidine ring, thus the adduct **4f** has *exo* configuration. The energy minimised conformations of compounds **4f** and **5f** (Figs. 4 and 5) also support the observed correlations by NOESY 1D experiments.

The elemental analyses data for compounds *endo*-**5** show that they are isomeric with the corresponding *exo*-**4**. The ^{1}H NMR spectra of the compounds show an AB system for the benzylic hydrogens (Table 2, NCH_2) at around 3.80, which is approximately 0.3 ppm shifted high-field with characteristic broadening for one of the protons. This may be due to the electron charge developed at C3 position. The proton at C-3 appears as a broad singlet 0.4 ppm downfield in comparison with the analogous proton of *exo*-**4**. The analogous benzylic (NCH_2) and C3 protons for *exo*-**4** compounds, however, showed approximately 0.3 ppm low-field and 0.2 ppm high-field shifts, thus appearing at around 4.09 and 3.83 ppm, respectively. Surprisingly, on treating the $CDCl_3$ or DMSO-d_6 solution of *endo*-**5** compounds with D_2O, the broad proton signal at C3 did not disappear. Moreover, the HMQC spectrum of *endo*-**5f** compound

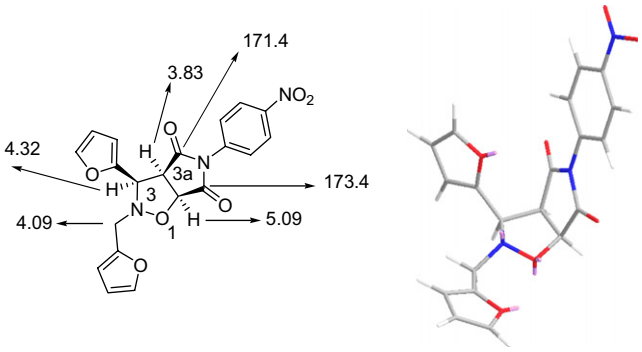


Figure 4. Some selected assignments for *exo*-**4f** and its energy minimised 3D model.

clearly revealed that this broad signal belongs to the proton at C3. The doublets of C6aH and C3aH protons at 5.15 and 4.0 ppm, respectively, with coupling constant ca. 7 Hz are not very much affected by the change in the *endo* adduct. There is only one carbonyl peak in the ^{13}C NMR spectra of *endo*-**5** compounds. This may provide another evidence for a serious intra-molecular compression in the *endo* adducts, which could lead to homolytic splitting of the π bond of the C4-carbonyl giving rise to a resonance-stabilised radical. The di-radical character of the adducts could also stem from the transition state, which would have paramagnetic character due to the presence of excited nitrone or maleimide at ambient light.[11]

The paramagnetic character of *endo*-**5** is reflected in their ^{13}C NMR spectra where the peaks for the C4 carbonyl carbons are not seen at all. The other carbons affected by the oxyl radical at C4 are generally broadened and in many cases (except **5f**) not seen. Peak broadenings are also seen in the aromatic carbon regions of *endo*-**5** compounds. The HMBC spectra of the compounds show that C3aH and C6aH are each correlating with the C═O at the C6. Finally, the NOESY 1D experiment confirmed the proposed stereochemistry in Figure 5 as detailed below. Irradiation of the proton signal at C6a enhanced the proton signal of C3a (3.20%). The irradiation of the proton signal at C3a not only enhanced the proton signal of C6aH, but also the proton signal of the 2-furyl ring at C3 by 11% and 4%, respectively. The irradiation of the broad singlet observed for C3H enhanced the signal of the same 2-furyl ring proton by 2%. TOCSY 1D experiment performed for

Table 2. Characteristic NMR data for compounds[a] *exo*-**4** and *endo*-**5**

4–5	*exo*-**4**						*endo*-**5**					
	NCH_2	C3H	C3aH	C6aH	C4	C6	NCH_2	C3H	C3aH	C6aH	C4[b]	C6
a	4.05	4.19	3.82	5.04	172.2	174.6	3.86	4.48	3.90	5.13		174.5
b	4.03	4.19	3.82	5.05	172.2	174.6	3.81	4.42	3.86	5.09		174.5
c	4.03	4.19	3.82	5.05	172.1	174.5	3.81	4.43	3.86	5.09		174.6
d	4.03	4.20	3.82	5.06	171.7	174.1	3.81	4.43	3.86	5.10		174.6
e	4.05	4.23	3.88	5.09	171.3	173.7	3.80	4.47	3.90	5.14		173.8
f	4.09	4.32	3.83	5.09	171.4	173.4	3.80	4.77	4.03	5.15		173.5
g	4.07	4.30	3.94	5.14	171.1	173.2	3.86	4.56	3.91	5.21		173.2
h	4.06	4.60	3.95	5.09	171.3	173.8	3.82	5.01	3.99	5.12		174.0
i	4.02	4.77	4.42	5.12	171.4	173.6						

[a] The 1D and 2D NMR experiments were performed in $CDCl_3$ at ambient temperature.
[b] The C4 carbonyl as well as those affected by the free radical atoms are not seen due to paramagnetic broadenings.

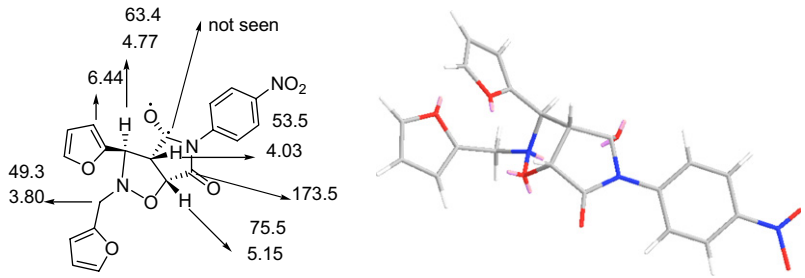


Figure 5. Some selected chemical shifts assignments for *endo*-**5f** and its energy minimised 3D model.

compound **5g** revealed that protons at C3, C3a and C6a are in the same spin system. HOMODEC experiment involving the irradiation of the broad singlet observed for C3H led to the transformation of the doublet of doublet for C3aH to a doublet (7.2 Hz as is the doublet of C6aH).

Adducts **4a** and **5a** were heated in solvents such as $CHCl_3$, benzene, toluene and xylene, for a long period of time, but no conversion to each other was observed. Direct heating of these adducts near their melting points led to the formation of corresponding nitrone and maleimide. Attempts to take their mass spectra again resulted in their fragmentation to the corresponding nitrones and maleimides. Adduct **5f** was also refluxed in THF for 10 h in the presence of $ZnBr_2$ but no conversion was observed. Adduct **5a** was refluxed in diethylamine for 3 h to give the corresponding *endo*-2-benzyl-N^5,N^5-diethyl-N^4,3-diphenylisoxazolidine-4,5-dicarboxamide **6a** in high yield (66%). The regio- and stereochemistry of the latter was easily deduced from its IR and NMR spectral data and a comparison with a similar ring opening product is given in Figure 6. The NOESY 1D experiments have also confirmed the assigned regio- and stereochemistry of the product. The irradiation of the amide hydrogen at 8.54 ppm enhanced the signal of the proton at 3.64 ppm by 1.40%, and the *ortho* protons signal at 7.45 ppm by 4.3%. The irradiation of the proton at 3.64 ppm enhanced the signals of protons at 4.93 and 8.54 ppm by 3.5% and 1.8%, respectively. The irradiation of the proton signal at C3 at 4.50 ppm only led to the enhancement of the proton signals for the C3-aromatic ring and the benzylic NCH_2 by 5.3% and 3.4%, respectively. And finally the irradiation of the proton signal at C5 enhanced the proton signal at C4 by 4.4%. This unequivocally proves the structure to be the product from the ring opening of corresponding *endo* adduct at the C6 carbonyl carbon.

In this case, the broad singlet appears as a clear doublet at 4.50 ppm in ^{1}H NMR and the second C═O peak was observed in ^{13}C NMR spectrum. The regioselectivity of the ring opening of *endo*-**5** compounds with diethylamine appears to be very similar to those of the previous adducts obtained from the imidazolin-3-oxides and maleimides. Refluxing compounds **4a** and **5a** in triethylamine did not induce any reaction. The inspection of the reaction mixture of *exo* adduct **4a** with diethylamine after 3 h did not reveal any of the deoxygenation product, instead two regioisomeric ring opening products and unreacted adduct **4a** were present.

3. Conclusions

We report herein the synthesis of a new class of compounds, namely *exo* and *endo*-2-benzyl-3,5-diphenyl-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-diones from the reaction of acyclic nitrones **1** or their complexes with $ZnBr_2$ **2** with *N*-arylmaleimides. The substituent effect on the *exo*–*endo* selectivity of the cycloaddition process without and in the presence of a Lewis acid was investigated and the *exo*–*endo* selectivity was shown to be a substituent dependant process. The competition of the π–π stackings of the aromatic rings of *N*-arylmaleimide and the aromatic rings of the nitrones is discussed as a reason for the observed selectivity. Unprecedented paramagnetic character of the *endo*-**5** adducts is also reported. Retrocycloaddition of the cycloadducts produce the corresponding nitrones and maleimides. The ring opening of the *exo* and *endo* adducts in the presence of secondary amines did not induce imine

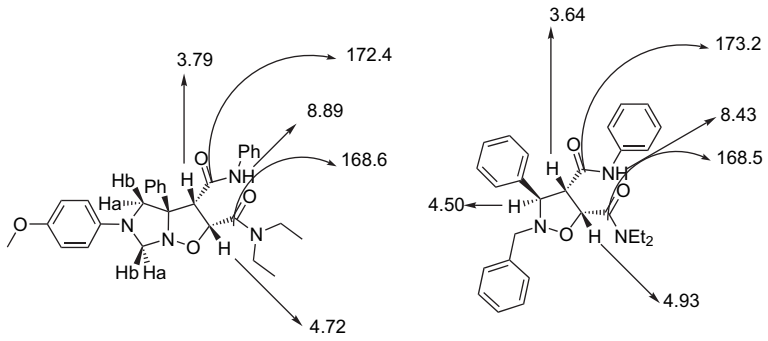


Figure 6. Some characteristic NMR assignments for compound **6a**.

formation instead gives the corresponding amides. Tertiary amines did not induce any reaction.

4. Experimental

4.1. General

Melting points were recorded on an Electrothermal Digital melting point apparatus. Infrared spectra were recorded on a Mattson 1000 FTIR. 1D and 2D NMR experiments were performed on a Varian Mercury Plus 400 MHz spectrometer. Visualisation was effected with UV light. Starting nitrones were prepared according to a method we have recently reported.[12] The maleimides used were prepared according to a new method, which will be reported elsewhere. The elemental analyses were performed on an EuroEA 3000 CHNS analyser. The magnetic susceptibilities of **1a**, **3a**, **4a** and **5a** were measured on Sherwood Scientific Magnetic susceptibility balance. The 3D modelling studies for *exo* and *endo* were performed using CS MOPAC Pro in Chem Office 8.

4.1.1. Furan-2-yl-*N*-(furan-2-ylmethylene)methanamine *N*-oxide 1b. Prepared according to a literature procedure.[12] Yield 1.05 g, 55%; white powder; mp 106–108 °C; IR (KBr) $\nu_{C=N}$ 1595 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 5.03 (2H, s), 6.42–6.57 (3H, m), 7.44–7.47 (3H, m), 7.76 (1H, d, J=3.6); ^{13}C NMR (100 MHz, $CDCl_3$): δ 61.8, 111.3, 112.6, 112.7, 115.8, 125.2, 144.1, 144.3, 146.2, 146.9. Anal. Calcd for $C_{10}H_9NO_3$ (191.18): C, 62.82; H, 4.74; N, 7.33. Found: C, 62.50; H, 4.80; N, 7.25.

4.1.2. *N*-((6,6-Dimethylbicyclo[3.1.1]hept-2-en-2-yl)-methylene)(phenyl)methanamine *N*-oxide 1g. Prepared according to a literature procedure.[12] Yield 0.31 g, 12%; white powder; mp 131–133 °C; IR (KBr) $\nu_{C=N}$ 1585 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 0.84 (3H, s), 1.23 (1H, d, J=9.6), 1.29 (3H, s), 1.63 (1H, s), 2.12–2.23 (1H, m), 2.40–2.56 (3H, m), 4.90 (2H, s), 6.65 (1H, s), 7.27–7.44 (5H, m), 7.75 (1H, s); ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.2, 26.1, 31.5, 32.7, 37.8, 40.3, 46.3, 70.4, 82.6, 128.7, 128.9, 129.1, 131.8, 133.5, 137.4. Anal. Calcd for $C_{17}H_{21}NO$ (255.35): C, 79.96; H, 8.29; N, 5.49. Found: C, 79.90; H, 8.15; N, 5.40.

4.2. Synthesis of Zn(II) nitrone complexes: general procedure

To a solution of $ZnBr_2$ (1 mmol, 0.225 g) in THF (8 mL) was added nitrone (2 mmol) and the reaction mixture was stirred under nitrogen atmosphere at room temperature for 30 min. The solvent was evaporated under reduced pressure and the residue was treated with ether to give a white powder.

4.2.1. Benzyl-benzylidene-amine oxide $ZnBr_2$ complex 2a. Yield 0.243 g, 74%; white powder; mp 165–168 °C; IR (KBr) $\nu_{C=N}$ 1628 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 5.34 (2H, s), 7.38–7.54 (9H, m), 8.22 (2H, d, J=7.6); ^{13}C NMR (100 MHz, $CDCl_3$): δ 70.1, 128.1, 129.1, 129.6, 129.9, 130.6, 131.6, 131.9, 133.5, 144.1. Anal. Calcd for $C_{28}H_{26}Br_2N_2O_2Zn$ (647.72): C, 51.92; H, 4.05; N, 4.32. Found: C, 51.63; H, 4.10; N, 4.25.

4.2.2. Furan-2-yl-*N*-(furan-2-ylmethylene)methanamine oxide $ZnBr_2$ complex 2b. Yield 0.155 g, 51%; white powder; mp 124–126 °C; IR (KBr) $\nu_{C=N}$ 1632 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 5.34 (2H, s), 6.45 (1H, dd, J=3.2, 1.6), 6.62–6.63 (1H, m), 6.73 (1H, d, J=2.4), 7.51 (1H, t, J=0.8), 7.54 (1H, s), 7.60 (1H, d, J=1.2), 8.14 (1H, d, J=3.6); ^{13}C NMR (100 MHz, $CDCl_3$): δ 60.7, 111.6, 114.05, 114.5, 123.2, 133.2, 144.5, 144.8, 144.9, 147.4. Anal. Calcd for $C_{20}H_{18}Br_2N_2O_6Zn$ (607.56): C, 39.54; H, 2.99; N, 4.61. Found: C, 39.51; H, 2.95; N, 4.65.

4.2.3. *N*-(2,3-Dimethoxybenzylidene)(phenyl)methanamine oxide $ZnBr_2$ complex 2d. Yield 0.299 g, 78%; white powder; mp 85–87 °C; IR (KBr) $\nu_{C=N}$ 1618 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.73 (3H, s), 3.83 (3H, s), 5.31 (2H, s), 7.04 (2H, d, J=4.8), 7.42 (3H, d, J=2.8), 7.53 (2H, s), 7.93 (1H, s), 8.63 (1H, t, J=4.4); ^{13}C NMR (100 MHz, $CDCl_3$): δ 56.2, 62.2, 70.4, 117.8, 122.5, 123.4, 124.8, 129.4, 129.8, 130.5, 131.9, 139.8, 149.7, 152.2. Anal. Calcd for $C_{32}H_{34}Br_2N_2O_6Zn$ (767.82): C, 50.06; H, 4.46; N, 3.65. Found: C, 50.43; H, 4.50; N, 3.58.

4.2.4. *N*-((6,6-Dimethylbicyclo[3.1.1]hept-2-en-2-yl)-methylene)(phenyl)methanamine oxide $ZnBr_2$ complex 2g. Yield 0.294 g, 80%; white powder; mp 141–143 °C; IR (KBr) $\nu_{C=N}$ 1602 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 0.83 (3H, s), 1.21 (1H, d, J=9.6), 1.27 (3H, s), 2.07 (1H, s), 2.43 (1H, s), 2.49 (3H, d, J=11.6), 5.08 (2H, s), 6.73 (1H, s), 7.38 (3H, s), 7.45 (2H, s), 7.63 (1H, s); ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.6, 26.1, 31.7, 33.7, 38.0, 40.1, 45.7, 69.5, 129.3, 128.5, 130.2, 132.3, 137.8, 141.7. Anal. Calcd for $C_{34}H_{42}Br_2N_2O_2Zn$ (735.91): C, 55.49; H, 5.75; N, 3.81. Found: C, 55.31; H, 5.80; N, 3.73.

4.2.5. *N*-(2,3-Dimethoxybenzylidene)(2,3-dimethoxyphenyl)methanamine oxide $ZnBr_2$ complex 2h. Yield 0.386 g, 87%; white powder; mp 130–133 °C; IR (KBr) $\nu_{C=N}$ 1625 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.78 (3H, s), 3.83 (3H, s), 3.86 (3H, s), 3.87 (3H, s), 5.35 (2H, s), 6.97–7.09 (4H, m), 7.27 (1H, s), 8.04 (1H, s), 8.63 (1H, dd, J=6.4, 3.6); ^{13}C NMR (100 MHz, $CDCl_3$): δ 56.1, 56.2, 61.3, 62.3, 65.5, 114.4, 117.4, 122.7, 123.4, 124.4, 124.7, 124.8, 125.8, 139.4, 148.1, 149.6, 152.1, 152.8. Anal. Calcd for $C_{36}H_{42}Br_2N_2O_{10}Zn$ (887.92): C, 48.70; H, 4.77; N, 3.15. Found: C, 48.51; H, 4.83; N, 3.10.

4.3. Synthesis of dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-diones 4a–i: general procedure

Method A: to a solution of acyclic nitrone **1** (0.25 mmol) in benzene (5 mL), *N*-arylmaleimide (0.25 mmol) was added and the reaction mixture was stirred at reflux for the specified times (Table 1). The solvent was evaporated and the residue was subjected to silica gel packed column and eluted with petroleum ether–ethyl acetate mixture. The *endo* and *exo* isomers were crystallised from ether and ether–ethanol mixture, respectively.

Method B: to a solution of nitrone $ZnBr_2$ complex **2** (0.25 mmol) in benzene (5 mL), *N*-arylmaleimide (0.5 mmol) was added and the reaction mixture was stirred at reflux for the specified times (Table 1). The solvent was evaporated and the residue was subjected to silica gel packed column

and eluted with petroleum ether–ethyl acetate mixture. The *endo* and *exo* isomers **4a** and **5a** were crystallised from ether and ether–ethanol mixture, respectively.

4.3.1. *exo*-2-Benzyl-3,5-diphenyl-dihydro-2*H*-pyrrolo-[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 4a. (See Table 1 for the yields of *exo* and *endo* adducts.) White needles; mp 154–155 °C; IR (KBr) $\nu_{C=O}$ 1719 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.83 (1H, d, J=15.2, NCH_2), 3.84 (1H, dd, J=9.2, 7.6, 3aH), 4.19 (1H, d, J=8.9, C3H), 4.23 (1H, d, J=15.2, NCH_2), 5.04 (1H, d, J=7.4, 6aH), 7.23–7.47 (15H, m); ^{13}C NMR (100 MHz, $CDCl_3$): δ 54.1, 58.4, 72.4, 76.8, 126.2, 127.7, 128.0, 128.6, 128.7, 128.9, 129.2, 129.3, 129.4, 131.6, 133.8, 135.8, 172.2, 174.6. MS *m*/*z* 211 (M^+) of the nitrone. Anal. Calcd for $C_{24}H_{20}N_2O_3$ (384.43): C, 74.98; H, 5.24; N, 7.29. Found: C, 75.12; H, 5.23; N, 7.27.

4.3.2. *exo*-2-Benzyl-5-(4-methoxyphenyl)-3-phenyl-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 4b. White needles; mp 171–173 °C; IR (KBr) $\nu_{C=O}$ 1716 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.81 (3H, s), 3.82 (1H, t, J=8.6, 3aH), 3.83 (1H, d, J=15.2, NCH_2), 4.19 (1H, d, J=8.8, C3H), 4.23 (1H, d, J=15.2, NCH_2), 5.05 (1H, d, J=7.2, 6aH), 6.95 (2H,d, J=9.2), 7.16 (2H, d, J=9.2), 7.23–7.38 (10H, m); ^{13}C NMR (100 MHz, $CDCl_3$): δ 53.8, 55.5, 58.0, 72.1, 76.8, 114.5, 127.2, 127.4, 127.8, 128.3, 128.5, 128.1, 129.1, 133.6, 135.6, 159.5, 172.2, 174.6. Anal. Calcd for $C_{25}H_{22}N_2O_4$ (414.45): C, 72.45; H, 5.35; N, 6.76. Found: C, 72.40; H, 5.30; N, 6.70.

4.3.3. *exo*-2-Benzyl-3-phenyl-5-*p*-tolyl-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 4c. White needles; mp 147–150 °C; IR (KBr) $\nu_{C=O}$ 1716 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 2.36 (3H, s), 3.82 (1H, dd, J=8.8, 7.2, 3aH), 3.84 (1H, d, J=16.0, NCH_2), 4.23 (1H, d, J=16.0, NCH_2), 4.19 (1H, d, J=8.8, C3H), 5.05 (1H, d, J=7.2, 6aH), 7.12 (2H, d, J=8.8), 7.23–7.38 (12H, m); ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.3, 53.9, 58.0, 72.1, 76.5, 125.7, 127.4, 127.8, 128.3, 128.5, 128.7, 129.0, 129.1, 129.8, 133.6, 135.6, 138.8, 172.1, 174.5. Anal. Calcd for $C_{25}H_{22}N_2O_3$ (398.45): C, 75.36; H, 5.57; N, 7.03. Found: C, 75.30; H, 5.60; N, 7.02.

4.3.4. *exo*-2-Benzyl-5-(4-chlorophenyl)-3-phenyl-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 4d. White needles; mp 174–175 °C; IR (KBr) $\nu_{C=O}$ 1720 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.82 (1H, dd, J=8.8, 7.2, 3aH), 3.84 (1H, d, J=15.2, NCH_2), 4.20 (1H, d, J=8.8, C3H), 4.24 (1H, d, J=15.2, NCH_2), 5.06 (1H, d, J=7.2, 6aH), 7.20–7.42 (14H, m); ^{13}C NMR (100 MHz, $CDCl_3$): δ 53.8, 58.0, 72.0, 76.4, 127.1, 127.4, 127.7, 128.3, 128.5, 129.1, 129.2, 129.4, 129.7, 133.4, 134.4, 135.4, 171.7, 174.1. Anal. Calcd for $C_{24}H_{19}ClN_2O_3$ (418.87): C, 68.82; H, 4.57; N, 6.69. Found: C, 68.75; H, 4.60; N, 6.75.

4.3.5. *exo*-2-Benzyl-5-(4-nitrophenyl)-3-phenyl-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 4e. Recrystallised from ether; white crystals; mp 166–168 °C; IR (KBr) $\nu_{C=O}$ 1721 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.85 (1H, d, J=15.2, NCH_2), 3.88 (1H, dd, J=9.2, 7.6, 3aH), 4.23 (1H, d, J=15.2, NCH_2), 4.23 (1H, d, J=9.2, C3H), 5.09 (1H, d, J=7.6, 6aH), 7.25–7.41 (10H, m), 7.51 (2H, d, J=9.6), 8.30 (2H, d, J=9.6); ^{13}C NMR (100 MHz, $CDCl_3$): δ 53.9, 58.1, 72.1, 76.4, 124.5, 126.4, 128.0, 127.6, 128.4, 128.6, 129.2, 129.4, 133.3, 135.2, 136.7, 146.9, 171.3, 173.7. MS *m*/*z* 211 (M^+) of the nitrone. Anal. Calcd for $C_{24}H_{19}N_3O_5$ (429.42): C, 67.13; H, 4.46; N, 9.79. Found: C, 67.05; H, 4.54; N, 9.80.

4.3.6. *exo*-3-(Furan-2-yl)-2-(furan-2-ylmethyl)-5-(4-nitrophenyl)-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 4f. From ethanol–ether; white crystals; mp 161–163 °C; IR (KBr) $\nu_{C=O}$ 1727 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.83 (1H, t, J=8.0, 3aH), 3.89 (1H, d, J=15.6, NCH_2), 4.27 (1H, d, J=15.2, NCH_2), 4.32 (1H, d, J=8.0, C3H), 5.09 (1H, d, J=8.0, 6aH), 6.30 (1H, d, J=2.8), 6.35 (1H, d, J=2.8), 6.40–6.42 (2H, m), 7.38 (1H, br s), 7.46 (1H, br s), 7.59 (2H, d, J=9.2), 8.33 (2H, d, J=9.2); ^{13}C NMR (100 MHz, $CDCl_3$): δ 50.0, 52.0, 64.8, 76.3, 110.5, 110.6, 110.8, 124.5, 126.7, 136.8, 142.7, 143.9, 145.6, 147.1, 148.8, 171.4, 173.4. MS *m*/*z* 191 (M^+) of the nitrone. Anal. Calcd for $C_{20}H_{15}N_3O_7$ (409.35): C, 58.68; H, 3.69; N, 10.27. Found: C, 58.60; H, 3.64; N, 10.35.

4.3.7. *exo*-2-Benzyl-3-(3-nitrophenyl)-5-(4-nitrophenyl)-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 4g. Ether–ethanol (1:4); white crystals; mp 115–117 °C; IR (KBr) $\nu_{C=O}$ 1727 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.92 (1H, d, J=14.8, NCH_2), 3.94 (1H, t, J=8.0, 3aH), 3.84 (1H, d, J=14.8, NCH_2), 4.30 (1H, d, J=8.0, C3H), 5.14 (1H, d, J=8.0, 6aH), 7.20–7.33 (5H, m), 7.50–7.65 (4H, m), 8.19–8.22 (2H, m), 8.32 (2H, d, J=9.2); ^{13}C NMR (100 MHz, $CDCl_3$): δ 54.0, 58.4, 70.9, 76.2, 122.7, 124.3, 124.6, 126.6, 127.9, 128.5, 128.9, 130.2, 133.9, 134.1, 135.7, 136.3, 147.2, 148.5, 171.1, 173.2. MS *m*/*z* 256 (M^+) of the nitrone. Anal. Calcd for $C_{24}H_{18}N_4O_7$ (474.42): C, 60.76; H, 3.82; N, 11.81. Found: C, 60.80; H, 3.88; N, 11.90.

4.3.8. *exo*-2-Benzyl-3-(2,3-dimethoxyphenyl)-5-(4-nitrophenyl)-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 4h. Ether–ethanol (1:4); white crystals; mp 90–92 °C; IR (KBr) $\nu_{C=O}$ 1727 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.85 (1H, d, J=15.6, NCH_2), 3.90 (3H, s), 3.95 (1H, dd, J=8.8, 7.2, 3aH), 3.99 (3H, s), 3.85 (1H, d, J=15.6, NCH_2), 4.60 (1H, d, J=8.8, C3H), 5.09 (1H, d, J=7.2, 6aH), 6.88–6.94 (2H, m), 7.02 (1H, t, J=7.6), 7.28–7.33 (5H, m), 7.43 (2H, d, J=8.8), 8.27 (2H, d, J=8.8); ^{13}C NMR (100 MHz, $CDCl_3$): δ 52.5, 55.7, 58.4, 60.9, 66.2, 76.4, 112.8, 117.5, 124.3, 124.4, 124.5, 126.5, 127.3, 127.5, 128.4, 135.6, 136.7, 146.9, 147.5, 152.7, 171.3, 173.8. MS *m*/*z* 271 (M^+) of the nitrone. Anal. Calcd for $C_{26}H_{23}N_3O_7$ (489.48): C, 63.80; H, 4.74; N, 8.58. Found: C, 63.68; H, 4.73; N, 8.65.

4.3.9. *exo*-2-(2,3-Dimethoxybenzyl)-3-(2-nitrophenyl)-5-(4-nitrophenyl)-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 4i. Ether–ethanol (1:4); white crystals; mp 212–214 °C; IR (KBr) $\nu_{C=O}$ 1723 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.60 (3H, s), 3.82 (3H, s), 3.90 (1H, d, J=15.6, NCH_2), 4.14 (1H, d, J=15.6, NCH_2), 4.42 (1H, dd, J=8.4, 8.0, 3aH), 4.77 (1H, d, J=8.4, C3H), 5.12 (1H, d, J=8.0, 6aH), 6.82–6.86 (1H, m), 7.0–7.05 (2H, m), 7.43 (2H, d, J=9.2), 7.48–7.60 (2H, m), 7.72–7.75 (1H, m), 8.17–8.20 (1H, m), 8.26 (2H, d, J=9.2); ^{13}C NMR (100 MHz, $CDCl_3$): δ 53.0, 53.6, 55.9, 60.2, 68.4, 76.0,

112.5, 122.6, 124.0, 124.5, 125.7, 126.4, 127.9, 128.3, 129.5, 130.7, 133.8, 136.5, 147.0, 147.2, 149.1, 152.4, 171.4, 173.6. MS *m/z* 316 (M^+) of the nitrone. Anal. Calcd for $C_{26}H_{22}N_4O_9$ (534.47): C, 58.43; H, 4.15; N, 10.48. Found: C, 58.60; H, 4.09; N, 10.40.

4.4. Synthesis of *endo* dihydro-2*H*-pyrrolo[3,4-*d*]-isoxazole-4,6(5*H*,6a*H*)-diones 5a–e

4.4.1. *endo*-2-Benzyl-3,5-diphenyl-dihydro-2*H*-pyrrolo-[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 5a. White needles; mp 164–165 °C; IR (KBr) $\nu_{C=O}$ 1713 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.76 (1H, d, *J*=14.4, NCH_2), 3.90 (1H, dd, *J*=8.0, 3.6, 3aH), 3.96 (1H, d, *J*=14.4, NCH_2), 4.48 (1H, br s, C3H), 5.13 (1H, d, *J*=7.4, 6aH), 7.23–7.6 (15H, m); ^{13}C NMR (100 MHz, $CDCl_3$): δ 56.8, 71.3, 75.9, 76.8, 125.0, 126.4, 127.5, 128.4, 128.5, 128.8, 128.9, 129.0, 129.3, 131.3, 136.0, 174.5. MS *m/z* 211 (M^+) of the nitrone. Anal. Calcd for $C_{24}H_{20}N_2O_3$ (384.43): C, 74.98; H, 5.24; N, 7.29. Found: C, 74.90; H, 5.20; N, 7.20.

4.4.2. *endo*-2-Benzyl-5-(4-methoxyphenyl)-3-phenyl-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 5b. White needles; mp 159–161 °C; IR (KBr) $\nu_{C=O}$ 1727 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.76 (1H, d, *J*=13.2, NCH_2), 3.84 (3H, s), 3.86 (1H, dd, *J*=7.2, 2.8, 3aH), 3.90 (1H, d, *J*=13.2, NCH_2), 4.42 (1H, br s, C3H), 5.09 (1H, d, *J*=7.2, 6aH), 7.01 (2H, d, *J*=8.8), 7.21–7.45 (12H, m); ^{13}C NMR (100 MHz, $CDCl_3$): δ 55.6, 75.9, 114.5, 114.6, 123.9, 127.5, 127.6, 128.4, 128.8, 128.9, 134.2, 136.1, 159.8, 174.5. Anal. Calcd for $C_{25}H_{22}N_2O_4$ (414.45): C, 72.45; H, 5.35; N, 6.76. Found: C, 72.50; H, 5.40; N, 6.70.

4.4.3. *endo*-2-Benzyl-3-phenyl-5-*p*-tolyl-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 5c. White needles; mp 123–125 °C; IR (KBr) $\nu_{C=O}$ 1727 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 2.41 (3H, s), 3.73 (1H, d, *J*=14.0, NCH_2), 3.86 (1H, dd, *J*=7.2, 3.2, 3aH), 3.91 (1H, d, *J*=14.0, NCH_2), 4.43 (1H, br s, C3H), 5.09 (1H, d, *J*=7.2, 6aH), 7.21–7.45 (14H, m); ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.3, 56.8, 71.2, 76.0, 126.1, 127.5, 128.3, 128.4, 128.7, 128.8, 128.9, 130.0, 136.1, 139.2, 174.6. Anal. Calcd for $C_{25}H_{22}N_2O_3$ (398.45): C, 75.36; H, 5.57; N, 7.03. Found: C, 75.70; H, 5.70; N, 7.00.

4.4.4. *endo*-2-Benzyl-5-(4-chlorophenyl)-3-phenyl-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 5d. White needles; mp 180–182 °C; IR (KBr) $\nu_{C=O}$ 1715 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.70 (1H, d, *J*=13.2, NCH_2), 3.86 (1H, dd, *J*=7.2, 3.2, 3aH), 3.90 (1H, d, *J*=13.2, NCH_2), 4.43 (1H, br s, C3H), 5.10 (1H, d, *J*=7.2, 6aH), 7.17–7.50 (14H, m); ^{13}C NMR (100 MHz, $CDCl_3$): δ 56.8, 72.2, 75.9, 127.6, 128.4, 128.9, 129.0, 129.5, 129.8, 134.8, 136.0. Anal. Calcd for $C_{24}H_{19}ClN_2O_3$ (418.87): C, 68.82; H, 4.57; N, 6.69. Found: C, 68.60; H, 4.50; N, 6.60.

4.4.5. *endo*-2-Benzyl-5-(4-nitrophenyl)-3-phenyl-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 5e. From ether; white crystals; mp 176–178 °C; IR (KBr) $\nu_{C=O}$ 1718 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.70 (1H, d, *J*=14.0, NCH_2), 3.90 (1H, dd, *J*=7.6, 3.2 3aH), 3.91 (1H, d, *J*=14.0, NCH_2), 4.47 (1H, br s, C3H), 5.14 (1H, d, *J*=7.2, 6aH), 7.18–7.44 (10H, m), 7.65 (2H, d, *J*=8.8), 8.35 (2H, d, *J*=8.8); ^{13}C NMR (100 MHz, $CDCl_3$): δ 56.8, 71.2, 75.8, 124.6, 126.9, 127.6, 128.4, 129.1, 135.9, 136.8, 147.2. MS *m/z* 211 (M^+) of the nitrone. Anal. Calcd for $C_{24}H_{19}N_3O_5$ (429.42): C, 67.13; H, 4.46; N, 9.79. Found: C, 67.14; H, 4.43; N, 9.70.

4.4.6. *endo*-3-(Furan-2-yl)-2-(furan-2-ylmethyl)-5-(4-nitrophenyl)-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 5f. From ether; white crystals; mp 128–130 °C; IR (KBr) $\nu_{C=O}$ 1726 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.71 (1H, d, *J*=14.4, NCH_2), 3.88 (1H, d, *J*=14.4, NCH_2), 4.03 (1H, d, *J*=7.2, 3aH), 4.77 (1H, br s, C3H), 5.15 (1H, d, *J*=7.2, 6aH), 6.20 (1H, d, *J*=2.8), 6.30–6.32 (1H, m) 6.40–6.46 (2H, m), 7.34 (1H, br s), 7.50 (1H, br s), 7.61 (2H, d, *J*=9.2), 8.34 (2H, d, *J*=9.2); ^{13}C NMR (100 MHz, $CDCl_3$): δ 49.3, 53.5, 63.4, 75.5, 77.2, 109.0, 110.5, 110.6, 111.4, 124.5, 126.9, 136.8, 142.4, 143.6, 147.2, 148.0, 149.1, 173.5. MS *m/z* 191 (M^+) of the nitrone. Anal. Calcd for $C_{20}H_{15}N_3O_7$ (409.35): C, 58.68; H, 3.69; N, 10.27. Found: C, 58.63; H, 3.80; N, 10.20.

4.4.7. *endo*-2-Benzyl-3-(3-nitrophenyl)-5-(4-nitrophenyl)-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 5g. From ether; white crystals; mp 188–192 °C; IR (KBr) $\nu_{C=O}$ 1729 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.75 (1H, d, *J*=13.6, NCH_2), 3.91 (1H, dd, *J*=7.6, 3.2, 3aH), 3.95 (1H, d, *J*=13.6, NCH_2), 4.56 (1H, br s, C3H), 5.21 (1H, d, *J*=7.6, 6aH), 7.14–7.18 (2H, m), 7.27–7.32 (3H, m), 7.63–7.67 (4H, m), 8.22–8.28 (2H, m), 8.39 (2H, d, *J*=9.2); ^{13}C NMR (100 MHz, $CDCl_3$): δ 56.2, 71.0, 75.8, 123.2, 123.9, 124.6, 126.8, 128.1, 128.5, 128.6, 130.2, 134.5, 134.8, 136.5, 147.3, 148.5, 173.2. MS *m/z* 256 (M^+) of the nitrone. Anal. Calcd for $C_{24}H_{18}N_4O_7$ (474.42): C, 60.76; H, 3.82; N, 11.81. Found: C, 60.85; H, 3.90; N, 11.60.

4.4.8. *endo*-2-Benzyl-3-(2,3-dimethoxyphenyl)-5-(4-nitrophenyl)-dihydro-2*H*-pyrrolo[3,4-*d*]isoxazole-4,6(5*H*,6a*H*)-dione 5h. From ether; white crystals; mp 176–177 °C; IR (KBr) $\nu_{C=O}$ 1729 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 3.73 (1H, d, *J*=14.4, NCH_2), 3.87 (3H, s), 3.91 (3H, s), 3.99 (1H, dd, *J*=7.2, 2.8, 3aH), 3.94 (1H, d, *J*=13.6, NCH_2), 5.01 (1H, br s, C3H), 5.12 (1H, d, *J*=7.2, 6aH), 6.96–7.02 (2H, m), 7.12–7.30 (6H, m), 7.66 (2H, d, *J*=9.2), 8.37 (2H, d, *J*=9.2); ^{13}C NMR (100 MHz, $CDCl_3$): δ 55.8, 56.4, 61.3, 76.2, 112.6, 120.46, 124.5, 126.9, 127.3, 128.07, 128.3, 129.5, 136.5, 136.9, 147.2, 147.5, 152.9, 174.0. MS *m/z* 271 (M^+) of the nitrone. Anal. Calcd for $C_{26}H_{23}N_3O_7$ (489.48): C, 63.80; H, 4.74; N, 8.58. Found: C, 63.70; H, 4.80; N, 8.50.

4.4.9. *endo*-2-Benzyl-N^5,N^5-diethyl-N^4,3-diphenyl-isoxazolidine-4,5-dicarboxamide 6a. A solution of **5a** (0.156 mmol, 0.06 g) in diethylamine (3 mL) was refluxed for 3 h. The precipitate formed was collected by filtration and dried on air. Yield 0.047 g, 66%. From ether–petroleum ether; white crystals; mp 193–195 °C; IR (KBr) $\nu_{C=O}$ 1689 cm^{-1}; ν_{NH} 3480 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 0.93 (6H, t, *J*=7.2), 2.43 (4H, q, *J*=7.2), 3.64 (1H, t, overlapping doublets, *J*=8.0, 7.2), 3.88 (1H, d, *J*=15.2), 4.06 (1H, d, *J*=15.2), 4.50 (1H, d, *J*=7.2), 4.93 (1H, d, *J*=8.0), 6.98 (1H, t, *J*=7.6), 7.13–7.50 (14H, m), 8.43 (1H, s); ^{13}C NMR (100 MHz, $CDCl_3$): δ 13.0, 41.9, 59.4, 61.3, 73.5, 79.9, 119.7, 123.8, 127.0, 127.9, 128.2, 128.6, 128.8,

137.9, 138.3, 138.8, 168.5, 173.2. Anal. Calcd for $C_{28}H_{31}N_3O_3$ (457.56): C, 73.50; H, 6.83; N, 9.18. Found: C, 73.53; H, 6.90; N, 9.10.

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10. Thermal isomerisations of the nitrones were not observed during the cycloadditions of compounds **1** with arylmaleimides. Surprisingly, there were no examples in the literature on the cycloaddition and stereoselectivity of the reaction of nitrones **1** with arylmaleimides.
11. The magnetic susceptibility measurements for *exo*-**4a** and *endo*-**5a** are μ_{eff}=0.84 and μ=1.35μ_B, respectively. The same measurements for nitrones **1a** and **3a** show that their magnetic moments are close to zero. We are going to publish the results of the ambient light photochemistry of some heteroaromatic *N*-oxides, which should have excited state similar to nitrones.
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