Synthesis of Novel Bis(benzoxazole) Derivatives by Tandem Claisen Rearrangement and Their Fluorescence Behavior

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Keywords: Ethers / Oxygen heterocycles / Fluorescence / Rearrangement

Novel bis(benzoxazole) derivatives were easily synthesized from isobutenyl bis(amide–ether)s by tandem Claisen rearrangement and subsequent intramolecular cyclization of the amide–phenol intermediates. The yields of the bis(benzoxazole)s depended on whether the reaction was carried out with or without solvent, as well as on the substituents on the aryl group and the carbonyl group. The solvent effect was dramatic. No significant difference in the overall reaction rate constant with variation of the substituents on the carbonyl group was observed, but the nature of the aryl group on the ether had a large effect on the tandem Claisen rearrangement. The corresponding amide–phenol derivatives were confirmed as intermediates in this rearrangement. The fluorescence quantum yields of the obtained bis(benzoxazole)s were high, but the yields were lower than those of the corresponding monobenzoxazoles.

Introduction

Much attention has been paid to benzoxazoles as they have a number of optical applications: they have been used as optical luminescents,[1] whitening agents,[2] and laser dyes.[3] Benzoxazoles also have other important uses: they can serve, for example, as intermediates for organic syntheses[4] and as therapeutic materials.[5] To date, a variety of synthetic methods for benzoxazoles have been reported, these molecules typically being synthesized by condensation of 2-aminophenol with benzaldehyde[6] or benzoic acid derivatives[7] and subsequent intramolecular cyclization.

The Claisen rearrangement attracts interest because of its extensive applications in organic synthesis. The potential for tandem Claisen rearrangements − that is, transposition at two reaction centers − extends the reaction's usefulness even further.[8] We have recently found that isobutenyl bis(aryl ether) derivatives are easily converted by tandem Claisen rearrangements into compounds possessing two phenolic hydroxy groups.[9] Especially notable is our observation that the rearrangement proceeds at lower temperature when a naphthyl unit is used as the aryl group.[10] Furthermore, we have demonstrated that some isobutenyl bis(aryl ether)s with amide groups at the *o*-positions are easily converted into bis(benzoxazole)s by heating, and that the reaction may proceed by tandem Claisen rearrangement.[11] However, we were unable to isolate isobutenyl bis(amidophenol) derivatives generated by the tandem Claisen rearrangement of isobutenyl bis(phenyl ether)s or isobutenyl bis(4-methylphenyl ether)s with amide groups at the *o*-positions. With their reactive phenol groups, these bis(amide phenol)s would be very useful for building highly functionalized molecules by this reaction system.

In this paper we discuss the reactions of a series of 1,3-bis[*o*-(acylamido)phenyloxy]-2-methylenepropanes by tandem Claisen rearrangement, the substituent effects on the reactions, and the reaction intermediates.

It is known that Claisen rearrangements of allyl aryl ethers generally proceed through the *o*-position, but that the *para* rearrangement can compete when the *p*-position is unsubstituted.[12] We therefore studied bis[*o*-(amido)phenyloxy]-2-methylenepropanes **1a** and **1b**, which have no substituent at the *p*-position of the phenoxy group, as well as *p*-substituted bis[*o*-(amido)phenyloxy]-2-methylenepropanes, designed to inhibit the rearrangement to the *p*-position. We also studied the rearrangements of precursors **1c**−**1i**, which have a range of substituents on the carbonyl group, to elucidate the effect of electron donation on the rearrangement. Furthermore, we investigated the rearrangements of precursor **1j**, possessing a 4-methoxyphenyl group, and precursors **1k** and **1l**, which have naphthyl ether units. The more electron-rich aryl ether group was expected to lower the rearrangement temperature, thereby facilitating isolation of the intermediates generated by the tandem Claisen rearrangement.

We also examined the fluorescence properties of the resulting bis(benzoxazole)s. It is well known that 2-arylbenz-

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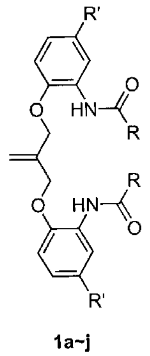
oxazoles are generally fluorescent reagents with high fluorescence quantum yields, and it was interesting to investigate whether two benzoxazoles in a molecule would affect each other's fluorescence behavior. In addition, examination of substituent effects on the fluorescence behavior of these molecules may help in the design and synthesis of new materials.

Results and Discussion

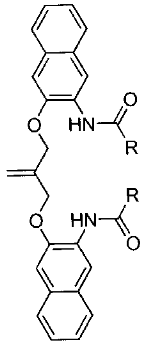
Syntheses of Bis(amide−ether)s 1a−1l

Bis(amide−ether)s **1a**−**1f** were prepared as follows. 2-Aminophenol or 2-amino-4-methylphenol were treated with various acyl chlorides in the presence of pyridine in dry dimethylformamide (DMF) at 0−20 °C for 12 h, and the resulting intermediates were etherified with 3-chloro-2-(chloromethyl)-1-propene in the presence of a base (NaH in DMF or KOH in EtOH) at 70 °C for 12 h. Diamide **1j** was prepared in good yield from the amide−phenol derivative obtained from the reduction of 4-methoxy-2-nitrophenol followed by treatment with acetic anhydride.



1a~j

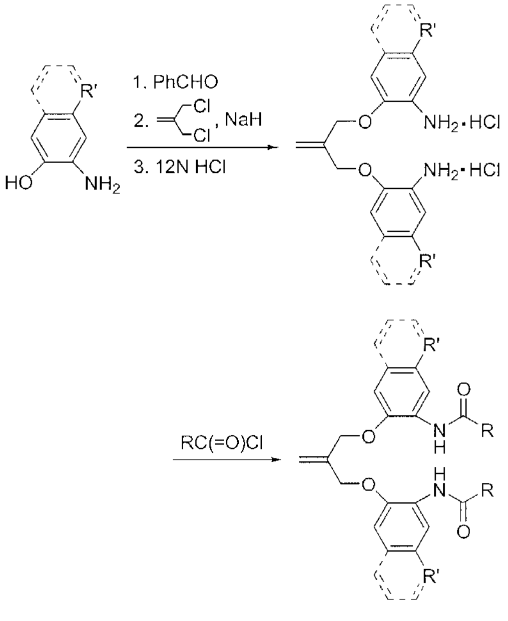
	R	R'
1a	CH_3	H
1b	C_6H_5	H
1c	CH_3	CH_3
1d	C_6H_5	CH_3
1e	p-$C_6H_5CH_3$	CH_3
1f	p-$C_6H_5NO_2$	CH_3
1g	o-$C_6H_5OCH_3$	CH_3
1h	m-$C_6H_5OCH_3$	CH_3
1i	p-$C_6H_5OCH_3$	CH_3
1j	CH_3	OCH_3



1k and **1l**

	R
1k	CH_3
1l	C_6H_5

All of the bis(amide−ether)s were obtained in good yields, with the exception of **1f**, which bears a nitro group (26% yield). However, **1f** could be obtained in 86% yield by treatment of bis(aminoaryloxy)-2-methylenepropane hydrochlorides with 4-nitrobenzoyl chloride. Bis(amide−ether)s **1g**−**1i**, **1k**, and **1l** were also synthesized from bis(aminoaryloxy)-2-methylenepropane hydrochlorides, which were useful and versatile for the introduction of various substituents on the amide groups. Firstly, the bis(aminoaryloxy)-2-methylenepropane hydrochlorides were prepared by a straightforward method involving a protection/deprotection process: 2-amino-4-methylphenol or 3-amino-2-naphthol were first treated with benzaldehyde to form 4-methyl-2-[(phenylmethylene)amino]phenol or 3-[(phenylmethylene)amino]-2-naphthol, which were etherified with 3-chloro-2-(chloromethyl)-1-propene in the presence of NaH in DMF and then deprotected with 12 N aqueous HCl in chloroform. The bis(amide−ether)s **1f**−**1i**, **1k**, and **1l** were then obtained by treatment of 1,3-bis(2-aminoaryloxy)-2-methylenepropane hydrochlorides with various acyl chlorides in the presence of pyridine in THF (Scheme 1).



Scheme 1

Thermal Reactions of the Bis(amide−ether)s

The thermal behavior of the bulk reactions of bis(amide−ether)s **1** was investigated by differential scanning calorimetry (DSC) analysis. Figure 1 shows the DSC curve of **1j** as a representative example.

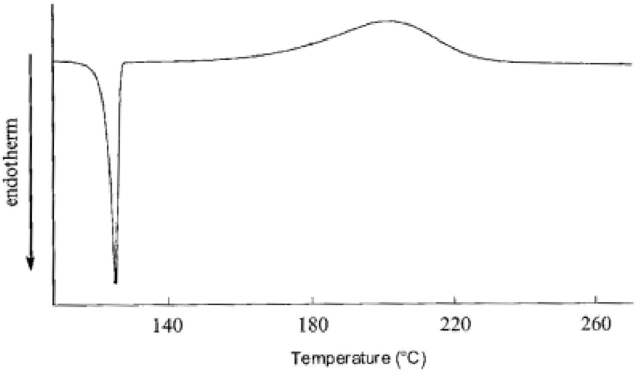
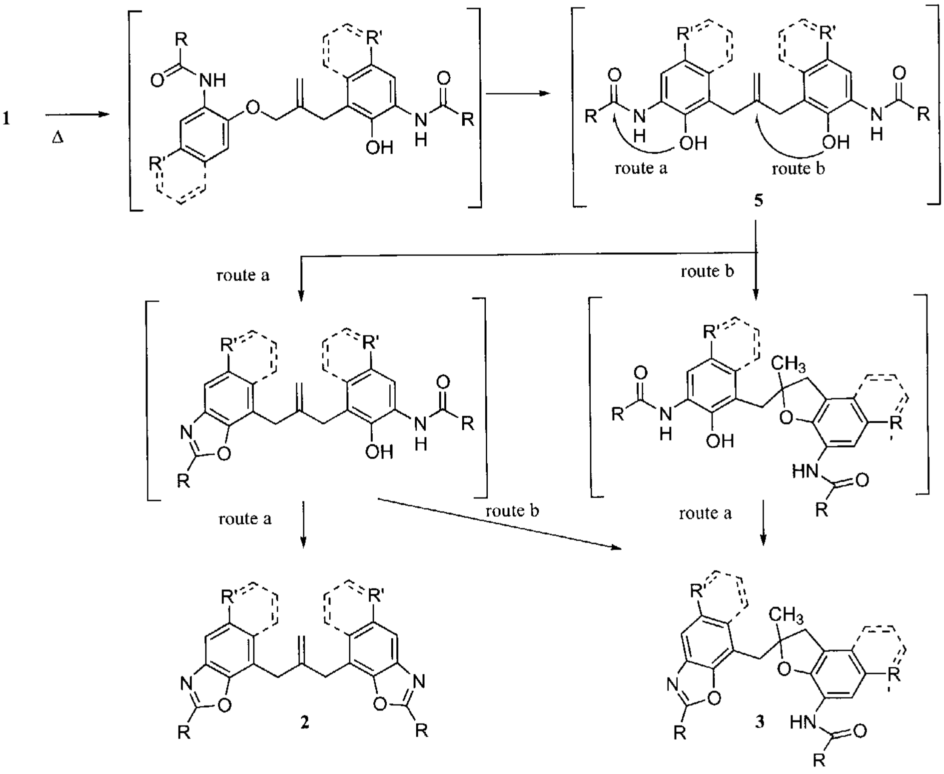


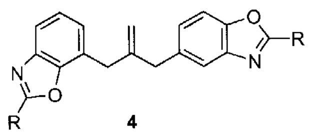
Figure 1. DSC curve of **1j**



Scheme 2

The DSC curves of **1** showed an endothermic peak for melting and a broad exothermic peak for the rearrangement and subsequent cyclization. All of the bis(amide−ether)s melted at 136.5−176.5 °C, except for **1f**. The rearrangement occurred after melting in every case except for **1f**, which began to rearrange during melting. The rearrangements of precursors **1** were carried out at 180 °C, both in the absence and in the presence of solvent, except for those of **1f** and **1g**. The bulk rearrangements of **1f** and **1g** were conducted at 190 °C for 24 h and at 210 °C for 4 d, respectively, because the former compound had a high melting point (188 °C), and the rearrangement of the latter was very slow.

When precursors **1** were heated without solvent or in *N*-methyl-2-pyrrolidone (NMP) at 180 or 190 °C under argon, mixtures of the corresponding bis(benzoxazole) derivatives **2** and dihydrobenzofuran derivatives **3** were obtained as the main products (compounds **4** were obtained from rearrangement to the *p*-position in the cases of **1a** and **1b**, each of which has no substituent at the *p*-position), as shown in Scheme 2 and structure of compound **4**.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The reaction mixtures were purified by gel permeation chromatography (eluent: chloroform) and then silica gel column chromatography to obtain both **2** and **3** (or **4**). The total isolated yields of **2** and **3** (or **4**) were high (> 84%), except for **1f** (53%) and **1g** (59%).

During the study of the bulk reactions of **1**, we found that the product ratios of bis(benzoxazole)s **2** and dihydrobenzofuran derivatives **3** were distinctly influenced by the substituents R and R′ on **1**. The results for the bulk reactions are summarized in Table 1.

Table 1. Rearrangement of **1a**−**1l** in absence of solvent

Run	Compound	R′	R	Yield[a] (%) **2**	**3**	**4**
1	**1a**	H	Me	71	13	5
2	**1b**	H	Ph	15	82	trace
3	**1c**	Me	Me	75	9	−
4	**1d**	Me	Ph	6	91	−
5	**1e**	Me	*p*-MeC_6H_4	4	91	−
6	**1f**	Me	*p*-$O_2NC_6H_4$	2	51	−
7[b]	**1g**	Me	*o*-$MeOC_6H_4$	43	16	−
8	**1h**	Me	*m*-$MeOC_6H_4$	8	91	−
9	**1i**	Me	*p*-$MeOC_6H_4$	60	39	−
10	**1j**	OMe	Me	88	4	−
11	**1k**	(Nap)	Me	32	67	−
12	**1l**	(Nap)	Ph	5	95	−

[a] Conditions: temperature 180 °C, reaction time 24 h, under argon. [b] The bulk reaction of **1g** was carried out for 4 d at 210 °C under Ar.

The bis(benzoxazole) derivatives were the main products obtained from the bulk reactions of **1a** (R′ = H, R = CH_3; 71%[13]), **1c** (R′ = CH_3, R = CH_3; 75%), and **1j** (R′ = OCH_3, R = CH_3; 88%). The yields of the corresponding dihydrobenzofurans **3** were low: 13% for **1a**, 9% for **1c**, and 4% for **1j**. The bulk reactions of **1b** (R′ = H, Ph), **1d**−**1f**, and **1i** (R′ = CH_3, R = Ph or various *p*-substituted phenyl groups) were also studied. The bulk reactions of all these compounds except for **1i** preferentially gave the dihydrobenzofuran derivatives **3**. These results contrast markedly with the results for **1a**, **1c**, and **1j** (compare Runs 1−6, 9, and 10).

Interestingly, the bulk reaction of precursor **1i** preferentially gave **2i** in 60% yield, even though it has an aryl-substituted carbonyl group. In order to investigate the effect of the aryl substituent on the ratio of products **2** and **3** in more detail, we studied the reactions of **1g**−**1i**, which each have a methoxy group at either the *o*-, the *m*-, or the *p*-position of the phenyl group. As shown in Table 1, treatment of **1g** and **1i**, with methoxy groups at the *o*-position and at the *p*-position, respectively, preferentially gave bis(benzoxazole)s **2g** and **2i**, respectively, whereas treatment of *meta*-substituted **1h** gave a drastically decreased ratio of bis(benzoxazole) **2h** to dihydrobenzofuran **3h** (8% to 91%); this ratio is similar to that obtained from **1b** and **1d**−**1f**. These results indicated that the **2/3** product ratios largely depended on the substituent adjacent to the carbonyl groups.

The bulk reactions of naphthyl-substituted **1k** and **1l** were carried out under the same conditions. The yield of **2k** (32%) obtained from **1k** was divergent from the yields of **2a**, **2c**, and **2j** from **1a**, **1c**, and **1j**, and was less than the yield of **3k** (67%; see Table 1, Run 11). The bulk reaction of **1l** gave **2l** and **3l** in 5% and 95% yields, respectively (Table 1, Run 12); these yields were similar to those obtained from **1b** and **1d**. These results indicated that introduction of the naphthyl group resulted in preferential conversion of **1** into **3**. We thus found that the substituents both on R and on R′ affected the **2/3** product ratio in the bulk reaction.

Next, in order to investigate the solvent effect, we carried out the rearrangements in NMP. The results are summarized in Table 2.

Table 2. Rearrangement of **1a**−**1l** in NMP

Run[a]	Compound	R′	R	Yield (%) 2	3	4
1	**1a**	H	Me	70	2	23
2	**1b**	H	Ph	81	9	trace
3[b]	**1c**	Me	Me	95	5	−
4	**1d**	Me	Ph	85	13	−
5	**1e**	Me	*p*-MeC_6H_4	80	11	−
6	**1f**	Me	*p*-$O_2NC_6H_4$	58	10	−
7[c]	**1g**	Me	*o*-$MeOC_6H_4$	−	−	−
8[d]	**1h**	Me	*m*-$MeOC_6H_4$	77	12	−
9[d]	**1i**	Me	*p*-$MeOC_6H_4$	61	15	−
10[e]	**1k**	(Nap)	Me	80	19	−
11	**1l**	(Nap)	Ph	51	47	−

[a] Unless otherwise noted, 50 mg of substrate **1** was heated at 180 °C in 0.4 mL of NMP under argon for 24 h. [b] Compound **1c** was heated at 180 °C for 84 h to complete the reaction. [c] The yields of **2g** and **3g** could not be determined because the reaction of **1g** in NMP gave a complex mixture. [d] Compounds **1h** and **1i** were heated at 210 °C in NMP under argon for 4 d. [e] Compound **1k** was heated at 190 °C in NMP under argon for 3 d.

The product ratios obtained from treatment of **1b**, **1d**−**1f**, and **1h** in NMP were dramatically different from the ratios obtained from the bulk reactions: the solution reactions of **1b**, **1d**−**1f**, and **1h**, which had mainly given **3** in the bulk reaction, preferentially gave **2**. As in the bulk reactions, the solution reactions of **1a**, **1c**, and **1j** predominantly gave the corresponding bis(benzoxazole) derivatives **2**. Overall, in NMP, bis(benzoxazole) derivatives **2** were preferentially produced regardless of the substituent: that is, regardless of the electronic effect. However, the thermal reactions of the naphthyl-substituted **1k** and **1l** in NMP gave higher proportions of product **3** than observed for **1c** and **1d**. We presume that the production mechanism of **3** (the addition of the OH group to C=C) could be different from that of **2** (the addition of the OH group to C=O, followed by dehydration) in terms of the polarization of the intermediate, in which a carbocation intermediate for **2** might more effectively be formed, resulting in the preferential production of **2**.

Substituent Effects on the Formation of Tandem Claisen Rearrangement Intermediates

It is well known that thermal reactions of *N*-(*o*-hydroxyphenyl)amides give 2-benzoxazoles by intramolecular cyclization between the hydroxy group and the *o*-amide group.[14] It is also known that Claisen rearrangement of allyl aryl ethers gives *o*-allylphenols, which upon additional heating undergo cyclization to produce the corresponding dihydrobenzofuran derivatives.[15] Taking these two facts together with the fact that we obtained two kinds of compounds, **2** and **3**, in our study, we infer that the rearrangement proceeds as follows: (*i*) the tandem Claisen rearrangement of the aryl isobutenyl ether group of **1** takes place to give 2-amidophenol derivatives **5**, and (*ii*) bis(benzoxazole) derivatives **2** are produced from **5** by an intramolecular reaction between the OH and the amide group and subsequent dehydration (Scheme 2, route a), while dihydrobenzofuran derivatives **3** are formed by the intramolecular attack of the OH group at the isobutenyl group of **5** (Scheme 2, route b).

We investigated the effects of substituents R and R′ on the formation of intermediates **5** in the reaction of **1** to produce **2** and **3**. Firstly, we confirmed that the formation of **2** or **3** did indeed proceed via intermediate **5**, generated by tandem Claisen rearrangement of **1**. To do this, we compared the thermal reactions of **1** and **5**. Thermal treatment of **5k** and **5l** was carried out at 180 °C for 24 h under argon in a manner similar to that used for **1k** and **1l**, respectively. The results are summarized in Table 3. It is noteworthy that the yields of products **2** and **3** from the bulk reactions of **1k** and **1l** were almost the same as those obtained from the bulk reactions of **5k** and **5l**. Furthermore, even in NMP, the reactions of **1k** and **1l** were similar to those of **5k** and **5l**. These results strongly supported our inference that **5** is an intermediate in the thermal reaction.

Table 3. Rearrangement of **1** and **5**[a]

Run[a]	Compound	Solvent	Yield (%) 2	Yield (%) 3
1	**1k**	none	32	67
2	**5k**	none	42	50
3	**1k**	NMP	80	19
4	**5k**	NMP	61	21
5	**1l**	none	5	95
6	**5l**	none	4	90
7	**1l**	NMP	51	47
8	**5l**	NMP	68	25

[a] The compounds were heated at 180 °C under argon for 24 h. When solvent was used, 50 mg of substrate was dissolved in 0.4 mL of NMP.

We next investigated the conversion of **1c**−**1k** at 180 °C over time, by means of a ^{1}H NMR method to compare the rates of the rearrangements of the differently substituted (R, R′) **1c**−**1k**. We determined the rearrangement rates and the 50% conversion times for **1c**−**1k** by curve fitting, using a first-order equation for the successive reactions (see Table 4).[16]

No significant rate constant differences (0.08−0.12) were observed for **1c**−**1i**, which have different R substituents, whereas the rate constants for **1c**, **1j**, and **1k** (R = CH_3), which have different R′ substituents, did differ significantly from one another (0.09, 0.31, and 2.25, respectively). This result indicates that R′ had a large effect on the tandem Claisen rearrangement of **1**, whereas R had little effect. The faster reaction rate of **1j** than of **1c** can be explained by the stronger electron-donating ability of R′.[17] As for the faster reaction of **1k**, this behavior might be explained by the different orbital symmetry, based on Woodward−Hoffmann principles,[18] between phenyl ring and naphthyl ring.[19]

The maximum yields of **5** as determined by ^{1}H NMR and the reaction times are also summarized in Table 4. Compounds **5** were not obtained quantitatively from **1c**−**1i** (R′ = CH_3) except in the case of **1g**, and the yields of **5** were low (27−48%) except in the case of **5g**. As the rearrangement rate constants for **1c**−**1i** were relatively small, this result might indicate that conversion of **1** to **5** was the rate-determining step in the thermal reaction. In contrast, interestingly, **1g** was quantitatively converted into **5g** after 1 h. It is possible that a hydrogen-bonding interaction in **5g** between the oxygen atom of the methoxy group at the *o*-position and the OH group, generated by the tandem Claisen rearrangement, effectively inhibited the subsequent intramolecular cyclization (routes a and b in Scheme 2).

From **1k** (R = CH_3), with a naphthyl group as R′, **5k** was formed in 92% yield after 3 min, perhaps because of the relatively fast rearrangement. These results indicate that the introduction of the naphthyl group and the stabilization of intermediate **5** by hydrogen-bond formation with the generated OH group were very useful for obtaining **5** quantitatively.

Another noteworthy finding is that there was a relationship between the reaction time trend and the **2/3** product ratio; the longer the reaction time, the greater the preference for formation of bis(benzoxazole)s **2**.

In view of the fact that substituents R had little or no effect on the rate constant for the thermal rearrangement, we can say that the nature of R does not affect the addition reaction between the generated hydroxy group and the double bond of the isobutenyl group to give **3**. It might therefore be reasonable to assume that the **2/3** product ratio is controlled by the rate of conversion of **5** into **2**. We therefore attempted to determine the substituent effect on the conversion of **5** into **2**. We assumed that the electron density on the carbon atom of the carbonyl group might affect the thermal reaction. Although we investigated the chemical shifts of the carbon signals due to the carbonyl groups in the ^{13}C NMR spectra of **1**, we observed no correlation between the chemical shift of the carbonyl signal of **1** and the **2/3** product ratio. We next calculated the electron distribution on the carbonium ion of the protonated carbonyl groups in compounds **1c**, **1d**, **1f**, **1g**, and **1i** on the basis of the reasonable assumption that the thermal reaction of **5** to give **2** proceeds through an intermediate with a carbonyl group protonated by the hydroxy group generated by the rearrangement. Interestingly, the calculated electron densities were in the order **1c** = **1g** (0.82) > **1i** (0.80) > **1f** (0.79) > **1d** (0.78).[20] This order is similar to that observed for the **2/3** product ratios: **1c** > **1g** > **1i** > **1d** > **1f**. In addition, the calculated densities followed the general order of the electron-donating ability of the substituents on the aromatic ring in R. From these results, we conclude that the stronger

Table 4. The rearrangement rates of **1** and the yields of intermediate **5**

Compound[a]	k_1	Conversion (50%) time of **1**	Yield of **5** (%) (time)
1c	0.09	7.8 min	48 (30 min)
1d	0.10	6.6 min	29 (20 min)
1e	0.12	5.7 min	27 (15 min)
1f	0.10	6.9 min	47 (30 min)
1g	0.09	7.8 min	93 (60 min)
1h	0.08	8.1 min	42 (20 min)
1i	0.11	6.6 min	40 (20 min)
1j	0.31	2.2 min	69 (15 min)
1k	2.25	0.3 min	92 (3 min)

[a] The compounds were heated at 180 °C under argon.

the electron-donating ability of the aromatic substituent R, the more bis(benzoxazole) is produced.

Fluorescence Properties

Benzoxazoles have many applications based on their optical properties; they have been used as fluorescent probes, scintillators, laser dyes, and so on. In addition, we have previously reported that the thermal reactions of amide derivatives **1** to give the bis(benzoxazole) derivatives **2** showed a fluorescent switching from "off" to "on," which indicates possible application as optical memory devices. From the viewpoint of materials design, investigation of substituent effects in the system is a significant basic study that should be undertaken. We therefore used UV and emission spectroscopy to compare the optical properties of compounds **2** with a variety of substituents. The UV spectra of **2** and the corresponding precursors **1** were measured at 25 °C in $CHCl_3$ (conc. 1×10^{-5} M). The emission spectra of **2** and **1** in $CHCl_3$ (1×10^{-6} M) were also measured. The fluorescence quantum yields were determined by using quinine sulfate in 1 N H_2SO_4 as a standard with $\varphi = 0.51$. The results are listed in Table 5, and two typical emission profiles (**1e** and **2e**) are shown in Figure 2.

Table 5. Fluorescence spectra

Compound[a]	$\lambda_{max\ (ab)}$ [nm]	$\lambda_{max\ (fl)}$ [nm]	φ
2c	277	none	–
2d	298, 308	369	0.43
2e	301, 311	368	0.53
2f	346	none	–
2g	317	363	0.51
2h	303	354	0.31
2i	314	356	0.55
2j	291	318[b]	–
2k	308	367	0.11
2l	333	444	0.18
6d	291	362	0.63

[a] The compounds were excited at 300 nm, and their fluorescence spectra were measured in $CHCl_3$ at 25 °C. The φ values were calculated with quinine sulfate in 1 N H_2SO_4 as a reference, which has a quantum yield of 0.51. [b] Compound **2j** was excited at 291 nm.

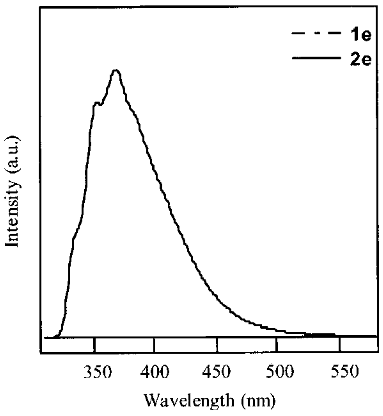

Figure 2. Fluorescence spectra of **1e** and **2e** in $CHCl_3$ (ex. 1×10^{-6} M, at 25 °C)

As was to be expected, emission spectra could be observed only for **1k** and **1l**, which have naphthyl units. Bis(benzoxazole)s **2c** (R = CH_3, R′ = CH_3) and **2j** (R = CH_3, R′ = OCH_3) did not show any fluorescence. Bis(benzoxazole)s **2d**, **2e**, and **2g**−**2i** (R = aryl) emitted purple fluorescence at around 354−369 nm upon excitation at 300 nm in $CHCl_3$. However, **2f** did not show fluorescence. This observation is consistent with the known fact that emission is generally reduced or quenched by the introduction of electron-withdrawing substituents such as the nitro group. The fluorescence quantum yields of bis(benzoxazole)s **2d**, **2e**, and **2g**−**2i** (R = aryl) were compared with that of 6-methyl-2-phenylbenzoxazole (**6d**) as the model compound. The quantum yields of the obtained bis(benzoxazole)s were somewhat smaller than that of the model compound ($\varphi_{\mathbf{2}} = 0.31-0.55$ vs. $\varphi_{\mathbf{6d}} = 0.63$). This difference might be caused by self-quenching between two neighboring benzoxazoles in the case of the bis(benzoxazole)s. We noted that naphthyl derivative **2k** (R = CH_3) showed some fluorescence, albeit weak, whereas **2c** and **2j** did not. Naphthyl derivative **2l** (R = Ph) showed a fluorescence quantum yield lower than that of **2d** (R = Ph, R′ = CH_3). Thus, the fluorescence properties could be controllable by appropriate selection of R and R′.

Conclusions

The thermal rearrangements of **1a**−**1l** gave the corresponding bis(benzoxazole) derivatives **2** and dihydrobenzofuran derivatives **3**. The **2**/**3** product ratio depended on the reaction conditions (either with solvent or without solvent) and on the nature of substituents R and R′. The corresponding bis(amide−phenol) derivatives were observed as intermediates in this rearrangement. The fluorescence quantum yields of the obtained bis(benzoxazole)s were high, but they were lower than those of the corresponding monobenzoxazoles.

Experimental Section

General: ^1H and ^{13}C NMR spectra were recorded with a Bruker AF 500 spectrometer, with tetramethylsilane (TMS) as an internal standard, in [D]chloroform ($CDCl_3$) or [D_6]dimethyl sulfoxide ([D_6]DMSO). IR spectra were obtained with a JASCO FT/IR 420. High-resolution mass spectra (HRMS) were recorded at 70 eV by electron impact. Thermal analyses were preformed with Seiko Instruments TGA/DTA 6300 and DSC 6300 analyzers. The melting points and rearrangement peaks were determined by DSC at a heating rate of 5 °C/min under nitrogen. UV and fluorescence spectra were measured with JASCO V 550 and FP 750 machines. Dehydrated NMP was purchased from Kanto Chemical Co. Ltd.

Preparation of 1,3-Bis(2-aminoaryloxy)-2-methylenepropane Hydrochlorides. General Procedure: Benzaldehyde (4.3 g, 40.1 mmol) was added to a dispersion of 2-amino-4-methylphenol (5.0 g, 40.1 mmol) in MeOH (30 mL), and the mixture was stirred for 5 h at room temperature. The mixture was filtered, and the solid protected hydroxyarylamine obtained was dried in vacuo. The solid was dissolved in dry DMF (30 mL), and NaH (60% in oil, 2.0 g, 52.1 mmol) and 3-chloro-2-(chloromethyl)propene (251 g, 20.1 mmol) were added to the solution. The reaction mixture was stirred overnight at 70 °C. The solvent was removed under vacuum, and the residue was dissolved in $CHCl_3$ and washed with water. After half of the solvent was removed, and 12 N HCl was added to the solution at room temp. The precipitate obtained was collected by filtration and washed three times with acetone.

1,3-Bis(2-amino-4-methylphenoxy)-2-methylenepropane Hydrochloride: Colorless solid, 82%, m.p. 100.7−102.0 °C. ^{1}H NMR ([D$_6$]DMSO): δ = 2.26 (s, 6 H, CH_3−), 4.82 (s, 4 H, −CH_2−), 5.52 (s, 2 H, CH_2=), 7.12−7.13 (m, 4 H, Ar), 7.23 (s, 2 H, Ar), 10.12 (br. s, 6 H, −NH_3) ppm. ^{13}C NMR ([D$_6$]DMSO): δ = 20.4, 69.0, 113.7, 116.2, 121.1, 124.5, 129.3, 130.4, 139.5, 149.2 ppm. IR (KBr): $\tilde{\nu}$ = 3398, 1637, 1508, 1273 cm^{-1}.

1,3-Bis(3-amino-2-naphthoxy)-2-methylenepropane Hydrochloride: Pale brown solid, 42%, m.p. 175.3−178.7 °C (decomp.). ^{1}H NMR ([D$_6$]DMSO): δ = 3.83 (br. s, 6 H, −NH_3), 5.03 (s, 4 H, −CH_2−), 5.66 (s, 2 H, CH_2=), 7.40 (t, *J* = 8.0 Hz, 2 H, Ar), 7.45 (t, *J* = 7.2 Hz, 2 H, Ar), 7.63 (s, 2 H, Ar), 7.80 (d, *J* = 8.0 Hz, 2 H, Ar), 7.83 (d, *J* = 7.2 Hz, 2 H, Ar), 7.84 (s, 2 H, Ar) ppm. ^{13}C NMR ([D$_6$]DMSO): δ = 68.9, 108.4, 116.2, 121.3, 123.3, 124.8, 126.6, 126.7, 127.2, 127.6, 132.6 ppm. IR (KBr): $\tilde{\nu}$ = 3421, 1641, 1510, 1476, 1258 cm^{-1}.

Preparation of Isobutenyl Bis(amide−ether)s 1

1,3-Bis[2-(acetylamino)phenoxy]-2-methylenepropane (1a): A solution of 2-(acetylamino)phenol (7.86 g, 52 mmol) in dry DMF (100 mL) was cooled in an ice bath, and NaH (1.32 g, 52 mmol) was added to the solution at 0 °C. 3-Chloro-2-(chloromethyl)propene (3.13 g, 25 mmol) was then added to the dispersion, and the mixture was warmed at 80 °C for 12 h. DMF was removed from the reaction mixture under vacuum, and the residue was dissolved in $CHCl_3$. The solution was washed three times with water and then dried with anhydrous $MgSO_4$. After evaporation of the solvent, the residue was recrystallized from CH_2Cl_2/ether (1:3) to afford a colorless solid in 80% yield (7.09 g), m.p. 128.1 °C. ^{1}H NMR ($CDCl_3$): δ = 2.08 (s, 3 H, CH_3−), 4.72 (s, 4 H, −CH_2−), 5.44 (s, 2 H, CH_2=), 6.91 (d, *J* = 7.8 Hz, 2 H, Ar), 6.98−7.02 (m, 4 H, Ar), 7.75 (br. s, 1 H, NH), 8.32 (d, *J* = 7.3 Hz, 2 H, Ar) ppm. ^{13}C NMR ($CDCl_3$): δ = 24.6, 69.8, 111.9, 117.6, 120.5, 121.9, 123.8, 128.1, 139.4, 146.7, 168.2 ppm. IR (KBr): $\tilde{\nu}$ = 3296, 1660, 1600, 1541, 1492, 1447, 1260 cm^{-1}. HRMS: calcd. for $C_{20}H_{22}N_2O_4$ 354.1578; found 354.1574.

Precursors 1b−1e, 1j: A solution of NaOH (6 mmol) in ethanol (50 mL) was warmed at 70 °C, and the 2-amidophenol derivatives (5 mmol) were added to the solution. 3-Chloro-2-(chloromethyl)propene was then added, and the solution was heated at 80 °C for 12 h. Ethanol was removed from the reaction mixture under vacuum, and the residue was dissolved in $CHCl_3$. The solution was washed three times with water and then dried with anhydrous $MgSO_4$. After evaporation of solvent, the residue was purified by silica gel column chromatography with CH_2Cl_2/ether (1:3) to give **1**.

Compound 1b: Colorless solid, yield 74% (0.89 g), m.p. 119.2 °C. ^{1}H NMR ($CDCl_3$): δ = 4.78 (s, 4 H, −CH_2−), 5.48 (s, 2 H, CH_2=), 6.77 (dd, J_1 = 7.7 Hz, J_2 = 1.9 Hz, 2 H, Ar), 7.02 (dt, J_1 = 7.7 Hz, J_2 = 1.9 Hz, 2 H, Ar), 7.05 (dt, J_1 = 7.7 Hz, J_2 = 1.7 Hz, 2 H, Ar), 7.40 (t, *J* = 7.3 Hz, 2 H, Ar), 7.51 (t, *J* = 7.3 Hz, 2 H, Ar), 7.80 (dd, J_1 = 8.6 Hz, J_2 = 1.4 Hz, 2 H, Ar), 8.51−8.55 (m, 4 H, Ar) ppm. ^{13}C NMR ($CDCl_3$): δ = 69.5, 111.6, 117.0, 120.4, 122.0, 124.0, 126.8, 128.1, 128.8, 131.8, 135.0, 139.4, 146.9, 165.2 ppm. IR (KBr): $\tilde{\nu}$ = 3431, 3338, 1656, 1602, 1531, 1452, 1335, 1258 cm^{-1}. HRMS: calcd. for $C_{30}H_{26}N_2O_4$ 478.1891; found 478.1803.

Compound 1c: Colorless solid, yield 70% (0.67 g), m.p. 143.4 °C. ^{1}H NMR ($CDCl_3$): δ = 2.06 (s, 3 H, CH_3−C(O)−), 2.30 (s, 3 H, *CH_3*−Ar), 4.68 (s, 4 H, −CH_2−), 5.40 (s, 2 H, CH_2=), 6.80 (m, 4 H, Ar), 7.73 (br. s, 2 H, NH), 8.17 (s, 2 H, Ar) ppm. ^{13}C NMR ($CDCl_3$): δ = 21.4, 25.1, 80.8, 112.5, 118.1, 121.5, 124.5, 128.4, 132.1, 140.1, 145.0, 168.6 ppm. IR (KBr): $\tilde{\nu}$ = 3288, 1660, 1543, 1494, 1262, 1216, 1135 cm^{-1}. HRMS: calcd. for $C_{22}H_{26}N_2O_4$ 382.1891; found 382.1929.

Compound 1d: Colorless solid, yield 79% (1.00 g), m.p. 131.8 °C. ^{1}H NMR ($CDCl_3$): δ = 2.33 (s, 6 H, CH_3−), 4.73 (s, 4 H, −CH_2−), 5.45 (s, 2 H, CH_2=), 6.79−6.80 (m, 4 H, Ar), 7.40 (t, *J* = 7.7 Hz, 4 H, Ar), 7.49 (t, *J* = 7.5 Hz, 2 H, Ar), 7.78−7.80 (m, 4 H, Ar), 8.36 (s, 2 H, Ar), 8.49 (br. s, 2 H, NH) ppm. ^{13}C NMR ($CDCl_3$): δ = 21.5, 70.2, 112.0, 117.3, 121.4, 124.6, 127.2, 128.3, 129.2, 132.0, 132.2, 135.5, 140.2, 145.3, 165.5 ppm. IR (KBr): $\tilde{\nu}$ = 3444, 3425, 1669, 1595, 1538, 1253 cm^{-1}. HRMS: calcd. for $C_{32}H_{30}N_2O_4$ 506.2204; found 506.2249.

Compound 1e: colorless solid, yield 64% (0.86 g), m.p. 162.9 °C. ^{1}H NMR ($CDCl_3$): δ = 2.33 (s, 6 H, CH_3−), 2.38 (s, 6 H, CH_3−), 4.72 (s, 4 H, −CH_2−), 5.44 (s, 2 H, CH_2=), 6.79 (s, 4 H, Ar), 7.18 (d, *J* = 7.9 Hz, 4 H, Ar), 7.69 (d, *J* = 8.1 Hz, 4 H, Ar), 8.36 (s, 2 H, Ar), 8.48 (br. s, 2 H, NH) ppm. ^{13}C NMR ($CDCl_3$): δ = 21.5, 21.9, 70.2, 112.1, 117.2, 121.3, 124.5, 127.2, 128.4, 129.9, 131.9, 132.7, 140.2, 142.6, 145.3, 165.5 ppm. IR (KBr): $\tilde{\nu}$ = 3437, 1671, 1612, 1596, 1539 cm^{-1}. HRMS: calcd. for $C_{34}H_{34}N_2O_4$ 534.2517; found 534.2582.

Compound 1j: 4-Methoxy-2-nitrophenol (17.7 mmol) was reduced under H_2 with 5% Pd/C (100 mg) as a catalyst in methanol for 1 d. After the methanol had been removed from the reaction mixture in vacuo, acetic anhydride (60 mL) was added to the residue. The solution was heated at 70 °C overnight. After the acetic anhydride had been removed from the reaction mixture, the residue was hydrolyzed with 1 N NaOH in water/methanol solution. After the hydrolysis was complete, the solution was neutralized with 1 N HCl, and 2-(acetylamino)-4-methoxyphenol was obtained in 69% yield. Compound **1j** was then synthesized according to the method used for **1c**−**1e**. Colorless solid, yield 82% (2.08 g), m.p. 112.5−113.5 °C. ^{1}H NMR ($CDCl_3$): δ = 2.05 [s, 6 H, CH_3−C(O)−], 3.78 (s, 6 H, *CH_3*O−Ar), 4.67 (s, 4 H, −CH_2−), 5.38 (s, 2 H, CH_2=), 6.56 (dd, *J* = 3.1, 8.9 Hz, 2 H, Ar), 6.86 (d, *J* = 8.9 Hz, 2 H, Ar), 7.92 (br. s, 2 H, NH), 8.08 (d, *J* = 2.2 Hz, 2 H, Ar) ppm. ^{13}C NMR ($CDCl_3$): δ = 24.7, 55.7, 71.9, 106.2, 108.8, 114.0, 118.4, 129.5, 139.6, 140.7, 154.8, 168.3 ppm. IR (KBr): $\tilde{\nu}$ = 3308, 1663, 1598, 1542, 1492, 1268 cm^{-1}. HRMS: calcd. for $C_{22}H_{26}N_2O_6$ 414.1789; found 414.1745.

Precursors 1f−1i, 1k−1l: A solution of acyl chloride (11 mmol) in dry DMF was added at 0 °C to a solution of 1,3-bis(2-aminoaryloxy)-2-methylenepropane hydrochloride (1.86 g, 5 mmol) and triethylamine (2.23 g, 22 mmol) in dry DMF. The mixture was stirred at 0 °C for 30 min and at room temp. for 3 h. DMF was then removed from the reaction mixture under vacuum, and the residue was dissolved in $CHCl_3$. The solution was washed three times with water and then dried with anhydrous $MgSO_4$. After evaporation of the solvent, the residue was purified by silica gel column chromatography (eluent ethyl acetate/hexane, 1:1) to give **1**.

Compound 1f: Yellow solid, yield 86% (2.57 g), m.p. 195.3 °C. ^{1}H NMR ($CDCl_3$): δ = 2.30 (s, 6 H, CH_3−), 4.74 (s, 4 H, −CH_2−), 5.44 (s, 2 H, CH_2=), 6.82 (t, *J* = 8.2 Hz, 2 H, Ar), 6.84 (t, *J* =

8.6 Hz, 2 H, Ar), 7.80 (d, J = 8.7 Hz, 4 H, Ar), 8.09 (d, J = 8.9 Hz, 2 H, Ar), 8.16 (s, 2 H, Ar), 8.45 (br. s, 1 H, NH) ppm. ^{13}C NMR (CDCl$_3$): δ = 20.2, 68.6, 114.8, 123.6, 126.1, 126.2, 126.7, 128.9, 129.4, 140.1, 149.0, 163.5 ppm. IR (KBr): $\tilde{\nu}$ = 3435, 3420, 1682, 1598, 1536, 1475, 1346, 1249 cm^{-1}. $C_{32}H_{28}N_4O_8$ (596.59): calcd. C 64.42, H 4.73, N 9.39; found C 64.30, H 4.56, N 9.13.

Compound 1g: Colorless solid, yield 85% (2.41 g), m.p. 117.2 °C. ^{1}H NMR (CDCl$_3$): δ = 2.30 (s, 6 H, CH_3−Ar), 3.82 (s, 6 H, CH$_3$−), 4.74 (s, 4 H, −CH$_2$−), 5.54 (s, 2 H, CH$_2$=), 6.70 (d, J = 8.3 Hz, 2 H, Ar), 6.76 (d, J = 8.2 Hz, 2 H, Ar), 6.89 (d, J = 8.3 Hz, 2 H, Ar), 7.11 (t, J = 7.5 Hz, 2 H, Ar), 7.45 (t, J = 7.4 Hz, 2 H, Ar), 8.29 (d, J = 8.7 Hz, 2 H, Ar), 8.47 (s, 2 H, Ar),10.45 (br. s, 2 H, NH) ppm. ^{13}C NMR (CDCl$_3$): δ = 21.5, 56.4, 69.6, 111.8, 112.1, 117.8, 121.92, 122.0, 122.4, 124.2, 128.8, 131.7, 132.8, 133.5, 141.2, 145.5, 157.7, 163.4 ppm. IR (KBr): $\tilde{\nu}$ = 3337, 1663, 1544, 1238 cm^{-1}. HRMS: calcd. for $C_{34}H_{34}N_2O_6$ 566.2415; found 566.2447.

Compound 1h: Colorless solid, yield 78% (2.21 g), m.p. 123.2 °C. ^{1}H NMR (CDCl$_3$): δ = 2.32 (s, 6 H, CH_3−Ar), 3.82 (s, 6 H, CH$_3$−), 4.72 (s, 4 H, −CH$_2$−), 5.54 (s, 2 H, CH$_2$=), 6.79 (m, 4 H, Ar), 7.02−7.04 (m, 2 H, Ar), 7.26−7.28 (m, 4 H, Ar), 7.42 (s, 2 H, Ar), 8.35 (s, 2 H, Ar), 8.49 (br. s, 2 H, NH) ppm. ^{13}C NMR (CDCl$_3$): δ = 21.1, 55.4, 69.7, 111.6, 112.4, 116.8, 117.9, 118.4, 120.9, 124.2, 127.8, 129.8, 131.6, 136.6, 139.8, 144.9, 156.0, 164.9 ppm. IR (KBr): $\tilde{\nu}$ = 3431, 1674, 1536, 1277 cm^{-1}. HRMS: calcd. for $C_{34}H_{34}N_2O_6$ 566.2415; found 566.2404.

Compound 1i: Colorless solid, yield 85% (2.41 g), m.p. 102.5−104.5 °C. ^{1}H NMR (CDCl$_3$): δ = 2.32 (s, 6 H, CH_3−Ar), 3.82 (s, 6 H, CH$_3$−), 4.72 (s, 4 H, −CH$_2$−), 5.44 (s, 2 H, CH$_2$=), 6.79 (m, 4 H, Ar), 6.84 (d, J = 8.9 Hz, 4 H, Ar), 7.74 (d, J = 8.9 Hz, 4 H, Ar), 8.35 (s, 2 H, Ar), 8.44 (br. s, 2 H, NH) ppm. ^{13}C NMR (CDCl$_3$): δ = 21.1, 55.40, 69.9, 111.7, 114.0, 117.1, 120.9, 123.9, 127.2, 128.1, 128.7, 131.6, 132.3, 144.9, 162.4, 164.7 ppm. IR (KBr): $\tilde{\nu}$ = 3434, 1672, 1538, 1250 cm^{-1}. HRMS: No peak was observed for **1i** (calcd. for $C_{34}H_{34}N_2O_6$ 566.2415), but peaks corresponding to two dehydrated compounds were observed: calcd. for $C_{34}H_{32}N_2O_5$ 548.2309; found 548.2275; calcd. for $C_{34}H_{30}N_2O_4$ 530.2204; found 530.2108.

Compound 1k: Colorless solid, yield 63% (1.43 g), m.p. 164.6 °C. ^{1}H NMR (CDCl$_3$): δ = 2.08 (s, 6 H, CH$_3$−), 4.91 (s, 4 H, −CH$_2$−), 5.58 (s, 2 H, CH$_2$=), 7.18 (s, 2 H, Ar), 7.35−7.38 (m, 4 H, Ar), 7.58 (dd, J_1 = 6.0 Hz, J_2 = 3.4 Hz, 2 H, Ar), 7.798 (dd, J_1 = 6.0 Hz, J_2 = 3.4 Hz, 2 H, Ar), 7.90 (br. s, 2 H, NH), 8.84 (s, 2 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 24.8, 69.6, 106.8, 117.2, 117.8, 124.7, 125.4, 126.2, 127.7, 129.3, 130.0, 139.0, 146.3, 168.3 ppm. IR (KBr): $\tilde{\nu}$ = 3436, 1682, 1541, 1258 cm^{-1}. $C_{28}H_{26}N_2O_4$ (454.52): calcd. C 73.99, H 5.77, N 6.16; found C 73.62, H 5.66, N 5.84.

Compound 1l: Colorless solid, yield 76% (2.20 g), m.p. 119.0 °C. ^{1}H NMR (CDCl$_3$): δ (s, 4 H, −CH$_2$−), 5.60 (s, 2 H, CH$_2$=), 7.19 (s, 2 H, Ar), 7.32 (t, J = 7.8 Hz, 4 H, Ar), 7.34−7.39 (m, 4 H, Ar), 7.43 (t, J = 7.2 Hz, 2 H, Ar), 7.56 (d, J = 8.1 Hz, 2 H, Ar), 7.79−7.82 (m, 6 H, Ar), 8.76 (br. s, 2 H, NH), 9.03 (s, 2 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 69.5, 106.8, 117.2, 117.3, 124.8, 125.5, 126.3, 126.7, 127.7, 127.8, 128.8, 129.4, 130.2, 131.8, 134.9, 139.0, 146.5, 165.3 ppm. IR (KBr): $\tilde{\nu}$ = 3436, 1672, 1539, 1271 cm^{-1}. HRMS: calcd. for $C_{38}H_{30}N_2O_4$ 578.2204; found 578.2079.

Preparation of Products 2−4 and 5

General Procedure for the Thermal Bulk Reaction: Compounds **1a−1l** (100 mg) were heated in sealed glass tubes. The reaction mixtures were purified by silica gel column chromatography (eluent: chloroform and ethyl acetate) to obtain the corresponding compounds **2** and **3** (and **4**). In scale-up experiments, we carried out the thermal reaction of compound **1c** on a 1-g scale. We were able to confirm that almost the same results were obtained as on a smaller scale.

General Procedure for the Thermal Reaction in NMP: Compounds **1a−1l** (100 mg) were dissolved in NMP (10 mL) in glass tubes with rubber stoppers and heated under argon. The solvent was removed at 100 °C under reduced pressure. The reaction mixtures were purified by silica gel column chromatography (eluent: chloroform and ethyl acetate.

Compound 2a: Colorless solid, yield of bulk reaction 71% (64 mg), yield of NMP reaction 70% (63 mg), m.p. 89.8 °C. ^{1}H NMR (CDCl$_3$): δ = 2.58 (s, 6 H, −CH_3), 3.59 (s, 4 H, −CH$_2$−), 4.93 (s, 2 H, CH$_2$=), 7.09 (d, J = 7.35 Hz, 2 H, Ar), 7.21 (t, J = 7.70 Hz, 2 H, Ar), 7.50 (d, J = 7.85 Hz, 2 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 14.9, 36.4, 114.6, 117.8, 122.7, 124.5, 125.6, 141.7, 145.2, 150.4, 163.9 ppm. IR (KBr): $\tilde{\nu}$ = 1614, 1577, 1427, 1268, 1175 cm^{-1}. HRMS: calcd. for $C_{20}H_{18}N_2O_2$ 318.1367; found 318.1362.

Compound 3a: Colorless oil, yield of bulk reaction 13% (11 mg), yield of NMP reaction 2% (2 mg). ^{1}H NMR (CDCl$_3$): δ = 1.44 (s, 3 H, CH$_3$−), 2.09 [s, 3 H, −C(O)−CH$_3$], 2.54 [s, 3 H, −N=C(−O)−CH$_3$], 2.96 (d, J = 15.4 Hz, 1 H, Ar−CH_2−), 3.11 (d, J = 13.8 Hz, 1 H, Ar−CH_2−), 3.19 (d, J = 15.4 Hz, 1 H, Ar−CH_2−), 3.28 (d, J = 13.8 Hz, 1 H, Ar−CH_2−), 6.75 (t, J = 7.7 Hz, 1 H, Ar), 6.79 (d, J = 6.8 Hz, 1 H, Ar), 7.07 (d, J = 7.6 Hz, 1 H, Ar), 7.17 (t, J = 7.7 Hz, 1 H, Ar), 7.47 (d, J = 7.85 Hz, 1 H, Ar), 8.00 (d, J = 7.85 Hz, 1 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 13.5, 23.6, 25.0, 39.4, 41.1, 88.9, 117.0, 117.8, 119.0, 119.1, 119.8, 121.5, 122.9, 125.1, 125.7, 140.3, 146.2, 149.7, 162.5, 167.0 ppm. IR (KBr): $\tilde{\nu}$ = 3277, 1671, 1624, 1577, 1541, 1438 cm^{-1}. HRMS: calcd. for $C_{20}H_{20}N_2O_3$ 336.1473; found 336.1478.

Compound 4a: Colorless solid, yield of bulk reaction 5% (4 mg), yield of NMP reaction 23% (21 mg), m.p. 77.4 °C. ^{1}H NMR (CDCl$_3$): δ = 2.61 (s, 3 H, −CH$_3$), 2.64 (s, 3 H, −CH_3), 3.44 (s, 2 H, −CH_2−), 3.53 (s, 2 H, −CH_2−), 4.88 (s, 1 H, CH_2=), 4.89 (s, 1 H, CH_2=), 7.06−7.09 (m, 2 H, Ar), 7.15 (t, J = 7.7 Hz, 1 H, Ar), 7.29 (d, J = 8.3 Hz, 1 H, Ar), 7.38 (s, 1 H, Ar), 7.43 (d, J = 8.0 Hz, 1 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 13.6, 28.7, 34.8, 41.4, 108.6, 112.9, 116.3, 118.6, 121.4, 123.0, 124.2, 124.5, 134.3, 140.3, 140.7, 145.6, 148.7, 162.6, 163.0 ppm. IR (KBr): $\tilde{\nu}$ = 1843, 1613, 1474 cm^{-1}. HRMS: calcd. for $C_{20}H_{18}N_2O_2$ 318.1367; found 318.1405.

Compound 2b: Colorless solid, yield of bulk reaction 15% (14 mg), yield of NMP reaction 81% (75 mg), m.p. 122.0 °C. ^{1}H NMR (CDCl$_3$): δ = 3.71 (s, 4 H, −CH$_2$−), 5.09 (s, 2 H, CH_2=), 7.18 (d, J = 7.00 Hz, 2 H, Ar), 7.27 (t, J = 7.8 Hz, 2 H, Ar), 7.42−7.48 (m, 6 H, Ar), 7.62 (dd, J = 0.9, 7.9 Hz, 2 H, Ar), 8.06 (dd, J = 1.4, 8.2 Hz, 4 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 35.6, 114.1, 117.5, 122.2, 124.0, 125.2, 126.5, 126.9, 128.2, 130.8, 141.4, 144.1, 149.2, 162.2 ppm. IR (KBr): $\tilde{\nu}$ = 1615, 1555, 1487, 1427 cm^{-1}. HRMS: calcd. for $C_{30}H_{22}N_2O_2$ 442.1680; found 442.1704.

Compound 3b: Colorless, yield of bulk reaction 82% (79 mg), yield of NMP reaction 9% (9 mg), m.p. 42.3 °C. ^{1}H NMR (CDCl$_3$): δ = 1.50 (s, 3 H, CH$_3$−), 3.16 (d, J = 15.4 Hz, 1 H, −CH$_2$−), 3.22 (d, J = 13.8 Hz, 1 H, −CH$_2$−), 3.36 (d, J = 15.4 Hz, 1 H, −CH$_2$−), 3.53 (d, J = 13.8 Hz, 1 H, −CH$_2$−), 6.92 (t, J = 7.5 Hz, 1 H, Ar), 6.95 (d, J = 7.2 Hz, 1 H, Ar), 7.22 (d, J = 6.6 Hz, 1 H, Ar), 7.30 (t, J = 7.7 Hz, 1 H, Ar), 7.38 (t, J = 7.9 Hz, 2 H, Ar), 7.43 (t, J =

7.2 Hz, 2 H, Ar), 7.48 (t, J = 7.5 Hz, 2 H, Ar), 7.61 (dd, J = 1.2, 8.3 Hz, 2 H, Ar), 7.69 (dd, J = 1.1, 8.0 Hz, 1 H, Ar), 7.84 (br. s, 1 H, NH), 8.10 (d, J = 7.0 Hz, 2 H, Ar), 8.27 (d, J = 8.0 Hz, 1 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 25.8, 40.6, 42.5, 60.4, 90.0, 118.6, 118.8, 120.3, 120.4, 121.0, 122.8, 124.4, 126.2, 126.8, 127.4, 127.5, 128.6, 128.9, 131.6, 131.6, 134.5, 141.9, 147.7, 150.5, 162.8, 164.9 ppm. IR (KBr): $\tilde{\nu}$ = 1675, 1626, 1531, 1437 cm^{-1}. HRMS: calcd. for $C_{30}H_{24}N_2O_3$ 460.1786; found 460.1761.

Compound 2c: Colorless solid, yield of bulk reaction 75% (68 mg), yield of NMP reaction 95% (86 mg), m.p. 104.2 °C. ^{1}H NMR (CDCl$_3$): δ = 2.42 [s, 6 H, $-N{=}C(-O)-CH_3$], 2.54 (s, 6 H, CH_3–Ar), 3.53 (s, 4 H, $-CH_2-$), 4.93 (s, 2 H, CH_2=), 6.87 (s, 2 H, Ar), 7.28 (s, 2 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 14.9, 21.8, 36.4, 114.5, 117.7, 121.9, 126.6, 134.2, 141.9, 145.3, 148.7, 163.9 ppm. IR (KBr): $\tilde{\nu}$ = 3448, 1617, 1578 cm^{-1}. HRMS: calcd. for $C_{22}H_{22}N_2O_2$ 346.1680; found 346.1711.

Compound 3c: Colorless oil, yield of bulk reaction 9% (8 mg), yield of NMP reaction 5% (5 mg). ^{1}H NMR (CDCl$_3$): δ = 1.48 [s, 3 H, $CH_3-C(-O-)$], 2.09 [s, 3 H, $-C(O)-CH_3$], 2.28 (s, 3 H, CH_3–Ar), 2.43 (s, 3 H, CH_3–Ar), 2.58 [s, 3 H, $-N{=}C(-O-)-CH_3$], 2.99 (d, J = 15.5 Hz, 1 H, $-CH_2-$), 3.10 (d, J = 13.8 Hz, 1 H, $-CH_2-$), 3.20 (d, J = 15.5 Hz, 1 H, $-CH_2-$), 3.27 (d, J = 13.8 Hz, 1 H, $-CH_2-$), 6.69 (s, 1 H, Ar), 6.94 (s, 1 H, Ar), 7.10 (br. s, 1 H, NH), 7.32 (s, 1 H, Ar), 7.90 (s, 1 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 13.5, 20.2, 20.4, 23.6, 24.9, 39.3, 41.2, 88.8, 116.9, 118.2, 118.3, 119.7, 121.0, 125.1, 127.0, 129.4, 132.6, 140.4, 144.2, 148.0, 162.6, 167.0 ppm. IR (KBr): $\tilde{\nu}$ = 3423, 1685, 1625 cm^{-1}. HRMS: calcd. for $C_{22}H_{24}N_2O_3$ 364.1786; found 364.1805.

Compound 2d: Colorless solid, yield of bulk reaction 6% (6 mg), yield of NMP reaction 85% (79 mg), m.p. 154.7 °C. ^{1}H NMR (CDCl$_3$): δ = 2.40 (s, 6 H, CH_3-), 3.65 (s, 4 H, $-CH_2-$), 5.10 (s, 2 H, CH_2=), 6.94 (s, 2 H, Ar), 7.37 (s, 2 H, Ar), 7.41–7.50 (m, 6 H, Ar), 8.04 (d, J = 6.1 Hz, 4 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 20.4, 35.2, 113.4, 116.9, 120.9, 125.8, 126.3, 126.4, 127.6, 130.1, 133.4, 141.0, 143.7, 146.9, 161.7 ppm. IR (KBr): $\tilde{\nu}$ = 1615, 1555, 1487, 1427 cm^{-1}. HRMS: calcd. for $C_{32}H_{26}N_2O_2$ 470.1993; found 470.2017.

Compound 3d: Colorless solid, yield of bulk reaction 91% (88 mg), yield of NMP reaction 13% (13 mg), m.p. 197.5–199.0 °C. ^{1}H NMR (CDCl$_3$): δ = 1.54 (s, 3 H, CH_3-), 2.36 (s, 3 H, CH_3–Ar), 3.82 (s, 3 H, CH_3-), 3.11 (d, J = 15.3 Hz, 1 H, $-CH_2-$), 3.15 (d, J = 13.7 Hz, 1 H, $-CH_2-$), 3.29 (d, J = 15.4 Hz, 1 H, $-CH_2-$), 3.44 (d, J = 13.8 Hz, 1 H, $-CH_2-$), 6.78 (s, 1 H, Ar), 7.02 (s, 1 H, Ar), 7.36–7.49 (m, 7 H, Ar), 7.63 (t, J = 7.2 Hz, 2 H, Ar), 7.83 (br. s, 1 H, NH), 8.10 (d, J = 7.0 Hz, 2 H, Ar), 8.12 (s, 1 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 20.3, 20.5, 24.7, 39.6, 41.6, 88.9, 117.5, 118.2, 118.8, 119.9, 121.2, 125.1, 125.7, 126.0, 126.3, 127.5, 127.7, 127.8, 129.5, 130.4, 130.6, 133.1, 133.6, 141.1, 144.7, 147.8, 161.8, 163.8 ppm. IR (KBr): $\tilde{\nu}$ = 3430, 1677, 1627, 1536, 1451 cm^{-1}. HRMS: calcd. for $C_{32}H_{28}N_2O_3$ 488.2098; found 488.2052.

Compound 2e: Colorless solid, yield of bulk reaction 4% (4 mg), yield of NMP reaction 80% (75 mg), m.p. 138.6 °C. ^{1}H NMR (CDCl$_3$): δ = 2.40 (s, 6 H, CH_3-), 2.41 (s, 6 H, CH_3-), 3.64 (s, 4 H, $-CH_2-$), 5.09 (s, 2 H, CH_2=), 6.92 (s, 2 H, Ar), 7.21 (d, J = 8.0 Hz, 4 H, Ar), 7.35 (s, 2 H, Ar), 7.85 (d, J = 8.2 Hz, 4 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 20.5, 20.6, 35.3, 113.4, 116.7, 120.9, 123.5, 125.9, 126.3, 128.4, 133.1, 140.6, 141.1, 143.8, 146.9, 162.0 ppm. IR (KBr): $\tilde{\nu}$ = 1610, 1583, 1557, 1499 cm^{-1}. HRMS: calcd. for $C_{34}H_{30}N_2O_2$ 498.2306; found 498.2285.

Compound 3e: Colorless solid, yield of bulk reaction 91% (88 mg), yield of NMP reaction 11% (11 mg), m.p. 120.7 °C. ^{1}H NMR (CDCl$_3$): δ = 1.52 (s, 3 H, CH_3-C-O-), 2.35 (s, 3 H, CH_3-), 2.38 (s, 3 H, CH_3-), 2.39(s, 3 H, CH_3-), 2.41 (s, 3 H, CH_3-), 3.08 (d, J = 15.3 Hz, 1 H, $-CH_2-$), 3.15 (d, J = 13.8 Hz, 1 H, $-CH_2-$), 3.28 (d, J = 15.3 Hz, 1 H, $-CH_2-$), 3.41 (d, J = 13.7 Hz, 1 H, $-CH_2-$), 6.75 (s, 1 H, Ar), 7.00 (s, 1 H, Ar), 7.16 (d, J = 7.8 Hz, 2 H, Ar), 7.21 (d, J = 7.9 Hz, 2 H, Ar), 7.43 (s, 1 H, Ar), 7.54 (d, J = 8.1 Hz, 2 H, Ar), 7.81 (br. s, 1 H, NH), 7.99 (d, J = 8.1 Hz, 2 H, Ar), 8.11 (s, 1 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 21.3, 21.4, 21.5, 21.5, 25.7, 40.6, 42.6, 89.8, 118.3, 119.1, 119.6, 120.7, 122.3, 124.2, 126.0, 126.7, 127.3, 128.4, 129.1, 129.5, 130.4, 131.8, 133.9, 141.8, 141.9, 142.1, 145.7, 148.6, 163.1, 164.8 ppm. IR (KBr): $\tilde{\nu}$ = 3440, 1674, 1627, 1611, 1539, 1502, 1456 cm^{-1}. HRMS: calcd. for $C_{34}H_{32}N_2O_3$ 516.2411; found 516.2440.

Compound 2f: Yellow solid, yield of bulk reaction 2% (2 mg), yield of NMP reaction 58% (54 mg), m.p. 236.6 °C. ^{1}H NMR (CDCl$_3$): δ = 2.42 (s, 6 H, CH_3-), 3.66 (s, 4 H, $-CH_2-$), 5.18 (s, 2 H, CH_2=), 7.01 (s, 2 H, Ar), 7.39 (s, 2 H, Ar), 8.09 (d, J = 8.7 Hz, 4 H, Ar), 8.25 (d, J = 8.7 Hz, 4 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 21.56, 36.2, 115.2, 118.5, 122.3, 124.0, 127.9, 128.1, 132.7, 135.2, 141.9, 144.3, 148.2, 149.2, 160.2 ppm. IR (KBr): $\tilde{\nu}$ = 1604, 1557, 1523, 1343 cm^{-1}. HRMS: calcd. for $C_{32}H_{24}N_4O_6$ 560.1694; found 560.1680.

Compound 3f: Yellow solid, yield of bulk reaction 51% (49 mg), yield of NMP reaction 10% (10 mg), m.p. 159.0–160.0 °C. ^{1}H NMR (CDCl$_3$): δ = 1.59 (s, 3 H, CH_3-C-O-), 2.38 (s, 3 H, CH_3-), 2.47 (s, 3 H, CH_3-), 3.13 (d, J = 13.9 Hz, 1 H, $-CH_2-$), 3.17 (d, J = 15.4 Hz, 1 H, $-CH_2-$), 3.30 (d, J = 15.3 Hz, 1 H, $-CH_2-$), 3.51 (d, J = 13.9 Hz, 1 H, $-CH_2-$), 6.84 (s, 1 H, Ar), 7.10 (s, 1 H, Ar), 7.52 (s, 1 H, Ar), 7.70–7.72 (m, 3 H, Ar), 8.07 (s, 1 H, NH), 8.17 (d, J = 8.7 Hz, 2 H, Ar), 8.22 (d, J = 8.7 Hz, 2 H, Ar), 8.25 (d, J = 8.8 Hz, 2 H, Ar) ppm. ^{13}C NMR ([D$_6$]DMSO): δ = 20.0, 20.4, 25.0, 41.0, 88.5, 117.5, 118.9, 121.2, 121.4, 122.1, 122.8, 126.1, 126.8, 127.4, 128.1, 128.4, 128.8, 131.4, 133.4, 138.7, 140.4, 147.1, 147.7, 147.8, 148.0, 158.9, 161.7 ppm. IR (KBr): $\tilde{\nu}$ = 3431, 1682, 1628, 1604, 1524, 1459, 1345 cm^{-1}. $C_{32}H_{26}N_4O_7$: calcd. C 66.43, H 4.53, N 9.68; found C 66.21, H 4.78, N 9.46.

Compound 2g: Colorless solid, yield of bulk reaction 43% (40 mg), m.p. 55.8–57.0 °C. ^{1}H NMR (CDCl$_3$): δ = 2.40 (s, 6 H, CH_3–Ar), 3.67 (s, 4 H, $-CH_2-$), 3.94 (s, 6 H, CH_3O-), 5.05 (s, 2 H, CH_2=), 6.95 (s, 2 H, Ar), 7.01–7.04 (m, 4 H, Ar), 7.43–7.45 (m, 4 H, Ar), 7.96 (d, J = 6.3 Hz, 2 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 20.5, 35.4, 55.0, 110.9, 113.1, 115.3, 117.1, 119.6, 120.9, 125.8, 130.0, 131.4, 132.9, 141.2, 144.0, 146.5, 157.3, 160.2 ppm. IR (KBr): $\tilde{\nu}$ = 1647, 1601, 1581 cm^{-1}. HRMS: calcd. for $C_{34}H_{30}N_2O_4$ 530.2204; found 530.2157.

Compound 3g: Colorless solid, yield of bulk reaction 16% (15 mg), m.p. 64.5–67.8 °C. ^{1}H NMR (CDCl$_3$): δ = 1.57 (s, 3 H, CH_3-C-O-), 2.36 (s, 3 H, CH_3-), 2.40 (s, 3 H, CH_3-), 2.99 (d, J = 13.8 Hz, 1 H, $-CH_2-$), 3.21 (d, J = 15.3 Hz, 1 H, $-CH_2-$), 3.26 (d, J = 15.2 Hz, 1 H, $-CH_2-$), 3.36 (s, 3 H, CH_3-), 3.54 (d, J = 13.8 Hz, 1 H, $-CH_2-$), 3.77 (s, 3 H, CH_3-), 6.77 (s, 1 H, Ar), 6.82 (d, J = 7.8 Hz, 1 H, Ar), 6.83 (d, J = 7.8 Hz, 1 H, Ar), 6.88 (t, J = 7.5 Hz, 1 H, Ar), 6.97–7.55 (m, 2 H, Ar), 7.33 (t, J_1 = 1.8 Hz, J_2 = 8.1 Hz, 1 H, Ar), 7.38 (t, J_1 = 1.8 Hz, J_2 = 8.0 Hz, 1 H, Ar), 7.48 (s, 1 H, Ar), 7.85 (dd, J_1 = 1.7 Hz, J_2 = 7.8 Hz, 1 H, Ar), 8.06 (dd, J_1 = 1.9 Hz, J_2 = 7.8 Hz, 1 H, Ar), 8.26 (s, 1 H, Ar), 10.19 (s, 1 H, NH) ppm. ^{13}C NMR (CDCl$_3$): δ = 21.4, 25.4, 40.9, 43.4, 55.4, 55.8, 60.4, 89.6, 111.1, 111.6, 115.6, 118.4, 119.2, 119.7, 120.1, 120.4, 120.6, 121.0, 121.3, 123.3, 125.7, 128.9, 130.4, 130.8, 132.1, 132.5, 132.7, 133.6, 142.3, 145.8, 148.4, 157.2, 158.1, 162.4 ppm. IR (KBr): $\tilde{\nu}$ = 3332, 1664, 1625, 1600, 1551, 1465 cm^{-1}: HRMS: calcd. for $C_{34}H_{32}N_2O_5$ 548.2309; found 548.2272.

Compound 2h: Colorless solid, yield of bulk reaction 8% (7 mg), yield of NMP reaction 77% (72 mg), m.p. 116.5 °C. ^{1}H NMR (CDCl$_3$): δ = 2.40 (s, 6 H, CH$_3$−), 3.64 (s, 4 H, −CH$_2$−), 3.87 (s, 6 H, CH$_3$O−), 5.12 (s, 2 H, CH$_2$=), 6.92 (s, 2 H, Ar), 7.21 (d, *J* = 8.0 Hz, 4 H, Ar), 7.35 (s, 2 H, Ar), 7.85 (d, *J* = 8.2 Hz, 4 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 14.1, 21.4, 36.1, 55.3, 111.6, 114.5, 117.8, 119.8, 121.9, 126.5, 128.3, 129.7, 134.2, 141.9, 144.8, 147.9, 159.7, 162.6 ppm. IR (KBr): $\tilde{\nu}$ = 1649, 1602, 1555 cm^{-1}. HRMS: calcd. for $C_{34}H_{30}N_2O_4$ 530.2204; found 530.2148.

Compound 3h: Colorless solid, yield of bulk reaction 91% (88 mg), yield of NMP reaction 12% (12 mg), m.p. 55.7−57.2 °C. ^{1}H NMR (CDCl$_3$): δ = 1.55 (s, 3 H, CH$_3$−C−O−), 2.35 (s, 3 H, CH$_3$−), 2.43 (s, 3 H, CH$_3$−), 3.11 (d, *J* = 15.3 Hz, 1 H, −CH$_2$−), 3.13 (d, *J* = 13.6 Hz, 1 H, −CH$_2$−), 3.29 (d, *J* = 15.4 Hz, 1 H, −CH$_2$−), 3.45 (d, *J* = 13.7 Hz, 1 H, −CH$_2$−), 3.84 (s, 3 H, CH$_3$−), 3.85 (s, 3 H, CH$_3$−), 6.78 (s, 1 H, Ar), 7.00−7.34 (m, 4 H, Ar), 7.09 (d, *J* = 7.6 Hz, 1 H, Ar), 7.27 (s, 1 H, Ar), 7.33 (t, *J* = 7.9 Hz, 1 H, Ar), 7.45 (s, 1 H, Ar), 7.58 (s, 1 H, Ar), 7.66 (d, *J* = 7.7 Hz, 1 H, Ar), 7.82 (s, 1 H, NH), 8.11 (s, 1 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 21.2, 21.4, 40.5, 42.6, 55.3, 55.3, 89.8, 111.6, 112.2, 117.7, 118.0, 118.1, 118.4, 119.1, 119.7, 119.7, 120.8, 122.1, 126.0, 128.1, 128.7, 129.4, 129.8, 130.3, 134.1, 135.9, 139.4, 141.9, 145.7, 148.7, 159.7, 159.8, 162.7, 164.6 ppm. IR (KBr): $\tilde{\nu}$ = 3429, 2920, 1677, 1585, 1536, 1458, 1288 cm^{-1}. HRMS: calcd. for $C_{34}H_{32}N_2O_5$ 548.2309; found 548.2250.

Compound 2i: Colorless solid, yield of bulk reaction 60% (56 mg), yield of NMP reaction 61% (57 mg), m.p. 189.2 °C. ^{1}H NMR (CDCl$_3$): δ = 2.40 (s, 3 H, CH$_3$−), 3.63 (s, 4 H, −CH$_2$−), 3.86 (s, 6 H, CH$_3$O−), 5.09 (s, 2 H, CH$_2$=), 6.91 (s, 2 H, Ar), 6.92 (d, *J* = 8.9 Hz, 4 H, Ar), 7.34 (s, 2 H, Ar), 7.97 (d, *J* = 8.9 Hz, 4 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 21.9, 36.7, 55.8, 114.6, 114.8, 118.0, 120.3, 122.2, 126.8, 129.5, 134.5, 142.6, 145.4, 148.3, 162.4, 163.3 ppm. IR (KBr): $\tilde{\nu}$ = 1606, 1260 cm^{-1}. HRMS: calcd. for $C_{34}H_{30}N_2O_4$ 530.2204; found 530.2193.

Compound 3i: Colorless solid, yield of bulk reaction 39% (38 mg), yield of NMP reaction 15% (14 mg), m.p. 61.0−63.3 °C. ^{1}H NMR (CDCl$_3$): δ = 1.53 (s, 3 H, CH$_3$−C−O−), 2.35 (s, 3 H, CH$_3$−), 2.42 (s, 3 H, CH$_3$−), 3.10 (d, *J* = 15.3 Hz, 1 H, −CH$_2$−), 3.14 (d, *J* = 13.8 Hz, 1 H, −CH$_2$−), 3.29 (d, *J* = 15.5 Hz, 1 H, −CH$_2$−), 3.43 (d, *J* = 13.6 Hz, 1 H, −CH$_2$−), 3.85 (s, 3 H, CH$_3$−), 3.86 (s, 3 H, CH$_3$−), 6.70 (s, 1 H, Ar), 6.86 (d, *J* = 8.7 Hz, 2 H, Ar), 6.91 (d, *J* = 8.9 Hz, 2 H, Ar), 6.98 (s, 1 H, Ar), 7.41 (s, 1 H, Ar), 7.62 (d, *J* = 8.9 Hz, 2 H, Ar), 7.75 (s, 1 H, Ar), 8.04 (d, *J* = 9.0 Hz, 2 H, Ar), 8.10 (s, 1 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 21.3, 21.5, 25.8, 40.7, 42.7, 55.4, 89.9, 113.8, 114.3, 118.2, 119.1, 119.6, 120.5, 122.4, 126.1, 126.9, 128.3, 128.6, 129.1, 129.3, 130.5, 133.9, 142.3, 145.7, 148.7, 162.2, 162.3, 163.1, 164.4 ppm. IR (KBr): $\tilde{\nu}$ = 3432, 1671, 1608, 1537, 1503, 1457 cm^{-1}. HRMS: calcd. for $C_{34}H_{32}N_2O_5$ 548.2309; found 548.2244.

Compound 2j: Colorless solid, yield of bulk reaction 88% (81 mg), m.p. 130.5−132.2 °C. ^{1}H NMR (CDCl$_3$): δ = 2.55 (s, 6 H, −N=C−CH$_3$), 3.52 (s, 4 H, −CH$_2$−), 3.82 (s, 6 H, C*H*$_3$O−Ar), 4.98 (s, 2 H, CH$_2$=), 6.59 (s, 2 H, Ar), 6.97 (s, 2 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 13.5, 35.0, 54.7, 99.5, 112.3, 113.7, 121.5, 140.9, 143.1, 143.6, 155.9, 163.2 ppm. IR (KBr): $\tilde{\nu}$ = 1606, 1260 cm^{-1}. HRMS: calcd. for $C_{22}H_{22}N_2O_4$ 378.1578; found 378.1601.

Compound 2k: Colorless solid, yield of bulk reaction 32% (29 mg), yield of NMP reaction 80% (77 mg), m.p. 181.2−182.0 °C. ^{1}H NMR (CDCl$_3$): δ = 2.58 (s, 6 H, −CH$_3$), 4.08 (s, 4 H, −CH$_2$−), 4.81 (s, 2 H, CH$_2$=), 7.40−7.45 (m, 4 H, Ar), 7.97−7.98 (m, 6 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 14.8, 33.2, 113.9, 114.9, 115.4, 124.1, 124.3, 125.1, 129.1, 130.3, 131.7, 140.6, 144.7, 149.9, 166.0 ppm. IR (KBr): $\tilde{\nu}$ = 1626, 1579 cm^{-1}. HRMS: calcd. for $C_{28}H_{22}N_2O_2$ 418.1680; found 418.1772.

Compound 3k: Colorless solid, yield of bulk reaction 67% (64 mg), yield of NMP reaction 19% (18 mg), m.p. 224.6−226.2 °C. ^{1}H NMR (CDCl$_3$): δ = 1.52 (s, 3 H, CH$_3$−C−O−), 1.92 (s, 3 H, CH$_3$−), 2.58 (s, 3 H, CH$_3$−), 3.40 (d, *J* = 15.1 Hz, 1 H, −CH$_2$−), 3.56 (d, *J* = 14.4 Hz, 1 H, −CH$_2$−), 3.61 (d, *J* = 15.1 Hz, 1 H, −CH$_2$−), 3.82 (d, *J* = 14.4 Hz, 1 H, −CH$_2$−), 6.96 (s, 1 H, Ar), 7.24 (t, *J* = 7.0 Hz, 1 H, Ar), 7.26 (m, 3 H, Ar), 7.43 (d, *J* = 8.1 Hz, 1 H, Ar), 7.74 (s, *J* = 8.1 Hz, 1 H, Ar), 7.86−7.94 (m, 2 H, Ar), 7.99 (d, *J* = 8.3 Hz, 1 H, Ar), 8.16 (br. s, 1 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 14.8, 24.6, 26.5, 36.8, 42.3, 91.8, 113.6, 116.1, 116.3, 117.8, 122.1, 123.5, 123.7, 124.1, 124.6, 124.8, 125.4, 127.4, 128.8, 129.3, 130.0, 131.1, 131.8, 140.5, 146.4, 150.0, 166.0, 168.2 ppm. IR (KBr): $\tilde{\nu}$ = 1693, 1626, 1587, 1542 cm^{-1}. HRMS: calcd. for $C_{34}H_{32}N_2O_3$ 436.1786; found 436.1798.

Compound 5k: Colorless solid, m.p. 119.0 °C. ^{1}H NMR (DMSO): δ = 2.18 (s, 6 H, CH$_3$−), 3.92 (s, 4 H, −CH$_2$−), 4.18 (s, 2 H, CH$_2$=), 7.25−7.26 (m, 4 H, Ar), 7.65−7.73 (m, 4 H, Ar), 8.03 (s, 2 H, Ar), 9.49 (br. s, 2 H, NH), 9.78 (s, 2 H, −OH) ppm. ^{13}C NMR (DMSO): δ = 24.1, 32.3, 109.9, 118.8, 119.7, 123.5, 123.7, 125.3, 128.0, 128.5, 128.6, 130.9, 145.8, 146.7, 170.4 ppm. IR (KBr): $\tilde{\nu}$ = 1672, 1648, 1590, 1536 cm^{-1}. HRMS: No peak for **5k** was observed (calcd. for $C_{28}H_{26}N_2O_4$ 454.1891), but peaks corresponding to two dehydrated compounds were observed: calcd. for $C_{28}H_{24}N_2O_3$ 436.17855; found 436.1798; calcd. for $C_{28}H_{22}N_2O_2$ 418.1680; found 418.1724.

Compound 2l: Colorless solid, yield of bulk reaction 5% (5 mg), yield of NMP reaction 51% (48 mg), m.p. 252.0−252.8 °C. ^{1}H NMR (CDCl$_3$): δ = 4.23 (s, 4 H, −CH$_2$−), 4.99 (s, 2 H, CH$_2$=), 7.39−7.47 (m, 4 H, Ar), 7.49−7.54 (m, 4 H, Ar), 7.55−7.59 (m, 2 H, Ar), 7.95 (d, *J* = 8.9 Hz, 2 H, Ar), 7.97 (s, 2 H, Ar), 8.06 (d, *J* = 8.6 Hz, 2 H, Ar), 8.08−8.11 (m, 4 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 33.3, 114.2, 115.2, 116.2, 123.9, 124.3, 125.3, 126.9, 128.0, 128.2, 128.8, 129.2, 130.8, 132.0, 141.0, 144.7, 148.8, 164.6 ppm. IR (KBr): $\tilde{\nu}$ = 1557, 1327 cm^{-1}. HRMS: calcd. for $C_{38}H_{26}N_2O_2$ 542.1993; found 542.2000.

Compound 3l: Colorless solid, yield of bulk reaction 95% (92 mg), yield of NMP reaction 47% (46 mg), m.p. 128.2−132.8 °C. ^{1}H NMR (CDCl$_3$): δ = 1.69 (s, 3 H, CH$_3$−C−O−), 3.61 (d, *J* = 15.1, 1 H, −CH$_2$−), 3.81 (d, *J* = 14.3, 1 H, −CH$_2$−), 3.83 (d, *J* = 15.0, 1 H, −CH$_2$−), 4.08 (d, *J* = 14.5, 1 H, −CH$_2$−), 7.25−7.40 (m, 4 H, Ar), 7.42−7.59 (m, 3 H, Ar), 7.47−7.48 (m, 1 H, Ar), 7.51 (t, *J* = 7.6, 2 H, Ar), 7.55−7.57 (m, 1 H, Ar), 7.57 (m, *J* = 7.6, 2 H, Ar), 7.88 (s, 1 H, Ar), 7.91 (d, *J* = 8.1, 1 H, Ar), 8.02 (d, *J* = 7.8, 1 H, Ar), 8.17 (d, *J* = 8.1, 1 H, Ar), 8.18 (s, 1 H, Ar), 8.21 (d, *J* = 7.0, 2 H, Ar), 8.87 (br. s, 1 H, Ar) ppm. ^{13}C NMR (CDCl$_3$): δ = 26.2, 37.0, 42.6, 92.1, 114.0, 116.6, 116.9, 117.8, 122.2, 123.7, 123.9, 124.4, 124.4, 125.4, 125.6, 126.7, 126.9, 127.7, 128.0, 128.5, 129.0, 129.2, 130.2, 131.6, 131.7, 132.2, 134.1, 141.0, 146.9, 149.7, 164.8, 164.9, IR (KBr): $\tilde{\nu}$ = 3425, 1677, 1631, 1598, 1539, 1491, 1447 cm^{-1}. HRMS: calcd. for $C_{38}H_{28}N_2O_3$ 560.9987; found 560.2056.

Compound 5l: Colorless solid, m.p. 119.0 °C. ^{1}H NMR (DMSO): δ = 3.99 (s, 4 H, −CH$_2$−), 4.24 (s, 2 H, CH$_2$=), 7.29−7.33 (m, 4 H, Ar), 7.57 (t, *J* = 6.4 Hz, 4 H, Ar), 7.63 (t, *J* = 6.1 Hz, 2 H, Ar), 7.74 (d, *J* = 7.9 Hz, 2 H, Ar), 7.79 (d, *J* = 7.9 Hz, 2 H, Ar), 8.05 (d, *J* = 6.2 Hz, 4 H, Ar), 8.19 (s, 2 H, Ar), 9.39 (br. s, 2 H, NH), 9.99 (s, 2 H, −OH) ppm. ^{13}C NMR (CDCl$_3$): δ = 32.4, 110.2, 120.0, 120.6, 123.8, 125.7, 128.0, 128.1, 128.2, 128.5, 129.0, 131.4, 132.4, 134.4, 146.5, 146.6, 166.7 ppm. IR (KBr): $\tilde{\nu}$ = 3403, 1655, 1538 cm^{-1}. HRMS: calcd. for $C_{38}H_{30}N_2O_4$ 578.2204; found 578.2182.

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[13] The yield of bis(benzoxazole)s obtained from **1a** represents the combined yields of **2a** and **4a**, because the Claisen rearrangement proceeded both at the *o*-position and at the *p*-position, therefore **2a**, **3a**, and **4a** were produced in the case of **1a**, with no substituent at the phenoxy group *p*-position.

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[16] $[\mathbf{1}]_t = [\mathbf{1}]_0 e^{-kt}$, *where* $[\mathbf{1}]_t$ *is the concentration of* **1** *at time t,* $[\mathbf{1}]_0$ *is the initial concentration of* **1**, *and k is the rate constant.*

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[19] Although it might be noticed that we have formulated our idea to interpret the different reaction rates between ***1c*** and ***1k*** in an indefinite way, it is supported by the most likely evidence: as suggested by the Woodward−Hoffmann rules, a key indication of a Claisen rearrangement is the σ-orbital coefficients of the HOMO of an aryl moiety. A conventional Hückel calculation showed that the absolute value of the coefficient at the 2-position of the phenoxy unit was 0.33, much smaller than the corresponding value (0.46) at the 1-position of a 2-naphthoxy unit. This implies that the thermal rearrangement of the naphthoxy unit takes place more easily than that of the phenoxy unit. We believe that this is the case for ***1c*** and ***1k***.

[20] The charge density was calculated by a electrostatic potential analysis using the ab initio Hartree−Fock method with the 6-311G** basis set.

Received October 19, 2001
[O01500]