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Abstract: Macrocyclic crown diamides with 16- or 24-membered rings containing E- and Z-olefinic double bonds were synthesized either by bisalkylation or by ring-closing metathesis (RCM) techniques. The two methods were evaluated and compared with regard to yield and to product stereochemistry. Isomerization of some Z-olefinic macrocycles to their corresponding E-isomers was achieved using Grubbs’ catalysts. Some of the required starting diols, diols and bishalo compounds were prepared by different routes including cross-metathesis (CM). The latter was compared with other investigated methods. Some of the olefinic macrocycles were subjected to cycloaddition reactions with diphenylacetylene to give the corresponding pyrazolino macrocycles. The latter showed interesting emission spectra.

Key words: ring-closing metathesis, E,Z isomerization, macrocyclic ether amidic, cycloaddition, pyrazolino macrocycles

Crown compounds and azacrown compounds constitute important macrocyclic groups in supramolecular chemistry. They have been shown to exhibit important applications including selective ion separation, detection, molecular recognition, catalysis, biological applications as well as many other interesting uses in diverse fields of supramolecular chemistry. Of particular interest are crown ethers incorporating amide groups, since such groups modify the binding properties of the crown compounds in favor of alkaline earth cations over alkali metal ions. Moreover, the number of ether oxygen atoms, amide carbonyl groups, ring size, lipophilic groups and other structural features control the selectivity towards different ions.

During the past decade, ring-closing metathesis (RCM) has emerged as a powerful tool for the construction of small-, medium- and large-ring systems. A large part of the success of this reaction has been due to the availability of well-defined catalysts such as those developed by Schrock and Grubbs.

In the present work the synthesis of each of the E and Z stereoisomers of macrocyclic crown diamides 2a–c, 3a–c, 6a–c and 7a–c with 16- and 24-membered rings was investigated by bisalkylation and also as E:Z mixtures by ring-closing metathesis using Grubbs’ catalysts I and II (Figure 1).

In the present study the effect of Grubbs’ catalysts I and II on the RCM reactions of 1a–c regarding the yield and the stereoselectivity of the E- and Z-olefinic macrocyclic crown diamides was investigated. Thus, RCM of the 1,4-dienes 1a–c using catalysts I and II (Scheme 1) gave a mixture of the corresponding isomeric macrocycles 2a–c and 3a–c, in the yields and E:Z ratios shown in Table 1.

From Table 1 it is clear that catalyst II is more active and leads to higher yield of the E-isomer. Thus, 2.5% and 1.25% of catalyst I and II are needed to accomplish the RCM of 1a and 1b, respectively (entries 1 and 3). However, only 1% of catalyst II is needed to achieve better RCM conversions (entries 2 and 4). On the other hand, RCM of 1c required 5% of either of the catalyst I or II to achieve 70% and 93% conversions, respectively (as monitored by TLC). Table 1 shows also the reported RCM synthesis of 6a,b and 7a,b from the corresponding appropriate 1,6-dienes 5a,b using catalyst I.

It is also concluded from these results that Grubbs’ catalyst II not only improved the yield of the RCM product but also increased the selectivity towards the E isomer. Therefore, in the present study we also investigated the possibility of Z-to-E isomerization of these olefinic macrocycles. Thus, treatment of 2a and 6a with Grubbs’ catalyst I showed complete recovery of unchanged starting materials. On the other hand, treatment of 2a, 6a and 6b with 1% of catalyst II led to 92% conversion of 2a into 3a (entry 7), 93% conversion of 6a into 7a (entry 10) and 100% conversion of 6b into 7b (entry 11). The Z-to-E isomerization promoted by Grubbs’ catalyst II is derived by two factors which are the more thermodynamic stability of the E isomer and by the reactivity of this catalyst towards polysubstituted olefins.

The pure Z macrocycles 2a–c were readily obtained in 42–50% yields via bisalkylation of the dipostassium salts 4a–c with (Z)-1,4-dichloro-2-butene in N,N-dimethylformamide. The pure E isomers 3a–c were similarly obtained in 68–80% yields by treatment of 4a–c with (E)-1,4-dichloro-2-butene. Similar bisalkylation of 4a–c with...
(Z)-1,4-bis(o-chloromethylphenoxy)-2-butene 8 and its E isomer 9 gave the corresponding Z macrocycles 6a–c (11–49%) and their E isomers 7a–c (39–56%), respectively.

The starting materials 8 and 9 required for the synthesis of the macrocycles 6 and 7 were obtained as outlined in Scheme 2 using two synthetic approaches.

The first synthetic approach (Scheme 2) starts with the reaction of the potassium salt of salicylaldehyde 10 with (Z)-1,4-dichloro-2-butene and (E)-1,4-dichloro-2-butene to give (Z)-1,4-bis(o-formylphenoxy)-2-butene 11 and the corresponding E isomer 12, respectively. Reduction of 11 and 12 with sodium borohydride in methanol gave the corresponding diols 13 and 14, respectively. Reaction of compounds 13 and 14 with thionyl chloride in chloroform gave the corresponding bischloro compounds 8 and 9, respectively, in 95% yield.

The second synthetic method (Scheme 2) attempted was the CM of o-allyloxybenzaldehyde (15), o-allyloxybenzyl alcohol (16) and o-allyloxybenzyl chloride (17) using Grubbs’ catalysts I and II. Results of CM are shown in Table 2. From Table 2 it is clear that the CM reactions can convert 15, 16 and 17 to the required product; however, as a mixture of E and Z isomers. It is also clear that Grubbs’ catalyst II gave better yield with better E selectivity compared to the same percent of catalyst I. Also, compound 11 was isomerized to the E isomer 12 with 89% conversion. Compounds 11 and 12 were also obtained as byproducts from the reaction of allylbenzene with o-allyloxybenzaldehyde using Grubbs’ catalyst I,12

The E/Z selectivity and isomerization in RCM reactions and practical solutions to this problem have been addressed in many reviews; e.g., the Prunet review13a as well as other papers.13b–d The problem has also been discussed in Blechert’s review on cross-metathesis13e and in Schmidt’s review on olefin metathesis.13f

Cycloaddition of the olefinic crown diamides 2a,b with diphenylnitritelluridine gave the corresponding condensed pyrazolino macrocycles 18a,b and 19a,b, respectively (Scheme 3). The latter exhibited absorption and interesting emission spectra in the UV–Vis region. Compounds 18, 19 showed absorption bands at λmax = 284–360 nm and emission bands at λmax = 436–463 nm.

In conclusion, RCM and CM techniques have shown to give efficient access to macrocycles and the required precursor bisolefinic compounds. The application of Grubbs’ catalysts of 1st and 2nd generation showed different behaviors. With other synthetic methods illustrates the synthetic potentialities of these novel catalytic techniques. The conversion of these olefinic macrocycles to photoluminescent pyrazolino derivatives paves the path for future applications.

Melting points are uncorrected. IR spectra were recorded in KBr disks on a Perkin–Elmer System 2000 FT-IR spectrophotometer. 1H and 13C NMR spectra were recorded on a Bruker DPX 400, 400 MHz super-conducting NMR spectrometer at 400 MHz and 100 MHz, respectively. Mass spectra were measured on VG AutoSpec-Q (high resolution, high performance, tri-sector GC/MS/MS) and with LCMS using Agilent 1100 series LC/MSD with an API-ES/
APCI ionization mode. The UV–Vis spectra were recorded on a Cary-5/Varian spectrophotometer and the emission spectra were recorded using a SIM AMINCO.BOWMAN series Luminescence spectrometer. Microanalyses were performed on a LECO CHNS-932 Elemental Analyzer. The UV-Vis absorption spectra of compounds 18a,b, 19a,b were scanned in chloroform at concentrations 1.0 × 10⁻⁴ M, 9.4 × 10⁻⁵ M, 1.4 × 10⁻⁴ M, 3.7 × 10⁻⁵ M, respectively, in the wavelength range 250–450 nm using a dry, clean, quartz cuvette of 1.0 cm path length. From the spectra obtained, absorbance values at λmax were used to calculate the extinction coefficient. The emission spectra of compounds 18a,b, 19a,b in chloroform at the above-mentioned concentrations were obtained after excitation at λ = 294, 285, 360, 284 nm, respectively.

The starting compounds 1a–c, 1,2-bis(2-hydroxybenzamido)cyclohexane were prepared as reported.

Scheme 1

APCI ionization mode. The UV–Vis spectra were recorded on a Cary-5/Varian spectrophotometer and the emission spectra were recorded using a SIM AMINCO.BOWMAN series Luminescence spectrometer. Microanalyses were performed on a LECO CHNS-932 Elemental Analyzer. The UV-Vis absorption spectra of compounds 18a,b, 19a,b were scanned in chloroform at concentrations 1.0 × 10⁻⁴ M, 9.4 × 10⁻⁵ M, 1.4 × 10⁻⁴ M, 3.7 × 10⁻⁵ M, respectively, in the wavelength range 250–450 nm using a dry, clean, quartz cuvette of 1.0 cm path length. From the spectra obtained, absorbance values at λmax were used to calculate the extinction coefficient. The emission spectra of compounds 18a,b, 19a,b in chloroform at the above-mentioned concentrations were obtained after excitation at λ = 294, 285, 360, 284 nm, respectively.

The starting compounds 1a–c, 1,2-bis(2-hydroxybenzamido)cyclohexane were prepared as reported.

**Scheme 1**

1,2-Bis(2-hydroxybenzamido)cyclohexane
A mixture of 1,2-cyclohexanediol (cis and trans isomers; 5.0 g, 43.8 mmol) and methyl salicylate (11.3 g, 87.4 mmol) was heated on a steam bath for 5 h. After cooling, the mixture was recrystallized from EtOH to give colorless crystals; yield: 8.4 g (54%); mp 238–239 °C.

IR: 3380, 3319, 3077, 2943, 2856, 2772, 1635, 1595, 1547, 1488, 1444, 1344, 1250, 1220, 1145, 815, 756 cm⁻¹.

**1H NMR (DMSO):**
δ = 1.33 (d, J = 9.7 Hz, 2 H), 1.51 (d, J = 9.7 Hz, 2 H), 1.74 (d, J = 7.9 Hz, 2 H), 1.94 (d, J = 12.0 Hz, 2 H), 4.02 (br, 2 H), 6.82 (m, 4 H), 7.33 (t, J = 7.6 Hz, 2 H), 7.76 (d, J = 7.5 Hz, 2 H), 8.71 (br, 2 H, NH), 12.21 (br, 2 H, OH).

**13C NMR (CDCl₃):**
δ = 22.6, 29.6, 50.2, 113.3, 115.3, 116.3, 125.9, 131.4, 158.1, 166.6.

MS: m/z = 354 [M⁺].
Anal. Calcd for C_{20}H_{22}N_{2}O_{4} (354.41): C, 67.78; H, 6.26; N, 7.95. Found: C, 67.52; H, 6.48; N, 8.22.

1,2-Bis(2-allyloxybenzamido)benzene (1b)

A solution of 1,2-bis(2-hydroxybenzamido)benzene 15 (0.35 g, 1 mmol) and KOH (0.12 g, 2 mmol) in MeOH (5 mL) was stirred for 5 min and the solvent was then removed in vacuo to give the corresponding potassium salt. To the latter were added DMF (10 mL) and allyl bromide (2 mmol). The reaction mixture was then heated under reflux for 15 min. The mixture was diluted with ice-water (20 mL). The precipitate was collected, washed with cold H_{2}O and finally crystallized from EtOH to give colorless crystals; yield: 0.28 g (66%); mp 120–122 °C.4a

**Scheme 2** Reagents and conditions: i) (Z)-1,4-dichloro-2-butene, DMF, 15 min reflux; ii) (E)-1,4-dichloro-2-butene, DMF, 15 min reflux; iii) NaBH_{4}, MeOH, stirring, 0–5 °C; iv) SOCl_{2}, CHCl_{3}, stirring, 2 h.

**Scheme 3**

**1,2-Bis(2-allyloxybenzamido)benzene (1b)**

A solution of 1,2-bis(2-hydroxybenzamido)benzene\(^{15}\) (0.35 g, 1 mmol) and KOH (0.12 g, 2 mmol) in MeOH (5 mL) was stirred for 5 min and the solvent was then removed in vacuo to give the corresponding potassium salt. To the latter were added DMF (10 mL) and allyl bromide (2 mmol). The reaction mixture was then heated under reflux for 15 min. The mixture was diluted with ice-water (20 mL). The precipitate was collected, washed with cold H_{2}O and finally crystallized from EtOH to give colorless crystals; yield: 0.28 g (66%); mp 120–122 °C.\(^{4a}\)

\(^{1}\)H NMR (CDCl_{3}); δ = 4.64 (d, J = 5.4 Hz, 4 H, OCH_{2}), 5.15 (d, J = 10.5 Hz, 2 H, CH_{2}), 5.22 (d, J = 17.2 Hz, 2 H, CH_{2}), 5.88 (m, 2 H, CH=), 6.78 (d, J = 8.3 Hz, 2 H), 7.14 (t, J = 7.5 Hz, 2 H), 7.29 (m, 2 H), 7.46 (dt, J = 1.5, 8.5 Hz, 2 H), 7.81 (m, 2 H), 8.30 (dd, J = 1.5, 7.8 Hz, 2 H), 9.91 (br, 2 H, NH).

\(^{13}\)C NMR (CDCl_{3}); δ = 69.1 (CH_{2}), 112.9, 119.1, 121.5, 121.7, 125.6, 126.0, 131.0, 131.8, 132.7, 133.2, 156.7, 164.1.

MS: \textit{m/z} = 428 [M\(^+\)].

Anal. Calcd for C_{26}H_{24}N_{2}O_{4} (428.49): C, 72.78; H, 6.65; N, 6.54. Found: C, 72.58; H, 6.61; N, 6.48.
1,2-Bis(2-allyloxybenzoylamino)cyclohexane (1c)
A solution of 1,2-bis(2-allyloxybenzoylamino)cyclohexane (0.5 mmol) and KOH (0.12 g, 2 mmol) in MeOH (5 mL) was stirred for 5 min and the solvent was then removed in vacuo to give 4c. To the latter, DMF (10 mL) and the allyl bromide (2 mmol) were added. The reaction mixture was then heated under reflux for 15 min. The mixture was diluted with ice-water (20 mL) and the precipitate was collected, washed with cold H₂O and crystallized from EtOH to give colorless crystals; yield: 0.34 g (79%); mp 118–119 °C.
IR: 3399, 3104, 3072, 3038, 2933, 2875, 1638, 1599, 1520, 1484, 1295, 1232, 990, 752 cm⁻¹.
1H NMR (CDCl₃): δ = 0.78 (t, J = 7.8 Hz, 3 H), 1.00–1.43 (m, 4 H), 1.81 (m, 2 H), 2.28 (d, J = 7.8 Hz, 2 H), 3.72 (br, 4 H, NCH₂), 4.69 (d, J = 7.8 Hz, 2 H), 4.73–4.81 (m, 4 H), 4.80 (s, 2 H), 5.29 (d, J = 1.7, 7.6 Hz, 2 H), 6.84 (br, 2 H, NH), 7.23 (s, 1 H, NH), 7.34–7.38 (dt, J = 1.7, 7.6 Hz, 2 H), 8.07–8.10 (dd, J = 1.7, 7.6 Hz, 2 H), 8.07–8.10 (dd, J = 1.7, 7.6 Hz, 2 H), 8.17 (br, 2 H, NH), 8.24 (dd, J = 1.5, 7.8 Hz, 2 H).
13C NMR (CDCl₃): δ = 24.8, 32.8, 53.3, 69.8, 112.8, 118.8, 121.1 (2 overlapped signals), 132.0, 132.4, 156.6, 156.3.
MS: m/z = 434 [M⁺].
Anal. Calcd for C₂₀H₁₄N₂O₄: C, 68.01; H, 5.64; N, 8.05.
\[^{1}H\ NMR\ (CDCl\_3): \; \delta = 1.39\ (m, 2\ H), 1.81\ (m, 2\ H), 1.44\ (m, 2\ H), 2.40\ (m, 2\ H), 3.99\ (m, 2\ H), 4.41\ (dt, J = 1.8, 12.2\ Hz, 2\ H, OCH\_3), 4.63\ (d, J = 12.3\ Hz, 2\ H, OCH\_3), 5.80\ (s, J = 1.9\ Hz, 2\ H, CH\_2=), 6.94\ (dd, J = 1.0, 8.2\ Hz, 2\ H), 7.07\ (t, J = 7.7\ Hz, 2\ H), 7.38\ (dt, J = 1.2, 8.2\ Hz, 2\ H), 7.48\ (br, 2\ H, NH), 7.72\ (dd, J = 1.6, 7.7\ Hz, 2\ H).

\[^{13}C\ NMR\ (CDCl\_3): \; \delta = 24.7, 32.8, 54.3, 71.2, 117.2, 122.6, 127.2, 127.6, 129.7, 131.8, 155.2, 167.4.

**MS:** \( m/c = 604\ [M^+] \).

Analyzed by: C\(_{38}\)H\(_{32}\)N\(_2\)O\(_6\) (612.7); C, 74.50; H, 5.26; N, 4.57. Found: C, 74.12; H, 5.16; N, 4.45.

(E)-1,12,16,21-Tetraoxa-5,8-diazapentabenzoi[b,f,j,n,v]cyclotetracos-18-ene-4,9-dione (7b)

Prepared from 4b and 8; colorless crystals (CHCl\(_3\)); yield: 0.46 g (53%); mp 248–250 °C.

IR: 3321, 3068, 2932, 2917, 1650, 1597, 1514, 1477, 1450, 1288, 1243, 1251, 1002, 914, 752 cm\(^{-1}\).

\[^{1}H\ NMR\ (CDCl\_3): \; \delta = 4.24\ (s, 4\ H, OCH\_3.CH), 5.10\ (s, 4\ H, OCH\_3), 5.84\ (s, 2\ H, CH\_2=), 6.81\ (d, J = 8.1\ Hz, 2\ H), 6.96\ (t, J = 7.4\ Hz, 2\ H), 7.05\ (t, J = 7.5\ Hz, 2\ H), 7.11\ (m, 2\ H), 7.14\ (d, J = 8.3\ Hz, 2\ H), 7.32–7.37\ (m, 4\ H), 7.43\ (dt, J = 1.7, 7.8\ Hz, 2\ H), 7.50\ (m, 2\ H), 8.10\ (dd, J = 1.6, 7.9\ Hz, 2\ H), 9.99\ (br, 2\ H, NH).

\[^{13}C\ NMR\ (CDCl\_3): \; \delta = 38.6, 60.8, 87.3, 113.0, 119.8, 120.5, 129.6, 131.7, 131.8, 132.5, 135.7, 154.6, 164.6.

**MS:** \( m/c = 612\ [M^+] \).

Analyzed by: C\(_{46}\)H\(_{32}\)N\(_2\)O\(_6\) (650.8); C, 74.50; H, 5.16; N, 4.45.

(E)-1,12,16,21-Tetraoxa-5,8-diazapentabenzoi[b,f,j,n,v]cyclotetracos-18-ene-4,9-dione (7b)

Prepared from 4b and 8; colorless crystals (CHCl\(_3\)); yield: 0.46 g (53%); mp 248–250 °C.

IR: 3321, 3068, 2932, 2917, 1650, 1597, 1514, 1477, 1450, 1288, 1243, 1251, 1002, 914, 752 cm\(^{-1}\).

\[^{1}H\ NMR\ (CDCl\_3): \; \delta = 4.24\ (s, 4\ H, OCH\_3.CH), 5.10\ (s, 4\ H, OCH\_3), 5.84\ (s, 2\ H, CH\_2=), 6.81\ (d, J = 8.1\ Hz, 2\ H), 6.96\ (t, J = 7.4\ Hz, 2\ H), 7.05\ (t, J = 7.5\ Hz, 2\ H), 7.11\ (m, 2\ H), 7.14\ (d, J = 8.3\ Hz, 2\ H), 7.32–7.37\ (m, 4\ H), 7.43\ (dt, J = 1.7, 7.8\ Hz, 2\ H), 7.50\ (m, 2\ H), 8.10\ (dd, J = 1.6, 7.9\ Hz, 2\ H), 9.99\ (br, 2\ H, NH).

\[^{13}C\ NMR\ (CDCl\_3): \; \delta = 38.6, 60.8, 87.3, 113.0, 119.8, 120.5, 129.6, 131.7, 131.8, 132.5, 135.7, 154.6, 164.6.

**MS:** \( m/c = 612\ [M^+] \).

Analyzed by: C\(_{46}\)H\(_{32}\)N\(_2\)O\(_6\) (650.8); C, 74.50; H, 5.16; N, 4.45.
pure enough by 1H NMR to be used without further purification in the next step.

IR: 3351, 3080, 3020, 2989, 2865, 2762, 1687, 1598, 1481, 1457, 1395, 1290, 1240, 1192, 1162, 1094, 998, 931, 841, 760, 658 cm\(^{-1}\).

1H NMR (CDCl\(_3\)): \(\delta = 4.68\) (m, 2 H, OCH\(_2\)), 5.36 (dd, \(J = 1.3, 10.4\) Hz, 1 H, CH\(_2\)) = 4.74 (dd, \(J = 1.3, 17.2\) Hz, 1 H, CH\(_2\)) = 6.06 (m, 1 H, CH\(_2\)), 6.99–7.05 (m, 2 H), 7.55 (m, 1 H), 7.86 (dd, \(J = 2.0, 8.0\) Hz, 1 H), 10.56 (s, 1 H, CHO).

MS: \(m/z = 262\) [M\(^+\)].

1.4-Bis-formylphenoxy)-2-butenes 13, 14; General Procedure

To a cold (0–5 °C) and stirred solution of bis(carbonyl)ethers 11 or 12 (10 mmol) in MeOH (100 mL) was added dropwise a solution of NaBH\(_4\) (2.57 g, 67 mmol) dissolved in H\(_2\)O (4.28 mL) and aq NaOH solution (4.28 mL, 2 N). The reaction mixture was returned to 0–5 °C and left stirring overnight. The insoluble material was filtered off and the solvent was removed in vacuo. The remaining material was crystallized from EtOH to give the corresponding diols 13 or 14.

(Z)-1,4-Bis-formylphenoxy)-2-butenes 11 and 12; General Procedure

A solution of salicylaldehyde (7.94 g, 65 mmol) and KOH (3.67 g, 65 mmol) in MeOH (25 mL) was stirred for 5 min and the solvent was then removed in vacuo to give the corresponding potassium salt \(\text{S} \cdot \text{KOH}\) (8.4 g, 87%); mp 150–152 °C.

Colorless crystals; yield: 8.4 g (87%); mp 150–152 °C.

IR: 3323, 3101, 3079, 2925, 2867, 2767, 1674, 1599, 1487, 1459, 1391, 1290, 1237, 1167, 1009, 990, 816, 759 cm\(^{-1}\).

1H NMR (CDCl\(_3\)): \(\delta = 4.45\) (d, \(J = 2.0\) Hz, 4 H, OCH\(_2\)), 6.58 (t, \(J = 7.4\) Hz, 2 H), 6.89 (t, \(J = 7.4\) Hz, 2 H), 7.88 (dd, \(J = 1.8, 7.8\) Hz, 2 H), 10.55 (s, 2 H, CHO).

13C NMR (CDCl\(_3\)): \(\delta = 68.0, 112.7, 121.1, 125.1, 127.8, 128.7, 135.9, 160.6, 189.6.

MS: \(m/z = 296\) [M\(^+\)].

Anal. Calcd for C\(_{18}\)H\(_{20}\)O\(_4\) (300.4): C, 72.96; H, 5.44. Found: C, 72.96; H, 5.44.

1,4-Bis-hydroxymethylphenoxy)-2-butenes 13, 14

To a cold (0–5 °C) and stirred solution of bis(carboxyanilides 11 or 12 (10 mmol) in MeOH (100 mL) was added dropwise a solution of \(\text{NaBH}_4\) (2.57 g, 67 mmol) dissolved in H\(_2\)O (4.28 mL) and aq NaOH solution (4.28 mL, 2 N). The reaction mixture was stirred for 2 h (0–5 °C) and kept in the refrigerator overnight. The insoluble material was filtered off and the solvent was removed in vacuo. The remaining material was crystallized from EtOH to give the corresponding diols 13 or 14.

(Z)-1,4-Bis-hydroxymethylphenoxy)-2-butenes 13

Colorless crystals; yield: 2.0 g (66%); mp 66–68 °C.

IR: 3366, 3066, 3028, 2924, 2872, 1601, 1491, 1454, 1289, 1233, 1116, 1015, 839, 754 cm\(^{-1}\).

1H NMR (CDCl\(_3\)): \(\delta = 2.72\) (s, 2 H, OH), 4.69 (s, 4 H, CH\(_2\)OH), 4.73 (d, \(J = 4.0\) Hz, 4 H, OCH\(_3\)), 5.99 (t, \(J = 4.0\) Hz, 2 H, CH\(_2\)OH), 6.89 (d, \(J = 8.2\) Hz, 2 H), 6.99 (t, \(J = 7.4\) Hz, 2 H), 7.28 (dt, \(J = 1.6, 7.8\) Hz, 2 H), 7.33 (dd, \(J = 1.2, 7.4\) Hz, 2 H).

13C NMR (CDCl\(_3\)): \(\delta = 61.6, 64.1, 111.3, 121.1, 128.7, 128.8, 129.4, 156.1.

MS: \(m/z = 300\) [M\(^+\)].


(E)-1,4-Bis-hydroxymethylphenoxy)-2-butenes 14

Colorless crystals; yield: 1.9 g (62%); mp 94–95 °C.

IR: 3326, 3242, 3065, 3025, 2925, 2888, 2849, 1690, 1489, 1431, 1373, 1227, 1044, 1027, 988, 837, 748 cm\(^{-1}\).

1H NMR (CDCl\(_3\)): \(\delta = 2.32\) (s, 2 H, OH), 4.67 (d, \(J = 2.0\) Hz, 4 H, OCH\(_3\)), 4.74 (s, 4 H, CH\(_2\)OH), 6.12 (t, \(J = 2.0\) Hz, 2 H, CH\(_2\)OH), 6.89 (d, \(J = 8.2\) Hz, 2 H), 6.99 (t, \(J = 7.4\) Hz, 2 H), 7.26–7.31 (m, 2 H), 7.33 (dd, \(J = 1.2, 7.3\) Hz, 2 H).

13C NMR (CDCl\(_3\)): \(\delta = 62.1, 67.6, 111.5, 121.0, 128.2, 128.9, 129.3, 156.2.

MS: \(m/z = 300\) [M\(^+\)].

1.4-Bis(o-chloromethylphenoxy)-2-butenes 8, 9; General Procedure
To a cold stirred solution (–10 °C) of diols 13 or 14 (10.9 mmol) in CHCl₃ (100 mL) was added dropwise a solution of SOCl₂ (5 mL) in CHCl₃ (5 mL). Stirring was continued for 2 h. The solvent was then removed in vacuo and the remaining solid was crystallized from EtOH to give 8 or 9.

(Z)-1,4-Bis(o-chloromethylphenoxy)-2-butene (8)
Colorless crystals; yield: 3.2 g (95%); mp 40–42 °C.

A solution of the substrates 3a–c; General Procedure

Table 1) or by comparing their signals with pure-
atives and pure E NMR signals prepared by bisylation method.

Isomerization Experiments of 2a and 6a,b, 11; General Procedure
A solution of 2a or 6a,b (1 mol) in CH₂Cl₂ (10 mL) and Grubbs’ catalyst I (1 mol % of the substrate) was heated under reflux for 1 h. The solvent was then evaporated in vacuo and the resulting reaction products, yields and Z/E ratios were then determined by ¹H NMR (Table 1) and by comparing their signals with pure-Z and pure-E NMR signals prepared by bisylation method.

Cross-Metathesis (CM) of 15–17; Synthesis of 8, 9 and 11–14; General Procedure
A solution of the substrates 15, 16 or 17 (1 mol) in CH₂Cl₂ (10 mL) and Grubbs’ catalyst I or II (1 mol % of the substrate) was heated under reflux for 2 h. The solvent was then evaporated in vacuo and the resulting reaction products were analyzed by ¹H NMR. The yield and Z/E ratios were then determined by ¹H NMR and compared with the pure Z and pure E NMR signals prepared by the other methods.

Cycloaddition Reactions of 2a,b, 3a,b; General Procedure
To a solution of 2a,b, 3a,b (0.31 mmol) and N-phenylbenzohydrazonoyl chloride³⁷ (1.26 mmol) in CHCl₃ (15 mL) was added Et₂N (0.5 mL). The reaction mixture was then heated under reflux for 24 h. The solvent was removed in vacuo and the resulting solid was washed with water and crystalized to give the corresponding corrisponding 18a,b, 19a,b.

(Z)-1,3-Diphenyl-1,12-dioxa-5,8-diazadibenzo[b,j]pyrazolinono[3,4-n]cyclohexadecane-4,9-dione (18a)
Prepared from 2a; colorless crystals (dilute EtOH); yield: 0.36 g (53%); mp 152–153 °C.
IR: 3408, 2926, 2855, 1650, 1600, 1531, 1482, 1455, 1368, 1301, 1216, 993, 758 cm⁻¹.

¹H NMR (CDCl₃): z = 3.57 (m, 2 H, NCH₃), 4.00 (m, 2 H, NCH₂), 4.17 (m, 2 H), 4.27 (t, J = 8.2 Hz, 1 H), 4.73 (m, 3 H), 6.27 (d, J = 8.3 Hz, 1 H), 6.94 (d, J = 8.3 Hz, 1 H), 7.03 (t, J = 7.4 Hz, 1 H), 7.12 (m, 2 H), 7.28–7.48 (m, 9 H), 7.77 (dd, J = 1.1, 7.2 Hz, 2 H), 7.87 (J = 6.1 Hz, 1 H, NH). 7.98 (t, J = 5.4 Hz, 1 H, NH), 8.07 (dd, J = 1.6, 7.6 Hz, 1 H), 8.18 (dd, J = 1.6, 7.7 Hz, 1 H).
13C NMR (CDCl₃): z = 38.8, 39.6, 47.9, 63.7, 64.1, 67.4, 112.6, 122.1, 122.2, 122.4, 123.2, 124.9, 125.6, 126.3, 128.1, 129.0, 129.9, 130.5, 132.2, 132.22, 132.4, 132.8, 146.2, 152.1, 155.1, 156.1, 165.4, 165.5.
MS: mlc = 546 [M⁺].
UV–Vis (abs): λmax (ε) = 294 (10680) nm.
UV–Vis (em): λmax (ε) = 463 (61890) nm.

(Z)-1,3-Diphenyl-1,12-dioxa-5,8-diazatribenz[b,j]pyrazolinono[3,4-n]cyclohexadecane-4,9-dione (18b)
Prepared from 2b; yellowish crystals [CH₂Cl₂–PE (40–60)]; yield: 0.34 g (45%); mp 274–276 °C.
IR: 3455, 2988, 2880, 1663, 1598, 1534, 1479, 1294, 1228, 1009, 753, 694 cm⁻¹.
¹H NMR (CDCl₃): z = 4.64–4.73 (m, 4 H), 4.84 (d, J = 10.8 Hz, 1 H), 4.90 (dd, J = 6.5, 12.2 Hz, 1 H), 6.86 (t, J = 7.3 Hz, 1 H), 6.98–7.01 (m, 3 H), 7.07 (t, J = 7.6 Hz, 1 H), 7.11 (d, J = 8.3 Hz, 1 H), 7.18 (t, J = 8.0 Hz, 2 H), 7.27 (d, J = 8.3 Hz, 1 H), 7.30–7.44 (m, 6 H), 7.48–7.55 (m, 2 H), 7.65–7.68 (m, 3 H), 7.76 (dd, J = 1.7, 7.7 Hz, 1 H), 7.85 (dd, J = 1.7, 7.7 Hz, 1 H), 9.54 (s, 1 H, NH), 9.61 (s, 1 H, NH).
13C NMR (DMSO): z = 48.0, 61.7, 65.2, 66.1, 113.8, 114.5, 115.5, 121.2, 121.8, 122.1, 122.7, 125.8, 125.8, 126.4, 126.5, 126.8, 129.1, 129.4, 129.5, 131.26, 131.32, 131.5, 131.8, 132.4, 133.5, 133.8, 134.5, 145.2, 150.3, 156.8, 163.6, 163.8.
MS: mlc = 594 [M⁺].
UV–Vis (abs): λmax (ε) = 285 (26626), 330 (shoulder, 13910) nm.
UV–Vis (em): λmax (ε) = 459 (172514) nm.
Anal. Calc. for C₂₅H₂₆N₂O₄ (594.7): C, 74.73; H, 5.08; N, 9.42. Found: C, 74.53; H, 4.99; N, 9.32.

(E)-1,3-Diphenyl-1,12-dioxa-5,8-diazadibenzo[b,j]pyrazolinono[3,4-n]cyclohexadecane-4,9-dione (19a)
Prepared from 3a; pale yellow crystals (CHCl₃); yield: 0.38 g (55%); mp 298–300 °C.
IR: 3426, 3161, 3068, 2998, 2964, 2938, 1643, 1598, 1532, 1494, 1302, 1321, 1036, 752, 690 cm⁻¹.

Prepared from 3b; colorless crystals (CHCl3); yield: 0.23 g (30%); mp 274–276 °C.

IR: 3385, 3053, 3005, 2933, 2880, 1652, 1597, 1494, 1453, 1384, 1317, 1237, 1136, 1028, 758 cm–1.

1H NMR (DMSO-d6): δ = 3.41 (m, 2 H, NCH2), 3.70 (m, 2 H, NCH2), 3.88 (t, J = 9.6 Hz, 1 H), 4.00 (m, 3 H), 4.55 (dd, J = 5.2, 8.8 Hz, 1 H), 5.40 (dd, J = 3.4, 10.3 Hz, 1 H), 6.85 (t, J = 7.6 Hz, 1 H), 7.00–7.08 (m, 3 H), 7.15 (d, J = 8.5 Hz, 1 H), 7.29–7.42 (m, 7 H), 7.47 (t, J = 7.5 Hz, 2 H), 7.79 (dt, J = 1.6, 7.7 Hz, 2 H), 7.95 (d, J = 8.1 Hz, 2 H), 8.48 (t, J = 5.6 Hz, 1 H, NH), 8.52 (t, J = 4.8 Hz, 1 H, NH).

13C NMR (DMSO): δ = 47.7 (2 × C), 61.1 (2 × C), 63.1, 65.1, 113.2, 113.9 (2 × C), 120.0, 121.4, 121.5, 123.7, 126.7, 126.6 (2 × C), 129.4, 129.6, 129.9, 131.3, 131.9, 132.8 (2 × C), 143.8, 148.4, 156.3, 156.4, 165.9, 165.92.

MS: m/z = 546 [M+].

UV–Vis (abs): λmax (e) = 290 (shoulder, 20000), 360 (37143) nm.

UV–Vis (em): λmax (e) = 450 (41909) nm.


Found: C, 72.61; H, 5.53; N, 10.21.

(E)-1,3-Diphenyl-1,1-dioxo-5,8-diazatribenzo[b,f,j]pyrazolino[3,4-α]cyclohexadecane-4,9-dione (19b)

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