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Double O–H insertion reactions of cyclic rhodium carbenoids: diastereoselective synthesis of macrocyclic oxindoles

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ABSTRACT

Double O–H insertion reactions of cyclic diazo amides **1** and dihydroxy compounds **2** in the presence of rhodium(II) acetate catalyst have been achieved, which ultimately led to the facile synthesis of prototype bis(3-oxy-1,3-dihydro-2*H*-indol-2-one) systems. This facile double O–H insertion reaction protocol was successfully applied to synthesize several C_2-symmetric macrocycles having oxindole units incorporated with complete diastereoselectivity.

α-Diazocarbonyl compounds, which serve as precursors to α-keto carbenes/carbenoids, have been extensively used in synthetic organic chemistry.[1] To generate an intermediate rhodium carbenoid, the reaction of α-diazocarbonyl compounds in the presence of rhodium(II) carboxylate is a well-described method, which can undergo an assortment of reactions such as C–H or heteroatom-H insertion, cyclopropanation, and ylide formation.[2,3] As an efficient method of construction of complex architectures from simple, readily available precursors, the catalytic insertion of α-diazocarbonyl compounds into X–H (X = C, N, O, S, etc.) bonds was widely utilized in organic synthesis. Oxygen–hydrogen insertion reactions by the metallo-carbenoids got significant interest among organic chemists as it provides a pathway for C–O bond formation providing a simple access to α-alkoxy or α-aryloxy ketones and esters as well as chiral oxygen containing molecular systems.[3,4] Initially, Casanova and Reichstein have observed in 1950 that heating of a steroidal diazo ketone in methanol in the presence of copper(II) oxide gave the corresponding methoxy ketone.[5] Later, Teyssié and co-workers have introduced[6] rhodium(II) acetate in 1973 as the best catalyst for effecting the O–H insertion process. The rhodium(II) carboxylates have been found to be the current catalysts of choice for many carbenoid transformations.[7] We have been extensively involved in developing new synthetic strategies,[8] C-alkylation[9] using diazocarbonyl compounds. In continuation of these efforts, we herein report an efficient double O–H insertion reaction to synthesize various synthetically useful bis(3-alkoxyindoles) and macrocycles in the presence of rhodium(II) acetate catalyst.

The required diazo amides **1a–d** were synthesized from the 3-diazooxindole[10] according to our earlier work.[9] Dihydroxy compounds were used as purchased. Initially, the reaction of 1 equiv of diazo amide **1a** with 0.5 equiv of ethylene glycol in the presence of a catalytic amount of $Rh_2(OAc)_4$ (1 mol %) in dichloromethane was performed. The reaction was followed by TLC and then chromatographic purification of the reaction mixture using column chromatography furnished product **3a** in 59% yield. Compound **3a** showed the presence of an amide carbonyl group in IR spectrum. A characteristic singlet at δ 4.98 ppm for oxindolyl 3,3′-protons in ^{1}H NMR spectrum confirms the O–H insertion. The ^{13}C and dept-135 spectra of **3a** revealed that a single peak for two CH_3 groups, a single peak for two 3,3′-carbons, four peaks for eight aromatic CH carbons, and three peaks for six quaternary carbons unequivocally confirm the structure[11] of **3a**. Ethylene glycol is not completely soluble in dichloromethane. We believed that better yields could be achieved if the solubility of the dihydroxy compound is increased. For this purpose, we chose to employ polar solvents such as THF, DMF, DMSO, or dioxane and these afforded only dimerization and decomposed products rather than insertion product **3a**. Thus, we have modified the reaction condition using dichloromethane–DMF (50:2) as a solvent system where the dihydroxy compound is completely soluble and the reaction successfully yielded **3a** with the isolated yield of 82%.

Subsequently, under the optimized reaction conditions, a variety of dihydroxy compounds were examined by employing various N-alkylated diazo amides. Thus, we investigated the rhodium(II)-catalyzed reaction of cyclic diazo amide **1a** with

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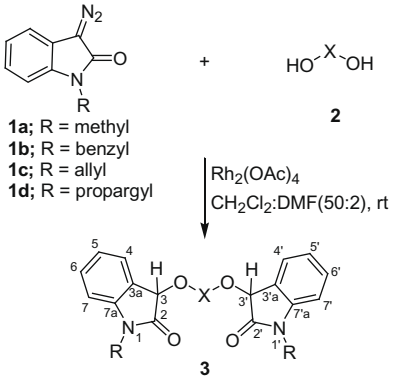
propane-1,3-diol, butane-1,4-diol, or hexane-1,6-diol to furnish the bis(3-oxy-1,3-dihydro-2*H*-indol-2-one) systems **3b–d,** respectively, in moderate to good yield (Table 1) as a result of double O–H insertion reaction. Similarly, reactions of other diazo amides **1b–d** with the appropriate dihydroxy compounds furnished the corresponding double O–H insertion products **3e–p**.

We further extended our studies to the double O–H insertion reaction methodology using dihydroxy compound having the aromatic spacer. Thus, the reaction of cyclic diazo amide **1a** and 1,4-benzenedimethanol in DCM/DMF (50:2) in the presence of $Rh_2(OAc)_4$ furnished the corresponding double O–H insertion product **3q**. Reactions of other diazo amides **1** were performed under a similar experimental condition to afford the corresponding insertion products **3r–t** (entries r–t, Scheme 1, Table 1). Furthermore, we embarked on the synthesis of bis(3-oxy-1,3-dihydro-2*H*-indol-2-one) systems using the readily available 1,5-decalinediol. Similar experimental condition was used for the successful acquisition of products **3u–x** with the prolonged reaction time (entries u–x, Scheme 1, Table 1).

All the above reactions were completed in less than an hour (Table 1) at room temperature in a facile manner to afford the bis(3-oxy-1,3-dihydro-2*H*-indol-2-one) systems **3**. An excess amount of 3-diazooxindoles was used for the expediency and their stoichiometry was not optimized. The presence of an excess amount of diazo amide led to the diazo dimerization reaction to provide the corresponding dimerized products under our experimental conditions, which were readily purified by column chromatography. It is relevant to mention that only one related report exists where the reaction of simple acyclic diazocarbonyl compounds[12] was studied with polyethylene glycols in the presence of $Cu(acac)_2$ catalyst. We have not obtained any other product resulting from the potential competitive cyclopropanation reaction[13] (when R = allyl, propargyl) of the diazo amides **1**.



Scheme 1. Intermolecular double O–H insertion reaction of diazo amides with various dihydroxy compounds.

Table 1
Reactions of cyclic diazo amides **1a–d** with dihydroxy compounds **2**

Entry	R	Spacer (X)	Reaction time (min)	Yield of **3**[a] (%)
a	CH_3	$-CH_2CH_2-$	10	82
b	CH_3	$-CH_2CH_2CH_2-$	12	80
c	CH_3	$-CH_2(CH_2)_2-CH_2-$	15	84
d	CH_3	$-CH_2(CH_2)_4-CH_2-$	10	86
e	CH_2Ph	$-CH_2CH_2-$	10	84
f	CH_2Ph	$-CH_2CH_2CH_2-$	12	80
g	CH_2Ph	$-CH_2(CH_2)_2-CH_2-$	10	75
h	CH_2Ph	$-CH_2(CH_2)_4-CH_2-$	05	78
i	Allyl	$-CH_2CH_2-$	10	75
j	Allyl	$-CH_2CH_2CH_2-$	15	78
k	Allyl	$-CH_2(CH_2)_2-CH_2-$	10	74
l	Allyl	$-CH_2(CH_2)_4-CH_2-$	12	72
m	Propargyl	$-CH_2CH_2-$	15	73
n	Propargyl	$-CH_2CH_2CH_2-$	12	80
o	Propargyl	$-CH_2(CH_2)_2-CH_2-$	10	82
p	Propargyl	$-CH_2(CH_2)_4-CH_2-$	10	76
q	CH_3	–*o*-Xylenyl–	32	75
r	CH_2Ph	–*o*-Xylenyl–	38	77
s	Allyl	–*o*-Xylenyl–	35	70
t	Propargyl	–*o*-Xylenyl–	36	75
u	CH_3	1,5-Decalenyl	40	68
v	CH_2Ph	1,5-Decalenyl	44	70
w	Allyl	1,5-Decalenyl	48	65
x	Propargyl	1,5-Decalenyl	40	75

[a] Yields (unoptimized) refer to isolated and chromatographically pure compounds **3**.

After obtaining the above encouraging results, we further envisaged to apply this intermolecular double O–H insertion reaction methodology to construct macrocyclic oxindoles. Our strategy for the construction of macrocycles was to employ rhodium(II) acetate-mediated insertion reaction using bis(3-diazo-2-oxindoles) **4**. It was envisaged that the resulting bis(rhodium(II) carbenoids) would undergo double O–H insertion reaction with a dihydroxy compound to result the formation of macrocyclic oxindoles.

Thus, the required bis(diazooxindole) **4a** was synthesized using 2 equiv of 3-diazooxindole and 1,4-dibromobutane in the presence of a catalytic amount of tetrabutylammonium iodide as phase transfer catalyst. Treatment of bis(diazo amide) **4a** and 1,3-propanediol in the presence of 1 mol % of $Rh_2(OAc)_4$ led to the interesting macrocyclic oxindole[14] **5a** in 75% yield via the double O–H insertion methodology using DCM/DMF (50:2) solvent system. There was the possibility for the formation of a mixture of two diastereomers, but we obtained only one diastereomer based on the crude ^1H NMR spectrum. The structure of macrocycle **5a** was also confirmed using single-crystal X-ray analysis (Fig. 1). Interestingly, the crystal structure analysis revealed that the C_2-symmetry having Ha,Hb protons is in *anti*-fashion.

Having validated our strategy toward the synthesis of a macrocyclic oxindole via O–H insertion methodology, attention then turned in assessing the feasibility of various ring sizes. Hence, the reactions of bis(diazo amides) **4a–b** and aliphatic dihydroxy compounds **2** were performed in the presence of rhodium(II) acetate catalyst. All these reactions successfully yielded the corresponding macrocyclic oxindoles[14] **5b–d**. We have chosen benzene-1,2-dimethanol instead of aliphatic dihydroxy compound to yield macrocycle **5e** in 65% yield. The *anti*-stereochemistry is tentatively assigned for other macrocycles based on the structure of **5a**. It is notable that the product due to the dimerization of diazo groups was not observed. This methodology represents the synthesis of macrocycles incorporating indole units in a diastereoselective manner. The reason for the diastereoselectivity might be the second O–H insertion reaction preferred to form only the thermodynamically more stable C_2-symmetric macrocyclic system (Scheme 2, Table 2).

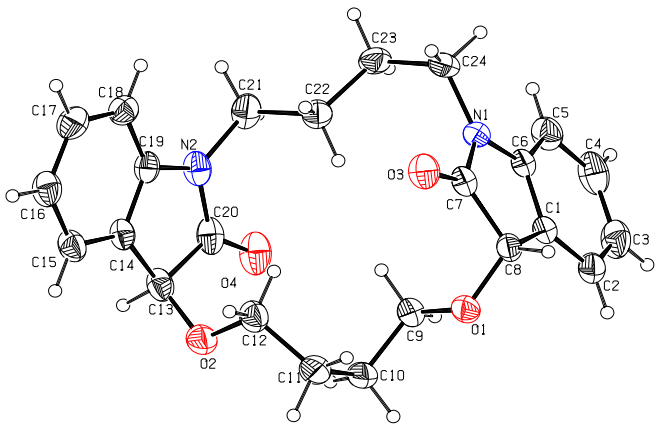
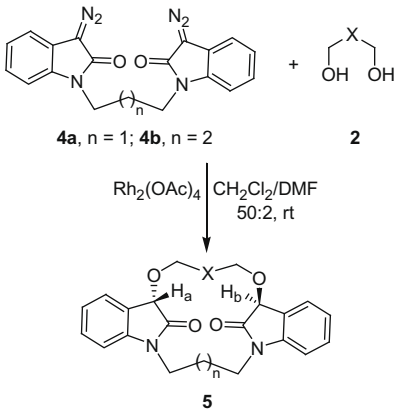


Figure 1. ORTEP view of compound **5a**.



Scheme 2. Synthesis of macrocyclic oxindoles via double O–H insertion reaction methodology.

Table 2
Reactions of bis(diazo amides) **4** with dihydroxy compounds **2**

Entry	*n*	X	Reaction time (min)	Yield of **5**[a] (%)
a	2	$-(CH_2)_2-$	40	75
b	2	$-CH_2-$	44	78
c	1	$-(CH_2)_4-$	45	70
d	1	$-(CH_2)_6-$	48	72
e	1	*p*-Xylenyl	55	65

[a] Yields (unoptimized) refer to isolated and chromatographically pure compounds **5**.

In conclusion, we have demonstrated a facile double O–H insertion reaction methodology using the diazo amides in the presence of rhodium(II) acetate catalyst. This approach furnished an assortment of prototype bis(3-oxy-1,3-dihydro-2*H*-indol-2-one) systems by forming two C–O bonds in a single synthetic step. This facile double O–H insertion reaction protocol was successfully applied to synthesize several C_2-symmetric macrocycles with oxindole units incorporated in a diastereoselective manner. Further study to find the reason for the high diastereoselectivity is in progress.

Acknowledgments

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11. *General procedure for the synthesis of bis(3-alkoxyoxindoles)* **3**: 1.0 mol % of $Rh_2(OAc)_4$ was added to a stirred solution of diazo amides **1** (3 mmol) and dihydroxy compounds **2** (1.0 mmol) in a freshly distilled 50 mL of dry dichloromethane. To this solution, 2 mL of freshly prepared dry DMF (distilled over CaH_2, stored over 5 Å molecular sieves under the argon balloon) was added for the better solubility of dihydroxy compounds. The reaction was monitored by TLC. After completion of the reaction, the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatography over silica gel.
All new compounds exhibited spectral data consistent with their structures. Selected spectral data: 3,3′-[Ethane-1,2-diylbis(oxy)]bis(1-methyl-1,3-dihydro-2*H*-indol-2-one) (**3a**): Red thick oil. IR (CH_2Cl_2): 2935, 1716, 1614, 1493, 1470, 1421, 1374, 1265, 1093, 1024, 896, 738 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 3.16 (6H, s, N–CH_3), 3.88–4.11 (4H, m, OCH_2), 4.98 (2H, s, OCH), 6.79 (2H, d, J = 7.3 Hz), 7.07 (2H, t, J = 7.5 Hz), 7.33 (2H, t, J = 7.4 Hz), 7.44 (2H, d, J = 7.2 Hz). ^{13}C NMR (50.3 MHz, $CDCl_3$): δ 26.6 (CH_3), 68.8 (CH_2), 68.0 (CH_2), 76.5 (CH), 108.8 (CH), 125.6 (*quat-C*), 126.1 (CH), 130.1 (CH), 144.8 (*quat-C*), 175.1 (*quat-C*). MS: m/z = 352 (M^+). Anal. Calcd for $C_{20}H_{20}N_2O_4$: C, 68.17; H, 5.72; N, 7.95. Found: C, 68.41; H, 5.70; N, 7.96. 3,3′-[Hexane-1,6-diylbis(oxy)]bis(1-methyl-1,3-dihydro-2*H*-indol-2-one) (**3d**): Yellow solid. Mp 109–111 °C (hexane/$CHCl_3$). IR (KBr): 2932, 1715,1614, 1493, 1469, 1373, 1350, 1264, 1113, 1046, 739 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 1.31–1.42 (4H, m), 1.55–1.66 (4H, m), 3.16 (6H, s, N–CH_3), 3.53–3.63 (2H, m, OCH_2), 3.71–3.82 (2H, m, OCH_2), 5.05 (2H, s, OCH), 6.79 (2H, d, J = 7.6 Hz), 7.07 (2H, t, J = 7.2 Hz), 7.28–7.39 (4H, m). ^{13}C NMR (50.3 MHz, $CDCl_3$): δ 26.4 (CH_2), 26.6 (N–CH_3), 30.4 (CH_2), 69.5 (OCH_2), 76.5 (OCH), 108.9 (CH), 123.5 (CH), 125.8 (CH), 125.9 (*quat-C*), 130.5 (CH), 144.9 (*quat-C*), 175.3 (*quat-C*). MS: m/z = 408 (M^+, 15.6), 190 (3.5), 162 (100), 146 (63), 91 (12.8). Anal. Calcd for $C_{24}H_{28}N_2O_4$: C, 70.57; H, 6.91; N, 6.86. Found: C, 70.73; H, 6.94; N, 6.87. 3,3′-[Propane-1,3-diylbis(oxy)]bis(1-allyl-1,3-dihydro-2*H*-indol-2-one) (**3j**): Red thick oil. IR (CH_2Cl_2): 2987, 1723 1613, 1489, 1468, 1362, 1265, 1182, 1107, 742 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 1.91 (2H, t, J = 6.1 Hz), 3.67–3.74 (2H, m, OCH_2), 3.81–3.88 (2H, m, OCH_2), 4.15–4.30 (4H, m, N–CH_2), 4.84 (2H, s, OCH), 5.11–5.28 (4H, m, C = CH_2), 5.67–5.81 (2H, m, CH = C), 6.26 (2H, d, J = 7.6 Hz), 7.08 (2H, t, J = 7.1 Hz), 7.21–7.33 (4H, m). ^{13}C NMR (50.3 MHz, $CDCl_3$): δ 21.3 (CH_2), 42.5 (N–CH_2), 66.1 (OCH_2), 66.2 (OCH_2), 76.3 (OCH), 109.6 (CH), 118.1 (CH_2), 123.2 (CH), 125.6 (*quat-C*), 125.8 (CH), 130.1 (CH), 131.6 (CH), 134.3 (*quat-C*), 174.7 (*quat-C*). MS: m/z = 418 (M^+). Anal. Calcd for $C_{25}H_{26}N_2O_4$: C, 71.75; H, 6.26; N, 6.69. Found: C, 71.59; H, 6.27; N, 6.67. 3,3′-[1,4-Phenylenebis(methyleneoxy)])]bis(1-methyl-1,3-dihydro-2*H*-indol-2-one) (**3q**): Red solid. Mp 137–139 °C (hexane/$CHCl_3$). IR (KBr): 2936, 1713, 1613, 1493, 1470, 1374, 1350, 1264, 1108, 1052, 753 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 3.17 (6H, s, N–CH_3), 4.83 (2H, s, OCH), 4.90 (4H, d, J = 14.8 Hz), 6.80 (2H, d, J = 7.8 Hz), 7.07 (2H, t, J = 7.6 Hz), 7.27–7.43 (8H, m). ^{13}C NMR (50.3 MHz, $CDCl_3$): δ 26.6 (N–CH_3), 71.1 (O–CH_2), 75.3 (OCH), 108.9 (CH), 123.5 (CH), 123.2 (CH), 125.9 (CH), 127.6 (*quat-C*), 129.0 (CH), 130.5 (CH), 137.8 (*quat-C*), 144.8 (*quat-C*), 175.3 (*quat-C*). MS: m/z = 428 (M^+). Anal. Calcd for $C_{26}H_{24}N_2O_4$: C, 72.88; H, 5.65; N, 6.54. Found: C, 72.69; H, 5.64; N, 6.55.
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14. *General procedure for the synthesis of macrocycles* **5**: 1.0 mol % of $Rh_2(OAc)_4$ was added to a stirred solution of bis(diazo amides) **4** (1.0 mmol) and dihydroxy compounds **2** (1.0 mmol) in a freshly distilled 50 mL of dry dichloromethane and 2 mL of dry DMF at room temperature under nitrogen atmosphere. The reaction was monitored by TLC. After completion of the reaction, the solvent was evaporated under reduced pressure and the residue purified by flash column chromatography over silica gel. All new compounds exhibited spectral data consistent with their structures. **5a**: IR (CH_2Cl_2): 3064, 2929, 2871, 1710 1611, 1486, 1466, 1351, 1299, 1222, 1159, 1116, 1093, 1048, 732, 699 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 1.58–1.48 (4H, m), 1.75–1.67 (4H, m), 2.75–2.70 (2H, m), 3.33–3.27 (4H, m), 3.98–3.91 (2H, m), 4.84 (2H, s, OCH), 6.76 (2H, d, J = 7.6 Hz), 7.02 (2H, t, J = 7.6 Hz), 7.32–7.25 (4H, m). ^{13}C NMR (50.3 MHz, $CDCl_3$): δ 24.7 (CH_2), 25.4 (CH_2), 39.5 (N–CH_2), 63.9 (OCH_2), 75.5 (OCH), 108.8 (CH), 122.9 (CH), 124.3 (*quat-C*), 125.9 (CH), 130.1 (CH), 143.6 (*quat-C*), 174.9 (C = O). MS: m/z = 406 (M^+). Anal. Calcd for $C_{24}H_{26}N_2O_4$: C, 70.92; H, 6.45; N, 6.89. Found: C, 70.97; H, 6.38; N, 6.92. X-ray Crystal data for compound **5a**. $C_{24}H_{26}N_2O_4$, M = 406.47, 0.30 × 0.24 × 0.12 mm^3, triclinic, P$\bar{1}$, a = 7.8002(14) Å, b = 11.382(2) Å, c = 12.097(2) Å, α = 94.574(3)°, β = 90.416(3)°, γ = 101.248(3)°, V = 1049.7(3) $Å^3$, T = 293(2) K, R_1 = 0.0766, wR_2 = 0.1927, on observed data,

$z = 2$, $D_{calcd} = 1.286$ mg/m^3, $F(0\,0\,0) = 432$, absorption coefficient = 0.091 mm^{-1}, $\lambda = 0.71073$ Å, 7575 reflections were collected on a Bruker Smart Apex CCD spectrometer, 3679 observed reflections ($I > 2\sigma(I)$). The largest difference peak and hole = 0.533 and −0.349 eA^{-3}, respectively. Crystallographic data for this compound have been deposited[15] with the Cambridge Crystallographic Data Center as supplementary publication number CCDC 711953. Compound **5b**: IR (CH_2Cl_2): 3064, 2929, 2866, 1707, 1613, 1487, 1466, 1349, 1214, 1161, 1087, 965, 876, 750, 732, 700, 651 cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.60–1.53 (2H, m), 1.75–1.67 (4H, m), 1.92–1.88 (2H, m), 3.57–3.33 (2H, m), 3.77–3.75 (2H, m), 3.99–3.96 (2H, m), 4.68 (2H, s, OCH), 6.79 (2H, d, J = 7.6 Hz), 7.07 (2H, t, J = 7.6 Hz), 7.35–7.27 (4H, m). ^{13}C NMR (50.3 MHz, $CDCl_3$): δ 25.6 (CH_2), 30.1 (CH_2), 39.4 (CH_2), 63.5 (OCH_2), 74.4 (OCH), 108.5 (CH), 122.9 (CH), 125.1 (*quat-C*), 126.1 (CH), 130.1 (CH), 144.2 (*quat-C*), 174.6 (C=O). MS: m/z = 392 (M^+). Anal. Calcd for $C_{23}H_{24}N_2O_4$: C, 70.39; H, 6.16; N, 7.14. Found: C, 70.31; H, 6.18; N, 7.17. Compound **5c**: IR (CH_2Cl_2): 3064, 2934, 2872, 1712, 1613, 1466, 1360, 1297, 1181, 1168, 1050, 750, 698 cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.63–1.23 (8H, m), 2.15–2.11 (2H, m), 3.50–3.41 (4H, m), 3.73–3.69 (2H, m), 4.06–4.00 (2H, m), 4.81 (2H, s, OCH), 6.85 (2H, d, J = 7.6 Hz), 7.08 (2H, t, J = 6.8 Hz), 7.35–7.31 (2H, m), 7.45 (2H, d, J = 7.6 Hz). ^{13}C NMR (50.3 MHz, $CDCl_3$): δ 24.3 (CH_2), 27.0 (CH_2), 29.6 (CH_2), 37.4 (CH_2), 67.0 (OCH_2), 74.9 (OCH), 108.3 (CH), 122.9 (CH), 125.2 (*quat-C*), 125.9 (CH), 129.9 (CH), 143.8 (*quat-C*), 174.9 (C = O). MS: m/z = 420 (M^+). Anal. Calcd for $C_{25}H_{28}N_2O_4$: C, 71.41; H, 6.71; N, 6.66. Found: C, 71.44; H, 6.68; N, 6.61. **5d**: IR (CH_2Cl_2): 2931, 1719, 1614, 1467, 1260, 1237, 1198, 1168, 1091, 1025, 908, 751 cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.63–1.14 (12H, m), 2.21–2.08 (2H, m), 3.37–3.46 (4H, m), 3.75–3.64 (2H, m), 4.09–3.98 (2H, m), 4.89 (2H, s, OCH), 6.89 (2H, d, J = 7.6 Hz), 7.09 (2H, t, J = 6.8 Hz), 7.35–7.27 (2H, m), 7.43 (2H, d, J = 7.6 Hz). ^{13}C NMR (50.3 MHz, $CDCl_3$): δ 19.2 (CH_2), 24.9 (CH_2), 25.6 (CH_2), 28.0 (CH_2), 29.2 (CH_2), 36.6 (CH_2), 67.7 (OCH_2), 75.2 (OCH), 108.2 (CH), 122.9 (CH), 125.4 (*quat-C*), 125.9 (CH), 130.0 (CH), 143.2 (*quat-C*), 174.6 (C = O). MS: m/z = 448 (M^+). Anal. Calcd for $C_{27}H_{32}N_2O_4$: C, 72.30; H, 7.19; N, 6.25. Found: C, 72.24; H, 7.21; N, 6.32. Compound **5e**: IR (CH_2Cl_2): 3431, 3059, 2925, 2852, 1712, 1612, 1488, 1467, 1298, 1188, 1169, 1092, 1053, 759, 700 cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.36–1.26 (2H, m), 3.76–3.71 (4H, m), 4.74 (2H, s, OCH), 5.00–4.86 (4H, m, benzylic-*H*), 6.78–6.75 (2H, m), 7.07 (2H, t, J = 7.6 Hz), 7.44–7.24 (8H, m). ^{13}C NMR (50.3 MHz, $CDCl_3$): δ 25.2 (CH_2), 37.7 (CH_2), 66.5 (OCH_2), 74.5 (OCH), 108.7 (CH), 123.2 (CH), 125.7 (CH), 127.9 (CH), 129.2 (CH), 129.7 (CH), 129.9 (CH), 130.2 (CH), 130.4 (CH), 134.8 (*quat-C*), 140.8 (*quat-C*), 142.9 (*quat-C*), 174.8 (C = O). MS: m/z = 440 (M^+). Anal. Calcd for $C_{27}H_{24}N_2O_4$: C, 73.62; H, 5.49; N, 6.36. Found: C, 73.67; H, 5.55; N, 6.31.

15. Copies of the data can be obtained, free of charge, on application to CCDC, 12 Union Road, Cambridge CB2 IEZ, UK {fax: +44 1223 336033 or e-mail: deposit@ccdc.cam.ac.uk}.