A New and Versatile Access to Polyazamacroheterocycles and Cryptands Through Ring-Closing Bis(hydroaminomethylation)

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The Rh^I-catalyzed hydroformylation of dienes in the presence of primary amines or secondary α,ω-diamines has been applied to macroheterocyclic ring synthesis. Starting from (hetero)diallylic systems, 12- to 36-membered polyheterocycles have been readily obtained in up to 56% yield. In addition, we show that the macrocyclic systems thus obtained can be debenzylated and that the resulting macrocyclic diamines undergo a second ring-closing bis(hydroaminomethylation) to give cryptand systems.

Introduction

Medium- and large-sized oxa- and azaheterocyclic systems are of interest for various applications by virtue of their unique and selective binding properties towards cations,[1] anions,[2] and neutral molecules.[1] Thus, they can be used as selectively coordinating ligands for metal ions,[3] as transport vehicles for contrast agents in magnetic resonance imaging,[4] as renal calculi dissolving agents,[5] or as linkers for monoclonal antibodies and radiometal ions in cancer treatment.[6] In addition, they are valuable building blocks for the construction of natural products with potential pharmaceutical activities.[7]

The synthesis of medium- and large-sized heterocyclic systems has been the subject of many investigations in recent years.[1−8] A common access to these heterocycles is provided by the Richman−Atkins approach,[9] which involves nucleophilic substitution of α,ω-dihalides, -tosylates, or -mesylates with α,ω-ditosylamides or α,ω-diols in the presence of a base. However, the requisite starting materials are sometimes difficult to obtain and all the nitrogen atoms in the resulting macrocycle generally tend to be protected with the same group.

We report herein on a new, effective, and versatile methodology for the synthesis of azamacroheterocyclic systems of type **8** starting from readily available diolefins of type **1** and diamines **5**. These components are allowed to react under hydroformylation conditions, leading to overall hydroaminomethylation[10] of each double bond[11] (hydroformylation/reductive amination of the dialdehyde intermediates).[12] The examples described include the formation of rings with up to 36 atoms and 9 heteroatoms in a one-pot procedure through a successive metal-catalyzed assembly of four molecules with the formation of four new bonds.

Results and Discussion

Hydroformylation of diolefinic systems of type **1** can be expected to lead to three regioisomeric dialdehydes (*n*,*n*, *n*,*iso*, *iso*,*iso*) and products derived therefrom, the precise outcome depending on the reaction conditions, the catalyst system, and the substitution pattern of the diolefin (Scheme 1).[11] In previous studies, we investigated the hydroformylation of α,ω-aza-, -oxa-, and -siladiolefins of type **1** (X = O, NR, SiR_2) in the presence of a secondary amine (morpholine) to give open-chain heterofunctionalized diamines or triamines of type **3**. In the case of the unsubstituted aza analogue of **1a** (R^1,R^2 = H, X = NAc), an overall *n*/*iso* ratio of 0.4 was observed, whereas the bis(methallylic) aza system of type **1c** (R^1,R^2 = CH_3, X = NAc) gave exclusively the products of the *n*,*n*-bis(hydroformylation).[13]

In the presence of the primary amines **4a** and **4b**, *N*-acetyldiallylamine (**1a**) is completely consumed, but cyclic products of type **6** are isolated in yields of just 15−33% (Scheme 2). The pyrrole derivatives **9a** and **9b** are isolated as side-products in yields of 7% and 6%, respectively. Their formation can be rationalized in terms of a mechanism akin to that delineated for the synthesis of pyrroles starting from 1,4-pentadienes under hydroformylation conditions.[14]

The 1,5-diazacyclooctanes **6a** and **6b** both result from an *iso*,*iso*-hydroformylation process. A nine-membered ring product, as might be expected[13] to result from an *n*,*iso*-hydroformylation, is not observed. In view of the presence of higher boiling side products, it can be assumed that, in accordance with common ring formation tendencies,[15] the formation of nine- or ten-membered rings of types **7** or **10** from the less favourable *n*,*iso* and *n*,*n* isomers of type **2** is suppressed in favour of oligo- or polymerization.[1,8,15] This tendency is increased if the unsubstituted allylic moieties of **1a** are replaced by one or two methallylic groups, as in **1b** and **1c**. Under these circumstances, the system is predisposed towards *n*,*iso*- or *n*,*n*-hydroformylation, respectively, and hence formation of the less favourable nine- and ten-membered rings of types **7** and **10** is disfavoured (Scheme 3). Accordingly, on allowing diolefin **1b** and

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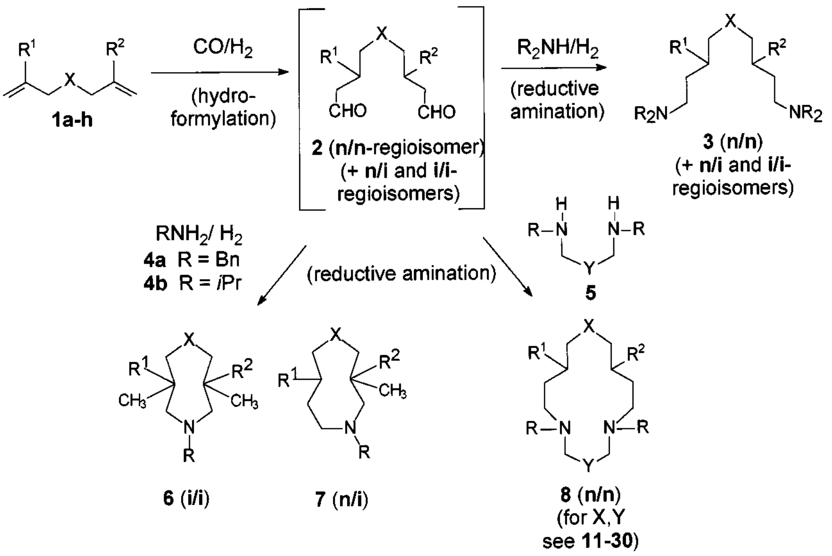
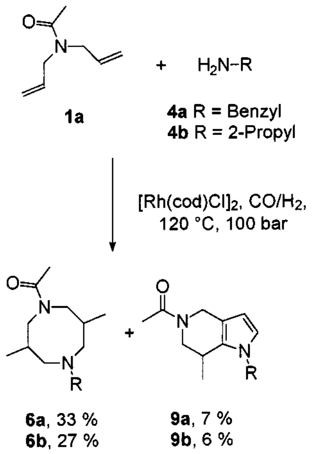
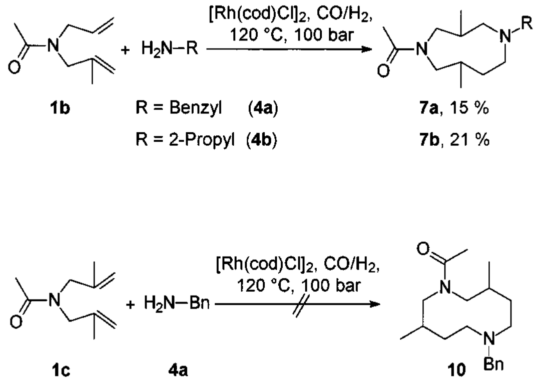


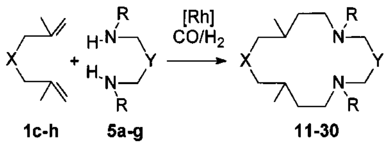
Scheme 1. Conversion of α,ω-diolefinic systems with amines under hydroformylation conditions



Scheme 2. Reactions of *N*-acetyldiallylamine (**1a**) with primary amines



Scheme 3. Reactions of *N*-acetyldiallylamines **1b**,**c** with primary amines



Scheme 4. Reactions of diamines **1c**−**h** with diolefins **5a**−**g**

amines **4a** and **4b** to react, 1,5-diazacyclononanes **7a** and **7b** are obtained in lower yields, whereas diazadecanes are not obtained, neither from **1b** nor from **1c**, the latter giving no cyclization products at all. On the other hand, reactions of these diolefins with secondary amines under hydroformylation conditions give excellent yields of bis(hydroaminomethylation) products of type **3**.[13]

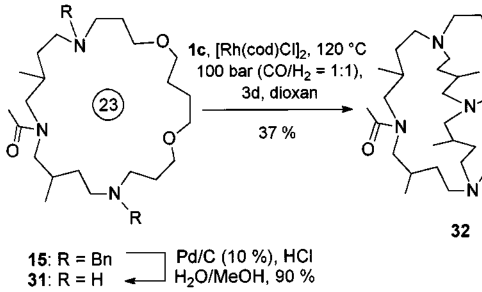
Generally speaking, the formation of medium-sized rings by hydroaminomethylation of diolefins with primary amines is thus rather inefficient. In contrast, larger rings (12−36 members) of type **8** are conveniently obtained from diolefins **1c**−**h** and diamines **5** in good yields (Scheme 4, Table 1). The ring size and the number of heteroatoms can be predetermined by variation of the chain between the two olefinic units in the diene **1c**−**h** and the chain between the two amine units in the diamine **5**. Thus, using diolefins **1a**−**h** and diamines **5a**−**g**, macroheterocyclic systems **11**−**30** are obtained with high regioselectivities and in surprisingly good yields. The latter can presumably be attributed to a template effect during catalysis, especially in the final ring-closing step (Table 1).

The macrocycles thus obtained bear benzyl protecting groups at the two nitrogen atoms stemming from the α,ω-diamine. These groups are stable under the reductive hydroformylation conditions. However, they can be cleaved under more forcing conditions, e.g. with hydrogen in the presence of a heterogeneous hydrogenation catalyst. Thus, the benzyl groups of **15** are cleaved hydrogenolytically in the presence of palladium on charcoal in 90% yield (Scheme 5). The debenzylated macroheterocyclic system **31** thus obtained undergoes further ring-closing bis(hydroaminomethylation) to give the cryptand system **32** in 37% yield. Surprisingly, this cyclization reaction can be carried out without applying sophisticated dilution procedures.[16] This is due to the fact that one of the cyclization components, the dialdehyde, is slowly generated from a nonreactive precursor, i.e. the diol-

Table 1. Synthesis of macroheterocycles **11−29** from diolefins **1c−h** and diamines **5a−g** through carbonylative hydroaminomethylation

Entry	**1**[a]	X	**5**	Y	R	Product	Ring size	Yield (%)
1	**1c**	NAc	**5a**	–	Bn	**11**	13	47
2	**1c**	NAc	**5b**	(CH_2)	Me	**12a**	14	39
3	**1c**	NAc	**5c**	(CH_2)	Bn	**12b**	14	31
4	**1c**	NAc	**5d**	$(CH_2)_2$	Et	**13a**	15	19
5	**1c**	NAc	**5e**	$(CH_2)_2$	Bn	**13b**	15	34
6	**1c**	NAc	**5f**	pyridine-2,6-diyl	Bn	**14**	16	56
7	**1c**	NAc	**5g**	$(CH_2)_2O(CH_2)_4O(CH_2)_2$	Bn	**15**	23	32
8[b]	**1d**	O	**5b**	(CH_2)	Me	**16**	14	26
9[b]	**1e**	$O(CH_2)_2O$	**5b**	(CH_2)	Me	**17**	17	28
10[b]	**1e**	$O(CH_2)_2O$	**5f**	pyridine-2,6-diyl	Bn	**18**	19	12
11[b]	**1e**	$O(CH_2)_2O$	**5g**	$(CH_2)_2O(CH_2)_4O(CH_2)_2$	Bn	**19**	26	23
12[b]	**1f**	$O(CH_2)_2[O(CH_2)_2O]_4$	**5a**	–	Bn	**20**	25	22
13[b]	**1f**	$O(CH_2)_2[O(CH_2)_2O]_4$	**5b**	(CH_2)	Me	**21**	26	20
14[b]	**1f**	$O(CH_2)_2[O(CH_2)_2O]_4$	**5g**	$(CH_2)_2O(CH_2)_4O(CH_2)_2$	Bn	**22**	35	24
15	**1g**	$AcN(CH_2)_3O(CH_2)_4O(CH_2)_3NAc$	**5b**	(CH_2)	Me	**23**	27	44
16	**1g**	$AcN(CH_2)_3O(CH_2)_4O(CH_2)_3NAc$	**5f**	pyridine-2,6-diyl	Bn	**24**	29	51
17	**1g**	$AcN(CH_2)_3O(CH_2)_4O(CH_2)_3NAc$	**5g**	$(CH_2)_2O(CH_2)_4O(CH_2)_2$	Bn	**25**	36	44
18	**1h**	–	**5a**	–	Bn	**26**	12	42
19	**1h**	–	**5b**	CH_2	Me	**27**	13	41
20	**1h**	–	**5e**	$(CH_2)_2$	Bn	**28**	14	45
21	**1h**	–	**5f**	pyridine-2,6-diyl	Bn	**29**	15	46
22	**1h**	–	**5g**	$(CH_2)_2O(CH_2)_4O(CH_2)_2$	Bn	**30**	22	48

[a] Typical reaction conditions: 0.9 mmol **1**, 0.9 mmol **5**, 1 mol-% $[Rh(cod)Cl]_2$, 100 mL dioxane, 120 °C, 100 bar CO/H_2 (1:1), 70 h. − [b] 0.9 mmol **1**, 0.9 mmol **5**, 1 mol-% $[Rh(cod)Cl]_2$, 100 mL dioxane, 75 °C, 100 bar CO/H_2 (1:1), 90 h.

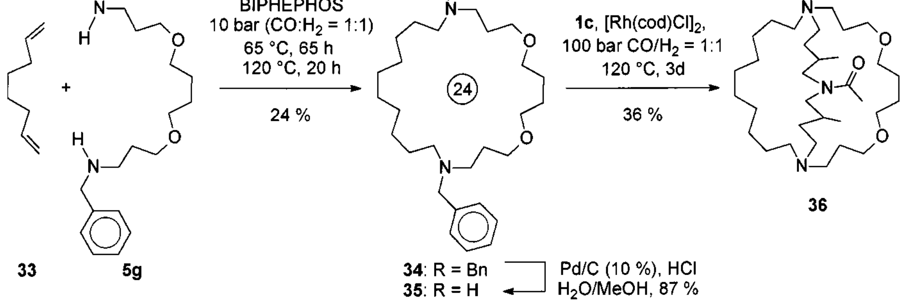


Scheme 5. Synthesis of cryptand **32** starting from the polyazamacrocycle **15**

efin. Since the hydroformylation of a methallylic unit is slow, only small amounts of the aldehyde or dialdehyde are present in the solution at any given time, thus leading to good cyclization yields.

Using this method, even macrocycles of type **15** with nonbranched methylene chains could be generated. For this purpose, 1,7-octadiene (**33**) was treated with diamine **5g** in the presence of BIPHEPHOS,[17] thereby generating the *n*,*n*-macrocycle **24** in 24% yield along with 13% of the regioisomeric *n*,*iso*-macrocycle (Scheme 6). It proved essential to use a temperature gradient during the course of this reaction in order to obtain the desired compounds. If the reaction mixture was worked-up without employing a high temperature period, the required final hydrogenation of the enamines did not take place; under the workup conditions, the enamine/imine products are unstable and undergo decomposition. With a longer low temperature period, the *n*/*iso* ratio increases (e.g. 40 h: 2.9; 65 h: 4.8; 90 h: 6.8). This implies that the hydroformylation is slow under the mild reaction conditions at 65 °C, but is nevertheless highly *n*-selective. Increase of the temperature to 120 °C leads to faster hydrogenation of the enamines. In addition, the unchanged 1,7-octadiene, i.e. that not yet hydroformylated during the low-temperature period, is now also hydroformylated. However, the selectivity of the hydroformylation under these conditions is lower and thus leads to a decreased *n*/*iso* ratio for a short low-temperature period.

The macrocycle **34** thus obtained could be debenzylated under the same reaction conditions as above, thereby affording **35** in 87% yield. A subsequent ring-closing hydroaminomethylation of the macrocyclic diamine **35** led to a



Scheme 6. Synthesis of cryptand **36** starting from 1,7-octadiene (**33**) and diamine **5g**

36% yield of the cryptand system **36**, incorporating a long aliphatic chain between the bridging nitrogen atoms.

Conclusion

In conclusion, a novel ring-closing bis(hydroaminomethylation) procedure has been developed as an efficient method for macroheterocyclic ring synthesis. Our method allows for wide variations in ring size, heteroatom and substitution patterns, and thus facilitates tailor-made syntheses of various macroheterocyclic systems. Furthermore, starting from *N*-benzyl-substituted systems, the synthesis of cryptands could be accomplished by subsequent hydrogenolysis of the benzyl group and successive hydroaminomethylation with a second diolefin of type **1**. Thus, the same methodology can be advantageously used for the synthesis of the first and the second ring system, and no high-dilution principle procedure has to be applied. Investigations concerning the complexation properties of the obtained cryptand systems are currently in progress.

Experimental Section

General Remarks: All general chemicals were purchased from commercial sources. Diolefinic ethers were obtained by means of Williamson ether syntheses, diolefinic amine derivatives by classical nucleophilic substitution reactions. The catalyst precursor [RhCl(cod)]$_2$ was prepared as described previously.[18] − Unless noted otherwise, ^{1}H and ^{13}C NMR spectra were recorded at room temperature with a Bruker DRX 400 spectrometer using CDCl$_3$ as solvent and TMS as an internal standard. The signals were assigned using DEPT, HH-, CH-, and long-range CH-correlation techniques. In the case of symmetric macroheterocycles, only one side is assigned. − Infrared spectra were recorded with a Nicolet Impact 400 D spectrometer using neat compounds as films between NaCl plates. − Mass spectra were recorded with a Finnigan CA 5 spectrometer. − Elemental analyses were performed with a Leco CHNS-932 analyzer. − Analytical gas chromatography was performed with a Fisons 8130 gas chromatograph with 30-m CP sil-5 capillaries. − GC-MS spectra were obtained using a similar capillary in combination with a Finnigan ITD 800 (MS).

Pressure reactions were carried out in autoclaves (type A, 250 mL, PTFE insert) from Berghof, Eningen. After charging the autoclave with the starting material, the catalyst precursor, and the solvent (dioxane), the reactor was flushed with argon, pressurized with 50 bar of hydrogen and 50 bar of carbon monoxide, and heated to the required reaction temperature. Following the reaction, the solvent was removed by rotary evaporation and the catalyst was filtered off by passage through a small pad of neutral alumina (activity III). The products were separated and purified by column chromatography using neutral alumina (activity III) from ICN Biomedicals, Eschwege.

Reaction of *N*-Acetyldiallylamine (1a) with 2-Propylamine (4b): 1a (696 mg, 5.0 mmol), **4b** (307 mg, 5.0 mmol), [Rh(cod)Cl]$_2$ (12 mg, 0.5 mol-%), and dioxane (50 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 40 h. The crude reaction products (548 mg) were purified by column chromatography with *n*-hexane/ethanol, 10:1, as eluent to give 306 mg (1.4 mmol, 27%) of 1-acetyl-5-isopropyl-3,7-dimethyl-1,5-diazacyclooctane (**6b**) and 66 mg (0.3 mmol, 6%) of 5-acetyl-1-isopropyl-7-methyl-1,4,6,7-tetrahydropyrrolo[3,2-*c*]pyridine (**9b**).

6b (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.84 (2 d, 6 H, ^3J = 6.5 Hz, CHCH_3), 0.89 (2 d, 6 H, ^3J = 6.5 Hz, NCHCH_3), 2.06 (s, 3 H, COCH$_3$), 2.07 (m, 4 H, CH-3, CHH-4), 2.56 (d*, 1 H, ^3J = 9.3 Hz, CH*H*-4), 2.63 (dd, 1 H, ^2J = 12.8 Hz, ^3J = 4.0 Hz, C*H*H-4), 2.75 (sept., 1 H, ^3J = 6.5 Hz, NCH), 3.13 (dd, 1 H, ^2J = 14.4 Hz, ^3J = 10.3 Hz, C*H*H-2), 3.23 (dd, 1 H, ^2J = 13.4 Hz, ^3J = 8.9 Hz, CH*H*-2), 3.33 (dd, 1 H, ^2J = 14.4 Hz, ^3J = 3.4 Hz, C*H*H-2), 3.44 (dd, 1 H, ^2J = 13.4 Hz, ^3J = 3.6 Hz, CH*H*-2). − ^{13}C NMR: δ = 17.0, 17.4 (CH*C*H$_3$), 17.2, 19.5 (NCH*C*H$_3$), 22.0 (CO*C*H$_3$), 31.5, 33.3 (CH, 3), 51.6, 54.8 (CH$_2$, 2), 54.5 (NCH), 56.2, 56.3 (CH$_2$, 4), 170.0 (*C*OCH$_3$). − IR: $\tilde{\nu}$ = 2960 cm^{-1} (vs), 2929 (vs), 2871 (s), 1650 (vs), 1645 (vs), 1457 (s), 1423 (s), 1381 (s), 1361 (s). − GC-MS; *m*/*z* (%): 226 [M$^+$] (100), 210 (30), 182 (10), 154 (10), 142 (13), 112 (25), 98 (11), 86 (12), 70 (13), 56 (21). − $C_{13}H_{26}N_2O$ (226.4): calcd. C 68.6, H 11.6, N 12.4; found C 68.6, H 12.0, N 12.8.

9b: ^{1}H NMR: δ = 1.23 (2 d, 3 H, ^3J = 6.8 Hz, CHCH_3), 1.43 (d, 6 H, ^3J = 6.7 Hz, NCHCH_3), 2.18 (s, 3 H, COCH$_3$), 2.95 (m, 1 H, CH-7), 3.50 (dd, ^2J = 13.4 Hz, ^3J = 3.6 Hz, CH*H*-6) 3.78 (d, ^2J = 13.4 Hz, CH*H*-6) [1 H], 3.95 (d, ^2J = 15.8 Hz, C*H*H-4), 5.19 (d, ^2J = 15.8 Hz C*H*H-4) [1 H], 4.20 (sept., 1 H, ^3J = 6.7 Hz, NCH), 3.03 (dd, ^2J = 12.7 Hz, ^3J = 3.6 Hz, C*H*H-6), 4.35 (d, ^2J = 14.8 Hz, CH*H*-4), 4.59 (m, C*H*H-6, CH*H*-4) [2 H], 5.98 (d, 1 H, ^3J = 2.7 Hz, CH-9), 6.64 (d, 1 H, ^3J = 2.7 Hz, CH-8). − ^{13}C NMR: δ = 19.2, 19.4 (CH*C*H$_3$), 21.7, 22.0 (CO*C*H$_3$), 23.7, 23.7, 24.4, 24.4 (NCH*C*H$_3$), 27.9, 28.3 (CH, 7), 40.9, 44.9 (CH$_2$, 4), 45.6, 50.6 (CH$_2$, 6), 46.4 (NCH), 103.9, 104.6 (CH, 9), 111.8, 112.6 (C$_q$, 3), 115.6 (CH, 8), 128.4, 130.2 (C$_q$, 2), 170.0, 170.3 (*C*OCH$_3$). − IR: $\tilde{\nu}$ = 2971 cm^{-1} (vs), 2930 (s), 1651 (vs), 1427 (vs), 1380 (s), 1300 (s), 1265 (s), 1247 (s), 1211 (s), 1020 (s), 731 (s). − GC-MS; *m*/*z*(%): 221 [M$^+$ + 1] (100), 177 (8), 162 (11), 149 (28), 134 (41), 119 (11), 106 (10), 94 (8), 80 (5). − $C_{13}H_{20}N_2O$ (220.3): calcd. C 70.9, H 9.2, N 12.7; found C 70.8, H 8.8, N 12.6.

Reaction of *N*-Acetyldiallylamine (1a) with Benzylamine (4a): 1a (500 mg, 3.6 mmol), **4a** (386 mg, 3.6 mmol), [Rh(cod)Cl]$_2$ (9 mg, 0.5 mol-%), and dioxane (50 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 40 h. The crude reaction products (730 mg) were purified by column chromatography with methyl *tert*-butyl ether (MTBE) as eluent to give 326 mg (1.2 mmol, 33%) of 1-acetyl-5-benzyl-3,7-dimethyl-1,5-diazacyclooctane (**6a**) and 72 mg (0.3 mmol, 7%) of 5-acetyl-1-benzyl-7-methyl-1,4,6,7-tetrahydropyrrolo[3,2-*c*]pyridine (**9a**).

6a (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.71 (2 d, 6 H, ^3J = 6.6 Hz, CHCH_3), 2.11 (2 s, 3 H, COCH$_3$), 2.20 (m, C*H*H-4), 2.43 (m, C*H*H-4) [1 H], 2.32 (m, CH-3), 2.60 (m, CH$_2$-4) [5 H], 3.28 (dd, ^2J = 13.6 Hz, ^3J = 7.8 Hz, C*H*H-2), 3.30−3.59 (m, CHH-2, benzyl CH$_2$), 3.92 (dd, ^2J = 13.2 Hz, ^3J = 9.4 Hz, CH*H*-2) [6 H], 7.24 (m, 5 H, benzyl). − ^{13}C NMR: δ = 19.4, 19.6 (CH*C*H$_3$), 22.3, 22.6 (CO*C*H$_3$), 28.4, 28.9 (CH, 3), 49.0, 53.0 (CH$_2$, 2), 57.9 (benzyl CH$_2$), 53.7, 58.7 (CH$_2$, 4), 127.0, 127.5 (CH, Bn), 128.0, 128.1 (CH, Bn), 128.8, 129.1 (CH, Bn), 142.0, 143.1 (C$_q$, Bn), 170.8 (*C*OCH$_3$). − IR: $\tilde{\nu}$ = 2961 cm^{-1} (vs), 2928 (s), 1650 (vs), 1646 (vs), 1453 (s), 1408 (s), 1031 (s), 736 (s). − GC-MS; *m*/*z* (%): 275 [M$^+$ + 1] (100), 216 (5), 168 (32), 140 (18), 126 (19), 106 (8), 91 (18).

9a: ^{1}H NMR: δ = 1.09 (2 d, 3 H, ^3J = 6.8 Hz, CH*C*H$_3$), 2.16 (s, 3 H, COCH$_3$), 2.81 (m, 1 H, CH-7), 3.00 (dd, ^2J = 12.7 Hz, ^3J = 3.8 Hz, C*H*H-6), 4.48 (dd, ^2J = 12.7 Hz, ^3J = 2.3 Hz, C*H*H-6) [1 H], 3.43 (dd, ^2J = 13.4 Hz, ^3J = 3.8 Hz, CH*H*-6), 3.68 (d, ^2J = 13.4 Hz, CH*H*-6) [1 H], 4.38 (m, CH*H*-4), 4.61 (d, ^2J = 14.8 Hz, CH*H*-4) [1 H], 5.03 (s, 2 H, benzyl CH$_2$), 4.00 (d, ^2J = 15.8 Hz, C*H*H-4), 5.07 (d, ^2J = 15.8 Hz, C*H*H-4) [1 H], 5.98 (m, 1 H, CH-9), 6.57 (m, 1 H, CH-8), 7.00 (m, 1 H, benzyl), 7.30 (m, 4 H, benzyl). − ^{13}C NMR: δ = 18.9, 19.0 (CH*C*H$_3$), 21.7, 22.0 (CO*C*H$_3$), 27.8, 28.3 (CH, 7), 41.0, 44.9 (CH$_2$, 4), 45.6, 50.7 (CH$_2$, 6), 49.8 (benzyl CH$_2$), 104.0, 104.7 (CH, 9), 113.1, 114.1 (C$_q$, 3), 121.2, 121.3 (CH, 8), 126.3, 126.4 (CH, Bn), 127.5 (CH, Bn), 128.7 (CH, Bn), 129.5, 131.3 (C$_q$, 2), 138.0, 138.2 (C$_q$, Bn), 170.0, 170.4 (*C*OCH$_3$). − IR: ṽ = 2975 cm^{-1} (w), 1628 (vs), 1601 (m), 1452 (s), 1447 (s), 1436 (s), 1294 (m), 1230 (s), 729 (s). − GC-MS; *m*/*z* (%): 268 [M$^+$] (100), 225 (11), 210 (22), 197 (33), 182 (38), 148 (10), 119 (10), 91 (40), 65 (12), 51 (10).

Reaction of *N*-Allyl-*N*-methallylacetamide (1b) with 2-Propylamine (4b): 1b (552 mg, 3.6 mmol), **4b** (210 mg, 3.6 mmol), [Rh(cod)Cl]$_2$ (9 mg, 0.5 mol-%), and dioxane (50 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (550 mg) were purified by column chromatography with MTBE/ethanol, 50:1, as eluent to give 182 mg (0.8 mmol, 21%) of 1-acetyl-5-isopropyl-3,8-dimethyl-1,5-diazacyclononane (**7b**).

7b (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.95 (m, 12 H, 4 × CHC*H*$_3$), 1.20 (m, C*H*H-7), 1.55 (m, CHH-7) [2 H], 2.05 (2 s, 3 H, COCH$_3$), 1.90 (m, CH), 2.10 (m, CH), 2.22 (m, CH) [2 H], 2.60 (m, CH*H*-6), 2.90 (m, NCH, CHH-2/9), 3.18 (m, CH*H*-6, CHH-2/9), 3.38 (m, CHH-2/9) [5 H], 2.38 (m, CHH-4, C*H*H-6), 3.49 (dd, ^2J = 14.6 Hz, ^3J = 4.1 Hz, CH*H*-4) [3 H], 3.71 (dd, ^2J = 12.8 Hz, ^3J = 4.1 Hz, CH*H*-2/9), 3.88 (d, ^2J = 12.8 Hz, CH*H*-2/9) [1 H]. − ^{13}C NMR: δ = 15.5, 15.7, 15.8, 16.1 (NCH*C*H$_3$), 18.4, 18.6, 19.2, 19.9 (CH*C*H$_3$), 19.6, 19.7, 20.4, 21.5 (CO*C*H$_3$), 21.7, 22.4, 22.6, 23.4 (CH*C*H$_3$), 28.9, 29.5, 30.8, 31.5 (CH), 32.5, 33.1, 33.3, 35.4 (CH$_2$, 7), 33.2, 33.6, 33.8, 36.5 (CH), 45.8, 47.5, 49.1, 49.8 (CH$_2$, 6), 53.7, 54.0, 54.5, 55.7 (NCH), 52.1, 54.5, 55.4, 55.9 (CH$_2$, 2/9), 57.2, 57.2, 57.7, 57.8 (CH$_2$, 9/2), 57.0, 57.1, 59.4, 59.5 (CH$_2$, 4), 170.7, 170.9, 171.0, 171.6 (*C*OCH$_3$). − IR: ṽ = 2961 cm^{-1} (vs), 2928 (vs), 2870 (vs), 2814 (s), 1651 (vs), 1645 (vs), 1457 (vs), 1436 (vs), 1411 (vs), 1381 (vs), 1361 (vs), 1277 (s), 1233 (s), 1199 (s), 1178 (s), 1165 (s), 1034 (s). − GC-MS; *m*/*z* (%): 241 [M$^+$ + 1] (100), 225 (12), 197 (10), 124 (25), 112 (25), 98 (23), 84 (21), 70 (15), 56 (18). − $C_{14}H_{28}N_2O$ (240.4): calcd. C 70.0, H 11.7, N 11.7; found C 69.8, H 11.4, N 11.6.

Reaction of *N*-Allyl-*N*-methallylacetamide (1b) with Benzylamine (4a): 1b (552 mg, 3.6 mmol), **4b** (386 mg, 3.6 mmol), [Rh(cod)Cl]$_2$ (9 mg, 0.5 mol-%), and dioxane (50 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (430 mg) were purified by column chromatography with MTBE as eluent to give 158 mg (0.5 mmol, 15%) of 1-acetyl-5-benzyl-3,8-dimethyl-1,5-diazacyclononane (**7a**).

7a (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.90 (m, 6 H, 2 × CHC*H*$_3$), 1.20−1.45 (m, C*H*H-7) 1.55−1.83 (m, CH, CH*H*-7), 2.22 (CH, CH$_2$-2/9, CH$_2$-6), 2.53 (CH$_2$-6, CH$_2$-2/9) [7 H], 2.04 (2 s, 3 H, COCH$_3$), 3.00 (m, 2 H, CH$_2$-2/9), 3.25−3.35 (m, benzyl CH$_2$, CH*H*-4, CH$_2$-2/9) 3.78 (m, CH$_2$-2/9, CH*H*-4) [5 H], 7.31 (m, 5 H, benzyl). − ^{13}C NMR: δ = 18.0, 18.4, 18.5, 19.0 (CH*C*H$_3$), 19.0, 19.7, 20.0, 20.8 (CH*C*H$_3$), 21.8, 22.5, 22.9 (CO*C*H$_3$), 28.1, 28.9, 31.3, 31.4 (CH), 31.6, 32.8, 33.3, 33.6 (CH$_2$, 7), 33.0, 33.4, 34.0, 35.8 (CH), 52.0, 52.3, 53.5, 54.8 (CH$_2$, 4), 51.8, 55.1 (benzyl CH$_2$), 55.1, 57.7, 57.8, 58.0 (CH$_2$, 2/9), 59.1, 59.6, 61.7, 61.8 (CH$_2$, 9/2), 62.9, 63.1, 63.7, 64.3 (CH$_2$, 4), 126.7, 126.9, 126.9 (CH, Bn), 128.0, 128.1, 128.2, 128.2 (CH, Bn), 128.6, 128.7, 129.2, 129.4 (CH, Bn), 139.5, 139.5, 139.6, 140.1 (C$_q$, Bn), 170.9, 171.3, 171.8, 172.0 (*C*OCH$_3$). − IR: ṽ = 2958 cm^{-1} (s), 2927 (s), 1647 (vs), 1454 (s), 1411 (s), 1364 (s), 1261 (s), 1171 (s), 1056 (s), 1028 (s), 798 (s), 739 (s). − GC-MS; *m*/*z* (%): 289 [M$^+$ + 1] (95), 197 (22), 172 (15), 158 (10), 126 (14), 114 (33), 98 (15), 91 (100), 84 (23).

Reaction of *N*-Acetyldimethallylamine (1c) with 1,2-Bis(benzylamino)ethane (5a): 1c (200 mg, 1.2 mmol), **5a** (276 mg, 1.2 mmol), [Rh(cod)Cl]$_2$ (5 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (996 mg) were purified by column chromatography with MTBE as eluent to give 237 mg (0.5 mmol, 47%) of 9-acetyl-1,4-dibenzyl-7,11-dimethyl-1,4,9-triazacyclotridecane (**11**).

11 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.72 (2 d, 3 H, ^3J = 6.5 Hz, CHC*H*$_3$), 0.81 (2 d, 3 H, ^3J = 7.0 Hz, CHC*H*$_3$), 1.30 (m, 1 H, C*H*H-6), 1.48 (m, 3 H, CH*H*-6), 2.10 (2 s, 3 H, COCH$_3$), 2.22 (m, 1 H, CH-7), 2.41 (8 H, CH-7, CH$_2$-3, CHH-5), 2.65 (m, 1 H, CH*H*-5), 3.03 (m, CHH-8), 3.92 (dd, ^2J = 13.2 Hz, ^3J = 9.4 Hz, C*H*H-8) [2 H], 3.28 (dd, ^2J = 13.6 Hz, ^3J = 7.8 Hz, CH*H*-8), 3.58 (dd, ^2J = 13.6 Hz, ^3J = 7.9 Hz, CH*H*-8) [1 H], 3.42 (m, 5 H, benzyl CH$_2$, CHH-8), 7.25 (m, 10 H, benzyl). − ^{13}C NMR ([D$_6$]DMSO, 70 °C): δ = 18.1, 18.5 (CH*C*H$_3$), 22.4, 22.9 (CO*C*H$_3$), 28.3 (CH, 7), 32.4 (CH$_2$, 6), 51.6 (CH$_2$, 5), 52.0, 53.4 (CH$_2$, 8), 53.8 (CH$_2$, 3), 58.7, 59.5 (benzyl CH$_2$), 126.9, 127.0 (CH, Bn), 128.2, 128.2 (CH, Bn), 129.4, 129.5 (CH, Bn), 139.5, 139.7 (C$_q$, Bn), 170.0, 170.5 (*C*OCH$_3$). − IR: ṽ = 2961 cm^{-1} (s), 1637 (vs), 1631 (vs), 1452 (s), 1262 (s), 1029 (s), 733 (vs). − MS; *m*/*z* (%): 435 [M$^+$] (6), 344 (100), 225 (8), 210 (21), 98 (18), 91 (53). − $C_{28}H_{41}N_3O$ (435.7): calcd. C 77.2, H 9.5, N 9.6; found C 77.3, H 9.6, N 9.5.

Reaction of *N*-Acetyldimethallylamine (1c) with 1,3-Bis(methylamino)propane (5b): 1c (200 mg, 1.2 mmol), **5b** (111 mg, 1.2 mmol), [Rh(cod)Cl]$_2$ (5 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (410 mg) were purified by column chromatography with MTBE as eluent to give 134 mg (0.5 mmol, 39%) of 10-acetyl-1,5,8,12-tetramethyl-1,5,10-triazacyclotetradecane (**12a**) as separated diastereoisomers in a 1:1 ratio.

12a (Diastereoisomer 1): ^{1}H NMR: δ = 0.83 (2 d, 6 H, ^3J = 6.8 Hz, CHC*H*$_3$), 1.27 (m, 2 H, C*H*H-7), 1.38 (m, 2 H, CH*H*-7), 1.52 (m, 2 H, CH$_2$-3), 1.78 (m, 2 H, CH$_2$-4), 1.98 (2 s, 6 H, NCH$_3$), 2.04 (s, 3 H, COCH$_3$), 2.17 (m, 4 H, CH-8, C*H*H-6), 2.35 (m, 2 H, CH*H*-6), 2.64 (m, 3 H, CH$_2$-4, C*H*H-9), 2.89 (t*, 1 H, *J* = 12.6 Hz, CH*H*-9), 3.18 (dd, 1 H, ^2J = 14.1 Hz, ^3J = 3.2 Hz, C*H*H-9), 3.92 (t*, 1 H, *J* = 12.6 Hz, CH*H*-9). − ^{13}C NMR: δ = 17.5, 17.5 (CH*C*H$_3$), 22.3 (CO*C*H$_3$), 24.5 (CH$_2$, 3), 24.6, 25.1 (CH, 8), 32.2 (CH$_2$, 7), 40.7 (NCH$_3$), 45.6, 50.8 (CH$_2$, 9), 52.8, 52.9 (CH$_2$, 4), 55.1, 55.2 (CH$_2$, 7), 170.8 (C$_q$, 17). − IR: ṽ = 2956 cm^{-1} (vs), 2930 (s), 2870 (s), 2783 (s), 1647 (vs), 1461 (vs), 1428 (s), 1354 (s), 1031 (s). − GC-MS; *m*/*z* (%): 298 [M$^+$ + 1] (54), 282 (19), 225 (10), 139 (32), 126 (52), 112 (41), 98 (73), 84 (45), 70 (33), 58 (100). − $C_{17}H_{35}N_3O$ (297.5): calcd. C 68.6, H 11.9, N 14.3; found C 68.3, H 11.8, N 13.7.

12a (Diastereoisomer 2): ^{1}H NMR: δ = 0.80 (2 d, 6 H, ^3J = 6.8 Hz, CHC*H*$_3$), 1.12 (m, 2 H, C*H*H-7), 1.47 (m, 4 H, CH*H*-7, CH$_2$-3), 1.98 (m, 4 H, C*H*H-4, CH-8), 2.00 (2 s, 6 H, NCH$_3$), 2.05 (s, 3 H, COCH$_3$), 2.18 (m, 2 H, C*H*H-6), 2.35 (m, 4 H, CH*H*-6, CH*H*-4), 2.95 (dd, 1 H, ^2J = 14.1 Hz, ^3J = 8.3 Hz, C*H*H-9), 3.20 (dd, 1 H, ^2J = 13.6 Hz, ^3J = 8.1 Hz, CH*H*-9), 3.48 (dd, 1 H, ^2J = 14.1 Hz, ^3J = 7.1 Hz, C*H*H-9), 3.70 (dd, 1 H, ^2J = 13.6 Hz, ^3J = 7.6 Hz, CH*H*-9). − ^{13}C NMR: δ = 17.9, 18.0 (CH*C*H$_3$), 22.4 (CO*C*H$_3$), 24.6 (CH$_2$, 3), 28.5, 28.2 (CH, 8), 31.3, 31.4 (CH$_2$, 7), 41.5, 41.6 (NCH$_3$), 47.0, 52.2 (CH$_2$, 9), 53.2, 53.3 (CH$_2$, 4), 56.4, 56.5 (CH$_2$, 6), 170.9 (C$_q$, 17). − IR: ṽ = 2954 cm^{-1} (vs), 2928 (vs), 2785 (vs), 1645 (vs), 1456 (vs), 1426 (vs), 1195 (m), 1033 (m). − GC-MS; *m/z* (%): 298 [M$^+$ + 1] (48), 282 (11), 225 (18), 139 (35), 126 (52), 112 (41), 98 (72), 84 (50), 70 (33), 58 (100). − $C_{17}H_{35}N_3O$ (297.5): calcd. C 68.6, H 11.9, N 14.3; found C 68.1, H 12.1, N 13.9.

Reaction of *N*-Acetyldimethallylamine (1c) with 1,3-Bis(benzylamino)propane (5c): **1c** (200 mg, 1.2 mmol), **5c** (293 mg, 1.2 mmol), [Rh(cod)Cl]$_2$ (5 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (653 mg) were purified by column chromatography with MTBE/petroleum ether (PE), 2:1, as eluent to give 159 mg (0.4 mmol, 31%) of 10-acetyl-1,5-dibenzyl-8,12-dimethyl-1,5,10-triazacyclotetradecane (**12b**).

12b (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.65 (2 d, 3 H, ^3J = 6.5 Hz, CHC*H*$_3$), 0.75 (d, ^3J = 6.5 Hz, CHC*H*$_3$), 0.78 (d, ^3J = 6.8 Hz, CHC*H*$_3$) [3 H], 1.14−1.43 (m, 3 H, CHH-7), 1.64 (m, 3 H, CH*H*-7, CH$_2$-3), 2.09 (2 s, 3 H, COCH$_3$), 2.08−2.68 (10 H, CH$_2$-4, CH$_2$-6, CH-8), 2.77 (dd, ^2J = 13.4 Hz, ^3J = 3.1 Hz, C*H*H-9), 3.00−3.67 (m, CH*H*-9, CH$_2$-15), 4.03 (t*, ^3J = 12.6 Hz, C*H*H-9) [8 H], 7.25 (m, 10 H, phenyl). − ^{13}C NMR: δ = 17.0, 17.4, 17.6 (CH*C*H$_3$), 22.3, 22.5 (CO*C*H$_3$), 25.7, 26.5 (CH$_2$, 3), 25.1, 25.8, 28.8, 29.4 (CH, 8), 31.5, 31.8, 32.5 (CH$_2$, 7), 50.4, 50.8, 51.0, 51.3, 51.3, 51.5, 51.5 (2 × CH$_2$, 4 + 6), 46.3, 49.0, 51.7, 54.1 (CH$_2$, 9), 58.5, 58.6, 59.0, 59.2 (CH$_2$, 15), 126.6, 126.7, 126.7 (CH, 19), 127.9, 128.0, 128.0 (CH, 17/18), 128.8, 128.9, 129.1 (CH, 18/17), 139.6, 139.7, 139.9, 140.0 (C$_q$, 16), 170.8, 171.1 (C$_q$, 21). − IR: ṽ = 2952 cm^{-1} (vs), 2926 (vs), 2869 (s), 2852 (s), 2794 (vs), 1645 (vs), 1452 (vs), 1426 (s), 1266 (m), 1125 (m), 698 (s). − MS: *m/z* (%) = 449 [M$^+$] (1), 358 (10), 212 (26), 189 (11), 135 (15), 106 (24), 98 (10), 91 (100), 79 (11), 65 (16), 41 (14). − $C_{29}H_{43}N_3O$ (449.7): calcd. C 77.5, H 9.6, N 9.3; found C 76.7, H 9.6, N 8.6.

Reaction of *N*-Acetyldimethallylamine (1c) with 1,4-Bis(ethylamino)butane (5d): **1c** (200 mg, 1.2 mmol), **5d** (166 mg, 1.2 mmol), [Rh(cod)Cl]$_2$ (5 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (473 mg) were purified by column chromatography with MTBE as eluent to give 74 mg (0.2 mmol, 20%) of 11-acetyl-1,6-diethyl-9,13-dimethyl-1,6,11-triazacyclopentadecane (**13a**) as separated diastereoisomers in a 1:1 ratio.

13a (Diastereoisomer 1): ^{1}H NMR: δ = 0.83 (d, 3 H, ^3J = 6.8 Hz, CHC*H*$_3$), 0.88 (d, 3 H, ^3J = 6.8 Hz, CHC*H*$_3$), 0.97 (t, 3 H, ^3J = 7.3 Hz, CH$_2$C*H*$_3$), 0.98 (t, 3 H, ^3J = 7.0 Hz, CH$_2$C*H*$_3$), 1.31 (m, 4 H, CH$_2$-4), 1.55 (m, 2 H, C*H*H-8), 2.11 (s, 3 H, COCH$_3$), 2.23 (m, 4 H, CH-9, C*H*H-5), 2.37 (8 H, CH*H*-5, CH$_2$-7, CH*H*-8), 2.43 (q, 4 H, ^3J = 7.0 Hz, C*H*$_2$CH$_3$), 2.69 (dd, 1 H, ^2J = 13.6 Hz, ^3J = 4.3 Hz, C*H*H-10), 3.07 (dd, 1 H, ^2J = 13.8 Hz, ^3J = 11.2 Hz, CH*H*-10), 3.23 (dd, 1 H, ^2J = 13.8 Hz, ^3J = 4.3 Hz, CH*H*-10), 4.00 (m, 1 H, C*H*H-10). − ^{13}C NMR: δ = 11.9, 12.0 (CH$_2$*C*H$_3$), 17.3, 17.4 (CH*C*H$_3$), 22.1 (CO*C*H$_3$), 26.7, 26.9 (CH$_2$, 4), 27.3, 27.7 (CH, 9), 33.1 (CH$_2$, 8), 47.2, 52.2 (CH$_2$, 10), 48.6, 48.6 (*C*H$_2$CH$_3$), 50.0, 50.1 (CH$_2$, 7), 53.8 (CH$_2$, 5), 170.9 (*C*OCH$_3$). − IR: ṽ = 2963 cm^{-1} (vs), 2928 (vs), 2871 (s), 2851 (s), 2799 (vs), 1651 (vs), 1646 (vs), 1456 (s), 1379 (s), 1070 (m). − MS: *m/z* (%) = 340 [M$^+$ + 1] (71), 310 (41), 253 (12), 168 (10), 154 (19), 140 (19), 124 (21), 112 (66), 98 (100), 84 (48), 72 (61), 56 (42).

13a (Diastereoisomer 2): ^{1}H NMR: δ = 0.88 (d, 3 H, ^3J = 6.7 Hz, CHC*H*$_3$), 0.91 (d, 3 H, ^3J = 6.7 Hz, CHC*H*$_3$), 0.98 (2 t, 3 H, ^3J = 7.2 Hz, CH$_2$C*H*$_3$), 1.30 (m, 2 H, C*H*H-8), 1.42 (m, 4 H, CH*H*-8, C*H*H-4), 1.49 (m, 2 H, CH*H*-4), 2.01 (m, 2 H, CH-9), 2.12 (s, 3 H, COCH$_3$), 2.39 (12 H, CH$_2$-5, CH$_2$-7, C*H*$_2$CH$_3$), 3.14 (dd, 1 H, ^2J = 13.5 Hz, ^3J = 5.1 Hz, C*H*H-10), 3.28 (dd, 1 H, ^2J = 13.8 Hz, ^3J = 10.5 Hz, CH*H*-10), 3.33 (dd, 1 H, ^2J = 13.8 Hz, ^3J = 5.3 Hz, CH*H*-10), 3.42 (dd, 1 H, ^2J = 13.5 Hz, ^3J = 10.8 Hz, C*H*H-10). − ^{13}C NMR: δ = 11.6, 11.7 (CH$_2$*C*H$_3$), 17.7, 18.0 (CH*C*H$_3$), 22.3 (CO*C*H$_3$), 25.7, 25.9 (CH$_2$, 4), 29.3, 29.4 (CH, 9), 32.5, 32.8 (CH$_2$, 8), 47.8, 47.9 (*C*H$_2$CH$_3$), 50.3, 50.5 (CH$_2$, 7), 52.9, 53.2 (CH$_2$, 5), 50.0, 54.7 (CH$_2$, 10), 171.1 (*C*OCH$_3$). − IR: ṽ = 2964 cm^{-1} (vs), 2930 (vs), 2870 (s), 2797 (s), 1651 (vs), 1456 (s), 1423 (s), 1380 (s), 1032 (m). − MS; *m/z* (%): 340 [M$^+$ + 1] (20), 310 (33), 281 (14), 253 (11), 154 (18), 139 (22), 126 (29), 112 (88), 98 (100), 84 (51), 72 (50), 56 (48). − $C_{20}H_{41}N_3O$ (339.6): calcd. C 70.7, H 12.2, N 12.4; found C 70.4, H 12.1, N 12.7.

Reaction of *N*-Acetyldimethallylamine (1c) with 1,4-Bis(benzylamino)butane (5e): **1c** (200 mg, 1.2 mmol), **5e** (319 mg, 1.2 mmol), [Rh(cod)Cl]$_2$ (5 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (612 mg) were purified by column chromatography with MTBE/PE, 3:1, as eluent to give 190 mg (0.4 mmol, 34%) of 11-acetyl-1,6-dibenzyl-9,13-dimethyl-1,6,11-triazacyclopentadecane (**13b**) as separated diastereoisomers in a 1:1 ratio.

13b (Diastereoisomer 1): ^{1}H NMR: δ = 0.56 (d, 3 H, ^3J = 6.8 Hz, CHC*H*$_3$), 0.58 (d, 3 H, ^3J = 6.5 Hz, CHC*H*$_3$), 1.12−1.38 (6 H, CH$_2$-8, C*H*H-4), 1.63 (m, 2 H, CH*H*-4), 2.08 (s, 3 H, COCH$_3$), 2.23 (m, 4 H, CH-9, C*H*H-5), 2.40 (m, 6 H, CH*H*-5, CH$_2$-7), 2.68 (dd, 1 H, ^2J = 12.8 Hz, ^3J = 3.6 Hz, C*H*H-10), 3.04 (t*, 1 H, *J* = 13.3 Hz, CH*H*-10), 3.18 (dd, 1 H, ^2J = 13.3 Hz, ^3J = 4.5 Hz, CH*H*-10), 3.49 (m, 4 H, benzyl CH$_2$), 4.02 (t*, 1 H, *J* = 12.8 Hz, C*H*H-10), 7.25 (m, 10 H, benzyl). − ^{13}C NMR: δ = 16.8, 17.2 (CH*C*H$_3$), 22.1 (CO*C*H$_3$), 26.8, 27.1 (CH$_2$, 4), 27.1, 27.4 (CH, 9), 33.1, 33.1 (CH$_2$, 8), 46.7, 52.0 (CH$_2$, 5), 50.5, 50.7 (CH$_2$, 4), 59.8 (benzyl CH$_2$), 126.6, 126.8 (CH, Bn), 128.0, 128.1 (CH, Bn), 128.8, 128.9 (CH, Bn), 140.3, 140.4 (C$_q$, Bn), 170.9 (*C*OCH$_3$). − IR: ṽ = 3027 cm^{-1} (m), 2954 (vs), 2926 (vs), 1645 (vs), 1453 (s), 1427 (s), 1071 (m).

13a (Diastereoisomer 2): ^{1}H NMR: δ = 0.79 (2 d, 6 H, ^3J = 6.8 Hz, CHC*H*$_3$), 1.26 (m, 2 H, C*H*H-8), 1.45 (6 H, CH*H*-8, CH$_2$-4), 2.09 (s, 3 H, COCH$_3$), 2.12−2.50 (10 H, CH-9, CH$_2$-5, CH$_2$-7), 3.15 (dd, 1 H, ^2J = 14.3 Hz, ^3J = 9.0 Hz, C*H*H-10), 3.25 (dd, 1 H, ^2J = 14.3 Hz, ^3J = 6.8 Hz, C*H*H-10), 3.31 (dd, 1 H, ^2J = 13.6 Hz, ^3J = 6.5 Hz, CH*H*-10), 3.50 (m, 5 H, benzyl CH$_2$, CH*H*-10), 7.29 (m, 10 H, benzyl). − ^{13}C NMR: δ = 17.5, 18.0 (CH*C*H$_3$), 22.4 (CO*C*H$_3$), 26.2, 26.4 (CH$_2$, 4), 29.4, 29.5 (CH, 9), 32.2, 32.6 (CH$_2$, 8), 50.9, 51.3 (CH$_2$, 7), 53.6, 53.9 (CH$_2$, 5), 49.9, 54.9 (CH$_2$, 10), 59.4, 59.4 (benzyl CH$_2$), 126.6, 126.8 (CH, Bn), 128.0, 128.0 (CH, Bn), 129.0, 129.0 (CH, Bn), 140.0, 140.2 (C$_q$, Bn), 171.3 (*C*OCH$_3$). − IR: ṽ = 2948 cm^{-1} (s), 2799 (s), 1645 (vs), 1452 (m), 1215 (m), 700 (s). − MS; *m/z* (%): 463 [M$^+$] (7), 372 (100), 211 (8), 174 (10), 160 (7), 146 (6), 98 (10), 91 (42), 84 (12), 69 (11). − $C_{30}H_{45}N_3O$ (463.7): calcd. C 77.7, H 9.8, N 9.1; found C 77.5, H 9.5, N 8.7.

Reaction of *N*-Acetyldimethallylamine (1c) with 2,6-Bis(benzylaminomethyl)pyridine (5f): **1c** (132 mg, 0.8 mmol), **5f** (250 mg, 0.8 mmol), [Rh(cod)Cl]$_2$ (3 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (500 mg) were purified by column chromatography with MTBE/petroleum ether (PE), 1:1, as eluent to give 226 mg (0.4 mmol, 56%) of 8-acetyl-3,13-dibenzyl-6,10-dimethyl-3,8,13,19-tetraazabicyclo[13.3.1]nonadeca-1(18),15(19),16-triene (**14**).

14 (1:1 Mixture of Diastereoisomers): ^{1}H NMR ([D$_6$]DMSO, 80 °C): δ = 0.62 (br. s, 6 H, CHC*H*$_3$), 1.18 (br. s, 2 H, C*H*H-5), 1.47 (br. s, 2 H, CH*H*-5), 1.85 (m, 2 H, CH-6), 1.91 (2 s, 3 H, COCH$_3$), 2.43 (br. s, 5 H, CH$_2$-4, C*H*H-7), 2.98 (br. s, 1 H, CH*H*-7), 3.21 (br. s, 1 H, CH*H*-7), 3.60 (9 H, CH*H*-7, CH$_2$-2, benzyl CH$_2$), 7.11 (d, 2 H, ^3J = 7.5 Hz, CH-18), 7.25 (m, 10 H, benzyl), 7.60 (m, 1 H, CH-17). − ^{13}C NMR ([D$_6$]DMSO, 80 °C): δ = 18.0, 18.3 (CH*C*H$_3$), 22.6, 22.7 (CO*C*H$_3$), 29.2, 29.5 (CH, 6), 31.6, 32.5 (CH$_2$, 5), 51.2, 51.7 (CH$_2$, 4), 48.2, 53.4 (CH$_2$, 7), 59.7, 59.8 (CH$_2$, 2/Bn), 60.0, 60.1 (CH$_2$, Bn/2), 123.0 (CH, 18), 127.6 (CH, Bn), 128.9 (CH, Bn), 129.6, 129.7 (CH, Bn), 137.1, 137.1 (CH, 17), 140.6 (C$_q$, Bn), 159.9 (C$_q$, 1), 170.1, 170.7 (COCH$_3$). − IR: $\tilde{\nu}$ = 2953 cm^{-1} (vs), 2926 (vs), 2793 (vs), 1644 (vs), 1454 (vs), 739 (vs), 699 (vs). − MS; *m*/*z* (%): 512 [M$^+$] (3), 422 (2), 279 (2), 149 (7), 100 (10), 91 (19), 84 (64), 69 (38), 56 (100), 43 (67). − C$_{33}$H$_{44}$N$_4$O (512.7): calcd. C 77.3, H 8.6, N 10.9; found C 77.1, H 8.8, N 10.5.

Reaction of *N*-Acetyldimethallylamine (1c) with 1,12-Bis(benzylamino)-4,9-dioxadodecane (5g): 1c (150 mg, 0.9 mmol), **5g** (338 mg, 0.9 mmol), [Rh(cod)Cl]$_2$ (4 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (700 mg) were purified by column chromatography with MTBE as eluent to give 166 mg (0.3 mmol, 32%) of 10-acetyl-5,15-dibenzyl-8,12-dimethyl-1,19-dioxa-5,10,15-triazacyclotricosane (**15**).

15 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.70 (2 d, 6 H, ^3J = 6.3 Hz, CHC*H*$_3$), 1.14 (m, 2 H, C*H*H-7), 1.53 (m, 2 H, CH*H*-7), 1.63 (br. s, 4 H, CH$_2$-22), 1.71 (quint, 4 H, ^3J = 5.9 Hz, CH$_2$-3), 1.87 (m, 2 H, CH-8), 2.04 (2 s, 3 H, COCH$_3$), 2.39 (t*, 4 H, ^3J = 5.5 Hz, CH$_2$-6), 2.48 (m, 2 H, C*H*H-4), 2.58 (m, 2 H, CH*H*-4), 2.93−3.22 (m, CH$_2$-9), 3.32 (dd, ^2J = 13.3 Hz, ^3J = 8.0 Hz, CH$_2$-9) [4 H], 3.43 (10 H, CH$_2$-2, CH$_2$-23, PhC*H*H), 3.59 (m, 2 H, PhCH*H*), 7.20 (m, 2 H, benzyl), 7.28 (m, 8 H, benzyl). − ^{13}C NMR ([D$_6$]DMSO, 85 °C): δ = 17.2, 17.5 (CH*C*H$_3$), 21.9, 21.9 (CO*C*H$_3$), 26.6, 26.6 (CH$_2$, 22), 27.5 (CH$_2$, 3), 29.2, 29.9 (CH, 8), 32.2 (CH$_2$, 7), 50.6 (CH$_2$, 4/6), 51.7 (CH$_2$, 6/4), 53.4 (CH$_2$, 9), 58.8, 58.8 (benzyl CH$_2$), 68.2 (CH$_2$, 2), 70.2 (CH$_2$, 23), 126.9 (CH, Bn), 128.3 (CH, Bn), 128.9 (CH, Bn), 140.3 (C$_q$, Bn), 170.0, 170.2 (*C*OCH$_3$). − IR: $\tilde{\nu}$ = 2928 cm^{-1} (vs), 2859 (vs), 1651 (vs), 1645 (vs), 1463 (s), 1454 (vs), 1435 (s), 1118 (vs), 698 (s). − MS: *m*/*z* (%) = 579 [M$^+$] (16), 536 (15), 488 (82), 236 (14), 210 (30), 167 (17), 149 (45), 134 (28), 100 (22), 91 (100), 71 (29), 57 (47), 43 (33). − C$_{36}$H$_{57}$N$_3$O$_3$ (579.9): calcd. C 74.6, H 9.9, N 7.2; found C 74.6, H 9.6, N 7.0.

Reaction of Dimethallyl Ether (1d) with 1,3-Bis(methylamino)propane (5b): 1d (227 mg, 1.8 mmol), **5b** (176 mg, 1.8 mmol), [Rh(acac)(CO)$_2$] (5 mg, 1 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 75 °C for 120 h. The crude reaction products (452 mg) were purified by column chromatography with MTBE as eluent to give 122 mg (0.5 mmol, 26%) of 3,6,10,13-tetramethyl-1-oxa-6,10-diazacyclotetradecane (**16**).

16 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.89 (d, 6 H, ^3J = 6.8 Hz, CHC*H*$_3$), 1.35 (m, 2 H, C*H*H-4), 1.59 (m, 4 H, CH*H*-4, CH$_2$-8), 1.75 (m, 2 H, C*H*H-7), 2.18−2.38 (6 H, CH-3, CH$_2$-5), 2.25 (s, 6 H, NCH$_3$), 2.62 (m, 2 H, CH*H*-7), 3.19 (dd, 2 H, ^2J = 9.2 Hz, ^3J = 7.8 Hz, C*H*H-2), 3.44 (dd, 2 H, ^2J = 9.2 Hz, ^3J = 2.6 Hz, CH*H*-2). − ^{13}C NMR: δ = 17.7 (CH*C*H$_3$), 22.3 (CH$_2$, 8), 30.0 (CH$_2$, 4), 31.2 (CH, 3), 43.8 (NCH$_3$), 52.3 (CH$_2$, 5/7), 53.1 (CH$_2$, 7/5), 75.3 (CH$_2$, 2). − IR: $\tilde{\nu}$ = 2950 cm^{-1} (vs), 2871 (vs), 2840 (vs), 2785 (vs), 1461 (s), 1116 (s), 1104 (s), 1075 (s). − MS; *m*/*z* (%): 257 [M$^+$ + 1] (100), 241 (5), 139 (25), 126 (20), 112 (21), 98 (23), 84 (24), 70 (15), 58 (78). − C$_{15}$H$_{32}$N$_2$O (256.4): calcd. C 70.3, H 12.6, N 10.9; found C 70.1, H 12.6, N 10.9.

Reaction of Ethylene Glycol Dimethallyl Ether (1e) with 1,3-Bis(methylamino)propane (5b): 1e (300 mg, 1.8 mmol), **5b** (176 mg, 1.8 mmol), [Rh(acac)(CO)$_2$] (5 mg, 1 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 75 °C for 90 h. The crude reaction products (427 mg) were purified by column chromatography with MTBE/2-propanol, 5:1, as eluent to give 147 mg (0.5 mmol, 28%) of 6,9,13,16-tetramethyl-1,4-dioxa-9,13-diazacycloheptadecane (**17**).

17 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.88 (2 d, 6 H, ^3J = 6.7 Hz, CHC*H*$_3$), 1.28 (m, 2 H, C*H*H-7), 1.58 (m, 2 H, CH$_2$-11), 1.78 (m, 4 H, CH*H*-7, CH-6), 2.21 (s, 6 H, NCH$_3$), 2.38 (m, 8 H, CH$_2$-8, CH$_2$-10), 3.24 (m, 2 H, C*H*H-5), 3.32 (m, 2 H, CH*H*-5), 3.49 (m, 2 H, C*H*H-3), 3.60 (m, 2 H, CH*H*-3). − ^{13}C NMR: δ = 17.0, 17.1 (CH*C*H$_3$), 24.1, 24.4 (CH$_2$, 11), 31.1, 31.2 (CH$_2$, 7), 31.5, 31.6 (CH, 6), 43.3, 43.4 (NCH$_3$), 54.5, 54.6 (CH$_2$, 8/10), 54.8, 54.8 (CH$_2$, 10/8), 70.6, 70.6 (CH$_2$, 3), 76.6, 76.8 (CH$_2$, 5). − IR: $\tilde{\nu}$ = 2951 cm^{-1} (vs), 2930 (vs), 2869 (vs), 2788 (vs), 1460 (m), 1116 (s). − GC-MS; *m*/*z* (%): 301 [M$^+$ + 1] (42), 271 (6), 139 (38), 126 (25), 112 (22), 86 (37), 70 (23), 58 (100). − C$_{17}$H$_{36}$N$_2$O$_2$ (300.5): calcd. C 68.0, H 12.1, N 9.3; found C 68.0, H 11.9, N 9.3.

Reaction of Ethylene Glycol Dimethallyl Ether (1e) with 2,6-Bis(benzylaminomethyl)pyridine (5f): 1e (136 mg, 0.8 mmol), **5b** (250 mg, 0.8 mmol), [Rh(acac)(CO)$_2$] (3 mg, 1 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 75 °C for 90 h. The crude reaction products (473 mg) were purified by column chromatography with PE/MTBE, 2:1, as eluent to give 48 mg (93 μmol, 12%) of 3,16-dibenzyl-6,13-dimethyl-8,11-dioxa-3,16,22-triazabicyclo[16.3.1]docosa-1(21),18(22),19-triene (**18**).

18 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.79 (d, 6 H, ^3J = 6.8 Hz, CH$_3$), 1.32 (m, 2 H, C*H*H-5), 1.53 (m, 2 H, CH*H*-5), 1.73 (m, 2 H, CH-6), 2.50 (m, 4 H, CH$_2$-4), 3.10 (m, 4 H, CH$_2$-7), 3.32 (s, 4 H, CH$_2$-9), 3.68 (m, 8 H, CH$_2$-2, benzyl CH$_2$), 7.24 (m, 2 H, CH-21), 7.31 (m, 6 H, benzyl), 7.42 (m, 4 H, benzyl), 7.58 (m, 1 H, CH-20). − ^{13}C NMR: δ = 17.6, 17.7 (CH$_3$), 30.9, 31.2 (CH, 6), 31.0, 31.4 (CH$_2$, 5), 51.3, 51.6 (CH$_2$, 4), 59.6, 59.7 (benzyl CH$_2$), 60.0, 60.1 (CH$_2$, 2), 70.4, 70.5 (CH$_2$, 9), 76.2, 76.4 (CH$_2$, 7), 121.0, 121.0 (CH, 21), 126.9 (CH, Bn), 128.2 (CH, Bn), 128.9 (CH, Bn), 136.3, 136.3 (CH, 20), 139.9 (C$_q$, Bn), 159.4, 159.5 (C$_q$, 1). − IR: $\tilde{\nu}$ = 3027 cm^{-1} (m), 2952 (vs), 2926 (vs), 2869 (vs), 2799 (s), 1454 (vs), 1112 (vs), 739 (s), 698 (vs). − MS; *m*/*z* (%): 515 [M$^+$] (67), 424 (26), 409 (38), 341 (10), 206 (13), 177 (33), 174 (24), 121 (17), 107 (57), 100 (16), 91 (100), 77 (15), 69 (23), 57 (29), 55 (39). − HRMS: calcd. for C$_{33}$H$_{45}$N$_3$O$_2$: 515.35120; found 515.3510.

Reaction of Ethylene Glycol Dimethallyl Ether (1e) with 1,12-Bis(benzylamino)-4,9-dioxadodecane (5g): 1e (136 mg, 0.8 mmol), **5b** (308 mg, 0.8 mmol), [Rh(acac)(CO)$_2$] (3 mg, 1 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 75 °C for 90 h. The crude reaction products (463 mg) were purified by column chromatography with PE/MTBE, 2:1, as eluent to give 105 mg (0.2 mmol, 23%) of 9,22-dibenzyl-6,25-dimethyl-1,4,13,18-tetraoxa-9,22-diazacyclohexacosane (**19**).

19 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.81 (d, 6 H, ^3J = 6.8 Hz, CH$_3$), 1.24 (m, 2 H, C*H*H-7), 1.62 (m, 6 H, CH$_2$-15, CH*H*-7), 1.72 (quint*, 4 H, ^3J = 6.5 Hz, CH$_2$-11), 1.79 (m, 2 H, CH-6), 2.42 (t, 4 H, ^3J = 7.4 Hz, CH$_2$-8), 2.52 (m, 4 H, CH$_2$-10), 3.23 (dd, 2 H, ^2J = 9.1 Hz, ^3J = 6.5 Hz, C*H*H-5), 3.29 (dd, 2 H, ^2J = 9.1 Hz, ^3J = 6.3 Hz, CH*H*-5), 3.40−3.58 (16 H, CH$_2$-3, CH$_2$-12, benzyl CH$_2$, CH$_2$-28), 7.22 (m, 2 H, benzyl), 7.29 (m, 8 H, benzyl). − ^{13}C NMR: δ = 17.1 (CH$_3$), 26.6 (CH$_2$, 15), 27.4 (CH$_2$, 11), 30.9 (CH$_2$, 7), 31.1, 31.2 (CH, 6), 50.1 (CH$_2$, 10), 51.4 (CH$_2$, 8), 58.8 (benzyl CH$_2$), 68.7 (CH$_2$, 14), 70.2, 70.3 (CH$_2$, 3), 70.6

(CH_2, 12), 76.8, 76.9 (CH_2, 5), 126.6 (CH, Bn), 128.0 (CH, Bn), 128.8 (CH, Bn), 140.1 (C_q, Bn). − IR: $\tilde{\nu}$ = 3026 cm^{-1} (m), 2948 (vs), 2929 (vs), 2857 (vs), 2797 (vs), 1453 (s), 1368 (s), 1115 (vs), 1028 (s), 698 (s). − MS; *m*/*z* (%): 583 [M^+ + 1] (18), 540 (13), 492 (100), 134 (14), 91 (29), 57 (9). − $C_{36}H_{58}N_2O_4$ (582.9): calcd. C 74.2, H 10.0, N 4.8; found C 74.1, H 9.9, N 4.8.

Reaction of Tetraethylene Glycol Dimethallyl Ether (1f) with 1,2-Bis(benzylamino)ethane (5a): 1f (200 mg, 0.7 mmol), **5a** (158 mg, 0.7 mmol), [Rh(acac)(CO)$_2$] (3 mg, 1 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 75 °C for 70 h. The crude reaction products (391 mg) were purified by column chromatography with MTBE/cyclohexane, 1:1, as eluent to give 82 mg (0.1 mmol, 22%) of 18,21-dibenzyl-15,24-dimethyl-1,4,7,10,13-pentaoxa-18,21-diazacyclopentacosane (**20**).

20 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.82 (d, 6 H, ^3J = 6.5 Hz, CH_3), 1.24 (m, 2 H, C*H*H-16), 1.63 (m, 2 H, CH*H*-16), 1.78 (m, 2 H, CH-15), 2.43 (t, 4 H, ^3J = 7.3 Hz, CH_2-17), 2.57 (m, 4 H, CH_2-19), 3.24 (m, 4 H, CH_2-14), 3.51 (m, 4 H, benzyl CH_2), 3.54 (m, 4 H, OCH_2), 3.64 (t*, 4 H, ^3J = 4.7 Hz, OCH_2), 5.69 (br. s, 8 H, OCH_2), 7.25 (m, 10 H, benzyl). − ^{13}C NMR: δ = 17.0 (CH_3), 30.7, 30.8 (CH_2, 16), 31.3, 31.4 (CH, 15), 51.4 (CH_2, 19), 51.8 (CH_2, 17), 59.0 (CH_2, 26), 70.5 (OCH_2), 70.7 (OCH_2), 70.8 (OCH_2), 70.8 (OCH_2), 76.8 (CH_2, 14), 126.8 (CH, Bn), 128.0 (CH, Bn), 128.8 (CH, Bn), 139.9 (C_q, Bn). − IR: $\tilde{\nu}$ = 2950 cm^{-1} (vs), 2927 (vs), 2867 (vs), 2804 (s), 1453 (s), 1111 (vs), 736 (s), 699 (s). − MS: *m*/*z* (%) = 570 [M^+] (2), 479 (13), 279 (7), 177 (10), 160 (47), 120 (17), 106 (13), 91 (100), 70 (18). − $C_{34}H_{54}N_2O_5$ (570.8): calcd. C 71.5, H 9.5, N 4.9; found C 71.2, H 9.2, N 4.5.

Reaction of Tetraethylene Glycol Dimethallyl Ether (1f) with 1,3-Bis(methylamino)propane (5b): 1f (300 mg, 1.0 mmol), **5b** (101 mg, 1.0 mmol), [Rh(acac)(CO)$_2$] (4 mg, 1 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 75 °C for 70 h. The crude reaction products (444 mg) were purified by column chromatography with MTBE/2-propanol, 20:1, as eluent to give 86 mg (0.2 mmol, 20%) of 15,18,22,25-tetramethyl-1,4,7,10,13-pentaoxa-18,22-diazacyclohexacosane (**21**).

21 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.91 (d, 6 H, ^3J = 6.8 Hz, CHC*H*$_3$), 1.28 (m, 2 H, C*H*H-16), 1.64 (m, 4 H, CH*H*-16, CH_2-20), 1.79 (m, 2 H, CH-15), 2.20 (s, 6 H, NCH_3), 2.36 (m, 8 H, CH_2-17, CH_2-19), 3.30 (d, 4 H, ^3J = 6.4 Hz, CH_2-14), 3.57 (m, 4 H, CH_2-12), 3.64 (m, 6 H, OCH_2), 3.67 (s, 6 H, OCH_2). − ^{13}C NMR: δ = 17.1 (CHC*H*$_3$), 25.1 (CH_2, 20), 30.9 (CH_2, 16), 31.5 (CH, 15), 42.4 (NCH_3), 55.3 (CH_2, 17/19), 55.3 (CH_2, 19/17), 70.4 (CH_2, 12), 70.6 (OCH_2), 70.6 (OCH_2), 70.7 (OCH_2), 76.7 (CH_2, 14). − IR: $\tilde{\nu}$ = 2950 cm^{-1} (vs), 2927 (vs), 2868 (vs), 2789 (s), 1117 (vs). − MS; *m*/*z* (%): 432 [M^+] (13), 403 (12), 336 (16), 248 (10), 139 (42), 126 (14), 112 (12), 98 (21), 89 (30), 84 (15), 58 (21), 45 (100). − $C_{23}H_{48}N_2O_5$ (432.6): calcd. C 63.9, H 11.2, N 6.5; found C 63.5, H 11.0, N 6.3.

Reaction of Tetraethylene Glycol Dimethallyl Ether (1f) with 1,12-Bis(benzylamino)-4,9-dioxadodecane (5g): 1f (200 mg, 0.7 mmol), **5g** (250 mg, 0.7 mmol), [Rh(acac)(CO)$_2$] (3 mg, 1 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 75 °C for 70 h. The crude reaction products (465 mg) were purified by column chromatography with MTBE as eluent to give 114 mg (0.2 mmol, 24%) of 18,31-dibenzyl-15,34-dimethyl-1,4,7,10,13,22,27-heptaoxa-18,31-diazacyclopentatricontane (**22**).

22 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.82 (d, 6 H, ^3J = 6.7 Hz, CH_3), 1.22 (m, 2 H, C*H*H-16), 1.59 (m, 6 H, CH*H*-16, CH_2-24), 1.71 (m, 4 H, CH_2-20), 1.78 (m, 2 H, CH-15), 2.42 (t, 4 H, ^3J = 7.3 Hz, CH_2-17), 2.49 (m, 4 H, CH_2-19), 3.22 (m, 4 H, CH_2-14), 3.34−3.59 (16 H, CH_2-12, CH_2-21, CH_2-23, benzyl CH_2), 3.64 (m, 12 H, CH_2-8, CH_2-9, CH_2-11), 7.18 (m, 2 H, benzyl), 7.28 (m, 8 H, benzyl). − ^{13}C NMR: δ = 17.1 (CH_3), 26.5 (CH_2, 24), 27.4 (CH_2, 20), 30.0 (CH_2, 16), 31.2 (CH, 15), 50.3 (CH_2, 19), 51.4 (CH_2, 17), 58.7 (benzyl CH_2), 68.9 (CH_2, 21), 70.3 (CH_2, 12), 70.6 (CH_2, 8/9/11/23), 70.6 (CH_2, 8/9/11/23), 70.7 (CH_2, 8/9/11/23), 76.8 (CH_2, 14), 126.6 (CH, Bn), 128.0 (CH, Bn), 128.8 (CH, Bn), 139.9 (C_q, Bn). − IR: $\tilde{\nu}$ = 2927 cm^{-1} (s), 2861 (vs), 1453 (m), 1114 (vs), 699 (m). − MS; *m*/*z* (%): 714 [M^+ − 1] (19), 671 (17), 623 (100), 134 (16), 91 (28). − $C_{42}H_{70}N_2O_7$ (715.0): calcd. C 70.6, H 9.9, N 3.9; found C 70.5, H 9.7, N 3.8.

Reaction of 4,17-Diacetyl-2,19-dimethyl-8,13-dioxa-4,17-diazaicosa-1,19-diene (1g) with 1,3-Bis(methylamino)propane (5b): 1g (250 mg, 0.6 mmol), **5b** (64 mg, 0.6 mmol), [Rh(cod)Cl]$_2$ (2 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (347 mg) were purified by column chromatography with MTBE/2-propanol, 1:1, as eluent to give 132 mg (0.3 mmol, 44%) of 5,19-diacetyl-4,10,14,19-tetramethyl-1,23-dioxa-5,10,14,19-tetraazacycloheptacosane (**23**).

23 (1:1 Mixture of Diastereoisomers): ^{1}H NMR ([D$_6$]DMSO, 80 °C): δ = 0.85 (m, 6 H, CHC*H*$_3$), 1.20 (br. s, 2 H, C*H*H-8), 1.42 (m, 2 H, CH*H*-8), 1.56 (br. s, 6 H, CH_2-3/12/26), 1.73 (m, 4 H, CH_2-3/12/26), 1.85 (m, 2 H, CH-7), 2.00 (br. s, 6 H, $COCH_3$), 2.13 (br. s, 6 H, NCH_3), 2.31 (m, 4 H, CH_2-6), 3.05−3.36 (20 H, OCH_2, CH_2-4). − ^{13}C NMR ([D$_6$]DMSO, 80 °C): δ = 17.2 (CHC*H*$_3$), 21.0, 21.2 (COC*H*$_3$), 24.8 (CH_2, 26), 26.1 (CH_2, 3/12), 26.2 (CH_2, 12/3), 27.5, 28.7, 29.5, 30.1 (CH, 7), 31.5 (CH_2, 8), 41.8, 41.9 (NCH_3), 42.8 (CH_2, 4), 45.2 (CH_2, 11), 50.3 (CH_2, 9), 54.4, 54.8, 54.9, 55.2, 55.3, 55.4 (CH_2, 6), 67.2, 67.8 (CH_2, 2), 69.9 (CH_2, 27), 169.4 (*C*OCH$_3$). − IR: $\tilde{\nu}$ = 2934 cm^{-1} (vs), 2859 (vs), 2792 (s), 1646 (vs), 1454 (vs), 1422 (vs), 1364 (s), 1115 (vs). − MS; *m*/*z* (%): 526 [M^+] (61), 512 (28), 497 (20), 455 (46), 430 (26), 412 (28), 398 (47), 327 (27), 299 (23), 257 (23), 215 (38), 185 (21), 139 (96), 126 (71), 112 (47), 98 (98), 84 (63), 70 (39), 58 (100), 44 (35). − HRMS: calcd. for $C_{29}H_{58}N_4O_4$: 526.4458; found 526.4458.

Reaction of 4,17-Diacetyl-2,19-dimethyl-8,13-dioxa-4,17-diazaicosa-1,19-diene (1g) with 2,6-Bis(benzylaminomethyl)pyridine (5f): 1g (250 mg, 0.6 mmol), **5f** (200 mg, 0.6 mmol), [Rh(cod)Cl]$_2$ (2 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (546 mg) were purified by column chromatography with MTBE/2-propanol, 20:1, as eluent to give 234 mg (0.3 mmol, 51%) of 8,21-diacetyl-3,26-dibenzyl-6,23-dimethyl-12,17-dioxa-3,8,21,26,32-pentaazabicyclo[26.3.1]dotriconta-1(32),28,30-triene (**24**).

24 (1:1 Mixture of Diastereoisomers): ^{1}H NMR ([D$_6$]DMSO, 80 °C): δ = 0.65 (br. s, 6 H, CHC*H*$_3$), 1.19 (br. s, 2 H, C*H*H-5), 1.49 (br. s, 2 H, CH*H*-5), 1.57 (br. s, 4 H, CH_2-14), 1.62 (br. s, 4 H, CH_2-10), 1.81 (br. s, 2 H, CH-6), 1.92 (br. s, 6 H, $COCH_3$), 2.48 (br. s, 4 H, CH_2-4), 2.98 (br. s, 4 H, CH_2-7), 3.18 (m, 4 H, CH_2-9), 3.35 (br. s, 8 H, CH_2-11, CH_2-13), 3.65 (m, 8 H, CH_2-2, benzyl CH_2), 7.28 (m, 12 H, CH-31, benzyl), 7.72 (m, 1 H, CH-30). − ^{13}C NMR ([D$_6$]DMSO, 80 °C): δ = 16.8, 17.1 (CHC*H*$_3$), 20.1, 20.9 (COC*H*$_3$), 26.2 (CH_2, 14), 27.6, 28.8 (CH_2, 10), 29.0, 29.8 (CH, 6), 31.5 (CH_2, 5), 42.1, 45.2 (CH_2, 9), 51.0 (CH_2, 4), 49.8, 54.4 (CH_2, 7), 58.5 (benzyl CH_2), 59.5 (CH_2, 2), 67.2, 67.8 (CH_2, 11), 70.0 (CH_2, 13), 120.7 (CH, 31), 126.6 (CH, Bn), 127.9 (CH, Bn), 128.6 (CH, Bn), 136.4 (CH, 30), 139.4 (C_q, Bn), 158.7 (C_q, 1), 169.4 ($COCH_3$). − IR: ṽ = 2930 cm^{-1} (vs), 2863 (vs), 2800 (s), 1651 (vs), 1590 (s), 1454 (vs), 1423 (vs), 1362 (s), 1114 (vs), 738 (s), 700 (s). − MS: *m*/*z* (%) = 742 [M^+] (100), 666 (17), 651 (81), 636 (36), 468 (41), 440 (20), 396 (55), 290 (17), 275 (15), 247 (20), 174 (31), 107 (30), 98 (26), 91 (68). − $C_{45}H_{67}N_5O_4$ (742.1): calcd. C 72.8, H 9.1, N 9.4; found C 73.0, H 9.1, N 9.3.

Reaction of 4,17-Diacetyl-2,19-dimethyl-8,13-dioxa-4,17-diazaicosa-1,19-diene (1g) with 1,12-Bis(benzylamino)-4,9-dioxadodecane (5g): **1g** (250 mg, 0.6 mmol), **5g** (227 mg, 0.6 mmol), $[Rh(cod)Cl]_2$ (2 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (565 mg) were purified by column chromatography with MTBE/2-propanol, 10:1, as eluent to give 212 mg (0.3 mmol, 44%) of 5,28-diacetyl-10,23-dibenzyl-7,26-dimethyl-1,14,19,32-tetraoxa-5,10,23,28-tetraazacyclohexatricontane (**25**).

25 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.78 (2 d, 6 H, ^3J = 6.5 Hz, CHC*H*$_3$), 1.22 (m, 2 H, C*H*H-8), 1.48 (m, 2 H, CH*H*-8), 1.62 (m, 8 H, CH_2-16, CH_2-35), 1.78 (10 H, CH-7, CH_2-3, CH_2-12), 2.02 (s, 3 H, $COCH_3$), 2.08 (s, 3 H, $COCH_3$), 2.45 (m, 8 H, CH_2-9, CH_2-11), 3.00 (dd, 1 H, ^2J = 14.3 Hz, ^3J = 8.9 Hz, C*H*H-6), 3.12 (m, 2 H, CHH-6), 3.28 (dd, 1 H, ^2J = 13.3 Hz, ^3J = 8.2 Hz, CH*H*-6), 3.38 (22 H, OCH_2, CH_2-4, PhC*H*H), 3.59 (m, 2 H, PhCH*H*), 7.22 (m, 2 H, benzyl), 7.28 (m, 8 H, benzyl). − ^{13}C NMR: δ = 17.1, 17.3 (CH*C*H$_3$), 21.4, 21.8 (CO*C*H$_3$), 26.5 (CH_2, 16 + 35), 27.3, 27.4 (CH_2, 12), 27.6, 28.8 (CH_2, 3), 29.3, 30.3 (CH, 7), 31.6, 31.7 (CH_2, 8), 43.5, 45.5 (CH_2, 4), 50.4 (CH_2, 11), 50.4, 50.5, 51.2, 51.3 (CH_2, 9), 50.6, 50.7, 55.7 (CH_2, 6), 58.6 (benzyl CH_2), 67.4, 68.3 (OCH_2), 68.8, 68.8 (OCH_2), 68.9, 70.5 (OCH_2), 70.7, 70.8 (OCH_2), 126.6, 126.7 (CH, Bn), 128.0, 128.1 (CH, Bn), 128.7 (CH, Bn), 137.7, 139.8 (C_q, Bn), 170.5, 170.7, 170.7 (*C*OCH$_3$). − IR: ṽ = 2935 cm^{-1} (s), 2859 (s), 1646 (vs), 1452 (s), 1423 (s), 1113 (vs). − MS; *m*/*z* (%): 809 [M^+] (6), 765 (33), 718 (99), 566 (15), 174 (9), 134 (54), 124 (14), 98 (30), 91 (100), 70 (13). − $C_{48}H_{80}N_4O_6$ (809.2): calcd. C 71.2, H 10.0, N 6.9; found C 71.2, H 9.9, N 6.9.

Reaction of 2,5-Dimethylhexa-1,5-diene (1h) with 1,2-Bis(benzylamino)ethane (5a): **1h** (100 mg, 0.9 mmol), **5a** (216 mg, 0.9 mmol), $[Rh(cod)Cl]_2$ (3 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (372 mg) were purified by column chromatography with *n*-hexane/MTBE, 6:1, as eluent to give 144 mg (0.4 mmol, 42%) of 1,4-dibenzyl-7,10-dimethyl-1,4-diazacyclododecane (**26**) as separated diastereoisomers in a 1:1 ratio.

26 (Diastereoisomer 1): ^{1}H NMR: δ = 0.76 (d, 6 H, ^3J = 6.4 Hz, CH_3), 1.17 (m, 4 H, C*H*H-6, C*H*H-8), 1.43 (m, 4 H, CH*H*-6, CH*H*-8), 2.09 (m, 2 H, CH-7), 2.28−2.57 (8 H, CH_2-3, CH_2-5), 3.39 (d, 2 H, ^2J = 13.7 Hz, PhC*H*H), 3.48 (d, 2 H, ^2J = 13.7 Hz, PhCH*H*), 7.24 (m, 10 H, benzyl). − ^{13}C NMR: δ = 21.5 (CH_3), 26.0 (CH, 7), 32.3 (CH_2, 8), 33.5 (CH_2, 6), 50.2 (CH_2, 5), 51.1 (CH_2, 3), 58.9 (benzyl CH_2), 126.4 (CH, Bn), 127.9 (CH, Bn), 129.0 (CH, Bn), 140.1 (C_q, Bn). − IR: ṽ = 2956 cm^{-1} (s), 2941 (s), 2867 (s), 2847 (s), 2781 (s), 1461 (s), 1449 (s), 1372 (s), 1093 (s), 727 (vs), 697 (vs).

26 (Diastereoisomer 2): ^{1}H NMR: δ = 0.82 (d, 6 H, ^3J = 6.8 Hz, CH_3), 1.41 (m, 4 H, CH_2-8), 1.52 (m, 4 H, CH_2-6), 1.70 (m, 2 H, CH-7), 2.51 (m, 8 H, CH_2-3, CH_2-5), 3.42 (s, 4 H, benzyl CH_2), 7.28 (m, 10 H, benzyl). − ^{13}C NMR: δ = 21.3 (CH_3), 30.1 (CH_2, 8), 31.2 (CH, 7), 31.6 (CH_2, 6), 49.9 (CH_2, 5), 50.5 (CH_2, 3), 59.2 (benzyl CH_2), 126.6 (CH, Bn), 127.9 (CH, Bn), 129.1 (CH, Bn), 140.0 (C_q, Bn). − IR: ṽ = 2951 cm^{-1} (vs), 2924 (vs), 2867 (s), 2790 (vs), 1452 (s), 730 (s), 698 (s). − MS: *m*/*z* (%) = 378 [M^+] (9), 287 (100), 239 (7), 134 (26), 91 (57). − $C_{26}H_{38}N_2$ (378.6): calcd. C 82.5, H 10.1, N 7.4; found C 82.7, H 10.2, N 7.2.

Reaction of 2,5-Dimethylhexa-1,5-diene (1h) with 1,3-Bis(methylamino)propane (5b): 1h (100 mg, 0.9 mmol), **5b** (92 mg, 0.9 mmol), $[Rh(cod)Cl]_2$ (3 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (251 mg) were purified by column chromatography with MTBE as eluent to give 89 mg (0.4 mmol, 41%) of 1,5,8,11-tetramethyl-1,5-diazacyclotridecane (**27**).

27 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.85 (2 d, 6 H, ^3J = 6.8 Hz, CHC*H*$_3$), 1.15 (m, 2 H, CHH-9), 1.28 (m, 3 H, C*H*H-9, C*H*H-7), 1.39 (m, 3 H, CH*H*-9, CH*H*-7), 1.52 (m, 2 H, CH_2-3), 1.61 (m, 2 H, CH-8), 2.07 (m, 1 H, C*H*H-4), 2.17 (2 s, 6 H, NCH_3), 2.20 (m, 2 H, C*H*H-6), 2.26−2.50 (4 H, CH*H*-4, CH*H*-6), 2.68 (m, 1 H, C*H*H-4). − ^{13}C NMR: δ = 21.0, 21.3 (CH*C*H$_3$), 24.1, 25.9 (CH_2, 3), 28.0, 31.4 (CH, 8), 32.1, 33.5 (CH_2, 9), 33.9, 34.4 (CH_2, 7), 42.6, 42.8 (NCH_3), 53.7, 54.3 (CH_2, 4), 54.2, 55.5 (CH_2, 6). − IR: ṽ = 2950 cm^{-1} (vs), 2925 (vs), 2867 (s), 2848 (s), 2836 (s), 2786 (vs), 1458 (s). − MS; *m*/*z* (%): 240 [M^+] (57), 225 (31), 211 (32), 126 (56), 98 (36), 86 (58), 71 (25), 64 (53), 58 (100), 44 (36). − $C_{13}H_{32}N_2$ (240.4): calcd. C 74.9, H 13.4, N 11.7; found C 74.9, H 13.5, N 11.3.

Reaction of 2,5-Dimethylhexa-1,5-diene (1h) with 1,4-Bis(benzylamino)butane (5e): 1h (100 mg, 0.9 mmol), **5e** (242 mg, 0.9 mmol), $[Rh(cod)Cl]_2$ (3 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (415 mg) were purified by column chromatography with *n*-hexane/MTBE, 6:1, as eluent to give 164 mg (0.4 mmol, 45%) of 1,6-dibenzyl-9,12-dimethyl-1,6-diazacyclotetradecane (**28**).

28 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.72 (d, 3 H, ^3J = 6.8 Hz, CH_3), 0.89 (d, 3 H, ^3J = 6.8 Hz, CH_3-20), 1.03−1.29 (4 H, CH_2-4, CH_2-8, C*H*H-10), 1.44 (m, 5 H, CH_2-4, CH_2-8, CH*H*-10), 1.71 (m, 5 H, CH-9, CH_2-4, CH_2-8), 2.18 (m, 3 H, CH_2-5, CH_2-7), 2.41 (m, 4 H, CH_2-5, CH_2-7), 2.73 (dt*, 1 H, *J* = 12.6 Hz, ^3J = 7.8 Hz, CH*H*-7), 3.22 (d, 1 H, ^2J = 13.6 Hz, PhCHH), 3.42 (d, 1 H, ^2J = 13.6 Hz, PhCHH), 3.52 (d, 1 H, ^2J = 13.6 Hz, PhCHH), 3.72 (d, 1 H, ^2J = 13.6 Hz, PhCHH), 7.28 (m, 10 H, benzyl). − ^{13}C NMR: δ = 20.1, 21.2 (CH_3), 23.9, 24.4 (CH_2, 4), 27.3, 30.4 (CH, 9), 30.8 (CH_2, 10), 31.9, 32.7 (CH_2, 8), 47.7, 52.4 (CH_2, 7), 50.1, 53.5 (CH_2, 5), 59.0, 59.1 (benzyl CH_2), 126.5, 126.5 (CH, Bn), 128.0 (CH, Bn), 128.8, 128.9 (CH, Bn), 140.3, 140.3 (C_q, Bn). − IR: ṽ = 2950 cm^{-1} (vs), 2926 (vs), 2867 (vs), 2791 (vs), 1452 (s), 733 (s), 697 (vs). − MS; *m*/*z* (%): 406 [M^+] (8), 315 (100), 91 (31), 84 (7). − $C_{28}H_{42}N_2$ (406.7): calcd. C 82.7, H 10.4, N 6.9; found C 82.8, H 10.6, N 6.8.

Reaction of 2,5-Dimethylhexa-1,5-diene (1h) with 2,6-Bis(benzylaminomethyl)pyridine (5f): 1h (100 mg, 0.9 mmol), **5f** (300 mg, 0.9 mmol), $[Rh(cod)Cl]_2$ (3 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (421 mg) were purified by column chromatography with MTBE as eluent to give 187 mg (0.4 mmol, 46%) of 3,12-dibenzyl-6,9-dimethyl-3,12,18-triazabicyclo[12.3.1]octadeca-1(17),14(18),15-triene (**29**).

29 (1:1 Mixture of Diastereoisomers): M.p. 44 °C. − ^{1}H NMR: δ = 0.75 (d, 3 H, ^3J = 6.3 Hz, CH_3), 0.80 (d, 3 H, ^3J = 6.5 Hz, CH_3), 0.88 (m, 4 H, CH_2-7), 1.27 (m, 5 H, CH-6, CHH-5), 1.39 (m, 1 H, CH*H*-5), 2.47 (m, 2 H, C*H*H-4), 2.53 (m, 2 H, CH*H*-4), 3.54 (s, 4 H, CH$_2$-2), 3.69 (m, 4 H, benzyl CH$_2$), 7.13 (m, 2 H, CH-17), 7.24 (m, 2 H, benzyl), 7.33 (t*, 4 H, ^3J = 7.5 Hz, benzyl), 7.44 (m, 4 H, benzyl), 7.52 (m, 1 H, CH-16). − ^{13}C NMR: δ = 20.9, 21.2 (CH$_3$), 30.4, (CH$_2$, 7), 29.7, 30.8 (CH, 6), 32.0, 32.1 (CH$_2$, 5), 50.3, 50.8 (CH$_2$, 4), 59.8, 59.8 (CH$_2$, 2/benzyl CH$_2$), 59.8, 59.9 (CH$_2$, benzyl CH$_2$/2), 122.4, 122.6 (CH, 17), 126.9 (CH, Bn), 128.2 (CH, Bn), 129.0 (CH, Bn), 136.2 (CH, 16), 140.0, 140.1 (C$_q$, Bn), 158.9, 159.1 (C$_q$, 1). − IR: $\tilde{\nu}$ = 2950 cm^{-1} (vs), 2925 (vs), 2867 (s), 2824 (s), 2798 (s), 1590 (m), 1455 (vs), 740 (s), 698 (vs). − MS; *m/z* (%): 455 [M$^+$] (100), 379 (16), 364 (53), 349 (57), 337 (10), 244 (11), 218 (9), 134 (9), 107 (87), 91 (72). − C$_{31}$H$_{41}$N$_3$ (455.7): calcd. C 81.7, H 9.1, N 9.2; found C 81.7, H 9.3, N 9.0.

Reaction of 2,5-Dimethylhexa-1,5-diene (1h) with 1,12-Bis(benzylamino)-4,9-dioxadodecane (5g): 1h (100 mg, 0.9 mmol), **5g** (337 mg, 0.9 mmol), [Rh(cod)Cl]$_2$ (3 mg, 0.5 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 70 h. The crude reaction products (502 mg) were purified by column chromatography with PE/MTBE, 3:1, as eluent to give 224 mg (0.4 mmol, 48%) of 5,14-dibenzyl-8,11-dimethyl-1,18-dioxa-5,14-diazacyclodocosane (**30**).

30 (1:1 Mixture of Diastereoisomers): ^{1}H NMR: δ = 0.73 (d, 6 H, ^3J = 6.5 Hz, CH$_3$), 1.18 (m, 6 H, CH$_2$-9, C*H*H-7), 1.38 (m, 2 H, CH-8), 1.56 (m, 2 H, CH*H*-7), 1.65 (m, 4 H, CH$_2$-21), 1.70 (quint, 4 H, ^3J = 6.0 Hz, CH$_2$-3), 2.37 (m, 4 H, CH$_2$-6), 2.51 (m, 4 H, CH$_2$-4), 3.43 (10 H, OCH$_2$, benzyl CH$_2$), 3.58 (m, 2 H, benzyl CH$_2$), 7.21 (m, 2 H, benzyl), 7.29 (m, 8 H, benzyl). − ^{13}C NMR: δ = 19.6, 19.7 (CH$_3$), 26.8 (CH$_2$, 21), 27.2, 27.3 (CH$_2$, 3), 31.0, 31.2 (CH, 8), 34.0, 34.3 (CH$_2$, 7), 34.4, 35.0 (CH$_2$, 9), 49.7, 49.8 (CH$_2$, 4), 51.9 (CH$_2$, 6), 59.0 (benzyl CH$_2$), 68.3, 68.4 (CH$_2$, 2), 70.6 (CH$_2$, 22), 126.5 (CH, Bn), 128.0 (CH, Bn), 128.7, 128.7 (CH, Bn), 140.2 (C$_q$, Bn). − IR: $\tilde{\nu}$ = 2949 cm^{-1} (vs), 2924 (vs), 2795 (s), 1453 (s), 1116 (vs), 732 (s), 698 (s). − MS; *m/z* (%): 522 [M$^+$] (20), 479 (14), 431 (100), 134 (18), 91 (27). − C$_{34}$H$_{54}$N$_2$O$_2$ (522.8): calcd. C 78.1, H 10.4, N 5.4; found C 78.3, H 10.3, N 5.3.

Debenzylation of 15: 15 (500 mg, 860 µmol), palladium on charcoal (10% Pd) (120 mg), concentrated hydrochloric acid (0.3 mL), and water/methanol (4:1) (10 mL) were stirred under hydrogen (1 bar) at room temperature for 24 h. After the addition of sodium hydroxide solution, the mixture was extracted with diethyl ether. The combined organic phases were dried with sodium sulfate. After evaporation of the solvent and kugelrohr distillation, 310 mg (776 µmol, 90%) of 10-acetyl-8,12-dimethyl-1,19-dioxa-5,10,15-triazacyclotricosane (**31**) was obtained as a 1:1 mixture of two diastereoisomers: ^{1}H NMR: δ = 0.88 (m, 6 H, CHC*H*$_3$), 1.33 (m, 2 H, C*H*H-7), 1.48 (m, 2 H, CH*H*-7), 1.63 (quint, 4 H, ^3J = 2.8 Hz, CH$_2$-22), 1.75 (quint, 4 H, ^3J = 6.0 Hz, CH$_2$-3), 1.94 (m, 4 H, CH-8, NH), 2.10 (s, 3 H, COCH$_3$), 2.68 (m, 8 H, CH$_2$-4, CH$_2$-6), 2.90 (dd, ^2J = 13.6 Hz, ^3J = 6.0 Hz, C*H*H-9), 3.61 (dd, ^2J = 13.6 Hz, ^3J = 9.0 Hz, C*H*H-9) [1 H], 3.10 (m), 3.21 (m), 3.37 (dd, ^2J = 13.6 Hz, ^3J = 7.0 Hz, CHH-9) [3 H], 3.43 (br. s, 4 H, CH$_2$-23), 3.52 (m, 4 H, CH$_2$-2). − ^{13}C NMR: δ = 17.5, 17.6, 17.7, 17.8 (CHCH$_3$), 22.1 (CO*C*H$_3$), 26.7, 26.8 (CH$_2$, 22), 29.7, 29.8 (CH$_2$, 3), 29.0, 29.1, 29.8, 30.2 (CH, 8), 34.6, 34.7, 34.8 (CH$_2$, 7), 47.4, 47.5, 47.5 (CH$_2$, 6), 47.8, 47.8, 47.9 (CH$_2$, 4), 49.6, 51.0, 54.0, 54.9 (CH$_2$, 9), 69.7, 69.7, 69.8 (CH$_2$, 2), 70.7, 70.8, 70.8 (CH$_2$, 23), 170.8 (*C*OCH$_3$). − IR (KBr plates): $\tilde{\nu}$ = 3326 cm^{-1} (br. m), 2930 (vs), 1644 (vs), 1115 (vs). − MS; *m/z* (%): 399 [M$^+$] (100), 356 (95), 285 (29), 98 (55). − C$_{22}$H$_{45}$N$_3$O$_3$ (399.6): calcd. C 66.1, H 11.4, N 10.5; found C 66.0, H 11.2, N 10.5.

Reaction of 1c with 31: 31 (200 mg, 469 µmol), **1c** (78 mg, 469 µmol), [Rh(cod)Cl]$_2$ (3 mg, 1 mol-%), and dry dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 65 h. The crude reaction products (344 mg) were purified by column chromatography with ethyl acetate/2-propanol, 10:1, as eluent giving 102 mg (171 µmol, 37%) of 1,28-diacetyl-17,21,26,30-tetramethyl-5,10-dioxa-1,14,19,28-tetraazabicyclo[12.9.9]dotriacontane (**32**) as a mixture of 4 diastereoisomers.[19] − ^{1}H NMR ([D$_6$]DMSO, 95 °C): δ = 0.78 (m, 12 H, CHC*H*$_3$), 1.25 (m, 7 H), 1.53 (br. s, 8 H), 1.85 (m, 3 H), 1.96 (s, 6 H, COCH$_3$), 2.40 (m, 12 H), 3.10 (m, 7 H), 3.32 (m, 10 H), 3.63 (m, 1 H). − ^{13}C NMR ([D$_6$]DMSO, 95 °C): δ = 17.3, 17.4, 17.5 (CH*C*H$_3$), 21.9 (CO*C*H$_3$), 26.3, 26.4, 26.5 (CH$_2$), 27.7, 28.2, 28.5 (CH$_2$), 29.5, 30.0, 31.5, 32.1, 32.3, 32.5 (CH), 32.6, 32.9, 33.4 (CH$_2$), 50.1, 51.4 (CH$_2$), 50.4, 50.7, 51.1, 51.3 (CH$_2$), 51.5, 51.7, 51.9, 52.3 (CH$_2$), 68.3, 68.4, 68.6 (CH$_2$), 70.2, 70.3 (CH$_2$), 170.1, 170.2 (*C*OCH$_3$). − IR (KBr plates): $\tilde{\nu}$ = 2955 cm^{-1} (vs), 1650 (vs), 1645 (vs), 1115 (s). − MS; *m/z* (%): 595 [M$^+$ + 1] (40), 551 (100), 410 (30), 154 (25), 98 (80). − HRMS calcd. for C$_{34}$H$_{66}$N$_4$O$_4$: 594.50842; found 594.5085.

Reaction of 1,7-Octadiene (33) with 1,12-Bis(benzylamino)-4,9-dioxadodecane (5g): 33 (300 mg, 2.8 mmol), **5g** (1042 mg, 2.8 mmol), [Rh(acac)(CO)$_2$] (8 mg, 1 mol-%), BIPHEPHOS (86 mg, 4 mol-%), and dioxane (100 mL) were placed in an autoclave, and the mixture was pressurized to 10 bar and heated to 65 °C for 65 h and then to 120 °C for 20 h. The crude reaction products (1448 mg) were purified by column chromatography with PE/MTBE, 10:1, as eluent to give 183 mg (35 µmol, 13%) of 5,15-dibenzyl-7-methyl-1,19-dioxa-5,15-diazacyclotricosane (**34a**) and 345 mg (66 µmol, 24%) of 5,16-dibenzyl-1,20-dioxa-5,16-diazacyclotetracosane (**34**).

34a: ^{1}H NMR: δ = 0.80 (d, 3 H, ^3J = 6.5 Hz, CH$_3$), 0.94 (m, 1 H, C*H*H-8), 1.28 (br. s, 8 H), 1.49 (m, 3 H), 1.69 (m, 9 H), 2.06 (dd, 1 H, ^2J = 12.3 Hz, ^3J = 6.0 Hz, C*H*H-6), 2.19 (dd, 1 H, ^2J = 12.3 Hz, ^3J = 8.1 Hz, CH*H*-6), 2.35 (t, 2 H, ^3J = 6.8 Hz, CH$_2$-14), 2.41 (dd, 1 H, ^2J = 12.3 Hz, ^3J = 6.0 Hz, C*H*H-4), 2.49 (m, 3 H, CH*H*-4, CH$_2$-16), 3.48 (m, 12 H, OCH$_2$, benzyl CH$_2$), 7.27 (m, 10 H, benzyl). − ^{13}C NMR: δ = 18.3 (CH$_3$), 26.6 (CH$_2$), 26.6 (CH$_2$), 26.7 (CH$_2$), 26.7 (CH$_2$), 27.3 (CH$_2$), 27.4 (CH$_2$), 27.5 (CH$_2$), 29.5 (CH$_2$), 29.7 (CH$_2$), 31.0 (CH, 7), 34.4 (CH$_2$, 8), 49.9 (CH$_2$, 16), 50.5 (CH$_2$, 4), 54.0 (CH$_2$, 14), 59.0 (benzyl CH$_2$), 59.6 (benzyl CH$_2$), 61.7 (CH$_2$, 6), 68.5 (CH$_2$, 2/18), 68.7 (CH$_2$, 18/2), 70.6 (CH$_2$, 20/23), 70.6 (CH$_2$, 23/20), 126.6 (CH, Bn), 126.6 (CH, Bn), 127.9 (CH, Bn), 128.0 (CH, Bn), 128.7 (CH, Bn), 128.8 (CH, Bn), 140.3 (C$_q$, Bn), 140.3 (C$_q$, Bn). − IR: $\tilde{\nu}$ = 3061 cm^{-1} (w), 2927 (vs), 2854 (vs), 2796 (s), 1115 (vs), 734 (s). − MS; *m/z* (%): 522 [M$^+$] (40), 479 (33), 431 (100), 134 (26), 91 (63). − C$_{34}$H$_{54}$N$_2$O$_2$ (522.8): calcd. C 78.1, H 10.4, N 5.4; found C 78.1, H 10.4, N 5.3.

34: ^{1}H NMR: δ = 1.27 (br. s, 12 H, CH$_2$-8, CH$_2$-9, CH$_2$-10), 1.45 (m, 4 H, CH$_2$-7), 1.64 (m, 4 H, CH$_2$-23), 2.69 (quint, 4 H, ^3J = 6.3 Hz, CH$_2$-3), 2.35 (t, 4 H, ^3J = 6.9 Hz, NCH$_2$), 2.49 (t, 4 H, ^3J = 6.5 Hz, NCH$_2$), 3.43 (t, 4 H, ^3J = 5.4 Hz, OCH$_2$), 3.48 (t, 4 H, ^3J = 6.3 Hz, OCH$_2$), 3.50 (s, 4 H, benzyl CH$_2$), 7.25 (m, 10 H, benzyl). − ^{13}C NMR: δ = 26.7 (CH$_2$), 27.0 (CH$_2$), 27.1 (CH$_2$), 27.5 (CH$_2$), 29.3 (CH$_2$, 3/23), 29.4 (CH$_2$, 23/3), 49.8 (NCH$_2$), 53.7 (NCH$_2$), 59.0 (benzyl CH$_2$), 68.5 (OCH$_2$), 70.7 (OCH$_2$), 126.6 (CH, Bn), 128.0 (CH, Bn), 128.7 (CH, Bn), 140.3 (C$_q$, Bn). − IR: $\tilde{\nu}$ = 3059 cm^{-1} (w), 2932 (vs), 2855 (vs), 2789 (s), 1115 (vs). − MS; *m/z* (%): 522 [M$^+$] (25), 479 (26), 431 (100), 279 (17), 149 (41), 91 (66). − C$_{34}$H$_{54}$N$_2$O$_2$ (522.8): calcd. C 78.1, H 10.4, N 5.4; found C 78.2, H 10.5, N 5.3.

Debenzylation of 34: 34 (618 mg, 1.2 mmol), palladium on charcoal (10% Pd) (140 mg), concentrated hydrochloric acid (0.54 mL), and ethanol (30 mL) were stirred under hydrogen (1 bar) at room temp.

for 24 h. After the addition of sodium hydroxide, the mixture was extracted with diethyl ether. The combined organic phases were dried with sodium sulfate. After evaporation of the solvent and kugelrohr distillation of the residue, 354 mg (1.0 mmol, 87%) of 1,20-dioxa-5,16-diazacyclotetracosane (**35**) was obtained. – ^1H NMR: $\delta = 1.30$ (br. s, 13 H), 1.49 (t, 5 H, $^3J = 6.5$ Hz), 1.64 (m, 4 H), 1.75 (quint, 4 H, $^3J = 6.0$ Hz), 2.50 (t, 4 H, $^3J = 6.3$ Hz, NCH_2), 2.62 (t, 4 H, $^3J = 6.6$ Hz, NCH_2), 3.42 (m, 4 H, OCH_2), 3.52 (t, 4 H, $^3J = 5.8$ Hz, OCH_2). – ^{13}C NMR: $\delta = 26.5$ (CH_2), 26.6 (CH_2), 28.6 (CH_2), 28.7 (CH_2), 29.2 (CH_2), 29.5 (CH_2), 47.7 (NCH_2), 49.3 (NCH_2), 69.9 (OCH_2), 70.6 (OCH_2). – IR (KBr plates): $\tilde{\nu} = 3340$ cm^{-1} (w), 2925 (vs), 2853 (vs), 1114 (vs). – MS; *m/z* (%): 342 [M$^+$] (37), 299 (67), 158 (14), 55 (29), 44 (100). – HRMS: calcd. for $C_{20}H_{42}N_2O_2$: 342.3246; found 342.3242.

Reaction of 1c with 35: 35 (107 mg, 312 μmol), **1c** (52 mg, 312 μmol), $[Rh(cod)Cl]_2$ (3 mg, 1 mol-%), and dry dioxane (80 mL) were placed in an autoclave, and the mixture was pressurized and heated to 120 °C for 65 h. The crude reaction products (220 mg) were purified by column chromatography with MTBE as eluent to give 62 mg (115 μmol, 37%) of 1-(27,31-dimethyl-5,10-dioxa-1,14,29-triazabicyclo[12.10.9]tritriacont-29-yl)-1-ethanone (**36**) as a mixture of two diastereoisomers.[19] – ^1H NMR ([D$_6$]DMSO, 70 °C): $\delta = 0.91$ (d, 6 H, $^3J = 6.8$ Hz, $CHCH_3$), 1.40 (m, 20 H), 1.69 (m, 8 H), 2.01 (m, 2 H), 2.06 (s, 3 H, $COCH_3$), 2.43 (m, 12 H), 3.14 (m, 2 H), 3.28 (m, 2 H), 3.48 (m, 8 H, OCH_2). – ^{13}C NMR ([D$_6$]DMSO, 95 °C): Due to the presence of a large number of conformers, no significant signals were observed. – IR (KBr plates): $\tilde{\nu} = 2927$ cm^{-1} (vs), 2854 (vs), 1651 (vs), 1645 (vs), 1114 (s). – MS; *m/z* (%): 537 [M$^+$] (79), 508 (8), 494 (100), 395 (24), 142 (27), 98 (39). – HRMS: calcd. for $C_{32}H_{63}N_3O_3$: 537.4869; found 537.4867.

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[1] [1a]C. J. Pedersen, in *Synthetic Multidentate Macrocyclic Compounds* (Eds.: R. M. Izatt, J. J. Christen), Academic Press, New York **1978**, p. 1. – [1b]T. A. Kaden, *Top. Curr. Chem.* **1984**, *121*, 154–179. – [1c]Y. Inoue, W. Gokel (Eds.), *Cation Binding by Macrocycles*, Marcel Dekker, New York, **1990**. – [1d]M. Hiraoka (Ed.), *Crown Ethers and Analogous Compounds*, Elsevier, Amsterdam, **1992**. – [1e]J. S. Bradshaw, K. E. Krakowiak, R. M. Izatt, *The Chemistry of Heterocyclic Compounds* (Ed.: E. C. Taylor), Wiley, New York, **1993**. – [1f]R. M. Izatt, K. Pawlak, J. S. Bradshaw, *Chem. Rev.* **1995**, *95*, 2529–2586. – [1g]S. Patai, Z. Rappoport (Eds.), *Crown Ethers and Analogs*, Wiley, New York, **1989**.

[2] [2a]F. P. Schmidtchen, M. Berger, *Chem. Rev.* **1997**, *97*, 1609–1646. – [2b]A. Bianchi, K. Bowman-James, E. García-España (Eds.), *The Supramolecular Chemistry of Anions*, Wiley-VCH, Weinheim, **1997**.

[3] [3a]M. L. Turonek, P. Moore, H. J. Clase, N. W. Alcock, *J. Chem. Soc., Dalton Trans.* **1995**, 3659–3666. – [3b]H. Graubaum, B. Costisella, R. Dambowsky, *J. Prakt. Chem./Chem.-Ztg.* **1998**, *340*, 165–170. – [3c]E. Kimura, T. Koike, *Chem. Commun.* **1998**, 1495–1500. – [3d]N. A. Bailey, D. E. Fenton, S. J. Kitchen, T. H. Lilley, M. G. Williams, P. A. Tasker, A. J. Leong, L. F. Lindoy, *J. Chem. Soc., Dalton Trans.* **1991**, 627–637.

[4] [4a]S. Aime, M. Botta, S. G. Crich, G. B. Giovenzana, G. Jommi, R. Pagliarin, M. Sisti, *J. Chem. Soc., Chem. Commun.* **1995**, 1885–1886. – [4b]J. Huskens, A. D. Sherry, *J. Am. Chem. Soc.* **1996**, *118*, 4396–4404.

[5] E. Kimura, *Top. Curr. Chem.* **1985**, *128*, 113–141.

[6] [6a]D. Parker, *Chem. Soc. Rev.* **1990**, *19*, 271–291. – [6b]K. Takenouchi, K. Watanabe, Y. Kato, T. Koike, E. Kimura, *J. Org. Chem.* **1993**, *58*, 1955–1958. – [6c]K. Takenouchi, M. Tabe, K. Watanabe, A. Hazato, Y. Kato, M. Shionoya, T. Koike, E. Kimura, *J. Org. Chem.* **1993**, *58*, 6895–6899. – [6d]T. J. Norman, D. Parker, L. Royle, A. Harrison, P. Antoniw, D. J. King, *J. Chem. Soc., Chem. Commun.* **1995**, 1877–1878.

[7] [7a]Y. Kuroki, K. Ishihara, N. Hanaki, S. Ohara, H. Yamamoto, *Bull. Chem. Soc. Jpn.* **1998**, *71*, 1221–1230. – [7b]A. Horni, A. Linden, M. Hesse, *Helv. Chim. Acta* **1998**, *81*, 1303–1318. – [7c]K. Drandarov, *Phytochemistry* **1997**, *44*, 971–973.

[8] [8a]H.-Y. An, J. S. Bradshaw, R. M. Izatt, *Chem. Rev.* **1992**, *92*, 543–572. – [8b]K. E. Krakowiak, J. S. Bradshaw, *Synlett* **1993**, 611–620. – [8c]A. V. Bordunov, J. S. Bradshaw, V. N. Pastushok, R. M. Izatt, *Synlett* **1996**, 933–948.

[9] J. E. Richman, T. J. Atkins, *J. Am. Chem. Soc.* **1974**, *96*, 2268–2270.

[10] [10a] P. Eilbracht, L. Bärfacker, C. Buß, C. Hollmann, B. E. Kitsos-Rzychon, C. L. Kranemann, T. Rische, R. Roggenbuck, A. Schmidt, *Chem. Rev.* **1999**, *99*, 3329–3365. – [10b] T. Rische, L. Bärfacker, P.Eilbracht, *Eur. J. Org. Chem.* **1999**, 653–660.

[11] C. L. Kranemann, P. Eilbracht, *Synthesis* **1998**, 71–77.

[12] [12a] For a short communication published in advance, see: C. L. Kranemann, P. Eilbracht, *Tetrahedron Lett.* **1999**, *40*, 7773–7776. For a recent intramolecular approach see: [12b] D. J. Bergmann, E. M. Campi, W. R. Jackson, A. F. Patti, D. Saylik, *Tetrahedron Lett.* **1999**, *40*, 5597–5600. – [12c] D. J. Bergmann, E. M. Campi, W. R. Jackson, A. F. Patti, *Chem. Commun.* **1999**, 1279–1280.

[13] C. L. Kranemann, L. Bärfacker, P. Eilbracht, *Eur. J. Org. Chem.* **1999**, 1907–1914.

[14] C. L. Kranemann, B. E. Kitsos-Rzychon, P. Eilbracht, *Tetrahedron* **1999**, *55*, 4721–4732.

[15] [15a] F. Vögtle, *Supramolecular Chemistry*, Wiley, New York, **1991**. – [15b] P. Gargano, L. Mandolini, *Gazz. Chim. Ital.* **1982**, *112*, 31–33.

[16] [16a] L. Rossa, F. Vögtle, *Top. Curr. Chem.* **1983**, *113*, 1–86. – [16b] P. Knops, N. Sendhoff, H.-B. Mekelburger, F. Vögtle, *Top. Curr. Chem.* **1992**, *161*, 1–36.

[17] G. D. Cuny, S. L. Buchwald, *J. Am. Chem. Soc.* **1993**, *115*, 2066.

[18] G. Giordano, R. Crabtree, *Inorg. Synth.* **1979**, *19*, 218–219.

[19] Owing to the large number of diastereoisomers and conformers, a more detailed assignment of the NMR signals was not possible.

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