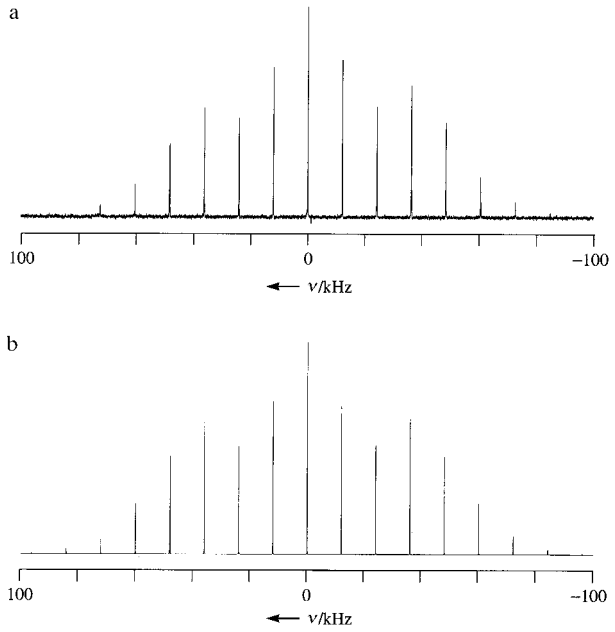

Figure 2. ^{14}N MAS NMR spectrum of ammonium thiocyanate at 28.809 MHz. a) Experimental spectrum; b) simulation with quadrupole coupling parameters taken from literature.[4]

20 ppm. Hereby, on the basis of the known crystal structure we have assumed axial symmetry of both tensors ($\eta = 0$). Evidently, three-coordinate nitrogen in hexagonal boron nitride can be safely distinguished from four-coordinate nitrogen in cubic boron nitride solely based on the isotropic chemical shift. The chemical shift found for the hexagonal modification is in relatively good agreement with a calculated value ($\delta = 56 \pm 5$ ppm with respect to NH_4Cl),[7] while χ is unexpectedly low. Note, however, that the strong dependence of the theoretical results for χ (0.75 – 1.33 MHz)[8] on the basis set already reveals some difficulties in these calculations. Furthermore, it is remarkable that the anisotropy of the chemical shift can be estimated from the side band pattern, although it is smaller than the sample rotation speed.

From the spectra in Figures 1 and 2 one may conclude that ^{14}N MAS NMR spectroscopy with contemporary spectrometers should also be feasible for larger χ values of about 1 MHz. Indeed we have also succeeded in detecting MAS side band patterns for glycine ($\chi = 1.25$ MHz[9]). However, to be able to analyze spectra in this regime of medium quadrupole couplings quantitatively, further developments are needed mainly in broad band spectral excitation. In this respect it is also significant that state-of-the-art commercial spectrometers now achieve 50 % larger resonance frequencies and three times faster sample spinning than are used in this work. These developments should drastically improve the performance of ^{14}N MAS NMR spectroscopy for larger quadrupole couplings. With such experiments, an important gap in the applicability of high-resolution NMR spectroscopy is finally closed.

Experimental Section

All NMR spectra were measured with a Unity 400 NMR spectrometer (Varian) and a 5-mm MAS probe head (Doty) at a resonance frequency of $\nu_0 = 28.809$ MHz and a sample rotation speed of 12 kHz. The length of a 90° pulse was 6 μs, to obtain more uniform excitation over a broader band and to improve sensitivity we have measured all spectra with excitation pulses of 2 μs duration. Cubic boron nitride (MICRONABN 300, DeBeers), hexagonal boron nitride (99 %, Aldrich), NH_4SCN, NH_4Cl, and glycine (Merck) were used without further purification. Spectra were simulated with the program WIN-MAS (Bruker). The anisotropy tensors for the two NMR transitions of a spin-1 nucleus are calculated from the shielding tensor $\boldsymbol{\sigma}$ and the quadrupole tensor $\boldsymbol{\chi}$ as $\boldsymbol{\sigma} \pm 3\boldsymbol{\chi}/(4\nu_0)$. The spectra of the two transitions were calculated separately and added. For NH_4SCN we have neglected $\boldsymbol{\sigma}$. Second-order contributions of the quadrupole coupling were neglected in the simulation of the side band patterns in both cases.

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Methyl Transfer from Methanol to Co – cobyrinate: A model for the Coenzyme B_{12} Dependent Methyltransferase?**

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Methanol can be used by certain methanogenic and acetogenic microorganisms as a source of methyl in the synthesis of methane and acetyl-CoA.[1–4] In the cases reported, Co – corrinoids function as prosthetic groups and form Co – CH_3 complexes, which transfer the methyl group to coenzyme M ($HSCH_2CH_2SO_3^-$) or possibly to tetrahydro-

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folate in the production of acetyl-CoA. Experiments with chiral CHDT groups have provided convincing evidence that methyl transfer to Co^{I} in enzymatic reactions involves a nucleophilic substitution.[5, 6] Since general experience shows that the OH groups have to be activated by an energy-consuming process to become a leaving group in substitution reactions, the activation in the enzymatic reactions has to be addressed.[7] Whereas protonation of N^5-methyltetrahydrofolate has been suggested to be the most effective mode of activation for the transfer of the N^5-methyl group to cob(I)alamin in the methionine synthase catalyzed methyl transfer, ubiquitous ATP might be the activator for methanol.[10]

However, it was recently reported that Zn^{2+} is essential for the transfer of the methyl group from methanol to Co^{I} in methanogenic bacteria. A Gibbs energy ΔG° of approximately $-7\ kJ\,mol^{-1}$ was found for the formation of methylcobalamin from cob(I)alamin and methanol.[11] The powerful Lewis acid Zn^{2+} is known to activate substrates for nucleophilic attack, for example, by water in hydrolytic enzymes.[12] Other examples of substrates activated by Zn^{2+} have recently been described.[13, 14]

After considering model systems for this reaction without transformation of methanol into methylphosphate or another ester, we concluded that a direct transfer of methyl from methanol might be possible if Co^{I} is used as a supernucleophile[15] and the leaving group is activated by reversible complexation of the OH group by a Lewis acid.[16] To assess the reactivity of methanol and to investigate the potential role of Zn^{2+} as activator in the S_N2 reaction involving Co^{I}, we studied the reaction shown in Scheme 1.

When the Co^{II} complex **1a** was treated in CH_3OH with an excess of $NaBH_4$ in the presence of $ZnCl_2$ at room temperature or at 37 °C, the color changed immediately from orange to dark green, indicating a reduction of Co^{II} to Co^{I}. No $Co-CH_3$ complex **2a** could be detected after 3 h under these conditions. However, when the mixture was heated under reflux for 3 h, **2a** and **3a** were formed in 15–20% yield and a ratio of 10:1. No methylation takes place in the absence of this Lewis acid. This result might be interpreted in terms of a methylation by CH_3OH activated by Zn^{2+} or an intra- or intermolecular methyl transfer from one of the methoxycarbonyl groups. An intramolecular S_N2 reaction is rather unlikely, because the short alkyl chains do not allow the stereoelectronically required linear alignment between the Co^{I} and the methoxycarbonyl group.[17, 18]

To exclude an intermolecular substitution at one of the methoxycarbonyl groups, the methylation reaction was carried out in CD_3OH as solvent. After 3 h only the CD_3-Co complex, but no **2a**, was detected. However, some of the CH_3O groups from the heptamethylcobyrinate **1a** were replaced by CD_3O. Similarly, in the reaction of the heptaethylester **1b** the $Co-CH_3$ complexes **2b** and **3b** rather than $Co-C_2H_5$ compounds were formed.[19] Partial transesterification was also observed in this case. To exclude an intermolecular methyl transfer from one of the ester groups completely, the methylation reaction was carried out with the heptaalkyl Co^{II} complex **1c**. This reacts in CH_3OH under reflux for 3 h to give a $Co-CH_3$ complex in 3% yield.[20]

Although these reactions have not yet been optimized, it is apparent that methanol can be used as a methylating agent for Co^{I}–corrinoids under conditions where no ATP is needed. The supernucleophilic Co^{I} complex reacts with methanol when the leaving group is activated by the Lewis acid $ZnCl_2$.[21] Methyl transfer from cobalt to thiols and the combination of the two reactions in a catalytic cycle will be investigated.

Experimental Section

Methylation with methanol: To a solution of **1a**[22] (25 mg, 0.022 mmol) in absolute CH_3OH (10 mL, deoxygenated by sonification under N_2 for 30 min) was added $NaBH_4$ (8.4 mg, 10 equiv) and $ZnCl_2$ (200 mg). The reaction mixture was stirred in the dark for 3 h at 100 °C. The $Co-CH_3$ complex **2a** was detected by thin layer chromatography (TLC) by comparison with a sample of **2a** prepared from MeI (**2a**: $R_f = 0.54$, **3a**: $R_f = 0.27$; CH_2Cl_2/Et_2O/THF 2/2/1[23]). For further identification of **2a**, the reaction mixture was worked up by adding $HClO_4$ (1 mL, 60%) and H_2O (2 mL) and extracted with CH_2Cl_2. After the solution was dried over $MgSO_4$ and solvent evaporated, the ^1H NMR spectrum of the crude product was measured in $CDCl_3$ with TMS as internal standard (**2a**: $\delta(Co-CH_3) = -0.13$, **3a**: $\delta(Co-CH_3) = -0.22$). The yield was determined from the ratio of the ^1H NMR signals for the protons on C(10) of all corrinoids to the $Co-CH_3$ peaks for the isomers **2a**/**3a**. The reactions with **1b**[19] and **1c**[24–26] were performed as with **1a.**

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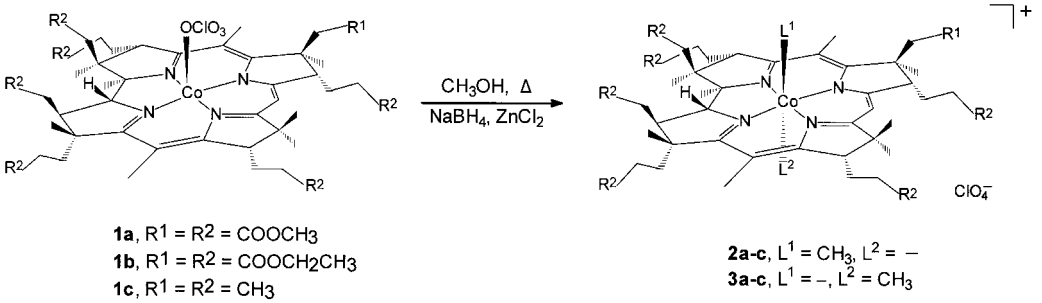
Supporting information available



1a, $R^1 = R^2 = COOCH_3$
1b, $R^1 = R^2 = COOCH_2CH_3$
1c, $R^1 = R^2 = CH_3$

2a-c, $L^1 = CH_3$, $L^2 = -$
3a-c, $L^1 = -$, $L^2 = CH_3$

Scheme 1. Methylation of Co complexes **1a–c**.

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Synthesis and Association Behavior of [4.4.4.4.4.4]Metacyclophanedodecayne Derivatives with Interior Binding Groups

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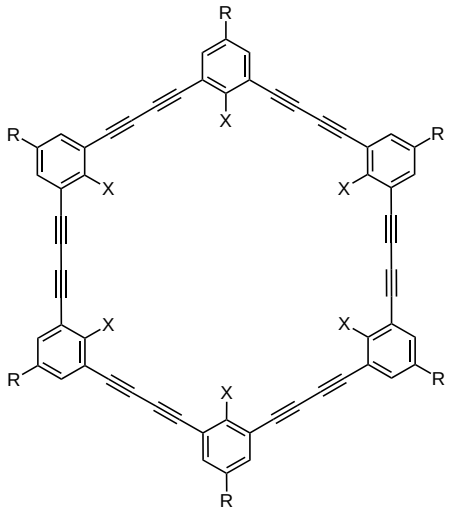
Recently Moore et al. disclosed the intriguing properties of phenylacetylene macrocycles (PAMs), which are based on self-organization properties owing to $\pi-\pi$ stacking interactions.[1] Moreover, Höger et al. reported the guest binding ability of a large macrocyclic metaparacyclophane to a large amine guest.[2] These properties based on weak intermolecular interactions can be fine-tuned by modifying the ring size, shape of the macrocycles, and the substituents on the periphery or interior of the macrocyclic framework. As an extension of our work on diethynylbenzene macrocycles (DBMs),[3] we disclose here the synthesis and novel association behavior of the hexameric DBM **1**, which has cyano groups in the interior of the macrocyclic framework. DBM **1** can be regarded as an extended derivative of the cyanospherand, which was shown to bind metal cations.[4] In contrast to the cyanospherand, we anticipated that **1** would be capable of binding relatively large molecules by ion-dipole or hydrogen-bonding interaction, because **1** possesses a well-defined cavity of about 7 Å diameter into which the geometrically ordered cyano groups are pointing. In addition, it is interesting to study the effect of cyano groups on the self-association behavior, since it has been well demonstrated that the $\pi-\pi$ interaction is sensitive to the substituent on aromatic rings.[5] It turned out that **1** exhibited novel association behavior; it



1	R=$CO_2C_8H_{17}$	X=CN
2	R=$CO_2C_8H_{17}$	X=H
3	R=H	X=CN
4	R=H	X=H

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