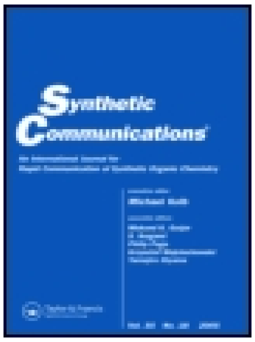


Synthetic Communications

An International Journal for Rapid Communication of Synthetic Organic Chemistry

ISSN: 0039-7911 (Print) 1532-2432 (Online) Journal homepage: http://www.tandfonline.com/loi/lsyc20

Synthesis and characterization of trans-di(nitrobenzo)- and di(aminobenzo)-18-crown-6 derivatives with high selectivity

Dongyun Wu, Chunhai Yi, Beibei Zhang & Bolun Yang

To cite this article: Dongyun Wu, Chunhai Yi, Beibei Zhang & Bolun Yang (2018): Synthesis and characterization of trans-di(nitrobenzo)- and di(aminobenzo)-18-crown-6 derivatives with high selectivity, Synthetic Communications, DOI: 10.1080/00397911.2017.1402350

To link to this article: https://doi.org/10.1080/00397911.2017.1402350

SYNTHETIC COMMUNICATIONS®
https://doi.org/10.1080/00397911.2017.1402350

Taylor & Francis
Taylor & Francis Group

Synthesis and characterization of *trans*-di(nitrobenzo)- and di(aminobenzo)-18-crown-6 derivatives with high selectivity

Dongyun Wu, Chunhai Yi, Beibei Zhang, and Bolun Yang

Shaanxi Key Laboratory of Energy Chemical Process Intensification, School of Chemical Engineering and Technology, Xi'an Jiaotong University, Xi'an, P.R. China

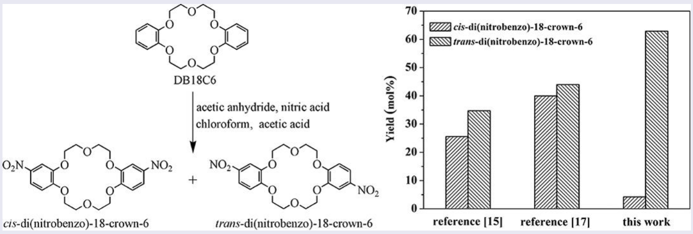
ABSTRACT

The dibenzo-18-crown-6 derivatives such as di(nitrobenzo)-18-crown-6 and di(aminobenzo)-18-crown-6 were synthesized by nitration reaction and catalytic hydrogenation with high selectivity. The chemical structures were determined by FTIR, ^{1}H NMR, ^{13}C NMR, and UV. Regarding the mixture of Ac_2O and HNO_3 as nitrating agent, the reaction exhibited commendable *trans*-isomer selectivity. Effects of nitrating agent ratio, reaction temperature and reaction time on yield of *trans*-di(nitrobenzo)-18-crown-6 were investigated. The yield of *trans*-di (nitrobenzo)-18-crown-6 was 62.9% for nitrating agent ratio of 1/1, reaction temperature of 50 °C and reaction time of 5 h. Moreover, effect of reaction time on *trans*-di(aminobenzo)-18-crown-6 was also studied.

ARTICLE HISTORY
Received 6 April 2017

KEYWORDS
Catalytic hydrogenation; high selectivity; nitration reaction; *trans*-di (aminobenzo)-18-crown-6; *trans*-di(nitrobenzo)-18-crown-6

GRAPHICAL ABSTRACT



Introduction

In 1967, Pedersen[1] at DuPont first synthesized the dibenzo-18-crown-6, and found that it possessed the selective cation-complexing properties. From then on, the research of crown ethers arouses great interest, and numerous types of crown ethers have been synthesized through approximate 50 years of development. Crown ethers are cyclic chemical compounds that consist of a ring including several ether groups. The most common crown ethers are cyclic oligomers of ethylene oxide, and the repeating unit is ethyleneoxy, $-CH_2CH_2O-$. Furthermore, crown ether derivatives containing other heteroatom are also synthesized, such as oxa-aza crown ether, azacrown ether, and thiacrown ether.

At present, crown ethers have been extensively applied in organic chemical reaction, polymerization reaction, inorganic chemistry, analytical chemistry, enrichment and separation of metal ions, and separation of chiral compounds.[2–7] For instance, B15C5

CONTACT Chunhai Yi ✉ chyi@mail.xjtu.edu.cn Shaanxi Key Laboratory of Energy Chemical Process Intensification, School of Chemical Engineering and Technology, Xi'an Jiaotong University, Xi'an 710049, P.R. China.

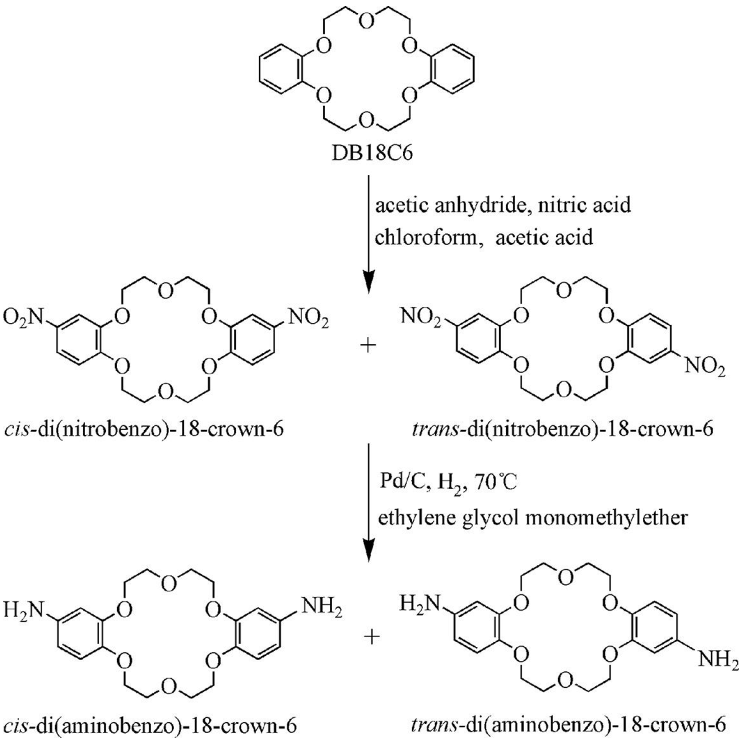
Supplemental data for this article can be accessed on the publisher's website.

was chosen as lithium isotopes separation extractant because its cavity size was closed to the ionic diameter of Li^+.[8] Since the micromolecule crown ethers have certain physiological toxicity, the derivatives of crown ethers have been synthesized for the enrichment and separation of metal ions, catalytic reaction and reverse osmosis membranes.[9–13] Yakshin et al.[14] synthesized the *cis*-di(nitrobenzo)-18-crown-6, *trans*-di(nitrobenzo)-18-crown-6, *cis*-di(aminobenzo)-18-crown-6 and *trans*-di(aminobenzo)-18-crown-6 for metal salt sorption from aqueous chloride solutions, and found that *trans*-di(nitrobenzo)-18-crown-6 possessed the highest sorption efficiency. Despite the superior property of *trans*-derivate, there are very few reports on the product selectivity for *cis*- and *trans*-derivates. Although Feigenbaum and Michel[15] and Saigo et al.[16] synthesized the di(nitrobenzo)-18-crown-6, the content of *cis*-isomer was almost the same as *trans*-isomer.

In this paper, derivates of dibenzo-18-crown-6 (DB18C6) were synthesized with high selectivity for *trans*-product. The physical properties of di(nitrobenzo)-18-crown-6 and di(aminobenzo)-18-crown-6 were characterized by FTIR, ^1H NMR, ^{13}C NMR and UV. The effects of synthesis parameters on yield of *trans*-di(nitrobenzo)-18-crown-6 and *trans*-di(aminobenzo)-18-crown-6 were investigated, and reaction conditions were optimized.

Discussion

The syntheses of DB18C6 derivatives are described in Scheme 1. The synthetic method is notable as it is easy to operate and shows a very high *trans*-selectivity. Di(nitrobenzo)-18-crown-6 was obtained from DB18C6 by nitration reaction. The product possessed a



Scheme 1. Reaction equations of di(nitrobenzo)-18-crown-6 and di(aminobenzo)-18-crown-6.

commendable selectivity for *trans*-di(nitrobenzo)-18-crown-6 compared with other literatures.[15,16] The corresponding di(aminobenzo)-18-crown-6 was obtained through catalytic hydrogenation of the nitro group.

In this work, a mixture of HNO_3 and Ac_2O as a low active nitrating agent was selected for the nitration of DB18C6 due to the fact that DB18C6 contains the ether groups (–O–), which are connected with the benzo ring and thus can promote the nitration reaction. The effect of nitrating agent ratio on the yield of *trans*-di(nitrobenzo)-18-crown-6 was studied. As shown in Table 1, the yield of *trans*-di(nitrobenzo)-18-crown-6 can reach up to 41.4% when the molar ratio of Ac_2O/HNO_3 was 1/1. By contrast, the yield decreased to only 27.9% with Ac_2O/HNO_3 molar ratio of 1.5/1, and no desired production can be detected for its molar ratio of 0.5/1. It means that the optimal proportion of Ac_2O/HNO_3 for the maximum yield of *trans*-di(nitrobenzo)-18-crown-6 is 1/1.

The reaction mechanism of the nitrating agent is mentioned below.

$$HNO_3 + (CH_3CO)_2O \rightleftharpoons CH_3CO_2NO_2 + CH_3COOH$$
$$HNO_3 + CH_3COOH \rightleftharpoons CH_3CO_2NO_2 + H_2O$$
$$(CH_3CO)_2O + H_2O \rightleftharpoons 2CH_3COOH$$

The reaction product of HNO_3 and Ac_2O is acetyl nitrate, which is nitrating agent with high reaction activity. Thus, the acetyl nitrate is the real nitrating agent in this reaction. On one side, Ac_2O can remove the water produced in step two and promote the nitrating reaction process. On the other side, the excessive Ac_2O is likely to bring about the vice-product, and reduce the yield of *trans*-di(nitrobenzo)-18-crown-6. Therefore, the optimum proportion of Ac_2O/HNO_3 is 1/1.

The effect of reaction temperature on yield of di(nitrobenzo)-18-crown-6 was investigated subsequently (Fig. 1). The results showed that the yield of *trans*-di(nitrobenzo)-18-crown-6 reached to a maximum and then decreased with increasing the reaction temperature. While the yield of *cis*-di(nitrobenzo)-18-crown-6 increased obviously with the reaction temperature. The highest yield of *trans*-di(nitrobenzo)-18-crown-6 reached 41.4% at the reaction temperature of 50 °C. When reaction temperature was below 50 °C, *trans*-di (nitrobenzo)-18-crown-6 yield increased with the reaction temperature due to the increase in reaction rate. For the reaction temperature higher than 50 °C, the *cis*-di(nitrobenzo)-18-crown-6 yield increased obviously, which led to a decline in *trans*-di(nitrobenzo)-18-crown-6 yield. Thus the optimal point of reaction temperature for the largest production of *trans*-di(nitrobenzo)-18-crown-6 is 50 °C.

The effect of reaction time on yield of di(nitrobenzo)-18-crown-6 was displayed in Figure 2. It was observed that the yield of *trans*-di(nitrobenzo)-18-crown-6 increased with the increase of reaction time, and reached to 62.9% when the reaction time was 5 h. However, due to the existence of multiple nitration by-products, the reaction yield would decrease if the reaction time continued to extend; therefore, the optimum reaction time is 5 h.

Table 1. Yield of di(nitrobenzo)-18-crown-6 for varied ratios of nitrating agent.*

Nitrating agent ratio/(mol/mol)	$Ac_2O/HNO_3 = 0.5/1$	$Ac_2O/HNO_3 = 1/1$	$Ac_2O/HNO_3 = 1.5/1$
Trans-di(nitrobenzo)-18-crown-6	None	41.4	27.9
Cis-di(nitrobenzo)-18-crown-6	None	5	1.2

*Reaction time: 6 h, reaction temperature: 50 °C.

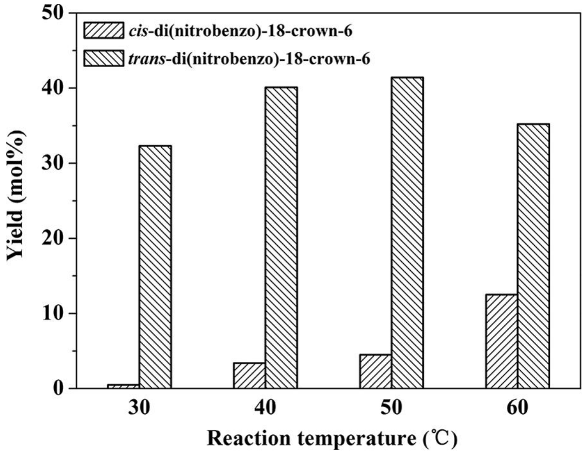


Figure 1. Yield of di(nitrobenzo)-18-crown-6 for different reaction temperature (Ac_2O/HNO_3 molar ratio: 1/1, reaction time: 6 h).

Figure 3 listed the comparison of di(nitrobenzo)-18-crown-6 yield between the current work and the references. Feigenbaum and Michel[15] and Deetz et al.[17] synthesized di (nitrobenzo)-18-crown-6 from DB18C6 nitrated with a mixture of nitric acid and acetic acid, and found that the percentages of *trans*-di(nitrobenzo)-18-crown-6 were 57.5% and 52.4%, respectively. In this study, the percentage of *trans*-di(nitrobenzo)-18-crown-6 accounted for 93.7% nitrated with a mixture of Ac_2O and HNO_3, indicating that the nitration agent possessed a high selectivity with *trans*-di(nitrobenzo)-18-crown-6 yield of 62.9% at the optimal condition.

Trans-di(aminobenzo)-18-crown-6 was prepared by the catalytic hydrogenation of *trans*-di(nitrobenzo)-18-crown-6. As shown in Figure 4, the productivity of *trans*-di(aminobenzo)-18-crown-6 increased gradually with the increase of reaction time. However, there was only 3.8% increase in the *trans*-di(aminobenzo)-18-crown-6 yield when the

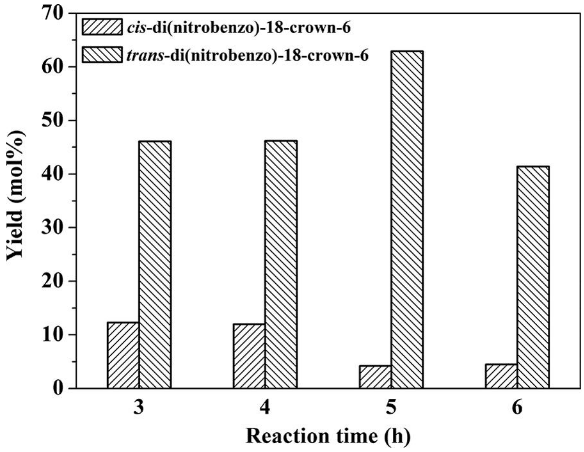


Figure 2. Yield of di(nitrobenzo)-18-crown-6 for different reaction time (Ac_2O/HNO_3 molar ratio: 1/1, reaction temperature: 50 °C).

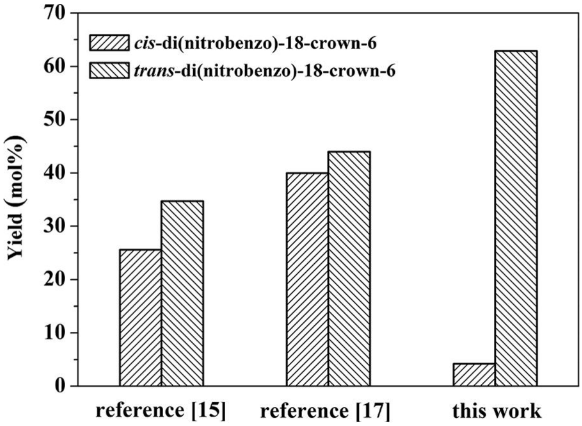


Figure 3. Yield of di(nitrobenzo)-18-crown-6 obtained in this study compared with the references.

reaction time was prolonged from 2 to 4 h. Therefore, the optimum reaction time is set as 2 h.

In conclusion, the derivatives obtained from DB18C6 were synthesized by nitration reaction and catalytic hydrogenation. The chemical structures of di(nitrobenzo)-18-crown-6 and di(aminobenzo)-18-crown-6 were certified by FTIR, ^{1}H NMR, ^{13}C NMR, and UV. Using Ac_2O and HNO_3 as nitrating agent, the nitration reaction can obtain a commendable selectivity, and the main product was *trans*-di(nitrobenzo)-18-crown-6. The yield of *trans*-di(nitrobenzo)-18-crown-6 was 62.9% for nitrating agent ratio of 1, reaction temperature of 50 °C and reaction time of 5 h. The di(aminobenzo)-18-crown-6 was prepared from di(nitrobenzo)-18-crown-6 by catalytic hydrogenation. The reaction yield of *trans*-di(aminobenzo)-18-crown-6 was 76.2% for the catalyst and *trans*-di(nitrobenzo)-18-crown-6 ratio of 0.04 (wt), hydrogen pressure of 0.35 MPa, reaction temperature of 70 °C and reaction time of 2 h.

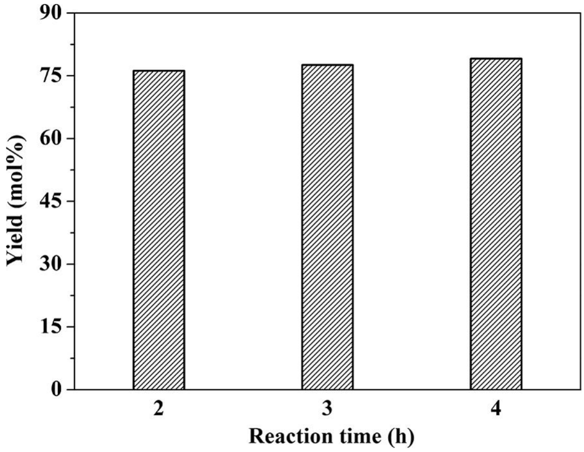


Figure 4. Yield of *trans*-di(aminobenzo)-18-crown-6 for different reaction time (hydrogen pressure: 0.35 MPa, reaction temperature: 70 °C).

Experimental section

General

Nitric acid, *N,N*-dimethyl formamide (DMF), ethylene glycol monomethyl ether, ethanol, acetic acid, trichloromethane and 10 wt% Pd/C catalyst were purchased from Sinopharm Chemical Reagent Co., Ltd. Acetic anhydride was purchased from West Long Chemical Co., Ltd. Dibenzo-18-crown-6 (DB18C6, 98%) was purchased from J&K Scientific Co., Ltd of Beijing, China. DMF and ethylene glycol monomethyl ether were purified by 5A molecular sieves before using. The other chemicals were used as received. Melting points were determined on the YRT-3 melting-point apparatus with open-ended capillary tubes. The UV spectrum was tested by UV-1900PPC. The element analysis was tested by Vario EL III. The FTIR spectra were measured with Nicolet Avatar 360 instrument with OMNI-sampler. The resolution of FTIR is 4 cm^{-1}. ^1H NMR spectra and ^{13}C NMR spectrum were measured on the Bruker AVIII 500WB at 60 °C and Bruker Avance 400 MHz at room temperature, respectively. The chemical shifts were recorded with tetramethylsilane as the internal standard.

Trans-*di(nitrobenzo)-18-crown-6*

About 5.1000 g of DB18C6, 105 mL of trichloromethane and 75 mL of acetic acid were added into a 250 mL round-bottomed flask equipped with a mechanical stirrer, and dissolved at room temperature. Then the mixture of acetic anhydride and nitric acid was added dropwise. The reaction mixture was refluxed at 50 °C for 5 h and then filtered. The filter cake was *trans*-di(nitrobenzo)-18-crown-6 and recrystallization was used by DMF at 150 °C. *Trans*-di(nitrobenzo)-18-crown-6 was obtained as a white powder by removing solvent in vacuum. Mp. 236.8–238.6 °C, lit[15,17] 247–252 °C or 237–242 °C. FTIR (KBr) 1592, 1516, 1346 ($-NO_2$), 897, 882 (C–N) cm^{-1}. ^1H NMR (500 MHz, DMSO) δ 7.87 (dd, 2H, $J = 9$, 2.6 Hz), 7.73 (d, 2H, $J = 2.6$ Hz), 7.16 (d, 2H, $J = 9$ Hz), 4.24 (m, 8H), 3.88 (m, 8H). UV (99.7% ethanol): λ_{max} (log ε) = 340 (4.47). Anal. Calcd for $C_{20}H_{22}N_2O_{10}$: C, 53.33; H, 4.89; N, 6.22%. Found: C, 53.12; H, 4.91; N, 6.18%.

Trans-*di(aminobenzo)-18-crown-6*

About 1.6500 g of above-produced *trans*-di(nitrobenzo)-18-crown-6 was dissolved in 100 mL ethylene glycol monomethyl ether, and subsequently 0.0660 g of 10 wt% Pd/C catalyst was added into cooled solution. The reaction was peformed at 70 °C under hydrogen pressure of 0.35 MPa for 2 h. The mixture was cooled to room temperature, discharged after the pressure released, and filtered to remove the Pd/C. The filtrate was distilled to remove the solvent under vacuum, and the crude *trans*-di(aminobenzo)-18-crown-6 product was recrystallized from the mixture of ethylene glycol monomethyl ether and ethanol. *Trans*-di(aminobenzo)-18-crown-6 of light brown powder was gained by removing solvent in vacuum. Mp. 187–191 °C, lit[15] 199–203 °C. FTIR (KBr) 3428, 3353 ($-NH_2$), 1613, 1515, 1278 (C–N) cm^{-1}. ^1H NMR (500 MHz, DMSO) δ 6.65 (d, 2H, $J = 8.4$ Hz), 6.27 (d, 2H, $J = 2.2$ Hz), 6.09 (dd, 2H, $J = 8.4$, 2.4 Hz), 4.52 (s, 4H), 4.03–3.94 (m, 8H), 3.85–3.77 (m, 8H). ^{13}C NMR (100 MHz, DMSO) δ 149.7, 143.9, 139.6, 116.1, 105.8, 101.1, 69.9, 69.6, 69.5, 68.2. UV (99.7% ethanol): λ_{max} (log ε) = 295 (4.53). Anal. Calcd for $C_{20}H_{26}N_2O_6$: C, 61.54; H, 6.67; N, 7.18%. Found: C, 61.52; H, 6.62; N, 6.87%.

Funding

This work is supported by the National Key R&D Program of China (2017YFB0603402), the National Natural Science Foundation of China (21576217), and the Fundamental Research Funds for the Central Universities (xjj2016044).

References

[1] Pedersen, C. J. *J. Am. Chem. Soc.* **1967**, *89*, 2495–2496.
[2] Safarbali, R.; Yaftian, M. R.; Zamani, A.; Ghorbanloo, M. *J. Iran. Chem. Soc.* **2016**, *13*, 2085–2091.
[3] Nishizawa, K.; Ishino, S.; Watanabe, H. *J. Nucl. Sci. Technol.* **1984**, *21*, 694–701.
[4] Pedersen, C. J. *J. Am. Chem. Soc.* **1967**, *89*, 7017–7036.
[5] Demlov, E. V. *Angew. Chem.* **1977**, *89*, 521–533.
[6] Cram, D. J.; Cram, J. M. *Science* **1974**, *183*, 803–809.
[7] Cram, D. J.; Cram, J. M. *J. Am. Chem. Soc.* **1976**, *98*, 3038–3041.
[8] Kitazawa, S.; Kimura, K.; Yano, H.; Shono, T. *J. Am. Chem. Soc.* **1984**, *106*, 6978–6983.
[9] Yu, H. L.; Wang, W. Y.; Hong, B.; Zong, Y.; Sia, Y. L.; Hu, Z. Q. *Phys. Chem. Chem. Phys.* **2016**, *18*, 26487–26494.
[10] Rapi, Z.; Grün, A.; Nemcsok, T.; Hessz, D.; Kállay, M.; Kubinyi, M.; Keglevich, G.; Bakó, P. *Tetrahedron: Asymmetry* **2016**, *27*, 960–972.
[11] Huang, H.; Li, M.; Zhang, L.; Hou, L. A. *Sci. Technol. Rev.* **2015**, *33*, 36–40.
[12] Ochkina, K. A.; Kulov, N. N.; Fomichev, S. V. *Theor. Found. Chem. Eng.* **1998**, *32*, 44–47.
[13] Chori, E. S. *J. Appl. Polym. Sci.* **1976**, *20*, 773–788.
[14] Yakshin, V. V.; Vilkova, O. M.; Tsarenko, N. A.; Tsivadze, A. Y. *Dokl. Chem.* **2010**, *430*, 32–34.
[15] Feigenbaum, W. M.; Michel, R. H. *J. Polym. Sci., Part A: Polym. Chem.* **1971**, *9*, 817–820.
[16] Saigo, K.; Lin, R.-J.; Kubo, M.; Youda, A.; Hasegawa, M. *Chem. Lett.* **1986**, *15*, 519–522.
[17] Deetz, M. J.; Shang, M.; Smith, B. D. *J. Am. Chem. Soc.* **2000**, *122*, 6201–6207.