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New triazole appended *tert*-butyl calix[4]arene conjugates: synthesis, Hg^{2+} binding studies

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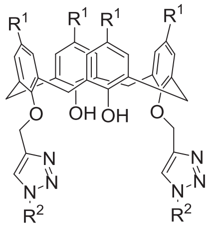
Several new conjugates of *tert*-butylcalix[4]arenes bearing different 1-substituted triazoles at the lower rim were synthesized via click chemistry. The products were tested towards complexation of metal ions exhibiting pronounced selectivity towards Hg^{2+}. The ^{1}H NMR titration results for ligand **12a** show formation of L:Hg^{2+} complexes with various stoichiometries, $\log\beta(1{:}1)=6.8$, $\log\beta(2{:}1)=11.9$, $\log\beta(2{:}2)=15.1$ in $CDCl_3$:CD_3CN 1:1.

1. Introduction

Among the heavy metals, mercury is a representative environmental contaminant due to the various ways it is produced, such as mining, fossil fuel combustion or destruction of solid waste.[1] Thus, to date many efforts have been devoted to develop better methods to detect and remove the mercury ion (Hg^{2+}) from contaminated sources. Different organic receptors that selectively extract these cations have been created and it is well established that organizing these receptors onto a framework with a fixed conformation improves the extraction efficiency.[2] Calixarenes, as platforms for receptors of heavy metals, have the advantage of easy availability and high versatility over the other potential candidates.[3]

1,2,3-Triazoles can coordinate to various metal ions serving as sensors,[4] producing defined cyclic structures and coordination polymers.[5] When attached to the calixarene scaffold, coordination properties of 1,2,3-triazoles are modulated, mainly in terms of selectivity. Among known calixarene derivatives of the general structure L, there are ligands selective for Pb^{2+},[6] Zn^{2+},[7] Cu^{2+},[8] Co^{2+},[9] Ag^{+},[10] Cs^{+},[11] Ca^{2+},[6b,12] bimodal receptors[13] and ditopic receptors for simultaneous complexation of Ca^{2+}/I^{-}[14] and various halides and monovalent cations.[15] Among the known ligands there is only one simple calixarene, di-functionalized with two 1-benzyl-1,2,3-triazoles (R^2=benzyl) exhibiting Hg^{2+} selectivity.[16] Such diverse complexation preferences indicate that selectivity is mostly determined by the additional R^2 substituents.



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In the current paper we modified the R^2 position with various substituents possessing additional potential binding sites. We present here the synthesis of new conjugates of *tert*-butylcalix[4]arenes bearing triazoles at the lower rim. Additionally, we synthesized a new triazole-modified calix[4]crown via click chemistry. The selective Hg^{2+} binding studies of one of the new triazole appended *tert*-butyl calix[4]arene conjugates are also presented.

2. Results and discussion

Our strategy was based on the use of the cone 1,3-dipropargylated *tert*-butylcalix[4]arene derivative[17] as a clickable

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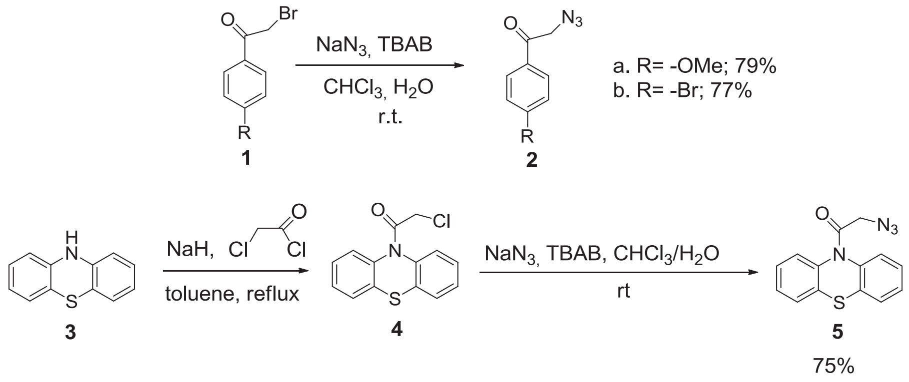
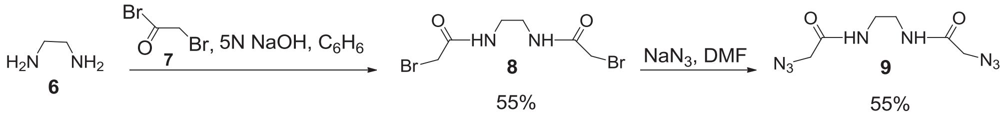
compound that should allow capping at its lower rim when reacted with azide and bis-azide reagents.

The precursor azides **2** have been synthesized from the corresponding ω-bromoacetophenones **1** using sodium azide in a biphasic chloroform/water system and tetra-*n*-butyl ammonium bromide (TBAB) as phase transfer catalyst (Scheme 1).[18] Phenotiazine azide **5** was synthesized in two steps starting from phenotiazine. First, the acylation of **3** using chloroacetyl chloride was performed[19] and then, using the same above mentioned conditions, the intermediate chloride **4** turned into azide **5** (Scheme 1).[19,20]



Scheme 1. The synthesis pathway of azides **2** and **5**.

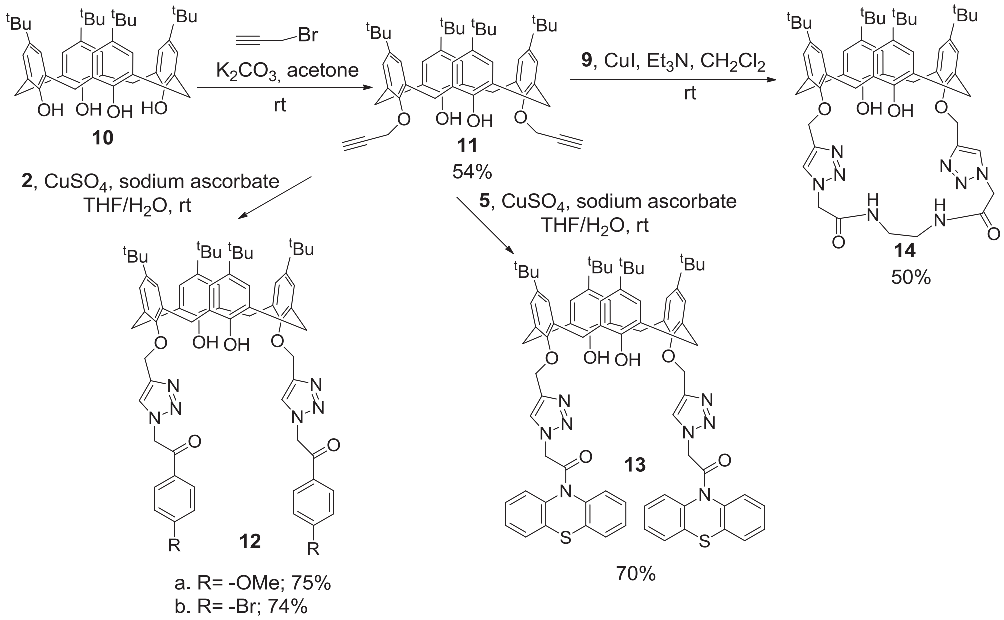
For the synthesis of diazide **9**, diamine **6** was first diacylated using bromoacetyl bromide **7**, and then treated with sodium azide in DMF (Scheme 2).



Scheme 2. The synthesis pathway of azide **9**.

The last step in the synthetic route for compounds **12**, **13** and **14** is depicted in Scheme 3 and involves dipolar cycloaddition of 25,27-bis(*O*-propargyl)calix[4]arene **11**[17] with azides **2**, **5** and **9** using clasical click chemistry conditions.

The ^{1}H NMR spectra of compounds **12a**, **12b** and **13** showed a cone conformation of these conjugates with the characteristic AB pattern for bridging calixarene CH$_2$ groups, whereas the four methylene groups of the two lower rim substituents appeared as two singlets at 4.82–4.97 ppm and 5.31–5.80 ppm, respectively (ESI). The protons of the newly formed triazole rings furnish a singlet at 7.74–8.08 ppm. Strong IR absorption bands for $C{=}O$ ketone bond appear at 1693 cm^{-1} for compound **12a** and at 1702 cm^{-1} for compound **12b**, while the OH groups absorb at 3425 cm^{-1} for **12a**



Scheme 3. The synthesis of triazoles **12**–**14** using click chemistry.

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