Tetrahedron 74 (2018) 2956–2966

Contents lists available at ScienceDirect

Tetrahedron

journal homepage: www.elsevier.com/locate/tet

Exploring structural and conformational behaviour of cyclophanes incorporating imidazole-2-thiones

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ARTICLE INFO

Article history:
Received 5 March 2018
Received in revised form
19 April 2018
Accepted 23 April 2018
Available online 26 April 2018

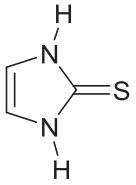
Keywords:
Imidazole-2-thiones
Cyclophanes
Conformations
Imidazolium salts

ABSTRACT

New cyclophanes containing two imidazole-2-thione moieties linked by two xylylene groups have been synthesized by the reaction of imidazolium-linked cyclophanes with sulfur in the presence of K_2CO_3. The conformational behaviour of the new cyclophanes was explored by NMR spectroscopy and X-ray diffraction studies. In cyclophanes containing *o*-xylylene or 2,4,6-trimethyl-*m*-xylylene linking groups, the imidazole-2-thione groups were mutually *syn* in both the solid state and in solution, the cyclophanes adopting a conformation reminiscent of the cone conformation of calix[4]arenes. Cyclophanes containing *p*-xylylene or *m*-xylylene linking groups exhibited two conformations in solution, one in which the imidazole-2-thione groups are mutually *syn*, the other in which they are mutually *anti*, and these conformations did not interconvert on the NMR timescale. Both conformations co-crystallised in the *m*-xylylene linked cyclophane, while for the *p*-xylylene-linked cyclophane the *anti* conformation crystallised separately.

1. Introduction

Imidazole-2-thione (1) and its derivatives have long been of interest due to their promise of applications in fields of medicine,[1–4] catalysis[5] and coordination chemistry,[6,7] and as precursors of halogen-free ionic liquids.[8]



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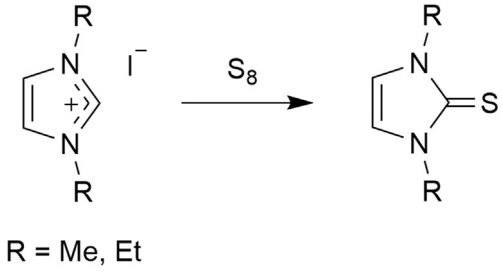
Probably the most important method of preparation of imidazole-2-thiones is by direct reaction between an imidazolium salt and elemental sulfur. For example, dialkylimidazolium iodides readily react with sulfur to form 1,3-dialkylimidazole-2-thiones (Scheme 1).[9–12]

The chemical structures of imidazole-2-thione and 1,3-dialkylimidazole-2-thiones have been studied theoretically[13,14] and experimentally.[12,15,16] The result of quantum-chemical studies of the imidazole-2-thione molecule indicate a non-uniform distribution of π-electron density around the C–S bond, with the negative charge concentrated on the exocyclic sulfur atom.[13,14] X-Ray studies of imidazole-2-thione[15] (and its derivatives,[12, 16]) showed that the imidazole-2-thione moiety is planar and that the C–S bond (~1.70 Å [15]) is longer than a typical C=S bond (e.g., C=S



Scheme 1.

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https://doi.org/10.1016/j.tet.2018.04.074
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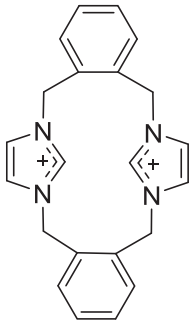
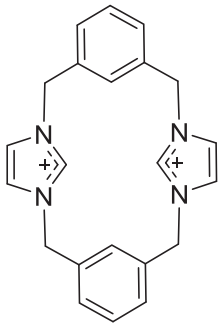
bond distance in thioacetone[17] ~1.63 Å). The bond lengths and angles in imidazole-2-thiones are similar to those in corresponding imidazolium salts (e.g., Fig. 1). Therefore, imidazole-2-thione can be more accurately represented as the resonance hybrid (**2**) (Scheme 2).[13,15,16]

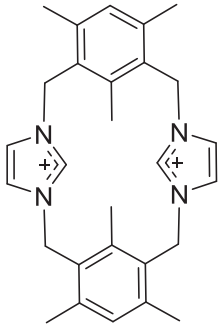
We have been interested in imidazolium-linked cyclophanes such as $\mathbf{3}^{2+}$ - $\mathbf{6}^{2+}$, and have studied their interesting conformational behaviour using X-ray diffraction and NMR methods.[19–21] While a great many imidazole-2-thiones are known,[22–27] including examples where imidazole-2-thione moieties are appendages to a calixarene.[28] There have been no reports of cyclophane structures analogous to $\mathbf{3}^{2+}$ - $\mathbf{6}^{2+}$ in which imidazole-2-thione moieties are part of a macrocyclic ring. As an extension of our work with imidazolium-linked cyclophanes, here we report the synthesis of some cyclophanes incorporating imidazole-2-thione units, and characterisation of their conformational behaviour in the solid state and in solution.



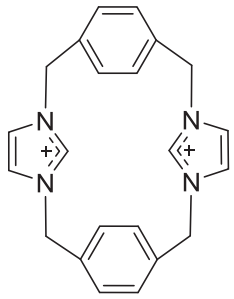
$\mathbf{3}^{2+}$



$\mathbf{4}^{2+}$



$\mathbf{5}^{2+}$

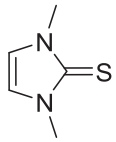


$\mathbf{6}^{2+}$

2. Results and discussion

2.1. Synthesis of the imidazole-2-thiones

The imidazole-2-thiones **7**–**13** were synthesized by reaction of the corresponding imidazolium salts with sulfur and K_2CO_3 in methanol at 40 °C overnight. In most cases the products were sufficiently pure for further use, but in some cases recrystallisation was required to obtain analytically pure samples. The conformations of the cyclophanes **10**–**13** were investigated using X-ray diffraction and NMR studies.



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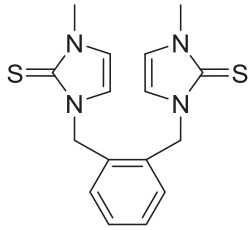

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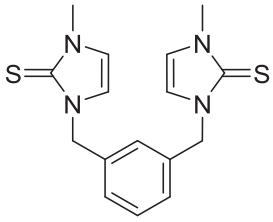

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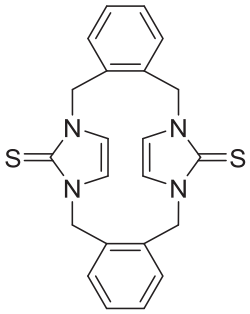

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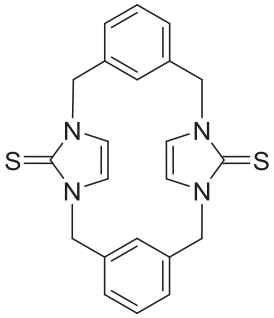

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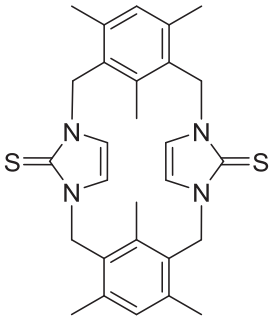

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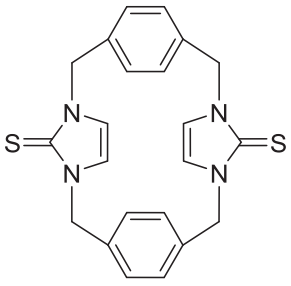

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