Tetrahedron 69 (2013) 3238–3248

Contents lists available at SciVerse ScienceDirect

Tetrahedron

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

Synthesis and ring-opening reaction of novel 1,3-dehydroadamantanes possessing phenyl and alkoxyl substituents

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ARTICLE INFO

Article history:
Received 11 December 2012
Received in revised form 9 February 2013
Accepted 12 February 2013
Available online 19 February 2013

Keywords:
1,3-Dehydroadamantanes
5-Phenyl-1,3-dehydroadamantane
5-Methoxy-1,3-dehydroadamantane
1,3-Dibromoadamantanes
1-Acetoxyadamantanes
1-Methoxyadamantanes
Ring-opening reaction

ABSTRACT

A series of novel 1,3-dehydroadamantanes (DHAs) possessing phenyl or alkoxyl substituents, such as 5-phenyl-1,3-dehydroadamantane, 5-butyl-7-phenyl-1,3-dehydroadamantane, 5-methoxy-1,3-dehydroadamantane, 5-butoxy-1,3-dehydroadamantane, 5-butyl-7-methoxy-1,3-dehydroadamantane, and 5-butoxy-7-butyl-1,3-dehydroadamantane were synthesized and subjected to react with acidic compounds. 1,3-Dibromoadamantanes carrying phenyl or alkoxyl substituents were converted into the corresponding DHAs via the intramolecular Wurtz-type coupling reactions with lithium metal in THF in 23–62% yields. Ring-opening reactions of DHAs readily occurred with acetic acid or methanol under acidic conditions to form various 1-acetoxyadamantanes or 1-methoxyadamantanes containing phenyl or alkoxyl groups. The resulting 1-butyl-3-methoxy-5-phenyladamantane, 1-acetoxy-3-butyl-5-phenyladamantane, 1-acetoxy-3-butyl-5-methoxyadamantane, 1-acetoxy-3-butoxy-5-butyladamantane, and 1-butoxy-3-butyl-5-methoxyadamantane possessed stereogenic center. The high reactivity of the inverted 1,3-carbon–carbon σ-bond in DHAs toward the acidic compounds indicated the high electron density, which was supported by the sp^2 character of cyclopropane rings in DHAs estimated by J_{C-H} coupling constants in the ^{13}C NMR analyzes.

1. Introduction

1,3-Dehydroadamantane (**1a**)[1,2] is a typical highly strained [3.3.1]propellane[3,4] derivative and shows high reactivity derived from inverted tetrahedral geometry at a bridgehead carbon similar to other propellane derivatives,[5] such as [1.1.1]-[6] and [2.2.2]propellanes.[7] In fact, the inverted 1,3-carbon–carbon σ-bond of **1a** readily undergoes free-radical and electrophilic ring-opening reactions with oxygen, bromine, and sulfuric acid to form 1,3-disubstituted adamantanes (Scheme 1).[1,2,8] It is also reported that a thermally stable insoluble polymeric product formed by heating **1a** at 160 °C.[2] Reactions of **1a** with a catalytic amount of trifluoromethanesulfonic acid (TfOH) or α,α′-azobisisobutyronitrile (AIBN) gave insoluble poly(1,3-adamantane)s, while no reaction of **1a** occurred with nucleophilic reagents, such as *n*-butyllithium (*n*-BuLi) or phenylmagnesium chloride.[9,10] Thus, the high electron density of **1a** and the ring-opening polymerizability under cationic and radical conditions are clearly demonstrated. More interestingly, **1a** readily underwent spontaneous copolymerization with electron-deficient monomers, such as acrylonitrile or methyl acrylate to give soluble copolymers with predominantly alternating sequences.[11] The copolymers derived from **1a** showed high thermal stability and high glass transition temperature (T_g) due to the introduction of a bulky and rigid adamantane-1,3-diyl framework in the main chain. These clearly indicate that **1a** can be positioned as an attractive cyclic monomer or a rigid building unit to affect the thermal property or solubility of resulting polymers.

Although several 1,3-dehydroadamantanes (DHAs) possessing alkyl substituents, such as 5-butyl (**1b**),[9] 5,7-dimethyl (**1c**),[12] and 5,7-dibutyl (**1d**) groups[10] have been synthesized from the corresponding 1,3-dibromoadamantanes (**3b**–**d**) (Scheme 2), the introduced substituents are rather limited due to the high reactivity of the parent DHA frameworks and the difficulty of their synthetic pathways. 5-Bromo-1,3-dehydroadamantane (**4**) was produced in situ via the debromination of 1,3,5-tribromoadamantane with *n*-BuLi in Et_2O in the presence of hexamethylphosphoric triamide (HMPA), but attempts at isolation were not successful (Scheme 3).[13] Pincock reported that **4** could be converted into 5-hydroxy- (**5**), 5-methoxy- (**13c**), and 5-cyano-1,3-dehydroadamantane (**6**) by treatment with hydroxide, methoxide, and cyanide, respectively.[13] The resultant DHAs carrying hydroxyl and methoxyl groups, **5** and **13c**, could not be isolated but easily decomposed in situ to afford ring-opening products due to their inherent instabilities, while a nitrile, **6**, was successfully isolated and showed the usual stability.[13,14] On the other hand, alkyl-substituted DHAs, such as **1b** and **1d** show the usual stability and ring-opening polymerizability,[9,10] similar to the case of **1a**. Thus, the reactivity and inherent stability of DHAs are largely affected by the introduced

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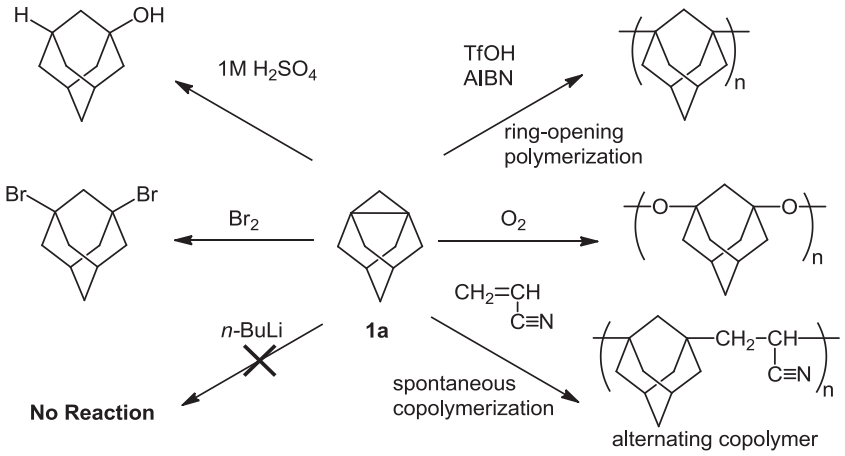
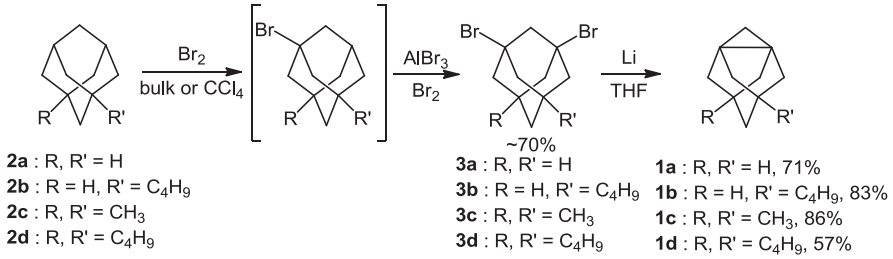
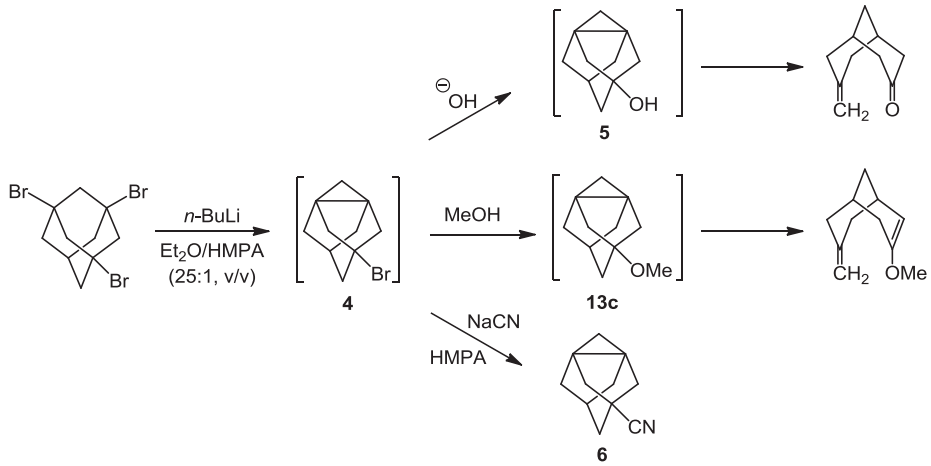
http://dx.doi.org/10.1016/j.tet.2013.02.042



Scheme 1. Ring-opening reactions of **1a**.



Scheme 2. Synthesis of alkyl-substituted DHAs.



Scheme 3. Synthesis and reaction of 5-bromo-1,3-dehydroadamantane (**4**) reported by Pincock.[13]

substituents and are of great interest from the viewpoints of organic chemistry and polymer chemistry.

In order to synthesize novel DHAs, corresponding 1,3-dibromoadamantanes are usually required as the starting materials for a lithium-mediated intramolecular Wurtz coupling reaction to form an internal 1,3-carbon–carbon σ-bond.[1,2,13,15] There are two strong requirements in the two-stage synthetic routes of DHAs. One is that the substituents on adamantyl skeletons should tolerate bromination reactions, and the other is that the substituents should be stable in the presence of excess lithium metal even after cyclization. In this paper, we have developed certain synthetic pathways for a series of novel DHAs carrying phenyl and alkoxyl substituents, and their normal stability is demonstrated. In particular, the stability of isolated 5-methoxy-1,3-dehydroadamantane (**13c**) is in sharp contrast to the previous literature.[13] The substituent effect observed in the ^{13}C NMR spectra of DHAs is also discussed. The ring-opening reactions of these DHAs with MeOH or AcOH are investigated to form the corresponding 1-methoxyadamantanes or 1-acetoxyadamantanes. The observed reactivity should be useful to predict the ring-opening polymerizability of these DHAs.

2. Results and discussion

2.1. Synthesis of 1,3-dibromoadamantanes

According to the synthetic procedure reported by Eguchi,[16] we synthesized 1-phenyladamantane (**8a**)[17] and 1-butyl-3-phenyladamantane (**8b**) via the coupling reaction of 1-bromoadamantane