

Efficient and General Synthetic Method for Preparing Oligoenynes with Either *trans*- or *cis*-Olefinic Configuration

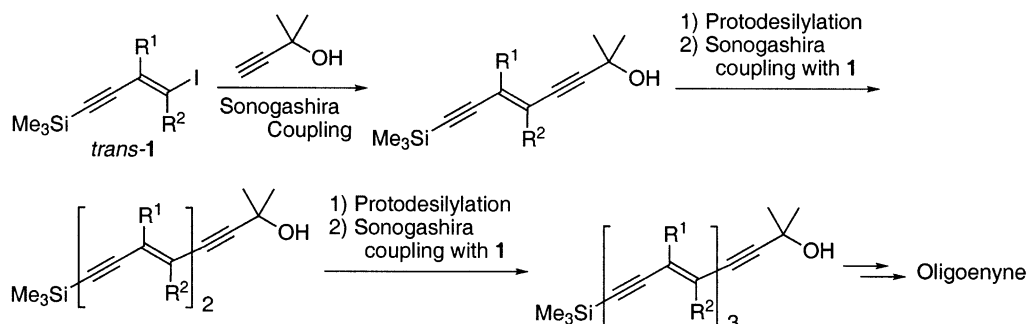
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ABSTRACT



Efficient and practical synthesis of a variety of 1-iodo-4-trimethylsilylbut-1-en-3-yne derivatives with *trans*- and *cis*-olefinic configuration, and their repeated use as building blocks for the synthesis of *trans*- and *cis*-oligoenynes, respectively, are described.

Linear polymers and oligomers containing an iteratively π -conjugated carbon scaffold such as the ene-, enyne-, endiyn-, and yne-scaffold exhibit a variety of interesting electronic and optical properties.¹ Because variations in their molecular structure such as the chain length, olefin-geometry, olefinic substituent, and end-capping group can result in significant modifications of their properties, the development of synthetic methodology which allows access to a wide range of each of these π -conjugated compounds has attracted continuing interest.² Herein, we report a highly efficient and general synthetic method for preparing oligoenynes with either *trans*- or *cis*-olefinic configuration. Polymers and oligomers having an enyne-scaffold can be prepared by topochemical solid-state polymerization of suitably prear-

ranged and substituted buta-1,3-diynes,³ a requirement, however, that severely limits their accessibility. Wudl and Bitter reported a synthetic method for preparing a systematic series of *trans*-oligoenynes using the coupling reaction of an alkynylmetal compound with *trans*-1,2-dihalo ethylene as the key reaction.⁴ However, extension of this coupling method for synthesizing oligoenynes having olefinic substituent(s) failed.⁵ An iterative approach to *cis*-oligoenynes with the Sonogashira coupling as the key reaction was reported by Hirsch and co-workers that allowed preparation of some kinds of oligoenyne with up to four triple and three double bonds, albeit the overall yield was rather low.⁶

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The characteristic features of our synthetic method for preparing oligoenynes include (1) efficient and practical synthesis of a variety of 1-iodo-4-trimethylsilylbut-1-en-3-yne derivative with *trans*- and *cis*-olefinic configuration, i.e., **1** and **2** shown in Figure 1, (2) repeated use of **1** and **2** as

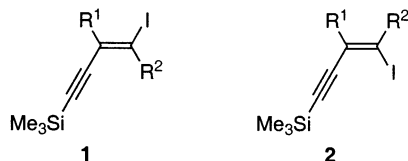
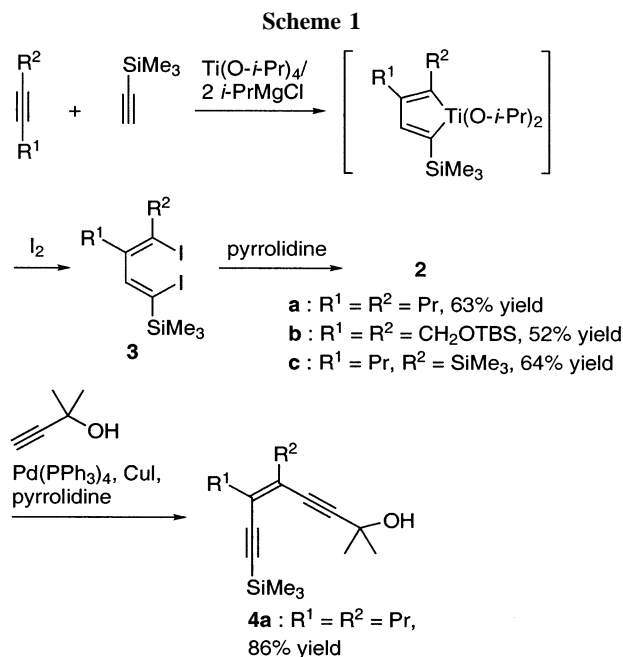


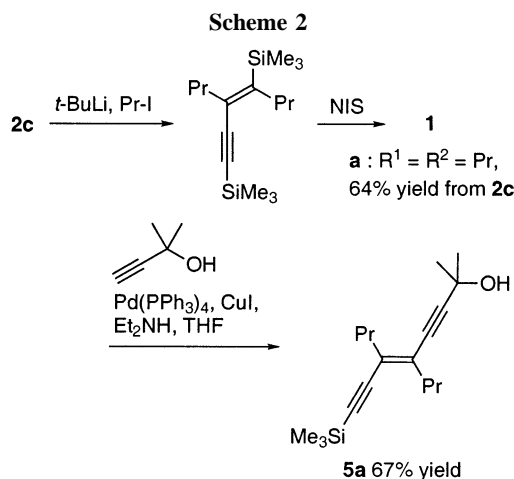
Figure 1.

building blocks, for the synthesis of *trans*- and *cis*-oligoenynes, respectively, and (3) use of the Sonogashira coupling reaction as the key carbon-elongation reaction.⁷

Recently, we have developed a one-pot method for synthesizing 1-trimethylsilyl-1,4-diiodo-1,3-alkadienes **3** via regioselective coupling of internal acetylenes and ethynyl-trimethylsilane mediated by a divalent titanium reagent Ti(O-*i*-Pr)₄/2 *i*-PrMgCl, and the following reaction of the resulting titanacyclopentadienes with I₂.^{8,9} We have now found that treatment of crude **3** with pyrrolidine afforded **2** in high overall yield as shown in Scheme 1. Meanwhile,

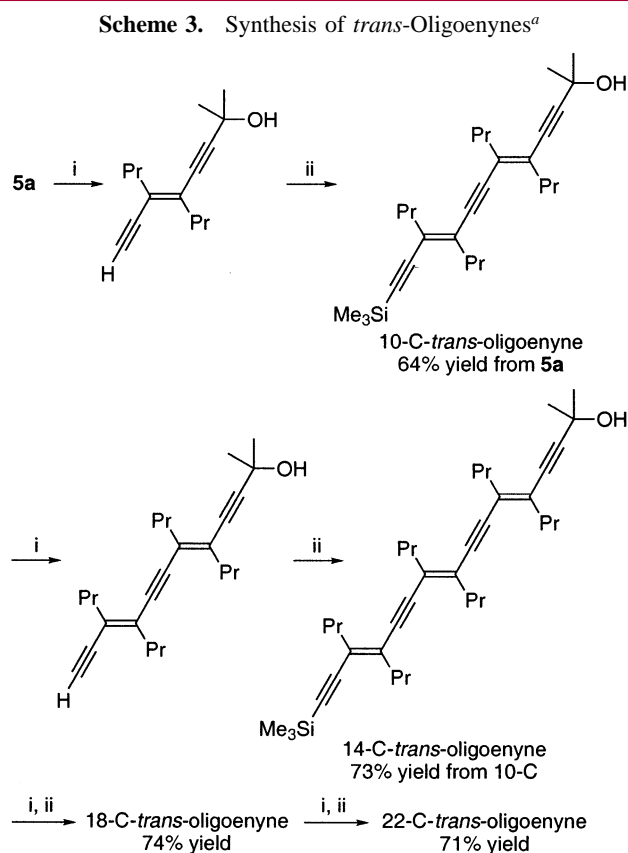


enynes **1** can be synthesized from **2** obtained by using 1-trimethylsilyl-1-alkynes as the internal acetylene by the conventional reaction sequence, as exemplified by the production of **1a** from **2c** as shown in Scheme 2. As also shown in Schemes 1 and 2, the Sonogashira coupling of **2** or **1** thus obtained with 3-methyl-1-butyn-3-ol provided



endiynes **4** and **5**, respectively, which can be utilized as the terminal unit for synthesizing polyenynol oligomers (vide infra).

Using **1a** and **5a** thus obtained, we carried out the synthesis of the corresponding *trans*-oligoenynes by sequential reactions which involve the Sonogashira coupling of **1a** with a terminal alkyne and removal of the trimethylsilyl group of the resulting product affording a new terminal alkyne, which

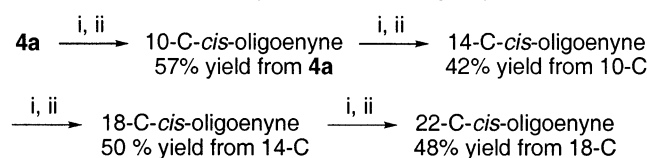


^a Reagents: (i) K₂CO₃, THF, MeOH, H₂O; (ii) **1a**, Pd(PPh₃)₄, CuI, Et₂NH, THF.

can be used for the next coupling with **1a**. Thus, oligoenyne with a 10-carbon atom backbone was prepared in 64% yield from **1a** and **5a** which, in turn, was converted into oligoenyne having a 14-carbon backbone in 73% yield by coupling, after desilylation, with **1a**. Applying these sequential reactions, oligoenynes with an 18- and a 22-carbon atom backbone were also prepared in good yield, respectively, as shown in Scheme 3. In the step of the Sonogashira coupling of **1a** with the terminal acetylenes, we used 2 equiv of **1a** to suppress production of the homo-coupling product of the terminal acetylenes. Even under these reaction conditions, 10–20% of the homo-coupling product was always coproduced; however, the homo-coupling product, which is a diol derivative, and the cross-coupling product, that is a monool derivative, and the starting nonpolar **1a** could be readily separated by column chromatography, and **1a** used in excess amount was recovered in excellent yield.

Using a similar reaction strategy, *cis*-oligoenynes having up to a 22-carbon atom backbone were prepared starting from **2a** and **4a** in the yields shown in Scheme 4. It should be

Scheme 4. Synthesis of *cis*-Oligoenynes^a



^a Reagents: (i) K₂CO₃, THF, MeOH, H₂O; (ii) **2a**, Pd₂(dba)₃, dppb, CuI, pyrrolidine.

noted that the Sonogashira coupling of **2a** with **4a** with the reagent shown in Scheme 3 afforded almost equal amounts of the cross- and homo-coupling products; however, use of Pd₂(dba)₃-dppb-CuI as the reagent improved the ratio of the cross- and homo-coupling products to 65:35. Thus, we used

the latter reagent for the Sonogashira coupling for the synthesis of *cis*-oligoenynes. In these reactions the resulting cross- and homo-coupling product also can be readily separated by column chromatography.

Oligoenynes thus obtained can be readily manipulated as exemplified by the transformation of 22-*C-trans*-oligoenylene shown in Scheme 5. Oligoenynes **7** having a different aryl end-cap can be readily synthesized by the successive deprotection of the trimethylsilyl group and 2-hydroxyisopropyl group and Sonogashira coupling, respectively, with an aryl iodide. The homo-coupling reaction of the oligoenyne under Hay condition¹⁰ after desilylation afforded poly- π -conjugated oligomer **8** with 12 triple and 10 double bonds.

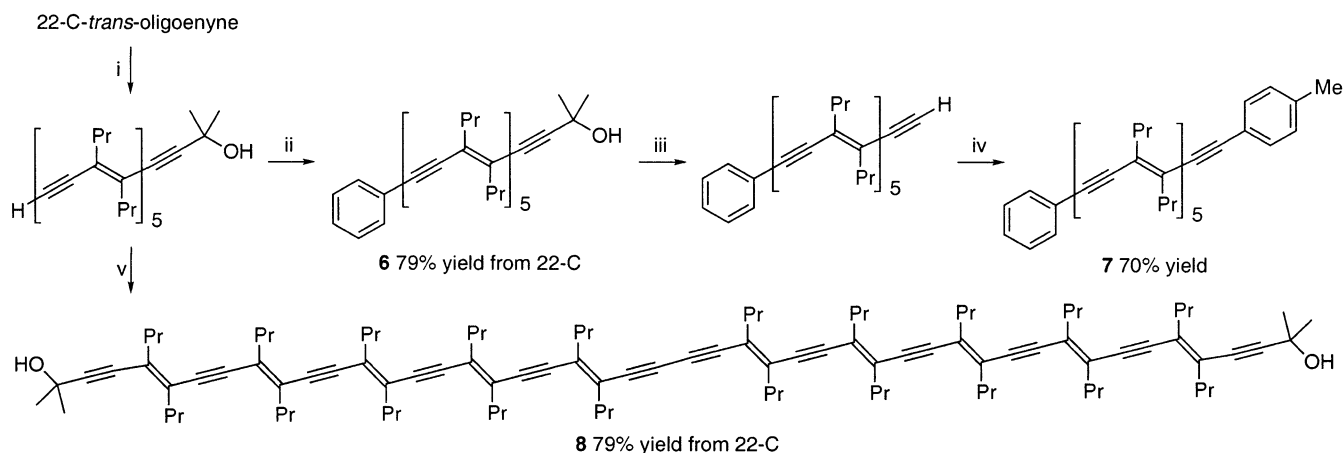
The electronic absorption spectra of the *trans*- and *cis*-oligoenynes thus prepared were measured in hexane at room temperature. The longest wavelength absorption maxima λ_{max} are summarized in Table 1. From Table 1, the following

Table 1. UV/Vis Data of *trans*- and *cis*-Oligoenynes

	λ_{max} [nm] (ϵ [M ⁻¹ cm ⁻¹])	
	<i>trans</i> -oligoenylene	<i>cis</i> -oligoenylene
10-C	346 (24 700)	343 (16 500)
14-C	385 (35 200)	348 (24 700)
18-C	386 (65 900)	351 (31 000)
22-C	400 (67 700)	340 (17 600)
6	401 (25 500)	
7	402 (21 600)	
8	427 (68 200)	

interesting trend can be seen, namely, that the longest energy electronic absorption in the series 10- to 14- to 18- to 22-*C*-oligoenynes goes from 346 to 385 to 386 to 400 nm for *trans*-oligoenynes, respectively, while for *cis*-oligoenynes, the conjugated lengths had already reached saturation and essentially the λ_{max} values for each of these *cis*-oligoenynes remained similar, around 345 nm.

Scheme 5. Manipulation of 22-*C-trans*-Oligoenyne^a



^a Reagents: (i) K₂CO₃, MeOH, THF, H₂O; (ii) PhI, Pd(PPh₃)₄, pyrrolidine; (iii) NaOH, toluene; (iv) 4-iodotoluene, Pd(PPh₃)₄, pyrrolidine; (v) CuCl, TMEDA, O₂.

Although we prepared oligoenynes using **1a** and **2a** as building blocks, a variety of **1** and **2** are accessible as shown in Schemes 1 and 2, and therefore, the present synthetic method might allow access to an oligoenyne with the designed structure.

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Supporting Information Available: Experimental procedures, spectroscopic data, and physical properties of **1a**, **2a**, **2c**, **4a**, **5a**, *trans*- and *cis*-oligoenynes, **6**, **7**, and **8**. This material is available free of charge via the Internet at <http://pubs.acs.org>.

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