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\[
\text{PhCOHN} + \text{Co}_2(\text{CO})_6 + \text{PhCOHN} \rightarrow \text{PhCOHN} + \text{PhCOHN}
\]
New approach to oligotriazoles using a cobalt complex of propargyl azides as a synthetic component

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According to the recent developments of Cu(I)-catalyzed azide-alkyne 1,3-dipolar cycloaddition (CuAAC) as the most useful ligation process in click chemistry, a variety of compounds with 1,4-disubstituted 1,2,3-triazole backbone have been synthesized. The 1,2,3-triazole linkage has been revealed to be a promising amide bond surrogate, particularly with respect to its structure and hydrogen-bonding ability, while it shows a higher chemical and biological stability in comparison with the amide bonds. Thus, it is now of great interest to elucidate the effects of replacement of an amide bond with a 1,2,3-triazole ring on the secondary structure as well as on the bioactivities in a wide range of amides. Recently, Angelo and Arora introduced a new class of oligotriazole as a peptidomimetic, named tirazolamer, in which the triazole rings and the sp3-hybridized carbons possessing amino acid side chains are alternately connected. They indicated that optically active trimeric and tetrameric triazolamers adopt zigzag conformations and show a potential inhibitory activity of HIV-1 protease.

Their synthetic method for preparation of triazolamer employs N-Boc propargylamines derived from amino acids as a synthetic component and involves a three-step iterative reaction sequence; diazotransfer to amines, CuAAC reaction of the resulting azides with N-Boc propargylamines, followed by deprotection of the amines. On the other hand, Hughes and co-workers described a more convenient synthesis of triazolamers employing propargyl azide possessing a trialkylsilyl group at the acetylenic terminal. Since the silyl group prevents the propargyl azides from self-polymerization by CuAAC reaction, extension of a triazolic chain can be attained by a two-step iterative reaction sequence involving CuAAC reaction and desilylation. In this letter, we wish to report a new approach to the synthesis of triazolamers utilizing a dicobalt hexacarbonyl complex of propargyl azides (CPA) as a synthetic component.

Alkenes are known to readily react with dicobalt octacarbonyl by simple mixing to the formation of alkyne–dicobalt hexacarbonyl complex, which can undergo oxidative degradation to liberate the alkenes. Thus, if the alkyne–cobalt complexes are inert to CuAAC, chain extension of triazolamers can be accomplished by only a repetition of CuAAC and oxidative deprotection of alkenes. Variety of CPAs can be readily prepared from not only propargyl azide with dicobalt octacarbonyl, but also propargyl alcohols or alk-3-en-1-ynes by Nicholas reaction via the alkyne–cobalt complexes.

We employed several types of CPA possessing a substituent (R) corresponding to the side chain of the natural amino acids. As...
we had expected, CPAs (2a–f) were readily prepared from the corresponding propargyl alcohols (1a–f) by Nicholas reaction using TMSN₃ and BF₃·ether (Table 1).⁹ Since 2g (R = CH₂CH₂SMe) possessing the side chain of methionine was found to be difficult to synthesize by the same method presumably due to the high nucleophilicity of sulfide group, it was prepared in a stepwise fashion from 1g in 61%; mesylation of the hydroxyl group 1g, nucleophilic substitution with sodium azide, followed by complexation with Co₂(CO)₈ (Eq 1).

Table 1. Preparation of CPA 2 by Nicholas Reaction

<table>
<thead>
<tr>
<th>CPA (2)</th>
<th>R</th>
<th>Reaction time</th>
<th>Yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>H</td>
<td>10 h</td>
<td>81</td>
</tr>
<tr>
<td>2b</td>
<td>Me</td>
<td>6 h</td>
<td>78</td>
</tr>
<tr>
<td>2c</td>
<td>i-Bu</td>
<td>3 h</td>
<td>88</td>
</tr>
<tr>
<td>2d</td>
<td>Bn</td>
<td>16 h</td>
<td>79</td>
</tr>
<tr>
<td>2e</td>
<td>CH₂OAc</td>
<td>8 h</td>
<td>71</td>
</tr>
<tr>
<td>2f</td>
<td>CH₂CH₂COOMe</td>
<td>5 h</td>
<td>86</td>
</tr>
</tbody>
</table>

⁹The reaction time of the second step.

⁹Yields from 1.

Scheme 1

We designed triazolamers possessing both amino and carboxyl groups on their termini to mimic the structure of peptide chains (Scheme 1). The CuAAC reaction between 2a and N-benzoylpropargylamine 3 was attempted under several conditions according to literatures,²b,¹⁰ and the best yield of 4a was obtained by using CuSO₄ and sodium L-ascorbate in a heterogeneous mixed solvent of dichloromethane and water (1 : 1).¹⁰b The crude reaction mixture obtained by CuAAC was directly treated with ceric ammonium nitrate (CAN) for deprotection of the alkyne followed by purification by column chromatography to give the corresponding monotriazole 4a in 76% yield.¹¹ The second reaction cycle was carried out on the resulting 4a using various types of CPA 2a–g under the same conditions, and bis(triazoles) 5 with various substituents were obtained in reasonable yields. The final elongation of 5 with methyl azidoacetate 6 gave tris(triazoles) 7 in good yields.

Epimerization at the asymmetric α-carbon of the carbonyl groups of peptide bonds has been a major challenge in peptide synthesis, as seen in its history. Thus, it is essential to employ synthetic methods free from racemization at the α-carbon in preparation of peptides. Since the same thing holds true for preparation of chiral triazolamers, we examined the possibility that our synthetic method is accompanied by epimerization at the asymmetric α-carbon between two triazoles and/or at the propargyl carbon of CPA. As shown in Scheme 2, by using (S)-2d,¹²,¹³ whose enantiomeric purity was 92% ee, we synthesized triazole 4d and bis(triazole) 8 in 79% and 75% yield, respectively. Both of them exhibited exactly the same enantiomeric purity as 2d (92% ee), indicating that no epimerization took place during a series of reactions for preparing triazolamers in the present procedure.

Scheme 2
References and notes


11. General procedure for chain extension by use of CPA. Preparation of 5d as a typical example. To a solution of 4a (120 mg, 0.500 mmol) and 2d (251 mg, 0.550 mmol) in CH2Cl2 (1.00 mL) were added an aqueous solution of CuSO4·5H2O (0.200 M, 0.50 mL) and an aqueous solution of sodium L-ascorbate (1.3 M, 0.50 mL). The resulting solution was stirred for 1.5 h at room temperature, and was diluted with CH2Cl2 and H2O. The organic layer was separated and washed with brine, dried over Na2SO4, and concentrated under vacuum. The crude mixture was dissolved in CH2Cl2 (1.50 mL) and an aqueous solution of sodium L-ascorbate (1.3 M, 0.50 mL). The reaction mixture was extracted with CH2Cl2, and the combined organic layers were washed with water, brine, dried over Na2SO4, and concentrated under vacuum. The residue was purified by flash column chromatography (hexane/EtOAc, 2:8) to give 5d (155 mg, 75% yield) as a white solid. mp 168–170 °C. H NMR (400 MHz, CDCl3) δ 7.61–7.76 (m, 2H), 7.67 (s, 1H), 7.56 (s, 1H), 7.54–7.39 (m, 3H), 7.25–7.19 (m, 3H), 7.04–6.98 (m, 2H), 6.85 (br. s, 1H), 5.66 (dd, J = 2.3, 5.5, 7.1 Hz, 1H), 5.60 (s, 2H), 4.72 (d, J = 5.5 Hz, 2H), 3.38 (dd, J = 5.5, 13.7 Hz, 1H), 3.34 (dd, J = 7.1, 13.7 Hz, 1H), 2.64 (d, J = 2.3 Hz, 1H). 13C NMR (100 MHz, CDCl3) δ 167.3, 144.9, 141.0, 134.0, 135.9, 131.7, 129.5, 128.6, 128.5, 127.7, 127.0, 122.3, 77.8, 77.2, 54.1, 45.4, 42.8, 35.4. HRMS m/z for C23H22N7O (M+H) +, calcd 412.1886, found 412.1876.


13. Recently, an asymmetric Nicholas reaction has been reported (see: ref. 14). Unfortunately, however, an enantioselective preparation of CPAs by Nicholas reaction have not appeared yet, to the best of our knowledge.