Platinum-catalyzed Tandem Carboalkoxylation-Claisen Rearrangement of Arylalkynes Bearing an *ortho*-1,5-Dihydro-3*H*-2,4-dioxepine Group

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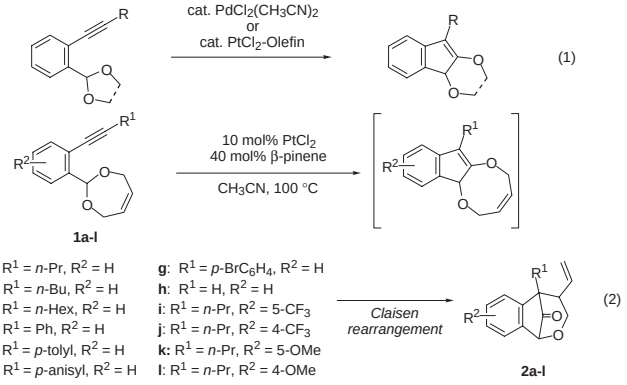
The platinum-catalyzed tandem carboalkoxylation-Claisen rearrangement reaction of arylalkynes **1** bearing an *ortho*-1,5-dihydro-3*H*-2,4-dioxepine group gave the corresponding tricyclic compounds **2** in good to allowable yields. For example, the reaction of 2-[2-(pent-1-ynyl)phenyl]-4,7-dihydro[1,3]dioxepin **1a**, 2-[2-(oct-1-ynyl)phenyl]-4,7-dihydro[1,3]dioxepin **1c**, and 2-[2-(phenylethynyl)phenyl]-4,7-dihydro[1,3]dioxepin **1d** in the presence of 10 mol % of $PtCl_2$ and 40 mol % of β-pinene in acetonitrile at 100 °C gave the corresponding tricyclic compounds **2a**, **2c**, and **2d** in 69, 63, and 50% yields, respectively.

Tandem reaction is one of the most powerful tools in organic synthesis since this process can construct complicated molecules by a single-step conversion. Especially, recent researches have revealed that transition metal catalysts enable to promote various kinds of tandem reactions, providing elaborate molecules in one pot.[1] However, the tandem reaction proceeding via addition of a carbon–oxygen bond to carbon–carbon multiple bond, so-called *carboalkoxylation*, has been rarely investigated.[2] Recently we reported that the platinum-catalyzed intramolecular carboalkoxylation of arylalkynes, which had an acyclic or cyclic acetal at the *ortho* position, gave the corresponding 1,2-dialkoxyindenes in good to excellent yields (Eq 1).[3] In the course of this investigation, we found that the reaction of arylalkynes **1** bearing an *ortho*-1,5-dihydro-3*H*-2,4-dioxepine group produced the corresponding tricyclic compounds **2** in good to allowable yields in the presence of catalytic amounts of $PtCl_2$ and β-pinene (Eq 2).

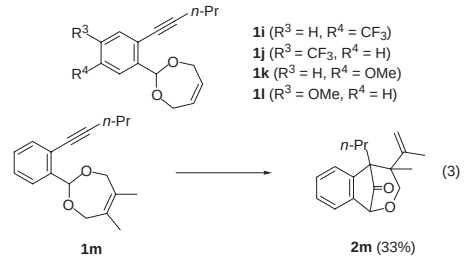


The results are summarized in Table 1. The reaction of 2-(2-pent-1-ynylphenyl)-4,7-dihydro[1,3]dioxepin **1a** in the presence of 10 mol % of $PtCl_2$ and 40 mol % of β-pinene in acetonitrile at 100 °C gave 1-(5-propyl-4-vinyl-1,3,4,5-tetrahydrobenz[*c*]-oxepin-5-yl)ethanone **2a** in 69% yield (Entry 1).[4] Other catalysts, such as $PtBr_2$, $Pt(PPh_3)_4$, $Ni(dppp)Cl_2$, $RhCl_3$, and $Y(OTf)_3$ did not promote this reaction at all. The reactions using other olefinic substrates (instead of β-pinene), such as benzoquinone, methylenecyclohexane, and isoprene, gave the product **2a** in lower yields.[5] The use of other solvents, such as CH_2Cl_2, benzene, toluene, and THF, was totally ineffective. The reaction of **1b** and **1c**, which had a *normal*-alkyl group as R^1 substituent, produced **2b** and **2c** in 56 and 63% yields, respectively (Entries 2 and 3). The reaction of **1d** , **1e**, **1f**, and **1g** bearing an arylethynyl group at the *ortho* position of the dioxepine group afforded the corresponding products **2d**, **2e**, **2f**, and **2g** in good to allowable yields (Entries 4–7). The reaction of the terminal alkyne **1h** proceeded sluggishly (Entry 8). The substrates bearing an electron withdrawing group on the aromatic ring were converted to the corresponding tricyclic compounds in good yields, while the reaction of **1k** and **1l**, which had a methoxy group on the benzene ring proceeded sluggishly (Entries 9–12). The reaction of **1m** bearing methyl groups both at the 5 and 6 position of the dioxepine moiety gave the product **2m** in 33% yield (Eq 3). The structures of the products **2** were determined by spectroscopic methods. Furthermore, the structure of **2f** was unambiguously determined by X-ray crystallographic analysis as shown in Figure 1.[6]

Table 1. Pt-catalyzed tandem carboalkoxylation-Claisen rearrangement of **1**

Entry	**1**	R^1	R^2	**2**	Yield / %
1	**1a**	*n*-Pr	H	**2a**	69
2	**1b**	*n*-Bu	H	**2b**	56
3	**1c**	*n*-Hex	H	**2c**	63
4	**1d**	Ph	H	**2d**	50
5	**1e**	*p*-tolyl	H	**2e**	52
6	**1f**	*p*-anisyl	H	**2f**	51
7	**1g**	*p*-BrC_6H_4	H	**2g**	35
8	**1h**	H	H	**2h**	20
9	**1i**	*n*-Pr	5-CF_3	**2i**	53
10	**1j**	*n*-Pr	4-CF_3	**2j**	45
11	**1k**	*n*-Pr	5-OMe	**2k**	23
12	**1l**	*n*-Pr	4-OMe	—	no reaction

[a]The reaction of **1** was carried out in the presence of 10 mol % of $PtCl_2$ and 40 mol % of β-pinene in CH_3CN at 100 °C for 17–90 h. [b]Isolated yield.



A plausible mechanism of the reaction of **1** is illustrated in Scheme 1. Platinum chloride is coordinated both by an oxygen atom of the dioxepine moiety and the alkyne moiety, forming

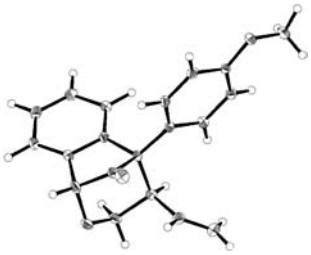
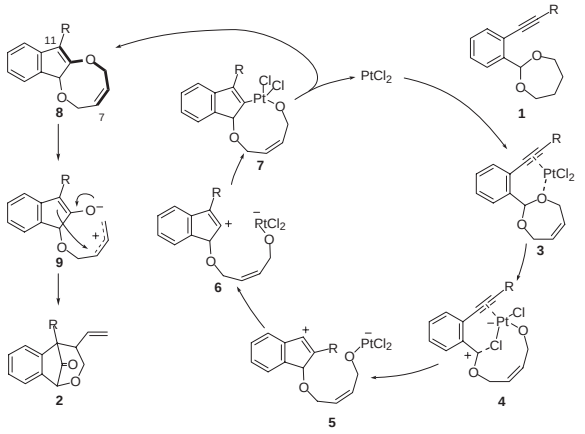


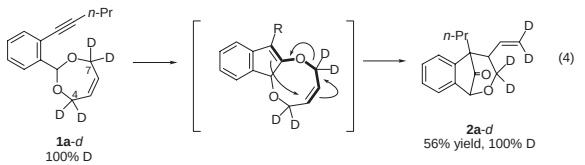
Figure 1. ORTEP drawing of **2f**.

the σ,π-chelate complex **3**.[3b] The C–O bond cleavage of the acetal moiety of **3** leads to the carbocation **4** in which the cation center is stabilized by intramolecular coordination of the chlorine atom. Nucleophilic attack of the alkynyl moiety to the carbocation, followed by the 1,2-alkyl rearrangement of the resulting vinyl cation intermediate **5** leads to the other vinyl cation species **6**, which is trapped by platinum to form the vinylplatinum intermediate **7**.[7] Reductive elimination of platinum chloride from **7** gives **8** which has an allyl vinyl ether moiety (1,5-diene system). Claisen rearrangement of **8** would take place under the reaction conditions, giving the product **2**. Since the distance between C7 and C11 of **8** (Scheme 1) is too long to occur Claisen-rearrangement concertedly, the product **2** would be formed through the zwitterionic intermediate **9**. It is not clear whether $PtCl_2$ participates in the Claisen-rearragenment.[8]

We conducted the reaction of **1a**-*d*, which had two deuteriums both at the 4 and 7 position of the dioxepine moiety (Eq 4). The reaction of **1a**-*d* under the same conditions as above produced **2a**-*d*, which had deuteriums at the terminal carbon of the vinyl group and at the methylene carbon of the tricyclic skeleton. This result corresponds with the proposed mechanism shown in Scheme 1.



Scheme 1.

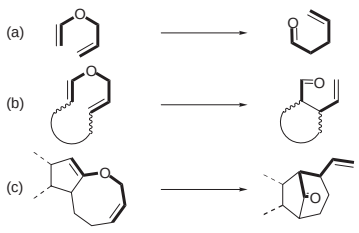


1a-*d*
100% D

2a-*d*
56% yield, 100% D

(4)

In conclusion, we are in a position to synthesize highly elaborate 1-(4-vinyl-1,3,4,5-tetrahydrobenz[*c*]oxepin-5-yl)ethanone derivatives **2** by the platinum-β-pinene-catalyzed tandem carboalkoxylation-Claisen rearrangement of *ortho*-alkenylphenyl-



Scheme 2. Claisen rearrangement; (a) acyclic allyl vinyl ethers, (b) cyclic allyl vinyl ethers, and (c) molecules having an allyl vinyl ether moiety in the fused ring system (the present reaction).

4,7-dihydro[1,3]dioxepins **1**, which are readily accessible from the corresponding *ortho*-alkynylbenzaldehyde.[9] In general, acyclic allyl vinyl ethers have been utilized in Claisen rearrangement reaction (Scheme 2, Type a).[10] However, the Claisen rearrangement using cyclic allyl vinyl ethers has been rarely investigated (Type b).[11] The present reaction, to the best of our knowledge, is the first example of Claisen rearrangement of fused bicyclic molecules bearing the vinyl allyl ether moiety in fused two-ring skeleton (Type c).

References and Notes

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4 General procedure of the reaction of **1**; To a mixture of $PtCl_2$ (13.3 mg, 0.05 mmol) and β-pinene (27.2 mg, 0.2 mmol) in acetonitrile (2 mL) was added **1** (0.5 mmol) under argon atmosphere in a Wheaton microreactor. After heating at 100 °C for 17–90 h, the reaction mixture was filtered through a short alumina column using hexane/ethyl acetate (4/1) as an eluent. Purification of the crude product by silica-gel column chromatography using hexane/ethyl acetate (49/1) as an eluent afforded **2**.

5 The reason for the activation of the carboalkoxylation reaction by β-pinene is not clear at present. See also Ref. 3b.

6 Crystallographic data of **2f** have been deposited with Cambridge Crystallographic Data Centre (CCDC) as supplementary publication no. CCDC-256881. Copies of the data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge, CB2 1EZ, UK; fax: +44 1223 336033; or deposit@ccdc.cam.ac.uk).

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8 The intermediate **8** was not isolated under the reaction conditions as above.

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