

Oppenauer-type synthesis of α,β -acetylenic ketones from tetra(phenylethynyl)tin and aromatic aldehydes

A. S. Levashov¹, D. S. Buryi¹, V. V. Konshin¹,
V. V. Dotsenko^{1,2}, I. V. Aksenova³ N. A. Aksenov³

¹*Kuban State University, 149 Stavropolskaya str, Krasnodar, 350040 Russia*
e-mail: aslevashov@mail.ru

²*ChemEx Lab, Vladimir Dal' Lugansk National University, 20A/7 Molodezhny,*
Lugansk, 91034 Russia

³*North-Caucasus Federal University, 1A Pushkina str., Stavropol, Russia*

Abstract

Tetra(phenylethynyl)tin reacts with aromatic aldehydes in the presence of a Lewis acid followed by the Oppenauer-type in situ oxidation of propargyl alcohols to give acetylenic ketones in a very good yield.

Keywords

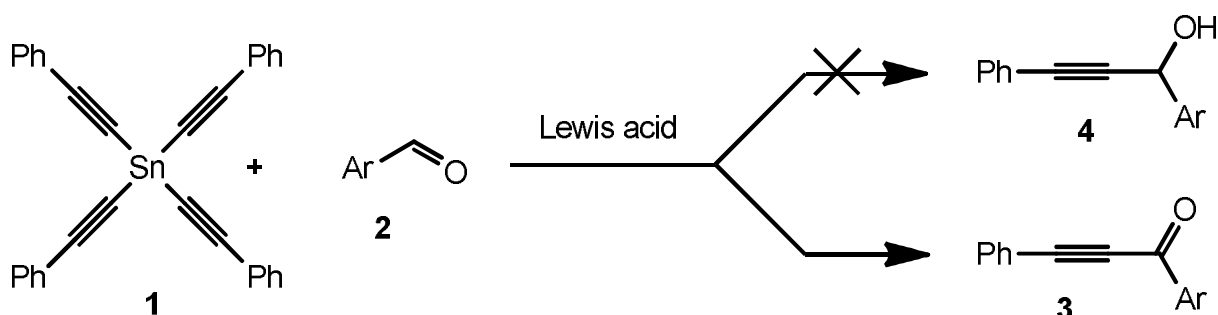
Organotin compounds, tetraalkynylstannane, Oppenauer oxidation, α,β -acetylenic ketones

α -Acetylenic ketones are highly reactive compounds widely used for the synthesis of various carbo- and heterocycles such as pyrroles [1], chromones [2, 3], indenones [4], quinolones [5], benzodiazepines [6], spirocycles [7], etc. One of the most general methods for the synthesis of α -acetylenic ketones is based on the reaction of metal acetylides with aldehydes, followed by oxidation of propargyl alcohols formed [2, 5, 8–11]. Trialkylstannylacetylenes $\text{Alk}_3\text{Sn}-\text{C}\equiv\text{C}-\text{R}$ are tolerant with respect to many functional groups, therefore they are actively used as alkynylating reagents as well as reagents in cross-coupling reactions [12, 13]. Prior we have developed effective methods for the preparation of tin tetraacetylides $(\text{RC}\equiv\text{C})_4\text{Sn}$ starting from terminal alkynes and tin tetrachloride [14, 15] or tin tetra(N,N-dialkylcarbamates) [16]. One may expect that the resulting tetraalkynylstannanes $(\text{RC}\equiv\text{C})_4\text{Sn}$ will have certain advantages over trialkylstannylacetylenes $\text{Alk}_3\text{Sn}-\text{C}\equiv\text{C}-\text{R}$, due to atom-efficiency and lower toxicity. To date, the properties of tin tetraacetylides

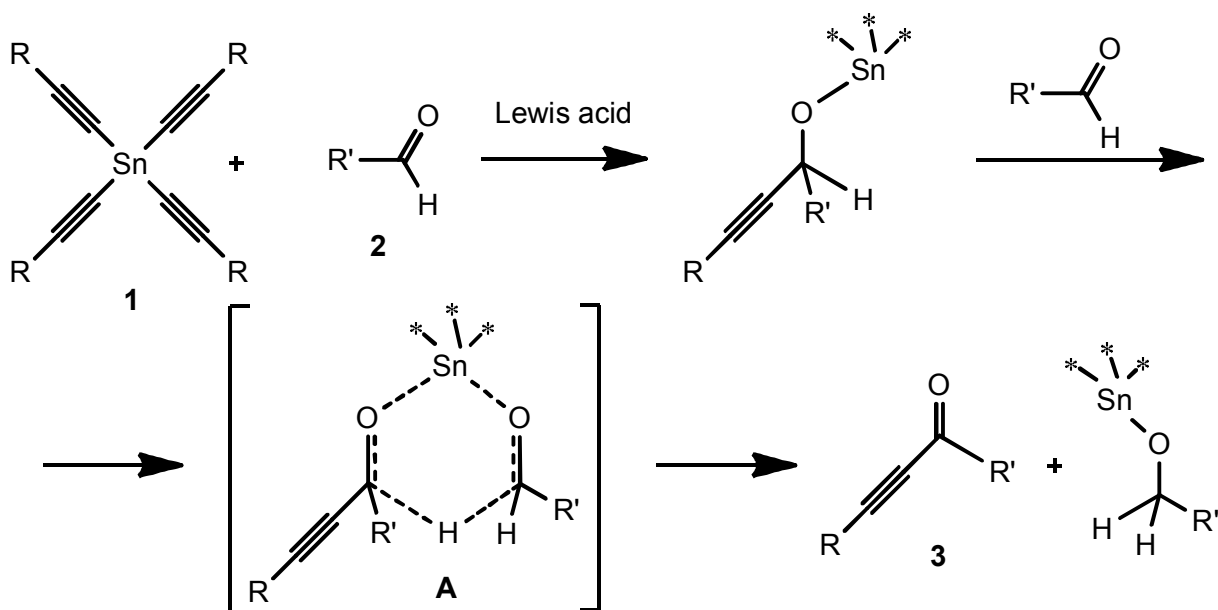
$(RC\equiv C)_4Sn$ have been studied insufficiently and their application in organic synthesis is limited to several reactions with organometallic or organoboron compounds [17, 18].

Recently we found that tetraalkynylstannanes $(RC\equiv C)_4Sn$ are useful in the Stille cross-coupling reaction with aryl halides [19]. Noteworthy that all four alkynyl fragments are involved into this process, *i.e.*, the reaction has a high E-factor, and gave relatively non-toxic inorganic tin(IV) halides as a by-products.

Here we studied the reactivity of $(RC\equiv C)_4Sn$ with respect to $ArCHO$. Thus, it was found that the reaction of tetra(phenylethynyl)tin **1** with aromatic aldehydes **2** occurred in the presence of $ZnCl_2$ at $60^\circ C$. However, α -acetylenic ketones **3** were obtained as the main products instead of expected propargyl alcohols **4**.



Presumably, the reaction proceeds through the Oppenauer oxidation step, similar to the oxidative addition of alkynes to $RCHO$ in the presence of $InBr_3$ [20]. The tin alkoxides formed in the first stage are rapidly oxidized by Oppenauer reaction with the second aldehyde molecule to form ketone **3** and the corresponding alcohol (detected by LCMS).



* = alkynyl or alkoxy

Target α -acetylenic ketones **3** were readily isolated by column chromatography eluting with toluene. The structure of the obtained compounds was confirmed by ^1H , ^{13}C NMR, IR spectroscopy, and LCMS data. The structure of 1-(2,3-dihydro-1,4-benzodioxin-6-yl)-3-phenylprop-2-yn-1-one was additionally confirmed by X-ray diffraction analysis.

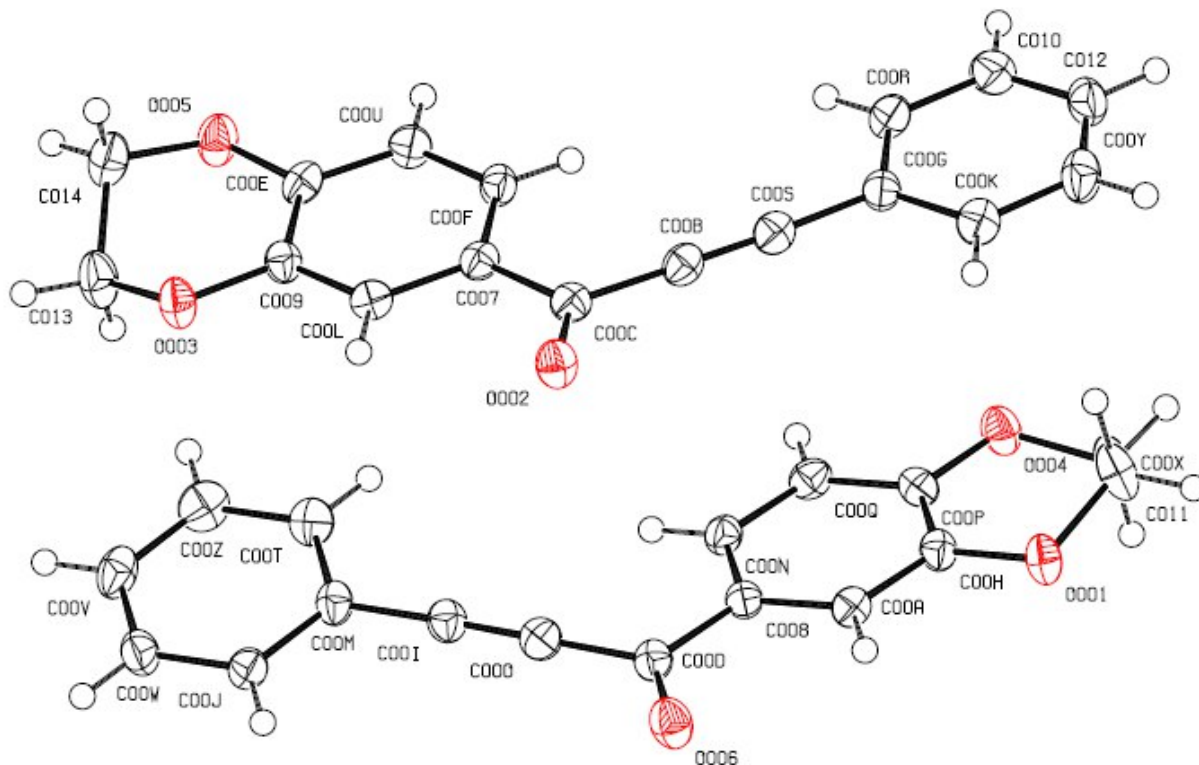


Figure 1. The structure of 1-(2,3-dihydro-1,4-benzodioxin-6-yl)-3-phenylprop-2-yn-1-one (by X-ray).

In summary, tetra(phenylethynyl)tin reacted with aromatic aldehydes in the presence of ZnCl_2 to form acetylenic ketones. The proposed reaction mechanism involves the Oppenauer oxidation of tin propargyl alcoholates.

Experimental

Tetra(phenylethynyl)tin was prepared according to the procedure [14].

Preparative procedure for the synthesis of **1,3-diphenylprop-2-yn-1-one**.

A 2-mL sealable Wheaton vial was charged with 10.4 mg (0.076 mmol) of anhydrous ZnCl_2 , toluene (0.8 mL), 100 mg (0.191 mmol) of tetra(phenylethynyl)tin and 155 μL (1.53 mmol) of freshly distilled PhCHO . A reaction mixture was stirred at 60 $^\circ\text{C}$ for 5 h, then treated with 1M aqueous HCl . The product was extracted with HCCl_3 and purified by column chromatography (eluent - PhMe). The yield of ketone $\text{Ph-C}\equiv\text{C-C(O)Ph}$ was

154.6 mg (98 %) as light yellow oil. ^1H NMR (400 MHz, CDCl_3) δ 7.39–7.53 (m, 5 H, Ar), 7.60–7.69 (m, 3 H, Ar), 8.22 (d, $J = 7.3$ Hz, 2 H, Ar); ^{13}C NMR (100 MHz, CDCl_3) δ 86.8, 93.1, 120.1, 128.6, 128.7, 129.5, 130.8, 133.0, 134.1, 136.8, 177.9. IR (liquid film, cm^{-1}) ν_{max} 3099.9, 3082.6, 3059.5, 3034.4, 2199.1 ($\text{C}\equiv\text{C}$), 1641.6 ($\text{C}=\text{O}$), 1597.2, 1581.8. MS (m/z , EI, 70 eV) (I_{rel} (%)): 206 (M^+ , 52), 178 (88), 152 (11), 129 (100), 101 (14), 89 (11), 77 (26), 76 (21), 75 (33), 51 (35).

1-(2,3-Dihydro-1,4-benzodioxin-6-yl)-3-phenylprop-2-yn-1-one was prepared similarly from tetra(phenylethynyl)tin (64.4 mg, 0.123 mmol) and 2,3-dihydro-1,4-benzodioxin-6-carbaldehyde (161.9 mg, 0.986 mmol). The reaction product was isolated by column chromatography, eluent – toluene. Yield 100 mg (77%), pale yellow crystals, mp 98.5–99.7°C (hexane–chloroform). IR spectrum (KBr), ν , cm^{-1} : 3065 ($\text{C}_{\text{sp}2}\text{-H}$), 2986, 2938, 2922, 2891, 2876 ($\text{C}_{\text{sp}3}\text{-H}$), 2203 ($\text{C}\equiv\text{C}$), 1626 ($\text{C}=\text{O}$), 1601, 1584. ^1H NMR spectrum (CDCl_3), δ , ppm: 4.28–4.30 (m, 2H, OCH_2), 4.32–4.34 (m, 2H, OCH_2), 6.95 (d, 1H, ArH, $J = 8.2$ Hz), 7.38–7.48 (m, 3H, ArH), 7.64–7.66 (m, 2H, ArH), 7.74–7.77 (m, 2H, ArH). ^{13}C NMR spectrum (CDCl_3), δ C, ppm: 64.2, 64.9, 87.0, 92.4, 111.5, 119.0, 120.4, 124.0, 128.7, 130.7, 131.1, 133.1, 143.5, 149.2, 176.6. Mass spectrum (EI, 70 eV), m/z (I_{rel} , %): 264 (100) [M] $^+$, 236 (53), 180 (49), 152 (50), 129 (65), 126 (15), 101 (11), 75 (18), 51 (23).

References

1. Zou, J., Zeng, G., Yang, R., and Yin, B., *Synthesis*, 2017, vol. 49, p. A-1.
2. Schmidt, B., Riemer, M., and Schilde, U., *Eur. J. Org. Chem.*, 2015, vol. 2015, p. 7602.
3. Jonušis, M., Šteinys, L., Bukšnaitienė, R., and Čikotienė, I., *Synthesis*, 2016, vol. 48, p. A-1.
4. Song, Y.-K., Qian, P.-C., Chen, F., Deng, C.-L., and Zhang, X.-G., *Tetrahedron*, 2016, vol. 72, p. 7589.
5. Shao, J., Huang, X., Hong, X., Liu, B., and Xu, B., *Synthesis*, 2012, vol. 44, no. 12, p. 1798.
6. Yin, L. and Wang, L., *Tetrahedron Lett.*, 2016, vol. 57, no. 52, p. 5935.
7. Clarke, A.K., James, M.J., Brien, P.O., Taylor, R.J.K., and Unsworth, W.P., *Angew. Chem. Int. Ed.*, 2016, vol. 55, p. 13798
8. Livingston, R., Cox, L.R., Odermatt, S., and Diederich, F., *Helv. Chim. Acta*, 2002, vol. 85, no. 10, p. 3052.

9. Müller, V.E., Beißner, C., Jäkle, H., Langer, E., Muhm, H., Odenigbo, G., Sauerbier, M., Segnitz, A., Streichfuß, D., and Thomas, R., *Lieb. Ann. Chem.*, 1972, vol. 754, p. 64.
10. Jong, T.-T. and Leu, S.-J., *J. Chem. Soc., Perkin Trans. 1*, 1990, no. 2, p. 423.
11. Ushijima, S., Dohi, S., Moriyama, K., and Togo, H., *Tetrahedron*, 2012, vol. 68, no. 5, p. 1436.
12. Suzuki, I., Esumi, N., Yasuda, M., and Baba, A., *Chem. Lett.*, 2015, vol. 44, no. 1, p. 38.
13. Okabe, T., Kuzuhara, D., Suzuki, M., Aratani, N., and Yamada, H., *Org. Lett.*, 2014, vol. 16, no. 13, p. 3508.
14. Levashov, A.S., Andreev, A.A., and Konshin, V.V., *Tetrahedron Lett.*, 2015, vol. 56, no. 14, p. 1870.
15. Russian Patent 2317993, 2006;
16. Levashov, A.S., Andreev, A.A., Buryi, D.S., and Konshin, V.V., *Russ. Chem. Bull.*, 2014, vol. 63, p. 775.
17. Jaumier, P., Jousseau, B., and Lahcini, M., *Angew. Chem. Int. Ed.*, 1999, vol. 38, p. 402.
18. Wrackmeyer, B. and Kehr, G., *J. Organomet. Chem.*, 1995, vol. 501, nos. 1–2, p. 87.
19. Levashov, A.S., Buryi, D.S., Goncharova, O.V., Konshin, V.V., Dotsenko, V.V., and Andreev, A.A., *New J. Chem.*, 2017, vol. 41, p. 2910.
20. Ogiwara, Y., Kubota, M., Kurogi, K., Konakahara, T., and Sakai, N., *Chem. Eur. J.*, 2015, vol. 21, no. 51, p. 18598.