

Solventless and Mild Procedure to Prepare Organotellurium(IV) Compounds under Microwave Irradiation

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Tellurium(IV) tetrachloride, *p*-methoxyphenyltellurium trichloride and the corresponding products of its reaction with alkynes were prepared under very mild reaction conditions, in absence of organic solvents and in short reaction times all assisted by microwave irradiation.

Keywords: hypervalent tellurium, microwave irradiation, biological activity

Introduction

The chemistry of organotellurium(II) compounds is well established¹⁻³ and found use in organic synthesis.⁴ The chemistry of organotellurium(IV), however, is still little developed⁵ and the reactions leading to them often employ solvents like carbon tetrachloride and benzene,¹⁻⁵ which are undesirable due to their harmful properties. Furthermore, these reactions take a considerable time to occur under reflux in the mentioned solvents.

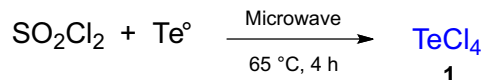
An interesting feature of organotellurium(IV) compounds is the discovery that some of them present important biological properties,^{6,7} and in a recent publication their unexplored therapeutic potential was pointed out.⁸ Among the organotellurium(IV) compounds showing biological activity are the diorganotellurium(IV) chlorides **3b**, which present, for example, cathepsin inhibitory action⁹ and protective effect in pilocarpine-induced status-epilepticus.¹⁰ This fact encourages the search for more practical and environmentally attractive methods for their preparation.

In this communication we report some reactions previously performed in the above mentioned solvents under reflux or under harsh reaction conditions, simply by keeping the reagents in contact in the absence of solvents for a short period of time under microwave irradiation. The reaction investigated in more detail was the addition of *p*-methoxyphenyltellurium trichloride to alkynes, which

was already studied using benzene as the solvent.¹¹⁻¹³ For comparison purposes, in the present work some examples of this reaction were performed by both methods.

Results and Discussion

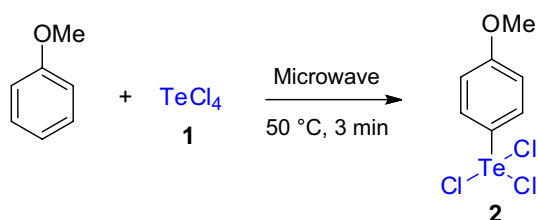
Tellurium tetrachloride is the reagent of choice to prepare a number of organotellurium(IV) compounds.¹⁻⁵ Classically, this compound is prepared in the laboratory by a tedious and hazardous method described in Inorganic Synthesis,¹⁴ which consists in the direct reaction of elemental tellurium with a stream of chlorine at high temperature, followed by distillation of the tellurium tetrachloride into glass ampoules. Recently, a more friendly method for the preparation of tellurium tetrachloride was described, consisting in the reaction of elemental tellurium with a six-fold excess of SO₂Cl₂ under reflux for 72 h, followed by distillation of the excess of SO₂Cl₂.¹⁵ In the present work, this method was improved by using a three-fold excess of SO₂Cl₂ over elemental tellurium under microwave irradiation at 100 W for 4 h at 65 °C. The excess of SO₂Cl₂ was removed by distillation and reused in further TeCl₄ preparations. The yield of TeCl₄ formed as a white solid was 94%, which was used for further reactions without previous purification (Scheme 1).



Scheme 1.

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In the past, the reaction of activated aromatic hydrocarbons with tellurium tetrachloride in carbon tetrachloride under reflux for several hours was the method of choice to prepare aryltellurium trichlorides.¹⁻⁵ In view of the hazards associated with the use of carbon tetrachloride as solvent, a more convenient method to prepare aryltellurium trichlorides is desirable. We found that tellurium tetrachloride heated at 120 °C reacts immediately with activated aromatic compounds in the absence of solvents with copious evolution of hydrochloric acid, giving the aryltellurium trichlorides in high yields.¹⁶ In the present work, this method was further improved by reacting the tellurium tetrachloride prepared as described above with anisole at 50 °C under microwave irradiation at 100 W for 3 min to give *p*-methoxyphenyltellurium trichloride in 86% yield (Scheme 2).



Scheme 2.

The *p*-methoxyphenyltellurium trichloride prepared as described above was used to investigate its addition reaction to alkynes under microwave irradiation in the absence of solvents (Scheme 3). This reaction has been investigated in our^{12,13} and other¹¹ laboratories using equimolar amounts of the alkyne and the aryltellurium trichloride in benzene under reflux. In order to compare the traditional method with the one developed in the present work, we repeated some of the previously performed reactions in benzene. The results are shown in Table 1. In the present method, the reagents were mixed in a pressure resistant tube equipped with a stirring bar and placed in a microwave oven apparatus.

After the time indicated in Table 1, the tube was opened and the solid was dissolved in chloroform and precipitated with hexane to give analytically pure samples with the yields shown in Table 1. As can be observed, the reaction time

changed from 8-10 h under reflux in benzene to 8-10 min at 70-75 °C under microwave irradiation at 100 W in the absence of solvents, and the yields improved from 58-74 to 68-85%. The extraction, drying and silica gel filtration steps were eliminated. The recrystallization process of the products obtained by this method was much easier as compared with the recrystallization of the products obtained when benzene was used as the reaction solvent. In all but one case a single product was formed. The structure assignment of the obtained products was made by comparison of their spectral data with those published previously, when a detailed study of the regio- and stereochemistry of the addition products of *p*-methoxyphenyltellurium trichloride to alkynes was made.¹³ In the reaction with propargyl alcohol (Table 1, entry 3d), a mixture of two products were formed. These results are in agreement with a previous work.¹³ Finally, the reduction of the tellurium(IV) compounds to tellurium(II) compounds was easily accomplished by reaction with a saturated solution of sodium bisulfite. This transformation was important to determine the isomer ratio in the reaction with propargyl alcohol (Table 1, entry 3d), since the chromatographic separation of the tellurium(IV) compounds failed (Scheme 4).

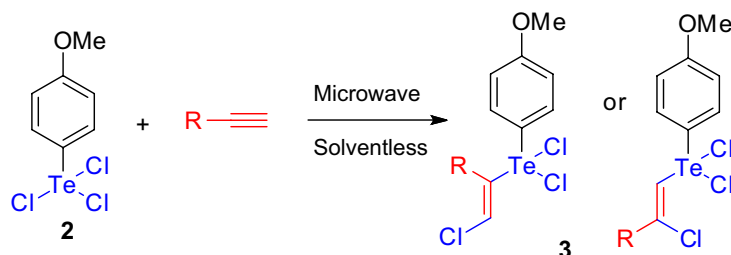
Conclusions

In conclusion, an easy and ecofriendly method to prepare tellurium(IV) compounds was developed using microwave irradiation of the reaction mixture in the absence of solvents. Under the conditions employed in this communication, the reactions occur in shorter reaction times and at lower temperatures than in the preceding published methods, avoiding the use of harmful solvents and harsh reaction conditions.

Experimental

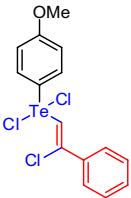
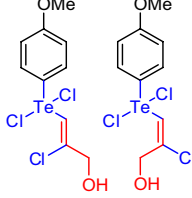
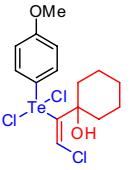
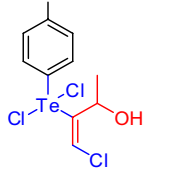
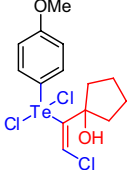
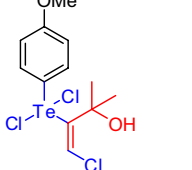
General information

Microwave reactions were performed with a CEM Discover Synthesis Unit (CEM Co., Matthews, NC, USA),

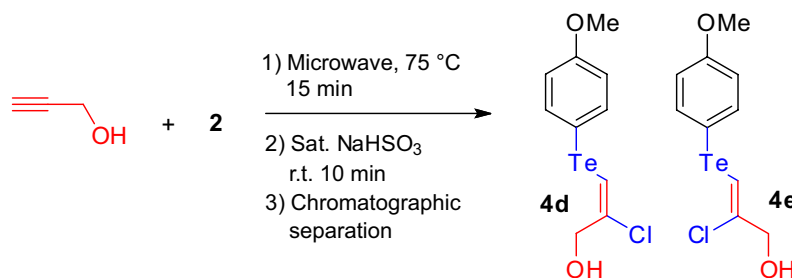


Scheme 3.

Table 1. Comparison of the results obtained under conventional heating and under microwave irradiation

Product	Method	Reaction time	Temperature / °C	Yield / %	Product	Method	Reaction time	Temperature / °C	Yield / %
3a 	A	10 h	Reflux	74	3d and 3e^a 	A	10 h	Reflux	65
	B	10 min	75	82		B	15 min	75	79
3b 	A	8 h	Reflux	63	3f 	A	10 h	Reflux	55
	B	15 min	70	79		B	15 min	75	68
3c 	A	8 h	Reflux	58	3g 	A	6 h	Reflux	60
	B	15 min	70	72		B	15 min	75	85

^aThe **3d/3e** compound mixture was reduced with excess sodium bisulfite and purified by column chromatography in silica gel, thus allowing the separation of the corresponding **4d** and **4e** tellurides. The spectral data of **4d** and **4e** are in agreement with published data.¹³ Method A: reflux in benzene; B: solventless under microwave irradiation.

**Scheme 4.**

with a continuous focused microwave power delivery system in a glass vessel (10 or 35 mL) sealed with Teflon cap, under magnetic stirring. Analytical thin layer chromatography (TLC) for monitoring reactions was performed using Merck 0.2 mm silica gel 60 F-254 Al-plates. Nuclear magnetic resonance (NMR) spectra were recorded on a Bruker AC 200 spectrometer (Bruker BioSpin GmbH, Rheinstetten, Baden-Württemberg, Germany) operating at 200, 50 and 63 MHz for ¹H, ¹³C and ¹²⁵Te NMR, respectively. CDCl₃ and DMSO-*d*₆ were used as solvents and as internal references, tetramethylsilane (TMS) for ¹H NMR, CDCl₃ for ¹³C NMR

and diphenylditelluride for ¹²⁵Te NMR, chemical shifts (δ) are given in parts *per* million and coupling constants (*J*) in Hz. All reagents are commercial grade and were pretreated before use, when needed (all reagents were purchased from Sigma-Aldrich Co., St. Louis, MO, USA).

Preparation of tellurium tetrachloride (1)

Reaction under conventional heating¹⁵

In a 500 mL round bottomed flask equipped with a reflux condenser, drying tube and a magnetic stirring bar,

were placed elemental tellurium (200 mesh) previously dried overnight in an oven at 100 °C (63.8 g, 0.5 mol) and SO₂Cl₂ (250 mL, 3.0 mol). The mixture was refluxed for 72 h until all the tellurium powder was consumed. After this time, the excess of SO₂Cl₂ was removed by distillation under vacuum. A white solid was obtained, which was submitted to high vacuum under a water bath heating to remove any trace of SO₂Cl₂ and then used without further purification. Yield: 119.8 g (89%).

Reaction under microwave irradiation

In a 50 mL round bottomed flask equipped with a Vigreux column (25 cm), a reflux condenser and a drying tube, were placed elemental tellurium (200 mesh) previously dried overnight in an oven at 100 °C (3.82 g, 30 mmol) and SO₂Cl₂ (7.5 mL, 90 mmol). The system was placed into the oven of a microwave apparatus and then it was irradiated for 4 h at 65 °C and at 100 W. After this time all the tellurium powder was consumed and the excess of SO₂Cl₂ was removed by distillation under vacuum, leaving behind a white solid which was submitted to high vacuum and heating as described above and then used for further reactions without purification. Yield: 7.59 g (94%).

Preparation of *p*-methoxyphenyltellurium trichloride (**2**)

Reaction under conventional heating

The procedure described by Cunha *et al.*¹⁶ was employed using the tellurium tetrachloride prepared as described for **1** (26.9 g, 100 mmol) and neat anisole (10.8 mL, 100 mmol). The yellow solid obtained was recrystallized from acetic acid. Yield: 24.2 g (71%); m.p.: 181-182 °C, literature:^{2,17} 182 °C.

Reaction under microwave irradiation

In a glass pressure resistant tube (35 mL) equipped with a magnetic stirring bar were placed tellurium tetrachloride prepared as described for **1** (1.02 g, 8 mmol) and neat anisole (0.87 mL, 8 mmol). The tube was closed and placed in the oven of a microwave apparatus and then irradiated for 3 min at 50 °C and at 100 W, after cooling to room temperature. The solid was washed with ethyl acetate (3 × 2 mL) and dried under reduced pressure. Yield: 2.34 g (86%); m.p.: 181-182 °C, literature:^{2,17} 182 °C.

Addition of *p*-methoxyphenyltelluriumtrichloride to alkynes, typical procedure

Reaction under conventional heating - general procedure

To a 100 mL round bottomed flask equipped with a reflux condenser and a magnetic stirring bar were

added *p*-methoxyphenyltellurium trichloride prepared as described for **2** (15 mmol), the alkyne (15 mmol) and benzene (50 mL). The mixture was heated under reflux for 8 h and the reaction was monitored by TLC eluting with a mixture of hexane:ethyl acetate (4:1). After all the alkyne was consumed, the mixture was treated with methanol: water (1:1) (3 × 30 mL) and extracted with ethyl acetate (3 × 25 mL). The organic phases were dried with MgSO₄ and the solvent was evaporated. The residue was filtered through silica gel eluting with ethyl acetate. After drying, filtering and evaporating the solvent, the residue was dissolved in chloroform and precipitated with hexane (for yields see Table 1).

Reaction under microwave irradiation - general procedure

To a glass pressure resistant tube (10 mL) equipped with a magnetic stirring bar were added the alkyne (1 mmol) and *p*-methoxyphenyltellurium trichloride (1 mmol). The tube was then placed in the oven of a microwave apparatus and irradiated. Temperature and irradiation time being modified depending on the used alkyne. After that, the tube was opened and the residue was dissolved in chloroform and precipitated with hexane.

Supplementary Information

Supplementary data are available free of charge at <http://jbcbs.sbg.org.br> as PDF file.

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