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Efficient Synthesis of 2,4-Bis(phenyl)-1,3-diselenadiphosphetane-2,4-diselenide (Woollins' Reagent)

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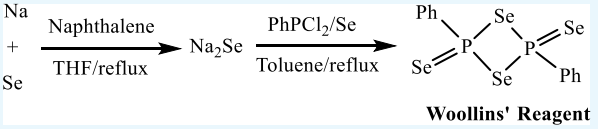
ABSTRACT: An improved approach for the preparation of 2,4-bis(phenyl)-1,3-diselena-2,4-diphosphetane-2,4-diselenide (Woollins' reagent) is described. Reacting dichlorophenylphosphine with Na_2Se which was *in situ* prepared from the reaction of elemental selenium and metal sodium in the presence of naphthalene in refluxing tetrahydrofuran generated Woollins' reagent with excellent purity and a yield of up to 96.4%.

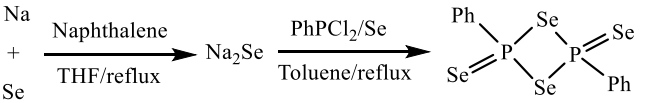


INTRODUCTION

The chemistry of 2,4-bis(phenyl)-1,3-diselena-2,4-diphosphetane-2,4-diselenide $(PhPSe_2)_2$ has received attention since it was suggested to be named as Woollins' reagent (**WR**).[1] **WR** has been used for a range of transformations and heterocycle syntheses for the past 2 decades.[2−14] It has been successfully applied as an efficient building unit or block to synthesize a series of 8-, 9-, and 10-membered selenophosphorus heterocycles with the P−Se−Se−P linkage[15] and unique octaselenocyclododecane with four carbon atoms and eight selenium atoms in this 12-membered cycle.[16] Another attractive application has been its ability to act as a highly chemoselective reagent, such as in the reduction of a wide range of 1,4-enediones and 1,4-ynediones in methanol, which led to saturated 1,4-diketones,[17] and the selective reduction of the double bond of 2-α,β-unsaturated thiazo and selenazolidinones, which gave the corresponding saturated heterocycles in good yields.[18] **WR** has also been used as a reducing reagent to transform porpholactone into dihydroporpholactone in 40% yield or into adjacent tetrahydroporpholactone in 75% isolated yield.[19] We have previously reported the synthetic method of **WR** involving liquid ammonia.[20]

RESULTS AND DISCUSSION

Here, we report a modified method for the synthesis of **WR**, which does not involve the use of liquid ammonia. We hope that this procedure will help facilitate further development of **WR**. The following procedure may be scaled down 5-fold or 10-fold with no loss of yield. The method involves the use of the unpleasant dichlorophenylphosphin; however, it avoids the handling of potentially hazardous liquid ammonia. In addition, the method produces a product of high purity in a higher yield and by a cleaner process, and the major advantage of this method is that it can be achieved on a large scale and at high quality by using normal glassware.



EXPERIMENTAL SECTION

Caution. This reaction involves toxic selenium powder, highly reactive sodium metal, and extremely malodorous *P,P*-dichlorophenylphosphine. The reactions should be carried out in a well-ventilated fume cupboard, and gloves should always be worn. The procedure should be performed under an inert atmosphere.

Sodium metal (in small pieces, 14.75 g, 640 mmol) was added to a solution of dry tetrahydrofuran (THF) (750 mL) and naphthalene (8.2 g, 64 mmol) at room temperature, resulting in a black suspension. Selenium (25.2 g, 320 mmol) was added, and the suspension was refluxed for 24 h to give Na_2Se as an off-white solid after THF was removed *in vacuo*. Toluene (750 mL) was added, $PhPCl_2$ (45.5 mL, 640 mmol) was added, and the mixture was refluxed further for 24 h. The reaction mixture was cooled to under 100 °C and filtered by passing through a thick layer of dry Celite to remove the NaCl (or using a filter cannula method). A second portion of selenium (42.1 g, 540 mmol) was added, and the reflux was continued for another 24 h. A second portion of $PhPCl_2$ (20 mL, 281 mmol) was added, and the mixture was refluxed for another 12 h. Upon cooling to room temperature, **WR** (81.65 g, 96.4%) was collected by filtration

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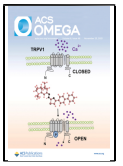

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and washing with cold dry toluene (100 mL × 3) and dry diethyl ester (100 mL) as a reddish-brown powder. Found (calcd for $C_{12}H_{10}P_2Se_4$): C 27.12 (27.09), H 1.82 (1.89) %. ^{31}P NMR (solid state): δ = 18.7 (s) ppm. Mass spectrum (ESI^+): M^+ 534. Powder X-ray diffraction (PXRD) is a useful method for checking for any impurities (Figure 1). The reaction may be scaled down 10-fold with no significant loss in yield.

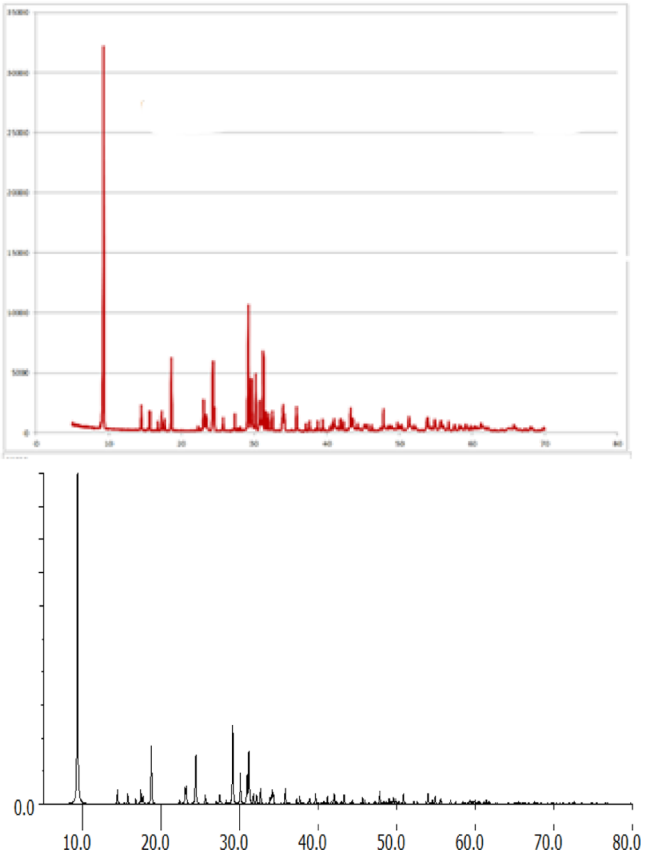
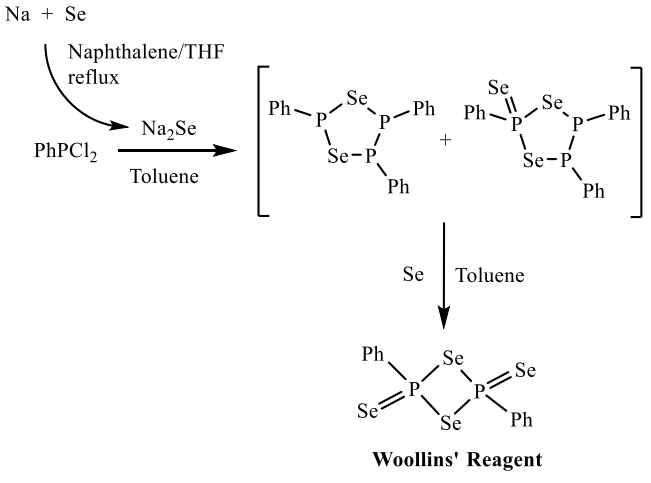


Figure 1. PXRD spectra of WR (upper trace) and the simulated pattern from the single-crystal data (lower trace).



PROPERTIES

WR is insoluble in a normal organic solvent but dissolves in toluene at elevated temperatures and can be stored in a fume cupboard at room temperature for several months without apparent decomposition.

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Notes

The authors declare no competing financial interest.

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