

Efficient Reductive Selenation of Aromatic Aldehydes to Symmetrical Diselenides with Se/CO/H₂O under Atmospheric Pressure

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Abstract: An efficient method for the synthesis of symmetrical diselenides is described. Reductive selenation of aromatic and heterocyclic aromatic aldehydes (ArCHO) with Se/CO/H₂O in DMF afforded diselenides (ArCH₂SeSeCH₂-Ar) in yields up to 94% under atmospheric pressure without use of a base.

Organic diselenides, as useful synthetic reagents and intermediates, play an important role in organoselenium chemistry because they are stable, easily handled, and reactive enough to produce electrophilic, nucleophilic, and radicophilic species.¹ General routes to organic diselenides involve reactions of metal diselenides with alkyl halides,² dimerization with seleno-cyanates,^{3–5} and oxidation of selenols⁶ or selenolates.⁷ Carbonyl compounds have also been used for this purpose. Both Margolis⁸ and Cohen⁹ reported that treatment of carbonyl compounds with hydrogen selenide generated from the reaction of Al₂Se₃ and water gave diselenides in the presence of organic base triethylamine. Diselenides were also syn-

TABLE 1. Reductive Selenation of Benzaldehyde (1a) to Dibenzyl Diselenide (1b)

entry ^a	solvent	temp (°C)	H ₂ O (mL)	yield (%) ^b
1	THF	60	2	
2	1,4-dioxane	95	2	
3	CH ₃ CN	75	2	
4	EtOH	75	2	
5	DMAC ^c	95	2	
6	DMSO	95	2	15
7	FP ^d	95	2	65
8	DMF	23	2	
9	DMF	60	2	67
10	DMF	80	2	85
11	DMF	95	2	94
12	DMF	95	0	
13	DMF	95	1	60
14	DMF	95	4	94

^a Reaction conditions: benzaldehyde, 2.5 mmol; Se, 2.5 mmol; bubbling CO, 0.1 MPa; solvent, 20 mL; 7.0 h. ^b Isolated yield of **1b**. ^c DMAC = *N,N*-dimethylacetamide. ^d FP = 1-formylpiperidine.

thesized from the reactions of aldehydes with sodium hydrogen selenide in the presence of an amine and sodium borohydride.¹⁰ Huang et al. reported that aldehydes reacted with elemental selenium and sodium borohydride to afford dibenzyl diselenides in the absence of an amine.¹¹ However, most of the known methods for preparation of diselenides suffer from disadvantages such as use of strong reducing agents and highly toxic gas, harsh reaction conditions, low yields, or complicated manipulations. Sonoda et al. discovered that elemental selenium can be readily reduced by carbon monoxide and water in the presence of base to produce hydrogen selenide, which was successfully applied to the synthesis of aliphatic diselenides from both aliphatic ketones and aldehydes¹² or from alkyl chlorides and acyl chlorides,¹³ respectively. Although Sonoda's method is relatively convenient and can be easily manipulated,^{12,13} the process is subject to relatively high pressure of CO (0.5–3.0 MPa), high temperature (120 °C), and long reaction times (e.g., 24 h), and when aromatic ketones ArC(=O)R' were used as the substrates, only reduction products ArCH₂R' instead of diselenides were obtained.¹⁴

In the course of our ongoing studies on selenium-catalyzed reductive carbonylation of nitroaromatic compounds with carbon monoxide,¹⁵ we have developed new

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
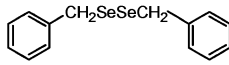
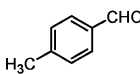
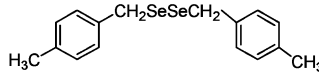

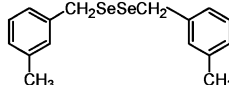

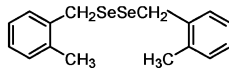
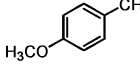
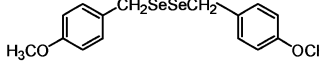

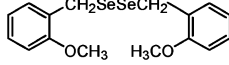
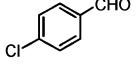
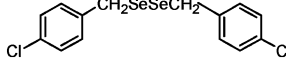
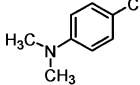
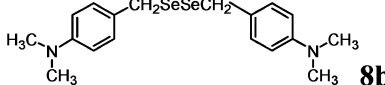


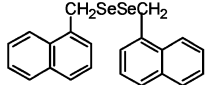
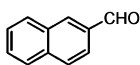
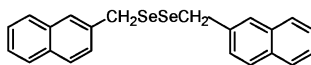

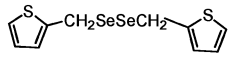

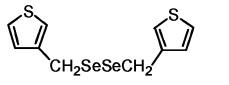

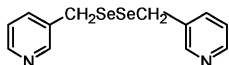
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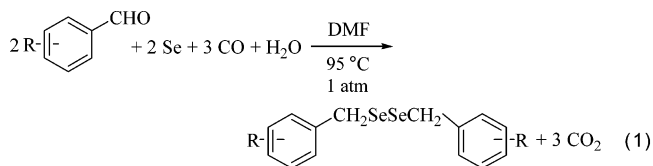
TABLE 2. Reductive Selenation of Aromatic and Heterocyclic Aromatic Aldehydes to Symmetrical Diselenides

entry ^a	aldehyde (ArCHO)	diselenide (ArCH ₂ SeSeCH ₂ Ar)	mp (°C)	reaction time (h)	yield (%) ^b
1	 1a	 1b	92-93 (90-91 ¹⁸)	7	94
2	 2a	 2b	58-59 (61-62 ^{10b})	9	92
3	 3a	 3b	Yellow liquid	7	89
4	 4a	 4b	80-81 (86-86.5 ^{2c})	11	80
5	 5a	 5b	72-73 (72 ⁹)	7	87
6	 6a	 6b	66-67 (- ¹⁹)	11	81
7	 7a	 7b	73-75 (76 ⁹)	9	36
8	 8a	 8b	102-104	12	45
9	 9a	no reaction		12	
10	 10a	 10b	102-103 (102 ⁹)	11	90
11	 11a	 11b	137-138 (134-135 ^{10b})	9	92
12	 12a	 12b	Yellow liquid	9	85
13	 13a	 13b	94-96	7	89
14	 14a	 14b	77-79	9	92

^a Reaction conditions: aldehyde, 2.5 mmol; Se, 2.5 mmol; bubbling CO, 0.1 MPa; water, 2 mL; DMF, 20 mL; 95 °C. ^b Isolated yield.

applications of the Se/CO/H₂O/DMF system from which dinitroaromatics can be reduced to mononitroanilines under atmospheric pressure.¹⁶ Keeping this result in mind, we investigated reactions of aromatic aldehydes with stoichiometric selenium under similar conditions and surprisingly found that these reactions led to symmetrical diselenides in the absence of base in excellent yields (eq 1). Herein we report a novel and efficient

synthesis of symmetrical diselenides from aromatic and heterocyclic aromatic aldehydes with Se/CO/H₂O in DMF under atmospheric pressure without use of a base.



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selenation of aromatic aldehydes may involve formation of selenol **F** by nucleophilic attack of H_2Se formed in situ to the carbonyl carbon atom of an aldehyde (Figure 1). Initially generated 2-hydroxylselenol **C** may be converted to diselenol **E** via an intermediate **D**, and further decomposition of **E** affords selenol **F**. Air-oxidation of **F** gives diselenide **1b** as the product.

In summary, we have developed an efficient synthetic method for symmetrical diselenides from aromatic aldehydes and less efficiency has been observed for aliphatic aldehydes. Further studies regarding the systematic extension of the method to synthesis of unsymmetrical diselenides (R_1SeSeR_2) with mixed aldehydes are underway.

Experimental Section

A typical synthetic procedure for symmetrical diselenides was carried out as follows. A 100-mL three-necked flask was charged with aldehyde (2.5 mmol), selenium (2.5 mmol), water (2 mL), and DMF (20 mL). Carbon monoxide was introduced and

bubbled into the reaction mixture with vigorous stirring at 95 °C for the given time. The reaction was monitored by TLC determination. After the reaction was complete, CO bubbling was stopped and the resultant mixture was stirred in air at ambient temperature for 30 min. Next, 20 mL of water was added, and the mixture was extracted with diethyl ether (3×40 mL). The organic phase was dried over anhydrous MgSO_4 and filtered, and the volatiles were evaporated under reduced pressure to afford the crude product. Further purification by column chromatography on silica gel or recrystallization gave the pure product. All products were identified by NMR and/or comparison with the authentic samples.

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Supporting Information Available: NMR spectral data for new compounds. This material is available free of charge via the Internet at <http://pubs.acs.org>.

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