

NOVEL SELENIUM CATALYZED SYNTHESIS OF ISOTHIOCYANATES FROM ISOCYANIDES AND ELEMENTAL SULFUR

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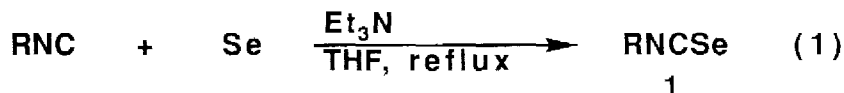
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SUMMARY. A variety of aliphatic and aromatic isothiocyanates were synthesized in good to excellent yields from corresponding isocyanides and elemental sulfur under mild conditions by use of catalytic amounts of elemental selenium.

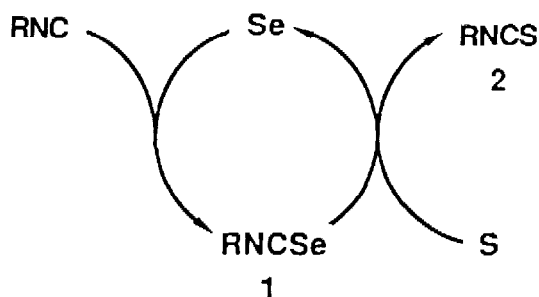
Development of new synthetic reactions utilizing the characteristics of heteroatoms has been currently explored.¹ In particular, organoselenium compounds have been shown as important reagents or intermediates in organic syntheses.² Recently we have found that selenium is the excellent catalyst for the reaction of carbon monoxide with amines and sulfur to produce thiocarbamic acids, isolated as *S*-alkyl thiocarbamates, where carbonyl sulfide is formed as an intermediate by the rapid Se-S exchange between sulfur and carbonyl selenide generated by the kinetically favorable reaction of carbon monoxide with selenium under basic conditions³

On the other hand, the reaction of isocyanides with elemental sulfur may be the most straightforward method for synthesis of isothiocyanates,⁴ but the reaction of aromatic isocyanides with sulfur is reported to be very sluggish,⁵ and moreover aliphatic isocyanides hardly react with sulfur.⁶

In contrast to this behavior towards elemental sulfur, isocyanides reacted easily with elemental selenium to give isoselenocyanates **1** in high yields in the presence of triethylamine (eq 1)⁷



Since isocyanides have an isoelectronic structure with carbon monoxide, if a similar type of Se-S exchange, observed in the reaction of carbon monoxide, proceeds between isoselenocyanates **1** and sulfur, a new selenium catalyzed synthesis of isothiocyanates **2** from isocyanides and elemental sulfur can be expected to accomplished (Scheme 1).



Scheme 1. Selenium Catalyzed Synthesis of Isothiocyanates 2.

The reaction of isoselenocyanates **1** with elemental sulfur was examined in detail and it was found that the Se-S exchange reaction occurred quantitatively in the presence of tertiary amine. For example, treatment of cyclohexyl isoseleno-cyanate **1a** (1 mmol) with sulfur (1 mmol) in refluxing THF (5 mL) containing triethylamine (1 mmol) for 6 h gave cyclohexyl isothiocyanate **2a** in 99 % yield together with deposition of a stoichiometric amount of elemental selenium (eq 2)



This successful result led us to attempt a catalytic reaction. To a mixture of elemental sulfur (3 mmol) and selenium (0.125 mmol, 5 mol% to isocyanide) and triethylamine (6 mmol) in THF (5 mL) was added cyclohexyl isocyanide (2.5 mmol), and the mixture was refluxed for 2 h. Glc analysis of the resulting mixture showed that isocyanide was completely consumed and isothiocyanate **2a** was formed in 95 % yield. Removal of the deposited selenium by filtration followed by distillation gave 89 % of **2a**. The evidence that isoselenocyanate **1a** could be always detected by glc analysis of the reaction mixture throughout the reaction period,⁸ may suggest that the Se-S exchange is the rate determining step of this catalytic cycle. Even when the amount of selenium catalyst was reduced to 0.5 mol%, **2a** was obtained in 99 % yield by prolonging the reaction period to 6.5 h.⁹ However, in the absence of selenium, reaction was extremely sluggish and gave a trace amount of **2a**. This clearly exhibits a high catalytic activity of selenium.

This catalytic reaction proceeds faster as the polarity of the solvents increases: in the order THF > 1,4-dioxane > chloroform > benzene. The reaction is very sluggish in the solvents of low polarity such as hexane and cyclohexane, probably partly due to the lower solubility of sulfur in these solvents.

In Table 1 are summarized the results of the formation of isothiocyanates **2** from corresponding isocyanides. Both aliphatic and aromatic isothiocyanates were prepared in good to excellent yields.

Table 1. Selenium Catalyzed Formation of Isothiocyanates **2**.^{a)}

entry	R	time, h	yield, % ^{b)}
1	cyclohexyl	2	89(95)
2	Me	1.5	(95)
3	n-Bu	2	73(93)
4	s-Bu	3	71(83)
5	t-Bu	5	58(81)
6	PhCH ₂	1	81(98)
7	allyl	7.5	53(62)
8	CH ₃ OC(O)CH ₂	0.5	(71)
9	C ₆ H ₅	2	91(93)
10	4-CH ₃ OC ₆ H ₄	0.5	82(94)
11	4-CH ₃ C ₆ H ₄	1	90(91)
12	2-CH ₃ C ₆ H ₄	1	89(91)
13	4-ClC ₆ H ₄	1	83(85)
14	2,6-(CH ₃) ₂ C ₆ H ₃	1	74(81)

a) Isocyanide (2.5 mmol), sulfur (3 mmol), selenium (0.125 mmol), triethylamine (6 mmol), THF (5 mL), reflux. b) Isolated yield (glc yield).

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8. After consumption of the isocyanide, isoselenocyanate **1a** remained was transformed to isothiocyanate **2a**.
9. When a smaller amount of triethylamine (1.5 mmol) was used, the reaction was also slow (6 h, 95 %).

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