J. Braz. Chem. Soc., Vol. 21, No. 9, 1616-1620, 2010.
Printed in Brazil - ©2010 Sociedade Brasileira de Química
0103 - 5053 $6.00+0.00

Article

An Approach to the Synthesis of Thioesters and Selenoesters Promoted by Rongalite®

Shao-Miao Lin,[a] Ji-Lei Zhang,[a] Jiu-Xi Chen,,[a] Wen-Xia Gao,[a] Jin-Chang Ding,[a,b] Wei-Ke Su[a,c] and Hua-Yue Wu*,[a]*

[a]*College of Chemistry and Materials Engineering, Wenzhou University, 325035 Wenzhou, P. R. China*

[b]*Wenzhou Vocational and Technical College, 325035 Wenzhou, P. R. China*

[c]*Zhejiang Key Laboratory of Pharmaceutical Engineering, College of Pharmaceutical Sciences, Zhejiang University of Technology, 310014 Hangzhou, P. R. China*

Rongalite® promove a clivagem de diarildissulfetos gerando os calcogenolatos correspondentes, que reagem facilmente com *N*-acilbenzotriazóis na presença de K_2CO_3, produzindo tioésteres em bons a excelentes rendimentos. As principais características desta metodologia são a não necessidade de catalisdores metálicos ou de reagentes caros e o alto rendimento. É digno de nota que as reações de disseleneto de difenila com *N*-acilbenzotriazóis são também conduzidas para produzir selenoésteres em bons rendimentos sob condições normais.

Rongalite® promotes cleavage of diaryldisulfides generating the corresponding chalcogenolate anions that then undergo facile reaction with *N*-acylbenzotriazoles in the presence of K_2CO_3 to afford thioesters in good to excellent yields. The important features of this methodology are no requirement of metal catalysts, without any expensive reagent and high yields. It is noteworthy that the reactions of diphenyl diselenide with *N*-acylbenzotriazoles are also conducted to afford selenoesters in good yields under the standard conditions.

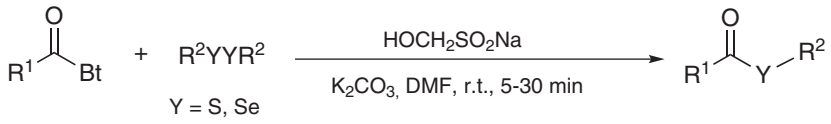
Keywords: Rongalite®, thioesters, selenoesters, *N*-acylbenzotriazoles, diaryl disulfide, diphenyldiselenide

Introduction

Thioesters have become increasingly important in the past few years because they have proven to be extremely useful intermediates for the preparation of heterocycles[1] and diverse ketones,[2] acyl radicals,[3] and biologically active compounds.[4] The typical procedure for the synthesis of thioesters involves the reaction of acylhalides with thiols,[5] thiol sodium salts[6] or disulfides.[7] In addition, carboxylic acids are also transformed into thioesters by treatment with arylthiocyanates and tributyl phosphine in dichloromethane[8] or with thiols by activated using tetramethyl fluoroformamidinium hexafluorophosphate,[9] diphosgene[10] and polyphosphate ester.[11] Recently, Katritzky and co-workers[12] introduced a new procedure for preparation of thioesters utilizing *N*-acylbenzotriazoles. Some other methods include palladium-catalyzed thiocarbonylation of iodoarenes with thiols in ionic liquid,[13] rhodium-catalyzed alkylthio exchange reaction of thioester and disulfide,[14] KF/Al_2O_3-catalyzed reaction of *N*-acylphthalimides with thiols[15] and copper-catalyzed coupling of aryl iodides and thiobenzoic acid.[16] However, these methods usually suffer from one or more limitations such as the use of unpleasant odor substrates thiols and expensive, toxic or metallic catalysts, long reaction times, unsatisfactory yields, as well as elevated temperature. Therefore, developing versatile approaches to synthesize thioesters still remains a highly desired goal in organic synthesis.

In continuation of our researches in developing novel synthetic routes for the formations of carbon-sulfur bonds[17] and Rongalite®-promoted organic reactions,[18] we here demonstrate further extension of this work together with application of Rongalite® (sodium formaldehyde sulfoxylate, $HOCH_2SO_2Na$) as an inexpensive reagent for the cleavage of diaryl disulfides or diphenyldiselenide and subsequent reaction with *N*-acylbenzotriazoles (Bt=1*H*-benzo[d][1,2,3]triazol-1-yl) to provide thioesters and selenoesters (Scheme 1).

*e-mail: jiuxichen@wzu.edu.cn, huayuewu@wzu.edu.cn

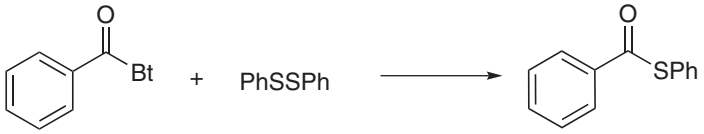


Scheme 1. Synthesis of thioesters and selenoesters.

Results and Discussion

At the onset of this work, we have investigated a variety of conditions with the model reaction of (1*H*-benzo[d][1,2,3]triazol-1-yl)(phenyl)methanone (**1a**) and diphenyl disulfide (**2a**) using Rongalite® as promoter (Table 1). First, we examined different solvents such as toluene, CH_2Cl_2, CH_3CN, H_2O, CH_3CH_2OH and DMF. Among the solvents screened, it was found that DMF is a much better solvent than all others tested (Table 1, entries 1-6). Next, we evaluated the loading amount of Rongalite®. No reaction was observed in the absence of Rongalite® and both starting materials were recovered in quantitative yields (Table 1, entry 7). In order to confirm, the amount of Rongalite® required for the above transformation, different experiments were carried out by varying the amount of Rongalite® (Table 1, entries 8-12). These results clearly indicate that, the use of 3 equiv. of Rongalite® is sufficient to promote the reaction in excellent yield. On the other hand, among the bases such as KF, Et_3N, K_3PO_4, K_2CO_3 and Cs_2CO_3 tested, K_2CO_3 was found to be the best (Table 1, entries 6 and 13-16). We also checked the effect of the amount of K_2CO_3, the desired product **3a** was afforded in 49% without K_2CO_3, increasing the amount of K_2CO_3 to 2 equiv., it was found that 1.5 equiv. resulted in excellent yield (Table 1, entries 17-20).

Table 1. Screening conditions for the synthesis of thioesters[a]



1a **2a** **3a**

Entry	Rongalite®/ (equiv.)	Solvent	Base	Yield/(%)[b]
1	3	toluene	K_2CO_3	NR
2	3	H_2O	K_2CO_3	NR
3	3	CH_2Cl_2	K_2CO_3	NR
4	3	CH_3CH_2OH	K_2CO_3	trace
5	3	CH_3CN	K_2CO_3	10
6	3	DMF	K_2CO_3	92
7	-	DMF	K_2CO_3	-
8	1	DMF	K_2CO_3	70
10	2	DMF	K_2CO_3	86
11	4	DMF	K_2CO_3	93
12	5	DMF	K_2CO_3	89
13	3	DMF	$KF{\cdot}2H_2O$	67
14	3	DMF	Et_3N	85
15	3	DMF	K_3PO_4	84
16	3	DMF	Cs_2CO_3	88
17	3	DMF	K_2CO_3	49[c]
18	3	DMF	K_2CO_3	81[d]
19	3	DMF	K_2CO_3	87[e]
20	3	DMF	K_2CO_3	86[f]

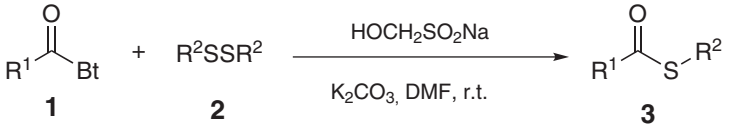
[a]Reaction conditions: 1*H*-1,2,3-benzotriazol-1-yl (phenyl) methanone **1a** (0.4 mmol), 1,2-diphenyldisulfane **2a** (0.2 mmol), $HOCH_2SO_2Na$, base, solvent, r.t., 5 min. [b]Isolated yields. [c]Without K_2CO_3. [d]0.5 equiv. of K_2CO_3. [e]1 equiv. of K_2CO_3. [f]2 equiv. of K_2CO_3. NR = No Reaction.

With the optimal conditions in hand, the scope of both disulfides and *N*-acylbenzotriazoles were explored and the results are summarized in (Table 2). As expected, this reaction proceeded smoothly and the desired products were afforded in good to excellent yields. A series of *N*-acylbenzotriazoles with either electron-donating or electron-withdrawing groups attached to aromatic ring were investigated. The substitution groups on the aromatic ring had no obvious effect on the yield. We also examined reaction of aliphatic *N*-acylbenzotriazole such as 1-(1*H*-benzo[d][1,2,3]triazol-1-yl)propan-1-one (**1d**), the desired products of **3j**-**3l** were afforded in good yields (Table 2, entries 10-12). Similarly, **3m** and **3n** were afforded from heterocyclic *N*-acylbenzotriazole such as (1*H*-benzo[d][1,2,3]triazol-1-yl) (furan-2-yl)methanone (**1e**) in moderate yields (Table 2, entries 13-14). Unfortunately, attempt to acylation of dibenzyl disulfide, an aliphatic disulfide, with (1*H*-benzo[d][1,2,3]triazol-1-yl)(phenyl)methanone (**1a**) failed to give the expected thioesters.

Interestingly, when cinnamic *N*-acylbenzotriazole (**1f**) was used, the corresponding multi-sulfur substitution compounds of **4a**-**4c** were afforded in moderate yields (Scheme 2).

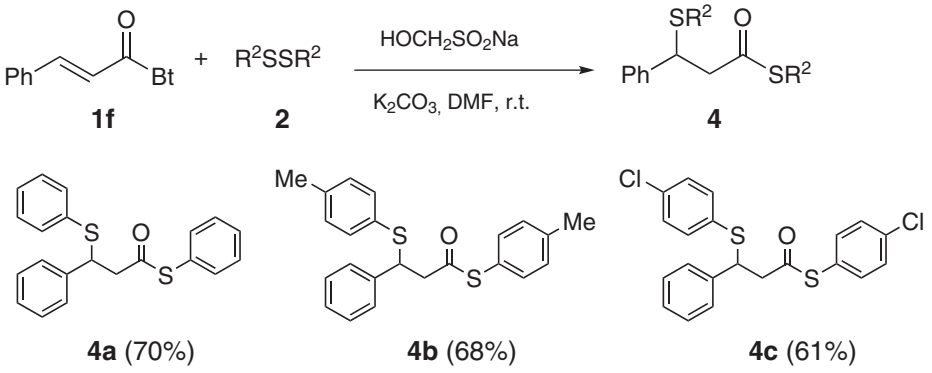
On the other hand, we extended this method to prepare selenoesters starting from *N*-acylbenzotriazoles. Selenoesters are important intermediates in several organic

Table 2. Synthesis of diverse thiol esters from *N*-acylbenzotriazoles with disulfides[a]

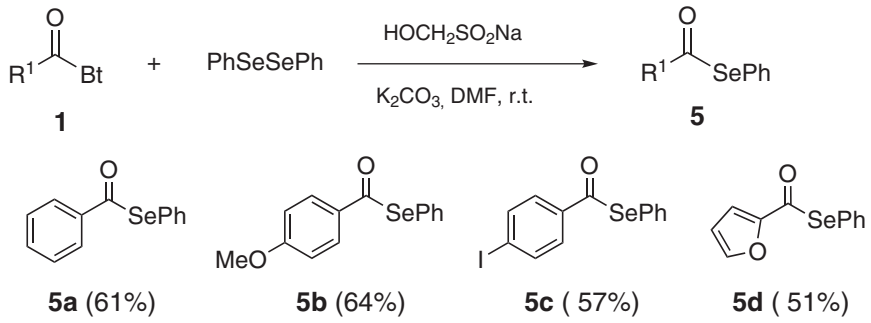


Entry	R^1 (**1**)	R^2	time / min	Product	Yield / (%)[b]
1	C_6H_5 (**1a**)	C_6H_5	5	**3a**	92
2	C_6H_5 (**1a**)	*p*-(Me)C_6H_4	5	**3b**	95
3	C_6H_5 (**1a**)	*p*-(Cl)C_6H_4	5	**3c**	90
4	*p*-(MeO)C_6H_4 (**1b**)	C_6H_5	5	**3d**	97
5	*p*-(MeO)C_6H_4 (**1b**)	*p*-(Me)C_6H_4	5	**3e**	93
6	*p*-(MeO)C_6H_4 (**1b**)	*p*-(Cl)C_6H_4	5	**3f**	98
7	*o*-(I)C_6H_4 (**1c**)	C_6H_5	15	**3g**	92
8	*o*-(I)C_6H_4 (**1c**)	*p*-(Me)C_6H_4	15	**3h**	93
9	*o*-(I)C_6H_4 (**1c**)	*p*-(Cl)C_6H_4	15	**3i**	88
10	Et (**1d**)	C_6H_5	20	**3j**	82
11	Et (**1d**)	*p*-(Me)C_6H_4	20	**3k**	83
12	Et (**1d**)	*p*-(Cl)C_6H_4	20	**3l**	80
13	2-furyl (**1e**)	C_6H_5	20	**3m**	62
14	2-furyl (**1e**)	*p*-(Me)C_6H_4	20	**3n**	67

[a]Reaction conditions: *N*-acylbenzotriazoles **1** (0.4 mmol), disulfides **2** (0.2 mmol), $HOCH_2SO_2Na$ (0.6 mmol), K_2CO_3 (0.3 mmol), DMF (3 mL), r.t., 5-30 min. [b]Isolated yield.



Scheme 2. The reaction of cinnamic *N*-acylbenzotriazole with diaryl disulfides.



Scheme 3. Synthesis of selenoesters from the reaction of *N*-acylbenzotriazoles with diphenyldiselenide.

transformations. Selenoesters have been used as precursors of acyl radicals[19] and anions,[20] mild acyl transfer reagents,[21] intermediates in the synthesis of ketones,[22] and for asymmetric aldol reactions.[23] Under the same conditions, we used diphenyldiselenide as source of selenolate anion, the reaction with *N*-acylbenzotriazoles afforded the corresponding selenoesters **5a**-**5d** in the presence of Rongalite® and K_2CO_3 (Scheme 3). However, acylation of aliphatic diselenide, such as dibenzyl diselenide and dimethyl diselenide, was still unsuccessful under the standard conditions.

In summary, *N*-acylbenzotriazoles have been introduced as new efficient *S*-acylating reagents. The reactions have been demonstrated under mild conditions to give diverse thioesters and selenoesters with moderate to good yield. Rongalite® as an inexpensive promoting reagent for these transformations can be substantiated by short reaction times, which is an additional advantage of this protocol. Efforts to explore the detailed mechanism and further applications of the present system in other transformations using disulfide and diselenide as a reaction partner are ongoing in our group.

Experimental

Chemicals and solvents were either purchased or synthesized by standard techniques. The reagents of *N*-acylbenzotriazoles were synthesized by reaction of the corresponding carboxylic acids with BtH and $SOCl_2$ following the reported one-step general procedure.[24] Melting points were recorded on Digital Melting Point Apparatus WRS-1B and are uncorrected. ^{1}H NMR and ^{13}C NMR spectra were taken on a Bruker DPX300 spectrometer using $CDCl_3$ or DMSO-d_6 as the solvent with tetramethylsilane (TMS) as an internal standard at room temperature. Chemical shifts were given in δ relative to TMS, the coupling constants *J* are given in Hz. Mass spectrometric analysis was performed on GC–MS analysis (SHIMADZU GCMS-QP2010). Elemental analysis was determined on a Carlo-Erba 1108 instrument.

*General procedure for the preparation of thioesters **3**, **4** and selenoesters **5***

A mixture of *N*-acylbenzotriazoles **1** (0.4 mmol), diaryl disulfides **2** or diphenyldiselenide (0.2 mmol), Rongalite® (3 equiv.), and K_2CO_3 (1.5 equiv.) in DMF (3 mL) was stirred for the corresponding time at room temperature under air. After the reaction was finished, the reaction mixture was washed with water, extracted with ethyl acetate (3 × 10 mL), the organic phase was separated and dried over anhydrous sodium sulfate, filtered and the solvent was evaporated under vacuum. The residue was purified by flash column chromatography (ethyl acetate or hexane/ethyl acetate) to afford the desired product thioesters **3** or selenoesters **5**. If cinnamic *N*-acylbenzotriazole **1f** was used the reaction substrate, the amount of diaryl disulfides **2** is 0.4 mmol.

Supplementary Information

Supplementary data are available free of charge at http://jbcs.sbq.org.br, as PDF file.

Acknowledgments

We are grateful to the National Key Technology R&D Program (No. 2007BAI34B00) and the Natural Science Foundation of Zhejiang Province (No. Y4080107) for financial support.

References

1. Chen, J.; Forsyth, C. J.; *Org. Lett.* **2003**, *5*, 1281; Brule, C.; Bouillon, J. P.; Nicolaï, E.; Portella, C.; *Synthesis* **2003**, 436.
2. McGarvey, G. J.; Williams, M.; Hiner, R. N.; Matsubara, Y.; Oh, T.; *J. Am. Chem. Soc.* **1986**, *108*, 4943; Conrow, R.; Portoghese, P. S.; *J. Org. Chem.* **1986**, *51*, 938; Shimizu, T.; Seki, M.; *Tetrahedron Lett.* **2002**, *43*, 1039; Dieter, R. K.; *Tetrahedron* **1999**, *55*, 4177; Ikeda, Z.; Hirayama, T.; Matsubara, S.; *Angew.*

Chem., Int. Ed. **2006**, *45*, 8200; Villalobos, J. M.; Srogl, J.; Liebeskind, L. S.; *J. Am. Chem. Soc.* **2007**, *129*, 15734.

3. Ozaki, S.; Adachi, M.; Sekiya, S.; Kamikawa, R.; *J. Org. Chem.* **2003**, *68*, 4586.
4. Turpin, J. M.; Song, Y.; Inman, J. K.; Huang, M.; Wallqvist, A.; Maynard, A.; Covell, D. G.; Rice, W. G.; Appella, E.; *J. Med. Chem.* **1999**, *42*, 67.
5. Detty, M. R.; Wood, G. P.; *J. Org. Chem.* **1980**, *45*, 80; Harpp, D. N.; Aida, T.; Chan, T. H.; *Tetrahedron Lett.* **1979**, *31*, 2853; Meshram, H. M.; Reddy, G. S.; Bindu, K. H.; Yadav, J. S.; *Synthesis* **1998**, 877; Shah, S. T. A.; Khan, K. M.; Hussain, H.; Hayat, S.; Voelter, W.; *Monatsh. Chem.* **2005**, *136*, 1583; Chen, R. E.; Zhang Y. M.; *Synth. Commun.* **1999**, *29*, 3699; Polshettiwar, V.; Kaushik, M. P.; *Catal. Commun.* **2005**, *6*, 191.
6. Tajima, Y.; Yoshida, A.; Takeda, N.; Oida, S.; *Tetrahedron Lett.* **1985**, *26*, 673; Haynes, R. K.; Vonwiller, S. C.; Stokes, J. P.; Merlino, L. M.; *Aust. J. Chem.* **1988**, *41*, 881; Choi, J.; Imai, E.; Mihara, M.; Oderaotoshi, Y.; Minakata, S.; Komatsu, M.; *J. Org. Chem.* **2003**, *68*, 6164.
7. Brindaban, C. R.; Tanmay, M.; *J. Org. Chem.* **2004**, *69*, 5793; Lakouraj, M. M.; Movassagh, B.; Fadaei, Z.; *Monatsh. Chem.* **2002**, *133*, 1085.
8. Grieco, P. A.; Yokoyama, Y.; Williams, E.; *J. Org. Chem.* **1978**, *43*, 1283.
9. Pittelkow, M.; Kamounah, F. S.; Boas, U.; Pedersen, B.; Christensen, J. B.; *Synthesis* **2004**, 2485.
10. Ravi, D.; Rama Rao, N.; Reddy, G. S. R.; Sucheta, K.; Jayathirtha Rao, V.; *Synlett* **1994**, 856.
11. Imamoto, T.; Kodera, M.; Yokoyama, M.; *Synthesis* **1982**, 134.
12. Katritzky, A. R.; Shestopalov , A. A.; Suzuki, K.; *Synthesis* **2004**, 1806.
13. Cao, H.; McNamee, L.; Alper, H.; *J. Org. Chem.* **2008**, *73*, 3530.
14. Arisawa, M.; Kubota, T.; Yamaguchi, M.; *Tetrahedron Lett.* **2008**, *49*, 1975.
15. Movassagha, B.; Zakinezhad, Y.; *J. Chem. Res. (S)* **2006**, 369.
16. Sawada, N.; Itoh, T.; Yasuda, N.; *Tetrahedron Lett.* **2006**, *47*, 6595.
17. Yang, X. L.; Xu, C. M.; Lin, S. M.; Chen, J. X.; Ding, J. C.; Wu, H. Y.; Su, W. K.; *J. Braz. Chem. Soc.* **2010**, *21*, 37; Xiao, H. L.; Chen, J. X.; Liu, M. C.; Zhu, D. J.; Ding, J. C.; Wu, H. Y.; *Chem. Lett.* **2009**, *38*, 170; Yang, X. L.; Xu, Y. L.; Chen, J. X.; Ding, J. C.; Wu, H. Y.; Su, W. K.; *J. Chem. Res.* **2009**, 682; Zhu, D. J.; Chen, J. X.; Xiao, H. L.; Liu, M. C.; Ding, J. C.; Wu, H. Y.; *Synth. Commun.* **2009**, *39*, 2895; Chen, J. X.; Wu, H. Y.; Jin, C.; Zhang, X. X.; Xie, Y. Y.; Su, W. K.; *Green Chem.* **2006**, *8*, 330; Chen, J. X.; Su, W. K.; Wu, H. Y.; Liu, M. C.; Jin, C.; *Green Chem.* **2007**, *9*, 972; Su, W. K.; Chen, J. X.; Wu, H. Y.; Jin, C.; *J. Org. Chem.* **2007**, *72*, 4524.
18. Guo, W. X.; Chen, J. X.; Wu, D. Z.; Ding, J. C.; Chen, F.; Wu, H. Y.; *Tetrahedron* **2009**, *65,* 5240.
19. Keck, G.; Grier, M. C.; *Synlett* **1999**, 1657; Boger, D. L.; Mathvink, R. J.; *J. Org. Chem.* **1992**, *57*, 1429; Chen, C.; Crich, D.; Papadatos, A.; *J. Am. Chem. Soc.* **1992**, *114*, 8313.
20. Hiiro, T.; Morita, Y.; Inoue, T.; Kambe, N.; Ogawa, A.; Ryu, I.; Sonoda, N.; *J. Am. Chem. Soc.* **1990**, *112*, 455.
21. Mukaiyama, T.; Araki, M.; Takei, H.; *J. Am. Chem. Soc.* **1973**, *95*, 4763; Anderson, R. J.; Henrick, C. A.; Rosenblum, L. D.; *J. Am. Chem. Soc.* **1974**, *96*, 3654; Sviridov, A. F.; Ermolenko, M. S.; Yashunsky, D. V.; Kochetkov, N. K.; *Tetrahedron Lett.* **1983**, *24*, 4355.
22. Back, T. G.; Kerr, R. G.; *Tetrahedron* **1982**, *38*, 3241; Back, T. G.; Kerr, R. G.; *Tetrahedron* **1985**, *41*, 4759.
23. Mukaiyama, T.; Uchiro, H.; Shiina, I.; Kobayashi, S.; *Chem. Lett.* **1990**, 1019; Kobayashi, S.; Uchiro, H.; Fujishita, Y.; Shiina, I.; Mukaiyama, T.; *J. Am. Chem. Soc.* **1991**, *113*, 4247; Suh, K. H.; Choo, D. J.; *Tetrahedron Lett.* **1995**, *36*, 6109.
24. Katritzky, A. R.; Zhang, Y.; Singh, S. K.; *Synthesis* **2003**, 2795.

Submitted: January 12, 2010
Published online: May 7, 2010