

Ytterbium metal promoted reaction of disulfides with 2-oxoimidazolidine-1-carbonyl chlorides[†]

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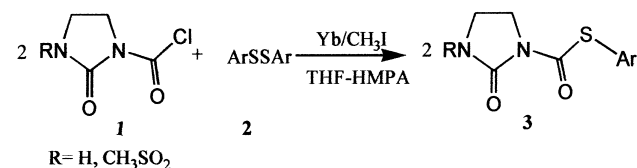
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In the presence of a catalytic amount of methyl iodide, ytterbium metal can promote the reductive acylation of disulfides with 2-oxoimidazolidine-1-carbonyl chlorides to give 2-oxoimidazolidine-1-carbonyl thioesters in good yields under neutral conditions.

Keywords: ytterbium, disulfides, imidazolidin-2-ones, thioesters, acylation

Thioesters are very important intermediates in organic synthesis.^{1–4} For example, they have been used as mild acyl transfer reagents,⁵ building blocks for heterocyclic compounds (oxazoles,⁶ β -lactones⁷), and precursors for asymmetric aldol reactions.⁸ Among several methods for the synthesis of thioesters,^{9–12} the use of sulfide anions to react with acylating agents is a convenient and common way.¹³ Taniguchi and his co-workers¹⁴ have reported that ytterbium metal could promote the sulfide anion reaction with $\alpha\beta$ -unsaturated ketones in the presence of benzophenone. Here we report the coupling reaction of disulfides with 2-oxoimidazolidine-1-carbonyl chlorides promoted by ytterbium metal to form 2-oxoimidazolidine-1-carbonyl thioesters in good yields. (Scheme 1)



Scheme 1

In our experimental work, it was found that when a solution of disulfide in tetrahydrofuran (THF) was added to the brown mixture of ytterbium metal in THF-HMPA, the colour of the solution gradually turned to green within 2 h. This observation suggested that the S–S bond was cleaved and the ytterbium

tri(arylthiolate) was formed.¹⁴ Subsequent nucleophilic substitution of 2-oxoimidazolidine-1-carbonyl chlorides by ytterbium tri(arylthiolate) [Yb(SAr)₃] gave the corresponding thioesters. The results are summarised in Table 1.

Table 1 shows that without HMPA the result of the reaction is not satisfactory, even at reflux temperature (Entries **3a**, **3h**). Table 1 also shows that electronic effect in the aromatic ring affects the yields of 2-oxoimidazolidine-1-carbonyl thioesters. If the substituted groups are electron-withdrawing groups the yields are higher than those of electron-donating groups. A possible mechanism¹⁴ is presented in Scheme 2.

Ytterbium metal is activated by CH₃I to give the activated [Yb*], which gradually donates three electrons to the disulfide to form [Yb(SAr)₃]. As a strong nucleophile, [Yb(SAr)₃] reacts with 2-oxoimidazolidine-1-carbonyl chloride to form the 2-oxoimidazolidine-1-carbonyl thioester.

In summary, ytterbium metal promoted intermolecular coupling reaction of disulfides with 2-oxoimidazolidine-1-carbonyl chlorides was studied, and a facile synthesis of 2-oxoimidazolidine-1-carbonyl thioesters was provided in good yields under mild and neutral conditions.

Experimental

Tetrahydrofuran was distilled from sodium-benzophenone immediately prior to use. Commercial hexamethylphosphoramide was dried over calcium hydride, distilled in vacuum and stored over 4 Å molecular sieves. All reactions were carried out under a dry nitrogen atmosphere. Melting points were uncorrected. Infrared spectra were recorded on a

Table 1 Reaction of disulfides with 2-oxoimidazolidine-1-carbonyl chloride promoted by ytterbium metal

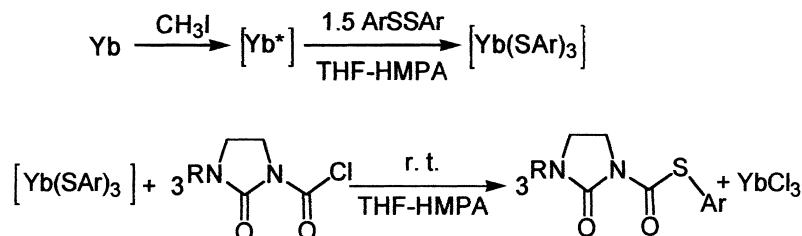
Entry	R	Ar	Temperature/°C	Reaction Time/h	Yield/% ^a
3a	H	C ₆ H ₅ -	20-25	4	76
	H	C ₆ H ₅ -	20-25	4	47 ^b
3b	H	<i>p</i> -ClC ₆ H ₄ -	20-25	3	81
3c	H	<i>p</i> -OCH ₃ C ₆ H ₄ -	20-25	3	81
3d	H	<i>p</i> -CH ₃ C ₆ H ₄ -	20-25	6	72
3e	H	<i>m</i> -OCH ₃ C ₆ H ₄ -	20-25	3	79
3f	CH ₃ SO ₂	C ₆ H ₅ -	20-25	4	75
3g	CH ₃ SO ₂	<i>o</i> -BrC ₆ H ₄ -	20-25	3	83
3h	CH ₃ SO ₂	<i>o</i> -ClC ₆ H ₄ -	20-25	3	80
	CH ₃ SO ₂	<i>o</i> -ClC ₆ H ₄ -	65-70	3	63 ^b
3i	CH ₃ SO ₂	<i>p</i> -ClC ₆ H ₄ -	20-25	3	80
3j	CH ₃ SO ₂	<i>p</i> -CH ₃ C ₆ H ₄ -	20-25	6	73

^aIsolated yield is based on disulfide and the reaction was carried on in THF-HMPA.

^bWithout the presence of HMPA

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[†] This is a Short Paper, there is therefore no corresponding material in *J Chem. Research (M)*.



Scheme 2

Bruker Vector 22 Spectrometer in KBr with absorption in cm^{-1} . ^1H NMR spectra were recorded on a Bruker AC-80 spectrometer as *D*-DMSO solutions. *J* values are in Hz. Chemical shifts are expressed in ppm downfield from internal tetramethylsilane. Mass spectra were recorded on a HP 5989B MS spectrometer. Microanalysis was carried out on a Carlo Erba 1106 instrument. 2-Oxoimidazolidine-1-carbonyl chlorides were prepared according to ref. 15.

General procedure: Ytterbium powder (0.173 g, 1 mmol) and a catalytic amount of CH_3I (1 drop) were added to a three-necked flask at room temperature under a nitrogen atmosphere. The metal was then warmed slightly to activate for about 15 min, and cooled to room temperature.¹⁶ Addition of THF (10 ml) gave a brown mixture to which HMPA (1 ml) was introduced, and then a solution of disulfide (1 mmol) in THF (1 ml) was added by syringe to the mixture at room temperature. The brown colour of the mixture gradually changed to green within 2 h. 2-Oxoimidazolidine-1-carbonyl chloride (3 mmol) was added directly to the mixture. After being stirred for a given time (see Table 1), the reaction mixture was quenched with dilute HCl (0.1 M) and extracted with ethyl acetate (3×30 ml). The crude product was isolated in the usual way and purified by preparative thin layer chromatography using ethyl acetate and cyclohexane (3 : 1) as eluent.

3a: white crystals, m.p. 152–154°C; ^1H NMR (CDCl_3 , 80 Hz) δ : 3.37 (t, *J* = 8.4 Hz, 2H), 3.74–3.89 (m, 2H), 7.34–7.56 (m, 5H), 7.81 (br, s, 1H); IR (KBr) ν_{max} : 3226, 3136, 2906, 1742, 1662, 1479, 1440, 1338, 1271, 905, 749, 706 cm^{-1} ; MS *m/z* (%) 222 (M^+ , 8), 110 (100), 84 (5), 77 (4), 70 (29); Anal. calcd for $\text{C}_{10}\text{H}_{10}\text{N}_2\text{O}_2\text{S}$: C 54.04, H 4.53, N 12.60; found C 54.18, H 4.43, N 12.47.

3b: light yellow crystals, m.p. 182–184°C; ^1H NMR (CDCl_3 , 80 Hz) δ : 3.37 (t, *J* = 10.2 Hz, 2H), 3.75–3.92 (m, 2H), 7.32(d, 2H, *J* = 7.0 Hz), 7.66 (d, 2H, *J* = 7.0 Hz), 7.86 (br, s, 1H); IR (KBr) ν_{max} : 3229, 3130, 2907, 1735, 1668, 1572, 1472, 1390, 1332, 1279, 1090, 1014, 908, 824 cm^{-1} ; MS *m/z* (%) 258 (M^+ , 9.1), 256 (M^+ , 26.3), 144 (100), 113 (36), 108 (25), 70 (46); Anal. calcd for $\text{C}_{10}\text{H}_9\text{ClN}_2\text{O}_2\text{S}$: C 46.79, H 3.53, N 10.91; found C 46.63, H 3.63, N 11.06.

3c: light yellow crystals, m.p. 184–185°C; ^1H NMR (CDCl_3 , 80 Hz) δ : 3.34 (t, *J* = 10.5 Hz, 2H), 3.73 (s, 3H), 3.79–3.92 (m, 2H), 7.02 (d, *J* = 8.8 Hz, 2H), 7.30 (d, *J* = 8.8 Hz, 2H), 7.79 (br, s, 1H); IR (KBr) ν_{max} : 3257, 3137, 2922, 1726, 1666, 1595, 1494, 1399, 1336, 1289, 1247, 1176, 1030, 906, 827, 816 cm^{-1} ; MS *m/z* (%) 252 (M^+ , 17), 140 (100), 125 (33), 113 (5), 70 (25); Anal. calcd for $\text{C}_{11}\text{H}_{12}\text{N}_2\text{O}_3\text{S}$: C 52.37, H 4.79, N 11.10; found C 52.46, H 4.68, N 10.98.

3d: light yellow crystals, m.p. 135–137°C; ^1H NMR (CDCl_3 , 80 Hz) δ : 2.34 (s, 3H), 3.35 (t, *J* = 8.7 Hz, 2H), 3.73–3.84 (m, 2H), 7.18 (d, 2H, *J* = 6.5 Hz), 7.38 (d, 2H, *J* = 6.5 Hz), 7.81 (br, s, 1H); IR (KBr) ν_{max} : 3230, 3136, 2920, 1725, 1656, 1484, 1400, 1335, 1287, 1066, 1017, 907, 809 cm^{-1} ; MS *m/z* (%) 236 (M^+ , 17), 124 (100), 113 (12), 91 (52), 70 (35); Anal. calcd for $\text{C}_{11}\text{H}_{12}\text{N}_2\text{O}_2\text{S}$: C 55.91, H 5.12, N 11.86; found C 56.02, H 5.01, N 11.73.

3e: light yellow crystals, m.p. 143–145°C; ^1H NMR (CDCl_3 , 80 Hz) δ_{H} : 3.39 (t, *J* = 7.0 Hz, 2H), 3.74 (s, 3H), 3.77–3.94 (m, 2H), 6.96–7.49 (m, 4H), 7.81 (br, s, 1H); IR (KBr) ν_{max} : 3410, 3072, 2990, 2917, 1739, 1657, 1588, 1477, 1417, 1288, 1023, 880, 802, 696 cm^{-1} ; MS *m/z* (%) 252 (M^+ , 17), 140 (100), 125 (33), 113 (5), 70 (25); Anal. calcd for $\text{C}_{11}\text{H}_{12}\text{N}_2\text{O}_3\text{S}$: C 52.37, H 4.79, N 11.10; found C 52.55, H 4.61, N 10.96.

3f: light yellow crystals, m.p. 164–166°C. ^1H NMR (CDCl_3 , 80 Hz) δ_{H} : 3.39 (s, 3H), 3.81–3.92 (m, 4H), 7.30–7.48 (m, 5H); IR (KBr) ν_{max} : 3016, 2936, 1723, 1677, 1472, 1441, 1400, 1345, 1279, 1168, 1127, 1015, 982, 946, 775, 751, 706 cm^{-1} ; MS *m/z* (%) 300 (M^+ , 32), 191 (77), 125 (21), 109 (62), 70 (100); Anal. calcd for $\text{C}_{11}\text{H}_{12}\text{N}_2\text{O}_4\text{S}_2$: C 43.99, H 4.03, N 9.33; found C 43.83, H 4.12, N 10.96.

3g: light yellow crystals, m.p. 179–181°C. ^1H NMR (CDCl_3 , 80 Hz) δ_{H} : 3.40 (s, 3H), 3.90–3.99 (m, 4H), 7.32–7.74 (m, 4H); IR (KBr) ν_{max} : 3032, 2936, 1739, 1681, 1475, 1390, 1351, 1277, 1250, 1167, 1125, 969, 767, 745, 565, 545 cm^{-1} ; MS *m/z* (%) 380 (M^+ , 6.8) 378

(M^+ , 7.2), 299 (80), 191 (43), 187 (20), 108 (72), 79 (100); Anal. calcd for $\text{C}_{11}\text{H}_{11}\text{BrN}_2\text{O}_4\text{S}_2$: C 34.84, H 2.92, N 7.39; found C 34.99, H 2.81, N 7.23.

3h: light yellow crystals, m.p. 176–178°C, ^1H NMR (CDCl_3 , 80 Hz) δ : 3.37 (s, 3H), 3.86–3.96 (m, 4H), 7.29–7.67 (m, 4H); IR (KBr) ν_{max} : 3017, 2934, 1747, 1672, 1573, 1472, 1350, 1286, 1237, 1172, 975, 773, 755, 564, 541 cm^{-1} ; MS *m/z* (%) 336 (M^+ , 2.6) 334 (M^+ , 7.1), 299 (26), 191 (19), 143 (29), 108 (29), 79 (100); Anal. calcd for $\text{C}_{11}\text{H}_{11}\text{ClN}_2\text{O}_4\text{S}_2$: C 39.46, H 3.31, N, 8.37; found: C 39.58, H 3.22, N, 8.19.

3i: light yellow crystals, m.p. 178–179°C; ^1H NMR (CDCl_3 , 80 Hz) δ : 3.36 (s, 3H), 3.88–3.96 (m, 4H), 7.25 (d, 2H, *J* = 7.0 Hz), 7.40 (d, 2H, *J* = 7.0 Hz); IR (KBr) ν_{max} : 3023, 2956, 1724, 1678, 1575, 1474, 1398, 1346, 1278, 1168, 980, 821 cm^{-1} ; MS *m/z* (%) 336 (M^+ , 4.2) 334 (M^+ , 11.7), 191 (72), 143 (30), 108 (31), 79 (100); Anal. calcd for $\text{C}_{11}\text{H}_{11}\text{ClN}_2\text{O}_4\text{S}_2$: C 39.46, H 3.31, N 8.37; found C 39.56, H 3.20, N 8.28.

3j: light yellow crystals, m.p. 149–151°C, ^1H NMR (CDCl_3 , 80 Hz) δ : 2.36 (s, 3H) 3.36 (s, 3H), 3.84–3.95 (m, 4H), 7.27(d, *J* = 6.5 Hz, 2H), 7.33 (d, *J* = 6.5 Hz, 2H); IR (KBr) ν_{max} : 3010, 2928, 1747, 1673, 1475, 1387, 1356, 1254, 1168, 975, 808, 772 cm^{-1} ; MS *m/z* (%) 314 (M^+ , 20), 191 (38), 123 (53), 91 (9), 79 (100); Anal. calcd for $\text{C}_{12}\text{H}_{14}\text{N}_2\text{O}_4\text{S}_2$: C 45.84, H 4.49, N 8.91; found C 45.71, H 4.57, N 9.03.

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