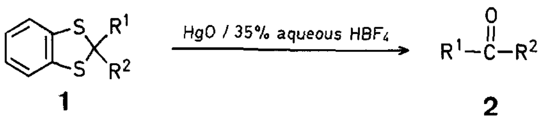
Mercury(II) Oxide/35% Aqueous Tetrafluoroboric Acid/Tetrahydrofuran: An Improved Reagent for the Hydrolysis of Cyclic Hemithioacetals, Dithioacetals, and Ortho Esters

Iacopo Degani, Rita Fochi, Valeria Regondi

Istituto di Chimica Organica, Via Bidone 36, I-10125 Torino, Italy

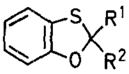
2-Substituted and 2,2-disubstituted 1,3-benzodithioles (**1**) can be obtained by several synthetic routes and have been recently proposed as useful precursors of carbonyl compounds **2**, i.e. aldehydes[1-9] and ketones[5,6,8,9].

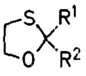


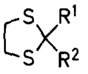
However, on the base of our experience, the hydrolysis of **1** to **2** is a crucial reaction and little has been hitherto reported in this regard[2,4,5,9]. The aim of the present work was chiefly to find an efficient procedure for the hydrolysis of **1**. After screening a number of the usual reagents employed for other dithioacetals[10], we found the use of mercury(II) oxide/boron trifluoride etherate[11] (Table 1, Method B) especially convenient. Nevertheless, because some of the tested reactions were very slow, we attempted to improve the hydrolysis conditions. This objective was attained simply by employing mercury(II) oxide/35% aqueous tetrafluoroboric acid/tetrahydrofuran instead of mercury(II) oxide/boron trifluoride etherate/aqueous tetrahydrofuran (Table 1, Method A). In fact, with the modified reagent, the reaction times were remarkably shortened, the yields were generally improved, there was no need for an inert atmosphere as required in the original procedure[11], and the manipulation of boron trifluoride etherate was avoided.

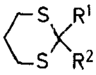
In addition, this reagent proved to be extremely efficient for the hydrolysis of other sulfurized precursors of carbonyl compounds, i.e. 1,3-benzoxathioles (**3**), 1,3-oxathiolanes (**4**), 1,3-dithiolanes (**5**), and 1,3-dithianes (**6**) (Table 2). The mildness of the reaction conditions was demonstrated by the hydrolysis of ortho esters **1k** (Table 1) and **3e, f** (Table 2) to the corresponding esters.

0039-7881/81/0132-0051 $ 03.00


3


4


5


6

All carbonyl compounds **2** were identified by comparison of their b.p. or m.p., ^{1}H-N.M.R. and I.R. spectra, and G.L.C. retention times with those of authentic samples of analytical purity.

The following compounds were prepared as previously reported: 1,3-benzodithioles **1a–d**[4], **1f–i**[8], **1k**[12]; 1,3-benzoxathioles **3a**[13], **3c–d**[14], **3e–f**[15]; 1,3-dithiane **6a**[16]. The other compounds were prepared according to the procedures cited in Table 3. Yields and physical data for these last compounds are reported in the same Table.

Hydrolysis of 2-Substituted and 2,2-Disubstituted 1,3-Benzodithioles (1) to Aldehydes, Ketones, and Esters (2); General Procedure:

Method A: Aqueous 35% tetrafluoroboric acid (10 ml) is added at room temperature to a suspension of mercury(II) oxide (4.33 g, 20 mmol) in tetrahydrofuran (50 ml). 1,3-Benzodithiole **1** (10 mmol) is dissolved in the minimum amount of tetrahydrofuran (3–5 ml) and then is added, in one portion, to the reaction mixture, under vigorous stirring. The reaction is moderately exothermic and the solid changes from orange to pale yellow and the upper solution also becomes yellow. The disappearance of **1** is checked by T.L.C. on silica using benzene/petroleum ether (1:1). After completion of the reaction, the suspension is diluted with petroleum ether (100 ml; other solvents also can be used, e.g. benzene, chloroform, etc.) and the organic layer is decanted. Then the inorganic material is extracted, under vigorous stirring, with the same solvent (3 × 50 ml). The combined extracts are washed successively with 10% potassium iodide solution, 5% sodium hydroxide solution, and water. After drying with sodium sulfate, the solvent is evaporated in vacuo by heating at 45–50 °C to afford virtually pure **2** (according to ^{1}H-N.M.R., T.L.C., and G.L.C. analysis); yields and reaction times are reported in Table 1.

Method B: The procedure previously reported for the hydrolysis of 1,3-dithianes[11] has been slightly modified as follows. A solution of 1,3-benzodithiole **1** (10 mmol) in the minimum of tetrahydrofuran (3–5 ml) is added at room temperature, in one portion and under vigorous stirring, to a mixture of boron trifluoride etherate (0.28 g, 20 mmol) and mercury(II) oxide (4.33 g, 20 mmol) in 15% aqueous tetrahydrofuran (30–40 ml). During the hydrolysis the orange solid becomes lighter and the upper solution orange. After disappearance of **1** (T.L.C.), the reaction mixture is worked up as indicated in Method A to afford pure **2** (purity control by ^{1}H-N.M.R., T.L.C., G.L.C.) see Table 1.

When R^1 in **1** is H and R^2 is an alkyl (**1d–f**), the amount of mercury(II) oxide necessary to complete the hydrolysis is 30 mmol for 10 mmol of **1** and the reaction must be run at reflux temperature.

Table 1. Hydrolysis at Room Temperature of 1,3-Benzodithioles **1** by Mercury(II) Oxide/35% Aqueous Tetrafluoroboric Acid (Method A) and Mercury(II) Oxide/Boron Trifluoride Etherate (Method B)

Substrate	Product	R^1	R^2	Method A		Method B		b.p. [°C]/760 torr or m.p. [°C]	
				Reaction time	Yield [%][a]	Reaction time	Yield [%][a]	found	reported
1a	**2a**	H	C_6H_5	10 min	94	3 h	90	b.p. 178–179°	b.p. 179°[17]
1b	**2b**	H	4-H_3CO—C_6H_4	< 5 min	94	10 min	90	b.p. 247–248°	b.p. 248°[17]
1c	**2c**	H	4-Cl—C_6H_4	15 min	100	9 h	87	m.p. 46–47°	m.p. 47°[17]
1d	**2d**	H	n-C_9H_{19}	15 min[b]	78	1 h[b]	75	b.p. 207–208°	b.p. 208–209°[17]
1e	**2e**	H	n-$C_{15}H_{31}$	15 min[b]	78	2 h[b]	73	m.p. 33–34°	m.p. 34°[17]
1f	**2f**	H	OHC—$(CH_2)_{10}$—	15 min[b]	70	2 h[b]	36	m.p. 65–66°	m.p. 65–66°[18]
1g	**2g**	H	C_6H_5—CH=CH	5 min	98	30 min	94	b.p. 252°	b.p. 252°[17]
1h	**2h**	C_6H_5	C_6H_5	10 min	100	8 h	98	m.p. 48–49°	m.p. 49°[17]
1i	**2i**	CH_3	C_6H_5	< 5 min	96	10 min	95	b.p. 201–202°	b.p. 202°[17]
1j	**2j**	CH_3	n-C_8H_{17}	< 5 min	95	<5 min	90	b.p. 209–210°	b.p. 209°[17]
1k	**2k**	C_2H_5O	C_6H_5	< 5 min	98	<5 min	94	b.p. 211°	b.p. 212°[17]
1l[c]	**2l**	—$(CH_2)_2$—CH(t-C_4H_9)—(CH_2)—		5 min	86	36 h	80	m.p. 49–50°	m.p. 49–50°[17]

[a] Yield of isolated pure carbonyl compound; purity control by ^{1}H-N.M.R., T.L.C. (conditions: SiO_2; benzene/petroleum ether, 1/1) and G.L.C. (conditions: SE 30, 5% over Varaport 30; temperature program 100→250 °C).

[b] Reaction carried out at reflux, using 30 mmol of mercury(II) oxide for 10 mmol of 1,3-benzodithiole (**1**).

[c] (1,3-Benzodithiole)-2-spiro-1′-(4′-t-butylcyclohexane).

Table 2. Hydrolysis of 1,3-Benzoxathioles (**3**), 1,3-Oxathiolanes (**4**), 1,3-Dithiolanes (**5**), and 1,3-Dithianes (**6**) by Mercury(II) Oxide/35% Aqueous Tetrafluoroboric Acid (Method A) at Room Temperature

Starting compound	R^1	R^2	Reaction time [min]	Yield [%][a] of **2**	b.p. [°C]/760 torr or m.p. [°C] of **2**	
					found	reported
3a	H	4-H_3C—C_6H_4	<5	92	b.p. 204–205°	b.p. 204–205°[17]
3b	H	n-C_9H_{19}	<5	92	b.p. 207–208°	b.p. 208–209°[17]
3c	CH_3	C_6H_5	<5	95	b.p. 201–202°	b.p. 202°[17]
3d	C_6H_{11}	C_6H_5	5	94	m.p. 59–60°	m.p. 59–60°[17]
3e	C_2H_5O	C_6H_5	<2	96	b.p. 211°	b.p. 212°[17]
3f	n-$C_8H_{17}O$	C_6H_5	<2	100	b.p. 189°/32	b.p. 189°/32[15]
4a	H	4-Br—C_6H_4	<2	93	m.p. 66–67°	m.p. 67°[17]
4b	C_6H_5	4-H_3CO—C_6H_4	<2	100	m.p. 61–62°	m.p. 61–62°[17]
5a	H	2-naphthyl	<2	100	m.p. 59°	m.p. 59°[17]
5b	C_6H_5	C_6H_5	5	97	m.p. 48–49°	m.p. 49°[17]
6a	H	4-H_3CO—C_6H_4	<2	100	b.p. 247–248°	b.p. 248°[17]
6b	H	n-C_9H_{19}	<2	100	b.p. 207–208°	b.p. 208–209°[17]
6c	C_6H_5	C_6H_5	<2	100	m.p. 48–49°	m.p. 49°[17]

[a] See footnote (a) of Table 1.

Table 3. Yields and Physical Data for 1,3-Benzodithioles (**1**), 1,3-Benzoxathioles (**3**), 1,3-Oxathiolanes (**4**), 1,3-Dithiolanes (**5**), and 1,3-Dithianes (**6**)

Compound	Yield [%]	m.p. [°C][a] or b.p. [°C]/torr	Molecular formula[b] or Lit. data		^{1}H-N.M.R. (CCl_4) δ [ppm]	Reference for Preparative Method
1e	100	38–39°	$C_{22}H_{36}S_2$	(364.7)	0.7–2.2 (m, $C_{15}H_{31}$); 4.75 (t, CH); 6.8–7.3 (m, 4H_{arom})	8
1g	96	80–81°	80°[19]		—	4
1j	98	160–161°/0.3	160–161°/0.3[5]		—	4
1l	94	49–50°	$C_{16}H_{22}S_2$	(278.5)	0.90 (s, t-C_4H_9); 1.1–2.2, 2.4–2.8 (2 m, 7:2, $H_{cyclohexane}$); 6.7–7.8 (m, 4H_{arom})	4
3b	35[d]	157–158°/0.4	$C_{16}H_{24}OS$	(264.4)	0.6–2.2 (m, C_9H_{19}); 5.98 (t, CH); 6.6–7.2 (m, 4H_{arom})	4,c
4a	83[d]	162–164°/0.6	C_9H_9BrOS	(245.2)	3.0–3.3, 3.6–4.0, 4.2–4.6 (3 m, 2:1:1, CH_2—CH_2); 5.85 (s, CH); 7.1–7.6 (m, 4H_{arom})	20
4b	55[d]	43–44°	$C_{16}H_{16}O_2S$	(272.4)	3.0–3.3, 4.0–4.3 (2m, 1:1, CH_2—CH_2); 3.70 (s, OCH_3); 6.6–6.9, 7.1–7.6 (2 m, 2:7, 9H_{arom})	20
5a	93	149–150°	$C_{13}H_{12}S_2$	(232.4)	3.3–3.6 (m, CH_2—CH_2); 5.78 (s, CH); 7.2–8.0 (m, 7H_{arom})	4,e
5b	70[d]	106–107°	106°[22]		—	4,e
6b	98	148–149°/1	112°/0.5[23]		—	16,21,f
6c	71[d]	110–111°	110°[24]		—	4,f

[a] From ethanol.

[b] All compounds gave satisfactory microanalysis (C ±0.18, H ±0.12, S ±0.17).

[c] Starting from o-mercaptophenol[25] purified as previously described[26].

[d] Purified by chromatography (SiO_2; eluent: benzene).

[e] Starting from 1,2-ethanedithiol.

[f] Starting from 1,3-propanedithiol.

Hydrolysis of 1,3-Benzoxathioles (3), 1,3-Oxathiolanes (4), 1,3-Dithiolanes (5), and 1,3-Dithianes (6):

The procedure is identical to that reported in Method A with the only differences indicated below.

For the hydrolysis of **3** and **4** (10 mmol), the following amounts of reagents are used: mercury(II) oxide (2.16 g, 10 mmol), aqueous 35% tetrafluoroboric acid (5 ml) and tetrahydrofuran (25 ml). In these cases, after the addition of **3** or **4** to the reaction mixture, a red or a colourless solution is obtained and, after dilution with petroleum ether, a yellow solid or a yellow oil is separated, respectively.

For the hydrolysis of **5** and **6** (10 mmol), the amounts of reagents are the following in all cases: mercury(II) oxide (4.33 g, 20 mmol), aqueous 35% tetrafluoroboric acid (10 ml) and tetrahydrofuran (50 ml). After the addition of **5** or **6** to the reaction mixture, mercury(II) oxide dissolves at once and a white precipitate appears.

Yields, reaction, times and physical properties for carbonyl compounds are reported in Table 2.

This work was supported by the C.N.R. (Italy).

Received: August 4, 1980

---

[1] J. Nakayama, M. Imura, M. Hoshino, *Chem. Lett.* **1975**, 1319.
[2] J. Nakayama, *Synthesis* **1975**, 170.
[3] J. Nakayama, *J. Chem. Soc. Perkin Trans. 1* **1976**, 540.
[4] I. Degani, R. Fochi, *Synthesis* **1976**, 759.
[5] I. Degani, R. Fochi, *J. Chem. Soc. Perkin Trans. 1* **1976**, 1886.
[6] I. Degani, R. Fochi, *Synthesis* **1977**, 263.
[7] S. Ncube, A. Pelter, K. Smith, *Tetrahedron Lett.* **1977**, 255.
[8] I. Degani, R. Fochi, *J. Chem. Soc. Perkin Trans. 1* **1978**, 1133.
[9] S. Ncube, A. Pelter, K. Smith, *Tetrahedron Lett.* **1978**, 2345.
[10] B. Grobel, D. Seebach, *Synthesis* **1977**, 357; and references therein.
[11] E. Vedejs, P. L. Fuchs, *J. Org. Chem.* **36**, 366 (1971).
[12] I. Degani, R. Fochi, P. Tundo, *J. Heterocycl. Chem.* **11**, 507 (1974).
[13] L. Costa, I. Degani, R. Fochi, P. Tundo, *J. Heterocycl. Chem.* **11**, 943 (1974).
[4] I. Degani, R. Fochi, P. Tundo, *Gazz. Chim. Ital.* **105**, 907 (1975).
[5] G. Aimo, I. Degani, R. Fochi, *Synthesis* **1979**, 223.
[6] D. Seebach, *Synthesis* **1969**, 17.
[7] I. Heilbronn, *Dictionary of Organic Compounds*, Eyre-Spottiswoode, London, 1965.
[8] I. Degani, R. Fochi, *J. Chem. Soc. Perkin Trans. 1* **1976**, 323.
[9] W. R. H. Hurtley, S. Smiles, *J. Chem. Soc.* **1927**, 534.
[20] G. Wilson, M. G. Huang, W. W. Schloman, *J. Org. Chem.* **33**, 2133 (1968).
[21] A. Hoppmann, P. Weyersthal, W. Zummack, *Justus Liebigs Ann. Chem.* **1977**, 1947.
[22] H. Fassbinder, *Ber. Dtsch. Chem. Ges.* **21**, 1473 (1888).
[23] D. Seebach, E. Wilka, *Synthesis* **1976**, 476.
[24] W. Autenrieth, K. Wolff, *Ber. Dtsch. Chem. Ges.* **32**, 1375 (1899).
[25] D. Greenwood, H. A. Stevenson, *J. Chem. Soc.* **1953**, 1514.
[26] I. Degani, R. Fochi, *Synthesis* **1976**, 757.