

A convergent, flexible synthesis of 1,3-dienes

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1,3-Dienes were prepared from 1,4-ketoxanthates, obtained by the radical addition reaction of an *S*-(2-oxoalkyl) xanthate to a terminal olefin, through the DBU induced thermal elimination of sulfur dioxide from the derived 2-sulfolenes.

The synthesis of 1,3-dienes from substituted 2,5-dihydrothiophene-1,1-dioxides (3-sulfolenes) by thermal or photochemical elimination of sulfur dioxide has been extensively studied.¹ The isomeric 4,5-dihydrothiophene-1,1-dioxides (2-sulfolenes) are reported to be in equilibrium with 3-sulfolenes under basic conditions.² The *in situ* isomerisation of 2-sulfolenes to 3-sulfolenes followed by thermal extrusion of sulfur dioxide has been noted but not fully exploited in synthesis because of a lack of convenient routes to the precursors.³ In this communication we report a new protocol for the synthesis of substituted 1,3-dienes from 1,4-ketoxanthates by a base induced thermal elimination of sulfur dioxide from the key intermediate 2-sulfolenes.

We have previously reported that various xanthates undergo a radical addition to olefinic traps with transfer of the xanthate group.⁴ In the case of *S*-(2-oxoalkyl) xanthates **1**, the radical addition to alkenes **2** initiated by a small amount of lauroyl peroxide in refluxing cyclohexane produces 1,4-ketoxanthates **3** as shown in Table 1. These adducts are in fact ideal intermediates for the synthesis of 2-sulfolenes: the xanthate functionality is readily cleaved by the action of ethylenediamine to give the corresponding thiol which, following a rapid work up and exposure to trifluoroacetic acid, ring-closes to the 4,5-dihydrothiophene.⁵ *In situ* oxidation with *m*-CPBA (2.05 eq.) finally gives the required 2-sulfolene intermediates **4** (Table 2).

With a good access to 2-sulfolenes in hand, we searched for suitable experimental conditions enabling their direct conversion into the corresponding 1,3-dienes. The conditions we explored using sulfolene **4a** are summarised in Table 3.

Table 1 Radical transfer reaction of xanthates **1** with olefins **2**

Entry	Xanthate R ¹ , R ²	Alkene R ³	Isolated yield
1	Ph, H	C ₆ H ₁₃	84%
2	Ph, H	CH ₂ SiMe ₃	72%
3	2-CH ₃ C ₆ H ₄	C ₆ H ₁₃	68%
4	4-MeOC ₆ H ₄ , H	C ₆ H ₁₃	92%
5	4-MeOC ₆ H ₄ , H		80%
6	4-BrC ₆ H ₄ , H	C ₆ H ₁₃	84% ^a
7	^t Bu, H	(CH ₂) ₉ OAc	74%
8		C ₆ H ₁₃	43%

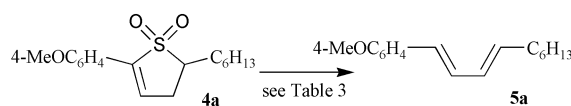
^a We thank Dr Peter Boutillier for performing this experiment.

Table 2 Transformation of xanthates **3** into 2-sulfolenes **4**

Entry	R ¹ , R ² and R ³	Isolated yield
1	R ¹ = Ph; R ² = H; R ³ = C ₆ H ₁₃	79%
2	R ¹ = Ph; R ² = H; R ³ = CH ₂ SiMe ₃	70%
3	R ¹ = 2-MeC ₆ H ₄ ; R ² = H; R ³ = C ₆ H ₁₃	62%
4	R ¹ = 4-MeOC ₆ H ₄ ; R ² = H; R ³ = C ₆ H ₁₃	77%
5	R ¹ = 4-MeOC ₆ H ₄ ; R ² = H; R ³ =	60%
6	R ¹ = 4-BrC ₆ H ₄ ; R ² = H; R ³ = C ₆ H ₁₃	81%
7	R ¹ = ^t Bu; R ² = H; R ³ = (CH ₂) ₉ OAc	72%
8	R ¹ , R ² = ; R ³ = C ₆ H ₁₃	48%

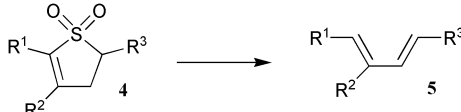
Initially, potassium carbonate, a potassium carbonate/imidazole mixture, and DBU, using toluene as the solvent, were investigated as possible bases. Only DBU gave any of the desired diene **5a**. In order to determine whether the base was essential for the transformation or whether the reaction was merely a thermal elimination, a control reaction in toluene was performed (see Table 3 entry 7). The starting material was recovered unchanged, indicating that DBU is essential for the thermal extrusion of sulfur dioxide under these reaction conditions. Of the solvents examined, cyclohexane was found to give the highest yields. It is interesting to note that DBU was reported to fail in an attempted isomerisation of a 2-sulfolene into a 3-sulfolene.^{3b}


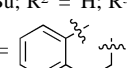
A variety of 2-sulfolenes **4** were subjected to DBU (1.2–1.3eq) in cyclohexane (*ca* 0.5 M) at reflux until the reaction was deemed to be complete by TLC. The results are compiled in Table 4.

Table 3 Investigation of conditions for 1,3-diene **5** formation

Entry	Base	Eq.	Time	Solvent	Yield (%)
1	K ₂ CO ₃	5.6	3	CH ₃ Ph/H ₂ O ^a	0 ^d
2	K ₂ CO	1.3	19	CH ₃ Ph ^a	0 ^d
	Imidazole	1.2			
3	DBU	41	1.5	none ^b	23
4	DBU	6.2	1.5	CH ₃ Ph ^c	55
5	DBU	1.2	3	Cyclohexane ^a	78
6	DBU	1.0	4	EtOH ^a	52
7	DBU	—	5	CH ₃ Ph ^a	0 ^d

^a Reflux. ^b Rt to 90 °C. ^c 90 °C ^d Recovered starting material unchanged.

Table 4 DBU induced thermal elimination of SO₂


Entry	R ¹ , R ² and R ³	Isolated yield
1	R ¹ = Ph; R ² = H; R ³ = C ₆ H ₁₃	61%
2	R ¹ = Ph; R ² = H; R ³ = CH ₂ SiMe ₃	69%
3	R ¹ = 2-MeC ₆ H ₄ ; R ² = H; R ³ = C ₆ H ₁₃	85%
4	R ¹ = 4-MeOC ₆ H ₄ ; R ² = H; R ³ = C ₆ H ₁₃	78%
5	R ¹ = 4-MeOC ₆ H ₄ ; R ² = H; R ³ = 	45%
6	R ¹ = 4-BrC ₆ H ₄ ; R ² = H; R ³ = C ₆ H ₁₃	63%
7	R ¹ = ^t Bu; R ² = H; R ³ = (CH ₂) ₉ OAc	0% ^a
8	R ¹ , R ² =  R ³ = C ₆ H ₁₃	64%

^a The desired product was obtained in a 42% yield by heating in DBU (2.4 eq.), as the solvent, at 160 °C for 5 h.

The thermal elimination of sulfur dioxide from 2,5-dihydrothiophenes-1,1-dioxides (3-sulfolenes) is known to occur in a suprafacial (*cis* elimination) manner with complete stereoselectivity.¹ The literature precedence¹ and the preliminary characterisation of the 1,3 dienes **5** obtained from the general procedure, indicate that a single isomer, the *trans, trans*-diene, is formed following the elimination.

In summary, we have succeeded in implementing a flexible, convergent route to dienes. Synthetically useful functionality may be introduced on either or both of the xanthate and olefinic

partners in the initial radical addition step. This intermolecular addition process brings together the ketone and thiol moieties necessary for the construction of the desired 2-sulfolene precursors. We have exploited their base induced isomerisation to generate dienes, but it is also worth underlining that 2-sulfolenes are in fact vinylic sulfones with a remarkably rich chemistry of their own.⁶

Notes and references

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