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Sulfite formation versus chlorination of benzyl alcohols with thionyl chloride

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ABSTRACT

Recently, we have reported the photolytic decay of a library of *para*-substituted dibenzylic sulfites in a Srinivasan–Griffin–Rayonet photochemical reactor. In an attempt to synthesize the complete library for that study we discovered that bis(*p*-methoxybenzyl) sulfite and bis(*p*-phenoxybenzyl) sulfite could not be formed and only their corresponding benzyl chlorides were synthesized. Thus, sulfite formation versus chlorination of a range of *para*-substituted benzyl alcohols with thionyl chloride was investigated. Sulfite formation was observed to be parabolically related to Swain and Lupton's Field $\mathfrak{F}$-values while chloride formation was found to be linearly related to Swain and Lupton's Field $\mathfrak{R}$-values.

Organosulfite is a rarely used functionality. Three most commonly studied compounds containing this structural moiety are dimethyl sulfite, diethyl sulfite, and propargite. Dimethyl sulfite is commonly used as an additive in some polymers as a means to prevent oxidation.[1–3] Recently, much effort has been done on its potential use as an electrolyte solvent for battery applications.[4–6] In addition to being an antioxidant,[5,6] diethyl sulfite has found use within the grain storage industry as an antifungal agent.[7] Unlike both dimethyl and diethyl sulfites, propargite is an unsymmetrical sulfite. It is a commonly used acaricide pesticide[8–10] and is conventionally known as Omite®. In addition to the killing of mites, it is also highly toxic to plankton,[11] fish,[12] and amphibians.[13] In the above examples, the synthesis of the sulfite moiety is accomplished by the reaction of an alcohol with thionyl chloride.

Chlorination with thionyl chloride is a technique that is covered in most undergraduate organic chemistry textbooks (Fig. 1) and is even performed in some undergraduate teaching laboratory settings. Less commonly taught, however, is that sulfite formation is also possible with the use of the same reagent but at different reactant equivalences (Fig. 1).

Recently, we synthesized a library of bis(benzyl) sulfites to study their photolytic decay profiles.[14] In the course of this investigation, we observed that the rate of photolytic decomposition was parabolically related to Swain and Lupton's Field ($\mathfrak{F}$-) values, regardless of

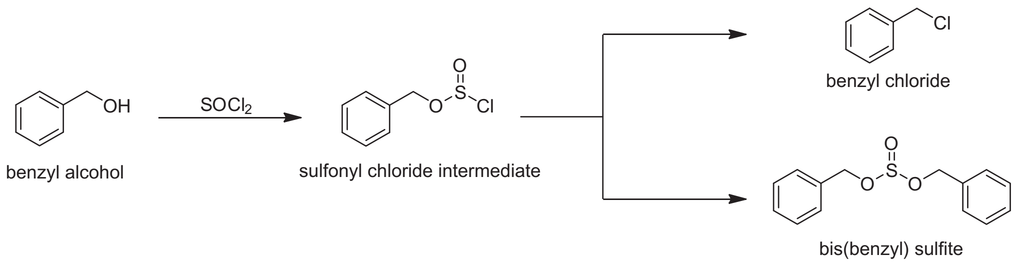

Figure 1. Chlorination and sulfite formation from the reaction of thionyl chloride and benzyl alcohol.

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Scheme 1. Possible mechanism for the formation of benzyl chlorides opposed to bis(benzyl) sulfites.

Table 1
Product % ratios determined by ^{1}H NMR, using 2:1 benzyl alcohols and thionyl chloride at different reaction times

X-Ph-CH_2OH	$R \times n$ times (min)	% chloride	% sulfite	% alcohol
H	5	11.2	55.3	33.5
	60	10.8	54.6	34.6
	120	12.3	54.9	32.8
	180	11.5	56.2	32.3
	240	9.9	57.3	32.8
	300	12.1	53.1	34.8
NO_2	5	34.0	15.4	50.6
	60	32.2	17.1	50.7
	120	32.8	16.2	51.0
	180	36.2	15.0	48.8
	240	34.8	13.8	51.4
	300	33.4	16.0	50.6
Cl	5	7.3	67.5	25.2
	60	5.1	66.9	28.0
	120	6.8	68.8	24.4
	180	8.2	68.1	23.7
	240	8.5	64.2	27.3
	300	7.0	67.1	25.9

Table 2
Product % ratios determined by ^{1}H NMR, using various benzyl alcohols (BA) at 5:1, 2:1, 1:1, 1:2, 1:5 ratios of BA/$SOCl_2$

X-Ph-CH_2OH	BA/$SOCl_2$	% chloride	% sulfite	% alcohol
H	5:1	0	23.4	76.6
	2:1	11.2	55.3	33.5
	1:1	80.4	12.6	7.0
	1:2	100	0	0
	1:5	100	0	0
Me	5:1	0	5.9	94.1
	2:1	32.7	39.8	27.5
	1:1	81.7	0	18.3
	1:2	100	0	0
	1:5	100	0	0
*t*Bu	5:1	6.4	10.4	83.2
	2:1	27.0	60.1	12.9
	1:1	74.4	0	25.6
	1:2	100	0	0
	1:5	100	0	0
Ph	5:1	0	14.0	86.0
	2:1	26.3	29.2	44.5
	1:1	66.1	0	33.9
	1:2	100	0	0
	1:5	100	0	0
OMe	5:1	19.1	0	80.9
	2:1	48.6	0	51.4
	1:1	88.1	0	11.9
	1:2	100	0	0
	1:5	100	0	0
OPh	5:1	16.5	4.6	78.9
	2:1	40.2	6.4	53.4
	1:1	66.1	0	33.9
	1:2	100	0	0
	1:5	100	0	0
Cl	5:1	0	22.1	77.9
	2:1	34.0	15.4	50.6
	1:1	64.8	4.5	30.7
	1:2	98.8	1.2	0
	1:5	100	0	0
Br	5:1	0	10.7	89.3
	2:1	35.6	30.1	34.3
	1:1	90.2	0	9.8
	1:2	100	0	0
	1:5	100	0	0
CF_3	5:1	0	16.9	83.1
	2:1	0	12.5	87.5
	1:1	0	11.6	88.4
	1:2	5.8	8.8	85.4
	1:5	100	0	0
CN	5:1	0	14.8	85.1
	2:1	0	39.1	60.9
	1:1	0	6.3	93.7
	1:2	6.2	17.5	76.2
	1:5	100	0	0
NO_2	5:1	0	13.7	86.3
	2:1	7.3	67.5	25.2
	1:1	59	17.7	23.3
	1:2	87.0	0	13.0
	1:5	100	0	0

the solvent employed. Interestingly, neither bis(*p*-methoxybenzyl) sulfite nor bis(*p*-phenoxybenzyl) sulfite could be synthesized in great enough quantity to further study, regardless of the reaction temperature, solvent, time, or base used. We proposed a possible mechanism for the formation of benzyl chlorides as opposed to bis(benzyl) sulfites (Scheme 1),[14] suggesting that electron donation from the ether oxygen led to the displacement of SO_2 prior to the attack of another equivalent of benzyl alcohol. Interestingly, the amounts of sulfite and chloride products formed from the other benzyl alcohols used were dependent on the substituent at the *para*-position. Herein, we report the results of our investigation of relative sulfite formation versus chlorination upon treatment of *para*-substituted benzyl alcohols with thionyl chloride.

The reported general procedure for the synthesis of sulfites from benzyl alcohols involves reacting benzyl alcohol with thionyl chloride and pyridine in a ratio of 2:1:2 for 5 h in dichloromethane.[15] Subsequent quenching with distilled water, washing twice with brine, drying on $MgSO_4$, concentrating under reduced pressure, and purification by column chromatography with 5:1 hexanes/ethyl acetate allowed for the isolation of unreacted starting materials, benzyl chlorides, and bis(benzyl) sulfites. We began by evaluating the reaction rate, using ^{1}H NMR to measure product distribution for reactions with a 2:1 ratio of benzyl alcohol/thionyl chloride at 5–300 min (Table 1). We were surprised and elated to observe that in all cases the reaction was complete within 5 min. We repeated this with 4-nitro- and 4-chlorobenzyl alcohols and again observed completion of the reaction within 5 min. Importantly, the ratios of chloride to sulfite to unreacted alcohol did not change over time, indicating the stability of the products in solution. Thus, all subsequent reactions were run for $\geqslant$5 min.

In order to ascertain the effect of the *para* substituent on the ratio of products, we examined the reactions of eleven different benzyl alcohols with thionyl chloride at five different ratios, 5:1, 2:1, 1:1, 1:2, and 1:5, respectively (Table 2). [All benzyl alcohols used were obtained from commercial sources with the exception of 4-cyanobenzyl alcohol which was initially reduced from its