Generation of Thioaldehydes from Sodium Thiosulphate *S*-Esters (Bunte Salts)

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Treatment of Bunte salts, ZCH_2SSO_3Na where Z is an electron-withdrawing group, with triethylamine and calcium chloride in the presence of cyclopentadiene or 2,3-dimethylbuta-1,3-diene gives the corresponding cycloadducts of the transient thioaldehydes, ZCHS; the cyclopentadiene adducts dissociate upon heating thereby allowing transfer of the thioaldehydes to dimethylbutadiene.

We have described the formation of the transient, dienophilic thioaldehyde, ethyl thioxoacetate (**2**; Z = EtO_2C) by treatment of ethoxycarbonylmethanesulphenyl chloride[1] (**1**; Z = EtO_2C, X = Cl) or *N*-(ethoxycarbonylmethylthio)phthalimide[2] (**1**; Z = EtO_2C, X = phthalimido) with triethylamine. We recognised that these reactions were but two of a general family of ionic, thiocarbonyl-forming, 1,2-eliminations (Scheme 1) wherein X is a leaving group forming a weak bond to sulphur and Z is a group able to enhance the acidity of the neighbouring methylene hydrogen atoms. To extend the scope, and to improve the synthetic convenience, of this route to thioaldehydes we have developed a strategy (Scheme 2) whereby both the leaving group X and the obligatory sulphur atom are introduced into the precursor (**1**) by nucleophilic substitution using readily available bromomethyl [(**3**)] or chloromethyl compounds. To date, the most suitable anion, ^-SX, has proved to be thiosulphate, $[SSO_3]^{2-}$.

The preparation (Scheme 2) of thiosulphate *S*-esters (**1**; X = SO_3Na), 'Bunte salts',[3] is known to proceed in high yield with a wide range of alkyl halides. Milligan and Swan[4] studied the reactions of carbamoyl derivatives, $RNHCOCH_2SSO_3Na$, with primary and secondary amines, R'_2NH, and obtained thio-oxamides, $RNHCOCSNR'_2$, and disulphides, $(RNHCOCH_2S)_2$. They suggested that the thio-oxamides were formed, in a complex manner, from thioaldehydes, RNHCOCHS. Later, Saville and Steer[5] obtained monothiobenzil, PhCOCSPh, by treating the desyl Bunte salt, $PhCOCH(Ph)SSO_3Na$, with sodium hydroxide, a method that has been extended by Thimm *et al.*[6] These observations encouraged us to study the elimination reactions of the Bunte salts (**1**; X = SO_3Na) in the presence of conjugated dienes in the hope of trapping the thioaldehydes (**2**) as cycloadducts.

$$\underset{(1)}{ZCH_2SX} + Et_3N \rightarrow \underset{(2)}{[ZCHS]} + Et_3\overset{+}{N}H + X^-$$

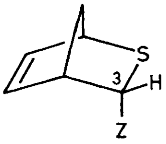
Scheme 1

$$\underset{(3)}{ZCH_2Br} + {}^-SX \rightarrow \underset{(1)}{ZCH_2SX} + Br^-$$

Scheme 2

We have obtained high yields of adducts under surprisingly mild conditions providing that the nucleophilic sulphite dianion is continuously removed from the reaction mixtures as its sparingly soluble calcium salt.

Thus, triethylamine was added slowly with stirring to the Bunte salt (**1**; X = SO_3Na) (typically 4 mmol) in methanol (10 ml) containing cyclopentadiene and calcium chloride dihydrate at room temperature. After 24 h, the mixture was acidified and extracted with chloroform. The extract, after being freed from salts by washing successively with dilute hydrochloric acid, dilute sodium hydroxide, and water, contained the *endo*- (**4**) and *exo*-adducts (**5**)† essentially free (n.m.r. control) from other materials. Purification by distillation (Kugelrohr), crystallisation, or chromatography gave the yields recorded in Table 1. Equimolar amounts of reactants were used throughout. Significantly, sodium *S*-4-nitrobenzyl thiosulphate (**1**; Z = $4\text{-}NO_2C_6H_4$, X = SO_3Na) gave a high



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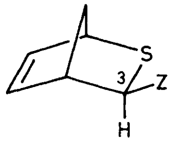

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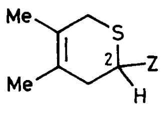

(6)

a; Z = EtO_2C
b; Z = PhNHCO
c; Z = PhCO
d; Z = NC
e; Z = $4\text{-}NO_2C_6H_4$

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† *Selected physical data* for cycloadducts: M.p.s, b.p.s (Kugelrohr distillation), and diagnostic ^1H n.m.r. ($CDCl_3$) signals were recorded as follows: (**4a**) and (**5a**), b.p. 95 °C (0.02 mbar); (**4a**), δ4.42 (d, *J* 4 Hz, 3-H); (**5a**), δ3.30 (br. s, 3-H); (**6a**), b.p. 110—120 °C (0.03 mbar), δ3.61 (t, *J* 6 Hz, 2-H); (**4b**) + (**5b**), m.p. 81—82 °C; (**4b**), δ5.10 (d, *J* 4 Hz, 3-H); (**5b**), δ4.04 (br. s, 3-H); (**6b**), m.p. 110—112 °C, δ3.65 (t, *J* 5 Hz, 2-H); (**4c**) and (**5c**), m.p. 88—89 °C; (**4c**), δ5.12 (d, *J* 4 Hz, 3-H); (**5c**), δ4.07 (br. s, 3-H); (**6c**), δ4.50 (t, *J* 6 Hz, 2-H); (**4d**) + (**5d**), b.p. 90 °C (0.02 mbar); (**4d**), δ4.27 (d, *J* 4 Hz, 3-H); (**5d**), δ3.28 (br. s, 3-H); (**6d**), b.p. 120 °C (0.02 mbar), δ3.76 (t, *J* 5 Hz, 2-H); (**4e**) + (**5e**), m.p. 76—78 °C; (**4e**), δ4.96 (d, *J* 4.5 Hz, 3-H); (**5e**), δ4.04 (br. s, 3-H); (**6e**), m.p. 64—64.5 °C, δ4.06 (t, *J* 7 Hz, 2-H).

Table 1. Cycloadducts of thioaldehydes, ZCHS (**2**), with conjugated dienes.

Bunte salt ($\mathbf{1}$; X = SO_3Na) Z	Cyclopentadiene Yield of (**4**) + (**5**), %	Cyclopentadiene (**4**) : (**5**) ratio[d]	2,3-Dimethylbuta-1,3-diene Yield of (**6**), %
a EtO_2C	67[a,b]	7 : 3[e]	68
b PhNHCO	66[c]	6 : 1	63
c PhCO	65[b]	7 : 3	65
d NC	77[c]	2 : 1[e]	51
e 4-$NO_2C_6H_4$	88[c]	7 : 1	55

[a] EtOH was used as solvent. [b] Separable by t.l.c. [c] Characterised as a mixture. [d] Determined by ^1H n.m.r. spectroscopy. [e] Unchanged by Kugelrohr distillation.

yield of adducts (**4e**) and (**5e**) whereas the unsubstituted benzyl derivative (**1**; Z = Ph, X = SO_3Na) gave no detectable amounts of the corresponding adducts. This illustrates the importance of methylene hydrogen acidity; conjugation of the thioformyl group with a benzene ring is not, in itself, adequate to facilitate elimination using triethylamine.

When cyclopentadiene was replaced as trapping agent by the less reactive 2,3-dimethylbuta-1,3-diene, the yields of cycloadducts (**6**), formed under the foregoing conditions, were consistently lower. However, acceptable yields were obtained using a less polar solvent system. Thus, triethylamine in benzene (5 ml) was added to the Bunte salt (typically 4 mmol) in ethanol (5 ml) and benzene (10 ml) containing calcium chloride dihydrate and 2,3-dimethylbuta-1,3-diene, with heating under reflux. Heating was continued for 4 h and the reaction mixtures were worked-up as before. The tabulated yields of the adducts (**6**)† are for purified materials. Apparently, competitive attack by nucleophiles (*e.g.* $SO_3{}^{2-}$) on the thioaldehydes is less important in less polar solvents, but the elimination reactions are generally slower.

We earlier reported[2] that the kinetically determined mixture of adducts (**4a**) and (**5a**) (1.4 mmol), when heated with 2,3-dimethylbuta-1,3-diene (1.54 mmol) in toluene under nitrogen at 120 °C (sealed tube) for 24 h, gave the adduct (**6a**) in 82% yield (after purification). Similarly, the adducts (**4b**) and (**5b**) gave (**6b**) (84%) and (**4c**) and (**5c**) gave (**6c**) (84%). This thermal transfer of thioaldehydes was slower with the cyano-adducts (**4d**) and (**5d**) but was complete in 48 h to give (**6d**) (79%). In contrast, transfer of 4-nitrothiobenzaldehyde from (**4e**) and (**5e**) to dimethylbutadiene was accomplished in benzene under reflux for 48 h to give (**6e**) (78%). It appears therefore that cyclopentadiene adducts are generally synthetically valuable, auxiliary sources of reactive thioaldehydes.

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