Studies of the Reactions of Anhydrosulphites of α -Hydroxycarboxylic Acids. Part VI.¹ Anhydrosulphite Synthesis and Characterisation

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The reaction of thionyl chloride with a-hydroxycarboxylic acids has been studied under conditions which favour anhydrosulphite formation. The most important impurity is shown to be the appropriate α -chloroacid chloride. The removal of this species is essential for controlled polymerisation of the anhydrosulphite, and is best achieved by chemical rather than physical methods. Physical data and characteristic spectral features of the ring are presented for several purified anhydrosulphites.

In connection with polymerisation studies we have prepared a range (Table 1) of anhydrosulphites with special reference to their purification and characterisation. Earlier work in this field ¹⁻⁸ has been summarised.

R1	\mathbb{R}^1	\mathbb{R}^2	R1 R2
î	(1) H	\mathbf{H}	(7) Bu Bu
-2^{2}	(2) H	Me	(8) -[CH ₂] ₃ -
R - C - CO	(3) Me	Me	(9) $-[CH_2]_4$ -
l `o	(4) Me	\mathbf{Et}	$(10) - [CH_2]_5 -$
Ĩ	(5) Et	\mathbf{Et}	$(11) - [CH_2]_6 -$
0-S0	(6) Pr	\mathbf{Pr}	

EXPERIMENTAL

Materials.---Reagents and solvents were purified as previously.2,3

a-Hydroxy-acids.—Acids which were not commercially available were prepared either by (i) modification of the conventional cyanohydrin route, bromination and subsequent hydrolysis of the parent carboxylic acid, or (ii) the reaction of the appropriate n-alkylmagnesium bromide on diethyl oxalate. References are included in Table 1.

Anhydrosulphites. Two routes were used: the action of thionyl chloride (i) on the appropriate α -hydroxy-acid or (ii) on its anhydrous copper(II) salt. Modifications required in individual cases are mentioned in the text. (a) Redistilled thionyl chloride (1.5 mole) was added slowly to a stirred solution of the acid (1.0 mole) in anhydrous ether (400 ml.) at -10° . The system was allowed to warm to 0° and then stirred for 16-20 hr. under reduced pressure (100-200 mm.), followed by 2 hr. at 20-30°. Finally, any residual ether and thionyl chloride was evaporated off under reduced pressure (1.0-5.0 mm.).

(b) To the dry anhydrous copper salt 5 (1.0 mole) slurried in dry ether (500 ml.) was added thionyl chloride (1.5 mole) at 0°, and the mixture was stirred for 20-30 min. The precipitate of copper chloride was filtered off and washed with anhydrous ether to remove any anhydrosulphite. The filtrate was then left for 1 hr. under reduced pressure (100-200 mm.) at room temperature and final traces of thionyl chloride were evaporated off as in (a).

The crude anhydrosulphite was obtained as a residual oil in both cases.

Chloride Titration .--- A modification of Ingram's potentiometric technique was used.⁹ To the accurately weighed anhydrosulphite (ca. 0.1 g.) was added an excess of water-

¹ Part V, B. W. Evans, D. J. Fenn, and B. J. Tighe, J. Chem. Soc. (B), 1970, 1049. ² B. J. Tighe and D. G. H. Ballard, J. Chem. Soc. (B), 1967,

702. ³ B. J. Tighe and D. G. H. Ballard, J. Chem. Soc. (B), 1967,

976. ⁴ A. J. Crowe and B. J. Tighe, *Chem. and Ind.*, 1969, 170.

acetone (3:1) (40 ml.) and a few drops of In-nitric acid. The solution was heated to 70° for 2-3 min., cooled, and titrated potentiometrically against 0.01N-silver nitrate with a silver/silver-silver chloride electrode system.

Purification.—(i) Treatment with triethylamine. An equimolar amount (with respect to chlorine-containing impurities) of pure triethylamine, was added dropwise as a 5% ethereal solution, to the crude anhydrosulphite, dissolved in ether at 0°. The precipitate was filtered off and ether was evaporated off from the filtrate leaving substantially chlorine-free anhydrosulphite.

(ii) Treatment with silver oxide.-This method has been discussed in connection with glycollic acid anhydrosulphite.⁵

(iii) Distillation. The crude anhydrosulphite was distilled under reduced pressure through a column packed with Raschig rings, or was kept in vacuo at a temperature between 60 and 90° until ca. 30% of the material had decomposed 2,3 and then distilled. Conventional short path distillation was also employed.

Sulphur Dioxide Estimation.—An accurately measured quantity of the anhydrosulphite was transferred to a kinetic apparatus ^{2,3} of known deadspace volume, containing either nitrobenzene or aqueous acetone. Following thermal decomposition or hydrolysis, the resultant yield of sulphur dioxide was calculated ² and the solid derivative (polymer or parent acid) removed for analysis.

G.l.c.—G.l.c. was carried out with a squalane column at temperatures between 40 and 80°.

RESULTS AND DISCUSSION

Table 1 lists methods of synthesis, yields, purity, and physical constants for the anhydrosulphites of a series of α -hydroxy-acids and Table 2 summarises yields of the various products obtained from the reaction of four α -hydroxy-acids with a 50% molar excess of thionyl chloride in diethyl ether.

Reactions which compete with anhydrosulphite formation are outlined in the scheme and chlorosulphinate decomposition to chloro-acid with subsequent formation of chloro-acid chloride is the most important side-reaction. When less than 50% molar excesses of thionyl chloride were used, unchanged acid was obtained and larger

⁵ M. D. Thomas and B. J. Tighe, J. Chem. Soc. (B), 1970,

1039. ⁶ D. J. Fenn, M. D. Thomas, and B. J. Tighe, J. Chem. Soc. (B), 1970, 1044.
7 S. Inoue, K. Tsubaki, and T. Tsurata, Polymer Letters, 1968, 6, 733; Makromol. Chem., 1969, 125, 170.
⁸ J. B. Rose and C. K. Warren, J. Chem. Soc., 1965, 791.
⁹ G. Ingram, Microchim Acta, 1956, 877.

J. Chem. Soc. (C), 1971

TABLE 1 α -Hydroxycarboxylic acid anhydrosulphites: synthesis, purification, and characterisation

		•			• -		-						
	T Parent	echniques e	mployed		Chlorine (moles anhydros	content /mole sulphite		Refrac-					Sulphur dioxide
	acid	Anhydro-			Before	After		tive			I.r. s	pectra	evolved
	syn-	sulphite	Puri-	Yield	puri-	puri-	B.p.	index	U.v. 9	spectra	$v_{\text{max.}}$	v_{max}	(% theor-
	thesis	synthesis	fication	(%)	fication	ncation	(°C/mm.)	$[n]_{D}$	Amax.	log ₁₀ ε	(C=0)	$(3\rightarrow 0)$	etical)
(1)	(5)	(6) and (7)	(9), (10), (11)	44 ·0	$5 imes10^{-2}$	5 imes10-3	68—70/10	1.4750 25	$210.5 \\ 291.5$	$2.091 \\ 3.0828$	1825	1245	98 ± 2
(2)	(5)	(7)	(8), (10), (11)	63.0	$6 imes 10^{-2}$	$8 imes10^{-3}$	70/12				1815	1235	97 ± 2
(3)	(5)	(6)	(8), (10), (11)	68 ·0	1.54×10^{-2}	$3.6 imes10^{-3}$	56-57/12	1.4312 20	$219.5 \\ 294.0$	3.0017 1.2667	1825	1250	99 ± 2
(4)	(5)	(6)	(10), (11)	55.0	$7 imes 10^{-2}$	$2.5 imes10^{-2}$	29.5 - 30/ 1.4	1.4358 23	$214.0 \\ 298.5$	3.0319 1.3220	1812	1250	97 ± 2
(5)	(1)	(6)	(9), (8), (11)	80.5	$1.5 imes10^{-1}$	$2.8 imes10^{-3}$	35-36/	1.4423 20	208.5 283.0	3.1219 2.3410	1815	1255	99 ± 2
(6) *	(2)	(6)	(9). (11)	50.5	1.0×10^{-1}	1.5×10^{-2}	63/0.7	1.4460 21	200 0	2 0 1 1 0	1805	1240	96 + 2
(7) *	(2) (2)	(6) and (7)	(9), [(11)]	35.0 +	3×10^{-1}	5×10^{-2}	84/1.2	1.4508 20			1810	1245	95 ± 2
(8) *	(3)	(6) and (7)	(9)	15.0^{+}	$2{\cdot}6 imes10^{-1}$	$1.6 imes 10^{-1}$			211.0 292.0	$\sim^3_{\sim 1}$	1815	1225	80 ± 5
(9) *	(5)	(6)	(9), (11)	74 ·0	$2{\cdot}0 imes10^{-1}$	$1.4 imes 10^{-3}$	69—70/ 0:7	1·4700 20	$202 \circ 211 \cdot 5$	3.0588	1818	1243	98 ± 2
10)	(5)	(6)	(9), (11)	69.5	$5.0 imes10^{-2}$	$1.0 imes 10^{-3}$	67/0.4	1.4782 20	207.5 274.5	3·4842	1810	1238	98 ± 2
11) *	(4)	(6)	(9), [(11)], (12)	30·0 [4·2] ‡	$8.0 imes 10^{-2}$	$5 imes 10^{-2}$	(M.p. 7—9°)			1 .102	1810	1235	93 ± 2

* Compounds not previously reported in the literature. † Not distilled. ‡ Distilled.

- Conventional cyanhydrin route but with THF as cosolvent.
- (2) Method due to H. Hepworth, J. Chem. Soc., 1919, 115, 1206.
- Method due to N. J. Demjanov and M. Dojarenko, Ber., 1922, 55B, 2737. Method due to B. Tchoubar, Bull. Soc. chim. France, 1947, 160, 680; (3)
- Commercially available.
- Thionyl chloride-acid. (6)
- Thionyl chloride-copper(II) (salt). Treatment with triethylamine. Treatment with silver oxide. **(**7)
- (8)
- (9)
- (10)Flash distillation.
- Fractional distillation using spinning band column. (11)

(12)Vacuum sublimation.

TABLE 2

Products obtained from the reaction of various α -hydroxy-acids with thionyl chloride (for reaction conditions see text) Reaction products

			¹		
	Unchanged	α-Chloro-acid	α-Chloro-acid	Anhydrosulphite	Oligomers
α-Hydroxy-acid	acid (%)	(%)	chloride (%)	(%)	(%)
Lactic	20 ± 10		< 10	20 ± 10	20 ± 10
α-Hydroxy isobutyric			15 ± 10	70 ± 10	< 10
1-Hydroxycyclopentane-1-carboxylic			20 ± 10	60 ± 15	< 10
Benzilic	80 + 15	< 10			



Reaction of a-hydroxy-acids with thionyl chloride

excesses produced larger yields of acid chloride. Modification of the synthesis by treatment of the copper salt of the hydroxy-acid with thionyl chloride is preferred for lactic acid.² It has been previously shown¹ that arylsubstituted derivatives are best prepared in this way.

Purification by fractional distillation was difficult due to the similar boiling points of α -chloro-acid chloride, the main impurity, and the anhydrosulphite. Repeated fractional distillation resulted in progressive decomposition of the desired material because of the low thermal stability of the anhydrosulphite. Treatment with triethylamine or silver oxide proved most successful in removing chlorine-containing impurities. Silver oxide treatment was preferable as less decomposition occurred during purification by this method.

Characterisation of anhydrosulphite by elementary analyses gave poor results probably due to thermal

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((instability and rapid hydrolysis. In the mass spectra, peaks at (M-64), (M-108), and (M-80) appear to be typical of compounds containing the anhydrosulphite ring. I.r. spectra showed a carbonyl group at $1815 \pm 10 \text{ cm}^{-1}$ and the S-O stretching frequency at 1240 cm^{-1} as a medium-intensity peak. Other absorptions which appear to be characteristic of the ring system are found

as medium intensity peaks at 1085 and 1045 cm.⁻¹. U.v. spectra show characteristic absorption at 214 \pm 6 nm.

We are grateful to the S.R.C. for a studentship (to G. P. B.).

[0/129 Received, January 28th, 1970]

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