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SOME REARRANGEMENTS OF 2,3- AND 2,10-OXYGENATED PINANE DERIVATIVES

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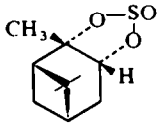
Abstract—Rearrangements of 2,3- and 2,10-oxido-pinanes and of cyclic sulphites and carbonates derived from 10β-pinane-2,10-diol and 10β-pinane-2,3α-diol are described.

DURING studies[1] concerned with establishing the stereochemistry of pinane derivatives oxygenated at the 2,3 and 10-positions we reported the formation of the cyclic sulphite (**1**) of 10β-pinane-2,3α-diol (**2**). While this cyclic sulphite sample has now been separated[2] by fractional crystallization into two isomers (A and B), epimeric at the



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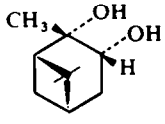

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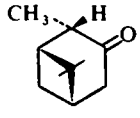

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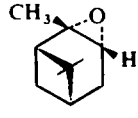

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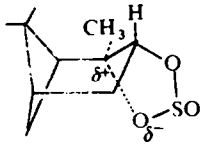

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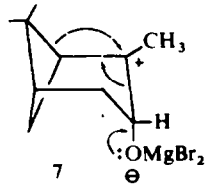

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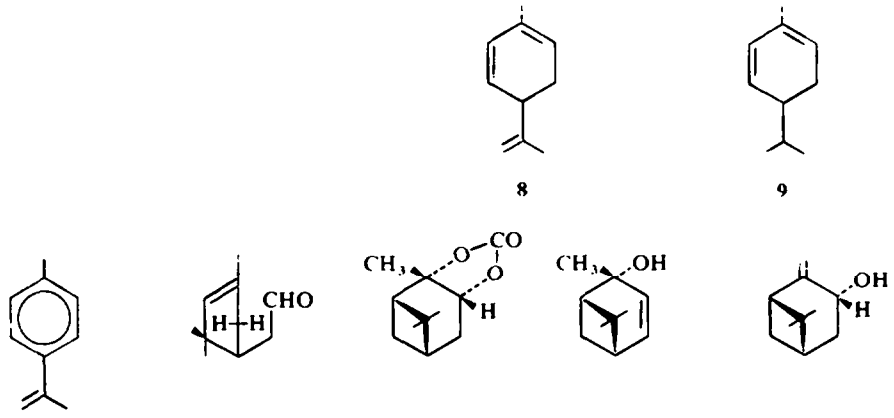
asymmetric S atom, the material used for pyrolysis in carbowax 400 at 200°—50 mm was the original mixture (1 : 1) of isomers. The distillate from the pyrolysis was shown (GLC) to consist of a mixture (98:2) of pinocamphone (**3**) and 2,2,3-trimethylcyclopent-3-en-1-acetaldehyde (**4**). In contrast, reaction of α-pinene oxide (2,3α-oxido-10β-pinane; **5**) with a Lewis acid, e.g. anhydrous $MgBr_2$,[3] gives essentially pure aldehyde (**4**). The origin of this marked difference in product compositions for two reactions, both of which involve ionization of a $C^{2\alpha}$-O bond, is clearly due to the differing conformational constraints imposed on the reacting molecule. In the pyrolysis of the cyclic sulphite mixture it seems probable that early in the process of breaking the C^2-O bond the reacting molecule would move towards a conformation (**6**) in which the 3β-H would be well-placed for migration to the 2β-position in concert with the C^2-O bond cleavage. In contrast to this limited, but significant, C^2—C^3 rotational mobility which can be accommodated by the flexible cyclic sulphite ring system, the pinane-ring conformations energetically available to the reacting molecule in the α-pinene oxide–$MgBr_2$ reaction are limited severely by the constraint imposed

by the attachment of the leaving group —O—$MgBr_2$ directly to C-3. For maximum residual solvation of the developing C^2-carbonium ion by the departing O atom of the epoxide, the axial cleavage[4] mode of reaction would be followed to give carbonium ion (**7**) at full charge separation. Throughout this process of charge separation in the C^2—O bond the C^3—H bond would be maintained in the plane of the developing C^2-carbonium ion, not a favourable position for hydride migration by the 3β-H. The collapse of carbonium ion (**7**) to give aldehyde (**4**) is envisaged as an essentially concerted process (see **7**).

Reaction of α-pinene oxide (**5**), in carbowax 400 at 50 mm, in a stream of SO_2 gas gave a distillate which appeared (GLC) to consist of five components. Fraction 1, separated by preparative GLC, was identified as the hydrocarbon (**8**; 10%) by its UV (λ_{max} 265 mμ; cf. α-phellandrene (**9**), λ_{max} 263 mμ)[5] and NMR spectra (Experimental).



8 **9** **10** **11** **12** **13** **14**

Fraction 2 was identified as *p*-cymene (11%). Fraction 3, a mixture of hydrocarbon (**10**; 7%) and aldehyde (**11**; 15%), was separated into its components by means of aldehyde-bisulphite salt formation. The remaining fractions 4 and 5 were identified (GLC and NMR) as aldehyde (**4**; 55%) and pinocamphone (**3**; 2%) respectively. It should be noted that α-pinene oxide (**5**) distils unchanged from carbowax at 200°—50 mm, while pinocamphone is unchanged by SO_2–carbowax at 200°.

Pyrolysis of the cyclic carbonate (**12**) in carbowax 400 at 50 mm in the presence of KCN gave a mixture of pinocamphone (**3**; 5%), 10β-pin-3-en-2-ol (**13**; 42%) and *trans*-pinocarveol (**14**; 53%). It seems probable that the reactions leading to the formation of allylic alcohols (**13** and **14**) are initiated by base-catalysed removal of a proton from C-4 and C-10 respectively, accompanied by C-O bond cleavage at the adjacent C atoms C-3 and C-2. The stereochemistry of the allylic alcohols (**13** and **14**) constitute additional evidence for the 2α,3α-stereochemistry[1] for the diol (**2**) from which the cyclic carbonate is derived.

Attempted reaction of 2,10-oxido-10β-pinane (**15**) with SO_2–carbowax 400 at 50 mm., and the cyclic sulphite (**16**) derived from 10β-pinane-2,10-diol on pyrolysis in carbowax 400 gave only low yields of volatile material consisting of a mixture (2 : 1) of *p*-cymene and α,p-dimethylstyrene (**10**).

Treatment of the cyclic sulphite (**16**) with pyridine at 115° for 2 hr gave a mixture (GLC and NMR) of 10α-pinan-10-al (**18**; 20%), 10β-pinan-10-al (**19**; 52%) and myrtenol (**20** : 28%). In contrast, reaction of 2,10-oxido-10β-pinane (**15**) and 2,10-oxido-10α-pinane (**21**) with SO_2–pyridine at 20° gave complex mixtures (see Exptl. for yields) containing 10α-pinan-10-al (**18**), myrtenol (**20**), *p*-mentha-1,8-dien-7-ol (**17**) and the cyclic sulphites (**16** and **22**). The notable feature of the relative yields of products from the epimeric epoxides (**15** and **21**) was that while the total yield of cyclic sulphites (**16** and **22**) was the same, the yield of the 2α-cyclic sulphite (**16**) was greater (2α-: 2β-; 3 : 1) from the α-epoxide (**15**) than from the β-epoxide (**21**) (2α-: 2β-; 1 : 1).

Reaction of the cyclic carbonate (**23**) with KCN in carbowax 400 at 50 mm. gave a mixture (2 : 1) of myrtenol (**20**) and 2,10-oxido-10β-pinane (**15**). It seems probable that the epoxide (**15**) is formed *via* the alkoxide ion[6] (**24**; see Fig. 1), but internal

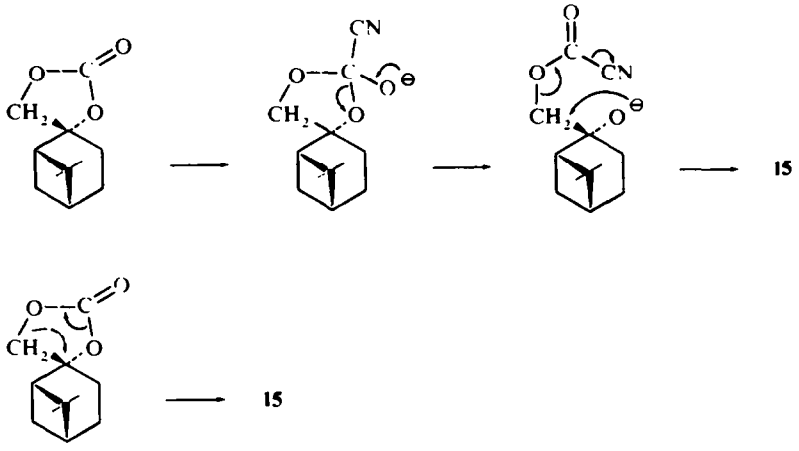
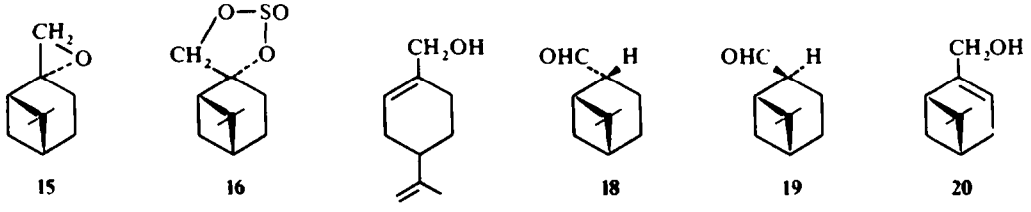
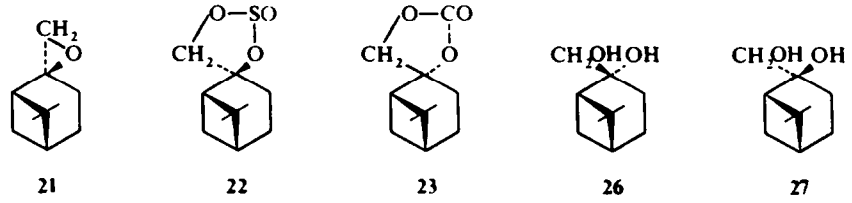


FIG. 1

collapse of the carbonate moiety (**25**) with extrusion of carbon dioxide may not be excluded.





Treatment of each of the epimeric epoxides (**15** and **21**) with BF_3-etherate in ether solution gave a mixture of the 10α- and 10β-pinan-10-als (**18** and **19**; total ca. 50%) and involatile polymeric material. The aldehydes (**18** and **19**) were identified (NMR and GLC) by comparison with authentic samples prepared independently by oxidation of the corresponding 10α- and 10β-pinan-10-ols.[7] The relative aldehyde product ratios were similar (10α-: 10β-; ca. 1 : 2) for the two epoxides (**15** and **21**) but favoured slightly that epimeric aldehyde which might have been considered to arise by concerted C^2—O bond cleavage and hydride migration. A similar pattern of rearrangement products has recently been noted[8] for epoxides derived from exocyclic methylene derivatives of steroids.

EXPERIMENTAL

Rotations ($CHCl_3$ solns at room temp): IR spectra (CS_2 solns unless otherwise stated, on a Perkin–Elmer 221 spectrometer); alumina used for chromatography (P. Spence, Grade H); NMR Spectra (determined on a Varian A-60 in CCl_4 with $CHCl_3$ and TMS as internal standards); Preparative GLC (Micro Tek 2500 II R, columns 0·25 in, aluminium packed with either 20% carbowax 20M or 20% S.E.30 on celite (30–80); Analytical GLC (Micro Tek 2500 II R or Aerograph 204, columns were 0·25 and 0·125 in, respectively packed with either 3% carbowax 20M, or S.E.30, or Apiezon L on Chromosorb G, non acid-washed and treated with HMDS).

Pyrolysis of cyclic sulphite (1). Cyclic sulphite[1] (2 g) dissolved in carbowax 400 (5 ml) was heated to 200° at 50 mm. The volatile products were distilled over in a stream of N_2. Ether (50 ml) was added to the distillate and the soln washed with sat $NaHCO_3$aq (2 × 50 ml). The soln was dried and the solvent removed to give an oil (1·1 g), shown by GLC to contain two compounds (98 : 2). The major compound was identified as **3**, by comparison with an authentic sample by GLC, ν_{max} 1709 cm^{-1}, and δ 0·90 ppm (8-Me), 1·33 ppm (9-Me) and 1·04 ppm (doublet $J = 7$ cs; 10-Me). The minor compound was identified (GLC) as **4**.

Reaction of α-pinene oxide (**5**) *with* SO_2

A stream of SO_2 gas was passed through a heated soln of α-pinene oxide (2 g) in carbowax 400 (5 ml) at 50 mm. The crude product (1·8 g), which distilled from the reaction mixture, was separated by GLC (20% carbowax 20M) into 5 fractions.

Fraction 1 was identified as **8** 10%), λ_{max} 265 mμ, δ 1·74 ppm (6H), 4·75 ppm (2H), 5·42 ppm (1H), 5·74 ppm (2H) and methylene region (3H).

Fraction 2 was identified as *p*-cymene (11%), δ 1·22 ppm (doublet, $J = 6·5$ cs; 6H), 2·29 ppm (3H), 2·79 ppm (quartet; 1H) and 7·15 ppm (4H).

Fraction 3 was shown (IR and NMR) to contain **10** (7%) and **11** (15%), which were separated by aldehyde–bisulphite salt formation. The hydrocarbon **10** was identified by ν_{max} 828, 891, 1670, 1795 and 1909 cm^{-1} and δ 2·12 ppm (3H), 2·33 ppm (3H), 4·98 ppm (1H), 5·22 ppm (1H) and 7·19 ppm (quartet; 4H). The aldehyde **11** was identified by comparison (GLC and NMR) with an authentic sample, δ 0·82 ppm (3H), 1·08 ppm (3H), 1·65 ppm (3H), 5·10 ppm (1H) and 9·73 ppm (1H).

Fraction 4 consisted of the **4** (55%), δ 0·78 ppm (3H), 1·00 ppm (3H), 1·65 ppm (3H), 5·26 ppm (1H) and 9·73 ppm (1H), identical in all respects with an authentic sample.

Fraction 5 consisted of **3** (2%) identical (GLC and NMR) with an authentic sample.

Cyclic carbonate (**12**). Pyridine (15 ml) was added to a soln of **26** 5 g) in ethyl chloroformate (15 ml). After the exothermic reaction, the crude product, isolated by means of ether, gave on distillation the *cyclic carbonate* (**12**; 2·7 g), b.p. 11 mm. ca. 140°, m.p. 80–82°, ν_{max} 1715, 1750 and 1815 cm^{-1} (Found: C, 67·8; H, 8·1. $C_{11}H_{16}O_3$ requires (C, 67·3; H, 8·2%); δ 0·88 ppm (3H), 1·35 ppm (3H), and 1·53 ppm (3H), and 4·50 ppm (quartet, J^{app} 8 c/s, 6 c/s; 1H).

Pyrolysis of the cyclic carbonate (**12**). A mixture of cyclic carbonate (1·5 g) and KCN (0·5 g) in carbowax 400 (15 ml) was heated to 200° at 50 mm in a stream of N_2. Analysis (GLC) of the crude distillate (1·04 g) showed the presence of 3 compounds in relative yields of 5%, 42% and 53% in order of elution. Compound 1 was identified (GLC) as **3**. Compounds 2 and 3 were isolated by GLC (on 20%

carbowax 20M). Compound 2 was identified as 10β-pin-3-en-2-ol by comparison (GLC and NMR) with an authentic sample, δ_{CDCl_3} 0·95 ppm (3H), 1·32 ppm (3H), 1·37 ppm (3H), 5·50 ppm (multiplet; 1H) and 6·27 ppm (multiplet; 1H). Compound 3 was identified as *trans*-pinocarveol (**14**) by comparison (IR and GLC) with an authentic sample, δ 0·63 ppm (3H), 1·28 ppm (3H) and 4·83 ppm (quartet; 1H).

Cyclic sulphite (**16**). To a soln of **26** (g) in pyridine (1 ml) at 0° was added thionyl chloride (0·5 ml). Isolation *via* pentane and crystallization from pentane gave the *cyclic sulphite* [**16**; 0·54 g) m.p. 78–80° (dec), ν_{max} (Nujol) 1202 cm^{-1}. δ 0·90 ppm (3H), 1·31 ppm (3H) and 4·28 ppm (quartet: 2H) Found: C, 56·1; H, 7·8; S, 14·2. $C_{10}H_{16}O_3S$ requires: C, 55·5; H, 7·4; S, 14·8%).

Reaction of cyclic sulphite (**16**). *with pyridine*

A soln of **16** (0·75 g) in pyridine (10 ml) was heated at 115° for 2 hr. The crude product extracted by means of pentane was an oil (0·30 g), shown by (GLC, NMR and IR) to consist of a mixture of **18** (20%), **19** (52%) and **20** (28%).

Pyrolysis of Cyclic sulphite (**16**). A soln of the cyclic sulphite (1 g) in carbowax 400 (5 ml) was heated at 50 mm. The crude distillate (0·15 g) was shown (GLC) to be a mixture of two compounds. Compound 1 was *p*-cymene (ca. 70%) while compound 2 was identified as **10** (ca. 30%).

Reaction of 2,10-*Oxido*-10β-*pinane* (**15**) *with* SO_2

SO_2 gas was bubbled through a soln of **15** (2 g) in carbowax 400 (5 ml) and the mixture heated at 50 mm. The crude distillate (0·38 g) was shown to be a mixture (2 : 1) of *p*-cymene and **10**.

Reaction of 2,10-*oxido-pinanes with pyridine*-SO_2

(a) 2, 10-*Oxido*-10β-*pinane* (**15**). The epoxide **15** (3 g) was added to a soln of SO_2 (1·35 g) in pyridine (10 ml) and the mixture kept at 20° for 12 hr. Isolation *via* ether gave a crude product (2·9 g), the IR and NMR spectra of which indicated the presence of cyclic sulphites. The crude product was treated with a soln of NaOH (3 g) in aqueous MeOH (1 : 1; 60 ml) and the mixture stirred for 1 hr. A ppt of Na_2SO_3 was formed. The terpene material (2·0 g) isolated *via* ether was shown to contain four major components (1–4) in relative yields (GLC) of 6·0, 20, 19 and 49% respectively. These components were separated by elution from alumina (10 g) in pentane–ether mixtures.

Component 1 was identified as **18** by comparison (GLC and NMR) with an authentic sample. Component 2 was identified as **20** by comparison (GLC and NMR) with an authentic sample. Component 3 was identified as **17**, δ 1·73 ppm (3H), 3·92 ppm (2H), 4·68 ppm (2H) and 5·63 ppm (1H), ν_{max} 3360, 2920, 1465, 1390, 1370, 1062, 970, 918 and 894 cm^{-1} (lit. cit.[9] 3340, 2940, 1440, 1378, 1365, 1057, 965, 915 and 886 cm^{-1}).

Component 4 was shown to consist of a mixture (3 : 1) of **26** and **27**. The major component was identified as diol **26** by comparison of the NMR spectra of an authentic sample[1] (δ 0·93 ppm (3H), 1·26 ppm (3H), and 3·38 ppm ($W_{\frac{1}{2}}$ = 3 cs; 2H)) and the mixture above. The minor component gave an NMR spectrum (by difference), δ 1·09 ppm (3H), and 1·25 ppm (3H; the marked difference in the 9-Me resonance (Δ 0·16 ppm) is consistent with the *syn*-axial positions of the 9-Me and the 2 β-OH group in diol (**27**).

Reaction of the diol mixture with *p*-toluenesulphonyl chloride in pyridine gave the mixed 2-hydroxy-10-tosylates, which on reduction with LAH in ether gave a mixture of 10α- and 10β-pinan-2-ols identified (GLC and NMR) with authentic samples.

(b) 2, 10-*Oxido*-10α-*pinane* (**21**). The epoxide **21** (3 g) was added to a soln of SO_2 (1·35 g) in pyridine (10 ml) and the mixture kept at 20° for 12 hr. Isolation *via* ether gave a crude product (2·3 g) the IR and NMR spectra of which indicated the presence of cyclic sulphites. Mild hydrolysis (as above) gave an oil (1·7 g), which was shown (GLC, etc) to consist of **18** (4·0%), **20** (29%), **17** (7%), **26** (28%), and **27** (28%).

Cyclic carbonate (**23**). Sodium (0·02 g) was dissolved in diethyl carbonate (4 g), **26** (5 g) added, and the mixture heated until no more EtOH distilled off. The solid residue (5·7 g), on crystallization from $CHCl_3$ gave the *cyclic carbonate* (2·2 g), m.p. 141–142°, δ_{CDCl_3} 0·83 ppm (3H), 1·26 ppm (3H) and 4·12 ppm (2H), ν_{max} (Nujol) 1795 cm^{-1} (Found: C, 67·3; H, 8·2. $C_{11}H_{16}O_3$ requires: C, 67·3; H, 8·2%).

Pyrolysis of the cyclic carbonate (**23**). A mixture of cyclic carbonate (1·5 g) and KCN (0·5 g) in carbowax 400 (15 ml) was heated to 200° at 50 mm in a stream of N_2. Analysis (GLC and NMR) of the crude distillate (0·9 g) indicated a mixture (2 : 1) of **20** and **15**.

BF_3-Etherate catalysed rearrangement of 2, 10-*oxidopinanes*

(a) 2,10-*Oxido-10β-pinane* (**15**). A dilute ethereal soln of BF_3–etherate (0·1 ml in 10 ml Et_2O) was added to a soln at 0° of **15** (0·5 g) in ether (100 ml) and the soln kept for 10 min. The reaction was quenched by addition of sat $NaHCO_3$aq. The crude product (0·44 g), isolated by means of ether, was shown (GLC and NMR) to contain pinan-10-als (ca. 51%) and polymeric material. The relative yield of **18** and **19** (2:3) was established by integration of the 10α CHO (δ 9·53 ppm) and 10β CHO (δ 9·67 ppm) signals in the NMR spectrum. The assignment of these signals to the epimeric aldehydes, and the retention times of the aldehydes on GLC, was confirmed by oxidation of the corresponding pinan-10-ols.[7]
(b) 2,10-*Oxido*-10α-*pinane* (**21**). Reaction of **21** (0·5 g), as above, gave a crude product (0·47 g) shown (GLC and NMR) to contain pinan-10-als (ca. 50%) and polymeric material. The relative yield of **18** and **19** was (1:2).

Attempted epimerization of pinan-10-*als* (**18** and **19**). The aldehyde (50 mg) was treated with BF_3–etherate in ether soln under the conditions of the epoxide reactions (above), but the reaction was continued for 30 min. Isolation by means of ether gave starting material (ca. 40 mg).

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