Tetrahedron Letters No. 49, pp 4951 - 4954, 1972. Pergamon Press. Printed in Great Britain.

ADDITION OF CHLOROSULPHONYL ISOCYANATE TO α- and β- PINENE

J.R. Malpass

Department of Chemistry, The University, Leicester, LE1 7RH [1a]

Department of Chemistry, The University, Bailrigg, Lancaster, [1b]

(Received in UK 6 October 1972; accepted for publication 1 November 1972)

In a reinvestigation[2] of the reaction of chlorosulphonyl isocyanate (CSI) with camphene[3] (1) we described the interception of an unstable N-chlorosulphonyl β-lactam (2) at -60°. At higher temperatures 2 reopened to dipole 3 and ultimately yielded 4 and 5 via Wagner Meerwein rearrangement followed by cyclisation through oxygen and nitrogen respectively. In view of this observation of iminolactone formation and the lack of support for proton transfer,[3] we have extended the reaction to cover a number of isomeric terpenes and report here results with α- and β-pinene.

β-Pinene (6) was chosen as a possible precursor of related iminolactones and lactams (e.g.9) but on reaction with CSI in CH_2Cl_2 at 0°, no evidence was obtained for any cyclisation products. Rather, a high yield (> 70% by NMR)[4a] was obtained of 10a, m.p. 91-6° ex ether/pentane, $\nu_{max}^{CH_2Cl_2}$ 3340, 1744, 1645cm^{-1}, NMR[5]: δ 8.92 b 1H(NH), 5.75 m 1H and 4.74 m 2H (olefinic), 3.13 bs 2H($-CH_2-CO-$), 2.3-1.9 m 5H(allylic CH), 1.75 s 3H($CH_3-C=C$),1.7 m 2H(CH_2). Reaction with thiophenol/pyridine in acetone followed by chromatography on florisil afforded amide 10b[5], m.p. 150-5°, $\nu_{max}^{CHCl_3}$ 3510, 3400, 1680cm^{-1}, which gave 11a,[6] m.p. 170-1° (Lit.[7] 172-3°) when heated with a molar equivalent of sulphur at 200°. On treatment of crude 10a with triethylamine,[8] nitrile 10c was isolated in 57% yield (after chromatography to remove some amide) and was aromatised directly and the product 11b hydrolysed to 11c, m.p. 50-51° (Lit.[7] 51-2°).

When the reaction was performed in $CDCl_3$ in an NMR tube at -70°, the olefinic absorption due to 6 was rapidly replaced by a peak at δ3.28 ascribed to the α-carbonyl protons of the sole product, β-lactam 7a. On warming to -40° in the probe of the spectrometer, the conversion of 7a to 10a could be readily monitored. Despite the extreme instability of 7a, the corresponding NH lactam 7b[6] could be isolated in 70% yield (after careful reaction in CH_2Cl_2 at -70° followed by work-up with thiophenol/pyridine/acetone[2] at -78° and chromatography) m.p. 114-5°, $\nu_{max}^{CH_2Cl_2}$ 3385, 1756cm^{-1}, NMR[5]: δ6.74 b 1H(NH), 2.76 d(J≈1Hz)2H($-CH_2-CO$), 1.26 s 3H, 0.85 s 3H.

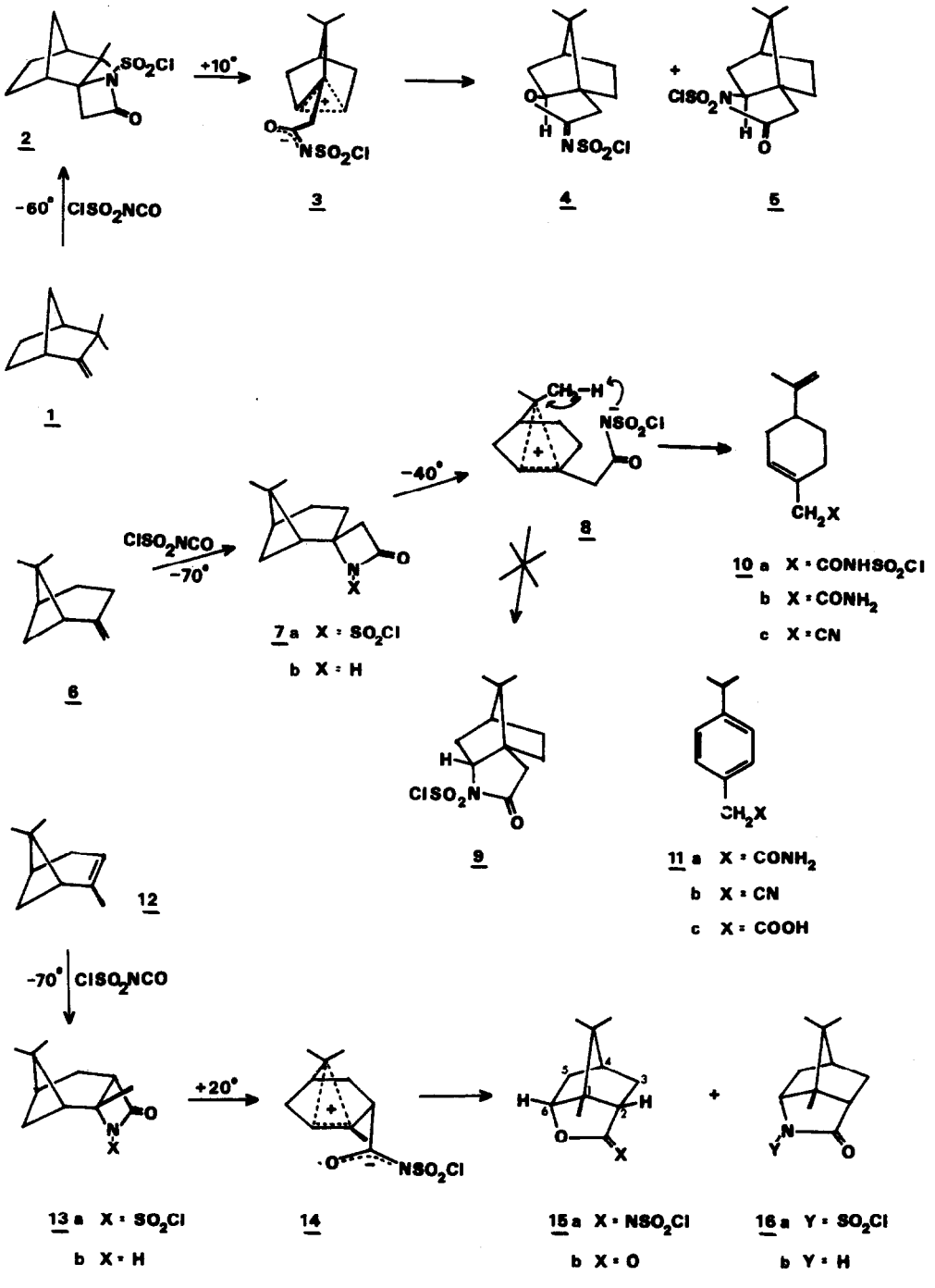
In contrast, α-pinene (12) reacted smoothly with CSI at low temperatures to yield a fairly stable, crystalline β-lactam 13a, $\nu_{max}^{CH_2Cl_2}$ 1810cm^{-1}, NMR:[5] δ3.35 dd (J=9.0,3.0 Hz)1H(-CH-CO), 1.84 s 3H, 1.38 s 3H, 0.94 s 3H which was again characterised as the NH lactam 13b,[6] m.p. 146-8°, $\nu_{max}^{CH_2Cl_2}$ 3395, 1755cm^{-1}.

The expected C-N bond cleavage in 13a occurred slowly even at 20° though transformation was complete within an hour in $CDCl_3$ at 40° to a mixture containing 15a and 16a in yields (NMR) of ca. 20% and 50% respectively.[4b] Fractional crystallisation afforded 15a[6] in 12% yield, m.p. 143-4°, $\nu_{max}^{CH_2Cl_2}$ 1610cm^{-1}, NMR:[5] δ4.88 bd(J=7.5 Hz)1H(H_6), 3.05 bd(J=10.0 Hz)1H(H_2), 1.18 s 3H, 1.02 s 3H, 0.98 s 3H. On warming with aqueous HCl and acetone, 15a was converted efficiently to lactone 15b,[6] m.p. ca.200-210°, sublimes above 80°, ν_{max}^{film} 1778cm^{-1}, NMR:[5] δ4.41 bd(J=7.5 Hz)1H, H_6, 1.12 s 3H, 0.94 s 6H. In this case H_2 was partially hidden under the complex signal due to the ring protons but could be discerned in C_6H_6. On addition of $Eu(DPM)_3$ a downfield shift revealed H_2 clearly as a very broad doublet. Spin-decoupling then demonstrated only small (ca. 1 Hz) W-coupling between H_2 and H_6. The characteristic broad doublet (J=7.5 Hz) for H_6 agrees well with the findings of Traylor[9a] in similar lactones (e.g. $J_{exo-5,exo-6}$ = 7 Hz, $J_{endo-5,exo-6}$=0) and the simplification of H_2 to a broad doublet of doublets (J=10.0,2.5 Hz) on irradiation of H_6 is in harmony with the work of Moriarty[9b] ($J_{exo-2,exo-3}$= 10.0-10.8 Hz, $J_{exo-2,endo-3}$= 2.0-3.0 Hz). The further slight broadening is ascribed to $J_{4,exo-6}$ and $J_{exo-2,4}$.[9b] The absence of additional 5.0 Hz coupling expected of $J_{1,exo-6}$ and $J_{1,exo-2}$ places a methyl group at C_1.

The major product 16a, $\nu_{max}^{CH_2Cl_2}$ 1769cm^{-1}, NMR:[5] δ4.23 bd (J=7.5 Hz) H_6, 1.16 s 3H, 0.98 s 6H was converted in 45% overall yield to 16b,[6] m.p. ca. 205-215°, sublimes above 140°, $\nu_{max}^{CHCl_3}$ 3440. 1694cm^{-1}, NMR:[5] δ3.37 bd (J=7.5 Hz) H_6,1.09 s 3H, 0.93 s 6H.

The primary formation of each β-lactam may be viewed as a kinetically controlled dipolar addition of the uniparticulate electrophile CSI[10,11] though the alternative π2s + π2a cycloaddition[12] cannot be excluded.

Turning to the secondary reactions achieved under conditions of thermodynamic control, whilst ring closure in 3 gives the exo-fused products 4 and 5,[14a] the nature of the cationic species 14 resulting from opening of 13a necessitates endo-attack to give the observed products of cyclisation through O(15) or N (16). A similar endo-ring closure in 3 would require the formation of products such as lactam 9 which are in fact highly strained. In view of this difficulty, the intermediate apparently foregoes cyclisation in favour of cleavage to 10a. Inspection of models reveals the ease with which the internal nucleophile N^- can reach a


2
+10°
3
4
5
-60° ClSO2NCO
1
-40°
8
CH2X
10 a X = CONHSO2Cl
b X = CONH2
c X = CN
ClSO2NCO
-70°
7 a X = SO2Cl
b X = H
6
9
11 a X = CONH2
b X = CN
c X = COOH
12
-70° ClSO2NCO
+20°
13 a X = SO2Cl
b X = H
14
15 a X = NSO2Cl
b X = O
16 a Y = SO2Cl
b Y = H

conformation 8 in which transfer of a methyl proton may initiate the observed fragmentation reaction; further evidence is being sought for such an unusual intramolecular proton transfer.

References and Footnotes

1.(a) Present address. (b) Thanks are due to I.C.I. for a Fellowship during which a part of this work was performed and to A.P. Coath and J.R. Middlebrook for some preliminary exploration.

2. J.R. Malpass and N.J. Tweddle, Chemical Communications, in the press.

3. R. Graf and H. Biener, Angew Chem, Internat. Edn., 2, 546, (1963).

4.(a) Minor products (possibly of double bond migration) are formed under certain conditions in this series. (b) The identity of other minor products is under study.

5. N.M.R. Spectra were measured in $CDCl_3$ at 60 MHz. Selected peaks are quoted in most cases, s = singlet, d = doublet, m = multiplet, b = broad.

6. All products exhibited satisfactory spectroscopic properties where details are not quoted; new compounds analysed correctly where stability allowed.

7. G.S. Skinner, J.A. Gladner and R.F. Heitmiller, J. Amer. Chem. Soc., 73, 2230, (1951).

8. H. Vorbrüggen, Tetrahedron Letters, 1631, (1968).

9.(a) A. Factor and T.G. Traylor, J. Org. Chem., 33, 2607, (1968), (b) K.C. Ramey, D.C. Lini, R.M. Moriarty, H. Gopal, and H.G. Walsh, J. Amer. Chem. Soc., 89, 2401, (1967).

10. L.A. Paquette, G.R. Allen, jun., and M.J. Broadhurst, J. Amer. Chem. Soc., 93, 4503, (1971)

11. By analogy with the camphene/CSI reaction[2] and with the related formation of unrearranged (but unstable) pinene hydrochloride and camphene hydrochloride in the controlled low-temperature addition of HCl to pinene and camphene, respectively.[13]

12. E.J. Moriconi, and W.C. Meyer, J. Org. Chem., 36, 2841, (1971).

13. J.A. Berson in Molecular Rearrangements, Part 1, Ed. P. de Mayo, Wiley, 1963.

14.(a) The ratio of O- and N- cyclisation may be controlled by variation of solvent polarity.[2] (b) The anticipated solvent control over the ratio 15:16 is under study.