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ADDITION OF HYDROGEN HALIDES TO ISOLONGIFOLENE : FORMATION OF NOVEL STERICALLY-DIVERTED BICYCLIC MONOOLEFINIC PRIMARY HALIDES+

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ABSTRACT: When the tricyclic isolongifolene 2 is exposed to HX(HBr, HI) in AcOH, a unique ring fragmentation takes place resulting in the formation of a novel bicyclic monoolefinic primary halide 9/10. The closely related tetracyclic cyclopropane isomer 14 of the tricyclic olefin 2, on reaction with HI in AcOH, also affords 10. Attempted solvolysis of 9 with $AgClO_4$ in 50% aqueous acetone generates essentially isolongifolene 2. These results can be best interpreted mechanistically in terms of a nonclassical carbocation 21. The bicyclic primary acetate 11 resulting from action of KOAc-DMF on 9/10, on hydrolysis with base gives the primary alcohol 12 which has been converted to the acid 13 by oxidation with Jones reagent.

LONGIFOLENE[1] 1 and its acid-catalysed isomer , isolongifolene[1] 2, are two interesting bridged tricyclic sesquiterpenes built on a bicyclo [2.2.1] heptane and constitute isoprene homologues of the monoterpene camphene 3 such that the double bond is exocyclic in 1 and endocyclic in 2. While the longifolyl cation 4 has been generated by exposing 1 to a hydrogen halide (HCl, HBr, HI) and its fate studied quite early in the history of longifolene, the potentially more interesting isolongifolyl cation 5, generated in the HX reaction on 2, has not received any attention so far. Some interesting results obtained in this connection are described below.

In longifolene 1 the ethylenic linkage is sterically shielded such that the approach of the nucleophile or the radical, in an olefin addition reaction, is essentially blocked; hence the product cannot be expected to be the result of a simple addition reaction but would always be complicated by the intervention of other pathways such as elimination/ rearrangement. Thus, treatment of 1 with hydrogen halide results in a 1,2-shift of the bridge to furnish longibornyl halide 6, the structure of which (X=Cl) was established[2] by X-ray analysis. The stereochemistry of the new

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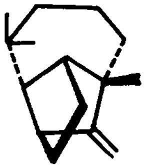

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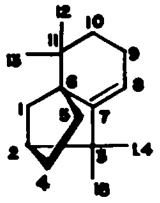

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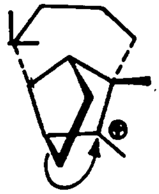

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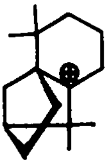

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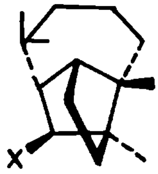

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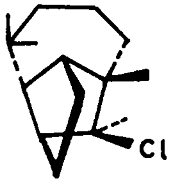

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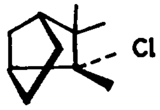

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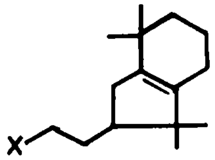
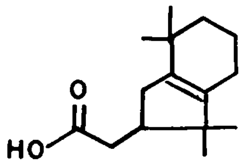


9 : X = Br
10 : X = I
11 : X = OAc
12 : X = OH



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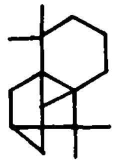

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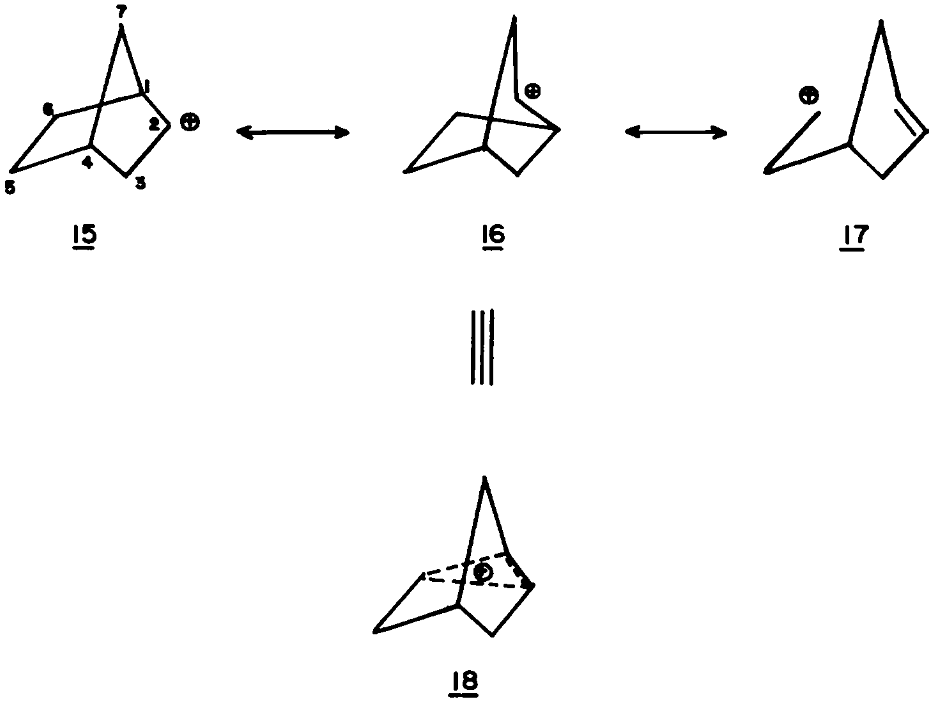
SCHEME 1 : WINSTEIN'S NONCLASSICAL STRUCTURE 18 FOR 2-NORBORNYL CATION 15

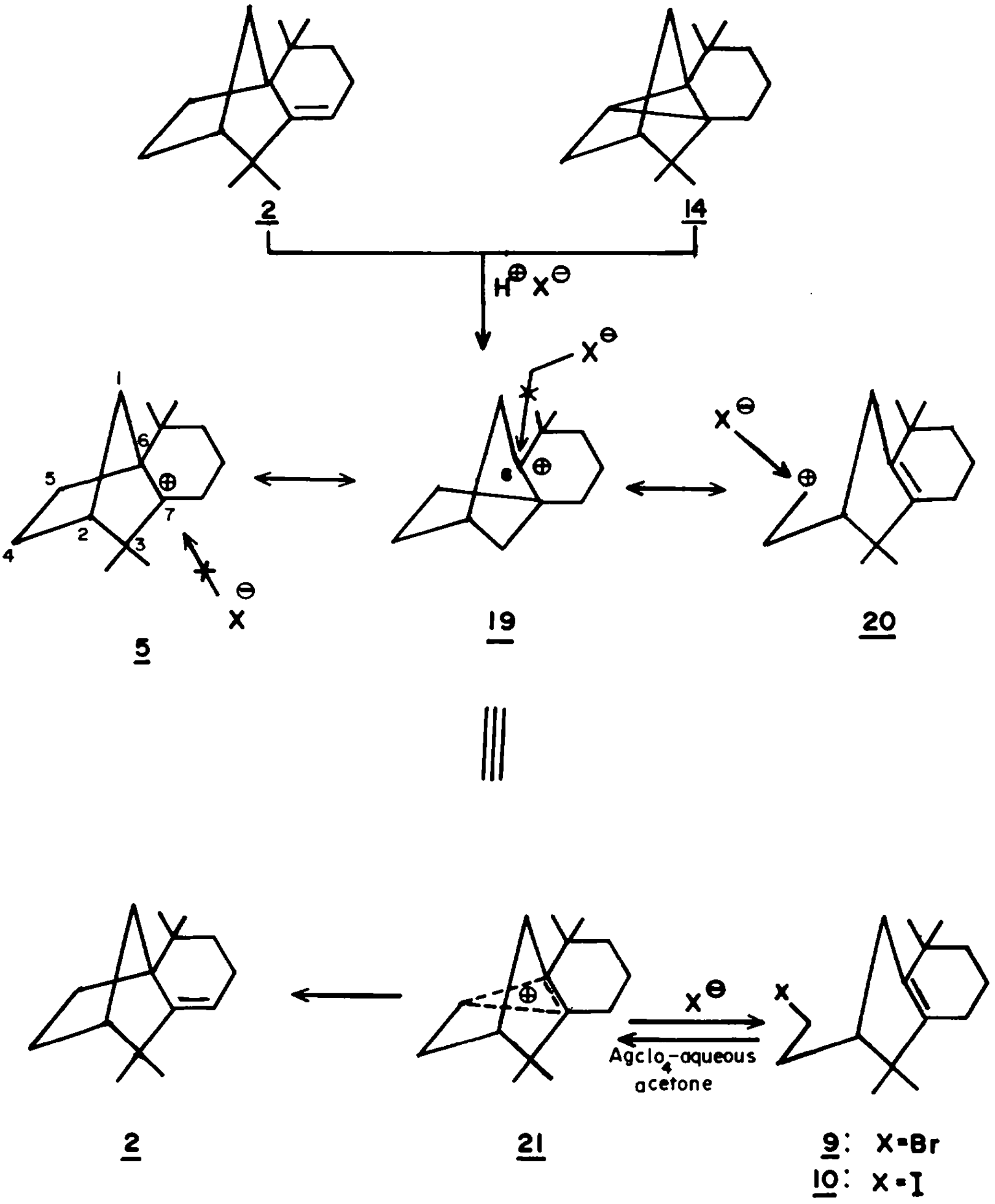


C-X bond, though in apparent contrast to the behaviour of camphene, is in accord with approach of halide from the less hindered endo-face. At one time, this transformation generated interest as an example of a rearrangement where a nonclassical carbocation was considered unimportant[3]. Another interesting feature is the failure to isolate the unrearranged tertiary halide 7 of longifolene 1, analogous to that of 8 in the case of camphene 3. The steric crowding at the more substituted end of the ethylenic bond in isolongifolene 2 is also quite severe and hence it is not surprising to find that many of its reactions involving additions to the ethylenic linkage are also dominated by steric diversion[4].

Unlike in the case of longifolene 1, which yields crystalline derivatives on exposure to hydrogen halides, isolongifolene 2 (prepared[5] by treatment of 1 in benzene with catalytic amount of BF_3OEt_2) gave only liquid halides. On reaction with 32% HBr in AcOH at ambient temperature (optimized for 10 hr with stirring), isolongifolene 2 gave essentially a single compound $C_{15}H_{25}Br$ (65% yield). That a unique reaction had taken place was clear from the spectral data of the compound. In particular, a 2H-multiplet at δ 3.32 in the PMR spectrum/two singlets at 139 and 141.6 ppm in the off-resonance CMR spectrum suggested a primarybromide/tetrasubstituted double bond which could be rationalized only on the basis of structure 9 for the product. When 2 was exposed to HI in AcOH a similar reaction took place to furnish the bicyclic primary iodide 10 in an improved yield (76%) The closely related tetracyclic cyclopropane isomer[6] 14 of the tricyclic olefin 2, on reaction with HI in AcOH, also afforded 10. On attempted sovolysis of 9 with $AgClO_4^7$ in 50% aqueous acetone, there was no evidence of any carbinol and the only isolated hydrocarbon was characterised as isolongifolene 2. These results can be best interpreted mechanistically in terms of a nonclassical carbonium 21 (Scheme 2, vide infra). In conformity with the assigned structures 9/10 for the halides, both gave the same primary acetate 11 on reaction with KOAc in DMF at 120°. Further chemical proof for the β -haloethyl substituent in 9/10 was obtained when Jones oxidation of the primary alcohol 12 (base hydrolysis of 11) gave the acid 13.

The theory of nonclassical ions[8] offers an explanation for many unique chemical, structural and kinetic peculiarities of bridged bicyclic compounds. It has expanded our knowledge of chemical bonds in carbocations by introducing electron-deficient bonds. Following Winstein's suggestion[9] of the nonclassical formula 18 for the 2-norbornyl cation (corresponding to three canonical forms 15/16/17; Scheme 1) we have invoked a bridged formula 21 (corresponding to the resonance forms 5/19/20) for the bicyclo [2.2.1] heptane-based tricyclic carbocation 5 namely isolongifolyl cation derived by protonation of 2 or its cyclopropane isomer 14 in the HX reaction). What is unique about this nonclassical cation 21 is that attack at the electron-deficient species 5/19 by the nucleophile X is effectively prohibited due to severe steric crowding at C-7/C-6, thus making the cation 20 the sole target of attack by X^-, inspite of 20 being energetically quite unfavourable. The isolongifolene-HX reaction thus appears to be the first example where steric diversion dictates product development from a

SCHEME 2.: NONCLASSICAL STRUCTURE 21 FOR ISOLONGIFOLYL CATION 5: TRICYCLIC ANALOGUE OF 18



nonclassical ion such that ring fragmentation of a tricyclic system generates a bicyclic olefinic product of the type 9/10.

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EXPERIMENTAL

All m.ps and b.ps are uncorrected. Light petroleum refers to the fraction b.p. 60°-80°. Solvent extracts were dried over anhydrous Na_2SO_4. Silver perchlorate was freshly prepared[10] and dried[11]. IR spectra (ν_{max} in cm^{-1}) were recorded as smear (liquid) on a Pye Unicam SP-3IR spectrophotometer. PMR spectra were taken on a Varian T60/FT-80/Brucker WH-90 spectrometer and mass spectra (MS) on a CEC spectrometer model 21-110B, using an ionizing voltage of 70 eV and a direct inlet system.

Addition of HBr to isolongifolene 2 : Formation of bicyclic bromide 9

A mixture of isolongifolene 2 (4 g) and 32% HBr in AcOH (50 ml) was stirred at room temperature (10 hr). The mixture was poured into water, extracted with light petroleum, washed with 5% aqueous $NaHCO_3$, brine, dried and solvent removed. Distillation gave 9 as a liquid b.p. 120°/1 mm (3.6 g, 65%). IR (smear) : 1585, 1380, 1360. PMR ($CDCl_3$) : δ 0.74, 0.92, 0.96, 0.98 (four tertiary Me singlets), 3.32 (m, 2H, $-CH-\underline{CH}_2Br$). CMR : ($CDCl_3$) off-resonance, 139 and 141.6 ppm (two singlets, $>C=C<$). MS : m/z 284, 286 (M^+). (Found : C, 63.5; H, 8.7; Br, 28.9; $C_{15}H_{25}Br$ requires C, 63.4; H, 8.8; Br, 27.8%).

Addition of HI to isolongifolene 2 : Formation of iodide 10

Hydrogen iodide [generated by the addition of iodine (4 g) in tetralin (30 ml) to boiling tetralin (50 ml)] was bubbled into a cooled (10°) solution of isolongifolene 2 in AcOH (50 ml) with dry N_2 as a sweep gas. The mixture was then stirred at room temperature for 24 hr and worked up as in the case of 9. The crude product was chromatographed on silica gel/IIa with TLC monitoring: Fr. 1, light petroleum, 5 x 50 ml, unchanged isolongifolene 2 (0.6 g) identified by IR/PMR. Fr 2, Light petroleum, 6 x 50 ml, iodide 10; liquid b.p. 130°/1 mm (5.2 g, 76%). IR (smear) 1680, 1380, 1360, 1190, 1170. PMR ($CDCl_3$) : δ 0.68, 0.88, 0.92 0.96 (four tertiary Me singlets), 3.13 (m, 2H, $CH_2-\underline{CH}_2-I$). MS : m/z 332 (M^+).

Action of KOAc-DMF on bromide 9 : Formation of Acetate 11

A mixture of 9 (2.8 g) in dry DMF (50 ml) and KOAc (unfused 1 g) was stirred at 120° for 36 hr. Excess DMF was removed under reduced pressure, the residue diluted with water, extracted with benzene, washed with brine, dried, solvent removed and the crude product chromatographed on silica gel/IIa : Fr. 1, light petroleum, 3 x 50 ml, unchanged bromide 9 (0.8 g) identified by IR/PMR. Fr. 2, light petroleum-benzene (1:1), 6 x 50 ml, pure, distilled at 130°/1.5 mm to afford colourless liquid acetate 11 (1.5 g, 57%). IR (smear): 1745, 1255, 1040 PMR ($CDCl_3$) : δ 0.72, 0.90, 0.92, 0.96 (four tertiary Me singlets), 2.04 (s, 3H, $OCOC\underline{H}_3$), 4.1 (m, 2H, ACO-$C\underline{H}_2$-CH_2). CMR : ($CDCl_3$) off-resonance 64.7 ppm (t, $\underline{C}H_2$-OAc), 139.2, 141.3 ppm (two singlets, $>C=C<$) and 171.4 ppm (s, O-$\overset{O}{\overset{\|}{\underline{C}}}$-$CH_3$). MS : m/z 264 ($M^+$). (Found : C, 77.8; H, 10.8; $C_{17}H_{28}O_2$ requires, C, 77.2; H, 10.6%).

Action of KOAc-DMF on iodide 10 : Formation of acetate 11

A mixture of iodide 10 (0.16 g) in dry DMF (15 ml) and KOAc (0.1g) was stirred at 120° for 18 hr and worked up as in the case of 9. The crude product was purified by chromatography on silica gel/IIa : Fr. 1, light petroleum, 5 x 10 ml, unchanged iodide 10 (0.06 g; IR/PMR), Fr. 2, light petroleum-benzene (1:1), 6 x 15 ml, pure, distilled, b.p. 150° (bath)/1 mm (0.1 g, 76%) identified as acetate 11 (IR/PMR)..

Hydrolysis of acetate 11 : Formation of alcohol 12

Acetate 11 (0.5 g) was hydrolysed with 15% aqueous ethanolic KOH (50 ml) at room temperature (18 hr). Usual workup followed by distillation furnished alcohol 12 as a liquid, b.p. 140° (bath)/1 mm, (0.35 g, 85%). IR (smear): 3350, 1380, 1360, 1060. PMR ($CDCl_3$) : δ 0.72, 0.92, 0.94, 0.96 (four tertiary Me singlets) and 3.66 (m, 2H, CH_2-$C\underline{H}_2$-OH). MS : m/z 222 (M^+). (Found : C, 82.0; H, 11.8; $C_{15}H_{26}O$ requires, C, 81.0; H, 11.7%).

Jones oxidation of the alcohol 12:Formation of acid 13

To a stirred solution of primary alcohol 12 (0.21 g) in acetone (5 ml) was added excess of Jones reagent and further stirred for 2 hr. Usual workup and distillation of the residue at 160° (bath)/1 mm afforded the acid 13 (0.1g; 45%). IR: (smear) 3400 ~ 2500, 1705, 1300 1240, 950. PMR (CCl_4) : δ 0.74, 0.92, 1.00 x 2 (four tertiary Me singlets), 11.1 (m, 1H, $COO\underline{H}$). MS : m/z 236 (M^+).

Addition of HI to cycloisolongifolene 14 : Formation of iodide 10

Through a solution of 14 (0.5 g) in ACOH (15 ml), HI was bubbled (generated as before from 1 gm of iodine in 30 ml of tetralin) under anhydrous conditions. The mixture was stirred at room temp. (18 hr) and worked up as in the case of 9, followed by silica gel chromatography of the crude product; Fr. 1, light petroleum, 5 x 5 ml, unchanged hydrocarbon 14 (IR/PMR). Fr. 2, light petroleum, 10 x 5 ml, was distilled to afford iodide 10 (IR/PMR).

Solvolysis of bromide 9 with $AgClO_4$-50% aq. acetone : Formation of isolongifolene 2

A mixture of 9 (0.5 g), 50% aqueous acetone (20 ml) and $AgClO_4$ (0.6 g) was stirred at room temp. (18 hr). The mixture was filtered, the filtrate diluted with water, extracted with EtOAc, washed with brine, dried, solvent removed and the product distilled, to obtain a liquid b.p. 120°/1 mm identified as isolongifolene 2.

REFERENCES

1. a) P.K.Jadhav and U.R.Nayak, J.Sci.Ind.Res. 39, 36 (1980).
   b) Sukh Dev, Prog.Chem.Org.Nat.Prod.. 40, 50 (1981).
2. R.H.Moffett and D.Rogers, Chem and Ind, 916 (1953).
3. P. Ourisson and G Ourission, Bull.Soc. Chim.France 1415 (1954).
4. J.S.Yadav, H.P.S.Chawla, Sukh Dev, A.S.C.Prakash Rao and U.R.Nayak Tetrahedron 33, 2441 (1977).
5. R.Ranganathan, U.R.Nayak, T.S.Santhanakrishnan and Sukh Dev, Tetrahedron , 26, 621 (1970).
6. T.S.Santhanakrishnan, R.R.Sobti, U.R.Nayak and Sukh Dev, Tetrahedron 26, 657 (1970)
7. R.Thimma Reddy and U.R.Nayak, Indian.J. Chem (in press)
8. a) C.A.Grob, Acc.Chem.Res. 16, 426 (1983).
   b) H.C.Brown, Acc. Chem.Res. 16, 432 (1983).
   c) G.A.Olah, G.K.Suryaprakash and M.Saunders, Acc.Chem.Res. 16, 440 (1983)
   d) C.Walling. Acc.Chem.Res. 16, 448 (1983)
   e) V.A.Barkhash "Non classical carbocations" in Topics in current chemistry Vol. 116/117 (Ed ch Rees) Springer-Verlag. New York, (1984), p. 1-266 and references cited therein.
9. S.Winstein and D.Trifan, J.Amer.Chem.Soc. 74, 1147, 1154 (1952)
10. R.S.Prasad, Ph.D. thesis, P. 160, Poona University (1976).
11. J.Radell, J.W.Connolly and A.J.Raymond, J.Amer.Chem.Soc. 83, 3958(1961)