

***trans*-Cycloalkenes. Part VI.¹ Addition of Iodine(I) Azide to *trans*-Cyclo-octene**

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Addition of iodine(I) azide to *trans*-cyclo-octene gave *trans*-1-azido-4-iodocyclo-octane (VI) as major product together with small amounts of 5-azidocyclo-octene (I) and 1-(4-iodocyclo-octyl)-5-methyltetrazole (II). Transannular rearrangement with 1,5-hydrogen shift is thus considered to be the predominant reaction pathway. The key information required for an assignment of structure to compound (VI) was provided by preparation of the labelled analogue from [1,2-²H₂]-*trans*-cyclo-octene. Both *cis*- and *trans*-1-methylcyclo-octene gave *cis*-cyclo-octenylmethyl azide on treatment with iodine azide.

A RANGE of addition reactions of the unusually strained olefin *trans*-cyclo-octene has been investigated (see ref.

¹ Part V, A. J. Bridges and G. H. Whitham, preceding paper.

2 and ref. 5 therein). Notably absent amongst these reactions are examples of (a) *anti*-additions and (b)

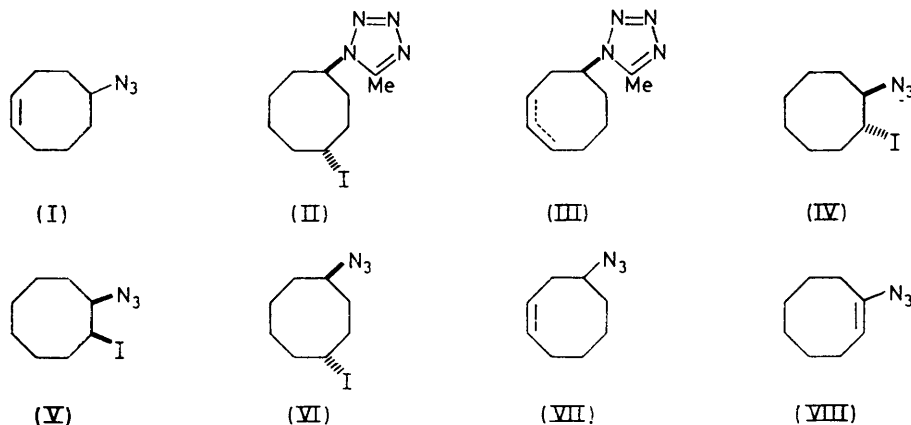
² K. T. Burgoine, S. G. Davies, and G. H. Whitham, *J.C.S. Perkin I*, 1975, 2629.

transannular processes. The reluctance of *trans*-cyclo-octene to undergo *anti*-addition has been ascribed to its unusual geometry, whereby only one face of the double bond is accessible.^{2,3} Thus reactions which characteristically proceed by *anti*-addition mechanisms with normal olefins are constrained to follow different pathways with *trans*-cyclo-octene, *e.g.* oxymercuration^{3,4} and addition of benzenesulphenyl chloride.² The absence of transannular reactions in additions to *trans*-cyclo-octene has been attributed to partial rehybridisation of the olefinic carbon atoms towards *sp*³, thus leading to relatively poor overlap between the transannular C-H bond and the inside lobe of the relevant 'trigonal' carbon atom.²

Recent results on the addition of iodine(I) azide to olefins⁵ have indicated that the relevant transition states are not very sensitive to steric hindrance to the attacking azide ion, possibly because of the high nucleophilicity of the latter. For this reason we investigated the addition of iodine(I) azide to *trans*-cyclo-octene since it seemed that this reagent stood a greater chance of effecting an *anti*-addition, or of forcing a transannular hydride shift.

RESULTS

Treatment of *trans*-cyclo-octene with iodine(I) azide in acetonitrile⁶ at -50° gave, after isolation and chromatography, one major and two minor products. The least



polar product (*ca.* 5%) was identified as 5-azidocyclo-octene (I) by comparison with authentic unsaturated azides. The other minor product (11% yield), the most polar component, was assigned the iodo-tetrazole structure (II). This assignment was partly based on dehydroiodination (potassium *t*-butoxide-ether) of (II) to the unsaturated tetrazole (III), which was in turn identified by the ¹H n.m.r. spectrum typical of analogous homoallylic cyclo-octene derivatives, *e.g.* 4-azidocyclo-octene (see below).

The major product (76%) from the reaction of iodine(I) azide with *trans*-cyclo-octene was readily shown to be an azido-iodo-cyclo-octane distinct from the 1,2-*trans*-isomer (IV) derived by addition of iodine(I) azide to *cis*-cyclo-octene.⁷ Clearly *trans*-cyclo-octene had not suffered iodine-catalysed isomerisation prior to addition. Two structures were considered for the major adduct, those of the *anti*-1,2-addition product (V) and the product of a transannular H shift (VI). Unfortunately ¹H n.m.r. double-irradiation experiments did not lead to a clear distinction, since the lack of coupling found between $>CHI$ and $>CHN_3$ might be due to an unfavourable conformational situation about C-1,C-2 in (V).

Conflicting evidence was provided by a comparative study of some reactions of authentic compound (IV) and the major adduct. Thus, solvolysis of either of these iodo-azides with silver(I) acetate in acetic acid (20 °C) gave the same homoallylic azide (VII), the latter structure being established through synthesis from the tosylate of cyclo-oct-3-enol.⁸ Treatment of the iodo-azide (IV) with potassium *t*-butoxide gave solely the vinyl azide (VIII), in agreement with a previous report.⁷ However, similar treatment of the unknown iodo-azide gave a mixture of the homoallylic (VII) and vinyl azides (VIII) in the ratio 40:1 (g.l.c.). Although this result strengthened the case in favour of the 1,4-structure (VI), it was not conclusive, since either the major (VII)

or minor (VIII) elimination product must have been formed by a transannular process.

In order to provide a decision between structures (V) and (VI), [1,2-²H₂]-*trans*-cyclo-octene was synthesised by the route summarised in the Scheme, and treated as before with iodine(I) azide. The major iodo-azide was isolated. The n.m.r. spectrum showed only the downfield multiplet attributed to $>CHN_3$; absorption due to $>CHI$ was absent. This result is incompatible with the 1,2-adduct structure (V) but satisfactorily explained by

⁵ A. Hassner, *Accounts Chem. Res.*, 1971, **4**, 9.

⁶ F. W. Fowler, A. Hassner, and L. A. Levy, *J. Amer. Chem. Soc.*, 1967, **89**, 2077.

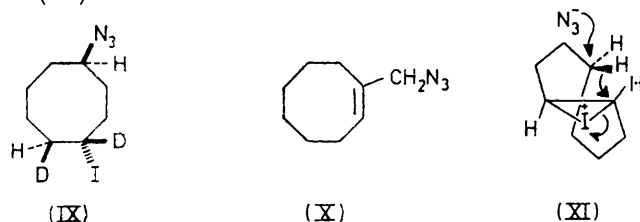
⁷ A. Hassner and F. W. Fowler, *J. Org. Chem.*, 1968, **33**, 2686.

⁸ A. C. Cope and P. E. Peterson, *J. Amer. Chem. Soc.*, 1959, **81**, 1643.

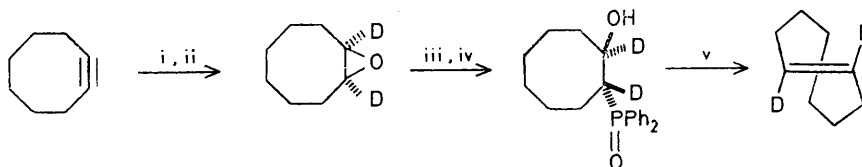
³ W. L. Waters, T. G. Traylor, and A. Factor, *J. Org. Chem.*, 1973, **38**, 2306.

⁴ V. I. Sokolov, L. L. Troitskaya, and O. A. Reutov, *Doklady Akad. Nauk S.S.S.R.*, 1966, **166**, 136; *J. Organometallic Chem.*, 1969, **17**, 323.

that of the 1,4-adduct (VI), which should be labelled as in (IX).



Attempted addition of iodine(I) azide to the tri-substituted alkenes *cis*- and *trans*-1-methylcyclo-octene gave, as the sole product in each case, the allylic azide

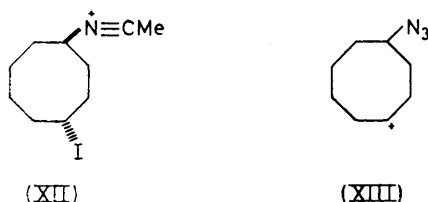


SCHEME Reagents: i, D_2 , Pd-CaCO₃; ii, AcOH-Na₂CO₃-AcONa; iii, LiPPh₂-[CH₂]₄O; iv, H₂O₂-AcOH; v, NaH-Me₂N-CHO

(X), identical with material synthesised from the corresponding allylic bromide.

DISCUSSION

The results show that the major product from addition of iodine(I) azide to *trans*-cyclo-octene is derived by a transannular process. Since only one such adduct is formed, and given the preferred twist conformation for *trans*-cyclo-octene,⁹ the only reasonable structure is that assigned (VI). This can be justified in terms of the transannular 1,5-hydride shift designated in the formula for the iodonium ion (XI).^{*} Analogous attack of solvent acetonitrile instead of azide ion would give the cation (XII), and cycloaddition of azide ion to the latter provides an explanation for formation of the tetrazole (II). Tetrazoles have been found previously as products of iodine(I) azide reactions in acetonitrile.¹⁰



The transannular reaction indicated in (XI) has analogy in the 1,5-hydrogen shift encountered on formolysis of *trans*-cyclo-octene oxide,¹¹ although in that case ring-contracted materials are the predominant products.¹²

An intriguing result is the observation that silver-acetate-catalysed acetolysis of (IV) or of (VI) gives the

^{*} Although it is not clear that free iodonium ions are involved as intermediates in iodine(I) azide additions to olefins, they provide a convenient vehicle for discussing the reactions.

⁹ O. Ermer, *Angew. Chem. Internat. Edn.*, 1974, **13**, 604; M. Traetteberg, *Acta Chem. Scand.*, 1975, **B29**, 29.

¹⁰ S. N. Moorthy, D. Devaprabhakar, and K. G. Das, *Tetrahedron Letters*, 1975, 257.

homoallylic azide (VII). Presumably (VII) is derived from the (solvated) 4-azidocyclo-octyl cation(XIII), though just why (XIII) should undergo proton loss from C-2 only, and why transannular H shift on solvolysis of (IV) should only give (XIII) (by 1,3- or 1,5-H shift) is unclear.

In the case of the reaction of 1-methyl-*trans*-cyclo-octene with iodine(I) azide the presence of the methyl group directs the reaction along a mundane route. Presumably the 2-iodo-1-methyl cation ion, being tertiary, is involved and proton loss to an allylic iodide is then followed by rapid reaction with azide ion to give (X).

EXPERIMENTAL

For instruments used see preceding paper; also for g.l.c. a column of PEG-S (10%) on Embacel was used, at 100 °C. The statement 'work-up in the usual way' means that the reaction mixture was poured into water and extracted with ether and the extract was washed successively with water and brine, and then dried over anhydrous sodium sulphate. Petrol refers to redistilled light petroleum (b.p. 30–40°).

Preparation of Iodine(I) Azide Adducts.—General procedure. A solution of the alkene (1.0 equiv.) in the minimum volume of dry diethyl ether was added dropwise to a stirred solution of iodine(I) azide⁶ at -35° (*trans*-alkenes) or 0° (*cis*-alkenes). The reaction was quenched after 1 h by pouring into ice-water. After washing with sodium thiosulphate solution and work-up in the usual way the products were isolated by p.l.c. (silica gel).

Reaction of trans-Cyclo-octene with Iodine(I) Azide.—trans-Cyclo-octene (1.85 g, 17 mmol) was treated as above to give a semi-solid shown by t.l.c. to contain one major and two minor components. These were separated by p.l.c. (eluant petrol) to give: (a) 5-azidocyclo-octene (I) (0.09 g, 5%) as an oil, *m/e* 152 ($M^+ + 1$, C₈H₁₄N₃), ν_{max} (film) 3 020 (=C-H str.) and 2 100 cm⁻¹ (N₃), τ 4.39 (2 H, m, H-1 and -2), 5.55 (1 H, m, H-5), and 7.50–8.60 (10 H, m, ring methylenes); and (b) 1-azido-4-iodocyclo-octane (VI) (3.60 g, 76%) as an unstable oil (Found: M^+ , 279.0233. C₈H₁₄N₃I requires M , 279.0234), ν_{max} (film) 2 100 cm⁻¹ (N₃), τ 5.44 (1 H, m, H-4), 6.39 (1 H, m, H-1), and 7.50–8.90 (12 H, m, ring methylene protons). The latter compound gave a single spot on t.l.c. under a range of conditions, and this together with the clean symmetrical peaks for H-4 (nonet) and H-1 (septet) in the n.m.r. spectrum indicated that it was a single stereoisomer. Treatment of the adduct (VI) with dimethyl acetylenedicarboxylate in acetonitrile¹³ at 40 °C for 72 h, gave dimethyl 1-(4-iodocyclo-octyl)-1,2,3-triazole-4,5-dicarboxylate as an uncrystallisable gum, *m/e*

¹¹ A. C. Cope, A. Fournier, and H. E. Simmons, *J. Amer. Chem. Soc.*, 1957, **79**, 3905.

¹² A. C. Cope, P. Scheiner, and M. J. Youngquist, *J. Org. Chem.*, 1963, **28**, 518.

¹³ T. Sasaki, K. Kanematsu, and Y. Yukimoto, *J. Org. Chem.*, 1972, **37**, 890.

421 (M^+ , $C_{14}H_{20}IN_3O_4$), ν_{\max} (film) 1 725 cm^{-1} (C=O), τ 5.00 (1 H, m, H-1'), 5.37 (1 H, m, H-4'), 6.00 and 6.05 (6 H, 2s, CO_2CH_3), and 7.20—8.80 (12 H, m, ring methylenes).

From the lowest band, (c), 1-(4-iodocyclo-octyl)-5-methyl-tetrazole (II) (0.51 g, 11%) was obtained as prisms (from petrol-dichloromethane), m.p. 130—131° (Found: C, 37.45; H, 5.4; N, 17.45. $C_{10}H_{17}IN_4$ requires C, 37.5; H, 5.3; N, 17.5%), ν_{\max} (CHCl_3) 1 440 cm^{-1} (tetrazole), τ 5.25—5.75 (2 H, m, H-1' and -2'), 7.44 (3 H, s, tetrazole CH_3), and 7.30—8.60 (12 H, m, ring methylenes). Treatment with potassium *t*-butoxide in dry diethyl ether at 20 °C, gave an inseparable mixture of the unsaturated tetrazoles (III) as needles (from petrol), m.p. 48—56°, *m/e* 192 (M^+ , $C_{10}H_{16}N_4$), ν_{\max} (KBr) 1 660 (C=C), 1 135, 1 095, and 720 cm^{-1} , τ 4.25 (2 H, m, olefinic), 5.55 (1 H, m, CHN), 7.43 and 7.48 (6 H, 2s, tetrazole methyls), and 7.55—8.90 (10 H, m, ring methylenes).

trans-1-Azido-2-iodocyclo-octane (IV),^{6,7}—*cis*-Cyclo-octene (0.16 g, 1.5 mmol) was treated with iodine(i) azide, as above, to give the product (IV) (0.35 g, 83%) as an unstable oil (Found: M^+ , 279.0233. Calc for $C_8H_{14}IN_3$: M , 279.0234; n.m.r. and i.r. data were in accord with literature values.^{6,7} Treatment with dimethyl acetylenedicarboxylate in refluxing acetonitrile for 8 h gave dimethyl 1-(2-iodocyclo-octyl)-1,2,3-triazole-4,5-dicarboxylate as prisms (from petrol-dichloromethane), m.p. 106—107° (Found: C, 39.95; H, 4.8; N, 9.95. $C_{14}H_{20}IN_3O_4$ requires C, 39.9; H, 4.75; N, 9.95%), ν_{\max} (CHCl_3) 1 725 cm^{-1} (C=O), τ 4.50 (1 H, m, H-1'), 4.85 (1 H, m, H-2'), 3.99 and 4.02 (6 H, 2s, CO_2CH_3), and 7.40—8.80 (12 H, m, ring methylenes).

Reactions of the Iodo-azides (IV) and (VI).—(a) *Solvolysis with silver acetate.* The iodo-azide (1.0 equiv.) was added with stirring to a solution of silver acetate (1.1 equiv.) in glacial acetic acid at 15 °C and stirred at 25 °C for 2 h. The mixture was filtered and worked up in the usual way to give 4-azido-*cis*-cyclo-octene (VII) as an oil in 83% yield from (IV) and 53% yield from (VI), *m/e* 151 (M^+ , $C_8H_{13}N_3$), ν_{\max} (film) 3 020 (=C-H str.) and 2 100 cm^{-1} (N_3), τ 4.32 (2 H, m, H-1 and -2), 6.50 (1 H, m, H-4), 7.63 (2 H, t, J 8 Hz, 2 H-3), and 7.70—9.20 (10 H, m, ring methylenes). G.l.c. and n.m.r. indicated that no other unsaturated azides were formed. From the solvolysis of (IV) a small amount (ca. 5%) of 2-azidocyclo-octyl acetate was obtained as an oil, ν_{\max} (film) 2 100 (N_3) and 1 730 cm^{-1} (C=O), τ 5.10 (1 H, m, H-1), 6.40 (1 H, m, H-2), 8.01 (3 H, s, Ac), and 7.80—9.00 (12 H, m, ring methylenes).

An authentic sample of the homoallylic azide (VII) was prepared in 66% yield by treatment of the oily toluene-*p*-sulphonate from cyclo-oct-3-enol⁸ [ν_{\max} (film) 1 360 and 1 180 cm^{-1} (tosylate), τ 2.23 and 2.70 (4 H, 2d, J 10 Hz, aromatic), 4.40 (2 H, m, H-1 and -2), 5.40 (1 H, m, H-4), 7.60 (3 H, s, aryl CH_3), and 7.50—9.00 (10 H, m, ring methylenes)], with sodium azide (2.0 equiv.) in dimethylformamide at 60 °C for 5 h. The product was obtained as an oil, identical with the above.

(b) *Formation of unsaturated azides.* The eliminations were carried out by the procedure of Hassner *et al.*,⁶ the crude unsaturated azide being purified by elution through a short column of silica gel with petrol. 1-Azido-4-iodocyclo-octane (VI) gave a 40:1 mixture (by g.l.c.) of 4-azidocyclo-octene (VII) and 1-azidocyclo-octene (VIII); there was no evidence for isomerisation of these azides under the above conditions. A portion of the product was separ-

ated by p.l.c. (eluant petrol) to give: (i) the product (VIII) as an oil identical with that obtained by elimination from *trans*-1-azido-2-iodocyclo-octane;⁶ and (ii) the product (VII), identical with the above.

[1,2- $^2\text{H}_2$]-*cis*-Cyclo-octene (with S. J. BAILEY¹⁴).—A solution of cyclo-octyne (2.50 g, 23.1 mmol) (prepared in 47% yield by a modification of the method of Meier *et al.*¹⁵) in spectroscopic grade cyclohexane (25 ml), was vigorously stirred with predeuteriated 5% Pd- CaCO_3 under deuterium gas at 20 °C and atmospheric pressure. After the calculated volume of gas had been taken up, the mixture was worked up to give the product (2.23 g), b.p. 135—139° at 760 mmHg, ν_{\max} (film) 2 220 cm^{-1} (C-D str.), τ 4.39 (residual olefinic protons, t, J 9 Hz, corresponding to a deuterium content of ca. 85%) and 7.85 (4 H, s, 2 H-3 and -8).

trans-2-Hydroxy[1,2- $^2\text{H}_2$]cyclo-octyl(diphenyl)phosphine Oxide.—Lithium diphenylphosphide (26.0 mmol) in tetrahydrofuran (10 ml) was added at 20 °C to a solution in tetrahydrofuran (5 ml) of [1,8- $^2\text{H}_2$]-9-oxa-*cis*-bicyclo-[6.1.0]nonane (1.43 g, 11.0 mmol) from buffered epoxidation¹⁶ of the alkene [ν_{\max} 2 200 cm^{-1} (C-D str.), τ 4.20 (residual oxiran protons, m) and 5.67 (2 H, m, deshielded ring methylenes)]. Work-up as described in ref. 17 gave the product (2.63 g, 71%) as prisms (from ethyl acetate), m.p. 157—158° (Found: C, 72.75; H+D, 7.75; P, 9.1. $C_{20}H_{23}D_2PO_2$ requires C, 72.7; H+D, 8.2; P, 9.4%. Calc. for $C_{20}H_{25}PO_2$: C, 73.15; H, 7.65; P, 9.4%), ν_{\max} (Nujol) 3 270 (OH), 2 160 (C-D str.), 1 445, 1 180, 1 120, and 720 cm^{-1} , τ 2.05—2.70 (10 H, m, aromatic), 4.97 (1 H, s, OH), and 7.70—9.00 (12 H, m, ring methylenes), M^+ 330.

1-Azido-4-iodo[4,5- $^2\text{H}_2$]cyclo-octane (IX).—Fragmentation of the phosphine oxide (1.09 g, 3.2 mmol) with sodium hydride (0.13 g, 80%) in dimethylformamide by the method of ref. 17 gave [1,2- $^2\text{H}_2$]-*trans*-cyclo-octene in 80% yield, ν_{\max} 2 220 (C-D str.) and 1 620 cm^{-1} , τ 4.55 (residual olefinic protons, m), 7.50—7.70 (2 H, m, deshielded ring methylenes), and 7.90—9.50 (10 H, m, ring methylenes). The alkene (0.36 g, 3.4 mmol) was immediately treated with iodine(i) azide as described above to give, after p.l.c., the product (IX) (0.70 g, 73%) as an unstable oil, *m/e* 281 (M^+ , $C_8H_{12}D_2IN_3$), ν_{\max} (film) 2 480 (C-D str.) and 2 100 cm^{-1} (N_3), τ 6.35 (1 H, m, H-1) and 7.50—8.80 (11 H, m, ring methylenes).

Reaction of 1-Methyl-trans-cyclo-octene with Iodine(i) Azide.—The alkene (0.25 g, 2.0 mmol) was treated as described above to give 1-azidomethylene-*cis*-cyclo-octene (X) (0.24 g, 73%) as an oil, *m/e* 165 (M^+ , $C_9H_{15}N_3$), ν_{\max} (film) 2 100 cm^{-1} (N_3), τ 4.36 (1 H, t, J 10 Hz, H-2), 6.34 (2 H, s, CH_2N_3), and 7.70—9.20 (12 H, m, ring methylenes). The same allylic azide was the product from a reaction of 1-methyl-*cis*-cyclo-octene with the reagent.

An authentic sample of (X) was prepared in 85% yield by treatment of 1-bromomethylene-*cis*-cyclo-octene [from *N*-bromosuccinimide and 1-methyl-*cis*-cyclo-octene, ν_{\max} (film) 1 650 cm^{-1} (C=C), τ 4.27 (1 H, t, J 10 Hz, H-2) and 6.10 (2 H, s, CH_2Br)], with sodium azide (2.0 equiv.) in dimethylformamide at 50 °C for 1 h (identical by t.l.c., g.l.c., n.m.r., and i.r.).

We thank Magdalen College, Oxford, for a Perkin Research Studentship (to R. C. H.).

[5/1011 Received, 28th May, 1975]

¹⁴ A. C. Cope, S. W. Fenton, and C. F. Spencer, *J. Amer. Chem. Soc.*, 1952, **74**, 5884.

¹⁵ A. J. Bridges and G. H. Whitham, *J.C.S. Chem. Comm.*, 1974, 142.

¹⁴ S. J. Bailey, Part II Thesis, Oxford, 1975.

¹⁵ H. Meier, *Synthesis*, 1972, 246, and personal communication.