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138. Reaction of 2-Methylnorborn-2-ene with N-Bromosuccinimide [1]

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(15. V. 70)

Summary. The reaction of 2-methylnorborn-2-ene with N-bromosuccinimide produced *exo*-3-bromo-2-methylenenorbornane and 2-methyl-3-bromonortricyclene in a 3:1 ratio. No 2-bromomethyl-norborn-2-ene was found. Most of the unreacted olefin was found to be isomerized to 2-methylenenorbornane.

The hydrolysis of 2-methyl-3-bromo-nortricyclene with silver acetate in a 50% mixture of acetone and water afforded the corresponding alcohol and acetate. *Exo*-3-bromo-2-methylene-norbornane on similar treatment gave the *exo*-3-hydroxy-2-methylene-norbornane and 2-hydroxymethyl-norbornane and 2-hydroxymethyl-norborn-2-ene and their corresponding acetates in a 3:2 ratio.

An ionic rather than a radical mechanism is proposed for the bromination reaction. In the solvolysis reactions of the resulting bromides the nature of the ionic intermediates is discussed.

Introduction. – The behaviour of N-bromosuccinimide (NBS) as a brominating agent towards bridged bicyclic olefins is capricious. When the allylic C-H bond lies in the nodal plane of the double bond, reactivity is usually directed towards the homoallylic position or the double bond itself [2]. When an allylic position is available, bromination is thought to proceed *via* allylic radicals which subsequently give the corresponding endocyclic allylic bromides [3].

As 2-methylnorborn-2-ene contains both these structural elements, its reactivity is of crucial interest. Furthermore, the properties of the bromides obtained relate to the problem of the nature of bridged cations.

Results. – 2-Methylnorborn-2-ene (I) and N-bromosuccinimide were allowed to react in boiling carbontetrachloride containing benzoyl peroxide. The resulting products were identified as *exo*-3-bromo-2-methylene-norbornane (II), 3-bromo-2-methyl-nortricyclene (III) and 2-methylenenorbornane (IV). The structures of II and III were assigned from a consideration of their NMR. and IR. spectra. The *exo* assignment of the bromine at C-3 in II was made on the basis of the magnitude of the coupling constant exhibited for C-3-H, ($^3J \sim 1.8$ Hz); a larger value (ca. 4 Hz) would

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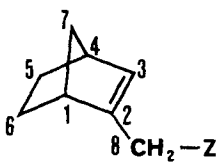
be expected for a 3-*exo*-proton. Further corroboration of its assigned structure was provided by the correspondance of the spectral properties of II and its hydroxy derivative [4].

For III, in which the nortricyclene structure was plainly evident, the only problem was to establish that the bromine was at C-3. The signal at 3.84 ppm (C*H*Br) showed as a doublet and fitted the C-3 assignment. The corresponding acetate, alcohol and ketone all had properties consonant with substitution at C-3 on the nortricyclene skeleton.

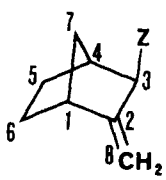
Hydrolysis of *exo*-3-bromo-2-methylene-norbornane (II) with silver acetate in aqueous acetone at 25° afforded the corresponding alcohol and acetate (V and VI) and also the products of allylic rearrangement *viz.*, 2-hydroxymethyl- and 2-acetoxymethyl-norborn-2-ene (VII and VIII) [5]. No other products were formed. All the structures were assigned unequivocally from their spectra which moreover, agreed perfectly with the values recorded in the literature [4] [5]. To simplify the problem of separation, the mixture V–VIII was first acetylated, thereby eliminating the alcohols V and VII. Similarly, reduction of the mixture with lithium aluminium hydride removed the two acetates VI and VIII. Subsequent chromatographic separation of the pair of alcohols and the pair of acetates was straightforward.

3-Bromo-2-methyl-nortricyclene (III) could not be completely freed from traces of isomer II. Hydrolysis with aqueous silver acetate gave mainly 3-hydroxy- and 3-acetoxy-2-methyl-nortricyclenes (IX and X) together with a small amount of the mixture V–VIII. Fortunately, recourse to acetylation and reduction facilitated separation and both IX and X were obtained pure. Oxidation of IX afforded the ketone XI. The observed carbonyl stretching frequency of 1756 cm^{-1} is that expected for the 3-ketone [6].

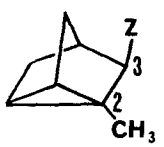
Discussion. – *Bromination.* To account for the fact that norbornene, on treatment with NBS, gave solely 3-bromonortricyclene (XII), two mechanisms were postulated, one involving the prior formation of a homoallylic radical XIII and another proceeding from the bromonium ion XIV [3a].



I Z = H
VII Z = OH
VIII Z = OAc
VIIIa Z = Br



II Z = Br
IV Z = H
V Z = OH
VI Z = OAc



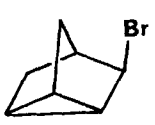
III Z = Br
IX Z = OH
X Z = OAc

When a methyl group is attached to the double bond, the formation of the allylic radical XV is possible. Three bromides might be expected to form from XV by attack at C-8 and on the *exo* and *endo* sides of C-3. However, only one of these bromides was isolated, *viz.* *exo*-3-bromo-2-methylene-norbornane (II). The absence of the other two can either be ascribed to unfavourable transition states for their forma-

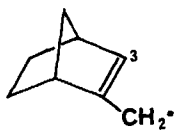
tion or that they were initially formed, but underwent rearrangement to the thermodynamically most stable bromide II.

Although radical XV might well be the origin of II, the tricyclic bromide III undoubtedly arises from an ionic precursor. The intermediacy of a radical such as the homoallylic structure XVI is unlikely, as it would be hard to explain the selective absence of the other homoallylic radical XVII, especially as there is neither reason nor means for XVII to convert to XVI. Consequently, for 2-methylnorbornene, unlike norbornene itself, the choice of intermediate is restricted to the *exo*-bromonium ion XVIII which on loss of a proton from C-6 affords 3-bromo-2-methyl-nortricyclene (III). Without further consideration, this duality of mechanism is sufficient to account for the products, since, after all, the reaction conditions are those in which radicals are expected to be formed. This statement corresponds to the observation made by *Davies & Parfitt* [7].

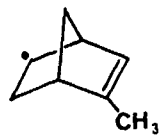
However, a more economical conclusion can be made on the basis of two important considerations. For derivatives of 2-methylnorborn-2-ene and 2-methylenenorbornane the structure with an exocyclic double bond is more stable [8] [9]. Unfortunately, this thermodynamic preference sheds no light on the nature of the different transition states for attack at C-3 or C-8 of the appropriate allylic cations, anions or radicals. Nevertheless, there is evidence that attack on the cations and radicals at least does afford products originating from attack at both termini of the allylic system. As will be discussed later, solvent attack on the 2-methylene-3-norbornyl cation gives substitution products with both exocyclic and endocyclic double bonds in a ratio of 3:2. Moreover, the reaction of N-bromosuccinimide with isokaurene and isophyllocladene gave in each case as major product the endocyclic allylic bromides [3a]. Therefore allylic radical XV would be expected to give at least some endocyclic product, *viz.* VIIIa. As none was observed, there is no strong reason for invoking XV as intermediate. Although



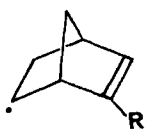
XII



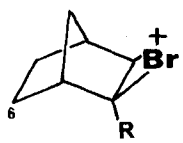
XV



XVII



XIII R = H
XVI R = CH_3



XIV R = H
XVIII R = CH_3

this first consideration does not permit the rigorous exclusion of XV, a second consideration renders superfluous its supplementary intermediacy. As the *exo*-bromonium ion XVIII has to be invoked to explain the formation of III anyway, it appears that at the moment of its losing a proton no distinction exists between the hydrogen on C-6 (to give III) and that on the methyl group (to give II). Thus as XVIII is bound

to give both products (II and III) an additional intermediate such as XV is not necessary.

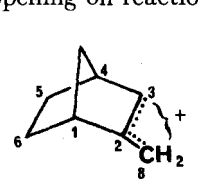
Recently a report [10] followed by some observations [7] has appeared concerning the treatment of 2-methylenenorbornane and 2-methylnorborn-2-ene with NBS under apparently the same conditions as used by us. Rather surprisingly, *Alden & Davies* detected no 2-methyl-3-bromo-nortricyclene or any isomerization of 2-methylnorbornene to 2-methylenenorbornane [10]. Furthermore, they observed that the principal product *exo*-3-bromo-2-methylenenorbornane was contaminated with 10–25% of another mono bromide which they did not separate and which they believed was the *endo* isomer. The use of *t*-butyl hypobromite as reagent gave similar results, except that none of the supposed *endo* product was detected. To account for their results the authors postulate the intermediacy of the allylic radical XV which undergoes preferential attack at C-3 in the radical chain termination step. The formation of the *endo* product was rationalized in terms of the differences in size between NBS and *t*-butyl hypobromite; the latter was reckoned to be the larger and therefore incapable of reacting on the *endo*, the presumably more hindered, side. Since they do not observe the tricyclic product III (or olefin isomerization) an ionic intermediate is not required and their proposed radical mechanism is adequate [10] [7].

A conclusion which may be drawn from these dramatic differences is that the formation of 3-bromo-2-methyl-nortricyclene is an index of ionic behaviour and that the balance between the ionic or radical course of NBS must be sensitive to very slight changes in reaction conditions.

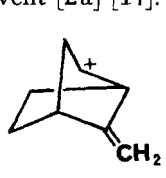
The isomerization of 2-methylnorborn-2-ene to 2-methylenenorbornane, a thermodynamically favoured process [8], seems to be a feature of the ionic, but not the radical mechanism. Although such endo-exo isomerizations are well known [11] and are expected to be symmetry-allowed, suprafacial processes in the excited state [12], the present example is probably not a simple process.

Both ionic and radical processes have been postulated to account for the formation of just the *exo*-5-bromo-4-methylene derivative from *exo-cis*-3,6-endoxo-4-methyl-Δ^4-tetrahydrophthalic anhydride [13]. However, *endo*-5-bromo or nortricyclene-type products were not observed despite the expectation of at least one from either process.

Solvolysis. The behaviour of 2-methyl-3-bromonortricyclene (III) with aqueous silver ion was entirely as expected and was exactly that exhibited by the *nor* compound, namely, generation of the extremely stable cyclopropylcarbinyl cation with no evidence of ring opening on reaction with solvent [2a] [14].



XIX



XX

On the other hand, the behaviour of *exo*-3-bromo-2-methylenenorbornene (II) under the same conditions displays a relevance to the so-called non-classical ion problem posed by the 2-norbornyl cation [15]. It seems reasonable to assume that

the derived 2-methylene-3-norbornyl cation (XIX) is stabilized exclusively as the allylic ion. Any participation or bridging by migration of the C4-C5 bond to the homoallylic ion XX will be opposed by the loss of delocalization of charge over the allylic portion [14] [16].

Thus the species XIX is clearly a non-equilibrating, classical ion. Its reaction with solvent is revealing. Significantly, the solvent attacked C-8 and *exo* at C-3 to about the same extent, but no *endo*-C-3 product was formed. It can be immediately concluded therefore that the particularity of *exo* attack is neither the exclusive hallmark of a supposed non-classical cation, nor that of an equilibrating classical 2-norbornyl cation mimicking a tiny windshield wiper. For comments on the appropriateness and the attribution of this whimsical term see [15], p. 345 and [17].

The formation of the 2-hydroxymethyl and 2-acetoxymethyl derivatives of norborn-2-ene (VII and VIII) is worthy of comment. Firstly, these C-2 derivatives are most probably the products of kinetic control, since the acetoxy and hydroxyl anions are not particularly good leaving groups and therefore VII and VIII will be denied the chance to equilibrate under the reaction conditions. Secondly, they are formed for the first time under conditions in which the intermediacy of the allylic ion XIX is not in doubt and in which other intermediates are absent[2]).

Clearly, the difference in energy between the apparent alternatives of placing either two sp^2 or just one sp^2 hybridized carbon atom in the ring plays little part in the choice of transition state. In other words, the preferred transition state does not resemble the more stable product [10] [18]. Further experiments are clearly necessary before the nature of the allylic cation can be fully evaluated.

We are indebted to the *Petroleum Research Fund*, administered by the American Chemical Society, for the generous provision of financial support for the major part of this research.

We are also grateful to Prof. *H. Krieger*, Oulu University, Finland, for kindly providing a sample of *endo*-3-hydroxy-2-methylene-norbornane, for comparative purposes.

Experimental

All boiling points are uncorrected. IR. spectra were recorded on a *Perkin-Elmer* 137-B Infracord spectrometer (NaCl prism calibrated with a film of polystyrene) as films, unless otherwise noted. NMR. spectra were taken on *Varian Associates* Model A-60 and HA 100 instruments using deuteriochloroform as solvent. Chemical shifts are expressed as ppm with reference to tetramethylsilane taken as zero. Gas phase chromatograms (GPC.) were performed on an *Aerograph* Autoprep 700 instrument. Microanalyses were performed by Dr. *G. Robertson, Jr.*, Florham Park, N.J., U.S.A. and in a few cases by the *Service Central de Microanalyse du C.N.R.S.*, Strasbourg, France.

2-Methylnorborn-2-ene (*I*). The *Diels-Alder* reaction of ethylene and methylcyclopentadiene dimer yielded 1- and 2-methylnorbornenes which were separated by distillation [19]. We are greatly indebted to the *Enjay Chemical Co.*, Plainfield, N.J., U.S.A. for the generous provision of methylcyclopentadiene dimers.

Reaction of 2-Methylnorborn-2-ene (*I*) *with N-Bromosuccinimide* (*NBS*). To a solution of 2-methylnorborn-2-ene (52 g) in carbon tetrachloride (280 ml), NBS (58 g) and benzoyl peroxide (0.25 g) were successively added. The resulting suspension, kept under nitrogen, was boiled under reflux and stirred vigorously for 4 hours, during which time it became deep red-brown in colour. On cooling, the succimimide was separated by filtration and carbon tetrachloride was removed by distillation. The residual dark brown oil was distilled to afford firstly unreacted starting material

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[2]) This is certainly not the case for the oxidation of I by lead tetraacetate, a reaction which is notorious for its lack of an unambigous mechanism (see [5], particularly footnote 23).

(b.p. 34–35°/25 Torr) then a mixture of two isomeric bromides, b.p. 86–90°/22 Torr (46.68 g, 69% yield; based on NBS).

The NMR. spectrum of the low boiling fraction revealed that it consisted of a mixture of 2-methylenenorbornane (IV) and 2-methylnorborn-2-ene (I) in a ratio of 87:13. The NMR. spectrum of the high boiling fraction revealed the presence of 2-methylene-*exo*-3-bromonorbornane (II) (75%) and 2-methyl-3-bromo-nortricyclene (III) (25%). 2-Methylene-*exo*-3-bromo-norbornane (II) was separated by successive fractional distillation through a *Vigreux* column (15 cm long) (b.p. 101–102°/34 Torr). The reaction proved to be perfectly reproducible. Removal of solvent and unreacted starting material under different conditions did not produce any product differences. Heating the product mixture (1 hr. at 100°) or treatment with trifluoroacetic acid left the product ratio unaltered.

2-Methylene-exo-*3-bromo-norbornane* (*II*). IR. spectrum: max. at 3060, 1661 and 897 cm^{-1} due to the exo-cyclic methylene group.

$C_8H_{11}Br$ (187.07) Calc. C 51.36 H 5.92 Br 42.72% Found C 51.64 H 5.82 Br 42.92%

2-Methyl-3-bromonortricyclene (*III*) was obtained contaminated by 12% of the isomeric bromide (fraction was collected at 86–88°/35 Torr). IR. spectrum: max. at 849 and 794 cm^{-1} indicative of the cyclopropane ring. NMR. spectrum: a sharp singlet at 1.23 ppm due to the methyl group and a doublet at 3.84 (^3J = 1.3 Hz) ascribable to the C_3 proton.

Treatment of 2-Methylene-exo-*3-bromo-norbornane* (*II*) *with Silver Acetate.* To a solution of II (10 g) in 50% aqueous acetone (100 ml), silver acetate (10 g) was added. Silver bromide was immediately deposited. The mixture was stirred at 25° for 30 min, then the precipitate was removed by filtration. Evaporation of the solvent yielded a colourless oil, which was dissolved in pyridine (50 ml) and acetic anhydride (50 ml). The resulting solution after standing for 4 hours was poured into icewater. Extraction was effected with ether. Evaporation of the solvent gave a colourless oil (8.2 g; 92%).

The NMR. spectrum and GPC. analysis revealed the presence of only two compounds: 2-methylene-*exo*-3-acetoxy-norbornane (VI) and 2-acetoxymethyl-norborn-2-ene (VIII) in the ratio 1.5–2.2 to 1. Separation of the two isomers was effected by column chromatography over silica gel impregnated with a 10% aqueous silver nitrate solution (1.8 g of acetates on 80 g of silica). Elution with 4.5% of ethyl ether in petroleum ether afforded 2-methylene-*exo*-3-acetoxy-norbornane (VI) (1.14 g). Further elution with 8–10% of ethyl ether in petroleum ether yielded 2-acetoxymethyl-norborn-2-ene (VIII) (0.60 g). Recovery was nearly quantitative (97%).

Separation was also effected by preparative GPC. A column of Carbowax 20M on Chromosorb W (20 feet × $^3/_8$ inch) using helium as carrier gas (100 ml/min) and temperature of 210° C (injection), 180° C (column) and 225° C (detector) gave a good separation. The retention times were 8.5 min. for 2-methylene-*exo*-3-acetoxy-norbornane (VI) and 10.2 min. for 2-acetoxymethyl-norborn-2-ene (VIII).

2-Methylene-exo-*3-acetoxy-norbornane* (*VI*). IR. spectrum: max. at 1742, 1669, 1235 and 907 cm^{-1}, indicative of the acetoxy group and an exocyclic methylene group.

$C_{10}H_{14}O_2$ (166.21) Calc. C 72.26 H 8.49% Found C 72.36 H 8.43%

2-Acetoxymethyl-norborn-2-ene (*VIII*). IR. spectrum: max. at 3030, 1735, 1635, 1235 and 815 cm^{-1}, characteristic of the acetoxymethyl grouping attached to an endocyclic double bond.

$C_{10}H_{14}O_2$ (166.21) Calc. C 72.26 H 8.49% Found C 72.23 H 8.69%

If the initially obtained colourless oil was dissolved in anhydrous ether (40 ml) and added dropwise to a suspension of lithium aluminium hydride (20 g) in ether and stirred for 4 hours at 25°, then a mixture of the two isomeric alcohols was obtained (5.95 g; 90%). Separation was effected by preparative GPC. using the same conditions as in the case of the acetates. Retention times were 10.8 min for 2-methylene-*exo*-2-hydroxy-norbornane (V) and 16.4 min for 2-hydroxymethyl-norborn-2-ene (VII).

2-Methylene-exo-*3-hydroxy-norbornane* (*V*). IR. spectrum: max. at 3300, 3030, 1664 and 897 cm^{-1}, revealing the hydroxyl and exocyclic methylene groups.

$C_8H_{12}O$ (124.18) Calc. C 77.37 H 9.73% Found C 77.64 H 9.71%

2-Hydroxymethyl-norborn-2-ene (*VII*). IR. spectrum: max. at 3280, 3025, 1629 and 808 cm^{-1} characteristic of the hydroxymethyl grouping attached to an endocyclic double bond.

$C_8H_{12}O$ (124.18) Calc. C 77.37 H 9.73% Found C 77.59 H 9.77%

Reduction of the Acetates. Reductions were carried out on the mixture of the acetates and also separately on each acetate. From the mixture of acetates, a mixture of two alcohols was obtained. From each acetate only the corresponding alcohol was obtained. The ratio of products was the same as the ratio for the starting materials. Yields were always high (93–97%). In a typical experiment a solution of the acetate (2.60 g) in anhydrous ether (30 ml) was added dropwise to a suspension of lithium aluminium hydride (1.75 g) in anhydrous ether (100 ml). The mixture was stirred at room temperature for 4 hours after which time the excess metal hydride was decomposed by the dropwise addition of a small quantity of water. The resulting mixture was filtered, the solvent was dried over anhydrous magnesium sulfate and then removed by evaporation. A colourless oil was obtained (1.86 g; 93%), which consisted of the alcohol or alcohols.

Acetylation of the Alcohols. As in the case of the reductions, acetylations were effected on the mixture of alcohols and also on the pure isomers. A mixture of the acetates (same ratio of the products as for reactants) or the single products were obtained respectively. The yields were generally high (92–97%).

In a typical experiment, the alcohol (4.0 g) was dissolved in dry pyridine (40 ml) to which was added acetic anhydride (40 ml). The mixture was allowed to stand at room temperature for 4 hours and was then poured into ice-water. Work-up gave a slightly yellowish oil (5.08 g; 97%).

Treatment of 2-methyl-3-bromonortricyclene (*III*) *with Silver Acetate.* The reaction was carried out in exactly the same way as for 2-methylene-*exo*-3-bromo-norbornane, followed by treatment with acetic anhydride in pyridine. From 2-methyl-3-bromo-nortricyclene (III) (2.65 g) containing about 15% of 2-methylene-*exo*-exo-3-bromo-norbornane), 2-methyl-3-acetoxy-nortricyclene contaminated by the two isomeric acetates was obtained (2.12 g; 90%). Purification of the main compound was effected by column chromatography over silica gel (95 g) impregnated with a 10% aqueous silver nitrate solution. Elution with 3% ethyl ether in petroleum ether gave pure 2-methyl-3-acetoxy-nortricyclene (X) (1.76g). Purification by preparative GPC was equally effective. The retention time was 6.5 min under the same conditions cited for the isomeric acetates.

2-Methyl-3-acetoxy-nortricyclene (*X*). IR. spectrum: max. at 1730, 850 and 797 cm^{-1}, characteristic of the cyclopropane ring and the acetoxy group. NMR. spectrum: sharp singlets at 1.11 and 2.02 ppm (methyl groups) and a doublet (^3J = 1.6 Hz) at 4.50 ppm due to the C-3 proton.

$C_{10}H_{14}O_2$ (166.21) Calc. C 72.26 H 8.49% Found C 72.37 H 8.68%

2-Methylnortricyclen-3-ol (*IX*). To a solution of 2-methyl-3-acetoxy-nortricyclene (X) (0.70 g) in anhydrous ether (40 ml) was added lithium aluminium hydride (0.45 g) in small portions. The mixture was stirred for 1 hour at room temperature and then excess reagent was decomposed by dropwise addition of a little water. The mixture was filtered, dried over anhydrous sodium sulfate and the ether was evaporated. A colourless oil was obtained (0.54 g; 99%). IR. spectrum[3]: max. at 3310, 3025, 848 and 794 cm^{-1}. NMR: singlet at 1.16 (CH_3) and a doublet (^3J = 1.8 Hz) at 3.59 ppm (C-3-H).

$C_8H_{12}O$ (124.18) Calc. C 77.37 H 9.73% Found C 77.28 H 9.76%

2-Methylnortricyclen-3-one (*XI*). To a solution of 2-methylnortricyclen-3-ol (IX) (0.42 g) in ether (5 ml) was slowly added a solution of sodium dichromate dihydrate and concentrated sulfuric acid (0.3 ml) in water (4 ml). The mixture was stirred for 3 hours at room temperature. Work-up and evaporation of ether gave a colourless oil (0.31 g; 76%). IR. spectrum[4]: max. at 3000, 1756 and 843 cm^{-1} characteristic of carbonyl at C-3 and the cyclopropane ring. NMR. spectra: the methyl group showed chemical shifts at 1.10, 1.04 and 0.97 ppm in $CDCl_3$, pyridine and benzene. The small positive solvent shift ($\Delta^{CDCl_3}_{C_6H_6}$ = +0.13 ppm) in benzene exludes placement of methyl at C-1 and according to a model[5]) appears to be compatible with structure XI in which the C-2 methyl lies very close to and just behind the reference plane through the carbonyl carbon atom [20]. The tiny

[3]) Recorded as a film on a *Beckman* Model IR8 spectrometer.

[4]) Recorded on a *Beckman* model IR8 spectrometer in carbon tetrachloride solution.

[5]) Framework Molecular Models, *Prentice-Hall, Inc.*, Englewood Cliffs, N.J., U.S.A.

shielding experienced in pyridine ($\Delta^{CDCl_3}_{C_5H_5N} = +0.06$ ppm) certainly fits structure XI, but should be a larger negative value for a reference plane drawn rigorously through the α-carbon atoms [21]. The 2,4-dinitrophenylhydrazone was prepared and recrystallized from ethanol-ethyl acetate; m. p. 207.5–209° (red). The UV. spectrum[6]) showed $\lambda^{EtOH}_{max} = 365$ nm ($\varepsilon = 23000$).

$C_{14}H_{14}N_4O_4$ (302.38) Calc. C 55.63 H 4.67 N 18.53% Found C 55.35 H 4.59 N 18.53%

NMR. Data. The chief spectral features of compounds II, V, VI, VII and VIII are listed in the Table. In all cases the spectra are not cleanly first order and consequently details of the intimate structure are not immediately apparent. No structural problem is posed by compounds VII and VIII. In the other compounds it is important to know unequivocally the stereochemistry at C-3. As II, V and VI gave similar spectra a proof of structure of one of them was taken as being sufficient for the other two. As an addition check on the structure of V its spectrum was analysed by using double irradiation with frequency sweep[7]). It was established that the C-3 proton was feebly coupled (< 1.0 Hz) to the proton responsible for the signal at 2.24 ppm, thereby indicating that the C-3 proton was *endo*. Further proof for the *endo* disposition was demonstrated by the coupling of the C_3 proton with the *anti* C-7 proton ($^4J \sim 1.5$ Hz) [22].

Chemical Shifts[a]) *and Structure*[b]) *of Signals due to the Protons on C-1, C-3, C-4 and C-8 of some Derivatives of Norbornene*

Compound	C-1-H	C-3-H	C-4-H	C-8-H
II	2.78 *m*, *w* = 6.0	4.44 *d* of *m* ($^3J = 1.8$) *w* of *m* = 4.0	2.56 *m*, *w* = 4.0	5.12 *s*, *w* = 2.5
V	2.66 *m*, *w* = 6.0	3.83 *m*, *w* = 4.0	2.24 *m*, *w* = 7.0	4.96 *m*, *w* = 3.5
VI	2.69 *m*, *w* = 5.5	5.02 *m*, *w* = 3.0	2.33 *m*, *w* = 6.5	4.95 *s*, *w* = 2.5
VII	2.81[c]) *d* (*w* = 1.8) of *m* (*w* = 6.0)	5.72 *m*, *w* = 6.0	2.81	4.15 *d*, *w* = 1.8
VIII	2.80[c]) *m*, *w* = 6.0	5.80 *m*, *w* = 6.0	2.80	4.58 *d*, *w* = 1.0

a) In ppm. In $CDCl_3$.
b) *s* = singlet, *d* = doublet, *m* = multiplet, *w* = width at half-height, all values are in Hz.
c) Signal completely overlapped with that of C-4-proton at 60 Hz.

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6) Recorded on a *Beckman* model DK-2 spectrophotometer.
7) We thank Dr. *K. C. Ramey* for performing this experiment.

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139. Über Pterinchemie

32. Mitteilung [1]

Synthese des natürlichen D-Neopterins und L-Monapterins[1])

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(20. V. 70)

Zusammenfassung. Bei der Kondensation von 2,4,5-Triamino-6-oxo-1,6-dihydropyrimidin mit dem Phenylhydrazon der D-Arabinose bzw. L-Xylose im wässerigen Methanol unter N_2 und anschliessender Oxydation der Kondensationsprodukte werden D-Neopterin bzw. L-Monapterin gebildet. Nach Reinigung und Umkristallisation aus Wasser werden beide Substanzen als farblose Kristalle in sehr hoher Ausbeute erhalten.

Bei der Beschreibung der Synthese von 6-(Polyhydroxyalkyl)-pterinen durch Kondensation von 1-Amino-2-ketopentosen (IIa) mit dem Pyrimidin I erwähnten wir in der 26. Mitteilung [2], dass die Aminoketosen (IIa) vorteilhaft durch Phenylhydrazinoketosen (IIb und c) ersetzt werden könnten. Hier beschreiben wir diese Methode, die Neopterin und Monapterin sehr rein und in hohen Ausbeuten liefert.

Das Prinzip der Synthese bleibt unverändert; man stellt das Hydrazon einer Aldopentose her, lagert dies in eine Hydrazinoketose nach *Amadori* um und kondensiert letztere mit dem Pyrimidin I zu einem Tetrahydropterin III, welches anschliessend zum Pterin IV oxydiert wird. D-Arabinose und L-Xylose werden zum Beispiel als Ausgangsmaterial für die Herstellung von D-Neopterin bzw. L-Monapterin verwendet. Ihre Phenylhydrazone sind in der Literatur nur kurz erwähnt [3] [4]; wir haben deshalb im experimentellen Teil dieser Arbeit eine Herstellungsmethode beider Substanzen und ihrer Enantiomeren genau angegeben.

Überraschenderweise, und im Gegensatz zu allen bis jetzt von uns studierten Beispielen, lassen sich nach der *Amadori*-Umlagerung die entsprechenden Phenylhydra-

[1]) Schweiz. Patent-Anmeldung Nr. 4979/67 vom 7.4.1967.