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Di-isophorone and Related Compounds. Part 8[1] 1-Aminodi-isophorane Derivatives

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The interaction of 1-chlorodi-isophor-2(7)-en-3-one or its 5,11-bisnor-homologue with potassium phthalimide yields the corresponding 1-phthalimido-compounds, which are converted into the 1-amines on treatment with hydrazine, followed by hydrolysis. 1-Aminodi-isophor-2(7)-ene is not accessible by this route, but its N-acyl-derivatives are obtainable directly from 1-hydroxydi-isophor-2(7)-ene by the *Ritter* reaction; the 3-keto-analogue reacts similarly. Some properties of the novel 1-aminodi-isophoranes are described.

(Keywords: Di-isophorones, 1-amino; Tricyclo[7.3.1.0^{2,7}]tridecanes)

Di-isophoron und verwandte Verbindungen. 8. Mitt. 1-Amino-di-isophoran Derivate

Die Einwirkung von Phthalimid-Kalium auf 1-Chlor-di-isophor-2(7)-en-3-on oder sein 5,11-Bis-nor-Homolog ergibt die entsprechenden 1-Phthalimido-Verbindungen, aus welchen durch Behandlung mit Hydrazin und darauffolgende Hydrolyse die primären 1-Amine erhältlich sind. 1-Amino-di-isophor-2(7)-en ist auf diese Weise nicht darstellbar, aber seine N-Acyl-derivate sind direkt aus 1-Hydroxy-di-isophor-2(7)-en mittels der *Ritter*-Reaktion zugänglich; die analoge 3-Keto-verbindung reagiert ebenso. Einige Eigenschaften der neuen 1-Amino-di-isophorane werden beschrieben.

Introduction

In spite of their manifold interest, nitrogenous bases derived from the di-isophorane ring-system have apparently not been described so far[2]. Amino-compounds of this series are evidently potentially useful intermediates in further syntheses; in particular, a knowledge of the formation and reactions of 1-aminodi-isophoranes should contribute to our understanding of C-1 bridgehead reactivity in this ring-system[2,3]. The insertion of nitrogen into the carbon skeleton of tricyclo[7.3.1.0^{2,7}]tridecane (**A**), the ultimate parent hydrocarbon of di-

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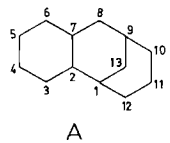
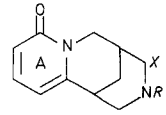
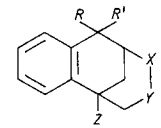
isophoranes[4], is known to result in physiologically active analogues such as quinolizidine alkaloids[5] (cytisins, **B**; angustifolin, **C**), synthetic analgesics (e.g. 1,5-methano-1,2,3,4,5,6-hexahydrobenzazocines[6], **D**, 6,7-benzomorphanes[7], **E**), and others[8]. The antiviral properties of 1-adamantamine[9], which bears an amino-group at a bridgehead of its bulky three-dimensional lipophilic hydrocarbon moiety, are also noteworthy and relevant. Accordingly, we have examined, as our first objective, potential syntheses and reactions of 1-(substituted)aminodi-isophoranes. Their unexpected cyclodehydration to a novel pentacyclic structure incorporating a ring-nitrogen atom, is of particular interest. The simplified nomenclature which was originally adopted[4] is again employed.



A



B: R=H or *Me*; X=H
C: R=H; X=$-CH_2CH=CH_2$
Ring A saturated



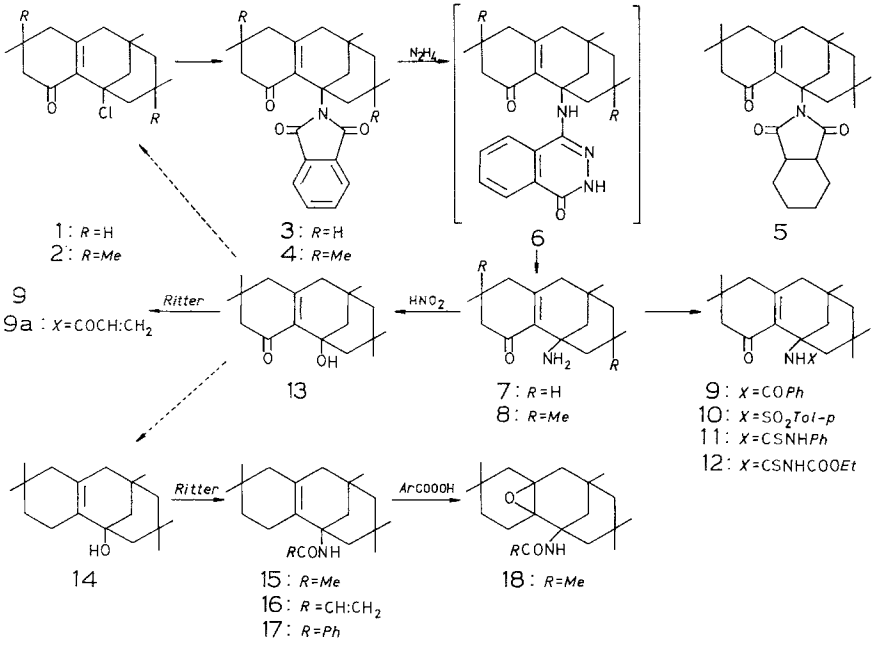
D: X=CH_2; Y=NMe; Z=H
E: X=NMe; Y=CH_2; Z=*Me*
R=R'=H

Results and Discussion

An obvious route to 1-aminodi-isophoranes is the nucleophilic replacement of the 1-substituent in the readily accessible 1-halogeno-analogues (**1**, **2**)[10]. Although 1-chlorodi-isophor-2(7)-en-3-one (**2**) undergoes solvolysis and hydrolysis with remarkable ease[2,3], its attempted ammonolysis under a variety of conditions, including the use of liquid ammonia, gave discouraging results. The desired replacement was effected indirectly by employing a modified *Gabriel* synthesis[11]. Condensation of 1-chlorodi-isophor-2(7)-en-3-one (**2**) or its 5,11-bisnor-homologue (**1**) with potassium phthalimide, though unsuccessful in the usual hydrocarbon solvents (e.g. xylene), occurred readily in dimethylformamide[12], affording the 1-phthalimido-derivatives (**3**, **4**) in good yield. The i.r. spectrum of **4** displays the expected[3,4] bands associated with its alicyclic and aromatic moieties and its functional groups (see Experimental).

Initial attempts to convert **4** into the parent amine **8** by conventional acid hydrolysis were unsuccessful. However, *Ing* and *Manske*'s[13,14] modification of *Gabriel*'s synthesis, employing hydrazine hydrate for cleaving the phthalimido-intermediates, afforded the 1-aminodi-isophor-2(7)-en-3-ones (**7**, **8**) readily in good yield. The reaction is thought to involve the initial ring-expansion of the phthalimido-substituent;

acid hydrolysis of the resulting intermediates (**6**) *in situ* produces the amines (**7**, **8**), together with the very sparingly soluble phthaloylhydrazide. Though isolable by basification and solvent extraction, the liquid amines were obtained advantageously as the crystalline (but very hygroscopic) hydrochlorides, and were further characterised as picrates. Nitrous acid smoothly converted 1-aminodi-isophor-2(7)-en-3-one (**8**) into di-isophor-2(7)-en-1-ol-3-one (**13**) (75%), i.e. the original source of the 1-halogenated starting material (**2**)[2,10], probably by a mechanism involving intermediate carbonium ions.



As in other bridgehead replacements in di-isophoranes[2,3], the structure and configuration of the ring system are thus seen to remain unaltered throughout.

1-Aminodi-isophor-2(7)-en-3-one (**8**) gave acylamido-derivatives (e.g. **9**, **10**), but attempts to obtain the 1-acetamido-derivative gave non-crystallisable liquids. The action of phenyl isothiocyanate or ethoxycarbonyl isothiocyanate[15] (on **8**) produced the appropriate substituted thioureas (**11**, **12**) which were required for cyclisation reactions in another connexion[16].

1-Chlorodi-isophor-2(7)-ene[10] failed to react with potassium phthalimide under the established conditions, presumably because of the absence of the activating influence of the 3-keto-group that promotes

the replacement in **1** and **2**. Since 1-aminodi-isophor-2(7)-enes were thus inaccessible by this route, alternative approaches were briefly explored.

Catalytic hydrogenation, normally the method of choice[3,4,10,17] for the removal of the 3-keto-function in the di-isophorone structure (**13**), did not afford the 3-deketo-compounds from their pre-formed 3-keto-analogues. Instead, **4** reacted rapidly with three (but no more) molecules of hydrogen, to yield a product which, on the basis of its composition, molecular weight, and spectral properties, is formulated as the 1-hexahydrophthaloyl-compound (**5**). Its i.r. spectrum, generally resembling that of its precursor (**4**), retained the prominent peaks due to the keto-groups, but lacked the absorption characteristics of the 1,2-disubstituted benzene ring. Unlike its aromatic analogue (**4**), **5** was not cleaved by the action of hydrazine.

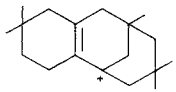
Another route to the desired 1-aminodi-isophorane derivatives appeared to be the *Ritter* reaction[18,19] involving the addition of nitriles to the 1-carbonium ion derived from **14**, followed by hydrolysis of the intermediate nitrilium salts. This is the preferred method of synthesising amides of tertiary carbinamides (i.e. $RR^1R^2C—NHCOR^3$), if not the only one of practical utility. The condensation of di-isophor-2(7)-en-1-ol (**14**) with aceto-, acrylo- and benzonitrile occurred readily in glacial acetic—concentrated sulphuric acid; subsequent dilution with water hydrolysed the intermediates to 1-acylamidodi-isophor-2(7)-enes (**15–17**) almost instantly in good overall yield.

The i.r. spectra of the 1-acylamidodi-isophor-2(7)-enes (**15–17**) are typical of associated amides. Peaks due to N—H stretching appear at 3,360-3,300 cm^{-1} and near 3,060 cm^{-1}, the latter masking, in the 1-benzamido-compound (**17**), the weak stretching absorption of the aromatic nucleus in this range. Prominent bands at 1,640-1,655 and 1,540-1,560 cm^{-1} are attributed respectively to the amido-carbonyl group, and to N—H bending in an associated amide.

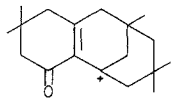
The "inert" 2,7-ethylenic bond[20] of the 1-acylamidodi-isophor-2(7)-enes retains its power of forming an oxirane-ring: thus, **15** was readily converted into the 2,7-epoxide (**18**) by 3-chloroperoxybenzoic acid[20]. Attempts to obtain this compound from the preformed 2,7-epoxydi-isophoran-1-ol[20] by the *Ritter* reaction gave only intractable oils, doubtless due to simultaneous attack of the strongly acid medium on the oxirane ring, which is liable to be cleaved under these conditions[21].

Semiquantitative data concerning solvolysis rates[22] of 1-halogeno-di-isophorones suggest that 1-carbonium ions derived from 3-ketodi-isophor-2(7)-enes (**G**) possess a higher ionic stability than their 3-deketo-analogues (**F**). Di-isophor-2(7)-enes incorporating the 3-keto-function (e.g. **13**) should therefore undergo the *Ritter* reaction even more readily than **14**; according to the available information[19a], the

alicyclic keto-group is not likely to interfere with its course. Although the expected 1-acylamido-derivatives (**9**, **9a**) were not obtainable from **13** under the established conditions, they were produced in good yield when concentrated sulphuric acid without diluent was used as the reaction medium. The identity of the 1-benzamido-compound (**9**) with the product of the benzoylation of **8** confirmed their structure.



F



G

Disappointingly, 1-acetamidodi-isophor-2(7)-ene (**15**) proved resistant to alkaline hydrolysis, so that the parent amine was not obtained. Hydrolysis rates of substituted amides are subject to steric retardation, but the existing measurements refer to the effect of bulky substituents in their acidic rather than their nitrogenous moiety (i.e. at C-2 or C-3 of $NH_2CO\text{-}CR^1R^2\text{-}CR^3R^4CH_3$)[23]. A model of **15** shows that the 1-acetamino-group is not subject to appreciable steric hindrance, and the reason for its stability remains at present undecided.

Experimental

The nomenclature employed is that proposed in the initial paper of this series[4]. This also gives general information concerning standard procedures, reagents, solvents, equipment, and abbreviations. Light petroleum had b.p. 60–80° unless otherwise specified. Catalytic hydrogenations were performed at rooom temperature and atmospheric pressure. Except for compounds **4** and **8**·**HCl**, unassigned peaks of the i.r. spectra are not recorded. The H^1-nmr spectra given in Parts 8 and 9 were recorded in $CDCl_3$ at 60 MHz, and are reported in ppm (δ) from *TMS* as the internal standard.

1-Phthalimidodi-isophor-2(7)-en-3-one (**4**)

A solution of 1-chlorodi-isophor-2(7)-en-3-one (**2**) (17.65 g, 0.06 mol) and potassium phthalimide (11.1 g, 0.06 mol) in dimethylformamide (180 ml) was boiled under reflux for 45 min. The orange-yellow liquid, cooled below 100°, was stirred into ice-water (1 l). The precipitate, coagulated by addition of sodium chloride if necessary, was crystallised from ethanol (100 ml), giving ivory needles of **4**, m.p. 161–163° (total, 15.9–17.5 g, 65–72%) (Found: C 76.4; H 7.3; N 3.3. *M*, mass-spectrometrically 405. $C_{26}H_{31}NO_3$ requires C 77.0; H 7.65; N 3.5%. *M*, 405). ν_{max} 3060 mw, 725 vs (*Ar*), 2960–2860 s, 1470, 1467 m d, 1370 s (CH_3, CH_2), 1385 s, 1370 s (CMe_2), 1770 s, 1705, 1685 vs d (CO, imide), 1645 vs (CO, ketone), 1627 vs (C = C, conjug.), 1450 m (C = C, arom.), 1065 s (? cycloalkane), 1435 m, 1350 s, 1320 vs, 1110 m, 945 m, 910 mw, 895 mw, 880, 875 s d, 800 s, 705 s, 680 s cm^{-1}. Nmr: δ[$CDCl_3$] 7.8–7.3 (4 H, C_6H_4), 2.8–0.7 (27 H, mult, CH aliph.) including three intense signals at 1.12, 1.02 and 0.82 (integration indistinct).

The 1-chloro-compound (**2**) was substantially recovered after interaction, as above, in boiling xylene (2 h). The use of 1-chlorodi-isophor-2(7)-ene in the foregoing procedure did not produce the 1-phthalimido-derivative, even on prolonged refluxing (24 h).

1-Hexahydrophthalimidodi-isophor-2(7)-en-3-one (**5**)

A solution of **4** (2.03 g, 0.005 mol) in glacial acid (60 ml) was hydrogenated over *Adams'* catalyst[24], uptake being complete after 3 h (420 cm^3; calc. for 0.3 g $PtO_2 \cdot H_2O$ and 3 mol eqlts.: 60 + 330 cm^3, at *NTP*). Addition of the filtered solution to water (500 ml) precipitated a white resin which hardened on storage and gave, on crystallisation from light petroleum (b.p. 40-60°, with addition of a little of b.p. 60-80°) minute prisms (1.45 g, 70%) of **5**, m.p. 116-118° (Found: C 76.7; H 9.0; N 3.3. *M*, mass-spectrometrically 411 w, 340 vs, i.e. *M*$^+$—71. $C_{26}H_{37}NO_3$ requires: C 75.9; H 9.0; N 3.4%. *M*, 411). ν_{max} 2945-2865 vs., 1465 s, 1340 vs. (CH_3, CH_2), 1770 ms, 1700-1685 vs br mult (CO, imide), 1655 vs (CO ketone), 1630 vs (C=C, conjug.), 1390 s sh, 1380-1360 vs (CMe_2), 1075 s (? cycloalkane) cm^{-1}.

After being treated with hydrazine hydrate-ethanol (as described for **4**, below), **5** was recovered (90%). It failed to give an oxime by the standard procedure[4], being recovered nearly quantitatively.

1-Aminodi-isophor-2(7)-en-3-one (**8**)

The foregoing 1-phthalimido-compound (**4**) (8.1 g, 0.02 mol) was dissolved in ethanol (50 ml) with warming, treated with hydrazine hydrate (1.25 g, 0.025 mol), and kept at ca. 60° for 15 min. The clear straw-coloured liquid was acidified with 3*N*-hydrochloric acid, heated to boiling, the separated phthaloylhydrazide (m.p. 330°, ca. 2.6 g, 80%) filtered off at the pump and rinsed with water. The filtrate was distilled to smaller bulk (atmospheric pressure, ca. 30 min, to remove most of the ethanol, final b.p. of liquid, 100-101°), set aside at 0°, the remainder of the phthaloylhydrazide (ca. 10%) filtered off at 0°, and washed with a little water. The combined filtrate and washing liquid was basified with 3*N*-sodium hydroxide, and the turbid liquid exhaustively extracted with ether. The dried (Na_2SO_4) extracts were treated with freshly prepared 3*N*-ethanolic hydrogen chloride (15 ml, 0.045 mol) and the turbid liquid immediately evaporated in a rotatory evaporator in a vacuum, affording **8** · HCl as a very hygroscopic pale ivory crystalline mass (5.0-5.6 g, 80-90%). ν_{max} 3450 s, 3150 ms (NH), 2960-2860 vs br, 1490 vs br, 1395-1385 vs, 1370 s (CH_3, CH_2), 1650 vs br (CO), 1630 s sh (C=C, conjug.), 1575 ms, 1280 s, 1195 m, 1040 m, 965 m cm^{-1}. The salt is freely soluble in water; the base **8** appears as a white cloudiness on addition of 3*N*-sodium hydroxide.

The *picrate* was obtained nearly quantitatively from equimolar quantities of **8** · HCl (aqueous solution) and 0.05 *M*-picric acid, as small prisms, m.p. 196-199° (decomp.) (from ethanol). (Found: C 57.2; H 6.3; N 10.65. $C_{18}H_{29}NO \cdot C_6H_3N_3O_7$ requires C 57.1; H 6.35; N 11.1%).

Action of Nitrous Acid. — To a stirred solution of **8** · HCl (0.93 g, 0.003 mol) in 1.5 *N*-acetic acid (25 ml) at 0°, sodium nitrite (4.15 g, 0.06 mol) in water (20 ml) was added dropwise. The resulting turbid yellow liquid slowly deposited an oil which solidified after being kept at 100° for 10 min and cooled, and gave di-isophor-2(7)-en-1-ol-3-one (**13**) (0.62 g, 75%) (from light petroleum b.p. 40-60°), identified by mixed m.p. and i.r. spectrum[4].

1-Benzamidodi-isophor-2(7)-en-3-one (**9**)

A solution of **8** · HCl (0.62 g, 0.002 mol) in anhydrous pyridine (10 ml) was treated with benzoyl chloride (0.70 g, 0.005 mol), kept at 100° for 15 min, then stirred into ice—concentrated hydrochloric acid (10 ml). The solidified yellow oil gave opaque lustrous neeles (0.5 g, 65%) of **9**, m.p. 137-139° (from ethanol).

(Found: C 79.25; H 8.3; N 3.8. $C_{25}H_{33}NO_2$ requires C 79.15; H 8.7; N 3.7%) ν_{max} 3325 s, 1555 s (NH), 3080 m, 715 vs, 690 vs (*Ar*), 2960-2860 vs, 1455 ms, 1360 s (CH_3, CH_2), 1665 vs (CO, ketone), 1635 vs (CO, *sec.* amide), 1605 ms, 1580 ms, 1495 ms (C=C, arom.), 1390 vs sh, 1375 vs (CMe_2) cm^{-1}. Nmr: δ[$CDCl_3$] 7.85-7.25 (5H, *Ph*), 2.4-0.8 (27H, mult, CH aliph.) including four intense signals at 1.08, 1.02 (9H, $3CH_3$), 0.94 (3H, CH_3) and 0.80 (3H, CH_3).

1-Toluene-p-sulphonamidodi-isophor-2(7)-en-3-one (**10**)

A solution of **8**·HCl (0.62 g, 0.002 mol) in pyridine (10 ml) was treated with toluene-*p*-sulphonyl chloride (0.48 g, 0.0025 mol), kept at 100° for 2 h, then stirred into ice—concentrated hydrochloric acid. The precipitate gave minute prisms (0.6 g, 70%) of **10**, m.p. 135-138° (from ethanol). (Found: C 70.1; H 7.5; N 3.4; S 7.4. $C_{25}H_{35}NO_3S$ requires C 69.9; H 8.2; N 3.3; S 7.5%). ν_{max} 3350 m (NH), 2970-2880 s, 1440 s (CH_3, CH_2), 1645 vs (CO), 1625 s sh (C=C, conjug.), 1390 s, 1375 vs (CMe_2), 1160 vs (SO_2), 820 m (4-sub. *Ar*) cm^{-1}.

No crystallisable acetyl-derivative was obtainable after keeping a solution of **8**·HCl in pyridine treated with acetyl chloride (1 mol) at room temperature for 4 h, or after refluxing one in acetic anhydride for 3 h.

1-(ω-Phenylthioureido)di-isophor-2(7)-en-3-one (**11**)

A solution of **8**·HCl (3.12 g, 0.01 mol) in pyridine (30 ml) was treated with phenyl isothiocyanate (1.48 g, 0.011 mol) and kept at 100° for 1 h. Addition to concentrated hydrochloric acid (30 ml)—ice gave a precipitate forming prismatic needles (2.3 g, 56%) of **11**, m.p. 232-234° (from ethanol). (Found: C 73.5; H 8.4; N 6.55; S 7.45. $C_{25}H_{34}N_2OS$ requires C 73.2; H 8.3; N 6.8; S 7.8%). ν_{max} 3200-3170 vs br (NH), 2950-2900 vs br, 1460 s, 1360 vs (CH_3, CH_2), 1390 s (CMe_2), 1660 vs (CO), 1615 w (C=C, conjug.), 1600 ms, 1500 s (C=C, arom.), 700 s (*Ar*) cm^{-1}. It did not undergo benzoylation under the usual conditions. It was recovered (80-85%) after being boiled in trifluoroacetic acid (b.p. 72°, 0.001 mol in 8 ml) for 12 h, or in dimethylformamide (0.001 mol in 12 ml) for 6 h, showing that cyclodehydration did not occur under these conditions.

700 s (*Ar*) cm^{-1}. It did not undergo benzoylation under the usual conditions. It

1-(ω-Ethoxycarbonylthioureido)di-isophor-2(7)-en-3-one (**12**)

A solution of **8**·HCl (1.56 g, 0.005 mol) in dimethylformamide (15 ml)—pyridine (12 ml)—triethylamine (3 ml) was treated at room temperature with ethoxycarbonyl isothiocyanate[15] (0.59 g, 0.0045 mol), set aside for 2 h, then stirred into concentrated hydrochloric acid (15 ml)—ice. The precipitate (1.15-1.32 g, 64-72%) gave massive lustrous prisms of **12**, m.p. 137-140° (from ethanol) (Found: C 64.4; H 8.3; N 6.9; S 8.0. $C_{22}H_{34}N_2O_3S$ requires C 65.0; H 8.4; N 6.9; S 7.9%). ν_{max} 3450 s, 3340 s, 3300 s (NH), 2965-2875 vs, 1480, 1470 s d, 1390-1350 vs mult (CH_3, CH_2), 1725 vs, 1710 vs (CO, ester), 1660 vs (CO, ketone), 1635 vs (C=C, conjug.) cm^{-1}. When pyridine (10 ml) alone was used as solvent, only small quantities of a brown resin were obtained.

1-Phthalimido-5,11-bisnordi-isophor-2(7)-en-3-one (**3**)

This was obtained from **1** (2.65 g, 0.01 mol) and potassium phthalimide (2.03 g, 0.011 mol) by boiling under reflux for 3 h in dimethylformamide (30 ml), followed by addition to water and crystallisation from ethanol (15 ml) as lustrous prisms (2.45 g, 64%), m.p. 164-166°. (Found: C 76.5; H 7.2; N 3.7. $C_{24}H_{27}NO_3$ requires C 76.4; H 7.2; N 3.7%). ν_{max} 3050 w, 1615 s sh, 730 vs (*Ar*),

2980-2870 vs, 1465, 1460 s d, 1385-1360 vs br (CH_3, CH_2), 1765 s, 1710, 1695 vs d (CO, imide), 1650 vs (CO, ketone), 1630 vs (C=C, conjug.) cm^{-1}. The lower homologue **1** required a longer time to react than **2** (see above).

1-Amino-5,11-bisnordi-isophor-2(7)-en-3-one (**7**)

This was produced from **3** (0.01 mol) by the procedure detailed for **8** (see above). It was isolated as **7** · HCl forming a crystalline powder (56%) and was characterised as the *picrate*, forming minute prisms, m.p. 228-231° (decomp.) (from ethanol). (Found: C 56.1; H 5.5; N 11.4. $C_{16}H_{25}NO \cdot C_6H_3N_3O_7$ requires C 55.5; H 5.9; N 11.8%).

The *1-benzamido-compound* (of **7**), obtained (35%) in the usual manner, formed prismatic needles, m.p. 134-137° (three times from ethanol) (Found: C 77.8; H 7.75; N 3.9. $C_{23}H_{29}NO_2$ requires C 78.6; H 8.3; N 4.0%). ν_{max} 3300 vs, 1555 s (NH), 3070 m, 1605 s, 1500 m, 720 vs br, 695 vs (*Ar*), 2960-2875 vs, 1465 m, 1460 ms, 1380 m br, 1360 m (CH_3, CH_2), 1665 vs br (CO, ketone), 1638 vs (CO, sec. amide), 1335 s, 1315, 1300 vs d (? C—N) cm^{-1}.

Ritter Reaction

1-Acylamidodi-isophor-2(7)-enes (**15**-**17**)

A stirred solution of di-isophor-2(7)-en-1-ol[10,17] (**14**) (1.31 g, 0.005 mol) in glacial acetic acid (25 ml) was slowly treated with concentrated sulphuric acid (4 ml). To the resulting warm pink solution, acetonitrile (4.1 g, 5 ml, 0.1 mol) was added dropwise, the liquid set aside for 20-30 min, then stirred into water. The resulting white precipitate gave, on crystallisation from ethanol, massive cubes (0.91 g, 60%) of the *1-acetamido-compound* (**15**), m.p. 169-171° (Found: C 79.6; H 10.5; N 4.2. *M*, mass-spectrometrically, 303. $C_{20}H_{33}NO$ requires C 79.2; H 10.9; N 4.6%. *M*, 303). ν_{max} 3300 s, 3070 w, 1555 vs (NH); 2950-2870 vs, 1460 ms, 1350 m (CH_3, CH_2), 1390 m, 1375 ms (CMe_2), 1655 vs br (CO) cm^{-1}. The compound (**15**) was substantially recovered after its solution in 60% ethanolic 2*N*-sodium hydroxide had been boiled under reflux for 4 h.

The use of benzonitrile (1.05 g, 0.01 mol) in the foregoing procedure gave the *1-benzamido-compound* (**17**) as felted needles (52%), m.p. 154-156° (from ethanol) (Found: C 82.4; H 10.0; N 3.6. $C_{25}H_{35}NO$ requires C 82.2; H 9.6; N 3.8%). ν_{max} 3300 ms, 1540 vs (NH), 3060 w, 1580 ms, 1500 ms, 720 ms, 695 s (*Ar*), 2950-2860 s, 1460 ms (CH_3, CH_2), 1640 vs (CO), 1395 w, 1360 ms (CMe_2) cm^{-1}.

The use of acrylonitrile (0.015 mol) similarly gave the *1-acryloylamido-compound* (**16**), forming lustrous needles (75%), m.p. 194-197° (from ethanol) (Found: C 80.2; H 10.2; N 3.95. $C_{21}H_{33}NO$ requires C 80.0; H 10.5; N 4.4%). ν_{max} 3355 s, 1560 vs br (NH), 2960-2870 vs, 1470, 1460 ms d (CH_3, CH_2), 1660 vs (CO), 1625 s (C=C, conjug.), 1420 ms, 895 w (:CH_2, terminal), 1390 mw, 1370 m (CMe_2) cm^{-1}.

Since the highly soluble low-melting starting material[10,17] (**14**) is difficult to isolate in the solid state, **13** (1.38 g, 0.005 mol) may be hydrogenated over *Adams'* catalyst[24] in glacial acetic acid (30 ml) and the resulting (filtered) solution used directly in the foregoing procedure. The yields of products so obtained are lower (43, 27 and 36%, respectively, for **15**, **17** and **16**).

Applied to **13** (using acetonitrile or benzonitrile) the general procedure gave only uncrystallisable oils. (But see below.)

1-Acetamido-2,7-epoxydi-isophorane (**18**)

Solutions of **15** (0.61 g, 0.002 mol) and 3-chloroperoxybenzoic acid (0.43 g, 0.0025 mol) in dichloromethane (each in 10 ml) were mixed and set aside at room temperature for 18–24 h. The liquid was successively washed with 10% sodium bisulphite, 5% sodium carbonate and saturated sodium chloride solutions and evaporated in a vacuum. The residual solid gave minute prisms (0.46 g, 72%) of **18**, m.p. 146–148° (from light petroleum) (Found: C 75.3; H 10.1; N 4.4. $C_{20}H_{33}NO_2$ requires C 75.2; H 10.3; N 4.4%). ν_{max} 3410 ms, 1540–1520 vs br (NH), 2960–2870 vs, 1460 s br, 1440 m (CH_3, CH_2), 1660 vs (CO), 1390 m, 1370 s (CMe_2), 1280 s, 875 m, 855 m (? C—O—C epoxide) cm^{-1}.—The compound was not obtainable directly by the action of acetonitrile in glacial acetic—concentrated sulphuric acid on 2,7-epoxydi-isophoran-1-ol[20]; this produced an intractable oil.

1-Benzamidodi-isophor-2(7)-en-3-one (**9**)

Finely powdered **13** (1.39 g, 0.005 mol) was dissolved in concentrated sulphuric acid (10 ml) with slight warming, the golden-yellow liquid cooled to 0° and treated with benzonitrile (0.62 g, 0.006 mol). The liquid was kept at room temperature for 1 h, then stirred into water: the resinous precipitate solidified on storage and more material separated. Crystallisation from ethanol gave lustrous microprisms (1.22 g, 64%) of **9**, identical with the benzoylation product of **8** (see above), by mixed m.p. 138–140° and i.r. spectrum.

The reactant **13** was recovered after being subjected to this reaction under the conditions applicable to **14** (use of glacial acetic acid as solvent).

1-Acryloylamidodi-isophor-2(7)-en-3-one

The use of acrylonitrile (0.4 g, 0.0075 mol) in the foregoing procedure gave, as crude product, a pale yellow finely divided solid. This produced faintly yellow microprisms (0.92 g, 56%) of the *1-acryloylamido-compound*, m.p. 128–130° (from light petroleum) (Found: C 76.1; H 9.6; N 4.25. $C_{21}H_{31}NO_2$ requires C 76.6; H 9.4; N 4.25%). ν_{max} 3300 s, 1550 vs d (NH), 3070 m (CH_2 of CH_2=CH.), 2960–2880 vs, 1470 ms, 1445 ms (CH_3, CH_2), 1390 m, 1375 vs (CMe_2), 1680 vs (CO), 1670 vs (CO, amide), 1650 s (C=C, conjug.), 1615 ms (exocyclic C=C), 1000 m (CH of CH_2=CH.) cm^{-1}.

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