THE DEAMINATION OF ALICYCLIC α-AMINOKETONES[1,2]

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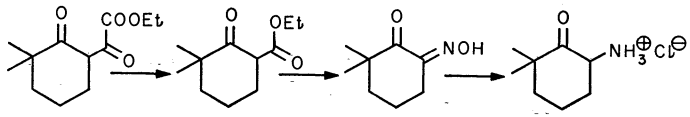
ABSTRACT

The deamination of α-aminocyclohexanones has been shown to give cyclopentane carboxylic acids, bicyclo[3,1,0]hexane-2-ones, and 2-methyl-2-cyclopentene-1-ones. Deamination of 3-*endo*-aminocamphor gave cyclocamphanone, 6-isopropenyl-6-methyl-2-cyclohexen-1-one, and 6-(1′-hydroxy-1′-methylethyl)-6-methyl-2-cyclohexen-1-one.

The formation of bicyclo[3,1,0]hexane by deamination of cyclohexylamine is reported for the first time. The difference between the products from it and bornylamine and those from the corresponding α-aminoketones are rationalized on the basis of the amount of C—C participation in the corresponding carbonium ions.

The nature and fate of carbonium-ion-like intermediates in reactions are very much dependent on the way in which they are formed, on the solvent, and on the steric and electronic environment in which they are developed. The purpose of this study (1) was to examine the fate of carbonium ions located α to a ketone carbonyl. In order to ensure as pure carbonium ion states as possible we generated them by deamination of α-aminoketones.

Preparation of 2-aminocyclohexanone by stannous chloride reduction of 2-oximinocyclohexanone gave a 35% yield of 2-aminocyclohexanone hydrochloride (2). The 2-amino-6,6-dimethylcyclohexanone was prepared as its hydrochloride (I) by the illustrated sequence. The β-keto ester was obtained by the method of Linstead (3). In order to avoid complicating the products unduly, the deaminations were carried out in water using acids whose anions had low nucleophilicity, i.e. sulphuric and perchloric acids, but without any attempt to remove the chloride ions from the original salt in the aminoketone cases.



I

The products from 2-aminocyclohexanone were separated into readily extractable neutral and acid fractions, and very water soluble material. The latter proved to be mainly adipic acid and 3-hydroxy-2-methylcyclopentanone.

The easily extracted acid (ca. 57%) yield had a strong unpleasant odor. It proved to be a mixture of a readily distillable acid (max. yield ca. 50%) and a non-volatile residue, which was not further studied. The volatile acid proved to be the expected cyclopentanecarboxylic acid, identified by comparison of its physical properties and those of its anilide and amide with authentic samples. This product had been observed earlier by Granger and Técher (4).[3] More recently Baumgarten and Anderson have reported the formation of this acid, and what are probably ϵ-hydroxycaproic and 5-hexenoic acids from 2-aminocyclohexanone (5). The readily extractable neutral products from the deamination of

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[1] *Issued as N.R.C. No. 7346.*

[2] *Presented in part in the Merck lecture of the Chemical Institute of Canada, June 14, 1960. See Chem. Can.* **13**, *40 (1961).*

[3] *We regret that we were unaware of their publication when our communications were submitted.*

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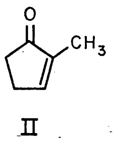
2-aminocyclohexanone contained diazoketone as one component, as shown by the characteristic band at 2100 cm^{-1} in its infrared spectrum. The mixture was separated by vapor phase chromatography, which showed that at least eight components were present.[4] The two major components were isolated on a preparative scale, then used to make reference solutions. These were used to estimate absolute yields by comparison of areas under the v.p.c. curves.

The main component was formed in an average yield of 16%. It analyzed correctly for C_6H_8O, had λ_{max} 227 mμ (ϵ 11,200) and 305 mμ (ϵ 51), and ν_{max} 1705 and 1665 cm^{-1}. Its n.m.r. spectrum had peaks corresponding to an allylic methyl group (τ 8.3) and one vinyl hydrogen (τ 2.7). These correspond to a methylcyclopentenone, with 2-methyl- and 3-methyl-2-cyclopenten-1-ones being the most probable structures. Both were synthesized by known procedures, the 2-methyl isomer following Godchot (6) and the 3-methyl isomer following Robinson (7). The deamination product was identical in all respects with 2-methyl-2-cyclopenten-1-one (II).[5]

The second most abundant component (6.5–9% yield) again analyzed for C_6H_8O. It had strong end absorption in the ultraviolet and ν_{max} 1727 cm^{-1}. This, and the n.m.r. spectrum, which contained no vinyl hydrogen signal, seemed only consistent with the compound being bicyclo[3,1,0]hexan-2-one (III).[6] Comparison of the dinitrophenylhydrazone of the compound with a sample of the derivative of bicyclo[3,1,0] hexan-2-one kindly provided by Dr. N. A. Nelson (8) proved this to be correct.

The other components could not readily be obtained pure with the preparative columns at our disposal. However, the absence of absorption near 1675 cm^{-1} in the infrared spectrum of the neutral product indicated that not more than a trace of conjugated cyclohexenone was present.



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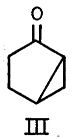
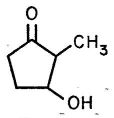
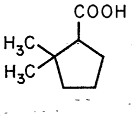


III



IV



V

A product that we infer to be 3-hydroxy-2-methylcyclopentanone (IV) remained in the aqueous phase after the deamination and separation of the ether layer. When this aqueous solution was made weakly alkaline (pH 8–10) and stirred with ether, 2-methyl-2-cyclopenten-1-one was formed and accumulated in the ether layer. The yield of the hydroxyketone was 7–10%.

The deamination of 6,6-dimethyl-2-aminocyclohexanone (I) gave up to 35% weight yield of methylene-chloride-extractable acid, of which over half was readily distilled under 15 mm pressure. The distillate, which was mainly one component, was purified by further

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[4] *In experiments with vapor phase chromatography of diazocamphor no peak was observed corresponding to the diazoketone or its thermal decomposition products. This behavior seems to be characteristic of compounds decomposing during passage through the column. Since no diazocyclohexanone passed unchanged through the v.p.c. columns, we conclude by analogy that none of the observed peaks were due to it or its thermal decomposition products. This conclusion was confirmed when the diazoketone in the total neutral products was destroyed by reaction with aqueous p-toluenesulphonic acid. Only minor changes in the quantity of the other products were observed, with no new product produced.*

[5] *The intensity of the ultraviolet maximum for 3-methyl-2-cyclopentenone cited by Robinson and co-workers is in error.*

[6] *With older instruments with more stray light, maxima in the vicinity of 210 mμ were observed with the bicyclic ketones obtained in this work. However, with a new Carey model 11 spectrophotometer these were absent. We hence consider it likely that all the maxima reported near 210 mμ for simple cyclopropyl ketones are spurious (see also ref. 9).*

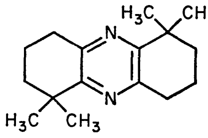
distillation. The acid analyzed for $C_8H_{14}O_2$. The n.m.r. spectrum of its methyl ester had peaks corresponding to two C-methyl groups (τ 8.8 to 9.1), the O-methyl group (τ 6.4), six methylene hydrogens (τ 7.8 to 8.7), and a single deshielded hydrogen as an apparent doublet with a spacing of 8 c.p.s. centered at τ 7.6. These facts and the origin of the acid suffice to prove it to be 2,2-dimethylcyclopentanecarboxylic acid (V). Attempts to convert it to the known 2,2-dimethylcyclopentanone were abortive.

Attempts to prepare V from 2-chloro-6,6-dimethylcyclohexanone under the conditions of the Favorskii reaction[7] failed to give appreciable amounts of the acid. Similarly the action of silver nitrate in aqueous alcohol (11) on 2-bromo-6,6-dimethylcyclohexanone gave no detectable amount of V, although much water-soluble material was produced. It thus appears that the deamination may provide a useful alternative to the Favorskii reaction when one carbon α to the ketone carbonyl is quaternary.

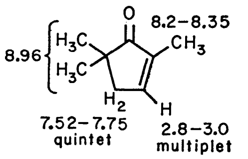
The aqueous solution from the deamination after removal of the readily extractable neutral and acidic products was concentrated to small volume, made strongly acid, and continuously extracted with chloroform. The crystalline acid obtained was identified by analysis and melting point as 2,2-dimethyladipic acid. A sample of the aqueous solution immediately after the deamination failed to give any bisdinitrophenylhydrazone of 6,6-dimethyl-1,2-cyclohexanedione, hence any of the corresponding α-ketol which had been formed must have been completely oxidized to the adipic acid by nitrous acid.

The maximum weight yield of readily extractable neutral products obtained from 6,6-dimethyl-2-aminocyclohexanone was 78%. This was distilled under 15 mm pressure. A relatively non-volatile crystalline residue was obtained with empirical formula $C_{16}H_{24}N_2$. Its infrared spectrum had no carbonyl or isolated azomethine absorption, and its ultraviolet absorption (λ_{max} 289 mμ, ϵ 12,340) was consistent with it being the octahydrophenazine VI. Its n.m.r. spectrum indicated the absence of aromatic hydrogens, the presence of four identical methyl groups (τ 8.75), and two groups of methylene hydrogens centered around τ 7.17 (4 H) and τ 8.17 (8 H) in agreement with this assignment.[8] The volatile neutral products contained diazoketone (ν_{max} 2100 cm^{-1}) and at least nine other components as shown by gas chromatography. The two major ones were shown to be analogous to those from aminocyclohexanone, but in a reversed yield ratio.

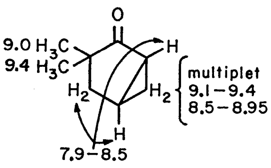
The substance corresponding to the first major peak from the gas chromatogram analyzed for $C_8H_{12}O$ and had λ_{max} 228 mμ (ϵ 10,800) and 317 mμ (ϵ 60) and had ν_{max} 1710 cm^{-1}. Its n.m.r. spectrum was consistent with it being 2,5,5-trimethyl-2-cyclopenten-1-one (VII) (see the chemical shift assignments on the figure, given as τ value for deuterochloroform solutions). The other major component also gave correct analyses for $C_8H_{12}O$.



VI



VII



VIII

Its ultraviolet spectrum (intense end absorption, λ_{max} 284 mμ, ϵ 46) and its infrared spectrum (ν_{max} 1725 cm^{-1}) resembled those of bicyclo[3,1,0]hexanone. Its n.m.r. spectrum confirmed its identity as 3,3-dimethylbicyclo[3,1,0]hexan-2-one VIII (see assignments on

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[7] *See reference 10 for leading references.*

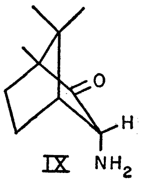
[8] *Baumgarten and Bower (2) observed the formation of decahydrophenazine from 2-aminocyclohexanone. Presumably the nitrous acid dehydrogenated the decahydro derivative in our case.*

the figure). The ratio of the areas under the peaks from the gas chromatogram corresponding to the cyclopentenone and the bicyclic ketone were approximately 1:2. The minor components were not identified.

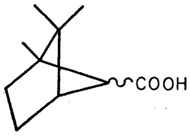
The bicyclic ketone gave no methylcyclopentanone when treated with dilute solutions of sodium hydroxide or perchloric acid in ethanol, hence it is very unlikely that VII was produced from VIII under the mild reaction conditions.

In order to provide the closest possible comparison of the above deaminations with that of a simple amine, we re-examined the deamination of cyclohexylamine. Under the same conditions as used for the aminocyclohexanone studies, the main product (ca. 80%) was cyclohexanol, as found by Hückel (12). Careful v.p.c. examination of the alcohol component failed to reveal the presence of any methylcyclopentanols or hydroxymethylcyclopentane. No cyclohexanone was present but a compound identified by its retention time on a v.p.c. column as cyclohexyl nitrite was formed in up to 14% yield. The hydrocarbon components gave a single peak using a polypropylene glycol column, but were resolved on a silver nitrate – glycol column into cyclohexene and bicyclo[3,1,0]hexane.[9] The yields of these averaged 4% and 2% respectively. No 1-methylcyclopentene was formed.

Finally, to extend our observations on the deamination of α-aminoketones we studied α-aminocamphor. Since the coupling of the 3-hydrogen (τ 5.5) with the bridgehead 4-hydrogen is 5 c.p.s. it appears that the amino group has the endo configuration[10] (13) shown in IX. Deamination of the aminoketone produced a small yield of crystalline acid. This appeared to be a mixture of isomers and was hence not further characterized. By analogy with the aminocyclohexanones this should have structure X.



IX



X

The neutral products contained around 18% of cyclocamphanone XI, identified by comparison with authentic material. Like the bicyclic ketones examined (III and VIII) this had no maximum near 210 mμ in its ultraviolet absorption spectrum.[6]

The major neutral product (62%) analyzed for $C_{10}H_{14}O$ and appeared to be a lightly substituted α,β-unsaturated ketone (λ_{max} 225 mμ (ε 13,940); ν_{max} 1680 cm^{-1}) containing a terminal methylene group (ν_{max} 898 cm^{-1}). Its n.m.r. spectrum showed the presence of one somewhat deshielded methyl group (singlet, τ 8.8), an allylic methyl group (singlet, τ 8.3), and the terminal methylene (τ 5.1 and 5.3, two hydrogens). The two vinyl hydrogens on the conjugated double bond appeared as a doublet centered at τ 4.1 (J = 10 c.p.s.) and a multiplet centered at τ 3.2. Reduction of the conjugated double bond with zinc and acetic acid gave a compound with ν_{max} 1710 and 898 cm^{-1}. Its n.m.r. spectrum showed little change except the loss of the signals at τ 4.1 and 3.2. Catalytic reduction of this product using palladium converted it to a dihydro compound, in whose infrared spectrum the 898 cm^{-1} band had disappeared. The signals at τ 5.1 and τ 5.3 were no longer present in its n.m.r. spectrum, and the low-field methyl of the parent compound now resonated at τ 9.1. Taking into account its origin, this evidence was only consistent with the deamination product being 6-isopropenyl-6-methyl-2-cyclohexene-1-one (XII). This

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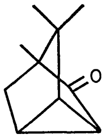
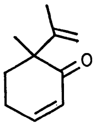
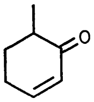
[9] *We are grateful to Dr. H. E. Simmons for a sample of pure bicyclo[3,1,0]hexane.*

[10] *We are grateful to Dr. F. A. L. Anet for suggesting this method of determining the configuration.*

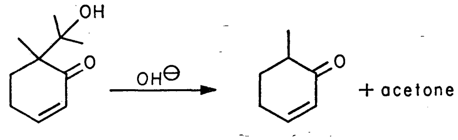

XI


XII


XIII

was proved correct by heating the compound in a 2:1 (v/v) mixture of 12 *N* sulphuric acid in methanol. A new α,β-unsaturated ketone was produced in good yield which analyzed for $C_7H_{10}O$. Its n.m.r. spectrum was in agreement with structure XIII and its 2,4-dinitrophenylhydrazone had the same melting point as that of 6-methyl-2-cyclohexen-1-one (14).

A third product of the deamination was at first missed because of its long retention time. It was observed, however, that if an ether solution of the neutral product was shaken with sodium carbonate solution, or if the mixture was chromatographed on neutral alumina, a new component appeared which was rapidly eluted from the v.p.c. column. This proved identical with XIII. Since XII is inert under these conditions, we conclude that the alkali or alumina was cleaving the alcohol XIV present in the products as shown:



XIV

The yield of XIV was estimated to be around 4%. As far as we are aware XII and XIV represent a new type of fission product of the camphor skeleton.

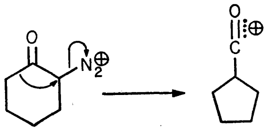
When diazocamphor was treated with acid, the three products XI, XII, and XIII were produced. This confirms the conclusion of Applequist that protonation of diazoalkanes gives the corresponding alkyldiazonium ions (15).

DISCUSSION

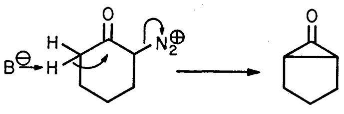
The generation of a carbonium ion adjacent to a carbonyl is an energetically unfavorable process due to proximity of the positive charge to the positive end of the carbonyl dipole. This is well illustrated by the inertness of α-haloketones to S_N1 solvolysis (16). It is to be expected then that the developing positive charge in processes which would lead to such a carbonium ion would be delocalized if possible by participation of nearby carbon–carbon and carbon–hydrogen bonds. This expectation is borne out by the high yields of unusual products in the α-aminoketone deaminations.

That some α-ketol is produced in the aminocyclohexanone deaminations seems certain since the adipic acids must arise by oxidation of these by nitrous acid. The cyclopentanecarboxylic acids most likely arise by one of three mechanisms:

(*a*) Rearrangement synchronous with C—N bond rupture, giving the acylium ion:

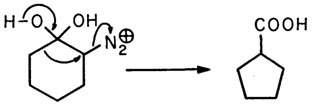


(*b*) Initial formation of a cyclopropanone as in the Favorskii reaction (8) followed by hydrolytic ring opening:



Since only very weak bases are present to accept the proton in the first stage, this would have the character of C—H bond participation in the dissociation.

(*c*) Hydration of the carbonyl followed by the concerted process shown:

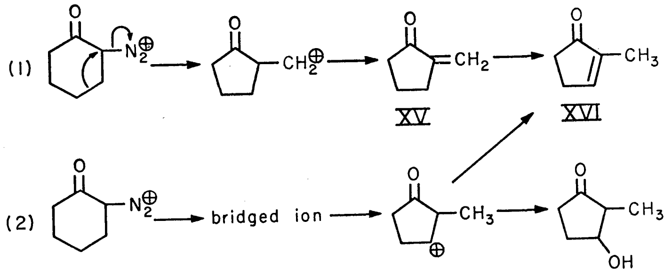


Since the dimethylcyclopentanecarboxylic acid was formed from 2-amino-6,6-dimethylcyclohexanone, for which mechanism (*b*) cannot operate, either (*a*) or (*c*) or both are valid mechanisms in this case.

Of the three mechanisms (*c*) seems to offer the path of least energy to the cyclopentanecarboxylic acids. The opposed dipoles in the amine salt and diazonium ion should favor hydration of the carbonyl (see for example chloral and mesoxalic acid). The diazonium ion could then dissociate, with participation of the 5,6 C—C bond aiding the electron release to the nitrogen. Since the *gem*-dimethyl group adjacent to the carbonyl would make the hydration less favorable on steric grounds, the lower yield of acid obtained in this case relative to aminocyclohexanone deamination can be accounted for.

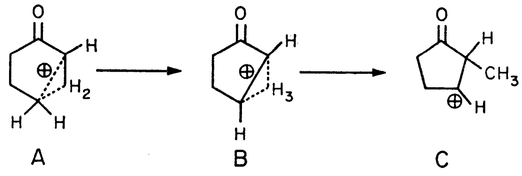
The major neutral products from the aminocyclohexanones, the bicyclo[3,1,0]hexanones, methylcyclopentenones, and 3-hydroxy-2-methylcyclopentanones, are unusual, although other cases of cyclopropane ring formation in deaminations and deoxygenations in aliphatic compounds have recently been reported (17, 18, 19). The fact that cyclohexenones are absent, or are formed in very low yield, is striking. In addition the relatively low yield of products derived from the α-ketols is in marked contrast to the 94% yield of cyclohexanol and cyclohexyl nitrite from cyclohexylamine.

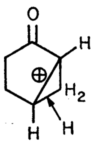
There appear to be only two simple routes, 1 or 2, to the methylcyclopentenones and 3-hydroxy-2-methylcyclopentanones:



Route 1 is indirect and involves the high energy primary carbonium ion. In addition the rearrangement of XV go XVI would not be expected to take place under the reaction condition (short exposure to a weakly acid medium). We hence consider route 2 to be the most probable one. It has the added attraction of providing a direct path to the three major neutral products.

We suggest that the first ion produced is A, in which the positive charge is delocalized by participation of the 3,4 carbon–carbon bond. This is then converted by hydride migration to B, which collapses to the classical ion C, the immediate precursor of the methylcyclopentenone and 3-hydroxy-2-methylcyclopentanone. The hydride transfer in the transition of A to B could involve the protonated cyclopropane D or the hydrogen-bridged non-classical ion E. It seems likely that E is the intermediate ion since in dilute acid D would rapidly lose a proton to give the bicyclic ketone III.[11]

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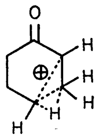
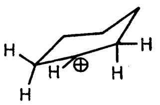

E


F

The bicyclohexanones could arise by proton expulsion from A, B, D, or E. An attractive possibility is that E can rearrange to D as well as to B, and that D in turn loses a proton to give the bicyclic ketones.

It now remains to reconcile the differences in product composition between the cyclohexylamine and aminocyclohexanone, and between the bornylamine and aminocamphor deaminations. We consider that these can be accounted for as follows:

The activation energy for the deamination of cyclohexylamine is so low that no assistance from external nucleophiles or neighboring C—C and C—H bonds is needed to aid the approach to the transition state.[12] The 'bare' carbonium ions that result react rapidly with nearby water molecules or nitrite ions.[13] The axial hydrogen on the α-carbon in the ideal planar state of the ion (F) is in a favorable stereo-electronic situation for elimination, and hence the few percent of cyclohexene formed probably arises from this state. The even smaller amount of bicyclo[3,1,0]hexane is presumably formed via a bridged-ion intermediate. No methylcyclopentene or 2-methylcyclopentanol could be detected among the products, which is consistent with the absence of well-developed C—C participation in the carbonium ion.

In contrast, the deamination of the α-aminocyclohexanones, for which we postulate a large amount of C—C participation, gave less than 25% of products derived from the simple carbonium ion. The major products, the bicyclic ketones and methylcyclopentenones, apparently arise from bridged ions as described above. No cyclohexenones could be detected, as expected if very little 'bare' carbonium ion was present in these cases.

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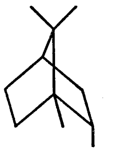
[11] *There is good evidence (20, 21) that symmetrically protonated cyclopropanes (22) are not intermediates in methyl migration in carbonium ion rearrangements, but in our opinion unsymmetrical 'edge-protonated' cyclopropanes are not excluded from consideration by their work. However, we believe such intermediates would give rise in high yield to cyclopropane.*

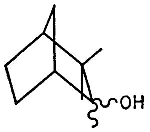
[12] *This is in agreement with the views of Cram and McCarty (23) and Ridd (24).*

[13] *The retention of configuration in the cyclohexanol (25) could be the result of reaction with water before the ideal planar state of the ion is reached, or selective reaction with the water molecules which had solvated the diazonium ion, on the face of the carbon from which the nitrogen had departed.*

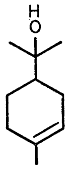
The deamination of 3-*endo*-aminocamphor gave as major products the monocyclic compounds XII and XIV (74%) and the tricyclic compound XI (18%). In contrast, the fairly comparable bornylamine (XVII) gave mainly camphene and camphene hydrate (XVIII) with 28% of α-terpeneol (XIX) (26). Isobornylamine (XX) gave over 90% camphene and camphene hydrate (27).



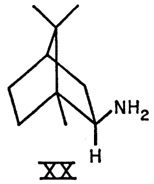
XVII



XVIII

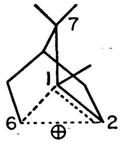


XIX

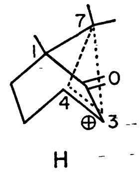


XX

As the positive charge develops on C-2 in the isobornylamine deamination it must be rapidly delocalized by formation of the bornonium ion G, which then gives nearly quantitatively camphene and camphene hydrate. Since in the deamination of bornylamine around 30% of the monocyclic α-terpineol was formed, we can thus conclude that at least this percentage of the molecules doesn't give rise to the ion G. The same conclusion follows from consideration of the fact that the participation of the 1,6 carbon–carbon bond would have to be subsequent to the departure of the nitrogen from the endo face of C-2. We hence suggest that in the bornylamine case an essentially bare carbonium ion is formed, which in part gives the bornonium ion and finally camphene and camphene hydrate, and in part captures the electron pair of the 1,7 carbon–carbon bond, giving the monocyclic terpineol.



G



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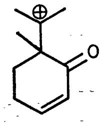
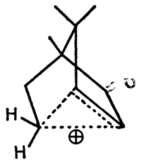


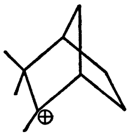
I

In the aminocamphor deamination no products with rearranged bicyclo[2,2,1]heptane skeleton were observed. We conclude that little bare carbonium ion was formed, consistent with the high activation energy which would be involved in juxtaposition of the two like charges. Instead the developing positive charge is delocalized by participation of the 4,7 carbon–carbon bond with formation of the rather high-energy bridged ion H. This collapses to the classical ion I in which good charge separation is achieved. I gives predominantly the diolefin XII but some of the tertiary alcohol is formed.

The cyclocamphanone formed from aminocamphor could arise from the bare carbonium ion or by conversion of H to the non-classical ion J followed by proton expulsion. The absence of tricyclic compound in the bornylamine case could be partly due to the lower



J



K

energy of the tertiary carbonium ion K compared to the corresponding secondary carbonium ion from the aminocamphor. This would favor formation of the rearranged skeleton in the former and the tricyclene in the latter case.

It seems desirable to study the deamination of the at-present unknown 3-bornanamines in order to have more perfect comparison with the behavior of aminocamphor.

EXPERIMENTAL

Infrared spectra were taken on a Perkin–Elmer Model 21 spectrophotometer and ultraviolet spectra determined in 95% ethanol on a Cary Model 11 spectrophotometer. Vapor phase chromatography (v.p.c.) was carried out using a Perkin–Elmer Model 154C instrument with thermistor detector. The analytic columns used were 1 m and 2 m × 0.25 in. stainless steel columns with polypropylene glycol on diatomaceous earth packing (column R) and a 2 m×0.25 in. silver nitrate in diethylene glycol on diatomaceous earth packing (column H). The preparative chromatography was done with a 3 m×1 in. column with type R packing. Yields were estimated in the cyclohexylamine and 2-aminocyclohexanone cases by diluting the total neutral extract in ether to a known volume and comparison of the peak areas in the v.p.c. of an aliquot of this with those from ether solutions containing known concentrations of the corresponding substances. In the 2-amino-6,6-dimethylcyclohexanone and aminocamphor cases the yields were estimated roughly by assuming equivalent peak areas per gram for all the volatile products. The n.m.r. spectra were determined in deuterochloroform with tetramethylsilane as internal standard using a Varian A-60 spectrometer.

Deamination of Cyclohexylamine

A solution of 5 g of cyclohexylamine perchlorate and 5 g of sodium nitrite in 20 ml of water was prepared. Five milliliters of ether was added, then the mixture was cooled in ice. To this was added dropwise with stirring 15 ml of 0.1 *N* perchloric acid during 15 minutes. The escaping gas was bubbled through a trap containing cold ether.[14] The reaction mixture was left 10 minutes in the cold bath, then 5 minutes at room temperature. It was neutralized using sodium bicarbonate, then extracted thoroughly with ether. The liquid remaining after careful distillation of the ether was analyzed using vapor phase chromatography on a polypropylene glycol column (Perkin–Elmer R). The main products were cyclohexanol (~80%) and cyclohexyl nitrite (12–14%) with a smaller fraction rich in cyclohexene. Rechromatography of the cyclohexene fraction on Column H showed it to be a mixture of cyclohexene (3–5% yield) and bicyclo[3,1,0]hexane (~2% yield). The latter had retention time identical with that of an authentic specimen.[9]

2-AMINOCYCLOHEXANONE

2-Aminocyclohexanone Hydrochloride[15]

The method of Jaeger and van Dijk (28) was used to prepare 2-isonitrosocyclohexanone.

The isonitrosoketone (9.5 g) was slowly added with shaking to a solution of 40 g of stannous chloride in 50 ml of concentrated hydrochloric acid. Then 24 g of mossy tin was added and the reaction mixture heated on a steam bath for 15 minutes. The resulting solution was diluted with 1 l. of water, and the tin precipitated using hydrogen sulphide. After filtration the clear solution was reduced to dryness *in vacuo* at 40° in a rotating evaporator.

The residue was recrystallized from absolute ethanol, giving 3.85 g (35%) of hydrochloride, m.p. 150–155°. A further recrystallization from ethanol – ethyl acetate gave colorless needles, m.p. 154–155°. Found: C, 47.87; H, 8.15; N, 9.28. Calc. for $C_6H_{12}ClNO$: C, 48.15; H, 8.08; N, 9.36.

Deamination of 2-Aminocyclohexanone Hydrochloride

(*a*) 2-Aminocyclohexanone hydrochloride (800 mg) was dissolved in 3 ml of 0.05 *N* H_2SO_4. To this solution 1.7 g of sodium nitrite, dissolved in 2 ml of water, was added slowly with shaking. The reaction mixture was left at room temperature for ½ hour. It was then basified with sodium bicarbonate and extracted with methylene chloride. The methylene chloride solution was dried and the solvent distilled, giving 400 mg of neutral residue.

The aqueous solution was acidified with 6 *N* H_2SO_4 and extracted with methylene chloride. Then methylene chloride solution was dried over anhydrous sodium sulphate and distilled, leaving 280 mg of acidic material.

(*b*) 2-Aminocyclohexanone hydrochloride (500 mg) was dissolved in 1 ml of water and to this solution 0.5 g of sodium nitrite in 1 ml of water was added. The reaction mixture was cooled in ice water for 10 minutes. Then, with stirring, 1.5 ml of 0.1 *N* perchloric acid was added dropwise to steadily liberate nitrous acid (time 20 minutes). The reaction was left for 10 minutes more in the cold bath and at room temperature for 5 minutes.

An acid-neutral separation as in (*a*) gave 219 mg of acidic material and 88 mg of neutral.

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[14] *The ether trap collected no significant amount of product.*

[15] *We thank Mr. Earl Brewer, who first prepared this compound.*

Many variations of these conditions were tried, including changing the nature of the acid and its concentration, and varying the temperature rate and order of addition. The conditions in (*b*) gave the highest yield of acid.

(*c*) 2-Aminocyclohexanone hydrochloride (200 mg) was dissolved in 2 ml of 0.2 *N* sulphuric acid and a solution of 0.5 g of sodium nitrite in 1 ml of water was added to it dropwise during 20 minutes. The reaction was then basified with sodium bicarbonate and a neutral acid separation was effected, giving 50 mg of neutral material and 48 mg of acid.

The Neutral Products

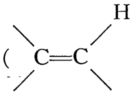
The bulk of the neutral product from deamination by method (*a*) was readily extractable into ether. An oil remained after careful distillation of the ether. This contained some 2-diazocyclohexanone, as indicated by the presence of a sharp band at 2100 cm^{-1} in the infrared spectrum of the residue. This absorption disappeared when the mixture was allowed to stand, or when an ether solution of the products was stirred in the presence of aqueous *p*-toluenesulphonic acid without significant change in the composition as indicated by v.p.c. The mixture was separated into two major and 5 minor components by a 2 m×1/4 in. column with R packing at 120° C and a flow rate of 120 cc/min. The minor components had retention times of 7, 13, 14, 15.5, and 22 minutes. The major components are described below.

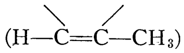
The presence of another neutral component which remained in the aqueous layers was proved by treatment of the latter with sodium carbonate in the presence of ether. Vapor phase chromatography of the ether solution after concentration showed that 2-methyl-2-cyclopentene-1-one had been produced in 7 to 10% yield.

Bicyclo[3,1,0]hexane-2-one

Retention time 26.5 minutes, yield 6.5–9.2%. It had ν_{max} 1727 cm^{-1}; its ultraviolet spectra showed strong end absorption (ϵ, 1625 at 210 mμ) and λ_{max} 277 mμ (ϵ 370). Found: C, 75.42; H, 8.28. Calc. for C_6H_8O: C, 74.97; H, 8.39. It gave a 2,4-dinitrophenylhydrazone, m.p. 182–185°. This showed no mixed m.p. depression with an authentic sample (m.p. 175–183°) of the dinitrophenylhydrazone of bicyclo[3,1,0]hexane-2-one kindly provided by Dr. N. A. Nelson, and the X-ray powder patterns of the two were identical. The n.m.r. spectrum of the ketone had a series of signals between τ 8.7 and τ 9.2 with intensity equivalent to two protons.

2-Methyl-2-cyclopentene-1-one

Retention time 19.0 minutes. Yield 12.5–19.5%. It had $\nu_{max}^{CS_2}$ 1705 cm^{-1} (C=O), 1640 cm^{-1}, and 785 cm^{-1} (); Its ultraviolet spectrum had λ_{max} 227 mμ (ϵ 11,220), 305 mμ (ϵ 51). Found: C, 74.80; H, 8.16. Calc. for C_6H_8O (96.12): C, 74.97; H, 8.39.

The n.m.r. spectrum of the ketone had a doublet (J = 1.5 c.p.s.) centered at τ 8.3 (), a series of signals from τ 7.8 to τ 7.3, and a multiplet centered at τ 2.7.

Cyclopentanecarboxylic Acid

The readily extractable acids from the deamination of 2-aminocyclohexanone were distilled over a short path at an air-bath temperature of 102° under 8 mm pressure. The clear colorless oil so obtained had a rancid odor. It had $n_D{}^{18}$ 1.4540 (reported 1.4534) (29). Found: C, 62.64; H, 8.60. Calc. for $C_6H_{10}O_2$: C, 63.13; H, 8.83. The maximum yield obtained using the conditions in (*b*) was 50%.

Its amide was prepared via the acid chloride ($SOCl_2$). After recrystallization from aqueous methanol and sublimation at 70°, 1×10^{-3} mm, it melted at 178–179°. Found: C, 63.38; H, 9.96. Calc. for $C_6H_{11}ON$: C, 63.68; H, 9.80.

The anilide of the acid was prepared from the acid chloride. After sublimation at 90°, 5×10^{-4} mm, it melted at 164–165°. Found: C, 76.03; H, 7.85; N, 7.49. Calc. for $C_{12}H_{15}ON$: C, 76.15; H, 7.99; N, 7.40.

The above derivatives had the same melting point as the amide and anilide of cyclopentanecarboxylic acid prepared by hydrolysis of cyclopentyl cyanide, and showed no mixed melting point depression with the corresponding authentic derivative.

Adipic Acid

Extraction of the acidic aqueous solution in a continuous liquid–liquid extractor using chloroform gave a small quantity of adipic acid characterized by melting point and mixed melting point.

2-AMINO-6,6-DIMETHYLCYCLOHEXANONE

2,2-Dimethyl-6-ethoxycarboxylcyclohexanone

A mixture of di- and tri-methylcyclohexanones from alkylation of 2-methylcyclohexanone (30) was treated with ethyl oxalate in the presence of sodium ethoxide. Only the 2,2-dimethylcyclohexanone formed an oxalyl derivative (3). This was decarboxylated in the presence of crushed soft glass, the optimum temperature being 170–180°. The resulting 2,2-dimethyl-6-ethoxycarbonylcyclohexanone was distilled: b.p. 125° C under 20 mm.

2,2-Dimethyl-6-isonitrosocyclohexanone

2,2-Dimethyl-6-ethoxycarbonylcyclohexanone (54 g) was stirred (vibro mixer) under nitrogen with a solution of 20 g of sodium hydroxide in 1 l. of H_2O until the solution clarified, i.e., the ester was completely in solution (3–5 hours).

The reaction mixture was cooled in ice and a solution of 17.5 g of sodium nitrite in 50 ml of water was added with stirring and sweeping with nitrogen. After 10 minutes, the solution was acidified with 3 *N* sulphuric acid and left for a further 15 minutes. The solution was then basified and extracted with ether to remove any unchanged ester. It was reacidified and extracted with ether. The ether extracts were dried over anhydrous sodium sulphate. On evaporation of the solvent, the isonitroso compound crystallized. Four crops of crystals totalling 26.7 g (63%) of the isonitroso compound were collected, melting from 110–114°. This was recrystallized from ether–pentane, giving 2,2-dimethyl-6-isonitrosocyclohexanone, m.p. 116–116.5°. Found: C, 62.10; H, 8.40; N, 9.21. Calc. for $C_8H_{13}O_2N$ (155.19): C, 61.91; H, 8.44; N, 9.03.

2-Amino-6,6-dimethylcyclohexanone Hydrochloride

2,2-Dimethyl-6-isonitrosocyclohexanone (3.24 g) was added slowly to a solution of 15 g of stannous chloride in 18 ml of concentrated hydrochloric acid. The mixture was then filtered and the filtrate evaporated to dryness under reduced pressure at 40° C. The residue was taken up in absolute ethanol, giving 2.26 g of crystals, m.p. 172–174° C. This was recrystallized from methanol – ethyl acetate to yield 2-amino-6,6-dimethylcyclohexanone hydrochloride, m.p. 181–182° C. Found: C, 53.47; H, 9.00; N, 7.92. Calc. for $C_8H_{16}ClNO$: C, 54.08; H, 9.07; N, 7.82. The carbon value was low because of traces of ammonium chloride that were difficult to remove.

Deamination of 2-Amino-6,6-dimethylcyclohexanone

(*a*) 2-Amino-6,6-dimethylcyclohexanone hydrochloride (500 mg) was dissolved in 2 ml of 0.05 *N* sulphuric acid and then a solution of 1 g of sodium nitrite in 1 ml of water was added (addition time 15 minutes). There was a vigorous evolution of gas and the reaction mixture became yellow. A layer of yellow oil separated from the solution.

The reaction mixture was basified with sodium bicarbonate and extracted with methylene chloride. The methylene chloride solution was dried over sodium sulphate and distilled, leaving a neutral residue of 230 mg. The aqueous solution was acidified with sulphuric acid and extracted with methylene chloride. The 114 mg of acid which was extracted contained some dimethyladipic acid and other high-boiling acids, so was purified by short-path distillation. The main fraction came over at 75°, 0.5 mm; yield around 60 mg.

(*b*) A solution of 500 mg of amine hydrochloride and 1 g of sodium nitrite in 3 ml of water was prepared. This was cooled to 0°, then 5 drops of 0.05 *N* perchloric acid added slowly with stirring. The mixture was left for 10 minutes in the ice bath, then 5 minutes in the air. A yellow oil separated during the reaction. The readily extractable product gave 273 mg of neutral material and 58 mg of acid.

(*c*) The amine hydrochloride (106 mg) was dissolved in 3 ml of 80% aqueous dioxane, and 1 ml of 5% acetic acid solution was added. This was cooled in an ice bath, then 250 mg of sodium nitrite added in small portions. After gas evolution ceased the reaction mixture was adjusted to pH 8 using sodium bicarbonate. Extraction with methylene chloride gave 30 mg of neutral product. The aqueous solution was then acidified and extracted with methylene chloride, giving 29 mg of acid. These conditions gave the highest yield of acid.

The neutral product from deaminations by method (*a*) was distilled over a short path at bath temperature up to 80° under 10 mm pressure. A residue remained which crystallized from acetone. The crystalline substance could also be obtained by solution of the total neutral product in acetone, from which solution it separated on standing. The more volatile neutral products were separated by vapor phase chromatography using a 2 m×0.25 in. column with R packing at 120° and a flow rate of 50 cc/min. The retention time will be cited in the description of the different compounds. Minor components with retention times of 12, 14, 21, 25, 38, and 42 minutes were not characterized.

sym-Octahydrophenazine VI

The crystalline solid after sublimation at 60°, 5×10^{-4} mm, melted at 125–126°. Its infrared spectrum had no OH, NH, or carbonyl stretching bands. It had λ_{max} 289(ϵ 12,340). Found: C, 78.61; H, 9.84; N, 11.57. Calc. for $C_{16}H_{24}NO$: C, 78.63; H, 9.90; N, 11.46.

2,5,5-Trimethyl-2-cyclopentene-1-one (VII)

Retention time 19 minutes. It had $\nu_{max}^{CS_2}$ 1710 cm^{-1} ($>$C=O), 1355 and 1380 cm^{-1} (*gem*-dimethyl), 828 cm^{-1} ($R_2C{=}CHR$); λ_{max} 228 mμ (ϵ 10,840), 317 mμ (ϵ 60). The maximum yield was approx. 23%. Found: C, 76.90; H, 9.59. Calc. for $C_8H_{12}O$ (124.18): C, 77.37; H, 9.74.

3,3-Dimethylbicyclo[3,1,0]-2-hexanone (VIII)

Retention time 35 minutes. It had $\nu_{max}^{CS_2}$ 1725 cm^{-1} (C=O), 1355 and 1380 cm^{-1} (*gem*-dimethyl); λ_{max} 284 mμ (ϵ 46). The maximum yield was approx. 46%. Found: C, 77.26; H, 9.60. Calc. for $C_8H_{12}O$: C, 77.37;

H, 9.74. The compound in dilute ethanol solution of perchloric acid or sodium hydroxide did not give any α,β-unsaturated ketone after several hours at room temperature (followed by ultraviolet absorption).

2,2-Dimethylcyclopentanecarboxylic Acid

The acid fractions from the deamination of 2-amino-6,6-dimethylcyclohexanone were distilled over a short path. The bulk of the volatile acid distilled at a bath temperature of 75° under 0.5 mm pressure. It had $\nu_{\max}^{CS_2}$ 1700 cm^{-1}. The maximum yield was 18%. Found: C, 67.34; H, 9.67. Calc. for $C_8H_{14}O_2$: C, 67.57; H, 9.93. The chloride of the acid was prepared by refluxing the acid for 0.5 hour with thionyl chloride This was converted to the *anilide*. After recrystallization from acetone–pentane and sublimation at 90°, 5×10^{-4} mm, this melted at 124.5–125.5°. Found: C, 77.49; H, 8.57; N, 6.44. Calc. for $C_{14}H_{19}NO$: C, 77.38; H, 8.81; N, 6.45.

The methyl ester of the acid, prepared using diazomethane, was distilled over a short path at 25° C under 0.5 mm pressure. It gave a single peak with retention time 30.5 minutes using a 2-m column with R packing at 120° C with flow rate 50 cc/min.

2,2-Dimethyladipic Acid

The acidic aqueous solution remaining after removal of the readily extractable neutral and acidic products from the deamination of 2-amino-6,6-dimethylcyclohexanone was concentrated under reduced pressure until salts began to crystallize. The mixture was extracted thoroughly with chloroform. The crystalline residue after evaporation of the chloroform melted at 88–89°. When recrystallized from chloroform–hexane it had m.p. 89–90° (lit. m.p. 89–90° (31)). Found: C, 54.98; H, 7.97. Calc. for $C_8H_{14}O_4$: C, 55.16; H, 8.10.

FAVORSKII AND COPE REACTIONS

2-Chloro-6,6-dimethylcyclohexanone

The chlorination of 2,2-dimethylcyclohexanone was carried out under conditions described in Organic Syntheses (32). The product melted at 62–63° after recrystallization from ether followed by sublimation under 1×10^{-2} mm. It had $\nu_{\max}^{CHCl_3}$ 1725 cm^{-1} and $\lambda_{\max}$ 287 mμ (ϵ 26). Found: C, 59.65; H, 8.09; Cl, 22.23. Calc. for $C_8H_{13}OCl$: C, 59.81; H, 8.15; Cl, 22.07.

Attempted Favorskii Reaction

(*a*) A solution of 2-chloro-6,6-dimethylcyclohexanone (300 mg) in 5 ml of 3% potassium hydroxide in 60% aqueous dioxane was heated on the steam bath for 1.5 hours then left at room temperature overnight. The bulk of the solvent was removed under reduced pressure, water added, and the neutral product (103 mg) extracted into methylene chloride. The aqueous layer was then acidified and extracted with the same solvent. No extractable acid was obtained.

(*b*) The chloroketone (250 mg) and 1.2 ml of 4% sodium ethoxide in ethanol were heated for 16 hours at 145°. After hydrolysis in aqueous alcohol 125 mg of neutral material but only a trace of readily extractable acid were obtained.

(*c*) To a solution of 284 mg of the chloroketone in 20 ml of ether was added 300 mg of dry powdered potassium hydroxide. The mixture was heated in the water bath for 2 hours. The readily extractable products were 172 mg of neutral material and 16 mg of acid. The latter had a different infrared spectrum from 2,2-dimethylcyclopentanecarboxylic acid.

2-Bromo-6,6-dimethylcyclohexanone

The bromoketone was formed rapidly when a solution of 1.05 molar equivalents of bromine in ethanol-free chloroform was added dropwise to 2,2-dimethylcyclohexanone in ethanol-free chloroform. After recrystallization from ether–pentane and sublimation at 40°, 1×10^{-3} mm, it melted at 57–58° and had $\nu_{\max}^{CHCl_3}$ 1725 cm^{-1} and $\lambda_{\max}$ 292 mμ (ϵ 32). Found: C, 47.05; H, 6.26. Calc. for $C_8H_{13}OBr$: C, 46.84; H, 6.36.

Action of Silver Nitrate on 2-Bromo-6,6-dimethylcyclohexanone (11)

A very slow reaction took place when a solution of 215 mg of the bromoketone and 510 mg of silver nitrate in approx. 75% aqueous ethanol stood at room temperature. After 6 hours' refluxing, however, 176 mg of silver bromide (1 molar equivalent) had precipitated. The readily extractable products were 55 mg of neutral material and a trace of acid.

α-AMINOCAMPHOR

Deamination of α-Aminocamphor

α-Aminocamphor hydrochloride (33) (1.2 g) was dissolved in 8 ml of 0.2 *N* sulphuric acid. A solution of 2 g of sodium nitrite was added dropwise with stirring while the temperature was held at 25° C (addition time 20 minutes). The mixture was then left for 10 minutes, basified with sodium bicarbonate, and extracted with methylene chloride. The neutral products recovered from the methylene chloride were examined using v.p.c. (column R, 1 m, 120° C, flow rate 120 cc/min). Two components were readily eluted, with retention times of 14 and 20 minutes. Their peak areas were in the ratio 1:5 respectively. When a methylene chloride solution of the neutral product was shaken with 5% sodium hydroxide solution and the contents of the organic phase re-examined a new component, with retention time 6 minutes under the above conditions, was observed. This component also appeared if the deamination mixture was adjusted to pH 9–10 after reaction, left for 0.5 hour, then extracted with methylene chloride.

Cyclocamphanone XI

Retention time, 14 minutes. It was identified by comparison of retention time and melting point with an authentic sample prepared according to Schiff (34) and Takeuchi (35).

Cyclocamphanone was unchanged after 1 hour in approx. 0.1 *N* sulphuric acid in 50% aqueous dioxane. A methylene chloride solution of the ketone was shaken for 10 minutes with 5% sodium hydroxide solution. No trace of other readily eluted compounds was detected by v.p.c. after this treatment. Hence, this ketone is not the source of other products under the conditions of deamination and subsequent work-up.

6-Isopropenyl-6-methyl-2-cyclohexene-1-one (XII)

Retention time 20 minutes. It was redistilled over a short path at 100°, 15 mm pressure, after recovery from the preparative v.p.c. column. It had λ_{max} 225 mμ (ϵ 8770) and 327 mμ (ϵ 57); $\nu_{max}^{CCl_4}$ 1680 cm^{-1} ($>$C=O), 1640 and 898 cm^{-1} ($>$C=CH$_2$). Found: C, 79.66; H, 9.32. Calc. for $C_{10}H_{14}O$: C, 79.95; H, 9.39.

6-Isopropenyl-6-methylcyclohexanone

6-Isopropenyl-6-methyl-2-cyclohexene-1-one (500 mg) was dissolved in glacial acetic acid. Zinc dust (ca. 0.5 g) was added, and the mixture stirred for 1 hour. It was then diluted with 10 ml of water, filtered, and the filtrate extracted with methylene chloride. The organic phase was washed with sodium bicarbonate solution, then with water. The product remaining in the methylene chloride was distilled over a short path at 100° under 15 mm pressure. It had $\nu_{max}^{CCl_4}$ 1710 cm^{-1} (C=O), 1640 and 895 cm^{-1}. Its n.m.r. spectrum contained a doublet centered at τ 5.2 (2 hydrogens, J = 10 c.p.s.). Found: C, 79.01; H, 10.46. Calc. for $C_{10}H_{16}O$: C, 78.98; H, 10.59.

6-Isopropyl-6-methylcyclohexanone

6-Isopropenyl-6-methylcyclohexanone in 95% ethanol over 30% Pd/C rapidly absorbed 1 mole of hydrogen. The product had $\nu_{max}^{CCl_4}$ 1705 cm^{-1}. Found: C, 77.92; H, 11.90. Calc. for $C_{10}H_{18}O$: C, 77.86; H, 11.76.

6-Methyl-2-cyclohexene-1-one

Retention time, 6 minutes. After collection from the preparative column it was distilled over a short path at 70° under 10 mm pressure. It had λ_{max} 225 mμ (ϵ 10,350), 317 mμ (ϵ 56); $\nu_{max}^{CCl_4}$ 1680 and 1620 cm^{-1}. Found: C, 76.58; H, 8.90. Calc. for $C_7H_{10}O$: C, 76.32; H, 9.15. It gave a dinitrophenylhydrazone, m.p. 161–162° (reported m.p. 162° (14)).

A solution of 6-isopropenyl-6-methyl-2-cyclohexene-1-one in a 2:1 mixture (v/v) of 12 *N* sulphuric acid and methanol was refluxed for 1 hour. The product had identical retention time on column R with the 6-methyl-2-cyclohexene-1-one from the deamination reaction.

Reactions of Diazocamphor

(*a*) Finely divided diazocamphor (34, 35) (50 mg) was suspended in 2 ml of 0.2 *N* sulphuric acid for a period of 1 hour. The mixture was basified with sodium carbonate and extracted with methylene chloride. The products were identified by v.p.c. using column R to be 6-isopropenyl-6-methyl-2-cyclohexene-1-one 6-methyl-2-cyclohexene-1-one, and cyclocamphanone.

(*b*) In order to simulate the deamination conditions, 50 mg of finely divided diazocamphor was suspended in 2 ml of 0.2 *N* sulphuric acid, and a solution of 0.5 g of sodium nitrite in 1 ml of water was added. The mixture was left at room temperature for 2 hours. It was then basified with sodium carbonate and extracted with methylene chloride. Vapor phase chromatography on column R showed the readily eluted products to be 6-isopropenyl-6-methyl-2-cyclohexene-1-one and cyclocamphanone.

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REFERENCES

1. (*a*) O. E. Edwards and M. Lesage. J. Org. Chem. **24**, 2071 (1959).
   (*b*) O. E. Edwards and M. Lesage. Chem. Ind. (London), 1107 (1960).
2. H. E. Baumgarten and F. A. Bower. J. Am. Chem. Soc. **76**, 4561 (1954).
3. G. H. Elliot and R. P. Linstead. J. Chem. Soc. 776 (1938).

4. R. Granger and H. Técher. Bull. Soc. Chim. France, 1317 (1958); Compt. Rend. **250**, 4378 (1960).
5. H. E. Baumgarten and C. H. Anderson. J. Am. Chem. Soc. **83**, 399 (1961).
6. M. Godchot. Compt. Rend. **158**, 506 (1914).
7. R. M. Acheson and R. Robinson. J. Chem. Soc. 1131 (1952).
8. N. A. Nelson and G. A. Mortimer. J. Org. Chem. **22**, 1146 (1957).
9. V. Georgian and N. Kundu. Chem. Ind. (London), 1755 (1962).
10. R. B. Loftfield. J. Am. Chem. Soc. **73**, 4707 (1951).
11. A. C. Cope and E. S. Graham. J. Am. Chem. Soc. **73**, 4702 (1951).
12. W. Hückel and R. Kupka. Chem. Ber. **89**, 1694 (1956).
13. F. A. L. Anet. Can. J. Chem. **39**, 789 (1961).
14. G. Stork and W. N. White. J. Am. Chem. Soc. **78**, 4604 (1956).
15. D. E. Applequist and D. E. McGreer. J. Am. Chem. Soc. **82**, 1965 (1960).
16. R. L. Shriner and R. C. Fuson. Identification of organic compounds. John Wiley and Sons, New York. 1940. p. 42.
17. M. S. Silver. J. Am. Chem. Soc. **82**, 2971 (1960).
18. P. S. Skell and I. Starer. J. Am. Chem. Soc. **82**, 2971 (1960).
19. W. G. Dauben and P. Lang. Tetrahedron Letters, No. 11, 453 (1962).
20. G. Karabatsos and J. D. Graham. J. Am. Chem. Soc. **82**, 5250 (1960).
21. P. S. Skell, I. Starer, and A. P. Krapcho. J. Am. Chem. Soc. **82**, 5257 (1960).
22. J. D. Roberts, C. C. Lee, and W. H. Saunders. J. Am. Chem. Soc. **76**, 4501 (1954).
23. D. J. Cram and J. E. McCarty. J. Am. Chem. Soc. **79**, 2866 (1957).
24. J. H. Ridd. Quart. Rev. (London), **15**, 418 (1961).
25. A. Streitweiser and C. E. Coverdale. J. Am. Chem. Soc. **81**, 4275 (1959).
26. W. Hückel and F. Nerdel. Ann. **528**, 57 (1937).
27. W. Hückel and P. Rieckman. Ann. **625**, 1 (1959).
28. F. M. Jaeger and J. A. van Dijk. Proc. Acad. Sci. Amsterdam, **39**, 384 (1936).
29. N. Zelinsky. Ber. **41**, 2627 (1908).
30. P. S. Adamson, A. M. Marlow, and J. L. Simonsen. J. Chem. Soc. 774 (1938).
31. G. Blanc. Bull. Soc. Chim. **33** (3), 879 (1905).
32. Organic syntheses. Vol. XXV. John Wiley and Sons, Inc., New York. p. 22.
33. L. Claisen and O. Manasse. Ann. **273**, 90 (1893).
34. R. Schiff. Ber. **14**, 1375 (1881).
35. K. Takeuchi. Inst. Phys. Chem. Res. (Japan) Sci. Papers, **23–24**, 288 (1934).