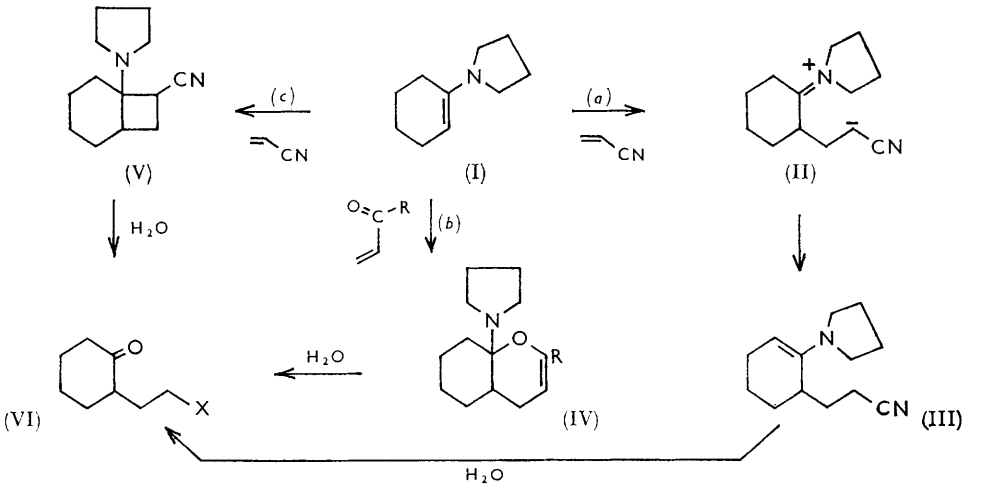
403. *The Reaction of Enamines with Electrophilic Olefins. A Synthesis of Cyclobutanes.*

By Ian Fleming and John Harley-Mason.

The addition of enamines to certain electrophilic olefins has been shown generally to give cyclobutanes. When the enamine is derived from an aldehyde the product is thermally stable, but when the enamine is derived from a ketone a new enamine is formed on heating. The cyclobutanes in both cases can frequently be degraded to cyclobutenes.

The preparation of enamines and their reaction with electrophilic olefins such as acrylonitrile is a well-known and powerful synthetic tool for the alkylation of carbonyl compounds. It was developed largely by Stork and his co-workers whose recent extensive Paper [1] describes the technique and range of the reaction which bears his name. In considering the mechanism of this reaction Stork and his co-workers [1] indicate several possibilities, which are illustrated below using the pyrrolidine enamine of cyclohexanone as an example. Path (*a*), which could apply to all electrophilic olefins, involves nucleophilic attack by the enamine carbon on the electrophilic carbon of the olefin, with the generation of a zwitterionic intermediate (II). Proton loss and gain, either by the intervention of a base or by an intramolecular pathway, could lead to a new enamine (III), which on hydrolysis would give the alkylated ketone (VI). Since the enamine (III) is both the final product of the reaction and the more stable of the two possible enamines, a decision, on the strength of this evidence, between base intervention and an intramolecular pathway is not possible. Path (*b*), which applies principally to unsaturated carbonyl compounds, involves reaction of a Diels–Alder type, in either one or two stages, with the generation of a dihydropyran (IV). Opitz and Loschmann [2] found dihydropyrans to be the final products of the reaction between aldehyde enamines and αβ-unsaturated aldehydes. A similar course was postulated for the reaction of several enamines with 2-chlorovinyl ketones.[3]



Path (*c*), leading to a cyclobutane adduct (V), could proceed either from the intermediate (II) by intramolecular attack, or by direct cycloaddition of the enamine to the

[1] Stork, Brizzolara, Landesman, Szmuszkovicz, and Terrell, *J. Amer. Chem. Soc.*, 1963, **85**, 207.
[2] Opitz and Loschmann, *Angew. Chem.*, 1960, **72**, 523.
[3] Schroth and Fischer, *Angew. Chem., Internat. Edn.*, 1963, **2**, 394.

electrophilic olefin. Such a course was observed by Brannock, Bell, Burpitt, and Kelley [4] in the reaction of enamines derived from secondary aldehydes with many electrophilic olefins. In these cases an intermediate zwitterion following path (*a*) could not lose a proton to regenerate an enamine. It was also observed by Berchtold and Uhlig [5] and by Brannock, Burpitt, Goodlett, and Thweatt [6] in the reaction of many enamines with methyl acetylenedicarboxylate, and by Opitz and his co-workers [7] in the reaction of enamines with ketens. Many of these examples may be regarded as special cases. Indeed, Stork and his co-workers [1] state: " In the absence of further data we see no reason to abandon the usual enamine alkylation mechanism [path (*a*)]."

We now report that the formation of a cyclobutane adduct [path (*c*)] is not confined to the special examples mentioned above but is the preferred course in the reaction of most enamines with several electrophilic olefins. Furthermore, the isolation of the cyclobutanes offers a very simple and frequently high-yield route to this class of compound.

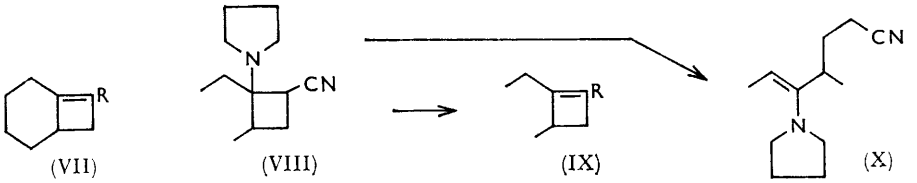
Under the conditions used by Stork and his co-workers,[1] namely twelve hours' refluxing in dioxan, the enamine (I) reacts with acrylonitrile to give the cyanoethylated enamine (III), as shown by infrared (i.r.) and nuclear magnetic resonance (n.m.r.) spectra of the product. However, when equimolar quantities of the reactants were mixed at room temperature, a mildly exothermic reaction ensued, and after twenty minutes the i.r. spectrum showed no absorption attributable to the enamine double bond. On cooling, a crystalline product was obtained, shown by the spectroscopic data and by degradation to be the cyclobutane (V). Hofmann degradation was achieved in good yield by quaternisation with methyl iodide and treatment with cold alkali, the bicyclo-octene (VII; R = CN) being immediately formed. This product showed strong unsaturated nitrile and double-bond i.r. absorption, and ultraviolet absorption due to a conjugated system. The n.m.r. spectrum showed no protons attached to a double bond. The presence of only one double bond was confirmed by conversion into the corresponding amide (VII; R = $CONH_2$) which very rapidly took up one equivalent of hydrogen on catalytic hydrogenation, to give the saturated amide. These observations fully support the cyclobutane structure for the initial adduct and the cyclobutene structure for the Hofmann degradation product.

On distillation at reduced pressure the cyclobutane (V) reverted to the starting enamine (I) and acrylonitrile. This showed that the initial reaction was readily reversible, and raised an interesting mechanistic point. The Stork reaction, leading to the new enamine (III), could still take place by path (*a*), without reversible formation of the cyclobutane (V) being on the direct path. Alternatively, the cyclobutane (V) may give directly the zwitterionic intermediate (II), which could lead to the enamine (III) by proton loss and gain. An indication that the cyclobutane (V) is on the direct path of the Stork reaction was shown by heating the cyclobutane (V) with an excess of piperidine. If the cyclobutane were to revert entirely to acrylonitrile and the enamine (I), then the acrylonitrile would be trapped by the piperidine, with which is reacts very rapidly to give 1-(2-cyanoethyl)piperidine. In fact the latter was obtained in 78% yield, but the enamine (III) was still isolated in 15% yield.

The reaction of acrylonitrile with enamines derived from other ketones showed similar features, but in no other case was the adduct corresponding to the cyclobutane (V) obtained crystalline. 3-*N*-Pyrrolidinylpent-2-ene (from diethyl ketone) and acrylonitrile again took about twenty minutes for reaction to go to completion. The spectroscopic data for the cyclobutane (VIII) were similar to those for the previous example. It was degraded to the cyclobutenenitrile (IX; R = CN) and the amide (IX; R = $CONH_2$). The cyclobutane adduct (VIII) was again thermally unstable; on distillation it reverted

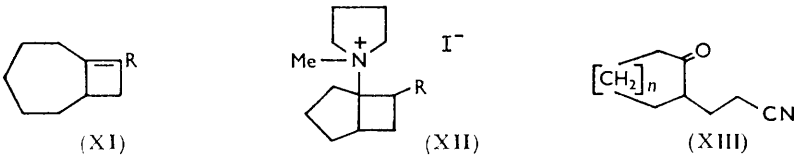
[4] Brannock, Bell, Burpitt, and Kelley, *J. Org. Chem.*, 1961, **26**, 625.
[5] Berchtold and Uhlig, *J. Org. Chem.*, 1963, **28**, 1459.
[6] Brannock, Burpitt, Goodlett, and Thweatt, *J. Org. Chem.*, 1963, **28**, 1464.
[7] Opitz and Zimmermann, *Annalen*, 1963, **662**, 178; Opitz and Kleemann, *ibid.*, 1963, **665**, 114.

to the starting materials, but refluxing in dioxan gave the enamine (X). In this case the addition of piperidine to the refluxing solution caused all the acrylonitrile to be trapped, and no rearrangement product was observed. 1-*N*-Pyrrolidinylcycloheptene reacted with acrylonitrile even more rapidly than 1-*N*-pyrrolidinylcyclohexene, reaction being complete,



(VII) (VIII) (IX) (X)

as judged by the i.r. spectrum, after two minutes. Hofmann degradation gave the unsaturated nitrile (XI; R = CN) which was converted into its amide (XI; R = $CONH_2$) and hydrogenated to the saturated amide. 1-*N*-Pyrrolidinylcyclopentene reacted with acrylonitrile more slowly than 1-*N*-pyrrolidinylcyclohexene, but the reaction did not appear to go to completion even after several hours. Nevertheless, the methiodide (XII; R = CN) of the crude adduct was obtained in 96% yield, but did not undergo Hofmann elimination; presumably the strain in the bicyclo[3,2,0]hept-1(7)-ene system is prohibitively great. With moist silver oxide, the hydrolysis product [the cyanoethylated ketone (XIII; $n = 1$)] was produced in low yield; with sodium hydroxide solution, the nitrile was simply hydrolysed to the amide (XII; R = $CONH_2$); and direct pyrolysis of the methiodide (XII; R = CN) gave the starting enamine, 1-*N*-pyrrolidinylcyclopentene. With both 1-*N*-pyrrolidinylcyclo-heptene and -pentene, hydrolysis of the crude adducts gave the cyanoethylated ketones (XIII; $n = 3$ and 1, respectively) in better yields than those obtained under the usual Stork reaction conditions.[1]

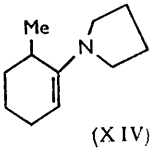


(XI) (XII) (XIII)

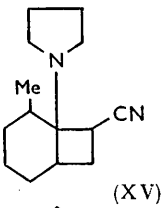
A limitation of the new reaction was observed with the enamine (XIV) from 2-methylcyclohexanone. As expected, this enamine reacted more slowly with acrylonitrile than 1-*N*-pyrrolidinylcyclohexene, taking several hours for the enamine i.r. absorption to reach a minimum. This absorption was finally very weak but could not be completely removed, even with an excess of acrylonitrile, indicating that the reaction is noticeably reversible even at room temperature. In the adduct (XV) the methyl group must be eclipsed either by the pyrrolidine group or by the cyclobutane ring; evidently this alters the free energy of the reaction sufficiently for the reversibility at room temperature to be observed. This reversibility was supported by two observations: (i) when the mixture was treated with methyl iodide the less basic enamine (XIV) reacted more rapidly than the crowded amine (XV) since the only methiodide obtained was that of the enamine (XIV); (ii) hydrolysis of the crude reaction mixture gave only 13% of cyanoethylated ketone, the major product being recovered 2-methylcyclohexanone (70%). Under the conditions used by Stork *et al.*[1] the yield was 55% since the adduct (XV) was presumably converted into a new enamine before hydrolysis.

The reaction of acrylonitrile with enamines derived from secondary aldehydes had been shown to give cyclobutanes.[4] Since these cannot lose a proton to revert to the more stable enamine system it was necessary to examine the reaction of primary aldehyde enamines with electrophilic olefins. Acrylonitrile reacted with 1-piperidinobutene (from n-butanal) to give the cyclobutane (XVI; R = CN), which gave a crystalline picrate and

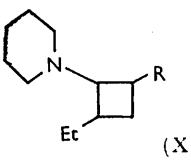
could be distilled unchanged. A similar reaction was observed between methyl acrylate and 1-piperidinobutene, to give the cyclobutane (XVI; R = CO_2Me), characterised as its amide (XVI; R = $CONH_2$). In both cases, Hofmann degradation and hydrolysis gave, by way of the cyclobutenes (XVII; R = CN or CO_2H), the unsaturated amide (XVII; R = $CONH_2$), which was hydrogenated to the saturated amide. The pyrrolidine enamine from methyl 4-formylhexanoate [itself prepared by hydrolysis of the cyclobutane (XVI; R = CO_2Me)] reacted slowly with acrylonitrile in refluxing dioxan, as expected, to give a cyclobutane (XVIII; R = CO_2Me), which was characterised as its amide (XVIII; R = $CONH_2$), thus confirming the observation that secondary aldehyde enamines also give cyclobutanes with electrophilic olefins.[4] The cyclobutane (XVIII; R = CO_2Me) was hydrolysed to the tertiary aldehyde (XIX). This hydrolysis, and the one described above, is plainly a reaction of the retro-Mannich type.



(XIV)



(XV)



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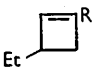

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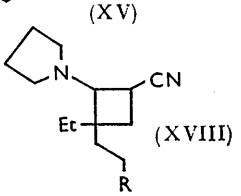

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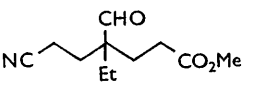
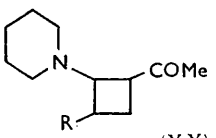


(XIX)

The reaction of methyl vinyl ketone with enamines derived from ketones is complex and will be discussed in a subsequent Paper.

As observed above, the products from primary aldehyde enamines and acrylonitrile and methyl acrylate were thermally stable. This was also the case with methyl vinyl ketone. Both 1-piperidinobutene and 1-piperidinopropene reacted with methyl vinyl ketone to give the distillable cyclobutyl ketones (XX; R = Et,Me). They showed no ultraviolet absorption above 210 mμ. The cyclobutane ring was readily hydrogenolysed, to give the ketone (XXII). Hofmann degradations were performed on the adducts (XX; R = Et,Me) but methiodide formation was slow and much starting material was recovered. The oily methiodides gave, on treatment with alkali, the crude cyclobutenyl ketones (XXI; Et,Me). Both of the crude cyclobutenyl ketones (XXI; R = Et,Me) showed i.r. and n.m.r. spectra consistent with this formulation. In particular, the ketone (XXI; R = Me) showed singlet absorption at τ 3·3 (olefinic proton), 7·9 (COMe), and 7·5 (Me), and a doublet at τ 8·9 (*C*-Me); only one proton, which was unresolved, was unaccounted for. But the same assignments decisively place all the carbon atoms of the molecule, and confirm the presence of the cyclobutene ring, and hence show the presence of a cyclobutane ring in the initial adduct.



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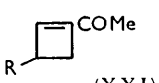
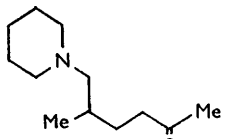


(XXI)



(XXII)

Finally, we found one example in which there was no evidence of cyclobutane formation. This was the reaction of methyl α-methylacrylate with 1-*N*-pyrrolidinylcyclohexene.

It was first confirmed that methyl acrylate reacted straightforwardly with the enamine. Reaction took no longer than the reaction with acrylonitrile, and went to completion, as judged by the i.r. spectrum of the mixture. In the case of methyl α-methylacrylate, cyclobutane formation would set up two adjacent quaternary carbon atoms, which process is known to be generally difficult. Indeed, cyclobutane formation was not observed. No diminution in the intensity of the enamine i.r. absorption was observed, even after one week. Alkylation, however, was achieved, presumably by path (*a*) as Stork *et al.* also showed,[1] when the mixture was refluxed in a polar solvent.

Experimental

Infrared spectra were taken on a Perkin–Elmer model 21 spectrometer fitted with sodium chloride prisms, using liquid films or Nujol mulls. Ultraviolet spectra were taken on a Cary recording spectrophotometer in 95% ethanol, except where otherwise stated. The n.m.r. spectra were taken on a Perkin–Elmer spectrometer operating at 40 Mc./sec., for carbon tetrachloride solutions except where otherwise stated, and using tetramethylsilane as an internal reference.

The enamines and the methyl vinyl ketone were distilled before use.

1-N-*Pyrrolidinylbicyclo*[4,2,0]*octane*-8-*carbonitrile* (V).—1-*N*-Pyrrolidinylcyclohexene [1] (22 g.), in pentane (20 ml.), was mixed with acrylonitrile (12 ml., 1·2 Equiv.) and kept at room temperature for 1 hr., until spontaneous warming ceased. (In another experiment, without solvent, the reaction took 20 min. for spontaneous heating to cease and the enamine i.r. absorption to disappear.) The mixture was kept at 0° overnight and cooled to −78°; fine needles of the *carbonitrile* (V) separated, m. p. 61—62°. A further crop was obtained from the mother-liquor (total 15·5 g., 52%) (Found: N, 13·7. $C_{13}H_{20}N_2$ requires N, 13·7%), $\nu_{max.}$ 2220s cm.$^{-1}$ (CN). Satisfactory carbon and hydrogen analyses could not be obtained owing to the instability of the product which decomposed and became oily after 2—3 days. There was no ultraviolet absorption, in ether solution, above 210 mμ. The n.m.r. spectrum was broad, relatively unresolved, and confined to the τ 7·0—8·7 region. The product was further characterised as its methiodide (see below).

Reactions of 1-N-*Pyrrolidinylbicyclo*[4,2,0]*octane*-8-*carbonitrile* (V).—(*a*) *Distillation.* The adduct (2·0 g.) was distilled, to give back 1-*N*-pyrrolidinylcyclohexene (1·3 g., 88%) at 75—80°/0·01 mm., and acrylonitrile in the liquid-nitrogen trap, identified by their i.r. spectra.

(*b*) *Pyrolysis.* The crude adduct, from 1-*N*-pyrrolidinylcyclohexene (11·5 g.) and an excess of acrylonitrile (10 ml.), was refluxed in dry dioxan (15 ml.) for 6 hr., to give crude 3-(2-cyanoethyl)-2-*N*-pyrrolidinylcyclohexene (7·7 g., 50%), b. p. 120—126°/0·05 mm., $\nu_{max.}$ 2250w (CN) and 1640s (NC:C) cm.$^{-1}$. The n.m.r. spectrum showed a triplet at τ 5·65 (J = 4 c./sec.).

(*c*) *Hydrolysis.* Crude adduct (7·5 g.), prepared in the absence of solvent, was refluxed in water (10 ml.) for 45 min. and the mixture extracted with ether, to give crude 2-(2-cyanoethyl)-cyclohexanone (5·47 g., 98% bases on starting enamine), b. p. 125—150°/12 mm. (lit.,[1] 141—145°/10 mm.); its 2,4-dinitrophenylhydrazone had m. p. 157—159° (lit.,[1] 154·5—156°). Stork *et al.*[1] reported that the cyclobutane rearranged to give the enamine in 80% yield.

(*d*) *Pyrolysis in the presence of piperidine.* The crystalline adduct (6·3 g.), in dry dioxan (10 ml.), was refluxed with piperidine (3 g., 1·25 Equiv.) for 12 hr. The mixture was refluxed for a further 1 hr. with water (4 ml.), to give: cyclohexanone (1·5 g.), b. p. <70°/14 mm.; 1-(2-cyanoethyl)piperidine (3·37 g., 78%), b. p. 105—110°/14 mm. (lit.,[8] 105°/11 mm.) [methiodide, m. p. 148—152° (lit.,[8] 152—154°); hydrochloride, m. p. 182—183° (lit.,[8] m. p. 181—182°)]; and 2-(2-cyanoethyl)cyclohexanone (0·7 g., 15%), b. p. 145—152°/14 mm. (lit.,[1] 141—145°/10 mm.), 2,4-dinitrophenylhydrazone, m. p. 154—156°, mixed m. p. with sample from (*c*) above, 153—156°.

(*e*) *Hofmann degradation.* (i) The crystalline adduct (9·0 g.), in dry ether (15 ml.) and methyl iodide (15 g.), was kept stoppered at room temperature for 10 days, to give the *methiodide* (13·7 g., 90%) as prisms, m. p. 205—208° (decomp.) (from ethanol) (Found: C, 48·6; H, 6·3; N, 7·8. $C_{14}H_{23}IN_2$ requires C, 48·5; H, 6·7; N, 8·1%), $\nu_{max.}$ 2240m cm.$^{-1}$ (CN). When the final mother-liquor, left after separation of 1-*N*-pyrrolidinylbicyclo[4,2,0]octane-8-carbonitrile

[8] Brockway, *Analyt. Chem.*, 1949, **21**, 1207.

(V) as described above, was similarly treated with methyl iodide, a further quantity of the same methiodide (3·9 g., 16%) was obtained, making a total yield, based on 1-*N*-pyrrolidinylcyclohexene, of 60%. (ii) Crude methiodide (27·5 g.) in water (300 ml.) was mixed with 10% sodium hydroxide solution (60 ml.), and the oil which separated immediately was extracted with ether, to give *bicyclo*[4,2,0]*oct*-1(8)-*ene*-8-*carbonitrile* (VII; R = CN) (10·0 g., 94%), b. p. 107—111°/14 mm., n_D^{18} 1·510 (Found: C, 81·5; H, 8·6; N, 10·6. $C_9H_{11}N$ requires C, 81·1; H, 8·3; N, 10·6%), $\nu_{max.}$ 2200s (conj. CN) and 1647s (C:C) cm.$^{-1}$, $\lambda_{max.}$ 223 mμ (ε 12,000). The n.m.r. spectrum showed only broad unresolved absorption in the τ 7·0—9·0 region. (iii) Bicyclo-[4,2,0]oct-1(8)-ene-8-carbonitrile (1·3 g.) in 3% hydrogen peroxide solution (50 ml.), with 10% sodium hydroxide solution (5 drops) and sufficient ethanol to make the mixture homogeneous, was kept at room temperature for 36 hr. On evaporation of the ethanol, *bicyclo*[4,2,0]*oct*-1(8)-*ene*-8-*carboxyamide* (VII; R = $CONH_2$) separated as platelets (0·55 g., 37%) from benzene and sublimed at 100°/0·05 mm., m. p. 143—144° (Found: C, 71·4; H, 8·6; N, 9·2. $C_9H_{13}NO$ requires C, 71·5; H, 8·7; N, 9·2%), $\nu_{max.}$ 3315s and 3115s (amide NH), 1680s, 1650s, and 1610s (amide I and II, and C:C) cm.$^{-1}$, $\lambda_{max.}$ 223 mμ (ε 12,120). (iv) Bicyclo[4,2,0]oct-1(8)-ene-8-carboxyamide (VII; R = $CONH_2$) (40 mg.), in ethanol (10 ml.), was hydrogenated at room temperature over Adams catalyst (8 mg.)for 1 min., after which time hydrogen absorption abruptly stopped (5·5 ml. absorbed; calc. 5·9 ml.). Filtration and evaporation gave *bicyclo*-[4,2,0]*octane*-8-*carboxyamide* (30 mg., 74%) as prisms from benzene, m. p. 226° (after vacuum sublimation) (Found: C, 70·3; H, 9·8; N, 9·1. $C_9H_{15}NO$ requires C, 70·5; H, 9·9; N, 9·1%), $\nu_{max.}$ 3320s and 3140s (amide NH), 1660s and 1623s (amide I and II) cm.$^{-1}$.

Reaction of 1-*Piperidino- and* 1-*Morpholine-cyclohexene with Acrylonitrile.*—Under the same conditions as for the reaction of 1-*N*-pyrrolidinylcyclohexene and acrylonitrile above, 1-piperidinocyclohexene [1] and 1-morpholinocyclohexene [1] showed only slight warming and the reaction took 12 hr. for the enamine i.r. absorption to reach a minimum and it never quite disappeared, even with an excess of acrylonitrile. Attempts to obtain a crystalline methiodide failed, and Hofmann degradation using moist silver oxide on the crude methiodides gave only 2 and <1%, respectively, of bicyclo[4,2,0]oct-1(8)-ene-8-carbonitrile, identified by its smell and i.r. spectrum.

Reaction of 3-N-*Pyrrolidinylpent*-2-*ene with Acrylonitrile.*—The pyrrolidine enamine from diethyl ketone [1] (7·6 g.) was mixed with acrylonitrile (2·5 g., 1·3 Equiv.) and kept at room temperature by occasional cooling. After 20 min., spontaneous warming ceased and the i.r. spectrum showed the complete disappearance of the enamine double bond. Removal of the excess of acrylonitrile under a vacuum at room temperature gave an oil whose n.m.r. spectrum showed protons in the olefin region centred at τ 4·2, whose area corresponded to only 0·012 of the area in the region τ 7·0—9·5, and the splitting and position of which were identical with those in acrylonitrile, showing that some acrylonitrile could not have been removed. The *C*-methyl region at τ 9·2 showed an overlapping doublet (J = 6 c./sec.) and a triplet (J = 6·4 c./sec.) consistent with the cyclobutane structure (VIII).

Reactions of the Adduct (VIII) *of* 3-N-*Pyrrolidinylpent*-2-*ene and Acrylonitrile.*—(*a*) *Distillation.* The adduct (2·4 g.) was distilled at <50°/0·1 mm., to give back 3-*N*-pyrrolidinylpent-2-ene (1·6 g., 92%), identified by its i.r. spectrum and conversion into diethyl ketone 2,4-dinitrophenylhydrazone, needles, m. p. 152—154° (lit.,[9] 156°).

(*b*) *Pyrolysis.* The adduct (2·0 g.) was refluxed in dry dioxan for 8 hr. The product (1·1 g., 55%), b. p. 105°/1·5 mm., showed strong absorption at 1640 (NC:C) and 2250m (CN) cm.$^{-1}$. Hydrolysis with water and treatment with Brady's reagent converted the pyrolysis product into *ethyl* 1-(2-*cyanoethyl*)*ethyl ketone* 2,4-*dinitrophenylhydrazone*, needles, m. p. 61—62° (from ethanol) (Found: C, 52·4; H, 5·5; N, 22·2. $C_{14}H_{17}N_5O_4$ requires C, 52·7; H, 5·4; N, 21·9%), $\nu_{max.}$ 2250w cm.$^{-1}$ (CN) and the usual dinitrophenylhydrazone absorptions.

(*c*) *Hydrolysis.* A little of the adduct was boiled with water and treated with Brady's reagent. The 2,4-dinitrophenylhydrazone, needles, m. p. 59° (from ethanol), had an identical i.r. spectrum with that obtained in (*b*) above.

(*d*) *Pyrolysis in the presence of piperidine.* The adduct (5·0 g.), in dry dioxan (10 ml.) and piperidine (2·4 g., 1·1 Equiv.), was refluxed for 6 hr. Distillation gave 3-*N*-pyrrolidinylpent-2-ene (1·8 g.), b. p. 75—95°/12 mm. (redistilled 1·6 g., 44%), b. p. 75—76°/12 mm. (lit.,[1] 62—

[9] Heilbron and Bunbury, "Dictionary of Organic Compounds," Eyre and Spottiswoode, London, 1953.

67°/8 mm.), identified by its i.r. spectrum and conversion into diethyl ketone 2,4-dinitrophenylhydrazone, m. p. 154—155·5°, mixed m. p. 154—155° (lit.,[8] 156°), and 1-(2-cyanoethyl)piperidine (2·4 g., 66%), b. p. 105—115°/11 mm., redistilled, b. p. 110°/11 mm. (lit.,[8] 105°/11 mm.), n_D^{21} 1·467 (lit.,[8] 1·469); methiodide m. p. 152—154° (lit.,[8] 158°); hydrochloride, m. p. 178—180° (lit.,[8] 181—182°).

(*e*) *Hofmann degradation.* The adduct (5·5 g.) and methyl iodide (15 g.) were kept in dry ether (15 ml.) at room temperature for 2 weeks. The mixture was shaken with water (50 ml.), separated, and the aqueous layer shaken with moist silver oxide (freshly prepared from 10 g. of $AgNO_3$) for 3 hr. Ether (50 ml.) was added and the mixture filtered. Evaporation of the ether layer gave an oil (0·35 g., 11%), b. p. 75—80°/14 mm. This was treated with alkaline hydrogen peroxide, as described above, to give 2-*ethyl*-3-*methylcyclobut*-1-*ene*-1-*carboxyamide* (IX; R = $CONH_2$) as fine needles, purified by sublimation, m. p. 93·5° (Found: N, 9·8. $C_8H_{13}NO$ requires N, 10·1%), $\nu_{max.}$ 3310s and 3140s (amide NH), 1670s (amide I), and 1610s cm.$^{-1}$ (amide II, and C:C), $\lambda_{max.}$ 223 mμ (ε 13,080). The oil, presumably 2-ethyl-3-methylcyclobut-1-ene-1-carbonitrile (IX; R = CN), had $\nu_{max.}$ 2200s (conj. CN) and 1640s cm.$^{-1}$ (conj. C:C), and the n.m.r. spectrum showed the same triplet and doublet in the *C*-methyl region as the original adduct; the rest of the absorption was relatively unresolved in the τ 6·9—8·3 region.

Reaction of 1-N-*Pyrrolidinylcycloheptene with Acrylonitrile.*—(*a*) 1-*N*-Pyrrolidinylcycloheptene [1] (11·7 g.) was mixed with acrylonitrile (4·7 ml.) and cooled immediately; after 2 min. no further warming occurred, and the i.r. spectrum showed no absorption due to the enamine double bond, and a strong band at 2230 cm.$^{-1}$ (CN). This product was kept stoppered in dry ether (20 ml.) with methyl iodide (20·0 g.) for 12 days. The methiodide separated as an oil which was dissolved in water (100 ml.), shaken with an excess of moist silver oxide for 2 hr., extracted with ether, filtered, and the filtrate evaporated, to give crude bicyclo[5,2,0]non-1(9)-ene-9-carbonitrile (XI; R = CN) (3·0 g., 29%) as an oil, whose i.r. and n.m.r. spectra closely resembled those of bicyclo[4,2,0]oct-1(8)-ene-8-carbonitrile but showed a small amount of ketonic impurity. It was characterised by hydrolysis to the amide and hydrogenation with Adams catalyst in ethanol, which was complete after absorption of 1 equiv. Filtration, and partial evaporation of the solvent, gave *bicyclo*[5,2,0]*nonane*-9-*carboxyamide*, prisms, m. p. 205·5° (from ethanol) (Found: C, 71·7; H, 9·9; N, 8·2. $C_{10}H_{17}NO$ requires C, 71·8; H, 10·2; N, 8·4%), $\nu_{max.}$ 3300s and 3120s (amide NH), 1656s and 1620s cm.$^{-1}$ (amide I and II).

(*b*) *Hydrolysis.* 1-*N*-Pyrrolidinylcycloheptene [1] (12·0 g.) was mixed carefully with acrylonitrile (4·8 g.) and cooled. After 5 min. at room temperature the mixture was refluxed with water (20 ml.) for 1 hr., extracted with ether, and distilled, to give cycloheptanone (4·5 g., 54%), b. p. <70°/14 mm., identified as its 2,4-dinitrophenylhydrazone, m. p. 146—148° (lit.,[9] 148°), and 2-(2-cyanoethyl)cycloheptanone (5·3 g., 44%), b. p. 162—165°/14 mm. (lit.,[1] 140—145°/10 mm.); semicarbazone, m. p. 164—166° (lit.,[1] 163—164°) (Found: N, 25·4. Calc. for $C_{11}H_{18}N_4O$: N, 25·2%). Stork *et al.*,[1] who rearranged the cyclobutane to the enamine, reported corresponding yields of 45 and 33%.

Reaction of 1-N-*Pyrrolidinylcyclopentene with Acrylonitrile.*—(*a*) 1-*N*-Pyrrolidinylcyclopentene [1] (21·0 g.) was mixed with acrylonitrile (12 ml.). Some spontaneous warming was observed during 30 min. but the enamine absorption continued to diminish in intensity during several hours, never completely disappearing. Treatment in dry ether (20 ml.) with methyl iodide (20 g.) at room temperature overnight gave 1-N-*pyrrolidinylbicyclo*[3,2,0]*heptane*-7-*carbonitrile methiodide* (XII; R = CN) (48·9 g., 96%), prisms, m. p. 205—208° (decomp.) (from ethanol) (Found: C, 47·4; H, 6·7; N, 8·1. $C_{13}H_{21}IN_2$ requires C, 47·0; H, 6·4; N, 8·4%), $\nu_{max.}$ 2228 cm.$^{-1}$ (CN), and no double-bond absorption. (i) The attempted Hofmann degradation with moist silver oxide, as described above, gave 2-(2-cyanoethyl)cyclopentanone (3·1 g., 15%), b. p. 95—97°/0·3 mm. (lit.,[1] 144—147°/13 mm.); 2,4-dinitrophenylhydrazone, m. p. 167—168·5° (lit.,[1] 166—167°) (Found: C, 52·8; H, 5·2; N, 22·4. Calc. for $C_{14}H_{15}N_5O_4$: C, 53·0; H, 4·8; N, 22·1%). (ii) The methiodide (8·5 g.) in water (30 ml.) was mixed with 10% sodium hydroxide solution (20 ml.). No oil separated. After keeping at room temperature overnight the addition of ether caused the precipitation of 1-N-*pyrrolidinylbicyclo*[3,2,0]*heptane*-7-*carboxyamide methiodide* (XII; R = $CONH_2$) (3·7 g., 41%), prisms, m. p. 237—239° (from water) (Found: C, 44·4; H, 7·0; N, 7·8. $C_{13}H_{23}IN_2O$ requires C, 44·6; H, 6·6; N, 8·0%), $\nu_{max.}$ 3350s, 3260m, 3200s, and 3150m (amide NH), and 1670s and 1597s cm.$^{-1}$ (amide I and II). (iii) The methiodide (5 g.) was pyrolysed at just above its m. p. in a distillation apparatus at water-pump pressure. The first distillate was 1-*N*-pyrrolidinylcyclopentene (0·8 g., 39%), b. p. <90°/13

mm., identified by its i.r. spectrum and conversion into cyclopentanone 2,4-dinitrophenylhydrazone, m. p. 142—144°, mixed m. p. 139—144° (lit.,[9] 145·5—146·5°), and into cyclopentanone semicarbazone, m. p. 198—201°, mixed m. p. 196—202° (lit.,[9] 203°). After this product had distilled, the pressure rose and decomposition set in.

(*b*) *Hydrolysis.* 1-*N*-Pyrrolidinylcyclopentene (7·5 g.) was mixed with acrylonitrile (3·7 ml.), as above, and the mixture refluxed with water (10 ml.) for 1·5 hr. The product, extracted with ether, was 2-(2-cyanoethyl)cyclopentanone (6·1 g., 82%), b. p. 145—152°/16 mm. (lit.,[1] 144—147°/13 mm.; 2,4-dinitrophenylhydrazone, m. p. 162—164° (lit.,[1] 166—167°). Stork *et al.*,[1] reported that the cyclobutane rearranged to the enamine in 67% yield.

Reaction of 3-*Methyl*-2-N-*pyrrolidinylcyclohexene with Acrylonitrile.*—(*a*) The enamine [1] from 2-methylcyclohexanone (19·1 g.) was mixed with acrylonitrile (8·0 ml.), and showed slight warming. After 2 hr. the enamine i.r. absorption was reduced in intensity and, after being kept overnight with more acrylonitrile (4 ml.), was further reduced. (The enamine absorption of this mixture could not be completely removed with more acrylonitrile.) The mixture (14·3 g.) was kept stoppered at room temperature with dry ether (10 ml.) and methyl iodide (35 g.) for 3 days. The filtrate was washed with acetone, to give unstable 3-*methyl*-2-N-*pyrrolidinylcyclohexene methiodide* (4·1 g., 23%), clusters, m. p. 240—242° (from ethanol) (Found: C, 46·5; H, 7·5; N, 4·8. $C_{12}H_{22}NI$ requires C, 46·9; H, 7·2; N, 4·6%), $\nu_{max.}$ 1640s cm.$^{-1}$ (C:C or C:N), and no CN absorption. The crystals darkened and became oily in a few days.

(*b*) *Hydrolysis.* The enamine [1] from 2-methylcyclohexanone (8·2 g.) was mixed with acrylonitrile (6·6 ml., 2 Equiv.) as above, kept overnight, and hydrolysed by refluxing with water (5 ml.) for 1 hr. The ether extract of the mixture gave, on removal of the solvent and distillation, (i) 2-methylcyclohexanone (3·8 g., 70%), b. p. 70—90°/20 mm., identified as its 2,4-dinitrophenylhydrazone, m. p. and mixed m. p. 134—136°, (ii) 1-(2-cyanoethyl)pyrrolidine (2·2 g., 36%), b. p. 105—115°/20 mm., identified as its methiodide, m. p. 120—121° (lit.,[10] 120—121°), and (iii) 2-(2-cyanoethyl)-6-methylcyclohexanone (1·1 g., 13%), b. p. 84—86°/0·1 mm. (lit.,[1] 132—133°/2 mm.), 2,4-dinitrophenylhydrazone, m. p. 150—151° (lit.,[1] 151—152°). Stork *et al.*[1] reported that, when the cyclobutane was rearranged to the enamine, the yield of cyanoethylated ketone was 55%.

Reaction of 1-*Piperidinobutene with Acrylonitrile.*—(*a*) 1-Piperidinobutene [11] (19 g.) in dry dioxan (10 ml.) was refluxed with acrylonitrile (12 ml.) for 4 hr., to give 3-*ethyl*-2-*piperidinocyclobutane carbonitrile* (XVI; R = CN) (21·8 g., 84%), b. p. 142—148°/13 mm., 90°/0·3 mm., n_D^{25} 1·480 [Found: C, 74·5; H, 10·2; N, 14·9%; *M* (cryoscopic in benzene), 187. $C_{12}H_{20}N_2$ requires C, 74·9; H, 10·4; N, 14·5%; *M*, 192], $\nu_{max.}$ 2220m cm.$^{-1}$ (cyclobutyl CN), and no absorption in the double-bond region; picrate, prisms, m. p. 180—182° (from ethanol) (Found: C, 50·9; H, 5·2; N, 16·4. $C_{18}H_{23}N_5O_7$ requires C, 51·3; H, 5·5; N, 16·6%).

(*b*) *Hofmann degradation.* The amine from (*a*) above (8 g.) was kept stoppered in dry ether (10 ml.) with methyl iodide (8 g.) for 3 days. The crude methiodide (6 g.) thus obtained was shaken with an excess of silver oxide in water (100 ml.) for 3 hr. Ether (50 ml.) was added, and the mixture was filtered, acidified with dilute nitric acid, and the ether layer evaporated, to give crude 3-ethylcyclobutenecarbonitrile (XVII; R = CN) (1·8 g., 94%), b. p. 58°/12 mm., $\nu_{max.}$ 2230s (conj. CN) and 1590m cm.$^{-1}$ (conj. C:C), which was not analytically pure after distillation but was characterised as the amide. The crude nitrile (40 mg.) was dissolved in a mixture of 3% hydrogen peroxide solution (6 ml.), 10% sodium hydroxide solution (1 drop), and ethanol (3 ml.), and kept overnight. On evaporation of the ethanol, 3-*ethylcyclobutenecarboxyamide* (XVII; R = $CONH_2$) (20 mg., 43%) was obtained as platelets, m. p. 150—152° (recryst. from acetone and sublimed at 100°/10^{-3} mm.) (Found: C, 67·3; H, 8·69; N, 11·5. $C_7H_{11}NO$ requires C, 67·2; H, 8·9; N, 11·2%), $\nu_{max.}$ 3310s and 3160s (amide NH), 1665s, 1630s and 1590m cm.$^{-1}$ (amide I and II, and C:C). 3-Ethylcyclobutenecarboxyamide (200 mg.), in ethanol (10 ml.), was hydrogenated at room temperature over Adams catalyst (1 mg.) for 10 min., and absorption then abruptly ceased (35·5 ml. absorbed; calc. 36 ml.). The mixture was filtered and evaporated, to give cis-3-*ethylcyclobutanecarboxyamide* (150 mg., 74%), plates, m. p. 158—159° (recryst. from ethanol and sublimed under a vacuum) (Found: N, 11·3. $C_7H_{13}NO$ requires N, 11·0%), $\nu_{max.}$ 3300s and 3170s (amide NH), and 1660s and 1630s cm.$^{-1}$

[10] Bates, Cymerman-Craig, Moyle, and Young, *J.*, 1956, 388.
[11] Mannich and Davidsen, *Chem. Ber.*, 1936, **69**, 2106.

(amide I and II). The n.m.r. spectrum showed an unsymmetrical triplet at τ 9·2 (*C*-methyl) and broad absorption in the τ 7·4—8·8 region.

Reaction of 1-*Piperidinobutene with Methyl Acrylate.*—(*a*) 1-Piperidinobutene (8·0 g.) was refluxed in purified dioxan (10 ml.) with methyl acrylate (6 ml.) for 3 hr., to give *methyl* 3-*ethyl*-2-*piperidinocyclobutanecarboxylate* (XVI; R = CO_2Me) (9·0 g., 70%), b. p. 140—142°/14 mm., n_D^{23} 1·4715 (Found: N, 6·4. $C_{13}H_{23}NO_2$ requires N, 6·2%), $\nu_{max.}$ 1740s cm.$^{-1}$ (ester C:O), and no double-bond absorption. The *picrate* formed prisms m. p. 132—135° (from ethanol) (Found: C, 49·8; H, 5·8; N, 12·2. $C_{19}H_{26}N_4O_9$ requires C, 50·2; H, 5·8; N, 12·3%). Heating the base (0·7 g.) in saturated methanolic ammonia (7 ml.) in a sealed tube at 100° for 4 hr. gave fine needles of 3-*ethyl*-2-*piperidinocyclobutanecarboxyamide* (0·14 g., 21%), m. p. 154° (from ethanol) (Found: C, 68·6; H, 11·2; N, 12·7. $C_{12}H_{22}N_2O$ requires C, 68·5; H, 11·5; N, 13·3%), $\nu_{max.}$ 3190s (NH), and 1660s and 1645s cm.$^{-1}$ (amide I and II).

Methyl 4-(N-*Pyrrolidinylmethylene*)*hexanoate.*—Methyl 4-formylhexanoate [1] (11·5 g.) was converted in the usual way [1] in 2 hr., in benzene, with pyrrolidine (7·5 ml.), into the *pyrrolidine enamine* (9·9 g., 64%), b. p. 96—97°/0·3 mm. (Found: C, 68·0; H, 9·8; N, 6·8. $C_{12}H_{21}NO_2$ requires C, 68·2; H, 10·0; N, 6·6%), $\nu_{max.}$ 1740s (ester C:O) and 1645s cm.$^{-1}$ (NC:C).

2-(3-*Cyano*-1-*ethyl*-2-N-*pyrrolidinylcyclobutyl*)*propionamide* (XVIII; R = $CONH_2$).—Methyl 4-(*N*-pyrrolidinylmethylene)hexanoate (8·0 g.) in dry dioxan (10 ml.) was refluxed with acrylonitrile (7 ml.) for 40 hr. Distillation gave unchanged enamine (4·0 g., 50%) and a crude ester, b. p. 143°/0·05 mm. (2·8 g., 36%). The i.r. spectrum indicated that the ester had been partly converted to the pyrrolidine amide which contaminated the product. The crude ester was characterised as its amide. The ester (210 mg.) was heated for 5 hr. at 100° in a sealed tube with methanol saturated with ammonia. The *amide* (XVIII; R = $CONH_2$) (185 mg., 93%), crystallised as fine clusters from light petroleum (b. p. 40—60°) and had m. p. 119—120° (from cyclohexane) (Found: C, 67·2; H, 9·2; N, 16·3. $C_{14}H_{23}N_3O$ requires C, 67·4; H, 9·3; N, 16·5%), $\nu_{max.}$ 3320m and 3120m (amide NH), 2240w (CN), and 1660s and 1620s cm.$^{-1}$ (amide I and II). From another preparation of the crude ester (11·5 g.), hydrolysis with aqueous sodium acetate and acetic acid [1] gave methyl 6-cyano-4-ethyl-4-formylhexanoate (XIX) (3·0 g., 38%), b. p. 136—138°/0·2 mm., characterised as its 2,4-*dinitrophenylhydrazone*, prisms, m. p. 105—107° (from methanol) (Found: C, 50·8; H, 5·4; N, 18·6. $C_{16}H_{21}N_5O_6$ requires C, 50·7; H, 5·6; N, 18·5%), $\nu_{max.}$ 3290m (NH), 2250w (CN), and 1734s cm.$^{-1}$ (ester C:O).

Reaction of 1-*Piperidinobutene with Methyl Vinyl Ketone.*—(*a*) *Methyl* 3-*ethyl*-2-*piperidinocyclobutyl ketone* (XX; R = Et). 1-Piperidinobutene [11] (15·1 g.)was cooled to 0°, stirred, and methyl vinyl ketone (8·0 g.) was added dropwise during 10 min. The mixture was stirred for 1 hr. at 0° and then kept at room temperature for 12 hr., during which the enamine band at 1650 cm.$^{-1}$ disappeared. Fractional distillation gave the *ketone* (16·0 g., 70·5%), b. p. 70—72°/0·1 mm. (Found: N, 6·6. $C_{13}H_{23}NO$ requires N, 6·7%), $\nu_{max.}$ 3035w (cyclobutyl CH) and 1680s cm.$^{-1}$ (cyclobutyl C:O). There was no ultraviolet absorption above 210 mμ. The n.m.r. spectrum showed relatively unresolved bands at (i) τ 5·6—6·2, (ii) τ 7·1—7·6, (iii) τ 8·1—8·7, and (iv) τ 9·0—9·3. The areas of these bands corresponded approximately to 2 : 4 : 14 : 3. The bands were assigned as follows: (i) to the cyclobutyl protons adjacent to the nitrogen atom and carbonyl group, (ii) to the protons of the piperidine ring adjacent to the nitrogen atom, (iv) to the *C*-methyl group, and (iii) to the remainder, in particular two prominent peaks at τ 8·4 and 8·5 are probably due to the COMe group; cf. the other reaction products of enamines with methyl vinyl ketone.

(*b*) *Hofmann degradation.* The crude adduct from (*a*) above (10·0 g.) in dry ether (10 ml.) was kept stoppered with methyl iodide (30 g.) for 6 days. The mixture was shaken with water and the organic layer evaporated, to give recovered methyl 3-ethyl-2-piperidinocyclobutyl ketone (XX; R = Et) (7·2 g., crude) identified from its i.r. spectrum. The aqueous layer was treated with 10% sodium hydroxide solution (10 ml.) and extracted with ether, to give *methyl* 3-*ethylcyclobutenyl ketone* (XXI; R = Et) (0·3 g., crude, 18% based on unrecovered starting material), $\nu_{max.}$ 1680s (conj. C:O) and 1590m cm.$^{-1}$ (conj. C:C), and a weak peak, due to a contaminant, at 1720 cm.$^{-1}$ (saturated ketone and aldehyde), $\lambda_{max.}$ 235 mμ. The *semicarbazone* formed needles, m. p. 152—153° (from ethanol) (Found: C, 59·5; H, 8·1; N, 22·6. $C_9H_{15}N_3O$ requires C, 59·7; H, 8·4; N, 23·1%). The n.m.r. spectrum of the crude ketone showed a weak doublet (J = 1·5 c./sec.) at τ 0·45, and a singlet at τ 7·95 due to the aldehyde and COMe groups of the contaminant, the intensity of which indicated that it was present to an extent less than 25%. The contaminant, probably methyl 4-formylpentyl ketone was detected as its

bis-2,4-*dinitrophenylhydrazone* [which could also have arisen by hydrolysis of the cyclobutene (XXI; R = Et)], orange powder, m. p. 151—154° (from chloroform–ethanol) (Found: C, 48·1; H, 4·4; N, 21·9. $C_{20}H_{22}N_8O_8$ requires C, 47·8; H, 4·4; N, 22·3%), $\lambda_{max.}$ 355 mμ (ε 39,400); the ultraviolet spectrum distinguished the bis-2,4-dinitrophenylhydrazone from the possible alternative, methyl 3-ethyl-2-(2,4-dinitrophenylhydrazino)cyclobutyl ketone 2,4-dinitrophenylhydrazone. The n.m.r. spectrum of the crude ketone also showed absorption due to the main product, at τ 3·28 (a singlet under relatively coarse resolution) (olefin proton in a cyclobutene ring, and the C:O group), a singlet at τ 7·5 (methylene group in the cyclobutene ring), a singlet at τ 7·9 (COMe group), and an unsymmetrical triplet at τ 9·0 (*C*-methyl group).

Reaction of 1-*Piperidinopropene with Methyl Vinyl Ketone.*—(*a*) *Methyl* 3-*methyl*-2-*piperidinocyclobutyl ketone* (XX; R = Me). 1-Piperidinopropene [11] (14·0 g.) was treated with methyl vinyl ketone (8·0 g.), as for the butene analogue above, to give the *ketone* (10·1 g., 37%), b. p. 62—64°/0·1 mm. (Found: N, 7·2. $C_{12}H_{21}NO$ requires N, 7·2%), $\nu_{max.}$ 3050w (cyclobutyl CH) and 1683s cm.$^{-1}$ (cyclobutyl C:O). The n.m.r. spectrum showed the same pattern of bands as its homologue derived from 1-piperidinobutene except for a doublet (J = 6 c./sec.) centred at τ 9·1 (*C*-methyl group), in place of the broad band at τ 9·0—9·3.

(*b*) *Hofmann degradation.* The distilled adduct from (*a*) above (22·0 g.) was kept stoppered in dry ether (10 ml.) and methyl iodide (30 g.) for 17 days. Treatment as for the butene analogue gave the starting adduct (7·5 g., 76%) and methyl 3-methylcyclobutenyl ketone (XXI; R = Me) (0·64 g., crude, 45% based on unrecovered starting material), characterised as its *semicarbazone*, clusters of needles, m. p. 167—168° (from aqueous ethanol) (Found: C, 57·5; H, 7·9; N, 24·7. $C_8H_{13}N_3O$ requires C, 57·5; H, 7·8; N, 25·1%). The ketone had $\nu_{max.}$ 1675s (conj. C:O) and 1590m cm.$^{-1}$ (conj. C:C), and the n.m.r. spectrum showed no aldehyde protons, a singlet at τ 3·3 (cyclobutene olefin proton *cis* to the carbonyl group), sharp singlets at τ 7·5 and 7·9 (methylene and COMe groups), and a doublet (J = 7 c./sec.) centred at τ 8·8 (*C*-methyl group); the only remaining proton was unresolved.

(*c*) *Hydrogenation.* The distilled adduct from (*a*) above (7·0 g.) was hydrogenated at room temperature in ethyl acetate (20 ml.) over Adams catalyst (240 mg.) for 18 hr. until hydrogen uptake had considerably slowed (928 ml. absorbed; calc. 800 ml.), to give *methyl* 3-*piperidinomethyl*-*n*-*butyl ketone* (XXII) (6·2 g., 89%), b. p. 70—72°/0·5 mm. (Found: C, 73·1; H, 12·0; N, 7·0. $C_{12}H_{23}NO$ requires C, 73·1; H, 11·8; N, 7·1%), $\nu_{max.}$ 1714s cm.$^{-1}$ (sat. C:O). The n.m.r. spectrum showed broad absorption in the τ 7·6—8·8 region, with a strong singlet at τ 7·95 (COMe) and a doublet at τ 9·2 (J = 6 c./sec.) (*C*-methyl group). This product gave no crystalline derivatives and failed to undergo Hofmann elimination.

Reaction of 1-N-*Pyrrolidinylcyclohexene with Methyl* α-*Methylacrylate.*—1-*N*-Pyrrolidinylcyclohexene (12·3 g.) was mixed with methyl α-methylacrylate (9·5 ml.) and kept at room temperature for 7 days. No warming was observed and the enamine i.r. absorption was undiminished. The mixture was refluxed in dry ethanol (15 ml.) for 24 hr., to give, after hydrolysis, 2-methyl 3-(2-oxocyclohexyl)propionate (1·5 g., 10%), b. p. 147—149°/17 mm. (lit.,[1] 148—150°/18 mm.), and an acidic oil, probably the corresponding acid, b. p. 160—195°/17 mm. (7·0 g., 47%); *semicarbazone*, prisms, m. p. 169—173° (from ethanol) (Found: C, 54·5; H, 8·0. $C_{11}H_{19}N_3O_3$ requires C, 54·8; H, 8·0%).

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