hr., the mixture was acidified with 10 ml. of 20% sulfuric acid, and the methanol was removed *in vacuo*. The residue, consisting of an orange oil and a clear aqueous layer, was shaken with 50 ml. of ether. The combined ethereal extracts were washed with 3–5-ml. portions of 10% sodium carbonate solution to remove 2-phenylindane-1,3-dione, and 3–5-ml. portions of 10% sodium bisulfite solution to remove unreacted benzaldehyde. Acidification of the sodium carbonate extracts furnished 0.11 g. of 2-phenylindane-1,3-dione. The yellow ethereal solution was dried and evaporated yielding a yellow oil. Benzene (120 ml.) was added to dissolve the oil, and crystals of I (0.39 g., m.p. 231–234°) separated. The mother liquor was chromatographed through a 3.5 × 12.5 cm. column of neutral alumina. Elution consecutively with benzene (1200 ml.), 10% chloroform in benzene (150 ml.), 30% chloroform in benzene (300 ml.), 50% chloroform in benzene (300 ml.), and chloroform yielded an additional 0.22 g. of I (m.p. 239–241°). The total yield of I was 0.61 g. (14% of theory).

Similarly, *dl-threo*-3-(α-hydroxybenzyl)phthalide gave I in 14% yield.

Action of Sulfuric Acid on I. A. Isolation of *trans*-3-Benzylidenephthalide.—A red solution of 0.1 g. (0.00023 mole) of I in 1 ml. of sulfuric acid (*d* 1.84) at room temperature was poured into 5 ml. of water after 45 sec. A strong odor of benzaldehyde was noted. The mixture was cooled 1 hr. and the precipitate collected. Recrystallization from methanol furnished pale yellow crystals of *trans*-3-benzylidenephthalide (0.04 g., 80%), m.p. 98–100°. Mixture melting point with authentic material was not depressed.

B. Isolation of Benzaldehyde.—A solution of 5 g. (0.012 mole) of I in 80 ml. of sulfuric acid (*d* 1.84) was left at room temperature for 5 min., then poured over a mixture of 100 g. of ice and 100 ml. of water. The aqueous mixture was extracted with three 100-ml. portions of ether, and the ethereal extracts were washed with three 125-ml. portions of 10% sodium bisulfite solution. The bisulfite extracts were acidified with hydrochloric acid (350 ml.) and re-extracted with two 150-ml. portions of ether. This ethereal solution was then treated with a solution of 6.0 g. of 2,4-dinitrophenylhydrazine in 5 ml. of sulfuric acid, 10 ml. of water, and 20 ml. of 95% alcohol. An orange precipitate of benzaldehyde 2,4-dinitrophenylhydrazone immediately separated and was collected and recrystallized from aqueous 2-methoxyethanol (Methyl Cellosolve) furnishing 1 g. (15% yield) of benzaldehyde 2,4-dinitrophenylhydrazone, m.p. 237° dec.

C. Prolonged Sulfuric Acid Treatment.—A red solution of 0.1 g. (0.00023 mole) of I in 10 ml. of sulfuric acid became brown after 30 min. at room temperature. The solution was poured into 100 ml. of cold water and a fine yellow precipitate separated. The precipitate was water soluble and slowly decomposed on heating. The product obtained from a similar treatment of *trans*-3-benzylidenephthalide with sulfuric acid also decomposed on heating without a sharp melting point. The infrared spectra of both products were identical.

Action of Aluminum Chloride on I. A. Isolation of *trans*-3-Benzylidenephthalide.—A mixture of 3.0 g. (0.023 mole) of anhydrous aluminum chloride, 100 ml. of dry benzene, and 1.0 g. (0.003 mole) of I was stirred at room temperature for 6 hr. After standing overnight, during which time the color changed from yellow to orange, 100 ml. of hydrochloric acid (36%) was added and the benzene layer was separated and dried. Benzene was removed *in vacuo* and the orange oily residue crystallized from 95% alcohol, furnishing 0.61 g. (91%) of *trans*-3-benzylidenephthalide, m.p. 95–105°. Mixture melting point with authentic material was not depressed.

B. Isolation of Benzaldehyde.—The above reaction was repeated and the oily orange residue was dissolved in 10 ml. of 95% alcohol. The alcohol solution was treated with a solution of 0.4 g. of 2,4-dinitrophenylhydrazine, 2 ml. of sulfuric acid, 10 ml. of 95% alcohol, and 3 ml. of water, and the resulting red-orange precipitate of benzaldehyde 2,4-dinitrophenylhydrazone collected; the yield was 0.66 g. (74%), m.p. 238–239° dec.

Action of Acetic Anhydride on I.—A solution of 1.0 g. (0.003 mole) of I in 30 ml. of acetic anhydride and 2 drops of sulfuric acid (*d* 1.84) was refluxed for 15 min. The red-brown solution was cooled to room temperature and poured into 100 ml. of water. A red-brown oil separated and after 1 hr. the mixture was extracted with two 100-ml. portions of ether. The extracts were combined and dried, followed by removal of the ether *in vacuo* giving a red-brown oil which yielded crystals of III (0.57 g., 43%), m.p. 199–201° (from 95% alcohol).

Anal. Calcd. for $C_{26}H_{22}O_6$: C, 72.54; H, 5.15. Found: 72.80; H, 5.18.

Infrared absorption (Nujol) was observed at 1730–1800 (acetate and lactone carbonyl absorption region) and 1215–1245 cm.$^{-1}$ (acetate ethereal oxygen). Ultraviolet absorption (ethanol) follows: 283 mμ (log ϵ 3.16), 276 (3.16), 268 (3.11), 264 (3.10), 262 (3.05), 258 (3.07), and 228 (4.02).

Lithium Aluminum Hydride Reduction of I.—A mixture of 0.3 g. (0.0079 mole) of lithium aluminum hydride in 150 ml. of ether (distilled from lithium aluminum hydride) was treated with 1.0 g. (0.003 mole) of I and refluxed with stirring for 5 hr. Excess lithium aluminum hydride was decomposed by addition of methanol, and the mixture was poured into 50 ml. of 20% sulfuric acid. Evaporation of the ether layer left a white crystalline product which was recrystallized from benzene–heptane furnishing 0.88 g. of IV, m.p. 186–187°.

Anal. Calcd. for $C_{29}H_{26}O_4$: C, 79.43; H, 5.98. Found: C, 79.88; H, 6.15.

Infrared absorption (Nujol) was observed at 3200 and 3500 cm.$^{-1}$ (hydroxyl) and no absorption was found in the carbonyl region (1650–1800 cm.$^{-1}$). Ultraviolet spectrum (ethanol) follows: 267 mμ sh (log ϵ 2.56), 264 (2.78), 261 (2.74), 257 (2.85), and 250 (2.72).

Chromium Trioxide Oxidation of IV.—A solution of 0.1 g. of IV in 1 ml. of acetic acid was treated with 1 ml. of acetic acid containing 0.01 g. (0.0001 mole) of chromium trioxide. The mixture was boiled for 1 min. and the green solution cooled, yielding white needles of I, 0.04 g., m.p. 220–224°. Mixture melting point with authentic I was not depressed.

Unsaturated Lactams from Ketones and Acrylonitrile

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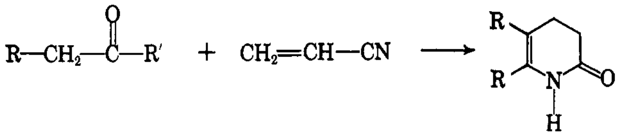
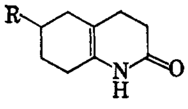
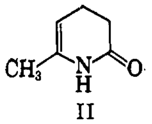
Ketones are known to react with acrylonitrile in the presence of an amine–acid catalyst to give good yields of α-monocyanoethyl ketones.[1] We wish to report a novel modification of this reaction whereby γ,δ-unsaturated lactams are formed in one step from a ketone and acrylonitrile when the reaction is carried out at elevated temperature in the presence of a trace amount of water.



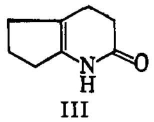
The following compounds have been prepared in this way: 1,2,3,4,5,6,7,8-octahydro-2-quinolone (Ia, 79% from cyclohexanone); 6-methyl-1,2,3,4,5,6,7,8-octahydro-2-quinolone (Ib, 55% from 4-methylcyclohexanone); 6-methyl-1,2,3,4-tetrahydro-2-pyridone (II, 15% from acetone); and 1,2,3,4,5,6,7-hexahydro-5H-1-pyrind-2-one (III, 18% from cyclopentanone). The



Ia, R = H
Ib, R = CH₃



II



III

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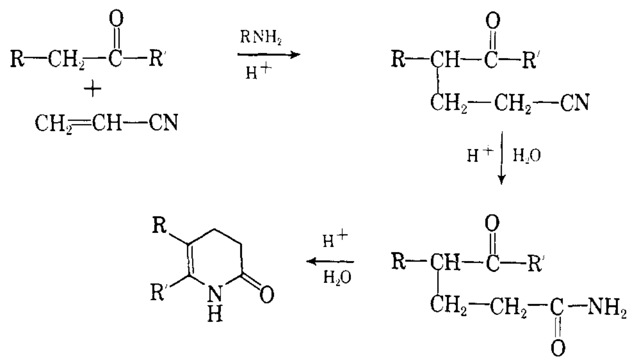
[1] H. Krimm, U. S. Patent 2,850,519 (1958).

structures of all compounds were confirmed by elemental analyses and infrared and n.m.r. spectra.

The reaction path involves formation of the α-monocyanoethyl ketone, hydrolysis to the amide, and cyclodehydration to the γ,δ-unsaturated lactam.



Thus, Ia can be formed either by heating 2-(2′-cyanoethyl)cyclohexanone with a trace of 90% sulfuric acid or 50% acetic acid or by heating 2-(2′-ketocyclohexyl)propionamide with a trace of 100% sulfuric acid or glacial acetic acid.

Experimental

1,2,3,4,5,6,7,8-Octahydro-2-quinolone (Ia).—A mixture of cyclohexanone (1960 g., 20 moles), technical acrylonitrile (1060 g., 20 moles), cyclohexylamine (101 g., 1.02 moles), and glacial acetic acid (23 g., 0.34 moles) were heated with vigorous stirring. At 90°, a strongly exothermic reaction occurred; when the exotherm had subsided, heating was resumed and the mixture was maintained at 200° for 4 hr.

The product was vacuum distilled to give 2360 g. (79%) of Ia, b.p. 150–152° (1 mm.). Recrystallization from methanol–water gave white needles, m.p. 144–145° (lit.[2,3] m.p. 143–144°, 144°).

The infrared spectrum contained strong absorptions at 1680 and 1640 cm.$^{-1}$. The n.m.r. spectrum showed an NH absorption at 9.4 p.p.m., no bridgehead absorption in the 3–5-p.p.m. region, and a ratio of NH to protons of 1:12.

Anal. Calcd. for $C_9H_{13}NO$: C, 71.48; H, 8.67; N, 9.26. Found: C, 71.48; H, 8.83; N, 9.18.

6-Methyl-1,2,3,4,5,6,7,8-octahydro-2-quinolone (Ib).—A mixture of 4-methylcyclohexanone (100 g., 0.89 mole), technical acrylonitrile (47 g., 0.89 mole), 4-methylcyclohexylamine (5 g.), and 50% acetic acid (2 ml.) was heated with vigorous stirring. After a mild exotherm at 90°, the mixture was heated to 200° for 4 hr. Upon cooling, a yellow solid mass formed. The solid was recrystallized from ethanol to give 75 g. (50%) of Ib, m.p. 138–139°. No attempt was made to obtain a second crop of product.

The infrared and n.m.r. spectra showed the same significant features as Ia and were consistent with the proposed structure.

Anal. Calcd. for $C_{10}H_{15}NO$: C, 72.69; H, 9.15; N, 8.48. Found: C, 72.54; H, 9.30; N, 8.70.

6-Methyl-1,2,3,4-tetrahydro-2-pyridone (II).—A mixture of acetone (116 g., 2.0 mole), acrylonitrile (53 g., 1.0 mole), ammonium acetate (3.8 g., 0.05 mole), and 3 ml. of 29% aqueous ammonia was charged into a 300-ml. pressure vessel. The vessel was placed in an oil bath at 225°. Pressure rose rapidly to 350 p.s.i.g. and fell slowly; after 40 min., the pressure was constant at 280 p.s.i.g. The vessel was cooled to room temperature and the reaction mixture was distilled. After a forerun of acetone, a fraction was collected at 95–100° (9 mm.).

The distillate was chilled in ice and the precipitated solid was filtered. Recrystallization from ethanol gave 16.6 g., (15%) of II, m.p. 119–120°.

The infrared spectrum contained strong absorption at 1685 and 1635 cm.$^{-1}$. The n.m.r. spectrum showed olefinic absorption at 5.5 p.p.m. and was otherwise consistent with the proposed structure.

Anal. Calcd. for C_6H_8NO: C, 72.06; H, 8.06; N, 14.01. Found: C, 72.02; H, 8.14; N, 14.20.

The mother liquor was redistilled at 108–110° at 14 mm. to give 55 g. (50%) of 5-oxohexanenitrile (lit.[4] b.p. 108–112° at 14 mm.). The identity was confirmed by comparison of its infrared spectrum with that of an authentic sample.

1,2,3,4,6,7-Hexahydro-5H-1-pyrind-2-one (III).—A mixture of cyclopentanone (84 g., 1.0 mole), acrylonitrile (53 g., 1.0 mole), ammonium acetate (3.8 g., 0.05 mole), and 3 ml. of 29% aqueous ammonia were charged into a 300-ml. pressure vessel. The vessel was placed in an oil bath at 220°. Pressure rose rapidly to 125 p.s.i.g. and fell slowly; after 30 min., the pressure was constant at 100 p.s.i.g. The product was worked up in the same way as the previous run to give 23 g. (18%) of III, m.p. 103.5–105°, and 20 g. (17%) of 2-(2′-cyanoethyl)cyclopentanone, b.p. 98–100° at 1 mm. (lit.[1] b.p. 98–105° at 0.9 mm.).

The infrared spectrum contained strong absorption at 1690 and 1640 cm.$^{-1}$. The n.m.r. spectrum contained no bridgehead proton absorption in the 3–5-p.p.m. region and was consistent with the proposed structure.

Anal. Calcd. for $C_8H_{11}NO$: C, 70.04; H, 8.08; N, 10.21. Found: C, 70.25; H, 8.12; N, 10.25.

Cyclization of 2-(2′-Cyanoethyl)cyclohexanone.—Samples (15.1 g., 0.1 mole) were heated at 200° for 4 hr. with the following catalysts: 1 ml. of glacial acetic acid, 1 ml. of concentrated sulfuric acid, 1 ml. of 50% acetic acid, and 1 ml. of 90% sulfuric acid. No change was observed with the first two, while essentially quantitative yields of Ia were obtained with the latter two.

Cyclization of 2-(2′-Ketocyclohexyl)propionamide.—Samples (16.9 g., 0.1 mole) were heated at 200° for 4 hr. with the same catalysts as the previous experiment. In all cases, essentially quantitative yields of Ia were obtained.

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An Improved Procedure for the Preparation of 2-Alkyl-5-carbethoxycyclopentanone

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2-Alkyl-5-carbethoxycyclopentanones are usually made through Dieckmann condensation of ethyl 2-alkyladipates which are prepared from 2-carbethoxycyclopentanones *via* 2-alkyl-2-carbethoxycyclopentanones.[1]

This paper describes an improved procedure for the preparation of 2-alkyl-5-carbethoxycyclopentanones from 2-alkyl-2-carbethoxycyclopentanones.

When ethyl 2-methyladipate was prepared from 2-methyl-2-carbethoxycyclopentanone[2,3] by treatment with a catalytic amount of sodium ethoxide in absolute ethanol,[3] the product, ethyl 2-methyladipate, was observed to be contaminated with 2-methyl-5-carbethoxycyclopentanone.[4] According to the present investigation, it was found that when 2-methyl-2-carbethoxycyclopentanone (I) was treated with equimolar sodium ethoxide in absolute ethanol, 2-methyl-5-carbethoxy-

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[4] For 2-methyl-2-carbethoxycyclohexanone, see D. K. Banerjee and S. N. Mahapatra, *Tetrahedron*, **11**, 234 (1960).