# By-products of the Robinson Annelation Reaction with Cyclohexanone, Cyclopentanone, and Cyclopentane-1,2-dione[1]

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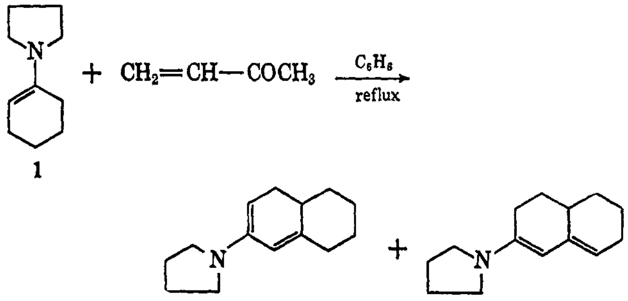
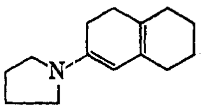
Reaction of the pyrrolidine enamine of cyclohexanone with methyl vinyl ketone was found to yield, in addition to the expected enamines of $\Delta^{1,9}$-octal-2-one, the saturated diketone **5**. Syntheses for 2,6-bis(3-keto-1-butyl)-cyclohexanone, a precursor for diketone **5**, and 2,5-bis(3-keto-1-butyl)cyclopentanone are described. The Robinson annelation reaction, which was successful with cyclopentanone, failed with cyclopentane-1,2-dione and cyclohexane-1,2-dione and the alternative products **27**, **28**, and **32** were isolated.

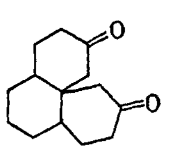
The Robinson annelation reaction[3] may yield, in addition to the expected cyclohexenone derivatives, bridged bicyclic compounds[4]; the presence of or absence of these by-products is often dependent on the reaction conditions. From a modification of this annelation reaction in which an enamine[5] serves as the active methylene component, the product mixture from the enamine **1** and methyl vinyl ketone was found[6] to contain both the expected octalones **6** and **7** and other products including a ketol and both stereoisomeric 2-decalones. The latter saturated ketones were believed[6] to arise from disproportionation of the intermediate enamine which has been suggested[5a] to have structure **3**. In the course of other work we have been led to examine annelation reactions with cyclohexanone, cyclopentanone, cyclopentane-1,2-dione, and cyclohexane-1,2-dione and report here the results of these studies.



**1** **2** **3**

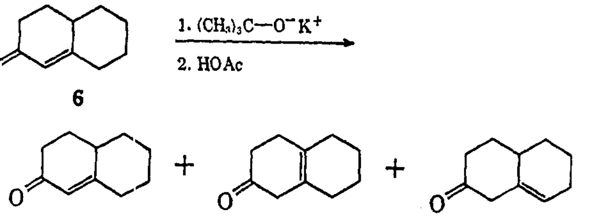


**4**



**5**

From the previously described[5a,6] reactions of 1-(1-pyrrolidino)cyclohexene (**1**) with methyl vinyl ketone, the enamine product separated by distillation had n.m.r. absorption (see Experimental) indicative of at least three types of vinyl protons. Hence, it is clear that this product is a mixture of isomeric enamines rather than the single isomer **3** previously suggested.[5a] The positions and areas of the n.m.r. peaks suggest that the mixture contains about 30% of enamine **2** and 65–70% of the isomer **3**; it is possible that 5–10% of the isomer **4** may also be present. When this crude reaction mixture was hydrolyzed prior to isolation, the previously reported mixture[5a,6,7] of the $\Delta^{1,9}$-octalone **6** (*ca.* 90%) and the $\Delta^{9,10}$ isomer **7** (*ca.* 10%) was obtained. Treatment of this octalone mixture with acid resulted in partial isomerization of the $\Delta^{9,10}$ isomer **7** to the conjugated ketone **6** (97% of the mixture after isomerization). The $\Delta^{8,9}$-octalone **8** was not detected by n.m.r. measurements on any of these unsaturated ketone mixtures.



**6** **6** **7** **8**

In an ancillary experiment, the octalone **6** was converted to its enolate anion and then quenched in acetic acid[8] to yield a mixture of octalones **6–8**. From the n.m.r. absorption (see Experimental) of the mixture, we estimate its approximate composition to be **6**, 15%; **7**, 30%; and **8**, 55%. Thus, in agreement with other product studies,[9] it would appear that the hexahydronaphthalene system of either an enolate anion or an enamine derived from a 2-ketone (*i.e.*, **6**) is most stable with the double bonds in the 1,2- and 8,9-positions (as in **3**) but other structural isomers are also present. The octalone mixture **6–8** was observed to isomerize on standing to a mixture in which only isomers

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[3] (a) E. C. duFeu, F. J. McQuillin, and R. Robinson, *J. Chem. Soc.*, 4060 (1937); (b) J. H. Brewster and E. L. Eliel, *Org. Reactions*, **8**, 99 (1953).

[4] (a) M. S. Julia, *Bull. soc. chim. France*, 780 (1954); (b) W. S. Johnson, J. J. Korst, R. A. Clement, and J. Dutta, *J. Am. Chem. Soc.*, **82**, 614 (1960); (c) W. G. Dauben and J. W. McFarland, *ibid.*, **82**, 4245 (1960); (d) T. A. Spencer, K. K. Schmiegel, and R. L. Williamson, *ibid.*, **85**, 3785 (1963); (e) R. D. Sands, *J. Org. Chem.*, **28**, 1710 (1963).

[5] (a) G. Stork, A. Brizzolara, H. Landesman, J. Szmuszkovicz, and R. Terrell, *J. Am. Chem. Soc.*, **85**, 207 (1963); (b) J. Szmuszkovicz, *Advan. Org. Chem.*, **4**, 1 (1964).

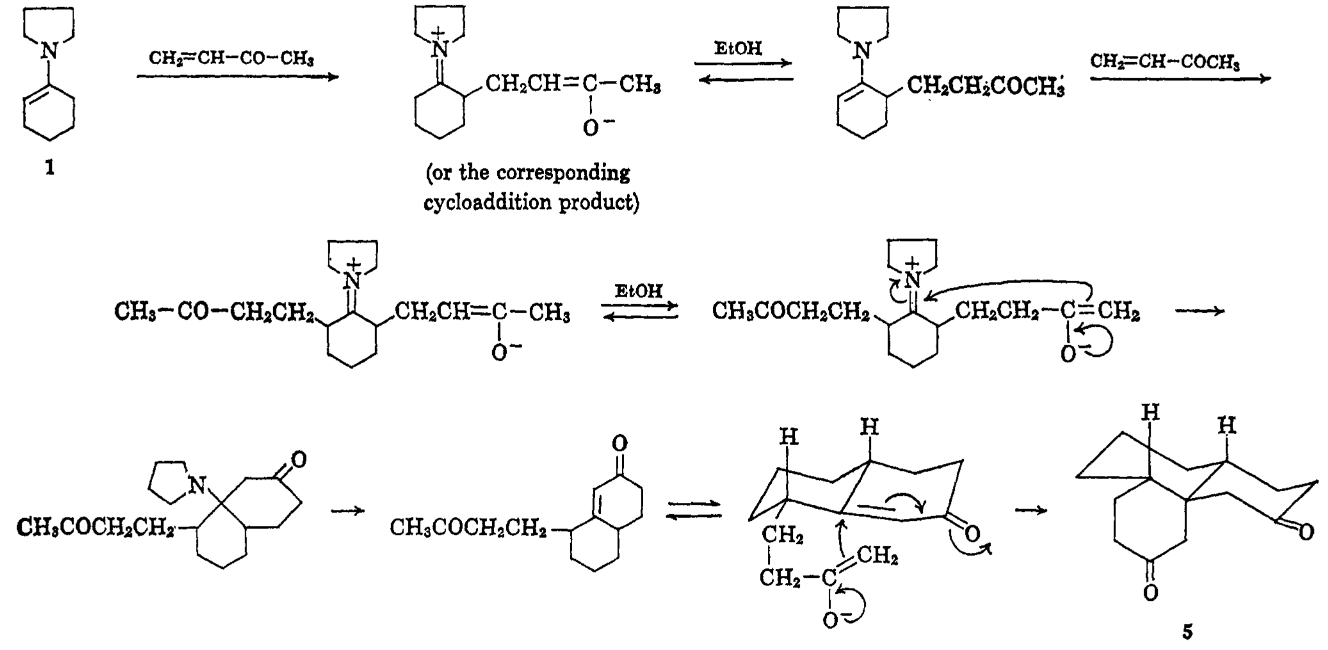
[6] R. L. Augustine and H. V. Cortez, *Chem. Ind.* (London), 490 (1963); also see T. A. Spencer and K. K. Schmiegel, *ibid.*, 1765 (1963).

[7] D. J. Baisted and J. S. Whitehurst, *J. Chem. Soc.*, 4089 (1961).

[8] The procedure of H. J. Ringold and S. K. Malhotra, *J. Am. Chem. Soc.*, **85**, 1538 (1963); H. J. Ringold and S. K. Malhotra, *Tetrahedron Letters*, **No. 15**, 669 (1962).

[9] (a) R. Bucourt, J. Tessier, and G. N. Nominé, *Bull. soc. chim. France*, 1923 (1963); (b) G. Just and F. E. Shortland, *Can. J. Chem.*, **42**, 470 (1964); (c) B. E. Edwards and P. N. Rao, *Angew. Chem.*, **76**, 795 (1964); (d) R. E. Ireland and L. N. Mander, *Tetrahedron Letters*, **No. 46**, 3453 (1964); (e) R. Sciaky and F. Mancini, *ibid.*, *No.* **2**, 137 (1965).

SCHEME I



1

5

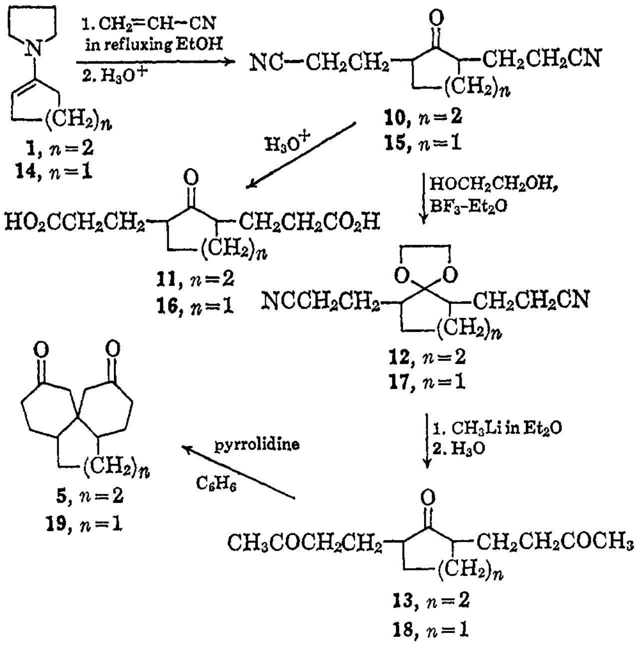
6 and 7 were detected, suggesting that unconjugated ketone 8 is less stable than its $\Delta^{9,10}$ isomer, compound 7.

In no case did we isolate from the reaction of the enamine 1 with methyl vinyl ketone either the previously reported[6a] disproportionation product, 2-decalone, or the other expected disproportionation product, 6-(1-pyrrolidino)-1,2,3,4-tetrahydronaphthalene. The reason for these differing results is not apparent to us. In seeking possible by-products formed during the preparation of enamines 2–4, we isolated from the distillation residue, after hydrolysis, a crystalline compound, m.p. 161–162°, which was subsequently shown to have structure 5. The yield of this diketone 5 could be increased to above 50% if the reaction of the enamine 1 with methyl vinyl ketone was effected either in ethanol solution or in the absence of a solvent.

The spectral properties of the product 5 established the presence of one or more saturated carbonyl functions and the absence of carbon–carbon double bonds and methyl groups. A negative tetranitromethane test and failure to absorb hydrogen over a platinum catalyst also attest to the absence of carbon–carbon double bonds. Treatment of either the enamine mixture 2–4 or the unsaturated ketone 6 with methyl vinyl ketone under a variety of conditions failed to yield the diketone 5 indicating that compounds 2–4 and 6 were not precursors of the by-product. Consideration of probable reaction paths for the reactants suggested the likelihood of the diketone structure 5 for this by-product as illustrated in Scheme I.[10] The enhanced yield in ethanol is in agreement with such a pathway since use of this solvent is known to promote the formation of 2,6- and 2,5-disubstituted Michael products from cyclohexanone and cyclopentanone enamines.[6a,11]

To establish the correctness of this carbon skeleton, we elected to synthesize the diketone 5 from the triketone 13 whose preparation is illustrated in Scheme II. The same synthetic procedure was also used for the cyclopentanone derivative 18. Although the usual ketalization conditions (ethylene glycol and *p*-toluenesulfonic acid in refluxing benzene) failed to form ketals 12 and 17 from the hindered ketones 10 and 15, the alternative procedure[12] employing boron trifluoride etherate in excess ethylene glycol was very effective. Reaction of the nitriles 12 and 17 with methylmagnesium bromide led to rather complex mixtures, possibly because precipitation of insoluble intermediates pre-

SCHEME II



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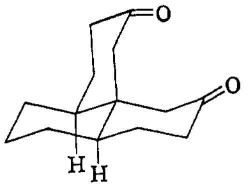
[10] Similar ring systems have been formed in heterocyclic series: (a) H. J. Backer and G. L. Wiggerink, *Rec. trav. chim.*, **60**, 453 (1941); (b) I. N. Nazarov, G. A. Shvekhgeimer, and V. A. Rudenko, *Zh. Obshch. Khim.*, **24**, 319 (1954); *Chem. Abstr.*, **49**, 4652 (1955).

[11] (a) T. L. Westman, R. Paredes, and W. S. Berg, *J. Org. Chem.*, **28**, 3512 (1963); (b) T. L. Westman and A. E. Kober, *ibid.*, **29**, 2448 (1964); (c) L. Mandell, B. A. Hall, and K. P. Singh, *ibid.*, **29**, 3067 (1964).

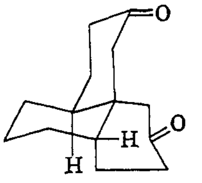
[12] (a) W. J. Adams, D. N. Kirk, D. K. Patel, V. Petrow, and J. A. Stewart-Webb, *J. Chem. Soc.*, 2298 (1954); (b) D. N. Kirk, D. K. Patel, and V. Petrow, *ibid.*, 1046 (1957).

vented complete reaction. However, reaction with methyllithium followed by acid hydrolysis of the intermediate ketal diimines produced the triketones **13** and **18** in good yield. Reaction of the triketone **13** with pyrrolidine in refluxing benzene produced the diketone **5** in 97% yield.

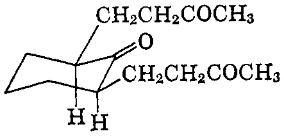
Three stereochemical arrangements are possible for the diketone **5**, namely, the isomer **5a** with one *cis* and one *trans* ring fusion, the isomer **5b** with two *cis* ring fusions, and the isomer **5c** with two *trans* ring fusions. Although isomers **5a** and **5b** can both adopt the relatively stable all-chair conformations indicated, the *trans,trans* isomer **5c** can only be formed with the introduction of substantial strain. The ease with which diketone **5** is formed *via* presumably reversible reactions therefore argues against stereoisomer **5c**. Furthermore, it would seem reasonable to suppose that the more stable diequatorial epimer **13a** of the triketone **13** serves as the precursor of **5** and, hence, should lead to isomer **5a** rather than **5b** or **5c**. Finally, the last step in the formation of **5** is believed to be the intramolecular Michael reaction indicated in Scheme I in which the enolate anion would be expected[13] to add to the conjugated system from an axial direction to form isomer **5a**. Further evidence indicating the correctness of the stereochemistry **5a** was obtained by reduction of the diketone with sodium borohydride. The resulting diol, believed to be **9** resulting from the reduction of each of the carbonyl groups in **5a** from the less hindered side, has infrared absorption (see Experimental) establishing the presence of an *intramolecular* hydrogen bond. This observation clearly excludes isomer **5b** since the oxygen functions of the corresponding diol are too far apart to permit intramolecular hydrogen bonding. Although we are unable to exclude rigorously the stereochemistry **5c** for the diketone, we believe the foregoing arguments make the stereochemistry **5a** for the diketone very probable.



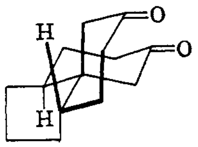
**5a**



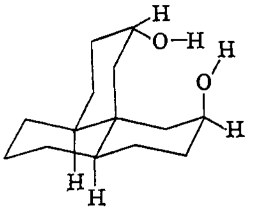
**5b**



**13a**

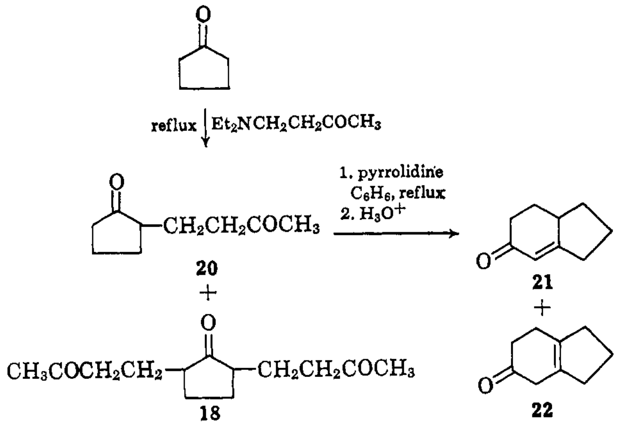


**5c**



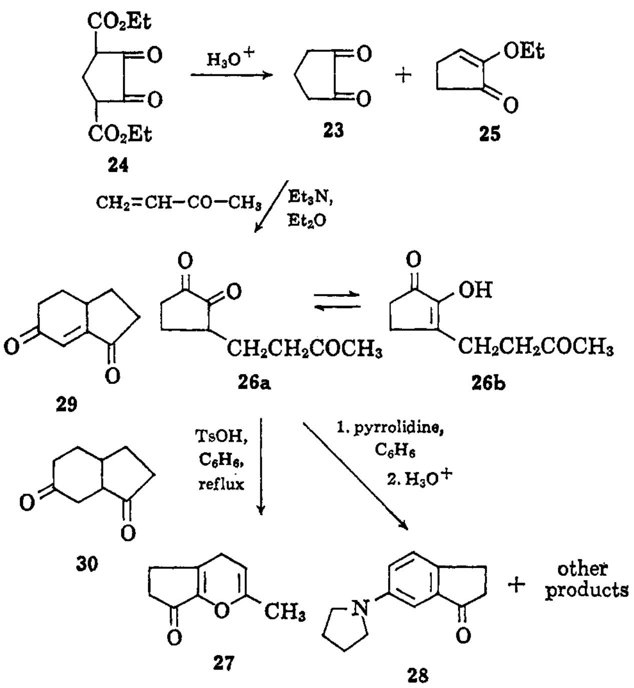
**9**

In exploring preparative routes for the tetrahydroindanone **21**[14] we found that refluxing a mixture of cyclopentanone and 1-diethylamino-3-butanone yielded a mixture of the diketone **20**[15] and the triketone **18**, presumably from formation and reaction of the diethylamino enamine of cyclopentanone with methyl vinyl ketone in the reaction vessel. Reaction of the diketone **20** with pyrrolidine in refluxing benzene yielded a mixture of the unsaturated ketones containing **21** (*ca.* 95%) and **22** (*ca.* 5%). Reaction of the triketone **18** with pyrrolidine in refluxing benzene afforded an unstable liquid product believed to be one or more of the stereoisomers of diketone **19**; however, we were unable to isolate a pure product.



Cyclopentane-1,2-dione (**23**) was prepared as previously described[16]; acid-catalyzed hydrolysis of the diester **24** yielded a mixture of the diketone **23** and the enol ether **25** (Scheme III). Reaction of the diketone

Scheme III



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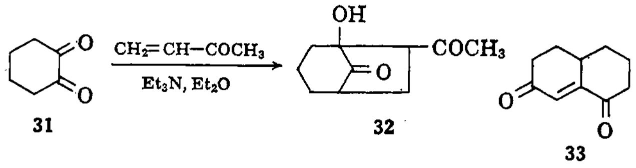
(13) (a) D. H. R. Barton, A. D. S. Campos-Neves, and A. I. Scott, *J. Chem. Soc.*, 2698 (1957); (b) W. S. Johnson, S. Shulman, K. L. Williamson, and R. Pappo, *J. Org. Chem.*, **27**, 2015 (1962).

(14) For previous preparations of this ketone, see (a) ref. 5a; (b) V. Prelog and M. Zimmerman, *Helv. Chim. Acta*, **32**, 2360 (1949); (c) E. D. Bergmann and R. Corett, *J. Org. Chem.*, **23**, 1507 (1958).

(15) For previous preparations of this diketone, see (a) N. S. Gill, K. B. James, F. Lions, and K. T. Patts, *J. Am. Chem. Soc.*, **74**, 4923 (1952); (b) N. C. Ross and R. Levine, *J. Org. Chem.*, **29**, 2341 (1964).

(16) (a) R. M. Acheson, *J. Chem. Soc.*, 4232 (1956); (b) G. Esse and E. Bucking, *Ann.*, **563**, 31 (1949).

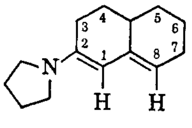


**31** **32** **33**

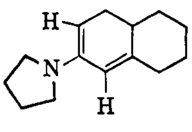
**23** with methyl vinyl ketone, catalyzed by triethylamine, produced the triketone **26** which was obtained as the enol form **26b**. A variety of attempts to cyclize the triketone **26** to the enedione **29** were unsuccessful. With acid catalysis,[17] the pyran **27** was the only product isolated. Attempts to effect cyclization of the triketone **26** with pyrrolidine led to a complex mixture from which the only pure product isolated was the indanone **28**. A partially purified product believed to be the saturated diketone **30** was also separated. Thus, disproportionation and/or air oxidation of the intermediate enamine was apparently observed in this case. The comparable reaction of cyclohexane-1,2-dione (**31**) with methyl vinyl ketone in the presence of triethylamine produced the hydroxy diketone **32** directly. A variety of efforts to convert this adduct **32** to the enedione **33** were unsuccessful.

## Experimental[18]

**Reaction of 1-(1-Pyrrolidino)cyclohexene (1) with Methyl Vinyl Ketone.**—Methyl vinyl ketone (21 g., 0.30 mole) was added, with stirring under a nitrogen atmosphere, to a solution of 48 g. (0.32 mole) of the pyrrolidine enamine **1**[5a] in 200 ml. of benzene. After the initial, vigorous reaction had subsided, the solution was refluxed overnight and then concentrated under reduced pressure. Distillation of the residual yellow-brown liquid afforded 47.58 g. (78.2%) of fractions containing mixtures of enamines **2–4**: (1) 3.63 g., b.p. 120–130° (3 mm.); (2) 3.85 g., b.p. 130–138° (3 mm.); and (3) 40.10 g., b.p. 138–140° (3 mm.) [b.p. 146–150° (0.3 mm.) is reported[5a] for a comparable product assigned structure **3**]. Redistillation of the latter fraction afforded a pale yellow liquid, $n^{22}\mathrm{D}$ 1.5808, which solidified when cooled below room temperature. This product has infrared absorption[19] at 1710 (weak, C=C or C=O impurity), 1655 (weak), 1630, and 1595 cm.$^{-1}$ (C=C, lit.[5a] 1630 and 1600 cm.$^{-1}$). The mass spectrum of the material has weak peaks at *m/e* 205, 204, 203, and 202 (the molecular ion from enamines **2–4** should be at *m/e* 203) with abundant peaks at *m/e* 201, 200, 173, 145, 91, 79, 51, 43, 41, and 39, suggesting that the sample has undergone substantial disproportionation and/or dehydrogenation in the heated inlet system. In agreement with this idea, the spectrum was found to change with time. The n.m.r. spectrum[20] has a broad peak (half-band width, 8.5 c.p.s.) at $\delta$ 5.07, a peak (half-band width, 2.5 c.p.s.) at $\delta$ 4.83, and a peak (half-band width, 3 c.p.s.) at $\delta$ 4.29 as well as complex multiplets in the regions $\delta$ 2.9–3.3 and 1.1–2.5. The areas of peaks at $\delta$ 5.07, 4.83, and 4.29 are in the ratio 0.67:1.0:0.30 (average values from two runs). The relatively sharp peak at $\delta$ 4.83 is believed attributable to the proton at C-1 in any of the enamine isomers **2–4**. The higher field peak at $\delta$ 4.29 is tentatively assigned to the proton at C-3[21] in isomer **2** and the peak at $\delta$ 5.07 is tentatively assigned to the proton at C-8 in isomer **3**.[22] Thus, the product is clearly a mixture of isomeric enamines and would appear to contain 65–70% of the isomer **3**, *ca.* 30% of the isomer **2**, and possibly a small amount of the isomer **4**.



**3**



**2**

From a comparable preparation where the crude product was hydrolyzed with an acetate buffer[23] prior to isolation, a mixture of octalones **6** and **7** (74% yield) was obtained as a colorless liquid: b.p. 85–86° (1 mm.), $n^{24.5}\mathrm{D}$ 1.5232 [lit.[5a] b.p. 135–138° (15 mm.)]. This mixture contained[24] the conjugated octalone **6** (*ca.* 90%, second eluted) and the unconjugated isomer **7** (*ca.* 10%, first eluted). The n.m.r. spectrum[25] of this mixture has a peak (half-band width, 4 c.p.s.) at $\delta$ 5.60 (*ca.* 90% of 1H, vinyl C–H of octalone **6**) with complex absorption in the region $\delta$ 1.0–3.0 (aliphatic C–H), but lacks absorption at $\delta$ 5.36 attributable to the vinyl proton of the subsequently discussed octalone **8**. When a solution of this octalone mixture (**6** and **7**) in ethanol containing 5% aqueous hydrochloric acid was stirred at room temperature, it was rapidly isomerized to a mixture containing[24] 97% of the conjugated ketone **6** and 3% of the unconjugated isomer **7**.

The residue remaining after the initial distillation of the above enamines was dissolved in a mixture[23] of water, acetic acid, and sodium acetate and the resulting mixture was refluxed for 4 hr. After the reaction mixture had been cooled, acidified with hydrochloric acid, and extracted with ether, the ethereal extract was dried and concentrated. An ethanol solution of the residue deposited 1.5 g. of the **diketone 5** as white needles, m.p. 161–162°. An additional 1.1 g. of the same diketone **5**, m.p. 156–159°, was recovered from the mother liquors. No other pure substances were isolated from the various neutral and basic fractions of the hydrolyzed residue.

The diketone **5** has infrared absorption[19] at 1712 cm.$^{-1}$ (C=O) with no absorption in the 3-$\mu$ region attributable to a hydroxyl function; the material has ultraviolet maxima[26] at 243 m$\mu$ ($\epsilon$ 32) and 287 m$\mu$ ($\epsilon$ 45) with $\epsilon$ 122 at 210 m$\mu$. The n.m.r. spectrum[4] of the material consists of a complex multiplet in the region $\delta$ 1.1–2.7 with no evidence for either a C-methyl groups or a vinyl C–H. An ethanol solution of the diketone **5** over the catalyst from platinum oxide absorbed no hydrogen.

*Anal.* Calcd. for $C_{14}H_{20}O_2$: C, 76.32; H, 9.15; mol. wt., 220. Found: C, 76.08; H, 9.07; mol. wt., 212 (vapor pressure in benzene), 220 (mass spectrum).

No evidence for the formation of the diketone **5** was found from reaction of the enamines **2–4** with methyl vinyl ketone in refluxing benzene, from the reaction of cyclohexanone with methyl vinyl ketone and potassium *t*-butoxide in 1,2-dimethoxyethane, or from the reaction of $\Delta^{1,9}$-octal-2-one (**6**) with methyl vinyl ketone and pyrrolidine in refluxing benzene. However, the yield of the diketone **5** could be increased substantially by use of one of the following procedures. The enamine **1** (3.0 g., 2.0 mmoles) was added, dropwise and with stirring under a nitrogen atmosphere, to 2.8 g. (4.0 mmoles) of pure methyl vinyl ketone. After the initial vigorous reaction had subsided, the mixture was heated to 90° for 1 hr. and then diluted with 6 ml. of benzene and refluxed overnight. After 5 ml. of aqueous acetate buffer[23] had been added, the resulting mixture was refluxed for 4 hr. The organic layer was separated, dried, and concentrated. Recrystallization of the residue from isopropyl alcohol afforded 2.2 g. (51%) of the diketone **5**, m.p. 160–162°, identified with the previous sample by comparison of infrared spectra.

A solution of 15.1 g. (0.10 mole) of the enamine **1** and 18.0 g. (0.30 mole) of methyl vinyl ketone in 35 ml. of absolute ethanol was refluxed for 4 hr., mixed with 15 ml. of acetate buffer,[23] and refluxed for an additional 2 hr. The resulting mixture was concentrated under reduced pressure, diluted with water, and ex-

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[17] *Cf.* C. B. C. Boyce and S. S. Whitehurst, *J. Chem. Soc.*, 2022 (1959).

[18] All melting points are corrected and all boiling points are uncorrected. Unless otherwise stated magnesium sulfate was employed as a drying agent. The infrared spectra were determined with a Perkin-Elmer Model 237 infrared recording spectrophotometer fitted with a grating. The ultraviolet spectra were determined with a Cary recording spectrophotometer, Model 14. The n.m.r. spectra were determined at 60 Mc. with a Varian Model A-60 n.m.r. spectrometer. The mass spectra were obtained with a CEC Model 21-120 mass spectrometer. The microanalyses were performed by Dr. S. M. Nagy and his associates and by the Scandinavian Microanalytical Laboratory.

[19] Determined as a solution in chloroform.

[20] Determined as a solution in deuteriochloroform.

[21] The C-2 proton in 6-methyl-1-(1-pyrrolidino)cyclohexene is found at $\delta$ 4.21: H. O. House and M. Schellenbaum, *J. Org. Chem.*, **28**, 34 (1963).

[22] The n.m.r. signals for the C-2 and C-4 vinyl protons of 1-diethylamino-1,3-butadiene are found in the region $\delta$ 4.2–5.2, whereas the vinyl protons at C-1 and C-3 give rise to n.m.r. peaks in the region $\delta$ 5.8–6.2: G. A. Berchtold and J. Ciabattoni, unpublished work.

[23] The proportions used in this solution were 25 ml. of water, 25 ml. of acetic acid, and 12.5 g. of sodium acetate.

[24] A gas chromatography column packed with Ucon Polar suspended on Chromosorb P was employed.

[25] Determined as a solution in carbon tetrachloride.

[26] Determined as a solution in 95% ethanol.

tracted with ether. After this ethereal solution had been dried and concentrated, recrystallization of the residue from isopropyl alcohol afforded 11.5 g. (52%) of the diketone **5**, m.p. 159–162°.

**Deconjugation of $\Delta^{1,9}$-Octal-2-one.**—To a solution of potassium *t*-butoxide, prepared from 8.27 g. (0.221 g.-atom) of potassium and 170 ml. of *t*-butyl alcohol, was added 3.00 g. (0.020 mole) of the octalone **6** (containing *ca.* 10% of the isomer **7**). The mixture was stirred for 1.5 hr. and then poured into 750 ml. of cold (0°) 10% aqueous acetic acid.[8] The resulting mixture was partially neutralized with sodium bicarbonate and then extracted with ether. The ethereal extract was concentrated, neutralized with excess aqueous sodium bicarbonate, taken up in ether, dried, and concentrated. Distillation of the residue afforded 1.901 g. (63.3% recovery) of fractions, b.p. 55–60° (0.3 mm.). The distillate has infrared absorption[25] at 1720 (unconjugated $C=O$), 1675 (conjugated $C=O$), and 1615 cm.$^{-1}$ (conjugated $C=C$) with n.m.r. peaks[25] at δ 5.60 (half-band width, 4 c.p.s.) and 5.36 (half-band width, 9 c.p.s.) as well as a multiplet in the region δ 2.7–3.0 and a complex multiplet in the region δ 1.0–2.7. The following assignments apppear to be appropriate: C-1 vinyl proton of **6**, δ 5.60; C-8 vinyl proton of **8**, δ 5.36; C-1 methylene group of **7** and **8**, δ 2.7–3.0 multiplet. If these assignments are correct, the composition of the mixture can be estimated to be 15% of **6**, 30% of **7**, and 55% of **8** from the areas under the various peaks.

**Preparation of the Diol 9.**—A solution of 1.00 g. (4.55 mmoles) of the diketone **5** and 555 mg. (14.5 mmoles) of sodium borohydride in 2.5 ml. of 1,2-dimethoxyethane was refluxed for 20 hr.[27] and then cooled and mixed with dilute aqueous hydrochloric acid. The precipitated solid (950 mg. or 95%) melted at 162–163° with softening at 158° after recrystallization from benzene. A 100-mg. portion of the product was chromatographed on 5.0 g. of Alcoa alumina (20–200 mesh). The product, 89 mg., eluted with 10% ethyl acetate in benzene, was recrystallized from benzene to separate the pure **diol 9** as colorless needles, m.p. 170.5–171°. The product has infrared bands[19] at 3595 and 3450 (broad) cm.$^{-1}$ (unassociated and associated O–H) with no absorption in the 6-$\mu$ region attributable to a carbonyl function. The infrared absorption in the 3-$\mu$ region was examined[28] in the concentration range 0.0016–0.0129 *M;* as the solution was diluted, the intensity of the band at 3620 cm.$^{-1}$ (unassociated O–H) decreased more rapidly than the intensity of the band at 3527 cm.$^{-1}$ (intramolecularly associated O–H) and a broad band at 3375 cm.$^{-1}$ (intermolecularly associated O–H) disappeared in the most dilute solution. The n.m.r. spectrum[20] of the diol has broad peaks at δ 4.17 (2H, >CH–O) and 3.29 (2H, shifted by the addition of pyridine, O–H) with a complex multiplet in the region δ 0.9–3.2 (20H, aliphatic C–H).

*Anal.* Calcd. for $C_{14}H_{24}O_2$: C, 74.95; H, 10.78. Found: C, 74.79; H, 10.63.

**Preparation of the Ethylene Ketal 12.**—Reaction of 10.0 g. (66.3 mmoles) of the enamine **1** with 20.0 g. (377 mmoles) of acrylonitrile in 50 ml. of ethanol as previously described[5a] afforded 12.3 g. (91%) of the **keto dinitrile 10** as a pale yellow oil, b.p. 165–167° (0.05 mm.) [lit.[5a] 178–180° (0.4 mm.)], $\bar{\nu}_{\max}$[19] 2250 ($C\equiv N$) and 1710 cm.$^{-1}$ ($C=O$). This product has complex n.m.r. multiplets[20] in the regions δ 2.2–2.9 (6H) and 1.1–2.2 (10H). Hydrolysis of a 1.00-g. (4.95-mmole) sample of the dinitrile **10** with refluxing aqueous hydrochloric acid for 3 hr. yielded 444 mg. (32%) of the **keto diacid 11** as white needles from an ethyl acetate–pentane mixture, b.p. 142–143° [lit.[5a] m.p. 142–143°]. To a solution of 2.04 g. (10.0 mmoles) of the keto dinitrile **10** in 33 g. (30 ml., 0.53 mole) of ethylene glycol was added, dropwise and with stirring, 6.0 ml. of boron trifluoride etherate. After the mixture had been stirred at 25° for 96 hr., it was poured into dilute, aqueous potassium hydroxide and extracted with ether. The ether extract was dried and concentrated; recrystallization of the residual solid from ethyl acetate separated 1.89 g. (77%) of the **ketal 12** as white needles, m.p. 95–96°. An additional recrystallization raised the melting point to 97–98°. This product has infrared absorption[19] at 2250 cm.$^{-1}$ ($C\equiv N$) with an n.m.r. peak[20] at δ 4.05 (4H, $CH_2$–O) as well as a complex multiplet in the region δ 1.0–2.6 (16 H).

*Anal.* Calcd. for $C_{14}H_{20}N_2O_2$: C, 67.71; H, 8.12. Found: C, 67.49; H, 8.11.

**Preparation of the Ethylene Ketal 17.**—Reaction of 55 g. (0.40 mole) of 1-(1-pyrrolidino)cyclopentene [b.p. 88–90° (15 mm.), lit.[5a] b.p. 88–92° (15 mm.)] with 100 g. (1.89 moles) of acrylonitrile in 250 ml. of absolute ethanol as previously described[11b] yielded 35.6 g. (47%) of the crude dinitrile **15** as colorless plates from aqueous ethanol, m.p. 55–60°. An additional recrystallization separated the pure **keto dinitrile 15**, m.p. 64–65° (lit.[11b] m.p. 63–65°), with $\bar{\nu}_{\max}$[19] 2250 ($C\equiv N$) and 1740 cm.$^{-1}$ (cyclopentanone $C=O$), a molecular ion peak at *m/e* 190, and a complex n.m.r. multiplet[19] in the region δ 1.1–2.8 with no absorption at lower field. The viscous liquid remaining after concentration of the mother liquors of the above crystallization was distilled to separate a fraction, b.p. 40–43° (0.4 mm.), whose spectra identify it as 3-ethoxypropionitrile.[29] This material has infrared absorption[25] at 2255 cm.$^{-1}$ ($C\equiv N$) with n.m.r. triplets[25] at δ 2.56 (2H, *J* = 6.5 c.p.s., $-CH_2-C\equiv N$) and 1.20 (3H, *J* = 7 c.p.s., $CH_3$) as well as an overlapping triplet (*J* = 6.5 c.p.s.) at δ 3.64 and a quadruplet (*J* = 7 c.p.s.) at δ 3.58 attributable to the $-CH_2-O-CH_2-$ grouping. A 1.00-g. (5.31-mmole) sample of the keto dinitrile **15** was hydrolyzed with refluxing aqueous hydrochloric acid to give 462 mg. (40%) of the **keto diacid 16** as colorless needles, m.p. 120–122° (lit.[11b] m.p. 121.5–122°) from an ethyl acetate–pentane mixture.

A solution of 3.80 g. (20 mmoles) of the keto dinitrile **15** and 13 ml. of boron trifluoride etherate in 66 g. (60 ml. or 1.06 moles) of ethylene glycol was stirred at 25° for 72 hr. and then poured into cold, dilute aqueous potassium hydroxide and extracted with ethyl acetate. After the organic extract had been dried and concentrated, the residue, a yellow oil which solidified on standing in the refrigerator, was recrystallized from an ethyl acetate–pentane mixture to separate 2.50 g. (60%) of the **ketal 17** as colorless needles, m.p. 95–96°. The product has infrared absorption[19] at 2250 cm.$^{-1}$ ($C\equiv N$) with n.m.r. peaks[20] at δ 4.03 and 3.96 (4H, $CH_2$–O) as well as a multiplet in the region δ 1.2–2.5 (14H).

*Anal.* Calcd. for $C_{13}H_{18}N_2O_2$: C, 66.64; H, 7.74; N, 11.96. Found: C, 66.29; H, 7.73; N, 11.82.

**Preparation of the Triketone 13.**—To a solution of 2.44 g. (9.92 mmoles) of the ketal **12** in 150 ml. of ether was added, dropwise and with stirring under a nitrogen atmosphere, 53.5 ml. of an ethereal solution containing 58.9 mmoles of methyllithium. The reaction mixture, in which a white precipitate formed almost immediately, was stirred for 6 hr. and then 100 ml. of 10% aqueous hydrochloric acid was added, dropwise and with stirring, to the reaction mixture. After the resulting mixture had been stirred for 1 hr., the ether layer was separated, combined with an ethereal extract of the aqueous layer, dried, and concentrated. Recrystallization of the residual white solid from an ethyl acetate–pentane mixture afforded 1.91 g. (81%) of the crude triketone as colorless needles, m.p. 65–68°. Further recrystallization gave the pure **triketone 13**, m.p. 69–70°, with infrared absorption[19] at 1710 cm.$^{-1}$ ($C=O$) and an n.m.r. singlet[20] at δ 2.14 ($CH_3$–CO) superimposed on a complex multiplet in the region δ 1.1–2.7.

*Anal.* Calcd. for $C_{14}H_{22}O_3$: C, 70.55; H, 9.31. Found: C, 70.38; H, 9.37.

A solution of 0.50 g. (2.1 mmoles) of the **triketone 13** and 0.35 g. (4.9 mmoles) of pyrrolidine in 15 ml. of benzene was refluxed for 18 hr. with continuous separation of water. The solution was cooled and mixed with 10 ml. of acetate buffer solution,[23] and the resulting mixture was refluxed for 3 hr. The organic layer was separated, combined with the benzene extract of the aqueous phase, dried, and concentrated. Recrystallization of the residue from an ethyl acetate–pentane mixture separated 0.45 g. (97%) of the diketone **5**, m.p. 160–162°, which was identified with the previously described sample by a mixture melting point determination and comparison of infrared spectra.

**Preparation of the Triketone 18.**—A mixture prepared from 712.6 mg. (3.05 mmoles) of the ketal **17** and 18.0 mmoles of methyllithium in 45 ml. of ether was stirred for 15 hr. at 25° and then treated with 25 ml. of 10% aqueous hydrochloric acid and stirred for an additional 1 hr. After the ethereal solution of the crude organic product had been separated, dried, and concentrated, the residual white solid was recrystallized from an ethyl acetate–pentane mixture to separate 520 mg. (76%) of the tri-

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(27) When a reaction time of only 2 hr. was employed, the reaction was incomplete as judged by the presence of infrared absorption attributable to a carbonyl function in the spectrum of the crude product.

(28) A solution in carbon disulfide was employed.

(29) G. C. Harrison and H. Diehl ("Organic Syntheses," Coll. Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1955, p. 372) reported b.p. 169–174° (760 mm.); H. R. Henze and T. R. Thompson [*J. Am. Chem. Soc.*, **65**, 1422 (1943)] reported b.p. 78° (25 mm.), $n^{20}_{D}$ 1.4061.

**ketone 18** as colorless needles, m.p. 82–83°. This product was identified with the subsequently described sample of the triketone by a mixture melting point determination and by comparison of the infrared and n.m.r. spectra of the two samples.

A solution of 1.0 g. (4.5 mmoles) of the triketone **18** and 0.35 g. (4.9 mmoles) of pyrrolidine in 10 ml. of benzene was refluxed overnight with continuous separation of water. Then 5 ml. of an acetate buffer solution[23] was added and refluxing was continued for 4 hr. A benzene solution of the crude organic product was washed successively with dilute, aqueous hydrochloric acid and aqueous sodium chloride and then dried and concentrated. The residual oil was distilled under reduced pressure in a short-path still to give 520 mg. of product as a colorless liquid which exhibited a single peak on gas chromatography[30] and rapidly turned yellow on exposure to air. Redistillation (139° at 0.08 mm.) afforded a sample of colorless liquid, believed to be the diketone **19** with infrared absorption[25] at 1720 cm.$^{-1}$ (C═O) but no absorption in the 3- or 6-$\mu$ region attributable to a hydroxyl group or a carbon–carbon double bond. The material has a complex n.m.r. multiplet[25] in the region $\delta$ 1.2–2.8 with no lower field absorption; the highest peak in the mass spectrum of the material is at *m/e* 206 (corresponding to $C_{13}H_{18}O_2^+$) with abundant fragment peaks at *m/e* 149, 148, 79, 77, 55, 41, and 39. We were unsuccessful in efforts either to crystallize this product or to obtain the liquid in analytically pure form.

**4-(2-Ketocyclopentyl)-2-butanone (20).**—A mixture of 29.70 g. (0.353 mole) of cyclopentanone and 25.26 g. (0.176 mole) of 1-diethylamino-3-butanone[31] was refluxed under a nitrogen atmosphere for 16 hr. and then cooled and poured onto a mixture of ice and hydrochloride acid. After the resulting mixture had been saturated with ammonium sulfate and extracted with ether, the ethereal solution was dried and concentrated. Fractional distillation of the residual liquid (28.85 g.) separated 14.57 g. of unchanged cyclopentanone, b.p. 54–55° (50 mm.), and 3.10 g. (18%) of the pure[32] **diketone 20**, b.p. 119–120° (9 mm.), $n^{26}\text{D}$ 1.4625 [lit.[15a] b.p. 144–146° (18 mm.)], with infrared absorption[25] at 1720 (C═O) and 1737 cm.$^{-1}$ (C═O in the five-membered ring) and n.m.r. absorption[25] at $\delta$ 2.50 (2H triplet with $J$ = 7 c.p.s., $-CH_2-CO$) and 2.08 (3H singlet, $CH_3-CO-$) superimposed on complex absorption in the region $\delta$ 1.3–2.8 (9H, aliphatic C–H). In subsequent runs the yield of the diketone **20** ranged from 24 to 49%.

The combined pot residues from several distillations were crystallized from a cyclohexane–ethyl acetate mixture to separate the **triketone 18** as white needles, m.p. 84–85°. This product has infrared absorption[19] at 1710 (C═O) with a shoulder at 1730 cm.$^{-1}$ (C═O in a five-membered ring) and an ultraviolet maximum[26] at 281 m$\mu$ ($\epsilon$ 65). The sample has an n.m.r. singlet[20] at $\delta$ 2.17 ($CH_3$–CO) superimposed on complex absorption in the region $\delta$ 1.2–2.9 (aliphatic C–H).

*Anal.* Calcd. for $C_{13}H_{20}O_3$: C, 69.61; H, 8.99. Found: C, 69.67; H, 8.98.

From a comparable reaction employing 29.7 g. (0.353 mole) of cyclopentanone and 32.45 g. (0.227 mole) of 1-diethylamino-3-butanone, the yields were 8.78 g. (25%) of the diketone **20** and 2.42 g. (5%) of the triketone **18**.

**Preparation of the Unsaturated Ketone 21.**—A solution of 20.3 g. (0.13 mole) of the diketone **20** and 10.0 g. (0.14 mole) of pyrrolidine in 250 ml. of benzene was refluxed for 16 hr. with continuous separation of water. The resulting solution was concentrated and the residual liquid ($\tilde{\nu}_{\max}$ 1595 and 1645 cm.$^{-1}$ attributable to the system $>N—C═C—C═C<$) was mixed with 50 ml. of acetate buffer solution.[23] After the resulting mixture had been refluxed for 4 hr., it was diluted with ether and washed successively with dilute, aqueous hydrochloric acid, water, and aqueous sodium chloride. The remaining ether solution was dried and concentrated; distillation of the residual yellow liquid afforded 13.96 g. (79%) of colorless liquid, b.p. 105° (5 mm.), $n^{26}\text{D}$ 1.5195 [for ketone **21** lit. b.p. 80–81° (0.4 mm.),[5a] 107–112° (12 mm.)[14b]], which contained[32] the $\alpha,\beta$-unsaturated ketone **21** (*ca.* 95%, second eluted) and the $\beta,\gamma$-unsaturated ketone **22** (*ca.* 5%, first eluted).[5a] After fractional distillation of this mixture of tetrahydroindanones **21** and **22**, a lower boiling fraction, b.p. 110–120° (15 mm.), was separated which contained[32] approximately 50% of the nonconjugated ketone **22**. A collected[32] sample of the ketone **22** has infrared absorption[52] at 1720 (C═O) and 1665 cm.$^{-1}$ (weak, C═C) with n.m.r. absorption[25] at $\delta$ 2.80 (2H, broad $-CH_2-CO-$) as well as complex absorption in the region $\delta$ 1.4–2.7 (10H, aliphatic C–H), but no absorption attributable to vinyl C–H bonds. The mass spectrum of the sample has a molecular ion peak at *m/e* 136.

Fractions from the above distillation which contained[32] 95% or more of the conjugated ketone **21** have infrared absorption[25] at 1678 (conjugated C═O) and 1665 cm.$^{-1}$ (conjugated C═C) with an ultraviolet maximum[26] at 237 m$\mu$ ($\epsilon$ 14,700). This sample has n.m.r. absorption[20] at $\delta$ 5.93 (1H, partially resolved multiplet, vinyl C–H) and complex absorption in the region $\delta$ 1.0–2.9 (11H, aliphatic C–H).

**Cyclopentane-1,2-dione (23).**—This diketone **23** isolated in 30% yield as tan prisms, m.p. 54.5–56° (lit.[16a] m.p. 55–56°), was prepared by the bromination of cyclopentanone followed by hydrolysis and oxidation as previously described.[16a] An attempt to prepare the same diketone **23** by the hydrolysis and decarboxylation[16b] of 82 g. (0.34 mole) of 3,5-dicarboethoxycyclopentane-1,2-dione (**24**) in refluxing 20% aqueous sulfuric acid, followed by continuous extraction of the product with ether afforded, after distillation, 14.29 g. of a liquid, b.p. 114–119° (38 mm.), which contained[33] the diketone **23** (*ca.* 30%, first eluted) and the enol ether **25** (*ca.* 70%, second eluted). A sample of the pure enol ether, apparently formed by the acid-catalyzed reaction of the diketone **23** with ethanol in the reaction mixture, was collected[33] and found to have infrared absorption[25] at 1730 (C═O) and 1630 cm.$^{-1}$ (C═C) with an ultraviolet maximum[26] at 252 m$\mu$ ($\epsilon$ 8150). For comparison, the diketone **23**, which clearly exists primarily as the enol tautomer, has infrared absorption[19] at 3350 (broad, associated O–H), 1700 (C═O), and 1655 cm.$^{-1}$ (C═C) with an ultraviolet maximum[26] at 253 m$\mu$ ($\epsilon$ 9000). The enol ether **25** has n.m.r. absorption[25] at $\delta$ 6.33 (1H, triplet, $J$ = 2.5 c.p.s., vinyl C–H), 3.88 (2H, quadruplet, $J$ = 7 c.p.s., $-CH_2-O$), and 1.33 (3H, triplet, $J$ = 7 c.p.s., $CH_3$) and complex absorption in the region $\delta$ 2.1–2.7 (4H, aliphatic $CH_2$).

*Anal.* Calcd. for $C_7H_{10}O_2$: C, 66.64; H, 7.99; mol. wt., 126. Found: C, 66.42; H, 8.10; mol. wt., 126 (mass spectrum).

**Preparation of the Triketone 26.**—A solution of 3.00 g. (30.6 mmoles) of the diketone **23** and 2.15 g. (30.7 mmoles) of methyl vinyl ketone in 10 ml. of ether was treated with 2.0 ml. (15 mmoles) of triethylamine and the resulting solution was stirred at room temperature under a nitrogen atmosphere for 2.5 hr. After the solvent had been removed, the dark residual liquid was distilled to separate 2.895 g. of the crude triketone, b.p. 140–150° (0.6 mm.), which solidified on standing. Recrystallization from an ether–cyclohexane mixture separated 1.66 g. of the triketone **26** as pale yellow prisms, m.p. 42–45°. Recrystallization and subsequent sublimation under reduced pressure afforded the pure **triketone 26** as white needles, m.p. 49–50°. The product, which exists in the **enol form 26b** gives an immediate greenish purple color with ferric chloride in aqueous ethanol and has infrared absorption[19] at 3490, 3340 (associated O–H), 1720 (C═O), and 1660 cm.$^{-1}$ (C═C) with an ultraviolet maximum[26] at 260 m$\mu$ ($\epsilon$ 12,900). The n.m.r. spectrum[25] of the product has a broad peak at $\delta$ 6.82 (1H, OH) with a singlet at $\delta$ 2.20 (3H, $CH_3-CO-$) and complex absorption in the region $\delta$ 2.3–3.0 (8H, aliphatic C–H) but no absorption attributable to a vinyl proton.

*Anal.* Calcd. for $C_9H_{12}O_3$: C, 64.27; H, 7.19; mol. wt., 168. Found: C, 64.26; H, 7.17; mol. wt., 168 (mass spectrum).

**Preparation of the Pyran 27.**—A solution of 1.00 g. (5.95 mmoles) of the triketone **26** and 103 mg. (0.6 mmole) of *p*-toluenesulfonic acid in 25 ml. of benzene was refluxed for 19 hr. under a nitrogen atmosphere and then cooled and washed with aqueous sodium bicarbonate. The organic phase was dried, concentrated, and distilled in a short-path still under reduced pressure to separate 570 mg. (64%) of the crude pyran **27** as a yellow solid, m.p. 68–102°. After an ethereal solution of the crude product had been washed with aqueous sodium bicarbonate, repeated recrystallization of the neutral fraction from hexane–ethyl acetate mixtures separated the pure **pyran 27** as pale yellow needles, m.p. 115.3–116.2°, with infrared absorption[19] at 1720 (C═O) and 1655 cm.$^{-1}$ (C═C) and an ultraviolet maxi-

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(30) A column packed with silicone gum suspended on diatomaceous earth was employed.

(31) A. L. Wilds, R. M. Novaks, and K. E. McCaleb, *Org. Syn.*, **37**, 18 (1957).

(32) A gas chromatography column packed with silicone fluid, no. 550, suspended on ground firebrick was employed.

(33) A gas chromatography column packed with silicone fluid, no. 710, suspended on ground firebrick was employed.

mum[26] at 282.5 mμ (ε 2780). The product has n.m.r. absorption[20] at δ 4.87 (1H, partially resolved multiplet, vinyl C–H), 3.13 (2H, partially resolved multiplet, $-\overset{|}{C}=\overset{|}{C}-CH-\overset{|}{C}=\overset{|}{C}-$), and 2.52 (3H singlet, $CH_3$–CO). The latter peak is superimposed on complex absorption in the region δ 1.5–2.8 (4H, aliphatic C–H).

*Anal.* Calcd. for $C_9H_{10}O_2$: C, 71.98; H, 6.71; mol. wt., 150. Found: C, 71.64; H, 6.64; mol. wt., 150 (mass spectrum).

**Reaction of the Triketone 26 with Pyrrolidine.**—A mixture of 858 mg. (5.11 mmoles) of the triketone **26**, 1.305 g. (18.4 mmoles) of pyrrolidine, 1.25 g. (10.4 mmoles) of anhydrous magnesium sulfate, and 15 ml. of benzene was heated to 50°, with stirring and under a nitrogen atmosphere, for 46 hr. after which time 20 ml. of 10% aqueous hydrochloric acid was added. The organic phase was diluted with ether, separated, washed with aqueous hydrochloric acid, dried, and concentrated. Chromatography of the residue (276 mg.) on 13.8 g. of Woelm alumina (activity grade III) separated the **pyrrolidylindanone 28** which crystallized from hexane as 41 mg. of yellow crystals, m.p. 97–98°. An additional 207 mg. of this same amino ketone **28**, m.p. 95–97°, was recovered from the aforementioned aqueous acid solution for a total yield of 248 mg. (25%). The amino ketone **28** has infrared absorption[25] at 1715 cm.$^{-1}$ (C=O) with ultraviolet maxima[26] at 246 mμ (ε 30,800) and 287 mμ (ε 2800).[34] The product has n.m.r. absorption[20] in the regions δ 6.9–7.8 (3H, aromatic C–H) and 1.8–3.8 (12H, aliphatic C–H).

*Anal.* Calcd. for $C_{13}H_{15}NO$: C, 77.58; H, 7.51; N, 6.96; mol. wt., 201. Found: C, 77.54; H, 7.57; N, 6.94; mol. wt., 201 (mass spectrum).

The mother liquors from the chromatographic fractions containing the amino ketone contained[35] a second minor component. An ether solution of the component was repeatedly washed with aqueous hydrochloric acid and then dried and concentrated. Sublimation of the residue afforded 9 mg. (1%) of the crude pyrone **27**, m.p. 105–107°, identified with the previously described sample by comparison of infrared and mass spectra. The later fractions from the chromatography, eluted with hexane–chloroform mixtures, afforded, after distillation in a short-path still, a few milligrams of a third component[35] as a yellow liquid, $n^{25}D$ 1.5430, with infrared absorption[25] at 1720 (C=O in a six-membered ring) and 1745 cm.$^{-1}$ (C=O in a five-membered ring). The mass spectrum of the material has a molecular ion peak at *m/e* 152 corresponding to a molecular formula $C_9H_{12}O_2$. This liquid is believed to be a partially purified sample of the saturated diketone **30**; however, our efforts to obtain enough of this product for characterization were not successful.

**Preparation of the Hydroxy Diketone 32.**—A solution of 5.10 g. (46.4 mmoles) of cyclohexane-1,2-dione,[36] 3.25 g. (46.4 mmoles) of methyl vinyl ketone, and 3.0 ml. of triethylamine in 20 ml. of ether was stirred at room temperature under a nitrogen atmosphere for 2.5 hr. Distillation of the reaction mixture separated 3.29 g. (40%) of the crude ketol **32** as a straw-colored liquid, b.p. 100–106° (0.01 mm.), $n^{24}D$ 1.5132, which slowly crystallized on standing, m.p. 122–132°. Repeated recrystallization from a hexane–ethyl acetate mixture separated one pure stereoisomer of the **hydroxy diketone 32** as white needles, m.p. 134–135.5°. The product has infrared absorption[19] at 3400 (broad, associated O–H), 1750 (C=O in a five-membered ring), 1705 (C=O), and 1365 cm.$^{-1}$ ($CH_3$–CO–) with an ultraviolet maximum[26] at 293 mμ (ε 54) and n.m.r. peaks[20] at δ 3.47 (1H, singlet, O–H) and 3.02 (1H, pair of doublets, $J$ = 7 and 11.5 c.p.s., CH–CO–) as well as a singlet at δ 2.38 (3H, $CH_3$–CO) superimposed on complex absorption in the region δ 1.2–2.8 (9H, aliphatic C–H).

*Anal.* Calcd. for $C_{10}H_{14}O_3$: C, 65.91; H, 7.74; mol. wt., 182. Found: C, 65.98; H, 7.74; mole wt., 182 (mass spectrum).

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[34] The corresponding maxima for *m*-dimethylaminoacetophenone are at 242 mμ (ε 39,900) and 360 mμ (ε 3470): A. E. Lutskiĭ and V. V. Dorofeev, *Zh. Obshch. Khim.*, **27**, 1064 (1957).

[35] A thin layer chromatographic plate coated with aluminum oxide and developed with either chloroform or a mixture of hexane and ethyl acetate was employed for this analysis.

[36] C. C. Hack, C. V. Banks, and H. Diehl, *Org. Syn.*, **32**, 35 (1952).

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# Perhydroindan Derivatives. V. The Synthesis of Some 3a-Substituted Derivatives[1a]

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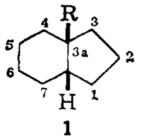
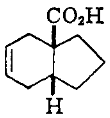
Several model compounds for ring closure studies have been prepared including 3a-carbomethoxymethyl-5-keto-*cis*-perhydroindan (**25**), 3a-acetyl-5-keto-*cis*-perhydroindan (**35**), and the epoxide of methyl 3-methylenecyclohexylacetate (**39**). The diazo ketones **3** and **27** were converted to the corresponding cyclopropyl ketones **4** and **26** and the reactions of these cyclopropyl ketones with hydrogen bromide and with lithium in ammonia were studied. Application of the Arndt–Eistert reaction to the diazo ketone **3** yielded, in addition to the expected product **5**, the cyclopropyl ketone **4** and two cyclobutanone derivatives **7** and **8**.

This study was prompted by a need for model compounds in the *cis*-fused perhydroindan series **1** which contained appropriate substituents at positions 3a and 5 to permit a study of the construction of a two-carbon bridge between these two positions. As a starting material, we utilized the unsaturated acid **2** which is readily accessible from the Diels–Alder reaction of 1,3-butadiene with cyclopentene-1-carboxylic acid.[2]



**1**



**2**

In following our initial plan, the conversion of the acid **2** to the homologous acid **6** *via* an Arndt–Eistert reaction,[3] the diazo ketone **3** was prepared and treated with silver benzoate and triethylamine in methanol.[4] The volatile product of this reaction proved to be a mixture containing only 50% of the desired ester **5** accompanied by 25% of the ketone **4**, as well as a mixture of ketones **7** and **8**.[5]

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[2] R. L. Kronenthal and E. I. Becker, *J. Am. Chem. Soc.*, **79**, 1095 (1957).

[3] (a) W. E. Bachmann and W. S. Struve, *Org. Reactions*, **1**, 38 (1942); (b) F. Weygand and H. J. Bestmann in "Newer Methods of Preparative Organic Chemistry," Vol. 3, W. Foerst, Ed., Academic Press Inc., New York, N. Y., 1964, p. 451.

[4] M. S. Newman and P. F. Beal, *J. Am. Chem. Soc.*, **72**, 5163 (1950).

[5] We have noted the formation of by-products in a previous application of this modification of the Arndt–Eistert procedure to an γ,δ-unsaturated diazo ketone derived from 3-cyclohexenylacetic acid: (a) H. O. House, R. G. Carlson, and H. Babad, *J. Org. Chem.*, **28**, 3359 (1963). (b) Interestingly, W. von E. Doering, E. T. Fossel, and R. L. Kaye [*Tetrahedron*, **21**, 25 (1965)] have recently reported finding no abnormal products from application of the Arndt–Eistert reaction to the δ,ε-unsaturated diazo ketope derived from 5-cycloheptenylcarboxylic acid.