linkage[23] and a weak-to-medium contaminating carbonyl band at 5.86 μ. The least contamination by carbonyl-containing materials was noted when the xanthate was prepared by successive treatment of *t*-butyl alcohol with sodium hydride, carbon disulfide and methyl iodide in anhydrous ether according to the method of Roberts.[13c] In this case the band at 5.86 μ was barely perceptible.

Decomposition of the xanthate in a water bath at 70–80° gave isobutylene, identified by passage through a solution of acetonitrile and sulfuric acid in acetic acid which yielded *N*-*t*-butylacetamide, m.p. 99–100.5° (lit.[24] m.p. 97–98°).

Hydrazinolysis of S-methyl t-butyl xanthate. A mixture of 78 g. of freshly prepared *S*-methyl *t*-butyl xanthate and 60 g. of hydrazine hydrate (100%) was stirred at room temperature for 12 hr. (spontaneous warming occurred at first). There was added 75 ml. of methylene dichloride and the mixture filtered to remove 3 g. of thiocarbohydrazide,[25] m.p. 166–170° dec., lit.[26] m.p. 168° dec. The aqueous phase was extracted with two additional 25-ml. portions of methylene dichloride, the combined extracts dried (magnesium sulfate), and the solvent removed from a water bath (15–20°) with the aid of a water aspirator (15–20 mm.). The residual cloudy oil amounted to 26.5 g. (37.6%). An immediate test of this material with an equivalent amount of benzaldehyde in ethanol gave a 72% yield of the *benzal derivative*, m.p. 106–107° dec., from methanol.

Anal. Calcd. for $C_{12}H_{16}N_2OS$: C, 60.98; H, 6.83; N, 11.86. Found: C, 61.14; H, 6.72; N, 11.78.

Addition of a test portion of crude *t*-butyl thionocarbazate to 48% aqueous hydrofluoric acid caused immediate vigorous gas evolution.

Cleavage of carbanilates by hydrogen chloride and bromide in nitromethane. The solutions of hydrogen halide were prepared by passing the anhydrous gas into nitromethane at room temperature for 30 min., the concentrations being determined by addition of an excess of aniline to an aliquot and weighing the precipitated aniline hydrohalide. Cleavages were carried out by dissolving 0.005 mole of the carbanilate in 20 ml. of the standard hydrogen halide–nitromethane solution and allowing the solutions to stand at room temperature for a maximum of 24 hr. The aniline hydrohalide was filtered, dried and weighed. The yield of aniline hydrohalide was generally in the range 60–95%. From the preparative point of view it is preferable to pass the anhydrous hydrogen halide directly into a solution of the carbamate in nitromethane for several minutes. For example methyl *N*-phenylthionocarbamate was partially cleaved by hydrogen chloride under these conditions.

t-Butyl 1-t-butylhydrazo-1,2-dicarboxylate (V). A solution of *t*-butylmagnesium chloride prepared from 6.44 g. of *t*-butyl chloride, 1.67 g. of magnesium, and 75 ml. of anhydrous ether was added dropwise over a period of 15 min. to a solution of 8 g. of *t*-butyl azodiformate in 75 ml. of anhydrous ether while cooling in an ice bath. The mixture was stirred for 10 hr. and then decomposed by the addition of 50 ml. of saturated ammonium chloride solution followed by 100 ml. of water. After filtration of the two layers the ether layer was allowed to evaporate spontaneously. The residual tacky solid (5 g., 50%) was recrystallized from nitromethane which gave 2.9 g. (29%) of white slightly tacky crystals, m.p. 119–130°. Recrystallization from low- (b.p. 60–90°) and high-boiling (b.p. 90–120°) ligroin (1:1) followed by nitromethane gave 2.6 g. (26%) of the pure ester, m.p. 136–137°.

Anal. Calcd. for $C_{14}H_{28}N_2O_4$: C, 58.30; H, 9.79. Found: C, 58.68; H, 9.82.

t-Butylhydrazine hydrochloride. A solution of 1 g. of *t*-butyl 1-*t*-butylhydrazo-1,2-dicarboxylate (V) in 12 ml. of nitromethane was treated with a stream of anhydrous hydrogen chloride for 3–5 min. After cooling the mixture in an ice bath there was obtained 0.4 g. (92%) of the hydrochloride, m.p. 184–187° dec. Recrystallization from ethanol-ether raised the m.p. to 191–194° dec. There was no depression in melting point on admixture with an authentic sample.[27]

2,3-Dicarbo-t-butoxy-2,3-diazabicyclo[2.2.1]hept-5-ene. A solution of 0.66 g. of cyclopentadiene (b.p. 40–42°) and 2.3 g. of *t*-butyl azodiformate in 3 ml. of benzene was allowed to stand at room temperature for 9 hr. Evaporation by means of a slight air draft left 2.7 g. (91.3%) of the adduct, m.p. 101–103.5°. Recrystallization from ligroin (b.p. 60–90°) gave tiny white crystals, m.p. 104–105.5°.

Anal. Calcd. for $C_{15}H_{24}N_2O_4$: C, 60.80; H, 8.16; N, 9.46. Found: C, 60.67; H, 8.29; N, 9.20.

AMHERST, MASS.

(23) R. Felumb [*Bull. soc. chim. France*, 890 (1957)] quotes the range 8.26–8.14 μ for the C=S stretching frequency in related compounds.

(24) J. J. Ritter and P. P. Minieri, *J. Am. Chem. Soc.*, 70, 4045 (1948).

(25) Identified by elemental analysis.

(26) R. Stolle and P. E. Bowles, *Ber.*, 41, 1099 (1908).

(27) We wish to thank Prof. P. A. S. Smith for kindly providing a sample of *t*-butylhydrazine hydrochloride.[28]

(28) P. A. S. Smith, J. M. Clegg, and J. Lakritz, *J. Org. Chem.*, 23, 1595 (1958).

[CONTRIBUTION FROM THE RESEARCH LABORATORIES, TENNESSEE EASTMAN CO., DIVISION OF EASTMAN KODAK CO.]

The Chemistry of Dimethylketene Dimer. III.[1] Reactions with Ammonia and Amines

ROBERT H. HASEK, EDWARD U. ELAM, AND JAMES C. MARTIN

Received March 20, 1961

Attempts to convert tetramethyl-1,3-cyclobutanedione (dimethylketene dimer, I) to a reported monoimine invariably led to the cleavage product, 2,2,4-trimethyl-3-oxovaleramide. This cleavage reaction also occurred with primary and secondary aliphatic and alicyclic amines. Aromatic amines did not react with I to any practical degree unless a mineral acid catalyst was present, in which case Schiff bases of I were formed.

Wedekind and Miller treated tetramethyl-1,3-cyclobutanedione (dimethylketene dimer, I) with aqueous ammonia at 80–130° and obtained a crystalline product, m.p. 108.5°, to which they assigned the monoimine structure II.[2] The evidence for this

(1) Paper II: R. H. Hasek, R. D. Clark, and J. H. Chaudet, *J. Org. Chem.*, 26, 3130 (1961).

(2) E. Wedekind and M. Miller, *Ber.*, 43, 834 (1910).

TABLE I

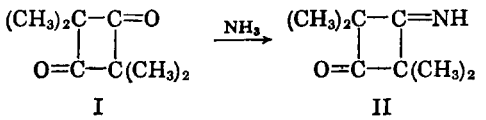
2,2,4-TRIMETHYL-3-OXOVALERAMIDES

$(CH_3)_2CHCOC(CH_3)_2CONRR'$

R	R'	M.P.	C, % Calcd.	C, % Found	H, % Calcd.	H, % Found	N, % Calcd.	N, % Found
—H	—H	110–111	61.1	61.3	9.6	9.6	8.9	8.9
$-C_2H_5$	—H	50–51	64.8	64.9	10.3	10.4	7.6	7.3
—*n*-C_4H_9	—H	30–31	67.6	67.2	10.9	10.9	6.6	6.6
—C_6H_{11}[a]	—H	94–95	70.3	70.1	10.4	10.5	5.9	5.8
—$CH_2CH_2NHCOCH_3$[b]	—H	159–160	59.5	59.7	9.2	9.7	11.6	11.5
—CH_2CH_2—[c]	—H	108–111	63.5	63.8	9.5	9.5	8.2	8.2
—$CH_2CH_2CH_2CH_2$—		[d]	68.2	68.0	10.0	9.8	6.6	6.6
—$CH_2CH_2CH_2CH_2CH_2$—		[e]	69.4	69.4	10.2	10.0	6.2	6.1
$-C_2H_5$	$-C_2H_5$	[f]	67.6	67.7	10.9	10.7	6.6	6.4

[a] Cyclohexyl. [b] Reaction product from 1 mole of tetramethyl-1,3-cyclobutanedione and 1.8 moles of ethylenediamine in 300 ml. of benzene was treated with 3 moles of acetic acid, and refluxed to remove water azeotropically. [c] Ethyl ether used as solvent; it was superior to benzene as reaction medium. [d] B.p. 115–118° (18 mm.), n_D^{20} 1.4802. [e] B.p. 134–136° (2.1 mm.), n_D^{20} 1.4831. [f] Very slow reaction (11% conversion after 3 days at 160°), b.p. 104–108° (3 mm.), n_D^{20} 1.4585.

structure was convincing: the product was weakly basic, formed a monophenylhydrazone, and was decomposed by acids to regenerate I. Elemental analyses of the compound and its phenylhydrazone were in excellent agreement with calculated values.

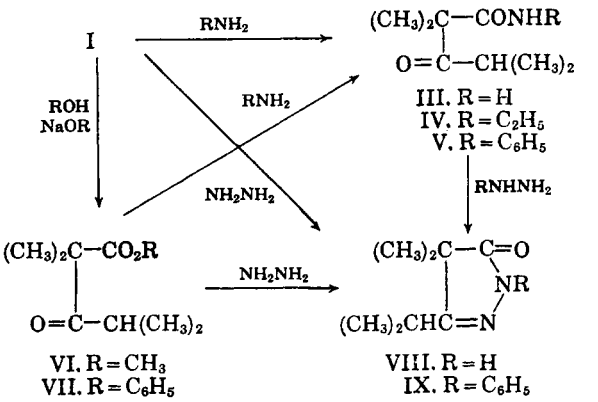


I II

Attempts to duplicate this work in these laboratories consistently gave an *addition* product of I and ammonia, $C_8H_{15}NO_2$ (III), a crystalline compound melting at 110–111°. Treatment of this product with phenylhydrazine gave a derivative melting at 67–68°, in contrast to the melting point of 162° reported by Wedekind and Miller for the phenylhydrazone of the monoimine II.

Examination of the infrared spectrum of III suggested that the compound was 2,2,4-trimethyl-3-oxovaleramide, and this structure was also indicated by NMR studies. The reaction product of III with phenylhydrazine was identified, on the basis of its infrared spectrum, as 3-isopropyl-4,4-dimethyl-1-phenyl-2-pyrazolin-5-one (IX), isomeric but not identical with the monophenylhydrazone of I, m.p. 122–123°. III reacted with hydrazine to form 3-isopropyl-4,4-dimethyl-2-pyrazolin-5-one (VIII), identical with a sample prepared from methyl 2,2,4-trimethyl-3-oxovalerate (VI) and hydrazine.[3] However, as this derivative could be prepared directly by action of hydrazine on I, the formation from III provided no proof of an acyclic structure of III.

Attempts to prepare 2,2,4-trimethyl-3-oxovaleramide by ammonolysis of the methyl ester VI were unsuccessful; similar failures have been reported,[4] although methyl 2,2-dimethylacetoacetate apparently forms an amide quite readily.[5] Ammonolysis of the more reactive phenyl 2,2,4-trimethyl-3-oxovalerate (VII) gave the amide, identical with III, and thus provided a synthesis from an acyclic intermediate. Additional evidence for the structure of III was its reduction by sodium borohydride to the corresponding hydroxyamide; this product was identical with that prepared by action of aqueous ammonia on the β-lactone of 3-hydroxy-2,2,4-trimethylvaleric acid.



VI. R = CH_3
VII. R = C_6H_5
III. R = H
IV. R = C_2H_5
V. R = C_6H_5
VIII. R = H
IX. R = C_6H_5

The cleavage of I by aliphatic and alicyclic amines was a general reaction, following the pattern of the ammonolysis reaction; representative amides prepared in this manner are listed in Table I. In general, the reaction with lower primary amines proceeded readily at moderate temperatures, but cleavage by secondary amines required extended reaction times at higher temperatures. Pyrrolidine, however, reacted quite vigorously, which indicated that the rate of aminolysis by higher amines is affected by steric factors.

The behavior of I with aromatic amines was a distinctly different matter. Staudinger speculated that I should react with aniline to form 2,2,4-trimethyl-3-oxovaleranilide (V), but was not able to

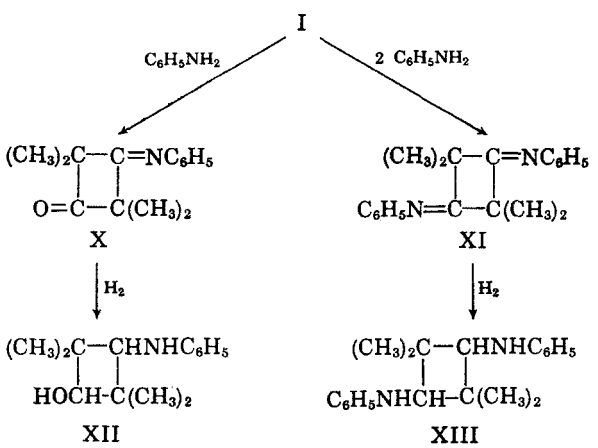
(3) R. H. Hasek, E. U. Elam, J. C. Martin, and R. G. Nations, *J. Org. Chem.*, 26, 700 (1961).

(4) L. L. Miller, Ph.D. thesis, Cornell University, 1937.

(5) H. Meyer, *Ber.*, 39, 198 (1906).

confirm this by experiment.[6] Mixtures of I and aniline, heated to 150–220°, generally gave unchanged I and isobutyranilide. In one instance, Staudinger obtained a new compound, m.p. 95–96°, but the analyses did not correspond to the calculated values for the ketoanilide V.[7] We prepared V by an alternate synthesis.[8] It melted at 94–95°, which indicated that Staudinger probably did obtain some of this material; however, it undoubtedly is difficult to prepare from I.

When a small amount of mineral acid was added to a toluene solution of I and aniline, the mixture evolved water when refluxed, and gave anils, or Schiff bases, of I. The monoanil (X) was a liquid, and the dianil (XI) was a solid, m.p. 141–142°; relative amounts were controlled by the molar ratio of aniline to I. Structures of these derivatives were confirmed by elemental analysis, infrared spectra, and by hydrogenation to the corresponding *N*-substituted anilines (XII and XIII).



The present work offers no proof that Wedekind and Miller's reaction product of dimethylketene dimer and ammonia was *not* the monoimine II. Although the melting point of our ketoamide III, prepared under substantially the same conditions, corresponded closely to the value reported for the monoimine, no derivative with the melting point of the phenylhydrazone reported by Wedekind and Miller was ever isolated. Moreover, the formation of imines of I is not restricted to the preparation of Schiff bases of aromatic amines; in the presence of an acid catalyst (amine salt), a diimine was prepared in about 15% yield from I and cyclohexylamine. Even in this case the major reaction was aminolysis to *N*-cyclohexyl-2,2,4-trimethyl-3-oxovaleramide (48% yield). Attempts to prepare imines of I with ammonia or methylamine in systems containing acidic materials were unsuccessful.

(6) H. Staudinger and St. Bereza, *Ber.*, **42**, 4911 (1909).
(7) H. Staudinger, *Ber.*, **44**, 521 (1911).
(8) To be described in a later publication of this series.

EXPERIMENTAL

2,2,4-Trimethyl-3-oxovaleramide (III). Reaction conditions substantially equivalent to those employed by Wedekind and Miller gave poor yields.[9] For example, a mixture of 100 g. of tetramethyl-1,3-cyclobutanedione and 500 g. of 28% aqueous ammonia was heated in a stainless steel rocking autoclave for 3 hr. at 100°, and then 3 hr. at 130°. The reaction product, a mixture of crystalline material and two liquid layers, was extracted with ether. Evaporation of the ether left 50 g. (45%) of crystalline material which, after one recrystallization from ethyl acetate, melted at 108–110°. The product was identical (melting point of a mixture and infrared spectrum) with the product prepared by the following procedure: A slurry of 273 g. of tetramethyl-1,3-cyclobutanedione and 500 ml. of benzene was placed in a 1-l. stainless steel rocking-type autoclave, and 200 ml. of anhydrous ammonia was injected from a blowcase. The mixture was heated for 6 hr. at 125°. The autoclave was cooled and vented, and the product was filtered to give 238 g. (78%) of crude 2,2,4-trimethyl-3-oxovaleramide, m.p. 103–108°. An additional 18 g. was obtained by evaporation of the filtrate. After recrystallization from benzene and then from water, the product melted at 110–111°.

The infrared spectrum of III (potassium bromide pellet) had bands at 2.95 and 3.15 μ (primary amide N—H stretching), a band at 5.98 μ with a shoulder at about 5.85 μ (C=O stretching), and a band at 6.15 μ. In chloroform solution, III gave a spectrum with the bands shifted to 2.88, 2.96, 5.95, and 6.30 μ, respectively. These spectra and band shifts are characteristic for a primary amide.

The NMR spectrum[10] showed a broad peak at −264 c.p.s. (primary amide), and a sharp peak at −54 c.p.s. characteristic for two equivalent methyl groups on the α-carbon atom. The spectrum also contained a group of peaks characteristic for an isopropyl group; the resonance of two equivalent methyl groups was split into a doublet (centered at −42 c.p.s., J = 7 c.p.s.) by the tertiary proton, and the tertiary proton resonance was split into seven peaks (centered at −122 c.p.s.) by interaction with the six methyl protons. Peak areas were consistent with these interpretations.

A mixture of 50 g. of phenyl 2,2,4-trimethyl-3-oxovalerate[8] and 150 g. of 20% aqueous ammonia was heated in a rocking autoclave at 120° for 4 hr. The product was filtered and recrystallized from a mixture of ethyl alcohol and hexane to give 32 g. (95%) of 2,2,4-trimethyl-3-oxovaleramide, m.p. 107–109°. This product did not depress the melting point of that prepared from tetramethyl-1,3-cyclobutanedione and ammonia.

3-Hydroxy-2,2,4-trimethylvaleramide. A suspension of 7 g. of 2,2,4-trimethyl-3-oxovaleramide (III, the ammonolysis product of I) in 100 ml. of water was heated to 50°, and a solution of 1 g. of sodium borohydride in 10 ml. of water was added. The ketoamide dissolved. The solution was allowed to stand for 2 hr. at room temperature, and excess sodium borohydride was decomposed by addition of 50 ml. of methanol. After most of the water had been evaporated on the steam bath, the product was recrystallized from toluene to give 4.6 g. (63%) of 3-hydroxy-2,2,4-trimethylvaleramide. m.p. 125–126°.

Anal. Calcd. for $C_8H_{17}NO_2$: N, 8.8. Found: N, 8.6.

The β-lactone of 3-hydroxy-2,2,4-trimethylvaleric acid was prepared by addition of dimethylketene to a solution of isobutyraldehyde in ether containing a small amount of zinc

(9) Wedekind and Miller heated 2 g. of I with 10 g. of 20% aqueous ammonia in a sealed tube at 80–100° for 3 hr., then 120–130° for 3 hr. They reported that the yield of crystalline product was nearly quantitative.

(10) The NMR spectrum was obtained with a Varian Associates Model V4300B spectrometer at 40 mc., with the sample dissolved in methylene chloride (15% solution). Chemical shifts were recorded relative to tetramethylsilane as an internal standard.

chloride.[11] A 5-g. sample was stirred with 28% aqueous ammonia at room temperature and the crystalline product was filtered, washed, and recrystallized from toluene. The infrared spectrum of the 3-hydroxy-2,2,4-trimethylvaleramide, m.p. 124–126°, was identical with that of the sodium borohydride reduction product of III.

Phenylhydrazine derivatives. A solution of 36 g. of 2,2,4-trimethyl-3-oxovaleramide (III) and 50 g. of phenylhydrazine in 250 ml. of acetic acid was refluxed for 4 hr. and poured onto 3 l. of flaked ice. The crude product was filtered, dried, and recrystallized from aqueous ethyl alcohol solution to give 21.5 g. (43%) of 3-isopropyl-4,4-dimethyl-1-phenyl-2-pyrazolin-5-one (IX), m.p. 67–68°.

Anal. Calcd. for $C_{14}H_{18}N_2O$: C, 73.0; H, 7.9; N, 12.2; O, 7.0. Found: C, 73.1; H, 8.4; N, 11.7; O, 7.0.

Small amounts of tetramethyl-1,3-cyclobutanedione (I) and phenylhydrazine were heated in a test tube for a few minutes. The mixture solidified when cooled, and was recrystallized three times from aqueous ethyl alcohol solution to give the monophenylhydrazone of I, m.p. 122–123°.

Anal. Calcd. for $C_{14}H_{18}N_2O$: C, 73.0; H, 7.9. Found: C, 72.8; H, 7.6.

The infrared spectrum of this derivative contained bands at 2.9 μ (N—H), 5.60 μ (cyclobutanone), and 5.88 μ (C=N, where carbon is part of a strained ring). A weak band at 6.01 μ was also noted. The position of the carbonyl band in this spectrum indicated that the cyclobutane ring was intact; this band is absent in the spectrum of the pyrazolinone IX, which absorbs at 5.86 μ in this region.

Hydrazine derivatives. A mixture of 15.7 g. of 2,2,4-trimethyl-3-oxovaleramide (III) and 16 g. of 95% hydrazine was refluxed gently until evolution of ammonia ceased. The two-phase product was evaporated on a steam bath, and the crystalline residue (13.6 g., 88%) was recrystallized successively from hexane, aqueous methanol solution, and hexane to give 3-isopropyl-4,4-dimethyl-2-pyrazolin-5-one (VIII), m.p. 80–81°.

Anal. Calcd. for $C_8H_{14}N_2O$: C, 62.3; H, 9.2. Found: C, 62.3; H, 9.1.

A solution of 86 g. of methyl 2,2,4-trimethyl-3-oxovalerate (VI) in 200 ml. of benzene was placed in a 500-ml. flask equipped with a reflux condenser, mechanical stirrer, and dropping funnel. After 31 g. of 95% hydrazine had been added slowly, the mixture was refluxed overnight. The product was cooled, the lower layer (10 ml.) was discarded, and the organic layer was washed with water. Crystals separated during this operation, and the product was heated on a steam bath to evaporate the benzene. The crude pyrazolinone VIII weighed 74 g. (96%). It was recrystallized from a mixture of benzene and hexane (1:3) to give a product melting at 79–80°.

Anal. Calcd. for $C_8H_{14}N_2O$: C, 62.3; H, 9.2. Found: C, 62.4; H, 9.1.

A solution of 70 g. of tetramethyl-1,3-cyclobutanedione in 200 ml. of benzene was warmed to 55°, and 32 g. of 95% hydrazine was added cautiously while the mixture was stirred. The reaction became vigorous enough to boil the benzene and was moderated by a cold water bath. After 1.5 hr., the mixture separated into two layers. The organic layer was washed with water, and the crystalline product which separated during this operation was filtered and recrystallized from water to give 47.5 g. of VIII, m.p. 77–78°. The melting point was unchanged by a second recrystallization from water. Additional product (18 g.) was obtained from the benzene filtrate.

Anal. Calcd. for $C_8H_{14}N_2O$: C, 62.3; H, 9.2; N, 18.2. Found: C, 62.3; H, 9.2; N, 18.2.

The infrared spectrum of VIII (KBr pellet) showed bands at 3.15 μ (N—H stretching) and 5.87 μ (C=O stretching).

The pyrazolinone VIII apparently crystallizes from water as a hydrate. An air-dried sample (from water) melted below 65° when placed on a melting-point block preheated to this temperature; when heated slowly, it melted sharply at 79–81°. The sample, containing 11.7% water (calcd. for VIII.-H_2O: 10.4% H_2O), was dried effectively in a vacuum oven at 50° or by recrystallization from a benzene-hexane mixture. The anhydrous material did not melt below 80° on a preheated block. Hydrate formation was evidently responsible for the crystallization noted when benzene solutions of VIII were washed with water.

Aminolysis products of tetramethyl-1,3-cyclobutanedione. A. N-Ethyl-2,2,4-trimethyl-3-oxovaleramide. Seventy grams of tetramethyl-1,3-cyclobutanedione was added to a solution of 45 g. of ethylamine in 200 ml. of benzene; the dione dissolved rapidly, but with no apparent heat of reaction. After standing overnight, the solution was heated on a steam bath to remove excess amine and solvent. The residue was recrystallized twice from pentane to give 75 g. (81%) of *N*-ethyl-2,2,4-trimethyl-3-oxovaleramide, m.p. 50–51°.

B. 1-(2,2,4-Trimethyl-3-oxovaleryl)pyrrolidine. Tetramethyl-1,3-cyclobutanedione (140 g.) was added slowly with stirring to 71 g. of pyrrolidine. The exothermic reaction was kept at 35° by use of a water bath. After addition was complete, the mixture was refluxed; the liquid temperature rose from 105° to 160° in 2 hr. The solution was then maintained at 150° for 8 hr. Examination by gas chromatography showed that the reaction was virtually complete. Distillation of the product through an 18-in. packed column gave 183 g. (86%) of 1-(2,2,4-trimethyl-3-oxovaleryl)pyrrolidine, b.p. 115–118° (1.8 mm.), n_D^{20} 1.4802.

C. 1-(2,2,4-Trimethyl-3-oxovaleryl)piperidine. A mixture of 140 g. of tetramethyl-1,3-cyclobutanedione and 85 g. of piperidine was refluxed with stirring. Over a period of 27 hr., the liquid temperature rose from 120° to 160°. The solution was heated at 150–155° for an additional 24 hr. Distillation through an 18-in. packed column gave unconverted piperidine and tetramethyl-1,3-cyclobutanedione and then 169 g. (75% conversion) of 1-(2,2,4-trimethyl-3-oxovaleryl)piperidine, b.p. 134–136° (2.1 mm.), n_D^{20} 1.4831.

D. N,N'-Dicyclohexyl-2,2,4,4-tetramethyl-1,3-cyclobutanediimine and N-cyclohexyl-2,2,4-trimethyl-3-oxovaleramide. A mixture of 100 g. of cyclohexylamine, 70 g. of tetramethyl-1,3-cyclobutanedione, and 5 g. of *p*-toluenesulfonic acid in 100 ml. of toluene was refluxed under a Dean-Stark trap for 24 hr. Approximately 8 ml. of water was collected in the trap. Distillation of the reaction product gave, after removal of toluene and unchanged cyclohexylamine, 94 g. of product boiling at 170–183° (15 mm.). The distillate solidified on cooling, m.p. 87–138°. It was recrystallized from acetonitrile to give 22 g. (14.6%) of *N,N'*-dicyclohexyl-2,2,4,4-tetramethyl-1,3-cyclobutanediimine, m.p. 145–151°. A second recrystallization from aqueous ethyl alcohol solution gave a pure sample, m.p. 152°.

Anal. Calcd. for $C_{20}H_{34}N_2$: C, 79.4; H, 11.3; N, 9.3. Found: C, 79.5; 79.3; H, 11.2, 11.1; N, 9.2.

The infrared spectrum of this compound contained a single strong band at 5.98 μ (C=N stretching).

Evaporation of the acetonitrile mother liquor gave 56.6 g. (48%) of crude *N*-cyclohexyl-2,2,4-trimethyl-3-oxovaleramide, m.p. 91–110°. After recrystallization from aqueous ethyl alcohol solution a sample melted at 92–96°.

Anal. Calcd. for $C_{14}H_{25}NO_2$: N, 5.9. Found: N, 6.1.

The infrared spectrum was identical with that of a sample, m.p. 94–95°, prepared by warming a mixture of cyclohexylamine and tetramethyl-1,3-cyclobutanedione in the absence of an acidic catalyst. The infrared spectrum showed bands at 3.0 μ (N—H), 5.85 μ (ketone carbonyl), and 6.15 μ (amide carbonyl).

2,2,4,4-Tetramethyl-3-phenyliminocyclobutanone (X). A solution of 280 g. of tetramethyl-1,3-cyclobutanedione, 186 g. of aniline, and 3 g. of *p*-toluenesulfonic acid in 700 ml. of toluene was refluxed through a 10-in. packed column equipped with a Dean-Stark trap. The theoretical amount of water (36 ml.) was collected in 6 hr. The reaction solution was washed with sodium bicarbonate solution and with water, dried over magnesium sulfate, and filtered. Distillation

(11) H. E. Zaugg, *Org. Reactions*, **8**, 313 (1954).

through an 18-in. packed column gave unchanged tetramethylcyclobutanedione and 263 g. (61%) of 2,2,4,4-tetramethyl-3-phenyliminocyclobutanone (X), b.p. 124–125° (7 mm.), n_D^{20} 1.5165.

Anal. Calcd. for $C_{14}H_{17}NO$: C, 78.1; H, 8.0; N, 6.5. Found: C, 77.8; H, 7.9; N, 6.4.

The infrared spectrum had bands at 5.55 μ (cyclobutanone) and 5.9 μ (C=N, where carbon is part of strained ring).

The distillation residue (98 g.) crystallized on cooling. After recrystallization from ethyl alcohol, 81 g. (28%) of 2,2,4,4-tetramethyl-*N,N'*-diphenyl-1,3-cyclobutanediimine, m.p. 140–142°, was recovered.

2,2,4,4-Tetramethyl-N,N'-diphenyl-1,3-cyclobutanediimine (XI). A solution of 140 g. of tetramethyl-1,3-cyclobutanedione, 232.5 g. of aniline, and 5 g. of *p*-toluenesulfonic acid in 700 ml. of toluene was refluxed through a 10-in. packed column equipped with a Dean-Stark trap. The theoretical amount of water (36 ml.) was collected in 8 hr. The reaction solution was washed with sodium bicarbonate solution and with water, dried over magnesium sulfate, filtered, and evaporated on the steam bath. The residual slurry of crystals was filtered and the crystals were washed with cold hexane. The crude product, 221 g. (76%), melted at 137–140°. An analytical sample, prepared by two successive recrystallizations from ethyl alcohol, melted at 141–142°.

Anal. Calcd. for $C_{20}H_{22}N_2$: C, 82.7; H, 7.6; N, 9.7. Found: C, 82.6, H, 7.4; N, 9.6.

The infrared spectrum contained a doublet at 5.9 and 5.95 μ indicative of C=N (carbon in strained ring).

3-Anilino-2,2,4,4-tetramethylcyclobutanol (XII). A solution of 100 g. of 2,2,4,4-tetramethyl-3-phenyliminocyclobutanone (X) in 300 ml. of ethyl alcohol was hydrogenated over 20 g. of copper chromite (Harshaw Chemical Company Cu-1106 P) catalyst in a rocking autoclave for 4 hr. at 175° and under 5000 p.s.i. pressure of hydrogen. The hydrogenation mixture was filtered to remove the catalyst, and the filtrate was distilled through an 18-in. packed column to give 9.4 g. of forerun, b.p. 122–139° (3 mm.), and 76.0 g. (75%) of 3-anilino-2,2,4,4-tetramethylcyclobutanol, b.p. 131–132° (1.5 mm.). The material solidified slowly on standing at room temperature.

Anal. Calcd. for $C_{14}H_{21}NO$: C, 76.7; H, 9.7; N, 6.4; neut. equiv., 219. Found: C, 76.7; H, 9.8; N, 6.4; neut. equiv., 219.

The infrared spectrum of this product, compared with that of the starting material, showed complete removal of absorption at 5.55 μ (C=O) and 5.9 μ (C=N). A new doublet (N—H and —OH) appeared at 2.8 and 2.9 μ.

2,2,4,4-Tetramethyl-N,N'-diphenyl-1,3-cyclobutanediamine (XIII). A solution of 30 g. of 2,2,4,4-tetramethyl-*N,N'*-diphenyl-1,3-cyclobutanediimine (XI) in 75 ml. of benzene was hydrogenated in a rocking autoclave over 5 g. of Raney nickel catalyst at 100° and under 1500 p.s.i. pressure of hydrogen for 2 hr. The product was filtered and evaporated on the steam bath to 30 g. of viscous residue, which slowly crystallized. The infrared spectrum of this crude 2,2,4,4-tetramethyl-*N,N'*-diphenyl-1,3-cyclobutanediamine showed complete disappearance of the doublet at 5.9 and 5.95 μ (C=N) and appearance of a new band at 2.9 μ (N—H). The crude product was purified by recrystallization from petroleum ether and then from ethyl alcohol; 10.7 g. was recovered, m.p. 109–111°.

Anal. Calcd. for $C_{20}H_{26}N_2$: C, 81.6; H, 8.9; N, 9.5; neut. equiv., 147. Found: C, 81.4; H, 9.0; N, 9.5; neut. equiv. (titration with perchloric acid), 146.

The residue from the recrystallizations was a viscous oil that continued to crystallize very slowly. Presumably, the hydrogenation product was a mixture of *cis* and *trans* isomers.

Acknowledgment. We are indebted to J. H. Chaudet,[12] R. D. Clark, W. Goodlett, R. G. Nations, and A. L. Thompson, of these laboratories, for contributions to these investigations.

KINGSPORT, TENN.

(12) Present address: Melpar, Inc., Falls Church, Va.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, L. S. COLLEGE, BIHAR UNIVERSITY]

Dihydroisocoumarins. I. Synthesis of 3,4-Dihydro-7,8-dimethoxyisocoumarin

PRATUL KUMAR BANERJEE AND D. N. CHAUDHURY

Received May 1, 1961

3,4-Dimethoxy-2-aminophenethyl alcohol (IV) was prepared by the reduction of methyl 2-nitrohomoveratrate successively with lithium aluminum hydride and sodium dithionite. In an alternative procedure, the reduction of 2-nitrohomoveratroyl chloride with sodium borohydride followed by sodium dithionite gave IV. On diazotization, Sandmeyer reaction and hydrolysis, IV afforded 3,4-dihydro-7,8-dimethoxyisocoumarin (V).

Interest in the chemistry of the dihydroisocoumarins, without any substituent in the lactone ring, stems from the studies in this laboratory, of the naturally occurring glucoside, blepherin,[1] which has been shown to be the first dihydrofuranodihydroisocoumarin to be detected in nature. Before attempting to synthesize the natural product it was thought desirable to synthesize a series of dimethoxydihydroisocoumarins having no substituent in the lactone ring and to compare their properties with those of the blepherigenin dimethyl ether.[1] The limited number of synthetic dihydroisocoumarins reported in the literature have substituents in the lactone ring. However, an obvious analogy with the use of 1-(2-amino-3-methoxyphenyl)propan-2-ol by Blair and Newbold[2] in the synthesis of 3,4-dihydro-8-methoxy-3-methylisocoumarin suggested 3,4-dimethoxy-2-aminophenethyl alcohol (IV) as an intermediate from which it was possible to achieve the synthesis of 3,4-dihydro-7,8-dimethoxyisocoumarin (V).

(1) D. N. Chaudhury, *J. Indian. Chem. Soc.*, **35**, 612 (1958).

(2) J. Blair and G. T. Newbold, *J. Chem. Soc.*, 2871 (1955).