The infrared spectra were recorded on Beckman IR-5A or IR-8 spectrophotometers either neat or, where necessary, as a solution in carbon disulfide. Analysis of the naphthylamine products was made by reference to a graph constructed from known mixtures of the isomeric naphthylamines in carbon disulfide.

Isomerization Studies.—A mixture of 4-aminobiphenyl (1 g) in *o*-dichlorobenzene (20 ml) containing aluminum chloride (0.6 g) was treated with hydrogen chloride gas and 1 drop of water. The reaction mixture was stirred at 10° for 2 hr, and then worked up by the standard procedure. The starting material was recovered unchanged in quantitative yield. A similar study of the isomeric naphthylamines was carried out. In both cases the isomers were recovered unchanged in essentially quantitative yield.

Acknowledgment.—We gratefully acknowledge support for this work by the National Institutes of Health, U. S. Public Health Service.

Chemistry of Dimethylketene Dimer. VI. Reactions of the β-Lactone Dimer of Dimethylketene with Enamines[1]

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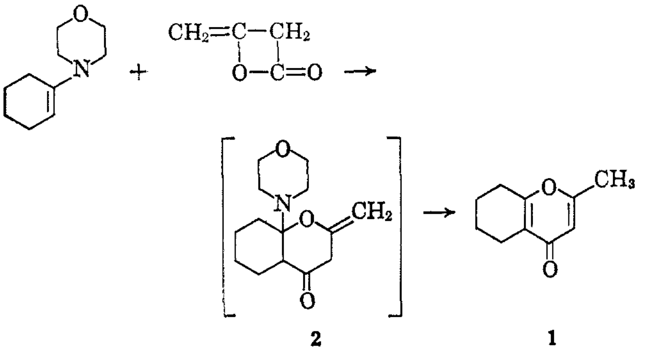
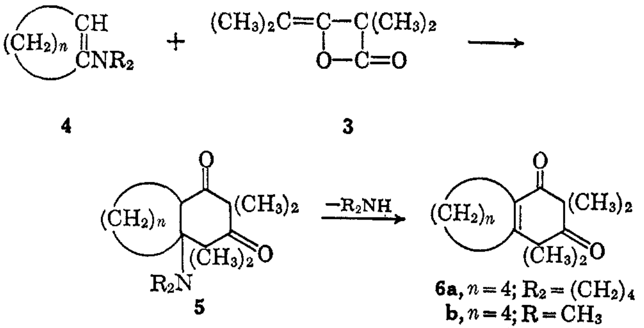
Received August 2, 1966

Enamines containing one β-hydrogen atom react with the lactone dimer of dimethylketene to form aminocyclohexanediones. These adducts lose amine to give cyclohexenediones. An enamine, a ketene O,N-acetal, and a ketene aminal, each containing two β-hydrogen atoms, were all acylated at the β carbon by the dimethylketene dimer. Enamines with no β hydrogen did not react.

Hünig, *et al.*, reported that 4-(1-cyclohexen-1-yl)-morpholine reacts with diketene to give 5,6,7,8-tetrahydro-2-methylchromone (**1**)[2]. They suggested a reaction mechanism involving acylation of the enamine and ring closure to an intermediate **2**, which stabilized itself by loss of amine and isomerization of the exocyclic double bond.

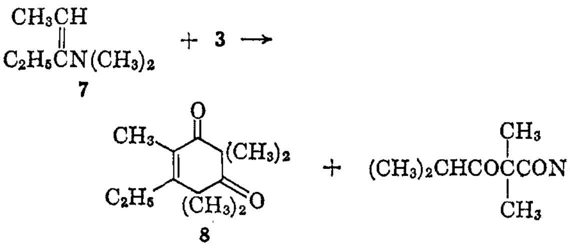


We found that the reaction of cyclohexenylamines with the lactone dimer of dimethylketene (**3**) differs from the behavior with diketene in that an alternate closure occurs to form a carbocyclic ring, and the intermediate adduct with the amine moiety is isolable. 1-(1-Cyclohexen-1-yl)pyrrolidine (**4a**) and **3**, heated on a steam bath for several hours, gave hexahydro-2,2,4,4-tetramethyl-4a-(1-pyrrolidinyl)-1,3(2H,4H)-naphthalenedione (**5a**) in 80% yield, and similar treatment of N,N-dimethyl-1-cyclohexen-1-ylamine (**4b**) with **3** gave the dimethylamino analog **5b**. The adduct **5a** showed variable stability;[3] one sample, stored at room temperature, changed slowly to a mixture of 5,6,7,8-tetrahydro-2,2,4,4-tetramethyl-1,3(2H,4H)-naphthalenedione (**6c**) and pyrrolidine. Distillation afforded pure **6c** in 88% yield. This elimination of amine was catalyzed by strong bases; **5a**, as well as the more stable **5b**, was converted rapidly into **6c** when refluxed in benzene containing a small amount of sodium methoxide.



6a, $n = 4$; $R_2 = (CH_2)_4$
b, $n = 4$; $R = CH_3$
c, $n = 4$
d, $n = 3$

Further work demonstrated that stability of the adduct **5** depends not only on the nature of the amine, but even more on the structure of the enamine involved. Treatment of enamines **4d** derived from cyclopentanone with the dimethylketene dimer **3** did not give the intermediate adducts **5**, but only the unsaturated diketone **6d**. Reaction of **3** with the acyclic enamine **7** likewise produced the cyclohexenedione **8** without detection of an intermediate. In these cases in which the amine was evolved during the addition reaction, some ketene dimer **3** was expended by reaction with the amine.[4]



The cyclic diketone structures of **5**, **6**, and **8**, rather than 4-pyranone derivatives **9** and **10** corresponding to the Hünig products, were indicated by nmr spectra.

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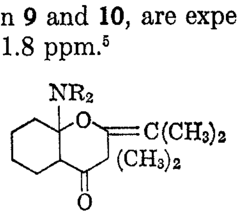
[1] Paper V in this series: R. H. Hasek, R. D. Clark, E. U. Elam, and R. G. Nations, *J. Org. Chem.*, **27**, 3106 (1962).

[2] S. Hünig, E. Benzing, and K. Hübner, *Chem. Ber.*, **94**, 486 (1961).

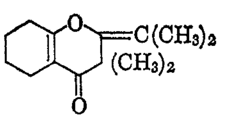
[3] Stability is associated with purity, in that more carefully purified samples were unchanged during prolonged storage.

[4] R. H. Hasek, R. D. Clark, E. U. Elam, and J. C. Martin, *J. Org. Chem.*, **27**, 60 (1962).

The methyl resonances of our products were located between 1.2 and 1.4 ppm; isopropylidene groups, like those in **9** and **10**, are expected to have chemical shifts of 1.7–1.8 ppm.[5]

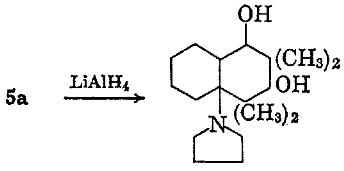


9

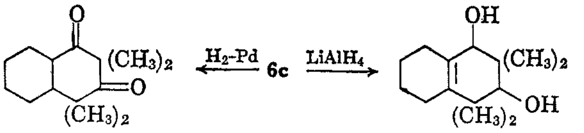


10

Reduction of **5a** and **6c** with lithium aluminum hydride gave the corresponding diols **11** and **12**. Considering the rearrangement reported during hydride reduction of similar systems,[5a] we do not regard these results as proof of structures. The resistance of **6c** to acid hydrolysis and its reduction by hydrogenation over palladium to hexahydro-2,2,4,4-tetramethyl-1,3-(2H,4H)-naphthalenedione (**13**) are more convincing evidence.

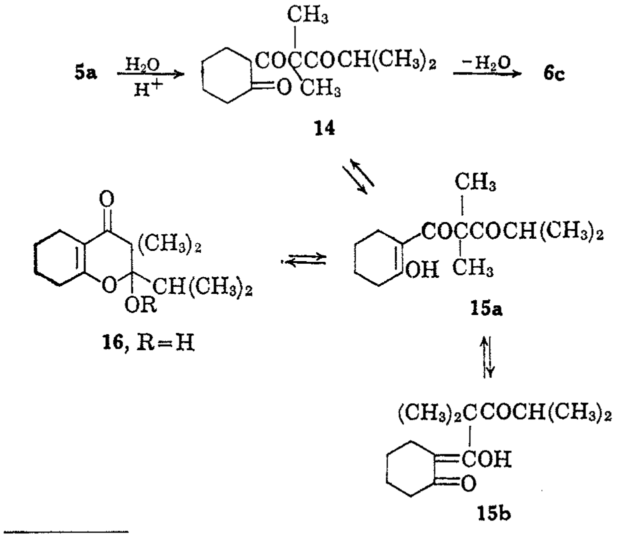


11



13 **12**

The hydrolysis of **5a** with aqueous hydrochloric acid gave a solid product which on standing slowly changed to **6c**.[3,6] This hydrolysis product may be written formally as the triketone **14**, but spectral data indicated its existence in both one enolic (**15a** or **b**) and a cyclic hemiketal (**16**) form. In carbon tetrachloride solution, **15** and **16** were present in about equal amounts; in more polar solvents ($CDCl_3$, CD_3COCD_3), **16** predominated and the infrared spectrum of a sample in a KBr disk indicated that only **16** was present. Treatment of a sample with hexamethyldisilazane afforded the trimethylsilyl derivative [**16**, R = $Si(CH_3)_3$] of the hemiketal.



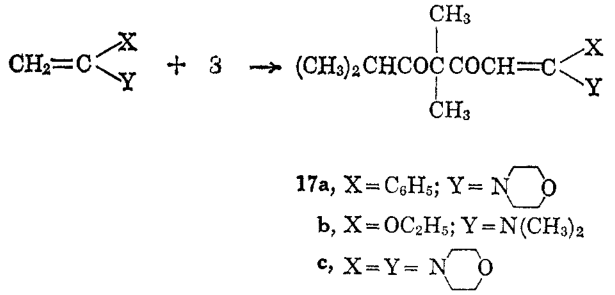
14

16, R=H

15a

15b

The reaction of dimethylketene lactone dimer with other types of enamines followed distinctly different paths. Enamines containing no β-hydrogen atoms, such as N,N-dimethylisobutenylamine, did not react with **3** even at 170°. Aldehyde-derived enamines containing a β hydrogen did react, but, instead of the expected products, we obtained materials which are probably derived from the enamine dimers. An enamine and analogous compounds containing the vinylidene group (two β-hydrogen atoms) reacted with **3** to form acyclic products **17a–c** by acylation at the β-carbon atom.



17a, X = C_6H_5; Y =

b, X = OC_2H_5; Y = $N(CH_3)_2$

c, X = Y =

Experimental Section

Materials.—3-Hydroxy-2,2,4-trimethyl-3-pentenoic acid β-lactone was obtained from Eastman Chemical Products, Inc. 4,4′-Vinylidenedimorpholine,[8] 1-ethoxy-N,N-dimethylvinylamine,[9] and the enamines[10] were prepared by methods described in the literature.

Hexahydro-2,2,4,4-tetramethyl-4a-(1-pyrrolidinyl)-1,3(2H,-4H)-naphthalenedione (**5a**).—1-(1-Cyclohexen-1-yl)pyrrolidine (37.5 g, 0.25 mole) and 3-hydroxy-2,2,4-trimethyl-3-pentenoic acid β-lactone (35 g, 0.25 mole) were combined and heated on a steam bath for 15 hr under a nitrogen atmosphere. The solid that formed when the mixture was cooled was removed by filtration to give 58 g (80%) of **5a**: mp 113–114°; infrared absorptions[11] (KBr), 5.84 and 5.96 μ; nmr spectrum[12] (pyridine), singlet at 1.27 (*gem*-dimethyl groups), singlets at 1.33 and 1.39 (*gem*-dimethyl groups), multiple peaks at 1.64 and 3.03 (pyrrolidinyl group), multiplet at 3.39 (methylidyne proton), and broad peaks from 0.5 to 3.0 ppm (methylene groups); ultraviolet absorptions[13] (C_2H_5OH), λ_{max} 305 mμ (log ε 2.47) and 245 mμ (log ε 3.27).

Anal. Calcd for $C_{18}H_{29}NO_2$: C, 74.2; H, 10.0; N, 4.8. Found: C, 74.2; H, 10.0; N, 4.8.

4a-(Dimethylamino)hexahydro-2,2,4,4-tetramethyl-1,3-(2H,-4H)-naphthalenedione (**5b**).—N,N-Dimethyl-1-cyclohexen-1-ylamine (**4b**, 25 g, 0.2 mole) and 3-hydroxy-2,2,4-trimethyl-3-pentenoic acid β-lactone (28 g, 0.2 mole) were combined and heated on a steam bath overnight under a nitrogen atmosphere. After cooling, 28 g (53%) of **5b** was removed by filtration as a crystalline solid. A sample recrystallized from a mixture of hexane and benzene melted at 149–150°; infrared absorptions (KBr), 5.87 and 5.98 μ.

Anal. Calcd for $C_{16}H_{27}NO_2$: C, 72.4; H, 10.3; N, 5.3. Found: C, 72.2; H, 10.6; N, 5.3.

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(5) (a) J. C. Martin, V. A. Hoyle, Jr., and K. C. Brannock, *Tetrahedron Letters*, 3589 (1965); (b) H. U. Hostettler, *ibid.*, 1941 (1965); (c) R. N. Pratt, S. A. Proctor, and G. A. Taylor, *Chem. Commun.*, 574 (1965).

(6) The ready cyclization of **14**, compared with less substituted derivatives,[7] is another illustration of the effect of geminal substitution.

(7) D. J. Baisted and J. S. Whitehurst, *J. Chem. Soc.*, 2340 (1965).

(8) H. Baganz and L. Domaschke, *Chem. Ber.*, **95**, 2095 (1962).

(9) H. Meerwein, W. Florian, N. Schön, and G. Stopp, *Ann. Chem.*, **641**, 1 (1961).

(10) (a) G. Stork, A. Brizzolara, H. Landesman, J. Szmuszkovicz, and R. Terrell, *J. Am. Chem. Soc.*, **85**, 207 (1963); (b) S. Hünig, K. Hübner, and E. Benzing, *Chem. Ber.*, **95**, 926 (1962).

(11) Infrared spectra were determined on a Baird AB-2 instrument.

(12) Nmr spectra were recorded on a Varian A-60 instrument at 60 Mc with tetramethylsilane as an internal standard.

(13) Ultraviolet spectra were recorded on a Cary spectrophotometer Model 14MS made by Applied Physics Corp. operating from 200 to 400 mμ.

5,6,7,8-Tetrahydro-2,2,4,4-tetramethyl-1,3(2H,4H)-naphthalenedione (6c).—Compound **5a** (79 g, 0.27 mole) was let stand at room temperature for 5 weeks, during which time this solid changed to an oil. Distillation of the oil through a 6-in. Vigreux column gave, after removal of a forerun rich in pyrrolidine, 52 g (88%) of **6c**: bp 95° (0.6 mm); n^{20}D 1.5115; infrared absorptions (smear), 5.88, 6.03, and 6.18 μ; nmr spectrum (neat), singlet at 1.26 (*gem*-dimethyl groups), singlet at 1.37 (*gem*-dimethyl groups), and multiplets at 1.72 and 2.39 ppm (methylene groups); ultraviolet absorption (C_2H_5OH), λ_{max} 242 mμ (log ϵ 3.94).

Anal. Calcd for $C_{14}H_{20}O_2$: C, 76.3; H, 9.2. Found: C, 76.2; H, 9.2.

Catalysis of Elimination Reaction by Sodium Methoxide.—A solution of **5a** (15 g, 0.052 mole) in benzene (50 ml) containing sodium methoxide (0.2 g) was refluxed for 1 hr. The solvent and pyrrolidine were removed under reduced pressure. An infrared spectrum of the residue (11.5 g) was identical with the spectrum of **6c**.

Treatment of **5b** under similar conditions led to rapid evolution of dimethylamine and formation of **6c**.

5,5,7,7-Tetramethyl-4,6(5H,7H)-indandione (6d).—N,N-Dimethyl-1-cyclopenten-1-ylamine (22.5 g, 0.2 mole) and 3-hydroxy-2,2,4-trimethyl-3-pentenoic acid β-lactone (28 g, 0.2 mole) were combined and heated on a steam bath for 24 hr. The mixture was distilled through a Nester/Faust spinning-band column to give, after removal of a 19-g forerun, 26.4 g of N,N,2,2,4-pentamethyl-3-oxovaleramide, bp 64–72° (0.5–0.7 mm), n^{20}D 1.4620.[14]

The distillation was continued to give, after removal of 3.7 g of an intermediate fraction, 14.3 g (35%) of **6d**: bp 80–82° (0.4–0.5 mm); n^{20}D 1.5069; nmr spectrum (neat), two singlets at 1.23 and 1.37 (methyl groups), quintet at 2.03 (methylene group), and overlapping peaks centered at 2.72 ppm (two methylene groups adjacent to olefinic linkage).

Anal. Calcd for $C_{13}H_{18}O_2$: C, 75.7; H, 8.8. Found: C, 75.6; H, 8.7.

5-Ethyl-2,2,4,4,6-pentamethyl-5-cyclohexene-1,3-dione (8).—1-Ethyl-N,N-dimethylpropenylamine (**7**) (20 g, 0.18 mole) and 3-hydroxy-2,2,4-trimethyl-3-pentenoic acid β-lactone (24.8 g, 0.18 mole) were combined and heated on a steam bath for 40 hr under a nitrogen atmosphere. Some of the lactone dimer was still present in the mixture at the end of this time. Distillation of the mixture through a 6-in. Vigreux column gave 14 g of a fraction boiling from 43 (34 mm) to 98° (2 mm), followed by 23.5 g of a fraction boiling at 98–134° (2 mm). The first fraction consisted mostly of the lactone dimer as indicated by its infrared spectrum. The second fraction consisted of two major components comprising approximately 39 and 58%, respectively. This second fraction was distilled through a Nester/Faust spinning-band column, and nine cuts of 1 ml each were taken. A good separation of the two components was not effected; however, the first and last cuts each contained one major component as shown by glpc analysis. The infrared spectrum of the first fraction, bp 73–75° (0.8 mm), n^{20}D 1.4605, was identical with that of N,N-2,2,4-pentamethyl-3-oxovaleramide. The last fraction was identified as **8**: bp 84° (0.9 mm); n^{20}D 1.4902; infrared absorptions (smear), 5.85, 6.03, and 6.18 μ; nmr spectrum (neat), singlets at 1.24 and 1.36 (two sets of *gem*-dimethyl groups), a singlet at 1.93 (methyl group), a quartet at 2.50, and a triplet at 1.24 ppm (ethyl group).

Anal. Calcd for $C_{13}H_{20}O_2$: C, 74.9; H, 9.7. Found: C, 74.6; H, 9.7.

Decahydro-2,2,4,4-tetramethyl-4a-(1-pyrrolidinyl)-1,3-naphthalenediol (11).—A solution of **5a** (29 g, 0.1 mole) in ether (50 ml) was added dropwise with stirring to a slurry of lithium aluminum hydride (4 g, 0.105 mole) in ether (150 ml). The resulting mixture was allowed to stand for 16 hr. Ethyl acetate (30 ml) followed by water (100 ml) was added slowly to the mixture. The mixture was filtered and the solid was washed with ether. Distillation of the ethereal filtrate gave 22 g (75%) of **11**, bp 165–170° (0.4 mm), which crystallized on standing, mp 110–120°. A sample recrystallized from hexane melted at 123–125°; infrared absorption (KBr), 3.0 μ (no bands between 5.6 and 6.3 μ); nmr spectrum ($CHCl_3$), five peaks at 0.97, 1.03, 1.07, 1.17, and 1.21 (methyl groups), unresolved peaks extending from about 1.3 to 2.3 (six methylene groups and two hydroxy groups), poorly resolved triplet at 3.02 (CH_2NCH_2), a single peak at 3.45, and a doublet at 3.03 ppm (two OCH groups).

Anal. Calcd for $C_{18}H_{33}NO_2$: C, 73.2; H, 11.3. Found: C, 73.3; H, 11.7.

1,2,3,4,5,6,7,8-Octahydro-2,2,4,4-tetramethyl-1,3-naphthalenediol (12).—Compound **6c** (22 g, 0.1 mole) was added dropwise with cooling to a slurry of lithium aluminum hydride (3 g, 0.078 mole) in ether (125 ml). The resulting mixture was allowed to stand for 16 hr. Ethyl acetate (20 ml) followed by water (100 ml) was added to the mixture. The mixture was filtered and the solid was washed with ether. Distillation of the combined filtrates gave, after removal of ether, 17.5 g (78%) of **12**, bp 120–122° (0.6 mm), which crystallized on standing, mp 104–108°. A sample washed with hexane melted at 105–108°; infrared absorption (KBr), 2.95 μ (strong), no bands in the carbonyl region from 5.6 to 6.2 μ; nmr spectrum ($CHCl_3$), peaks at 0.83 (area showed peak to be due to methyl group of isomer present in the amount of 40%), 1.00, and 1.11 (methyl groups), broad peak at 1.68 (two methylene groups), and a broad peak at 2.03 ppm (two methylene groups adjacent to olefinic linkage and two hydroxy groups). The presence of hydroxy groups was shown by area and shift with temperature. Also, when trichloroacetyl isocyanate was added, the area of the peak at 2.03 decreased to become equal to the area of the peak at 1.68. The spectrum also showed four single peaks at 3.22, 3.36, 3.45, and 3.57 ppm (two OCH groups). When trichloroacetyl isocyanate was added, all four peaks were shifted downfield by *ca.* 1.6 ppm.[15]

Anal. Calcd for $C_{14}H_{24}O_2$: C, 74.9; H, 10.8; mol wt, 224. Found: C, 75.1; H, 10.7; mol wt (ebullioscopic in benzene), 227.

Hexahydro-2,2,4,4-tetramethyl-1,3(2H,4H)-naphthalenedione (13).—Compound **6c** (25 g, 0.11 mole) was dissolved in hexane (100 ml) and hydrogenated over 2 g of 5% palladium-on-carbon catalyst at 75° and 1500 psi. The catalyst was removed by filtration, and about two-thirds of the solvent was removed by distillation under reduced pressure. The residue was chilled to give 10 g (41%) of **13**. Glpc analysis of this crude material showed only one component. A sample recrystallized from pentane melted at 79–82°; infrared absorptions (KBr), 5.89 and 5.97 μ; nmr spectrum (CCl_4), four peaks at 1.13, 1.19, 1.26, and 1.33 (methyl groups), a broad peak at 3.12 (methylidyne proton adjacent to carbonyl), a broad peak at 2.45 (methylidyne proton adjacent to *gem*-dimethyl group), and overlapping peaks extending from 1.3 to 2.1 ppm (four methylene groups).

Anal. Calcd for $C_{14}H_{22}O_2$: C, 75.6; H, 10.0. Found: C, 75.8; H, 10.0.

2,2,4-Trimethyl-1-(2-oxocyclohexyl)-1,3-pentanedione (14).—Compound **5a** (25 g, 0.086 mole) was combined with a solution of 30 ml of concentrated hydrochloric acid in 40 ml of water. The resulting solution was allowed to stand at room temperature for 12 hr and then heated on a steam bath for 2.5 hr. After the solution was cooled, the mixture was extracted with ether, and the organic layer was evaporated on a steam bath to give 15 g (73%) of **14** as a crystalline solid. A sample recrystallized from a pentane–ether mixture melted at 104–105°; infrared absorptions (KBr, only hemiketal form **16** present), 2.97 and 6.20 μ; infrared absorptions (CCl_4, approximately 1:1 mixture of an enol **15** and hemiketal **16**), 2.75, 2.85, 5.83, 5.99, 6.10, and 6.30 μ; nmr spectrum ($CDCl_3$, enol form **15**), doublet at 1.08 and septet at 2.90 (isopropyl group), singlet at 1.39 (*gem*-dimethyl groups), multiplets at 1.65 and 2.22 (methylene groups), and broad singlet at 16.58 ppm (enol proton); nmr spectrum ($CDCl_3$, hemiketal form **16**), doublets at 1.03 and 1.10 and septet at 2.18 (isopropyl group on asymmetric carbon atom), singlets at 1.19 and 1.26 (*gem*-dimethyl groups), multiplets at 1.65 and 2.22 (methylene groups), and a singlet at 3.35 ppm (*t*-hydroxy group) which disappeared after addition of trichloroacetyl isocyanate.[15]

Anal. Calcd for $C_{14}H_{22}O_3$: C, 70.6; H, 9.3. Found C, 70.8; H, 9.6.

2,3,5,6,7,8-Hexahydro-2-isopropyl-3,3-dimethyl-2-(trimethylsiloxy)chromone [16, R = $Si(CH_3)_3$].—The procedure of Friedman and Kaufman was followed.[16] Hexamethyldisilazane (1 g) re-

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[14] Authentic N,N-2,2,4-pentamethyl-3-oxovaleramide was prepared from **3** and dimethylamine according to the method of R. H. Hasek, R. D. Clark, E. U. Elam, and J. C. Martin, *J. Org. Chem.*, **27**, 60 (1962). This material boiled at 62–64° (0.6 mm); n^{20}D 1.4591; infrared (smear), 5.85 and 6.10 μ; nmr spectrum ($CDCl_3$), doublet at 1.03 (6 H) and septet at 2.87 (1 H) (isopropyl group), singlet at 1.13 (6 H) (*gem*-dimethyl groups), and a singlet at 2.90 (6 H) ppm (dimethylamino group). *Anal.* Calcd for $C_{10}H_{19}NO_2$: C, 64.8; H, 10.3. Found: C, 64.7; H, 10.2.

[15] V. W. Goodlett, *Anal. Chem.*, **37**, 431 (1965).

[16] S. Friedman and M. L. Kaufman, *ibid.*, **38**, 144 (1966).

fluxed overnight in 3 ml of dimethyl sulfoxide. The upper phase was separated and distilled. A middle fraction, 0.7 g, bp 80° (0.6 mm), was the pure trimethylsiloxy derivative: infrared absorptions (CCl$_4$), 5.95, 6.10, 7.98, 8.33, 8.55, 9.02, 9.22, 10.10, 11.26, 11.55, and 11.88 μ; nmr spectrum (CDCl$_3$), singlet at 0.18 (trimethylsiloxy group), two doublets at 0.92 and 1.00 and a septet at *ca.* 2.22 (isopropyl group on asymmetric carbon atom), singlets at 1.11 and 1.14 (*gem*-dimethyl groups), and multiplets at 1.68 and 2.21 ppm (methylene groups).

5,6,7,8-Tetrahydro-2,2,4,4-tetramethyl-1,3(2H,4H)-naphthalenedione (6c).—A sample of **14** (14 g, 0.059 mole) was allowed to stand at room temperature for approximately 5 weeks. During this time a new liquid phase appeared. The mixture was filtered to give 6.5 g of a solid which had an infrared spectrum identical with that of **14**. The infrared spectrum of the filtrate (7 g) was identical with that of **6c**. The presence of water in this filtrate was indicated by a band in the infrared spectrum at 3.0 μ and also by glpc analysis.

4,4,6-Trimethyl-1-morpholino-1-phenyl-1-heptene-3,5-dione (17a).—4-(1-Phenylvinyl)morpholine[10b] (4.75 g, 0.025 mole) and 3-hydroxy-2,2,4-trimethyl-3-pentenoic acid β-lactone (3.5 g, 0.025 mole) were heated under nitrogen at 130° for 10 hr. After the reaction mixture cooled, 1.2 g (15%) of the acylation product was separated by filtration and washed with benzene: mp 157–160°; infrared absorptions (CHCl$_3$), 5.87, 6.06, 6.52, 7.98, 8.92, 9.18, 9.80, and 10.65 μ; nmr spectrum (CDCl$_3$), doublet at 1.06 and septet at 2.90 (isopropyl group), singlet at 1.27 [*gem*-dimethyl groups), triplets at 3.10 and 3.69 (methylene groups), singlet at 5.23 (olefinic proton), and multiplet from 7.0 to 7.6 ppm (phenyl group).

1-(Dimethylamino)-1-ethoxy-4,4,6-trimethyl-1-heptene-3,5-dione (17b).—3-Hydroxy-2,2,4-trimethyl-3-pentenoic acid β-lactone (25 g, 0.18 mole) was combined with 1-ethoxy-N,N-dimethylvinylamine (20.5 g, 0.18 mole), and the resulting mixture was heated on a steam bath. An exothermic reaction occurred and the temperature rose to 140°. The mixture was then heated on a steam bath for an additional hour and allowed to stand for several hours at room temperature. Distillation of the mixture gave 36 g (77%) of **17b**: bp 123–125° (0.6 mm); n^{20}D 1.5148; infrared absorptions (smear), 5.9, 6.17, and multiplicity of bands at 6.5–7.0 μ; nmr spectrum (neat), doublet at 1.02 and septet at 2.90 (isopropyl group), singlet at 1.26 (*gem*-dimethyl groups), triplet at 1.32 and quartet at 4.26 (ethoxy group), singlet at 3.03 (dimethylamino group), and a singlet at 4.57 ppm (olefinic proton).

Anal. Calcd for C$_{14}$H$_{25}$NO$_3$: C, 65.8; H, 9.9; N, 5.5. Found: C, 65.9; H, 9.7; N, 5.8.

4,4,6-Trimethyl-1,1-dimorpholino-1-heptene-3,5-dione (17c).—4,4′-Vinylidenedimorpholine (12 g, 0.061 mole) and 3-hydroxy-2,2,4-trimethyl-3-pentenoic acid β-lactone (8.5 g, 0.061 mole) were combined and heated on a steam bath for 15 hr. The resulting viscous oil on treatment with hexane gave 14 g (68%) of **17c**. A sample recrystallized from hexane–acetone melted at 126–127°; infrared absorptions (KBr), 5.9, 6.24, 6.65, and 6.95 μ; nmr spectrum (CCl$_4$), doublet at 1.00 and a septet at 2.87 (isopropyl group), a singlet at 1.23 (*gem*-dimethyl groups), broad peaks at 3.22 and 3.70 (methylene groups), and a singlet at 4.37 ppm (olefinic proton).

Anal. Calcd for C$_{18}$H$_{31}$N$_2$O$_4$: C, 63.7; H, 9.2; N, 8.3. Found: C, 63.6; H, 9.1; N, 8.5.

Acknowledgment.—The authors thank V. Wilson Goodlett for interpretation of nmr spectra.

Notes

A Versatile New Enamine Synthesis

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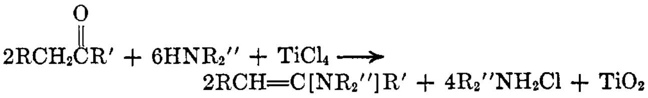
Received September 7, 1966

A general method for converting carbonyl compounds into enamines using titanium tetrachloride and free amine is described. Highly hindered as well as ordinary enamines can be prepared this way.

Recently we reported the synthesis of sterically hindered enamines and enamines of volatile amines, using tetrakis(dimethylamino)titanium as aminating agent.[1] While this method works quite well, its main drawback is in the necessity to synthesize the Ti(NR$_2$)$_4$ compounds.[2] We would now like to report a more straightforward method, using readily available starting materials, that appears to be a general enamine synthesis.

Results and Discussion

Allowing a stoichiometric mixture of titanium tetrachloride, secondary amine, and aldehyde or ketone to react leads directly and rapidly to enamine formation. This method is similar to the method reported by Blanchard[3] and other methods employing drying agents with two important differences. First, the TiCl$_4$ is a more effective water scavenger, and, second, it can act catalytically[4] in the Lewis acid sense to polarize the carbonyl bond. Table I lists the enamines prepared in this work, several of which were reported in ref 1.



$$2\mathrm{RCH_2}\overset{\overset{\displaystyle\mathrm{O}}{\|}}{\mathrm{C}}\mathrm{R'} + 6\mathrm{HNR_2''} + \mathrm{TiCl_4} \longrightarrow 2\mathrm{RCH{=}C[NR_2'']R'} + 4\mathrm{R_2''NH_2Cl} + \mathrm{TiO_2}$$

While carbonyl compounds less hindered than those in Table I, such as cyclohexanone and phenylacetaldehyde, are readily converted to their enamines by this method, examples more hindered are not. Several days is required for any visible reaction in the case of 2,2,4-trimethyl-3-pentanone and 2,6-di-*t*-butylcyclohexanone is inert under the reaction conditions.

Of particular interest is the high yield of N,N,2,2-tetramethyl-1-methylenepropylamine from pinacolone since a previous report[5] suggested that it could not be

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(1) H. Weingarten and W. A. White, *J. Org. Chem.*, in press.

(2) D. C. Bradley and T. M. Thomas, *J. Chem. Soc.*, 3857 (1960).

(3) E. P. Blanchard, Jr., *J. Org. Chem.*, **28**, 1397 (1963).

(4) Although the TiCl$_4$ may perform a function similar to acid catalysts in other types of carbonyl addition reactions, it is, clearly, not a *true* catalyst, being consumed in the reaction.

(5) P. Nelson and A. Pelter, *J. Chem. Soc.*, 5142 (1965).