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 $C_{18}H_{31}N_2O_4$: C, 63.7; H, 9.2; N, 8.3. Found: C, 63.6; H, 9.1; N, 8.5.

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Notes

A Versatile New Enamine Synthesis

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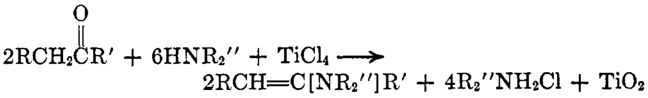
A general method for converting carbonyl compounds into enamines using titanium tetrachloride and free amine is described. Highly hindered as well as ordinary enamines can be prepared this way.

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



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

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.

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.

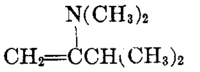
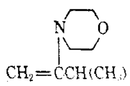
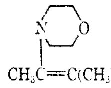
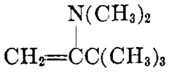
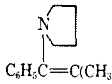
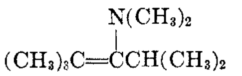
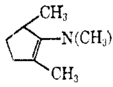
[2] D. C. Bradley and T. M. Thomas, *J. Chem. Soc.*, 3857 (1960).

[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).

TABLE I

Enamine	Yield,[a] %	Anal, % Calcd C	 Calcd H	 Calcd N	 Found C	 Found H	 Found N	Mol wt[b]	Bp (mm), °C	$n^{25}D$	Nmr,[c] τ
 $CH_2{=}C(N(CH_3)_2)CH(CH_3)_2$ N,N,2-Trimethyl-1-methylenepropylamine	57	74.3	13.3	12.4	74.4	13.1	12.8	113	56(83)	1.4403	(s) 5.95, 6.13, 7.58; (m) 7.63; (d) 8.90 (1:1:6:1:6)
 4-(3-Methyl-1-buten-2-yl)morpholine  4-(3-Methyl-2-buten-2-yl)morpholine	55[d]	69.6	11.0	9.0	69.8	10.9	8.7	155	100(35)	1.4710	(s) 5.89, 6.09; (m) 6.40, 7.61, 7.90; (d) 8.95 (1:1:4:4:1:6) (s) 8.20, 8.48; (m) 6.48, 7.52 (3:6:4:4)
 $CH_2{=}C(N(CH_3)_2)C(CH_3)_3$ N,N,2,2-Tetramethyl-1-methylenepropylamine	94	75.5	13.5	11.0	75.9	13.1	10.7	127	57(71)	1.4293	(s) 5.31, 5.57, 7.57, 8.82 (1:1:6:9)
 1-(1-Phenyl-2-methylpropenyl)pyrrolidine	62	83.6	9.5	7.0	83.6	9.5	7.4	201	86(1)	1.5442	(m) 7.15, 8.43; (s) 8.05, 8.40 (4:4:3:3)
 $(CH_3)_3C{=}C(N(CH_3)_2)CH(CH_3)_2$ N,N,2-Trimethyl-1-isopropylpropenylamine	72	76.6	13.5	9.9	76.9	13.1	10.0	141	82(82)	1.4397	(s) 7.46, 8.32, 8.40; (d) 8.91; (m) 7.28 (6:3:3:6:1)
 N,N,2,5-Tetramethyl-1-cyclopenten-1-ylamine	86	77.7	12.3		77.6	12.3		139	61(17)	1.4699	(s) 7.46; (d) 8.98; (m) 7.40, 8.28, 8.60 (6:3:4:3:1)

[a] No special effort was made to optimize yields. [b] Molecular weights were determined by mass spectroscopy. [c] Benzene solvent, TMS internal standard. [d] Mixture, 1:2.4.

made with $B[N(CH_3)_2]_3$ and we were only able to obtain moderate yields[1] using $Ti[N(CH_3)_2]_4$. Experiments monitored by nmr lead us to the conclusions that in the metal amide reaction significant amounts of metal enolate, $CH_2{=}C(OM)C(CH_3)_3$, is formed which is not aminated but engages in condensation reactions. This is apparently minimized in the $TiCl_4$, secondary amine system.

Also worth pointing out is our observation that the more highly hindered ketones of the series react more rapidly with dimethylamine than with the stronger cyclic amines, pyrrolidine and morpholine. We ascribed this to be the greater tendency for the cyclic bases to coordinate with the $TiCl_4$.

Several other metal halide systems were examined, since one can imagine a number of potential Lewis acid drying agents similar to $TiCl_4$. The following were found to be active: $AlCl_3$, $SnCl_4$, $FeCl_3$, $AsCl_3$, and $SbCl_3$. These experiments were carried out with 3-methyl-2-butanone and dimethylamine in nmr tubes using benzene as solvent. Although the above mentioned metal halides are active, none appeared better than the titanium derivative.

Since the system is heterogeneous, it has been difficult to obtain mechanistic data. However, it seems likely the two most important features of the mechanism are coordination of the titanium atom with the carbonyl oxygen preparing the carbonyl group for reaction with amine base followed eventually by transfer of the oxygen atom to titanium.

Experimental Section

Proton nmr spectra were obtained from a Varian Model A-60 spectrometer at a frequency of 60.000 Mc. Most of the ketones were obtained in high purity from Chemical Samples Co., Columbus, Ohio. The other reagents and solvents were the best commercial grades available.

Enamine Synthesis. General Method.—To a 2-l., four-necked flask fitted with a stirrer, condenser, N_2 gas line, thermometer, and dropping funnel is added 500 ml of solvent (benzene, *n*-pentane, or ethyl ether). To this is added 0.1 mole of ketone and a solution of amine (excess) in 100 ml of solvent. To the resulting solution is added, over a 20–60-min period, 0.055 mole $TiCl_4$ in an additional 100 ml of solvent (benzene or *n*-pentane). The temperature is kept between 0° and 10° during this addition. When the $TiCl_4$ addition is complete, the mixture is allowed to stir at room temperature for several hours. The more hindered ketones required longer reaction times and the progress of the reaction is followed by nmr analysis of aliquots. The reaction mixture is then filtered and the solvent is removed. The residual oil is distilled at reduced pressure. All operations described above are carried out under an atmosphere of dry nitrogen.