solvent–metaphosphate complexes ($O(CH_2CH_2)_2O^+-PO_3^{2-}$ and $CH_3C{\equiv}N^+-PO_3^{2-}$) analogous with the known sulfonato species. The metaphosphate ion is of course likely to be highly reactive (by analogy with its isoelectronic sulfur analogue) and will therefore complex with even weakly nucleophilic agents. The mechanisms which could involve such an intermediate must therefore be very close to a borderline where the intermediate does not exist (concerted transfer of the $-PO_3^{2-}$ group)[5,25] or exists only in an encounter complex (preassociation stepwise mechanism).[5,25] Kirby and Varvoglis[26] showed that pyridine attack on 2,4-dinitrophenyl phosphate dianion is independent of the pyridine structure although the reaction is second order. The β_L for pyridine attack on the dianion of aryl phosphates is −1.03[26] and this agrees with almost (but not complete) fission of the P–O bond, when compared with a β_{EQ} of −1.35, in the rate-controlling transition state. These results are consistent with the preassociation stepwise mechanism where a metaphosphate ion, formed in an encounter complex with pyridine and aryl oxide ion, is too unstable to exist as a free species.

Acknowledgment. We are grateful to the S.E.R.C. (N.B) for a C.A.S.E. studentship and to I.C.I. Organics Division for financial assistance. We thank N.A.T.O. for a travel grant in partial support of this work (R.G. 115 80).

Registry No. Phenyl phosphate, 701-64-4; phenyl phosphate bis(cyclohexylamine) salt, 13798-39-5; 3-chlorophenyl phosphate, 77368-40-2; 3-chlorophenyl phosphate bis(cyclohexylamine) salt, 88766-69-2; 4-nitrophenyl phosphate, 330-13-2; 4-nitrophenyl phosphate bis(cyclohexylamine) salt, 52483-84-8; 4-methoxyphenyl phosphate, 27856-12-8; 4-methoxyphenyl phosphate bis(cyclohexylamine) salt, 75378-48-2; 3,4,5-trichlorophenyl phosphate, 88766-68-1; 3,4,5-trichlorophenyl phosphate bis(cyclohexylamine) salt, 88766-70-5; 4-methylphenyl phosphate, 6729-45-9; 4-methylphenyl phosphate bis(cyclohexylamine) salt, 88766-71-6; 3-nitrophenyl phosphate, 13388-91-5; 3-nitrophenyl phosphate bis(cyclohexylamine) salt, 14545-82-5.

(25) Jencks, W. P. *Chem. Soc. Rev.* **1981**, *10*, 345.
(26) Kirby, A. J.; Varvoglis, A. G. *J. Chem. Soc. B* **1968**, 135.

A Facile Synthesis of 3,4-Dienamides by the Reaction of Propargyl Alcohols with Cyclic Amide Acetals and Their Stereoselective Rearrangement to 2(*E*),4(*Z*)-Dienamides Promoted with Alumina. Total Synthesis of Isochavicine

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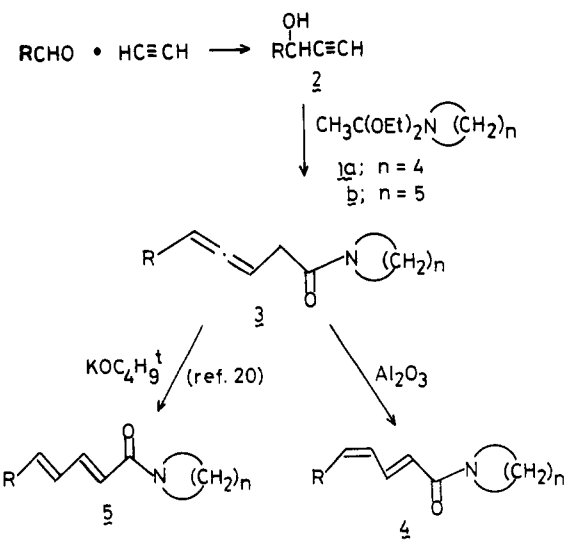
Thermal condensation of propargyl alcohols with acetals of 1-acetylpyrrolidine and 1-acetylpiperidine gave 3,4-dienamides in good yields. Alumina promoted the rearrangement of β-allenic amides to 2(*E*),4(*Z*)-dienamides stereoselectively. Its application to the synthesis of isochavicine of pepper components is described. Carbon-13 NMR data of these dienamides were obtained.

The dienamide is an important structural feature of a number of natural products, which have been reported to be active both physiologically and insecticidally. Examples of piperidine and pyrrolidine dienamides are piperine,[1] chavicine,[1] and isochavicine[1] of peper components, trichostachine,[2] trichonine,[3] and piperstachine,[4] which were isolated from the stem of piper *trichostachyon C. DC.* (family Piperacease). Representative, classical synthesis of the conjugated dienamide involves successive Knovenagel condensations.[2,5,6] The dienoic acid as a key intermediate can be prepared also by the combination of Wittig reaction and hydrogenation of acetylenic compounds.[7]

Scheme I

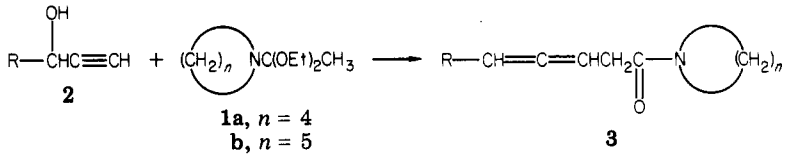


Since Meerwein[8] reported the preparation of the acetals of *N,N*-dialkylamides, their reactions with allylic[9-14] and

(1) (a) Cazeneuve, P.; Caillot, O. *Bull. Soc. Chim. Fr.* **1877**, *27*, 290. (b) Labruyire, B. *J. Agr. Food Chem.* **1966**, *14*, 469. (c) Lurik, B. B.; Kamennov, N. A.; Vlkov, Yu. P. *Khim-Favir. Zh.* **1971**, *5*, 15. (d) Grewe, R.; Freist, W.; Neumann, H.; Kersten, S. *Chem. Ber.* **1970**, *103*, 3752. (e) DeCleyn, R.; Verzele, M. *Chromatographia* **1975**, *8*, 342. (f) DeCleyn, R.; Verzele, M. *Bull. Soc. Chim. Belg.* **1975**, *84*, 435. (g) Harvill, E. K.; Hartzell, A., Arthur, J. M. *Contrib. Boyce Thompson Inst.* **1943**, *13*, 87; *Chem. Abstr.* **1943**, *37*, 5802.
(2) Singh, J.; Dhar, K. L.; Atal, C. K. *Tetrahedron Lett.* **1969**, 4975.
(3) Singh, J.; Dhar, K. L.; Atah, C. K. *Tetrahedron Lett.* **1971**, 2119.
(4) Joshi, B. S.; Viswanathan, N.; Gawad, D. H.; Philipsborn, W. von *Helv. Chim. Acta* **1975**, *58*, 1551.
(5) Ruegheimer, G. *Chem. Ber.* **1882**, *15*, 1390.
(6) Normant, H.; Feugeas, C. *C. R. Hebd. Seances Acad. Sci.* **1964**, *258*, 2846.
(7) For example, see: (a) Burden, R. S.; Crombie, L. *J. Chem. Soc.* **1969**, 2477. (b) Sehlosser, M.; Christmann, K. F. *Liebigs Ann. Chem.* **1967**, *708*, 1. (c) Baumann, M.; Hoffmann, W. *Synthesis* **1977**, 681.
(8) Meerwein, H.; Florian, W.; Schon, N.; Stopp, G. *Liebigs Ann. Chem.* **1961**, *641*, 1.

0022-3263/84/1949-1204$01.50/0

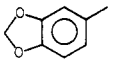
Table I. Synthesis of 3,4-Dienamides 3 by the Reaction of Propargyl Alcohols 2 with Amide Acetals 1



2

1a, $n = 4$
b, $n = 5$

3

compd[a]	R	n	yield,[b] %	IR (neat), cm^{-1}	^1H NMR ($CDCl_3$), ppm
3a	H	4	65 (95)[c]	1950, 1635, 1440, 870	1.9 (m, 4), 3.0 (m, 2), 3.45 (m, 4), 4.7 (m, 2), 5.34 (m, 1)
3b	H	5	79 (87)[c]	1950, 1635, 1440, 1250, 1220, 850	1.60 (br s, 6), 3.10 (m, 2), 3.54 (m, 4), 4.76 (m, 2), 5.79 (m, 1)
3c	CH_3	5	77	1970, 1640, 1440, 1255, 1218, 850	1.62 (m, 9), 2.97 (dd, 2, J = 3.5, 7), 3.47 (m, 4), 5.13 (m, 2)
3d	C_3H_7	4	54[c,d]	1965, 1640, 1435, 1165, 860	0.92 (t, 3, J = 6), 1.1-1.7 (m, 2), 1.7-2.5 (m, 6), 3.00 (dd, 2, J = 3.5, 7), 3.45 (m, 4), 5.2 (m, 2)
3e	C_3H_7	5	77	1965, 1640, 1440, 1255, 1218, 850	0.93 (t, 3, J = 6), 1.60 (m, 8), 1.97 (m, 2), 2.95 (dd, 2, J = 3.5, 7), 3.4 (m, 4), 5.13 (m, 2)
3f	C_5H_{11}	5	70	1962, 1640, 1440, 1255, 1220, 852	0.90 (t, 3, J = 6), 1.32 (m, 6), 1.63 (m, 6), 2.04 (m, 2), 3.05 (dd, 2, J = 3.5, 7), 3.50 (m, 4), 5.22 (m, 2)
3g	C_6H_{13}	5	88 (100)[c]	1965, 1640, 1440, 1255, 1219, 850	0.90 (t, 3, J = 6), 1.35 (m, 4), 1.6 (m, 6), 2.0 (m, 2), 2.93 (dd, 2, J = 3.5, 7), 3.42 (m, 4), 5.12 (m, 2)
3h	C_9H_{19}	4	57 (74)[e]	1952, 1640, 1440, 1255, 1222, 865	0.90 (t, 3, J = 6), 1.27 (br s, 14), 1.6-2.2 (m, 6), 2.88 (dd, 2, J = 3.5, 7)
3i	C_9H_{19}	5	79	1970, 1638, 1442, 1255, 1220, 855	0.90 (t, 3, J = 6), 1.29 (br s, 14), 1.60 (m, 6), 2.0 (m, 2), 2.98 (dd, 2, J = 3.5, 7), 3.45 (m, 4), 5.08 (m, 2)
3j		5	86	1950, 1630, 1443, 1250, 1040, 820	1.60 (s, 6), 3.20 (m, 2), 3.50 (m, 4), 5.6-6.3 (m, 2), 5.92 (s, 2), 6.78 (m)

[a] All compounds gave satisfactory elemental analyses. [b] Isolated yield unless otherwise noted. [c] Based on ^1H NMR analysis. [d] Accompanied with 2(*E*),4(*Z*)-dienamide (**4d**) (18%) and 2(*E*),4(*E*)-dienamide (**5d**) (28%). [e] Based on the consumed alcohol.

alkynic alcohols[15-19] to give unsaturated amides have been investigated by several groups. This paper deals with the syntheses of 3,4- and 2,4-dienamides of pyrrolidine and piperidine by the reaction of 1-acetylpyrrolidine diethyl acetal (**1a**) and 1-acetylpiperidine diethyl acetal (**1b**) with propargyl alcohols, including the total synthesis of isochavicine communicated by us earlier in a preliminary form.[20] Furthermore, we describe the stereoselective rearrangement of 3,4-dienamides to 2(*E*),4(*Z*)-dienamides promoted with alumina and its application for the new synthesis of isochavicine. The reaction sequence is summarized in Scheme I.

Several propargyl alcohols were prepared,[21] and allowed to react with amide acetals. These reactions usually gave β-allenic amides (**3**) in good yields, as summarized in Table I. The reaction of 1-hexyn-3-ol (**2d**) with **1a** also gave a significant amount of two stereoisomers of 1-(1-oxo-2,4-octadienyl)pyrrolidine in addition to the expected product, 1-(1-oxo-3,4-octadienyl)pyrrolidine (**3d**). These were assigned to 2(*E*),4(*Z*)- and 2(*E*),4(*E*)-isomers (**4d** and **5d**, respectively) by NMR analysis. We could not find any reason for this exceptional result.

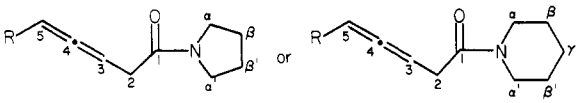
The best evidence to support the allenic amide structure of **3** comes from ^{13}C NMR data, which are shown in Table II. Assignments are consistent with the multiplicities observed in off-resonance decoupled spectra. The signals due to the central carbons of allene bonds appear in the expected range,[22] δ 204–209. The signals due to cyclic methylene carbons were distinguished from those of straight-chain methylenes by a selective proton decoupling technique in connection with the ^1H NMR spectra. The signals due to aromatic carbons of β-allenic amide **3j** were assigned by comparison with literature data.[23]

Recently we reported the highly stereoselective rearrangement of β-allenic esters to 2(*E*),4(*Z*)-dienoates promoted with alumina.[24] Treatment of β-allenic amides **3** with 4–7 equiv of alumina at the reflux temperature of benzene gave 2(*E*),4(*Z*)-dienamides **4** in high yields with 74–95% stereoselectivity. These results are summarized in Table III.

In 1970, Grewe et al.[25] reported the synthesis of isochavicine (**4j**) via several steps including Wittig reaction and palladium-catalyzed hydrogenation. We have found

(9) Wick, A. E.; Felix, D.; Steen, K.; Eschenmoser, A. *Helv. Chim. Acta* **1964**, *47*, 2425.
(10) Felix, D.; Gschwend-Steen, K.; Wick, A. E.; Eschenmoser, A. *Helv. Chim. Acta* **1969**, *52*, 1030.
(11) Sucrow, W.; Richter, W. *Tetrahedron Lett.* **1970**, 3675.
(12) Sucrow, W. *Tetrahedron Lett.* **1970**, 4725.
(13) Parker, K. A.; Kosley, R. W., Jr.; Buchwald, S. L.; Petraitis, J.J. *J. Am. Chem. Soc.* **1976**, *98*, 7104.
(14) Jenkins, P. R.; Gut, R.; Wetter, H.; Eschenmoser, A. *Helv. Chim. Acta* **1979**, *62*, 1922.
(15) Henrick, C. A.; Siddall, J. B. U.S. Patent 3770783, 1973.
(16) Parker, K. A.; Kosley, R. W., Jr. *Tetrahedron Lett.* **1975**, 3039.
(17) Parker, K. A.; Kosley, R. W., Jr. *Tetrahedron Lett.* **1976**, 341.
(18) Parker, K. A.; Petraitis, J. J. *Tetrahedron Lett.* **1977**, 4561.
(19) Parker, K. A.; Petraitis, J. J.; Kosley, R. W., Jr.; Buchwald, S. L. *J. Org. Chem.* **1982**, *47*, 389.
(20) Tsuboi, S.; Takeda, A. *Tetrahedron Lett.* **1979**, 1043.
(21) For example, see: Brandsma, L. "Preparative Acetylenic Chemistry"; Elsevier Publishing Company: Amsterdam, 1971; Chapter 4.
(22) Steur, R.; van Dongen, J. P. C. M.; de Bie, M. J. A.; Drenth, W.; de Haan, J. W.; van de Ven, L. J. M. *Tetrahedron* Lett. **1971**, 3307.
(23) Wenkert, E.; Cochran, D. W.; Hagaman, E. W.; Lewis, R. B.; Schell, F. M. *J. Am. Chem. Soc.* **1971**, *93*, 6271.
(24) Tsuboi, S.; Masuda, T.; Takeda, A. *J. Org. Chem.* **1982**, *47*, 4478.
(25) Grewe, R.; Freist, W.; Neumann, H.; Kersten, S. *Chem. Ber.* **1970**, *103*, 3752.

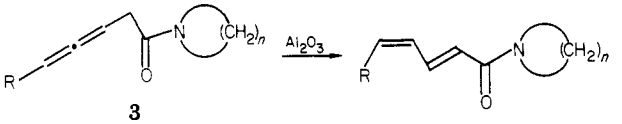
Table II. ^{13}C NMR Spectral Data of 3,4-Dienamides 3[a]



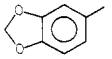
compd	chemical shift, ppm													
	C_1 α	C_2 α′	C_3 β	C_4 β′	C_5 γ	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
3a	168.9	35.0	84.3	208.9	75.4									
	45.7	46.6	24.4	26.1										
3b	168.7	33.9	84.7	208.9	75.6									
	42.7	46.9	25.5	26.4	24.4									
3c	169.4	34.8	84.7	205.5	86.6	14.2								
	42.8	47.0	25.6	26.5	24.5									
3d	169.4	36.0	84.8	204.7	91.6	30.8	22.4	13.6						
	45.7	46.6	24.4	26.1										
3e	169.0	34.9	85.4	204.8	91.8	30.9	22.5	13.6						
	42.8	47.0	25.7	26.6	24.6									
3f	169.1	34.9	85.3	204.5	92.0	28.8[a]	28.7[a]	31.3	22.4	14.0				
	42.7	46.9	25.5	26.4	24.5									
3h	169.3	36.0	84.8	204.6	91.8	28.7	29.5[b]	29.6[b]	29.3[b]	29.2[b]	29.1[b]	31.9	22.7	14.1
	45.7	46.6	24.4	26.1										
3i	169.2	34.9	85.2	204.6	92.1	28.7	29.5[c]	29.5[c]	29.3[c]	29.3[c]	29.3[c]	31.9	22.6	14.0
	42.8	47.0	25.6	26.5	24.5									
3j[e]	168.9	34.2	89.9[d]	205.5	95.4[d]									
	42.9	46.9	25.5	26.4	24.4									

[a-d] Assignments may be interchangeable. [e] Other signals at 101.2, 106.8, 108.4, 120.8, 128.2, 147.0, and 148.2 ppm are assigned to the carbons of the 3,4-(methylenedioxy)phenyl group.[23]

Table III. Rearrangement of β-Allenic Amides 3 to 2(*E*),4(*Z*)-Dienamides 4 Promoted with Alumina



3 4

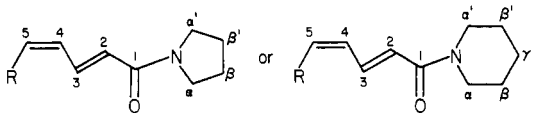
compd[a]	R	n	yield,[b] %	purity,[c] %	IR (neat), cm^{-1}	^1H NMR ($CDCl_3$), ppm
4c	CH_3	5	99	74	1640, 1615, 1590	1.62 (m, 6), 1.84 (m, 3), 3.49 (m, 4), 5.5-6.4 (m, 3), 7.46 (dd, 1, *J* = 11)
4d	C_3H_7	4	80	>95[d]	1640, 1610, 1600	0.92 (t, 3, *J* = 6), 1.45 (m, 2), 1.90 (m, 4), 2.25 (m, 2), 3.47 (m, 4), 5.66 (dt, 1, *J* = 8, 11.5), 6.02 (d, 1, *J* = 15), 6.08 (t, 1, *J* = 11.5), 7.43 (dd, 1, *J* = 10.5, 15.0)
4e	C_3H_7	5	94	77	1640, 1610, 1590	0.95 (t, 3, *J* = 6), 1.60 (m, 8), 2.25 (m, 2), 3.48 (m, 4), 5.40-6.35 (m, 3), 7.2-7.6 (dd, 1, *J* = 11, 14.5)
4f	C_5H_{11}	5	95	77	1642, 1615, 1598	0.90 (t, 3), 1.38 (m, 6), 1.62 (m, 6), 2.25 (m, 2), 3.50 (m, 4), 5.4-6.3 (m, 3), 7.43 (dd, 1, *J* = 10.5, 14.5)
4g	C_6H_{13}	5	96	77	1649, 1620, 1600	0.90 (t, 3, *J* = 6), 1.34 (m, 8), 1.62 (m, 6), 2.27 (m, 2), 3.50 (m, 4), 5.6-6.4 (m, 3), 7.43 (dd, 1, *J* = 10, 14)
4h	C_9H_{19}	4	88	74	1652, 1620, 1600	0.90 (t, 3, *J* = 6), 1.28 (br s, 14), 1.95 (m, 4), 2.35 (m, 2), 3.60 (br t, 4, *J* = 7), 5.7-6.4 (m, 3), 7.76 (dd, 1, *J* = 11, 14.5)
4i	C_9H_{19}	5	84	93	1640, 1615, 1596	0.94 (t, 3, *J* = 7), 1.27 (br s, 14), 1.63 (m, 6), 2.0-2.4 (m, 2), 3.56 (m, 4), 5.6-6.45 (m, 3), 7.62 (dd, 1, *J* = 11, 15)
4j[e]		5	87	>95[d]		

[a] All compounds gave satisfactory elemental analyses. [b] Isolated yield. [c] Percentage of the 2(*E*),4(*Z*)-isomer, determined by ^{13}C NMR analysis unless otherwise indicated. The minor component was identified as the 2(*E*),4(*E*)-isomer. [d] Pure by ^1H NMR. [e] Spectral data were identical with those reported in the literature.[1d,e]

that treatment of **3j** with alumina gave exclusively **4j** in 87% yield. This route is considerably more attractive than the known method[25] and will be suitable for large scale preparations.

The lower stereoselectivity of the present rearrangement compared to that of the rearrangement of β-allenic esters[24] might be attributable to the susceptibility of 3,4-dienamides **3** to heat because the prolonged reaction of **2** with

Table IV. ^{13}C NMR Spectral Data of 2(*E*),4(*Z*)-Dienamides 4



compd	chemical shift, ppm													
	C_1 α	C_2 α′	C_3 β	C_4 β′	C_5 γ	C_6	C_7	C_8	C_9	C_{10}	C_{11}		C_{13}	C_{14}
4c	165.7	120.6	133.5	128.0	137.0	13.9								
	43.1	46.6	25.7	26.6	24.7									
4d	165.0	121.9	136.6	127.0	139.7	30.1	22.7	13.7						
	45.9	46.5	24.3	26.1										
4e	165.6	120.6	137.3	127.2	139.2	30.1	22.7	13.6						
	43.0	46.9	25.6	26.6	24.6									
4f	165.6	120.5	137.3	126.8	139.5	28.1	29.1	31.4	22.4	13.9				
	43.1	46.9	25.4	26.4	24.5									
4g	165.6	120.6	137.4	127.1	139.5	28.3	29.0[a]	29.5[a]	31.7	22.6	14.1			
	43.2	46.9	25.6	26.5	24.7									
4h	165.1	121.9	136.7	126.9	140.1	28.3	29.3[b]	29.5[b]	29.3[b]	29.5[b]	29.3[b]	31.9	22.7	14.1
	45.9	46.4	24.3	26.1										
4i	165.8	120.6	137.6	127.1	139.7	28.3	29.3[c]	29.5[c]	29.5[c]	29.5[c]	29.3[c]	31.9	22.7	14.1
	43.3	46.9	25.6	26.6	24.7									
4j[e]	165.7	123.2[d]	138.3	127.3	135.7									
	43.4	47.0	25.9	26.8	24.7									

[a-d] Assignments may be interchangeable. [e] Other signals at 101.4, 108.6, 109.6, 123.8,[d] 131.0, 147.7, and 148.1 ppm are assigned to the carbons of 3,4-(methylenedioxy)phenyl group.[23]

1 sometimes gave a small amount of the stereoisomeric mixture of the corresponding 2,4-dienamide in addition to **3**.

Carbon-13 NMR spectra of 2(*E*),4(*Z*)-dienamides **4** prepared in this work were measured and tentatively assigned as shown in Table IV.[26] In general, the allylic carbons of cis olefins appeared at higher field than those of the trans isomers as a result of steric effect.[27] Chemical shifts of the carbons except amide groups were very similar to those of 2(*E*),4(*Z*)-dienoic esters reported previously.[24]

With this method a variety of 5-alkyl- or 5-aryl- substituted 2,4- and 3,4-dienamides can be prepared in moderate to excellent yield in an experimentally simple fashion from aldehyde, acetylene, and acetals of 1-acetylpyrrolidine or 1-acetylpiperidine.

Experimental Section

The melting points and boiling points are uncorrected. Elemental analyses were carried out by Eiichiro Amano of our laboratory. IR spectra were obtained with a Hitachi Model EPI-S2 infrared spectrophotometer. ^1H NMR spectra (60 MHz) were recorded with a Hitachi Model R-24 apparatus. ^{13}C NMR spectra were obtained with a JEOL JNM-FX100 apparatus, with $CDCl_3$ as a solvent. All chemical shifts are reported in δ units downfield from internal Me_4Si, and the *J* values are given in herz. Propargyl alcohols **2** were prepared by the method described in the previous paper.[21,24] Weakly basic alumina (200–300 mesh) for column chromatography, which was purchased from Katayama Chemical Industries Co., Ltd., was used for the preparation of 2(*E*),4-(*Z*)-dienamides after being dried at 200–250 °C (10 mm).

1-Acetylpyrrolidine was prepared by adding a solution of acetyl chloride in dry ether to a cold solution of pyrrolidine in dry ether: yield 79%; bp 62 °C (1 mm) [lit.[28] bp 107–108 °C (13 mm)]; IR (neat) 1630 (amide C=O)(lit.[29] 1626 cm^{-1}); ^1H NMR ($CDCl_3$) δ 1.91 (s, 3 H, $COCH_3$), 1.6–2.3 (m, 4 H, 2 α-CH_2), 3.35 (m, 4 H, 2 β-CH_2); ^{13}C NMR ($CDCl_3$) δ 22.5 (CH_3), 24.6 and 26.1 (C-β), 45.5 and 47.4 (C-α), 169.0 (C=O).

1-Acetylpiperidine was obtained in the same way as described above: yield 83%; bp 64 °C (3 mm)[lit.[30] bp 125 °C (30 mm)]; IR (neat) 1640 cm^{-1} (amide C=O); ^1H NMR ($CDCl_3$) δ 1.61 (m, 6 H, 3 CH_2), 2.06 (s, 3 H, $COCH_3$), 3.50 (m, 4 H, 2 α-CH_2); ^{13}C NMR ($CDCl_3$) δ 21.4 (CH_3), 24.4 (γ-CH_2), 25.5 and 26.4 (2 β-CH_2), 42.3 and 47.4 (2 α-CH_2), 168.6 (C=O).

1-Acetylpyrrolidine diethyl acetal (1a) was prepared by the same procedure for dimethylacetamide diethyl acetal:[8] yield 50% from 1-acetylpyrrolidine; bp 70–72 °C (6 mm); IR (neat) 1650, 1625 cm^{-1}; ^1H NMR (neat) 1.09 (t, J = 6 Hz, CH_3CH_2O), 1.27 (s, $CH_3C(OEt)_2$), 1.5–2.1 (m, 2 CH_2 of pyrrolidine), 2.5–2.9 (m, 2 CH_2 of pyrrolidine), 3.45 (m, OCH_2CH_3).

1-Acetylpiperidine diethyl acetal (1b) was also obtained in the same way as **1a**:[8] yield 49% from 1-acetylpiperidine; bp 44–45 °C (2 mm); IR (neat) 1080 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.0–1.8 (m, CH_3, 2 OCH_2CH_3, 3 CH_2 of piperidine), 3.3–4.0 (m, 2 OCH_2CH_3, 2 CH_2 of piperidine).

1-(1,3-Benzodioxol-5-yl)-2-propyn-1-ol (2j) was prepared by the methods reported previously.[20] Spectral data were shown in the previous paper.[20] Anal. Calcd for $C_{10}H_8O_3$: C, 68.18; H, 4.58. Found: C, 68.22; H, 4.40.

Preparation of 3,4-Dienamides (3). Representative procedures are described below. Alcohols **2** were purified by distillation and dried over activated 4-Å molecular sieves. Acetals **1** were added via syringe to the reaction vessel. Reactions of amide acetals (**1**) with alcohols (**2**) were carried out in dry glassware under an atomosphere of dry nitrogen to protect from moisture. Some representative preparations of **3** are described below.

1-(1-Oxo-3,4-pentadienyl)pyrrolidine (3a). A solution of propargyl alcohol (**2a**) (0.56 g, 10 mmol) and **1a** (2.24 g, 12 mmol) in 250 mL of dry benzene was heated under reflux for 13 h. Removal of the solvent gave 1.95 g (95% yield) of crude **3a**, whose NMR analysis showed 73% purity. Purification by preparative TLC (silica gel PF_{254}, 2:1 hexane:acetone, R_f 0.25) gave 0.98 g (65%) of pure **3a**. Spectral data are shown in Tables I and II.

1-(1-Oxo-3,4-pentadienyl)piperidine (3b) was prepared analogously from **2a** (0.392 g, 7 mmol) and **1b** (1.55 g, 7.71 mmol). Crude product (1.90 g, 87% yield by ^1H NMR) was purified by short-pass distillation giving 0.909 g (79%) of **3b**: bp 120 °C (2 mm). Spectral data are shown in Tables I and II.

1-(1-Oxo-3,4-octadienyl)pyrrolidine (3d), (2*E*,4*Z*)-1-(1-Oxo-2,4-octadienyl)pyrrolidine (4d), and (2*E*,4*E*)-1-(1-Oxo-2,4-octadienyl)pyrrolidine (5d). A solution of 1-hexyn-3-ol (**2d**)

(26) The signals of olefinic carbons were resolved with the aid of selective decoupling technique. The spectrum of isochavicine was assigned by comparison with that of piperine. See ref 23.

(27) Dorman, D. E.; Jautelat, M.; Roberts, J. D. *J. Org. Chem.* **1971**, *36*, 2757.

(28) Nielsen, E. B.; Schellman, J. A. *J. Phys. Chem.* **1967**, *71*, 2297.

(29) Thompson, H. W.; Popplewell, R. J. *Z. Elektrochem.* **1960**, *64*, 746; *Chem. Abstr.* **1960**, *54*, 20480e.

(30) Schotten, C. *Chem. Ber.* **1882**, *15*, 426.

(0.392 g, 4 mmol) and **1a** (0.76 g, 4.06 mmol) in 10 mL of benzene was heated at reflux temperature for 2 h. Removal of the solvent gave a pale brown oil (0.877 g), which was a 54:18:28 mixture of **3d**, **4d**, and **5d** (by NMR analysis). TLC analysis (two developments on silica gel GF_{254}, 3:1 hexane:acetone) showed three spots present very closely at R_f values 0.36, 0.42, and 0.48, respectively. Preparative TLC (silica gel PF_{254}, 3:1 hexane:acetone) yielded 0.126 g (16%) of **4d** (R_f 0.48), 0.379 g (49%) of **3d** (R_f 0.42), and 0.196 g (25%) of **5d** (R_f 0.36). Spectral data of **3d** and **4d** are shown in Tables I–IV.

5d: IR (neat) 1645, 1620, 1595, 1420, 1000 cm^{-1}; ^1H NMR (CCl_4) δ 0.92 (t, 3 H, J = 6 Hz, CH_3), 1.40 (m, 2 H, CH_3CH_2), 1.7–2.3 (m, 6 H, $\overline{CH_2CH_2NCH_2CH_2}$ and CH_2CH=), 3.43 (m, 4 H, CH_2NCH_2), 5.96 (d, 1 H, J = 15 Hz, C_2-H), 5.8–6.2 (m, 2 H, C_4-H and C_5-H), 7.09 (m, 1 H, C_3-H); mass spectrum, m/e (relative intensity) 193 (M^+, 43), 178 (8), 164 (27), 150 (95), 123 (100), 98 (22), 95 (45), 84 (45), 81 (75). Anal. Calcd for $C_{12}H_{19}NO$: C, 74.57; H, 9.91; N, 7.25%. Found: C, 74.72; H, 9.82; N, 7.05%.

1-(1-Oxo-3,4-tetradecadienyl)pyrrolidine (3h). A solution of 1-dodecyn-3-ol (**2h**)(0.40 g, 2.2 mmol) and **1a** (0.535 g, 2.86 mmol) in 72 mL of xylene was heated under reflux for 16 h. After removal of the solvent, the residual oil (0.90 g) was subjected to preparative TLC (silica gel, 3:1 hexane:acetone) to yield 0.35 g (57%, 74% yield from consumed **2h**) of **3h** (R_f 0.28) along with the recovery of 88 mg of **2h** (R_f 0.51). Spectral data are shown in Tables I and II.

1-[5-(1,3-Benzodioxol-5-yl)-1-oxo-3,4-pentadienyl]-piperidine (3j) was prepared as described previously.[20] IR and ^1H NMR spectra have been reported previously.[20] ^{13}C NMR data are shown in Table II. Anal. Calcd for $C_{17}H_{19}NO_3$: C, 71.56; H, 6.71; N, 4.91%. Found: C, 71.43; H, 6.60; N, 5.12%.

General procedure for the transformation of 3 to 4 was similar to that described in the previous paper.[24] Some representative experiments are shown below.

(2*E*,4*Z*)-1-(1-Oxo-2,4-octadienyl)pyrrolidine (4d). A mixed solution of 20 mg (0.109 mmol) of **3d**, 50 mg of alumina, and 3 mL of benzene was heated at reflux temperature for 2 h. The mixture was filtered, and the filtrate was concentrated in vacuo to give 16 mg (80%) of **4d** (pure by ^1H NMR). Spectral data are shown in Tables III and IV.

(2*E*,4*Z*)-1-(1-Oxo-2,4-decadienyl)piperidine (4f). A mixed solution of 106 mg (0.451 mmol) of **3f**, 520 mg of alumina, and 2 mL of benzene was heated at reflux temperature for 2 h. The mixture was worked up analogously to give 100 mg (95%) of **4f** (77% pure by ^{13}C NMR). Spectral data were shown in Tables III and IV.

(2*E*,4*Z*)-1-(1-Oxo-2,4-tetradecadienyl)pyrrolidine (4h) and (2*E*,4*E*)-1-(1-Oxo-2,4-tetradecadienyl)pyrrolidine (5h). A mixed solution of 57 mg (0.206 mmol) of **3h**, 150 mg of alumina, and 1 mL of benzene was heated at reflux temperature for 3 h. The mixture was worked up analogously to give 50 mg (88%) of **4h**, which was shown by ^{13}C NMR analysis to be a 74:26 mixture of **4h** and **5h**: mp 48–50 °C. The components were isolated by preparative TLC (silica gel PF_{254}, 3:1 hexane:acetone). A major fraction of R_f 0.34 gave pure **4h**: mp 62–63 °C; IR and NMR (see Tables III and IV). A minor fraction of R_f 0.27 yielded pure **5h**: mp 36–38 °C; IR (neat) 1622, 1598, 1425, 1005 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.2–7.6 (m, 1 H, C_3–H), 6.0–6.4 (m, 3 H, C_2–H, C_4–H, C_5–H), 3.55–3.75 (m, 4 H, $-CH_2NCH_2-$), 1.6–2.3 (m, 6 H, CH_2CH= and $\overline{CH_2CH_2NCH_2CH_2}$), 1.26 (br s, 14 h, $(CH_2)_7$), 0.90 (t, J = 7 Hz, 3 H, CH_3). Anal. Calcd for $C_{18}H_{31}NO$: C, 77.92; H, 11.26; N, 5.05. Found: C, 77.85; H, 11.12; N, 5.14.

(2*E*,4*Z*)-1-[5-(1,3-Benzodioxol-5-yl)-1-oxo-2,4-pentadienyl]piperidine (Isochavicine) (4j). A mixed solution of 23 mg (0.0807 mmol) of **3j**, 140 mg of alumina, and 2 mL of benzene was heated at reflux temperature for 2 h. The mixture was filtered, and the filtrate was concentrated in vacuo to give 20 mg (87%) of **4j** (pure by ^1H NMR). IR and ^1H NMR spectra were identical with those in the literature.[1d,f] ^{13}C NMR data are shown in Table IV.

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Registry No. **1a**, 88855-23-6; **1b**, 71627-25-3; **2a**, 107-19-7; **2c**, 2028-63-9; **2d**, 105-31-7; **2f**, 818-72-4; **2g**, 7383-20-2; **2h**, 81929-17-1; **2j**, 2620-47-5; **3a**, 88855-24-7; **3b**, 88855-25-8; **3c**, 88855-26-9; **3d**, 88855-27-0; **3e**, 88855-28-1; **3f**, 88855-29-2; **3g**, 88855-30-5; **3h**, 88855-31-6; **3i**, 88855-32-7; **3j**, 71627-26-4; **4c**, 88855-33-8; **4d**, 88855-34-9; **4e**, 88855-35-0; **4f**, 88855-36-1; **4g**, 88855-37-2; **4h**, 88855-38-3; **4i**, 88855-39-4; **4j**, 30511-77-4; **5d**, 88855-40-7; **5h**, 88855-41-8; 1-acetylpyrrolidine, 4030-18-6; 1-acetylpiperidine, 618-42-8.

Synthesis and Crystallography of 2,3,3,5,6,6-Hexamethyl-3,6-dihydropyrazine Hexahydrate and 3-Amino-3-methyl-2-butanone Hydrochloride

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The X-ray crystal structures and chemical reactions of 2,3,3,5,6,6-hexamethyl-3,6-dihydropyrazine hexahydrate and 3-amino-3-methylbutanone hydrochloride are described.

We previously reported on our synthetic attempts to prepare α-amino ketones.[1,2] We were intrigued by the fact that all attempts to hydrate propargyl derivatives led ultimately to material that is spectroscopically best described as a dimer (1) rather than monomer (2). For example, IR 1657 cm^{-1} (no 1680–1720 cm^{-1}), ^1H NMR δ 1.30 (s, 6 H), 2.00 (s, 3 H), and ^{13}C NMR 22.91, 28.45, 56.14, and 169.64 ppm were obtained.

This dimer had previously been prepared by Gabriel[3] from the well-known synthesis carrying his name and while

(1) Chiu, S. K.; Dube, M. F.; Keifer, L.; Szilagyi, S.; Timberlake, J. W. *J. Org. Chem.* **1978**, *43*, 61.

(2) Kovacic, P.; Lisiak, M.; Zawalski, R. C.; Luedtke, A.; Timberlake, J. W. *Tetrahedron Lett.* **1980**, *21*, 425.

(3) Gabriel, S. *Chem. Ber.* **1911**, *44*, 57.

0022-3263/84/1949-1208$01.50/0