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Intramolecular Diels–Alder Reaction of Alkenyl Oxazole-5-carbamates and *N*-Alkenyl-oxazole-5-carboxamides

SADAKATSU SHIMADA* and TOSHIAKI TOJO

Research Laboratories of Production Technology, Daiichi Seiyaku Co., Ltd., 16–13, Kitakasai, 1-chome, Edogawa-ku, Tokyo 134, Japan

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Intramolecular cycloaddition of *N*-allyl-4-methyloxazole-5-carboxamides (**1**) gave the corresponding 6a-acetyl-2-hydroxy-6-oxotetrahydrofuro[2,3-*c*]pyrrolidines (**3**). Tricycloadducts (**6**) were obtained by the intramolecular Diels–Alder reaction of *N*-(3-butenyl)-4-methyl-*N*-phenyloxazole-5-carboxamides (**4**). Hydrolysis of the tricycloadducts (**6**) afforded 7a-acetyl-2-hydroxy-7-oxo-6-phenyl-tetrahydrofuro[2,3-*c*]piperidines (**8**). Treatment of the tricycloadducts (**6**) with acetic acid gave 1,2,3,4-tetrahydroisoquinolin-1-ones (**10**), 8a-hydroxy-1,2,3,4,5,6-hexahydroisoquinoline-1,6-diones (**9′**) and 8a-hydroxy-1,2,3,4,5,8-hexahydroisoquinoline-1,8-diones (**9**).

Similar intramolecular cycloaddition of alkenyl 4-methyloxazole-5-carbamates (**11**) is also described.

Keywords——intramolecular Diels–Alder reaction; *N*-alkenyl-oxazole-5-carboxamide; tricycloadduct; alkenyl oxazole-5-carbamate; tetrahydrofuro[2,3-*c*]pyrrolidine; tetrahydroisoquinoline

Many intermolecular Diels–Alder reactions of oxazoles with dienophiles to form the pyridine skelton have been reported.[2] It was also reported that some oxazoles reacted only with an electron-deficient dienophile, such as maleimide.[3] Recently, Mukaiyama *et al.* reported the intramolecular Diels–Alder reaction of furans with sterically hindered dienophiles to obtain the cycloadducts.[4]

We now wish to report an intramolecular Diels–Alder reaction of less reactive oxazoles, such as oxazole-5-carboxamides and oxazole-5-carbamates, with olefins to yield tricycloadducts.

When *N*-allyl-4-methyloxazole-*N*-phenyl-5-carboxamide (**1c**) was refluxed in xylene for 3 h, 2-hydroxy-6a-acetyl-6-oxo-tetrahydrofuro[2,3-*c*]pyrrolidine (**3c**) was obtained in 18% yield. Heating **1c** in 50% aqueous dioxane at 100 °C for 5 h gave **3c** in 93% yield. However, when *N*-allyl-4-methyloxazole-5-carboxamide (**1a**) was refluxed in xylene for 10 h, no product was obtained, and the unchanged **1a** was recovered.

On the basis of these results, the reaction process may be as shown in Chart 1. The first step of the reaction may be the formation of the tricycloadduct (**2**). Subsequent hydrolysis of the tricycloadduct (**2**) may give the tetrahydrofuro[2,3-*c*]pyrrolidine (**3**).

The elemental analysis of **3c** showed its composition to be $C_{14}H_{15}NO_4$. The infrared (IR) spectrum showed absorptions due to a hydroxy group at 3440 cm^{-1}, an acetyl carbonyl group at 1705 cm^{-1} and an amide carbonyl group at 1670 cm^{-1}. Proton nuclear magnetic resonance (^{1}H-NMR) signals at δ 5.82 and 5.87 (total 1H, each d, C_2–H) indicated that the compound (**3c**) must be an anomeric mixture of 2α-hydroxy and 2β-hydroxy forms of **3c**. From the integrated areas, the ratio of the 2α-hydroxy form to the 2β-hydroxy form of **3c** was concluded to be approximately 55 : 45. In order to confirm the structure of **3c**, the following reactions were carried out. Treatment of **3c** with acetic anhydride afforded monoacetates of **3c**. On treatment with hydrogen chloride in ethanol, **3c** gave 2-ethoxy-6a-acetyltetra-

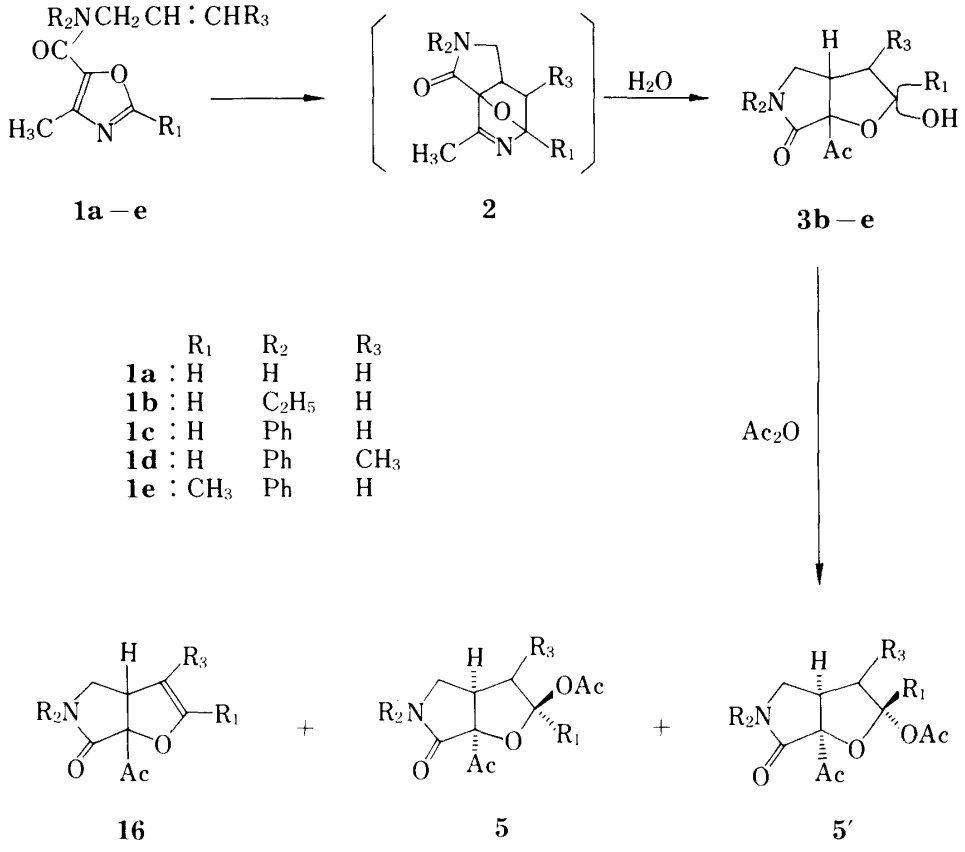


Chart 1

TABLE I. Tetrahydrofuro[2,3-*c*]pyrrolidines (**3**)

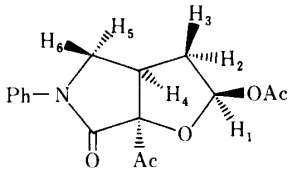
Compd. No.	R_1	R_2	R_3	Reaction conditions			Yield (%)
				Solvent	Temp. (°C)	Time (h)	
3b	H	Et	H	Dioxane–H_2O	100	3	45
3c	H	Ph	H	Dioxane–H_2O	100	5	93
3c	H	Ph	H	Toluene	110	4	54
3c	H	Ph	H	Xylene	140	3	18
3d	H	Ph	Me	Dioxane–H_2O	100	100	73
3e	Me	Ph	H	Dioxane–H_2O	100	24	91

hydrofuro[2,3-*c*]pyrrolidine (**19c**). Treatment of **3c** with 2,4-dinitrophenylhydrazine gave the 2,4-dinitrophenylhydrazone of **3c**. These results, along with the ^{1}H-NMR data, indicate that **3c** must be 2-hydroxy-6a-acetyl-6-oxo-tetrahydrofuro[2,3-*c*]pyrrolidine. Similar reactions were attempted with *N*-allyl-4-methyloxazole-5-carboxamides (**1b—e**), and the results are shown in Table I.

The acetylation of **3c** afforded 2β-acetoxy-6a-acetyl-6-oxo-tetrahydrofuro[2,3-*c*]pyrrolidine (**5c**) and 2α-acetoxy-6a-acetyl-6-oxo-tetrahydrofuro[2,3-*c*]pyrrolidine (**5c′**) in 30 and 13% yields, respectively. In the ^{1}H-NMR spectrum of **5c′**, all the signals due to non-equivalent protons appeared independently and their assignments were established by decoupling experiments. The signal of C_2–H (δ 6.58), which was shifted to lower field than that of **3c** (δ 5.87), was assigned to a proton on a carbon bearing an acetoxy group. When H_1 (δ 6.58, d, J=5 Hz) was irradiated, the multiplet signal at δ 2.58 was changed into a double

doublet, which was assigned to H_2 on the C_3 position. Upon irradiation of H_2 (δ 2.58), H_1 (δ 6.58) changed into a singlet, and the multiplet at δ 3.33 and the double doublet at δ 2.11 were also changed into a double doublet-like signal (J=8, 2 Hz) and a doublet-like signal, respectively. From these observations, the multiplet at δ 3.33 was assigned to H_4 (bridge head

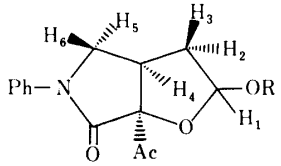
TABLE II. Spin Decoupling Experiments with **5c'**



Decoupled proton	Irradiated at δ					
	6.58 H_1	2.58 H_2	2.11 H_3	3.33 H_4	4.26 H_5	3.76 H_6
6.58 (d, 5)	—	s				
2.58 (m)	dd (8, 14)	—	dd (5, 8)	Varied		
2.11 (dd)		d-like (*ca.* 1)	—	d (14)		
3.33 (m)		dd-like (8, 2)	Varied	—		t-like
4.26 (dd)				d (8)	—	d (8)
3.76 (dd)				d (8)	d (2)	—

Abbreviations are the same as in Experimental. Coupling constants in parentheses are given in Hz.

TABLE III. ^{1}H-NMR Data for Tetrahydrofuro[2,3-*c*]pyrrolidines



Compd. OR	H_1	H_2	H_3	H_4	H_5	H_6
5c β-OAc	6.54 (d) J_{1-3}=4	2.50 (m) J_{2-3}=14 J_{2-4}=8	2.10 (m) J_{3-4}=8	3.38 (m) J_{4-5}=8	3.63 (dd) J_{5-6}=12	4.23 (d)
5c' α-OAc	6.58 (d) J_{1-2}=5	2.58 (m) J_{2-3}=14 J_{2-4}=8	2.11 (d like) J_{3-4}=*ca.* 1	3.33 (m) J_{4-5}=8 J_{4-6}=2	3.76 (dd) J_{5-6}=8	4.26 (dd)
3c β-OH	5.82 (d) J_{1-3}=4	2.35 (m) J_{2-3}=14 J_{2-4}=8	1.98 (m) J_{3-4}=8	3.36 (m) J_{4-5}=8	3.62 (dd) J_{5-6}=8	4.21 (d)
3c' α-OH	5.87 (d) J_{1-3}=4	2.35 (m) J_{2-3}=15 J_{2-4}=8	2.04 (d like) J_{3-4}=*ca.* 1	3.36 (m) J_{4-5}=8 J_{4-6}=3	3.86 (dd) J_{5-6}=8	4.21 (dd)

TABLE IV. Acetylations of **3**

Compd. No.	R_1	R_2	R_3	Yields (%)		
				5	**5′**	**16**
3b	H	Et	H	26	41	—
3c	H	Ph	H	13	30	—
3d	H	Ph	Me	—	71[a]	8
3e	Me	Ph	H	—	—	67

a) *cis, trans* Mixture.

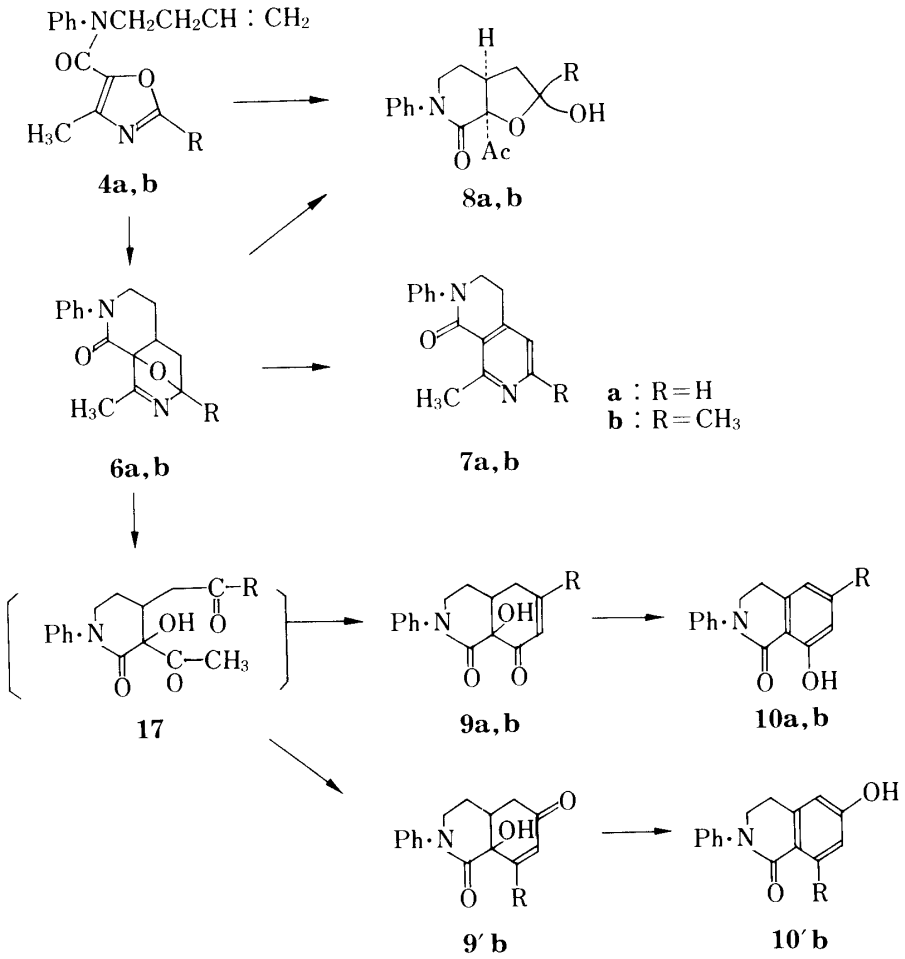


Chart 2

proton) and the double doublet at δ 2.11 was assigned to H_3 on the C_3 position. These results are shown in Table II.

The configuration of the acetate (**5c′**) was deduced from the observed H,H-coupling constants. Thus, **5c′** was assigned as 2α-acetoxy-6a-acetyl-6-oxo-tetrahydrofuro[2,3-*c*]-pyrrolidine. The assignments of **3c** and **3c′** were performed by means of spin decoupling experiments and comparisons of the data with those of the acetates (**5c**, **5c′**). These data are shown in Table III.

Similarly, the acetylations of **3b**—**e** gave the acetates (**5**, **5′**) and the dihydrofuro-[2,3-*c*]pyrrolidines (**16**); the results are summarized in Table IV.

Because of their instability, we could not isolate the tricycloadducts (**2**) by the reaction of

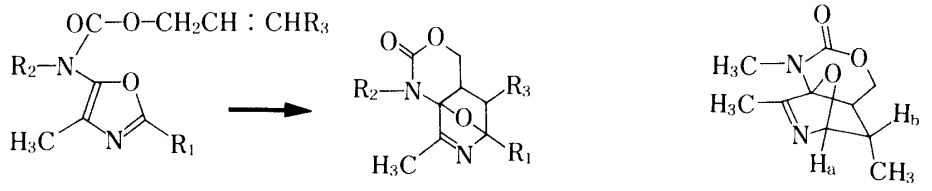
N-allyl-4-methyloxazole-5-carboxamides (**1**). However, we were able to obtain the tricycloadducts by the intramolecular Diels–Alder reaction of *N*-(3-butenyl)-4-methyl-*N*-phenyloxazole-5-carboxamides (**4**). When *N*-(3-butenyl)-4-methyl-*N*-phenyloxazole-5-carbaxamide (**4a**) was refluxed for 24 h in xylene, 10-methyl-2-oxo-3-phenyl-11-oxa-3,9-diazatricyclo[6.2.1.$0^{1,6}$]undec-9-ene (**6a**) was obtained in 38% yield along with unchanged **4a** (32%). The structure of **6a** was confirmed by the spectral data and the elemental analysis.

The hydrolysis of **6a** gave 7a-acetyl-2-hydroxy-7-oxo-6-phenyltetrahydrofuro[2,3-*c*]piperidine (**8a**) in quantitative yield. On heating of **6a** in xylene for 5 d, it was dehydrated to afford 8-methyl-1-oxo-2-phenylpiperidino[3,4-*c*]pyridine (**7a**) in 32% yield. Treatment of **6a** with acetic acid gave 8-hydroxy-2-phenyl-1,2,3,4-tetrahydroisoquinolin-1-one (**10a**).

Similar intramolecular reaction of *N*-(3-butenyl)-2,4-dimethyl-*N*-phenyloxazole-5-carboxamide (**4b**) afforded the tricycloadduct (**6b**) in 64% yield. Treatment of **6b** with acetic acid gave 8-hydroxy-6-methyl-2-phenyl-1,2,3,4-tetrahydroisoquinolin-1-one (**10b**), 8a-hydroxy-8-methyl-2-phenyl-1,2,3,4,5,6-hexahydroisoquinoline-1,6-dione (**9b′**) and 8a-hydroxy-6-methyl-2-phenyl-1,2,3,4,5,8-hexahydroisoquinoline-1,8-dione (**9b**) in yields of 5, 16 and 32%, respectively. The compounds **9b** and **9b′** had the same molecular formula, and their IR spectra indicated the presence of a hydroxy group and carbonyl groups. These results show that the structure of **9b** is isomeric with that of **9b′**. In the ^{1}H-NMR spectra of **9b** and **9b′**, the methyl proton signal of **9b′** appeared at lower field than that of **9b** (δ 2.22 and 1.92 for **9b′** and **9b**, respectively), suggesting that the methyl group in **9b′** is located at the peri position with respect to the carbonyl group. On the basis of these spectral data, **9b** and **9b′** were assigned as 8a-hydroxy-6-methyl-2-phenyl-1,2,3,4,5,8-hexahydro isoquinoline-1,8-dione and 8a-hydroxy-8-methyl-2-phenyl-1,2,3,4,5,6-hexahydroisoquinoline-1,6-dione. The structures of **9b** and **9b′** were further confirmed by converting them to 8-acetoxy-6-methyl-2-phenyl-1,2,3,4-tetrahydroisoquinoline-1-one (**18b**) and 6-acetoxy-8-methyl-2-phenyl-1,2,3,4-tetrahydroisoquinolin-1-one (**18b′**), respectively.

Compounds **9b** and **9b′** might be formed from **6** by the aldol condensation of **17** as shown in Chart 2.

We next investigated an intramolecular Diels–Alder reaction of alkenyl 4-methyloxazole-5-carbamates (**11**). When a solution of *trans*-crotonyl *N*,4-dimethyloxazole-5-carbamate (**11d**) in xylene was heated at 140 °C for 88 h, 2,7,10-trimethyl-3-oxo-4,11-dioxa-2,9-diazatricyclo[6.2.1.$0^{1,6}$]undec-9-ene (**12d**) was obtained in 45% yield. The structure of **12d** was assigned on the basis of the analytical and spectral data. The configuration of **12d** was confirmed by the ^{1}H-NMR spectrum. The coupling constant (4.5 Hz) between H_a and H_b of **12d** suggests a dihedral angle of about 40°. Thus, the structure of **12d** was determined to be as shown in Chart 3.



11a–i **12a–i** **12d**

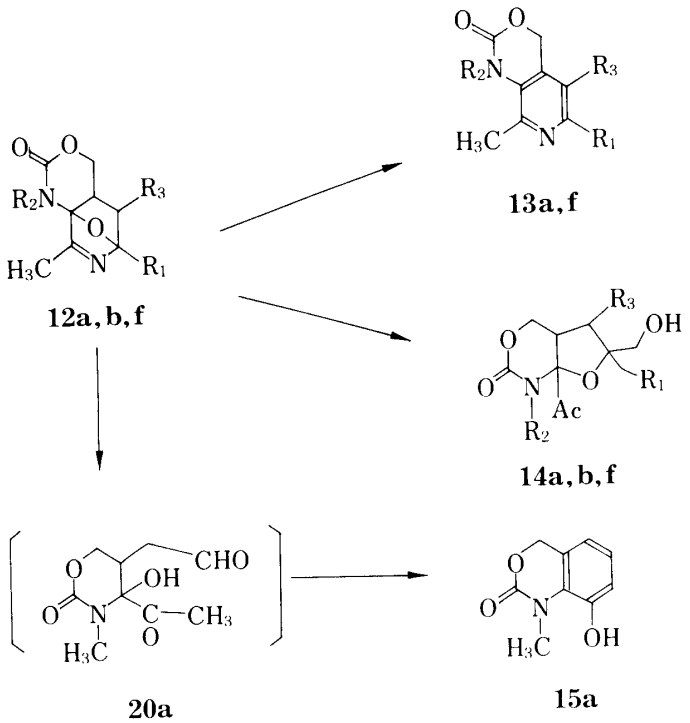
Chart 3

As summarized in Table V, similar reaction of alkenyl oxazole-5-carbamates (**11a—h**) afforded the corresponding cycloadducts (**12a—h**). These adducts (**12**) were converted into 8-methyl-4*H*-pyrido[3,4-*d*][1,3]oxazinones (**13**), 7a-acetyltetrahydrofuro[2,3-*c*][1,3]oxazinones (**14**) and benzoxazinones (**15**).

TABLE V. 10-Methyl-3-oxo-4,11-dioxa-2,9-diazatricyclo-[6.2.1.$0^{1,6}$]undec-9-ene (**12**)

Compd. No.	Substituent			Reaction conditions		Yield **12** (%)	Recovery **11** (%)
	R_1	R_2	R_3	Temp. (°C)	Time (h)		
12a	H	Me	H	110	64	29	60
12a	H	Me	H	140	24	83	—
12b	H	Bz	H	110	64	31	60
12b	H	Bz	H	140	24	81	11
12c	H	Iso-Pr	H	140	80	33	30
12d	H	Me	Me	140	88	45	35
12e	H	Bz	Me	140	72	42	—
12f	Me	Me	H	140	72	50	19
12g	Me	Bz	H	140	72	73	—
12h	Me	Bz	Me	140	72	5	89

Me = methyl; Bz = benzyl; iso-Pr = isopropyl.



	R_1	R_2	R_3
20a	H	CH_3	H
20b	H	benzyl	H
20f	CH_3	CH_3	H

Chart 4

In view of these results, the intramolecular Diels–Alder reactions of oxazoles appear to be applicable to the synthesis of various heterocycles.

Experimental

Melting points were determined on a Yanagimoto hot plate apparatus and are uncorrected. ^{1}H-NMR spectra

Table VI. Yields and Properties of **1**

Compd. No.	Substituent R_1	R_2	R_3	Appearance	Yield (%)	IR cm^{-1}	MS *m/e* (%)	^{1}H-NMR ($CDCl_3$) *J*=Hz
a	H	H	H	Oil	45	3350 1620	166 (M^+, 13) 110 (100)	2.55 (3H, s), 4.05 (2H, t, *J*=6.5), 5.20 (1H, dd, *J*=2, 12), 5.35 (1H, dd, *J*=2, 6), 5.90 (1H, m), 6.30 (1H, br), 7.75 (1H, s).
b	H	Et	H	Oil	65	1620	194 (M^+, 24) 110 (100)	2.36 (3H, s), 1.25 (3H, t), 3.53 (2H, q), 4.10 (2H, d, *J*=5), 5.07 (1H, d, *J*=16), 5.30 (1H, d, *J*=11), 5.90 (1H, m), 7.88 (1H, s).
c	H	Ph	H	Oil	82	1635	242 (M^+, 15)	2.40 (3H, s), 4.45 (2H, d, *J*=7), 5.18 (1H, dd, *J*=2, 16), 5.25 (1H, dd, *J*=2, 12), 7.0—7.5 (5H, m).
d	H	Ph	Me	Oil	95	1630	256 (M^+, 14) 146 (100)	2.32 (3H, s), 1.65 (3H, t), 4.35 (2H, br), 5.56 (2H, br), 6.8—7.5 (6H, m).
e	Me	Ph	H	Oil	75	1630	256 (M^+, 15) 124 (100)	2.05 (3H, s), 2.29 (3H, s), 4.43 (2H, d, *J*=6), 5.12 (1H, dd, *J*=16), 5.15 (1H, d, *J*=11), 5.95 (1H, m).

Table VII. Yields and Properties of **11**

Compd. No.	Substituent R_1	R_2	R_3	Appearance	Yield (%)	IR cm^{-1}	MS *m/e*	Formula	Analysis (%) Calcd (Found) C	H	N
a	H	Me	H	Oil	77	1720 1660	196 (M^+) 82	$C_9H_{12}N_2O_3$	55.09 (55.12)	6.17 (6.30)	14.28 (14.16)
b	H	Bz	H	Oil	91	1720 1660	272 (M^+) 91	$C_{15}H_{16}N_2O_3$	66.16 (66.32)	5.92 (6.08)	10.29 (10.47)
c	H	Iso-Pr	H	Oil	51	1720 1660	224 (M^+)	$C_{11}H_{16}N_2O_3$	58.91 (59.31)	7.19 (7.02)	12.49 (12.27)
d	H	Me	Me	Oil	56	1720 1660	210 (M^+) 82	$C_{10}H_{14}N_2O_3$	57.13 (57.45)	6.71 (6.43)	13.33 (13.14)
e	H	Bz	Me	Oil	85	1720 1660	286 (M^+) 91	$C_{16}H_{18}N_2O_3$	67.11 (67.28)	6.34 (6.26)	9.78 (9.53)
f	Me	Me	H	Oil	60	1720 1660	210 (M^+) 82	$C_{10}H_{14}N_2O_3$	57.13 (57.38)	6.71 (6.53)	13.33 (12.77)
g	Me	Bz	H	Oil	75	1720	286 (M^+) 91	$C_{16}H_{18}N_2O_3$	67.11 (66.96)	6.34 (6.44)	9.78 (9.42)
h	Me	Bz	Me	Oil	83	1720 1660	300 (M^+) 91	$C_{17}H_{20}N_2O_3$	67.98 (67.94)	6.71 (6.81)	9.33 (9.54)

were recorded on a JEOL model JNM-PMX 60 or a Varian XL-200 spectrometer. Tetramethylsilane was used as an internal standard. Chemical shifts are expressed in δ values. The following abbreviations are used: s=singlet, d=doublet, t=triplet, m=multiplet, br=broad and dd=double doublet. IR spectra were obtained with a Hitachi model 260 spectrometer. Mass spectra (MS) were measured with a JEOL TMS D 300 mass spectrometer.

***N*-Allyl-4-methyloxazole-5-carboxamide (1a—e)**——General Procedure: A mixture of 4-methyloxazole-5-carboxylic acid[5] (15 mmol) and thionyl chloride (30 ml) was refluxed for 4 h. The mixture was concentrated *in vacuo* and the residue was dissolved in toluene (2 ml). The toluene solution was added dropwise to a solution of *N*-allylamine (15 ml) in pyridine (40 ml), and the reaction mixture was stirred for 30 min at room temperature. After removal of the solvent by evaporation *in vacuo*, the residue was diluted with $CHCl_3$. The $CHCl_3$ solution was washed successively with sat. $CuSO_4$, 1 N HCl, 5% aq. $NaHCO_3$ and water. The organic layer was concentrated *in vacuo* and

the residue was purified by silica gel column chromatography using $CHCl_3$ as an eluent to give the oxazole (**1**). Yields and spectral data for **1** are shown in Table VI.

***N*-(3-Butenyl)-4-methyl-*N*-phenyloxazole-5-carboxamide (4a, b)**——The oxazoles (**4a**, **b**) were prepared from 4-methyloxazole-5-carboxylic acid and *N*-(3-butenyl)aniline in a manner similar to that described for the preparation of **1**. Yields and spectral data for **4** are as follows:

N-(3-butenyl)-4-methyl-*N*-phenyloxazole-5-carboxamide (**4a**): Pale yellow oil. Yield, 70%. MS *m/e* (%): 256 (M^+, 4), 215 (25), 110 (100). IR ν_{max}^{KBr} cm^{-1}: 1630. ^{1}H-NMR ($CDCl_3$) δ: 2.31 (3H, s, CH_3), 2.40 (2H, q, CH_2), 3.90 (2H, t, J=7.5 Hz, N–CH_2), 5.00 (1H, d, J=12 Hz), 5.02 (1H, d, J=14 Hz), 5.45—6.11 (1H, m), 6.9—7.5 (5H, m, C_6H_5).

N-(3-Butenyl)-2,4-dimethyl-*N*-phenyloxazole-5-carboxamide (**4b**): Yield, 74%, pale brown oil. MS *m/e* (%): 270 (M^+, 1.8), 229 (21), 124 (100). IR ν_{max}^{KBr} cm^{-1}: 1630. ^{1}H-NMR ($CDCl_3$) δ: 2.03 (3H, s, CH_3), 2.26 (3H, s, CH_3), 2.40 (2H, q, J=7.5 Hz, CH_2), 3.90 (2H, t, J=7.5 Hz, N–CH_2), 5.00 (1H, d, J=12 Hz), 5.03 (1H, d, J=16 Hz), 5.70 (1H, m), 6.9—7.4 (5H, m, C_6H_5).

Allyl 4-Methyloxazole-5-carbamate (11a—h)——The oxazole-5-carbamates (**11a—h**) were prepared by the alkylation of allyl 4-methyloxazole-5-carbamate, prepared from 4-methyloxazole-5-isocyanate,[6] with alkyl halides according to the literature.[6] Yields and spectral data for **11** are listed in Table VII.

Intramolecular Diels–Alder Reaction of 1——Reaction in Toluene: A solution of an *N*-allyl-4-methyloxazole-5-carboxamide (**1**) (10 mmol) in toluene (100 ml) was heated under reflux for 5 h. After removal of the solvent by evaporation under reduced pressure, the residue was purified by silica gel column chromatography to give the corresponding 2-hydroxy-6a-acetyl-6-oxo-tetrahydrofuro[2,3-*c*]pyrrolidine (**3**).

Reaction in Dioxane–H_2O: A solution of **1** (10 mmol) in 50% dioxane–H_2O (100 ml) was refluxed for 5—100 h. The reaction mixture was worked up in a manner similar to that described above to give **3**. The yields of **3** are summarized in Table I. The data for **3** are as follows:

6a-Acetyl-5-ethyl-2-hydroxy-6-oxo-tetrahydrofuro[2,3-*c*]pyrrolidine (**3b**): Pale brown oil, MS *m/e* (%): 213 (M^+, 75). IR ν_{max}^{KBr} cm^{-1}: 3360, 1700, 1675. ^{1}H-NMR ($CDCl_3$) δ: 1.12 (3H, t, CH_3), 1.6—2.6 (2H, m, CH_2), 2.37, 2.42 (total 3H, each s, CH_3CO), 2.90—3.90 (5H, m), 4.90 (1H, br, exchangeable, OH), 5.70, 5.80 (total 1H, each d, J=6 Hz).

6a-Acetyl-2-hydroxy-6-oxo-5-phenyltetrahydrofuro[2,3-*c*]pyrrolidine (**3c**): Colorless amorphous material (triturated with isopropyl ether). MS *m/e* (%): 261 (M^+, 100), 219 (99), 218 (91), 176 (91). IR ν_{max}^{KBr} cm^{-1}: 3440, 1705, 1670. ^{1}H-NMR was shown in Table III.

6a-Acetyl-2-hydroxy-3-methyl-6-oxo-5-phenyltetrahydrofuro[2,3-*c*]pyrrolidine (**3d**): Pale brown oil. MS *m/e* (%): 275 (M^+, 82), 176 (100). IR ν_{max}^{KBr} cm^{-1}: 3400, 1710, 1680. ^{1}H-NMR ($CDCl_3$) δ: 1.05, 1.20 (total 3H, each s, CH_3), 2.41, 2.48 (total 3H, each s, CH_3CO), 5.4—5.6 (1H, m), 7.1—7.8 (5H, m, C_6H_5).

6a-Acetyl-2-hydroxy-2-methyl-6-oxo-5-phenyltetrahydrofuro[2,3-*c*]pyrrolidine (**3e**): mp 102—108 °C (colorless prisms from isopropyl ether). MS *m/e* (%): 275 (M^+, 80), 232 (95), 176 (100). IR ν_{max}^{KBr} cm^{-1}: 3400, 1715, 1675. ^{1}H-NMR ($CDCl_3$) δ: 1.60, 2.11 (total 3H, each s, CH_3), 2.39 (3H, s, CH_3CO), 7.0—7.8 (6H, m, C_6H_5+OH). *Anal.* Calcd for $C_{15}H_{17}NO_4$: C, 65.44; H, 6.22; N, 5.09. Found: C, 65.37; H, 6.12; N, 5.14.

Acetylation of 3b—e——A tetrahydrofuro[2,3-*c*]pyrrolidine (**3**) (1.0 g) was acetylated with AcOH (5 ml) and Ac_2O (10 ml) at 110 °C for 7 h. After removal of the excess reagents, the residue was diluted with $CHCl_3$. The $CHCl_3$ solution was washed with 5% aq. $NaHCO_3$. The solvent was removed by evaporation *in vacuo* and the residue was adsorbed on a silica gel column. The column was developed with $CHCl_3$ to give the corresponding 2β-acetoxy-6aα-acetyl-6-oxo-tetrahydrofuro[2,3-*c*]pyrrolidine (**5**), 2α-acetoxy-6aα-acetyl-6-oxo-tetrahydrofuro[2,3-*c*]-pyrrolidine (**5′**) and 6a-acetyldihydrofuro[2,3-*c*]pyrrolidine (**16**). The yields of **5**, **5′** and **16** are shown in Table IV. The data for **5**, **5′** and **16** are given below.

2α-Acetoxy-6aα-acetyl-5-ethyl-6-oxo-tetrahydrofuro[2,3-*c*]pyrrolidine (**5b′**): Colorless oil. MS *m/e* (%): 255 (M^+, 19), 196 (100). IR ν_{max}^{KBr} cm^{-1}: 1740, 1700, 1680. ^{1}H-NMR ($CDCl_3$) δ: 1.13 (3H, t, J=7.5 Hz, CH_3), 2.03 (3H, s, CH_3CO), 2.38 (3H, s, CH_3CO), 6.43 (1H, d, J=5 Hz, C_2–H).

2β-Acetoxy-6aα-acetyl-5-ethyl-6-oxo-tetrahydrofuro[2,3-*c*]pyrrolidine (**5b**): Colorless oil. MS *m/e* (%): 255 (M^+, 19), 196 (100). IR ν_{max}^{KBr} cm^{-1}: 1740, 1710, 1680. ^{1}H-NMR ($CDCl_3$) δ: 1.15 (3H, t, J=7.5 Hz, CH_3), 1.8—2.8 (2H, m, CH_2), 1.97 (3H, s, CH_3CO), 2.40 (3H, s, CH_3CO), 6.52 (1H, d, J=5 Hz, C_2–H).

2α-Acetoxy-6aα-acetyl-6-oxo-5-phenyltetrahydrofuro[2,3-*c*]pyrrolidine (**5c′**): mp 152—154 °C (colorless needles from benzene). MS *m/e* (%): 303 (M^+, 44), 218 (100). IR ν_{max}^{KBr} cm^{-1}: 1740, 1710, 1690. *Anal.* Calcd for $C_{16}H_{17}NO_5$: C, 63.36; H, 5.65; N, 4.62. Found: C, 63.37; H, 5.69; N, 4.59.

2β-Acetoxy-6aα-acetyl-6-oxo-5-phenyltetrahydrofuro[2,3-*c*]pyrrolidine (**5c**): mp 88—91 °C (colorless prisms from benzene). MS *m/e* (%): 303 (M^+, 55), 218 (100). *Anal.* Calcd for $C_{16}H_{17}NO_5$: C, 63.36; H, 5.65; N, 4.62. Found: C, 63.13; H, 5.66; N, 4.64. IR ν_{max}^{KBr} cm^{-1}: 1730, 1720, 1690.

6aα-Acetyl-2-hydroxy-3-methyl-6-oxo-5-phenyltetrahydrofuro[2,3-*c*]pyrrolidine (**5d**): mp 110 °C (colorless prisms from AcOEt). MS *m/e* (%): 317 (M^+, 62), 232 (100). IR ν_{max}^{KBr} cm^{-1}: 1745, 1720, 1690. ^{1}H-NMR ($CDCl_3$) δ: 1.10 (3H, d, J=7.5 Hz, CH_3), 1.89, 2.08 (total 3H, each s, CH_3CO), 2.20 (1H, m, CH), 2.39, 2.46 (total 3H, each s, CH_3CO), 6.15, 6.43 (total 1H, each d, C_2–H). *Anal.* Calcd for $C_{17}H_{19}NO_5$: C, 64.34; H, 6.04; N, 4.41. Found: C, 64.20; H, 5.99; N, 4.40.

6aα-Acetyl-4aα,*H*-3-methyl-6-oxo-5-phenyldihydrofuro[2,3-*c*]pyrrolidine (**16d**): mp 67—68 °C (colorless prisms from AcOEt). MS *m/e* (%): 257 (M^+, 44), 258 ($M^+ + 1$, 22), 105 (100). IR ν_{max}^{KBr} cm^{-1}: 1710, 1680. ^{1}H-NMR ($CDCl_3$) δ: 1.70 (3H, s, CH_3), 2.49 (3H, s, CH_3), 3.73 (1H, d, J=6.5 Hz), 3.75 (1H, d, J=10 Hz), 4.18 (1H, dd, J=6.5 Hz, J=10 Hz), 6.20 (1H, diffused d, J=*ca.* 1 Hz, C_2–H). *Anal.* Calcd for $C_{15}H_{15}NO_3$: C, 70.02; H, 5.88; N, 5.44. Found: C, 69.65; H, 5.95; N, 5.46.

6aα-Acetyl-4aα,*H*-2-methyl-6-oxo-5-phenyldihydrofuro[2,3-*c*]pyrrolidine (**16e**): mp 87—89 °C (colorless prisms from $CHCl_3$). MS *m/e* (%): 257 (M^+, 44), 258 ($M^+ + 1$, 13), 105 (100). IR ν_{max}^{KBr} cm^{-1}: 1710, 1670. ^{1}H-NMR ($CDCl_3$) δ: 1.83 (3H, s, CH_3), 2.40 (3H, s, CH_3), 3.4—4.2 (3H, m), 4.60 (1H, s), 7.0—7.7 (5H, m, C_6H_5). *Anal.* Calcd for $C_{15}H_{15}NO_3$: C, 70.02; H, 5.88; N, 5.44. Found: C, 69.49; H, 5.93; N, 5.33.

Reaction of 3c with EtOH–HCl——Compound **3c** (0.3 g) was treated with conc. HCl (10 ml) and EtOH (10 ml) at room temperature for 20 h, then reaction mixture was poured into 5% aq. $NaHCO_3$ and the whole was extracted with $CHCl_3$. After removal of the solvent, the residue was purified by silica gel column chromatography ($CHCl_3$) to give 6aα-acetyl-2α-ethoxy-6-oxo-5-phenyltetrahydrofuro[2,3-*c*]pyrrolidine (**19c′**) (0.021 g, 6%) and 6aα-acetyl-2β-ethoxy-6-oxo-5-phenyltetrahydrofuro[2,3-*c*]pyrrolidine (**19c**) (0.05 g, 15%).

19c′: Colorless oil. MS *m/e* (%): 289 (M^+, 66), 218 (100). ^{1}H-NMR ($CDCl_3$) δ: 1.25 (3H, t, J=7 Hz, CH_3), 1.6—2.8 (2H, m, CH_2), 2.45 (3H, s, CH_3CO), 3.2—4.1 (4H, m), 4.20 (1H, dd, J=7 Hz, J=10 Hz), 5.42 (1H, d, J=5 Hz), 7.2—7.9 (5H, m, C_6H_5). IR ν_{max}^{KBr} cm^{-1}: 1710, 1685.

19c: Colorless oil. MS *m/e* (%): 289 (M^+, 40), 175 (100). ^{1}H-NMR ($CDCl_3$) δ: 1.03 (3H, t, J=7 Hz, CH_3), 1.9—2.5 (2H, m, CH_2), 2.40 (3H, s, CH_3CO), 2.9—3.8 (4H, m), 4.08 (1H, dd, J=9 Hz, J=18 Hz), 5.32 (1H, d, 5 Hz), 7.1—7.8 (5H, m, C_6H_5). IR ν_{max}^{KBr} cm^{-1}: 1710, 1685.

Reaction of 3c with 2,4-Dinitrophenylhydrazine——A mixture of **3c** (0.15 g), EtOH (20 ml), 2,4-dinitrophenylhydrazine (0.1 g) and 50% H_2SO_4 (2 ml) was stirred for 3 h at room temperature. The resulting precipitates were collected and washed with EtOH to give the crude hydrazone. Recrystallization from EtOH afforded 6aα-(2,4-dinitrophenylhydrazono)ethyl-2-ethoxy-6-oxo-5-phenyltetrahydrofuro[2,3-*c*]pyrrolidine (0.16 g, 67%) as yellow prisms, mp 210 °C. MS *m/e* (%): 469 (M^+, 70), 228 (100). IR ν_{max}^{KBr} cm^{-1}: 3410, 1705. ^{1}H-NMR ($CDCl_3$) δ: 1.19 (3H, t, CH_3), 2.29 (3H, s, CH_3), 5.40 (1H, d, J=4 Hz, C_2–H). *Anal.* Calcd for $C_{22}H_{23}N_5O_7$: C, 56.28; H, 4.94; N, 14.92. Found: C, 56.15; H, 4.93; N, 15.03.

10-Methyl-2-oxo-3-phenyl-11-oxa-3,9-diazatricyclo[6.2.1.0^{1,6}]undec-9-ene (6a)——A solution of **4a** (1.0 g) in xylene (100 ml) was heated under reflux for 24 h. After removal of the solvent by evaporation *in vacuo*, the residue was chromatographed on a column of alumina with a mixture of isopropyl ether and ethyl acetate (2 : 1) to give **6a** (0.38 g, 38%) along with unchanged **4a** (0.32 g). Pale brown oil. MS *m/e* (%): 256 (M^+, 16), 110 (100). IR ν_{max}^{KBr} cm^{-1}: 1620. ^{1}H-NMR ($CDCl_3$) δ: 2.15 (3H, s, CH_3), 5.85 (1H, d, J=3 Hz), 7.30 (5H, s, C_6H_5). *Anal.* Calcd for $C_{15}H_{16}N_2O_2$: C, 70.29; H, 6.29; N, 10.93. Found: C, 70.18; H, 6.39; N, 10.88.

8,10-Dimethyl-2-oxo-3-phenyl-11-oxa-3,9-diazatricyclo[6.2.1.0^{1,6}]undec-9-ene (6b)——The oxazole (**4b**) was refluxed in xylene for 6 d. The reaction mixture was treated in a manner similar to that described for the preparation of **6a** to give **6b** (0.64 g, 64%) as pale brown needles. mp 135—136 °C (AcOEt). MS *m/e* (%): 270 (M^+, 83), 229 (100). IR ν_{max}^{KBr} cm^{-1}: 1640. ^{1}H-NMR ($CDCl_3$) δ: 1.83 (3H, s, CH_3), 2.12 (3H, s, CH_3), 1.0—2.2 (5H, m), 3.70 (2H, t, CH_2), 7.30 (5H, s, C_6H_5). *Anal.* Calcd for $C_{16}H_{18}N_2O_2$: C, 71.09; H, 6.71; N, 10.36. Found: C, 71.05; H, 6.70; N, 10.28.

8-Methyl-1-oxo-2-phenylpiperidino[3,4-*c*]pyridine (7a)——A solution of **4a** (1.0 g) in xylene (100 ml) was heated at 140 °C for 5 d. The solvent was removed by evaporation under reduced pressure and the residue was applied to an alumina column. Elution with ethyl acetate afforded **7a** (0.32 g, 32%) as pale yellow plates. mp 128—130 °C (AcOEt). MS *m/e* (%): 238 (M^+, 100). IR ν_{max}^{KBr} cm^{-1}: 1640. ^{1}H-NMR ($CDCl_3$) δ: 2.93 (3H, s, CH_3), 3.08 (2H, t, J=6 Hz, CH_2), 3.96 (2H, t, J=6 Hz, CH_2), 7.05 (1H, d, J=5 Hz, pyridine ring proton), 7.40 (5H, s, C_6H_5), 8.50 (1H, d, J=5 Hz, pyridine ring proton). *Anal.* Calcd for $C_{15}H_{14}N_2O$: C, 75.60; H, 5.92; N, 11.76. Found: C, 75.87; H, 6.09; N, 11.65.

Hydrolysis of 6——A mixture of **6** (10 mmol) in dioxane (100 ml) and H_2O (100 ml) was refluxed for 1 h. After removal of the solvent, the residue was chromatographed on a silica gel column with $CHCl_3$ as an eluent to give 7a-acetyl-2-hydroxy-7-oxo-6-phenyltetrahydrofuro[2,3-*c*]piperidine (**8**).

7a-Acetyl-2-hydroxy-7-oxo-6-phenyltetrahydrofuro[2,3-*c*]piperidine (**8a**): Yield, 100% (pale yellow oil). MS *m/e* (%): 275 (M^+, 7), 232 (100). IR ν_{max}^{KBr} cm^{-1}: 3390, 1705, 1650. ^{1}H-NMR ($CDCl_3$) δ: 2.29, 2.50 (total 3H, each s, CH_3CO), 1.5—2.5 (5H, m), 5.70, 5.76 (total 1H, each d, C_2–H), 7.25 (5H, s, C_6H_5). *Anal.* Calcd for $C_{15}H_{17}NO_4$: C, 65.44; H, 6.23; N, 5.09. Found: C, 65.28; H, 6.39; N, 5.18.

7a-Acetyl-2-hydroxy-2-methyl-7-oxo-6-phenyltetrahydrofuro[2,3-*c*]piperidine (**8b**): Yield, 100% (yellow viscous oil). MS *m/e* (%): 289 (M^+, 15), 246 (100). IR ν_{max}^{KBr} cm^{-1}: 3450, 1700, 1640. ^{1}H-NMR ($CDCl_3$) δ: 2.12 (3H, s, CH_3CO), 2.27 (3H, s, CH_3CO), 7.28 (5H, s, C_6H_5), 7.58 (1H, br, exchangeable, OH). *Anal.* Calcd for $C_{16}H_{19}NO_4$: C, 66.42; H, 6.62; N, 4.84. Found: C, 66.12; H, 6.58; N, 4.80.

Reaction of 6a with Acetic Acid——A solution of **6a** (0.63 g) in acetic acid (10 ml) was heated at 110 °C for 0.5 h. After removal of the excess reagent, the residue was chromatographed on a silica gel column. The column was developed successively with $CHCl_3$, ethyl acetate and methanol. The first eluate gave 8-hydroxy-2-phenyl-1,2,3,4-tetrahydroisoquinolin-1-one (**10a**) (0.09 g, 5%) as pale brown oil. MS *m/e* (%): 239 (M^+, 35), 238 (100). IR ν_{max}^{KBr} cm^{-1}: 3325, 1640, 1610. ^{1}H-NMR ($CDCl_3$) δ: 3.10 (2H, t, J=6 Hz, CH_2), 3.94 (2H, t, J=6 Hz, CH_2), 6.00 (1H, br,

exchangeable, OH), 6.3—7.1 (3H, m), 7.40 (5H, s, C_6H_5). *Anal.* Calcd for $C_{15}H_{13}NO_2$: C, 75.30; H, 5.48; N, 5.85. Found: C, 75.12; H, 5.21; N, 5.66. The second eluate afforded **7a** (0.02 g, 4%).

Reaction of 6b with Acetic Acid——Treatment of **6b** (0.5 g) with acetic acid (4 ml) at 110 °C for 0.5 h. After removal of the reagent, the residue was purified by silica gel column chromatography. The first $CHCl_3$ eluate was collected and concentrated to give 8-hydroxy-6-methyl-2-phenyl-1,2,3,4-tetrahydroisoquinolin-1-one (**10b**) (0.025 g, 5%) as pale brown prisms. mp 114—117 °C ($CHCl_3$). MS *m/e* (%): 253 (M^+, 25), 252 (100). IR ν_{max}^{KBr} cm^{-1}: 3400, 3300, 1620. ^{1}H-NMR ($CDCl_3$) δ: 1.25 (3H, s, CH_3), 3.00 (2H, t, J=6 Hz, CH_2), 3.90 (2H, t, J=6 Hz, CH_2), 6.30 (1H, d, J=*ca.* 1 Hz), 6.37 (1H, d, J=*ca.* 1 Hz), 7.37 (5H, s, C_6H_5). The second ethyl acetate eluate was collected and concentrated to afford 8a-hydroxy-8-methyl-2-phenyl-1,2,3,4,5,6-hexahydroisoquinoline-1,6-dione (**9b'**) (0.08 g,

Table VIII. Data for Tricycloadducts (**12**)

No.	Appearance mp (°C)	Recryst. solvent	MS *m/e* (%)	Formula	Analysis (%) Calcd (Found)		
					C	H	N
a	114 (Prisms)	A	196 (M^+, 1.6) 68 (100)	$C_9H_{12}N_2O_3$	55.09 (54.84)	6.17 (5.99)	14.28 (14.10)
b	170 (Prisms)	B	272 (M^+, 30) 91 (100)	$C_{15}H_{16}N_2O_3$	66.16 (66.38)	5.92 (5.83)	10.29 (10.08)
c	128 (Prisms)	A	224 (M^+, 5)	$C_{11}H_{16}N_2O_3$	58.91 (59.08)	7.19 (7.09)	12.49 (12.49)
d	141 (Needles)	A	210 (M^+, 1.4) 82 (100)	$C_{10}H_{14}N_2O_3$	57.13 (57.37)	6.71 (6.72)	13.33 (13.70)
e	152 (Prisms)	B	286 (M^+, 10) 82 (100)	$C_{16}H_{18}N_2O_3$	67.11 (67.42)	6.34 (6.42)	9.78 (9.85)
f	165 (Needles)	A	210 (M^+, 7) 82 (100)	$C_{10}H_{14}N_2O_3$	57.13 (57.33)	6.71 (6.65)	13.33 (13.32)
g	112 (Prisms)	B	286 (M^+, 5) 96 (100)	$C_{16}H_{18}N_2O_3$	67.11 (67.25)	6.34 (6.40)	9.78 (9.36)
h	132 (Prisms)	B	300 (M^+, 5) 82 (100)	$C_{17}H_{20}N_2O_3$	67.98 (68.11)	6.71 (6.71)	9.33 (9.51)

A: $CHCl_3$–isopropyl ether (1 : 2).
B: $CHCl_3$.

Table VIII. Data for Tricycloadducts (**12**) (continuation)

No.	IR cm^{-1}	^{1}H-NMR ($CDCl_3$) J=Hz							
		CH_3	R_1		R_2		CH_2		R_3
a	1700	2.13	5.69		3.66		4.03,	4.33	
	1615	(3H, s)	(1H, d, 4)		(3H, s)		(1H, dd)	(1H, dd)	
b	1700	2.05	5.71	7.1—7.7,	4.20,	4.96	4.03,	4.33	
	1620	(3H, s)	(1H, d, 3)	(5H, m)	(1H, d)	(1H, d)	(1H, dd)	(1H, dd)	
c	1710	2.20	5.70	1.33,	1.59,	3.30	4.03,	4.40	
	1620	(3H, s)	(1H, d, 3)	(3H, d)	(3H, d)	(1H, m)	(1H, dd)	(1H, dd)	
d	1720	2.17	5.53		3.08		4.02,	4.46	0.98
	1620	(3H, s)	(1H, d, 4)		(3H, s)		(1H, dd)	(1H, dd)	(3H, d, 7)
e	1700	2.10	5.60	7.0—7.5,	4.16,	4.96	4.02,	4.43	0.98
	1615	(3H, s)	(1H, d, 4)	(5H, m)	(1H, d)	(1H, d)	(1H, dd)	(1H, dd)	(3H, d, 7)
f	1715	2.13	1.80		3.13		4.01,	4.33	
	1620	(3H, s)	(3H, s)		(3H, s)		(1H, dd)	(1H, dd)	
g	1700	2.00	1.80	7.0—7.5,	4.20,	4.80			
	1620	(3H, s)	(3H, s)	(5H, m)	(1H, d)	(1H, d)			
h	1695	2.05	1.77	7.1—7.5,	4.20,	4.90			0.97
	1620	(3H, s)	(3H, s)	(5H, m)	(1H, d)	(1H, d)			(3H, d, 7)

16%) as a pale brown oil. MS *m/e* (%): 271 (M^+, 40), 106 (100). IR ν_{max}^{KBr} cm^{-1}: 3250, 1650. ^{1}H-NMR ($CDCl_3$) δ: 2.29 (3H, s, CH_3), 1.5—3.0 (5H, m), 3.70 (2H, t, J=6 Hz, CH_2), 4.42 (1H, br, OH), 5.86 (1H, s), 7.2—7.3 (5H, m, C_6H_5). *Anal.* Calcd for $C_{16}H_{17}NO_2$: C, 70.83; H, 6.32; N, 5.16. Found: C, 70.72; H, 6.19; N, 5.01. The third ethyl acetate eluate was collected and concentrated to give 8a-hydroxy-6-methyl-2-phenyl-1,2,3,4,5,8-hexahydroisoquinoline-1,8-dione (**9b**) (0.16 g, 32%) as pale yellow prisms. mp 197—199 °C ($CHCl_3$). MS *m/e* (%): 271 (M^+, 15). 106 (100). IR ν_{max}^{KBr} cm^{-1}: 3250, 1680, 1620. ^{1}H-NMR ($CDCl_3$) δ: 1.90 (3H, s, CH_3), 1.6—3.0 (5H, m), 3.60 (2H, t, CH_2), 5.72 (1H, s), 7.28 (5H, s, C_6H_5). *Anal.* Calcd for $C_{16}H_{17}NO_3$: C, 70.83; H, 6.32; N, 5.16. Found: C, 70.17; H, 6.17; N, 5.19.

8-Acetoxy-6-methyl-2-phenyl-1,2,3,4-tetrahydroisoquinolin-1-one (18b)——From **10b**: A solution of **10b** (50 mg) in acetic acid (6 ml) and acetic anhydride (5 ml) was refluxed for 3 h. After removal of the reagents by evaporation, the residue was purified by silica gel preparative thin-layer chromatography (TLC), developing with $CHCl_3$–AcOEt (5 : 1) to afford **18b** (50 mg, 87%) as a pale yellow oil. MS *m/e* (%): 295 (M^+, 5.5), 253 (100). IR ν_{max}^{KBr} cm^{-1}: 1760, 1650, 1615. ^{1}H-NMR ($CDCl_3$) δ: 2.30 (3H, s, CH_3), 2.39 (3H, s, CH_3CO), 3.05 (2H, t, J=6.5 Hz, CH_2), 3.90 (2H, t, J=6.5 Hz, CH_2), 6.83 (1H, s), 6.93 (1H, s). *Anal.* Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.74. Found: C, 73.02; H, 5.99; N, 4.81.

From **9b**: Compound **9b** (40 mg) was treated with acetic acid (6 ml) and acetic anhydride (5 ml) at 110 °C for 6 h. The reaction mixture was worked up in a manner similar to that described above to give **18b** (36 mg, 81%).

From **6b**: Compound **6b** (50 mg) was treated with acetic acid (6 ml) and acetic anhydride (5 ml) at 110 °C for 5 h. After work-up in the usual manner, the crude acetate was purified by silica gel preparative TLC to afford **18b** (35 mg).

6-Acetoxy-8-methyl-2-phenyl-1,2,3,4-tetrahydroisoquinolin-1-one (18b′)——A mixture of **9b′** (45 mg), AcOH (6 ml) and Ac_2O (5 ml) was heated under reflux for 5 h. The reaction mixture was treated in the same way as **18b** to yield **18b′** (30 mg, 61%) as a pale yellow oil. MS *m/e* (%): 295 (M^+, 43), 253 (45), 148 (100). IR ν_{max}^{KBr} cm^{-1}: 1750, 1650. ^{1}H-NMR ($CDCl_3$) δ: 1.30 (3H, s, CH_3), 1.70 (3H, s, CH_3), 3.08 (2H, t, J=6 Hz, CH_2), 3.94 (2H, t, J=6 Hz, CH_2), 7.33 (5H, s, C_6H_5). *Anal.* Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.75. Found: C, 73.45; H, 6.01; N, 4.61.

Diels–Alder Reaction of Allyl *N*-Substituted-4-methyloxazole-5-carbamate (11)——A solution of **11** (10 mmol) in xylene (100 ml) was heated at 140 °C for 24—88 h. The solvent was removed by evaporation under reduced pressure. The residue was applied to a silica gel column and eluted with $CHCl_3$. The first eluate gave the starting material (**11**). The second eluate gave the tricycloadduct (**12**). Yields are summarized in Table V. Data for **12** are listed in Table VIII.

Reaction of 12 with AcOH——A solution of the tricycloadduct (**12a**) (1.0 g) in AcOH (20 ml) was heated under reflux for 2 h. After removal of the excess reagent by evaporation, the residue was purified by silica gel column

Table IX. Hydrolysis of Tricycloadducts (**12**)

Compd. No.	R_1	R_2	R_3	Reaction conditions			Yield of **14** (%)
				Reagent	Temp. (°C)	Time (h)	
12a	H	Me	H	AcOH	70	1	38
12b	H	Bz	H	AcOH	70	1	42
12f	Me	Me	H	1 N HCl	Room temp.	1	95

Table X. 7a-Acetyl-6-hydroxytetrahydrofuro[2,3-*d*]oxazin-2-one (**14**)

Compd. No.	Appearance mp (°C)	IR ν_{max}^{KBr} cm^{-1}	Formula	Analysis (%) Calcd (Found)		
				C	H	N
14a	Oil	3300 1720 1650	$C_9H_{13}NO_5$	50.23 (50.46)	6.09 (6.10)	6.51 (6.43)
14b	119 (AcOEt)	3260 1710 1650	$C_{15}H_{17}NO_5$	61.79 (62.24)	5.83 (5.86)	4.81 (4.80)
14f	Oil	3400 1720 1675	$C_{10}H_{15}NO_5$	52.39 (52.68)	6.60 (6.42)	6.11 (6.09)

chromatography. The first eluate gave 8-hydroxy-1-methyl-4*H*[1,3]benzoxazin-2-one (**15a**) (0.38 g, 38%). mp 238 °C (pale yellow needles from AcOEt). MS *m/e* (%): 179 (M^+, 45), 134 (100). IR ν_{max}^{KBr} cm^{-1}: 3200, 1670. ^{1}H-NMR ($CDCl_3$) δ: 3.53 (3H, s, N–CH_3), 5.00 (2H, s, CH_2), 6.4—7.0 (3H, m), 9.10 (1H, br, exchangeable, OH). *Anal.* Calcd for $C_9H_9NO_3$: C, 60.33; H, 5.06; N, 7.82. Found: C, 60.37; H, 5.08; N, 7.29. The second eluate afforded 1,8-dimethyl-4*H*-pyrido[3,4-*d*][1,3]oxazin-2-one (**13a**) (0.06 g, 6%). mp 122—124 °C (pale yellow needles from AcOEt). MS *m/e* (%): 178 (M^+, 100). IR ν_{max}^{KBr} cm^{-1}: 1700. ^{1}H-NMR ($CDCl_3$) δ: 2.66 (3H, s, CH_3), 3.49 (3H, s, N–CH_3), 7.08 (1H, d, J=4.5 Hz, pyridine ring proton), 8.17 (1H, d, J=4.5 Hz, pyridine ring proton). *Anal.* Calcd for $C_9H_{10}N_2O_2$: C, 60.86; H, 5.63; N, 15.65. Found: C, 61.04; H, 5.71; N, 15.51.

Hydolysis of 12——HCl (1 N; 1.5 ml) was added dropwise to a solution of the tricycloadduct (**12**) (1 mmol) in dioxane (4 ml) with stirring at room temperature. After removal of the solvent, the residue was purified by silica gel column chromatography to give 7a-acetyl-6-hydroxy-4*H*-tetrahydrofuro[2,3-*d*][1,3]oxazin-2-one (**14**). Yields are summarized in Table IX. Data for **14** are listed in Table X.

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References and Notes

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