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Reactions of 1-Unsubstituted Tautomeric 2-Pyridones with Benzyne

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The reactions of 1-unsubstituted 2-pyridones with benzyne afforded the Diels–Alder adduct, 5,6-benzo-2-azabarrelen-3(2*H*)-ones, together with a large amount of the Michael-type adduct, 2-phenoxypyridines.

Keywords——Diels–Alder reaction; 2-pyridone; benzyne; 5,6-benzo-2-azabarrelen-3(2*H*)-one; 2-phenoxypyridine

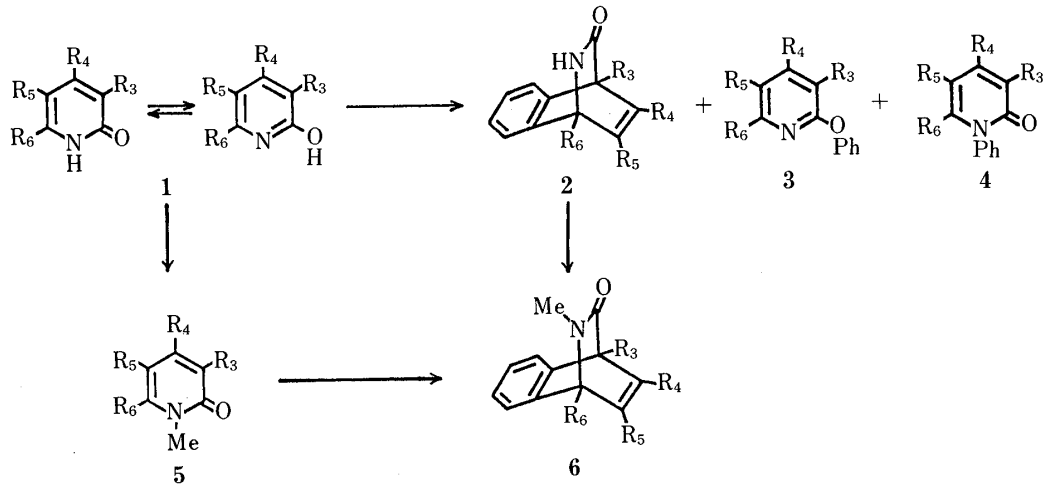
In contrast to the substantial amount of experimental work done on the Diels–Alder reaction of 1-substituted 2-pyridones with a veriety of dienophiles including benzyne in recent years,[1] similar reactions of 1-unsubstituted 2-pyridones have received little attention, and only the Michael-type addition to the oxygen and/or nitrogen atom has been reported.[1a,2] The only example of the formation of the Diels–Alder adduct with 1-unsubstituted 2-pyridones in the literature is the reaction with N-phenylmaleimides.[3] Earlier attempts at such reactions with benzyne were reported to result only in the formation of 1-phenyl-2-pyridone and 2-phenoxypyridine in rather poor yield,[2a] and the formation of the Diels–Alder adduct of 1-unsubstituted 2-pyridones with benzyne was unknown prior to our preliminary publication,[4] although 5,6-benzo-2-azabarrelen-3(2*H*)-one had already been prepared by a less direct route involving the reaction of 3-isoquinolines with maleic anhydride derivatives followed by successive hydrolysis and oxidative decarboxylation.[5]

Reactions of 2-pyridones with highly reactive dienophiles such as benzyne are of interest in connection with the structure–reactivity–chemoselectivity relationship of the tautomeric equilibria, and the resulting Diels–Alder adducts could be converted not only to analogs which are of potential use as central nervous system active agents,[3a,5,6] but also to hitherto unknown 5,6-benzo-2-azabarrelenes which contain many interesting physical and chemical features for study.[1i]

The present work was therefore undertaken to define the scope and limitations of the formation of the Diels–Alder adducts in such reactions.

Results and Discussion

The reactions of 2-pyridones with benzyne were carried out according to a procedure essentially identical with that reported by Bauer and co-workers[2a] (Chart 1). A solution of anthranilic acid in a mixed solvent of acetone and chloroform was added dropwise to a solution of 2-pyridones and isopentyl nitrite in chloroform under nitrogen bubbling at 40—70 °C. Work-up and chromatographic separation over alumina with chloroform as an eluent led to the isolation of two products (in most cases), which were identified as 5,6-benzo-2-azabarrelen-3(2*H*)-ones (**2**) and 2-phenoxypyridines (**3**). In several cases, 1-phenyl-2-pyridones (**4**) were also obtained. The product yields are summarized in Table I.



a : $R_3=R_4=R_5=R_6=H$ **i** : $R_3=H$, $R_4=R_5=R_6=Me$ **p** : $R_3=Me$, $R_4=Ph$, R_5–$R_6=-(CH_2)_3-$
b : $R_3=Me$, $R_4=R_5=R_6=H$ **j** : $R_3=R_4=R_5=R_6=Me$ **q** : $R_3=R_4=R_6=Me$, $R_5=Ph$
c : $R_3=R_5=R_6=H$, $R_4=Me$ **k** : $R_3=R_5=R_6=H$, $R_4=Ph$ **r** : $R_3=CN$, $R_4=H$, $R_5=R_6=Me$
d : $R_3=R_4=R_6=H$, $R_5=Me$ **l** : $R_3=R_5=H$, $R_4=Ph$, $R_6=Me$ **s** : $R_3=Me$, $R_4=R_5=H$, $R_6=Br$
e : $R_3=R_4=R_5=H$, $R_6=Me$ **m**: $R_3=R_6=Me$, $R_4=Ph$, $R_5=H$ **t** : $R_3=R_4=R_5=H$, $R_6=Cl$
f : $R_3=R_5=Me$, $R_4=R_6=H$ **n** : $R_3=H$, $R_4=Ph$, $R_5=R_6=Me$ **u** : $R_3=H$, $R_4=Me$, R_5–$R_6=-CH_2CH_2O-$
g : $R_3=R_5=H$, $R_4=R_6=Me$ **o** : $R_3=R_5=R_6=Me$, $R_4=Ph$ **v** : $R_3=R_4=R_5=H$, $R_6=OMe$
h : $R_3=R_4=H$, $R_5=R_6=Me$

Chart 1

TABLE I. Reactions of 2-Pyridones with Benzyne

2-Pyridones	Product composition (%)				Total recovery (%)[c]
	2	**3**	**4**	**1**	
1a	7[a]	35	4	1	46
1b	4[a]	48	0	2[a]	54
1c	12[a]	29	0	12[a]	53
1d	17[a]	45	0	31[a]	93
1e	4[a]	74	0	17[a]	95
1f	15[a]	45	0	27[a]	87
1g	4	79	0	13[a]	96
1h	6	73	0	19	98
1i	5	75	0	19	99
1j	8	77	0	11	96
1l	8	75	0	15	98
1m	7	69	0	13	89
1n	14	74	0	10	98
1o	26	66	0	7	99
1p	30	41	0	11	82
1q	14	78	0	7	99
1s	7	35	7	0	49
1t	1	33	11	0	45
1u	30[b]	0	0	0	30

a) Yields with a small amount of contamination. *b*) Based on a naphthalene derivative derived from a spontaneous retro Diels–Alder reaction. *c*) The lower values are mainly due to the difficulty in recovery of the starting 2-pyridones.

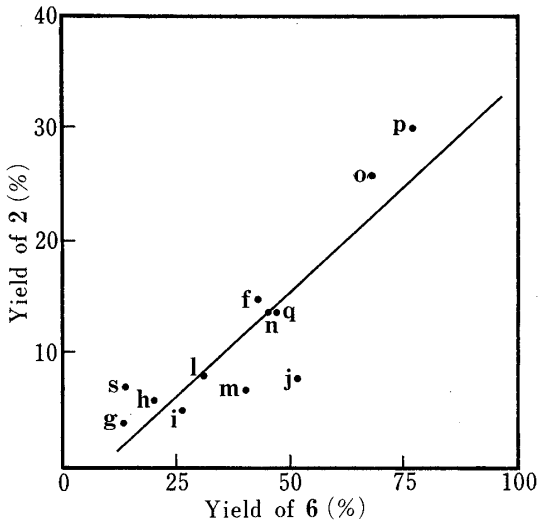


Fig. 1

The structures of these products were consistent with the elemental analyses and the spectral properties (*vide infra*). Further proof of the structures of **2** was provided by the facile conversion to 1-methyl derivatives (**6**) on treatment of several selected derivatives (**2l**, **2m**, **2o**, and **2p**) with methyl iodide.

All the 2-pyridones examined afforded the Diels–Alder adduct (**2**), although the yields varied with the substituents. The product yields listed in Table I were all obtained from the reactions under similar experimental conditions so that comparisons of reactivity can be made; no attempt was made to optimize the yields. The yield was found to be very sensitive to the rate of dropwise addition of anthranilic acid.

With a view to evaluating the substituent effect on the Diels–Alder reactivity of the pyridone tautomer, the reactions of 1-methyl-2-pyridones (**5**) with benzyne were also studied under conditions similar to those used for the 1-unsubstituted derivatives (Chart 1), and the product yields were plotted against those of **2**, as shown in Fig. 1.

It can be seen from Fig. 1 that the yields of the Diels–Alder adducts tend to increase as the introduced substituents increase. The nature of substituent effects on the reactivity and chemoselectivity in the reactions of 2-pyridones with benzyne was discussed in detail in a separate paper.[7]

The physicochemical constants for new compounds among **2**, **6** and **3** obtained in the present work are summarized in Tables II—IV, respectively.

The proton nuclear magnetic resonance (^{1}H-NMR) spectra of **2** and **6** were similar to each other, differing only as expected for the change of 1-methyl substituent. The signals of the bridgehead proton and the allylic proton were observed at 4.6—4.9 ppm and 6.0—6.5 ppm, respectively, and the signals due to the methyl groups were at higher magnetic field than those of the starting 2-pyridones, (**1** and **5**). The infrared (IR) spectra of **2** and **6** showed strong carbonyl stretching bands at 1660—1680 cm^{-1}, which are characteristics of the nonconjugated amide structure. The mass spectra (MS) did not show an intense molecular ion peak; retro Diels–Alder fragmentation occurs easily to produce a base peak corresponding to the mass of the aromatic naphthalene derivatives. For 6-alkoxy 2-pyridones, (**1u**, **5u**, and **5v**), the Diels–Alder adducts were obtained as the naphthalene derivatives. Apparently, an alkoxy substituent facilitates the elimination of the amido bridge. All the spectral features were consistent with the assigned structures.

2-Phenoxypyridines (**3**), which were obtained in the greatest yields among the products, were obtained in high yields in the reactions of the 6-methyl derivatives (**1e**, **1g—o**, and **1q**).

TABLE II. 5,6-Benzo-2-azabarrelen-3(2*H*)-ones[a)]

Compd. No.	mp (°C)	IR (cm^{-1})	Formula	Analysis (%) Calcd (Found)		
				C	H	N
2b	151—153	3170	$C_{12}H_{11}NO$	77.81	5.99	7.56
		1675		(77.57	6.05	7.51)
2c	147—149	3190	$C_{12}H_{11}NO$	77.81	5.99	7.56
		1667		(77.84	5.98	7.54)
2d	176—177	3200	$C_{12}H_{11}NO$	77.81	5.99	7.56
		1665		(77.60	5.99	7.52)
2e	190—191	3140	$C_{12}H_{11}NO$	77.81	5.99	7.56
		1670		(77.62	5.95	7.50)
2f	147—148	3160	$C_{13}H_{13}NO$	78.36	6.58	7.03
		1675		(78.11	6.73	7.04)
2g	200—202	3180	$C_{13}H_{13}NO$	78.36	6.58	7.03
		1675		(78.09	6.51	7.03)
2h	228—230	3150	$C_{13}H_{13}NO$	78.36	6.58	7.03
		1680		(78.11	6.73	7.04)
2i	197	3190	$C_{14}H_{15}NO$	78.84	7.09	6.57
		1675		(78.87	7.23	6.47)
2j	232—233	3140	$C_{15}H_{17}NO$	79.26	7.54	6.16
		1670		(79.27	7.59	6.18)
2l	244—247	3130	$C_{18}H_{15}NO$	82.73	5.79	5.36
		1680		(82.66	5.81	5.32)
2m	203—205	3170	$C_{19}H_{17}NO$	82.88	6.22	5.09
		1675		(82.69	6.19	5.05)
2n	241—243	3150	$C_{19}H_{17}NO$	82.88	6.22	5.09
		1680		(82.93	6.26	5.07)
2o	206—208	3150	$C_{20}H_{19}NO$	83.01	6.62	4.84
		1675		(82.74	6.78	4.75)
2p	223—224	3150	$C_{21}H_{19}NO$	83.69	6.35	4.65
		1662		(83.79	6.33	4.56)
2q	234—236	3150	$C_{20}H_{19}NO$	83.01	6.62	4.84
		1670		(83.26	6.53	4.94)
2s	195—196	3160	$C_{12}H_{10}BrNO$	54.57	3.82	5.30
		1675		(54.60	3.70	5.35)
2t[b)]			$C_{11}H_8ClNO$			

The structures were readily identified by the ring proton signals at lower magnetic field than those of the 2-pyridones in the ^{1}H-NMR spectra and the absence of the carbonyl stretching band in the IR spectra.

1-Phenyl-2-pyridones (**4**), the other Michael-type adduct, were obtained only in the reactions of **1a**, **1s**, and **1t**, and the rather high yields with compounds **1s** and **1t**, which tend to exist as the 2-pyridinol form,[8)] seem to show that the 2-pyridinol form is responsible for the formation of 1-phenyl-2-pyridones (**4**). The structures were easily identified by the similarity of the chemical shifts of the ring protons and the methyl protons with those of the starting 2-pyridone in the ^{1}H-NMR spectra and the existence and absence of the carbonyl stretching band and the NH stretching band in the IR spectra, respectively.

Experimental

All the melting points and boiling points are uncorrected. IR spectra were recorded with a JASCO A-102 infrared spectrophotometer in KBr disks unless otherwise specified.

TABLE II. (continued)

Compd. No.	^{1}H-NMR δ (ppm, J=Hz)	MS m/e (% rel. int.)
2b	1.78 (3H, s), 5.07 (1H, m), 6.43 (1H, q, J=7, 2), 6.63—7.63 (5H, m), 7.83 (1H, br s)	185 (M^+, <1), 143 (13), 142 (100), 115 (21)
2c	1.93 (3H, d, J=2), 4.20 (1H, d, J=1), 5.05 (1H, m), 6.35 (1H, m), 6.70—7.43 (5H, m)	185 (M^+, 1), 143 (12), 142 (100), 141 (56), 115 (17)
2d	1.87 (3H, d, J=1), 4.28 (1H, q, J=6, 2), 4.73 (1H, q, J=5, 2), 6.30 (1H, m), 6.82—7.33 (4H, m), 7.87 (1H, br s)	185 (M^+, <1), 143 (12), 142 (100), 141 (62), 115 (20)
2e	1.90 (3H, s), 4.42 (1H, m), 6.43 (1H, q, J=7, 2), 6.72—7.40 (6H, m)	185 (M^+, <1), 143 (13), 142 (100), 141 (51), 115 (21)
2f	1.73 (3H, s), 1.83 (3H, d, J=1), 4.75 (1H, q, J=5, 2), 5.97 (1H, m), 6.87—7.37 (1H, m), 8.53 (1H, br s)	199 (M^+, <1), 157 (14), 156 (100), 155 (19), 141 (60), 128 (12), 115 (14)
2g	1.83 (3H, s), 1.90 (3H, d, J=2), 4.17 (1H, d, J=2), 6.03 (1H, q, J=4, 2), 6.63—7.50 (5H, m)	199 (M^+, 1), 157 (13), 156 (100), 155 (15), 141 (55), 128 (11), 115 (15)
2h	1.83 (3H, d, J=1), 1.86 (3H, s), 4.38 (1H, q, J=6, 2), 6.53 (1H, m), 6.88—7.58 (5H, m)	199 (M^+, 3), 157 (14), 156 (100), 155 (16), 141 (76), 115 (14)
2i	1.65 (3H, s), 1.82 (6H, s), 4.12 (1H, d, J=2), 6.85—7.35 (4H, m), 8.08 (1H, br s)	213 (M^+, 5), 170 (100), 155 (98), 105 (66)
2j	1.71 (6H, s), 1.76 (3H, s), 1.86 (3H, s), 6.80—7.47 (4H, m), 7.65 (1H, br s)	227 (M^+, 3), 184 (100), 169 (73)
2l	1.98 (3H, s), 4.93 (1H, m), 6.60 (1H, m), 6.87—7.60 (10H, m)	261 (M^+, 1), 219 (19), 218 (100), 217 (28), 215 (21), 203 (11), 202 (21)
2m	1.62 (3H, s), 1.93 (3H, s), 6.28 (1H, s), 6.77—7.37 (10H, m)	275 (M^+, 1), 233 (28), 232 (100), 231 (15), 217 (41), 216 (21), 215 (33), 108 (13)
2n	1.83 (3H, s), 1.93 (3H, s), 4.57 (1H, d, J=2), 6.85—7.38 (9H, m), 7.93 (1H, br s)	275 (M^+, 11), 233 (22), 232 (100), 217 (39), 216 (17), 215 (36), 202 (17)
2o	1.48 (3H, s), 1.59 (3H, s), 1.91 (3H, s), 7.00—7.55 (9H, m), 7.76 (1H, br s)	289 (M^+, 4), 246 (100)
2p	1.50—3.14 (6H, m), 1.62 (3H, s), 6.79—7.66 (9H, m), 7.96 (1H, br s)	301 (M^+, 2), 258 (100)
2q	1.59 (6H, s), 1.82 (3H, s), 6.83 (1H, br s), 6.96—7.54 (9H, m)	289 (M^+, 6), 246 (100)
2s	1.78 (3H, s), 5.00 (1H, m), 6.50 (1H, d, J=2), 6.93—7.37 (4H, m), 7.92 (1H, br s)	222 (M^+ +2-HNCO, 73), 220 (M^+ −HNCO, 82), 141 (100)
2t[b]	4.70 (1H, q, J=6, 2), 6.68—7.67 (7H, m)	

a) Compound **2a** has been described previously. Compound **2u** was obtained as the naphthalene derivative **2u'** derived by a spontaneous retro Diels–Alder reaction. See Experimental. *b*) Not purified.

The ^{1}H-NMR spectra were recorded on a Hitachi R-24B spectrometer in deuterochloroform solution. Chemical shifts are quoted relative to tetramethylsilane as an internal standard. The mass spectra were measured with a JEOL JMS-D300 spectrometer.

Preparation of 2-Pyridones——2-Pyridones (**1a—j**, **1o**, **1p**, and **1s—y**) were described in a previous paper.[9] 4-Phenyl-(**1k**)[10] and 3-cyano-5,6-dimethyl-2-pyridone (**1r**)[11] were prepared by the cited methods.

4-Phenyl derivatives (**1l—n**, and **1g**) were prepared from the appropriate α-benzoylpropionitrile and ketone according to the method of Hauser and Eby.[12] 6-Methyl-4-phenyl (**1l**) and 3,6-dimethyl-4-phenyl-2-pyridone (**1m**) are known compounds.[12]

TABLE III. 5,6-Benzo-2-methyl-2-azabarrelen-3-ones[a)]

Compd. No.	Yield (%)	mp (°C)	IR (cm^{-1})	Formula	Analysis (%) Calcd (Found)		
					C	H	N
6f	43	131—132	1665	$C_{14}H_{15}NO$	78.84	7.09	6.57
					(78.81	7.14	6.55)
6g	13	b)	1660[c)]	$C_{14}H_{15}NO$		—[d)]	
6h	20	b)	1655[c)]	$C_{14}H_{15}NO$		—[d)]	
6i	26	111—113	1663	$C_{15}H_{17}NO$	79.26	7.54	6.16
					(79.00	7.66	6.14)
6j	51	146—148	1665	$C_{16}H_{19}NO$	79.63	7.94	5.80
					(79.40	8.09	5.73)
6l	31	186—187	1665	$C_{19}H_{17}NO$	82.88	6.23	5.09
					(82.78	6.25	5.10)
6m	40	116—118	1665	$C_{20}H_{19}NO$	83.01	6.62	4.84
					(82.86	6.62	4.74)
6n	46	117—118	1665	$C_{20}H_{19}NO$	83.01	6.62	4.84
					(82.75	6.68	4.85)
6o	68	144—145	1660	$C_{21}H_{21}NO$	83.13	6.98	4.62
					(83.29	7.03	4.68)
6p	77	145—146	1660	$C_{22}H_{21}NO$	83.77	6.71	4.44
					(83.54	6.68	4.41)
6q	47	141—143	1675	$C_{21}H_{21}NO$	83.13	6.98	4.62
					(82.99	6.95	4.61)
6r	18	121—122	2250	$C_{15}H_{14}N_2O$	75.61	5.92	11.76
			1675		(75.66	6.02	11.69)
6s	14	136—138	1665	$C_{13}H_{12}BrNO$	56.14	4.35	5.04
					(55.86	4.30	4.95)
6t[e)]	Trace		1675[c)]	$C_{12}H_{10}ClNO$			

5,6-Dimethyl-4-phenyl-2-pyridone (1n)——The same treatment of α-benzoylacetonitrile and 2-butanone afforded the title compound, as white needles, mp 218—222 °C. *Anal.* Calcd for $C_{13}H_{13}NO$: C, 78.36; H, 6.57; N, 7.02. Found: C, 78.58; H, 6.42; N, 7.04. IR ν_{max}^{KBr} cm^{-1}: 3600—3100 (NH), 1650 (C=O). ^{1}H-NMR δ: 1.87 (3H, s), 2.37 (3H, s), 6.27 (1H, s), 7.07—7.50 (5H, m), 13.43 (1H, br s). MS *m/e* (%): 199 (M^+, 100), 198 (23), 171 (28), 170 (45).

3,4,6-Trimethyl-5-phenyl-2-pyridone (1q)——This compound was prepared from 2-phenylbutyronitrile and 2-butanone by the same method as above and obtained as white plates, mp 255—257 °C. *Anal.* Calcd for $C_{14}H_{15}NO$: C, 78.84; H, 7.08; N, 6.56. Found: C, 78.72; H, 7.15; N, 6.53. IR ν_{max}^{KBr} cm^{-1}: 3200—2400 (NH), 1640 (C=O). ^{1}H-NMR δ: 1.88 (3H, s), 2.11 (6H, s), 7.01—7.53 (5H, m), 13.20 (1H, br s). MS *m/e* (%): 213 (M^+, 78), 212 (100), 194 (21), 184 (18).

Preparation of 1-Methyl-2-pyridones (5a—u)——A 2-pyridone (**1**) (0.02 mol), potassium carbonate (0.07 mol) and methyl iodide (0.07 mol) were refluxed in acetone (100 ml) in a sealed tube for 4 h. The reaction mixture was cooled, and potassium carbonate was filtered off. The acetone was evaporated off and a small amount of water was added to the residue. This solution was extracted with chloroform. The organic layer was dried and the solvent was removed *in vacuo* to give the crude 1-methylated product (**5**), which was purified by distillation or sublimation.

1-Methyl-(**5a**),[13)] 1,3-dimethyl-(**5b**),[14)] 1,4-dimethyl-(**5c**),[15)] 1,5-dimethyl-(**5d**),[15)] 1,6-dimethyl-(**5e**),[16)] 1,4,6-trimethyl-(**5g**),[13)] 1,5,6-trimethyl-(**5h**),[11)] 1,3,4,5,6-pentamethyl-(**5j**),[17)] 1-methyl-4-phenyl-(**5k**),[11)] 1,6-dimethyl-4-phenyl-(**5l**),[11)] and 6-chloro-1-methyl-2-pyridone (**5t**),[8a)] 2,3,6,7-tetrahydro-4,7-dimethyl-6-oxo-furo[2,3-*b*]pyridine (**5u**),[18)] and 6-methoxy-1-methyl-2-pyridone (**5v**),[19)] have been described in the literature.

1,3,5-Trimethyl-2-pyridone (5f)——bp 102.5—103.0 °C (3 mmHg). IR ν_{max}^{neat} cm^{-1}: 1665 (C=O). ^{1}H-NMR: 2.02 (3H, s), 2.10 (3H, s), 3.48 (3H, s), 6.95 (1H, s), 7.03 (1H, s). MS *m/e* (%): 137 (M^+, 100), 112 (22), 109 (22), 108 (67), 96 (13), 94 (26), 69 (26), 68 (13), 67 (17).

1,4,5,6-Tetramethyl-2-pyridone (5i)——mp 87—89 °C. *Anal.* Calcd for $C_9H_{13}NO$: C, 71.49; H, 8.66; N, 9.26. Found: C, 71.27; H, 8.91; N, 9.08. IR ν_{max}^{KBr} cm^{-1}: 1665 (C=O). ^{1}H-NMR δ: 2.00 (3H, s), 2.12 (3H, s), 2.27 (3H, s), 3.52 (3H, s), 6.25 (1H, s). MS *m/e* (%): 151 (M^+, 91), 122 (68), 121 (100).

1,3,6-Trimethyl-4-phenyl-2-pyridone (5m)——mp 95—96 °C. *Anal.* Calcd for $C_{14}H_{15}NO$: C, 78.84; H, 7.08; N, 6.56. Found: C, 78.90; H, 7.14; N, 6.59. IR ν_{max}^{KBr} cm^{-1}: 1630 (C=O). ^{1}H-NMR δ: 2.07 (3H, s), 2.35 (3H, s), 3.54 (3H,

TABLE III. (continued)

Compd. No.	^{1}H-NMR δ (ppm, J=Hz)	MS m/e (% rel. int.)
6f	1.78 (3H, s), 1.93 (3H, s), 2.84 (3H, s), 4.60 (1H, d, J=2), 5.97 (1H, m), 6.82—7.37 (4H, m)	213 (M^+, <1), 157 (17), 156 (100), 141 (14)
6g	1.92 (6H, s), 2.73 (3H, s), 4.28 (1H, d, J=2), 5.93 (1H, m), 6.83—7.37 (4H, m)	213 (M^+, 3), 157 (23), 156 (100), 155 (20), 142 (10), 141 (93), 128 (14), 115 (19)
6h	1.78 (3H, d, J=2), 1.97 (3H, s), 2.72 (3H, s), 4.43 (1H, d, J=6), 6.33—6.56 (1H, m), 6.86—7.35 (4H, m)	213 (M^+, <1), 157 (15), 156 (100), 155 (12), 141 (64), 115 (12)
6i	1.70 (3H, s), 1.87 (3H, s), 1.92 (3H, s), 2.73 (3H, s), 4.23 (1H, s), 6.50—7.60 (4H, m)	227 (M^+, 1), 171 (14), 170 (100), 155 (58)
6j	1.71 (6H, s), 1.79 (3H, s), 1.93 (3H, s), 2.79 (3H, s), 6.95—7.35 (4H, m)	241 (M^+, 5), 184 (100)
6l	2.00 (3H, s), 2.77 (3H, s), 5.00 (1H, d, J=2), 6.47 (1H, d, J=2), 6.62—7.57 (9H, m)	275 (M^+, 4), 218 (100), 217 (31), 215 (22), 202 (20)
6m	1.66 (3H, s), 1.82 (3H, s), 2.80 (3H, s), 6.23 (1H, s), 6.58—7.40 (9H, s)	289 (M^+, 5), 233 (21), 232 (100), 217 (28), 216 (13), 215 (21), 202 (12)
6n	1.85 (3H, s), 1.98 (3H, s), 2.80 (3H, s), 4.73 (1H, s), 6.73—7.60 (9H, m)	289 (M^+, 24), 233 (24), 232 (100), 217 (35), 215 (24), 185 (18), 184 (24)
6o	1.50 (3H, s), 1.62 (3H, s), 2.00 (3H, s), 2.89 (3H, s), 6.50—7.41 (9H, m)	303 (M^+, 2), 246 (100)
6p	1.50—3.00 (6H, m), 1.63 (3H, s), 2.80 (3H, s), 6.77—7.37 (9H, m)	315 (M^+, <1), 259 (24), 258 (100), 257 (10), 243 (27), 228 (12), 215 (10), 115 (10), 114 (10)
6q	1.55 (3H, s), 1.63 (3H, s), 1.87 (3H, s), 2.83 (3H, s), 6.82—7.43 (9H, m)	303 (M^+, 5), 247 (22), 246 (100), 231 (21), 216 (15), 215 (18), 108 (12)
6r	1.85 (3H, d, J=1), 1.94 (3H, s), 2.78 (3H, s), 6.47 (1H, m), 6.80—7.67 (4H, m)	238 (M^+, <1), 182 (16), 181 (100), 180 (16), 166 (62)
6s	1.80 (3H, s), 2.88 (3H, s), 4.83 (1H, d, J=2), 6.48 (1H, d, J=2), 6.88—7.40 (4H, m)	279 (M^++2, <1), 277 (M^+, <1), 223 (13), 222 (95), 221 (17), 220 (100), 142 (12), 141 (95), 140 (15), 139 (21), 115 (27)
6t[e]	2.87 (3H, s), 4.67 (1H, q, J=6, 2), 6.62 (1H, q, J=7, 2), 6.68—7.97 (5H, m)	

a) Compounds **6a**—**e**, and **6k** have been described in the literature. Compounds **6t** and **6u** were obtained as naphthamide derivatives, **6t'** and **6u'**. See Experimental. *b*) Not crystallized. *c*) In $CHCl_3$. *d*) Not analyzed. *e*) Not purified.

s), 5.93 (1H, s), 7.07—7.50 (5H, m). MS m/e (%): 213 (M^+, 65), 212 (100), 184 (19), 56 (17).

1,5,6-Trimethyl-4-phenyl-2-pyridone (5n)——mp 120—121 °C. *Anal.* Calcd for $C_{14}H_{15}NO$: C, 78.84; H, 7.08; N, 6.56. Found: C, 78.99; H, 7.11; N, 6.58. IR ν_{max}^{KBr} cm^{-1}: 1640 (C=O). ^{1}H-NMR δ: 1.95 (3H, s), 2.39 (3H, s), 3.62 (3H, s), 6.43 (1H, s). MS m/e (%): 213 (M^+, 90), 212 (100), 184 (38), 56 (23).

1,3,5,6-Tetramethyl-4-phenyl-2-pyridone (5o)——mp 91—92 °C. *Anal.* Calcd for $C_{15}H_{17}NO$: C, 79.26; H, 7.53; N, 6.16. Found: C, 79.00; H, 7.59; N, 6.13. IR ν_{max}^{KBr} cm^{-1}: 1630 (C=O). ^{1}H-NMR δ: 1.83 (3H, s), 1.85 (3H, s), 2.35 (3H, s), 3.62 (3H, s), 6.90—7.50 (5H, m). MS m/e (%): 227 (M^+, 64), 226 (100), 198 (16), 56 (23).

2,5,6,7-Tetrahydro-1,3-dimethyl-4-phenyl-1*H*-cyclopenta[*b*]pyridin-2-one (5p)——mp 117—118 °C. *Anal.* Calcd for $C_{16}H_{17}NO$: C, 80.30; H, 7.15; N, 5.85. Found: C, 80.41; H, 7.19; N, 5.85. IR ν_{max}^{KBr} cm^{-1}: 1640 (C=O). ^{1}H-NMR δ: 1.97 (3H, s), 2.03 (2H, m), 2.50 (2H, m), 2.93 (2H, br t, J=7 Hz), 3.53 (3H, s), 6.97—7.43 (5H, m). MS m/e (%): 239 (M^+, 58), 238 (100), 210 (11), 115 (10), 68 (8).

TABLE IV. 2-Phenoxypyridines[a)]

Compd. No.	mp (°C) or bp (°C/mmHg)	Formula	Analysis (%) Calcd (Found)		
			C	H	N
3c	94—95/1	$C_{12}H_{11}NO$		—[b)]	
3f	113—114/1	$C_{13}H_{13}NO$		—[b)]	
3h	115—116/1	$C_{13}H_{13}NO$		—[b)]	
3i	138—139/1	$C_{14}H_{15}NO$		—[b)]	
3j	66—68	$C_{15}H_{17}NO$	79.26	7.54	6.16
			(79.28	7.60	6.19)
3l	60—63	$C_{18}H_{15}NO$	82.73	5.79	5.36
			(82.96	5.92	5.32)
3m	80—83	$C_{19}H_{17}NO$	82.88	6.23	5.09
			(83.12	6.22	5.13)
3n	53—55	$C_{19}H_{17}NO$	82.88	6.23	5.09
			(82.70	6.19	5.10)
3o	83—85	$C_{20}H_{19}NO$	83.01	6.62	4.84
			(82.79	6.66	4.78)
3p	70—72	$C_{21}H_{19}NO$	83.69	6.35	4.65
			(83.50	6.39	4.67)
3q	65—68	$C_{20}H_{19}NO$	83.01	6.62	4.84
			(83.28	6.66	4.84)
3s	113—114/0.5	$C_{12}H_{10}BrNO$		—[b)]	

1,3,4,6-Tetramethyl-5-phenyl-2-pyridone (5q)——mp 126—128 °C. *Anal.* Calcd for $C_{15}H_{17}NO$: C, 79.26; H, 7.53; N, 6.16. Found: C, 79.22; H, 7.52; N, 6.20. IR ν_{max}^{KBr} cm^{-1}: 1630 (C=O). ^{1}H-NMR δ: 1.87 (3H, s), 2.12 (6H, s), 3.58 (3H, s), 6.98—7.53 (5H, m). MS *m/e* (%): 227 (M^+, 78), 226 (100), 198 (18), 56 (28).

3-Cyano-1,5,6-trimethyl-2-pyridone (5r)——mp 84—86 °C. *Anal.* Calcd for $C_9H_{10}N_2O$: C, 66.69; H, 6.21; N, 17.27. Found: C, 66.90; H, 6.32; N, 17.19. IR ν_{max}^{KBr} cm^{-1}: 2200 (C≡N), 1630 (C=O). ^{1}H-NMR δ: 2.13 (3H, s), 2.40 (3H, s), 3.57 (3H, s), 7.55 (1H, s). MS *m/e* (%): 165 (M^+, 100), 164 (58), 133 (42), 119 (26), 64 (19), 56 (16).

5-Bromo-1,3-dimethyl-2-pyridone (5s)——mp 106—107 °C. *Anal.* Calcd for C_7H_8BrNO: C, 41.61; H, 3.99; N, 6.93. Found: C, 41.34; H, 3.92; N, 7.05. IR ν_{max}^{KBr} cm^{-1}: 1650 (C=O). ^{1}H-NMR: 2.13 (3H, d, J=2 Hz), 3.48 (3H, s), 7.30 (2H, s). MS *m/e* (%): 203 (M^++2, 100), 201 (M^+, 91), 175 (15), 174 (35), 173 (17), 122 (20), 94 (37), 54 (33), 52 (13), 51 (24).

Reactions of 1-Methyl-2-pyridones with Benzyne——A 1-methyl-2-pyridone (**5**) (0.002 mol) and isopentyl nitrite (0.53 g) were dissolved in 80 ml of dry chloroform. After bubbling of nitrogen into the solution for 0.5 h, anthranilic acid (0.38 g) dissolved in acetone (20 ml) and dry chloroform (30 ml) was added dropwise during 2 h under nitrogen bubbling at 70 °C. The mixture was further heated for 2 h, then the solvent was evaporated off under reduced pressure. The residue was chromatographed on alumina using chloroform as an eluent to give the 2-methyl-5,6-benzo-2-azabarrelen-3(2*H*)-one (**6**), which was recrystallized from ethanol.

Compounds **6a**—**e**[1a)] and **6k**[5)] were obtained in 10, 14, 10, 13, 13, and 22% yields, respectively, and have been described in the literature. The analytical data for other compounds (**6f**—**j**, **6l**—**s**, and **6t**) are given in Table III.

For the reactions of **5u** and **5v**, the products were obtained as naphthamide derivatives (**6u'** and **6v'**) of the Diels–Alder adducts (**6u** and **6v**).

2,3-Dihydro-4-methylnaphtho[1,2-*b*]furan-5-(*N*-methyl)-carbamide (6u')——Yield 77%, mp 224—225 °C. *Anal.* Calcd for $C_{15}H_{15}NO$: C, 74.67; H, 6.27; N, 5.80. Found: C, 74.55; H, 6.31; N, 5.72. IR ν_{max}^{KBr} cm^{-1}: 3250 (NH), 1640 (C=O). ^{1}H-NMR δ: 2.28 (3H, s), 3.05 (3H, d, J=5 Hz), 3.17 (2H, t, J=9 Hz), 5.92 (1H, br s), 7.22—8.03 (4H, m). MS *m/e* (%): 242 (M^+, 10), 241 (54), 239 (13), 212 (16), 211 (100), 210 (10), 209 (27), 181 (13), 153 (11), 152 (16).

4-Methoxy-*N*-methyl-1-naphthamide (6v')——Yield 37%, mp 177—179 °C. *Anal.* Calcd for $C_{13}H_{13}NO$: C, 72.54; H, 6.09; N, 6.51. Found: C, 72.68; H, 6.14; N, 6.48. IR ν_{max}^{KBr} cm^{-1}: 3300 (NH), 1635 (C=O). ^{1}H-NMR δ: 3.00 (3H, d, J=5 Hz), 3.95 (3H, s), 6.00 (1H, br s), 6.63 (1H, d, J=8 Hz), 7.45 (1H, d, J=8 Hz), 7.37—8.40 (4H, m). MS *m/e* (%): 215 (M^+, 50), 186 (20), 185 (100), 157 (27), 142 (13), 127 (17), 114 (27).

Reaction of 1-Unsubstituted 2-Pyridones with Benzyne——The reactions were performed with 2-pyridones (**1a**—**j**, **1l**—**q**, and **1s**—**u**) in the same manner as above. In the chromatographic separations of the products on alumina in chloroform, the 2-phenoxypyridine (**3**) or the 1-phenyl-2-pyridone (**4**) was firstly eluted, followed by the Diels–Alder

TABLE IV. (continued)

Compd. No.	^{1}H-NMR δ (ppm, J=Hz)	MS m/e (% rel. int.)
3c	2.28 (3H, s), 6.63 (1H, s), 6.70 (1H, d, J=5), 6.88—7.50 (5H, m), 7.95 (1H, d, J=5)	185 (M^+, 98), 184 (100), 157 (25), 156 (55)
3f	2.17 (3H, s), 2.23 (3H, s), 6.82—7.43 (6H, m), 7.73 (1H, s)	199 (M^+, 100), 198 (84)
3h	2.19 (3H, s), 2.39 (3H, s), 6.53 (1H, d, J=8), 6.88—7.55 (6H, m)	199 (M^+, 80), 198 (31), 171 (73) 170 (100), 156 (24), 130 (11), 129 (11)
3i	2.20 (3H, s), 2.13 (3H, s), 2.40 (3H, s), 6.38 (1H, s), 6.78—7.48 (5H, m)	213 (M^+, 100), 212 (43), 185 (60), 184 (70)
3j	2.12 (3H, s), 2.16 (6H, s), 2.33 (3H, s), 6.78—7.42 (5H, m)	227 (M^+, 100), 226 (61), 199 (53), 198 (74), 184 (28), 118 (11)
3l	2.38 (3H, s), 6.72 (1H, s), 6.80—7.57 (10H, m), 6.92 (1H, s)	261 (M^+, 100), 260 (69), 233 (58), 232 (24), 115 (24)
3m	2.18 (3H, s), 2.32 (3H, s), 6.72 (1H, s), 6.93—7.45 (10H, m)	275 (M^+, 75), 274 (100), 246 (21), 167 (24), 138 (30), 128 (29), 115 (30)
3n	2.05 (3H, s), 2.42 (3H, s), 6.47 (1H, s), 6.78—7.38 (10H, m)	275 (M^+, 100), 274 (37), 248 (14), 247 (66), 246 (39), 167 (11), 129 (19), 128 (13)
3o	1.90 (3H, s), 1.95 (3H, s), 2.38 (3H, s), 6.88—7.58 (10H, m)	289 (M^+, 100), 288 (93), 261 (28), 260 (23)
3p	1.96 (2H, qui, J=7), 2.09 (3H, s), 2.65 (2H, t, J=7), 2.93 (2H, t, J=7), 6.93—7.61 (10H, m)	301 (M^+, 70), 300 (100), 272 (11)
3q	1.98 (3H, s), 2.08 (3H, s), 2.23 (3H, s), 6.67—7.60 (10H, m)	289 (M^+, 100), 288 (75), 261 (42), 260 (32), 151 (24), 150 (37), 121 (17), 118 (14), 115 (15)
3s	2.30 (3H, s), 6.77—7.43 (5H, s), 7.52 (1H, d, J=2), 7.93 (1H, d, J=2)	265 (M^++2, 97), 264 (77), 263 (M^+, 100), 262 (63), 156 (38)

a) Compounds **3a**, **3b**, **3d**, **3e**, **3g**, and **3v** have been described in the literature. See Experimental. *b*) Not analyzed.

adduct, the 5,6-benzo-2-azabarrelen-3(2*H*)-one (**2**). After evaporation of solvent, the residue was purified by recrystallization from ethanol or distillation under reduced pressure.

5,6-Benzo-2-azabarrelen-3(2*H*)-one (**2a**)[1f] and 2-phenoxypyridines, (**3a**,[20] **3b**,[21] **3d**,[21] **3e**,[20] and **3t**[22]) have been described in the literature. The analytical data for other 5,6-benzo-2-azabarrelen-3(2*H*)-ones (**2b—j**, **2l—q**, **2s**, and **2t**) and 2-phenoxypyridines (**3c**, **3f**, **3h—j**, **3l—q**, and **3s**) are given in Tables II and IV. For the reaction of **1u** the naphthalene derivative (**2u'**) derived from the Diels–Alder adduct (**2u**) by a spontaneous retro Diels–Alder reaction was obtained. The 1-phenyl-2-pyridone (**4**) was obtained only in the reactions of **1a**, **1s**, and **1v**. 1-Phenyl-2-pyridone (**4a**) has been described before.[2a]

2,3-Dihydro-4-methylnaphtho[1,2-*b*]furan (2u')——mp 67—69 °C. *Anal.* Calcd for $C_{13}H_{12}O$: C, 84.75; H, 6.57. Found: C, 84.71; H, 6.62. ^{1}H-NMR δ: 2.20 (3H, s), 2.95 (2H, t, J=8 Hz), 4.50 (2H, t, J=8 Hz), 6.60—7.90 (5H, m). MS m/e (%): 185 (M^+, 15), 184 (100), 183 (26), 169 (14), 155 (17), 141 (21), 115 (16).

5-Bromo-3-methyl-1-phenyl-2-pyridone (4s)—This compound was not obtained in a pure form. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1655 (C=O). ^{1}H-NMR δ: 2.15 (3H, s), 6.95—7.50 (7H, m).

6-Chloro-1-phenyl-2-pyridone (4t)——mp 116—117 °C. *Anal.* Calcd for $C_{11}H_8ClNO$: C, 64.25; H, 3.92; N, 6.81. Found: C, 64.46; H, 3.95; N, 6.83. IR ν_{max}^{KBr} cm^{-1}: 1670 (C=O). ^{1}H-NMR δ: 6.28 (1H, d, J=7 Hz), 6.50 (1H, d, J=9 Hz), 7.03—7.70 (6H, m). MS m/e (%): 207 (M^++2, 17), 205 (M^+, 53), 177 (134), 171 (14), 170 (100), 77 (42), 51 (31).

Methylation of 5,6-Benzo-2-azabarrelen-3(2*H*)-ones (2l, 2m, 2o, and 2p) with Methyl Iodide——The 5,6-benzo-2-azabarrelen-3-(2*H*)-one (0.66 mmol), methyl iodide (1.0 g, 7.0 mmol) and potassium carbonate (1.0 g, 7.2 mmol) were stirred in *N*,*N*-dimethyl formamide (10 ml) at room temperature for 12 h. After the filtration of the reaction mixture, the solvent was evaporated off and the residue was dissolved in chloroform (100 ml). This solution was washed with a

small amount of water, dried and evaporated *in vacuo*. The crude material was purified by recrystallization from ethanol. All the analytical data for the product agreed with those for the product obtained by the reaction of the corresponding 1-methyl-2-pyridone with benzyne. The yields of these reactions were almost quantitative and no other methylated product was obtained.

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