Catalytic Action of Azolium Salts. IV.[1] Preparations of 4-Aroylquinazolines and 4-Aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines by Catalytic Action of 1,3-Dimethylimidazolium Iodide

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The ability of 1,3-dimethylimidazolium iodide (1) to catalyze the aroylation of the chloroheteroarenes 4—8 with arenecarbaldehydes 3 as sources of the aroyl groups was examined in order to develop a preparative method of aroylheteroarenes. In the presence of 1, the treatment of the 4-chloroquinazolines (4: 2-H, 5: 2-Me, 6: 2-Ph) with arenecarbaldehyde 3 in refluxing THF (tetrahydrofuran) or dioxane led to the 4-aroylquinazolines (9: 2-H, 10: 2-Me, 11: 2-Ph) in excellent yields, as had been found with 1,3-dimethylbenzimidazolium iodide (2). Similar reaction of the 4-chloro-1*H*-pyrazolo[3,4-*d*]pyrimidines (7: 1-Ph, 8: 1-Me) with arenecarbaldehyde 3 yielded the corresponding 4-aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines (12: 1-Ph, 13: 1-Me). Compound 1 seems to catalyze the aroylation of a wider range of arenecarbaldehydes 3 as compared with 2.

Keywords 1,3-dimethylimidazolium iodide; catalytic aroylation; aroylheteroarene; chloroheteroarene; arenecarbaldehyde

Previously, we reported that 1,3-dimethylbenzimidazolium iodide (**2**) was an effective catalyst for the preparation of 4-aroylquinazolines and 4-aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines by treatment of the corresponding chloroheteroarenes with arenecarbaldehyde **3** in the presence of sodium hydride (NaH). By analogy with the benzoin condensation catalyzed by thiazolium salt,[2] the aroylation proceeds through the formation of the key intermediate A-2 from arenecarbaldehyde and the ylide (Z^-) which is generated by expulsion of the C^2-hydrogen of **2**. Furthermore, 1,3-dimethylimidazolium iodide (**1**) could be used as a catalyst for the aroylation of *N*-phenylbenzimidoyl chloride and the aroylated compounds were generated through the formation of a key intermediate A-2 (Z = imidazolium) similar to that in the case of **2**.

In the aroylation of *N*-phenylbenzimidoyl chloride, we found that use of **1** as a catalyst was more effective than that of **2**.[1] We then examined the catalytic behavior of **1** for the aroylations of the 4-chloroquinazolines (**4**—**6**) and the 4-chloro-1*H*-pyrazolo[3,4-*d*]pyrimidines (**7**, **8**). In the present paper, we wish to describe in detail the results of these aroylations.

The reaction of 4-chloroquinazoline (**4**) with *p*-substituted benzaldehydes **3a**, **3b**, **3e**, and **3g** in tetrahydrofuran (THF) in the presence of a catalytic amount of **1** (0.3 molar ratio) resulted in aroylation to give the corresponding ketones **9a**, **9b**, **9e**, and **9g** in moderate yields (method A). Under the same conditions, the yields of the ketones obtained by the reaction catalyzed by **1** were less than those given in the literature for **2**.[3] For example, in the reaction with *p*-fluorobenzaldehyde (**3a**) catalyzed by **2**, an 82% yield of the ketone **9a** was obtained, but the same reaction catalyzed by **1** afforded the ketone **9a** in 52% yield. These results suggested that the nucleophilic activity of the key intermediate A-2 derived from **1** was less than that in the case of **2**. We considered that for achievement of the aroylation with good yield, stronger reaction conditions were required. Namely, aroylation with **3a** in refluxing dioxane as the reaction solvent gave the ketone in good yield (89%). A similar result was obtained in the reaction with *p*-methoxybenzaldehyde (**3g**). In refluxing THF the aroylation of **4** with **3g** for 2.5 h gave the corresponding ketone **9g** in 68% yield, but same reaction in refluxing dioxane for only 0.5 h gave the ketone **9g** in excellent yield (92%).

The reaction of 2-methyl-4-chloroquinazoline (**5**) and 2-phenyl-4-chloroquinazoline (**6**) with *p*-substituted benzaldehydes proceeded similarly. In refluxing THF or dioxane, the aroylation of the chloroquinazolines **5** and **6** with several arenecarbaldehydes **3a**—**3h** catalyzed by **1** afforded the aroylquinazolines **10** and **11** in moderate to good yields.

Aroylations of 4-chloro-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**7**) and 4-chloro-1-methyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**8**) catalyzed by **1** afforded the corresponding ketones **12** and **13** in good yields. Moreover, reaction of **7** with *p*-cyanobenzaldehyde (**3i**) which has a strongly electron-withdrawing substituent, not only in dioxane but

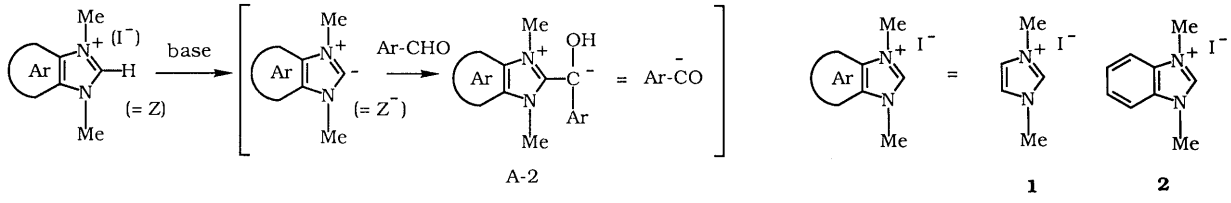


Chart 1

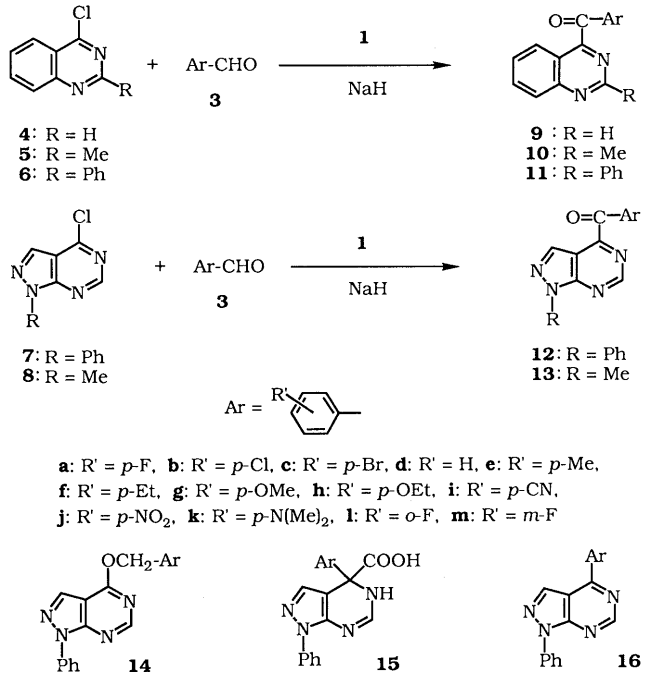


Chart 2

Table I. Aroylation of Chloroheteroarenes (**4**—**8**) with Arenecarbaldehydes **3** in Refluxing THF Catalyzed by 1,3-Dimethylimidazolium Iodide (**1**)

Compd. **4**—**8**	Aldehyde **3**	Reaction time (min)	Ketone **9**—**13**	Yield (%)
4	**3a**	30	**9a**[a]	52
4	**3b**	30	**9b**[a]	69
4	**3c**	60	**9c**[a]	59
4	**3d**	60	**9d**[a]	85
4	**3e**	60	**9e**[a]	78
4	**3g**	150	**9g**[a]	68
4	**3i**	30	**9i**	62
5	**3a**	30	**10a**	84
5	**3c**	30	**10c**	72
5	**3d**	60	**10d**[a]	77
6	**3b**	30	**11b**[a]	56
6	**3c**	30	**11c**[a]	74
6	**3d**	40	**11d**[a]	85
6	**3g**	50	**11g**	38
7	**3c**	30	**12c**[b]	57
7	**3d**	30	**12d**[b]	83[c]
7	**3e**	40	**12e**[b]	54
7	**3f**	60	**12f**	88
7	**3g**	60	**12g**[b]	77
7	**3h**	60	**12h**[b]	70
7	**3i**	60	**12i**	52
8	**3c**	30	**13c**[b]	79
8	**3d**	75	**13d**[b]	76
8	**3f**	70	**13f**	81
8	**3g**	120	**13g**[b]	97
8	**3h**	60	**13h**	95

a) Melting points, elemental analyses, and spectral data are shown in reference 3. *b*) Melting points, elemental analyses, and spectral data are shown in reference 4. *c*) Gave **14d** in 1% yield.

also in THF resulted in the formation of the ketone (**12i**) in moderate yields (58%, 52%), whereas the aroylation in THF catalyzed by **2** gave the ketone in only 8% yield.[4] As shown in Tables I and II, similar results were obtained

Table II. Aroylation of Chloroheteroarenes (**4**—**8**) with Arenecarbaldehydes **3** in Refluxing Dioxane Catalyzed by 1,3-Dimethylimidazolium Iodide (**1**)

Compd. **4**—**8**	Aldehyde	Reaction time (min)	Ketone	Yield (%)
4	**3a**	30	**9a**	89
4	**3e**	30	**9e**	85
4	**3g**	30	**9g**	92
4	**3i**	10	**9i**[a]	76 (4)[c]
5	**3g**	30	**10g**[a]	59
6	**3a**	30	**11a**[b]	72
7	**3i**	15	**12i**[b]	58 (12)[c]
4	**3l**	30	**9l**	85
6	**3l**	30	**11l**	74
7	**3l**	30	**12l**	82
8	**3l**	30	**13l**	76
4	**3m**	30	**9m**	88
6	**3m**	30	**11m**[a]	66
7	**3m**	30	**12m**	92
8	**3m**	30	**13m**	64

a) Melting points, elemental analyses, and spectral data are shown in reference 3. *b*) Melting points, elemental analyses, and spectral data are shown in reference 4. *c*) The yield in the aroylation catalyzed by **2** under the same conditions.

Table III. Aroylation of Chloroheteroarenes (**6**—**8**) with Arenecarbaldehydes **3** in DMF Catalyzed by 1,3-Dimethylimidazolium Iodide (**1**)

Compd. **6**—**8**	Aldehyde **3**	Reaction conditions		Products, yield (%)			
		Time (min)	Temp.[a]	Ketone		Others	
6	**3a**	30	r.t.	**11a**	86		
6	**3b**	30	r.t.	**11b**	77		
6	**3g**	10	80	**11g**	76		
6	**3h**	10	80	**11h**[b]	97		
7	**3c**	20	r.t.	**12c**	76	**15c**	14
7	**3g**	20	r.t.	**12g**	56	**16g**	15
7	**3j**	30	80	**12j**	—[c]		
7	**3k**	30	80	**12k**	—[d]		
8	**3j**	30	80	**13j**	—[e]		

a) r.t. = room temperature. *b*) Melting points, elemental analysis, and spectral data are shown in reference 3. *c*) Recovery of starting **7** in 56% yield. *d*) Recovery of starting **7** in 62% yield. *e*) Recovery of starting **8** in 43% yield.

in the reaction of **4** with **3i**. Furthermore, the aroylation with *o*-fluorobenzaldehyde (**3l**) or *m*-fluorobenzaldehyde (**3m**) was achieved in refluxing dioxane to give the corresponding ketone in good yield, as shown in Table II.

We reported that use of DMF (*N*,*N*-dimethylformamide) as the reaction solvent for the aroylation catalyzed by **2** was effective and gave the ketone in excellent yield.[3,4] We then carried out the aroylation in DMF (method B). As illustrated in Table III, we obtained similar results with **1** and **2**. Thus, use of DMF was more effective and the corresponding ketones were obtained in good yields. In the case of *p*-methoxybenzaldehyde (**3g**), the aroylation of **6** in THF for 1 h gave a 38% yield of the ketone **11g**, but the reaction in DMF at 80°C for only 10 min gave the ketone **11g** in 76% yield. However, in the case of the aroylation in DMF, further reaction of the produced ketone, such as aryl migration and subsequent oxidation, proceeded, giving the carboxylic acid **15** and the arylheteroarene **16**.

TABLE IV. Aroylation of Chloroheteroarenes (**4**—**8**) with Heteroarenecarbaldehydes **3** Catalyzed by Azolium Salts (**1** or **2**)

Compound	Catalyst	Aldehyde	Reaction conditions			Products, yield (%)		
				Time (min)	Temp.[a]	Ketone		Recovery
4	**1**	**3n**	Dioxane	30	Refl.	**9n**	19	43
4	**2**	**3n**	Dioxane	30	Refl.	**9n**	—	32
4	**2**	**3n**	THF	30	Refl.	**9n**	—	22
4	**1**	**3o**	THF	60	Refl.	**9o**	42	
4	**1**	**3o**	Dioxane	30	Refl.	**9o**	76	
4	**2**	**3o**	Dioxane	30	Refl.	**9o**	21	11
4	**1**	**3o**	DMF	30	80	**9o**	92	
4	**1**	**3p**	THF	60	Refl.	**9p**[b]	17	42
4	**1**	**3p**	Dioxane	30	Refl.	**9p**	32	12
4	**2**	**3p**	Dioxane	30	Refl.	**9p**	2	28
4	**1**	**3r**	THF	60	Refl.	**9r**[b]	57	
5	**1**	**3r**	THF	30	Refl.	**10r**	78	
6	**1**	**3n**	Dioxane	30	Refl.	**11n**	18	12
6	**1**	**3n**	DMF	10	r.t.	**11n**	72	
6	**1**	**3o**	THF	60	Refl.	**11o**	49	
6	**1**	**3p**	Dioxane	60	Refl.	**11p**	61	
7	**1**	**3o**	DMF	30	80	**12o**[c]	73 (62)[d]	
7	**1**	**3q**	DMF	20	r.t.	**12q**[c]	65	
7	**1**	**3q**	THF	30	Refl.	**12q**	74 (15)[e]	
7	**1**	**3r**	THF	30	Refl.	**12r**[c]	30	
7	**2**	**3r**	THF	30	Refl.	**12r**	66	
8	**1**	**3n**	DMF	10	r.t.	**13m**	67	
8	**1**	**3r**	THF	30	Refl.	**13r**[c]	85 (48)[f]	

a) Refl. = reflux, r.t. = room temperature. *b*) Melting points, elemental analyses, and spectral data are shown in reference 3. *c*) Melting points, elemental analyses, and spectral data are shown in reference 4. *d*) The yield in the aroylation catalyzed by **2** in DMF at room temperature for 1 h.[4] *e*) The yield in the aroylation catalyzed by **2** in refluxing THF for 1 h.[4] *f*) The yield in the aroylation catalyzed by **2** in refluxing THF for 20 min.[4]

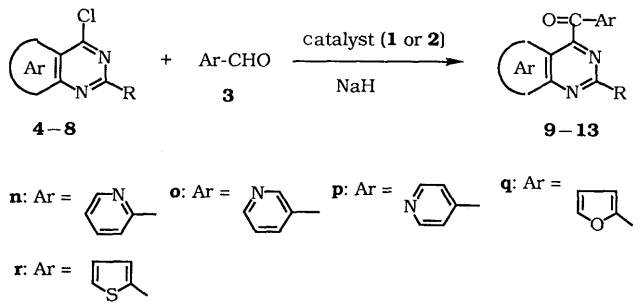


Chart 3

Next, we used heteroarenecarbaldehydes **3n**—**3r** as aroyl sources for the catalytic aroylation. Aroylation of **4** catalyzed by **2** with pyridinecarboxaldehydes (**3n**—**3p**), whose nitrogen included in the pyridine ring withdraws the electron of the carbonyl carbon similarly to a nitro group on a benzene ring, failed to proceed, but in the presence of **1** the aroylation occurred to give the corresponding ketones in moderate to good yields. In the case of 2-furaldehyde (**3q**), the aroylation of **7** catalyzed by **1** gave the ketone **12q** in 74% yield, but the reaction catalyzed by **2** under similar conditions gave **12q** in only 15% yield. On the other hand, aroylation with *p*-nitrobenzaldehyde (**3j**) having a strongly electron-accepting group or with *p*-*N*,*N*-dimethylaminobenzaldehyde (**3k**) having a strongly electron-donating group was unsuccessful with either **1** or **2**. The reason was given in the previous papers.[3,4]

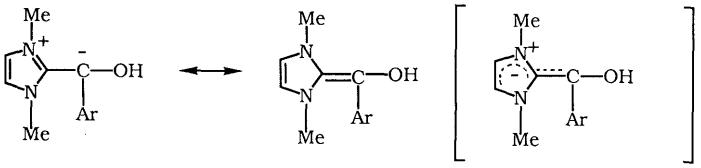
When the reaction of **7** with benzaldehyde (**3d**) in the absence of the catalyst **1** in THF was carried out, the aroylation failed to proceed and the starting 4-chloropyrazolopyrimidine **7** was recovered in 82% yield. The aroylation under the same conditions described above but in the presence of **1** (0.1 molar ratio) gave the ketone in 78% yield. These results support the conclusion that the azolium salt **1** acts as a catalyst in the aroylation system. The formation process of the ketones in the presence of 1,3-dimethylimidazolium iodide (**1**) is presumed to be similar.[3,4]

The formation pathways of the carboxylic acid **15** and the arylheteroarene **16** derived from the ketone have been reported.[3,5]

It is considered that for successful aroylation catalyzed by **1**, more drastic reaction conditions are required in comparison with **2**, because the nucleophilic activity of the key intermediate A-2 derived from **1** is less than that of **2**. The difference of nucleophilic activity of the key intermediates A-2 derived from **1** and **2** may be explained in terms of the electron density of the anion and the "soft and hard principle," and another factor is steric hindrance. The electron density of the intermediate A-2 (Z = imidazolium) may greater than that of the intermediate A-2 (Z = benzimidazolium), but the latter is more "soft." The anion A-2 (Z = benzimidazolium) would be bulkier than the anion A-2 (Z = imidazolium). The reactivity of the intermediate A-2 may be determined by these factors, though the details are not clear.

The results obtained by reaction in refluxing THF are illustrated in Table I, those in refluxing dioxane in Table II, and those in DMF in Table III. Table IV illustrates the results obtained by aroylation with heteroarenecarbaldehydes. The structures of the ketones newly ob-

A-2 (Z = imidazolium)



A-2 (Z = benzimidazolium)

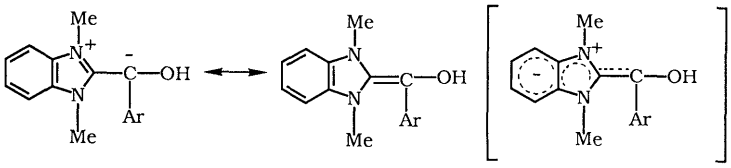


Chart 4

tained in this paper are supported by elemental analyses and MS, IR, and NMR spectra as shown in Tables V—VII. The identity of other ketones was confirmed by comparison with authentic samples. 4-Benzyloxy-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**14d**) was confirmed by a mixed melting point test with an authentic sample prepared from 4-chloropyrazolopyrimidine **7** and benzyl alcohol.

In conclusion, 1,3-dimethylimidazolium iodide (**1**) can be used as a catalyst for nucleophilic aroylation in a similar manner to 1,3-dimethylbenzimidazolium iodide (**2**). Stronger reaction conditions were required to achieve the aroylation catalyzed by **1**, though the catalytic action of **1** was effective with a wider range of arenecarbaldehydes **3**.

Experimental

All melting points are uncorrected. IR spectra were recorded on a JASCO A-102 diffraction grating IR spectrometer. ^{1}H-NMR spectra were measured at 60 MHz on a JEOL PMX60SI NMR spectrometer, and ^{13}C-NMR spectra were taken at 270 MHz on a JEOL JNM-GSX270 FT-NMR spectrometer. Chemical shifts are quoted in parts per million (ppm) with tetramethylsilane as an internal standard, and coupling constants (J) are given in Hz. The following abbreviations are used: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, and dd = double doublet. MS were recorded on a JEOL JMS D-100 mass spectrometer. Column chromatography was carried out on SiO_2.

1,3-Dimethylimidazolium Iodide (1) Compound **1** was prepared by the methylation of 1-methylimidazole with methyl iodide according to Brittelli's method[6] in 96% yield.

Reaction of the 4-Chloroquinazolines 4,[7,8] 5,[9] and 6[8] and 4-Chloropyrazolopyrimidines 7[10] and 8[10] with Arenecarbaldehydes 3 Catalyzed by 1,3-Dimethylimidazolium Iodide (1), General Procedure for Method A Sodium hydride (50% in oil, 173 mg, 3.6 mmol) was added to a stirred solution of chloroheteroarene (3 mmol), arenecarbaldehyde (**3**, 3.6 mmol), and 1,3-dimethylimidazolium iodide (**1**, 224 mg, 1 mmol) in 20 ml of THF or dioxane. The mixture was refluxed for an appropriate time (see Tables I and II) in an oil bath with stirring. After cooling, the mixture was poured onto an ice-H_2O mixture, and extracted with $CHCl_3$. The extract was dried over Na_2SO_4, and concentrated to dryness. The residue was chromatographed on a column of SiO_2 with benzene then $CHCl_3$ gave the ketone. In the case of the reaction of **7** with **3d** in refluxing THF, the fraction eluted with benzene gave the ketone **12d** together with **14d** in 1% (10 mg) yield. In the case of the reaction of **4** with **3n** in refluxing dioxane, the fraction eluted with benzene gave the ketone and unchanged **4** in 43% (212 mg) yield. The same reaction catalyzed by **2** in THF afforded the starting **4** in 22% (109 mg) yield. Recoveries of the starting chloroheteroarenes are shown in Tables I—IV.

General Procedure for Method B Sodium hydride (50% in oil, 173 mg, 3.6 mmol) was added to a stirred solution of chloroheteroarene (3 mmol), arenecarbaldehyde (**3**, 3.6 mmol), and 1,3-dimethylimidazolium iodide (**1**, 224 mg, 1 mmol) in 20 ml of DMF. Stirring was continued (reaction conditions are shown in Table III), then the mixture was poured onto an ice-H_2O mixture, and extracted with AcOEt. The extract was dried over Na_2SO_4, and concentrated to dryness. The residue was chromatographed on a column of SiO_2 with benzene then $CHCl_3$. The fraction eluted with $CHCl_3$ gave the ketone. In the case of the reaction of **7** with **3c**, after extraction the H_2O layer was acidified with acetic acid and the carboxylic acid **15c** was obtained in 14% (167 mg) yield. Recrystallization from MeOH gave colorless prisms, mp 224—225 °C (lit.,[5] 223—224 °C). In the case of the reaction of **7** with **3g**, the fraction eluted with $CHCl_3$ gave the arylpyrazolopyrimidine **16g** in 15% (136 mg) yield. Recrystallization from benzene–petroleum benzin gave colorless needles, mp 149—149.5 °C (lit.,[5] 150—151 °C).

Reaction of 4-Chloropyrazolo[3,4-*d*]pyrimidine (7) with Benzaldehyde (3d) (Absence of 1) Sodium hydride (50% in oil, 173 mg, 3.6 mmol) was added to a solution of 4-chloropyrazolo[3,4-*d*]pyrimidine (**7**, 692 mg, 3 mmol) and benzaldehyde (**3d**, 382 mg, 3.6 mmol) in THF (20 ml). The mixture was refluxed for 1 h with stirring, poured onto an ice-H_2O mixture, and extracted with $CHCl_3$. The extract was dried over Na_2SO_4, and concentrated to dryness. The residue was passed through a column of SiO_2 with benzene then $CHCl_3$. The fraction eluted with benzene afforded the starting **7** in 82% (567 mg) yield.

Reaction of 4-Chloropyrazolo[3,4-*d*]pyrimidine (7) with Benzaldehyde (3d) in the Presence of 1 (0.1 Molar Ratio) Sodium hydride (50% in oil, 173 mg, 3.6 mmol) was added to the solution of 4-chloropyrazolo[3,4-*d*]pyrimidine (**7**, 692 mg, 3 mmol), benzaldehyde (**3d**, 382 mg, 3.6 mmol), and 1,3-dimethylimidazolium iodide (**1**, 134 mg, 0.6 mmol) in THF (20 ml). The mixture was refluxed for 1 h with stirring, poured onto ice-H_2O mixture, and extracted with $CHCl_3$. The extract was dried over Na_2SO_4, and concentrated to dryness. The residue was passed through a column of SiO_2 with benzene then $CHCl_3$. The fraction eluted with benzene gave the ketone **12d** in 78% (702 mg) yield. Recrystallization from petroleum benzin gave pale yellow needles.

Preparation of 4-Benzyloxy-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (14d) Sodium hydride (50% in oil, 192 mg, 4 mmol) was added to a solution of 4-chloro-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**7**, 461 mg, 2 mmol) and benzyl alcohol (432 mg, 4 mmol) in THF (20 ml), and the mixture was refluxed for 1 h. The resultant mixture was poured onto an ice-H_2O mixture, and extracted with $CHCl_3$. The extract was dried over Na_2SO_4, and concentrated to dryness. The residue was passed through a short column of SiO_2 with benzene. The first fraction gave 4-benzyloxy-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**14d**) and recrystallization from petroleum benzin gave colorless needles (461 mg, 76%), mp 115—117 °C. *Anal.* Calcd for $C_{18}H_{14}N_4O$: C, 71.51; H, 4.67; N, 18.53. Found: C, 71.54; H, 4.72; N, 18.45. ^{1}H-NMR ($CDCl_3$): 8.63 (1H, s, C^6-H), 8.20 (1H, s, C^3-H), 8.24—8.12 (2H, m, aromatic H), 7.58—7.28 (8H, m, aromatic H), 5.60 (2H, s, CH_2).

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TABLE V. Melting Points, Mass Spectral Data, and Elemental Analyses for the Ketones (**9**—**13**)

Compound	mp (°C)	Formula	Analysis (%) Calcd			Found			MS *m/z* M^+
			C	H	N	C	H	N	
9l	84—85[a,f]	$C_{15}H_9FN_2O$	71.42	3.60	11.11	71.64	3.49	11.14	252
9m	90—91.5[a,f]	$C_{15}H_9FN_2O$	71.42	3.60	11.11	71.11	3.60	11.38	252
9n	125—126[b,g]	$C_{14}H_9N_3O$	71.48	3.86	17.86	71.68	3.75	17.82	235
9o	101—103[c,f]	$C_{14}H_9N_3O$	71.48	3.86	17.86	70.91	3.82	17.58	235
10a	148—150[a,g]	$C_{16}H_{11}FN_2O$	72.17	4.16	10.52	72.17	4.25	10.04	266
10c	132—133[a,g]	$C_{16}H_{11}BrN_2O$	58.74	3.39	8.56	58.78	3.36	8.53	326, 328
10r	138—140[d,g]	$C_{14}H_{10}N_2OS$	66.12	3.96	11.02	66.05	3.90	11.08	254
11f	105—107[e,f]	$C_{23}H_{18}N_2O$	81.63	5.36	8.28	81.28	5.44	8.40	338
11g	135[e,f]	$C_{22}H_{16}N_2O_2$	77.63	4.74	8.23	77.68	4.73	8.25	340
11l	94—95[e,f]	$C_{21}H_{13}FN_2O$	76.82	3.99	8.53	76.87	4.02	8.51	328
11n	140—142[c,g]	$C_{20}H_{13}N_3O$	77.15	4.21	13.50	77.01	4.27	13.45	311
11o	163—164[c,g]	$C_{20}H_{13}N_3O$	77.15	4.21	13.50	77.35	4.17	13.49	311
11p	158—160[c,g]	$C_{20}H_{13}N_3O$	77.15	4.21	13.50	77.03	4.14	13.31	311
12f	85—86[d,f]	$C_{20}H_{16}N_4O$	73.15	4.91	17.06	73.19	4.91	17.03	328
12h	172—173[c,g]	$C_{20}H_{16}N_4O_2$	69.76	4.68	16.27	69.50	4.66	16.03	344
12l	126—128[c,g]	$C_{18}H_{11}FN_4O$	67.92	3.48	17.60	67.74	3.49	17.45	318
12m	129—129.5[c,g]	$C_{18}H_{11}FN_4O$	67.92	3.48	17.60	67.77	3.48	17.60	318
13f	57—59[a,f]	$C_{15}H_{14}N_4O$	67.65	5.30	21.04	67.66	5.32	20.79	266
13h	139—140[e,g]	$C_{15}H_{14}N_4O_2$	63.82	5.00	19.85	63.56	4.95	19.51	282
13l	145—146[e,f]	$C_{13}H_9FN_4O$	60.94	3.54	21.87	60.87	3.52	21.92	256
13m	116—117[c,g]	$C_{13}H_9FN_4O$	60.94	3.54	21.87	60.96	3.55	21.69	256
13n	156—157[c,f]	$C_{12}H_9N_5O$	60.25	3.79	29.27	60.15	3.74	29.13	238

a) Yellowish powder. *b*) Colorless needles. *c*) Yellow needles. *d*) Yellow prisms. *e*) Pale yellow needles. *f*) Recrystallized from petroleum benzin. *g*) Recrystallized from MeOH.

TABLE VI. IR and ^{1}H-NMR Spectral Data for the Ketones (**9**—**13**)

Compound	IR ν_{max}^{KBr} cm^{-1}	^{1}H-NMR ($CDCl_3$) δ (ppm)
9l	1675 (CO)	9.20 (1H, s, C^2-H), 6.70—8.20 (8H, m, aromatic H)
9m	1675 (CO)	9.30 (1H, s, C^2-H), 7.20—8.15 (8H, m, aromatic H)
9n	1695 (CO)	9.21 (1H, s, C^2-H), 7.15—8.50 (8H, m, aromatic H)
9o	1675 (CO)	9.26 (1H, s, C^2-H), 9.02 (1H, d, J=3 Hz),[a] 8.70 (1H, dd, J=5, 2 Hz),[b] 7.20—8.32 (6H, m, aromatic H)
10a	1675 (CO)	6.95—8.10 (8H, m, aromatic H), 2.95 (3H, s, Me)
10c	1670 (CO)	7.40—8.00 (8H, m, aromatic H), 2.90 (3H, s, Me)
10r	1640 (CO)	7.00—8.35 (7H, m, aromatic H), 2.95 (3H, s, Me)
11f	1670 (CO)	8.51—8.72 (2H, m), 7.49—8.20 (9H, m, aromatic H), 7.31 (2H, d, J=7 Hz),[c] 2.72 (2H, q, J=7 Hz, $C\underline{H}_2CH_3$), 1.26 (3H, t, J=7 Hz, $CH_2C\underline{H}_3$)
11g	1650 (CO)	8.40—8.55 (2H, m), 7.25—8.05 (9H, m, aromatic H), 6.80 (2H, d, J=8 Hz),[d] 3.80 (3H, s, OMe)
11l	1675 (CO)	8.40—8.60 (2H, m), 6.90—8.30 (11H, m, aromatic H)
11n	1695 (CO)	7.45—8.61 (13H, m, aromatic H)
11o	1670 (CO)	9.12 (1H, d, J=2 Hz),[a] 8.65 (1H, dd, J=6, 2 Hz),[b] 7.20—8.50 (11H, m, aromatic H)
11p	1680 (CO)	7.25—8.80 (13H, m, aromatic H)
12f	1650 (CO)	9.05 (1H, s, C^6-H), 8.47 (1H, s, C^3-H), 7.00—8.25 (9H, m, aromatic H), 2.68 (2H, q, J=7 Hz, $C\underline{H}_2CH_3$), 1.22 (3H. t, J=7 Hz, $CH_2C\underline{H}_3$)
12h	1640 (CO)	9.11 (1H, s, C^6-H), 8.50 (1H, s, C^3-H), 7.20—8.30 (7H, m, aromatic H), 6.88 (2H, d, J=8 Hz),[e] 4.18 (2H, q, J=8 Hz, $OC\underline{H}_2CH_3$), 1.42 (3H, t, J=8 Hz, $OCH_2C\underline{H}_3$)
12l	1680 (CO)	9.05 (1H, s, C^6-H), 8.55 (1H, s, C^3-H), 6.85—8.24 (9H, m, aromatic H)
12m	1655 (CO)	9.12 (1H, s, C^6-H), 8.55 (1H, s, C^3-H), 7.00—8.25 (9H, m, aromatic H), 4.08 (3H, s, NMe)
13f	1655 (CO)	9.02 (1H, s, C^6-H), 8.29 (1H, s, C^3-H), 8.02 (2H, d, J=8 Hz),[f] 7.19 (2H, d, J=8 Hz),[c] 4.10 (3H, s, NMe), 2.70 (2H, q, J=8 Hz, $C\underline{H}_2CH_3$), 1.25 (3H, t, J=8 Hz, $CH_2C\underline{H}_3$)
13h	1640 (CO)	9.03 (1H, s, C^6-H), 8.30 (1H, s, C^3-H), 8.15 (2H, d, J=9 Hz),[g] 6.86 (2H, d, J=9 Hz),[e] 4.10 (3H, s, –NMe), 4.08 (2H, q, J=8 Hz, $OC\underline{H}_2CH_3$), 1.45 (3H, t, J=8 Hz, $OCH_2C\underline{H}_3$)
13l	1675 (CO)	9.02 (1H, s, C^6-H), 8.41 (1H, s, C^3-H), 6.89—7.90 (4H, m, aromatic H), 4.14 (3H, s, NMe)
13m	1655 (CO)	9.02 (1H, s, C^6-H), 8.35 (1H, s, C^3-H), 7.08—8.06 (4H, m, aromatic H), 4.12 (3H, s, NMe)
13n	1660 (CO)	9.42 (1H, d, J=2 Hz), 9.11 (1H, s, C^6-H), 8.49 (1H, s, C^3-H), 8.75 (1H, dd, J=6, 2 Hz), 8.40—8.70 (1H, m), 7.40 (1H, dd, J=8, 4 Hz), 4.19 (3H, s, NMe)

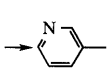
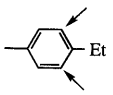
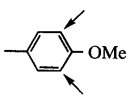
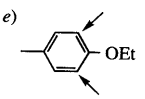
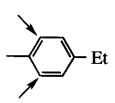
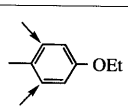
a)  *b*)  *c*)  *d*)  *e*)  *f*)  *g*) 

TABLE VII. ^{13}C-NMR Spectral Data for the Ketones (**11**—**13**)

Compound	^{13}C-NMR ($CDCl_3$) δ (ppm)
11n	120.6 (s), 124.2 (d), 125.5 (d), 127.6 (d), 127.7 (d), 128.5 (d), 128.7 (d), 129.2 (d), 130.7 (d), 134.3 (d), 137.0 (d), 137.7 (s), 149.6 (d), 151.6 (s), 153.3 (s), 159.8 (s), 165.5 (s), 193.7 (s, CO)
12f	15.1 (q, $CH_2\underline{C}H_3$), 29.1 (t, $\underline{C}H_2CH_3$), 113.9 (s), 121.3 (d), 126.9 (d), 128.0 (d), 129.2 (d), 131.3 (d), 132.7 (s), 135.0 (d), 138.4 (s), 151.2 (s), 153.9 (s), 154.6 (d), 156.2 (s), 191.1 (s, CO)
12h	14.6 (q, $OCH_2\underline{C}H_3$), 63.9 (t, $O\underline{C}H_2CH_3$), 114.3 (d), 121.5 (d), 127.1 (d), 127.7 (s), 129.3 (d), 133.7 (d), 135.1 (d), 138.4 (s), 153.9 (s), 154.6 (s), 156.9 (s), 163.9 (s), 189.7 (s, CO)
12l[a]	112.6 (s), 115.8 (d), 116.8 (d), 121.3 (d), 124.2 (d), 124.3 (d), 126.9 (d), 129.2 (d), 131.3 (d), 131.4 (d), 134.5 (d), 134.9 (d), 138.3 (s), 153.9 (s), 154.7 (s), 155.1 (d), 155.6 (s), 166.9 (s), 191.9 (s, CO)
12m[a]	113.7 (s), 117.4 (d), 118.4 (d), 121.3 (d), 126.9 (d), 127.1 (d), 129.2 (d), 129.9 (d), 130.2 (d), 134.9 (d), 137.1 (s), 136.8 (s), 138.3 (s), 153.9 (s), 154.6 (d), 154.9 (s), 156.9 (s), 168.0 (s), 190.0 (s, CO)
13f	14.6 (q, $OCH_2\underline{C}H_3$), 34.0 (q, –NMe), 63.9 (t, $O\underline{C}H_2CH_3$), 112.4 (s), 114.3 (d), 127.8 (s), 133.6 (d), 154.9 (d), 156.5 (s), 163.8 (s), 189.9 (s, CO)
13h	34.0 (q, NMe), 111.9 (s), 123.2 (d), 131.0 (s), 133.6 (d), 138.2 (d), 152.2 (d), 153.6 (d), 153.9 (s), 154.1 (d), 154.3 (s), 190.8 (s, CO)
13l[a]	34.0 (q, NMe), 111.1 (s), 115.9 (d), 116.9 (d), 124.2 (d), 124.3 (d), 131.4 (d), 133.2 (d), 134.5 (d), 134.9 (d), 154.4 (s), 154.6 (d), 155.7 (s), 167.0 (s), 192.2 (s, CO)
13m[a]	34.0 (q, NMe), 112.2 (s), 117.3 (d), 118.3 (d), 120.3 (d), 121.3 (d), 126.9 (d), 127.1 (d), 129.8 (d), 130.2 (d), 133.5 (d), 136.9 (s), 154.1 (d), 154.6 (s), 156.9 (s), 167.9 (s), 190.3 (s, CO)

a) The spectrum was observed with ^{13}C–^{19}F coupling.

References

1) Part III: A. Miyashita, H. Matsuda, T. Higashino, *Chem. Pharm. Bull.*, **40**, 2627 (1992).
2) *a*) R. Breslow, *Chem. Ind.* (London), **1957**, 893; *b*) *Idem*, *J. Am. Chem. Soc.*, **80**, 3719 (1958); *c*) R. Breslow, E. McNelis, *ibid.*, **81**, 3080 (1959); *d*) *Idem*, *ibid.*, **82**, 2394 (1960); *e*) T. Ugai, T. Tanaka, S. Dokawa, *Yakugaku Zasshi*, **63**, 296 (1943).
3) A. Miyashita, H. Matsuda, C. Iijima, T. Higashino, *Chem. Pharm. Bull.*, **40**, 43 (1992).
4) A. Miyashita, H. Matsuda, C. Iijima, T. Higashino, *Chem. Pharm. Bull.*, **38**, 1147 (1990).
5) T. Higashino, Y. Matsushita, M. Takemoto, E. Hayashi, *Chem. Pharm. Bull.*, **31**, 3951 (1983).
6) D. R. Brittelli, J. Buriak, B. E. Smart, *Org. Synth.*, **64**, 92 (1986).
7) T. Higashino, *Yakugaku Zasshi*, **80**, 245 (1960).
8) M. M. Endicott, E. Wick, M. L. Mercury, M. M. Sherrill, *J. Am. Chem. Soc.*, **68**, 1299 (1946).
9) H. C. Scarborough, B. C. Lawes, J. L. Minielli, J. L. Compton, *J. Org. Chem.*, **27**, 957 (1962).
10) C. C. Cheng, R. K. Robins, *J. Org. Chem.*, **23**, 191 (1958).