Catalytic Action of Azolium Salts. IX.[1] Synthesis of 6-Aroyl-9*H*-purines and Their Analogues by Nucleophilic Aroylation Catalyzed by Imidazolium or Benzimidazolium Salt

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In the presence of 1,3-dimethylimidazolium iodide (1), 6-chloro-9-phenyl-9*H*-purine (7) and 4-chloro-5,6-dimethylpyrrolo[2,3-*d*]pyrimidines 40—42 underwent nucleophilic aroylation with arenecarbaldehydes (5) to give the corresponding fused aroylpyrimidines 8 and 43—45. 1,3-Dimethylbenzimidazolium iodide (2) was an effective catalyst for the similar synthesis of 7-aroyl-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines 16—21. In the synthesis of 4-aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines 26—32, both azolium salts 1 and 2 were effective as catalysts. Moreover, 4-aroyl-7*H*-pyrrolo[2,3-*d*]pyrimidines 43—45 were obtained in good yields *via* the 4-tosyl derivatives, in the presence of catalytic amounts of sodium *p*-toluenesulfinate (46) and the imidazolium salt 1. This catalytic aroylation was found to be a facile and useful method for the synthesis of 6-aroyl-9*H*-purines and their analogues.

Key words 6-aroyl-9-phenyl-9*H*-purine; catalytic aroylation; arenecarbaldehyde; imidazolium salt; benzimidazolium salt; fused aroylpyrimidine

Purine derivatives and their analogues have critical roles in various biological processes and have potential as drugs because of their biological activities.[2] However, no systematic method of introducing a carbonyl group into a purine skeleton has yet been reported. We have already shown that azolium salts, such as 1,3-dimethylimidazolium iodide (**1**) and 1,3-dimethylbenzimidazolium iodide (**2**), are effective catalysts for nucleophilic introduction of aroyl groups into heteroarenes, *e.g.*, chloroquinazoline (**3**) and chlorophenylpyrazolopyrimidine (**4**).[3] Here, we wish to report the synthesis of 6-aroyl-9-phenyl-9*H*-purines **8** and their analogues by means of this catalytic aroylation.

It is known that the electrophilic activity of 6-chloro-9-phenyl-9*H*-purine (**7**) is low in comparison with that of other fused pyrimidines such as 4-chloroquinazoline (**3**) and 4-chlorophenylpyrazolopyrimidine (**4**). For example, synthesis of 1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine-4-carbonitrile (**6**) could be achieved by substitution of chlorophenylpyrazolopyrimidine (**4**) with cyanide ion (CN^-), but 9-phenyl-9*H*-purine-6-carbonitrile (**9**) could not be obtained in this way.[4]

Chart 2 shows the results obtained by our aroylation catalyzed by the azolium salts **1** or **2** under several reaction conditions. In the case of benzaldehyde (**5a**), the aroylation of **7** catalyzed by the imidazolium salt **1** in *N*,*N*-dimethylformamide (DMF) at room temperature for 5 min proceeded to give 6-benzoyl-9-phenyl-9*H*-purine (**8a**) in 89% yield. In contrast, the similar reaction catalyzed by the benzimidazolium salt **2** gave the ketone **8a** in only 2% yield. Similar results were obtained in refluxing tetrahydrofuran (THF). Namely, under the same conditions, the ketone **8a** was obtained in 51% yield in the presence of the imidazolium salt **1**, but in only 11% yield in the presence of the benzimidazolium salt **2**. Thus, the

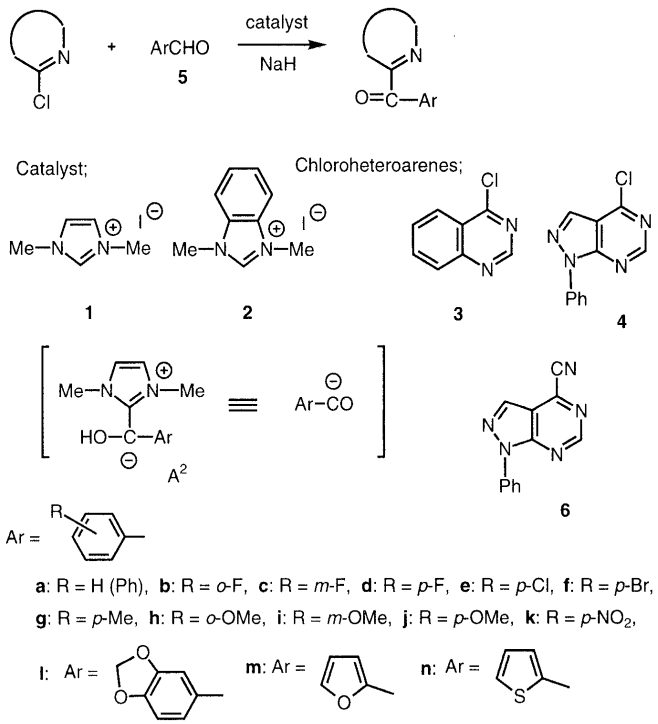
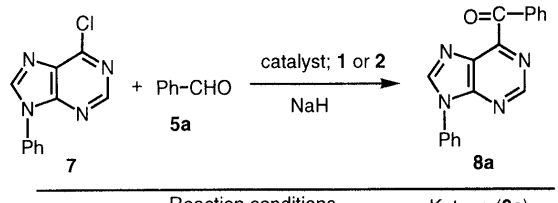


Chart 1



Catalyst	Reaction conditions: Solvent	Temp.	Time (min)	Ketone (**8a**) Isolated yield (%)
1	THF	Reflux	5	51 (15)[a]
1	DME[b]	Reflux	15	58
1	DMF	r.t.	5	89
1	DMF	80°	10	78
2	THF	Reflux	10	11 (23)[a]
2	DMF	r.t.	5	2 (93)[a]

a) Recovery of the starting **7**.
b) DME = dimethoxyethane.

Chart 2

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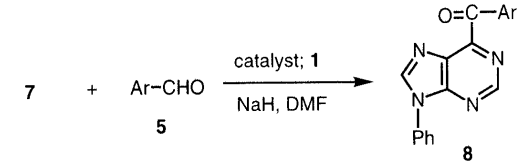


Aldehyde	Reaction conditions Temp.(°C)	Time (min)	Ketone (8)	Isolated yield (%)
5e	r.t.	5	8e	74
5f	r.t.	5	8f	78
5g	r.t.	5	8g	68
5h	r.t.	30	8h	12 (51)[a]
5i	r.t.	5	8i	78
5j	r.t.	5	8j	66
5l	r.t.	20	8l	44

a) Recovery of the starting **7**.

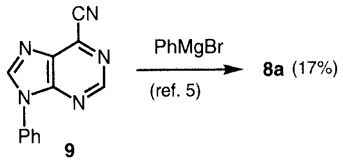


Chart 3

imidazolium salt **1** is a more effective catalyst than the benzimidazolium salt **2**.

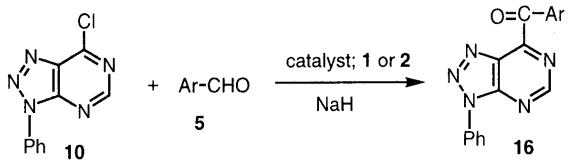
In the presence of the imidazolium salt **1**, **7** was successfully aroylated with *p*-chlorobenzaldehyde (**5e**), *p*-bromobenzaldehyde (**5f**), *m*-anisaldehyde (**5i**), *p*-anisaldehyde (**5j**), *p*-tolualdehyde (**5g**), and piperonal (**5l**), as shown in Chart 3. The yields of the ketones **8** were moderate to good. On the other hand, in the case of *o*-anisaldehyde (**5h**), the aroylation did not proceed well, presumably because of steric hindrance; in DMF for 30 min the ketone **8h** was formed in only 12% yield, together with recovery of the starting **7** (51%).

Existing methods to synthesize the ketone **8a** afford poor yields.[5] For example, the ketone **8a** was obtained by the treatment of 9-phenyl-9*H*-purine-6-carbonitrile (**9**) with phenylmagnesium bromide (PhMgBr) in 17% yield.[5a] In contrast, the catalytic aroylation is easy and simple.

This catalytic aroylation method was next applied to the synthesis of aroylpurine analogues such as 7-aroyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines (8-azapurines), 4-aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines (7-deaza-8-azapurines), and 4-aroylpyrrolo[2,3-*d*]pyrimidines (7-deazapurines).

We have already reported the synthesis of 7-aroyl-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines **16** through nucleophilic aroylation catalyzed by the benzimidazolium salt **2**.[6] To clarify the catalytic abilities of the azolium salts **1** and **2**, the yields of aroyltriazolopyrimidine **16** obtained by using the two azolium salts **1** and **2** as catalysts were compared. As shown in Chart 4, marked differences were observed, and the benzimidazolium salt **2** was found to be a more effective catalyst than the imidazolium salt **1**.

Using the benzimidazolium salt **2**, several 7-aroyltriazolopyrimidines **16**—**21** were synthesized (Table 1). These results and the synthetic route to the starting 7-chlorotriazolopyrimidines **11**—**15** are shown in Chart 5.



Aldehyde	Reaction conditions Solvent	Temp.	Time (min)	Ketone 16; Isolated yield (%)	Catalyst 1	Catalyst 2
5a	THF	Reflux	30	16a	– (56)[b]	56[a]
5a	DMF	80	10	16a	– (42)	71
5b	Dioxane	Reflux	60	16b	28 (12)	73
5d	THF	Reflux	60	16d	32 (22)	93
5e	THF	Reflux	30	16e	– (63)	63[a]
5e	Dioxane	Reflux	30	16e	39 (15)	73
5h	THF	Reflux	30	16h	– (65)	33[a]
5j	THF	Reflux	30	16j	– (33)	78[a]

a) Reported in the previous paper.[3] *b*) Recovery of the starting **10**.

Chart 4

Table 1. Synthesis of 7-Aroyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines **16**—**21** by Aroylation of 7-Chloro-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines **10**—**15** with Arenecarbaldehydes **5** Catalyzed by the Benzimidazolium Salt (**2**)

Substrates Chloro compd.	Aldehyde	Reaction time (min)	Ketone Isolated yield (%)	
10	5f	20	16f	32 (66)[a]
10	5k	30	16k	23[b]
10	5m	40	16m	40
10	5n	30	16n	54
11	5a	30	17a	63
11	5f	15	17f	71
11	5j	30	17j	46
12	5a	30	18a	62
12	5f	10	18f	73
12	5j	10	18j	50
13	5a	30	19a	63
13	5f	20	19f	65
13	5j	30	19j	69
14	5a	20	20a	54
14	5f	30	20f	57
14	5j	30	20j	52
15	5a	20	21a	73
15	5f	60	21f	53
15	5j	30	21j	59

a) Obtained in DMF at 80 °C for 3 min. *b*) Carried out in dioxane.

In the case of the pyrazolopyrimidines, we have reported that the aroylation using arenecarbaldehyde (**5**) catalyzed by either of the azolium salts **1** and **2** proceeded successfully. To clarify the generality of this aroylation method, we further examined the synthesis of several aroylpyrazolopyrimidines catalyzed by **1** and **2**.[3a,3d] Several 4-chloro-1*H*-pyrazolo[3,4-*d*]pyrimidines, that is, 4-chloro-1,6-dimethyl- (**26**),[7] 4-chloro-6-ethyl-1-methyl- (**27**),[4] 4-chloro-1-methyl-6-phenyl- (**28**),[7] 4-chloro-3-methyl-1-phenyl- (**29**), 4-chloro-6-methyl-1-phenyl- (**30**),[7] 4-chloro-6-ethyl-1-phenyl- (**31**), and 4-chloro-1,6-diphenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**32**), were used as the starting compounds. As shown in Chart 6 and Table 2, the corresponding 4-aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines **33**—**39** were synthesized in good yields. In the synthesis

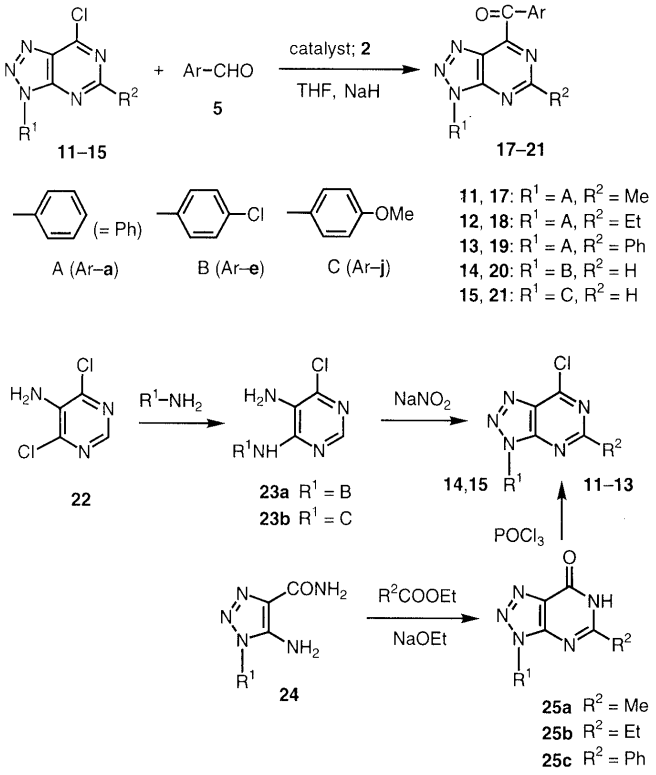


Chart 5

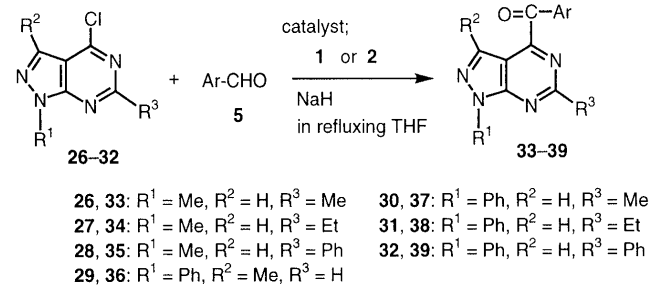


Chart 6

Table 2. Synthesis of 4-Aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines **33**—**39** by Aroylation of 4-Chloro-1*H*-pyrazolo[3,4-*d*]pyrimidines **26**—**32** with Arenecarbaldehydes **5** Catalyzed by an Azolium Salt **1** or **2**

Substrates		Reaction conditions		Ketone; Isolated yield (%)	
Chloro compd.	Aldehyde	Catalyst	Time (min)		
26	**5a**	**1**	30	**33a**	89
26	**5a**	**2**	30	**33a**	48 (23)[a]
26	**5d**	**1**	20	**33d**	86
26	**5j**	**1**	30	**33j**	57
27	**5a**	**1**	50	**34a**	92
27	**5a**	**2**	60	**34a**	22 (18)[a]
27	**5j**	**1**	40	**34j**	67
28	**5a**	**1**	30	**35a**	95
28	**5a**	**2**	30	**35a**	58
28	**5d**	**2**	15	**35d**	97
28	**5j**	**1**	20	**35j**	77
29	**5a**	**1**	40	**36a**	52
29	**5a**	**2**	60	**36a**	15 (35)[a]
29	**5j**	**1**	30	**36j**	79
29	**5n**	**1**	30	**36n**	55
30	**5a**	**1**	30	**37a**	76
30	**5a**	**2**	30	**37a**	29
30	**5b**	**1**	30	**37b**	36
30	**5c**	**1**	20	**37c**	52
30	**5d**	**1**	30	**37d**	49
30	**5h**	**1**	60	**37h**	— (14)[a]
30	**5i**	**1**	30	**37i**	55
30	**5j**	**1**	30	**37j**	55
30	**5j**	**2**	20	**37j**	99
30	**5n**	**2**	30	**37n**	36
31	**5a**	**1**	30	**38a**	51
31	**5j**	**1**	30	**38j**	60
31	**5n**	**1**	20	**38n**	52
32	**5a**	**2**	30	**39a**	72
32	**5d**	**1**	15	**39d**	51
32	**5i**	**1**	20	**39i**	69
32	**5j**	**1**	30	**39j**	94
32	**5m**	**2**	20	**39m**	31
32	**5n**	**1**	30	**39n**	66

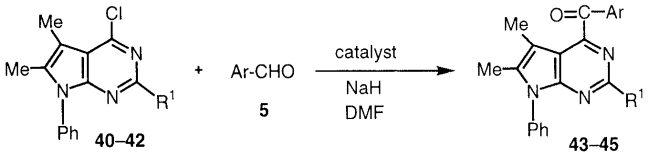
a) Recovery of the starting compound.

of **33**—**39**, it seems that the catalytic ability of the imidazolium salt **1** is more effective than that of the benzimidazolium salt **2**, though both **1** and **2** were effective.

In the case of the pyrrolopyrimidine **40**, the aroylation with **5a** did not proceed in the presence of the benzimidazolium salt **2**, whereas 4-benzoyl-5,6-dimethyl-7-phenyl-7*H*-pyrrolo[2,3-*d*]pyrimidine (**43a**) was obtained by aroylation catalyzed by the imidazolium salt **1**. However, the yield of **43a** was moderate because of the low electrophilicity of the chloropyrrolopyrimidine **40**. In the synthesis of pyrrolopyrimidinecarbonitrile (**48**) from **40**, we have shown that sodium *p*-toluenesulfinate (**46**) acts as an effective catalyst through *in situ* formation of the tosylpyrrolopyrimidine **47**.[4b] As shown in Chart 7, in the presence of sodium *p*-toluenesulfinate (**46**), the synthesis of 4-aroylpyrrolopyrimidines **43**—**45** catalyzed by the imidazolium salt **1** was achieved in good yields. This reaction probably also proceeds through the tosyl derivatives, because the reaction of the tosylpyrrolopyrimidine **47** with benzaldehyde (**5a**) was efficiently catalyzed by the imidazolium salt **1**. The imidazolium salt **1** is a more effective catalyst than the benzimidazolium salt **2** in the aroylation of pyrrolopyrimidines.

The intermediates (A^2-1, B^2-1) formed between azolium ylides (A^1, B^1) and arenecarbaldehyde **5** are key compounds in this aroylation (Chart 8), and the ease of formation of the ketones might be correlated to the catalytic activity of the azolium salts **1** and **2**. We considered that the reactivity of the intermediates depends on the electron density of the anion center and/or the soft–hard nature. The calculated HOMOs of the adducts are shown in Chart 8.[8] However, no marked differences were apparent. Our research on the reactivity at the C^4-position of fused pyrimidines toward carbanions suggested that the order of reactivity is triazolopyrimidine > pyrazolopyrimidine > purine > pyrrolopyrimidine.[9] The calculated atomic charges at the C^4-position of fused pyrimidines, however, could not explain the differences of the catalytic ability of the azolium salts **1** and **2**.

This aroylation proceeds through an addition–elimination mechanism for nucleophilic substitution of aromatic compounds (*S*N*Ar*). Namely, it involves formation of the adduct between the nucleophiles and chloroheteroarenes. The reaction requires sufficient electrophilicity of chloroheteroarenes and sufficient nucleophilicity of the inter-



40 + **5a** → **43a** (catalyst, NaH, DMF 120 °C)

5	Cat.	Ketone (43) Isolated yield (%)	
5a	**1**	**43a**	62
5a	**2**	**43a**	– (42)[a]

a) Recovery of the starting **40**.

40–42 + Ar-CHO (**5**) → **43–45** (catalyst; **1** or **2**, Me–C6H4–SO_2Na (**46**), NaH, DMF)

Substrates			Reaction conditions		Ketone	
Chloro compd.	Aldehyde	Catalyst	Temp. (°C)	Time (min)	Isolated yield (%)	
40	**5a**	**1**	120	30	**43a**	96
40	**5a**	**2**	120	15	**43a**	12 (25)[a]
40	**5e**	**1**	120	15	**43e**	95
40	**5g**	**1**	120	15	**43g**	96
40	**5j**	**1**	120	10	**43j**	65
40	**5l**	**1**	120	10	**43l**	96
40	**5n**	**1**	120	15	**43n**	56
41	**5a**	**1**	Reflux	20	**44a**	56
41	**5a**	**2**	Reflux	20	**44a**	– (33)[a]
42	**5a**	**1**	Reflux	20	**45a**	42
42	**5e**	**1**	Reflux	20	**45e**	32
42	**5j**	**1**	Reflux	20	**45j**	36

a) Recovery of the starting compound (**40** or **41**).

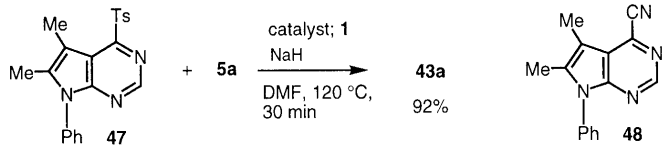
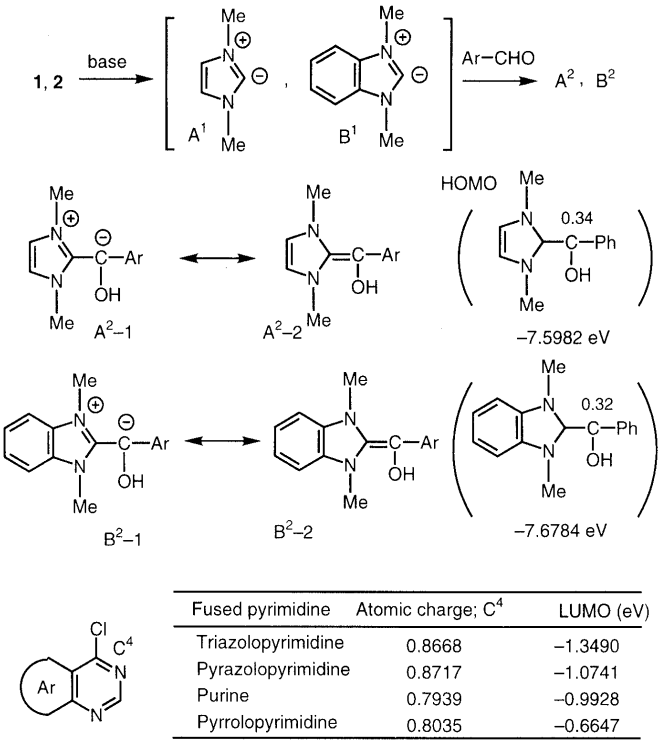


Chart 7

mediates (A^2-1, B^2-1). We considered that the adduct (A^2-1, a nucleophile) generated from the imidazolium salt **1** and arenecarbaldehyde **5** is more active than that (B^2-1) generated from the benzimidazolium salt **2**, because the acidity at the C^2-hydrogen of the imiazolium salt **1** is lower than that of the benzimidazolium salt **2**.[10] In general, a carbanion that is generated by the expulsion of hydrogen at a position having low acidity is more active than one generated at a position having high acidity. To achieve the aroylation, the chloro compounds must undergo addition with nucleophiles, followed by the release of the chloro group. Compounds having low electrophilic activity, *e.g.*, purines and pyrrolopyrimidines, require powerful nucleophiles, such as the adduct derived from **1**. Chloro compounds having sufficient electrophilicity, *e.g.*, triazolopyrimidines, can react with the adduct derived from **2**. This is because the adduct derived from **2** is softer than that from **1**. The calculations of LUMO for the chloropurine and its analogues indicate that triazolopyrimidines show the greatest softness. The calculated LUMOs are shown in Chart 8. However, the details remain to be fully established.

In conclusion, 6-aroyl-9-phenyl-9*H*-purines **8** and their analogues were synthesized in moderate to good yields by nucleophilic aroylation using arenecarbaldehydes **5**. The



Fused pyrimidine	Atomic charge; C^4	LUMO (eV)
Triazolopyrimidine	0.8668	–1.3490
Pyrazolopyrimidine	0.8717	–1.0741
Purine	0.7939	–0.9928
Pyrrolopyrimidine	0.8035	–0.6647

Chart 8

imidazolium salt **1** and the benzimidazolium salt **2** are both effective catalysts in this aroylation, but show different catalytic abilities in the aroylations of several fused pyrimidines. In pyrrolopyrimidines, the aroylation could be achieved by using the imidazolium salt (**1**) and sodium *p*-toluenesulfinate (**46**), as dual catalysts.

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 or at 270 MHz on a JEOL JNM-GSX270 FT-NMR spectrometer, and ^{13}C-NMR spectra were taken at 67.8 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 hertz (Hz). Mass spectra (MS) were recorded on a JEOL JMS-DX303 mass spectrometer.

Benzoylation of 6-Chloro-9-phenyl-9*H*-purine (7) with Benzaldehyde (5a) Catalyzed by Azolium Salt (1 or 2) Sodium hydride (60% in oil, 60 mg, 1.5 mmol) was added to a stirred mixture of 6-chloro-9-phenyl-9*H*-purine (**7**, 231 mg, 1.0 mmol), an azolium salt [1,3-dimethylimidazolium iodide (**1**, 75 mg, 0.3 mmol) or 1,3-dimethylbenzimidazolium iodide (**2**, 91 mg, 0.3 mmol)], and benzaldehyde (**5a**, 127 mg, 1.2 mmol) in 8 ml of solvent (DMF, THF, or DME), and the mixture was stirred under appropriate conditions (see Chart 2). The reaction mixture was poured into ice–H_2O and extracted with AcOEt (DMF) or $CHCl_3$ (THF or DME). The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene then $CHCl_3$. The first fraction eluted with $CHCl_3$ gave recovered **7** and the second fraction gave the ketone **8a**. (If the purification was difficult, the yields were determined from the ^{1}H-NMR spectrum based on integration of the C^2-proton signal). These results are shown in Chart 2.

Synthesis of 6-Aroyl-9-phenyl-9*H*-purines 8. General Procedure Sodium hydride (60% in oil, 62 mg, 1.5 mmol) was added to a stirred solution of 6-chloro-9-phenyl-9*H*-purine (**7**, 231 mg, 1.0 mmol), 1,3-dimethylimidazolium iodide (**1**, 75 mg, 0.3 mmol), and an arenecarbaldehyde (**5**, 1.2 mmol) in DMF (8 ml), and the mixture was stirred under appropriate conditions (see Chart 3). The reaction mixture was poured into ice–H_2O and extracted with AcOEt. The organic layer

Table 3. Melting Points and Elemental Analyses for 6-Aroyl-9-phenyl-9*H*-purines **8**

Compd.	mp (°C)	Apperance (Recrystalization solvent)	Formula	Analysis (%) Calcd (Found)		
				C	H	N
8a	183—184 (lit.,[5] 184—185)	Colorless needles (MeOH)	$C_{18}H_{12}N_4O$			
8e	239—241	Colorless needles (MeOH)	$C_{18}H_{11}ClN_4O$	64.58 (64.57)	3.31 (3.04)	16.74 (16.79)
8f	242—243	Slightly yellow needles ($CHCl_3$–MeOH)	$C_{18}H_{11}BrN_4O$	57.01 (57.03)	2.92 (2.67)	14.77 (14.82)
8g	187—188	Colorless needles ($CHCl_3$–MeOH)	$C_{19}H_{14}N_4O$	72.60 (72.30)	4.49 (4.64)	17.82 (17.88)
8h	129—131	Yellow prisms (MeOH)	$C_{19}H_{14}N_4O_2$	69.08 (68.53)	4.27 (4.18)	16.96 (17.14)
8i	135—136	Slightly brown granules (MeOH)	$C_{19}H_{14}N_4O_2$	69.08 (68.88)	4.27 (4.22)	16.96 (17.02)
8j	196—198	Yellow needles (MeOH)	$C_{19}H_{14}N_4O_2$	69.08 (68.88)	4.27 (4.27)	16.96 (16.92)
8l	221—222	Slightly orange powder (MeOH)	$C_{19}H_{12}N_4O_3$	66.28 (65.98)	3.51 (3.30)	16.27 (16.32)

Table 4. IR and ^{1}H-NMR Spectral Data for 6-Aroyl-9-phenyl-9*H*-purines **8**

Compd.	IR (KBr) cm^{-1}	^{1}H-NMR ($CDCl_3$) δ
8a	1667 (CO)	7.50—7.55 (3H, m, aromatic H), 7.62—7.67 (3H, m, aromatic H), 7.74—7.77 (2H, m, aromatic H), 8.10 (2H, d, J=7.3 Hz, aromatic H), 8.48 (1H, s, C^8-H), 9.18 (1H, s, C^2-H)
8e	1672 (CO)	7.50—8.09 (9H, m, aromatic H), 8.48 (1H, s, C^8-H), 9.18 (1H, s, C^2-H)
8f	1669 (CO)	7.51—8.02 (9H, m, aromatic H), 8.03 (1H, s, C^8-H), 9.18 (1H, s, C^2-H)
8g	1660 (CO)	2.45 (3H, s, CH_3), 7.32 (2H, d, J=8 Hz), 7.52—7.76 (5H, m, aromatic H), 8.00 (2H, d, J=8 Hz), 8.46 (1H, s, C^8-H), 9.17 (1H, s, C^2-H)
8h	1660 (CO)	3.51 (3H, s, OCH_3), 6.97 (1H, d, J=8.3 Hz, aromatic H), 7.11—7.17 (1H, m, aromatic H), 7.50—7.90 (7H, m, aromatic H), 8.46 (1H, s, C^8-H), 9.09 (1H, s, C^2-H)
8i	1672 (CO)	3.88 (3H, s, OCH_3), 7.18—7.43 (2H, m, aromatic H), 7.50—7.77 (7H, m, aromatic H), 8.47 (1H, s, C^8-H), 9.17 (1H, s, C^2-H)
8j	1662 (CO)	3.90 (3H, s, OCH_3), 6.98—7.00 (2H, m), 7.51—7.76 (5H, m, aromatic H), 8.09—8.12 (2H, m), 8.46 (1H, s, C^8-H), 9.16 (1H, s, C^2-H)
8l	1660 (CO)	6.09 (2H, s, –OCH_2O–), 6.80 (1H, d, J=7.8 Hz), 7.51—7.77 (7H, m, aromatic H), 8.46 (1H, s, C^8-H), 9.16 (1H, s, C^2-H)

Table 5. ^{13}C-NMR Spectral Data for 6-Aroyl-9-phenyl-9*H*-purines **8**

Compd.	^{13}C-NMR ($CDCl_3$) δ
8a	123.7 (d), 128.6 (d), 128.9 (d), 130.1 (d), 130.8 (d), 132.3 (s), 133.9 (s), 134.1 (d), 135.3 (s), 145.7 (d), 152.5 (d), 153.0 (s), 153.5 (s), 191.4 (s, CO)
8e	123.8 (d), 128.97 (d), 129.04 (d), 130.2 (d), 132.2 (d), 132.3 (s), 133.7 (s), 133.9 (s), 140.8 (s), 145.9 (d), 152.5 (d), 152.8 (s), 153.2 (s), 190.1 (s, CO)
8f	123.8 (d), 129.0 (d), 129.6 (s), 130.2 (d), 131.9 (d), 132.3 (d), 133.9 (s), 134.2 (s), 144.1 (s), 145.9 (d), 152.5 (d), 152.7 (s), 153.2 (s), 190.3 (s, CO)
8g	21.9 (Me), 123.7 (d), 128.9 (d), 129.3 (d), 130.1 (d), 130.9 (d), 132.2 (s), 132.9 (s), 134.0 (s), 145.3 (s), 145.5 (d), 152.6 (d), 152.9 (s), 154.0 (s), 191.0 (s, CO)
8h	55.7 (OMe), 112.0 (d), 121.1 (d), 123.6 (d), 123.7 (s), 126.9 (s), 128.8 (d), 130.1 (d), 131.0 (s), 131.3 (d), 134.2 (s), 134.8 (d),145.3 (d), 152.7 (d), 154.8 (s), 159.5 (s), 192.8 (s, CO)
8i	55.6 (OMe), 114.3 (d), 121.0 (d), 123.7 (d), 124.1 (d), 128.9 (d), 129.5 (d), 130.1 (d), 132.2 (s), 133.9 (s), 136.6 (s), 145.6 (d), 152.7 (d), 153.0 (s), 153.7 (s), 159.8 (s), 191.2 (s, CO)
8j	55.6 (OMe), 114.0 (d), 123.7 (d), 128.4 (s), 128.9 (d), 130.1 (d),132.2 (s), 133.3 (d), 134.0 (s), 145.4 (d), 152.6 (d), 152.9 (s), 154.4 (s), 164.5 (s), 189.7 (s, CO)
8l	102.1 (–OCH_2O–), 108.1 (d), 109.8 (d), 123.7 (d), 128.5 (d), 128.9 (d), 130.1 (d), 132.2 (s), 134.0 (s), 139.3 (s), 145.5 (d),148.3 (s), 152.6 (d), 152.9 (s), 153.0 (s), 154.2 (s), 189.3 (CO)

was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene and $CHCl_3$. The fraction eluted with $CHCl_3$ gave the corresponding ketone **8**. These results are shown in Chart 3. Appearance, elemental analyses, and spectral data for the 6-aroyl-9-phenyl-9*H*-purines **8** are shown in Tables 3, 4, and 5.

Synthesis of 7-Aroyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines 16. General Procedure Sodium hydride (60% in oil, 180 mg, 4.5 mmol) was added to a stirred solution of 7-chloro-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]-pyrimidine (**10**, 694.5 mg, 3.0 mmol), an arenecarbaldehyde (**5**, 3.6 mmol), and an azolium salt (**1**; 224 mg, 1.0 mmol or **2**; 274 mg, 1.0 mmol) in THF (20 ml) or dioxane (20 ml), and the mixture was refluxed with stirring (see Chart 4). The reaction mixture was poured into ice–H_2O, and extracted with $CHCl_3$. The organic layer was dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene then $CHCl_3$. The fraction eluted with $CHCl_3$ gave the corresponding ketone **16**.

Reaction in DMF: The reaction mixture was poured into ice–H_2O, and extracted with AcOEt. Work-up as described above gave the ketones **16**.

Yields, appearance, melting points, and spectral data are shown in Chart 4, and Tables 6 and 7.

Synthesis of 7-Aroyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines 17—21 Catalyzed by Benzimidazolium Iodide (2). General Procedure Sodium hydride (60% in oil, 180 mg, 4.5 mmol) was added to a stirred solution of a 7-chloro-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine (**11**—**15**, 3.0 mmol), an arenecarbaldehyde (**5**, 3.6 mmol), and the benzimidazolium salt (**2**, 274 mg, 1.0 mmol) in THF (20 ml), and the mixture was refluxed with stirring (see Table 1). The reaction mixture was poured into ice–H_2O, and extracted with $CHCl_3$. The organic layer was dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene then $CHCl_3$. The fraction eluted with $CHCl_3$ gave the corresponding ketone **17**—**21**. Yields, appearance, melting points, and spectral data are shown in Chart 5, and Tables 6 and 7.

Preparation of 7-Chloro-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines 11—15. Chlorination of 3*H*-1,2,3-Triazolo[4,5-*d*]pyrimidin-7(6*H*)-ones 25. General

Table 6. Appearance, Formula, Elemental Analyses, and MS Data for 7-Aroyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines **16**—**21**

Compd.	mp (°C)	Appearance (Recrystallization solvent)	Formula	Analysis (%), Calcd (Found)			MS (*m*/*z*) M^+
				C	H	N	
16b	184—185	Yellow needles (MeOH)	$C_{17}H_{10}FN_5O$	63.95 (63.76)	3.16 (3.10)	21.93 (21.90)	319
16d	142—142.5	Yellow needles (MeOH)	$C_{17}H_{10}FN_5O$	63.95 (63.90)	3.16 (3.16)	21.93 (21.92)	319
16f	200—201	Colorless scales (MeOH)	$C_{17}H_{10}BrN_5O$	53.70 (53.60)	2.65 (2.56)	18.42 (18.52)	380
16k	222—223	Yellow needles (MeOH)	$C_{17}H_{10}N_6O_3$	58.96 (58.72)	2.91 (2.82)	24.27 (24.91)	
16m	143—145	Yellow needles (MeOH)	$C_{15}H_9N_5O_2$	61.86 (61.66)	3.11 (3.05)	24.04 (24.90)	291
16n	143.5—145	Colorless scales (MeOH)	$C_{15}H_9N_5OS$	58.62 (58.66)	2.95 (2.91)	22.79 (22.79)	307
17a	118—119	Yellow prisms (MeOH)	$C_{18}H_{13}N_5O$	68.56 (68.24)	4.16 (4.23)	22.21 (22.04)	315
17f	163—164	Yellow needles (Petroleum benzin)	$C_{18}H_{12}BrN_5O$	54.84 (54.77)	3.07 (3.12)	17.76 (17.67)	
17j	149—151	Yellow needles (MeOH)	$C_{19}H_{15}N_5O_2$	66.08 (66.08)	4.38 (4.45)	20.28 (20.04)	
18a	99—100	Yellow needles (Petroleum benzin)	$C_{19}H_{15}N_5O$	69.25 (69.10)	4.59 (4.66)	21.26 (21.27)	329
18f	133—133.5	Yellow needles (MeOH)	$C_{19}H_{14}BrN_5O$	55.90 (55.52)	3.46 (3.53)	17.15 (17.24)	
18j	120—122	Yellow needles (MeOH)	$C_{20}H_{17}N_5O_2$	66.84 (66.78)	4.77 (4.72)	19.49 (19.34)	
19a	175—176	Yellow needles (Benzene)	$C_{23}H_{15}N_5O$	73.20 (73.45)	4.01 (4.03)	18.56 (18.49)	
19f	213—214	Yellow needles ($CHCl_3$–MeOH)	$C_{23}H_{14}BrN_5O$	60.54 (61.04)	3.09 (2.86)	15.35 (15.66)	
19j	191—192	Yellow needles (Benzene)	$C_{24}H_{17}N_5O_2$	70.75 (70.89)	4.21 (4.23)	17.19 (17.13)	407
20a	190—192	Yellow scales (Benzene–petroleum benzin)	$C_{17}H_{10}ClN_5O$	60.82 (61.01)	3.00 (2.98)	20.86 (20.86)	
20f	192—194	Yellow plates (DMF)	$C_{17}H_9BrClN_5O$	49.24 (49.19)	2.19 (2.17)	16.89 (16.73)	
20j	187—188	Yellow needles (Benzene)	$C_{18}H_{12}ClN_5O_2$	59.11 (59.28)	3.31 (3.30)	19.15 (18.88)	
21a	146—147	Yellow needles (Benzene–petroleum benzin)	$C_{18}H_{13}N_5O_2$	65.25 (64.95)	3.94 (3.93)	21.14 (20.86)	
21f	207—210	Yellow plates (DMF)	$C_{18}H_{12}BrN_5O_2$	52.70 (52.41)	2.95 (2.94)	17.07 (17.01)	
21j	185—187	Yellow needles (Benzene)	$C_{19}H_{15}N_5O_3$	63.15 (63.35)	4.18 (4.20)	19.38 (19.34)	

Procedure A solution of a 3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidin-7(6*H*)-one (**25**,[11] 20 g) in $POCl_3$ (300 ml) and *N*,*N*-dimethylaniline (10 ml) was refluxed for 1 h with stirring. The reaction mixture was concentrated under reduced pressure. The residue was dissolved in a small portion of $CHCl_3$. This solution was poured into ice–H_2O and the whole was extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene and $CHCl_3$. The fraction eluted with $CHCl_3$ gave the corresponding 7-chloro-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine **11**—**13**.

7-Chloro-5-methyl-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine (**11**): Yield 76%. Colorless needles (benzene–petroleum benzin), mp 114—116 °C. *Anal.* Calcd for $C_{11}H_8ClN_5$: C, 53.78; H, 3.28; N, 28.51. Found: C, 53.76; H, 3.26; N, 28.54. ^{1}H-NMR ($CDCl_3$) δ: 2.90 (3H, s, Me), 7.25—8.40 (5H, m, aromatic H).

7-Chloro-5-ethyl-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine (**12**): Yield 94%. Colorless powder (benzene–petroleum benzin), mp 96 °C. *Anal.* Calcd for $C_{12}H_{10}ClN_5$: C, 55.50; H, 3.88; N, 26.97. Found: C, 55.54; H, 3.92; N, 27.06. ^{1}H-NMR ($CDCl_3$) δ: 1.45 (3H, t, J=7 Hz, CH_2CH_3), 3.13 (2H, q, J=7 Hz, CH_2CH_3), 7.25—7.81 (5H, m, aromatic H).

7-Chloro-3,5-diphenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine (**13**): Yield 61%. Colorless needles (benzene), mp 190—191 °C. *Anal.* Calcd for $C_{16}H_{10}ClN_5$: C, 62.45; H, 3.28; N, 22.76. Found: C, 62.45; H, 3.31; N, 22.52. ^{1}H-NMR ($CDCl_3$) δ: 7.25—7.77 (6H, m, aromatic H), 8.12—8.65 (4H, m, aromatic H).

Formation of Triazole Ring. Preparation of 5-Amino-4-anilino-6-chloropyrimidines 23. General Procedure A solution of 4-amino-4,6-dichloropyrimidine (**22**, 1.64 g, 10.0 mmol) and an aniline derivative (12.0 mmol) in a mixture of H_2O (27 ml), EtOH (4 ml), and concentrated HCl (0.4 ml) was refluxed for 8 h. Water (20 ml) was added, and the resulting mixture was cooled to room temperature with stirring. The solution was allowed to stand in refrigerator at 4 °C overnight, and the separated solid was collected and dried to give 5-amino-4-anilino-6-chloropyrimidines **23**.

5-Amino-6-chloro-4-(4-chloroanilino)pyrimidine (**23a**): Yield 76%. Colorless needles (MeOH–H_2O), mp 220—222 °C (lit.,[12] 222 °C)

5-Amino-6-chloro-4-(4-methoxyanilino)pyrimidine (**23b**): Yield 82%. Colorless needles from MeOH–H_2O, mp 202—205 °C. *Anal.* Calcd for $C_{11}H_{11}N_4ClO$: C, 52.70; H, 4.42; N, 22.35. Found: C, 52.67; H, 4.30; N, 22.20. ^{1}H-NMR (d_6-DMSO) δ: 3.74 (3H, s, OMe), 5.20 (2H, br s, NH_2), 6.83 (2H, d, J=9 Hz), 7.52 (2H, d, J=9 Hz), 7.73 (1H, s, C^2-H), 8.36 (1H, br s, NH).

Preparation of 7-Chloro-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines 14 and 15. General Procedure A solution of sodium nitrate ($NaNO_2$, 2.0 g) in H_2O (20 ml) was slowly added to a stirred solution of a 5-amino-4-anilino-6-chloropyrimidine (**23**, 2.35 g) in AcOH (20 ml) under cooling with ice–H_2O, and the mixture was stirred for 30 min under

Table 7. Melting Points, and IR and ^{1}H-NMR Spectral Data for 7-Aroyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidines **16**—**21**

Compd.	IR (KBr) cm^{-1}	^{1}H-NMR ($CDCl_3$) δ
16b	1680 (CO)	6.90—8.35 (9H, m, aromatic H), 9.28 (1H, s, C^5-H)
16d	1670 (CO)	6.94—7.70 (5H, m, aromatic H), 7.93—8.20 (4H, m, aromatic H), 9.21 (1H, s, C^5-H)
16f	1680 (CO)	7.34—8.23 (9H, m, aromatic H), 9.25 (1H, s, C^5-H)
16k	1680 (CO) 1530, 1340 (NO_2)	7.43—7.58 (3H, m, aromatic H), 8.05—8.23 (2H, m), 8.25 (4H, s), 9.30 (1H, s, C^5-H)
16m	1650 (CO)	6.53—6.65 (1H, m), 7.41—7.80 (5H, m), 8.05—8.24 (2H, m), 9.27 (1H, s, C^5-H)
16n	1640 (CO)	7.12—8.33 (8H, m, aromatic H), 9.32 (1H, s, C^5-H)
17a	1680 (CO)	2.95 (3H, s, CH_3), 7.30—7.59 (6H, m, aromatic H), 7.86—8.24 (4H, m, aromatic H)
17f	1680 (CO)	2.98 (3H, s, CH_3), 7.35—8.30 (9H, m, aromatic H)
17j	1670 (CO)	2.97 (3H, s, CH_3), 3.85 (3H, s, OCH_3), 6.90 (2H, d, J=9 Hz, aromatic H), 7.43—7.65 (3H, m), 8.00 (2H, d, J=9 Hz, aromatic H), 8.02—8.38 (2H, m, aromatic H)
18a	1676 (CO)	1.46 (3H, t, J=7 Hz, $CH_2C\underline{H}_3$), 3.21 (2H, q, J=7 Hz, $C\underline{H}_2CH_3$), 7.30—7.60 (6H, m, aromatic H), 7.78—8.29 (4H, m, aromatic H)
18f	1675 (CO)	1.48 (3H, t, J=7 Hz, $CH_2C\underline{H}_3$), 3.25 (2H, q, J=7 Hz, $C\underline{H}_2CH_3$), 7.40—8.30 (m, 9H, aromatic H)
18j	1660 (CO)	1.45 (3H, t, J=8 Hz, $CH_2C\underline{H}_3$), 3.39 (2H, q, J=8 Hz, $C\underline{H}_2CH_3$), 3.78 (3H, s, OCH_3), 6.90 (2H, d, J=8 Hz, aromatic H), 7.48—7.70 (3H, m, aromatic H), 8.02 (2H, d, J=8 Hz, aromatic H), 8.07—8.40 (2H, m, aromatic H)
19a	1663 (CO)	8.01—8.60 (6H, m, aromatic H), 7.39—7.64 (9H, m, aromatic H)
19f	1670 (CO)	7.40—8.60 (14H, m, aromatic H)
19j	1664 (CO)	3.84 (3H, s, OCH_3), 6.80—7.03 (2H, d, J=9 Hz, aromatic H), 7.30—7.59 (6H, m, aromatic H), 7.96 (2H, d, J=9 Hz, aromatic H), 8.26—8.57 (4H, m, aromatic H)
20a	1670 (CO)	7.57 (2H, d, J=9 Hz, aromatic H), 7.43—8.27 (5H, m, aromatic H), 8.25 (2H, d, J=9 Hz, aromatic H), 9.37 (1H, s, C^5-H)
20f	1680 (CO)	7.55 (2H, d, J=9 Hz, aromatic H), 7.62 (2H, d, J=8 Hz, aromatic H), 7.96 (2H, d, J=8 Hz, aromatic H), 8.24 (2H, d, J=9 Hz, aromatic H), 9.34 (1H, s, C^5-H)
20j	1655 (CO)	3.90 (3H, s, OCH_3), 6.97 (2H, d, J=9 Hz, aromatic H), 7.58 (2H, d, J=9 Hz, aromatic H), 8.07 (2H, d, J=9 Hz, aromatic H), 8.28 (2H, d, J=9 Hz, aromatic H), 9.36 (1H, s, C^5-H)
21a	1655 (CO)	3.91 (3H, s, OCH_3), 7.13 (2H, d, J=9 Hz, aromatic H), 7.50—8.40 (5H, m, aromatic H), 8.06 (2H, d, J=9, aromatic H), 9.37 (1H, s, C^5-H)
21f	1680 (CO)	3.91[a] (3H, s, OCH_3), 7.25 (2H, d, J=9 Hz, aromatic H), 7.80 (2H, d, J=8 Hz, aromatic H), 8.02 (2H, d, J=8 Hz, aromatic H), 8.06 (2H, d, J=9 Hz, aromatic H), 9.45 (1H, s, C^5-H)
21j	1660 (CO)	3.90 (6H, s, $OCH_3\times2$), 7.00 (2H, d, J=9 Hz, aromatic H), 7.16 (2H, d, J=9 Hz, aromatic H), 8.06 (4H, d, J=9 Hz, aromatic H), 9.33 (1H, s, C^5-H)

a) Measured in DMSO-d_6.

cooling on ice–H_2O then for 30 min at room temperature. It was poured into ice–H_2O, and the separated solid was collected, washed with H_2O, and dried. The solid was recrystallized from benzene-petroleum benzin to give the corresponding 7-chloro-3-phenyl-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine **14** or **15**.

7-Chloro-3-(4-chlorophenyl)-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine (**14**): Yield 93%. Colorless needles (benzene–petroleum benzin), mp 168—170 °C. *Anal.* Calcd for $C_{10}H_5Cl_2N_5$: C, 45.14; H, 1.89; N, 26.32. Found: C, 45.04; H, 1.92; N, 26.05. ^{1}H-NMR ($CDCl_3$) δ: 7.60 (2H, d, J=9 Hz), 8.26 (2H, d, J=9 Hz), 9.03 (1H, s, C^5-H).

7-Chloro-3-(4-methoxyphenyl)-3*H*-1,2,3-triazolo[4,5-*d*]pyrimidine (**15**): Yield 84%. Colorless needles (benzene–petroleum benzin), mp 145—146 °C. *Anal.* Calcd for $C_{11}H_8ClN_5O$: C, 50.49; H, 3.08; N, 26.76. Found: C, 50.53; H, 3.01; N, 26.75. ^{1}H-NMR ($CDCl_3$) δ: 3.90 (3H, s, OMe), 7.08 (2H, d, J=9 Hz), 8.06 (2H, d, J=9 Hz), 8.97 (1H, s, C^5-H).

Synthesis of 4-Aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines 33—39. General Procedure Sodium hydride (60% in oil, 144 mg, 3.6 mmol) was added to a stirred solution of a 4-chloro-1*H*-pyrazolo[3,4-*d*]pyrimidine (**26**—**32**, 3.0 mmol), an arenecarbaldehyde (**5**, 3.6 mmol), and an azolium salt (**1**, 224 mg, 1.0 mmol or **2**, 272 mg, 1.0 mmol) in THF (20 ml), and the mixture was refluxed with stirring (see Table 2). The reaction mixture was poured into ice–H_2O, and the whole was extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene then $CHCl_3$. The fraction eluted with $CHCl_3$ gave the corresponding ketone **33**—**39**.

Yields and reaction conditions are shown in Table 2. Recrystallization solvent, appearance, melting point, and spectral data for the 4-aroylpyrazolopyrimidines **33**—**39** are shown in Tables 8 and 9.

Preparation of 4-Chloro-1*H*-pyrazolo[3,4-*d*]pyrimidines. General Procedure A mixture of 1*H*-pyrazolo[3,4-*d*]pyrimidin-4(5*H*)-one[7,13] (20 g) and $POCl_3$ (100 ml) was refluxed for 2 h with stirring. The reaction mixture was concentrated under reduced pressure, and the residue was dissolved in a small portion of $CHCl_3$, then the solution was poured into ice–NH_4OH, and the whole was extracted with $CHCl_3$. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on Al_2O_3 with $CHCl_3$ to afford the corresponding 4-chloro-1*H*-pyrazolo[3,4-*d*]pyrimidine **29**, **31**, and **32**. Synthesis of several chloropyrazolopyrimidines (**26**,[7b] **27**,[4b] **28**,[4b] **30**[4b]) has already been reported.

4-Chloro-3-methyl-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**29**): Yield 89%. Colorless powder (petroleum benzin), mp 105—107 °C. *Anal.* Calcd for $C_{12}H_9ClN_4$: C, 58.91; H, 3.71; N, 22.90. Found: C, 59.05; H, 3.67; N, 22.97. ^{1}H-NMR ($CDCl_3$) δ: 2.54 (3H, s, Me), 6.95—8.18 (5H, m, aromatic H), 8.52 (1H, s, C^6-H).

4-Chloro-6-ethyl-1-phenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**31**): Yield 95%. Yellowish needles (petroleum benzin), mp 60—62 °C. *Anal.* Calcd for $C_{13}H_{11}ClN_4$: C, 60.35; H, 4.29; N, 21.66. Found: C, 60.53; H, 4.30; N, 21.70. ^{1}H-NMR ($CDCl_3$) δ: 1.40 (3H, t, J=7 Hz, $CH_2C\underline{H}_3$), 3.05 (2H, q, J=7 Hz, $C\underline{H}_2CH_3$), 7.15—7.55 (3H, m), 7.99 (1H, s, C^3-H), 8.00—8.20 (2H, m).

4-Chloro-1,6-diphenyl-1*H*-pyrazolo[3,4-*d*]pyrimidine (**32**): Yield 68%. Colorless powder (benzene–petroleum benzin), mp 154—156 °C. *Anal.* Calcd for $C_{17}H_{11}ClN_4$: C, 66.56; H, 3.61; N, 18.26. Found: C, 66.39; H, 3.56; N, 18.19. ^{1}H-NMR ($CDCl_3$) δ: 7.20—7.65 (6H, m), 8.20 (1H, s, C^3-H), 8.22—8.60 (4H, m).

Synthesis of 4-Benzoyl-5,6-dimethyl-7-phenyl-7*H*-pyrrolo[2,3-*d*]pyrimidine (43a) by Aroylation with Benzaldehyde Catalyzed by an Azolium Salt 1 or 2 Imidazolium Salt (**1**): Sodium hydride (60% in oil, 160 mg, 4.0 mmol) was added to a mixture of 4-chloro-5,6-dimethyl-7-phenyl-7*H*-pyrrolo[2,3-*d*]pyrimidine (**40**,[4b] 773 mg, 3.0 mmol), benzaldehyde (**5a**, 382 mg, 3.6 mmol), and the imidazolium salt (**1**, 224 mg, 1.0 mmol) in DMF (20 ml), and the mixture was stirred at 120 °C for 15 min. The reaction mixture was poured into ice–H_2O and extracted with AcOEt.

Table 8. Formula, Melting Points, Elemental Analyses, and MS Data for 4-Aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines **33**—**39**

Compd.	mp (°C)	Appearance (Recrystallization solvent)	Formula	Analysis (%), Calcd (Found)			MS (*m/z*) M^+
				C	H	N	
33a	126—127	Yellow needles (Petroleum benzin)	$C_{14}H_{12}N_4O$	66.65 (66.64)	4.79 (4.88)	22.21 (22.07)	252
33d	98—99	Yellow granules (Petroleum benzin)	$C_{14}H_{11}FN_4O$	62.22 (62.72)	4.10 (4.12)	20.73 (20.42)	270
33j	137—138	Yellow needles (Petroleum benzin)	$C_{15}H_{14}N_4O_2$	63.82 (63.72)	5.00 (5.02)	19.85 (19.77)	282
34a	71—72	Yellow needles (Petroleum benzin)	$C_{15}H_{14}N_4O$	67.65 (67.72)	5.30 (5.28)	21.04 (21.09)	266
34j	131—131.5	Yellow needles (Petroleum benzin)	$C_{16}H_{16}N_4O_2$	64.85 (64.91)	5.44 (5.40)	18.91 (18.81)	296
35a	109—110	Yellow needles (Petroleum benzin)	$C_{19}H_{14}N_4O$	72.60 (72.70)	4.49 (4.49)	17.82 (17.29)	314
35d	115—117	Colorless needles (Petroleum benzin)	$C_{19}H_{13}FN_4O$	68.67 (68.40)	3.94 (4.13)	16.86 (16.71)	332
35j	135—136	Yellow needles (MeOH)	$C_{20}H_{16}N_4O_2$	69.76 (69.78)	4.68 (4.73)	16.27 (16.40)	344
36a	114—115.5	Yellow needles (MeOH)	$C_{19}H_{14}N_4O$	72.60 (72.69)	4.49 (4.60)	17.83 (17.69)	314
36j	180—181	Yellow needles (MeOH)	$C_{20}H_{16}N_4O_2$	69.75 (69.67)	4.68 (4.65)	16.27 (16.40)	344
36n	138—138.5	Yellow needles (MeOH)	$C_{17}H_{12}N_4OS$	63.73 (63.75)	3.78 (3.73)	17.49 (17.50)	320
37a	124—125	Yellow needles (MeOH)	$C_{19}H_{14}N_4O$	72.60 (72.36)	4.49 (4.44)	17.83 (17.94)	314
37b	139.5—140	Yellow needles (MeOH)	$C_{19}H_{13}FN_4O$	68.67 (68.70)	3.94 (3.97)	16.86 (16.91)	332
37c	94—96	Yellow needles (MeOH)	$C_{19}H_{13}FN_4O$	68.67 (68.41)	3.94 (3.88)	16.86 (16.93)	332
37d	123—123.5	Yellow needles (MeOH)	$C_{19}H_{13}FN_4O$	68.67 (68.62)	3.94 (3.94)	16.86 (16.80)	332
37i	110.5—112	Yellow needles (MeOH)	$C_{20}H_{16}N_4O_2$	69.75 (69.41)	4.68 (4.60)	16.27 (16.26)	344
37j	153.5—155	Orange needles (MeOH)	$C_{20}H_{16}N_4O_2$	69.75 (69.50)	4.68 (4.60)	16.27 (16.04)	344
37n	178.5—179	Yellow needles (MeOH)	$C_{17}H_{12}N_4OS$	63.73 (63.52)	3.78 (3.72)	17.49 (17.50)	320
38a	107—108	Yellow needles (MeOH)	$C_{20}H_{16}N_4O$	73.15 (73.52)	4.91 (4.91)	17.06 (16.64)	328
38j	108—109	Yellow needles (Petroleum benzin)	$C_{21}H_{18}N_4O_2$	70.38 (70.51)	5.06 (5.11)	15.63 (15.39)	358
38n	158—159	Yellow needles (MeOH)	$C_{18}H_{14}N_4OS$	64.65 (64.58)	4.22 (4.19)	16.75 (16.68)	334
39a	153—153.5	Yellow needles (MeOH)	$C_{24}H_{16}N_4O$	76.58 (76.45)	4.28 (4.19)	14.89 (14.85)	376
39d	178—179	Yellow needles (MeOH)	$C_{24}H_{15}FN_4O$	73.09 (72.60)	3.83 (3.75)	14.21 (13.75)	394
39i	166—167	Yellow needles (MeOH)	$C_{25}H_{18}N_4O_2$	73.87 (74.01)	4.46 (4.35)	13.79 (13.83)	406
39j	178—180	Yellow needles (MeOH)	$C_{25}H_{18}N_4O_2$	73.87 (74.03)	4.46 (4.37)	13.79 (13.61)	406
39m	225—226	Orange needles (MeOH)	$C_{22}H_{14}N_4O_2$	72.12 (71.84)	3.85 (3.87)	15.29 (15.14)	366
39n	226—227	Yellow needles (MeOH)	$C_{22}H_{14}N_4OS$	69.09 (68.83)	3.69 (3.60)	14.65 (14.58)	382

The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene to afford 4-benzoyl-5,6-dimethyl-7-phenyl-7*H*-pyrrolo[2,3-*d*]pyrimidine (**43a**) in 62% yield (608 mg).

Benzimidazolium Salt (**2**): The same reaction using 1,3-dimethylbenzimidazolium iodide (**2**, 274 mg, 1.0 mmol) instead of **1** was carried out (120 °C, 1 h). Work-up as described above gave the recovered starting 40 in 42% yield.

Synthesis of 4-Aroyl-5,6-dimethyl-7-phenyl-7*H*-pyrrolo[2,3-*d*]pyrimidines 43—45 by Double-Catalytic Aroylation Using 1,3-Dimethylimidazolium Iodide (1) and Sodium *p*-Toluenesulfinate (46). General Procedure Sodium hydride (60% in oil, 144 mg, 3.6 mmol) was added to a mixture of a 4-chloropyrrolo[2,3-*d*]pyrimidine (**40**—**42**,[4b] 3.0 mmol), an arenecarbaldehyde (**5**, 3.6 mmol), sodium *p*-toluenesulfinate (**46**, 178 mg, 1.0 mmol), and the imidazolium salt (**1**, 224 mg, 1.0 mmol) in DMF (20 ml), and the whole was stirred under appropriate conditions (see Chart 7). The reaction mixture was poured into ice–H_2O and extracted with AcOEt. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene and/or $CHCl_3$. The fraction eluted with $CHCl_3$ gave the corresponding 4-aroyl-5,6-dimethyl-7-phenyl-7*H*-pyrrolo[2,3-*d*]pyrimidine (**43**—**45**). These results are shown in Chart 7. Appearance, spectral data, and elemental analyses for the aroylpyrazolopyrimidines (**43**—**45**) are shown in Tables 10 and 11.

Table 9. IR and ^{1}H-NMR Spectral Data for 4-Aroyl-1*H*-pyrazolo[3,4-*d*]pyrimidines **33**—**39**

Compd.	IR (KBr) cm^{-1}	^{1}H-NMR ($CDCl_3$) δ
33a	1670 (CO)	2.91 (3H, s, Me), 4.14 (3H, s, N-Me), 7.47—7.63 (3H, m, aromatic H), 8.23 (2H, m, aromatic H), 8.33 (1H, s, C^3-H).
33d	1670 (CO)	2.92 (3H, s, Me), 4.15 (3H, s, N-Me), 7.16—7.29 (2H, m), 8.33—8.38 (3H, m)
33j	1660 (CO)	2.91 (3H, s, Me), 3.89 (3H, s, OMe), 4.13 (3H, s, N-Me), 6.97 (2H, dd, J=9, 2 Hz, aromatic H), 8.27 (2H, dd, J=9, 2 Hz, aromatic H), 8.31 (1H, s, C^3-H)
34a	1650 (CO)	1.47 (3H, t, J=8 Hz, $CH_2C\underline{H}_3$), 3.16 (2H, q, J=8 Hz, $C\underline{H}_2CH_3$), 4.11 (3H, s, N-Me), 7.25—7.55 (3H, m, aromatic H), 8.15—8.20 (2H, m, aromatic H), 8.32 (1H, s, C^3-H)
34j	1645 (CO)	1.45 (3H, t, J=8 Hz, $CH_2C\underline{H}_3$), 3.12 (2H, q, J=8 Hz, $C\underline{H}_2CH_3$), 3.81 (3H, s, OMe), 4.07 (3H, s, N-Me), 6.81—6.93 (2H, m, aromatic H), 8.12—8.21 (2H, m, aromatic H), 8.28 (1H, s, C^3-H)
35a	1670 (CO)	4.16 (3H, s, N-Me), 7.30—7.60 (6H, m, aromatic H), 8.38 (1H, s, C^3-H), 8.20—8.60 (4H, m, aromatic H)
35d	1670 (CO)	3.95 (3H, s, N-Me), 6.93—8.31 (9H, m, aromatic H), 8.18 (1H, s, C^3-H)
35j	1660 (CO)	3.84 (3H, s, OMe), 4.14 (3H, s, N-Me), 6.96 (2H, d, J=8 Hz, aromatic H), 7.31—7.42 (3H, m, aromatic H), 8.31 (2H, d, J=8 Hz, aromatic H), 8.30 (1H, s, C^3-H), 8.39—8.55 (2H, m, aromatic H)
36a	1665 (CO)	2.50 (3H, s, Me), 7.10—7.55 (6H, m, aromatic H), 7.79—8.16 (4H, m, aromatic H), 8.96 (1H, s, C^6-H)
36j	1655 (CO)	2.48 (3H, s, Me), 3.80 (3H, s, OMe), 6.80—7.42 (5H, m, aromatic H), 7.80—8.16 (4H, m, aromatic H), 8.98 (1H, s, C^6-H)
36n	1640 (CO)	2.70 (3H, s, Me), 7.01—7.80 (5H, m, aromatic H), 7.93—8.25 (3H, m, aromatic H), 9.00 (1H, s, C^6-H)
37a	1660 (CO)	2.89 (3H, s, Me), 7.12—7.60 (6H, m, aromatic H), 8.05—8.28 (4H, m, aromatic H), 8.38 (1H, s, C^3-H)
37b	1670 (CO)	2.85 (3H, s, Me), 6.85—7.92 (7H, m, aromatic H), 8.07—8.30 (2H, m, aromatic H), 8.44 (1H, s, C^3-H)
37c	1660 (CO)	2.85 (3H, s, Me), 6.95—7.54 (5H, m, aromatic H), 7.73—8.21 (4H, m, aromatic H), 8.37 (1H, s, C^3-H)
37d	1660 (CO)	2.90 (3H, s, Me), 6.91—7.61 (5H, m, aromatic H), 8.05—8.38 (4H, m, aromatic H), 8.41 (1H, s, C^3-H)
37i	1660 (CO)	2.90 (3H, s, Me), 3.80 (3H, s, OMe), 7.06—7.82 (7H, m, aromatic H), 8.03—8.25 (2H, m, aromatic H), 8.37 (1H, s, C^3-H)
37j	1650 (CO)	2.92 (3H, s, Me), 3.83 (3H, s, OMe), 6.86 (2H, d, J=8.4 Hz, aromatic H), 6.83—7.49 (3H, m, aromatic H), 8.16 (2H, d, J=8.4 Hz, aromatic H), 8.04—8.22 (2H, m, aromatic H), 8.35 (1H, s, C^3-H)
37n	1650 (CO)	2.93 (3H, s, Me), 7.02—7.37 (5H, m, aromatic H), 8.01—8.45 (3H, m, aromatic H), 8.61 (1H, s, C^3-H)
38a	1660 (CO)	1.55 (3H, t, J=8 Hz, $CH_2C\underline{H}_3$), 3.25 (2H, q, J=8 Hz, $C\underline{H}_2CH_3$), 7.22—7.66 (6H, m, aromatic H), 8.13-8.40 (4H, m, aromatic H), 8.49 (1H, s, C^3-H)
38j	1640 (CO)	1.53 (3H, t, J=7.8 Hz, $CH_2C\underline{H}_3$), 3.23 (2H, q, J=7.8 Hz, $C\underline{H}_2CH_3$), 3.89 (3H, s, OMe), 6.77—7.66 (5H, m, aromatic H), 8.10—8.38 (4H, m, aromatic H), 8.44 (1H, s, C^3-H)
38n	1640 (CO)	1.60 (3H, t, J=7.8 Hz, $CH_2C\underline{H}_3$), 3.30 (2H, q, J=7.8 Hz, $C\underline{H}_2CH_3$), 7.03—7.80 (5H, m, aromatic H), 8.11—8.50 (3H, m, aromatic H), 8.69 (1H, s, C^3-H)
39a	1660 (CO)	7.07—7.60 (10H, m, aromatic H), 8.10—8.42 (5H, m, aromatic H), 8.44 (1H, s, C^3-H)
39d	1670 (CO)	6.97—7.91 (7H, m, aromatic H), 8.10—8.53 (8H, m, aromatic H)
39i	1660 (CO)	3.82 (3H, s, OMe), 7.02—8.52 (14H, m, aromatic H), 8.48 (1H, s, C^3-H)
39j	1650 (CO)	3.80 (3H, s, OMe), 6.86 (2H, d, J=8.8 Hz, aromatic H), 6.82—7.60 (6H, m, aromatic H), 8.25 (2H, d, J=8.8 Hz, aromatic H), 8.12—8.52 (4H, m, aromatic H), 8.42 (1H, s, C^3-H)
39m	1650 (CO)	6.75 (1H, dd, J=3.6, 1.8 Hz), 7.34—8.40 (12H, m, aromatic H), 8.75 (1H, s, C^3-H)
39n	1650 (CO)	7.10—8.46 (13H, m, aromatic H), 8.67 (1H, s, C^3-H)

Synthesis of 5,6-Dimethyl-7-phenyl-4-tosyl-7*H*-pyrrolo[2,3-*d*]pyrimidine (47) A solution of 4-chloropyrrolopyrimidine (**40**, 1032 mg, 4.0 mmol) and sodium *p*-toluenesulfinate (**46**, 1460 mg, 8.2 mmol) in DMF (20 ml) was stirred at 120 °C for 1 h. The reaction mixture was poured into ice–H_2O and extracted with AcOEt. The organic layer was washed with brine, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene to afford 5,6-dimethyl-7-phenyl-4-tosyl-7*H*-pyrrolo[2,3-*d*]pyrimidine (**47**) in 69% yield (1019 mg). Colorless needles (benzene–petroleum benzin), mp 209—210 °C. *Anal.* Calcd for $C_{21}H_{19}N_3O_2S$: C, 66.82; H, 5.07; N, 11.13. Found: C, 66.70; H, 5.13; N, 11.11. IR (KBr) cm^{-1}: 1310, 1150 (SO_2). ^{1}H-NMR ($CDCl_3$) δ: 2.31 (3H, s, Me), 2.46 (3H, s, Me), 2.70 (3H, s, Me), 7.15—7.60 (7H, m, aromatic H), 7.90 (2H, d, J=9 Hz, aromatic H), 8.50 (1H, s, C^2-H).

Reaction of the 4-Tosylpyrrolopyrimidine 47 with Benzaldehyde (5a) Catalyzed by Imidazolium Salt 1 Sodium hydride (60% in oil, 144 mg, 3.6 mmol) was added to a mixture of 5,6-dimethyl-7-phenyl-4-tosyl-7*H*-pyrrolo[2,3-*d*]pyrimidine (**47**, 1131 mg, 3.0 mmol), benzaldehyde (**5a**, 382 mg, 3.6 mmol), and the imidazolium salt (**1**, 224 mg, 1.0 mmol) in DMF (20 ml), and the whole was stirred at 120 °C for 30 min. The reaction mixture was poured into ice–H_2O and extracted with AcOEt. The organic layer was washed with H_2O, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on SiO_2 with benzene to afford 4-benzoyl-5,6-dimethyl-7-phenyl-7*H*-pyrrolo[2,3-*d*]pyrimidine (**43a**) in 92% yield (903 mg).

References and Notes

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Table 10. Formula, Melting Points, MS Data, and Elemental Analyses for the 4-Aroyl-7-phenyl-7*H*-pyrrolo[2,3-*d*]pyrimidines **43**—**45**

Compd.	mp (°C)	Appearance (Recrystallization solvent)	Formula	Analysis (%), Calcd (Found)			MS (*m*/*z*) M^+
				C	H	N	
43a	142—144	Yellow needles (Petroleum benzin)	$C_{21}H_{17}N_3O$	77.14 (76.98)	5.23 (5.16)	12.79 (12.79)	327
43e	180	Yellow needles (MeOH)	$C_{21}H_{16}ClN_3O$	69.71 (69.77)	4.46 (4.51)	11.61 (11.31)	
43g	156—157	Yellow scales (Petroleum benzin)	$C_{22}H_{19}N_3O$	77.40 (77.24)	5.61 (5.49)	12.31 (12.20)	
43j	130—132	Yellow needles (Petroleum benzin)	$C_{22}H_{19}N_3O_2$	73.93 (74.12)	5.36 (5.29)	11.76 (11.69)	
43l	160—161	Yellow needles (Petroleum benzin)	$C_{22}H_{17}N_3O_3$	71.15 (71.32)	4.61 (4.50)	11.31 (11.26)	
43n	122—124	Yellow needles (Petroleum benzin)	$C_{19}H_{15}N_3OS$	68.45 (68.41)	4.53 (4.51)	12.60 (12.48)	
44a	113—117	Yellow needles (Petroleum benzin)	$C_{22}H_{19}N_3O$	77.39 (77.12)	5.61 (5.63)	12.31 (12.15)	341
45a		Yellowish oil	$C_{23}H_{21}N_3O$				355
45e		Yellowish oil	$C_{23}H_{20}ClN_3O$				389
45j	103—105	Yellow granules (petroleum benzin)	$C_{24}H_{23}N_3O_2$	74.78 (74.77)	6.01 (5.93)	10.90 (10.68)	

Table 11. IR and ^{1}H-NMR Spectral Data for the 4-Aroyl-7-phenyl-7*H*-pyrrolo[2,3-*d*]pyrimidines **43**—**45**

Compd.	IR (KBr) cm^{-1}	^{1}H-NMR ($CDCl_3$) δ
43a	1668 (CO)	2.32 (3H, s, Me), 2.43 (3H, s, Me), 7.34—7.82 (8H, m, aromatic H), 8.06—8.27 (2H, m, aromatic H), 8.96 (1H, s, C^2-H)
43e	1665 (CO)	2.17 (3H, s, Me), 2.27 (3H, s, Me), 7.20—7.60 (7H, m, aromatic H), 7.95 (2H, d, J=8 Hz, aromatic H), 8.75 (1H, s, C^2-H)
43g	1662 (CO)	2.15 (3H, s, Me), 2.27 (3H, s, Me), 2.43 (3H, s, Me), 7.29—7.65 (7H, m, aromatic H), 7.92 (2H, d, J=8 Hz, aromatic H), 8.83 (1H, s, C^2-H)
43j	1650 (CO)	2.13 (3H, s, Me), 2.24 (3H, s, Me), 3.86 (3H, s, OMe), 6.91 (2H, d, J=9 Hz, aromatic H), 7.28—7.60 (5H, m, aromatic H), 7.95 (2H, d, J=9 Hz, aromatic H), 8.77 (1H, s, C^2-H)
43l	1655 (CO)	2.14 (3H, s, Me), 2.27 (3H, s, Me), 6.05 (2H, s, CH_2), 6.84 (1H, d, J=8 Hz, aromatic H), 7.31—7.65 (7H, m, aromatic H), 8.79 (1H, s, C^2-H)
43n	1650 (CO)	2.25 (6H, s, 2×Me), 7.00—7.90 (8H, m, aromatic H), 8.76 (1H, s, C^2-H).
44a	1680 (CO)	2.10 (3H, s, Me), 2.25 (3H, s, Me), 2.70 (3H, s, Me), 7.20—8.10 (10H, m, aromatic H)
45a	1670 (CO)	1.30 (3H, t, J=7 Hz, $CH_2C\underline{H}_3$), 2.20 (3H, s, Me), 2.22 (3H, s, Me), 2,96 (2H, q, J=7 Hz, $C\underline{H}_2CH_3$), 7.23—8.10 (10H, m, aromatic H)
45e	1670 (CO)	1.26 (3H, t, J=8 Hz, $CH_2C\underline{H}_3$), 2.08 (3H, s, Me), 2.20 (3H, s, Me), 2.92 (2H, q, J=8 Hz, $C\underline{H}_2CH_3$), 7.20—8.02 (9H, m, aromatic H)
45j	1660 (CO)	1.32 (3H, t, J=8 Hz, $CH_2C\underline{H}_3$), 2.10 (3H, s, Me), 2.23 (3H, s, Me), 2.48 (2H, q, J=8 Hz, $C\underline{H}_2CH_3$), 3.90 (3H, s, OMe), 6.90—8.08 (9H, m, aromatic H)

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