Fused Pyrimidines by a Tandem Aza-Wittig/Electrocyclic Ring Closure Strategy: Synthesis of Pyrazolo[3,4-*d*]pyrimidine, [1,2,3]Triazolo[4,5-*d*]pyrimidine, and Thiazolo[4,5-*d*]pyrimidine Derivatives

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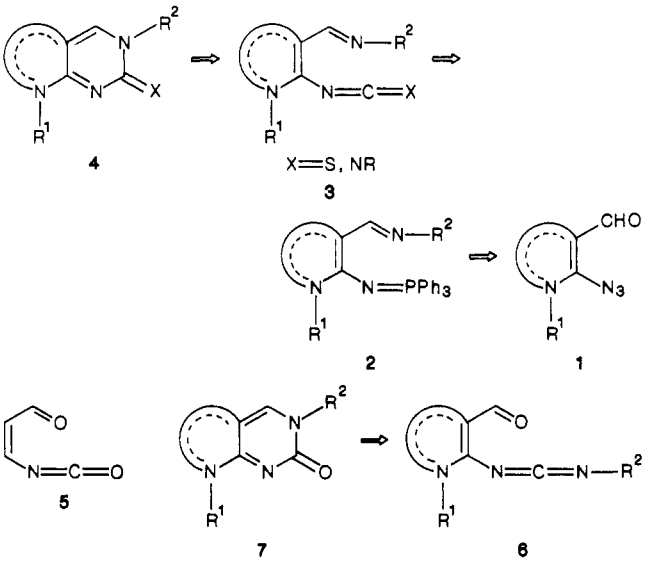
The aza-Wittig reaction of iminophosphoranes derived from 5-azido-4-formylazoles or 4-azido-5-formylazoles with heterocumulenes leads to functionalized fused pyrimidines. Iminophosphoranes **12**, derived from 5-azido-4-formylpyrazole, react under mild conditions with isocyanates, carbon disulfide, and carbon dioxide to give the pyrazolo[3,4-*d*]pyrimidines **14**, **17**, and **19** respectively. Compounds **19** can also be prepared from iminophosphorane **11** and isocyanates. In methylene chloride at room temperature, iminophosphoranes **12** react with acyl chlorides to form pyrazolo[3,4-*d*]pyridinium salts **20**. Iminophosphoranes derived from 5-azido-4-formyl-[1,2,3]triazole, react with isocyanates to yield [1,2,3]triazolo[4,5-*d*]pyrimidines **25**. Similarly, iminophosphoranes **33**, derived from 4-azido-5-formylthiazole, react with isocyanates and carbon disulfide to form thiazolo[4,5-*d*]-pyrimidines **35** and **36**. The 5-formyl-2-phenyl-4-[(triphenylphosphoranylidene)amino]thiazole **37** reacts with aromatic isocyanates, yielding 6-aryl-5-oxo-5,6-dihydrothiazolo[4,5-*d*]pyrimidines **39**.

The structural diversity and biological importance of fused pyrimidines have made them attractive targets for synthesis over many years. Recent development of physiologically highly potent purine analogues with interesting (antiviral, antiallergic, radioprotective, and specially anticancer) activities have promoted a great current interest in facile and general routes to these molecules in synthetically useful yields.

The two most important approaches for the synthesis of pyrazolo[3,4-*d*]pyrimidines involve annulation of a pyrimidine ring onto the preformed pyrazole ring. The first route involves reactions of 5-amino-4-cyanopyrazoles with carbon disulfide,[1] thioamide[2], nitriles,[3] guanidine,[4] and formamide or ureas,[5] in some cases the amino group is previously converted into an ethoxymethylene[6] or an acylamino group.[7] The second approach involves reaction of formamides, ureas, or thioureas with 4-amido-5-aminopyrazoles[8] or 5-amino-4-(ethoxycarbonyl)pyrazoles.[9] Similarly, the most attractive methods for the preparation of [1,2,3]triazolo[4,5-*d*]pyrimidines are based on the annulation of a pyrimidine ring onto an existing [1,2,3]triazole ring, and they have been comprehensively reviewed.[10] No generally useful procedures for the preparation of thiazolo[4,5-*d*]pyrimidines have been reported. It has been briefly mentioned[11] that the reaction of 4-amino-5-amidothiazoles with orthoformates in the presence of acetic anhydride leads to the desired thiazolo[4,5-*d*]pyrimidines.

The aza-Wittig reaction of iminophosphoranes with

Chart I



heterocumulenes, e.g. carbon dioxide, carbon disulfide, and isocyanates, or isothiocyanates is a very useful reaction in synthetic heterocyclic chemistry.[12] Consequently, improvements that increase the efficiency or enlarge its applicability are desirable, and the discovery of novel functionalized iminophosphoranes bearing a moiety able to react with the aza-Wittig product is important in this respect.[13]

In the course of our studies directed toward the synthesis of fused heterocycles, we had occasion to explore heterocyclization reactions of carbodiimides and isothiocyanates.[14] We now report a fundamentally new approach

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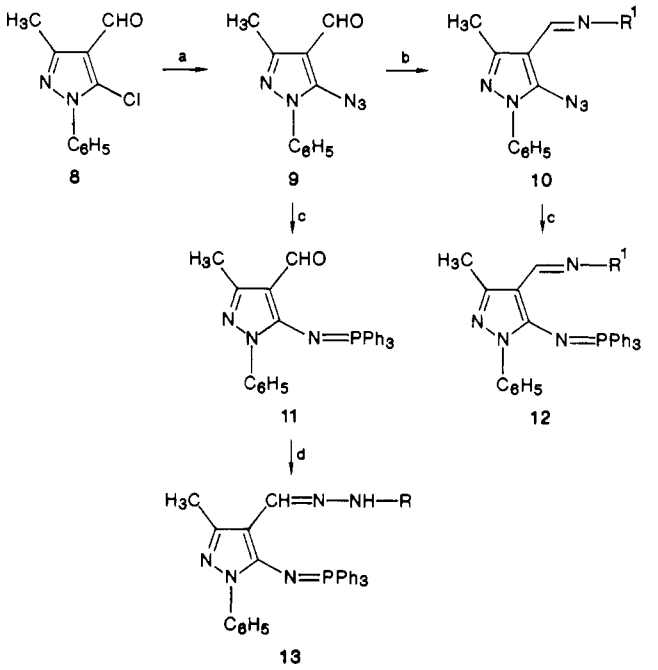
Scheme I[a]



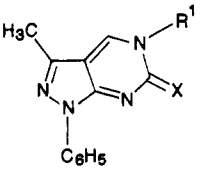
[a] (a) NaN_3, DMSO, 60 °C; (b) R^1NH_2, EtOH, room temperature; (c) Ph_3P, CH_2Cl_2, room temperature; (d) $RNHNH_2$, EtOH, AcOH, room temperature.

to the synthesis of pyrazolo[3,4-*d*]pyrimidines, [1,2,3]triazolo[4,3-*d*]pyrimidines(8-azapurines), and thiazolo[4,5-*d*]pyrimidines. Our approach is centered on the aza-Wittig reaction of iminophosphoranes with heterocumulenes to give a 1,3,5-hexatriene moiety containing a nitrogen atom at one end and cumulated double bond at the other, which subsequently undergoes electrocyclic ring closure to give the cyclic valence tautomer pyrimidine ring. Relatively few examples of thermal induced 6π-electrocyclizations of conjugated heterocumulenes have been documented; it has only been mentioned for the thermal cyclization of β-carbamoylvinyl isocyanates[15] type **5**, (1*Z*)-1,3-diene isocyanates,[16] styryl isocyanates,[17] and β-substituted vinyl ketenes.[18] In each case the heterocumulene was intermediate in a complex reaction sequence and was not isolated. We report here the first preparation, isolation, and cyclization of systems of type **3**, in which the central carbon–carbon double bond belongs to an heteroaromatic ring. We also wish to report the preparation of system of type **6** and its cyclization to a pyrimidine ring **7** (Chart I).

Results and Discussion

A. Preparation of Pyrazolo[3,4-*d*]pyrimidines. The 5-chloro-4-formylpyrazole **8** was prepared by a previously reported procedure.[19] Compound **8** reacts with sodium azide in dimethyl sulfoxide at 60 °C to give the 5-azido-4-formylpyrazole **9** in 67% yield, which by treatment with aromatic amines in ethanol at room temperature leads to the corresponding 5-azidopyrazoles **10** (Scheme I). The preparation of the desired iminophosphoranes **11** and **12** was accomplished very easily through the classical Staudinger reaction[20] of 5-azidopyrazoles **9** and **10** with triphenylphosphine in dry methylene chloride at room temperature; iminophosphorane **13** was prepared from **11** and (*p*-nitrophenyl)hydrazine.

Table I. Pyrazolo[3,4-*d*]pyrimidines



compd	R^1	X	yield, %	mp, °C
14a	C_6H_5	C_2H_5N	63	178–179
14b	C_6H_5	$CH_2{=}CHCH_2N$	72	158–159
14c	C_6H_5	3-Cl-C_6H_4N	65	193–195
14d	C_6H_5	4-Cl-C_6H_4N	65	166–167
14e	C_6H_5	4-H_3CO-C_6H_4N	67	119–120
14f	4-H_3C-C_6H_4	C_2H_5N	61	120–121
14g	4-H_3C-C_6H_4	$CH_2{=}CHCH_2N$	60	129–130
14h	4-H_3C-C_6H_4	4-Cl-C_6H_4N	62	199–200
14i	4-H_3C-C_6H_4	4-H_3CO-C_6H_4N	70	132–134
15a	4-O_2N-C_6H_4	C_6H_5N	45	221–222
15b	4-O_2N-C_6H_4	3-Cl-C_6H_4N	42	301–302
15c	4-O_2N-C_6H_4	4-Cl-C_6H_4N	40	290–292
17a	C_6H_5	S	97	141–142
17b	4-H_3C-C_6H_4	S	75	152–153
19a	C_6H_5	O	50	223–224
19b	4-H_3C-C_6H_4	O	59	239–240
19c	4-H_3CO-C_6H_4	O	49	232–233
19d	4-Cl-C_6H_4	O	40	244–245

The reaction of iminophosphoranes **12** with isocyanates in dry methylene chloride at room temperature gave triphenylphosphine oxide and the corresponding pyrazolo[3,4-*d*]pyrimidines **14**, the yield of the isolated product being higher than 60%. Similarly, iminiphosphorane **13** reacted with isocyanates in dry toluene at reflux temperature to give the pyrazolo[3,4-*d*]pyrimidines **15** in moderate yields (Scheme II). We believe that the mechanisms of these conversions involve initial aza-Wittig reaction between the iminophosphorane and the isocyanate to give a carbodiimide[21] as highly reactive intermediate, which easily undergoes electrocyclic ring closure to give the fused pyrimidine. This assumption is supported by the isolation of the intermediate carbodiimides in the reaction of iminophosphorane **13** with isocyanates in dry methylene chloride at room temperature.

When iminophosphoranes **12** were treated with carbon disulfide in dry methylene chloride at room temperature, pyrimidines **17** were formed in high yields. The mechanisms of the conversion **12** → **17** is supported by the isolation in some cases of the isothiocyanate **16**, which by heating in dry toluene at reflux temperature was converted into the corresponding fused pyrimidine in nearly quantitative yield (Table I).

Reaction of iminophosphorane **11** with isocyanates in dry toluene at reflux temperature resulted in the formation of the corresponding pyrazolo[3,4-*d*]pyrimidines **19** directly in moderate yields. Presumably, the **11** → **19** conversion involves initial aza-Wittig reaction between imino-

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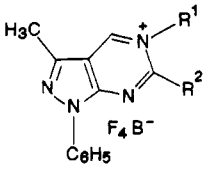
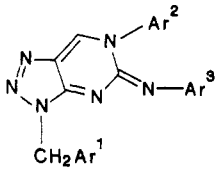
Table II. Pyrazolo[3,4-*d*]pyridinium Tetrafluoroborates (20)



compd	R^1	R^2	yield, %	mp, °C
20a	C_6H_5	C_2H_5	45	193–194
20b	C_6H_5	4-H_3C-C_6H_4	50	199–200
20c	C_6H_5	4-H_3CO-C_6H_4	56	208–209
20d	C_6H_5	4-Cl-C_6H_4	54	249–250
20e	4-H_3C-C_6H_4	C_2H_5	46	177–178
20f	4-H_3C-C_6H_4	4-H_3CO-C_6H_4	56	243–244
20g	4-H_3C-C_6H_4	4-Cl-C_6H_4	52	195–196

Table III. [1,2,3]Triazolo[4,5-*d*]pyrimidines (25)



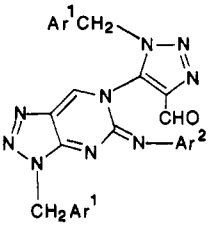
compd	Ar^1	Ar^2	Ar^3	yield, %	mp, °C
25a	4-CH_3O-C_6H_4	C_6H_5	4-Cl-C_6H_4	50	153–154
25b	4-CH_3O-C_6H_4	4-H_3C-C_6H_4	4-Cl-C_6H_4	71	131–132
25c	4-CH_3O-C_6H_4	4-H_3C-C_6H_4	4-CH_3O-C_6H_4	61	124–125

phosphorane **11** and isocyanate to give a carbodiimide, which undergo electrocyclic ring closure to give an unstable 1,3-oxazine-2-imine **18**, which by a typical Dimroth rearrangement undergoes ring opening and closure to furnish **19**. Limited success was met upon treatment of **11** with isocyanates in dry methylene chloride at room temperature, this gave **19** in a disappointing yield of 15%. However compounds **19** were also prepared in good yields from iminophosphoranes **12** and carbon dioxide at 90 °C in a sealed glass tube.

On the other hand, the reaction of iminophosphoranes **12** with acyl chlorides in dry methylene chloride at room temperature gave the corresponding pyrazolo[3,4-*d*]pyrimidinium salts **20** in good yields, (Table II). Presumably the **12** → **20** transformation involves the initial formation of an imidoyl chloride[22] as intermediate and subsequent cyclization by intramolecular nucleophilic attack of the nitrogen atom of the aldimine group would give the corresponding pyrazolo[3,4-*d*]pyrimidinium salts **20**.

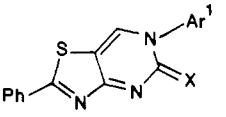
B. Preparation of [1,2,3]Triazolo[4,5-*d*]pyrimidines. 5-Chloro-4-formyl-1-(*p*-methoxybenzyl)-1*H*-[1,2,3]triazole (**21**) was prepared by a previously reported procedure.[23] Compound **21** reacted with sodium azide in dimethyl sulfoxide at 60 °C to give 5-azido-4-formyl-1-(*p*-methoxybenzyl)-1*H*-[1,2,4]triazole (**22**) in 89% yield, which by treatment with aromatic amines in ethanol at room temperature gave the corresponding 5-azido[1,2,3]-triazoles **23** (Scheme III). Compound **23** reacted with triphenylphosphine in dry methylene chloride at room temperature to give the iminophosphorane **24** in 77–94% yields. The reaction of iminophosphoranes **24** with several aromatic isocyanates at room temperature directly gave [1,2,3]triazolo[4,5-*d*]pyrimidines **25** in good yields (Table III). The carbodiimide was indeed an intermediate in this reaction (as evidenced by IR) but was never present in high concentration. Iminophosphoranes **24**, however, proved to be recalcitrant to cyclization by reaction with carbon disulfide. It failed to form the [1,2,3]triazolo[4,5-*d*]pyrimidines **26**.

Table IV. [1,2,3]Triazolo[4,5-*d*]pyrimidines (29)



compd	Ar^1	Ar^2	yield, %	mp, °C
29a	4-CH_3O-C_6H_4	C_6H_5	32	212–213
29b	4-CH_3O-C_6H_4	4-H_3C-C_6H_4	33	239–240
29c	4-CH_3O-C_6H_4	4-H_3CO-C_6H_4	31	240–241
29d	4-CH_3O-C_6H_4	4-Cl-C_6H_4	36	235–236

Table V. Thiazolo[4,5-*d*]pyrimidines



compd	Ar^1	X	yield, %	mp, °C
35a	C_6H_5	4-CH_3-C_6H_4N	60	177–178
35b	C_6H_5	4-CH_3O-C_6H_4N	62	196–199
35c	4-CH_3-C_6H_4	4-CH_3-C_6H_4N	66	202–204
35d	4-CH_3-C_6H_4	4-CH_3O-C_6H_4N	65	210–212
36a	C_6H_5	S	54	198
36b	4-CH_3-C_6H_4	S	50	150–151
39a	C_6H_5	O	73	200–201
39b	4-CH_3-C_6H_4	O	70	188–189
39c	4-CH_3O-C_6H_4	O	69	215–216

On the other hand, the iminophosphorane **27**, available from **22** and triphenylphosphine, does not react with isocyanates in methylene chloride at room temperature; however, it reacts with aromatic isocyanates in dry toluene at reflux temperature to give the tricyclic compounds **29** (Scheme IV, Table IV).

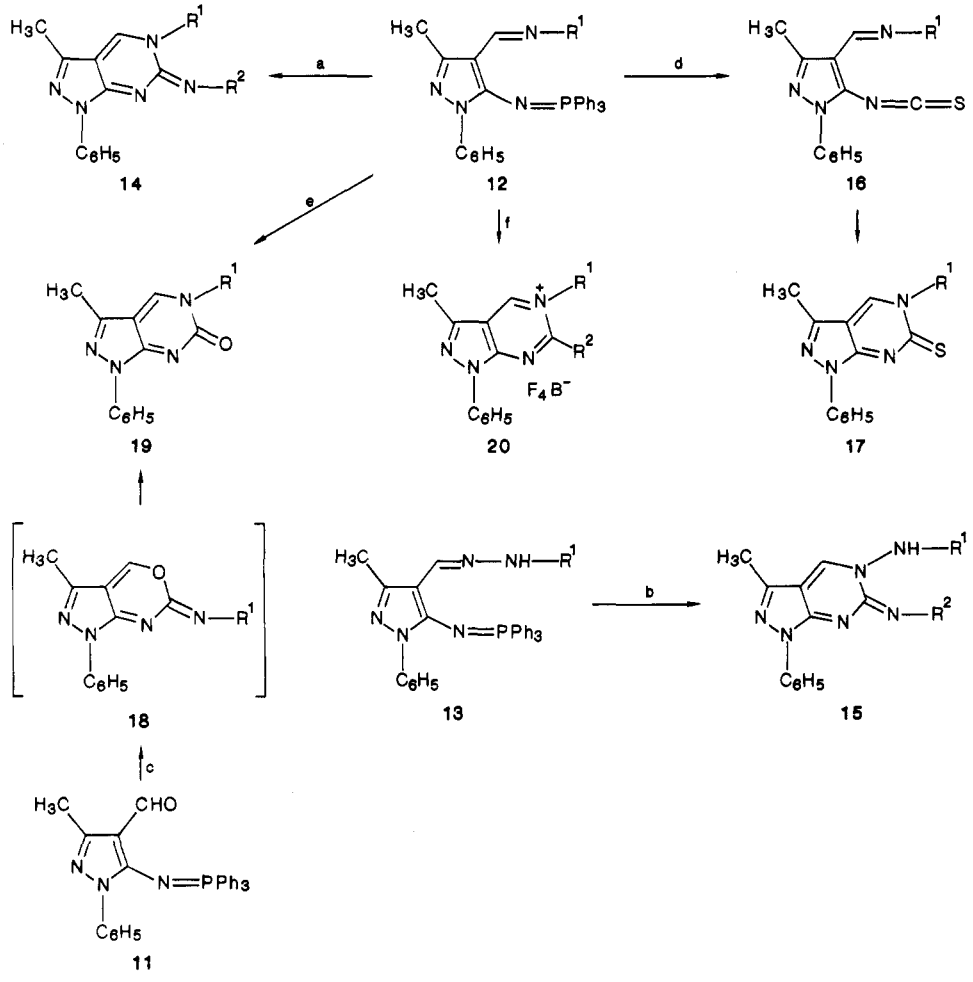
This conversion can be understood by an initial aza-Wittig reaction between two molecules of starting iminophosphorane to give the aldimine **28** as intermediate which reacts with isocyanates to give **29**. The structure **29** is derivable from mass and IR spectral data and from NMR absorption as summarized in the Experimental Section. The assignment is consistent with ^1H NMR evidence as the two methoxy groups are magnetically nonequivalent and there are two signals for the two methylene moieties. The presence of a formyl group in the product is supported by the signal at δ 182.70 in the ^{13}C NMR spectra.

C. Preparation of Thiazolo[4,5-*d*]pyrimidines. Iminophosphoranes **33**, readily available from 4-chloro-5-formyl-2-phenylthiazole **30**[19] by sequential treatment with sodium azide, aromatic amines, and triphenylphosphine, reacted with aromatic isocyanates in dry methylene chloride at room temperature to give the corresponding carbodiimides **34** in good yields. When compounds **34** were heated at temperatures slightly above their melting points, they underwent electrocyclic ring closure to give thiazolo[4,5-*d*]pyrimidines **35** in good yields. Iminophosphoranes **33** also reacted directly with carbon disulfide at room temperature to yield the thiazolo[4,5-*d*]pyrimidines **36** (Scheme V, Table V).

On the other hand, iminophosphorane **37**, available from 4-azido-5-formyl-2-phenylthiazole **31** and triphenyl-

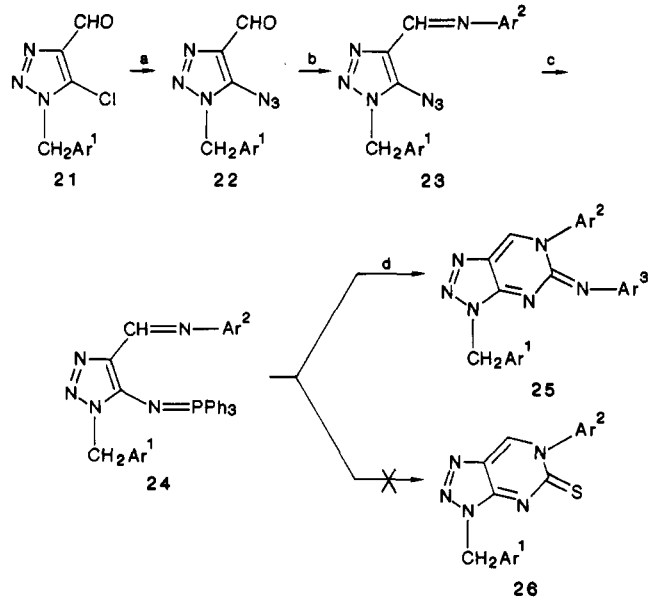
(22) Zbiral, E.; Baner, E. *Phosphorus* **1972**, *2*, 35.
(23) Olesen, P. H.; Nielsen, F. E.; Pedersen, E. B.; Becher, J. *J. Heterocycl. Chem.* **1984**, *21*, 1603.

Scheme II[a]



[a] (a) R^2NCO, CH_2Cl_2, room temperature; (b) R^2NCO, toluene, reflux; (c) R^1NCO, toluene, reflux; (d) CS_2, CH_2Cl_2, room temperature; (e) CO_2, toluene, sealed tube 90 °C; (f) R^2COCl, CH_2Cl_2, room temperature.

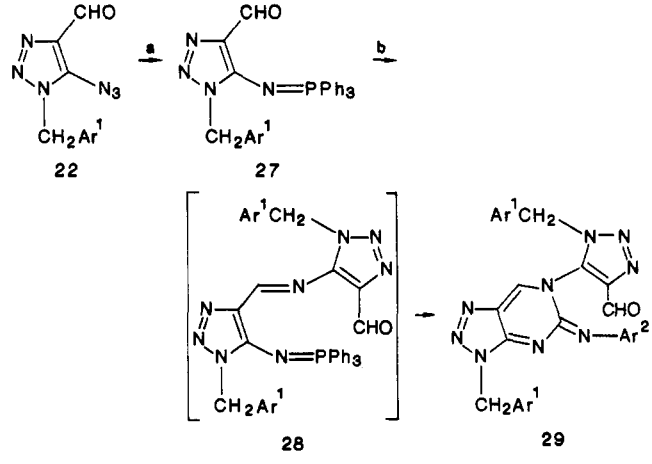
Scheme III[a]



[a] (a) NaN_3, DMSO, 60 °C; (b) Ar^2NH_2, EtOH, room temperature; (c) Ph_3P, CH_2Cl_2, room temperature; (d) Ar^3NCO, CH_2Cl_2, room temperature.

phosphine, reacted with isocyanates to yields carbodiimides **38**, which by heating in toluene at reflux temperature underwent electrocyclic ring closure followed by a Dimroth-type rearrangement to give thiazolo[4,5-*d*]pyrimidines **39**.

Scheme IV[a]

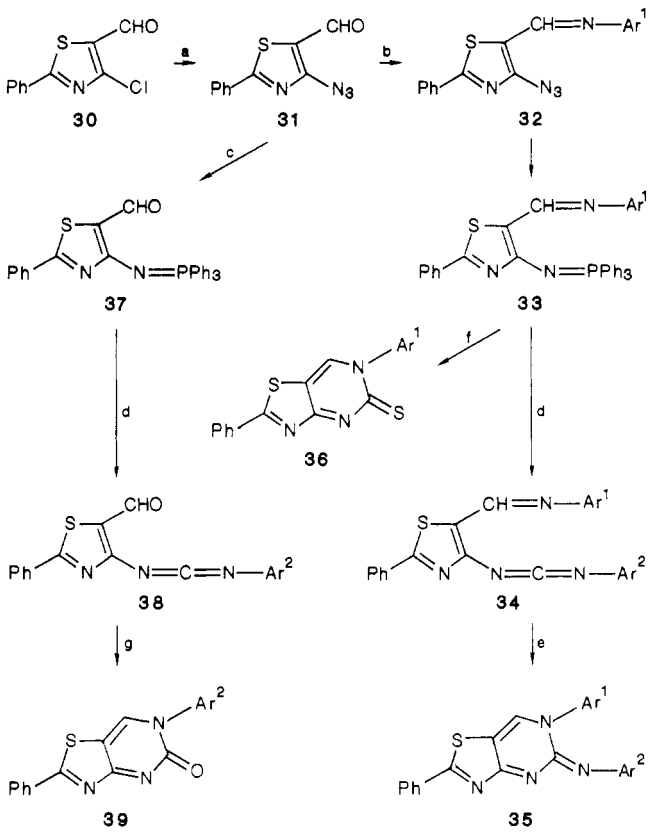


[a] (a) Ph_3P, CH_2Cl_2, room temperature; (b) Ar^2NCO, toluene, reflux.

Concluding Remarks

The methodology described in this paper affords a new and general route to fused pyrimidines with variable substituents at the pyrimidine ring. These relatively

Scheme V[a]



[a] (a) NaN_3, DMSO, 60 °C; (b) Ar^1NH_2, EtOH, room temperature; (c) Ph_3P, CH_2Cl_2, room temperature; (d) Ar^2NCO, CH_2Cl_2, room temperature; (e) heating; (f) CS_2, room temperature; (g) toluene, reflux.

complex structures, which would be difficult to prepare by classical synthetic routes, are assembled in a simple one-pot procedure in high yields, mild reaction conditions, and from readily available starting materials. Application of this annelation approach to a number of other fused pyrimidines can be anticipated.

Experimental Section

General Methods. All melting points were determined on a Kofler hot-plate melting point apparatus and are uncorrected. IR spectra were obtained as Nujol emulsions or KBr disks on a Nicolet FT-5DX spectrophotometer. NMR spectra were recorded on one of the following spectrometers: Varian FT-80 or JEOL JNM-PMX 60, and chemical shifts are expressed in parts per million (δ) relative to internal Me_4Si. Mass spectra were recorded on one of the following spectrometers: Hewlett-Packard 5993C or Varian Mat 311A. Microanalysis were performed on a Perkin-Elmer 240C instrument or by Novo A/S Bagsvaerd, Denmark.

Materials. 5-Chloro-4-formyl-3-methyl-1-phenyl-1*H*-pyrazole[19] **8**, 5-chloro-4-formyl-1(*p*-methoxybenzyl)-1*H*-[1,2,3]triazole[23] **21**, and 4-chloro-5-formyl-2-phenylthiazole[19] **30** were prepared as described in the literature.

Preparation of Azidoformylazoles (9, 22, and 31). To a well-stirred solution of sodium azide (7.8 g, 120 mmol) in 100 mL of DMSO was added the appropriate chloroformylazole **8**, **21**, **30** (40 mmol). The reaction mixture darkness, and the temperature was slowly raised to 60 °C for 1 h. After being cooled to room temperature, the reaction mixture was poured into 200 mL of cold water. The aqueous phase was extracted with ether (3 × 100 mL), and the organic layer was dried over anhydrous sodium sulfate and filtered. Concentration to dryness yielded a crude material, which was recrystallized from the appropriate solvent.

5-Azido-4-formyl-3-methyl-1-phenyl-1*H*-pyrazole (9): yield 67%; mp 42 °C dec (cyclohexane); IR (KBr) 2160 (azide), 1670 cm^{-1} (CHO); ^1H NMR ($CDCl_3$) δ 2.50 (s, 3 H, CH_3), 7.50 (s, 5 H, aryl), 10.00 (s, 1 H, CHO); ^{13}C NMR ($CDCl_3$) δ 12.6, 112.2, 124.1, 128.4, 129.0, 136.9, 140.3, 151.9, 183.5; ^{15}N NMR ($CDCl_3$) δ 83.86 (s, α-N_3), 203.01 (t, J = 2 Hz, N-1), 232.38 (s, γ-N_3), 235.52 (s, β-N_3), 292.69 (q, J = 3.2 Hz, N-2); mass spectrum, m/e (relative intensity) 227 (40, M^+), 199 (24), 105 (16), 77 (100). Anal. Calcd for $C_{11}H_9N_5O$: C, 58.14; H, 3.99; N, 30.82. Found: C, 57.86; H, 4.00; N, 30.32.

5-Azido-4-formyl-1-(*p*-methoxybenzyl)-1*H*-[1,2,3]triazole (22): yield 89%; mp 68 °C dec (ether); IR (KBr) 2170 (azide), 1690 cm^{-1} (CHO); ^1H NMR ($CDCl_3$) δ 3.80 (s, 3 H, OCH_3), 5.30 (s, 2 H, CH_2), 6.80 (d, 2 H, J = 9 Hz), 7.30 (d, 2 H, J = 9 Hz), 10.00 (s, 1 H, CHO); ^{13}C NMR ($CDCl_3$) δ 50.7 (CH_2), 55.4 (CH_3O), 114.4, 125.5, 129.8, 136.8, 138.2, 160.0, 185.1 (CHO); ^{15}N NMR ($CDCl_3$) δ 80.99 (s, α-N_3), 232.09 (s, γ-N_3), 239.10 (t, J = 1.8 Hz, N-3), 240.19 (s, β-N_3), 355.83 (t, J = 2.1 Hz, N-2), 360.81 (s, N-1); mass spectrum, m/e (relative intensity) 258 (38, M^+), 146 (44), 121 (100), 78 (24). Anal. Calcd for $C_{11}H_{10}N_6O_2$: C, 51.15; H, 3.90; N, 32.25. Found: C, 51.65; H, 3.96; N, 32.36.

4-Azido-5-formyl-2-phenylthiazole (31): yield 78%; mp 136 °C dec (acetone); IR (KBr) 2260 (azide), 1665 cm^{-1} (CHO); ^1H NMR ($CDCl_3$) δ 7.30–8.20 (m, 5 H, aryl), 9.90 (s, 1 H, CHO); mass spectrum, m/e (relative intensity) 230 (10, M^+), 202 (8), 129 (15), 104 (100). Anal. Calcd for $C_{10}H_6N_4OS$: C, 52.17; H, 2.63; N, 24.33. Found: C, 52.21; H, 2.59; N, 24.52.

4-[(*N*-Arylimino)methyl]-5-azido-3-methyl-1-phenyl-1*H*-pyrazoles (10). To a solution of 5-azido-4-formyl-3-methyl-1-phenyl-1*H*-pyrazole (**9**) (15.5 g, 20 mmol) in 90 mL of anhydrous ethanol were added the appropiate amine (22 mmol) and 2 mL of acetic acid. The reaction mixture was kept at room temperature for 6 h. The crystalline precipitated was collected, washed with ether and recrystallized from ethanol to give **10** as colorless crystals.

4-[(*N*-Phenylimino)methyl]-5-azido-3-methyl-1-phenyl-1*H*-pyrazole (10a): yield 50%; mp 68 °C; IR (KBr) 2160 cm^{-1} (azide); ^1H NMR ($CDCl_3$) δ 2.50 (s, 3 H, CH_3), 7.50 (s, 5 H, aryl), 8.60 (s, 1 H, CH); mass spectrum, m/e (relative intensity) 302 (18, M^+), 274 (56), 77 (100). Anal. Calcd for $C_{17}H_{14}N_6$: C, 67.54; H, 4.67; N, 27.80. Found: C, 67.45; H, 4.72; N, 27.70.

4-[(*N*-*p*-Tolylimino)methyl]-5-azido-3-methyl-1-phenyl-1*H*-pyrazole (10b): yield 96%; mp 86 °C; IR (Nujol) 2146 cm^{-1} (azide); ^1H NMR ($CDCl_3$) δ 2.33 (s, 3 H, CH_3), 2.56 (s, 3 H, CH_3), 7.20–7.50 (m, 4 H, aryl), 8.63 (s, 1 H, CH); ^{13}C NMR ($CDCl_3$) δ 12.85 (CH_3), 20.81 (CH_3), 110.89, 120.56, 123.97, 127.74, 128.82, 129.65, 135.44, 136.71, 137.69, 149.41, 149.80, 150.16; mass spectrum, m/e (relative intensity) 316 (1, M^+), 289 (22), 288 (81), 287 (23), 274 (2), 201 (16), 200 (91), 199 (18), 185 (26), 183 (52), 156 (16), 132 (12), 107 (34), 106 (43), 105 (14), 91 (49), 77 (100). Anal. Calcd for $C_{18}H_{16}N_6$: C, 68.34; H, 5.10; N, 26.56. Found: C, 68.53; H, 5.24; N, 26.17.

5-[(Triphenylphosphoranylidene)amino]-1*H*-pyrazoles (11 and 12). A solution of triphenylphosphine (0.83 g, 3.2 mmol) in 10 mL of dry methylene chloride was added dropwise under nitrogen at 0 °C to a solution of the appropiate 5-azido-1*H*-pyrazole **9** or **10** (3.2 mmol) in 20 mL of the same solvent. The reaction mixture was stirred at room temperature for 16 h, and the solvent was removed off under reduced pressure at 25 °C. The residual material was recrystallized from methylene chloride/hexane (1:1) to give the corresponding iminophosphorane **11** or **12**.

4-Formyl-3-methyl-1-phenyl-5-[(triphenylphosphoranylidene)amino]-1*H*-pyrazole (11): yield 82%; mp 129 °C; IR (Nujol) 1659 cm^{-1} (CHO); ^1H NMR ($CDCl_3$) δ 2.36 (s, 3 H, CH_3), 7.20–7.70 (m, 20 H, aryl), 9.20 (s, 1 H, CHO); mass spectrum, m/e (relative intensity) 461 (54, M^+), 460 (27), 384 (25), 336 (49), 260 (30), 183 (100), 108 (61), 77 (34). Anal. Calcd for $C_{29}H_{24}N_3OP$: C, 75.47; H, 5.24; N, 9.10. Found: C, 75.38; H, 5.32; N, 9.18.

4-[(*N*-Phenylimino)methyl]-3-methyl-1-phenyl-5-[(triphenylphosphoranylidene)amino]-1*H*-pyrazole (12a): yield 80%; mp 180–182 °C; IR (Nujol) 1613 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.60 (s, 3 H, CH_3), 6.50–6.80 (m, 3 H, aryl), 7.10–7.80 (m, 22 H, aryl), 8.15 (s, 1 H, CH=N); mass spetrum, m/e (relative intensity) 356 (32, M^+), 459 (38), 274 (57), 262 (28), 183 (100), 108 (68), 91 (11), 77 (54). Anal. Calcd for $C_{35}H_{29}N_4P$: C, 78.34; H, 5.45; N, 10.44. Found: C, 78.25; H, 5.53; N, 10.58.

4-[(*N*-*p*-Tolylimino)methyl]-3-methyl-1-phenyl-5-[(triphenylphosphoranylidene)amino]-1*H*-pyrazole (12b): yield 81%; mp 176 °C; IR (Nujol) 1613 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.30

(s, 3 H, CH_3), 2.56 (s, 3 H, CH_3), 6.50 (d, 2 H, J = 8 Hz), 7.00 (d, 2 H, J = 8 Hz), 7.20–7.80 (m, 20 H, aryl), 8.10 (s, 1 H, CH=N); mass spectrum, m/e (relative intensity) 550 (16, M^+), 473 (61), 288 (27), 183 (48), 108 (36), 91 (22), 77 (20), 55 (100). Anal. Calcd for $C_{36}H_{31}N_4P$: C, 78.53; H, 5.67; N, 10.17. Found: C, 78.62; H, 5.69; N, 10.23.

Preparation of Iminophosphorane (13). To a solution of iminophosphorane **11** (2.30 g, 5 mmol) in 85 mL of anhydrous ethanol were added (*p*-nitrophenyl)hydrazine (0.76 g, 5 mmol) and acetic acid (0.3 mL). The resultant solution was stirred at room temperature for 2 h, whereupon the solvent was removed under reduced pressure. The resultant crude product was purified by recrystallization from methylene chloride/hexane (1:1) to give **13**: 2.29 g (77%); mp 232–233 °C, yellow crystals; IR (Nujol) 3364, 3182, 1608, 1302, 1296 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.44 (s, 3 H, CH_3) 6.70 (d, 2 H, J = 9.1 Hz), 6.92 (s, 1 H, NH), 7.14–7.61 (m, 20 H, aryl), 8.00 (d, 2 H, J = 9.1 Hz); mass spectrum, m/e (relative intensity) 596 (3, M^+), 262 (54), 184 (25), 183 (100), 152 (15), 108 (59), 77 (27). Anal. Calcd for $C_{35}H_{29}N_6O_2P$: C, 70.46; H, 4.90; N, 14.09. Found: C, 70.37; H, 4.85; N, 13.93.

General Procedure for the Preparation of 6-[Aryl(or alkyl)imino]-3-methyl-1-phenyl-5-substituted-5,6-dihydro-1*H*-pyrazolo[3,4-*d*]pyrimidines (14 and 15). Method A. To a solution of iminophosphorane **12** (15 mmol) in 25 mL of dry methylene chloride was added the appropriate isocyanate (5 mmol). The reaction mixture was stirred at room temperature for 5 h and then evaporated to dryness. The residue was slurried in cold ether (10 mL), stirred for 30 min, and filtered. The crude product was recrystallized from ethanol to give **14** as crystalline solids.

Method B. To a solution of iminophosphorane **13** (2.98 g, 5 mmol) in 50 mL of dry toluene was added the appropriate isocyanate (5 mmol). The reaction mixture was stirred at reflux temperature for 7 h. After cooling, the precipitated solid was separated by filtration, dried, and recrystallized from acetonitrile to give **15** as crystalline solids.

14a: yield 63%; mp 178–179 °C orange prisms; IR (Nujol) 1659, 1625, 1500, 1325, 1279, 764, 690 cm^{-1}; ^1H NMR ($CDCl_3$ + TFA) δ 1.30 (t, 3 H, J = 7.5 Hz CH_2CH_3), 2.75 (s, 3 H, CH_3), 3.80 (q, 2 H, CH_2CH_3), 7.50–8.20 (m, 10 H, aryl), 8.95 (s, 1 H, pyrimidine ring); mass spectrum, m/e (relative intensity) 329 (36, M^+), 328 (100), 315 (12), 314 (55), 300 (13), 225 (10), 129 (12), 95 (10), 77 (81), 69 (48). Anal. Calcd for $C_{20}H_{19}N_5$: C, 72.93; H, 5.81; N, 21.26. Found: C, 73.05; H, 5.73; N, 21.17.

14b: yield 72%; mp 158–159 °C orange prisms; IR (Nujol) 1659, 1602, 1579, 1353, 1279, 1115, 917, 758, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.31 (s, 3 H, CH_3), 4.72 (d, 2 H, J = 7 Hz), 5.17–5.52 (m, 2 H), 5.81–6.40 (m, 1 H), 7.15–7.37 (m, 8 H), 7.84 (s, 1 H), 8.06 (d, 2 H, J = 9 Hz); mass spectrum, m/e (relative intensity) 341 (10, M^+), 300 (10), 256 (18), 103 (15), 91 (11), 77 (100). Anal. Calcd for $C_{21}H_{19}N_5$: C, 73.88; H, 5.61; N, 20.51. Found: C, 73.71; H, 5.69; N, 20.43.

14c: yield 65%; mp 193–195 °C, yellow prisms; IR (Nujol) 1659, 1608, 1597, 1342, 1211, 1070, 884, 869, 752, 724 cm^{-1}; ^1H NMR ($CDCl_3$ + TFA) δ 2.60 (s, 3 H, CH_3), 7.30–8.30 (m, 14 H, aryl), 9.05 (s, 1 H); mass spectrum, m/e (relative intensity) 413 (19, M^+ + 2), 412 (37), 411 (50, M^+), 410 (100), 396 (10), 334 (5), 155 (10), 77 (89). Anal. Calcd for $C_{24}H_{18}ClN_5$: C, 69.99; H, 5.61; N, 20.51. Found: C, 73.71; H, 4.33; N, 20.43.

14d: yield 65%; mp 166–167 °C yellow prisms; IR (Nujol) 1659, 1602, 1557, 1319, 1217, 1013, 917, 820, 764, 605 cm^{-1}; ^1H NMR ($CDCl_3$ + TFA) δ 2.71 (s, 3 H, CH_3), 7.40–8.20 (m, 14 H, aryl), 9.06 (s, 1 H, H-4 pyrimidine ring); mass spectrum, m/e (relative intensity) 413 (19, M^+ + 2), 412 (40), 411 (52, M^+), 410 (100), 396 (3), 300 (15), 111 (20), 77 (98). Anal. Calcd for $C_{24}H_{18}ClN_5$: C, 69.99; H, 4.40; N, 17.80. Found: C, 69.84; H, 4.53; N, 17.83.

14e: yield 67%; mp 119–120 °C orange prisms; IR (Nujol) 1658, 1607, 1533, 1414, 1329, 1284, 1210, 1035, 757, 723 cm^{-1}; ^1H NMR (DMSO-d_6) δ 2.50 (s, 3 H, CH_3), 3.85 (s, 3 H, CH_3O), 7.00–8.30 (m, 14 H, aryl), 9.05 (s, 1 H, H-4 pyrimidine ring); mass spectrum, m/e (relative intensity) 407 (91, M^+), 406 (100), 300 (10), 183 (9), 118 (15), 117 (8), 116 (15), 77 (95). Anal. Calcd for $C_{25}H_{21}N_5O$: C, 73.69; H, 5.19; N, 17.19. Found: C, 73.78; H, 5.29; N, 17.29.

14f: yield 61%; mp 120–121 °C orange prisms; IR (Nujol) 1659, 1596, 1562, 1500, 1421, 1281, 1228, 992, 764, 752 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.47 (t, 3 H, J = 7 Hz), 2.33 (s, 6 H), 4.17 (q, 2 H, J = 7 Hz), 7.11–7.48 (m, 7 H, aryl), 7.93–8.12 (m, 3 H, aryl); mass spectrum, m/e (relative intensity) 343 (66, M^+), 342 (28), 328 (29), 315 (15), 314 (33), 226 (20), 225 (100), 158 (16), 119 (72), 118 (22), 91 (35), 77 (91). Anal. Calcd for $C_{21}H_{21}N_5$: C, 73.44; H, 6.16; N, 20.39. Found: C, 73.56, H, 6.29; N, 20.18.

14g: yield 60%; mp 129–130 °C, orange prisms; IR (Nujol) 1659, 1602, 1580, 1548, 1354, 1280, 1116, 923, 764, 719, 680, 665 cm^{-1}; ^1H NMR δ ($CDCl_3$) 2.30 (s, 3 H, CH_3), 2.31 (s, 3 H, CH_3), 4.71 (d, 2 H, J = 6 Hz), 5.20–5.43 (m, 2 H), 5.90–6.27 (m, 1 H), 7.10–7.49 (m, 7 H), 7.88 (s, 1 H), 8.06 (d, 2 H, J = 8.3 Hz); mass spectrum, m/e (relative intensity) 355 (3, M^+), 251 (10), 183 (12), 156 (10), 131 (25), 116 (15), 106 (12), 105 (9), 91 (46), 77 (100). Anal. Calcd for $C_{22}H_{21}N_5$: C, 74.34; H, 5.96; N, 19.70. Found: C, 74.50; H, 5.92; N, 19.84.

14h: yield 62%; mp 199–200 °C, yellow prisms; IR (Nujol) 1653, 1602, 1579, 1551, 1319, 1217, 1007, 820, 758, 747 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.38 (s, 3 H, CH_3), 2.46 (s, 3 H, CH_3), 7.20–7.70 (m, 1 H), 8.00 (s, 1 H), 8.23 (d, 2 H); mass spectrum, m/e (relative intensity) 427 (10, M^+ + 2), 426 (20), 425 (30, M^+), 157 (11), 155 (21), 115 (18), 113 (16), 111 (38), 91 (92), 77 (100). Anal. Calcd for $C_{25}H_{20}ClN_5$: C, 70.50; H, 4.73; N, 16.44. Found: C, 70.72; H, 4.65; N, 16.38.

14i: yield 70%; mp 132–134 °C, orange prisms; IR (Nujol) 1659, 1597, 1500, 1240, 821, 753, 719 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.35 (s, 3 H, CH_3), 2.43 (s, 3 H, CH_3), 3.80 (s, 3 H, CH_3O), 6.86 (d, 2 H, J = 9 Hz), 7.23–7.75 (m, 9 H, aryl), 7.95 (s, 1 H), 8.23 (d, 2 H, J = 9 Hz); mass spectrum, m/e (relative intensity) 421 (100, M^+), 420 (91), 406 (41), 183 (10), 155 (11), 121 (10), 118 (20), 91 (56), 77 (97). Anal. Calcd for $C_{26}H_{23}N_5O$: C, 74.10; H, 5.50; N, 16.61. Found: C, 73.95; H, 5.63; N, 16.58.

15a: yield 45%; mp 221–222 °C, red prisms; IR (Nujol) 3318, 1659, 1596, 1574, 1500, 1336, 1319, 837, 758 cm^{-1}; ^1H NMR (DMSO-d_6) δ 2.42 (s, 3 H, CH_3), 6.95 (d, 2 H, J = 9 Hz), 7.60–8.70 (m, 12 H aryl), 8.98 (s, 1 H, N-4 pyrimidine ring), 9.60 (s, 1 H, NH); mass spectrum, m/e (relative intensity) 437 (5, M^+), 300 (14), 239 (13), 237 (73), 162 (52), 161 (17), 150 (13), 135 (33), 134 (66), 133 (100), 122 (24), 91 (25), 77 (74). Anal. Calcd for $C_{24}H_{18}N_6O_2$: C, 65.89; H, 4.38; N, 2.41. Found: C, 65.77; H, 4.33; N, 22.36.

15b: yield 42%; mp 301–302 C, red prisms; IR (Nujol) 3224, 1670, 1591, 1501, 1310, 1256, 1113, 1030, 773, 758 cm^{-1}; ^1H NMR (DMSO-d_6) δ 2.44 (s, 3 H CH_3), 7.00 (d, 2 H, J = 9 Hz), 7.56–8.67 (m, 11 H, aryl), 9.00 (s, 1 H, H-4 pyrimidine ring), 9.51 (s, 1 H NH); mass spectrum, m/e (relative intensity) 473 (2, M^+ + 2), 471 (6, M^+), 337 (3), 335 (9), 226 (71), 225 (22), 183 (10), 156 (2), 138 (40), 129 (33), 127 (100), 91 (18), 77 (80). Anal. Calcd for $C_{24}H_{17}ClN_6O_2$: C, 61.10; H, 3.84; N, 20.77. Found: C, 60.95; H, 3.73; N, 20.78.

15c: yield 40%; mp 290–292 °C, red crystals; IR (Nujol) 3325, 1664, 1602, 1557, 1500, 1308, 1294, 1172, 1013, 826, 767 cm^{-1}; ^1H NMR (DMSO-d_6) δ 2.41 (s, 3 H, CH_3), 7.20 (d, 2 H, J = 9 Hz), 7.50–8.20 (m, 9 H), 8.55 (d, 2 H, J = 9 Hz, aryl), 9.08 (s, 1 H, H-4 pyrimidine ring), 9.89 (s, 1 H, NH); mass spectrum, m/e (relative intensity) 473 (10, M^+ + 2), 471 (30 M^+), 337 (5), 336 (8), 335 (15), 334 (14), 259 (12), 227 (11), 226 (84), 225 (25), 184 (16), 183 (9), 150 (17), 138 (38), 127 (100), 91 (30), 77 (73). Anal. Calcd for $C_{24}H_{17}ClN_6O_2$: C, 61.10; H, 3.84; N, 20.77. Found: C, 61.19; H, 4.03; N, 20.58.

General Procedure for the Preparation of 3-Methyl-1-phenyl-5-substituted-6-thioxo-5,6-dihydro-1*H*-pyrazolo[3,4-*d*]pyrimidines (17). To a solution of iminophosphorane **12** (5 mmol) in 25 mL of dry methylene chloride was added excess of carbon disulfide (6 mL). The reaction mixture was stirred under nitrogen at room temperature for 6 h. The solution was concentrated to dryness, and the residual material was recrystallized from methylene chloride to give **17**.

When the reaction was carried out at the same conditions in only 2 h, the reaction product was found to be the isothiocyanate **16**, which undergoes cyclization by heating in dry toluene solution to give the fused pyrimidines **17** in almost quantitative yields.

17a: yield 97%; mp 141–142 °C, yellow prisms; IR (Nujol) 1642, 1596, 1545, 1512, 1325, 1118, 1098, 1070, 758, 690 cm^{-1}; ^1H NMR ($CDCl_3$ + TFA) δ 2.78 (s, 3 H, CH_3), 7.60–8.30 (m, 10 H, aryl), 9.50 (s, 1 H, H-4 pyrimidine ring); mass spectrum, m/e (relative intensity) 318 (61, M^+), 317 (100), 287 (20), 129 (15), 91 (15), 77 (69). Anal. Calcd for $C_{18}H_{14}N_4S$: C, 67.90; H, 4.43; N, 17.59.

Found: C, 67.98; H, 4.57; N, 17.50.

17b: yield 75%; mp 152–153 °C, yellow prisms; IR (Nujol) 1642, 1596, 1545, 1506, 1319, 1228, 1109, 1092, 1058, 1007, 826, 758, 763, 713 cm^{-1}; ^1H NMR ($CDCl_3$ + TFA) δ 2.56 (s, 3 H, CH_3), 2.78 (s, 3 H CH_3), 7.45–7.80 (m, 7 H, aryl), 8.00–8.30 (m, 2 H, aryl), 9.45 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 332 (64, M^+), 331 (100), 290 (10), 214 (15), 158 (20), 91 (30), 77 (55). Anal. Calcd for $C_{19}H_{16}N_4S$: C, 68.65; H, 4.85; N, 16.85. Found: C, 68.52; H, 4.90; N, 16.79.

General Procedure for the Preparation of 3-Methyl-1-phenyl-5-substituted-6-oxo-5,6-dihydro-1*H*-pyrazolo[3,4-*d*]pyrimidines (19). Method A. A solution of the appropriate isocyanate (8 mmol) in 10 mL of dry toluene was added dropwise to a well-stirred solution of iminophosphorane **11** (2.30 g, 5 mmol) in 50 mL of the same solvent. The resultant solution was stirred at reflux temperature for 5 h. After cooling, the precipitated solid was separated by filtration, dried, and recrystallized from toluene to give **19**.

Method B. The appropriate iminophosphorane **12** (3 mmol), dry toluene (20 mL), and excess of solid carbon dioxide were heated in a sealed tube at 90 °C for 8 h. After cooling, the solvent was removed under reduced pressure and the crude product was slurried with ether (20 mL), filtered, and recrystallized from toluene to give **19** as crystalline solids.

19a: yield 50%; mp 223–224 °C, yellow prisms; IR (Nujol) 1687, 1591, 1557, 1534, 1500, 1205, 1160, 1030, 724, 696 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.55 (s, 3 H, CH_3), 7.40–7.83 (7, 10 H, aryl), 8.55 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 302 (100, M^+), 301 (50), 287 (5), 285 (14), 260 (5), 208 (5), 205 (10), 169 (15), 157 (15), 156 (5), 155 (10), 77 (84). Anal. Calcd for $C_{18}H_{14}N_4O$: C, 71.51; H, 4.67; N, 18.53. Found: C, 71.63; H, 4.59; N, 18.60.

19b: yield 59%; mp 239–240 °C, yellow prisms; IR (Nujol) 1670, 1591, 1540, 1298, 1279, 1155, 945, 888, 820, 755 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.43 (s, 3 H, CH_3), 2.56 (s, 3 H, CH_3), 7.40–7.80 (m, 7 H aryl), 8.45 (d, 2 H, J = 9 Hz, aryl), 8.55 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 316 (100, M^+), 315 (42), 300 (10), 299 (17), 288 (5), 274 (10), 225 (18), 224 (20), 223 (31), 198 (64), 197 (10), 157 (15), 117 (7), 91 (83), 77 (99). Anal. Calcd for $C_{19}H_{16}N_4O$: C, 72.14; H, 5.10; N, 17.71. Found: C, 72.25; H, 5.05; N, 17.79.

19c: yield 49%; mp 232–233 °C, yellow prisms; IR (Nujol) 1670, 1596, 1543, 1511, 1251, 1172, 1030, 775, 752, 696 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.53 (s, 3 H, CH_3), 3.82 (s, 3 H, CH_3O), 6.95 (d, 2 H, J = 9 Hz, aryl), 7.22–7.50 (m, 5 H, aryl), 7.76 (d, 2 H, J = 9 Hz, aryl), 8.56 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 332 (99, M^+), 331 (21), 317 (26), 290 (100), 256 (10), 225 (11), 223 (15), 198 (20), 185 (13), 157 (15), 156 (8), 121 (20), 107 (17), 77 (100). Anal. Calcd for $C_{19}H_{16}N_4O_2$: C, 68.66; H, 4.85; N, 16.86. Found: C, 68.56; H, 4.92; N, 16.94.

19d: yield 40%; mp 244–245 °C, yellow prisms; IR (Nujol) 1693, 1631, 1591, 1297, 1178, 1030, 824, 754, 721, 694 cm^{-1}; ^1H NMR ($CDCl_3$ + TFA) δ 2.59 (s, 3 H, CH_3), 6.90 (d, 2 H, J = 9 Hz, aryl), 7.30–7.57 (m, 5 H, aryl), 7.69 (d, 2 H, J = 9 Hz, aryl), 8.55 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 339 (5, M^+ + 1 + 2), 338 (33, M^+ + 2), 337 (15, M^+ + 1), 336 (100, M^+), 310 (2), 308 (6), 225 (20), 198 (21), 156 (12), 91 (57), 77 (89). Anal. Calcd for $C_{18}H_{13}ClN_4O$: C, 64.20; H, 3.89; N, 16.34. Found: C, 64.31; H, 3.78; N, 16.40.

General Procedure for the Preparation of 3-Methyl-1-phenyl-5,6-disubstituted-1*H*-pyrazolo[3,4-*d*]pyrimidinium Cations (20). To a solution of iminophosphorane **12** (5 mmol) in 50 mL of dry methylene chloride was added the appropriate acyl chloride (5 mmol). The reaction mixture was stirred under nitrogen at room temperature for 16 h, and then the solvent was removed off under reduced pressure. The residual material was dissolved in 25 mL of ethanol, and tetrafluoroboric acid (10 mL) was added. The solution was stirred at room temperature for 2 h, and the separated solid was collected by filtration and recrystallized from ethanol to give **20**.

20a: yield 45%; mp 193–194 °C, white prisms; IR (Nujol) 1647, 1591, 1528, 1058, 1030, 775, 689 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.30 (t, 3 H, CH_2CH_3), 2.61 (s 3 H, CH_3), 2.42 (q, 2 H, CH_2CH_3), 7.39–7.55 (m, 8 H, aryl), 8.01–8.14 (m, 2 H, aryl), 9.04 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 316 (54, $M^+ - BF_4$), 315 (5), 300 (6), 183 (8), 157 (7), 155 (5), 132 (40), 118 (5), 105 (6), 104 (6), 91 (10), 77 (100). Anal. Calcd for $C_{20}H_{19}BF_4N_4$: C, 59.68; H, 4.76; N, 13.93. Found: C, 59.69; H, 4.80; N, 13.91.

20b: yield 50%; mp 199–200 °C, white prisms; IR (Nujol) 1642, 1596, 1058, 769, 696 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.29 (s, 3 H, CH_3), 2.72 (s, 3 H, CH_3), 7.07–7.54 (m, 12 H, aryl), 8.08 (d, 2 H, J = 6.5 Hz, aryl), 9.37 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 377 (5, $M^+ - BF_4$), 201 (22), 194 (11), 182 (10), 183 (23), 155 (27), 154 (20), 153 (34), 91 (21). Anal. Calcd for $C_{25}H_{21}BF_4N_4$: C, 64.69; H, 4.56; N, 12.07. Found: C, 64.50; H, 4.60; N, 12.10.

20c: yield 56%; mp 208–209 °C, pale yellow prisms; IR (Nujol) 1642, 1613, 1495, 1262, 1177, 1058, 843, 786, 769 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.90 (s, 3 H, CH_3), 3.95 (s, 3 H CH_3O), 7.00 (d, 2 H, J = 9 Hz, aryl), 7.50–8.50 (m, 12 H, aryl), 9.73 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 394 (10, $M^+ - BF_4$), 393 (12), 210 (26), 183 (4), 157 (4), 155 (7), 147 (12), 103 (24), 102 (13), 91 (10), 77 (68). Anal. Calcd for $C_{25}H_{21}BF_4N_4O$: C, 62.52; H, 4.41; N, 11.66. Found: C, 62.49; H, 4.48; N, 11.69.

20d: yield 54%; mp 249–250 °C, white prisms; IR (Nujol) 1642, 1596, 1551, 1517, 1489, 1058, 837, 786, 769, 696 cm^{-1}; ^1H NMR ($CDCl_3$ + TFA) δ 2.73 (s, 3 H, CH_3), 7.30–7.57 (m, 12 H, aryl), 8.00 (d, 2 H, J = 7 Hz, aryl), 9.50 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 400 (5), 399 (7), 398 (15), 397 (22), 325 (3), 324 (11), 323 (7), 322 (37), 216 (33), 214 (100), 183 (2), 156 (2), 141 (19), 139 (54), 92 (15).

20e: yield 46%; mp 177–178 °C, white prisms; IR (Nujol) 1647, 1596, 1553, 1523, 1506, 1251, 1121, 1058, 928, 781, 724, 696 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.28 (t, 3 H, CH_2CH_3), 2.36 (s, 3 H, CH_3), 2.70 (s, 3 H, CH_3), 2.74 (q, 2 H, CH_2CH_3), 6.90 (d, 2 H, J = 9 Hz, aryl), 7.29–7.65 (m, 7 H, aryl), 9.20 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 330 (20, $M^+ - BF_4$), 329 (33), 201 (27), 199 (39), 183 (37), 156 (5), 146 (13), 131 (5), 107 (13), 106 (10), 91 (24), 77 (64). Anal. Calcd for $C_{21}H_{21}BF_4N_4$: C, 60.60; H, 5.08; N, 13.46. Found: C, 60.69; H, 5.12; N, 13.52.

20f: yield 56%; mp 243–244 °C, pale yellow prisms; IR (Nujol) 1642, 1608, 1591, 1511, 1262, 1183, 1058, 792, 764, 724, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.38 (s, 3 H, CH_3), 2.71 (s, 3 H, CH_3), 2.83 (s, 3 H, CH_3O), 6.83 (d, 2 H, J = 9 Hz aryl), 7.35–7.75 (m, 9 H, aryl), 8.26 (d, 2 H, J = 9 Hz, aryl), 9.46 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 407 (10, $M^+ - BF_4$), 225 (20), 224 (100), 183 (30), 135 (73), 107 (22), 106 (24), 91 (54), 77 (78). Anal. Calcd for $C_{26}H_{23}BF_4N_4O$: C, 63.18; H, 4.69; N, 11.33. Found: C, 63.30; H, 4.71; N, 11.29.

20g: yield 52%; mp 195–196 °C, pale yellow prisms; IR (Nujol) 1647, 1596, 1092, 1053, 819, 787, 764 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.41 (s, 3 H, CH_3), 2.77 (s, 3 H, CH_3), 6.90 (d, 2 H, J = 9 Hz aryl), 7.20–7.68 (m, 9 H, aryl), 8.30 (d, 2 H, J = 9 Hz, aryl), 9.51 (s, 1 H, H-4 pyrimidine ring); mass spectrum, *m/e* (relative intensity) 413 (1, M^+ + 2), 411 (3, M^+) 230 (15), 228 (15), 199 (55), 156 (36), 139 (33), 137 (100), 107 (18), 106 (18), 105 (17), 91 (21), 77 (54). Anal. Calcd for $C_{25}H_{20}BClF_4N_4$: C, 60.21; H, 4.04; N, 11.23. Found: C, 60.28; H, 4.12; N, 11.29.

4-[(*N*-Arylimino)methyl]-5-azido-1-(*p*-methoxybenzyl)-1*H*-[1,2,3]triazoles (23). To a solution of 5-azido-4-formyl-1-(*p*-methoxybenzyl)-1*H*-[1,2,3]triazole (**22**) (2.58 g, 10 mmol) in 60 mL of anhydrous ethanol were added the appropriate amine (12 mmol) and 2 mL of acetic acid. The reaction mixture was stirred at room temperature for 2 h. The separated solid was collected by filtration, dried, and recrystallized from ether to give **23** as crystalline solids.

4-[(*N*-Phenylimino)methyl]-5-azido-1-(*p*-methoxybenzyl)-1*H*-[1,2,3]triazole (23a): yield 70%; mp 79–80 °C, yellow crystals; IR (Nujol) 2146, 1630, 1557, 1517, 1262, 1183, 1030, 877, 849, 758, 735, 696 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.73 (s, 3 H, CH_3O), 5.25 (s, 2 H, CH_2Ar), 6.81 (d, 2 H, J = 8.7 Hz, aryl), 7.16–7.31 (m, 7 H, aryl), 8.64 (s, 1 H, aldiminic proton); mass spectrum, *m/e* (relative intensity) 333 (3, M^+), 305 (1), 187 (1), 157 (2), 136 (7), 135 (62), 134 (53), 121 (100), 106 (2), 105 (1), 104 (9), 91 (11), 77 (67). Anal. Calcd for $C_{17}H_{15}N_7O$: C, 61.25; H, 4.54; N, 29.41. Found: C, 61.34; H, 5.48; N, 29.52.

4-[(*N*-*p*-Tolylimino)methyl]-5-azido-1-(*p*-methoxybenzyl)-1*H*-[1,2,3]triazole (23b): yield 82%; mp 101–102 °C, yellow crystals; IR (Nujol) 2157, 1630, 1557, 1517, 1275, 1183, 1024, 883, 832, 809 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.23 (s, 3 H, CH_3), 3.88 (s, 3 H, CH_3O), 5.43 (s, 2 H, CH_2Ar), 7.10 (d, 2 H, J = 9 Hz, aryl),

7.45 (s, 4 H, aryl), 7.60 (d, 2 H, J = 9 Hz, aryl), 8.90 (s, 1 H, aldiminic proton); mass spectrum, m/e (relative intensity) 347 (2, M^+), 319 (1), 187 (5), 135 (60), 134 (32), 121 (100), 118 (10), 106 (3), 105 (3), 91 (12), 77 (87). Anal. Calcd for $C_{18}H_{17}N_7O$: C, 62.24; H, 4.93; N, 28.22. Found: C, 62.36; H, 5.17; N, 28.11.

5-[(Triphenylphosphoranylidene)amino]-1*H*-[1,2,3]triazoles (24 and 27). A solution of triphenylphosphine (0.83 g, 3.2 mmol) in 20 mL of dry methylene chloride was added dropwise under nitrogen at 0 °C to a solution of the appropriate 5-azido-1-(*p*-methoxybenzyl)-1*H*-[1,2,3]triazole **22** or **23** (3.2 mmol) in 30 mL of the same solvent. The resultant solution was stirred at room temperature for 16 h and concentrated to dryness. The residual material was recrystallized from methylene chloride/hexane (1:1) to give the corresponding iminophosphorane **24** or **27** as crystalline solid.

4-[(*N*-Phenylimino)methyl]-1-(*p*-methoxybenzyl)-5-[(triphenylphosphoranylidene)amino]-1*H*-[1,2,3]triazole (24a): yield 96%; mp 192–193 °C, pale yellow prisms; IR (Nujol) 1636, 1577, 1308, 1177, 1130, 1108, 1030, 950, 882, 735, 688 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.85 (s, 3 H, CH_3O), 5.52 (s, 2 H, CH_2Ar), 7.00 (d, 2 H, J = 9 Hz, aryl), 7.20–7.90 (m, 22 H, aryl), 8.55 (s, 1 H aldiminic proton); mass spectrum, m/e (relative intensity) 567 (10, M^+), 262 (100), 185 (49), 184 (24), 183 (98), 134 (31), 121 (70), 108 (66), 95 (84). Anal. Calcd for $C_{35}H_{30}N_5OP$: C, 74.06; H, 5.33; N, 12.34. Found: C, 73.95; H, 5.26; N, 12.26.

***N*-[(*N*-*p*-Tolylimino)methyl]-1-(*p*-methoxybenzyl)-5-[(triphenylphosphoranylidene)amino]-1*H*-[1,2,3]triazole (24b):** yield 77%; mp 162–163 °C, yellow prisms; IR (Nujol) 1636, 1551, 1512, 1245, 1109, 1030, 888, 821, 724, 713, 700 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.32 (s, 3 H, CH_3), 3.83 (s, 3 H, CH_3O), 5.56 (s, 2 H, CH_2Ar), 6.30 (d, 2 H, J = 9 Hz, aryl), 7.10–7.90 (m, 21 H, aryl), 8.23 (s, 1 H, aldiminic proton); mass spectrum, m/e (relative intensity) 581 (10, M^+), 263 (21), 262 (100), 185 (37), 183 (93), 121 (77), 108 (84), 107 (25), 91 (25). Anal. Calcd for $C_{36}H_{32}N_5OP$: C, 74.40; H, 5.55; N, 12.05. Found: C, 74.57; H, 5.33; N, 11.92.

4-Formyl-1-(*p*-methoxybenzyl)-5-[(triphenylphosphoranylidene)amino]-1*H*-[1,2,3]triazole (27): yield 90%; mp 115–116 °C, pale yellow prisms; IR (Nujol) 1676, 1540, 1511, 1240, 1177, 1115, 1036, 837, 809, 718, 696 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.71 (s, 3 H, CH_3O), 5.36 (s, 2 H, CH_2Ar), 6.66 (d, 2 H, J = 8.8 Hz, aryl), 7.13 (d, 2 H, J = 8.8 Hz, aryl), 7.32–7.72 (m, 15 H, aryl), 9.39 (s , 1 H, CHO); mass spectrum, m/e (relative intensity) 492 (5, M^+), 464 (5), 288 (16), 262 (40), 186 (5), 185 (40), 184 (20), 183 (100), 121 (55), 108 (23), 107 (12), 78 (13), 77 (19). Anal. Calcd for $C_{29}H_{25}N_4O_2P$: C, 70.72; H, 7.23; N, 11.37. Found: C, 70.84; H, 7.16; N, 11.43.

General Procedure for the Preparation of 6-(Arylimino)-1-(*p*-methoxybenzyl)-5-substituted-5,6-dihydro-1*H*-[1,2,3]triazolo[4,5-*d*]pyrimidines (25). To a solution of the appropriate iminophosphorane **24** (5 mmol) in 30 mL of dry methylene chloride was added the isocyanate (5 mmol). The reaction mixture was stirred at room temperature for 7 h and the evaporated to dryness. The oil residue was slurried in cold ether (15 mL) and stirred for 30 min, and the separated solid was collected by filtration and recrystallized from ethanol to give **25** as crystalline solids.

25a: yield 50%; mp 153–154 °C; IR (Nujol) 1614, 1545, 1511, 1249, 1034, 725 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.90 (s, 3 H, CH_3O), 5.40 (s, 2 H, CH_2Ar), 6.90–7.80 (m, 13 H, aryl), 9.98 (s, 1 H, H-4 pyrimidine ring); mass spectrum, m/e (relative intensity) 444 (2, $M^+ + 2$), 443 (3, $M^+ + 1$), 442 (5, M^+) 163 (5), 129 (5), 122 (13), 121 (100), 113 (5), 111 (15), 91 (10), 77 (16). Anal. Calcd for $C_{24}H_{19}ClN_6O$: C, 65.09; H, 4.32; N, 18.97. Found: C, 64.92; H, 4.37; N, 18.08.

25b: yield 71%; mp 131–132 °C, pale yellow prisms; IR (Nujol) 1613, 1540, 1511, 1251, 1115, 1092, 820, 761 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.40 (s, 3 H, CH_3), 4.10 (s, 3 H, CH_3O), 5.82 (s, 2 H, CH_2Ar), 7.10–8.00 (m, 12 H, aryl), 9.93 (s, 1 H, H-4 pyrimidine ring); mass spectrum, m/e (relative intensity) 458 (2, $M^+ + 2$), 456 (6, M^+), 429 (3), 427 (9), 151 (9), 149 (27), 127 (3), 125 (4), 121 (100), 113 (3), 111 (10), 91 (20). Anal. Calcd for $C_{25}H_{21}ClN_6O$: C, 65.72; H, 4.63; N, 18.39. Found: C, 65.63; H, 4.75; N, 18.53.

25c: yield 61%; mp 124–125 °C, orange prisms; IR (Nujol) 1613, 1540, 1511, 1245, 1177, 1036, 926, 724 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.42 (s, 3 H, CH_3), 3.91 (s, 3 H, CH_3O), 5.80 (s, 2 H, CH_2Ar), 7.10–8.10 (m, 12 H, aryl), 9.91 (s, 1 H, H-4 pyrimidine ring); mass spectrum, m/e (relative intensity) 453 (5, M^+), 187 (10), 186 (30), 185 (10), 149 (20), 135 (10), 134 (20), 133 (20), 121 (100), 108 (30), 91 (67), 77 (30). Anal. Calcd for $C_{26}H_{24}N_6O_2$: C, 69.01; H, 5.35; N, 18.57. Found: C, 68.85; H, 5.21; N, 18.39.

General Procedure for the Preparation of [1,2,3]Triazolo[4,5-*d*]pyrimidines (29). To a solution of iminophosphorane **27** (2.46 g, 5 mmol) in 50 mL of dry toluene was added the appropriate isocyanate (5 mmol). The deep red solution was stirred at reflux temperature for 5 h. After cooling, the precipitated solid was separated by filtration, dried, washed with cold ether (10 mL), and recrystallized from ethanol to give **29** as crystalline solids.

29a: yield 32%; mp 212–213 °C, yellow prisms; IR (Nujol) 1670, 1642, 1557, 1240, 1200, 1030, 792 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.83 (s, 3 H, CH_3O), 3.90 (s, 3 H, CH_3O), 5.23 (s, 2 H, CH_2Ar), 5.46 (s, 2 H, CH_2Ar), 6.75–7.85 (m, 13 H, aryl), 8.83 (s, 1 H, H-4 pyrimidine ring), 10.36 (s, 1 H, CHO); ^{13}C NMR ($CDCl_3$) δ 48.20 (CH_2), 54.88 (CH_3O), 54.98 (CH_3O), 113.54, 113.98, 126.69, 126.87, 127.75, 129.19, 129.43, 129.62, 133.93, 141.45, 145.96, 148.47, 152.93, 153.99, 158.62, 159.06, 182.72 (CHO); mass spectrum, m/e (relative intensity) 547 (26, M^+), 490 (4), 370 (8), 122 (10), 121 (100), 77 (10). Anal. Calcd for $C_{29}H_{25}N_9O_3$: C, 63.61; H, 4.60; N, 23.02. Found: C, 63.72; H, 4.65; N, 23.15.

29b: yield 33%; mp 239–240 °C, orange prisms; IR (Nujol) 1670, 1642, 1557, 1517, 1240, 1177, 1036, 990, 798 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.35 (s, 3 H, CH_3), 3.83 (s, 3 H, CH_3O), 3.90 (s, 3 H, CH_3O), 5.20 (s, 2 H, CH_2Ar), 5.43 (s, 2 H, CH_2Ar), 6.80–7.60 (m, 12 H, aryl), 8.73 (s, 1 H, H-4 pyrimidine ring), 10.26 (s, 1 H, CHO); ^{13}C NMR ($CDCl_3$) δ 20.67 (CH_3), 48.26 (CH_2), 54.93 (CH_3O), 55.06 (CH_3O), 113.52, 113.98, 126.70, 126.62, 127.67, 127.85, 129.64, 129.73, 133.95, 138.86, 139.12, 146.01, 148.69, 152.91, 154.14, 158.67, 182.63 (CHO); mass spectrum, m/e (relative intensity) 561 (7, M^+), 533 (5), 505 (5), 385 (8), 347 (6), 136 (10), 135 (10), 122 (15), 121 (100), 107 (10), 91 (20), 77 (19). Anal. Calcd for $C_{30}H_{27}N_9O_3$: C, 64.16; H, 4.85; N, 22.45. Found: C, 64.22; H, 4.78; N, 22.57.

29c: yield 31%; mp 240–241 °C, orange prisms; IR (Nujol) 1670, 1647, 1551, 1523, 1251, 1177, 1115, 1030, 972 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.80 (s, 3 H, CH_3O), 3.90 (s, 3 H, CH_3O), 3.96 (s, 3 H, CH_3O), 5.53 (s, 2 H, CH_2Ar), 5.60 (s, 2 H, CH_2Ar), 7.00 (d, 2 H, J = 9 Hz, aryl), 7.10–7.40 (m, 8 H, aryl), 7.70 (d, 2 H, J = 9 Hz, aryl), 9.43 (s, 1 H, H-4 pyrimidine ring), 9.80 (s, 1 H, CHO); ^{13}C NMR (DMSO-d_6) δ 48.25 (CH_2), 54.86 (CH_3O), 55.06 (CH_3O), 55.48 (CH_3O), 113.51, 113.99, 114.34, 126.83, 127.66, 127.86, 128.20, 129.66, 129.73, 133.93, 134.36, 146.86, 148.88, 152.86, 154.32, 158.67, 159.10, 159.56, 182.82 (CHO); mass spectrum, m/e (relative intensity) 577 (10, M^+), 549 (5), 520 (5), 400 (5), 363 (10), 240 (18), 121 (100), 136 (20), 108 (10), 77 (19). Anal. Calcd for $C_{30}H_{27}N_9O_4$: C, 62.38; H, 4.71; N, 21.82. Found: C, 62.42; H, 4.77; N, 21.95.

29d: yield 36%; mp 235–236 °C, orange prisms; IR (Nujol) 1670, 1647, 1557, 1517, 1240, 1177, 1087, 1030, 849, 782 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.83 (s, 3 H, CH_3O), 3.90 (s, 3 H, CH_3O), 5.40 (s, 2 H, CH_2Ar), 5.56 (s, 2 H, CH_2Ar), 6.90–7.90 (m, 12 H, aryl), 9.50 (s, 1 H, H-4 pyrimidine ring), 10.16 (s, 1 H, CHO); ^{13}C NMR (DMSO-d_6) δ 48.30 (CH_2Ar), 54.94 (CH_3O), 55.07 (CH_3O), 113.54, 114.01, 126.78, 127.81, 129.10, 129.40, 129.59, 129.77, 133.93, 140.30, 145.96, 148.72, 153.04, 154.06, 158.71, 159.12, 182.27 (CHO); mass spectrum, m/e (relative intensity) 583 (2, $M^+ + 2$), 581 (6, M^+), 406 (2), 404 (6), 367 (3), 365 (9), 136 (10), 135 (10), 121 (100), 77 (14). Anal. Calcd for $C_{29}H_{24}ClN_9O_3$: C, 59.85; H, 4.16; N, 21.66. Found: C, 60.01; H, 4.27; N, 21.47.

5-[(*N*-Arylimino)methyl]-4-azido-2-phenylthiazoles (32). To a solution of 4-azido-5-formyl-2-phenylthiazoles **31** (1.15 g, 5 mmol) in 60 mL of methylene chloride were added the appropriate aromatic amine (5 mmol) and acetic acid (2 mL). The solution was stirred at room temperature for 1 h, and then the solvent was removed off under reduced pressure at 25 °C, and the residual material was recrystallized from methylene chloride/hexane (1:1) to give **32** as crystalline solids.

5-[(*N*-Phenylimino)methyl]-4-azido-2-phenylthiazole (32a): yield 70%; mp 133–134 °C, yellow crystals; IR (Nujol) 2123, 1613, 1585, 1528, 1223, 1013, 758, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.11–7.44 (m, 8 H, aryl), 7.86–7.98 (m, 2 H, aryl), 8.41 (s, 1 H,

aldiminic proton); mass spectrum, m/e (relative intensity) 305 (3, M^+), 278 (10), 277 (20), 276 (12), 263 (2), 159 (7), 105 (66), 104 (100), 91 (87), 77 (32). Anal. Calcd for $C_{16}H_{11}N_5S$: C, 62.93; H, 3.63; N, 22.93. Found: C, 63.05; H, 3.58; N, 22.87.

5-[(*N*-*p*-Tolylimino)methyl]-4-azido-2-phenylthiazole (32b): yield 75%; mp 134–135 °C, yellow prisms; IR (Nujol) 2129, 1613, 1595, 1527, 1227, 1027, 792, 764, 696 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.36 (s, 3 H, CH_3), 7.00–7.52 (m, 7 H, aryl), 7.88–7.92 (m, 2 H, aryl), 8.56 (s, 1 H, aldiminic proton); mass spectrum, m/e (relative intensity) 319 (4, M^+), 293 (14), 291 (52), 290 (16), 190 (15), 163 (16), 161 (26), 129 (12), 118 (100), 106 (63), 91 (78), 77 (29). Anal. Calcd for $C_{17}H_{13}N_5S$: C, 63.93; H, 4.10; N, 21.93. Found: C, 64.01; H, 4.18; N, 22.04.

4-[(Triphenylphosphoranylidene)amino]thiazoles (33) and (37). A solution of triphenylphosphine (1.31 g, 5 mmol) in 50 mL of dry methylene chloride was added dropwise under nitrogen to well-stirred solution of the appropriate 4-azidothiazole **31** or **32** (5 mmol) in 20 mL of the same solvent at 0 °C. The reaction mixture was stirred at room temperature for 16 h. The solvent was removed off under reduced pressure, and the crude product was recrystallized from methylene chloride/hexane (1:1) to give the iminophosphoranes **33** or **37** as crystalline solids.

5-[(*N*-Phenylimino)methyl]-2-phenyl-4-[(triphenylphosphoranylidene)amino]thiazole (33a): yield 88%; mp 215–216 °C, orange prisms; IR (Nujol) 1585, 1500, 1200, 1109, 911, 718, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.23–8.33 (m, 2 H, aryl), 9.25 (s, 1 H, aldiminic proton); mass spectrum, m/e (relative intensity) 539 (6, M^+), 462 (12), 435 (5), 277 (10), 262 (33), 261 (11), 185 (18), 184 (19), 183 (100), 108 (45), 104 (13), 77 (22). Anal. Calcd for $C_{34}H_{26}N_3PS$: C, 75.67; H, 4.86; N, 7.79. Found: C, 75.72; H, 4.93; N, 7.69.

5-[(*N*-*p*-Tolylimino)methyl]-2-phenyl-4-[(triphenylphosphoranylidene)amino]thiazole (33b): yield 68%; mp 226–227 °C, red prisms; IR (Nujol) 1574, 1517, 1200, 1138, 1115, 911, 820, 730, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.30 (s, 3 H, CH_3), 7.12–7.89 (m, 24 H, aryl), 8.99 (s, 1 H, aldiminic proton); mass spectrum, m/e (relative intensity) 553 (3, M^+), 435 (7), 278 (28), 277 (71), 262 (32), 261 (11), 185 (20), 184 (18), 183 (100), 153 (12), 152 (3), 121 (22), 108 (34), 107 (31), 106 (15), 105 (8), 91 (34), 77 (51). Anal. Calcd for $C_{35}H_{28}N_3PS$: C, 75.93; H, 5.10; N, 7.59. Found: C, 75.88; H, 5.17; N, 7.67.

5-Formyl-2-phenyl-4-[(triphenylphosphoranylidene)amino]thiazole (37): yield 80%; mp 195–196 °C, yellow prisms; IR (Nujol) 1669, 1500, 1211, 1183, 1149, 1109, 973, 905, 769, 718, 707 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.53–7.88 (m, 18 H, aryl), 8.01–8.40 (m, 2 H, aryl), 10.12 (s, 1 H, CHO); mass spectrum, m/e (relative intensity) 464 (2, M^+), 435 (2), 278 (47), 277 (100), 201 (22), 199 (27), 185 (10), 183 (22), 107 (5), 77 (50). Anal. Calcd for $C_{28}H_{21}N_2OPS$: C, 72.40; H, 4.56; N, 6.06. Found: C, 72.51; H, 4.70; N, 6.13.

General Procedure for the Preparation of 5-(Arylimino)-2-phenyl-6-substituted-5,6-dithiothiazolo[4,5-*d*]pyrimidines (35). A solution of the appropriate isocyanate (5 mmol) in 10 mL of methylene chloride was added dropwise under nitrogen to a well-stirred solution of iminophosphorane **33** (5 mmol), in the same solvent (50 mL). The reaction mixture was stirred at room temperature for 5 h, the solvent was removed off under reduced pressure, and the solid residue was treated with dry ether (20 mL) and filtered. The solid carbodiimide was heated in an oil bath at 200 °C for 2 h. The corresponding thiazolo[4,5-*d*]-pyrimidine **35** was separated of the triphenylphosphine oxide by sublimation under reduced pressure and purified by recrystallization from methylene chloride/hexane (1:1).

35a: yield 60%, mp 177–178 °C, brown crystals; IR (Nujol) 1625, 1602, 1545, 1251, 1163, 1126, 758, 718, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.13 (s, 3 H, CH_3), 6.70–7.80 (m, 15 H, aryl); mass spectrum, m/e (relative intensity) 394 (2, M^+), 319 (20), 305 (79), 304 (32), 202 (69), 174 (23), 147 (21), 121 (10), 104 (42), 103 (18), 91 (19), 77 (100). Anal. Calcd for $C_{24}H_{18}N_4S$: C, 73.07; H, 4.60; N, 14.20. Found: C, 73.12; H, 4.58; N, 14.28.

35b: yield 62%; mp 198–199 °C, brown crystals; IR (Nujol) 1602, 1545, 1511, 1245, 1177, 1030, 826, 759, 724 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.83 (s, 3 H, CH_3O), 7.00–8.10 (m, 15 H, aryl); mass spectrum, m/e (relative intensity) 410 (1, M^+), 303 (21), 302 (32), 288 (12), 224 (3), 186 (13), 135 (19), 121 (13), 107 (39), 106 (28), 91 (20), 77 (100). Anal. Calcd for $C_{24}H_{18}N_4OS$: C, 70.22; H, 4.42; N, 13.64. Found: C, 70.35; H, 4.50; N, 13.56.

35c: yield 66%; mp 202–204 °C, brown crystals; IR (Nujol) 1602, 1550, 1245, 809, 764, 684 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.23 (s, 6 H, CH_3), 7.15–7.44 (m, 14 H, aryl); mass spectrum, m/e (relative intensity) 408 (3, M^+), 317 (3), 223 (18), 222 (100), 221 (29), 149 (24), 107 (38), 106 (37), 104 (12), 103 (12), 91 (28), 77 (18). Anal. Calcd for $C_{25}H_{20}N_4S$: C, 73.50; H, 4.93; N, 13.71. Found: C, 73.45; H, 4.87; N, 13.89.

35d: yield 65%; mp 210–212 °C, brown crystals; IR (Nujol) 1604, 1548, 1511, 1338, 1245, 1177, 1115, 1030, 962, 805, 764, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.37 (s, 3 H, CH_3), 3.79 (s, 3 H, CH_3O), 7.16–7.50 (m, 14 H, aryl); mass spectrum, m/e (relative intensity) 424 (3, M^+), 335 (11), 211 (16), 208 (22), 194 (19), 179 (22), 168 (24), 166 (32), 165 (35), 155 (24), 154 (30), 153 (35), 148 (25), 135 (14), 121 (11), 120 (30), 117 (22), 107 (22), 103 (32), 98 (67), 91 (38), 84 (100), 77 (27). Anal. Calcd for $C_{25}H_{20}N_4OS$: C, 70.73; H, 4.75; N, 13.19. Found: C, 70.85; H, 4.64; N, 13.24.

6-Aryl-2-phenyl-5-thioxo-5,6-dihydrothiazolo[4,5-*d*]pyrimidines (36). To a well-stirred solution of the appropriate iminophosphorane **33** (5 mmol) in 75 mL of dry methylene chloride was added under nitrogen 15 mL of carbon disulfide. The resultant solution was stirred at room temperature for 15 h, and then the solvent was removed off under reduced pressure. The residual material was slurried with ether (15 mL), filtered, dried, and recrystallized from ethanol to give **36** as crystalline solid.

36a: yield 54%; mp 198 °C, red prisms; IR (Nujol) 1608, 1200, 1081, 945, 775, 764, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.35–8.70 (m, 10 H, aryl), 9.40 (s, 1 H, H-7 pyrimidine ring); mass spectrum, m/e (relative intensity) 321 (30, M^+), 320 (100), 199 (15), 121 (27), 115 (54), 104 (15), 77 (67). Anal. Calcd for $C_{17}H_{11}N_3S_2$: C, 63.53; H, 3.45; N, 13.07. Found: C, 63.60; H, 3.30; N, 13.18.

36b: yield 50%; mp 150–151 °C, red prisms; IR (Nujol) 1608, 1594, 1200, 1081, 946, 775, 764, 695 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.30 (s, 3 H, CH_3), 7.10–7.30 (m, 9 H, aryl), 9.35 (s, 1 H, H-7 pyrimidine ring); mass spectrum, m/e (relative intensity) 335 (25, M^+), 334 (100), 149 (15), 135 (4), 121 (13), 118 (27), 103 (10), 91 (72), 77 (61). Anal. Calcd for $C_{18}H_{13}N_3S_2$: C, 64.45; H, 3.91; N, 12.52. Found: C, 64.31; H, 4.02; N, 12.64.

6-Aryl-2-phenyl-5-oxo-4,5-dihydrothiazolo[4,5-*d*]pyrimidines (39). A solution of the appropriate isocyanate (3 mmol) in 5 mL of dry toluene was added under nitrogen to a solution of iminophosphorane **37** (1.39 g, 3 mmol) in 30 mL of the same solvent. The reaction mixture was heated at reflux temperature for 5 h. After cooling, the precipitated solid was separated by filtration, dried, and recrystallized from ethanol to give **39** as crystalline solids. When the reaction was carried out at room temperature, the crude product was found to be a mixture of carbodiimide **38**, thiazolo[4,5-*d*]pyrimidine **39**, and triphenylphosphine oxide.

39a: yield 73%; mp 200–201 °C, brown prisms; IR (Nujol) 1660, 1591, 1528, 1313, 973, 775, 718, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.40–8.10 (m, 8 H, aryl), 8.26–8.60 (m, 2 H, aryl), 9.40 (s, 1 H, H-7 pyrimidine ring); mass spectrum, m/e (relative intensity) 305 (82, M^+), 304 (33), 263 (5), 202 (100), 174 (24), 147 (20), 104 (34), 99 (52), 77 (94). Anal. Calcd for $C_{17}H_{11}N_3OS$: C, 66.87; H, 3.63; N, 13.76. Found: C, 66.98; H, 3.78; N, 13.65.

39b: yield 70%; mp 188–189 °C, red prisms; IR (Nujol) 1660, 1596, 1325, 1194, 1109, 764, 724, 684 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.43 (s, 3 H, CH_3), 7.23–8.40 (m, 10 H, aryl), 8.56 (s, 1 H, H-7 pyrimidine ring); mass spectrum, m/e (relative intensity) 319 (67, M^+), 318 (22), 277 (5), 217 (12), 216 (100), 188 (13), 161 (21), 118 (20), 99 (65), 91 (62), 77 (10). Anal. Calcd for $C_{18}H_{13}N_3OS$: C, 66.69; H, 4.10; N, 13.16. Found: C, 67.75; H, 4.18; N, 12.99.

39c: yield 69%; mp 215–216 °C, brown prisms; IR (Nujol) 1660, 1609, 1588, 1527, 1323, 988, 775, 717, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.83 (s, 3 H, CH_3O), 7.10–8.00 (m, 9 H, aryl), 8.66 (s, 1 H, H-7 pyrimidine ring); mass spectrum, m/e (relative intensity) 335 (5, M^+), 293 (4), 272 (40), 204 (23), 149 (33), 134 (21), 123 (93), 122 (23), 108 (100), 106 (13), 77 (10). Anal. Calcd for $C_{18}H_{13}N_3O_2S$: C, 64.46; H, 3.91; N, 12.53. Found: C, 64.52; H, 3.84; N, 12.59.

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Registry No. 8, 947-95-5; 9, 114362-54-8; **10a**, 114362-55-9;

10b, 114362-56-0; **11**, 115437-27-9; **12a**, 114362-57-1; **12b**, 114362-58-2; **13**, 115437-28-0; **14a**, 114362-61-7; **14b**, 115437-29-1; **14c**, 115437-30-4; **14d**, 114362-59-3; **14e**, 114362-60-6; **14f**, 114362-63-9; **14g**, 115437-31-5; **14h**, 115437-32-6; **14i**, 114362-62-8; **15a**, 115437-33-7; **15b**, 115437-34-8; **15c**, 115437-35-9; **16** (R_1 = Ph), 115437-71-3; **16** (R_1 = H_3C-*p*-C_6H_4), 115437-72-4; **17a**, 114362-64-0; **17b**, 114362-65-1; **19a**, 115437-36-0; **19b**, 115437-37-1; **19c**, 115437-38-2; **19d**, 115437-39-3; **20a**, 115437-41-7; **20b**, 115437-43-9; **20c**, 115437-45-1; **20d**, 115437-47-3; **20e**, 115437-49-5; **20f**, 115437-51-9; **20g**, 115437-53-1; **21**, 97326-47-1; **22**, 115437-25-7; **23a**, 115437-54-2; **23b**, 115437-55-3; **24a**, 115437-56-4; **24b**, 114362-66-2; **25a**, 115462-12-9; **25b**, 114362-67-3; **25c**, 114362-68-4; **27**, 115437-57-5; **29a**, 115462-13-0; **29b**, 115462-14-1; **29c**, 115462-15-2; **29d**, 115462-16-3; **30**, 108263-77-0; **31**, 115437-26-8; **32a**, 115437-58-6; **32b**, 115437-59-7; **33a**, 115437-60-0; **33b**, 115437-61-1; **35a**, 115437-63-3; **35b**, 115437-64-4; **35c**, 115437-65-5; **36d**, 115437-66-6; **36a**, 115437-67-7; **36b**, 115437-68-8; **37**, 115437-62-2; **38** (Ar^2= Ph), 115437-73-5; **38** (Ar^2 = H_3C-*p*-C_6H_4), 115437-74-6; **38** (Ar^2 = H_3CO-*p*-C_6H_4), 115437-75-7; **39a**, 115437-69-9; **39b**, 115437-70-2; **39c**, 115462-17-4; $PhNH_2$, 62-53-3; H_3C-*p*-$C_6H_4NH_2$, 106-49-0; C_2H_5NCO, 109-90-0; H_2C=$CHCH_2$-NCO, 1476-23-9; Cl-*m*-C_6H_4NCO, 2909-38-8; Cl-*p*-C_6H_4NCO, 104-12-1; H_3CO-*p*-C_6H_4NCO, 5416-93-3; PhNCO, 103-71-9; C_2H_5COCl, 79-03-8; H_3C-*p*-C_6H_4COCl, 874-60-2; H_3CO-*p*-C_6H_4COCl, 100-07-2; Cl-*p*-C_6H_4COCl, 122-01-0; H_3C-*p*-C_6H_4NCO, 622-58-2; (*p*-nitrophenyl)hydrazine, 100-16-3.

Reaction of Thioaldehydes with 5-Alkoxyoxazoles: A Route to 3-Thiazolines

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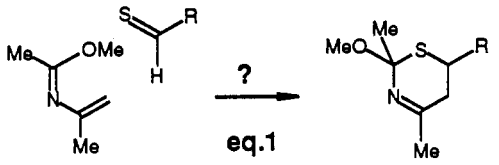
Generation of thioaldehydes **4** by photolysis of **15** or by thermolysis of **9** in the presence of oxazoles **2** or **3** affords **7** or **8**, respectively. Thermally generated thioacetone reacts similarly to give **16** and **17**. A mechanism involving an unstable Diels–Alder adduct **5** is most likely.

As part of our investigation of thioaldehyde chemistry,[1] we were interested to know whether Diels–Alder addition of these highly reactive dienophiles might take place with 2-aza-1,3-dienes.[2] The resulting adducts (eq 1) would be of interest due to their relationship to the cephalosporins. Attempts to trap thermally[1b] or photochemically[1a] generated RCH=S (R = CO_2Et, Ph, CH_2CH_2Ph) according to eq 1 did not result in detectable thioaldehyde adducts. In



an attempt to increase trapping efficiency by constraining the diene to the cisoid conformation, we next examined several oxazoles as potentially reactive 2-azadienes. The oxazole **1** proved too unreactive to intercept the thioaldehydes **4** prior to thioaldehyde decomposition, but the exceptionally activated 5-alkoxyoxazoles[3] **2** and **3** did afford 1:1 adducts in good yield. Spectroscopic evidence and chemical derivatization experiments established that the major product has the 3-thiazoline structure **7** (from **2**) or **8** (from **3**). The Diels–Alder adducts **5** or **6** were not detected.[4]

Table I

entry	RCHS	oxazole	precursor/ method[a]	yield,[b] %	product
1	**4a**	2	**15a**/B	0	
2	**4a**	2	**9a**/A1	81	**7a**
3	**4a**	3	**15a**/B	55	**8a**
4	**4a**	3	**9a**/A1	25	**8a**
5	**4b**	2	**15b**/B	0	
6	**4b**	2	**9b**/A1	59	**7b** (1:1)[c]
7	**4b**	3	**15b**/B	85	**8b** (2.5:1)
8	**4b**	3	**9b**/A1	85–95	**8b** (2.5:1)
9	**4c**	2	**15c**/B	0	
10	**4c**	2	**9c**/A2	95	**7c** (1:1)[c]
11	**4c**	3	**15c**/B	67	**8c** (2.5:1)
12	**4c**	3	**9c**/A2	92	**8c** (1:1)
13	**4d**	2	**15d**/B	0	
14	**4d**	2	**9d**/A2	70	**7d** (2:1)
15	**4d**	3	**15d**/B	35–50[e]	**8d** (>95:5)
16	**4d**	3	**9d**/A2	93	**8d** (>10:1)
17	**4e**	2	**15e**/B	0	
18	**4e**	2	**9e**/A2	29–34	**7e** (1:1)[c,d]
19	**4e**	3	**15e**/B	76	**8e** (2:1)[c]
20	**4e**	3	**9e**/A2	46[f]	**8e** (3:1)[c]

[a] See the Experimental Section: A1, 135–145 °C; A2, 105–115 °C; B, $h\nu$, 25 °C. [b] Isolated yields. [c] Diastereomers not completely separable. [d] Product aromatizes readily to thiazole. [e] Product unstable to $h\nu$ conditions. [f] 42% (1:1 ratio) of ester exchanged (R = CO_2Me) products **8f**.

In a representative example, the cyclopentadiene adduct **9b** of the photochemically generated thioacetaldehyde[1a] was heated with **3** at 140 °C. The product contains characteristic methyl ester signals in the NMR spectrum and therefore cannot be **5** or **6**. Among the remaining structural possibilities, **8b** and **10** are not easily distinguished by spectroscopic evidence. However, reduction of **8b** with sodium cyanoborohydride and trifluoroacetic acid gave a thiazolidine **11**, characterized by typical vicinal coupling in the NMR spectrum (major diastereomer, $J_{4,5}$ = 9.7 Hz). Similar coupling was observed in the product

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(4) The absence (<5%) of these potentially unstable products was established by NMR analysis of sealed reaction tubes.

0022-3263/88/1953-4663$01.50/0