SYNTHESIS OF 1,3,4-THIADIAZINES AND 1,3,4-OXADIAZINES

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Abstract - This review summarizes several methods for the synthesis of 1,3,4-thiadiazines and 1,3,4-oxadiazines reported in 1960s - 1990s.

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I. Introduction

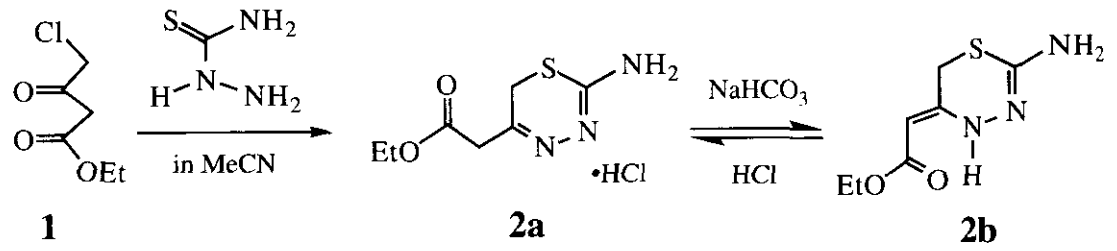
The synthesis of 1,3,4-thiadiazine or 1,3,4-oxadiazine derivatives has been reported up to date by many research groups, and useful compounds have been found in some of the 1,3,4-thiadiazine or 1,3,4-oxadiazine derivatives with the natures of the phosphodiesterase inhibitor,[1] antimicrobial for plants,[2] and dyestuff,[3] which have appeared in the patent literatures. Henceforward, the cooperative works of the synthetic chemists with other research groups would have continued to search for more useful and potent compounds. However, there have been few reviews or monographs[4] summarizing various methods for the synthesis of the condensed and noncondensed 1,3,4-thiadiazines or 1,3,4-oxadiazines. Accordingly, a prompt publication would be desired concerning a review or monograph on the general synthesis of the 1,3,4-thiadiazine or 1,3,4-oxadiazine derivatives. In this review, we summarize the synthesis of the condensed and noncondensed 1,3,4-thiadiazine or 1,3,4-oxadiazine derivatives.

II. Synthesis of 1,3,4-Thiadiazines and 1,3,4-Oxadiazines

1. From the Reaction of α-Halogenomethyl Ketones or α-Bromo-α-cyanoacetyl Derivatives with Thiosemicarbazide

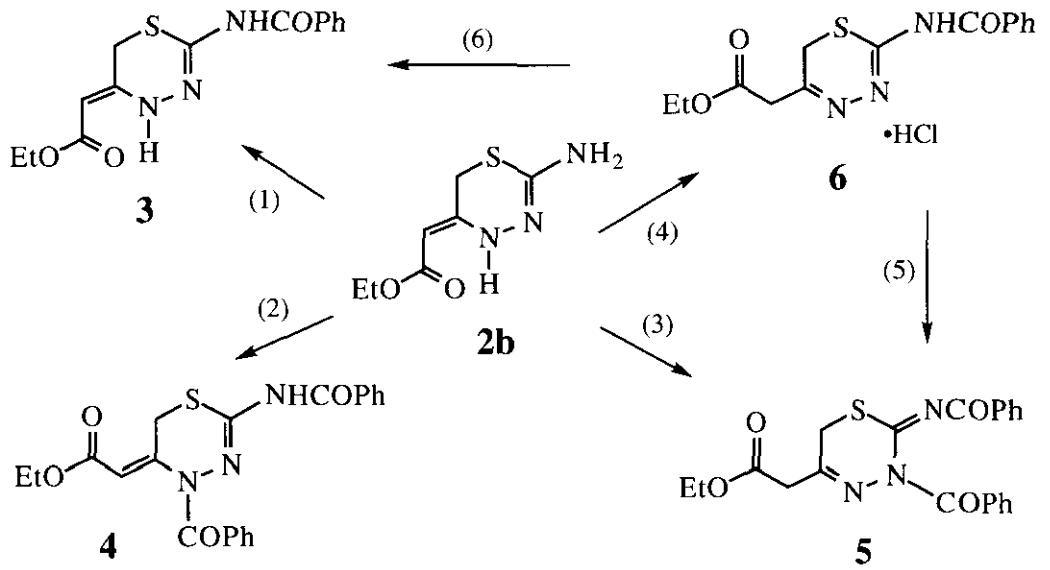
The reaction of ethyl 4-chloroacetoacetate (**1**) with thiosemicarbazide under heating in acetonitrile gave the 1,3,4-thiadiazine hydrochloride (**2a**), whose treatment with sodium bicarbonate afforded the enamine tautomer (**2b**) (Scheme 1).[5] In this reaction, change of conditions such as solvent polarity, solvent acidity, and reaction temperature gave thiazole or thiazoline derivatives. Compound (**2b**) was converted into the various derivatives (**3**-**6**) under diverse reaction conditions shown in Scheme 2.[5] Treatment of the hydrochloride (**6**) with sodium bicarbonate also provided the enamine tautomer (**3**). The reaction of the α-

Scheme 1



1 **2a** **2b**

Scheme 2



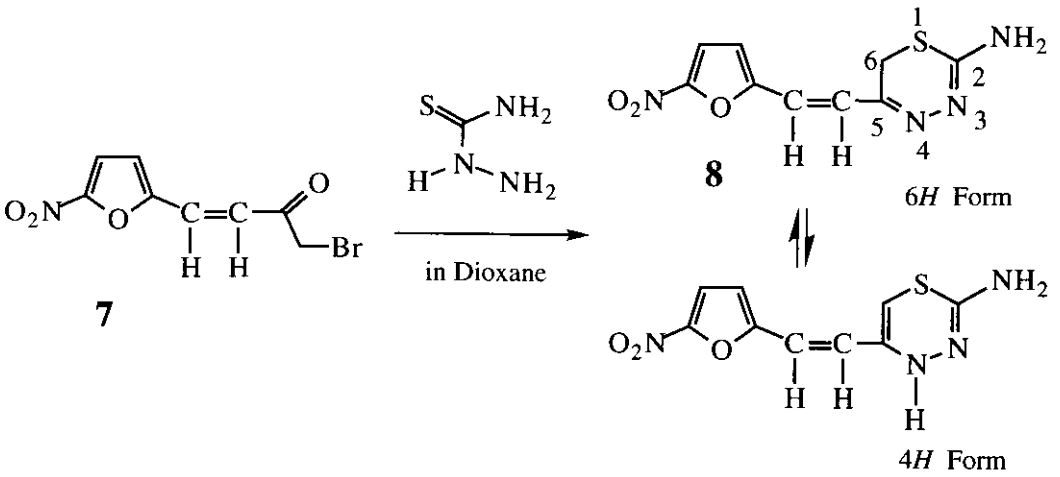
3 **6** **2b** **4** **5**

(1) PhCOCl / Pyridine / MeCN, (2) 2 PhCOCl / NEt_3 / EtOH, (3) 2 PhCOCl / $NaHCO_3$ / $CHCl_3$, (4) PhCOCl / C_6H_6, (5) PhCOCl / $NaHCO_3$ / $CHCl_3$, (6) $NaHCO_3$

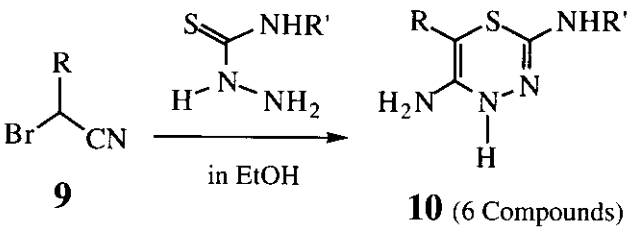
bromo ketone (**7**) with thiosemicarbazide and then sodium bicarbonate gave the 1,3,4-thiadiazine (**8**), whose tautomerism between the 6*H* and 4*H* forms was supported by the NMR spectral data (Scheme 3).[6] The methylenic proton (C_6-H_2) signal of the 6*H* form and the vinylic proton (C_6-H) signal of the 4*H* form were observed at δ 3.62 and 7.07 ppm.

The reaction of the α-bromo-α-cyanoacetyl derivatives (**9**) with 4-substituted thiosemicarbazides afforded the 2,5-diamino-1,3,4-thiadiazines (**10**) (Scheme 4).[7] On the other hand, the reaction of compound (**9**, R = $CONH_2$) with 2,4-disubstituted thiosemicarbazides provided the 5-amino-2-imino-1,3,4-thiadiazines (**11**) (Scheme 5).[7]

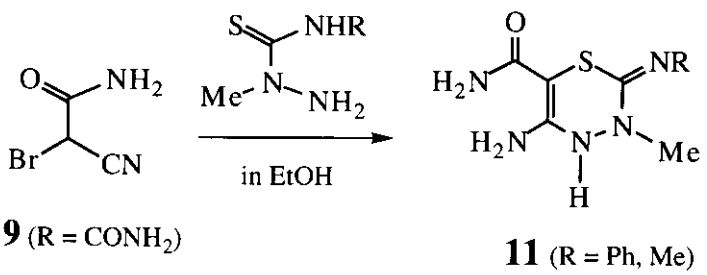
Scheme 3



Scheme 4



Scheme 5

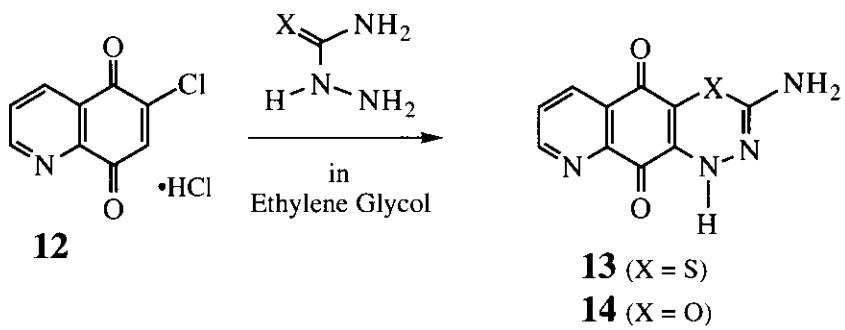


2. From the Reaction of Halogenoquinones with Thiosemicarbazide or Semicarbazide

The reaction of 6-chloroquinoline-5,8-dione hydrochloride (**12**) with thiosemicarbazide or semicarbazide gave 2-amino-4*H*-1,3,4-thiadiazino[6,5-*g*]quinoline-5,10-dione (**13**) or 2-amino-4*H*-1,3,4-oxadiazino[6,5-*g*]quinoline-5,10-dione (**14**), respectively (Scheme 6).[8] The

reaction of 2,3-dichloronaphthoquinone (**15**) with thiosemicarbazide afforded the naphtho[2,3-*e*][1,3,4]thiadiazine (**16**) (Scheme 7).[9]

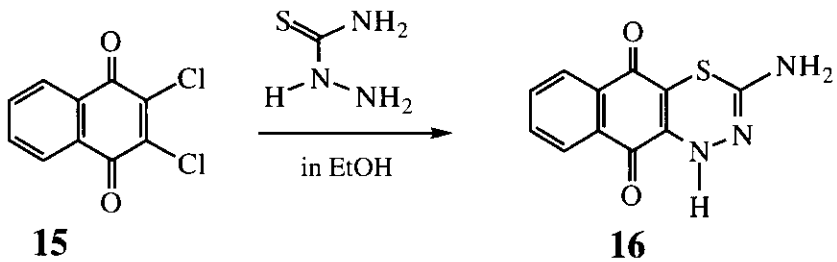
Scheme 6



12

13 (X = S)
14 (X = O)

Scheme 7

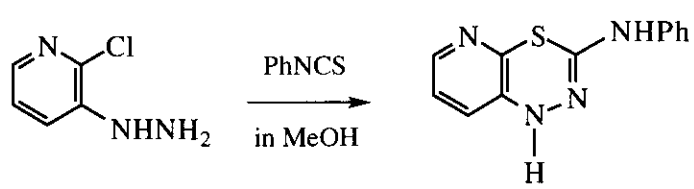


15 **16**

3. From the Reaction of (*o*-Halogenoheteroaryl)hydrazines with Isothiocyanates or Carbon Disulfide

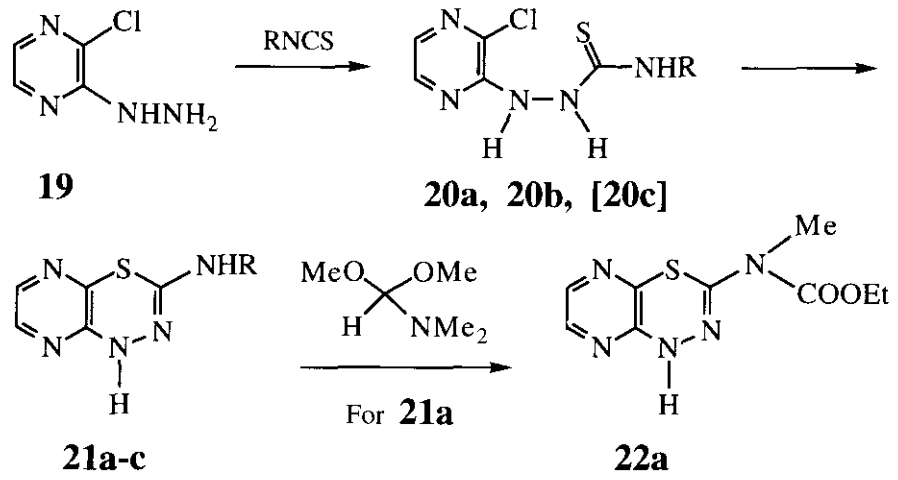
The reaction of 2-chloro-3-hydrazinopyridine (**17**) with phenyl isothiocyanate gave the pyrido[3,2-*e*][1,3,4]thiadiazine (**18**) (Scheme 8).[10] The reaction of 2-chloro-3-hydrazinopyrazine (**19**) with isothiocyanates afforded the adducts (**20a-c**), which were cyclized

Scheme 8

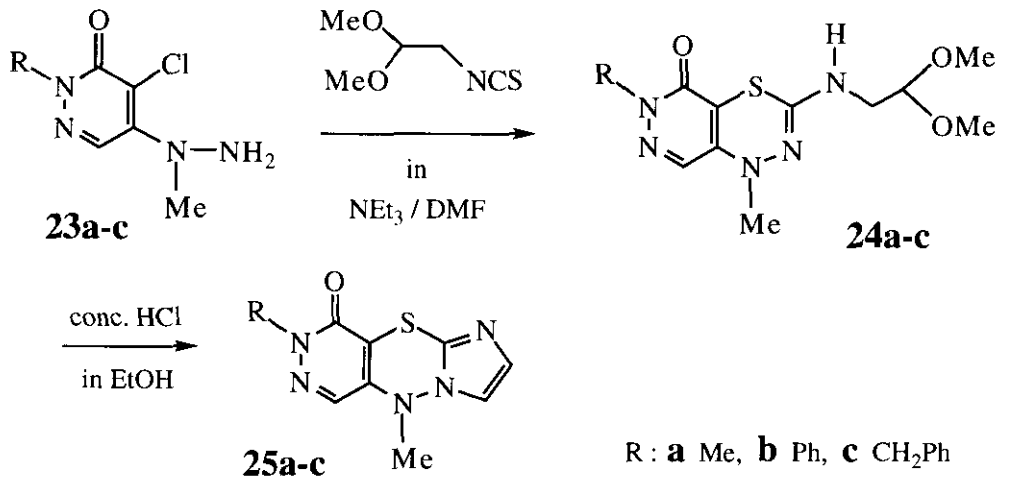


17 **18**

Scheme 9



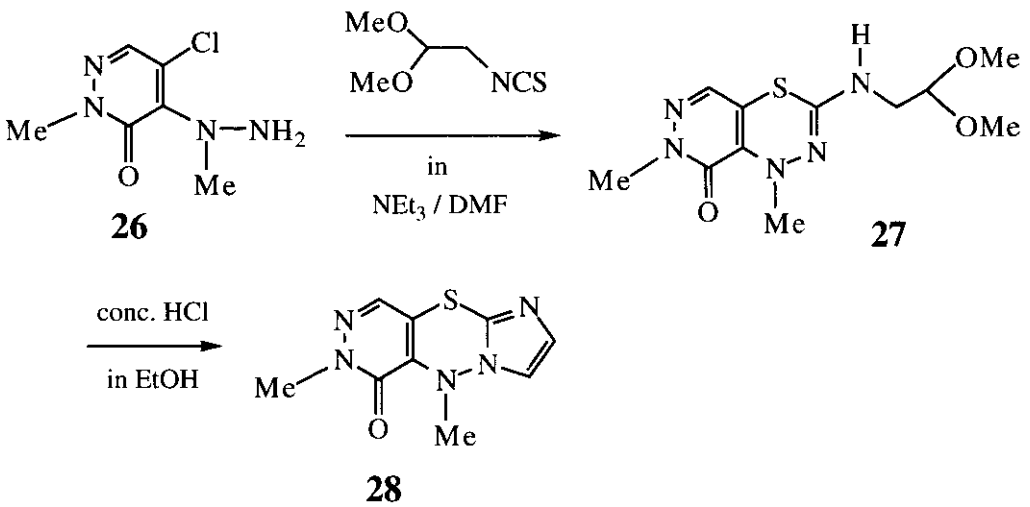
Scheme 10



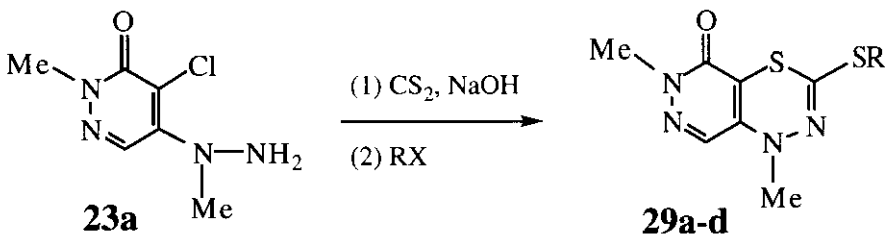
into the pyrazino[2,3-*e*][1,3,4]thiadiazines (**21a-c**), respectively (Scheme 9).[11] Compound (**21a**) was methylated with *N,N*-dimethylformamide dimethyl acetal to provide the *N*-methyl carbamate (**22a**). The reaction of the 4-chloro-5-(1-methylhydrazino)pyridazin-3-ones (**23a-c**) with 2,2-dimethoxyethyl isothiocyanate in the presence of triethylamine produced the pyridazino[4,5-*e*][1,3,4]thiadiazin-8-ones (**24a-c**), which were further cyclized into the imidazo[2,1-*b*]pyridazino[4,5-e][1,3,4]thiadiazin-9-ones (**25a-c**), respectively (Scheme 10).[12] Similarly, the 5-chloro-4-(1-methylhydrazino)pyridazin-3-one (**26**) was

converted into the pyridazino[4,5-*e*][1,3,4]thiadiazin-5-one (**27**), which was cyclized into the imidazo[2,1-*b*]pyridazino[4,5-*e*][1,3,4]thiadiazin-6-one (**28**) (Scheme 11).[12] The reaction

Scheme 11



Scheme 12

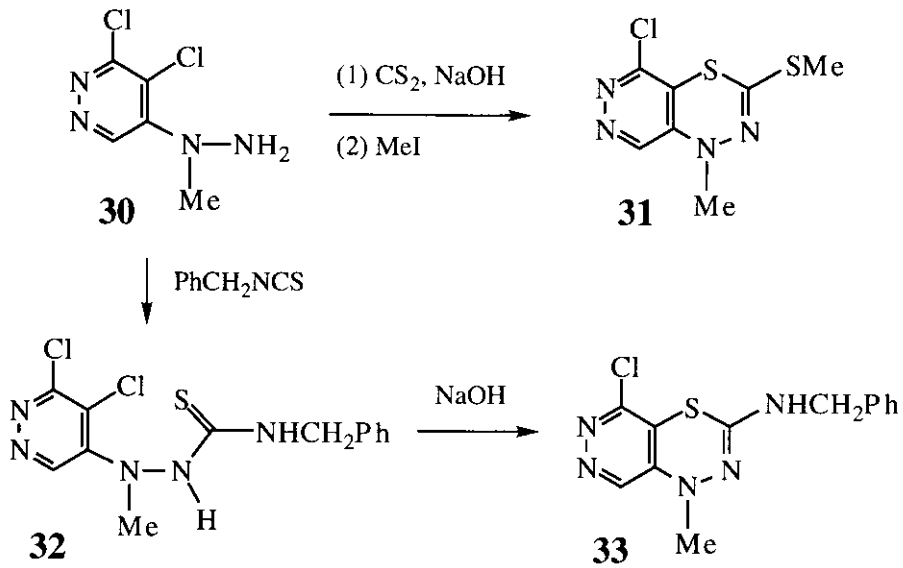


R : **a** Me, **b** CH_2Ph, **c** CH_2COPh, **d** CH_2COOEt

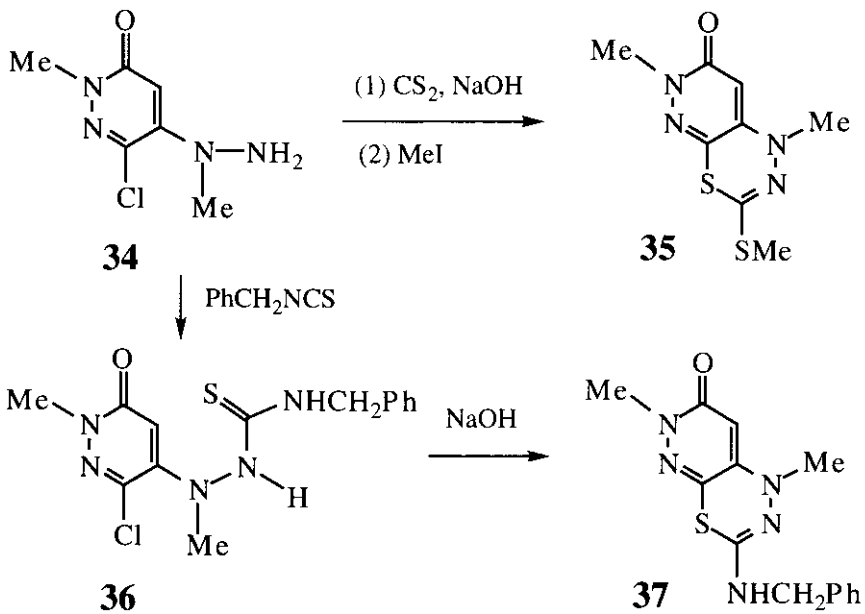
of compound (**23a**) with carbon disulfide/alkyl halide gave the 2-alkylthiopyridazino[4,5-*e*][1,3,4]thiadi-azin-8-ones (**29a-d**) (Scheme 12).[13] The reaction of 3,4-dichloro-5-(1-methylhydrazino)-pyridazine (**30**) with carbon disulfide/methyl iodide gave the 2-methylthiopyridazino[4,5-*e*][1,3,4]thiadiazine (**31**), while the reaction of compound (**30**) with benzyl isothiocyanate afforded the adduct (**32**), whose reaction with sodium hydroxide provided the 2-benzylaminopyridazino[4,5-*e*][1,3,4]thiadiazine (**33**) (Scheme 13).[13] The reaction of the 6-chloro-5-(1-methylhydrazino)pyridazin-3-one (**34**) with carbon disulfide/methyl iodide gave the 2-methylthiopyridazino[5,6-*e*][1,3,4]thiadiazin-6-one (**35**),

while the 2-benzylamino-pyridazino[5,6-*e*][1,3,4]thiadiazin-6-one (**37**) was produced from compoound (**34**) *via* the adduct (**36**) (Scheme 14).[13]

Scheme 13



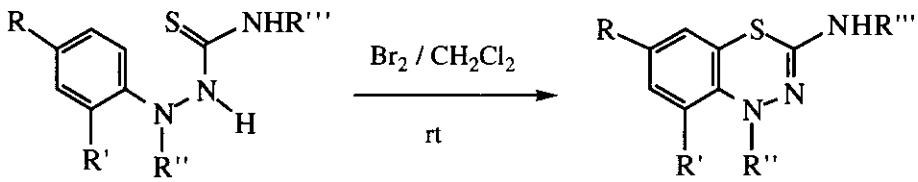
Scheme 14



4. From the Reaction of 4-Aryl- or 4-Heteroarylthiosemicarbazides with Oxidizing Agents

The reaction of the 1-phenylthiosemicarbazides (**38**) with bromine gave the 1,3,4-benzothiadiazines (**39**) (Scheme 15).[14] The reaction of the 5-(1-methylhydrazino)pyridazin-3-one (**40**) with alkyl or aryl isothiocyanates afforded the 1-(pyridazin-5-yl)thiosemicarbazides (**41a-c**), whose reaction with *N*-bromosuccinimide produced the pyridazino[4,5-*e*][1,3,4]thiadiazin-8-ones (**42a-c**), respectively (Scheme 16).[13] The reaction of the 1,3-di-

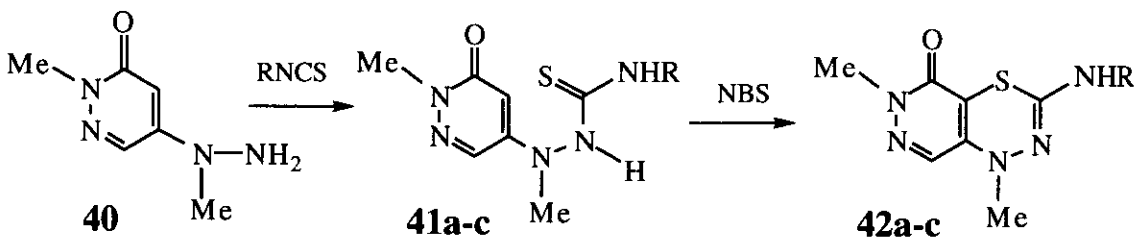
Scheme 15



38 **39** (8 Compounds)

R = H, Me, Br, R' = H, Me, R'' = H, Me, R''' = *t*-Bu, Me, *i*-Pr, Ph

Scheme 16

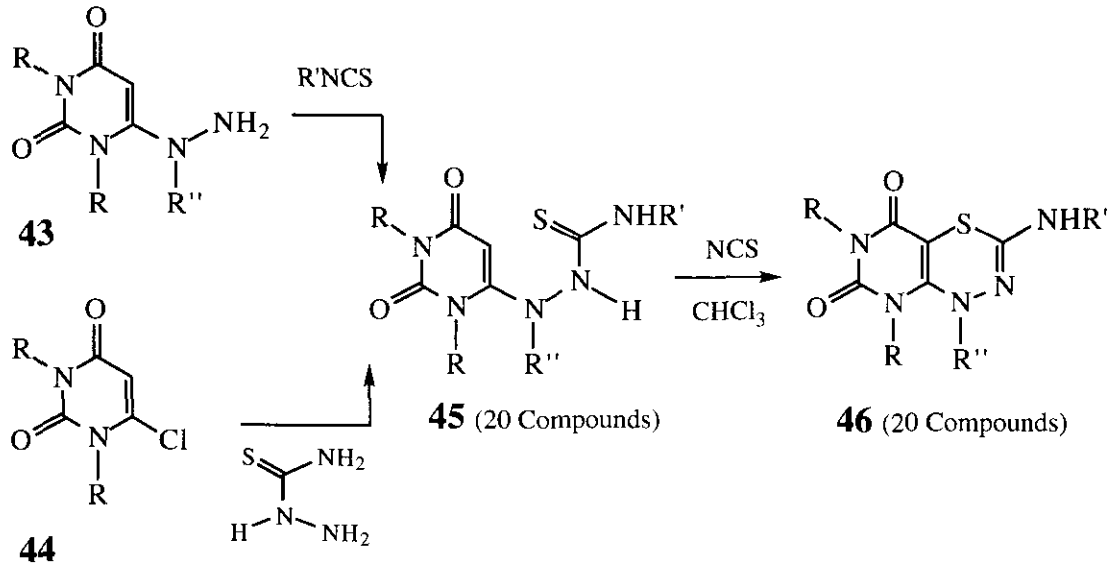


40 **41a-c** **42a-c**

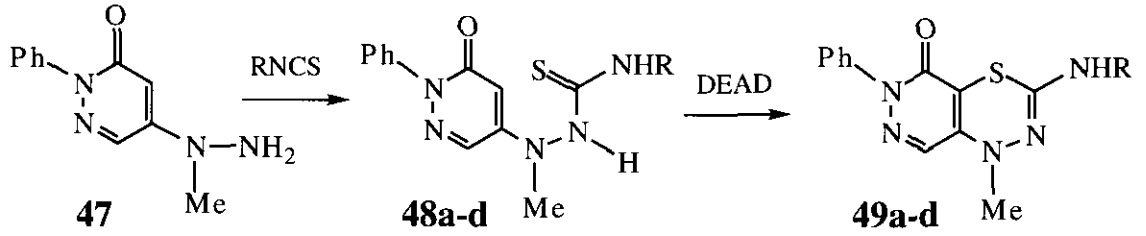
R : **a** Me, **b** Ph, **c** CH_2Ph

alkyl-6-hydrazinouracils (**43**) with isothiocyanates or the reaction of the 1,3-dialkyl-6-chlorouracils (**44**) with thiosemicarbazide produced the 1-(1,3-dialkyluracil-6-yl)thiosemicarbazides (**45**), whose reaction with *N*-chlorosuccinimide gave the pyrimido[4,5-*e*][1,3,4]thiadiazines (**46**) (Scheme 17).[15] The reaction of the 5-(1-methylhydrazino)-pyridazin-3-one (**47**) with isothiocyanates afforded the 1-(pyridazin-5-yl)thiosemicarbazides (**48a-d**), whose reaction with diethyl azodicarboxylate provided the pyridazino[4,5-*e*][1,3,4]thiadiazin-8-ones (**49a-d**), respectively (Scheme 18).[16]

Scheme 17



Scheme 18

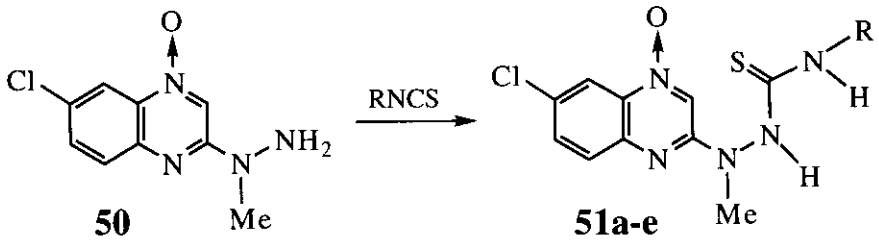


DEAD - Diethyl Azodicarboxylate R : **a** Ph, **b** C_6H_4-4-Br, **c** C_6H_4-4-Me, **d** CH_2Ph

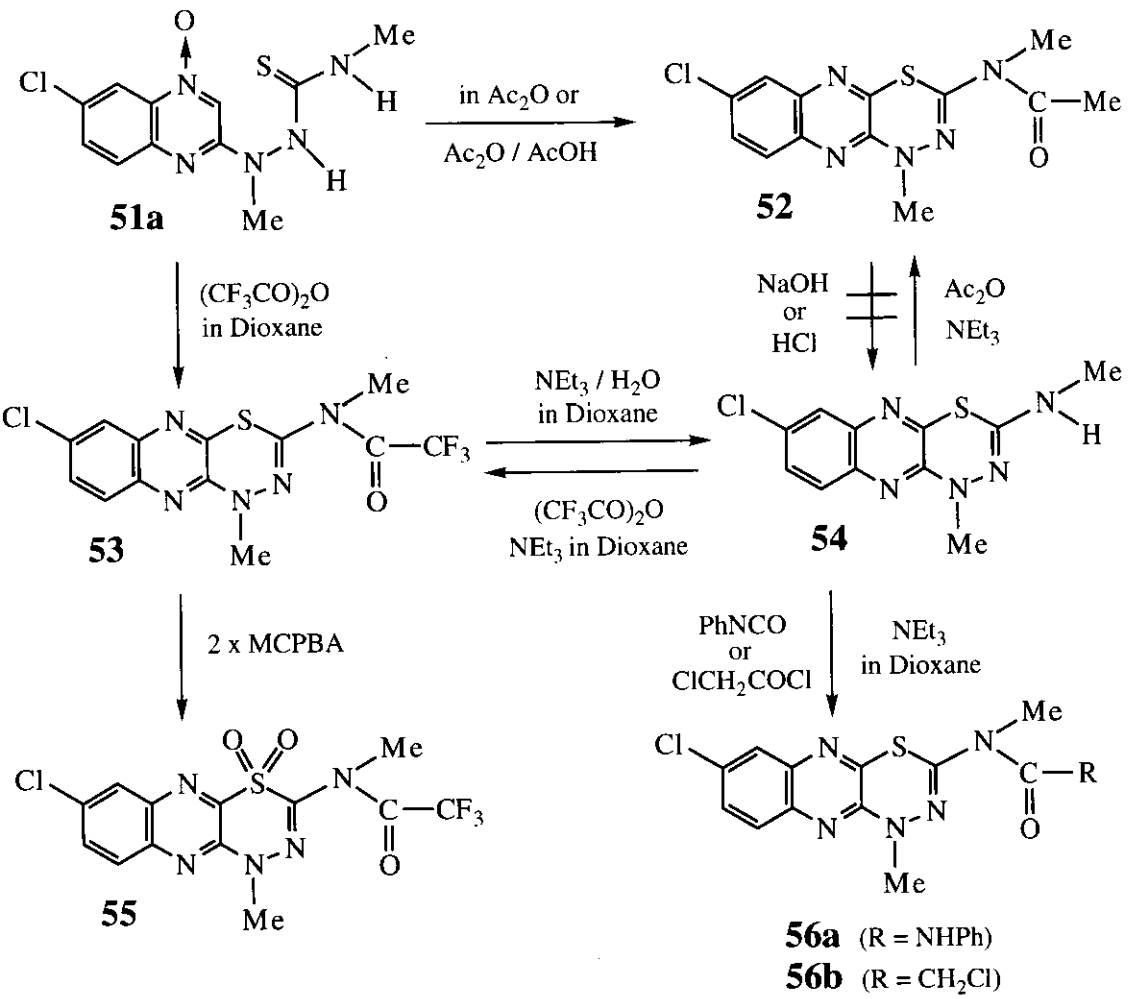
5. From the Reaction of 2-Hydrazinoquinoxaline 4-Oxides

The reaction of 6-chloro-2-(1-methylhydrazino)quinoxaline 4-oxide (**50**) with various isothiocyanates gave the 4-substituted 1-(quinoxalin-2-yl)thiosemicarbazides (**51a-e**) (Scheme 19). The reaction of compound (**51a**) with acetic anhydride effected cyclization to afford the 2-acetamido-1,3,4-thiadiazino[5,6-*b*]quinoxaline (**52**), and the reaction of compound (**51a**) with trifluoroacetic anhydride provided the 2-trifluoroacetamido-1,3,4-thiadiazino[5,6-*b*]quinoxaline (**53**) (Scheme 20).[17] The trifluoro-acetyl group of compoound (**53**) was easily hydrolyzed to give the 2-methylamino derivative (**54**), while the acetyl goroup of compound (**52**) was hardly eliminated. The reaction of compound (**53**) with

Scheme 19



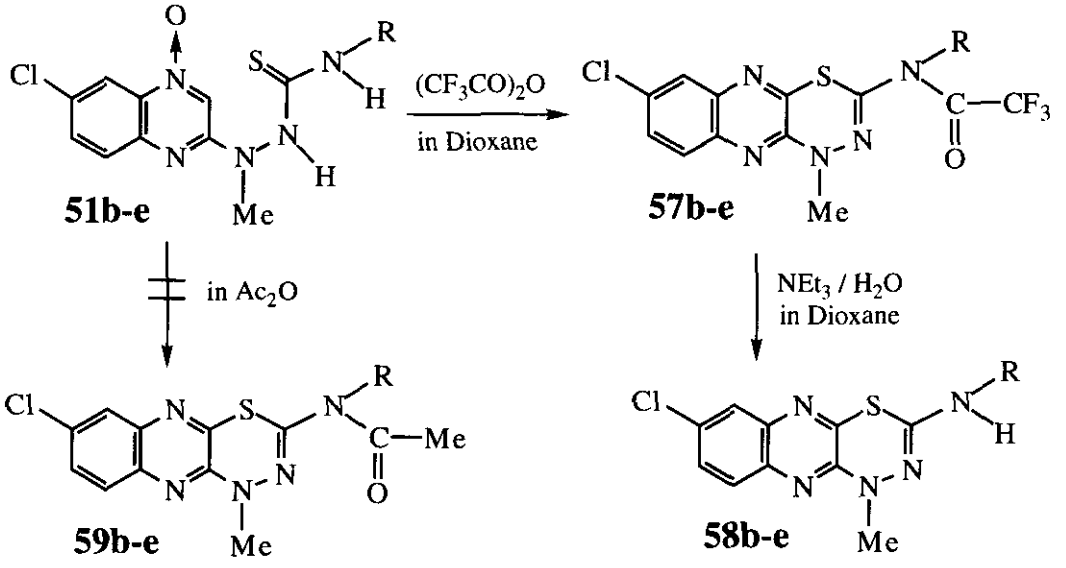
Scheme 20



m-chloroperbenzoic acid afforded the 1,1-dioxide (**55**), and the reaction of compound (**54**) with phenyl isocyanate or chloroacetyl chloride provided the ureido (**56**) or chloroacetyl

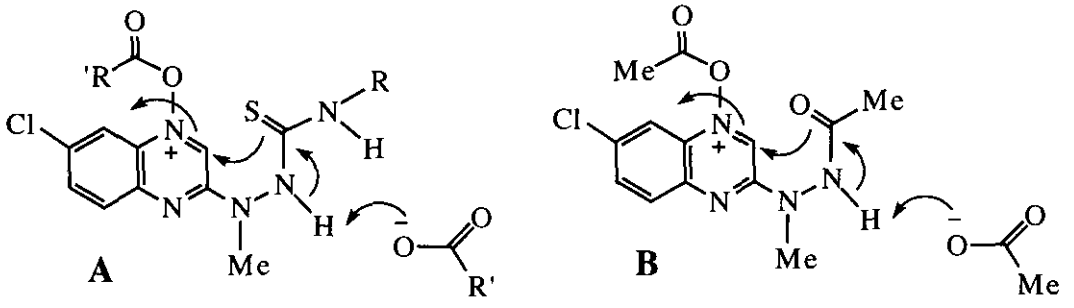
(**56b**) derivative. The reaction of compounds (**51b-e**) with trifluoroacetic anhydride gave various 2-trifluoroacetamido derivatives (**57b-e**), which were hydrolyzed to change into the arylamino and benzylamino derivatives (**58b-e**), respectively (Scheme 21).[18] However, compounds (**51b-e**) were not converted into the 2-acetamido derivatives (**59b-e**).

Scheme 21



R : **b** Ph, **c** C_6H_4-4-Cl, **d** C_6H_4-4-Br, **e** CH_2Ph

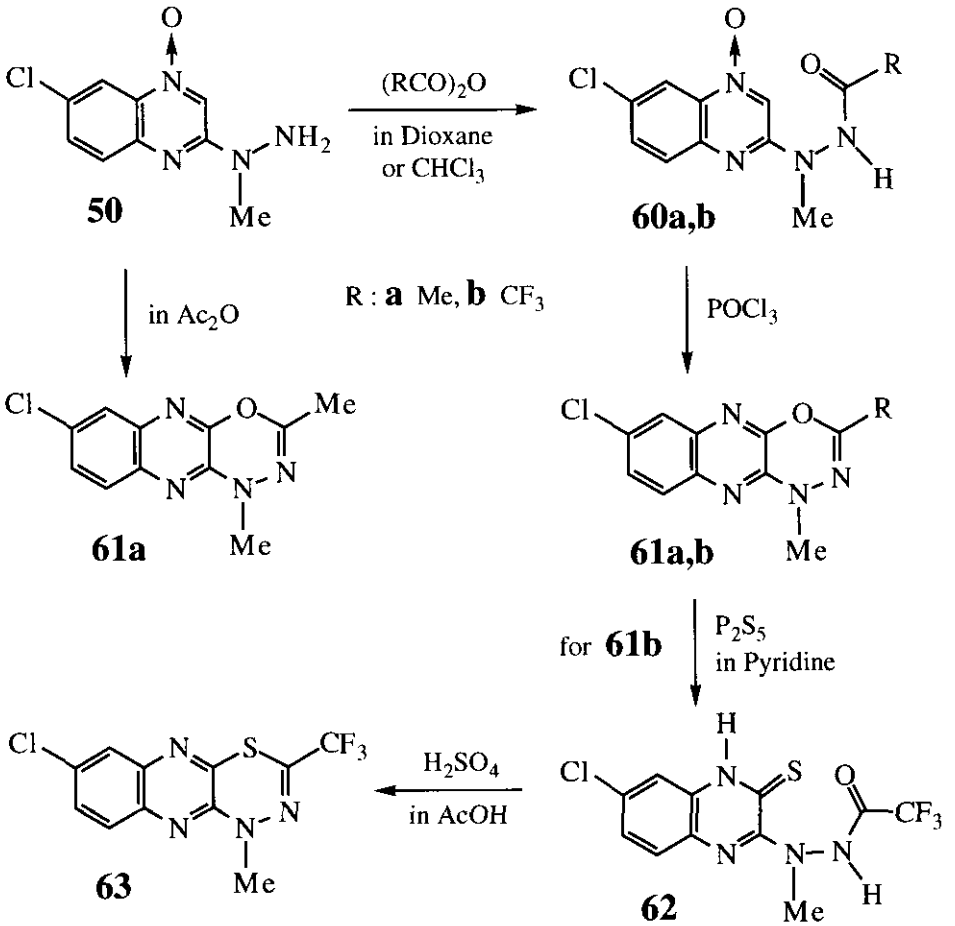
Chart 1



The cyclization of compounds (**51**) into the 1,3,4-thiadiazino[5,6-*b*]quinoxalines would proceed *via* an acylated intermediate **A** shown in Chart 1. On the other hand, the reaction of compound (**50**) with acetic anhydride would give an acetylated intermediate **B**, which is cyclized into the 2-methyl-1,3,4-oxadiazino[5,6-*b*]quinoxaline (**61a**) (Scheme 22).[19]

However, the yield is low (23%) in this reaction. Accordingly, the 2-methyl (**61a**) or 2-trifluoromethyl (**61b**) derivative of 1,3,4-oxadiazino[5,6-*b*]quinoxaline was synthesized *via* the acetyl (**60a**) or trifluoroacetyl (**60b**) derivative [overall yield: (**61a**) (58%), (**61b**) (56%)]. Compound (**61b**) was further transformed into the 2-trifluoromethyl-1,3,4-thiadiazino[5,6-*b*]quinoxaline (**63**) *via* compound (**62**).

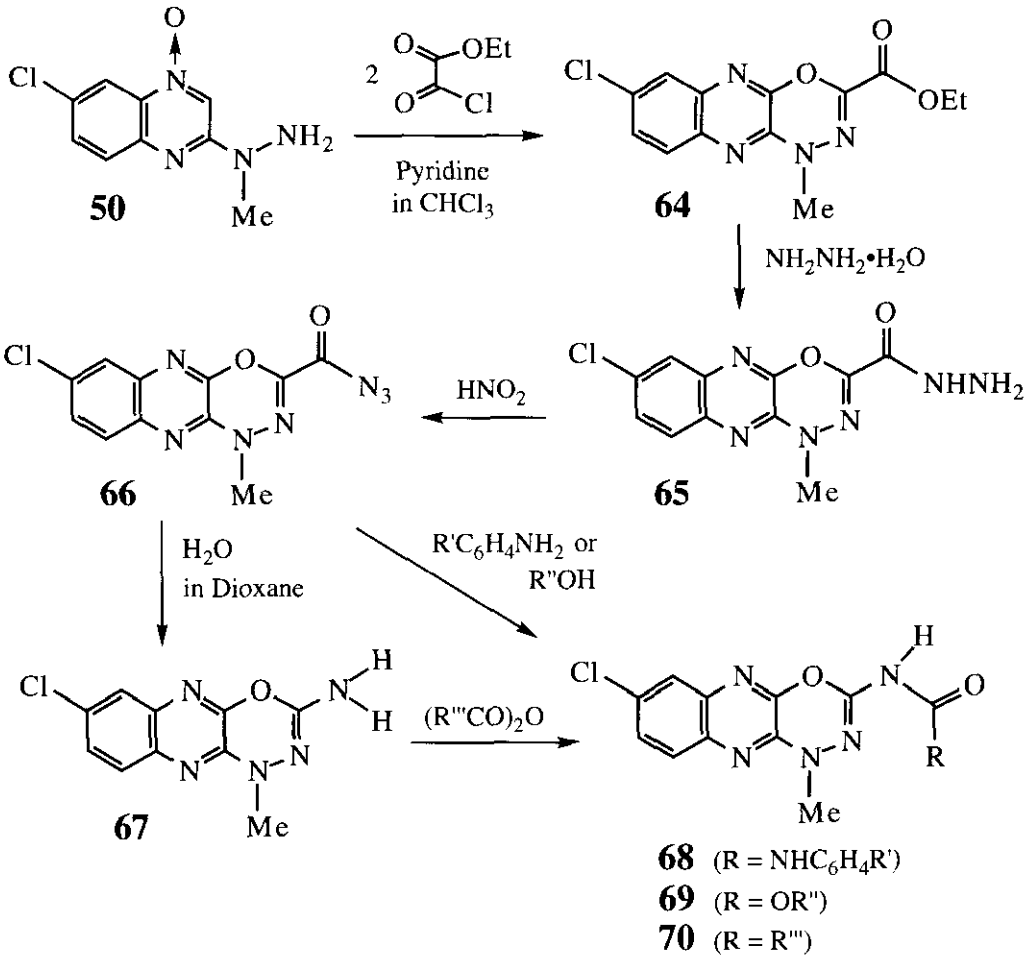
Scheme 22



The reaction of compound (**50**) with 2-fold molar amount of ethyl chloroglyoxalate gave the 1,3,4-oxadiazino[5,6-*b*]quinoxaline-2-carboxylate (**64**), whose reaction with hydrazine hydrate afforded the acyl hydrazide (**65**) (Scheme 23).[20] The reaction of compound (**65**) with nitrous acid provided the acyl azide (**66**), whose reaction with water provided the 2-amino derivative (**67**). The reaction of the acyl azide (**66**) with amines or alcohols

produced the ureido (**68**) or carbamate (**69**) derivatives, while the reaction of the 2-amino derivative (**67**) with anhydrides gave the 2-acylamino derivatives (**70**).

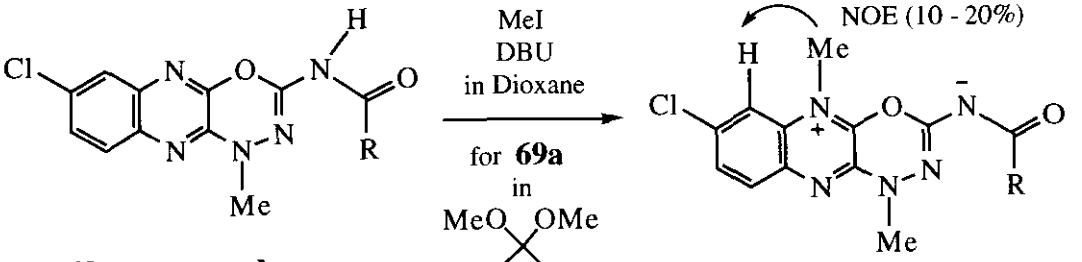
Scheme 23



R' = 4-F, 3-F, 3-CF_3 ; R" = Et, Bu, $(CH_2)_3Cl$; R''' = CF_3, Me, CH_2Cl

The reaction of compounds (**69a,b**) and (**70a,b**) with methyl iodide/1,8-diazabicyclo[5.4.0]-undec-7-ene (DBU) afforded the N_{10}-methyl derivatives (**71a,b**) and (**72a,b**), respectively (Scheme 24).[21] The structure of the N_{10}-methyl derivatives (**71a,b**) and (**72a,b**) was supported by the NOE between the C_9-H and N_{10}-Me protons. The reaction of compound (**69a**) with *N,N*-dimethylformamide dimethyl acetal also resulted in the N_{10}-methylation to provide compound (**71a**). Moreover, compound (**70a**) was found to exist as the N_{10}-H form,

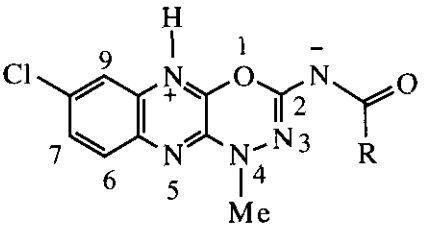
Scheme 24



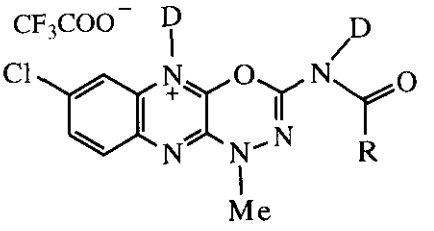
69 (R : **a** OEt, **b** OBu)
70 (R : **a** CF_3, **b** Me)

71 (R : **a** OEt, **b** OBu)
72 (R : **a** CF_3, **b** Me)

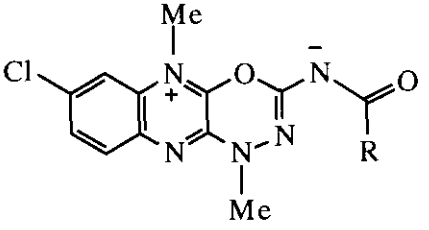
Chart 2



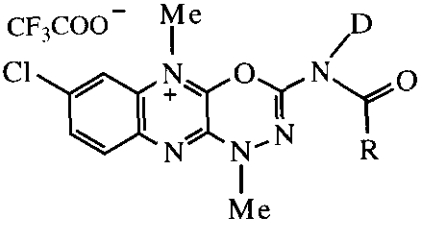
69 a,b , 70 a,b in DMSO-d_6
C_{9a} δ 130.8 - 131.6 ppm
C_{10a} δ 149.1 - 149.8 ppm



69 a,b , 70 a,b in TFA-d_1
C_{9a} δ 129.0 - 129.2 ppm
C_{10a} δ 148.4 - 148.8 ppm



71 a,b , 72 a,b in DMSO-d_6
C_{9a} δ 131.6 - 132.0 ppm
C_{10a} δ 149.1 - 149.2 ppm

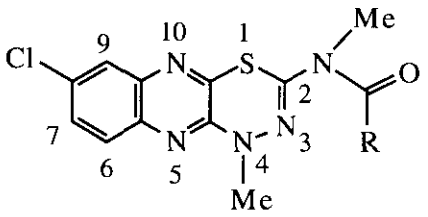


71 a,b , 72 a,b in TFA-d_1
C_{9a} δ 131.6 - 131.9 ppm
C_{10a} δ 147.9 - 148.1 ppm

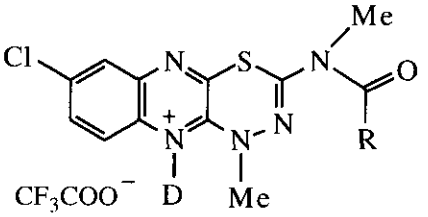
but not as the C_2-NH form, from the NOE between the NH and C_9-H protons. The N_{10}-H form of compounds (**69a,b**) and (**70a,b**) and the N_{10}-Me form of compounds (**71a,b**) and (**72a,b**) were also supported by the NMR spectral data in deuteriodimethyl sulfoxide (DMSO-d_6) and in deuteriotrifluoroacetic acid (TFA-d_1) (Chart 2).[21] Especially, the

chemical shifts of the C_{9a} and C_{10a} carbons in DMSO-d_6 were similar to those in TFA-d_1. On the contrary, the N_5-deuteration was suggested in the 1,3,4-thiadiazino[5,6-*b*]quinoxalines (**52**) and (**53**) from the comparison of the carbon chemical shifts in DMSO-d_6 with those in TFA-d_1 (Chart 3).[22] Namely, the C_{4a} and C_{5a} carbon chemical shifts were shielded in TFA-d_1 when compared with those in DMSO-d_6. On the other hand, the C_{9a} and C_{10a} carbon chemical shifts were deshielded in TFA-d_1 when compared with those in DMSO-d_6.

Chart 3



52 , 53 in DMSO-d_6



52 , 53 in TFA-d_1

Chemical Shift (δ ppm)		
	52	**53**
C_{4a}	144.9	143.8
C_{5a}	139.1	139.0
C_{9a}	130.0	130.5
C_{10a}	136.0	132.8

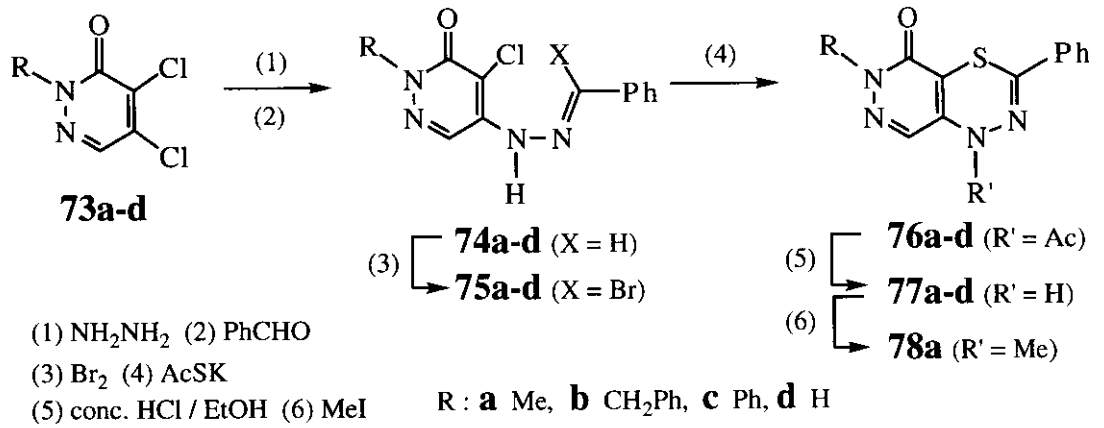
Chemical Shift (δ ppm)		
	52	**53**
C_{4a}	138.0	138.2
C_{5a}	126.5	126.5
C_{9a}	135.8	136.3
C_{10a}	148.8	146.8

6. From the Reaction of Hydrazonyl Halides with Thioacetate or Acetate

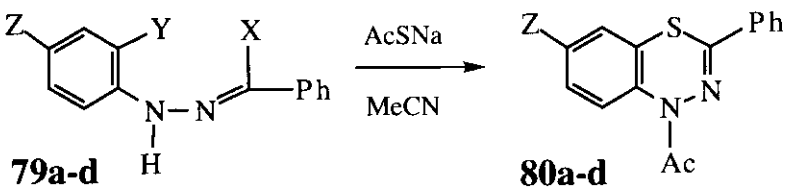
The reaction of the 4,5-dichloropyridazin-3-ones (**73a-d**) with hydrazine and then benzaldehyde gave the hydrazone (**74a-d**), whose reaction with bromine afforded the hydrazonyl bromides (**75a-d**), respectively (Scheme 25).[23,24] The reaction of compounds (**75a-d**) with potassium thioacetate provided the 4-acetylpyridazino[4,5-*e*][1,3,4]thiadiazines (**76a-d**), whose hydrolysis with concentrated hydrochloric acid/ethanol gave the pyridazino[4,5-*e*][1,3,4]-thiadiazines (**77a-d**), respectively. The reaction of compound (**77a**) with methyl iodide afforded the 4,7-dimethyl derivative (**78a**). The reaction of the

hydrazonyl halides (**79a -d**) with sodium thioacetate provided the 1,3,4-benzothiadiazines

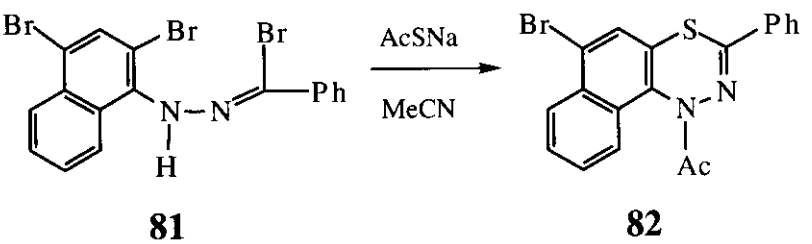
Scheme 25



Scheme 26



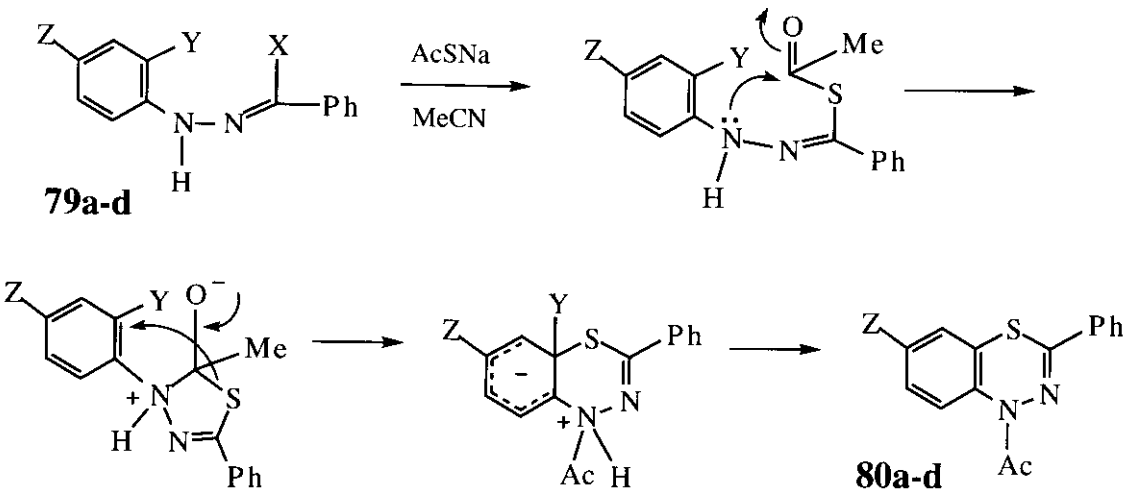
Scheme 27



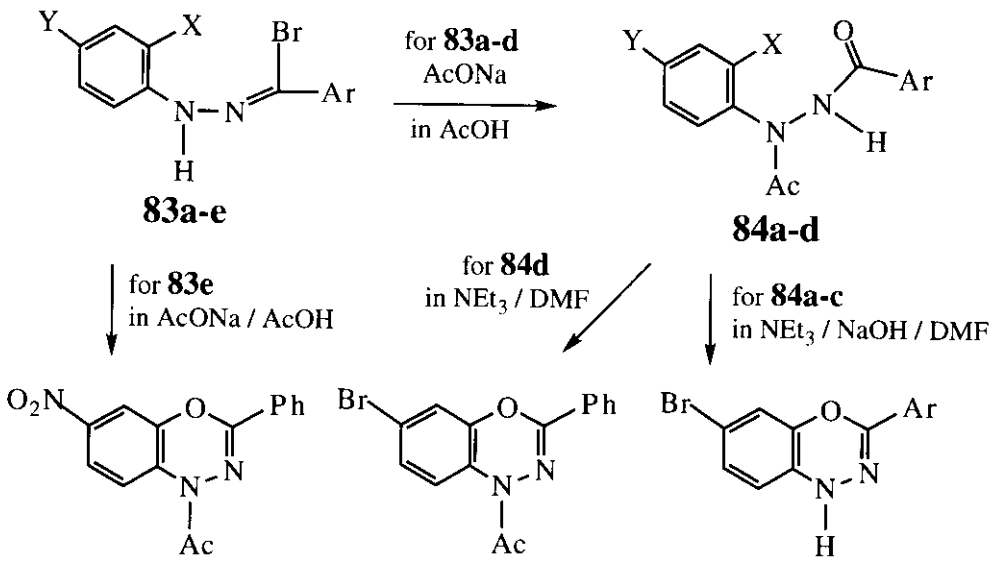
(**80a-d**), respectively (Scheme 26),[25] and the the reaction of the hydrazonyl bromide (**81**) with sodium thioacetate similarly produced the naphtho[1,2-*e*][1,3,4]thiadiazine (**82**) (Scheme 27).[25] The reaction mechanism is shown in Scheme 28.[26,27] The reaction of the hydrazonyl bromides (**83a-d**) or (**83e**) with sodium acetate gave the acetyl group-migrated

products (**84a-d**) or 1,3,4-benzoxadiazine (**84e**), respectively (Scheme 29).[28] The reaction of compounds (**84a -c**) with triethylamine/sodium hydroxide or the reaction of compound

Scheme 28



Scheme 29



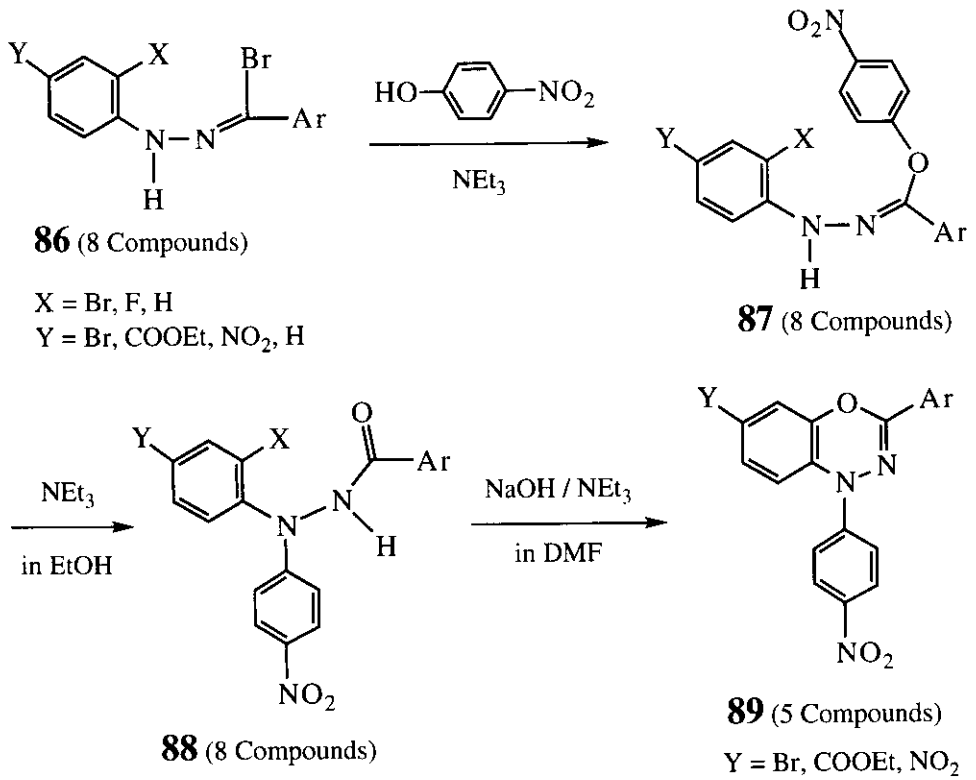
a Ar = 4-MeO-C_6H_4, X = Y = Br
b Ar = 5-Br-Thienyl, X = Y = Br
c Ar = 4-Cl-C_6H_4, X = Y = Br
d Ar = Ph, X = F, Y = Br
e Ar = Ph, X = Br, Y = NO_2

(**84d**) with triethylamine afforded the 1,3,4-benzoxadiazines (**85a-c**) or 4-acetyl derivative (**85d**), respectively.

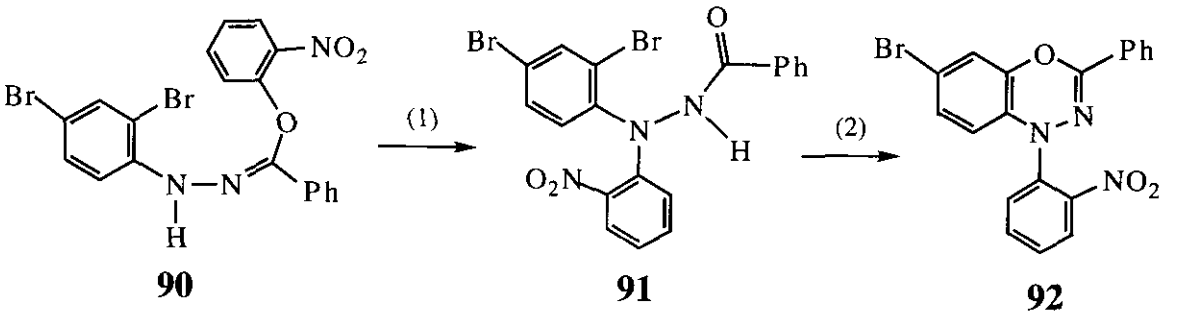
7. By the Smiles Rearrangement

The reaction of the hydrazonyl bromides (**86**) with *p*-nitrophenol and triethylamine gave the hydrazonyl *p*-nitrophenyl ethers (**87**), whose boiling in triethylamine/ethanol effected the Smiles rearrangement to afford the acylhydrazides (**88**) (Scheme 30).[28] Subsequent boiling of compounds (**88**) and sodium hydroxide/triethylamine in *N,N*-dimethylformamide provided the 4-(4-nitrophenyl)-1,3,4-benzoxadiazines (**89**). The 4-(2-nitrophenyl)-1,3,4-benzoxadiazine (**92**) was produced *via* the Smiles rearrangement of the hydrzonyl *o*-nitrophenyl ether to the arylhydrazide (**91**) (Scheme 31).[29] The reaction of 2,4-dinitrofluorobenzene (**93**) with *N'*-phenylbenzothiohydrazide or dithizone in triethylamine/acetonitrile gave the 1,3,4-benzothiadiazines (**94**) *via* the Smiles rearrangement

Scheme 30



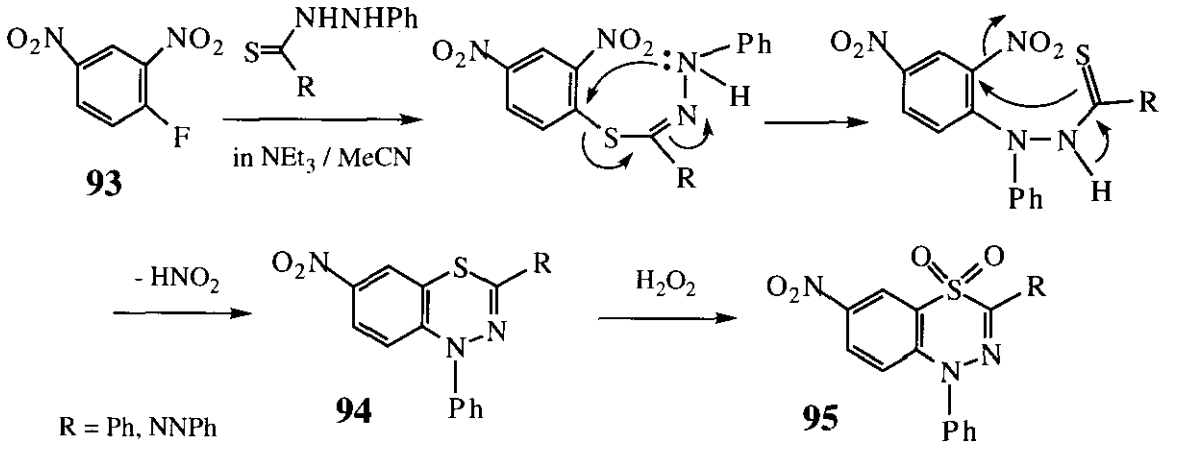
Scheme 31



90 **91** **92**

(1) NEt_3 / Ethanol, (2) NaOH / NEt_3 / DMF

Scheme 32



93 **94** **95**

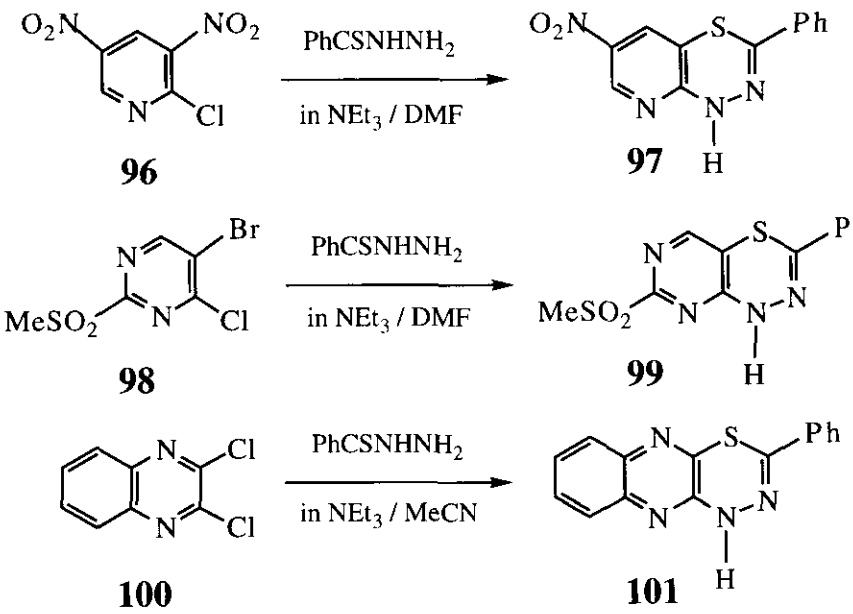
R = Ph, NNPh

(Scheme 32).[30] The oxidation of compounds (**94**) with hydrogen peroxide afforded the 1,1-dioxides (**95**). The reaction of compounds (**96**,**98**, and **100**) with benzothiohydrazide and triethylamine provided the heterocycle-condensed 1,3,4-thiadiazines (**97**, **99**, and **101**), respectively, *via* the Smiles rearrangement (Scheme 33).[31]

8. From the Reaction of 1-Halogeno-2-nitro- or 1,2-Dihalogenoaromatic Compounds with Acyl Hydrazide

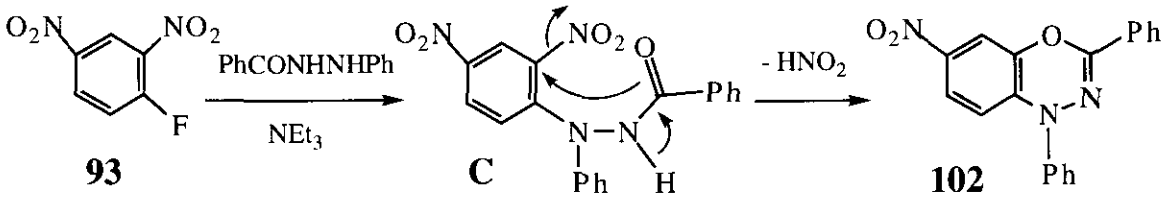
The reaction of compound (**93**) with *N'*-phenylbenzohydrazide and triethylamine gave the 1,3,4-benzoxadiazine (**102**) *via* an intermediate **C** (Scheme 34).[30] Similarly, the reaction of compounds (**96**, **104**, **106**, and **100**) with *N'*-phenylbenzohydrazide and triethylamine

Scheme 33



afforded the heterocycle-condensed 1,3,4-oxadiazines (**103**, **105**, **107**, and **108**), respectively (Scheme 35).[30]

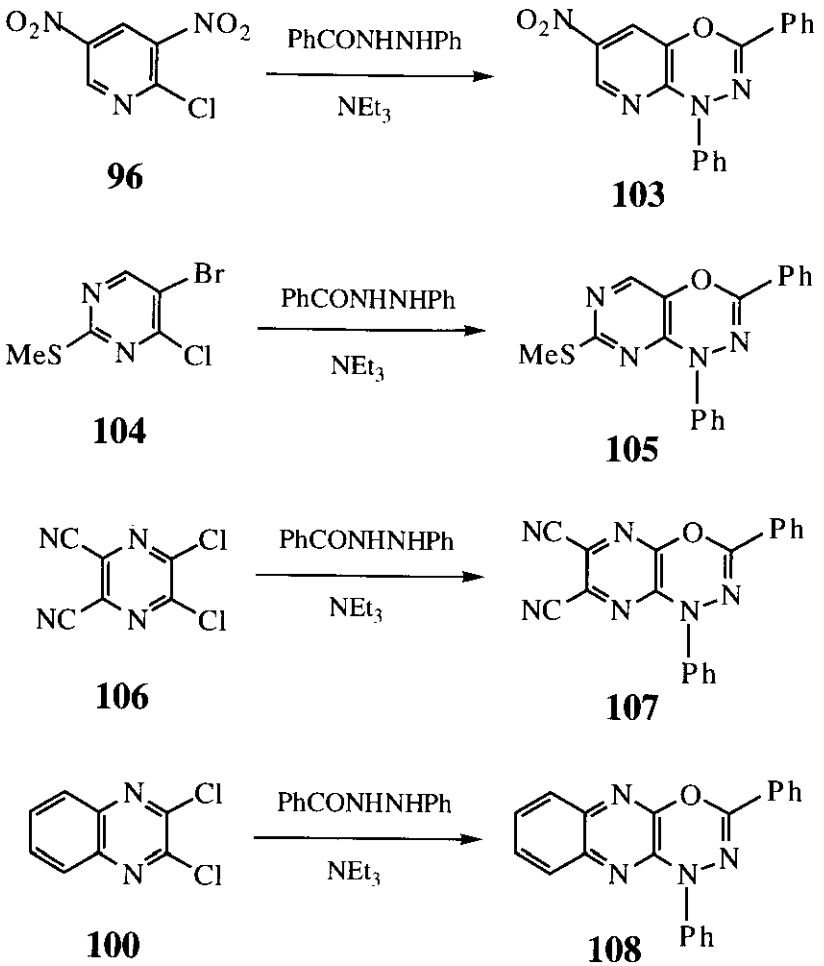
Scheme 34



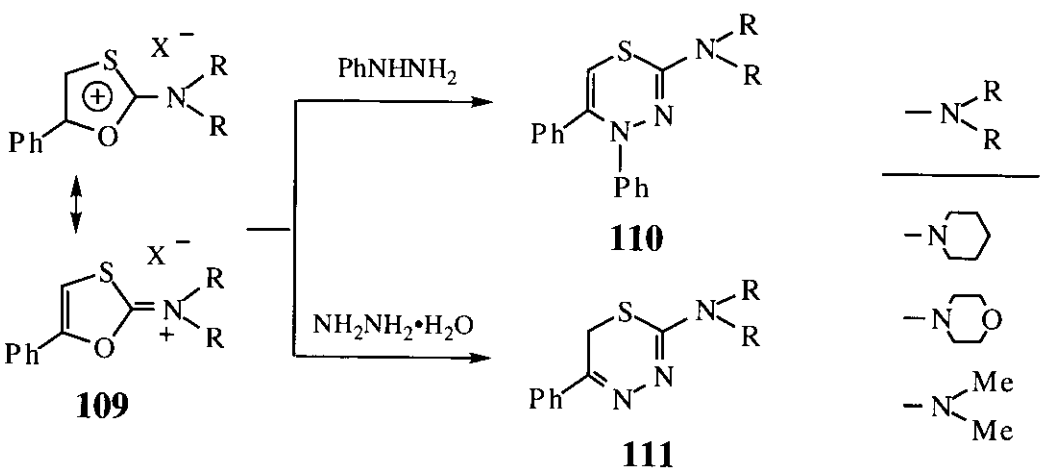
9. By the Ring Transformation

The reaction of the 1,3-oxathiolium salts (**109**) with phenylhydrazine or hydrazine hydrate resulted in ring transformation to give the 4,5-diphenyl-1,3,4-thiadiazines (**110**) or 5-phenyl-1,3,4-thiadiazines (**111**), respectively (Scheme 36).[32,33] The reaction of the 3-amino-2-imino-2,3-dihydro[4,5-*b*]quinoxalines (**112**) with carbon disulfide effected ring transformation to afford the 2-mercapto-1,3,4-thiadiazino[5,6- *b*]quinoxalines (**113**),

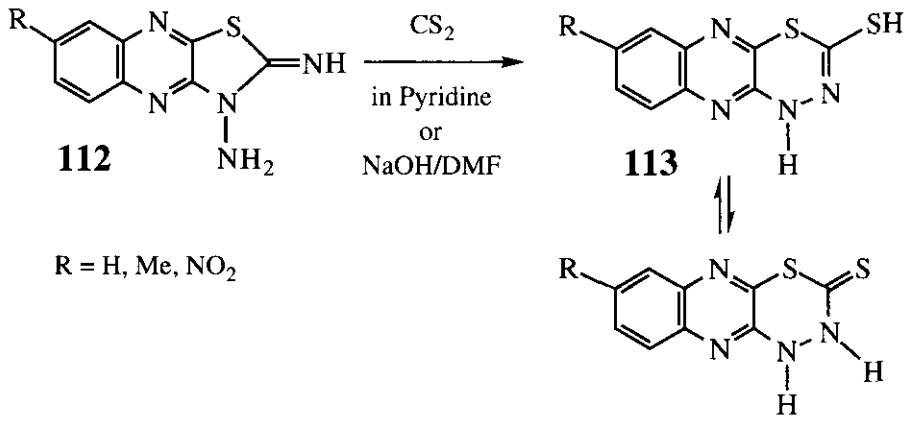
Scheme 35



Scheme 36



Scheme 37

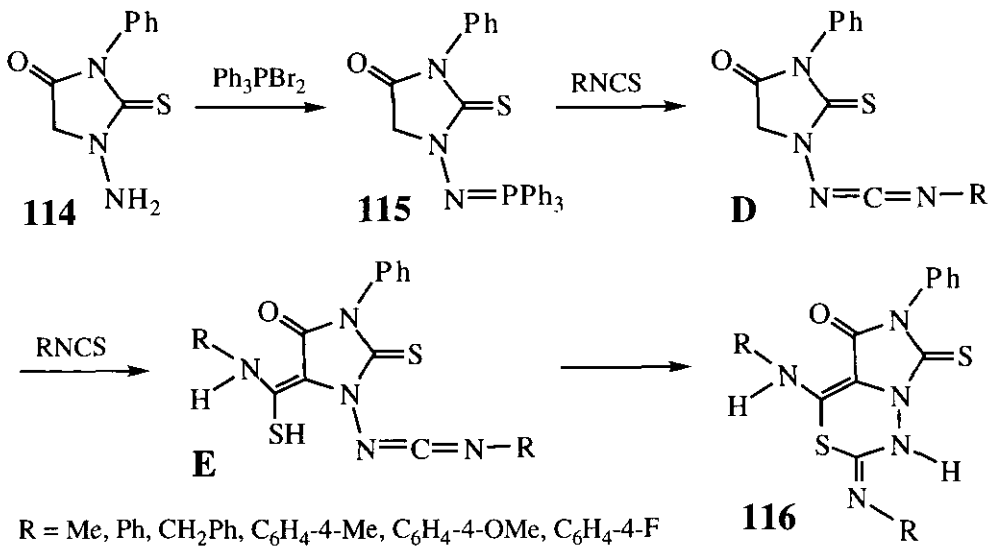


(Scheme 37).[34,35] The 2-mercapto and 2-thione tautomers are shown in the original paper,[34] but there is no description for detailed spectral data.

10. From the Reaction of *N*-Iminophosphorane with Isothiocyanates or Isocyanates

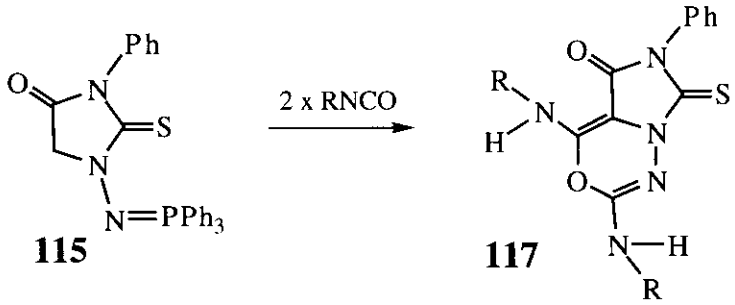
The reaction of 1-amino-3-phenyl-2-thioxo-4-imidazolidin-4-one (**114**) with triphenylphosphine dibromide gave the iminophosphorane (**115**), whose reaction with various isothiocyanates afforded the imidazo[1,5-*d*][1,3,4]thiadiazines (**116**) *via* intermediates **D**

Scheme 38



and **E** (Scheme 38).[36] When isocyanates were used in place of isothiocyanates in the above reaction, the imidazo[1,5-*d*][1,3,4]oxadiazines (**117**) were obtained from the iminophosphorane (**115**) (Scheme 39).[36]

Scheme 39



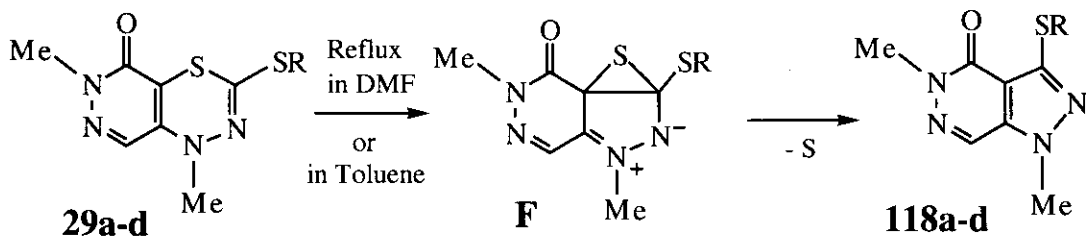
115 **117**

R = C_3H_7, Ph, CH_2Ph, C_6H_4-4-Me, C_6H_4-4-OMe, C_6H_4-4-F

III.Ring Contraction of Condensed 1,3,4-Thiadiazines through Sulfur Extrusion

When a solution of compounds (**29a-d**) in *N,N*-dimethylformamide or toluene was refluxed, the pyrazolo[3,4-*d*]pyridazin-4-ones (**118a-d**) were produced *via* an intermediate **F** accompanying with sulfur extrusion (Scheme 40).[13] The reaction proceeded so rapidly in *N,N*-dimethylformamide (within 1 hour) in comparison with that in toluene (12 hours). Similarly, compounds (**42a-c**) were converted into the pyrazolo[3,4-*d*]pyridazin-4-ones (**119a-c**), respectively (Scheme 41).[13] The reaction of compounds (**76a-d** or **77a-d**) in methanolic potassium hydroxide gave the pyrazolo[3,4-*d*]pyridazin-4-ones (**120a-d**), respec-

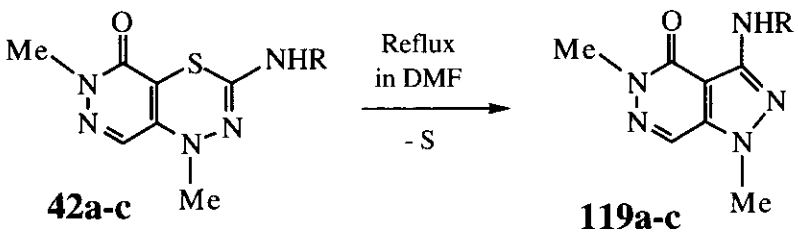
Scheme 40



29a-d **F** **118a-d**

R : **a** Me, **b** CH_2Ph, **c** CH_2COPh, **d** CH_2COOEt

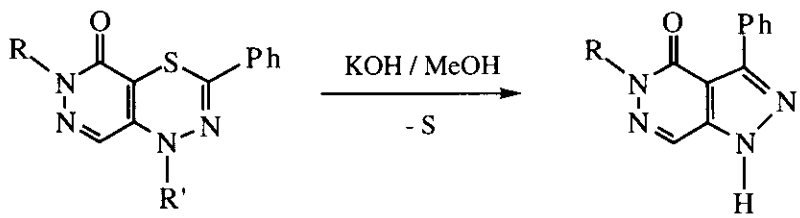
Scheme 41



42a-c **119a-c**

R : **a** Me, **b** Ph, **c** CH_2Ph

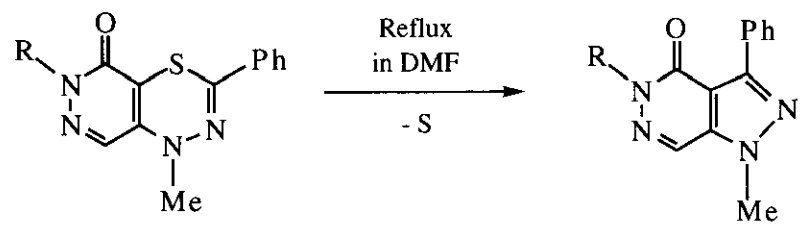
Scheme 42



76a-d (R' = Ac)

77a-d (R' = H)

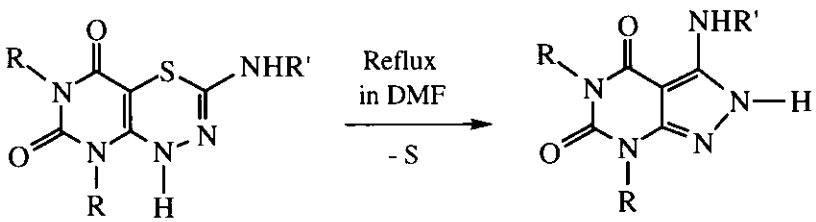
120a-d



78a **121a**

R : **a** Me, **b** CH_2Ph, **c** Ph, **d** H

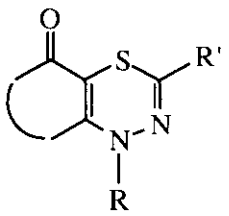
Scheme 43



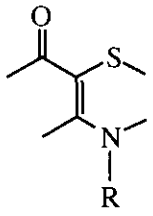
46 (14 Compounds) **122** (14 Compounds)

tively. In the case of the N_4-acetyl derivative (**76a-d**), the reaction was carried out under reflux. On the other hand, reflux of compound (**78a**) in *N,N*-dimethylformamide afforded compound (**121a**) (Scheme 42).[23,24] The reaction of the pyrimido[4,5-e][1,3,4]thiadiazine-6,8-diones (**46**) under reflux in *N,N*-dimethylformamide resulted in desulfurization to provide the pyrazolo[3,4-*d*]pyrimidine-4,6-diones (**122**) (Scheme 43).[15]

Chart 4

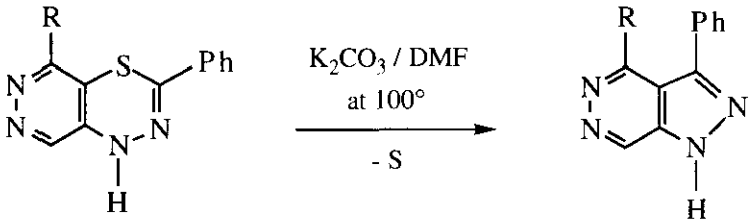


Condensed 1,3,4-Thiadiazines



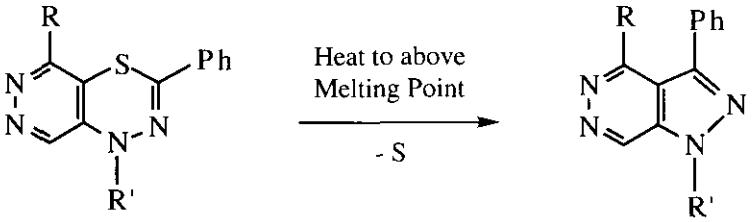
β-Amino-α-thioenone Moiety

Scheme 44



123a-d **124a-d**

R : **a** Cl, **b** Morpholin-4-yl, **c** Piperidin-1-yl, **d** $NHCH_2Ph$



123a-f **124a-f**

e R = Cl, R' = Me, **f** R = Cl, R' = CH_2Ph

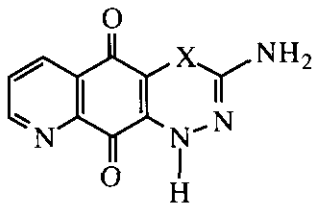
Thus, the sulfur extrusion easily takes place in the condensed 1,3,4-thiadiazines (**29**, **42**,

46, **76**, **77**, and **78**) having the β-amino-α-thioenone moiety (Chart 4),[13,24] while the N_4-proton is necessary for the ring contraction of the pyrimido[4,5-*e*][1,3,4]thiadiazine-6,8-diones (**46**) into the pyrazolo[3,4-*d*]pyrimidine-4,6-diones (**122**).[15] However, strong reaction conditions are required for the desulfurization of the 8-substituted pyridazino[4,5-*e*][1,3,4]thiadiazines (**123a-f**) into the pyrazolo[3,4-*d*]pyridazines (**124a-f**) (Scheme 44), presumably due to the lack of the β-amino-α-thioenone function.[24] Compounds (**35** and **37**) (Scheme 14) possessing the β-aminoenone (but not β-amino-α-thioenone) moiety are inert for the above sulfur extrusion.[13]

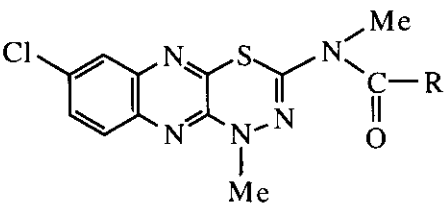
IV. Biologically Active 1,3,4-Thiadiazines and 1,3,4-Oxadiazines

The 1,3,4-thiadiazino[6,5-*g*]quinoline (**13**) and 1,3,4-oxadiazino[6,5-*g*]quinoline (**14**) (Chart 5) showed a remarkable activity against *Micrococcus roseus*, but these compounds exhibited no activity against *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, and *Serratia* sp.[8] The 1,3,4-thiadiazino[5,6-*b*]quinoxalines (**52** and **53**) and 1,3,4-oxadiazino[5,6-*b*]quino-

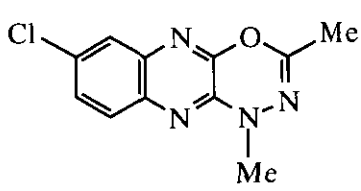
Chart 5



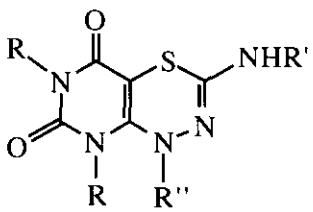
13 (X = S)
14 (X = O)



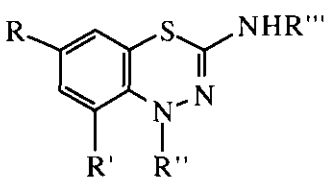
52 R = Me
53 R = CF_3



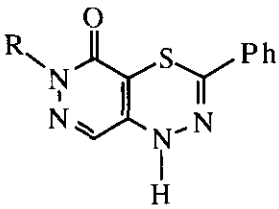
61a



46



39



77a-d

xaline (**61a**) showed an excellent activity against *Sphaerotheca fuliginea*.[37] The pyrimido[4,5-*e*][1,3,4]thiadiazines (**46**)[15] were reported to be useful as hypotensive, diuretic, antiinflammatory, and antigastric ulcer agents,[1] and the phosphodiesterase 50% inhibitory concentrations of compounds (**46**) were 10-112 μM (theophilline, 143 μM). The 1,3,4-benzothiadiazines (**39**)[14] were developed as plant disease-controlling agents, and these compounds completely prevented rice seedling from infection with *Pyricularia orizae*.[2] The pyridazino[4,5-*e*][1,3,4]thiadiazines (**77a-d**) had a herbicidal activity.[13,38] Especially, compound (**77a**) (R = Me) at 50 g/are controlled *Digitaria sanguinalis*, *Cyperus microiria*, *Amaranthus*, *Portulaca oleracea*, *Calinsoga ciliata*, and *Brassica* in rice by above 90%.[13,38]

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