

Reactions of 1-aryl-2,2-dihalogenoethanone oximes with tetrasulfur tetranitride (S_4N_4): a general method for the synthesis of 3-aryl-4-halogeno-1,2,5-thiadiazoles

Sung Cheol Yoon, Jaeock Cho and Kyongtae Kim *

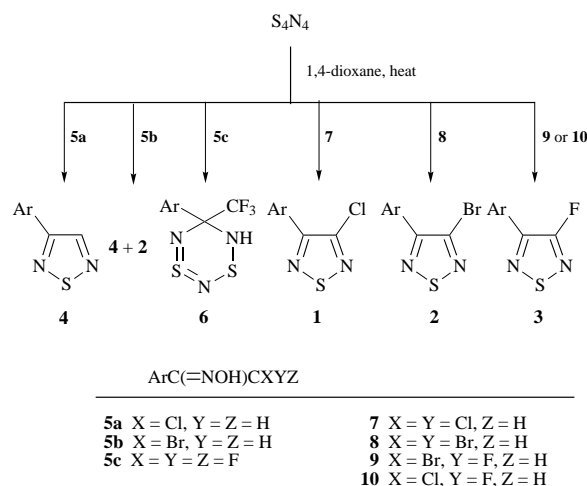
Department of Chemistry, Seoul National University, Seoul 151-742, Korea

1-Aryl-2,2-dichloro-7, 1-aryl-2,2-dibromo-8, 1-aryl-2-bromo-2-fluoro-9 and 1-aryl-2-chloro-2-fluoro-ethanone oximes 10 have been prepared by allowing the corresponding ketones to react with hydroxylamine hydrochloride in EtOH at room temperature. Stereochemical assignments for the oximes were made on the basis of 1H NMR spectroscopic evidence and an X-ray crystallographic analysis of 1-(3-chlorophenyl)-2,2-dichloroethanone oxime 7f. The 1-aryl-2,2-dihalogenoethanone oximes react with tetrasulfur tetranitride in refluxing 1,4-dioxane to give 3-aryl-4-chloro-1, 3-aryl-4-bromo-2, and 3-aryl-4-fluoro-1,2,5-thiadiazoles 3 in 69–98, 49–99, and 32–65% yields, respectively. A mechanism for the formation of the 1,2,5-thiadiazoles is proposed.

Introduction

3-Aryl-4-halogeno-1,2,5-thiadiazoles 1–3 have attracted much attention since the 3-chloro-, 3-fluoro, 3-aryl-4-chloro, and/or 3-aryl-4-fluoro-derivatives show herbicidal¹ or nematocidal effects.² The synthesis of 3-chloro- and 3-aryl-4-chloro-1,2,5-thiadiazoles has been extensively studied by Weinstock and co-workers³ in a method involving the reaction of sulfur monochloride (S_2Cl_2) with α -aminoacetonitrile bisulfate, α -aminophenylacetonitrile hydrochloride, isonitrosophenylacetonitrile, or glyoxime in DMF at different reaction temperatures. This method has been widely utilized for the synthesis of 3-bromo- and 3-chloro-1,2,5-thiadiazoles. Alternatively, 3-aryl-4-chloro-1 and 3-aryl-4-bromo-1,2,5-thiadiazoles 2 have been prepared by reactions of the corresponding 4-hydroxy compounds with phosphorous oxychloride³ and phosphorus oxybromide,⁴ respectively, and 3-aryl-4-fluoro-1,2,5-thiadiazoles 3 by treating the corresponding chloro analogues with potassium fluoride at elevated temperature.²

Recently we reported a facile and much improved synthesis of 3-aryl-1,2,5-thiadiazoles 4, by allowing 1-aryl-2-chloroethanone oximes 5a to react with S_4N_4 in refluxing 1,4-dioxane;⁵ no chlorine-containing 1,2,5-thiadiazoles 1 were detected. However, treatment of 1-aryl-2-bromoethanone oximes 5b under the same conditions gave compounds 2 as the minor and compounds 4 as the major products (Scheme 1).



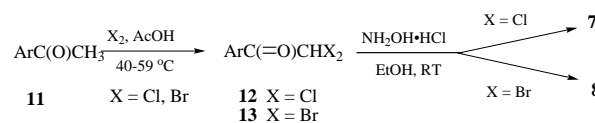
Scheme 1

In order to widen the scope of the reaction with α -halogeno ketoximes, the readily available 1-aryl-2,2,2-trifluoroethanone oximes 5c were treated with S_4N_4 in refluxing 1,4-dioxane,⁶ to give 5-aryl-5-trifluoromethyl-5H-1,3,2,4,6-dithiadiazines 6 as the major products. Because of this unexpected result together with the formation of 2 from the reactions of 5b with S_4N_4 , we have investigated on the reactions of the 1-aryl-2,2-dihalogenoethanone oximes 7–10 with S_4N_4 and describe herein our results.

Results and discussion

Synthesis of compounds 7–9

Although the synthesis and stereochemistry of *E*- and *Z*-5a and 5b have been much studied,⁷ the 1-aryl-2,2-dihalogenoethanone oximes 7–10 have received little attention, apart from 2,2-dichloro-1-phenylethanone oxime 7a (Ar = Ph) a patent for which describes its importance as an anti-herbicide.⁸ Since attempted synthesis of 7a according to literature procedures failed, reactions under different conditions were studied,⁹ and compounds 7 finally prepared *via* the 1-aryl-2,2-dichloroethanones 12; the latter were prepared by chlorination of 1-arylethanones 11 according to a little modified literature procedures¹⁰ in good to moderate yields (Scheme 2). Reaction



Scheme 2

times, yields, and melting points of compounds 7 are summarized in Table 1.

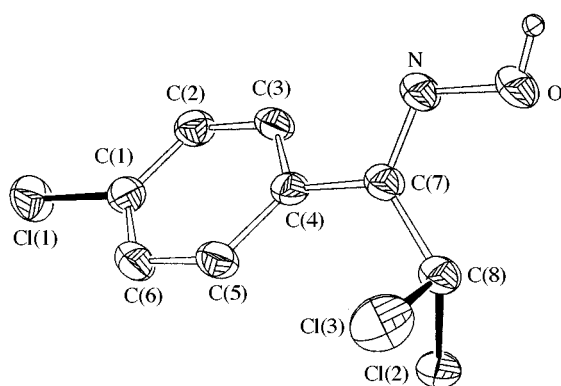
Of the compounds 12 prepared,¹⁰ 12i [Ar = 4-Cl₂CH₂C(O)C₆H₄], 12j [Ar = 3-Cl₂CHC(O)C₆H₄], and 12k [4-Cl₂CHC(O)biphenyl] are new. All of the compounds 7 except for 7a⁸ are new and their structures were assigned on the basis of spectroscopic data and elemental analyses.

The 1H NMR spectra of compounds 7a–b, 7d, 7g, h and 7j exhibited two singlets at 6.48 and 7.40, 6.45 and 7.30, 6.41 and 7.60, 6.50 and 7.41, 6.48 and 7.37, 6.47 and 7.34 ppm, respectively, which were assigned to be methine proton signals of *E*- and *Z*-oximes in view of the reported chemical shifts of methylene protons of *Z*- (4.42 ppm) and *E*-2-bromo-1-phenylethanone oximes (4.30 ppm).⁷ However, compounds 7c,

Table 1 Reaction times, yields, and melting points of 1-aryl-2,2-dichloroethanone oximes **7**

Compd.	Ar	Time (t/h)	Yield (%) ^a	Mp (T/°C)
7a	C ₆ H ₅	24	86	Liquid ^b
7b	4-MeC ₆ H ₄	24	81	Liquid ^b
7c	4-O ₂ NC ₆ H ₄	34	73	112–114 ^c
7d	3-O ₂ NC ₆ H ₄	47	58	Liquid ^b
7e	4-BrC ₆ H ₄	48	85	92–94 ^c
7f	4-ClC ₆ H ₄	49	82	98–100 ^d
7g	4-FC ₆ H ₄	27	84	Liquid ^b
7h	3-Cl,4-MeOC ₆ H ₃	72	34	Liquid ^b
7i	4-Cl ₂ CH(HON=C)C ₆ H ₄	72	82	170–172 ^c
7j	3-Cl ₂ CH(HON=C)C ₆ H ₄	72	53	Liquid ^b
7k	4'-Cl ₂ CH(HON=C)biphenyl-4-yl	72	86	133–135 ^c

^a Isolated yield. ^b *E/Z* mixture. ^{c,d,e} CHCl₃, CCl₄, and EtOH were used as solvents for recrystallization, respectively.

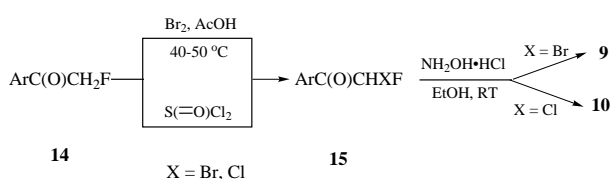
**Fig. 1** ORTEP drawing of compound **7f**

7e, and **7f** exhibited only a singlet at 7.58, 7.50, and 7.42 ppm. Therefore, they were assigned as *Z*-oximes. This was confirmed by a X-ray single crystallographic analysis of compound **7f** for which Fig. 1 shows an ORTEP drawing and Tables 2 and 3, respectively, list selected bond distances and angles.

1-Aryl-2,2-dibromoethanone oximes **8** were prepared from 1-aryl-2,2-dibromoethanones **13** under the same conditions as for compounds **7** in good to moderate yields (Scheme 2). Compounds **13** prepared according to the literature procedures¹¹ are known except for **13g** (Ar = 4-FC₆H₄, X = Br), **13i** (Ar = 3-MeOC₆H₄, X = Br), **13k** [Ar = 4-Br₂CHC(O)C₆H₄, X = Br], **13l** [Ar = 3-Br₂CHC(O)C₆H₄, X = Br], and **13m** (Ar = 4-Br₂CHC(O)biphenyl, X = Br). Reaction times, yields, and melting points for compounds **8** are summarized in Table 4.

For compounds **8a**, **8d**, **8g**, and **8l**, the presence of two singlets at 6.59 and 7.44, 6.42 and 7.59, 6.46 and 7.24, and 6.43 and 7.29 ppm, respectively suggested that, as with compounds **7**, each product was a mixture of *E*- and *Z*-oximes. Other compounds **8** exhibited a singlet in the range of 7.18–8.16 ppm, indicating the formation of a single isomer, *i.e.* *Z*-oximes.

Similarly, 1-aryl-2-bromo-**9** and 2-chloro-2-fluoro-ethanone oximes **10** were prepared *via* the corresponding 1-aryl-2-halogeno-2-fluoroethanones **15** which were, in turn, prepared by treatment of 1-aryl-2-fluoroethanones **14**¹² with bromine or thionyl chloride, respectively, according to literature procedures¹³ (Scheme 3). Yields of **15** decreased with reaction

**Scheme 3****Table 2** Selected bond lengths (Å) for compound **7f**^a

Cl(1)–C(1)	1.736(3)	N–C(7)	1.282(4)
Cl(2)–C(8)	1.768(3)	C(4)–C(7)	1.481(4)
Cl(3)–C(8)	1.787(3)	C(7)–C(8)	1.502(4)
O–N	1.389(3)		

^a Crystallographic numbering scheme, see Fig. 1.

Table 3 Selected bond angles (°) for compound **7f**^a

C(7)–N–O	113.9(2)	N–C(7)–C(8)	121.1(2)
C(3)–C(4)–C(5)	118.7(3)	C(4)–C(7)–C(8)	123.1(2)
C(3)–C(4)–C(7)	119.8(2)	C(7)–C(8)–Cl(2)	112.1(2)
C(5)–C(4)–C(7)	121.6(3)	C(7)–C(8)–Cl(3)	110.1(2)
N–C(7)–C(4)	115.8(2)	Cl(2)–C(8)–Cl(3)	110.1(2)

^a Crystallographic numbering scheme, see Fig. 1.

Table 4 Reaction times, yields, and melting points of 1-aryl-2,2-dibromoethanone oximes **8**

Compd.	Ar	Time (t/h)	Yield (%) ^a	Mp (T/°C)
8a	C ₆ H ₅	48	61	Liquid ^b
8b	4-MeC ₆ H ₄	72	58	105–107 ^c
8c	4-O ₂ NC ₆ H ₄	72	72	125–127 ^c
8d	3-O ₂ NC ₆ H ₄	48	75	Liquid ^b
8e	4-BrC ₆ H ₄	48	80	100–101 ^c
8f	4-ClC ₆ H ₄	86	82	108–109 ^d
8g	4-FC ₆ H ₄	48	84	Liquid ^b
8h	4-MeOC ₆ H ₄	36	74	97–99 ^d
8i	3-MeOC ₆ H ₄	63	66	80–82 ^d
8j	C ₁₀ H ₈	96	61	97–98 ^c
8k	4-Br ₂ CH(HON=C)C ₆ H ₄	72	76	176–178 ^d
8l	3-Br ₂ CH(HON=C)C ₆ H ₄	72	93	Liquid ^b
8m	4'-Br ₂ CH(HON=C)biphenyl-4-yl	72	80	173–175 ^d

^a Isolated yield. ^b *E/Z* mixture. ^{c,d} CCl₄ and EtOH were used as solvents for recrystallization, respectively.

temperatures >50 °C, whereas the reaction proceeded very slowly at <40 °C. Reaction times and yields of **9**, **10**, and **15** are summarized in Table 5.

All of compounds **15** prepared are known, whereas compounds **9** and **10** are new. ¹H NMR spectra of **9a** and **10** show two singlets at 6.71 and 7.54 ppm due to the methine protons for the *E*- and *Z*-forms. For compounds **7–10**, it has been found that where they exist as solids they appear to be solely *Z*-isomers, whereas products which are oils are mixtures of *E*- and *Z*-geometrical isomers showing a preference for the latter form. The formation of *Z*-isomers in preference to *E*-isomers may be due to the ease of formation of hydrogen bonding between the OH group and the halogen atoms of α,α -dihalogeno ketoximes.

Reactions of 1-aryl-2,2-dihalogenoethanone oximes **7–10** with S₄N₄

The reactions of **7** and **8** with S₄N₄ in refluxing 1,4-dioxane gave **1** and **2**, respectively. Compounds **9** and **10** reacted with S₄N₄ to give **3** under the same reaction conditions. The reactions of **7** and **8** were quenched when no spot corresponding to **7** (*R_F* ≈ 0.09, C₆H₆) and **8** (*R_F* ≈ 0.20, C₆H₆) was observed on TLC, whereas those of **9** (*R_F* ≈ 0.08, C₆H₆) and **10** (*R_F* ≈ 0.07, C₆H₆) were quenched when the spot corresponding to S₄N₄ (*R_F* = 0.51, C₆H₆–hexane, 1 : 1) had disappeared on TLC by the time the colour of the solution became reddish brown. Reaction times, yields and melting points of compounds **1–3** are summarized in Tables 6, 8, and 10, respectively, and their analytical IR, and ¹H NMR data are summarized in Tables 7, 9, and 11, respectively.

Of the compounds listed in Table 7, compounds **2a** and **2f** were reported to be prepared by treating 3-hydroxy-4-phenyl- and 3-(4-chlorophenyl)-4-hydroxy-1,2,5-thiadiazoles with phosphorus oxybromide in 61 and 85% yields,⁴ respectively.

Table 5 Reaction times, yields, and melting points of 1-aryl-2-bromo-**9** and 2-chloro-2-fluoro-ethanone oximes **10**, and 1-aryl-2-halogeno-2-fluoroethanones **15**

Compound	Ar	X	Time (t/h)	Yield (%) ^a	Compound	Time (t/h)	Yield (%) ^a	Mp (T/°C)
15a	C ₆ H ₅	Br	7	78	9a	48	84	Liquid ^b
15b	4-MeC ₆ H ₄	Br	5	73	9b	48	91	94–96 ^c
15c	4-BrC ₆ H ₄	Br	9	71	9c	3	89	101–103 ^c
15d	C ₆ H ₅	Cl	15	49	10	24	71	Liquid ^b

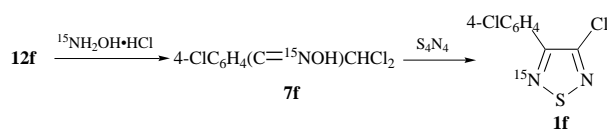
^a Isolated yield. ^b *E/Z* mixture. ^c CHCl₃ was used as a solvent for recrystallization.

Table 6 Reaction times, yields, and melting points of 3-aryl-4-chloro-1,2,5-thiadiazoles **1**

Compound	Ar	Time (t/h)	Yield (%) ^c	Mp (T/°C)
1a	C ₆ H ₅	4	98	31–33 ^c (lit., ² 31.5–32.5)
1b	4-MeC ₆ H ₄	3	74	Liquid (lit., ² 27–28)
1c	4-O ₂ NC ₆ H ₄	3	85	101–103 ^c
1d	3-O ₂ NC ₆ H ₄	4	94	97–98 ^c
1e	4-BrC ₆ H ₄	6	97	69–71 ^c (lit., ² 74–75.5)
1f	4-ClC ₆ H ₄	6	98	38–39 ^c (lit., ² 37.5–38.5)
1g	4-FC ₆ H ₄	3	98	35–37 ^c (lit., ² 35–36.5)
1h	3-Cl-, 4-MeOC ₆ H ₃	12	84	83–85 ^c
1i	4-Y-C ₆ H ₄ ^b	3	78	129–131 ^d
1j	3-Y-C ₆ H ₄ ^b	3	69	124–125 ^d
1k	4-Y-biphenyl ^b	5	91	159–161 ^d

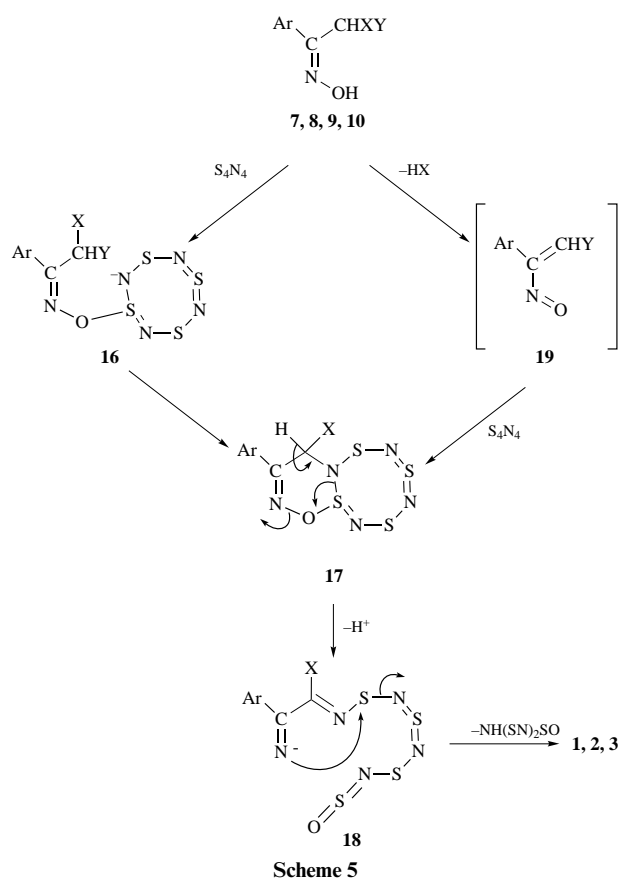
^a Isolated yield. ^b Y = 3-chloro-1,2,5-thiadiazol-4-yl. ^{c,d} Hexane and EtOH were used as solvents for recrystallization, respectively.

The mechanism for the formation of compounds **1–3** is uncertain as shown in a variety of the reactions with S₄N₄ previously studied.¹⁴ In order to determine the source of nitrogen atoms of compounds **1–3**, ¹⁵N-labelled hydroxylamine hydrochloride (¹⁵NH₂OH HCl, 99 atom%) was used to prepare the ¹⁵N-labelled oxime **7f**, from which **1f** was obtained (Scheme 4).



Mass spectral data for **1f** obtained from the ¹⁵N-labelled oxime **7f** shows the fragments having mass number (*m/z*) 231 (97.6%, M⁺) and 233 (76.5%, M⁺ + 2), whereas that of **1f** obtained from ¹⁵N-unlabelled oxime **7f** shows the fragments of mass number (*m/z*) 230 (97.6%, M⁺) and 232 (82.1, M⁺ + 2). The results indicate clearly that ¹⁵N atom of **7f** is involved as one of the nitrogen atoms of 1,2,5-thiadiazole ring. Since the mass spectra of **1f** formed *via* ¹⁵N-labelled and ¹⁵N-unlabelled oximes **7f** show the fragments having (*m/z*) 138 and 137, corresponding to the molecular weight of ¹⁵N-labelled and ¹⁵N-unlabelled 4-chlorobenzonitriles, respectively, the N-5 atom of **1f** is thought to originate from the oxime nitrogen atom.

On the basis of these results, we propose the following pathway in which nucleophilic attack of the hydroxy group of dihalogeno ketoximes **7–10** on the tetravalent sulfur atom of S₄N₄ gives the intermediate **16**; subsequently, nucleophilic displacement of the halogen atom on this by the amide ion gives a cyclic intermediate **17**. Deprotonation of this, followed by cleavage of the N–S and N–O bonds gives an imide ion **18**, which then cyclizes to give **1** and HS₃N₃O. Alternatively, formation of the intermediate **17** might be explained on the basis of [4 + 2] cycloaddition between S₄N₄ and the nitroso olefin **19**¹⁵ which is believed to be readily formed in the presence of base existing in the reaction mixtures (Scheme 5).



The incorporation of an oxime nitrogen into the 1,2,5-thiadiazoles is in contrast with the proposed mechanism for the formation of 3,4-diphenyl-1,2,5-thiadiazole by reaction of benzil monooxime with S₄N₄, in which the =NOH group was completely eliminated and the two nitrogen atoms of 1,2,5-thiadiazole originate from S₄N₄.¹⁶

In conclusion, the geometry of 1-aryl-2,2-dihalogenoethanone oximes has been assigned on the basis of ¹H NMR spectroscopic data and a X-ray single crystallographic analysis in which solid oximes appear to be *Z*-isomers. However, oily liquid oximes exist as a mixture of *E*- and *Z*-isomers, showing preference for the latter. We have demonstrated the synthetic utility of S₄N₄ by isolation of excellent yields of 1,2,5-thiadiazoles having a chlorine **1** or a bromine atom **2** at C-3 from the reactions with 1-aryl-2,2-dichloro-**7** and 1-aryl-2,2-dibromo-ethanone oximes **8**, respectively. Similarly compounds **3** were obtained from the reactions with 1-aryl-2-bromo-**9** and 1-aryl-2-chloro-2-fluoroethanone oximes **10** in fair yields. It has been shown that the 2-nitrogen atom of **1** has its origin in the oxime nitrogen atom of **7**.

Experimental

All melting points were determined on a Fisher–Johns melting point apparatus and are uncorrected. IR spectra were obtained on a Shimadzu IR-470 IR spectrophotometer for samples of

Table 7 Analytical, IR, and ¹H NMR data for 3-aryl-4-chloro-1,2,5-thiadiazoles **1**

Compound (Formula)	Found (%) (Required)				$\nu_{\max}^a/\text{cm}^{-1}$	δ_{H} (CDCl ₃ ; 80 MHz)	<i>m/z</i> (EI)
	C	H	N	S			
1c (C ₈ H ₄ ClN ₃ O ₂ S)	39.7 (39.8)	1.7 (1.7)	17.4 (17.4)	13.3 (13.3)	1597, 1517, 1350, 1161, 979, 739, 704	8.44 (4 H, dd, <i>J</i> 15.8, 9.2, ArH)	241 (100%, M ⁺), 243 (37.3, M ⁺ + 2), 211 (60.6), 213 (23.1), 195 (27.4), 197 (10.4), 180 (7.0), 160 (29.9)
1d (C ₈ H ₄ ClN ₃ O ₂ S)	39.75 (39.8)	1.7 (1.7)	17.4 (17.4)	13.3 (13.3)	1523, 1338, 1258, 1174, 998, 899, 877, 835, 810, 765, 717, 666	7.64 (1 H, t, <i>J</i> 7.9, ArH), 8.34 (2 H, d, <i>J</i> 7.9, ArH), 8.83 (1 H, s, ArH)	241 (100%, M ⁺), 243 (37.9, M ⁺ + 2), 211 (22.6), 213 (8.3), 195 (51.9), 197 (19.3), 180 (9.3), 160 (26.2)
1h (C ₉ H ₆ Cl ₂ N ₂ OS)	41.4 (41.4)	2.3 (2.3)	10.7 (10.7)	12.25 (12.2)	1590, 1504, 1343, 1280, 1159, 1062, 1018, 992, 813, 733, 698	3.83 (3 H, s, MeO), 7.00 (1 H, d, <i>J</i> 8.7, ArH), 7.89 (1 H, d, <i>J</i> 8.7, ArH), 8.02 (1 H, s, ArH)	260 (100%, M ⁺), 262 (69.2, M ⁺ + 2), 264 (14.2, M ⁺ + 4), 245 (40.9), 247 (26.5), 199 (20.2), 167 (17.4)
1i (C ₁₀ H ₄ Cl ₂ N ₄ S ₂)	38.1 (38.1)	1.3 (1.3)	17.7 (17.8)	20.4 (20.3)	1351, 1171, 880, 853, 839, 820, 561	8.10 (4 H, s, ArH)	314 (100, M ⁺), 316 (73.9, M ⁺ + 2), 318 (17.4, M ⁺ + 4), 253 (63.0), 255 (26.6), 221 (19.8), 160 (28.5)
1j (C ₁₀ H ₄ Cl ₂ N ₄ S ₂)	38.1 (38.1)	1.3 (1.3)	17.75 (17.8)	20.4 (20.3)	3067, 1339, 1304, 1251, 1170, 969, 826, 799	7.59 (1 H, t, <i>J</i> 14, ArH), 8.18 (2 H, d, <i>J</i> 14, ArH), 8.66 (1 H, s, ArH)	314 (100%, M ⁺), 316 (73.7, M ⁺ + 2), 318 (17.0, M ⁺ + 4), 253 (54.9), 255 (22.3), 221 (15.8), 160 (30.2)
1k (C ₁₆ H ₈ Cl ₂ N ₄ S ₂)	49.0 (49.1)	2.05 (2.1)	14.3 (14.3)	16.4 (16.4)	3079, 3046, 1607, 1458, 1350, 932, 799, 780	7.74 (4 H, d, <i>J</i> 8.2, ArH), 8.06 (4 H, d, <i>J</i> 8.2, ArH)	390 (100%, M ⁺), 392 (76.3, M ⁺ + 2), 394 (20.5, M ⁺ + 4), 297 (65.5), 263 (30.9), 236 (51.9), 204 (72.6)

^a IR spectra for **1c–h** were taken neat and KBr was used for those of **1i–k**

Table 8 Reaction times, yields, and melting points of 3-aryl-4-bromo-1,2,5-thiadiazoles **2**

Compd.	Ar	Time (<i>t</i> /h)	Yield (%) ^a	Mp (<i>T</i> /°C)
2a	C ₆ H ₅	3	95	57–59 ^c (lit., ⁴ 59–60)
2b	4-MeC ₆ H ₄	3	92	27–29 ^c
2c	4-O ₂ NC ₆ H ₄	3	99	101–102 ^c
2d	3-O ₂ NC ₆ H ₄	3	98	102–103 ^c
2e	4-BrC ₆ H ₄	4	97	82–84 ^c
2f	4-ClC ₆ H ₄	3	96	66–67 ^c (lit., ⁴ 60–61)
2g	4-FC ₆ H ₄	3	98	58–60 ^c
2h	4-MeOC ₆ H ₄	3	94	75–77 ^c
2i	3-MeOC ₆ H ₄	5	95	Liquid
2j	2-Naphthyl	4	86	70–71 ^c
2k	4-Y-C ₆ H ₄ ^b	12	93	135–137 ^d
2m	3-Y-C ₆ H ₄ ^b	3	49	128–129 ^d
2n	4-Y-biphenyl-4-yl ^b	5	86	176–178 ^d

^a Isolated yield. ^b Y = 3-bromo-1,2,5-thiadiazol-4-yl. ^{c,d} Hexane and EtOH were used as solvents for recrystallization, respectively.

KBr pellets or thin films. ¹H NMR spectra were determined on a Brüker 80 MHz spectrometer using tetramethylsilane as internal standard; *J* values are given in Hz. Mass spectra were obtained by electron impact at 70 eV at the Inter-University Center for Natural Sciences Research Facilities. Elemental analyses were determined by the Korea Basic Science Center. Column chromatography was performed on silica gel (Merck, 70–230, ASTM).

Tetrasulfur tetranitride was prepared by the reaction of sulfur monochloride with ammonia gas at room temperature.¹⁷ 1-Aryl-2,2-dichloroethanones **12** were prepared according to literature procedures¹⁰ except for the amount of chlorine gas employed (7–10 equiv.) and the reaction temperature (40–59 °C): 2,2-dichloro-1-phenylethanone **12a**,¹⁸ liquid (Found: C, 50.75; H, 3.2; Cl, 37.0. C₈H₆Cl₂O requires C, 50.9; H, 3.2; Cl, 37.5%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1705 (C=O); $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 6.84 (1 H, s, CHCl₂), 7.53 (3 H, m, Ph) and 8.08 (2 H, m, Ph); 2,2-dichloro-1-(4-methylphenyl)ethanone **12b**, mp 55–56 °C (from CCl₄) (lit.,¹⁰ 54.5–55.3 °C); 2,2-dichloro-1-(4-nitrophenyl)ethanone **12c**, mp 27–28 °C (from CCl₄) (lit.,¹⁰ 27–28 °C); 2,2-

dichloro-1-(3-nitrophenyl)ethanone **12d**, pale yellow oil (Found: C, 41.0; H, 2.15; Cl, 30.2; N, 5.9. C₈H₅Cl₂NO₃ requires C, 41.1; H, 2.15; Cl, 30.3; N, 6.0%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1699 (C=O); $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 6.63 (1 H, s, CHCl₂), 7.76 (1 H, t, *J* 8, ArH), 8.48 (2 H, d, *J* 8, ArH) and 8.89 (1 H, s, ArH); 1-(4-bromophenyl)-2,2-dichloroethanone **12e**, mp 61–62 °C (from CCl₄) (lit.,¹⁰ 61.6–62 °C); 1-(4-chlorophenyl)-2,2-dichloroethanone **12f**, mp 47–48 °C (from CCl₄) (Found: C, 42.95; H, 2.3; Cl, 47.8. C₈H₅Cl₃O requires C, 43.0; H, 2.25; Cl, 47.6); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1701 (C=O); $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 6.58 (1 H, s, CHCl₂) and 7.67 (4 H, dd, *J* 31, 8, ArH); 2,2-dichloro-1-(4-fluorophenyl)ethanone **12g**, mp 38–40 °C (from CCl₄) (Found: C, 46.4; H, 2.4; Cl, 34.3. C₈H₅Cl₂FO requires C, 46.4; H, 2.4; Cl, 34.25); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1702 (C=O); $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 6.62 (1 H, s, CHCl₂), 7.17 (1 H, t, *J* 9, ArH) and 8.08 (2 H, m, ArH); 1-(3-chloro-4-methoxyphenyl)-2,2-dichloroethanone **12h**, mp 71–73 °C (from CCl₄) (lit.,¹⁹ 72–73 °C); 1,4-bis(dichloroacetyl)benzene **12i**, mp 154–156 °C (from CHCl₃) (Found: C, 40.0; H, 2.0; O, 10.7. C₁₀H₆Cl₄O₂ requires C, 40.0; H, 2.0; O, 10.7%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1690 (C=O); $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO})$; 80 MHz) 7.81 (2 H, s, CHCl₂), 8.23 (4 H, s, ArH); 1,3-bis(dichloroacetyl)benzene **12j**, oil (Found: C, 40.0; H, 2.0; O, 10.8. C₁₀H₆Cl₄O₂ requires C, 40.0; H, 2.0; O, 10.7%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1700 (C=O); $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO}; 80 \text{ MHz})$ 7.60 (2 H, s, 2CH), 7.70 (1 H, t, *J* 8, ArH), 8.33 (2 H, d, *J* 8, ArH) and 8.75 (1 H, s, ArH); 4,4'-bis(dichloroacetyl)biphenyl **12k**, mp 162–164 °C (from CHCl₃) (Found: C, 51.15; H, 2.7; O, 8.6. C₁₆H₁₀Cl₄O₂ requires C, 51.1; H, 2.7; O, 8.5%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1693 (C=O); $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO}; 80 \text{ MHz})$ 7.80 (2 H, s, CHCl₂), 7.49 and 7.83 (8 H, 2 d, *J* 8.3, ArH). 1-Aryl-2,2-dibromoethanones **13** were prepared by the literature methods¹¹: 2,2-dibromo-1-phenylethanone **13a**, mp 36–37 °C (from CCl₄) (lit.,¹¹ 36 °C); 2,2-dibromo-1-(4-methylphenyl)ethanone **13b**, mp 99–100 °C (from CCl₄) (lit.,¹¹ 98–99 °C); 2,2-dibromo-1-(4-nitrophenyl)ethanone **13c**, mp 54–55 °C (from CCl₄) (lit.,¹¹ 54–55 °C); 2,2-dibromo-1-(3-nitrophenyl)ethanone **13d**, mp 54–55 °C (from CCl₄) (lit.,¹¹ 55–56 °C); 1-(4-bromophenyl)-2,2-dibromoethanone **13e**, mp 91–92 °C (from CCl₄) (lit.,¹¹ 93–94 °C); 1-(4-chlorophenyl)-2,2-dibromoethanone **13f**, mp 92–93 °C (from CCl₄) (lit.,¹¹ 93–94 °C); 2,2-dibromo-1-(4-fluorophenyl)ethanone **13g**, oil (Found: C, 32.5; H, 1.7; O, 5.4.

Table 9 Analytical, IR, and ¹H NMR data for 3-aryl-4-bromo-1,2,5-thiadiazoles **2**

Compound (Formula)	Found (%) (Required)				$\nu_{\max}^a/\text{cm}^{-1}$	$\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$	m/z (EI)
	C	H	N	S			
2a (C ₈ H ₅ BrN ₂ S)	39.8 (39.85)	2.1 (2.1)	11.6 (11.6)	13.4 (13.3)	3060, 1442, 1353, 1147, 966, 835	7.48 (3 H, m, PhH), 7.92 (2 H, m, PhH)	240 (46.6%, M ⁺), 242 (50.3, M ⁺ + 2), 135 (100)
2b (C ₉ H ₇ BrN ₂ S)	42.4 (42.4)	2.8 (2.8)	11.0 (11.0)	12.6 (12.6)	3025, 1615, 1521, 1451, 1410, 1349, 1253, 1189, 1160, 1141, 1040, 1028, 982, 820	2.42 (3 H, s, Me), 7.56 (4 H, dd, <i>J</i> 4.2, 8, ArH)	254 (57.2%, M ⁺), 256 (44.0, M ⁺ + 2), 149 (100)
2c (C ₈ H ₄ BrN ₃ O ₂ S)	33.6 (33.6)	1.4 (1.4)	14.7 (14.7)	11.2 (11.2)	1597, 1517 (s), 1349 (s), 1331, 1313, 1297, 1163, 981, 860, 853, 835, 716	8.23 (4 H, dd, <i>J</i> 14, 8, ArH)	285 (29.2%, M ⁺), 287 (27.5, M ⁺ + 2), 160 (100)
2d (C ₈ H ₄ BrN ₃ O ₂ S)	33.6 (33.6)	1.4 (1.4)	14.7 (14.7)	11.2 (11.2)	3091, 1613, 1532, 1491, 1344, 1262, 1162, 1094, 1078, 1011, 826, 803, 723	7.67 (1 H, t, <i>J</i> 7, ArH), 8.32 (2 H, d, <i>J</i> 7, ArH), 8.83 (1 H, s, ArH)	285 (31.6%, M ⁺), 287 (29.5, M ⁺ + 2), 160 (100)
2e (C ₈ H ₄ Br ₂ N ₂ S)	30.0 (30.0)	1.3 (1.3)	8.7 (8.75)	10.05 (10.0)	1590, 1498, 1450, 1398, 1350, 1142, 958, 813	7.69 (4 H, dd, <i>J</i> 17, 8, ArH)	318 (44.0%, M ⁺), 320 (89.3, M ⁺ + 2), 322 (39.9, M ⁺ + 4), 213 (100), 215 (95.1)
2f (C ₈ H ₄ BrClN ₂ S)	34.8 (34.9)	1.45 (1.5)	10.1 (10.2)	11.7 (11.6)	1597, 1502, 1451, 1348, 1145, 1092, 1019, 967, 827	8.25 (4 H, dd, <i>J</i> 18, 7, ArH)	274 (18.2%, M ⁺), 276 (22.8, M ⁺ + 2), 169 (100)
2g (C ₈ H ₄ BrFN ₂ S)	37.0 (37.1)	1.55 (1.6)	10.8 (10.8)	12.4 (12.4)	3086, 1602, 1517, 1452, 1348, 1237, 1161, 963, 835	7.14 (2 H, m, ArH), 7.87 (2 H, m, ArH)	258 (73.0%, M ⁺), 260 (73.8, M ⁺ + 2), 153 (100), 137 (23.1), 139 (23.8), 121 (30.9)
2h (C ₉ H ₇ BrN ₂ OS)	39.8 (39.9)	2.6 (2.6)	10.3 (10.3)	11.9 (11.8)	1453, 1349, 1302, 1258, 1181, 1143, 1030, 963, 822	3.86 (3 H, s, OMe), 7.36 (4 H, dd, <i>J</i> 17, 8, ArH)	270 (99.2%, M ⁺), 272 (100, M ⁺ + 2), 165 (71.7), 150 (22.8), 133 (45.6)
2i (C ₉ H ₇ BrN ₂ OS)	39.85 (39.9)	2.6 (2.6)	10.3 (10.3)	11.9 (11.8)	3009, 1603, 1585, 1460, 1361, 1250, 1150, 1052, 1003, 863, 791	3.87 (3 H, s, MeO), 7.03 (1 H, m, ArH), 7.47 (3 H, m, ArH)	270 (60.9%, M ⁺), 272 (63.6, M ⁺ + 2), 165 (100)
2j (C ₁₂ H ₇ BrN ₂ S)	49.4 (49.5)	2.4 (2.4)	9.5 (9.6)	11.1 (11.0)	3056, 1593, 1475, 1331, 1140, 1106, 982, 931, 858, 813, 749	7.50 (2 H, m, ArH), 7.85 (4 H, m, ArH), 8.47 (1 H, s, ArH)	290 (16.2%, M ⁺), 292 (15.3, M ⁺ + 2), 153 (100)
2k (C ₁₀ H ₄ Br ₂ N ₄ S ₂)	29.75 (29.7)	1.0 (1.0)	13.8 (13.9)	15.9 (15.9)	3042, 1590, 1465, 1338, 967, 840, 742	8.06 (4 H, s, ArH)	402 (51.2%, M ⁺), 404 (100, M ⁺ + 2), 406 (56.7, M ⁺ + 4), 297 (47.8), 299 (51.0), 265 (11.6), 267 (11.7), 160 (33.9)
2l (C ₁₀ H ₄ Br ₂ N ₄ S ₂)	29.8 (29.7)	1.0 (1.0)	13.8 (13.9)	15.9 (15.9)	3072, 1342 (s), 1315, 1251, 1168, 966, 821, 794, 689, 534	7.63 (1 H, t, <i>J</i> 15, ArH), 8.12 (2 H, d, <i>J</i> 15, ArH), 8.46 (1 H, s, ArH)	402 (48.2%, M ⁺), 404 (100, M ⁺ + 2), 406 (52.2, M ⁺ + 4), 297 (48.7), 299 (50.0), 265 (21.8), 267 (25.8), 160 (56.1)
2m (C ₁₆ H ₈ Br ₂ N ₄ S ₂)	40.1 (40.0)	1.7 (1.7)	11.6 (11.7)	13.4 (13.35)	3088, 3045, 1603, 1466, 1349, 928, 819, 789	7.89 (8 H, dd, <i>J</i> 13.6, 8.3, ArH)	480 (49.6%, M ⁺), 482 (100, M ⁺ + 2), 484 (54.0, M ⁺ + 4), 376 (50.2), 378 (49.3), 344 (24.1), 346 (26.2), 204 (46.7)

^a IR spectra of **2a–j** were taken neat and KBr was used for those of **2k–m**.

Table 10 Reaction times, yields, and melting points of 3-aryl-4-fluoro-1,2,5-thiadiazoles **3**

Compound	Ar	Time (t/h)	Yield (%) ^a	Mp (T/°C) ^b
3a	C ₆ H ₅	5	32	45–46 (lit., ² 45)
3b	4-MeC ₆ H ₄	3	47	56–57
3c	4-BrC ₆ H ₄	3	61	76–77
3d	C ₆ H ₅	3	65	45–46 (lit., ² 45)

^a Isolated yields. ^b CCl₄ was used as a solvent for recrystallization.

C₈H₅Br₂FO requires C, 32.5; H, 1.7; O, 5.4%; $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1693 (C=O); $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 6.61 (1 H, s, CHBr₂), 7.14 (2 H, t, *J* 8.3, ArH) and 8.16 (2 H, dd, *J* 8.3, 3.5, ArH); 2,2-dibromo-1-(4-methoxyphenyl)ethanone **13h**, mp 92–93 °C (from CCl₄) (lit.,²⁰ 92–93 °C); 2,2-dibromo-1-(3-methoxyphenyl)ethanone **13i**, oil (Found: C, 35.05; H, 2.6; O, 10.4. C₉H₈Br₂O₂ requires C, 35.1; H, 2.6; O, 10.4%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1693 (C=O); $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 3.26 (3 H, s, MeO), 6.59 (1 H, s, CHBr₂) and 6.61–7.11 (4 H, m, ArH); 2,2-dibromo-1-(2-naphthyl)ethanone **13j**, mp 100–102 °C (from CCl₄) (lit.,¹¹ 101–102 °C); 1,4-bis(dibromoacetyl)benzene **13k**, mp 166–168 °C (from CHCl₃) (Found: C, 25.15; H, 1.3; O, 6.7. C₁₀H₅Br₄O₂ requires C, 25.1; H, 1.3; O, 6.7%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1690 (C=O); $\delta_{\text{H}}(\text{CDCl}_3\text{--}[\text{2H}_6\text{d}]\text{--DMSO}; 80 \text{ MHz})$ 7.81 (2 H, s, CHBr₂) and 8.23 (4 H, s, ArH); 1,3-bis(dibromoacetyl)benzene **13l**, mp 54–55 °C (from CHCl₃) (Found: C, 25.1; H, 1.3; O, 6.8. C₁₀H₆Br₄O₂ requires C, 25.1; H,

1.3; O, 6.7%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1693 (C=O); $\delta_{\text{H}}(\text{CDCl}_3\text{--}[\text{2H}_6\text{d}]\text{--DMSO}; 80 \text{ MHz})$ 7.59 (2 H, s, CHBr₂), 7.69 (1 H, t, *J* 8, ArH), 8.32 (2 H, d, *J* 8, ArH) and 8.75 (1 H, s, ArH); 4,4'-bis(dibromoacetyl)biphenyl **13m**, mp 216–217 °C (from CHCl₃) (Found: C, 34.6; H, 1.8; O, 5.8. C₁₆H₁₀Br₄O₂ requires C, 34.7; H, 1.8; O, 5.8%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 1690 (C=O); $\delta_{\text{H}}(\text{CDCl}_3\text{--}[\text{2H}_6\text{d}]\text{--DMSO}; 80 \text{ MHz})$ 7.79 (2 H, s, CHBr₂) and 7.50 and 7.80 (8 H, 2 d, *J* 8.2, ArH).

General procedure for the preparation of 1-aryl-2,2-dichloroethanone oximes **7**

To a solution of **12** (6–12 mmol) in EtOH (30 ml) was added hydroxylamine hydrochloride (18–36 mmol). The mixture was stirred for an appropriate time at room temperature. The hydrochloride salt disappeared slowly as the reaction proceeded and a clean solution resulted. After solvent removal, water (30 ml) was added to the reaction mixture to give white solids **7**, which were filtered off and recrystallized from CHCl₃. When, upon addition of water, yellowish white liquids formed at the bottom of the flask, the mixtures were extracted with EtOAc (100 ml × 2) and the extracts dried (MgSO₄). Evaporation of the extracts gave residues which were chromatographed (silica gel column: 2 × 10 cm) with benzene as eluent to give compounds **7** contaminated with **12**. The crude oximes **7c** and **7e** were recrystallized from CHCl₃ and that of **7f** from CCl₄. Yields, reaction times and melting points of compounds **7** are summarized in Table 1.

Table 11 Analytical, IR, and ¹H NMR data for 3-aryl-4-fluoro-1,2,5-thiadiazoles 3

Compd. (Formula)	Found (%) (Required)				$\nu_{\max}^a/\text{cm}^{-1}$	$\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$	m/z (EI)
	C	H	N	S			
3b (C ₉ H ₇ FN ₂ S)	55.6 (55.7)	3.6 (3.6)	14.4 (14.4)	16.6 (16.5)	3072, 1613, 1510, 1435, 1302, 1284, 1190, 1037, 823, 736	2.35 (3 H, s, Me), 7.54 (4 H, dd, <i>J</i> 49, 8, ArH)	194 (100%, M ⁺), 149 (1.06), 116 (2.2)
3c (C ₈ H ₄ BrFN ₂ S)	37.05 (37.1)	1.55 (1.6)	10.8 (10.8)	12.4 (12.4)	3071, 1588, 1495, 1445, 1309, 1124, 958, 810	7.66 (4 H, dd, <i>J</i> 22, 8, ArH)	258 (100%, M ⁺), 260 (94.7, M ⁺ + 2), 215 (2.43), 197 (12.1), 182 (4.3)

^a IR spectra were taken neat.

2,2-Dichloro-1-phenylethanone oxime 7a. *E/Z* mixture (46:54) (Found: C, 47.0; H, 3.5; N, 6.9. C₈H₆Cl₂NO requires C, 47.1; H, 3.5; N, 6.9%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3296 (OH), 3056 and 1599; $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 6.48 and 7.40 (1 H, 2 s, CHCl₂), 7.36 (3 H, m, ArH), 7.71 (2 H, m, ArH) and 9.61 (1 H, s, br, OH); m/z (EI) 203 (100%, M⁺), 205 (66.2, M⁺ + 2) and 207 (9.8, M⁺ + 4).

2,2-Dichloro-1-(4-methylphenyl)ethanone oxime 7b. *E/Z* mixture (41:59) (Found: C, 49.6; H, 4.2; N, 6.4. C₉H₉Cl₂NO requires C, 49.6; H, 4.2; N, 6.4%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3296 (OH), 3040 and 1603; $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 2.33 (3 H, s, Me), 6.45 and 7.30 (1 H, 2 s, CHCl₂), 7.38 (4 H, dd, *J* 16, 8, ArH) and 8.82 (1 H, s, OH); m/z (EI) 217 (100%, M⁺), 219 (67.3, M⁺ + 2) and 221 (11.4, M⁺ + 4).

2,2-Dichloro-1-(4-nitrophenyl)ethanone oxime 7c. *Z*-form (Found: C, 38.5; H, 2.45; N, 11.2. C₈H₆Cl₂N₂O₃ requires C, 38.6; H, 2.4; N, 11.25%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3216 (OH), 3040, 1600, 1520s and 1346s; $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO}; 80 \text{ MHz})$ 7.58 (1 H, s, CHCl₂), 8.12 (4 H, dd, *J* 20, 7, ArH) and 13.07 (1 H, s, OH); m/z (EI) 248 (100%, M⁺), 250 (65.9, M⁺ + 2) and 252 (10.5, M⁺ + 4).

2,2-Dichloro-1-(3-nitrophenyl)ethanone oxime 7d. *E/Z* mixture (36:64) (Found: C, 38.65; H, 2.5; N, 11.2. C₈H₆Cl₂N₂O₃ requires C, 38.6; H, 2.4; N, 11.25%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3392 (OH), 3040, 1610, 1520s and 1345s; $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO}; 80 \text{ MHz})$ 6.41 and 7.60 (1 H, 2 s, CHCl₂), 7.97 (4 H, m, ArH) and 9.50 and 10.12 (1 H, 2 s, OH); m/z (EI) 248 (100%, M⁺), 250 (63.8, M⁺ + 2) and 252 (8.9, M⁺ + 4).

1-(4-Bromophenyl)-2,2-dichloroethanone oxime 7e. *Z*-form (Found: C, 33.9; H, 2.1; N, 4.9. C₈H₆BrCl₂NO requires C, 34.0; H, 2.1; N, 4.95%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3312 (OH), 3040 and 1587; $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO}; 80 \text{ MHz})$ 7.50 (1 H, s, CHCl₂), 7.52 (4 H, dd, *J* 20, 8, ArH), 12.42 (1 H, s, OH); m/z (EI) 281 (100%, M⁺), 283 (163.2, M⁺ + 2), 285 (74.8, M⁺ + 4), 287 (9.7, M⁺ + 6).

1-(4-Chlorophenyl)-2,2-dichloroethanone oxime 7f. *Z*-form (Found: C, 40.5; H, 2.5; N, 5.9. C₈H₆Cl₃NO requires C, 40.3; H, 2.5; N, 5.9%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3295 (OH), 3040 and 1588; $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 7.42 (1 H, s, CHCl₂), 7.45 (4 H, dd, *J* 23, 8, ArH) and 9.23 (1 H, s, br, OH); m/z (EI) 237 (100%, M⁺), 239 (97.5, M⁺ + 2) and 241 (30.8, M⁺ + 4).

2,2-Dichloro-1-(4-fluorophenyl)ethanone oxime 7g. *E/Z* mixture (16:84) (Found: C, 43.2; H, 2.7; N, 6.3. C₈H₆Cl₂FNO requires C, 43.3; H, 2.7; N, 6.3%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3264 (OH), 3040 and 1597; $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 6.50 and 7.41 (1 H, 2 s, CHCl₂), 6.99 (2 H, m, ArH), 7.76 (2 H, m, ArH), 9.83 and 10.23 (1 H, 2 s, br, OH); m/z (EI) 221 (100%, M⁺), 223 (65.5, M⁺ + 2) and 225 (11.1, M⁺ + 4).

1-(3-Chloro-4-methoxyphenyl)-2,2-dichloroethanone oxime 7h. *E/Z* mixture (31:69) (Found: C, 40.2; H, 3.0; N, 5.2. C₉H₈Cl₂NO₂ requires C, 40.3; H, 3.0; N, 5.2%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3360 (OH), 3024 and 1594; $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 3.83 (3 H, s, MeO), 6.48 and 7.37 (1 H, 2 s, CHCl₂), 6.91 and 6.95 (1 H, 2 d, *J* 8.8, 8.2, ArH), 7.60 (2 H, m, ArH) and 8.50 (1 H, s, br, OH); m/z (EI) 267 (100%, M⁺), 269 (96.7, M⁺ + 2) and 271 (32.1, M⁺ + 4).

1,4-Bis(dichloroacetyl)benzene dioxime 7i. *Z*-form (Found: C,

36.4; H, 2.45; N, 8.5; O, 9.8. C₁₀H₈Cl₄N₂O₂ requires C, 36.4; H, 2.4; N, 8.5; O, 9.7%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 3280 (OH), 3042 and 1610; $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO}; 80 \text{ MHz})$ 7.18 (2 H, s, CHCl₂), 7.50 (2 H, s, ArH), 7.84 (2 H, s, ArH), 11.93 (1 H, s, OH) and 12.70 (1 H, s, OH).

1,3-Bis(dichloroacetyl)benzene dioxime 7j. *E/Z* mixture (33:67) (Found: C, 36.45; H, 2.45; N, 8.5; O, 9.6. C₁₀H₈Cl₄N₂O₂ requires C, 36.4; H, 2.4; N, 8.5; O, 9.7%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 3290 (OH), 3026 and 1600; $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO}; 80 \text{ MHz})$ 6.47 and 7.34 (2 H, 2 s, 2 × CHCl₂), 7.33 (2 H, m, ArH), 8.45 (2 H, m, ArH) and 11.34 and 12.01 (2 H, 2 s, OH).

4,4'-Bis(dichloroacetyl)biphenyl dioxime 7k. *Z*-form (Found: C, 47.4; H, 3.0; N, 6.8; O, 7.8. C₁₆H₁₂Cl₄N₂O₂ requires C, 47.3; H, 3.0; N, 6.9; O, 7.9%); $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ 3280 (OH), 3042 and 1602; $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO}; 80 \text{ MHz})$ 7.70 (2 H, s, CHCl₂), 7.49 (4 H, d, *J* 8.2, ArH), 7.79 (4 H, 2 d, *J* 8.2, ArH), 11.97 (1 H, s, OH) and 12.63 (1 H, s, OH).

General procedure for the preparation of 3-aryl-4-chloro-1,2,5-thiadiazoles 1

To a solution of **7** (0.63–2.3 mmol) in 1,4-dioxane (10–15 ml) was added S₄N₄ (0.63–2.3 mmol). The mixture was heated at reflux until no spot corresponding to **7** was observed on TLC ($R_{\text{F}} \approx 0.09$, C₆H₆), after which the solvent was removed *in vacuo*. The residue was extracted with CHCl₃ (150 ml) and the extracts were evaporated. Chromatography of the residue on a silica gel column (2 × 12 cm) using hexane (200 ml) as eluent gave sulfur and a minute amount of unknown compounds. Elution with hexane–benzene (3:1; 120 ml) gave compounds **1**. Elution with the same solvent mixture (1:1; 100 ml) gave unchanged S₄N₄. Reaction times, yields, and melting points of compounds **1** prepared are summarized in Table 6 and their analytical, IR and ¹H NMR data in Table 7.

General procedure for the preparation of 1-aryl-2,2-dibromoethanone oximes 8

The experimental procedures are basically the same as those for the preparation of **7**. Reaction times, yields, and melting points of compounds **8** are summarized in Table 8.

2,2-Dibromo-1-phenylethanone oxime 8a. *E/Z* mixture (29:71) (Found: C, 32.8; H, 2.4; N, 4.75. C₈H₇Br₂NO requires C, 32.8; H, 2.4; N, 4.8%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3298 (OH), 3046, 1491, 1399, 1281, 996, 950, 845, 781 and 694; $\delta_{\text{H}}(\text{CDCl}_3; 80 \text{ MHz})$ 6.59 and 7.44 (1 H, 2 s, CHBr₂), 7.42 (3 H, m, ArH), 7.73 (2 H, m, ArH) and 9.23 and 9.77 (1 H, 2 s, OH).

2,2-Dibromo-1-(4-methylphenyl)ethanone oxime 8b. *Z*-form (Found: C, 35.2; H, 2.95; N, 4.5. C₉H₉Br₂NO requires C, 35.2; H, 2.95; N, 4.6%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3297 (OH), 3040 and 1600; $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO}; 80 \text{ MHz})$ 2.35 (3 H, s, Me), 6.65 (1 H, s, CHBr₂), 7.58 (4 H, dd, *J* 54, 8, ArH) and 10.03 (1 H, s, OH); m/z (EI) 305 (14.4% M⁺), 307 (27.2, M⁺ + 2), 309 (13.0, M⁺ + 4) and 134 (100).

2,2-Dibromo-1-(4-nitrophenyl)ethanone oxime 8c. *Z*-form (Found: C, 28.5; H, 1.8; N, 8.3. C₈H₆Br₂N₂O₃ requires C, 28.4; H, 1.8; N, 8.3%); $\nu_{\max}(\text{neat})/\text{cm}^{-1}$ 3296 (OH), 3030, 1602, 1570s and 1347s; $\delta_{\text{H}}(\text{CDCl}_3\text{-}[^2\text{H}_6\text{]}\text{-DMSO}; 80 \text{ MHz})$ 7.54 (1 H, s,

CHBr₂), 8.11 (4 H, dd, *J* 22, 8, ArH) and 10.87 (1 H, s, OH); *m/z* (EI) 338 (0.8%, M⁺), 340 (1.2, M⁺ + 2), 342 (0.7, M⁺ + 4) and 117 (100).

2,2-Dibromo-1-(3-nitrophenyl)ethanone oxime 8d. *E/Z* mixture (36:64) (Found: C, 28.4; H, 1.8; N, 8.3. C₈H₆Br₂N₂O₃ requires C, 28.4; H, 1.8; N, 8.3%); ν_{\max} (neat)/cm⁻¹ 3408 (OH), 3088, 1613, 1592s and 1350s; δ_{H} (CDCl₃-[²H₆]-DMSO; 80 MHz) 6.42 and 7.59 (1 H, 2 s, CHBr₂), 7.96 (4 H, m, ArH), 9.29 and 9.88 (1 H, 2 s, OH); *m/z* (EI) 338 (3.2%, M⁺), 340 (4.8, M⁺ + 2), 342 (2.6, M⁺ + 4) and 117 (100).

1-(4-Bromophenyl)-2,2-dibromoethanone oxime 8e. *Z*-form (Found: C, 25.8; H, 1.6; N, 3.8. C₈H₆Br₃NO requires C, 25.8; H, 1.6; N, 3.8%); ν_{\max} (KBr)/cm⁻¹ 3280 (OH), 3041 and 1588; δ_{H} (CDCl₃-[²H₆]-DMSO; 80 MHz) 7.45 (1 H, s, CHBr₂), 7.66 (4 H, dd, *J* 21, 8, ArH) and 11.10 (1 H, s, OH); *m/z* (EI) 368 (1.5%, M⁺), 370 (5.1, M⁺ + 2), 372 (6.1, M⁺ + 4), 374 (1.7, M⁺ + 6) and 182 (100).

1-(4-Chlorophenyl)-2,2-dibromoethanone oxime 8f. *Z*-form (Found: C, 29.3; H, 1.85; N, 4.3. C₈H₆Br₂NO requires C, 29.35; H, 1.85; N, 4.3%); ν_{\max} (KBr)/cm⁻¹ 3292 (OH), 3040 and 1591; δ_{H} (CDCl₃-[²H₆]-DMSO; 80 MHz) 7.42 (1 H, s, CHBr₂), 7.59 (4 H, dd, *J* 35, 8.4, ArH) and 12.59 (1 H, s, OH); *m/z* (EI) 325 (4.0%, M⁺), 327 (6.7, M⁺ + 2), 329 (4.8, M⁺ + 4) and 136 (100).

2,2-Dibromo-1-(4-fluorophenyl)ethanone oxime 8g. *E/Z* mixture (34:66) (Found: C, 30.9; H, 1.9; N, 4.55. C₈H₆Br₂FNO requires C, 30.9; H, 1.9; N, 4.5%); ν_{\max} (neat)/cm⁻¹ 3288 (OH), 3040 and 1598; δ_{H} (CDCl₃-[²H₆]-DMSO; 80 MHz) 6.46 and 7.24 (1 H, 2 s, CHBr₂), 6.45 (4 H, m, ArH) and 8.63 and 9.40 (1 H, 2 s, OH); *m/z* (EI) 309 (2.0%, M⁺), 311 (5.5, M⁺ + 2), 313 (3.5, M⁺ + 4) and 151 (100).

2,2-Dibromo-1-(4-methoxyphenyl)ethanone oxime 8h. *Z*-form (Found: C, 33.4; H, 2.8; N, 4.3. C₉H₉Br₂NO requires C, 33.5; H, 2.8; N, 4.3%); ν_{\max} (KBr)/cm⁻¹ 3296 (OH), 3039 and 1603; δ_{H} (CDCl₃-[²H₆]-DMSO; 80 MHz) 3.87 (3 H, s, MeO), 7.47 (1 H, s, CHBr₂), 7.51 (4 H, dd, *J* 70, 8, ArH) and 10.63 (1 H, s, OH); *m/z* (EI) 321 (3.5%, M⁺), 323 (3.9, M⁺ + 2), 325 (2.9, M⁺ + 4) and 135 (100).

2,2-Dibromo-1-(3-methoxyphenyl)ethanone oxime 8i. *Z*-form (Found: C, 33.4; H, 2.8; N, 4.4. C₉H₉Br₂NO requires C, 33.5; H, 2.8; N, 4.3%); ν_{\max} (KBr)/cm⁻¹ 3302, 1600, 1507, 1437, 1299, 1189, 1020, 961 and 832; δ_{H} (CDCl₃-[²H₆]-DMSO; 80 MHz) 3.87 (3 H, s, MeO), 7.09 (1 H, m, ArH), 7.48 (1 H, s, CHBr₂), 7.52 (3 H, m, ArH) and 9.72 (1 H, s, OH); *m/z* (EI) 321 (1.9%, M⁺), 323 (2.3, M⁺ + 2), 325 (1.7, M⁺ + 4) and 135 (100).

2,2-Dibromo-1-(2-naphthyl)ethanone oxime 8j. *Z*-form (Found: C, 40.1; H, 2.65; N, 4.05. C₁₂H₉Br₂NO requires C, 40.0; H, 2.6; N, 4.1%); ν_{\max} (KBr)/cm⁻¹ 3280 (OH), 3072 and 1597; δ_{H} (CDCl₃-[²H₆]-acetone; 80 MHz) 7.45 (2 H, m, ArH), 7.83 (4 H, m, ArH), 8.16 (1 H, s, CHBr₂), 8.68 (1 H, s, ArH) and 10.85 (1 H, s, OH); *m/z* (EI) 341 (2.7%, M⁺), 343 (3.0, M⁺ + 2), 345 (2.5, M⁺ + 4) and 153 (100).

1,4-Bis(dibromoacetyl)benzene dioxime 8k. (Found: C, 23.6; H, 1.6; N, 5.6; O, 6.4. C₁₀H₈Br₄N₂O₂ requires C, 23.65; H, 1.6; N, 5.5; O, 6.3%); ν_{\max} (KBr)/cm⁻¹ 3280 (OH), 3042 and 1610; δ_{H} (CDCl₃-[²H₆]-DMSO; 80 MHz) 7.18 (2 H, s, 2 × CHBr₂), 7.50 (2 H, s, ArH), 7.84 (2 H, s, ArH), 11.93 (1 H, s, OH) and 12.70 (1 H, s, OH).

1,3-Bis(dibromoacetyl)benzene dioxime 8l. (Found: C, 23.7; H, 1.6; N, 5.5; O, 6.2. C₁₀H₈Br₄N₂O₂ requires C, 23.65; H, 1.6; N, 5.5; O, 6.3%); ν_{\max} (neat)/cm⁻¹ 3296s, 3040, 2880, 1435, 1377, 1264, 1045, 979, 806 and 714; δ_{H} (CDCl₃; 80 MHz) 6.43 (1 H, s, CHBr₂), 7.29 (1 H, s, CHBr₂), 7.30 (2 H, m, ArH), 8.40 (2 H, m, ArH), 9.21 (1 H, s, OH) and 9.89 (1 H, s, OH).

4,4'-Bis(dibromoacetyl)biphenyl dioxime 8m. (Found: C, 33.0; H, 2.1; N, 4.75; O, 5.45. C₁₆H₁₂Br₄N₂O₂ requires C, 32.9; H, 2.1; N, 4.8; O, 5.5%); ν_{\max} (KBr)/cm⁻¹ 3285 (OH), 3040 and 1608; δ_{H} (CDCl₃-[²H₆]-DMSO; 80 MHz) 7.66 (8 H, dd, *J* 24, 8.3, ArH), 7.75 (2 H, s, 2 × CHBr₂), 11.93 (1 H, s, OH) and 12.52 (1 H, s, OH).

General procedure for the preparation of 3-aryl-4-bromo-1,2,5-thiadiazoles 2

To a solution of **8** (1.0–3.6 mmol) in 1,4-dioxane (15 ml) was added S₄N₄ (1.0–4.2 mmol). The mixture was heated at reflux until no spot corresponding to **8** was observed on TLC (*R*_F ≈ 0.2, C₆H₆). After solvent removal *in vacuo* from the reaction mixture, the residue was chromatographed on a silica gel column (2 × 10 cm, 70–230 mesh). Hexane (200 ml) as eluent gave sulfur and hexane–benzene (4:1; 200 ml) gave unchanged S₄N₄; subsequently the same mixture (2:1; 200 ml) gave compounds **2**. Reaction times, yields, and melting points of compounds **2** are summarized in Table 8 and their analytical, IR, and ¹H NMR data in Table 9.

General procedure for the preparation of 1-aryl-2-bromo-2-fluoroethanones 8 14

To a solution of the appropriate 1-aryl-2-fluoroethanone⁹ **13** (5.7–8.0 mmol) in glacial acetic acid (15–30 ml) was added bromine (7.5–8.2 mmol). The mixture was stirred for 5–10 h at 40–50 °C and quenched when no spot corresponding to **13** appeared on TLC (*R*_F ≈ 0.4, ethyl acetate–*n*-hexane, 1:4). The reaction mixture was worked up as described in the literature. Reaction times and yields of **14** are summarized in Table 5. 2-Bromo-2-fluoro-1-phenylethanone **14a**, mp 55–56 °C (lit.¹³ 55 °C); 2-bromo-2-fluoro-1-(4-methylphenyl)ethanone **14b**, mp 64–66 °C (Found: C, 46.7; H, 3.95; Br, 34.8. C₉H₈BrFO requires C, 46.8; H, 3.9; Br, 34.6%); ν_{\max} (KBr)/cm⁻¹ 1698 (CO); δ_{H} (CDCl₃; 80 MHz) 2.41 (3 H, s, Me), 6.67 (d, 1 H, *J* 51, CHBrF) and 7.75 (4 H, dd, *J* 39, 8, ArH); *m/z* (EI) 230 (51.6%, M⁺), 232 (52.9, M⁺ + 2), 151 (32.6) and 91 (100); 2-bromo-2-fluoro-1-(4-bromophenyl)ethanone **14c**, mp 96–98 °C (Found: C, 32.4; H, 1.7; Br, 54.2. C₈H₅Br₂FO requires C, 32.5; H, 1.7; Br, 54.0%); ν_{\max} (KBr)/cm⁻¹ 1702 (C=O); δ_{H} (CDCl₃; 80 MHz) 6.69 (1 H, d, *J* 51, CHBrF) and 7.99 (4 H, d, *J* 8.4, ArH); *m/z* (EI) 294 (23.8%, M⁺), 296 (47.1, M⁺ + 2), 298 (19.2, M⁺ + 4), 215 (100) and 217 (98.2); 2-chloro-2-fluoro-1-phenylethanone **14d**, mp 45–46 °C (lit.¹³ 45 °C).

General procedure for the preparation of 1-aryl-2-bromo-9 and 1-aryl-2-chloro-2-fluoroethanone oximes 10

The experimental procedures are basically the same as those for the preparation of **7** except for quenching of the reaction by addition of water to the mixture when no spot corresponding to **13** had appeared on TLC (*R*_F ≈ 0.4, ethyl acetate–hexane, 1:4). Reaction times, yields, and melting points of **9** and **10** are summarized in Table 5.

2-Bromo-2-fluoro-1-phenylethanone oxime 9a. *Z*-form (Found: C, 41.4; H, 3.0; N, 6.0. C₈H₇BrFNO requires C, 41.4; H, 3.0; N, 6.0%); ν_{\max} (neat)/cm⁻¹ 3312 (OH), 3072, 1452, 1382, 1314, 1159, 1095, 1066, 954, 772 and 398; δ_{H} (CDCl₃-[²H₆]-acetone; 80 MHz) 7.35 (3 H, m, PhH), 7.56 (1 H, d, *J* 48, CHBrF), 7.64 (2 H, m, PhH) and 10.12 (1 H, s, OH).

2-Bromo-2-fluoro-1-(4-methylphenyl)ethanone oxime 9b. *Z*-form (Found: C, 43.7; H, 3.7; N, 5.8. C₉H₉BrFNO requires C, 43.9; H, 3.7; N, 5.7%); ν_{\max} (neat)/cm⁻¹ 3296 (OH), 1607, 1514, 1475, 1443, 1094, 1063, 957, 820 and 746; δ_{H} (CDCl₃-[²H₆]-acetone; 80 MHz) 2.35 (3 H, s, Me), 7.50 (1 H, d, *J* 50, CHBrF), 7.61 (4 H, dd, *J* 43, 8, ArH) and 11.12 (1 H, s, OH); *m/z* (EI) 245 (20.4%, M⁺), 247 (17.4, M⁺ + 2) and 123 (100).

2-Bromo-2-fluoro-1-(4-bromophenyl)ethanone oxime 9c. *Z*-form (Found: C, 30.85; H, 1.9; N, 4.5. C₈H₆Br₂FNO requires C, 30.9; H, 1.9; N, 4.5%); ν_{\max} (neat)/cm⁻¹ 3298 (OH), 1603, 1509, 1430, 1045, 972, 896, 880 and 753; δ_{H} (CDCl₃-[²H₆]-acetone; 80 MHz) 7.53 (1 H, d, *J* 48, CHBrF), 7.58 (4 H, dd, *J* 15, 8, ArH) and 10.94 (1 H, s, OH).

2-Chloro-2-fluoro-1-phenylethanone oxime 10. *E/Z* mixture (Found: C, 51.15; H, 3.8; N, 7.45; O, 8.6. C₈H₇ClFNO requires C, 51.2; H, 3.8; N, 7.5; O, 8.5%); ν_{\max} (neat)/cm⁻¹ 3312 (OH), 3072, 1572, 1470, 1101, 1066, 967 and 797; δ_{H} (CDCl₃; 80 MHz) 6.71 and 7.54 (1 H, 2 d, *J* 48, CHClF), 7.62 (2 H, m, PhH), 7.34

(3 H, m, PhH), 9.59 and 10.04 (1 H, 2 s, OH); m/z (EI) 187 (31.8%, M^+), 189 (11.7, $M^+ + 2$), 120 (65.4) and 77 (100).

General procedure for the preparation of 3-aryl-4-fluoro-1,2,5-thiadiazoles 3

To a solution of **14** (1.5–1.6 mmol) in 1,4-dioxane (15 ml) was added S_4N_4 (1.5–1.6 mmol). The mixture was heated at reflux until no spot corresponding to **14** was observed on TLC ($R_F \approx 0.18$, C_6H_6). After removal of the solvent *in vacuo* from the reaction mixture, the residue was chromatographed on a silica gel column (2×10 cm). Hexane (200 ml) as eluent gave a sulfur and hexane–benzene (4:1; 200 ml) gave unchanged S_4N_4 . Subsequent elution with the same solvent mixture (2:1; 200 ml) gave compounds **3**. Reaction times, yields, and melting points of compounds **3** are summarized in Table 10, and their analytical, IR, and 1H NMR data in Table 11.

X-Ray structure analysis of compound 7f

Crystal data: $C_8H_6Cl_3NO$, $M = 238.49$, Triclinic, $a = 6.467$ (3), $b = 7.218$ (2), $c = 11.038$ (5) Å, $\alpha = 85.79$ (3), $\beta = 74.33$ (4), $\gamma = 76.13$ (3)°, $V = 481.6$ (3) Å³ [by least-squares refinement on diffractometer angles for 25 automatically centred reflections with $23 \leq 2\theta \leq 30^\circ$, $\lambda = 0.71096$ Å, $T = 293$ (2) K], space group $P\bar{1}$ $Z = 2$, $D_x = 1.645$ g cm⁻³, colourless crystals were grown from $CHCl_3$, $F(000) = 240.00$, $\mu(Mo-K\alpha) = 9.1$ cm⁻¹.

Data collection and processing. An Enraf-Nonius CAD-4 diffractometer, graphite-monochromated Mo-K α radiation, $\omega/2\theta$ scans with ω scan width (0.65 + 0.35 tan θ)°; 1536 reflections measured ($1.8 \leq \theta \leq 25^\circ$, $0 \leq h \leq 7$, $-8 \leq k \leq 8$, $-12 \leq l \leq 13$), giving 1404 with $I \geq 2\sigma(I)$.

Structure solution and refinement. Automatic direct methods²¹ (all non-H atoms). Full-matrix least-squares refinement²² on F^2 with all non-H atoms anisotropic; hydrogen atoms were located from the successive electron density maps and their positions and isotropic thermal parameters were refined with no constraint. Final R_1 [$I \geq 2\sigma(I)$] = 0.0345; wR_2 [all data] = 0.1225, $S[F^2] = 0$ for 119 refined parameters (R indices defined in ref. 21). The final ΔF synthesis showed no peaks outside the range $-0.417 \rightarrow +0.528$ e Å⁻³. Fig. 1 was produced using SHELXTL/PC.²³ Atomic coordinates and equivalent isotropic and anisotropic displacement parameters, and bond distances and angles, have been deposited at the Cambridge Crystallographic Data Centre and are available on request. Any such request should be accompanied by a full bibliographic citation for this work together with the reference number 207/156.†

Acknowledgements

The authors are grateful for the financial support by the center for Basic Science Research Institute Program, Ministry of Education (BSRI-96-3417).

† For details of the deposition scheme, see 'Instructions for Authors', *J. Chem. Soc., Perkin Trans 1*, available via the RSC web pages (<http://www.rsc.org/authors>).

References

- 1 K. D. Kearney, Eur. Pat. Appl., EP 0 414 511/1990 (*Chem. Abstr.*, 1991, **115**, 29 342s).
- 2 J. F. Engel and J. M. Puglis, U.S. Patent 4 555 521/1985 (*Chem. Abstr.*, 1986, **124**, 64 226b).
- 3 (a) L. M. Weinstock, P. Davis, B. Handelsman and R. Tull, *J. Org. Chem.*, 1967, **32**, 2823; (b) Y. Hanasaki, H. Watanabe, K. Katsuura, H. Takayama, S. Shirakawa, K. Yamaguchi, S. Sakai, K. Ijichi, M. Fujiwara, K. Konno, T. Yokota, S. Shigeta and M. Baba, *J. Med. Chem.*, 1995, **38**, 2038.
- 4 Y. Hanazaki, H. Watanabe and K. Tsuzuki, Jpn. Kokai Tokkyo Koho, JP 05, 163 257/1993 (*Chem. Abstr.*, 1993, **119**, 271 175j).
- 5 K. Kim and J. Cho, *Heterocycles*, 1994, **38**, 1859.
- 6 K.-J. Kim, H.-S. Lee and K. Kim, *J. Heterocycl. Chem.*, 1996, **33**, 295.
- 7 (a) J. H. Smith, J. H. Heidema, E. T. Kaiser, J. B. Wetherington and J. W. Moncrief, *J. Am. Chem. Soc.*, 1972, **94**, 9274; (b) J. H. Smith, J. H. Heidema, E. T. Kaiser, J. B. Wetherington and J. W. Moncrief, *J. Am. Chem. Soc.*, 1972, **94**, 9276.
- 8 D. R. Baker and A. D. Gutman, U.S. Patent 4 441 916/1984 (*Chem. Abstr.*, 1984, **101**, 50 147c).
- 9 When the reaction of **11a** with hydroxylamine hydrochloride was carried out at reflux temperature, a mixture of **7a**, **5a**, and 2,2,2-trichloro-1-phenylethanone oxime was formed.
- 10 R. N. McDonald and R. C. Cousine, *J. Org. Chem.*, 1980, **45**, 2976.
- 11 (a) V. P. Kravets, G. I. Cherveniyuk and G. V. Grinev, *Zh. Org. Khim.*, 1966, **2**, 1244; (b) K. Kim, J. Cho and S. C. Yoon, *J. Chem. Soc., Perkin Trans. 1*, 1995, 253.
- 12 X. Creary, *J. Org. Chem.*, 1987, **52**, 5026.
- 13 (a) F. Bergman, A. Kalmus and S. Vromen, *J. Am. Chem. Soc.*, 1955, **77**, 2494; (b) G. A. Olah, J. T. Welch, Y. D. Vandar, M. Nojima, I. Kerekes and J. A. Olah, *J. Org. Chem.*, 1979, **44**, 3872.
- 14 (a) S. Mataka, A. Hosoki, K. Takahashi and M. Tashiro, *J. Heterocycl. Chem.*, 1980, **17**, 1681; (b) D. H. Barton and W. A. Bubb, *J. Chem. Soc., Perkin Trans. 1*, 1977, 916; (c) T. Tashiro and S. Mataka, *Chem. Lett.*, 1976, 627.
- 15 The formation of the nitroso olefins **19** in the presence of $NaHCO_3$ or Na_2CO_3 was confirmed by trapping experiments.
- 16 S. Mataka, K. Takahashi, S. Ishii and M. Tashiro, *J. Chem. Soc., Perkin Trans. 1*, 1979, 2905.
- 17 *Gmelin's Handbook of Inorganic Chemistry*, Sulfur-Nitrogen Compounds, Part 2 B, ed. B. Heibel, Springer-Verlag, Berlin, 8th edn., 1984, ch. 5, p.127.
- 18 F. Weygand and H. J. Bestmann, *Chem. Ber.*, 1957, **90**, 1230.
- 19 K. Kurosawa and K. Yamaguchi, *Bull. Chem. Soc. Jpn.*, 1981, **54**, 1757.
- 20 G. Weber, S. Hauptmann, H. Wilde and G. Mann, *Synthesis*, 1983, **3**, 191.
- 21 G. M. Sheldrick, SHELXS-86, *Acta Crystallogr., Sect. A*, 1990, **46**, 467.
- 22 G. M. Sheldrick, SHELXS-93, University of Göttingen, Germany, 1993.
- 23 G. M. Sheldrick, SHELXTL/PC version 5.03, Siemens Analytical Instrumentation Inc., Madison, WI, 1994.

Paper 7/04408I

Received 23rd June 1997

Accepted 11th September 1997