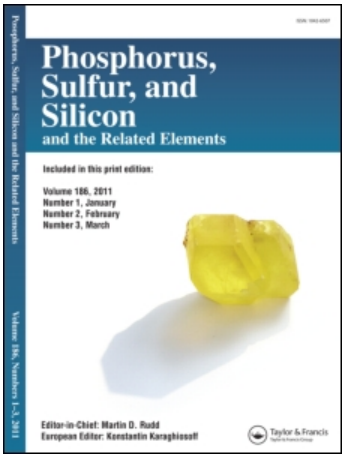

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NOVEL GREEN PROCEDURE FOR THE SYNTHESIS OF 2-ARYLBENZOTHIAZOLES UNDER MICROWAVE IRRADIATION IN PEG 200 OR PEG 400

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An improved green procedure for the synthesis of 2-aryl- and 2-hetarylbenzothiazoles by condensation of equivalent amounts of 2,2′-diaminodiphenyldisulfides or 2-aminothiophenols and various aromatic aldehydes in PEG 200/400 under microwave irradiation has been developed. This method allows the synthesis of 2-arylbenzothiazoles in high yields and with high purity regardless of the state of the starting compounds (liquid or solid) or the nature of the substituents in the aromatic ring.

Keywords 2-Aminothiophenols; arylbenzothiazoles; 2,2′-diaminodiphenyldisulfides; green chemistry; microwave

INTRODUCTION

Benzothiazoles are an important group of heterocyclic compounds that have numerous applications based on their wide spectrum of biological and biophysical properties.[1–4] 2-Arylbenzothiazoles are known as antifungal,[5] antimicrobial, and antitumor agents.[6] The presence of a benzothiazolyl moiety in these compounds, including 2-hetarylbenzothiazoles, determines the fluorescence properties and their potential use as fluorescent markers for biostructures,[7] e.g., thioflavine T[8] and the well-known DNA intercalator TOTO-1 (Figure 1), and as intermediates for the preparation of other derivatives and dyes.[9,10]

The known methods for the synthesis of benzothiazoles include two main routes: (i) condensation of *o*-aminothiophenols or derivatives such as 2,2′-diaminodiphenyldisulfides with aldehydes, carboxylic acids, or their derivatives in the presence of different catalysts and solvents[11–20] and (ii) oxidative cyclization of thioanilides under basic conditions.[9,21–24] The intermediate Schiff bases formed by 2-aminothiophenol and benzaldehydes cyclize spontaneously to give the corresponding dihydrobenzothiazoles. These compounds are then oxidized by air to give benzothiazoles.[20,25,26] The reaction conditions often involve

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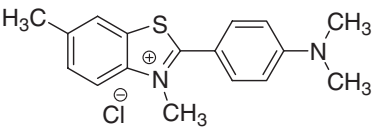
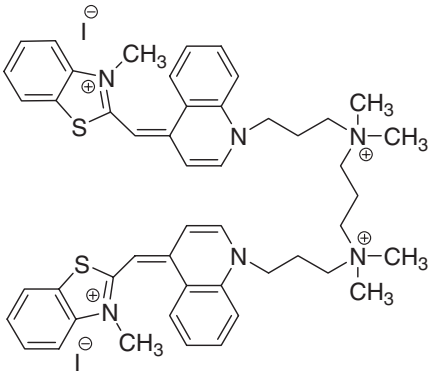


Thioflavine T (Basic Yellow 1)



TOTO-1

Figure 1 Chemical structures of thioflavine T and TOTO-1, a fluorescent DNA intercalator that contains the benzothiazole heterocycle as an end group.

relatively high temperatures and long reaction times.[11,15,17,22,27] In some cases the experimental procedures for the isolation of the product require laborious techniques such as extraction and distillation.[9,19,23,24]

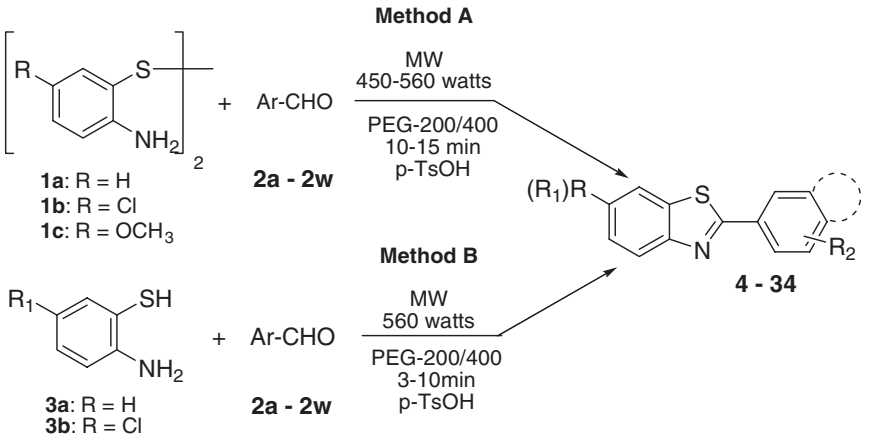
The advantages offered by the use of microwave irradiation in heterocyclic synthesis[28] have been applied to some of the methods described above in an effort to simplify and improve the procedures. In recent years, a wide range of practical applications has been identified for microwave irradiation in the synthesis of 2-substituted benzothiazoles. Most of the reported methods that involve the use of microwaves concern the condensation of *o*-aminothiophenol with various aromatic aldehydes and derivatives in short reaction times. These procedures tend to give higher product yields and proceed under solvent-free conditions.[29–36] However, some limitations are associated with this approach; these include elevated temperatures, the use of toxic metallic compounds, and laborious isolation techniques.

A literature survey reveals that the synthesis of the benzothiazole moiety from diphenyldisulfides under microwave irradiation has not been reported to date. The methods in which disulfides are used as starting materials include (i) direct reaction with substituted benzaldehydes in the presence of a catalytic amount of *p*-toluenesulfonic acid, triphenylphosphine as a reducing agent, and toluene as a solvent[18–20,22] under reflux for 14–24 hours, and (ii) oxidative cyclization of the corresponding benzanilides.[15–17]

RESULTS AND DISCUSSION

We report in this article a general and environmentally friendly procedure for the synthesis of benzothiazoles by reaction of 2,2′-diaminodiphenyldisulfides **1a–1c** (Method

A) or 2-aminothiophenols **3a** and **3b** (Method B) with different benzaldehydes in polyethylene glycol (PEG) 200 or PEG 400 (known as an ecofriendly reaction medium) under microwave irradiation (Scheme 1). The application of PEGs in synthetic organic chemistry represents both an opportunity and a challenge, and the wide availability of PEGs at low cost may give such processes a promising future in green chemistry.[37] These methods can be applied to the synthesis of a variety of 2-aryl- and 2-hetarylbenzothiazoles with different substituents in the aromatic nucleus. This approach gives products with high purity and in short reaction times, typically 3–15 min.



Scheme 1 Preparation of 2-aryl and 2-hetarylbenzothiazoles under microwave irradiation.

The methods reported for the synthesis of arylbenzothiazoles under microwave irradiation give low yields for some substituted aryl systems.[24,29] These results are attributed to the nature and the position of the substituents. For example, similar procedures under solvent-free conditions show lower yields for 2-arylbenzothiazoles bearing a hydroxyl (yield 53%) or nitro (yield 61%) group in the *para*-position of the aryl ring.[24]

During our investigations to find the optimal conditions for the condensation reaction, we discovered a significant restriction for the use of microwaves under solvent-free conditions. This approach only works well if the starting materials are liquids or low-melting compounds (i.e., below 100°C). If one of the starting materials is a solid with melting point over 100°C, the method either does not proceed at all or proceeds only partially upon prolonged microwave irradiation, even at higher power. The reaction between 2,2′-diaminodiphenyldisulfide (**1a**) and *p*-nitrobenzaldehyde (**2h**) using PEG-200/400 as solvent or in solvent-free conditions was carried out in the presence of either *p*-TsOH or $SnCl_2 \cdot 2H_2O$.[19,20] The progress of the reaction was monitored by TLC in each case. In the reactions under solvent-free conditions, starting materials were still present as a mixture with the product even when using microwave irradiation at the highest power and for prolonged reaction times (over 20 min). The use of $SnCl_2$ as a catalyst under solvent-free conditions did not increase the purity of the products for the same irradiation time.

Studies aimed at optimizing the condensation reaction according to Method A were carried out with 2,2′-diaminodiphenyldisulfide and aldehyde **2a** (Table I). The best yield of **4** was obtained by irradiating the reaction mixture for 15 (3 × 5) minutes at 560 W (Table I, entry 17) in the presence of the green solvent PEG 200/400 and *p*-toluenesulfonic acid as a

Table I Optimization of conditions for the microwave synthesis of product **4** by Methods A and B

Entry	MW (Watts)	Irradiation time (min)	Method A yield (%)[a]	Method B yield (%)[a]
1	80	2	No reaction	No reaction
2	80	4	No reaction	No reaction
3	290	2	No reaction	No reaction
4	290	4 (2 × 2)	No reaction	No reaction
5	480	2	10	23
6	480	4	29	30
7	480	8 (2 × 4)	45	59
8	560	2	24.5	26
9	560	4	28	67
10	560	5	30	89
11	560	6	32	87
12	560	6 (2 × 3)	34	70
13	560	8 (2 × 4)	56	67
14	560	10	58	68
15	560	10 (2 × 5)	67	—
16	560	12 (2 × 6)	89	—
17	560	15 (3 × 5)	93	—
18	800	1	22	43
19	800	3	Decomposition	Decomposition

catalyst. Complete consumption of the starting materials (i.e., they were no longer detected by TLC) was considered to represent the end of the reaction. Irradiation at lower power did not lead to a high enough temperature for the two solids to react (Table I, entries 1–4) and irradiation at higher power led to decomposition (Table I, entries 18 and 19).

Bearing in mind the results described above, we also optimized the conditions used for the synthesis by Method B. These studies were carried out with 2-aminothiophenol (**3a**) and benzaldehyde (**2a**) (Table I). Of the conditions tested (Table I), the best results were obtained by irradiation of the reaction mixture for 5 min at 560 W in the presence of *p*-toluenesulfonic acid and using the green solvent PEG 200/400, which is easily recovered when working with larger amounts (Table I, entry 10). Microwave irradiation at lower (Table I, entries 1–7) or higher (Table I, entries 18 and 19) power did not improve the yield of **4**. Lower yields were also obtained when attempting the condensation by irradiation of the mixture in two separate periods of 2 × 3 and 2 × 4 minutes (Table I, entries 12 and 13). The same yield of **4** was obtained when the reaction was conducted in PEG 200 as the solvent.

The optimal conditions found for the condensation of **1a–c** or **3a** with the given aldehydes to obtain **4** were successfully applied to the reactions of **1a–c**, **3a**, **3b** and different aromatic aldehydes bearing strong electron-donating and electron-withdrawing substituents (Table II). However, in some cases it was observed that the optimal irradiation time found for **4** led to decomposition of the condensation product, as was the case for compounds **11** and **14** (Table II). Consequently, the irradiation time had to be reduced to 3 min to obtain a good yield of the arylbenzothiazole derivatives. In contrast, longer reaction times were needed to complete the reaction of some aldehydes, such as **2r** and **2t**, with two periods of 5 min being the best choice for compounds **21** and **23** (Table II). These changes in the reaction times enabled the benzothiazole derivative to be obtained with high purity and in good-to-excellent yield, regardless of the nature of the substituent on the aromatic

Table II Starting materials, benzothiazoles **4–34** isolated yields, and melting points

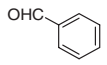
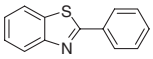
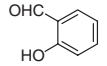
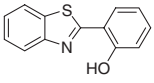
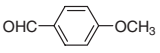
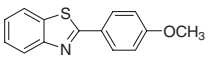
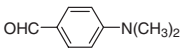
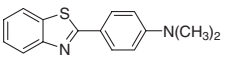
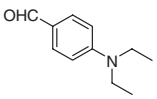
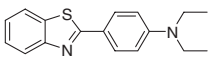
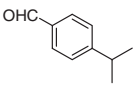
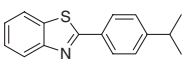
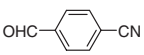
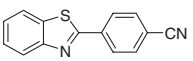
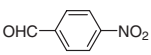
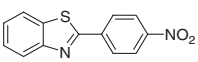
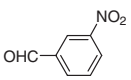
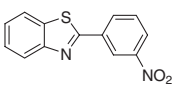
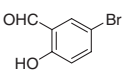
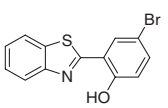
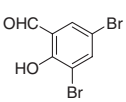
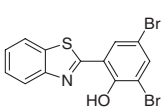
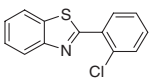
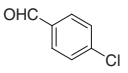
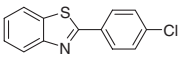
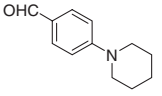
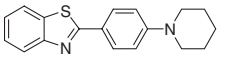
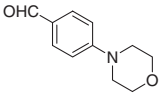
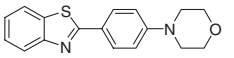
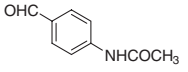
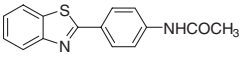
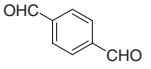
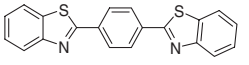
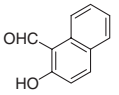
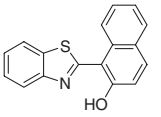
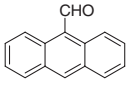
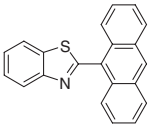
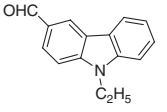
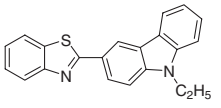
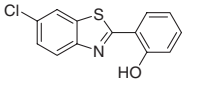
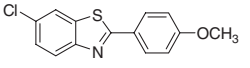
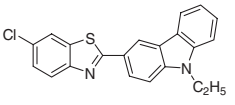
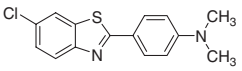
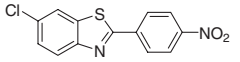
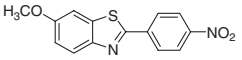
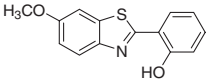
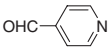
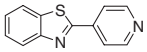
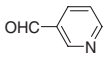
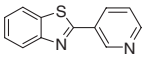
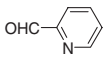
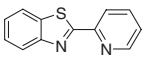
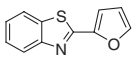
Starting material	MW (time, min)	Method	Aldehydes **2a–2w**	Benzo-thiazole product no.	Benzothiazole product structure	Yield (%)[a]	Mp/mp(lit.) (°C)
1a	5	A	 **2a**	**4**		**89**	102–104/ 102[14]; 113–114[10]
3a	15	B				**93**	
1a	10	A	 **2b**	**5**		**89**	118–120/ 120–121[17]
3a	5	B				**86**	
1a	15	A	 **2c**	**6**		**82**	90–92/ 101[17]; 121–122[23]
3a	5	B				**92**	
1a	10	A	 **2d**	**7**		**92**	154–156/ 174–175[10]
3a	10	B				**93**	
3a	10	B	 **2e**	**8**		**97**	124–126/ 125–126[10]
3a	10	B	 **2f**	**9**		**89**	74–75
3a	5	B	 **2g**	**10**		**83**	115–117
1a	15	A	 **2h**	**11**		**84**	224–226/ 229–230[25]
3a	3	B				**86**	
3a	3	B	 **2i**	**12**		**92**	177–178
3a	10	B	 **2j**	**13**		**88**	156–158
3a	3	B	 **2k**	**14**		**83**	149–151
3a	10	B	 **2l**	**15**		**82**	76–78/ 84–85[25]; 125[17]

Table II Starting materials, benzothiazoles **4–34** isolated yields, and melting points (*Continued*)

Starting material	MW (time, min)	Method	Aldehydes **2a–2w**	Benzo-thiazole product no.	Benzothiazole product structure	Yield (%)[a]	Mp/mp(lit.) (°C)
3a	10	B	 **2m**	**16**		**93**	106–108/ 119–121[17]
3a	5	B	 **2n**	**17**		**94**	166–168
3a	5	B	 **2o**	**18**		**89**	273–275
3a	5	B	 **2p**	**19**		**94**	220–222
3a	5	B	 **2q**	**20**		**97**	257–259
3a	2 × 5	B	 **2r**	**21**[b]		**77**	105–107
3a	10	B	 **2s**	**22**[b]		**92**	219–220/ 212–213[10]
3a	2 × 5	B	 **2t**	**23**		**62**	141–142
1b	10	B	**2b**	**24**		**85**	144–146
3b	15	B	**2c**	**25**		**78**	136–138
1b	15	B	**2t**	**26**		**58**	148–150

(Continued on next page)

Table II Starting materials, benzothiazoles **4–34** isolated yields, and melting points (*Continued*)

Starting material	MW (time, min)	Method	Aldehydes **2a–2w**	Benzo-thiazole product no.	Benzothiazole product structure	Yield (%)[a]	Mp/mp(lit.) (°C)
3b	10	B	**2d**	**27**		**92**	199–201
1b	5	B	**2h**	**28**		**85**	208–210
1c	15	B	**2h**	**29**		**69**	156–158
1c	15	B	**2b**	**30**		**71**	132–134
1a	10	A	 **2u**	**31**		**96**	135–136/ 133–134[10]
3a	10	B				**80**	
1a	10	A	 **2v**	**32**		**95**	137–138/ 127[10]
3a	10	B				**90**	
1a	10	A	 **2w**	**33**		**93**	136–137/ 137–138[10]
3a	10	B				**85**	
1a	10	B	 **2x**	**34**		**92**	103/105[10]

[a]Isolated yields.
[b]Reactions were carried out with addition of DMSO (1 mL).

ring.[24] An excellent yield was also obtained in the double condensation reaction to give dibenzothiazole **20** (Table II). The use of the carbazole derivative **2t** as a heteroaromatic aldehyde produced benzothiazole **23** as the condensation product, albeit in moderate yield. It is worth noting that for some compounds, such as **21** and **22**, which were obtained from the 2-naphthol analog (**2r**) and 9-anthranylaldehyde (**2s**), respectively (Table II), better yields were achieved by adding DMSO (1 mL) as a co-solvent. This behavior is related to the ability of DMSO to act as an oxidant, which leads to a significant improvement in the yields.[11]

The condensation reaction was also attempted with 2-amino-5-chlorothiophenol **3b** and arylaldehydes bearing strong electron-donating or electron-withdrawing substituents (**2c**, **2d**, and **2h**). In all cases, the reaction gave excellent yields of the corresponding condensation products **25**, **27**, and **28** (Table II).

In the reactions involving heteroaryl aldehydes **2u–2w**, we observed that the yields of the corresponding benzothiazoles **31–33** were higher on using 2,2′-diaminodiphenyldisulfide **1a** as the starting material (Table II).

In summary, we report a simple and general experimental procedure for the preparation of 2-aryl- and 2-hetarylbenzothiazoles under microwave irradiation (Table II). This

approach requires short reaction times, has an easy workup procedure, and ensures reduced environmental impact. The method also gives products in excellent yields and with high purity regardless of the substituents in the arylaldehydes and the state (solid or liquid) of the starting compounds used.

CONCLUSIONS

The synthetic procedure reported here is a reliable, simple, highly reproducible process. The procedure is also very energy efficient as it involves very short reaction times (3–15 min). The green solvent PEG 200 or PEG 400 is used, and this ensures reduced environmental impact. The proposed method is very versatile, as a variety of different starting materials can be used. The use of 2,2′-diaminodiphenyldisulfides as starting materials does not require the addition of reducing agents to the reaction mixture. The reaction products are obtained in high yields and with high purity. In most cases, the yields are higher than those obtained using similar methods reported in the literature. Furthermore, column chromatography was not necessary for product purification.

EXPERIMENTAL

^{1}H NMR spectra were recorded on Varian 200 MHz and Bruker Avance II+ 600 spectrometers in DMSO-d_6 as solvent. The reactions were monitored by TLC (Merck F 254 silica gel; dichloromethane:*n*-heptane, 3:2). Melting points were obtained on a Kofler apparatus and are uncorrected. 2-Aminothiophenol (**3a**) and aldehydes **2a**–**2x** were commercial products; 2-amino-5-chlorothiophenol (**3b**) and 2,2-diaminodiphenyldisulphides (**1a**–**1c**) were synthesized by known procedures.[38,39] A Neo MWO-M8205 commercial microwave oven operating at a *frequency* of 2450 MHz with a power ranging from 80 to 800 Watts was used.

The analytical data for all known compounds were compared with those reported in the literature. The compounds that have not been reported previously were characterized by NMR spectroscopy and elemental analysis (Table III).

Method A

The appropriate 2,2′-diaminodiphenyldisulfide **3a**–**3c** (2.5 mmol), the corresponding aldehyde **2a**–**2x** (5 mmol), PEG 200/400 (5 mL), and *p*-TsOH (0.1 mmol) were placed in a 25 mL Erlenmeyer flask. The reaction mixture was irradiated for 10–15 min at 560 W (450 W for compounds **31**, **32**, **33**, **34**) in a microwave oven. The mixture was allowed to cool to room temperature, and ethanol (10 mL) was added. In some cases the products **3**–**34** crystallized, and in other cases they were precipitated by dilution with cold water (50 mL). The compounds were isolated by filtration.

Method B

o-Aminothiophenol **1a** or **1b** (5 mmol), the corresponding aldehyde **2a**–**2x** (5 mmol), PEG 200/400 (5 mL), and *p*-TsOH (0.1 mmol) were placed in a 25 mL Erlenmeyer flask. The reaction mixture was irradiated for 3–10 min at 560 W in a microwave oven. The mixture was allowed to cool down to room temperature, and EtOH (10 mL) was added.

Table III Elemental analysis and ^{1}H NMR data of the unknown compounds

Product	Molecular formula (mw)	Analysis C% Calc. found	H% Calc. found	N% Calc. found	^{1}H NMR [DMSO-d_6, δ(ppm)]
9	**$C_{16}H_{15}NS$** (253.36)	75.85 / 75.39	5.97 / 5.84	5.53 / 5.52	^{1}H NMR (200 MHz): 1.23 d (6H, CH($\underline{CH_3}$)$_2$); 3.05 h (1H, $\underline{CH}$(CH_3)$_2$); 7.43–7.55 m (4H, ArH); 7.99–8.05 m (3H, ArH); 8.12 d (1H, ArH)
10	**$C_{14}H_8N_2S$** (236.29)	71.16 / 70.66	3.41 / 3.32	11.86 / 11.36	^{1}H NMR (200 MHz): 7.48–7.61 m (3H, ArH); 8.03 d (1H, ArH); 8.11 d (1H, ArH); 8.19 d (1H, ArH); 8.26–8.29 m (2H, ArH)
12	**$C_{13}H_8N_2O_2S$** (256.28)	60.93 / 60.42	3.15 / 3.23	10.93 / 10.62	^{1}H NMR (200 MHz): 7.48–7.63 m (2H, ArH); 7.83–7.87 m (1H, ArH); 8.12–8.23 m (2H, ArH); 8.39–8.51 m (2H, ArH); 8.82 s (1H, ArH)
13	**$C_{13}H_8BrNOS$** (306.18)	51.00 / 50.59	2.63 / 2.59	4.57 / 4.72	^{1}H NMR (200 MHz): 7.04 d (1H, ArH); 7.39–7.59 m (3H, ArH); 8.06 d (1H, ArH); 8.13 d (1H, ArH); 8.37 d (1H, ArH); 11.7 br s (1H, OH)
14	**$C_{13}H_7Br_2NOS$** (385.07)	40.55 / 41.01	1.83 / 2.32	3.64 / 4.12	^{1}H NMR (200 MHz): 7.04 d (1H, ArH); 7.40–7.57 m (2H, ArH); 8.06 d (1H, ArH); 8.13 d (1H, ArH); 8.38 s (1H, ArH); 11.70 s (1H, OH)
17	**$C_{18}H_{18}N_2S$** (294.41)	73.43 / 74.01	6.16 / 5.90	9.51 / 9.50	^{1}H NMR (200 MHz): 1.59 brs (6H, $CH_2\underline{CH_2}CH_2$); 3.23 d (4H, $CH_2\underline{NCH_2}$); 7.03 d (2H, ArH); 7.33–7.38 m (1H, ArH); 7.44–7.49 m (1H, ArH); 7.86–7.94 m (3H, ArH); 8.04 d (1H, ArH)
18	**$C_{17}H_{16}N_2OS$** (296.39)	68.89 / 69.31	5.44 / 5.79	9.45 / 9.46	^{1}H NMR (200 MHz): 3.41 d (4H, $CH_2\underline{OCH_2}$); 3.74 d (4H, N($\underline{CH_2}$)$_2$); 7.07 d (2H, ArH); 7.35–7.40 m (1H, ArH); 7.45–7.50 m (1H, ArH); 7.91–7.96 m (3H, ArH); 8.05 d (1H, ArH)
19	**$C_{15}H_{12}N_2OS$** (268.33)	67.14 / 66.86	4.51 / 4.23	10.44 / 10.03	^{1}H NMR (200 MHz): 2.08 s (3H, CH_3); 7.39–7.83 m (2H, ArH); 7.89 d (2H, ArH); 7.99–8.09 m (3H, ArH); 8.13 d (1H, ArH); 10.26 s (1H, NH)
20	**$C_{20}H_{12}N_2S_2$** (344.45)	69.74 / 69.21	3.51 / 3.12	8.13 / 7.86	^{1}H NMR (200 MHz): 7.47–7.64 m (4H, ArH); 8.12 d (2H, ArH); 8.20 d (2H, ArH); 8.28–8.34 m (4H, ArH)
21	**$C_{17}H_{11}NOS$** (277.34)	73.62 / 73.12	4.00 / 4.00	5.05 / 5.39	^{1}H NMR (200 MHz): 7.3–7.6 m (5H, ArH); 7.89 d (1H, ArH); 7.97 d (1H, ArH); 8.10–8.18 m (2H, ArH); 8.25 d (1H, ArH)
23	**$C_{21}H_{16}N_2S$** (328.43)	76.80 / 76.27	4.91 / 4.67	8.53 / 8.54	^{1}H NMR (200 MHz): 1.16 t (3H, $NCH_2\underline{CH_3}$); 4.50 q (2H, $N\underline{CH_2}$CH3); 7.27–7.32 m (1H, ArH); 7.39–7.47 m (1H, ArH); 7.49–7.58 m (2H, ArH); 7.68 d (1H, ArH); 7.78 d (1H, ArH); 8.03 d (1H, ArH); 8.12 d (1H, ArH); 8.18 d (1H, ArH); 8.37 d (1H, ArH); 8.91 s (1H, ArH)
24	**$C_{13}H_8ClNOS$** (261.73)	59.66 / 59.19	3.08 / 2.89	5.35 / 4.92	^{1}H NMR (600 MHz): 7.05 t (1H, ArH); 7.12 d (1H, ArH); 7.18 d (1H, ArH); 7.40 t (1H, ArH); 7.70 d (1H, ArH); 7.89 d (1H, ArH); 8.12 d (1H, ArH); 11.52 s (1H, OH)
25	**$C_{14}H_{10}ClNOS$** (275.75)	60.98 / 60.79	3.66 / 3.11	5.08 / 4.82	^{1}H NMR (600 MHz): 3.87 s (3H, CH_3); 7.13 d (2H, ArH); 7.55 dd (1H, ArH); 8.00 d (1H, ArH); 8.04 d (2H, ArH); 8.28 d (1H, ArH)
26	**$C_{21}H_{15}ClN_2S$** (362.88)	69.51 / 69.75	3.08 / 3.43	5.35 / 5.61	^{1}H NMR (600 MHz): 1.31 t (3H, $NCH_2\underline{CH_3}$); 4.45 q (2H, $N\underline{CH_2}$CH3); 7.20 t (2H, ArH); 7.46 t (2H, ArH); 7.56 d (2H, ArH); 7.60 d (2H, ArH); 8.15 d (2H, ArH)
27	**$C_{15}H_{13}ClN_2S.H_2O$**(306.81)	58.72 / 58.43	4.93 / 4.24	9.13 / 9.01	^{1}H NMR (200 MHz): 3.04 s (6H, N(CH_3)$_2$); 6.83 d (2H, ArH); 7.48–7.53 m (1H, ArH); 7.87–7.93 m (3H ArH); 8.21 d (1H, ArH)
28	**$C_{13}H_7ClN_2O_2S$** (290.72)	53.71 / 54.15	2.43 / 2.86	9.64 / 9.75	^{1}H NMR (200 MHz): 7.93 d (1H, ArH); 7.41–7.45 m (1H, ArH); 8.12–8.21 m (5H, ArH)
29	**$C_{14}H_{10}N_2O_3S$** (286.31)	58.73 / 58.49	3.52 / 3.24	9.78 / 9.31	^{1}H NMR (600 MHz): 3.80 s (3H, CH_3); 7. 20 d (1H, ArH); 7.53 d (2H, ArH); 7.79 d (1H, ArH); 8.03 d (1H, ArH); 8.16 d (2H, ArH)
30	**$C_{14}H_{11}NO_2S$** (257.31)	65.35 / 64.91	4.31 / 4.11	5.44 / 5.08	^{1}H NMR (600 MHz): 3.86 s (3H, CH_3); 7.01 t (1H, ArH); 7.07 d (1H, ArH); 7.14 dd (1H, ArH); 7.39 t (1H, ArH); 7.72 d (1H, ArH); 7.95 d (1H, ArH); 8.09 d (1H, ArH); 11.56 s (1H, OH)

In some cases the products **3**–**34** crystallized, and in other cases they were precipitated by dilution with cold water (50 mL). The compounds were isolated by filtration.

Analytical samples of the products were obtained by recrystallization from ethanol.

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