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Allylation of Aldiminomercaptotriazinones Using Allyl Halides and Allylmetal Compounds

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ABSTRACT: *Allylation of 4-amino-3-mercapto-6-methyl-4*H*-1,2,4-triazin-5-one (***1***) and its arylideneamino derivatives* **5** *was performed through two different methods. Reaction of* **1** *and* **5** *with allylic bromides* **2** *in the presence of sodium ethoxide afforded a mixture of* S- *and* N*-allylated products. Treatment of arylimines* **5** *with allylic zinc bromides* **9** *and triallylborane reagents* **12** *did not affect the hetero-ring opening but the C=N bond of the lateral chain underwent the addition reaction yielding the* C*-allylated products* **10**. © 2003 Wiley Periodicals, Inc. Heteroatom Chem 14:280–287, 2003; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/hc.10144

INTRODUCTION

The synthesis of a substituted 1,2,4-triazine ring is a topic of continuous interest because of the number of biologically active molecules containing this moiety [1–8]. Introduction of allyl and vinyl groups in the triazines has shown potent biological significance [9–11]. In recent years, considerable progress has been made in the nucleophilic addition of allylmetal reagents to imines, especially those derived from amino acids, affording secondary homoallylamines [12–15]. Although various procedures for imine allylation have been investigated previously, no reports have appeared where such allylating reagents are utilized in the allylation of heterocyclic compounds containing an exocyclic C=N bond. Our continuous interest in the synthesis of homoallylic amines [16–20] led us to outline suitable conditions for introducing allylic groups into 1,2,4-triazinones through two different methods.

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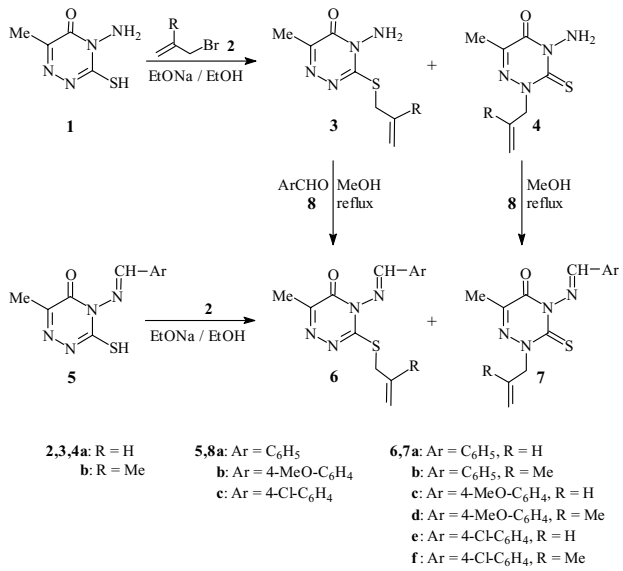
RESULTS AND DISCUSSION

When a mixture of 4-amino-3-mercapto-6-methyl-4*H*-1,2,4-triazin-5-one (**1**) and an allyl bromide (**2**) in ethanol was stirred at room temperature in the presence of sodium ethoxide as a base, a mixture of the S-allylated product 4-amino-3-allylthio-6-methyl-4*H*-1,2,4-triazin-5-one (**3**) and the N-allylated product 4-amino-2-allyl-3-thio-6-methyl-4*H*-1,2,4-triazin-5-one (**4**) was obtained. Under the same experimental conditions, arylimines **5** were also found to react with **2** to afford a mixture of S- and N-allylated products **6** and **7** (Scheme 1). The results together with the reaction conditions are summarized in Table 1.

It should be mentioned that the composition of S- and N-allylated products was affected somewhat by the reaction temperature. When the reaction was performed under reflux, a higher ratio of S- vs. N-allylated product was obtained (Table 1). For example, on refluxing **1** with **2a**, the ratio of S- vs. N-allylation was found to be 75:25 (Table 1, run 2) while at room temperature the ratio was 59:41 (Table 1, run 1). The same trend was observed in the case of the reaction of **5a** with **2a** (Table 1, runs 4 and 5). Therefore, the reaction was performed at room temperature to obtain the product mixture with higher proportions of N-allylated derivatives.



SCHEME 1

It is quite possible that the reasons should be no different from the reasons given previously for similar ambident nucleophiles containing a conjugated S–C=N system [21–23].

The structures of the S- and N-allylated products were confirmed from their analytical and spectral data. IR and ^{1}H NMR spectra of compounds **6** and **7** showed no signals attributed for the NH groups. Moreover, the mass spectra of the S-allylated products indicated the same parent peak as the N-allylated products (see Experimental section). The structural identifications were also further supported by the following chemical conversions: Treatment of **3** and **4** with arylaldehydes (**8**) in refluxing methanol furnished the products which proved to be identical with authentic specimens of the corresponding arylideneamino derivatives of the type **6** and **7**, respectively (Scheme 1).

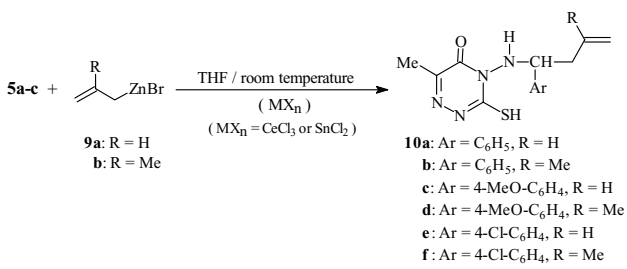
Stimulated by recent reports of Barbier procedures exploiting bimetal redox systems for the synthesis of homoallylic amines [16,24,25], analogous Barbier allylation of arylimines **5** were investigated. The Barbier procedure, which generally requires room temperature for the formation of the allylic metal species in situ, can be applied to the preparation of homoallylic amines provided that the metal (zinc) is unreactive towards the imine.

At first, a mixture of benzaldimine **5a**, the metal (zinc), and **2a** was stirred in anhydrous THF at room temperature. The Zn-mediated reaction was found to be slow and could not be driven to completion even on prolonging the reaction time for several days. The secondary homoallylic amine 4-(4-phenylbut-1-en-4-yl)amino-3-mercapto-6-methyl-4*H*-1,2,4-triazin-5-one (**10a**) was obtained with only 66% yield, along with unreacted starting material of 34%, as deduced by ^{1}H NMR spectroscopy of the crude reaction product mixture (Scheme 2, Table 2, run 1). Addition of a catalytic amount of anhydrous metal salt (MX_n) to the reaction mixture was sometimes useful in such reactions [24–26]. Thus, a catalytic amount of Lewis acid such as $CeCl_3$ and $SnCl_2$ (0.15 mmol/mmol of imine) was investigated, and it was found that $CeCl_3$ and $SnCl_2$ gave excellent results (Table 2). For example, by adding a catalytic amount of $CeCl_3$ to the reaction mixture, the reaction was completed within 6 h and **10a** was obtained in an isolated yield of 95% (run 2). The use of a Lewis acid not only allows an essentially complete transformation of the starting imine **5a**, but also enhances markedly the reaction rate. It should be mentioned that the use of more than 0.15 mmol $CeCl_3$ or $SnCl_2$/mmol of **5** has no further effect on the reaction rate and/or the reaction yield. The allylation reaction with methallylzinc bromide

TABLE 1 Alkylation of Triazines **1** and **5** with Allylic Bromides **2**, Using EtONa[a]

Run			*Time (h)*	*Product (% Yield)*[b]	*Ratio of S/N*[c]
1	**1**	**2a**	6	**3a** (54), **4a** (35)	59:41
2	**1**	**2a**	1	**3a** (69), **4a** (23)	75:25
3	**1**	**2b**	6	**3b** (67), **4b** (25)	74:26
4	**5a**	**2a**	5	**6a** (62), **7a** (30)	66:44
5	**5a**	**2a**	0.5	**6a** (67), **7a** (22)	73:27
6	**5a**	**2b**	5	**6b** (51), **7b** (39)	59:41
7	**5b**	**2a**	3	**6c** (54), **7c** (30)	66:34
8	**5b**	**2b**	3	**6d** (60), **7d** (33)	67:33
9	**5c**	**2a**	3	**6e** (52), **7e** (30)	65:35
10	**5c**	**2b**	3	**6f** (56), **7f** (34)	60:40

[a]All reactions were performed at room temperature except runs 2 and 5, which were performed at reflux.
[b]Yields refer to those isolated after purification by means of column chromatography over silica gel (eluent: ether/petroleum ether—3:7).
[c]Ratios of S- vs. N-allylation were deduced by ^{1}H NMR spectroscopy of the crude mixture.



SCHEME 2

TABLE 2 Nucleophilic Addition of Allylic Zinc Reagents **9** to Arylimines **5**[a,b]

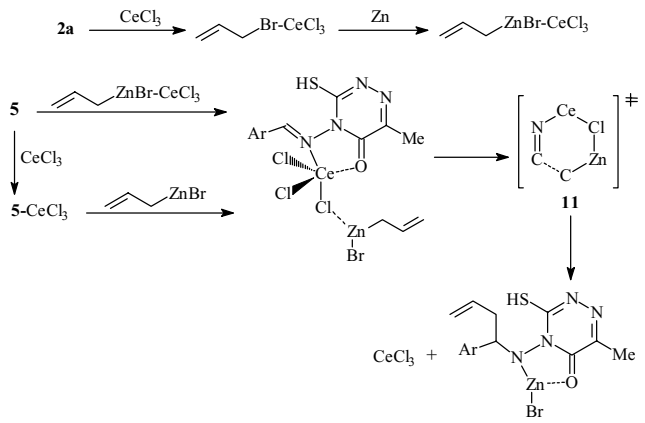
Run			*Additives (MX_n)*	*Product*	*Yield (%)*[c]
1	**5a**	**9a**	–	**10a**	66[d]
2	**5a**	**9a**	$CeCl_3$	**10a**	95
3	**5a**	**9a**	$SnCl_2$	**10a**	94
4	**5a**	**9b**	$CeCl_3$	**10b**	91
5	**5a**	**9b**	$SnCl_2$	**10b**	88
6	**5b**	**9a**	$CeCl_3$	**10c**	92
7	**5b**	**9a**	$SnCl_2$	**10c**	90
8	**5b**	**9b**	$CeCl_3$	**10d**	93
9	**5b**	**9b**	$SnCl_2$	**10d**	91
10	**5c**	**9a**	$CeCl_3$	**10e**	92
11	**5c**	**9a**	$SnCl_2$	**10e**	97
12	**5c**	**9b**	$CeCl_3$	**10f**	91
13	**5c**	**9b**	$SnCl_2$	**10f**	95

[a]All reactions were performed in the presence of 0.15 mmol of Lewis acid/mmol of imine except run 1, which was performed without additives.
[b]All reactions were performed in THF at room temperature for 6 h except run 1, which was performed for 3 days.
[c]In all cases, yields are isolated yields.
[d]Unreacted starting imine **5a** (34%) was present in the crude product mixture.

(**9b**), in presence of a catalytic amount of $CeCl_3$ or $SnCl_2$, also proceeded with similar ease providing the corresponding homomethallylic amines (Scheme 2, Table 2).

The structure of the secondary homoallylic amines **10** was deduced from their microanalytical and spectral data. For example, their ^{1}H NMR spectra showed no signal of imine protons (CH=N) that should have appeared in the region of δ 8.91–9.30 ppm as in the case of the starting arylimines **5**, indicating that the addition takes place exclusively at the exocyclic C=N bond.

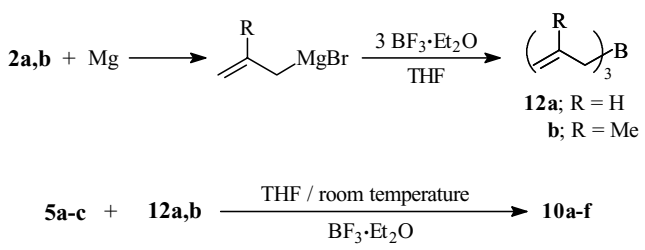
By analogy to the mechanism that was proposed by Basile et al. [24] for the metal salt-catalyzed (or mediated) addition of organometallic reagents to arylimines derived from (S)-valinate, a plausible mechanism of the $CeCl_3$-catalyzed, Zn-mediated reaction of **5** is outlined in Scheme 3. The salt undoubtedly acts as a Lewis acid, activating the imine towards the addition of allylzinc bromide. However, the salt may also have a role in the preliminary activation of allyl bromide towards the oxidative addition of Zn [24]. The addition of allylzinc bromide to **5**-$CeCl_3$ can take place through the formation of a three component complex, where $CeCl_3$ plays a double role of Lewis acid (Ce towards **5**) and Lewis base (Cl towards Zn of allylzinc bromide). Then, the secondary homoallylic amine may be produced through a cyclic six-membered transition state **11** (Scheme 3). On the other hand, the $SnCl_2$-catalyzed, Zn-mediated Barbier reaction can proceed through



SCHEME 3 Proposed mechanism of zinc-mediated, $CeCl_3$-catalyzed Barbier allylation of arylimines **5**.

two concomitant reactions of Zn: the oxidative addition to allyl bromide affording the reactive allylzinc bromide, and the redox reaction with $SnCl_2$ producing Sn and $ZnCl_2$. Unreactive allyltin species may be produced in part from Sn and allyl bromide. In addition to this, either $SnCl_2$ and/or $ZnCl_2$ might be able to activate the imine towards the organometallic addition, through the formation of chelated complex, similarly to that formed with $CeCl_3$.

Another attractive synthesis of **10**, using allylic metal reagents can be based on the allylboration of **5**. The allylboron reagent **12** [27] in THF was treated with imine **5** at room temperature, affording the homoallylamine **10** after the usual work-up procedure (Scheme 4, Table 3). Initially, benzaldimine **5a** was allowed to react with triallylboron reagent (**12a**) at room temperature. Complete conversion to **10a** was observed within 20 h, as evidenced not only by thin layer chromatography (TLC) but also by ^{1}H NMR spectroscopy (run 1). When the same reaction was performed in the presence of a stoichiometric amount of BF_3 etherate as a Lewis acid, the allylboration reaction was found to proceed smoothly within only 3 h (run 2). Thus, the addition of BF_3 etherate to the reaction mixture is useful to activate the imine towards the allylating reagent. Trimethallylboron



SCHEME 4

TABLE 3 Nucleophilic Addition of Triallylboranes **12** to Arylimines **5**[a,b]

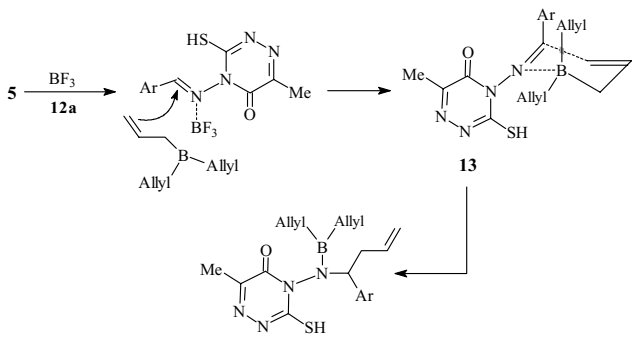
Run			*Product*	*Yield (%)*[c]
1	**5a**	**12a**	**10a**	89
2	**5a**	**12a**	**10a**	94
3	**5a**	**12b**	**10b**	93
4	**5b**	**12a**	**10c**	94
5	**5b**	**12b**	**10d**	96
6	**5c**	**12a**	**10e**	93
7	**5c**	**12b**	**10f**	95

[a]Reactions were carried out in THF in presence of equimolecular amounts of $BF_3{\cdot}Et_2O$ except run 1, which was performed without additives.
[b]All reactions were performed at room temperature for 3 h except run 1, which was performed for 20 h.
[c]In all cases, yields are isolated yields.

(**12b**) was also found to react smoothly with arylimines **5** affording the corresponding homomethallylic amines in high yields (Table 3). This method presents a particularly convenient and efficient route to the homoallylic amines **10**, with almost quantitative isolated yield.

Based on a previous publications [17–19] including the nucleophilic addition of allylboranes to chiral and prochiral arylimines, a probable path is outlined in Scheme 5. The reaction of **5** with allylborane reagents **12** can be explained on the basis of a six-membered cyclic transition state. Thus, the C—C bond-forming step can take place via the chair transition state **13** in which all steric interactions are apparently reduced.

It is worth mentioning that under similar reaction conditions, when 4-amino-3-mercapto-6-methyl-4*H*-1,2,4-triazin-5-one (**1**) was exposed to the allylating reagents **9a** and **12a**, the starting material was recovered almost unchanged. This fact indicates that the allylic zinc and triallylborane reagents do not open the hetero-ring in the 1,2,4-triazinone derivatives **5** and the carbanion of the allylic reagent attacks the exocyclic electrophilic carbon atom with the formation of the corresponding saturated derivatives **10**. This result also shows that under these conditions, these allylating reagents do not attack the carbonyl or the thione group of the aminomercaptotriazinone ring.



SCHEME 5 Proposed mechanism of allylation of arylimines **5**, using triallylboranes **12**.

In conclusion, S-, N-, and C-allylated products were obtained by the appropriate choice of the reactions. The simplicity of the allylation reaction could suggest an application of this method to other heterocyclic compounds containing an exocyclic C=N bond. The biological activity of the newly synthesized compounds is under investigation.

EXPERIMENTAL

Melting points were determined using a Gallenkamp electrothermal melting temperature apparatus and are uncorrected. Solvents and reagents were purified according to standard laboratory techniques. Reaction courses and product mixtures were routinely monitored by TLC using Merck precoated silica gel plates (Merck 5554, $60F_{254}$). Chromatographic purification was done with 200–400 mesh silica gel. IR spectra were recorded on Perkin-Elmer 1420 spectrophotometer using KBr Wafer technique. ^{1}H- and ^{13}C NMR spectra were recorded on a Varian EM-400 MHz spectrometer using $CDCl_3$ as a solvent and $SiMe_4$ as an internal reference. Chemical shifts are expressed in δ ppm and coupling constants J are given in hertz. Mass spectra were taken at an ionizing voltage of 70 eV on a Quattro II Triple quadrupole mass spectrometer. The microanalyses were performed by the microanalytical center at Cairo University.

General Procedure for the Reaction of **1** *and* **5** *with Allylic Bromides* **2** *Using Sodium Ethoxide*

Into a stirred solution of sodium (5 mmol) in absolute ethanol (20 ml) was added 1,2,4-triazinone **1** or **5** (5 mmol) at room temperature. After 5 min, the reaction mixture was treated with allylic bromide **2** (5 mmol) and stirred further for 3–6 h (see Table 1) at the same temperature (or at reflux for 0.5–1 h, entries 2 and 5, Table 1). The solvent was removed under reduced pressure and the residue chromatographed by silica gel column chromatography (eluent: ether/petroleum ether—3:7) to yield the corresponding S- and N-allylated products. The reaction yields and the S/N-ratios are shown in Table 1.

*4-Amino-3-allylthio-6-methyl-4*H*-1,2,4-triazin-5-one (***3a***).* m.p. 165°C (ethanol); (Found: C, 42.47; H, 5.02; N, 28.11; S, 15.98. Calc. for $C_7H_{10}N_4OS$:

C, 42.41; H, 5.08; N, 28.26; S, 16.17%); ν_{max}/cm^{-1} 3280 (NH_2), 1682 (C=O), 755 (C–S–C); δ_H 2.25 (3H, s, CH_3), 3.72 (2H, d, J = 6.20, SCH_2), 5.23 (2H, dd, J = 4.88 and 5.37, CH_2=C), 5.85–5.99 (1H, m, CH=C), 6.34 (2H, s, NH_2); δ_C 17.04 (CH_3), 32.88 (SCH$_2$), 118.58 (CH$_2$=CH), 133.02 (CH=CH$_2$), 152.66 (C-6), 153.90 (C-3), 160.37 (C-5); *m/z* 198 ($M^{+\cdot}$), 170, 158, 157, 130, 115, 42.

4-Amino-2-allyl-3-thio-6-methyl-4H-1,2,4-triazin-5-one (**4a**). m.p. 199°C (ethanol); (Found: C, 42.43; H, 5.09; N, 28.33; S, 16.19. Calc. for $C_7H_{10}N_4OS$: C, 42.41; H, 5.08; N, 28.26; S, 16.17%); ν_{max}/cm^{-1} 3334 (NH_2), 1688 (C=O), 1255 (C=S); δ_H 2.28 (3H, s, CH_3), 3.75 (2H, d, J = 6.20, NCH_2), 5.27 (2H, dd, J = 4.88 and 5.37, CH_2=CH), 5.89–6.01 (1H, m, CH=CH$_2$), 7.35 (2H, s, NH_2); δ_C 17.31 (CH_3), 33.81 (NCH$_2$), 119.32 (CH$_2$=CH), 131.82 (CH=CH$_2$), 152.60 (C-6), 159.41 (C-5), 168.01 (C-3); *m/z* 198 ($M^{+\cdot}$), 157, 146, 118, 105, 91, 42, 41.

*4-Amino-3-methallylthio-6-methyl-4*H-*1,2,4-triazin-5-one* (**3b**). m.p. 158°C (ethanol); (Found: C, 45.33; H, 5.68; N, 26.40; S, 15.15. Calc. for $C_8H_{12}N_4OS$: C, 45.27; H, 5.70; N, 26.39; S, 15.11%); ν_{max}/cm^{-1} 3330 (NH_2), 1685 (C=O), 644 (C–S–C); δ_H 1.72 (3H, s, CH$_2$=CCH_3), 2.33 (3H, s, COCCH_3), 3.80 (2H, s, SCH_2), 4.79 (2H, d, J = 11.69, C=CH_2), 6.67 (2H, s, NH_2); δ_C 17.38 (COCCH$_3$), 25.51 (CH$_2$=CCH$_3$), 52.23 (SCH$_2$), 114.81 (CH$_2$=C), 143.71 (CH$_2$=C), 152.68 (C-6), 154.46 (C-3), 158.71 (C-5); *m/z* 212 ($M^{+\cdot}$), 184, 156, 130, 118, 105, 56.

*4-Amino-2-methallyl-3-thio-6-methyl-4*H-*1,2,4-triazin-5-one* (**4b**). m.p. 156–158°C (ethanol); (Found: C, 45.32; H, 5.82; N, 26.35; S, 15.16. Calc. for $C_8H_{12}N_4OS$: C, 45.27; H, 5.70; N, 26.39; S, 15.11%); ν_{max}/cm^{-1} 3257 (NH_2), 1697 (C=O), 1270 (C=S); δ_H 1.83 (3H, s, CH$_2$=CCH_3), 2.49 (3H, s, COCCH_3), 3.99 (2H, s, NCH_2), 4.79 (2H, d, J = 11.70, CH_2=C), 6.81 (2H, s, NH_2); δ_C 17.03 (COCCH$_3$), 26.03 (CH$_2$=CCH$_3$), 51.24 (NCH$_2$), 111.89 (CH$_2$=C), 140.33 (C=CH$_2$), 151.43 (C-6), 158.11 (C-5), 170.10 (C-3).

*4-Benzylideneamino-3-allylthio-6-methyl-4*H-*1,2,-4-triazin-5-one* (**6a**). m.p. 202°C (methanol); (Found: C, 58.81; H, 4.90; N, 19.62; S, 11.18. Calc. for $C_{14}H_{14}N_4OS$: C, 58.72; H, 4.93; N, 19.56; S, 11.20%); ν_{max}/cm^{-1} 1665 (C=O), 685 (C–S–C); δ_H 2.5 (3H, s, CCH_3), 3.89 (2H, d, J = 6.25, SCH_2), 5.29 (2H, dd, J = 4.88 and 5.37, CH_2=C), 5.96–6.22 (1H, m, CH=C), 7.46–7.87 (5H, m, Ph), 9.37 (1H, s, PhCH=N); δ_C 17.56 (CH_3), 34.22 (SCH$_2$), 119.21 (CH_2=CH), 129.01, 129.19, 132.09, 132.24 (C-aromatic), 133.09 (CH=CH$_2$), 150.44 (C-6), 156.15 (C-3), 157.97 (C-5), 165.36 (PhCH=N); *m/z* 286 ($M^{+\cdot}$), 259, 231, 158, 146, 130, 115, 42.

*4-Benzylideneamino-2-allyl-3-thio-6-methyl-4*H-*1,2,4-triazin-5-one* (**7a**). m.p. 188°C (ethanol); (Found: C, 58.70; H, 4.88; N, 19.49; S, 11.09. Calc. for $C_{14}H_{14}N_4OS$: C, 58.72; H, 4.93; N, 19.56; S, 11.20%); ν_{max}/cm^{-1} 1668 (C=O), 1265 (C=S); δ_H 2.38 (3H, s, CH_3), 3.83 (2H, d, J = 6.25, NCH_2), 5.28 (2H, dd, J = 4.88 and 5.37, CH_2=C), 5.88–6.02 (1H, m, CH=C), 7.40–7.91 (5H, m, Ph), 8.92 (1H, s, PhCH=N); δ_C 17.03 (CH_3), 31.11 (NCH$_2$), 117.37 (CH$_2$=CH), 131.07 (CH=CH$_2$), 128.97, 129.37, 131.70, 133.30 (C-aromatic), 147.22 (C-6), 167.73 (C-5), 169.70 (PhCH=N), 173.26 (C-3); *m/z* 286 ($M^{+\cdot}$), 231, 197, 158, 146, 118, 42.

*4-Benzylideneamino-3-methallylthio-6-methyl-4*H-*1,2,4-triazin-5-one* (**6b**). m.p. 143°C (ethanol); (Found: C, 59.90; H, 5.35; N, 18.57; S, 10.70. Calc. for $C_{15}H_{16}N_4OS$: C, 59.98; H, 5.37; N, 18.65; S, 10.67%); ν_{max}/cm^{-1} 1672 (C=O), 668 (C–S–C); *m/z* 300 ($M^{+\cdot}$), 158, 146, 105, 91, 56, 55.

*4-Benzylideneamino-2-methallyl-3-thio-6-methyl-4*H-*1,2,4-triazin-5-one* (**7b**). m.p. 213°C (methanol); (Found: C, 60.05; H, 5.39; N, 18.69; S, 10.56. Calc. for $C_{15}H_{16}N_4OS$: C, 59.98; H, 5.37; N, 18.65; S, 10.67%); ν_{max}/cm^{-1} 1670 (C=O), 1240 (C=S); *m/z* 300 ($M^{+\cdot}$), 272, 158, 146, 118, 105, 56.

*4-(4-Methoxybenzylidene)amino-3-allylthio-6-methyl-4*H-*1,2,4-triazin-5-one* (**6c**). m.p. 180°C (methanol); (Found: C, 56.82; H, 5.09; N, 17.67; S, 10.07. Calc. for $C_{15}H_{16}N_4O_2S$: C, 56.88; H, 5.09; N, 17.69; S, 10.10%); ν_{max}/cm^{-1} 1683 (C=O), 691 (C–S–C); δ_H 2.49 (3H, s, CH_3), 3.81 (2H, d, J = 6.25, SCH_2), 3.96 (3H, s, OCH_3), 5.15–5.37 (2H, dd, J = 4.88 and 5.37, CH_2=C), 5.91–6.08, (1H, m, CH=C), 6.98 (2H, d, J = 8.79, Ar–H), 7.81 (2H, d, J = 8.79, Ar–H), 9.16 (1H, s, ArCH=N); δ_C 17.61 (CH_3), 34.23 (SCH$_2$), 55.52 (OCH$_3$), 119.18 (CH$_2$=CH), 132.19 (CH=CH$_2$), 114.55, 124.74, 131.25, 134.83 (C-aromatic), 150.47 (C-6), 156.01 (C-3), 163.77 (C-5), 165.49 (ArCH=N); *m/z* 316 ($M^{+\cdot}$), 286, 157, 158, 130, 170, 105, 42.

*4-(4-Methoxybenzylidene)amino-2-allyl-3-thio-6-methyl-4*H-*1,2,4-triazin-5-one* (**7c**). m.p. 199–201°C (methanol); (Found: C, 56.77; H, 5.02; N, 17.61; S, 10.18. Calc. for $C_{15}H_{16}N_4O_2S$: C, 56.88; H, 5.09; N, 17.69; S, 10.10%); ν_{max}/cm^{-1} 1660 (C=O), 1255 (C=S); δ_H 2.17 (3H, s, CH_3), 3.73 (2H, d, J = 6.25, NCH_2), 4.07 (3H, s, OCH_3), 5.26 (2H, dd, J = 4.88

and 5.37, CH_2=CH), 5.99–6.21, (1H, m, CH=CH_2), 7.07 (2H, d, J = 8.79, Ar–H), 7.93 (2H, d, J = 8.79, Ar–H), 9.27 (1H, s, ArCH=N); δ_C 17.50 (CH_3), 32.21 (NCH_2), 54.33 (OCH_3), 117.13 (CH_2=CH), 117.23, 126.21, 130.99, 133.28 (C-aromatic), 134.11 (CH=CH_2), 148.20 (C-6), 167.70 (C-5), 169.33 (ArCH=N), 173.00 (C-3).

*4-(4-Methoxybenzylidene)amino-3-methallylthio-6-methyl-4*H-*1,2,4-triazin-5-one* (**6d**). m.p. 149°C (methanol); (Found: C, 58.11; H, 5.40; N, 16.83; S, 9.64. Calc. for $C_{16}H_{18}N_4O_2S$: C, 58.16; H, 5.49; N, 16.96; S, 9.71%); ν_{max}/cm^{-1} 1682 (C=O), 689 (C–S–C); δ_H 1.63 (3H, s, CH$_2$=CCH_3), 2.41 (3H, s, COCCH_3), 3.62 (2H, s, SCH_2), 4.17 (3H, s, OCH_3), 4.69 (2H, d, J = 11.70, CH_2=C), 6.97 (2H, d, J = 8.79, Ar–H), 7.81 (2H, d, J = 8.79, Ar–H), 8.68 (1H, s, ArCH=N); δ_C 17.36 (COCCH$_3$), 26.91 (CH$_2$C=CCH$_3$), 50.44 (SCH$_2$), 55.59 (OCH$_3$), 116.91 (CH_2=C), 114.81, 124.04, 131.15, 138.20 (C-aromatic), 140.81 (C=CH$_2$), 149.21 (C-6), 159.01 (C-3), 163.50 (C-5), 168.43 (ArCH=N).

*4-(4-Methoxybenzylidene)amino-2-methallyl-3-thio-6-methyl-4*H-*1,2,4-triazin-5-one* (**7d**). m.p. 179°C (ethanol); (Found: C, 58.08; H, 5.61; N, 17.03; S, 9.58. Calc. for $C_{16}H_{18}N_4O_2S$: C, 58.16; H, 5.49; N, 16.96; S, 9.71%); ν_{max}/cm^{-1} 1680 (C=O), 1265 (C=S); δ_H 1.79 (3H, s, CH$_2$=CCH_3), 2.44 (3H, s, COCCH_3), 3.60 (2H, s, NCH_2), 4.38 (3H, s, OCH_3), 4.78 (2H, d, J = 11.70, CH_2=C), 7.01 (2H, d, J = 8.79, Ar–H), 7.76 (2H, d, J = 8.79, Ar–H), 8.72 (1H, s, ArCH=N); δ_C 17.02 (COCCH$_3$), 27.03 (CH$_2$=CCH$_3$), 52.24 (NCH$_2$), 55.54 (OCH$_3$), 112.11 (CH$_2$=C), 114.65, 124.30, 128.40, 138.86 (C-aromatic), 142.20 (C=CH$_2$), 148.58 (C-6), 163.13 (C-5), 167.32 (ArCH=N), 171.91 (C-3).

*4-(4-Chlorobenzylidene)amino-3-allylthio-6-methyl-4*H-*1,2,4-triazin-5-one* (**6e**). m.p. 196°C (ethanol); (Found: C, 52.38; H, 4.11; N, 17.55; Cl, 10.95; S, 9.05. Calc. for $C_{14}H_{13}ClN_4OS$: C, 52.42; H, 4.08; N, 17.46; Cl, 11.05; S, 9.10%); ν_{max}/cm^{-1} 1685 (C=O), 731 (C–S–C); δ_H 2.45 (3H, s, CH_3), 3.78 (2H, d, J = 6.25, SCH_2), 5.23 (2H, dd, J = 4.88 and 5.37, CH_2=C), 5.89–6.15 (1H, m, CH=C), 6.85 (2H, d, J = 8.6, Ar–H), 7.72 (2H, d, J = 8.6, Ar–H), 8.85 (1H, s, ArCH=N).

*4-(4-Chlorobenzylidene)amino-2-allyl-3-thio-6-methyl-4*H-*1,2,4-triazin-5-one* (**7e**). m.p. 226°C (ethanol); (Found: C, 52.37; H, 4.00; N, 17.33; Cl, 11.01; S, 9.26. Calc. for $C_{14}H_{13}ClN_4OS$: C, 52.42; H, 4.08; N, 17.46; Cl, 11.05; S, 9.10%); ν_{max}/cm^{-1} 1691 (C=O), 1245 (C=S); δ_H 2.19 (3H, s, CH_3), 3.80 (2H, d, J = 6.25, NCH_2), 5.31 (2H, dd, J = 4.88 and 5.37, CH_2=C), 5.98–6.14 (1H, m, CH=CH_2), 7.01 (2H, d, J = 8.6, Ar–H), 7.82 (2H, d, J = 8.6, Ar–H), 8.47 (1H, s, ArCH=N).

*4-(4-Chlorobenzylidene)amino-3-methallylthio-6-methyl-4*H-*1,2,4-triazin-5-one* (**6f**). m.p. 217°C (ethanol); (Found: C, 53.91; H, 4.56; N, 16.70; Cl, 10.55; S, 9.52. Calc. for $C_{15}H_{15}ClN_4OS$: C, 53.81; H, 4.51; N, 16.73; Cl, 10.59; S, 9.58%); ν_{max}/cm^{-1} 1695 (C=O), 690 (C–S–C); δ_H 1.52 (3H, s, CH$_2$=CCH_3), 2.33 (3H, s, COCCH_3), 3.55 (2H, s, SCH_2), 4.69 (2H, d, J = 11.70, CH_2=C), 7.51 (2H, d, J = 8.6, Ar–H), 8.38 (2H, d, J = 8.60, Ar–H), 8.96 (1H, s, ArCH=N).

*4-(4-Chlorobenzylidene)amino-2-methallyl-3-thio-6-methyl-4*H-*1,2,4-triazin-5-one* (**7f**). m.p. 251°C (ethanol); (Found: C, 53.98; H, 4.43; N, 16.61; Cl, 10.60; S, 9.55. Calc. for $C_{15}H_{15}ClN_4OS$: C, 53.81; H, 4.51; N, 16.73; Cl, 10.59; S, 9.58%); ν_{max}/cm^{-1} 1695 (C=O), 1270 (C=S); δ_H 1.60 (3H, s, CH$_2$=CCH_3), 2.43 (3H, s, COCCH_3), 3.65 (2H, s, NCH_2), 4.75 (2H, d, J = 11.70, CH_2=C), 7.43 (2H, d, J = 8.6, Ar–H), 8.44 (2H, d, J = 8.6, Ar–H), 8.98 (1H, s, ArCH=N).

Typical Procedure for the Condensation of **3** *and* **4** *with Arylaldehydes* **8**

A mixture of **3a** (0.99 g, 5 mmol) and benzaldehyde (**8a**) (0.58 g, 5.5 mmol) in anhydrous methanol (25 ml) was refluxed for 3 h. The solid product that separated on cooling was filtered off, washed with methanol, dried, and recrystallized from methanol to afford **6a** (1.27 g, 89%).

The same procedure was applied as well to the reaction of **3a** with **8b,c**; **3b** with **8a–c**; and **4a,b** with **8a–c**. After recrystallization, the products **6b** (1.32 g, 88%), **6c** (1.44 g, 91%), **6d** (1.50 g, 90%), **6e** (1.39 g, 87%), **6f** (1.49 g, 89%), **7a** (1.26 g, 88%), **7b** (1.41 g, 94%), **7c** (1.42 g, 90%), **7d** (1.54 g, 93%), **7e** (1.41 g, 88%), and **7f** (1.52 g, 91%), respectively, were obtained.

*Synthesis of 4-(1-Arylallyl)amino-3-mercapto-6-methyl-4*H-*1,2,4-triazin-5-ones* (**10**)

Method A Using Allylic Zinc Reagents **9** *(General Procedure).* The salts (ca 0.15 mmol) were dried and weighed in the apparatus used for the subsequent reaction. $SnCl_2$ was heated under vacuum at 120°C for 0.5 h, and anhydrous $CeCl_3$ was obtained by heating $CeCl_3 \cdot 7H_2O$ at 150°C for 2 h before use. To the salt were added THF (5 ml), Zn powder (0.13 g, 2 mmol), and a solution of arylimine **5** (1 mmol) and allyl bromide **2** (1.5 mmol) in THF (5 ml). The

reaction mixture was stirred at room temperature under nitrogen for 6 h, then quenched with 5 ml of 2 M HCl and extracted with chloroform (3 × 25 ml). The combined organic extracts were washed with water (2 × 25 ml), brine (25 ml), and dried over anhydrous $MgSO_4$. The solvent was evaporated till dryness under reduced pressure. The residue thus obtained was washed with petroleum ether (40–60°C) and crystallized from ethanol to afford **10** (see Table 2). The same procedure was applied as well in the absence of the salt.

Method B Using Triallylboranes **12** *(General Procedure).* To a THF (5 ml) solution of $BF_3{\cdot}Et_2O$ (0.61 ml, 5 mmol) under nitrogen was added a THF solution of allylmagnesium bromide (15 mmol, 1.2 M) at 0°C. After it had been stirred at room temperature for 0.5 h, the resulting triallylborane solution was cooled to 0°C, and then $BF_3 \cdot Et_2O$ (0.6 ml, 5 mmol) and a solution of arylimine **5** (4 mmol) in THF (5 ml) were added. The reaction mixture was stirred further for 3 h at room temperature and quenched with 10 ml of 2 M HCl aqueous solution. Usual extractive work-up with chloroform and removal of the solvent followed by crystallization from ethanol afforded **10** (see Table 3). The same procedure was also applied in the absence of BF_3 etherate.

4-(4-Phenylbut-1-en-4-yl)amino-3-mercapto-6-methyl-4 H-*1,2,4-triazin-5-one (***10a***).* m.p. 152°C; (Found: C, 58.44; H, 5.52; N, 19.44; S, 11.18. Calc. for $C_{14}H_{16}N_4OS$: C, 58.31; H, 5.59; N, 19.43; S, 11.12%); ν_{max}/cm^{-1} 3275 (NH), 1705 (C=O), 1255 (C=S); δ_H 1.98 (1H, s, CHN*H*), 2.22–2.52 (5H, m, CH_3 + CHCH_2), 3.44–3.52 (1H, m, PhC*H*), 4.96–5.09 (2H, m, CH_2=CH), 5.59–5.76 (1H, m, C*H*=CH_2), 7.33–7.91 (5H, m, Ph), 12.98 (1H, s, S*H*); *m/z* 288 ($M^{+\cdot}$), 260, 232, 204, 178, 158, 146, 131, 105.

4-(4-Phenyl-2-methylbut-1-en-4-yl)amino-3-mercapto-6-methyl-4 H-*1,2,4-triazin-5-one (***10b***).* m.p. 136°C; (Found: C, 59.66; H, 5.52; N, 18.61; S, 10.48. Calc. for $C_{15}H_{18}N_4OS$: C, 59.58; H, 5.60; N, 18.53; S, 10.60%); ν_{max}/cm^{-1} 3290 (NH), 1695 (C=O), 1270 (C=S); δ_H 1.77 (3H, s, CH_2=CCH_3), 1.82–2.45 (4H, m, CHN*H* + COCCH_3), 3.2–3.36 (2H, m, CHCH_2), 3.78–3.94 (1H, m, PhC*H*), 4.74 (2H, d, J = 14.64, CH_2=C), 7.51–7.91 (5H, m, Ph), 13.54 (1H, s, S*H*).

4-[4-(4-Methoxyphenyl)but-1-en-4-yl]amino-3-mercapto-6-methyl-4 H-*1,2,4-triazin-5-one (***10c***).* m.p. 118°C; (Found: C, 56.64; H, 5.73; N, 17.51; S, 10.18. Calc. for $C_{15}H_{18}N_4O_2S$: C, 56.58; H, 5.70; N, 17.60; S, 10.07%); ν_{max}/cm^{-1} 3320 (NH), 1711 (C=O), 1290 (C=S); δ_H 2.17 (3H, s, CH_3), 2.02–2.39 (3H, m, CHN*H* + CH_2), 3.41–3.59 (1H, m, ArC*H*), 3.84 (3H, s, OCH_3), 5.04–5.12 (2H, m, CH_2=CH), 5.63–5.75 (1H, m, C*H*=CH_2), 6.98 (2H, d, J = 8.79, Ar–H), 8.06 (2H, d, J = 8.79, Ar–H), 13.56 (1H, s, S*H*).

4-[4-(4-Methoxyphenyl)-2-methylbut-1-en-4-yl]-amino-3-mercapto-6-methyl-4 H-*1,2,4-triazin-5-one (***10d***).* m.p. 193°C; (Found: C, 57.62; H, 5.89; N, 16.75; S, 9.78. Calc. for $C_{16}H_{20}N_4O_2S$: C, 57.81; H, 6.06; N, 16.85; S, 9.65%); ν_{max}/cm^{-1} 3335 (NH), 1690 (C=O), 1278 (C=S); δ_H 1.77 (3H, s, CH_2=CCH_3), 1.82–1.93 (1H, m, CHN*H*), 2.18–2.42 (5H, m, COCCH_3 + CH_2), 3.41–3.57 (1H, m, ArC*H*), 3.76 (3H, s, OCH_3), 4.87 (2H, d, J = 14.64, CH_2=C), 7.08 (2H, d, J = 8.79, Ar–H), 7.99 (2H, d, J = 8.79, Ar–H), 13.61 (1H, s, S*H*); *m/z* 332 ($M^{+\cdot}$), 305, 277, 157, 105, 91, 115, 175.

4-[4-(4-Chlorophenyl)but-1-en-4-yl]amino-3-mercapto-6-methyl-4 H-*1,2,4-triazin-5-one (***10e***).* m.p. 121°C; (Found: C, 50.63; H, 4.59; N, 16.76; Cl, 10.49; S, 9.60. Calc. for $C_{14}H_{15}ClN_4OS$: C, 50.52; H, 4.54; N, 16.83; Cl, 10.65; S, 9.63%); ν_{max}/cm^{-1} 3295 (NH), 1686 (C=O), 1255 (C=S); δ_H 1.98–2.53 (6H, m, CHN*H* + CH_3 + CHCH_2), 3.46–3.54 (1H, m, ArC*H*), 5.06–5.22 (2H, m, CH_2=CH), 5.68–6.84 (1H, m, C*H*=CH_2), 7.51 (2H, d, J = 8.6, Ar–H), 8.11 (2H, d, J = 8.6, Ar–H), 13.66 (1H, s, S*H*).

4-[4-(4-Chlorophenyl)-2-methylbut-1-en-4-yl]-amino-3-mercapto-6-methyl-4 H-*1,2,4-triazin-5-one (***10f***).* m.p. 102–104°C; (Found: C, 53.60; H, 5.18; N, 16.56; Cl, 10.53; S, 9.60. Calc. for $C_{15}H_{17}ClN_4OS$: C, 53.49; H, 5.09; N, 16.63; Cl, 10.52; S, 9.52%); ν_{max}/cm^{-1} 3280 (NH), 1703 (C=O), 1276 (C=S); δ_H 1.77 (3H, s, CH_2=CCH_3), 1.80–1.86 (1H, m, CHN*H*), 2.15–2.36 (5H, m, COCCH_3 + CH_2), 4.87 (2H, d, J = 14.64, CH_2=C), 7.34 (2H, d, J = 8.6, Ar–H), 8.19 (2H, d, J = 8.6, Ar–H), 12.74 (1H, s, S*H*).

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