

# 1,3,5-Trisubstituted 1,3,5-Triazinane-2-thiones from 1,3,5-Trisubstituted 1,3,5-Triazinanes and Organic Isothiocyanates<sup>1</sup>

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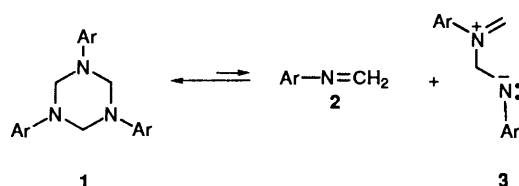
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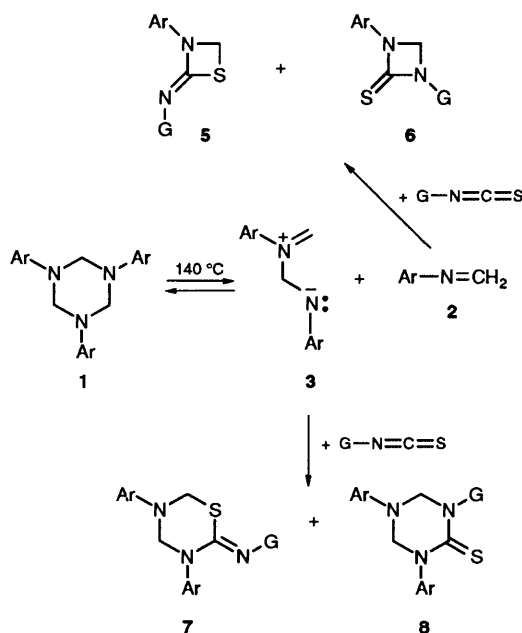
1,3,5-Trisubstituted 1,3,5-triazinane-2-thiones **8** were obtained in high yields by the uncatalysed reaction between 1,3,5-triaryl or -trialkyl 1,3,5-triazinanes **1** with aryl or alkyl isothiocyanates **4** at 130 °C. Only the reaction of 1,3,5-triaryl-1,3,5-triazinanes **1** with alkyl isothiocyanates **4** failed. Although no other type of cyclization was detected, the systems in which the substituent in **4** was different from that in **1** exhibited more or less extensive random redistribution of the substituents, according to a retrocyclization–recyclization mechanism. X-Ray crystallographic data were obtained for two derivatives **8f** and **8m**. <sup>1</sup>H and <sup>13</sup>C NMR data, as well as electron impact fragmentations, were collected and are discussed.

1,3,5-Triaryl-1,3,5-triazinanes **1** are the shelf-stable but prompt suppliers of monomeric *N*-methyleneanilines **2** and their dimers **3**, both of which are transient intermediates in many reactions (see Scheme 1).<sup>2</sup> Isolation of either **2** or **3** depends on the nature



Scheme 1

of the reacting partner and, to a much lesser extent, on the reaction conditions. Cyclizations have been described, *inter alia*, with carbon disulfide<sup>3</sup> and oxalyl chloride.<sup>1</sup> We report here the preliminary results obtained in the reactions between **1** and organic isothiocyanates **4**, potentially yielding an array of products of the type shown in Scheme 2.

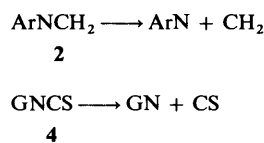


Scheme 2

## Results and Discussion

The uncatalysed reaction of an aryl isothiocyanate **4a–d**, G = aromatic, Ar, with a similarly substituted 1,3,5-triaryl-1,3,5-triazinane, **1a**, **1c**, **1d** and **1f**, at 130 °C for a few hours, produced the 1,3,5-triaryl-1,3,5-triazinane-2-thiones **8a–d** in high yields (64–90%); in these reactions, none of the alternative cyclic products of the type **5**, **6** and **7** was observed (Scheme 1). However, attempts to extend the cyclization to reaction partners carrying different substituents (G ≠ Ar) yielded a solid mixture consisting of the expected product **i-8<sup>1</sup>** (Scheme 3), accompanied by variable amounts of by-products such as **s-8<sup>3</sup>** (and/or **s-8<sup>4</sup>**), **s-8<sup>6</sup>**, **s-8<sup>5</sup>** and, possibly, **s-8<sup>2</sup>** (isomeric with **i-8<sup>1</sup>**), containing the same heterocyclic ring with all the possible substituent combinations, indicating the occurrence of scrambling. Pure single compounds could be obtained from some of the mixtures by careful recrystallizations. The results are collected in Table 1.

The retrocyclizations observed in this work may be considered to involve a generalized complete cleavage of all N=C bonds, both of the original isothiocyanates **4** and the monomeric imines **2**, with subsequent random fragment recombination producing several different isomers of **8** (see Scheme 4). Alternatively, one may look at the reaction as a

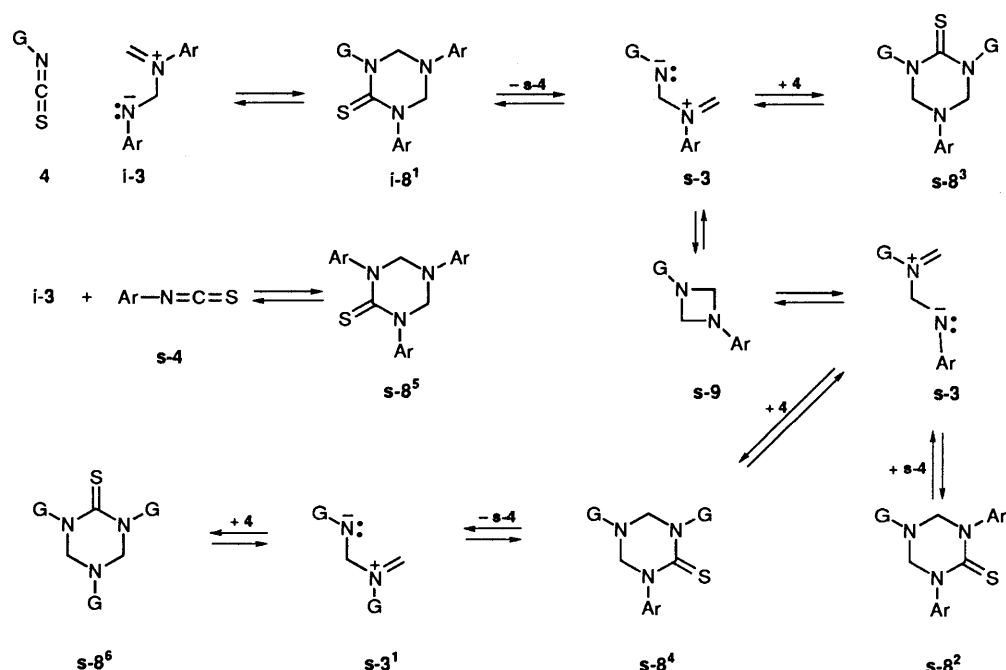


Scheme 4

substituent interchange, either within an individual molecule (isomerization) or between any two molecules (allobaric molecules). Each system may then give rise to six different products of type **8**, four of which are isomeric pairs.

The occurrence and, to a rough approximation, the extent of this randomization was investigated by mass spectrometry. Fig. 1 shows the parent ion region of the mass spectra of the crude triazinane-2-thiones **s-8f<sup>6</sup>**, **i-8f<sup>1</sup>**, **s-8<sup>3</sup>** or **s-8f<sup>4</sup>** and **s-8f<sup>5</sup>**, as obtained from the reaction between **1c** and **4a**. Fig. 2 shows the parent ion region of the mass spectra of the crude triazinane-2-thiones **s-8g<sup>6</sup>**, **i-8g<sup>1</sup>**, **s-8g<sup>3</sup>** or **s-8g<sup>4</sup>** and **s-8<sup>5</sup>** obtained in the reaction between **1d** and **4a**.

On the basis of the mechanism shown in Scheme 2, the extent of the rearrangement is expected to depend on several factors: (a) the excess of **4**, (b) the reaction temperature, (c) the reaction



**Scheme 3** The letter *i* preceding an identifying number indicates an initial reagent, whereas *s* indicates the analogous reagent formed in the process. Isomeric products are identified by an arabic superscript. Product **s-8<sup>2</sup>** is the isomer of **i-8<sup>1</sup>** and **s-8<sup>3</sup>** is the isomer of **s-8<sup>4</sup>**.

**Table 1** 1,3,5-Trisubstituted 1,3,5-triazinane-2-thiones **8** prepared

Triazinane (G)	Isothiocyanate (G')	Yield (%)	M.p. (T/°C)	Recrystn. solvent(s)	Product	(Ar)	(Ar)	(G)
<b>1a</b> (C <sub>6</sub> H <sub>5</sub> )	<b>4a</b> (C <sub>6</sub> H <sub>5</sub> )	90	163	Pr <sup>i</sup> OH	<b>8a</b>	C <sub>6</sub> H <sub>5</sub>	C <sub>6</sub> H <sub>5</sub>	C <sub>6</sub> H <sub>5</sub>
<b>1c</b> (4-MeOC <sub>6</sub> H <sub>4</sub> )	<b>4b</b> (4-MeOC <sub>6</sub> H <sub>4</sub> )	90	188	Hexane/CH <sub>2</sub> Cl <sub>2</sub>	<b>8b</b>	4-MeOC <sub>6</sub> H <sub>4</sub>	4-MeOC <sub>6</sub> H <sub>4</sub>	4-MeOC <sub>6</sub> H <sub>4</sub>
<b>1d</b> (4-FC <sub>6</sub> H <sub>4</sub> )	<b>4c</b> (4FC <sub>6</sub> H <sub>4</sub> )	70	202	Hexane/CH <sub>2</sub> Cl <sub>2</sub>	<b>8c</b>	4-FC <sub>6</sub> H <sub>4</sub>	4-FC <sub>6</sub> H <sub>4</sub>	4-FC <sub>6</sub> H <sub>4</sub>
<b>1f</b> (4-ClC <sub>6</sub> H <sub>4</sub> )	<b>4d</b> (4-ClC <sub>6</sub> H <sub>4</sub> )	64	236 <sup>a</sup>	Hexane/AcOEt	<b>8d</b>	4-ClC <sub>6</sub> H <sub>4</sub>	4-ClC <sub>6</sub> H <sub>4</sub>	4-ClC <sub>6</sub> H <sub>4</sub>
<b>1b</b> (4-MeC <sub>6</sub> H <sub>4</sub> )	<b>4a</b>	85	178	Hexane/AcOEt	<b>8e<sup>b</sup></b>	4-MeC <sub>6</sub> H <sub>4</sub>	4-MeC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>
<b>1c</b>	<b>4a</b>	90	128	Hexane/CHCl <sub>3</sub>	<b>8f<sup>b</sup></b>	4-MeOC <sub>6</sub> H <sub>4</sub>	4-MeOC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>
<b>1d</b>	<b>4a</b>	90	191	Pr <sup>i</sup> OH	<b>8g<sup>b</sup></b>	4-FC <sub>6</sub> H <sub>4</sub>	4-FC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>
<b>1e</b> (3-ClC <sub>6</sub> H <sub>4</sub> )	<b>4a</b>	70	186	Pr <sup>i</sup> OH	<b>8h<sup>b</sup></b>	3-ClC <sub>6</sub> H <sub>4</sub>	3ClC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>
<b>1f</b>	<b>4a</b>	80	186	Pr <sup>i</sup> OH	<b>8i<sup>b</sup></b>	4-ClC <sub>6</sub> H <sub>4</sub>	4-ClC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>
<b>1g</b> (4-BrC <sub>6</sub> H <sub>4</sub> )	<b>4a</b>	68	181	Pr <sup>i</sup> OH	<b>8j<sup>b</sup></b>	4-BrC <sub>6</sub> H <sub>4</sub>	4-BrC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>
<b>1h</b> (C <sub>7</sub> H <sub>7</sub> )	<b>4a</b>	90	126	Pr <sup>i</sup> OH	<b>8k</b>	C <sub>7</sub> H <sub>7</sub>	C <sub>7</sub> H <sub>7</sub>	C <sub>6</sub> H <sub>5</sub>
<b>1i</b> (C <sub>6</sub> H <sub>11</sub> )	<b>4a</b>	90	178	Cyclohexane	<b>8l</b>	C <sub>6</sub> H <sub>11</sub>	C <sub>6</sub> H <sub>11</sub>	C <sub>6</sub> H <sub>5</sub>
<b>1i</b>	<b>4e</b> (C <sub>2</sub> H <sub>5</sub> )	60	100	Hexane	<b>8m</b>	C <sub>6</sub> H <sub>11</sub>	C <sub>6</sub> H <sub>11</sub>	C <sub>2</sub> H <sub>5</sub>
<b>1a</b>	<b>4e</b>	Trace	—	—	<b>8n</b>	C <sub>6</sub> H <sub>5</sub>	C <sub>6</sub> H <sub>5</sub>	C <sub>2</sub> H <sub>5</sub>
<b>1a</b>	<b>4f</b> (C <sub>6</sub> H <sub>11</sub> )	Trace	—	—	<b>8o</b>	C <sub>6</sub> H <sub>5</sub>	C <sub>6</sub> H <sub>5</sub>	C <sub>6</sub> H <sub>11</sub>
<b>1b</b>	<b>4f</b>	Trace	—	—	<b>8p</b>	4-MeC <sub>6</sub> H <sub>4</sub>	4-MeC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>11</sub>
<b>1c</b>	<b>4f</b>	Trace	—	—	<b>8q</b>	4-MeOC <sub>6</sub> H <sub>4</sub>	4-MeOC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>11</sub>
<b>1f</b>	<b>4f</b>	Trace	—	—	<b>8r</b>	4-ClC <sub>6</sub> H <sub>4</sub>	4-ClC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>11</sub>

<sup>a</sup> Decomposition temperature. <sup>b</sup> Mixture of scrambling products.

duration, and (*d*) the relative thermodynamic stability of the possible products. Kinetic factors (other than temperature) may also play a minor role.

The influence of the temperature may show up when (*a*) the temperature at which the inception process yielding **i-8<sup>1</sup>** occurs at a reasonable rate is lower than that at which scrambling

begins (no decomposition of the adduct), or (*b*) the decomposition temperature of the adduct is lower than the temperature at which it forms at a reasonable rate. In (*a*), it is possible to obtain the adduct **i-8<sup>1</sup>** alone, in (*b*), the possibility of obtaining a single secondary adduct **s-8** is very remote. The reaction duration would have an effect on the outcome only if

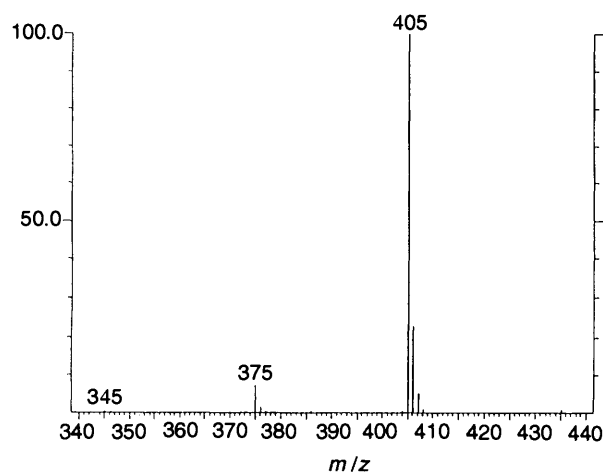


Fig. 1 Mass spectral expansion (direct inlet) of the mixture obtained from the reaction between **1c** and **4a**

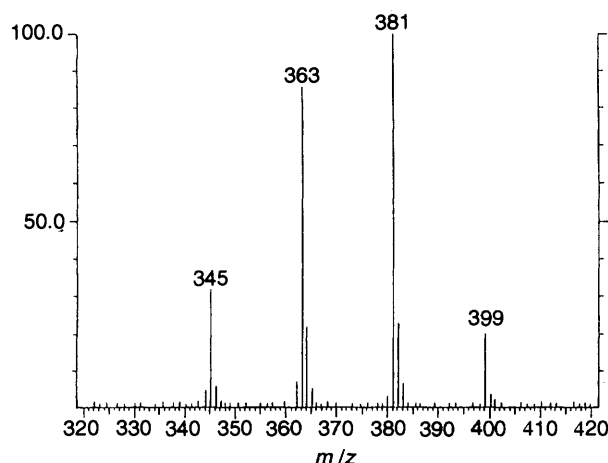


Fig. 2 Mass spectral expansion (direct inlet) of the mixture obtained from the reaction between **1d** and **4a**

the rate of formation of the initial adduct were much faster than the decomposition rate. Finally, nothing can be stated so far concerning the relative thermodynamic stabilities of isomeric and non-isomeric products.

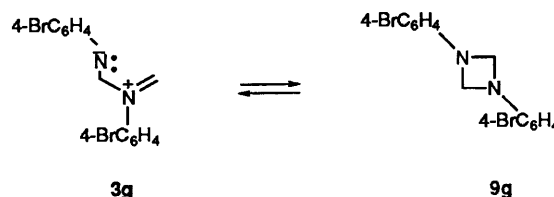
The reaction between **1c** and **4a** was found to yield a solid product, obtained in 90% yield directly by dilution with Et<sub>2</sub>O of the reaction mixture, having the same molecular weight (by MS) as both **i-8f**<sup>1</sup> and its symmetrical isomer **s-8**<sup>2</sup>. The presence of the latter, however, was ruled out by the appearance in the <sup>1</sup>H NMR spectrum of two separated and slightly broadened peaks for two different methylene groups and of two distinct A<sub>2</sub>B<sub>2</sub> quartets for two 4-methoxyphenyl groups located in different chemical environments. The <sup>13</sup>C NMR spectrum confirmed the structural assignment, evidencing the presence of two methoxy carbons at δ 55.33 and 55.56 and two methylene carbons at δ 70.62 and 70.84. The original crude precipitate also contained traces of two compounds having lower molecular weight, **s-8f**<sup>3</sup> or **s-8f**<sup>4</sup> (M<sup>+</sup> at *m/z* 375), and a compound with higher molecular weight, **s-8f**<sup>5</sup> (M<sup>+</sup> at *m/z* 435).

Literature reports on the 1,3,5-triazinane-2-thione system **8** are limited to the thermolysis of two 2-imino-1,3-thiazetanes in the presence of organic isothiocyanates; this reaction produced *N*-substituted derivatives of **8** in very poor yields and a cumbersome chromatographic separation was required in order to obtain the pure product from the multicomponent mixture.<sup>4</sup> Furthermore, the starting materials are uncommon and rather unstable. The synthetic method we report here is, therefore, of interest, providing an easy access to this class of

heterocycles. Moreover, in view of the novelty of the compounds, the X-ray crystal structure of **i-8f**<sup>1</sup> was determined, as discussed later.

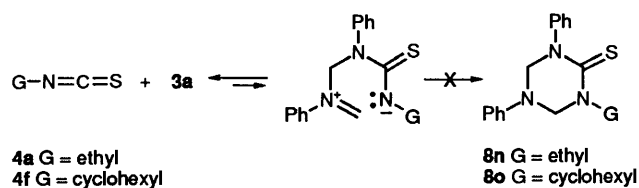
A product study of the thermolysis of **i-8f**<sup>1</sup> at 150 °C was carried out during 20 h. These compounds **8** appeared to be stable when heated *in vacuo*, generally below their melting point, for the short time necessary to introduce them in the direct inlet system of the ion source of a mass spectrometer; whenever pure compounds were so analysed, no scrambling was observed. However, under the thermolysis conditions indicated above, **i-8f**<sup>1</sup> gave rise to several monomeric and oligomeric products, identified by MS analysis: **4a**, 4-methoxyphenyl isothiocyanate **4b**, **2a** (from **1a**), 4-methoxy-*N*-methylethaniline **2c** from the thermal decomposition of its trimer **1c** under analytical conditions, 1,3,5-triphenyltriazinane-2-thione **s-8f**<sup>6</sup>, 1,5-bis(4-methoxyphenyl)-3-phenyltriazinane-2-thione **i-8f**<sup>1</sup> or 1,3-bis(4-methoxyphenyl)-5-phenyltriazinane-2-thione **s-8f**<sup>2</sup>, 5-(4-methoxyphenyl)-1,3-diphenyltriazinane-2-thione **3-8f**<sup>3</sup> or 3-(4-methoxyphenyl)-1,5-diphenyltriazinane-2-thione **s-8f**<sup>4</sup>, and 1,3,5-tris(4-methoxyphenyl)triazinane-2-thione **s-8f**<sup>5</sup>.

Although the reaction between **1c** and **4a** gave practically a single product, extensive scrambling was generally observed in the reaction between a variety of compounds **1** (**1b**, **1d-g**) and **4a**. In fact, the reaction between **1b** and **4a**, under exactly the same conditions employed for **1c**, gave a solid mixture (ca. 85%) containing all the possible scrambled products from the triphenyl **s-8e**<sup>6</sup> through to the tri-*p*-tolyl derivative **s-8e**<sup>5</sup>, in comparable concentrations. An attempt to carry out the reaction between 1,3,5-tris(4-bromophenyl)triazinane-2-thione **1g** and **4a** (molar ratio 1 : 3.3) in xylene at reflux temperature (ca. 140 °C) revealed the influence of the solvent: no reaction occurred after 40 h. This striking solvent effect suggests that a polar medium is essential for the reaction, as to be expected if a high-energy polar intermediate, such as the zwitterion **3g**, must be formed from **1g**. It is possible that in non-polar solvents, an unreactive ring structure **9g** is present instead of **3g** or the latter is too short lived (see Scheme 5).<sup>5</sup>

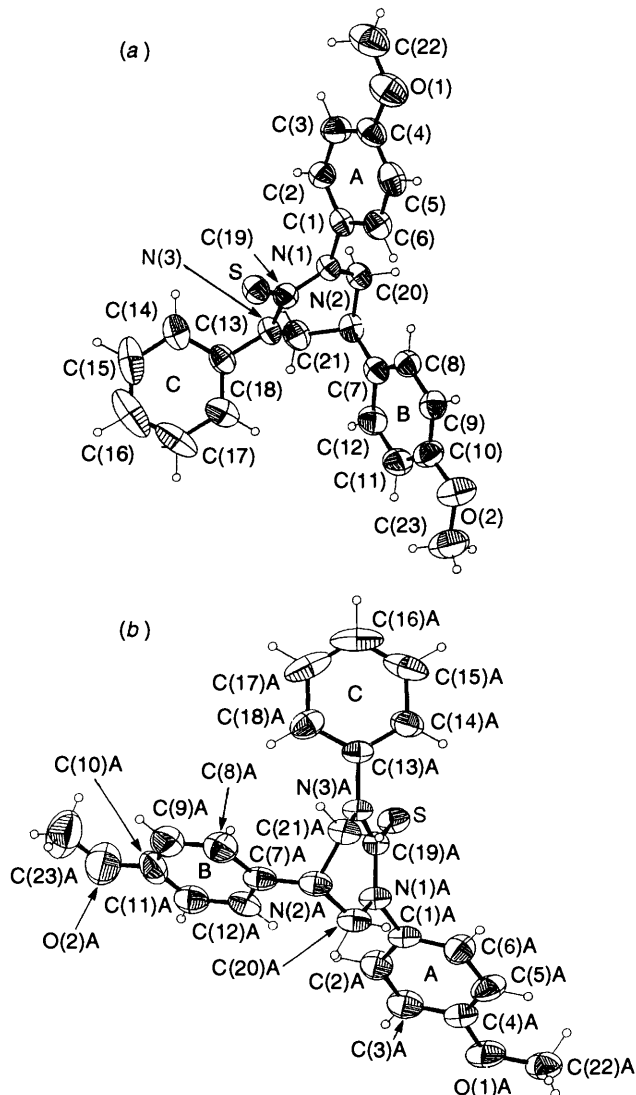


Scheme 5

Several aliphatic analogues of **8** have been prepared previously, in fair to excellent yields, by the zinc chloride-catalysed reaction between lower *N*-trialkyl-1,3,5-triazinanes (alkyl = Me through Bu<sup>t</sup>) and lower alkyl isothiocyanates (alkyl = Me or Et). Our work has shown that the reaction between the crowded 1,3,5-tri(cyclohexyl)triazinane **1i** and ethyl isothiocyanate **4e** gives 1,5-di(cyclohexyl)-3-ethyltriazinane-2-thione **8m** in 55% yield in an unoptimized experiment. Thus, the catalyst does not seem to be an essential requirement. The structure of **8m** was elucidated on the basis of two pseudo-triplets, each accounting for one proton and occurring in well separated regions of the <sup>1</sup>H NMR spectrum. The structure was supported by the presence of peaks characteristic of the cyclohexyl group in two different chemical environments. An analogous situation was observed for the single compound **8k**, obtained from the reaction of 1,3,5-tri-benzyl-1,3,5-triazinane **1h** with phenyl isothiocyanate **4a**. It should be mentioned that two alkyl isothiocyanates, the ethyl derivative **4e** and the cyclohexyl derivative **4f**, failed to react with **1a-c** and **1f** under similar conditions, only traces of the

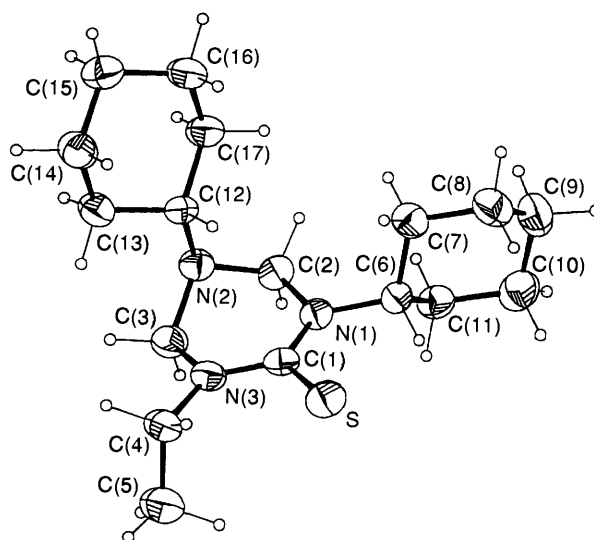


Scheme 6

Fig. 3 ORTEP view of the conformers *i-8f*<sup>1</sup>

expected products being detected (see Scheme 6). However, ethyl isothiocyanate **4e** gave the expected product **8m** in the reaction with 1,3,5-tricyclohexyl-1,3,5-triazinane **1i**. It was also observed that the scrambling reaction occurred to a lesser extent in those products **8** carrying the greater number of *N*-alkylated fragments formed in the retrocyclization. In order to investigate the relative reactivities of the triaryl- and trialkyl-1,3,5-triazinanes **1a** and **1i**, a competitive experiment was performed, in which a less than equivalent amount of **4a** was allowed to react with equimolar concentrations of **1a** and **1i**; the latter was by far the more reactive (87 vs. 13%). The observation supports the hypothesis that 1,3,5-triaryl-1,3,5-triazinanes are of relatively lower reactivity than 1,3,5-trialkyl-1,3,5-triazinanes.

**Structure of *i-8f*<sup>1</sup>.**—The crystal of *i-8f*<sup>1</sup> is formed from discrete units represented in an ORTEP view in Fig. 3 with the labelling scheme. Selected bond distances and angles are

Fig. 4 ORTEP view of the **8m** molecule

reported in Table 2. Two independent molecules which differ only in a slightly different orientation of the 4-methoxyphenyl moiety (A) with respect to the adjacent phenyl (B) and 4-methoxyphenyl (C) moieties constitute the asymmetric units. The dihedral angles between the respective mean planes are  $\widehat{A-B}$   $4.8(1)^\circ$  in the first molecule and  $10.0(1)^\circ$  in the second,  $\widehat{B-C}$   $53.2(29)^\circ$  in the first and  $59.0(2)^\circ$  in the second, while the  $\widehat{A-C}$  angles are comparable in the two molecules, being  $48.5(2)^\circ$  and  $49.1(29)^\circ$ , respectively. The molecular conformation of the heterocyclic ring is a flattened half-chair for both molecules; it is a chair in the parent compound 1,3,5-triphenyl-1,3,5-triazinane.<sup>2a</sup> The additional presence of the C=S function acts as a constraint for close-to-planar geometry for the heterocyclic ring, with consequent conformational changes of the ring itself. The minimum value of the asymmetry parameters of Cremer and People<sup>6</sup> is associated with a binary axis passing through N(2), C(19) (the latter is attached to the sulfur atom) in both molecules. The phenyl group occupies the equatorial-like position, the values of the torsional angles are  $10.8(5)^\circ$  and  $-5.5(6)^\circ$ , respectively, for S-C(19)-N(3)-C(13) and S-C(19)A-N(3)A-C(13)A; the bulkier 4-methoxyphenyl group adjacent to the C=S group takes up an equatorial position [torsion angles S-C(19)-N(11)-C(1)  $-17.7(5)^\circ$  and S-C(19)A-N(1)A-C(1)A  $-16.9(5)^\circ$ ]. The 4-methoxyphenyl attached to the nitrogen apex of the half-chair is in an axial-like position in both molecules. The respective torsion angles, C(20)-N(2)-C(7)-C(8)  $-1.2(6)^\circ$  and C(20)A-N(2)A-C(7)A-C(8)A  $172.7(4)^\circ$ , are in order to avoid intramolecular lone pair interaction with the p-orbitals of the other ring nitrogens.

**Structure of **8m**.**—The structure of **8m** consists of well separated molecules, the asymmetric unit being in this case a single molecule of which an ORTEP view is shown in Fig. 4 with the atom labelling scheme. Selected bond distances and angles are shown in Table 3. The heterocyclic ring presents a half-chair conformation as in *i-8f*<sup>1</sup>. The deviations of the five atoms that form the almost planar part of the chair have a range of mean out-of-plane distances of  $-0.048(4)$  to  $0.038(3)$  Å, with the sulfur atom  $-0.126(1)$  Å below the plane and on the same side as the N(2) nitrogen which is  $-0.703(3)$  Å below. The cyclohexyl group attached to N(2) is in an axial position while the N(1) cyclohexyl substituent is equatorial. Both cyclohexyl groups have the usual chair conformation. The tertiary hydrogens on the two cyclohexyl moieties point essentially in the same direction, quite like the sulfur in the C=S bond.

**Table 2** Selected bond distances (Å) and angles (°) with esds in parentheses for **18f**<sup>1</sup>

Bond lengths (Å)			
S(1)–C(19)	1.691(4)	N(1)–C(19)	1.355(5)
N(1)–C(20)	1.470(5)	N(1)–C(1)	1.438(5)
N(2)–C(20)	1.446(6)	N(2)–C(21)	1.448(6)
N(2)–C(7)	1.439(6)	N(3)–C(19)	1.354(5)
N(3)–C(21)	1.477(5)	N(3)–C(13)	1.449(5)
O(1)–C(4)	1.374(7)	O(1)–C(22)	1.394(9)
O(2)–C(10)	1.383(6)	O(2)–C(23)	1.419(9)
S(1)A–C(19)A	1.675(4)	N(1)A–C(19)A	1.362(5)
N(1)A–C(20)A	1.479(5)	N(1)A–C(1)A	1.443(5)
N(2)A–C(20)A	1.432(6)	N(2)A–C(21)A	1.443(5)
N(2)A–C(7)A	1.426(6)	N(3)A–C(19)A	1.364(5)
N(3)A–C(21)A	1.485(5)	N(3)A–C(13)A	1.434(5)
O(1)A–C(4)A	1.361(5)	O(1)A–C(22)A	1.426(7)
O(2)A–C(10)A	1.342(8)	O(2)A–C(23)A	1.316(11)
Bond angles (°)			
C(20)–N(1)–C(1)	115.1(3)	C(19)–N(1)–C(1)	121.6(3)
C(19)–N(1)–C(20)	122.6(4)	C(21)–N(2)–C(7)	114.6(4)
C(20)–N(2)–C(7)	117.1(3)	C(20)–N(2)–C(21)	107.4(4)
C(21)–N(3)–C(13)	114.7(3)	C(19)–N(3)–C(13)	123.6(3)
C(19)–N(3)–C(21)	120.9(4)	N(1)–C(19)–N(3)	117.0(4)
S(1)–C(19)–N(3)	122.5(3)	S(1)–C(19)–N(1)	120.5(3)
N(1)–C(20)–N(2)	111.6(4)	N(2)–C(21)–N(3)	109.3(4)
C(4)–O(1)–C(22)	118.6(5)	C(10)–O(2)–C(23)	117.6(5)
N(1)–C(1)–C(6)	121.0(4)	N(1)–C(1)–C(2)	119.6(4)
N(2)–C(7)–C(12)	119.3(4)	N(2)–C(7)–C(8)	123.3(4)
N(3)–C(13)–C(18)	120.5(4)	N(3)–C(13)–C(14)	118.8(5)
C(20)A–N(1)A–C(1)A	115.3(3)	C(19)A–N(1)A–C(1)A	121.1(3)
C(19)A–N(1)A–C(20)A	122.9(3)	C(21)A–N(2)A–C(7)A	113.7(4)
C(20)A–N(2)A–C(7)A	117.5(4)	C(20)A–N(2)A–C(21)A	106.9(4)
C(21)A–N(3)A–C(13)A	116.0(3)	C(19)A–N(3)A–C(13)A	122.7(3)
C(19)A–N(3)A–C(21)A	120.8(3)	N(1)A–C(19)A–N(3)A	115.8(3)
S(1)A–C(19)A–N(3)A	122.6(3)	S(1)A–C(19)A–N(1)A	121.5(3)
N(1)A–C(20)A–N(2)A	111.9(4)	N(2)A–C(21)A–N(3)A	109.1(3)
C(4)A–O(1)A–C(22)A	117.5(4)	C(10)A–O(2)A–C(23)A	118.2(7)
N(1)A–C(1)A–C(6)A	120.0(4)	N(1)A–C(1)A–C(2)A	120.8(4)
N(2)A–C(7)A–C(12)A	123.0(4)	N(2)A–C(7)A–C(8)A	118.4(4)
N(3)A–C(13)A–C(18)A	119.0(4)	N(3)A–C(13)A–C(14)A	120.0(4)

The overall orientation of the cyclohexyl ring [C(6)–C(11)] is nearly perpendicular to the planar part of the heterocyclic moiety [significant torsion angles are C(1)–N(1)–C(6)–C(7) – 100.9(4)° and C(2)–N(1)–C(6)–C(11) – 49.1(4)°]. The other cyclohexane moiety [C(12)–C(17)] appears aligned with the heterocyclic ring like the nearest part of the heterocyclic half-chair [significant torsion angles are C(2)–N(2)–C(12)–C(13) – 175.3(3)° and C(3)–N(2)–C(12)–C(17) – 174.3(3)°].

**Mass Spectrometry.**—The main decomposition pathway for the ions **10**, obtained by electron impact on **8**, is the retrocyclization, shown by the fact that when the aryl isothiocyanates have an electron-releasing substituent such as **8b**, the intensity of the corresponding ion **11** is greater than that of the monomeric ion **12**. The opposite effect was evidenced for electron-withdrawing substituents, such as **8d** and **8c**. The same pattern was observed by considering the ions' intensities as well as the intensities of the secondary fragmentations derived from them. Furthermore, metastable transitions were detected for the corresponding reactions (see Scheme 7). The parent ions of **8** generated at 70 eV are of low intensity, but become the base peaks at 20 eV; the parent ion at 70 eV of the fully aliphatic 1,3,5-triazinane **1i**, though, was more intense at 70 eV (Table 4). When two *N*-substituents are the same, as in **8**, two isomers are possible. Mass spectrometry then provides the most rapid identification of the compound under examination and also allows the detection of even minor concentrations of the other isomer simply by identifying the presence of **11a** and **11b**. An expansion of the low intensity higher mass region of the fully

**Table 3** Selected bond distances (Å) and angles (°) with esds in parentheses for **8m**

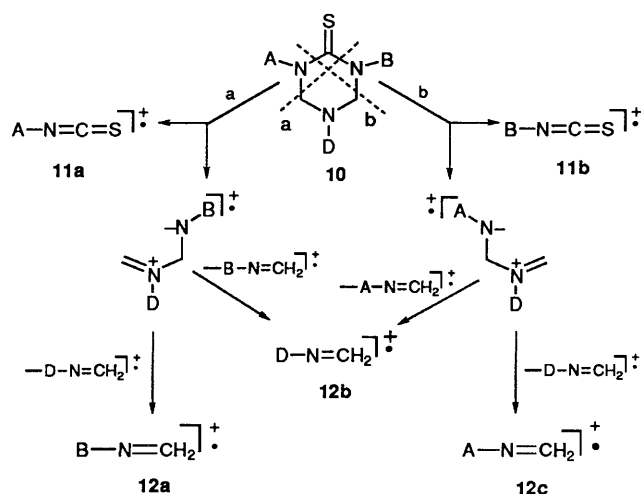
Bond lengths (Å)			
S–C(1)	1.693(4)	N(1)–C(1)	1.363(6)
N(1)–C(2)	1.486(5)	N(1)–C(6)	1.473(5)
N(2)–C(3)	1.452(6)	N(2)–C(2)	1.453(5)
N(2)–C(12)	1.500(5)	N(3)–C(1)	1.362(6)
N(3)–C(3)	1.474(5)	N(3)–C(4)	1.467(6)
C(4)–C(5)	1.499(6)		
Bond angles (°)			
C(2)–N(1)–C(6)	116.7(3)	C(1)–N(1)–C(6)	120.9(3)
C(1)–N(1)–C(2)	122.4(3)	C(2)–N(2)–C(12)	113.3(3)
C(3)–N(2)–C(12)	114.9(3)	C(3)–N(2)–C(2)	105.5(3)
C(3)–N(3)–C(4)	117.6(3)	C(1)–N(3)–C(4)	122.2(4)
C(1)–N(3)–C(3)	120.3(4)	N(1)–C(1)–N(3)	116.7(4)
S–C(1)–N(3)	121.1(3)	S–C(1)–N(1)	122.2(3)
N(2)–C(3)–N(3)	111.2(3)	N(1)–C(2)–N(2)	111.8(3)
N(3)–C(4)–C(5)	112.6(4)	N(1)–C(6)–C(11)	111.7(3)
N(1)–C(6)–C(7)	111.6(3)	N(2)–C(12)–C(17)	109.6(3)
N(2)–C(12)–C(13)	110.3(3)		

aromatic, and inspection of the entire spectra of monoaromatically or fully aliphatically substituted derivatives reveal the elimination of a methyleneimine molecule from the parent ion to yield the cyclic ion **14** (see Scheme 8). The intermediate ion **13** is also capable of undergoing a 1,2-migration of an aryl group: this reaction was inferred by the constant presence of ions **15** in the mass spectra of **8**.

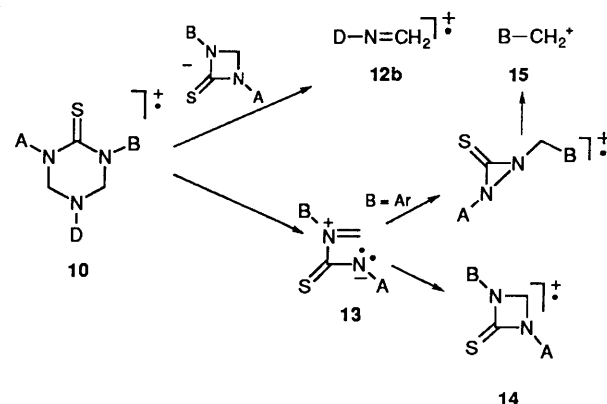
**Table 4** Properties of 1,3,5-trisubstituted 1,3,5-triazinane-2-thiones **8** isolated

Compound	$\nu_{\max}(\text{KBr})/\text{cm}^{-1}$	$\delta_{\text{H}}^a$	$\delta_{\text{C}}^a$	$m/z$ (%) <sup>b</sup>
<b>8a</b>	1485, 1470, 1290, 1270, 1200, 685, 535	5.20 (4 H, s), 7.10–7.48 (15 H, m)	69.44, 119.23, 123.51, 127.63, 127.92, 129.34, 129.73, 143.97, 146.66, 180.95 (C=S)	345 (M <sup>+</sup> , 13), 240 (3), 151 (2), 135 (35), 106 (20), 105 (100), 104 (71), 91 (10), 77 (81), 63 (4), 52 (12), 51 (37)
<b>8b</b>	1500, 1460, 1280, 1235, 1190, 1175, 1035, 1020, 825, 540	3.78 (6 H, s), 3.83 (3 H, s), 5.10 (4 H, s), 6.91 (4 H, pseudo d, <i>J</i> 9), 6.94 (2 H, pseudo d, <i>J</i> 9), 7.13 (4 H, pseudo d, <i>J</i> 9), 7.22 (2 H, pseudo d, <i>J</i> 9)	55.26, 55.48, 70.66, 114.50, 114.83, 121.67, 128.87, 136.97, 140.63, 156.16, 158.49, 181.48 (C=S)	435 (M <sup>+</sup> , 1), 165 (28), 150 (20), 135 (100), 120 (59), 92 (14), 77 (7), 65 (14), 64 (9), 51 (6)
<b>8c</b>	1490, 1465, 1400, 1290, 1240, 1210, 1185, 1155, 1140, 1085, 1030, 825, 710, 655, 530	5.83 (4 H, s), 7.74–7.97 (12 H, m)	70.33, 121.63, 121.79, 129.51, 129.68, 139.68, 139.75, 143.14, 143.19, 181.55 (C=S)	399 (M <sup>+</sup> , 2), 153 (26), 124 (10), 123 (100), 122 (45), 109 (5), 95 (52), 75 (19), 69 (4), 61 (6)
<b>8d</b>	1470, 1400, 1360, 1295, 1190, 1080, 1035, 1000, 825, 800, 540	5.33 (4 H, s), 7.25 (6 H, pseudo d, <i>J</i> 8.6), 7.40 (6 H, pseudo d, <i>J</i> 8.6)	68.22, 120.05, 126.70, 128.89, 129.30, 129.79, 131.82, 142.67, 145.21, 180.20 (C=S)	453 (M <sup>+</sup> , 1), 451 (M <sup>+</sup> , 1), 449 (M <sup>+</sup> , 2), 447 (M <sup>+</sup> , 2), 169 (17), 141 (50), 139 (100), 138 (46), 111 (32), 75 (18), 51 (8)
<b>8k</b>	1485, 1450, 1420, 1320, 1280, 1240, 1150, 1130, 1060, 935, 745, 730, 690	3.87 (2 H, s), 4.28 (2 H, s), 4.54 (2 H, s), 5.20 (2 H, s)	54.05, 55.52, 65.32, 70.40, 127.36, 127.64, 127.68, 128.12, 128.39, 128.43, 128.59, 128.79, 129.31, 136.52, 136.96, 144.87, 179.83 (C=S)	373 (M <sup>+</sup> , 4), 254 (12), 253 (8), 196 (3), 148 (7), 135 (42), 118 (14), 106 (22), 91 (100), 77 (36), 63 (7), 51 (19), 42 (36)
<b>8l</b>	2920, 2840, 1480, 1440, 1280, 1230, 1120, 1055, 750, 685	1.10–2.20 (20 H, m), 2.75–2.95 (1 H, m), 4.46 (2 H, s), 4.57 (2 H, s), 5.35–5.05 (1 H, m), 7.16–7.46 (5 H, m)	24.75, 25.50, 25.58, 29.84, 31.01, 55.48, 58.28, 59.78, 66.59, 68.04, 127.14, 128.05, 129.18, 145.11, 178.88 (C=S)	357 (M <sup>+</sup> , 4), 246 (6), 135 (56), 125 (23), 105 (37), 96 (12), 83 (36), 82 (96), 77 (52), 55 (100), 51 (23), 41 (72)
<b>8m</b>	2900, 2820, 1485, 1445, 1335, 1290, 1235, 1120, 1090, 1070, 890, 680	1.00–1.97 (23 H, m), 2.49–2.63 (1 H, m), 3.85 (2 H, q, <i>J</i> 7.08), 4.28 (2 H, d, <i>J</i> 1.01), 4.30 (2 H, d, <i>J</i> 1.01), 5.27–5.48 (1 H, m)	12.75, 24.91, 25.60, 25.66, 25.73, 30.03, 31.13, 46.97, 55.91, 58.41, 59.51, 63.02, 177.70 (C=S)	309 (M <sup>+</sup> , 25), 255 (3), 198 (33), 197 (9), 135 (10), 169 (13), 165 (15), 126 (18), 125 (31), 112 (34), 111 (18), 96 (17), 83 (53), 82 (90), 58 (58), 55 (100)

<sup>a</sup> In CDCl<sub>3</sub> solvent, tetramethylsilane as internal standard. <sup>b</sup> Recorded at 70 eV.

**Scheme 7**

<sup>1</sup>H and <sup>13</sup>C NMR Spectra.—The methylene proton and <sup>13</sup>C resonances, as well as the thiocarbonyl <sup>13</sup>C resonances, are shifted downfield when aryl substituents are replaced by alkyl substituents (Table 4). These resonances can, therefore, be used as a tool for the identification of isomers. The proton resonances of the methylene groups are usually sharp singlets, but

**Scheme 8**

tend to broaden or appear as poorly resolved triplets when the methylene groups are not chemically equivalent. The chemical shifts of different pairs of methylene group protons of **8m** were identified: the benzyl methylenes resonate at  $\delta$  3.87 and 5.20 while those between the nitrogen atoms resonate at  $\delta$  4.28 and 4.54. These assignments permit identification of the sharp triplet of triplets centred at  $\delta$  5.35 in the spectrum of **8m** as arising from the single proton of the cyclohexyl group attached to the amide

nitrogens. A similar assignment was made for the single proton at  $\delta$  5.35 in the spectrum of **8l**.

## Experimental

**Materials.**—Isothiocyanates **4a–f** were commercially available (Aldrich); 1,3,5-trisubstituted 1,3,5-triazinanes **1a–i** were prepared according to the amine paraformaldehyde method.<sup>2a,b</sup>

**Equipment.**—IR spectra were recorded on a Jasco DS-702G spectrophotometer and samples were examined as KBr pellets. Electron impact (70 eV) mass spectra were obtained from a Finnigan 1020 apparatus. In addition to the parent ion, only the most intense peaks are reported for the new derivatives. <sup>1</sup>H NMR and <sup>13</sup>C NMR data were obtained from a Bruker AC-F 200 spectrometer, using CDCl<sub>3</sub> as the solvent and tetramethylsilane as the internal standard.

**Crystallographic Measurements.**—**Crystal data:** **i-8f**<sup>1</sup> C<sub>23</sub>H<sub>23</sub>O<sub>2</sub>N<sub>3</sub>S, *M* = 405.52, monoclinic, space group *C*<sub>2</sub>, *a* = 13.830(3), *b* = 14.643(3), *c* = 24.753(4) Å,  $\beta$  = 120.85(4)°, *V* = 4303(2) Å<sup>3</sup>, *Z* = 8, *D*<sub>x</sub> = 1.25 g cm<sup>-3</sup>, *F*(000) = 1712,  $\mu$  = 1.35 cm<sup>-1</sup> for Mo-K $\alpha$  radiation,  $\lambda$  = 0.710 69 Å.

**8m** C<sub>17</sub>H<sub>31</sub>N<sub>3</sub>S, *M* = 309.52, monoclinic space group *P*<sub>2</sub><sub>1</sub>/*n*, *a* = 9.246(2), *b* = 11.100(3), *c* = 17.382(3) Å,  $\beta$  = 99.65(3)°, *V* = 1759(1) Å<sup>3</sup>, *Z* = 4, *D*<sub>x</sub> = 1.17 g cm<sup>-3</sup>, *F*(000) = 680,  $\mu$  = 1.46 cm<sup>-1</sup> for Mo-K $\alpha$  radiation,  $\lambda$  = 0.710 69 Å. Suitable crystals were obtained from EtOH. Unit cell intensity data were obtained by using a Philips PW1100 diffractometer. Reflections were measured at 294 K by the  $\theta/2\theta$  scan method with a scan speed of 1.80° min<sup>-1</sup>, scan width 1.20°. Background counts at both ends of the scan of 20 s. Because of the low absorption coefficients, no absorption corrections were applied to the intensity data. The structures were solved by direct methods with the SHELX-86 program.<sup>7</sup> The hydrogen atoms were introduced at the idealized positions (*d*<sub>C–H</sub> fixed 0.98 Å for compound **i-8f**<sup>1</sup> and 1.06 Å for compound **8m**; unique thermal factor *U* = 0.07 Å<sup>2</sup>). The non-hydrogen atoms were refined anisotropically. The final Fourier difference maps showed no significant peaks. In both structures, the shift/error ratio in the final refinement was less than 0.04. Final *R* = 0.0415 and *R*<sub>w</sub> = 0.0464 with *w* = [ $\sigma^2(F_o) + 0.000 728 F_o^2$ ]<sup>-1</sup> for **i-8f**<sup>1</sup>; *R* = 0.0367 and *R*<sub>w</sub> = 0.0371 with *w* = [ $\sigma^2(F_o) + 0.000 675 F_o^2$ ]<sup>-1</sup> for **8m**. Calculations were performed using SHELX-76.<sup>8</sup> Atomic scattering factors were taken from ref. 9. The ORTEP program was used for drawings.<sup>10</sup> Additional material available from the Cambridge Crystallographic Data Centre comprises the atomic coordinates, thermal parameters and remaining bond lengths and angles.\*

**Reactions Between 1 and 4: General Procedure.**—A mixture of **1** (4.0 mmol) and **4** (8.0 mmol) was kept at 130 °C for 24 h in a dry argon atmosphere. Any volatile material was then removed under reduced pressure. The solid residue was directly analysed by complete evaporation of a small amount into the ion source of a mass spectrometer. The composition of the vapour was continuously monitored by multiple selective ion recording (the four possible allobaric parent ions in the cases where *G* ≠ Ar or Alk). Full spectra were retrieved whenever suitable. By this procedure, it was found that all four allobaric products were present to different extents, although a precise determination of their relative concentrations was not attempted. Recrystallization from suitable solvents yielded pure products in many instances (**8a–i**, Table 1); no attempt was made to separate all the allo- and iso-bars present in the reaction mixtures. Data on the reactions and isolated compounds are collected in Tables 1 and 2.

A reaction between **1g** and **4a**, performed in xylene at 140 °C for 40 h, gave only extensive formation of 1,3,5,7-tetraphenyl-1,3,5,7-tetrazocane, but no compound **8**.

**Thermolysis of 8f.**—Compound **8f** was kept at 150 °C for 20 h. Direct inlet MS analysis allowed the identification of the following products: **i-8f**<sup>1</sup> or **s-8f**<sup>2</sup>, **s-8f**<sup>3</sup> or **s-8f**<sup>4</sup>, **s-8f**<sup>5</sup> and **s-8f**<sup>6</sup>.

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\* For details of the CCDC deposition scheme, see 'Instructions for Authors,' *J. Chem. Soc., Perkin Trans. 1*, 1994, issue 1.