N-Alkenyl Acylketene *S,N*-Acetals from 2,3-Dihydro-1,3-benzothiazoles and Carboxylic Anhydrides. X-Ray Molecular Structure of 2-(Butyrylmethylene)-*N*-(cyclohex-1-enyl)-2,3-dihydro-1,3-benzothiazole

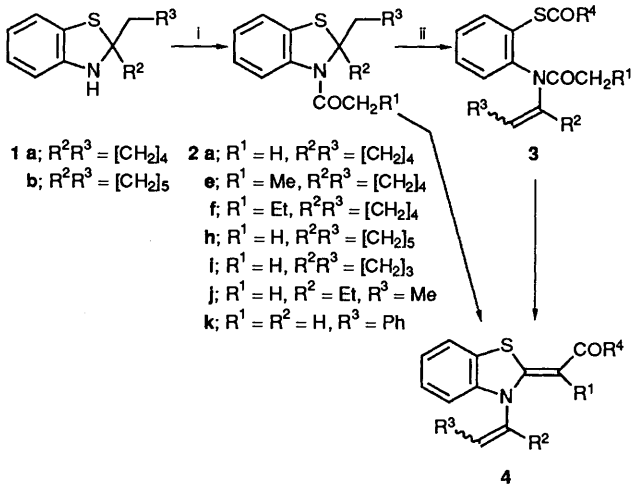
Giuseppe Trapani,*[a] Andrea Latrofa,[a] Antonia Reho,[a] Massimo Franco,[a] Gaetano Liso*[a] and Francesca Stasi[b]

[a] *Dipartimento Farmaco-chimico, Università di Bari, Via Amendola 173, 70126 Bari, Italy*
[b] *Dipartimento Geomineralogico, Università di Bari, Via Salvemini, 70124 Bari, Italy*

Depending on the reaction conditions or starting materials used, 2,3-dihydro-1,3-benzothiazoles **1** or their *N*-acyl derivatives **2** react with carboxylic anhydrides to yield the corresponding enamides **3** and/or *N*-alkenyl acylketene *S,N*-acetals **4**. The structural assignments of these last compounds are based on spectroscopic data. X-Ray evidence for title compound **4c** is also reported. A possible reaction pathway for formation of products **4** is suggested.

N-Alkyl acylketene *S,N*-acetals are well recognized, versatile intermediates in the synthesis of heterocyclic compounds [1] and cyanine dyes [2] as well as being known to possess interesting biological properties.[3] To date, *N*-alkenyl analogues have not been described in the literature. We now report that some of these last compounds have been obtained by reaction of 2,3-dihydro-1,3-benzothiazoles with carboxylic anhydrides.

A previous paper from this laboratory[4] reported that enamides **3** (Scheme 1) are obtained in good yield by treatment of 2,3-dihydro-1,3-benzothiazoles **1** or their *N*-acyl derivatives **2** with acetic, trifluoroacetic (TFAA), or propionic anhydrides. Further work, described herein, showed that, depending on the reaction conditions or starting materials used, the enamide **3** and/or *N*-alkenyl acylketene *S,N*-acetal **4** are obtained. Thus, on heating, at reflux, a solution of 3-acetyl-2,3-dihydro-1,3-benzothiazole-2-spiro-1′-cyclohexane **2a** in propionic anhydride for 4 h, one hour longer than the times previously used[4] for the preparation of compound **3b**, the corresponding compound **4** together with its overacylated product **5** and compound **3b** were obtained in 35, 10 and 38% yield, respectively. On the other hand, by replacing the propionic anhydride with butyric anhydride and by heating the resulting reaction mixture at reflux for 2 h, compound **4c** was obtained in very high yield (95%). The ^{1}H NMR spectra of the compounds **4b** and **4c** are characterized by two 1-proton signals, namely a singlet at δ 5.80 and a multiplet at δ 5.8–6.0. In their ^{13}C NMR spectra a signal attributable to a quaternary carbon occurred at low field (δ_C 194.8 for **4b** and 194.2 for **4c**). These features and, in particular, the presence, in their mass spectra, of a base peak at *m/z* 228, indicative of the loss of an R^4CO moiety from the corresponding molecular ions, led us to assign the acylketene *S,N*-acetal structure **4** (Table 1). X-Ray analysis confirmed the structure of compound **4c** and revealed the (*Z*)-configuration at the carbon–carbon double bond of enamino ketone moiety. Details of this analysis are given in the Experimental section. Fig. 1 depicts a general view of the molecular structure of compound **4c**. The acylketene *S,N*-acetals (**4a**, **d–j**, **n**) were similarly obtained in moderate to good yield starting from the required carboxylic anhydride and *N*-acyl-2,3-dihydrobenzothiazoles **2** (Table 1). By using aliphatic carboxylic anhydrides the reaction proceeded in satisfactory yield with spiro- rather than non-spiro-*N*-acyl-2,3-dihydro-



Scheme 1 *Reagents:* i, $(R^1CH_2CO)_2O$; ii, $(R^4CO)_2O$.[a] For compounds **3** and **4**:

a; R^1 = H, R^2R^3 = $[CH_2]_4$, R^4 = Me
b; R^1 = H, R^2R^3 = $[CH_2]_4$, R^4 = Et
c; R^1 = H, R^2R^3 = $[CH_2]_4$, R^4 = Pr
d; R^1 = H, R^2R^3 = $[CH_2]_4$, R^4 = Ph
e; R^1 = Me, R^2R^3 = $[CH_2]_4$, R^4 = Pr
f; R^1 = R^4 = Et, R^2R^3 = $[CH_2]_4$
g; R^1 = Et, R^2R^3 = $[CH_2]_4$, R^4 = Pr
h; R^1 = H, R^2R^3 = $[CH_2]_5$, R^4 = Pr
i; R^1 = H, R^2R^3 = $[CH_2]_3$, R^4 = Pr
j; R^1 = H, R^2 = Et, R^3 = R^4 = Me
k; R^1 = R^2 = H, R^3 = Ph, R^4 = Me
l; R^1 = Me, R^2R^3 = $[CH_2]_4$, R^4 = Et
m; R^1 = H, R^2R^3 = $[CH_2]_5$, R^4 = Me
n; R^1 = H, R^2R^3 = $[CH_2]_5$, R^4 = Et

[a] R^1 and R^4 where appropriate.

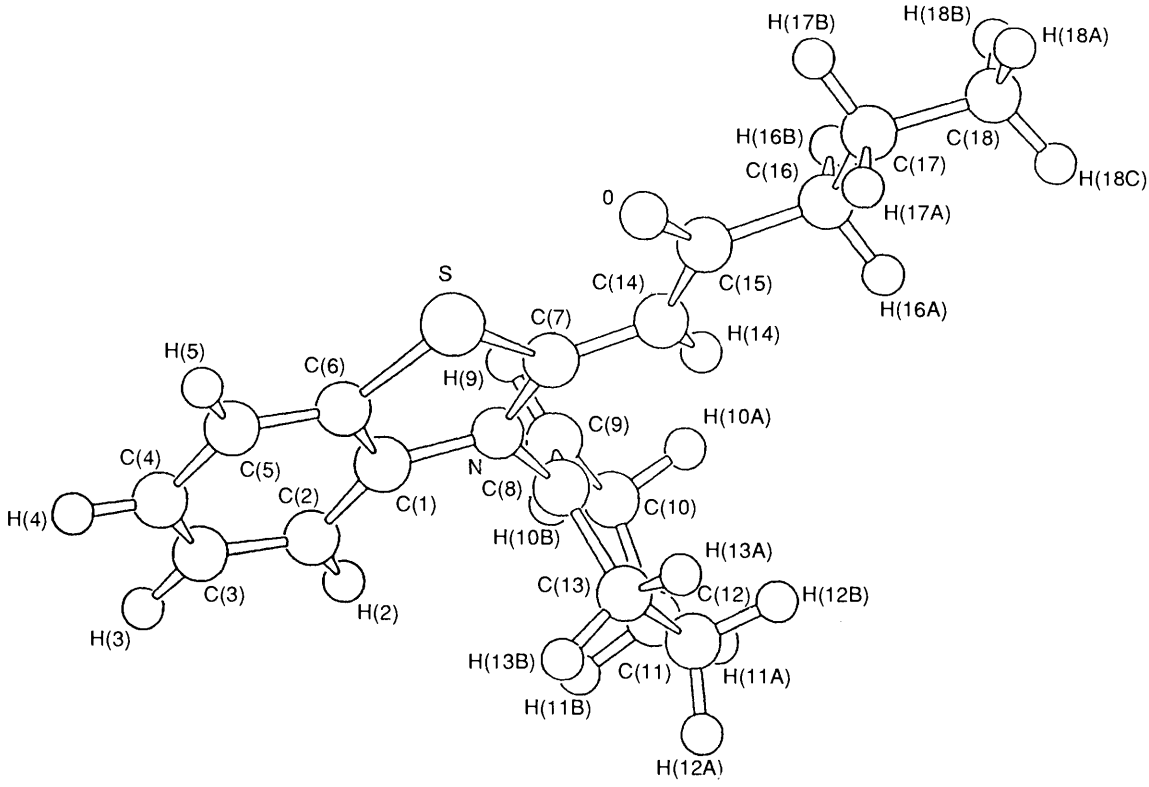


Fig. 1 A SCHAKAL plot of compound **4c** with atom labelling

Table 1 Reaction of 3-acyl-2,3-dihydro-1,3-benzothiazoles **2** and other products with carboxylic acid anhydrides

		Reaction conditions	Product distribution (Yield %)[a]		
Substrate	Acid anhydride $[(R^3CO)_2O]$	Substrate/Reflux time (mmol) (*t*/h)	**3**	**4**	**2** or **5**
2a	$(Ac)_2O$	40/[b]		**4a** (95)	
2a	$(EtCO)_2O$	35/4	**3b** (38)	**4b** (35)	**5** (10)
3b	$(EtCO)_2O$	1.5/15		**4b** (15)	**5** (30)
4b	$(EtCO)_2O$	3.5/4			**5** (55)
2a	$(PrCO)_2O$	40/2		**4c** (95)	
2a	$(PhCO)_2O$	4/[c]		**4d** (15)	
2e	$(PrCO)_2O$	23/2	**3e** (33)	**4e** (50)	
3e	$(PrCO)_2O$	1.5/4		**4e** (40)	
2f	$(EtCO)_2O$	36/5	**3f** (15)	**4f** (25)	
2f	$(PrCO)_2O$	25/2		**4g** (70)	
2h	$(PrCO)_2O$	45/2.5		**4h** (65)	
2i	$(PrCO)_2O$	20/2		**4i** (25)	
2j	$(Ac)_2O$	25/[d]		(*E*,*Z*)-**4j** (13)	
				(*Z*,*Z*)-**4j** (15)	
2k	$(Ac)_2O$	33/[d]	(*E*)-**3k**[e] (25)		
1a	$(EtCO)_2O$	45/1	**31** (35)[f]	**41** (13)[f]	**2e** (52)[f]
1a	$(EtCO)_2O$	45/2	**31** (45)[f]	**41** (20)[f]	**2e** (30)[f]
1a	$(EtCO)_2O$	45/3	**31** (12)	**41** (60)	**2e** (7)
1h	$(Ac)_2O$	53/[b]		**4m** (75)	
2h	$(EtCO)_2O$	23/5		**4n** (45)	

[a] Isolated yield after column chromatography. [b] Reagents heated at 140 °C for 8 h in a sealed tube. [c] Reagents heated at 170 °C for 24 h. [d] Reagents heated at 140 °C for 100 h in a sealed tube. [e] The configuration of compound **3k** was established by ^1H NMR spectroscopy. [f] Yield estimated by GC-MS analysis.

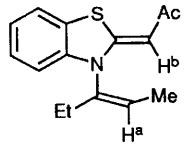
benzothiazole substrates **2** (compare the yields of entries for **2a**, **2e**, **2f**, **2h** with that of **2j**). Since the reaction of benzoic anhydride with the spiro compound **2a** afforded the corresponding compound **4** in low yield, further reactions of benzoic anhydrides with other compounds **2** were not performed.[1] ^{13}C NMR chemical shifts and the multiplicities displayed by selected carbons in the proton-coupled spectra of compounds **4a–d**, **f**, **l** are reported in Table 2.

The compounds **4a**, **b**, **h–j**, **m**, **n** probably possess (*Z*)-geometry at the double bond of the enamino ketone moiety. Such structural assignments followed from the fact that the ^1H NMR spectra of these compounds displayed at the same chemical shift (δ 5.80) the one-proton signal due to the olefinic proton of the enamino ketone group, as found for compound **4c** whose (*Z*)-geometry was established by X-ray analysis (see later). Furthermore, starting from the non-spiro compound **2j** two isomers of the corresponding compound **4** were obtained and were separated by column chromatography.

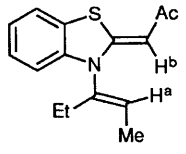
Table 2 ^{13}C NMR chemical shifts for solutions in $CDCl_3$ and recorded as δ-values from Me_4Si as internal standard. The multiplicities observed in the proton-coupled spectra are in parentheses

	Compound					
	4a	**4b**	**4c**	**4d**	**4f**	**4l**
Quaternary C	191.1	194.8	194.2	184.5	195.8	195.9
	159.7	159.4	159.4	161.8	155.7	155.6
	139.4	139.3	139.4	139.6	140.6	140.7
	134.4	134.2	134.3	139.5	136.1	137.1
	126.7	126.6	126.7	134.5[a]	127.8	127.6
					105.3	98.1 (q)
CH	131.3	131.1	131.2	131.7	129.1	130.3
	126.7	126.0	126.0	130.7[a]	125.5	125.6
	122.4	122.2	122.3	128.2[a]	122.4	122.4
	122.0	121.8	121.9	127.0	121.3	121.4
	110.3 (dd)	110.1 (dd)	110.2	126.4	110.3	110.4
	90.9 (dq)	89.7 (dt)	90.3	122.9		
				122.2		
				110.6 (dd)		
				87.9 (d)		
CH_2	25.2	34.6	43.8	25.5	30.4	31.7
	24.8	25.0	25.0	24.9	27.0	27.9
	22.5	24.6	24.7	22.6	25.0	24.7
	21.4	22.4	22.4	21.5	22.0	22.1
		21.2	21.3		21.2	21.3
			19.1		19.3	
Me	28.8	9.6	13.9		15.2	13.7
					9.3	9.0

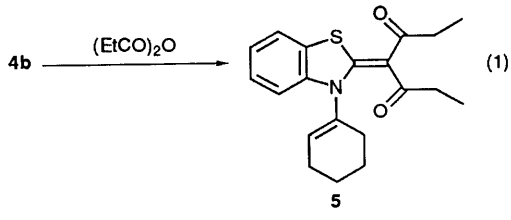
[a] Signal due to two carbon atoms.



(*Z*, *Z*) - **4j**



(*E*, *Z*) - **4j**



(1)

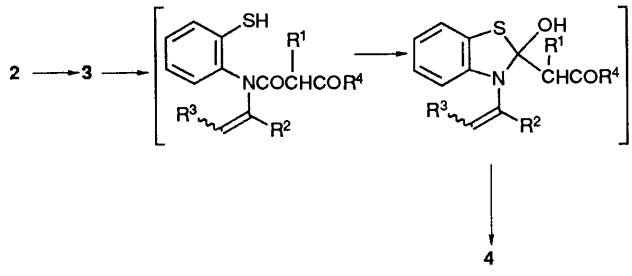
5

These compounds are *E* and *Z* stereoisomers at the double bond of the enamine moiety. The structural assignments followed from their ^1H NMR spectra. In particular, the spectrum of the (*Z*,*Z*)-isomer shows a doublet at δ 1.94 and a quartet at δ 5.71 for the protons of the methyl group linked to the β-enamine carbon (Me) (see above) and the olefinic β-enamine proton (H^a), respectively. In contrast, the spectrum of the (*E*,*Z*)-isomer is characterized by a doublet of triplets at higher field (δ 1.46) and a quartet of triplets at lower field (δ 5.95).

Such configurational assignments are consistent with the deshielding effects of the benzene ring and of the carbon–carbon double bond of the enamino ketone moiety on the protons of the methyl group in the (*Z*,*Z*)-isomer and on the olefinic proton (H^a) in the (*E*,*Z*)-isomer. Furthermore, conclusive evidence was obtained by means of NOE experiments. Thus, in the (*Z*,*Z*)-isomer, irradiation of the methyl group at δ 1.94 showed a significant NOE at H^b (25% enhancement) while in the (*E*,*Z*)-isomer no effect was observed upon irradiation of H^a or Me. The NOE enhancement that we observed is the one expected for the assigned structure (*Z*,*Z*)-**4j**.

Chemical evidence for the enamino ketone character occurring in compound **4b** was obtained by reflux of its solution in propionic anhydride. Such treatment led to the formation of the overacylated product **5** [equation (1)].

The acylketene *S*,*N*-acetals **4b**, **e** have also been obtained by reflux of a solution of the corresponding enamide **3** in the appropriate anhydride. Hence, it appears that the conversion **2** → **4** might involve the enamide **3** as an intermediate. A plausible reaction pathway for formation of product **4**, involving an S → C acyl shift in the enamide intermediate **3**, is outlined in Scheme 2.



Scheme 2

The foregoing results, taken together with those previously reported,[4] suggest that by carrying out the reaction between a substrate **1** and a carboxylic acid anhydride for a very short reflux time or at lower temperatures produces reaction mixtures containing a preponderance of the corresponding *N*-acylated product **2**. Formation of compounds **3** and **4** required a longer reaction time at higher temperatures. As a typical example, the progress of the reaction of spiro compound **1a** with propionic anhydride was monitored by GC-MS analysis and the results are collected in Table 1. In conclusion, it has been shown that

2,3-dihydrobenzothiazoles of type **1** and **2** are starting materials in the synthesis of *N*-alkenyl acylketene *S,N*-acetals **4**.

Experimental

M.p.s were measured on a Büchi apparatus and are uncorrected. IR spectra were recorded on a Perkin-Elmer 257 infrared spectrophotometer for Nujol mulls for solids or KBr disks or as liquid films. NMR spectra (internal standard Me_4Si) were taken in $CDCl_3$ on Varian EM-390 (^1H) and Varian XL-200 (NOE for **4j** and ^{13}C) spectrometers. *J*-Values are given in Hz. Mass spectra were obtained on a Perkin-Elmer 270 low-resolution spectrometer. Elemental analyses were performed on Carlo Erba model 1106 analyser. GC-MS analysis was carried out on a Hewlett-Packard 5995 C-CG/MS instrument. Column chromatography on silica gel (Merck 70–325 mesh) were carried out with light petroleum (b.p. range 40–70 °C)–ethyl acetate (8:2 v/v) as eluent. Commercial-grade carboxylic anhydrides were used without further purification. The 2,3-dihydro-1,3-benzothiazoles **1a**[6] and **1h**,[6] 3-acyl-2,3-dihydro-1,3-benzothiazoles **2a**,[7] **2h**,[7] **2i**,[7] **2j**,[8] **2k**[8] and the enamide **3b**[4] were prepared by the reported procedures.

Preparation of 3-*Acyl*-2,3-*dihydro*-1,3-*benzothiazoles* **2e** *and* **2f**.—*General procedure.* A mixture of the 2,3-dihydro-1,3-benzothiazole **1a** (40 mmol) and the appropriate carboxylic anhydride (100 cm^3) was refluxed for 15 min. The solvent was then evaporated off under reduced pressure and the residue was purified by column chromatography. The following compounds were thus prepared.

N-*Propionyl*-2,3-*dihydro*-1,3-*benzothiazole*-2-*spiro*-1′-*cyclohexane* **2e** (93%), m.p. 93–94 °C (from light petroleum) (Found: C, 70.1; H, 7.7; N, 5.4. $C_{15}H_{19}NOS$ requires C, 68.94; H, 7.33; N, 5.36%); ν_{max}/cm^{-1} 1660 (C=O); δ_H 1.23 (3 H, t, Me), 1.1–3.0 (10 H, m, CH_2), 2.63 (2 H, q, CH_2) and 6.8–7.2 (4 H, m, ArH); *m/z* 261 (M^+, 22), 205 (36) and 162 (100%).

N-*Butyryl*-2,3-*dihydro*-1,3-*benzothiazole*-2-*spiro*-1′-*cyclohexane* **2f** (91%), m.p. 99–100 °C (from light petroleum) (Found: C, 70.2; H, 8.0; N, 5.1. $C_{16}H_{21}NOS$ requires C, 69.79; H, 7.69; N, 5.09%); ν_{max}/cm^{-1} 1670 (C=O); δ_H 0.99 (3 H, t, Me), 1.0–3.0 (12 H, m, CH_2), 2.60 (2 H, t, CH_2), 6.8–7.2 (4 H, m, ArH); *m/z* 275 (M^+, 17), 205 (41) and 62 (100%).

2-(*Butyrylmethylene*)-N-(*cyclohex*-1-*enyl*)-2,3-*dihydro*-1,3-*benzothiazole* **4c**.—*Typical procedure.* A mixture of *N*-acetyl-2,3-dihydro-1,3-benzothiazole-2-spiro-1′-cyclohexane **2a** (9.88 g, 40 mmol) in butyric anhydride (100 cm^3) was refluxed for 2 h. The solvent was evaporated off under reduced pressure and the residue was purified by column chromatography to give *compound* **4c** (11.4 g, 95%), m.p. 107–109 °C (from light petroleum) (Found: C, 72.2; H, 7.1; N, 4.7. $C_{18}H_{21}NOS$ requires C, 72.21; H, 7.07; N, 4.68%); ν_{max}/cm^{-1} 1610 (C=O); δ_H 0.95 (3 H, t, Me), 1.5–2.5 (10 H, m, CH_2), 2.35 (2 H, t, CH_2), 5.80 (1 H, s, =CH), 5.8–6.0 (1 H, m, =C*H*CH_2) and 6.8–7.5 (4 H, m, ArH); *m/z* 299 (M^+, 19) and 228 ($M^+ - CH_3[CH_2]_2CO$, 100%).

Starting material and reaction conditions used in all following cases are reported in Table 1.

2-(*Acetylmethylene*)-N-(*cyclohex*-1-*enyl*)-2,3-*dihydro*-1,3-*benzothiazole* **4a**. M.p. 122–123 °C (from light petroleum–MeOH) (Found: C, 71.2; H, 6.3; N, 5.1. $C_{16}H_{17}NOS$ requires C, 70.83; H, 6.32; N, 5.16%); ν_{max}/cm^{-1} 1610 (C=O); δ_H 1.6–2.4 (8 H, m, CH_2), 2.20 (3 H, s, Me), 5.80 (1 H, s, =CH), 5.8–6.0 (1 H, m, =C*H*CH_2) and 6.8–7.5 (4 H, m, ArH); *m/z* 271 (M^+, 20) and 228 ($M^+ - CH_3CO$, 100%).

N-(*Cyclohex*-1-*enyl*)-2-(*propionylmethylene*)-2,3-*dihydro*-1,3-*benzothiazole* **4b**. M.p. 103–104 °C (from propan-2-ol) (Found: C, 72.0; H, 7.0; N, 4.85. $C_{17}H_{19}NOS$ requires C, 71.56; H, 6.71; N, 4.91%); ν_{max}/cm^{-1} 1618 (C=O); δ_H 1.15 (3 H, t, Me), 1.6–2.4 (8 H, m, CH_2), 2.43 (2 H, q, CH_2), 5.80 (1 H, s, =CH), 5.8–6.0 (1 H, m, =C*H*CH_2) and 6.8–7.5 (4 H, m, ArH); *m/z* 285 (M^+, 18) and 228 ($M^+ - CH_3CH_2CO$, 100%).

Table 3 Non-hydrogen fractional atomic co-ordinates ($\times 10^4$) with esds in parentheses

	x	*y*	*z*
S	4 463(2)	4 194(1)	2 722(2)
O	7 565(5)	5 454(3)	3 550(5)
N	3 450(6)	2 628(4)	−231(5)
C(1)	2 062(8)	2 363(5)	151(7)
C(2)	527(8)	1 464(6)	−833(8)
C(3)	−677(8)	1 383(6)	−228(9)
C(4)	−361(9)	2 163(7)	1 353(9)
C(5)	1 191(9)	3 051(6)	2 345(8)
C(6)	2 411(8)	3 166(6)	1 741(7)
C(7)	4 861(8)	3 569(5)	979(7)
C(8)	3 440(7)	1 861(5)	−1 739(7)
C(9)	2 956(7)	2 051(5)	−3 389(7)
C(10)	2 807(8)	1 220(5)	−5 003(7)
C(11)	2 978(10)	138(6)	−4 555(8)
C(12)	3 998(12)	202(7)	−2 838(9)
C(13)	3 937(8)	915(5)	−1 247(7)
C(14)	6 339(8)	3 970(5)	869(7)
C(15)	7 700(8)	4 961(5)	2 223(7)
C(16)	9 303(8)	5 384(5)	2 015(8)
C(17)	10 717(8)	6 346(6)	3 636(9)
C(18)	12 309(9)	6 716(6)	3 430(10)

N-(*Cyclohex*-1-*enyl*)-2-(*dipropionylmethylene*)-2,3-*dihydro*-1,3-*benzothiazole* **5**. M.p. 139–141 °C (from propan-2-ol) (Found: C, 70.1; H, 6.8; N, 3.9. $C_{20}H_{23}NO_2S$ requires C, 70.36; H, 6.79; N, 4.10%); ν_{max}/cm^{-1} 1685 (C=O); δ_H 1.10 (6 H, t, Me), 1.5–2.0 (4 H, m, CH_2), 2.1–2.9 (8 H, m, CH_2), 5.9–6.1 (1 H, m, =C*H*CH_2) and 7.0–7.6 (4 H, m, ArH); *m/z* 341 (M^+, 10), 284 ($M^+ - CH_3CH_2CO$, 88) and 228 (100%).

2-(*Benzoylmethylene*)-N-(*cyclohex*-1-*enyl*)-2,3-*dihydro*-1,3-*benzothiazole* **4d**. M.p. 46–48 °C (from light petroleum–MeOH) (Found: C, 75.3; H, 5.65; N, 4.3. $C_{21}H_{19}NOS$ requires C, 75.65; H, 5.74; N, 4.20%); ν_{max}/cm^{-1} 1600 (C=O); δ_H 1.5–2.5 (8 H, m, CH_2), 5.8–6.0 (1 H, m, =C*H*CH_2), 6.53 (1 H, s, =CH), 6.9–7.5 (7 H, m, ArH) and 7.8–8.1 (2 H, m, ArH); *m/z* 333 (M^+, 23) and 228 ($M^+ - PhCO$, 100%).

2-(1-*Butyrylethylidene*)-N-(*cyclohex*-1-*enyl*)-2,3-*dihydro*-1,3-*benzothiazole* **4e**. M.p. 167–169 °C (from light petroleum) (Found: C, 73.1; H, 7.6; N, 4.4. $C_{19}H_{23}NOS$ requires C, 72.82; H, 7.40; N, 4.47%); ν_{max}/cm^{-1} 1600 (C=O); δ_H 0.97 (3 H, t, Me), 1.6–2.7 (12 H, m, CH_2), 2.27 (3 H, s, Me), 5.9–6.1 (1 H, m, =CH), 6.9–7.5 (4 H, m, ArH); *m/z* 313 (M^+, 8) and 242 ($M^+ - CH_3[CH_2]_2CO$, 100%).

S-2-[N-(*Cyclohex*-1-*enyl*)*propionamido*]*phenyl Thiobutyrate* **3e**. *Oil* (Found: C, 69.0; H, 7.7; N, 4.2. $C_{19}H_{25}NO_2S$ requires C, 68.86; H, 7.60; N, 4.23%); ν_{max}/cm^{-1} 1705 (C=O) and 1605 (C=O); δ_H 0.99 (6 H, t, Me), 1.4–2.4 (12 H, m, CH_2), 2.60 (2 H, t, CH_2), 5.2–6.0 (1 H, br s, =CH) and 7.1–7.6 (4 H, m, ArH); *m/z* 331 (M^+, 3) and 204 (100%).

N-(*Cyclohex*-1-*enyl*)-2-(1-*propionylpropylidene*)-2,3-*dihydro*-1,3-*benzothiazole* **4f**. M.p. 100–103 °C (Found: C, 73.0; H, 7.4; N, 4.5. $C_{19}H_{23}NOS$ requires C, 72.82; H, 7.40; N, 4.47%); ν_{max}/cm^{-1} 1605 (C=O); δ_H 1.00 (3 H, t, Me), 1.20 (3 H, t, Me), 1.6–2.9 (12 H, m, CH_2), 5.9–6.1 (1 H, m, =CH) and 6.9–7.5 (4 H, m, ArH); *m/z* 313 (M^+, 11) and 256 ($M^+ - CH_3CH_2CO$, 100%).

S-2-[N-(*Cyclohex*-1-*enyl*)*butyramido*]*phenyl Thiopropionate* **3f**. *Oil* (Found: C, 69.0; H, 7.5; N, 4.2. $C_{19}H_{25}NO_2S$ requires C, 68.86; H, 7.60; N, 4.23%); ν_{max}/cm^{-1} 1710 (C=O) and 1670 (C=O); δ_H 0.6–1.1 (3 H, br s, Me), 1.20 (3 H, t, Me), 1.3–2.5 (12 H, m, CH_2), 2.63 (2 H, q, CH_2), 5.6 (1 H, br s, =CH) and 7.1–7.6 (4 H, m, ArH); *m/z* 331 (M^+, 4) and 204 (100%).

2-(1-*Butyrylpropylidene*)-N-(*cyclohex*-1-*enyl*)-2,3-*dihydro*-

Table 4 Bond lengths (Å) and angles (°) and relevant torsion angles (°), with esds in parentheses

S–C(6)	1.752(6)	C(6)–S–C(7)	91.6(3)
S–C(7)	1.758(5)	C(1)–N–C(7)	116.8(5)
O–C(15)	1.249(6)	C(1)–N–C(8)	121.2(5)
N–C(1)	1.398(7)	C(7)–N–C(8)	121.7(5)
N–C(7)	1.377(7)	N–C(1)–C(2)	127.6(9)
N–C(8)	1.466(8)	N–C(1)–C(6)	110.6(5)
C(1)–C(2)	1.378(7)	C(2)–C(1)–C(6)	121.8(6)
C(1)–C(6)	1.405(7)	C(1)–C(2)–C(3)	117.8(8)
C(2)–C(3)	1.373(8)	C(2)–C(3)–C(4)	121.6(6)
C(3)–C(4)	1.395(8)	C(3)–C(4)–C(5)	120.1(6)
C(4)–C(5)	1.383(8)	C(4)–C(5)–C(6)	119.4(6)
C(5)–C(6)	1.380(7)	S–C(6)–C(1)	111.7(5)
C(7)–C(14)	1.360(7)	S–C(6)–C(5)	128.9(6)
C(8)–C(9)	1.328(6)	C(1)–C(6)–C(5)	119.4(6)
C(8)–C(13)	1.464(7)	S–C(7)–N	109.2(5)
C(9)–C(10)	1.513(7)	S–C(7)–C(14)	124.5(4)
C(10)–C(11)	1.482(8)	N–C(7)–C(14)	126.3(5)
C(11)–C(12)	1.369(8)	N–C(8)–C(9)	119.0(4)
C(12)–C(13)	1.518(7)	N–C(8)–C(13)	114.6(5)
C(14)–C(15)	1.425(7)	C(9)–C(8)–C(13)	126.3(5)
C(15)–C(16)	1.509(7)	C(8)–C(9)–C(10)	120.4(5)
C(16)–C(17)	1.517(9)	C(9)–C(10)–C(11)	112.3(5)
C(17)–C(18)	1.499(8)	C(10)–C(11)–C(12)	119.6(6)
		C(11)–C(12)–C(13)	117.3(6)
S–C(6)–C(1)–N	−1.4(11)	C(8)–C(13)–C(12)	111.9(5)
S–C(6)–C(1)–C(2)	179.0(8)	C(7)–C(14)–C(15)	120.3(5)
S–C(6)–C(5)–C(4)	−179.7(8)	O–C(15)–C(14)	120.6(6)
S–C(7)–N–C(1)	−5(11)	O–C(15)–C(16)	121.3(5)
N–C(1)–C(2)–C(3)	−178.5(9)	C(14)–C(15)–C(16)	118.1(5)
N–C(8)–C(13–C(12)	−176.6(8)	C(15)–C(16)–C(17)	113.8(5)
C(1)–N–C(7)–C(14)	179.7(9)	C(16)–C(17)–C(18)	112.7(5)

1,3-*benzothiazole* **4g**. M.p. 114–116 °C (from light petroleum–ethyl acetate) (Found: C, 73.4; H, 7.8; N, 4.2. $C_{20}H_{25}NOS$ requires C, 73.36; H, 7.70; N, 4.21%); ν_{max}/cm^{-1} 1670 (C=O) and 1605 (C=O); δ_H 0.97 (3 H, t, Me), 0.99 (3 H, t, Me), 1.6–2.9 (14 H, m, CH_2), 5.9–6.1 (1 H, m, =CH) and 6.9–7.5 (4 H, m, ArH); *m*/*z* 327 (M^+, 10) and 256 ($M^+ - CH_3[CH_2]_2CO$, 100%).

2-(*Butyrylmethylene*)-N-(*cyclohept*-1-*enyl*)-2,3-*dihydro*-1,3-*benzothiazole* **4h**. M.p. 73–74 °C (from light petroleum) (Found: C, 73.0; H, 7.65; N, 4.45. $C_{19}H_{23}NOS$ requires C, 72.82; H, 7.40; N, 4.47%); ν_{max}/cm^{-1} 1615 (C=O); δ_H 0.95 (3 H, t, Me), 1.5–2.0 (8 H, m, CH_2), 2.2–2.5 (6 H, m, CH_2), 5.80 (1 H, s, =CH), 6.10 (1 H, t, =C*H*CH_2) and 6.9–7.6 (4 H, m, ArH); *m*/*z* 313 (M^+, 19) and 242 ($M^+ - CH_3[CH_2]_2CO$, 100%).

2-(*Butyrylmethylene*)-N-(*cyclopent*-1-*enyl*)-2,3-*dihydro*-1,3-*benzothiazole* **4i**. M.p. 142–143 °C (from light petroleum–ethyl acetate) (Found: C, 71.45; H, 7.0; N, 4.85. $C_{17}H_{19}NOS$ requires C, 71.56; H, 6.71; N, 4.91%); ν_{max}/cm^{-1} 1620 (C=O); δ_H 0.95 (3 H, t, Me), 1.5–2.0 (4 H, m, CH_2), 2.1–2.9 (6 H, m, CH_2), 5.80 (1 H, s, =CH), 6.0–6.2 (1 H, m, =C*H*CH_2) and 6.9–7.7 (4 H, m, ArH); *m*/*z* 285 (M^+, 25) and 214 ($M^+ - CH_3[CH_2]_2CO$, 100%).

2-(*Acetylmethylene*)-N-(*pent*-2-*en*-3-*yl*)-2,3-*dihydro*-1,3-*benzothiazole* **4j**. (Z,Z)-*Isomer:* m.p. 89–91 °C (Found: C, 69.3; H, 6.9; N, 5.8. $C_{15}H_{17}NOS$ requires C, 69.48; H, 6.61; N, 5.40%); ν_{max}/cm^{-1} 1610 (C=O); δ_H(200 MHz) 0.94 (3 H, t, Me), 1.94 (3 H, d, Me), 2.21 (3 H, s, Me), 2.2–2.7 (2 H, m, CH_2), 5.71 (1 H, q, =C*H*Me), 5.80 (1 H, s, =CH) and 6.7–7.5 (4 H, m, ArH); *m*/*z* 259 (M^+, 25) and 216 ($M^+ - COCH_3$, 100%).

(E,Z)-*Isomer:* m.p. 124–125 °C (Found: C, 69.3; H, 6.8; N, 5.1%); ν_{max}/cm^{-1} 1610 (C=O); δ_H (200 MHz) 1.10 (3 H, t, Me), 1.46 (3 H, dt, *J* 6 and 1, Me), 2.20 (3 H, s, Me), 2.0–2.4 (2 H, m, CH_2), 5.80 (1 H, s, =CH), 5.95 (1 H, qt, *J* 6 and 1, C*H*Me) and 6.8–7.6 (4 H, m, ArH); *m*/*z* 259 (M^+, 27) and 216 ($M^+ - COCH_3$, 100%).

S-2-(N-*Styrylacetamido*)*phenyl Thioacetate* **3k**. *Oil* (Found: C, 69.65; H, 5.5; N, 4.6. $C_{18}H_{17}NO_2S$ requires C, 69.44; H, 5.50; N, 4.50%); ν_{max}/cm^{-1} 1710 (C=O) and 1685 (C=O); δ_H 1.80 (3 H, s, Me), 2.23 (3 H, s, Me), 5.13 (1 H, d, *J* 15, =C*H*Ph), 7.1–7.8 (9 H, m, ArH) and 8.18 (1 H, d, *J* 15, =CHN); *m*/*z* 311 (M^+, 39) and 136 (100%).

N-(*Cyclohex*-1-*enyl*)-2-(1-*propionylethylidene*)-2,3-*dihydro*-1,3-*benzothiazole* **4l**. M.p. 197–198 °C (from light petroleum) (Found: C, 72.1; H, 7.2; N, 4.7. $C_{18}H_{21}NOS$ requires C, 72.21; H, 7.07; N, 4.68%); ν_{max}/cm^{-1} 1610 (C=O); δ_H 1.15 (3 H, t, Me), 1.6–2.4 (8 H, m, CH_2), 2.25 (3 H, s, Me), 2.57 (2 H, q, CH_2), 5.9–6.1 (1 H, m, =CH) and 6.9–7.5 (4 H, m, ArH); *m*/*z* 299 (M^+, 10) and 242 ($M^+ - CH_3CH_2CO$, 100%).

S-2-[N-(*Cyclohex*-1-*enyl*)*propionamido*]*phenyl Thiopropionate* **3l**. M.p. 54 °C (from propan-2-ol) (Found: C, 69.2; H, 7.45; N, 4.4. $C_{18}H_{23}NO_2S$ requires C, 68.87; H, 7.31; N, 4.41%); ν_{max}/cm^{-1} 1715 (C=O) and 1680 (C=O); δ_H 1.20 (6 H, t, Me), 1.6–2.5 (10 H, m, CH_2), 2.60 (2 H, q, CH_2), 5.5 (1 H, br s, =CH) and 7.1–7.6 (4 H, m, ArH); *m*/*z* 317 (M^+, 3) and 204 (100%).

2-(*Acetylmethylene*)-N-*cyclohept*-1-*enyl*)-2,3-*dihydro*-1,3-*benzothiazole* **4m**. M.p. 125–126 °C (Found: C, 71.7; H, 6.8; N, 4.7. $C_{17}H_{19}NOS$ requires C, 71.56; H, 6.71; N, 4.91%); ν_{max}/cm^{-1} 1610 (C=O); δ_H 1.6–2.0 (6 H, m, CH_2), 2.20 (3 H, s, Me), 2.2–2.5 (4 H, m, CH_2), 5.80 (1 H, s, =CH), 6.10 (1 H, t, =C*H*CH_2) and 6.9–7.6 (4 H, m, ArH); *m*/*z* 285 (M^+, 17) and 242 ($M^+ - CH_3CO$, 100%).

N-(*Cyclohept*-1-*enyl*)-2-(*propionylmethylene*)-2,3-*dihydro*-1,3-*benzothiazole* **4n**. M.p. 96–98 °C (from light petroleum) (Found: C, 72.6; H, 7.5; N, 4.7. $C_{18}H_{21}NOS$ requires C, 72.21; H, 7.07; N, 4.68%); ν_{max}/cm^{-1} 1615 (C=O); δ_H 1.18 (3 H, t, Me), 1.6–2.0 (6 H, m, CH_2), 2.2–2.6 (6 H, m, CH_2), 5.80 (1 H, s, =CH), 6.10 (1 H, t, =C*H*CH_2) and 6.9–7.5 (4 H, m, ArH); *m*/*z* 299 (M^+, 18) and 242 ($M^+ - CH_3CH_2CO$, 100%).

X-Ray Structure Determination of Compound **4c**.—

Crystal data. $C_{18}H_{21}NOS$, M_r = 299.43, triclinic, space group $P\bar{1}$, *a* = 9.562(1), *b* = 12.487(2), *c* = 8.070(1) Å, α = 95.77(1), β = 110.03(1), γ = 110.79(1)°, *V* = 818.83 Å^3, *Z* = 2, D_x = 1.214 g cm^{-3}, λ(Mo-Kα) = 0.710 69 Å, μ = 1.57 cm^{-1},

T = 298 K. The Niggli-reduced cell had parameters a = 8.070, b = 9.562, c = 12.434 Å, α = 100.986, β = 106.539, γ = 110.030°; transformation matrix 001/100/111.

A yellow, transparent crystal with approximate dimensions 0.8 × 0.3 × 0.1 mm was used in the measurement of cell parameters and 3820 reflections (2362 unique) were recorded by a Nonius CAD-4 diffractometer, ω-2θ scan mode and a variable scan speed of 1.0–4.0 ° min^{-1}, using graphite-monochromated Mo-Kα radiation in the θ range $2 \leqslant \theta \leqslant 25°$. Lorentz and polarization correction; absorption ignored; no correction for secondary extinction.

Crystal-structure solution. The structure was solved by direct methods using the SIR88 package.[9] The structure was refined by full-matrix least-squares procedure by SHELX76[10] using 1207 independent reflections with $I > 3\sigma(I)$. Atomic scattering factors and anomalous dispersion factors were taken from SHELX76.[10] Reflections 100, −100, −120, 230, 0–11, −463, −4–13, affected by non-systematic error, were omitted in the last cycles. After anisotropic least-squares refinement for C, S, N and O atoms, the difference electron-density synthesis showed the H-atom positions. H-atoms were introduced into the model with geometrically calculated positions [d(C–H) 1.08 Å] and with two refined isotropic temperature factors (one for Me groups and one for H-atoms of CH and CH_2 groups). Final R 0.050, wR 0.057 with $w = 1/[\sigma^2(F_0) + 0.001(F_0)^2]$. The flexibility of the cyclohexene ring, resulting in conformational disorder, could explain the high thermal factors of C(11) and C(12) and the unusually short distance C(11)–C(12) = 1.369 Å. Crystal cohesion is due mainly to Van der Waals forces. The C(5)–H(5)···O(1 − x, 1 − y, 1 − z) and C(9)–H(9)···O(1 − x, 1 − y, 1 − z) interactions may be considered as intermolecular hydrogen bonds. The geometrical features of these contacts are: C(5)–H(5) 1.08, H(5)···O 2.178(10), C(5)···O 3.218(11) Å, C(5)–H(5)···O 161.9(10)°; C(9)–H(9) 1.08, H(9)···O 2.265(18), C(9)···3.333(17) Å, C(9)–H(9)···O 170.6(10)°. The H···O < 2.75 and C···O < 3.50 Å distances and the angle C–H···O < 180° observed with reference to Van der Waals radii of 1.20, 1.70, 1.52 Å for H-, C- and O-atoms respectively, can be considered as hydrogen-bond parameters.[11,12]

The final atomic parameters are given in Table 3, and bond distances, bond angles and selected torsion angles in Table 4. The numbering scheme is given in Fig. 1.

Acknowledgements

Thanks are due to Professor V. Bertolasi (Dipartimento di Chimica, Università di Ferrara) for making available the X-ray equipment.

References

1 V. Aggarwal, A. Kumar, H. Ila and H. Junjappa, *Synthesis*, 1981, 157; N. Aggarwal, H. Ila and H. Junjappa, *Synthesis*, 1982, 65; 1983, 147; R. T. Chakrasali, H. Ila and H. Junjappa, *Synthesis*, 1988, 87.
2 A. Kodak-G., *Ger. Pat.* 670 505/1939 (*Chem. Abstr.*, 1939, **33**, 6613_2); L. G. S. Brooken and F. L. White (to Eastman Kodak Co.), *US Pat.* 2 112 139/1938 (*Chem. Abstr.*, 1938, **32**, 3713).
3 K. Hirai and A. Takamizawa (to Shionogi and Co. Ltd.) *Japan* 74 35, 275/1974 (*Chem. Abstr.*, 1975, **83**, 10035t); W. Hanefield and B. Borho, *Arch. Pharm.* (*Weinheim, Ger.*), 1989, **322**, 593.
4 G. Trapani, A. Reho, A. Latrofa and G. Liso, *Synthesis*, 1988, 84.
5 E. Keller, SHAKAL88. A Fortran Program for the Graphic Representation of Molecular and Crystallographic Models, 1988.
6 G. Trapani, A. Reho, A. Latrofa, F. Morlacchi and G. Liso, *J. Chem. Res.* (*S*), 1986, 96.
7 G. Liso, G. Trapani, A. Reho and A. Latrofa, *Synthesis*, 1985, 288.
8 M. Hori, T. Kataoka, H. Shimizu and Y. Imai, *Chem. Pharm. Bull.*, 1979, **27**, 1983.
9 M. C. Burla, M. Camalli, G. Cascarano, C. Giacovazzo, G. Polidori, R. Spagna and D. Viterbo, *J. Appl. Crystallogr.*, 1989, **22**, 389.
10 G. M. Sheldrick, SHELX76. Program for Crystal Structure Determination. Univ. of Cambridge, England, 1976.
11 V. Bertolasi, V. Ferretti and G. Gilli, *J. Chem. Soc., Perkin Trans. 2*, 1990, 283.
12 R. Taylor and O. Kennard, *J. Am. Chem. Soc.*, 1982, **104**, 5063.

Paper 0/04389C
Received 28*th September* 1990
Accepted 2*nd January* 1991