A Study of Three Reactions leading to Isomeric 2-(*N,N*-Disubstituted Amino)thiazol-5-yl Ketones

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N-Imidoyl-*N,N*-disubstituted thioureas react with α-halogeno ketones in the presence of triethylamine to give the expected 2-(*N,N*-disubstituted amino) thiazol-5-yl ketones in high yield. The corresponding reactions of *N*-acyl-*N,N*-disubstituted thioureas lead to mixtures of these products and isomers which arise from rearrangement between cyclic intermediates. Mixtures of the isomeric thiazolyl ketones are also formed by treating *N,N*-disubstituted thioureas with 2-bromo 1,3-diketones. The mixtures from the second and third routes contain the same products but in significantly different proportions. A mechanistic scheme which accounts for the main findings was developed.

During the work 40 new 2-(*N,N*-disubstituted amino)thiazol-5-yl ketones were prepared and their structures rigorously established; characteristic mass spectral fragmentation patterns were particularly useful in identifying the substituents at positions 4 and 5 of the thiazole ring.

This work is concerned with the three routes to isomeric 2-(*N,N*-disubstituted amino)thiazol-5-yl ketones set out as reactions (**I**), (**II**), and (**III**) in Scheme 1. To shorten and clarify presentation of the results the Scheme is organised as follows. The pairs of R^1 and R^2 groups used are denoted by letters A—T, and the disubstituted amino groups by the symbol Ⓝ; the corresponding structures are shown beneath the reaction sequences. Thus, for example, reaction (**I**)**Bb** is that between $Bu^tCONHCSN(Me)Ph$ (**2b**; $R^i = Bu^t$) and $MeCOCH_2Cl$ (**1**; R^2 = Me, Hal = Cl). The product (**4**) from a reaction (**I**) in which the 4-substituent (R^1) is derived from the *N*-acylthiourea (**2**) is termed the 'non-rearranged' product (NP), and that (**9**) in which the 4-substituent (R^2) comes from the α-halogeno ketone (**1**), the 'rearranged' product (RP). These descriptions are also used with reaction (**III**), where the R^1 group originates from an *N*-imidoylthiourea (**10**). Although the terms NP and RP cannot be applied to reaction (**II**) the results are presented in a way which facilitates comparison with those of reaction (**I**). For example, reaction (**I**)**Db** gives mainly the RP (**9**; R^1 = Ph, R^2 = Me). Since the major product of reaction (**II**)**Db** is the same compound it is again formulated in this way rather than in the alternative (identical) manner (**4**; R^1 = Me, R^2 = Ph).

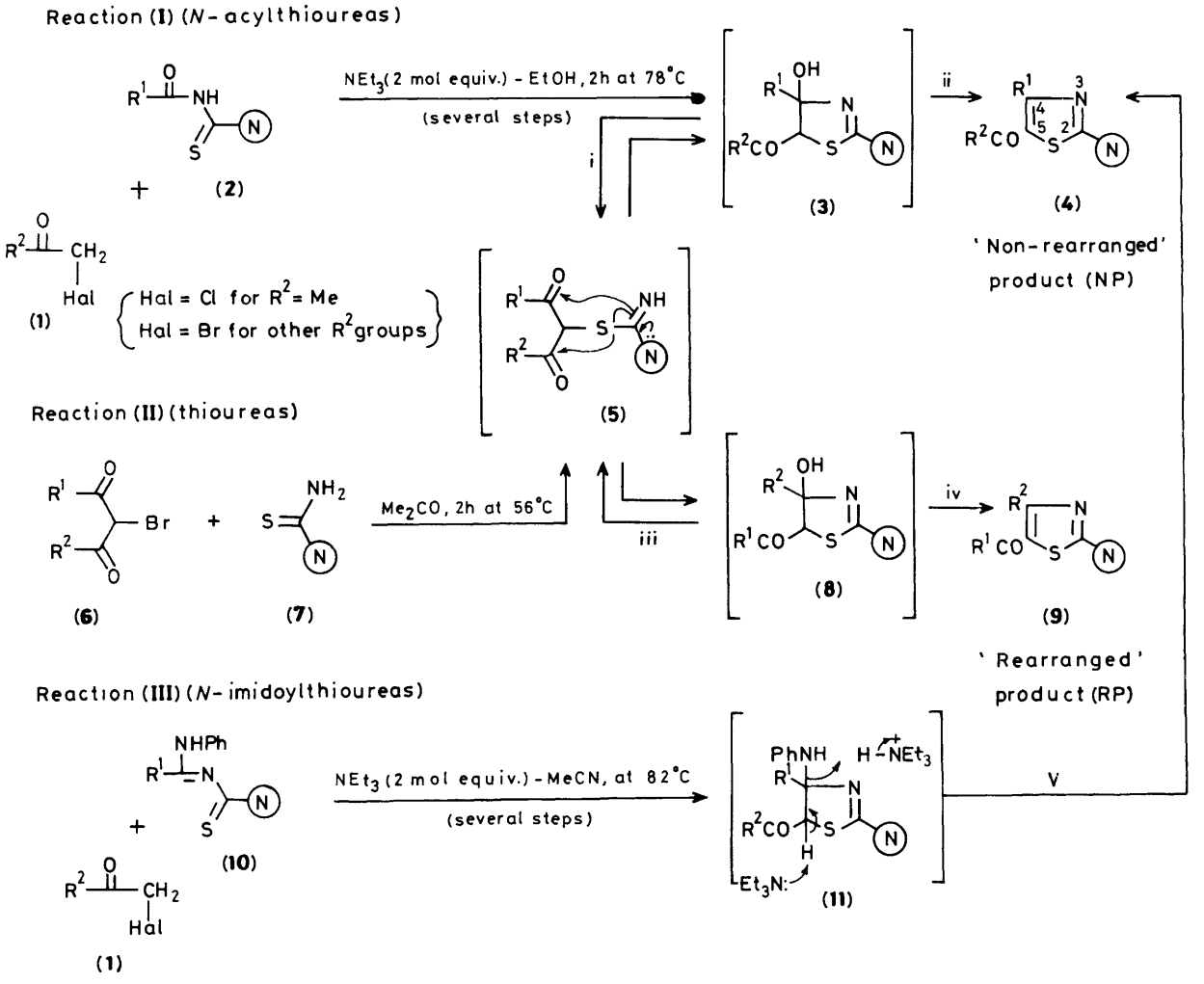
In a previous paper [1a] the literature on reactions (**I**)[2] and (**III**)[3] was discussed, and the results obtained with two sets of these reactions, (**Db**) and (**De**), were reported. Reactions (**III**) led cleanly to the expected NPs (**4**), but reactions (**I**) afforded mixtures consisting mainly of the RPs (**9**). The observation that for one set a new approach, reaction (**II**)**Db**, also gave a mixture in which the RP predominated was a key feature in the development of the mechanistic interpretation shown in Scheme 1.

A range of substrates has now been studied. Elucidation of the products' structures is based on three compounds, (**4Da**), (**4Db**), and (**9Db**), for which the deductions from various spectrometric examinations had been verified by chemical and crystallographic methods.[1] For sets with R^2 = Me (**B, D, J, N,** and **Q**) there is a consistent difference between the NPs and RPs in their ^1H n.m.r. spectra: the MeCO signal of the NP(**4**) is at higher field (by *ca.* δ 0.4) than the 4-Me signal of the RP(**9**). Distinction between the isomers of all the sets is readily made by m.s. examination, as shown in Scheme 2. The mass numbers of major peaks from R^2CO^+ or $[M - R^2]^+$ ions, or from both, identify the R^2 group, and fragmentation of the former gives $[R^2]^+$ ions which are also prominent when the group is aromatic. Eliminations from the $[M - R^2]^+$ ions lead to ions, formulated as $[R^1C{:}C{:}S]^+$, with *m/z* values characteristic of the R^1 group. The relative abundancies of these four peaks confirm the structural information provided by their mass numbers. Variation of the substituents in the 2-amino group has little effect on the abundancies, and all the compounds of a particular type [*e.g.* the six with structure (**9D**)] give values close to the averages in Scheme 2. (Although the most intense peak of several spectra arises from the M^+ ion the strongest of each group of the four peaks considered here is represented as the base peak in order to facilitate comparisons.) The results reflect the changing stability of the $[R^2CO]^+$ and $[R^1C{:}C{:}S]^+$ ions according to the group contained in the expected order, *viz.*, *p*-methoxyphenyl, phenyl and 2-thienyl > *p*-chlorophenyl > *p*-nitrophenyl > alkyl groups. However, the $[R^1C{:}C{:}S]^+$ ion is formed by secondary fragmentation and its abundance will depend not only on its stability but also on the favoured direction of the initial fragmentation, to a $[R^2CO]^+$ or a $[M - R^2]^+$ ion, which is determined by the nature of the R^2 group. The results are satisfactorily rationalised by dividing the present compounds into three categories (R^1 and R^2 both aliphatic, both aromatic, one aliphatic and one aromatic) and then considering the relative stabilities of the ions formed in the initial and subsequent fragmentations.

For sets with R^2 = Me the RP:NP ratios of reactions (**I**) and (**II**) were obtained by ^1H n.m.r. measurements. (Four reactions, identified in Scheme 1, are from an early phase of this study when the integrations were less precise.) Mass spectrometry was used for the other sets, the results being calibrated by examining RP/NP mixtures of known composition. The ratios given without qualification in Scheme 1 are thought to be reliable. However for several reactions (with very high or very low ratios, or where there were variations between the m.s. runs) the possible errors are greater, and in these cases approximate rather than precise values are recorded. Crystallisation of the mixtures obtained in most of the reactions afforded the major products, the yields being high in cases with high or low ratios [*e.g.*, (**I**)**Bb** → (**9Bb**), (**I**)**Tb** → (**4Tb**)]. For completeness the mixtures from four reactions [(**I**)**Be**, (**I**)**Da**, (**II**)**Db**, and (**I**)**Je**] were separated chromatographically to give the isomeric products in amounts consistent with the observed RP:NP ratios.

Reaction (**III**) is straightforward. In every case studied the expected isomer was formed in high yield as the sole product, as would be expected from the original work [4] which prompted the development of reactions (**I**) and (**III**), and the recent

Scheme 1. Formation of isomeric 2-(*N*,*N*-disubstituted amino)thiazol-5-yl ketones



	N		R^1	R^2		R^1	R^2		R^1	R^2
a	NMe_2	**A**	Me	Me	**H**	Ph	C_6H_4Cl-*p*	**O**	C_6H_4Cl-*p*	Ph
b	N(Me)Ph	**B**	Bu^t	Me	**I**	Ph	$C_6H_4NO_2$-*p*	**P**	$C_6H_4NO_2$-*p*	Ph
c	$-\overline{N(CH_2)_3CH_2}$	**C**	Bu^t	C_6H_4OMe-*p*	**J**	C_6H_4OMe-*p*	Me	**Q**	2-Thienyl	Me
d	$-\overline{N(CH_2)_4CH_2}$	**D**	Ph	Me	**K**	C_6H_4OMe-*p*	Bu^t	**R**	2-Thienyl	Pr^i
e	$-\overline{N(CH_2)_2OCH_2CH_2}$	**E**	Ph	Bu^t	**L**	C_6H_4OMe-*p*	Ph	**S**	2-Thienyl	Bu^t
f	$-\overline{N(CH_2)_5CH_2}$	**F**	Ph	Ph	**M**	C_6H_4OMe-*p*	C_6H_4NO-*p*	**T**	Thienyl-2-yl	Ph
		G	Ph	C_6H_4OMe-*p*	**N**	C_6H_4Cl-*p*	Me			

Reaction	Ratio RP:NP	Product(s) isolated	Reaction	Ratio RP:NP	Product(s) isolated	Reaction	Ratio RP:NP	Product(s) isolated
(I)Af	—	**(4Af)**[a]	**(III)Ee**	—	**(4Ee)**	**(I)Ob**	1:2.5	—
(I)Bb	18:1	**(9Bb)**	**(I)Ff**	—	**(4Ff)**[a]	**(III)Ob**	—	**(4Ob)**
(II)Bb	12:1	**(9Bb)**	**(III)Gb**	—	**(4Gb)[=(9Lb)]**	**(I)Oe**	*ca.* 1:2	**(4Oe)**
(I)Be	3.5:1	**(9Be),(4Be)**	**(III)Ge**	—	**(4Ge)**	**(I)Pe**	1:5	**(4Pe)**
(III)Cf	—	**(4Cf)**	**(III)Hb**	—	**(4Hb)**	**(I)Qa**	4:1	**(9Qa)**
(I)Da	3:1	**(9Da),(4Da)**[b]	**(I)He**	<1:4	**(4He)**	**(I)Qb**	>20:1	**(9Qb)**
(II)Da	2:1	—	**(III)Ie**	—	**(4Ie)**[a]	**(I)Qc**	>4:1[d]	**(9Qc)**
(I)Db	10:1	**(9Db)**[c]	**(I)Jb**	>20:1	**(9Jb)**	**(I)Qd**	>4:1[d]	**(9Qd)**
(II)Db	3:1	**(9Db),(4Db)**[b]	**(III)Jb**	—	**(4Jb)**	**(I)Qe**	9:1	**(9Qe)**
(III)Db	—	**(4Db)**[c]	**(I)Je**	8.5:1	**(9Je),(4Je)**	**(II)Qe**	5:1	**(9Qe)**
(I)Dc	>4:1[d]	**(9Dc)**	**(I)Jf**	2.5:1	**(9Jf)**	**(III)Qe**	—	**(4Qe)**
(I)Dd	>4:1[d]	**(9Dd)**	**(I)Kf**[f]	—	—	**(I)Qf**	7:1	**(9Qf)**
(I)De	8:1	**(9De)**[c]	**(I)Lb**	3:1	**(9Lb)**	**(I)Re**	*ca.* 3:1	**(9Re)**
(III)De	—	**(4De)**[c]	**(III)Lb**	—	**(4Lb)**	**(III)Se**	—	**(4Se)**
(I)Df	5:1	**(9Df)**	**(I)Lf**	2:1	**(9Lf)**	**(I)Tb**	*ca.* 1:5	**(4Tb)**

Reaction	Ratio RP:NP	Product(s) isolated	Reaction	Ratio RP:NP	Product(s) isolated	Reaction	Ratio RP:NP	Product(s) isolated
(II)Df	2.5:1	**(9Df)**	**(I)Mf**	>20:1	**(9Mf)**	**(II)Tb**	1:2	—
(III)Df	—	**(4Df)**[e]	**(I)Nb**	14:1	**(9Nb)**	**(I)Te**	*ca.* 1:4	**(4Te)**
(I)Ee[f]	—	—	**(III)Nb**	—	**(4Nb)**	**(II)Te**	1:1.5	—

Characterisation data for the new thiazol-5-yl ketones **(4Af)**, **(9Bb)**, **(4Be)**, **(9Be)**, **(4Cf)**, **(9Da)**, **(9Dc)**, **(9Dd)**, **(9Df)**, **(4Df)**, **(4Ee)**, **(4Ff)**, **(4Gb)**, **(4Ge)**, **(4Hb)**, **(4He)**, **(9Jb)**, **(4Jb)**, **(4Je)**, **(9Je)**, **(9Jf)**, **(4Lb)**, **(9Lf)**, **(9Mf)**, **(9Nb)**, **(4Nb)**, **(4Ob)**, **(4Oe)**, **(4Pe)**, **(9Qa)**, **(9Qb)**, **(9Qc)**, **(9Qd)**, **(9Qe)**, **(4Qe)**, **(9Qf)**, **(9Re)**, **(4Se)**, **(4Tb)**, and **(4Te)** are recorded in *Supplementary Publication* No. SUP 56694 (3pp.): for details of the Supplementary publications Scheme see Instructions for Authors, (1987), *J. Chem. Soc., Perkin Trans. 1*, 1987, Issue 1.

[a] $R^1 = R^2$, structures **(4)** and **(9)** are identical [b] Ref. 1*b*. [c] Ref. 1*a*. [d] ^1H n.m.r. integrations not accurate. [e] Also prepared from the *N*-isopropylbenzimidoyl compound **(10)Df** with $NHPr^i$ in place of NHPh. [f] Mixture of unidentified compounds formed. [g] Ref. 3.

conversion[5] of *N*-amidinothioureas into 5-acyl-2,4-diaminothiazoles. Triethylamine will act as a base in the steps leading to the cyclic intermediate **(II)**; presumably the triethylammonium cation so formed assists in making the subsequent loss of aniline (step v) faster than the corresponding dehydrations (steps ii and iv) of reaction **(I)**. Thus the fast irreversible conversion of the intermediate **(11)** into the NP**(4)** prevents the incursion of rearrangement. Reaction **(III)** provides an unambiguous route to thiazol-5-yl ketones of specified structure, and is effective when applied to a hindered α-halogeno ketone (Bu^tCOCH_2Br) which did not condense satisfactorily with an *N*-acylthiourea [*cf.* reactions **(I)Ee** and **(III)Ee**]. Another comparison illustrates the superiority of reaction **(III)** as a preparative method. Reaction **(I)Ob** gives a mixture from which neither component was obtained by crystallisation. However one product **(4Ob)** is formed cleanly in reaction **(III)Ob** and the second **(4Hb)** in reaction **(III)Hb**. [Structures **(9Ob)** and **(4Hb)** are identical.]

It is known[6] that dehydrations such as steps ii and iv of reactions **(I)** and **(II)** are irreversible, and the present results require steps i and iii to be reversible. More information about the relative rates of these processes is required before a complete interpretation of the observed RP:NP ratios can be attempted, and only the main features are discussed here. The ratios, which range from >20:1 to <1:4, should be strongly influenced by the relative electrophilicities of the R^1CO and R^2CO groups in the intermediate **(5)** common to the two reactions. To account for the results on this basis alone requires that the reactivity of the carbonyl centre varies according to the attached group as follows: Me > $C_6H_4NO_2$-*p* > C_6H_4Cl-*p* > Ph > C_6H_4OMe-*p* ≈ 2-Thienyl > Bu^t. This order (apart, possibly, from the precise positions of the methyl and thien-2-yl groups) is the expected one; it allows prediction of the major isomer in a particular case but does not lead to a satisfactory quantitative treatment of the results from the various combinations of R^1 and R^2 groups.

Although the ratios for a corresponding pair of **(I)** and **(II)** reactions are similar the values are not equal [*e.g.*, 18:1 for **(I)Bb** and 12:1 for **(II)Bb**]. A possible cause of such differences is that the dehydrations (steps ii and iv) are not much slower than the interconversions between the cyclic and open-chain intermediates (steps i and iii). In reaction **(II)** both cyclic intermediates arise directly from the open-chain precursor **(5)**, but in reaction **(I)** the intermediates are formed in the sequence **(3)** → **(5)** → **(8)**. Competition between steps i and ii would lead to partial removal of intermediate **(3)** and, consequentially, a lower RP:NP ratio in reaction **(I)** than in reaction **(II)**. Most of the results run counter to this theory: in five pairs (with high ratios for both reactions) the **(II)** reactions have the lower values and in only two pairs (with low ratios) are the lower values associated with the **(I)** reactions. It seems more likely that the discrepancies between the results of reactions **(I)** and **(II)** originate from a marked difference in the experimental conditions. While an excess of triethylamine is present in reaction **(I)** the hydrogen bromide generated in reaction **(II)** is not neutralised, and the dehydrations should be catalysed in the ensuing acidic medium.[6] Further work, to examine the pH dependence of both reactions, is planned.

With sets of reactions **(I)** having common R^1 and R^2 groups the RP:NP ratios are seen to be influenced by the nature of the disubstituted amino centre in the *N*-acylthiourea **(2)**. Although only one complete set, **(I)Da**—**(I)Df**, is available a comparison between the *N*-methyl-*N*-phenylamino **(b)** and hexahydroazepin-1-yl **(f)** compounds can be made here and in several incomplete sets. It emerges that in all the sets [fortuitously, ones having high ratios for the **(b)** compounds] the **(f)** compounds have appreciably lower values. Changing the disubstituted amino group is unlikely to affect the relative rates of the dehydrations (ii and iv) but it may be expected to alter the balance between the alternative ring-closures (depicted in Scheme 1) of the open-chain intermediate **(5)**. Both should be faster in the hexahydroazepin-1-yl compounds, and the higher reactivity should result in less discrimination between the carbonyl groups and hence RP:NP ratios which are closer to unity than are those of the related *N*-methyl-*N*-phenylamino compounds.

Experimental

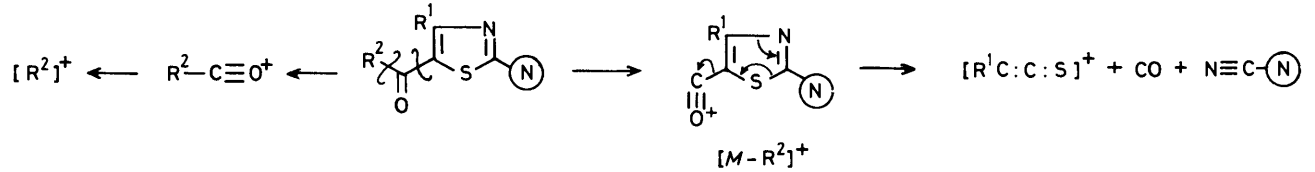
General directions are as in ref. 1. Petroleum refers to light petroleum, b.p. 80—100 °C, which was dried over Na and distilled.

The Thioureas **(7)** *and Substituted Thioureas* **(2)** *and* **(10)**.—Apart from the following these were prepared as described earlier.[1,7] The general procedure[7] was used for the conversion of hexahydroazepine into *hexahydroazepin-1-yl cyanide* (82%), b.p. 115—116 °C/10 mmHg (Found: C, 67.8; H, 9.8; N, 22.6. $C_7H_{12}N_2$ requires C, 67.7; H, 9.7; N, 22.6%); *m/z* 124 (M^+, 83%) and 42 (100), and of this cyanide into 1-*thiocarbamoylhexahydroazepine* **(7f)** (79%), m.p. 146—147 °C (from EtOH) (Found C, 52.9; H, 8.9; N, 17.6. $C_7H_{14}N_2S$ requires C, 53.1; H, 8.9; N, 17.7%), *m/z* 158 (M^+, 100%). The standard methods[1] were used for converting 4-methoxybenzoyl chloride into 1-[N-(4-*methoxybenzoyl*)*thiocarbamoyl*]*hexahydroazepine* **(2f**; R^1 = C_6H_4OMe-*p*)(82%), m.p. 153—154 °C (Found: C, 61.5; H, 6.8; N, 9.6. $C_{15}H_{20}N_2O_2S$ requires C, 61.6; H, 6.9; N, 9.6%), *m/z* 427 (M^+, 42%) and 135 (100), and *N*-phenylbenzimidoyl chloride into 1-[N-(N-*phenylbenzimidoyl*)*thiocarbamoyl*]*hexahydroazepine* **(10f**; R^1 = Ph)(79%), m.p. 110—112 °C (from EtOH) (Found: C, 71.4; H, 6.8; N. 12.4. $C_{20}H_{23}N_3S$ requires C, 71.2; H, 6.9; N, 12.45%), *m/z* 337 (M^+, 24%) and 180 (100).

The 2-*Bromo* 1,3-*Diketones* **(6)**.—The method (Br_2 in CCl_4—H_2O at 0 °C) described previously[8] was used to brominate four 1,3-diketones: $MeCOCH_2COR$; R = Bu^t (prepared as in ref. 9), R = Ph (commercially available), and R = 2-thienyl, and 2-(2-thenoyl)-acetophenone. The products, which were shown by ^1H n.m.r. examination to be mainly (93—96%) the 2-bromo 1,3-diketones, were used immediately in reactions **(II)**.

The 1,3-diketones based on thiophene were prepared as

Scheme 2. Mass spectra of 2-(*N*,*N*-disubstituted amino)thiazol-5-yl ketones. For each type the results are the averages of the compounds with different 2-amino groups, and the strongest of the four peaks shown is given an abundance of 100



Type	R¹	R²	Relative abundancies of peaks: R^2CO^+	$[R^2]^+$	$[M - R^2]^+$	$[R^1C{:}C{:}S]^+$
4A	Me	Me	45	—	100	16
4B	Bu^t	Me	35	—	100	15
9B	Me	Bu^t	—	6	100	15
4C	Bu^t	C_6H_4OMe-*p*	100	20	3	2
4D	Ph	Me	50	—	100	53
9D	Me	Ph	84	100	34	8
4E	Ph	Bu^t	—	10	100	30
4J	C_6H_4OMe-*p*	Me	46	—	100	65
9J	Me	C_6H_4OMe-*p*	100	18	18	15
4N	C_6H_4Cl-*p*	Me	54	—	100	80
9N	Me	C_6H_4Cl-*p*	100	79	75	14
4F	Ph	Ph	90	100	7	57

Type	R¹	R²	Relative abundancies of peaks: R^2CO^+	$[R^2]^+$	$[M - R^1]^+$	$[R^1C{:}C{:}S]^+$
4G	Ph	C_6H_4OMe-*p*	100	15	15	35
4L	C_6H_4OMe-*p*	Ph	92	100	7	62
4H	Ph	C_6H_4OMe-*p*	100	78	61	78
4O	C_6H_4Cl-*p*	Ph	83	100	37	50
4I	Ph	$C_6H_4NO_2$-*p*	50	—	20	100
4P	$C_6H_4NO_2$-*p*	Ph	85	100	27	8
9M	$C_6H_4NO_2$-*p*	C_6H_4OMe-*p*	100	14	—	3
4Q	2-Thienyl	Me	21	—	62	100
9Q	Me	2-Thienyl	100	14	8	7
9R	Pr^i	2-Thienyl	100	12	5	6
4S	2-Thienyl	Bu^t	—	—	100	32
4T	2-Thienyl	Ph	90	100	31	90

follows. A stirred suspension of NaH (50% dispersion in oil; 10.6 g) in dry Et_2O (200 ml) containing ethyl thiophene-2-carboxylate (17.2 g) was boiled under reflux. A solution of Me_2CO (6.4 g) in Et_2O (20 ml) was added during 10 min, and the stirred mixture was boiled under reflux for 3 h. EtOH (40 ml) was added cautiously, the mixture was shaken with ice–water (200 ml), and the layers were separated. The aqueous layer was washed with Et_2O, and acidified with 10M-HCl. The material isolated by extraction with Et_2O was distilled to give 1-(2-*thenoyl*)*acetone* (11.6 g), b.p. 79—81 °C/1.5 mmHg, m.p. 28—30 °C (Found: C, 57.4; H, 5.0; S, 18.8. $C_8H_8O_2S$ requires C, 57.1; H, 4.8. S, 19.1%), *m*/*z* 168 (M^+, 40%), 125 (100), and 111 (95).

The foregoing experiment was repeated using acetophenone (13.2 g) in place of Me_2CO. Distillation of the product gave 2-(2-*thenoyl*)*acetophenone* (14.8 g), b.p. 142—146 °C/0.1 mmHg, m.p. 93—94 °C (from EtOH) (Found: C, 67.8; H, 4.3. $C_{13}H_{10}O_2S$ requires C, 67.8; H, 4.4%), *m*/*z* 230 (M^+, 85%), 111 (90), and 105 (100).

Reactions (**I**), (**II**) *and* (**III**).—The procedures of the following examples were used generally. The systematic names and the yields of the products isolated in the series of experiments, and the characterisations of the new compounds are shown as Table 1 in Supplementary Publication No. SUP 56694 (3 pp.).*

Experiment (**I**)**Df**. A stirred solution of 1-(*N*-benzoylthiocarbamoyl)hexahydroazepine (**2f**; R^1 = Ph) (2.62 g), chloroacetone (0.93 g), and NEt_3 (2.02 g) in EtOH (40 ml) was boiled under reflux for 2 h, cooled, poured into brine (80 ml), and extracted with Et_2O. The ^1H n.m.r. spectrum (examined at 300 MHz) of the material (2.89 g) so obtained had signals at δ 2.36 and 1.96 in the ratio 5:1. Two crystallisations from petroleum gave 5-*benzoyl*-2-(*hexahydroazepin*-1-*yl*)-4-*methylthiazole* (**9Df**) (1.77 g), m.p. 84—85 °C.

Experiment (**II**)**Df**. A stirred solution of 2-acetyl-2-bromoacetophenone (**6**; R^1 = Ph, R^2 = Me) (2.4 g) and 1-thiocarbamoylhexahydroazepine (**7f**) (1.6 g) in Me_2CO (50 ml) was boiled under reflux for 2 h, cooled, and poured into brine (110 ml). Basification with 18M-NH_3 and extraction with Et_2O gave material (2.86 g) with signals at δ 2.36 and 1.96 in the ratio 2.5:1. Three crystallisations from petroleum gave compound (**9Df**) (0.98 g), m.p. and mixed m.p. 83—84 °C.

Experiment (**III**)Df. A stirred solution of 1-[*N*-(*N*-phenylbenzimidoyl)thiocarbamoyl]hexahydroazepine (**10f**; R^1 = Ph) (2.0 g), chloroacetone (0.61 g), and NEt_3 (1.21 g) in dry MeCN (30 ml) was boiled under reflux for 2 h, cooled, and poured into brine (70 ml). Extraction with CH_2Cl_2 gave material (1.91 g) with a signal at δ 1.96 but no signal at δ *ca.* 2.4. Crystallisation from petroleum gave 5-*acetyl*-2-(*hexahydroazepin*-1-*yl*)-4-*phenylthiazole* (**4Df**) (1.61 g), m.p. 76—77 °C.

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