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THE REARRANGEMENT OF 3,4-DISUBSTITUED-Δ^2-1,2,4-OXADIAZOLIN-5-THIONES

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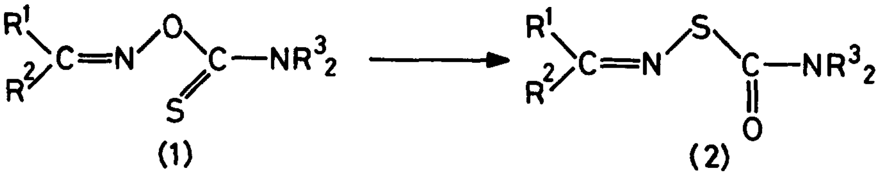
Summary

The light and metal catalysed rearrangement of 3,4-disubstituted-Δ^2-1,2,4-oxadiazolin-5-thiones (3) to the corresponding Δ^2-1,2,4-thiodiazolin-5-ones (4) is described. The thermal stability of (3) is in great contrast to the ease of rearrangement of the acyclic analogues. The rearrangements of (3) and (4) under electron impact are described.

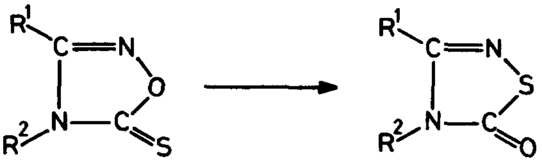
The uncatalysed thermal rearrangement of O-methyleneaminothionecarbonates (1) to S-methyleneaminothiocarbonates (2) has been the subject of a careful investigation.[1]


(1) (2)

The reaction proceeds at ambient temperature in polar or non-polar solvents and is insensitive to changes in the polarity of R^1 and R^2. Hence it is clear that the transition state of intermediate involves little charge separation, a finding in contrast to the apparently closely related rearrangement of thionecarbamates to thiocarbamates.[2] It was suggested that a radical pair was involved in the rearrangement and this suggestion was further backed by e.s.r. measurements and the results of cross-over experiments. The difficult problem of distinguishing the contribution to the rearrangement of a concerted 1,3-sigmatropic shift was left unresolved.

One of us (D.S.) has recently made 3,4-disubstituted-Δ-1,2,4-oxadiazolin-5-thiones (3a-p) readily available.[3] Such substances are closely analogous to compounds (1) and it was of interest to examine their possible rearrangement to 3,4-disubstituted-Δ^2-1,2,4-thiodiazolin-5-ones (4a-p).

If the thermal uncatalysed isomerisation of (1) to (2) proceeds mainly via radical pairs then the isomerisation of (3) to (4) could proceed by a similar mechanism, the thermodynamic driving force[4] being similar in both cases. Moreover the rearrangement should be relatively insensitive to the type of alkyl or aryl group attached as R^1 as there is little charge delocalisation. On the other hand, the ring compounds (3) differ from (1) in that a ground state concerted 1,3-sigmatropic shift is sterically inhibited in (3), and hence if this is a major pathway for the rearrangement then unlike (1) compounds (3) should be thermally stable.



(3) (4)

	R^1	R^2		R^1	R^2		R^1	R^2		R^1	R^2
(a)	Me	Me	(e)	Et	Me	(i)	Pr^n	Me	(m)	Bu^n	Me^n
(b)	Me	Et	(f)	Et	Et	(j)	Pr^n	Et	(n)	Ph	Me
(c)	Me	Pr^n	(g)	Et	Pr^n	(k)	Pr^n	Pr^n	(o)	Ph	Et
(d)	Me	Bu^n	(h)	Et	Bu^n	(l)	Pr^n	Bu^n	(p)	Ph	Ph

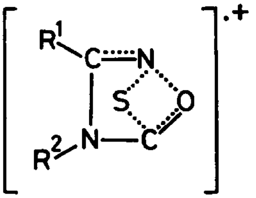
Compound (3b) was heated for 4h at 200° in diphenyl ether but no change whatsoever could be detected. After 10h at 200° (3b) had almost all decomposed, but very little (4b) could be detected, the organic material recovered being almost completely (3b). Similar results were obtained with (3h) and (3i). When compound (3l) was heated at 280° in a sealed tube, no (4l) could be detected in the extensively decomposed product. We conclude therefore that compounds (3a-m) are thermally stable, in strong contrast to compounds (1).

When R^1 = Ph ((3n), (3o) and (3p)) then thermal rearrangement and decomposition proceed together. The optimal conditions found for the rearrangement were to heat the substances in diphenyl ether for 8h at 200°. This allowed (4n), (4o) and (4p) to be isolated in yields of 63%, 62.5% and 61% respectively. After heating for 4h in the same conditions very substantial amounts of starting materials were obtained. Thus when R^1 = Ph it is possible to induce thermal rearrangement of compounds (3). However the difference between the stringent conditions required compared with the ease of thermal rearrangement of the acyclic analogues is striking.

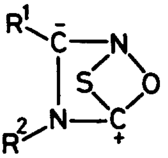
There are several possible reasons for the relative thermal stability of (3) as compared with (1). It may well be that a concerted 1,3-sigmatropic shift is a large element in the rearrangements of (1). Alternatively there may be some aromatic character associated with substances (3) leading to a high activation energy for rearrangement by whatever mechanism.[5]

We then subjected compounds 3 (a to p) to photolysis (dry methanol, 12 SW Hanovia low pressure photochemical reactor) and noted that if irradiation were allowed to continue compounds (4) were the sole products. We could detect no trace of compounds (3) at the end of any irradiation whether starting with (3) or (4). The reaction seems to be quite general and provides one method for the production of the difficultly accessible heterocycles (4). The ready photolytic, excited state rearrangement contrasts strongly with the thermal stability of compounds (3).

In view of the excited state lability of compounds (3), we have studied the mass spectra of compounds 3 (a to p) and 4 (a to p). The series of compounds (3) gave very similar mass spectra to compounds (4) when run under similar conditions. Compounds run at 250°/70 e.v. always had a prominent R^1CNS fragment, this frequently being the base peak. Lowering the source voltage or the temperature generally lowered the intensity of this ion from compounds (3), the latter being rather surprising in view of the thermal stability of these compounds. The ions due to R^1CNO and R^2CNO were almost never evidenced and even with compounds (3) the ion due to R^2CNS was of very low intensity. There is always the possibility of a thermal metal-surface catalysed rearrangement but even at a source temperature as low as 40°C (3e) gave a peak at m/e 87 (mass measured as EtCNS) of intensity 64 in relation to the base peak (M^+). Hence we feel that R^1CNS must arise largely by rearrangement of the molecular ion rather than rearrangement of the molecule. Somewhat similar mass spectrometric rearrangements have been previously considered,[6] these including the rearrangement of N-alkylphthalimides, N-phenylthionoamides,[7] thione-esters and thionocarbonates. It has been proposed that the rearrangements may proceed via an electronically excited 4-membered ring transition state or intermediate. Such a mechanism in the present case would point to structure (5) a similar type of structure (6) being possible for the light catalysed reaction.



(5)



(6)

Obviously kinetic studies will tell whether a charged intermediate or transition state such as (6) occurs in the photoisomerisation. Somewhat similar 1,3-oxathietane ring systems have been suggested for some isosteric substitution reactions.[8]

In order to test whether the thermal rearrangement of compounds (3) was sensitive to metal catalysis, (3i) was heated in diphenyl ether for 4h at 160° in the presence of a little iron powder. The compound was recovered unchanged. However, when the same compound was subjected to the same treatment in the presence of a catalytic quantity of copper powder, it was completely converted to (4i). We find that the copper catalysed reaction is general, reaction normally being complete in ca. 4h at 180° and in this way were able to completely rearrange compounds 3 (a, b, f, i, h, n, o and p). The reaction is not fast (e.g. rearrangement of (3i) was not completed after 22h at 130°) but is efficient and is our recommended method for the production of 3,4-disubstituted-Δ^2-1,2,4-thiadiazolin-5-ones (4). Currently the mechanism of the copper catalysed rearrangement is unknown.

Quantitative kinetic studies remain to be carried out, but clearly the rearrangements of compounds (3) show marked divergencies from those of compounds (1).

Acknowledgment

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