Tetrahedron Vol 37, No 14, pp 2485 to 2488, 1981
Printed in Great Britain

0040-4020/81/142485-04$02.00/0
Pergamon Press Ltd

NOVEL HETEROPENTALENES. SYNTHESIS OF HETEROPENTALENES FROM TETRAHYDROIMIDAZO [1,2-d]-(1,2,4)-THIADIAZOLES AND CONVERSION OF CERTAIN HETEROPENTALENES TO BENZOTHIAZOLE DERIVATIVES

ROGER J. S. BEER,* HARDEV SINGH and, in part, DAVID WRIGHT
The Robert Robinson Laboratories, University of Liverpool, P.O. Box 147, Liverpool, L69 3BX, England

and

LARS KR. HANSEN
Department of Chemistry, Institute of Mathematical and Physical Sciences, University of Tromsø, P.O. Box 953, 9001, Tromsø, Norway

(*Received in the UK 22 September* 1980)

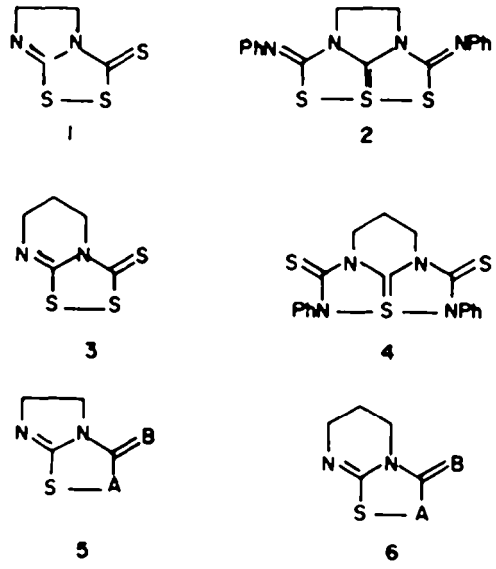
Abstract—Oxidation of 1 - phenylcarbamoylimidazolidine - 2 - thione gives 2,3,5,6 - tetrahydro - 2 - phenylimidazo[1,2-*d*] - (1,2,4) - thiadiazole - 3 - one which undergoes addition reactions with heterocumulenes leading to various heteropentalenes. Oxidation of 1 - phenylthiocarbamoylimidazolidine - 2 - thione yields 1 - (benzothiazol - 2 - yl) - imidazolidine - 2 - thione, also obtained by acid catalysed decomposition of 3,4 - ethano - 2,3,4,5 - tetrahydro - 2,5 - bisphenylimino - 1,6,6aS^{IV} - trithia - 3,4 - diazapentalene. A similar acid catalysed decomposition to a benzothiazole occurs with 2,3,4,5 - tetrahydro - 1,6 - diphenyl - 3,4 - propano - 6aS^{IV} - thia - 1,3,4,6 - tetraazapentalene - 2,5 - dithione.

The imidazodithiazole **1**, originally obtained by oxidation of disodium ethylenebisdithiocarbamate[1] and subsequently synthesised from the *S*-benzylthio and *S*-phenacyl derivatives of ethylene thiourea (2 - imidazolidinethione),[2] reacts at room temperature with phenyl isothiocyanate to give the trithiadiazapentalene **2**. Under similar conditions, the dithiazole **3** gives a product formulated as the thiatetra - azapentalene - 2,5 - dithione **4**[2]. The structure of the analogous 2,5 - dione, obtained by treating **3** with phenyl isocyanate, has been confirmed by X-ray crystallography[3] as has the structure of compound **2**.[4]

These reactions of bicyclic compounds **1** and **3** suggest the intervention of related intermediates, for example **5** (A = S, B = NPh) or **5** (A = NPh, B = S) and analogous compounds of type **6**. Such intermediates should be accessible by oxidation of suitable derivatives of 2 - imidazolidinethione and hexahydropyrimidine - 2 - thione. Thus, in attempting to find more direct routes to heteropentalenes of type **2**, we examined the oxidation of 1 - carbamoyl - and 1 - thiocarbamoylimidazolidine - 2 - thiones.

1 - Phenylcarbamoylimidazolidine - 2 - thione **7**, on treatment with bromine, readily gave the desired product **8** and, as expected, this compound underwent a variety of addition reactions with heterocumulenes, summarised in Scheme 1. Attempts to isolate the 1:1 addition product of **8** with phenyl isothiocyanate were unsuccessful. With one mole of the heterocumulene, heteropentalene **2** was obtained in 45% yield. We infer that the first-formed adduct is unstable and breaks down with liberation of phenyl isocyanate.

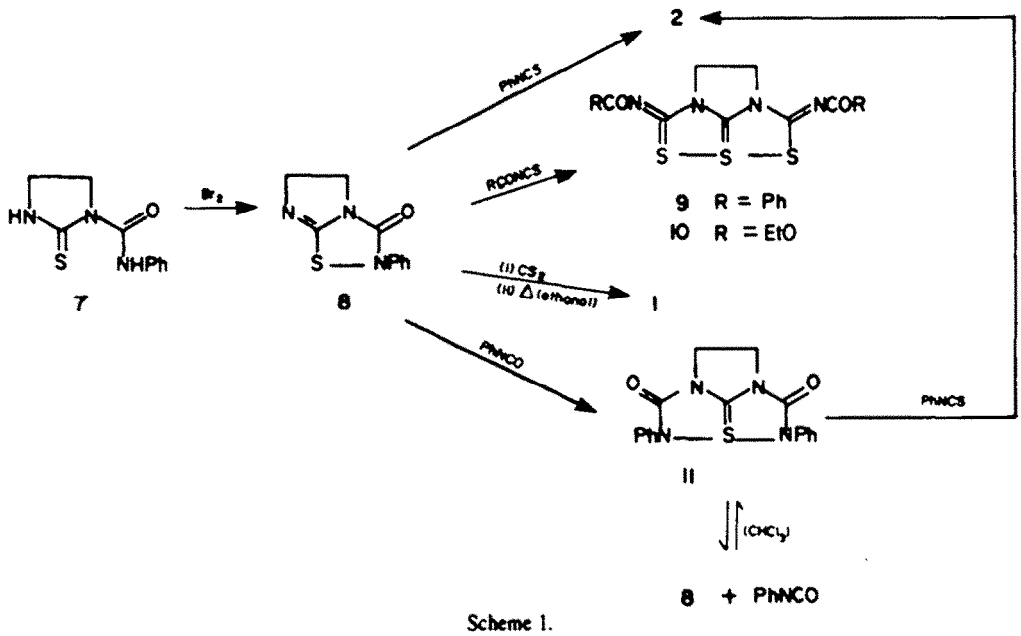
The heteropentalene **11** also shows evidence of instability, although it was isolated in pure form. Infrared and NMR data indicate that this adduct partially dissociates in solution; not surprisingly, it reacts rapidly with phenyl isothiocyanate to give heteropentalene **2** in high yield.



Scheme 1.

These results support our previously expressed view[2] that the ethano bridge causes strain in imidazolidine-based heteropentalenes (e.g. **11**) with a (presumed) linear N–S–N system and that this strain is relieved when the longer linear S–S–S system is present (as in **2**).

Unstable solid adducts were also formed when the thiadiazole **8** was treated with carbon disulphide and with sulphur dioxide. The carbon disulphide adduct decomposed in warm ethanol to give the dithiazole **1**.



Scheme 1.

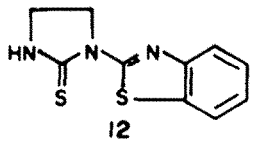
Bicyclic compounds **5** (A = NMe, B = S) and **5** (A = NMe, B = O) were obtained by bromine oxidation of 1 - methylthiocarbamoylimidazolidine - 2 - thione and 1 - methylcarbamoylimidazolidine - 2 - thione. The addition reactions of these analogues of compound **8** have not been studied in detail but, with phenyl isothiocyanate, both compounds were converted to heteropentalene **2**.

Oxidation of 1 - phenylthiocarbamoylimidazolidine - 2 - thione with bromine gave a product of rhe required composition but its properties were not those expected of either the thiadiazole **5** (A = NPh, B = S) or the dithiazole **5** (A = S, B = NPh). In particular, it was unreactive towards phenyl isothiocyanate. Interestingly, this product proved to be identical with a compound obtained from heteropentalene **2**, in earlier studies, by treatment with acids and subsequently prepared in better yield by heating the heteropentalene in acetic acid.

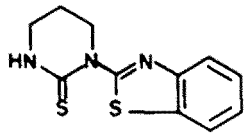
Heteropentalene **4** is converted to the benzothiazole derivative **13** under acidic conditions. This became clear when, in the course of attempts to obtain crystals suitable for study by X-ray crystallography, compound **4** was recrystallised from boiling acetic acid. The structure which emerged was that of the benzothiazole **13**.[3] The exact mechanism of formation of the benzothiazole is not known but it seems clear that, under acidic conditions, the sulphur atom of one of the phenyl isothiocyanate residues in **4** becomes electrophilic in character and attacks the adjacent benzene ring.

By analogy, we formulate the acid catalysed decomposition product of heteropentalene **2**, which is also the oxidation product of 1 - phenylthiocarbamoylimidazolidine - 2 - thione, as the benzothiazole **12**. This structure is consistent with the spectroscopic data and explains the lack of reactivity towards phenyl isothiocyanate, which is in marked contrast to the behaviour of the bicyclic compounds of type **5**.

The structural work on compound **13** will be fully described elsewhere but Fig. 1 gives some of the derived bondlengths and bond angles. The central part of the molecule is almost planar; it is of interest that the sulphur atom of the benzothiazole system takes up the position adjacent to the thione sulphur atom, and that the

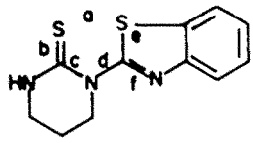


12



13

two sulphur atoms (presumably oppositely charged) have a separation of 2.925 Å, which corresponds to the Huggins "constant energy" distance.[5] Similar separations have been found in isothiathiophthens and related systems,[6] and in some 4 - thiazoline derivatives.[7]



Selected bond lengths (Å)

a	2.925(1)	d	1.409(2)
b	1.695(2)	e	1.759(2)
c	1.371(2)	f	1.301(2)

Selected bond angles (°)

ab	85.35(4)	de	124.7(1)
bc	123.9(1)	ae	80.00(4)
cd	125.4(1)	ef	116.5(1)

Fig. 1.

EXPERIMENTAL

1-Phenylcarbamoylimidazolidine-2-thione (7)

Prepared by D'Angeli's method,[8] this compound formed colourless needles, m.p. 202° (lit.[8] m.p. 202–203°). The same product was obtained quantitatively when imidazolidine - 2 - thione (10.2 g) was heated with phenylisocyanate (11.9 g) for 3 h at 150°; ν_{max} (Nujol) 1666 cm^{-1}; λ_{max} (EtOH) 208, 255 nm (ϵ 10,800, 18,300); δ ($CDCl_3$) 3.35 (2H, t); 4.36 (2H, t); 7.10–7.60 (5H, m); M^+ *m/e* 221. (Found: C, 54.0; H, 5.0; N, 19.2. Calc. for $C_{10}H_{11}N_3OS$: C, 54.3; H, 5.0; N, 19.0%).

1-Methylcarbamoylimidazolidine-2-thione

The product obtained by heating imidazolidine - 2 - thione (10.2 g) and methyl isocyanate (5.7 g) under reflux for 2 h crystallised from methanol in colourless prisms (12.4 g), m.p. 229–230°; ν_{max} 1660 cm^{-1}; λ_{max} (EtOH) 207, 237, 254 nm (ϵ 8,200, 14,100, 16,200); δ (d_4MeOH) 2.84 (3H, s); 3.64 (2H, t); 4.14 (2H, t); M^+ *m/e* 159. (Found: C, 37.45; H, 5.8; N, 26.1. $C_5H_9N_3OS$ requires C, 37.7; H, 5.7; N, 26.4%).

1-Methylthiocarbamoylimidazolidine-2-thione

Prepared by D'Angeli's method,[9] this compound formed colourless prisms from aqueous ethanol, m.p. 200–201° (lit.[9] m.p. 202–203°); M^+ *m/e* 175.

2,3,5,6 - Tetrahydro - 2 - phenylimidazo[1,2-d] - (1,2,4) - *thiadiazole - 3 - one* (8)

Bromine, diluted with a little chloroform, was added gradually to a stirred suspension of 1 - phenylcarbamoylimidazolidine - 2 - thione (5 g) in dry ethanol (100 ml) until a permanent yellow colouration was observed. The colourless crystals (6.7 g) obtained by washing the precipitated product with ethanol and then with ether proved to be the analytically pure hydrobromide of the title compound, m.p. 195–196°; ν_{max} (KBr disc) 1720 cm^{-1}; λ_{max} (MeOH) 255 nm (ϵ 9,600); M^+ *m/e* 219. (Found: C, 39.9; H, 3.35; N, 14.0. $C_{10}H_9N_3OS{\cdot}HBr$ requires C, 40.0; H, 3.3; N, 14.0%).

The corresponding base, obtained by treating the hydrobromide with saturated aqueous sodium hydrogencarbonate, crystallised from methylene chloride–hexane in fine colourless needles, m.p. 172–173°; ν_{max} (Nujol) 1710 cm^{-1}; λ_{max} (MeOH) 250 nm (ϵ 16,900); δ ($CDCl_3$) 3.92 (2H, t); 4.38 (2H, t); 7.20–7.50 (5H, m); M^+ *m/e* 219. (Found: C, 54.7; H, 4.2; N, 19.2. $C_{10}H_9N_3OS$ requires C, 54.8; H, 4.1; N, 19.2%).

2,3,5,6 - Tetrahydro - 2 - methylimidazo[1,2 - d] - (1,2,4) - *thiadiazole - 3 - thione* (5, A = NMe, B = S)

Prepared in 80% yield by the method used for the foregoing imidazothiadiazole, this product crystallised from chloroform–hexane in colourless prisms, m.p. 160–161°; λ_{max} (EtOH) 240 nm (ϵ 10,600); δ ($CDCl_3$) 3.1 (3H, s); 3.82 (2H, t); 4.36 (2H, t); M^+ *m/e* 173. (Found: C, 34.4; H, 4.3; N, 24.0. $C_5H_7N_3S_2$ requires C, 34.7; H, 4.05; N, 24.3%).

Treatment of this imidazothiadiazole with an excess of phenyl isothiocyanate in methylene chloride for 2 h at room temperature gave the heteropentalene 2 in 86% yield.

2,3,5,6 - Tetrahydro - 2 - methylimidazo[1,2 - d] - (1,2,4) - *thiadiazole - 3 - one* (5, A = NMe, B = O)

The hydrobromide of this product, obtained in quantitative yield by oxidation of 1 - methylcarbamoylimidazolidine - 2 - thione with bromine in ethanol as described above, formed colourless prisms, m.p. 181–182°; ν_{max} 1724 cm^{-1}; λ_{max} (MeOH) 225, 254 nm (ϵ 5300, 6800); M^+–HBr, *m/e* 157 (Found: C, 25.2; H, 3.5; N, 17.7. $C_5H_7N_3OS{\cdot}HBr$ requires C, 25.2; H, 3.4; N, 17.65%). The corresponding base was not obtained in analytically pure condition but was converted, with phenyl isothiocyanate, to the heteropentalene 2 in 68% yield.

Reactions of 2,3,5,6 - Tetrahydro - 2 - phenylimidazo[1,2 - d] - (1,2,4) - *thiadiazole - 3 - one* (8)

(*a*) *With phenyl isothiocyanate.* An excess of phenyl isothiocyanate (3.5 g) was added gradually to a stirred solution of the imidazothiadiazole (2 g) in methylene chloride (150 ml). Stirring was continued after completion of the addition for 2 h. The residue left after evaporation of solvent was triturated with light petroleum (b.p. 60–80°) and the solid product crystallised from benzene-light petroleum yielding bright yellow needles (3.3 g), m.p. 162–163°, identical with an authentic sample of heteropentalene 2 (lit. m.p.[2] 163°). The same product was obtained in 45% yield when only one equivalent of phenyl isothiocyanate was added.

(*b*) *With benzoyl isothiocyanate.* Treatment of the imidazothiadiazole (2 g) with benzoyl isothiocyanate (4 g) in warm methylene chloride gave analytically pure 2,5 - bisbenzoylimino - 3,4 - ethano - 2,3,4,5 - tetrahydro - 1,6,6a S^{IV} - trithia - 3,4 - diazapentalene 9 as yellow crystals (3.4 g), m.p. 184–185° (Found: C, 53.3; H, 3.5; N, 13.0. $C_{19}H_{14}N_4O_2S_3$ requires C, 53.5; H, 3.3; N, 13.15%).

(*c*) *With ethoxycarbonyl isothiocyanate.* The product, 3,4 - ethano - 2,5 - bisethoxycarbonylimino - 2,3,4,5 - tetrahydro - 1,6,6a S^{IV} - trithia - 3,4 - diazapentalene 10 was obtained in 85% yield as a yellow crystalline powder, m.p. 157–158° (Found: C, 36.6; H, 4.0; N, 15.2. $C_{11}H_{14}N_4O_4S_3$ requires C, 36.5; H, 3.9; N, 15.5%).

(*d*) *With carbon disulphide.* An excess of carbon disulphide was added to a solution of the imidazothiadiazole in chloroform. The pale yellow adduct, m.p. 94–96°, which slowly separated, was unstable in solution. When warmed in ethanol it afforded 5,6 - dihydroimidazo[2,1 - *c*] - (1,2,4) - dithiazole - 3 - thione 1, identical with an authentic specimen. The unstable adduct was regenerated when the imidazodithiazole - 3 - thione was treated with phenyl isocyanate.

(*e*) *With sulphur dioxide.* When sulphur dioxide was passed through a solution of the imidazothiadiazole in methylene chloride, a colourless solid separated but attempts to purify this presumed 1:1 adduct, m.p. *ca.* 163° (decomp.), were not successful.

(*f*) *With phenyl isocyanate.* To a stirred suspension of the imidazothiadiazole (2 g) in dry tetrahydrofuran (150 ml) phenyl isocyanate (1.1 g) was added all at once. The mixture became clear and then deposited a colourless solid which was collected after 1 h and washed with ether to give colourless needles (2 g) of 3,4 - ethano - 2,3,4,5 - tetrahydro - 1,6, - diphenyl - 6a S^{IV} - thia - 1,3,4,6 - tetraazapentalene - 2,5 - dione 11, m.p. 163–164°; ν_{max} (Nujol) 1690–1720 cm^{-1}; ν_{max} ($CHCl_3$) 1705 and 2250 cm^{-1}. (C=O and N=C=O bonds); NMR signal due to undissociated product 11: δ ($CDCl_3$) 4.52 (s); signals due to the imidazothiadiazole 8, δ ($CDCl_3$) 3.9 (t) and 4.39 (t); the integral values indicate *ca.* 33% dissociation (Found: C, 60.3; H, 4.4; N, 16.7. $C_{17}H_{14}N_4O_2S$ requires C, 60.4; H, 4.1; N, 16.6%).

This adduct reacted rapidly with an excess of phenyl isothiocyanate in methylene chloride to give heteropentalene 2 in 68% yield.

1 - (Benzothiazol - 2 - yl) - imidazolidine - 2 - thione (12)

Bromine, diluted with chloroform, was added gradually to a stirred suspension of 1 - phenylthiocarbamoylimidazolidine - 2 - thione[10] (5 g) in dry ethanol (100 ml) until a yellow colouration persisted. Stirring was continued for 1 h and the white precipitate was then collected, washed with a little ethanol, and treated with aqueous sodium hydrogencarbonate. Recrystallisation from hexane–methylene chloride gave the title compound as colourless needles (4.1 g), m.p. 225–227°; λ_{max} (EtOH) 225, 263, 288, 303 nm (ϵ 17,500, 15,800, 17,500, 22,100); δ ($CDCl_3$) 3.86 (2H, t); 4.66 (2H, t); 6.50 (1H, NH), 7.25–7.81 (4H, m); M^+ *m/e* 235 (Found: C, 50.9; H, 3.8; N, 17.8. $C_{10}H_9N_3S_2$ requires C, 51.1; H, 3.8; N, 17.9%).

When heteropentalene 2 was heated in acetic acid at 100° for 5 min., the same product was obtained.

1 - (Benzothiazol - 2 - yl) - hexahydropyrimidine - 2 - thione (13)

A solution of heteropentalene 4 (0.5 g) in acetic acid (40 ml) was boiled until the volume has been reduced to 10 ml. The benzothiazole (0.1 g) slowly separated from the cooled solution; m.p. 206–208; M^+ *m/e* 249; δ ($CDCl_3$ and d_6-DMSO) 2.12 (2H, m); 3.33 (2H, t); 4.41 (2H, t); 7.23–7.83 (4H, 2d and 2t); 9.50 (1H, NH) (Found: C, 53.3; H, 4.6; N, 16.75. $C_{11}H_{11}N_3S_2$ requires C, 53.0; H, 4.4; N, 16.9%).

REFERENCES

[1]C. W. Pluijgers, J. W. Vonk and G. D. Thorn, *Tetrahedron Lett.* 1317 (1971) and refs. therein.

[2]R. J. S. Beer, N. H. Holmes and A. Naylor, *J. Chem. Soc. Perkin I* 2909 (1979).

[3]L. Kr. Hansen, unpublished data.

[4]K-T. Wei, I. C. Paul, R. J. S. Beer and A. Naylor, *J. Chem. Soc. Chem. Commun.* 264 (1975).

[5]M. L. Huggins, *J. Am. Chem. Soc.* **75**, 4126 (1953).

[6]R. J. S. Beer, D. Frew, P. L. Johnson and I. C. Paul, *Chem. Comm.* 154 (1970); J. Sletten, *Acta Chem. Scand.* **A28**, 989 (1974); J. Sletten and M. Velsvik, *ibid.* **27**, 3881 (1973); F. Leung and S. C. Nyburg, *Can. J. Chem.* **50**, 324 (1972).

[7]R. J. S. Beer, D. McMonagle, M. S. S. Siddiqui, A. Hordvik and K. Jynge, *Tetrahedron* **35**, 1199 (1979).

[8]F. D'Angeli, C. D. Bello and V. Giormani, *Gazzetta Chim. Ital.* **94**, 1342 (1964).

[9]F. D'Angeli and A. Bandel, *Tetrahedron Lett.* 5 (1961).

[10]F. D'Angeli, A. Bandel and V. Giormani, *J. Org. Chem.* **28**, 1596 (1963)