

Reactions of Carbodi-imides with Toluene-*p*-sulphonyl Azide in the Presence of Copper or Pentacarbonyliron

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Reactions of carbodi-imides (1a—d) with toluene-*p*-sulphonyl azide in the presence of copper powder afforded guanidines (3a—d). Reactions with pentacarbonyliron instead of copper powder also gave the guanidines (3). These reactions are thought to proceed by initial formation of an azide-metal complex and/or a nitrene-metal complex, followed by insertion of the carbodi-imides into a metal-nitrogen bond. When the reactions were carried out in pyridine in the absence of metal, a tetrazole (11) and *N*-pyridinotoluene-*p*-sulphonamide were the major products.

WE have reported previously that carbodi-imides and isocyanates are useful reagents for syntheses of heterocyclic compounds.¹⁻⁵ Reactions of carbodi-imides with 1,3-dipolar compounds, however, have been much less investigated than those of other heterocumulenes such as isocyanates and ketens. Reactions of azides with vinyl-

tempts to prepare compounds of type (3) in the absence of copper were unsuccessful, only polymeric materials being obtained (but see below for reactions in pyridine).

To clarify the mechanism, the reaction in carbon tetrachloride was studied and its progress monitored by n.m.r. After a few hours new peaks appeared at δ 0.9, 1.9, and

Reactions of carbodi-imides (1a—d) with the azide (2) in the presence of a metal in chloroform

Run no	Carbodi-imide	Metal	Reaction time (h) ^a	Product	M.p. (°C)	$\nu_{\max.}/\text{cm}^{-1}$ ^b		Yield (%) ^c
						NH	C=N	
1	(1a)	Cu	25	(3a)	148—149	3 230	1 620	72
2 ^d	(1a)	Cu	51	(3a)				14
3 ^e	(1a)	Cu	33	(3a)				81
4	(1b)	Cu	13	(3b)	196—197	3 230	1 615	86
5	(1c)	Cu	13	(3c)	116—117	3 280	1 620	57
6	(1d)	Cu	50	(3d)	144—145	3 350	1 620	39
7	(1b)	Fe(CO) ₅	62	(3b)				66
8	(1c)	Fe(CO) ₅	57	(3c)				30
9	(1d)	Fe(CO) ₅	85	(3d)				24

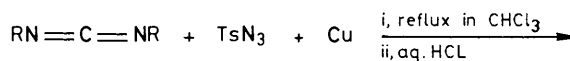
^a Reactions monitored by i.r. spectroscopy. ^b Nujol mulls. ^c Based on carbodi-imide. ^d Catalytic amounts of copper were used (Cu : TsN₃ 1 : 10). ^e Carbodi-imide (1a) added after refluxing TsN₃ and Cu for 20 h.

ideneamines,⁶ isocyanates,⁷ and allenes⁸ are known to give various heterocyclic compounds, but no reports of reactions with carbodi-imides have appeared. In this paper, we report reactions of carbodi-imides with toluene-*p*-sulphonyl azide.

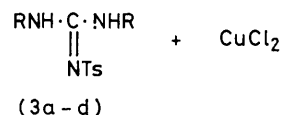
An equimolar mixture of bis-*o*-chlorophenylcarbodi-imide (1a), toluene-*p*-sulphonyl azide (2), and copper powder was refluxed in chloroform; treatment with aqueous hydrochloric acid then afforded 1,3-bis-*o*-chlorophenyl-2-*p*-tolylsulphonylguanidine (3a) in 72% yield (Table). All efforts to isolate intermediates failed. The identification of (3a) was based on spectral data, elemental analysis, and an independent synthesis from the carbodi-imide (1a) and toluene-*p*-sulphonamide. The carbodi-imides (1b—d) reacted similarly.

When the copper-azide ratio was reduced to 1 : 10, the yield of the guanidine (3a) was decreased to 14%. This implies that the reactions proceed *via* a 1 : 1 complex of copper with either the azide or the carbodi-imide. At-

2.3 which increased as a peak at δ 2.3 [due to methyl protons of the azide (2)] decreased. The same new peaks were also observed when a mixture of only the azide (2) and copper powder was refluxed in carbon tetrachloride.



(1a—d) (2)



a; R = *o*-ClC₆H₄

b; R = *o*-MeC₆H₄

c; R = Ph

d; R = cyclohexyl Ts = *p*-MeC₆H₄·SO₂

These results suggest that the reaction proceeds by initial formation of a copper-azide (4) and/or copper-nitrene complex (5). Kwart and Kahn^{9,10} suggested the formation of such complexes in reactions of tosyl azide with

¹ I. Yamamoto, Y. Tabo, H. Gotoh, T. Minami, Y. Ohshiro, and T. Agawa, *Tetrahedron Letters*, 1971, 2295.

² I. Yamamoto, H. Gotoh, T. Minami, Y. Ohshiro, and T. Agawa, *J. Org. Chem.*, 1974, **39**, 3516.

³ I. Yamamoto, S. Ynagi, A. Mamba, and H. Gotoh, *J. Org. Chem.*, 1974, **39**, 3924.

⁴ I. Yamamoto, T. Furukawa, H. Nakajima, and H. Gotoh, *J.C.S. Perkin I*, 1976, 1597.

⁵ I. Yamamoto, A. Mamba, and H. Gotoh, *J.C.S. Perkin I*, 1976, 2243.

⁶ W. J. Kauffman, *J. Org. Chem.*, 1970, **35**, 4233.

⁷ S. M. A. Hai and W. Lwowski, *J. Org. Chem.*, 1973, **38**, 2442; J. M. Vandensavel, G. Smets, and G. L'abbe, *ibid.*, p. 375.

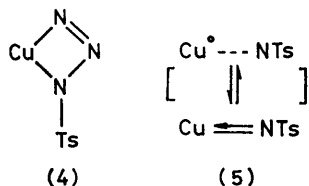
⁸ R. F. Beiholder and H. Schechter, *J. Amer. Chem. Soc.*, 1968, **90**, 1231.

⁹ H. Kwart and A. A. Kahn, *J. Amer. Chem. Soc.*, 1967, **89**, 1950.

¹⁰ H. Kwart and A. A. Kahn, *J. Amer. Chem. Soc.*, 1967, **89**, 1951.

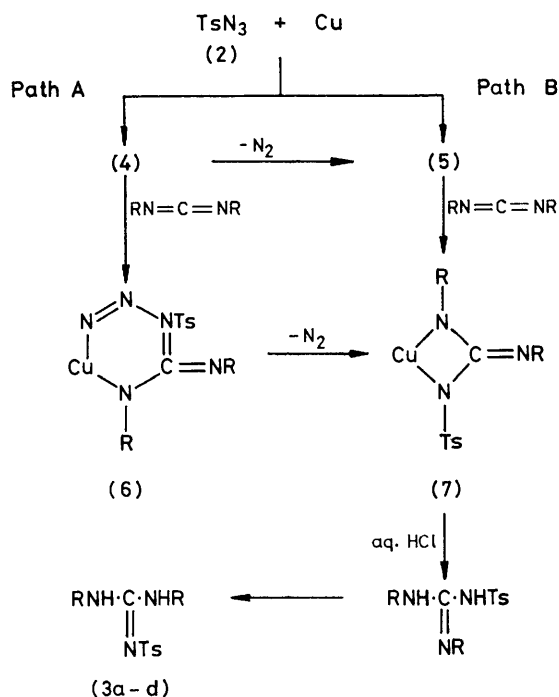
alkenes, sulphoxides, and methanol in the presence of copper.

When the carbodi-imide (1a) was added to a refluxing mixture of the azide (2) and copper in chloroform (from which nitrogen had been evolved) after the disappearance of the characteristic azide i.r. absorption, and the



resulting mixture was then further refluxed for 13 h (a little more nitrogen evolved) and treated with aqueous hydrochloric acid, the guanidine (3a) was obtained in 81% yield. This supports our view that the azide (2) reacts initially with the copper to form a complex (4) and/or (5).

On the basis of the foregoing results, the mechanism shown in the Scheme is suggested. Two pathways (A

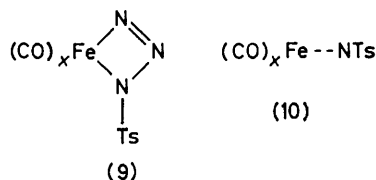


SCHEME

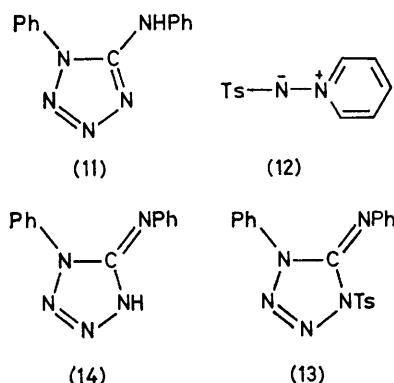
and B) can be envisaged for the formation of the products (3a—d). Path A involves insertion of the carbodi-imide (1) into the copper–nitrogen bond of (4) to form an intermediate (6), which could decompose to a complex (7) with loss of nitrogen. In Path B interaction of the complex (5) with the carbodi-imide (1) leads directly to (7). The fact that the refluxing solution of the azide and copper powder evolved nitrogen indicates that Path B is probably the major pathway but Path A cannot be ex-

cluded. The complex (7) would be expected to be readily decomposed by hydrochloric acid to give the asymmetric guanidine (8), which would isomerize to the symmetrical guanidine (3). If these reactions were to proceed *via* another type of copper complex, such as a dichloroamine–copper complex derived from decomposition of chloroform, other types of guanidine should be obtained. Complexes of type (7) have not been reported previously, and we were unable to obtain further satisfactory evidence for their existence.

Reactions with pentacarbonyliron instead of copper, at room temperature in chloroform, also afforded the guanidines (3b—d) in 24—66% yields (Table). We were able to isolate a complex from the azide (2) and pentacarbonyliron in an aprotic nonpolar solvent (*e.g.* in benzene) as reported by Abramovitch *et al.*¹¹ but in chloroform we could not isolate Abramovitch's complex. Furthermore, when the reaction was monitored by i.r. spectroscopy only a weak peak was observed in the NH region. Thus the major intermediate cannot be a sulphonamide.¹² We therefore suggest that the reactions proceed *via* an azide–iron complex (9) and/or a nitrene–iron complex (10), but probably not *via* a complex of the type described by Abramovitch¹¹ nor *via* a sulphonamide.¹²



When an equimolar mixture of the carbodi-imide (1c) and the azide (2) was refluxed in pyridine for 62 h under nitrogen, 5-anilino-1-phenyltetrazole (11) and *N*-pyridinotoluene-*p*-sulphonamidate (12) were isolated in 24 and 70% yields, respectively. The structure of (11) was



established from spectral data and an independent synthesis from the carbodi-imide (1c) and hydrazoic acid. The formation of (12) can be explained in terms of base-catalysed cycloaddition of the carbodi-imide to the azide to give the tetrazole (13), which could be hydrolysed

¹¹ R. A. Abramovitch, G. N. Knaus, and R. W. Stowe, *J. Org. Chem.*, 1974, **39**, 2135.

¹² R. A. Abramovitch, C. I. Azogu, and R. G. Sutherland, *Tetrahedron Letters*, 1971, 1637; R. A. Abramovitch, G. N. Knaus, and V. Uma, *J. Org. Chem.*, 1974, **39**, 1101.

during column chromatography on alumina to (14); this could then isomerize to the tetrazole (12). Attempts to isolate compound (13) or (14) did not succeed. The dipolar product (12) presumably arises from the pyridine and the nitrene generated from the azide (2).^{13,14}

EXPERIMENTAL

Reactions of Carbodi-imides (1a—d) with Toluene-p-sulphonyl Azide (2) in the Presence of Copper.—General procedure. All these reactions (Table) were carried out by the same procedure except run no. 3. For example (a) a mixture of the carbodi-imide (1a) (6.58 g, 25 mmol), the azide (2) (4.93 g, 25 mmol), and copper powder (1.6 g, 25 mg atom) in chloroform (40 ml) was refluxed for 25 h and to the resulting solution was added 10% hydrochloric acid (50 ml). After 1 h, the mixture was extracted with chloroform and the extract washed with water, dried (CaCl₂), and evaporated. The residue was chromatographed on alumina to afford 1,3-bis-o-chlorophenyl-2-p-tolylsulphonylguanidine (3a) (7.8 g; 72%); m.p. 148—149° (Found: C, 55.5; H, 4.1; N, 9.2. C₂₀H₁₇Cl₂N₃O₂S requires C, 55.3; H, 3.9; N, 9.7%).

(b) *Run no. 3.* A mixture of the carbodi-imide (1a) (6.58 g, 25 mmol) and copper powder (1.6 g, 25 mg atom) in chloroform was refluxed for 20 h (nitrogen evolved), then the carbodi-imide (1a) (6.58 g, 25 mmol) in chloroform was added

dropwise, and the resulting mixture was refluxed for 13 h. After work-up as above, the yield of guanidine (3a) was 8.8 g (81%).

Reactions of the Carbodi-imides (1b—d) with the Azide (2) in the Presence of Pentacarbonyliron.—General procedure. To a mixture of the azide (2) (5.0 g, 25 mmol) and pentacarbonyliron (3.1 ml, 25 mmol) was added the carbodi-imide (1b) (5.5 g, 25 mmol), and the mixture was stirred for 62 h. After work-up as above, the yield of guanidine (3b) was 5.9 g (66%); m.p. 196—197°.

Reaction of the Carbodi-imide (1c) with the Azide (2) in Pyridine.—A mixture of the carbodi-imide (1c) (4.9 g, 25 mmol) and the azide (2) (5.0 g, 25 mmol) in pyridine (40 ml) was refluxed for 80 h. After removal of pyridine, the mixture was chromatographed on alumina [benzene-ethanol (99:1) and ethanol as eluants] to afford 5-anilino-1-phenyl-tetrazole (11) and N-pyridinyltoluene-p-sulphonamidate (12) in 24 (1.4 g) and 70% yields, respectively. Compound (11) had m.p. 158—159°; ν_{\max} 3 200 cm⁻¹ (NH); *m/e* (75 eV) 237 (M⁺), 212, and 209 (Found: C, 65.8; H, 4.8; N, 29.5. C₁₃H₁₁N₅ requires C, 65.8; H, 4.7; N, 29.5). Compound (12) had m.p. 209—210.5°; *m/e* 248 (M⁺) (Found: C, 57.8; H, 5.0; N, 11.1. C₁₂H₁₂N₂O₂S requires C, 58.1; H, 4.9; N, 11.3%).

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¹³ R. A. Abramovitch, and T. Takaya, *J. Org. Chem.*, 1972, **37**, 2022.

¹⁴ D. S. Breslow, 'Nitrenes,' ed. W. Lwowski, Wiley-Interscience, New York, 1970, pp. 277—299.