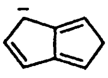
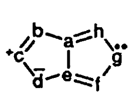
Substituted Tetrahydro Imidazo[4,5-*d*][1,2,3]triazoles and Hexahydrobutanoimidazo[4,5-*d*][1,2,3]triazoles from the Reaction of 1,2,3-Triazolium-1-imides with Aryl Isocyanates and Isothiocyanates. Azolium 1,3-Dipoles

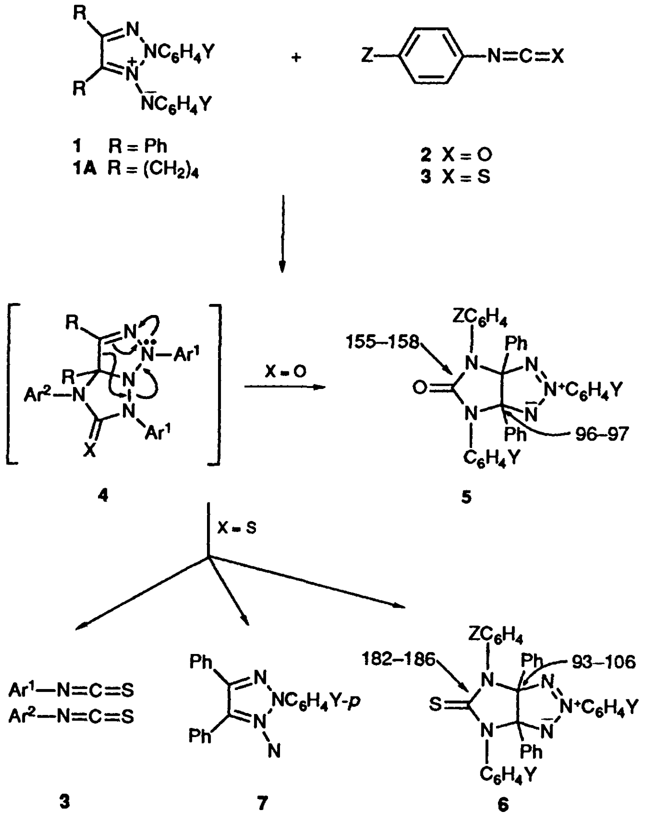
Richard N. Butler* and David M. Colleran
Chemistry Department, University College, Galway, Ireland

The reaction of aryl substituted 1,2,3-triazolium-1-imide 1,3-dipoles with substituted aryl isocyanates and isothiocyanates gave new ring systems based on the imidazo[4,5-*c*][1,2,3]triazole structure. With the isothiocyanates an apparent exchange of aryl groups between the dipole and recovered isothiocyanate dipolarophile shed light on the initial intermediate in the reaction.

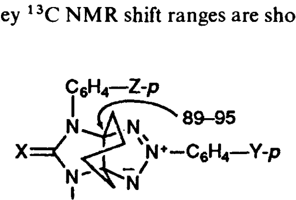
The heteropentalene systems based on the pentalene dianion **A** have attracted major interest.[1–5] There is a large number[3] of possible molecular types with both classical[4] and non-classical[5] structures. These arise from 10 possible neutral bonding arrangements which are isoconjugate with the pentalene dianion, four of which are non-classical mesomeric betaine structures.[5] One of these four is structure **B** and known examples[3–5] of this category include the 1,2,3-triazol-2-ium-1-ide moiety fused to a range of other azoles including triazoles, pyrazoles, oxadiazoles and thiadiazoles.[3–5] Conspicuous by its absence[3–5] however, in this series is an imidazole ring fused to the 1,2,3-triazole system, *i.e.* structure **C**. We now report substituted derivatives of this ring structure. In exploring the synthetic scope[6–9] of the triazolium imide 1,3-dipoles **1** we are examining their reactions with cumulene systems and have observed interesting behaviour with isocyanates **2**, and isothiocyanates **3** (Scheme 1). The dipoles **1** reacted with these dipolarophiles at the N=C bond by the route which we have previously established[7,8] as a general reaction namely a cycloaddition followed by a 1,4-N→C sigmatropic rearrangement in the initial adduct **4**. Thus, when treated with the isocyanates **2** under reflux in acetone the triazolium imides **1** gave high yields of the new oxoimidazoltriazolines **5** (Table 1), derivatives of the azapentalene structure **C**. With dipoles **1** (RR, $[CH_2]_4$), derived from cyclohexa-1,2-diene, the products were the interesting new penta-aza propellanes **8**, a hexahydrobutanoimidazo[4,5-*d*][1,2,3]triazole system (Table 1). The reactions with the isothiocyanates **3** similarly occurred on the N=C bond and gave the corresponding thione products **6** and **9** (Table 2). However these reactions also gave an added insight into the initial adduct **4** which has never been directly detected. The sulfur derivatives of the intermediate **4** (X=S) appear to be significantly less stable than the oxygen series **4** (X=O) and this instability was increased by either electron donating or withdrawing substituents in any of the *N*-aryl rings of **4** (X=S) (Table 2, Entries 1-5, 8-12). Thus at reflux temperatures in acetone the products of the reaction of the series **1** (Y ≠ H), with **3** (Z=H), or of **1** (Y=H) with **3** (Z ≠ H) gave mainly the triazoles **7**, small quantities of the imidazotriazolines **6** and two aryl isothiocyanates, one of which was the original reactant and the other of which had exchanged its aryl group for an aryl group from the dipole **1** (Table 2, Entries 8, 9, 11, 12). The formation of both types of isothiocyanates accompanying the products **7** lends support for the intermediates **4** which can readily fragment to all of these products. Furthermore the fragmentation could be restrained by lowering the temperature resulting in improved yields of **6** and reduced yields of **7**, thereby indicating a competition between fragmention and rearrangement in the intermediates **4** (X=S) [Tables 2, Entries 5–7].


A


B
C a, e, g = C; b, c, d, h, f = N



Scheme 1 Some key ^{13}C NMR shift ranges are shown



8 X = O
9 X = S

The structures of the new products were established by microanalyses, IR spectra, ^1H and ^{13}C NMR spectra. The oxo

Table 1 Products (X=O)[a]

Entry	Compound	Y	Z	M.p. (T/°C)[b]	Yield (%)	Microanalysis (%) Found (required)		
						C	H	N
1	**5a**	H	NO_2	259–260	92	71.3 (71.7)	4.4 (4.35)	15.4 (15.2)
2	**5b**	H	Br	236	81	67.55 (67.6)	4.0 (4.1)	12.0 (11.95)
3	**5c**	H	H	232–233	91	77.8 (78.1)	4.8 (4.9)	13.5 (13.8)
4	**5d**	H	MeO	222–223	87	75.8 (75.95)	5.1 (5.05)	13.5 (13.05)
5	**5e**	NO_2	NO_2	302[c]	95	61.4 (61.7)	3.3 (3.4)	17.4 (17.45)
6	**5f**	Br	Br	275	90	52.9 (53.2)	2.9 (2.95)	9.1 (9.4)
7	**5g**	MeO	MeO	173	90	72.2 (72.4)	5.3 (5.2)	11.7 (11.7)
8	**5h**	NO_2	H	277	89	66.3 (66.3)	3.9 (3.85)	16.5 (16.4)
9	**5i**	Br	H	269[c]	90	59.45 (59.5)	3.6 (3.5)	10.4 (10.5)
10	**5j**	Me	H	237–238	82	78.3 (78.5)	5.4 (5.4)	13.0 (13.1)
11	**5k**	MeO	H	228–229	82	73.9 (74.05)	5.0 (5.1)	12.0 (12.35)
12	**8a**	H	H	152	82	72.9 (73.35)	6.05 (5.6)	17.0 (17.1)
13	**8b**	NO_2	H	262–263	82	59.8 (60.1)	4.0 (4.2)	19.6 (19.6)

[a] All reactions in acetone under reflux. [b] All recrystallised from EtOH unless otherwise stated. [c] From acetone.

Table 2 Products[a] (X=S) (i) Z=H (Reactions in acetone), (ii) Y=H (reactions under reflux), (iii) Y=H (reactions in acetone under reflux with **1a**)

(i)

			Products						Microanalyses for compound **6** (%) Found (required)		
Entry	Y	Temp.[b]	Compd.	M.p. (T/°C)	Yield (%)	Compd.	M.p. (T/°C)	Yield (%)	C	H	N
1	H	Reflux	**6a**	265–266	88	**7a**	123	<1	75.8 (75.7)	4.9 (4.8)	13.05 (13.4)
2	MeO	Reflux	**6b**	254–255	48	**7b**	92–92	30	71.6 (72.05)	4.9 (5.0)	11.7 (12.0)
3	Me	Reflux	**6c**	238	34	**7c**	111–112	51	76.3 (76.2)	5.35 (5.25)	12.4 (12.7)
4	Br	Reflux	**6d**	—	<1	**7d**	144–145	88	—	—	—
5	NO_2	Reflux	**6e**	227–228	<1	**7e**	161–162	90	64.2 (64.6)	3.6 (3.75)	16.4 (16.0)
6	NO_2	Ambient	**6e**	227–228	27	**7e**	161–162	63	64.2 (64.6)	3.6 (3.75)	16.4 (16.0)
7	NO_2	2 °C	**6e**	227–228	36	**7e**	161–112	46	64.2 (64.6)	3.6 (3.75)	16.4 (16.0)

(ii)

	Z	Compd.	M.p. (T/°C)	Yield (%)	Yield of *7a* (%)	Yield of PHNCS (%)	Yield of ZC_6H_4NCS (%)
8	NO_2	**6f**	247–248	11	80	46	22
9	Br	**6g**	261	30	57	29	25
10	H	**6a**	265–266	88	<1	<1	<1
11	MeO	**6h**	231–232	35	46.5	2	40
12	Me	**6i**	231	42	48	10	35

(iii)

	Z	Compd.	M.p. (T/°C)	Yield (%)	Microanalysis (%) Found (Required)		
					C	H	N
13	NO_2	**9a**	137–138	71	57.8 (58.2)	4.2 (4.1)	18.7 (19.0)
14	H	**9c**	210–212	80	70.3 (70.6)	5.2 (5.4)	16.0 (16.45)

[a] All recrystallised from EtOH unless otherwise stated. [b] Reaction conditions.

series **5** and **8** showed strong amido IR bands at 1700–1725 cm^{-1} and a C=O ^{13}C signal at 155–157.5 ppm. For the thione series **6** and **9** the C=S ^{13}C signal was at 182–185.5 ppm. All of the compounds showed the characteristic bridgehead carbons at 89–102 ppm in their ^{13}C NMR spectra. As expected for those cases where the substituents Y and Z (Scheme 1) were the same the products have a plane of symmetry thereby halving the number of ^{13}C signals and showing only one bridgehead carbon. Throughout the full series of compounds all of the other signals in the spectra were as expected for the structures shown.

Experimental

M.p.s were measured on an Electrothermal apparatus and are uncorrected. Elemental analyses were performed on a Perkin Elmer 240 CHN Analyser. NMR spectra were measured with a JEOL JNM-GX 270 FT NMR spectrometer with tetramethylsilane as internal reference and $CDCl_3$ as solvent, J values are given in Hz. The substrates **1** and **1A** were prepared as previously described[6–9] and the series **2** and **3** were supplied by Aldrich. The cycloaddition reactions were carried out in acetone at the temperatures indicated until TLC showed complete reaction. For cases with a single product, the solvent was removed and the residue crystallised from ethanol. For cases involving mixtures of products the residue was separated on a flash column of silica gel (230–400 mesh ASTM) using light petroleum (b.p. 40–60 °C)–dichloromethane gradient mixtures as eluents. The following are some examples:

2,3a,4,6,6a-*Pentaphenyl*-5-*oxo*-3,3a,4,4a,6,6a-*hexahydroimidazo*[4,5-d][1,2,3]*triazol*-2-*ium*-3-*ide* **5c**. A solution of 1,2-diphenyl-1,2-bisphenylazoethene (2,4,5-triphenyl-2*H*-triazol-1-

ium-1-*N*-phenylimide) **1c** (1.0 g, 2.58 mmol) in acetone (25 cm^3) was treated with phenyl isocyanate (0.3 cm^3, 2.8 mmol) and stirred under reflux for 3 h. The solvent was removed under reduced pressure and the residue crystallised from ethanol to give **5c** (1.18 g, 91%), m.p. 232–233 °C (from EtOH); ν_{max}/cm^{-1} 1714 (C=O); δ_H(CDCl$_3$) 8.46 (2 H, d, *J* 8.05, 2-N-Ph, H$_{ortho}$), 7.82 (4 H, d, *J*, 8.6, 4-N-Ph, H$_{ortho}$), 6.91–7.58 (m, remaining Ar); δ_C(CDCl$_3$) 156.4 (C=O), 140.3, 137.05, 132.5, 129.3, 128.4, 128.1, 127.8, 127.65, 124.75, 124.05, 123.05 and 96.7 (bridgehead C-3a, C-6a).

2,4,6-*Triphenyl*-5-*thioxo*-3,3a,4,4a,5,5a-*hexahydro*-3a,6a-*butanoimidazo*[4,5-d]*triazol*-2-*ium*-3-*ide*, **9c**. A solution of 1,2-bisphenylazocyclohexene (2-phenyl-4,5,6,7-tetrahydro-2*H*-benzo[d]triazol-1-ium-1-*N*-phenylimide) **1A** (Y = H) (0.5 g, 1.7 mmol) in acetone (10 cm^3) was treated with phenyl isothiocyanate (0.22 cm^3, 1.8 mmol) and stirred under reflux for 30 min. The solvent was removed under reduced pressure and the residue crystallised from ethanol to give **9c** (0.6 g, 82%), m.p. 211–212 °C (from EtOH); δ_H(CDCl$_3$) 8.23 (2 H, d, *J* 7.7, 8-N-Ph, H$_{ortho}$), 7.33–7.62 (m, remaining Ar), 1.89–2.13 (m, 4 H) and 1.48–1.69 [m, 4 H, (CH$_2$)$_4$]; δ_C 183.1 (C=S), 140.1, 137.45, 132.3, 129.55, 129.2, 128.9, 128.3, 122.7, 93.6 (bridgehead C-1, C-6), 27.95 and 17.3 (CH$_2$)$_4$.

References

1 C. A. Ramsden, *Tetrahedron*, 1977, **33**, 3203.

2 K. T. Potts, *Chem. Heterocycl. Compd.*, 1977, **30**, 317.

3 J. Elguero, R. M. Claramunt and A. J. H. Summers, *Adv. Het. Chem.*, 1978, **22**, 182.

4 K. H. Pilgrim, *Comprehensive Heterocyclic Chemistry*, eds. A. R. Katritzky and C. W. Rees, vol. 6 (ed. K. T. Potts), Pergamon Press, Oxford, 1984, part 4B, p. 973.

5 C. A. Ramsden, *Comprehensive Heterocyclic Chemistry*, eds. A. R. Katritzky and C. W. Rees, vol. 6, (ed. K. T. Potts), Pergamon Press, Oxford, 1984, part 4B, p. 1027.

6 R. N. Butler, P. D. O'Shea, D. Cunningham and P. McArdle, *J. Chem. Soc., Perkin Trans. 1*, 1989, 371.

7 R. N. Butler, A. M. Evans, E. McNeela, G. A. O'Halloran, P. D. O'Shea, D. Cunningham and P. McArdle, *J. Chem. Soc., Perkin Trans. 1*, 1990, 2527.

8 R. N. Butler, A. M. Evans, A. M. Gillan, J. P. James, E. McNeela, D. Cunningham and P. McArdle, *J. Chem. Soc., Perkin Trans. 1*, 1990, 2537.

9 R. N. Butler, A. M. Gillan, S. Collier and J. P. James, *J. Chem. Res. (S)*, 1987, 332.

Paper 2/02636H
Received 20*th May* 1992
Accepted 3*rd June* 1992