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SUBSTITUENT AND COORDINATION EFFECTS IN SINGLET REACTIONS OF 3-DIAZO-3H-1,2,4-TRIAZOLES WITH SUBSTITUTED BENZENES AND NITRO COMPOUNDS

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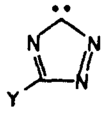
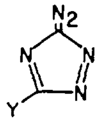
Abstract: 3-Diazo-3H-1,2,4-triazoles convert to singlet 3H-1,2,4-triazol-3-ylidenes which (1) effect directed electrophilic substitutions of benzenes and (2) coordinate with benzenoid substituents and nitro compounds to give decomposition or rearrangement products.

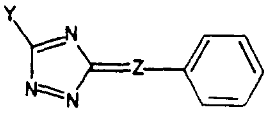
Aromatic substitution by carbenes is important synthetically and mechanistically.$^{1a-o}$ We now report the effects of substituents on the reactions of benzenes with 3H-1,2,4-triazol-3-ylidene (1) and 5-phenyl-3H-1,2,4-triazol-3-ylidene (2) as generated from 3-diazo-3H-1,2,4-triazole (3) and 3-diazo-5-phenyl-3H-triazole (4).^{1p} These investigations reveal (1) impressive orientational selectivities in aromatic substitution by kinetically insensitive electrophilic carbenes, (2) substitution patterns consistent with addition of singlet carbenes (1 and 2) to varied benzenes followed by dipolar ring-opening and hydrogen migration, (3) the abilities of carbenes to coordinate with benzene substituents (Z) to form ylides 5 and 6 which enter into and/or alter the substitution reactions and (4) effective oxygen transfer processes from nitrobenzene into 1 and 2. Because of the behavior of 2 with nitrobenzene, its reactions with representative primary and secondary nitro compounds have also been studied.



1, Y = H
2, Y = C_6H_5

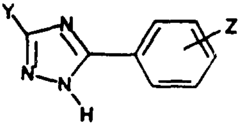


3, Y = H
4, Y = C_6H_5

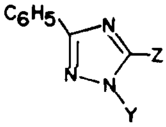


5, Y = H
6, Y = C_6H_5

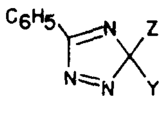
Photolyses and thermolyses of 3 and 4 in varied benzenes have now been found to result in aromatic substitution to give 5-(substituted-phenyl)-1H-1,2,4-triazoles (7) and 5-(substituted-phenyl)-3-phenyl-1H-1,2,4-triazoles (8).^{1q} Products of ring expansion of the benzenes are not obtained. As summarized in Table 1, ortho- and para- rather than meta-substitutions are the principal reactions of 1 and 2 with anisole, toluene, chlorobenzene



7, Y = H
8, Y = C_6H_5



9, Y = H , Z = $CH_2C_6H_5$
10, Y = C_6H_5, Z = Cl
11, Y = C_6H_5, Z = Br
12, Y = $CF_2C_6H_5$, Z = F



13, Y = H, Z = $CH_2C_6H_5$
14, Y = $CF_2C_6H_5$, Z = F

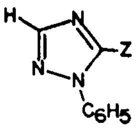
and bromobenzene. Insertion of 4 into the methyl group of toluene also occurs to give 5-benzyl-3-phenyl-1*H*-1,2,4-triazole (9, 12%) presumably upon rearrangement of 5-benzyl-3-phenyl-5*H*-1,2,4-triazole (13). *Meta*-substitutions are the major reactions of methyl benzoate and benzonitrile with 1 and of *α,α,α*-trifluorotoluene with 1 and 2. 5-Fluoro-1-(*α,α*-difluorobenzyl)-3-phenyl-1*H*-1,2,4-triazole (12, 6-7%) also arizes from *α,α,α*-trifluorotoluene and 2, possibly by (1) insertion of 4 into a C-F bond of the toluene and rearrangement of 3-(*α,α*-difluorobenzyl)-3-fluoro-5-phenyl-3*H*-1,2,4-triazole (14) and/or (2) abstraction of fluorine by 4 (via an ylide of type 6) and capture of the *α,α*-difluorobenzyl moiety.

Table 1. Percentage Compositions of 7 and 8 from Photolyses and Thermolyses of 1 and 2 in Substituted Benzenes; Relative Thermal Molar Reactivities of 1 with Substituted Benzenes.

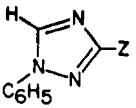
Z in C_6H_5Z	7 from 1 Δ,%[a]			7 from 1 hr,%[b]			Rel. React. of 1[c] with C_6H_5Z	8 from 2 Δ,%[d]		
	o	m	p	o	m	p		o	m	p
OCH_3	52	8	40	53	10	37	1.32	42	--	58
CH_3	57	9	33	59	10	31	1.09	67	--	33
H							1.00			
Cl	51	9	40	76	8	16	0.67	9	--	91
Br	58	--	42	63	--	37		55	--	45
CF_3	--	84	16	--	83	17	0.63	--	100	--
CO_2CH_3	33	67	--	53	47	--				
CN	11	75	14	20	62	18				
NO_2		100	--		100			--	100	--

[a] Effected at 80°C. [b] Irradiation in Pyrex with an Hanovia 450 watt medium pressure Hg lamp at 0-10°C. [c] Relative molar reactivities of 1 at 80°C with mixtures of a substituted benzene and benzene. [d] Isomer percentages from reactions of the indicated benzenes with 2 at 60°C.

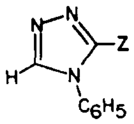
Of special interest is that thermolysis or photolysis of 3 in chlorobenzene yields (~5%) 5-chloro-1-phenyl-1*H*-1,2,4-triazole (15), 3-chloro-1-phenyl-1*H*-1,2,4-triazole (17) and 3-chloro-4-phenyl-*H*-1,2,4-triazole (19) along with products of aromatic substitution. Similarly, 1 and bromobenzene give 5-bromo-1-phenyl-1*H*-1,2,4-triazole (16), 3-bromo-1-phenyl-1*H*-1,2,4-triazole (18) and 3-bromo-4-phenyl-4*H*-1,2,4-triazole (20). Further, 2 reacts with chlorobenzene and bromobenzene to yield 5-chloro-1,3-diphenyl-1*H*-1,2,4-triazole (10, ~1%) and 5-bromo-1,3-diphenyl-1*H*-1,2,4-triazole (11, 12%) respectively. Formation of 10, 11 and 15-20 presumably involves coordination of 1 and 2 with the halo atoms in chlorobenzene and bromobenzene to form ylides 5 (Z = Cl and Br) and 6 (Z = Cl and Br) which then isomerize.[1r]



15, Z = Cl
16, Z = Br

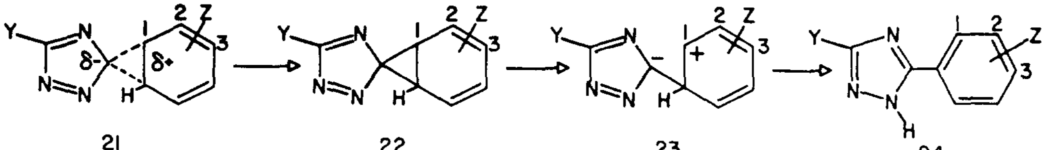


17, Z = Cl
18, Z = Br



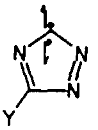
19, Z = Cl
20, Z = Br

Photolyses of 3 and 4 in matrix in tetrahydrofuran at 77°K give no signals for 1 and 2 as triplets. The relative molar reactivities of 1 with the benzenes (Table 1) are : anisole > toluene > benzene > chlorobenzene > *α,α,α*-trifluorotoluene. Also, 1 reacts slightly faster with benzene-d_6 than with benzene ($^kD/^kH$ = 1.04). These experiments along with the directing effects of substituents are interpreted to indicate (Eq 1) that (1) 1 and 2 add to benzenes as *electrophilic singlets* rather than by insertion into C-H bonds, (2) carbenic attacks on the benzenes occur by *rate-determining, low activation energy processes* and (3) the highly selective substitution patterns come from *formation* of spiro[norcara-2,4-diene-7,3'-[1,2,4]-triazoles] (22) which then collapse *heterolytically* to 23 with major substituent control (Eq 1). Of particular interest is that the overall results are not accommodated by addition to the benzenes by 1 or 2 as *diradical singlets* (25; Y = H or C_6H_5) or *triplets* (26; Y = H or C_6H_5) or by rearrangements of 22 by *diradical processes* via 27. Further, the above experiments support the postulate that azolylidenes having nitrogen in an *alpha* position react with various substrates as S_2-like singlets (such as 28-29) rather than as triplets.[10]



(1)

21 22 23 24



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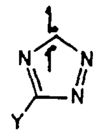

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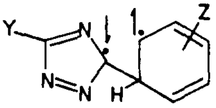

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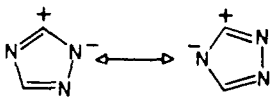
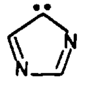


28 29

In previous research 4*H*-imidazolylidene (30) was found to attack nitrobenzene primarily at an *ortho*-position (61-97%).[10] For conversion of nitrobenzene by 30 to 4-(*o*-nitrophenyl)-4*H*-imidazole (31), substitution is presumed to involve coordination with the nitro group, possibly as in 32, and then reorganization.[10] Study has now concentrated on the behavior of



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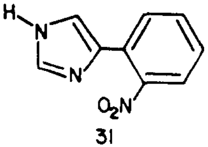

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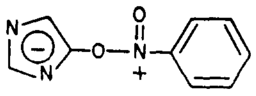
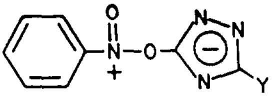


32

nitrobenzene with 1 and 2. Of note is that 4 reacts with nitrobenzene at 60°C or photolytically at 0°C to give 5-(*m*-nitrophenyl)-3-phenyl-1*H*-1,2,4-triazole (24, Y = C_6H_5, Z = 2-NO_2; 17%) along with nitrosobenzene (34, 75%), benzonitrile (36, Y = C_6H_5; 83%) and a mixture (~3 equiv) of nitrogen (37) and carbon monoxide (38) in ~2:1 ratio. Similarly, thermolyses of 3 in nitrobenzene at 80°C and at 185°C yield 5-(*m*-nitrophenyl)-1*H*-1,2,4-triazole (24, Y = H, Z = 2-NO_2; 52 and 38%), 34 (48 and 62%), hydrogen cyanide (36, Y = H), 37 and 38. Clearly, the nitro group is *meta*-directing in the substitutions of nitrobenzene by 1 and 2.[10] Thus, *substituent-controlled, dipolar ring-openings* of 22 (Y = C_6H_5, Z = 2- and 3-NO_2; Y = H, Z =

2- and 3-NO_2) as in Eq 1 account for formation of 24 (Y = C_6H_5, Z = 2-NO_2; Y = H, Z = 2-NO_2) from nitrobenzene with 2 and with 1.

An additional important feature of the behavior of nitrobenzene with 3 and with 4 is oxygen-abstraction to yield 34 effectively.[1s] The oxygen-transfer processes to give 34 apparently involve coordination of 1 and 2 with the nitro group in nitrobenzene and fragmentation of 33 (Y = H and C_6H_5) to 1,2,4-triazol-3-ones 35 (Y = H and C_6H_5). Triazol-3-ones 35 (Y = H and C_6H_5), as yet undetected intermediates and members of an unreported heterocyclic system, presumably collapse to 36 (Y = H and C_6H_5), 37 and 38. For intermediates 33 to convert to 34 and 35 whereas 32 isomerizes to 31 is remarkably subtle[10] and thus the reactions of nitrobenzene with other diazo compounds and carbenes are to be studied in detail.



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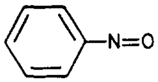

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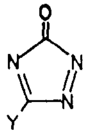


35

$Y{-}C{\equiv}N$

36

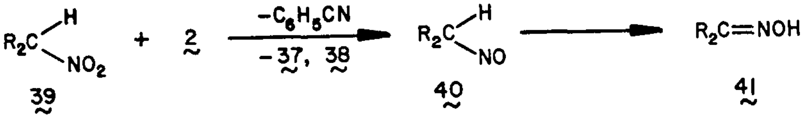
$N{\equiv}N$

37

$C{=}O$

38

Investigation has been initiated of the behavior of 2 with varied nitro compounds (39). Thermolyses of 4 in nitroethane, 1-nitropropane, 2-nitropropane, nitrocyclohexane and 2-methyl-2-nitropropane, respectively, at 80°C occur with oxygen transfer to give ethanal oxime (>30%), propanal oxime (>48%), propanone oxime (98%), cyclohexanone oxime (86%) and 2-methyl-2-nitrosopropane (86%) along with benzonitrile (36, Y = C_6H_5; 66-99%) resulting from decompositions of 35 (Y = C_6H_5). The oximes (41) formed arise from oxygen abstraction from 39 by 2 and tautomerization of the nitroso compounds (40) initially generated (Eq 2).



(2)

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References and Notes

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