The Reaction of Certain Heterocyclic Azides with Triphenylphosphine

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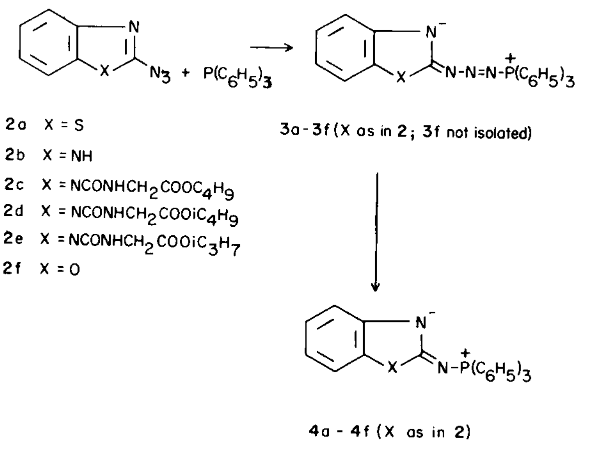
Azidobenzothiazole and azidobenzimidazole and certain of its derivatives react with triphenylphosphine to give isolatable adducts which decompose thermally to give the corresponding phosphinimines. 2-Azidobenzoxazole gives an adduct which loses nitrogen at 15-20° and gives the phosphinimine directly. Methylation of the phosphinimines occurs at the hetero nitrogen, whereas benzoylation occurs at the *exo* nitrogen atom. The structures of the alkylation and aroylation products of the phosphinimines were established.

It is known that tertiary phosphines react with a wide variety of covalent azides to give nitrogen and phosphinimines. In a few instances an intermediate complex of the azide and phosphine has been isolated, but in most cases the complexes decompose spontaneously to phosphinimines at room temperature or below (1,2). The crystalline complexes formed from triphenylphosphine and triphenylmethylazide or 9-phenyl-9-fluorenylazide are examples of stable complexes (3). These complexes melt with decomposition at 104-105° and 73-74°, respectively (3).

In the course of our investigation of the reactions of heterocyclic azides (4), we have studied the reaction of some heterocyclic azides with triphenylphosphine (**1**). The azides **2a**-**2e** gave stable complexes (**3a**-**3e**) with **1**, but **2f** formed an unstable complex and the phosphinimine (**4f**) was isolated from the reaction mixture. The complexes **3a**-**3e** were converted in high yields to the phosphinimines **4a**-**4e** in hot toluene. These reactions are illustrated in Scheme I.

Scheme I

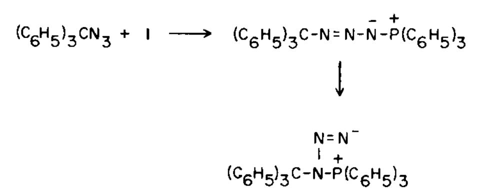


2a X = S
2b X = NH
2c X = $NCONHCH_2COOC_4H_9$
2d X = $NCONHCH_2COOiC_4H_9$
2e X = $NCONHCH_2COOiC_3H_7$
2f X = O

3a-3f (X as in 2; 3f not isolated)

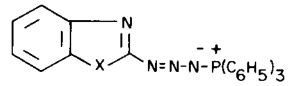
4a - 4f (X as in 2)

The formation of stable complexes from azidobenzimidazole or benzothiazole and unstable complexes in the case of benzoxazole was of interest. The stability of the complex formed from triphenylmethylazide and **1** has been attributed to steric effects which prevent the formation of a transition state such as **5** (3), but this explanation is not adequate for the heterocyclic azides.



5

An attractive possibility is that the stable complexes are best represented by the cyclic structure **7** and the unstable complex by the open-chain structure **6**.



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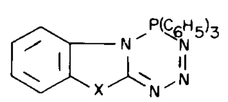


7 (X = S, NH)

The failure of **6** to cyclize could be due to the electronegativity of the heterocyclic oxygen (X = O) which prevents the development of a negative charge in the hetero nitrogen atom, whereas the less electronegative sulfur and nitrogen do not prevent this cyclization. An alternate explanation is that the additional resonance

TABLE I

Physical Properties of Compounds

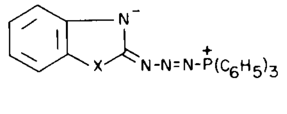
Compound Number	Empirical Formula	Analyses Calcd. / Found C	H	N	P	Mp, °C	Yield %	Method of Preparation	Ultraviolet Spectra in Acetonitrile λ (ε x 10^{-3})
2a	$C_7H_4N_4S$							Ref. 4	
2b	$C_7H_5N_5$							Ref. 4	232 (9.1) 284 (12.8)
2c	$C_{14}H_{16}N_6O_3$	53.2 52.9	5.1 5.0	26.6 26.7		67	80	A	236 (12.3) 283 (13.8)
2d	$C_{14}H_{16}N_6O_3$	53.2 52.7	5.1 5.1	26.6 26.4		90	83	A	-- --
2e	$C_{13}H_{14}N_6O_3$	51.6 51.9	4.7 4.9	27.8 27.7		113	78	A	
2f	$C_7H_4N_4O$							Ref. 4	
3a	$C_{25}H_{19}N_4PS$	68.5 68.3	4.4 4.5	12.8 12.5	7.1 6.9	75 dec.	82	B	220 (32.0) 266 (11.5) 290 (8.6) 352 (6.2)
3b	$C_{25}H_{20}N_5P$	71.2 71.3	4.8 4.8	16.6 16.4	7.4 7.2	103 dec.	87	B	290 (14.2)
3c	$C_{32}H_{31}N_6O_3P$	66.4 66.3	5.4 5.5	14.5 14.4		112 dec.	79	B	266 (14.9) 290 (13.7) 273 (14.6) 350 (6.3)
3d	$C_{32}H_{31}N_6O_3P$	66.4 66.4	5.4 5.2	14.5 14.6		104 dec.	76	B	
3e	$C_{31}H_{29}N_6O_3P$	65.9 65.8	5.2 5.0	14.9 14.8		128 dec.	84	B	
4a	$C_{25}H_{19}N_2PS$	73.1 73.4	4.7 4.2	6.8 6.6	7.5 7.5	138	93	C	
4b	$C_{25}H_{20}N_3P$	76.3 76.6	5.1 4.9	10.7 10.5		224	82	C	218 (56.2)~255 (8.4) 296 (15.2)
4c	$C_{32}H_{31}N_4O_3P$	69.8 69.9	5.7 5.4	10.2 10.2		134	80	C	222 (48.0) 266 (11.7) 272 (11.0) 296 (12.8)
4d	$C_{32}H_{31}N_4O_3P$	69.8 69.5	5.7 5.8	10.2 10.4		155	77	C	
4e	$C_{31}H_{29}N_4O_3P$	69.4 69.2	5.4 5.4	10.4 10.2		217	86	C	
4f	$C_{25}H_{19}N_2OP$	76.1 76.3	4.9 5.3	7.1 7.1		176	84	C	
9a	$C_{26}H_{22}ClN_2O_4PS$	59.5 59.4	4.2 4.1	5.3 5.3		258	73	D	224 (48.2) 273 (14.5) 293 (13.9) 298 (21.8)
9b	$C_{26}H_{23}ClN_3O_4P$	61.5 61.7	4.6 4.5	8.3 8.0		243	67	D	217 (50.8) 276 (11.9) 269 (8.1) 293 (20.5)
9c	$C_{26}H_{22}ClN_2O_5P$	61.4 61.3	4.4 4.4	5.5 5.3		240	69	D	

TABLE I (continued)

Physical Properties of Compounds

Compound Number	Empirical Formula	Analyses Calcd. / Found C	H	N	P	Mp, °C	Yield %	Method of Preparation	Ultraviolet Spectra in Acetonitrile λ (ε x 10⁻³)
10a	$C_8H_8N_2S$	Ref. 5				123			264 (8.7) 301 (4.8)
10b	$C_8H_9N_3$	Ref. 6				202			252 (6.4) 287 (6.9)
10c	$C_8H_8N_2O$	Ref. 7				91			244 (8.3) 287 (6.9)
10a perchlorate	$C_8H_9ClN_2O_4S$	36.3 36.0	3.4 3.2	10.6 10.5		205	88	E	253 (7.8) 276 (5.4) 284 (4.9) 305 (6.9)
10b perchlorate	$C_8H_{10}ClN_3O_4$	38.8 38.5	4.1 4.2	17.0 16.8		180	83	E	275 (7.6) 278 (6.9)
10c perchlorate	$C_8H_9ClN_2O_5$	38.6 38.9	3.6 3.8	11.3 11.5		234	91	E	228 (9.2) 263 (4.8) 277 (2.1)
11a	$C_8H_8N_2S$	Ref. 5				138	65	F	267 (14.4) 296 (3.0)
11b	$C_8H_8N_2O$	64.8 64.6	5.4 5.3	18.9 18.7		109	75	F	243 (14.7) 278 (7.6)
11a perchlorate	$C_8H_9ClN_2O_4S$	36.3 36.3	3.4 3.6	10.5 10.5		147	88	E	263 (13.1) 284 (4.4)
11b perchlorate	$C_8H_9ClN_2O_5$	38.6 38.6	3.6 3.7	11.3 11.0		148	87	E	248 (10.1) 284 (6.4)
13a(11)	$C_{14}H_{10}N_2OS$	66.1 66.1	4.0 3.9	11.0 10.7		186	86	G, H	229 (22.4) 266 (10.5) 296 (16.6)
13b	$C_{14}H_{11}N_3O$	Ref. 8				242	89	G	220 (18.2) 266 (7.0) 299 (18.2)
13c	$C_{14}H_{10}N_2O_2$	70.6 70.4	4.2 4.4	11.8 11.5		182	76	G	230 (12.2)~266 (9.5) 297 (17.4)
13d	$C_{21}H_{15}N_3O_2$	73.9 73.7	4.4 4.6	12.3 12.3		214	81	G	248 (20.1) 306 (15.6) 325 (15.4)
14a	$C_{15}H_{12}N_2OS$	67.1 66.9	4.5 4.3	10.4 10.1		155	84 76	G H	236 (18.6) 264 (4.0) 283 (3.5) 329 (29.4)
14b	$C_{15}H_{12}N_2O_2$	71.4 71.3	4.8 5.0	11.1 10.8		140	86 55	G H	236 (15.3)~261 (5.2) 273 (5.9) 306 (25.8)
14c	$C_{15}H_{13}N_3O$	71.7 71.8	5.2 5.6	16.7 16.3		160	71 61	G H	258 (6.6) 269 (3.7) 319 (30.4)
14a perchlorate	$C_{15}H_{13}ClN_2O_5S$	48.8 48.8	3.6 3.4	7.6 7.6		250	78	I	237 (19.4) 262 (5.2) 275 (4.3) 284 (3.9)
15a	$C_{15}H_{12}N_2OS$	67.1 67.4	4.5 4.4	10.4 10.7		113	82	G	280 (16.2) 289 (15.4) 300 (14.8)
15b	$C_{15}H_{12}N_2O_2$	71.4 71.4	4.8 5.1	11.1 11.0		80	76	G	243 (12.8) 292 (12.0)

energy which is derived from contributors such as **8** stabilizes the complexes. The complexes **3a-3e** do not



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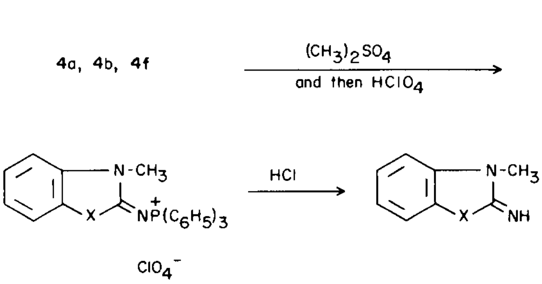
show absorption in the 4-μ region in a potassium bromide disk or in a Nujol mull. The stable triphenylmethyl complex was reported (3) to show no absorption in this region in the solid state, but to absorb in solution. This effect was attributed to dissociation of the complex in solution. Since the evidence relating to the structure of the complexes formed from azides and **1** is inconclusive, we have arbitrarily used the open-chain structures **3a-3e**.

The phosphinimines **4a-4f** are stable crystalline solids which react with methyl sulfate to give phosphiniminium salts (isolated as the perchlorate), in which the alkylation has taken place exclusively on the hetero nitrogen. The structure of the phosphiniminium salts **9a-9c** are derived from their hydrolysis products **10a-10c** whose structures have been established (5,6,7). See Scheme II. The structure of the product obtained from the hydrolysis of **9b** was established as 2-amino-1-methylbenzimidazole (**10b**), as shown by its infrared spectrum and its resistance to alkaline hydrolysis (6).

Scheme II



9a X = S

9b X = NH

9c X = O

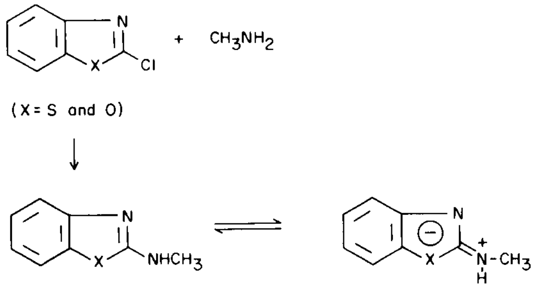
10a X = S

10 b (see text)

10 c X = O

The imino compounds **10a** and **10c** show a strong sharp absorption at 3.1 μ and give 1-methyl-2-benzothiazolone and 1-methyl-2-benzoxazolone on alkaline hydrolysis.

In order to determine whether other methylated isomers were formed during the methylation of the phosphinimines, the isomeric amino derivatives **11a** and **11b** were prepared by the following reaction:



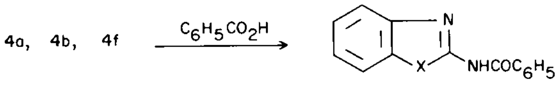
11a X = S

11b X = O

12

The corresponding benzimidazole derivative could not be prepared by this procedure. Compound **11b** has been described as a gum (7), but we find that it is crystalline and melts at 109°. The infrared spectra of **11a** and **11b** showed strong broad absorption in the region 3.2-3.5 μ, as do their corresponding perchlorate salts. This characteristic can be rationalized by postulating that the structure of these compounds is represented by the charged structure **12**. VPC analysis showed no trace of **11a** or **11b** in the products which were obtained by alkylation of the phosphinimines **4a** and **4f**.

Benzoic acid reacts with **4b** in xylene to give 2-benzamidobenzimidazole (**13b**), which had previously been synthesized from benzocyanamide and *o*-phenylenediamine hydrochloride (8). Benzoic acid also reacts with **4a** and **4f** to give the corresponding benzamido derivatives **13a** and **13c**.



13a X = S

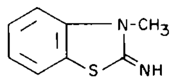
13b X = NH

13c X = O

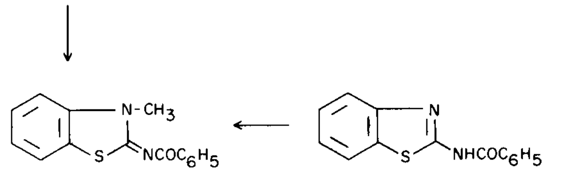
13d X = $NCOC_6H_5$

A benzimidazole phosphinimine which contained an amide group on the heterocyclic nitrogen atom (such as **4c**) reacted with benzoic acid with the loss of the carbamoyl group to give 2-benzamidobenzimidazole (**13b**). The benzamido compounds **13a-13c** were also prepared by the benzoylation of the 2-amino derivatives of benzothiazole, benzimidazole, and benzoxazole, respectively. The initial product which is obtained from the benzoylation of 2-aminobenzimidazole is 1-benzoyl-2-benzamido-benzimidazole (**13d**), but recrystallization of this compound from pyridine-methanol gave **13b**.

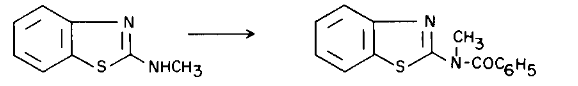
The assignment of the structures **13a-13c** to the benzoylation products of the phosphinimines was based on the following evidence. The benzoylation of **10a** gives **14a** which was also obtained by methylation of **13a**, and the benzoylation of 2-methylaminobenzothiazole (**11a**) gives **15a**, as shown below:



10a



14a 13a

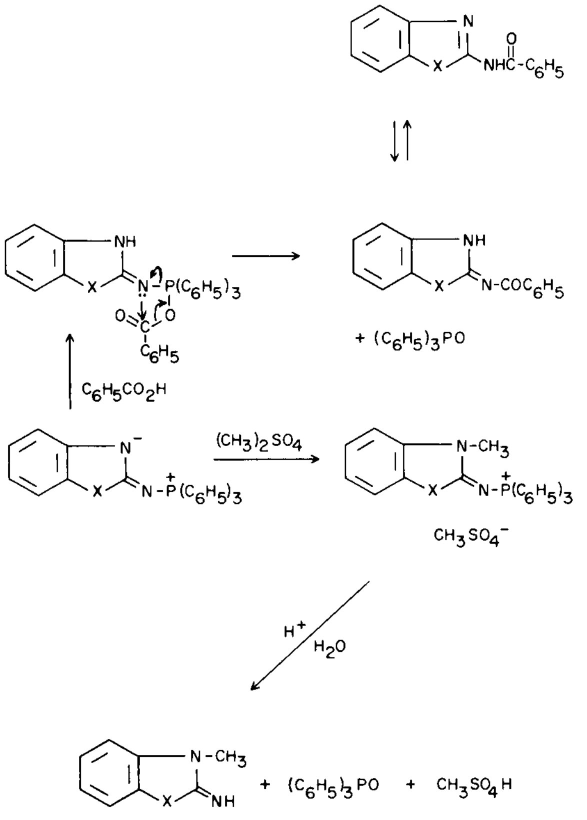


11a 15a

The ultraviolet spectra of **13a** and **15a** are nearly identical and are quite different from the spectrum of **14a**. The corresponding compounds (**14b**, **14c**, and **15b**) were prepared in the benzoxazole and benzimidazole series with comparable results.

The fact that methylation of the phosphinimines takes place at a hetero nitrogen atom and benzoylation occurs at the exocyclic nitrogen atoms can be rationalized on the basis of the following reaction scheme (9):

Scheme III



EXPERIMENTAL

The preparations of 2-azidobenzothiazole (**2a**), 2-azidobenzimidazole (**2b**), and 2-azidobenzoxazole (**2f**) have been described (4). The azides **2c**, **2d**, and **2e** were prepared by Method A, and the data relating to these and the other compounds described in this paper are collected in Table I.

Method A.

A mixture of 0.05 mole of **2b** and 0.05 mole of the isocyanatoacetate (10) in 100 ml. of acetonitrile was heated on the steam bath for 1 hour. The solution was concentrated to dryness and the residue was crystallized from petroleum ether (bp. 63-75°).

Method B.

A mixture of 0.023 mole of the azide and 0.02 mole of triphenylphosphine in 25 ml. of chloroform (or acetonitrile) was stirred until complete solution resulted, 100 ml. of ether was added and the precipitate was collected. The product was purified by precipitation of a chloroform solution with ether.

Method C.

A mixture of 5 g. of the adduct and 75 ml. of toluene was refluxed 1 hour, cooled, and the solid was collected and recrystallized.

Method D.

A mixture of 0.02 mole of the phosphinimine and 0.04 mole of dimethyl sulfate was heated at 90-95° for 4 hours and then poured into methanol which contained 3 ml. of 70% perchloric acid. The solution was chilled and the solid which separated was collected.

Method E.

A mixture of 2 g. of the phosphiniminium salt (**9a-9c**) 50 ml. of methanol and 2 ml. of 70% perchloric acid was heated until the solid dissolved, and then chilled. The solid was collected and crystallized.

Method F.

A mixture of 0.1 mole of 2-chlorobenzothiazole or 2-chlorobenzoxazole, 40 ml. of methylamine (40% in water), and 50 ml. of methanol was heated at 125° for 3 hours under pressure. The reaction mixture was cooled and the solid was collected.

Method G.

A solution of 0.02 mole of 2-aminobenzothiazole, 2-aminobenzimidazole, or 2-aminobenzoxazole, and 4 ml. of benzoyl chloride in 30 ml. of pyridine was heated for 15 minutes at 90-100°. Water (30 ml.) was added to the reaction mixture and the precipitate was collected and crystallized.

Method H.

A solution of 0.02 mole of the phosphinimine, 2.0 g. of benzoic acid, and 50 ml. of xylene was heated to reflux for 2 hours, chilled, and the solid was collected.

Method I.

A mixture of 5 g. of **13a** and 10 ml. of dimethyl sulfate was heated for 3 hours on the steam bath, and methanol (25 ml.) and 4 ml. of 70% perchloric acid were added to give the perchlorate salt of **14a** which, when made alkaline, gave **14a**.

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