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PHOTOCHEMISTRY – IX[1]

FORMATION OF CYCLOPROPENYL KETONES AND FURANS FROM PYRIDAZINE N-OXIDES BY IRRADIATION

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Abstract – Photolyses of unsubstituted and methyl substituted pyridazine 1-oxides afforded the corresponding cyclopropenyl ketones (**6**) and furans (**7**), respectively. Photolysis of 3-phenyl-, 3-methoxy- and 3-hydroxy-pyridazine 1-oxides afforded furans alone, whereas 3-aminopyridazine 1-oxides gave levulinonitriles and 3-cyanopropionaldehydes (**11**). Mechanism of their formation are discussed.

Concerning the photolyses of pyridazine N-oxides, Ogata *et al.*[2] reported on the formation of the corresponding deoxygenated pyridazines (**8**) as main products in 6–20% yields, and on the formation of trace amounts (0·2%) of acetylpyrazoles along with **8** in cases of 3-chloro-6-methylpyridazine 1-oxide and 3-methoxy-6-methylpyridazine 1-oxide. Then, Buchardt *et al.*[3] reported on the formation of 3-benzoylpyrazole (**5**) from 3,6-diphenylpyridazine 1-oxide in 75% yield, explaining that the diazoketo compound (**3**) might be the intermediate, as shown in the following scheme.

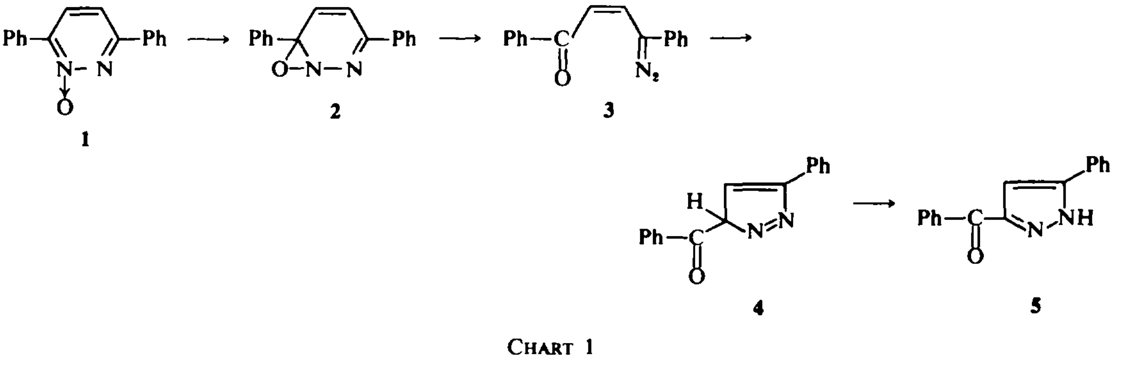


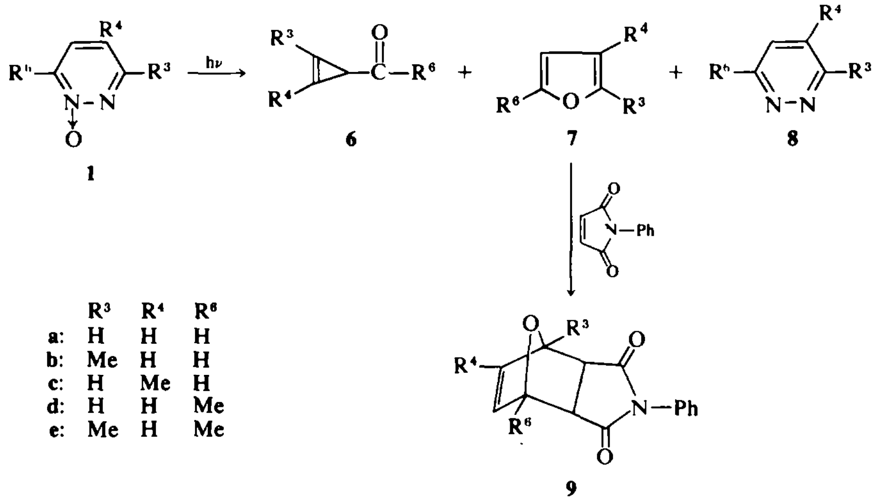
CHART 1

Meanwhile, we have reported[4] the photo-induced oxygenation by the O atom of the pyridazine N-oxide. In this reaction, the formation of the compounds which lacked N atoms were recognized. Thus, we have examined the photolysis of tri- and tetra-phenylpyridazine N-oxides in expectation of the formation of nitrogen-eliminated compounds besides pyrazoles. In fact, 1,2-dibenzoylethenes, tri- and tetra-phenylfurans, 1-(1,2,3-triphenylcyclopropenyl)-$\Delta^{3,6}$-bicyclo[3,2,0]heptadien-2-one, and 3-benzoyl-1,2-diphenyl-1-cyclopropene were obtained.[5] Therefore, we have re-examined the photolyses of various kinds of pyridazine N-oxides (**1a–j**), including **1a**, **1d**, and **1e**, which were reported to give only deoxygenated pyridazines. We now report that two kinds of compounds, i.e., cyclopropenyl ketones and furans were obtained in ratios depending on the kinds of the substituents in the 3-position.[6]

6-Unsubstituted pyridazine 1-oxide (**1a–c**) was irradiated in dichloromethane to give the corresponding 3-formylcyclopropene (**6a–c**) and furans (**7a–c**) in 8–10% and 5–10% yields, respectively. Similarly, 6-methylpyridazine 1-oxides (**1d** and **1e**) afforded the corresponding 3-acetylcyclopropenes (**6d** and **6e**) and 3-methylfurans (**7d** and **7e**) in *ca* 10% and 5–8% yields, respectively. And it is natural that from **1b** and **1c**, the same product, i.e., 1-methyl-3-formylcyclopropene (**6b**) was obtained, and from **1b** and **1d** the same compound, i.e., 2-methylfuran (**7b**) was obtained. As the b.ps of the furans (**7a–e**) were too low to be isolated, N-phenylmaleimide was added to form the adducts[7] (**9**).

In all the photolyses, the corresponding parent pyridazines (**8**) were obtained in 20–35% yields, but any other characteristic product was not isolated. Irradiation in other solvents such as methanol and acetone resulted in decreased yields.

Spectral data of cyclopropenyl ketones (**6**) thus



	R^3	R^4	R^6
a:	H	H	H
b:	Me	H	H
c:	H	Me	H
d:	H	H	Me
e:	Me	H	Me

CHART 2

Table 1. Spectral data of cyclopropenyl ketones

Compound	$m/e\,(M^+)$	IR $\nu_{C=O}^{liq}$ cm^{-1}	NMR: δ (CCl_4)	J (cps)
6a	68	1720	2·22 (1H, d.d., H_3), 2·27 (2H, d., H_1 and H_2) 8·74 (1H, d., —CHO).	
6b	82	1720	2·16 (1H, d.d., H_3), 2·29 (3H, b.s., 1-CH_3) 6·52 (1H, b., H_2), 8·72 (1H, d., —CHO).	$J_{1,2} = 1·2$
6d	82	1695	1·89 (3H, s., —$COCH_3$), 2·29 (1H, b., H_3) 6·95 (2H, d., H_1 and H_2).	$J_{1,3} = 0·9–1·2$
6e	96	1690	1·84 (3H, s., —$COCH_3$), 2·18 (1H, d., H_3) 2·20 (3H, s., 1-CH_3), 6·40 (1H, d., H_2)	$J_{3,-CHO} = 6·0$

obtained are shown in Table 1 and these data are well in accord with those[8] of 3-acetylcyclopropenes and other cyclopropenes. The furans (**6**), were all known compounds and were confirmed by comparison with authentic samples and their adducts (**9**).

Next, the primary amines such as n-butylamine, cyclohexylamine, and aniline were allowed to react with these cyclopropenyl ketones (**6**) to afford the corresponding N-substituted pyrroles. On the other hand, irradiation of a mixture of the pyridazines and the amines in dichloromethane also afforded the corresponding N-substituted pyrroles and the yields were somewhat higher in the latter case. A separate paper has been published.[9]

The photolysis was carried out on pyridazine N-oxides having a substituent other than a Me group in the 3-position. Thus, 3-phenylpyridazine 1-oxide (**1f**) and 3-methoxypyridazine 1-oxide (**1g**) afforded 2-phenylfuran (**7f**) and 2-methylfuran (**7g**) in 40–50% yields. Irradiation of 3-hydroxypyridazine 1-oxide (**1h**) in methanol gave unsaturated γ-lactone (**10**), isomeric with 2-hydroxyfuran, in 50–55% yield. Irradiation of 3-aminopyridazine 1-oxides (**1i** and **1j**) in methanol afforded 3-cyanopropionaldehyde (**11i**) from **1i** in 3–4% yield, and levulinonitrile (**11j**) from **1j** in 10–12% yield.

In all these pyridazine N-oxides (**1f–j**), the parent pyridazines (**8**) were obtained in 20–30% yields, but any other characteristic product was not isolated and identified. The compounds (**7, 10,** and **11**) were known compounds and were confirmed in comparison with authentic samples.

Concerning the formation of these compounds, the following mechanism is proposed. In the case of 3-aminopyridazine 1-oxide, unstable 2-aminofuran is formed initially, which is then easily con-

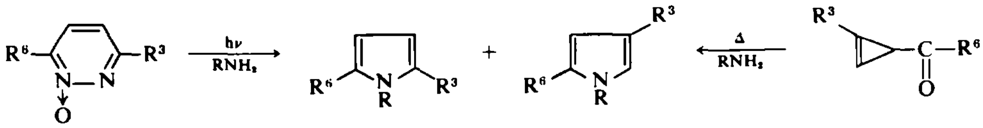
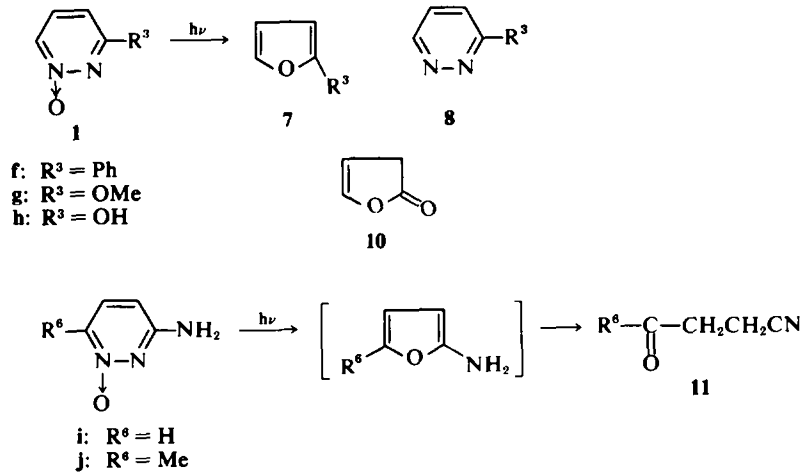


CHART 3



f: $R^3 = Ph$
g: $R^3 = OMe$
h: $R^3 = OH$

i: $R^6 = H$
j: $R^6 = Me$

Chart 4

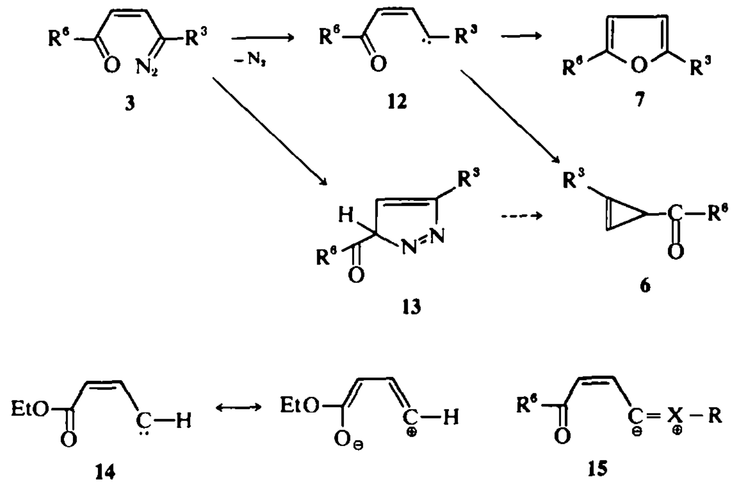


Chart 5

verted into its imino isomer,[10] followed by ring fission to give **11**. These furans might be formed from the carbene (**12**) derived from the diazo intermediate by elimination of molecular nitrogen, to which Buchardt *et al.** have already referred.

As for the formation of cyclopropenes, molecular nitrogen might be eliminated from the intermediate (**13**). By analogy with this pathway, Jorgenson[11] reported that photolysis of β-cyclopropenylacrylic esters resulted in the formation of furans and cyclopropenes *via* the carbene (**14**). Accordingly, the products in the present work also might be formed from the carbene (**12**).

The formation of cyclopropenes from furans by photo-rearrangement in vapor[12] and liquid[13] phase has been reported. But, under the present conditions, irradiation of furans did not afford cyclopropenes. In cases of **1a–e**, both **6** and **7** were obtained in a ratio of 1 : 1, whereas in cases of **1f–j**, interestingly, only furans (**7**) were obtained in moderate yields. The reason might be as follows.

Cyclization of the carbene may occur through two pathways. When the α-position of the carbene is a hetero atom or phenyl group, the contribution of the formula **15** become predominant and yields furans rather than cyclopropenes.

EXPERIMENTAL

Photolyses were carried out in an immersion apparatus equipped with a 200W high pressure mercury lamp (Nikko Sekiei Co., Japan) and cooled internally with running water. IR spectra were determined with a JASCO

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*According to the private communication, 3,6-diphenylpyridazine 1-oxide afforded 2,5-diphenylfuran along with 3-benzoylpyrazole. By varying the temperature of the solution or the intensity of the light, one of these two products could be obtained preferentially.

IRA-1 spectrometer and MS spectra were recorded on a Hitachi RMS-4 instrument. NMR spectra were recorded on Hitachi R-20 and R-22 spectrometers in CCl_4 or $CDCl_3$ soln using TMS as internal standard. M.ps were measured on a Yamato MP-1 apparatus and are uncorrected. Microanalyses were performed in the analytical laboratory of this school by Miss T. Kihara and Mrs. K. Shiobara. Column and thin layer chromatography were carried out with alumina and silica gel obtained from Merck Co. Ltd.

General procedure of the photolysis. A soln of **1** (2–3 g) dissolved in CH_2Cl_2 (200–300 ml) was irradiated for 3–4 hr under N_2. The mixture was evaporated *in vacuo*. The residue was distilled under reduced pressure (5–10 mmHg) below 80–90° to give **6** and **11**, checking each fraction by GL and TL chromatography. The residue after distillation was dissolved in benzene and chromatographed on alumina. From the eluate with a mixture of benzene and CH_2Cl_2 (1 : 1) or CH_2Cl_2, deoxygenated pyridazines (**8**) were obtained in 20–35% yields. In the case of **1f**, the mixture was evaporated and the residue was chromatographed on alumina, eluting with benzene. The eluate was evaporated and the residue was purified by distillation to give **7f**.

The furans obtained from **1a–e** had too low b.ps to be isolated so N-phenylmaleimide was added and the mixture stirred at room temp for 2 days, followed by removal of the solvent. The residue was chromatographed on alumina to give the corresponding adducts (**9**).

As for pyridazines, **8i** and **8j** were confirmed by reduction of **1i** and **1j** with Pd-charcoal.[24] Other pyridazines were confirmed in comparison with authentic samples.

Photolysis of pyridazine 1-oxide (**1a**),[14] *3-methylpyridazine 1-oxide* (**1b**),[15] *4-methylpyridazine 1-oxide* (**1c**),[16] *6-methylpyridazine 1-oxide* (**1d**),[15] *and 3,6-dimethylpyridazine 1-oxide* (**1e**).[17] According to the general procedure, photolysis was carried out to afford the corresponding ketones **6**, whose spectral, physical, and analytical data are collected in Tables 1 and 2.

Furans were obtained as adducts (**9**) with N-phenylmaleimide, and confirmed in comparison with the adducts obtained from authentic samples.* **9a**: colorless flakes, m.p. 145–147° (from benzene), yield 5%. IR: 1725 cm^{-1}, MS (*m/e*); 241 (M^-). (Found: C, 69·59; H, 4·71; N, 6·05. Calcd. for $C_{14}H_{11}O_3N$: C, 69·70; H, 4·59; N, 5·80%). **9b**: colorless needles, m.p. 128–129° (from benzene), yields 9% from **1b** and 8% from **1d**. IR; 1725 cm^{-1}, MS (*m/e*); 255 (M^+). (Found: C, 70·64; H, 4·97; N, 5·84. Calcd. for $C_{15}H_{13}O_3N$: C, 70·58; H, 5·13; N, 5·49%). **9c**: colorless needles, m.p. 132–133° (from benzene), yield 7%. IR; 1720 cm^{-1}, MS (*m/e*); 255 (M^+). (Found: C, 70·44; H, 5·01; N, 5·28. Calcd. for $C_{15}H_{13}O_3N$: C, 70·58; H, 5·13; N, 5·49%). **9e**: colorless needles, m.p. 117–119° (from benzene), yield 10%. IR; 1720 cm^{-1}, MS (*m/e*); 269 (M^+) (Found: C, 71·13; H, 5·37; N, 4·96. Calcd. for $C_{16}H_{15}O_3N$: C, 71·36; H, 5·61; N, 5·20%). *2,5-Dimethylfuran* (**7e**)[18] could be isolated without making the adduct, yield *ca* 9%.

Photolysis of 3-phenylpyridazine 1-oxide (**1f**),[19] *3 methoxy-pyridazine 1-oxide* (**1g**),[20] *and 3-hydroxypyridazine 1-oxide* (**1h**).[20] According to the general procedure, *2-phenylfuran* (**7f**),[21] bp_2 120° (bath temp), MS (*m/e*); 144 (M^+), was obtained from **1f**, yield 51%. From **1g**, *2-methoxyfuran* (**7g**),[22] bp_{10} 50° (bath temp), MS (*m/e*); 98 (M^+), was obtained, yield 46%. From **1h**, *β-γ-butenolide*,[23] bp_{20} 65° (bath temp), IR; 1790 cm^{-1}, MS (*m/e*); 84 (M^+), was obtained, yield 55%. Spectral data of these compounds (**7f–g**) are in accord with those of authentic samples.

Photolysis of 3-aminopyridazine 1-oxide (**1i**) *and 3-amino-6-methylpyridazine 1-oxide* (**1j**).[24] According to the general procedure, *3-cyanopropionaldehyde* (**11i**),[25] bp_{20} 80° (bath temp), IR: 2240 and 1725 cm^{-1}, MS (*m/e*): 83 (M^+), was obtained, yield 3–4%. From **1j**, *levulinonitrile* (**11j**),[26] bp_{15} 80° (bath temp), IR; 2230 and 1720 cm^{-1}, MS (*m/e*); 97 (M^+), was obtained, yield 10–12%. Spectral data of these compounds (**11**) are well in accord with those of authentic samples synthesized by alternative routes.

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Table 2. Physical and analytical data of cyclopropenes

Compound	Yield (%)	b.p./mmHg (bath temp)	Molecular formula	Analyses (%) Calcd. C	H	Found C	H
6a	8	45/10	C_4H_4O	70·57	5·92	70·32	6·07
6b	9 (from **1b**) 7 (from **1c**)	50/10	C_5H_6O	73·14	7·37	73·43	7·10
6d	9	40/5	C_5H_6O	73·14	7·37	72·89	7·36
6e	11	40·4	C_6H_8O	74·97	8·39	75·15	8·72

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*The authentic samples were obtained from Tokyo Chemical Ind. Co. Ltd., Tokyo, Japan.

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