TABLE III

CHARACTERIZATION OF SUBSTITUTED PHENYLGLYOXALS

Substituent	Synthetic procedure	Mp of hydrate, °C	Mp of dioxime, °C	Elemental analysis of dioxime, % C	H	N
H	A	76-77	174-176	58.53	4.91	17.06 calcd
				58.70	5.10	17.04 obsd
p-CH_3	A	98-99	166.5-168.2	60.67	5.66	15.96
				60.81	5.63	15.87
p-OCH_3	B	126-127.5	152-153	55.67	5.19	14.43
				55.85	5.14	14.26
p-Br	B	133.5-134.9	167.5-168.5	39.53	2.90	11.52
				39.74	3.14	11.39
p-Cl	B	120-122	159-160	48.38	3.55	14.10
				48.28	3.73	14.33
p-Ph	B	116-118	216-218	69.99	5.03	11.66
				70.02	4.94	11.59
m-OCH_3	B	77-78.5	163.5-164.8	55.67	5.19	14.43
				55.73	5.10	14.55
p-NO_2	A	131-132 (3 mm)[a]	186-188	45.94	3.37	20.09
				45.92	3.54	20.40
p-OH	A	86.5-87.5	190-193	53.33	4.48	15.55
				53.15	4.73	15.86

[a] Boiling point of p-NO_2 derivative.

solutions of convenient concentrations. Use of stock solutions without ethanol gave the same rate data. The initial concentrations of substituted phenylglyoxals in the reaction cell were generally *ca.* 10^{-4} *M*.

Carbonyl Stretching Frequencies.—The ketone and aldehyde carbonyl stretching frequencies were measured on a Perkin-Elmer 621 recording spectrophotometer using very slow scan rates and expanded scales. Generally, the range 1800–1600 cm^{-1} was scanned over a 1-hr period, and a polystyrene standard was added to the cell holder immediately after the carbonyl band was passed in order to accurately locate the carbonyl stretching frequency. This procedure gave values reproducible to ±1.5 cm^{-1}.

The ketone carbonyl stretching frequencies of the substituted phenylglyoxal hydrates were measured in Nujol mulls. The ketone and aldehyde carbonyl stretching frequencies of the unhydrated compounds were determined in dilute acetonitrile solutions. Although carbonyl frequencies are generally measured in carbon tetrachloride solutions, it was found that the unhydrated phenylglyoxals in carbon tetrachloride rapidly deteriorate, presumably by polymerization. Only a trace of water is required to initiate polymerization. Acetonitrile solutions were sufficiently stable to allow slow scanning rates to be used. The anhydrous solutions were prepared by warming acetonitrile solutions of the hydrates over molecular sieves, with repeated transfers to fresh molecular sieves.

Dehydrogenation of α-(Phenylthio)cyclohexanone Accompanying Oxime Formation

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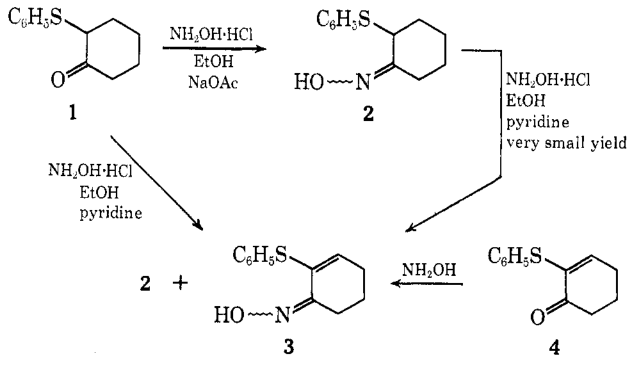
Treatment of **1** with hydroxylamine hydrochloride in ethanol–pyridine gave **3**. Compound **3** is the product of a novel oxidation–reduction reaction in the course of which a new carbon–carbon double bond is introduced.

In the course of the reaction of 2-(phenylthio)cyclohexanone (**1**) with hydroxylamine hydrochloride we have made the following observations. When the reaction was run with ethanol as the solvent and sodium acetate as the base the expected product, oxime **2**, was obtained as a mixture of *Z* and *E* isomers. On the other hand, with ethanol as the solvent and pyridine as the base, oxime **2** was obtained accompanied by an additional product **3**, clearly a result of an oxidation–reduction process. Treatment of oxime **2** under the conditions for the conversion of **1** to **3** produced very little of **3**. The resulting mixture was subjected to gc and mass spectral analysis of the TMS derivatives (*cf.* Experimental Section) and it was shown that less than 5% of **3** was produced by this route.



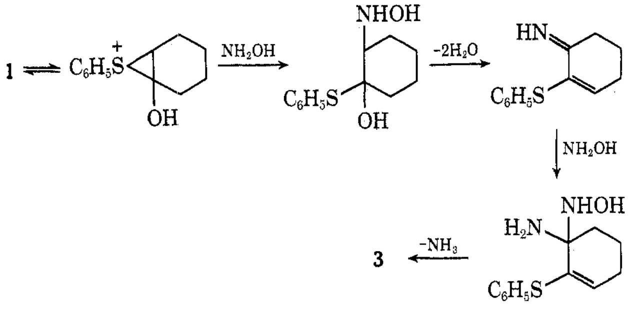
one isomer

The structure of **3** was supported by (a) the nmr spectrum, which was compatible with the presence of one vinyl proton adjacent to a methylene group, and (b) the mass spectrum, which showed a molecular ion at *m/e* 219. The TMS derivative of **3** showed a molecular ion at *m/e* 291, which clearly indicated that **3** is a dehydro derivative of **2**. When the mass spectra of **2** and **3** were compared it was realized that the loss of the radical $C_6H_5S·$ from the molecular ion leads to the most intense ion *m/e* 112 ($M^+ - C_6H_5S·$) in the case of **2**. This loss is a minor process in the case of **3**; the intensity of the *m/e* 110 ion ($M^+ - C_6H_5S·$) was less than 8% of the base peak. This observation confirms the proposal that the C_6H_5S in **3** is attached to a C=C bond. The mass spectra of the TMS derivatives of **2** and **3** show a similar behavior: an intense ion at *m/e* 184 ($293 - C_6H_5S\cdot$) in the case of **2**-TMS, and a very weak ion at *m/e* 182 ($291 - C_6H_5S\cdot$) in the case of **3**-TMS.

The structure of **3** was unequivocally established by synthesis from the 2-(phenylthio)-2-cyclohexenone (**4**).[1]

We propose the following mechanism for the conversion of **1** to **3** (Scheme I).

SCHEME I

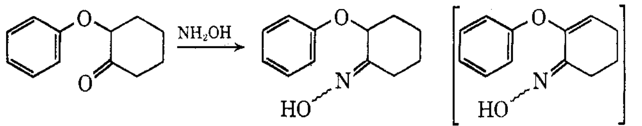


The overall reaction can be summarized as

$$1 + 2NH_2OH \longrightarrow 3 + NH_3 + 2H_2O$$

Alternative mechanisms, which proceed *via* the initial formation of oxime **2**, do not play a major role because we have demonstrated that oxime **2** produces very little of **3** when subjected to the conditions used for the conversion of **1** to **3**.

Participation of sulfur in the proposed mechanism shown in Scheme I is supported by the fact that in the following reaction the formation of **6** was not observed and only the expected oxime **5** was obtained.



5

not formed
6

Experimental Section

Melting points were taken in a capillary tube and are uncorrected. Uv spectra were determined in 95% EtOH using a Cary Model 14 spectrophotometer. Ir spectra were determined in Nujol using a Perkin-Elmer Model 421 recording spectrophotometer. Nmr spectra were recorded on a Varian Model A-60A; chemical shifts were recorded in parts per million downfield from Me_4Si; $CDCl_3$ was used as a solvent. Mass spectra were recorded using an LKB-9000 gc-mass spectral unit. The silica gel used for chromatography was obtained from E. Merck A. G., Darmstadt, Germany.

2-(Phenylthio)cyclohexanone (*Z*)- [and (*E*)-] Oxime (2). Reaction of 2-(Phenylthio)cyclohexanone (1) with Hydroxylamine HCl and NaOAc in Ethanol.—A solution of 2-thiophenylcyclohexanone[2] (5 g, 0.0243 mol) in 70 ml of ethanol was added to a solution of hydroxylamine hydrochloride (3.5 g, 0.0486 mol) and sodium acetate (6 g, 0.0729 mol) in 20 ml of water. The mixture was stirred for 20 hr and then concentrated *in vacuo* at 32° to a small volume. Ether and H_2O were added, the aqueous layer was extracted once with ether, and the combined ether solution was washed with H_2O and saturated salt solution, dried ($MgSO_4$), and evaporated.[3] Crystallization from ether-petroleum ether (bp 30-60°) gave 2.7 g of the *Z-E* mixture of oxime **2** melting at 74-80°: uv sh 213 nm (ϵ 11,650); λ_{max} 256 (4350); ir 3280 (OH); 1660 (C=N), 1585, 1480 (C=C), 1025 (NO), 980, 970, 925, 895, 885, aromatic 750, 705, 695 cm^{-1}; nmr showed a ratio of *ca.* 14% (*Z*)-oxime and 86% (*E*)-oxime based on the -SCH- positions at δ 5.1 and 4.0, respectively; mass spectrum *m/e* 221 (M^+), 204 ($M^+ - OH$), 112 ($M^+ - SC_6H_5$), 110 ($C_6H_5SH^+$)

Anal. Calcd for $C_{12}H_{15}NOS$: C, 65.12; H, 6.83; N, 6.33; S, 14.49. Found: C, 65.38; H, 6.95; N, 6.17; S, 14.55.

The filtrate was evaporated to give 3.1 g of an oil. Ir, uv, mass spectrum, and nmr were identical with those of the above solid.

In another seemingly identical experiment nmr showed 100% (*E*)-oxime, indicating ready equilibration of the (*Z*)- and (*E*)-oxime mixture.

2-(Phenylthio)-2-cyclohexenone Oxime (3). A. Reaction of 2-(Phenylthio)cyclohexanone (1) with Hydroxylamine HCl in Ethanol and Pyridine.—A mixture of 2-thiophenylcyclohexanone (10 g, 0.0485 mol), hydroxylamine hydrochloride (10 g, 0.144 mol), 10 ml (0.127 mol) of pyridine, and 80 ml of ethanol was refluxed for 17 hr, evaporated at 50° *in vacuo*, and worked up as usual.[3] The residue (10.3 g) was crystallized from ether-petroleum ether to give 2.8 g of crude **3**: mp 111-115°, raised to 133-134° on recrystallization from methanol; uv λ_{max} 217 nm (ϵ 16,100), sh 233 (13,300), 280 (3050); ir 3230 (OH), 1655 (weak, broad, C=N/C=C), 1625, 1595, 1580, 1570; 1000, 960 (NO); aromatic 760, 740, 710, 700 cm^{-1}; nmr (100 MHz) δ 9.94 (s, 1, OH), 7.35 (m, 5, aromatic H), 6.10 (t, 1, vinyl H, J = 4.8 Hz), 2.75 (t, 2, CH_2C=N, J = 6.0 Hz), 2.21 (q, 2, SC=$CHCH_2$), 1.74 (quintet, 2, $CH_2CH_2CH_2$, J = 6 Hz); mass spectrum 219 (M^+), 202 ($M^+ -$ OH).

Anal. Calcd for $C_{12}H_{13}NOS$: C, 65.72; H, 5.97; N, 6.39; S, 14.62. Found: C, 65.50; H, 5.89; N, 6.32; S, 14.63.

The yield of **3** was improved to 27% when the original crude reaction product was chromatographed on silica gel (1:100) using 30% EtOAc-cyclohexane as the eluent.

When the above experiment was repeated using 10 g (0.0485 mol) of **1**, 33.3 g (0.485 mol) of hydroxylamine hydrochloride, 33.3 ml (0.411 mol) of pyridine, and 240 ml of ethanol, analysis of the product on the LKB-9000 showed compound **1**, 1.74%; diphenyl disulfide, 5.96%; compound **2**, 78.96% (±2%); and compound **3**, 13.33%.

B. Reaction of 2-(Phenylthio)-2-cyclohexenone (4) with Hydroxylamine.—A mixture of **4**[1] (0.15 g, 0.74 mmol), hydroxylamine hydrochloride (0.15 g), 0.15 ml of pyridine, and 2 ml of ethanol was refluxed for 22 hr, evaporated, and worked up as usual[3] to give 0.119 g of crude **3**. Analysis on the LKB-9000 showed diphenyl disulfide, 1.3% (M^+ 218); compound **3**, 96.88% (M^+ 219); unknown impurity, 1.8% (M^+ 281). Crystallization from methanol gave pure **3**, mp 136-137°, which was identical with the sample obtained previously as shown by tlc (silica gel, 20% ethyl acetate-cyclohexane), ir, uv, and nmr.

Reaction of 2 with Hydroxylamine HCl in Ethanol and Pyridine.—A mixture of **2** (0.5 g),[4] hydroxylamine hydrochloride (0.5 g), 0.5 ml of pyridine, and 4 ml of ethanol was refluxed for 17.5 hr. It was evaporated *in vacuo* and worked up as usual[3] to give 0.4 g of a yellow oil which solidified on standing.

Nmr showed a ratio of *ca.* 25% (*Z*)-oxime and 75% (*E*)-oxime **2** based on the -SCH positions at δ 5.10 and 4.0, respectively. No vinyl hydrogen was detectable by nmr.

Some of this material (*ca.* 10 mg) was dissolved in chloroform and treated with 100 μl of Regisil RC-2.[5] The resulting TMS-ether mixture was analyzed on the LKB-9000 mass spectrometer using a 6-ft, 3.8% UC-N-98 column on Diatoport S (80-100 mesh) at 200°. The mixture contained five components which were identified by their mass spectra. The composition was as follows: compound **1**, 0.95% (M^+ 206); diphenyl disulfide, 3.17% (M^+ 218); compound (*Z*)-**2**, 4.6% (M^+ 293); compound (*E*)-**2**, 86.9% (M^+ 293); compound **3**, 4.36% (M^+ 291).

Reaction of 2-Phenoxycyclohexanone with Hydroxylamine HCl

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[1] T. Mukaiyama, T. Adachi, and T. Kumamoto, *Bull. Chem. Soc. Jap.*, **44**, 3155 (1971). We thank Professor T. Mukaiyama of the Tokyo Institute of Technology, Tokyo, Japan, for a generous sample of 2-(phenylthio)-2-cyclohexenone.

[2] F. Winternitz, N. J. Antia, M. Tumlirova, and R. Lachazette, *Bull. Soc. Chim. Fr.*, 1817 (1956).

[3] This work-up was employed in subsequent experiments, but the ether extract was first washed with 10% aqueous hydrochloric acid solution.

[4] *Ca.* 100% (*E*)-oxime by nmr; gc-mass spectral analysis of the TMS derivative showed no **3** present.

[5] Purchased from Regis, 99% bissilyltrifluoroacetamide (BSTFA) and 1% trimethylchlorosilane.

in Ethanol and Pyridine. 2-Phenoxycyclohexanone (*Z*)- [and (*E*)-] Oxime (5).[2]—A mixture of 2-phenoxycyclohexanone[2] (10, g, 0.0525 mol), hydroxylamine hydrochloride (10 g, 0.144 mol), 10 ml of pyridine, and 80 ml of ethanol was refluxed for 17 hr and worked up as usual.[3] The crude product (10.43 g) showed a ratio of *ca.* 25% (*Z*)-oxime and 75% (*E*)-oxime **5** based on the -OCH- positions at δ 5.70 and 4.82, respectively. No vinyl hydrogen was detectable by nmr. The mass spectrum showed a molecular ion at *m/e* 205 and a peak at 203 (*ca.* 2%) which can be due either to M − 2 ion, or less likely, to a dehydro compound. The above oxime mixture showed the same nmr and mass spectra after distillation at 0.05 mm (bp 145–155°).

Registry No.—**1**, 27920-40-7; (*Z*)-**2**, 36540-08-6; (*E*)-**2**, 36540-09-7; **3**, 36540-10-0; (*Z*)-**5**, 36540-11-1; (*E*)-**5**, 36540-12-2.

The Reactivity of Diazo Ketones. II.[1]
Reaction of α-Diazo Ketones with Sulfur Dioxide

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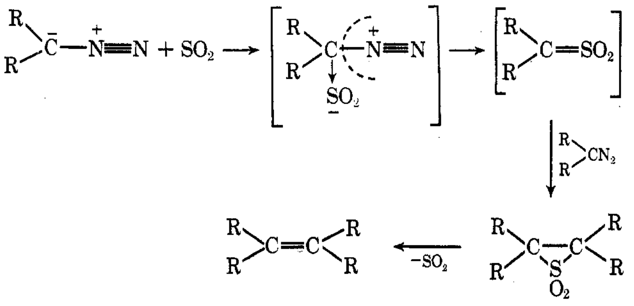
Reactions of some α-diazo ketones with sulfur dioxide were carried out by means of pyrolysis or photolysis. The reactions appeared to proceed *via* a free ketocarbene and a remarkable substituent effect was observed. Diazo ketones of the type $PhCN_2COR$ (R = Ph, Me) gave six-membered cyclic sulfones and sultones, while diazo ketones of the type RCN_2COPh (R = H, Me) gave products resulting from a 1,2-hydrogen shift or a 1,3-dipolar addition reaction of the ketocarbene intermediate. The mechanism of these reactions and the radical reactivity of the PhCCOR type ketocarbenes are discussed in this report.

A number of reactions of sulfur dioxide with diazo alkanes have been reported.[2,3] These reactions proceed readily at low temperature to form either stable or transient episulfones, followed by evolution of sulfur dioxide to give olefins. The proposed mechanism is as follows (Scheme I).

SCHEME I

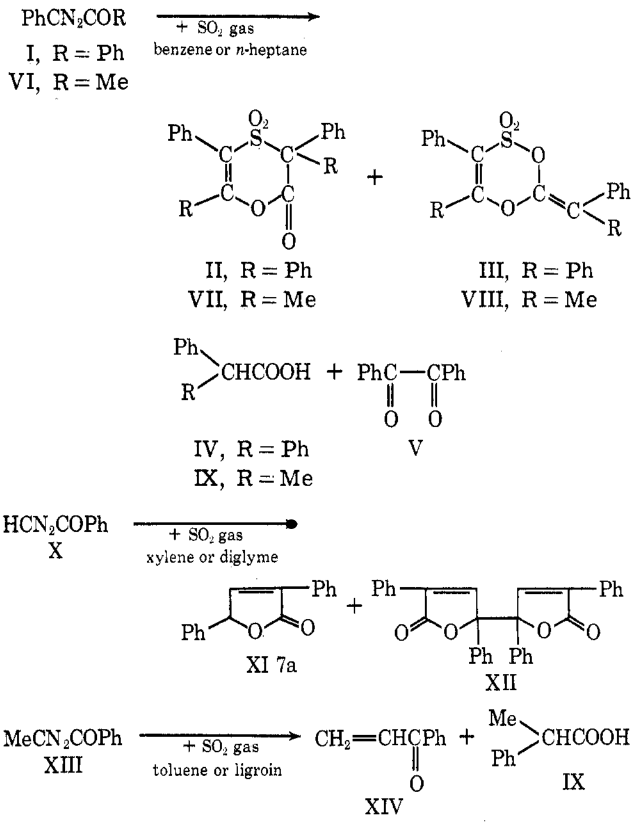
REACTION OF DIAZO ALKANE WITH SO_2



In a preceding communication,[1] we reported that the reaction of azibenzil (I) with sulfur dioxide did not proceed at room temperature, but proceeded at elevated temperature or by means of photolysis to give the cyclic sulfone II and sultone III,[4] instead of the expected episulfone or olefin (Scheme II). In order to obtain further information on the scope and mechanism of this reaction, the reactions of several α-diazo ketones with sulfur dioxide were investigated.

SCHEME II

THERMAL REACTIONS OF α-DIAZO KETONES WITH SO_2



These reactions proceeded only under conditions of pyrolysis or irradiation, and gave products which were different from those expected by analogy to the reaction of diazo alkanes with sulfur dioxide. Moreover, a significant substituent effect was observed; diazo ketones of structure A gave six-membered cyclic sulfones and sultones, while those of structure B gave no such sulfones or sultones, but rather products in which sulfur dioxide was not incorporated.

$C_6H_5CN_2COR$ $RCN_2COC_6H_5$

A, R = C_6H_5, CH_3 B, R = H, CH_3

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(1) T. Nagai, M. Tanaka, and N. Tokura, *Tetrahedron Lett.*, 6293 (1968).

(2) (a) H. Staudinger and F. Pfenninger, *Chem. Ber.*, **49**, 1941 (1916); (b) H. Kloosterziel and H. J. Backer, *Recl. Trav. Chim. Pays-Bas*, **71**, 1235 (1952); (c) G. Hesse and E. Reichold, *Ber.*, **90**, 2106 (1957); (d) G. Opitz and K. Fischer, *Angew. Chem.*, **77**, 41 (1965).

(3) (a) L. V. Vargha and E. Kovacs, *Chem. Ber.*, **75**, 794 (1942); (b) G. Hesse, E. Reichold, and S. Majmudar, *ibid.*, **90**, 2106 (1957); (c) G. Hesse and S. Majmudar, *ibid.*, **93**, 1129 (1960).

(4) In the previous communication,[1] four-membered cyclic structures were postulated for the cyclic sulfone and sultone. Storthers, Danks, and King have proposed six-membered ring sulfone and sultone from the analysis of ^{13}C nmr spectra of the two compounds [*Tetrahedron Lett.*, 2551 (1971)]. Recently, the X-ray analyses of these compounds made by the present authors have also supported the six-membered sulfone. The details of the result are to be published shortly [N. Yasuoka, N. Kasai, M. Tanaka, T. Nagai, and N. Tokura, *Acta Crystallogr.*, No. 12 (1972)].