The Structure of Amidoximes

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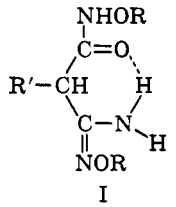
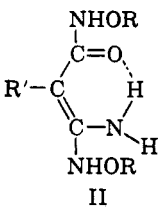
Infrared and nuclear magnetic resonance spectroscopy established that amidoximes and their O-acyl derivatives exist in solutions in the amino oxime form. The structure of α-amidoxime hydroxamic acids and their dibenzoyl derivatives were determined by infrared and proton magnetic resonance techniques. Present evidence indicated the absence of tautomerism in these systems and in the simpler amidoximes. Crystalline phenylacetamidoxime was found to exist as a mixture of neutral and zwitterionic species according to its infrared spectrum.

Assignment of a detailed structure to α-amidoxime hydroxamic acids (I, R = H), and their dibenzoyl derivatives[1,2] proved difficult since their infrared spectra (solid state) possessed bands between 1500–4000 cm.$^{-1}$ not usually shown by either amidoximes or hydroxamic acids. This system (I) presented an interesting β-keto ketimine system ostensibly capable of extensive tautomerisms, and it was felt that the extraneous bands in the infrared spectra of I might be explained if I existed as a mixture of tautomers. For example, the keto enamine (II) and enol ketimine (III) forms appear to represent particularly favored hydrogen-bonded tautomers of I and it was of interest to



I



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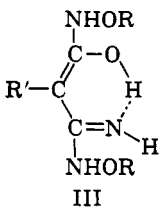


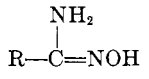
III

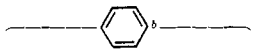
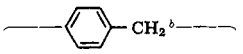
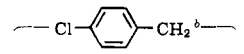
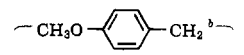
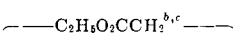
establish if an equilibrium existed between I and II or III. Before attacking the problem of the structure of I, it was necessary to study the spectra of model amidoximes and hydroxamic acids, as well as their O-acyl derivatives for possible tautomerism.[3]

Amidoximes.—In surveying the literature,[4-14] it became apparent that tautomerism in simple amidoximes had been subject to some debate. Most authors accepted the structure of amidoximes to be the "amino oxime" form (IV), with only one proponent[8] in favor of the "imino hydroxylamine" structure (V).

TABLE I

INFRARED ABSORPTIONS[a] OF AMIDOXIMES



									
Nujol	$CHCl_3$	Nujol	$CHCl_3$	Nujol	$CHCl_3$	Nujol	$CHCl_3$	Nujol	$CHCl_3$
	3617 m		3628 m		3622 m		3626 m		3617 m
	3528 m		3533 m		3535 m		3529 m		3517 m
3470 m		3470 m		3489 m		3490 s		3508 m	
	3417 m		3423 m		3418 m		3416 m		
3365 m		3380 m		3369 m		3385 s		3388 m	3397 m
3215 m-b	3248 m-b	3290 s-b	3240 m-b		3220 m-b		3235 m-b		3250 m-b
		3180 sh		3148 m-b		3130 sh		3156 m	
						3060 s-b		3080 m-b	
								1721 vs	1734 vs
		1691 m							
1651 vs	1651 vs	1656 vs	1670 vs	1660 vs	1668 vs	1662 vs	1669 vs	1676 vs	1666 vs
1598 sh		1606 m	1607 sh			1616 m	1614 m		
1589 m	1583 s	1591 sh	1575 m	1587 s	1586 s	1582 s	1586 s	1590	1584 s
1503 vw	1504 m	1493 m	1496 m	1494 m	1494 s	1516 vs	1515 vs		

[a] Values are in cm.$^{-1}$. [b] R group. [c] L. Bauer, C. N. V. Nambury, and C. L. Bell, *Tetrahedron*, **20**, 165 (1964).

We have re-examined the spectra of benzamidoxime and phenylacetamidoxime (IV, R = C_6H_5 and $C_6H_5CH_2$) and several other related amidoximes in some detail and have listed the bands between 1500–4000 cm.$^{-1}$

(1) H. Modeen, *Ber.*, **27**, 261 (1894).

(2) L. Bauer and C. N. V. Nambury, *J. Org. Chem.*, **26**, 4917 (1961).

(3) Few entire infrared spectra of these compounds have been published and the data from the literature is scant. For literature references on infrared spectra of hydroxamic acids, see C. L. Bell, C. N. V. Nambury, and L. Bauer, *ibid.*, **26**, 4923 (1961); see also O. Exner and B. Kakáč, *Collection Czech. Chem. Commun.*, **28**, 1656 (1963).

(4) J. Barrans, R. Mathis-Noël, and F. Mathis, *Compt. rend.*, **245**, 419 (1957).

(5) W. J. Orville-Thomas and A. E. Parsons, *Trans. Faraday Soc.*, **54**, 460 (1958).

(6) D. Prevoršek, *Compt. rend.*, **247**, 1333 (1958); *J. Phys. Chem.*, **66**, 769 (1962).

(7) C. S. Hollander, R. A. Yocoskie, and P. L. de Benneville, *J. Org. Chem.*, **23**, 1112 (1958).

(8) H E. Ungnade and L. W. Kissinger, *ibid.*, **23**, 1794 (1958).

(9) E. N. Zil'berman and N. A. Rybakova, *J. Gen. Chem. USSR*, **29**, 3310 (1959).

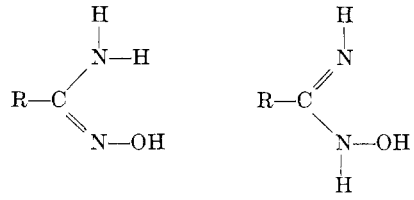
(10) (a) J. Mollin and F. Kašpárek, *Collection Czech. Chem. Commun.*, **26**, 1882 (1961); (b) J. Mollin, *et. al.*, *Monatsh.*, **92**, 1201 (1961).

(11) F. Eloy and R. Lenaers, *Chem. Rev.*, **62**, 155 (1962).

(12) H. E. Ungnade, L. W. Kissinger, A. Narath, and D. C. Barham, *J. Org. Chem.*, **28**, 134 (1963).

(13) F. Eloy, R. Lenaers, and C. Moussebois, *Helv. Chim. Acta*, **45**, 437 (1962).

(14) R. Buyle, F. Eloy, and R. Lenaers, *ibid.*, **46**, 1073 (1963).



IV (*syn* or *anti*, for the oxime part) V

in Table I. In the solid state, the free OH stretching absorption was not observed but was easily discernible in chloroform solution near 3620 cm.$^{-1}$. In solution as well as the solid state amidoximes are obviously highly associated. Structure IV for amidoximes was easily demonstrated by proving the presence of the amine group.

The asymmetric and symmetric NH_2 stretching modes were observed as two sharp bands near 3500 and 3400 cm.$^{-1}$, either in chloroform, benzene, acetonitrile, or in the solid state. In addition to these two sharp bands, broad absorption occurs between 2500 and 3300 cm.$^{-1}$ (see Table I), attributable to associated OH and NH stretching frequencies. Benzamidoxime and phenylacetamidoxime were partially deuterated and the six bands listed for each in Table II are confirming evidence for the presence of NH_2 group.[15]

TABLE II

ABSORPTION BANDS ARISING FROM PARTIAL DEUTERATION

	Assignments, cm.$^{-1}$					
	—NH_2—		—ND_2—		—NHD—	
Substance	ν_a	ν_s	ν_a	ν_s	ν_{NH}	ν_{ND}
Benzamidoxime						
Fluorolube	3467	3367	2577	2457	3417	2512
Phenylacetamidoxime						
Fluorolube	3461	3376	2591	2446	3416	2526
Benzene	3517	3414	2626	2486	3471	2551
O-Benzoylphenyl-acetamidoxime					3487	
Fluorolube	3522	3412	2626	2481	3442	2561

All of the amidoximes exhibited a very strong band between 1650 and 1670 cm.$^{-1}$ both in the solid state and in solution. Deuteration did not diminish the intensity of this band but caused it to shift some 15–25 cm.$^{-1}$ to a lower frequency. This absorption arises from the C=N stretching motion. The NH_2 scissor mode was easily recognized as a band in the 1575- and 1620-cm.$^{-1}$ region which disappeared upon deuteration.[16]

N.m.r. peaks which are listed in Table III verify the amino oxime structure for these amidoximes in chloroform solution. The last two peaks disappeared upon deuteration as was expected. The chemical shifts agree with those recently reported for oxamidoxime.[12]

TABLE III

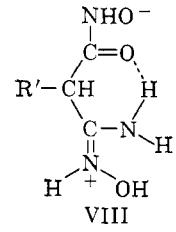
CHEMICAL SHIFTS (δ)[a]

	Assignments			
Compound	C_6H_5	CH_2	NH_2	OH
Phenylacetamidoxime	7.23	3.40	4.55	9.46
O-Benzoylphenylacetamidoxime	7.67	3.41	6.55	..
Benzamidoxime	7.21	..	5.18	9.80

[a] In parts per million in deuteriochloroform.

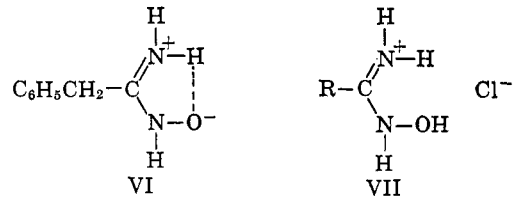
The infrared spectra of two amidoxime esters, the O-acetyl derivative of benzamidoxime[18] and the O-benzoyl derivative of phenylacetamidoxime, are given in Table IV. These compounds possess an NH_2 group based on the same criteria used for the amidoximes (see Tables II and III) and have the same structural features established for amidoximes.

α-Amidoxime Hydroxamic Acids.—As mentioned in the introduction these compounds represent a unique system capable of extensive tautomerism and hydrogen bonding. In addition one might also consider complete transfer of a proton from the weakly acidic hydroxamic acid to the weakly basic amidoxime group to form a



VIII

zwitterion, VIII. A study of the solution spectra of compounds was not possible since the α-amidoxime hydroxamic acids were not soluble in solvents transparent in the infrared in the regions of interest. Spectra in the solid state are listed in Table V. In the region between 2000 and 4000 cm.$^{-1}$ all of these compounds show a considerable number of bands which is



VI VII

The high-frequency band at 1691 cm.$^{-1}$ involves principally the >C=N$^+$< stretching mode, which is in agreement with the assignment made for the band found in the vicinity of 1700 cm.$^{-1}$ in N-alkyl amidinium chlorides [J. C. Grivas, and A. Taurius, *Can. J. Chem.*, **37**, 1260 (1959); and P. Bassignana, C. Cogrossi, G. Polla, and S. Franco, *Ann. chim.* (Rome), 1212 (1963)]. Other amidoxime cations exhibited these high-frequency bands, carbethoxyformamidoxime hydrochloride at 1701 cm.$^{-1}$ (in CH_3CN)[8] and 2-carbethoxyacetamidoxime hydrochloride[17] at 1696 cm.$^{-1}$ (Fluorolube).

It should also be pointed out that the existence of different forms for phenylacetamidoxime as suggested would lead to a different pattern of bands in the NH stretching region compared with those of the other amidoximes. Comparison of the spectra reported in Table I shows that this is indeed the situation; a strong broad band appearing at 3290 cm.$^{-1}$ for phenylacetamidoxime is absent in the spectra of the other amidoximes. However, phenylacetamidoxime hydrochloride also has a strong band at 3285 cm.$^{-1}$ as well as the band at 1685 cm.$^{-1}$. On the basis of this observation, one can surmise that phenylacetamidoxime exists partly as the neutral molecule IV and partly as the proton transferred species VI in the crystalline state.

(15) An example of this method can be seen in the paper of A. J. Boulton and A. R. Katritzky [*Tetrahedron*, **12**, 51 (1961)] who established the presence of the amino group in tautomeric aminoisoxazoles. For hydrogen bonding and partial deuteration, see also A. N. Hambly and B. V. O'Grady [*Chem. Ind.* (London), 459 (1962)] and A. G. Moritz [*Spectrochim. Acta*, **18**, 671 (1962)].

(16) The infrared spectrum of one of the model compounds, phenylacetamidoxime, posed a perplexing problem since crystalline samples exhibited a medium to strong band at 1691 in addition to the expected very strong band at 1656 cm.$^{-1}$ (KBr, Nujol, and Fluorolube). This spurious band vanished in the liquid film and solution spectra, but is clearly discernible in the previously published infrared spectrum of solid phenylacetamidoxime.[4] Apparently, this band was unique for phenylacetamidoxime itself since two ring-substituted compounds, *viz.*, *p*-chloro and *p*-methoxyphenylacetamidoxime, did not absorb above 1670 cm.$^{-1}$. Deuterium exchange of phenylacetamidoxime moved the very strong band at 1656 to 1640 cm.$^{-1}$ and that at 1691 to a shoulder at 1675 cm.$^{-1}$. These shifts can be accounted for if, in the cystalline form, phenylacetamidoxime exists as a mixture of IV (R = $C_6H_5CH_2$) and the tautomeric dipolar species VI.

(17) See ref. *c*, Table I.

(18) We gratefully acknowledge the gift of this compound from Dr. G. Strani Angelini Francesco, Rome, Italy.

TABLE IV

INFRARED ABSORPTIONS BANDS[a] OF O-ACYL AMIDOXIMES AND DIBENZOHYDROXAMIC ACID

$C_6H_5C(NH_2)=NOCOCH_3$		$C_6H_5CH_2C(NH_2)=NOCOC_6H_5$		$C_6H_5CONHOCOC_6H_5$	
Nujol	$CHCl_3$	Nujol	$CHCl_3$	Nujol	$CHCl_3$
	3535 m		3530 m		
3455 m	3425 m	3500 m	3470 m		
3340 m		3385 m			
					3240 m-b
				3165 m-b	
	1761 vs			1768 vs	1766 vs
1746 vs			1740 s		
		1721 s			1701 s
1625 vs	1638 vs		1649 vs	1643 m-b	
		1611 s			
1597 m	1586 m	1601 sh	1602 m	1601 m	1601 m
1559 m	1576 sh	1578 m	1585 m	1578 m	1584 m

[a] In the range of 1500–4000 cm.$^{-1}$.

TABLE V

INFRARED ABSORPTION BANDS[a] OF α-AMIDOXIME HYDROXAMIC ACIDS (I, R = H) AND THEIR BENZOYL DERIVATIVES (I, R = COC_6H_5)

Parent compound, R′			Benzoyl derivatives, R′			
H	Cyclohexyl	Benzyl	H	*sec*-Butyl	Cyclohexyl	Benzyl
	3483 m		3520 m	3495 m	3480 m	3504 m
	3398 sh	3447 s				
3362 m	3363 m	3352 s		3378 m	3370 m	3355 m
3282 sh	3233 m		3277 s			
3217 s-b		3167 vs-b	3192 s			
		3062 s		3100 m-b	3092 m-b	3130 m-b
			3005+w			
			2960+vw	2970+m	2960+s	2970+vw
2930+m	2940+m	2915+m		2940+m		
2850+w	2865+m	2865*w	2870+sh	2880+sh	2870+m	2870+sh
2500 m-vb						
			1776 s	1770 s	1768 s	1775 s
			1727 s	1741 s	1738 s	1741 s
1690 m	1673 sh	1681 s	1681 s	1696 s	1695 s	1700 s
	1660 vs		1655 sh			1650 vs
1646 vs-vb	1644 sh	1635 vs	1630 vs	1640 vs	1636 vs	
			1600 m	1605 m	1601 m	1603 m
1569 w-b	1589 m	1603 s	1583 m	1582 m	1584 m	
1520 m	1511 m-b	1495 m	1504 m	1500 m-b	1513 m	1499 m
1422+m	1454+m-b	1453*m	1456+m	1456+m	1459+m	1459+m

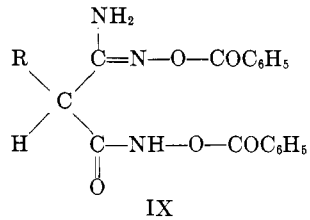
[a] Spectra were determined in Nujol mull and the values are given in cm.$^{-1}$. Bands marked with an asterisk (*) were determined in Fluorolube mull, those with a plus (+) in KBr disks.

an indication of bonded NH and OH groups. If these compounds are represented by structure I (R = H), one might predict the stretching vibrations of C=N of amidoximes and C=O of the hydroxamic acid group around 1660 cm.$^{-1}$ and the NH_2 scissor mode around 1600 cm.$^{-1}$, the latter disappearing upon deuteration. However when R = R′ = H, the spectra showed a medium band at 1690, a very strong band at 1646, and a weak broad band at 1569 cm.$^{-1}$. Deuteration extinguished the 1690 band and moved the broad absorption from 1646 to 1636 cm.$^{-1}$. This behavior does suggest to us that this compound exists as a zwitterion VIII. The band at 1690 cm.$^{-1}$ is characteristic of the amidoxime cation while that at 1646 cm.$^{-1}$ is indicative of the hydroxamate ion. The carbonyl frequency of the benzohydroxamate ion in Nujol showed up at 1621 cm.$^{-1}$, and its aliphatic counterpart would be expected to absorb higher by some 10–20 cm.$^{-1}$. Furthermore, this compound showed no NH_2 scissor deformation mode in the vicinity of 1600, but rather a very large broad band between 2200 and 2950 cm.$^{-1}$ which is characteristic of amine salts. On the other hand, in dimethyl sulfoxide the proton magnetic resonance spectrum of I (R = R′ = H) exhibited two signals, one at 5.32 and the other at 9.08 p.p.m., with the intensities in the ratio of 2:3. This indicated that in this solvent the molecule has structure I (R = R′ = H), since no shift in the $-NH_2$ signal (5.32 p.p.m.) (compared with simple amidoxime, see Table III) had occurred, and the other signal (9.08 p.p.m.) representing the two –OH and the hydroxamic acid >NH proton is at a position consistent for these three protons in rapid exchange.

The other two parent compounds (R′ = cyclohexyl and benzyl, R = H) presented a different picture in their infrared spectra. They showed a doublet indicative of an NH_2 group at 3483, 3363 and 3435, 3340 cm.$^{-1}$, respectively. This compared well with positions shown by the parent amidoximes in the solid state. Furthermore, both of these compounds absorbed around 1580–1590 cm.$^{-1}$ as would be expected if an NH_2 group were present. Both compounds again showed intense absorption in the 1630–1660-cm.$^{-1}$ region. The cyclohexyl parent had the band come to a peak at 1660 (where it is predicted) while the benzyl parent showed its mean peak at 1630 cm.$^{-1}$. The proton resonance spectra in dimethyl sulfoxide clearly

indicated an unperturbed amino group (5.25 p.p.m.) firmly establishing I for the structure of these compounds in this solvent.

Dibenzoyl Derivatives of α-Amidoxime Hydroxamic Acids.—These derivatives were more amenable to spectroscopic study than their parent compounds since they were all soluble in dimethyl sulfoxide and the *sec*-butyl derivative was moderately soluble in chloroform. Examination of the n.m.r. spectrum of the *sec*-butyl derivative (IX, R = *sec*-C_4H_9) in deuteriochloroform showed a broad band at 5.82 p.p.m., which integrated to two protons with respect to the ten aromatic protons and to one hydrogen on the active methylene (–CH–) group at 3.28 p.p.m. (a doublet). When this solution was shaken with D_2O a definite dim-



IX

inution of this band at 5.82 p.p.m. was observed; thus establishing the presence of the $-NH_2$ group. The n.m.r. spectrum of the same compound in dimethyl sulfoxide revealed a fairly sharp band at 6.40 p.p.m. (two protons). This band was assigned to the NH_2 group of the O-acyl amidoxime part of the molecule. However, there is also a band at 12.51 p.p.m. (one proton) which was assigned to the NH proton of O-acyl hydroxamic part of the molecule. Two other dibenzoyl derivatives IX, with R as hydrogen and benzyl, displayed similar shifts in dimethyl sulfoxide for these protons: 12.38 and 12.36 p.p.m., respectively, for the NH proton, and 6.68 and 6.61 p.p.m. for the NH_2 protons. All attempts to establish the presence of an NH_2 group in these molecules using infrared and partial deuteration (as described above) failed. However, since the n.m.r. spectrum clearly indicated the presence of an NH_2 and NH group in the molecule, the infrared solution spectrum between 1500–1800 cm.$^{-1}$ can be interpreted. The infrared spectra of two model compounds, O-benzoyl phenylacetamidoxime [$C_6H_5CH_2$–$C(NH_2)$=N–O–COC_6H_5] and dibenzohydroxamic acid [$C_6H_5CONHOCOC_6H_5$] (Table V) helped to corroborate the assignments of the bands of the dibenzoyl α-amidoxime hydroxamic acids. The highest frequency band (1780–1765 cm.$^{-1}$) represents the ester C=O stretching frequency of the O-acyl hydroxamic acid portion of IX,[19] and the band corresponding to the amide C=O in the hydroxamic acid portion was found in the region 1655–1645 cm.$^{-1}$.[19] The amidoxime ester portion [$-C(NH_2)$=$NOCOC_6H_5$] caused absorptions near 1750 and 1715 cm.$^{-1}$, representing the C=O and C=N stretching modes, respectively.

Deuteration caused remarkably little shift in the four major bands, but a medium band near 1585 cm.$^{-1}$ disappeared and was hence assigned to the $-NH_2$ scissor deformation.

This study has shown that α-amidoxime hydroxamic acids and their esters have the amidoxime portion in the amine oxime form, the hydroxamic acid portion in the keto hydroxylamine form.

(19) For other examples of this assignment, see O. Exner and B. Kakáč, *Collection Czech. Chem. Commun.*, **25**, 2530 (1960).

Experimental[20]

Preparation of Amidoximes.—These were obtained most conveniently from the reaction of a nitrile with hydroxylamine in boiling ethanol, in the absence of inorganic salts as suggested by the method of Palazzo, *et al.*[21]

p-Chlorophenylacetamidoxime was prepared in 81% yield after a 2-hr. reaction period. It crystallized from ethanol in colorless needles, m.p. 103–104°.

Anal. Calcd. for $C_8H_9ClNO_2$: N, 15.18. Found: N, 14.90.

p-Methoxyphenylacetamidoxime was prepared in 66% yield (3-hr. reaction time). It crystallized from benzene in colorless rhombs, m.p. 108–109°.

Anal. Calcd. for $C_9H_{12}N_2O_2$: N, 15.54. Found: N, 15.57.

Phenylacetamidoxime was prepared by the method of Tiemann as used by Knudsen[22,23] and was recrystallized from benzene, m.p. 63–64°, lit.[22,23] m.p. 67°.

O-Benzoylphenylacetamidoxime.—The preparation in the literature was improved considerably by the following procedure. Phenylacetamidoxime (1.5 g.) in pyridine (15 ml.) was mixed with benzoyl chloride (2.0 ml.) at 0°. After standing at 25° for 3 hr., the mixture was added to ice–water (75 ml.). The crystals (2.4 g.) were washed successively with water, dilute hydrochloric acid, and again with water. Recrystallization from benzene and then from ethanol afforded crystals, m.p. 143–144°, lit.[23] m.p. 144°.

Amidoxime Hydrochlorides.—Phenylacetamidoxime hydrochloride was prepared by passing a stream of dry hydrogen chloride gas through a solution of phenylacetamidoxime (1.0 g.) in mixture of dry ether (20 ml.) and benzene (5 ml.). The salt crystallized from ethanol in colorless prisms, m.p. 152–153°, lit.[23] m.p. 155°.

Deuteration of Amidoximes and Derivatives. A. Benzamidoxime was readily deuterated by one crystallization from deuterium oxide.

B. Phenylacetamidoxime when crystallized from deuterium oxide was partly decomposed. The following procedure was adopted for the exchange. The amidoxime (0.5 g.) in benzene (5 ml.) was stirred with deuterium oxide (4 ml.) at 45° for 10 min. The benzene layer was separated, the solvent was removed *in vacuo*, and the crystalline residue was dried *in vacuo*.

C. α-Amidoximeacetohydroxamic acid (I, R = R′ = H) (50 mg.) was stirred with deuterium oxide (1.0 ml.) at 25° for 15 min., filtered, and dried at 25° *in vacuo*.

D.—Dibenzoyl α-Amidoxime Hydroxamic Acids (XII).—The general procedure for these water-insoluble compounds was carried out as follows. A solution of the derivative (150 mg.) in tetrahydrofuran (1.5 ml.) and deuterium oxide (2 ml.) was boiled for 15 min. Solvents were removed *in vacuo*; the residue was boiled down once with dry benzene (10 ml.), and then it was dried *in vacuo*.

E.—Phenylacetamidoxime hydrochloride was exchanged by dissolving in deuterium oxide and removing solvents *in vacuo* over sulfuric acid.

Infrared spectra were determined using a Beckman IR-4 spectrophotometer with sodium chloride optics. Absorption frequencies were calibrated against the known frequencies of a film of polystyrene. The intensities which are recorded next to each band are classified on an arbitrary scale (in per cent absorption): 10, vw; 10–20, w; 20–80, m; 80–90, s; and above 90, vs.

Infrared Absorptions (1500–4000 cm.$^{-1}$) for Amidoxime Hydrochlorides (Fluorolube Mulls).—Phenylacetamidoxime hydrochloride had bands at 3285 s, 3175 vs, 3015 vs-b, 2865 vs, 1685

(20) All melting points are uncorrected. Analyses were performed by Dr. Kurt Eder, Geneva, Switzerland, and by Micro-Tech Laboratories, Skokie, Ill.

(21) G. Palazzo, M. Tavella, G. Strani, and B. Silvestrini, *J. Med. Pharm. Chem.*, **4**, 351 (1961).

(22) F. Tiemann and P. Krüger, *Ber.*, **17**, 1685 (1884).

(23) P. Knudsen, *ibid.*, **18**, 1068 (1885).

vs, 1624 m, 1600 w, 1587 w, and 1497 cm.$^{-1}$ m. 2-Carbethoxyacetamidoxime hydrochloride[17] had bands at 3377 s, 3138 sh, 2976 vs, 2825 vs, 1749 vs, 1696 vs, 1630 m, and 1545 cm.$^{-1}$ w.

The n.m.r. spectra were determined on a Varian A-60 spectrometer using tetramethylsilane as an internal reference for the chemical shifts which are reported.

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Dithiolium Derivatives. IV.[1-3] Reaction of Secondary Amines with Substituted 3-Methylthio-1,2- and 2-Methylthio-1,3-dithiolium Perchlorates

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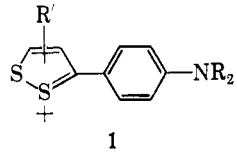
The pseudo-aromatic 3-methylthio-1,2- and 2-methylthio-1,3-dithiolium cationoid systems undergo a facile reaction with secondary amines; aliphatic amines and arylalkylamines yield N,N-disubstituted aminodithiolium derivatives, whereas diphenylamine affords *p*-phenylaminophenyldithiolium adducts. The structures of these products were assigned on the basis of n.m.r. spectra, and by unequivocal syntheses in the cases of methylaniline and diphenylamine. A series of 35 new aminodithiolium derivatives, including a dianion derived from piperazine, are described.

The similarity of electrophilic properties of substituted 1,2- and 1,3-dithiolium cationoid systems has been discussed recently by several investigators. Thus, tertiary aromatic amines such as dimethylaniline can undergo reaction with substituted 1,2-dithiolium salts,[5a] and with 2-methylthio-5-substituted benzo-,[6] 2-methylthio-4-substituted,[1a] and unsubstituted[5b] 1,3-dithiolium salts. The products of these reactions are the highly conjugated and intensely colored N,N-disubstituted *p*-aminophenyl-1,2- and 1,3-dithiolium derivatives, *e.g.*, **1** and **2**. A further common reaction of



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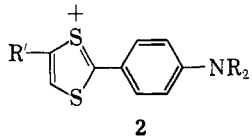

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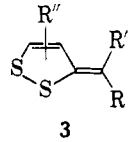

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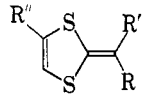

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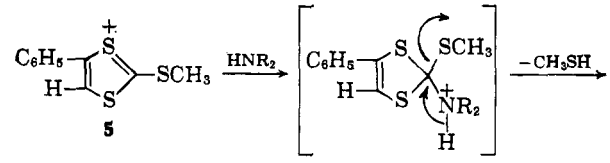
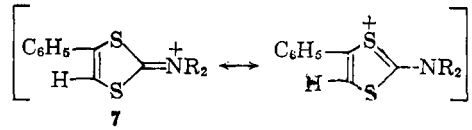
these two systems is condensation with active methylene compounds to yield substituted 1,2-dithiol-3-ylidene (**3**),[7] 1,3-dithiol-2-ylidene (**4**),[1a] and dithiafulvalene[8] derivatives.

That the reactivity of the 1,2- and 1,3-dithiolium systems parallel one another has been further demonstrated in these laboratories. Investigations into the nature of reactivity of 2-methylthio-4-phenyl-1,3-dithiolium perchlorate (**5**) have shown that, when **5** is suspended in tetrahydrofuran (THF) at room temperature in the presence of an aliphatic secondary amine, a good yield of the corresponding 2-dialkylamino-4-phenyl-1,3-dithiolium perchlorate (**7**) is obtained. In view of the susceptibility of the 1,3-dithiolium cation to nucleophilic attack at the C-2 atom, the course of the reaction can be depicted formally as an attack of the secondary amine at C-2 to afford **6**, which can then spontaneously expel methyl mercaptan to form the more stable dialkylamino dithiolium system. In



5 **6**



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analogy to the 1,3-dithiolium series, 3-methylthio-5-phenyl-1,2-dithiolium perchlorate also undergoes reaction with secondary amines to afford the hitherto unknown N,N-disubstituted 3-amino-5-phenyl-1,2-dithiolium perchlorates (**10**).

In intermediate **9**, two competing 1,2-elimination possibilities exist. Pathway 1 involves rupture of the exocyclic C–S bond to eliminate methyl mercaptan and generate the stable dithiolium system **10** whereas, in pathway 2, the endocyclic C–S bond is broken to afford **11**, a species which can undergo further decomposition.[9] Intermediate species similar to **9** and **11** have been postulated by Klingsberg for the reaction of substituted

(1) Previous papers in this series: (a) E. Campaigne and R. D. Hamilton, *J. Org. Chem.*, **29**, 1711 (1964); (b) E. Campaigne, R. D. Hamilton, and N. W. Jacobsen, *ibid.*, **29**, 1708 (1964); (c) E. Campaigne and N. W. Jacobsen, *ibid.*, **29**, 1703 (1964).

(2) A portion of this material was presented before the Division of Organic Chemistry, 147th National Meeting of the American Chemical Society, Philadelphia, Pa., April, 1964, Abstracts, p. 28N.

(3) The support of this research by a grant from the Petroleum Research Fund, administered by the American Chemical Society, to Indiana University, and a grant from Mead Johnson and Co., Evansville, Ind., is hereby gratefully acknowledged.

(4) Abstracted in part from the forthcoming Ph.D. Thesis of R. D. H.

(5) (a) E. Klingsberg and A. M. Schreiber, *J. Am. Chem. Soc.*, **84**, 2941 (1962); (b) E. Klingsberg, *ibid.*, **84**, 3410 (1962).

(6) (a) L. Soder and R. Wizinger, *Helv. Chim. Acta*, **42**, 1733 (1959); (b) L. Soder and R. Wizinger, *ibid.*, **42**, 1779 (1959); (c) R. Wizinger and D. Dürr, *ibid.*, **46**, 2167 (1963).

(7) Y. Mollier and N. Lozac'h, *Bull. soc. chim. France*, 157 (1963).

(8) A. Lüttringhaus, E. Futterer, and H. Prinzbach, *Tetrahedron Letters*, 1209 (1963).

(9) Attack at the C-5 atom in **8**, a possibility raised by a referee, would similarly lead to ring opening and decomposition, but would seem to be less likely owing to a lesser degree of stabilization of the carbonium ion at this position.