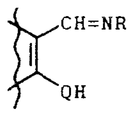
CHEMISTRY OF HYDROXY, MERCAPTO, AND SELENOLO ALDIMINES OF THE HETEROAROMATIC SERIES (REVIEW)

V. P. Litvinov, A. F. Vaisburg,
and V. Yu. Mortikov

The review is devoted to the modern state of the chemistry of o-substituted hydroxy, mercapto, and selenolo aldimines of the heteroaromatic series. Data on methods of synthesis and the reactivities of the aldimines are presented. Some problems involving the structure of these compounds are examined.

1. INTRODUCTION

o-Hydroxy, o-mercapto, and o-selenolo aldimines of the heteroaromatic series have now been attracting attention for about 30 years. This is due to a number of factors. First, these aldimines are convenient models for the study of possible prototropic tautomerism (and the associated tautomerism of electrons) and are therefore of interest as potential thermo- and solvatochromes. On the other hand, the presence of closely situated proton-donor and proton-acceptor functions in the molecules of these compounds creates the possibility for the formation of an intramolecular hydrogen bond, the study of which is of great theoretical value. The investigation of the chemical transformations of hydroxy, mercapto, and selenolo aldimines has revealed their high reactivities and, consequently, the prospect of using them in organic synthesis. Of particular interest is the ability of these aldimines to form chelate compounds that have been found to be inhibitors of the oxidation of hydrocarbons, thermal and light stabilizers of polymers [1], and electron-donor components in charge-transfer complexes [2].



Q=O, S, Se; R=H, alkyl, aryl

Everything stated above explains the existence of a large number of publications devoted to studies of hydroxy, mercapto, and selenolo aldimines. However, the literature does not contain studies that set out to shed light on the entire body of accumulated experimental material (the available review publications reflect the achievements of one or another school in the area under consideration [3, 4]). In the present review we therefore attempted to correlate and systematize the literature data on the methods of synthesis, structure, and chemical properties of o-hydroxy, o-mercapto, and o-selenolo aldimines of the heteroaromatic series.

2. METHODS OF SYNTHESIS

Most of the methods for the synthesis of hydroxy, mercapto, and selenolo aldimines are based on reactions leading to the construction of a hydroxy(mercapto, selenolo)-aldimine fragment in a heteroring. Oxo derivatives of heteroaromatic systems, o-halo aldehydes, and o-alkylmercapto aldehyde dialkylacetals most often serve as the starting compounds, while hydroxy, mercapto, and selenolo aldehydes, β-enamino ketones, and β-keto enol ethers are reaction intermediates.

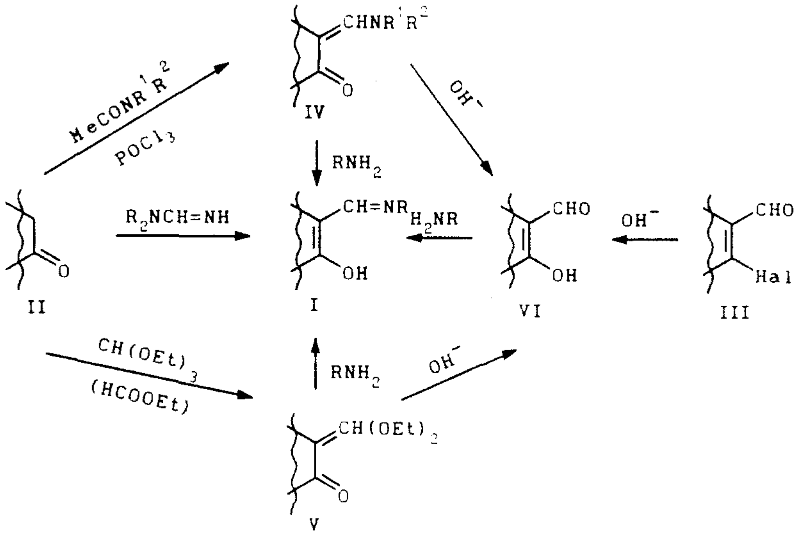
All-Union Scientific-Research Institute of the Genetics and Selection of Industrial Microorganisms, Moscow 113545. N. D. Zelinskii Institute of Organic Chemistry, Russian Academy of Sciences, Moscow 117913. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 1, pp. 5-21, January, 1992. Original article submitted May 28, 1991.

0009-3122/92/2801-0003$12.50

Aldimines of the type under consideration are brightly colored crystalline substances that melt over a broad temperature range. They are stable in the solid state and, in most cases, in organic solvents.

Hydroxy Aldimines

Hydroxy aldimines of the pyrazole [5-10], pyrrole [11-14], furan [11], thiophene [11, 15-18], imidazole [19, 20], 1,2,3-triazole [21], isoquinoline [22], benzo[b]furan [23], and benzo[b]selenophene [33] series (I), which were obtained in 40-90% yields, have been described.

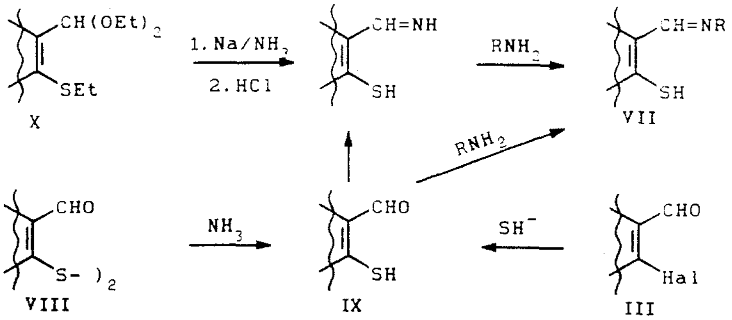


R = H, alkyl, aryl R_1=R_2=Me; R_1=Me, R_2=Ph; Hal=Cl

The most general methods for the synthesis of these compounds are presented in Scheme 1, starting from oxo derivatives II and III through the intermediately formed β-enamino ketones IV, β-keto enol ethers V, or o-hydroxy aldehydes VI.

Mercapto Aldimines

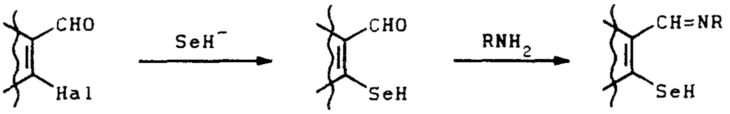
Mercapto aldimines of the pyrazole [6, 9, 10, 34, 35], pyrrole [11, 12, 14, 34], furan [11, 34, 36] thiophene [11, 34, 37-50, 51-53], imidazole [19], benzo[b]thiophene [54-57], benzo[b]furan [57-59], and thieno[3,2-b]thiophene [54] series (VII), which were obtained in 40-90% yields starting from o-halo aldehydes III and o-formylhetaryl disulfides VIII through the intermediately formed mercapto aldehydes IX or from o-alkylmercapto aldehyde dialkylacetals X (Scheme 2).



A method for the synthesis of mercapto aldimines, particularly compounds of the thiophene series, starting from the corresponding β-enamino thiones has been described [52, 53]; a method for the synthesis of mercapto aldimines using organolithium reagents is also known [60].

Selenolo Aldimines

Selenolo aldimines of the pyrazole [6, 9, 10, 61], pyrrole [11, 14, 62], furan [11, 36], thiophene [11], benzo[b]thiophene [55, 56], and benzo[b]furan series (XI), which were obtained in 45-80% yields starting from o-halo aldehydes III through the intermediately formed selenolo aldehydes XII, have been described in the literature.



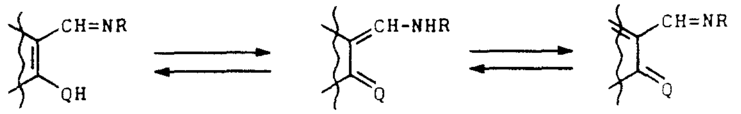
III XII XI

R =H, alkyl, aryl Hal-Cl, Br

The synthesis of selenolo aldimines using organolithium reagents is also known [64].

3. STRUCTURE

Nuclear magnetic resonance (NMR) [6, 9-11, 14, 19-21, 23, 26, 27, 31-33, 47, 53, 57, 58, 63, 65-74], electronic [10, 11, 14, 19, 23, 26, 27, 31-33, 53, 56, 63, 75], and vibrational spectroscopy [10, 11, 14, 19, 21, 23, 26, 27, 31-33, 37, 39, 46, 47, 53, 54, 56-58, 63, 70, 71], x-ray diffraction analysis [4, 76-78], and quantum-chemical methods [65, 79, 80] have been used to study the structure of hydroxy, mercapto, and selenolo aldimines of the heteroaromatic series that potentially may exist in one of several possible tautomeric forms, e.g., A-C or their equilibrium mixture.



A B C

Q=O, S, Se

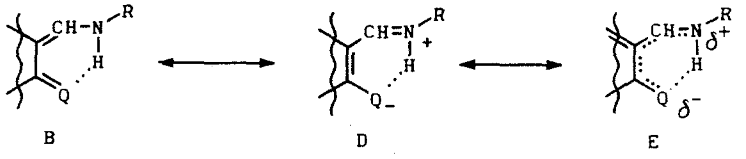
In contrast to the analogous aldimines of the benzene series, for which an equilibrium of the A ⇄ B type is characteristic [81, 82], heteroaromatic hydroxy, mercapto, and selenolo aldimines do not undergo such transformations in most cases; this is most likely due to the lower degree of "aromatic character" of the aromatic heterorings as compared with benzene or naphthalene.

Signals of two protons at 8-9 and 10-16 ppm, which show up in the form of doublets with spin-spin coupling constants (SSCC) J = 12-15 Hz and are related to the CH and NH protons, respectively (see structures B, D, and E below), are present at weak field in the PMR spectra of the enumerated aldimines with an aryl substituent attached to the nitrogen atom.

The electronic spectra of the enumerated aldimines contain an intense long-wave band at 370-560 nm. As a rule, two characteristic bands at 1600-1630 and 1650-1680 cm^{-1} (out-of-ring $C\underline{\cdots}C$ and $C\underline{\cdots}C^{\delta-}$ bonds; see structure E below) are present in the IR spectra of the hydroxy aldimines, while a characteristic band at 1630-1660 cm^{-1} (a $C\underline{\cdots}N^{\delta+}$ bond; see structure E below) is present in the spectra of mercapto and selenolo aldimines.

Thione enamine structure B with an intramolecular hydrogen bond (IMHB) N—H...Q, the strength of which was assumed to change symbatically with respect to the magnitude of the chemical shift of the NH proton, was assigned to aldimines of the type under consideration in the initial stages of the study of their structure [9, 11, 14, 65, 66, 69-71, 74].

However, in a study of the ^{13}C NMR spectra of hydroxy, mercapto, and selenolo aldimines of the pyrazole and pyrrole series [73], particularly when the chemical shifts of the carbon atoms bonded directly to exocyclic heteroatom Q (Q = O, S, Se) were compared, it was concluded that the C=Q bonds in tautomeric form B have low double-bond character and, consequently, that the multiplicity of the heteroring bonds and the C—N bond in the enamine fragment increase, which made it possible to speak of the significant contribution of resonance form D to tautomeric form B.



The joint realization of forms B and D gives mesomeric structure E with general "equalization" of the bonds in the chelate ring; when Q changes (Q = O, S, Se), the polarized character in the chelate ring of the aldimines increases. Hydroxy aldimines, for which the highest degree of double-bond character of the C—Q bond (Q = O) is characteristic, prove to be the least polarized [73].

It is interesting to note that the PMR, UV, and IR spectra of 3-mercapto-2-thenylidene(3-thiono-2-thienylidene)methylamine (XIII) [53] differ from the spectra of the aldimines under discussion and correspond completely to thione enamine structure B without a bipolar contribution.

The data from electronic [63, 75, 83] and vibrational [56] spectroscopy, as well as from x-ray diffraction analysis [4, 76-78], confirm the conclusions drawn on the basis of ^{13}C NMR spectroscopy regarding the existence of hydroxy, mercapto, and selenolo aldimines of the heteroaromatic series in the form of mesomeric structure E with an NH...Q IMHB.

It was also shown that the strength of this IMHB does not correlate with the magnitude of the chemical shift of the NH proton [72], as was previously assumed [9,11,14,65,66,69-71,74].

4. CHEMICAL PROPERTIES

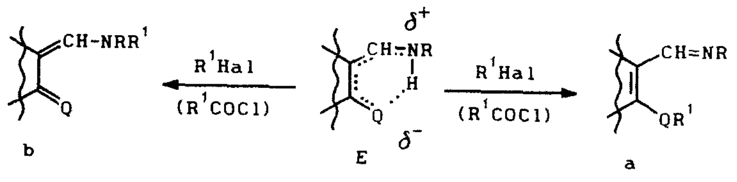
The chemical properties of hydroxy, mercapto, and selenolo aldimines of the heteroaromatic series are represented by reactions that lead either to ortho bifunctional derivatives or to condensed heterocycles. This fact makes aldimines of the type under consideration convenient intermediate compounds in a synthetic respect.

One of the most important properties of aldimines is their ability to form complexes of the chelate type with transition metals [1, 59, 64, 84-90]. However, this question is of independent interest and is not illuminated in the present review for this reason.

For simplicity in setting forth the material and to avoid confusion in the nomenclature hydroxy, mercapto, and selenolo aldimines are most often depicted in the form of aldimine rather than enamine or bipolar structures.

Alkylation and Acylation Reactions

From the structure of hydroxy, mercapto, and selenolo aldimines depicted in the form of structure E one should expect dual reactivity of these compounds in alkylation and acylation reactions: the formation of either Q-alkylation products (acylation) (compounds *a*) or N-alkylation products (acylation) (compounds b) or mixtures of products *a* and b.



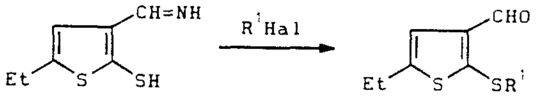
No examples of the alkylation of hydroxy aldimines are available in the literature. Mercapto and selenolo aldimines are alkylated by alkyl (and aryl) halides in the presence of bases to give S(Se)-alkylation products (*a*). For example, 2 methylmercapto-1-phenyl-5-methyl-3-pyrazolidenephenyl(methyl)amines were obtained in the alkylation of 5-mercapto-1-phenyl-3-methyl-4-pyrazolidenephenyl(methyl)amines (XIV, R = Me, Ph) [91].

XIV

R=Me, Ph

Similar derivatives are formed in the alkylation of bis(2-mercapto-5-ethyl-3-thenylidene)benzidine with benzyl chloride [37], 2,2-bis(5-mercapto-4-iminomethyl-2-thienyl)butanes with 2,4-dinitrochlorobenzene [46], or 2-mercapto-3-furylidenephenylamine with methyl iodide [58].

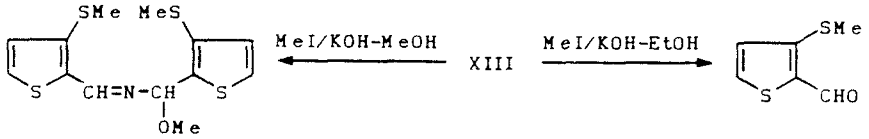
The alkylation of N-methyl-2,5-dimercapto-3,4-diiminomethylpyrrole with methyl chloroacetate [92], mercapto aldimines of the pyrrole, furan, and thiophene series with chloroacetic acid [36, 93], or selenolo aldimines of the pyrazole, pyrrole, furan, and thiophene series with chloroacetic acid [36, 61, 62, 93] gave the corresponding carbomethoxymethylmercapto and carboxymethylmercapto(seleno) derivatives, which were used in the synthesis of bisthienopyrrole [93], thienopyrrole [93], selenophenopyrrole [36, 62], thieno- and selenophenofurans [36, 93], thieno- and selenophenothiophenes [36, 93], and selenophenopyrazole [61].



XV

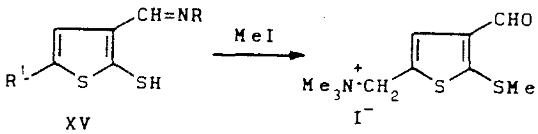
R^1=Me, 2,4-dinitrophenyl: Hal = Cl, I

In addition to alkylation of the mercapto group, hydrolysis of the azomethine group occurs in the reaction of N-unsubstituted mercapto aldimines with alkylating agents in the presence of aqueous solutions of bases, and o-alkylmercapto aldehydes are isolated as reaction products. Thus, for example, 2-mercapto-5-ethyl-3-thienylideneamine (XV, R = H) reacts with methyl iodide or 2,4-dinitrochlorobenzene to give 2-methylmercapto(2,4-dinitrophenylmercapto)-5-ethyl-3-formylthiophenes [37, 52]. 2-Mercapto-3-benzo[b]thenylideneamine and 2-mercapto-5-ethyl-3-thieno[3,2-b]thenylideneamine behave similarly in alkylation reactions [54].



The alkylation of XIII with methyl iodide in the presence of KOH/MeOH leads to α-methoxy-3-(methylmercapto)-N-(3-methylmercapto-2-thenylidene)-2-thenylamine (55%), while alkylation of the same compound with methyl iodide in the presence of KOH/EtOH gives 3-methylmercapto-2-formylthiophene (83%) [53].

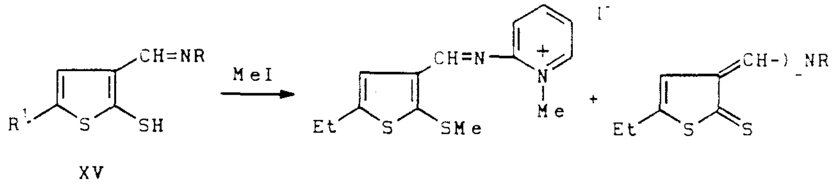
The alkylation of 2-mercapto-5-dimethylaminomethyl-3-thenylidenecyclohexylamine with methyl iodide



XV

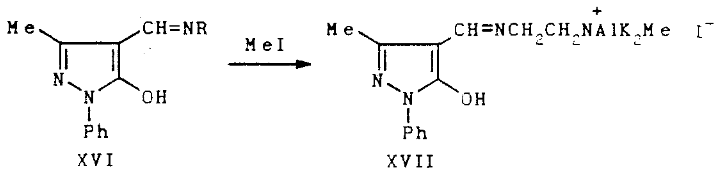
XV, R=cyclohexyl; R^1 =CH_2NMe_2

is accompanied by hydrolysis of the azomethine group and quaternization of the nitrogen atom of the side chain to give 2-methylmercapto-5-dimethylaminomethyl-3-formylthiophene methiodide [42], while the alkylation of mercapto aldimine XV (R = α-pyridyl) leads to a mixture of 5-methylmercapto-2-ethyl-4-thenylidene-α-aminopyridinium methiodide and N,N-bis(5-ethyl-2-thiono-3-thenylidenomethyl)-α-aminopyridine [40].



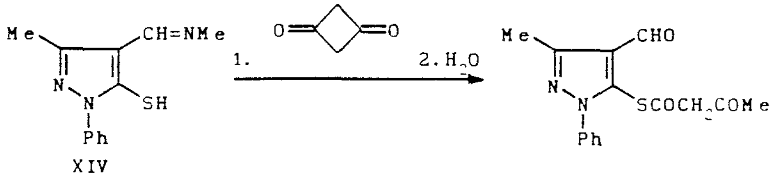
XV, R=α-pyridyl

Treatment of 1-phenyl-3-methyl-5-hydroxy-4-pyrazolidenedialkylaminoethylamines XVI with methyl iodide also leads to quaternization products, viz., XVII; O-alkylation does not occur in this case [7].

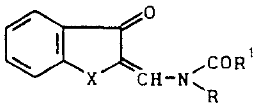


XVI R=$CH_2CH_2NMe_2$, $CH_2CH_2NEt_2$ etc. XVII Alk=Me,Et etc.

In contrast to alkylation, the acylation of hydroxy, mercapto, and selenolo aldimines has been studied to a lesser extent. As an example of S-acylation one can cite the reaction of 5-mercapto-1-phenyl-3-methyl-4-pyrazolidenemethylamine (XIV, R = Me) with diketene and water, which leads to 5-acetonylcarbonylmercapto-1-phenyl-3-methyl-4-formylpyrazole [35].

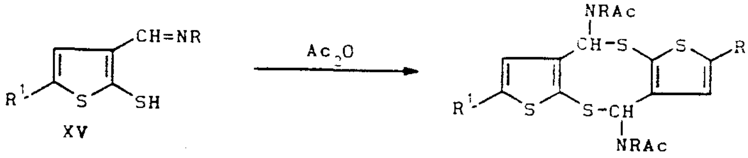


Examples of N-acylation are the consecutive reaction of 3-hydroxy-2-benzo[b]thenylideneamines with sodium isopropoxide and chlorides of various acids to give N-acyl derivatives XVIII [91], the analogous reaction of 3-hydroxy-2-benzo[b]thenylideneamines and 3-hydroxy-2-indolideneamines with acetyl chloride to give homologs of XVIII [94], and the synthesis of 4,9-bis(N-acetyl-N-cyclohexylamino)-4H,9H-dithieno[2,3-b,2,3-f]-5,10-dithiocines (R^1 = H, Et) from mercapto aldimines XV of the thiophene series and acetic anhydride [39].



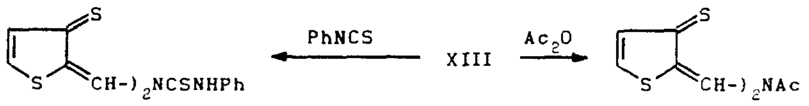
XVIII

(XVIII) X=S, NMe; R=alkyl, aryl; R^1=alkyl, Bz



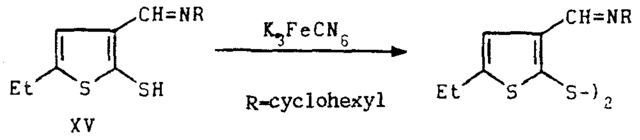
(XV) R=cyclohexyl; R^1=H, Me

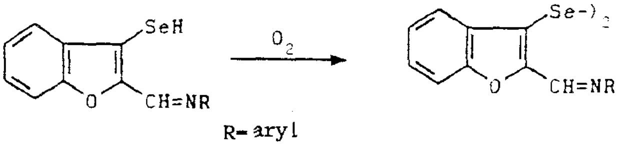
Here, one can cite the reaction of XIII with phenyl isothiocyanate and acetic anhydride to give bis(3-thiono-2-thienylidene)phenylthiourea and bis(3-thiono-2-thienylidene)acetylamine [53].



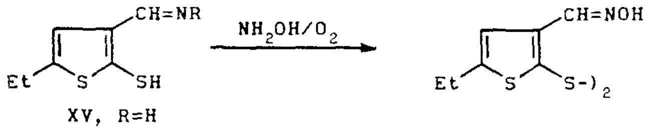
Oxidation and Reduction Reactions

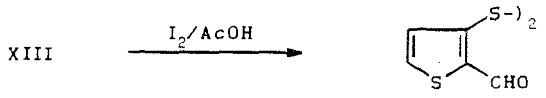
The presence of formally SH and SeH groups in mercapto and selenolo aldimine molecules predetermines their ability to undergo oxidation to the corresponding disulfides and diselenides. Thus, for example, treatment of 2-mercapto-5-ethyl-3-thenylidenecyclohexylamine (XV) with potassium ferricyanide in the presence of a base gives bis(5-ethyl-3-thenylidene-2-cyclohexylamino) disulfide [95], while 3-selenolo-2-benzo[b]furylidenearylamines are oxidized to bis(2-benzo[b]furylidene-3-arylamino) diselenides by air oxygen during brief storage in solutions [63].



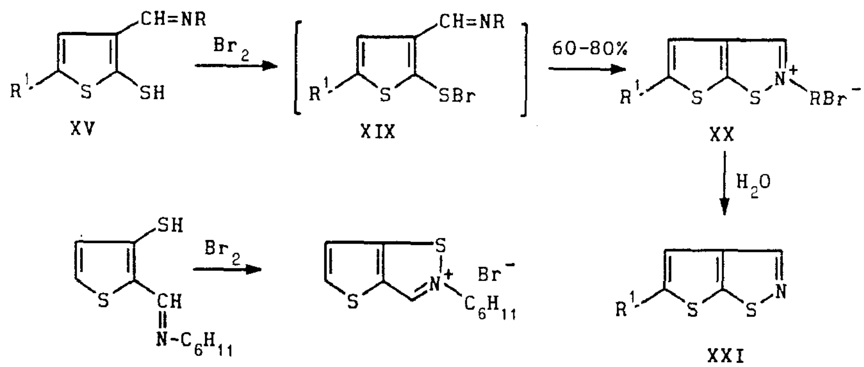


Treatment of XIII with iodine in acetic acid gives bis(2-formylthienyl) 3-disulfide [53], while mercapto aldimine XV (R = H) is converted to bis(5-ethyl-3-hydroximinomethylthienyl) 2-disulfide on reacting with hydroxylamine and, probably, air oxygen [37].

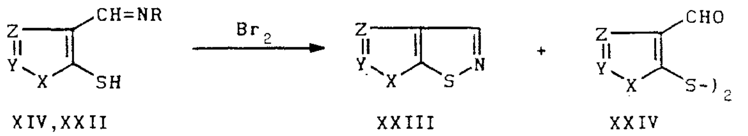




The oxidation of mercapto and selenolo aldimines with elementary bromine, which is accompanied by the formation of N—Q bonds, proved to be more interesting in a synthetic respect. Thus the reaction of mercapto aldimines XV with bromine leads, through the intermediately formed sulfenyl bromides XIX, to isothiazolium bromides XX [39, 95], which readily exchange a bromide ion to give iodides, picrates, and perbromides [95]. The hydrolysis of XX (R^1 = Et) leads to 5-ethylthieno[3,2-d]isothiazole (XXI, R^1 = Et) [95]. Thienoisothiazole XXI (R^1 = Ph) was also obtained in 90% yield by bromination of 2-mercapto-5-phenyl-3-thenylideneamine [85], while bromination of 3-mercapto-2-thenylidenecyclohexylamine was used to synthesize 2-cyclohexylthieno[2,3-d]isothiazolium bromide (74% yield), which was also readily converted to the corresponding iodide, picrate, or perbromide [96].

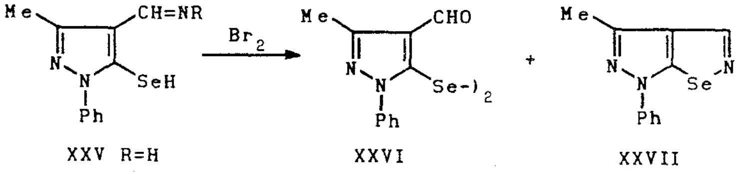


The bromination of mercapto aldimines of the pyrazole (XIV, R = H) and furan and pyrrole series (XXII, R = H) proceeds somewhat differently. Thus in the case of aldimines of the pyrazole and furan series the principal products, in addition to condensed isothiazoles XXIII, were bis(1-phenyl-3-methyl-4-formyl-5-pyrazolyl) and bis(2-phenyl-4-formyl-5-furanyl) disulfides XXIV in 87% and 70% yields. Only a disulfide (XXIV, X = NMe, Y = CPh, Z = CH) was isolated in the reaction of a mercapto aldimine of the pyrrole series (XXII, X = NME, Y = CPh, Z = CH) with bromine [85].

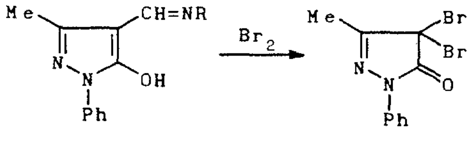


X=NPh, Y=N, Z=CMe; X=O, Y=CPh, Z=CH; X=NMe, Y=CPh, Z=CH; R=H

A mixture of two products, viz., bis(1-phenyl-3-methyl-4-formyl-5-pyrazolyl) diselenide (XXVI, 28%) and 1-phenyl-3-methylpyrazolo[4,5-d]isoselenazole (XXVII, 60%), was obtained in the bromination of 5-selenolo-1-phenyl-3-methyl-4-pyrazolideneamine (XXV, R = H) [97]. It should be noted that the bromination

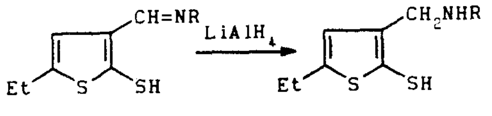


of a hydroxy aldimine of the pyrazole series (XVI, R = H) does not lead to the corresponding pyrazoloisoxazole: the reaction product was 1-phenyl-3-methyl-4,4-dibromo-5-pyrazolone (90% yield) [85].



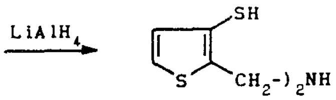
(XVI), R=H

Reactions involving the reduction of hydroxy, mercapto, and selenolo aldimines (reduction of formally the C=N bonds) are represented to a much smaller extent in the literature. Thus treatment of mercapto aldimines XV (R = H, cyclohexyl) with lithium aluminum hydride gives 2-mercapto-5-ethyl-3-thenylamines, which were isolated in the form of hydrochlorides and used in the synthesis of dihydrothieno[3,2-e]thienothiazines and thienothiazole XXI (R^1 = H) [98, 95]:



XV

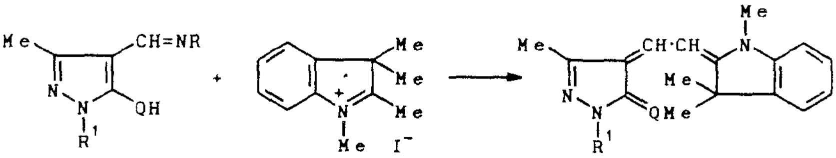
XIII



Bis(3-mercapto-2-thenyl)amine, which was also isolated in the form of the hydrochloride, was similarly obtained by reduction of XIII [53].

Condensation Reactions

Condensation reactions with various CH acids (reactions with the participation of formally an azomethine group) are of significance among the chemical properties of aldimines of the type under consideration.

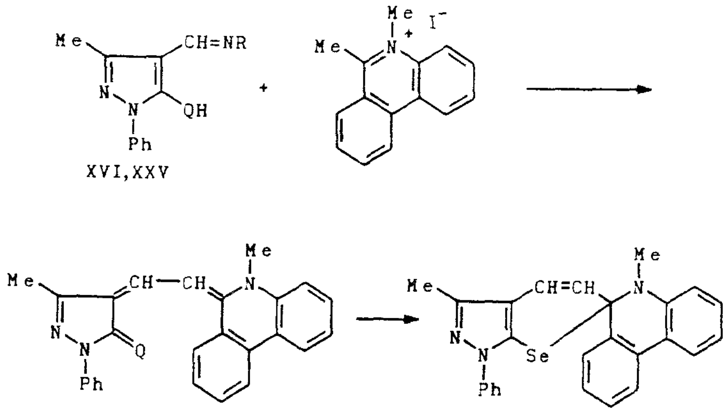


XIV,XVI,XXV XXVIII

R=H, Me; Q=O, S, Se; R^1=Me, Ph

Examples of reactions of this sort are the reactions of hydroxy, mercapto, and selenolo aldimines of the pyrazole series (XVI, XIV, and XXV) with 1,2,3,3-tetramethylindolinium and 5,6-dimethylphenanthridinium iodides, as a result of which merocyanine dyes XXVIII and XXIX are formed [35, 99]. Here, one should note that spiro compounds XXX were isolated along with dyes XXIX in the reaction of selenolo aldimines XXV with 5,6-dimethylphenanthridinium iodide [99].

Dyes similar to XXVIII and XXIX were also obtained as a result of the reaction of hydroxy aldimines of the isoquinoline series — 1,2-dihydro-3-hydroxy-4-isoquinolidenearylamino-2-one with 1,2- and 1,4-dimethylpyridinium, 1,2-dimethylquinolinium, and 1,2-dimethylbenzothiazolium iodides; the products were obtained in 46-70% yields [22].

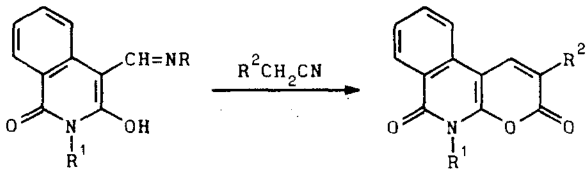


XVI,XXV

XXIX XXX

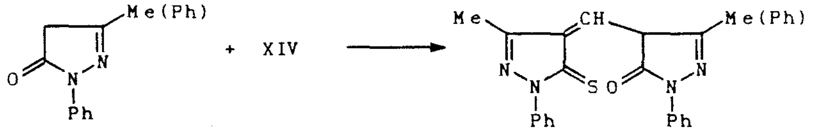
Q=O, Se; R=H, Me

In addition, the indicated aldimines were converted to 5,6-dihydro-3H-pyrano[2,3-c]isoquinoline-3,6-diones in 51-74% yields on reaction with nitriles of the $CH_2(CN)_2$, $NCCH_2COOEt$, $PhCH_2CN$, etc. type in the presence of bases [22].



R^1=H, Me; R^2=CN, COOEt, SO_2Ph

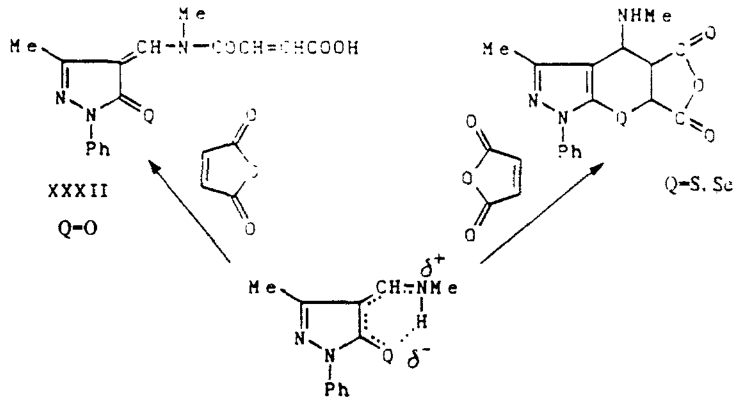
Oxanoles XXXI were obtained by refluxing a mercapto aldimine of the pyrazole series (XIV, R = H) with 1-phenyl-3-R-pyrazol-5-ones (R = Ph, Me) [35].



XXXI

Cycloaddition Reactions

The chemical nature of hydroxy, mercapto, and selenolo aldimines of the heteroaromatic series is manifested most clearly in their reactions with compounds that contain an activated double bond. There are not many examples of reactions of this type. Nevertheless, they make it possible to establish an unequivocal relationship between the structure and reactivity of aldimines.



XXXII

Q=O

Q=S, Se

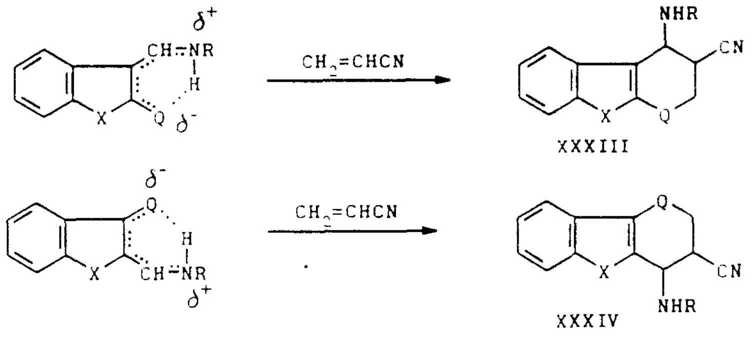
XIV,XVI,XXV

Thus 1-phenyl-3-methyl-5-mercapto(selenolo)-4-pyrazolidenemethylamines (XIV and XXV) react with maleic anhydride to give 1,4-dipolar cycloaddition products — 1-phenyl-3-methyl-4-methylamino-4,5,6-tetrahydrothio(seleno)pyrano[2,3-d]pyrazole-5,6-dicarboxylic acid anhydrides [100]. It was shown that the reaction is first order in both reactants and proceeds via a concerted mechanism [101].

It is interesting to note that the oxygen analog of mercapto and selenolo aldimines XIV and XXV, viz., hydroxy aldimine XVI, does not form a cycloadduct with maleic anhydride but gives an N-acyl derivative (XXXII) [100]; this was explained by the insufficient (for the occurrence of dipolar cycloaddition) polarized character of the chelate ring of XVI.

This fact, as well as the increase in the rate of the reaction with maleic anhydride on passing from mercapto aldimine XIV to selenolo aldimine XXV, confirms the conclusion that the polarized character of the chelate fragment of the aldimines increases with a change in Q in the order O, S, Se (see the "Structure" section) (see scheme at the top of the next page).

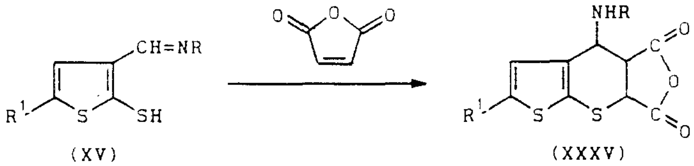
The reaction of mercapto and selenolo aldimines of the benzo[b]furan and benzo[b]thiophene series — 2-mercapto(selenolo)-3-benzo[b]furylidene(thenylidene)arylamines and 3-mercapto(selenolo)-2-benzo[b]furylidene-(thenylidene)arylamines — with acrylonitrile to give condensed thio- and selenopyrans XXXIII and XXXIV was studied in [72]; it was shown that the reaction rate is determined not only by the degree of polarized character of the chelate fragment of the



X=O, S; Q=S, Se; R=aryl

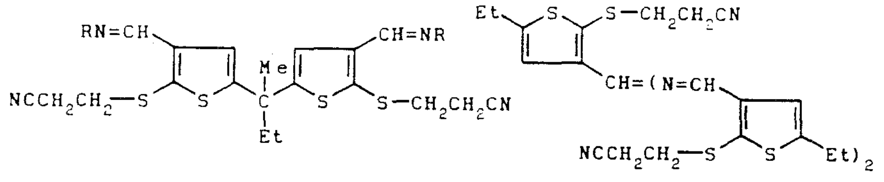
aldimines (the Se derivatives react faster than the S analogs) but also by the strength of the IMHB: 3-mercapto(selenolo) derivatives with weaker IMHB react faster than their isomers — 2-mercapto(selenolo) derivatives with stronger IMHB [72].

Reactions of mercapto aldimines of the thiophene series with maleic anhydride and acrylonitrile have also been described.



R=cyclohexyl R¹=Me, OMe

Thus aldimines XV (R = cyclohexyl, R^1 = Et, OMe) react with maleic anhydride to give cycloadducts XXXV [102], 2,2-bis[(5-mercapto-4-(N-cyclohexyliminomethyl)-2-thienyl]butane reacts with acrylonitrile to give 2,2-bis[5-(β-cyanoethylmercapto)-4-(N-cyclohexyliminomethyl)-2-thienyl]butane [46], while aldimine XV (R = H) in a similar reaction gives 3-[[3-[bis[[2-(2-cyanoethyl)mercapto]-5-ethyl-3-thenylidene]amino]methyl-5-ethyl-2-thienyl]mercapto]propionitrile (47% yield) [37].

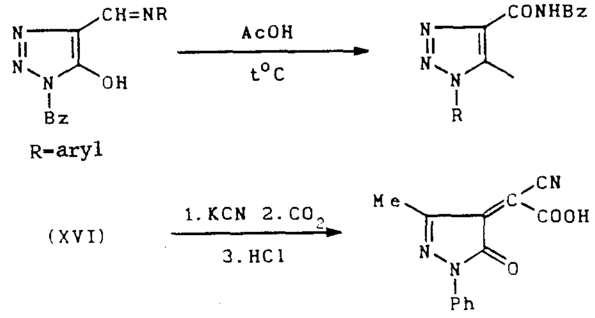


R=cyclohexyl

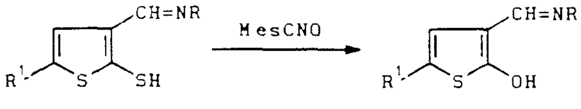
Other Reactions

Photochemical transformations of mercapto and selenolo aldimines have been described in the literature. Thus mercapto aldimine XIV (R = H), upon irradiation with UV light or light in the violet region, forms a mixture of four products: a pyrazoloisothiazole (XXIII), 2-mercapto-1-phenyl-3-methyl-4-formylpyrazole, a disulfide (XXIV, X = NPh, Y = N, Z = CMe), and 1-phenyl-3-methyl-4-formylpyrazole (XXXVI) in 24%, 36%, 12%, and 16% yields, respectively [103], while selenolo aldimine XXV (R = H) under similar conditions gives isoselenazole XXVII, diselenide XXVI, and aldehyde XXXVI in 40%, 40%, and 10% yields, respectively [97].

The recyclization of 5-hydroxy-1-benzyl-4-arylaminomethyl-1,2,3-triazoles by heating or refluxing in acetic acid to 1-aryl-1,2,3-triazole-4-carboxylic acid benzylamides [21], the synthesis of 1-phenyl-3-methyl-5-oxopyrazolidene-4-malonic acid from hydroxy aldimine XVI by its successive reaction with KCN, CO_2, and HCl



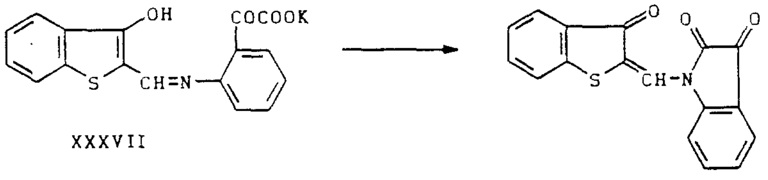
[104], and the reaction of mercapto aldimines of the thiophene series (XV, R = cyclohexyl, R^1 = Et, OMe) with mesitonitrile oxide, which leads to the corresponding hydroxy aldimines — 2-hydroxy-5-ethyl(methoxy)-4-thenylidenecyclohexylamines [18] — are also known.



(XV)

R-cyclohexyl,R¹-Et, OMe

2-(N-Isatinomethylene)-3(2H)-benzo[b]thienone (95% yield) was obtained in the reaction of a hydroxy aldimine of the benzo[b]thiophene series (XXXVII) with acetic anhydride [105]. In addition, among the chemical properties of aldimines of the type under consideration one should cite their hydrolysis to give the corresponding aldehydes (see the "Methods of Synthesis" section).



XXXVII

These are the currently known chemical properties of hydroxy, mercapto, and selenolo aldimines of the heteroaromatic series. They encompass a large number of chemical reactions, by means of which derivatives of various types can be obtained. These are bifunctional compounds that are capable, in turn, of undergoing further chemical transformations [36, 62, 95], condensed heterocyclic systems [72, 95, 100, 102], substances with a "long" conjugation chain that absorb in the visible region of the spectrum and are therefore of interest as dyes [22, 35, 99], and new tautomeric systems that have photo- and solvatochromism [91, 94, 105].

All of the information set forth above makes it possible to conclude that studies of aldimines of the type under consideration as convenient intermediates in organic synthesis and in the search for substances with practically useful properties among the products of their transformations hold promise.

LITERATURE CITED

1. L. I. Belen'kii, E. P. Zakharov, M. A. Kalik, V. P. Litvinov, F. M. Stoyanovich, S. Z. Taits, and B. P. Fabrichnyi, *New Directions in the Chemistry of Thiophene* [in Russian], Ya. L. Gol'dfarb (ed.), Nauka, Moscow (1976).
2. V. P. Litvinov, I. L. Sokol'skaya, V. Yu. Mortikov, and Yu. P. Popov, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 8, 1777 (1980).

3. Ya. L. Gol'dfarb and M. A. Kalik, *Usp. Khim.*, **41**, 679 (1972).
4. V. A. Bren', *Khim. Geterotsikl. Soedin.*, No. 7, 878 (1986).
5. B. A. Porai-Koshits and I. Ya. Kvitko, *Zh. Obshch. Khim.*, **34**, 2999 (1964).
6. L. N. Kurkovskaya, N. N. Shapet'ko, E. D. Samartseva, Yu. N. Koshelev, É. M. Sof'ina, and I. Ya. Kvitko, *Zh. Org. Khim.*, **11**, 1734 (1975).
7. B. A. Porai-Koshits, I. Ya. Kvitko, É. A. Shutkova, and T. M. Galkina, *Zh. Org. Khim.*, **2**, 174 (1966).
8. I. Ya. Kvitko and B. A. Porai-Koshits, *Zh. Obshch. Khim.*, **34**, 3005 (1964).
9. L. N. Kurkovskaya, N. N. Shapet'ko, I. Ya. Kvitko, Yu. N. Koshelev, and É. M. Sof'ina, *Zh. Org. Khim.*, **9**, 821 (1973).
10. L. N. Kurkovskaya, N. N. Shapet'ko, I. Ya. Kvitko, Yu. N. Koshelev, and E. D. Samartseva, *Zh. Org. Khim.*, **10**, 2210 (1974).
11. L. N. Kurkovskaya, N. N. Shapet'ko, N. B. Sokolova, and I. Ya. Kvitko, *Zh. Org. Khim.*, **11**, 1091 (1975).
12. I. Ya. Kvitko and N. B. Sokolova, *Khim. Geterotsikl. Soedin.*, No. 6, 791 (1972).
13. I. Ya. Kvitko and E. A. Panfilova, *Khim. Geterotsikl. Soedin.*, No. 4, 507 (1973).
14. E. A. Panfilova, I. Ya. Kvitko, L. N. Kurkovskaya, and A. V. El'tsov, *Zh. Org. Khim.*, **14**, 2208 (1978).
15. Ya. L. Gol'dfarb and M. A. Kalik, *Khim. Geterotsikl. Soedin.*, No. 2, 178 (1971).
16. Ya. L. Gol'dfarb, M. A. Kalik, and V. K. Zav'yalova, *Zh. Org. Khim.*, **15**, 1540 (1979).
17. Ya. L. Gol'dfarb and M. A. Kalik, *Khim. Geterotsikl. Soedin.*, No. 2, 171 (1971).
18. M. A. Kalik, Ya. L. Gol'dfarb, and M. M. Krayushkin, *Khim. Geterotsikl. Soedin.*, No. 6, 854 (1986).
19. R. V. Khazeeva, I. Ya. Kvitko, A. V. El'tsov, and L. N. Kurkovskaya, *Zh. Obshch. Khim.*, **47**, 1201 (1977).
20. I. Ya. Kvitko, R. V. Khazeeva, and A. V. El'tsova, *Khim. Geterotsikl. Soedin.*, No. 10, 1384 (1975).
21. P. H. Olesen, F. E. Nielsen, E. B. Pedersen, and J. Becher, *J. Heterocycl. Chem.*, **21**, 1603 (1984).
22. O. S. Wolfbeis, I. Trummer, and A. Kneierzinger, *Liebigs Ann. Chem.*, No. 5, 811 (1981).
23. V. A. Bren', Zh. V. Bren', and V. I. Minkin, *Khim. Geterotsikl. Soedin.*, No. 2, 154 (1973).
24. Ya. L. Gol'dfarb, V. P. Litvinov, V. S. Bogdanov, G. V. Isagulyants, É. G. Ostapenko, and A. A. Greish, *Izv. Akad.Nauk SSSR, Ser. Khim.*, No. 10, 2284 (1974).
25. R. N. Glauert and F. G. Mann, *J. Chem. Soc.*, No. 6, 2127 (1952).
26. V. A. Bren', V. I. Usacheva, V. I. Minkin, and M. V. Nekhoroshev, *Khim. Geterotsikl. Soedin.*, No. 5, 635 (1975).
27. V. A. Bren', V. I. Usacheva, and V. I. Minkin, *Khim. Geterotsikl. Soedin.*, No. 7, 920 (1972).
28. V. P. Litvinov, L. N. Smirnov, Ya. L. Gol'dfarb, N. N. Petukhova, and É. G. Ostapenko, *Khim. Geterotsikl. Soedin.*, No. 4, 480 (1975).
29. F. Krollpfeifer, *Liebigs Ann. Chem.*, **462**, 46 (1928).
30. V. P. Litvinov, Ya. L. Gol'dfarb, and É. G. Ostapenko, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 10, 2279 (1974).
31. L. M. Sitkina, V. A. Bren', and V. I. Minkin, *Khim. Geterotsikl. Soedin.*, No. 4, 499 (1975).
32. L. M. Sitkina, A. D. Dubonosov, A. É. Lyubarskaya, V. A. Bren', and V. I. Minkin, *Khim. Geterotsikl. Soedin.*, No. 7, 921 (1985).
33. V. I. Minkin, V. A. Bren', and G. D. Palui, *Khim. Geterotsikl. Soedin.*, No. 6, 781 (1975).
34. L. V. Adam and I. Ya. Kvitko, *Khim. Geterotsikl. Soedin.*, No. 4, 561 (1987).
35. I. Ya. Kvitko and B. A. Porai-Koshits, *Zh. Org. Khim.*, **5**, 1685 (1969).
36. I. Ya. Kvitko, N. B. Sokolova, and L. S. Éfros, *Khim. Geterotsikl. Soedin.*, No. 5, 715 (1973).
37. Ya. L. Gol'dfarb, M. A. Kalik, and M. L. Kirmalova, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 4, 701 (1962).
38. Ya. L. Gol'dfarb, M. A. Kalik, and M. M. Polonskaya, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 5, 897 (1966).
39. Ya. L. Gol'dfarb and M. A. Kalik, *Khim. Geterotsikl. Soedin.*, No. 3, 475 (1969).
40. Ya. L. Gol'dfarb and M. A. Kalik, *Khim. Geterotsikl. Soedin.*, No. 7, 902 (1972).
41. Ya. L. Gol'dfarb and M. A. Kalik, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 7, 1583 (1975).
42. Ya. L. Gol'dfarb and M. A. Kalik, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 7, 1578 (1976).
43. Ya. L. Gol'dfarb, M. A. Kalik, and A. A. Dudinov, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 6, 1449 (1977).
44. Ya. L. Gol'dfarb, M. A. Kalik, and Z. G. Kozlova, *Khim. Geterotsikl. Soedin.*, No. 10, 1331 (1980).
45. Ya. L. Gol'dfarb, M. A. Kalik, and V. K. Zav'yalova, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 12, 2771 (1981).
46. Ya. L. Gol'dfarb, M. A. Kalik, and M. L. Kirmalova, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 10, 1801 (1963).
47. Ya. L. Gol'dfarb and M. A. Kalik, *Khim. Geterotsikl. Soedin.*, No. 10, 1323 (1970).

48. Ya. L. Gol'dfarb and Ya. L. Danyushevskii, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 7, 1345 (1964).
49. V. S. Bogdanov, Ya. L. Danyushevskii, and Ya. L. Gol'dfarb, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 3, 675 (1970).
50. Ya. L. Gol'dfarb, I. A. D'yachenko, and S. G. Mairanovskii, *Khim. Geterotsikl. Soedin.*, No. 3, 309 (1975).
51. Ya. L. Gol'dfarb, M. A. Kalik, and M. L. Kirmalova, *Khim. Geterotsikl. Soedin.*, No. 1, 62 (1967).
52. Ya. L. Gol'dfarb and M. A. Kalik, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 9, 2072 (1973).
53. Ya. L. Gol'dfarb, M. A. Kalik, and M. L. Kirmalova, *Khim. Geterotsikl. Soedin.*, No. 1, 71 (1967).
54. Ya. L. Gol'dfarb, S. A. Ozolin', and V. P. Litvinov, *Zh. Obshch. Khim.*, **37**, 2220 (1967).
55. V. P. Litvinov, Ya. L. Gol'dfarb, and V. Yu. Mortikov, *Khim. Geterotsikl. Soedin.*, No. 7, 905 (1979).
56. V. Yu. Mortikov, V. P. Litvinov, and Ya. L. Gol'dfarb, *Khim. Geterotsikl. Soedin.*, No. 8, 1052 (1984).
57. V. A. Bren', V. I. Usacheva, V. A. Bren', B. Ya. Simkin, and V. I. Minkin, *Khim. Geterotsikl. Soedin.*, No. 5, 631 (1974).
58. A. F. Vaisburg, V. Yu. Mortikov, and V. P. Litvinov, *Khim. Geterotsikl. Soedin.*, No. 5, 598 (1985).
59. V. P. Litvinov, V. Yu. Mortikov, and A. F. Vaisburg, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 2, 422 (1990).
60. V. P. Litvinov, Ya. L. Gol'dfarb, V. V. Zelentsov, L. G. Bogdanova, and N. N. Petukhova, *Khim. Geterotsikl. Soedin.*, No. 5, 486 (1974).
61. Yu. N. Koshelev, I. Ya. Kvitko, and E. D. Samartseva, *Zh. Org. Khim.*, **8**, 2204 (1972).
62. I. Ya. Kvitko and N. B. Sokolov, *Khim. Geterotsikl. Soedin.*, No. 4, 565 (1973).
63. V. P. Litvinov, V. A. Petukhov, V. Yu. Mortikov, and A. F. Vaisburg, *Khim. Geterotsikl. Soedin.*, No. 6, 774 (1986).
64. Ya. L. Gol'dfarb, V. P. Litvinov, and V. Yu. Mortikov, *Khim. Geterotsikl. Soedin.*, No. 7, 898 (1979).
65. V. S. Bogdanov, M. A. Kalik, G. M. Zhidomirov, N. D. Chuvylkin, and Ya. L. Gol'dfarb, *Zh. Org. Khim.*, **7**, 1953 (1971).
66. V. S. Bogdanov, M. A. Kalik, and Ya. L. Gol'dfarb, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 10, 2413 (1970).
67. I. Ya. Kvitko, L. N. Kurkovskaya, R. V. Khazeeva, and A. V. El'tsov, *Khim. Geterotsikl. Soedin.*, No. 12, 1677 (1978).
68. V. S. Bogdanov, V. P. Litvinov, Ya. L. Gol'dfarb, N. N. Petukhova, and E. G. Ostapenko, *J. Prakt. Chem.*, **316**, 970 (1974).
69. V. S. Bogdanov, M. A. Kalik, Ya. L. Danyushevskii, and Ya. L. Gol'dfarb, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 12, 2782 (1967).
70. V. S. Bogdanov, Ya. L. Danyushevskii, and Ya. L. Gol'dfarb, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 13, 675 (1970).
71. V. S. Bogdanov, M. A. Kalik, I. P. Yakovlev, and Ya. L. Gol'dfarb, *Zh. Obshch. Khim.*, **40**, 2102 (1970).
72. A. F. Vaisburg, V. Yu. Mortikov, and V. P. Litvinov, *Izv. Akad. Nauk SSSR, Ser. Khim.*, No. 2, 416 (1990).
73. L. N. Kurkovskaya, L. N. Shapet'ko, I. Ya. Kvitko, L. V. Alam, E. A. Panfilova, and A. V. El'tsov, *Zh. Struk. Khim.*, **19**, 620 (1978).
74. L. N. Kurkovskaya, N. N. Shapet'ko, I. Ya. Kvitko, and Yu. N. Koshelev, *Zh. Org. Khim.*, **8**, 215 (1972).
75. Zh. V. Bren', V. I. Usacheva, G. D. Palui, V. A. Bren', and V. I. Minkin, *Khim. Geterotsikl. Soedin.*, No. 5, 619 (1977).
76. S. M. Aldoshin, L. O. Atovmyan, O. A. D'yachenko, V. I. Minkin, V. A. Bren', G. D. Palui, and Zh. V. Bren', *Zh. Struk. Khim.*, **25**, 106 (1984).
77. L. G. Kuz'mina, Yu. T. Struchkov, M. A. Kalik, and Ya. L. Gol'dfarb, *Khim. Geterotsikl. Soedin.*, No. 12, 1625 (1978).
78. V. N. Nesterov, V. E. Shklover, Yu. T. Struchkov, V. P. Litvinov, A. F. Vaisburg, and V. Yu. Mortikov, *Khim. Geterotsikl. Soedin.*, No. 6, 779 (1986).
79. I. Ya. Kvitko, *Zh. Org. Khim.*, **15**, 2590 (1979).
80. V. I. Minkin, V. A. Kosobutskii, B. Ya. Simkin, and Yu. A. Zhdanov, *J. Mol. Struct.*, **24**, 237 (1975).
81. V. I. Minkin, L. P. Olekhnovich, L. E. Nivorozhkin, Yu. A. Zhdanov, and M. I. Knyazhanskii, *Zh. Org. Khim.*, **6**, 348 (1970).
82. L. N. Kurkovskaya, R. N. Nurmukhametov, and D. N. Shigorin, *Zh. Struk. Khim.*, **21**, 61 (1980).
83. R. N. Nurmukhametov, O. N. Betin, and D. N. Shigorin, *Dokl. Akad. Nauk SSSR*, **230**, 146 (1976).
84. A. V. El'tsov, I. Ya. Kvitko, S. P. Fradkina, and E. A. Panfilova, *Zh. Obshch. Khim.*, **49**, 417 (1979).

85. L. V. Alam, I. Ya. Kvitko, and A. V. El'tsov, *Zh. Org. Khim.*, **13**, 863 (1977).
86. V. I. Bregadze, N. G. Furmanova, L. M. Golubinskaya, Y. Y. Kompan, Yu. T. Struchkov, V. A. Bren' (Bren), Zh. V. Bren' (Bren), A. E. Lyubarskaya, V. I. Minkin, and L. M. Sitkina, *J. Organomet. Chem.*, **192**, 1 (1980).
87. V. I. Usacheva, Zh. V. Bren', V. A. Bren', and V. I. Minkin, *Khim. Geterotsikl. Soedin.*, No. 5, 623 (1975).
88. Zh. V. Bren', V. A. Bren', L. M. Sitkina, and V. I. Minkin, *Khim. Geterotsikl. Soedin.*, No. 1, 65 (1979).
89. L. M. Sitkina, V. A. Bren', L. M. Golubinskaya, A. D. Dubonosov, A. É. Lyubarskaya, V. I. Bregadze, and V. I. Minkin, *Zh. Org. Khim.*, **16**, 2345 (1980).
90. V. A. Bren' and Zh. V. Bren', *Koordinats. Khim.*, **4**, 1499 (1978).
91. G. D. Palui, A. É. Lyubarskaya, B. Ya. Simkin, V. A. Bren', Yu. A. Zhdanov, M. I. Knyazhanskii, V. I. Minkin, and L. P. Olekhnovich, *Zh. Org. Khim.*, **15**, 1348 (1979).
92. E. A. Panfilova, I. Ya. Kvitko, A. D. Kuptsov, and A. V. El'tsov, *Zh. Org. Khim.*, **17**, 1564 (1981).
93. I. Ya. Kvitko, N. B. Sokolova, S. P. Fradkina, and A. V. El'tsov, *Zh. Org. Khim.*, **12**, 1574 (1976).
94. G. D. Palui, L. M. Sitkina, A. D. Dubonosova, V. I. Minkin, V. A. Bren', O. I. Lantsova, and I. V. Grabchak, *Khim. Geterotsikl. Soedin.*, No. 4, 466 (1988).
95. Ya. L. Gol'dfarb, M. A. Kalik, and M. L. Kirmalova, *Khim. Geterotsikl. Soedin.*, No. 2, 220 (1965).
96. Ya. L. Gol'dfarb and M. A. Kalik, *Khim. Geterotsikl. Soedin.*, No. 6, 1022 (1967).
97. N. I. Rtishchev, A. V. El'tsov, I. Ya. Kvitko, and L. V. Alam, *Zh. Obshch. Khim.*, **55**, 2358 (1985).
98. Ya. L. Gol'dfarb, M. A. Kalik, and M. L. Kirmalova, *Khim. Geterotsikl. Soedin.*, No. 1, 59 (1967).
99. I. Ya. Kvitko, V. P. Martynova, R. P. Ponomareva, and N. S. Fedorova, *Khim. Geterotsikl. Soedin.*, No. 3, 384 (1975).
100. G. K. Lebedeva, I. Ya. Kvitko, and A. V. El'tsov, *Khim. Geterotsikl. Soedin.*, No. 4, 527 (1979).
101. I. Ya. Kvitko, I. I. Potapochkina, and L. A. Brindza, *Khim. Geterotsikl. Soedin.*, No. 5, 616 (1986).
102. V. A. Kalik, Ya. L. Gol'dfarb, and M. M. Krayushkin, *Chemica Scripta*, **28**, 311 (1988).
103. N. I. Rtishchev, A. V. El'tsov, I. Ya. Kvitko, L. V. Alam, and E. G. Bocharova, *Zh. Obshch. Khim.*, **54**, 152 (1984).
104. N. P. Smirnova, I. Ya. Kvitko, and A. V. El'tsov, *Zh. Org. Khim.*, **21**, 657 (1985).
105. Zh. V. Bren', V. P. Rybalkin, and V. A. Bren', *Khim. Geterotsikl. Soedin.*, No. 9, 1217 (1989).