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CYANOAMINO-*sym*-TRIAZINES (Review)

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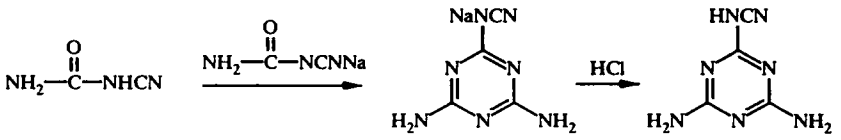
*Data on the synthesis, transformations, and applications of cyanoamino-*sym*-triazines are reviewed.*

The discovery of herbicidal activity in the derivatives of *sym*-triazine and their large-scale use in agriculture in the fight against weeds [1-4] gave impetus to the vigorous development of the chemistry of cyanoamino-*sym*-triazines, which are of potential interest as agents for the protection of plants. As a result of the development of effective methods of synthesis, the highly reactive cyanoamino-*sym*-triazines became available and convenient reagents for the production of various derivatives of *sym*-triazine. Pesticides recommended for wide application in agriculture have been found among the cyanoamino-*sym*-triazines that have now been synthesized.

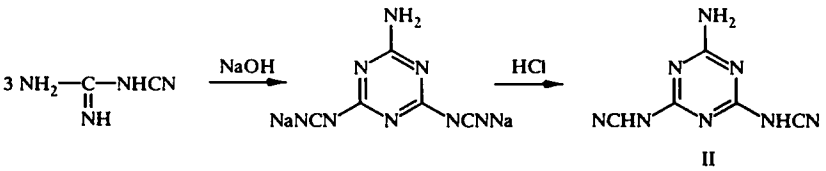
The present review is the first attempt at the systematic treatment of data on methods for the synthesis and applications of cyanoamino-*sym*-triazines.

1. METHODS FOR THE SYNTHESIS OF CYANOAMINO-*sym*-TRIAZINES

The first representative of this series of compounds described in the literature [5] was 2,4-diamino-6-cyanoamino-*sym*-triazine, the so-called cyanomelamine (I), which was obtained by Kaiser and Redmon in 1950 by the intermolecular heterocyclization of cyanoguanidine and its sodium salt:



Cyanoguanidine and its derivatives have subsequently been used many times for the synthesis of cyanoaminotriazines. A method for the production of 2-amino-4,6-dicyanoamino-*sym*-triazine (II) was developed on the basis of the cyclotrimerization of cyanoguanidine [6]:



II

2-Cyanoaminodialkyl-*sym*-triazines (III) were obtained by the cyclocondensation of cyanoguanidine with various imidic esters [7]:

Armenian Agricultural Academy, Erevan. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 1, pp. 17-40, January, 1998. Original article submitted June 5, 1996.

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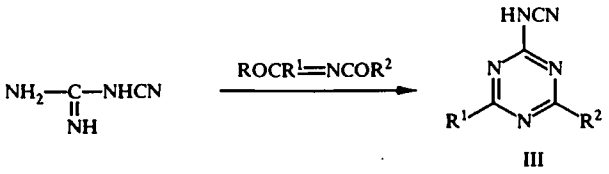
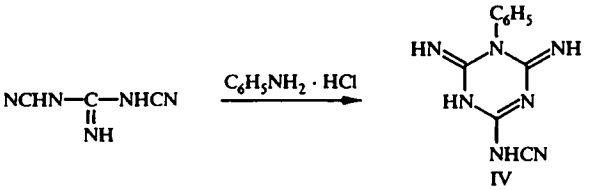


III

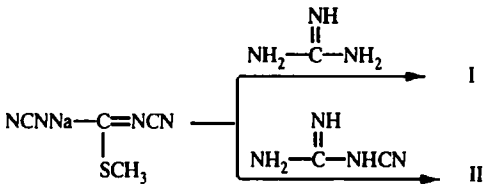
R^1, R^2 = alkyl, halogenoalkyl, arylalkyl

With aniline hydrochloride, dicyanoguanidine forms cyanoaminotetrahydro-*sym*-triazine (IV) [8]:



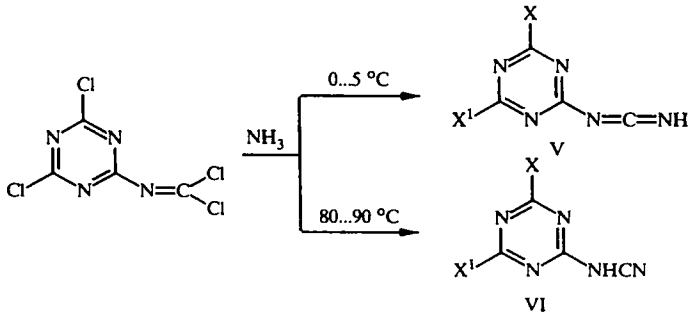
IV

The action of the sodium salt of N,N-dicyano-S-methylthiourea on guanidine and N-sodiocyanoguanidine leads to the formation of cyano- and dicyanomelamines [9]:



The presented methods are based on the construction of the molecules of cyanoamino-*sym*-triazines from acyclic fragments. Another approach to the synthesis of these compounds is also possible, i.e., the introduction of the cyanoamino group into the already prepared triazine ring through substitution or modification of the various substituents.

The nature of the reaction of the tetramer of cyanogen chloride (2,4-dichloro-6-dichlorocyanato-*sym*-triazine) with a concentrated aqueous solution of ammonia depends on the temperature. Thus, carbodiimido-*sym*-triazines (V) are formed at low temperature, and the isomeric cyanoamino derivatives (VI) are formed at low temperature [10]:

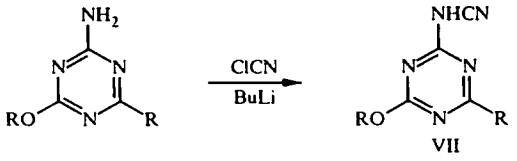


V

VI

X = X^1 = Cl, X = X^1 = NH_2; X = Cl, X^1 = NH_2

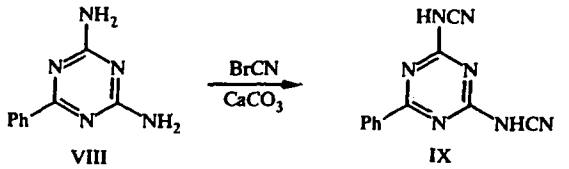
In the presence of a strong base (butyllithium), cyanogen chloride is capable of cyanating the amino group of amino-*sym*-triazines with the formation of the cyanoamino derivatives (VII) [11].



VII

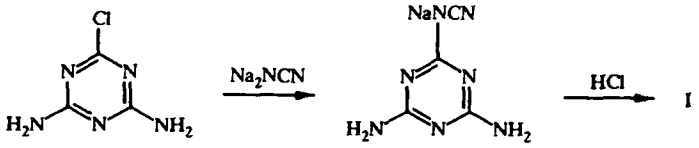
R = alkyl

An analogous process is observed with cyanogen bromide in the presence of potassium carbonate. Under these conditions, for example, exhaustive cyanation of 2,4-diamino-6-phenyl-*sym*-triazine (VIII) leads to the formation of 2,4-biscyanoamino-6-phenyl-*sym*-triazine (IX) [12]:



VIII IX

A convenient method for the introduction of a cyanoamino group into the *sym*-triazine ring is the nucleophilic substitution of a halogen atom. Thus, Bieling and coauthors [13] first realized the cyanoamination of chloro-*sym*-triazine with sodiocyanamide:

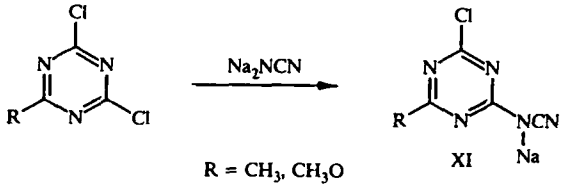


Subsequently, many other chloro-*sym*-triazines were brought into this reaction. It is interesting that the action of sodium cyanamide on cyanuric chloride in the presence of aqueous alkali leads to the nucleophilic substitution of only one chlorine atom [14]:

X

As a result of an improvement in the preparation method, the yield of compound (X) was increased from 60% to 95% [15].

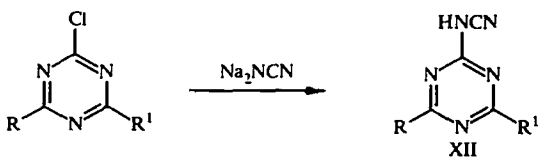
In the case of 2,6-dichloro-6-methyl(methoxy)-*sym*-triazines in reaction with sodiocyanamide in an aqueous or water–acetone medium, the chlorine atom at position 2 is substituted [15, 16]:



R = CH_3, CH_3O XI

The reaction of 2-chloro-4,6-bisalkylamino-*sym*-triazines with sodium cyanamide in decalin at high temperature gave 2-cyanoamino-4,6-bisalkylamino-*sym*-triazines [17].

In an aqueous medium or in DMFA and DMSO, monochloro-*sym*-triazines also undergo cyanoamination, giving satisfactory yields of the expected cyanoaminotriazines (XII) [18-20]:

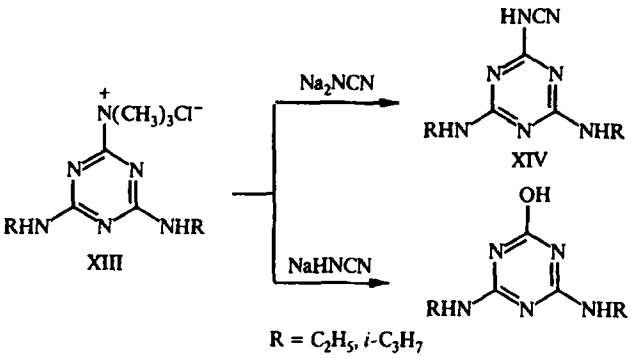


XII

R,R^1 = CH_3, R, R^1 = alkyl(aryl)amino, R = alkylamino, R = CH_3O, CH_3S

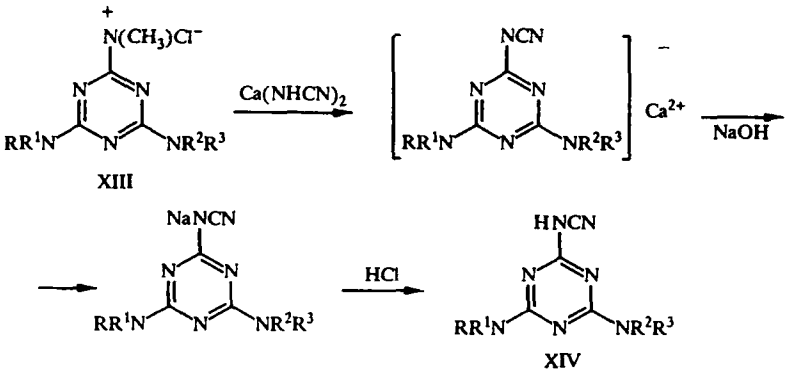
A highly effective method was developed for the production of cyanoamino-*sym*-triazines on the basis of trimethyl-*sym*-triazinylammonium chloride (XIII), which is formed easily during the action of triethylamine on chloro-*sym*-triazines in aprotic solvents. On account of the extreme ease of their reaction with various nucleophiles, these salts have been used successfully

and repeatedly for the production of many derivatives of *sym*-triazine [21-23]. If neutral sodiocyanamide in water is used, the salts (XIII) undergo not only cyanoamination but also partial hydrolysis to hydroxy compounds. The formation of the latter is suppressed to a considerable degree if acidic sodium cyanamide is used [23]:



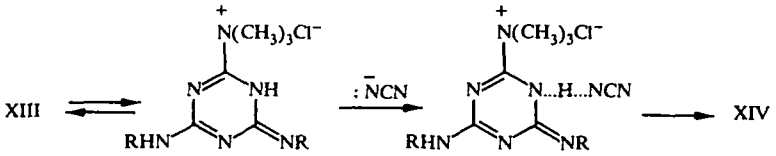
R = C_2H_5, *i*-C_3H_7

However, the most effective and convenient cyanoaminating agent was acidic calcium cyanamide, which is moreover the most readily accessible salt among the acidic salts of cyanamide. Here, the desired 2-cyanoamino-4,6-bisalkyl(dialkyl)amino-*sym*-triazines (XIV) are formed almost without the hydroxy-*sym*-triazines as side products and with high yields (80% or more) [23-27].



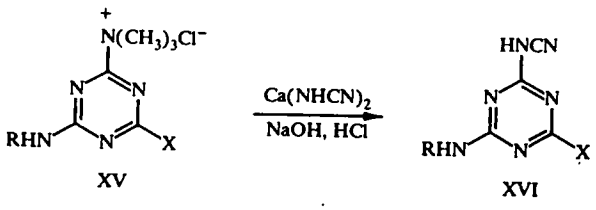
R, R^2 = H; R^1, R^3 = alkyl; R, R^1, R^2, R^3 = alkyl

Salts of type (XIII) with an alkylamino radical change into compounds (XIV) more easily than the salts containing a dialkylamino group. This is probably explained by the amine–imine tautomerism characteristic of triazines having at least one alkylamino group in their composition. As a result of the approach of the NCN^- anion to the imine form and the formation of hydrogen bond between the nucleophile and the substrate, cyanoamination takes place more readily than in the case of the dialkylamino derivatives incapable of such tautomerism [23]:



R = alkyl

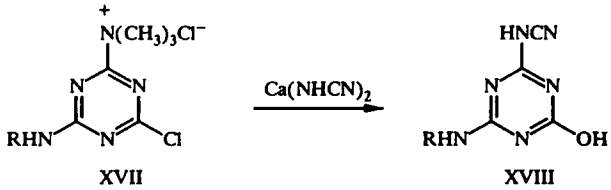
The ease with which the salts (XIII) enter into cyanoamination makes it possible to synthesize cyanoamino-*sym*-triazines at room or even lower temperature. Therefore, in spite of the strongly alkaline reaction medium, created as a result of the release of triethylamine and the use of sodium hydroxide for the treatment of the calcium salts, the indicated method for the production of cyanoamino-*sym*-triazines can be used successfully for the salts (XV) containing methoxy-, methylthio-, and cyanoalkylamino groups sensitive to alkaline agents [28, 29]:



XV XVI

R = C_2H_5, *i*-C_3H_7; X = CH_3O, CH_3S, $NHC(CH_3)_2CN$

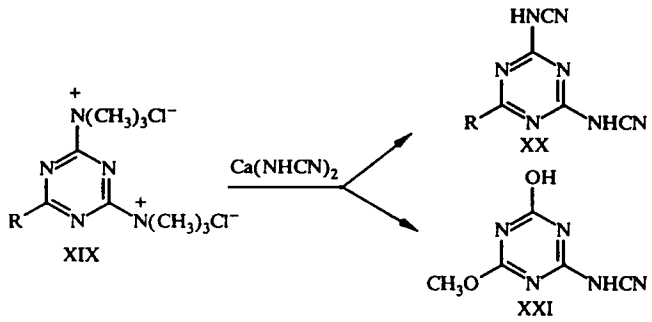
An exception is salts of type (XVII) (X = Cl). Under the influence of the strongly electron-accepting ammonium cation, the C−Cl covalent bond in such salts is more polar than in the usual monochlorotriazines. Under the conditions of the cyanation reaction, the salts therefore undergo both cyanoamination and hydrolysis with the formation of the 2-hydroxy derivatives (XVIII) [28]:



XVII XVIII

R = C_2H_5, *i*-C_3H_7

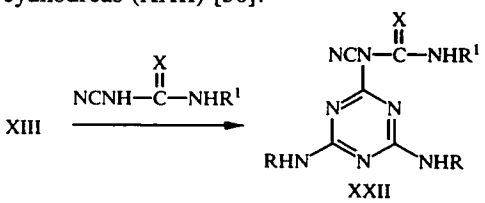
The cyanoamination of the bisammonium salts (XIX) is also unusual. The compounds (XX) expected here are formed with low yields, while the methoxy analog is converted into 2-hydroxy-4-methoxy-6-cyanoamino-*sym*-triazine (XXI) [29]:



XIX XX XXI

R = C_2H_5NH, $(CH_3)_2N$, CH_3O

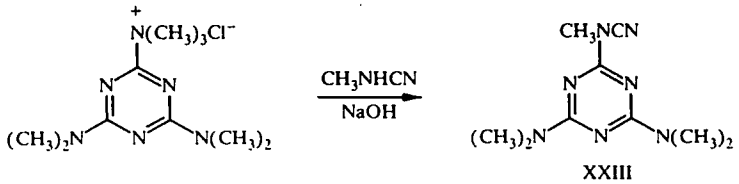
The reactions of salts of type (XIII) with the functional derivatives of cyanamide, containing a second concurrent NH-acidic center of amine residue, take place strictly regioselectively at the NH group of the cyanamide fragment. The salts (XIII) also react in this way with cyanoguanidine, cyanourea, and their derivatives, leading to the formation of N-*sym*-triazinyl-N-cyanoguanidines and N-*sym*-triazinyl-N-cyanoureas (XXII) [30]:



XIII XXII

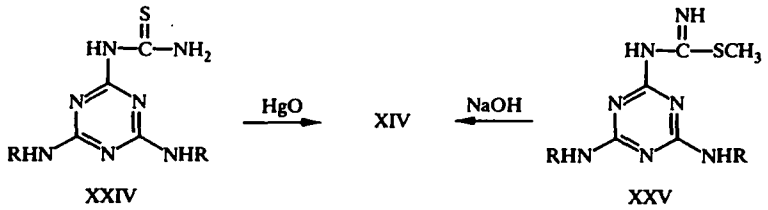
R = C_2H_5, *i*-C_3H_7, R^1 = H, Ar, $ArSO_2$; X = O, NH

The general approach to the synthesis of cyanoamino-*sym*-triazines using salts of type (XIII) can be successfully extended to the production of N-alkylcyanoaminotriazines, as demonstrated in [31] for the case of the synthesis of 2,4-bisdimethylamino-6-N-methyl-N-cyanoamino-*sym*-triazine (XXIII).



XXIII

The transformation of *sym*-triazinylthioureas (XXIV) and *sym*-triazinylisothioureas (XXV) into cyanoaminotriazines [29] can also be regarded as a method for their production:



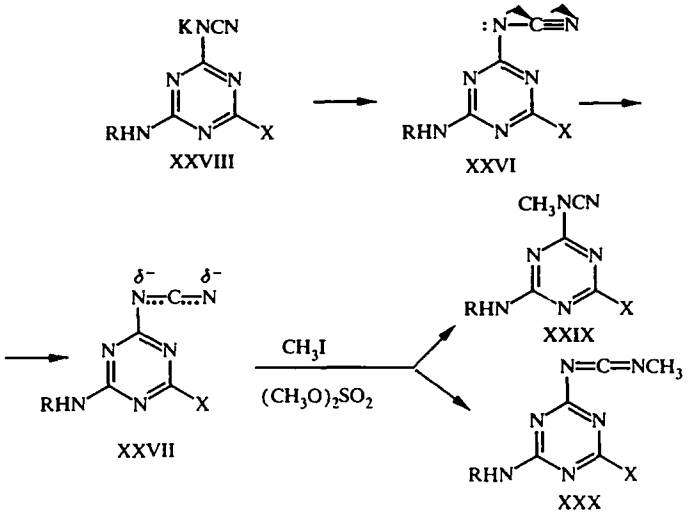
2. REACTIONS OF CYANOAMINO-*sym*-TRIAZINES

The presence of the cyanoamino group in the molecules of the cyanoaminotriazines determines their specific chemical properties, characteristic both, as expected, of NH acids and of nitriles in isolation. However, many transformations of this series of compounds and particularly their heterocyclization take place at the above-mentioned reaction centers both in a stepwise manner and simultaneously.

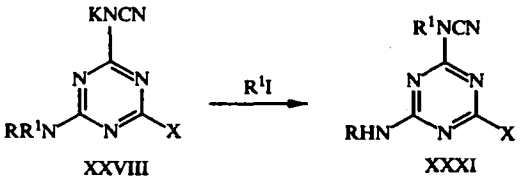
2.1. N-Methylation, Alkylation, and Acylation

Being NH acids, cyano-*sym*-triazines dissolve readily in aqueous and alcohol solutions of alkalis. In acetone under the influence of powdered potassium and sodium hydroxides and also of potassium carbonate crystalline salts, fully stable in air and in aqueous solutions, are formed. Among the N-metallated compounds their N-potassium derivatives, in particular, which are characterized by the ease of formation and high nucleophilicity, are of practical interest and have found wide synthetic application. This, indeed, has given rise to successful syntheses of many N-substituted derivatives of cyanoamino-*sym*-triazines, based on the reactions of these salts with alkylating agents.

The N-methylation of potassiocyanoaminotriazines with methyl iodide and dimethyl sulfate [32-35] in acetone leads quantitatively to the expected N-methylcyano-*sym*-triazines (XXIX). In an aqueous and even a water–acetone medium, the yields of compounds (XXIX) are reduced appreciably on account of the formation of the isomeric N-methylcarbodiimido-*sym*-triazines (XXX). This must be explained by the dissociation of the salts (XXVIII) with the formation of cyanoamino ions, which are stabilized into carbodiamino anions on account of the delocalization of the negative charge. Being ambident, the carbodiamino anions are methylated at both nitrogen atoms [35]:



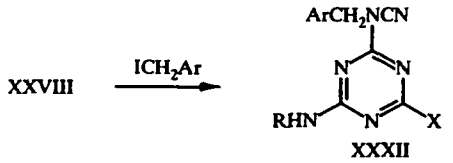
The role of water in the formation of compounds (XXX) is confirmed by the data from IR spectroscopy, according to which salts of type (XXVIII) contain only the carbodiimide group in aqueous solutions and the cyanoamino group in the crystalline state. The optimum conditions for the alkylation of potassiocyanoamino-*sym*-triazines are obtained in the reaction with alkyl iodides and bromides in acetone. It was also established that alkylation is accelerated by catalytic amounts of pyridine and DMFA [35]:



XXVIII XXXI

R = CH_3, C_2H_5, i-C_3H_7; X = C_6H_5NH, CH_3O, CH_3S;
R^1 = C_2H_5, i-C_3H_7, t-C_4H_9

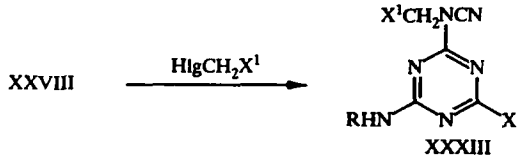
Under the influence of arylalkyl halides, produced in acetone from the chloromethyl derivatives by the Finkelstein exchange reaction, the salts (XXVIII) form N-arylmethyl-N-cyanoamino-*sym*-triazines almost quantitatively [36]:



XXVIII XXXII

R = CH_3, C_3H_7, i-C_3H_7, s-C_4H_9; X = C_3H_7NH, $N(CH_3)_2$, Cl, CH_3O, CH_3S;
Ar = C_6H_5, 4-ClC_6H_4, 4-$CH_3OC_6H_4$, 2-NO_2-4-$CH_3OC_6H_3$

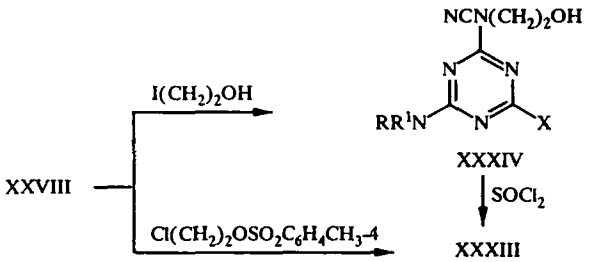
The regioselective nature of the reaction of the iodine and partly bromine derivatives with the salts (XXVIII) forms the basis of their successful chloroalkylation in DMFA in the presence of catalytic amounts of Catamine AB [37]:



XXVIII XXXIII

R, R^1 = CH_3, R = H, R^1 = C_2H_5; X = CH_3O, CH_3S, $(CH_3)_2N$;
X^1 = $ClCH_2$, $Cl(CH_2)_2$; Hlg = Br, I

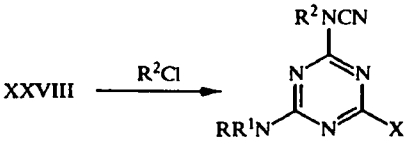
N-Cyano-N-2-chloroethylamino-*sym*-triazines were also synthesized with 2-chloroethyl tosylate as alkylating agent and by the chlorination of N-cyano-N-2-hydroxyethylamino-*sym*-triazines (XXXIV), obtained by the reaction of the salts (XXVIII) with iodohydrin, by thionyl chloride [38]:



XXVIII XXXIV XXXIII

R, R^1 = CH_3; R = H, i-C_3H_7; X = Cl, CH_3S, $(CH_3)_2N$, i-C_3H_7NH

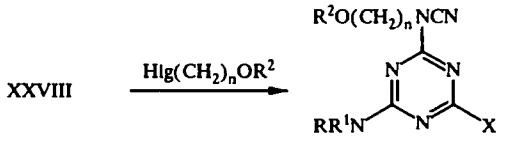
It was shown that monochloromethyl alkyl ethers react with the salts (XXVIII) extremely readily with the formation of the normal alkylation products — the N-alkoxyalkyl derivatives (XXXV). The analogous reactions with the participation of biselectrophiles (1,2-dichloroethyl ethyl ether and 2,3-dichlorotetrahydrofuran) are distinguished by high regioselectivity [38, 39]:



XXXV

R, R^1 = CH_3; R = H, R^1 = C_2H_5; R = H, R^1 = i-C_3H_7; X = $(CH_3)_2N$;
R^2 = CH_3OCH_2, $C_2H_5O(CH_2)_2OCH_2$, $Cl(CH_2)_2OCH_2$, $ClCH_2CHOC_2H_5$, 

Whereas the α-chloro ethers react with potassiocyanoaminotriazines in acetone at room temperature, their β analogs react under harsher conditions in DMFA, at increased temperature, and under the conditions of phase-transfer catalysis or in the presence of sodium iodide [38, 39]:

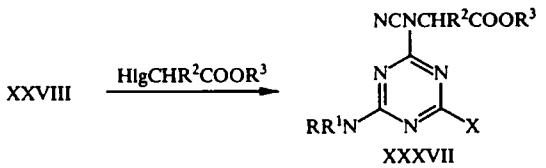


XXXVI

Hlg = Cl, Br; n = 1, 2

R, R^1 = CH_3; R = H, R^1 = C_2H_5; R = H, R^1 = i-C_3H_7; X = $(CH_3)_2N$,
C_2H_5NH; R^2 = CH_3CO, C_6H_5, 2-$CH_3C_6H_4$, 4-ClC_6H_4, 2,4-$Cl_2C_6H_3$

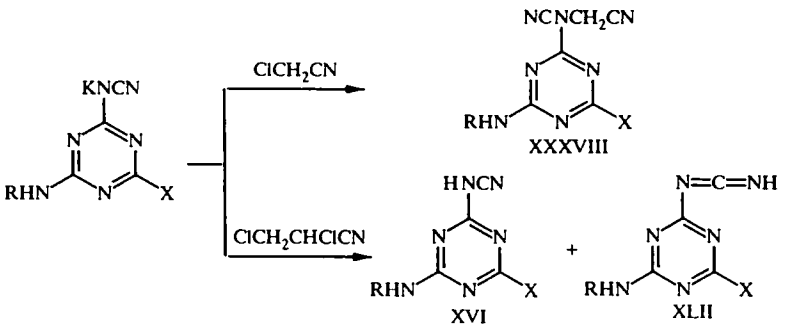
Chloroacetic, propionic, and bromomalonic esters proved extremely reactive toward cyanoaminotriazines. The conditions of this process, leading to the formation of derivatives of amino acids of the *sym*-triazine series (XXXVII), were indicated in [40-43]:



XXXVII

R, R^1 = CH_3, C_2H_5; R = H, R^1 = CH_3, C_2H_5, i-C_3H_7, i-C_4H_9, s-C_4H_9, t-C_4H_9;
X = Cl, CH_3O, CH_3S, C_2H_5NH, i-C_3H_7NH, $(CH_3)_2N$; R^2 = H, CH_3; R^3 = CH_3, C_2H_5

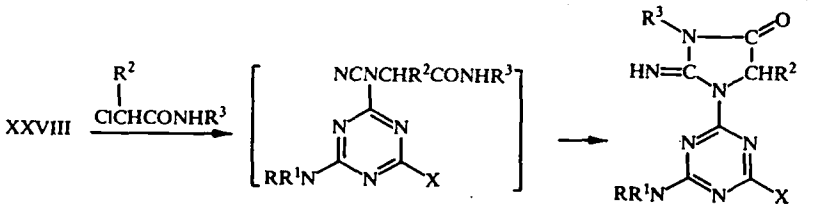
The potassium salts of cyanoaminotriazines react normally with chloroacetonitrile, forming the N-cyano-N-cyanomethyl derivatives (XXXVIII). In reaction with α,β-dichloroacetonitrile, the salts (XXVIII) act as dechlorinating agents, being converted here into a mixture of cyanoamino and carbodiimide derivatives [40]:



XXXVIII XVI XLII

R = C_2H_5, i-C_3H_7; X = CH_3O, CH_3S

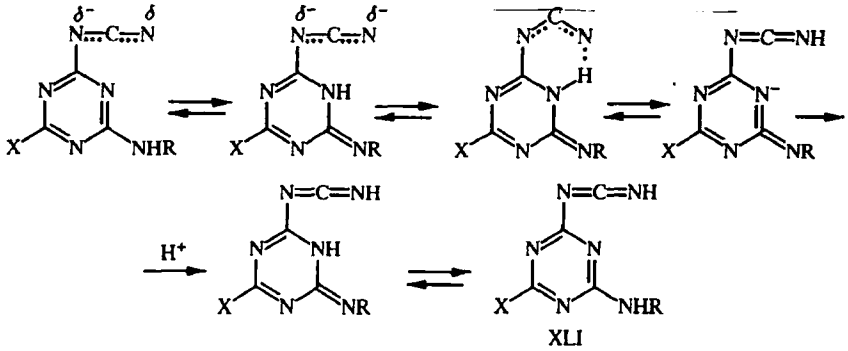
The reaction of the salts (XXVIII) with N-substituted amides of carboxylic acids is accompanied by intramolecular cyclization with the formation of cyclic guanidines (XL) [44, 45]:



XXXIX XL

R = H, R^1 = CH_3, C_2H_5, *i*-C_3H_7, *s*-C_4H_9, *t*-C_4H_9, $C_6H_5CH_2$; X = Cl, CH_3O, CH_3S, C_2H_5NH, $(CH_3)_2N$;
R^2 = H, CH_3; R^3 = CH_2COOCH_3, $CH_2COOC_2H_5$, Ar

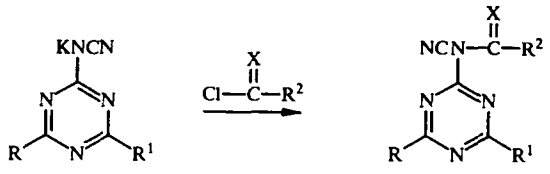
During the Schotten–Baumann acylation of the salts (XXVIII), mixtures of isomeric cyanoamino- and carbodiimido-*sym*-triazines were formed instead of the expected N-acylcyanoaminotriazines [46]. Here, the acid chloride probably acts as a donor of hydrochloric acid, under the action of which the salts (XXVIII) are converted into the above-mentioned mixtures. If carbon dioxide is passed through aqueous solutions of the salts (XXVIII) at low temperature, only the carbodiimide derivatives (XLI) are formed exclusively from salts containing an alkylamino group. This must be explained by the transfer of a hydrogen-bonded proton from this group to the carbodiimide ion and subsequent protonation of the obtained anion according to the following scheme:



XLI

R = C_2H_5, *i*-C_3H_7, *s*-C_4H_9, *t*-C_4H_9; X = CH_3O, CH_3S, C_2H_5NH, *i*-C_3H_7NH

The salts (XXVIII) containing dialkylamino, methoxy, and methylthio groups are therefore acylated normally and form the N-acyl derivatives (XLII) [47, 48]:

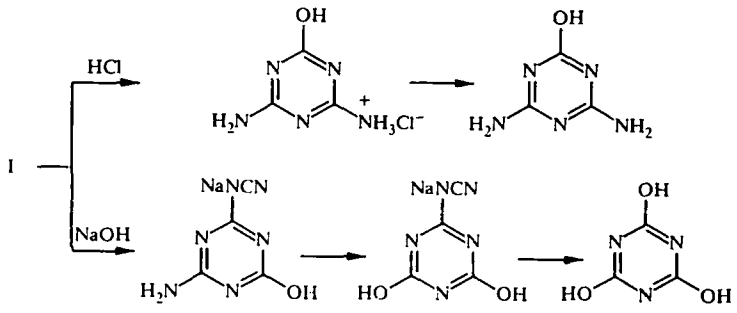


XLII

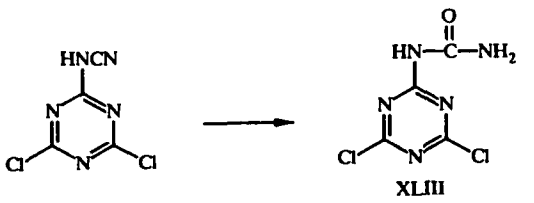
R = CH_3O, CH_3S, $(CH_3)_2N$; R^1 = $(CH_3)_2N$, CH_3O; R^2 = $ArOCH_2$, $(CH_3)_2N$; X = O, S

2.2. Action of Acids and Bases

During the action of hydrochloric acid and aqueous solutions of sodium hydroxide, compound (I) is hydrolyzed according to the following scheme [13]:



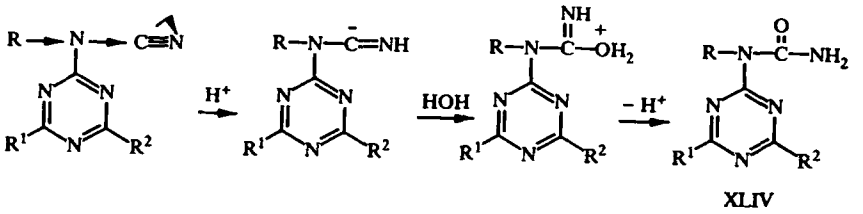
2-Cyanoamino-4,6-dichloro-*sym*-triazine is converted by the action of 100% sulfuric acid into the ureido derivative (XLIII) [49]:



XLIII

Cyanoaminotriazines of types (XII, XIV, XVI) dissolve in concentrated hydrochloric acid with retention of the cyano group. Under analogous conditions the N-alkyl(alkenyl)-substituted compounds (XXIX, XXXI) are converted into the hydrochlorides of N-alkyl(alkenyl)triazinylureas (XLIV).

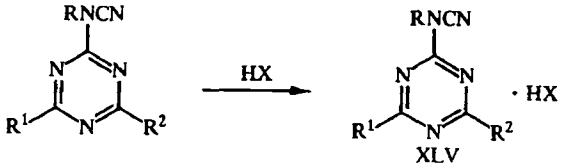
The ease of hydrolysis of the cyano group in the compounds must be explained by its increased polarizability under the influence of the electron-donating hydrocarbon radical [50]:



XLIV

R = H, CH_3, C_2H_5, $CH_2=CH-CH_2$; R^1, R^2 = alkylamino, dialkylamino;
R^2 = Cl, CH_3O, CH_3S

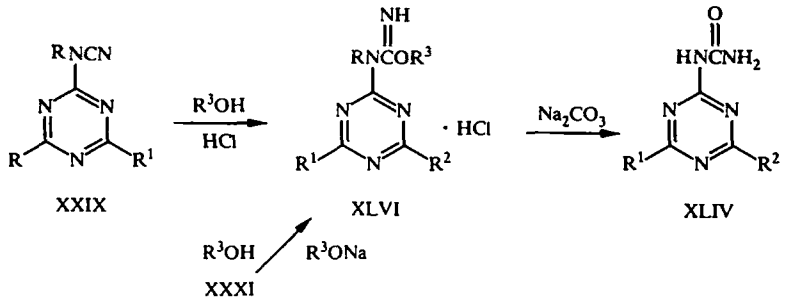
The action of inorganic and organic acids on the derivatives of cyanoaminotriazines in aprotic solvents leads to formation of the salts (XLV), in which the triazine component acts as a monoacidic base [29]:



XLV

X = Cl, HSO_4, H_2PO_4, SCN, CH_3COO, CH_3CCl_2COO;
R = alkyl, alkenyl, alkynyl; R^1, R^2 = alkyl(dialkyl)amino

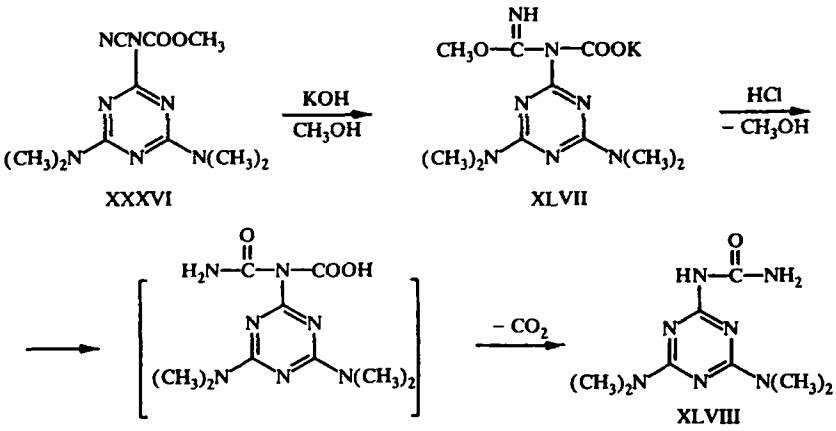
In the presence of hydrogen chloride, the derivatives (XXIX, XXXI) add the elements of alcohol with the formation of the hydrochlorides of N-*sym*-triazinyl-O-alkylisoureas (XLVI), which are converted in the presence of water or by the action of water into the urea derivatives (XLIV) [51]:



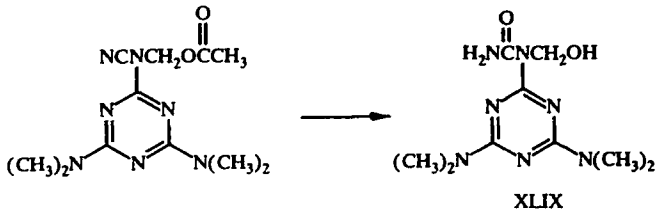
XXIX XLVI XLIV XXXI

Compounds (XLVI) were also obtained during the treatment of the products from the reaction of cyanoamino compounds with alcohols in the presence of sodium alcoholates with hydrogen chloride [52].

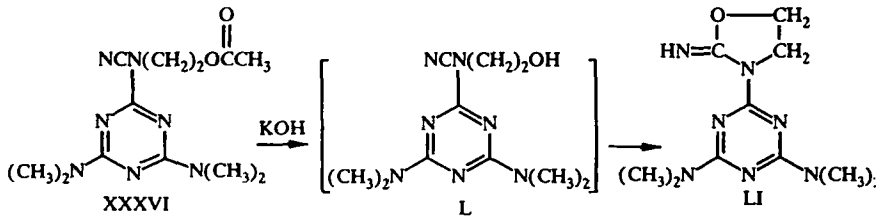
If there is an ester function in the molecules of cyanoaminotriazines, hydrolysis takes place at the two reaction centers and leads to the formation of N,N-disubstituted ureas or the products from their intramolecular cyclization. Thus, compounds (XLII) are converted by the action of an alcohol solution of potassium hydroxide into the potassium salts of N-carboxy-N-*sym*-triazinyl-O-methylisoureas (XLVII), which are imidic esters unstable in an acidic medium, and derivatives of carbamic acid, which eliminate methanol and carbon dioxide under the influence of hydrochloric acid with conversion into the urea derivatives (XLVIII) [51]:



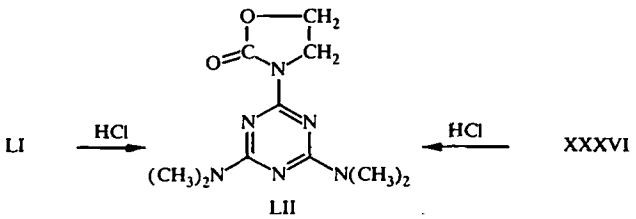
Under the conditions of both acid and alkaline hydrolysis, 2,4-bisdimethylamino-N-cyanoamino-*sym*-triazine forms the N-hydroxymethylurea derivative (XLIX) [39]:



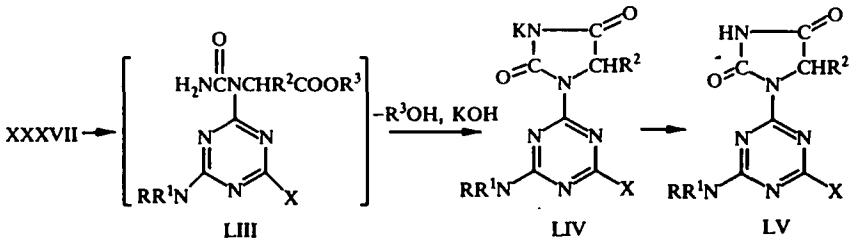
Somewhat unexpected was the result from alkaline hydrolysis of compound (XXXVI) [R = R^1 = CH_3, X = $(CH_3)_2N$, R^2 = CH_3CO]. Instead of the expected N-cyano-N-hydroxyethylamino derivative (L), the product from its intramolecular cyclization (LI) was obtained [39]:



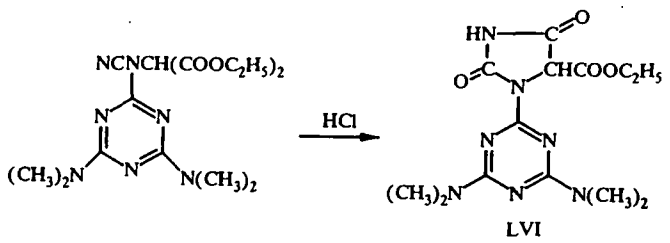
The compound (LII) formed during hydrolysis with hydrochloric acid was identical with the product from hydrochloric acid treatment of compound (XXXVI):



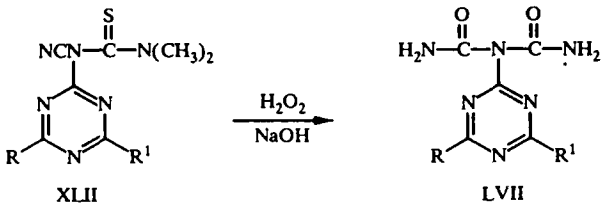
Alkaline hydrolysis of compounds (XXXVII) leads to the unexpected formation of an imidazoline ring. Here, compounds (LIII) are probably formed as intermediates. By releasing alcohol, they are converted into N-potassiohydantoinyl-*sym*-triazines (LIV), which change into the free bases (LV) when acidified [40-43]:



Another representative of this series of compounds, N-cyano-*sym*-triazinylmalonic ester, undergoes heterocyclization in an acidic medium with the participation of one ethoxycarbonyl group and the formation of compound (LVI) [43]:



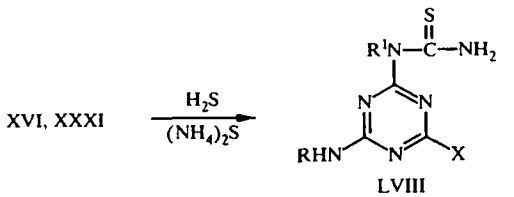
Desulfurization of the derivatives of *sym*-triazinylthiourea (XLII) [R = $(CH_3)_2N$, R^1 = $(CH_3)_2N$, CH_3S] with hydrogen peroxide in the presence of alkali gave *sym*-triazinyl biurates (LVII) [47, 51]:



R = $(CH_3)_2N$; R^1 = $(CH_3)_2N$, CH_3S

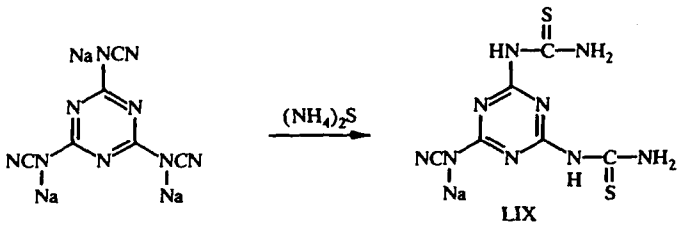
Since hydrolysis of the cyano group to a carbamide group occurs here in addition to substitution of the sulfur by oxygen, it seemed of interest to study the behavior of cyanoaminotriazines and their N-alkyl derivatives under the conditions of the Radishevskii reaction. As a result, a preparative method was developed for the production of *sym*-triazinylureas, giving higher yields than the usual alkaline hydrolysis [53].

The cyano groups in compounds (XVI, XXXI) add hydrogen sulfide in the presence of ammonium sulfide with the formation of *sym*-triazinylthioureas (LVIII) [29]:



Cyanoaminotriazines react with ammonium sulfide more readily than the N-alkyl derivatives. The presence of the methoxy (methyl) group in the triazine ring facilitates the addition of hydrogen sulfide to the cyano group to a significant degree. Thus, the reaction of compound (XXXI) (R, R^1 = alkyl, X = CH_3O, CH_3S) also takes place at room temperature [29].

In reaction with ammonium sulfide, the sodium salt of triscyanoamino-*sym*-triazine forms the sodium salt of 2,4-bisthioureido-6-cyanoamino-*sym*-triazine (LIX):

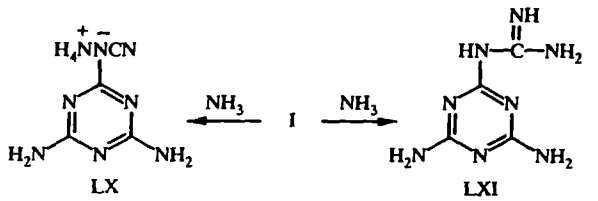


LIX

The thiolysis of the various cyanoamino-*sym*-triazines can also be realized successfully by the action of a mixture of hydrogen sulfide and ammonia [54, 55].

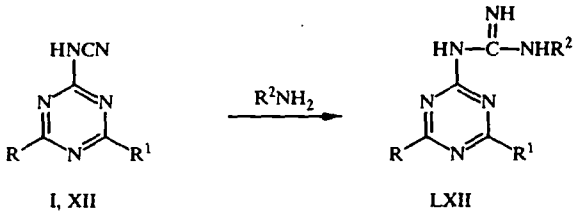
2.3. Action of Ammonia, Amines, Hydrazine, and Their Derivatives

The cyanomethylamine (I) is converted into the ammonium salt (LX) by the action of aqueous ammonia and into 2,4-diamino-*sym*-triazinyl-6-guanidine (LXI) by the action of gaseous ammonia [13]:



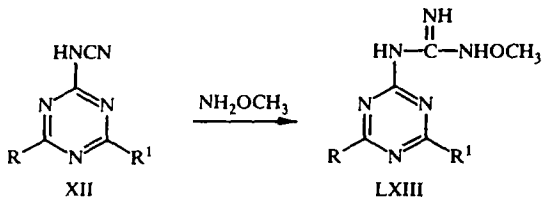
LX LXI

With primary alkyl-, cycloalkyl-, and arylamines, compounds (I) and (XII) (R, R^1 = CH_3; R, R^1 = CH_3O) form N,N'-disubstituted guanidines (LXII) [54]:



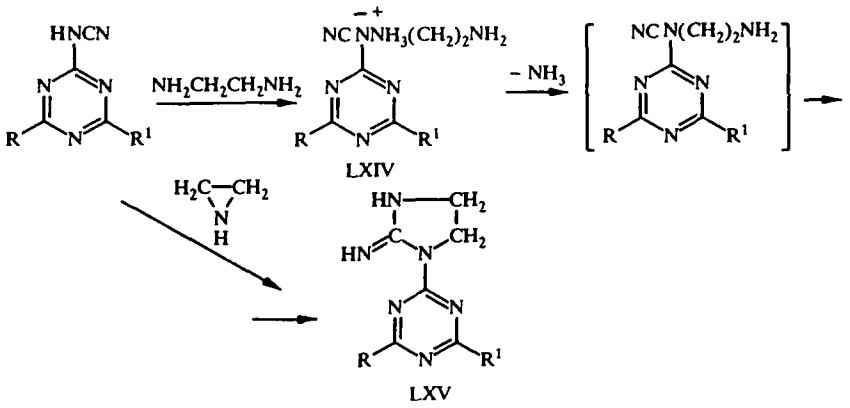
I, XII LXII

The synthesis of N-*sym*-triazinyl-N-methoxyguanidines (LXIII), based on the reaction of cyanoamino-*sym*-triazines with methoxyamine, has been described [55, 56]:



XII LXIII

Ethylenediamine reacts with cyanoamino-*sym*-triazine like a monoacidic base. When heated, the 2-aminoethylammonium salts (LXIV) obtained here release ammonia, and the obtained N-2-aminoethylation products immediately undergo cyclization to iminoimidazolidinyl-*sym*-triazines (LXV), which are also formed during aminoethylation with ethylene imine [57]:

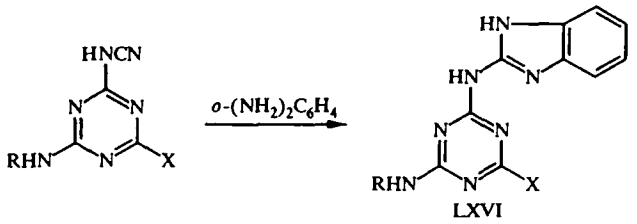


LXIV

LXV

R, R^1 = alkyl(dialkyl)amino

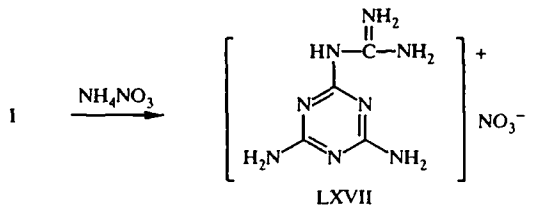
If *o*-phenylenediamine hydrochloride is used, benzimidazolyl-*sym*-triazines (LXVI) are formed [58]:



LXVI

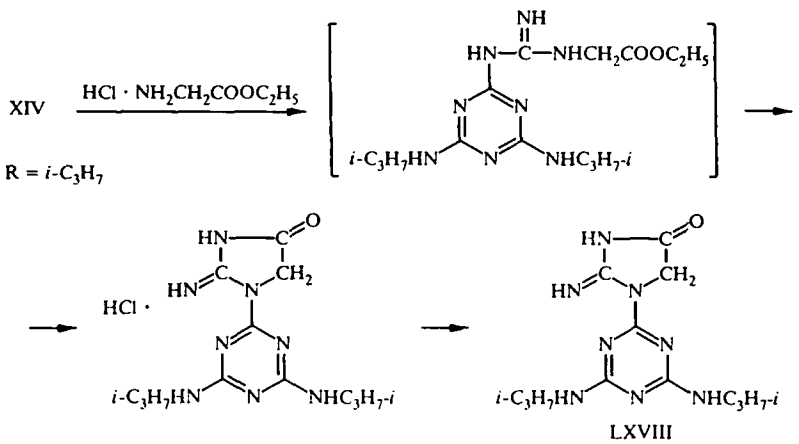
R = alkyl, X = alkylamino, CH_3O, CH_3S

Ammonium salts and amine salts are also capable of reacting with cyanoamino-*sym*-triazine. Thus, guanidinotriazine nitrate (LXVII) was obtained by melting ammonium nitrate with cyanomelamine [13]:



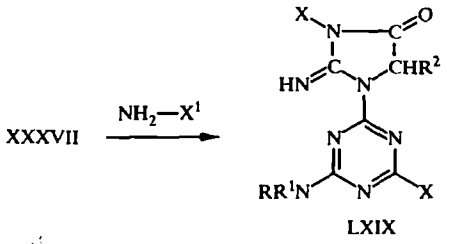
LXVII

With the hydrochloride of glycine ethyl, ester compound (XIV) formed imidazolidinyl-*sym*-triazine, which was converted into the free base (LXVIII) [58]:



LXVIII

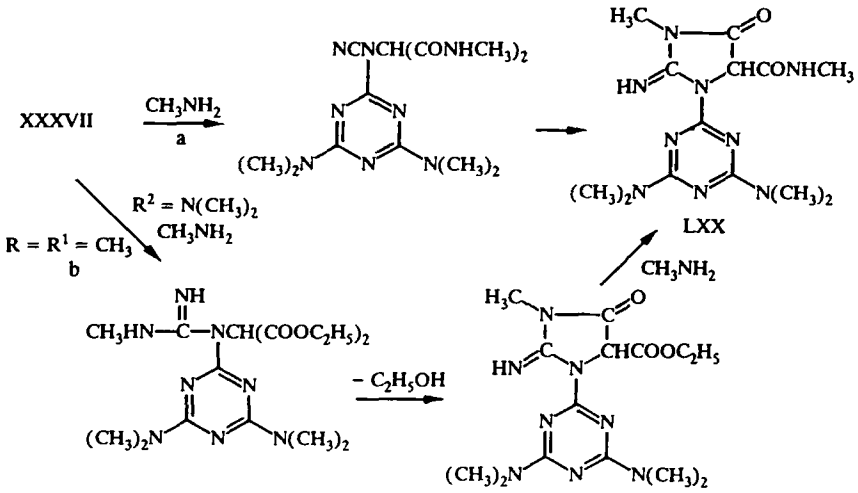
Under the influence of ammonia, amines, and hydrazine, compound (XXXVII) undergoes cyclization to the fully substituted imidazolidinyl-*sym*-triazines (LXIX) [42, 59-61]:



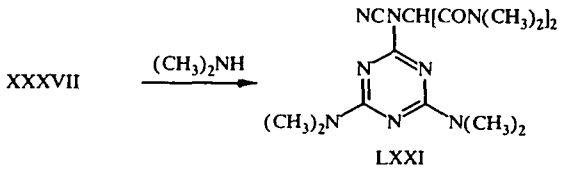
LXIX

R, R^1 = alkyl, R^2 = H, CH_3; X = dialkylamino, CH_3O, CH_3S; X^1 = H, CH_3, NH_2

The mechanism of the formation of compounds (LXIX) was studied for the case of the reaction of N-cyano-N-*sym*-triazinylaminomalonic ester with methylamine, which may take place according to one of the following schemes:

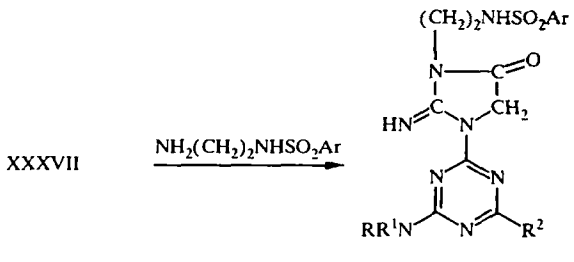


During the aminolysis of compound (XXXVII) with dimethylamine, the dimethylamide (LXXI) with an open chain and incapable of cyclization was obtained. This confirms that compounds (LXX) are formed according to scheme *a* [60]:



LXXI

The reaction of the esters (XXXVII) with 2-aminoethylsulfonamides leads to the formation of imidazolinyl-*sym*-triazines (LXXII) [58]:

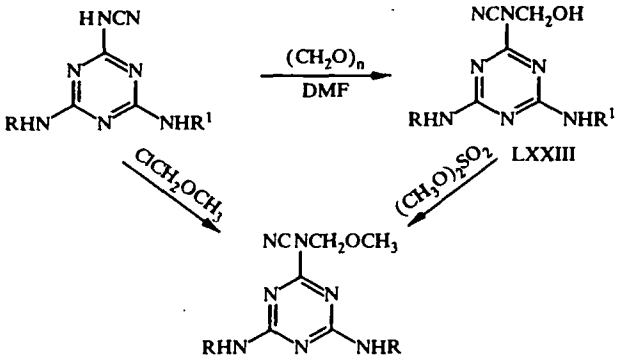


LXXII

R = H, R^1 = *i*-C_3H_7; R, R^1 = CH_3; R^2 = *i*-C_3H_7NH, $(CH_3)_2N$, CH_3O, CH_3S; Ar = 4-$CH_3C_6H_4$, 4-ClC_6H_4

2.4. Addition to Aldehydes, Oxides, and Isocyanates

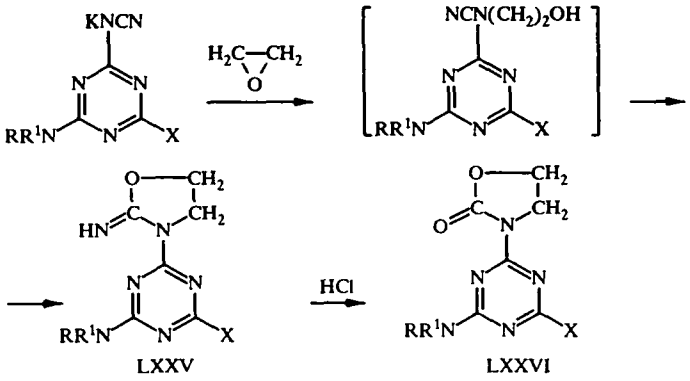
The derivatives of triazine containing several nucleophilic NH centers in the form of cyanoamino and alkylamino groups undergo regioselective hydroxymethylation under the influence of formaldehyde with the formation of N-cyano-N-hydroxymethylamino-*sym*-triazines (LXXIII). The structure of the latter was confirmed by their O-methylation, and the obtained compounds were identical with the products (LXXIV) from N-methoxymethylation of the potassium salts of the corresponding cyanoamino-*sym*-triazines [38].



LXXIV

R, R^1 = C_2H_5, *i*-C_3H_7

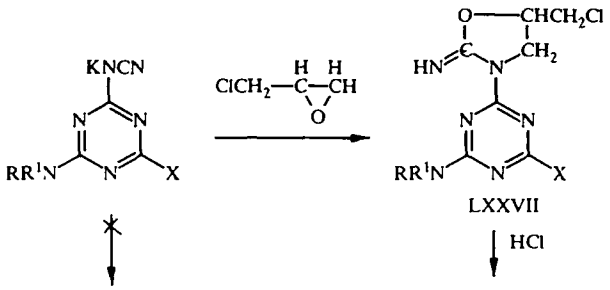
With ethylene oxide, the potassium salts of cyanoamino-*sym*-triazines form iminooxazolidinyl-*sym*-triazines (LXXV), which are hydrolyzed by the action of hydrochloric acid to the oxo derivatives (LXXVI) [62]:



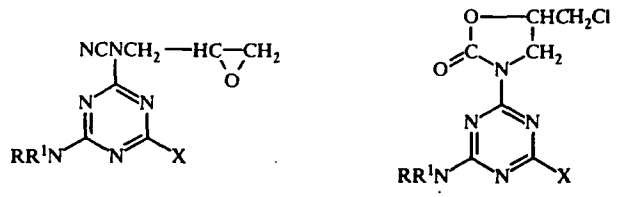
LXXV LXXVI

R, R^1 = CH_3; R = H, R^1 = CH_3, *i*-C_3H_7, *s*-C_4H_9; X = Cl, CH_3O, CH_3S, C_2H_5NH, *i*-C_3H_7NH

Indirect evidence for the formation of the intermediate N-cyano-N-2-hydroxyethylamino-*sym*-triazines is provided by the result of alkaline hydrolysis of N-cyano-N-2-acetoxyamino-*sym*-triazines (XXXVI), also leading to the formation of compounds (LXXV) [39].



LXXVII

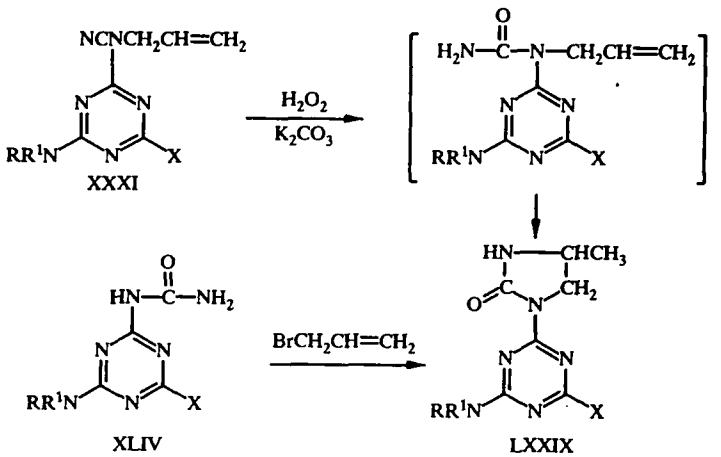


LXXVIII

R, R^1 = CH_3; R = H, R^1 = CH_3, *i*-C_3H_7, *s*-C_4H_9; X = Cl, CH_3O, CH_3S, C_2H_5NH, *i*-C_3H_7NH

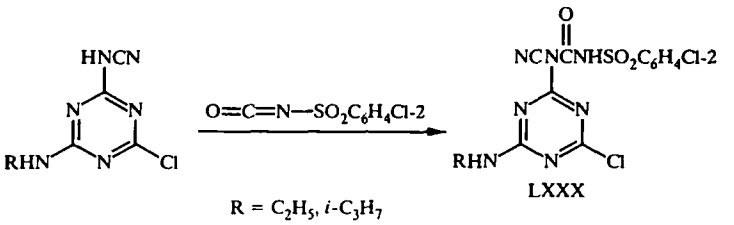
With the potassium salts of cyanoaminotriazines, epichlorohydrin does not react as a halogen derivative but like ethylene oxide with the formation of iminochloromethyloxazolidinyl-*sym*-triazines (LXXVII), which readily change into compounds (LXXVIII) in an acidic medium [62].

During the oxidation of N-cyano-N-allylamino-*sym*-triazines with hydrogen peroxide in the presence of potassium carbonate the imidazolidinyl-*sym*-triazines (LXXIX) were obtained instead of the expected N-cyano-N-epoxypropylamino-*sym*-triazines. N-Allyl-N-*sym*-triazinylureas are presumably formed initially and then undergo cyclization, as confirmed by special experiments on the allylation of *sym*-triazinylureas [63]:



XXXI XLIV LXXIX

The addition reactions of cyanoaminotriazines to isocyanates are also distinguished by high regioselectivity. It was established that 2-chloro-4-alkylamino-6-cyanoamino-*sym*-triazines react at the cyano group under the influence of 2-chlorobenzenesulfonyl cyanate with the formation of derivatives of N-cyanourea (LXXX) [53]:



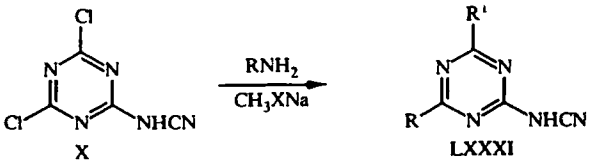
LXXX

R = C_2H_5, *i*-C_3H_7

2.5. Other Reactions of Cyanoamino-*sym*-triazines

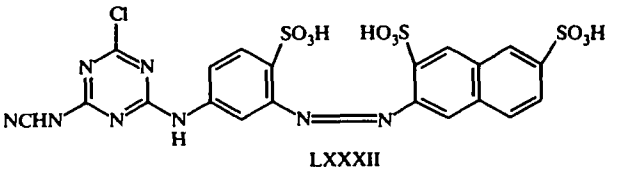
Reactions of substituted cyanoamino-*sym*-triazines taking place at other substituents in the ring without affecting the cyanoamino group are known. The chlorine derivatives and the corresponding quaternary ammonium salts are of definite synthetic interest in this connection.

The comparatively easily obtainable 2,4-dichloro-6-cyanoamino-*sym*-triazine (VIII) reacts readily with various nucleophiles. Thus, the action of alkylamines leads to the formation of 2-chloro-4-alkylamino-6-cyanoamino-*sym*-triazines. The treatment of compound (X) with sodium methoxide and methanethiolate leads to the formation of the mono- and dimethoxy and methylthio derivatives (LXXXI) [16, 64].



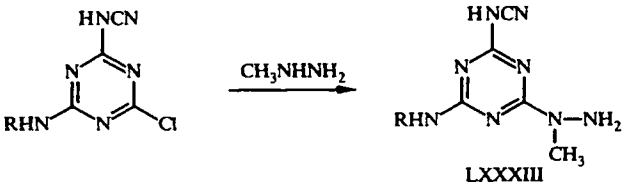
X = O, S; R = C_2H_5NH, i-C_3H_7NH, CH_3O; R^1 = Cl, CH_3O, CH_3S

The use of the same 2,4-dichloro derivative for the synthesis of the substituted azo compound (LXXXII), employed in the production of polyamide fibers, has been described.



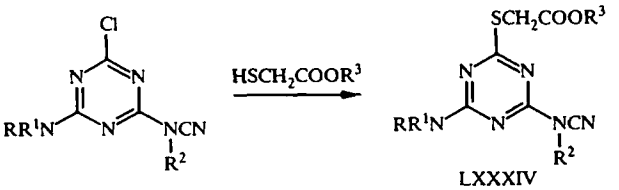
LXXXII

In spite of the sensitivity of cyanoamino-*sym*-triazines to hydrazine and its derivatives, 2-chloro-4-alkylamino-6-cyanoamino-*sym*-triazines only form the products from substitution of the chlorine atom by a methylhydrazine group [36]:



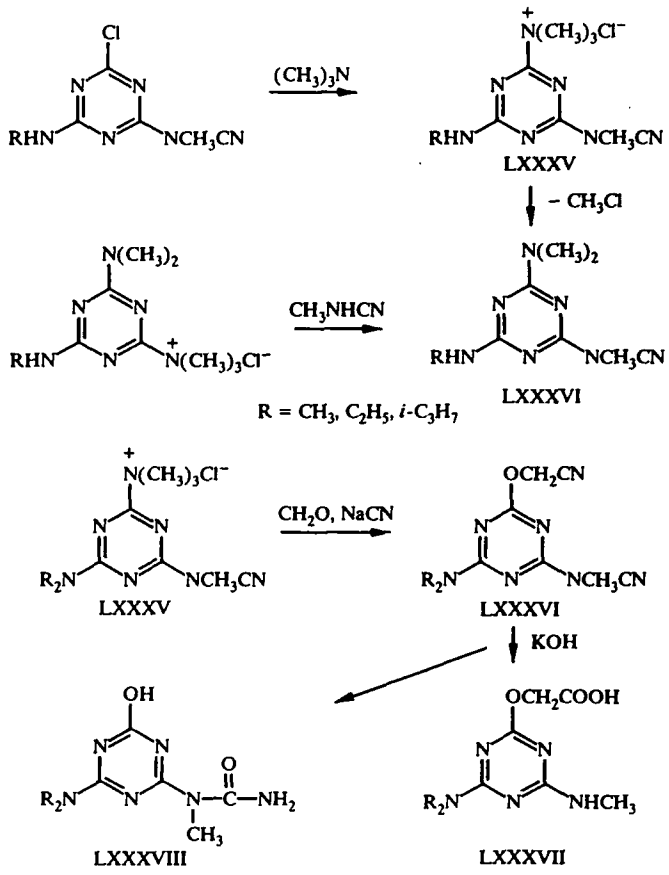
R = alkyl

Alkoxycarbonylmethylthiotriazines (LXXXIV) were synthesized by the reaction of the chlorine derivatives of cyanoaminotriazines with thioglycolic esters [65]:

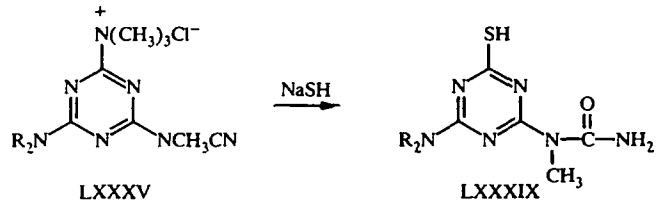


R = H, R^1 = alkyl; R^2 = H, CH_3; R^3 = CH_3, C_2H_5

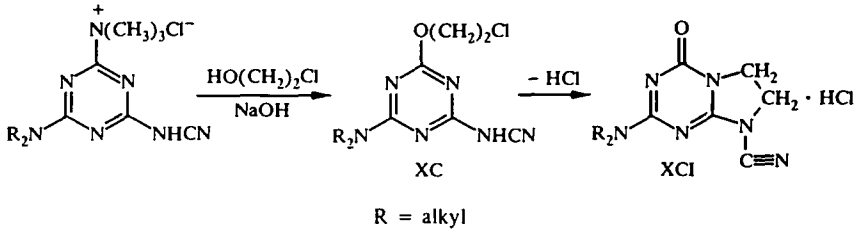
The action of gaseous trimethylamine on such chlorine derivatives does not affect the cyano group and leads to the formation of the respective salts. Among them, the trimethyl(4-alkylamino-6-N-methyl-N-cyanoamino-*sym*-triazin-2-yl)ammonium chlorides (LXXXV) are unstable and eliminate methyl chloride even at room temperature with the formation of 2-dimethylamino-4-alkylamino-6-N-methyl-N-cyanoamino-*sym*-triazines (LXXXVI), the structure of which was confirmed by an alternative synthesis. In the presence of a dialkylamino group, the salts of this series (LXXXV) acquire some stability and enter into reactions with functionally substituted alcohols. The action of a cyanomethylating mixture on the salts led to the formation of the cyanomethoxytriazines (LXXXVI), an attempt at the conversion of which into the corresponding acids led to the products from various degrees of hydrolysis (LXXXVII, LXXXVIII).



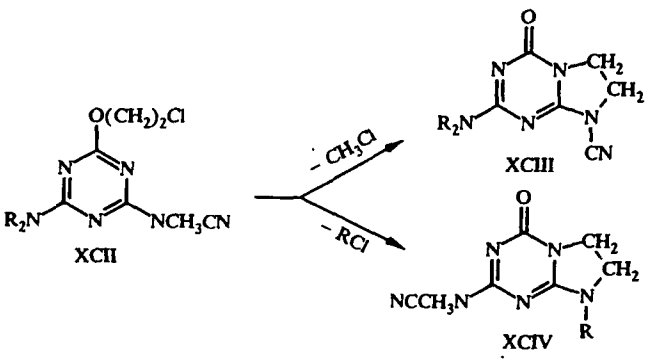
It was also impossible to avoid the hydrolysis of the N-methylcyanoamino group in the above-mentioned salts during the action of sodium hydrosulfide in aqueous solution [66]:



The action of ethylene chlorohydrin on the salts in an aqueous medium at low temperature and in the presence of alkali gave chloroethoxycyanoamino-*sym*-triazines (XC). Like the related 2-chloroethoxy-4,6-bisalkyl(dialkyl)amino-*sym*-triazines [67], they rearrange when heated in toluene with the formation of imidazo-*sym*-triazines. Here, the 2-dialkylamino-4-chloroethoxy-6-cyanoamino-*sym*-triazines undergo dehydrochlorination and change into the hydrochlorides of imidazo-*sym*-triazines (XCI) [68]:



In the meantime, under analogous conditions 2-dialkylamino-4-chloroethoxy-6-N-methyl-N-cyanoamino-*sym*-triazines (XCII) eliminate the alkyl chloride with the formation of a mixture of two imidazo-*sym*-triazines (XCIII, XCIV) [69]:



The practical significance of cyanoamino-*sym*-triazines, as seen from the present review, is determined primarily by their use as accessible starting materials for the synthesis of derivatives of *sym*-triazines not having competing methods of synthesis. These compounds include, in particular, ureido-, thioureido-, guanidino-, and heteroaryl-*sym*-triazines.

The derivatives of cyanoaminotriazines are also of separate interest as pesticides. In this respect, special significance was acquired by 2-N-alkylcyanoamino-4,6-bisalkyl-*sym*-triazines, of which 2-N-methyl-N-cyanoamino-4,6-bisisopropylamino-*sym*-triazine and its sulfate were recommended under the names of metazine and sulfazine respectively for widespread use in agriculture against weeds in potatoes, maize, sunflowers, cotton, and carrots [29, 70-79].

High herbicidal activity and selectivity against a series of cultures is exhibited by the derivatives of 2-N-methyl-N-cyanoamino-4-alkylamino-6-methoxymethylamino-, 2-N-methoxymethyl-N-cyanoamino-4,6-bisisopropylamino-, and 2-methoxy-N-*sec*-butylamino-6-N-benzyl-N-cyanoamino-*sym*-triazines and also N-(2-chlorophenylsulfonyl)-N-cyano-N-(4-ethylamino-6-alkylamino-*sym*-triazin-2-yl)ureas [51, 53, 80].

Many derivatives exhibit clearly defined fungicidal activity. Of them it is necessary to mention in particular 2-cyanoamino(methylcyanomethyl)-4-alkyl(dialkyl)amino-6-methoxycarbonylmethylthio-, 2-N-methoxymethyl-N-cyanoamino-4-dimethylamino(methylthio)-6-dimethylamino-, and 2-methylthio-4-dimethylamino-6-N-cyanoamino-*sym*-triazines [51, 53, 80].

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