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Multicomponent cascade heterocyclisation as a promising route to targeted synthesis of polyfunctional pyridines †

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Contents

I.	Introduction	69
II.	Cascade heterocyclisation involving α,β-unsaturated carbonyl compounds	70
III.	Cascade heterocyclisation involving 1,3-dicarbonyl compounds	73
IV.	Cascade heterocyclisation involving pyridinium ylides	76
V.	Cascade heterocyclisation in the synthesis of fused heterocycles	78

Abstract. The review surveys the state-of-the-art in the methodology of multicomponent cascade heterocyclisation and its prospects as applied to the targeted synthesis of polyfunctional pyridines and their hydrogenated and fused analogues. The bibliography includes 405 references.

I. Introduction

A fundamental problem of synthetic organic chemistry is to design new chemo-, regio-, stereo- and enantioselective methods for the synthesis of polyfunctional carbo- and heterocycles possessing practically important properties. Such methods should not only be based on simple and commercially available substrates and reagents and characterised by low cost of the final products but also be ecologically safe.

In this connection, recent years have witnessed a rapidly growing interest in the one-pot synthesis involving two groups of reactions. One group includes successive reactions in the course of which another reagent, substrate or catalyst is added or the reaction temperature is changed without isolation of intermediates. Another group includes cascade reactions proceeding under the same conditions without the addition of any other reagents or catalysts. In these processes, the functional groups that are formed in earlier steps are transformed in each subsequent step. This type of processes is referred to as domino or tandem reactions. It should be noted that there is no strict difference between these terms.

Multicomponent cascade processes are of particular interest, which is reflected in the reviews [1 – 11] that have been published. These reactions can serve as the basis for both targeted organic synthesis and combinatorial chemistry, which allows one to synthesise simultaneously several thousand samples for biological screening with the use of automated efficient approaches.[12 – 20]

Analysis of named reactions in organic chemistry shows that many of these reactions, particularly, those giving rise to heterocyclic compounds, are based on the methodology of multicomponent cascade heterocyclisation. Examples are the Hantzsch reaction involving cyclocondensation of β-keto esters or β-diketones with aldehydes and ammonia to form substituted pyridines,[21, 22] the Gattermann – Skita reaction, *viz*., the synthesis of pyridine derivatives by condensation of sodium malonate with dichloromethylamine (as a version of the Hantzsch reaction),[23] the Guareschi – Thorpe reaction, *viz*., the preparation of pyridine derivatives by cyclocondensation of ester (amide) of cyanoacetic acid or α-allylacetoacetic ester with ammonia,[24, 25] the Doebner reaction involving condensation of aromatic, heteroaromatic or fused polycyclic amines with aldehydes or pyruvic acid to yield quinolinecarboxylic acids,[26] the Ullmann – Fetvadjan reaction, *viz*., the synthesis of benzacridines by condensation of β-naphthol with aldehydes and aromatic amines [27] and many other reactions.

In the last 15 years, the chemistry of functionalised pyridinechalcogenones has been extensively developed, which is reflected in many reviews [28 – 41] and dissertations [42 – 54] that have been published. This is associated with both a theoretical interest in this class of organic compounds and a very broad spectrum of the practical uses of pyridine derivatives. For example, more than 10% of the most commonly used modern medicines contain pyridine or the hydrogenated pyridine ring.[55] A new class of calcium antagonists was constructed on the basis of 1,4-dihydropyridines [56, 57] (in particular, the drug nifedipine used for the treatment of high blood pressure and stenocardia [55]). Among these compounds are highly efficient cardiotonics [58 – 107] (including the drugs amrinone and milrinone [98 – 107]), tranquilisers [108 – 118] and compounds possessing antiinflammatory, hypoglycemic, antiulcer, antispasmodic, antifungal, antibacterial, pesticide and other biological activities.[112 – 142] Pyridine derivatives are used as the starting substrates for the construction of new CH-antioxidants,[143 – 146] analogues of folic acid,[147] vitamin B_6,[148] other biologically active compounds [143, 147 – 151] and models of the redox coenzymes NAD and NADP.[125] Here, it is worthwhile mentioning that substituted cyclopentaspiropiperidone is used in the synthesis of the known anxiolytic buspirone which prevents drug adaptation.[152] The only known natural alkaloid containing a nitrile group, *viz*., 3-cyano-4-methoxy-1-methyl-1*H*-pyridin-2-one,[153] also belongs to this class of compounds.

In the last decade, the development of the chemistry of functionally substituted pyridines was stimulated mostly by the fact that among compounds of this class are highly active inhibitors of HIV-1 specific reverse transcriptase (potent agents

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† Dedicated to Professor Salo Gronowitz (Department of Organic Chemistry 1, Lund University, Sweden), in whose laboratory I worked in 1979 – 1980, on his 75th birthday.

for AIDS treatment),[154–166] agents for protection of skin during UV radiation (diethone), an antihypertensive and antianginal drug [foridone (riodipine)], a neurotropic and antidiabetic drug (cerebrocrast), a neuroprotective agent (glutapyrone), an agent promoting growth of agricultural animals (diludin) and amphiphilic compounds possessing properties of cell-transfection agents necessary for gene therapy.[167]

Besides, compounds of this class can be used as stabilisers for polymers and lacquers,[168] pigments and diazo components in the synthesis of dyes,[169–176] acid–base indicators in titrimetric analysis,[177] liquid crystals[178] and other compounds of practical importance.

Considerable practical potential of pyridinechalcogenones and their derivatives have given impetus to the development of procedures for their synthesis, which would enable one to overcome inactivity of the pyridine core in functionalisation with the use of electrophilic substitution. It appeared that this purpose could be accomplished by performing the synthesis under conditions of one-pot multicomponent cascade heterocyclisation.

The success of this methodology depends radically on the starting substrates and reagents, which should be readily available and possess polyfunctional properties. The simplest and most convenient procedures for the synthesis of functionalised pyridinechalcogenones are based on the use of cyanoacetamides and their thio and seleno analogues, malononitrile, cyanoacetic ester and other CH-acids as reagents. The presence of several reactive centres in these compounds is responsible for the diversity of their highly regioselective (often stereoselective) chemical transformations, which proceed under mild conditions and with the use of rather simple apparatus. The tremendous synthetic potential of these reagents was considered in the monograph[34] and reviews.[28, 39, 40]

Aliphatic, aromatic and heteroaromatic mono- and dicarbonyl compounds, their enamines, cycloalkanones, *etc*. are used as substrates in multicomponent heterocyclisation.

The direction of the reactions can be easily changed by varying the reaction conditions or the nature of the substituents in the substrates and reagents.

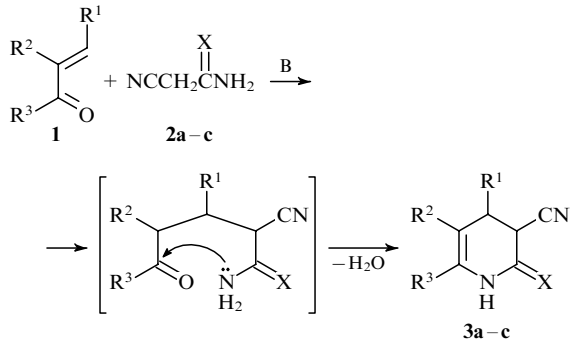
The successful use of the methodology of multicomponent cascade heterocyclisation is exemplified primarily by the development of regio- and stereoselective procedures for the preparation of previously unknown partially hydrogenated pyridinechalcogenones, polyfunctional 1,4- and 3,4-dihydropyridines, 1,2,3,4-tetrahydropyridines, 6-oxo-1,2,3,4-tetrahydropyridine-2-thiolates of non-betaine origin, 4,5-*trans*-6-hydroxy-1,4,5,6-tetrahydropyridine-2-thiolates, tetrahydropyridones, spiro-fused partially hydrogenated pyridines and quinolines and other compounds of the pyridine series, which potentially possess biological activities and are promising substrates for fine organic synthesis. The main procedures for the preparation of partially hydrogenated pyridinechalcogenones involve the same approaches that were successfully used in the synthesis of their aromatic analogues, *viz*., condensation of α,β-unsaturated carbonyl, 1,3-dicarbonyl compounds and their enamines, α,β-unsaturated nitriles and other substrates with CH-acids (cyanoacetamide, its thio and seleno analogues, malononitrile, derivatives of cyanoacetic acid, *etc*.).[28, 42–46, 179–194] It was postulated that Michael adducts and partially hydrogenated pyridinechalcogenones are formed as intermediates of cascade heterocyclisation. In many cases, these intermediates were isolated as stable compounds and their structures and reactivities were studied in sufficient detail.

It should be emphasised that the tremendous synthetic potential of this methodology is based on the possibility of varying the nature of the starting substrate with retention of the structure of the reagent, by changing the nature of the reagent with retention of the type of substrate used, by varying simultaneously the nature of both components of the reaction or by changing their ratio and number.

The present review surveys for the first time data on the application of multicomponent cascade heterocyclisation to the synthesis of pyridine derivatives, which have been published in the last 15 years. The synthesis methods are classified according to the nature of the reagents and substrates used. Emphasis is given to the development of optimum methods for the preparation of partially hydrogenated pyridinechalcogenones and their derivatives, which show the most promise from the practical viewpoint.

II. Cascade heterocyclisation involving α,β-unsaturated carbonyl compounds

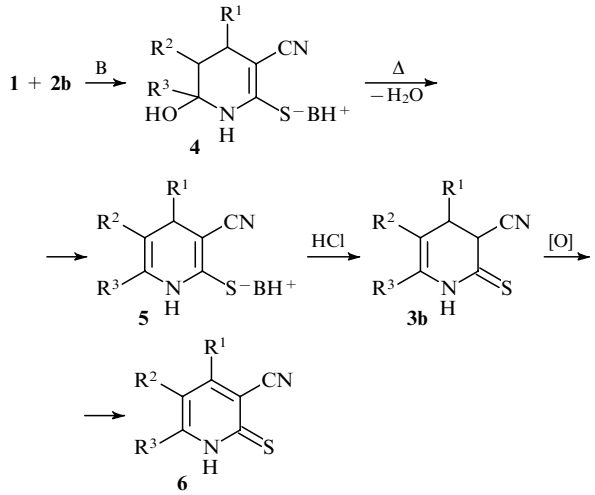
The reactions of α,β-unsaturated carbonyl compounds **1** with CH-acids of type **2** in the presence of organic bases proceed through the cascade heterocyclisation mechanism. The first step affords Michael adducts, whose subsequent cyclocondensation gives rise to 3,4-dihydro-1*H*-pyridine-2-chalcogenones **3**.



1 **2a–c** **3a–c**

R^1, R^2, R^3 = Alk, Ar, Het; X = O (**a**), S (**b**), Se (**c**);
B is an organic base.

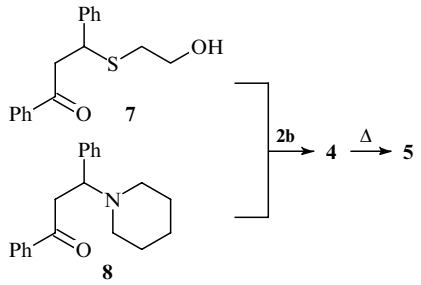
The formation of 3,4-dihydro-1*H*-pyridine-2-chalcogenones **3b** as intermediates in the reactions of arylideneacetone or arylideneacetophenone with cyanothioacetamide (**2b**) was described for the first time in 1980.[195] Later on, it was demonstrated that treatment of compounds **1** with amide **2b** in ethanol in the presence of an equimolar amount of an organic base at 20 °C afforded hydrogenated 3-cyano-1*H*-pyridine-2-thiones **3b**, which were isolated and characterised as stable salts **4** and **5**.[196–202] Substituted 3,4-dihydropyridinethiones **3b** can be formed by treating salts **5** with hydrochloric acid. These compounds are rather stable, although they are oxidised with atmospheric oxygen on storage in solution to form 3-cyano-1*H*-pyridine-2-thiones **6**.



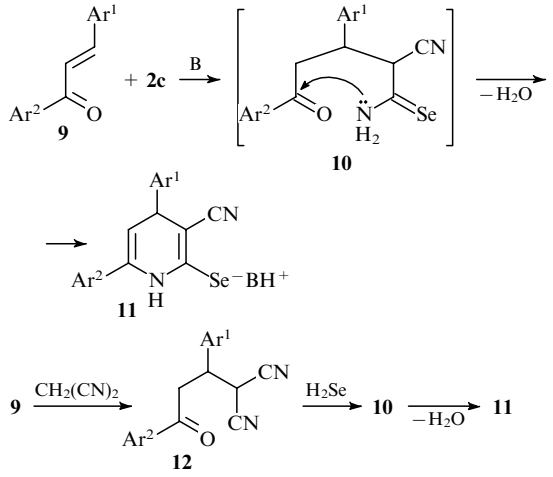
4 **5** **3b** **6**

R^1 = Ph, 4-MeC_6H_4, 4-$MeOC_6H_4$, 4-FC_6H_4, 4-ClC_6H_4, 4-BrC_6H_4, 3-$NO_2C_6H_4$, 4-$NO_2C_6H_4$, 3-Py, 4-Py; R^2 = H, Me, Ph, COMe, CO_2Me, CO_2Et; R^3 = Me, Ph.

Salts **4** and **5** were also prepared by the reactions of amide **2b** with ketones **7**[203] and **8**,[201] respectively.



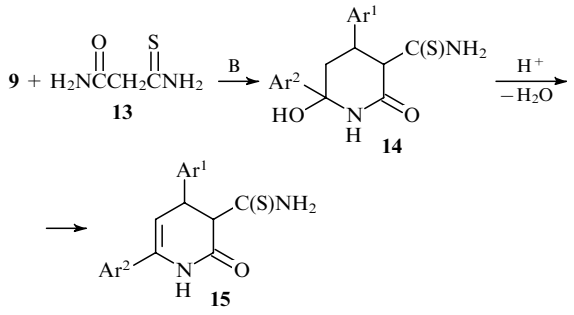
The reactions of chalcones **9** with cyanoselenoacetamide (**2c**) in the presence of an excess of *N*-methylmorpholine afforded Michael adducts **10**. Under the reaction conditions, the latter underwent cyclisation to give 1,4-dihydropyridine-2-selenolates **11** in 60%–90% yields.[45,46,204,205] The latter compounds were also prepared by the reactions of chalcones **9** with malononitriles followed by the reactions of the resulting δ-keto dinitriles **12** with hydrogen selenide.



Ar^1 = Ph, 3-FC_6H_4, 4-FC_6H_4, 2-thienyl;
Ar^2 = Ph, 4-ClC_6H_4, 2-Py; B is *N*-methylmorpholine.

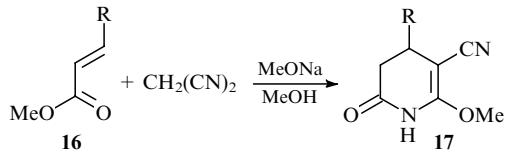
Condensation of aryl(hetaryl) chalcones with amides **2a**,**b** in the presence of alkali metal alkoxides or amines as catalysts was used also for the preparation of a series of 3,4-dihydro derivatives of 3-cyano-1*H*-pyridin-2-ones and -2-thiones.[206,207]

The reactions of ketones **9** with thiocarbamoylacetamide (**13**) in the presence of piperidine or sodium methoxide produced substituted piperidones **14**, which were transformed into pyridones **15** in an acidic medium.[208,209]



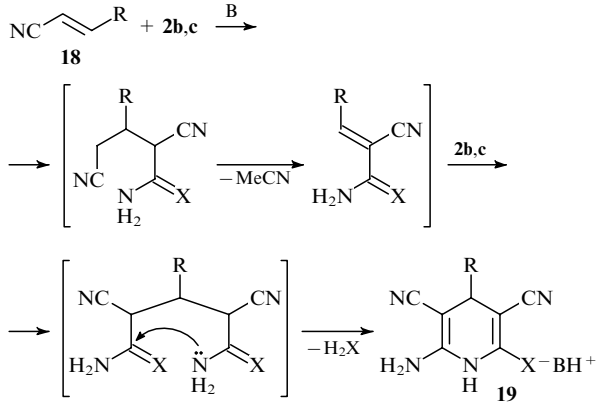
Ar^1 = Ph, 4-ClC_6H_4, 4-$NO_2C_6H_4$; Ar^2 = Ph; B = MeONa, piperidine.

The use of sodium methoxide as a catalyst in the reactions of substituted methyl acrylates **16** with malononitrile gave rise to 3,4-dihydro-1*H*-pyridin-2-ones **17** in 49%–85% yields.[210]



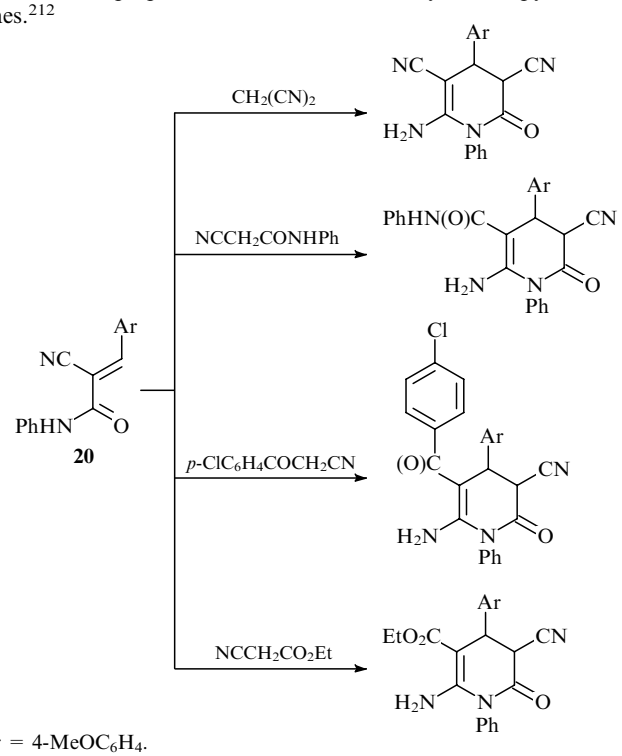
R = Alk, Ar.

The reactions of 3-phenyl- and 3-(2-furyl)acrylonitriles (**18**) with cyanothio(seleno)acetamides (**2b,c**) in the presence of a twofold excess of *N*-methylmorpholine at room temperature afforded substituted 1,4-dihydropyridine-2-thiolates (selenolates) **19**.[45,46,211] The reactions of amides **2b**,**c** with ethyl 3-phenylacrylate and ethyl 3-(2-furyl)acrylates proceeded analogously.



R = Ph, 2-furyl; X = S, Se; B is *N*-methylmorpholine.

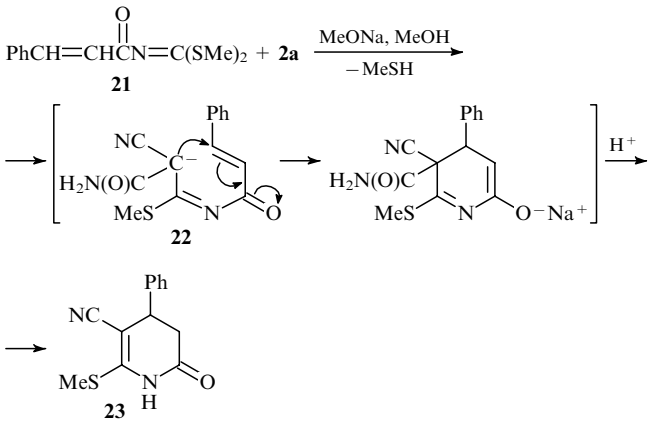
The reactions of anilides of 2-cyanocinnamic acid and other 3-aryl-2-cyanoacrylic acids **20** with CH-acids were successfully used for the preparation of various 3,4-dihydro-1*H*-pyridin-2-ones.[212]



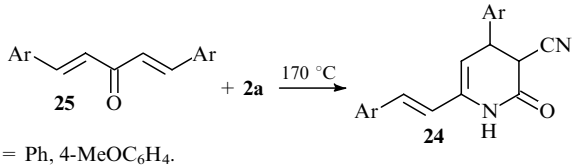
Ar = 4-$MeOC_6H_4$.

Condensation of α,β-unsaturated carbonyl compound **21** with amide **2a** in the presence of sodium methoxide in methanol proceeded through the intermediate formation of Michael adduct

22 with elimination of methanethiol to give 5-cyano-6-methylthio-4-phenyl-3,4-dihydro-1*H*-pyridin-2-one (**23**) in 70% yield.[213]

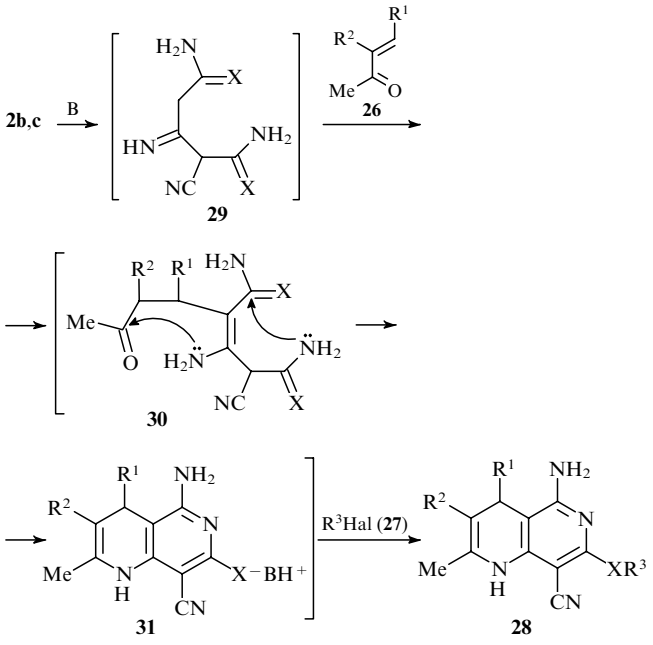


With the aim of preparing substituted 3-cyano-3,4-dihydro-1*H*-pyridin-2-ones **24**, a mixture of pentadienone **25** and cyanoacetamide (**2a**) was heated at 170 °C without a solvent in a sealed tube. Pyridones **24** were obtained in 32% – 37% yields.[214]



Ar = Ph, 4-MeOC$_6$H$_4$.

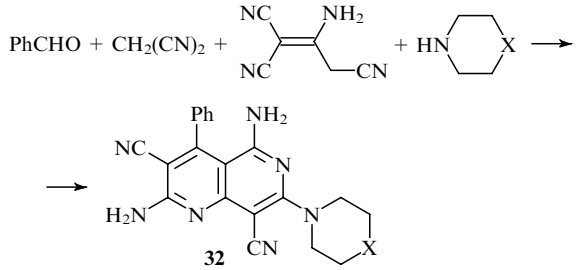
Multicomponent cascade heterocyclisation involving α,β-unsaturated ketones and amides **2b**,**c** was used with advantage in the synthesis of functionalised naphthyridines, which possess a broad spectrum of biological activities.[215, 216] In particular, these compounds were used for the design of drugs exhibiting cardiotonic,[63] antitubercular,[217] antitumour,[218, 219] anti-HIV [220 – 222] and other activities. However, available procedures for the synthesis of naphthyridines are rather complicated and involve many steps, whereas sulfur- and selenium-containing analogues remain virtually unknown. Studies performed by our research group showed for the first time that condensation of unsaturated ketones **26** with amides **2b**,**c** and alkyl halides **27** in the presence of *N*-methylmorpholine proceeded as cascade heterocyclisation to



R^1 = Ar, Het; R^2 = COMe, CO$_2$Et; R^3 = Alk, CH$_2$CH=CH$_2$; X = S, Se; Hal = I, Br, Cl; B is *N*-methylmorpholine.

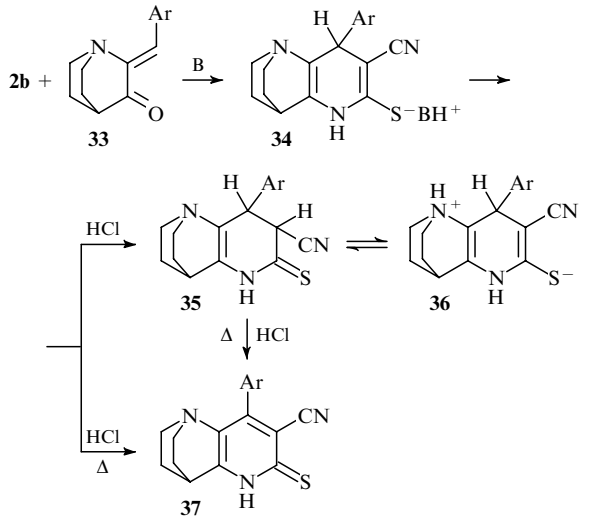
yield previously unknown polyfunctionalised 1,6-naphthyridines **28**.[53, 223 – 228] In the first step, amide **2** undergoes Thorpe dimerisation to form imino nitrile **29**, which is involved in the Michael addition with ketone **26** to form adduct **30**. Under the reaction conditions, the latter undergoes cyclocondensation to produce salt **31**, which is regioselectively alkylated with alkyl halides **27** giving rise to 1,4-dihydro-1,6-naphthyridines **28**.

Multicomponent cascade heterocyclisation of benzaldehyde with malononitrile and its dimer in the presence of a twofold excess of piperidine or morpholine afforded previously unknown 2,5-diamino-3,8-dicyano-4-phenyl-7-piperidino(morpholino)-1,6-naphthyridines (**32**) in high yields. The reaction not only gave rise to the complex naphthyridine system but also was accompanied by the insertion of a fragment of the saturated nitrogen heterocycle, which was used as the catalyst, into the naphthyridine system.[53, 224]



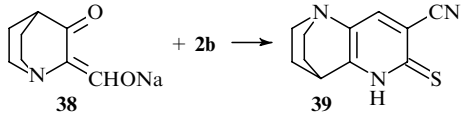
X = CH$_2$, O.

The reactions of 2-arylidenequinuclidin-3-ones **33** with cyanothioacetamide (**2b**) in the presence of piperidine also proceeded through a mechanism of cascade heterocyclisation to form piperidinium 4-aryl-3-cyano-5,8-ethano-1,4,5,6,7,8-hexahydro-1,5-naphthyridine-2-thiolates **34**, whose treatment with hydrochloric acid gave rise to 4-aryl-3-cyano-5,8-ethano-3,4,5,6,7,8-hexahydro-1*H*-1,5-naphthyridine-2-thiones **35**, which were in tautomeric equilibrium with betaines **36**.[229] Heating of salts **34** or thiones **35** in ethanol in the presence of hydrochloric acid led to their dehydrogenation to form naphthyridinethiones **37**.

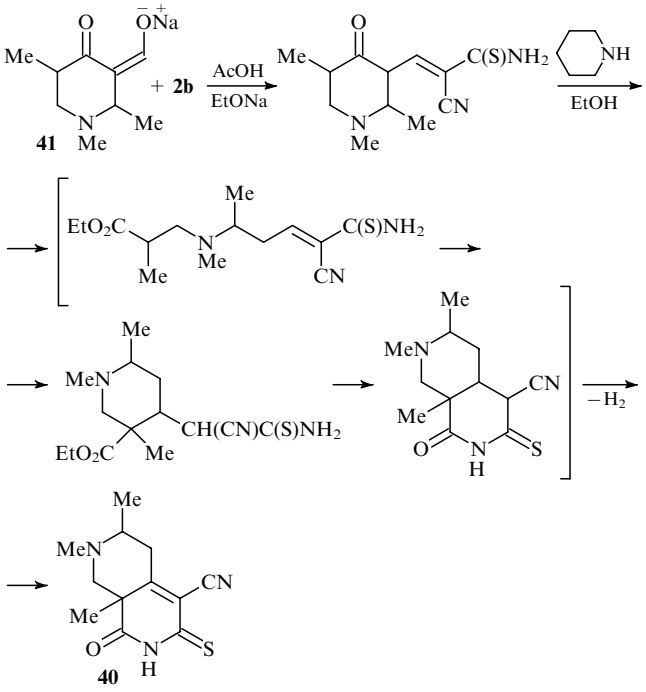


Ar = Ph, 4-FC$_6$H$_4$; B is piperidine.

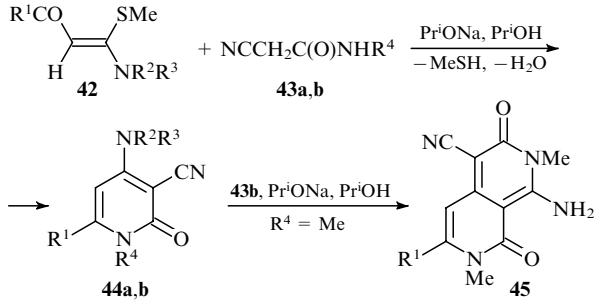
Another example of the highly regioselective synthesis of the 1,5-naphthyridine system is condensation of the sodium salt of 2-formylquinuclidone (**38**) with cyanothioacetamide (**2b**) giving rise to 3-cyano-1*H*-1,5-naphthyridine-2-thione (**39**).[230]



4-Cyano-6,7,8a-trimethyl-3-thioxo-1,2,3,5,6,7,8,8a-octahydro-2,7-naphthyridin-1-one (**40**) was synthesised by cascade heterocyclisation of the sodium salt of 3-formyl-1,2,5-trimethyl-4-piperidone (**41**) with amide **2b**.[45, 231]

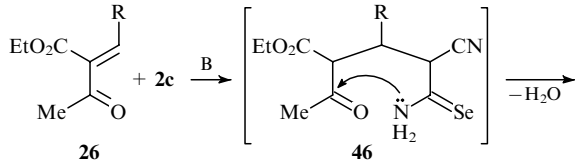


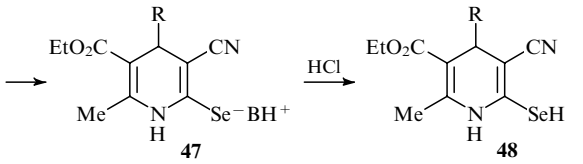
Condensation of β-enamino carbonyl compounds **42** with substituted cyanoacetamides **43a**,**b** proceeds through a mechanism of cascade heterocyclisation with elimination of methanethiol followed by the formation of 4-dialkylaminopyridones **44a**,**b** containing the β-enaminoamide fragment. Pyridone **44b** reacts with the second molecule of *N*-methylcyanoacetamide (**43b**) to give naphthyridinedione **45**.[232]



R^1 = Me, Ph, 4-ClC_6H_4, 4-$MeOC_6H_4$; R^2 = Et, Ph, $CH_2CH(OEt)_2$, Bn; R^3 = H; R^3-R^4 = $(CH_2)_2O(CH_2)_2$; R^4 = H (**a**), Me (**b**).

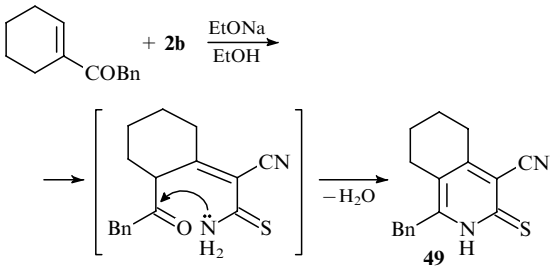
Benzylidene- and 2-furfurylideneacetoacetic esters (**26**) smoothly reacted with selenoamide **2c** under mild conditions (anhydrous ethanol, 20 °C), the reagent ratio playing an essential role.[45, 233–235] When the reagents were taken in a ratio of 1 : 1, the reaction afforded adducts **46**, which underwent cyclisation to 1,4-dihydropyridine-2-selenolates **47**. Treatment of the latter with hydrochloric acid yielded 1,4-dihydropyridine-2-selenols **48**.





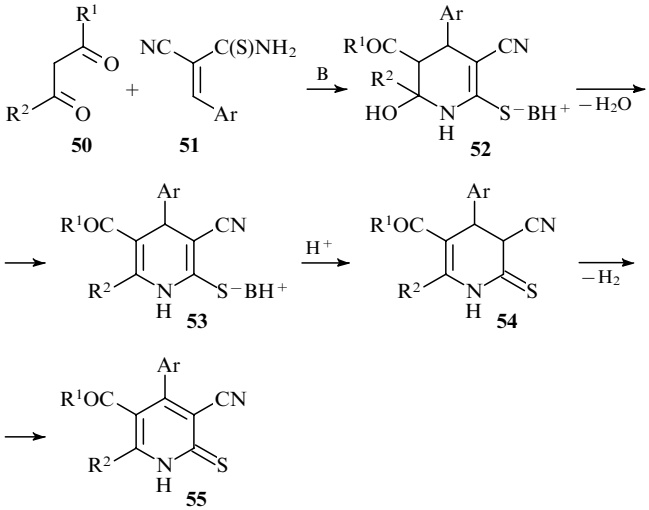
R = Ph, 2-furyl; B is a base.

The reaction of 1-phenylacetylcyclohexene with thioamide **2b** in the presence of sodium ethoxide in alcohol afforded pyridinethione **49** containing a fragment of the alkaloid papaverine.[236]



III. Cascade heterocyclisation involving 1,3-dicarbonyl compounds

Like α,β-unsaturated analogues, 1,3-dicarbonyl compounds **50** and their enamines react with cyanothioacetamide derivatives, *viz*., arylidenecyanothioacetamides **51**, in the presence of base catalysts to form 3-cyano-1*H*-pyridine-2-thiones or their salts.[33, 237–254] In some cases, intermediate tetrahydropyridine-2-thiolates **52** were isolated. Subsequent elimination of water from these compounds affords 3-cyano-1,4-dihydropyridine-2-thiolates **53**. Acidification of salts **52** and **53** gave rise to 3-cyano-3,4-dihydro-1*H*-pyridine-2-thiones **54**. In solutions, the latter compounds underwent dehydrogenation to form 3-cyano-1*H*-pyridine-2-thiones **55**.

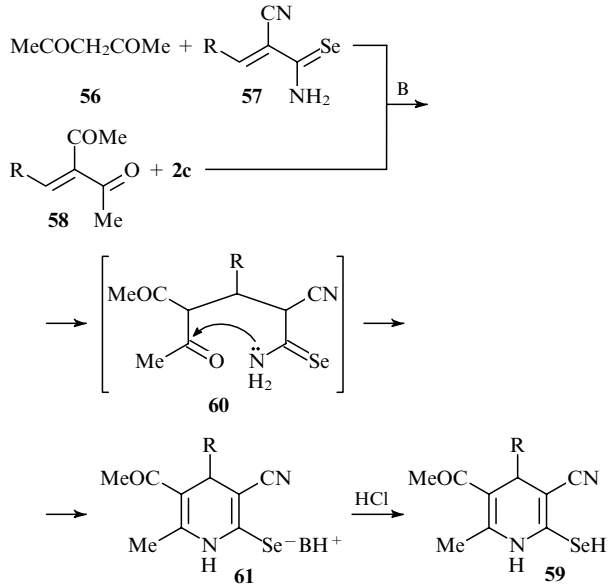


R^1 = Ph, OEt; R^2 = Me, CF_3; Ar = Ph, 3-FC_6H_4, 4-FC_6H_4, 4-ClC_6H_4, 4-BrC_6H_4, 4-$NO_2C_6H_4$; B is a base.

β-Enamine derivatives of 1,3-dicarbonyl compounds reacted with amides **51** also in the absence of base catalysts to produce the corresponding 1,4-dihydropyridine-2-thiolates in high yields.

The reaction of acetylacetone (**56**) with 2-furfurylidenecyanoselenoacetamide (**57**) or the reaction of an unsaturated carbonyl compound, *viz*., 2-furfurylideneacetylacetone (**58**), with cyanoselenoacetamide (**2c**) afforded 5-acetyl-3-cyano-4-(2-furyl)-6-methyl-1,4-dihydropyridine-2-selenol (**59**) in ~ 80% yield.[45, 255] These reactions proceeded through a mechanism of cascade heterocyclisation and involved the intermediate formation of

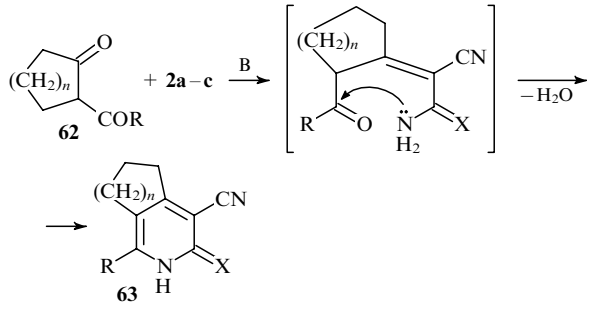
Michael adduct **60** and stable selenolate **61**, whose acidification gave selenol **59**. The reactions of amide **57** with acetoacetic ester or its enamine proceeded analogously to form 5-ethoxycarbonyl-substituted selenol of type **59**.



R is 2-furyl.

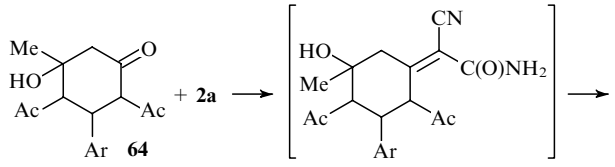
It should be emphasised that due to their diversity and high reactivity, 1,3-dicarbonyl compounds are the most convenient building blocks for the regio- and stereoselective synthesis of hydrogenated sulfur- and selenium-containing pyridines and their fused analogues that are difficult to prepare. For this purpose, acetylacetone, benzoylacetone, dibenzoylmethane, 2-thenoyltrifluoroacetone, β-keto amides (acetylacetamide, acetylacetanilides), ethyl butyrylacetate, acetoacetic and malonic esters and cyclic mono- and diketones were successfully used.[45,46,256–303]

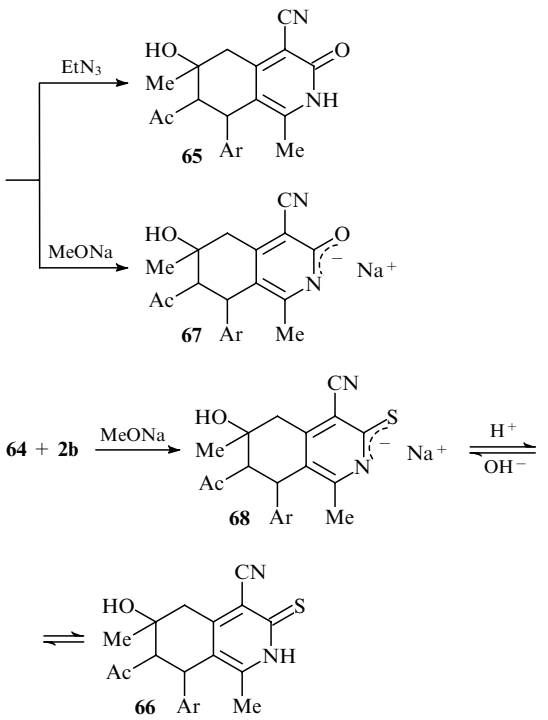
Thus, the use of 2-acylcycloalkanones **62** as substrates and cyanoacetamides **2a** as reagents made it possible to develop convenient procedures for the regioselective synthesis of fused 3-cyano-1*H*-pyridine-2-chalcogenones **63**.[44,188,304–316]



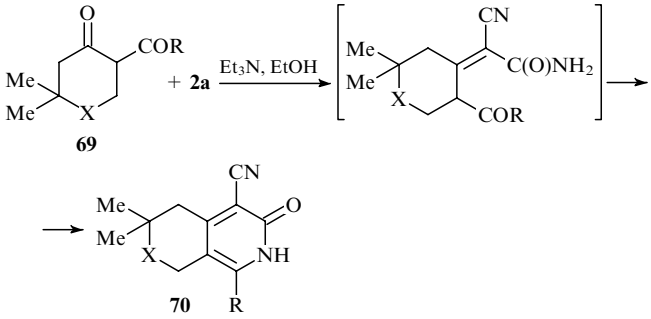
R = Alk, Ar; n = 1, 2; X = O, S, Se.

The reactions of amides **2a**,**b** with 2,4-diacetyl-3-aryl-5-hydroxy-5-methylcyclohexanones **64** afforded 7-acetyl-8-aryl-4-cyano-6-hydroxy-1,6-dimethyl-5,6,7,8-tetrahydro-2*H*-isoquinolin-3-ones **65**, corresponding thiones **66** and their sodium salts **67** and **68** in high yields.[314]



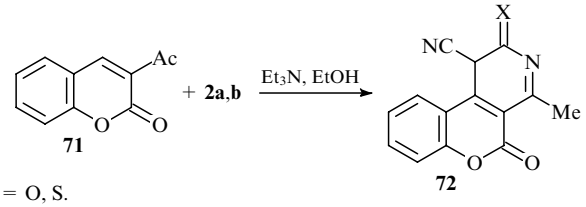


Of numerous reactions of amide **2a** with 2-acylcycloalkanones,[269,272,315–318] noteworthy is the condensation with tetrahydropyrans or -thiopyrans **69** in ethanol in the presence of triethylamine giving rise to previously unknown 6-oxopyrano(thiopyrano)[3,4-*c*]pyridines **70**.[117,315,316]



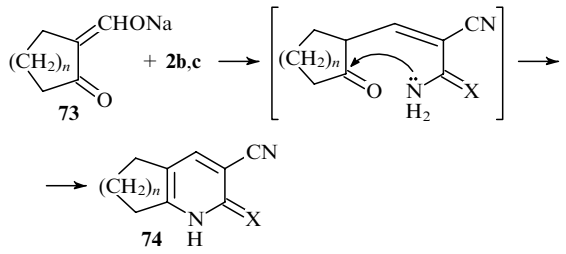
R = Alk, Ar; X = O, S.

Derivatives of coumarin or its fused analogues exhibit antibacterial, cardiovascular and hypothermal activities. Procedures for the synthesis of substituted coumarins are being developed with the aim of searching for new drugs. Thus, the reactions of 3-acetylcoumarin (**71**) with amides **2a**,**b** in the presence of bases giving rise to oxo and thioxo derivatives of benzopyrano[3,4-*c*]-pyridine **72** have been studied.[318]



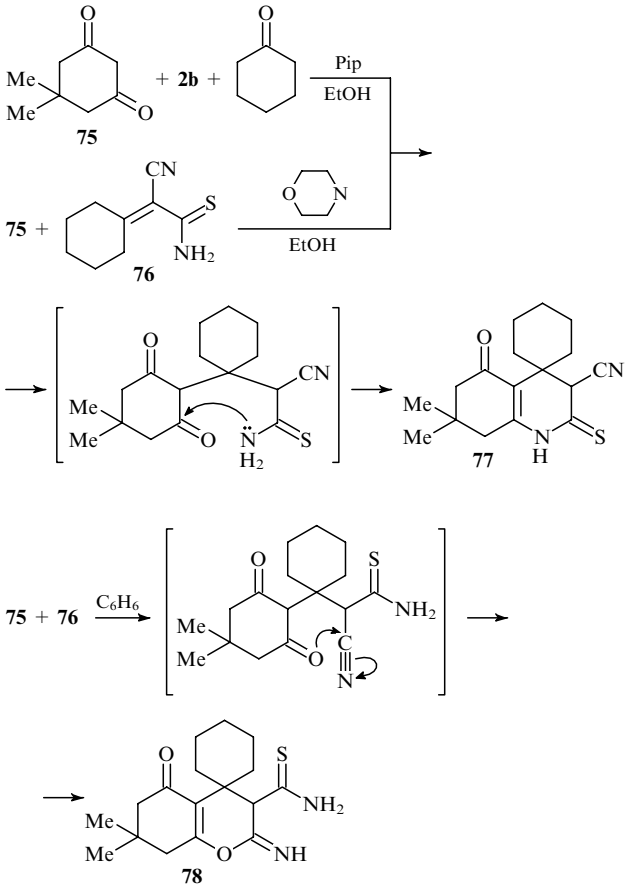
X = O, S.

Cascade heterocyclisation of amides **2b**,**c** with sodium salts of 2-hydroxymethylidenecycloalkanones **73** was examined. It was demonstrated that these reactions proceeded regioselectively to produce fused 3-cyano-1*H*-pyridine-2-thiones(selenones) **74**.[44,308,319–326]

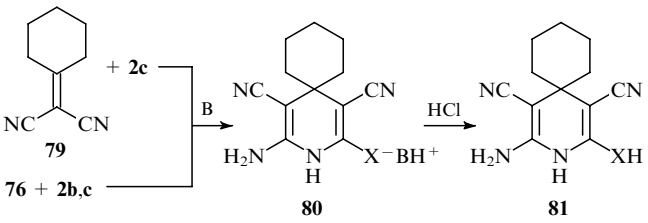


n = 1, 2; X = S, Se.

The methodology of cascade heterocyclisation is unique as can be exemplified by the synthesis of previously unknown quinoline- and pyridine-thiones containing a spiro-fused fragment. For instance, three-component condensation of dimedone (**75**), cyanothioacetamide (**2b**) and cyclohexanone in the presence of piperidine in ethanol or the reaction of diketone **75** with cyclohexylidenecyanothioacetamide (**76**) in ethanol in the presence of morpholine afforded previously unknown 3-cyano-7,7-dimethyl-5-oxospiro[cyclohexane-1,4′-octahydroquinoline]-2-thione (**77**).[45, 293] The use of benzene as the solvent changed the direction of the latter reaction with the resulting formation of 2-iminopyran **78**.

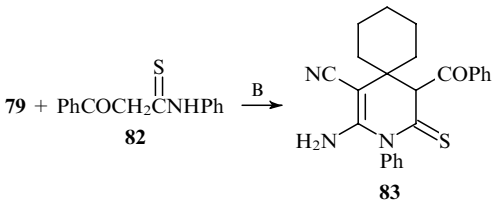


Spiro-fused partially hydrogenated pyridine-2-thiolates(selenolates) were also prepared with the use of other reagents. For example, the reaction of cyclohexylidenemalononitrile (**79**) with cyanoselenoacetamide (**2c**) or the reaction of cyclohexylidenecyanothioacetamide (**76**) with amides **2b**,**c** or malononitrile in ethanol in the presence of *N*-methylmorpholine gave rise to salts **80**, which were transformed into 6-amino-3,5-dicyanospiro[cyclohexane-1,4′-dihydropyridine]-2-thiol(selenol) (**81**) upon treatment with hydrochloric acid.[45, 282, 327, 328]

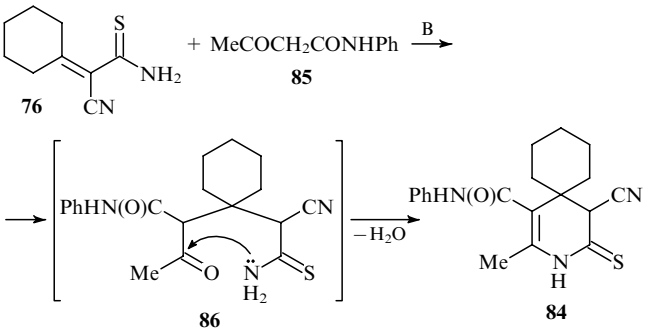


X = S, Se; B is *N*-methylmorpholine.

The reaction of dinitrile **79** with anilide **82** afforded partially hydrogenated polyfunctionalised spiro-fused pyridinethione **83**.[328]

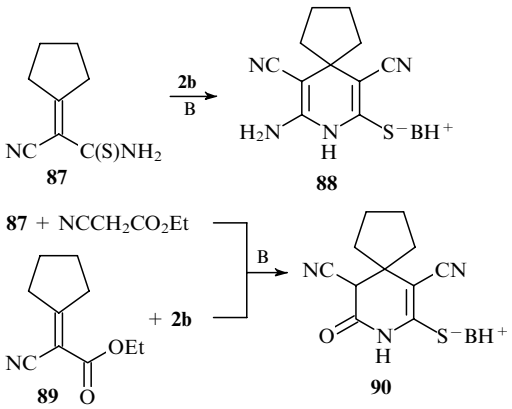


In turn, spiro[cyclohexane-1,4′-pyridine]-2-thione **84** was prepared in 87% yield by the reaction of thioamide **76** with acetoacetanilide (**85**) in ethanol in the presence of *N*-methylmorpholine.[46, 263]

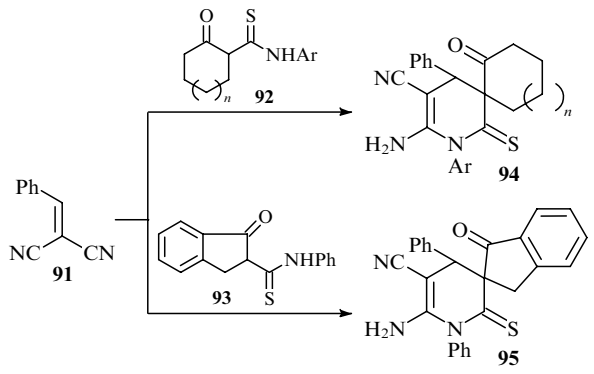


B is *N*-methylmorpholine.

An analogous reaction of cyclopentylidenecyanothioacetamide (**87**) with cyanothioacetamide (**2b**) produced 6-amino-3,5-dicyanospiro[cyclopentane-1,4′-dihydropyridine]-2-thiolate (**88**).[283] The reaction of amide **87** with cyanoacetic ester or the reaction of amide **2b** with cyclopentylidenecyanoacetic ester (**89**) afforded 3,5-dicyano-6-oxospiro[cyclopentane-1,4′-tetrahydropyridine]-2-thiolate (**90**).[329]

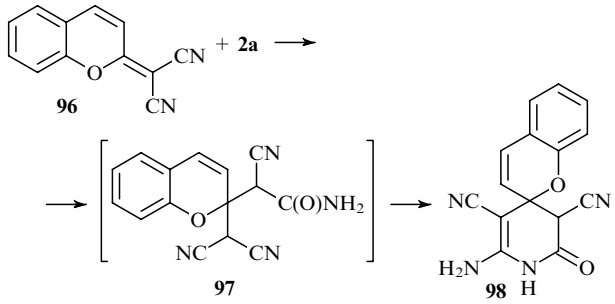


Benzylidenemalononitrile (**91**) reacted with anilides of 2-oxocycloalkanethiocarboxylic (**92**) and 3-oxo-2,3-dihydroindene-2-thiocarboxylic acids (**93**) to form spiro-fused pyridinethiones **94** and **95**, respectively.[330, 331]

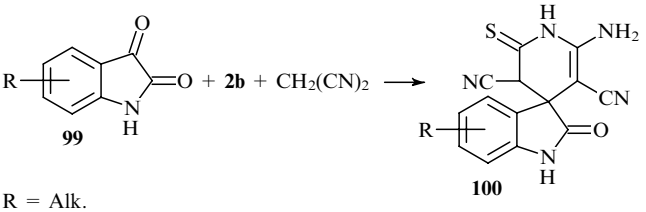


Ar = Ph, 4-MeC$_6$H$_4$, 4-MeOC$_6$H$_4$, 4-ClC$_6$H$_4$, 4-BrC$_6$H$_4$; n = 0–2.

On refluxing in ethanol in the presence of piperidine, cyanoacetamide (**2a**) added to chromenylidenemalononitrile (**96**) to give adduct **97**, which underwent intramolecular cyclisation *in situ* yielding spiro-fused pyridone **98**.[331]

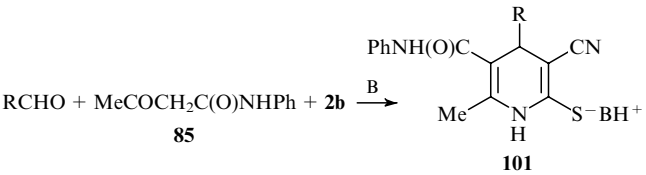


Three-component heterocyclisation of diketone **99**, amide **2b** and malononitrile in ethanol in the presence of piperidine giving partially hydrogenated pyridinethione **100** provides another example of the synthesis of spiro-fused pyridinechalcogenones.[332]



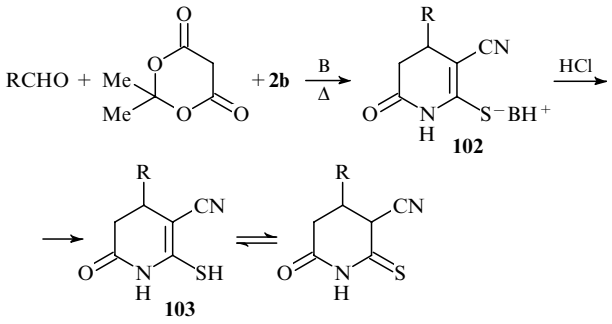
R = Alk.

It should be noted that in the last decade, three-component cascade heterocyclisation of amides of cyanoacetic acid or its thio and seleno derivatives with aliphatic, aromatic or heterocyclic aldehydes and 1,3-dicarbonyl compounds in the presence of an excess of an organic base was successfully used in the synthesis of 1*H*-pyridine-2-chalcogenones, their hydrogenated analogues and salts (see Refs 44–46, 199, 233, 241, 243, 244, 256, 257, 259, 262–268, 270, 271, 274, 276, 279, 284–286, 289–291, 293, 294, 302 and 333–339). The synthesis of salts of 4-(aryl,hetaryl)-3-cyano-6-methyl-5-phenylcarbamoyl-1,4-dihydropyridine-2-thiolates **101** from aromatic or heterocyclic aldehydes, amide **2b** and acetoacetanilide (**85**) in the presence of an excess of *N*-methylmorpholine [257, 259, 337] provides an example.



R = Ph, 2-ClC$_6$H$_4$, 2-MeC$_6$H$_4$, 3-Py, 2-thienyl; B is *N*-methylmorpholine.

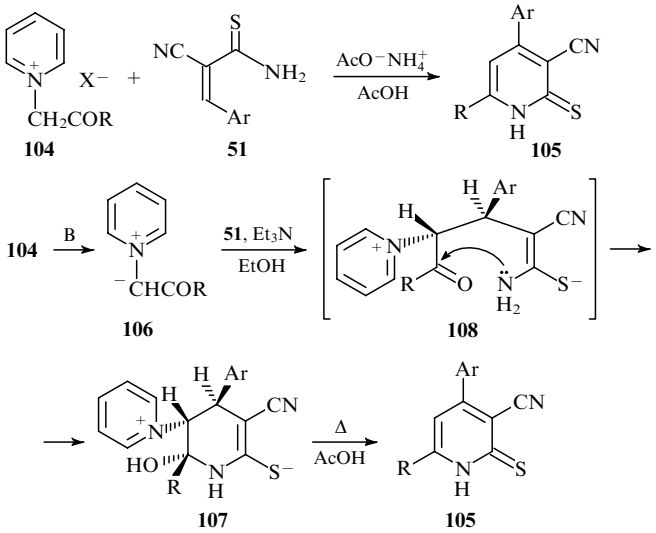
Cyclic diketones [cyclohexane-1,3-dione, dimedone, isopropylidenemalonate (Meldrum's acid)] were also used as 1,3-dicarbonyl substrates in three-component heterocyclisation.[262, 285, 286, 295] For example, 4-(aryl,hetaryl)-3-cyano-6-oxo-1,4,5,6-tetrahydropyridine-2-thiolates **102** were prepared by refluxing an equimolar mixture of the corresponding aldehyde, amide **2b** and Meldrum's acid in alcohol in the presence of *N*-methylmorpholine for 3 h. Acidification of thiolates **102** with 10% hydrochloric acid to pH 5 afforded 4-(aryl,hetaryl)-5-cyano-6-thio-3,4-dihydro-1*H*-pyridin-2-ones **103**.[285]



R = 4-MeC$_6$H$_4$, 1-naphthyl, 2-furyl, 2-thienyl; B is *N*-methylmorpholine.

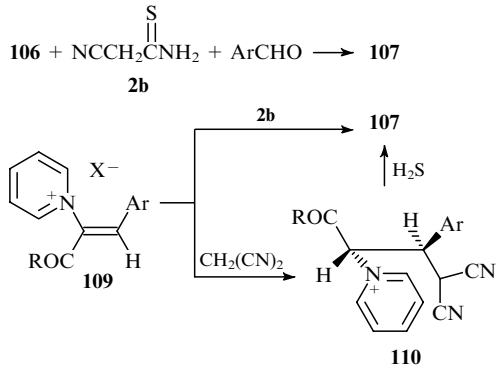
IV. Cascade heterocyclisation involving pyridinium ylides

Pyridinium ylides, which are generated *in situ* from quaternised pyridines, are widely used in fine organic synthesis,[340–343] including the preparation of 4,6-disubstituted 3-cyano-1*H*-pyridine-2-thiones (see Refs 43, 44, 126, 327 and 344–354). It was noted that the nature of the final products depends on the reaction conditions. Thus, heating of arylidenecyanothiacetamides **51** with pyridinium salts **104** in the presence of ammonium acetate in acetic acid gave rise to 4,6-disubstituted 3-cyano-1*H*-pyridine-2-thiones **105**.[346] By contrast, the reactions of pyridinium ylides **106** generated from salts **104** with amides **51** in ethanol in the presence of triethylamine at room temperature afforded *trans*,*trans*-1,4,5,6-tetrahydropyridine-2-thiolates **107**, which were isolated and characterised as stable crystalline salts.[345–348, 351, 355–367] The high selectivity of these reactions results from the stereoselectivity of the addition of ylides **106** to amides **51**. Subsequent cyclisation of adducts **108** proceeded with retention of the *trans* arrangement of the hydrogen atoms.[44, 346, 362] Heating of salts **107** in acetic acid in the presence of ammonium acetate afforded thiones **105**.



R = Me, OMe, NH$_2$, Ph, 3-Py; Ar = Ph, 3-FC$_6$H$_4$, 4-FC$_6$H$_4$, 4-ClC$_6$H$_4$, 4-NO$_2$C$_6$H$_4$, 3-Py; X = I, Br; B is a base.

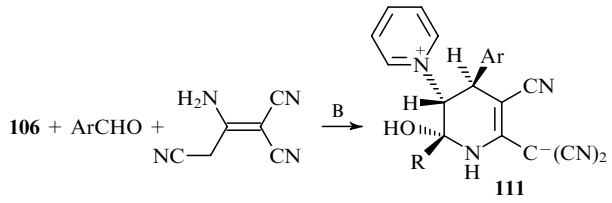
Thiolates **107** were also synthesised without the preliminary preparation of thioamides **51** by three-component condensation of pyridinium ylides **106**, cyanothioacetamide (**2b**) and aromatic aldehydes [346, 347, 351] as well as by the reaction of pyridinium salt **109** with amide **2b**.[360] The use of malononitrile instead of amide **2b** in the reaction with the *E* isomer of compound **109** resulted in the formation of *trans*-adducts **110**, whose treatment with hydrogen sulfide produced *trans*-substituted tetrahydropyridines **107**.



R = Me, OMe, NH_2, Ph; Ar = Ph, 4-ClC_6H_4, 4-BrC_6H_4, 4-FC_6H_4, 4-$MeOC_6H_4$, 3-Py, 4-Py; X = Cl, Br.

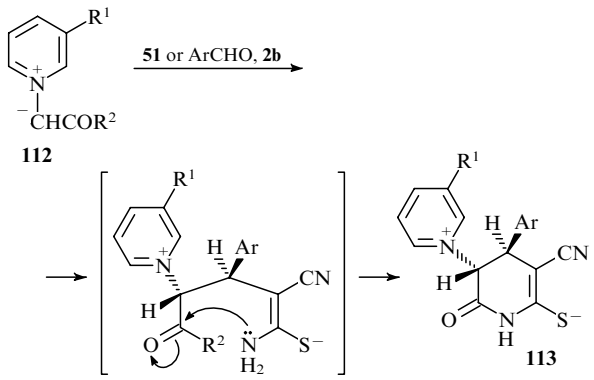
Isoquinolinium ylides also found application in the synthesis of thiolates.[347]

Stereoselective three-component condensation of pyridinium ylides **106**, aromatic aldehydes and 2-amino-1,1,3-tricyanopropene afforded *trans*-6-R-4-aryl-3-cyano-6-hydroxy-5-pyridinio-1,4,5,6-tetrahydropyridine-2-dicyanomethylides **111**, which are difficult to prepare.[345, 346]



Ar = Ph, 4-FC_6H_4, 4-ClC_6H_4, 4-BrC_6H_4, 4-$MeOC_6H_4$;
R = Me, OMe, NH_2, Ph, 3-Py.

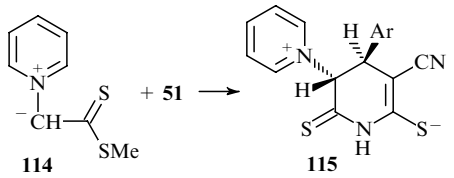
The reactions of *meta*-substituted pyridinium ylides **112** with arylidenecyanothioacetamides **51** provided the basis for regio- and stereoselective procedures for the synthesis of *trans*-4-aryl-3-cyano-6-oxo-5-pyridinio-1,4,5,6-tetrahydropyridine-2-thiolates (**113**).[44, 223, 345, 353–355] Tetrahydropyridines **113** were also synthesised by one-pot heterocyclisation of pyridinium ylides **112** with aromatic aldehydes and cyanothioacetamide (**2b**) without the preliminary preparation of unsaturated amides **51**.[44, 345]



R^1 = Me, Br, NH_2; R^2 = Me, Ph, NH_2, OMe;
Ar = Ph, 4-FC_6H_4, 4-ClC_6H_4, 4-BrC_6H_4, 4-HOC_6H_4, 4-$MeOC_6H_4$, 2-$NO_2C_6H_4$, 3-Py, 4-Py.

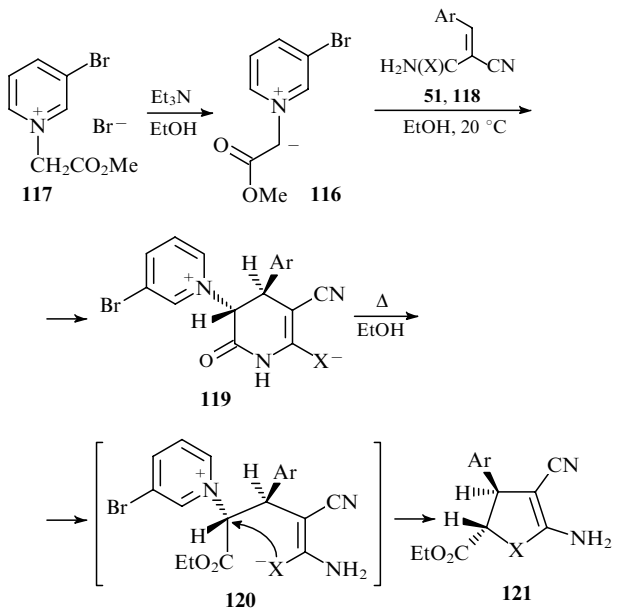
Various pyridinium ylides are used for the preparation of 4-aryl-3-cyano-6-oxo-5-pyridinio-1,4,5,6-tetrahydropyridin-2-olates.[346, 353–356, 368]

Cascade heterocyclisation of pyridinium ylide **114** with amides **51** gave rise to *trans*-substituted 6-thioxo-1,4,5,6-tetrahydropyridine-2-thiolates **115**.[223, 346, 353, 355]



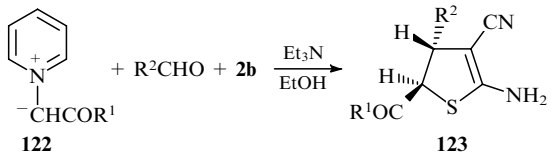
Ar = 4-HOC_6H_4, 4-$MeOC_6H_4$, 4-FC_6H_4, 4-ClC_6H_4, 4-BrC_6H_4, 3-Py.

It was found that the direction of cascade heterocyclisation involving pyridinium ylides depends on the reaction temperature. For example, the reactions of 3-bromopyridinium ylide **116** generated from salt **117** with unsaturated nitriles **51** and **118** at room temperature in ethanol in the presence of triethylamine proceeded stereo- and atroposelectively to yield *trans*-substituted 1,4,5,6-tetrahydropyridines **119**. Heating of the latter compounds in ethanol led to alcoholysis and opening of the tetrahydropyridine ring at the amide bond to give the corresponding intermediates **120**. The subsequent intramolecular nucleophilic substitution proceeded with elimination of 3-bromopyridine and retention of the *trans*-arrangement of the hydrogen atoms and produced the corresponding *trans*-dihydrofurans and -thiophenes **121**.[43, 44, 344, 349, 350, 354, 369] Five-membered heterocycles **121** were also generated in high yields without isolation of intermediates **119** and **120** by the reactions of ylide **116** with nitrile **51** or **118**, respectively, in ethanol at ~80 °C.



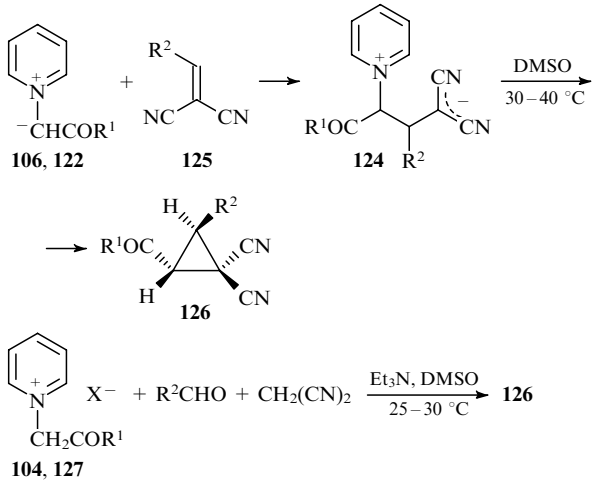
Ar = 3-Py, 4-FC_6H_4, 2-$MeOC_6H_4$; X = S (**51**), O (**118**).

Three-component cascade heterocyclisation of ylide **122**, aromatic aldehydes and amide **2b** in ethanol in the presence of triethylamine at room temperature gave previously unknown adamantylcarbonyldihydrothiophenes **123** in 62%–95% yields.[43, 343, 349]



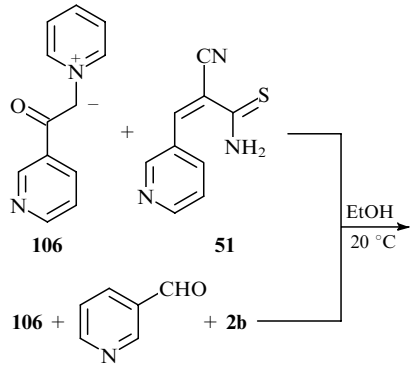
R^1 is 1-adamantyl; R^2 = 4-Py, 4-FC_6H_4, 4-ClC_6H_4.

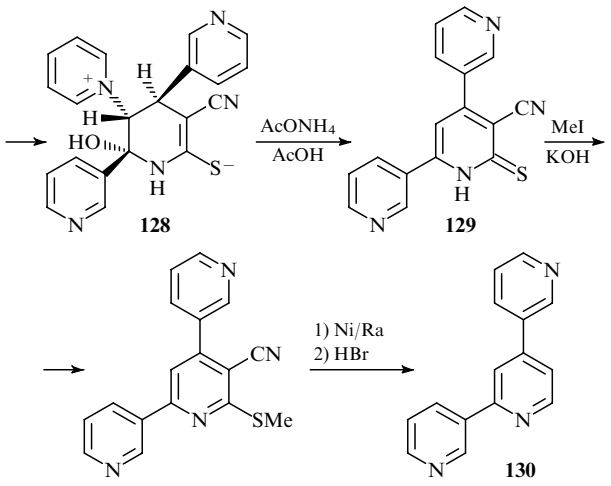
Considerable synthetic potential of pyridinium ylides enables one to use these compounds for the development of fundamentally new approaches to functionalised cyclopropanes. For example, heating of betaines **124**, which were generated by the reactions of pyridinium ylides **106** and **122** with arylidenemalononitriles **125**, in DMSO at 30–40 °C led to intramolecular 1,3-elimination of pyridine to form *trans*-cyclopropanes **126** in 80%–96% yields.[43, 344, 357, 370, 371] Compounds **126** can also be prepared in 78%–94% yields by three-component condensation of salts **104** or **127** with aromatic aldehydes and malononitrile in DMSO in the presence of triethylamine at 25–30 °C.



R^1 = NH_2, Me (**104**, **106**), 1-adamantyl (**122**, **127**);
R^2 = 4-ClC_6H_4, 4-BrC_6H_4, 4-IC_6H_4, 3-Py, 4-Py, 2-thienyl.

The synthesis of nicoteline, *viz*., 2,4-bis(3-pyridyl)pyridine, which is a minor alkaloid from tobacco *Nickotiana tabacum*,[43, 44, 344, 351] provides yet another example of the successful use of the methodology of cascade heterocyclisation involving pyridinium ylides. Thus, the reaction of ylide **106** (R = 3-Py) with amide **51** (Ar = 3-Py) in ethanol at room temperature gave rise to 4,5-*trans*-3-cyano-6-hydroxy-4,6-bis(3-pyridyl)-5-pyridinio-1,4,5,6-tetrahydropyridine-2-thiolate (**128**) in 98% yield. This compound was also synthesised in 92% yield by three-component condensation of ylide **106** (R = 3-Py), 3-pyridinecarbaldehyde and amide **2b** under analogous conditions. Heating of thiolate **128** in acetic acid in the presence of ammonium acetate afforded thione **129** in 83% yield. The latter was transformed into nicoteline **130** in 82% yield by successive alkylation, hydrogenolysis in



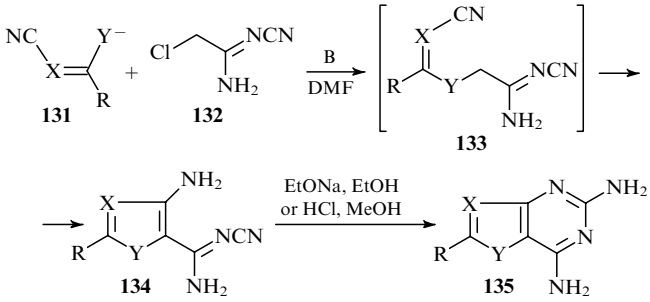


the presence of Raney nickel and decyanation in an acidic medium.

V. Cascade heterocyclisation in the synthesis of fused heterocycles

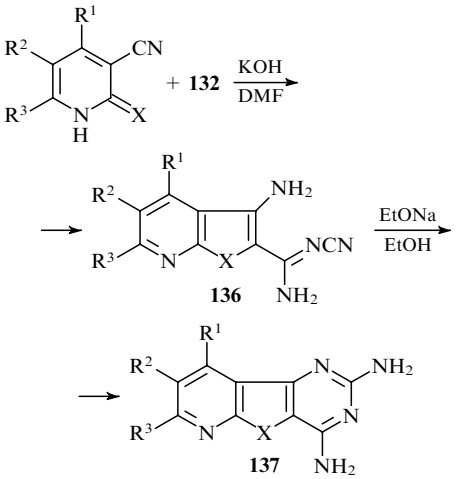
Functionalised fused heterocycles are of equal or even higher practical interest than the corresponding mononuclear heterocyclic systems. However, most of the available procedures for their synthesis are rather laborious, involve many steps and often require drastic conditions, which eventually leads to a substantial decrease in the yields and an increase in the cost of the final products. The use of the strategy of cascade heterocyclisation allows one not only to eliminate these drawbacks but also to construct polyfunctional annelated heterocycles, which are impracticable to prepare by conventional methods. The methodology of cascade heterocyclisation involving simple and available substrates and reagents provided the basis for the development of convenient procedures for the synthesis of different classes of fused heterocycles, such as thieno[3,2-*b*]pyridines, thieno[3,2-*d*]-pyrimidines, thiazolo[4,5-*b*]pyridines, thiazolo[4,5-*d*]pyrimidines, pyrido[3′,2′:4,5]thieno[3,2-*b*]pyridines, pyrido[3′,2′:4,5]thieno-[3,2-*d*]pyrimidines, pyrido[3′,2′:4,5]thieno(selenopheno)[3,2-*d*]-pyrimidines, quinuclidino[2″,3″:5′,6′]pyrido[3′,2′:4,5]thieno-[3,2-*d*]pyrimidines, pyrimido[4′,5′:4,5]thieno[2,3-*c*]-2,7-naphthyridines, pyrido[2″,3″:4′,5′]thieno[3′,2′:4,5]thieno[3,2-*b*]pyridines, *etc*.[50, 52, 371–390]

The successful application of the strategy of cascade heterocyclisation can be exemplified by regioselective procedures for the synthesis of thieno-, selenopheno- and thiazolodiaminopyrimidines on the basis of vicinal mercapto(hydroseleno)nitriles **131** and *N*-cyanochloroacetamidine (**132**). The reactions start with regioselective alkylation at the chalcogen atom to form intermediates **133**, which undergo Thorpe–Ziegler cyclisation giving rise to compounds **134**. The latter are transformed into hetarylpyrimidines **135** by heating in ethanol in the presence of sodium ethoxide or by treatment with hydrochloric acid in methanol.[50, 373, 375]



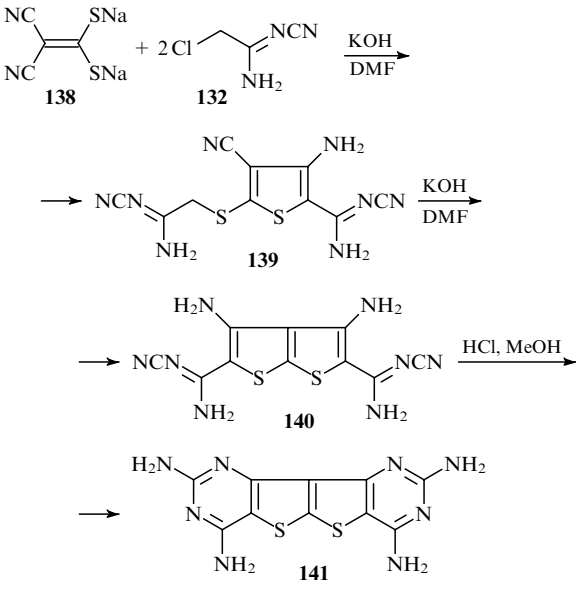
R = NHPh, $NHCH_2CH{=}CH_2$; X = N, CCN; Y = S, Se;
B is a base.

An analogous reaction of amidine **132** with 1*H*-pyridine-2-chalcogenones in DMF in the presence of an excess of KOH involved two successive steps, *viz*., nucleophilic substitution and Thorpe–Ziegler condensation, and produced thieno(selenopheno)[2,3-*b*]pyridines **136**.[373] Refluxing of the latter compounds with sodium ethoxide in ethanol afforded 2,4-diaminopyrido[3′,2′:4,5]thieno(selenopheno)[3,2-*d*]pyrimidines **137**. The latter compounds can also be synthesised without isolation of intermediates **136**.[372, 373]

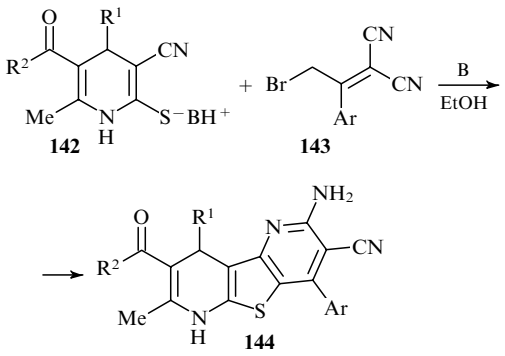


R^1 = H, Me, CF_3, 4-ClC_6H_4; R^2 = H; R^3 = Me, Ph, 4-MeC_6H_4;
$R^2–R^3$ = , $(CH_2)_4$; X = S, Se.

The reaction with the use of sodium 2,2-dicyanoethylene-1,1-dithiolate (**138**) as the nitrile component proceeded through the successive formation of compounds **139** and **140** to give tetraannelated heterocycle **141** as the final product.[50, 373, 375]

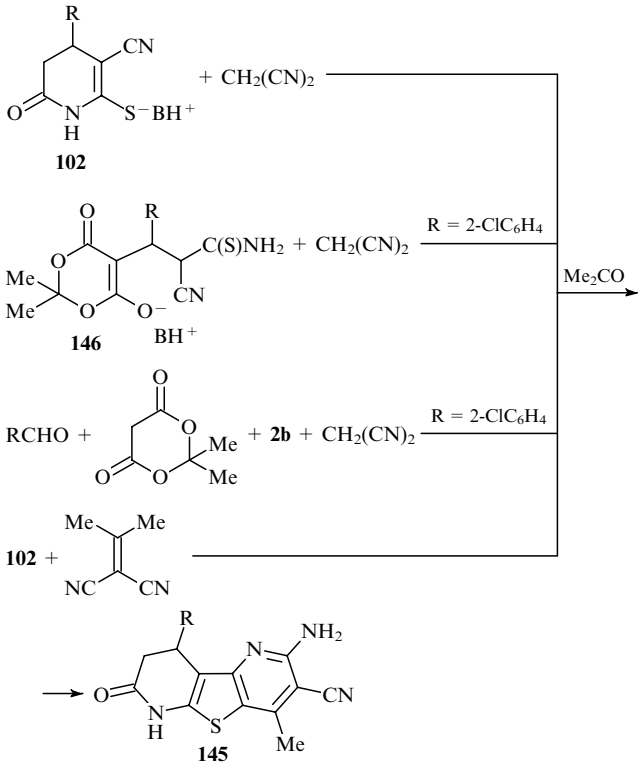


Of other numerous examples of the employment of cascade heterocyclisation in the synthesis of fused heterocyclic systems, noteworthy is the preparation of pyridothienopyridines, pyridothienopyrimidines and their hydrogenated analogues.[52, 380–383, 387, 391, 392] For example, the reactions of piperidinium 3-cyano-1,4-dihydropyridine-2-thiolates **142** with 2-bromo-1-arylethylidenemalononitriles **143** produced 2,5-dihydropyrido[3′,2′:4,5]thieno[3,2-*b*]pyridines **144** in high yields.[52, 381] This procedure can also be used for the synthesis of functionalised pyrido[3′,2′:4,5]thieno[3,2-*d*]pyrimidines.



R^1 = 4-$MeOC_6H_4$, 2-$NO_2C_6H_4$, 2-thienyl; R^2 = Me, OEt;
Ar = Ph, 4-BrC_6H_4; B is piperidine.

Tetrahydropyridothienopyridines **145** were synthesised by three-component cascade heterocyclisation of tetrahydropyridine-2-thiolates **102**, malononitrile and acetone in refluxing ethanol. These compounds were also prepared by the reactions of precursors of thiolates **102**, *viz*., the corresponding Michael adducts **146**, with malononitrile and acetone, by condensation of 2-chlorobenzaldehyde, Meldrum's acid, cyanothioacetamide (**2b**), malononitrile and acetone in the presence of *N*-methylmorpholine or by refluxing a mixture of thiolate **102**, isopropylidenemalononitrile and acetone in ethanol.[391, 392]



R = Ph, 4-MeC_6H_4, 2-ClC_6H_4, 2-$MeOC_6H_4$, 2,5-$(MeO)_2C_6H_3$, 3,4-$(MeO)_2C_6H_3$, 3,4,5-$(MeO)_3C_6H_2$, 4-$EtOC_6H_4$, 3,4-$(OCH_2O)C_6H_3$, 1-naphthyl, 2-thienyl; B is *N*-methylmorpholine.

Recent advances in cascade heterocyclisation have been discussed in the reviews [389, 390, 393–395] and studies.[396–405]

* * *

Due to elaboration of fundamentals of one-pot cascade heterocyclisation of carbonyl compounds and CH-acids under the conditions of base catalysis, one can easily perform the regio- and stereoselective synthesis of polyfunctional heterocycles, in particular, of substituted pyridinechalcogenones and their hydrogenated and fused analogues. An important advantage of this

approach is the simplicity and accessibility of substrates and reagents, *viz*., of aromatic and heteroaromatic aldehydes, cycloalkanones, acyclic and cyclic mono- and dicarbonyl compounds, α,β-unsaturated carbonyl compounds, cyanoacetamides and their thio and seleno analogues.

Undoubtedly, this methodology shows promise for the development of procedures for the preparation of new classes of heterocyclic compounds.

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References

1. I Ugi, A Domling, B Werner *J. Heterocycl. Chem.* **37** 647 (2000)
2. V P Litvinov *Vestn. RFFI* 2003 (in the press)
3. L F Tietze, U Beifuss *Angew. Chem., Int. Ed. Engl.* **32** 131 (1993)
4. L F Tietze *J. Heterocycl. Chem.* **27** 47 (1990)
5. L F Tietze *Chem. Rev.* **96** 115 (1996)
6. S E Denmark, A Thorarensen *Chem. Rev.* **96** 137 (1996)
7. J D Winkler *Chem. Rev.* **96** 167 (1996)
8. I Ryu, N Sonoda, D P Curran *Chem. Rev.* **96** 177 (1996)
9. P J Parsons, C S Penkett, A J Shell *Chem. Rev.* **96** 195 (1996)
10. K K Wang *Chem. Rev.* **96** 207 (1996)
11. A Padwa, M D Wingarten *Chem. Rev.* **96** 223 (1996)
12. Z Hippe, I Ugi (Eds) *Multicomponent Reactions and Combinatorial Chemistry (German-Polish Workshop), Rzeszow, 1997* (Munich: University of Technology Rzeszow/Technical University, 1998)
13. L A Thompson, J A Ellman *Chem. Rev.* **96** 555 (1996)
14. E S Osborne, A D Ellington *Chem. Rev.* **97** 349 (1997)
15. R R Breaker *Chem. Rev.* **97** 371 (1997)
16. G P Smith, V Petrenko *Chem. Rev.* **97** 391 (1997)
17. K S Lam, M Lebl, V Krchnak *Chem. Rev.* **97** 411 (1997)
18. A Nefzi, J M Ostersh, R A Houghten *Chem. Rev.* **97** 449 (1997)
19. M C Pirrung *Chem. Rev.* **97** 473 (1997)
20. D J Gravert, K D Janda *Chem. Rev.* **97** 489 (1997)
21. A Hantzch *Liebigs Ann. Chem.* **215** 72 (1882)
22. D M Stout, A I Meyers *Chem. Rev.* **82** 223 (1982)
23. L Gattermann, A Skita *Berichte* **49** 494 (1916)
24. I Guareschi *Chem. Zbl.* **11** 684 (1905)
25. G A R Kon, J F Thorpe *J. Chem. Soc.* **115** 686 (1919)
26. O Doebner *Berichte* **27** 352 (1894)
27. F Ullmann, A Fetvadjan *Berichte* **36** 1027 (1903)
28. V P Litvinov, L A Rodinovskaya, Yu A Sharanin, A M Shestopalov, A Senning *Sulfur Rep.* **13** 1 (1992)
29. F M Abdel-Galil, Sh M Sherif, M H Elnagdi *Heterocycles,* **24** 2023 (1986)
30. B Y Riad, A M Negm, S E Abdou, H A Daboun *Heterocycles,* **26** 205 (1987)
31. M H Elnagdi, Sh M Sherif, R M Mohareb *Heterocycles* **26** 497 (1987)
32. L A Rodinovskaya, V K Promonenkov, Yu A Sharanin, V P Litvinov, A M Shestopalov, in *Organicheskaya Khimiya (Itogi Nauki i Tekhniki)* [Organic Chemistry (Advances in Science and Engineering Series)] (Moscow: Izd. VINITI, 1989) Vol. 17, p. 3
33. V P Litvinov, V K Promonenkov, Yu A Sharanin, A M Shestopalov, in *Organicheskaya Khimiya (Itogi Nauki i Tekhniki)* [Organic Chemistry (Advances in Science and Engineering Series)] (Moscow: Izd. VINITI, 1989) Vol. 17, p. 72
34. Yu A Sharanin, V K Promonenkov, V P Litvinov, in *Organicheskaya Khimiya (Itogi Nauki i Tekhniki)* [Organic Chemistry (Advances in Science and Engineering Series)] (Moscow: Izd. VINITI, 1991) Vol. 20, Pt. 1
35. A E Sausin'sh, G Ya Dubur *Khim. Geterotsikl. Soedin.* 435 (1992) [a]
36. A E Sausin'sh, G Ya Dubur *Khim. Geterotsikl. Soedin.* 579 (1993) [a]
37. Ya Ozols, B Vigante, G Dubur *Khim. Geterotsikl. Soedin.* 1603 (1994) [a]
38. Yu A Sharanin, M P Goncharenko, V P Litvinov *Usp. Khim.* **67** 442 (1998) [*Russ. Chem. Rev.* **67** 393 (1998)]
39. V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 2123 (1998) [b]
40. V P Litvinov *Usp. Khim.* **68** 817 (1999) [*Russ. Chem. Rev.* **68** 737 (1999)]
41. V P Litvinov, S G Krivokolysko, V D Dyachenko *Khim. Geterotsikl. Soedin.* 579 (1999) [a]
42. Yu A Sharanin, Doctoral Thesis in Chemical Sciences, Institute of Organic Chemistry, Academy of Sciences of the USSR, Moscow, 1988
43. A.M.Shestopalov, Doctoral Thesis in Chemical Sciences, Institute of Organic Chemistry, Academy of Sciences of the USSR, Moscow, 1991
44. L A Rodinovskaya, Doctoral Thesis in Chemical Sciences, Institute of Organic Chemistry, Russian Academy of Sciences, Moscow, 1994
45. V D Dyachenko, Doctoral Thesis in Chemical Sciences, Institute of Organic Chemistry, Russian Academy of Sciences, Moscow, 1998
46. S G Krivokolysko, Doctoral Thesis in Chemical Sciences, Institute of Organic Chemistry, Russian Academy of Sciences, Moscow, 2001
47. E E Apenova, Candidate Thesis in Chemical Sciences, Institute of Organic Chemistry, Academy of Sciences of the USSR, Moscow, 1986
48. V N Nesterov, Candidate Thesis in Chemical Sciences, Institute of Organic Chemistry, Academy of Sciences of the USSR, Moscow, 1987
49. G E Khoroshilov, Candidate Thesis in Chemical Sciences, Institute of Organic Chemistry, Russian Academy of Sciences, Moscow, 1993
50. V A Artemov, Candidate Thesis in Chemical Sciences, Institute of Organic Chemistry, Russian Academy of Sciences, Moscow, 1995
51. N G Frolova, Candidate Thesis in Chemical Sciences, Institute of Organic Chemistry, Russian Academy of Sciences, Moscow, 1997
52. V L Ivanov, Candidate Thesis in Chemical Sciences, Institute of Organic Chemistry, Russian Academy of Sciences, Moscow, 1997
53. S V Roman, Candidate Thesis in Chemical Sciences, Khar'kov National University, Khar'kov, 2001
54. Ya Yu Yakunin, Candidate Thesis in Chemical Sciences, Khar'kov National University, Khar'kov, 2001
55. E Lukevits *Khim. Geterotsikl. Soedin.* 723 (1995) [a]
56. V V Kastron, R O Vitolin', G Ya Dubur *Khim.-Farm. Zh.* **24** (6) 14 (1990) [c]
57. I E Kirule, A A Krauze, A Kh Velena, D Yu Antipova, G Ya Arnitsane, I A Vutsina, G Ya Dubur *Khim.-Farm. Zh.* **26** (11–12) 59 (1992) [c]
58. GDR P. 234 574; *Chem. Abstr.* **105** 208 775 (1986)
59. Jpn. P. 6 097 960; *Chem. Abstr.* **104** 19 516 (1986)
60. US P. 4 555 517; *Chem. Abstr.* **104** 148 755 (1986)
61. US P. 4 539 321; *Chem. Abstr.* **104** 62 077 (1986)
62. Jpn. P. 6 094 964; *Chem. Abstr.* **104** 5780 (1986)
63. US P. 4 567 186; *Chem. Abstr.* **105** 42 768 (1986)
64. Eur. P. 167 121; *Chem. Abstr.* **105** 42 839 (1986)
65. Jpn. P. 6 204 270; *Chem. Abstr.* **106** 156 296 (1987)
66. Span. P. 549 790; *Chem. Abstr.* **106** 84 403 (1987)
67. Span. P. 544 504; *Chem. Abstr.* **107** 7070 (1987)
68. Jpn. P. 61 180 770; *Chem. Abstr.* **106** 67 120 (1987)
69. US P. 4 650 806; *Chem. Abstr.* **106** 213 774 (1987)
70. Jpn. P. 61 229 865; *Chem. Abstr.* **106** 156 291 (1987)
71. Jpn. P. 61 243 080; *Chem. Abstr.* **106** 67 299 (1987)
72. Jpn. P. 61 291 570; *Chem. Abstr.* **106** 176 191 (1987)
73. Eur. P. 207 500; *Chem. Abstr.* **106** 119 711 (1987)
74. Jpn. P. 61 218 589; *Chem. Abstr.* **106** 84 605 (1987)
75. WO PCT 8 800 468; *Chem. Abstr.* **109** 129 026 (1988)
76. WO PCT 8 801 508; *Chem. Abstr.* **109** 93 054 (1988)
77. Jpn. P. 6 377 879; *Chem. Abstr.* **109** 128 986 (1988)
78. US P. 4 731 371; *Chem. Abstr.* **109** 73 346 (1988)
79. GDR. P. 256 131; *Chem. Abstr.* **110** 63 770 (1989)
80. WO PCT 8 601 202; *Chem. Abstr.* **111** 194 606 (1989)
81. Jpn. P. 01 279 884; *Chem. Abstr.* **112** 198 358 (1990)
82. Eur. P. 347 027; *Chem. Abstr.* **113** 58 944 (1990)
83. US P. 4 866 074; *Chem. Abstr.* **113** 152 440 (1990)
84. Pol. P. 167 298; *Chem. Abstr.* **125** 142 574 (1996)
85. R Troschuetz, L Gruen *Arch. Pharm. (Weinheim, Ger.)* **326** 857 (1993); *Chem. Abstr.* **120** 217 537 (1994)
86. G A Youngdale, T F Oglia *J. Med. Chem.* **28** 1790 (1985)

87. H Landmann, H Lowe *Pharmazie* **41** 169 (1986)
88. L Mosti, G Menozzi, P Schenone *Actual. Chim. Ther.* **15** 113 (1988); *Chem. Abstr.* **111** 7188 (1989)
89. L Mosti, G Menozzi, P Scvhenone, P Dorigo, R M Gaion, F Benetollo, G Bombier *Eur. J. Med. Chem.* **24** 517 (1989)
90. E G Paronikyan, S N Sirakanyan, G Kh Grigoryan, A S Noravyan *Arm. Khim. Zh.* **42** 505 (1989)
91. H Fukatsu, Y Kato, S Murase, S Nakagawa *Heterocycles* **29** 1517 (1989)
92. V Hagen, E Klauschenz, A Rumler, A Hagen, S Heer, R Mitzner, H Hiedrich, D Lohmann *Pharmazie* **45** 189 (1990)
93. L V Ershov, A V Kadushkin, V G Granik, O V Dolgun, A V Denisov, S D Yuzhakov, M D Mashkovskii *Khim.-Farm. Zh.* **26** (9–10) 51 (1992) [c]
94. M Yamanaka, Sh Suda, Y Kabasawa, T Ogawa, K Sawada, H Ohhara *Chem. Pharm. Bull.* **40** 1486 (1992)
95. V Gomez-Parra, M Del Carmen Gomez, F Sanchez, V Stefani *Arch. Pharm. (Weinheim, Ger.)* **325** 483 (1992); *Chem. Abstr.* **117** 251 207 (1992)
96. A Krauze, V N Garalene, G Ya Dubur *Khim.-Farm. Zh.* **27** (1) 39 (1993)
97. L Mosti, P Schenone, M Jester, P Dorigo, R M Gaion, D Fraccorollo *Eur. J. Med. Chem.* **28** 853 (1993)
98. A A Alousi, J M Canter, M J Montenaro, D J Fort, R A Ferrari *J. Cardiovasc. Pharm.* **5** 792 (1983)
99. A A Alousi, G P Stankus, J C Stuart, L H Walton *J. Cardiovasc. Pharm.* **5** 804 (1983)
100. C S Maskin, L Sinoway, B Chadwick, E N Sonneblick, T H LeJemtel *Circulation* **67** 1065 (1983)
101. D S Biam, A V McDowell, J Cherniles, E S Monrad, J A Parker, J Edelson, E Braunwald, W Grossman *Engl. J. Med.* **309** 748 (1983)
102. E S Monrad, D S Baim, H S Smith, A Lanoue, E Braunwald, W Grossman *Circulation* **71** 972 (1985)
103. K M Borow, P C Come, A Neumann, D S Baim, E Braunwald, W Grossman *Am. J. Cardiol.* **55** 726 (1985)
104. A Ward, R N Brogden, R C Heel, T M Speight, G S Avery *Drugs* **26** 468 (1983)
105. D W Robertson, E E Beedle, J K Swartzendruber, N D Jones, T K Elreyzey, R F Kauffman, H Wilson, E S Hayes *J. Med. Chem.* **29** 635 (1986)
106. Span. P. 543 212; *Chem. Abstr.* **107** 58 866 (1987)
107. X Zheng, Z Feng, Y Liu *Zhongguo Yiyao Gongye Zazhi* **21** 486 (1990); *Chem. Abstr.* **115** 8524 (1991)
108. V V Kuznetsov *Khim.-Farm. Zh.* **25** (7) 61 (1991) [c]
109. Eur. P. 564 358; *Chem. Abstr.* **120** 164 006 (1994)
110. Y Xu, Z Zhu, Z Tong, D Peng, L Duan *Zhongguo Yiyao Gongye Zazhi* **24** 49 (1993); *Chem. Abstr.* **120** 8556 (1994)
111. G Guillaumet *J. Pharm. Bull.* **49** 216 (1994)
112. H Niedrich, H-U Heyne, E Schroetter, H-J Jaensch, H-J Heidrich, G Faust, D Lohman *Pharmazie* **41** 173 (1986)
113. L W Singh, H Ila, H Junjappa *Indian J. Chem., Sect. B* **26** 607 (1987); *Chem. Abstr.* **108** 221 566 (1987)
114. BRD Appl. 3 725 357; *Chem. Abstr.* **109** 92 824 (1988)
115. Pol. P. 150 312; *Chem. Abstr.* **114** 64 264 (1991)
116. J Wang, G Han, G Jiang *Yingyong Huaxue* **8** 38 (1991); *Chem. Abstr.* **115** 71 425 (1991)
117. E G Paronikyan, S N Sirakanyan, A S Noravyan, D A Melkonyan *Arm. Khim. Zh.* **44** 250 (1991)
118. O H Hishmat, H I El-Diwani, Sh M A Bakr, S S Mahmoud, S A Nada *Arch. Pharm. Res.* **16** 168 (1993); *Chem. Abstr.* **120** 315 144 (1994)
119. V A Adhikari, V V Badiger *Indian J. Chem., Sect. B* **30** 946 (1991); *Chem. Abstr.* **115** 256 108 (1991)
120. G M Cingolani, F Gualtieri, M Pigini *J. Med. Chem.* **12** 531 (1969)
121. Eur. P. 333 020; *Chem. Abstr.* **112** 118 659 (1990)
122. Eur. P. 308 020; *Chem. Abstr.* **112** 118 654 (1990)
123. O H Hishmat, F M Abdel Galil, D S Farrag *Pharmazie* **45** 793 (1990)
124. O H Hishmat, J A A Miky, N M Saleh *Pharmazie* **44** 823 (1989)
125. R Benoit, J Duflos, G Dupas, J Bourguignon, G Queguiner *J. Heterocycl. Chem.* **26** 1595 (1989)
126. A M Shestopalov, Yu A Sharanin, L A Rodinovskaya, V Yu Mortikov, V P Litvinov, V K Promonenkov, in *Khimiya i Tekhnologiya Piridinsoderzhashchikh Pestitsidov (Tez. Dokl. Vsesoyuz. Konf.), Chernogolovka, 1988* [The Chemistry and Technology of Pyridine-Containing Pesticides (Abstracts of Reports of the All-Union Conference), Chernogolovka, 1988] p. 122
127. Russ. P. 1 657 495; *Byull. Izobret.* (23) (1991)
128. WO PCT 9 117 987; *Chem. Abstr.* **117** 48 568 (1992)
129. WO PCT 9 222 532; *Chem. Abstr.* **118** 191 556 (1993)
130. F Guerrera, L Salerno, M C Sarvas, M A Siracusa, S Oliveri, R Minardi *Farmaco* **48** 1725 (1993)
131. V G Kul'nevich, E A Kaigorodova, I S Arustamova, L V Korobchenko, G V Vladyko, E I Boreko *Khim.-Farm. Zh.* **24** (2) 132 (1990) [c]
132. M V Mezintseva, A V Kadushkin, L M Alekseeva, A S Sokolova, V G Granik *Khim.-Farm. Zh.* **25** (4) 19 (1991) [c]
133. V Yu Mortikov, V P Litvinov, A M Shestopalov, Yu A Sharanin, E E Apenova, G A Galegov, I I Abdullaev, T B Asadullaev, F I Abdullaev *Khim.-Farm. Zh.* **25** (5) 41 (1991) [c]
134. M Yu Yure, E Yu Gudrinietse, in *Karbonil'nye Soedineniya v Sinteze Geterotsiklov (Tez. Dokl.), Saratov, 1992* [Carbonyl Compounds in the Synthesis of Heterocycles (Abstracts of Reports), Saratov, 1992] Pt. 1, p. 57
135. WO PCT 9 113 055; *Chem. Abstr.* **115** 279 621 (1991)
136. M Inouye, K Kim, T Kiato *J. Am. Chem. Soc.* **114** 778 (1992)
137. L R Tsel', Yu V Nemal'tsev *Bioorg. Khim.* **19** 760 (1993) [d]
138. H C Davis, R G Gedir, E M Edward *Eur. J. Med. Chem.* **20** 381 (1985)
139. WO PCT 9 105 556; *Chem. Abstr.* **115** 92 686 (1991)
140. Can. P. 2 027 169; *Chem. Abstr.* **115** 135 931 (1991)
141. C N O'Callaghan, T B H McMurry, Ch J Cardin, D J Wilcock *J. Chem. Soc., Perkin Trans. 1* 2479 (1993)
142. J A A Miky *Al-Azhar Bull. Sci.* **6** 1127 (1995); *Chem. Abstr.* **126** 131 363 (1997)
143. Ya F Freimanis (Ed.) *Ordena Trudovogo Krasnogo Znameni Institut Organicheskogo Sinteza* (Order of Labour Red Banner Institute of Organic Synthesis) (Riga: Zinatne, 1982)
144. M Yu Lidak *Khim. Geterotsikl. Soedin.* 5 (1985) [a]
145. G Ya Dubur, in *IV Vsesoyuz. Konf. po Khimii Azotsoderzhashchikh Geterotsiklov (Tez. Dokl.), Novosibirsk, 1987* [The IVth All-Union Conference on the Chemistry of Nitrogen-Containing Heterocycles (Abstracts of Reports), Novosibirsk, 1987] p. 15
146. E Ya Kazush, E I Sagun, G D Tirzit, G Ya Dubur *Khim. Geterotsikl. Soedin.* 641 (1994) [a]
147. E C Taylor, K F McDaniel, J C Warner *Tetrahedron Lett.* **28** 1977 (1987)
148. USSR P. 1 298 211; *Byull. Izobret.* (11) 100 (1987)
149. S N Kvak, E A Kaigorodova, V N Zaplishnyi, in *6-e Soveshchanie po Khimicheskim Reaktivam (Tez. Dokl.), Baku, 1993* [The Sixth Meeting on Chemical Reagents (Abstracts of Reports), Baku, 1993] p. 125
150. WO PCT 9 313 104; *Chem. Abstr.* **119** 271 139 (1993)
151. Eur. P. 624 583; *Chem. Abstr.* **122** 81 132 (1995)
152. US P. 5 185 329; *Ref. Zh. Khim.* 10 O 222P (1994)
153. T A Henry *The Plant Alkaloids* (London: Churihil, 1949)
154. M E Goldman, J H Nunberg, J A O'Brien, J C Quintero, W A Schleif, K F Freund, S L Gaul, W S Saari, J S Wai, J M Hoffman, P S Anderson D J Hupe, E A Emini, A M Stern *Proc. Natl. Acad. Sci. USA* **88** 6863 (1991)
155. W A Saari, J M Hoffman, J S Wai, T J Fisher, C S Rooney, A M Smith, C M Thomas, M E Goldman, J A O'Brien, J H Numberg, J C Quintero, W A Schleif, E A Emini, A M Stern, P S Anderson *J. Med. Chem.* **34** 2922 (1991)
156. J H Nunberg, W A Schleif, E J Boots, J A O'Brien, J C Quintero, J M Hoffman, E A Emini, M E Goldman *J. Virol.* **65** 4887 (1991)
157. M E Goldman, J H Nunberg, J A O'Brien, T I Ruffing, J C Quintero, W A Schlef, E J Boots, K F Freund, S L Gaul, W S Saari, J S Wai, J M Hoffman, C S Ronney, P S Anderson, E A Emini, in *Challenge of the 1990's, New Diseases and New Therapies, Aids and Bening Prostatic Hypertrophy* (Eds P Luthy, R G Douglas) (Philadelphia, NY: Hanley and Belfus Medical Publishers, 1992) p. 111

158. J M Hoffman, J C Wai, C M Thomas, R B Levin, J A O'Brien, M E Goldman *J. Med. Chem.* **35** 3784 (1992)
159. W S Saari, J S Wai, T E Fisher, C M Thomas, J M Hoffman, C S Ronney, A M Smith, J H Jones, D I Bamburgere, M E Goldman, J A O'Brien, J H Nunberg, J C Quintero, P S Anderson *J. Med. Chem.* **35** 3792 (1992)
160. I N Houpis, A Molina, J Lynch, R A Reamer, R P Volante, P J Reider *J. Org. Chem.* **58** 3176 (1993)
161. Eur. P. 462 800; *Chem. Abstr.* **116** 128 678 (1992)
162. Eur. P. 481 802; *Chem. Abstr.* **117** 131 074 (1992)
163. WO PCT 9 222 531; *Chem. Abstr.* **118** 191 555 (1993)
164. US P. 5 202 243; *Chem. Abstr.* **119** 70 543 (1993)
165. Br. P. 2 273 928; *Chem. Abstr.* **121** 255 655 (1994)
166. US P. 5 364 776; *Chem. Abstr.* **122** 79 224 (1995)
167. G Duburs *Khim. Geterotsikl. Soedin.* 1147 (2001) [a]
168. BRD Appl. 3 844 355; *Ref. Zh. Khim.* 10 H 108P (1991)
169. US P. 5 326 872; *Chem. Abstr.* **122** 33 540 (1995)
170. BRD Appl. 3 637 091; *Ref. Zh. Khim.* 5 N 200P (1989)
171. H Mustroph *Z. Chem.* **29** 422 (1989)
172. Pol. P. 147 477; *Ref. Zh. Khim.* 13 N 225P (1990)
173. N R Ayyangar, K V Spinivasan *Colourage* **37** 78 (1990)
174. D W Rangnekar, P Y Kamar *Indian J. Fibre Text. Res.* **16** 223 (1991)
175. D W Rangnekar, P Y Kamar *Indian J. Fibre Text. Res.* **17** 92 (1992)
176. BRD Appl. 4 122 866; *Ref. Zh. Khim.* 9 N 141P (1994)
177. V V Mikhaylova, J T Angelova *Dokl. Bulg. Akad. Nauk* **44** 65 (1991)
178. A I Pavlyuchenko, N I Smirnova, T A Mikhailova, E I Kovshev, V V Titov *Zh. Org. Khim.* **22** 1061 (1986) [e]
179. A Dornuv, E Neuse *Arch. Pharm. (Weinheim, Ger.)* **288** 174 (1955)
180. K Wallenfels, H Schuly *Liebegs Ann. Chem.* **621** 215 (1959)
181. F Brodi, P R Rubi, in *Pyridine and Its Derivatives* Vol. 14, Pt. 1 (Ed. E Klinsberg) (New York: Interscience, 1960) p. 99
182. H Tekelmann, in *Pyridine and Its Derivatives* Vol. 14, Pt. 3 (Ed. R A Abramovitch) (New York: Interscience, 1974) p. 597
183. U Schmidt, H Kubitzek *Chem. Ber.* **93** 1559 (1960)
184. E Yu Gudrinietse, A V Nikitenko *Izv. Akad. Nauk Latv. SSR, Ser. Khim.* 569 (1972)
185. A A Krauze, Z A Bomika, A M Shestopalov, L A Rodinovskaya, Yu E Pelcher, G Ya Dubur, Yu A Sharanin, V K Promonenkov *Khim. Geterotsikl. Soedin.* 377 (1981) [a]
186. Yu A Sharanin, L A Rodinovskaya, A M Shestopalov, in *Uspekhi Khimii Azotistykh Heterotsiklov (Tez. Dokl. III Vsesoyuz. Konf.), Rostov-na-Donu, 1983* [Progress in the Chemistry of Nitrogeneous Heterocycles (Abstracts of Reports of the IIIth All-Union Conference), Rostov on Don, 1983] p. 145
187. L A Rodinovskaya, Yu A Sharanin, V P Litvinov, A M Shestopalov, V K Promonenkov, B M Zolotarev, V Yu Mortikov *Zh. Org. Khim.* **21** 2439 (1985) [e]
188. A M Shestopalov, L A Rodinovskaya, V K Promonenkov, Yu A Sharanin, S N Melenchuk, A S Demerkov, in *Vsesoyuznoe Soveshchanie po Khimii i Tekhnologii Piridinovykh Osnovanii dlya Proizvodstva Khimicheskikh Sredstv Zashchity Rastenii (Tez. Dokl.), Moskva, 1983* [All-Union Meeting on the Chemistry and Technology of Pyridine Bases for Production of Chemical Means of Plant Protection (Abstracts of Reports), Moscow, 1983] p. 45
189. E V Narushyavichus, V N Garalene, A A Krauze, G Ya Dubur *Khim.-Farm. Zh.* **23** 1459 (1989) [c]
190. L A Rodinovskaya, A M Shestopalov, Yu A Sharanin, V P Litvinov, in *Enaminy v Organicheskom Sinteze (Tez. Dokl.), Sverdlovsk, 1990* [Enamines in Organic Synthesis (Abstracts of Reports), Sverdlovsk, 1990] p. 48
191. G Wagner, H Vieweg, S Leistner, N Bohm, U Krasselet, V Hahfeld, J Prantz, R Grupe *Pharmazie* **45** 102 (1990)
192. V Krstic, M Misic-Vucovic, M Radojkovic-Velickovic *J. Chem. Res. (S)* 82 (1991); *Chem. Abstr.* **115** 29 067 (1991)
193. L A Rodinovskaya, A M Shestopalov, V P Litvinov, in *The 15th International Symposium on the Organic Chemistry of Sulfur. (Abstracts of Reports), Caen, 1992* p. 132
194. V K Promonenkov, A M Shestopalov, Yu A Sharanin, V P Litvinov, L A Rodinovskaya, B M Zolotarev, V D Sokovykh, B V Rozynov, Ya Ya Krymskii *Zh. Org. Khim.* **21** 1963 (1985) [e]
195. J Pelc'er, A Krause, Z Bomika, G Duburs, in *The 9th International Symposium on the Organic Chemistry of Sulfur. (Abstracts of Reports), Riga, 1980* p. 108
196. A A Krauze, Z A Kalme, Yu E Pelcher, I V Dipan, G Ya Dubur *Khim. Geterotsikl. Soedin.* 1515 (1983) [a]
197. A A Krauze, R O Vitolinya, G V Zarin'sh, Yu E Pelcher, Z A Kalme, A A Kimenis, G Ya Dubur *Khim.-Farm. Zh.* **19** 540 (1985) [c]
198. M J Rubio, C Seoane, A Susacta *Liebigs Ann. Chem.* 210 (1986)
199. A A Krauze, E E Liepin'sh, Yu E Pelcher, Z A Kalme, G Ya Dubur *Khim. Geterotsikl. Soedin.* 75 (1987) [a]
200. A A Krauze, E E Liepin'sh, Yu E Pelcher, G Ya Dubur *Khim. Geterotsikl. Soedin.* 124 (1987) [a]
201. A A Krauze, R O Vitolinya, M R Romanova, G Ya Dubur *Khim.-Farm. Zh.* **22** 548 (1988) [c]
202. A A Krauze, R O Vitolinya, M R Romanova, G Ya Dubur *Khim.-Farm. Zh.* **22** 855 (1988) [c]
203. A A Krauze, G Ya Dubur *Khim. Geterotsikl. Soedin.* 1142 (1988) [a]
204. Yu A Sharanin, V D Dyachenko, V P Litvinov, A V Turov *Zh. Obshch. Khim.* **61** 942 (1991) [f]
205. V P Litvinov, Yu A Sharanin, A M Shestopalov, V D Dyachenko *Synlett* 87 (1992)
206. G E H Elgemeie, H F Zohdi, S M Sherif *Phosphorus Sulfur Silicon Relat. Elem.* **54** 215 (1990)
207. P Coudert, J Conquelet, P Tronche, F Leal *J. Heterocycl. Chem.* **30** 1093 (1993)
208. A A Krauze, E E Liepin'sh, G Ya Dubur *Khim. Geterotsikl. Soedin.* 994 (1987) [a]
209. A A Krauze, E E Liepin'sh, G Ya Dubur *Khim. Geterotsikl. Soedin.* 787 (1989) [a]
210. P Victory, R Nomen, O Colomina, M Carriga, A Cvespo *Heterocycles* **23** 1135 (1985)
211. S G Krivokolysko, V D Dyachenko *Ukr. Khim. Zh.* **62** 61 (1996)
212. M A E Khalifa, G H Tammam, A A A Elbanany *Arch. Pharm. (Weinheim, Ger.)* **316** 822 (1983)
213. M Richter, A Vogt, M Augustin, K Strauss *Z. Chem.* **29** 443 (1989)
214. N A Hassan, A F Elkafvawy, M Eiborai *Rev. Roum. Chim.* **28** 715 (1983)
215. V P Litvinov, S V Roman, V D Dyachenko *Usp. Khim.* **69** 218 (2000) [*Russ. Chem. Rev.* **69** 201 (2000)]
216. V P Litvinov, S V Roman, V D Dyachenko *Usp. Khim.* **70** 345 (2001) [*Russ. Chem. Rev.* **70** 299 (2001)]
217. A S Noravyan, E G Paronikyan, S A Vartanyan *Khim.-Farm. Zh.* **19** 790 (1986) [c]
218. I C Ivanov, E V Stoyanov, P S Denkova, V S Dimitrov *Liebigs Ann.-Recueil* 1777 (1997)
219. US P. 5 391 554; *Ref. Zh. Khim.* 14 O 37P (1996)
220. H I El-Subbagh, A H Abadi, I E Al-Khawad, K A Al-Rashood *Arch. Pharm. (Weinheim, Ger.)* **332** 19 (1999)
221. BRD Appl. 4 425 650; *Ref. Zh. Khim.* 1 O 81P (1998)
222. Y-S Oh, Ch Sung-Hye *J. Heterocycl. Chem.* **35** 17 (1998)
223. L A Rodinovskaya, A M Shestopalov, V P Litvinov *Dokl. Akad. Nauk* **330** 597 (1993) [g]
224. S V Roman, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1435 (1999) [a]
225. V D Dyachenko, S V Roman, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 121 (2000) [b]
226. S V Roman, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 555 (2000) [a]
227. V P Litvinov, S V Roman, V D Dyachenko *Dokl. Akad. Nauk* **374** 218 (2000) [g]
228. S V Roman, V D Dyachenko, V P Litvinov, in *Organicheskii Sintez i Kombinatornaya Khimiya (Tez. Dokl. Mezhdunar. Konf.), Zvenigorod, 1999* [Organic Synthesis and Combinatorial Chemistry (Abstracts of Reports of International Conference), Zvenigorod, 1999] p. P-58
229. A M Shestopalov, V Yu Mortikov, Yu A Sharanin, A V Turov, V P Litvinov *Zh. Org. Khim.* **25** 1980 (1989) [e]

230. A M Shestopalov, V N Nesterov, Yu A Sharanin, V P Litvinov, V Yu Mortikov, V E Shklover, Yu T Struchkov *Khim. Geterotsikl. Soedin.* 557 (1989) [a]
231. V A Artemov, A M Shestopalov, V P Litvinov *Khim. Geterotsikl. Soedin.* 512 (1996) [a]
232. V Aggarwal, G Singh, H Ila, H Junjappa *Synthesis* 214 (1982)
233. V D Dyachenko, S G Krivokolysko, V N Nesterov, V P Litvinov *Khim. Geterotsikl. Soedin.* 1243 (1996) [a]
234. V D Dyachenko, S G Krivokolysko, V P Litvinov *Khim. Geterotsikl. Soedin.* 560 (1997) [a]
235. V D Dyachenko, S G Krivokolysko, V P Litvinov *Khim. Geterotsikl. Soedin.* 666 (1997) [a]
236. Yu A Sharanin, A M Shestopalov, L A Rodinovskaya, V K Promonenkov, V P Litvinov *Zh. Org. Khim.* **20** 2442 (1984) [e]
237. A A Krauze, E E Liepin'sh, Yu E Pelcher, Z A Kalme, I V Dipan, G Ya Dubur *Khim. Geterotsikl. Soedin.* 95 (1985) [a]
238. V P Litvinov, Yu A Sharanin, L A Rodinovskaya, A V Shestopalov, V Yu Mortikov, in *The 11th International Symposium on the Organic Chemistry of Sulfur. (Abstracts of Reports), Lindau, 1984* B 3.23
239. A Krause, in *The 3rd Conference of Young Scientists on Organic and Bioorganic Chemistry (Abstracts of Reports), Prague, 1984* p. 83
240. A A Krauze, Yu E Pelcher, Z A Kalme, Ya G Dubur *Khim. Geterotsikl. Soedin.* 1694 (1984) [a]
241. J L Soto, C Seoane, M E Rubio, J M Botoya *Org. Prep. Proced. Int.* **16** 11 (1984)
242. Yu A Sharanin, M P Goncharenko, A M Shestopalov *Zh. Org. Khim.* **21** 2470 (1985) [e]
243. V P Litvinov, V K Promonenkov, Yu A Sharanin, A M Shestopalov, L A Rodinovskaya, V Yu Mortikov, V S Bogdanov *Izv. Akad. Nauk SSSR, Ser. Khim.* 2101 (1985) [b]
244. Yu A Sharanin, L A Rodinovskaya, A M Shestopalov, V P Litvinov, V K Promonenkov, V Yu Mortikov *Zh. Org. Khim.* **21** 683 (1985) [e]
245. V N Nesterov, V E Shklover, Yu T Struchkov, Yu A Sharanin, A M Shestopalov, L A Rodinovskaya *Acta Crystallogr., Sect. C* **41** 1191 (1985)
246. Yu A Sharanin, A M Shestopalov, V P Litvinov, V Yu Mortikov, L A Rodinovskaya, M P Goncharenko, V K Promonenkov *Zh. Org. Khim.* **22** 1962 (1986) [e]
247. Yu A Sharanin, A M Shestopalov, L A Rodinovskaya, V N Nesterov, V E Shklover, V K Promonenkov, V P Litvinov *Zh. Org. Khim.* **22** 2600 (1986) [e]
248. A A Krauze, E E Liepin'sh, Yu E Pelcher, G Ya Dubur, A Kalme *Khim. Geterotsikl. Soedin.* 630 (1986) [a]
249. H A Hommouda, A M El-Reedy, S M Hussian *J. Heterocycl. Chem.* **23** 1203 (1986)
250. M H Elnagdi, F M Abdelrazek, N S Ibrahim, A V Erian *Tetrahedron* **45** 3597 (1989)
251. G E H Elgemeie, H A Regaila, N Shehata *Sulfur Lett.* **9** 253 (1989)
252. A A Krauze, A G Odynets, A A Verreva, S K Germane, A N Kozhukhov, G Ya Dubur *Khim.-Farm. Zh.* **25** (7) 40 (1991) [c]
253. L A Rodinovskaya, A M Shestopalov, V P Litvinov, in *The 15th International Symposium on the Organic Chemistry of Sulfur. (Abstracts of Reports), Caen, 1992* p. 168
254. A A Krauze, V N Garalene, G Ya Dubur *Khim.-Farm. Zh.* **26** (5) 40 (1992) [c]
255. V P Litvinov, V D Dyachenko *Dokl. Akad. Nauk* **352** 636 (1997) [g]
256. V D Dyachenko, Yu A Sharanin *Zh. Obshch. Khim.* **62** 948 (1991) [f]
257. V P Litvinov, Yu A Sharanin, M P Goncharenko, V D Dyachenko, A M Shestopalov *Izv. Akad. Nauk SSSR, Ser. Khim.* 1888 (1991) [b]
258. V N Nesterov, V D Dyachenko, Yu A Sharanin, Yu T Struchkov *Izv. Akad. Nauk, Ser. Khim.* 437 (1996) [b]
259. L A Rodinovskaya, A M Shestopalov, E V Belukhina, V P Litvinov *Khim. Geterotsikl. Soedin.* 851 (1995) [a]
260. V D Dyachenko, S G Krivokolysko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1232 (1996) [a]
261. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 672 (1997) [a]
262. V D Dyachenko, V N Nesterov, S G Krivokolysko, V P Litvinov *Khim. Geterotsikl. Soedin.* 785 (1997) [a]
263. V D Dyachenko, S G Krivokolysko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1533 (1997) [a]
264. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1381 (1998) [a]
265. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1425 (1998) [a]
266. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 228 (1999) [a]
267. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 230 (1999) [a]
268. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 516 (1999) [a]
269. S G Krivokolysko, V V Dotsenko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1256 (1999) [a]
270. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1370 (1999) [a]
271. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1645 (1999) [a]
272. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1691 (1999) [a]
273. Ya Yu Yakunin, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1667 (2000) [a]
274. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 345 (2000) [a]
275. S G Krivokolysko, V V Dotsenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1272 (2000) [a]
276. S G Krivokolysko, V D Dyachenko, E B Rusanov, V P Litvinov *Khim. Geterotsikl. Soedin.* 525 (2001) [a]
277. S G Krivokolysko, K A Frolov, V P Litvinov *Khim. Geterotsikl. Soedin.* 699 (2001) [a]
278. S G Krivokolysko, V D Dyachenko, A N Chernega, V P Litvinov *Khim. Geterotsikl. Soedin.* 790 (2001) [a]
279. S G Krivokolysko, V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1076 (2001) [a]
280. V P Litvinov, S G Krivokolysko, E B Rusanov *Dokl. Akad. Nauk* **377** 493 (2001) [g]
281. S G Krivokolysko, A N Chernega, E B Rusanov, V P Litvinov *Dokl. Akad. Nauk* **377** 638 (2001) [g]
282. S G Krivokolysko, E B Rusanov, V P Litvinov *Dokl. Akad. Nauk* **379** 340 (2001) [g]
283. V D Dyachenko, S G Krivokolysko, V N Nesterov, Yu T Struchkov, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 2535 (1996) [b]
284. V D Dyachenko, S G Krivokolysko, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 1849 (1997) [b]
285. V D Dyachenko, S G Krivokolysko, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 1852 (1997) [b]
286. V D Dyachenko, S G Krivokolysko, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 2016 (1997) [b]
287. S G Krivokolysko, V D Dyachenko, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 166 (1999) [b]
288. Ya Yu Yakunin, V D Dyachenko, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 196 (1999) [b]
289. S G Krivokolysko, V D Dyachenko, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 2333 (1999) [b]
290. S G Krivokolysko, V D Dyachenko, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 173 (2000) [b]
291. S G Krivokolysko, V D Dyachenko, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 485 (2000) [b]
292. S G Krivokolysko, V D Dyachenko, A N Chernega, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 733 (2000) [b]
293. V D Dyachenko, S G Krivokolysko, Yu A Sharanin *Zh. Org. Khim.* **33** 1084 (1997) [e]
294. V D Dyachenko, S G Krivokolysko, V N Nesterov, V P Litvinov *Zh. Org. Khim.* **33** 1580 (1997) [e]
295. V D Dyachenko, S G Krivokolysko, V P Litvinov *Zh. Org. Khim.* **34** 750 (1998) [e]
296. V D Dyachenko, S G Krivokolysko, V P Litvinov *Zh. Org. Khim.* **34** 927 (1998) [e]

297. S G Krivokolysko, V D Dyachenko, V N Nesterov, Yu A Sharanin, Yu T Struchkov *Zh. Org. Khim.* **35** 966 (1999) [e]
298. S G Krivokolysko, V D Dyachenko, V P Litvinov, in *Karbonil'nye Soedineniya v Sinteze Geterotsiklov (Tez. Dokl. 6-i Vseros. Konf.), Saratov, 1996* [Carbonyl Compounds in the Synthesis of Heterocycles (Abstracts of Reports of the Sixth All-Russian Conference), Saratov, 1996] p. 23
299. V D Dyachenko, S G Krivokolysko, V P Litvinov, in *Organicheskii Sintez i Kombinatornaya Khimiya (Tez. Dokl. Mezhdunar. Konf.), Zvenigorod, 1999* [Organic Synthesis and Combinatorial Chemistry (Abstracts of Reports of the International Conference), Zvenigorod, 1999] p. P-88
300. S G Krivokolysko, V D Dyachenko, V P Litvinov, in *XX Vserossiiskaya Konferentsiya po Khimii i Tekhnologii Organicheskikh Soedinenii Sery (Tez. Dokl.), Kazan', 1999* [The XXth All-Russian Conference on the Chemistry and Technology of Organic Compounds of Sulfur. (Abstracts of Reports), Kazan', 1999] p. 175
301. S G Krivokolysko, V P Litvinov, in *Shkola Molodykh Uchenykh 'Organicheskaya Khimiya v XX Veke' (Tez. Dokl.), Zvenigorod, 2000* [The School of Young Scientists 'Organic Chemistry in the XXth Century (Abstracts of Reports), Zvenigorod, 2000] p. 57
302. V L Abramenko, S G Krivokolysko, V P Litvinov, in *1-ya Vserossiiskaya Konferentsiya po Khimii Geterotsiklov Pamyati A N Kosta (Tez. Dokl.), Suzdal', 2000* [The First All-Russian Conference on the Chemistry of Heterocycles Dedicated to A N Kost Memory (Abstracts of Reports)], Suzdal', 2000] p. 76
303. S G Krivokolysko, K A Frolov, Yu N Lysenko, A N Chernega, E B Rusanov, V P Litvinov, in *Khimiya i Biologicheskaya Aktivnost' Sinteticheskikh i Prirodnykh Soedinenii. Azotistye Geterotsikly i Alkaloidy (Tez. Dokl.), Moskva, 2001* [The Chemistry and Biological Activity of Synthetic and Natural Compounds. Nitrogeneous Heterocycles and Alkaloids (Abstracts of Reports), Moscow, 2001] Vol. 2, p. 167
304. Yu A Sharanin, A M Shestopalov, L A Rodinovskaya, V D Dyachenko, in *Khimicheskie Sredstva Zashchity Rastenii. (Tez. Dokl.), Ufa, 1982* [Chemical Means of Plant Protection (Abstracts of Reports), Ufa, 1982] p. 155
305. Yu A Sharanin, L A Rodinovskaya, V K Promonenkov, A M Shestopalov *Zh. Org. Khim.* **19** 1781 (1983) [e]
306. Yu A Sharanin, A M Shestopalov, V K Promonenkov, L A Rodinovskaya *Zh. Org. Khim.* **20** 1539 (1984) [e]
307. A M Shestopalov, L A Rodinovskaya, Yu A Sharanin, V P Litvinov *Zh. Obshch. Khim.* **58** 840 (1988) [f]
308. F Freeman, T I Ito *J. Org. Chem.* **34** 3670 (1969)
309. K Gewald, W Schill *J. Prakt. Chem.* **313** 678 (1971)
310. J W Ducker, M J Gunter *Aust. J. Chem.* **28** 581 (1975)
311. B Green, I S Khaldem, R I Grane, S S Newaz *Tetrahedron* **32** 2997 (1976)
312. A J Fatiadi *Synthesis* 165 (1978)
313. A I Ozols, Yu E Pelcher, Z A Kalme, Yu Yu Popelis, I V Turovskis, G Ya Duburs *Khim. Geterotsikl. Soedin.* 59 (1996) [a]
314. S G Pilosyan, V V Dabaeva, B Dzh Enokyan, Z A Abgaryan, S Noravyan *Arm. Khim. Zh.* **41** 687 (1988)
315. E G Paronikyan, S N Sirakanyan, S V Lindeman, M S Aleksanyan, A A Karapetyan, A S Noravyan, Yu T Struchkov *Khim. Geterotsikl. Soedin.* 1137 (1989) [a]
316. T R Kasturi, H R Y Jois *Indian J. Chem., Sect. B* **29** 615 (1990); *Chem. Abstr.* **113** 211 803 (1990)
317. T A Smirnova, M Yu Gavrilov *Khim. Geterotsikl. Soedin.* 370 (1996) [a]
318. N A Ismail, F A Khalifa, A A M El Din *Heterocycles* **32** 1101 (1991)
319. V B Lemke *Annalen* **478** 176 (1930)
320. E Gordar, R P Mariella *J. Am. Chem. Soc.* **79** 1402 (1957)
321. L A Rodinovskaya, A M Shestopalov, V P Litvinov, L A Khoroshilova, in *15-ya Ukrainskaya Konferentsiya po Organicheskoi Khimii (Tez. Dokl.), Uzhgorod, 1986* [The 15th Ukrainian Conference on Organic Chemistry (Abstracts of Reports), Uzhgorod, 1986] p. 255
322. V P Litvinov, Yu A Sharanin, L A Rodinovskaya, V N Nesterov, V E Shklover, Yu T Struchkov *Kondensirovannye Piridiny. Soobshchenie 8. 5,6-Pentametilen-3-tsianopiridin-2(1N)-tion i -Selenon v Sinteze 3-Aminotieno- i -Seleno[2,3-b]-piridinov. Kristallicheskaya Struktura 3-Amino-2-benzoil-5,6-pentametilenselenofeno[2,3-b]piridina* {Condensed Pyridines. Report 8. 5,6-Pentamethylene-3-cyanopyridine-2(1*N*)-thione and -selenone in Synthesis of 3-Aminothieno- and -seleno[2,3-*b*]pyridines. Crystal Structure of 3-Amino-2-benzoyl-5,6-pentamethyleneselenopheno[2,3-b]pyridine}; article deposited in the VINITI No. 1985-B (Moscow, 1988)
323. V P Litvinov, Yu A Sharanin, L A Rodinovskaya, V N Nesterov, V E Shklover Yu T Struchkov *Chem. Scr.* **29** 327 (1989)
324. L A Rodinovskaya, E V Belukhina, A M Shestopalov, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 489 (1994) [b]
325. R N Galeeva, M Yu Gavrilov, M E Konshin *Izv. Vyssh. Uchebn. Zaved., Khim. Khim. Tekhnol.* **39** 7 (1996)
326. F F Abdel-Latif *Pharmazie* **45** 283 (1990)
327. V D Dyachenko, V P Litvinov *Dokl. Akad. Nauk* **355** 62 (1997) [g]
328. K Bogdanowicz-Szwed, M Ciechanowicz-Rutkowska, A Gzarny, G Filippini, T Pilati, B Rys *Liebigs Ann. Chem.* 633 (1994)
329. V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 208 (1998) [a]
330. K Bogdanowicz-Szwed, M Krasodomska, M Lipovska, B Rys, A Skonecka *Monatsh. Chem.* **124** 721 (1993)
331. J Zied, A-M El-Torgomon, S El-Konsy, A Khattab *Arch. Pharm. (Weinheim, Ger.)* **321** 589 (1991)
332. F F Abdel-Latif *Phosphorus Sulfur Silicon Relat. Elem.* **53** 145 (1990)
333. G E H Elgemeie, A H H Elghandour *Bull. Chem. Soc. Jpn.* **63** 1230 (1990)
334. A A Krauze, Kh-I Unsh', G Ya Dubur *Khim. Geterotsikl. Soedin.* 1674 (1991) [a]
335. V D Dyachenko, S G Krivokolysko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1099 (1996) [a]
336. V D Dyachenko, A E Mitroshin, V P Litvinov *Khim. Geterotsikl. Soedin.* 1235 (1996) [a]
337. V D Dyachenko, S G Krivokolysko, V P Litvinov *Khim. Geterotsikl. Soedin.* 672 (1997) [a]
338. V D Dyachenko, S G Krivokolysko, V P Litvinov *Khim. Geterotsikl. Soedin.* 81 (1998) [a]
339. V P Litvinov *Zh. Org. Khim.* **29** 2070 (1993) [e]
340. V P Litvinov *Zh. Org. Khim.* **30** 1572 (1994) [e]
341. V P Litvinov *Zh. Org. Khim.* **31** 1441 (1995) [e]
342. V P Litvinov, A M Shestopalov *Zh. Org. Khim.* **33** 975 (1997) [e]
343. O P Bogomolova, Candidate Thesis in Chemical Sciences, Institute of Organic Chemistry, Russian Academy of Sciences, Moscow, 1992
344. Yu A Sharanin, G E Khoroshilov, O M Nefedov, V P Litvinov, A M Shestopalov *Zh. Org. Khim.* **25** 1315 (1989) [e]
345. A M Shestopalov, L A Rodinovskaya, V P Litvinov, Yu A Sharanin *Dokl. Akad. Nauk SSSR* **314** 870 (1990) [g]
346. A M Shestopalov, Yu A Sharanin, L A Rodinovskaya, V P Litvinov *Zh. Org. Khim.* **26** 1588 (1990) [e]
347. A M Shestopalov, L A Rodinovskaya, Yu A Sharanin, V P Litvinov *Izv. Akad. Nauk SSSR, Ser. Khim.* 2593 (1990) [b]
348. A M Shestopalov, O P Bogomolova, L A Rodinovskaya, V P Litvinov, in *The 14th International Symposium on the Organic Chemistry of Sulfur (Abstracts of Reports), Lodz, 1990* p. 17
349. A M Shestopalov, O P Bogomolova, L A Rodinovskaya, V P Litvinov, Yu A Sharanin *Dokl. Akad. Nauk SSSR* **317** 112 (1991) [g]
350. L A Rodinovskaya, O P Bogomolova, A M Shestopalov, V P Litvinov *Dokl. Akad. Nauk* **324** 585 (1992) [g]
351. A M Shestopalov, L A Rodinovskaya, B Buinitskii, M Mikolaichik, V P Litvinov *Dokl. Akad. Nauk* **323** 1116 (1992) [g]
352. A M Shestopalov, O P Bogomolova, L A Rodinovskaya, V P Litvinov, B Bujnicki, M Mikolajczyk, V N Nesterov, Yu T Struchkov *Heteroat. Chem.* **4** 593 (1993)

353. L A Rodinovskaya, A M Shestopalov, V P Litvinov *Dokl. Akad. Nauk* **339** 214 (1994) [g]
354. A M Shestopalov, V P Litvinov, L A Rodinovskaya, Yu A Sharanin *Synthesis* 402 (1991)
355. A M Shestopalov, Yu A Sharanin, L A Rodinovskaya, V P Litvinov *Zh. Org. Khim.* **26** 1571 (1990) [e]
356. A M Shestopalov, V P Litvinov, L A Rodinovskaya, Yu A Sharanin *Izv. Akad. Nauk SSSR, Ser. Khim.* 146 (1991) [b]
357. V P Litvinov, A M Shestopalov, L A Rodinovskaya, V Yu Mortikov, in *IV Vsesoyuz. Konf. po Khimii Azotsoderzhashchikh Geterotsiklov (Tez. Dokl.), Novosibirsk, 1987* [The IVth All-Union Conference on the Chemistry of Nitrogen-Containing Heterocycles (Abstracts of Reports), Novosibirsk, 1987] p. 185
358. A M Shestopalov, Yu A Sharanin, A S Demerkov, L A Rodinovskaya, in *Estestvennye Nauki — Narodnomu Khozyaistvu (Tez. Dokl. Regional'noi Nauchno-Tekhnicheskoi Konf.), Perm', 1988* [Natural Sciences for National Economy (Abstracts of Reports of the Regional Scientific and Technical Conference), Perm', 1988] p. 126
359. A M Shestopalov, Yu A Sharanin, V P Litvinov *Khim. Geterotsikl. Soedin.* 363 (1990) [a]
360. A M Shestopalov, Yu A Sharanin, V K Promonenkov *Khim. Geterotsikl. Soedin.* 370 (1990) [a]
361. A M Shestopalov, Yu A Sharanin, L A Rodinovskaya, V P Litvinov *Zh. Org. Khim.* **26** 1578 (1990) [e]
362. L A Rodinovskaya, A M Shestopalov, O P Bogomolova, V P Litvinov, in *18-ya Konferentsiya po Khimii i Tekhnologii Organicheskikh Soedinenii Sery (Tez. Dokl.), Kazan', 1992* [The 18th Conference on the Chemistry and Technology of Organic Compounds of Sulfur (Abstracts of Reports), Kazan', 1992] p. 169
363. A M Shestopalov, O P Bogomolova, V P Litvinov *Izv. Akad. Nauk SSSR, Ser. Khim.* 1630 (1991) [b]
364. O P Bogomolova, A M Shestopalov, L A Rodinovskaya, V P Litvinov, in *Vsesoyuznaya Konferentsiya po Khimii Dikarbonil'nykh Soedinenii (Tez. Dokl.), Riga, 1991* [All-Union Conference on the Chemistry of Dicarbonyl Compounds (Abstracts of Reports), Riga, 1991] p. 32
365. A M Shestopalov, L A Rodinovskaya, O P Bogomolova, V P Litvinov, in *V Vsesoyuznaya Konferentsiya po Khimii Azotsoderzhashchikh Geterotsiklicheskikh Soedinenii (Tez. Dokl.), Chernogolovka, 1991* [The Vth All-Union Conference on the Chemistry of Nitrogen-Containing Heterocyclic Compounds (Abstracts of Reports), Chernogolovka, 1991] p. 94
366. O P Bogomolova, in *The 8th Conference of Young Scientists on Organic and Bioorganic Chemistry (Abstracts of Reports), Riga, 1991* p. 47
367. A M Shestopalov, O P Bogomolova, V P Litvinov *Synthesis* 277 (1991)
368. K Geval'd *Khim. Geterotsikl. Soedin.* 1299 (1976) [a]
369. V P Litvinov, A M Shestopalov, Yu A Sharanin, V Yu Mortikov *Dokl. Akad. Nauk SSSR* **309** 115 (1989) [g]
370. A M Shestopalov, Yu A Sharanin, V P Litvinov, O M Nefedov *Zh. Org. Khim.* **25** 1111 (1989) [e]
371. V A Artyomov, L A Rodinovskaya, A M Shestopalov, V P Litvinov *Mendeleev Commun.* 149 (1993)
372. V A Artemov, L A Rodinovskaya, A M Shestopalov, V P Litvinov *Khim. Geterotsikl. Soedin.* 122 (1994) [a]
373. V A Artemov, A M Shestopalov, V P Litvinov *Zh. Org. Khim.* **31** 127 (1995) [e]
374. V A Artemov, A M Shestopalov, V P Litvinov *Zh. Org. Khim.* **31** 595 (1995) [e]
375. V A Artyomov, L A Rodinovskaya, A M Shestopalov, V P Litvinov *Tetrahedron* **52** 1011 (1996)
376. V P Litvinov, V A Artyomov, L A Rodinovskaya, A M Shestopalov, in *The 16th International Symposium on the Organic Chemistry of Sulfur (Abstracts of Reports), Merzeburg, 1994* p. 295
377. V L Ivanov, V A Artemov, A M Shestopalov, V P Litvinov *Khim. Geterotsikl. Soedin.* 659 (1995) [a]
378. V L Ivanov, V A Artemov, L A Rodinovskaya, A M Shestopalov, V N Nesterov, Yu T Struchkov, V P Litvinov *Khim. Geterotsikl. Soedin.* 115 (1996) [a]
379. V L Ivanov, V A Artemov, A M Shestopalov, V N Nesterov, Yu T Struchkov, V P Litvinov *Khim. Geterotsikl. Soedin.* 413 (1996) [a]
380. V A Artemov, V L Ivanov, L A Rodinovskaya, A M Shestopalov, V P Litvinov *Khim. Geterotsikl. Soedinen.* 553 (1996) [a]
381. V L Ivanov, V A Artemov, A M Shestopalov, V P Litvinov *Khim. Geterotsikl. Soedin.* 837 (1997) [a]
382. V A Artyomov, V L Ivanov, A M Shestopalov, V P Litvinov *Tetrahedron* **53** 13351 (1997)
383. V A Artemov, V L Ivanov, A V Koshkarev, A M Shestopalov, V P Litvinov *Khim. Geterotsikl. Soedin.* 104 (1998) [a]
384. V L Ivanov, V A Artemov, A M Shestopalov, V P Litvinov *Khim. Geterotsikl. Soedin.* 263 (1998) [a]
385. V A Artemov, V L Ivanov, V P Litvinov *Khim. Geterotsikl. Soedin.* 435 (2000) [a]
386. V L Ivanov, V A Artemov, A M Shestopalov, V N Nesterov, V P Litvinov, in *19-ya Vserossiiskaya Konferentsiya po Khimii i Tekhnologii Organicheskikh Soedinenii Sery (Tez. Dokl.), Kazan', 1995* [The 19th All-Russian Conference on the Chemistry and Technology of Organic Compounds of Sulfur (Abstracts of Reports), Kazan', 1995] p. 142
387. V L Ivanov, V A Artemov, A M Shestopalov, V P Litvinov, in *Khimiya Azotistykh Geterotsiklov (Tez. Dokl. Mezhinstitutskogo Kollokviuma), Chernogolovka, 1995* [The Chemistry of Nitrogeneous Heterocycles (Abstracts of Reports of International Colloquium), Chernogolovka, 1995] p. 143
388. V A Artyomov, V L Ivanov, A M Shestopalov, V P Litvinov, in *The 12th Symposium on the Chemistry of Heterocyclic Compounds and 6th Blue Danube Symposium on the Heterocyclic Chemistry. (Abstracts of Reports), Brno, 1996* p. 5
389. V P Litvinov, Ya Yu Yakunin, V D Dyachenko *Khim. Geterotsikl. Soedin.* 41 (2001) [a]
390. V P Litvinov *Khim. Geterotsikl. Soedin.* 12 (2002) [a]
391. V V Dotsenko, S G Krivokolysko, V P Litvinov, A N Chernega *Izv. Akad. Nauk, Ser. Khim.* 339 (2002) [b]
392. V V Dotsenko, S G Krivokolysko, A N Chernega, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 1432 (2002) [b]
393. V P Litvinov, V D Dyachenko *Usp. Khim.* **66** 1025 (1997) [*Russ. Chem. Rev.* **66** 923 (1997)]
394. V P Litvinov *Usp. Khim.* **68** 45 (1999) [*Russ. Chem. Rev.* **68** 39 (1999)]
395. V P Litvinov, M-G A Shvekhgeimer *Zh. Org. Khim.* **36** 329 (2000) [e]
396. N G Frolova, V K Zav'yalova, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 938 (1996) [b]
397. N G Frolova, V K Zav'yalova, V P Litvinov *Izv. Akad. Nauk, Ser. Khim.* 2719 (1996) [b]
398. V L Ivanov, V A Artemov, A M Shestopalov, V N Nesterov, Yu T Struchkov, V P Litvinov *Khim. Geterotsikl. Soedin.* 413 (1996) [a]
399. V D Dyachenko, S G Krivokolysko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1094 (1996) [a]
400. V D Dyachenko, S G Krivokolysko, Yu A Sharanin, V P Litvinov *Khim. Geterotsikl. Soedin.* 909 (1997) [a]
401. V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 1384 (1997) [a]
402. V D Dyachenko, V P Litvinov *Khim. Geterotsikl. Soedin.* 213 (1998) [a]
403. G V Klokol, S G Krivokolysko, V D Dyachenko V P Litvinov *Khim. Geterotsikl. Soedin.* 1363 (1999) [a]
404. S G Krivokolysko, V P Litvinov *Khim. Geterotsikl. Soedin.* 552 (2000) [a]
405. S G Krivokolysko, V D Dyachenko, V N Nesterov, V P Litvinov *Khim. Geterotsikl. Soedin.* 344 (2001) [a]

[a] — *Chem. Heterocycl. Compd. (Engl. Transl.)*
[b] — *Russ. Chem. Bull., Int. Ed. (Engl. Transl.)*
[c] — *Pharm. Chem. J. (Engl. Transl.)*
[d] — *Russ. J. Bioorg. Chem. (Engl. Transl.)*
[e] — *Russ. J. Org. Chem. (Engl. Transl.)*
[f] — *Russ. J. Gen. Chem. (Engl. Transl.)*
[g] — *Dokl. Chem. (Engl. Transl.)*