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New potential of the classical Biginelli reaction

S V Vdovina, V A Mamedov

Contents

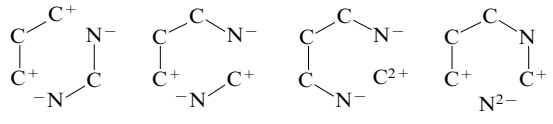
I.	Introduction	1017
II.	Mechanism of the Biginelli reaction	1018
III.	Synthesis of dihydropyrimidinones using immobilised components of the Biginelli reaction	1020
IV.	Synthesis of dihydropyrimidinones by the one-pot Biginelli reaction	1021
V.	Supplements	1026

Abstract. The published data on the Biginelli reaction are generalised and systematised. The major attention is focused on the publications of the last seven years. Possible reaction mechanisms and its application for the synthesis of 3,4-dihydropyrimidin-2(1*H*)-one derivatives are considered. Examples of rare versions of this reaction are given. The bibliography includes 115 references.

I. Introduction

Pyrimidinones and their derivatives play an important role in human vital functions. The pyrimidine structural fragment is the component of a series of natural compounds (nucleic acids, vitamin B_1), synthetic medicines (barbiturates) chemotherapeutic drugs (fluorouracil). Biological importance of pyrimidine derivatives caused a significant interest in their synthesis.

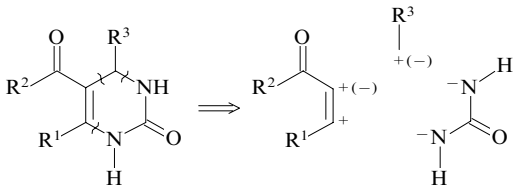
The strategy for the pyrimidine ring closure includes four main approaches (**I**–**IV**) based on condensation of different fragments.



I **II** **III** **IV**

The most popular is approach **I**, *i.e.*, the coupling of compounds providing a three-carbon fragment and an N–C–N fragment. This method is called 'common synthesis' due to its general applicability for the preparation of a wide range of pyrimidine derivatives and experimental simplicity. β-Dicarbonyl compounds, *viz.*, dialdehydes, keto aldehydes, aldehydo and keto esters), β-aldehydonitriles, cyanoacetic acid derivatives (for example, ethyl ethoxymethylcyanoacetate), dinitriles, *etc.*, are most often used as synthetic equivalents of the three-carbon synton C^+-C-C^+.

In 1891, an Italian chemist Biginelli suggested [1] yet another version of the pyrimidine ring construction based on the use of β-dicarbonyl compounds as a source of a two-carbon fragment in accordance with the retrosynthetic scheme given below where one carbonyl group remains intact. Later, this method for the synthesis of pyrimidine structures has been named the Biginelli reaction.



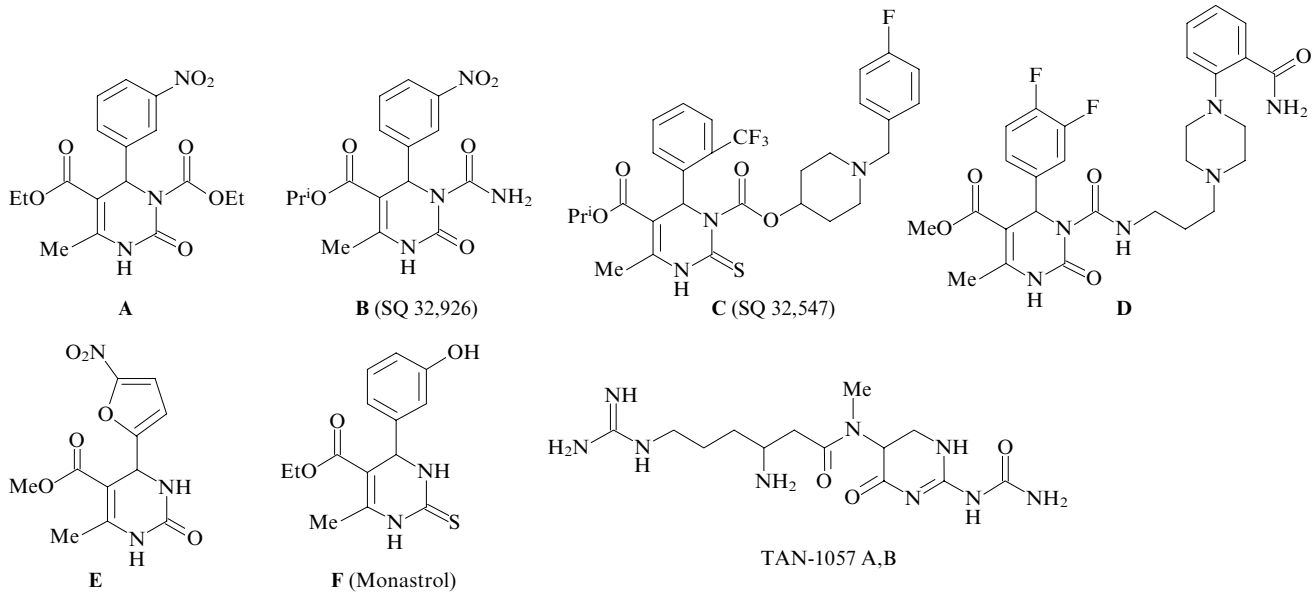
A β-dicarbonyl compound, an aldehyde and urea are used as the reactants.

This reaction has been ignored for more than a century. However, lately a great number of compounds with valuable properties has been discovered among 3,4-dihydropyrimidinones (DHPM). Some of them are used in medicine as calcium channel-blocking agents (**A**), as antihypertensive drugs (**B**, **C**) and α_{1a}-antagonists (**D**). Other exhibit pronounced antiviral (**E**) and antitumour (**F**) activities.[2] Natural dipeptide antibiotic TAN-1057 A,B (Ref. 3) having a strong antistaphylococcus activity has been designed based on dihydropyrimidine derivatives. In addition, it was found that some alkaloids isolated from seaweeds, which contain a dihydropyrimidinone-5-carboxylate ring, are powerful HIV inhibitors.[4]

The Biginelli reaction is attractive, because substituents that can readily be transformed into different functional groups required for further syntheses, can easily be intro-

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duced into the reaction products. However, in its classic version (catalyst HCl, solvent EtOH), the yields of this one-pot reaction are low (20% – 50%) and it takes a long time (15 – 20 h).[1,5–10]

Due to low efficiency of the classical method of coupling and great demand in 3,4-dihydropyrimidine derivatives as components of pharmaceutical compositions, more than one hundred publications appeared to date that describe improved procedures, which are, in essence, modifications of the classical one-pot Biginelli synthesis. The starting reagents (a dicarbonyl compound, an alhehyde or urea), catalysts and solvents vary in these methods. Polyphosphate ester (PPE),[7,11–13] montmorillonite clays,[14,15] Yb^{III}-resins,[16] molecular iodine,[17,18] different organic[19,20] and inorganic[1,5–10,21] acids, Lewis acids [$BF_3 \cdot OEt_2$,[21] $FeCl_3$,[22–24] ZnI_2,[25] $InCl_3$,[26] $LaCl_3$,[27] $LiClO_4$,[28] $Mn(OAc)_3$ (Ref. 29)], metal triflates,[30–32] ionic liquids like 1-n-butyl-3-trimethylimidazolium tetrafluoroborate bmim[BF_4],[33] alkylammonium perhalophosphates and perhaloaluminates,[34] *etc*. are used as catalysts instead of hydrochloric acid. A great number of solvents has been suggested for the reaction: alcohols, acetonitrile, tetrahydrofuran, dimethylformamide, dichloromethane, water. It is known that sonication,[35–37] microwave[12,38–44] and infrared[45] irradiation, as well as application of high pressure[46] accelerate the Biginelli reaction and increase the product yields.

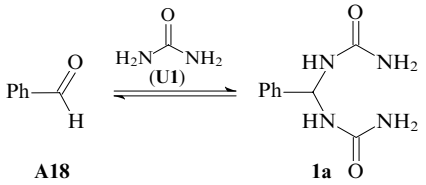
Despite availability of numerous original publications devoted to the Biginelli reaction, no comprehensive review on this topic has yet been published. Syamala[47] considered different three-component reactions, that is why the material on the Biginelli reaction cannot be exhaustive. A review by Kappe[48] was published 15 years ago, but it is over the last decade that many new versions of the classic reaction have appeared. Recent review[49] by Kappe is worth noting; it is devoted to the methods of solid-phase synthesis and the application of the combinational chemistry approaches, as well as to the role of the Biginelli reaction in the synthesis of natural compounds.

At present, diverse reagents are used in the Biginelli reaction. They are systematised and listed in Supplement 1, where their notation used in the text and the tables is also given. A variety of combinations of the reactants used under different conditions are described in the literature. In order to present this material in the most complete and compact way, it is arranged in the form of tables.

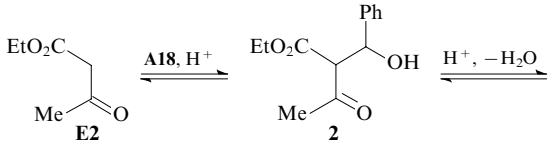
Among publications devoted to modified methods for the preparation of the 'Biginelli compounds', there are only several works where the mechanism of the reaction is discussed. It is remarkable that until now the details of the mechanism have not been completely clarified, and there are different points of view concerning this problem.[48]

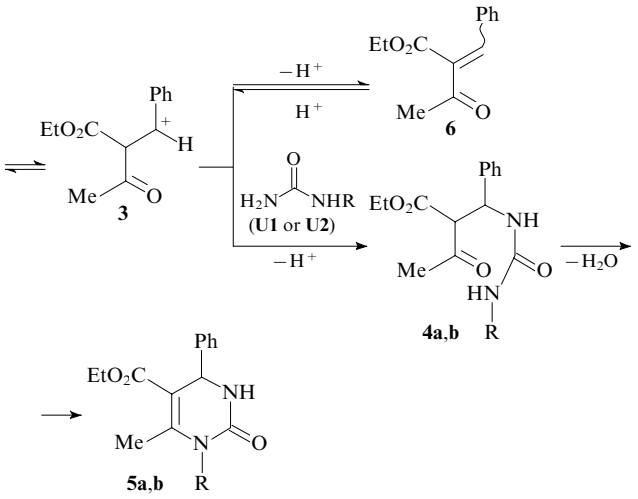
II. Mechanism of the Biginelli reaction

At first it was supposed[5] that the primary bimolecular condensation product of benzaldehyde (**A18**) with urea (**U1**), *i.e*. the first intermediate of this reaction, is *N*,*N*′-benzylidenebisurea (**1a**). For this reason, this mechanism was named urea-crotonic.



Later, the so-called carbocationic mechanism has been suggested,[50] where acid-catalysed aldol condensation was the first and rate-limiting step.





R = H (**a**), Me (**b**).

It was supposed that upon acid catalysis, benzaldehyde (**A18**) and ethyl acetoacetate (**E2**) react to form the corresponding aldol **2**, which dehydrates in the presence of an acid into resonance-stabilised carbocation **3**. The reaction of the latter with urea (**U1**) or *N*-methylurea (**U2**) results in urea derivative **4**, which is cyclised into the Biginelli compound **5**. This mechanism is supported by the fact that, irrespective of the action of the acid catalyst, the reaction of enone **6** with *N*-methylurea affords dihydropyrimidinone **5b** in moderate yield.[50] Protonation of enone **6** results in the carbocationic intermediate **3**, which reacts with urea (**3** → **4** → **5**).

About a decade ago, the mechanism of the Biginelli condensation was reinvestigated[51] using the data from ^{1}H and ^{13}C NMR spectroscopy in order to determine possible intermediates of this reaction.

Three possible sequences of the reaction of the starting components have been considered:

1) ethyl acetoacetate + benzaldehyde + urea,

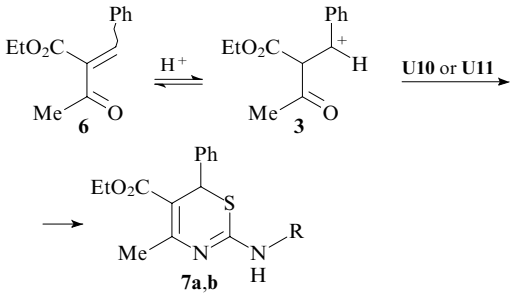
2) ethyl acetoacetate + urea + benzaldehyde,

3) benzaldehyde + urea + ethyl acetoacetate.

Let us consider in more detail these pathways.

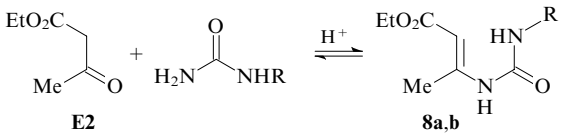
The first version (ethyl acetoacetate + benzaldehyde + urea) corresponds essentially to the above-considered carbocationic mechanism based on acid-catalysed aldol condensation. Although the aldol condensation is more often initiated by bases, a possibility of an acid-catalysed reaction of benzaldehyde with a 1,3-dicarbonyl compound cannot be ruled out. The final products of this condensation should be predominantly α,β-unsaturated carbonyl compounds (like **6**) rather than β-hydroxycarbonyl (aldol) products **2**. In the case of the reaction of benzaldehyde with ethyl acetoacetate, no evidence for aldol reaction or other reactions of these compounds that could occur at room temperature was obtained by ^{1}H or ^{13}C NMR spectroscopy. Benzaldehyde does not react with ethyl acetoacetate under the conditions where the Biginelli condensation proceeds readily. This fact excludes the carbocationic mechanism as the major reaction pathway, because, according to this mechanism, this reaction is the first stage.

The possibility of the formation of the carbocationic intermediate (**3**) in the Biginelli condensation is even smaller, if thiourea is substituted for urea. Both thiourea (**U10**) and *N*-methylthiourea (**U11**) react with benzaldehyde and ethyl acetoacetate under the standard conditions of the Biginelli reaction to give the expected dihydropyrimidine-2-thiones (the Biginelli compounds). A the same time, the acid-catalysed reaction of intermediate **3** with thioureas **U10**, **U11** affords isomeric 2-amino-1,3-thiazines **7a**,**b** in excellent yields. However, the fact that the three-component Biginelli reaction with thioureas does not result in thiazine products **7** rules out the intermediate of carbocation **3**.



R = H (**a**), Me (**b**).

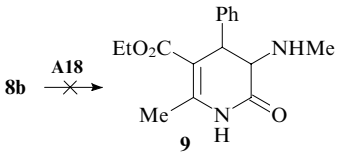
If the reaction follows the second pathway (ethyl acetoacetate + urea + benzaldehyde), 'urea-crotonic' intermediates **8a**,**b** might be formed. This reaction occurs on keeping a mixture of ethyl acetoacetate and urea in a dessicator over concentrated sulfuric acid for several days, which is at variance with the conditions for the classical Biginelli reaction.



R = H (**U1**), Me (**U2**).

R = H (**a**), Me (**b**).

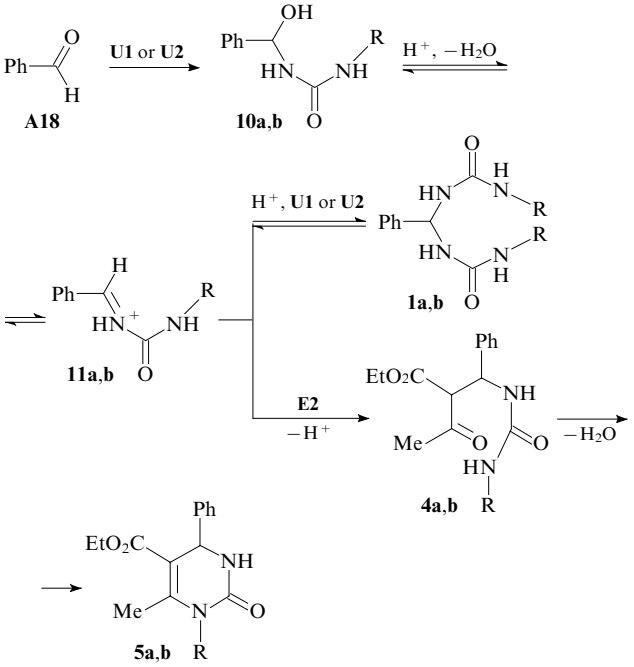
Another argument against the transient formation of this compound is that *N*-methylurea (**U2**) reacts with ethyl acetoacetate to form a single regioisomer **8b** with the methyl substituent at the terminal amino group. Cyclocondensation of putative intermediate **8b** with benzaldehyde (following the [5 + 1] scheme) should result in the *N*-substituted dihydropyrimidinone **9**, as the Biginelli product, which is observed for neither the three-component Biginelli reaction nor the reaction of urea derivative **8b** with benzaldehyde. In both cases, only isomeric dihydropyrimidinone **5b** is formed.



Thus, this reaction sequence is also non-realistic.

The third pathway (benzaldehyde + urea + ethyl acetoacetate), *i.e.*, the urea-crotonic mechanism consisting of nucleophilic addition of urea to benzaldehyde to form *N*-(1-hydroxybenzyl)urea **10**, seems the most preferable. In the presence of acid, hemiaminal intermediate **10** undergoes dehydration, and the equilibrium shifts towards the reactive *N*-carbamoyliminium ion **11**. In the absence of 1,3-dicarbonyl compound, the second equivalent of urea reacts with cation **11** to form bisureas **1a**,**b**, which can be easily isolated from the reaction mixture due to low sol-

ubility. Thus, the presence of ethyl acetoacetate in the reaction mixture presumes its reaction (probably, as the enol tautomer) with cation **11** to form intermediates **4a**,**b**, which are further cyclised to the Biginelli compounds **5a**,**b**. However, in the ^{1}H NMR spectra of the samples taken after definite intervals, no signals for intermediates **10**, which are represented in the suggested scheme, were observed.



R = H (**a**), Me (**b**).

The first addition stage (**A18** → **10**) seems to be the limiting stage of the process, while two subsequent stages [acid-catalysed dehydration (**10** → **11**) and addition of the second equivalent of urea to the cation (**11** → **1**)] are fast, which prevents detection of intermediate **10** by spectral methods.

Remarkable that the Biginelli reaction with non-symmetrical dicarbonyl compounds virtially always occurs regioselectively and the products, dihydropyrimidinones, are obtained in high yields. If keto esters or keto amides are used as dicarbonyl compounds, the keto group, in which the carbon atom is more electrophilic, always participates in the cyclisation (its substituent occupies position 6), while the ester or amide group occupies position 5 in the DHPM ring. If a non-symmetrical diketone is involved in the reaction, the direction is determined by the balance between steric and electronic factors. The carbonyl group bearing a less bulky and more electron-withdrawing substituent takes part in cyclisation. Thus in the case of $MeCOCH_2COPh$ and Ph groups (**K5**), the benzoyl group appears in position 5, while the Me substituent occupies position 6; at the same time, for diketone **K2** with Me and CF_3 groups, the acetyl group occupies position 5, while the CF_3 group goes to position 6. In order to avoid confusion, substituents in diketones in Supplement 1 are denoted so that in the Biginelli reaction, R^1 is at position 6 of DHPM and $R^2C(O)$ is at position 5.

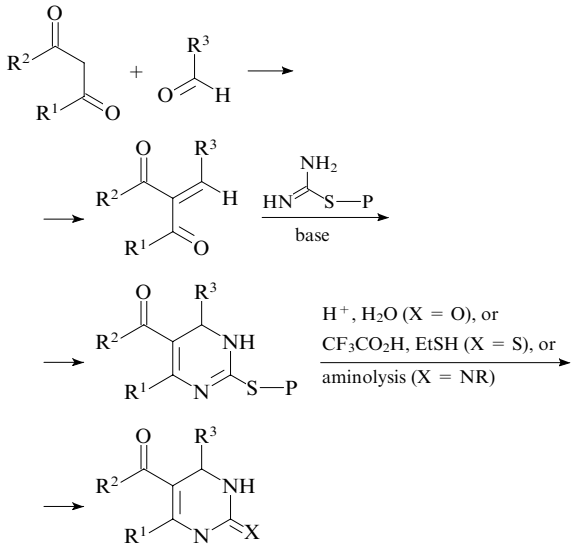
In the case of monosubstituted ureas, the position of a substituent at the nitrogen atom seems to be determined by steric factors. The substituent in the product occupies position 1.

III. Synthesis of dihydropyrimidinones using immobilised components of the Biginelli reaction

The majority of currently existing methods for the preparation of 3,4-dihydropyrimidinones are modifications of the one-pot Biginelli synthesis, however, first publications after almost a hundred-year oblivion of this reaction were devoted to the synthesis of dihydropyrimidinones with the use of immobilised reagents.

The strategy of such syntheses is reduced to the preparation of DHPM derivatives on solid supports [49, 52–59] or in a liquid phase [52, 53, 60] with recourse to different polymers and resins. Currently, these methods are supplemented with microwave irradiation.[52, 53] In this case, either of the three components can be immobilised. However, most often it is urea [49, 54, 55] or a β-dicarbonyl compound,[49, 56, 57] while immobilised aldehydes came to use only in the last three years.

These syntheses can be carried out by two methods. In both cases, the first stage is immobilisation of one of the reactants on a carrier. The first method consists of acid-catalysed coupling of the immobilised compound with two other reactants to form a dihydropyrimidine derivative. In the last stage, the DHPM molecule is removed from the carrier. The second method [58] includes condensation of a dicarbonyl compound with aldehyde in the presence of a base (the Knoevenagel condensation) to give an enone, which then reacts with an immobilised isothiourea in the presence of a base. This reaction results in the immobilised 2-thio derivative of DHPM, which, after the corresponding treatment, gives the target Biginelli compounds in high overall yields.[58] This method is named the Atwal modification, because it is similar to the method for the synthesis of 3-substituted DHPM starting from *O*-methylisourea or *S*-(4-methoxybenzyl)isothiourea suggested by Atwal *et al.*[61] Although this approach requires preliminary synthesis of the enone, it is rather attractive, because it ensures high yields of DHPM, which are difficult to obtain by the one-pot Biginelly process.



P is polymer.

All these methods can be divided into three groups deppending on the carriers used and the phase where the processes proceed:

1) liquid-phase processes with the use of polymers;[53, 60]

2) solid-phase syntheses on carriers;[49, 53 – 59]

3) processes with the use of soluble polymeric supports.[52]

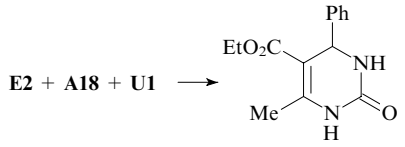
All these methods have their advantages and drawbacks. In liquid-phase syntheses, substances bound to the polymer can possess low reactivity; identification of intermediates becomes problematic, difficulties arise in separation of pyrimidinones obtained from admixture of the polymer.[53, 60] Solid-phase strategies provide possibility to avoid recrystallisation and chromatographic purification of the products obtained, which is sometimes rather important. Their drawback consists of uneconomical consumption of the reactants.[53 – 59] Soluble polymeric supports are devoid of the above-mentioned disadvantages; these supports allow fast change in the reaction conditions (transition from the solid to the liquid phase and *vice versa*) and the economic use of the reactants. That is why processes on soluble polymeric supports find wide application.[52] Disadvantages of this method are complex instrumentation and often their multi-stage nature; however, it does not influence the yields and purity of the reaction products. Microwave irradiation at the stage of the Biginelli reaction decreases the duration of these processes. It is noteworthy that application of immobilised reagents allows the parallel syntheses of vast libraries of DHPM derivatives.[57, 58] However, most researches give preference to the one-pot method for the preparation of dihydropyrimidinones from classical components of the Biginelli reaction suggesting improved versions of the implementation of this condensation, because multistage processes with the use of polymeric supports are laborious, and carriers are expensive.

IV. Synthesis of dihydropyrimidinones by the one-pot Biginelli reaction

1. Classical combination of reactants in the Biginelli reaction

The most popular product of the Biginelli reaction is ethyl 6-methyl-2-oxo-4-phenyl-1,2,3,4-tetrahydropyrimidine-5-carboxylate synthesised by the condensation of the classical reactants, *viz*., ethyl acetoacetate (**E2**), benzaldehyde (**A18**) and urea (**U1**). More than 60 sets of reaction conditions for the synthesis of this compound are given in Table 1.

Table 1. The versions of the classical Biginelli reaction: ethyl acetoacetate + benzaldehyde + urea.



Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
PPE	THF	Δ	24 h	94	7	(TMS)Cl, NaI	MeCN	room temperature, stirring	30 min	98	67
PPE	–	μν	90 s	85	11						
Mont. KSF	–	130 °C	48 h	82	14						
Mont. KSF	MeOH	Δ	8 – 10 s	92	15	LiBr	MeCn	Δ	3 h	92	68
Yb^{III}-Resin	–	120 °C	48 h	80	16	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	97	69
I_2	PhMe	Δ	4 h	95	17						
TsOH	H_2O	stirring	5 min	91	19	NH_2SO_3H	EtOH	20 – 30 °C, stirring	40 min	62	69
SSA	EtOH	Δ	6 h	91	20						
$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	94	21	$Cu(OTf)_2$	MeCN	25 °C, stirring	6 h	95	70
H_2SO_4	EtOH	Δ	18 h	71	21	NH_4Cl	–	100 °C	3 h	90	71
$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	4 h	94	22	TsOH	–	μν	5 min	92	72
$FeCl_3 \cdot 6H_2O$	EtOH	Δ	4 h	94	23	$CuCl_2 \cdot 2H_2O$	–	100 °C	60 min	96	73
$NiCl_2 \cdot 6H_2O$, HCl	EtOH	Δ	5 h	97	23	$CuCl_2 \cdot 2H_2O$	–	μν	1 min	98	73
						$CuSO_4 \cdot 5H_2O$	–	100 °C	70 min	96	73
$InCl_3$	THF	Δ	7 h	95	26	$CuSO_4 \cdot 5H_2O$	–	μν	1 min	98	73
$LiClO_4$ or LiOTf	MeCN	Δ	6 h	89	28	HBO_3	glacial AcOH	100 °C	0.5 – 2 h	97	74
$Mn(OAc)_3 \cdot 2H_2O$	MeCN	Δ	2 h	96	29						
$Yb(OTf)_3$, AcOH	EtOH	120 °C	10 min	92	30	$ZnCl_2$	–	80 °C	20 min	73	75
$Bi(OTf)_3$	MeCN	room temperature, stirring	1 h	90	31	PABC	EtOH	Δ	2 h	94	76
						$CdCl_2$	MeCN	Δ	4 h	83	77
						$Cu(NTf_2)_2$	H_2O	stirring	24 h	88	78
CAN	MeOH	US	3.5 h	92	35	$Sr(OTf)_2$	–	70 °C	4 h	97	79
–	–	100 – 150 °C	1 h	81	36	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	3 h	88	80
TAFF	–	IR	2 h	55	45	$RuCl_3$	–	100 °C	30 min	91	81
$Yb(OTf)_3$	–	100 °C	20 min	98	62	$CHCl_2CO_2H$	–	90 °C	30 min	91	82
$LaCl_3 \cdot 7H_2O$, HCl	EtOH	Δ	5 h	95	63	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	92	83
HCl	EtOH	US	2 – 5 min	95	64	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	87	83
FSA	EtOH	Δ	84 h	65	65	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	93	83
$InBr_3$	EtOH	Δ	7 h	98	66	Dowex-50W	–	130 °C	3 h	90	84

Table 1 (continued).

Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
$PhB(OH)_2$	MeCN	Δ	18 h	87	85	BDMPEAB	–	100 °C	20 min	96	90
VCl_3	MeCN	Δ	2 h	96	86	NH_4Br	–	100 °C	20 min	81	90
bmim[BF_4]	–	100 °C	30 min	95	87	–	–	100 °C	20 min	73	90
bmim[PF_6]	–	100 °C	30 min	94	87	PPAA	EtOAc	Δ	6 h	77	91
bmimCl	–	100 °C	30 min	56	87	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	95	92
CNSP	H_2O	80 °C	4.5 h	92	88						
$Yb(OTf)_3$	THF	stirring	–	87	89	(TMS)Cl	DMF	20 °C	14 h	80	93

Note. Hereinafter, the following notation is used: BDMPEAB is butyldimethyl(1-phenylethyl)ammonium bromide; bmim is 1-n-butyl-3-methylimidazolium; CAN is cerium ammonium nitrate; CNSP is CeO_2 nanoparticles on a 4-vinylpyridine – *p*-divinylbenzene copolymer; FSA is silica aerogel containing ferrihydrate particles ($5\,Fe_2O_3 \cdot 9\,H_2O$); Mont. KSF is montmorillonite caoline; PABS is complex obtained by the interaction of polyaniline with BiOCl in acetone; PPAA is propanephosphonic anhydride; PPE is polyphosphoric ester; Pro-Me is methyl ester of L-proline; SSA is silica gel with grafted sulfo groups; TAFF is a bentonite glue (74.5% SiO_2, 9.3% Al_2O_3, 4.0% CaO, 1.3% Fe_2O_3, 0.4% MgO, 0.4% K_2O, 0.4% TiO_2, 9.7% H_2O); TMS is trimethylsilyl; IR is IR irradiation; US is sonication; Δ is boiling; μν is microwave irradiation.

As is seen from Table 1, the highest yields (up to 98%) and the shortest reaction times (1 – 1.5 min) are achieved where the Biginelli condensation is assisted by microwave irradiation.[11, 73] In this case, however, the isolation technique of the target product becomes more complicated; besides, decomposition of urea occurs.[94]

It was shown [64] that sonication (sonochemical synthesis) accelerates more than 40-fold the formation of ethyl 4-R-6-methyl-2-oxo- and 4-R-6-methyl-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylates, *i.e.*, the synthesis lasts for 2 – 5 min. The amount of side products decreases due to high selectivity of the process, in most cases, no additional purification (crystallisation) is required, which leads to simplification of the process and to an increase in the yields of the target compounds to 90% – 95% irrespective of the aldehyde.

Environmentally safe versions of the Biginelli reaction are of special note, namely, the use of montmorillonite clays as a catalyst, as well as reactions under catalyst-free and solvents-free conditions.

Environmentally friendly montmorillonite clays are often used in organic synthesis due to their availability. They are easy in handling, provide high yields of target products, ensure high selectivity of the processes and can easily be separated from the reaction mixtures. The Biginelli reaction can be performed under solvent-free condition with the use of montmorillonite KSF, though this process has its drawbacks, for example, long duration (8 – 10 h).[15]

It was found [36, 90] that the Biginelli reaction is efficiently accomplished using mixture of pure reactants at 100 – 105 °C for 20 min – 1 h without solvents and catalysts; high and moderate yields are achieved.

2. New combinations of reactants in the Biginelli reaction

At present, when choosing reactants for the Biginelli condensation, it is aldehydes that are varied most often, while keto esters, which are the source of a two-carbon fragment for the DHPM molecule, are replaced much more rarely. Examples where keto esters with a benzoyl fragment (for instance, **E16**, **E17**) are used are especially seldom; in most cases, the presence of this fragment prevents the formation of the pyrimidine ring (see, for example, Refs 95 – 97). The yields of final products in these cases are usually not high.[21, 27, 41, 95]

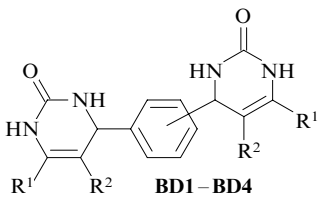
The most successful method for the synthesis of ethyl 2-oxo-4,6-diphenyl-1,2,3,4-tetrahydropyrimidine-5-carboxylate is stirring of a mixture of reactants in acetonitrile at room temperature with the addition of catalytic amounts of trimethylsilyl chloride and sodium iodide.[76]

As for β-dicarbonyl compounds as a source of a two-carbon fragment for the Biginelli reaction, keto esters have been the most comprehensively studied. However, a range of reactants used is gradually widening due to inclusion of diketones, keto amides, cyclic imides, *etc*. Among diketones, as among keto esters, derivatives with benzoyl groups (for example, **K5** – **K9**), which are difficult to inroduce into the DHPM molecule by other methods, are especially interesting.

Different combinations of the starting components and reaction conditions for the one-pot process are summarised in Supplement 2. Combinations of components are given in series according to the carbonyl compound used: keto esters (**E1** – **E35**), then diketones (**K1** – **K13**), keto amides and their analogues (**Am1** – **Am8**) and, finally, equivalents of dicarbonyl compounds (**Eq1**, **Eq2**) (Supplement 1).

Mono- and bisreactant, either of three, can be used in the Biginelli reaction. In the latter case, the products contain two dihydropyrimidinone fragments.

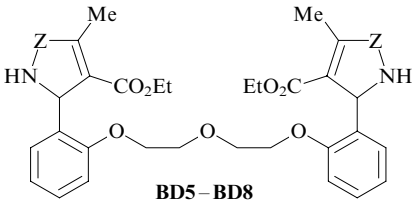
Thus Tu *et al*. reported [92] the one-pot synthesis of rigidly oriented bis(dihydropyrimidinones) **BD1** – **BD4** from iso- (**A89**) and terephthalic aldehydes (**A90**). Compound **BD2** is also described in other publications.[27, 97]



BD1 – **BD4**

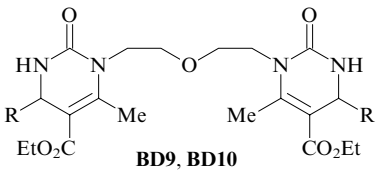
Isomers *meta* (**BD1**, **BD3**), *ortho* (**BD2**, **BD4**);
R^1 = Me, R^2 = CO_2Et (**BD1**, **BD2**);
$R^1 – R^2$ = $(CH_2)_3C(O)$ (**BD3**, **BD4**).

Zhidovinova *et al*.[103] used podands with the terminal aldehyde (**A91**) or urea (**U15**) fragments; derivatives of **BD5** – **BD8** and **BD9**, **BD10**, respectively, were obtained.



BD5 – BD8

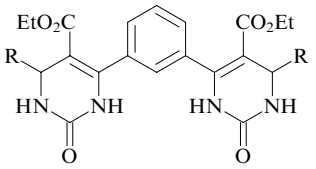
Z = NHC(O) (**BD5**), NHC(S) (**BD6**), [X = CH (**BD7**), N (**BD8**)].



BD9, **BD10**

R = Me (**BD9**), Ph (**BD10**).

The Biginelli reaction of compound **E35** with two keto ester fragments in the benzene ring reacted [104, 105] with urea and different aldehydes (**A18**, **A19**, **A31**, **A64**, **A66**, **A71**, **A72**) to afford bis(dihydropyrimidinones) **BD11 – BD17** as the reaction products.



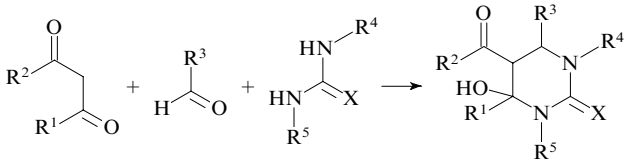
BD11 – BD17

R = Ph (**BD11**), PhCH═CH (**BD12**), 4-$Me_2NC_6H_4$ (**BD13**), 4-ClC_6H_4 (**BD14**), 2,4-$Cl_2C_6H_3$ (**BD15**), 4-BrC_6H_4 (**BD16**), 4-IC_6H_4 (**BD17**).

The conditions of the reaction with bis-reagents and the product yields are listed in Table 2.

These bis(dihydropyrimidinones), undoubtedly, are of interest, because biological activity of bisheterocyclic compounds, as a rule, is highly competitive with that of their monocyclic analogues.[106, 107]

Three-component condensation of β-dicarbonyl compounds with aldehydes and urea does not always result in 3,4-dihydropyrimidinones. In some cases, hydroxy tetrahydropyrimidinones (THPM) were isolated in moderate and high yields as intermediate or final products (Table 3).



THPM

As a rule, this result is obtained, if a dicarbonyl compound contains a strong electron-withdrawing group, for example, CF_3, C_3F_7, $CHCl_2$, *etc.* (compounds **E20 – E24**, **E26**, **K2**, **K3**, **K6 – K8**, **K10**, **K11**). Usually, hydroxy tetrahydropyrimidinones can be converted into DHPM by boiling (for example, in benzene or toluene) with an acidic catalyst (*p*-TsOH).

The formation of 4-hydroxytetrahydropyrimidinones containing strong electron-withdrawing groups, which is not typical of the Biginelli reaction, can be considered as a confirmation of the fact that the limiting stage of dehydration is protonation of the hydroxyl oxygen atom.

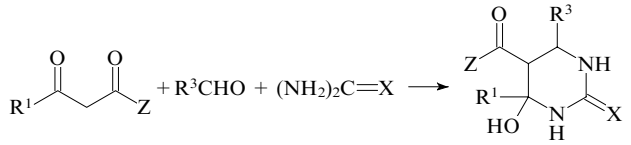
Table 2. Preparation of bis(dihydropyrimidinones) by the Biginelli reaction.

Product	Reactants	Reaction conditions	Reaction time	Yield (%)	Ref.	Product	Reactants	Reaction conditions	Reaction time	Yield (%)	Ref.
BD1	**E2** + **A89** + **U1**	*a*	0.5 – 2 h	96	92	**BD8**	**E2** + **A91** + **U17**	*c*	10 min	60	103
BD2	**E2** + **A90** + **U1**	*a*	0.5 – 2 h	99	92		**E2** + **A91** + **U17**	*d*	32 h	42	103
	E2 + **A90** + **U1**	*b*	10 min	78	27	**BD9**	**E2** + **A2** + **U15**	*c*	7 min	62	103
	E2 + **A90** + **U1***	65 °C	4 h	85	97		**E2** + **A2** + **U15**	*d*	30 h	38	103
BD3	**K12** + **A89** + **U1**	*a*	0.5 – 2 h	92	92	**BD10**	**E2** + **A18** + **U15**	*c*	7 min	65	103
BD4	**K12** + **A90** + **U1**	*a*	0.5 – 2 h	95	92		**E2** + **A18** + **U15**	*d*	26 h	45	103
BD5	**E2** + **A91** + **U1**	*c*	5 min	50	103	**BD11**	**E35** + **A18** + **U1**	*e*	25 h	56	104, 105
	E2 + **A91** + **U1**	*d*	30 h	30	103	**BD12**	**E35** + **A19** + **U1**	*e*	25 h	59	104, 105
BD6	**E2** + **A91** + **U10**	*c*	5 min	45	103	**BD13**	**E35** + **A31** + **U1**	*e*	25 h	60	104, 105
	E2 + **A91** + **U10**	*d*	30 h	25	103	**BD14**	**E35** + **A64** + **U1**	*e*	25 h	66	104, 105
BD7	**E2** + **A91** + **U16**	*c*	10 min	56	103	**BD15**	**E35** + **A66** + **U1**	*e*	25 h	50	104, 105
	E2 + **A91** + **U16**	*d*	30 h	40	103	**BD16**	**E35** + **A71** + **U1**	*e*	25 h	53	104, 105
						BD17	**E35** + **A72** + **U1**	*e*	25 h	52	104, 105

Note.

Notation	Catalyst	Solvent	Other conditions
a	$KHSO_4$	ethylene glycol	100 °C
b	$Yb(OTf)_3$	EtOH	100 °C
c	HCl	EtOH	US
d	HCl	EtOH	Δ
e	(TMS)Cl	DMPA + MeCN	80 °C

Table 3. Formation of tetrahydropyrimidinones under the conditions of the Biginelli reaction.



X = O, S; Z = R^2 or OR^2.

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E20 + **A18** + **U1**	HCl	EtOH	Δ	6 h	75	108
E21 + **A18** + **U1**	bmim[BF_4]	–	100 – 125 °C	6 h	78	33
	$ZrCl_4$	EtOH	Δ	6 h	80	99
E21 + **A18** + **U10**	bmim[BF_4]		100 – 125 °C	6 h	85	33
	HCl	EtOH	Δ	6 h	43	108
E21 + **A39** + **U1**	$ZrCl_4$	EtOH	Δ	6 h	85	99
E21 + **A60** + **U10**	bmim[BF_4]	–	100 – 125 °C	6 h	77	33
E22 + **A18** + **U1**	HCl	EtOH	Δ	6 h	79	108
E22 + **A18** + **U10**	HCl	EtOH	Δ	6 h	50	108
E23 + **A18** + **U1**	HCl	EtOH	Δ	6 h	73	108
E23 + **A18** + **U10**	HCl	EtOH	Δ	6 h	47	108
E24 + **A18** + **U1**	HCl	EtOH	Δ	6 h	80	108
E24 + **A18** + **U10**	HCl	EtOH	Δ	6 h	45	108
E26 + **A18** + **U1**	$InBr_3$	THF	Δ	24 h	70	109
E26 + **A18** + **U10**	$InBr_3$	THF	Δ	24 h	65	109
E26 + **A23** + **U1**	$InBr_3$	THF	Δ	24 h	67	109
E26 + **A23** + **U10**	$InBr_3$	THF	Δ	24 h	62	109
E26 + **A45** + **U1**	$InBr_3$	THF	Δ	24 h	86	109
E26 + **A64** + **U1**	$InBr_3$	THF	Δ	24 h	84	109
E26 + **A64** + **U10**	$InBr_3$	THF	Δ	24 h	88	109
E26 + **A84** + **U1**	$InBr_3$	THF	Δ	24 h	71	109
K2 + **A18** + **U1**	HCl	EtOH	Δ	6 h	32	108
K3 + **A18** + **U1**	HCl	EtOH	Δ	6 h	33	108
K6 + **A18** + **U1**	$Yb(OTf)_3$	–	100 °C	20 min	98	62
	HCl	EtOH	Δ	6 h	42	108
K6 + **A18** + **U10**	HCl	EtOH	Δ	6 h	30	108
K7 + **A18** + **U1**	bmim[BF_4]	–	80 – 100 °C	1 – 2 h	62	33
	HCl	EtOH	Δ	6 h	38	108
K7 + **A18** + **U10**	bmim[BF_4]	–	80 – 100 °C	1 – 2 h	66	33
	HCl	EtOH	Δ	6 h	36	108
K7 + **A60** + **U1**	bmim[BF_4]	–	80 – 100 °C	1 – 2 h	92	33
K7 + **A60** + **U10**	bmim[BF_4]	–	80 – 100 °C	1 – 2 h	84	33
K7 + **A88** + **U1**	bmim[BF_4]	–	80 – 100 °C	1 – 2 h	34	33
K8 + **A18** + **U1**	AcOH	MeOH	Δ	4 h	91	110
K8 + **A45** + **U1**	AcOH	MeOH	Δ	4 h	93	110
K8 + **A71** + **U1**	AcOH	MeOH	Δ	4 h	80	110
K8 + **A72** + **U1**	AcOH	MeOH	Δ	4 h	71	110
K10 + **A18** + **U1**	$Yb(OTf)_3$	–	100 °C	20 min	99	62
K11 + **A18** + **U1**	bmim[BF_4]	–	20 – 30 °C	30 min	75	33
K11 + **A18** + **U10**	bmim[BF_4]	–	20 – 30 °C	30 min	88	33
K11 + **A60** + **U1**	bmim[BF_4]	–	20 – 30 °C	30 min	92	33
K11 + **A60** + **U10**	bmim[BF_4]	–	20 – 30 °C	30 min	83	33
K11 + **A88** + **U1**	bmim[BF_4]	–	20 – 30 °C	30 min	82	33

3. Side reactions

An advantage of the Biginelli reaction is its high selectivity. However, even this reaction is sometimes accompanied by side processess.

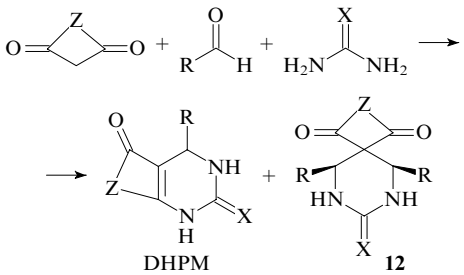
When cyclic dicarbonyl compounds are used, the standard Biginelli reaction products are often formed in low yields (11% – 25%) (Table 4); in this case, spiroheterocyclic compounds are isolated as major (sometimes the only) products, which can be considered as a result of four-component condensation of a cyclic dicarbonyl compound, two aldehyde molecules and urea.[101, 111, 112]

Table 4. Formation of spiroheterocyclic compounds **12** under the conditions of the Biginelli reaction.

Reactants	Reaction conditions	Yield (%)	Ref.	Reactants	Reaction conditions	Yield (%)	Ref.
E31 + **A18** + **U1**	*d*	see [a]	111	**K12** + **A60** + **U1**	*g*	80	102
E32 + **A18** + **U1**	*f*	56	112	**K12** + **A64** + **U1**	*g*	70	102
E32 + **A23** + **U1**	*f*	54	112	**Am5** + **A18** + **U1**	*f*	71	112
E32 + **A60** + **U1**	*f*	53	112	**Am5** + **A23** + **U1**	*f*	70	112
E32 + **A64** + **U1**	*f*	52	112	**Am5** + **A60** + **U1**	*f*	63	112
K12 + **A18** + **U10**	*g*	77	102	**Am5** + **A64** + **U1**	*f*	68	112
K12 + **A23** + **U1**	*g*	78	102	**Am6** + **A18** + **U1**	*f*	69	112
K12 + **A23** + **U10**	*g*	79	102	**Am6** + **A23** + **U1**	*f*	71	112
K12 + **A34** + **U1**	*g*	69	102	**Am6** + **A60** + **U1**	*f*	62	112
				Am6 + **A64** + **U1**	*f*	63	112

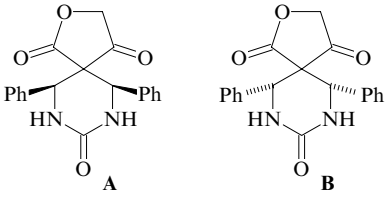
[a] In this case, two isomers are formed.

Note. Notation	Catalyst	Solvent	Other conditions	Reaction time /h
d	HCl	EtOH	Δ	3
f	–	–	80 °C	4
g	(TMS)Cl	DMF + MeCN	stirring	2

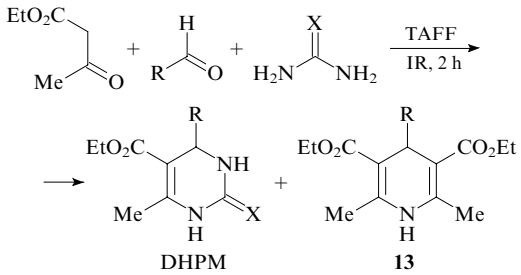


R = Ph, 4-MeC$_6$H$_4$, 4-FC$_6$H$_4$, 4-ClC$_6$H$_4$, 4-O$_2$NC$_6$H$_4$; X = O, S;
Z = CH$_2$O, OCMe$_2$O, NHC(O)NH, NMeC(O)NMe.

If dicarbonyl compound is non-symmetrical (for example, keto lactone **E31**), spiroheterocyclic compounds are formed as a stereoisomeric pair (**A** and **B**).[112]



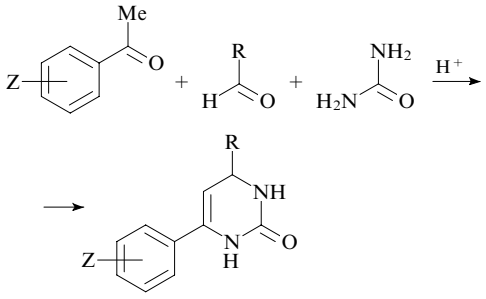
Another example of a side reaction is the Hantzsch condensation. Dihydropyridines **13** were obtained in low yields (6%–11%) together with dihydropyrimidinones as the major products.[45] Probably, urea or thiourea undergoes partial decomposition under the action of IR radiation to form ammonia; the latter reacts with aldehyde and ethyl acetoacetate resulting in the corresponding dihydropyridines.



R = Ph, 4-MeC$_6$H$_4$, 4-MeOC$_6$H$_4$, 2-ClC$_6$H$_4$; X = O, S.

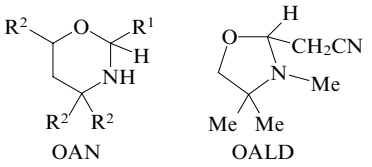
4. Miscellaneous methods for the synthesis of Biginelli compounds

Dihydropyrimidinone derivatives can also be synthesised by the three-component condensation of aromatic ketones, aldehydes and urea.[113,114] The reaction is catalysed by Lewis acids [FeCl$_3$, (TMS)Cl,[113] ZnI$_2$].[114]



R = Ph, 4-MeC$_6$H$_4$, 2-ClC$_6$H$_4$, 4-ClC$_6$H$_4$, 4-O$_2$NC$_6$H$_4$; Z = H, 4-Me, 4-Bu^t, 4-HO, 4-CHO, 2-MeO, 3-MeO, 4-MeO, 3-MeO-4-HO, 3,4-(MeO)$_2$, 2-Cl, 4-Cl, 3-Br, 2,4-Cl$_2$, 2,6-Cl$_2$, 3,5-Br$_2$-4-HO.

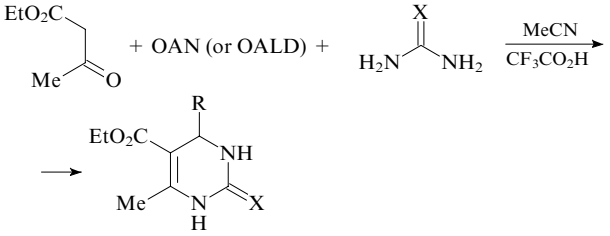
The formation of the Biginelli products was also observed, when oxazinanes (OAN) and oxazolidines (OALD) were used as a source of a one-carbon fragment instead of aromatic aldehydes.[115]



OAN OALD

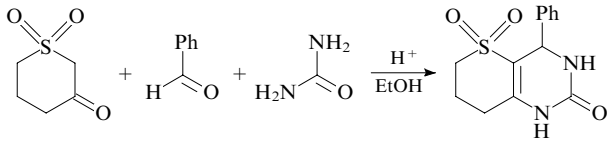
R^2 = H: R^1 = H, 4-$MeOC_6H_4$, 3,4-$(MeO)_2C_6H_3$, 3,4,5-$(MeO)_3C_6H_2$, 2-$O_2NC_6H_4$, 3-$O_2NC_6H_4$; R^2 = Me: R^1 = Me, Et, Ph, CH_2CO_2Et.

Application of these compounds allows the preparation of dihydropyrimidinones with fragments which are impossible to introduce using corresponding aldehydes due to their instability or low reactivity (aliphatic aldehydes)[71,82,95] of the latter under the conditions of the Biginelli reaction.



R = H, Me, Et, CH_2CO_2Et, CH_2CN, Ph, 2-$O_2NC_6H_4$, 3-$O_2NC_6H_4$, 4-$MeOC_6H_4$, 3,4-$(MeO)_2C_6H_3$; X = O, S.

Remarkably under these conditions, cyclic ketones also give the Biginelli products.[92,100–102] Thus tetrahydrothiopyran-3-one *S*,*S*-dioxide gave the corresponding dihydropyrimidinone in a yield of ~64%.[100]



* * *

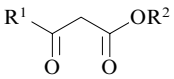
An analysis of the published data shows that at present there is a great number of experimental methods for performing the Biginelli reaction differing in the reactants, reaction conditions, catalysts, *etc*. It is noteworthy that the comparison of efficiency of different approaches is not a simple task, moreover, many exotic methods did not find wide application due to high cost and low availability of the corresponding reagents. The material considered in this review provides an idea on the progress in this very important reaction of synthetic organic chemistry.

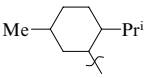
This work was performed with the financial support of the Russian Foundation for Basic Research (Project No. 07-03-00 613-a) and the State contract No. 02.512.11.2237 of the Federal target programme 'Research and Development of Priority Directions of Scientific and Technical Complex of Russia for 2007–2012'.

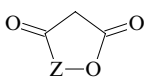
V. Supplements

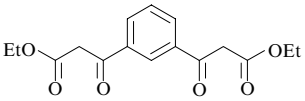
Supplement 1. Compound used in the Biginelli reaction.

a. Dicarbonyl compounds

Keto esters (**E**) 

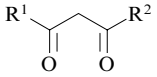
Compound	R^1	R^2	Compound	R^1	R^2	Compound	R^1	R^2
E1	Me	Me	**E10**	Me	$BnN(Ph)(CH_2)_2$	**E21**	CF_3	Et
E2	Me	Et	**E11**	Et	Me	**E22**	CHF_2CF_2	Me
E3	Me	Pr^i	**E12**	Et	Et	**E23**	n-C_3F_7	Me
E4	Me	Bu^t	**E13**	Pr^n	Et	**E24**	n-C_4F_9	Et
E5	Me	CH_2=CH	**E14**	cyclo-C_3H_5	Me	**E25**	$CHCl_2$	Me
			E15	Bu^t	Me	**E26**	CCl_3	Et
E6	Me		**E16**	Ph	Et	**E27**	ribosyl	Et
			E17	Ph	Bn	**E28**	galactosyl	Et
E7	Me	Ph	**E18**	$Ph(CH_2)_2$	Et	**E29**	mannosyl	Et
E8	Me	PhCH=$CHCH_2$	**E19**	$MeOCH_2$	Me	**E30**	indol-3-yl	Me
E9	Me	Ph_2CHCH_2	**E20**	CHF_2	Et			



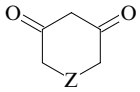
Z = CH_2 (**E31**), $OCMe_2$ (**E32**), *o*-phenylene (**E33**), 4-Me-1,2-phenylene (**E34**),  (**E35**).

Supplement 1 (continued).

Diketones (**K**)

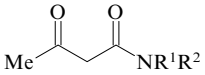


Compound	R^1	R^2	Compound	R^1	R^2	Compound	R^1	R^2
K1	Me	Me	**K5**	Me	Ph	**K9**	Ph	ferrocenyl
K2	CF_3	Me	**K6**	CF_3	Ph	**K10**	CF_3	2-thienyl
K3	CHF_2CF_2	Me	**K7**	CHF_2CF_2	Ph	**K11**	CF_3	CF_3
K4	Me	ferrocenyl	**K8**	$CHCl_2$	Ph			

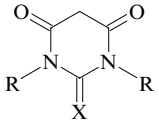


Z = CH_2 (**K12**), CMe_2 (**K13**).

Keto amides and their analogues (**Am**)

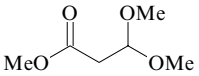


R^1 = H: R^2 = H (**Am1**), Me (**Am2**), Ph (**Am3**); R^1 = R^2 = Et (**Am4**).

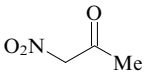


X = O: R = H (**Am5**), Me (**Am6**); X = S: R = H (**Am7**), Ph (**Am8**).

Equivalents of dicarbonyl compounds (**Eq**):



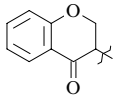
(**Eq1**),

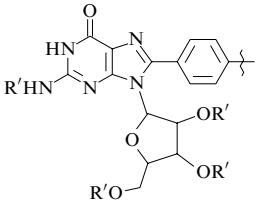


(**Eq2**).

b. Aldehydes (**A**)

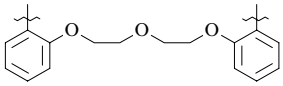
Monoaldehydes RCHO

Compound	R	Compound	R	Compound	R
A1	H	**A31**	4-$Me_2NC_6H_4$	**A61**	3,4-$F_2C_6H_3$
A2	Me	**A32**	2-$O_2NC_6H_4$	**A62**	2-ClC_6H_4
A3	Et	**A33**	3-$O_2NC_6H_4$	**A63**	3-ClC_6H_4
A4	Pr^n	**A34**	4-$O_2NC_6H_4$	**A64**	4-ClC_6H_4
A5	Pr^i	**A35**	2-O_2N-4-MeC_6H_3	**A65**	2,3-$Cl_2C_6H_3$
A6	Bu^n	**A36**	2-O_2N-5-ClC_6H_3	**A66**	2,4-$Cl_2C_6H_3$
A7	Bu^i	**A37**	2-HOC_6H_4	**A67**	3,4-$Cl_2C_6H_3$
A8	Bu^t	**A38**	3-HOC_6H_4	**A68**	3,5-$Cl_2C_6H_3$
A9	n-C_5H_{11}	**A39**	4-HOC_6H_4	**A69**	2-BrC_6H_4
A10	$Pr^nC(Me)H$	**A40**	2-HO-4-ClC_6H_3	**A70**	3-BrC_6H_4
A11	$CHEt_2$	**A41**	2-HO-4-BrC_6H_3	**A71**	4-BrC_6H_4
A12	cyclo-C_6H_{11}	**A42**	2-HO-5-BrC_6H_3	**A72**	4-IC_6H_4
A13	n-C_6H_{13}	**A43**	2-$MeOC_6H_4$	**A73**	1-naphthyl
A14	n-C_7H_{15}	**A44**	3-$MeOC_6H_4$	**A74**	2-naphthyl
A15	n-C_9H_{19}	**A45**	4-$MeOC_6H_4$	**A75**	anthracen-9-yl
A16	Bn	**A46**	2,4-$(MeO)_2C_6H_3$	**A76**	benzodioxol-5-yl
A17	$Ph(CH_2)_2$	**A47**	2,5-$(MeO)_2C_6H_3$	**A77**	ferrocenyl
A18	Ph	**A48**	3,4-$(MeO)_2C_6H_3$	**A78**	ribosyl
A19	PhCH═CH	**A49**	3,5-$(MeO)_2C_6H_3$	**A79**	galactosyl
A20	PhC≡C	**A50**	3,4,5-$(MeO)_3C_6H_2$	**A80**	mannosyl
A21	2-MeC_6H_4	**A51**	2-MeO-5-BrC_6H_3	**A81**	pyrrol-2-yl
A22	3-MeC_6H_4	**A52**	3-MeO-4-HOC_6H_3	**A82**	2-pyridyl
A23	4-MeC_6H_4	**A53**	3-MeO-4-HO-5-$O_2NC_6H_2$	**A83**	indol-2-yl
A24	2,5-$Me_2C_6H_3$	**A54**	2-$EtOC_6H_4$	**A84**	2-furyl
A25	2-$(CH_2$═$CH)C_6H_4$	**A55**	3,4-$(EtO)_2C_6H_3$	**A85**	3-furyl
A26	2-$(CH_2$═$CHCH_2)C_6H_4$	**A56**	3-(cyclo-C_5H_9)O-4-$MeOC_6H_3$	**A86**	3-nitrofuran-2-yl
A27	4-NCC_6H_4	**A57**	3-$PhOC_6H_4$		
A28	see [a]	**A58**	2-FC_6H_4	**A87**	
A29	2-$F_3CC_6H_4$	**A59**	3-FC_6H_4		
A30	4-$F_3CC_6H_4$	**A60**	4-FC_6H_4		
				A88	2-thienyl

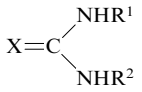
[a] R =  (R′ = $Pr^iC(O)$).

Supplement 1 (continued).

Dialdehydes $Z(CHO)_2$

Z is *m*-phenylene (**A89**), *p*-phenylene (**A90**),  (**A91**).

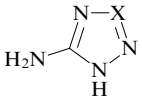
c. Ureas and their equivalents (**U**)

Ureas and thioureas 

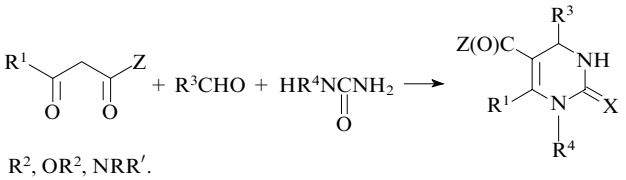
Compound (X = O)	R^1	R^2	Compound (X = S)	R^1	R^2
U1 [a]	H	H	**U10** [a]	H	H
U2	H	Me	**U11**	H	Me
U3	H	All	**U12**	H	Ph
U4	H	Ph	**U13**	H	2-$F_3CC_6H_4$
U5	H	Bn	**U14**	H	4-FC_6H_4
U6	H	ribosyl			
U7	H	galactosyl			
U8	H	mannosyl			
U9	Me	Me			

[a] Urea (**U1**) and thiourea (**U10**) were sometimes used as hydrogensulfates $X{=}C(NH_2)(NH_3^+)HSO_4^-$. In these cases, they are denoted in Supplement 2 as **U1*** and **U10***, respectively. Final products were isolated as free bases, that is why the use of **U1** and **U1*** as reagents (and also **U10** and **U10***) resulted in the same dihydropyrimidinone.

Bisurea (**U15**) $H_2NC(O)NH(CH_2)_2O(CH_2)_2$.

Urea equivalents  X = CH (**U16**), N (**U17**).

Supplement 2. The versions of performing the one-pot Biginelli reaction.



Z = R^2, OR^2, NRR'.

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E1 + **A4** + **U1**	Pro-Me · HCl	EtOH	Δ	18 h	63	95
E1 + **A5** + **U1**	CH_2ClCO_2H	–	90 °C	5 h	50	82
	VCl_3	MeCN	Δ	2 h	80	86
E1 + **A18** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	51	6
	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	3 h	90	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	3 h	88	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	3 h	70	10
	Mont. KSF	MeOH	Δ	8 – 10 h	90	15
	Yb^{III}-Resin	–	120 °C	48 h	71	16
	I_2	MeCN	Δ	6.5 h	93	18
	SSA	EtOH	Δ	6 h	96	20
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	88	21
	H_2SO_4	EtOH	Δ	18 h	42	21
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	86	22
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	86	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	92	23
	$InCl_3$	THF	Δ	9 h	91	26
	$LiClO_4$ or LiOTf	MeCN	Δ	6 h	90	28
	$Bi(OTf)_3$	MeCN	stirring	1.5 h	85	31
	(TMS)OTf	MeCN	room temperature, stirring	20 min	90	32

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E1 + A18 + U1	bmim[$AlCl_4$]	–	120 – 125 °C	1 h	78	34
	–	–	100 – 105 °C	1 h	80	36
	$Yb(OTf)_3$	–	100 °C	20 min	98	62
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	97	63
	$InBr_3$	EtOH	Δ	7 h	98	66
	NH_4Cl	–	100 °C	3 h	92	71
	$Sr(OTf)_2$	–	70 °C	4 h	93	79
	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	2.5 h	94	80
	CH_2ClCO_2H	–	90 °C	3 h	92	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	93	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	85	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	86	83
	VCl_3	MeCN	Δ	2 h	92	86
	BDMPEAB	–	100 °C	30 min	98	90
	NH_4Br	–	100 °C	30 min	87	90
	–	–	100 °C	30 min	81	90
	(TMS)Cl	DMF	20 °C	14 h	62	93
	Pro-Me · HCl	EtOH	Δ	18 h	99	95
E1 + A18 + U1*	–	–	65 °C	2 h	93	97
E1 + A18 + U10	I_2	MeCN	Δ	6 h	91	18
	$[NHEt_3][PF_6]$	–	120 – 125 °C	1 h	83	34
	CH_2ClCO_2H	–	90 °C	5 h	83	82
	VCl_3	MeCN	Δ	2 h	85	86
E1 + A21 + U1	$Yb(OTf)_3$	EtOH	100 °C	10 min	73	27
E1 + A23 + U1	$InBr_3$	EtOH	Δ	7 h	97	66
	CH_2ClCO_2H	–	90 °C	3 h	93	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	96	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	94	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	96	83
	CNSP	H_2O	80 °C	4.5 h	89	88
	BDMPEAB	–	100 °C	60 min	98	90
	NH_4Br	–	100 °C	60 min	85	90
	–	–	100 °C	60 min	80	90
E1 + A23 + U10	$LaCl_3$	EtOH	120 °C	20 min	58	27
E1 + A24 + U1	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	96	21
	H_2SO_4	EtOH	Δ	18 h	62	21
E1 + A27 + U2	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	81	96
E1 + A30 + U1	Yb^{III}-Resin	–	120 °C	48 h	65	16
E1 + A31 + U1	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	4 h	88	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	4 h	82	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	4 h	68	10
	(TMS)OTf	MeCN	room temperature, stirring	15 min	88	32
	$Sr(OTf)_2$	–	70 °C	4 h	90	79
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	88	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	80	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	82	83
E1 + A31 + U10	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	4 h	86	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	4 h	84	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	4 h	69	10
	(TMS)OTf	MeCN	room temperature, stirring	20 min	86	32
E1 + A32 + U1	H_3BO_3	AcOH	100 °C	0.5 – 2 h	95	74
	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	10 h	81	80
	VCl_3	MeCN	Δ	2 h	87	86
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	90	92
E1 + A32 + U10	VCl_3	MeCN	Δ	2 h	80	86
E1 + A33 + U1	NH_4Cl	–	100 °C	3 h	80	71
	$Sr(OTf)_2$	–	70 °C	4 h	93	79
E1 + A34 + U1	Yb^{III}-Resin	–	120 °C	48 h	61	16
	I_2	MeCN	Δ	7 h	90	18
	SSA	EtOH	Δ	6 h	95	20
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	92	21

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E1 + **A34** + **U1**	H_2SO_4	EtOH	Δ	18 h	41	21
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	4 h	88	22
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	4 h	87	23
	$NiCl_2 \cdot 6H_2O$, HCl	EtOH	Δ	5 h	90	23
	$InCl_3$	THF	Δ	6 h	91	26
	$Bi(OTf)_3$	MeCN	stirring	2 h	87	31
	$Yb(OTf)_3$	–	100 °C	20 min	91	62
	$LaCl_3 \cdot 7H_2O$, HCl	EtOH	Δ	5 h	68	63
	$InBr_3$	EtOH	Δ	7 h	72	66
	NH_4Cl	–	100 °C	3 h	79	71
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	92	74
	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	4 h	86	80
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	75	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	69	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	73	83
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	93	92
	Pro-Me · HCl	EtOH	Δ	18 h	68	95
E1 + **A34** + **U1***	–	–	65 °C	3 h	92	97
E1 + **A34** + **U9**	Dowex-50W	–	130 °C	3 h	62	84
E1 + **A36** + **U1**	H_3BO_3	AcOH	100 °C	0.5 – 2 h	90	74
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	89	92
E1 + **A39** + **U1**	VCl_3	MeCN	Δ	2 h	90	86
	BDMPEAB	–	100 °C	45 min	99	90
	NH_4Br	–	100 °C	45 min	90	90
	–	–	100 °C	45 min	80	90
E1 + **A43** + **U1**	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	4 h	73	80
	$FeCl_3$, $Si(OEt)_4$	cyclo-$C_6H_{11}OH$	Δ	3 h	88	90
E1 + **A44** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	71	16
	$Sr(OTf)_2$	–	70 °C	4 h	89	79
	Pro-Me · HCl	EtOH	Δ	18 h	82	95
E1 + **A45** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	43	6
	Yb^{III}-Resin	–	120 °C	48 h	71	16
	I_2	MeCN	Δ	6.5 h	88	18
	SSA	EtOH	Δ	6 h	95	20
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	87	21
	H_2SO_4	EtOH	Δ	18 h	28	21
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	4 h	88	22
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	4 h	88	23
	$NiCl_2 \cdot 6H_2O$, HCl	EtOH	Δ	5 h	85	23
	$InCl_3$	THF	Δ	7 h	92	26
	$Bi(OTf)_3$	MeCN	stirring	1.75 h	88	31
	$Yb(OTf)_3$	–	100 °C	20 min	99	62
	$LaCl_3 \cdot 7H_2O$, HCl	EtOH	Δ	5 h	82	63
	$InBr_3$	EtOH	Δ	7 h	94	66
	NH_4Cl	–	100 °C	3 h	90	71
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	94	74
	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	4 h	92	80
	CH_2ClCO_2H	–	90 °C	3 h	97	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	97	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	90	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	95	83
	VCl_3	MeCN	Δ	2 h	88	86
	CNSP	H_2O	80 °C	5 h	87	88
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	90	92
	Pro-Me · HCl	EtOH	Δ	18 h	86	95
E1 + **A45** + **U1***	–	–	65 °C	3 h	83	97
E1 + **A46** + **U1**	$CeCl_3 \cdot 7H_2O$	EtOH	Δ	2.5 h	95	11
	$CeCl_3 \cdot 7H_2O$	H_2O	Δ	2.5 h	90	11
	$CeCl_3 \cdot 7H_2O$	–	Δ	2.5 h	75	11
	(TMS)OTf	MeCN	room temperature, stirring	15 min	95	32
E1 + **A50** + **U1**	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	62	27

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E1 + **A51** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	89	96
E1 + **A52** + **U1**	$Sr(OTf)_2$	–	70 °C	4 h	85	79
	Pro-Me · HCl	EtOH	Δ	18 h	70	95
E1 + **A53** + **U1**	$Sr(OTf)_2$	–	70 °C	4 h	88	79
E1 + **A57** + **U1**	VCl_3	MeCN	Δ	2 h	86	86
E1 + **A60** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	70	16
	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	81	27
	$Yb(OTf)_3$	–	100 °C	20 min	81	62
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	89	74
	VCl_3	MeCN	Δ	2 h	86	86
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	87	92
E1 + **A61** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	36	6
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	88	21
	H_2SO_4	EtOH	Δ	18 h	62	21
E1 + **A62** + **U1**	NH_4Cl	–	100 °C	3 h	85	71
E1 + **A63** + **U1**	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	88	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	83	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	90	83
E1 + **A64** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	71	16
	I_2	MeCN	Δ	7 h	89	18
	SSA	EtOH	Δ	6 h	94	20
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	95	21
	H_2SO_4	EtOH	Δ	18 h	56	21
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	96	22
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	96	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	94	23
	$InCl_3$	THF	Δ	6 h	93	26
	–	–	100 – 105 °C	1 h	83	36
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	96	63
	$InBr_3$	EtOH	Δ	7 h	93	66
	NH_4Cl	–	100 °C	3 h	85	71
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	98	74
	$Sr(OTf)_2$	–	70 °C	4 h	93	79
	CH_2ClCO_2H	–	90 °C	3 h	97	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	90	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	85	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	91	83
	VCl_3	MeCN	Δ	2 h	65	86
	BDMPEAB	–	100 °C	40 min	97	90
	NH_4Br	–	100 °C	40 min	86	90
	–	–	100 °C	40 min	79	90
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	95	92
E1 + **A64** + **U1***	–	–	65 °C	3 h	94	97
E1 + **A64** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	92	96
E1 + **A66** + **U1**	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	4 h	90	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	4 h	84	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	4 h	70	10
	SSA	EtOH	Δ	6 h	96	10
	(TMS)OTf	MeCN	room temperature, stirring	18 min	90	32
	$Yb(OTf)_3$	–	100 °C	20 min	83	62
	CH_2ClCO_2H	–	90 °C	3 h	93	82
E1 + **A66** + **U1***	–	–	65 °C	2.5 h	95	97
E1 + **A68** + **U10**	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	87	40
E1 + **A69** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	68	16
E1 + **A71** + **U1**	Pro-Me · HCl	EtOH	Δ	18 h	69	95
E1 + **A73** + **U1**	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	4 h	86	80
E1 + **A73** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	84	96
E1 + **A75** + **U1**	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	19 h	95	80
E1 + **A76** + **U1**	VCl_3	MeCN	Δ	2 h	82	86
E1 + **A77** + **U1**	$InCl_3 \cdot 4\,H_2O$	EtOH	Δ	6 h	68	98
E1 + **A82** + **U1**	$Bi(OTf)_3$	MeCN	stirring	3 h	89	31

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E1 + A86 + U1	$Yb(OTf)_3$	EtOH	100 °C	10 min	34	27
E1 + A88 + U1	bmim[$AlCl_4$]	–	120 – 125 °C	1 h	80	34
	VCl_3	MeCN	Δ	2 h	85	86
E1 + A88 + U2	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	82	96
E1 + A88 + U10	bmim[$AlCl_4$]	–	120 – 125 °C	1 h	84	34
	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	85	96
E2 + A1 + U1	$InBr_3$	EtOH	Δ	7 h	80	66
E2 + A1 + U10	$InBr_3$	EtOH	Δ	7 h	70	66
E2 + A2 + U1	PPE	THF	Δ	24 h	53	7
	$InCl_3$	THF	Δ	7 h	75	26
	$Yb(OTf)_3$	EtOH	100 °C	20 min	67	27
	HCl	EtOH	US	2 – 5 min	92	64
	$InBr_3$	EtOH	Δ	7 h	75	66
	NH_4Cl	–	100 °C	3 h	42	71
E2 + A3 + U1	ZnI_2	MeCN	80 °C, 300 MPa	4 h	73	25
E2 + A4 + U1	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	4 h	83	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	4 h	76	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	4 h	73	10
	I_2	PhMe	Δ	4.2 h	76	17
	I_2	MeCN	Δ	7 h	79	18
	SSA	EtOH	Δ	6 h	86	20
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	73	22
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	72	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	64	23
	ZnI_2	MeCN	80 °C, 300 MPa	4 h	37	25
	$InCl_3$	THF	Δ	7 h	85	26
	(TMS)OTf	MeCN	room temperature, stirring	20 min	83	32
	–	–	100 – 105 °C	1 h	78	36
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	60	63
	NH_2SO_3H	EtOH	US, 20 – 30 °C	1 h	70	69
	NH_4Cl	–	100 °C	3 h	78	71
	CH_2ClCO_2H	–	90 °C	5 h	75	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	57	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	55	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	54	83
	BDMPEAB	–	100 °C	25 min	86	90
	NH_4Br	–	100 °C	25 min	64	90
	–	–	100 °C	25 min	52	90
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	85	92
E2 + A4 + U1*	–	–	65 °C	2 h	91	97
E2 + A4 + U10	I_2	MeCN	Δ	6.5 h	82	18
	ZnI_2	MeCN	80 °C, 300 MPa	4 h	11	25
E2 + A5 + U1	ZnI_2	MeCN	80 °C, 300 MPa	4 h	77	25
	(TMS)OTf	MeCN	room temperature, stirring	25 min	80	32
	CH_2ClCO_2H	–	90 °C	5 h	47	82
	VCl_3	MeCN	Δ	2 h	87	86
	CNSP	H_2O	80 °C	5.5 h	76	88
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	86	92
	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	77	96
E2 + A6 + U1	Mont. KSF	–	130 °C	48 h	86	14
	$Yb(OTf)_3$	–	100 °C	40 min	87	62
	NH_4Cl	–	100 °C	3 h	65	71
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	110 min	80	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1.5 min	80	73
	$CuSO_4 \cdot 5\,H_2O$	–	100 °C	110 min	85	73
	$CuSO_4 \cdot 5\,H_2O$	–	μν	1.5 min	85	73
	$ZnCl_2$	–	80 °C	40 min	38	75
E2 + A7 + U1	ZnI_2	MeCN	80 °C, 300 MPa	4 h	55	25
E2 + A8 + U10	ZnI_2	MeCN	80 °C, 300 MPa	4 h	10	25
E2 + A9 + U1	I_2	MeCN	Δ	7 h	80	18
	$LiClO_4$ or LiOTf	MeCN	Δ	7 h	82	28

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + **A9** + **U1**	LiBr	MeCN	Δ	4 h	72	68
	PABC	EtOH	Δ	4 h	86	76
	$Cu(NTf_2)_2$	H_2O	stirring	24 h	80	78
	$Yb(NTf_2)_2$	H_2O	stirring	71 h	55	78
	$RuCl_3$	–	100 °C	90 min	76	81
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	50	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	47	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	52	83
	bmim[BF_4]	–	100 °C	30 min	93	87
	BDMPEAB	–	100 °C	65 min	92	90
	NH_4Br	–	100 °C	65 min	79	90
	–	–	100 °C	65 min	66	90
E2 + **A10** + **U1**	ZnI_2	MeCN	80 °C, 300 MPa	4 h	60	25
E2 + **A11** + **U1**	ZnI_2	MeCN	80 °C, 300 MPa	4 h	77	25
E2 + **A12** + **U1**	$LiClO_4$ or LiOTf	MeCN	Δ	8 h	87	28
	$Bi(OTf)_3$	MeCN	stirring	3.5 h	83	31
	CAN	MeOH	US	3.5	87	35
	(TMS)Cl, NaI	MeCN	stirring	45 min	84	67
	$Cu(OTf)_2$	MeCN	70 °C	12 h	60	70
	$CdCl_2$	MeCN	Δ	6 h	82	77
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	68	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	61	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	65	83
E2 + **A13** + **U1**	I_2	PhMe	Δ	4.1 h	69	17
	SSA	EtOH	Δ	6 h	84	20
	$InCl_3$	THF	Δ	8 h	81	26
	$Bi(OTf)_3$	MeCN	stirring	4 h	58	31
	CAN	MeOH	US	3.5 h	85	25
	–	–	100 – 105 °C	1 h	80	26
	NH_2SO_3H	EtOH	US, 0 – 30 °C	1 h	89	67
	$RuCl_3$	–	100 °C	95 min	74	82
	BDMPEAB	–	100 °C	55 min	93	90
	NH_4Br	–	100 °C	55 min	86	90
	–	–	100 °C	55 min	75	90
	PPAA	EtOAc	Δ	6 h	53	91
	(TMS)Cl	DMF	20 °C	14 h	37	93
E2 + **A13** + **U1***	–	–	65 °C	2 h	89	97
E2 + **A13** + **U10**	I_2	MeCN	Δ	7 h	83	18
	$CdCl_2$	MeCN	Δ	6 h	82	77
E2 + **A14** + **U1**	(TMS)Cl	DMF	20 °C	14 h	32	93
E2 + **A15** + **U1**	$Cu(OTf)_2$	MeCN	70 °C	12 h	60	70
	BDMPEAB	–	100 °C	65 min	91	90
	NH_4Br	–	100 °C	65 min	78	90
	–	–	100 °C	65 min	68	90
E2 + **A16** + **U1**	CAN	MeOH	US	6 h	91	33
	$Yb(OTf)_3$	THF	stirring	–	82	89
E2 + **A17** + **U1**	$LiClO_4$ or LiOTf	MeCN	Δ	7 h	81	28
E2 + **A18** + **U1**	$ZrCl_4$	EtOH	Δ	4 h	90	98
E2 + **A18** + **U1***	–	–	65 °C	2 h	93	97
E2 + **A18** + **U2**	PPE	THF	Δ	24 h	95	7
	PPE	–	μν	90 s	89	11
	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	18	27
	(TMS)Cl	DMF	20 °C	14 h	73	93
	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	85	96
E2 + **A18** + **U5**	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	43	27
	PPE	THF	Δ	24 h	91	28
E2 + **A18** + **U6**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	48	43
E2 + **A18** + **U7**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	41	43
E2 + **A18** + **U8**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	40	43
E2 + **A18** + **U9**	Dowex-50W	–	130 °C	3 h	59	43
E2 + **A18** + **U10**	PPE	–	μν	90 s	82	11

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + A18 + U10	I_2	MeCN	Δ	6.5 h	92	18
	TsOH	H_2O	stirring	15 min	81	19
	SSA	EtOH	Δ	6 h	93	20
	$InCl_3$	THF	Δ	9 h	91	26
	$LaCl_3$	AcOH + EtOH	120 °C	10 min	56	27
	–	EtOH	μν	3 min	44	42
	Al_2O_3	–	μν	9 min	85	42
	–	–	μν	2.5 min	90	42
	TAFF	–	IR	2 h	45	45
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	96	63
	HCl	EtOH	US	2 – 5 min	90	64
	$InBr_3$	EtOH	Δ	7 h	94	66
	(TMS)Cl, NaI	MeCN	stirring	30 min	90	67
	LiBr	MeCN	Δ	3 h	85	68
	NH_4Cl	–	100 °C	3 h	88	71
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	60 min	97	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1.5 min	88	73
	$CuSO_4 \cdot 5\,H_2O$	–	100 °C	70 min	97	73
	$CuSO_4 \cdot 5\,H_2O$	–	μν	1.5 min	88	73
	$Sr(OTf)_2$	–	70 °C	4 h	92	79
	$RuCl_3$	–	100 °C	50 min	86	81
	CH_2ClCO_2H	–	90 °C	5 h	84	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	94	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	86	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	91	83
	$PhB(OH)_2$	MeCN	Δ	18 h	60	85
	VCl_3	MeCN	Δ	2 h	92	86
	$Yb(OTf)_3$	THF	stirring	–	81	89
	BDMPEAB	–	100 °C	53 min	93	90
	NH_4Br	–	100 °C	53 min	77	90
	–	–	100 °C	53 min	75	90
	PPAA	EtOAc	Δ	6 h	80	91
	$ZrCl_4$	EtOH	Δ	5 h	90	98
E2 + A18 + U10*	–	–	65 °C	2 h	91	97
E2 + A18 + U11	PPE	–	μν	90 s	78	11
	$LaCl_3$	EtOH	120 °C	10 min	41	27
E2 + A18 + U13	–	EtOH	μν, Δ	11 min	86.4	38
E2 + A18 + U14	–	EtOH	μν, Δ	6 min	82.4	38
E2 + A19 + U1	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	4.5 h	88	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	4.5 h	83	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	4.5 h	77	10
	Mont. KSF	–	130 °C	48 h	70	14
	I_2	MeCN	Δ	7 h	82	18
	SSA	EtOH	Δ	6 h	90	20
	$Yb(OTf)_3$	–	100 °C	20 min	81	22
	$InCl_3$	THF	Δ	9 h	90	26
	$LiClO_4$ or LiOTf	MeCN	Δ	7 h	83	28
	$Bi(OTf)_3$	MeCN	stirring	1.5 h	82	31
	(TMS)OTf	MeCN	room temperature, stirring	15 min	88	32
	CAN	MeOH	US	4 h	85	35
	–	–	100 – 105 °C	1 h	78	36
	HCl	EtOH	US	2 – 5 min	95	64
	$InBr_3$	EtOH	Δ	7 h	68	66
	(TMS)Cl, NaI	MeCN	stirring	45 min	85	67
	LiBr	MeCN	Δ	5 h	81	68
	NH_2SO_3H	EtOH	US, 20 – 30 °C	25 min	90	69
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	100 min	82	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1 min	85	73
	$CuSO_4 \cdot 5\,H_2O$	–	100 °C	110 min	82	73
	$CuSO_4 \cdot 5\,H_2O$	–	μν	1 min	85	73
	$ZnCl_2$	–	80 °C	60 min	36	75

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + A19 + U1	PABC	EtOH	Δ	4 h	98	76
	$CdCl_2$	MeCN	Δ	4 h	82	77
	$RuCl_3$	–	100 °C	55 min	89	81
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	90	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	89	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	88	83
	$Yb(OTf)_3$	THF	stirring	–	81	89
	$ZrCl_4$	EtOH	Δ	6 h	83	98
E2 + A19 + U1*	–	–	65 °C	2 h	96	97
E2 + A20 + U1	PPE	THF	Δ	24 h	92	7
E2 + A21 + U1	PPE	–	μν	90 s	86	11
	$InBr_3$	EtOH	Δ	7 h	94	66
	NH_4Cl	–	100 °C	3 h	81	71
	$Cu(NTf_2)_2$	H_2O	stirring	24 h	77	78
E2 + A22 + U1	$PhB(OH)_2$	MeCN	Δ	18 h	75	85
E2 + A23 + U1	Mont. KSF	MeOH	Δ	8 – 10 h	88	15
	I_2	PhMe	Δ	3 h	89	17
	I_2	MeCN	Δ	7 h	86	18
	$LiClO_4$ or LiOTf	MeCN	Δ	7 h	89	28
	TAFF	–	IR	2 h	50	45
	$InBr_3$	EtOH	Δ	7 h	98	66
	(TMS)Cl, NaI	MeCN	stirring	45 min	89	67
	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	87	69
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	60 min	95	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1 min	97	73
	PABC	EtOH	Δ	4 h	96	76
	$CdCl_2$	MeCN	Δ	3.3 h	90	77
	$Sr(OTf)_2$	–	70 °C	4 h	87	79
	$RuCl_3$	–	100 °C	50 min	90	81
	CH_2ClCO_2H	–	90 °C	3 h	86	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	95	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	92	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	94	83
	$PhB(OH)_2$	MeCN	Δ	18 h	70	85
	CNSP	H_2O	80 °C	5 h	88	88
	BDMPEAB	–	100 °C	61 min	97	90
	NH_4Br	–	100 °C	61 min	86	90
	–	–	100 °C	61 min	85	90
	PPAA	EtOAc	Δ	6 h	69	91
	$ZrCl_4$	EtOH	Δ	4 h	88	98
E2 + A23 + U10	$Bi(OTf)_3$	MeCN	stirring	2 h	90	31
	TAFF	–	IR	2 h	53	45
	$InBr_3$	EtOH	Δ	7 h	94	66
	$Sr(OTf)_2$	–	70 °C	4 h	92	79
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	96	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	93	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	94	83
E2 + A25 + U1	HCl	MeOH	Δ	15 h	–	8
E2 + A26 + U1	HCl	MeOH	Δ	15 h	39	8
E2 + A28 + U1	I_2	PhMe	Δ	3 – 5 h	–	17
E2 + A29 + U1	PPE	THF	Δ	24 h	68	7
	PPE	–	μν	90 s	76	11
E2 + A30 + U1	Yb^{III}-Resin	–	120 °C	48 h	70	16
	$Bi(OTf)_3$	MeCN	stirring	2 h	85	31
	$Yb(OTf)_3$	–	100 °C	40 min	87	62
	PPAA	EtOAc	Δ	6 h	73	91
E2 + A31 + U1	$FeCl_3 \cdot 6\,H_2O$	EtOH	Δ	4 h	80	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	81	23
	$Bi(OTf)_3$	MeCN	stirring	2 h	92	31
	CAN	MeOH	US	4 h	88	35
	$Cu(OTf)_2$	MeCN	50 °C	9 h	65	70

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + A31 + U1	H_3BO_3	AcOH	100 °C	0.5 – 2 h	86	74
	PABC	EtOH	Δ	6 h	93	76
	$CdCl_2$	MeCN	Δ	4.3 h	88	77
	$Sr(OTf)_2$	–	70 °C	4 h	93	79
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	94	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	90	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	96	83
	PPAA	EtOAc	Δ	6 h	16	91
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	86	92
	$ZrCl_4$	EtOH	Δ	6 h	90	98
E2 + A31 + U9	Dowex-50W	–	130 °C	3 h	27	84
E2 + A31 + U10	$Sr(OTf)_2$	–	70 °C	4 h	86	79
E2 + A32 + U1	PPE	THF	Δ	24 h	84	7
	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	5 h	82	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	5 h	78	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	5 h	65	10
	I_2	PhMe	Δ	3.5 h	80	17
	SSA	EtOH	Δ	6 h	87	20
	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	54	27
	$Mn(OAc)_3 \cdot 2\,H_2O$	MeCN	Δ	4 h	77	29
	(TMS)OTf	MeCN	room temperature, stirring	20 min	82	32
	(TMS)Cl, NaI	MeCN	stirring	1 h	90	67
	VCl_3	MeCN	Δ	2 h	90	86
	BDMPEAB	–	100 °C	65 min	99	90
	NH_4Br	–	100 °C	65 min	85	90
	–	–	100 °C	65 min	82	90
E2 + A32 + U1*	–	–	65 °C	2.5 h	92	97
E2 + A32 + U9	Dowex-50W	–	130 °C	3 h	62	84
E2 + A32 + U10	(TMS)Cl, NaI	MeCN	stirring	1 h	85	67
	VCl_3	MeCN	Δ	2 h	85	86
E2 + A33 + U1	PPE	THF	Δ	24 h	87	7
	PPE	–	μν	90 s	93	11
	I_2	PhMe	Δ	3.4 h	92	17
	SSA	EtOH	Δ	6 h	93	20
	$Mn(OAc)_3 \cdot 2\,H_2O$	MeCN	Δ	4 h	75	29
	NH_2SO_3H	EtOH	US, 20 – 30 °C	30 min	91	69
	$Cu(OTf)_2$	MeCN	60 °C	9 h	75	70
	NH_4Cl	–	100 °C	3 h	80	71
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	60 min	86	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1.5 min	88	73
	$ZnCl_2$	–	80 °C	20 min	72	75
	$CdCl_2$	MeCN	Δ	3.3 h	92	77
	$Sr(OTf)_2$	–	70 °C	4 h	94	79
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	89	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	80	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	90	83
	Dowex-50W	–	130 °C	3 h	93	84
	$PhB(OH)_2$	MeCN	Δ	18 h	75	85
	$Yb(OTf)_3$	THF	stirring	–	90	89
E2 + A33 + U1*	–	–	65 °C	3 h	92	97
E2 + A33 + U2	HCl	MeOH	Δ	4 h	60	9
	$InBr_3$	EtOH	Δ	7 h	95	66
	Dowex-50W	–	130 °C	3 h	63	84
E2 + A33 + U4	HCl	MeOH	Δ	6 h	52	9
E2 + A33 + U9	Dowex-50W	–	130 °C	3 h	58	84
E2 + A33 + U10	PPE	–	μν	90 s	71	11
	SSA	EtOH	Δ	6 h	92	20
	–	EtOH	μν, Δ	4 min	78	38
	NH_4Cl	–	100 °C	3 h	78	71
	$Sr(OTf)_2$	–	70 °C	4 h	92	79
	$Yb(OTf)_3$	THF	stirring	–	88	89

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + **A33** + **U10***	–	–	65 °C	3 h	93	97
E2 + **A33** + **U14**	–	EtOH	μν, Δ	7 min	70	38
E2 + **A34** + **U1**	PPE	THF	Δ	24 h	77	7
	PPE	–	μν	90 s	86	11
	Mont. KSF	MeOH	Δ	8 – 10 h	89	15
	Yb^{III}-Resin	–	120 °C	48 h	72	16
	I_2	PhMe	Δ	4.7 h	89	17
	I_2	MeCN	Δ	7.5 h	89	18
	TsOH	H_2O	stirring	15 min	90	19
	SSA	EtOH	Δ	6 h	94	20
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	91	21
	H_2SO_4	EtOH	Δ	18 h	54	21
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	83	22
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	83	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	86	23
	$InCl_3$	THF	Δ	6 h	93	26
	$LiClO_4$ or LiOTf	MeCN	Δ	5 h	90	28
	$Bi(OTf)_3$	MeCN	stirring	2 h	85	31
	CAN	MeOH	US	7 h	85	35
	–	–	100 – 105 °C	1 h	85	36
	$Yb(OTf)_3$	–	100 °C	20 min	94	62
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	80	63
	$InBr_3$	EtOH	Δ	7 h	86	66
	(TMS)Cl, NaI	MeCN	stirring	1 h	86	67
	LiBr	MeCN	Δ	5 h	93	68
	NH_2SO_3H	EtOH,	US, 20 – 30 °C	40 min	94	69
	$Cu(OTf)_2$	MeCN	70 °C	12 h	60	70
	NH_4Cl	–	100 °C	3 h	83	71
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	60 min	90	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1 min	92	73
	$CuSO_4 \cdot 5\,H_2O$	–	100 °C	70 min	90	73
	$CuSO_4 \cdot 5\,H_2O$	–	μν	1 min	92	73
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	89	74
	$ZnCl_2$	–	80 °C	12 min	85	75
	PABC	EtOH	Δ	6 h	93	76
	$CdCl_2$	MeCN	Δ	5.3 h	89	77
	$Sr(OTf)_2$	–	70 °C	4 h	98	79
	$RuCl_3$	–	100 °C	72 min	84	81
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	90	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	86	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	91	83
	bmim[BF_4]	–	100 °C	30 min	92	87
	bmim[PF_6]	–	100 °C	30 min	90	87
	CNSP	H_2O	80 °C	5 h	84	88
	BDMPEAB	–	100 °C	45 min	98	90
	NH_4Br	–	100 °C	45 min	89	90
	–	–	100 °C	45 min	83	90
	PPAA	EtOAc	Δ	6 h	74	91
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	92	92
	$ZrCl_4$	EtOH	Δ	6 h	88	98
E2 + **A34** + **U1***	–	–	65 °C	3 h	96	97
E2 + **A34** + **U2**	Dowex-50W	–	130 °C	3 h	69	84
	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	89	96
E2 + **A34** + **U9**	Dowex-50W	–	130 °C	3 h	65	84
E2 + **A34** + **U10**	I_2	MeCN	Δ	7 h	90	18
	$InBr_3$	EtOH	Δ	7 h	70	66
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	86	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	80	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	87	83
E2 + **A35** + **U1**	$Cu(OTf)_2$	MeCN	60 °C	9 h	70	70
E2 + **A37** + **U1**	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	61	23

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + **A37** + **U1**	$NiCl_2 \cdot 6H_2O$, HCl	EtOH	Δ	5 h	58	23
	$InCl_3$	THF	Δ	7 h	91	26
	$LaCl_3 \cdot 7H_2O$, HCl	EtOH	Δ	5 h	76	63
	LiBr	MeCN	Δ	4.75 h	82	68
	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	91	69
	$Cu(OTf)_2$	MeCN	50 °C	6 h	80	70
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	86	74
	I_2	MeCN	Δ	8 h	71	75
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	52	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	57	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	60	83
	$Yb(OTf)_3$	THF	stirring	–	86	89
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	86	92
E2 + **A38** + **U1**	SSA	EtOH	Δ	6 h	93	20
	$InCl_3$	THF	Δ	9 h	88	26
	$InBr_3$	EtOH	Δ	7 h	90	66
	LiBr	MeCN	Δ	5 h	88	68
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	73	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	70	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	71	83
	$Yb(OTf)_3$	THF	stirring	–	81	89
E2 + **A38** + **U1***	–	–	65 °C	3 h	91	97
E2 + **A38** + **U9**	Dowex-50W	–	130 °C	3 h	38	84
E2 + **A38** + **U10**	PPE	–	μν	10 – 20 s	60	12
	I_2	MeCN	Δ	8 h	76	18
	$Yb(OTf)_3$	EtOH	100 °C	20 min	45	27
	(TMS)OTf	MeCN	room temperature, stirring	15 min	95	32
	$RuCl_3$	–	100 °C	65 min	89	81
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	71	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	68	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	62	83
	$Yb(OTf)_3$	THF	stirring	–	80	89
E2 + **A38** + **U10***	–	–	65 °C	3 h	90	97
E2 + **A39** + **U1**	Mont. KSF	–	130 °C	48 h	88	14
	TsOH	H_2O	stirring	15 min	92	19
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	4 h	84	22
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	4 h	84	23
	$NiCl_2 \cdot 6H_2O$, HCl	EtOH	Δ	5 h	87	23
	$InCl_3$	THF	Δ	8 h	91	26
	$Mn(OAc)_3 \cdot 2H_2O$	MeCN	Δ	4 h	79	29
	$LaCl_3 \cdot 7H_2O$, HCl	EtOH	Δ	5 h	89	63
	$InBr_3$	EtOH	Δ	7 h	93	66
	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	92	69
	$Cu(OTf)_2$	MeCN	40 °C	5 h	90	70
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	89	74
	$ZnCl_2$	–	80 °C	50 min	73	75
	PABC	EtOH	Δ	5 h	92	76
	$Cu(NTf_2)_2$	H_2O	stirring	24 h	71	78
	$Sr(OTf)_2$	–	70 °C	4 h	88	79
	$RuCl_3$	–	100 °C	85 min	84	81
	$PhB(OH)_2$	MeCN	Δ	18 h	91	85
	VCl_3	MeCN	Δ	2 h	92	86
	BDMPEAB	–	100 °C	55 min	98	90
	NH_4Br	–	100 °C	55 min	86	90
	–	–	100 °C	55 min	77	90
	PPAA	EtOAc	Δ	6 h	44	91
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	87	92
	$ZrCl_4$	EtOH	Δ	5 h	98	98
E2 + **A39** + **U10**	$Bi(OTf)_3$	MeCN	stirring	2.5 h	87	31
	PABC	EtOH	Δ	6 h	82	76
	$Sr(OTf)_2$	–	70 °C	4 h	87	79
	CH_2ClCO_2H	–	90 °C	5 h	79	82

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + A39 + U10	$ZrCl_4$	EtOH	Δ	6 h	80	98
	VCl_3	MeCN	Δ	2 h	86	86
E2 + A40 + U1	$Mn(OAc)_3 \cdot 2\,H_2O$	MeCN	Δ	3 h	85	29
	$Cu(OTf)_2$	MeCN	50 °C	6 h	85	70
E2 + A41 + U1	$Cu(OTf)_2$	MeCN	70 °C	9 h	65	70
E2 + A42 + U1	$Cu(OTf)_2$	MeCN	70 °C	9 h	80	70
E2 + A43 + U1	SSA	EtOH	Δ	6 h	92	14
	PPAA	EtOAc	Δ	6 h	86	91
E2 + A43 + U1*	–	–	65 °C	2 h	96	97
E2 + A44 + U1	Yb^{III}-Resin	–	120 °C	48 h	68	16
	I_2	PhMe	Δ	4 h	95	17
	$InCl_3$	THF	Δ	9 h	90	26
	$Bi(OTf)_3$	MeCN	stirring	3 h	85	31
	–	–	100 – 105 °C	1 h	82	36
	$Sr(OTf)_2$	–	70 °C	4 h	94	79
	$RuCl_3$	–	100 °C	55 min	87	81
	PPAA	EtOAc	Δ	6 h	81	91
E2 + A44 + U10	$InCl_3$	THF	Δ	9 h	90	26
	–	–	100 – 105 °C	1 h	82	36
	$RuCl_3$	–	100 °C	50 min	89	81
E2 + A45 + U1	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	2.5 h	95	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	3 h	90	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	10 h	80	10
	Mont. KSF	–	130 °C	48 h	79	14
	Mont. KSF	MeOH	Δ	8 – 10 h	82	15
	Yb^{III}-Resin	–	120 °C	48 h	72	16
	I_2	PhMe	Δ	3.8 h	91	17
	I_2	MeCN	Δ	6.5 h	87	18
	TsOH	H_2O	stirring	15 min	94	19
	SSA	EtOH	Δ	6 h	95	20
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	85	21
	H_2SO_4	EtOH	Δ	18 h	37	21
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	94	22
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	94	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	90	23
	$InCl_3$	THF	Δ	9 h	90	26
	$Bi(OTf)_3$	MeCN	stirring	1.5 h	95	31
	(TMS)OTf	MeCN	room temperature, stirring	15 min	95	32
	–	–	100 – 105 °C	1 h	83	36
	TAFF	–	IR	2 h	62	45
	$Yb(OTf)_3$	–	100 °C	20 min	96	62
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	93	63
	FSA	EtOH	Δ	84 h	61	65
	$InBr_3$	EtOH	Δ	7 h	97	66
	(TMS)Cl, NaI	MeCN	stirring	40 min	90	67
	LiBr	MeCN	Δ	3.25 h	94	68
	NH_2SO_3H	EtOH	US, 20 – 30 °C	30 min	62	69
	$Cu(OTf)_2$	MeCN	40 °C	5 h	90	70
	NH_4Cl	–	100 °C	3 h	84	71
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	60 min	96	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1.5 min	99	73
	$CuSO_4 \cdot 5\,H_2O$	–	100 °C	70 min	96	73
	$CuSO_4 \cdot 5\,H_2O$	–	μν	1.5 min	99	73
	PABC	EtOH	Δ	2 h	98	76
	$CdCl_2$	MeCN	Δ	4.3 h	81	77
	$RuCl_3$	–	100 °C	45 min	93	81
	CH_2ClCO_2H	–	90 °C	3 h	95	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	96	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	91	83

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + **A45** + **U1**	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	92	83
	$PhB(OH)_2$	MeCN	Δ	18 h	97	85
	VCl_3	MeCN	Δ	2 h	90	86
	bmim[BF_4]	–	100 °C	30 min	95	87
	bmim[PF_6]	–	100 °C	30 min	98	87
	CNSP	H_2O	80 °C	5 h	86	88
	BDMPEAB	–	100 °C	45 min	96	90
	NH_4Br	–	100 °C	45 min	88	90
	–	–	100 °C	45 min	75	90
	PPAA	EtOAc	Δ	6 h	59	91
	$ZrCl_4$	EtOH	Δ	5 h	97	98
E2 + **A45** + **U1***	–	–	65 °C	2.5 h	89	97
E2 + **A45** + **U9**	Dowex-50W	–	130 °C	3 h	56	84
E2 + **A45** + **U10**	I_2	MeCN	Δ	6 h	87	18
	TAFF	–	IR	2 h	58	45
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	85	63
	$InBr_3$	EtOH	Δ	7 h	98	66
	LiBr	MeCN	Δ	3.5 h	88	68
	NH_4Cl	–	100 °C	3 h	86	71
	PABC	EtOH	Δ	5 h	85	76
	CH_2ClCO_2H	–	90 °C	5 h	86	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	97	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	91	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	93	83
	$PhB(OH)_2$	MeCN	Δ	18 h	75	85
E2 + **A45** + **U14**	–	EtOH	μν, Δ	6 min	75.2	38
E2 + **A46** + **U1**	$Mn(OAc)_3 \cdot 2\,H_2O$	MeCN	Δ	3 h	82	29
	$RuCl_3$	–	100 °C	40 min	92	81
E2 + **A47** + **U1**	BDMPEAB	–	100 °C	35 min	93	90
	NH_4Br	–	100 °C	35 min	84	90
	–	–	100 °C	35 min	84	90
E2 + **A48** + **U1**	PPE	THF	Δ	24 h	75	7
	SSA	EtOH	Δ	6 h	94	20
	$Yb(OTf)_3$	EtOH	100 °C	10 min	52	27
	$LiClO_4$ or LiOTf	MeCN	Δ	8 h	87	28
	$Mn(OAc)_3 \cdot 2\,H_2O$	MeCN	Δ	3.5 h	94	29
	CAN	MeOH	US	4.5 h	92	35
	LiBr	MeCN	Δ	3 h	93	68
	$Cu(OTf)_2$	MeCN	50 °C	6 h	85	70
	I_2	MeCN	Δ	6 h	87	75
	$CdCl_2$	MeCN	Δ	4.3 h	90	77
	BDMPEAB	–	100 °C	35 min	97	90
	NH_4Br	–	100 °C	35 min	93	90
	–	–	100 °C	35 min	72	90
	PPAA	EtOAc	Δ	6 h	47	91
E2 + **A49** + **U1**	I_2	PhMe	Δ	3.7 h	92	17
E2 + **A50** + **U1**	I_2	PhMe	Δ	3.8 h	94	17
	$Bi(OTf)_3$	MeCN	stirring	1 h	89	31
	CAN	MeOH	US	3.5 h	90	35
	$Cu(OTf)_2$	MeCN	50 °C	6 h	85	70
	$CdCl_2$	MeCN	Δ	4 h	91	77
E2 + **A50** + **U1***	–	–	65 °C	2 h	90	91
E2 + **A50** + **U9**	Dowex-50W	–	130 °C	3 h	48	84
E2 + **A52** + **U1**	I_2	MeCN	Δ	8 h	90	18
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	86	22
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	86	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	88	23
	$Yb(OTf)_3$	EtOH	100 °C	15 min	46	27
	$Mn(OAc)_3 \cdot 2\,H_2O$	MeCN	Δ	4 h	76	29
	–	–	100 – 105 °C	1 h	85	36

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + **A52** + **U1**	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	92	63
	LiBr	MeCN	Δ	3 h	91	68
	NH_2SO_3H	EtOH	US, 20 – 30 °C	30 min	96	69
	$Cu(OTf)_2$	MeCN	50 °C	6 h	85	70
	$Sr(OTf)_2$	–	70 °C	4 h	95	79
	BDMPEAB	–	100 °C	35 min	96	90
	NH_4Br	–	100 °C	35 min	91	90
	–	–	100 °C	35 min	73	90
E2 + **A52** + **U10**	I_2	MeCN	Δ	7.5 h	88	18
E2 + **A55** + **U1**	$LiClO_4$ or LiOTf	MeCN	Δ	8 h	90	28
E2 + **A56** + **U1**	$Cu(OTf)_2$	MeCN	50 °C	6 h	80	70
E2 + **A57** + **U1**	$LiClO_4$ or LiOTf	MeCN	Δ	6 h	90	28
	PABC	EtOH	Δ	4 h	96	76
	$CdCl_2$	MeCN	Δ	4 h	89	77
	VCl_3	MeCN	Δ	2 h	92	86
	BDMPEAB	–	100 °C	60 min	97	90
	NH_4Br	–	100 °C	60 min	92	90
	–	–	100 °C	60 min	84	90
	$ZrCl_4$	EtOH	Δ	4 h	96	98
E2 + **A59** + **U1**	$Yb(OTf)_3$	AcOH + EtOH	120 °C	20 min	49	27
	–	EtOH	μν, Δ	6 min	80	38
	$Yb(OTf)_3$	THF	stirring	–	80	89
E2 + **A60** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	68	16
	SSA	EtOH	Δ	6 h	92	20
	–	EtOH	μν, Δ	6 min	86	38
	$Yb(OTf)_3$	–	100 °C	20 min	94	62
	VCl_3	MeCN	Δ	2 h	88	86
	$ZrCl_4$	EtOH	Δ	5 h	95	98
E2 + **A60** + **U1***	–	–	65 °C	3 h	90	97
E2 + **A60** + **U12**	–	EtOH	μν, Δ	6 min	88	38
E2 + **A60** + **U13**	–	EtOH	μν, Δ	10 min	65	38
E2 + **A61** + **U1**	PPE	THF	Δ	24 h	84	7
	PPE	–	μν	90 s	87	11
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	81	21
	H_2SO_4	EtOH	Δ	18 h	66	21
	$Yb(OTf)_3$	EtOH	100 °C	10 min	61	27
E2 + **A62** + **U1**	PPE	THF	Δ	24 h	83	7
	PPE	–	μν	90 s	95	11
	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	68	27
	$Mn(OAc)_3 \cdot 2\,H_2O$	MeCN	Δ	2.5 h	76	29
	TAFF	–	IR	2 h	60	45
	$InBr_3$	EtOH	Δ	7 h	75	66
	$Cu(OTf)_2$	MeCN	50 °C	9 h	70	70
	NH_4Cl	–	100 °C	3 h	85	71
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	93	74
	$ZnCl_2$	–	80 °C	40 min	41	75
	$Cu(NTf_2)_2$	H_2O	stirring	24 h	34	78
	$Yb(NTf_2)_2$	H_2O	stirring	24 h	38	78
	$Ni(NTf_2)_2$	H_2O	stirring	24 h	25	78
	$Sr(OTf)_2$	–	70 °C	4 h	88	79
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	91	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	89	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	89	83
	$Yb(OTf)_3$	THF	stirring	–	73	89
	PPAA	EtOAc	Δ	6 h	86	91
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	91	92
E2 + **A62** + **U10**	TAFF	–	IR	2 h	60	45
	$Yb(OTf)_3$	THF	stirring	–	78	89

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + **A63** + **U1**	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	82	22
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	82	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	95	23
E2 + **A63** + **U1**	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	87	63
	$InBr_3$	EtOH	Δ	7 h	70	66
	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	94	69
	$Cu(OTf)_2$	MeCN	60 °C	9 h	80	70
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	90	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	90	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	87	83
	$PhB(OH)_2$	MeCN	Δ	18 h	76	85
	PPAA	EtOAc	Δ	6 h	86	91
E2 + **A64** + **U1**	Mont. KSF	–	130 °C	48 h	76	14
	Mont. KSF	MeOH	Δ	8 – 10 h	89	15
	Yb^{III}-Resin	–	120 °C	48 h	65	16
	I_2	MeCN	Δ	8 h	91	18
	TsOH	H_2O	stirring	15 min	90	19
	SSA	EtOH	Δ	6 h	95	20
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	92	21
	H_2SO_4	EtOH	Δ	18 h	56	21
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	93	22
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	93	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	82	23
	$InCl_3$	THF	Δ	6.5 h	92	26
	$Mn(OAc)_3 \cdot 2\,H_2O$	MeCN	Δ	3.5 h	78	29
	$Bi(OTf)_3$	MeCN	stirring	1 h	93	31
	CAN	MeOH	US	4 h	89	35
	–	–	100 – 105 °C	1 h	85	36
	$Yb(OTf)_3$	–	100 °C	20 min	97	62
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	92	63
	FSA	EtOH	Δ	84 h	34	65
	$InBr_3$	EtOH	Δ	7 h	86	66
	(TMS)Cl, NaI	MeCN	stirring	30 min	92	67
	LiBr	MeCN	Δ	4.5 h	86	68
	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	94	69
	$Cu(OTf)_2$	MeCN	50 °C	4 h	85	70
	NH_4Cl	–	100 °C	3 h	83	71
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	60 min	97	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1 min	96	73
	$CuSO_4 \cdot 5\,H_2O$	–	100 °C	60 min	97	73
	$CuSO_4 \cdot 5\,H_2O$	–	μν	1 min	96	73
	$ZnCl_2$	–	80 °C	10 min	71	75
	PABC	EtOH	Δ	5 h	88	76
	$CdCl_2$	MeCN	Δ	5 h	89	77
	$Cu(NTf_2)_2$	H_2O	stirring	24 h	74	78
	$Sr(OTf)_2$	–	70 °C	4 h	95	79
	$RuCl_3$	–	100 °C	40 min	87	81
	CH_2ClCO_2H	–	90 °C	3 h	98	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	91	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	87	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	92	83
	VCl_3	MeCN	Δ	2 h	90	86
	bmim[BF_4]	–	100 °C	30 min	96	87
	bmim[PF_6]	–	100 °C	30 min	98	87
	BDMPEAB	–	100°C	25 min	87	90
	NH_4Br	–	100 °C	25 min	81	90
	–	–	100 °C	25 min	72	90
	PPAA	EtOAc	Δ	6 h	69	91
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	93	92
	$ZrCl_4$	EtOH	Δ	6 h	95	98

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + A64 + U1*	–	–	65 °C	3.5 h	95	97
E2 + A64 + U10	I_2	MeCN	Δ	7 h	88	18
	LiBr	MeCN	Δ	4 h	81	68
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	75 min	95	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1.5 min	97	73
	$Sr(OTf)_2$	–	70 °C	4 h	93	79
	$RuCl_3$	–	100 °C	60 min	91	81
	CH_2ClCO_2H	–	90 °C	5 h	87	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	85	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	81	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	80	83
E2 + A65 + U1	PPE	THF	Δ	24 h	79	7
	PPE	–	μν	90 s	–	11
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	93	74
E2 + A66 + U1	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	92	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	91	23
	$Yb(OTf)_3$	–	100 °C	20 min	89	62
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	93	63
	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	86	69
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	94	74
	$CdCl_2$	MeCN	Δ	5 h	93	77
	CH_2ClCO_2H	–	90 °C	3 h	89	82
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	91	92
E2 + A67 + U1	$LiClO_4$ or LiOTf	MeCN	Δ	10 h	85	28
	CAN	MeOH	US	5 h	90	35
	$PhB(OH)_2$	MeCN	Δ	18 h	78	85
	PPAA	EtOAc	Δ	6 h	77	91
E2 + A68 + U1	$PhB(OH)_2$	MeCN	Δ	18 h	80	85
E2 + A69 + U1	Yb^{III}-Resin	–	120 °C	48 h	63	16
	$Yb(OTf)_3$	MeCN	μν, 120 °C	15 min	73	39
	$Yb(OTf)_3$	–	100 °C	40 min	97	62
E2 + A70 + U1	I_2	PhMe	Δ	3.6 h	91	17
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	83	22
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	83	23
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	94	23
	$Yb(OTf)_3$	MeCN	μν, 120 °C	15 min	85	39
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	97	63
E2 + A71 + U1	I_2	PhMe	Δ	4 h	90	17
	$Yb(OTf)_3$	MeCN	μν, 120 °C	15 min	77	39
	$Yb(OTf)_3$	THF	stirring	–	82	89
	BDMPEAB	–	100 °C	60 min	92	90
	NH_4Br	–	100 °C	60 min	87	90
	–	–	100 °C	60 min	75	90
E2 + A71 + U9	Dowex-50W	–	130 °C	3 h	42	84
E2 + A73 + U1	$LiClO_4$ or LiOTf	MeCN	Δ	8 h	87	28
	–	–	100 – 105 °C	1 h	83	36
	(TMS)Cl, NaI	MeCN	stirring	30 min	84	67
	$Cu(OTf)_2$	MeCN	50 °C	6 h	85	70
	PABC	EtOH	Δ	5 h	88	76
	$RuCl_3$	–	100 °C	70 min	86	81
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	77	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	79	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	70	83
E2 + A73 + U3	$Yb(OTf)_3$	EtOH	100 °C	10 min	41	27
E2 + A74 + U1	CAN	MeOH	US	4.5 h	84	35
	$CdCl_2$	MeCN	Δ	4.3 h	89	77
E2 + A75 + U1	$LiClO_4$ or LiOTf	MeCN	Δ	12 h	81	28
E2 + A76 + U1	I_2	MeCN	Δ	7 h	84	18
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	82	22
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	4 h	82	23

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + A76 + U1	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	82	23
	$LiClO_4$ or LiOTf	MeCN	Δ	7 h	90	28
	–	–	100 – 105 °C	1 h	85	36
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	91	63
	LiBr	MeCN	Δ	3.5 h	91	68
	NH_2SO_3H	EtOH	US, 20 – 30 °C	50 min	89	69
	$Cu(OTf)_2$	MeCN	50 °C	6 h	85	70
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	90	74
	$ZnCl_2$	–	80 °C	40 min	62	75
	$CdCl_2$	MeCN	Δ	5 h	86	77
	VCl_3	MeCN	Δ	2 h	85	86
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	90	92
E2 + A76 + U10	LiBr	MeCN	Δ	3.5 h	87	68
E2 + A77 + U1	$InBr_3$	EtOH	Δ	7 h	86	99
	$InCl_3 \cdot 4\,H_2O$	EtOH	Δ	7 h	69	99
E2 + A77 + U10	$InCl_3 \cdot 4\,H_2O$	EtOH	Δ	10 h	79	99
E2 + A78 + U1	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	63	43
E2 + A79 + U1	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	65	43
E2 + A80 + U1	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	57	43
E2 + A81 + U1	LiBr	MeCN	Δ	3.5 h	94	68
	$CdCl_2$	MeCN	Δ	5 h	87	77
E2 + A82 + U1	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	30	27
	$CdCl_2$	MeCN	Δ	4 h	80	77
E2 + A83 + U10	EtOH	–	μν	> 24 min	41	42
	Al_2O_3	–	μν	10 min	82	42
	–	–	μν	4 min	84	42
E2 + A84 + U1	I_2	MeCN	Δ	7.5 h	72	18
	$NiCl_2 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	56	23
	$Yb(OTf)_3$	EtOH	100 °C	20 min	50	27
	$LiClO_4$ or LiOTf	MeCN	Δ	5 h	85	28
	$Bi(OTf)_3$	MeCN	stirring	4 h	90	31
	CAN	MeOH	US	3 h	87	35
	$LaCl_3 \cdot 7\,H_2O$, HCl	EtOH	Δ	5 h	67	63
	$InBr_3$	EtOH	Δ	7 h	95	66
	LiBr	MeCN	Δ	4.5 h	85	68
	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	87	69
	$Cu(OTf)_2$	MeCN	70 °C	6 h	70	70
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	60 min	80	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1.5 min	82	73
	$CuSO_4 \cdot 5\,H_2O$	–	100 °C	70 min	80	73
	$CuSO_4 \cdot 5\,H_2O$	–	μν	1.5 min	82	73
	$ZnCl_2$	–	80 °C	10 min	77	75
	PABC	EtOH	Δ	4 h	85	76
	$CdCl_2$	MeCN	Δ	3 h	90	77
	$Sr(OTf)_2$	–	70 °C	4 h	90	79
	$RuCl_3$	–	100 °C	45 min	90	81
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	95	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	90	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	91	83
	CNSP	H_2O	80 °C	6 h	82	88
	$Yb(OTf)_3$	THF	stirring	–	87	89
	PPAA	EtOAc	Δ	6 h	30	91
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	85	92
	$ZrCl_4$	EtOH	Δ	6 h	84	98
E2 + A84 + U10	–	EtOH	μν	3 min	42	42
	Al_2O_3	–	μν	8.5 min	81	42
	–	–	μν	1.5 min	86	42
E2 + A86 + U1	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	35	27
E2 + A88 + U1	PPE	THF	Δ	24 h	86	7
	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	89	27

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E2 + A88 + U1	$LiClO_4$ or LiOTf	MeCN	Δ	5 h	90	28
	CAN	MeOH	US	3.5 h	90	35
	HCl	EtOH	US	2 – 5 min	93	64
	$InBr_3$	EtOH	Δ	7 h	90	66
	(TMS)Cl, NaI	MeCN	stirring	45 min	87	67
	$CdCl_2$	MeCN	Δ	5 h	80	77
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	93	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	91	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	92	83
	$PhB(OH)_2$	MeCN	Δ	18 h	82	85
	VCl_3	MeCN	Δ	2 h	87	86
	CNSP	H_2O	80 °C	6 h	78	88
	PPAA	EtOAc	Δ	6 h	69	91
E2 + A88 + U10	$InBr_3$	EtOH	Δ	7 h	86	66
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	60 min	92	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1.5 min	90	73
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	89	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	85	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	84	83
E3 + A18 + U1	PPE	THF	Δ	24 h	84	7
	Yb^{III}-Resin	–	120°	48 h	78	16
	$Yb(OTf)_3$	EtOH	100 °C	10 min	50	27
	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	3 h	85	80
E3 + A30 + U1	Yb^{III}-Resin	–	120 °C	48 h	68	16
E3 + A33 + U1	PPE	–	μν	90 s	94	11
	$Yb(OTf)_3$	EtOH	100 °C	15 min	73	27
E3 + A33 + U3	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	34	27
E3 + A34 + U1	Yb^{III}-Resin	–	120 °C	48 h	73	16
E3 + A44 + U1	Yb^{III}-Resin	–	120 °C	48 h	73	16
E3 + A45 + U1	Yb^{III}-Resin	–	120 °C	48 h	75	16
E3 + A60 + U1	Yb^{III}-Resin	–	120 °C	48 h	71	16
E3 + A64 + U1	Yb^{III}-Resin	–	120 °C	48 h	64	16
E3 + A69 + U1	Yb^{III}-Resin	–	120 °C	48 h	70	16
E4 + A18 + U1	PPE	–	μν	90 s	81	11
	$Yb(OTf)_3$	EtOH	100 °C	10 min	49	27
	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	4 h	92	80
E4 + A48 + U10	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	3 h	95	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	3 h	86	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	3 h	71	10
	(TMS)OTf	MeCN	stirring	15 min	95	32
E4 + A50 + U1	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	2.5h	95	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	2.5 h	90	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	2.5 h	80	10
	(TMS)OTf	MeCN	stirring	15 min	95	32
E4 + A85 + U1	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	3 h	93	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	3 h	85	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	3 h	70	10
	(TMS)OTf	MeCN	stirring	15 min	93	32
E5 + A18 + U10	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	46	41
E5 + A23 + U10	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	67	41
E5 + A33 + U2	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	51	27
	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	35	41
E5 + A33 + U9	PPE	THF	Δ	24 h	85	13
	NaH	Me_2SO_4 + PhMe	70 °C	6 h	85	13
E5 + A33 + U10	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	61	41
E5 + A62 + U10	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	37	41
E5 + A64 + U10	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	74	41
E5 + A71 + U1	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	48	41
E6 + A18 + U1	NH_4Cl	MeOH	US, 60 °C	5 h	65	37

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E6 + **A33** + **U1**	NH_4Cl	MeOH	US, 60 °C	3.5 h	65	37
E7 + **A18** + **U1**	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	62	41
	NH_4Cl	–	100 °C	3 h	80	71
	$FeCl_3$, $Si(OEt)_4$	Pr^iOH	Δ	6 h	79	80
	$FeCl_3$, $Si(OEt)_4$	Bu^iOH	Δ	4 h	86	80
E7 + **A18** + **U2**	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	28	41
E7 + **A18** + **U9**	PPE	THF	Δ	24 h	–	13
	NaH	Me_2SO_4 + PhMe	70 °C	6 h	–	13
E7 + **A23** + **U1**	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	43	41
E7 + **A45** + **U1**	NH_4Cl	–	100 °C	3 h	75	71
E7 + **A65** + **U2**	PPE	THF	Δ	24 h	93	7
	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	25	27
E7 + **A65** + **U9**	PPE	THF	Δ	24 h	93	13
	NaH	Me_2SO_4 + PhMe	70 °C	6 h	84	13
E8 + **A18** + **U1**	NH_4Cl	MeOH	US, 60 °C	3.5 h	75	37
E8 + **A33** + **U1**	NH_4Cl	MeOH	US, 60 °C	3.5 h	70	37
E9 + **A18** + **U1**	NH_4Cl	MeOH	US, 60 °C	3.5 h	75	37
E9 + **A33** + **U1**	NH_4Cl	MeOH	US, 60 °C	3.5 h	73	37
E10 + **A18** + **U1**	NH_4Cl	MeOH	US, 60 °C	2.5 h	80	37
E10 + **A33** + **U1**	NH_4Cl	MeOH	US, 60 °C	3 h	90	37
E11 + **A18** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	81	21
	H_2SO_4	EtOH	Δ	18 h	42	21
	$InCl_3$	THF	Δ	6 h	95	26
E11 + **A18** + **U10**	HCl	EtOH	Δ	63 h	30	24
	H_3BO_3	AcOH	100 °C	6 h	62	24
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	5 h	38	24
E11 + **A21** + **U10**	HCl	EtOH	Δ	140 h	16	24
	H_3BO_3	AcOH	100 °C	6.5 h	15	24
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	6 h	78	24
E11 + **A22** + **U10**	HCl	EtOH	Δ	133 h	24	24
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	6 h	46	24
E11 + **A23** + **U10**	HCl	EtOH	Δ	245 h	35	24
	H_3BO_3	AcOH	100 °C	7 h	14	24
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	5 h	14	24
E11 + **A32** + **U10**	HCl	EtOH	Δ	196 h	11	24
	H_3BO_3	AcOH	100 °C	7 h	24	24
E11 + **A33** + **U10**	HCl	EtOH	Δ	70 h	16	24
	H_3BO_3	AcOH	100 °C	7.5 h	62	24
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	5.5 h	8	24
E11 + **A34** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	90	21
	H_2SO_4	EtOH	Δ	18 h	64	21
	$InCl_3$	THF	Δ	6 h	91	26
	–	–	100 – 105 °C	1 h	83	36
E11 + **A42** + **U10**	HCl	EtOH	Δ	35 h	26	24
	H_3BO_3	AcOH	100 °C	7.5 h	93	24
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	5 h	58	24
E11 + **A43** + **U10**	HCl	EtOH	Δ	35 h	17	24
	H_3BO_3	AcOH	100 °C	7.5 h	12	24
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	3 h	52	24
E11 + **A45** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	85	21
	H_2SO_4	EtOH	Δ	18 h	25	21
	$InCl_3$	THF	Δ	8 h	91	26
E11 + **A54** + **U10**	HCl	EtOH	Δ	56 h	29	24
	H_3BO_3	AcOH	100 °C	8.5 h	21	24
E11 + **A58** + **U10**	HCl	EtOH	Δ	70 h	8	24
	H_3BO_3	AcOH	100 °C	8.5 h	17	24
E11 + **A59** + **U10**	HCl	EtOH	Δ	126 h	10	24
	$FeCl_3 \cdot 6H_2O$, HCl	EtOH	Δ	5 h	77	24

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E11 + **A61** + **U1**	PPE	–	μν	90 s	65	11
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	82	21
	H_2SO_4	EtOH	Δ	18 h	55	21
	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	64	27
E11 + **A62** + **U10**	HCl	EtOH	Δ	105 h	12	24
	H_3BO_3	AcOH	100 °C	8.5 h	30	24
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	5.5 h	26	24
E11 + **A63** + **U10**	HCl	EtOH	Δ	175 h	36	24
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	42	24
E11 + **A64** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	89	21
	H_2SO_4	EtOH	Δ	18 h	66	21
	$InCl_3$	THF	Δ	7 h	92	26
	–	–	100 – 105 °C	1 h	85	36
E11 + **A64** + **U10**	HCl	EtOH	Δ	112 h	26	24
	H_3BO_3	AcOH	100 °C	9 h	12	24
E11 + **A65** + **U2**	$Yb(OTf)_3$	EtOH	100 °C	10 min	26	27
E11 + **A70** + **U10**	HCl	EtOH	Δ	154 h	21	24
	$FeCl_3 \cdot 6\,H_2O$, HCl	EtOH	Δ	5 h	69	24
E11 + **A71** + **U10**	HCl	EtOH	Δ	105 h	12	24
	H_3BO_3	AcOH	100 °C	8 h	21	24
E12 + **A18** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	83	21
	H_2SO_4	EtOH	Δ	18 h	41	21
	$InCl_3$	THF	Δ	7 h	89	26
	–	–	100 – 105 °C	1 h	81	36
E12 + **A34** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	90	21
	H_2SO_4	EtOH	Δ	18 h	44	21
	$InCl_3$	THF	Δ	6 h	90	26
	–	–	100 – 105 °C	1 h	85	36
E12 + **A45** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	79	21
	H_2SO_4	EtOH	Δ	18 h	40	21
	$InCl_3$	THF	Δ	8 h	85	26
E12 + **A48** + **U1**	$CeCl_3 \cdot 7\,H_2O$	EtOH	Δ	3 h	91	10
	$CeCl_3 \cdot 7\,H_2O$	H_2O	Δ	3 h	89	10
	$CeCl_3 \cdot 7\,H_2O$	–	Δ	3 h	73	10
	(TMS)OTf	MeCN	stirring	15 min	91	32
E12 + **A61** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	82	21
	H_2SO_4	EtOH	Δ	18 h	61	21
E12 + **A64** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	84	21
	H_2SO_4	EtOH	Δ	18 h	46	21
	$InCl_3$	THF	Δ	6 h	92	26
E13 + **A18** + **U1**	Mont. KSF	MeOH	Δ	8 – 10 h	80	15
	$InCl_3$	THF	Δ	9 h	84	26
	$LiClO_4$ or LiOTf	MeCN	Δ	10 h	75	28
E13 + **A34** + **U1**	$Yb(OTf)_3$	EtOH	100 °C	10 min	41	27
E14 + **A18** + **U1**	CNSP	H_2O	80 °C	10 h	55	88
E14 + **A60** + **U1**	CNSP	H_2O	80 °C	10 h	51	88
E15 + **A18** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	85	6, 21
	H_2SO_4	EtOH	Δ	18 h	32	21
E16 + **A18** + **U1**	Mont. KSF	–	130 °C	48 h	75	14
	SSA	EtOH	Δ	6 h	87	20
	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	70	21
	H_2SO_4	EtOH	Δ	18 h	10	21
	(TMS)Cl, NaI	MeCN	stirring	40 min	83	67
	NH_4Cl	–	100 °C	3 h	77	71
	Pro-Me · HCl	EtOH	Δ	18 h	10	95
E16 + **A18** + **U1***	–	–	65 °C	4 h	91	97
E16 + **A18** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	91	96
E16 + **A23** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	81	96

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
E16 + **A27** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	85	96
E16 + **A33** + **U1**	$Yb(OTf)_3$	AcOH + EtOH	120 °C	20 min	40	27
E16 + **A34** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	97	96
E16 + **A34** + **U9**	Dowex-50W	–	130 °C	3 h	55	84
E16 + **A51** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	93	96
E16 + **A64** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	94	96
E16 + **A73** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	90	96
E16 + **A88** + **U2**	$ZnBr_2$	$(CH_2Cl)_2$	Δ	24 h	91	96
E17 + **A18** + **U1**	$Yb(OTf)_3$	MeCN	μν, 120 °C	20 min	17	41
E18 + **A18** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	80	16
E18 + **A44** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	70	16
E18 + **A45** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	75	16
E18 + **A60** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	73	16
E19 + **A33** + **U1**	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	35	27
E19 + **A61** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	42	6
E19 + **A84** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	31	6
E20 + **A18** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	18 h	39	6
E21 + **A23** + **U1**	CAN	MeOH	US	5 h	88	35
E21 + **A45** + **U1**	CAN	MeOH	US	4 h	88	35
E21 + **A76** + **U1**	CAN	MeOH	US	4.5 h	90	35
E25 + **A18** + **U1**	HCl	dioxane	85 – 90 °C	1 h	60	59
E25 + **A23** + **U1**	HCl	dioxane	85 – 90 °C	1 h	72	59
E25 + **A33** + **U1**	HCl	dioxane	85 – 90 °C	1 h	27	59
E25 + **A60** + **U1**	HCl	dioxane	85 – 90 °C	1 h	68	59
E25 + **A61** + **U1**	HCl	dioxane	85 – 90 °C	1 h	70	59
E25 + **A62** + **U1**	HCl	dioxane	85 – 90 °C	1 h	65	59
E25 + **A65** + **U1**	HCl	dioxane	85 – 90 °C	1 h	32	59
E25 + **A73** + **U1**	HCl	dioxane	85 – 90 °C	1 h	64	59
E27 + **A18** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	92	43
E27 + **A78** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	42	43
E28 + **A18** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	75	43
E28 + **A79** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	35	43
E29 + **A18** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	70	43
E29 + **A80** + **U1**	$BF_3 \cdot OEt_2$, CuCl, AcOH	THF	Δ	24 h	36	43
E30 + **A64** + **U1**	[pyrH]OTs	–	–	–	61	100
E33 + **A18** + **U1**	VCl_3	MeCN	Δ	2 h	90	86
E33 + **A32** + **U1**	VCl_3	MeCN	Δ	2 h	82	86
E33 + **A57** + **U1**	VCl_3	MeCN	Δ	2 h	86	86
E33 + **A64** + **U1**	VCl_3	MeCN	Δ	2 h	85	86
E34 + **A18** + **U1**	VCl_3	MeCN	Δ	2 h	86	86
E34 + **A39** + **U1**	VCl_3	MeCN	Δ	2 h	85	86
E34 + **A60** + **U1**	VCl_3	MeCN	Δ	2 h	75	86
E34 + **A64** + **U1**	VCl_3	MeCN	Δ	2 h	82	86
K1 + **A18** + **U1**	Mont. KSF	–	130 °C	48 h	74	14
	Yb^{III}-Resin	–	120 °C	48 h	71	16
	I_2	MeCN	Δ	6 h	85	18
	SSA	EtOH	Δ	6 h	87	20
	$InCl_3$	THF	Δ	7 h	94	26
	$Yb(OTf)_3$	EtOH	100 °C	10 min	53	27
	$LiClO_4$ or LiOTf	MeCN	Δ	7 h	88	28
	$[NHEt_3][PF_6]$	–	120 – 125 °C	1h	88	34
	–	–	100 – 105 °C	1 h	85	36
	$Yb(OTf)_3$	–	100 °C	20 min	94	62
	(TMS)Cl, NaI	MeCN	stirring	50 min	85	67
	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	96	69
	NH_4Cl	–	100 °C	3 h	79	71
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	60 min	96	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	2 min	98	73

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
K1 + **A18** + **U1**	$CuSO_4 \cdot 5\,H_2O$	–	100 °C	70 min	96	73
	$CuSO_4 \cdot 5\,H_2O$	–	μν	2 min	98	73
	$ZnCl_2$	–	80 °C	10 min	80	75
	CH_2ClCO_2H	–	90 °C	3 h	88	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	93	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	89	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	90	83
	VCl_3	MeCN	Δ	2 h	85	86
	bmim[BF_4]	–	100 °C	30 min	99	87
	CNSP	H_2O	80 °C	5 h	78	88
	Pro-Me · HCl	EtOH	Δ	18 h	66	95
K1 + **A18** + **U1***	–	–	65 °C	2 h	87	97
K1 + **A18** + **U10**	I_2	MeCN	Δ	6 h	86	18
	SSA	EtOH	Δ	6 h	93	20
	$InCl_3$	THF	Δ	7 h	92	26
	bmim[Al_2Cl_7]	–	120 – 125 °C	1 h	80	34
	–	–	100 – 105 °C	1 h	81	36
	$ZnCl_2$	–	80 °C	60 min	89	75
	VCl_3	MeCN	Δ	2 h	80	86
	PPAA	EtOAc	Δ	6 h	72	91
K1 + **A18** + **U10***	–	–	65 °C	2 h	92	97
K1 + **A19** + **U1**	$ZnCl_2$	–	80 °C	60 min	48	75
K1 + **A21** + **U1**	(TMS)Cl, NaI	MeCN	stirring	45 min	90	67
K1 + **A22** + **U1**	$Yb(OTf)_3$	EtOH	100 °C	10 min	68	27
K1 + **A23** + **U1**	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	65 min	93	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1.5 min	95	73
K1 + **A32** + **U1**	(TMS)Cl, NaI	MeCN	stirring	1 h	86	67
	VCl_3	MeCN	Δ	2 h	80	86
K1 + **A33** + **U1**	[$NHEt_3$][PF_6]	–	120 – 125 °C	1 h	86	34
K1 + **A34** + **U1**	I_2	MeCN	Δ	8 h	85	18
	SSA	EtOH	Δ	6 h	92	20
	$Yb(OTf)_3$	–	100 °C	20 min	90	62
	NH_2SO_3H	EtOH	US, 20 – 30 °C	50 min	92	69
	NH_4Cl	–	100 °C	3 h	83	71
	$CuCl_2 \cdot 2\,H_2O$	–	100 °C	60 min	80	73
	$CuCl_2 \cdot 2\,H_2O$	–	μν	1.5 min	80	73
	$CuSO_4 \cdot 5\,H_2O$	–	100 °C	70 min	80	73
	$CuSO_4 \cdot 5\,H_2O$	–	μν	1.5 min	80	73
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	92	74
	$ZnCl_2$	–	80 °C	30 min	78	75
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	71	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	70	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	72	83
	bmim[BF_4]	–	100 °C	30 min	92	87
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	91	92
K1 + **A34** + **U1***	–	–	65 °C	3 h	90	97
K1 + **A34** + **U10**	[$NHEt_3$][PF_6]	–	120 – 125 °C	1 h	74	34
	bmim[$AlCl_4$]	–	120 – 125 °C	1 h	70	34
K1 + **A39** + **U1**	$ZnCl_2$	–	80 °C	30 min	85	75
	VCl_3	MeCN	Δ	2 h	82	86
K1 + **A44** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	65	16
	$InCl_3$	THF	Δ	9 h	92	26
	PPAA	EtOAc	Δ	6 h	60	91
K1 + **A45** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	71	16
	I_2	MeCN	Δ	7 h	83	18
	SSA	EtOH	Δ	6 h	86	20
	$InCl_3$	THF	Δ	9 h	91	26
	$Yb(OTf)_3$	–	100 °C	20 min	91	62
	(TMS)Cl, NaI	MeCN	stirring	40 min	90	67

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
K1 + **A45** + **U1**	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	97	69
	NH_4Cl	–	100 °C	3 h	86	71
	H_3BO_3	AcOH	100 °C	0.5 – 2 h	93	74
	CH_2ClCO_2H	–	90 °C	3 h	94	82
	$H_3PW_{12}O_{40}$	MeCN	80 °C	1 h	91	83
	$H_3PMo_{12}O_{40}$	MeCN	80 °C	1 h	87	83
	$H_4SiW_{12}O_{40}$	MeCN	80 °C	1 h	86	83
	VCl_3	MeCN	Δ	2 h	88	86
	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	91	92
	Pro-Me · HCl	EtOH	Δ	18 h	22	95
K1 + **A45** + **U1***	–	–	65 °C	3 h	81	97
K1 + **A57** + **U1**	VCl_3	MeCN	Δ	2 h	85	86
K1 + **A60** + **U1**	Yb^{III}-Resin	–	120 °C	48 h	70	16
	VCl_3	MeCN	Δ	2 h	80	86
K1 + **A60** + **U10**	$[NHEt_3][PF_6]$	–	120 – 125 °C	1 h	89	34
	bmim$[AlCl_4]$	–	120 – 125 °C	1 h	72	34
K1 + **A63** + **U1**	PPAA	EtOAc	Δ	6 h	64	91
K1 + **A64** + **U1**	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	92	69
	$ZnCl_2$	–	80 °C	13 min	78	75
	CH_2ClCO_2H	–	90 °C	3 h	97	82
	VCl_3	MeCN	Δ	2 h	86	86
K1 + **A64** + **U10**	$[NHEt_3][PF_6]$	–	120 – 125 °C	1 h	86	34
	bmim$[Al_2Cl_7]$	–	120 – 125 °C	1 h	74	34
	VCl_3	MeCN	Δ	2 h	82	86
K1 + **A66** + **U1**	NH_2SO_3H	EtOH	US, 20 – 30 °C	40 min	85	69
K1 + **A82** + **U1**	$InCl_3$	THF	Δ	6 h	93	26
	–	–	100 – 105 °C	1 h	81	36
K1 + **A84** + **U1**	$InCl_3$	THF	Δ	8 h	90	26
	–	–	100 – 105 °C	1 h	80	36
	$ZnCl_2$	–	80 °C	10 min	78	75
K1 + **A88** + **U1**	bmim$[Al_2Cl_7]$	–	120 – 125 °C	1 h	80	34
K4 + **A18** + **U1**	$InBr_3$	EtOH	Δ	14 h	86	99
K4 + **A18** + **U10**	$InBr_3$	EtOH	Δ	12 h	96	99
K4 + **A23** + **U1**	$InBr_3$	EtOH	Δ	36 h	73	99
	$InCl_3 \cdot 4\,H_2O$	EtOH	Δ	14 h	82	99
K4 + **A34** + **U1**	$InCl_3 \cdot 4\,H_2O$	EtOH	Δ	36 h	70	99
K4 + **A64** + **U1**	$InBr_3$	EtOH	Δ	36 h	62	99
K5 + **A18** + **U1**	Mont. KSF	–	130 °C	48 h	74	14
	I_2	MeCN	Δ	6 h	85	18
	$InCl_3$	THF	Δ	9 h	88	26
	–	–	100 – 105 °C	1 h	83	36
K5 + **A18** + **U10**	$InCl_3$	THF	Δ	8 h	90	26
	–	–	100 – 105 °C	1 h	80	36
K5 + **A34** + **U9**	Dowex-50W	–	130 °C	3 h	50	84
K5 + **A45** + **U1**	$InCl_3$	THF	Δ	9 h	90	26
	–	–	100 – 105 °C	1 h	82	36
K9 + **A18** + **U1**	$InBr_3$	EtOH	Δ	36 h	42	99
K10 + **A18** + **U1**	$Bi(OTf)_3$	MeCN	stirring	3 h	87	31
	NH_4Cl	–	100 °C	3 h	89	71
K12 + **A4** + **U1**	(TMS)Cl	DMF + MeCN	stirring	3 h	93	101
K12 + **A4** + **U10**	(TMS)Cl	DMF + MeCN	stirring	3 h	77	101
K12 + **A5** + **U1**	(TMS)Cl	DMF + MeCN	stirring	3 h	82	101
K12 + **A6** + **U10**	(TMS)Cl	DMF + MeCN	stirring	3 h	80	101
K12 + **A7** + **U1**	(TMS)Cl	DMF + MeCN	stirring	3 h	86	101
K12 + **A7** + **U10**	(TMS)Cl	DMF + MeCN	stirring	3 h	85	101
K12 + **A13** + **U1**	(TMS)Cl	DMF + MeCN	stirring	3 h	83	101
K12 + **A18** + **U1**	(TMS)Cl	DMF + MeCN	stirring	3 h	86	101

Supplement 2 (continued).

Reactants	Catalyst	Solvent	Other conditions	Reaction time	Yield (%)	Ref.
K12 + **A18** + **U10**	(TMS)Cl	DMF + MeCN	stirring	2 h	21	101
K12 + **A23** + **U10**	(TMS)Cl	DMF + MeCN	stirring	2 h	11	101
K12 + **A33** + **U1**	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	92	92
	(TMS)Cl	DMF + MeCN	stirring	2 h	90	101
K12 + **A33** + **U10**	(TMS)Cl	DMF + MeCN	stirring	3 h	80	101
K12 + **A34** + **U1**	(TMS)Cl	DMF + MeCN	stirring	2 h	25	101
K12 + **A34** + **U10**	(TMS)Cl	DMF + MeCN	stirring	3 h	74	101
K12 + **A43** + **U10**	(TMS)Cl	DMF + MeCN	stirring	2 h	85	101
K12 + **A58** + **U1**	(TMS)Cl	DMF + MeCN	stirring	2 h	90	101
K12 + **A58** + **U10**	(TMS)Cl	DMF + MeCN	stirring	2 h	82	101
K12 + **A60** + **U1**	(TMS)Cl	DMF + MeCN	stirring	2 h	23	101
K12 + **A60** + **U10**	(TMS)Cl	DMF + MeCN	stirring	3 h	76	101
K12 + **A62** + **U1**	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	91	92
K12 + **A64** + **U1**	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	93	92
K12 + **A64** + **U10**	(TMS)Cl	DMF + MeCN	stirring	2 h	13	101
K12 + **A66** + **U1**	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	95	92
K12 + **A67** + **U1**	$KHSO_4$	ethylene glycol	100 °C	0.5 – 2 h	95	92
K12 + **A69** + **U1**	(TMS)Cl	DMF + MeCN	stirring	2 h	93	101
K12 + **A69** + **U10**	(TMS)Cl	DMF + MeCN	stirring	2 h	92	101
K12 + **A88** + **U1**	$[NHEt_3][PF_6]$	–	120 – 125 °C	1 h	65	34
K13 + **A18** + **U1**	VCl_3	MeCN	Δ	2 h	80	86
K13 + **A18** + **U10**	H_2SO_4	H_2O	Δ	3 h	98	102
	$[NHEt_3][BF_4]$	–	120 – 125 °C	1 h	70	34
K13 + **A31** + **U1**	H_2SO_4	H_2O	Δ	3 h	95	102
K13 + **A31** + **U10**	H_2SO_4	H_2O	Δ	3 h	94	102
K13 + **A32** + **U1**	VCl_3	MeCN	Δ	2 h	80	86
K13 + **A34** + **U10**	$[NHEt_3][BF_4]$	–	120 – 125 °C	1 h	68	34
K13 + **A39** + **U1**	VCl_3	MeCN	Δ	2 h	82	86
K13 + **A45** + **U1**	VCl_3	MeCN	Δ	2 h	85	86
K13 + **A57** + **U1**	VCl_3	MeCN	Δ	2 h	88	86
K13 + **A60** + **U1**	VCl_3	MeCN	Δ	2 h	85	86
K13 + **A64** + **U1**	H_2SO_4	H_2O	Δ	3 h	95	102
K13 + **A64** + **U10**	H_2SO_4	H_2O	Δ	3 h	93	102
K13 + **A73** + **U1**	H_2SO_4	H_2O	Δ	3 h	90	102
K13 + **A73** + **U10**	H_2SO_4	H_2O	Δ	3 h	94	102
Am1 + **A18** + **U12**	HCl	EtOH	100 °C	15 min	21	27
Am1 + **A34** + **U1**	HCl	EtOH	100 °C	15 min	59	27
Am2 + **A32** + **U1**	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	66	27
Am3 + **A18** + **U1**	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	55	27
Am3 + **A52** + **U1**	HCl	EtOH	100 °C	15 min	28	27
Am3 + **A62** + **U1**	$LaCl_3$	AcOH + EtOH	120 °C	10 min	89	27
Am4 + **A71** + **U1**	$Yb(OTf)_3$	AcOH + EtOH	120 °C	10 min	61	27
Am7 + **A18** + **U10**	AcOH	EtOH	Δ	48 h	65	44
	$AlCl_3$, HCl	MeOH	μν	7.5 h	82	44
Am7 + **A76** + **U10**	AcOH	EtOH	Δ	25 h	68	44
	$AlCl_3$, HCl	MeOH	μν	3.5 h	86	44
Am7 + **A84** + **U10**	AcOH	EtOH	Δ	24 h	63	44
	$AlCl_3$, HCl	MeOH	μν	6 h	84	44
Am8 + **A18** + **U10**	AcOH	EtOH	Δ	48 h	64	44
	$AlCl_3$, HCl	MeOH	μν	8 h	80	44
Am8 + **A76** + **U10**	AcOH	EtOH	Δ	26 h	67	44
	$AlCl_3$, HCl	MeOH	μν	3.5 h	87	44
Am8 + **A84** + **U10**	AcOH	EtOH	Δ	24 h	62	44
	$AlCl_3$, HCl	MeOH	μν	6.5 h	83	44
Eq1 + **A18** + **U1**	$Yb(OTf)_3$	EtOH	100 °C	20 min	31	27
Eq1 + **A50** + **U1**	HCl	EtOH	100 °C	20 min	31	27
Eq1 + **A61** + **U1**	$Yb(OTf)_3$	EtOH	100 °C	20 min	35	27
Eq2 + **A18** + **U1**	$LaCl_3$	AcOH + EtOH	120 °C	15 min	83	27

References

1. P Biginelli *Chem. Ber.* **24** 2962 (1891)
2. G C Rovnyak, S D Kimball, B Beyer, G Cucinotta, J D DiMarco, J Gougoutas, A Hedberg, M Malley, J P McCarthy, R Zhang, S Moreland *J. Med. Chem.* **38** 119 (1995)
3. M Brands, R Endermann, R Gahlmann, J Krüger, S Raddatz *Bioorg. Med. Chem. Lett.* **13** 241 (2003)
4. B B Snider, Z Shi *J. Org. Chem.* **58** 3828 (1993)
5. K Folkers, T B Johnson *J. Am. Chem. Soc.* **55** 3784 (1933)
6. T G Steele, C A Coburn, M A Patane, M G Bock *Tetrahedron Lett.* **39** 9315 (1998)
7. C O Kappe, S F Falsone *Synlett* 718 (1998)
8. B Jauk, F Belaj, C O Kappe *J. Chem. Soc., Perkin Trans. 1* 307 (1999)
9. H Namazi, Y R Mirzaei, H Azamat *J. Heterocycl. Chem.* **38** 1051 (2001)
10. D S Bose, L Fatima, H B Mereyala *J. Org. Chem.* **68** 587 (2003)
11. C O Kappe, D Kumar, R S Varma *Synthesis* 1799 (1999)
12. C O Kappe, O V Shishkin, G Uray, P Verdino *Tetrahedron* **56** 1859 (2000)
13. B Schnell, W Krenn, K Faber, C O Kappe *J. Chem. Soc., Perkin Trans. 1* 4382 (2000)
14. F Bigi, S Carloni, B Frullanti, R Maggi, G Sartori *Tetrahedron Lett.* **40** 3465 (1999)
15. H Lin, J Ding, X Chen, Z Zhang *Molecules* **5** 1240 (2000)
16. A Dondoni, A Massi *Tetrahedron Lett.* **42** 7975 (2001)
17. R S Bhosale, S V Bhosale, Sh V Bhosale, T Wang, P K Zubaidha *Tetrahedron Lett.* **45** 9111 (2004)
18. K V N S Srinivas, B Das *Synthesis* 2091 (2004)
19. A K Bose, M S Manhas, S Pednekar, S N Ganguly, H Dang, W He, A Mandadi *Tetrahedron Lett.* **46** 1901 (2005)
20. P Salehi, M Dabir, M A Zolfigol, M A B Fard *Tetrahedron Lett.* **44** 2889 (2003)
21. E H Hu, D R Sidler, U-H Dolling *J. Org. Chem.* **63** 3454 (1998)
22. J I Lu, H Ma *Synlett* 63 (2000)
23. J I Lu, Y Bai *Synthesis* 466 (2002)
24. I S Zorkun, S Saraç, S Çelebi, K Erol *Bioorg. Med. Chem.* **14** 8582 (2006)
25. G Jenner *Tetrahedron Lett.* **45** 6195 (2004)
26. B C Ranu, A Hajra, U Jana *J. Org. Chem.* **65** 6270 (2000)
27. A Stadler, C O Kappe *J. Comb. Chem.* **3** 624 (2001)
28. J S Yadav, B V S Reddy, R Srinivas, C Venugopal, T Ramalingam *Synthesis* 1341 (2001)
29. K A Kumar, M Kasthuraiah, C S Reddy, C D Reddy *Tetrahedron Lett.* **42** 7873 (2001)
30. S Antoniotti *Synlett* 1566 (2003)
31. R Varala, M M Alam, S R Adapa *Synlett* 67 (2003)
32. D S Bose, R K Kumar, L Fatima *Synlett* 279 (2004)
33. E S Putilova, N A Troitskii, S G Zlotin, O G Khudina, Ya V Burgart, V I Saloutin, O N Chupakhin *Zh. Org. Khim.* **42** 1407 (2006) [a]
34. E S Putilova, G V Kryshtal', G M Zhdankina, N A Troitskii, S G Zlotin *Zh. Org. Khim.* **41** 524 (2005) [a]
35. J S Yadav, B V S Reddy, K B Reddy, K S Raj, A R Prasad *J. Chem. Soc., Perkin Trans. 1* 1939 (2001)
36. B C Ranu, H Alakananda, S S Dey *Org. Process Res. Dev.* **6** 817 (2002)
37. H A Stefani, C B Oliveira, R B Almeida, C M P Pepeira, R C Braga, R Cella, V C Borges, L Savegnago, C W Nogueira *Eur. J. Med. Chem.* **41** 513 (2006)
38. A Dandia, M Saha, H Taneja *J. Fluorine Chem.* **90** 17 (1998)
39. J Wannberg, D Dallinger, C O Kappe, M Larhed *J. Comb. Chem.* **7** 574 (2005)
40. A Lengar, C O Kappe *Org. Lett.* **6** 771 (2004)
41. B Desai, D Dallinger, C O Kappe *Tetrahedron* **62** 4651 (2006)
42. M Kidwai, S Saxena, R Mohan, R Venkataramanan *J. Chem. Soc., Perkin Trans. 1* 1845 (2002)
43. A Dondoni, A Massi *Mol. Diver.* **6** 261 (2003)
44. M Kidvai, R Mokhan, S Saksena *Izv. Akad. Nauk, Ser. Khim.* 2323 (2003) [b]
45. R Osnaya, G A Arroyo, L Parada, F Delgado, J Trujillo, M Salmón, R Miranda *Arkivoc* (xi) 112 (2003)
46. I P Sedishchev, G A Gazieva, A N Shumskii, E S Putilova, V M Zhulin *Kondens. Sredy Mezhfaz. Granitsy* **4** 225 (2002)
47. M Syamala *Org. Prep. Proced. Int.* **37** 103 (2005)
48. C O Kappe *Tetrahedron* **49** 6937 (1993)
49. C O Kappe *Acc. Chem. Res.* **33** 879 (2000)
50. F Sweet, J D Fissekis *J. Am. Chem. Soc.* **95** 8741 (1973)
51. C O Kappe *J. Org. Chem.* **62** 7201 (1997)
52. M Xia, Y-G Wang *Tetrahedron Lett.* **43** 7703 (2002)
53. M Xia, Y-G Wang *Synthesis* 262 (2003)
54. P Wipf, A Cunningham *Tetrahedron Lett.* **36** 7819 (1995)
55. M J Lusch, J A Tallarico *Org. Lett.* **6** 3237 (2004)
56. M G Valverde, D Dallinger, C O Kappe *Synlett* 741 (2001)
57. L Zhang, T M Rana *J. Comb. Chem.* **6** 457 (2004)
58. G A Gross, H Wurziger, A Schober *J. Comb. Chem.* **8** 153 (2006)
59. R Péres, T Beryozkina, O I Zbruyev, W Haas, C O Kappe *J. Comb. Chem.* **4** 501 (2002)
60. J-C Legeay, J J V Eynde, J P Bazureau *Tetrahedron* **61** 12386 (2005)
61. K S Atwal, G C Rovnyak, B C O'Reilly, J Schwartz *J. Org. Chem.* **54** 5898 (1989)
62. Y Ma, C Qian, L Wang, M Yang *J. Org. Chem.* **65** 3864 (2000)
63. J Lu, Y Bai, Z Wang, B Yang, H Ma *Tetrahedron Lett.* **41** 9075 (2000)
64. M S Zhidovinova, O V Fedorova, G L Rusinov, I G Ovchinnikova *Izv. Akad. Nauk, Ser. Khim.* 2389 (2003) [b]
65. S Martínez, M Meseguer, L Casas, E Rodríguez, E Molins, M Moreno-Mañas, A Roig, R M Sebastián, A Vallribera *Tetrahedron* **59** 1553 (2003)
66. N-Y Fu, Y-F Yuan, Z Cao, S-W Wang, J-T Wang, C Peppe *Tetrahedron* **58** 4801 (2002)
67. G Sabitha, G S K K Reddy, C S Reddy, J S Yadav *Synlett* 858 (2003)
68. G Maiti, P Kundu, C Guin *Tetrahedron Lett.* **44** 2757 (2003)
69. J Li, J-F Han, J-H Yang, T-S Li *Ultrason. Sonochem.* **10** 119 (2003)
70. A S Paraskar, G K Dewkar, A Sudalai *Tetrahedron Lett.* **44** 3305 (2003)
71. A Shaabani, A Bazgir, F Teimouri *Tetrahedron Lett.* **44** 857 (2003)
72. M S Manhas, S N Ganguly, S Mukherjee, A K Jain, A K Bose *Tetrahedron Lett.* **47** 2423 (2006)
73. M Gohain, D Prajapati, J S Sandhu *Synlett* 235 (2004)
74. S Tu, F Fang, C Miao, H Jiang, Y Feng, D Shi, X Wang *Tetrahedron Lett.*. **44** 6153 (2003)
75. Q Sun, Y-Q Wang, Z-M Ge, T-M Cheng, R-T Li *Synthesis* 1047 (2004)
76. B Gangadasu, S Palaniappan, V J Rao *Synlett* 1285 (2004)
77. A V Narsaiah, A K Basak, K Nagaiah *Synthesis* 1253 (2004)
78. I Suzuki, Y Suzumura, K Takeda *Tetrahedron Lett.* **47** 7861 (2006)
79. W Su, J Li, Z Zheng, Y Shen *Tetrahedron Lett.* **46** 6037 (2005)
80. I Cepanec, M Litvić, A Bartolinčić, M LovricZh *Tetrahedron* **61** 4275 (2005)
81. S K De, R A Gibbs *Synthesis* 1748 (2005)
82. Y Yu, D Liu, C Liu, G Luo *Bioorg. Med. Chem. Lett.* **17** 3508 (2007)
83. E Rafiee, H Jafari *Bioorg. Med. Chem. Lett.* **16** 2463 (2006)
84. K Singh, D Arora, S Singh *Tetrahedron Lett.* **47** 4205 (2006)
85. A Debache, B Boumoud, M Amimour, A Belfaitah, S Rhouati, B Carboni *Tetrahedron Lett.* **47** 5697 (2006)
86. G Sabitha, G S K K Reddy, K B Reddy, J S Yadav *Tetrahedron Lett.* **44** 6497 (2003)
87. J Peng, Y Deng *Tetrahedron Lett.* **42** 5917 (2001)
88. G Sabitha, K B Reddy, J S Yadav, D Shailaja, K S Sivudu *Tetrahedron Lett.* **46** 8221 (2005)
89. Y Huang, F Yang, C Zhu *J. Am. Chem. Soc.* **127** 16386 (2005)
90. K R Reddy, C V Reddy, M Mahesh, P V K Raju, V V N Reddy *Tetrahedron Lett.* **44** 8173 (2003)
91. F L Zumpe, M Flüβ, K Schmitz, A Lender *Tetrahedron Lett.* **48** 1421 (2007)

92. S Tu, F Fang, S Zhu, T Li, X Zhang, Q Zhuang *Synlett* 537 (2004)
93. S I Zav'yalov, L B Kulikova *Khim.-Farm. Zh.* (7 – 8) 116 (1992) [c]
94. A Stadler, C O Kappe *J. Chem. Soc., Perkin Trans. 2* 1363 (2000)
95. J Mabry, B Ganem *Tetrahedron Lett.* **47** 55 (2006)
96. A A A Abdel-Fattah *Synthesis* 2358 (2003)
97. P Salehi, M Dabiri, M A Zolfigol, M Baghbanzadeh *Heterocycles* **65** 1177 (2005)
98. C V Reddy, M Mahesh, P V K Raju, T R Babu, V V N Reddy *Tetrahedron Lett.* **43** 2657 (2002)
99. N-Y Fu, Y-F Yuan, M-L Pang, J-T Wang, C Peppe *J. Organomet. Chem.* **672** 52 (2003)
100. M M Abelman, S C Smith, D R James *Tetrahedron Lett.* **44** 4559 (2003)
101. Y Zhu, Y Pan, S Huang *Heterocycles* **65** 133 (2005)
102. Z Hassani, M R Islami, M Kalantari *Bioorg. Med. Chem. Lett.* **16** 4479 (2006)
103. M S Zhidovinova, O V Fedorova, G L Rusinov, I G Ovchinnikova *Mol. Diver.* **6** 323 (2003)
104. S V Vdovina, L V Mustakimova, V A Mamedov *Zh. Org. Khim.* **44** 638 (2008) [a]
105. V A Mamedov, S V Vdovina, E I Vorkunova, L V Mustakimova, A F Saifina, A T Gubaidullin, I Kh Rizvanov, Ya A Levin, I A Litvinov *Izv. Akad. Nauk, Ser. Khim.* 1233 (2008) [b]
106. J Guillon, P Grellier, M Labaied, P Sonnet, J-M Léger, R Déprez-Poulain, I Forfar-Bares, P Dallemagne, N Lemaître, F Péhourcq, J Rochette, C Sergheraert, C Jarry *J. Med. Chem.* **47** 1997 (2004)
107. S Raines, S Y Chai, F P Palopodi *J. Heterocycl. Chem.* **13** 711 (1976)
108. V I Saloutin, Ya V Burgart, O G Kuzueva, C O Kappe, O N Chupakhin *J. Fluorine Chem.* **103** 17 (2000)
109. M A P Martins, M V M Teixeira, W Cunico, E Scapin, R Mayer, C M P Pepeira, N Zanatta, H G Bonacorso, C Peppe, Y-F Yuan *Tetrahedron Lett.* **45** 8991 (2004)
110. V A Mamedov, L V Mustakimova, A T Gubaidullin, S V Vdovina, I A Litvinov, V S Reznik *Khim. Geterotsikl. Soedin.* 1414 (2006) [d]
111. G Byk, H E Gottlieb, J Herscovici, F Mirkin *J. Comb. Chem.* **2** 732 (2000)
112. A Shaabani, A Bazgir, H R Bijanzadeh *Mol. Diver.* **8** 141 (2004)
113. Z-T Wang, L-W Xu, C-G Xia, H-Q Wang *Tetrahedron Lett.* **45** 7951 (2004)
114. B Liang, X Wang, J-X Wang, Z Du *Tetrahedron* **63** 1981 (2007)
115. K Singh, J Singh, P K Deb, H Singh *Tetrahedron* **55** 12873 (1999)

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