



Application of Ionic Liquids in Michael Addition Reactions

by Haiying DU

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The definition of ionic liquids

An ionic liquid (IL) is a salt in the liquid state. In some contexts, the term has been restricted to salts whose melting point is below some arbitrary temperature, such as 100 °C (212 °F). While ordinary liquids such as water and gasoline are predominantly made of electrically neutral molecules, ILs are largely made of ions and short-lived ion pairs.

The advantage of ionic liquids

-  Greener solvents, suitable for a range of organic reactions
-  Providing possibilities such as control of product distribution, enhanced rate and reactivity
-  Ease of product recovery, catalyst immobilization, and recycling



The important of Michael addition

The Michael addition reaction as a model reaction, which constitutes as one of the most important classes of new carbon–carbon bond-forming reactions for the preparation of organic target products in synthetic organic chemistry

So I choose the topic that

<Application of Ionic Liquids in Michael Addition Reactions>

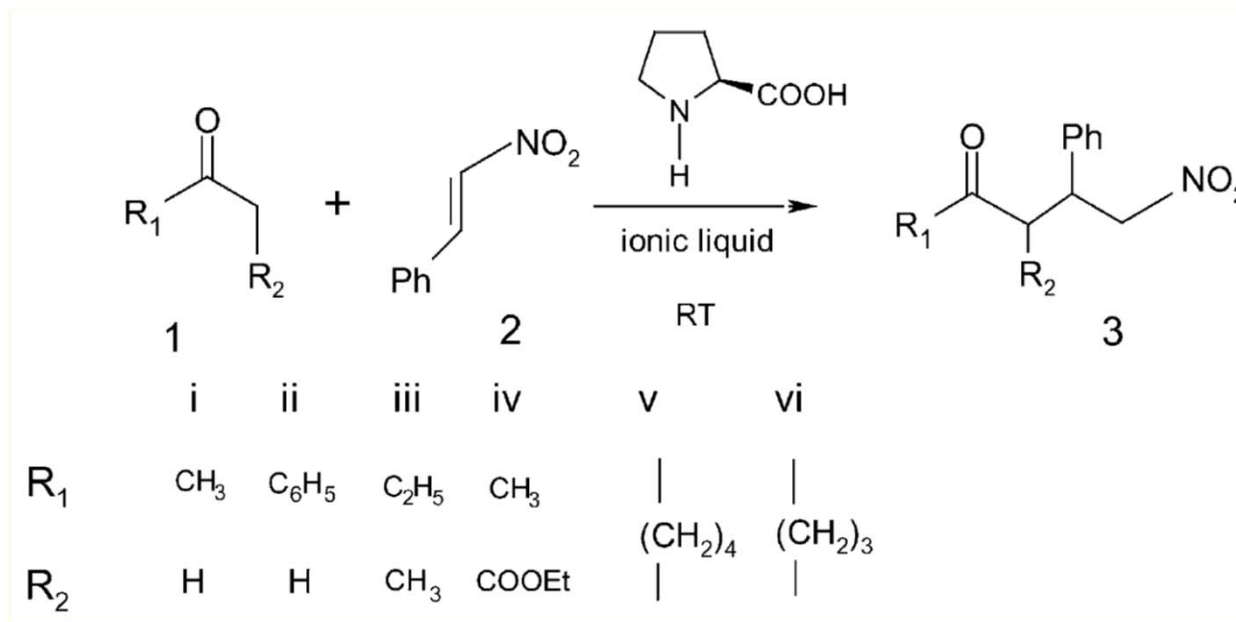
<Application of Ionic Liquids in Michael Addition Reactions>

- (a) Berner, O. M.; Tedeschi, L.; Enders, D. Eur. J. Org.Chem. 2002, 1877–1894
- (b) Krause, N.; Hoffmann-Röder, A. Synthesis 2001, 171–196
- (c) Sibi, M. P.; Manyem, S. Tetrahedron 2000, 56, 8033–8061



The use of ionic liquids as reactions medium

L-proline catalysed Michael addition of ketones to nitrostyrene in ionic liquid



[bmim]Cl

1-butyl-3-methylimidazolium chloride

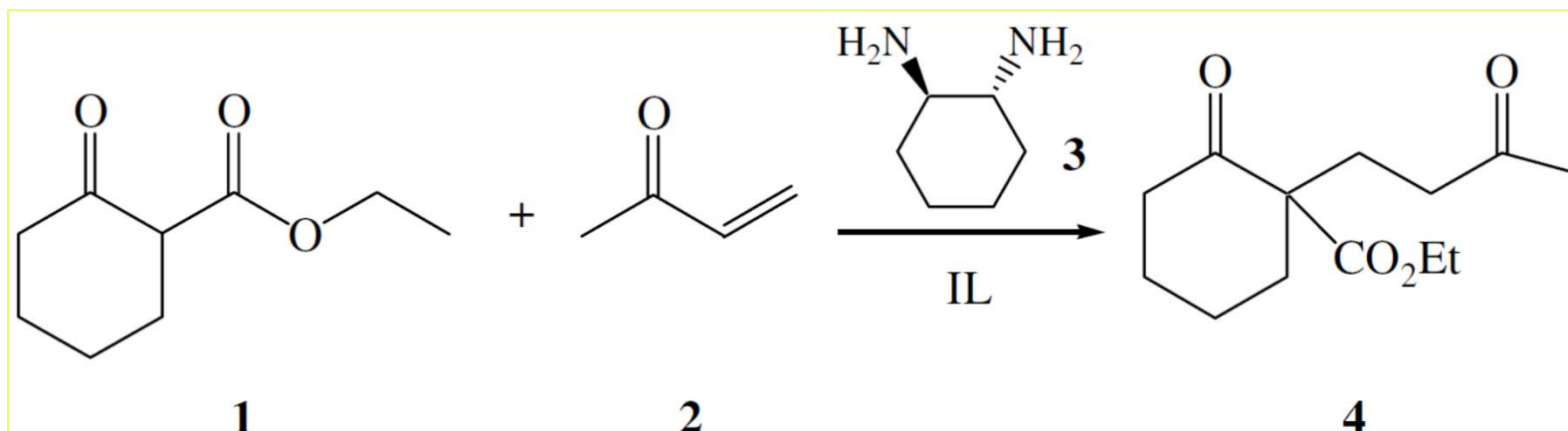
[MOEMIM]OMs

1-methoxyethyl-3-methylimidazolium methanesulphonate

1. Ionic liquids can act as an efficient media for enhancing the selectivity of L-proline catalysed Micheal reaction
2. Catalyst recovery and solvent reusability
3. The catalytic activity was strongly dependent on the nature of the ionic liquid, which influenced the yield and selectivity of the reaction
4. The structure of ionic liquid can be well modulated to meet the needs of a sepcific process

The use of ionic liquids as reactions medium

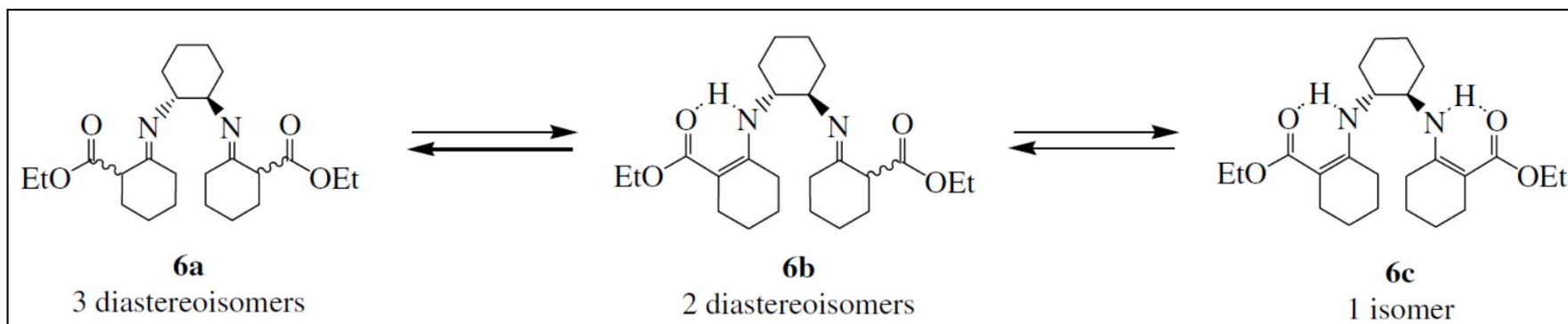
The asymmetric Michael addition of ethyl cyclohexanone-2-carboxylate to methyl vinyl ketone
In [bmim]BF₄ facilitated by (R,R)-trans-1,2-diaminocyclohexane



3 can facilitate the Michael addition of reaction through two different pathways. It can abstract the proton in the α position of the donor, thus, triggering a basic catalysis leading to a racemic mixture of the product. In alternative, the diamine can react with 1 forming a composite mixture of isomers 6a–c in prototropic equilibrium.



The use of ionic liquids as reactions medium

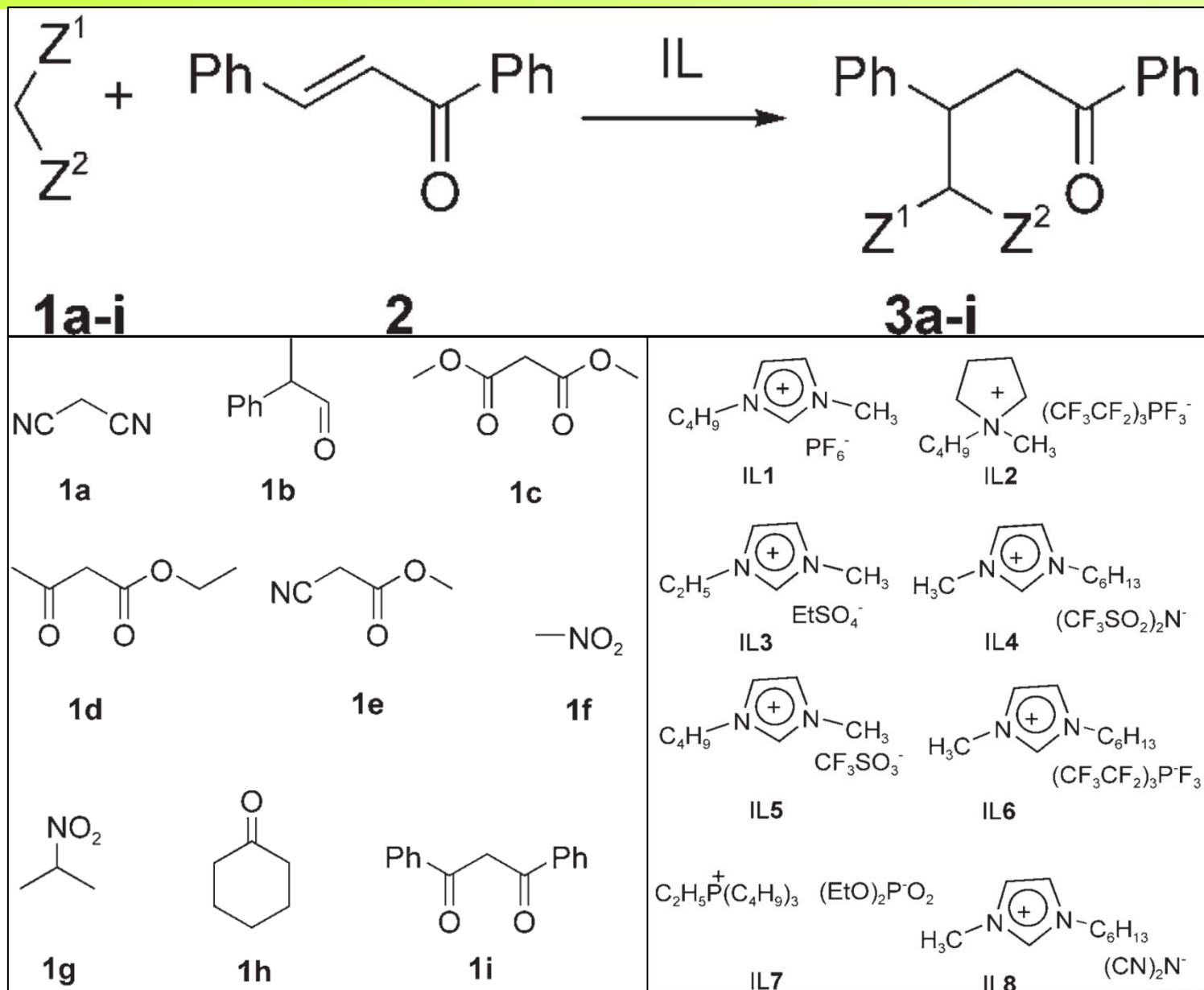


Prototropic equilibria involving the adducts between 1 and 3.

1. In tetrafluoroborate based ionic liquids fair yields and enantimeric excesses up to 91%
2. Possibly recyclable, catalytic systems that exhibit higher activity than those obtainable with classic solvents





The use of ionic liquids as reactions medium




The use of ionic liquids as reactions medium

In summary

 The Michael addition of malononitrile and several other methylene active compounds proceeds successfully in pure ionic liquids, without any additional catalyst.

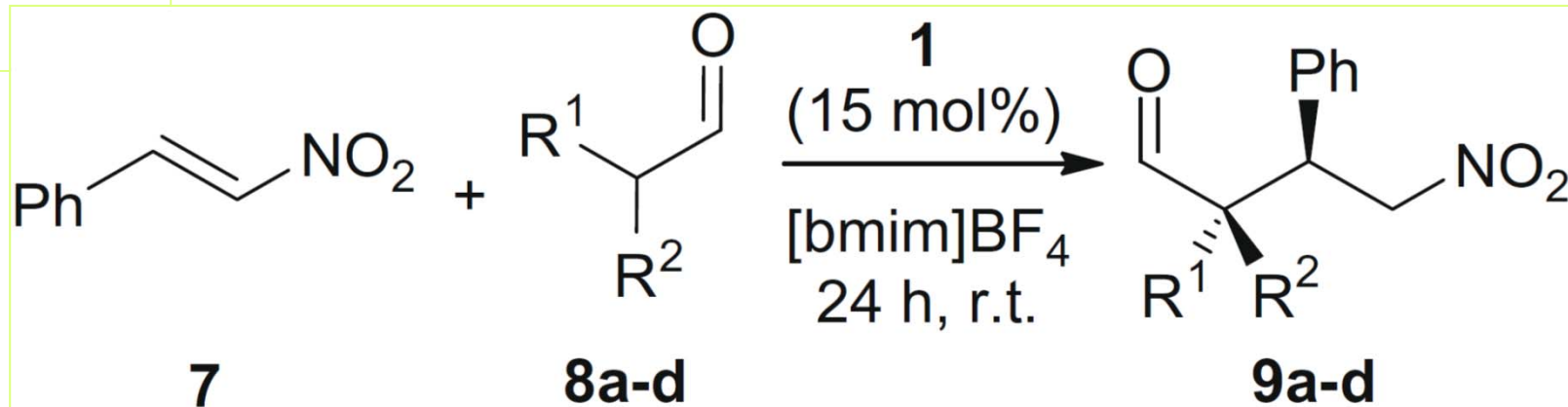
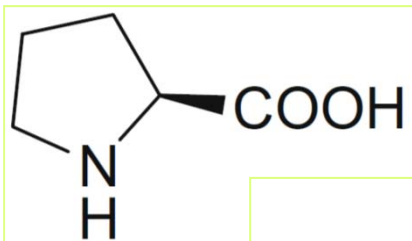
 This observation can be explained by the different dissociation constants of C-H acids in ionic liquids relative to classical solvents

 Observed that piperidine-catalysed (5 mol%) reactions in ionic liquids proceed much faster than the same reactions in dichloromethane.

**Green
solvents**



The use of ionic liquids as reactions medium

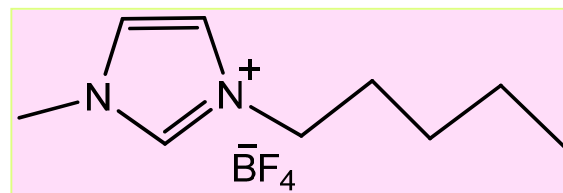


Michael addition of various aldehydes to nitrostyrene

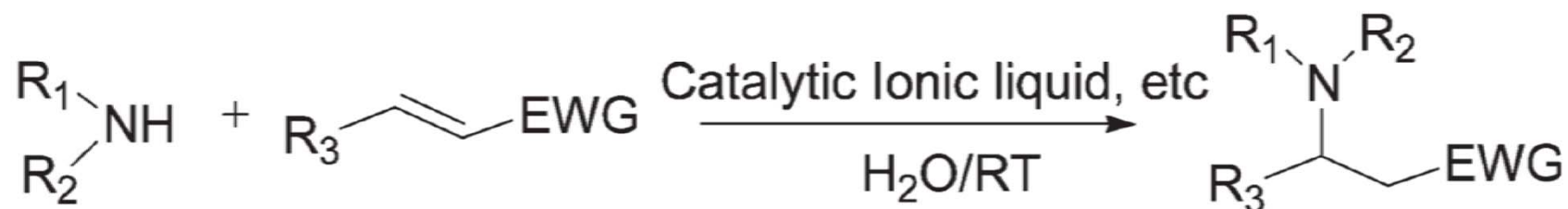
R ¹	R ²	Product	Yield ^a (%)	dr ^b (<i>syn/anti</i>)	ee ^c (%)
H	<i>i</i> Pr	9a	85	96:4	38
H	Me	9b	77	95:5	19
H	Et	9c	80	94:6	20
Me	Me	9d	78	—	30

L-Proline-catalyzed Michael additions of several other aliphatic aldehydes 8b-d to β -nitrostyrene 7 in [bmim]BF₄. Products 9b-d were isolated in high yields, excellent *syn/anti* ratio from 94:6 to 96:4 and moderate ee

The use of ionic liquids as reactions catalyst



BmimBF₄



EWG = CN, COOEt, COOCH₃, COCH₃

- Utilized a variety of aliphatic amines successfully with different α,β -unsaturated compounds catalyzed by the simple hydrophilic ionic liquid, bmimBF₄.
- Interestingly, all the aliphatic amines gave almost quantitative yields with α,β -ethylenic compounds.



The use of ionic liquids as reactions catalyst

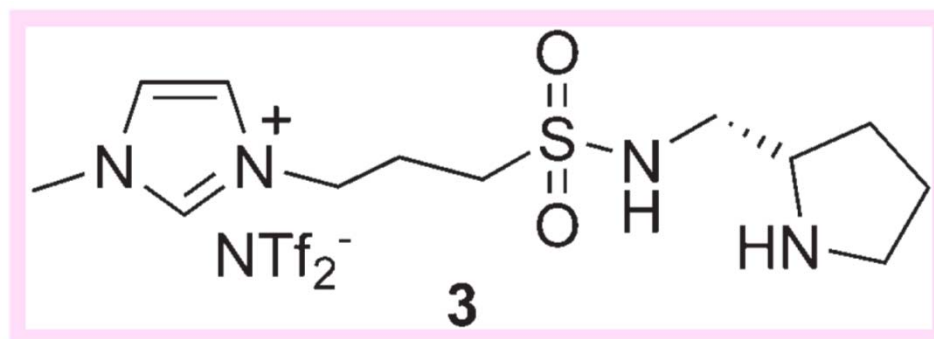
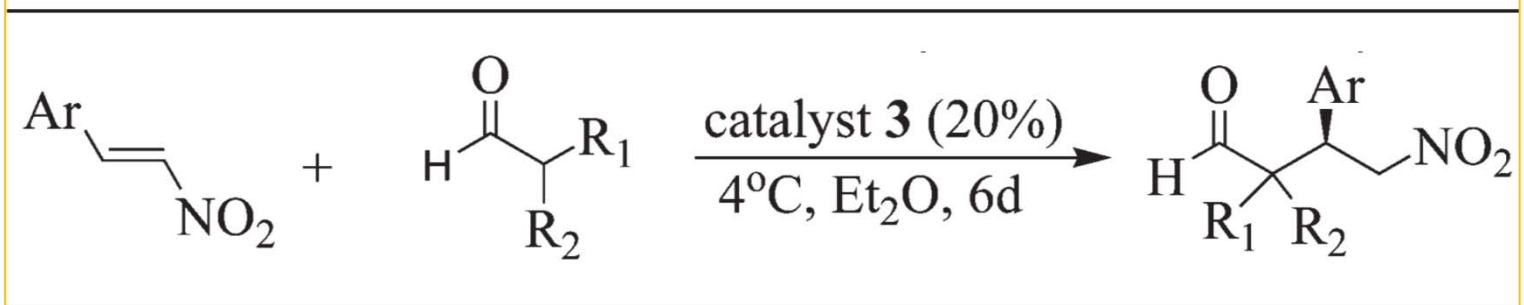


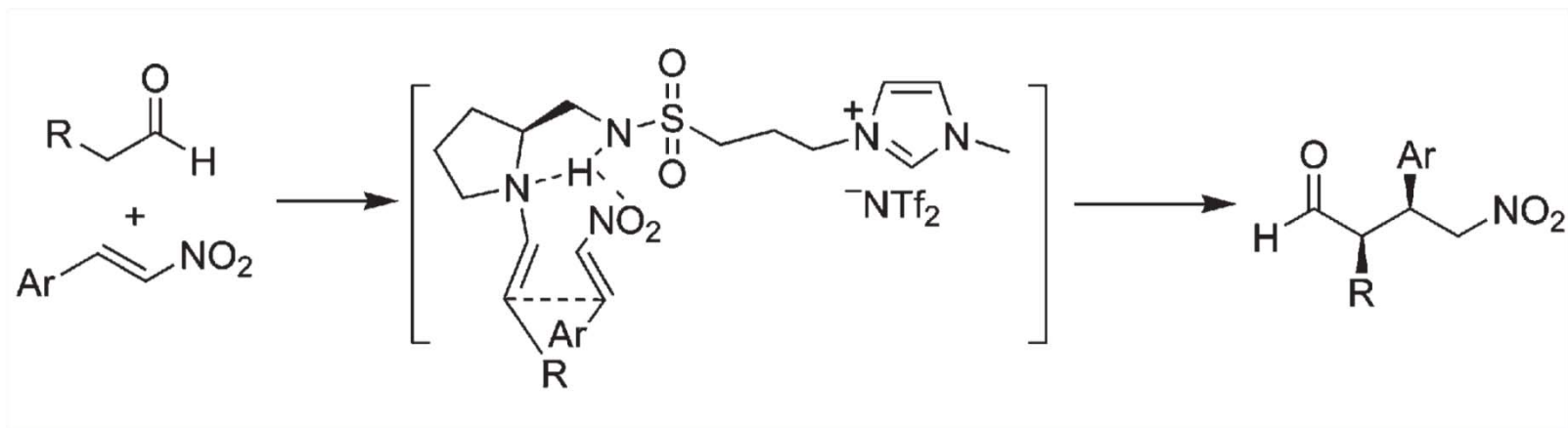
Table 2 Michael addition reactions of aldehydes to *trans*-nitrostyrenes catalyzed by **3**



- All aldehydes can undergo Michael reactions with different aryl-substituted nitrostyrenes.
- Giving the corresponding Michael adducts in moderate yields(29-64%), good enantioselectivities (64-82%ee),and high diastereoselectivities.

The use of ionic liquids as reactions catalyst

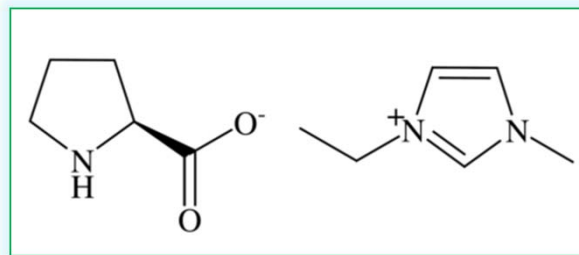
Mechanism for the Michael addition using catalyst 3



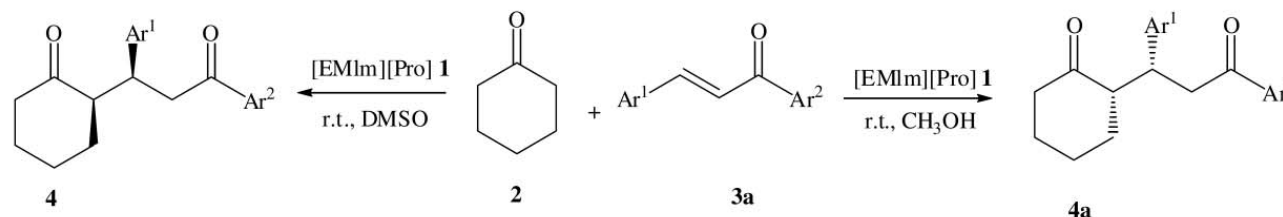
It is obvious that N-H acidic hydrogen plays an important role in the reaction by forming hydrogen bonds to the nitrostyrene substrate in a manner that C-C bond formation would take place by the preferential enamine addition to the less hindered *Si* face of the nitrostyrene.



The use of ionic liquids as reactions catalyst



[EMIm][Pro] 1



Entry	Ar ¹	Ar ²	Conditions ^d	t (h)	Yield ^a (%)	dr ^b	ee ^{b,c} (%)
1	Ph	Ph	A	4	98	20:80	86
2	4-MeC ₆ H ₄	Ph	A	4	90	5:95	37
3	4-ClC ₆ H ₄	Ph	A	4	98	4:96	60
4	Ph	4-ClC ₆ H ₄	A	4	97	15:85	23
5	4-BrC ₆ H ₄	Ph	A	4	80	23:77	44
6	Ph	4-NH ₂ C ₆ H ₄	A	8	87	4:96	94
7	2-ClC ₆ H ₄	4-MeC ₆ H ₄	A	4	99	1:99	29
8	Ph	Ph	B	4	95	12:88	-78
9	4-MeC ₆ H ₄	Ph	B	4	98	16:84	-72
10	4-ClC ₆ H ₄	Ph	B	4	94	10:90	-65
11	Ph	4-ClC ₆ H ₄	B	4	88	8:92	-72
12	4-BrC ₆ H ₄	Ph	B	4	90	10:90	-39
13	Ph	4-NH ₂ C ₆ H ₄	B	8	85	4:96	-91
14	2-ClC ₆ H ₄	4-MeOC ₆ H ₄	B	4	99	4:96	-16

^a Isolated yields after column chromatography.

^b Determined by HPLC analysis on a chiral AD-H column.

^c An inverse configuration determined by HPLC analysis on a chiral AD-H column.

^d Conditions A: reaction performed in CH₃OH; conditions B: reaction performed in DMSO.

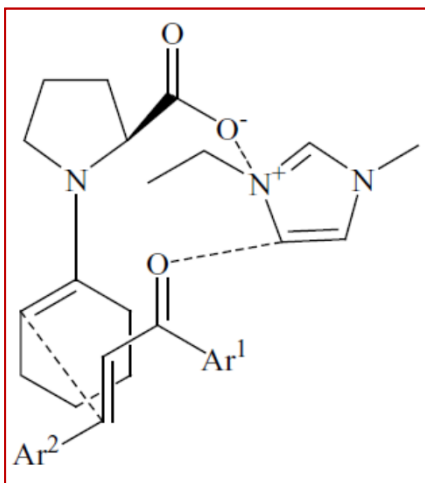


The use of ionic liquids as reactions catalyst

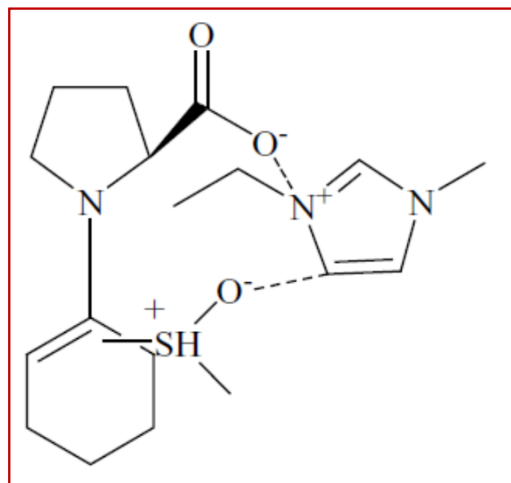
Catalytic asymmetric Michael addition of cyclohexanone 2 with chalcone 3

◆ Notably, the solvent-dependent inversion of the enantioselectivity took place in all reactions. Products obtained from DMSO mostly displayed a higher ee value than those obtained from CH₃OH.

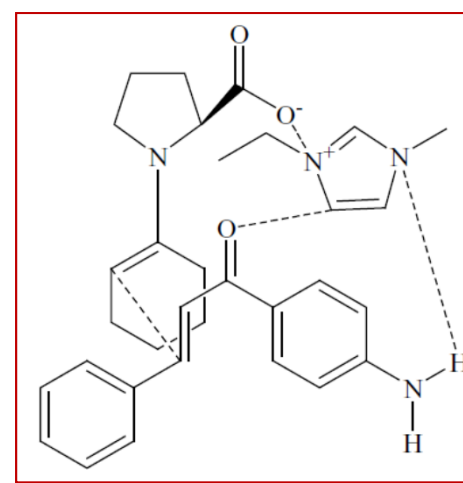
C: assumed that between catalyst 1 and the amine group there was probably a strong hydrogen-bond to anchor the substrate in a firm way.



A
In MeOH



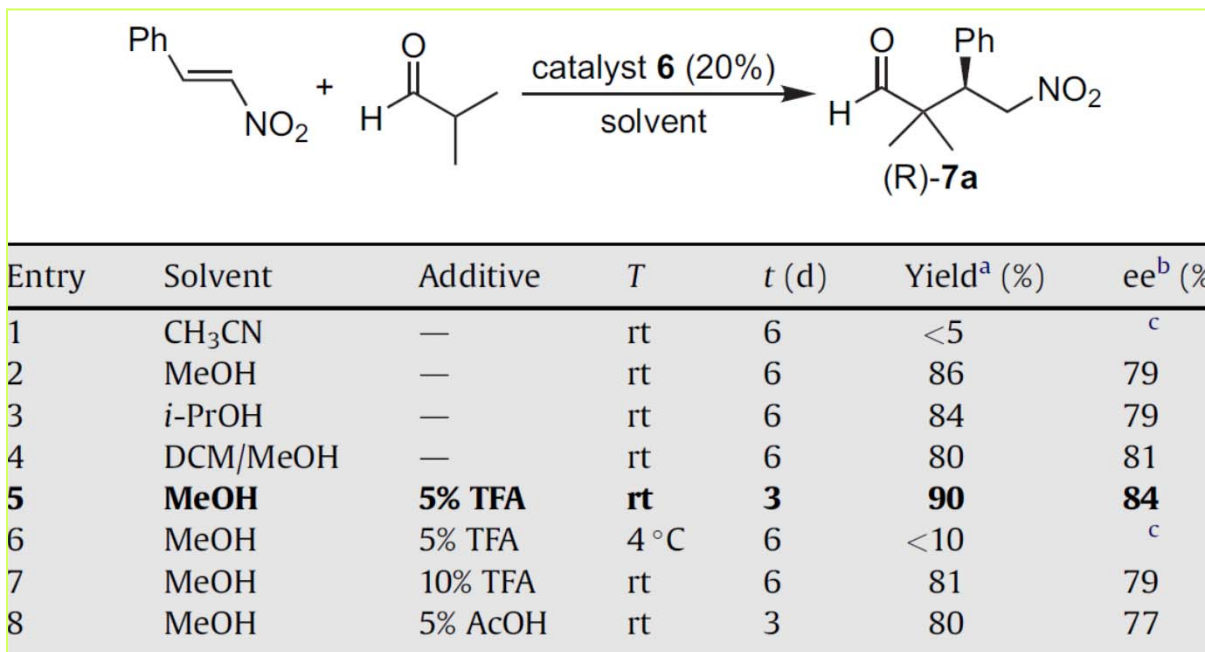
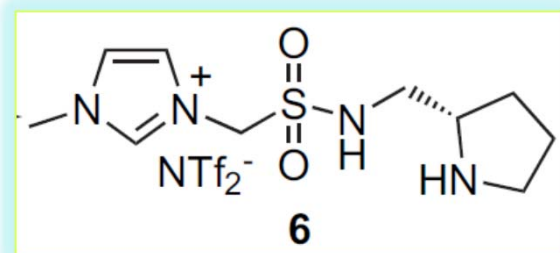
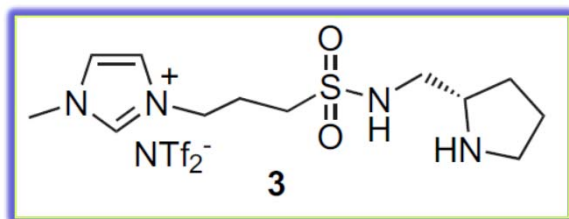
B
In DMSO



C



The use of ionic liquids as reactions catalyst

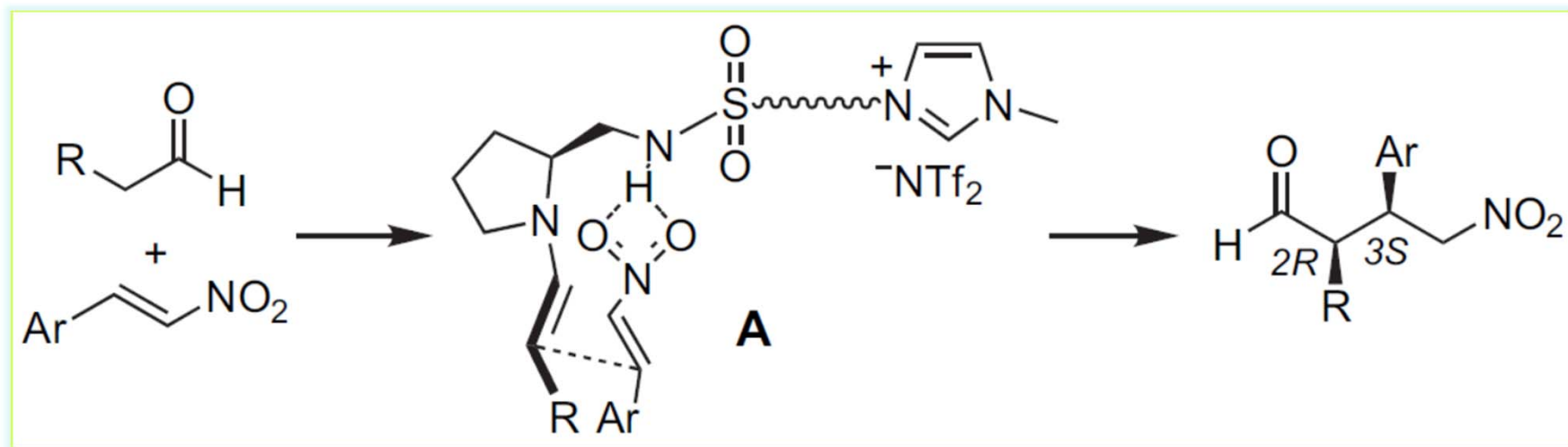


Noteworthy, catalyst 6 exhibited superior enantiocontrol, compared to catalyst 3 in MeOH and *i*-PrOH. The introduction of the electron-withdrawing imidazolium cation in close proximity to the NH in catalyst 6 increases the strength of hydrogen bond interaction in the transition state, which results in enhanced stereochemical control.

Interestingly, the addition of a catalytic amount of the organic acid, TFA, dramatically increased the reaction rate, along with an improvement in the ee of 84% with MeOH. The observation indicates that acidic additives in the reaction accelerate the formation of the enamine intermediate and promote the catalytic cycle.

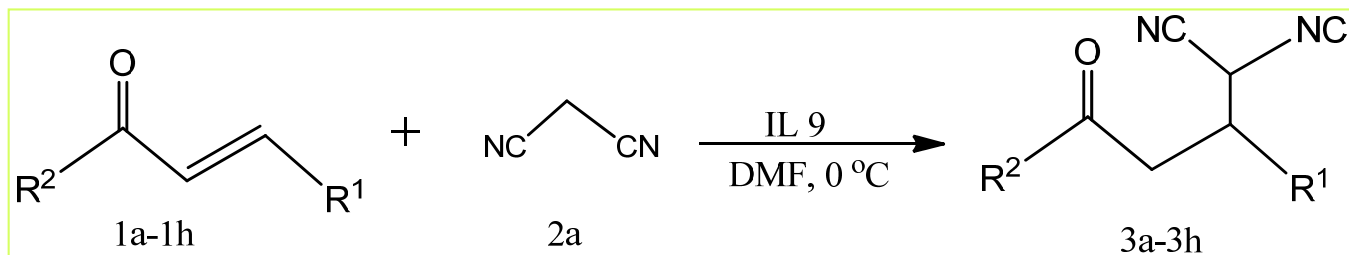
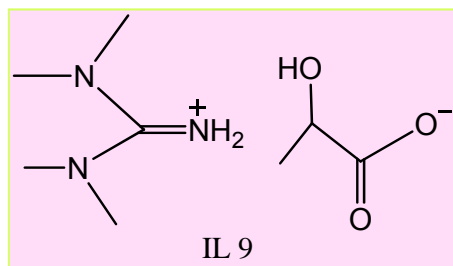
The use of ionic liquids as reactions catalyst

Mechanism for the Michael addition using catalysts 3 and 6



✿ It is obvious that the N-H acidic hydrogen plays an important role in the reaction by forming hydrogen bonds to the nitrostyrene substrate in a manner that the C-C bond formation would take place by the preferential enamine addition to the less hindered Si-face of the nitrostyrene generating 2R,3S configuration of products.

The use of ionic liquids as reactions catalyst

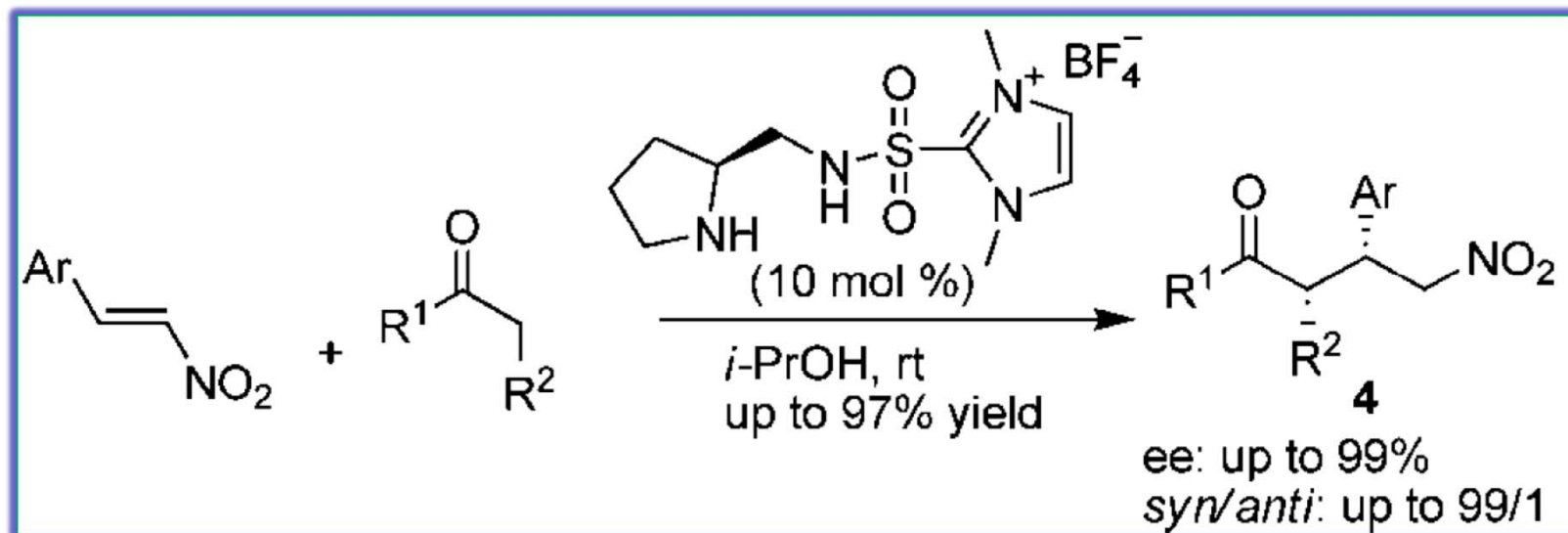


Entry	Chalcone	Substrate		Time/h	Product ^a	Yield(%) ^b
		R ¹	R ²			
1	1a	C ₆ H ₅	C ₆ H ₅	2.3	3a	99
2	1b	C ₆ H ₅	4-CH ₃ C ₆ H ₄	4.1	3b	99
3	1c	C ₆ H ₅	4-OCH ₃ C ₆ H ₄	3.2	3c	98
4	1d	C ₆ H ₅	2-OCH ₃ C ₆ H ₄	3.3	3d	99
5	1e	C ₆ H ₅	3,4-O ₂ CH ₂ C ₆ H ₃	4.5	3e	99
6	1f	C ₆ H ₅	4-ClC ₆ H ₄	2.5	3f	97
7	1g	4-ClC ₆ H ₄	4-ClC ₆ H ₄	1.6	3g	99
8	1h	4-ClC ₆ H ₄	4-OCH ₃ C ₆ H ₄	2.5	3h	98

a. The products are obtained by direct filtration; *b.* isolated yields.

1. All products could be obtained in high purity by simple filtration and wash with water.
2. Simple procedure ,very mild conditions , and quantitative yields

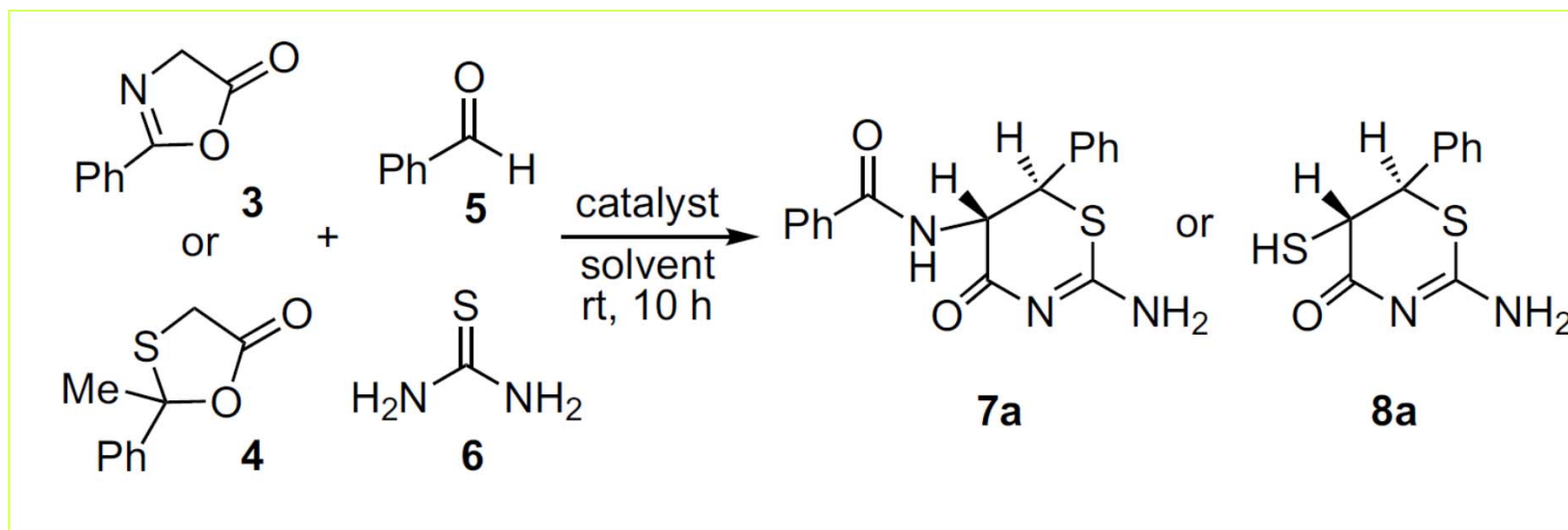
The use of ionic liquids as reactions catalyst



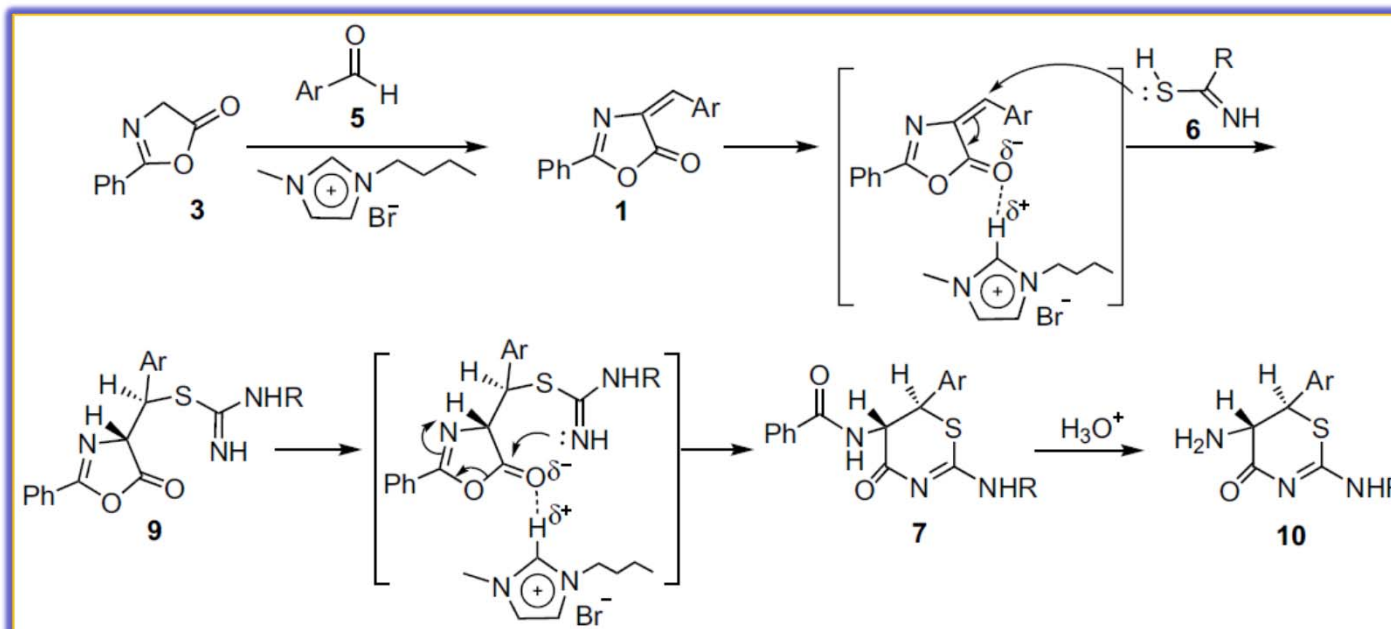
1. All 6-membered ring ketones can efficiently undergo Michael reactions with different aryl-substituted nitroolefins
2. Highly efficient, asymmetric Michael addition reactions of ketones and aldehyde to nitroolefins
3. The catalyst is readily recovered and reused for at least five times without significant loss of catalytic activity and stereoselectivity



The use of ionic liquids as reactions catalyst



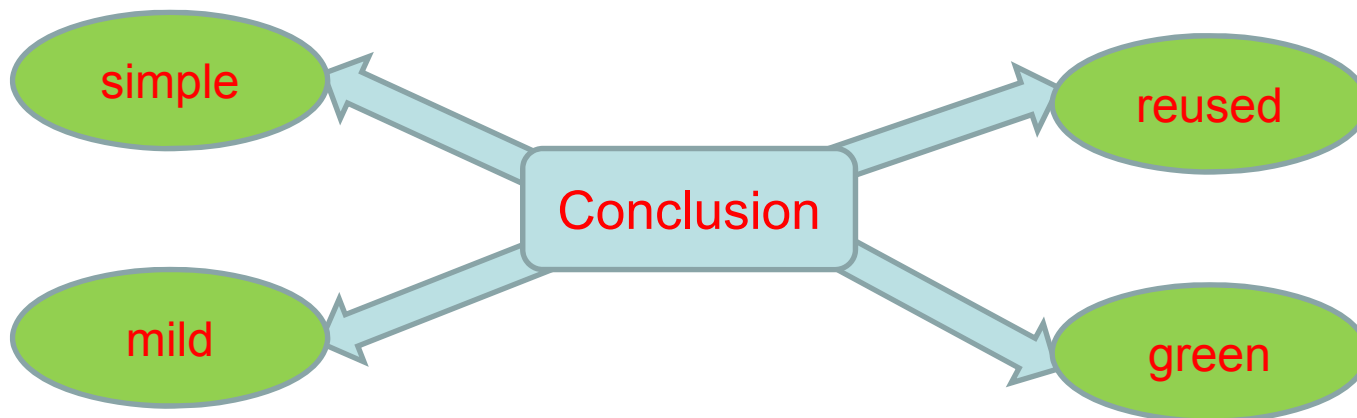
Mechanism



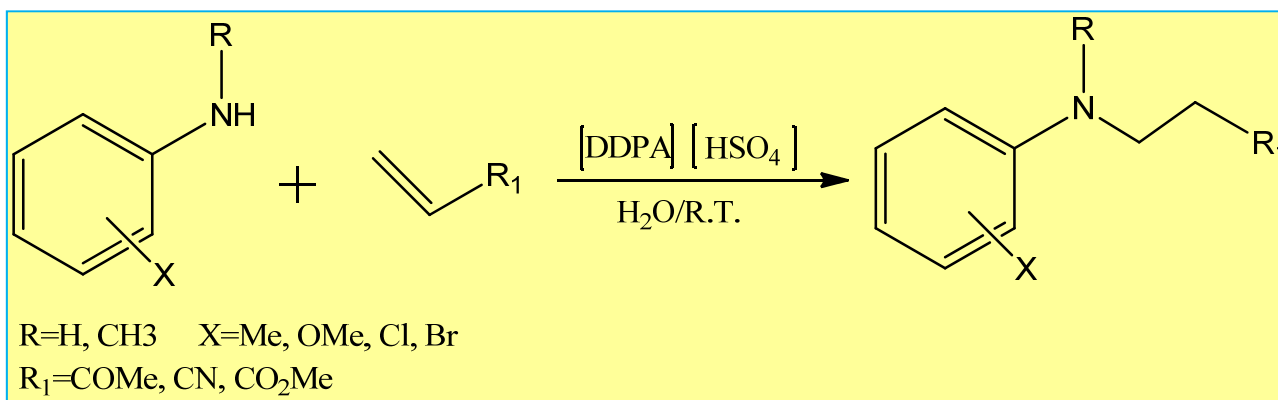
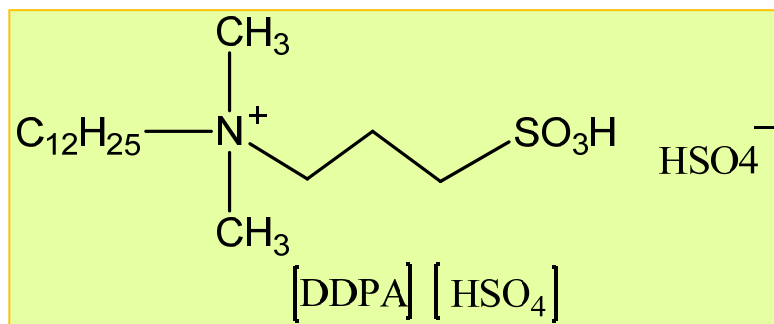
The use of ionic liquids as reactions catalyst

In summary

1. The first ionic liquid-promoted one-pot diastereoselective synthesis of 2,5 diamino- /2-amino -5-mercapto-1,3-thiazin-4-ones using masked amino/mercapto acids
2. The one-pot diastereoselective synthesis is operationally simple, high yielding , and performed at r.t.
3. Using the ionic liquid [Bmim]Br as an environmentally benign catalyst

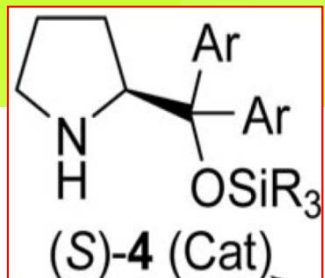


The use of ionic liquids as reactions catalyst

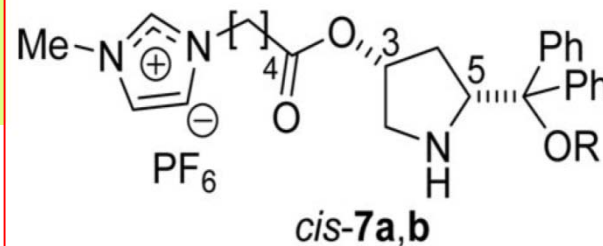
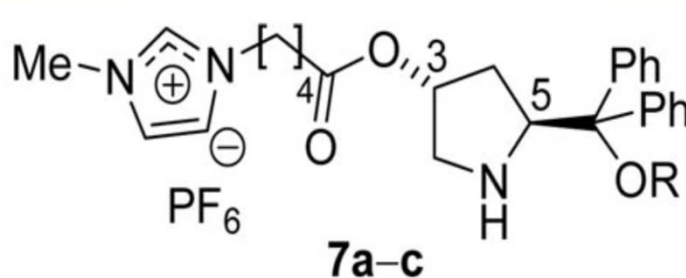


- Aromatic amines with α,β -unsaturated compounds catalyzed by [DDPA][HSO₄] to produce β -amino compounds.
- High yields of the products, short reaction times, mild reaction conditions and simple procedure.

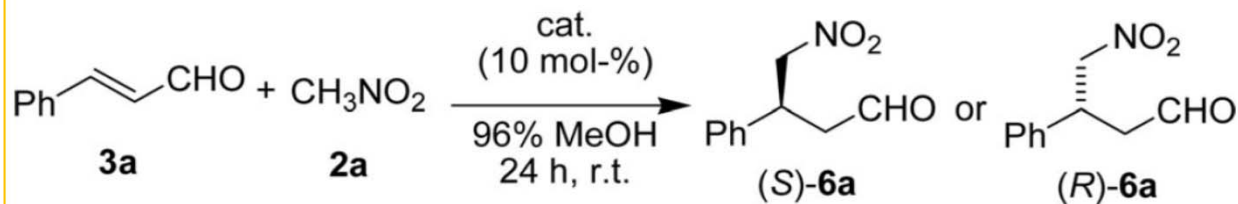




4a



7: R = SiMe₃ (a), H (b), SiEt₃ (c)



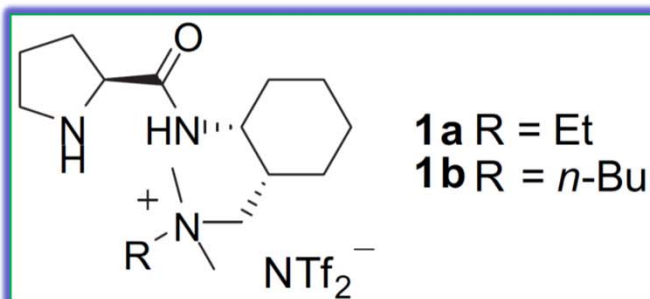
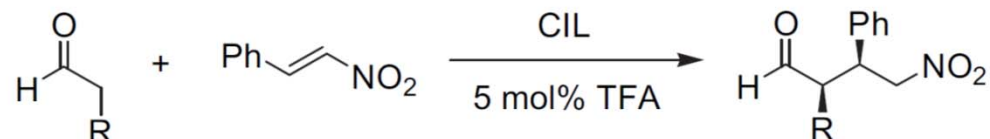
Entry	Catalyst	Time [h]	Product	% Conversion ^[b]	% ee ^[c]
1	7a	24	(S)-6a	>99	94
2	7b	48	(S)-6a	>99	70
3 ^[d]	7b	48	(S)-6a	66	68
4	7c	24	(S)-6a	5 (11 ^[e])	n.d.
5	4a	24	(S)-6a	>99 (12 ^[d,f] , 90 ^[g])	95 (95 ^[g])
6	<i>cis</i> -7a	24	(R)-6a	>99	94
7	<i>cis</i> -7b	72	(R)-6a	>99	62

Finding that in 96% MeOH compounds 2a and 3a were completely converted in the presence of homogeneous catalyst 4a into adduct (S)-6a, whereas in dry MeOH having no activating additives compound (S)-6a reportedly was formed in as low as 12% yield.

From the table, we can obtain that enantiomer (R)-6a was the major product of the reactions between compounds 2a and 3a in the presence of catalysts *cis*-7a and *cis*-7b. Moreover, conversions and enantioselectivities in these reactions were similar to those in the reactions catalyzed by trans-isomers 7a and 7b, where opposite enantiomer (S)-6a was formed.

The use of ionic liquids as reactions catalyst

Michael addition of aldehydes to *trans*- β -nitrostyrene^a



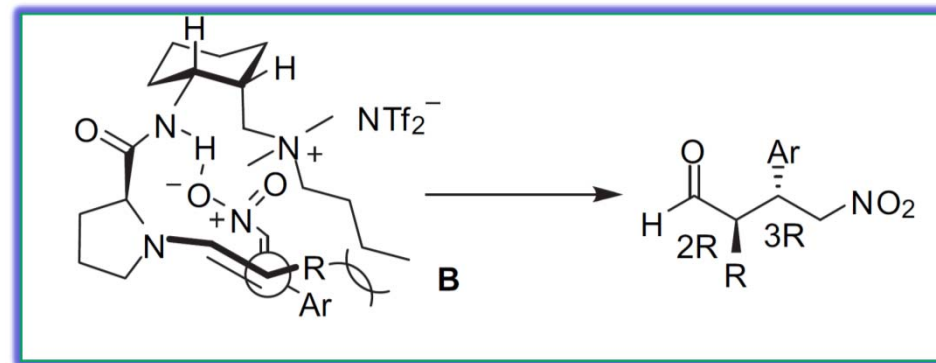
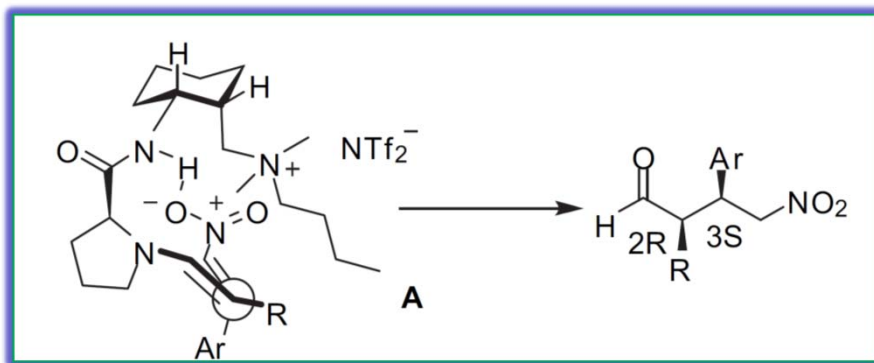
Entry	R	CIL	T (h)	Yield ^b (%)	dr ^c (<i>syn/anti</i>)	ee ^d (%) <i>syn</i> (<i>anti</i>)	Pr.
1	Me	1a	12	95	68/32	84 (81)	8a
2		1b	12	95	77/23	88 (89)	
3	Et	1a	12	96	82/18	76 (75)	8b
4		1b	12	99	89/11	87 (82)	
5	<i>n</i> -Pr	1a	24	96	80/20	75 (71)	8c
6		1b	24	98	87/13	81 (78)	
7	<i>i</i> -Pr	1a	60	37	97/3	77	8d
8		1b	60	84	99/1	82	
9	<i>n</i> -Bu	1a	36	97	73/27	72 (73)	8e
10		1b	36	99	90/10	80 (77)	

^a The reaction was conducted with β -nitrostyrene (0.1 mmol), aldehyde (0.6 mmol), and CIL **1a** (20 mol %) in 1 mL of THF or CIL **1b** (15 mol %) in 1 mL of DCM at rt.

^b Isolated yield.

1. Excellent yields (95-99%) , moderate to high diastereoselectivities
2. Enantioselectivities(72-88%) the enantioselectivity decreased slightly with the increase of carbon chain length of aldehydes, for either CIL **1a** or **1b** was used

The use of ionic liquids as reactions catalyst



- The bulky IL group and the hydrogen bonding between the amide NH and the nitro group of nitroolefin are considered to be important to the high catalytic activity and the stereoselectivity.
- The possible ionic attraction between ammonium cation and nitro group of the substrate should also contribute to stabilization of the intermediate. The enamine tends to attack from the less hindered Si face of the nitroolefin. (2R, 3S) configuration of the corresponding adduct is generated preferentially (Fig. A).
- The flexible butyl side chain of ammonium group may cause moderate repulsive interaction with anaryl group of nitroolefin (Fig. B).
- The moderate diastereoselectivity of the reaction could be rationalized by considering this weak interaction.

Quininium bromide 1

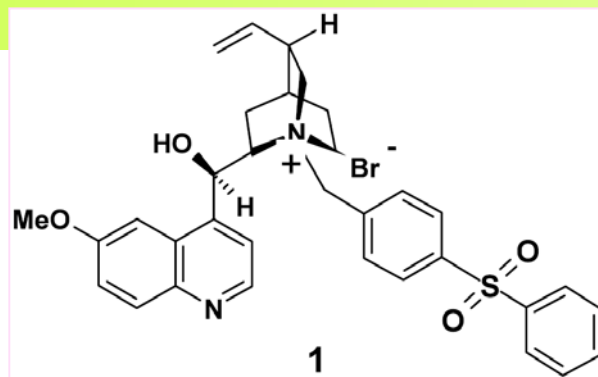
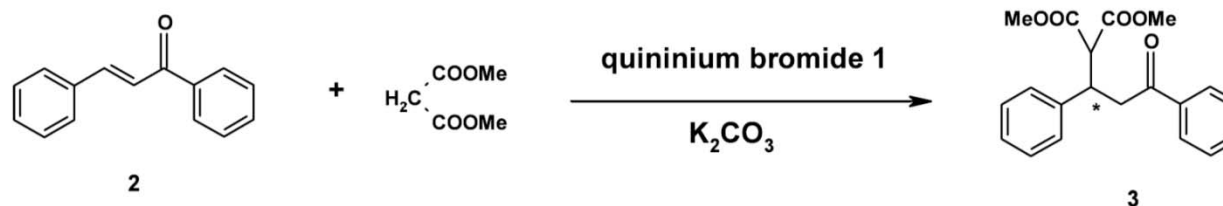


Table 1. Catalytic enantioselective Michael addition of dimethyl malonate to 1,3-diphenylprop-2-en-1-one in ionic liquids and organic solvents



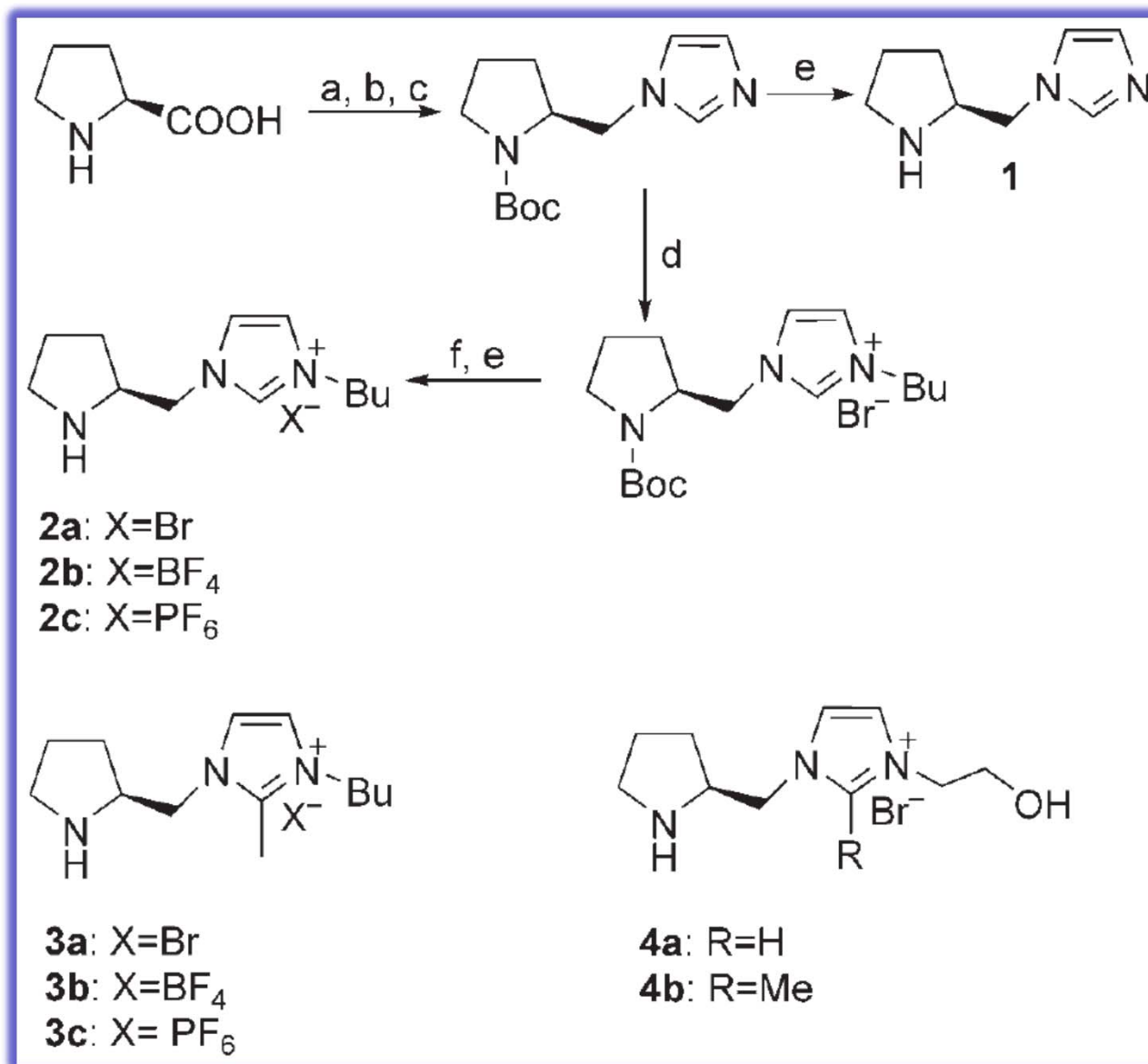
Entry	Solvents	Temp. (°C)	Time (h)	Yield (%) ^a	ee (%) ^b	[α] _D ²⁶
1	DMSO	28	6	96	61	+20.31
2	Toluene	28	8	92	56	+18.64
3	DCM	0	6	94	46	+15.31
4	[bmim]PF ₆	28	3	99	50	-16.64
5	[bmim]BF ₄	28	4	97	44	-14.65
6	[bpy]BF ₄	28	4	97	42	+13.98

^a Isolated yields are shown.

^b Enantiomeric excesses were determined from optical rotations.

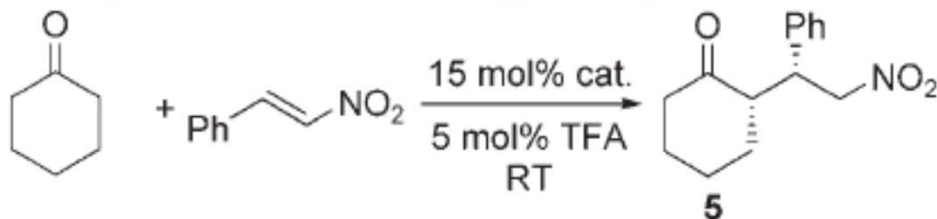


The use of ionic liquids as reactions medium and catalyst

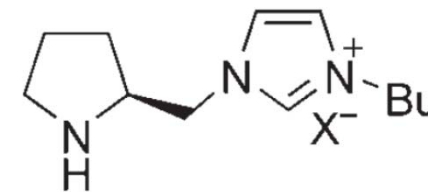


The use of ionic liquids as reactions medium and catalyst

Table 1: The effect of chiral ionic-liquid catalysts in asymmetric Michael additions of cyclohexanone and *trans*- β -nitrostyrene.^[a]



Entry	Catalyst	<i>t</i> [h]	Yield [%] ^[b]	<i>syn/anti</i> ^[c]	<i>ee</i> [%] ^[d]
1	1	18	97	97:3	91
2	2a	10	99	99:1	98
3 ^[e]	2a	20	99	99:1	97
4	2b	8	100	99:1	99
5 ^[f]	2b	8	97	97:3	94
6 ^[g]	2b	24	99	96:4	91
7 ^[h]	2b	48	96	97:3	93
8	2c	12	86	98:2	87
9	3a	20	97	97:3	97
10	3b	16	100	96:4	94
11	3c	12	40	96:4	82
12	4a	18	86	97:3	89
13	4b	18	25	94:6	70



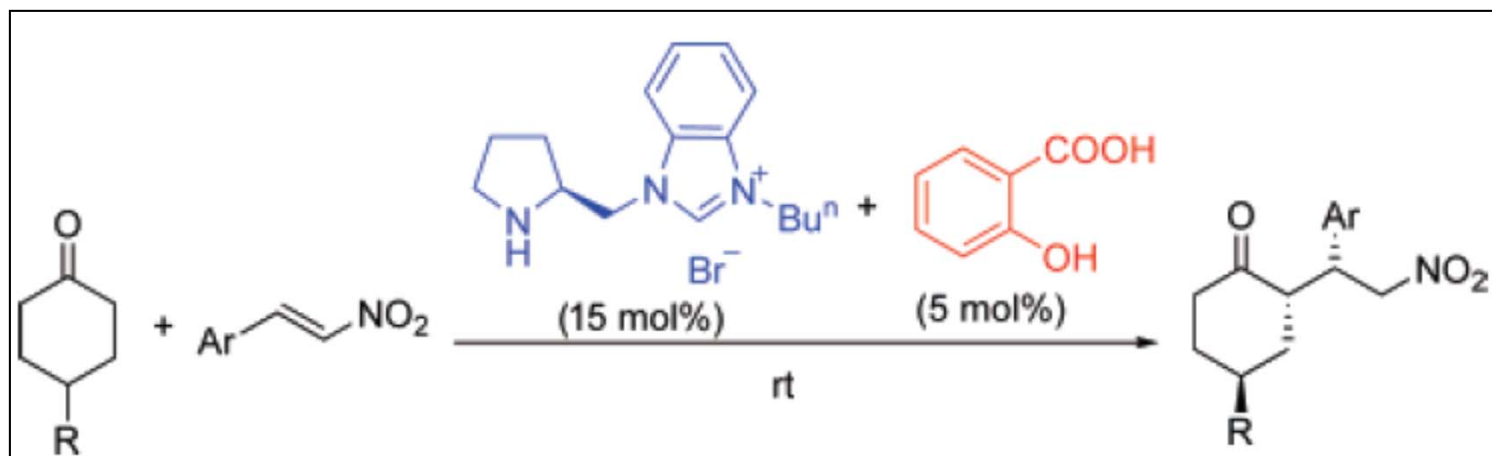
2a: X=Br

2b: X=BF₄

2c: X=PF₆



The use of ionic liquids as reactions medium and catalyst

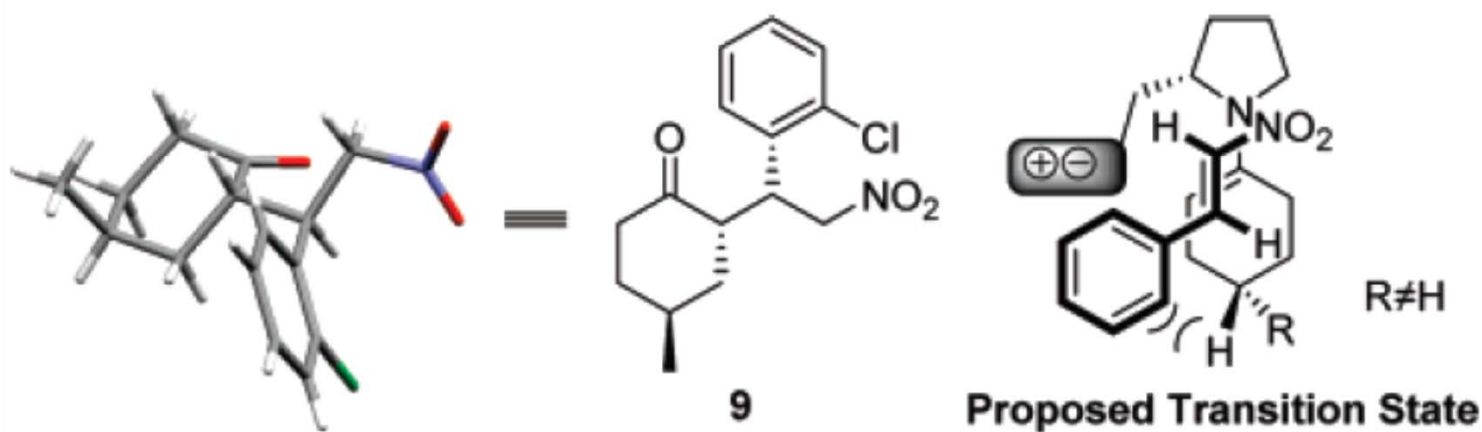


entry	R	Ar	T (h)	yield (%) ^b	dr ^c	ee (%) ^d
1	Me	Ph	10	89 (7)	6.2:1	97
2	Me	4-ClPh	10	89 (8)	6.1:1	99
3	Me	2-ClPh	10	99 (9)	>10:1	97
4	Me	4-MePh	16	89 (10)	7.0:1	98
5	Me	4-PhPh	12	92 (11)	6.0:1	94
6	Me	4-MeOPh	21	94 (12)	7.6:1	97
7	Me	4-NO ₂ Ph	3	88 (13)	5.0:1	98
8	Me	2-NO ₂ Ph	3	93 (14)	4.4:1	97
9 ^e	Me	2-NO ₂ Ph	4	99 (14)	4.8:1	97



The use of ionic liquids as reactions medium and catalyst

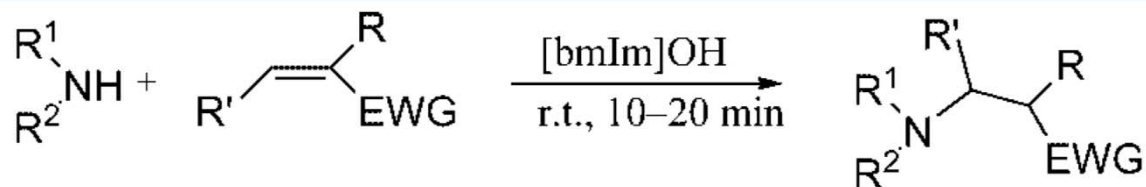
SCHEME 2. X-ray Crystal Structure of **9** (left) and the Proposed Transition State (right)



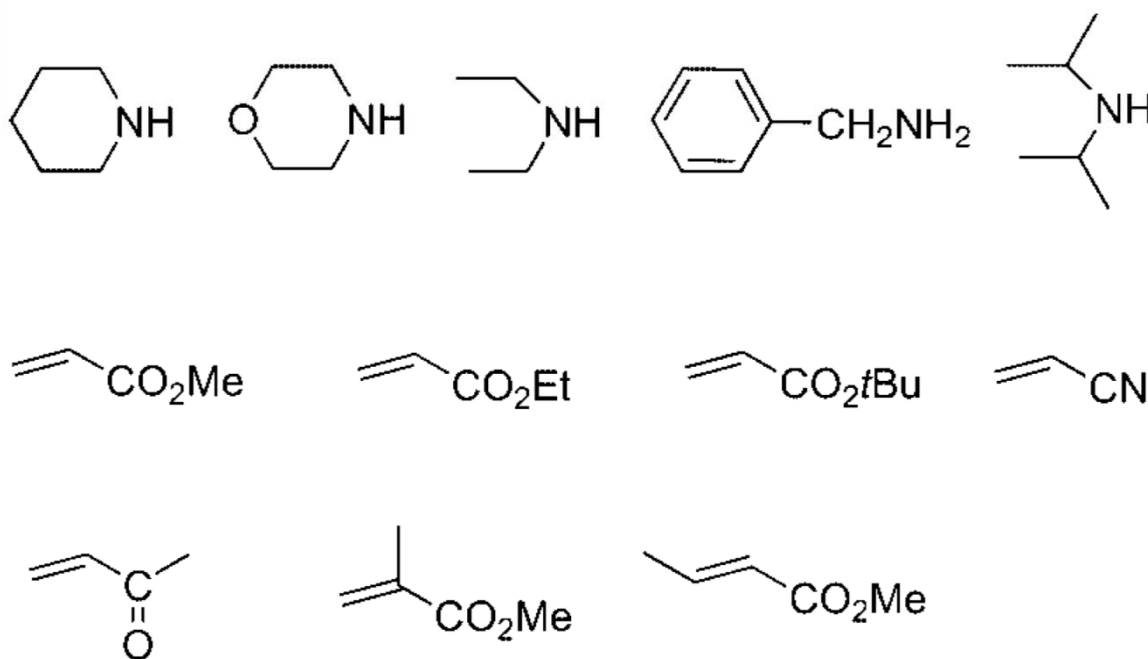
Functionalized chiral ionic liquids were found to be highly effective and reusable organocatalysts for asymmetric Michael additions of 4-substituted cyclohexanones. The desymmetrization reaction afforded the desired Michael adducts bearing three carbon stereocenters with up to 99% ee.



The use of ionic liquids as reactions medium and catalyst



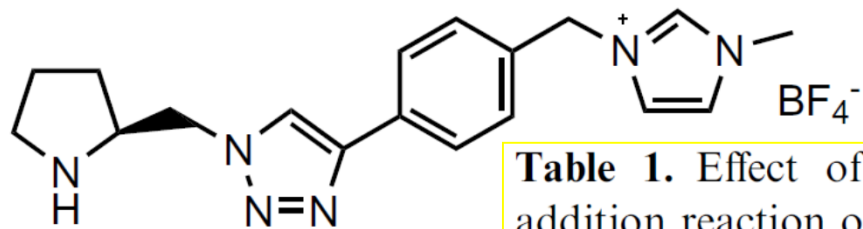
EWG = CN, COCH₃, CO₂CH₃



1. Amines exhibited higher nucleophilicity in ionic liquids than in organic solvents
2. The hydroxide anion of the ionic liquid [bmim]OH might assist in the formation of nucleophilic anions generated from amines, which should increase the nucleophilicity of amines

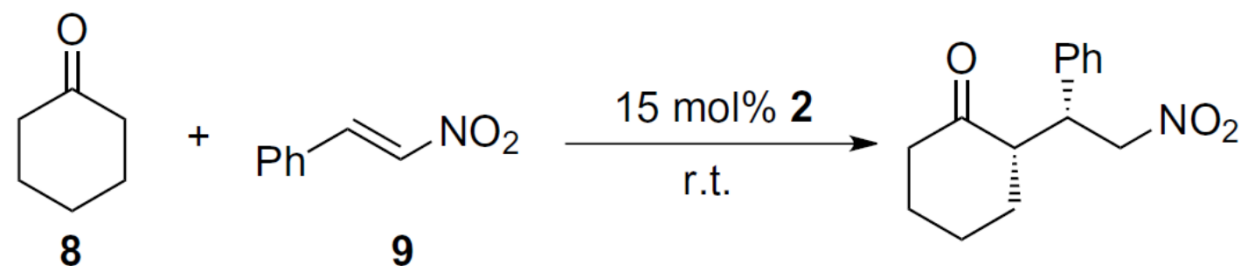
Michael additions between amines and α,β -unsaturated carbonyl compounds





2

Table 1. Effect of IL-supported catalyst in the asymmetric Michael addition reaction of cyclohexanone and *trans*- β -nitrostyrene^b



Entry	Solvent	Additive	Time (h)	Yield ^c (%)	dr ^d (<i>syn/anti</i>)	ee ^e (%)
1	DMSO	—	72	41	n.d. ^a	n.d.
2	CHCl ₃	—	72	34	n.d.	n.d.
3	H ₂ O	—	72	29	n.d.	n.d.
4	—	—	72	47	n.d.	n.d.
5	DMSO	TFA ^a	48	90	94:6	88
6	CHCl ₃	TFA	48	95	96:4	92
7	H ₂ O	TFA	48	94	93:7	90
8	—	TFA	48	97	97:3	94
9 ^f	—	TFA	48	89	96:4	94
10 ^g	—	TFA	72	90	96:4	93
11	—	TosOH	72	73	94:6	93
12	—	AcOH	72	60	95:5	83

IL-supported catalyst retained, good activity and high selectivity.

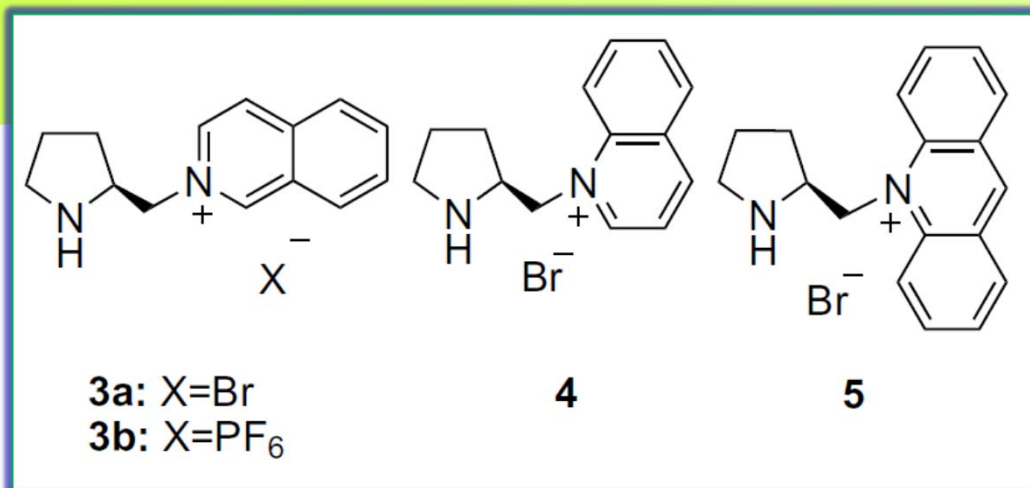
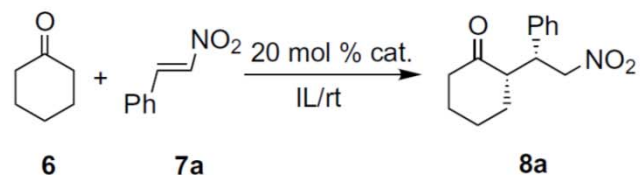


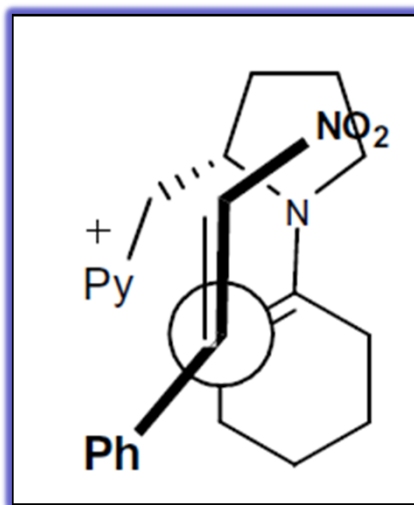
Table 1. Organocatalyzed direct Michael addition of cyclohexanone **6** to *trans*- β -nitrostyrene **7a** in ILs^a



Entry	Cat.	IL	Time (h)	Yield ^b (%)	dr ^c (<i>syn/anti</i>)	ee ^d (%)
1	1	BMImPF ₆	48	93	91/9	28
2	2	BMImPF ₆	48	19	91/9	7
3	3a	BMImPF₆	48	88	96/4	95
4	3b	BMImPF ₆	48	90	90/10	41
5	4	BMImPF ₆	48	74	91/9	8
6	5	BMImPF ₆	48	8	91/9	23
7	1	BMImBF ₄	24	94	90/10	68
8	2	BMImBF ₄	48	80	91/9	4
9	3a	BMImBF₄	20	95	93/7	99
10	3b	BMImBF₄	20	95	96/4	93
11	4	BMImBF ₄	24	92	91/9	17
12	5	BMImBF ₄	48	92	91/9	52

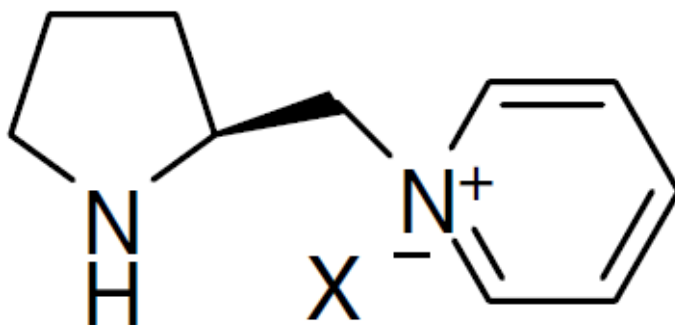
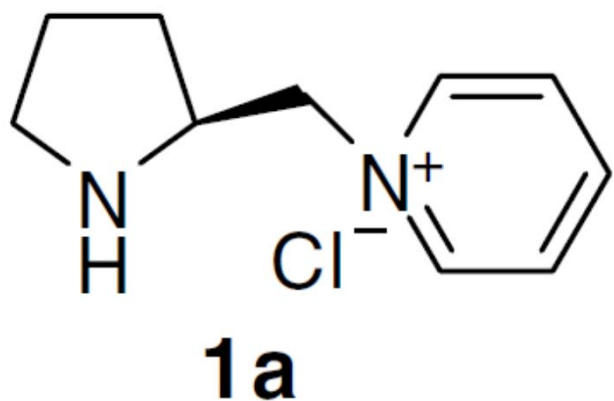


The use of ionic liquids as reactions medium and catalyst



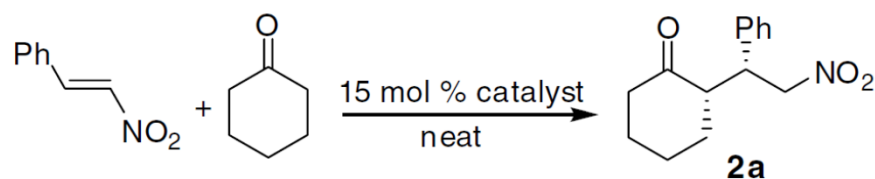
1. Pyrrolidine–pyridinium conjugates must catalyze a Re-face attack on 6 via an enamine transition state, in which the Si-face was shielded by the pyridinium moiety on the catalyst as outlined.
2. The ionic liquid BMImBF₄ might play a key role in stabilizing the formed iminium-ion transition state, owned a greater charge density than the initial reaction molecules, by operating favorable electrostatic interactions, which led to the enhancement of the overall reaction efficiency.





1b: X=BF₄
1c: X=PF₆
1d: X=NTf₂

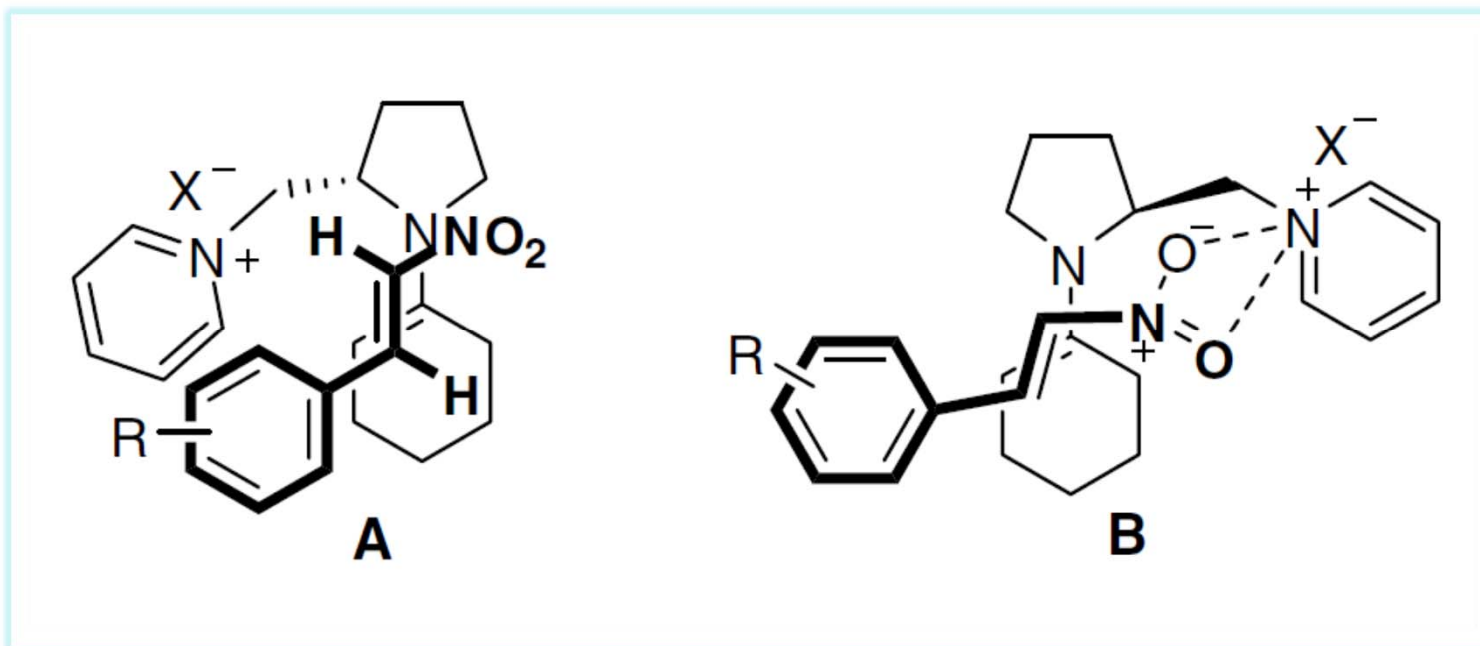
The effect of catalyst in the Michael reaction of cyclohexanone and nitrostyrene



Entry	Catalyst	TFA ^a (mol %)	<i>T</i>	Time (h)	Yield ^b (%)	ee ^c (%) (<i>syn</i>)	dr ^d (<i>syn/anti</i>)
1	1a	—	rt	36	74	99	98/2
2	1a	5	rt	36	91	99	97/3
3	1b	—	rt	36	75	94	>99/1
4	1b	5	rt	16	95	98	99/1
5	1b	5	4 °C	30	92	99	>99/1
6	1c	—	rt	72	90	93	99/1
7	1c	5	rt	48	92	86	95/5
8	1d	—	rt	43	81	95	96/4
9	1d	5	rt	16	95	93	96/4
10 ^e	1b	5	4 °C	30	90	99	99/1
11 ^f	1b	5	4 °C	30	82	94	96/4

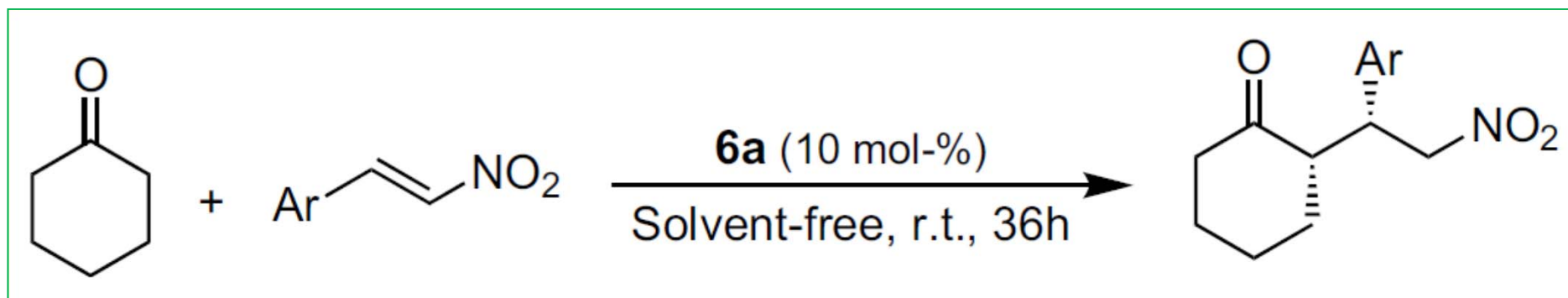
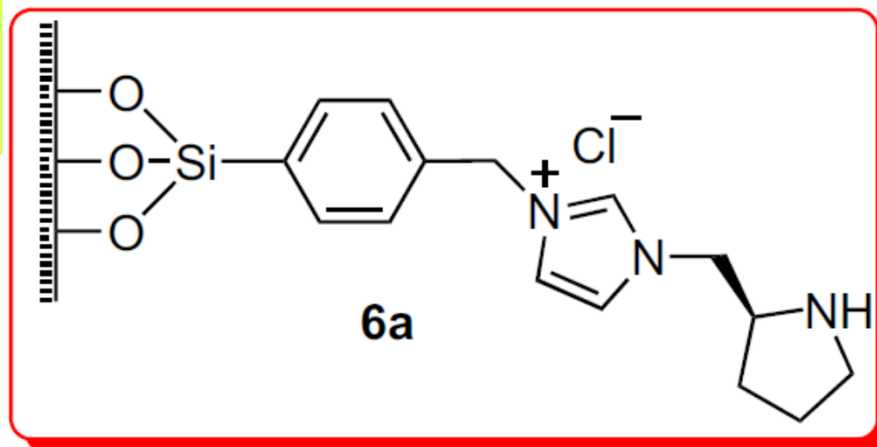


The use of ionic liquids as reactions medium and catalyst



1. The high diastereo- and enantioselectivities may be explained by an acyclic synclinal transition **state A**, in which the pyridinium ring plays an important role in shielding the si-face of enamine double bond.
2. The possible ionic attraction between pyridinium cation and nitro group of the substrate (transition **state B**) should also contribute to the enantioselectivity observed.





Synthesis of silica gel supported pyrrolidine-based chiral ionic liquid and its application in asymmetric Michael addition to nitrostyrenes.

Yield: up to 96%
ee: up to >99%
dr: up to >99:1



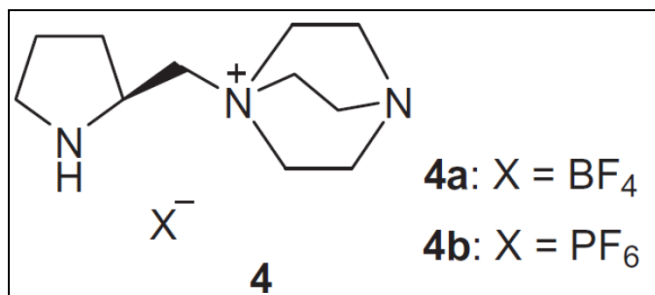
The use of ionic liquids as reactions medium and catalyst

In summary

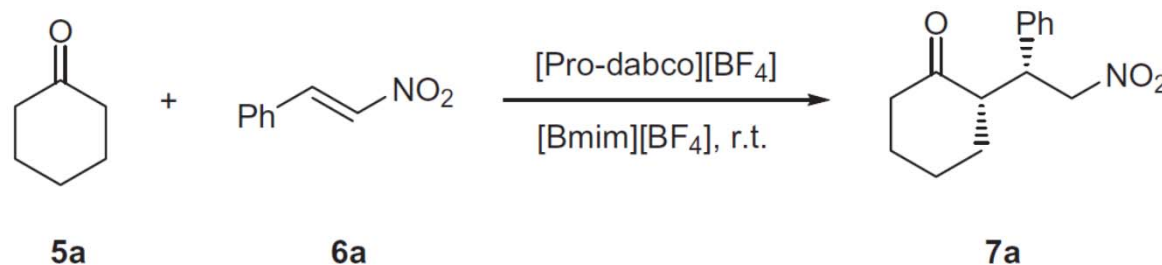
1. Developed a novel silica gel supported pyrrolidine-based chiral ionic liquids, which are capable of catalyzing Michael addition reaction of ketones with nitrostyrenes in good yields, excellent enantioselectivities and high diastereoselectivities.
2. The method is operationally simple, the catalyst can be easily recycled, and reused six times without a significant loss of catalytic activity and stereoselectivity.



Recycling studies of ionic liquid [Pro-dabco][BF₄] catalyzed Michael addition of cyclohexanone to trans-b-nitrostyrene



1. The first chiral quaternary alkylammonium ionic liquid in an asymmetric Michael reaction.
2. The chiral ionic liquid were easily prepared from L-prolinol
3. Highly enantioselective and diastereoselective
4. The solvent were readily recovered and reused at five times without a significant loss of catalytic activity.



Cycle	<i>t</i> (h)	Yield ^b (%)	dr ^c (<i>syn/anti</i>)	ee ^d (%)
1	22	100	96:4	91
2	29	97	96:4	91
3	35	95	93:7	90
4	41	88	95:5	92
5	43	93	96:4	91
6	62	90	95:5	91

^a All reactions were conducted in [Bmim][BF₄] (0.5 mL) using **5a** (0.1 mL, 1.0 mmol) and **6a** (15 mg, 0.1 mmol) in the presence of 20 mol % of the catalyst.

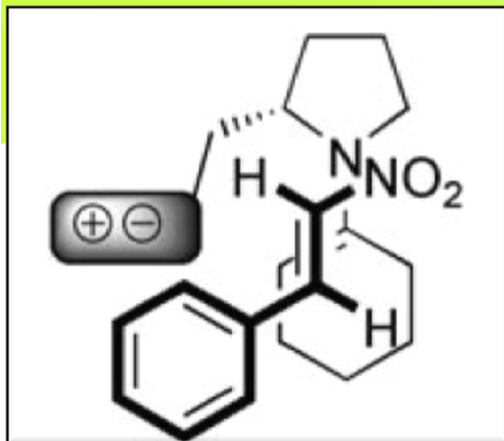
^b Isolated yield.

^c Determined by ¹H NMR spectroscopy.

^d Determined by HPLC analysis (chiralcel AD-H column).

shown in Table 2, catalyst **4a** could be recycled and reused at least five more times without any loss of stereoselectivity (ee >90%; *syn/anti* >93:7) but a slight decrease in activity was observed in cycles 2–6.





the ionic-liquid moiety would effectively shield the *Si* face of the enamine double bond in the ketone donor and the reaction would occur through a *Re-Re* approach

The pyrrolidine–ionic-liquid conjugates have several noteworthy features:

- 1) they can very efficiently catalyze the Michael additions for a broad range of Michael donors (both ketones and aldehydes) and Michael acceptors (nitroolefins) with **high yields (up to 100%), excellent enantioselectivity (up to 99% ee), and very good diastereoselectivity (syn/anti up to 99:1);**
- 2) the ionic-liquid moiety can not only act as a phase tag to facilitate **recycling** and **reuse** of the catalyst but can also function as an **efficient chiral-induction group to ensure high selectivity;**
- 3) the modular and tuneable features of ionic liquids promise further developments.



Conclusion



Ionic liquids as environmental-friendly solvents and catalysts with high activity and selectivity and easily recovered materials were used to replace solvent and catalysts.



Using the traditional solvent generally suffered from disadvantages such as waste production, corrosion and environmental problems.



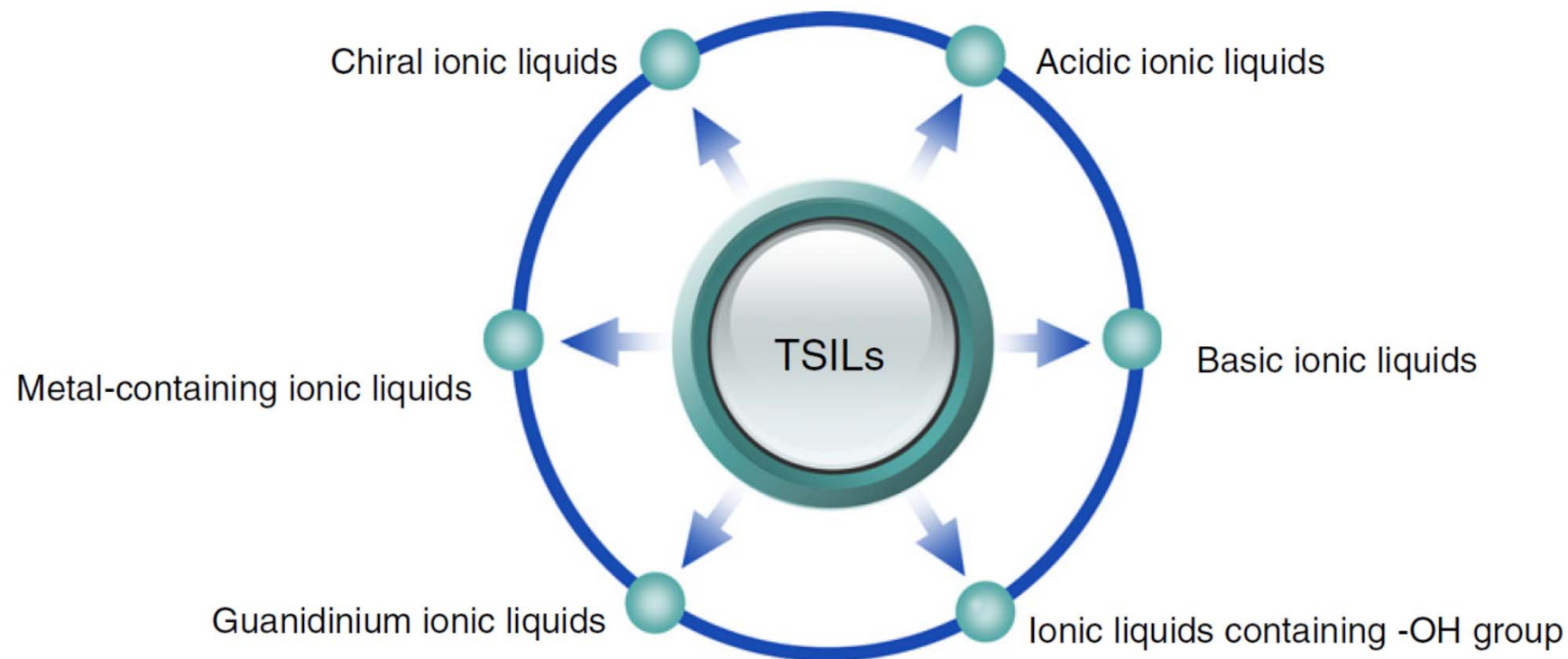
Ionic liquids offering a new possibility for developing environmentally friendly catalysts .They are flexible, nonvolatile, noncorrosive, and immiscible with many organic solvents.



Ionic liquids have been used in catalyzed processes in Michael addition, especially task-specific ionic liquids.



Task-Specific Ionic liquids





Thank you for your attention!