ULRASOUND ASSISTED ORGANIC SYNTHESIS (A REVIEW)

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تهدف هذه الدراسة المرجعية إلى إظهار الدور الفعال لتقنية الأشعة فوق الصوتية التي استخدمت في تحضير عدد من المركبات العضوية بواسطة تفاعلات الألكلة، التكاثف، الإضافة وعدد من التفاعلات المختلفة التي تضمنها هذا من البحث المرجعي. الحقيقة أن هناك عدة أسباب جوهرية دفعت العلماء إلى استخدام هذه التقنية، ولكن أهمها هو تطبيق تقنيات تحد بقدر الإمكان من إنتاج المخلفات الملوثة للبيئة.

This review shows the influence of ultrasound on the development of chemical reactions and to highlight some recent applications of sonochemistry in several organic synthesis such as, alkylation, condensation, cycloaddition, and other miscellaneous reactions which are reviewed here.
The driving force for these developments has many facets, but the increasing requirement for environmentally clean technology that minimizes the production of waste at source is an important factor.

Contents

2- Literature Survey

This literature survey of ultrasound transformations covers the literature published during the period (1980- 2007). The reactions have been classified into sub-classes and the main reference in each class is represented by a graphical abstract format.

2. 1 Introduction

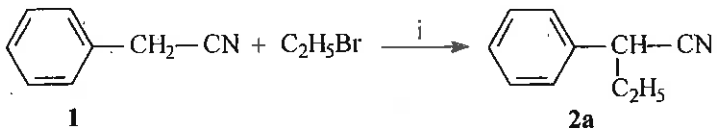
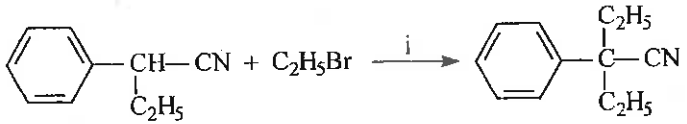
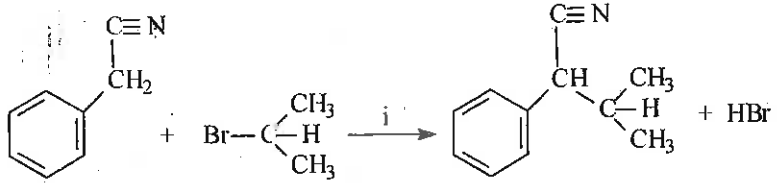
The application of powerful Ultrasound "Sonochemistry" in chemical processes is one of a number of intensification technologies that have undergone serious and wide-ranging development. The enormous influence of ultrasound on chemical reactions, particularly in organic synthesis, has been widely exploited for more than two decades as reflected in the large number of books devoted to this specific use of ultrasound over this period [1-7].

The chemical effects of ultrasound have three types of reactions: homogeneous sonochemistry of liquid, heterogeneous sono=-hemistery of liquid- liquid or liquid-solid systems, and thirdly sonocatalysis (which overlaps the first two) [8].

Abbreviations

U.S	Ultrasound.
PTC	Phase transfer catalyst.
TBAHS	Tetrabutyl ammonium hydrogen sulfate.
TBABr	Tetrabutyl ammonium bromide.
NMP	N- methyl pyrrolidinone.
TBAN	t-Butylammonium natrate.
PPh_3	Triphenylphosphine.
DIAD	Dialkyl azodicarboxylate.
THF	Tetrahydrofuran
Py	Pyridine.
OMIBr	1- Octyl-3- methylimidazolium bromide
PTSA	Toluene-*p*- sulfonamide.
TBSCl	t-Butyl dimethylsilyl chloride.
DMF	Dimethyl formamide.
DDQ	2,3- Dichloro-5,6-dicyano-1,4-benzoquinone.
$[HMI][BF_4]$	1-Hexyl-3-methylimidazolium tetrafluoroborate.
PTSA	Toluene-*p*- sulfonic acid.
9-BBN	9- Borabicyclo[3.3.1]nonane.
TBAB	Tetrabutyl ammonium bromide.
DBSA	Dodecyl benzene sulfonic acid.
CAN	Ceric ammonium nitrate.
TSO	Tosylate.

2.2 Alkylation

Conditions	Type of reaction/ yield (s)/ number of examples	Reference (s)	
		Described	Additional
 **1** **2a**	C-alkylation of phenyl acetonitrile yield **2a**=21%-68%	[9]	
 **2b**	yield **2b**=32%-79% (2-examples)	[9]	
(i) KOH (solid), TBAHS, U.S, 150 min **PTC reaction schem**			
 **1** **2**	C-alkylation of benzyl cyanide yields = 60% (2- examples)	[10]	

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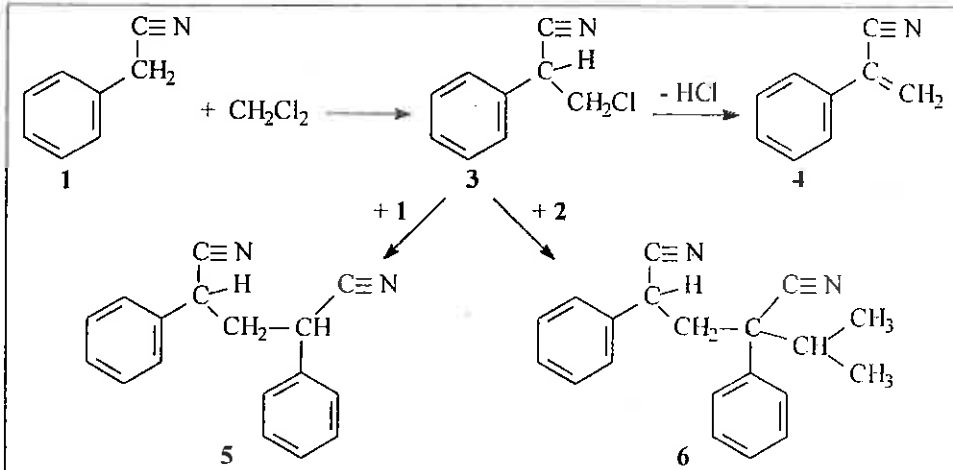
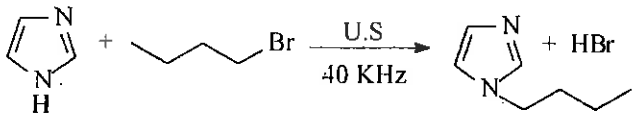
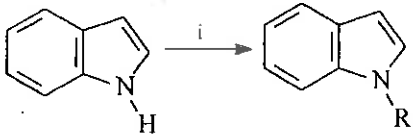
 (i) NaOH, TBABr, U. S 25 kHz **PTC reaction scheme**			
	N- alkylation of imidazole yield = high (1- example)	[11]	
 (i) RBr, KOH (solid), TBAN, U.S	N- alkylation of indole yield = 90% (1- example)	[12]	
$Ph_2NH + BrCH_2Ph \xrightarrow[\text{Toluene}]{\text{PTC/OH}} Ph_2NCH_2Ph$ U.S at 20 and 40 kHz	N-alkylation of diphenylamine yield = 90% (1-example)	[13]	

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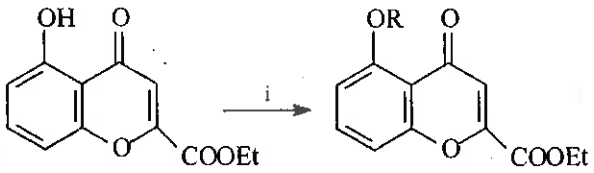
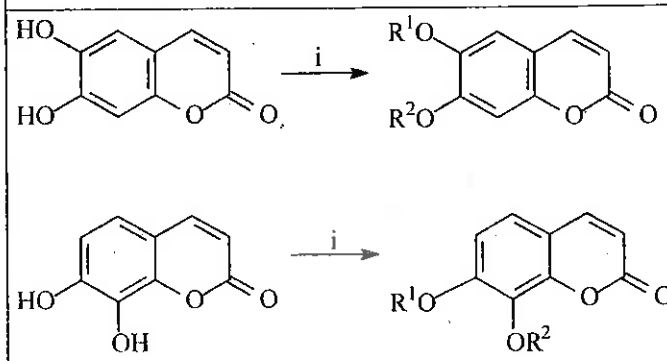
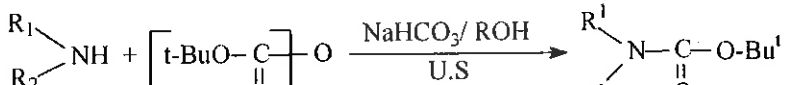
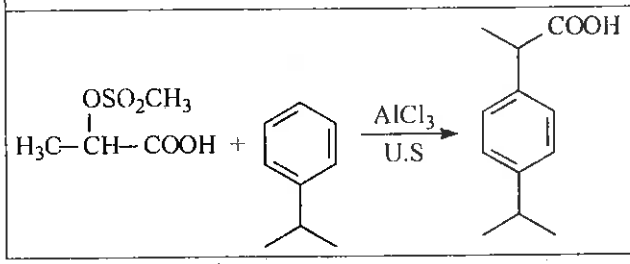
 (i) R-X, K_2CO_3, NMP, U.S 20 kHz	O- alkylation of 5-hydroxy-4-oxo-4 *H*-1-benzopyran-2-carboxylic acid ethyl ester yields = 97% -100 (3-examples)	[12]	
 (i) ROH, PPh_3, DIAD, THF, U.S, 45 min.	Monoalkylation of dihydroxy coumarins yields= 11%-65% (7- examples) yields= 4%-61% (14- examples)	[14] [14]	
	N- benzylation of indole yield = 95% (1- example)	[13]	
	Friedel-Crafts alkylation yield = 50% (1-example)	[12]	[15]

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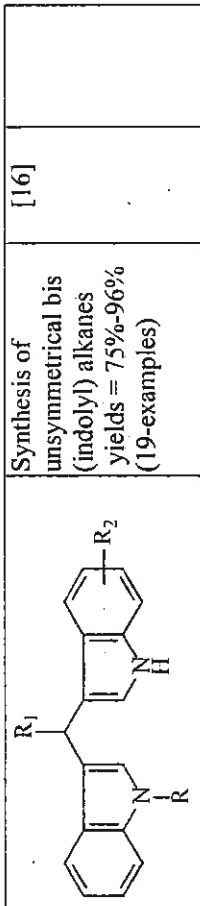
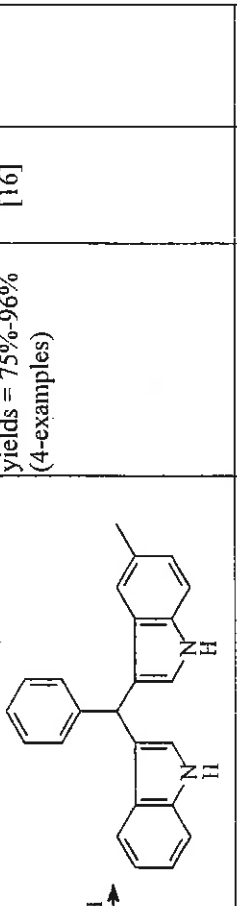
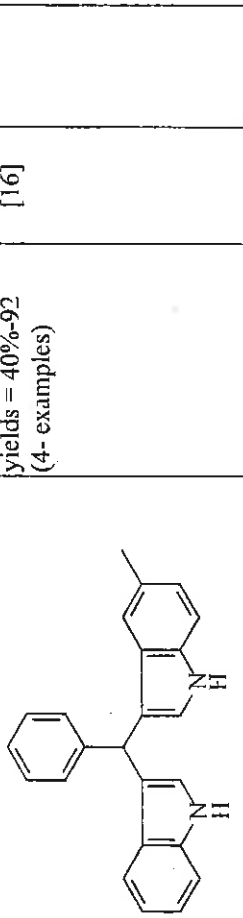
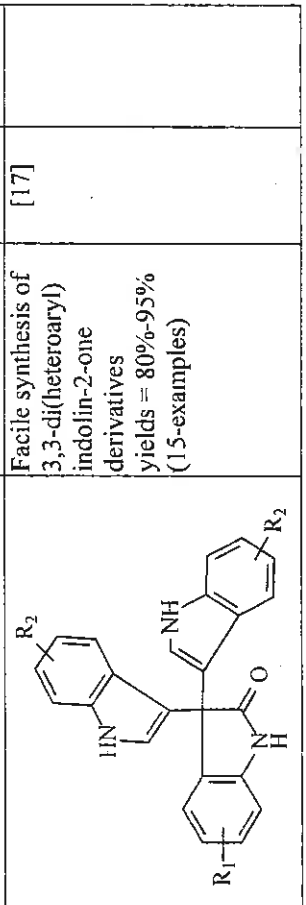
	Synthesis of unsymmetrical bis (indolyl) alkanes yields = 75%-96% (19-examples)	[16]
	yields = 75%-96% (4-examples)	[16]
	yields = 40%-92 (4- examples)	[16]
	Facile synthesis of 3,3-di(heteroaryl) indolin-2-one derivatives yields = 80%-95% (15-examples)	[17]

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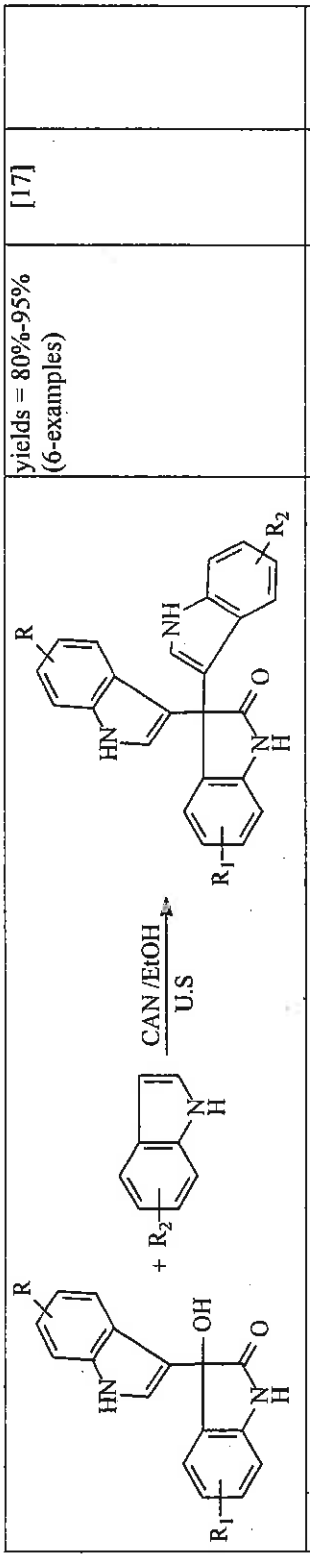
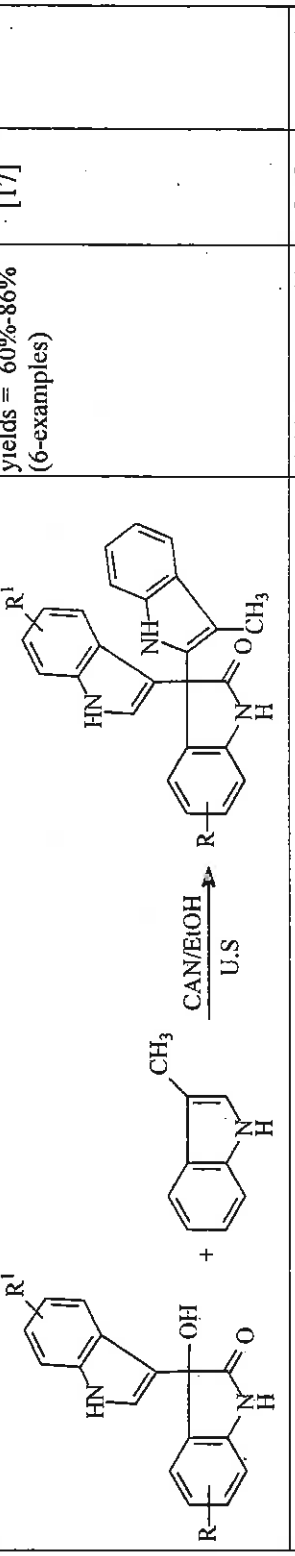
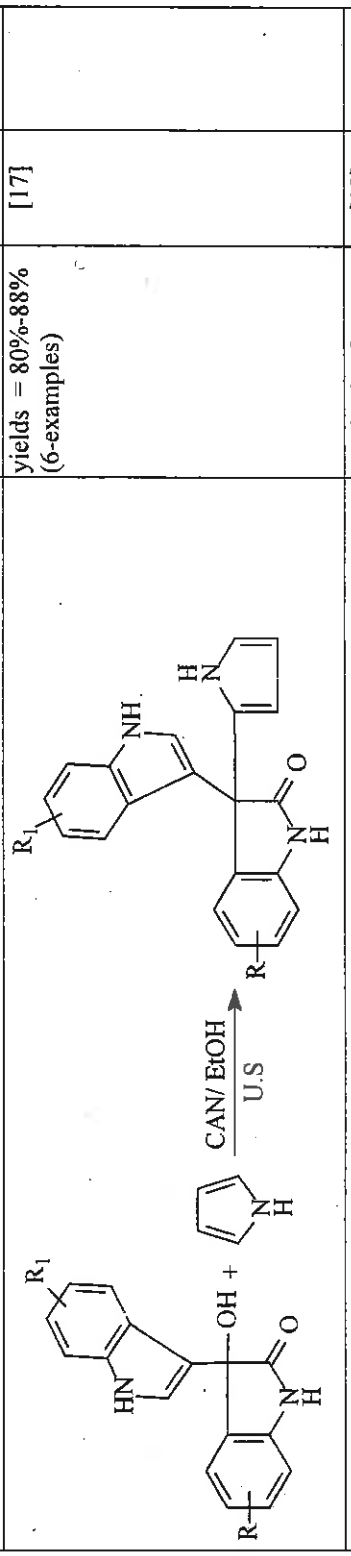
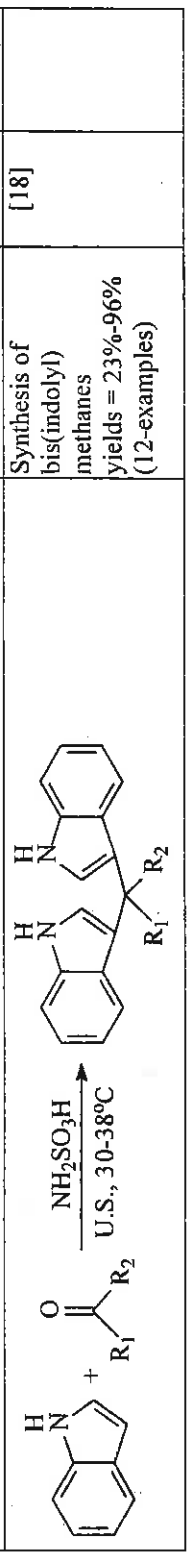
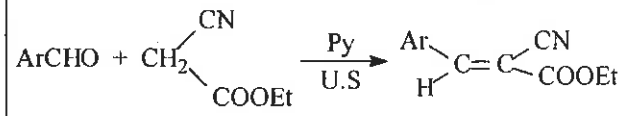
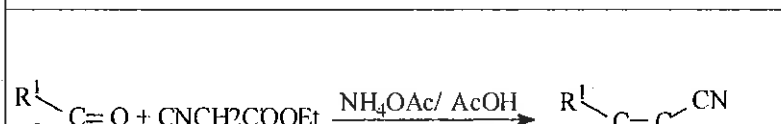
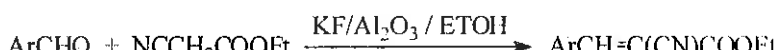
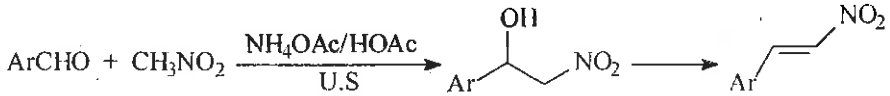
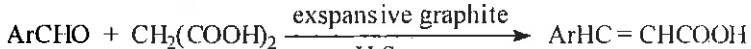
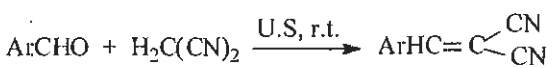
	yields = 80%-95% (6-examples)	[17]
	yields = 60%-86% (6-examples)	[17]
	yields = 80%-88% (6-examples)	[17]
	Synthesis of bis(indolyl) methanes yields = 23%-96% (12-examples)	[18]

2. 3. Condensation

Conditions	Type of reaction/ yield (s)/ number of examples	Reference (s)	
		Described	Additional
	Knoevenagel condensation yields = 80% -90% (12- examples)	[19]	
	Knoevenagel condensation yields = 55%- 89% (6- examples) low yields for (2- examples)	[19]	
	Knoevenagel condensation yields = 97%-99% (11-examples)	[19]	
	Synthesis of nitroalkenes yields = 85%-99% (7-examples)	[19]	[20]
	Knoevenagel condensation yields = 65%-98% (11- examples)	[19]	
	Knoevenagel condensation yields = 70%- 98% (14- examples)	[19]	

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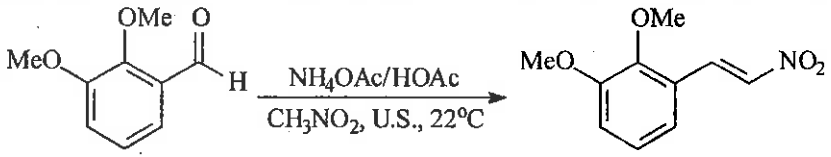
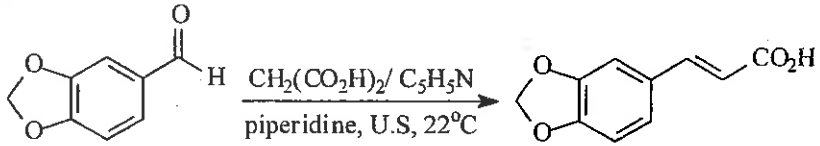
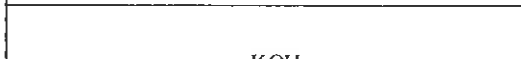
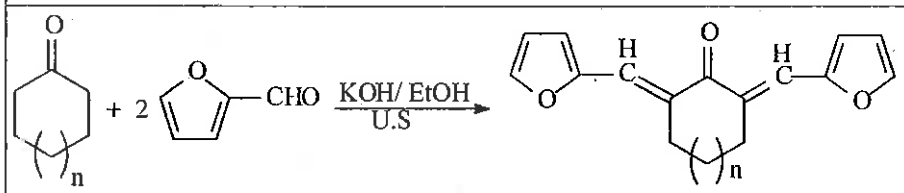
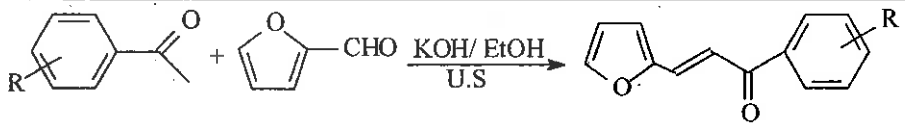
	Knoevenagel Aldol condensation yields = 51%- 99% (10- examples)	[21]	[22,23]
	Knoevenagel Aldol condensation yields = 61%-99% (6 – examples)	[21]	
	Knoevenagel condensation yields = 80%-96% (12 – examples)	[24]	
	Claisen- Schmidt condensation yields = 52%- 97% (10- examples)	[19]	
	Claisen- Schmidt condensation yields = 68%- 96% (4- examples)	[19]	
	Claisen- Schmidt condensation yields = 78%- 96% (5- examples)	[19]	

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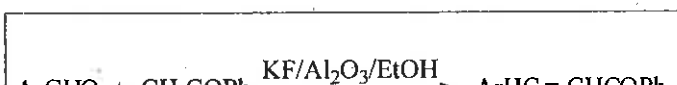
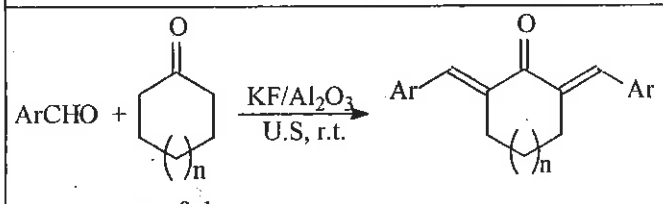
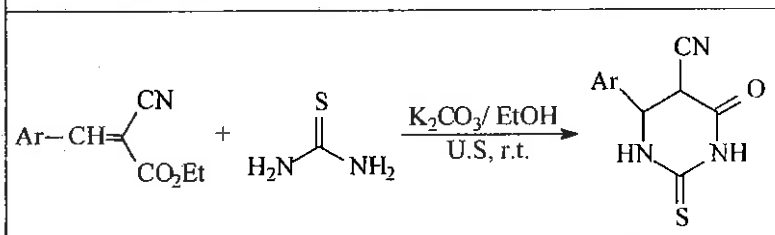
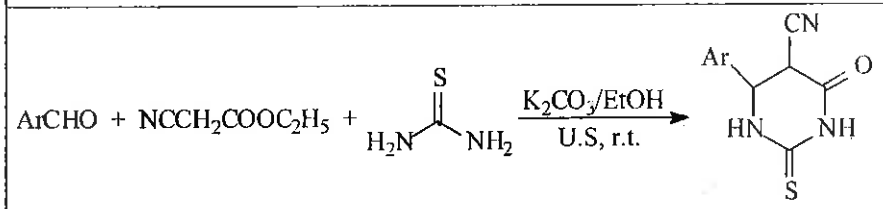
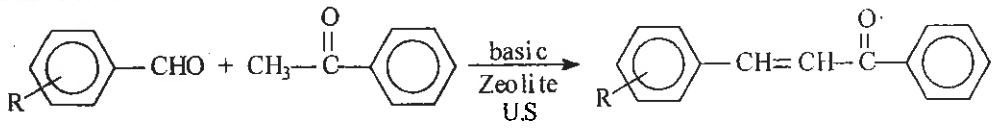
	Claisen- Schmidt condensation yields = 80%- 98% (11- examples)	[19]	[25]
	Claisen- Schmidt condensation yields = 60%- 96% (10- examples)	[19]	
	Synthesis of 4-oxo-2-Thio-xohexahydropyrimi-dines **a-** by two steps yields = 51%- 98% (13- examples)	[19]	[26]
	**b-** One- pot yields = 20%-90% (12-examples)		
	Claisen-Schmidt condensation yield = over 95% (1-example)	[27]	[28-33]

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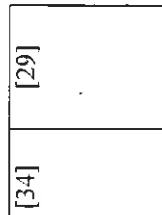
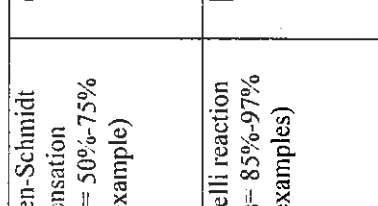
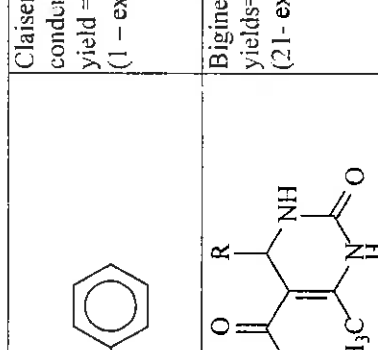
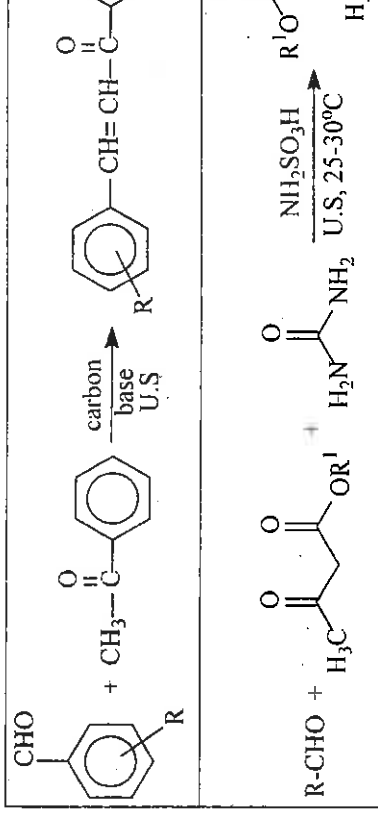
	Claisen-Schmidt condensation yield = 50%-75% (1 – example)	[34]	[29]
	Biginelli reaction yields= 85%-97% (21- examples)	[35]	
	One-pot condensation yields = 55%-94% (27- examples)	[36]	
	Biginelli condensation yields = 59.7%-91.2% (16 – examples)	[37]	

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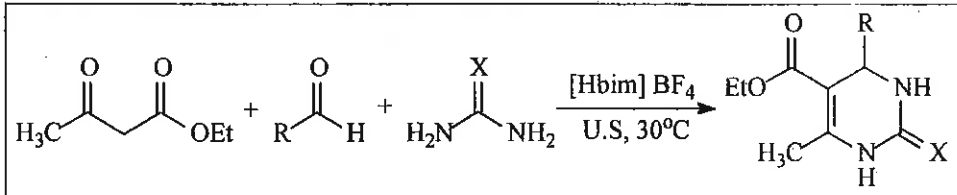
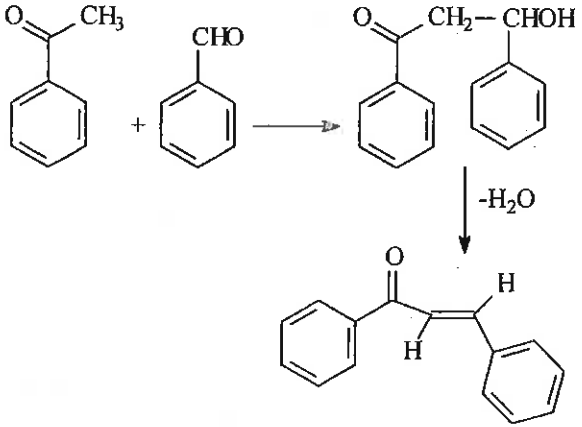
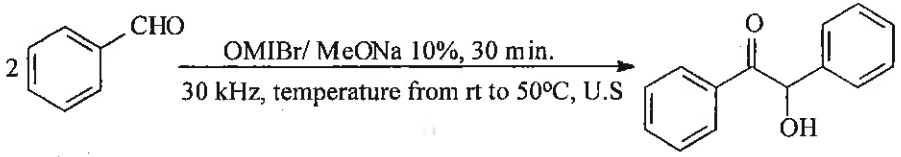
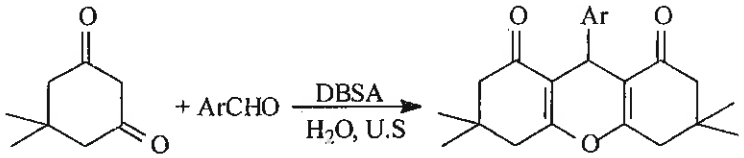
	Synthesis of 3,4-dihydropyrimidine -2-(1*H*)-ones yields = excellent (2 – examples)	[38]	
	Aldol condensation yields = 75%-95% (13- examples)	[39]	[40]
	Benzoin condensation yield = 99%-97% recycling	[41]	
	Synthesis of 1,8-dioxo-octahydro- xanthene derivatives yields = 89%-94% (15 – examples)	[42]	

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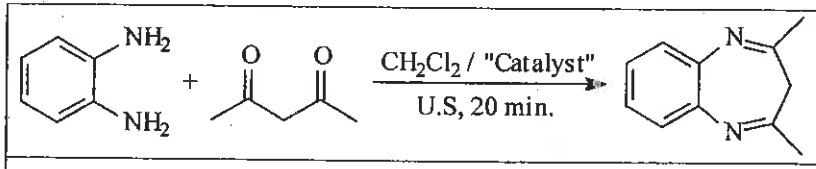
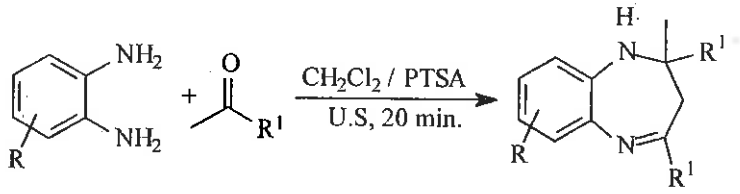
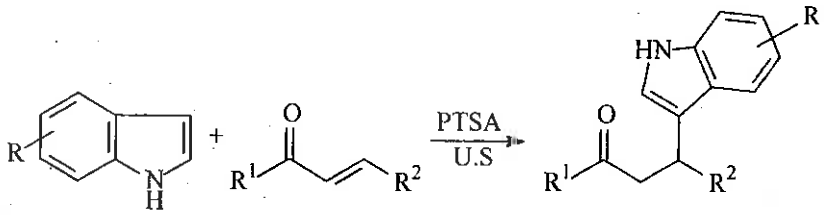
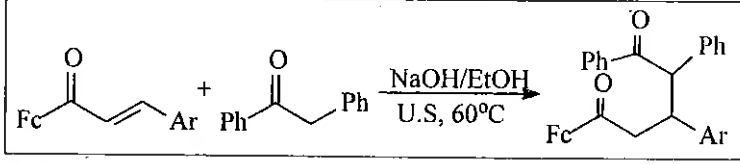
	Synthesis of 1,5-benzo diazepines yields =77%-87% (6 – examples)	[43]	
	yields = 78%-85% (9 – examples)		

2.4 Cycloaddation

Conditions	Type of reaction/ yield (s)/ number of examples	Reference (s)	
		Described	Additional
	Michael addition yields = 60%-94% (16-examples)	[44]	
	Michael addition yields = 82%-96% (11-examples)	[45]	

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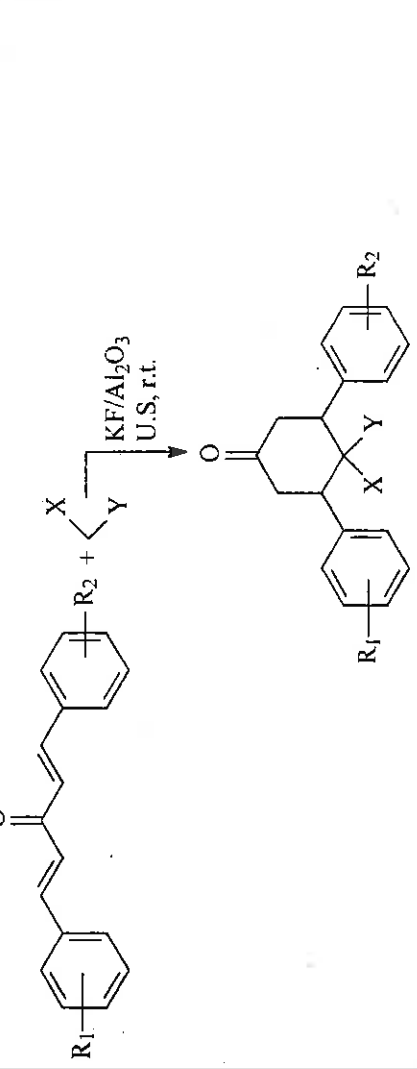
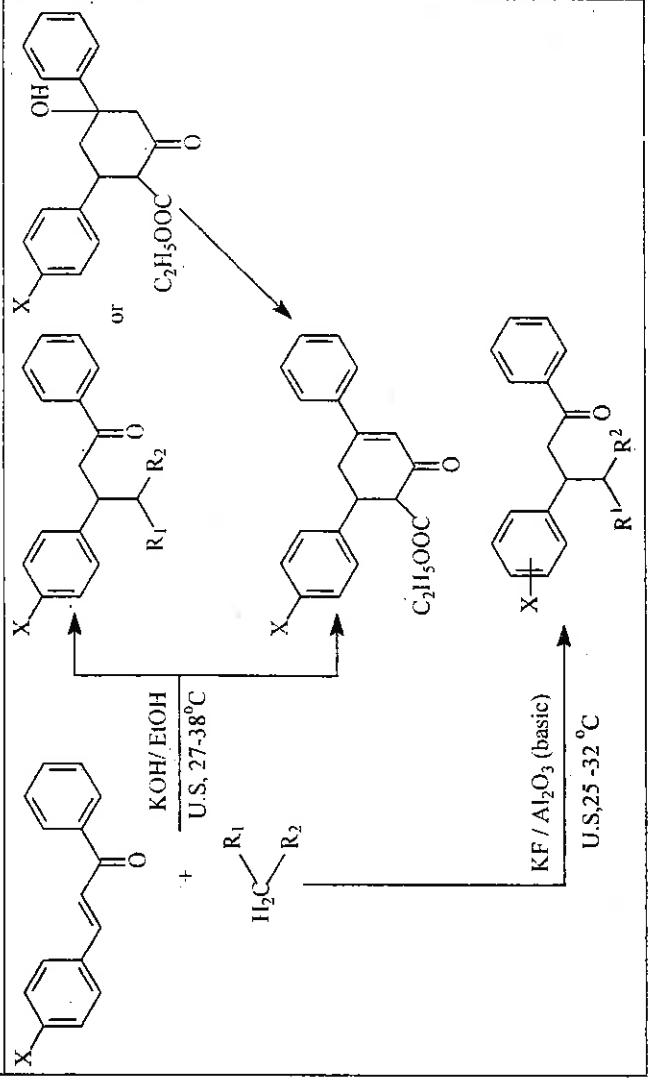
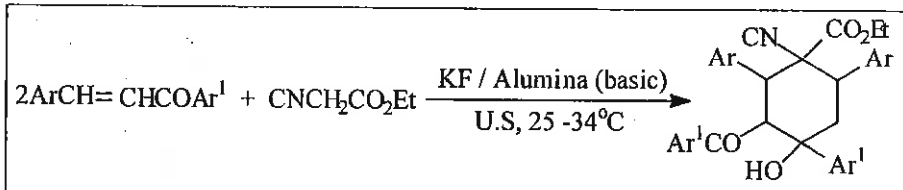
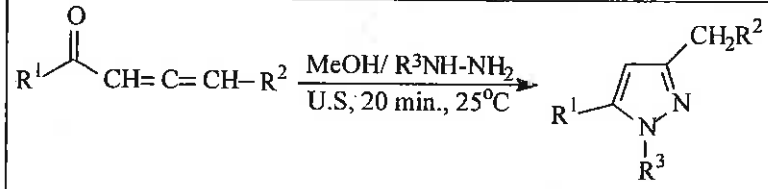
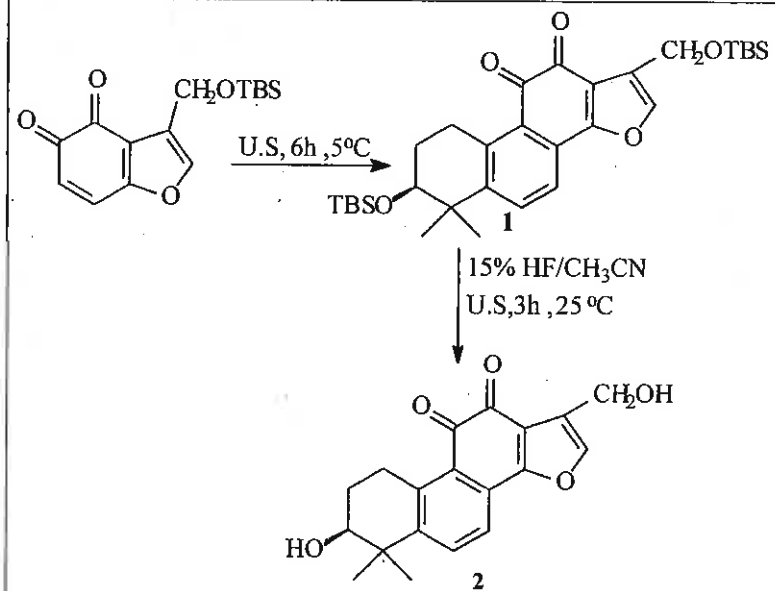
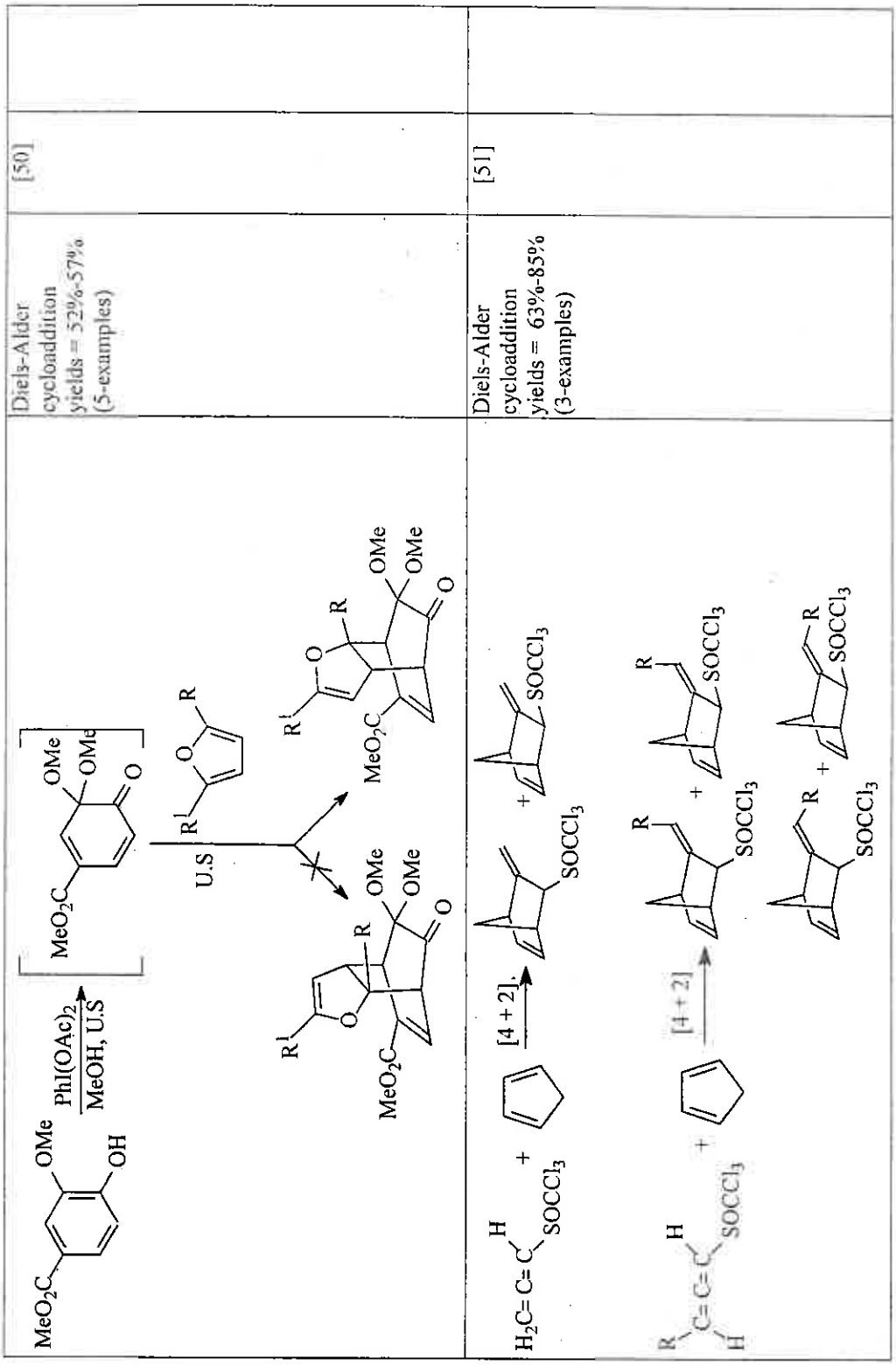
	Michael addition yields = 73%-91% (16-examples)	[46]
	Michael addition yields = 72%-98% (8 – examples) yields = 87%-97% (4 – examples)	[19]
	Michael addition yields = 46% - 93% (16- examples)	[19]

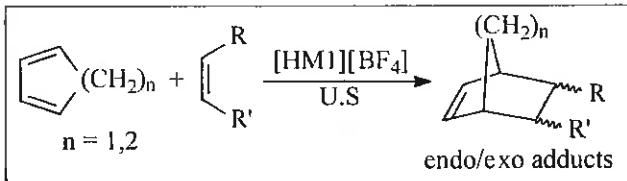
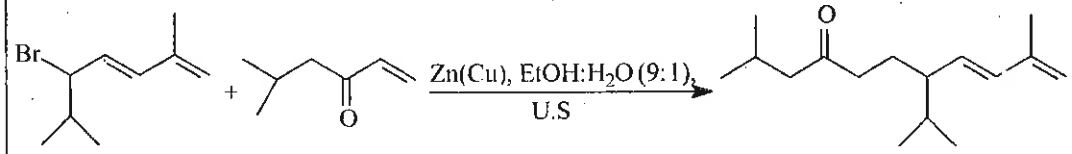
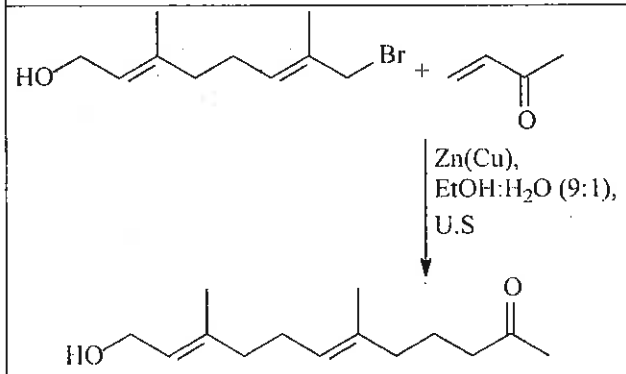
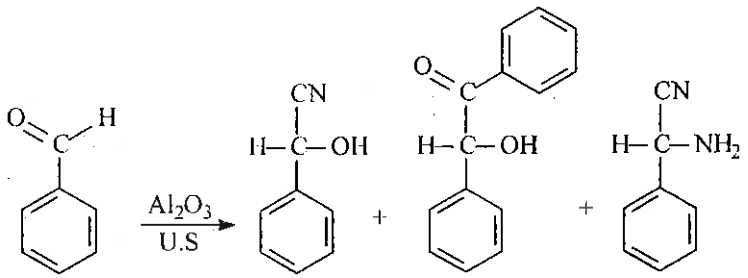
Continued

	Synthesis of 2-aroyl-1,3,5-triaryl-4-carbethoxy-4-cyanocyclohexanols yields = 0%-96% (15 – examples)	[19]	[47]
	Synthesis of pyrazole Fatty ester derivatives yields = 83%,52%, 86% (3 – examples)	[48]	
	Diels-Alder reaction yield = 31% ,**1** (1-example) yield = 85%, **2** (1-example)	[49]	

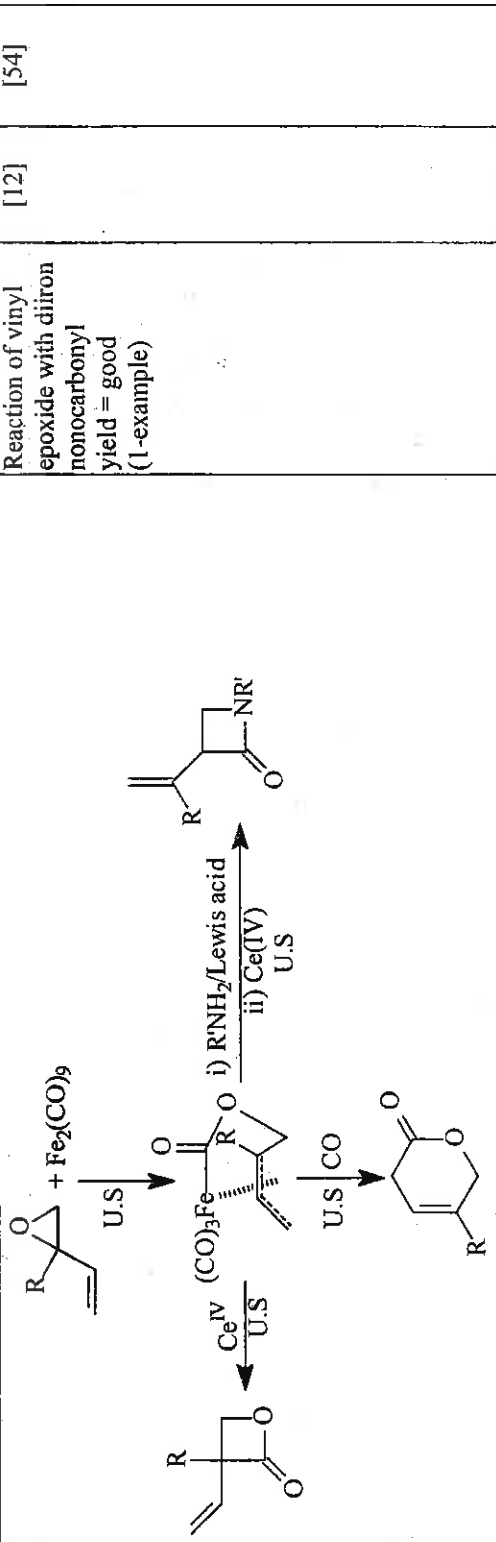
Continued

	Diels-Alder cycloaddition yields = 52%-57% (5-examples)	[50]
	Diels-Alder cycloaddition yields = 63%-85% (3-examples)	[51]

Continued

	Cycloaddition reaction yields = 5.8%-100% (13-examples)	[52]	
	Synthesis of (±)-7-isopropyl-2,10-dimethyl-8(E),10-undecadien-4-one yield = 66% (1-example)	[53]	
	Synthesis of 3,7-dimethyl-11-oxo-2(E), 6(E)-dodecadienol (oxocrinol) yield = 63% (1-example)	[53]	
	Strecker synthesis of an aminonitrile yield = 90% (1-example)	[12]	

2.5 Miscellaneous Synthesis

Conditions	Type of reaction/ yield(s)/ number of examples	Reference(s)	
		Described	Additional
	Reaction of vinyl epoxide with diiron nonocarbonyl yield = good (1-example)	[12]	[54]
	Wittig reaction (1-example)	[12]	
	Hydroboration/oxidation of vinyl groups yield = 99% (1-example)	[12]	[55]

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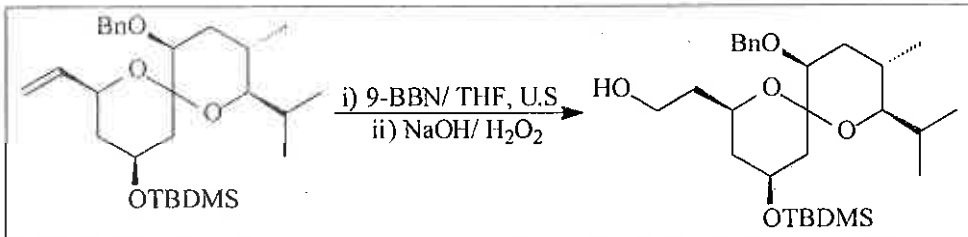
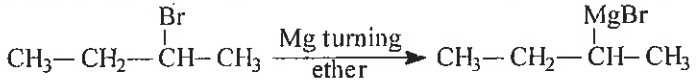
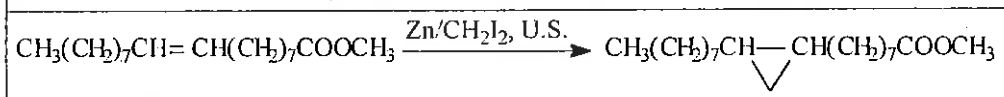
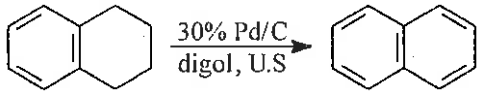
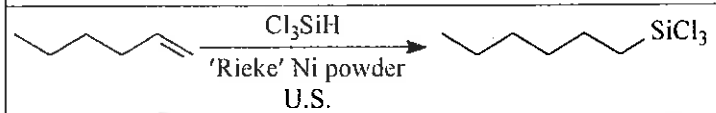
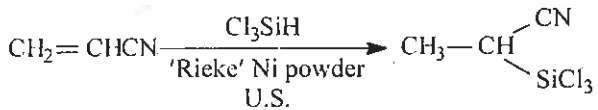
	yield = 89% (1-example)	[12]	
	Grignard reagent synthesis (1-example)	[12]	
	Simmons-Smith reaction yield = good (1-example)	[12]	[56]
	The dehydration of tetrahydronaphthalene yield =over 80% (1-example)	[12]	[57]
	Preparation of organosilicon compounds yield = 94% (1-example)	[12]	[58]
	yield = 93% (1-example)	[12]	

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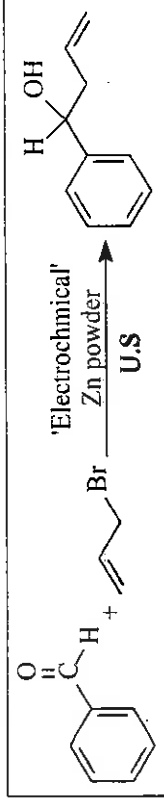	Synthesis of 1-phenyl-3-buten-1-ole yield = 82% (1-example)	[12]	[59]
	Ullmann coupling reaction yield = 80% (1-example)	[12]	
	Synthesis of arylhydrozone at ambient conditions yields = 90%-96% (12-examples)	[60]	
	Synthesis of chiral allylic alcohols promoted by indium metal yields = 85%-94% (10-examples)	[61]	
	Pinacol coupling of aromatic aldehydes and ketones yields = 20%-95% (12-examples)	[62]	

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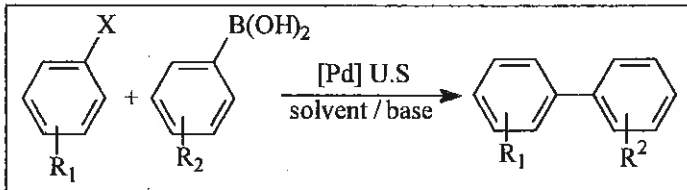
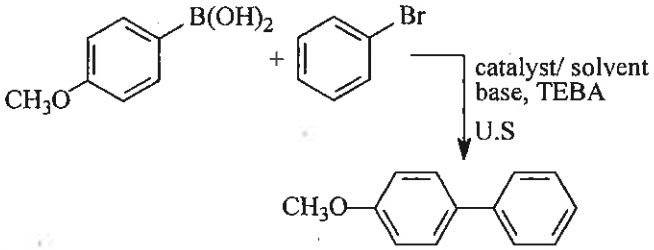
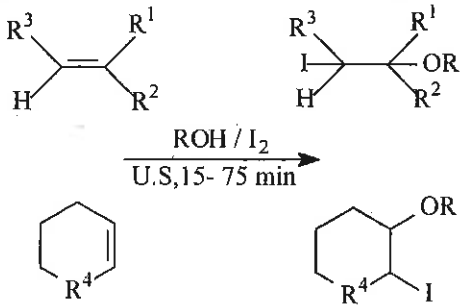
	Suzuki cross-coupling reaction yields =21%-95% (6-examples)	[63]	
	yields =22%-68% (7-examples)	[63]	
	Regioselective Synthesis of β-iodoethers yields = 70%-92% (9-examples)	[64]	
	Hydrogenation of perfluoroalkyl alkenes yields = 64%-82% (5-examples)	[65]	

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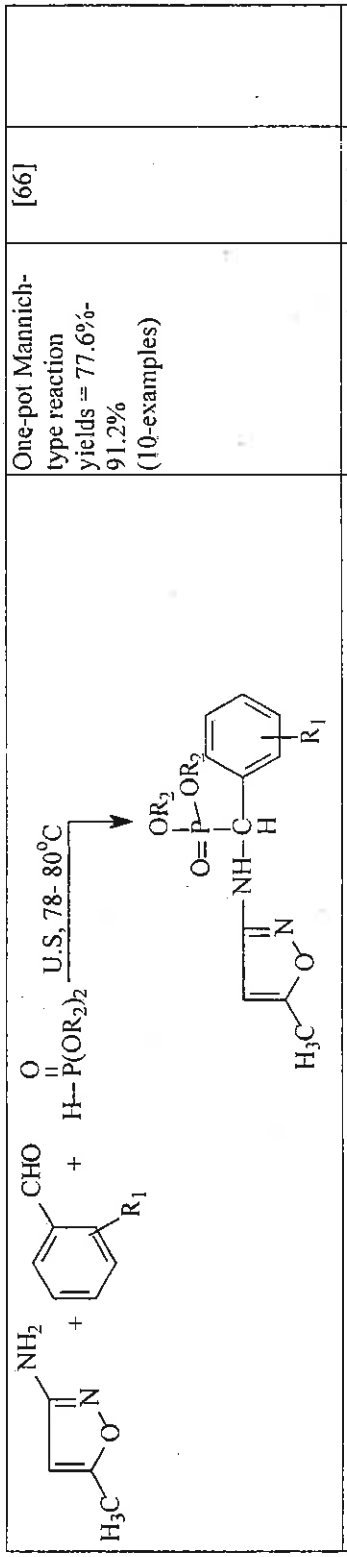
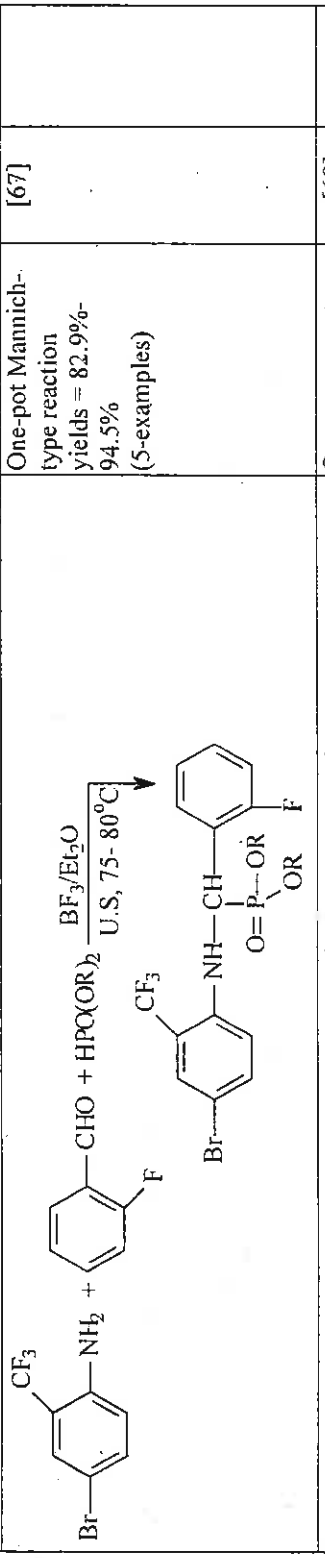
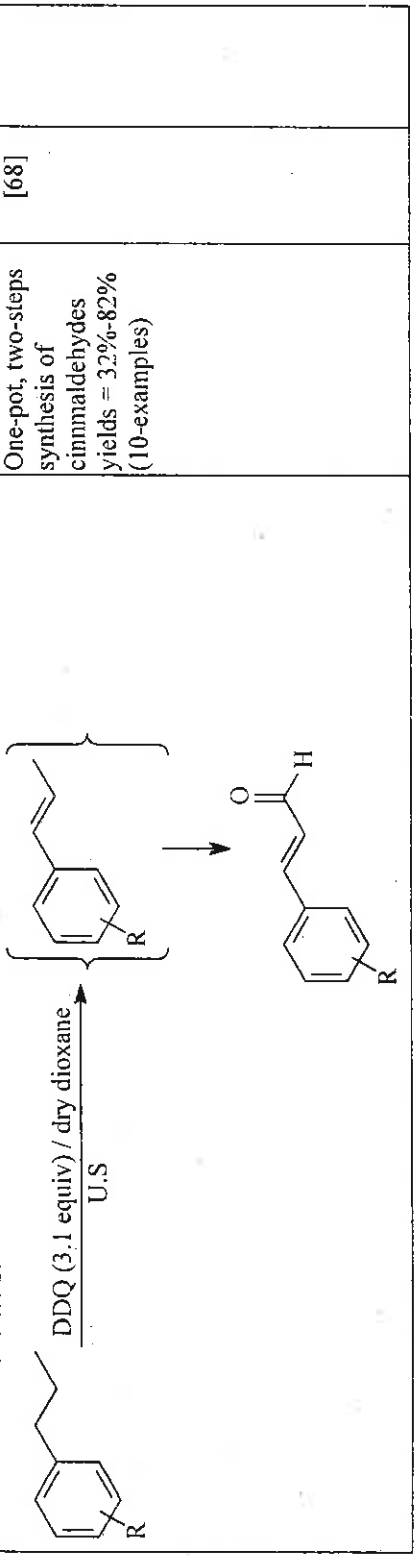
	One-pot Mannich-type reaction yields = 77.6%-91.2% (10-examples)	[66]
	One-pot Mannich-type reaction yields = 82.9%-94.5% (5-examples)	[67]
	One-pot, two-steps synthesis of cinnmaldehydes yields = 32%-82% (10-examples)	[68]

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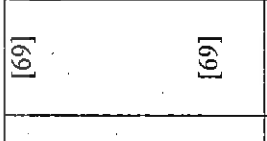
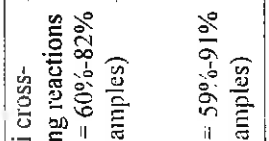
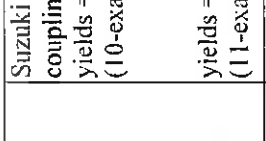
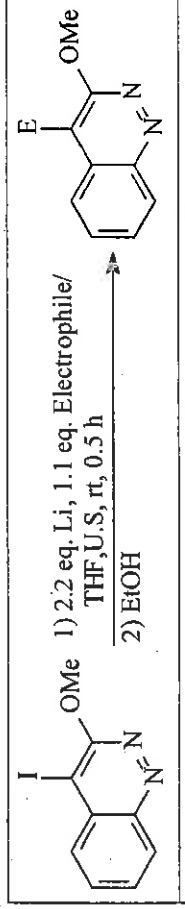
	Suzuki cross-coupling reactions yields = 60%-82% (10-examples)	[69]
	yields = 59%-91% (11-examples)	[69]
	Al/Hg reduction of nitroalcohols yields = 54%-92% (5-examples)	[70]
	Barbier type reaction yields = 22%-55% (8-examples)	[71]
	yields = 38%-72% (6-examples)	[71]

Continued

	1) 2.2 eq. Li, 1.1 eq. Electrophile/ THF,U.S, rt, 0.5 h 2) EtOH	yields = 35%-64% (2-examples)	[71]
	1) 2.2 eq. Li, 1.1 eq. Electrophile/ THF,U.S, rt, 0.5 h 2) EtOH	yields = 33%- 70% (6- examples)	[71]
	1) 2.2 eq. Li, 1.1 eq. Electrophile/ THF,U.S, rt, 0.5 h 2) EtOH	yields = 21% - 58% (6- examples)	[71]

Conclusion

In conclusion, the above survey shows that ultrasound sonochemistry has many useful and promising future applications in chemistry in general and particularly in organic chemistry. It is now considered to be useful and valuable tool in the synthesis of many organic compounds of various reactions. Although it is a fairly new technique, it is now increasingly used in research as the present survey shows and has potential for industrial use. This is due to the fact that U.S technology has versatile applications and can be used in many different organic synthesis. But the most important reason for its wide use is that it is an environamentally clean technology that limits the production of harmful wastes.

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