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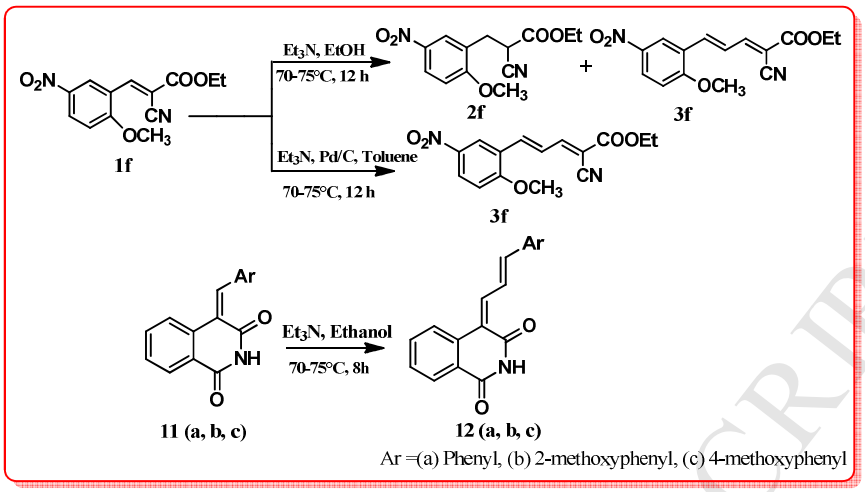
Graphical Abstract



Reaction of 3-Arylidenepropenoic acid derivatives with triethylamine and other amines; unexpected reductions and vinylogations

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ABSTRACT

Exposure of ethyl 2-cyano-3-(2-methoxy-5-nitrophenyl)acrylate **1f** to triethylamine in hot ethanol resulted in the formation of the dihydro derivative **2f** and vinylogue **3f** in high yields. Single crystal X-ray data are provided for **3f**. Similar reactions were observed for various analogues. The reaction was studied changing aryl substituent, amines and solvents. Pyridyl, thienyl analogues were also examined. The study was extended to cyclic molecules incorporating such systems like thiazolidinedione **8**, 3-cyanocoumarin **9** and 4-arylidene-isoquinoline-2,4-diones **11**. The last group gave vinylogated products, 4-cinnamylidene-isoquinolinediones and 4-hydroxylated species. A few examples of arylidene derivatives from malononitrile, ethyl acetoacetate, acetyl acetone and ethyl methylsufonylacetate were investigated. Ethyl cinnamate and β-nitrostyrene were unaffected. The reaction is considered to be possibly radical mediated, since addition of free radical quencher suppressed the reaction. Contrary to the effects of thermal conditions, irradiation of **1f** in ethanol at 254 and 365 nm gave complex mixtures. A few other interesting observations in this study are noted: vinylogation of **1f** with acetaldehyde to **3f**; formation of **3f** from **1f** by the treatment with triethylamine, palladium carbon and reduction of **1f** to **2f** by triethylammmonium formate in DMF.

Keywords:
3-Aryl-2-cyanoprop-2-enoates
Triethylamine
Reduction
Vinylogation

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1. Introduction

In the course of our successful endeavors to achieve a new synthesis of entacapone[1a,1b] from the precursor 2-cyano-*N*,*N*-diethyl-3-(3-hydroxy-4-methoxy-5-nitrophenyl)acrylamide by demethylation with triethylamine under mild conditions, we encountered an interesting and unexpected reaction with compound **1f** having a methoxyl group para to the nitro in the 3-aryl-2-cyanopropenoic ester system. The reaction led to the dihydro derivative **2f** and **3f**, a vinylogue of **1f**.[1a] We report in this paper single crystal X-ray data of **3f** (supplementary section) and also experimental details of the reaction involving reduction and vinylogation as well as unpublished work encampassing extension of the scope of the novel reaction. The preliminary communication summarized our important findings and gave a speculative mechanism.

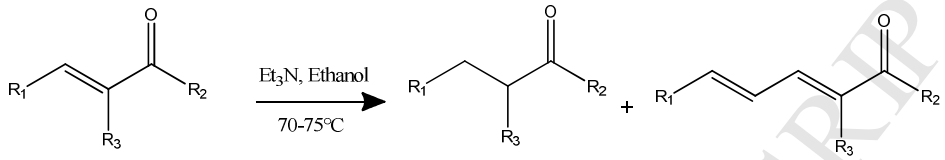
2. Results and discussion

Reaction of **1f** with triethylamine led to dihydro derivative **2f** and butadiene **3f**. Their structures were confirmed by extensive NMR and mass spectral data and comparison with authentic compounds. In the case of **3f** single crystal X-ray studies (**Fig. 1)** corroborated the structure and defined its geometry. Crystal data are given in (Table 1, supplementary section).

As an extension of the novel reaction we prepared various substituted of 3-aryl-2-propenoic acid derivatives (Table 2, supplementary section) and subjected them to reaction with triethylamine in ethanol, with the results recorded in (Table 3). The composition of the reaction mixture was analyzed using proton NMR spectra. The following diagnostic peaks were used among other features. Dihydro compounds **2**; two multiplets for 1H each between δ 3 and 4 ppm; butadienes **3** proton multiplet around 7.5 ppm; unreacted starting material, singlet at about 8.6 ppm and hydrolysed aldehyde, singlet at around δ 10.5 ppm. Dihydro derivatives **2** were generally synthesized for reference purposes by treatment of **1** with sodium borohydride in ethanol.

Butadiene derivatives **3a** and **3b** were made for reference purposes by reaction of cinnamaldehyde and 2-methoxycinnamaldehyde with ethyl cyanoacetate.

Table 3: Analysis of reaction products of 1(a-t) in triethylamine - data of dihydro derivatives, butadienes, starting materials 1(a-t) and hydrolyzed aldehydes (see table 2 for structural details)



1(a-t) 2(a-t) 3(a-t)

Compounds	% ratio (By NMR)			
	2(a-t) Dihydro %	3(a-t) Butadiene%	Aldehyde %	starting material %
1a	15	0	0	85
b	24	16	--	56
c	16	0	7	76
d	6.5	0	0	93.5
e	15	5	03	74
f	48.5	48.5	0	03
g	Major [i]	0	0	0
h	38	13	11	38
i	5	0	0	95
j	iii			
k	50	0	46	traces
l	Major [ii]	0	0	0
m	50	0	25	25
n	53	--	46	traces
o	No reaction			
p	Decarboxyethoxylated product		04	
q	The major product corresponds to the products obtained by attempted reduction with $NaBH_4$ in ethanol			
r	iii			
s	08	08	08	74
t	No reaction			

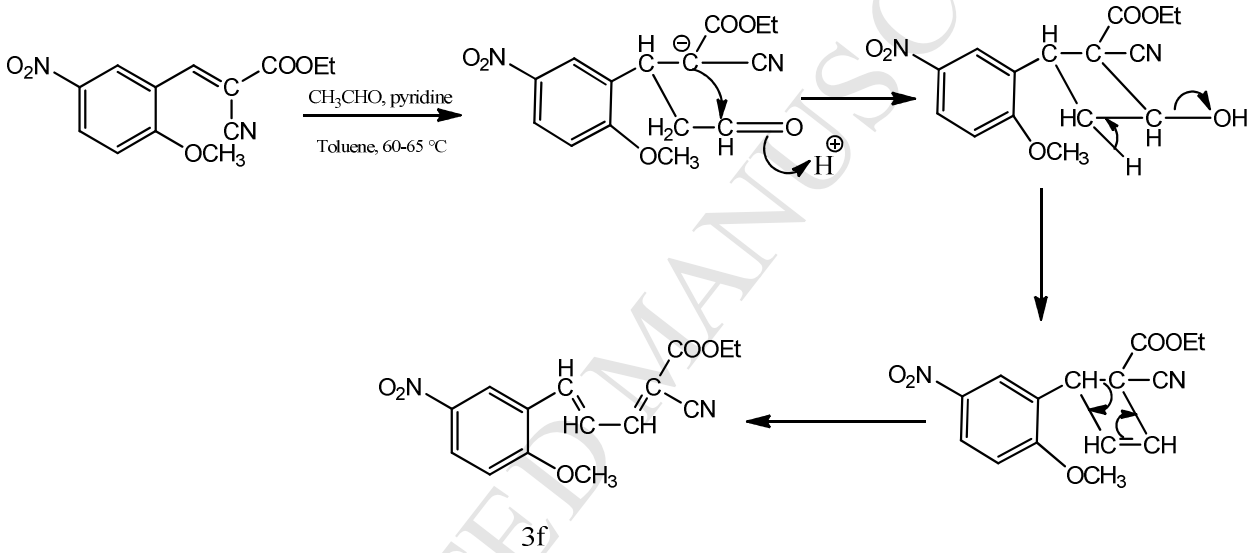
i Diagnostic peaks were seen over a curvy base line in the ^{1}H-NMR spectrum. Hence presence of starting material and butadiene could not be estimated.

ii rest unanalyzable humps

iii complex mixture

Butadiene **3f** which was the first novel compound observed in our triethylamine reactions was synthesized by heating **1f** with acetaldehyde solution in toluene at 60-65°C for 14 h in presence of pyridine. We consider it unlikely that **1f** would split under these conditions ejecting ethyl cyanoacetate and that the resultant aldehyde would react with acetaldehyde to give the cinnamaldehyde which could then condense with ethyl cyanoacetate to form **3f**.

It is tempting to speculate that the reaction may proceed as follows.



Scheme 1. Synthesis of **3f**

A scifinder search revolved that such a reaction is not known and hence further extension would be warranted. Cross over experiments may throw light on this reaction.

We have already mentioned in the earlier communication that the reduction–vinylogation reaction was probably radical mediated. In this connection we studied the 1H-NMR of **1f** in DMSO-d6 solution in the presence of triethylamine from 25 to 50°C but observed no line broadening which can be expected to happen if radicals had been created.

Towards gleaning more insight we conducted the reaction of **1f** with triethylamine in ethanol at 70 to 75°C under a few different conditions;

a) In the presence of free radical scavenger

b) Under irradiation.

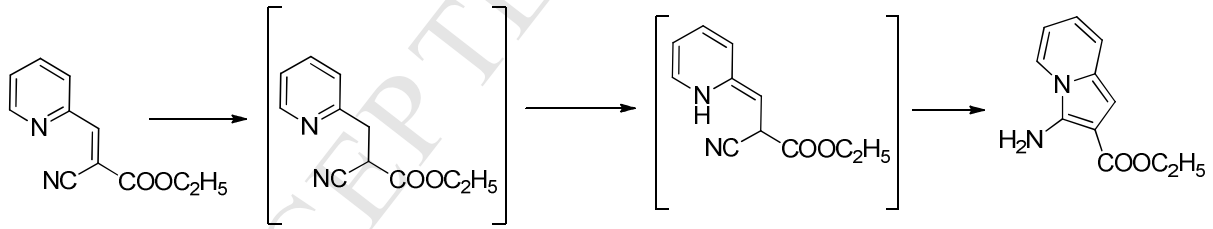
c) In the presence of furan to trap the diethyl-vinylamine.

The reaction of **1f** with triethylamine in ethanol at 70-75°C was suppressed by addition of 10% 2, 6-ditertiarybutyl phenol and almost complete suppression was observed by the addition of 10% of TEMPO. The reaction was complex in the presence of dibenzoylperoxide and also when the reaction solution was irradiated at 254 nm and 365 nm. In an attempt to capture the postulated intermediate N, N-diethylvinylamine with the diene, furan triethylamine reaction of **1f** was conducted in the presence of furan. Surprisingly there was no reaction at all! It is possible that the furan we used contained some peroxides (Sigma Aldrich data). An electron deficient diene would have been more appropriate but we could not access one readily. We have speculated in the earlier communication that the reduction –vinylogation reaction of triethylamine may be dependent on the reduction potential of 3-aryl-2-cyanopropenoic acid derivatives. Our observation that the thermal nonreactivity of phenazine towards triethylamine in ethanol in contract to its behavior on irradiation [2] may be attributed to this factor.

While this work was in progress we came across reports of reduction of acrylic and cinnamic esters by Pd/C and triethylamine (no hydrogen) in toluene at 140°C.[3] When we subjected **1f** to these reagents at 70-75°C for 12 h, to our surprise we obtained the butadiene **3f** with no evidence for the formation of the dihydro derivative **2f!** Entry 1 in (Table 4) shows that in the absence of Pd/C, the reaction leads to about 84% recovery of **1f** and formation of about equal amounts (7%, 8%) of **2f** and **3f**. Similar reactions were observed with **1a** and the o-methoxy derivative **1b**,

where at the end of the reaction period of 12 h, NMR analysis of the product mixture showed it to be containing almost 50% each of starting material and butadiene with no evidence for the formation of **2a** and **2b**. We propose to study the generality of the reaction and report results in due course. The fate of two hydrogen atoms released concomitant with the formation of butadienes is an intriguing issue to be solved. Reaction of **1f** with triethylammonium formate in DMF [4] formed the dihydro derivative **2f** to the extent of 80% (NMR), the rest being accounted for by un reacted starting material.

In our preliminary communication we had mentioned extension of the study to analogues of **1f** wherein the aryl substituents have been varied: **1a, 1e, 1g** and **1h** and also to hetero aryl analogues 2-thienyl **1i**, 2-pyridyl **1j**, 3-pyridyl **1k** and 4-pyridyl **1l** for which experimental details are provided; $NaBH_4$ reduction of **1j** has been reported to give the interesting ethyl 3-aminoindolizine-2-carboxylate **4** as shown in (**Scheme 2**). The triethylamine reaction of **1j**, however gave a complex mixture in which we could not locate **4**.



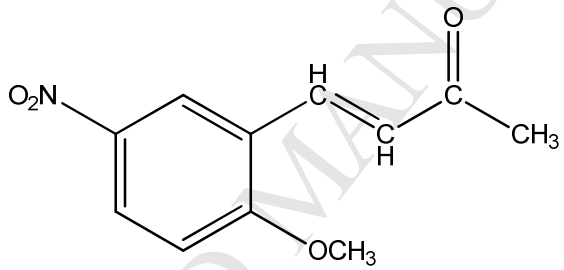
1j 4

Scheme 2. Formation of ethyl 3-aminoindolizine-2-carboxylate

We next explored the behavior of arylidenemalononitriles **1m** and **1n** wherein the ester group in **1b** and **1f** had been replaced by a CN group. Both underwent reduction to the extent of 50%, the rest being accounted for by unchanged starting material 25% and aldehyde 25%. The

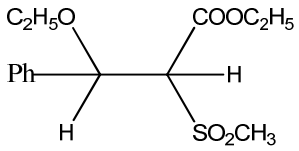
diethylamide **1o** corresponding to **1f** was mostly unreacted. Obviously, the diethyl carbamoyl group is less electron withdrawing than ester or nitrile.

1p representing **1f** with the nitrile group being replaced by a $COCH_3$ group was reduced to the extent of 2%, the major product being the decarboxyethoxylated product **5**. The structure was deduced from mass (220.0) and ^1H NMR spectrum. The latter showed the presence of a trans-ethylene system (6.85, d, J 16.5Hz, 7.80, d, J 16.5Hz) and the absence of the ester group. It appears that the adjacent CH_3CO group to carboethoxy group in **1p** has made the latter vulnerable to ethanol which possibly leaves as diethyl carbonate.



5

It was of interest to study an analogue of **1f** in which a CN group has been replaced by a CH_3SO_2 moiety. Condensation of benzaldehyde with ethyl methylsulfonyl acetate gave the benzylidene compound **1q** ^{1}HNMR (400MHz, $CDCl_3$) 1.25 (3H, t, J 7.0Hz), 3.24(3H, s, OMe), 4.4 (2H, q, J 7.0Hz), 7.39-7.46(5H, m), 7.83(1H, s, vinyl). Reaction of **1q** with triethylamine in ethanol at 70-75°C for 12 h led largely to the diasteroisomeric ethanol addition products **6** and **7** (stereochemistry unspecified) in the ratio of 3:1. These also resulted in an attempted reduction of **1q** with $NaBH_4$ in ethanol.



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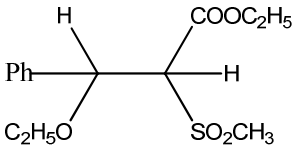


7

The product was gummy and no attempt was made to separate the pure components and assign appropriate structures.

Condensation product of 2-methoxy-5-nitrobenzaldehyde with diacetyl in presence of piperidine catalyst gave the aldol. Dehydration with acetic anhydride gave the required product **1r**. Upon reaction of **1r** with triethylamine under standard conditions; a complex mixture of products was obtained NMR analysis of which indicated significant formation of the dihydro derivative and starting aldehyde. The study was extended to **l** carrying only one EWG at the nonaryl terminal of the ethylenic system. Ethyl cinnamate did not react with triethylamine to any detectable extent. The 2-methoxy analogue **1s** was obtained by a literature procedure involving condensation of 2-methoxybenzaldehyde with the half ester of malonic acid with concomitant decarboxylation.[5] **1s** upon reaction with triethylamine was affected to about 25%, most of the rest being starting material. The product mixture analyzed by 1H NMR showed it to consist of the dihydro derivative (8%), butadiene (8%) and starting aldehyde (8%) besides **1s**. β-Nitro styrene **1t** did not undergo any reaction with triethylamine under the standard conditions. Our observations so far have not helped us to define the structural requirement for reduction – vinylogation in systems represented by **1**.

The reaction of **1f** with various amines, solvents and at different temperatures have been studied; results are presented in the table 4. It is to be noted that di-isopropylethylamine (DIPE) in ethanol gave mostly the dihydro derivative **2f** with some minor impurities (NMR). Pure **2f**

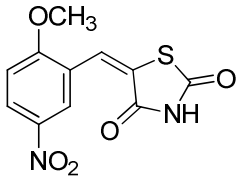
was isolated in 70% yield. *It seems to be possible to use DIPE for reduction of such electron deficient systems in lieu of $NaBH_4$ or catalytic reduction.*

Table 4: Reaction of 1f with various amines and solvents at different temperatures

Solvent	**Base**	**Temperature in °C**	**SM**	**Aldehyde**	**Dihydro**	**Butadiene**
Toluene	Triethylamine	70-75	84	01	08	07
Dioxane	Triethylamine	70-75	46	03	28	23
Acetonitrile	Triethylamine	70-75	15	06	58	21
Xylene	Triethylamine	70-75	85	0	07	06
Ethanol	Triethylamine	40-45	No reaction			
Ethanol	Triethylamine	60-65	Reaction initiated (about 8% dihydro)			
Ethanol	Triethylamine	70-75	06	0	49	45
Ethanol	Diethylamine	50-55	91	Traces	5	4
Toluene	Diethylamine	50-55	90	01	05	04
Ethanol	Ethylamine	50-55	Complex			
Ethanol	Piperidine	50-55	Complex			
Ethanol	Diisopropylethylamine	70-75	0	0	100	0
Acetonitrile	Diisopropylethylamine	60-65	0	0	85(15% unknown)	
Ethanol	*N*,*N*-dimethylisopropylamine	70-75	85	0	14	-
Ethanol	Dimethylcyclohexamine	70-75	94	01	05	trace
Ethanol	1-vinyl-2-pyrrolidone	70-75	No reaction			
Ethanol	*N*-benzyldimethylamine	70-75	96	04	0	0
Ethanol	*N*, *N*-diethylaniline	70-75	18	01	43	19
Ethanol	Ethyl vinyl ether	70-75	63	0	36	0
Ethanol	---	70-75	No reaction			
Acetonitrile	---	70-75	No reaction			

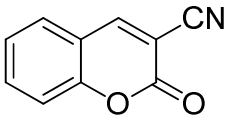
We extended the scope of our study to reactions of molecules containing conjugated systems in a cyclic framework.

5-(2-Methoxy-5-nitrobenzylidene)thiazolidine-2,4-dione **8** obtained by reaction of 2-methoxy-5-nitrobenzaldehyde with thiazolidine-2, 4-dione, was unaffected by triethylamine.



8

The cyanocoumarin **9** was prepared by condensing salicylaldehyde with ethyl cyanoacetate [6] and subjected to reaction with triethylamine under standard conditions. The crude product was an intractable mixture. In the complex NMR spectrum, an aldehyde CH was seen at δ 10.85 ppm and the signals for the CH_2 and CH_3 of triethylamine at δ 3.18 and 1.3 ppm. In the mass spectrum a peak at 102 was from triethylamine. In the negative mode, a strong peak at m/z 186 could not be assigned to any reasonable structure.



9

Interesting results were observed with the 4-arylidene-isoquinoline-2, 4-diones **11(a-d)** obtained by condensation of isoquinoline-1, 3-dione **10** with benzaldehydes **(Scheme 3)**. The products were complex but chromatographic purification afforded the cinnamylidene- isoquinolinediones **12(a, b, c) (Scheme 4)** as mentioned in our preliminary communications. The reaction mixture from **12a** was investigated in detail by LC-MS NMR studies. The chromatogram was compared

with those of **11a**, **12a** and **13**, the dihydro derivatives of **11a** made for reference purpose by catalytic reduction.[7a] LC-MS of the mixture from **12a** showed peaks with RT 2.80 (32%), 3.08 (13%), 3.19(10%) and 3.5(30.5%). The peak at RT 3.5 with mass of 274 (MH-) was identified as being due to butadiene **12a** with a characteristic dd in the NMR spectrum at δ 8.7 ppm due to the β proton. Pure **12a** was isolated in 27% yield by chromatography and was identified with the product from **10** and cinnamaldehyde.

The other major peak at RT 2.80 had a mass of 266 (MH-) is considered to be hydroxylated species **15a** arising from the radical **14**. **15a** has been reported in literature[7b] from the photochemical addition of toluene to phthalonimide. The NMR spectrum of **15a** has an AB quartet δ 3.14 (1H, d, J 12.8Hz) and 3.23 (1H, d, J 12.8Hz) due to the benzylic CH_2 and dd at δ 6.70 ppm with J 7.1Hz due to the ortho protons of the phenyl group as characteristic features. The NMR spectrum of the crude triethylamine reaction product of **11a** did exhibit such peaks predominantly at δ 3.14 (1H, d, J 13Hz), 3.26(1H, d, J 12.9Hz), 6.7(2H, d, J 7.1Hz). It is to be noted that the major difference in the NMR spectra of **15a** and **13** is that benzylic CH_2 in the latter is coupled to C (4)H, while in the former C4 is attached to the OH. **15a** is obviously formed from **14** by reaction with hydroxyl radical arising from the solvent ethanol. We had postulated that radical **14** could dimerise but there was no evidence for such a dimeric product in a careful scrutiny of the LC-MS.

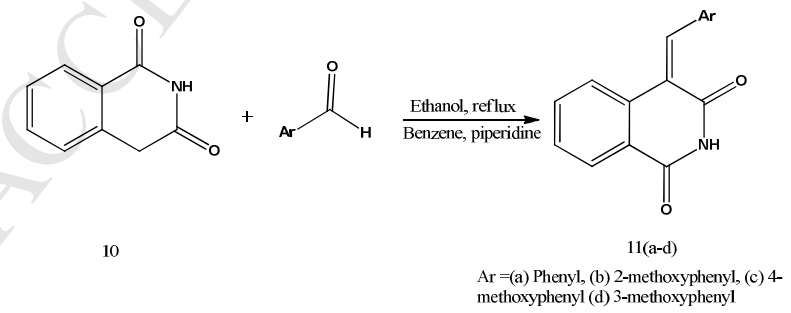
The minor products with RT 3.08 (13%) and 3.19 (10%) with respective masses of 408 and 311 have not yet been securely identified. The dihydro derivative **13** was present if at all to a negligible extent.

The complex NMR spectrum of the crude product form **11b** showed that it was largely unchanged (ene proton at δ 8.35 ppm). Diagnostic signals for the butadiene **12b** were seen as dd

at δ 8.7 ppm. The presence of the hydroxylated species **15b** was indicated by the AB quartet at δ 3.2(J 13Hz) and 3.3(J 13Hz). The LCMS showed three significant peaks at RT 2.84(13.7%), 3.25(69%), and 3.54(10.4%). The peak at RT 3.5 was due to unchanged **11b**, m/z 278 (MH-) and the peak at 3.54 was due to the butadiene **12b** with m/z 306(MH+). The most polar peak at R.T 2. 84 min with m/z 296 (MH-) was considered to be the hydroxylated species **15b** in analogy to **15a**. Butadiene **12b** was isolated from the mixture by chromatography in 8% yield.

The complex NMR spectrum of the crude product from **11c** showed about equal amounts of unreacted **11c** (ene proton signal at δ 8.2 ppm), butadiene **12c** (quartet at δ 8.16 ppm) and the hydroxylated species **14c** AB quartet (δ 3.11 and 3.18 ppm). Pure **12c** was isolated in 19% yield by chromatography.

The NMR spectrum of the crude product from **11d** revealed the presence of four Ar OMe signals in near equal quantities. Significant quantity of unreacted **11d** was identified by the signal at δ 8.22 ppm. Butadiene **12d**, quartet (δ 8.6ppm) and 4-hydroxy derivative **14d** (AB quartet at δ 3.15 and 3.22 ppm) were present. Our earlier speculation of formation of dimeric products is seen now to be erroneous. In all cases, characteristic singlets for the proton of the aldehyde used for preparing **11** were seen between δ 9.9 and 10.5 ppm.

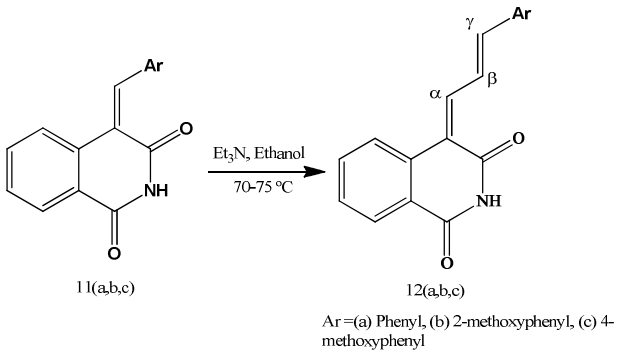


10

11(a-d)

Ar =(a) Phenyl, (b) 2-methoxyphenyl, (c) 4-methoxyphenyl (d) 3-methoxyphenyl

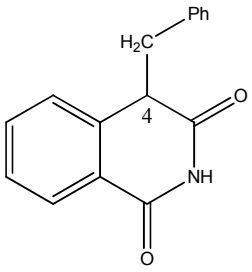
Scheme 3. Synthesis of arylidene isoquinoline-1, 3-dione



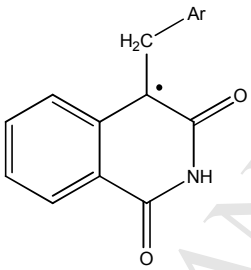
11(a,b,c) 12(a,b,c)

Ar =(a) Phenyl, (b) 2-methoxyphenyl, (c) 4-methoxyphenyl

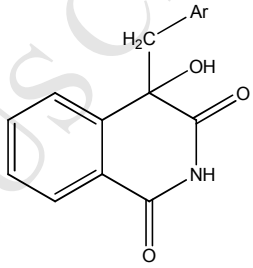
Scheme 4. Formation of 4-cinnamylidene-isoquinolinediones



13



14



15(a, b, c, d)

a) Ar= C_6H_5
b) Ar= 2-OCH_3-C_6H_4
c) Ar= 4-OCH_3-C_6H_4
d) Ar= 3-OCH_3-C_6H_4

3. Conclusions

Our study demonstrates that reaction of highly unsaturated systems like **1f** can undergo reduction and vinylogation with triethylamine in hot ethanol. The two reactions occur to varying degrees depending upon nuclear substituents, solvents and amines. In one case at least **1f**, diisopropylethylamine (DIPE) gave the dihydro derivative **2f** as the single observed product. Homologation was also observed in an unsaturated cyclic system, 4-arylideneisoquinoline-1, 3-dione **11**. In these cases, additionally hydroxylated products at C-4 were obtained rather than the dihydro species. Observations reported in this study need to be followed up by further mechanistic studies and structure- reactivity correlations.

4.0. Experimental

4.1. General

All chemicals used for synthesis were from commercial sources and used without further purification, unless otherwise indicated. The products were isolated by column chromatography over silica gel 230-400 mesh. IR spectra were recorded by using Perkin Elmer-Spectrum BX FT-IR spectrometer. ^{1}H NMR and ^{13}C NMR were recorded at 300MHz or 400MHz and ^{13}C spectra at 75MHz with TMS as an internal standard. Mass spectra were obtained in Agilent 1200 Series LC/MSD VL system. Photo reactions were carried out in Heber immersion type photo reactor (125 and 400 watts). Melting points were determined by using Buchi melting point-545 instrument and are uncorrected. Analytical thin-layer chromatography (TLC) was carried out on Merck silica gel 60G-254 plates (25mm) and developed with solvents mentioned. The purity of compounds was analyzed by using HPLC Agilent 1200 instrument.

4.2. General experimental procedure for triethylamine reactions- formation of butadienes and dihydro derivatives

To a solution of 3-aryl-2-cyanoprop-2-enoic acid derivatives (0.01mol) in ethanol (20 mL), was added a solution of triethylamine (0.03mol) in ethanol (20 mL) and the mixture heated at 70-75°C for 12 h. After completion of the reaction, ethanol was completely distilled off under vacuum. The residue was dissolved in dichloromethane, washed with water and the organic layer distilled off completely under vacuum to afford crude product mixture from which the butadiene and dihydro derivatives were obtained by column chromatography (20% ethyl acetate / hexane).

4.3. General conditions for borohydride reduction of 3-aryl-2-cyanoprop-2-enoic acid derivatives

Sodium borohydride powder (0.01mol) was added to a stirred solution of 3-aryl-2-cyanoprop-2-enoic acid derivatives (0.01mol) in ethanol (10mL). The resulting suspension was stirred at 20-25°C until the TLC test shows disappearance of starting material. Ethanol was distilled off under reduced vacuum to afford crude products and the dihydro derivatives were obtained by column chromatography (30% ethyl acetate / hexane).

4.3.1. Ethyl 2-cyano-3-phenylacrylate **(1a)**

nmax (liquid film) 3000, 2979, 2223, 1726, 1607 cm^{-1}; dH (400MHz $CDCl_3$) 1.4(3H, t, J 7.15Hz, $OCH_2C\mathbf{H}_3$), 4.4(2H, q, J 7.14Hz, $OC\mathbf{H}_2CH_3$), 7.5(3ArH, m), 8.0(2ArH, d, J 7.14Hz), 8.2(1H, s, vinyl); m/z 200.2 (MH-). Data were consistent with reported values in the literature.[8]

Action of triethylamine on (**la**) in hot ethanol

NMR spectrum showed about 15% of dihydro derivative **2a**, the rest was unreacted starting material, butadiene was not formed.

Authentic dihydro **2a**[9]and butadiene **3a**[10] were prepared as per literature.

The dihydro compound **2a** was identical with the authentic sample (TLC and NMR). (1.5g, 75%) as colourless oil; nmax (liquid film) 3000, 2979, 2244, 1726 cm^{-1}; dH (400MHz, $CDCl_3$) 1.3 (3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 3.2(1H, dd, J 13.8, 8.4Hz, $C\mathbf{H}_2$-CH), 3.3(1H, dd, J 13.8, 5.8Hz, $C\mathbf{H}_2$-CH), 3.8(1H, dd, J 8.4, 5.8Hz, CH_2-C**H**), 4.2(2H, q, J 7.15Hz, $OC\mathbf{H}_2CH_3$), 7.23-7.38(5ArH, m); m/z 202.1(MH-)

The butadiene compound **3a** was prepared from cinnamaldehyde and ethyl cyanoacetate. (2.0g, 88%) as yellow coloured powder; nmax (liquid film) 2988, 2947, 2205, 1747, 1602 cm^{-1}; dH(400MHz, $CDCl_3$) 1.4 (3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 4.3(2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$), 7.30 (2H, m, -C**H**=C**H**-CH=), 7.42(3ArH, m), 7.58(2ArH, m), 8.02(1H, dd, J 7.7, 3.1Hz, -CH=CH-C**H**=); m/z 227.2 (MH-).

4.3.2 Ethyl 2-cyano-3-(2-methoxyphenyl)acrylate **(1b)**

nmax (liquid film) 3073, 2942, 2223, 1596cm^{-1}; dH (400MHz, $CDCl_3$) 1.4(3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 3.9(3H, s, OMe), 4.4(2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$), 6.9(1ArH, d, J 8.3Hz), 7.0(1ArH, t, J 7.5Hz), 7.5(1ArH, t, J 7.2Hz), 8.28(1ArH, d, J 7.7Hz), 8.75(1H, s, vinyl); HRMS (CI, NH_3): MNa^+, found *m/z* 254.0795. $C_{13}H_{13}NO_3Na$ requires *m/z* 254.0788. Data are consistent with the reported literature.[11]

Action of triethylamine on (**1b**) in hot ethanol

The crude product was characterized by NMR spectrum which showed approximately unreacted starting material about 56%, butadiene 16% and dihydro compound24%. The crude mixture was separated by column chromatography.

Dihydro compound (**2b**):

Rf (30% EtOAc/hexanes) 0.65; (1.5g, 65%), as a white solid; mp 111-112°C (EtOAc-hexane); dH (400MHz, $CDCl_3$) 1.27 (3H, t, *J* =7.15Hz, $OCH_2C\mathbf{H}_3$), 3.11(1H, dd, J 13.4, 3.3Hz,), 3.36(dd, *J* =13.4, 6.6Hz, 2H), 3.85(3H, s, OMe), 3.92(1H, dd, J 3.3, 6.6Hz, CH_2-C**H**), 4.24(2H, q, J 7.15Hz, $OC\mathbf{H}_2CH_3$), 6.93(2ArH, m), 7.2(1ArH, dd, J 7.4, 1.4Hz), 7.29(1ArH, dd, J 9.3,1.6Hz,); HRMS (CI, NH_3): MNa^+, found *m/z* 256.0951. $C_{13}H_{15}NO_3Na$ requires *m/z* 256.0944. This was identical with an authentic sample obtained by reducing **1b** with sodium borohydride in ethanol (mix mp 112-113°C).

Butadiene compound (**3b**):

Rf (30% EtOAc/hexanes) 0.75; mp 104-105°C (EtOAc-hexane); dH (400MHz, $CDCl_3$) 1.4 (3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 3.9(3H, s, OMe), 4.3(2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$), 6.9(1H, d, J 8.2Hz, -CH=C**H**-CH=), 7.0(1H, t, J 7.4Hz, -C**H**=CH-CH=), 7.40(2ArH, m), 7.61(m, 2ArH), 8.0(1H, d, J 11.7Hz, -CH=CH-C**H**=); dC (100.6 MHz, $CDCl_3$) 162.43, 158.47, 156.39, 144.18, 132.48, 128.69, 123.61, 123.45, 120.88, 114.68, 111.22, 103.32, 62.03, 55.51, 14.08; HRMS (CI, NH_3):

MNa^+, found *m/z* 280.0945. $C_{15}H_{15}NO_3Na$ requires *m/z* 280.0944. The butadiene was identical with the authentic sample (mix mp 103-104°C).[8, 12]

Reaction in toluene leads to 5% butadiene and 10% dihydro derivatives the rest being starting material. There was no reaction in acetonitrile. The reaction with diisopropylethylamine, in ethanol or in acetonitrile showed complete disappearance of starting material, no hydrolyzed aldehyde and major formation of dihydro derivative.

4.3.3 Ethyl 2-cyano-3-(3-methoxyphenyl)acrylate (**1c**) [13]

nmax (liquid film) 3078, 2940, 2230, 1730, 1598cm^{-1}; dH (400MHz, $CDCl_3$) 1.4 (3H, t, J 7.1Hz, , $OCH_2C\mathbf{H}_3$), 3.9 (3H, s, OMe), 4.4(2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$), 7.1(1ArH, dd, J 6.4, 1.8Hz), 7.4(1ArH, t, J 8.0Hz), 7.5(1ArH, d, J 7.7Hz), 7.49(1ArH, d, J 7.7Hz,), 8.2(1H, s, vinyl); m/z 231.1(MH+).

Action of triethylamine on (**1c**) in hot ethanol

NMR analysis of crude product indicated the formation of dihydro derivative **2c** for about 16%, hydrolyzed aldehyde about 7%. Approximately 76% of starting material did not undergo reaction.

Authentic **2c** was made from **1c** by reduction with sodium borohydride in ethanol.

Rf (30% EtOAc/hexanes) 0.60; (1.5g, 65%) as a orange oil; nmax (liquid film) 3070, 2982, 2251, 1744cm^{-1}; dH (400MHz, $CDCl_3$) 1.27(3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 3.1(1H, dd, J 13.8, 8.5Hz, $C\mathbf{H}_2$-CH), 3.25(1H, dd, J 13.8, 5.8Hz, $C\mathbf{H}_2$-CH), 3.7(1H, dd, J 8.5, 5.8Hz, CH_2-C**H**), 3.8(3H, s, OMe), 4.24(2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$), 6.8(3ArH, m), 7.3(1ArH, q, J 7.1, 2.3Hz); m/z 232.1(MH-).

4.3.4 Ethyl 2-cyano-3-(4-methoxyphenyl)acrylate (**1d**)

nmax (liquid film) 3093, 2982, 2233, 1596cm^{-1}; dH (300MHz, $CDCl_3$) 1.3 (3H, t, J 7.2Hz, $OCH_2C\mathbf{H}_3$), 3.89(3H, s, OMe), 4.4(2H, q, J 7.2Hz, $OC\mathbf{H}_2CH_3$), 7.0(2ArH, d, J 9.0Hz), 8.0(2ArH, d, J 9.0Hz), 8.2(1H, s, vinyl); m/z 231.1(MH+). Data are consistent with the values reported in literature.[14]

Action of triethylamine on (**1d**) in hot ethanol

NMR spectrum of the crude product showed almost completely unchanged starting material, the rest was approximately 6.5% of dihydro derivatives **2d** (δ 3.1-3.3 ppm).

4.3.5 Ethyl 3-(4-chlorophenyl)-2-cyanoacrylate (**1e**)

nmax (liquid film) 3073, 2962, 2213, 1743, 1662, 807cm^{-1}; dH (400MHz, $CDCl_3$) 1.4 (3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 4.4(2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$), 7.48(2ArH, m), 7.93(2ArH, m), 8.2(1H, s, vinyl); m/z =234.2(MH-). Data are consistent with reported literature values.[8]

Action of triethylamine on (**1e**) in hot ethanol.

The NMR spectrum of crude product indicated that the dihydro derivative **2e** was formed to about 17% the rest was almost completely starting material.

Authentic **2e** was prepared by reduction of **1e** with sodium borohydride.

(1.3g, 50%), as a colourless oil, nmax (liquid film) 3089, 2983, 2251, 1596, 807cm^{-1}; dH (300MHz, $CDCl_3$) 1.27 (3H, t, J 7.16Hz, $OCH_2C\mathbf{H}_3$), 3.10 (1H, dd), 3.18(1H, dd) 3.6 (1H, dd), 4.2(2H, q, *J*= 7.14Hz, $OC\mathbf{H}_2CH_3$), 7.15(2ArH, m), 7.3(2ArH, m).

4.3.6 Ethyl 2-cyano-3-(2-methoxy-5-nitrophenyl)acrylate (**1f**) [1a]

Ethyl cyanoacetate (11.3g, 0.1mol) was taken in ethanol (100 mL) to which added 2-3 drops of piperidine were added and the mixture stirred for 10-15 min. 2-Methoxy-5-nitrobenzaldehyde [4] (18.1g, 0.1mol) was added slowly to the mixture which was then stirred at 25-30°C until a TLC

test showed the reaction was complete. The precipitate was filtered off, washed with ethanol and then recrystallized from the ethanol to afford **1f**. Rf (50% EtOAc/hexanes) 0.67; mp 186-188°C(lit., [1a] 186-187°C); nmax (liquid film) 3074, 2954, 2226, 1721, 1603, 1518, 1354 cm^{-1}; dH (400MHz, $CDCl_3$) 1.4 (3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 4.4(2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$), 4.0(3H, s, OMe), 7.0(1ArH, d, J 9.2Hz), 8.39(1ArH, dd, J 9.2, 2.8Hz), 8.4(1H, s, vinyl), 9.0(1ArH, d, J 2.6Hz); HRMS (CI, NH_3): MH^+, found *m/z* 277.0816. $C_{13}H_{13}N_2O_5$ requires *m/z* 277.0819.

Action of triethylamine on (**1f**) in hot ethanol

The NMR spectrum showed the mixture to have approximately 3% starting material, 48.5% butadiene and 48.5% dihydro compound. The HPLC analysis gave the composition as starting material 8%, 23% butadiene **3f** and dihydro compound **2f** 65%. The mismatch is obviously due to the fact that the HPLC area% has not been corrected for the response factor. The crude mixture was separated by column chromatography (20% EtOAC / hexanes) to get **3f** in the earlier fraction and **2f** in the later fraction.

Authentic dihydro **2f**[1a] and butadiene **3f**[1a] were prepared.

Dihydro compound (**2f**)

Rf (50% EtOAc/hexanes) 0.65; (1.5g, 53%) as a off white solid, mp 110-111°C (lit., [1a] 112-113°C); nmax (liquid film) 3074, 2919, 2253, 1739, 1509, 1346 cm^{-1}; Purity: 97.25 % (HPLC); dH (400MHz, $CDCl_3$) 1.32 (3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 3.22 (1H, dd, J 8.5, 13.7Hz, $C\mathbf{H}_2$-CH), 3.40(1H, dd, *J*=6.8,13.7Hz, $C\mathbf{H}_2$-CH), 3.92(1H, dd, *J*=8.5, 6.5Hz, CH_2-C**H**), 4.0(3H, s, OMe), 4.3(q, J 7.1Hz, 2H, $OC\mathbf{H}_2CH_3$), 7.0(1ArH, d, J 9.0Hz), 8.13(1ArH, d, J 2.6Hz), 8.25(1ArH, dd, J 9.0, 2.7Hz); HRMS (CI, NH_3): MH+ found *m/z* 279.0970, $C_{13}H_{15}N_2O_5$ requires *m/z* 279.0975.

Butadiene compound (**3f**)

Rf (50% EtOAc/hexanes) 0.90; (1.2g, 40%) as a light green solid, mp 186-188°C(lit., [1a] 187-188°C); nmax (liquid film): 2988, 2947, 2223, 1715, 1605, 1522, 1346 cm^{-1}; Purity**:** 95.92 % (HPLC); dH (400MHz, $CDCl_3$) 1.39 (3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 4.00(3H, s, OMe), 4.33 (2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$), 7.11 (1ArH, d, J 9.1Hz), 7.47(1H, dd, J 10.6, 15.2Hz, -C**H**=CH-CH=), 7.53 (1H, d, J 15.2Hz, -CH=C**H**-CH=), 8.01 (1H, d, J 10.6Hz, -CH=CH-C**H**=), 8.28 (1ArH, dd, J 9.0, 2.5Hz,), 8.43 (1ArH, d, J 2.5Hz); dC (75 MHz, $CDCl_3$) 162.53, 162.03, 155.09, 141.65, 141.12, 127.28, 126.07, 124.36, 114.21, 111.25, 106.00, 105.98, 62.48, 56.61, 14.12; m/z 301.8 (MH-); HRMS (CI, NH_3): MH+ found *m/z* 303.0974. $C_{15}H_{15}N_2O_5$ requires *m/z* 303.0975.

Acetaldehyde (0.88g, 0.02mol) was added to toluene (20mL) containing **1f** (2.77g, 0.01mol) and catalytic amount of pyridine and the solution heated to 60 to 65°C for 14 h. After completion of the reaction, toluene was completely distilled off under vacuum. The residue was dissolved in dichloromethane, washed with water and the organic layer distilled off completely under vacuum to afford crude product mixture from which the butadiene **3f** was obtained by column chromatography (20% EtoAc/ hexanes); (1.5g, 49%) as a light green colored solid.

4.3.7 Ethyl 2-cyano-3-(4-nitrophenyl)acrylate (**1g**)

nmax (liquid film) 3073, 2942, 2220, 1733, 1521, 1338cm^{-1}; dH (400MHz, $CDCl_3$) 1.4 (3H, t, J 7.15Hz, $OCH_2C\mathbf{H}_3$), 4.4(2H, q, J 7.12Hz, $OC\mathbf{H}_2CH_3$), 8.1(2ArH, d, J 5.1Hz,), 8.3(1H, s, vinyl), 8.4(2ArH, d, J 4.9Hz,); m/z 246.1(MH-). Data are consistent with reported literature values.[15]

Action of triethylamine on (**1g**) in hot ethanol

NMR spectrum of the crude product showed only diagnostic peaks for the dihydro derivative **2g** seen over a curvy base line. Hence presence of starting material and butadiene could not be estimated.

Attempted reduction of **1g** with sodium borohydride in ethanol led to a mixture of the dihydro derivative **2g** and alcohol formed by reduction of the ester.

4.3.8 Methyl 2-cyano-3-(2-methoxy-5-nitrophenyl)acrylate (**1h**)

This was prepared by the conditions used for **1f**, (2.75g, 76%) as a white solid; mp 152-153°C (MeOH); nmax (liquid film) 3074, 2954, 2223, 1735, 1600, 1542, 1371cm^{-1}; dH (300MHz, $CDCl_3$) 4.0(3H, s, OC**H**$_3$), 4.1(3H, s, OMe), 7.1(1ArH, d, J 9.2Hz), 8.44(1ArH, dd, J 9.2, 2.7Hz), 8.5(1H, s, vinyl), 9.13(1ArH, d, *J*= 2.6Hz); HRMS (CI, NH_3): MNa$^+$, found *m/z* 285.0493, $C_{12}H_{10}N_2NaO_5$ requires *m/z* 285.0482.

Action of triethylamine on (**1h**) in hot methanol

The NMR spectrum of the crude product showed a mixture of approximately unreacted starting material about 38%, 13% butadiene, 38% dihydro and 11% of starting aldehyde (diagnostic peak for butadiene δ 7.51 ppm, dihydro δ 3.3 -3.4 ppm as in **2f**).

4.3.9 Ethyl 2-cyano-3-(thiophen-2-yl)acrylate (**1i**)

nmax (liquid film) 3073, 2942, 2230, 1723, 1610 cm^{-1}; dH (400MHz, $CDCl_3$) 1.38 (3H, t, J 7.1Hz, OCH_2C**H**$_3$), 4.37(2H, q, J 7.1Hz, OC**H**$_2CH_3$), 7.22(1ArH, dd, J 3.8, 1.1Hz), 7.7(1ArH, d, J 1.1Hz,), 7.8(1ArH, d, J 3.7Hz), 8.3(1H, s, vinyl); HRMS (CI, NH_3): MNa+ found *m/z* 230.0252. $C_{10}H_9NO_2S$ Na requires *m/z* 230.0252. Above data are in agreement with the reported values.[16]

Action of triethylamine on (**1i**) in hot ethanol

The NMR spectrum indicated formation of about 5% dihydro (δ 3.45, 3.75 ppm). The rest was starting material.

4.3.10 Ethyl 2-cyano-3-(pyridin-2-yl)acrylate (**1j**)

nmax (liquid film) 3080, 2870, 2226, 1714, 1626 cm^{-1}; dH (400MHz, $CDCl_3$) 1.4 (3H, t, *J* = 7.1Hz, $OCH_2C\mathbf{H}_3$), 4.3(2H, q, *J*= 7.1Hz, $OC\mathbf{H}_2CH_3$), 7.4(1ArH, m), 7.82(1ArH, m), 7.9(1ArH, d, J 7.8Hz,), 8.28(1H, s, vinyl), 8.8(1ArH, d, J 4.6Hz,); m/z 203.1(MH+); Data agree with the reported values.[17]

Action of triethylamine on (**1j**) in hot ethanol

NMR spectrum of crude product was very complex but showed no starting material.

Sodium borohydride reduction of (**1j**) is reported in the literature to give ethyl 3-aminoindolizine-2-carboxylate.[16b] nmax (liquid film) 3056, 2939, 2251, 1743 cm^{-1}; dH (300MHz, DMSO) 1.28 (3H, t, J 6.9Hz), 4.24(2H, q, J 6.9Hz), 6.12(NH_2, br s), 6.40(3ArH, m), 7.16(1ArH, q, J 2.7Hz), 7.77(1ArH, d, J 5.7Hz).

It was not possible to ascertain whether (ethyl 3-aminoindolizine-2-carboxylate) was present in the crude triethylamine reaction product.

Methyl 2-cyano-3-(pyridin-2-yl)acrylate was also reduced by $NaBH_4$ to give respective methyl 3-aminoindolizine-2-carboxylate (1.2g, 60%), as a white solid; mp 105-106°C; nmax (liquid film) 3422, 2925, 2221, 1681, 1609 cm^{-1}; dH (300MHz, $CDCl_3$) 3.88 (3H, s, CH_3), 4.8(br s, NH_2), 6.44(2ArH, t, J 6.6Hz), 6.55(1ArH, s), 7.20(1ArH, d, J 9.9Hz), 7.40(1H, s); m/z 189.0 (MH-).

4.3.11 Ethyl 2-cyano-3-(pyridin-3-yl)acrylate (**1k**)

nmax (liquid film) 3090, 2906, 2221, 1715, 1613 cm^{-1}; dH (400MHz, $CDCl_3$) 1.3 (3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 3.4(2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$), 7.5(1ArH, dd, J 8.1, 4.8 Hz), 7.8(1ArH, dd,

J 4.8, 1.4Hz), 7.9(1ArH, d, J 2Hz), 8.2(1H, s, vinyl), 8.6(1ArH, d, J 8.2Hz); m/z 203.1(MH+). Data confirm to the reported literature.[16]

Action of triethylamine on (**1k**) in hot ethanol

The NMR spectrum of the crude product was complex but it could be roughly estimated that almost 53% of dihydro and aldehyde were present.

4.3.12 Ethyl 2-cyano-3-(pyridin-4-yl)acrylate (**1l**)

nmax (liquid film) 3060, 2981, 2253, 1754, 1632 cm^{-1}; dH (400MHz, $CDCl_3$) 1.4(3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 4.4(2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$), 7.8(2ArH, br s), 8.18(1H, s, vinyl), 8.9 (2ArH, br s); HRMS (CI, NH_3): MH+ found *m/z* 203.0819. $C_{11}H_{10}N_2O_2$ requires *m/z* 203.0821. Data are consistent with those reported in literature.[18]

Action of triethylamine on (**1l**) in hot ethanol

(1.2g, 59%), as a colourless oil; Rf (50% EtOAc/hexanes) 0.55; nmax (liquid film) 3060, 2981, 2253, 1720cm^{-1}; dH (400MHz, $CDCl_3$) 1.27 (3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 3.20 (1H, dd, J 14.0, 8.1, $C\mathbf{H}_2$-CH), 3.22(1H, dd, J 14.0, 5.9Hz, $C\mathbf{H}_2$-CH), 3.77(1H, dd, J 8.1, 5.9Hz, CH_2-C**H**), 4.26(2H, q, J 7.1Hz, $OC\mathbf{H}_2CH_3$) 7.24(d with fine structure, 2ArH), 8.60(d with fine structure, 2ArH); HRMS (CI, NH_3): MNa+ found *m/z* 227.0797. $C_{11}H_{12}N_2O_2Na$ requires *m/z* 227.0796. NMR spectrum of crude product showed almost complete consumption of starting material and formation of dihydro compound **2l** as the major product, residual triethylamine and unidentified products.

Authentic **2l** was made for **1l** by reduction with sodium borohydride in ethanol. Obtained as a colourless oil; (1.7g, 85%) as colourless oil; nmax (liquid film) 3035, 2910, 2223, 1716 cm^{-1}. dH (400MHz, $CDCl_3$) 1.27 (3H, t, J 7.1Hz, $OCH_2C\mathbf{H}_3$), 3.20 (1H, dd, J 14.0, 8.1,$C\mathbf{H}_2$-CH),

3.22 (1H, dd, J 14.0, 5.9Hz, C**H**$_2$-CH), 3.77(1H, dd, J 8.1, 5.9Hz, CH$_2$-C**H**), 4.26(q, J 7.1Hz, 2H, OC**H**$_2$CH$_3$) 7.24(2ArH, d, J 4.5Hz), 8.60(2ArH, d, J 4.6Hz); m/z 203.1(MH-).

4.3.13 (2-Methoxybenzylidene) propanedinitrile (**1m**)

nmax (liquid film) 3080, 2954, 2223, 1618, 1335 cm^{-1}; dH (400MHz, $CDCl_3$) 3.92 (3H, s, OMe), 6.98(1ArH, d, J 8.3Hz,), 7.08(1ArH, t, J 7.6Hz), 7.58(1ArH, t with fine structure), 8.18(1ArH, dd, J 8.0, 1.52Hz), 8.3(1H, s, vinyl); Data match values with the one reported in literature.[19]

Action of triethylamine on (**1m**) in hot ethanol

The NMR of the crude product showed clearly the presence of dihydro derivatives to about 50% and unreacted starting material 25%, hydrolyzed product 2-methoxybenzaldehyde about 25%. There was no obvious presence of butadiene.

Reduction of (**1m**) using $NaBH_4$

(1.1g, 59%), as a colorless oil, Rf (50% EtOAc/hexanes) 0.50; nmax (neat) 3080, 2954, 2223, 1335 cm^{-1}; dH (400 MHz, $CDCl_3$) 3.3 (2H, d, J 7.7Hz, C**H**$_2$-CH), 3.8(3H, s, OMe), 4.16(1H, t, J 7.7Hz, CH$_2$-C**H**), 6.91(1ArH, d, J 8.2Hz), 6.96(1ArH, t, J 7.4Hz), 7.2(1ArH, d, J 7.0), 7.35(1ArH, m); m/z 187.1(MH+).

4.3.14 (2-Methoxy-5-nitrobenzylidene)propanedinitrile (**1n**)

Malononitrile (6.6g, 0.1mol) was taken in ethanol (100mL) to which were added 2-3 drops of piperidine and the mixture stirred for 10 min. 2-Methoxy-5-nitrobenzaldehyde (18.1g, 0.1mol) was added slowly to the mixture which was then stirred at 25-30°C until a TLC test showed the reaction was complete. The precipitate was filtered off, washed with ethanol and recrystallized from ethanol to afford **1n**; nmax (liquid film) 3080, 2948, 2232, 1606, 1338 cm^{-1}; dH (400MHz, $CDCl_3$) 4.07 (3H, s, OMe), 7.12(d, J 9.2Hz, 1H), 8.2(1H, s, vinyl), 8.46(1ArH, dd, J 9.2,

2.6Hz,), 9.0(1ArH, d, J 2.6Hz); HRMS (CI, NH_3): MNa^+, found *m/z* 252.0376. $C_{11}H_7N_3O_3Na$ requires *m/z* 252.0380.

Action of triethylamine on (**1n**) in hot ethanol

NMR spectrum of the crude product showed about 46% aldehyde, traces starting material and about 53% dihydro compound 3.26 (2H, d, J 7.7Hz), 4.06(1H, t, J 7.7Hz). Authenticate dihydro compound for reference purposes could not be made by the usual $NaBH_4$ reduction of **1n** since one CN group also got reduced in the process.

4.3.15 2-Cyano-N, N-diethyl-3-(2-methoxy-5-nitrophenyl)acrylamide (**1o**)

To a solution of *N*, *N*-diethylcyanoacetamide (14.1g, 0.1mol) in toluene (100mL) was added IRA 96 resin (0.2g) and 2-methoxy-5-nitrobenzaldehyde (18.1g, 0.1mol). Then the mixture was heated to reflux, released water being collected azeotropically, until TLC test showed the absence of starting materials. The reaction mixture was filtered hot. The filtrate was evaporated completely and the residue was purified with ethanol to afford **1o**. (2.2g, 73%) as a white solid; mp 134-135°C (EtOH); nmax (liquid film) 3074, 2934, 2212, 1633, 1518, 1342 cm^{-1}; dH (400MHz, $CDCl_3$) 1.2 (6H, br s $(CH_3)_3$), 3.5(4H, br s,$(CH_2)_2$), 4.0(3H, s, OMe), 7.0(1ArH, d, J 9.2Hz), 7.94(1H, s, vinyl), 8.3(1ArH, dd, J 9.2, 2.3Hz), 9.0(1ArH, d, J 2.4Hz,); m/z 303.2 (MH+).

(1o) was unaffected by triethylamine in hot ethanol under the usual conditions.

4.3.16 Ethyl 2-(2-methoxy-5-nitrobenzylidene)-3-oxobutanoate (**1p**).

Ethyl acetoacetate (1.30g, 0.01mol) was added to a solution of 2-methoxy-5-nitrobenzaldehyde (1.81g, 0.01mol) in ethanol (20mL). The reaction mass cooled to 0-5°C, and saturated with HCl gas. The precipitate product was filtered off to afford **1p**. (1.93g, 65%) as a white solid; mp 113-114°C (EtOH); Rf (50% EtOAc/hexanes) 0.68; nmax (liquid film) 3078, 2944, 1730, 1656, 1342 cm^{-1}; dH (400MHz, $CDCl_3$) 1.3 (3H, t, J 7.18Hz, $OCH_2C\mathbf{H}_3$), 2.44(3H, s, $C\mathbf{H}_3$), 4.0(3H, s,

OMe), 4.4(2H, q, J 7.1Hz, OC**H**$_2$CH$_3$), 7.0(1ArH, d, J 9.1Hz), 7.8(1H, s, vinyl), 8.28(1ArH, dd, J 9.1, 2.8Hz), 8.3(1ArH, d, J 2.8Hz); m/z 293.1(M+).

Action of triethylamine on (**1p**) in hot ethanol

The reaction of **1p** with triethylamine was carried out in ethanol at 70-75°C for 12 h. After completion of the reaction, ethanol was completely distilled off. The NMR of the crude product clearly showed absence of starting material, trace of hydrolyzed aldehyde (about 4%). Besides small amounts unidentified materials the major product was the decarboethoxylated, i.e 2-methoxy-5-nitrobenzylideneacetone; dH(400MHz, $CDCl_3$) 2.40 (3H, s, C**H**$_3$), 4.02 (3H, s, OMe), 6.85 (1H, d, J 16.4 Hz), 7.0 (1ArH, d, J 9Hz,), 7.80(1H, d, J 16.4Hz), 8.26 (1ArH, dd, J 9.3, 2.7 Hz), 8.4(1ArH, d, J 2.7 Hz); m/z 220(MH-).

4.3.17 Ethyl 2-(methylsulfonyl)-3-phenylacrylate (**1q**)

nmax (liquid film) 2985, 2932, 1731, 1622, 1140 cm^{-1}; dH (400MHz, $CDCl_3$) 1.25 (3H, t, J 7.0Hz), 3.24(3H, s, C**H**$_3$), 4.4 (2H, q, J 7.0Hz), 7.39-7.46(5H, m), 7.83(1H, s, vinyl); HRMS (CI, NH_3): MNa+ found *m/z* 277.0514. $C_{12}H_{14}O_4SNa$ requires *m/z* 277.0511. Data match values in reported literature. [20]

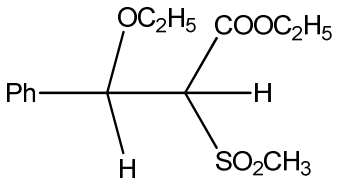
Action of triethylamine on (**1q**) in hot ethanol

The NMR spectrum of the product had traces of the hydrolyzed product. The major products (**6, 7**) corresponded to the ones obtained by reaction of **1q** with $NaBH_4$ in ethanol.

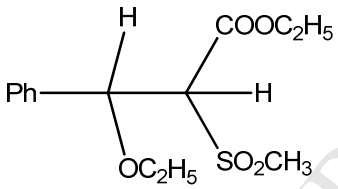
Attempted reduction of (**1q**) using $NaBH_4$

NMR and mass spectra clearly showed that reduction had not taken place and ethanol had added to the double bond. This addition can lead to diastereoisomeric products. These were present in the NMR spectrum in the ratio of 3:1. Reaction as usual gave a colourless oil product. dH (400MHz, $CDCl_3$) 1.0 (3H, t, J 7.1Hz), 1.12(3H, t, J 7.1Hz), 4.99 (PhCH, d, J 10Hz), 5.07

(PhCH, d, J 6H); HRMS (CI, NH_3): MNa+ found *m/z* 323.0931. $C_{14}H_{20}O_5SNa$ requires *m/z* 323.0929.



6



7

4.3.18 3-(2-Methoxy-5-nitrobenzylidene)pentane-2, 4-dione (**1r**).

2, 4-Pentadione (1.0g, 0.01mol) was added to a solution of 2-methoxy-5-nitrobenzaldehyde (1.8g, 0.01mol) in methanol (20mL). The reaction mass was cooled to 0-5°C, then HCl gas was passed until saturation. Reaction mass was filtered to give the aldol.

The product was taken in acetic anhydride and heated to 60-65°C for 30 min to effect dehydration of the aldol. The reaction mass was cooled to 20-25°C and dropped into ice cold water. Ethyl acetate was added and the mass stirred. The ethyl acetate layer was separated and distilled off completely under vacuum. The solid obtained was characterized as **1r**. (1.8g, 68%) as a off white solid; mp 176-177°C (EtOH); nmax (liquid film) 3082, 2947, 1708, 1548, 1353 cm^{-1}; dH (400MHz, $CDCl_3$) 2.32 (3H, s, C**H**$_3$), 2.46(3H, s, C**H**$_3$), 4.0(3H, s, OMe), 7.0(1ArH, d, J 9.1Hz), 7.6(1H, s), 8.26(1ArH, d, J 2.8), 8.28(1ArH, dd, J 9.1, 2.8Hz); HRMS (CI, NH_3): MH+ found *m/z* 264.0868. $C_{13}H_{14}NO_5$ requires *m/z* 264.0869.

Action of triethylamine on (**1r**) in hot ethanol.

NMR of the crude product could not be analyzed.

4.2.19 Ethyl 3-(2-methoxyphenyl)acrylate (**1s**) [151]

nmax (liquid film) 3080, 2979, 1618, 1710, 1631 cm^{-1}; dH (400MHz, $CDCl_3$) 1.32 (3H, t, J 7.1Hz, OCH_2C**H**$_3$), 3.9(3H, s, OMe), 4.25(2H, q, J 7.1Hz, OC**H**$_2CH_3$), 6.5(1H, d, J 16.1Hz),

7.0(2ArH, m), 7.3(1ArH, t, J 7.0Hz), 7.5(1ArH, d, J 6.0Hz), 8.0(1H, d, *J*=6.1Hz); m/z 206.2(MH+).

Action of triethylamine on (**1s**) in hot ethanol

The NMR spectrum of crude product indicated that there was about 8% each of dihydro derivatives and butadiene derivatives and 8% of hydrolyzed aldehyde, the rest being starting material.

4.3.20 β-Nitro styrene (**1t**) [21]

nmax (liquid film) 3064, 1561, 1366, 1224 cm^{-1}; dH (300MHz, DMSO) 7.4-7.6 (3ArH, m), 7.8-7.9(2ArH, m), 8.13(1H, d, J 13.5Hz), 8.24(1H, d, J 13.5Hz); m/z 160.2 (MH^-).

(1t) was unaffected by triethylamine in hot ethanol.

4.3.21 5-(2-Methoxy-5-nitrobenzylidene)thiazolidine-2,4-dione (**8**)

Aqueous potassium carbonate (1.3g, 0.01mol) was added to a solution of 2-methoxy-5-nitrobenzaldehyde (1.8g, 0.01mol) and thiazolidine-2,4-dione (1.1g, 0.01mol) in ethanol (20mL). The reaction mass stir for 12 h at 20-25°C. Ethanol was completely distilled off under vacuum, acetic anhydride (10ml) was added to the residue heated to 70-75°C for 2hr and then cooled to 20-25°C. Reaction mass was filtered to give (**8**). (1.75g, 57%) as a yellow solid; mp 176-177°C (EtOH); nmax (liquid film) 3164, 2955, 1708, 1664 cm^{-1}; dH (400MHz, DMSO) 4.03 (3H, s, OMe), 7.34(1ArH, d, J 9.2Hz), 7.7 (1H, s), 8.2(1ArH, s), 8.34(1ArH, dd, J 9.2, 2.7Hz), 12.72(NH, br s); HRMS (CI, NH_3): MH+ found *m/z* 281.0222. $C_{11}H_9N_2O_5S$ requires *m/z* 281.0222.

(8) was unaffected by triethylamine in hot ethanol under the usual conditions.

4.3.22 2-Oxo-2H-chromene-3-carbonitrile (3-cyanocoumarin) (**9**)

nmax (liquid film) 3064, 2230, 1705, 1690 cm^{-1}; dH (400MHz, DMSO) 7.5 (m, 2ArH), 7.8(m, 2ArH), 8.9(s, 1H); m/z 204.1(MH^+). Data are consistent with the reported values.[6]

Action of triethylamine on (**9**) in hot ethanol

Reaction of **9** with triethylamine in ethanol at 70-75°C for 12hr gave a complex mixture of products.

4.3.22 2, 4-isoquinoline-1,3-dione (Homophthalimide) **(10)** [7a]

nmax (liquid film) 3167, 2964, 1704, 1462 cm^{-1}; dH (400MHz, DMSO) 4.1 (2H, s), 7.3(1ArH, d, J 7.6Hz), 7.44(1ArH, t, J 7.5Hz,), 7.6(1ArH, t, J 7.5Hz), 8.0(1ArH, d, J 7.8Hz), 11.3(NH, br s); m/z 160.2 (MH-).

4.3.23 Preparation of substituted arylidene isoquinoline-1, 3-diones

Compound **(11a)** [7a]

nmax (liquid film) 3165, 3067, 2917, 1705, 1682cm^{-1}; dH (400MHz, $CDCl_3$) 7.3 (1ArH, m), 7.4(6ArH, m), 7.6(1ArH, dd, J 7.9, 0.5Hz), 8.2(1ArH, dd, J 6.6, 1.1Hz), 8.3(1H, s), 8.5(NH, br s); HRMS (CI, NH_3): MH+ found *m/z* 250.0861. $C_{16}H_{12}NO_2$ requires *m/z* 250.0863.

Compound **(11b)**

Homophthalimide (1.6g, 0.01mol) and 2-methoxybenzaldehyde (1.3g, 0.01mol) as per reference.[7a] 2.0g (72%), mp 189-190°C (EtOH); nmax (liquid film) 3197, 3073, 2949, 1705, 1673 cm^{-1}; dH (400MHz, $CDCl_3$) 3.8 (3H, s, OMe), 6.9(1ArH, t, J 7.5Hz), 7.0(1ArH, d, J 8.3Hz), 7.4(4ArH, m), 7.7(1ArH, d, J 7.6Hz), 8.32(1ArH, dd, J 6.4, 1.4Hz), 8.4(s, 1H), 8.5(NH, br s); m/z 278.2(MH-).

Compound **(11c)**

Condensation of anisaldehyde under conditions used for **11b** gave **11c**. (1.9g, 69%), mp 199-200°C (EtOH); nmax (liquid film) 3171, 3068, 2964, 1678cm^{-1}; dH(400MHz, $CDCl_3$) 3.8(3H, s, OMe), 6.9(2ArH, d, J 8.7Hz), 7.4(2ArH, m), 7.5(2ArH, d, J 8.4Hz), 7.8(1ArH, d, J 7.6Hz), 8.1(1H, s), 8.2(1ArH, dd, J 6.3, 1.5Hz), 8.28(NH, br s); m/z 279.1(M+)

Compound **(11d)**

Condensation of 3-methoxybenzaldehyde under conditions used for **11b** gave **11d**. (2.0g, 72%), mp 176-177°C (EtOH); nmax (liquid film) 3160, 3058, 2960, 1710, 1675cm^{-1}; dH (400MHz, $CDCl_3$) 3.77(3H, s), 6.93(2ArH, dd, J 8.5, 2.4Hz), 6.95(1ArH, s), 7.0(1ArH, d, J 7.2Hz), 7.30(1ArH, dd, J 9.0, 3.2Hz,), 7.33(1ArH, d, J 6.5Hz), 7.42(1ArH, dd, J 7.5, 1.0Hz), 7.64(1ArH, d, J 7.8Hz), 8.22(1ArH, d, J 6.7Hz), 8.24(1H, s), 8.32(NH); m/z 278.1(MH-)

4.3.24 Action of triethylamine on arylideneisoquinoline-dione in hot ethanol.

A solution of substituted benzylideneisoquinoline-dione (0.01mol) and triethylamine (0.03mol) in ethanol (10mL) was heated at 70-75°C for 8 h. The reaction mass was cooled to 0-5°C, the precipitate was filtered off, washed and recystallized with ethanol to afford crystalline products. In the case of **12a**, the crude product had to be chromatographed.

Compound **(12a)**

The NMR spectrum of the crude product was very complex and could not be analyzed qualitatively or quantitatively. It showed peaks for hydrolyzed product, benzaldehyde, butadiene and possible reduced products. Chromatographic separation gave butadiene **12a** as a yellow powder; (0.75g, 27%), mp 227-228 ºC (EtOAc-hexane); Rf (50% EtOAc/hexanes) 0.66; nmax (liquid film) 3162, 3050, 2850, 1685, 1669 cm^{-1}; dH (400MHz, $CDCl_3$) 7.2(1H, d, J 13.5Hz, β), 7.4(m, 3ArH), 7.5(1ArH, t, J 7.7Hz), 7.6(3ArH, m), 7.7(1H, d, J 11.4Hz, γ), 7.9(1H, d, J 8.1Hz, α), 8.2(NH, br s), 8.3(1ArH, dd, J 7.6, 1.19Hz), 8.7(1ArH, dd, J 13.5, 11.4Hz); HRMS (CI, NH_3): MH+ found *m/z* 276.1017. $C_{18}H_{14}NO_2$ requires *m/z* 276.1019.

This was identical with a standared sample made from homophthalimide and cinnamaldehyde.[1a] (mp 226-228ºC, mix mp 227-229ºC)

Compound **(12b)**

Pure **12b** crystallized out of the reaction as a yellow coloured powder; (0.25g, 8.1%), mp 148-149ºC (EtOH); Rf (50% EtOAc/hexanes) 0.70; nmax (liquid film) 3150, 3056, 2930, 1675,

1658 cm^{-1}; dH (400MHz, DMSO) 3.9 (3H, s, OMe), 7.0 (1ArH, t, J 7.3Hz), 7.1(1H, d, J 8.1Hz, β), 7.4(1H, dd, J 7.3, 1.5Hz, α), 7.5(1ArH, t, J 7.5Hz), 7.6(1ArH, dd, J 7.7Hz, 1.3), 7.7(2ArH, m), 8.1(1ArH, q, J 18.4, 11.3Hz), 8.2(1H, d, J 8.1Hz, γ), 8.7(1ArH, q, J 15.6, 11.3 Hz), 11.4(NH); HRMS (CI, NH_3): MH+ found *m/z* 306.1124. $C_{19}H_{16}NO_3$ requires *m/z* 306.1124.

This was identical with an authentic standared sample made from homophthalimide and 2-methoxycinnamaldehyde in ethanol and catalytic amounts of piperidine; mp 148-150ºC and mixed mp 148-149°C.

Compound **(12c)**

Pure **12c** crystallized out of the reaction as a red coloured powder; (0.6g, 19%), mp 228-230ºC (EtOH); Rf (50% EtOAc/hexanes) 0.74; nmax (liquid film) 3170, 3072, 2960, 1690, 1658 cm^{-1}; dH (400MHz, $CDCl_3$) 3.8(3H, s, OMe), 6.9(2ArH, d, J 8.7Hz), 7.1(1H, d, J 15.3Hz, β), 7.45(1ArH, t), 7.6(2ArH, d, J 8.7Hz), 7.7(1ArH, unresolved triplet), 7.75(1H, d, J 12Hz, γ), 7.8(1H, d, J 8.1Hz, α), 8.2(NH, br s), 8.3(1ArH, dd, J 6.6, 1.1Hz), 8.6(1ArH, q, J 15, 12Hz); HRMS (CI, NH_3): MH+ found *m/z* 306.1126. $C_{19}H_{16}NO_3$ requires *m/z* 306.1124.

4.3.25 Photoirradiation reaction

Irradiation **1f** and triethylamine in ethanol at 254 and 365 nm for 12hr resulted in complete destruction of starting material and formation of unidentified products.

Irradiation of **1s** and triethylamine in ethanol at 254 and 365 nm for 12hr followed by NMR analysis showed almost complete recovery of starting material.

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