CONDENSATION OF CINNAMONITRILES WITH ARYLACETONITRILES

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Abstract - The Michael addition of arylacetonitriles to
Michael acceptors such as α,β-unsaturated nitriles occurred
with a stoichiometric amount of sodium ethoxide to give only
the 1,4-addition product in pure diastereomeric form. The
structures of the reaction products were established by infra-
red, H-1 and C-13 nuclear magnetic resonance spectroscopy as
well as by elemental analysis. The diastereomeric purity was
determined by chromatographic and NMR measurements using
achiral lanthanide shift reagents techniques. The observed
resonances did not show any resolution of the diastereomeric
proton signals. The stereochemistry and absolute configuration
of the condensation product were established from X-ray
crystallography.

The Michael reaction of 3-aryl-1-phenyl-2-propen-1-ones with ethyl phenylacetate
in the presence of sodium ethoxide at room temperature gave the corresponding
ethyl-β-aryl-γ-benzoyl-α-phenylbutrates.[1] However, when the same ketones were
refluxed with ethyl phenylacetate, they gave the corresponding 4-aryl-3,6-diphenyl-
3,4-dihydro-2H-pyran-2-ones. The reaction of these products with hydrazine hydrate
afforded the corresponding hydrazones and 2-pyridones, respectively.

The condensations of other active methylene compounds with different α,β-un-
saturated Michael acceptors were also reported.[2-8] For example, when 3-aryl-1-
phenyl-2-propen-1-ones and aroylphenylacetylenes reacted under reflux for three
hours with cyanoacetamide in presence of sodium ethoxide gave the corresponding
4-aryl-3-cyano-6-phenyl-2-(1H)pyridones. However, when the 2-propen-1-ones were
refluxed with cyanoacetamide for one hour in the presence of piperidine, they
gave the corresponding 4-aryl-3-cyano-3,4-dihydro-6-phenyl-(2H)pyridones which
upon heating with selenium gave the corresponding 2-pyridones. The present work
was intended to study the condensation of different substituted cinnamonitriles
with different arylacetonitriles and numerous new compounds are obtained. In
addition, the diastereomeric purity of the reaction products was examined.
<u>Results and Discussion</u> - Our interest in the condensation reactions of α,β-un-
saturated Michael acceptors with arylacetonitriles prompted us to extend our study
to include the condensations of α,β-unsaturated nitriles. Thus the reaction of
cinnamonitriles <u>1</u> with arylacetonitriles <u>2</u> were carried out in the presence of a
suspension of sodium ethoxide in dry ether. In each case, a single diastereomer
of 2,3-diarylglutaronitriles <u>3</u> was obtained from the reaction mixture as a result
of Michael condensation of the carbanion ArC̄HCN with the double bond of the

α,β-unsaturated nitriles $\underline{1}$, as shown in Scheme 1.
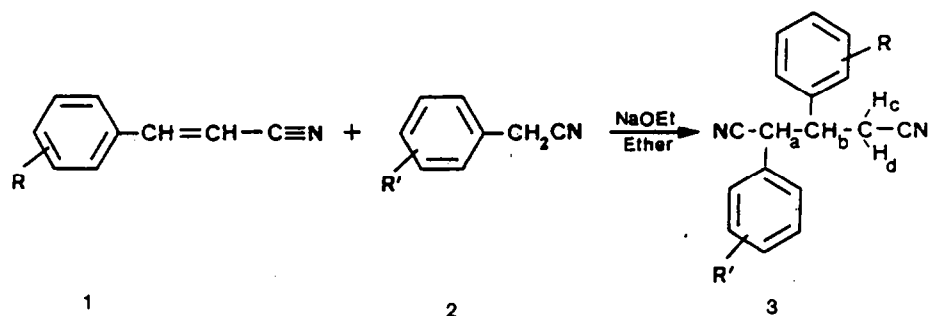
3	R	R'
a	H	3,4-Dichloro
b	H	2,4-Dichloro
c	H	4-Chloro
d	H	4-Bromo
e	H	3-Chloro
f	H	2-Fluoro
g	H	2,6-Dichloro
h	H	2-Methyl
i	H	3-Methyl
j	H	2-Chloro
k	4-Chloro	2,6-Dichloro
l	4-Methoxoy	2,6-Dichloro
m	2,3-Dimethoxy	4-Chloro
n	2,3-Dimethoxy	2,6-Dichloro

Scheme 1

The structures of the glutaronitriles $\underline{3}$a-n were fully characterized by infrared, proton and carbon-13 nuclear magnetic resonance spectroscopy and elemental analyses. The IR spectral data shows the presence of the C$\equiv$N stretching frequency at 2240 to 2280 cm^{-1} in accordance with the expected value. The proton NMR chemical shifts and splitting patterns are also consistent with the suggested structure. The two diastereomeric protons H$_c$ and H$_d$ show two doublets at around δ2.80 and 2.90. A multiplet at 3.39 assigned to H$_b$ was also observed. The highly acidic proton H$_a$ appeared as a doublet at 4.32. The C-13 NMR spectral data shown in Table I are also in agreement with the suggested structure.

The diastereomeric purity of these glutaronitriles was determined by measuring the NMR spectra in the presence of achiral lanthanide shift reagent which has been reported as a convenient method for the separation of diastereomeric proton signals.[9] The incremental addition of achiral lanthanide shift-reagent, Europium (III)-tris(1,1,1,2,2,3,3-heptafluoro-7,7-dimethyl-4,6-octa-

nedionate): {Eu(fod)$_3$}, to the glutaronitriles 3a-n resulted in a large down field

Table I. ^{13}C-Chemical shift values for 2,3-diarylglutaronitriles 3

$$
\begin{array}{ccccc}
 & \overset{\displaystyle Ar'}{\underset{\underset{2}{\mid}}{CH}} & \overset{\displaystyle Ar}{\underset{\underset{3}{\mid}}{CH}} & & \\
NC - & CH - & CH - & CH_2 - & CN \\
\underset{1}{\mid} & \underset{2}{\mid} & \underset{3}{\mid} & \underset{4}{\mid} & \underset{5}{\mid} \\
\end{array}
$$

3	C-1	C-2	C-3	C-4	C-5
a	117.3	46.9	22.2	41.8	116.7
b	117.0	44.4	22.0	39.9	116.6
c	117.8	46.7	22.0	41.9	116.9
d	117.7	46.7	22.1	42.1	116.8
e	117.9	46.8	21.2	42.8	116.7
f	117.3	45.3	22.1	36.9	116.4
g	117.9	46.8	21.2	42.7	116.7
h	118.6	45.6	20.8	40.5	117.0
i	118.4	46.9	21.1	43.3	117.0
j	117.8	46.6	22.0	42.0	116.8

lanthanide shift without the resolution of any proton signals due to different diastereomers (Table II). This observation indicates the formation of a single diastereomer of the newly formed chiral product. The synthesis of a single diastereomer was also confirmed from the homogeneous nature of the product which was evident from a combination of simple H-NMR and melting points as well as by chromatographic TLC data. The diastereomeric purity was also confirmed by the fact that a small difference in chemical yields for glutaronitriles IIIa-n was observed before and after crystallization which excludes the possibility of a selective crystallization of one diastereomer from a mixture containing both diastereomers.

Table II. A downfield induced chemical shift ($\Delta\delta$) for each proton at (1:1) molar ratios of lanthanide shift reagent, europium (III)-tris-(1,1,1,2,2,3,3-heptafluoro-7,7-dimethyl-4,6-octanedionate), and the glutaronitriles,3.

3	H$_a$	H$_b$	H$_c$ and H$_d$
c	1.29	0.93	1.13
f	1.72	1.17	1.46
g	2.33	0.75	0.86
h	1.86	1.76	1.96
i	1.51	1.18	1.67
j	1.20	0.73	1.08
k	0.92	0.93	0.84
m	3.93	2.74	1.96
n	3.23	3.57	2.35

The prediction of the stereochemical outcome of Michael reaction is inevitably complicated by the possible intervention of retrograde Michael reactions and by further transformation of the initial Michael adduct. Other stereochemical questions related to the Michael condensation have been explored but no clear-cut generalization are evident. the stereochemistry of the nucleophilic addition to double bonds has been studied only in cyclic systems where the reaction has been shown to be stereoselective with syn-addition reported in some cases[10], and anti-addition in others.[11] When cyclic unsaturated ketones were used as Michael acceptors, many of the stereochemical results obtained are explicable as attack of the enolates from the less hindered side of the carbon-carbon double bond.[12-16] Unfortunately, this prediction has not been tested to open chain olefins.

The fact that sodium ethoxide forms a suspension in ether, this makes the generation of the carbonion slow and hence become more selective in attacking the α,β-unsaturated nitrile.

X-ray Analysis of 3i

The X-ray molecular plot given in figure 1 as reproduced for compound 3i indicated that the stereochemistry of the reaction product is the R,R diastereomeric type. The crystal system was orthorhombic and the space group was Pbca. The crystal data and data collection parameters are given in Table III.

Fluctuations of <2% in the intensities of two standard reflections were observed during the course of data collection
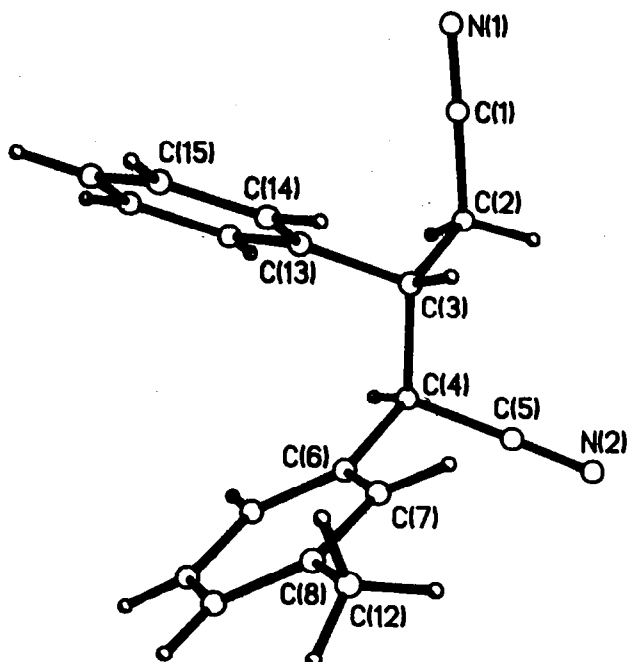

Figure 1: Molecular plot of $C_{18}H_{16}N_2$

Table III. Table of crystal data and data collection parameters for $C_{18}H_{16}N_2$.

formula	$C_{18}H_{16}N_2$
fw	260.34
color and habit	colorless plates
crystal system	orthorhombic
space group	Pbca
a, Å	10.371(4)
b, Å	16.279(8)
c, Å	17.168(9)
V, Å^3	2898(2)
T, deg	130 K
Z	8
cryst dimens, mm	0.28 x 0.43 x 0.60
d_{calcd}. g cm^{-3}	1.19
radiation, (Å)	Mo Kα,(λ = 0.71069)
μ (Mo Kα), cm^{-1}	0.66
range of transmission factors	0.95 - 0.98
diffractometer	$P2_1$, graphite monochromator
scan method	ω, range, 1.3° offset for bkgnd
scan speed, deg min^{-1}	12
2θ range, deg	0 - 50 h,k,l
octants collected	2557
n. data collected	2557
no. unique data	1927 [I>2σ(I)]
no. data used in refinement	184
no. parameters refined	0.046
R^1	$0.055[w = (\sigma^2(F_O)+0.00442F_O^2)^{-1}]$
R_w^{17}	

Only random fluctuations of <2% in the intensities of two standard reflections were observed during the course of data collection. The structure was solved by direct methods.[18,19] Hydrogen atoms bonded to the carbon atoms were included at calculated positions using a riding model, with C-H of 0.96 Å and U_H=1.2 U_C. All nonhydrogen atoms were refined with anisotropic thermal parameters. The largest feature of a final difference map was 0.20e Å^{-3} in height.

A list of atomic coordinates and isotropic thermal parameters as well as those of the hydrogen atom coordinate are given in Tables IV and V respectively.

Table IV. Atomic coordinates (x10^4) and isotropic
thermal parameters (A^{2}x10^3) for $C_{18}H_{16}N_2$

	x	y	z	U
N(1)	2755(2)	976(1)	2577(1)	31(1)*
N(2)	-1033(2)	742(1)	5313(1)	32(1)*
C(1)	1850(2)	991(1)	2959(1)	23(1)*
C(2)	664(2)	1016(1)	3423(1)	22(1)*
C(3)	504(2)	1850(1)	3843(1)	21(1)*
C(4)	-845(2)	1850(1)	4238(1)	22(1)*
C(5)	-958(2)	1230(1)	4836(1)	25(1)*
C(6)	-1117(2)	2716(1)	4603(1)	22(1)*
C(7)	-360(2)	3000(1)	5217(1)	24(1)*
C(8)	-526(2)	3785(1)	5525(1)	25(1)*
C(9)	-1509(2)	4275(1)	5220(1)	29(1)*
C(10)	-2280(2)	3996(1)	4617(1)	30(1)*
C(11)	-2084(2)	3219(1)	4300(1)	26(1)*
C(12)	353(2)	4096(1)	6152(1)	33(1)*
C(13)	674(2)	2580(1)	3303(1)	21(1)*
C(14)	1573(2)	3181(1)	3492(1)	28(1)*
C(15)	1722(2)	3869(1)	3025(1)	34(1)*
C(16)	980(2)	3960(1)	2361(1)	33(1)*
C(17)	86(2)	3363(1)	2163(1)	31(1)*
C(18)	-68(2)	2677(1)	2634(1)	28(1)*

* Equivalent isotropic U defined as one third of the
trace of the orthogonalised U_{ij} tensor

Table V. H-Atom coordinates (x10^4) and isotropic
thermal parameters (A^{2}x10^3) for $C_{18}H_{16}N_2$

	x	y	z	U
H(2A)	-62	931	3086	25
H(2B)	697	586	3805	25
H(3)	1172	1890	4228	24
H(4)	-1475	1787	3838	25
H(7)	289	2647	5433	54
H(9)	-1655	4813	5431	65
H(10)	-2955	4338	4415	67
H(11)	-2608	3031	3875	60
H(12A)	-51	4520	6454	38
H(12B)	1130	4305	5922	38
H(12C)	557	3639	6483	38
H(14)	2095	3117	3950	62
H(15)	2340	4284	3162	77
H(16)	1081	4437	2038	73
H(17)	-420	3424	1699	70
H(18)	-695	2268	2498	62

Furthermore, the anisotropic thermal parameters, bond lengths, and bond angles
for the same molecular plot are given in Tables VI and VII, respectively.

Table VI. **Anisotropic thermal parameters** ($A^2 \times 10^3$) **for** $C_{18}H_{16}N_2$

	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
N(1)	32(1)	29(1)	33(1)	0(1)	4(1)	4(1)
N(2)	41(1)	26(1)	30(1)	4(1)	9(1)	-1(1)
C(1)	28(1)	17(1)	22(1)	2(1)	-3(1)	2(1)
C(2)	25(1)	18(1)	23(1)	3(1)	1(1)	-0(1)
C(3)	24(1)	20(1)	21(1)	-1(1)	-1(1)	-0(1)
C(4)	23(1)	22(1)	21(1)	-1(1)	-0(1)	-1(1)
C(5)	27(1)	22(1)	25(1)	-4(1)	4(1)	-1(1)
C(6)	23(1)	24(1)	19(1)	1(1)	4(1)	-1(1)
C(7)	24(1)	26(1)	22(1)	2(1)	3(1)	2(1)
C(8)	29(1)	27(1)	19(1)	2(1)	6(1)	-1(1)
C(9)	39(1)	23(1)	26(1)	1(1)	7(1)	2(1)
C(10)	31(1)	29(1)	29(1)	6(1)	0(1)	8(1)
C(11)	24(1)	30(1)	23(1)	2(1)	4(1)	0(1)
C(12)	41(1)	32(1)	26(1)	-5(1)	2(1)	-6(1)
C(13)	22(1)	19(1)	21(1)	-0(1)	4(1)	3(1)
C(14)	29(1)	24(1)	31(1)	-1(1)	-1(1)	-2(1)
C(15)	38(1)	21(1)	44(1)	2(1)	6(1)	-5(1)
C(16)	43(1)	23(1)	34(1)	8(1)	13(1)	6(1)
C(17)	37(1)	31(1)	24(1)	4(1)	3(1)	7(1)
C(18)	31(1)	27(1)	25(1)	-0(1)	3(1)	-1(1)

The anisotropic temperature factor exponent takes the form:

$$-2\pi^2 (h^2 a^{*2} U_{11} + \ldots + 2hka^*b^*U_{12})$$

Table VII. **Bond lengths** (A) **and angles** (deg) **for** $C_{18}H_{16}N_2$

N(1)-C(1)	1.146(3)	N(2)-C(5)	1.143(3)
C(1)-C(2)	1.465(3)	C(2)-C(3)	1.546(3)
C(3)-C(4)	1.556(3)	C(3)-C(13)	1.518(3)
C(4)-C(5)	1.478(3)	C(4)-C(6)	1.526(3)
C(6)-C(7)	1.393(3)	C(6)-C(11)	1.394(3)
C(7)-C(8)	1.394(3)	C(8)-C(9)	1.396(3)
C(8)-C(12)	1.498(3)	C(9)-C(10)	1.384(3)
C(10)-C(11)	1.392(3)	C(13)-C(14)	1.390(3)
C(13)-C(18)	1.392(3)	C(14)-C(15)	1.386(3)
C(15)-C(16)	1.384(3)	C(16)-C(17)	1.384(3)
C(17)-C(18)	1.388(3)		

N(1)-C(1)-C(2)	178.0(2)	C(1)-C(2)-C(3)	111.6(2)
C(2)-C(3)-C(4)	109.1(2)	C(2)-C(3)-C(13)	113.0(2)
C(4)-C(3)-C(13)	110.3(2)	C(3)-C(4)-C(5)	110.6(2)
C(3)-C(4)-C(6)	111.9(2)	C(5)-C(4)-C(6)	109.8(2)
N(2)-C(5)-C(4)	178.2(2)	C(4)-C(6)-C(7)	120.2(2)
C(4)-C(6)-C(11)	120.3(2)	C(7)-C(6)-C(11)	119.5(2)
C(6)-C(7)-C(8)	121.4(2)	C(7)-C(8)-C(9)	118.1(2)
C(7)-C(8)-C(12)	120.5(2)	C(9)-C(8)-C(12)	121.4(2)
C(8)-C(9)-C(10)	121.0(2)	C(9)-C(10)-C(11)	120.4(2)
C(6)-C(11)-C(10)	119.5(2)	C(3)-C(13)-C(14)	119.1(2)
C(3)-C(13)-C(18)	121.9(2)	C(14)-C(13)-C(18)	118.9(2)
C(13)-C(14)-C(15)	120.6(2)	C(14)-C(15)-C(16)	120.0(2)
C(15)-C(16)-C(17)	120.0(2)	C(16)-C(17)-C(18)	119.9(2)
C(13)-C(18)-C(17)	120.5(2)		

EXPERIMENTAL

Unless otherwise stated, IR spectra were measured with a Pye-Unicam SP 300 spectrophotometer as KBr pellets. ^{1}H and ^{13}C NMR spectra were measured with a Bruker WP 20-SY spectrometer for solutions in deutrated chloroform containing tetramethylsilane as internal standard. Compounds were analyzed at the M-H-W Laboratories, Phoenix, Arizona, USA. Melting points were determined with an Electrothermal melting point apparatus and were uncorrected. R_f values were

measured using silica gel plates developed in diethyl ether-chloroform mixture
(1:3) as an eluent.

General Procedure

In each condensation, arylacetonitrile (0.0172 mol) was dissolved in dry ether
(200 ml), containing sodium ethoxide (1.17 g, 0.0172 mol). To this suspension,
cinnamonitriles (0.0172 mol) was added. The mixture was stirred at room temper-
ature for 2-6 days. For compounds 3g,h,k-n, a solid was separated, filtered off
and crystallized from the appropriate solvent. For compounds 3a-f,i, the reaction
mixture poured into water (150 ml). The organic layer was separated, dried over
magnesium sulfate and evaporated to furnish a solid or in some cases an oily
material which was treated with the appropriate solvent to supply a crude product.
The aqueous layer neutralized with 10% hydrochloric acid and extracted with ether.
The ether extract dried over magnesium sulfate and evaporated to give unreacted
nitriles.

<u>2-(3,4-Dichlorophenyl-3-phenylglutaronitrile (3a)</u>: The crude oily material
obtained from extraction was treated with petroleum ether (40-60°C) to supply
a solid which was crystallized from ethanol to give 3.8 g (70%) of 3a. M.p. 132-
134°C. ^{1}H-NMR (CDCl$_3$): δ2.8 (two doublets, 2H, H$_c$ and H$_d$), 3.39 (m, 1H, H$_b$),
4.32 (d, J = 11.2 Hz, 1H, H$_a$), 6.92-7.32 (m, 8H, aromatics). Found: C, 64.78;
H, 4.15; N, 8.66; Cl, 22.44. C$_{17}$H$_{12}$N$_2$Cl$_2$ requires: C, 64.78; H, 3.84; N, 8.88;
Cl, 22.50. R$_f$: 0.81.

<u>2-(2,4-Dichlorophenyl)-3-phenylglutaronitrile (3b)</u>: The rude oily product was
treated with petroleum-ether (40-60°C) to furnish a solid material which was
crystallized from ethanol to give 3.98 g (74%) of 3b. M.p. 117-118°C. ^{1}H-NMR
(CDCl$_3$): δ3.00 (two doublets, 2H, H$_c$ and H$_d$), 3.35 (m, 1H, H$_b$), 4.85 (d, J = 12.5
Hz, 1H, H$_a$), 6.93-7.47 (m, 8H, aromatics). Found: C, 64.71; H, 3.84; N, 8.65;
Cl, 21.62. C$_{17}$H$_{12}$N$_2$Cl$_2$ requires: C, 64.78; H, 3.84; N, 8.88; Cl, 22.5. R$_f$: 0.93.

<u>2-(4-Chlorophenyl)-3-phenylglutaronitrile (3c)</u>: The crude oily material was
treated with petroleum-ether (40-60°C) to give a solid which was after crystalliz-
ation from ethanol supplied 4.10 g (85%) of 3c. M.p. 117-119°C. ^{1}H-NMR (CDCl$_3$):
δ2.77 (two doublets, 2H, H$_c$ and H$_d$), 3.37 (m, 1H, H$_b$), 4.30 (d, J = 11.5 Hz,1H,H$_a$),
7.13-7.27 (m, 9H, aromatics): Found: C, 72.74; H, 4.49; N, 9.79; Cl, 11.83.
C$_{17}$H$_{13}$N$_2$Cl requires: C, 72.73; H, 4.67; N, 9.98; Cl, 12.63. R$_f$: 0.85.

<u>2-(4-Bromophenyl)-3-phenylglutaronitrile (3d)</u>: The crude product was crystallized
from ethanol to give 4.02 g (72%) of 3d. M.p. 121-123°C). ^{1}H-NMR (CDCl$_3$): δ2.70
(two doublets, 2H, H$_c$ and H$_d$), 3.39 (m, 1H, H$_b$), 4.29 (d, J = 11.7 Hz, 1H, H$_a$),
6.97-7.53 (m, 9H, aromatics). Found: C, 63.01; H, 4.25; N, 8.51; Br, 23.80.
C$_{17}$H$_{13}$N$_2$Br requires: C, 62.78; H, 4.03; N, 8.61; Br, 24.57. R$_f$: 0.86.

<u>2-(3-Chlorophenyl)-3-phenylglutaronitrile (3e)</u>: The oily material was treated
with petroleum-ether (40-60°C) to give a solid which was after crystallization
from methanol furnished 3.90 g (81%) of 3e. M.p. 125-127°C. ^{1}H-NMR (CDCl$_3$):δ2.92
(two doublets, 2H, H$_c$ and H$_d$), 3.46 (m, 1H, H$_b$), 4.15 (d, J = 12.0 Hz, 1H, H$_a$),
7.30-7.56 (m, 9H, aromatics). Found: C, 72.85; H, 4.78; N, 9.85; Cl, 12.09,
C$_{17}$H$_{13}$N$_2$Cl requires: C, 72.73; H, 4.67; N, 9.98; Cl, 12.63. R$_f$: 0.84.

<u>2-(2-Fluorophenyl)-3-phenylglutaronitrile (3f)</u>: The crude material was crystall-
ized from ethanol to furnish 4.18 g (72%) of 3f. M.p. 127-129°C. ^{1}H-NMR (CDCl$_3$):
δ2.80 (two doublets, 2H, H$_c$ and H$_d$), 3.50 (m, 1H, H$_b$), 4.50 (d, J = 12.2 Hz;1H,H$_a$),
7.01-7.39 (m, 9H, aromatics). Found: C, 77.06; H, 5.29; N, 10.84; F, 6.96.
C$_{17}$H$_{13}$N$_2$F requires: C, 77.25; H, 4.96; N, 10.60; F, 7.19. R$_f$: 0.83.

<u>2-(2,6-Dichlorophenyl)-3-phenylglutaronitrile (3g)</u>: The crude material was cryst-
allized from ethanol to afford 3.79 g (70%) of 3g. M.p. 128-129°C. ^{1}H-NMR (CDCl$_3$):
δ2.85 (two doublets, 2H, H$_c$ and H$_d$), 3.35 (m, 1H, H$_b$), 4.21 (d, J = 11.8 Hz,1H,H$_a$),
7.21-7.35 (m, 8H, aromatics) Found: C, 65.40; H, 4.12; N, 8.78; Cl, 22.28.

$C_{17}H_{12}N_2Cl_2$ requires: C, 64.78; H, 3.84; N, 8.88; Cl, 22.50. R_f: 0.81.

2-(2-Tolyl)-3-phenylglutaronitrile (3h): The crude product was crystallized from methanol to give 3.26 g (73%) of **3h**. M.p. 133-135°C. ^{1}H-NMR (CDCl$_3$): δ2.90 (two doublets, 2H, H_c and H_d), 3.44 (m, 1H, H_b), 4.20 (d, J = 11.5 Hz, 1H, H_a), 7.31-7.55 (m, 8H, aromatics), 2.31 (s, 3H, CH$_3$-). Found: C, 83.01; H, 6.17; N, 10.58. $C_{18}H_{16}N_2$ requires: C, 83.37; H, 5.8; N, 10.80. R_f: 0.86.

2-(3-Tolyl)-3-phenylglutaronitrile (3i): The oily product was treated with petroleum-ether (40-60°C) to give a solid which after crystallization from ethanol afforded 2.90 g (65%) of **3i**. M.p. 132-134°C. ^{1}H-NMR (CDCl$_3$): δ 2.88 (two doublets, 2H, H_c and H_d), 3.47 (m, 1H, H_b), 4.14 (d, J = 11.6 Hz, 1H, H_a), 7.35-7.50 (m, 8H, aromatics), 2.32 (s, 3H, CH$_3$). Found: C, 83.06; H, 6.30; N, 10.63. $C_{18}H_{16}N_2$ requires: C, 83.37; H, 5.83; N, 10.80. R_f: 0.89.

2-(2-Chlorophenyl)-3-phenylglutaronitrile (3j): The crude product was crystallized from glacial acetic acid to furnish 3.86 g (80%) of **3j**. M.p. 149-151°C. ^{1}H-NMR (CDCl$_3$): δ2.90 (two doublets, 2H, H_c and H_d), 3.65 (m, 1H, H_b), 4.63 (d, J = 11.8, 1H, H_a), 7.37-7.49 (m, 9H, aromatics). Found: C, 72.82; H, 4.71; N, 9.89; Cl, 12.23. $C_{17}H_{13}N_2Cl$ requires: C, 72.73; H, 4.67; N, 9.98; Cl, 12.63. R_f: 0.88.

2-(2,6-Dichlorophenyl)-3-(4-Chlorophenyl)glutaronitrile (3k): The crude material was crystallized from glacial acetic acid to afford 4.80 g (80%) of **3k**. M.p. 171-173°C. ^{1}H-NMR (CDCl$_3$): δ 2.53 (two doublets, 2H, H_c and H_d), 3.89 (m, 1H, H_b), 4.97 (d, J = 12.4 Hz, 1H, H_a), 7.14-7.35 (7H, m, Aromatics). Found: C, 58.51; H, 3.17; N, 7.93; Cl, 30.26. $C_{17}H_{11}N_2Cl_3$ requires: C, 58.39; H, 3.15; N, 08.01; Cl, 30.44. R_f: 0.92.

2-(2,6-Dichlorophenyl)-3-(4-methoxyphenyl)glutaronitrile (3l): The crude product was crystallized from acetic acid to give 5.04 g (85%) of **3l**. M.p. 191-193°C. ^{1}H-NMR (CDCl$_3$): δ2.50 (two doublets, 2H, H_c and H_d), 3.39 (m, 1H, H_b), 4.98 (d, J = 11.8 Hz, 1H, H_a), 7.29-7.51 (7H, m, Aromatics), 3.84 (s, 3H, -OCH$_3$). Found: C, 62.73; H, 4.18; N, 7.96; Cl, 20.09. $C_{18}H_{14}N_2Cl_2O$ requires: C, 62.563; H, 4.06; N, 8.12; Cl, 20.56. R_f: 0.84.

2-(4-Chlorophenyl)-3-(2,3-dimethoxyphenyl)glutaronitrile (3m): The crude product was crystallized from aqueous acetic acid to give 4.34g (74%) of **3m**. M.p. 173-174°C. ^{1}H-NMR (CDCl$_3$): δ 2.79 (two doublets, 2H, H_c and H_d), 3.27 (m, 1H, H_b), 4.34 (d, J = 12.0 Hz, 1H, H_a), 7.12-7.25 (m, 7H, aromatics), 3.87 (s, 3H, -OCH$_3$), 3.78 (s, 3H, -OCH$_3$). Found: C, 66.63; H, 4.92; N, 8.10; Cl, 10.16. $C_{19}H_{17}N_2ClO_2$ requires: C, 66.97; H, 4.99; N, 8.22; Cl, 10.40. R_f: 0.83.

2-(2,6-Dichlorophenyl)-3-(2,3-dimethoxyphenyl)glutaronitrile (3n): The crude material was crystallized from glacial acetic acid to supply 5.29 (82%) of **3n**. M.p. 205-207°C. ^{1}H-NMR (CDCl$_3$): δ 2.90 (two doublets, 2H, H_c and H_d), 3.65 (m, 1H, H_b), 4.63 (d, J = 11.6 Hz, 1H, H_a), 7.37-7.50 (m, 9H, aromatics). Found: C, 60.67; H, 4.34; N, 7.32; Cl, 18.91. $C_{19}H_{16}N_2Cl_2O_2$ requires: C, 60.82; H, 4.27; N, 7.47; Cl, 18.19. R_f: 0.93.

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