CHAPTER-III

SYNTHESIS OF ISOCOUMESTAN AND COUMESTAN DERIVATIVES

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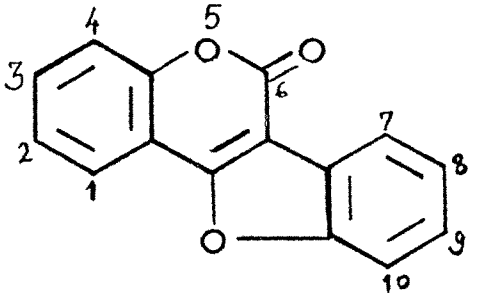
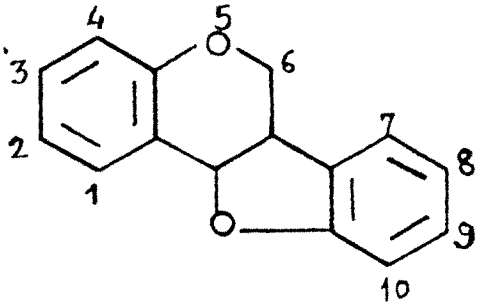
Benzofuro (3,2-c)-benzopyran-6(H)-ones, generally known as coumestans constitute an important class of compounds having estrogenic and phytoalexin activities.[1-4] The parent compound coumestan (1) is not so far known to occur in nature, but number of its oxygenated derivatives have been isolated from variety of natural sources. The common names like coumestan, coumarano coumarin, benzofuro-α-benzopyrans or coumarino benzofuran have been given to this class of compounds. The usual numbering pattern in coumestans is shown in structure (1). Pterocarpan (2) is the reduced form of coumestan (1).

Coumestans have been isolated from different plant sources belonging to the families of leguminose, papilinoaceae and compositae. They are ultimate oxidation products and occur in various parts of plants like seeds, roots and leaves. The first natural compound of this series is viz. Wedelactone (3) was isolated by Govindachari et al.[5] A remarkable feature of the majority of natural coumestans is the presence of resorcinol unit in both the benzene rings, i.e. all of them have oxygen functions at C-3 and C-9 positions. Some of the naturally occurring coumestans are Wedelactone (3), Salvitol, Saphoracoumestan,[6] Trifoliol,[7] Repensol,[8] Coumestrol,[9] Medicagol,[10] Wairol[11] shown in structures 4 and 5.



(1)



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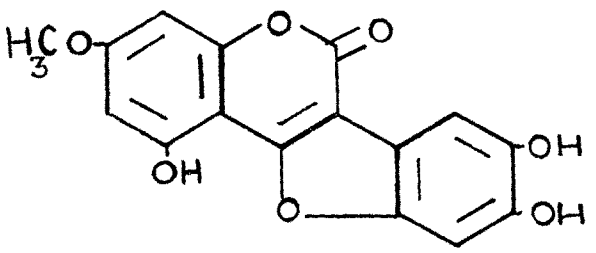

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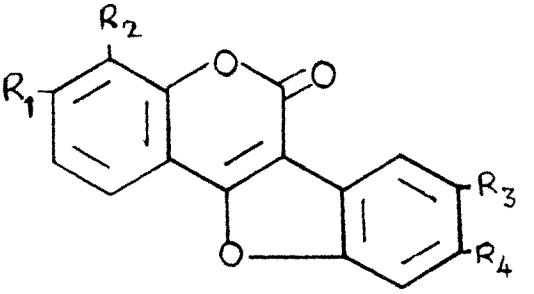
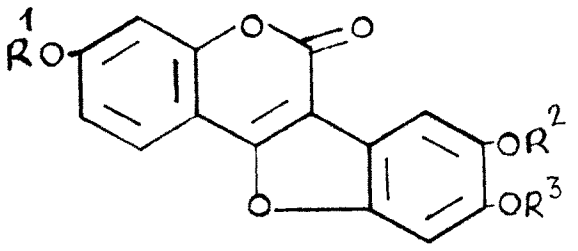


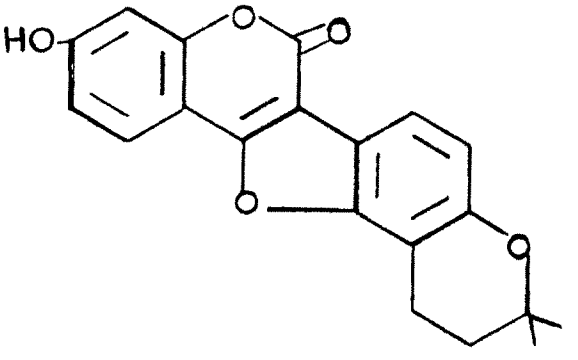
(4)

(4)	R_1	R_2	R_3	R_4	
	OCH_3	OH	H	H	Salvitol
	OH	OCH_3	$-O-CH_2-O-$		Saphoracoumestan[6]

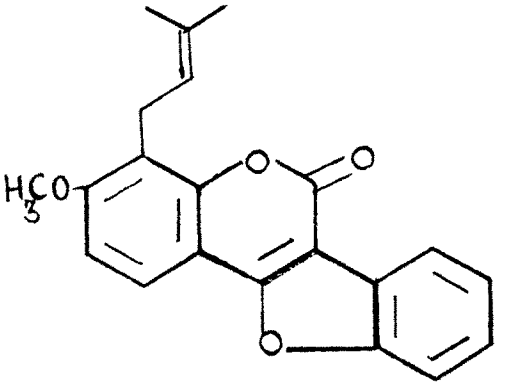


(5)

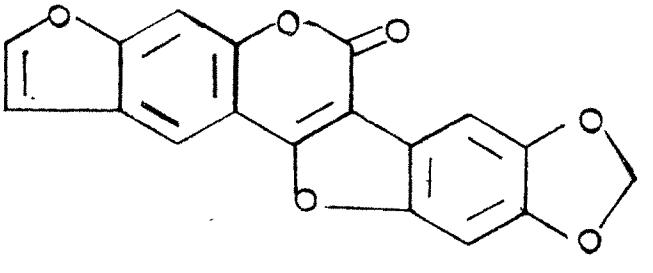
(5)	R^1	R^2	R^3	
	H	CH_3	H	Trifoliol[7]
	H	H	H	Coumestrol[9]
	CH_3	H	H	Repensol[8]
	H	$-O-CH_2-O-$		Medicagol[10]
	H	CH_3	CH_3	Wairol[11]



(6)



(7)



(8)

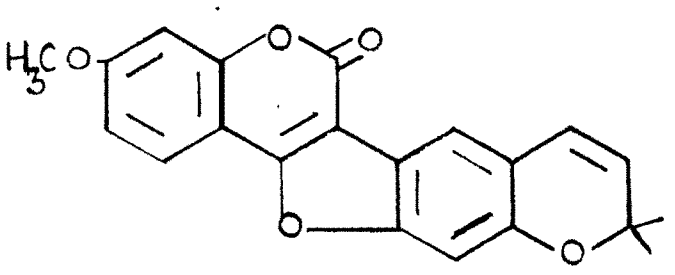
Some complex coumestans have either fused furan or pyran ring. A few of them have prenyl unit in one of the benzene rings. Some of them are Sojagol[12](6), Phaseol[13](7), Erosnin[14] (8), Tuberstan[15](9), Isopsoralidin[16] (10), Saphoracoumestan[17] (11).

METHODS OF SYNTHESIS OF COUMESTANS

Coumestan is a compound in which coumarin ring is fused to benzofuran ring. In this ring system the C-3 C-4 bond of coumarin and C-2 C-3 bond of benzofuran is commonto each other. The methods reported for the synthesis of coumestan thus involve either construction of furan ring on a preformed 3-aryl coumarin or construction of coumarin ring on a preformed 2-arylbenzofuran ring system.

Reterosynthetic analysis of coumestan suggests that there could be different approaches for the synthesis of coumestan ring system. [Scheme-1]

There are four different possible methods for the synthesis of coumestans as shown in Scheme-1. The first approach involves construction of a furan ring on preformed 3-(2-hydroxy phenyl)-4-hydroxy coumarin (12). Robertson[18a] and Govindachari[18b] independently synthesised several coumestans using this approach [Scheme-2].



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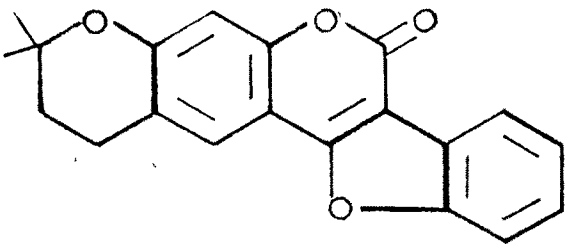
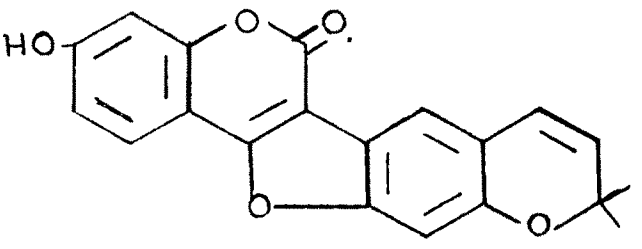
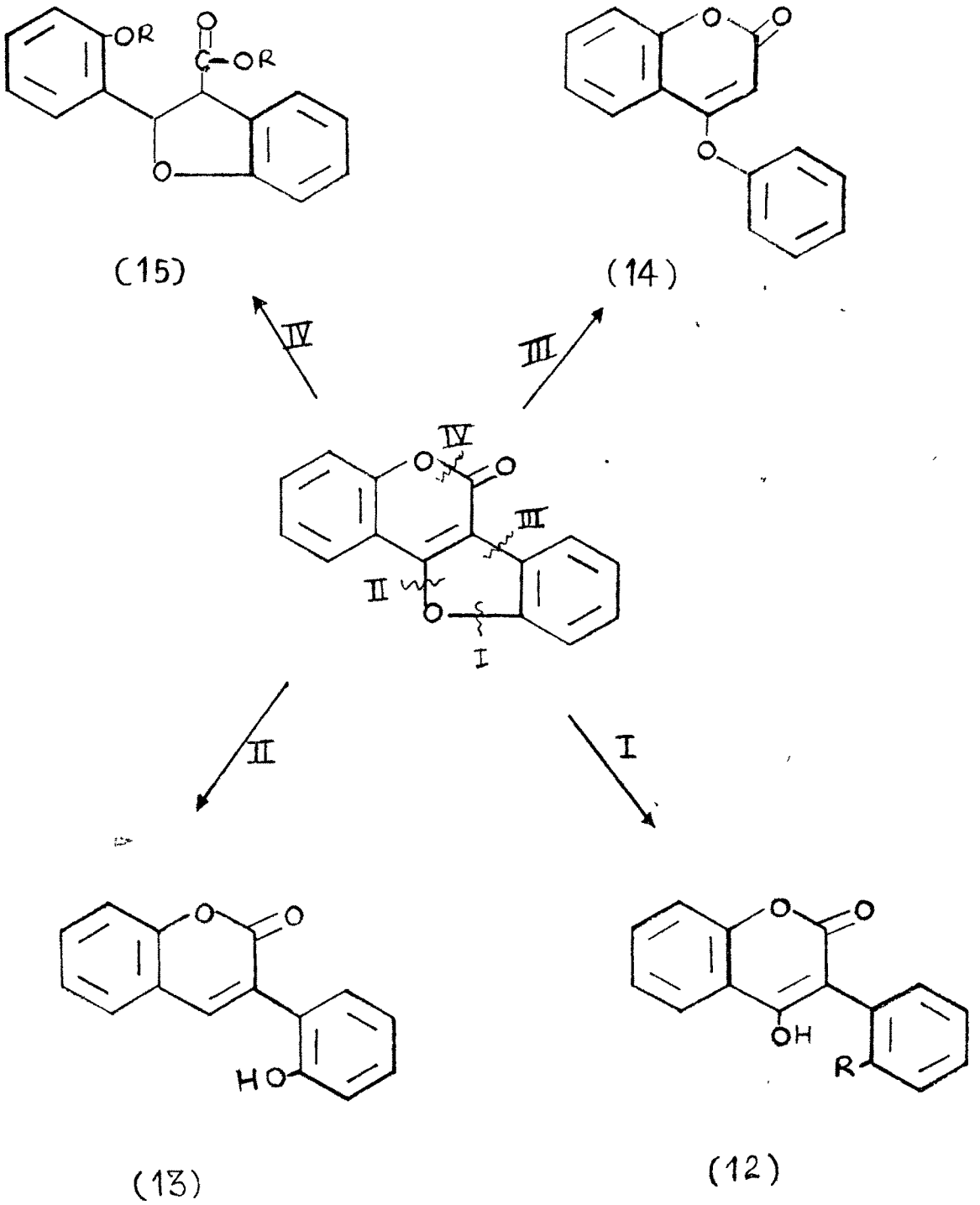


(10)



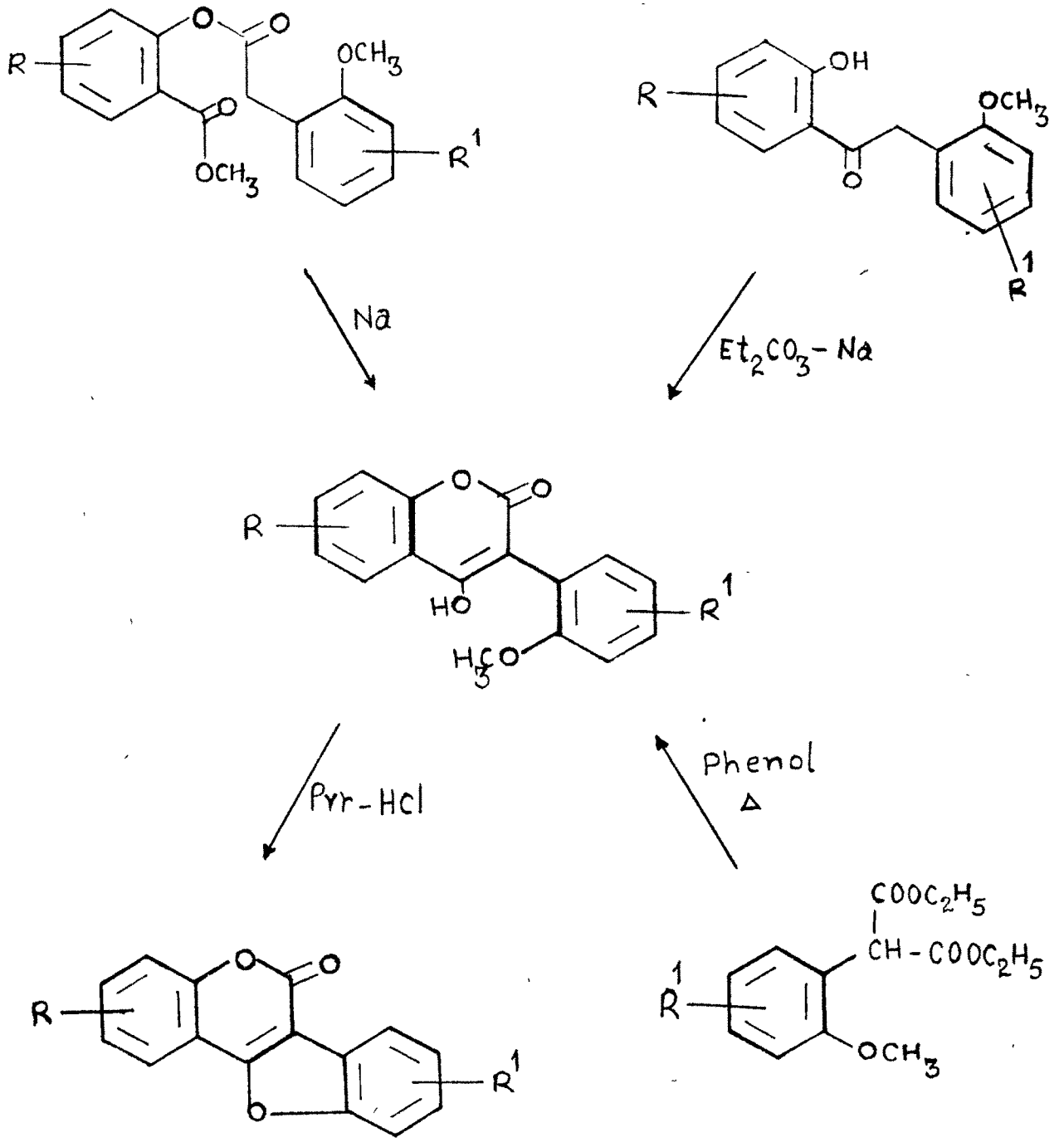
(11)

Scheme-1



18(b) 18(a)

Scheme-2 Govindachari et al & Robertson et al



Subba Rao and coworkers[19] have reported a method which involves condensation of 4-hydroxy coumarin with 2-chloro-cyclohexanone to provide an intermediate (16) which on intra-molecular cyclisation followed by dehydrogenation with pallad-ised charcoal gave coumestan. [Scheme-3]

Kappe and Schmidt[20] cyclised 4-hydroxy-3-phenylcoumarins (17) and its substituted derivatives by refluxing them in diphenyl ether in presence of palladised charcoal (10%) to obtain coumestans and its derivatives such as coumestrol. [Scheme-4]

Wanzlick[21] synthesised coumestans by oxidative coupling of 4-hydroxy coumarin with catechol in presence of potassium ferricynide and sodium aetate in aqueous solution. [Scheme-5]

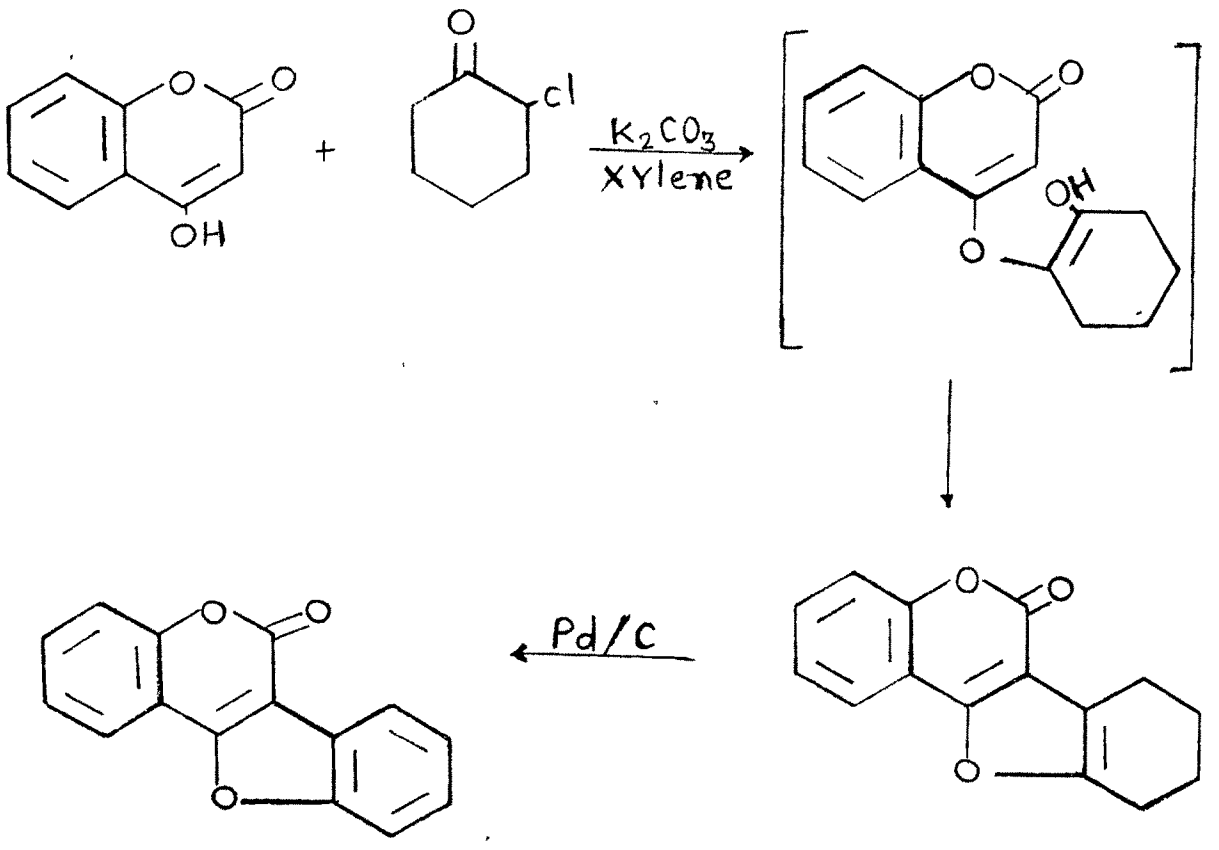
Pulla Rao and Srimannarayana[22] and Srihari and Sunder-murthy[23] have synthesised several coumestans by this method.

Kurosawa[24] used the approach II shown in [Scheme-1] to synthesise coumestan in which intermediate (17) formed is cyclised by lead tetraacetate to give coumestan [Scheme-6]

Similarly Wadia and coworkers[25] have synthesised coumestan using this approach. [Scheme-7]

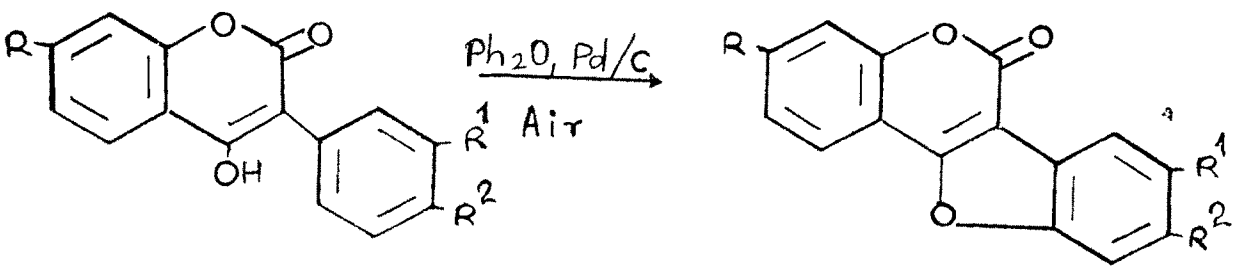
A method reported by Singh and Singh[26] involves the formation of intermediate (18) [Scheme-8] and used the approach

Scheme-3 Subba Rao & Coworkers[19]



Coumestan

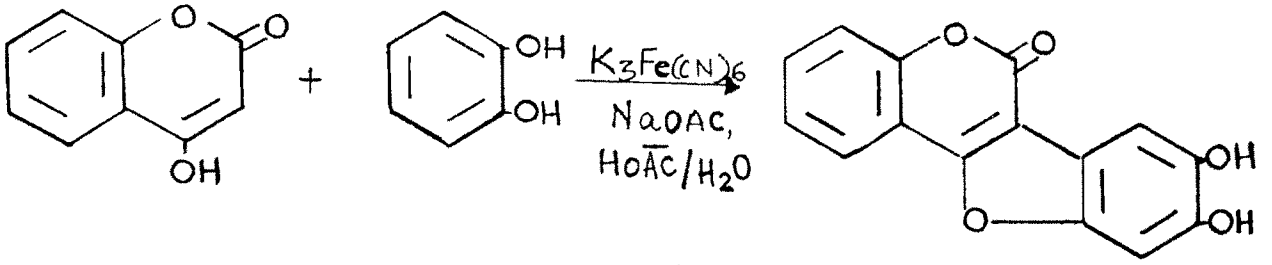
Scheme-4 Kappe & Schmidt[20]



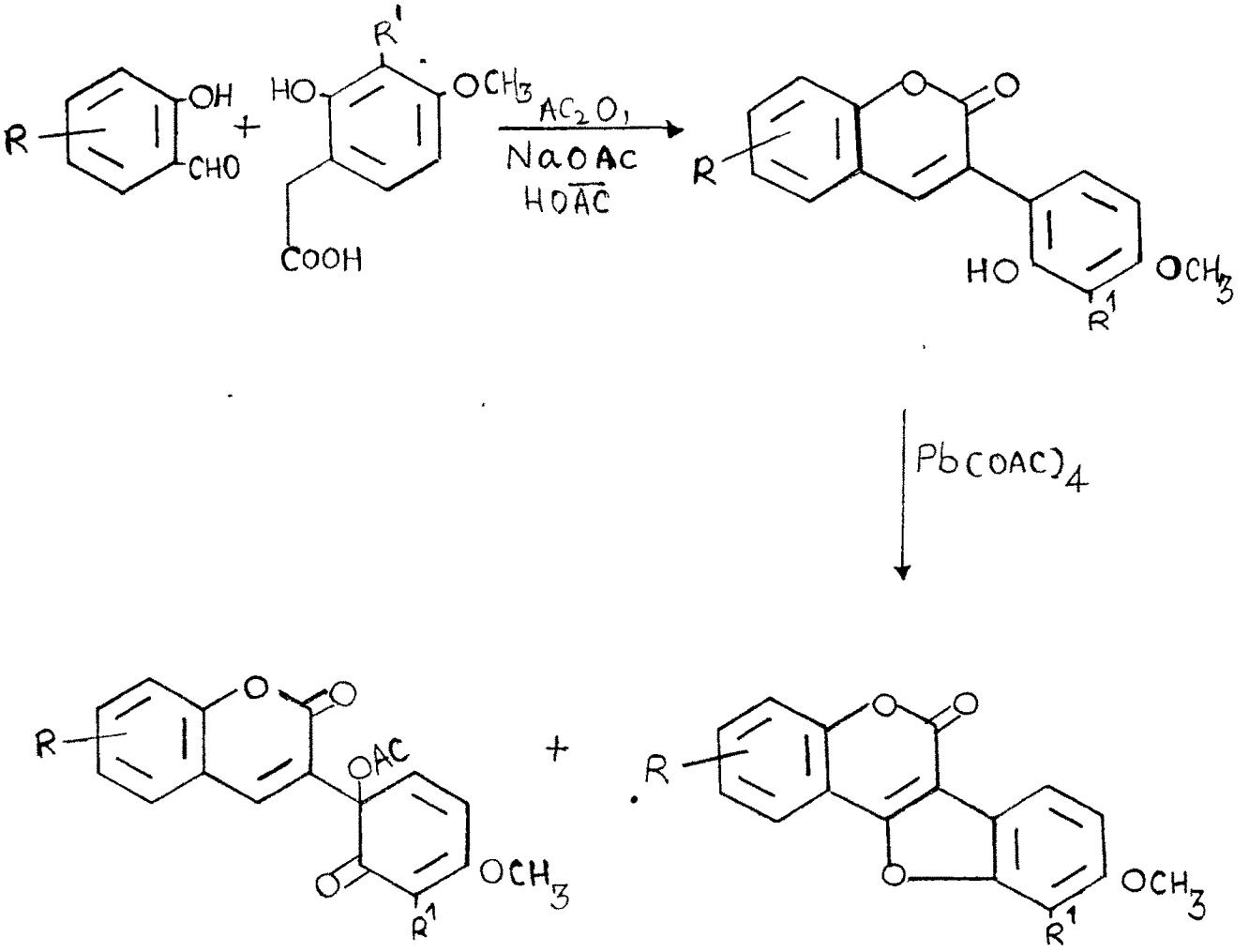
R = H, R^1 = H, R^2 = H Coumestan

R = OH, R^1 = OH, R^2 = OH Coumestrol

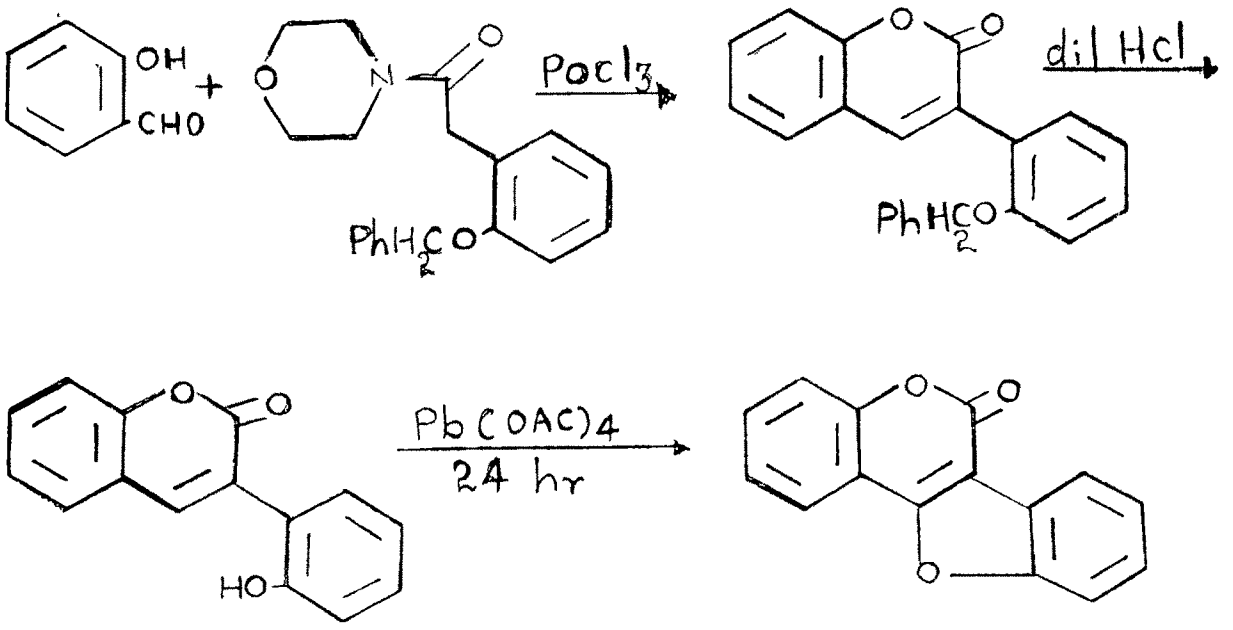
Scheme-5 Wanzlick et al[21]



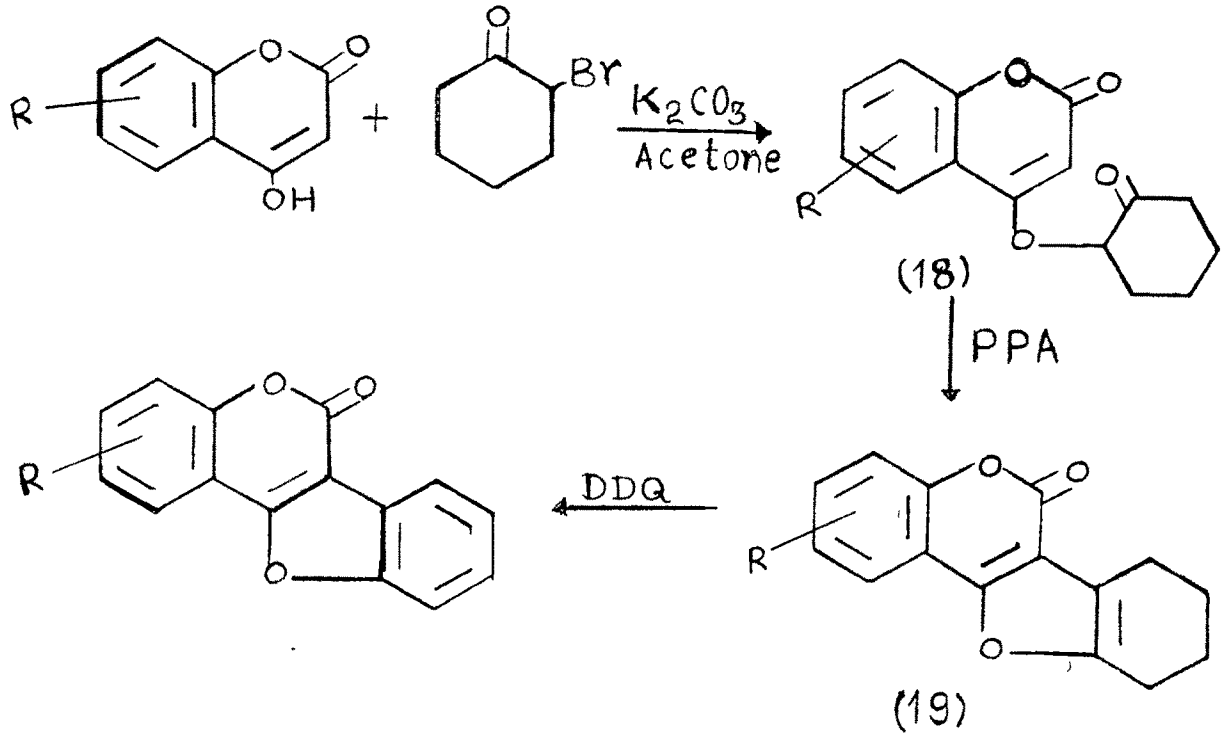
Scheme-6 Kurosawa et al[24]



Scheme-7 Wadia & Coworkers[25]



Scheme-8 Singh & Singh[26]



III as shown in [Scheme-1]. The intermediate (18) was cyclised with PPA to tetrahydrocoumestan (19) which onoxidation with DDQ provided coumestan [Scheme-8].

Jurd and coworkers[27] synthesised coumestans using approach IV shown in Scheme-9. In his method compound (21) shown in Scheme-1, was prepared by hydrogen peroxide oxidation of appropriately substituted flavilium salts (20). The hydroxyesters (21) were then hydrolysed and lactonised to give coumestans [Scheme-9].

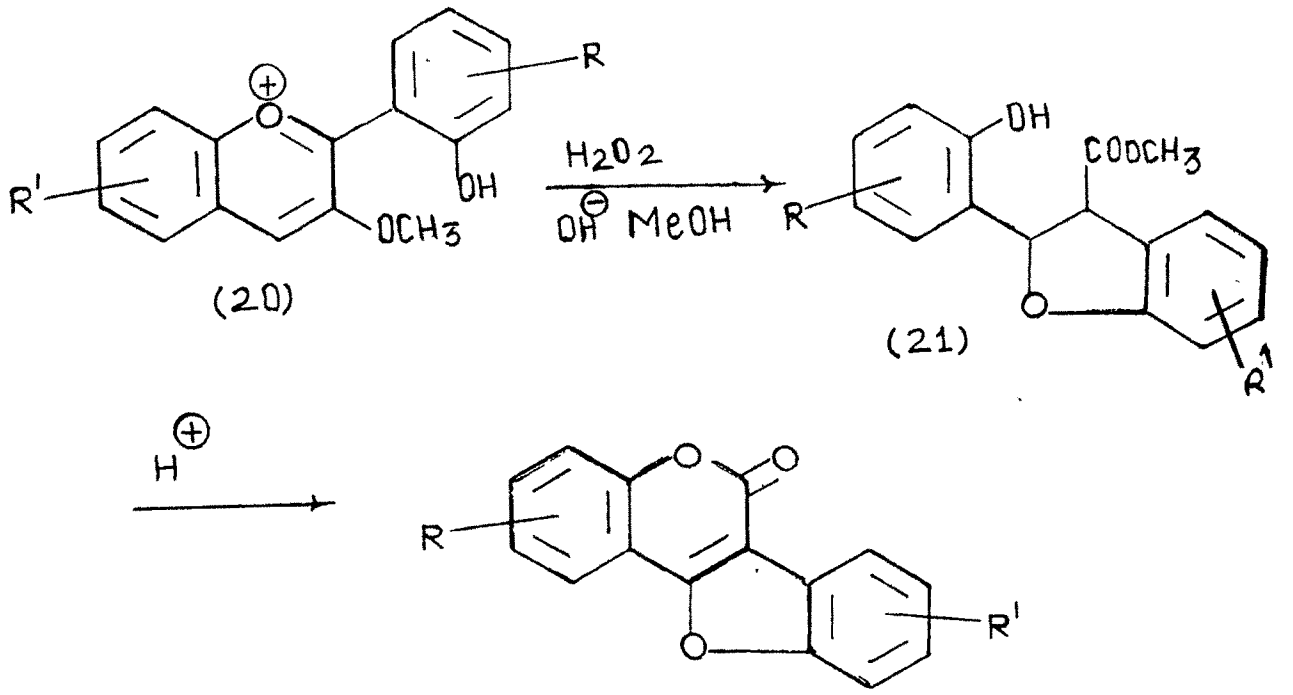
Wheeler and coworkers[28] had suggested the synthesis of coumestrol by intramolecular oxidative coupling of suitably substituted resorcinol as shown in [Scheme-10].

Ponder and Mcpherson[29] carried out synthesis of coumestan by condensation of benzoquinone with β-keto esters using zinc chloride and ethanol to give intermediate (22) which was further cyclised with pyridine-HCl to give coumestan (23) [Scheme-11].

Dholakia and Trivedi[30] had synthesised several coumestans by oxidative coupling of catechol with different substituted 4-hydroxy coumarins. Unlike Wanzlick, they had used potassium periodate for oxidative coupling.

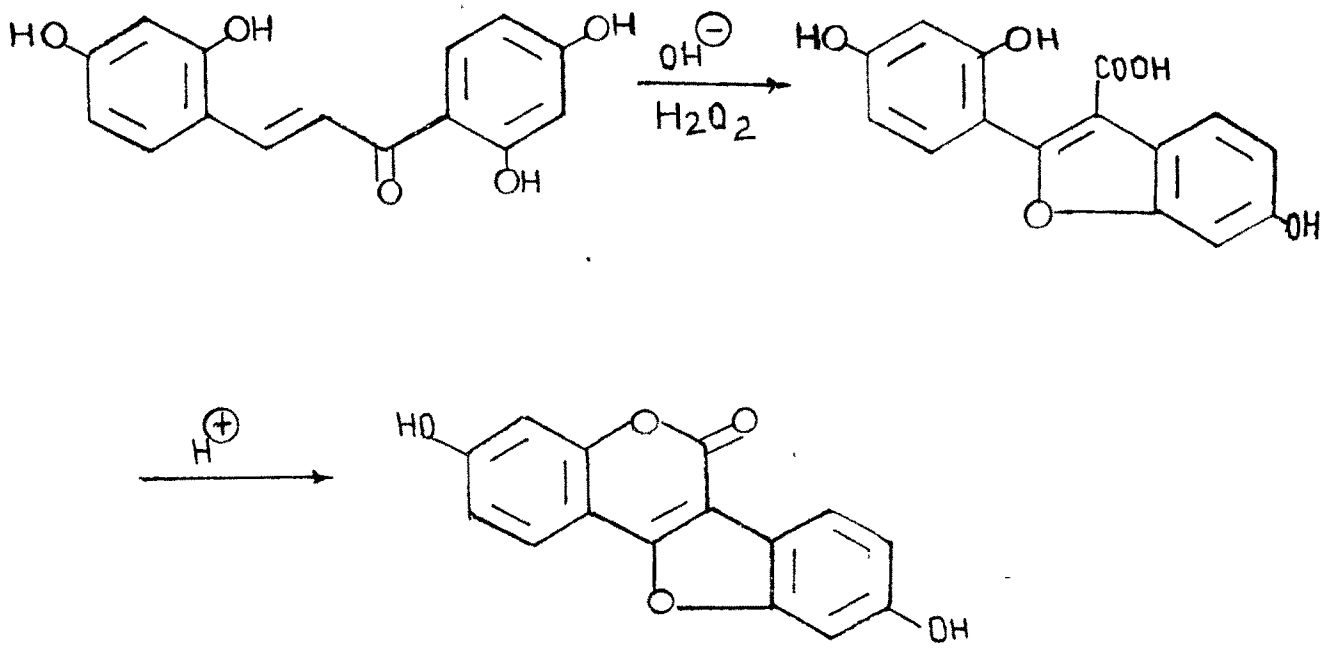
4-Hydroxy-6-methyl coumarin (24) on condensation with

Scheme - 9 Jurd and Coworkers[27]

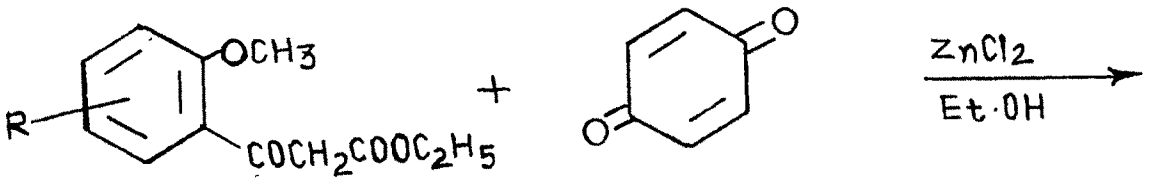


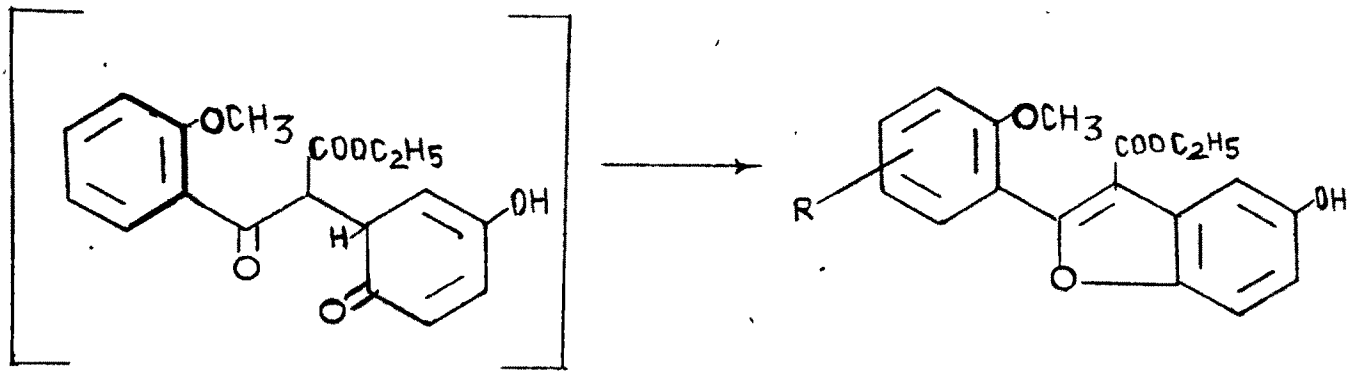
(20) (21)

Scheme - 10 Wheeler and Coworkers[28]

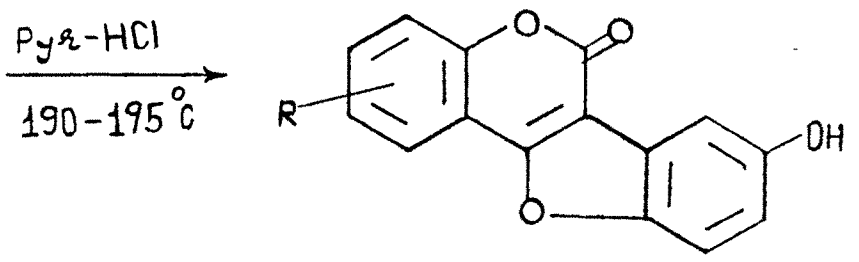


Scheme - 11 Ponder and Mcpherson[29]





(22)



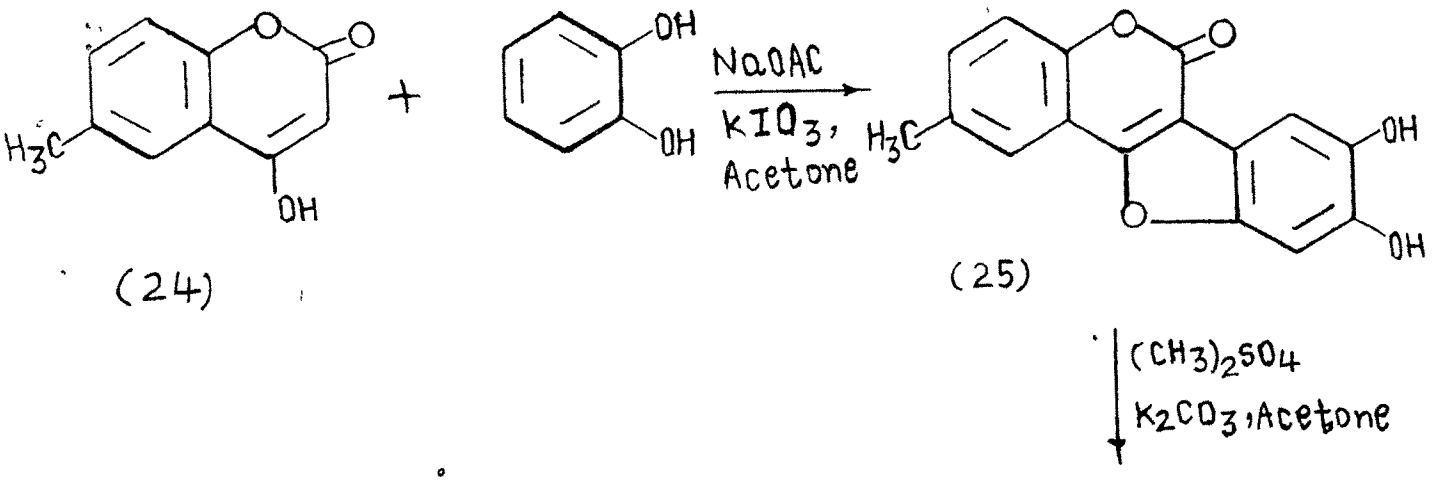
(23)

catechol in presence of potassium periodate and sodium acetate in aqueous acetone gave 2-methyl-8,9-dihydroxy-6-oxo-6(H)-benzofuro (3,2-c)-benzopyran (25) which on methylation with dimethyl sulfate in acetone gave 2-methyl-8,9-dimethoxy-6-oxo-6(H)-benzofuro (3,2-c)-benzopyran (26) [Scheme-12]. Similarly 4-hydroxy-7-methoxy-8-methyl coumarin, 4-hydroxy-5-methoxy coumarin and 4-hydroxy-7,8-dimethoxy coumarin were condensed with catechol and subsequently methylated to give (26a), (26b), (26c) and (26d) respectively. [Scheme-12]

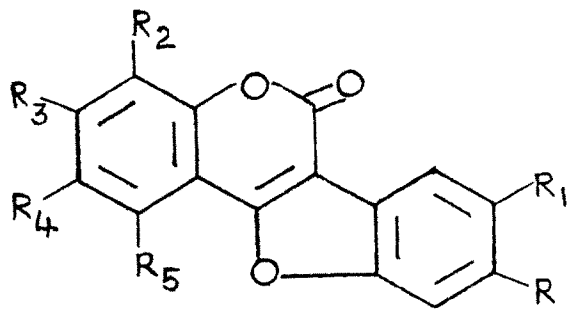
Shah and Trivedi[31] had synthesised 5'-methyl-11,12-dimethoxy-furo (2,3-h) coumestan (31) and 5',8-dimethyl-11,12-dimethoxyfuro (3,2-g) coumestan (33) by Wanzlick's method using potassium periodate. 4-Allyl-2-hydroxy acetophenone (27) on condensation with diethylcarbonate and pulverised sodium gave 4-hydroxy-7-allyloxy coumarin (28). This on oxidative coupling with catechol in presence of potassium periodate gave 3-allyloxy-8,9-dihydroxy coumestan (29) [Scheme-13], which on methylation with dimethylsulfate gave (30). This on Claisen rearrangement followed by cyclisation and dehydrogenation gave (31). Similarly (33) was synthesised by carrying out same series of reactions on 4-allyl-2-hydroxy-3-methyl acetophenone (32). [Scheme-14]

Shah and Trivedi[32] had also synthesised some pyrano-coumestan derivatives by starting with 6-acetyl-2,2-dimethyl-

Scheme-12 Dholakia and Trivedi[30]



(24) (25)



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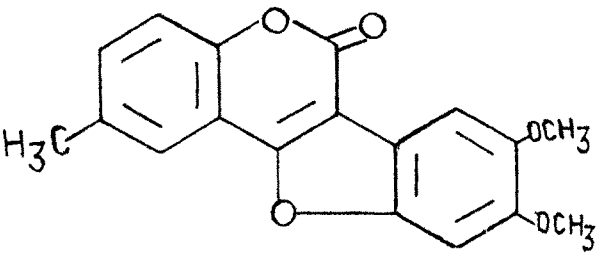


(26)

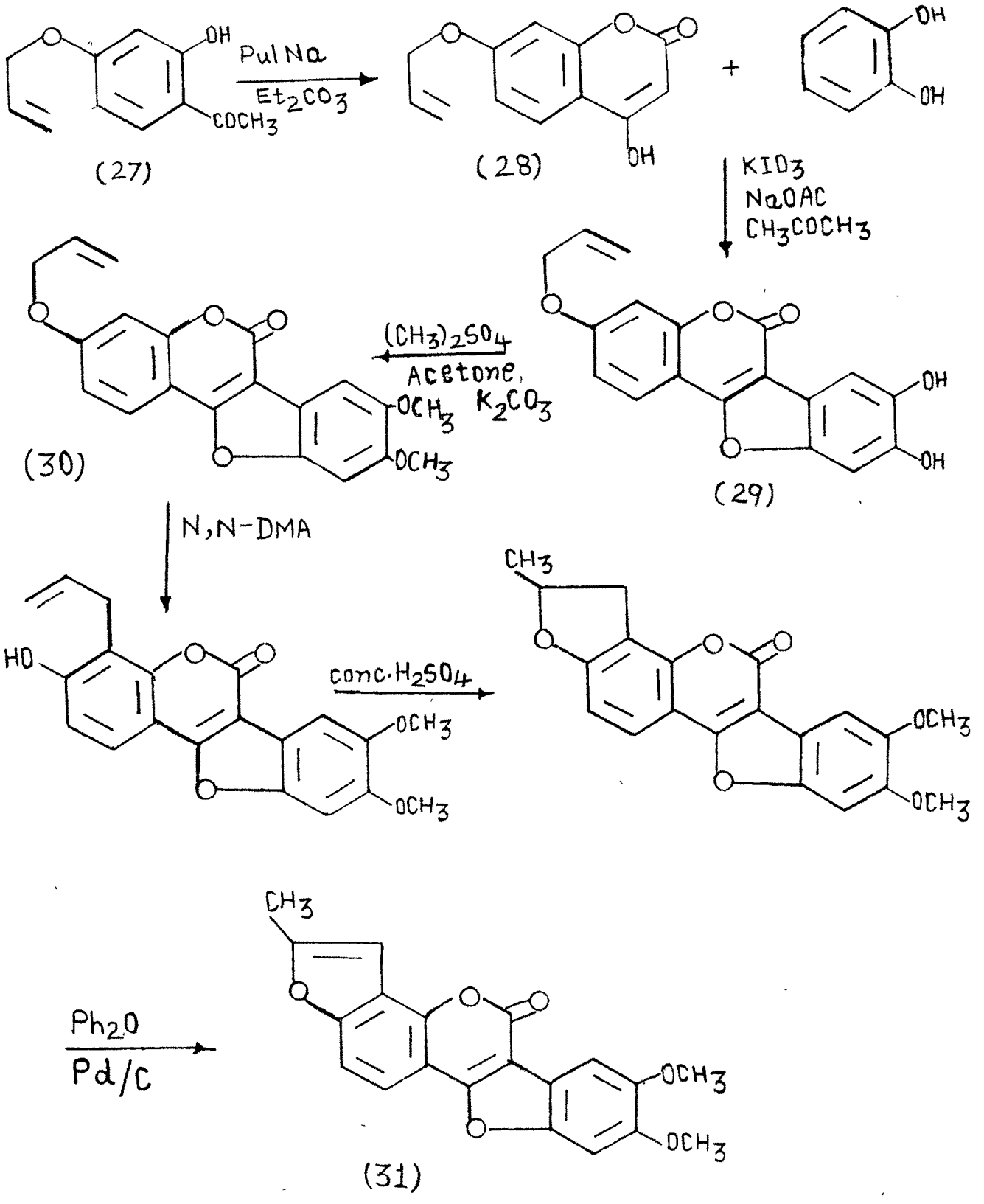
26a $R = R_1 = R_4 = OCH_3$, $R_2 = R_3 = R_5 = H$

26b $R = R_1 = R_3 = OCH_3$, $R_2 = CH_3$, $R_4 = R_5 = H$

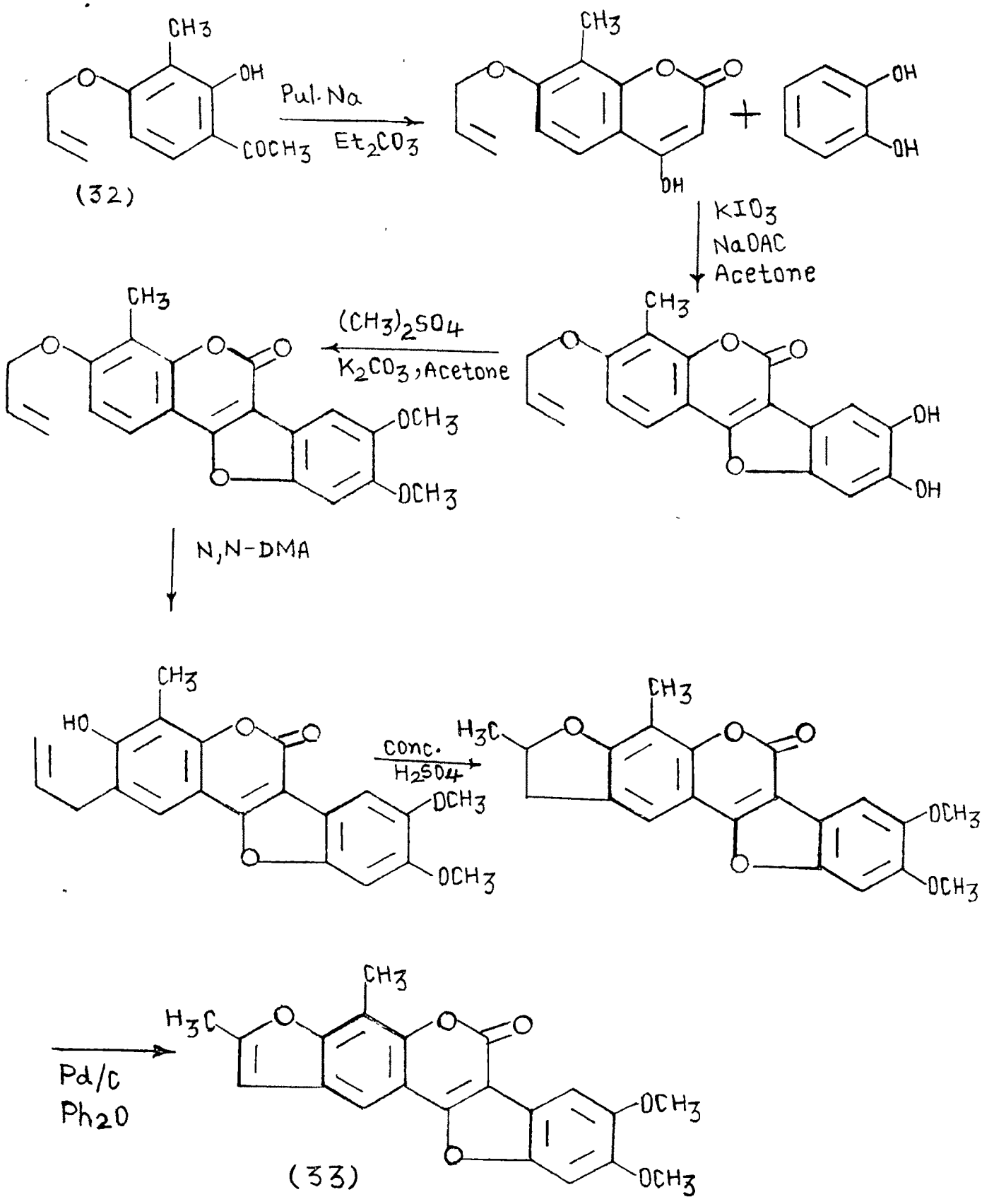
26c $R = R_1 = R_5 = OCH_3$, $R_2 = R_3 = R_4 = H$

26d $R = R_1 = R_2 = R_3 = OCH_3$, $R_4 = R_5 = H$

Scheme - 13 Shah and Trivedi[31]



Scheme-14 Shah and Trivedi[31]



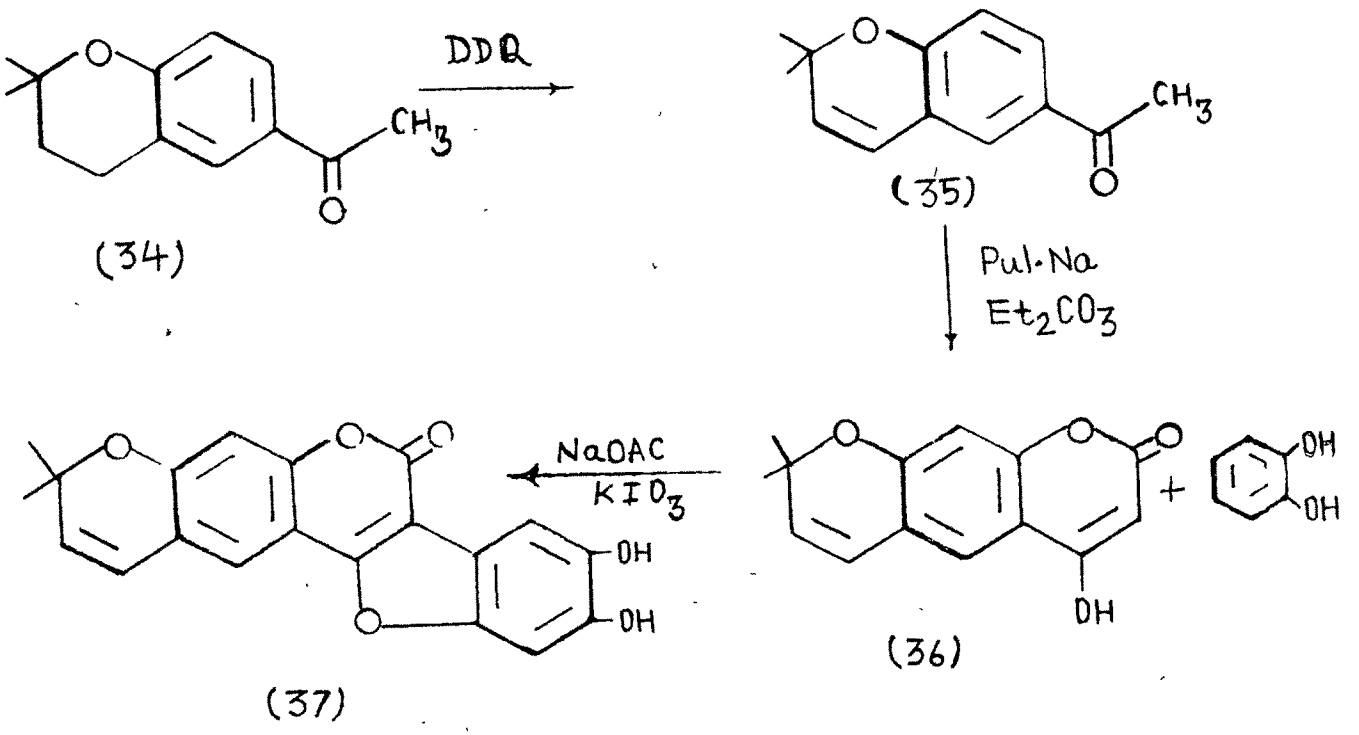
5-hydroxy-3,4-dihydrochromene (34) which was dehydrogenated by DDQ to give (35) [Scheme-15]. This on condensation with diethylcarbonate and sodium gave 4-hydroxy coumarin derivative (36), which on oxidative coupling with catechol using potassium periodate gave 8,9-dihydroxy-2,2-dimethylpyrano (3,2-g) coumestan (37). [Scheme-15]

Jain et al.[33a] had synthesised several coumestans using this method. Mali and coworkers[33b] had synthesised coumestan fromanisole involving heteroatom directed lithiation with n-BuLi followed by treatment with diethyloxalate which gave (35a) which by Wittig reaction gave the ester which on heating with pyridine-hydrochloride gave coumestan (35b). [Scheme-15a]

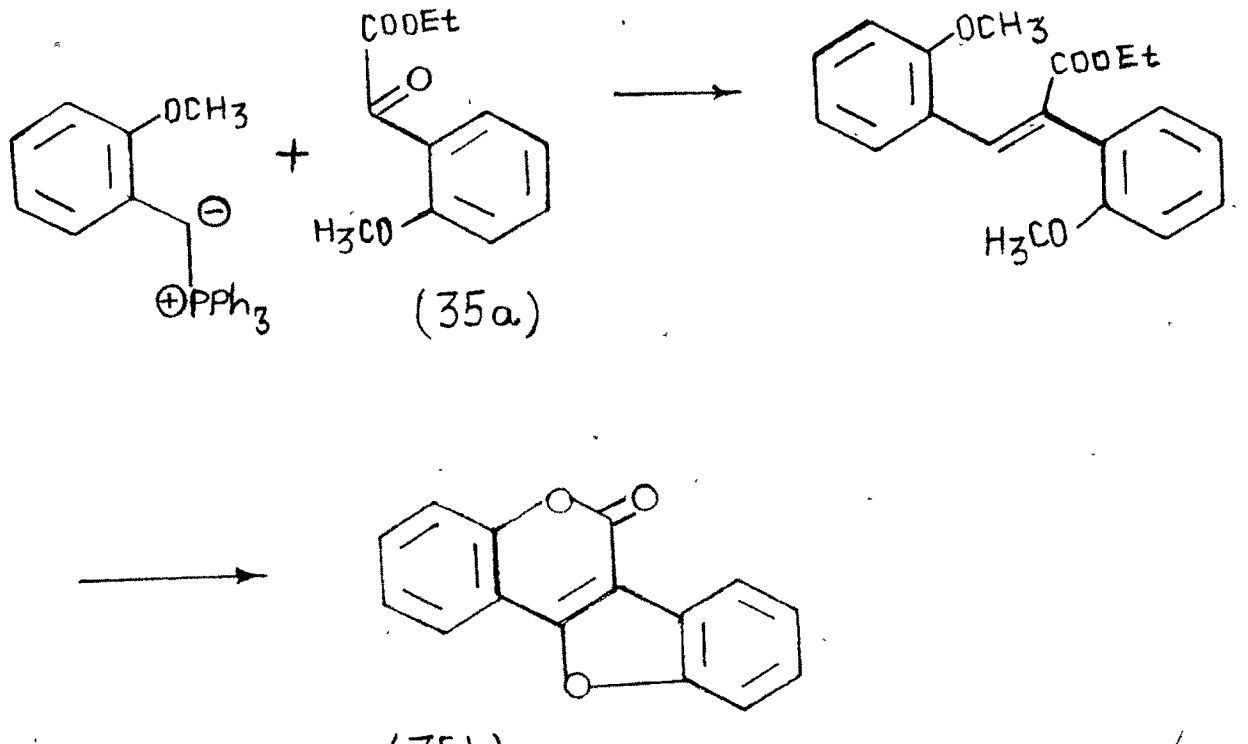
There are many reports for the synthesis of coumestans but there are few for the synthesis of isocoumestans. Robertson[34] and coworkers synthesised isocoumestan (38) by condensing β-coumarono-2-carboxylate with resorcinol. [Scheme-16]

Chatterjea et al.[35] synthesised isocoumestan, using 3-hydroxy coumarin and catechol by Wanzlick's method. Later on Sundermurthy and coworkers[36] synthesised 11,12-dihydroxy isocoumestan (41) and 11,12-diacetoxy isocoumestans (42) by condensing 3-hydroxy coumarin with p-benzoquinone. [Scheme-17]. 3-Hydroxy-4-[2-(p-benzoquinoxy)] coumarin (39) was acetylated to give (40) which on deacetylation followed by

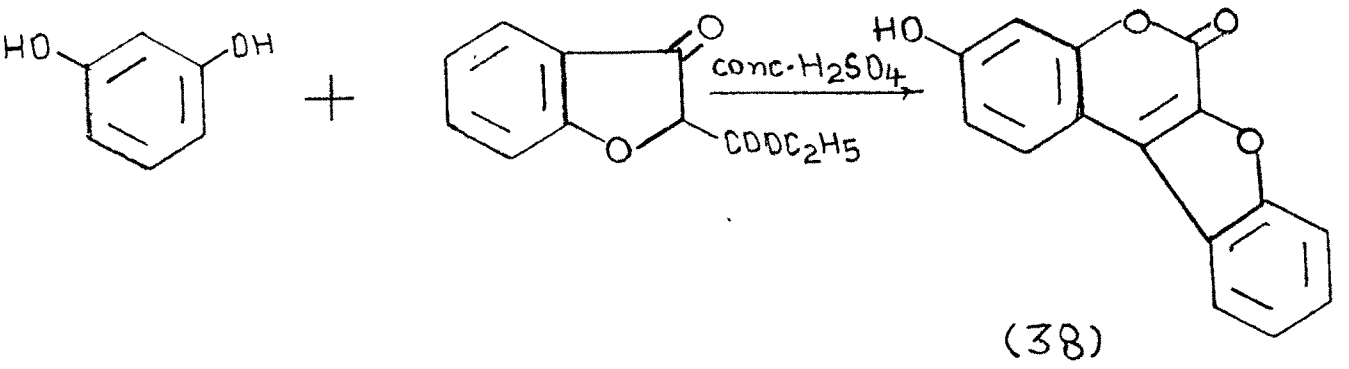
Scheme - 15 Shah and Trivedi[32]



Scheme - 15a Mali and Coworkers[33b]

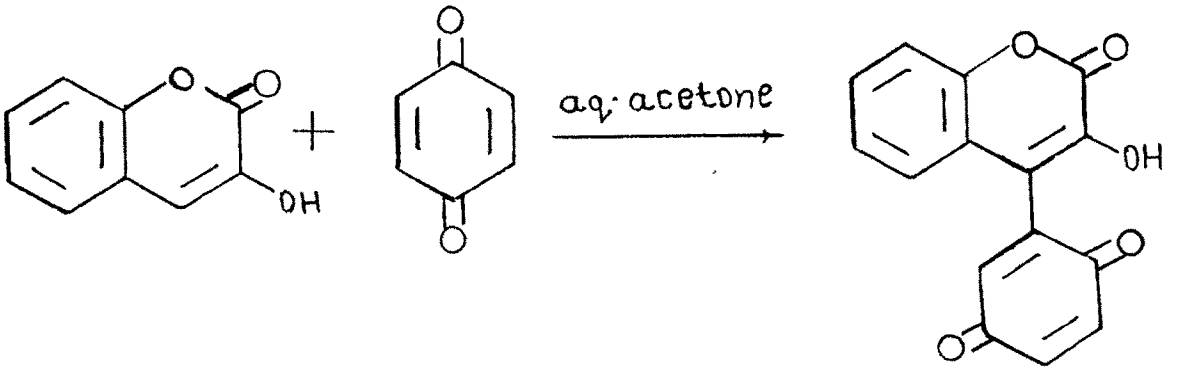


Scheme-16 Robertson and Coworkers[34]



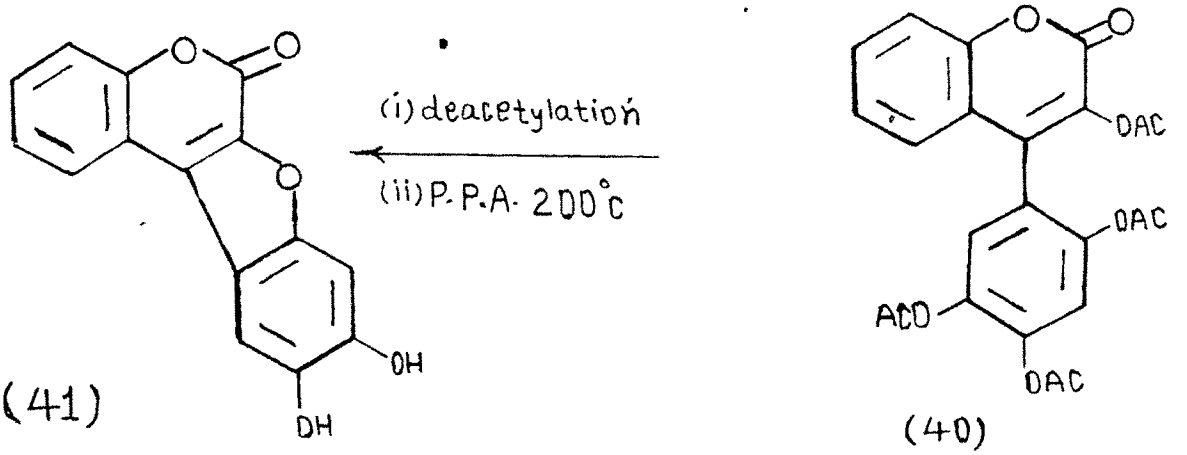
(38)

Scheme-17 Sundermurthy and Coworkers[36]



(39)

Thiele's Acetylation



(41)

(40)

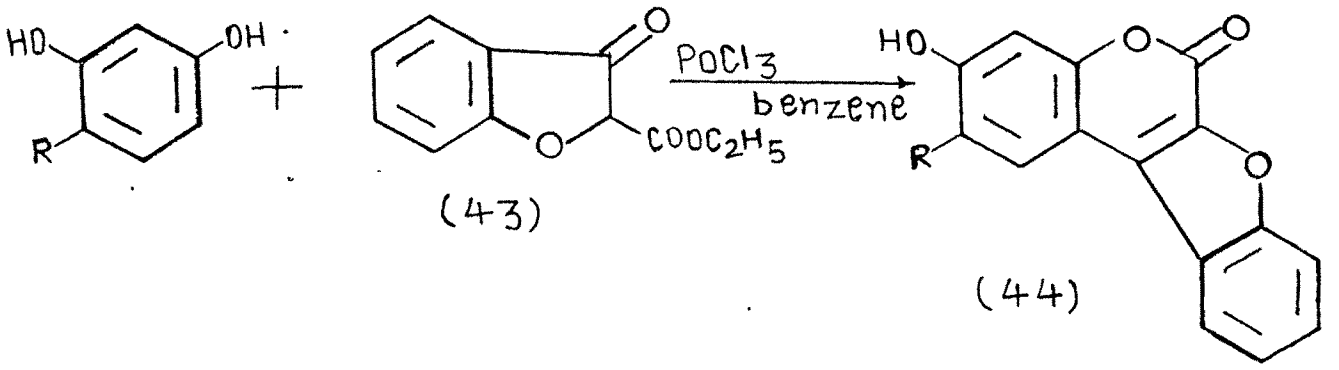
cyclisation gave (41) which on acetylation gave (42). [Scheme-17]. The same compound was also obtained by oxidative coupling of 3-hydroxy coumarin with catechol by Wanzlick method.

Mahesh and coworkers [37] synthesised number of 3-hydroxy isocoumestans (44) and 3-hydroxy naphthol (1,2-b)-furo (2,3-c)-[1]-benzopyran-6(H)-ones (46) by condensation of resorcinol with ethyl 2,3-dihydro-3-oxo-benzofuran-2-carboxylate (43) and ethyl-2,3-dihydro-3-oxonaphthol (1,2-b) furan-2-carboxylate (45) [Scheme-18] and prepared corresponding alkyl ethers.

Paradkar and coworkers [38] developed a new method in which both benzofuran and coumarin rings are simultaneously formed when benzophenone derivative is reacted with diethylbromomalonate. They had synthesised simple isocoumestan by condensing 2,2'-dihydroxy-benzophenone (47) with diethylbromomalonate. [Scheme-19]

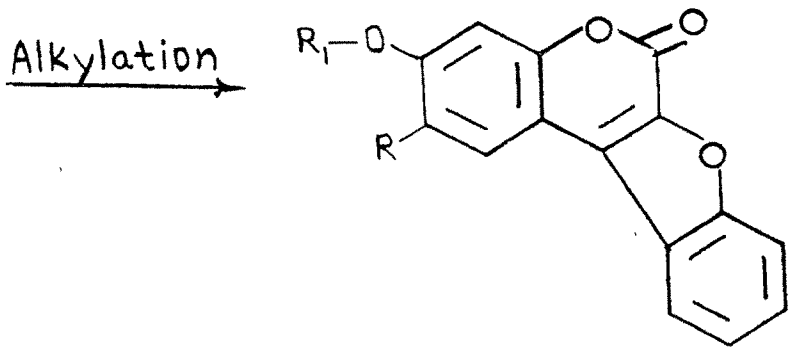
Wadia and coworkers [39] developed a new synthesis of isocoumestans. They prepared a complex of $POCl_3$ and N,N-diethylchloroacetamide which on reaction with o-hydroxy-benzophenone (48) gave 3-chloro-6-arylcoumarins (49) which on cyclisation in aq. KOH gave isocoumestan (50). [Scheme-20]

Scheme - 18 Mahesh and Coworkers[37]

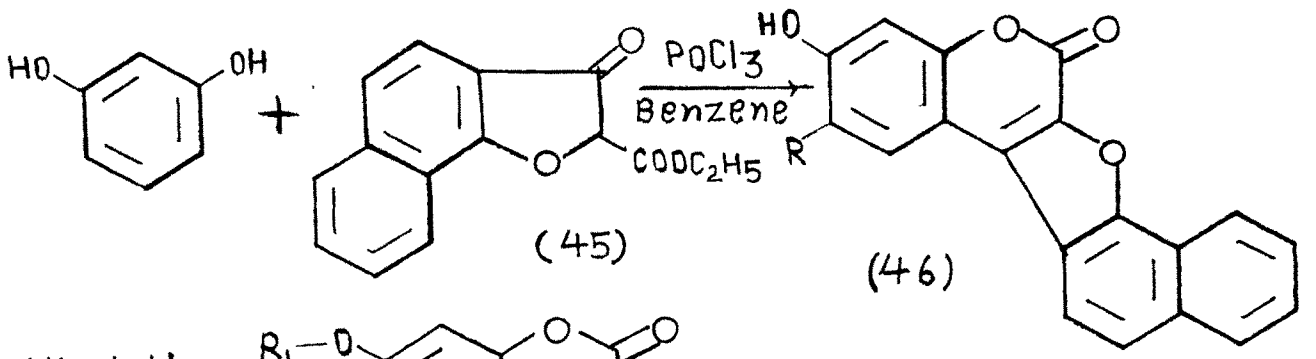


(43)

(44)

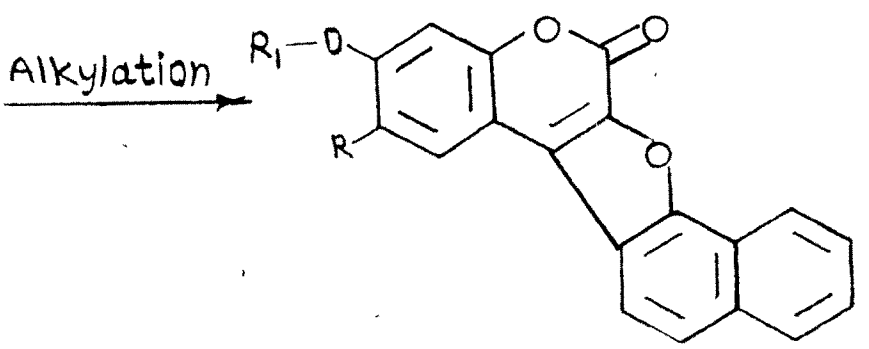


Scheme - 18 Mahesh and Coworkers[37]

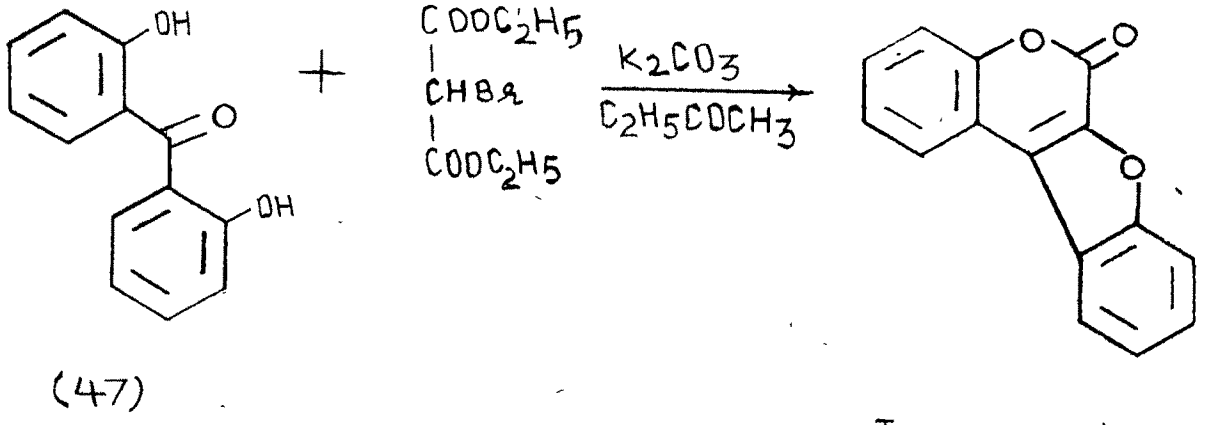


(45)

(46)



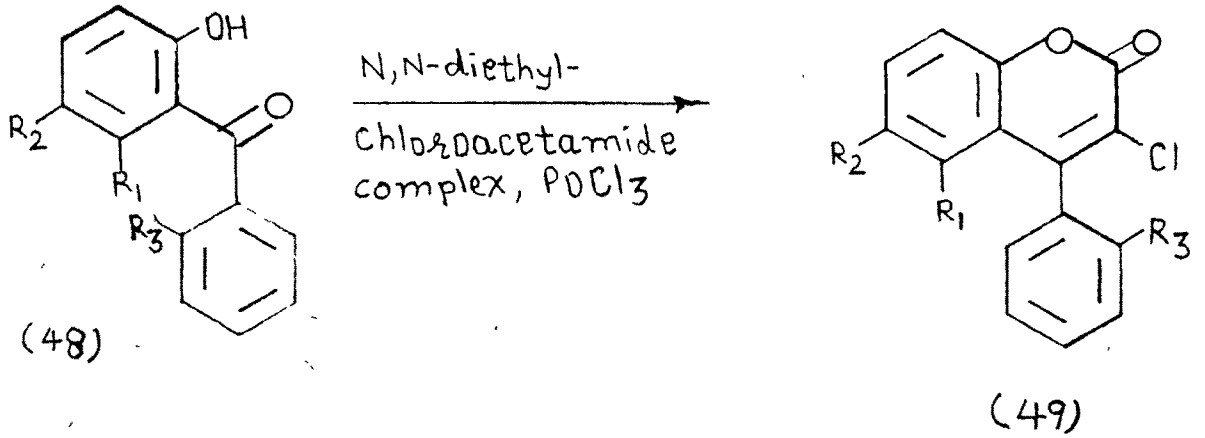
Scheme - 19 Paradkar and Coworkers[38]



(47)

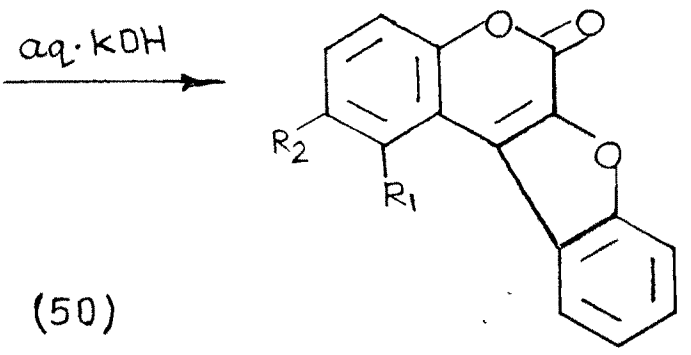
Isocoumestan

Scheme - 20 Wadia and Coworkers[39]



(48)

(49)



(50)

PRESENT WORK

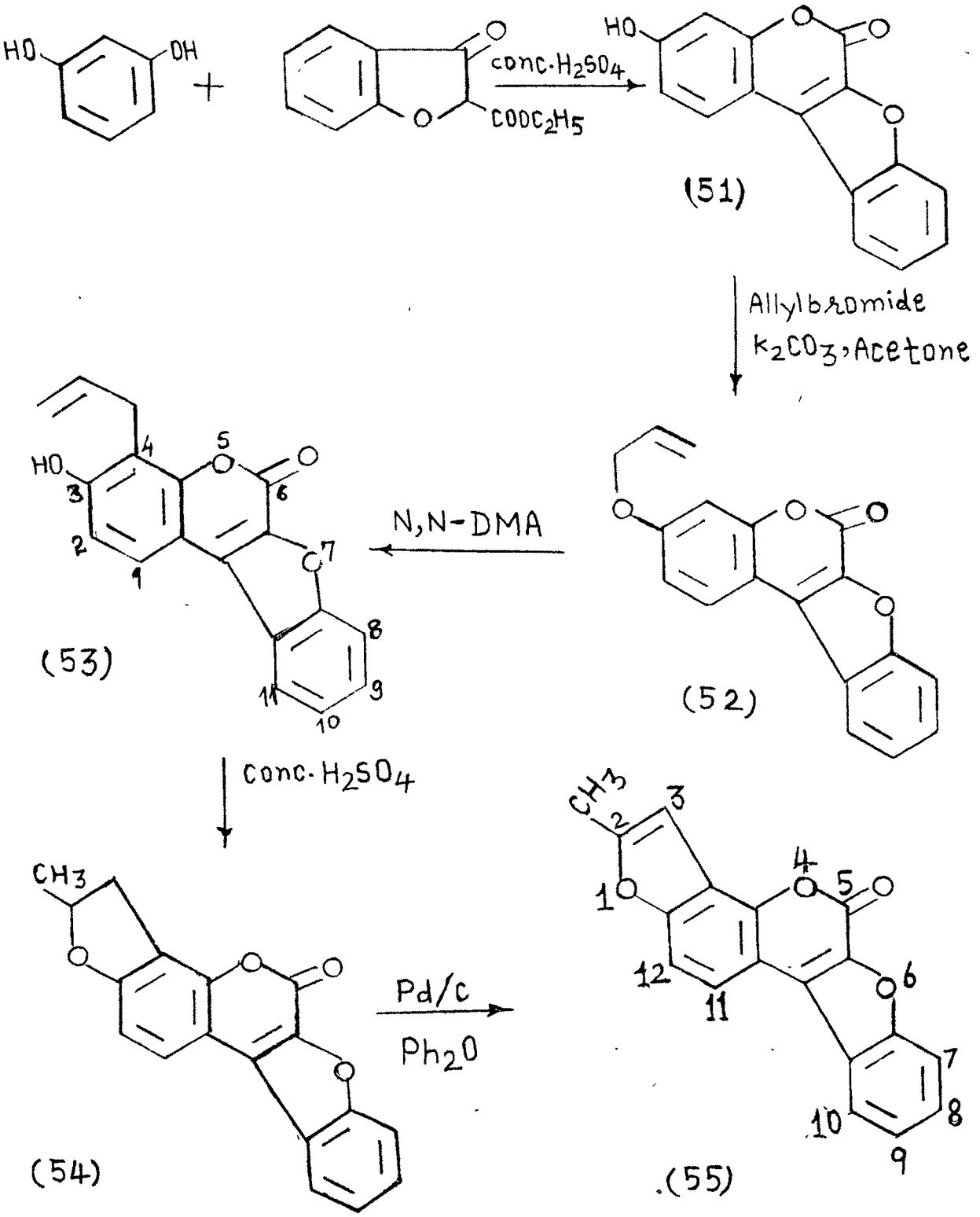
As described earlier, Shah and Trivedi[31,32] synthesised several furo and pyrano coumestans. In continuation of this work, several furo and pyrano isocoumestans, difurocoumestans and benzofuro coumestans are synthesised to evaluate their biological activities.

Synthesis of 2-methyl-furo (2,3-h)-benzofuro(2,3-c)-benzopyran-5(H)-one (55)

Resorcinol on condensation with 2-carbethoxy-3-2(H)-benzofuranone[34] gave 3-hydroxy benzofuro(2,3-c)-benzopyran-6(H)-one (51). This when refluxed with allylbromide in presence of anhydrous potassium carbonate and dry acetone gave 3-allyloxy-benzofuro (2,3-c)-benzopyran-6(H)-one (52). The structure of this compound was established by its PMR spectra taken in $CDCl_3$. The multiplet at δ 4.5-4.65 is for $-O-\underline{CH}_2-CH=CH_2$ group. Multiplet at δ 5.2-5.45 is for terminal $-\underline{CH}_2$ of allyl group. Multiplet at δ 5.8-6.2 is for $-CH_2-\underline{CH}=CH_2$ group, at C-3. Singlet at δ 6.8 is for proton at C-4. Multiplet from δ 6.95 to 8.05 is for all remaining aromatic protons.

Compound (52) on Claisen rearrangement in boiling N.N-dimethylaniline gave 3-hydroxy-4-allyl-benzofuro (2,3-c)-benzopyran-6(H)-one (53). The structure of this compound was established by PMR spectra recorded in DMSO-d_6 of its

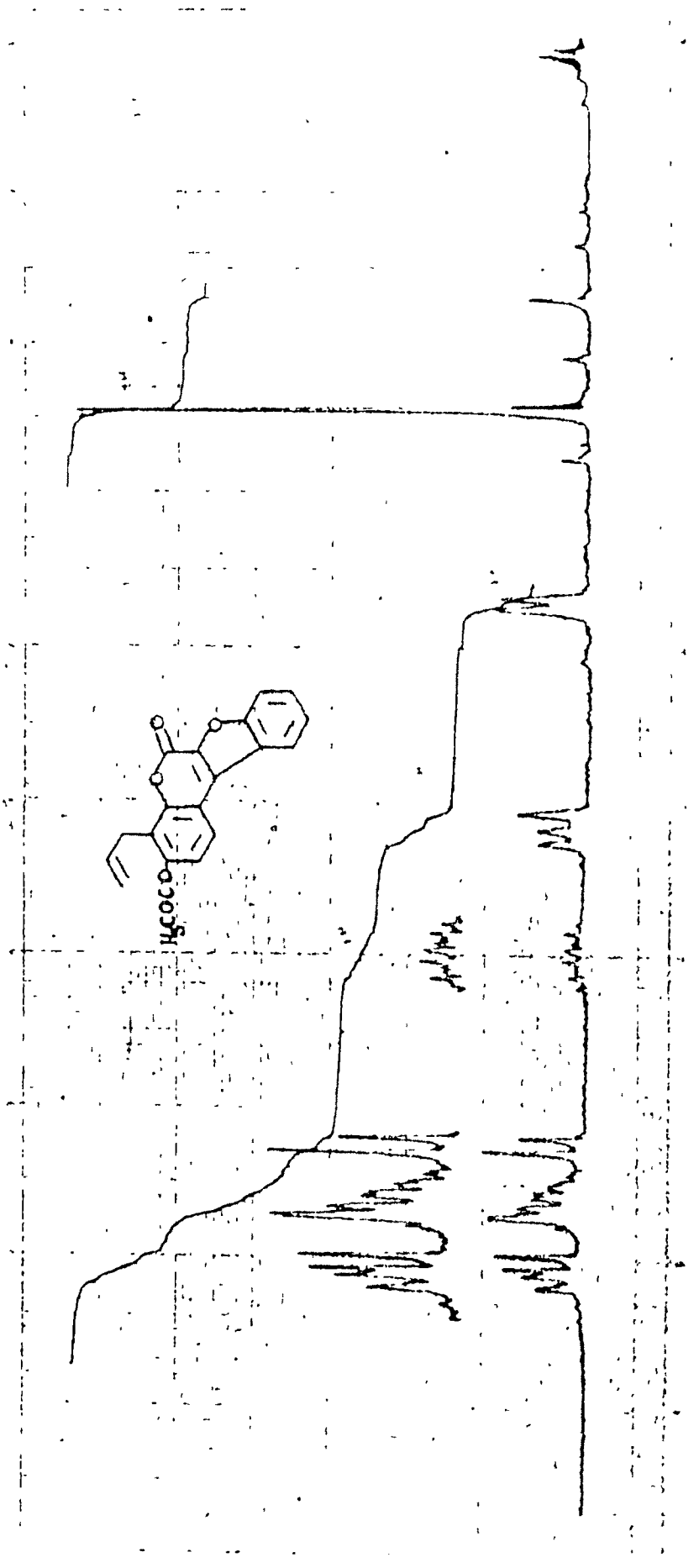
Scheme - 21


HO
OH
conc.H2SO4
COOC2H5
(51)
Allylbromide
K2CO3, Acetone
(52)
N,N-DMA
(53)
conc.H2SO4
(54)
Pd/C
Ph2O
(55)

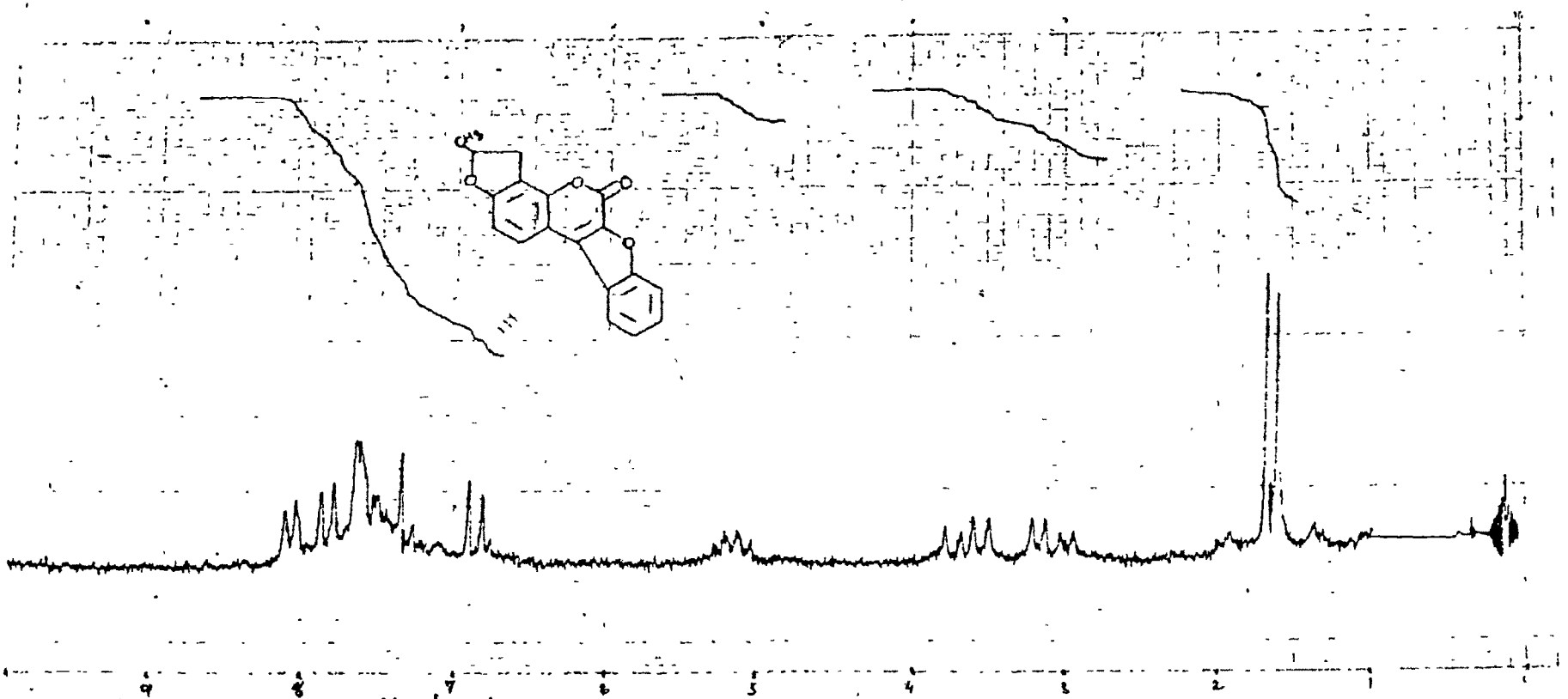
acetoxy derivative prepared by refluxing (53) with anhydrous sodium acetate and acetic anhydride. (Fig. 1) The singlet at δ 2.35 is for $-CH_3$ of acetoxy group at C-3. Doublet at δ 3.6 is for $-CH_2$ group at ether linkage of allyl group ($-O-\underline{CH_2}CH=CH_2$). Multiplet at δ 5.1 for terminal $-CH_2$ of allyl group ($-CH_2-CH=\underline{CH_2}$). Another multiplet at δ 5.9 is for $-CH_2-\underline{CH}=CH_2$ group. Two doublets at δ 7.2 (J=9Hz) and 8.0 (J=9Hz) indicated orthocoupling of two protons at C-1 and C-2. Multiplet at δ 7.2-8.1 indicated four aromatic protons at C-8, C-9, C-10 and C-11.

Compound (53) on cyclisation with conc. H_2SO_4 (80%) gave 2-methyl-dihydrofuro (2,3-h)-benzofuro (2,3-c)-benzopyran-6(H)-one (54). [Scheme-21] The structure of this compound was also established by its PMR spectrum taken in $CDCl_3$. (Fig. 2). The doublet at δ 1.6 for three protons indicated methyl group at C-2. Two double doublets at δ 2.8-3.2 (J=18, 8Hz) and 3.4-3.8 (J=18,8Hz) indicated two protons at C-3. Multiplet at δ 5.1 indicated one proton at C-2. Two doublets at δ 6.8 and 8.0 (J=9Hz) indicated orthocoupling of protons at C-1 and C-12 respectively. Multiplet at δ 7.2-7.8 indicated four aromatic protons at C-7, C-8, C-9 and C-10.

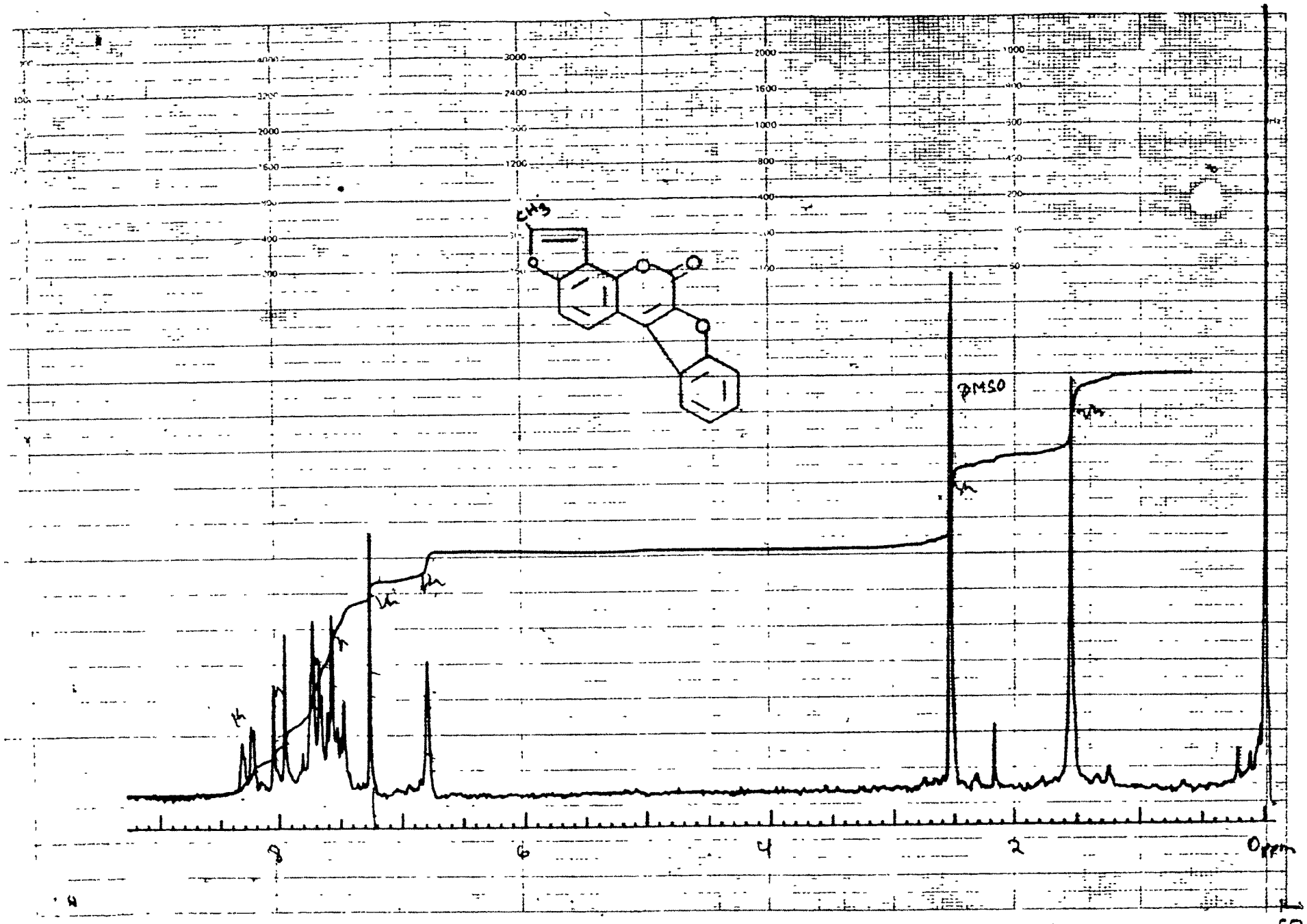
Compound (54) on dehydrogenation with palladised charcoal (10%) in boiling diphenylether gave 2-methyl furo (2,3-h)-benzofuro (2,3-c)-benzopyran-6(H)-one (55). The structure



(Fig-1) : 3-Acetoxy-4-allyl-benzofuro-(2,3-c)-benzopyran-6(H)-one (53).



(fig-2) : 2-Methyl-dihydrofuro(2,3-b)-benzofuro(2,3-c)-benzopyran-6(H)-one (54)



(fig-3): 2-Methylfuro (2,3-b)-benzofuro (2,3-c)-benzopyran-6(H)-one. (55)

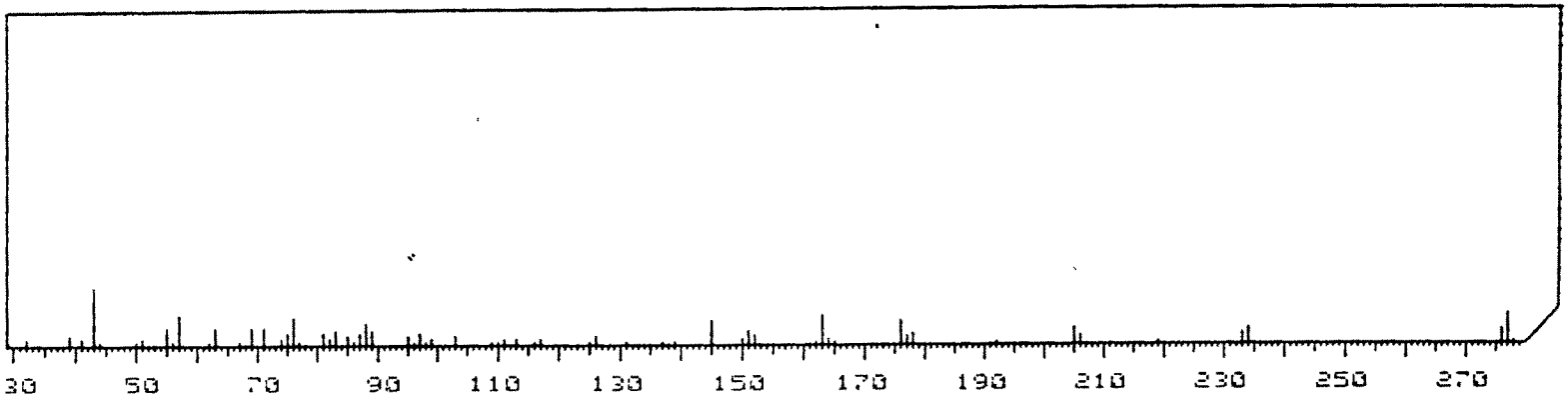
of this compound was established by its PMR spectrum taken in DMSO-d_6. (Fig. 3). Singlet at δ 1.55 is for methyl group at C-2. Singlets at δ 2.2 and 2.5 are due to DMSO-d_6. Singlet at δ 6.8 indicated proton at C-3. Singlet at δ 7.2 indicated proton at C-10. Two doublets at δ 7.5 and 8.3 (J=9Hz) indicated orthocoupling of two protons at C-11 and C-12 respectively. Multiplet or rather mixed doublets at δ 7.55-8.1 indicated remaining aromatic protons at C-7, C-8 and C-9. The structure of this compound was further confirmed by its mass spectrum which showed molecular ion peak at m/e 290. (Fig.4)

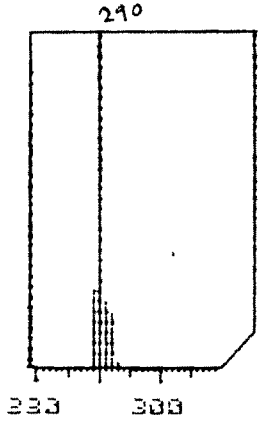
In order to synthesise linear furo isocoumestan the method established by Pardanani[40] and Trivedi and Desai and Trivedi[41] was adopted. (51) on bromination of 3-hydroxy benzofuro (2,3-c)-benzopyran-6(H)-one with bromine in acetic acid gave 3-hydroxy-4-bromobenzofuro (2,3-c)-benzopyran-6(H)-one (56). This was allylated with allylbromide in presence of anhydrous potassium carbonate and dry acetone to give 3-allyloxy-4-bromo-benzofuro (2,3-c) benzopyran-6(H)-one (57). This was subjected to Claisen rearrangement by refluxing in N,N-dimethylaniline. On working up the reaction mixture gave 3-hydroxy-4-allyl-benzofuro (2,3-c)-benzopyran-6(H)-one (53) alongwith p-bromo-N,N-dimethylaniline and not 2-allyl-3-hydroxy-benzofuro (2,3-c)-benzopyran-6(H)-one as expected. It gave the same product as obtained earlier by Claisen rearrangement of 3-allyloxy-benzofuro-(2,3-c)-benzopyran-6(H)-one. In this reaction, bromine was

FILENAME:RL0113.01
COMMENT:N.65

MODE: EI
EV: 70 GAIN: 3.8
II TEMP: 250 ICHN SPEED: 8
DI TEMP: 86

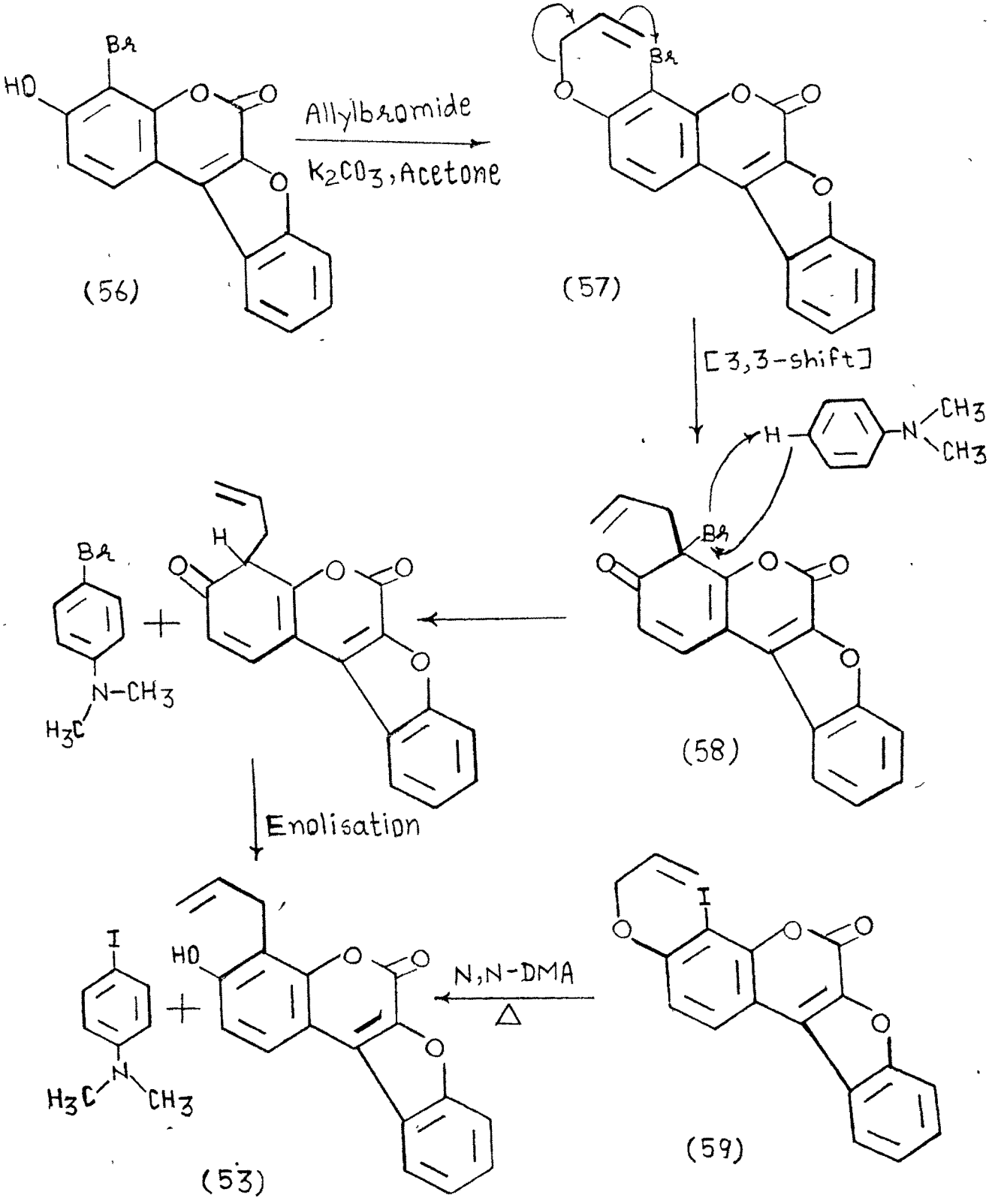
DATA	R.T.	PEAK	MASS RANGE		BASE PEAK	TOTAL	RAW-	B.G.
55	3.2	272	31-	390	382300(290)	1976051	0-	0
		41	32-	293	382000(293)	1763260	0-	3





(fig-4): 2-Methyl furo (2,3-h)-benzofuro (2,3-c)-benzopyran-4(4H)-one(55)

Scheme - 22


Br
HO
Allylbromide
K_2CO_3, Acetone
(56)
(57)
[3,3-shift]
H
N
CH_3
CH_3
Br
(58)
Br
N-CH_3
H_3C
H
Enolisation
I
HO
N,N-DMA
Δ
H_3C
N
CH_3
(53)
I
(59)

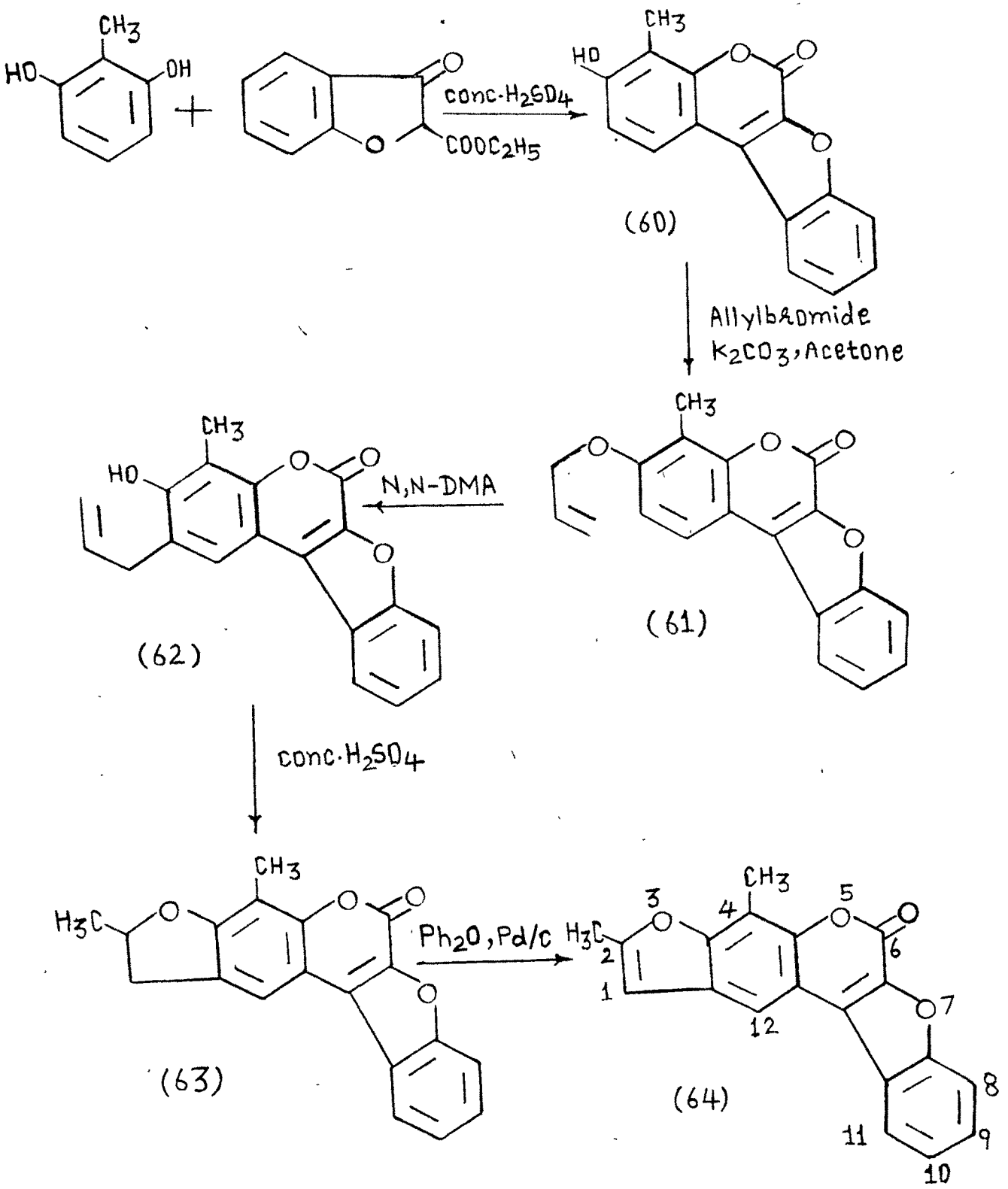
eliminated first and allyl group migrated to the 4-position instead of going to 2-position. The formation of p-bromo-N,N-dimethylaniline can be explained on the basis of the attack of N,N-dimethylaniline on o-bromo-cyclohexadienone intermediate (58) formed after the rearrangement of allyl group in the position-8. [Scheme-22]

Similarly 3-allyloxy-4-iodo-benzofuro (2,3-c)-benzopyran-6(H)-one (59) on Claisen rearrangement also gave (53) alongwith p-iodo-N,N-dimethylaniline. Thus attempts to prepare linear furisocoumestans failed by this procedure. Synthesis of linear furoisocoumestan was carried out by blocking the 4-position by methyl group.

Synthesis of 2,4-dimethyl-furo-(3,2-g)-benzofuro (2,3-c)-benzopyran-6(H)-one (64)

2-Methyl resorcinol on condensation with 2-crbethoxy-3-2(H)-benzofuranone gave 3-hydroxy-4-methyl-benzofuro (2,3-c) benzopyran-6(H)-one (60). This on allylation with allylbromide in presence of anhydrous potassium carbonate and dry acetone gave 3-allyloxy-4-methyl-benzofuro (2,3-c)-benzopyran-6(H)-one (61). This compound on Claisen rearrangement in boiling N,N-dimethylaniline gave 2-allyl-3-hydroxy-4-methyl-benzofuro (2,3-c)-benzopyran-6(H)-one (62) [Scheme-23]. Due to the presence of methyl group at C-4, allyl group migrated to

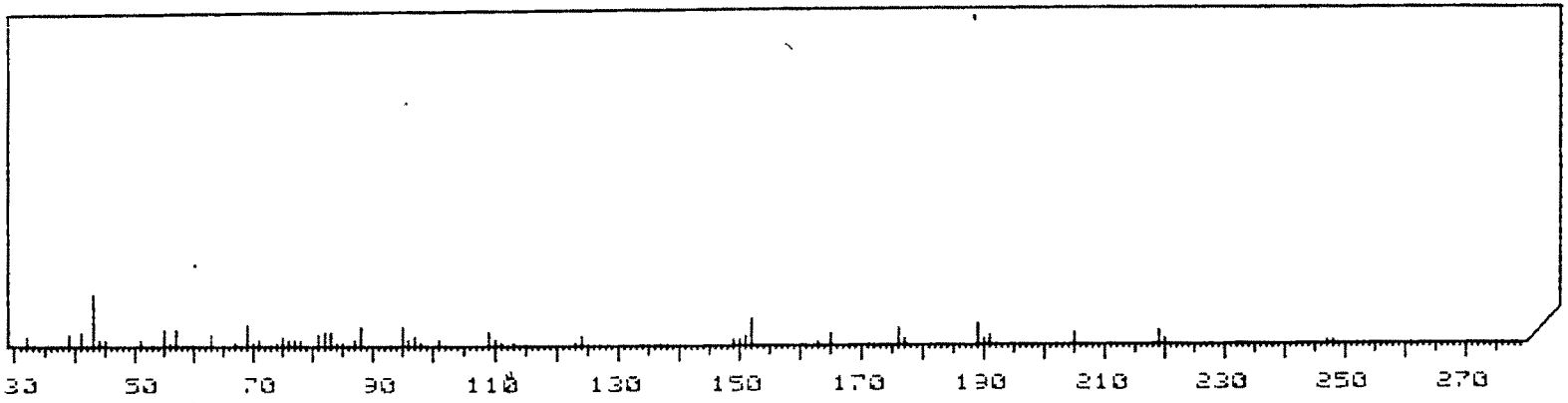
Scheme - 23

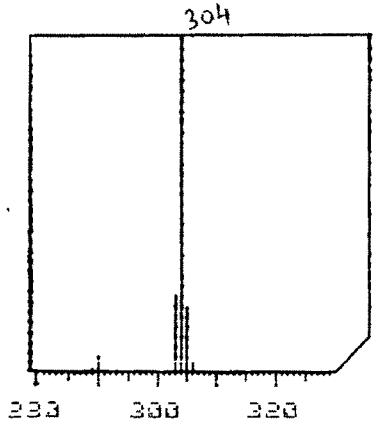

CH3
HO
OH
conc·H2SO4
COOC2H5
(60)
Allylbromide
K2CO3, Acetone
N,N-DMA
(62)
(61)
conc·H2SO4
Ph2O, Pd/C
(63)
(64)

FILENAME:RL3113.04
COMMENT:

MODE: EI
EV: 73 GAIN: 3.8
IS TEMP: 250 SCAN SPEED: 8
DI TEMP: 115

DATA	R.T.	PEAK	MASS RANGE		BASE PEAK	TOTAL	RAW-	B.G.
38	1.3	372	31-	386	354530(304)	1551200	0-	0
		91	32-	306	354503(304)	1471182	0-	0





(fig-5): 2,4-dimethyl furo (3,2-g)-benzofuro (2,3-c)-benzopyran-6(H)-one. (64)

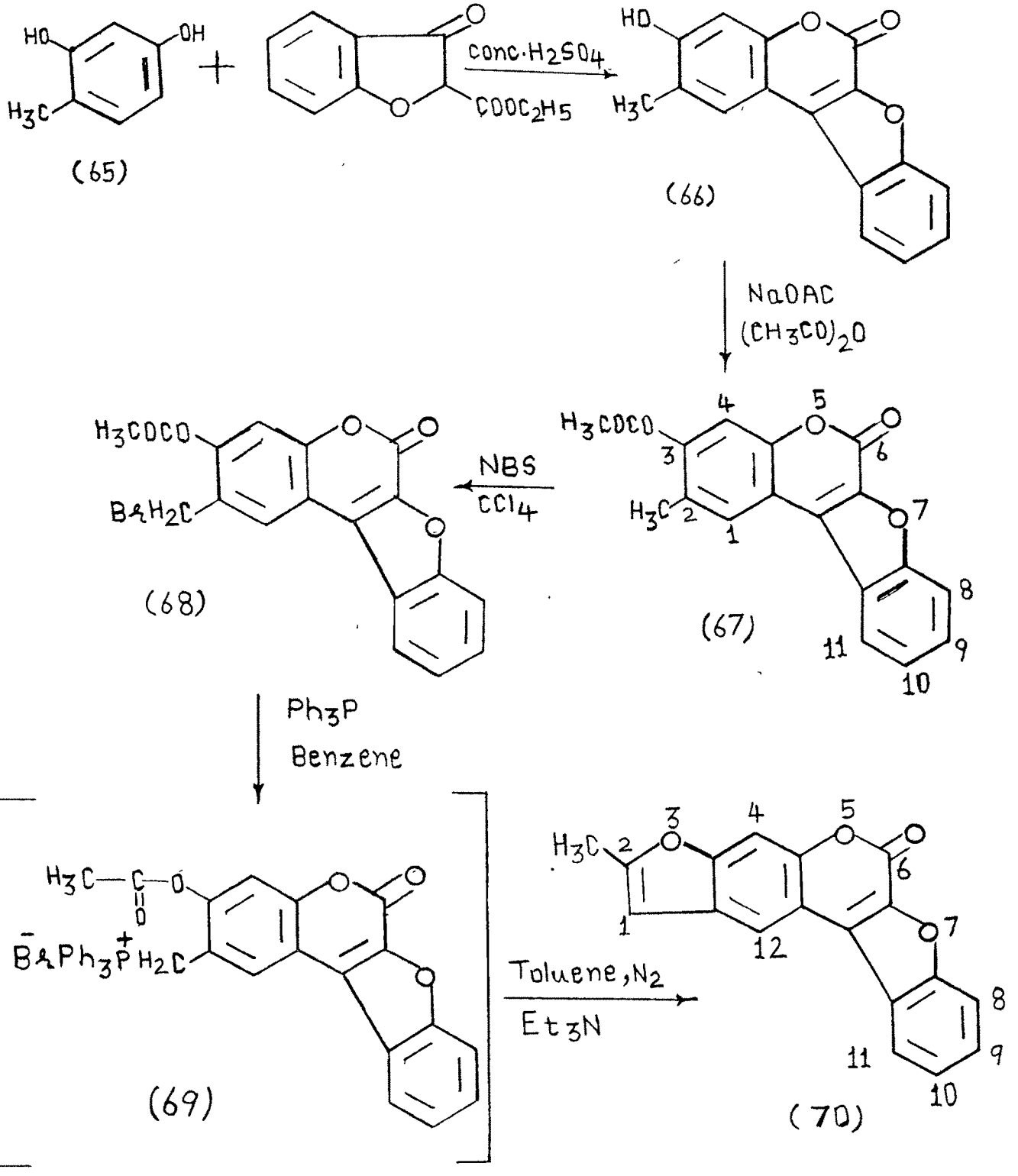
vacant C-2 position only and cyclisation of compound (62) in conc. H_2SO_4 (80%) gave the product 2,4-dimethyl-dihydro-furo-(3,2-g)-benzofuro-(2,3-c)-benzopyran-6(H)-one (63) [Scheme-23]. This compound on dehydrogenation with palladised charcoal (10%) in boiling diphenyl ether gave 2,4-dimethyl-furo-(3,2-g) benzofuro-(2,3-c)benzopyran-6(H)-one (64). [Scheme-23]. Since this compound was insoluble in DMSO-d_6, it was not possible to record PMR of this compound. But the structure of this compound was established by its mass spectrum, which showed molecular ion peak at m/e 304. (Fig. 5).

In this synthesis of linear furoisocoumestan methyl substitution at C-4 of isocoumestan ring was necessary. To get linear furoisocoumestan, without methyl substitution at C-4 of isocoumestan ring, regiospecific method of intra-molecular Wittig reaction described in Chapter II for synthesis of furocoumarins was adopted.

Synthesis of 2-methyl-furo (3,2-g)-benzofuro-(2,3-c)-benzopy-ran-6(H)-one (70)

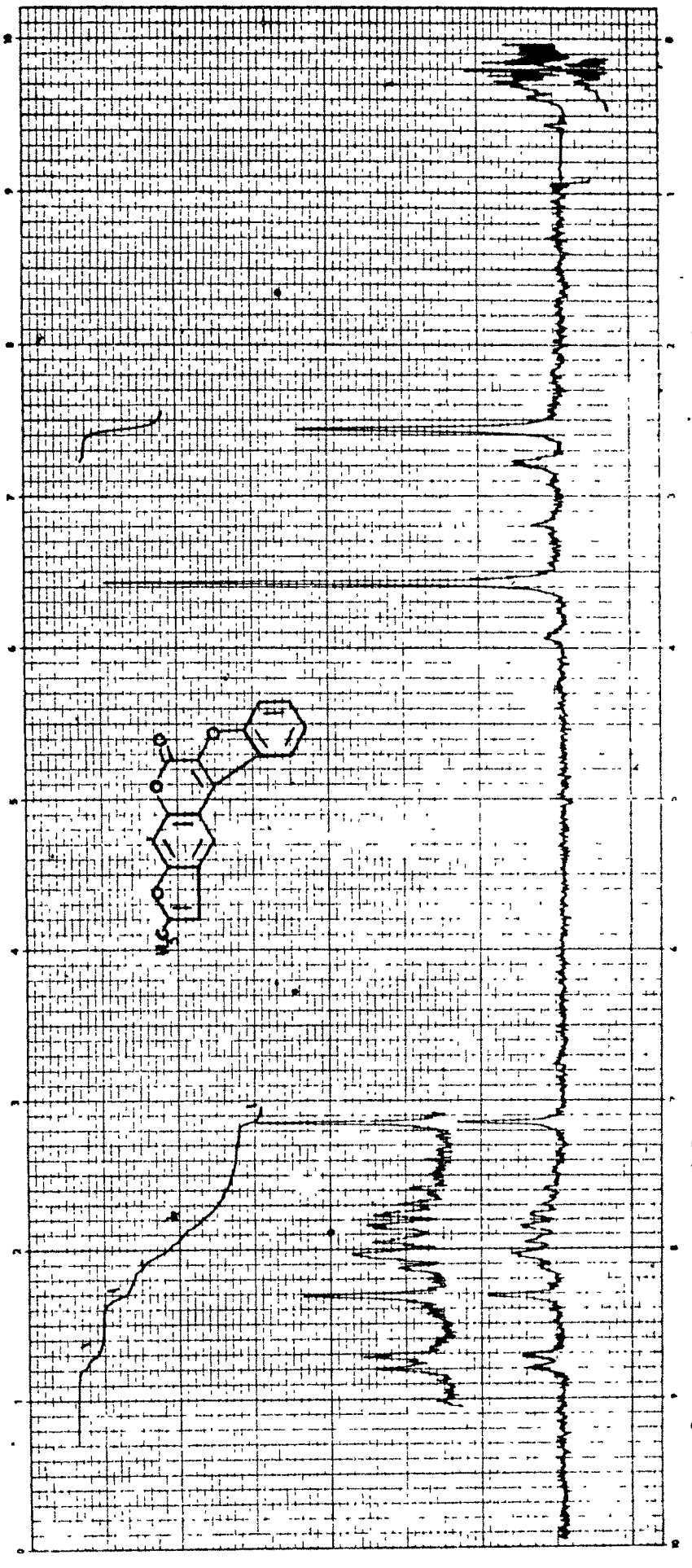
β-Resorsaldehyde on reduction with zinc dust and HCl gave 4-methyl resorcinol (65), which on condensation with 2-carbethoxy-3-2(H)-benzofuranone gave 3-hydroxy-2-methyl-benzofuro-(2,3-c)-benzopyran-6(H)-one (66). This compound on acetylation with sodium acetate and acetic anhydride gave 3-acetoxy-2-methyl-benzofuro-(2,3-c)-benzopyran-6(H)-one (67).

Scheme - 24


HO
OH
H3C
(65)
conc.H2SO4
COOC2H5
HO
H3C
(66)
NaOAC
(CH3CO)2O
H3COCO
H3C
(67)
NBS
CCl4
H3COCO
BrH2C
(68)
Ph3P
Benzene
H3C—C—O
BrPh3P+H2C
(69)
Toluene, N2
Et3N
H3C
(70)

The structure of this compound was confirmed by its elemental analysis. Compound (67) on reaction with N-bromosuccinimide in presence of light and benzoylperoxide in carbon tetrachloride gave 3-acetoxy-2-bromomethyl-benzofuro-(2,3-c)-benzopyran-6(H)-one (68) [Scheme-24]. The structure of this compound was confirmed by its elemental analysis. Compound (68) on reaction with triphenylphosphine gave its corresponding phosphonium salt (69) which was not isolated. In the same reaction flask toluene and triethylamine was added and reaction was carried out under the atmosphere of nitrogen to give the product 2-methyl-furo-(3,2-g)-benzofuro (2,3-c)-benzopyran-6(H)-one (70) [Scheme-24]. The structure of this compound was established by its PMR spectrum taken in DMSO-d_6 (Fig.6). The singlet at δ 2.35 indicated the presence of methyl group of furan ring at C-2. Singlet at δ 6.95 indicated proton at C-1. Two doublets at δ 7.45 and 8.55 (J=9Hz) indicated C-8 and C-9 protons. Two doublets at δ 7.6 and 7.85 (J=9Hz) indicated orthocoupling of two protons at C-10 and C-11 respectively. Two singlets at δ 7.75 and 8.1 indicated two aromatic protons at C-12 and C-4 respectively.

In order to synthesize furo isocoumestan without any substitution in furan ring, a dihydro benzofuran ring was first prepared. It was then condensed with suitable β-ketonic ester followed by dehydrogenation to obtain furoisocoumestan ring system.



(fig-6) : 2-Methyl furo (3,2-g) -benzopyran-6(H)-one (70).

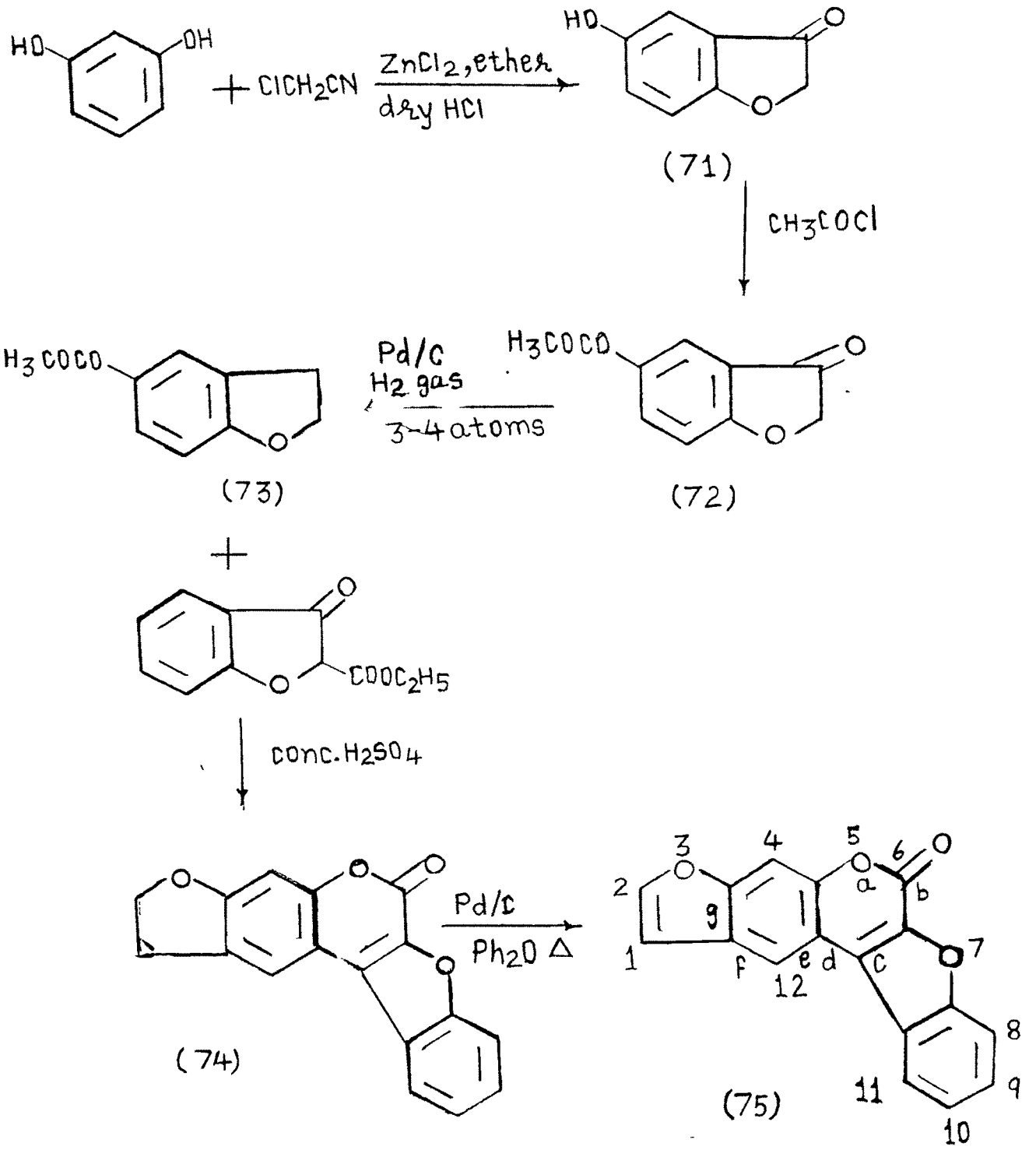
Synthesis of furo (3,2-g)-benzofuro (2,3-c)-benzopyran-6(H)-one (75)

Resorcinol on condensation with chloroacetonitrile[42] in presence of anhydrous zinc chloride and dry HCl gas gave 6-hydroxy-coumaran-3-one (71). This on acetylation with acetyl chloride and ethylacetate gave 6-acetoxy coumaran-3-one (72). This on reduction with hydrogen in the presence of palladised charcoal (10%) under pressure gave 6-acetoxy coumaran (73). This compound on condensation with 2-carbethoxy-3-2(H)-benzofuranone gave dihydrofuro (2,3-g)-benzofuro (2,3-c)-benzopyan-6(H)-one (74). The structure of this compound was established by analysis and its mass spectrum which showed the molecular ion peak at m/e 278. (Fig. 7a). The peak at 165 is due to the breaking of isocoumestan ring and loss of CO from coumarin ring.

Compound (74) on dehydrogenation with palladised charcoal (10%) in boiling diphenyl ether gave (2,3-g)-furo-benzofuro (2,3-c)-benzopyran-6(H)-one (75) [Scheme-25]. The structure of this compound was established by analysis and its mass spectrum which showed molecular ion peak at m/e 276. (Fig.7b)

After synthesising some furoisocoumestans it was thought of interest to synthesise some pyranoisocoumestans.

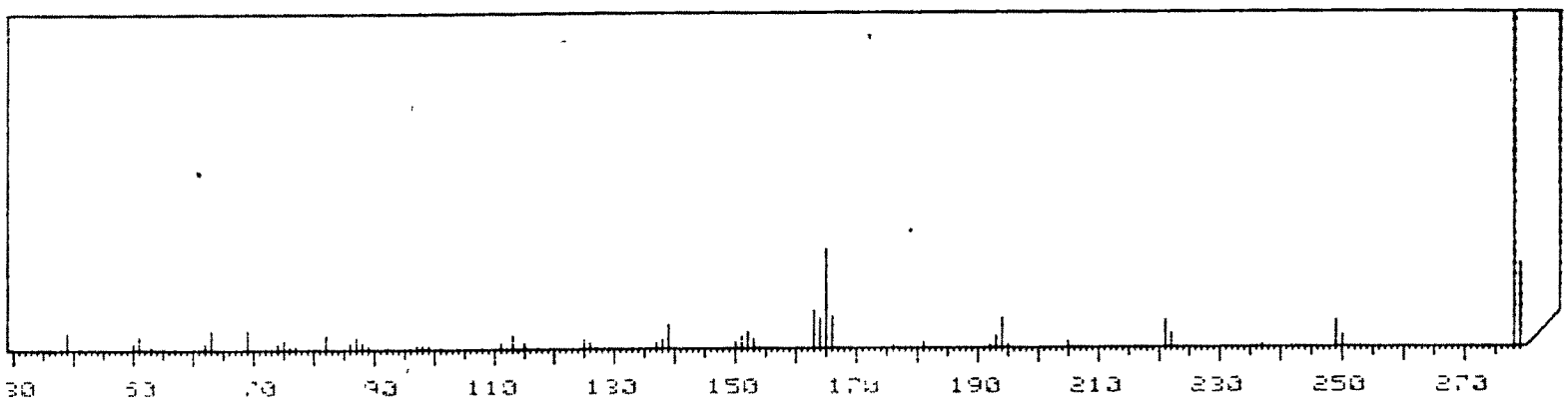
Scheme - 25

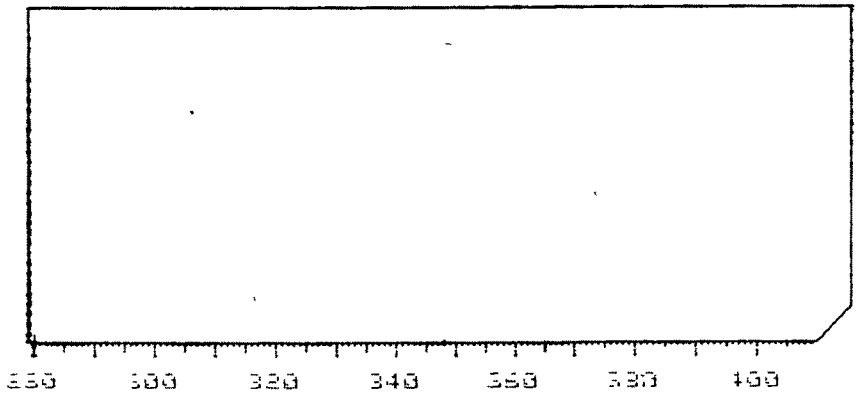

HO
OH
+ ClCH2CN
ZnCl2, ether
dry HCl
HO
(71)
CH3COCl
H3COCO
Pd/C
H2 gas
3-4 atoms
H3COCO
(73)
(72)
+
COOC2H5
conc. H2SO4
Pd/C
Ph2O Δ
(74)
(75)
1
2
3
4
5
6
7
8
9
10
11
12
a
b
c
d
e
f
g

SP 115

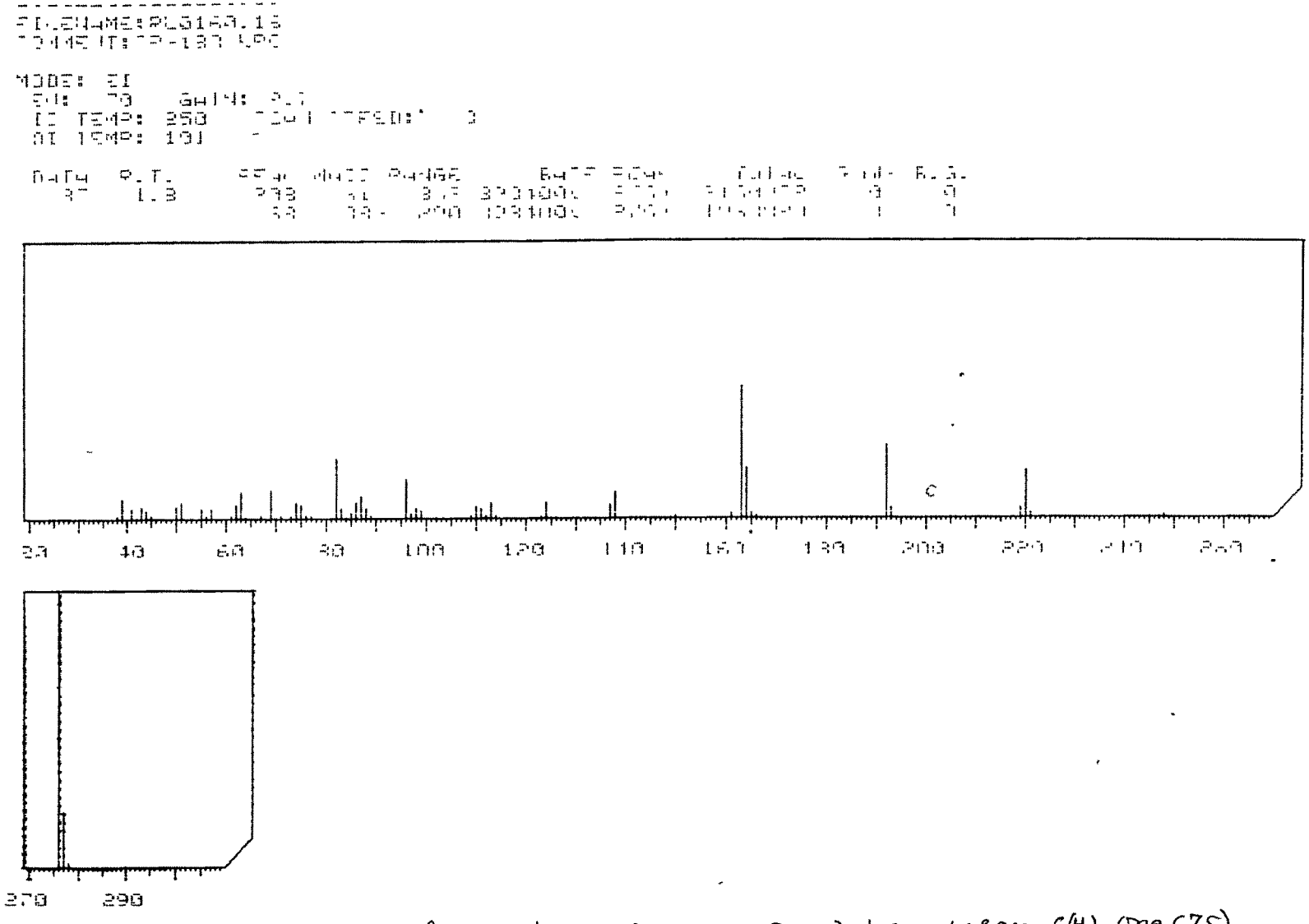
BATCH	R.T.	PEAK MASS RANGE	BASE PEAK	TOTAL	RMV-	B.G.
53	2.4	137 31- 377	439500	2780	1795302	0- 0
		165 31- 377	439500	2780	1733979	0- 0

279





(fig 7a): Dihydrofuro (2,3-g)-benzofuro (2,3-c) - benzopyran-6(H)-one (74).

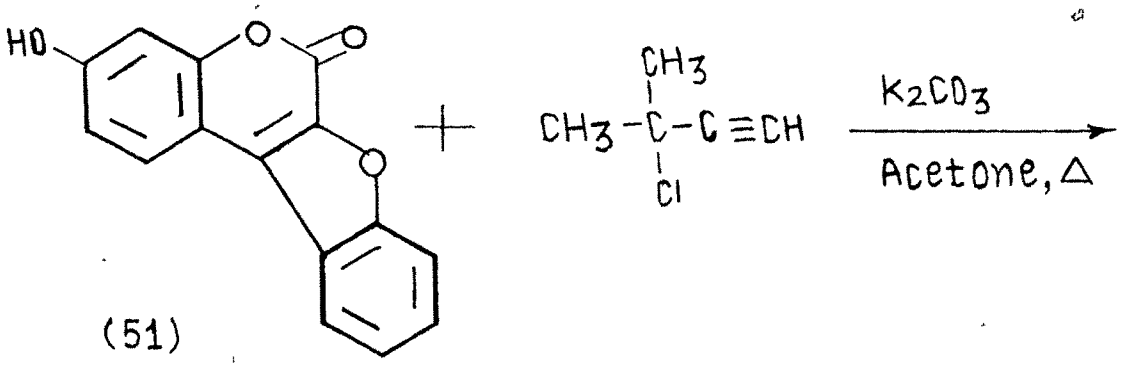


(fig-7b) · (2,3-g)-furo-benzofuro(2,3-c)-benzopyran-6(H)-one (75).

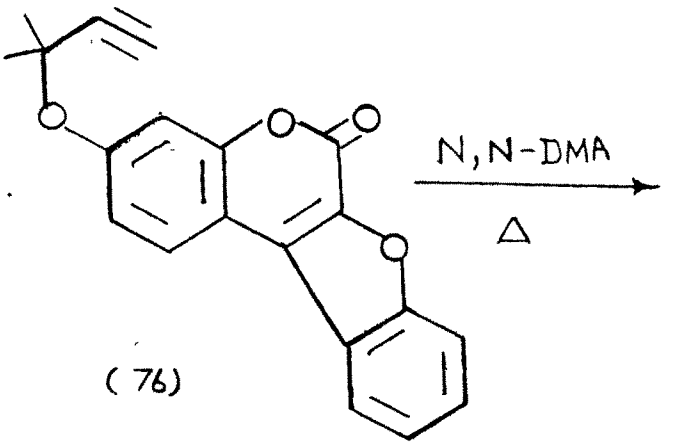
Synthesis of 2,2-dimethyl-pyrano (2,3-h)-benzofuro (2,3-c)-benzopyran-6(H)-one (77)

3-Hydroxy-benzofuro (2,3-c)-benzopyran-6(H)-one (51) was condensed with 3-chloro-3-methyl-but-1-yne in presence of anhydrous potassium carbonate and few crystals of potassium iodide by refluxing the mixture in dry acetone. On working up the reaction mixture, pure 3-(1,1-dimethyl-3-prop-2-ynyloxy) -benzofuro (2,3-c)-benzopyran-6(H)-one (76) was obtained. [Scheme-26]. The structure of (76) was assigned on the basis of PMR spectrum which exhibited the following signals. (Fig.8) Singlet at δ 1.7 for six protons indicated two methyl groups. Another singlet at δ 2.65 indicated acetylenic proton. The broad multiplet at δ 7.15-8.15 indicated seven aromatic protons IR spectrum showed band at 3200 cm^{-1} for terminal alkyne group. Ether (76) was subjected to Claisen rearrangement by refluxing in N,N-dimethylaniline for 6 hrs. On working up the reaction mixture, the crude product obtained was purified to give 2,2-dimethyl-pyrano (2,3-h)-benzofuro-(2,3-c)-benzopyran-6(H)-one (77). The structure of (77) was assigned on the basis of its PMR spectrum taken in $CDCl_3$. (Fig. 9). It exhibited singlet at δ 1.5 for six protons indicating two methyl groups at C-2. Doublet at δ 5.8, J=9Hz is for proton at C-3. The another doublet at δ 6.8, J=9Hz indicated proton at C-4. These two doublets at δ 5.8 and 7.8 indicated benzopyran type structure. Two doublets at δ 6.85 and 6.95,

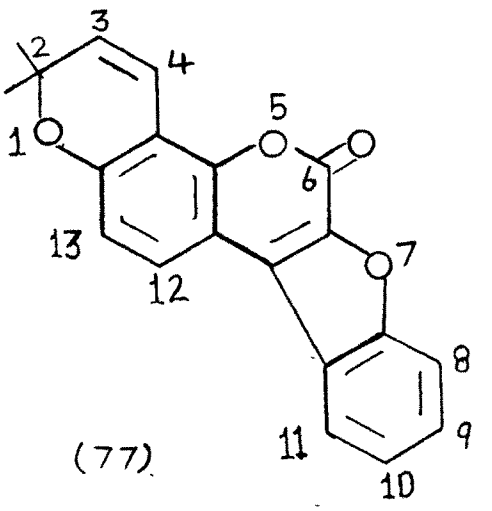
Scheme - 26



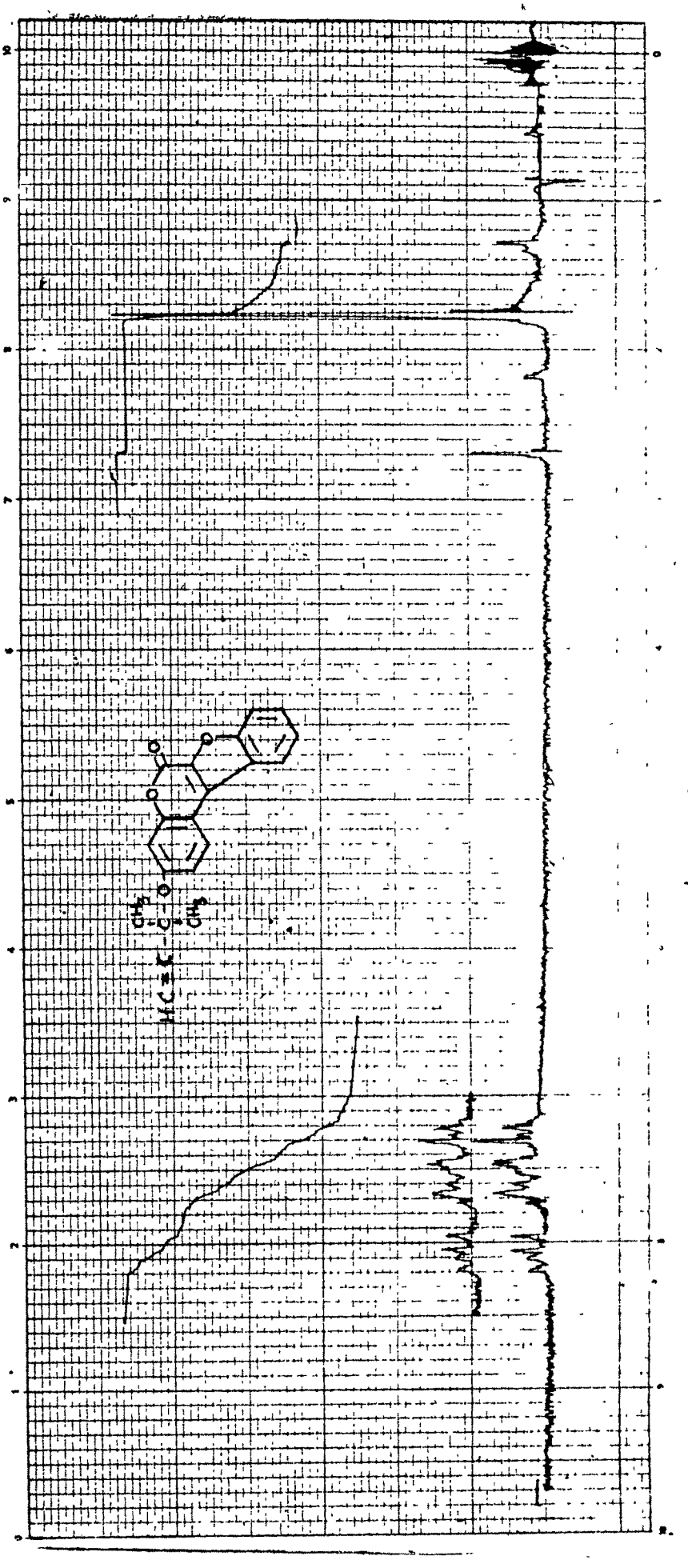
(51)



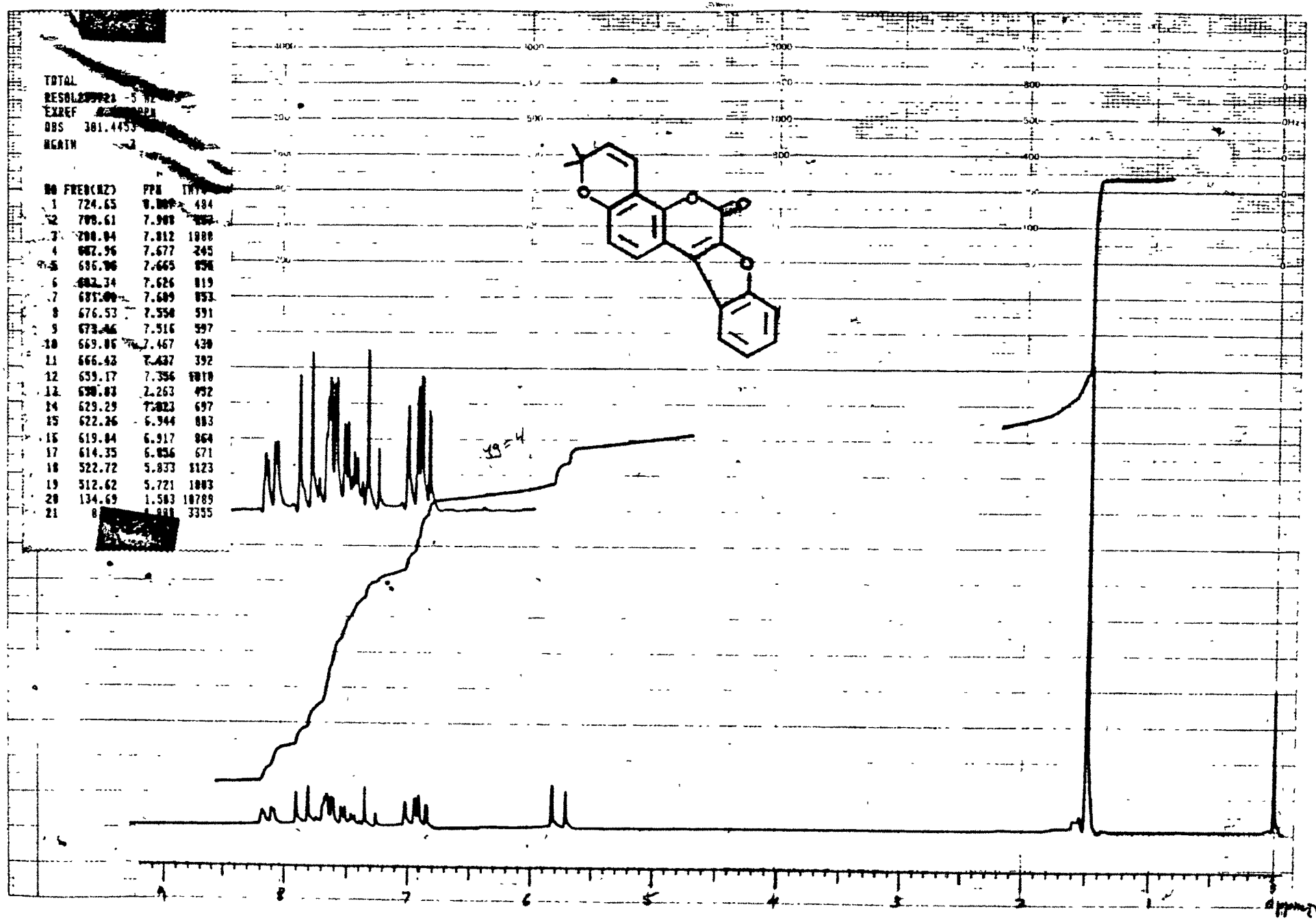
(76)



(77)



(fig-8): 3-(1,1-dimethyl-3-prop-2-ynyloxy)-benzofuro(2,3-c)-benzopyran-6(H)-one(76).



(fig-9): 2,2-dimethyl-pyrano(2,3-h)-benzofuro-(2,3-c)-benzopyran-6(H)-one (77)

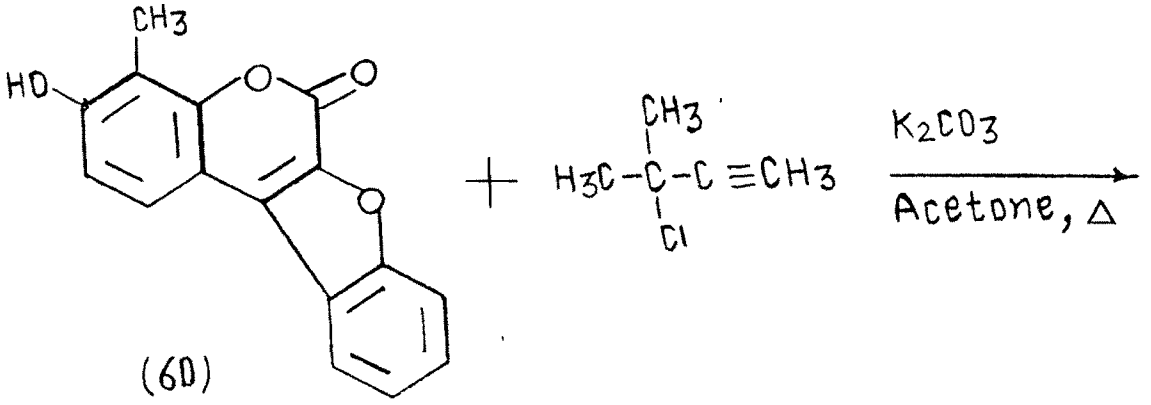
J=8Hz indicated orthocoupling at C-13 and C-12 respectively. Multiplets from δ 7.25-8.2 indicated remaining four aromatic protons at C-8, C-9, C-10 and C-11 (Fig. 9).

In order to synthesise linear pyrano isocoumestan ring system, same series of reactions were carried out by starting with 2-methyl resorcinol.

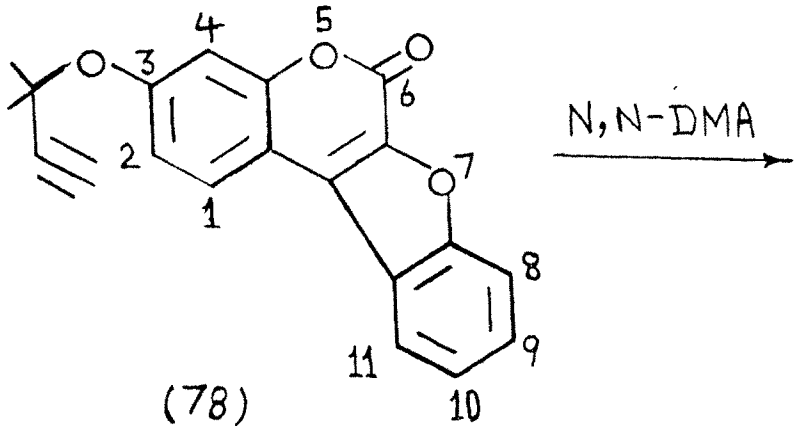
Synthesis of 3,3,5-trimethyl-pyrano (3,2-g)-benzofuro-(2,3-c)-benzopyran-7(H)-one (79)

3-Hydroxy-4-methyl-benzofuro (2,3-c)-benzopyran-6(H)-one (60) was condensed with 3-chloro-3-methylbut-1-yne in presence of anhydrous potassium carbonate and few crystals of potassium iodide by refluxing the mixture in dry acetone. On working up the reaction mixture pure 3-(1,1-dimethyl-3-prop-2-ynyloxy)-4-methyl-benzofuro-(2,3-c)-benzopyran-6(H)-one (78) [Scheme-27] was obtained. The structure of this compound was assigned on the basis of its PMR spectrum taken in DMSO-d_6 (Fig. 10). It exhibited the signals as follows : Singlet at δ 1.8 for three protons indicated $-CH_3$ group of propynyl side chain. Singlet at δ 1.9 indicated another methyl group of propynyl side chain. Singlet at δ 2.2 is for $-CH_3$ group at C-4. Singlet at δ 3.3 is for acetylenic proton. The doublet at δ 7.1, J=9Hz indicated proton at C-1. The another doublet at δ 8.4, J=9Hz indicated orthocoupling of proton C-2 with C-1. Multiplet from δ 7.5 to 8.25 indicated four aromatic protons of isocoumestan ring at C-8, C-9, C-10 and C-11.

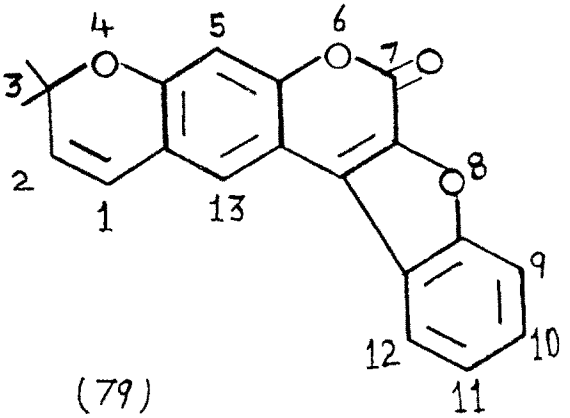
Scheme-27



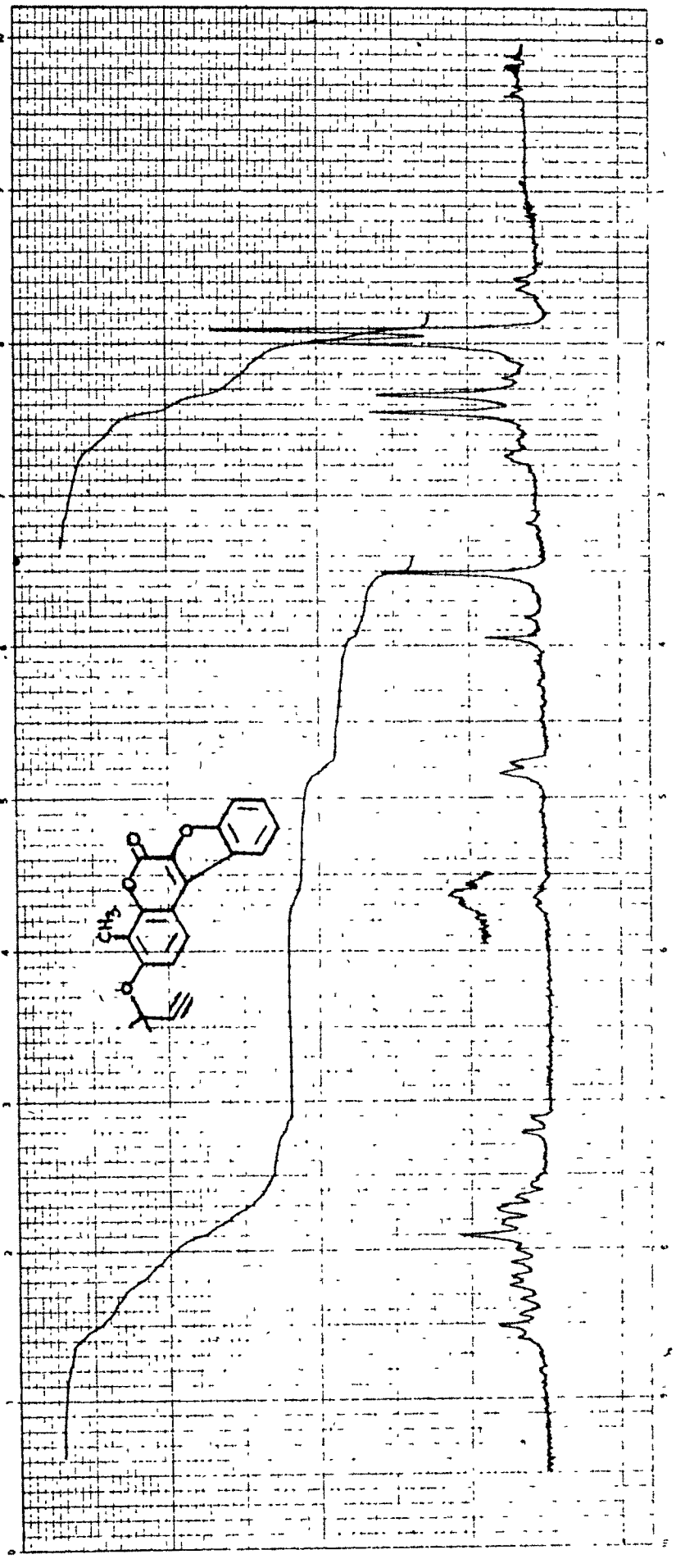
(60)



(78)

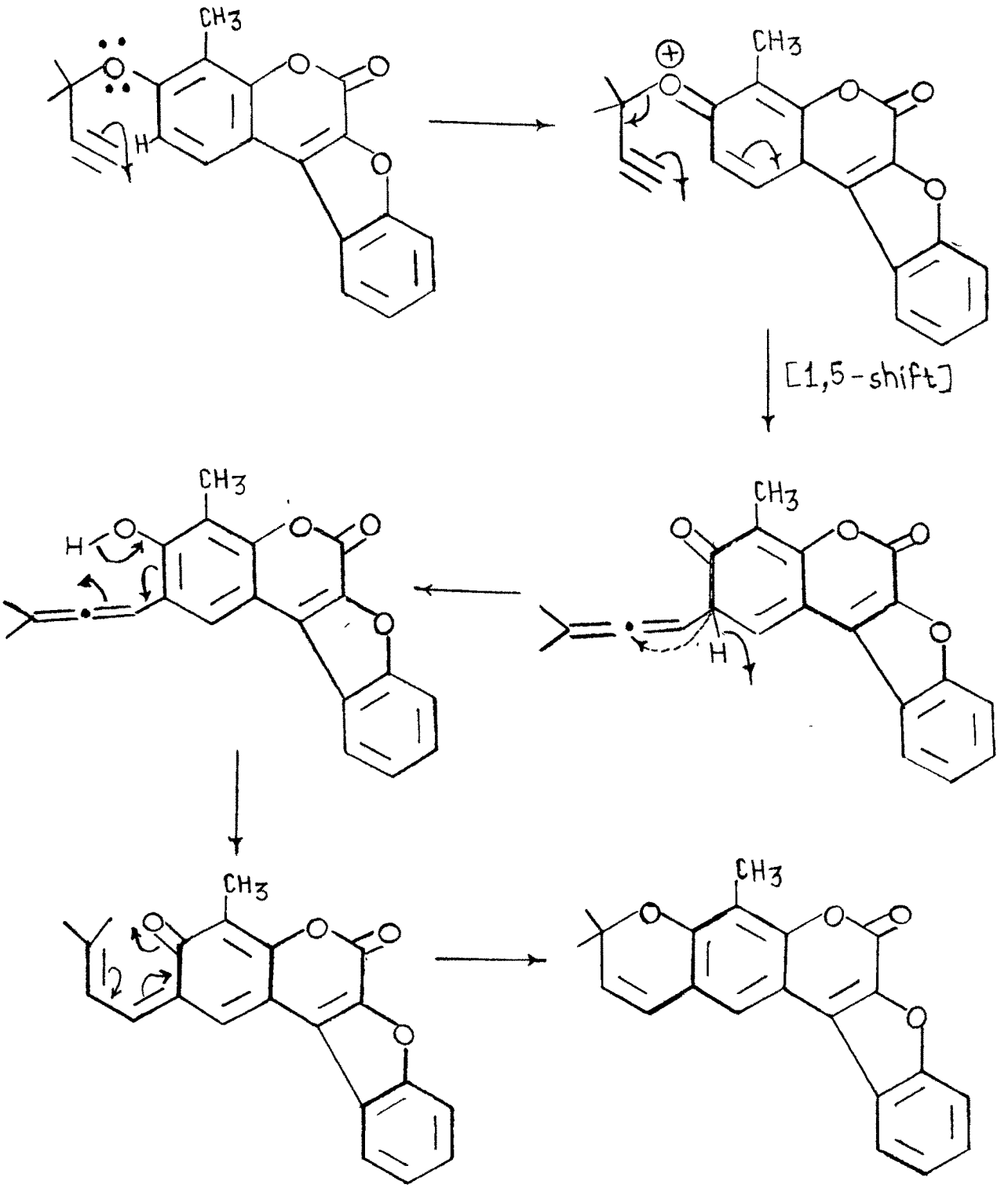


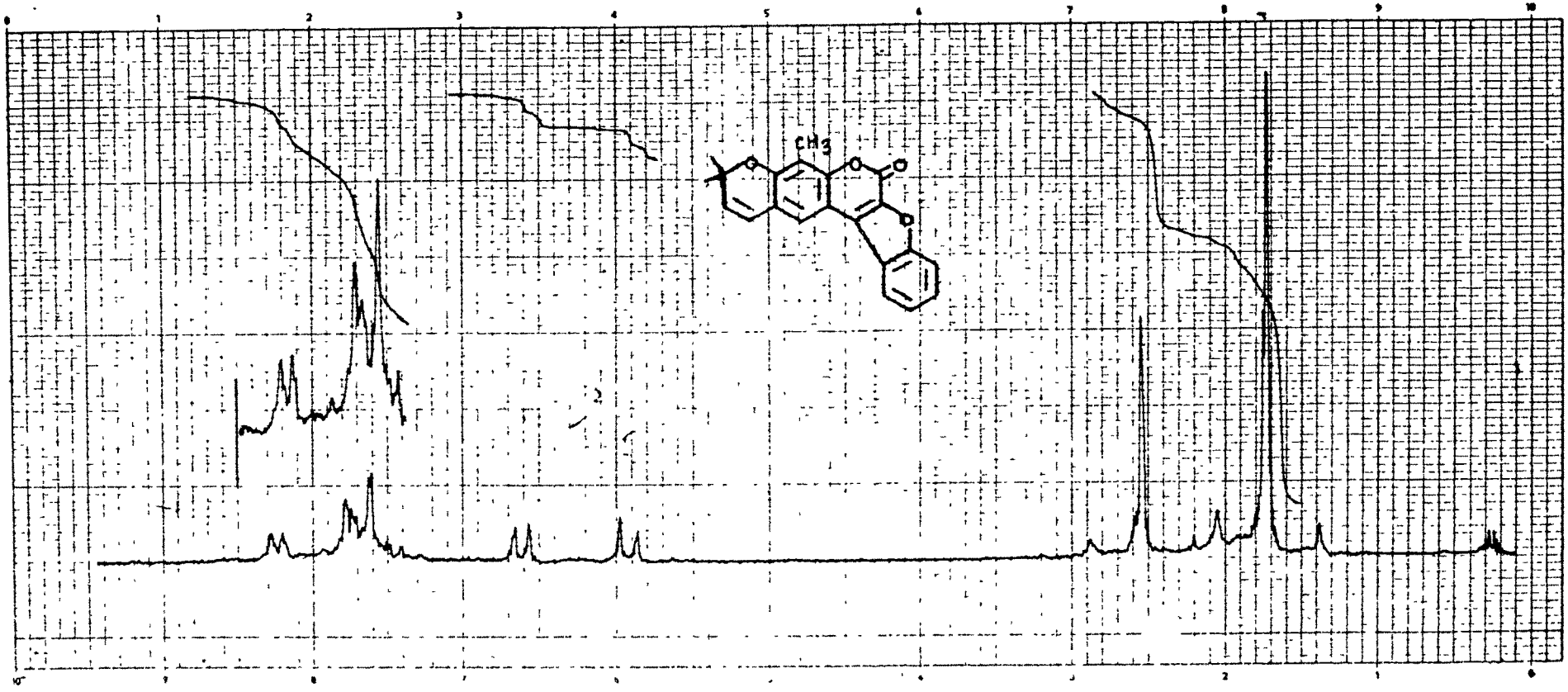
(79)



(Fig-10) : 3-(1,1-dimethyl-3-propp-2-ynyloxy)-4-methyl-benzofuro-(2,3-c)-benzopyran-6(H)-one (78).

Scheme - 28





(fig-11): 3,3,5-trimethyl-pyrano(3,2-g)-benzofuro(2,3-c)-benzopyran-7(H)-one (79).

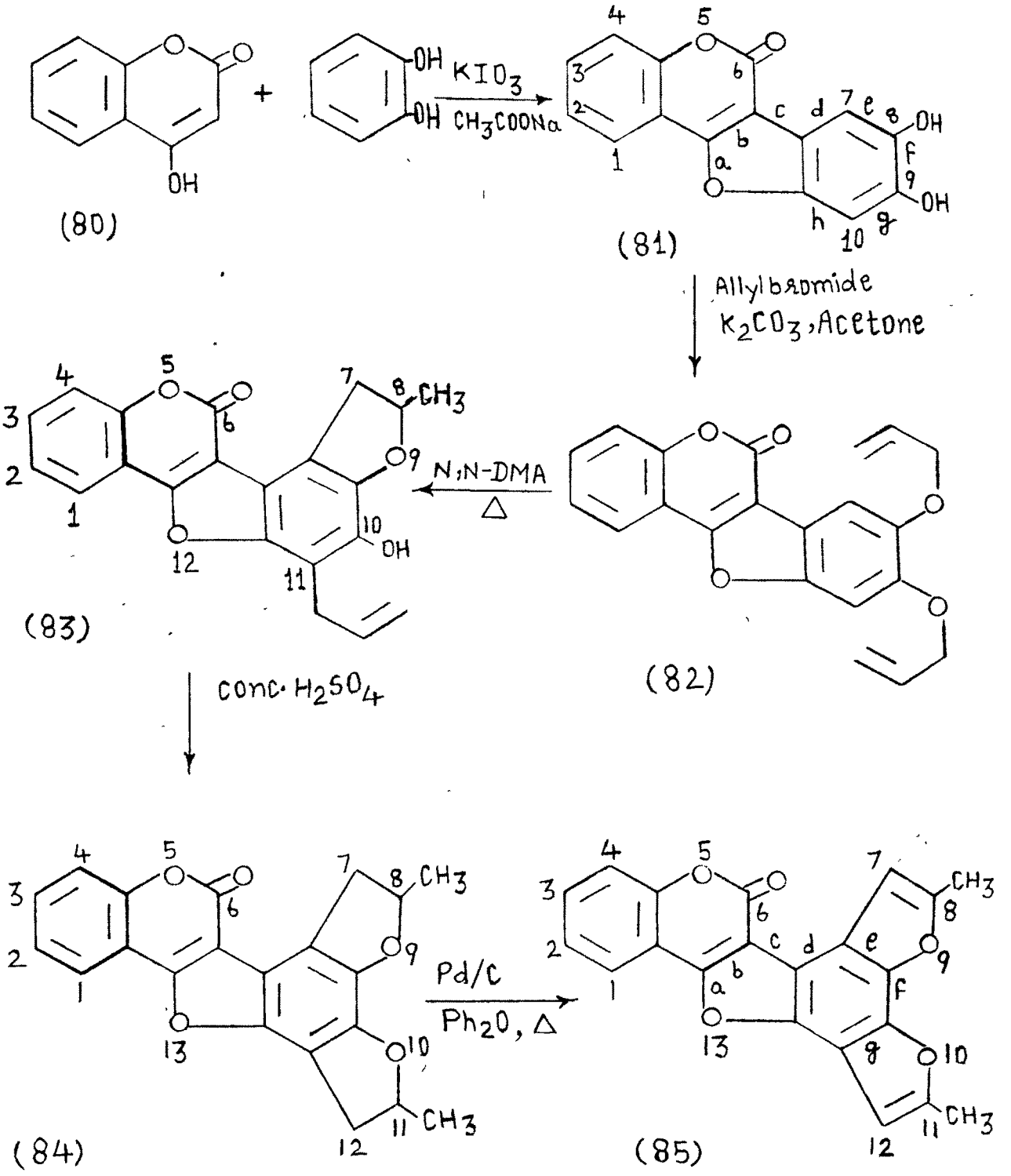
Compound (78) when subjected to Claisen rearrangement in boling N,N-dimethylaniline for 6 hrs. gave the product 3,3,5-trimethyl-pyrano-(3,2-g)-benzofuro (2,3-c)-benzopyran-7(H)-one (79). [Scheme-27]. The structure of this compound was assigned on the basis of its PMR spectrum recorded in ($CDCl_3$). The signals shown by (79) are as follows (Fig. 11). Singlet at δ 1.5 for six protons indicated two methyl groups at C-3 Singlet at δ 2.35 indicated methyl group at C-5. The doublet at δ 5.7, J=9Hz, indicated proton at C-1. The another doublet at δ 6.4, J=9Hz, indicated proton at C-2. Two doublets at δ 5.7 and 6.4 indicated the presence of pyrano ring in the compound. Singlet at δ 7.3 indicated proton at C-13. A multiplet from δ7.2-8.0 indicated four aromatic protons at C-9, C-10, C-11 and C-12. Mechanism of the Claisen rearrangement is shown in [Scheme-28].

In continuation of the work carried out by Shah and Trivedi,[31] it was thought of interest to study Claisen rearrangement in diallyloxy coumestans and synthesis difurano coumestans and benzofurano coumestans.

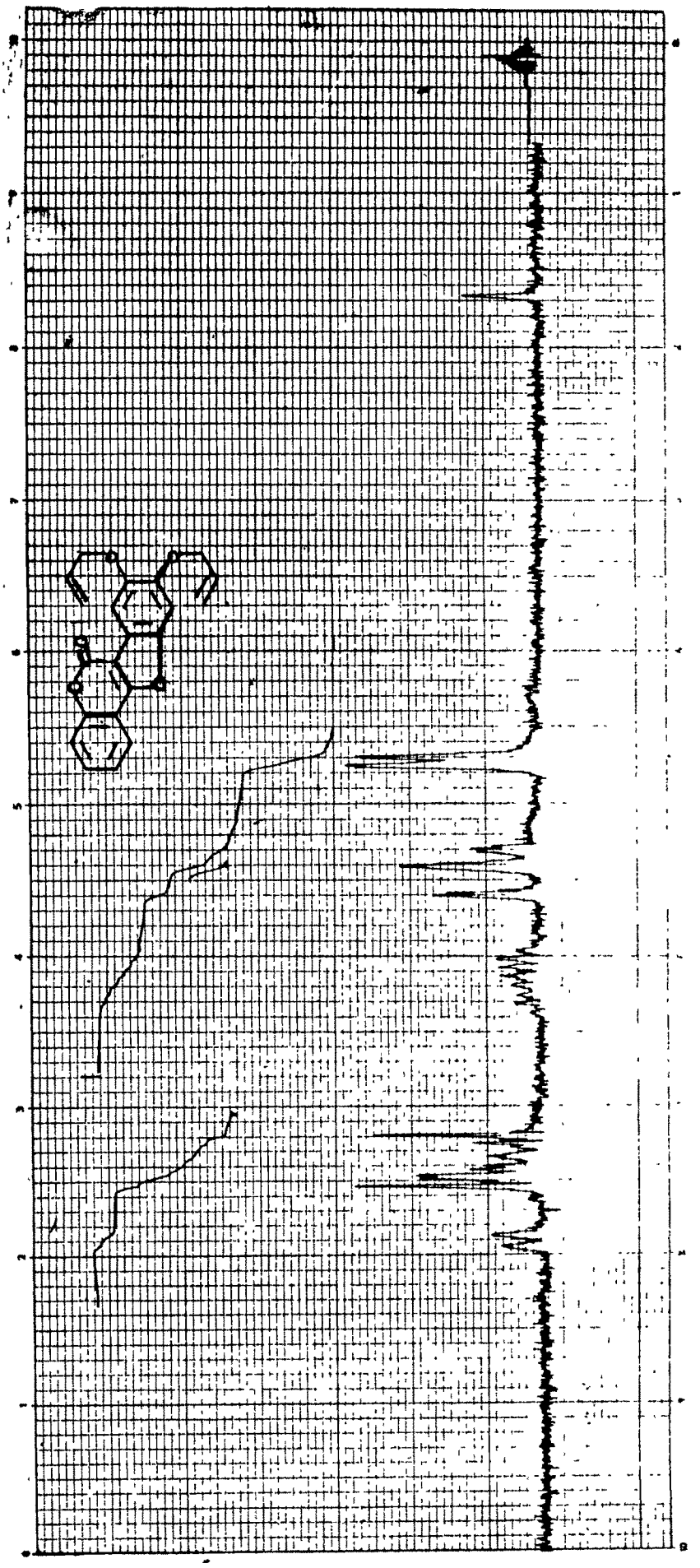
Synthesis of 8,11-dimethyl-difuro (2,3-e ; 2',3'-g)-bezopyran-(3,2-c) ~~(2,3-c)~~-6(H)-one (85)

4-Hydroxy coumarin (80) was condensed with catechol in presence of potassium periodate and sodium acetate to give 8,9-dihydroxy-benzofuro-(3,2-c)-benzopyran-6(H)-one (81). This compound was condensed with allylbromide (2 mole) in

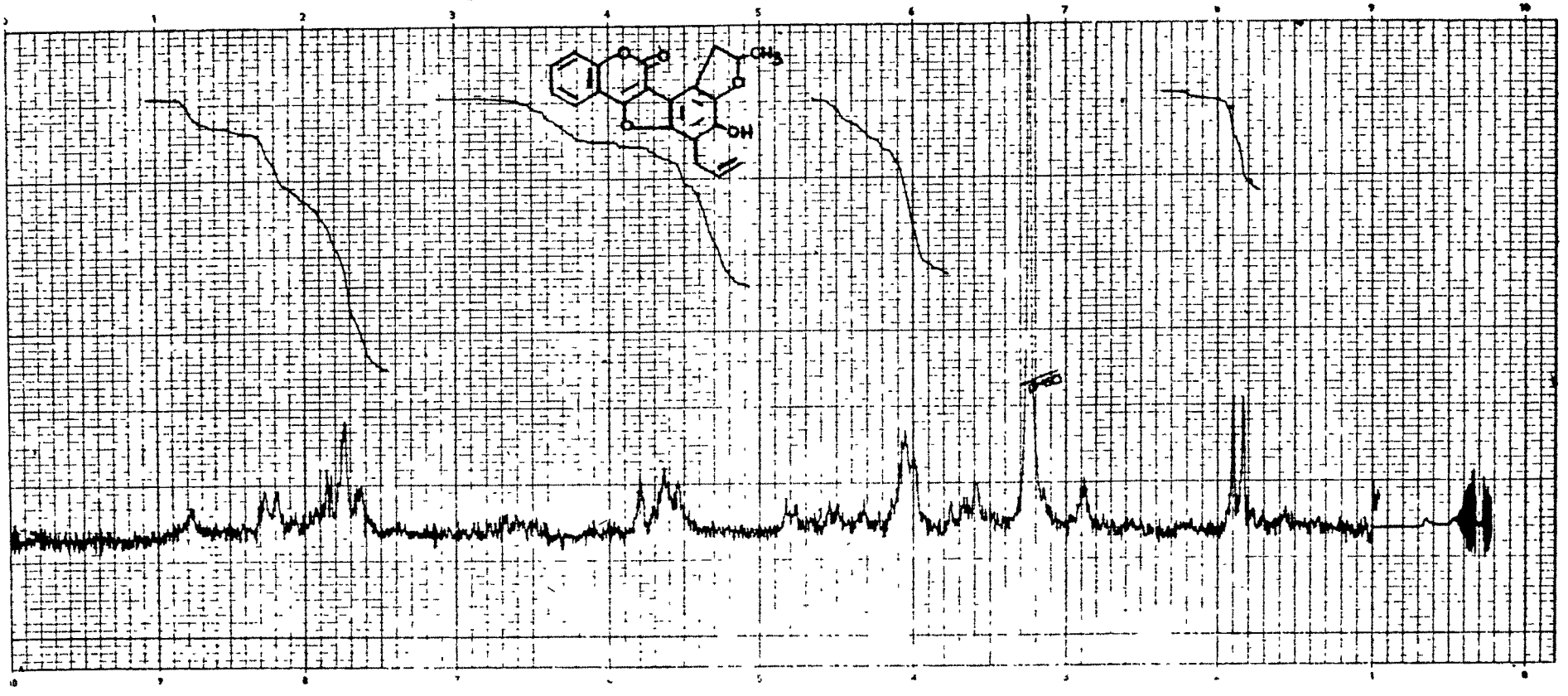
Scheme - 29


KIO3
CH3COONa
(80)
(81)
Allyl bromide
K2CO3, Acetone
N,N-DMA
Δ
(82)
(83)
conc. H2SO4
Pd/C
Ph2O, Δ
(84)
(85)

presence of anhydrous potassium carbonate and dry acetone, which gave 8,9-diallyloxy-benzofuro-(3,2-c)-benzopyran-6(H)-one (82). The structure of this compound was established by its PMR spectrum (Fig. 12). The double doublet at δ 4.6 for four protons indicated -O-$\underline{CH}_2$-CH=CH_2 group. Multiplet at δ 5.2-5.5 for four protons indicated terminal methylene group. The another multiplet at δ 5.9-6.3 indicated two -$\underline{CH}$=CH_2 protons. The multiplet from δ 7.1-7.9 indicated all aromatic protons. (82) was subjected to Claisen rearrangement in boiling N,N-dimethylaniline for 6 hrs. On working up the reaction mixture, the product obtained was 11-allyl-10-hydroxy-8-methyl-dihydrofuro (2,3-e)-benzofuro (3,2-c)-benzopyran-6(H)-one (83). As discussed in Chapter-II, Claisen rearrangement of 6,7-diallyloxy-4-methyl-coumarin, gave in this rearrangement also, a compound (90) similarly where one allyl group migrated and other allyl group got cyclised after migration is obtained. The structure of this compound was established by its PMR spectrum [Scheme-29]. The signals of PMR spectrum taken in ($CDCl_3$ + drop of DMSO-d_6) are as follows : (Fig. 13). The doublet at δ 1.6 indicated methyl group at C-8. The double doublets from δ 3.0-3.3 (J=18,8Hz) indicated proton at C-7. The other multiplet at δ 3.6-4.2 indicated other proton at C-7 and two protons of allyl group at C-11. The multiplet at δ 5.1-5.55 indicated terminal methylene protons of allyl group and one proton of dihydrofuran



(fig-12) : 8, 9- diethyloxy-benzofuro (3, 2-c)-benzopyran-6H)-one (82).



(fig-13): 11-Allyl-10-hydroxy-8-methyl-dihydrofuro (2,3-e)-benzofuro (3,2-c) benzopyran-6(H)-one (83).

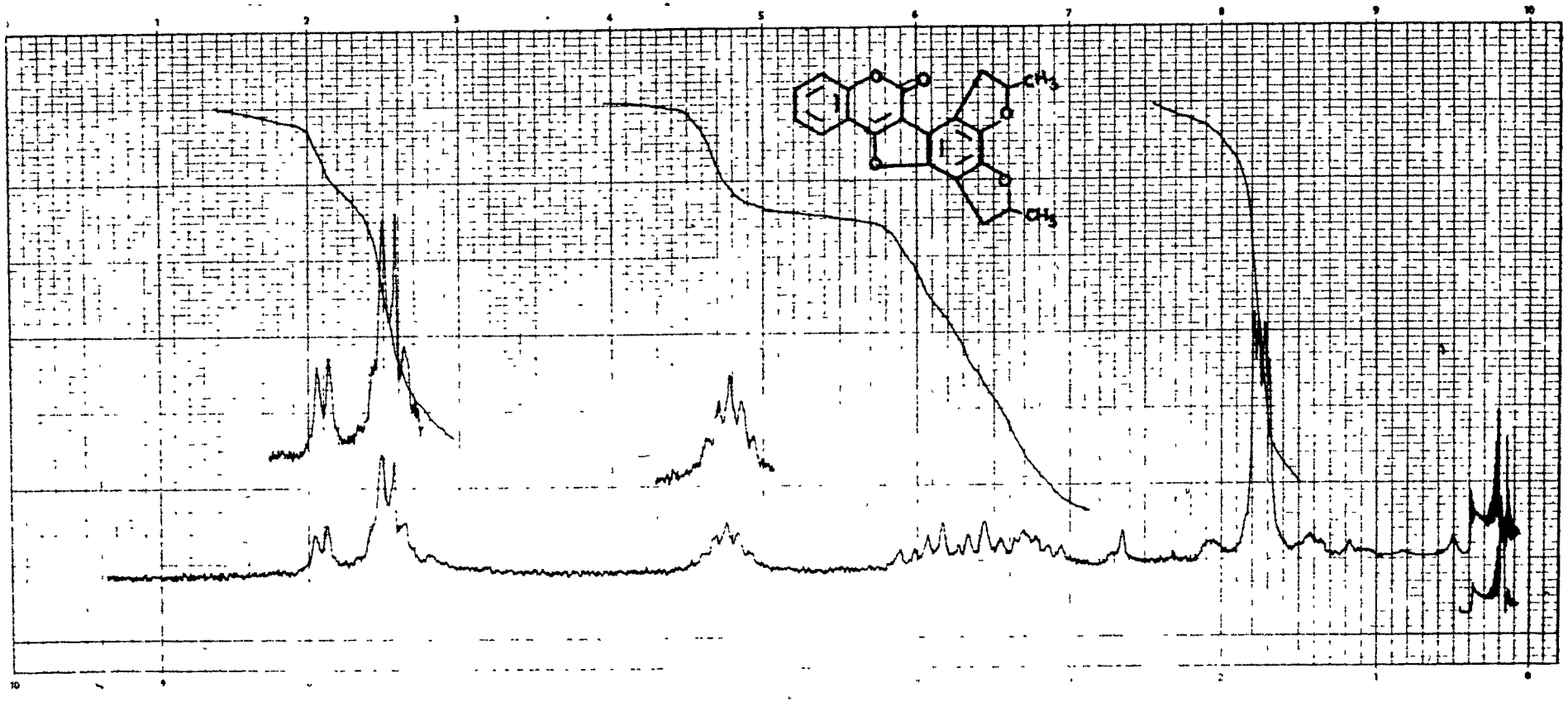
ring at C-8. The multiplet at δ6.0-6.4 indicated -CH=CH_2 proton of allyl group. Multiplet from δ7.3-8.0 indicated four aromatic protons at C-1, C-2, C-3 and C-4.

(83) on cyclisation in conc. H_2SO_4 (80%) gave 8,11-dimethyl-dihydrodifuro (2,3-e : 2',3'-g)-benzofuro (3,2-c)-benzopyran-6(H)-one (84) [Scheme-29]. This compound was insoluble in aq. NaOH, indicating that no free dihydroxy group is present. The structure of this compound was established by its PMR spectrum taken in ($CDCl_3$) (Fig. 14). The doublet at δ 1.5 indicated methyl group at C-8. The another doublet at δ 1.6 indicated $-CH_3$ group at C-11. The two double doublets mixed with each other at δ 2.8-4.0 (J=18,8Hz) indicated protons at C-7 and C-12. Multiplet at δ 4.8-5.2 indicated two protons at C-8 and C-11. The multiplet at δ 7.05-7.8 indicated four aromatic protons at C-1, C-2,C-3 and C-4. (Fig. 14)

Compound (84) on dehydrogenation with palladised charcoal (10%) in boiling diphenylether gave 8,11-dimethyl-difuro-(2,3-e : 2',3'-g)-benzofuro (3,2-c)-benzopyran-6(H)-one (85). The structure of this compound was established by its elememental analysis and mass spectrum. It showed molecular ion peak at m/e 344 (Fig. 15).

Synthesis of 10,11-dimethoxy-dibenzofuro (3,2-c :'3',2'-g)-benzopyran-8(H)-one (92)

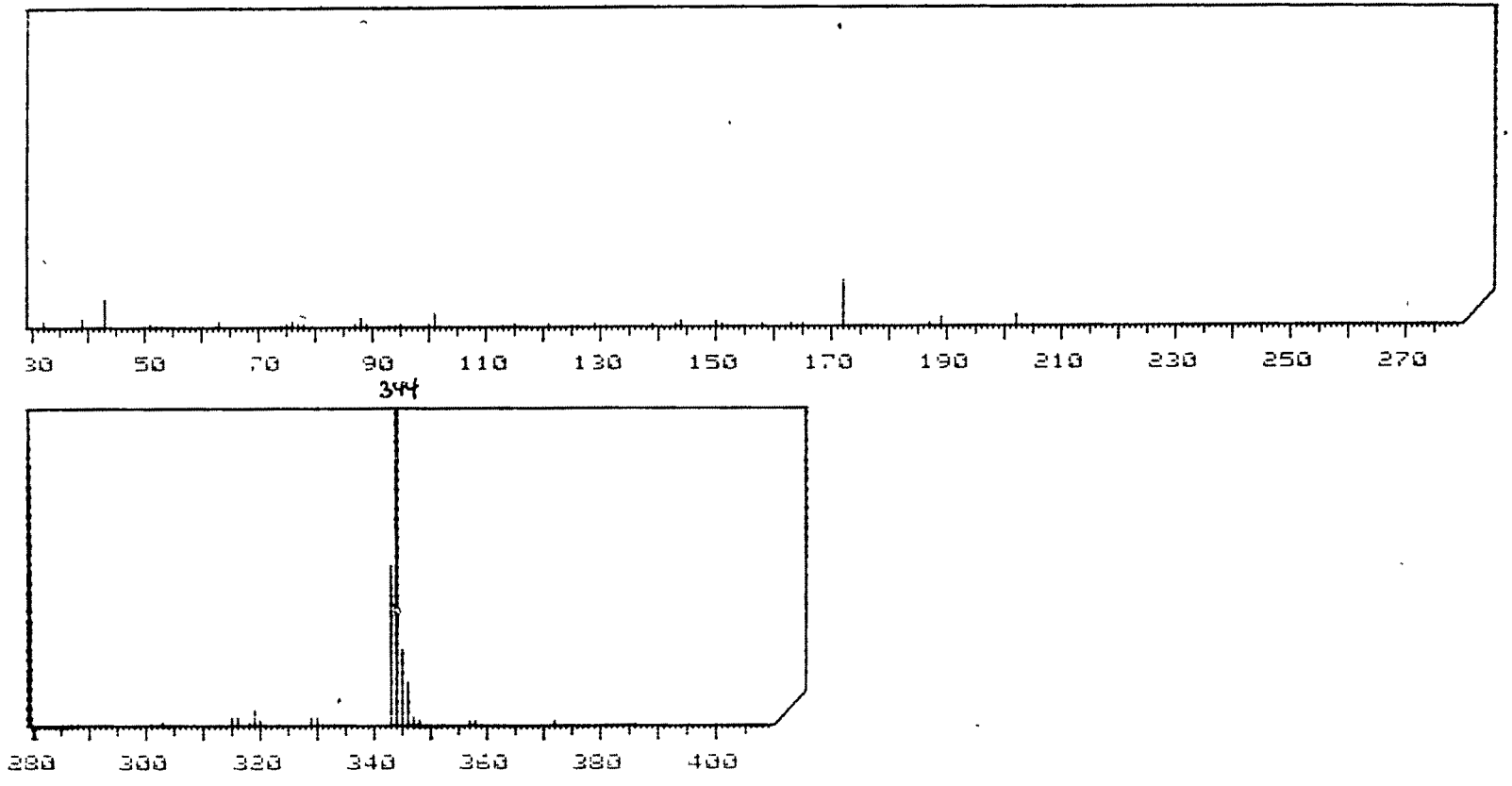
2,4-Dihydroxy acetophenone (86) on condensation with



(fig-14) : 8, 11 – dimethyldihydrofuro (2, 3 – e : 2', 3' – g) – benzofuro (3, 2 – c) – benzopyran – 6(H) – one. (84)

SP 117

DATA	R.T.	PEAK	MASS RANGE		BASE PEAK	TOTAL	RAW-	B.G.
53	3.1	338	32-	403	338403(| 344)	1333372	0-	0
		332	32-	403	338403(| 344)	1331334	0-	0



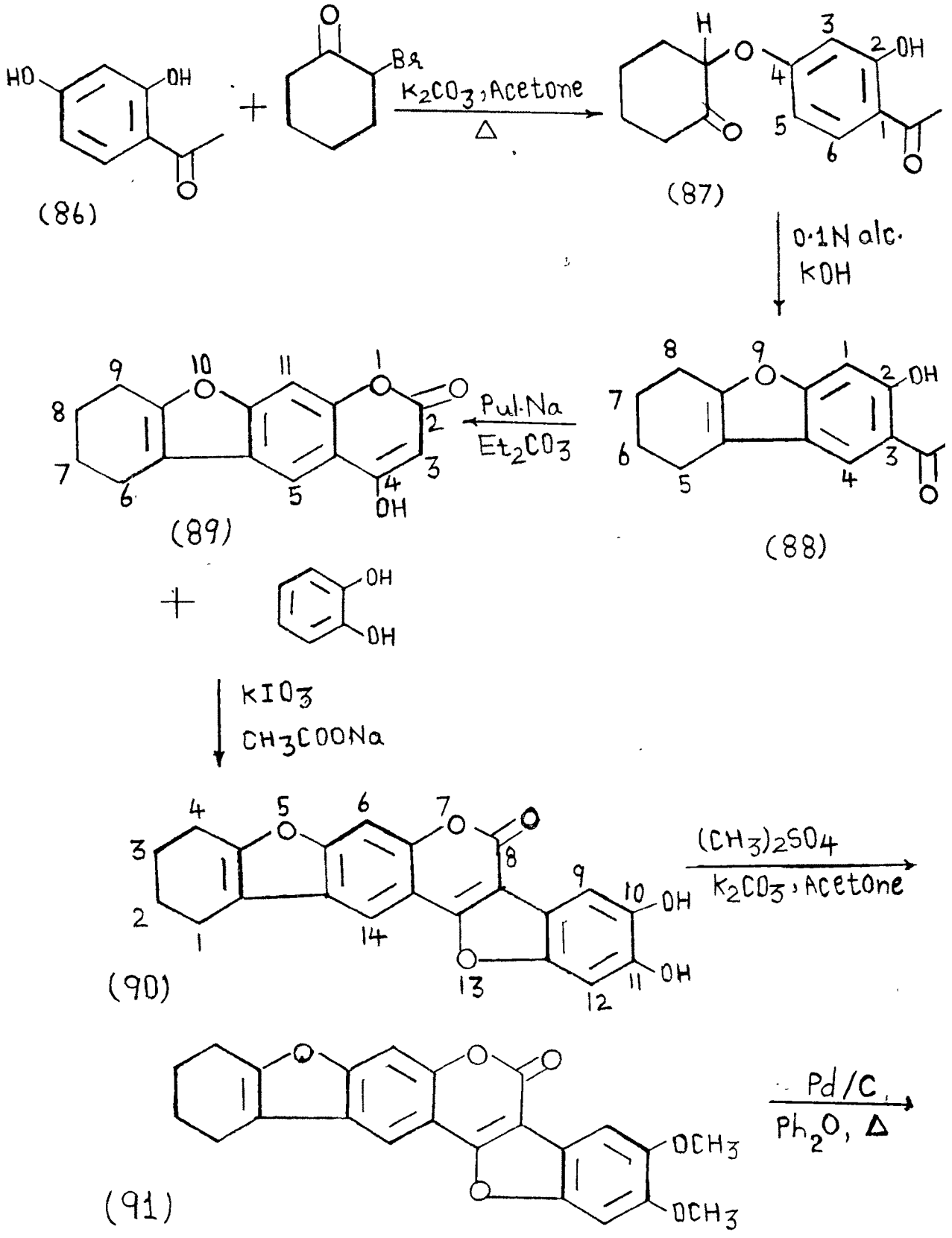
(fig-15): 8,11-dimethyl-difuro-(2,3-e:2',3'-g)-benzofuro-(3,2-c)-benzopyran-6(H)-one. (85).

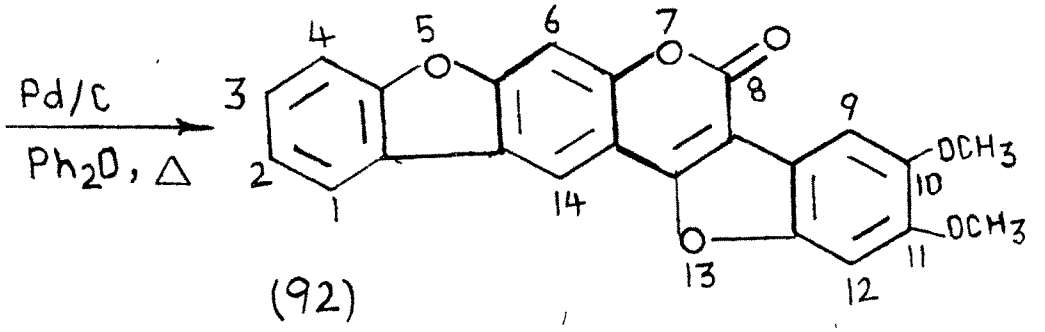
2-bromocyclohexanone in presene of anhydrous potassium carbonate and dry acetone gave 4-cyclohexan-2-onyloxy-2-hydroxy-acetophenone (87) [Scheme-30]. This on cyclisation with O.1N alcoholic potassium hydroxide gave 5,6,7,8-tetrahydro-2-hydroxy-3-acetyl-dibenzofuran (88) [Scheme-30]. The structure of this compound was established by itsPMR spectrum in ($CDCl_3$) (Fig. 16). The multiplet at δ 1.6-2.0 indicated four protons of $-CH_2$ group at C-6 and C-7. Multiplet at δ 2.4-2.8 indicated 4 protons of $-CH_2$ group at C-5 and C-8. Singlet at δ 2.6 indicated $-CH_3$ of acetyl group. Singlet at δ 6.9 indicated C-1 proton while singlet at δ 7.7 indicated proton at C-4. Singlet at δ 12.0 indicated chelated -OH group at C-2. The linear fusion of the ring can be explained on the basis of intramolecular aldol condensation in which the phenoxide ion (88a) attack the exocyclic carbonyl group through the carbanion generated at para position to phenoxide ion to give (88b) followed by abstraction of the proton at the ring junction to regnerate the phenoxide ion (88c) which on protonation eliminates water from the β-hydroxydihydrofuran to give (88) [Scheme-31].

43

The compound (88) on condensation with diethyl carbonate in the presence of pulverised Na gave 4-hydroxy-6,7,8,9-tetrahydro-2(H)-benzofuro (3,2-g)-benzopyran-2(H)-one (89) [Scheme-30]. The structure of this compound was established by its PMR spectrum taken in ($DMSO-d_6$) (Fig. 17). The multiplet

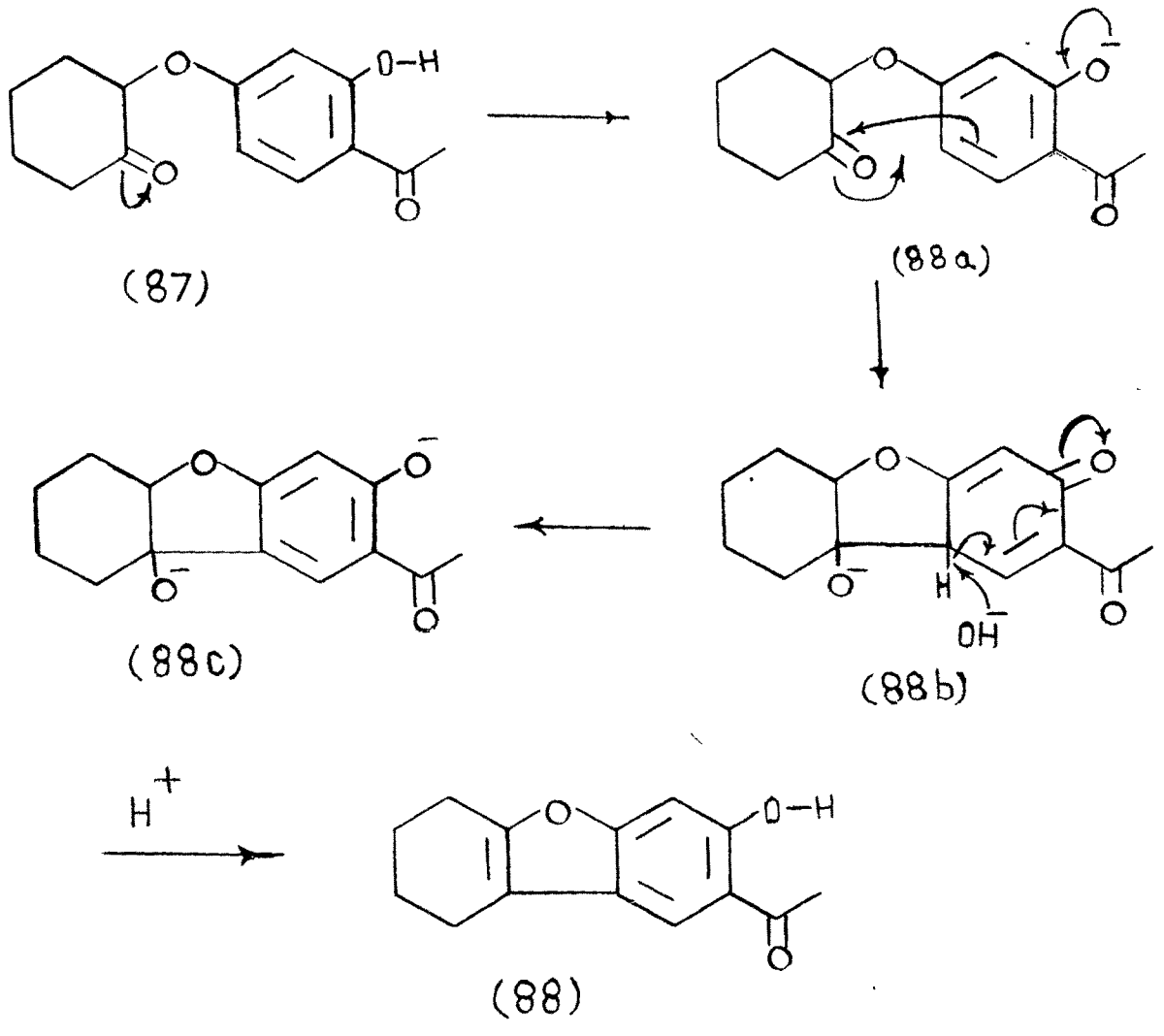
Scheme - 3D


HO
OH
Br
K_2CO_3, Acetone
Δ
(86)
(87)
0·1N alc. KOH
Pul·Na
Et_2CO_3
(89)
(88)
OH
OH
KIO_3
CH_3COONa
(90)
$(CH_3)_2SO_4$
K_2CO_3, Acetone
Pd/C
Ph_2O, Δ
OCH_3
OCH_3
(91)



(92)

Scheme - 31



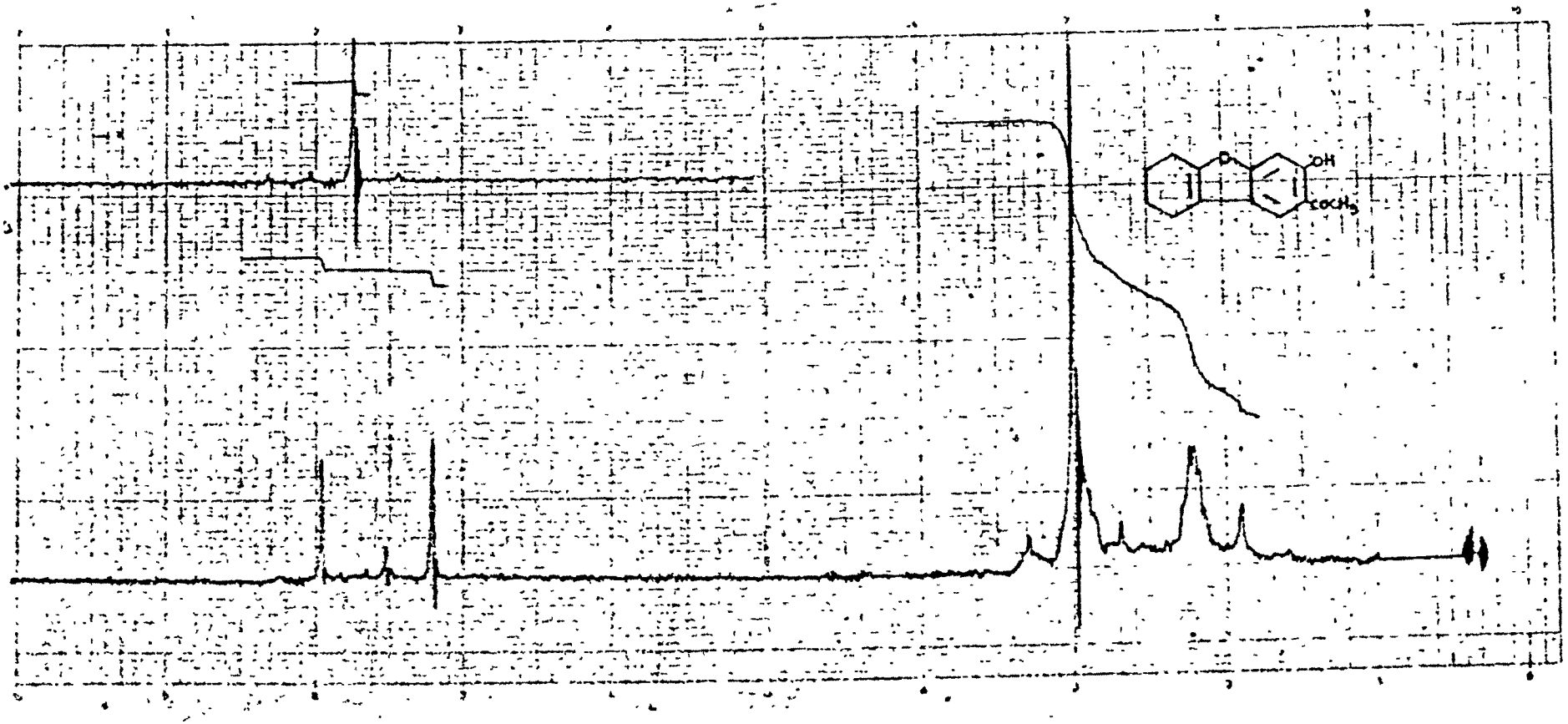
(87)

(88a)

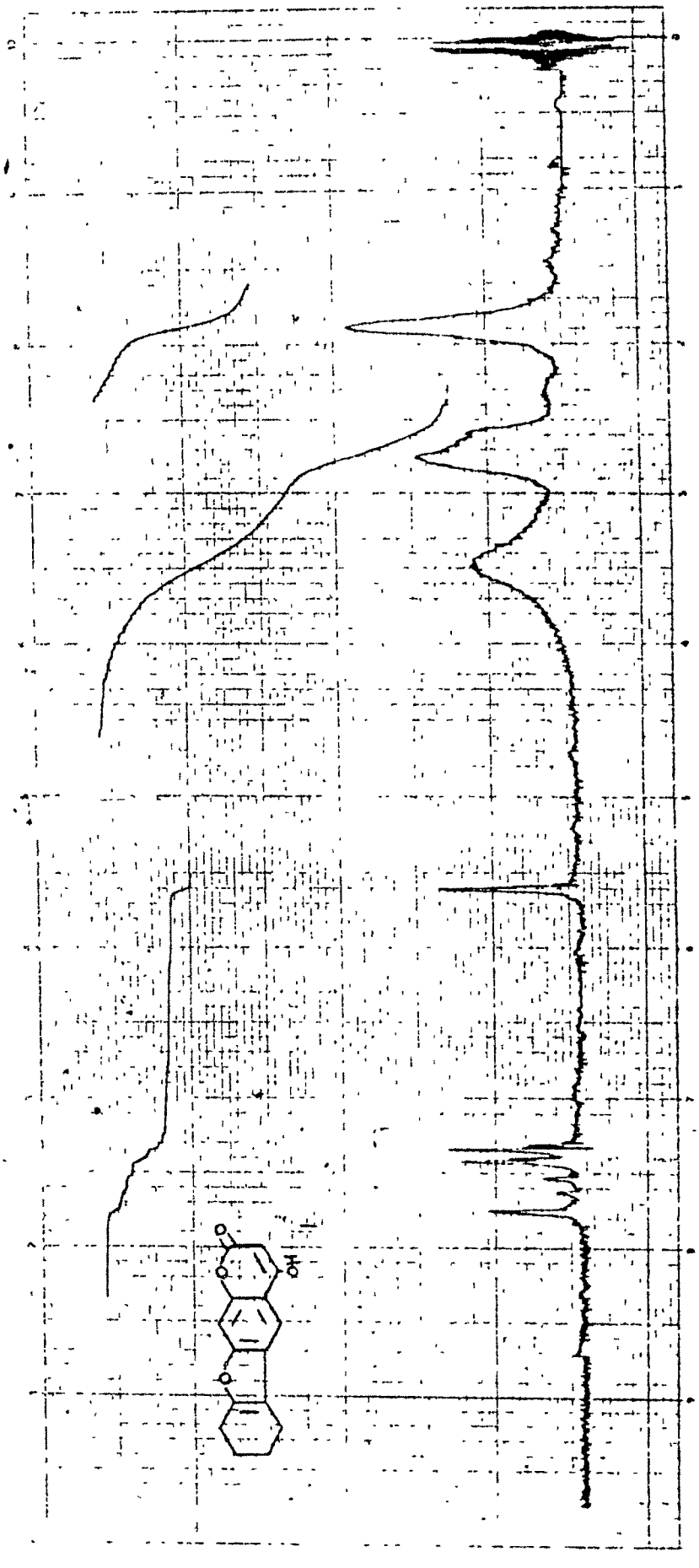
(88b)

(88c)

(88)



(fig-16): 5,6,7,8 - tetrahydro - 2- hydroxy - 3-acetyl-dibenzofuran (88).

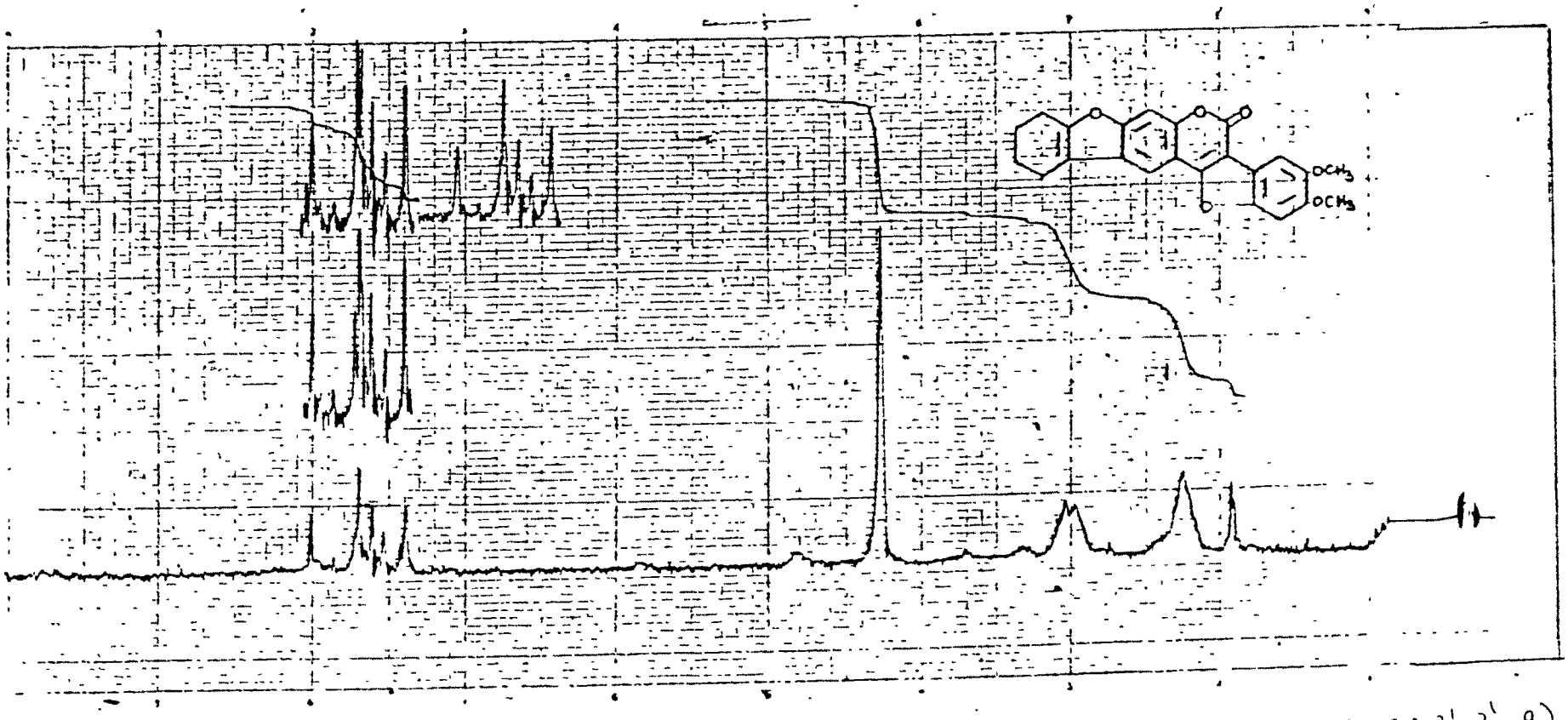


(Fig-17) : 4-Hydroxy-6,7,8,9-tetrahydro-benzofuro-(3,2-g) benzopyran-2(H)-one. (89).

at δ 1.6-2.0 indicated four protons at C-7 and C-8. The another multiplet at δ 2.4-2.8 indicated four protons at C-6 and C-9. Singlet at δ 5.4 indicated proton at C-3. Singlet at δ 7.25 is due to proton at C-11. The another singlet at δ 7.65 indicated proton at C-5.

Compound (89) when condensed with catechol by Wanzlick's method using sodium acetate, potassium periodate and aqueous acetone gave 10,11-dihydroxy-1,2,3,4-tetrahydro dibenzofuro (3,2-c : 3',2'-g)-benzopyran-8(H)-one (90). The product obtained was directly methylated with dimethylsulfate in presence of anhydrous potassium carbonate and dry acetone to obtain 10,11-dimethoxy-1,2,3,4-tetrahydro-dibenzofuro-(3,2-c : 3',2'-g) benzopyran-8(H)-one (91). The structure of this compound was established by its PMR spectrum taken in ($CDCl_3$). Multiplet at δ 1.7 to 2.0 is for 4 protons at C-2 and C-3. The another multiplet at δ 1.5-2.8 is for 4 protons at C-1 and C-4. Singlet at δ 4.0 is for two $-OCH_3$ groups at C-10 and C-11. Singlet at δ 7.1 is for proton at C-14. The other singlet at δ 7.25 is for aromatic proton at C-12. Singlet at δ 7.3 is for aromatic proton at C-9. Singlet at δ 7.4 is for aromatic proton at C-6. (fig-18)

Compound (91) on dehydrogenation with palladised charcoal (10%) in boiling diphenylether gave 10,11-dimethoxy-dibenzofuro (3,2-c : 3',2'-g)-benzopyran-8(H)-one (92). The structure

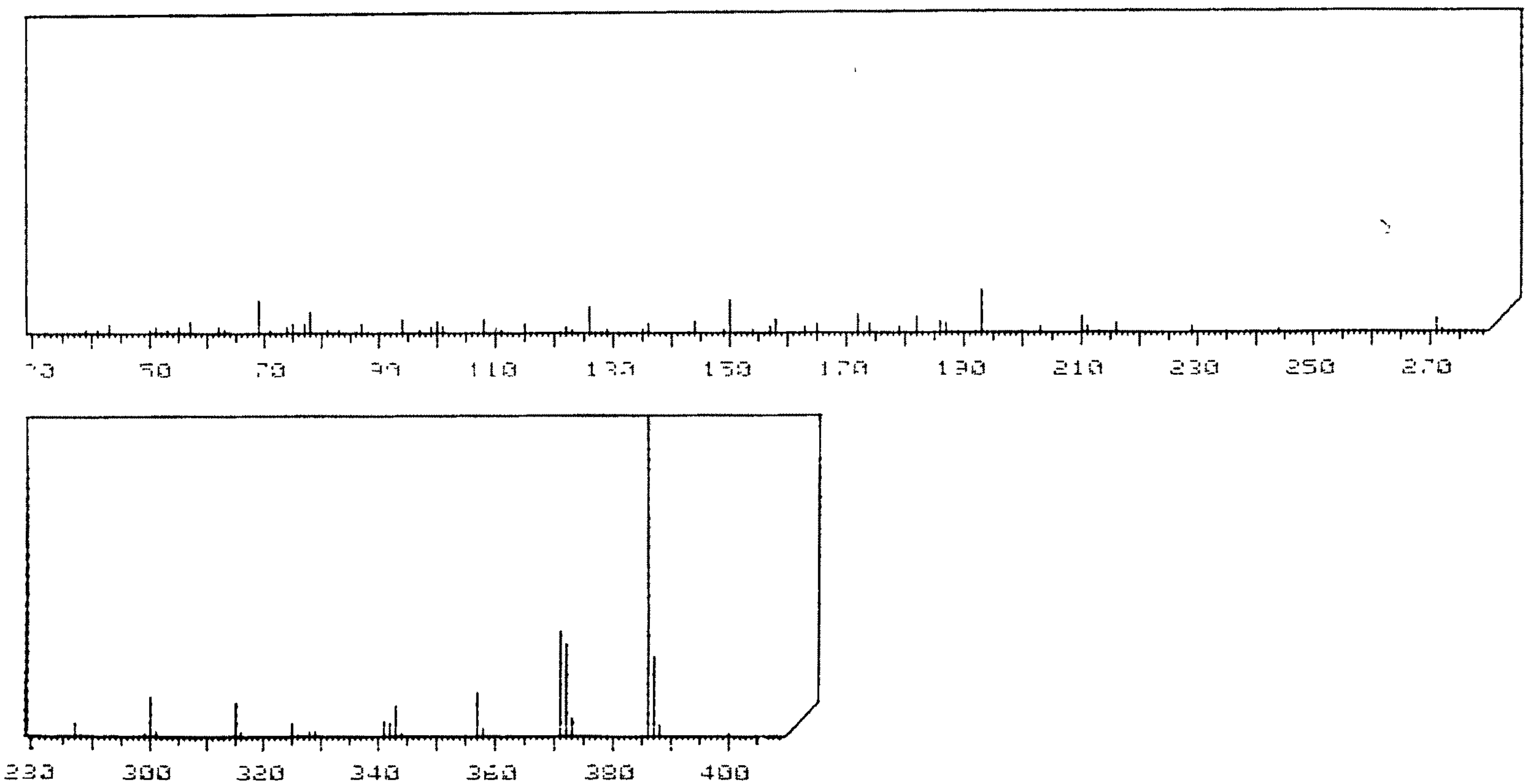


(fig-18) : 10, 11-dimethoxy-1, 2, 3, 4-tetrahydro-dibenzofuro-(3, 2-c : 3', 2'-g) benzopyran-8(H)-one (91)

FILENAME:RL0113.05
COMMENT:KK39

MODE: EI
EV: 70 GAIN: 3.8
IS TEMP: 250 SCAN SPEED: 3
DI TEMP: 147

DATA	R.T.	PEAK	MASS RANGE	BASE PEAK		TOTAL	RAW-	B.S.
41	2.3	234	31- 400	393800	336	2505235	3-	3
		122	32- 400	393800	336	2233170	3-	0



(fig-19): 10, 11-dimethoxy-dibenzofuro (3, 2-c : 3', 2'-g) - benzopyran 8(H) - one. (92)

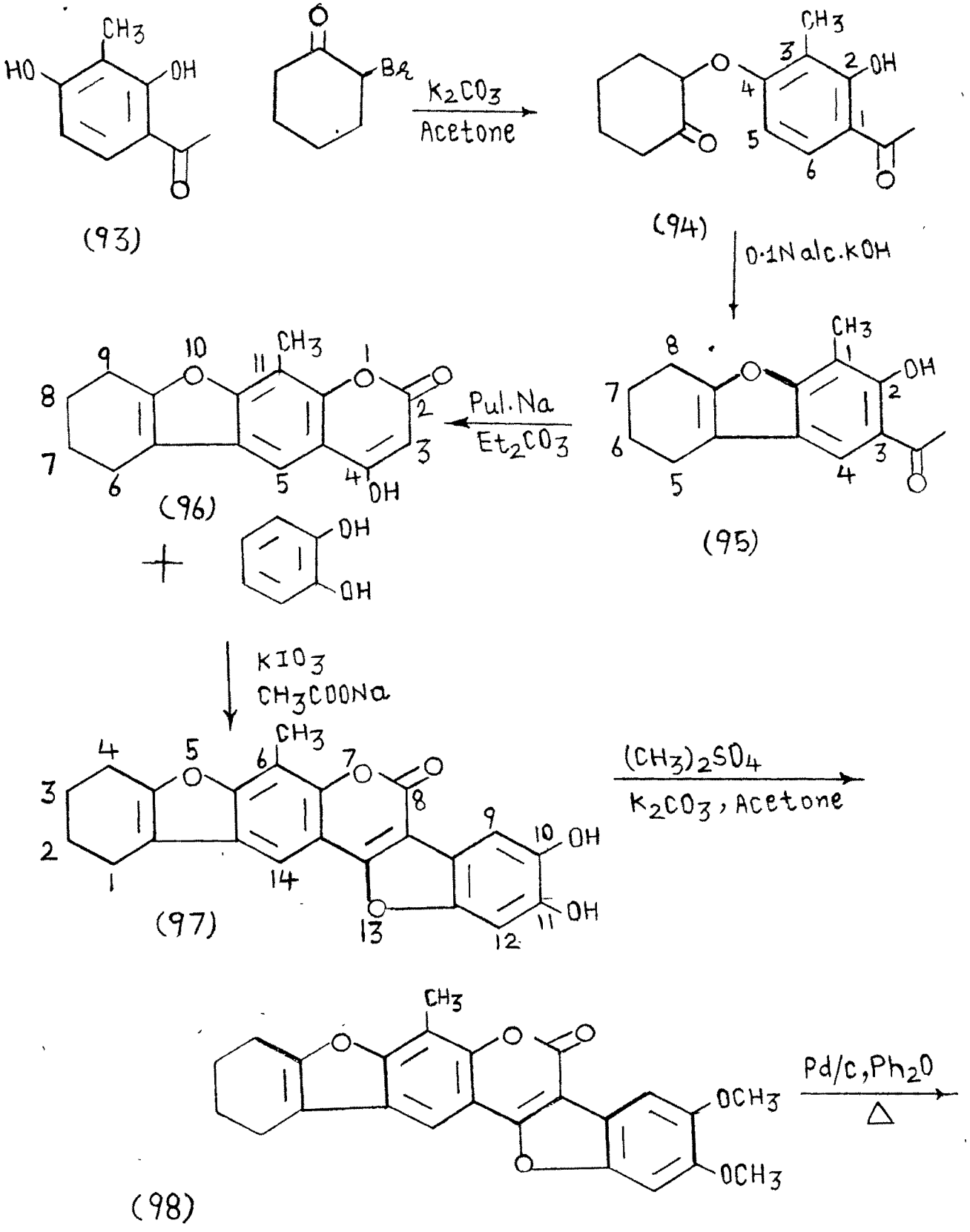
of this compound was proved by its mass spectrum. The molecular ion peak was obtained at M/e 386 (Fig. 19). The another peak at 358 indicated elimination of neutral molecule CO from the parent compound.

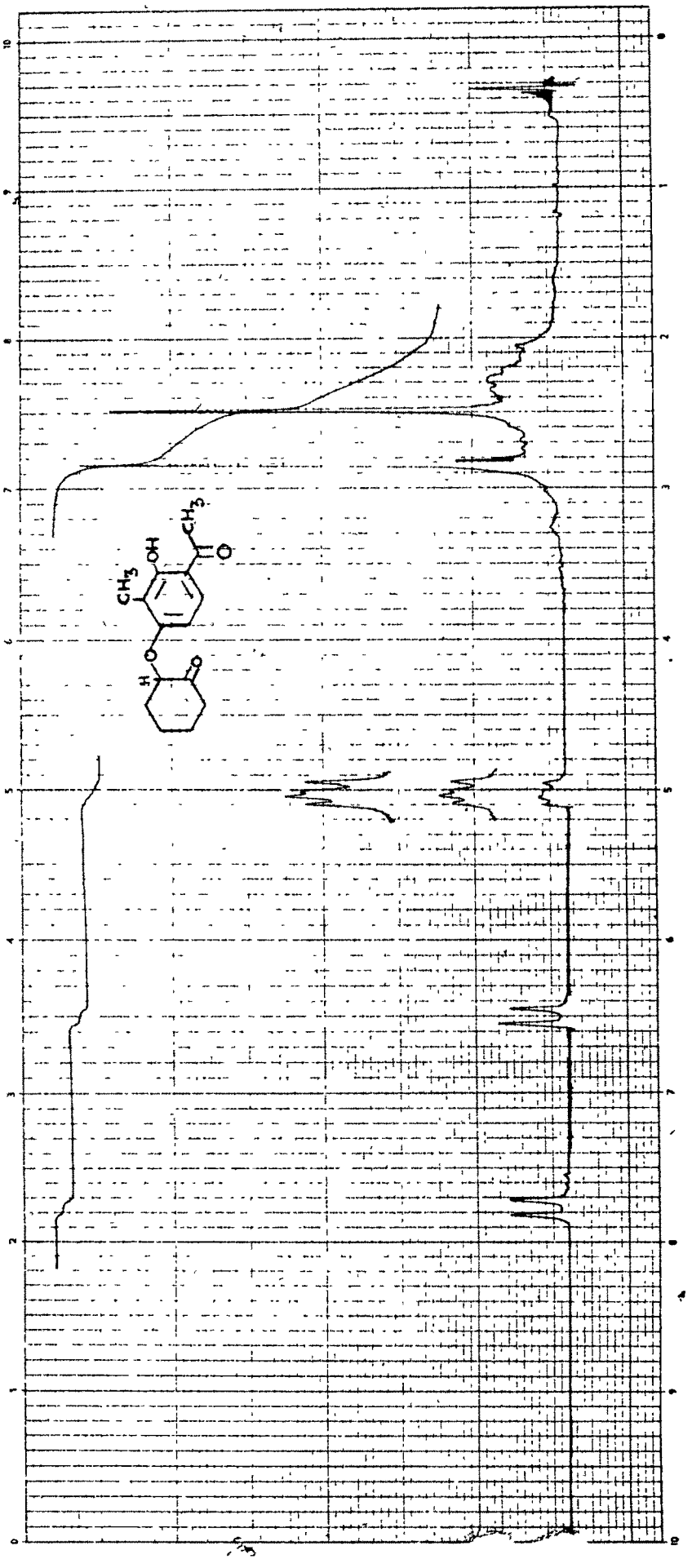
Synthesis of 10,11-dimethoxy-6-methyl-dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one (99)

2,4-Dihydroxy-3-methylacetophenone (93) when condensed with 2-bromocyclohexanone in presence of anhydrous potassium carbonate and dry acetone gave 4-cyclohexan-2-onyloxy-2-hydroxy-3-methylacetophenone (94) [Scheme-32]. The structure of this compound was established by its PMR spectrum taken in ($CDCl_3$) (Fig. 20). Singlet at δ 2.2 is for methyl group at C-3. Another singlet at δ 2.55 is for $-CH_3$ of acetyl group. Multiplet at δ 1.7-2.6 indicated all methylene ($-CH_2-$) protons of cyclohexanone ring. Triplet at δ 4.7 is for proton of ($H_2C-\underset{\underset{O}{|}}{CH}-\underset{\underset{O}{||}}{C}-$). Two doublets at δ 6.2 and 7.45, J=9Hz indicated orthocoupling of two protons at C-5 and C-6.

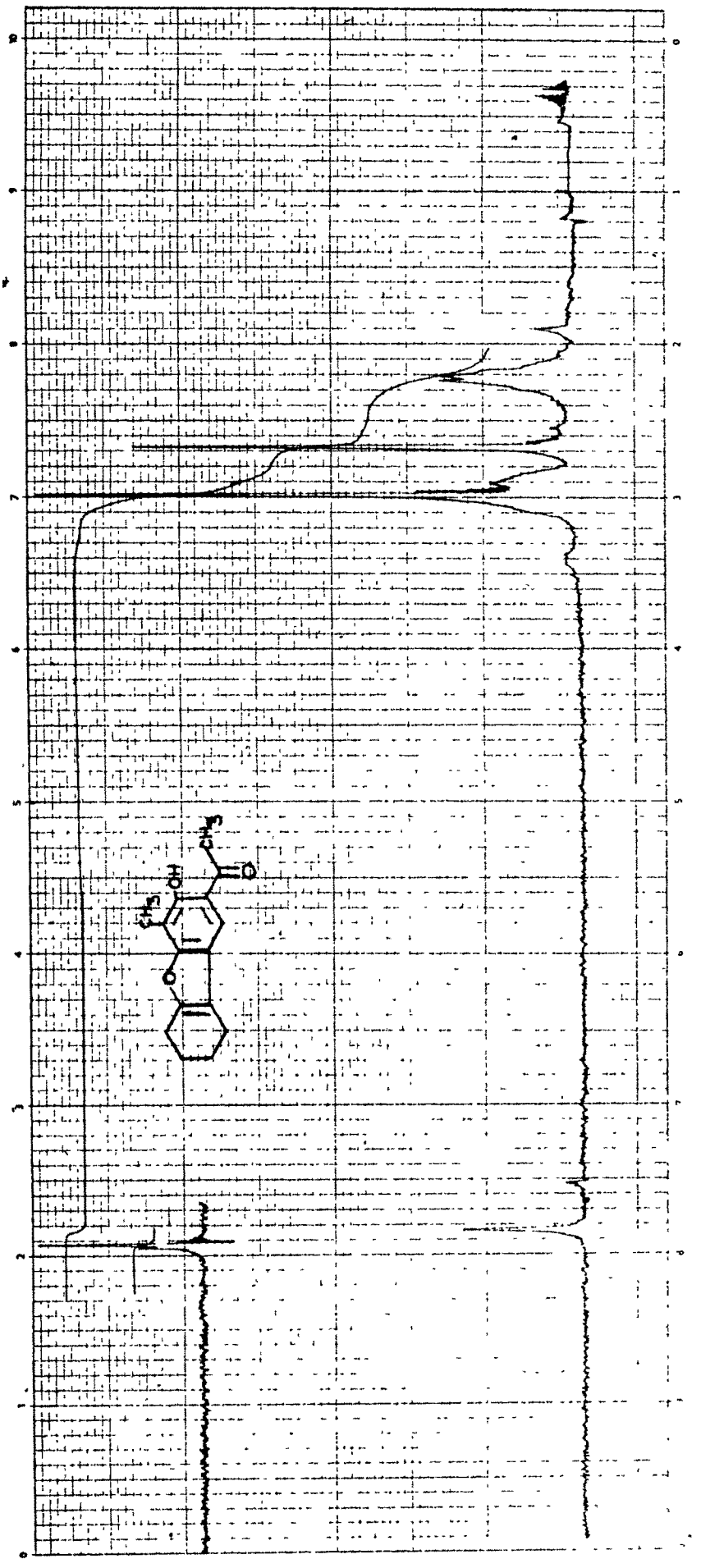
Compound (94) on cyclisation with 0.1N alcoholic potassium hydroxide gave 5,6,7,8-tetrahydro-3-acetyl-2-hydroxy-1-methyl-dibenzofuran (95) [Scheme-32]. The structure of this compound was established by its PMR spectrum taken in ($CDCl_3$) (Fig. 21). The signals are as follows : Multiplet at δ 1.7-2.0 is due to $-CH_2$ group at C-6 and C-7. Singlet at δ 2.45 is

Scheme - 32


CH3
HO
OH
Br
K2CO3
Acetone
(93)
(94)
0·1N alc.KOH
(95)
Pul.Na
Et2CO3
(96)
OH
OH
KIO3
CH3COONa
(97)
(CH3)2SO4
K2CO3, Acetone
OCH3
OCH3
Pd/c, Ph2O
△
(98)



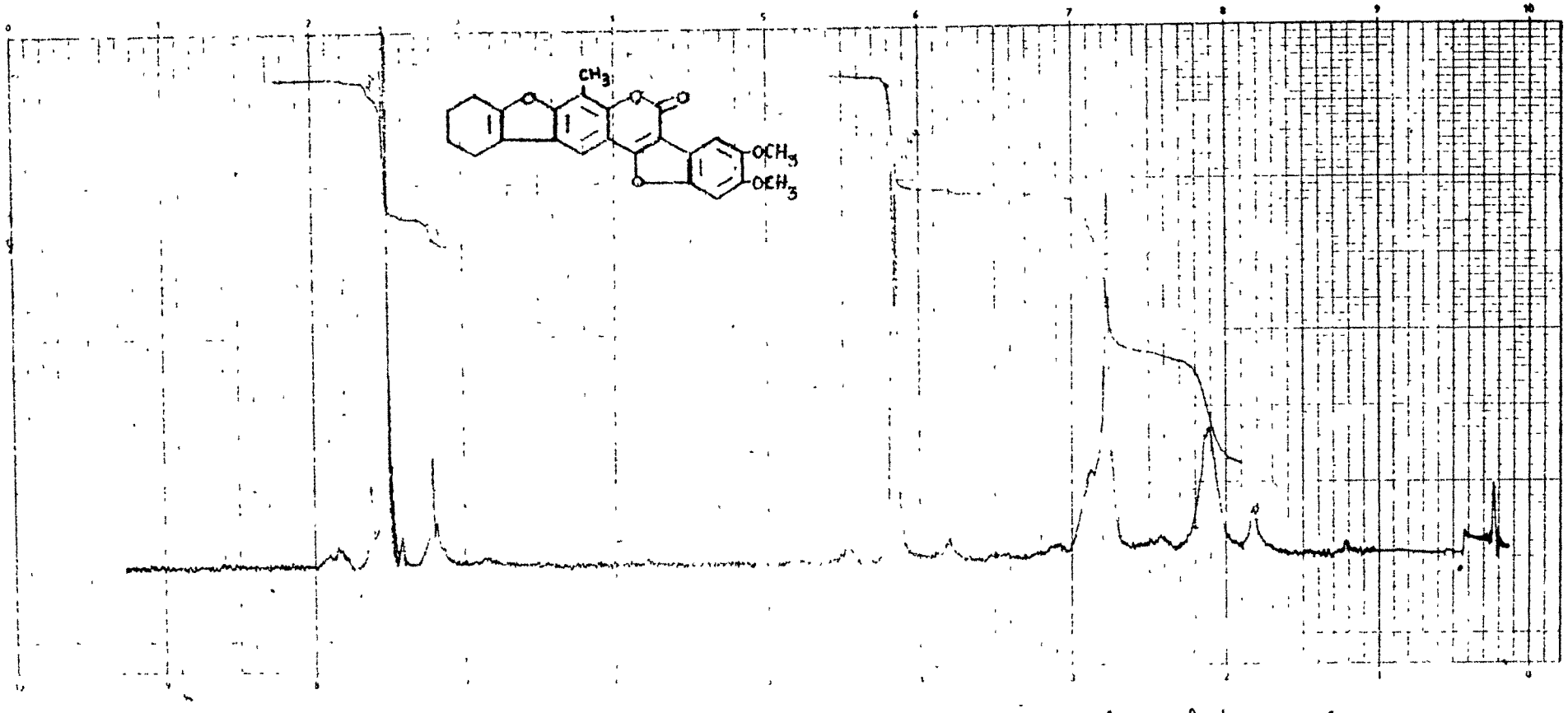
(Fig - 20) : 4-Cyclohexan-2-oxyloxy-2-hydroxy-3-methyl acetophenone. (94).



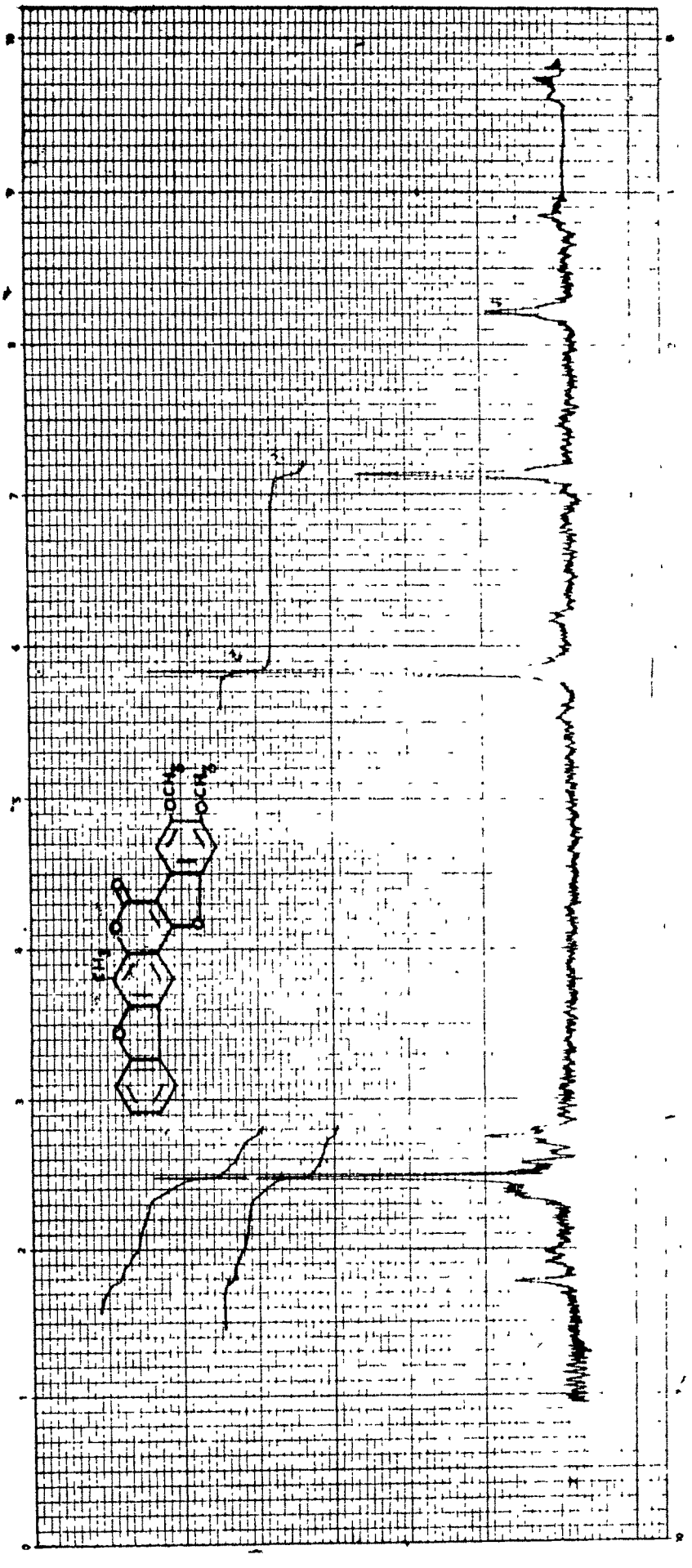
(fig-21) : 5, 6, 7, 8 - tetrahydro - 3-acetyl - 2-hydroxy - 1-methyl dibenzofuran (9S)

of $-CH_3$ group at C-1. Multiplet at δ 2.5-2.8 indicated $-CH_2$ group at C-5 and C-8. Singlet at δ 2.7 indicated $-CH_3$ of acetyl group. Singlet at δ 7.5 indicated aromatic proton at C-4. Singlet at δ 12.6 is due to -OH group at C-2.

(95) on condensation with diethylcarbonate in presence of sodium gave 11-methyl-4-hydroxy-6,7,8,9-tetrahydro (2,3-g) benzofuro-benzopyran-2(H)-one (96). The compound is soluble in sodium bicarbonate which indicated the presence of weakly acidic 4-hydroxy group. (96) when condensed with catechol using potassium periodate, sodium acetate and aqueous acetone gave 10,11-dihydroxy-6-methyl-1,2,3,4-tetrahydro-dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one (97). The product obtained was used directly for further reaction. (97) was condensed with dimethyl sulfate in presence of anhydrous potassium carbonate in dry acetone gave 10,11-dimethoxy-6-methyl-1,2,3,4-tetrahydro-dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one (98) [Scheme-32]. The structure of this compound was established by its PMR spectrum taken in ($CDCl_3$) (Fig. 22). The broad multiplet at δ 1.75-2.0 indicated 4 protons at C-2 and C-3. Singlet mixed with multiplet at δ 2.5-2.8 indicated methyl group at C-6 and four protons at C-1 and C-4. Two singlets at δ 3.95 and 4.0 indicated two $-OCH_3$ groups at C-10 and C-11 respectively. Three singlets at δ 7.0, 7.3 and 7.4 indicated three aromatic protons at C-9, C-12 and C-14 respectively.



(fig-22): 10,11-Dimethoxy-6-methyl-1,2,3,4-tetrahydro-dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one (98)



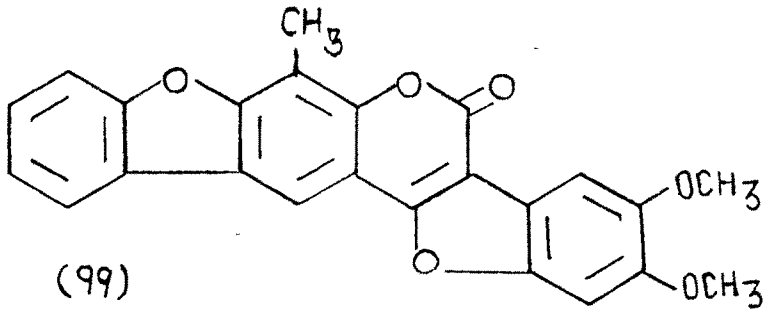
(fig-23) : 10,11-dimethoxy-6-methyl-dibenzofuro-c3,2-c:3',2'-g) benzopyran-8(H)-one (**99**).

(98) when refluxed in diphenylether with palladised charcoal (10%) gave 10,11-dimethoxy-6-methyl-dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one (99). The structure of this compound was established by its PMR spectrum taken in ($CDCl_3$) (Fig. 23). The singlet at δ 1.6 indicated $-CH_3$ group at C-6. The another singlet at δ 4.0 indicated two $-OCH_3$ groups at C-10 and C-11. Multiplet at δ 6.9-8.05 indicated seven aromatic protons.

Synthesis of dibenzofuro (3,2-c : 3',2'-g)-benzopyran-8(H)-one (102)

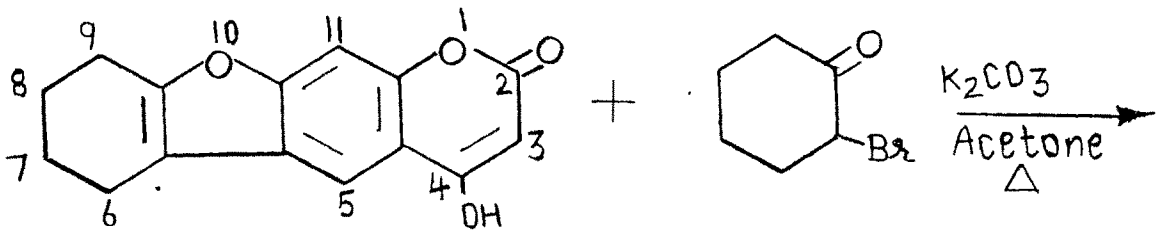
4-Hydroxy-6,7,8,9-tetrahydro-benzofuro (3,2-g)-benzopyran-2(H)-one (89) was condensed with 2-bromocyclohexanone in presence of anhydrous potassium carbonate in dry acetone to give 6,7,8,9-tetrahydro-4-(cyclohexanoloxy)-benzofuro (3,2-g)-benzopyran-2(H)-one (100) [Scheme-33]. The structure of this compound was established by its mass spectrum and IR spectrum. It showed molecular ion peak at m/e 352 (Fig. 24). The IR spectrum showed two bands at 1710 cm^{-1} and 1735 cm^{-1} indicating the presence of two carbonyl groups.

(100) on trituration in Conc. H_2SO_4 (80%) eliminated water molecule and gave the cyclised product, 1,2,3,4,9,10,11,12-octahydrodibenzofuro (3,2-c : 3',2'-g)-benzopyran-8(H)-one (101) [Scheme-33]. The structure of this compound was established by its PMR spectra taken in ($CDCl_3$) and IR spectrum.

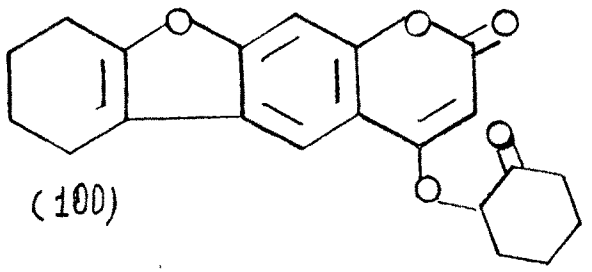


(99)

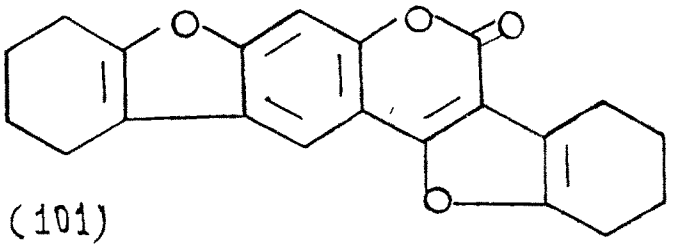
Scheme - 33



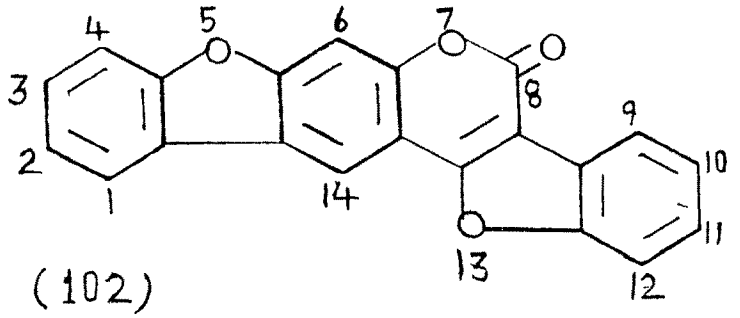
(89)



(100)



(101)

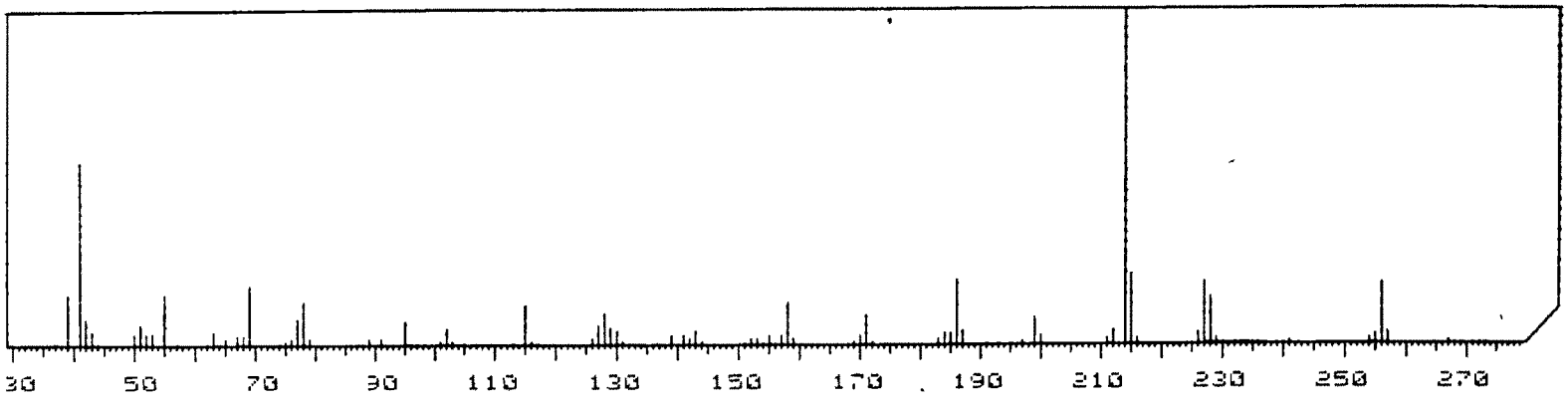


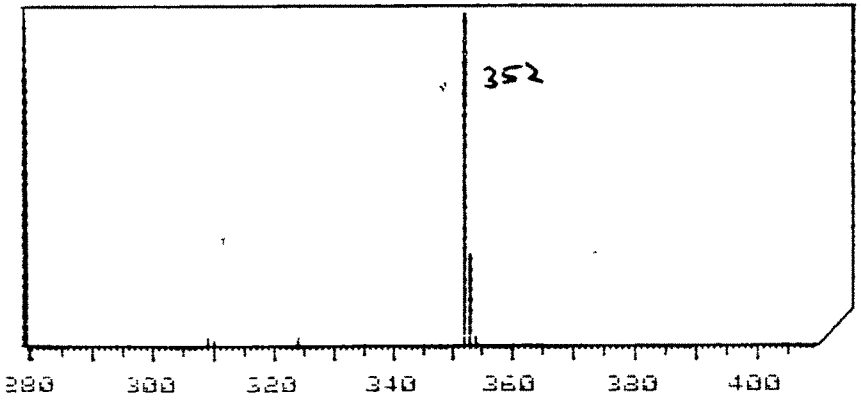
(102)

SP 108

MODE: EI
E V: 70 GAIN: 3.6
IT TEMP: 275 SCAN SPEED: 3
DI TEMP: 133

DATA	R.T.	PEAK	MASS RANGE	BASE PEAK	TOTAL	RAW-	B.G.
59	2.4	245	31- 368	313903(	214)	2635123	0- 0
		242	31- 368	313900(	214)	2624335	0- 0

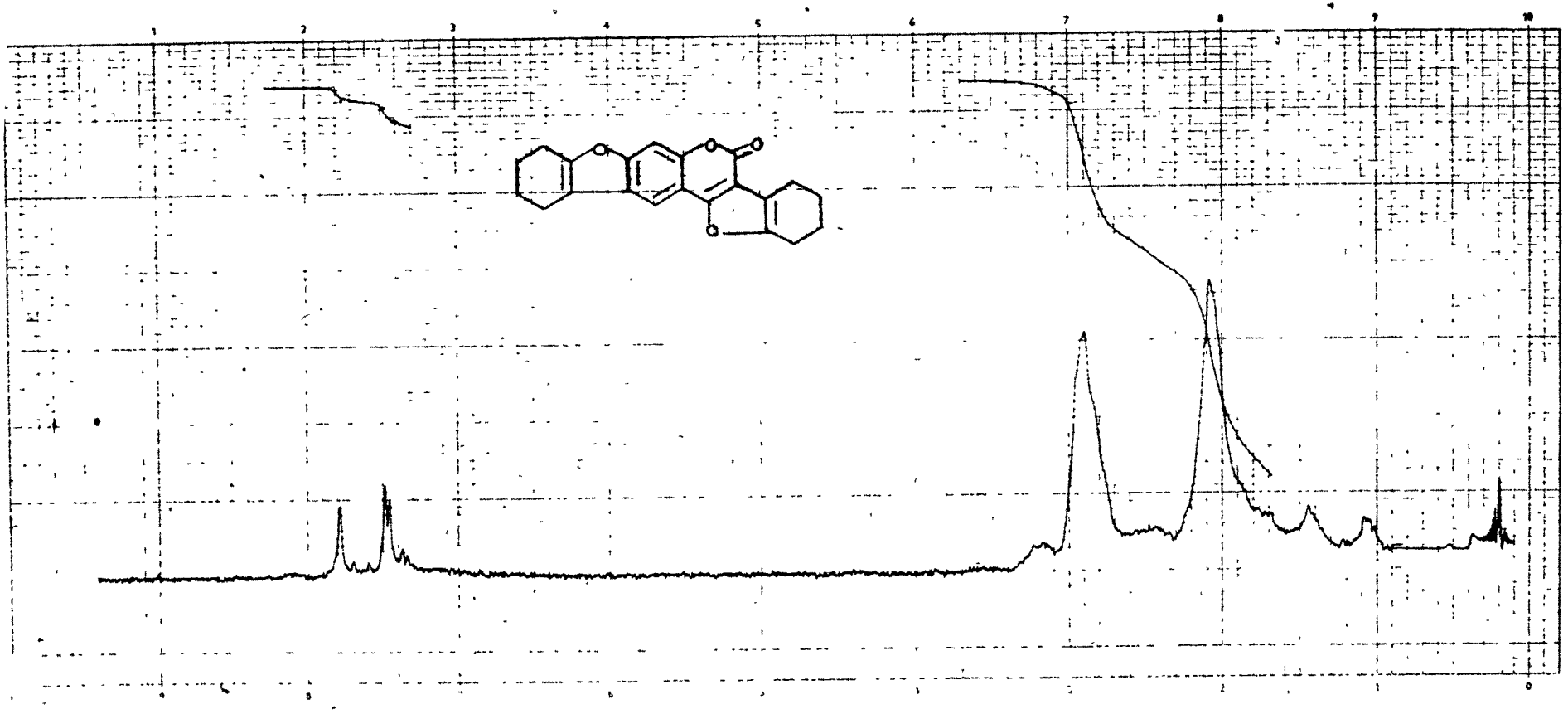




(fig-24): 6,7,8,9-tetrahydro-4-(cyclohexanoyloxy)-benzo furo(3,2-g)-benzopyran 2(H)-one. (100).

The IR spectrum showed only one band at 1735 cm^{-1} for carbonyl group. Disappearance of other band at 1710 cm^{-1} indicated that cyclisation has taken place. The signals of PMR spectrum confirmed the structure (Fig. 25). Broad multiplet at δ 1.6-2.1 indicated protons at C-2 and C-3 and C-10 and C-11. The another broad multiplet at δ 2.45-2.95 indicated protons at C-1 and C-4 and C-9 and C-12. Singlet at δ 7.25 indicated aromatic proton at C-6 while another singlet at δ 7.6 indicated aromatic proton at C-14.

Compound (101) on dehydrogenation in boiling diphenyl-ether with palladised charcoal (10%) gave dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one (102) [Scheme-33]. The structure of this compound was proved by its mass spectrum which showed molecular ion peak at m/e 326. (Fig. 26).



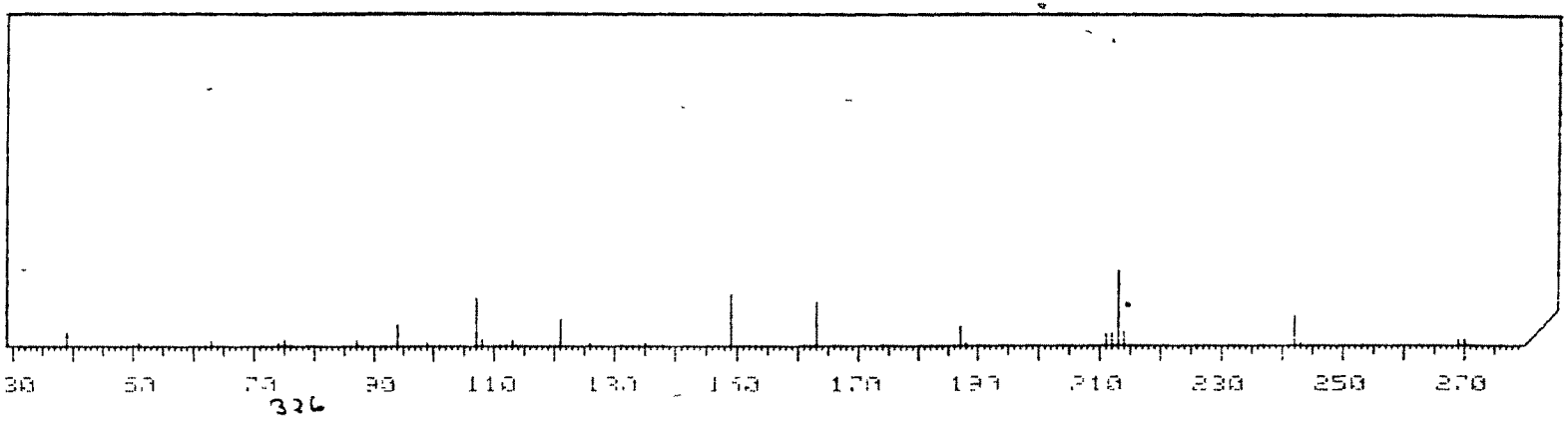
(fig-25): 1, 2, 3, 4, 9, 10, 11, 12 - Octahydrodibenzofuro (3, 2-c : 3', 2'-g) benzopyran-8(H)-one. (101).

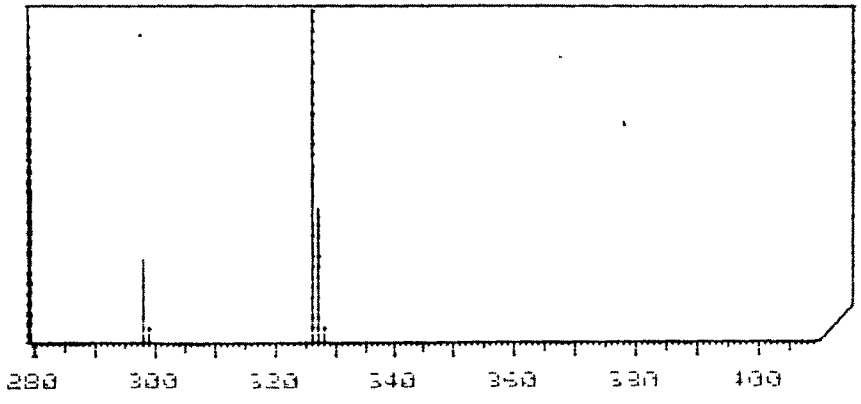
FILENAME:RL0133.03
COMMENT:AR

SP-122

MODE: EI
EM: 70 GAIN: 3.6
IC TEMP: 275 SCAN SPEED: 9
DI TEMP: 141

PATH	R.T.	FEAK	MASS RANGE		BASE	PEAK	TOTAL	RAW-	B.G.
50	2.4	198	32-	348	439500	326	1632387	0-	0
		155	32-	348	439500	326	1623232	0-	3





(fig-26): Dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one.
(102).

EXPERIMENTAL

E X P E R I M E N T A L

All melting points are uncorrected. PMR spectra recorded on Perkin-Elmer R-32 Spectrometer (90 MHz), using TMS as internal standard. Silica gel used for column chromatography with mesh size 60-120.

3-Hydroxy-benzofuro (2,3-c)-benzopyran-6(H)-one (51)

A mixture of resorcinol (12.0 g) and 2-carbethoxy-3-2(H)-benzofuranone (6.8 g) in conc. H_2SO_4 (85%) (20 ml) was kept at room temperature for 2 days, then treated with ice water. The product was repeatedly triturated with water and crystallised from alcohol. M.p. 310°C, (decomposes), yield 7.2 g (Lit.[34] 311°C decomposes).

3-Allyloxy-benzofuro-(2,3-c)-benzopyran-6(H)-one (52)

A mixture of 3-hydroxy benzofuro (2,3-c)-benzopyran-6(H)-one, (2.5 g) allylbromide (1.2 ml) and anhydrous potassium carbonate (5.0 g) was refluxed in dry acetone (150 ml) for 8 hrs. Excess of acetone was distilled out and poured into ice-cold water. The solid obtained was filtered and washed with aq. NaOH to remove unreacted isocoumestan crystallised from benzene. M.p. 170°C. Yield (2.0 g).

Analysis	:	Found	:	C, 74.43%	;	H, 4.60%
$C_{18}H_{12}O_4$	:	requires	:	C, 73.97%	;	H, 4.11%

4-Allyl-3-hydroxy-benzofuro (2,3-c)-benzopyran-6(H)-one (53)

3-Allyloxy-benzofuro (2,3-c)-benzopyran-6-(H)-one (1.0g) was refluxed in N,N-dimethylaniline (10 ml) for 6 hrs. It was poured into ice HCl (1:1). The product obtained was filtered and treated with aq. NaOH. On acidification it gave the product. It was crystallised from benzene-alcohol mixture. M.p. 260°C, yield (0.6 g).

Analysis : Found : C, 73.39% ; H, 4.54%

$C_{18}H_{12}O_4$: requires : C, 73.97% ; H, 4.11%

3-Acetoxy-4-allyl benzofuro (2,3-c)-benzopyran-6(H)-one

A mixture of 4-allyl-3-hydroxy-benzofuro (2,3-c)-benzopyran-6(H)-one (1.0 g), anhydrous sodium acetate (1.0 g) and acetic anhydride (5.0 ml) were heated in waterbath for 8 hrs. It was poured into ice. The product obtained was filtered and washed with aq. NaOH to remove unreacted compound. It was crystallised from ethanol. M.p. 192°C, yield (0.9 g).

Analysis : Found : C, 72.28% ; H, 4.28%

$C_{20}H_{14}O_5$: requires : C, 71.85% ; H, 4.19%

2-Methyl-dihydrofuro-(2,3-h)-benzofuro-(2,3-c)-benzopyran-6(H)-one (54)

4-Allyl-3-hydroxy-benzofuro-(2,3-c)-benzopyran-6(H)-one

(1.0 g) was triturated with conc. H_2SO_4 (80%) and then heated in waterbath for 10-15 minutes. It was poured into ice-cold water. The product obtained was filtered and washed with aq. NaOH to remove unreacted compound. It was purified by column chromatography using benzene, it crystallised from benzene. M.p. 210°C, yield (0.5 g).

Analysis	:	Found	:	C, 74.23%	;	H, 4.55%
$C_{18}H_{12}O_4$	:	requires	:	C, 73.97%	;	H, 4.11%

2-Methyl-furo-(2,3-h)-benzofuro-(2,3-c)-benzopyran-6(H)-one (55)

A mixture of compound (54) (0.5 g) and palladised charcoal (10%) (0.35 g) were refluxed in diphenyl ether (10 ml) for 16 hrs. The reaction mixture was filtered hot & diphenyl ether was removed by steam distillation. The product was purified by column chromatography, using benzene, it crystallised from benzene. M.p. 278°C, yield (0.25 g).

Analysis	:	Found	:	C, 74.29%	;	H, 3.50%
$C_{18}H_{10}O_4$	:	requires	:	C, 74.48%	;	H, 3.45%

3-Hydroxy-4-bromo-benzofuro-(2,3-c)benzopyran-6(H)-one (56)

3-Hydroxy-benzofuro-(2,3-c) benzopyran-6(H)-one ~~3-Hydroxy-benzofuro-(2,3-c) benzopyran-6(H)-one~~ (2.5 g) dissolved in acetic acid (20 ml) stirred, with the addition of bromine in acetic acid (1 ml, 30%) for 2 hrs. It was poured into ice-cold water.

The solid obtained was filtered, dried and crystallised from acetic acid. M.p. 245°C, Yield (2.2 g).

3-Allyloxy-4-bromo-benzofuro-(2,3-c)-benzopyran-6(H)-one (57)

A mixture of 3-hydroxy-4-bromo-benzofuro (2,3-c)-benzopyran-6(H)-one (1.0 g), allylbromide (1.2 ml) and anhydrous potassium carbonate (4.0 g) was refluxed in dry acetone for 12 hrs. It was worked out as usual. The product obtained was filtered and washed with aq. NaOH to remove unreacted compound, it crystallised from ethanol. M.p. 170°C, Yield(0.95g)

Analysis : Found : C, 58.30% ; H, 3.15%

$C_{18}H_{11}O_4Br$: requires : C, 58.22% ; H, 2.97%

Claisen rearrangement of Compound (57)

3-Allyloxy-4-bromo-benzofuro (2,3-c)-benzopyran-6(H)-one (1.0 g) was refluxed in N,N-dimethylaniline (10 ml) for 6 hrs. It was worked out as usual. The product obtained was crystallised from benzene-alcohol mixture, showed same M.p. and m.m.p. as (53). M.p. 260°C, yield (0.35 g).

Some product was deposited on wall of air condensor, was scratched out and identified as p-bromo-N,N-dimethyl-aniline.

3-Hydroxy-4-iodo-benzofuro (2,3-c)-benzopyran-6(H)-one (58)

[illegible] 3-Hydroxy-benzofuro-(2,3-c)-benzopyran-6(H)-one (2.0 g) dissolved in (1:1) liq.

NH_3 : water (25 ml) was stirred. Iodine (1.0 g) dissolved in saturated solution of KI (3.0 g) was added and stirring was continued for 3 hrs. It was poured into ice-cold H_2SO_4 (1:1). The solid obtained was filtered, dried and crystallised from methanol. M.p. 240°C, Yield (2.1 g).

3-Allyloxy-4-iodo-benzofuro (2,3-c)-benzopyran-6(H)-one (59)

A mixture of 3-hydroxy-4-iodo-benzofuro (2,3-c)-benzopyran-6(H)-one (1.0 g), allylbromide (0.8 ml), anhydrous potassium carbonate (4.0 g) was refluxed in dry acetone (100 ml) for 12 hrs. It was worked out as usual. The product obtained was filtered, washed with aq. NaOH to remove unreacted compound. It was crystallised from benzene-alcohol mixture. M.p. 162°C, Yield (0.9 g).

Analysis	:	Found	:	C, 52.09%	;	H, 3.10%
$C_{18}H_{11}O_4I$	:	requires	:	C, 51.68%	;	H, 2.63%

Claisen rearrangement of (59)

3-Allyloxy-4-iodo-benzofuro (2,3-c)-benzopyran-6(H)-one (1.0 g) was refluxed in N,N-dimethylaniline (10 ml) for 6 hrs. It was worked out as usual. The product obtained was crystallised from benzene-alcohol mixture. It showed m.p. and m.m.p. same as (53). M.p. 260°C, Yield (0.3 g).

Some product was deposited on wall of air condensor was scratched out and identified as p-iodo-N,N-dimethylaniline.

3-Hydroxy-4-methyl-benzofuro-(2,3-c)-benzopyran-6(H)-one (60)

A mixture of 2-methyl resorcinol (5.0 g) and 2-carbethoxy-3-(2H)-benzofuranone (6.5 g) in conc. H_2SO_4 (85%) (10 ml) was kept at room temperature for 2 days. Then it was poured into ice-cold water. The solid obtained was filtered dried and crystallised from ethanol. M.p. 315°C, Yield (5.0 g).

Analysis	:	Found	:	C, 72.00%	;	H, 3.25%
$C_{16}H_{10}O_4$	:	requires	:	C, 72.28%	;	H, 3.76%

3-Allyloxy-4-methyl-benzofuro (2,3-c)-benzopyran-6(H)-one (61)

A mixture of 3-hydroxy-4-methyl benzofuro-(2,3-c)-benzopyran-6(H)-one (2.6 g), allylbromide (1.2 ml) and anhydrous potassium carbonate (8.0 g) was refluxed in dry acetone (200 ml) for 8 hrs. Excess of acetone was distilled out and it was poured into ice-cold water. The solid obtained was filtered and washed with aq. NaOH to remove unreacted compound. It crystallised from alcohol. M.p. 197°C, Yield (2.5 g).

Analysis	:	Found	:	C, 75.88%	;	H, 4.60%
$C_{19}H_{14}O_4$	:	requires	:	C, 75.84%	;	H, 4.66%

2-Allyl-3-hydroxy-4-methyl-benzofuro (2,3-c)-benzopyran-6(H)-one (62)

3-Allyloxy-4-methyl-benzofuro (2,3-c)-benzopyran-6(H)-one (1.0 g) was refluxed in N,N-dimethylaniline (10 ml) for 6

hrs. It was then poured into ice-cold HCl (1:1).The product obtained was treated with diluted aq. NaOH. On acidification with conc. HCl, it gave the product. It was filtered and purified by column chromatography using benzene, it crystallised from benzene-alcohol mixture. M.p.220°C, Yield (0.65 g).

Analysis : Found : C, 75.44% ; H, 4.59%

$C_{19}H_{14}O_4$; requires : C, 75.84% ; H, 4.66%

2,4-Dimethyl-dihydrofuro (3,2-g)-benzofuro (2,3-c)-bezopyran-6(H)-one (63)

2-Hydroxy-3-allyl-4-methyl-benzofuro (2,3-c)-benzopyran-6(H)-one (1.0 g) was triturated with conc. H_2SO_4 (80%) and then heated in waterbath for 10 minutes. It was poured into crushed ice. The solid obtained was filtered and washed with dil. aq. NaOH to remove unreacted compound. It was purified by column chromatography using benzene, it crystallised from benzene-alcohol mixture. M.p. 302°C, Yield (0.68 g).

Analysis : Found : C, 75.40% ; H, 4.62%

$C_{19}H_{14}O_4$: requires : C, 75.85% ; H, 4.66%

2,4-Dimethyl-furo (3,2-g)-benzofuro (2,3-c)-benzopyran-6(H)-one (64)

2,4-Dimethyl-dihydrofuro-(3,2-g)-benzofuro-(2,3-c)-benzopyran-6(H)-one (0.5 g) and palladised charcoal (10%) (0.35 g)

were refluxed in diphenylether (10 ml) for 14 hrs. It was filtered hot and diphenylether was removed by steam distillation. The dproduct obtained was purified by preparative TLC using benzene and crystallised from benzene. M.p. 280°C, Yield (0.25 g).

Analysis	:	Found	:	C, 74.54%	;	H, 3.93%
$C_{19}H_{12}O_4$	:	requires	:	C, 74.99%	;	H, 3.94%

3-Hydroxy-2-methyl-benzofuro-(2,3-c)-benzopyran-6(H)-one (66)

A mixture of 4-methyl resorcinol (4.0 g) and 2-carbethoxy-3-(2H)-benzofuranone (6.0 g) was taken in conc. H_2SO_4 (80%) & kept overnight for 2 days. It was poured into ice-cold water. The solid obtained was filtered and crystallised from ethanol. M.p. 317°C, Yield (4.8 g).

Analysis	:	Found	:	C, 71.88%	;	H, 3.38%
$C_{16}H_{10}O_4$	:	requires	:	C, 72.18%	;	H, 3.76%

3-Acetoxy-2-methyl-benzofuro-(2,3-c)-benzopyran-6(H)-one (67)

A mixture of 3-hydroxy-2-methyl-benzofuro (2,3-c)-benzopyran-6(H)-one (3.0 g) anhydrous sodium acetate (6.0 g) and acetic anhydride (5.0 ml) was heated in waterbath for 8 hrs. It was poured into ice-cold water. The solid obtained was filtered, dried and crystallised from ethanol. M.p. 231°C, Yield (3.3 g).

Analysis	:	Found	:	C, 69.80%	;	H, 4.29%
$C_{18}H_{12}O_5$	:	requires	:	C, 70.13%	;	H, 3.90%

3-Acetoxy-2-bromomethyl-benzofuro (2,3-c)-benzopyran-6(H)-one (68)

3-Acetoxy-2-methyl-benzofuro (2,3-c)-benzopyran-6(H)-one (3.0 g) was dissolved in carbon tetrachloride and chloroform mixture. N-bromosuccinimide (1.78 g) and benzoylperoxide (0.2-0.3 g) were added and refluxed under light for 16 hrs. It was filtered and solvent was removed. The product obtained was purified by column chromatography using benzene. It was crystallised from benzene. M.p. 300°C, Yield (2.8 g).

Analysis : Found : C, 55.32% ; H, 2.42%

$C_{18}H_{11}O_5Br$: requires : C, 55.81% ; H, 2.84%

2-Methyl-furo-(3,2-g)-benzofuro (2,3-c)-benzopyran-6(H)-one (70)

3-Acetoxy-2-bromomethyl-benzofuro (2,3-c)-benzopyran-6(H)-one (1.0 g) was dissolved in acetonitrile (100 ml) and triphenyl phosphine (1.0 g) was added to it. It was refluxed under the atmosphere of N_2 for 8 hrs. Then solvent was removed and oil obtained was suspended in dry toluene. Triethyl-amine (2-3 ml) was added and refluxed under atmosphere of N_2 for 16 hrs. Then it was filtered hot and toluene was distilled out. The product obtained was crysttallised from benzene-alcohol mixture. M.p. 333°C, decomposes. Yield (0.7 g)

Analysis : Found : C, 74.73% ; H, 4.16%

$C_{18}H_{10}O_4$: requires : C, 74.48% ; H, 3.44%

6-Hydroxy-coumaran-3-one (71)

Dry hydrogen chloride was passed for 35 minutes through a well stirred mixture of resorcinol (6.0 g), chloroacetonitrile (4.0 g), powdered anhydrous zinc chloride (4.0 g) and dry ether (40 ml). The ketemine hydrochloride was separated and washed by decantation with two portions (10 ml) of dry ether. Water was added (200 ml) and ether was removed completely and solution was heated for 10 minutes. On cooling and chilling product separated out was added to a hot solution of potassium acetate (5.0 g) in absolute ethanol (20 ml) and refluxed for 15 minutes. It was cooled and poured into ice-cold water (50-60 ml). The product separated out was filtered and crystallised from hot water. M.p. 243°C, Yield 3.5 g. (reported[42] M.p. 243°C)

6-Acetoxy coumaran-3-one (72)

A mixture of 6-hydroxy-coumaran-3-one (4.0 g), acetyl chloride (8 ml) and ethylacetate (20 ml) was refluxed for 3 hrs. The solvent was removed and poured into ice-cold water. The product obtained was filterd, dried and crystallised from benzene. M.p. 78°C (reported[42] 79°C), Yield (3.5 g)

6-Acetoxy coumaran (73)

To a mixture of 6-acetoxy coumaran-3-one (6.0 g) in glacial acetic acid (20 ml) with palladised charcoal (10%)

(1.2 g), hydrogen gas was passed under 3-4 atoms. Pressure at 65°C with stirring till further drop of pressure stops (5-6 hrs.) It was filtered, acetic acid was distilled out and poured into ice-cold water. The product obtained was filtered, dried and crystallised from benzene. Filtrate on neutralisation with sodium bicarbonate gave the product. M.p. 71°C. (Reported [42] 73°C), Yield (2.0 g).

Dihydrofuro-(3,2-g)-benzofuro (2,3-c)-benzopyran-6(H)-one (74)

6-Acetoxy coumaran (1.78 g) and 2-carbethoxy-3-(2H)-benzofuranone (2.06 g) were mixed in conc. H_2SO_4 (80%) (5-6 ml) and kept it overnight for 2 days. It was poured into ice-cold water. The product obtained was filtered and crystallised from ethanol. M.p. 268°C, Yield (1.8 g).

Analysis	:	Found	:	C, 72.93%	;	H, 4.04%
$C_{17}H_{10}O_4$	:	requires	:	C, 73.38%	;	H, 3.60%

Furo-(2,3-g)-benzofuro (2,3-c)-benzopyran-6(H)-one (75)

(2,3-g)-dihydrofuro-benzofuro (2,3-c)-benzopyran-6(H)-one (0.8 g) was refluxed in diphenylether (10 ml) with palladised charcoal (10%) (0.4 g) for 10 hrs. It was filtered hot, dihenyether was removed and product obtained was crystallised from alcohol-DMF mixture. M.p. 279°C, Yield (0.6 g).

Analysis	:	Found	:	C, 73.44%	;	H, 3.31%
$C_{17}H_8O_4$	:	requires	:	C, 73.91%	;	H, 2.90%

3-(1,1-dimethyl-3-prop-2-ynyloxy)-benzofuro-(2,3-c)-benzopyran-6(H)-one (76)

A mixture of 3-hydroxy-benzofuro-(2,3-c)-benzopyran-6(H)-one (2.52 g) 3-chloro-3methyl-but-1-yne (1.2 ml) and anhydrous potassium carbonate (10 g) was refluxed in acetone (100 ml) and DMF (10 ml) with stirring with few crystals of KI for 36 hrs. The excess of acetone was distilled out and it was poured in ice-cold water. The product obtained was filtered and washed with aq. NaOH to remove unreacted compound. It was filtered, dried and crystallised from benzene. M.p. 176°C, Yield (2.4 g).

Analysis : Found : C, 75.91% ; H, 4.89%

$C_{20}H_{14}O_4$: requires : C, 75.47% ; H, 4.43%

2,2-Dimethyl-pyrano-(2,3-h)-benzofuro-(2,3-c)-benzopyran-6(H)-one (77)

3-(1,1-dimethyl-3-prop-2-ynyloxy)-benzofuro-(2,3-c)-benzopyran-6(H)-one (2.0 g) was refluxed in N,N-dimethyl-aniline (10 ml) for 6 hrs. It was then poured into ice-cold HCl (1:1). The product obtained was filtered, and purified by column chromatography using benzene, it crystallised from benzne. M.p. 212°C, Yield (1.2 g).

Analysis : Found : C, 75.01% ; H, 4.11%

$C_{20}H_{14}O_4$: requires : C, 75.48% ; H, 4.40%

3-(1,1-dimethyl-3-prop-2-ynyloxy)-4-methyl-benzofuro-(2,3-c)-benzopyran-6(H)-one (78)

A mixture of 3-hydroxy-4-methyl-benzofuro (2,3-c)-benzopyran-6(H)-one (2.65 g), 3-chloro-3-methyl-but-1-yne (1.3 ml) and anhydrous potassium carbonate (10.0 g) was refluxed in dry acetone (100 ml) and DMF (10 ml) with stirring with few crystals of KI for 38 hrs. The excess of acetone was distilled out and poured into ice-cold water. The product obtained was washed with aq. NaOH to remove unreacted compound. It was filtered, dried and purified by column chromatography using benzene, crystallised from benzene. M.p. 195°C, Yield (2.0 g).

Analysis : Found : C, 75.70% ; H, 5.20%

$C_{21}H_{16}O_4$: requires : C, 75.91% ; H, 4.81%

3,3,5-Trimethyl-pyrano-(3,2-g)-benzofuro-(2,3-c)-benzopyran-7(H)-one (79)

Compound (78) (2.0 g) was refluxed in N,N-dimethylaniline (10 ml) for 6 hrs. It was poured into ice-cold HCl (1:1) The product obtained was filtered and found to be insoluble in NaOH. It was purified by preparative TLC using benzene. It showed bluish yellow fluorescence in UV light. It was crystallised from benzene. M.p. 252°C, Yield (0.9 g).

Analysis : Found : C, 75.49% ; H, 4.90%

$C_{21}H_{16}O_4$: requires : C, 75.91% ; H, 4.81%

8,9-Dihydroxy-benzofuro-(3,2-c)-benzopyran-6(H)-one (81)

A mixture of 4-hydroxy coumarin, (1.6 g) and sodium acetate (2.5 g) was dissolved in (1:1) acetone : water (15 ml). To it catechol (1.1 g) was added. Then mixture of potassium iodate (6.5 g) and sodium acetate (2.5 g) dissolved in water (50-60 ml) was added dropwise to the above mixture with contineous stirring in 15-20 minutes. It was stirred further 15 minutes. The solid separated out was filtered and washed several times with water. The product showed green colouration with neutral $FeCl_3$. M.p. of crude product is 285°C, Yield (1.5 g). It was used directly for further reaction.

8,9-Diallyloxy-benzofuro (3,2-c)-benzopyran-6(H)-one (82)

A mixture of 8,9-dihydroxy-benzofuro (3,2-c)-benzopyran-6(H)-one (2.6 g) anhydrous potassium carbonate (7-8 g) and allylbromide (4.0 ml) was refluxed in dry acetone (150 ml) for 8-10 hrs. Excess of acetone was distilled and poured into water. The product obtained was filtered and washed with aq. NaOH to remove unreacted compound. The product was purified by column chromatography using benzene as eluting solvent. It was crystallised from benzene. M.p. 144°C, Yield (1.2 g).

Analysis : Found : C, 72.81% ; H, 4.76%

$C_{21}H_{16}O_5$: requires : C, 72.41% ; H, 4.60%

11-Allyl-10-hydroxy-8-methyl-dihydrofuro-(2,3-e)-benzofuro-(3,2-c)-benzopyran-6(H)-one (83)

8,9-Diallyloxy-benzofuro-(3,2-c)-benzopyran-6(H)-one (1.0 g) was refluxed in N,N-dimethylaniline (10 ml) for 6 hrs. It was poured into ice-HCl (1:1). The product obtained was filtered, dried and purified by column chromatography using benzene, it crystallised from benzene. M.p. 185°C, Yield (0.55 g)

Analysis : Found : C, 72.86% ; H, 4.81%

$C_{21}H_{16}O_5$: requires : C, 72.41% ; H, 4.60%

8,11-Dimethyl-dihydrodifuro-(2,3-e : 2',3'-g)-benzofuro (3,2-c)-benzopyran-6(H)-one (84)

11-Allyl-10-hydroxy-8-methyl-dihydrofuro (2,3-e)-benzofuro (3,2-c)-benzopyran-6(H)-one (1.0 g) was triturated with con. H_2SO_4 (80%) and then heated in waterbath for 10 minutes. It was poured into ice-cold water and left overnight. It was filtered and washed with aq. dil. NaOH to remove unreacted compound, purified by column chromatography using benzene, it crystallised from benzene. M.p. 232°C, Yield (0.45 g).

Analysis : Found : C, 72.83% ; H, 4.05%

$C_{21}H_{14}O_5$: requires : C, 72.41% ; H, 4.59%

8,11-Dimethyl-difuro-(2,3-e : 2',3'-g)-benzofuro-(3,2-c)-benzopyran-6(H)-one (85)

Compound (84) (0.4 g) was refluxed in diphenyl ether (10 ml) with palladised charcoal (10%) (0.35 g) for 8 hrs. Diphenylether was removed and product obtained was purified by column chromatography using benzene. It was crystallised from benzene. M.p. 305°C, Yield (0.25 g).

Analysis : Found : C, 73.06% ; H, 3.91%

$C_{21}H_{12}O_5$: requires : C, 73.25% ; H, 3.49%

4-Cyclohexan-2-onyloxy-2-hydroxy-acetophenone (87)

A mixture of resacetophenone (6.0 g), bromocyclohexanone (5.2 ml) and anhydrous potassium carbonate (15.0 g) was refluxed in dry acetone (150 ml) for 8 hrs. It was worked out as usual. The brown product obtained was purified by column chromatography using pet. ether : benzene (1:1) mixture, it crystallised from benzene-pet. ether. White shining crystals showed M.p. 136°C, Yield (4.5 g).

Analysis : Found : C, 67.92% ; H, 6.47%

$C_{14}H_{16}O_4$: requires : C, 67.74% ; H, 6.45%

5,6,7,8-Tetrahydro-2-hydroxy-3-acetyl-dibenzofuran (88)

4-Cyclohexan-2-onyloxy-2-hydroxy acetophenone (1.0 g) was

dissolved in 0.1N alcoholic KOH (100 ml) and refluxed in waterbath for 8 hrs. The excess of alcohol was distilled out and poured into ice. On acidification with conc. HCl the product obtained was purified by column chromatography using benzene. It was crystallised from benzene. M.p. 182°C, Yield (0.6 g).

Analysis : Found : C, 73.50% ; H, 6.50%

$C_{14}H_{14}O_3$: requires : C, 73.05% ; H, 6.09%

6,7,8,9-Tetrahydro-4-hydroxy-benzofuro-(3,2-g)-benzopyran-2(H)-one (89)

5,6,7,8-Tetrahydro-2-hydroxy-3-acetyl-dibenzofuran (1.0 g) dissolved in diethyl carbonate (10.0 ml) was added slowly to pulverised Na (2.0) g and heated in waterbath for 10 hrs. Alcohol was added to decompose unreacted sodium metal and poured into ice-cold water, acidified with conc. HCl. The product obtained was crystallised from alcohol. M.p. 280°C, Yield (0.8 g).

Analysis : Found : C, 70.09% ; H, 4.97%

$C_{15}H_{12}O_4$: requires : C, 70.33% ; H, 4.69%

10,11-Dihydroxy-1,2,3,4-tetrahydro-dibenzofuro-(3,2-c): 3',2'-g) benzopyran-8(H)-one (90)

A mixture of above 4-hydroxy coumarin (1.5 g), catechol

(1.1 g), sodium acetate (2.0 g) was dissolved in (1:1) acetone : water mixture and stirred continuously. A mixture of aqueous solution of sodium acetate (2.0 g) and potassium iodate (4.5 g) was added to it slowly within 15-20 minutes with stirring. It was poured into water and filtered, washed several times with water. The crude product obtained was used directly for further reaction.

10,11-dimethoxy-1,2,3,4-tetrahydro-dibenzofuro-(3,2-c : 3',2'-g) -benzopyran-8(H)-one (91)

A mixture of compound (90) (1.0 g), anhydrous potassium carbonate (4.0 g) and dimethylsulfate (1.8 ml) was refluxed in dry acetone (100 ml) for 8 hrs. The excess of acetone was removed and poured into water. The product obtained was filtered and washed with aq. sodium hydroxide to remove unreacted compound. It was purified by column chromatography using benzene, it crystallised from benzene. M.p. 220°C, Yield (0.8 g).

Analysis	:	Found	:	C, 70.34%	:	H, 4.61%
$C_{23}H_{18}O_6$	:	requires	:	C, 70.76%	:	H, 4.62%

10,11-Dimethoxy-dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H) one (92)

A mixture above methylether (91) (0.5 g) and palladised

charcoal (10%) (0.35 g) was refluxed in diphenyl ether (10 ml) for 25 hrs. It was filtered hot and diphenyl ether was removed and product obtained was purified by column chromatography using benzene. It crystallised from benzene. M.p. 260°C, Yield (0.25 g).

Analysis : Found : C, 71.53% ; H, 4.08%.

$C_{23}H_{14}O_6$: requires : C, 71.50% ; H, 3.63%

4-Cyclohexan-2-onyloxy-2-hydroxy-3-methylacetophenone (94)

A mixture of 2-methyl resacetophenone (6.3 g) bromocyclohexanone (5.2 ml) and anhydrous potassium carbonate (15.0 g) was refluxed in dry acetone (150 ml) for 8 hrs. It was worked out as usual. The product obtained was purified by column chromatography using benenze, it crystallised from benzene. M.p. 125°C, Yield (4.2 g).

Analysis : Found : C, 69.12% ; H, 6.99%

$C_{15}H_{18}O_4$: requires : C, 68.70% ; H, 6.87%

5,6,7,8-Tetrahydro-2-hydroxy-1-methyl-3-acetyl-dibenzofuran (95)

4-Cyclohexan-2-onyloxy-2-hydroxy-3-methyl acetophenone (1.0 g) was dissolved in 0.1N alcoholic KOH (100 ml) and refluxed for 8 hrs. The excess of alcohol was distilled out and poured into ice. It was acidified with conc. HCl.

The product obtained was purified by column chromatography using benzene, it crystallised from benzene. M.p. 148°C, Yield (0.5 g).

Analysis : Found : C, 73.35% ; H, 6.62%

$C_{15}H_{16}O_3$: requires : C, 73.77% ; H, 6.56%

11-Methyl-4-hydroxy-6,7,8,9-tetrahydro-benzofuro (2,3-g)-benzopyran-2(H)-one (96)

Compound (95) (1.0 g) was dissolved in diethyl carbonate (10 ml) and added slowly to the pulverised Na (2.0 g) and heated in waterbath for 8 hrs. Alcohol was added to decompose unreacted Na and then poured into ice. It was acidified with conc. HCl. The product obtained crystallised from ethanol. M.p. 301°C, Yield (0.9 g).

Analysis : Found : C, 70.93% ; H, 4.70%

$C_{16}H_{14}O_4$: requires : C, 71.11% ; H, 5.19%

10,11-Dihydroxy-6-methyl-1,2,3,4-tetrahydro-dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one (97)

A mixture of above 4-hydroxycoumarin (96) (2.5 g), catechol (1.1 g), sodium acetate (2.5 g) was dissolved in (1:1) acetone : water mixture (20 ml) and stirred contineously. A mixture of aqueous solution of sodium acetate (2.5 g) and potassium iodate (6.5 g) was added to it slowly within 15-20 minutes with stirring. It was poured into water. The

product obtained was filtered and washed with water several times ~~compound~~. The crude product obtained was used directly for further reaction.

10,11-Dimethoxy-6-methyl-1,2,3,4-tetrahydro-dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one (98)

A mixture of compound (97) (1.5 g), anhydrous potassium carbonate (6.0 g) and dimethylsulfate (1.4 ml) was refluxed in dry acetone (100 ml) for 8 hrs. The excess of acetone was removed and poured into water. The product obtained was filtered and washed with aq. NaOH to remove unreacted compound. It was purified by column chromatography using benzene, it crystallised from benzene. M.p. 273°C, Yield (1.1 g).

Analysis	:	Found	:	C, 71.25%	;	H, 5.40%
$C_{24}H_{20}O_6$	:	requires	:	C, 71.29%	;	H, 4.95%

10,11-Dimethoxy-6-methyl-dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one (99)

A mixture of above dimethylether (98) (0.8 g) and palladised charcoal (10%) (0.5 g) was refluxed in diphenyl ether (10 ml) for 20 hrs. It was filtered hot and diphenyl ether was removed. The product obtained was purified by column chromatography using benzene, it crystallised from benzene. M.p. 279°C, Yield (0.50 g).

Analysis : Found : C, 72.50% : H, 4.44%

$C_{24}H_{16}O_6$: requires : C, 72.00% : H, 4.00%

6,7,8,9-Tetrahydro-4-(cyclohexan-2-onyloxy)-benzofuro (3,2-g)-benzopyran-2(H)-one (100)

4-Hydroxy-6,7,8,9-tetrahydro-benzofuro-(3,2-g)-benzopyran-2(H)-one (1.0 g) was refluxed with anhydrous potassium carbonate (4.0 g) and 2-bromocyclohexanone (0.9 ml) in dry acetone (100 ml) for 10 hrs. It was worked out as usual. The product obtained was purified by column chromatography using benzene. It was crystallised from benzene-alcohol mixture. M.p. 252°C, yield (0.9 g).

Analysis : Found : C, 71.20% ; H, 5.92%

$C_{21}H_{20}O_5$: requires : C, 71.59% ; H, 5.68%

1,2,3,4,9,10,11,12-octahydro-dibenzofuro-(3,2-c : 3',2'-g)-benzopyran-8(H)-one (101)

Compound (100) (0.8 g) was triturated with conc. H_2SO_4 (80%) and heated in waterbath for 20 minutes. It was left overnight. Next day poured into ice-cold water. The product obtained was fitered and crystallised from alcohol-benzene mixture. M.p. 160°C, Yield (0.65 g).

Analysis : Found : C, 75.41% : H, 5.85%

$C_{21}H_{18}O_4$: requires : C, 75.44% ; H, 5.39%

Dibenzofuro (3,2-c : 3',2'-g)-benzopyran-8(H)-one (102)

1,2,3,4,9,10,11,12-octahydrodibenzofuro-(3,2-c : 3',2'-g) benzopyran-8(H)-one (0.4 g) was refluxed with palladised charcoal (10%) (0.3 g) in diphenylether (10 ml) for 20 hrs. It was filtered hot and diphenylether was removed. The product obtained was crystallised from benzene-alcohol mixture. M.p. 238°C, Yield (0.168 g).

Analysis	:	Found	:	C, 76.88%	:	H, 3.56%
$C_{21}H_{10}O_4$	:	requires	:	C, 77.31%	;	H, 3.07%

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