Chapter 2

Section 1

Synthesis and Characterisation of Antioxidants based on Hindered phenol and Hindered amines

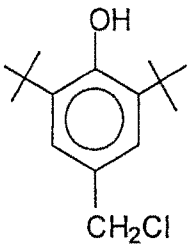
Chloromethyl group has become a convenient source for the introduction of amino methyl group in the synthetic organic chemistry because chloromethyl group can be easily converted in to aminomethyl group by treatment with aliphatic, aromatic or heterocyclic amines in appropriate solvent.

The aminomethyl linkage can also be introduced by the application of Mannich reaction. The essential feature of this reaction is the replacement of the active hydrogen atom by amino methyl or N-substituted amino methyl group. Phenols, ketones, aldehydes, acids, esters, acetylenes, nitro compounds and heterocyclic ring systems containing either oxygen, nitrogen, sulphur, phosphorus or arsenic are found to undergo this reaction. When aqueous formaldehyde is used, condensation is carried out with or without solvent. Alcohol, acetic acid and benzene have been generally employed as solvents.

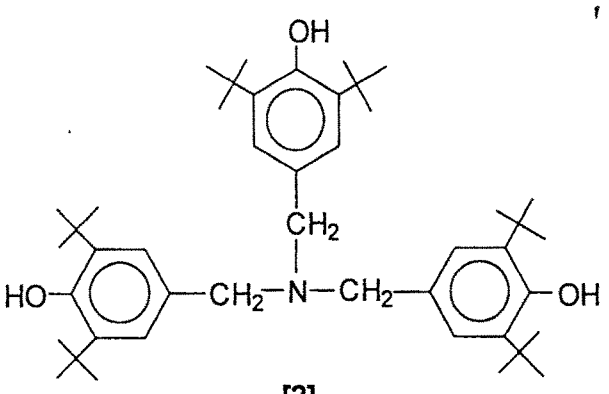
2,6-Di-tert-butyl-4-chloromethyl phenol **1** is an important intermediate for the synthesis of variety of antioxidants used in various applications. Various scientific groups reported different methods to synthesise chloromethyl derivative **1**.

Neureiter[1] synthesised chloromethyl derivative **1** by refluxing a mixture of 2,6-di-tert-butyl phenol, formalin solution and con. HCl in heptane for 6-14 hr under N_2 atmosphere.

Bolle et al.[2] prepared chloromethyl derivative **1** by treating a mixture of 2,6-di-tert-butyl-4-methyl phenol with dry $HCl_{(g)}$ at 5^0C for 4 hr. They also reported the synthesis of tris-(3,5-di-tert-butyl-4-hydroxybenzyl) amine **2** by treating compound **1** with ammonia.



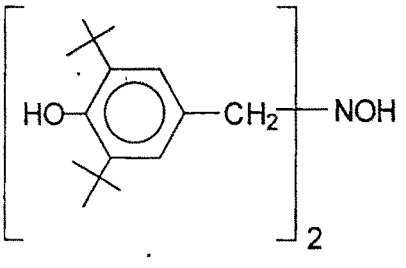
[1]



[2]

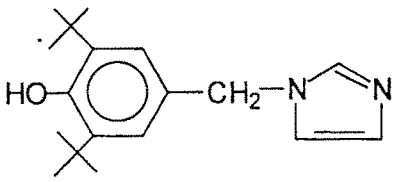
Geigy[3] reported the synthesis of chloromethyl derivative **1** by treating a mixture of 2,6-di-tert-butyl phenol, formalin solution and zinc chloride with dry HCl gas. Compound **1** was also synthesised by treating a dispersion of para formaldehyde in acetic acid with dry HCl gas and 2,6-di-tert-butyl phenol was added with constant flow of dry HCl gas.[4]

Klemchuck and Peter[5] performed reaction between 2,6-di-tert-butyl-4-chloromethyl phenol and hydroxylamine hydrochloride and synthesised compound **3**, which was found to be an efficient antioxidant in lard.

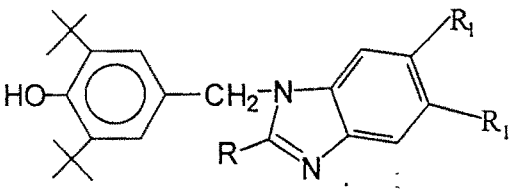


[3]

Antioxidants **4** and **5** (R=H, Me, CH_2OH; R_1=H, CH_3) were synthesised by *Nicoleta et al.*[6] by condensing chloromethyl derivative **1** with imidazole and benzimidazole derivatives respectively.



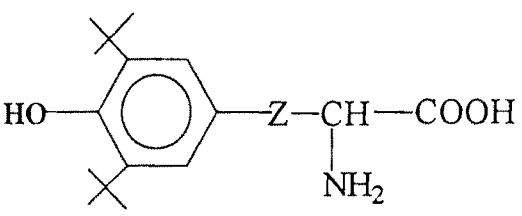
[4]



[5]

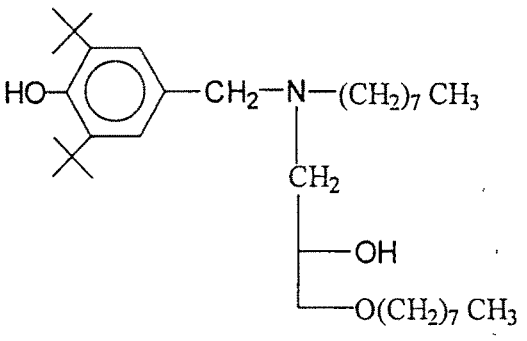
Lev et al.[7] synthesised antioxidants based on hindered phenol and hindered amines by condensing chloromethyl derivative **1** with aromatic diamine such as benzidine and *p*-phenylenediamine.

Veronika et al.[8] reported the synthesis of 3,5-di-tert-butyl-4-hydroxy tyrosine **6** ($Z=CH_2$) from chloromethyl derivative **1** and $HCONHCH(COOEt)_2$. They have also reported the synthesis of 3,5-di-tert-butyl-4-hydroxy phenyl glycine **6** (Z=bond) from 2,6-$(Me_3C)_2C_6H_3OH$ and ClCOCOOEt in four steps. Compound **6** can be used to spin label peptide.



[6]

Antoine et al.[9] synthesised N-(3,5-di-tert-butyl-4-hydroxybenzyl)-N-(2-hydroxy-3-octyloxy propyl) octyl amine 7 by reaction of chloromethyl derivative 1 with 1-octyl amino-3-octyloxy-2-propanol as a fuel additive .



[7]

From the literature survey it is revealed that among the antioxidants based on hindered phenols, the combination of hindered phenol and aminomethyl group is less extensively studied. Hindered phenols impart various degree of colour to the material due to the formation of quinonoid transformation products.[10] Most of the amine antioxidants are coloured and formed highly coloured oxidation products. Thus their uses are generally limited to those for which discoloration is not a draw back.[11] Moreover many of the new antioxidants synthesised are based on hindered phenol group with another group containing nitrogen. sulphide, triazine, phosphate and phosphite. These combinations would give active materials having the advantage of two or more stabilising moieties. So it is anticipated that the combination of hindered phenol group with aminomethyl group would give better stabilisation efficiency with minimum discolouration.

With these in view, the following antioxidants are synthesised and the structures are assigned on the basis of elemental analysis, IR, NMR and Mass spectral studies.

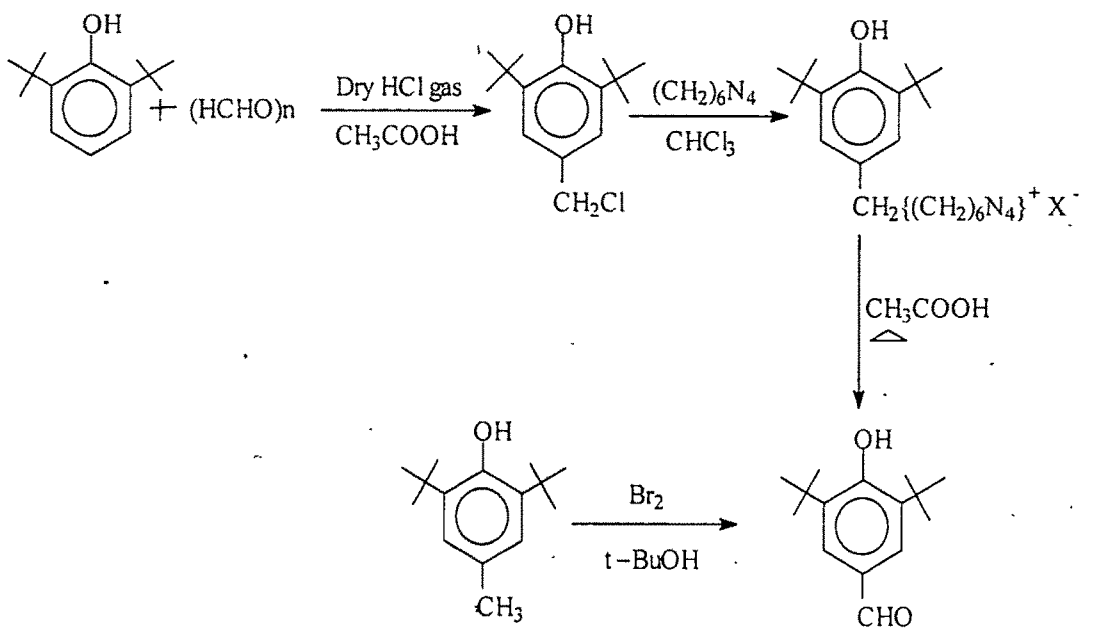
Present Work

2,6-Di-tert-butyl-4-chloromethyl phenol was synthesised from 2,6-di-tert-butyl phenol according to reported procedure[4].

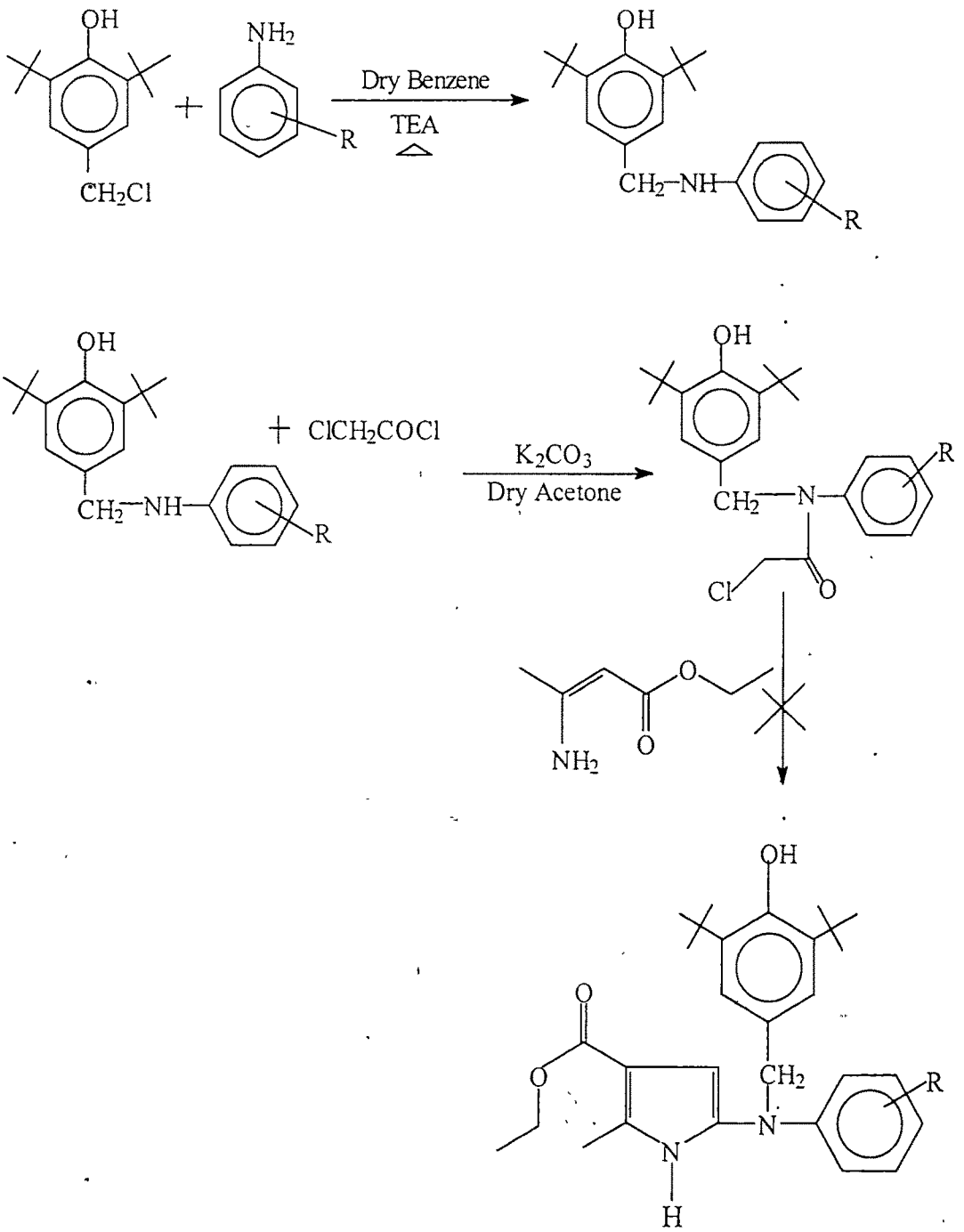
2,6-Di-tert-butyl-4-chloromethyl phenol **1** is reported to be a highly viscous liquid, very hygroscopic in nature[12] and undergoes decomposition on heating. So the purification was found to be difficult. Due to this reason it was directly converted in to the corresponding aldehyde by the application of Sommlet reaction (Scheme 1). The product obtained is compared with the aldehyde obtained by the oxidation of 2,6-di-tert-butyl-4-methyl phenol by bromine in tert-butyl alcohol and found to be the same.

Synthesis of N-substituted-3,5-di-tert-butyl-4-hydroxybenzylamine [AO1 to AO11]

2,6-Di-tert-butyl-4-chloromethyl phenol on condensation with different primary aromatic and alicyclic amines in the presence of base afforded N-substituted-3,5-di-tert-butyl-4-hydroxybenzylamine (Scheme 2). Structures of all these synthesised compounds have been established on the basis of elemental analysis, IR, NMR and Mass spectral studies. Spectral data of representative compound **AO1** is discussed. The IR spectrum taken using KBr of compound **AO1** (Fig.1) exhibited absorption band at 3622 cm^{-1} due to OH stretching frequency of hindered phenolic group. The band appeared at 3450 cm^{-1} indicated the presence of -NH group. Band observed in the region of 2900-2800 cm^{-1} is due to the presence of aromatic CH stretching frequency. Unequal bands appeared at 1385, 1375cm^{-1} are due to CH bending frequency for tert-butyl group. The ^1H NMR (Fig. 2) spectrum recorded

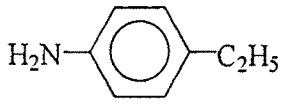

OH
+ (HCHO)n
Dry HCl gas
CH3COOH
CH2Cl
(CH2)6N4
CHCl3
CH2{(CH2)6N4}+ X-
CH3COOH
Br2
t-BuOH
CH3
CHO

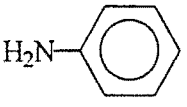
Scheme 1

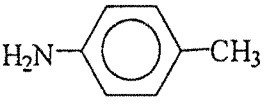

OH
NH2
Dry Benzene
TEA
R
CH2Cl
CH2–NH
+ ClCH2COCl
K2CO3
Dry Acetone
Cl
O
NH2
N
H

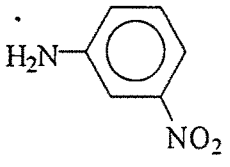
Scheme 2

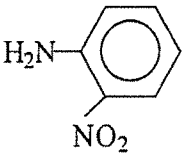
In Scheme 2 amines are

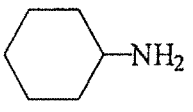


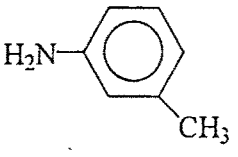


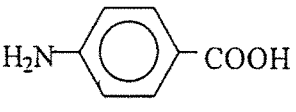


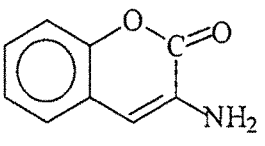


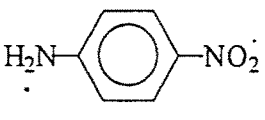


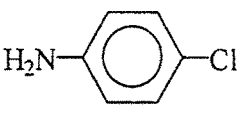












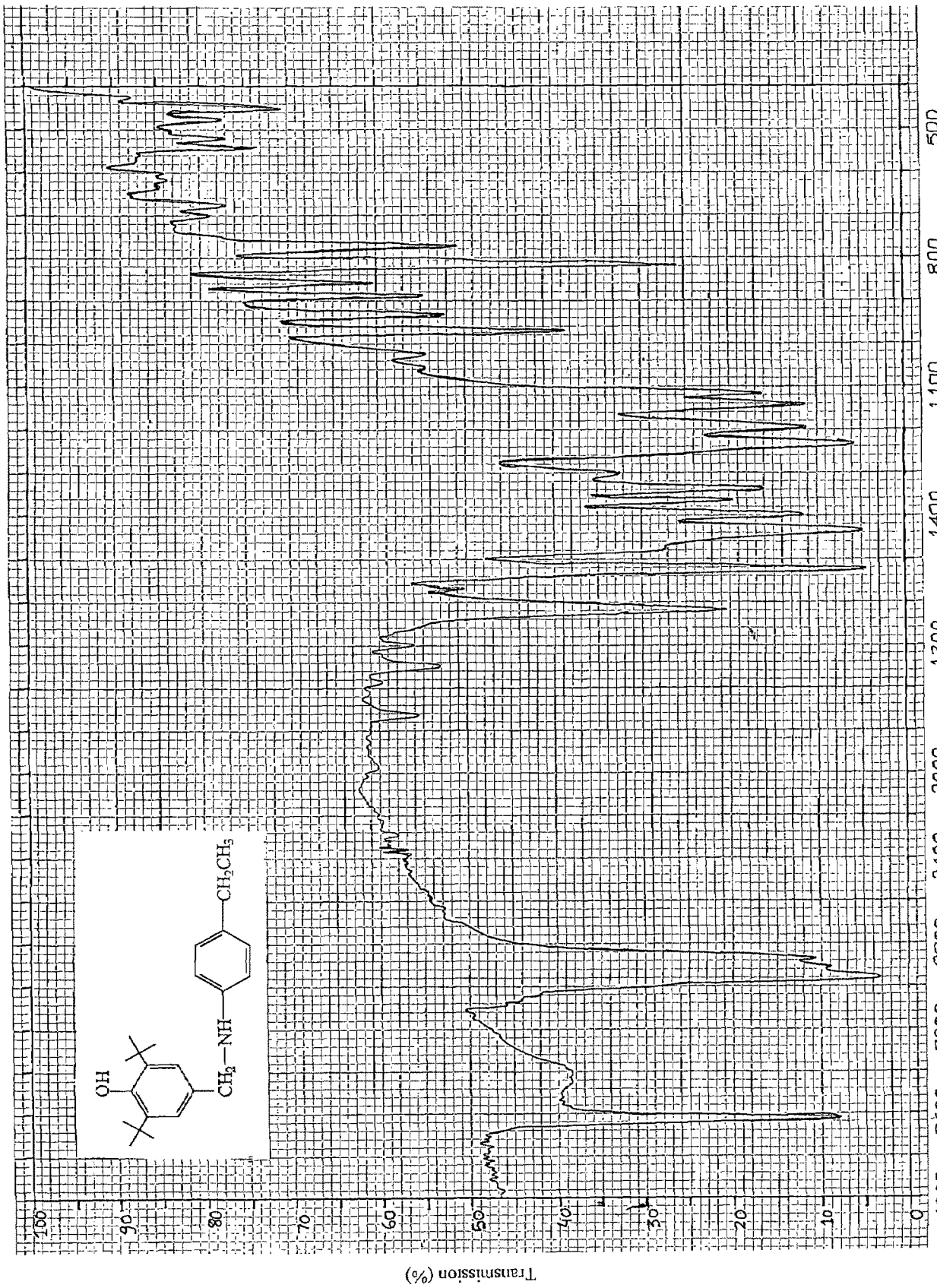

Transmission (%)
100
90
80
70
60
50
40
30
20
10
0
4000
3600
3200
2800
2400
2000
1700
1400
1100
800
500
Wavenumber (cm-1)
OH
CH2—NH
CH2CH3

Figure 1

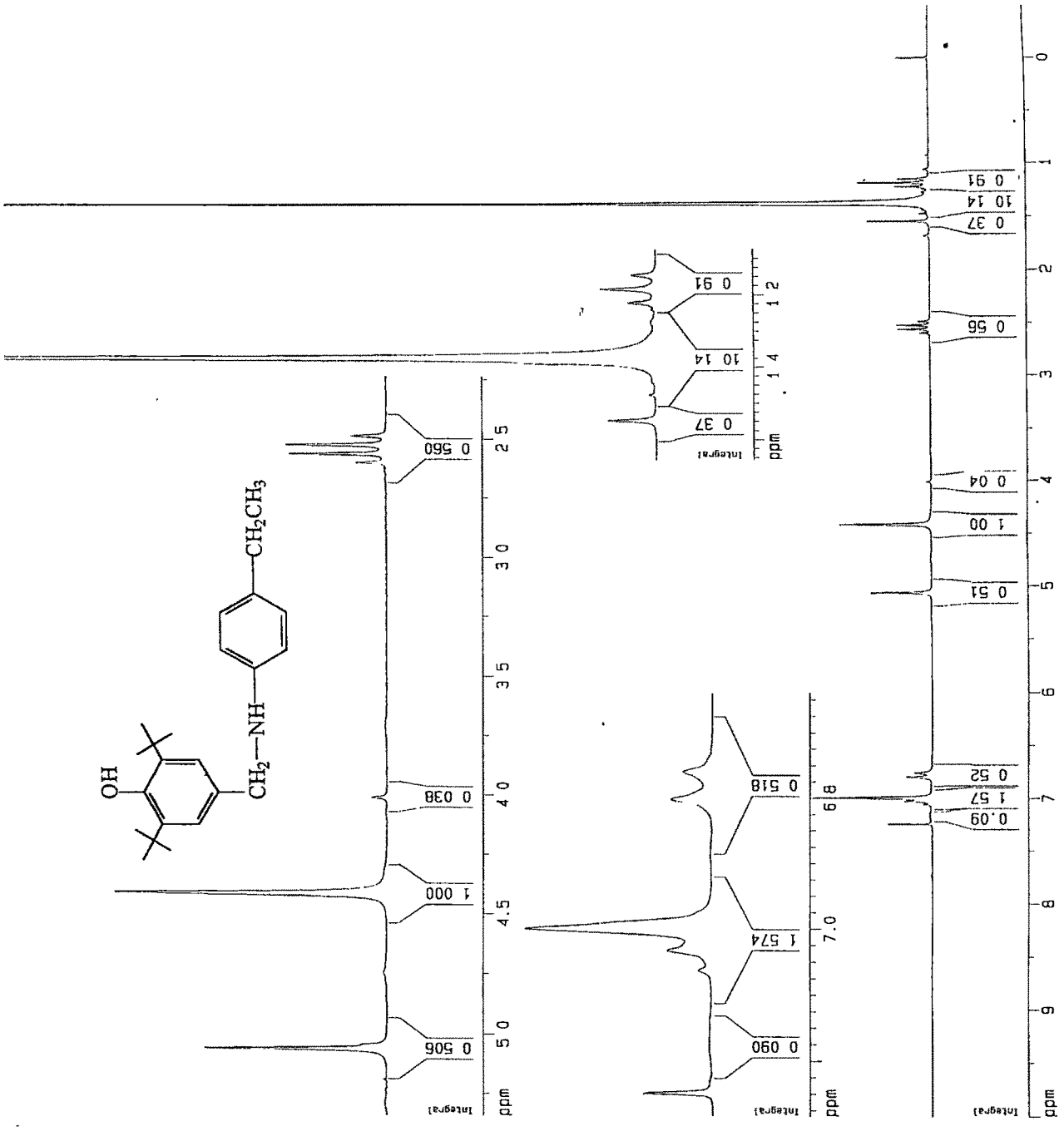

OH
CH2—NH
CH2CH3
0.506
0.038
1.000
0.560
0.090
1.574
0.518
0.09
1.57
0.52
0.51
1.00
0.04
0.56
0.37
10.14
0.91
ppm

Figure 2

in $CDCl_3$ using TMS as internal standard showed a triplet at δ 1.2 and quartet at δ 2.5 are due to the presence of ethyl group. Singlet that appeared at δ 1.37 for eighteen protons showed the presence of two tert-butyl groups. Singlet at δ 4.41 indicated the methylene protons attached to aromatic ring. Singlet at δ 5.1 was observed due to OH proton. Signals at δ 6.8 and δ 7.0 showed the presence of aromatic protons. Mass spectrum (Fig. 3) exhibited molecular ion peak at M/Z 339(M^+), peaks at 219 [M^+ -NH-C_6H_4-CH_2CH_3] and 121 [M^+-4,3,5-(OH)$C(CH_3)_3C(CH_3)_3$-C_6H_2-CH_2-] supporting the formation of amino methyl linkage in the molecule.

Synthesis of N-chloroacetyl-N-substituted-3,5-di-tert-butyl-4-hydroxy benzylamine. [BO1-BO11]

N-Substituted-3,5-di-tert-butyl-4-hydroxybenzylamine [AO10-AO11] on reaction with chloroacetyl chloride in the presence of base gave N-chloroacetyl-N-substituted-3,5-di-tert-butyl-4-hydroxybenzylamine [BO1-BO11]. Elemental analysis, IR and NMR spectral data have been used to confirm the structures of all the synthesised compounds. IR and NMR spectra of representative compound **BO8** are discussed. The IR spectrum (Fig. 4) taken using KBr pellet has shown band at 3610 cm^{-1} due to OH stretching frequency of hindered phenolic group. Band at 1680 cm^{-1} indicated the presence of carbonyl group. ^1H NMR spectrum (Fig. 5) recorded in $CDCl_3$ using TMS as internal standard showed singlet at δ 1.37 due to the presence of eighteen tert-butyl protons. Singlet due to two protons at δ 3.81 indicated the presence of two methylene protons of CH_2-N group. Singlet observed at δ 4.78 corresponds to methylene protons of CH_2-CO. Phenolic OH appeared at δ 5.25 as singlet. Aromatic protons of phenol ring appeared at δ 6.89 for two protons. Two doublets correspond to two protons each at δ 6.95 and δ 7.32 with same J value 9 Hz showed the presence of ortho coupled protons in aromatic ring.

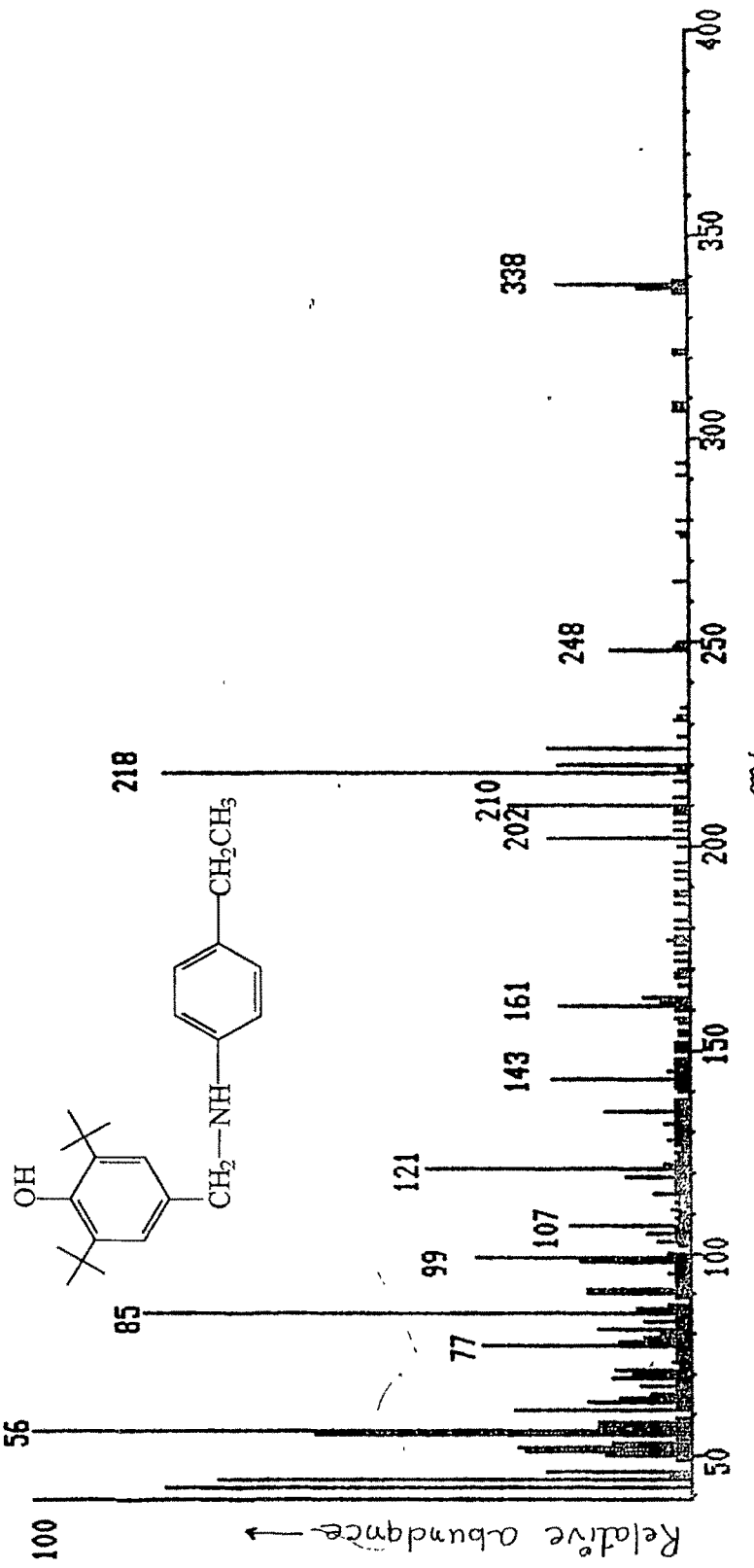

Relative Abundance
m/z
100
56
85
77
99
107
121
143
161
202
210
218
248
338
50
100
150
200
250
300
350
400
OH
CH2—NH
CH2CH3

Figure 3

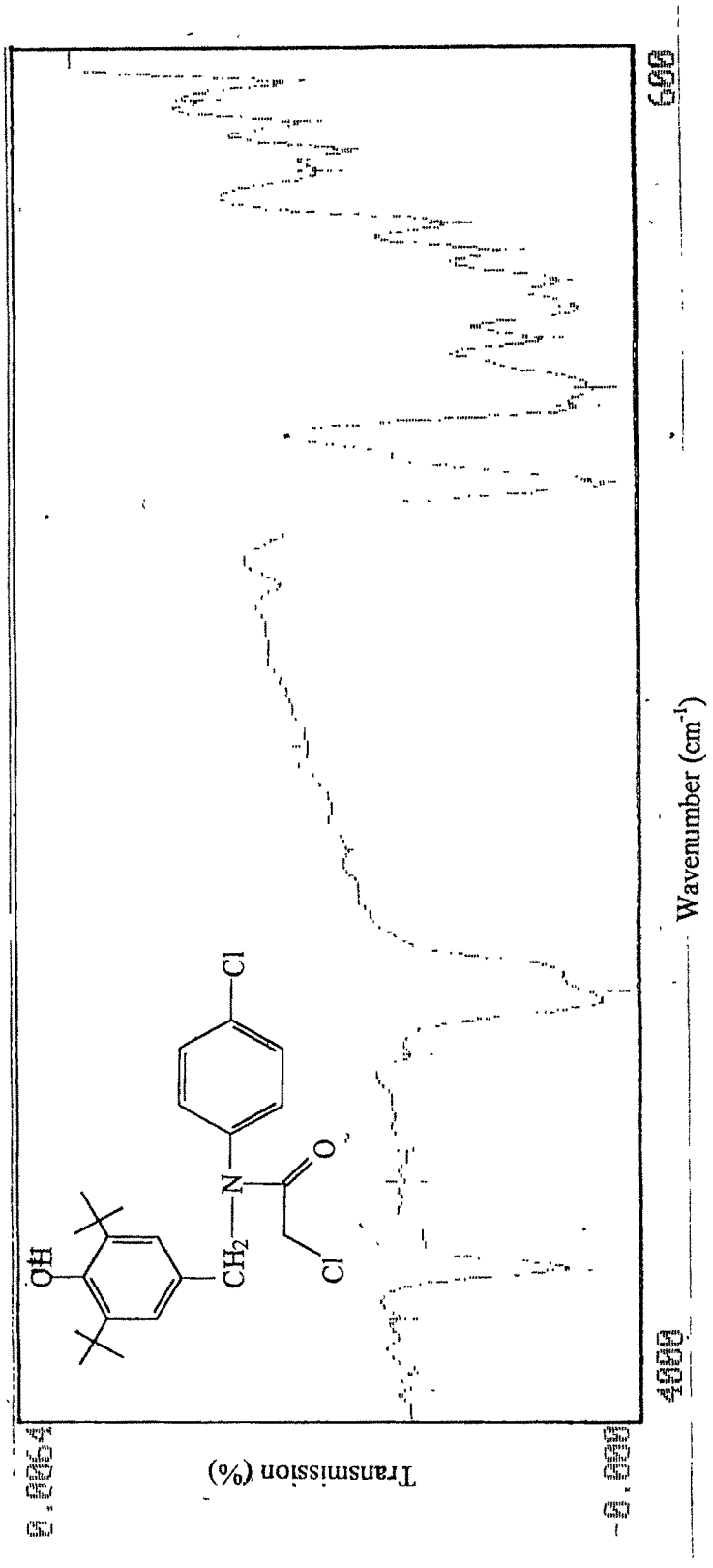


Figure 4

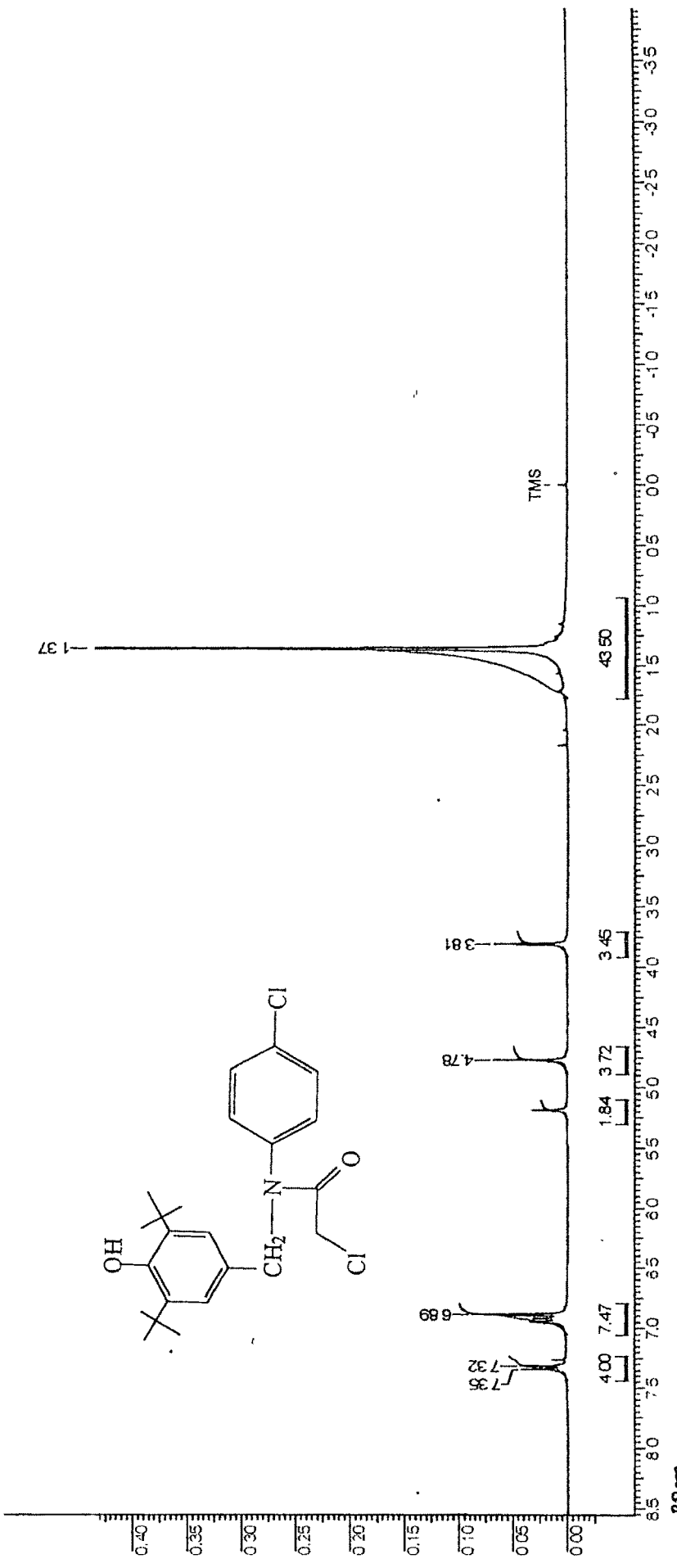

1.37
TMS
4.50
3.81
3.45
4.78
3.72
1.84
6.89
7.47
7.36
7.32
4.00
OH
CH2
N
O
Cl
Cl
ppm

Figure 5

An attempt was made to build up the pyrrole ring on N-substituted amino methyl group by the application of Hantzsch synthesis.

N-Chloroacetyl-N-substituted benzylamine **[BO1- BO11]** on reaction with ethyl amino crotonate in the presence of base (TEA) at different temperatures using solvents like ethanol and dimethylformamide did not give the expected 2-(N-3,5-di-tert-butyl-4-hydroxy-N-substituted phenyl)-4-carbphenoxy-5-methylpyrrole.

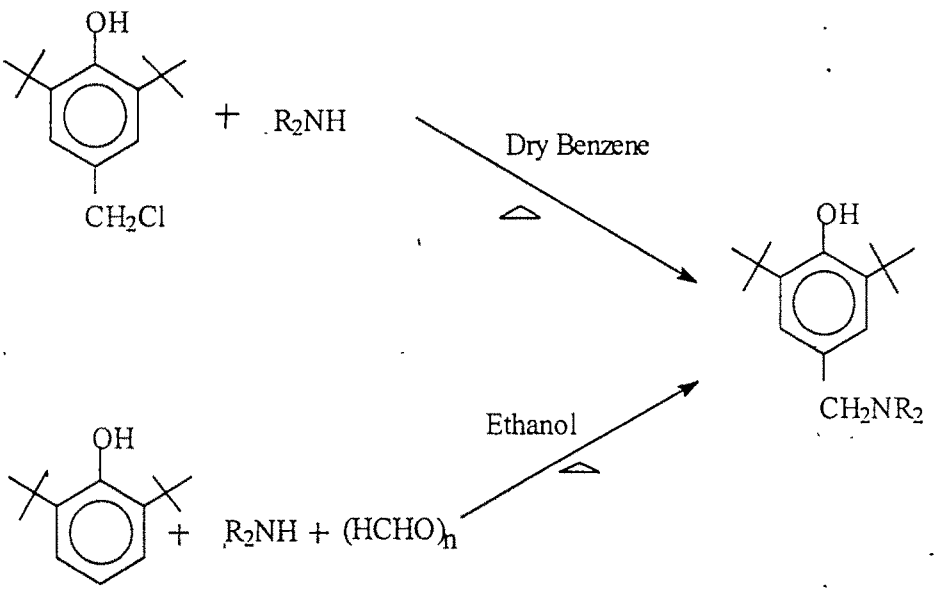
Synthesis of N,N-disubstituted-3,5-di-tert-butyl-4-hydroxybenzylamine.

Method 1

2,6-Di-tert-butyl-4-chloromethyl phenol on condensation with different secondary aliphatic and alicyclic amine in the presence of base yielded N,N-disubstituted-3,5-di-tert-butyl-4-hydroxybenzylamine [AO12-AO15]. (Scheme 3)

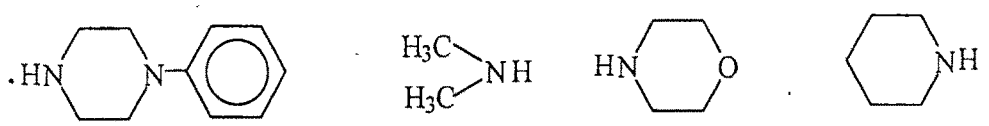
Method 2

A different route was followed for the synthesis of N,N-disubstituted-3,5-di-tert-butyl-4-hydroxybenzylamine, in which 2,6-di-tert-butyl phenol on Mannich reaction with secondary aliphatic amine or heterocyclic amine in the presence of formalin afforded compounds **AO12** to **AO15.** Structures of the synthesised compounds have been established on the basis of elemental analysis, IR, NMR and Mass spectral studies. IR spectrum of **AO12** (Fig. 6) exhibited band at 3622cm^{-1} due to hindered phenolic group., Absence of absorption band at 3450cm^{-1} indicated the absence of -NH group. Absorption bands in the region of 1380, 1375 cm^{-1} showed the presence of tert-butyl group. ^{1}H NMR spectrum (Fig. 7) taken in $CDCl_3$ using TMS as internal standard showed signals at δ 1.44 corresponding to eighteen protons for two tert-butyl groups. Broad signals at δ 2.7 and δ 3.19 indicated the presence of methylene protons present in piperazine ring. Signal at δ 3.59 indicated the presence of methylene protons attached to aromatic ring.



Mannich reaction

Where amines are



Scheme 3

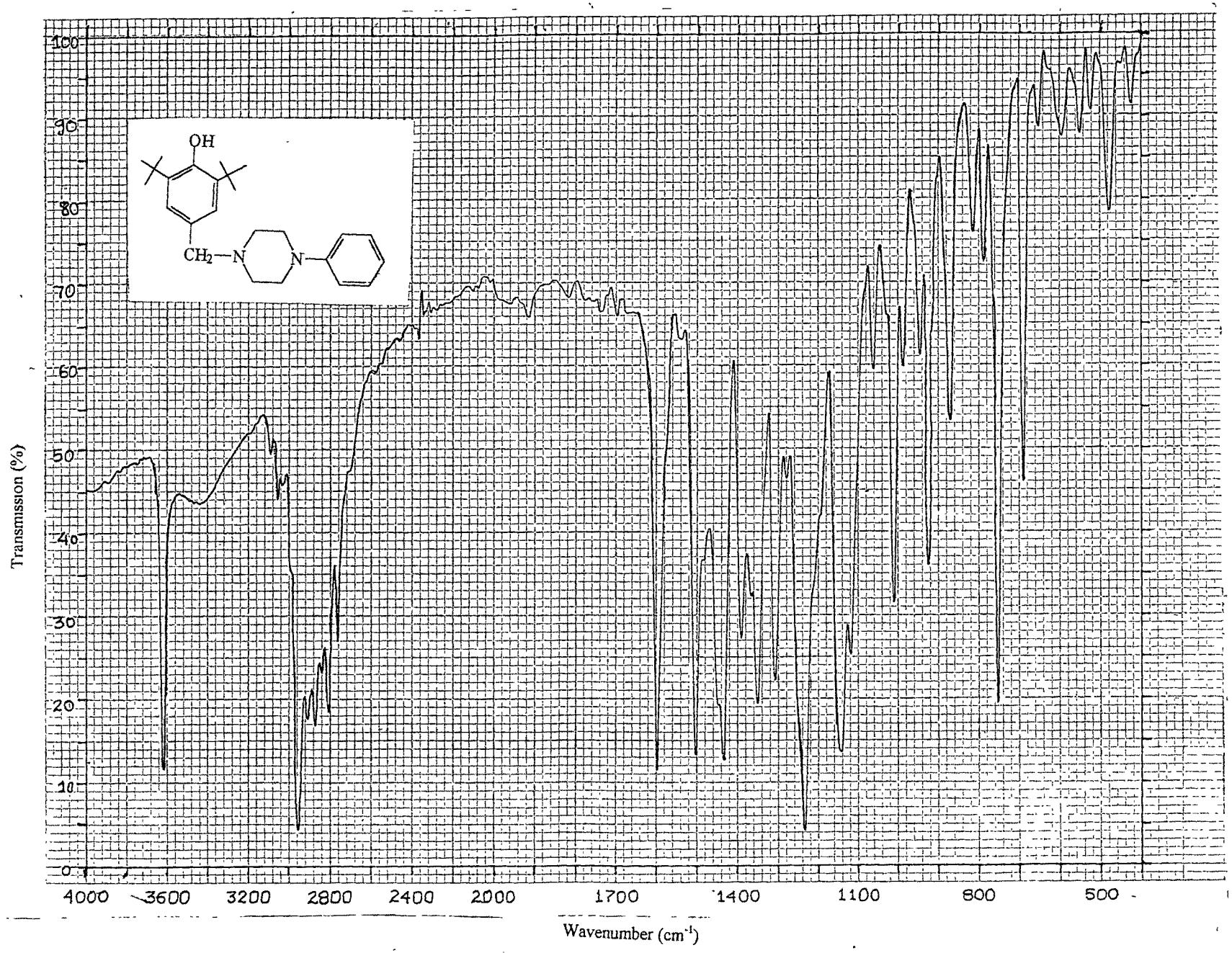

OH
CH2—N
N
100
90
80
70
60
50
40
30
20
10
0
Transmission (%)
4000
3600
3200
2800
2400
2000
1700
1400
1100
800
500
Wavenumber (cm-1)

Figure 6

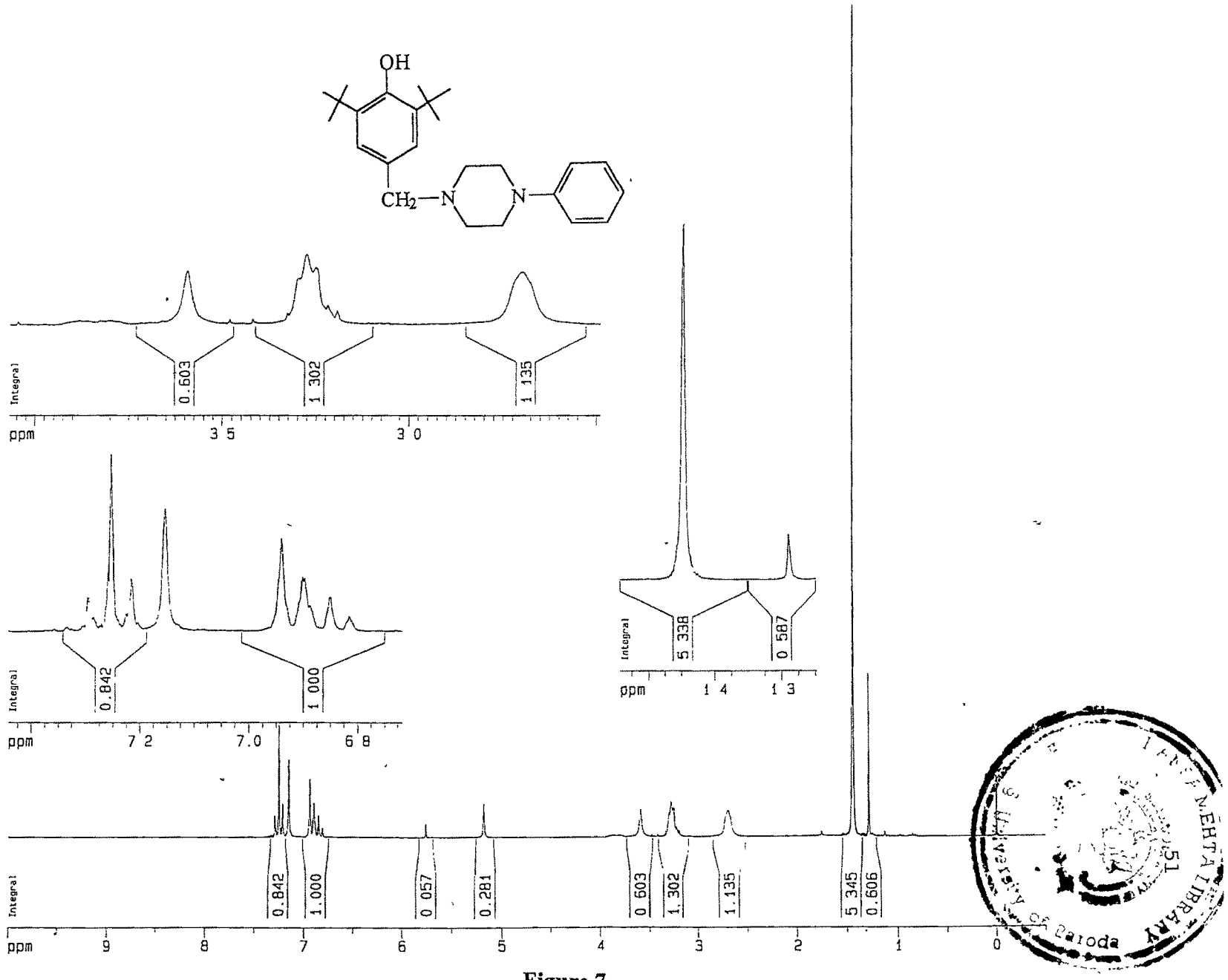


Figure 7

Multiplet obtained in the region of δ 6.8 to δ 7.0 showed the presence of aromatic protons. Signal observed at δ 7.24 is due to two aromatic protons present in phenol ring. Mass spectrum of the compound **AO12** (Fig. 8) exhibited molecular ion peak at 380, peak at 219 is for [M^+- 161 (C_6H_5N $(CH_2)_2$. $(CH_2)_2.N^+$)] supporting formation of CH_2-NH linkage in the molecule. Peak at 132 is due to [161 - 29(CH_2=NH)], 104 [132-28(CH_2=CH_2)], 77 [104-27(HCN)].

From all the synthesised antioxidants, **AO1, AO3, AO4, AO12** and **AO15** were selected for the activity evaluation and synthesised in sufficient quantity (~10 gm each). Antioxidants **AO3, AO4** and **AO12** were selected for activity evaluation in base fuel and **AO1, AO12** and **AO15** were selected for polypropylene copolymer. The procedure for evaluation of antioxidant activity in base fuel is discussed in this chapter and that in PPCP is discussed in chapter 5.

Experimental

Melting points were taken in open capillary paraffin bath and were uncorrected. Elemental analyses were performed on Perkin-Elmer-2400 (Norwalk, CT) C, H, N and S analyser. IR spectra were recorded on Shimadzu - IR 408 (Japan) spectrophotometer as KBr pellets. NMR spectra were recorded on Brukers-200mHz (Wissenbourg-France) spectrophotometer using $CDCl_3$ as solvent and TMS as internal standard. Signal positions (δ value) were measured relative to the TMS signal (δ 0). Mass spectra were recorded on Fillisinnigan MAT-1020B instrument. Analytical TLC was performed on precoated E. Merck silica gel 60 F_{254} aluminium plates.

2,6-Di-tert-butyl-4-chloromethyl phenol was synthesised from 2,6-di-tert-butyl phenol according to the procedure reported by *Geigy*.[4]

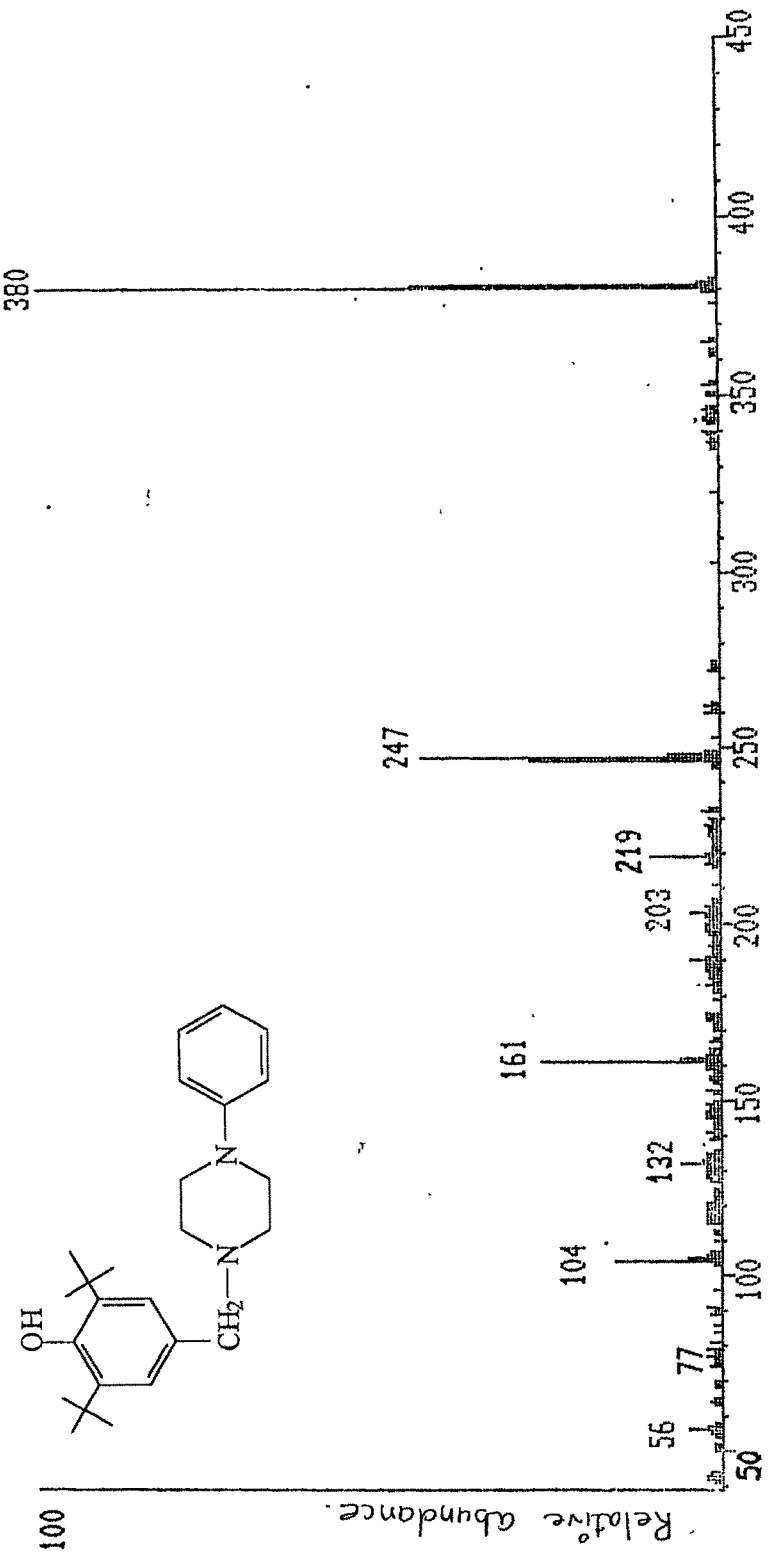

100
Relative abundance
50
56
77
104
132
161
203
219
247
380
m/z
OH
CH2
N
N

Figure 8

The crude slurry (0.1mol) obtained by chloromethylation of 2,6-di-tert-butyl phenol was dissolved in chloroform (30ml) and hexamine (0.3mol) was added to it. The mixture was refluxed at 80^0C for 3 hr and excess of chloroform was removed by distillation. Solid hexamine complex obtained was refluxed with glacial acetic acid (30ml) at 120^0C for about 2 hr. The reaction mixture was cooled and solid obtained was filtered, dried and crystallised from ethanol. m.p. 189^0C, yield 82% (Scheme 1).

3,5-Di-tert-butyl-4-hydroxybenzaldehyde was also prepared by oxidation of 2,6-di-tert-butyl-4-methyl phenol with bromine in tert-butyl alcohol according to the method reported by *Coppinger and Campbell.*[13]

These two products were compared by co-spotting and mixed melting point techniques. R_f values of both these compounds were same on TLC (mobile phase 50:50:: Benzene : Pet-ether) and mixed melting point of the mixture did not show any depression.

The results confirmed that the compound formed by the application of Sommlet reaction is 3,5-di-tert-butyl-4-hydroxybenzaldehyde and the aldehydic group is formed from the chloromethyl group at position para to hydroxy group.

N-Substituted-3,5-di-tert-butyl-4-hydroxybenzylamine [AO1-AO11].

Appropriate amine (0.3mol) was dissolved in dry benzene (50ml) and triethyl-amine (0.1mol) was added to this mixture. 2,6-Di-tert-butyl-4-chloromethyl phenol (0.1mol) in dry benzene (10ml) was added drop wise to this reaction mixture with constant stirring at room temperature. The mixture was refluxed for 8 hr. Benzene layer was washed with dil. HCl followed by water and was removed by distillation. Product obtained after removal of benzene was dried and crystallised from

appropriate solvents. Yield, melting point, molecular formula, molecular weight and elemental analysis of the synthesised compounds are reported in Table 1.

N-Chloroacetyl-N-substituted-3,5-di-tert-butyl-4-hydroxybenzylamine [BO1-BO11]

N-Substituted-3,5-di-tert-butyl-4-hydroxybenzylamine (0.1mol) was dissolved in dimethylformamide (10ml) and triethylamine (0.1mol) was added to it followed by chloroacetyl chloride (0.1mol). The reaction mixture was stirred for 6 hr at room temperature and was poured in cold water. Solid, which separated out, was filtered, dried and crystallised from appropriate solvents. Yield, melting point, molecular formula, molecular weight and elemental analysis of the synthesised compounds are reported in Table 2.

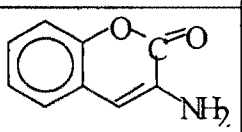
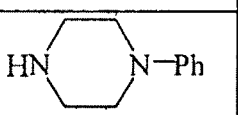
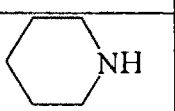
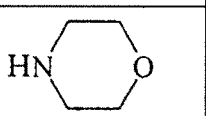
N,N-Disubstituted-3,5-di-tert-butyl-4-hydroxybenzylamine. [AO12-AO15]

(Method 1)

To a stirring solution of 2,6-di-tert-butyl-4-chloromethyl phenol (0.1mol) in dry benzene (50ml), triethylamine (0.1mol) and secondary amine (0.1mol) were added. The reaction mixture was refluxed for 6 hr. The benzene layer was washed with dil. HCl followed by water and was dried over sodium sulphate. The product obtained after removal of benzene was dried and crystallised from appropriate solvents.

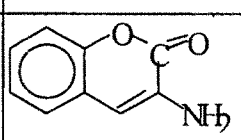
(Method 2)

To 2,6-di-tert-butyl phenol (0.1mol) in ethanol (25ml), formalin (30%, 0.3mol) and secondary amine (0.1mol) were added. The mixture was refluxed for 5 hr. It was allowed to cool and was poured in water. The solid separated out was filtered, dried and crystallised from appropriate solvents.Compounds obtained from method 1 and 2 were compared by mixed-melting point and co-spotting techniques.

Code*	Amines	Yield (%)	M.P (^{0}C)	M.F. (Mol.Wt.)	Elemental Analysis (Calc./Obs.) (%)		
					C	*H*	*N*
AO1^{B}	*p*-$C_2H_5C_6H_4NH_2$	69	197	$C_{23}H_{33}NO$ (339 .52)	81.03 81.41	9.78 9.73	3.79 4.12
AO2^{P}	$C_6H_5NH_2$	70	177	$C_{21}H_{29}NO$ (311.47)	81.01 81.10	9.32 9.17	4.50 4.90
AO3^{A+B}	*p*-$CH_3C_6H_4NH_2$	74	185	$C_{22}H_{31}NO$ (325 .49)	81.20 81.65	9.53 9.93	4.30 4.29
AO4^{B}	*p*-$NO_2C_6H_4NH_2$	80	198	$C_{21}H_{28}N_2O_3$ (356.14)	70.75 71.12	7.86 7.90	7.86 7.82
AO5^{B}	*m*-$NO_2C_6H_4NH_2$	81	140	$C_{21}H_{28}N_2O_3$ (356.14)	70.75 71.18	7.86 7.91	7.86 7.87
AO6^{A+B}	*0*-$NO_2C_6H_4NH_2$	78	240	$C_{21}H_{28}N_2O_3$ (356.14)	70.75 71.13	7.86 7.82	7.86 7.70
AO7^{B+P}	$C_6H_{11}NH_2$	75	130	$C_{21}H_{34}NO$ (317.18)	79.45 79.00	10.71 10.32	4.41 4.32
AO8^{P}	*p*-$ClC_6H_4NH_2$	70	121	$C_{21}H_{28}ClNO$ (344.5)	72.93 72.55	8.32 8.10	4.04 4.05
AO9^{B+P}	*m*-$CH_3C_6H_4NH_2$	67	187	$C_{22}H_{31}NO$ (325.4)	67.69 67.57	9.53 9.32	4.30 4.27
AO10^{B}	*p*-$CO_2HC_6H_4NH_2$	80	207	$C_{22}H_{29}NO_3$ (355.48)	74.36 74.68	8.37 8.16	3.94 4.05
AO11^{B+P}		71	160	$C_{24}H_{29}NO_3$ (379 .50)	75.98 76.19	7.65 7.40	3.69 3.70
AO12^{P}		79	140	$C_{25}H_{36}N_2O$ (380.57)	78.90 79.29	9.40 9.75	6.30 6.24
AO13^{P}	$(CH_3)_2NH$	81	93	$C_{17}H_{29}NO$ (263 .42)	77.56 77.51	11.10 10.82	5.32 5.23
AO14^{P}		62	80	$C_{20}H_{33}NO$ (303 .49)	79.16 78.70	10.80 10.94	4.60 4.28
AO15^{P}		61	82	$C_{19}H_{31}NO_2$ (305.12)	74.75 74.50	10.16 9.83	4.59 4.58

*Solvent used for crystallisation
A= Alcohol, B= Benzene, P= Petroleum ether

Table 1

Code*.	Amines	Yield (%)	M.P. (^{0}C)	M.F. (Mol.Wt.)	Elemental Analysis (Calc. / Obs.) (%)		
					C	H	N
BO1^{P}	*p*-$C_2H_5C_6H_4NH_2$	73	98	$C_{25}H_{34}ClNO_2$ (415.5)	72.20 71.80	7.97 8.06	3.36 3.51
BO2^{P}	$C_6H_5NH_2$	80	70	$C_{23}H_{30}ClNO$ (387.5)	71.22 70.71	7.74 7.66	3.61 3.56
BO3^{B+P}	*p*-$CH_3C_6H_4NH_2$	65	118	$C_{24}H_{32}ClNO_2$ (401.5)	71.73 70.46	7.79 7.67	3.48 3.38
BO4^{B+P}	*p*-$NO_2C_6H_4NH_2$	68	92	$C_{23}H_{29}ClN_2O_4$ (432.5)	63.81 63.14	6.70 6.90	6.47 6.35
BO5^{B+P}	*m*-$NO_2C_6H_4NH_2$	78	100	$C_{23}H_{29}ClN_2O_4$ (432.5)	63.81 63.34	6.70 6.59	6.47 6.01
BO6^{B}	*0*-$NO_2C_6H_4NH_2$	75	182	$C_{23}H_{29}ClN_2O_4$ (432.5)	63.81 63.64	6.70 6.69	6.47 6.61
BO7^{B+P}	$C_6H_{11}NH_2$	65	143	$C_{23}H_{35}ClNO_2$ (392.5)	70.31 69.91	8.91 9.09	3.56 3.32
BO8^{B+P}	*p*-$ClC_6H_4NH_2$	58	128	$C_{23}H_{29}ClNO_2$ (422)	65.40 65.00	6.87 6.93	3.31 3.05
BO9^{P}	*m*-$CH_3C_6H_4NH_2$	67	102	$C_{24}H_{32}ClNO_2$ (432.5)	71.73 71.52	7.97 7.85	3.48 3.50
BO10	*p*-$CO_2HC_6H_4NH_2$	Product not isolated					
BO11^{B+P}		67	110	$C_{26}H_{30}ClNO_4$ (455.5)	68.49 68.21	6.58 6.35	3.07 3.24

|*Solvent used for crystallisation

A = Alcohol, B = Benzene, P = Petroleum ether

Table 2

Evaluation of Antioxidant Activity in Base Fuel

Lubricants and lubricating oils are the most important class of materials that require antioxidant protection because most of them function at high temperature where number of physical and chemical changes involve a complex pattern of thermolytic and oxidative reactions. To avoid or delay the oxidation of oil at high temperature, antioxidants are added, of which, phenolic and amine antioxidants are preferred[14].

2,6-Di-tert-butyl-4-methyl phenol (BHT) and derivatives of 1,4-diamino benzene are widely used as antioxidants for gasoline. Substituted phenolic compounds in combination with ester, amine and polyamines are also used as fuel additive for the prevention and control of engine deposit[15-17].

Gao et al.[18] reported that oil soluble organo molybdenum compounds in combination with phenolic or aminic antioxidants have been used to improve the dispersancy retention capability of crankcase lubricants.

Youssif et al.[19] observed that heterocyclic compounds including triazine, triazole and oxazolines have been used as antioxidant in turbine aviation oils. They also reported an important observation that heterocyclic compounds are more stable at high temperature than other amines and amides, so that lifetime of oil can be improved with them.

Nitrogen heterocyclics like pyrazolines and their derivatives are used for long term storage liquid fuels as well as metal deactivating additives for light fuels due to their action as multifunctional inhibitors as reported by *Boneva et al.*[20]

Ravi and Ravi[21] reported the use of sulphurised olefin with thiadiazole derivative as antioxidant in lubricating oil as extreme pressure additive.

BHT is used as a potent antioxidant in hydraulic fuel. However BHT suffers from a major draw back, high volatility. Volatility can be minimised by replacing the methyl group at the position para to hydroxy group in BHT by long aliphatic group[22].

Most of the amine antioxidants are coloured and produce colour during oxidation, limiting their use to applications where discoloration can be tolerated[11].

Requirement for an antioxidant in Base fuel

The ideal antioxidant should have proper melting temperature, less volatility and is required to withstand harsh conditions of processing. It should minimise the deterioration of lubricant by retarding viscosity increase and preventing metal corrosion. It should not produce any coloration at high temperature during the process and end-use. Apart from these the antioxidant should possess appropriate thermal decomposition temperature and should be soluble in base fuel under the given experimental conditions.

Following antioxidants were selected for the activity evaluation in base fuel and were synthesised in sufficient quantities. (~10gm each)

1) 4'-Methylphenyl-3,5-di-tert-butyl-4-hydroxybenzylamine **[AO3]**

2) 4'-Nitrophenyl-3,5-di-tert-butyl-4-hydroxybenzylamine **[AO4]**

3) 1-(3',5'-Di-tert-butyl-4'-hydroxy benzyl)-4-phenyl piperazine **[AO12]**

Out of three antioxidants selected for activity evaluation **AO3** and **AO4** were found to be insoluble in base oil at 0.5wt.% level, hence they were not further tested.

Antioxidant activity of synthesised compound **AO12** was evaluated in base fuel (MS) and base fuel (FCC gasoline) and compared with commercially used sample UOP-5 by Indian Oil Corporation Limited [I.O.C.L.] using standard test method for oxidation stability of aviation fuels (Potential residue method) ASTM-D873-94.

This method is used for the determination of tendency of aviation reciprocating, turbine and jet engine fuels to form gum and deposit under accelerated aging condition. These results can be used to indicate storage stability of fuels. Amount of potential gum formed indicates the effectiveness of antioxidant added to it.

Thermal decomposition temperature of antioxidant **AO12** was measured using TA instrument DSC-2910 (USA) and was found to be 252.2^{0}C

Evaluation of Antioxidant Activity by Potential Residue Method.

Experimental procedure

The bomb and fuel, which are to be tested, are allowed to attain 15-25^{0}C. 100ml of sample was added to a weighed glass sample container and sample container was placed in the bomb. The bomb was closed and oxygen was introduced using quick release coupling until a pressure of 689 to 703 kpa was attained. The gas present in the bomb was allowed to escape slowly through the needle valve at the rate of 345 kpa/min. The charging and exhausting of the oxygen was repeated once more in order to flush out the air present originally.

Oxygen was introduced in a bomb until a pressure of 689 to 703 kpa attained. The charge bomb was placed in an oxidation bath with out shaking. Starting time was noted during the immersion of bomb in oxidation bath. The bomb was kept in an oxidation bath for 4 hr at 100^0C. At the completion of oxidation period, the bomb was removed from the oxidation bath and cooled with water. Pressure was released slowly at 345 kpa/min. The sample container was removed from bomb. The amount of soluble and insoluble gum was measured. The amount of potential gum tells about effectiveness of antioxidant added to fuels.

The above mentioned oxidation procedure was performed using synthesised antioxidant and commercial antioxidant [UOP-5] added individually to base fuel (MS) having composition reformat 40%, SR naphtha 30%, FCC gasoline 30% by volume and to base fuel (FCC gasoline) at two different concentration of 10 ppm and 20 ppm level.

Oxidation of base fuel (MS) and base fuel (FCC gasoline) was also carried out with out adding antioxidant and used as reference.

The amount of potential gum formed with synthesised antioxidant and without antioxidant in base fuel is listed in Table 3 and in Table 4.

Samples	Potential gum, mg/100ml
Base fuel (MS)	4.8
Base fuel + UOP-5(10ppm)	3.4
Base fuel + AO12 (10ppm)	3.8
Base fuel + UOP-5(20ppm)	3.4
Base Fuel + AO12 (20ppm)	3.6

Table 3

Samples	Potential gum, mg/100ml
Base fuel (FCC gasoline)	8.6
Base fuel + UOP-5(20ppm)	6.2
Base fuel + AO12(20ppm)	7.2

Table 4

Results and Discussion

From the Table 3 and Table 4, it has been shown that in the absence of antioxidant, the degradation of base fuel (MS) and base fuel (FCC gasoline) are very fast. This is probably because gasoline and fuels contain unsaturated hydrocarbon that oxidise easily on storage forming free radicals, thus degradation leading to the formation of soluble and insoluble gum.

The amount of potential gum formation in the absence of antioxidant in base fuel (MS) is 4.8mg/100ml, while potential gum formation in base fuel (FCC gasoline) is 8.6mg/100ml. However, with the commercially available antioxidant UOP-5 the potential gum formation in base fuel (MS) is 3.4mg/100ml at 10ppm and 20ppm level. This value in base fuel (FCC gasoline) is 6.2mg/100 ml at 20ppm level. These values of potential gum suggest that UOP-5 can resist the oxidation of base fuels and hence it is an effective antioxidant for base fuel. With the synthesised antioxidant **AO12,** the potential gum formation values are quite comparable with that of base fuel with UOP-5. The potential gum formation values in base fuel (MS) with antioxidant **AO12** at 10 ppm level is 3.8mg/100ml and at 20ppm level is 3.6 mg/100ml. The potential gum formation value in base fuel (FCC gasoline) with **AO12** at 20ppm level is found to be 7.2mg/100ml. Above results indicate that compound **AO12** prevents the oxidation of base fuels and can act as an effective antioxidant for base fuels. Here activity is due to the presence of hindered phenolic group in combination with hindered amino group, which exhibit the effect of auto synergism i.e. presence of two chemically different antioxidant functionality in the same molecule. The new antioxidant has good thermal stability and excellent stabilising property. The newly synthesised antioxidant is white in colour and does not impart any coloration during the processing at high temperature. Based on the above facts it can be concluded that this antioxidant is a novel antioxidant for base fuel and its performance is comparable with commercial sample UOP-5.

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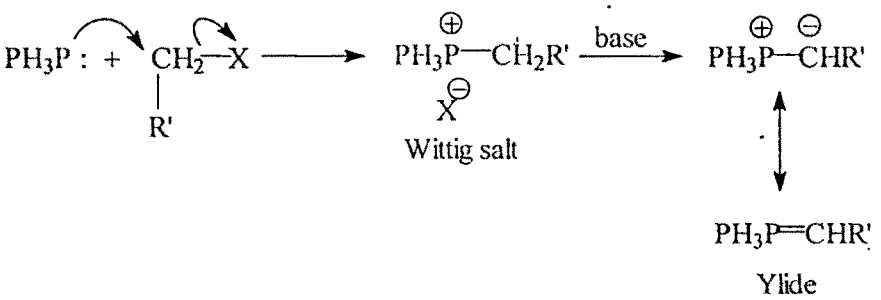
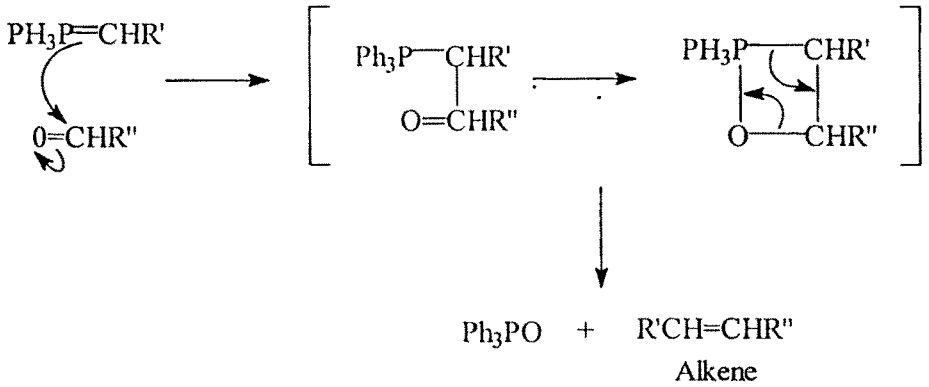
Chapter 2
Section 2

Synthesis of Antioxidants by the Application of Wittig reaction.

Wittig reaction was discovered in 1953 by *George Wittig* and is extensively used for carbon-carbon bond formation. Quaternisation of triphenylphosphine with an alkyl halide gives a quaternary phosphonium halide, which under the influence of strong base eliminates hydrogen halide to give an alkylidene phosphorane (an ylide). Ylide reacts with an aldehyde or ketone to give first an intermediate betaine, which rearranges to the oxaphosphetane followed by elimination of triphenylphosphine oxide to form an alkene.



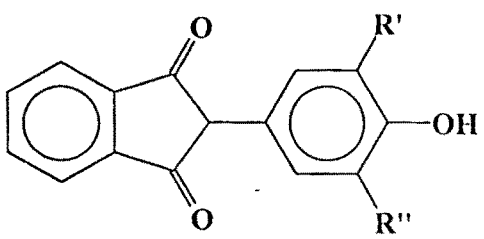


The advantage of this reaction is that the mild conditions do not normally promote structure isomerisation and for this reason alkene of unambiguous structure may be synthesised.

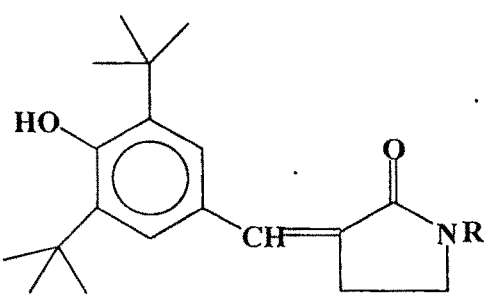
Nauta et al.[1] have reported the synthesis and anti-inflammatory activity of substituted 2-(4-hydroxyphenyl)-1,3-indanedione **2** (R'=Me, R"=CMe_3 or R'=R"=CMe_3). They have achieved the synthesis of these compounds by the Wittig reaction of triphenyl-3-phthalidyl phosphonium bromide and the appropriate 4-hydroxy benzaldehyde. The reported compounds showed appreciable activity.

Synthesis of α-(3,5-di-tert-butyl-4-hydroxybenzylidene)-γ-butyrolactone was reported by *Watanabe et al.*[2] by the condensation of 3,5-di-tert-butyl-4-hydroxy benzaldehyde with α-tert-butyl phenylphosphoranylidene-γ-butyrolactone. This butyrolactone on hydrolysis yielded β-carboxy-β-(2-hydroxyethyl)-3,5-di-tert-butyl-4-hydroxystyrene. The synthesised compounds showed anti-inflammatory, analgesic and anti-pyretic activity and were used in pharmaceutical formulations. They exhibited pharmacological activity in rats and in mice.

Ikuta et al.[3] reported the synthesis and anti-inflammatory activity of 3-(3,5-di-tert-butyl-4-hydroxybenzylidene) pyrrolidin-2-one **3**. They have synthesised compound **3** (R=Ac) by reacting the Wittig salt of bromo pyrrolidinone with 3,5-di-tert-butyl-4-hydroxybenzaldehyde.



[2]

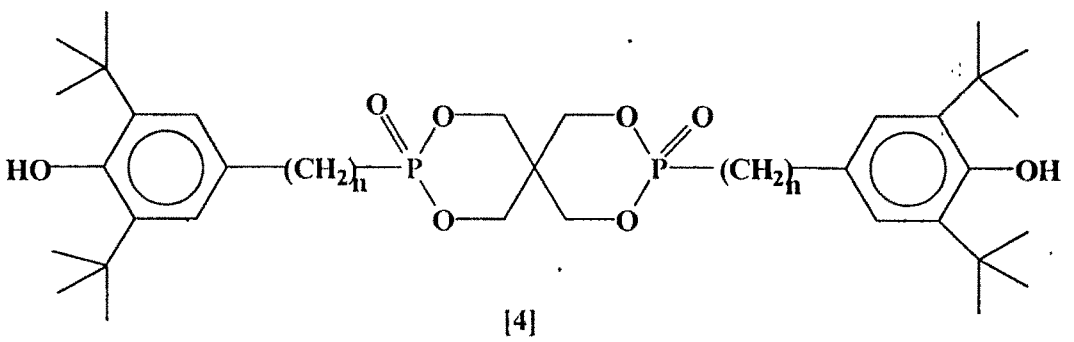


[3]

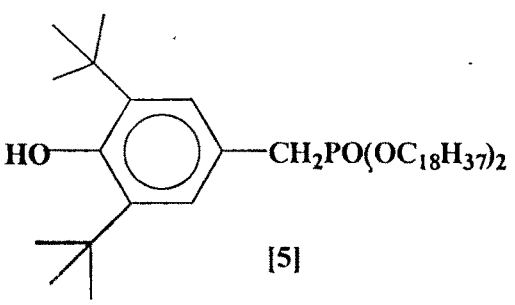
3,3'-(Di-tert-butyl-4-hydroxybenzyl) phosphinylidenedipropionitrile was synthesised from 2,6-di-tert-butyl-4-chloromethyl phenol and bis(2-cyanoethyl) phosphine oxide. Reported compounds possess good heat and light stabilising property for polymers as reported by *William et al.*[4]

Ingenium et al.[5] have reported the synthesis of polypropylene stabiliser **4** by condensing 3,9-dimethoxy-2,4,8,10-tetraoxa-3,9-diphosphaspiro [5,5] hendecance with 3,5-di-tert-butyl-4-hydroxybenzylchloride in the presence of alkaline catalyst.

John[6] synthesised phosphonate derivatives as stabilisers for polypropylene by heating the appropriate phenolic alkyl halide with a tertiary phosphite. Thus 2,6-di-tert-butyl-4-chloromethyl phenol on reaction with $P(OC_{18}H_{37})_3$ in hexane gave phosphonate derivative **5**. This compound was tested in unstablised polypropylene powder.



[4]



[5]

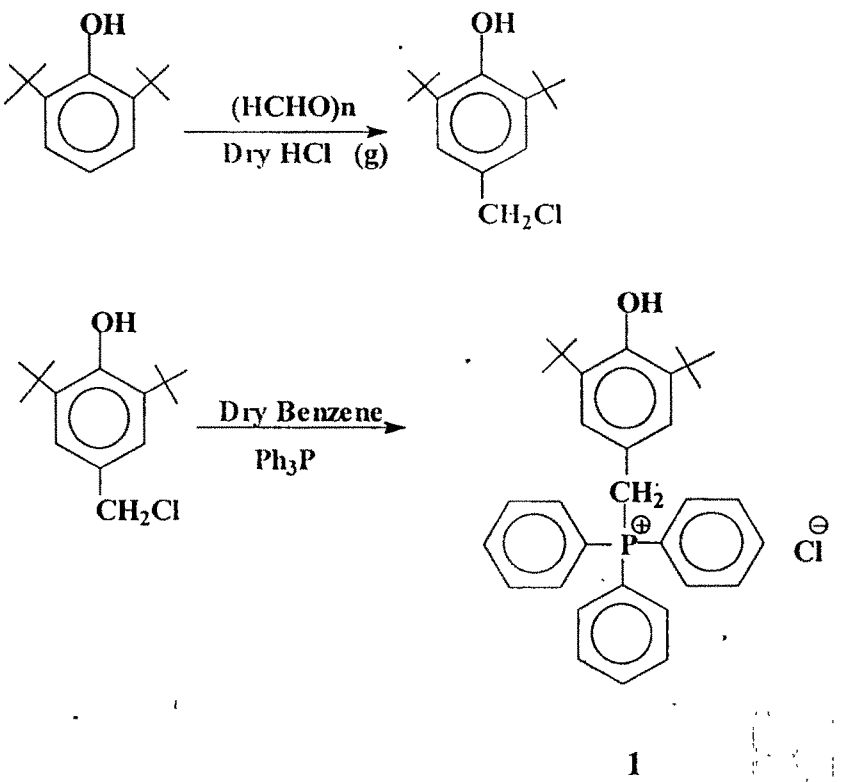
From the literature references, it has been observed that the combination of hindered phenol and phosphonate showed reasonably good antioxidant activity. Literature data also revealed that the formation of ethylenic linkage at the position para to hydroxyl group involves the reaction between 3,5-di-tert-butyl-4-hydroxy benzaldehyde and various Wittig salts. Antioxidants based on hindered phenol in combination with phosphite are also reported in literature by the reaction between 2,6-di-tert-butyl-4-chloromethyl phenol and trialkyl phosphite. A draw back of phosphite stabilisers is their sensitivity towards hydrolysis to generate phosphorus acid, which can corrode the processing equipments.[7]

By considering the importance of phosphorus atom in antioxidant molecule, it was thought worth while to synthesise antioxidant based on hindered phenol in combination with phosphine and to study the performance of it in polypropylene-copolymer. 3,5-Di-tert-butyl-4-hydroxyphenyl triphenylphosphoniumchloride was synthesised by the reaction of 2,6-di-tert-butyl-4-chloromethyl phenol and triphenylphosphine, which on reaction with aldehydes and ketone could afford ethylenic linkage at the position para to hydroxyl group.

Present Work

2,6-Di-tert-butyl-4-chloromethyl phenol was synthesised according to the method reported by Geigy[8].

Synthesis of 3,5-di-tert-butyl-4-hydroxybenzyl triphenylphosphoniumchloride 1.
Wittig salt 1 was synthesised (Scheme 1) from 2,6-di-tert-butyl-4-chloromethyl phenol and triphenylphosphine in dry benzene. Structure of this Wittig salt has been established on the basis of elemental analysis and NMR spectral study. ^1H NMR spectrum (Fig. 1) recorded in $CDCl_3$ using TMS as internal standard showed singlet at δ 1.19 for eighteen protons is due to the presence of two tert-butyl


OH
(HCHO)n
Dry HCl (g)
OH
CH2Cl
OH
CH2Cl
Dry Benzene
Ph3P
OH
CH2
P
Cl

1

Scheme 1

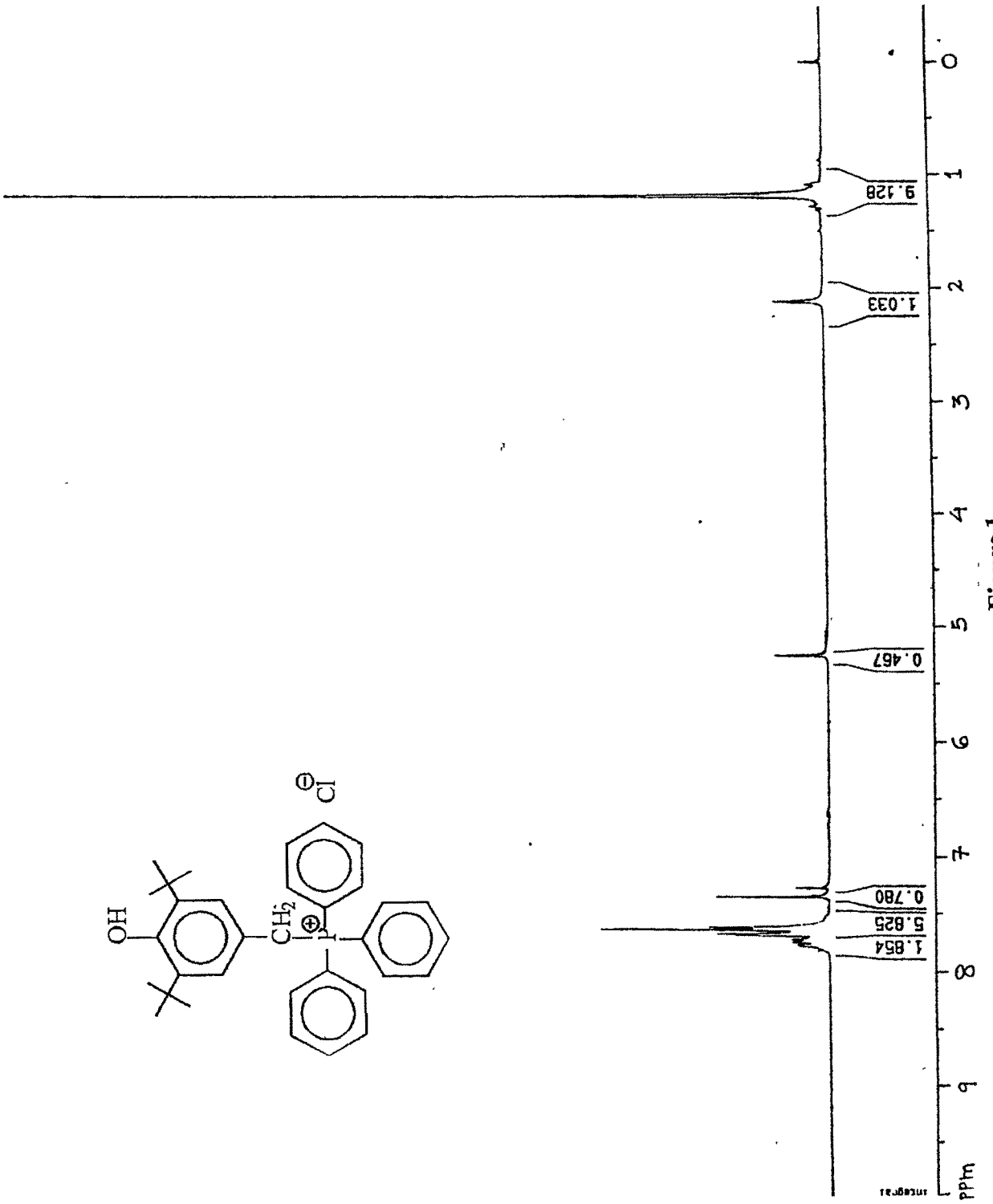

9.128
1.033
0.467
0.780
5.825
1.854
integral
PPm
0
1
2
3
4
5
6
7
8
9
OH
CH2
P
Cl

Figure 1

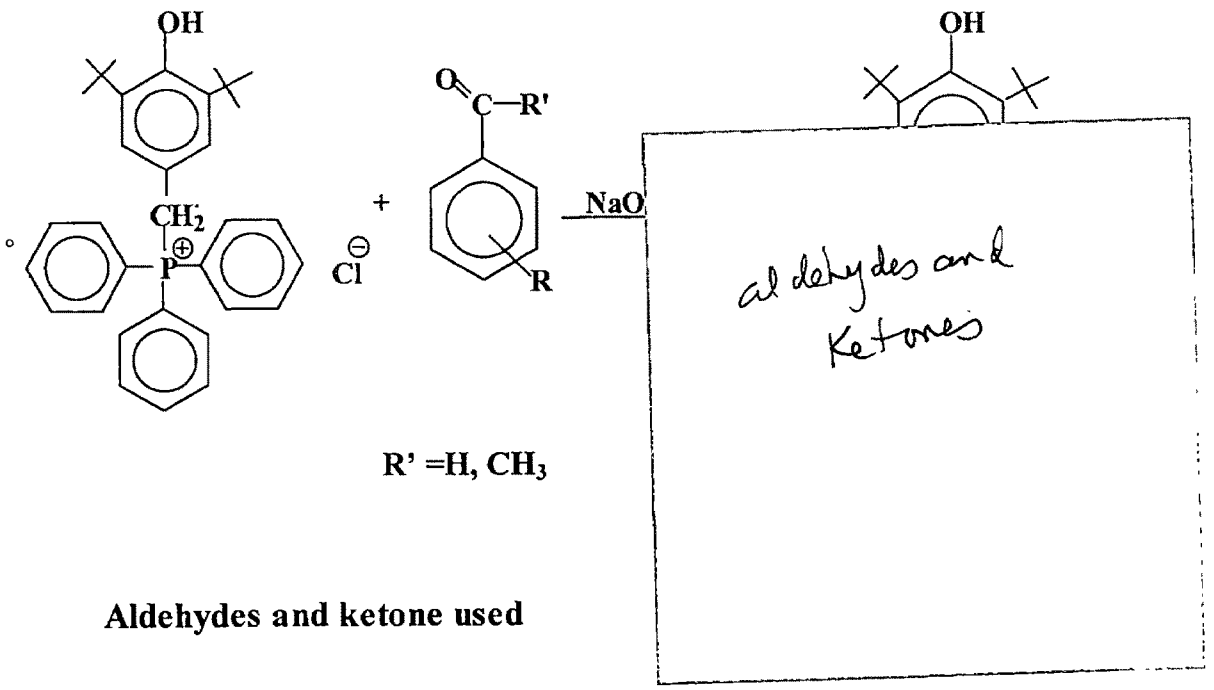
groups. Singlet at δ 2.1 for two protons confirmed the presence of methylene group attached to aromatic ring. Phenolic OH appeared at δ 5.25 as singlet. Two aromatic protons of phenol ring appeared at δ 7.35 as singlet. All the fifteen protons of phenyl ring appeared as multiplet in the range of δ 7.61 to 7.80.

Synthesis of 1-(3',5'-di-tert-butyl-4'-hydroxyphenyl)-2-(substituted phenyl) ethylene **[WR1-WR12]**

Wittig salt **1** on reaction with different aromatic aldehydes (Scheme 2) in the presence of base afforded 1-(3'.5'-di-tert-butyl-4'-hydroxyphenyl)-2-(substituted phenyl) ethylene. Structure of the synthesised compounds has been established on the basis of elemental analysis and NMR spectral technique. ^{1}H NMR spectrum of the representative compound is discussed here. ^{1}H NMR spectrum (Fig. 2) of compound **WR1** recorded in $CDCl_3$ using TMS as internal standard showed two singlets at δ 1.36 and δ 1.49 for eighteen protons, which indicated the presence of two tert-butyl groups. Phenolic proton appeared as singlet at δ 5.29 and at δ 5.42. Singlet observed at δ 7.14 for two protons is due to the presence of two aromatic protons in phenol ring. Peaks observed at δ 7.26 and δ 7.36 are due to four aromatic protons. Two ethylenic protons appeared at δ 7.66 and at δ 8.16 with J = 9.0 Hz as doublet. NMR data indicated that compound exists in two isomeric forms E and Z.

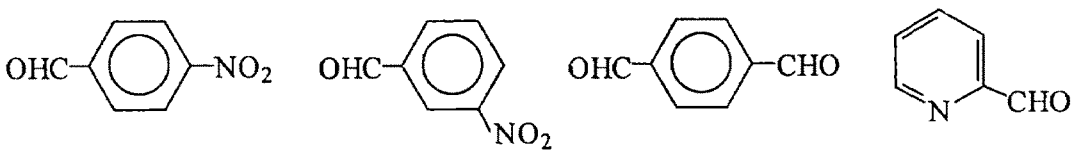
Synthesis of 1-(3',5'-di-tert-butyl-4'-hydroxyphenyl)-2-methyl-2-phenylethylene

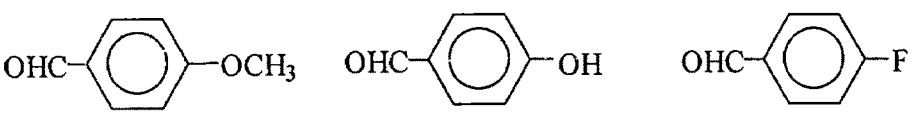
Wittig salt **1** on reaction with acetophenone in the presence of base afforded 1-(3`.5`-di-tert-butyl-4`-hydroxyphenyl)-2-methyl-2-phenylethylene (Scheme 2). Structure of the synthesised compound has been established on the basis of elemental analysis and NMR spectral study. ^{1}H NMR spectrum (Fig. 3) of **WR13** recorded in $CDCl_3$ using TMS as internal standard showed singlet at δ1.43 for eighteen protons confirmed the presence of two tert-butyl groups. Methyl group

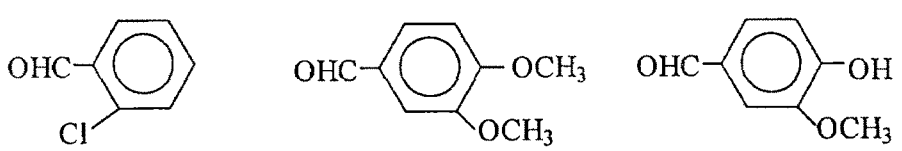


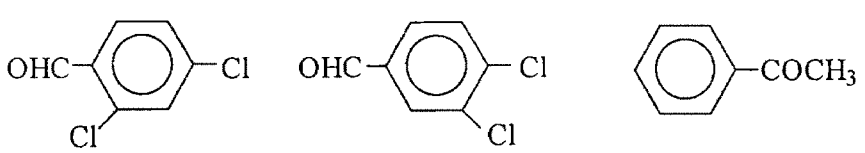
R' =H, CH_3

Aldehydes and ketone used









Scheme 2

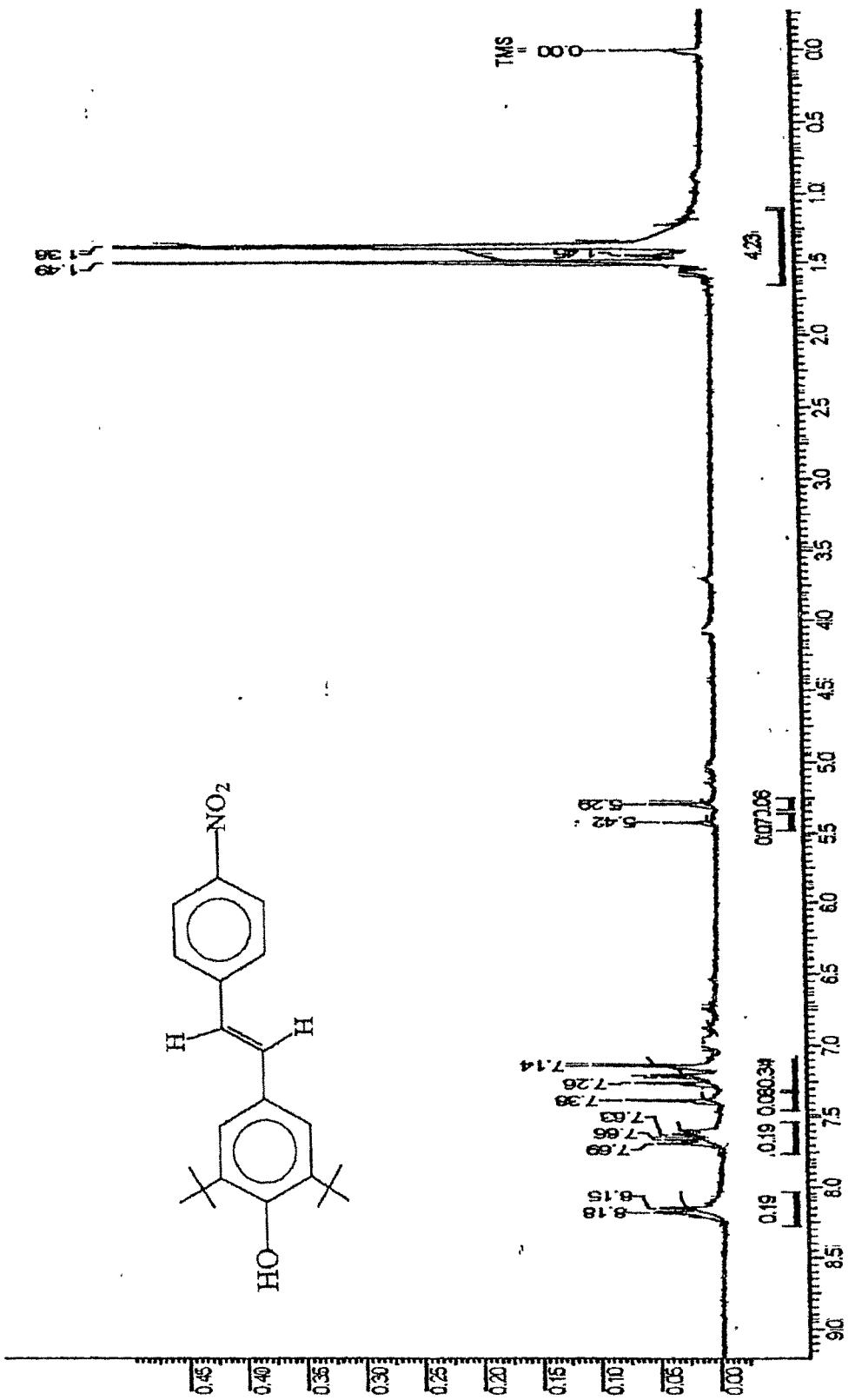

TMS
0.00
1.46
4.23
5.29
5.42
0.07
2.06
7.14
7.26
7.38
7.63
7.66
7.69
8.15
8.18
0.19
0.19
0.08
0.39
NO2
H
H
HO

Figure 2

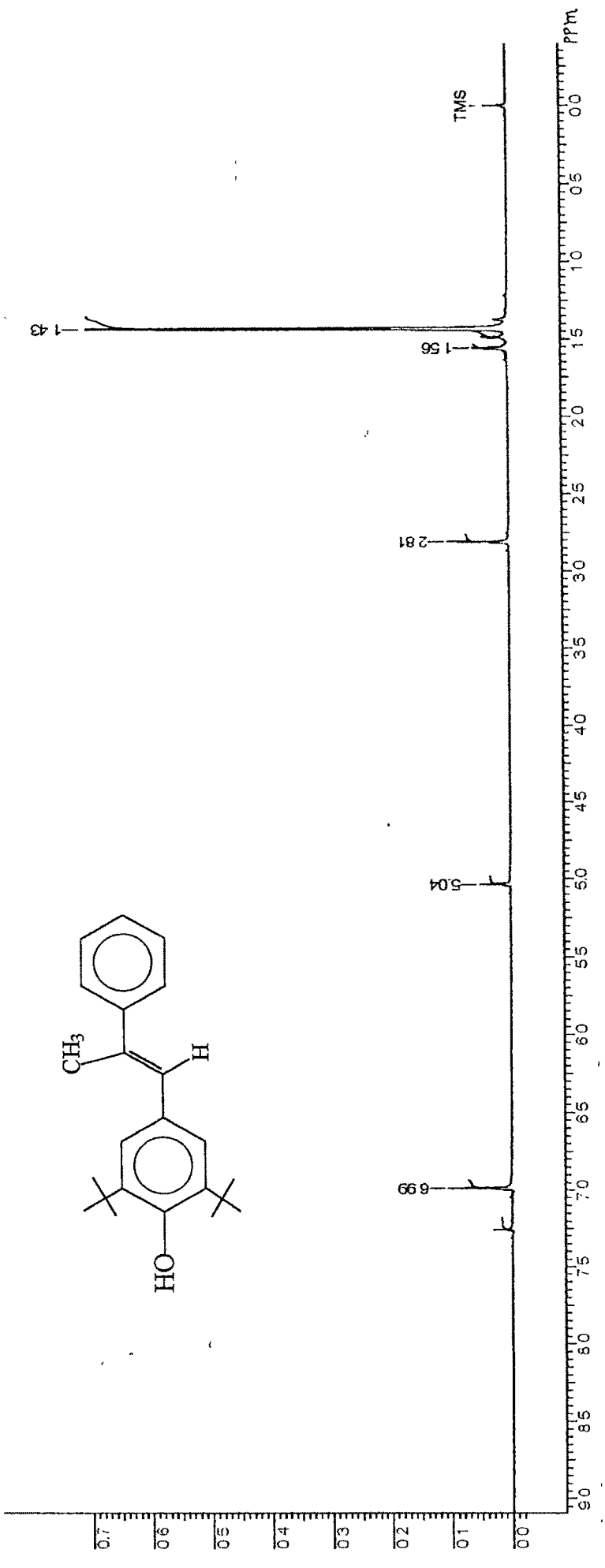


Figure 3

resonated at δ 1.56 as singlet. Methine group appeared at δ 2.81 as singlet. Phenolic group appeared at δ 5.04. Five aromatic protons resonated at δ 6.99 as singlet. Two aromatic protons of phenol ring were observed at δ 7.25 as singlet.

Experimental

All the melting points were determined in open capillaries using paraffin bath and were uncorrected. Microanalyses of the compounds were done on Coleman C, H analyser. IR spectra were r[illegible] Perkin Elmer-781 spectrophotometer using KBr pellet technique. ^{1}H [illegible]uker-200MHz spectrophotometer using [illegible]rnal standard. Coupling constant values [illegible]hromatography with mesh size 60-120. A[illegible]ated E. Merck silica gel 60 F_{254} aluminiu[illegible]

are all of these compounds new compounds? If not, those which have been made before should be cited with a literature reference

2,6-Di-tert-butyl-4-chloro[illegible]omethylation of 2,6-di-tert-butyl phenol a[illegible].

Preparation of 3,5-di-tert-butyl-4-hydroxybenzyl triphenylphosphoniumchloride, Wittig salt 1

2,6-Di-tert-butyl-4-chloromethyl phenol (0.01mol) was dissolved in dry benzene (50ml), and to this triphenylphosphine (0.01mol) was added. The reaction mixture was refluxed for 6 hr. The product precipitated out during the reaction was filtered, washed with hot benzene and dried. m.p. 230^{0}C, yield 92%.

Elemental analysis	Found:	C, 76.50	H, 7.40
$(C_{33}H_{38}ClOP)/516.5$	Calc.:	C, 76.66	H, 7.35%

Preparation of 1-(3',5'-di-tert-butyl-4'-hydroxyphenyl)-2-(substituted phenyl) ethylene

3,5-Di-tert-butyl-4-hydroxybenzyl triphenylphosphoniumchloride (0.01mol) was dissolved in dichloromethane (50ml). To this, sodium hydroxide (0.01mol) was added and the mixture was stirred for about 0.5 hr. Aldehyde was added to this mixture and was stirred for 6 hr at room temperature. The mixture was decomposed in cold dil. HCl. Dichloromethane layer was washed with water and the residue obtained after distillation of dichloromethane was purified through column chromatography using petroleum ether as eluent. The product obtained was crystallised from appropriate solvents

Preparation of 1-(3',5'-di-tert-butyl-4'-hydroxyphenyl)-2-methyl-2-phenyl ethylene

Acetophenone (0.01mol) was added to homogeneously stirred mixture of 3,5-di-tert-butyl–4-hydroxybenzyl triphenylphosphoniumchloride (0.01mol) and K_2CO_3 (0.01mol) in dichloromethane (25ml). The mixture was stirred for 6 hr at room temperature. Dichloromethane layer was washed with dil. HCl and then with distilled water. Product obtained after removal of dichloromethane was purified through column chromatography using petroleum ether as solvent. m.p. 160-62^0 C, yield 69%.

Elemental analysis	Found:	C, 85.74	H, 9.31
$(C_{23}H_{30}0)/322$	Calc.:	C, 85.27	H, 9.72%

Yield, melting point, molecular formula, molecular weight and elemental analysis of synthesised compounds are shown in Table 1.

Code (*)	Aldehydes	Yield (%)	M.P. (^{0}C)	M.F. (Mol. Wt.)	Elemental Analysis (Calc./Obs.) (%)		
					C	H	N
WR1 (B)	4-$NO_2C_6H_4$ CHO	60	198	$C_{22}H_{27}NO_3$ (353)	74.78 75.02	7.64 8.35	3.93 3.71
WR2 (B+P)	3-$NO_2C_6H_4$ CHO	56	124	$C_{22}H_{27}NO_3$ (353)	74.78 74.38	7.64 7.91	3.93 4.26
WR3 (B+P)	1,4-$(CHO)_2$ C_6H_4	62	149	$C_{38}H_{50}O_2$ (538)	84.75 84.20	9.29 9.42	--
WR4 (A+B)	1-C_5H_4NCHO	40	251	$C_{21}H_{27}NO$ (309)	81.55 81.77	8.73 9.10	4.53 4.26
WR5 (B+P)	4-$OCH_3C_6H_4$ CHO	52	169	$C_{23}H_{30}O_2$ (338)	81.65 81.33	8.80 8.24	--
WR6 (B+P)	4-OHC_6H_4 CHO	50	221	$C_{22}H_{28}O_2$ (324)	81.48 81.41	8.64 8.75	--
WR7 (B+P)	4-FC_6H_4CHO	59	163	$C_{22}H_{27}FO$ (326)	80.98 81.41	8.28 8.75	--
WR8 (P)	2-ClC_6H_4CHO	41	95	$C_{22}H_{27}ClO$ (342.5)	76.85 76.61	8.15 8.05	--

WR9 (B)	3,4-$(OCH_3)_2$ C_6H_3CHO	75	133	$C_{24}H_{32}O_3$ (368)	78.26 / 79.02	8.69 / 8.29	--
WR10 (P)	3,4-(OCH_3) $(OH)C_6H_3CHO$	72	151	$C_{23}H_{30}O_3$ (354)	77.96 / 78.05	8.47 / 8.41	--
WR11 (A+B)	3,4-$(Cl)_2C_6H_3$ CHO	55	213	$C_{22}H_{26}Cl_2O$ (377)	77.96 / 78.05	8.47 / 8.41	--
WR12 (B)	2,4-$(Cl)_2C_6H_3$ CHO	52	187	$C_{22}H_{26}Cl_2O$ (377)	69.84 / 69.72	7.14 / 7.05	--
	Ketone						
WR13 (B+P)	$C_6H_5COCH_3$	80	161	$C_{23}H_{30}O$ (322)	85.74 / 85.27	9.31 / 9.72	--

* Solvent used for Crystallisation

A= Alcohol, B= Benzene, P= Pet. ether

Table 1

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