CHAPTER IIIA: A CONVENIENT METHOD FOR THE SYNTHESIS OF AROMATIC ALDEHYDES
Summary

A convenient route for the preparation of aromatic aldehydes is described in this Chapter. Benzyl ketones 4 obtained by Freidel-Craft's acylation were reduced to homobenzylic alcohols 5. 5 underwent a ready fragmentation to give aromatic aldehydes 6.
Introduction

Aromatic aldehydes are colourless or pale yellow, water-immiscible, liquids or solids with low melting points and are generally volatile in steam. Many members of the series have characteristic odours; benzaldehyde itself, which occurs in nature in the leaves or kernels of apricots and peaches has an odour of bitter almonds. Phenolic aldehydes, such as salicylaldehyde and their ethers such as vanillin and piperonal, also have good odours and are synthesised on a large scale for use in the flavouring and perfumery industries.

Benzaldehyde is also an important industrial material, being used in the food, beverage, and pharmaceutical industries as a flavouring and in the fine chemicals industry as intermediate in the synthesis of other perfumery and flavouring chemicals (e.g. cinnamaldehyde). Benzaldehyde and many other substituted benzaldehydes (e.g. o-chlorobenzaldehyde, c-formylbenzene sulphononic acid) are intermediates in the synthesis of triphenylmethane dyestuffs which are used extensively in the paper, printing and synthetic fibre industries.

Synthesis of aromatic aldehydes

The methods of introduction of the formyl group into the aromatic ring are numerous and are discussed in detail below.
Synthesis of aromatic aldehydes by oxidation of methyl group.

Chromium trioxide in acetic anhydride is a reagent of choice for the conversion of methyl substituted aromatics to aldehydes. In this method further oxidation of aldehydes to acid is prevented by the formation of the intermediate diacetate which is stable to the reaction conditions. Hydrolysis in aqueous ethanol gives the aldehyde in good yield (Chart I, Scheme I). A similar transformation, which can be accomplished using chromyl chloride as the oxidising agent, is known as the Staudinger reaction. The reaction is carried out using carbon tetrachloride or carbon disulfide as solvent (Chart I, Scheme II). More recently the oxidising agent ammonium cerium (IV) nitrate has been used to perform this transformation under mild conditions in high yields (Chart I, Scheme III). The use of manganese oxide and selenium oxide have been also reported in few cases.

Synthesis of aromatic aldehydes from halomethyl compounds

This group of synthetic method represents an important class of reaction, since the halomethylated aromatics are readily available starting materials, formed either by the halogenation of methyl aromatics (e.g. using N-halosuccinimides) or by direct halomethylation (using formaldehyde-hydrogen chloride).
CHART I

SCHEME I

\[ \text{CH}_3 \begin{array}{c} \text{CrO}_3 \\
\text{H}_2\text{SO}_4 \\
\text{Ac}_2\text{O}, 5-10^\circ\text{C} 
\end{array} \rightarrow \text{CH(OAc)}_2 \]

\[ \text{CH(OAc)}_2 \begin{array}{c} \text{H}_2\text{SO}_4 \\
\text{H}_2\text{O}, \text{EtOH} 
\end{array} \rightarrow \text{CHO} \]

SCHEME II

\[ \text{CH}_3 \begin{array}{c} (\text{NH}_4)_2\text{Ce(NO}_3)_6 
\end{array} \rightarrow \text{CH}_2\text{ONO}_2 \rightarrow \text{CH}_2\text{OH} \rightarrow \text{CHO} \]

SCHEME III

\[ \text{CO} + \text{HCl} + \text{AlCl}_3 \rightarrow \text{HCO}^+\text{AlCl}_4^- \]

SCHEME IV

\[ \text{HCN} \begin{array}{c} \text{HCl}, \text{AlCl}_3 
\end{array} \rightarrow \text{CH}^+\text{=NH}_2\text{Cl} \rightarrow \text{CHO} \]

SCHEME V

\[ \text{X} = \text{NMe}_2, \text{OMe} \]

SCHEME VI

\[ \text{X} = \text{NMe}_2, \text{OMe} \]

SCHEME VII

\[ \text{OH} \begin{array}{c} \text{CH}_2=\text{NH}_2 
\end{array} \rightarrow \text{OH} \rightarrow \text{OH} \rightarrow \text{CHO} \]

\[ \text{OH} \begin{array}{c} \text{CH}^\equiv\text{NH} 
\end{array} \rightarrow \text{CH}^\equiv\text{NH} \]
The older methods of converting $\text{CH}_2 \text{X} \rightarrow \text{CHO}$ such as the sommelet\textsuperscript{9} and kronnek\textsuperscript{10} process are indirect but give good overall yields. The practical advantage of these indirect method is that there is no need to purify the lachrymatory, unstable and often carcinogenic halomethyl starting material. More recently, however, specific oxidising agents such as dimethyl sulfoxide\textsuperscript{11}, pyridine $N$-oxides\textsuperscript{12}, sodium salt of 2-nitropropane\textsuperscript{13} (called the Hass reaction), mercuric and silver nitrate\textsuperscript{14} have been used successfully to transform halomethyl compounds to aldehydes.

**Other methods of preparation of aromatic aldehydes**

**Gatterman-Koch reaction**

Gatterman-Koch reaction\textsuperscript{15,16} is a method of inserting CO into an aromatic $\sigma$-H bond using $\text{HCl}$ and typical Friedel-Crafts catalysts, such as aluminium chloride (Chart I, Scheme IV).

**Gatterman reaction**

Since the Gatterman-Koch reaction fails with phenols and phenol ethers, Gatterman developed a second formylation method involving the reaction of the aromatic substrate with HCN and $\text{HCl}$, usually in the presence of a Lewis acid\textsuperscript{17} (Chart I, Scheme V).
Vilsmeier-Haack reaction

Formylation of electron rich aromatics using N,N-dimethylformamide (DMF), and phosphorus oxychloride (POCl₃) is known as Vilsmeier-Haack reaction. Reaction between DMF and POCl₃ gives a reactive species, which react with electron rich aromatic systems (Chart I, Scheme VI) to give aldehydes.

Duff reaction

Reaction of electron-rich aromatics such as phenols and aromatic amines with hexamethylenetetramine in the presence of glycerol or acetic acid is referred to as Duff's reaction (Chart I, Scheme VII).

Reimer-Tiemann reaction

Reaction of electron rich aromatics and heteroaromatics, such as phenol using chloroform and alkali is known as the Reimer-Tiemann reaction (Chart II, Scheme I).

New methods for aromatic aldehyde synthesis

P.G. Gassman discovered a method by which formyl group can be introduced ortho to phenol. A crucial step in this reaction was that a [2,3]-sigmatropic shift is used to form the new carbon-carbon bond (Chart II, Scheme II).

M.V. Snatt developed a method based on the fact that amidomethyl group is preferentially brominated even
CHART I

SCHEME I

\[
\begin{align*}
\text{CHCl}_3 & \xrightarrow{\text{NaOH}} \text{CCl}_3 & \xrightarrow{\text{Cl}^-} \text{CCI}_2 & \xrightarrow{\text{phenoxide}} & \text{CCI}_2 \\
\text{H}_2\text{O} & \xrightarrow{} & \text{H} & \text{CHCl}_2 & \xrightarrow{\text{phenoxide}} & \text{H} & \text{CHO} \\
\text{SCHEME II}
\end{align*}
\]

\[\text{OH} \xrightarrow{\text{NCS}, R^1 \text{CH}_2 \text{SR}^2} \xrightarrow{\text{CH}_2\text{Cl}_2, -70^\circ \text{C}} \text{O} \xrightarrow{\text{Et}_3\text{N}} \text{OH} \xrightarrow{i) \text{HgO}, \text{BF}_3, ii) \text{Na}_2\text{CO}_3, \text{H}_2\text{O}} \text{CHO} \]

\[X = \text{H, Me, OMe}\]

[2, 3] Shift

\[\text{SCHEME III}
\]

\[\text{SCHEME IV}
\]

\[\text{SCHEME V}
\]

\[\text{Ar} - \text{C} - \text{CH}_2 - \text{C}_6\text{H}_5 \xrightarrow{\text{Pb(OAc)}_4} \text{Ar} - \text{C} - \text{C} + \left[ \text{C}_6\text{H}_5 - \text{CH}_2 \right] \]

\[\text{C}_6\text{H}_5 - \text{CH}^* \xrightarrow{\text{Pb(OAc)}_4} \text{C}_6\text{H}_5 - \text{CH}_2 - \text{OAc} \]

.
in the presence of methyl group. This bromination is brought about by N-bromosuccinimide (NBS). Subsequent dehydrobromination and hydrolysis gave aldehydes (Chart II, Scheme III).
Though a variety of methods\textsuperscript{23,24,25} are available for the synthesis of aldehydes, this area continues to attract attention\textsuperscript{21,22} since the aldehydes are important intermediates in synthetic organic chemistry. Our work in synthetic chemistry is directed towards the development of new methods and reactions. In this Chapter we present a new route for the synthesis of aromatic aldehydes.

Several examples of the fragmentation of alcohols on treatment with lead tetraacetate to furnish carbonyl compounds according to Chart I, Scheme IV, are reported.

This reaction is particularly facile when the substrates are homoallylic alcohols since the fragmentation to carbonyl compounds also leads to the formation of stable allylic radicals. Hence we anticipated that secondary homobenzylic alcohols would readily fragment to furnish aromatic aldehydes according to Chart II, Scheme V, since the relatively stable benzyl radicals are formed as intermediates. Benzyl ketones\textsuperscript{4} are readily available compounds. They are prepared generally by the Friedel-Craft's acylation of the corresponding aromatic hydrocarbon with phenyl acetic acid in which case the acylating agent was polyphosphoric acid or phenyl acetyl chloride using \( \text{AlCl}_3 \) as Lewis acid.
All the benzyl ketones 4a-g (Chart III) used by us are known compounds. 1-(4-methoxy phenyl)-2-phenyl ethanone 4c was prepared by polyphosphoric acid reaction as given in literature. The remaining benzyl ketones 1-(2,5-dimethoxy phenyl)-2-phenyl ethanone 4a, 1-(4-methyl phenyl)-2-phenyl ethanone 4b, 1-(2,4-dimethoxy phenyl)-2-phenyl ethanone 4d, 1-(3,4-dimethoxy phenyl)-2-phenyl ethanone 4f and 1-(4-chlorophenyl)-2-phenyl ethanone 4g were obtained by similar reaction and are known in the literature.

The alcohols 5a-g were obtained by performing sodium borohydride reduction in ethanol at room temperature on benzyl ketone 4a-g. All the alcohols are known in the literature i.e. 5b, 5c, 5d, 5e, 5f and 5g. Melting points were in agreement with literature values. In the case of new alcohols 5a and 5f satisfactory elemental analysis and structure assigned are in agreement with NMR and IR spectra. IR spectrum of 5a showed band at 3571 cm\(^{-1}\) (OH stretching). Similarly 5f showed 3448 cm\(^{-1}\) (OH stretching).

Having obtained the homobenzylic alcohols 5a-g it was now only left to subject them to fragmentation reaction with lead tetraacetate. This was brought about by stirring the mixture of homobenzylic alcohols, lead tetraacetate in refluxing benzene.
Reagents: i) C₆H₅CH₂COCl/AlCl₃ or C₆H₅CH₂CO₂H/Poly phosphoric acid.
   ii) NaBH₄/EtOH, iii) Pb(OAc)₄

FOR ALL COMPOUNDS IN THE SERIES

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<th>Entry</th>
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<tr>
<td>g</td>
<td>Cl</td>
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Synthesis of aldehydes 6 a–g.
The aldehydes $6_a$-$g$ thus obtained were characterized by IR and NMR spectra. The identities of the aldehydes $6_a$, $6_b$, $6_c$, $6_e$ and $6_g$ have been confirmed by comparing TLC behaviour with authentic samples. $6_b$ was characterized as its 2,4-dinitrophenyl hydrazone (see Table).

In these fragmentation reactions benzyl acetate is formed as by-product. In all cases except $6_b$ the aldehydes could be separated from the accompanying benzyl acetate by fractional distillation. Though the route presented here involves three steps, it is attractive since all the three steps are comparatively easy to carry out and proceed in good yields. The good advantage of our method is that the secondary homobenzylic alcohols $5_a$-$g$ being solid, it gives an opportunity to employ the pure alcohol for fragmentation.
1-(2,5-Dimethoxyphenyl)-2-phenyl ethanone 4a

To a mixture of phenyl acetic acid (3 g, 0.022 M), polyphosphoric acid (prepared from 50 g of $P_2O_5$ + 21 g of phosphoric acid) was added 2a (3.0 g, 0.022 M) at 70-75°C for about 10-15 minutes with vigorous stirring and the temperature slowly raised to 95°C and maintained for about 1.5 hours. The mixture was cooled and poured into ice cold water (200 ml) and extracted with ether (3x100 ml). The etheral layer was washed with water, 10% solution of sodium bicarbonate, brine, dried and evaporated to give the residue which on distillation under vacuum gave 4a (4.8 g, 87%), b.p. 190°C (bath)/0.7 mm. On keeping 4a slowly solidified to give m.p. 47°C (Lit. m.p. 49°C).

1-(4-Methoxy phenyl)-2-phenyl ethanone 4b

Starting from phenyl acetic acid (3.0 g, 0.022 M), polyphosphoric acid (50.0 g, $P_2O_5 + 21.0$ g $H_3PO_4$) and toluene 3b (2.0 g, 0.022 M) and employing the method given above (see preparation of 4a) ketone 4b (3.8 g, 84%), m.p. 108°C (Lit. m.p. 109-111°C) was obtained.

1-(4-Methoxy phenyl)-2-phenyl ethanone 4c

Starting from phenyl acetic acid (13.0 g, 0.022 M), polyphosphoric acid (50.0 g, $P_2O_5 + 21.0$ g $H_3PO_4$) and anisole 3c (2.2 g, 0.022 M) and employing the method given
above (see preparation of 4a) ketone 4c (3.6 g, 74%), m.p. 74° (Lit.28 m.p. 74-5°) was obtained.

1-(2,4-Dimethoxy phenyl)-2-phenyl ethanone 4d

Starting from phenyl acetic acid (3.0 g, 0.022 M), polyphosphoric acid (50.0 g P₂O₅ + 21.0 g H₃PO₄) and resorcinol dimethyl ether 3d (3.0 g, 0.022 M) and employing the method given above (see preparation of 4a) ketone 4d (4.4 g, 80%), m.p. 46° (Lit.36 m.p. 45-6°) was obtained.

1-(3,4-Dimethoxy phenyl)-2-phenyl ethanone 4e

Starting from phenyl acetic acid (3.0 g, 0.022 M), polyphosphoric acid (50.0 g P₂O₅ + 21.0 g H₃PO₄) and catechol dimethyl ether 3e (3.0 g, 0.022 M) and employing the method given above (see preparation of 4a) ketone 4e (4.1 g, 73%), m.p. 84° (Lit.31 82-3°) was obtained.

1-(3-Nitro-4-methoxy phenyl)-2-phenyl ethanone 4f

This compound was prepared as given in the literature32.

1-(4-Chlorophenyl)-2-phenyl ethanone 4g

This compound was prepared as given in the literature33.

PREPARATION of ALCOHOLS

1-(2,5-Dimethoxy phenyl)-2-phenyl ethanol 5a

A mixture of 4a (2.5 g, 0.01 M), sodium borohydride (0.38 g, 0.01 M), ethanol (50 ml) and water (10 ml) stirred at room temperature for 3 hours and then extracted with
ether (2x50 ml). The ethereal layer was washed with water, dried and evaporated to give 5a (2.4 g, 94%), recrystallised from petroleum ether. M.p. 55-60°.

IR spectrum (Nujol) showed bands at 3571 cm^{-1} (hydroxyl stretching).

NMR spectrum (CCl_{4}) showed signals at 2.83 (2H, d, J=6 Hz, -CH_{2}), 3.63 (3H, s, -OCH_{3}), 3.7 (3H, s, -OCH_{3}), 5.0 (1H, m, -CHOH), 6.6 (2H, s, aromatic protons at C-3 and C-4), 6.7 (1H, s, C-6 aromatic proton), 7.0 (5H, s, aromatic protons).

**Analysis:**

Found: C, 74.49; H, 7.00.

C_{16}H_{18}O_{3} requires C, 74.39; H, 7.00.

1-(4-Methyl phenyl)-2-phenyl ethanol 5b

5b was prepared in the same manner given above (see procedure 5a). M.p. 68° (Lit. 34 m.p. 66.8-68.2°).

1-(4-Methoxy phenyl)-2-phenyl ethanol 5c

Procedure similar to 5a gave 5c (93%), m.p. 57° (Lit. 35 m.p. 58°).

1-(2,4-Dimethoxy phenyl)-2-phenyl ethanol 5d

5d was prepared in the same manner as in 5a to give 5d (90%), m.p. 43° (Lit. 36 m.p. 42-44°).

1-(3,4-Dimethoxy phenyl)-2-phenyl ethanol 5e

Following procedure similar to 5a gave 5e (93%), m.p. 69-70° (Lit. 31 m.p. 68-70°).
l-(3-Nitro-4-methoxy phenyl)-2-phenyl ethanol 5f

Prepared according to procedure given as under 5a to give 5f (82%), m.p. 68-70°.

IR spectrum (Nujol) showed bands at 3448 cm\(^{-1}\) (OH, stretching), 1515 and 1340 cm\(^{-1}\) (NO\(_2\) group).

NMR spectrum (CD\(_3\)\(_2\)CO) showed signals at 8 2.88 (2H, d, J=6 Hz, -CH\(_2\)-), 3.83 (3H, s, -OCH\(_3\)), 4.8 (1H, t, J = 6 Hz, -CHOH), 7.5 (1H, s, aromatic proton ortho to nitro group).


C\(_{15}\)H\(_{15}\)NO\(_4\) requires C, 65.92; H, 5.53.

l-(4-Chloro-phenyl)-2-phenyl ethanol 5g

Prepared in the similar manner as in 5a to give 5g (96%), b.p. 140°/0.5 mm (Lit.\(^3\) b.p. 213°/20 mm).

GENERAL PROCEDURE FOR FRAGMENTATION REACTION

p-Anisaldehyde 6c

A mixture of 5c (6.85 g, 0.03 M), dry benzene (120 ml) and lead tetraacetate (33.3 g, 0.075 M) was heated under reflux with stirring for 6 hours and subsequently cooled to room temperature. The excess of lead tetraacetate was destroyed by adding ethylene glycol. The benzene layer was washed with water, brine, dried and the solvent was evaporated. The residue was fractionally distilled using a vigreux column (length 6 inches). The fraction with
b.p. 55-60°/1.4 mm (yield 2.8 g) was composed almost entirely of benzyl acetate identified by comparison of GLC, IR and NMR with those of an authentic sample. The residue left after removal of benzyl acetate was distilled with bulb-to-bulb distillation unit to furnish p-anisaldehyde 6c, b.p. 71°/1.4 mm (yield 2.6 g) Lit. b.p. 93-4°/4-5 mm. The identity of the product 6c was confirmed by comparison of GLC, IR and NMR with an authentic sample.

Similarly alcohols 5a, 5b, 5d, 5e, 5f and 5g were transformed to aldehydes 6a, 6b, 6d, 6e, 6f and 6g (see Table -1).

<table>
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<th>Table 1 : Aldehydes 6a-g synthesised</th>
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The IR and NMR spectra of the products were in agreement with the structures assigned. The identities of aldehydes $6a$, $6b$, $6c$, $6e$ and $6g$ have been confirmed by comparing GLC behaviour with authentic samples.

a. Characterized as 2,4-dinitrophenyl hydrazone, m.p. and mixed m.p. with authentic sample $255^\circ$.\textsuperscript{38}
REFERENCES


32. O. Behoghel and H. Ratz, Ber., 72, 1257 (1939).


CHAPTER IIIB: FRAGMENTATION STUDIES ON HOMOBENZYLIC ALCOHOLS USING LEAD-TETRAACETATE AND CERIC AMMONIUM NITRATE: A METHOD FOR THE CONVERSION OF ACID TO ALDEHYDE GROUP
Summary

This Chapter deals with the comparative study of fragmentation of different tertiary homoallylic alcohols under variety of experimental conditions. The outcome of such a study was the conversion of acid into an aldehydic function. In general esters of acid \( R = \text{aromatic or aliphatic} \) were transformed to tertiary homobenzyl alcohol 20. It was found out that when \( R \) (aromatic), the reagent of choice for fragmentation of 20 was ceric ammonium nitrate to give benzyl ketone 21, and when \( R \) (aliphatic) the reagent of choice was lead tetraacetate-iodine to afford benzyl ketone 21. 21 was reduced to secondary homobenzyl alcohols 22 by using sodium borohydride in ethanol. 22 (\( R = \text{aromatic} \)) gave aldehyde 23 (aromatic) with lead tetraacetate and when 22 (\( R = \text{aliphatic} \)) gave aldehydes 23 (aliphatic) with lead tetraacetate-iodine.
Introduction

Aldehydes occupy a central position in the series of oxidation level found among organic compounds. They may act as electrophiles and also by removal of α-proton give rise to nucleophilic anions. This variety of possible reaction makes them potentially very valuable intermediates, but complicates their synthesis, since they are often unstable particularly in basic and oxidising media. Examples are however widespread in nature and exhibit widely differing but often highly important physiological activity e.g. glucose 1, pyridoxyl phosphate 2, streptomycin 3 etc. (Chart I).

In recent years several excellent reagents are available for the selective transformations. A range of different metal hydrides with various degree of selectivity has been introduced over the last two decades. These reagents have been extensively used for the synthesis of aldehydes by the partial reduction of carboxylic acids and its derivatives. Reviews on these metallic hydrides have been published\(^1\),\(^2\). It is the purpose of this brief review in this Chapter to give an impression that this transformation is still getting predominant importance in synthetic organic chemistry. An attempt is made here to give methods that have appeared in the past few years. The transformation of aromatic as well as aliphatic acids
to corresponding aldehydes will be discussed.

**Aliphatic aldehydes from acids and their derivatives**

In order to reduce acids to corresponding aldehydes, it is usually necessary to convert the acids into a more nucleophilically labile derivatives. However there are some exceptions to this. For e.g. lithium-methyl amine reduction[^3] and diamino-aluminium hydrides[^4] are known to reduce acids to aldehydes. Methyl esters are reduced to aldehydes by diamino aluminium hydrides[^5] and sodium bis-(methoxy ethoxy)aluminium hydride[^2]. In some cases acyl malonic esters can be reduced by sodium borohydride under conditions such that retro-aldol fission of the product leads directly to the aldehydes[^6]. Thiol esters, RCOSR are reduced to aldehydes by treatment with Raney nickel[^7]. Quite a variety of tertiary amides have been reduced to aldehydes with lithium aluminium hydride[^2], but more recently the simple N,N-dimethyl amides have been used with lithium bis-(ethoxy)aluminium hydride or alkoxy aluminium hydride as the reactant[^2].

Nordin[^8] synthesised 2-oxazoline derivatives 1 from acids. 1 was methylated to give 2-oxazoline methiodides 2, which underwent reduction with sodium borohydride in methanol to give dihydro-2-oxazoline derivative 3. 3 on acid hydrolysis gave aldehydes (Chart I, Scheme I).
Doleschall\textsuperscript{9,10} developed a very simple and efficient method based on the availability of triazolium salt \textsuperscript{4}. Methanolic solution of these salts are reduced with sodium borohydride to give dihydro triazole \textsuperscript{2}. \textsuperscript{2} was decomposed in aqueous sulfuric acid to give the desired aldehydes (Chart I, Scheme II).

In Meyer's synthesis\textsuperscript{11} of aldehydes, \textsuperscript{5,6-dihydro-1,3-oxazines} \textsuperscript{7} saved as precursor to aldehydes. The conversion of \textsuperscript{7} to aldehydes was brought about by controlled sodium borohydride (at \(-40^\circ\text{C}\)) reduction to \textsuperscript{7a}, followed by acidic work-up. One advantage of above method is avoidance of the strongly reducing lithium aluminium hydride (Chart I, Scheme III).

Watanabe et al.\textsuperscript{12} provided a method by which acyl chloride was converted to acyl carbonyl ferrate \textsuperscript{8}, by treatment with disodium tetracarbonyl ferrate \textsuperscript{2\textsuperscript{b}}. \textsuperscript{8}, after quenching with acetic acid furnished corresponding aldehydes in high yields (Chart I, Scheme IV).

Disodium tetracarbonyl ferrate \textsuperscript{2\textsuperscript{b}} is also shown to react with various anhydrides\textsuperscript{13} to give acyl carbonyl ferrates \textsuperscript{2}, which are then converted to aldehydes by quenching with acetic acid (Chart II, Scheme I). The above procedure was later modified\textsuperscript{14} by taking carboxylic ethyl carbonic anhydride \textsuperscript{9} and disodium tetracarbonyl ferrate \textsuperscript{2\textsuperscript{b}} (Chart II, Scheme II).
**CHART I**

**SCHEME I**

\[ R - \text{COOH} \rightarrow 1 \rightarrow \text{MeI} \rightarrow 2 \rightarrow \text{NaBH}_4 \rightarrow R - \text{CHO} \]

**SCHEME II**

\[ R - \text{COOH} \rightarrow 1) \text{SOCl}_2 \rightarrow 2) \phi - \text{NH-N}=C\text{SMe} \rightarrow 6a \rightarrow \text{NaBH}_4 \rightarrow 5 \rightarrow \text{H}_2\text{O}^+ \rightarrow R - \text{CHO} \]

**SCHEME III**

\[ \text{NaBH}_4 \rightarrow 7a \rightarrow \text{H}_2\text{O}^+ \rightarrow R - \text{CHO} \]

**SCHEME IV**

\[ R - \text{C-Cl} + \text{Na}_2\text{Fe(CO)}_4 \rightarrow 7b \rightarrow \text{Na}^+\left[ \text{Fe(CO)}_4 \text{COR} \right]^+ + \text{NaCl} \]

\[ 8 + \text{ACOH} \rightarrow R - \text{C-H} \]
It was shown that the combination of triethylsilane and transition metal (Pd) reduces acid chlorides to aldehydes, however α-branching in the alkyl group of acid lowers the yield of aldehyde (Chart II, Scheme III).

A different approach by Fujita et al. in involves conversion of carboxylic acids into their 2-thiazoline-2-thiol esters, which on reduction with di-isobutyl aluminium hydride (DIBAH) gives aldehydes (Chart II, Scheme IV).

Brown et al. have developed a method involving rapid reduction of carboxylic acid with borane-dimethyl sulfide, followed by oxidation of the resultant trialkoxyboroxine with pyridinium chlorochromate in refluxing dichloromethane furnished aldehydes (Chart II, Scheme V).

Aromatic aldehydes from acids and their derivatives

An early review in this subject discussed seven methods for the conversion of acids or their derivatives to aldehydes, but these methods have been superceded by reduction using complex metal hydrides which are selective and experimentally easier to carry out. Hence these methods will be discussed briefly.

A modified version of Rosenmund reduction, developed by scientists at Hoffman-La-Roche converts
**Chart II**

**Scheme I**

\[ R\text{-COOH} \rightarrow R\text{-C}O\text{-O} + Na_2Fe(CO)_4 \rightarrow Na^{+}[Fe(CO)_4COR]^{-} \]

\[ 7b \]

\[ 8 + ACOH \rightarrow R\text{-C}-H \]

**Scheme II**

\[ R\text{-COOH} \xrightarrow{ClCOCOEt/NEt_3} R\text{-C}O\text{-O} + Na_2Fe(CO)_4 \rightarrow R\text{-C}-Fe(CO)_4 \xrightarrow{H^+} R\text{-CHO} \]

\[ 9b \]

**Scheme III**

\[ R\text{-C}-Cl \xrightarrow{Et_3SiH/Pd} R\text{-CHO} \]

**Scheme IV**

\[ R\text{-C-OH} \xrightarrow{1) SOCl_2} R\text{-C}-S\text{-N} \xrightarrow{2) DIBAH} R\text{-CHO} \]

\[ 10 \]

**Scheme V**

\[ R\text{-C-OH} \xrightarrow{H_3B:S(CH_3)_2} \frac{1}{3}(R\text{-CH}_2\text{-OBO})_3 \xrightarrow{\text{OCl}_3} R\text{-CHO} \]

**Scheme VI**

\[ \text{MeO} \text{COCl} \xrightarrow{H_2 Pd-BaSO_4} \text{Quinoline/Sulfur} \xrightarrow{NaOAc} \text{MeO} \text{CHO} \]
aromatic acid chloride to aldehyde in the presence of catalyst. The catalyst usually palladium or barium sulfate, is poisoned with a suitable additive e.g. quinoline-sulfur. (This is done to reduce the activity of the catalyst to try to prevent over reduction). Sodium acetate is also used to scavenge the hydrochloric acid liberated during the process (Chart II, Scheme VI).

Indirect methods for converting aromatic acid chlorides to aldehydes include the hydrolysis of Reissert compounds, reductive desulphurization of thiol esters using Raney nickel, the Sonn-Muller method via imidoyl chlorides and the McFadyen-Stevans reaction.

Reese et al. reported a modified McFadyen-Stevans reaction. Use of 2,4,6-triisopropylbenzenesulphonyl hydrazide (TPSH) instead of toluene-p-sulphonyl hydrazide leads to much milder conditions with an efficient separation of aromatic aldehydes (Chart III, Scheme I). 11 was prepared by allowing acid chlorides to react with TPSH. 11 decomposed on reflux with anhydrous potassium carbonate in methanol to give aldehydes.

An alternative reagent which is suitable only for the synthesis of aromatic and hetero-aromatic aldehydes is the phospholene, readily prepared from isoprene and dichlorophenyl phosphine. Reaction of 12 with aroyl chlorides gives a salt 13, which is hydrolysed by water to give the aldehydes in good yield (Chart III, Scheme II).
**Chart I**

**Scheme I**

\[
R-\text{COOH} \xrightarrow{1)} \text{SOCl}_2 \xrightarrow{2)} \text{TPSH} \rightarrow \text{SO}_2\text{NHNH-CR} \xrightarrow{\text{K}_2\text{CO}_3} \text{MeOH} \rightarrow R-\text{CHO}
\]

TPSH = \[
\begin{array}{c}
\text{SO}_2\text{NHNH}_2
\end{array}
\]

**Scheme II**

\[
\text{Ph} + \text{PhPCl}_2 \rightarrow \text{H}_{2}\text{O} \rightarrow \text{PhPCl}_2 \xrightarrow{\text{ArCOCl/NEt}_3} \text{Reflux} \rightarrow \text{Ar-CHO}
\]

**Scheme III**

\[
R-\text{COCl} + H\text{Fe(CO)}_4 \rightarrow [R-\text{C-Fe(CO)}_4] \rightarrow R-\text{CHO} + H\text{Fe}_3(\text{CO})_{11}
\]

**Scheme IV**

\[
\text{Ph(OAc)}_4 - \text{I}_2 \rightarrow \text{I}
\]

**Scheme V**

\[
\begin{array}{c}
\text{MeO-} \xrightarrow{\text{Pb(OAc)}_4} \text{MeO-} \xrightarrow{\text{Reflux}} \text{MeO-} \xrightarrow{[\text{MeO-}]} \text{MeO-} \xrightarrow{\text{MeO-} \cdot \text{CH}_2-\text{φ}} + [\text{φ-\text{CH}_2}]
\end{array}
\]
Hydridotetracarbonylferrate anion \( \text{I}^{1+} \) reacts with acid chlorides to generate the aldehydes \( \text{II}_4 \) and the salt of known hyridotriironundecarbonyl \( \text{I}_6 \). Acyl hyride complex \( \text{I}_5 \) is the intermediate for these reactions (Chart III, Scheme III).

Another closely related reaction to above is reduction of acid chlorides with \( \text{Na}_2\text{Fe}(\text{CO})_4 \) as reported by Watanabe and co-workers\(^{12} \) (Chart I, Scheme IV).
PRESENT WORK

Having come to realize that the partial reduction of acids to aldehydes continues to enjoy the popularity of synthetic organic chemist, we decided to devise a new route for the same. Our strategy for this transformation involves three steps. Namely,

1) Conversion of esters (of aromatic and aliphatic acid) to benzyl ketones.
2) Transformation of benzyl ketones to homobenzylic alcohols.
3) Fragmentation of homobenzylic alcohols to aldehydes.

Several methods are known in the literature for the synthesis of benzyl ketones\textsuperscript{25}, because of their importance in medicinal chemistry. Our method for the synthesis of benzyl ketones involves the transformation of ester 19a and 19h to tertiary homobenzylic alcohol 20a and 20h by performing Grignard reaction with benzylmagnesium chloride. The alcohols 20a and 20h can lead to benzyl ketone 21a and 21h by fragmentation reaction (Chart V).

It was reported by us\textsuperscript{26} that secondary homobenzylic alcohols can be readily fragmented to give aldehydes (Eqn.I)

\[ \text{Ar-CH}_2\text{-C} - \text{R} \xrightarrow{\text{Pb(OAc)}_4} \text{Ar-CH}_2\text{-OAc} + \text{R-CHO} \]
using lead tetraacetate in refluxing benzene.

It appears reasonable to expect that tertiary homobenzylic alcohol 20a should fragment (in good yields) more readily than the secondary homobenzylic alcohol (Eqn.I) for two reasons,

1. Since the alcohol is tertiary other types of oxidations can be suppressed.

2. The presence of bulky substituents on the hydroxyl bearing carbon results in steric strain which can be relieved by ejection of one of the benzyl substituents.

However the tertiary alcohol 20a was virtually recovered unchanged on heating with lead tetraacetate in refluxing benzene. Lead tetraacetate and pyridine in refluxing benzene also did not bring about fragmentation of 20a to benzyl ketone 21a. It is well known that pyridine is known to catalyze such lead tetraacetate reactions.

Majerski et al. have fragmented alcohol 17 to ketone 18 in the presence of lead tetraacetate-iodine (Chart III, Scheme IV). The identical conditions as given by above reference, were also tried out to bring

* It is known in the literature that secondary alcohols can be oxidised to ketones in the presence of LTA.

\[ R-\text{CH(OH)}-R' \rightarrow R-\text{C}O-R' \]
CHART IV
SCHEME I

[Diagram of chemical reactions]

R\(^1\) = H, R\(^2\) = OH  
R\(^1\) = OH, R\(^2\) = H

25

2 CAN  
50% aq. CH\(_3\)CN

\[ \text{CH}_\text{N} \]

26  27  27\(\alpha\)

SCHEME II

20a

\[ \text{MeO} - \phi - \text{CH}_2 - \phi \]

20h

\[ \text{n-C}_{15}\text{H}_{31} - \phi \]

Pb (OAc\(_4\)) - I\(_2\)

\[ \phi - \text{CH}_2 - \phi \]

21h

\[ \phi - \text{CH}_2 - \text{OAc} \]

SCHEME III

20a

\[ \text{MeO} - \phi - \text{CH}_2 - \phi \]

21a

\[ \phi - \text{CH}_2 - \text{ONO}_2 \]

30
about the fragmentation of alcohol 20a to ketone 21a. The reaction indeed succeeded, however the yields were very low. These experiments suggested that probably the alcohol 20a is not transformed to the required reactive intermediate 24 due to steric hindrance (Chart III, Scheme V).

Trahanovsky et al. 29 reported that oxidation of either exo or endo-2-norboranol 25 with 2 equivalents of ceric ammonium nitrate (CAN) in 50% aqueous acetonitrile at 50° gave 3 and 4-cyclopentane acetaldehydes 26 and 27 along with 27a (Chart IV, Scheme I). In another experiment 30 alcohol 28 was fragmented to 29 by using ceric ammonium nitrate (CAN) (Chart IV, Scheme I).

We took advantage of above mentioned references 29,30 and the same conditions were performed on alcohol 20a. Excellent yields of benzyl ketone 21a (77%) were obtained with ceric ammonium nitrate (CAN) in acetonitrile. Hence this procedure was utilized for the preparation of benzyl ketones 21b-e from tertiary homobenzylic alcohol 20b-e. Mechanism involving single electron transfer for the above fragmentation reaction has been described (Chart IV, Scheme II). Benzyl nitrate 30 (formed by the reaction of benzyl radical and CAN) is the by-product in these reactions. An efficient separation of 21a from 30 can be affected by passing through alumina column. 30 is eluted
out with petroleum ether and the benzyl ketone are eluted with petroleum ether + 50% benzene (see experimental).

The benzyl alcohols 22a-e were obtained by carrying out sodium borohydride reduction on ketones 21a-e. Alcohols 21a-e were fragmented to aldehydes by the procedure described by us 26.

The alcohol 20h did not fragment to give benzyl ketone 21h when ceric ammonium nitrate in acetonitrile was used 29. However, satisfactory yields of benzyl ketone 21h was obtained when lead tetraacetate-iodine was employed. A mechanism showing hypiodites as intermediates is described in Chart IV, Scheme III. Benzyl acetate 31 formed as by-product can be removed by distillation under vacuum. The undistilled residue was then chromatographed over alumina to give 21h (see experimental). Hence this procedure was employed for the preparation of benzyl ketones 21f, 21g and 21i also from alcohols 20f, 20g and 20i.

The benzyl ketones 21f-i were reduced with sodium borohydride in ethanol to give homobenzylic alcohols 22f-i. Heating secondary homobenzylic alcohol 22h with lead tetraacetate-benzene did not prove satisfactory for the preparation of aldehyde 23h, showing that 22h is far less reactive than 22a. However when heated with lead tetraacetate-benzene in the presence of iodine 28, the
CHART V

\[ R-\text{COOEt} \xrightarrow{i} R-C\text{CH}_2-\phi \xrightarrow{ii} R-C\text{CH}_2-\phi \]

\[ R-\text{CHO} + \phi-\text{CH}_2-O\text{Ac} \]

Reagents:

i) $\phi-\text{CH}_2-MgCl$/Ether

ii) Pb(OAc)$_4$ - I$_2$/Benzene

or $(\text{NH}_4)_2\text{Ce(NO}_3)_6$/Acetonitrile

iii) NaBH$_4$ /EtOH

iv) LTA - I$_2$/Benzene

FOR ALL THE COMPOUNDS IN THE SERIES

<table>
<thead>
<tr>
<th>ENTRY</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
<th>i</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>MeO-</td>
<td>Me-</td>
<td>Cl-</td>
<td>H-</td>
<td>Me-</td>
<td>n-C$<em>6$H$</em>{13}$</td>
<td>n-C$<em>{13}$H$</em>{27}$</td>
<td>n-C$<em>{15}$H$</em>{31}$</td>
<td>n-C$<em>{17}$H$</em>{35}$</td>
</tr>
</tbody>
</table>
alcohol 22h furnished the aldehyde 23h in satisfactory yields. This procedure was found suitable for the preparation of aldehydes 23f, 23g and 23i from alcohols 22f, 22g and 23i.

The alcohols 20a-i were prepared by the action of benzylmagnesium chloride on the ethyl esters 19a-i.

The systematic studies described here provide a convenient route for the preparation of aldehydes and benzyl ketones. Incidentally the transformation aliphatic ester → 20 → 21 → 22 → 23 carried out by us in the course of this work constitute a route for the conversion of aliphatic acids to the corresponding aldehydes. The experiments carried out in this study together with previous work (Chapter IIIa) provide a route for the conversion of aromatic acids to the corresponding aldehydes.
EXPERIMENTAL PROCEDURE

2-(4-Methoxy phenyl)-1,3-diphenyl propan-2-ol 20a

To a well stirred solution of benzylmagnesium chloride (prepared from magnesium (2.04 g, 0.085 g atom) and benzyl chloride (10.7 g, 0.085 M) was added a solution of 19a (5.0 g, 0.03 M) in 25 ml ether at 0°. The mixture stirred for 20 hours at room temperature and quenched by adding saturated solution of ammonium chloride at 0°. The ether layer was separated and aqueous layer extracted with ether (2x50 ml). The combined ether extracts were washed with water, brine, dried and evaporated to give a solid, which upon recrystallization from petroleum ether gave 20a (7.8 g, 83%), m.p. 91-92°.

IR spectrum (Nujol) showed band at 3636 cm⁻¹ (OH stretching).

NMR spectrum (CDCl₃) showed signals at δ 1.63 (1H, s, OH exchanges on addition of D₂O), 3.06 (4H, q, J₆₋₋₇ = 14 Hz, CH₂-Ar), 5.6 (3H, s, OCH₃), 6.6-7.0 (14H, m, aromatic protons).

Analysis: Found C, 82.73; H, 6.97.

C₂₂H₂₂O₂ requires C, 82.98; H, 6.96.

Alcohol 20b-e were prepared in the similar manner given above.
2-(4-Methyl phenyl)-1,3-diphenyl propan-2-ol 20b

M.p. 81-2° (recrystallised from petroleum ether).
IR spectrum (Nujol) showed band at 3523 cm$^{-1}$ (for OH).
NMR spectrum (CCl$_4$) showed signals at $\delta$ 2.23 (3H, $J_{AB} = 14$ Hz, CH$_2$Ar), 3.1 (4H, $q$, 7.0-7.2 (14H, m, aromatic protons).
Analysis: Found C, 87.53; H, 7.35.
C$_{22}$H$_{22}$O requires C, 87.37; H, 7.33.

2-(4-Chloro-phenyl)-1,3-diphenyl propan-2-ol 20c

M.p. 80-1° (recrystallised from petroleum ether).
IR spectrum (Nujol) showed band at 3536 cm$^{-1}$ (for OH).
NMR spectrum (CCl$_4$) showed signals at $\delta$ 1.7 (1H, exchangeable on addition of D$_2$O), 3.06 (4H, $q$, $J_{AB}$ = CH$_2$Ar), 6.8-7.2 (14H, m, aromatic protons).
Analysis: Found C, 78.59; H, 6.00.
C$_{21}$H$_{19}$ClO requires C, 78.12; H, 5.89.

1,2,3-Triphenyl propan-2-ol 20d

M.p. 84-5° (recrystallised from petroleum ether).
IR spectrum (Nujol) showed band at 3571 cm$^{-1}$ (for OH).
NMR spectrum (CCl$_4$) showed signals at $\delta$ 1.66 (1H, exchanges on addition of D$_2$O), 3.06 (4H, $q$, $J_{AB}$ = CH$_2$Ar), 6.6-7.1 (14H, m, aromatic protons).
Analysis: Found C, 87.21; H, 7.03.
C$_{21}$H$_{20}$O requires C, 87.46; H, 6.99.
2-(2-Methyl phenyl)-1,3-diphenyl propan-2-ol 20e

B.p. 176°(bath)/0.3 mm.

IR spectrum (liquid film) showed band at 3550 cm\(^{-1}\)
(for hydroxyl).

\(\text{NMR spectrum (CCl}_4\) showed signals at }<\text{2.36 (3H, s, CH}_3\text{-Ar)}\),
3.16 (4H, q, \(J_\text{AB}=13\text{ Hz, CH}_2\text{-Ar) }, 6.7-7.1 (14H, m, aromatic protons)."

**Analysis:** Found C, 86.92; H, 7.14.

\(\text{C}_{22}\text{H}_{22}\text{O requires } C, 87.37; H, 7.33.\)

**GENERAL PROCEDURE FOR FRAGMENTATION BY CERIC AMMONIUM NITRATE.**

1-(4-Methoxy phenyl)-2-phenyl ethanone 21a

To 20a (1.0 g, 0.0031 M) in acetonitrile (4 ml)
was added ceric ammonium nitrate (3.4 g, 0.0062 M) in acetonitrile (1 ml) and water (5 ml). The mixture was warmed upto 50-55° and maintained at hot temperature till the orange yellow colour of ceric ammonium nitrate disappeared (about 10 minutes). The mixture was then diluted with water (50 ml) and extracted with ether (3x25 ml). The ether layer was washed with water, dried and concentrated to give a syrup. This syrup was chromatographed over alumina (30.0 g, grade II). The alumina column was eluted successively with (i) petroleum ether (ii) petroleum ether + 10% benzene (iii) petroleum ether + 50% benzene.
The fraction eluted with petroleum ether + 50% benzene was composed entirely of 21a (0.537 g, 77%), m.p. 72-73° (Lit.31 m.p. 74-75°).

Similarly alcohols 20b-e gave benzyl ketones 21b-e (see Table 1).

Table 1: Benzyl ketones 21a-e synthesised

<table>
<thead>
<tr>
<th>Name</th>
<th>Compound</th>
<th>M.p. or Lit. m.p.</th>
<th>Lit. m.p.</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-(4-Methoxy phenyl) -2-phenyl ethanone</td>
<td>21a</td>
<td>72-3°</td>
<td>74-5°</td>
<td>31</td>
</tr>
<tr>
<td>1-(4-Methyl phenyl) -2-phenyl ethanone</td>
<td>21b</td>
<td>109°</td>
<td>109-111°</td>
<td>38</td>
</tr>
<tr>
<td>1-(4-Chloro phenyl) -2-phenyl ethanone</td>
<td>21c</td>
<td>106-7°</td>
<td>106-7°</td>
<td>33</td>
</tr>
<tr>
<td>1-Phenyl-2-ethanone</td>
<td>21d</td>
<td>52-3°</td>
<td>55-6°</td>
<td>34</td>
</tr>
<tr>
<td>1-(2-Methyl phenyl) -2-phenyl ethanone</td>
<td>21e</td>
<td>158°/8 mm</td>
<td>172-3/10 mm</td>
<td>35</td>
</tr>
</tbody>
</table>

Conversion of benzyl ketones to homobenzylic alcohols and to aldehydes have been already discussed in Chapter IIIa.
GENERAL PROCEDURE FOR CONVERSION OF ALIPHATIC ACIDS TO ALDEHYDES

1-Phenyl-2-benzyl-heptadecan-2-ol 20h

To a well stirred solution of benzylmagnesium chloride [prepared from magnesium (2.5 g, 0.105 g atom) and benzyl chloride (13.25 g, 0.105 M)] was added ethyl palmitate 19h (10.0 g, 0.035 M) in ether (30 ml) at 0°. The mixture left stirred at room temperature for 20 hours and then quenched with saturated solution of ammonium chloride at 0°. Ether layer was separated from aqueous layer. Aqueous layer was extracted with ether (2x100 ml). The combined ether extract was washed with water, brine, dried and evaporated to give viscous liquid weighing (12.2 g, 83%).

The IR spectrum (liquid film) showed band at 3509 cm⁻¹ (OH, stretching).

NMR spectrum (CDCl₃) showed signals at < 0.96-1.33 (31H, methylene and methyl of aliphatic side chain), 2.73 (4H, s, -CH₂-Ar), 7.2 (10H, s, aromatic protons).

For analytical purpose the sample 20h was purified by preparative layer chromatography. (PLC plate was prepared from SiO₂ in a slurry made from distilled water). The plate was developed in petroleum ether + 10% ethyl acetate.

Analysis: Found C, 84.84; H, 11.07
C₃₀H₄₀O requires C, 85.24; H, 10.97.
Similarly alcohols 20f, 20g and 20i were prepared from the esters 19f, 19g and 19i. The properties and other features of above mentioned alcohols are outlined in the Table 2 and Table 3.

Table 2 - Alcohols 20f-i synthesised

<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular Formula</th>
<th>Yield %</th>
<th>Microanalysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Phenyl-2-benzyl-octan-2-ol (20f)</td>
<td>C_{21}H_{28}O</td>
<td>80</td>
<td>C 85.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H 9.46</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>85.08</td>
</tr>
<tr>
<td>1-Phenyl-2-benzyl-pentadecan-2-ol (20g)</td>
<td>C_{28}H_{42}O</td>
<td>81</td>
<td>C 84.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H 10.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>85.22</td>
</tr>
<tr>
<td>1-Phenyl-2-benzyl-heptadecan-2-ol (20h)</td>
<td>C_{30}H_{46}O</td>
<td>83</td>
<td>C 84.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H 11.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10.73</td>
</tr>
<tr>
<td>1-Phenyl-2-benzyl-nonadecan-2-ol (20i)</td>
<td>C_{32}H_{50}O</td>
<td>78</td>
<td>C 85.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>85.27</td>
</tr>
</tbody>
</table>

Table 3 - NMR values of alcohol 20f-i

<table>
<thead>
<tr>
<th>Compound</th>
<th>NMR shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>20f</td>
<td>0.9-1.2  (13H, methylene and methyl of aliphatic side chain), 2.7 (4H, s, -CH_{2}-Ar), 7.0 (10H, s, aromatic protons).</td>
</tr>
<tr>
<td>20g</td>
<td>0.95-1.26 (27H, methylene and methyl of aliphatic side chain), 2.73 (4H, s, -CH_{2}-Ar), 7.13 (10H, s, aromatic protons).</td>
</tr>
<tr>
<td>20h</td>
<td>0.96-1.33 (31H, methylene and methyl of aliphatic side chain), 2.73 (4H, s, -CH_{2}-Ar), 7.2 (10H, s, aromatic protons).</td>
</tr>
<tr>
<td>20i</td>
<td>0.98-1.3 (35H, methylene and methyl of aliphatic side chain), 2.7 (4H, s, -CH_{2}-Ar), 7.13 (10H, s, aromatic protons).</td>
</tr>
</tbody>
</table>
1-Phenyl-2-heptadecanone 21h

A mixture of alcohol 20h (1.0 g, 0.0023 M), dry benzene (30 ml), iodine (0.588 g, 0.0023 M) and lead tetraacetate (2.4 g, 0.0055 M) was heated under reflux with stirring for 6 hours and then cooled to room temperature. The excess of lead tetraacetate was destroyed by adding ethylene glycol. The benzene layer was washed with aqueous sodium thiosulphate solution, water, brine, dried and the solvent removed; from the resulting product, benzyl acetate was distilled out by heating in a distillation apparatus under vacuum (10 mm) and raising the bath temperature to 100°. The undistilled material was chromatographed over alumina (30.0 g, Grade II). The alumina column was eluted with petroleum ether to yield 21h (0.410 g, 57%), m.p. 45-6°.

IR spectrum (Nujol) showed band at 1725 cm⁻¹ (for carbonyl).

NMR spectrum (CCl₄) showed signals at 2.3 (2H, t, J = 7 Hz, CH₂-CO⁻), 3.56 (2H, s, -CH₂-Ar), 7.1 (5H, s, aromatic protons).

Following the similar procedure alcohols 20f, 20g and 20i were transformed to benzyl ketones 21f, 21g and 21i. The properties of benzyl ketones are being present in the Table 4.

**Table 4 - Benzyl ketones 21f-i synthesised**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Molecular Formula</th>
<th>Yield</th>
<th>M.p.</th>
<th>Microanalysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Phenyl-2-octanone (21f)</td>
<td>C_{14}H_{20}O</td>
<td>51</td>
<td>165°/1 mm</td>
<td>C 82.41 82.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H 9.31 9.80</td>
</tr>
<tr>
<td>1-Phenyl-2-pentadecanone (21g)</td>
<td>C_{21}H_{34}O</td>
<td>55</td>
<td>215°/0.6 mm</td>
<td>C 83.01 83.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H 11.41 11.33</td>
</tr>
<tr>
<td>1-Phenyl-2-heptadecanone (21h)</td>
<td>C_{23}H_{38}O</td>
<td>57</td>
<td>45-6°</td>
<td>C 83.65 83.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H 11.94 11.79</td>
</tr>
<tr>
<td>1-Phenyl-2-nonadecanone (21i)</td>
<td>C_{25}H_{40}O</td>
<td>58</td>
<td>53-4°</td>
<td>C 83.54 83.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H 11.93 11.81</td>
</tr>
</tbody>
</table>

The IR and NMR spectral details on the benzyl ketones are being given in Table 5.
Table 5 - NMR and IR spectral properties of 21f, 21g and 21i

<table>
<thead>
<tr>
<th>Compound</th>
<th>IR (cm⁻¹) for carbonyl</th>
<th>NMR (δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21f</td>
<td>1712</td>
<td>0.9-1.3 (11H, methyl and methylenes of aliphatic side chain), 2.33 (2H, t, J=6 Hz, CH₂-CH₂-CO⁻), 3.63 (2H, s, -CH₂Ar), 7.16 (5H, s, aromatic protons).</td>
</tr>
<tr>
<td>21g</td>
<td>1709</td>
<td>0.9-1.23 (25H, methyl and methylenes of aliphatic side chain), 2.3 (2H, t, J=6Hz, CH₂-CH₂-CO⁻), 3.7 (2H, s, -CH₂Ar), 7.06 (5H, s, aromatic protons).</td>
</tr>
<tr>
<td>21i</td>
<td>1709</td>
<td>0.83-1.23 (33H, methyl and methylene of aliphatic side chain), 2.36 (2H, t, J=6Hz, CH₂-CH₂-CO⁻), 3.56 (2H, s, CH₂Ar), 7.2 (5H, s, aromatic protons).</td>
</tr>
</tbody>
</table>

1-Phenyl-2-heptadecanol 22h

A mixture of 21h (1.0 g, 0.003 M), sodium borohydride (0.114 g, 0.003 M), ethanol (15 ml) and water (2 ml) were magnetically stirred for 4 hours at room temperature and then diluted with excess of water (25 ml). The mixture extracted with ether (2x50 ml). The ether layer was washed with water, brine, dried and evaporated to give solid residue which on recrystallization with petroleum ether gave 22h (0.909 g, 91%), m.p. 62⁰ (Lit. 36 m.p. 63.1-64.2⁰).
IR spectrum (Nujol) showed band at 3448 cm⁻¹ (OH stretching).

NMR spectrum (CDCl₃) showed signals at 0.93-1.33 (3H, methyl and methylene of aliphatic side chain), 2.7 (2H, m, -CH₂-Ar), 3.6 (1H, m, -CHOH), 7.03 (5H, s, aromatic proton).

Analysis: Found C, 82.98; H, 11.97.

C₂₃H₄₀O requires C, 83.06; H, 12.13.

The remaining alcohols 22f, 22g and 22i were prepared in the same manner. The properties of these alcohols are being presented in Table 6.

**Table 6 - Alcohols 22f, 22g and 22i synthesised**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Found</td>
</tr>
<tr>
<td>22f</td>
<td>92</td>
<td>a</td>
<td>a</td>
<td>C 81.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H 10.86</td>
</tr>
<tr>
<td>22g</td>
<td>85</td>
<td>52-3°</td>
<td>55°</td>
<td>C 82.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H 12.20</td>
</tr>
<tr>
<td>22i</td>
<td>96</td>
<td>66°</td>
<td>68-9°</td>
<td>C 82.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H 12.03</td>
</tr>
</tbody>
</table>

[a - purified by column chromatography].
Characteristic band in 1a and signals in NMR for the alcohols 21f, 21g and 21i are given in Table 7.

Table 7 - NMR and IR spectral details on 21f, 21g and 21i

<table>
<thead>
<tr>
<th>Compound</th>
<th>IR (cm$^{-1}$) for hydroxyl</th>
<th>NMR (δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21f</td>
<td>3571</td>
<td>0.93-1.36 (13H, methyl and methylenes of aliphatic side chain), 2.65 (2H, m, CH$_2$-Ar), 3.7 (1H, m, -CHOH), 7.2 (5H, s, aromatic protons).</td>
</tr>
<tr>
<td>21g</td>
<td>3548</td>
<td>0.9-1.3 (27H, methyl and methylenes of aliphatic side chain), 2.63 (2H, m, CH$_2$-Ar), 3.63 (1H, bm, -CHOH), 7.03 (5H, s, aromatic protons).</td>
</tr>
<tr>
<td>21i</td>
<td>3548</td>
<td>0.8-1.23 (35H, methyl and methylenes of aliphatic side chain), 2.7 (2H, m, -CH$_2$-Ar), 3.71 (1H, m, -CHOH), 7.1 (5H, s, aromatic protons).</td>
</tr>
</tbody>
</table>

Hexadecanal 23h

A mixture of 22h (1.0 g, 0.003 M), dry benzene (15 ml), iodine (0.768 g, 0.003 M) and lead tetraacetate (3.1 g, 0.007 M) was heated under reflux with stirring for 4 hours and then cooled to room temperature. The excess of lead tetraacetate was destroyed by adding ethylene glycol. The benzene layer
was washed with aqueous sodium thiosulphate solution, water, brine, dried and the solvent evaporated. To the residue which weighed (1.2 g) was added 2,4-dinitrophenyl hydrazone (1.1 g) in ethanol (10 ml). The mixture was boiled for few minutes and left for crystallization. On cooling the yellow-crusts of 2,4-dinitrophenyl hydrazone of hexadecanal 23h separated out as shining particle (0.630 g, 67%), m.p. 104-6° (Lit. 37 m.p. 105-6°).

The similar experimental conditions were performed on the alcohols 22f, 22g and 22i to furnish the corresponding aldehydes 23f,23g and 23i respectively. The yield and m.ps. of 2,4-dinitrophenyl hydrazones of above derivatives are given in Table 8.

Table 8 - Aldehydes 23f-i synthesised

<table>
<thead>
<tr>
<th>Compound</th>
<th>Yield %</th>
<th>m.p. of 2,4-DNP</th>
<th>Lit. m.p. of 2,4-DNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>23f</td>
<td>56</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>23g</td>
<td>58</td>
<td>105°</td>
<td>106-7° 39</td>
</tr>
<tr>
<td>23h</td>
<td>67</td>
<td>104-6°</td>
<td>105-6° 37</td>
</tr>
<tr>
<td>23i</td>
<td>58</td>
<td>103-5°</td>
<td>106.5-107° 38</td>
</tr>
</tbody>
</table>

The identity and yield of 23f was established on the basis of GLC comparison with authentic sample of heptanal.
NMR SPECTRUM OF 2-(4-METHOXY PHENYL)-1,3-DIPHENYLPROPAN-2-OL (20g)

NMR SPECTRUM OF 1-PHENYL-2-BENZYL-PENTADECAN-2-OL (20g)
NMR SPECTRUM OF 1-(4-METHOXY PHENYL)-2-PHENYL ETHANONE. (21a)

NMR SPECTRUM OF 1-PHENYL-2-PENTADECANONE. (21g)
NMR SPECTRUM OF 1-(4-METHOXY PHENYL)-2-PHENYL ETHANOL (22a)

NMR SPECTRUM OF 1-PHENYL-2-PENTADECANOL (22g)
NMR SPECTRUM OF MIXTURE OF p-ANISALDEHYDE (23a) AND BENZYL ACETATE.

NMR SPECTRUM OF MIXTURE OF MYRISTALDEHYDE (23g) AND BENZYL ACETATE.
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