SUMMARY

Among the hydroxyanthracene derivatives there has been very little work done on 1- and 2-anthrol. It was therefore thought of interest to study various reactions on these hydroxyanthracene derivatives.

Chapter I. General Introduction : Pattern of addition and substitution in anthracene and hydroxyanthracenes.

Chapter II. Some Reactions on 1- and 2- anthrol.

The Gattermann reaction on 1-anthrol gave a product to which the 4-formyl-1-anthrol structure has been assigned on the basis of its properties. Further, upon methylation and subsequent oxidation with alkaline potassium permanganate this product gave 1-hydroxyanthraquinone-4-carboxylic acid, previously synthesised by Birukoff (Ber., 1887, 20, 2438) by a different method. 4-Formyl-1-anthrol has been reduced by Clemmensen's method to 4-methyl-1-anthrol.

1-Anthrol on Friedel-Crafts acetylation yielded a ketone which has been assigned the 2-acetyl-1-anthrol structure. On methylation and oxidation with sodium hypochlorite solution it gave an anthraquinone derivative which on further oxidation with the same reagent yielded the known 1-methoxyanthraquinone-2-carboxylic acid, found identical on direct comparison with an authentic specimen prepared from 2-methylanthraquinone through a series of known reactions.

The Nencki acetylation of 1-anthrol also provided the same ketone in good yield, but the Fries rearrangement of 1-anthrolacetate at 140° gave the ketone in poor yield. At room temperature, 2-acetyl-1-anthrol and 4-acetyl-1-anthrol were both formed in poor yield.

Laska and Haller (German Patent 559, 333. Chem. Abstr., 1933, 27, 735) prepared an acid m.p. 200° by heating the alkali salt of 1-anthrol at about 220° with carbon dioxide under pressure and assigned 1-anthrol-2-carboxylic acid structure to this substance. Kranzlein and Corell (German Patent 564, 129 Chem. Abstr., 1933, 27, 1000) claim to have prepared the same acid (m.p. 268°) by fusing a compound they believed to be 2-carboxy-1-anthracene-sulphonic acid with alkali. In view of this discrepancy it was thought of interest to prepare this acid and to establish its structure. 1-Anthrol on heating with potassium bicarbonate at 120° in glycerine for 4 hours gave the desired acid m.p.200°. Through a series of reactions it was converted into the known 1-methoxyanthraquinone-2-carboxylic acid which confirmed the structure assigned by Laska and Haller (loc.cit.).

The Gattermann reaction on 2-anthrol gave 1-formyl-2-anthrol described earlier by Jain and Seshadri (J. Sci. Industr. Res., 1956, 15B, 61). Its structure was independently proved by converting it into the known 2-methoxyanthraquinone-1-carboxylic acid (Ch. Marschalk, Bull. Soc. Chim., 1939, 6, 655). 1-Formyl-2-anthrol has been reduced by Clemmensan's method to 1-methyl-2-anthrol which

was also obtained on reduction of 1-methyl-2-hydroxy-anthraquinone with aluminium amalgam in aqueous alcoholic ammonia solution.

Upon Friedel-Crafts acetylation, both at room temperature as well as on the steam bath, 2-anthrol yielded a ketone (A) m.p.113°, which gave a bluish colouration with alcoholic ferric chloride which turned greenish on standing. The ketone was methylated and the methyl ether oxidised with sodium hypochlorite solution to the known 2-methoxy-anthraquinone-1-carboxylic acid (Ch. Marschalk, loc.cit.). 1-Acetyl-2-anthrol structure has therefore been assigned to the ketone (A). The Fries rearrangement of 2-anthrolacetate at room temperature in nitrobenzene solution also provided the same ketone. Jain and Seshadri have reported that in the Fries migration of 2-anthrolacetate at 140°, without using any solvent, a product, m.p. 219° was obtained, which according to them was 1-acetyl-2-anthrol. Very recently, after the work described here was published, Ferrari and Hunsberger (J. Org. Chem., 1960, 25, 485) confirmed the work described here and ~~have~~ showed that the product obtained by Jain and Seshadri was 3-acetyl-2-anthrol.

Direct carboxylation of 2-anthrol under various conditions, did not succeed. Attempts to synthesise 2-hydroxy-anthracene-1-carboxylic acid through other routes also did not succeed. 2-Methoxy-anthraquinone-1-carboxylic acid on reduction with aluminium amalgam in aqueous alcoholic ammonia gave 2-methoxyanthracene-1-carboxylic acid. Demethylation of

the acid by heating with hydriodic acid in acetic anhydride solution gave 2-hydroxy-9,10-dihydroanthracene-1-carboxylic acid.

Another approach was then tried. The methoxy ester of the acid was subjected to demethylation with anhydrous aluminium chloride at 80° when methyl-2-hydroxyanthracene-1-carboxylate was obtained. This ester on hydrolysis with sodium hydroxide by keeping it overnight at room temperature gave 2-anthrol, decarboxylation having occurred simultaneously with hydrolysis.

Chapter III. Synthesis of some anthra α- and anthra γ-pyrones.

The synthesis of anthra α- and γ-pyrones was undertaken next.

1-Anthrol on Pechmann condensation with ethyl acetoacetate and ethyl benzoylacetate in the presence of 80 % sulphuric acid yielded products to which the structures 4'-methyl-1,2-anthra-α-pyrone and 4'-phenyl-1,2-anthra-α-pyrone respectively have been assigned. On treatment with alkali and dimethyl sulphate they yielded acrylic acids, which is a characteristic test for coumarin derivatives. The same α-pyrones were obtained when phosphorus pentoxide was used as the condensing agent instead of sulphuric acid (Simonis reaction).

The Kostanecki-Robinson acetylation of 2-acetyl-1-anthrol furnished 2'-methyl-3'-acetyl-1,2-anthra-γ-pyrone.

On deacetylation it afforded 2'-methyl-1,2-anthra-γ-pyrone, which yielded a styryl derivatives with benzaldehyde and 2-acetyl-1-anthrol on hydrolysis. The same ketone on Kostanecki-Robinson benzoylation gave 2'-phenyl-3'-benzoyl-1,2-anthra-γ-pyrone, which on debenzoylation furnished 2'-phenyl-1,2-anthra-γ-pyrone. 2'-Methyl- and 2'-phenyl-1,2-anthra-γ-pyrone were also obtained by refluxing 1-anthrol with ethyl acetoacetate and ethyl benzoylacetate respectively in diphenyl ether solution (cf. Desai, Trivedi and Sethna, J. M. S. University of Baroda, 1955, IV, No. 2, 1.).

2-Acetyl-1-anthrol on condensation with benzaldehyde in presence of alkali yielded 2-hydroxy-anthryl styryl ketone. On heating its ethanol solution with dilute sulphuric acid it isomerised to 2'-phenyl-2',3'-dihydro-1,2-anthra-γ-pyrone. This as well as the styryl ketone on dehydrogenation with selenium dioxide in isoamyl alcohol gave 2'-phenyl-1,2-anthra-γ-pyrone, identified by direct comparison with the product described above.

In the Pechmann condensation of 2-anthrol with ethyl acetoacetate in presence of either concentrated or 80 % sulphuric acid a pure condensation product could not be obtained. However, in the presence of phosphorus pentoxide (Simonis reaction) 2'-methyl-2,1-anthra-γ-pyrone was obtained. This gave a styryl derivative with benzaldehyde and on hydrolysis gave 1-acetyl-2-anthrol. A similar reaction with ethyl benzoylacetate gave 2'-phenyl-2,1-anthra-γ-pyrone. 1-Formyl-2-anthrol on Perkin acetylation afforded 2,1-anthra-

α-pyrone. The same α-pyrone was also obtained by the Knoevenagel condensation of malonic ester with 1-formyl-2-anthrol and subsequent hydrolysis and decarboxylation of ethyl 2,1-anthra-α-pyrone-3'-carboxylate formed.

1-Acetyl-2-anthrol on Kostanecki-Robinson acetylation gave 2'-methyl-3'-acetyl-2,1-anthra-γ-pyrone. On deacetylation it gave 2'-methyl-2,1-anthra-γ-pyrone described above. The same ketone on Kostanecki-Robinson benzoylation gave 2'-phenyl-3'-benzoyl-2,1-anthra-γ-pyrone which on debenzoylation gave 2'-phenyl-2,1-anthra-γ-pyrone, described before.

1-Acetyl-2-anthrol on condesnsation with benzaldehyde in presence of alkali yielded 2'-phenyl-2',3'-dihydro-2,1-anthra-γ-pyrone. This on dehydrogenation with selenium dioxide in isoamyl alcohol gave 2'-phenyl-2,1-anthra-γ-pyrone, identified by direct comparison with the product described before.

Chapter IV. Synthesis of some anthra-furan derivatives.

2-Acetyl-1-anthrol on condensation with ethyl bromoacetate furnished ethyl 2-acetyl-1-anthroxyacetate, which on hydrolysis gave 2-acetyl-1-anthroxyacetic acid. On heating with sodium acetate and acetic anhydride it afforded 3-methyl-anthra (1,2-b) furan. It has been ascertained that the meso position is not involved in the ring closure.

1-Formyl-2-anthrol on condensation with ethyl bromoacetate gave ethyl-1-formyl-2-anthroxyacetate which on

hydrolysis and cyclisation gave anthra (2,1-b) furan. Through the same series of reactions, 1-acetyl-2-anthrol furnished 1-methyl-anthra (2,1-b) furan.

Chapter V. Synthesis of some anthraquinone derivatives.

There is no reference in the literature to the building up of the α-pyrone, γ-pyrone or furan ring on the anthraquinone ring system. It was therefore thought of interest to explore the possibility of synthesising these compounds. Survey of the literature showed that there is no simple method of synthesising 2-acetyl-1-hydroxyanthraquinone and 1-acetyl-2-hydroxyanthraquinone had not been synthesised at all. Attempts to synthesise them by subjecting 1-hydroxy- and 2-hydroxyanthraquinone to Friedel-Crafts acetylation did not succeed. Fries rearrangement of the 1- and 2-acetoxyanthraquinone also did not succeed, only the corresponding hydroxyanthraquinones were obtained. Pechmann, as well as Simonis reaction on 1-hydroxy- and 2-hydroxy-anthraquinone did not succeed. In view of all this, it was thought of interest to study the controlled oxidation of the anthracene derivatives, described earlier.

The acetoxy derivative of 2-acetyl-1-anthrol on oxidation with chromic acid in acetic acid at 65°, furnished after hydrolysis 2-acetyl-1-hydroxyanthraquinone. This ketone was next subjected to Kostanecki-Robinson acetylation. No pure product could be isolated, but, the desired 2'-methyl-

1,2-(9,10-dihydro-9,10-dioxo) anthra-γ-pyrone was synthesised by oxidising 2'-methyl-1,2-anthra-γ-pyrone with sodium dichromate in acetic acid at room temperature. The same ketone on Kostanecki-Robinson benzoylation afforded the 2'-phenyl-3'-benzoyl-1,2-(9,10-dihydro-9,10-dioxo) anthra-γ-pyrone which on hydrolysis with sulphuric acid gave 2'-phenyl-1,2-(9,10-dihydro-9,10-dioxo) anthra-γ-pyrone, identical with the product obtained by the oxidation of 2'-phenyl-1,2-anthra-γ-pyrone with chromic acid in acetic acid. 4'-Methyl-1,2-anthra-α-pyrone on oxidation with sodium dichromate in acetic acid at room temperature afforded the corresponding anthraquinone α-pyrone.

Attempts to synthesise the furan derivative by the oxidation of the corresponding anthra-furan derivative did not succeed, as the furan ring was found to be susceptible to oxidation, 2-acetyl-1-hydroxyanthraquinone being obtained in the oxidation of 3-methyl-anthra (1,2-b) furan. The synthesis of the furan derivative was however achieved by subjecting ethyl 2-acetyl-1-anthroxyacetate to oxidation with chromic acid in acetic acid. Ethyl 2-acetyl-1-(9,10-dihydro-9,10-dioxo-) anthroxyacetate so obtained was hydrolysed to the corresponding acid which was then cyclised by boiling with acetic anhydride and sodium acetate to furnish 3-methyl-(9,10-dihydro-9,10-dioxo-) anthra (1,2-b) furan.

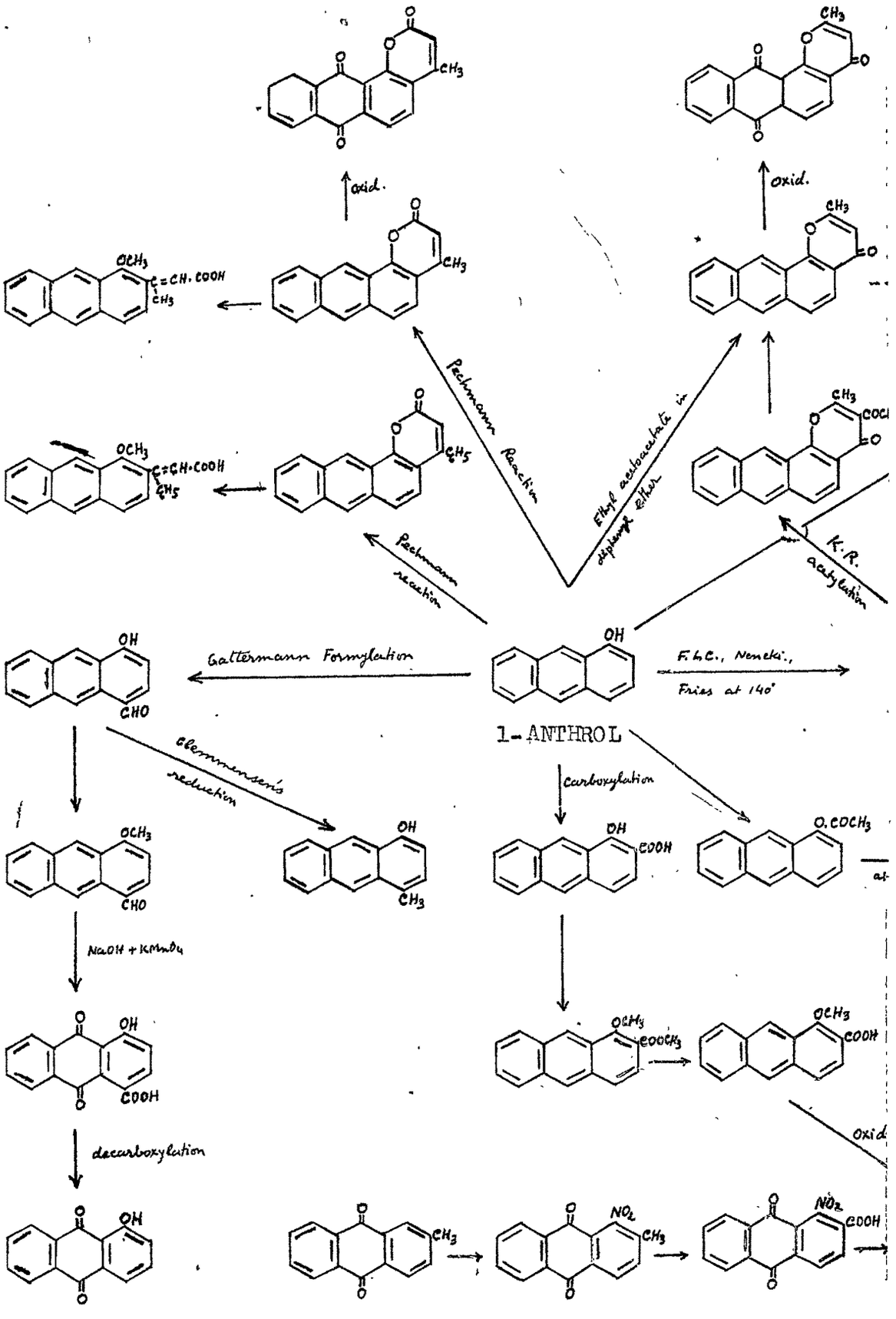
The acetoxy derivative of 1-acetyl-2-anthrol on oxidation with chromic acid in acetic acid at room

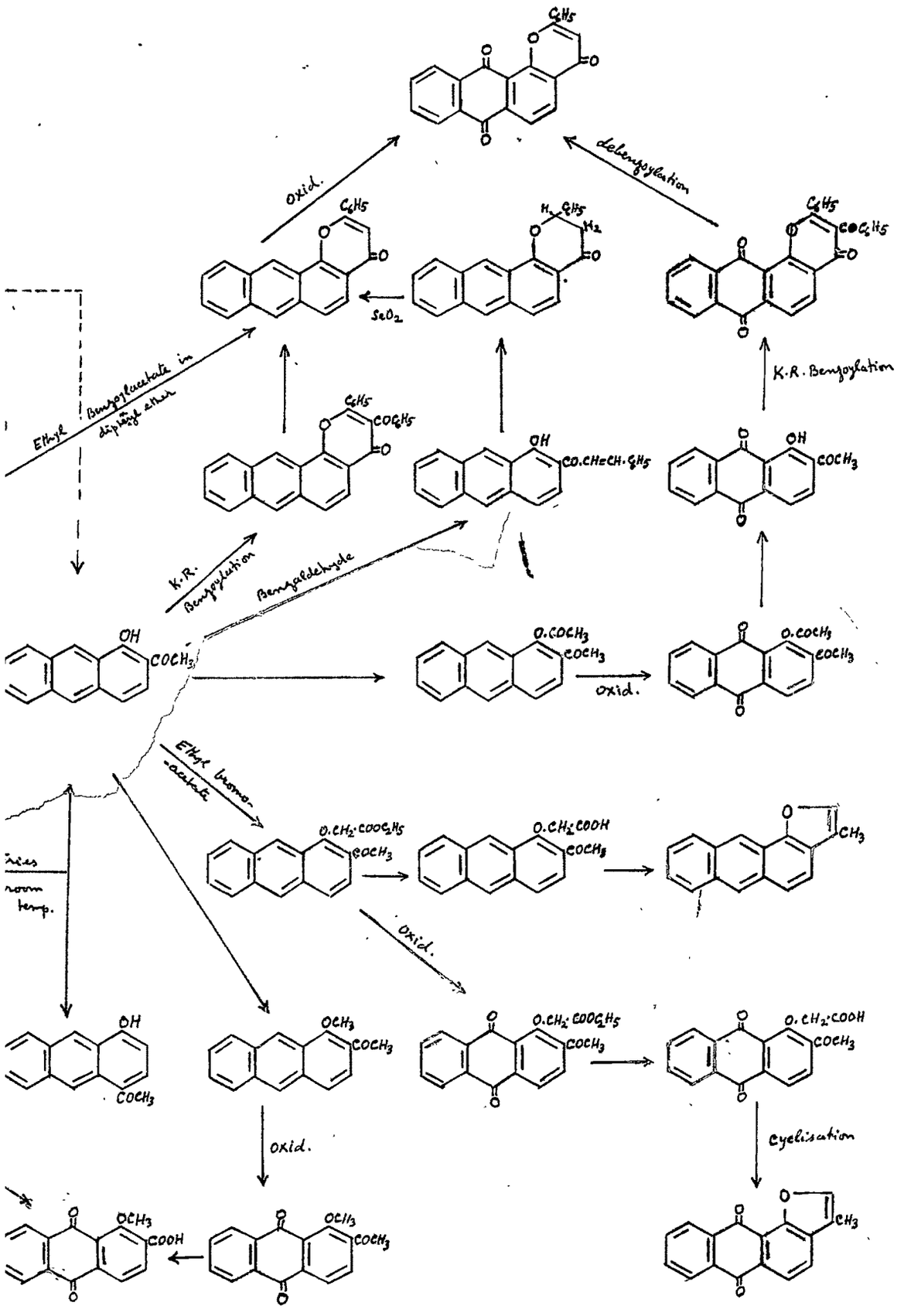
temperature and hydrolysis gave 1-acetyl-2-hydroxyanthraquinone.

1-Acetyl-2-hydroxyanthraquinone on Kostanecki-Robinson acetylation did not give a pure product with definite m.p. but the oxidation of 2'-methyl-2,1-anthra-γ-pyrone with sodium dichromate in acetic acid gave the desired 2'-methyl-2,1-(9,10-dihydro-9,10-dioxo-) anthra-γ-pyrone. 1-Acetyl-2-hydroxyanthraquinone, however, on Kostanecki-Robinson benzoylation afforded 2'-phenyl-3'-benzoyl-2,1-(9,10-dihydro-9,10-dioxo-) anthra-γ-pyrone, identical with the product obtained on oxidation of 2'-phenyl-3'-benzoyl-2,1-anthra-γ-pyrone with sodium dichromate in acetic acid at room temperature. The oxidation of 2'-phenyl-2,1-anthra-γ-pyrone in a similar way furnished 2'-phenyl-2,1-(9,10-dihydro-9,10-dioxo-) anthra-γ-pyrone.

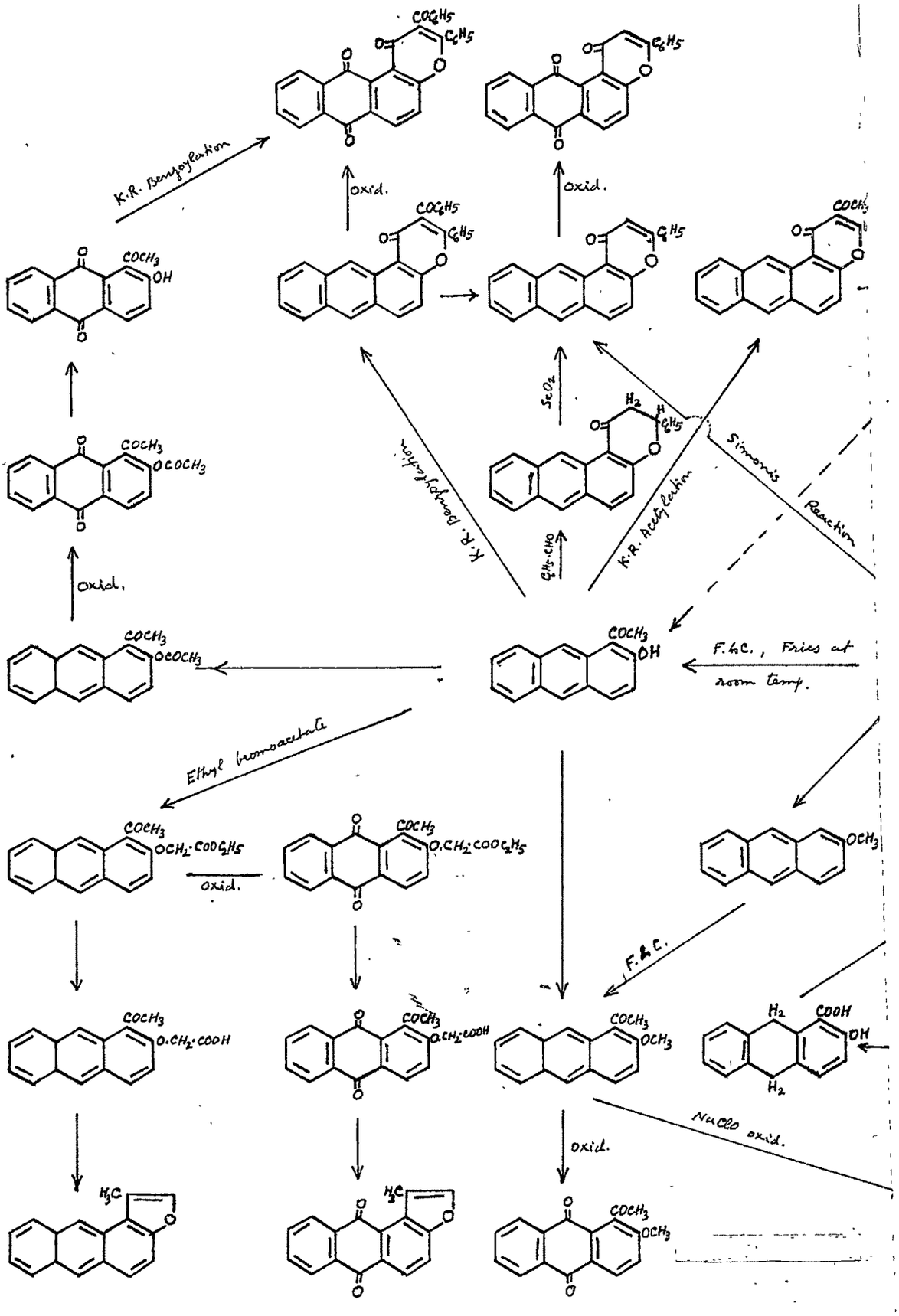
Ethyl-1-ℓ-acetyl-2-anthroxyacetate on oxidation with sodium dichromate in acetic acid gave ethyl 1-acetyl-2-(9,10-dihydro-9,10-dioxo-) anthroxyacetate which on hydrolysis and cyclisation afforded 1-methyl-(9,10-dihydro-9,10-dioxo-) anthra (2,1-b) furan.

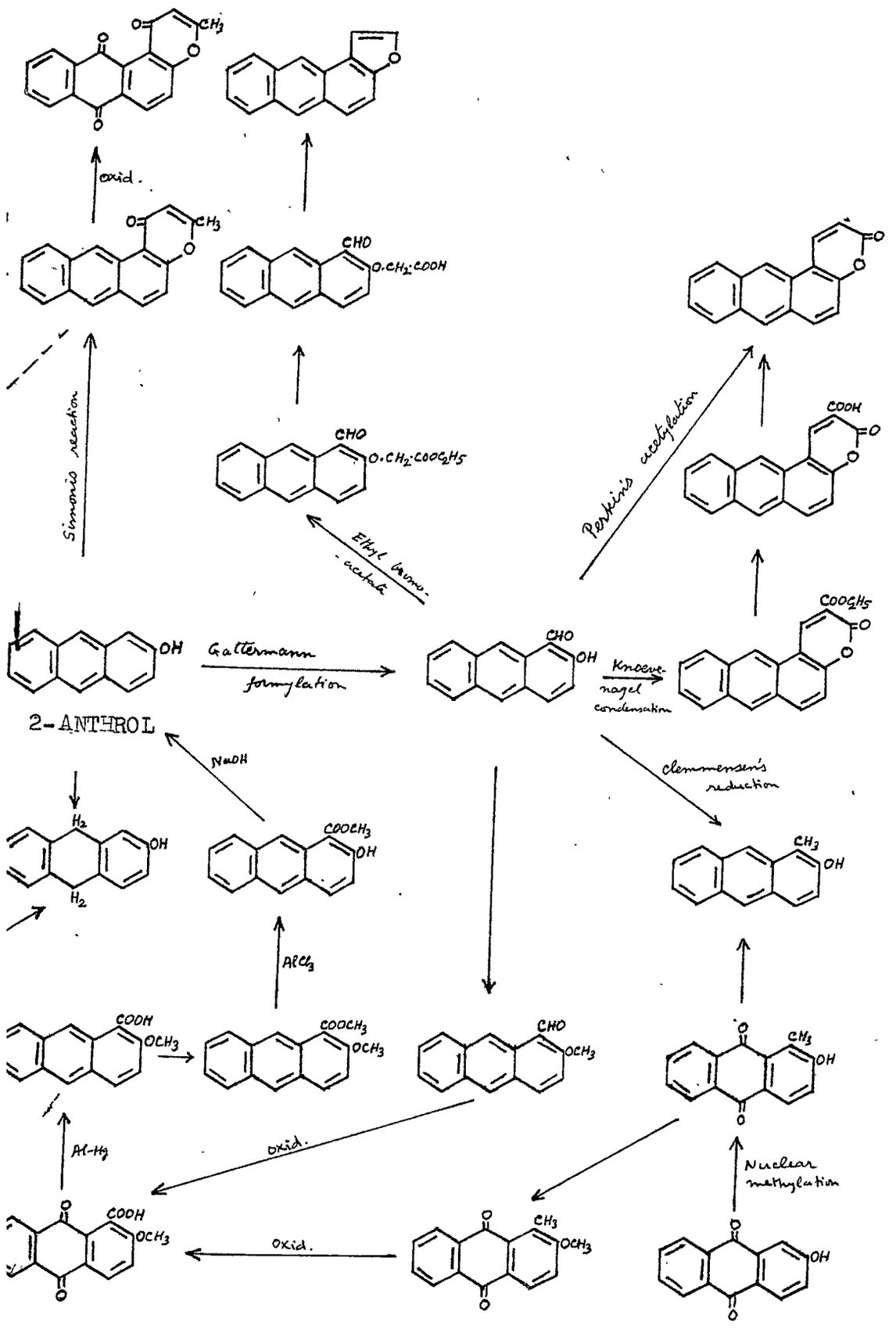
REACTIONS ON 1-ANTHROL AND ITS DERIVATIVES




Debenzoylation
oxid.
SeO2
K.R. Benzoylation
Benzaldehyde
Ethyl Benzoylacetate in dry ether
K.R. Benzoylation
oxid.
Ethyl bromo-acetate
ice
room temp.
oxid.
oxid.
cyclisation

REACTIONS ON 2-ANTHROL AND ITS DERIVATIVES




oxid.
Simonis reaction
Ethyl bromo-acetate
Perkin's acetylation
Gattermann formylation
Knoevenagel condensation
2-ANTHROL
NaOH
Clemmensen's reduction
AlCl3
Al-Hg
oxid.
oxid.
Nuclear methylation