Our results are shown in Fig. 2. The temperature and alkali effects are practically the same as those which have been observed in this Laboratory with the trioses,[2] certain hexoses[7,8] and maltose.[9]

(c) **Acetic and Formic Acids.**—Previously it has been thought that the presence of acetic acid in these reactions might be due to a decomposition of pyruvic aldehyde into acetaldehyde and carbon monoxide, which, in turn, would yield acetic and formic acids, respectively. If this were true, then these acids should also show maximum yields, because the tendency of the pyruvic aldehyde toward a minimum after the maximum, has been thought to be due to the increasing rate of lactic acid formation with the increasing normality of the alkali. That these general considerations are also true in the alkaline decomposition of the pentoses may be seen in Figs. 3 and 4. It is also conceivable that the glycol aldehyde which is formed in the decomposition of the 2,3-pentose enediols as well as the 1,2-triose and 2,3-hexose enediols may also give rise to acetic acid formation.[10]

From the data presented in this report it is clear that any pentoses which might possibly form in the alkaline decomposition of the hexose sugars are to be considered as possible sources of pyruvic aldehyde, lactic, acetic and formic acids.

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[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF DENVER]

A MODIFICATION OF THE SKRAUP SYNTHESIS OF QUINOLINE

BY ESSIE WHITE COHN

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The Skraup synthesis is widely used as a method for the preparation of quinoline and its derivatives. The synthesis, when performed in the manner advocated by Skraup, is often accompanied by a violent reaction. In addition, the yields obtained are variable and often low. To overcome the disadvantages of the original Skraup method, various improvements have been published from time to time.

To date the most important of the improvements made have been the ferrous sulfate modification of Clarke and Davis,[1] the acetic acid modification of Cohn and Gustavson[2] and a thorium–vanadium oxide method of Darzens, Delaby and Hiron.[3] The ferrous sulfate modification gives a very much better yield than does the original Skraup method. The re-

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[9] Evans and Benoy, THIS JOURNAL, **52**, 294 (1930).

[10] (a) R. C. Hockett, Master's Thesis, The Ohio State University, **1928**; (b) G. P. Hoff, Doctor's Dissertation, **1925**; (c) *cf.* Evans, *Chemical Reviews*, **6**, 306 (1929).

[1] Clarke and Davis, "Organic Syntheses," John Wiley and Sons, Inc., New York, **1922**, Vol. II, p. 79.

[2] Cohn and Gustavson, THIS JOURNAL, **50**, 2709 (1928).

[3] Darzens, Delaby and Hiron, *Bull. soc. chim.*, **47**, 227 (1930).

action, however, is sometimes violent. The acetic acid modification accomplishes a complete removal of all traces of violence. The yields obtained by this method are smaller than those of the ferrous sulfate modification. The modification which has been named the thorium–vanadium oxide modification gives good yields. The violence of reaction has been avoided by adding sulfuric acid in three stages, controlling the temperature at which the reaction mixture is refluxed and by stirring.

Since each of these methods leaves something to be desired from the standpoint of smoothness in the first method, of yield in the second and of convenience in the third, the present paper presents a method which moderates the violence of the reaction and produces yields comparable with those obtained by other methods. This method will be termed a boric acid modification.

Experimental

The boric acid modification of the ferrous sulfate modification method for preparing quinoline may be carried out as follows. The reagents are placed in a liter flask in the order given: 14 g. of ferrous sulfate, 38 g. of aniline, 29.5 g. of mononitrobenzene. Twenty-five grams of boric acid is dissolved in 150 g. of glycerol, heat being used to effect solution of the boric acid. The boric acid–glycerol mixture when cooled is added to the contents in the liter flask and the whole mixed. Finally, 69.8 cc. of 95% sulfuric acid is added, the contents mixed well, connected with a reflux condenser and heated over a free flame until the boiling point is reached. The mixture in the flask is kept simmering for a period of refluxing from nine to twenty hours, depending upon the yield desired. It is then cooled and diluted with water. The flask is connected with steam distillation apparatus and steam is passed in until the distillate is clear. The contents of the flask are cooled and made alkaline with about 250 cc. of a 60% sodium hydroxide solution. The sodium hydroxide is added cautiously with frequent cooling of the flask. The contents of the flask are again distilled with steam. The current of steam is discontinued when the distillate is clear. The distillate is dissolved in sulfuric acid (25.7 cc. of 95% sulfuric acid diluted with an equal volume of water). The mixture is cooled, sodium nitrite added until a drop of the solution causes a starch–potassium iodide spot to turn blue and the material is allowed to stand for about an hour. The contents of the flask are again made alkaline and steam distilled until the distillate is clear. The distillate is extracted with ether, the ether evaporated and the resulting product of quinoline weighed. Comparisons are based on the weight of quinoline obtained at this stage, although further purification is effected by distillation.

The following table shows a comparison of yields obtained by three methods of preparing quinoline for a five-hour period of refluxing. The yields are based on the same quantity of aniline and approximately the same quantities of materials with the exception of ferrous sulfate, acetic acid and boric acid.

Method	Time of heating, hours	Average yield, g.
Ferrous sulfate modification	5	30
Acetic acid modification	5	25
Boric acid modification	5	38

Figure 1 shows the yield obtained in the boric acid modification method as the time of refluxing was varied. For a fifteen-hour refluxing, the yield of quinoline is 90% of the theoretical based upon the amount of aniline originally added.

The theory for the action of boric acid is believed to be similar to that of the acetic acid modification of Cohn and Gustavson,[2] namely, that an intermediate semi-stable glycerol borate is formed which hydrolyzes, gradually liberating glycerol.

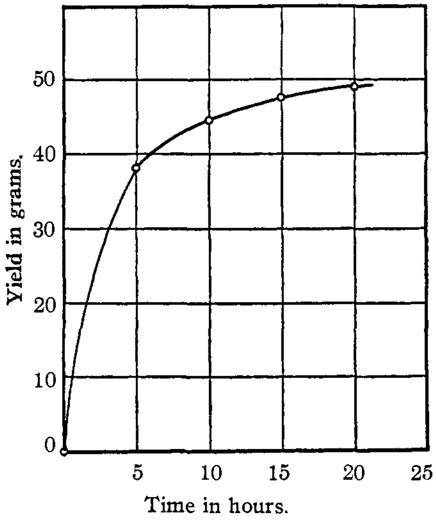

Fig. 1.—Yield of quinoline with time of refluxing.

A Measure of the Vigor of the Initial Reaction.—To obtain a more definite measure of the violence of the various reaction mixtures used in the synthesis of quinoline, the rate of rise of temperature under uniform heating conditions was obtained for each. The method used was to place in an 8-inch pyrex test-tube a fixed volume of the mixture to be tested. The tube was placed in an electrically heated vertical tube furnace of small heat capacity constructed for this experiment. The furnace was started in all cases at a temperature of 20° and was heated by a current of 1.80 amperes with constant stirring of the mixture. The increase in temperature with time was noted. Figure 2 shows typical curves obtained. These curves represent in a graphic manner the relative vigor of the reactions encountered in each case. The temperature at which bubbles began to escape is marked with an arrow. This point may not represent the boiling point of the mixture as a whole. Curve A represents the temperature–time curve above 120° for the original Skraup mixture. The temperature at which bubbles escape from the solution is approximately 146°. It will be noted that the temperature rise above this point is extremely rapid, reaching within the next minute about 175°. The

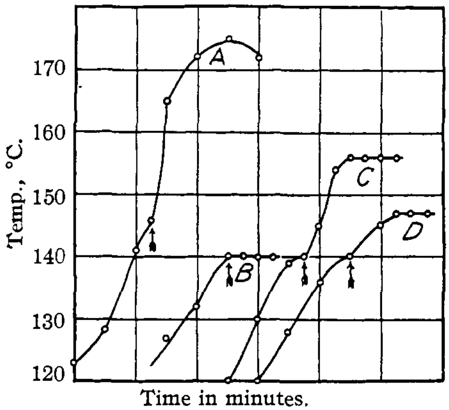

Fig. 2.—Comparative initial rise of temperature with time of heating.

rapid change in temperature is apparently related to the violence of the reaction. Curve B indicates the entire lack of violence found in the acetic acid modification. In Curve C, representing the curve obtained in the ferrous sulfate modification, the rise of temperature after the evolution of bubbles can be seen to approximate 15° within one-half minute. In Curve D, which represents the data from the boric acid modification, the rise of temperature is approximately one-half of that found in Curve C and, as will be noted by the slopes of the two curves, the rise is more gradual.

Summary

1. It has been found possible to decrease the violence of the reaction of the ferrous sulfate modification of the Skraup quinoline synthesis by the addition of boric acid.
2. The yield of quinoline has been increased by the addition of the boric acid.
3. A comparison of the vigor of the reactions has been obtained.

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[CONTRIBUTION FROM THE CHEMICAL RESEARCH LABORATORY, THE UPJOHN COMPANY]

THE STEROLS OF ERGOT. II. THE OCCURRENCE OF DIHYDRO-ERGOSTEROL

BY FREDERICK W. HEYL AND ORLO F. SWOAP[1]

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Recently[2] we briefly described the preliminary fractionation of "ergosterol" from ergot fat. Crude ergosterol was prepared from an ether solution of the unsaponifiable fraction by precipitation with petroleum ether. We have now studied this ether–petroleum ether filtrate. Originally our expectation was that fungisterol might be found there in such proportion that its isolation would be somewhat more readily accomplished. In this study we have incidentally isolated pure α-dihydro-ergosterol, which was first described by Windaus and Brunken.[3] They report a specific rotation of −19.3°, and a melting point of 173–174°. The acetate melts at 180–181° and for $[\alpha]_D$ they found −21.0° Heilbron, Johnstone and Spring[4] report that the melting point of α-dihydro-ergosterol acetate varies from 179–180 to 173°, depending upon the duration of the acetylation process. The rotation, $[\alpha]^{21}_{5461}$, varied from −25.3 to −30.3°.

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[1] Holder of the Upjohn Coöperative Fellowship at Kalamazoo College (1929–1930). This paper is based upon the thesis presented by Mr. Swoap to the Faculty of Kalamazoo College, in partial fulfilment of the requirements for the degree of Master of Science.

[2] Hart and Heyl, THIS JOURNAL, **52**, 2013 (1930).

[3] Windaus and Brunken, *Ann.*, **460**, 232 (1928).

[4] Heilbron, Johnstone and Spring, *J. Chem. Soc.*, 2248 (1929).