Addition in one of the carbonyl groups would best account for all the properties of the substance.

While it is to be expected that water would split off from a compound containing a carbon atom united with two hydroxyls, our knowledge of the behavior of such a group in the neighborhood of other radicals is limited and a hydrate of the 2,7-sulfonate such as indicated is not impossible. Addition appears to be represented in many chemical reactions.

MIDDLETOWN, CONN.

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF JOHNS HOPKINS UNIVERSITY.]

THE IDENTIFICATION OF ACIDS.

BY E. EMMET REID.

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Progress in the investigation of natural products and in the analysis of artificial mixtures depends greatly on the possibility of preparing crystalline derivatives of the substances under investigation. We have satisfactory crystalline derivatives of aldehydes and of alcohols in the phenylurethanes and α- and β-naphthylurethanes, and of aldehydes in the phenylhydrazones and substituted phenylhydrazones.

As organic acids occur in natural products in great variety and have been produced synthetically in immense numbers, their positive identification is of the utmost importance. Usually the amides, anilides and *p*-toluides are relied upon for the identification of acids, but, in some cases, these are difficult to prepare.

It is desirable to have several series of derivatives so that if one fails in a particular case, another may be available. In important cases, in order to avoid the possibility of error, it is often necessary to prepare several different derivatives. Hence, a new series of crystalline derivatives, which are readily made from acids, may be of use.

p-Nitrobenzyl bromide was prepared by Wachendorf[1] in 1877 by heating *p*-nitrotoluene and bromine in a sealed tube. He found that it reacted readily with sodium acetate to give the acetate m. p. 78°.

Now a derivative of acetic acid, which is formed readily from sodium acetate, crystallizes well, is not too soluble in alcohol, and melts sharply at a conveniently high temperature, is very desirable as a means of isolating and identifying acetic acid. It seems remarkable that advantage has not been taken of this observation. The identification of organic substances was not so much an object in Wachendorf's time, and his work seems to have been overlooked. His statements about the ready formation of *p*-nitrobenzyl acetate suggested the present work. It was thought that other *p*-nitrobenzyl esters might likewise be formed readily and might have convenient properties.

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[1] *Ann.*, 185, 266 (1877).

Other chemists, from time to time, have made *p*-nitrobenzyl esters and also ethers of alcohol and phenols. Some of these have been made from the chloride or iodide. There has been no systematic investigation of *p*-nitrobenzyl esters from this standpoint.

p-Nitrobenzyl bromide has been found to be a most convenient and satisfactory reagent for the identification of acids. Like other benzyl halides, it reacts promptly with sodium or potassium salts of organic acids. This is a great advantage, since these salts are easy to obtain from almost any acid. The *p*-nitrobenzyl esters so formed are usually only moderately soluble in dilute alcohol, from which they frequently crystallize well, and a large proportion of them are solids melting at convenient but well scattered temperatures.

It is obvious that *p*-nitrobenzyl chloride and iodide might be employed instead of the bromide, and the literature shows that a number of *p*-nitrobenzyl esters and other derivatives have been made by the use of these halides, but the bromide is preferable to the chloride in that it reacts more satisfactorily; on the other hand, it is preferable to the iodide since the iodide is much less soluble and any of it which fails to react is more difficult to separate from the reaction product by crystallization.

Historical.

p-Nitrobenzyl chloride, m. 71°, was made by Beilstein and Geitner (*Ann.*, **139**, 337 (1866)) by nitrating benzyl chloride and also by Wachendorf by chlorinating *p*-nitrotoluene.

p-Nitrobenzyl bromide, m. 99°, was prepared by Wachendorf (*Ann.*, **185**, 271 (1877)).

p-Nitrobenzyl iodide, m. 127°, was obtained by Kumpf (*Ann.*, **224**, 99 (1884)) from the action of the chloride on potassium iodide in alcohol.

p-Nitrobenzyl cyanide, m. 117°, first obtained by Radziszewski (*Ber.*, **3**, 198 (1870)) by nitrating benzyl cyanide, has been frequently studied on account of the remarkable colored salts which it forms with alkalies.

p-Nitrobenzyl alcohol, m. 93°, was made by Grimaux (*Compt. rend.*, **65**, 211; *Z. Chem.*, **1867**, 562) from the aldehyde and alkali, and by Beilstein and Kuhlberg (*Ann.*, **147**, 340–4 (1868)) by saponification of the acetate. According to Dieffenbach (*D. R. P.*, 214,949 (1907)) it may be obtained by oxidation of *p*-nitrotoluene by lead peroxide and sulfuric acid.

p-Nitrobenzyl acetate, m. 78°, was obtained by Grimaux by nitrating benzyl acetate and by boiling the chloride, in alcohol, with potassium acetate. Beilstein and Kuhlberg also nitrated benzyl acetate and Wachendorf found that *p*-nitrobenzyl bromide reacts readily with sodium or silver acetate to give the acetate.

p-Nitrobenzyl oxalate was made by Beilstein and Kuhlberg by nitrating benzyl oxalate, but they do not give its melting point or any of its other properties.

p-Nitrobenzyl thiocyanate, *p*-$NO_2C_6H_4CH_2.CNS$, was prepared by Henry (*Ber.*, **2**, 638 (1869)) by nitrating benzyl thiocyanate and also by heating *p*-nitrobenzyl chloride with potassium thiocyanate in alcohol. He obtained it in small white needles by crystallization from alcohol but gives no melting point.

p-Nitrobenzyl nitrate, m. 71°, was made by Beilstein and Kuhlberg (*Ann.*, **147**, 341 (1868)) by the action of strong nitric acid on *p*-nitrobenzyl alcohol and by Staedel

(*Ann.*, **217**, 214 (1883)) by the same method and also from silver nitrate and *p*-nitrobenzyl chloride in alcohol.

p-Nitrobenzyl mercaptan, *p*-$NO_2C_6H_4CH_2.SH$, m. 140°, was prepared by Strakosch (*Ber.*, **5**, 698 (1872)) from *p*-nitrobenzyl chloride and alcoholic ammonium sulfide.

p-Nitrobenzyl sulfide, $(NO_2C_6H_4CH_2)_2S$, m. 159°, was obtained by O. Fischer (*Ber.*, **28**, 1338 (1895)) in repeating work of Strakosch.

p-Nitrobenzyl disulfide, $(NO_2C_6H_4CH_2)_2S_2$, m. 89°, was obtained by Strakosch by oxidation of the mercaptan.

p-Nitrobenzyl phthalate, $(NO_2C_6H_4CH_2.OCO)_2C_6H_4$, m. 154–5°, was made by Meyer and Jugilewitsch (*Ber.*, **30**, 782 (1897)) from *p*-nitrobenzyl iodide and silver phthalate.

p-Nitrobenzyl urethane, *p*-$NO_2C_6H_4CH_2.NHCO_2C_2H_5$, m. 118°, was prepared by Hantzsch (*Ber.*, **31**, 180 (1898)) from *p*-nitrobenzyl amine and ethyl chloroformate and also by nitrating benzyl urethane.

p-Nitrobenzyl ethyl nitrolate, *p*-$NO_2C_6H_4CH_2.ON{:}C(NO_2)CH_3$, m. 72–3°, was obtained by Graul and Hantzsch (*Ber.*, **31**, 2875 (1898)) from the silver salt of ethyl nitrolic acid, in ether suspension, and *p*-nitrobenzyl iodide.

p-Nitrobenzyl chloroformate, *p*-$NO_2C_6H_4CH_2.CO_2Cl$, m. 32°, the carbamate, *p*-$NO_2C_6H_4CH_2.CO_2NH_2$, m. 154°, and the nitrocarbamidate, *p*-$NO_2C_6H_4CH_2.CO_2NHNO_2$, m. 140°, and various salts and ethers of the last were made by Thiele and Dent (*Ann.*, **302**, 259–62 (1898)).

p-Nitrobenzyl succinate, $(NO_2C_6H_4CH_2.OCOCH_2.)_2$, m. 90°, was obtained by Meyer and Marx (*Ber.*, **41**, 2462–3 (1908)) by heating together *p*-nitrobenzyl iodide and silver succinate.

p-Nitrobenzyl sodium thiosulfate, *p*-$NO_2C_6H_4CH_2.NaSO_3S$, was made by Price and Twiss (*J. Chem. Soc.*, **93**, 1403 (1908)) by boiling *p*-nitrobenzyl chloride and sodium thiosulfate in 50% alcohol.

p-Nitrobenzyl sodium selenosulfate, *p*-$NO_2C_6H_4CH_2.NaSO_3Se$, was prepared in a similar way by Price and Jones (*J. Chem. Soc.*, **95**, 1732 (1909)).

p-Nitrobenzyl diselenide, (*p*-$NO_2C_6H_4CH_2.)Se_2$, m. 107.5°, was prepared by Price and Jones from the selenosulfate.

Experimental.

The Reagent.—Wachendorf prepared *p*-nitrobenzyl bromide by heating *p*-nitrotoluene with the calculated amount of bromine for some hours to 125–130° in a sealed tube. Several satisfactory preparations have been made by this method. In one case the temperature went to 175° for a short time and the product obtained was found extremely difficult to purify and most of it was lost in the process. The best plan, so far found, is to heat the *p*-nitrotoluene for an hour to 125–30° with half the calculated amount of bromine. The tube is then opened and the hydrobromic acid is allowed to escape. The other half of the bromine is put in and the tube again sealed and heated to the same temperature for several hours. The product is dissolved out of the tube with hot alcohol from which nearly all of it separates on cooling. The solid thus obtained, which should be nearly white, is dissolved in boiling 95% alcohol, 10 cc. alcohol to 1 g. of the solid. To the boiling solution is added half as much water as there is alcohol and the boiling solution filtered quickly through a hot filter. A very little powdered animal charcoal may be added before filtering. The *p*-nitrobenzyl bromide is deposited at once in fine, pure white needles m. 99.0°. The cold mother liquor contains a very small amount which may be precipitated by the addition of water. So far about half of the calculated amount has been obtained as the pure product. It is hoped that a more convenient method of preparation may be found. Several are being tried.

The vapors of the hot alcoholic solution of the bromide are irritating to the eyes and nose but the reagent itself when once purified is almost odorless and can be handled without discomfort.

Method of Work.

The formation of esters from salts by the action of alkyl halides is usually carried on in alcoholic solution, but the sodium and potassium salts of many acids are only slightly soluble in strong alcohol and do not react well in this medium. On the other hand, the organic halides are insoluble in water and cannot be used in water solution. Hence a mixture of alcohol and water has been used, and commonly a mixture of 1 volume of water to 2 volumes of 95% alcohol which is here designated as 63% alcohol. All the alcohol percentages given below are calculated from the volumes of alcohol and water measured out, the contraction on mixing being disregarded.

A boiling mixture of 5 cc. water and 10 cc. 95% alcohol dissolves 1.0 g. of *p*-nitrobenzyl bromide readily and, by rapid work, this solution may be filtered through a hot folded filter. It is very nearly saturated while hot and, on cooling, deposits practically all of the *p*-nitrobenzyl bromide in good crystals. On the other hand, there is enough water in this 63% alcohol so that it will dissolve 1 g. of the sodium or potassium salt of almost any organic acid, even at room temperature, and so that the sodium or potassium bromides formed during the reaction remain in solution even at 0° or below.

The required amount of the salt of the acid is put into a 100 cc. Erlenmeyer flask, with 5 cc. of water to dissolve it, and then 10 cc. of 95% alcohol and 1.0 g. of *p*-nitrobenzyl bromide are added.

In practically all of the preparation 1.0 g. of the *p*-nitrobenzyl bromide, which will be spoken of as the reagent, has been used. This has proved to be a convenient amount, not so large as to be expensive in the way of materials, and large enough to give amounts of products that can be readily worked with by ordinary methods.

The yields after several recrystallizations are usually sufficient for combustion analysis. It is believed that good results might, in many cases, be obtained with 0.1 g. and even less of the reagent, and correspondingly small quantities of the salts and solvents.

The reagent and salts were weighed on a balance sensitive to 0.01 g. and the alcohol and water were measured from pipets.

The reaction is carried on in a flask connected with a return condenser. The mixture is kept quietly boiling on a steam bath.

An excellent yield of *p*-nitrobenzyl acetate was obtained in 15 minutes boiling. Thirty minutes was first adopted as the time of heating and, later, this was extended to 1 hour for monobasic acids. In preparations from salts of dibasic acids, where excess of the salt is not used, it is considered to be better to boil for 2 hours or more.

With monobasic acids, an excess of the salt has been used so as to hasten the completion of the reaction and to make sure of using up all of the reagent. An excess of the salt is easily washed out of the product by dilute alcohol or water while an excess of the reagent is not so readily removed. In case of a rare acid the excess of salt used would be cut down.

If it is required to prepare an ester from a solution of an unknown acid, a portion of such a solution is neutralized by a standard solution of alcoholic caustic soda or potash and the amount of the reagent required is calculated from amount of alkali used. As the molecular weight of the reagent is 216, 21.6 mg. are equivalent to each 1.00 cc. of *N* alkali used in the making of the salt. The solution of the salt is evaporated to dryness, taken up in the appropriate amount of water and, to this solution, the appropriate amounts of alcohol and reagent are added. The salt must be left slightly acid, rather than alkaline, since a small amount of alkali, in presence of alcohol, would transform the *p*-nitrobenzyl esters into ethyl esters. A number of the salts used in the present work were made from the acid and sodium ethylate in absolute alcohol, since salts for another investigation were being thus prepared.[1]

Since a salt of a dibasic acid, *e. g.*, sodium tartrate, might react in two ways:

(1) $Na_2C_4H_4O_6 + NO_2C_6H_4CH_2Br \longrightarrow NO_2C_6H_4CH_2.NaC_4H_4O_6 + NaBr.$

(2) $Na_2C_4H_4O_6 + 2NO_2C_6H_4CH_2Br \longrightarrow (NO_2C_6H_4CH_2)_2C_4H_4O_6 + 2NaBr.$

The product in Reaction 1, being a sodium salt, would probably be soluble in water and unsuitable for the present purpose. Since Reaction 1 would be favored by the presence of excess of the salt, it is better, when working with salts of polybasic acids, to use exactly the calculated amount of salt and reagent, or a slight excess of the reagent.

On heating the mixture of salt, reagent, and solvent to boiling, a clear solution should be obtained. As the reaction takes place, there may be a separation of the *p*-nitrobenzyl ester even from the hot solution, in case it is particularly insoluble. If this takes place, more alcohol is added from time to time, in sufficient amount to keep the esters in solution. At the end of the reaction period the reaction mixture is cooled quickly, with vigorous shaking. In case the ester does not separate readily, the

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[1] For these I am indebted to Dr. H. H. Lloyd of this laboratory.

mixture is heated and small portions of water are added till separation of ester does take place on cooling. In some cases the ester separates as an emulsion and may become crystalline on cooling and shaking. Sometimes ice water or a freezing mixture may be used to advantage. Some esters seem to be really oils as all attempts to crystallize them have failed.

The crystals are filtered on a disc of filter paper on a 25 mm. Büchner funnel with suction. The crystals are washed twice with alcohol of the same strength as the mother liquor and then twice with water. The crystals left on the paper are called first crystallization-first crop, which is abbreviated as "1st 1st."

The filtrate is diluted with several volumes of water and again filtered. This gives a second crop of crystals which is designated as "1st 2nd." These crops of crystals are allowed to dry between layers of filter paper, weighed, and then melting points taken. The first crop is dissolved in hot dilute alcohol and brought to crystallization again. The crystals are filtered off as before and are designated as "2nd 1st" and the filtrate is diluted with water as before and the crystals so obtained filtered off and called "2nd 2nd."

Recrystallization is carried out till a constant melting point is obtained. As the object has been to obtain high purity rather than large yields, all the second crops, except as noted in several special cases, have been discarded. The process may be represented in diagram.

$$\begin{tikzcd}
\text{1st, 1st} \arrow[r] \arrow[dr] & \text{2nd, 1st} \arrow[r] \arrow[dr] & \text{3rd, 1st} \arrow[r] \arrow[dr] & \text{4th, 1st} \arrow[r] \arrow[dr] & \text{etc.} \\
\text{1st, 2nd} & \text{2nd, 2nd} & \text{3rd, 2nd} & \text{4th, 2nd} & {}
\end{tikzcd}$$

In some cases, as with the di-ester of oxalic acid, which is very slightly soluble even in hot, strong alcohol, purification was effected by extracting the product with several portions of 63% alcohol before recrystallization.

In each case, the amount and strength of the alcohol needed for dissolving a particular crop of crystals is estimated from the record of the conditions under which the crystals were obtained. If it is estimated that 15 cc. of the 63% alcohol will be required, the crystals are dissolved in 10 cc. of 95% alcohol and to the boiling solution, 5 cc. of water are added slowly. More alcohol, or more water, is added as may be required. The dissolving for recrystallization is carried on in a flask with return condenser just as in the original preparation.

For the melting points any method that gives reproducible and consistent results is sufficient, as the highest accuracy is not required. In this work a simple short-neck round-bottom flask, holding about 80 cc., was used with concentrated sulfuric acid as the liquid. The same thermometer was used in all the work and the melting points given are all comparable. No stem corrections have been applied since they would be less than 1°. Pure benzoic acid of which the m. p. is given as 121.25°, corrected, melted at 121.6° with this thermometer and apparatus. To eliminate various errors, it is better to melt specimens of successive crystallizations side by side.

The melting point tubes were prepared from thin-walled tubing so that they had very thin walls. They are 1 to 2 mm. inside diameter.

RESULTS.

p-Nitrobenzyl Esters of Monobasic Aliphatic Acids.

Formic Acid.—A mixture of 1 g. potassium formate, 1.0 g. reagent, and 15 cc. 63% alcohol was boiled 30 minutes. As no crystals formed on cooling, 5 cc. water were added which caused turbidity. At 0° crystals formed, 1st 1st 0.27 g. m. 31°, 1st 2nd 0.04 g. m. 30°. The 1st 1st was dissolved in 10 cc. hot 50% alcohol and yielded, in freezing mixture, 2nd 1st 0.19 g. m. 31°. The mother liquor remained clear on dilution with water. The formate is rather soluble in dilute alcohol.

Acetic Acid.—A mixture of 1 g. potassium acetate, 1 g. reagent and 15 cc. 63% alcohol was boiled 15 minutes. On slow cooling large flat needles separated, 2 to 3 mm. wide by 10 to 20 mm. long. The 1st 1st was 0.74 g. m. 78°, 1st 2nd 0.09 g. m. 61–6°, calculated yield 0.90 g. Wachendorf gives 78° as melting point.

Propionic Acid.—The sodium propionate was made from the acid and sodium ethylate in absolute alcohol. About a gram of the salt was present to 12 cc. of the mixture and much of the salt precipitated out. The addition of 5 cc. water made a clear solution to which was added 1.0 g. of the reagent. The mixture was boiled 1 hour. On cooling, the solution remained clear, but the addition of 5 cc. water caused the formation of an emulsion which formed crystals at 0°. 1st 1st 0.69 g. m. 30.5°, 1st 2nd 0.10 g. m. 30°. Recrystallized from 15 cc. 53% alcohol, it gave 2nd 1st 0.55 g. m. 31.0°. 2nd 2nd 0.05 g. m. 33°.

Butyric Acid.—A mixture of 1 g. sodium butyrate, 1.0 g. reagent and 15 cc. 63% alcohol was boiled 30 minutes. Crystals separated on cooling in a freezing mixture. 1st 1st m. 19°. This was dissolved in 15 cc. hot 63% alcohol and gave 2nd 1st m. 29–31°, 2nd 2nd pasty. Recrystallization from 10 cc. 63% alcohol gave 3rd 1st 0.18 g. m. 34°, 3rd 2nd 0.08 g. m. 32–3°. Recrystallization from 5 cc. 63% alcohol gave 4th 1st 0.09 g. m. 35° and 4th 2nd 0.01 g. m. 35°.

Esters of Polybasic Aliphatic Acids.

Oxalic Acid.—A mixture of 0.5 g. potassium oxalate, $K_2C_2O_4.H_2O$, 15 cc. 63% alcohol, and 1.0 g. reagent was boiled 30 minutes. Crystals separated immediately on cooling, 1st 1st m. 97°, 1st 2nd m. 95°. The main portion was boiled with 27 cc. 63% alcohol and the solution filtered. This gave crystals m. 97–8° which proved to be the unchanged reagent.

The small amount of white powder which did not dissolve melted at 202°. This was boiled with 60 cc. 85% alcohol and the solution poured off. It gave, on cooling, 0.01 g. crystals m. 204°. The residue was boiled with 60 cc. 95% alcohol and this gave 0.01 g. crystals m. 204°. The mother liquor gave, on dilution with water, only a trace of precipitate. This ester is remarkable for its slight solubility in strong boiling alcohol. Apparently about 6000 cc. of boiling 95% alcohol would be required for the solution of 1 g. of the ester. This should make possible the isolation of traces of oxalic acid in the presence of large amounts of formic, acetic, butyric, and other organic acids.

Malonic Acid.—A mixture of 0.6 g. potassium malonate, $K_2C_3H_2O_4.2H_2O$, 15 cc. 63% alcohol, and 1.0 g. reagent was boiled 30 minutes. An oil separated after 15 minutes heating. On cooling, crystals formed. 1st 1st 0.47 g. m. 72°, 1st 2nd 0.04 g. m. 92°. The 1st 1st was boiled with 40 cc. 63% alcohol but it did not dissolve till 40 cc. 95% alcohol had been added. This solution gave, on cooling, fine granular crystals, 2nd 1st 0.30 g. m. 85°, 2nd 2nd 0.03 g. m. 60–5°. Recrystallized from 70 cc. 65% alcohol, 3rd 1st 0.27 g. m. 85.5°. This ester is far more soluble than the oxalate but is still only slightly soluble, even in boiling alcohol.

Tartaric Acid.—A mixture of 0.5 g. potassium tartrate, $K_2C_4H_4O_6.{}^1/_2H_2O$, 15 cc. 63% alcohol, and 1.0 g. reagent was boiled 30 minutes. Fine crystals separated during the boiling. 1st 1st 0.67 g. m. 133–6°, 1st 2nd 0.06 g. m. 96°. The first crop was recrystallized from 30 cc. 79% alcohol and gave 2nd 1st m. 146° and 2nd 2nd 0.11 g. m. 97°. Recrystallization from 35 cc. 81% alcohol gave 3rd 1st 0.21 g. m. 164° and 3rd 2nd 0.09 g. m. 97°. The second crop was mixed with an equal amount of the reagent and the mixture melted at 99° showing that this and, probably, the previous second crops are the unchanged reagent. The 3rd 1st was recrystallized from 20 cc. 79% alcohol and gave 4th 1st 0.19 g. m. 163° and only a trace of 4th 2nd. The m. p. 163° is taken as the correct value.

The yield of the ditartrate was small but the experiment shows that it can be separated from a considerable amount of the unchanged reagent.

Citric Acid.—A mixture of 0.6 g. potassium citrate, $K_3C_6H_5O_7.H_2O$, 15 cc. 63% alcohol, and 1.0 g. reagent was boiled for 30 minutes. An oil separated out during the boiling. The 1st 1st was 0.45 g. m. 98° and 1st 2nd 0.07 g. m. 94°. The m. p. 98° is suspiciously near to 99°, the m. p. of the reagents, and accordingly a mixed melting point was made of the two which was 85–6°, showing that the two were not the same. The 1st 1st was boiled with 45 cc. 63% alcohol and only a part of it dissolved. The solution was poured off and gave 2nd 1st m. 101°. The mother liquor was boiled again with the undissolved ester and gave another portion m. 102°. This seems to be the desired citrate. Apparently it requires some 300 parts of boiling 63% alcohol to dissolve it.

Esters of Aromatic Acids.

Benzoic Acid.—A mixture of 1.5 g. potassium benzoate, $C_6H_5CO_2K.3H_2O$, 15 cc. 63% alcohol, and 1.0 g. reagent was boiled 30 minutes. The ester began to separate out in 10 minutes and 10 cc. more of the same strength alcohol were added when all went into solution. The 1st 1st was 1.12 g. m. 89° and 1st 2nd 0.03 g. m. 67–75°, calculated yield 1.19 g. Recrystallization from 25 cc. 63% alcohol gave 2nd 1st m. 89° and 2nd 2nd m. 88°.

o-**Toluic Acid.**—The salt was made from 1 g. of the acid and concentrated sodium ethylate in absolute alcohol. The solution was clear. To it was added 5 cc. water and 1 g. reagent and the mixture boiled for 35 minutes. The 1st 1st was 1.19 g. m. 90.7° and 1st 2nd 0.03 g. m. 89°. Calculated 1.25 g. Recrystallization from 25 cc. boiling 76% alcohol gave 2nd 1st 1.12 g. m. 90.7° and 2nd 2nd 0.03 g. m. 90°.

o-**Nitrobenzoic Acid.**—The salt was made by neutralizing 1 g. of the acid by a concentrated solution of sodium ethylate in absolute alcohol, which gave a clear solution. 5 g. water and 1.0 g. reagent were added to this and the mixture boiled for 1 hour. In 10 minutes oil began to separate and 10 cc. 95% alcohol were added. The 1st 1st was 1.17 g. m. 111.2° and 1st 2nd 0.04 g. m. 96–8°, calculated yield 1.39 g. Recrystallization from 32 cc. 73% alcohol gave 2nd 1st 1.14 g. m. 111.8° and 2nd 2nd 0.02 g. m. 109°.

o-**Chlorobenzoic Acid.**—The sodium salt was made by neutralizing 1 g. of the acid by concentrated sodium ethylate in absolute alcohol. To this solution were added 5 cc. water and 1.0 g. reagent and the mixture boiled 1 hour. In 10 minutes oil began to separate out and 10 cc. 95% alcohol were added. The 1st 1st was 1.24 g. m. 106° and 1st 2nd 0.06 g. m. 100°, calculated 1.35 g. Recrystallization from 27.5 cc. 77% alcohol gave 2nd 1st 1.20 g. m. 106° and 2nd 2nd 0.04 g. m. 101°.

o-**Aminobenzoic Acid.**—The sodium salt was made from 1 g. of the acid and sodium ethylate in absolute alcohol. Much of the salt separated out but the addition of 5 cc. water gave a clear solution. To this 1.0 g. reagent was added and the mixture boiled for 1 hour. As the solution remained clear on cooling, 5 cc. water were added which caused the separation of the ester. The 1st 1st was 0.93 g. m. 202–5° and 1st 2nd 0.34 g. m. 202°. Recrystallization from 35 cc. 78% alcohol gave 0.78 g. m. 205–10° with evolution of gas, and 2nd 2nd 0.08 g. m. 194–8°. This ester is by no means as satisfactory as others since it melts at so high a temperature and with decomposition. It is much more soluble in cold dilute alcohol than esters of other aromatic acids.

p-Bromobenzoic Acid.—The sodium salt was made from 1 g. of the acid and sodium ethylate. To this were added 5 cc. water and 1.0 g. reagent and the mixture boiled 1 hour. Crystals began to separate during the heating and 40 cc. 95% alcohol were added to keep them in solution. On cooling, the solution was a solid mass of felted needles, long and very slender. The 1st 1st was 1.31 g. m. 140.5° and 1st 2nd 0.12 g. m. 140.5°, calculated yield 1.55 g. Recrystallization from 60 cc. 95% alcohol gave 2nd 1st 1.23 g. m. 139.5° and 2nd 2nd 0.07 g. m. 137°.

2,4-Dinitrobenzoic Acid.—The sodium salt was made from 1 g. of the acid and concentrated sodium ethylate, in absolute alcohol, and much of the salt separated out, but dissolved to a clear solution on the addition of 5 cc. water. To this was added 1.0 g. reagent and the mixture boiled 1 hour. Oil soon separated and 55 cc. 95% alcohol were added but this did not dissolve all of the ester. The hot solution was poured off and the residue treated with 50 cc. 95% alcohol. The 1st 1st was 1.21 g. m. 141.7°, 150 cc. boiling 95% alcohol gave 2nd 1st 1.07 g. m. 142° and 2nd 2nd and 1st 2nd 0.05 g. m. 89°, calculated, 1.61 g. Recrystallization from 150 cc. boiling 95% alcohol gave 2nd 1st 1.07 g. m. 142° and 2nd 2nd 0.08 g. m. 141°. This ester is remarkable for its extremely slight solubility even in hot, strong alcohol.

Phenylpropiolic Acid.—A mixture of 0.8 g. potassium propiolate, 15 cc. 63% alcohol, and 1.0 g. reagent was boiled 45 minutes. Oil began to separate in 10 minutes and 15 cc. 63% alcohol were added. The 1st 1st was 0.89 g. m. 75°, 2nd 2nd 0.13 g. m. 70–80°, calculated 1.30 g. Recrystallization from 40 cc. 79% alcohol gave 2nd 1st 0.69 g. m. 77° and 2nd 2nd 0.11 g. m. 62°. Recrystallization from 30 cc. 79% alcohol gave 3rd 1st 0.61 g. m. 84° and 3rd 2nd 0.04 g. m. 83°. Recrystallization from 40 cc. 71% alcohol gave 4th 1st 0.55 g. m. 83° and 4th 2nd 0.02 g. m. 83°.

p-Nitrobenzyl Esters which are Liquids.

Esters were made in the usual way from salts of isobutyric, isovaleric, caprylic, lactic, and α-hydroxybutyric acids. In each case the ester seemed to form but the products were all oils which could not be induced to solidify.

p-Nitrobenzyl Esters of Inorganic Acids.

A mixture of 1 g. potassium iodide, 15 cc. 63% alcohol, and 1.0 g. reagent was boiled 40 minutes. The iodide began separating in a very short time and 15 cc. more of the same alcohol were added. The 1st 1st was 0.98 g. m. 125.3°. The 1st 2nd was not saved. Recrystallization from 27 cc. 63% alcohol gave 2nd 1st m. 127°. This compound was made by Kumpf,[1] who heated equivalent amounts of p-nitrobenzyl chloride and potassium iodide in strong alcohol. He mentions the separation of

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[1] *Ann.*, **224**, 99–100 (1884).

iodine during the reactions. He got the iodide to melt at 127° after repeated recrystallization from alcohol.

Thiocyanic Acid.—A mixture of 1 g. potassium thiocyanate, KCNS, 15 cc. 63% alcohol, and 1.0 g. reagent was boiled 30 minutes. On cooling, the mixture was only turbid and 5 cc. water were added, which caused the separation of crystals. The 1st 1st was 0.75 g. m. 84°, 1st 2nd 0.04 g. m. 85°, calculated 0.90 g. Recrystallization gave 2nd 1st 0.69 g. m. 85°, 2nd 2nd no appreciable amount. Recrystallization from 10 cc. 50% alcohol gave 3rd 1st 0.65 g, m. 85°. The di-*p*-nitrobenzyl malonate, described above, melts also at 85°. A mixed melting point was made with equal amounts of the two esters. The mixture melted at 62°.

This ester was made by Henry[1] by nitrating benzyl thiocyanate and[2] also from *p*-nitrobenzyl chloride and potassium thiocyanate in alcohol. He recrystallized it from alcohol and obtained small needles but did not determine the melting point.

Cyanic Acid.—A mixture of 1 g. potassium cyanate, 15 cc. 63% alcohol, and 1 g. reagent was boiled 30 minutes. Crystals separated from the hot solution. The 1st 1st was 0.20 g. m. 185–95° and 1st 2nd 0.29 g. m. 160–5°. The first crop was recrystallized from 40 cc. 79% alcohol and gave 2nd 1st, which melted at 160–70°. The melting points were not sharp and the preparation was abandoned.

Nitrous Acid.—The usual mixture containing 1 g. potassium nitrite was boiled 30 minutes. Crystals separated from the hot solution. The 1st 1st was 0.09 g. m. about 265°. As the amount was small and the m. p. inconveniently high, the preparation was abandoned.

Hydrocyanic Acid.—An attempt was made to prepare a compound from this in the usual way but there seemed to be reduction of the nitro group and a brown nondescript product was obtained. The cyanide is well known and has been prepared in several different ways.

The reagent was boiled with potassium chloride and nitrate in the usual mixtures and products obtained melting at 76° and 85–90°, respectively. It is evident that reactions had taken place in both cases but that they were incomplete. Since potassium chloride and nitrate are as stable as the bromide there is no driving force to carry the reaction to completion and we probably have balanced reactions. It is easy to prepare pure *p*-nitrobenzyl iodide from the bromide and potassium iodide, but a number of trials have shown that it is difficult to prepare *p*-nitrobenzyl bromide from the chloride and potassium bromide.

The results are brought together in tabular form, the first and second columns giving the weights of the first and second crops of crystals, the fourth and fifth the first and last melting points and the last two, the

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[1] *Ber.*, 2, 638 (1869).

approximate number of cubic centimeters of hot and cold alcohol, of the strength given in the seventh column, required to dissolve 1 g. ester.

TABLE I.

Yields, Melting Points, and Approximate Solubilities of Esters.

	1st 1st. G.	1st 2nd. G.	Total. G.	Calc. G.	First.	Final.	Alcohol. %.	Hot. Cc.	Cold. Cc.
Formate	0.27	0.04	0.31	0.84	31°	31°	50	40	125
Acetate	0.74	0.09	0.83	0.90	78°	..	63	..	170
Propionate	0.69	0.10	0.79	0.97	30.5°	31°	53	21	200
Butyrate	..	..	..	1.03	19°	35°	63	25	100
Benzoate	1.12	0.03	1.15	1.19	89°	89°	63	22	800
o-Toluate	1.19	0.03	1.22	1.25	90.7°	90.7°	76	22	800
o-Nitrobenzoate	1.17	0.04	1.21	1.39	111.2°	111.8°	73	28	1600
o-Chlorbenzoate	1.24	0.06	1.30	1.35	106°	106°	78	22	690
o-Aminobenzoate	0.93	0.34	1.27	1.26	202°	205°	77	37	470
p-Brombenzoate	1.31	0.12	1.43	1.55	140.5°	139.5°	95	57	860
2,4-Dinitrobenzoate	1.21	0.05	1.26	1.61	141.7°	142.0°	95	124	1870
Phenylpropiolate	0.89	0.13	1.02	1.30	75°	83°	79	44	400
Thiocyanate	0.75	0.04	0.79	0.90	84°	85°	50	13	500
Iodide	0.98[1]	..	..	1.21	123.5°	127°	63	27	..
Oxalate	0.32	0.05	0.37	0.84	97°	204°	95	6000	..
Malonate	0.47	0.04	0.51	0.87	72°	85.5°	79	170	2600
Tartrate	0.67	0.06	0.73	0.98	133°	163°	79	100	..
Citrate	0.45	0.07	0.52	0.82	98°	102°	70	250	..

Discussion of Results.

With benzoic acid and its substitution products the yields of esters are practically quantitative, and even the crude reaction product melts within 1° of the final melting point without recrystallization. The lower aliphatic monobasic acids, except acetic, give rather low melting esters but the yields are good. The yields of esters of polybasic acids leave much to be desired. The reaction does not seem to go to completion so readily and the product frequently contains much of the unchanged reagent. The esters of such acids are remarkable for their slight solubility in even strong boiling alcohol. This property makes them easy to isolate and might make possible the separation and identification of these acids from mixtures with other acids.

Since a number of the aliphatic acids give esters that melt too low, other reagents are being sought that will give higher melting esters.

It is intended to apply the information gained to the detection of some of these acids in mixtures, but it is thought best to study the properties of a considerable number of the pure esters before attempting to separate them from mixtures. The work is being actively continued.

Summary.

It has been found that *p*-nitrobenzyl bromide may serve as a convenient reagent for the identification of acids. It readily forms esters

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[1] Part lost.

of acids when boiled, in dilute alcohol solution, with the alkali salts of the acids. Many of these esters are readily purified by recrystallization from more or less dilute alcohol and have convenient melting points.

The following esters have been thus prepared:

p-Nitrobenzyl formate, $HCO_2.CH_2C_6H_4NO_2$, m. 31°;
Acetate, $CH_3CO_2.CH_2C_6H_4NO_2$, m. 78°;
Propionate, $C_2H_5CO_2.CH_2C_6H_4NO_2$, m. 31°;
Butyrate, $C_3H_7CO_2.CH_2C_6H_4NO_2$, m. 35°;
Benzoate, $C_6H_5CO_2.CH_2C_6H_4NO_2$, m. 89°;
o-Toluate, *o*-$CH_3C_6H_4CO_2.CH_2C_6H_4NO_2$, m. 90.7°;
o-Nitrobenzoate, *o*-$NO_2C_6H_4CO_2.-CH_2C_6H_4NO_2$, m. 111.8°;
o-Chlorobenzoate, *o*-$ClC_6H_4CO_2.CH_2C_6H_4NO_2$,m. 106°;
Anthranilate, *o*-$NH_2C_6H_4CO_2.CH_2C_6H_4NO_2$, m. 205°;
p-Bromobenzoate, *p*-$BrC_6H_4CO_2.CH_2C_6H_4NO_2$, m. 139.5°;
2,4-Dinitrobenzoate, 2,4-$(NO_2)_2C_6H_3CO_2.CH_2C_6H_4NO_2$, m. 142.0°;
Phenylpropiolate, $C_6H_5C \vdots CCO_2.CH_2C_6H_4NO_2$, m. 83°;
Thiocyanate, $CNS.CH_2C_6H_4NO_2$, m. 85°;
Oxalate $(.CO_2.CH_2C_6H_4NO_2)_2$, m. 204°;
Malonate, $CH_2(CO_2.CH_2C_6H_4NO_2)_2$, m. 85.5°;
Tartrate, $(.HOCHCO_2.CH_2C_6H_4NO_2)_2$, m. 163°;
Citrate, $C_3H_5O\text{-}(CO_2.CH_2C_6H_4NO_2)_3$, m. 102°.

BALTIMORE, MD.

[CONTRIBUTION FROM THE LABORATORY OF FOOD CONTROL, BUREAU OF CHEMISTRY, DEPARTMENT OF AGRICULTURE.]

THE IDENTIFICATION AND ESTIMATION OF LACTIC ACID IN BIOLOGICAL PRODUCTS. FIRST PAPER.[1]

BY I. K. PHELPS AND H. E. PALMER.

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It is very obvious that there is need for a method by which the identification of lactic acid and its estimation quantitatively can be accomplished. The fact that no salts of lactic acid insoluble in water have been discovered is, perhaps, the chief cause of the absence of such a method. This paper records some of the results obtained in the search for such a method, studying, in particular, the solubility of various salts and derivatives of lactic acid in organic solvents for the purpose of determining lactic acid in biological products whether natural or fermented.

Irvine[2] resolved racemic lactic acid into its optically active components by means of the difference in solubility of their morphine salts in

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[1] Read at the 20th annual meeting of the Association of American Dairy, Food and Drug Officials, Detroit, Michigan, August 5–11, 1916. Published by permission of the Secretary of Agriculture.

[2] Irvine, *J. Chem. Soc.*, **89**, 935 (1906).