

data now available indicate, of two straight lines which intersect at a concentration in the neighborhood of 0.1 equivalent. From this point of intersection upward the curves for these salts are in all respects like those for the alkali metal formates.¹ It is therefore clear that two sets of values can be found for the terms λ_0 and K in the equation given on a previous page. The values calculated for the tables are those referring to the points on the middle portion of each of the curves.

We are as yet unable to give a satisfactory explanation of the behavior of these alkaline earth formates. It is quite likely that these salts ionize into a metal formate ion which in the more dilute solutions is somewhat decomposed into the simple metal ion and that this second ionization becomes sufficiently great at the concentration where the two lines intersect to effect the conductivity appreciably. It is not clear why, if this interpretation is correct, there should be a sharp break at this point. It was our intention to investigate these questions further by studies on the solubilities of these formates in the presence of salts with common ions and also to make possible the measurement of the conductivities at still lower concentrations by reducing the conductivity of the solvent by new means which have been partially worked out, but this intention was frustrated by the necessity of taking up work of more immediate importance in connection with the war. While this work is therefore in a sense incomplete it was thought desirable to publish it in its present form because reference has to be made in the data here presented in the next two papers of this series which are to be published soon.

CHICAGO, ILLINOIS.

[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF THE ARKANSAS AGRICULTURAL EXPERIMENT STATION AND OF THE JOHNS HOPKINS UNIVERSITY.]

THE IDENTIFICATION OF ACIDS. IV. PHENACYL ESTERS.

By J. B. RATHER² AND E. EMMET REID.

Received August 9, 1918.

In several recent papers³ *p*-nitrobenzyl esters of a large number of acids have been described, and it has been shown that such esters are readily formed and that many of them are useful for identification purposes; but some of the esters melted too low, some too high, and others had undesirable properties. The presence of the nitro group leads to

¹ In the reproduction of the curve for sodium formate, the upper portion which deviates from the straight line is not shown.

² The experimental work described in this paper, except that relating to the preparation of the reagent and that with phenacyl chloride was carried out in the laboratory of the Department of Agricultural Chemistry of the Arkansas Agr. Exp. Station. Thanks are due to Prof. J. Sam Guy of the University of Arkansas for some of the acids used.

³ THIS JOURNAL, 39, 124, 304, 701, 1727 (1917).

side reactions with salts of strongly reducing acids. Besides, it is convenient to have several series of derivatives since one may be of use in a particular case in which the other is not available and, in important cases, more than one derivative is desirable. In the identification of acids in mixtures all possible help is needed.

A study of the known derivatives of phenacyl alcohol, $C_6H_5COCH_2OH$, suggested that its esters might be of use for identification purposes. Experiment has justified this hope. Phenacyl bromide resembles *p*-nitrobenzyl bromide in reacting readily with the sodium salts of organic acids.



Phenacyl bromide has the advantage of being easily prepared, though the work of Brewster¹ has made *p*-nitrobenzyl bromide so readily available that there is now not much choice. Phenacyl chloride has been tried with several acids but reacts much slower and gives lower yields though the same esters are obtained.

The presence of the ketone group in the ester gave promise that phenylhydrazones, oximes, semicarbazones, etc., might be prepared, and further means of identification afforded. Experiment has shown that the phenylhydrazones are not readily formed and that the oximes, though they can be prepared, are difficult to purify and low melting so that they are not of use for identification purposes. The semicarbazones have not yet been studied.

In the present work special attention has been given to acids that occur in neutral products.

Historical.

Though phenacyl alcohol has long been known, having been prepared by Graebe,² Zincke,³ Hunnius,⁴ and others, and though a number of its ethers have been made, the acetate, benzoate, thiocyanate, and cyanide are the only esters that have been described.

Phenacyl acetate was first made by Graebe from the chloride and potassium acetate, and later prepared from the alcohol and acetic anhydride by Hunaeus and Zincke,⁵ who could not get it pure from phenacyl chloride and potassium acetate. They give 49° as the melting point. Hunnius⁶ used phenacyl bromide with potassium acetate in alcohol solution, and gives the melting point as 40°. Evans⁷ heated the bromide with sodium acetate in glacial acetic acid.

¹ THIS JOURNAL, 40, 406 (1918).

² Ber., 4, 35 (1871).

³ Ann., 216, 307 (1883).

⁴ Ber., 10, 2010 (1877).

⁵ Ibid., 10, 1488 (1877).

⁶ Ibid., 10, 2009 (1877).

⁷ Am. Chem. J., 35, 120 (1906).

Phenacyl benzoate, m. p. 117° , was obtained by Hunaeus and Zincke from benzoic anhydride and the alcohol. Hunnius prepared the same ester from the bromide and silver benzoate in toluene.

Phenacyl thiocyanate, m. p. 74° , was made by Dyckerhoff¹ from the chloride and potassium thiocyanate in alcohol solution. Arapides² substituted the bromide and barium thiocyanate. Phenacyl cyanide, m. p. $80-1^{\circ}$, was prepared by Obrégia³ from the bromide and potassium cyanide. Phenacyl bromide, m. p. 50° , was first prepared by Emerling and Engler⁴ from acetophenone and bromine without solvent. Hunnius⁵ used carbon disulfide as a solvent. Staedel and Kleinschmidt⁶ improved the method of Hunnius by passing a current of carbon dioxide through the reaction mixture to eliminate the hydrobromic acid. Möhlau⁷ added 133.5 g. bromine to 100 g. acetophenone in 500 g. glacial acetic acid at room temperature, finally warming on steam bath till the liquid became clear, pouring into water and pressing out the crystals. He reported 80% of the theoretical yield. This is the method that has been in general use since that time. Collet⁸ prepared it from bromoacetyl chloride and benzene by the Friedel and Crafts reaction but does not state the yield.

Experimental.

The Reagent.—The method of preparation of the phenacyl bromide, or ω -bromoacetophenone, used in this work, was a modification of that given by Möhlau, the chief difference being in the use of less solvent.

To 20 g. acetophenone, dissolved in 30 g. glacial acetic acid, 28 g. bromine is added slowly and with constant shaking. If, toward the end of the preparation, the hydrobromic acid is not given off readily, the reaction flask is put in hot water for a few minutes. The color of the solution lightens to a straw-yellow. After all the bromine has been added and the whole has begun to cool (heat is developed in the bromination) pour into ice water, let stand an hour, then filter with suction. The yield is 25-30 g. of phenacyl bromide, $C_6H_5COCH_2Br$. These crystals are light yellow in color and when recrystallized from hot alcohol are almost white. A high degree of purity is not essential for satisfactory results. Phenacyl bromide melts at 50° .

Method of Work.—The method of preparation of the phenacyl esters was in general similar to that used by Reid (*loc. cit.*) in the preparation of

¹ *Ber.*, 10, 119 (1877).

² *Ann.*, 249, 10 (1888).

³ *Ibid.*, 266, 326 (1891).

⁴ *Ber.*, 4, 148 (1871).

⁵ *Ibid.*, 10, 2007 (1877).

⁶ *Ibid.*, 13, 837 (1880).

⁷ *Ibid.*, 15, 2464 (1882).

⁸ *Bull. soc. chim.*, [3] 17, 68 (1897).

the *p*-nitrobenzyl esters of acids. As used in the present work it was as follows:

One gram (approximately $\frac{1}{200}$ gram molecular weight) of the phenacyl bromide, designated in this paper as the "reagent," slightly more than the equivalent amount of the acid, and slightly less than the amount of sodium carbonate necessary to neutralize the acid, and 15 cc. of 63% alcohol, were boiled in a 75 cc. Erlenmeyer flask under a reflux condenser, on a water bath. To prepare this mixture the acid and the carbonate were heated with 5 cc. water until solution took place, the reagent was added, and then 10 cc. of 95% alcohol. Where the sodium salts of the acids were at hand they were used instead of the mixture of acid and sodium carbonate. The heating was continued for one hour with monobasic acids, two hours with dibasic acids, and three hours with tribasic acids. Frequently the amount of alcohol was insufficient to keep the ester from precipitating. In these cases 95% alcohol was added until solution took place. In the case of polybasic acids the reagent was always present in slight excess. After boiling, the solution was cooled rapidly under the tap with constant shaking. The crystals were filtered on a Hirsch funnel using a 9 cm. filter folded to fit, with the aid of a rubber stopper, water, and suction. The funnel was 25 mm. in diameter at the plate, and the removal of the filter paper removed the crystals without loss. The crystals were washed with two portions of alcohol of the same strength as the alcohol in the reaction flask, 5 cc. being used each time, and then twice with water. The filtrate and washings were diluted with water and a second crop of crystals filtered off.

The preparations with phenacyl chloride were made in exactly the same way except that 0.77 g. of the reagent was used and the heating was continued for two or more hours.

The reagent, acids and salts were weighed to 0.01 g. and the alcohol and water measured from pipets.

Recrystallization was carried out until constant melting points were obtained. All the second crops, except where otherwise noted, were discarded after their weight and melting points had been determined, the object being high purity rather than large yields. In each case, the amount and strength of alcohol needed for dissolving a particular crop of crystals were estimated from the record of the conditions under which the crystals were obtained. Where dilute alcohol was used in the recrystallization, the product was dissolved in 95% alcohol and the required amount of water added to the boiling solution.

The melting points were determined in a round bottom flask with conc. sulfuric acid as the liquid. The same thermometer was used throughout the work with the bromide and no stem corrections were applied. The melting-point tubes were prepared from small test-tubes and had

very thin walls. They were 1 to 2 mm. inside diameter. In order to eliminate various errors, specimens of successive crystallizations were melted side by side.

Results.

The results are given in tabular form, the first line representing the original preparation and the succeeding lines the recrystallizations of the product. In the preparation of the esters, 15 cc. of 63% alcohol was always used at the start but 95% alcohol was frequently added during the reaction to keep the product in solution and sometimes water was added at the end to cause it to separate out. Under "solvent" are given the volume and strength of the alcohol from which the crystals were obtained.

TABLE I.—RESULTS.

Acid.	Solvent.		First crop.		Second crop.		Yield. %.	Cc. solvent to dissolve 1 g.	
	Vol. Cc.	%.	Wt.	M. p.	Wt.	M. p.		Hot.	Cold.
Acetic.....	15	63	0.66	37°	0	..	73	12	..
	7.5	37	0.46	40°	0	..			
	7.5	37	0.23	40.0°	0	..			
Lactic.....	25	37	0.70	89°	0	..	70	21	..
	15	37	0.38	91°	0	..			
	20	72	0.17	95-6°	0	..			
	10	21	0.07	96°	0	..			
Palmitic..... 0.5 g. reagent	25	76	0.83	53-4°	0.05	75-8°	100	21	1750
	17.5	81	0.76	52.5°	0.01	50°			
	15	95	0.70	52.5°	0.01	52°			

The ester was washed with warm water to free it from soap. Another preparation gave an ester, m. 52.0°.

Stearic.....	30	79	0.87	63-4°	0.05	60-5°	92	16	700
0.5 g. reagent	14	82	0.82	64.0°	0.02	64.0°			

Another preparation melted at 64.5°.

Esters of Dibasic Aliphatic Acids.

Succinic.....	40	83	0.69	147.5-8.5°	0.02	141°	87	51	3300
	35	95	0.66	148°	0.01	147.5°			

Another preparation melted at 147.5°.

Glutaric.....	15	63	0.83	102-5°	0.01	102.5°	91	18	..
	15	63	0.81	104.5°	Trace	..			
	15	63	0.76	104.5°	0	..			
Pyrotartaric...	15	63	0.78	101°	0.02	100°	90	18	1300
	15	63	0.72	101.5°	0.01	101°			
Malic.....	15	63	0.65	97°	0.05	104-6°	80	23	167
	15	63	0.39	106°	0.09	106°			
Tartaric.....	15	63	0.51	128-30°	0.11	130°	65	30	167
	15	63	0.39	130°	0.09	130°			

Another preparation melted at 130°.

Saccharic.....	20	47	0.10	114-5°	0.03	..	9	100	..
	10	47	0.09	120°	Trace	120°			

TABLE I—(continued).

Acid.	Solvent.		First crop.		Second crop.		Yield. %.	Solubilities in alcohol.	
	Vol. Cc.	%.	Wt.	M. p.	Wt.	M. p.		Hot.	Cold.
Maleic.....	15	63	0.42	105-14°	0.04	..	51	35	500
	15	63	0.32	119°	0.03	123°			
	15	63	0.24	119°	0.02	127°			

These seemed to be progressive decomposition.

Fumaric.....	15	63	0.60	197.5°	0.01	190°	74	1200	..
	60	95	0.05	197.5°	—	..			

This ester is extremely insoluble in even hot 95% alcohol. A part of the ester was lost by spurting out during its preparation. Only 0.5 g. was taken for recrystallization. Another preparation melted at 197°.

Esters of Tribasic Aliphatic Acids.

Citraconic....	20	47	0.35	100°	Trace	..	39	28	..
	10	47	0.22	108.5°	Trace	..			
	13	40	0.19	108.5°	Trace	..			
Itaconic.....	15	63	0.75	78°	0.03	77°	87	20	500
	15	63	0.64	79.5°	0.03	79.5°			
Citric.....	15	63	0.68	0.10	85-7°	78	14	250
	10	95	0.40	104°	0.04	103°			
	5	95	0.35	104°	Trace	104°			

Rapid cooling causes the ester to separate as a gum but with very slow cooling it is obtained as white granules.

Aconitic.....	20	73	gum	gum	..	57	10	..
	5	95	0.50	90-1°	Trace	..			
	5	95	..	90°	Trace	..			

This ester is yellow, the only colored one so far found. It is difficult to prepare as it separates as a gum which becomes crystalline only after long standing.

Esters of Aromatic Acids.

For the acids that follow only 0.8 g. reagent was used.

Benzoic.....	20	73	0.88	119°	0.05	114°	97	17	1500
	15	63	0.80	118.5°	0.01	117°			

Two preparations from phenacyl chloride melted at 119°.

Salicylic.....	20	73	0.81	109.5°	0.03	45°	80	19	1500
	15	63	0.73	110°	0.01	110°			
<i>o</i> -Cresotic....	40	83	0.84	138.5-9°	0.03	138°	84	26	1100
	22	86	0.78	138.5°	0.02	138.5°			
<i>m</i> -Cresotic....	15	63	0.90	115°	0.01	102°	88	17	1500
	15	63	0.86	116.5°	0.01	110°			
	15	63	0.80	116.5°	0.01	112°			
<i>p</i> -Cresotic....	45	83	0.93	145°	0.05	135°	95	32	600
	30	45	0.82	145.5°	0.05	144°			
Mandelic.....	20	47	0.80	84-5°	0.06	83-4°	83	12	..
	10	47	0.78	84.5°			
<i>o</i> -Amino- benzoic....	90	90	0.13	177-8°	0.73	153-4°	13	385	..

TABLE I—(continued).

Acid.	Solvent.		First crop.		Second crop.		Yield. %.	Solubilities in alcohol.		
	Vol. Cc.	%.	Wt.	M. p.	Wt.	M. p.		Hot.	Cold.	
	50	95	0.09	181-2°	0	..				
	40	95	0.08	181-2°				
The large 1st 2nd was acid to phenolphthalein and must have been largely the free acid.										
Cinnamic....	35	81	0.97	140.5°	0.02	138°	88	23	2300	
	23	82	0.92	140.5°	0.01	140.5°				
A preparation from phenacyl chloride melted at 142° with different thermometer.										
<i>p</i> -Bromo-										
benzoic....	80	72	1.12	88°	0.28	>150°	70	17	85	
From chloride	18	79	0.89	87°	0.20	85°				
<i>p</i> -Nitro-										
benzoic....	45	84	0.94	129°	0.04	128°	69	21	500	
From chloride	20	95	0.86	128.4°	0.04	128°				

Acids from which Crystalline Esters were Not Obtained.

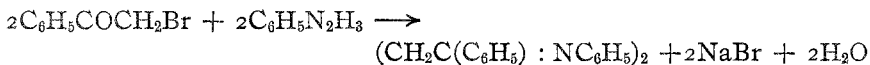
Formic, butyric, valeric and oleic acids gave oily products which could not be induced to crystallize. All attempts to prepare the ester of oxalic acid failed, though the sodium, potassium, and ammonium salts were tried. Asparaginic and gallic acids gave unsatisfactory gums. Naphthionic acid was tried without success. Reid could not obtain *p*-nitrobenzyl esters of sulfonic acids.

Derivatives of Phenacyl Esters.

Since the phenacyl esters, $C_6H_5COCH_2CO_2R$, contain the ketone group it was hoped that phenylhydrazones, oximes and semi-carbazones could be prepared and that some of these might be crystalline solids even when the esters from which they were derived are liquids. These derivatives would thus supplement the phenacyl esters in the identification of acids, provided they could be readily prepared and purified.

Phenylhydrazones.—The preparation was attempted from (1) ester and phenylhydrazine in alcohol with heat, (2) ester and phenylhydrazine in glacial acetic acid, with and without heat, (3) ester and phenylhydrazine acetate in alcohol with heat. Only by (1) could crystalline products be obtained with uniformity. Products supposed to be phenylhydrazones were prepared from phenacyl benzoate, m. p. 135.5°; salicylate, valerate, m. p. 132-3°; butyrate, m. p. 135°. Mixed melting points made, using pairs of these, indicated that they are identical.

Hess¹ found that phenylhydrazine reacts with phenacyl bromide to give what he considered to be tetraphenyltetracarbazone, thus:



¹ *Ann.*, 232, 235 (1886).

He described this compound as yellow needles, m. p. 137°. Analyses of several of our products gave figures far removed from those required for phenylhydrazones but approximating those calculated for Hess' compound. Hence it is concluded that phenacyl esters react with phenyl hydrazine with the splitting off of the acid radicle and that the products are all essentially Hess' tetraphenyltetracarbazone, some of them being purer than others.

Oximes.—Phenyl benzoate oxime was prepared from the ester and hydroxylamine by heating in dilute alcohol solution. It crystallized after standing several days. Recrystallization from petroleum ether gave needles, m. p. 92°, containing 5.59% N, calculated 5.85%. Oximes were similarly prepared from formate, cinnamate, and mandelate but these were oils. The oximes are very soluble in methyl and ethyl alcohols, ether, chloroform, benzene, carbon tetrachloride and acetone and only slightly soluble in petroleum ether.

Oximes of phenacyl esters can be obtained but are of no value for identification.

Comparison of Phenacyl and *p*-Nitrobenzyl Esters.

Of the acids used, satisfactory comparisons may be made in the case of acetic, palmitic, succinic, malic, tartaric, maleic, fumaric, citric, benzoic, salicylic, *o*-, *m*- and *p*-cresotic, *o*-aminobenzoic and cinnamic, since all of these acids give crystalline derivatives with both reagents. With these the average yield of phenacyl esters was 77%, *o*-aminobenzoic being the only one giving a really poor yield, while the average yield of the *p*-nitrobenzyl esters was 62%, phenacyl bromide giving particularly good yields of esters with the polybasic acids, malic, succinic, fumaric and citric.

Of these 15 acids the average melting point of the phenacyl esters is 121.9° and of the *p*-nitrobenzyl esters, 117.6°, a difference of 4.3° in favor of the phenacyl, though in 6 cases of the 15 the *p*-nitrobenzyl esters are the higher melting ones. There is usually a considerable difference in the melting points of the phenacyl and *p*-nitrobenzyl esters of any one acid.

Disregarding sulfonic acids, which do not give derivatives with either reagent, of 120 acids so far studied, 96, or 80% have given crystalline *p*-nitrobenzyl esters, 19 liquid esters, and 5 otherwise unsatisfactory compounds, while from 33 acids tried with the new reagent, 26 crystalline, 4 liquid, and 3 otherwise unsatisfactory esters have been obtained. Formic acid gives a crystalline *p*-nitrobenzyl ester, m. p. 31°, but a liquid phenacyl, and the phenacyl acetate melts rather low and is difficult to purify. Stearic acid gives a satisfactory phenacyl ester but with *p*-nitrobenzyl bromide a small amount of a compound, m. p. 285°, was obtained which does not seem to be the desired ester.

Especially interesting is phenacyl lactate, m. p. 96°, which is obtained in good yield, since this acid is important and difficult to identify.

The initial purity of the phenacyl esters is usually high, the first melting point seldom being more than one or two degrees lower than the final.

So far as our study goes, phenacyl bromide appears as a convenient and useful reagent for the identification of acids, superior in some cases to *p*-nitrobenzyl bromide.

Summary.

It has been found that phenacyl bromide may serve as a convenient reagent for the identification of acids. It is easily prepared and it readily forms esters of acids when boiled, in dilute alcohol solution, with the alkali salts of the acids. Many of these esters are solids easily purified by recrystallization from dilute alcohol and have convenient melting points.

The following esters of phenacyl alcohol have been prepared and studied and their properties tabulated:

Acetate (40°)	<i>o</i> -Cresotate (138.5°)	<i>p</i> -Nitrobenzoate (128.4°)
Aconitate (90°)	<i>p</i> -Cresotate (145.5°)	Palmitate (52.5°)
<i>o</i> -Aminobenzoate (181-2°)	Fumarate (197.5°)	Pyrotartarate (101.5°)
Benzoate (118.5°)	Glutarate (104.5°)	Saccharate (120°)
<i>p</i> -Bromobenzoate (87°)	Itaconate (79.5°)	Salicylate (110°)
Cinnamate (140.5°)	Lactate (96°)	Stearate (64°)
Citraconate (108.5°)	Malate (106°)	Succinate (148°)
Citrate (104°)	Maleate (119°)	Tartrate (130°)
<i>m</i> -Cresotate (116.5°)	Mandelate	

BALTIMORE, MARYLAND.

[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF COLUMBIA UNIVERSITY,
No. 316.]

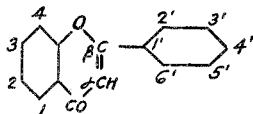
THE SYNTHESIS OF AMINOFLAVONES, OF FLAVONE-AZO-BETA-NAPHTHOL DYES, AND OF OTHER FLAVONE DERIVATIVES.¹

BY MARSTON TAYLOR BOGERT AND JOSEPH K. MARCUS.

Received October 15, 1918.

Introductory.

Many of the yellow coloring matters occurring in the plant kingdom have been shown to be hydroxy derivatives of flavone (benz-2-phenyl- γ -pyrone) (I). Aside from the general interest attaching to these compounds



(I)

¹ The subject matter of this article forms part of a dissertation submitted by Joseph K. Marcus to the Faculty of Pure Science of Columbia University in partial fulfillment of the requirements of the degree of Doctor of Philosophy.