works well: A mixture of 10 g. of potassium ribonate and 80 cc. of glacial acetic acid was heated at 60° for twenty minutes. The mixture was filtered and kept at 15° for three hours. The resulting acid (6 g.), m. p. 110–112°, was purified by recrystallization from methanol (m. p. 112–113°).

Anal. Calcd. for $C_5H_{10}O_6$: C, 36.15; H, 6.07. Found: C, 36.33; H, 6.25; $[\alpha]^{25}D$ −17.0° (*C*, 4% in water); $[\alpha]^{25}D$ −17.3° (*C*, 4% in methanol).

d-Ribonic acid is unstable at room temperature as indicated by a lowering of the melting point of several degrees after twenty-four-hour storage. Acetylation of the acid by the procedure of Robbins and Upson[6] gave tetraacetyl-*d*-ribonic acid (15%), triacetyl-*d*-ribonolactone (about 10%), and an intractable oil.

Triacetyl-*d*-ribonolactone.—Dry hydrogen chloride was passed into a suspension of 20 g. of *d*-ribonolactone in 100 cc. of acetic anhydride at 10° until saturation was complete. The solution was heated to 50° for one hour and then concentrated to dryness under reduced pressure. The residue was recrystallized from a mixture of acetic acid and water; yield 88% (81.5 g.), m. p. 54–56°.

Anal. Calcd. for $C_{11}H_{14}O_8$: C, 48.17; H, 5.15. Found: C, 48.36; H, 5.44; $[\alpha]D_{25}$ + 27° (*C*, 2% in chloroform).

Tetraacetyl-*d*-ribonitrile.—A mixture of 5 g. of tetraacetyl-*d*-ribonamide, 6 g. of phosphorus oxychloride and 20 cc. of alcohol-free chloroform was refluxed for three hours. The cooled solution was cautiously stirred into 50 cc. of ice-water and the organic layer separated. The aqueous fraction was extracted with three 20-cc. portions of chloroform and the combined chloroform extracts were washed with ice water and aqueous sodium bicarbonate solution. After drying over anhydrous sodium sulfate, the chloroform was removed completely by distillation *in vacuo* and the crystalline residue was recrystallized from 10 cc. of ether; weight 4.4 g., melting at 66–68°. A second recrystallization from ether or methanol gave analytically pure product melting at 71–72°. *Anal.* Calcd. for $C_{13}H_{17}O_8N$: C, 49.52; H, 5.39; N, 4.44. Found: C, 49.58; H, 5.37; N, 4.51; $[\alpha]^{25}D$ +34.45° (*C*, 3% in chloroform).

Tetraacetyl-*d*-arabononitrile was prepared by heating the acetylated amide with 3 parts of phosphorus oxychloride at 80° for thirty minutes. The product was isolated by removing the phosphorus oxychloride under reduced pressure, dissolving the residue in chloroform and washing the latter with ice water to remove acidic constituents. From this point on, the procedure described above was used. From 10 g. of amide, 9 g. of product (94% yield), melting at 116–118° was obtained. Recrystallization from benzene gave an analytically pure product (m. p. 120–121°). *Anal.* Found: C, 49.66; H, 5.61; N, 4.29; $[\alpha]^{25}D$ −3.5° (in chloroform).

Pentaacetyl-*d*-gluconitrile was prepared in the same manner as was tetraacetyl-*d*-arabononitrile; yield of pure nitrile 89% (m. p. 84–85°).

We are indebted to Drs. R. T. Major and J. R. Stevens for their interest and valuable suggestions.

Summary

1. The direct acetylation of salts of *d*-ribonic acid and *d*-arabonic acid to the corresponding fully acetylated acids is described.

2. Acetylated aldonic amides may be converted to the corresponding nitriles in excellent yields by the action of phosphoryl chloride; this step constitutes a general method for preparing fully acetylated aldonic nitriles.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF MISSOURI]

The Effect of Bases on the Hydrogenation of Alkylphenols in the Presence of Raney Nickel

BY HERBERT E. UNGNADE AND DOROTHY V. NIGHTINGALE

It has been shown previously that small amounts of 40% aqueous sodium hydroxide will promote the hydrogenation of ortho disubstituted alkylphenols, *p*-phenylphenol and acylphenols in the presence of Raney nickel. The behavior of simple alkyl phenols was anomalous since aqueous alkali did not appreciably affect their hydrogenation.[1]

Further investigation has shown that phenol and alkylphenols are hydrogenated more rapidly and at lower temperatures when a small amount of the corresponding phenoxide is present during the hydrogenation. This effect is masked by water, which hinders the hydrogenation, and thus could not be observed with aqueous base.

The hydrogenations were carried out as described previously, with carefully purified compounds. Sodium or sodium hydroxide was added to the hot melted phenols. After the reaction was complete, 3 g. of Raney nickel catalyst[2] was added to the hot liquid and mixed thoroughly. The mixture was immediately hydrogenated at 130–150 atm.[3]

The ease of hydrogenation (or activity of the catalyst) was determined by observing the temperature of initial hydrogen absorption and by comparison of the isothermal rates. The relative order was the same for both methods.

The hydrogenation products were washed from the liner with benzene and then distilled under atmospheric pressure through a one-foot column packed with Pyrex helices. The constants of the cyclohexanols are given in Table I. The yields were quantitative except for mechanical losses.

The results of fourteen hydrogenations carried out at 100° with 0.53 mole of phenol each show the following:

A quantitative conversion to cyclohexanol can be accomplished in 0.6 hr. with 0.4 mole % of so-

(1) Ungnade and McLaren, THIS JOURNAL, **66**, 118 (1944).

(2) The catalyst was dried by blotting with filter paper. Portions of catalyst were used from the same preparation within a short period of time in order to minimize the effect of age. All catalysts were found to change in activity with time. The activity decreased most rapidly when the catalyst was stored under 95% ethanol, least rapidly when absolute alcohol was used.

(3) The catalyst was partially inactivated if the mixture was allowed to stand at this point.

TABLE I

Cyclohexanol	B. p., °C.	M. p., °C.	$n^{30}D$	Phenylurethan m. p., °C.	α-Naphthylurethan m. p., °C.
Cyclohexanol	158–159		1.4642	82–82.5	
trans-2-Methyl	163–164		1.4602	105–106	
trans-3-Methyl	168–169		1.4545	91–92	
trans-4-Methyl	170–171		1.4551	124–125	
(1^t),2^c,4^t-Dimethyl	177–178		1.4544	95–96	
(1^t),2^c,5^t-Dimethyl[a]	175–176		1.4555	116–117	
3,4-Dimethyl	188–189.5		1.4570	123.5–124.5[b]	
(1^t),3^c,5^c-Dimethyl	183–184		1.4525	109–110	
2-*t*-Butyl-4-methyl	215–219		1.4680		131–132
2-*t*-Butyl-4-methyl		112–113			
2,4,6-Trimethyl[c]	183–185	69–70			
2,3,5-Trimethyl	189.5–190.5		1.4527		148–148.5

[a] The product is unchanged by heating with sodium. [b] This urethan separates in small amounts from the mixture obtained by hydrogenation in presence of phenoxide. *Anal.* Calcd. for $C_{18}H_{21}NO_2$: C, 72.87; H, 8.50. Found: C, 72.64; H, 8.72. [c] The reaction mixture gave 19–30% of the solid isomer.

dium phenoxide. The rate is unchanged by increasing the amount of phenoxide to 2 mole %. In the absence of the phenoxide the time necessary for this same reaction is three hours or longer. Polar solvents such as methanol (50 cc.) increase the time required somewhat, but in methylcyclohexane (50 cc.) no hydrogen is absorbed until the temperature is raised to 125°. When 1 cc. of 40% aqueous sodium hydroxide is added to the phenol the time required for complete hydrogenation is nearly doubled (one hour). With 4 cc. of 10% sodium hydroxide solution the conversion requires two hours. Potassium phenoxide acts similarly to sodium phenoxide. Piperidine (0.25 cc.) in the place of sodium phenoxide retards the hydrogenation.

The data are in agreement with the assumption that the phenolate ion is more easily hydrogenated than phenol.

In the absence of sodium cresoxide the three cresols (0.5 mole) are hydrogenated at 120° in the order *p* (1.8 hr.), *m* (2.6 hr.), *o* (6.0 hr.). The starting temperatures are 70, 75 and 80°, respectively.[4] When the hydrogenations are carried out under identical conditions but in the presence of 0.3 mole % of the corresponding sodium salts all isomers are completely reduced in half an hour and the hydrogen absorption starts at 60°. The products in either case are nearly pure *trans* isomers.

Four xylenols (2,4-, 2,5-, 3,4- and 3,5-dimethylphenols, 0.5 mole each) have been hydrogenated with essentially similar results. In the absence of base or phenoxide 3,5-dimethylphenol is the most readily hydrogenated while the xylenols with *o*-methyl groups are the most difficult to reduce. In the presence of 0.4 mole % of their sodium salts, all of them are completely reduced to the cyclohexanols in 0.3 hr. at 170° and in all cases the absorption of hydrogen starts at 85°.

Essentially the same isomers are produced with or without added phenoxide. A new geometric isomer is obtained in small quantity along with the normal product from 3,4-dimethylphenol when the phenoxide is present. (1^c),3^c,5^c-Dimethylcyclohexanol occasionally accompanies the (1^t),3^c,5^c -form in small amounts but its occurrence has not been correlated with any particular experimental condition.

The two trimethylcyclohexanols (2,4,6 and 2,3,5) (0.15 mole) are hydrogenated at nearly the same rate (0.3 hr.) with 0.5 mole % of their respective sodium salts at 170°. The ease of hydrogenation of the two isomers differs when the salts are absent.

Solvents play the same role in all these hydrogenations as they do in the case of phenol. The effect of water is particularly noticeable with 2-*t*-butyl-4-methylphenol. Our earlier observations[1] have shown the hydrogenation of this compound to proceed less readily in the presence of aqueous alkali. When the anhydrous sodium salt (1.2 mole %) is used instead, the time of hydrogenation is reduced from two hours to twelve minutes at 170° for 0.18 mole. The solid isomer of 2-*t*-butyl-4-methylcyclohexanol is formed along with the liquid isomer when the hydrogenation is carried out at 220° in the absence of base or phenoxide, or at the same temperature, with aqueous sodium hydroxide. Reduction of this phenol at 190° by itself or at 220° with 1.2 mole % of its sodium salt gives only the liquid isomer. When the hydrogenation is carried out at 220° without base the product contains 25% of low-boiling material indicating hydrogenolysis. No low-boiling fractions are obtained when the hydrogenations are carried out in the presence of the corresponding phenoxides.

Summary

The hydrogenation of alkylphenols is promoted by small amounts of the anhydrous sodium salts of these phenols.

The promoting effect is greatest in the absence of solvents and within limits is independent of the amount of phenoxide added.

In isomeric methyl phenols the ortho substituted compounds reduce more slowly than the

(4) See also Yamamoto, *J. Chem. Soc. Japan*, **60**, 451 (1939).

others. In presence of their sodium salts, however, these isomers are hydrogenated at the same rate.

When the cyclohexanols can exist in *cis–trans* forms, the ratio of the products is not appreciably altered by the presence of the sodium salts except at high temperatures.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, DUKE UNIVERSITY]

The Acylation of Methyl Ketones with Aliphatic Esters by Means of Sodium Amide. Synthesis of β-Diketones of the Type $RCOCH_2COR$[1]

BY JOE T. ADAMS AND CHARLES R. HAUSER

The acylation of methyl ketones with esters by means of sodium, sodium ethoxide or sodium amide is the common method for the preparation of β-diketones having the reactive methylenic group.

$$RCO_2C_2H_5 + CH_3COR \longrightarrow RCOCH_2COR + C_2H_5OH$$

While acetylations with ethyl acetate have generally been satisfactory,[2] acylations with higher aliphatic esters have previously given only fair yields of the β-diketones.[3,4] In the present investigation good yields of β-diketones have been obtained from various aliphatic esters and methyl ketones by means of sodium amide.

In preliminary experiments using molecular equivalents of ethyl *n*-butyrate, methyl isobutyl ketone and sodium amide the yield of the β-diketone was 44% when the sodium derivative of the ketone was first prepared and the ester added, but only 36% when a mixture of the ester and ketone was added to the sodium amide in accordance with the more common practice.[4] The former procedure was therefore adopted.

Although Claisen[5] reported a 77% yield in the acetylation of acetophenone with ethyl acetate using two equivalents of sodium amide to one of the ketone, later workers[4] used no appreciable excess of sodium amide in acylations of aliphatic ketones with higher aliphatic esters and obtained much lower yields. We have found that the presence of excess sodium amide has a very favorable influence on the yield of β-diketone, at least in the cases studied. Our results are summarized in Table I. With each of the first six ester–ketone combinations listed in the table, the acylations were carried out using molecular equivalents of sodium amide and ketone, and also using two equivalents of sodium amide to one of the ketone. It can be seen that the yields obtained in the presence of the extra equivalent of sodium amide are twice those obtained using only an equivalent of the base. The influence of excess ester on the yield is much less pronounced. This is shown by the fact that, in the acylation of methyl *n*-propyl ketone with ethyl *n*-butyrate, the yield was only slightly higher with two equivalents of ester to one of ketone than with equivalents of ester and ketone. To obtain optimum yields, however, excess of the ester was generally used.

Except possibly when the β-diketone fails to form a copper salt, the procedure using excess sodium amide is preferred. The β-diketone from ethyl *n*-valerate and methyl *t*-butyl ketone failed to form a copper salt, and when the reaction was carried out in the presence of excess sodium amide, it was rather difficult to isolate the β-diketone in the pure condition. Two products obtained from side reactions were isolated in this case, *n*-valeramide formed by the reaction of the sodium amide with the carbonyl group of the ester, and ethyl *n*-valeryl-*n*-valerate which is the self-condensation product of the ester. In the corresponding experiment using equivalents of reactants none of the amide was found, although some of the self-condensation product of the ester was isolated. These types of side reaction probably also accompanied the other acylations, especially when excess sodium amide was used, but the β-diketones were readily isolated in the form of their copper salts.

In addition to the good yield of the methyl derivative, $C_2H_5COCH_2COC_2H_5$, obtained from methyl ethyl ketone and ethyl propionate using excess sodium amide, a low yield (13%) of the methylene derivative, $C_2H_5COCH(CH_3)COCH_3$, was isolated. A very low yield (2%) of the corresponding methylene derivative was obtained from methyl *n*-propyl ketone and ethyl propionate. No attempt was made to isolate methylene derivatives in the experiments with methyl isobutyl or methyl *n*-amyl ketones. In all cases studied thus far, the methyl derivatives were readily isolated in good yields essentially free from the methylene derivatives.

For acylations with the esters higher than ethyl acetate listed in Table I, sodium amide is superior to sodium ethoxide or metallic sodium. Two of those listed, the acylations of methyl *t*-butyl ketone with ethyl *n*-valerate and with ethyl pivalate, have failed in the presence of sodium

(1) Paper XXVI on "Condensations"; paper XXV, THIS JOURNAL, **66**, 1037 (1944).

(2) See especially Sprague, Beckham and Adkins, *ibid.*, **56**, 2665 (1934).

(3) Morgan and Thomason, *J. Chem. Soc.*, **125**, 756 (1924).

(4) Fischer and Orth, "Die Chemie des Pyrrols," Akademische Verlagsgesellschaft, Leipzig, 1934, p. 402.

(5) Claisen, *Ber.*, **38**, 694 (1905).