XXXVIII. THE CONDENSATION OF AROMATIC ALDEHYDES WITH PYRUVIC ACID.

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(Received June 18th, 1913.)

In a preliminary communication published by one of us [Smedley, 1912], and in the foregoing paper [Smedley and Lubrzyńska, 1913], the condensation of certain fatty aldehydes with pyruvic acid in very dilute alkaline solution has been described.

In order to obtain a better knowledge of the reaction and hence possibly to overcome some difficulties with which we found ourselves confronted in our experiments in the aliphatic series we have investigated the behaviour of certain aromatic aldehydes under similar conditions. A number of the $\beta\gamma$ -unsaturated α -keto-acids have been prepared and converted by oxidation with hydrogen peroxide into the corresponding unsaturated acids containing one carbon atom less than the original keto-acid.

Claisen and Claparède [1882] studied the action of anhydrous hydrochloric acid on a mixture of benzaldehyde and pyruvic acid and obtained from the mixture cinnamoyl formic acid. This reaction was further studied by Erlenmeyer, junr. [1899, 1901], who showed that in addition to the above product γ -phenyl- β -benzylidene- α -ketobutyrolactone is formed:

The condensations of benzaldehyde, cinnamic aldehyde, piperonal and anisic aldehyde with pyruvic acid have been studied in dilute alkaline solution. The reactions proceed in all cases readily at the laboratory temperature. The amount of potash used was generally such that the strength of the solution was from 1/40 to 1/10 normal, and the mixture was allowed to stand at the temperature of the laboratory for periods varying from 2 to 7 days. As the reaction proceeds the aldehyde disappears and the

liquid gradually becomes yellow. When the reaction is completed, the keto-acid is thrown down on acidifying the liquid, and after purification, is oxidised to the corresponding $\alpha\beta$ -unsaturated acid.

Yellow crystalline products are formed by the condensation of anisic aldehyde and piperonal respectively with pyruvic acid, the formulae of which are shown on analysis to agree with those required for the β -unsaturated α -keto-acids:

After we had completed the above series of experiments, we found that we had overlooked two papers by Erlenmeyer, junr. [1903, 1904], in which he had described the condensation of benzaldehyde and cinnamic aldehyde respectively with pyruvic acid in the presence of strong caustic soda (10 %). The products which we obtained on condensing cinnamic aldehyde with pyruvic acid were similar to those described by Erlenmeyer. He isolated two forms, an orange-red, melting at 75° and gradually converted *in vacuo* into a yellow form melting at 107°. Our products melted at 73° and 104° (uncorrected) respectively.

From anisic aldehyde and pyruvic acid yellow crystals melting at 130° were obtained. Piperonal under similar conditions gives beautiful yellow needles which at a temperature of about 70° undergo a remarkable transition into a deep orange-red form and finally melt at 163°. On keeping the red form so obtained in an evacuated desiccator or in a well-stoppered bottle it was still unchanged after a month had elapsed. If however it was exposed to the air it was gradually reconverted into the yellow variety.

On oxidation with the calculated quantity of hydrogen peroxide in neutral solution at the ordinary temperature the keto-acids split off carbon dioxide and form unsaturated acids:

Silver oxide which was successfully used to oxidise the corresponding keto-acids in the fatty series [Smedley, 1912], was found to be without action in the aromatic series.

EXPERIMENTAL.

Condensation of piperonal with pyruvic acid. 4 g. of pyruvic acid and 6 g. of piperonal were shaken up with 1 litre of water and 140 cc. N. KOH added; the mixture was allowed to stand at the ordinary temperature for a week, during which it became yellow. The small amount of unchanged

piperal was filtered off and the solution neutralised with 36 cc. N. H_2SO_4 . The neutral solution was extracted with ether several times to free it from traces of unchanged aldehyde. Air was drawn through to remove the last traces of ether and the solution acidified. A yellow solid was precipitated and allowed to settle: it was then filtered off and well washed with cold water. After several recrystallisations from dilute alcohol it was obtained in beautiful yellow needles which turned to deep orange-red at about 70° and melted at 163° .

0.1062 g.; 0.2336 g. CO_2 ; 0.0368 g. H_2O .

C 59.98 %; H 3.85 %.

Calc. for $\text{C}_{11}\text{H}_8\text{O}_6$, C 60.00 %; H 3.63 %.

Condensation of anisic aldehyde with pyruvic acid. 5 g. anisic aldehyde and 3.5 g. pyruvic acid were shaken up with 1 litre of water and 70 cc. N. KOH added, the mixture being allowed to stand for 4 days during which a yellow colour developed. It was then neutralised with 25.05 cc. N. H_2SO_4 and the mixture treated exactly as in the case of the condensation of piperal with pyruvic acid.

The yellow needles finally obtained melted at 130° and no change in colour was observed either on standing or on heating.

0.1100 g.; 0.2585 g. CO_2 ; 0.0500 g. H_2O .

C 64.09 %; H 5.00 %.

Calc. for $\text{C}_{11}\text{H}_{10}\text{O}_4$, C 64.07 %; H 4.85 %.

The specimen, part of which gave the above results on analysis, was allowed to remain in a closed test-tube for two weeks and then analysed:

0.0972 g.; 0.2330 g. CO_2 ; 0.0407 g. H_2O .

C 65.32 %; H 4.63 %.

A week later it was again analysed:

0.1208 g.; 0.2927 g. CO_2 ; 0.0562 g. H_2O .

C 65.98 %; H 5.16 %.

The acid was then recrystallised and again analysed:

0.1244 g.; 0.2972 g. CO_2 ; 0.0564 g. H_2O .

C 65.11 %; H 5.06 %.

The preparation was repeated and the freshly prepared product analysed:

0.1169 g.; 0.2743 g. CO_2 ; 0.0518 g. H_2O .

C 64.10 %; H 4.91 %.

The acid therefore on standing undergoes a slight decomposition, the nature of which was not ascertained.

Condensation of cinnamic aldehyde with pyruvic acid. 5 g. cinnamic aldehyde and 4 g. pyruvic acid were shaken up with 1 litre of water and 80 cc. of normal potash. The mixture was allowed to stand for 4 days at the

ordinary temperature, neutralised and treated as in the experiments already described with piperonal and anisic aldehyde.

The condensation product was obtained in two forms; red crystals melting at 73° , which pass gradually into a yellow substance melting at 104° . In one experiment red crystals melting at 73° were exposed in an evacuated desiccator for 48 hours: they had then become yellow and melted at 95° . After another 24 hours the melting point was 101° and after recrystallisation from dilute alcohol it rose to 103° . Analysis showed that the composition of the two forms after drying in a vacuum desiccator was identical.

0.1274 g.; 0.3344 g. CO_2 ; 0.0600 g. H_2O .

C 71.58%; H 5.17%.

Calc. for $\text{C}_{12}\text{H}_{10}\text{O}_3$, C 71.28%; H 4.95%.

Oxidation of dioxymethylene-benzylidene-pyruvic acid:

The keto-acid was dissolved in alcohol, neutralised with potash and the theoretical quantity of hydrogen peroxide then added. It is important that no excess of the peroxide be present or the yield will be found to be diminished. The oxidation product was heated for an hour on a water-bath to complete the reaction and then acidified. A very pale yellow acid was precipitated, which after one recrystallisation was almost white and melted at 242° .

0.1074 g.; 0.2462 g. CO_2 ; 0.0423 g. H_2O .

C 62.47%; H 4.37%.

0.1148 g.; 0.2690 g. CO_2 ; 0.0458 g. H_2O .

C 62.51%; H 4.32%.

Calc. for $\text{C}_{10}\text{H}_8\text{O}_4$, C 62.50%; H 4.16%.

Oxidation of cinnamylidene-pyruvic acid:

The oxidation was carried out in a manner similar to that just described for the piperonal product. The acid obtained after recrystallisation from benzene and from alcohol melted at 165° and was therefore identical with the cinnamylidene-acetic acid prepared by Perkin from malonic acid and cinnamic aldehyde, melting at 165° .

0.0844 g.; 0.2335 g. CO_2 ; 0.0442 g. H_2O .

C 75.47%; H 5.80%.

After again recrystallising:

0.1093 g.; 0.3052 g. CO_2 ; 0.0578 g. H_2O .

C 76.12%; H 5.85%.

Calc. for $\text{C}_{11}\text{H}_{10}\text{O}_2$, C 75.86%; H 5.74%.

Oxidation of methoxy-benzylidene-pyruvic acid:

This acid was dissolved in alcohol, carefully neutralised with potash and hydrogen peroxide added. In this case it was found that the best yield was obtained on adding 1.5 times the theoretical quantity of the peroxide. After several recrystallisations, the acid melted at 172°. Analysis gave the following result:

0.1020 g.; 0.2517 g. CO₂; 0.0530 g. H₂O.

C 67.23 %; H 5.70 %.

Calc. for C₁₀H₁₀O₃, 67.41 %; H 5.62 %.

Condensation of benzaldehyde with pyruvic acid. The condensation was carried out as in the cases already described, but the intermediate keto-acid was not isolated. The product was at once oxidised in neutral solution with hydrogen peroxide.

It was found in this case of the greatest importance to have the solution exactly neutral and to avoid any excess of the peroxide.

On acidification, cinnamic acid was precipitated. It was identified by taking the melting-point of a specimen mixed with pure Kahlbaum's cinnamic acid.

The yields in the above experiments varied from 50–70 % of the theoretical.

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