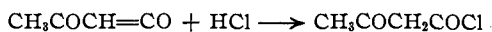


[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF NORTHWESTERN UNIVERSITY]

Acetoacetyl Chloride

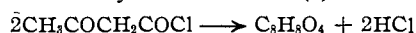
BY CHARLES D. HURD AND CHARLES D. KELSO

Since acetylketene, in conjunction with its resonance isomer β -crotonolactone, is the structure¹ of the dimer of ketene it seemed reasonable to think that acetoacetyl chloride could be synthesized from it by reaction with hydrogen chloride. Such proved to be the case.



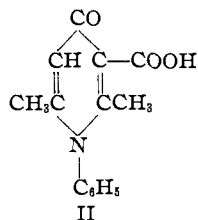
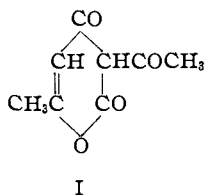
In the present synthesis low temperatures were found to be necessary because of the instability of acetoacetyl chloride at temperatures above -20° . A slight excess of hydrogen chloride was used in the synthesis and this excess remained in solution at the low temperature used. It was possible to remove this hydrogen chloride by vacuum treatment.

When acetoacetyl chloride was warmed to room temperature dehydroacetic acid (I) was formed

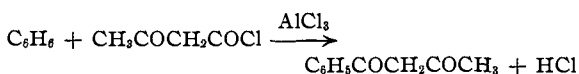


Half of the hydrogen chloride was eliminated in three hours.

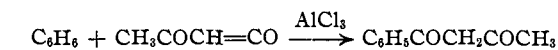
Low temperature (-60°) reactions of the acid chloride with alcohol or aniline gave rise to ethyl acetoacetate, $\text{CH}_3\text{COCH}_2\text{COOC}_2\text{H}_5$, and acetoacetanilide, $\text{CH}_3\text{COCH}_2\text{CONHC}_6\text{H}_5$, respectively. When acetoacetyl chloride was treated at room temperature with aniline there was formed 1-phenyllutidone-3-carboxylic acid (II).



Another reaction investigated was that of acetoacetyl chloride and benzene in the presence of aluminum chloride. Benzoylacetone was produced.

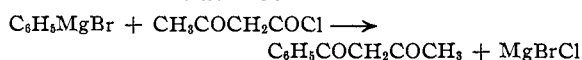


Acetylketene also formed benzoylacetone in a similar type of reaction but the yield was smaller.



(1) Hurd and Williams, *THIS JOURNAL*, **58**, 964 (1936); Hurd and Abernethy, *ibid.*, **62**, 1147 (1940).

The behavior of acetoacetyl chloride toward the Grignard reagent was studied also. A fair yield of benzoylacetone was formed with phenylmagnesium bromide at -50° .



Several other β -diketones were synthesized to test the generality of this reaction. These included 2,4-octanedione from butylmagnesium bromide, 2,4-undecanedione from heptylmagnesium bromide, 2,4-dodecanedione from octylmagnesium bromide, and 5-methyl-2,4-undecanedione from 2-octylmagnesium bromide. This work will be reported in a subsequent article.

Experimental Part

Acetylketene, or "diketene," was generously donated for this study by the Carbide and Carbon Chemicals Corporation. We are very grateful for this assistance. This material was always redistilled before use: b. p. 42° (30 mm.).

Preparation of Acetoacetyl Chloride.—Dry hydrogen chloride was passed into 5 g. of cold acetylketene. At the outset the temperature was held near the freezing point of the acetylketene (-7°) but the temperature was changed to -50° or below as rapidly as the ability to withstand crystallization would permit. Usually this was only a few minutes. The cooling bath was solid carbon dioxide and acetone. When hydrogen chloride escaped through the outlet tube the reaction was stopped. The reaction mixture solidified on prolonged standing at -78° .

Analysis showed the presence of 107–109% of the theoretical amount of halogen, hence the product was contaminated with hydrogen chloride. It was kept at -70° , subjected to a vacuum of 20 mm. for five minutes and re-analyzed. The Cl-content was 104% of the theoretical. Another vacuum treatment for four minutes at -70° resulted in a solid which analyzed correctly (99.67, 99.20%) for halogen. This material was not stored but was used promptly for each experiment.

Method on Analysis.—A small dewar flask (7 cm. long by 1 cm. inside diameter) served as a weighing bottle. It was chilled to about -75° by rinsing it with butyl ether at -78° . Then 0.5 cc. of the cold butyl ether was added. The flask was stoppered and weighed, after which a 0.4-g. portion of the acetoacetyl chloride was introduced. The flask was reweighed and lowered carefully into a 500-cc. Erlenmeyer flask containing an excess of dilute base. Analysis for chloride ion followed the usual Volhard method.

Melting Point.—A three-junction copper-constantan thermocouple was calibrated at the melting points of ice, mercury and carbon tetrachloride. The acetoacetyl chloride, prepared as described above, analyzed for 99.3% of the theoretical amount of chlorine. This material melted sharply between -50 and -51° .

Behavior on Warming.—A 7-g. sample of acetoacetyl chloride which contained the equivalent of 1.9 g. of hydrogen chloride was allowed to come slowly to room temperature. The hydrogen chloride which was evolved was collected in standard alkali. At the end of three hours, 1.0 g. of hydrogen chloride was evolved. Only 0.15 g. was lost after another forty hours. Dehydroacetic acid crystals were deposited.

To this reaction product was added a slight excess of aniline. The reaction proceeded without warming, and much heat was evolved. Dehydroacetic acid reacts with aniline but heat is necessary to make the reaction take place. The product was treated with dilute hydrochloric acid to remove aniline and aniline hydrochloride. The solid was filtered off and recrystallized twice from alcohol. The melting point was 260–265° with decomposition. The neutral equivalent was found to be 235, which indicates that the product was 1-phenyllutidone-3-carboxylic acid.²

Reaction with Aniline at -60°.—Acetoacetyl chloride, prepared from 2.5 g. of acetylketene, was dissolved in 10 cc. of dry ether. Six grams of aniline in 20 cc. of dry ether was cooled to -60°. The acid chloride solution was poured into the aniline solution in small portions, both solutions being kept at -60° or below. This mixture was allowed to stand at -60° for three hours. The mixture was treated with water. The white solid dissolved completely. The layers were separated. The ether layer was dried and evaporated. The residue was a gummy mass which would not recrystallize from alcohol or ligroin. The residue was dissolved in ether and treated with 6 cc. of concentrated hydrochloric acid diluted with 20 cc. of water. This treatment removed the excess of aniline and removal of the ether yielded 2.3 g. of a solid which, when recrystallized from ligroin, melted at 84–85°, the melting point of acetoacetanilide. The yield was 44%.

Evaporation of the original aqueous layer yielded 3.8 g. of solid, presumably aniline hydrochloride, the theoretical amount being 3.85 g.

Reaction with Alcohol at -60°.—The reaction was run in the same manner as the previous reaction, using 2.5 g. of acetoacetyl chloride in 10 cc. of ether and 1.6 g. of absolute alcohol in the same volume of ether. The oil obtained from the aqueous layer yielded 1.6 g. (27% yield) of ethyl acetoacetate, b. p. 98° (65 mm.); semicarbazone, m. p. 120°.

Friedel-Crafts Reaction.—Thirty-six grams of benzene and 10.8 g. of acetoacetyl chloride, made by passing an excess of dry hydrogen chloride into 7.6 g. of acetylketene and then evacuating to 20 mm. at -70° until the weight of the product checked the calculated weight to 0.1 g., were placed in a flask and cooled to -50°. Twelve grams of aluminum chloride was added in portions with stirring over a period of two hours. Between additions the reaction mixture was allowed to warm up until the reaction appeared to be proceeding too vigorously. The dry-ice and acetone bath was then used to freeze out the reactants.

This means of controlling the reaction was used until all the aluminum chloride was added. The mixture was allowed to warm up slowly. A sirupy layer settled to the bottom. The benzene was decanted and the sirupy layer was hydrolyzed with dilute hydrochloric acid. A semi-solid mass was obtained. On steam distillation of it, a little liquid was noted, then 3.6 g. (27% yield) of solid benzoylacetone was collected separately. It melted³ at 59–60°. There was a non-volatile residue which was not characterized.

Friedel-Crafts Reaction with Acetylketene.—Thirty-nine grams of benzene and 8.4 g. of acetylketene were placed in a flask and cooled to -5°. Twenty-nine grams of aluminum chloride was added in portions as before and the reaction was controlled as above. The product was isolated by the same technique as above. The steam distillation yielded 1.7 g. of benzoylacetone melting at 59–60°. The yield is 10.5%.

In this reaction, 2.2 moles of aluminum chloride per mole of acetylketene was used, while in the preceding reaction, 1.1 moles of catalyst per mole of acid chloride was used.

Reactions of Acetoacetyl Chloride and Phenylmagnesium Bromide.—Phenylmagnesium bromide (0.2 mole in 250 cc. of ether) was prepared in the usual manner in an atmosphere of nitrogen. The reagent was filtered and transferred to a separatory funnel and dropped into 0.1 mole (12 g.) of acetoacetyl chloride in 150 cc. of dry ether at -60°, over a period of one and one-half hours in an atmosphere of nitrogen. The reaction mixture was allowed to stand overnight. The mixture was hydrolyzed with water and acetic acid after removal of most of the ether. The oil was removed from the aqueous layer by ether extraction. The extract was dried over sodium sulfate, the ether removed and the oil distilled at 20 mm. pressure. Two grams of an oil which partially solidified on standing was obtained in the boiling range 128–130° at 20 mm. The residue would not distil at a bath temperature of 250°. Recrystallization from ligroin gave a solid melting at 58–59°. This material and the products from the Friedel-Crafts reaction gave semicarbazones melting at 242–247° with decomposition. This is the melting point recorded for the disemicarbazone of benzoylacetone.³

The yield of benzoylacetone from this reaction is 12%.

Summary

Acetoacetyl chloride has been prepared from acetylketene and hydrogen chloride. It is unstable above -20°. Decomposition at room temperature yields dehydroacetic acid. Reactions with aniline, alcohol, and phenylmagnesium bromide are described.

Both acetoacetyl chloride and acetylketene undergo the Friedel-Crafts reaction with benzene and aluminum chloride.

EVANSTON, ILLINOIS

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(2) Conrad and Guthzeit, *Ber.*, **20**, 161 (1887).

(3) Michael and Ross, *This Journal*, **53**, 2394 (1931).