Moles of Diphenylzinc	Moles of Diphenylmercury	$x_t/c_t \times 10^2$	$x_c/c_c \times 10^2$	Yield trans-I, %	Yield cis-I, %
0.03[a]	—	63.0 ± 0.1	-1.2 ± 0.4	71.7	0
0.03[b, c]	0.03	104.8 ± 0.1	9.92 ± 0.6	59.6	16.5
0.03[c, d]	0.03	83.0 ± 0.1	10.5 ± 0.6	47.3	17.4
0.015[b, e]	0.075	55.8 ± 0.2	70.1 ± 1.2	15.8	58.1
0.026[a, f]	0.130	77.0 ± 0.2	-4.9 ± 0.9	87.5	0

[a] Diluted 1:1000. [b] Diphenylmercury was added to diphenylzinc in dimethylformamide and then the diazonium salt in dimethylformamide was added. [c] Diluted 1:500. [d] Diphenylmercury was added to the diazonium salt in dimethylformamide and then diphenylzinc added. [e] Diluted 1:250. [f] Carried out as a heteroegenous reaction in diethyl ether.

phenylmercury from 7.82 g. of diphenylmercury and 10.1 g. of zinc in 75 ml. of xylene and 200 ml. of dry dimethylformamide cooled to 0° was added 2.00 g. of *trans*-I and the reaction mixture stirred for 4 hr. Steam distillation and chromatography gave 1.85 g. of azobenzene, m.p. 67.5–70.5°, or 93% recovery. The infrared spectrum was identical with that of the starting material.

Stability of trans-I to benzenediazonium fluoborate. To 3.84 g. of benzenediazonium fluoborate in 75 ml. of xylene and 200 ml. of dimethylformamide at 0° was added 2.00 g. of *trans*-I. Examination of the ultraviolet initially and after 17 hr. at 0° showed no change in the concentration of azobenzene during that period. A further period of 6 hr. at room temperature during which time the diazonium salt underwent extensive decomposition also showed no loss of azo absorption.

Reaction of benzenediazonium fluoborate with phenylmagnesium bromide. To 100 ml. of dimethylformamide at 0° containing 1.34 g. of benzenediazonium fluoborate was added the Grignard reagent prepared from 2.20 g. of bromobenzene and 0.39 g. of magnesium turnings in 50 ml. of ether (filtered under nitrogen pressure). After 15 min. at 0° the mixture was acidified and steam distilled to yield only a few milligrams of red oil. Steam distillation of 3.0 g. of azobenzene in 100 ml. of dimethylformamide after acidification showed that 2.95 g. (98%) could be recovered.

URBANA, ILL.

[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF THE UNIVERSITY OF CALIFORNIA]

Ketone Synthesis by the Grignard Reaction with Acid Chlorides in Presence of Ferric Chloride

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A detailed analysis has been made, by use of gas chromatography, of the products of the reaction between a Grignard reagent and an acid chloride, in presence of ferric chloride. Under the most favorable conditions, there may be obtained yields of about 75% for a simple ketone and of about 50% for a δ-keto ester. Use of an ether-toluene solvent avoids the unworkable masses frequently encountered at −60° when ether alone is used as solvent. Yields in the reaction are lowered by two-fold or more if too dilute solutions are used. Yields are similarly lowered by presence of an ester group intermolecularly or intramolecularly. Yields of δ-keto esters are improved by use of larger amounts of ferric chloride and an excess of Grignard reagent. The data indicate that numerous complexes are formed, some of them irreversibly at −60°, between the reactants and the solvents for the reaction. In addition, ferric chloride forms a stable complex with five moles of capryl chloride.

Subsequent to the report[2] that use of a copper vessel leads to improved yields of ketones from the reaction of a Grignard reagent with an acid chloride, it was determined[3] that cuprous chloride is an effective catalyst for this synthesis. A later investigation[4] of the catalytic effects of various Lewis acids demonstrated that ferric chloride is the most effective of the several metallic halides that were tested. It was also learned that yields are improved, in the case of an unhindered ketone, by lowering the temperature. At −65° with ferric chloride catalyst, 2-hexanone was obtained in yields of 70–75%.

Two groups of investigators[4,5] who have proposed explanations of the remarkable catalytic effect of ferric chloride have suggested that the ferric chloride forms a coordination complex with oxygen in the acid chloride, and thus polarizes and activates the carbonyl group. It was later suggested[6] that any intermediate involving coordination of the ferric chloride with oxygen is inconsistent with the observed fact that ferric chloride specifically catalyzes the Grignard reaction with an acid chloride in great preference to other carbonyl groups. It was further suggested that the

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[1] Recipient of a National Science Foundation Summer Fellowship, 1959, and Cooperative Fellowship, 1959, 1960.

[2] C. J. Stehman, N. C. Cook, and F. C. Whitmore, *J. Am. Chem. Soc.*, **71**, 1509 (1949).

[3] N. C. Cook and W. C. Percival, *J. Am. Chem. Soc.*, **71**, 4141 (1949).

[4] W. C. Percival, R. B. Wagner, and N. C. Cook, *J. Am. Chem. Soc.*, **75**, 3731 (1953).

[5] R. T. Morrison and M. Wishman, *J. Am. Chem. Soc.*, **76**, 1059 (1954).

[6] J. Cason and E. J. Reist, *J. Org. Chem.*, **23**, 1668 (1958).

TABLE I

REACTION AT −60° OF BUTYLMAGNESIUM BROMIDE WITH CAPRYL CHLORIDE[a]

Run No.	Mole % $FeCl_3$[b]	Ratio[b] of C_4H_9Br	Molar Concn.[c] Capryl Chloride	Yield Data,[d] % Ketone	 *tert*-Alcohol	 Capric acid	 C_4H_9 recovered in products
1[e]	0	1.10	0.56	13	4	60	19
2[e]	2	1.10	.56	53	1	40	50
3	2.5	1.20	.56	60	3	33	55
4	2	1.35	.56	76	3	15	61
5	2	1.20	.19	31	6	60	36
6	3	1.15	.28	28	1	65	26
7[f]	2.5	1.20	.33	44	2	50	40
8[fg]	2.5	1.20	.33	38	7	50	43
9[f]	3.5	1.20	.33	32	4	[h]	33
10[f]	9	1.20	.33	45	2	38	41
11[i]	2.5	1.20	.56	39	7	52	44
12[j]	3	1.20	.56	25	5	62	29
13[j]	25.	1.20	.50	35	1	55	31
14[j]	2.5	1.20	.28	25	3	70	25

[a] Reactions were carried out as described in the Experimental. Unless otherwise specified for a specific run, 0.02 mole of the acid chloride and ferric chloride were dissolved in ether-toluene solvent (2:1), the Grignard reagent was added in ether, and total reaction time was 1–1.5 hr. Many of the data represent averages from two or more runs, or the more informative of similar runs. [b] Mole per cent of ferric chloride and ratio of butyl bromide are related to moles of capryl chloride. [c] Molar concentration of capryl chloride is based on total solvent, including that in which Grignard reagent is added. [d] Yield data were determined by gas chromatography as described in Experimental. Since the yield of Grignard reagent was 85–90%, based on butyl bromide, figures in the last column may be subtracted from 90 to give approximate amounts of Grignard reagent not engaging in reaction at the low temperature. Capric acid results from hydrolysis of capryl chloride not reacting. [e] Reaction time 2 hr. instead of usual 1 hr. [f] Solvent was 2:3 ratio of ether:toluene instead of usual 2:1 ratio. [g] Reaction time 3.5 hr. instead of usual 1 hr. [h] After the usual reaction time, 0.1 mole of methanol was added at −60°, then the reaction was worked up; 62% methyl caprate was recovered, with no capric acid. [i] In this run, there was added 0.5 mole of methyl caprate per mole of capryl chloride. There was recovered 85% of the added ester when the reaction was worked up. [j] In these runs, there was added 1 mole of methyl caprate per mole of capryl chloride. Work-up gave 90–98% recovery of the added ester. In Run 13, the ether:toluene ratio was 1:1 instead of the usual 2:1.

data then available could be rationalized on the basis of a mechanism similar to that which had been proposed[7] for reaction of an organocadmium reagent with an acid chloride. The essential features of this mechanism are extraction of halogen by the Lewis acid to give the acylonium ion and reaction of this ion with the Grignard reagent. Further investigation of the mechanism of this reaction[8] has revealed a more complex situation, and the present report is concerned with features of the reaction which are of interest for its general application in synthesis.

For relatively unhindered compounds, best yields are obtained in the presently discussed reaction at about −60°[4]; however, many reactants, especially ester acid chlorides and di-acid dichlorides,[6] give entirely unworkable masses at this temperature, when ether is used as solvent. This difficulty has been obviated by use of a mixture of toluene and ether as solvent, and it was found possible to synthesize 5-tetradecanone in the rather good yields previously reported[4] for 2-hexanone. The best conditions are believed to be those recorded for Run 4 in Table I (Run I-4). In contrast with the previous work,[4] in which the effect of an excess of acid chloride was examined, the present work has sought to establish the optimum excess of Grignard reagent, as illustrated in Runs 1-2 to I-4. In many instances, especially with ester acid chlorides, the acid chloride is the more valuable reagent.

In the course of these preparations, it was learned[9] that a relatively high concentration of reactants is necessary for realization of good yields. The significant difference in yields is illustrated by a comparison of Run I-3 with Runs I-5 to I-10. Although there is some variation in yield for similar runs, it drops as the concentration is lowered. Moreover, if the ratio of ferric chloride is increased (Run I-10) until its concentration is actually higher than in Run I-3, the yield is not improved significantly. Change of the ratio of ether to toluene in the solvent also seems to have a minor effect.

The effect of dilution, especially the nonlinearity of the effect, as well as other data discussed below, indicate the importance of complexes which inactivate the reactants at low temperature. Decreasing the ratio of ether in the solvent has little effect. Without ferric chloride present, most of the Grignard reagent seems to be entirely inactivated

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(7) J. Cason, *J. Org. Chem.*, **13**, 227 (1948).

(8) J. Cason and K. W. Kraus, following paper in this journal.

(9) This problem was not encountered by the previous investigators,[4] for the lowest concentration employed was about 0.7*M* in acid chloride. For many runs described in the present report, lower concentrations were used in order to avoid unstirrable masses; however, an increase in the ratio of toluene allowed higher concentrations.

towards reaction with either the acid chloride or the ketone formed. The results in Run I-1, obtained at twice the normal reaction time, were not significantly affected by longer or shorter reaction times. The exothermic reaction appears to be essentially completed as the Grignard reagent is added. In the more dilute solution in the presence of ferric chloride, the yield of ketone is actually decreased by a prolonged reaction time (Run I-8), as more tertiary alcohol is formed. In all the runs, including those giving rather good yields, the amount of Grignard reagent consumed in forming the products detected in the reaction mixture (Table I, last column) always falls rather short of the amount of reagent used. Furthermore, the recovered capric acid is present in larger amount as the yield of ketone is lower. This capric acid results from hydrolysis of acid chloride which remains at the end of the reaction, in spite of the fact that Grignard reagent also remains unconsumed. In one run (I-9), there was sought verification of the actual presence of acid chloride at the end of the reaction. Methanol was added at low temperature before the work-up, and this resulted in recovery of methyl caprate instead of capric acid. The persistence of reactants after completion of reaction was also observed in reaction of ester acid chlorides, as described in Table III. In one run (III-17) the reaction mixture was allowed to warm up, after the usual low-temperature reaction sequence, and in this case all the Grignard reagent could be accounted for in the detected products.

There was observed considerable evidence that ferric chloride forms complexes with acid chlorides, as well as with solvent. The solutility behavior in solutions of ferric chloride and γ-carbomethoxybutyryl chloride, as described in the Experimental, indicates dissociation of an acid-base complex on warming from −60° to room temperature. Experiments carried out with capryl chloride and ferric chloride are summarized in Table II. It may be noted that the amount of acid chloride detected by gas chromatography does not change significantly after 60 mole per cent of Grignard reagent has been added. This observation, as well as runs using large amounts of ferric chloride (Table III), suggests that there is a finite rate of reaction of Grignard reagent with ferric chloride at −60°, and destruction of the ferric chloride may be the factor bringing the reactions to a halt. Other observations,[8] however, cast doubt on this conclusion, and further investigation is indicated.

As the data in Table II indicate that one mole of ferric chloride complexes about five moles of capryl chloride, an ether solution of ferric chloride and capryl chloride, in 1:5 ratio, was evaporated to leave a residue of orange crystals, whose infrared absorption was at 5.75 μ, with no absorption at 5.55 μ characteristic of capryl chloride.

TABLE II

COMPLEX FORMATION BETWEEN CAPRYL CHLORIDE AND FERRIC CHLORIDE[a]

Reaction No.	Point of Sampling	Results of Gas Chromatography
1	Capryl chloride in ether-toluene solv.	100% Capryl chloride
	9 mole % $FeCl_3$ added	45% Capryl chloride
	60 mole % C_4H_9MgBr added	40% Capryl chloride
	Additional 60 mole % C_4H_9MgBr added	0% Capryl chloride
	Methanol added; reaction worked up	60% Methyl caprate 40% Ketone
2	Capryl chloride in ether-toluene solv.	100% Capryl chloride
	19 mole % $FeCl_3$ added	20% Capryl chloride
	Methanol added	100% Methyl caprate

[a] The capryl chloride solution was maintained at −60° ± 2°, with stirring. Samples were withdrawn in a hypodermic syringe and injected into gas chromatography at 170°. A section of glass wool, which was inserted at the injection site, absorbed most of the nonvolatile material. When plugging of the column occurred, the glass wool was replaced.

Complex formation also appears to occur between an ester and ferric chloride or the Grignard reagent; in fact, it seems probable that ester and Grignard reagent form an unreactive complex at −60°. It may be noted, in Runs I-11 to I-14, that addition of ester to the reaction lowers the yield as drastically as does dilution of the solution, in spite of the fact that the ester is recovered unchanged. The intermolecular effect of ester is similar to that of dilution, in that relatively little tertiary alcohol is formed, although the yield of ketone is substantially reduced. The existence of the ester effect is of particular significance if reaction with an ester acid chloride is desired. The more informative runs carried out with ester acid chlorides are summarized in Table III.

In the Grignard reaction with the ester acid chloride of suberic acid (Runs III-1 and III-2), results with and without ferric chloride are similar to those recorded in Table I (compare Runs I-1, I-6, and I-14 with III-1 and III-2). Addition of a small percentage of ferric chloride causes an increase in the yield of keto ester, as the ratio of hydroxy ester remains low; and addition of the ester function does not further lower the yield obtained in dilute solution. When the ester acid chloride of glutaric acid is used the results are rather different from those obtained with the suberic acid derivative. With the lower concentations of reactants (Runs III-3 to III-6), the yield of keto ester is improved very little by addition of a small amount of ferric chloride, and the amount of hydroxy ester becomes larger than that of keto ester. These results strongly suggest the formation of cyclic intramolecular complexes of ferric chloride with the ester acid chloride. Interestingly enough, at higher concentrations of reactants, the formation of larger amounts of hydroxy ester is eliminated, but

TABLE III

REACTION AT LOW TEMPERATURE OF BUTYLMAGNESIUM BROMIDE WITH ESTER ACID CHLORIDES[a]

Run No.	Mole % $FeCl_3$[b]	Ratio[b] of C_4H_9Br	Molar Concn.[c] Ester Acid Chloride	Yield Data,[d] %		
				Keto ester	Hydroxy ester	Half ester
1[a]	0	1.22	0.20	12	5	—
2[a]	2	1.22	.20	32	12	50
3	0	1.20	.20	6	8	—
4	2	1.20	.20	12	21	—
5[e]	2.5	1.15	.18	7	28	—
6	2	1.27	.37	11	24	—
7	2.5	1.20	.56	16	5	76
8	25.	1.20	.50	17	3	79
9	45	1.20	.50	38	5	54
10	55	1.20	.50	41	2	55
11	65	1.20	.50	32	0	65
12	75	1.20	.50	22	0	72
13	105	1.22	.05	6	0	—
14[f]	50	1.20	.60	38	0	51
15	50	1.80	.50	51	7[g]	25
16	50	2.10	.50	50	12[g]	20
17[h]	0	1.20	.50	4	39[g]	—

[a] Runs 1 and 2 utilized the methyl ester acid chloride of suberic acid; the other runs utilized the methyl ester acid chloride of glutaric acid. Reactions were carried out as described in the Experimental and as specified for Table I, note a. [b] Mole per cent of ferric chloride and ratio of butyl bromide are related to moles of ester acid chloride. [c] Molar concentration of ester acid chloride is based on total solvent, including that in which Grignard reagent is added. [d] Yield data were determined by gas chromatography, as described in Experimental. Half ester was not determined in runs where no entry appears in that column. [e] This run carried out at −25°. [f] Solvent for this run was a 1:1 mixture of tetrahydrofuran and toluene. [g] Gas chromatography showed 10–15% of higher molecular weight compounds, presumably resulting from further reaction of hydroxy ester with Grignard reagent. [h] After the usual procedure for reaction at −60°, the mixture was allowed to warm spontaneously to +10° (15 min. required, exothermic reaction), then heated under reflux for 30 min. During the reflux period, the condenser was attached to a trap cooled in Dry Ice–acetone. No volatile material was collected in the trap. The detected products of the reaction represented 93% of the butyl bromide used; whereas in the other runs in this table, only 5–55% of the butyl bromide was accounted for.

the yield of keto ester remains quite low (Run III-7). Furthermore, an increase of ferric chloride to 25% has little effect on the yield of keto ester, whereas the yield is increased more than two-fold at 45-55% ratio of ferric chloride. Decrease in yield at higher ratios of ferric chloride may be ascribed to reaction of the Grignard reagent with ferric chloride. Although there appears to be little hope for detailed correlation of these effects, it seems clear that the reaction mixtures contain numerous molecular complexes which are not in equilibrium with each other at the low temperature.

For synthesis of δ-keto esters, the best conditions appear to be those of Run III-15. The yield is less than may be obtained by use of an organocadmium reagent; however, application of the cadmium reagent is limited to aryl or *n*-alkyl groups.

EXPERIMENTAL

Materials. All starting materials were distilled through a 24-inch column of the simple Podbielniak type.[10] Capryl chloride, prepared from commercial capric acid by use of thionyl chloride, had b.p. 116°/24 mm., n_D^{25} 1.4393, infrared absorption 5.55 μ. Methyl caprate, prepared by esterification of commercial capric acid, had b.p. 100–101°/24 mm., n_D^{25} 1.4231, infrared absorption 5.74 μ. γ-Carbomethoxybutyryl chloride, prepared by way of the half ester by a procedure[11] similar to that described for β-carbomethoxypropionyl chloride, had b.p. 106.5°/19 mm., infrared absorption 5.55 and 5.74 μ. Methyl hydrogen suberate, prepared by controlled esterification of suberic acid by a procedure similar to that published[12] for ethyl half esters, had b.p. 155.5°/4 mm., n_D^{25} 1.4423, infrared absorption 5.74 and 5.85 μ. 7-Carbomethoxyheptanoyl chloride, prepared from the half ester with thionyl chloride, had b.p. 121°/5.5 mm., n_D^{25} 1.4479, infrared absorption 5.55 and 5.74 μ.

General procedure for Grignard reactions with acid chlorides. Results of reactions under specific conditions are summarized in Tables I and III. The general procedure is described.

An 0.02-mole sample of the acid chloride or ester acid chloride was dissolved in a mixture of dry ether and dry toluene and placed in a 60-ml., three necked round bottomed flask equipped with a sealed stirrer, a thermometer, a dropping funnel and a condenser which was connected to a nitrogen line. A nitrogen atmosphere was maintained throughout the procedure. The solution was cooled to −60°,[13] then anhydrous ferric chloride was added in those reactions in which the catalyst was employed. The ferric chloride was kept dry by weighing under 1 ml. of anhydrous toluene, then it was dissolved by addition of 2 ml. of ether, and this solution was added to the reaction flask. Next there was added dropwise, with stirring, a solution in 10 ml. of ether of Grignard reagent prepared from equimolar amounts of magnesium and distilled butyl bromide. Rate of addition was adjusted so as to allow maintaining of the temperature at −60° (30–60 min. required), then the mixture was stirred 30 min. after completion of addition. The reaction mixture was decomposed

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[10] J. Cason and H. Rapoport, *Laboratory Text in Organic Chemistry*, Prentice-Hall, Englewood Cliffs, N. J., 1950, p. 237.

[11] J. Cason, *Org. Syntheses*, **25**, 19 (1945).

[12] S. Swann, Jr., R. Oehler, and R. J. Buswell, *Org. Syntheses*, **Col. Vol. II**, 276 (1943).

[13] All specified reaction temperatures were maintained within a range of ±2°.

with ice and water, then acidified to Congo Red. The aqueous phase was separated and extracted with three 15-ml. portions of ether. The original organic phase and the extracts were washed with two 30-ml. portions of water and one 30-ml. portion of saturated sodium chloride solution. After the total extracts had been dried over anhydrous sodium sulfate, the volume was adjusted to 100 ml. and aliquots of this solution were used for gas chromatography as described below.

Analysis of reaction mixtures by gas chromatography. Chromatography was on silicone grease partitioning agent, prepared as previously described[14]; column, 1.5 m. × 8 mm. o.d. Pyrex glass; temperature 190–225°; helium flow rate, 85–90 ml./min.; pressure, 16–17 cm. mercury. Quantitative analysis was based on comparison of areas under peaks obtained from the reaction mixture with areas under peaks obtained from injection of solutions of known concentration in the respective components. The reference solutions were always injected sequentially with the unknowns, and components for preparing these solutions were usually obtained by collecting samples corresponding to the respective peaks during gas chromatography of reaction mixtures. Separation of samples was usually accomplished by chromatography on a 3-m. × 15 mm. o.d. column. Purity of the collected material was checked by rechromatography.

Reactions with capryl chloride. Gas chromatography at 200° showed three peaks beyond the solvent peak. Peak 1, retention time (from point of injection to maximum in peak) 3:13 (min., sec.), gave the same retention time and peak shape as capric acid. Peak 2, retention time 6:23, showed a carbonyl band in the infrared at 5.84 μ and gave a negative test for unsaturation with bromine in carbon tetrachloride; so it was assigned to 5-tetradecanone. Peak 3, retention time 9:30 gave a positive test for unsaturation; so it was assigned to the mixture of olefins resulting from dehydration of the tertiary alcohol.

In runs in which methyl caprate was included, chromatography was carried out at 165° in order to permit good separation of the ester from the acid. Typical retention times were: methyl caprate, 6:18, capric acid, 8:21.

Reactions with 7-carbomethoxyheptanoyl chloride. Gas chromatography at 225° showed three peaks. Peak 1, retention time 3:18, had the same retention time and peak shape as methyl hydrogen suberate. Peak 2, retention time 5:42, showed carbonyl absorption in the infrared at 5.75 and 5.84 μ, and gave a negative test for unsaturation; so it was assigned to the keto ester. Peak 3, retention time 9:18, showed carbonyl absorption at 5.75 μ only and gave a positive test for unsaturation; so it was assigned to the unsaturated esters resulting from dehydration of the hydroxy ester.

Reactions with γ-carbomethoxybutyryl chloride. Chromatography at 190° gave four peaks. Peak 1, retention time 2:15, could be removed by extraction of the solution with sodium carbonate; so it was assigned to methyl hydrogen glutarate. Peak 2, retention time 4:03, showed carbonyl absorption in the infrared at 5.75 and 5.84 μ, and gave a negative test for unsaturation; thus it was assigned to the keto ester. Peak 3, retention time 7:12, showed carbonyl absorption in the infrared at 5.75 μ only, and gave a positive test for unsaturation; so it was assigned to the unsaturated esters resulting from dehydration of the hydroxy ester. Peak 4, retention time 12:45, was assigned to the hydroxy ester. On chromatography at higher temperature, peak 4 was diminished or eliminated, with a proportionate increase in Peak 3. The total from peaks 3 and 4 is reported as hydroxy ester in Table III.

Solubility behavior of ferric chloride and γ-carbomethoxybutyryl chloride in ether-toluene. An 0.55-g. sample of anhydrous ferric chloride was weighed under 3 ml. of dry toluene, then 20 ml. of dry ether was added to dissolve the ferric chloride. This solution was centrifuged, then the clear supernatant solution was added by pipette to a solution of 0.54 g. of γ-carbomethoxybutyryl chloride at room temperature. When the mixed solution was allowed to separate by standing, a small dark-colored liquid layer separated below the larger yellow layer. The dark layer was insoluble in ether, toluene, or water; however, the water with which the dark layer was shaken became yellow, and the organic layer became soluble in ether or toluene.

When the original two-phase solution was cooled with stirring to −60°, a homogeneous green solution was formed. Re-warming of the homogeneous solution caused separation into two phases again.

If initial mixing of the solution, as described above, were at −60°, the homogeneous solution formed directly, but separation into two phases occurred on warming.

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(14) J. Cason and W. T. Miller, *J. Org. Chem.*, **24**, 1814 (1959).

[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF THE UNIVERSITY OF CALIFORNIA]

Mechanism of the Reactions of Grignard Reagents and of Organocadmium Reagents with Acid Chlorides in Presence of Ferric Chloride

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Both Grignard and organocadmium reagents, at −10° in presence of ferric chloride, will react with the ester acid chloride of an unsymmetrical dibasic acid without rearrangement, provided that the acid chloride function is unhindered. If the acid chloride is hindered, yield in the reaction is very low, and rearrangement occurs. These data are interpreted as indicating a dual reaction path. One route (leading to rearrangement) involves formation of an intermediate acylonium ion, as previously suggested, while the other route is an assisted reaction in which halogen is extracted by the Lewis acid from the acid chloride, as the alkyl of the organometallic reagent attacks the carbonyl carbon. It is proposed that inactivation of the components of these reactions at low temperature is caused by formation of a cyclic complex containing the acid chloride (or an ester), the Lewis acid, and the organometallic reagent. Use of the organocadmium reagent in presence of ferric chloride at low temperature appears to be the preferred method for avoiding rearrangement in reaction with the ester acid chloride of an unsymmetrical dibasic acid; however, the acid chloride function must be unhindered.

In a previous report,[2] it was suggested that the Grignard reaction with an acid chloride in the presence of ferric chloride proceeds by a mechanism similar to that which had been proposed[3] for reaction of the organocadmium reagents. According to this mechanism, the function of the ferric chloride