

Anal. Calcd. for $C_{16}H_{22}ClNO_2$: Cl, 11.99; N, 4.74. Found: Cl, 12.29; N, 4.94.

3-p-Chlorophenyl-3-(β-diethylaminoethyl)-2-pyrrolidinone. Conversion of 4 g. (0.016 mole) of the lactone gave 2.2 g. (48%) of the pyrrolidinone which boiled at 175–180° (0.2 mm.).

Anal. Calcd. for $C_{16}H_{23}ClN_2O$: C, 65.23; H, 7.87; N, 9.50. Found: C, 64.95; H, 7.67; N, 9.11.

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Derivatives of Ferrocene. V. The Preparation of Some *N*-Substituted Ferrocenecarboxamides¹

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Many years ago Leuckart reported that the reaction of benzene with phenyl isocyanate in the presence of aluminum chloride produced good yields of benzanilide.² Leuckart extended the reaction to other benzene derivatives as well as to thiophene.^{3,4} Since the original references, however, this convenient preparation of anilides has seldom been reported in the chemical literature.⁴

It was of interest to us to determine if this reaction of phenyl isocyanate with aluminum chloride could be applied to the aromatic-type compound ferrocene, and further, to determine if other alkyl and aryl isocyanates could be reacted in a similar manner. As is indicated in Table I, the reaction of ferrocene with various alkyl and aryl isocyanates in the presence of aluminum chloride appears to be a general method for the preparation of *N*-alkyl- and *N*-arylferrocenecarboxamides. The yields are very satisfactory when compared to other methods of synthesis (see below), especially the yields based on the readily recovered, unreacted ferrocene.

(1) Presented in part before the Division of Organic Chemistry at the 131st Meeting of the American Chemical Society, Miami, Fla., April 10, 1957.

(2) R. Leuckart, *Ber.*, **18**, 873 (1885).

(3) R. Leuckart and M. Schmidt, *Ber.*, **18**, 2338 (1885).

(4) There has just appeared an article in which *N*-phenylferrocenecarboxamide (m.p. 205–207°) was prepared by this procedure, in order to prove that the Beckmann rearrangement product of the *p*-toluenesulfonate of benzoylferrocene oxime was this same anilide: N. Weliky and E. S. Gould, *J. Am. Chem. Soc.*, **79**, 2742 (1957).

The reaction of ferrocenoyl chloride with aniline produced *N*-phenylferrocenecarboxamide in 19% yield. During the preparation of the acid chloride from carboxyferrocene and phosphorus pentachloride, however, appreciable decomposition occurred. This fact may be responsible for the low yield of the anilide. *N*-Phenylferrocenecarboxamide was also isolated in 9.7% yield from the reaction of lithioferrocene with phenyl isocyanate, followed by chromatography on alumina.

The stability of the *N*-substituted ferrocene carboxamides was determined under both basic and acidic conditions. Of the two possible methods for determining the stability, *i.e.* the determination of the amine produced or the determination of the amount of carboxamide remaining, the latter procedure was employed for convenience. The extensive decomposition of the carboxylic acid in the hydrolytic media precluded its use in a quantitative determination.

As can be seen from Table II, the *N*-aryl and the *N*-octadecyl compounds are quite stable under vigorous hydrolysis conditions, whereas the *N*-ethyl derivative was partially degraded in alkali, and no starting material was recovered from the acid treatment. The stability of these amides may be due in part to their insolubility in the hydrolytic medium; however, it was noted that all of the amides exhibited some solubility in the aqueous ethanol, and the *N*-ethyl derivative was nearly completely soluble at room temperature.

EXPERIMENTAL⁵

Starting materials. The phenyl, 4-bromophenyl, 4-biphenyl, 1-naphthyl and ethyl isocyanates used were Eastman reagents. The *n*-octadecyl isocyanate was a gift from Mr. Milton Kosmin, Monsanto Chemical Company, Dayton, Ohio, and was distilled before use, b.p. 145–147°/0.045 mm. Ferrocene was generously supplied by Dr. R. L. Pruett, Linde Air Products Company, Tonawanda, N. Y. Carboxy- and 1,1'-dicarboxyferrocene were prepared by a modification⁶ of the procedure originally reported by Benkeser *et al.*⁷

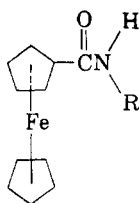
Preparation of N-substituted ferrocenecarboxamides from ferrocene, aluminum chloride, and isocyanates. All compounds listed in Table I were prepared by essentially the same procedure, using a slight excess of both aluminum chloride and isocyanate to ferrocene. The preparation of *N*-4-bromophenylferrocenecarboxamide is given as a typical example.

A solution of 21.8 g. (0.11 mole) of 4-bromophenyl isocyanate and 14.7 g. (0.11 mole) of anhyd. aluminum chloride in 400 ml. of methylene chloride (dried over calcium hydride) was added with stirring under a nitrogen atmosphere and over a period of 30 min. to a solution of 18.6 g. (0.10 mole) of ferrocene in 200 ml. of the same solvent. The reaction mixture was stirred at room temperature for 20 hrs., hydrolyzed with 200 ml. of 10% hydrochloric acid and filtered, leaving 10.0 g. of a yellow-brown crystalline solid. The filtrate was separated into phases, the organic phase

(5) All analyses were performed by the Schwarzkopf Microanalytic Laboratory, Woodside 77, N. Y.

(6) D. W. Mayo, P. D. Shaw, and M. D. Rausch, *Chem. & Ind. (London)*, 1388 (1957).

(7) R. A. Benkeser, D. Goggin, and G. Schroll, *J. Am. Chem. Soc.*, **76**, 4025 (1954).

TABLE I
 N-SUBSTITUTED FERROCENECARBOXAMIDES^a


R	Physical Appearance	M.P., ^e °C.	Con- ver- sion, %	Yield, ^h %	C	Caled.			Analyses			
						H	Fe	N	C	H	Fe	N
Phenyl	Orange needles ^b	215–216 ^f	57	67	66.91	4.96	18.30	4.59	67.14	5.23	18.31	4.43
									67.03	5.20	18.35	4.59
4-Bromophenyl	Orange crys- tals ^b	239–240 ^f	47	66	53.16	3.67	14.54	3.65	53.12	3.79	14.36	3.49 ⁱ
									53.23	3.83	14.37	3.70
4-Biphenyl	Orange-red crystals ^b	242.5–243.5 ^f	23	68	72.46	5.02	14.65	3.67	73.11	5.02	14.25	3.79
									72.94	5.20	14.18	3.83
1-Naphthyl	Golden-brown powder ^c	>280 ^g	39	51	71.01	4.82	15.72	3.94	70.93	4.95	15.63	3.99
									70.82	5.02	15.67	3.71
Ethyl	Yellow-orange needles ^b	164.4–164.8	30	37	60.73	5.88	21.72	5.45	60.89	5.99	22.00	5.69
									60.72	5.85	22.00	5.47
<i>n</i> -Octadecyl	Light-yellow powder ^d	116.8–117.0	58	63	72.33	9.84	11.60	2.91	72.45	9.96	11.37	3.00
									72.42	9.91	11.35	3.18

^a Carbonyl absorption occurred in all cases at 1635 cm.⁻¹ except for the 1-naphthyl (1630) and *n*-octadecyl (1625). ^b From 95% ethanol. ^c From methyl isobutyl ketone. ^d From ligroin, b.p. 66–75°. ^e All melting points are corrected. ^f Melts with decomposition. ^g Slowly chars on heating over 280°. ^h Yield based on recovered ferrocene. ⁱ Br, calcd. 20.81; found, 20.69, 20.89. ^j Using a 2.5 molar excess of both ethyl isocyanate and aluminum chloride.

 TABLE II
 STABILITY OF N-SUBSTITUTED FERROCENECARBOXAMIDES

Compound	Acidic	Basic
	Hydrolysis ^a Amide	Hydrolysis ^b Amide
	Recovered, %	Recovered, %
<i>N</i> -Phenylferrocenecarboxamide	64	93
<i>N</i> -4-Bromophenylferrocenecarboxamide	91	91
<i>N</i> -4-Biphenylferrocenecarboxamide	98	100
<i>N</i> -1-Naphthylferrocenecarboxamide	88	96
<i>N</i> -Ethylferrocenecarboxamide	0	81
<i>N</i> - <i>n</i> -Octadecylferrocenecarboxamide	98	99

^a In 30 ml. of 6*N* aqueous-ethanolic hydrochloric acid (2:1). ^b In 30 ml. of 39% aqueous-ethanolic potassium hydroxide (2:1).

was washed several times with water, and the solvent was evaporated. The resulting residue was combined with the filtered material, and this mixture was extracted four times with 10-ml. portions of hot ligroin, b.p. 66–75°, to remove the unreacted ferrocene⁸; after recrystallization, 3.40 g. of ferrocene was recovered. The crude product remaining after ligroin extraction was recrystallized once from acetone and once from 95% ethanol to produce 14.6 g. of *N*-4-bromophenylferrocenecarboxamide, described in Table I. From the blue acidic phase and washings, after reduction with zinc dust, was obtained an additional 1.85 g. of ferrocene, for a total ferrocene recovery of 5.25 g.

(8) In the preparation of *N*-ethyl- and *N*-*n*-octadecylferrocenecarboxamide this step was omitted, due to the solubility of these products in hot ligroin.

During one preparation of *N*-phenylferrocenecarboxamide, the reaction mixture was stirred at reflux overnight instead of at room temperature. The yield of product did not appear to increase, and the product obtained was less pure than that obtained from the room temperature reaction.

Several reactions of ferrocene with a 2.5 molar excess of both phenyl isocyanate and aluminum chloride failed to produce the expected *N,N'*-diphenylferrocenedicarboxamide. Similar experiments using ethyl isocyanate were also not successful. It should be pointed out that Leuckart was likewise not successful in introducing more than one carboxyanilide group into biphenyl.²

Preparation of N-phenylferrocenecarboxamide from carboxyferrocene and aniline. Ferrocene monocarboxylic acid (1.5 g.) was suspended in 10 ml. of benzene followed by the addition of 1.5 g. of phosphorus pentachloride. An immediate exothermic reaction took place with the evolution of gas and within a few minutes the solid mixture had completely dissolved. The clear dark red solution was shaken for 3 hr. and then the solvent removed under reduced pressure. The black tarry residue was treated with a solution of 2 g. of aniline dissolved in 10 ml. of benzene. The mixture was warmed on the steam bath for 3 min. and then diluted with 300 ml. of benzene, followed by 30 ml. of water. The phases were separated and the organic layer washed, first with dilute hydrochloric acid (15 ml.), then with dilute sodium hydroxide (15 ml.), and finally with distilled water (20 ml.). The benzene solution was dried over anhydrous magnesium sulfate and the solvent removed under reduced pressure yielding a dark amorphous solid. One crystallization from benzene gave *N*-phenylferrocenecarboxamide (370 mg., 19% yield) as orange needles, m.p. 212–213°.

Reaction of lithio- and dilithioferrocene with phenyl isocyanate. A solution of 8.18 g. (0.044 mole) of ferrocene in 250 ml. of freshly distilled tetrahydrofuran was added, with stirring and under a nitrogen atmosphere, to 330 ml. of 1.06 molar *n*-butyllithium in ethyl ether at –40°. The reaction mixture was slowly warmed to room temperature (about 2.5 hr.) and stirred at room temperature for an

additional 1.5 hr. The resulting solution of mono- and dilithioferrocene was transferred to an addition funnel and rapidly added (15 min.) to a solution of 47.8 g. (0.40 mole) of phenyl isocyanate in 200 ml. of ethyl ether. Vigorous refluxing occurred during the addition. The orange reaction mixture was stirred at room temperature for 20 hr. and then hydrolyzed with 250 ml. of 10% hydrochloric acid. The phases were separated, the aqueous phase was extracted with ether, and the combined ether portion was dried over anhyd. sodium sulfate. After the solvent was evaporated, the residue was extracted five times with 100-ml. portions of hot ligroin, b.p. 66–75°. The yellow powder which remained weighed 30.0 g.

One-half (15.0 g.) of the above mixture was washed with 50 ml. of chloroform and filtered from 1.8 g. of an insoluble white solid, identified as *sym*-diphenylurea, m.p. 238–239°. The chloroform solution was placed on a 4 × 75 cm. column packed with activated alumina, and the mixture chromatographed using benzene and benzene-chloroform mixtures. Two bands developed, a broad yellow band followed by a bright orange band.

From the first band, after recrystallization of the product from 95% ethanol, 0.65 g. of *N*-phenylferrocenecarboxamide, m.p. 214–215°, was obtained. On this basis, the yield of *N*-phenylferrocenecarboxamide was 9.7%. Mixed melting points with samples of this anilide obtained from the other procedures were undepressed, and the infrared spectra (cesium bromide pellets) of all three anilides were identical.

From the second band was obtained a very small amount of material, which after recrystallization from chloroform

produced about 0.03 g. of an orange crystalline solid. This material has not as yet been characterized.

Attempted alkaline hydrolysis of N-substituted ferrocenecarboxamides. Each of the *N*-substituted ferrocenecarboxamides (1.00 g.) listed in Table I was suspended in 30 ml. of a 2:1, water:95% ethanol solution containing 11.7 g. of potassium hydroxide. The mixtures were refluxed for 24 hr., cooled to room temperature and filtered to remove unreacted starting material. The residues were washed with water and the washings combined with the filtrates. These solutions were cooled in an ice bath and acidified with concentrated hydrochloric acid to give only a trace of a red-brown precipitate. The unreacted starting material was dried and weighed.

Attempted acid hydrolysis of N-substituted ferrocenecarboxamides. Each of the *N*-substituted ferrocenecarboxamides (1.00 g.) listed in Table I was suspended in 30 ml. of a 2:1, water:95% ethanol solution, 6*N* in hydrochloric acid and the mixtures refluxed for 16 hr. They were then cooled to room temperature and filtered. The filtrates were discarded, and the residues were suspended in 20 ml. of a 5% aqueous solution of sodium carbonate. The mixtures were allowed to stand at room temperature with occasional stirring for 3 hr. and then filtered. The colorless filtrates were discarded, and the residues were dried and weighed.

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