INTRODUCTION OF AROMATIC AND HETEROCYCLIC RADICALS INTO FERROCENE. THE REACTION OF BROMOFERROCENE WITH ORGANOMAGNESIUM COMPOUNDS

Chemistry

1965

SovietRxiv

Abstract

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UDC 547.257.2 + 547.254.6

Chemistry

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INTRODUCTION OF AROMATIC AND HETEROCYCLIC RADICALS INTO FERROCENE. THE REACTION OF BROMOFERROCENE WITH ORGANOMAGNESIUM COMPOUNDS

In our previous papers we described the replacement of halide in haloferrocenes by various groups under the action of copper salts (^{1}). Through halogen derivatives of ferrocene it proved possible to carry out the synthesis of oxyferrocene, 1,1′-dioxyferrocene, ferrocenylamine, diferrocenylamine, phenylferrocenylamine, diphenylferrocenylamine, ferrocenyl azide (with subsequent conversion to diazo compounds of ferrocene), ferrocenyl aryl sulfones, and other ferrocene derivatives.

We have also shown that, on heating bromoferrocene with tetraaryl- and tetraheterocyclylboron salts in the presence of cuprous bromide, bromine is replaced by aromatic and heterocyclic radicals (^{2}). This reaction is of interest for obtaining heterocyclic derivatives of ferrocene; as regards arylferrocenes, in this case the most widely used method of synthesis is the arylation of ferrocene with aryldiazonium salts.

In the present work the reaction of bromoferrocene with organomagnesium compounds has been investigated.

If an ethereal solution of a Grignard reagent is added to a mixture of bromoferrocene, cuprous bromide, and copper, and the ether is then distilled off and the reaction mixture heated under nitrogen at 130°, phenyl-, α-thienyl-, and α-naphthylferrocenes are obtained in 75–85% yield:

$$\mathrm{BrFc} + \mathrm{ArMgBr} \xrightarrow{\mathrm{Cu_2Br_2{+}Cu}} \mathrm{ArFc}$$

In the case of an alicyclic Grignard reagent, cyclohexylmagnesium chloride, the reaction proceeds differently: the principal reaction becomes the reduction of bromoferrocene to ferrocene; cyclohexene was also isolated from the reaction mixture.

As we showed earlier, sodium pyrrole reacts with bromoferrocene in the presence of cuprous bromide to form N-pyrrolylferrocene (²). On interaction of bromoferrocene with pyrrolylmagnesium bromide in the presence of $Cu_2Br_2 + Cu$, however, a mixture of α- and β-pyrrolylferrocenes is formed:

$$\text{BrFc} + \text{(pyrrolyl)MgBr} \xrightarrow{Cu_2Br_2+Cu} \alpha\text{-pyrrolylFc} + \beta\text{-pyrrolylFc}$$

This difference in the behavior of sodium pyrrole and pyrrolylmagnesium bromide is fully analogous to the results obtained in the action of alkyl halides on these organometallic compounds (³).

α- and β-pyridylferrocenes were separated chromatographically on Al_2O_3 by elution with a heptane–benzene mixture (4 : 1), with α-pyridylferrocene being eluted first.

The structure of the compounds obtained was determined on the basis of NMR spectra*. In the spectrum of N-pyrrolylferrocene, the pyrrole protons form two peaks of equal intensity: α-protons at δ 6.92, β-protons at δ 6.18. In the spectrum of α-pyridylferrocene, the intensity ratio of the peaks of the α-protons (δ 6.70) and β-protons (δ 6.12) is 1 : 2; in the spectrum of β-pyridylferrocene the reverse picture is observed: the ratio of the areas of the α-protons (6.68) and β-protons (6.23) is 2 : 1.

Bromoindolylmagnesium behaves somewhat differently in this reaction:

$$\text{BrFc} + \text{IndolylMgBr} \xrightarrow{Cu_2Br_2+Cu} \text{N-indolylferrocene} + \beta\text{-indolylferrocene}$$

in this case N- and β-indolylferrocenes are formed.

In the NMR spectrum of β-indolylferrocene there is no β-proton peak at δ 6.50.

Experimental Part

1. Phenylferrocene. Phenylmagnesium bromide, obtained from 1.20 g of bromobenzene and 0.4 g of magnesium in 15 ml of anhydrous ether, was added to a mixture of 0.5 g of bromoferrocene, 0.1 g of cuprous bromide, and 0.05 g of molecular copper. The solution thereby became dirty green. Air was displaced with nitrogen, the ether was distilled off, and the reaction mixture was heated on a silicone bath at 130° for 40 min. After cooling of the reaction mixture, ether was added, then water and dilute HCl were added dropwise; the ether layer was separated, washed with water, dried over $MgSO_4$, the ether was distilled off, and the residue was chromatographed on Al_2O_3 in heptane. First a mixture of bromoferrocene and ferrocene was eluted, then diphenyl and finally phenylferrocene; yield 0.37–0.40 g (75–81% of theory), mp 110–111° (from alcohol), gives no melting-point depression with an authentic sample. Lit.: mp 110-111° (^{4}).

2. ***α*-Thienylferrocene.** *α*-Thienylmagnesium iodide, obtained from 1.75 g of *α*-iodothiophene and 0.4 g of magnesium in 15 ml of anhydrous ether, was added to a mixture of 0.5 g of bromoferrocene, 0.1 g of cuprous bromide, and 0.05 g of molecular copper. The reaction and separation of the reaction mixture were carried out in the same way as for phenylferrocene. 0.44 g (87% of theory) of *α*-thienylferrocene was obtained, mp 116.5-117.5° (from alcohol); with an authentic sample, obtained by us earlier (^{1}), it gives no melting-point depression.

3. ***α*-Naphthylferrocene.** *α*-Naphthylmagnesium bromide, obtained from 1.55 g of *α*-bromonaphthalene and 0.4 g of magnesium in 15 ml of anhydrous ether, was added to a mixture of 0.5 g of bromoferrocene, 0.1 g of cuprous bromide, and 0.05 g of molecular copper. The reaction and separation of the reaction mixture were carried out in the same way as for phenylferrocene. 0.43 g (73% of theory) of *α*-naphthylferrocene was obtained, mp 93.5-94.5° (from methanol). Lit.: mp 93-95° (^{5}).

Found, %: C 76.81; 76.76; H 5.31; 5.17; Fe 17.59; 17.87
$C_{20}H_{16}Fe$. Calculated, %: C 76.94; H 5.17; Fe 17.89

4. ***α*- and *β*-Pyridylferrocenes.** Pyridylmagnesium bromide, obtained from 1.35 g of pyrrole, was added to a mixture of 1 g of bromoferrocene, 0.2 g of cuprous bromide, and 0.05 g of molecular copper. Air was displaced with nitrogen, ether—distilled off, and the reaction mixture was heated on a silicone bath at 120° for 40 min. After cooling, ether and water were added; the reaction mixture was filtered off and thoroughly washed on the filter with benzene; the organic layer was separated, washed with water, and dried with $MgSO_4$. After removal of the solvent the residue was triturated with Al_2O_3 and chromatographed. Heptane first elutes a mixture of bromoferrocene and ferrocene, then a little diferrocenyl, and benzene elutes pyrrolylferrocenes. After repeated chromatography on Al_2O_3 ($l = 65$, $d = 1.6$ cm, activity III-IV) with a heptane—benzene mixture (4 : 1), a band of *α*-pyrrolylferrocene is eluted first, and then *β*-pyrrolylferrocene. Yield of *α*-pyrrolylferrocene 0.07 g (15% of theory), mp 148-149.5° (under N_2) (from hexane).

Found, %: C 66.81; 67.03; H 5.37; 5.33; Fe 22.29; 22.27
$C_{14}H_{13}FeN$. Calculated, %: C 66.96; H 5.22; Fe 22.24

Yield of *β*-pyrrolylferrocene 0.05 g (11% of theory), mp 118-188.5° (under N_2) (from hexane).

* The authors express their gratitude to V. I. Sheichenko, a member of the physicochemical research laboratory of the Institute of Chemistry of Natural Compounds, Academy of Sciences of the USSR, where the NMR spectra were measured. All spectra were recorded at 60 MHz in $CDCl_3$, using tetramethylsilane as internal standard.

Found, %: C 67.01; 66.91; H 5.24; 5.14; Fe 22.19; 22.48
$C_{14}H_{13}FeN$. Calculated, %: C 66.96; H 5.22; Fe 22.24

5. **N- and β-Indolylferrocenes.** Indolylmagnesium bromide, prepared from 0.88 g of indole, was added to a mixture of 0.5 g of bromoferrocene, 0.1 g of cuprous bromide, and 0.05 g of molecular copper. The reaction and decomposition of the reaction mixture were carried out in the same way as in the preparation of pyrrolylferrocenes. On chromatography on Al_2O_3 ($l = 65$, $d = 1.6$ cm, activity III-IV), heptane first eluted a mixture of bromoferrocene and ferrocene (0.24 g), then 0.02-0.03 g of diferrocenyl, and then 0.08-0.09 g (14-16% of theory) of N-indolylferrocene, mp 89-90°; with an authentic sample prepared by us earlier ([1]), it gives no melting-point depression. A heptane—benzene mixture (1 : 1) elutes first indole and then β-indolylferrocene, yield 0.06 g (11% of theory), mp 133-134.5° (under N_2) (from hexane).

Found, %: C 72.14; 72.04; H 4.92; 4.99; Fe 18.58; 18.47; N 4.72
$C_{18}H_{15}FeN$. Calculated, %: C 71.78; H 5.02; Fe 18.55; N 4.65

6. **Reaction of cyclohexylmagnesium chloride with bromoferrocene in the presence of a copper catalyst.** Cyclohexylmagnesium chloride, prepared from 0.90 g of chlorocyclohexane and 0.4 g of magnesium in 15 ml of absolute ether, was added to a mixture of 0.5 g of bromoferrocene, 0.1 g of cuprous bromide, and 0.05 g of molecular copper. The air was displaced with nitrogen, and the ether was distilled off from the reaction mixture. As the temperature is raised, cyclohexene begins to distill off together with the ether. The reaction mixture was then heated at 130° for 40 min. After the usual work-up and chromatography on Al_2O_3, 0.28 g (80% of theory) of ferrocene was isolated, mp 171-173° (from methanol).

To the ethereal distillate was added a solution of 2 g of mercuric acetate in 30 ml of methanol; after 2 days the solution was filtered, evaporated to $ 10*ml*, *andpouredintoa*10^6$).

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Received
28 V 1965

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Note: Figure translations are in progress. See original paper for figures.