

The Synthesis of Ferrocene, Cymantrene and their Various Carbonyl Derivatives, Comparative Analysis of Smoke Reducing Properties of these Compounds

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Abstract – The paper mainly studies the synthesis of new alkyl, oxyalkyl, carbinol (carbinolate) cluster and binuclear derivatives of ferrocene carbinol and carbinolate derivatives of cymantrene. We presented the data on preparation of nanocomposite solutions used as neutralizers of exhaust gases for diesel fuels. Some aspects of producing non-waste technologies of ferrocene (cymantrene) and some of its derivatives were also studied.

Keywords – The Synthesis of Various New Ferrocene and Cymantrene Derivatives, Nanocomposite Solutions, Carbinolcarbinolate Derivatives of Ferrocene (Cymantrene), Antidetonation and Neutralizers of Exhaust Gases of Motor and Diesel Fuels.

I. INTRODUCTION

It is known from literature that ferrocene is a potential smoke reducer for hydrocarbon containing fuels, while cymantrene is more effective antidetonator [1, 2].

Recently, definite reorientation of research work caused by both development of technology, and increase of demands to ecologically pure fuels and their combustion products has occurred due to complication of ecological problems caused mostly by motor vehicles [3].

In this connection, the search and use of new ecologically safe and more effective organometallic (aliphatic, cyclic, heterocyclic) compounds and their derivatives with various functional groups of most transition metals is present [4].

Such type highly soluble organometallic compounds, in relevant hydrocarbon fuels, due to its high dispersity are effective neutralizers of unburned residues that are thrown into atmosphere by engines.

The present work deals with the synthesis of new carbinol (carbonilate) derivatives of industrial organometallic compounds of ferrocene $(C_6H_6)_2Fe$ and cymantrene $(OC)_3MnC_5H_5$ and studying the use of nanocomposite solutions as combustion catalysts and carbon deposition with low-octane number of diesel and motor fuels.

If we consider that at present hazardous substances of exhaust gases, particularly unburned residues of diesel and non-standard motor fuels which contaminate air are most pressing and urgent problems of ecology [5]. Great flow of motor vehicles led to that the pollution level of atmosphere in major industrial cities is 5-10 times higher than the sanitary norms.

Fuel resource shortages have also increased due to impetuous growth of transport fleet which account for about 50% of atmospheric pollution with nitrogen oxide, carbon compound [6].

Under modern conditions expensive rhodium-platinum (palladium-ruthenic) catalysts are used as neutralizers for exhausted gases of both gasoline automobiles and piston engine vehicles [7-8].

As many researchers state, effective work of such catalysts are provided only with complex microprocessor system with feedback fuel supply [9].

The quality of diesel and nonstandard motor fuels are of special interest. Their exhaust gases contain various unburned organic compounds, and under solar light, rains and other factors, they turn to complex and hazardous substances. Therefore, the aim of these investigations is directed to the search of cheaper and ecologically pure neutralizers for exhaust gases of diesel and motor fuels.

II. EXPERIMENTAL PART

1. Synthesis of carbinol, carbonilate derivatives of ferrocene (cymantrene) I-IV, $LMC_5H_4C(R_1R_2)OH$ (I-III); $LMC_5H_4C(R_1R_2)OLi$ (II, IV); $LM = C_5H_5Fe, (OC)_3Mn$; $R_1 = R_2 = Ar, alk$. Above mentioned derivatives of ferrocene and cymantrene were obtained by using the reaction (1) between lithic organometallic compounds of ferrocene $C_5H_5FeC_5H_4Li$ (cymantrene, $(OC)_3MnC_5H_4Li$) obtained by method [10] and some aromatic and aliphatic ketons. For this purpose, first 0.1 mol of ferrocene (cymantrene) is metallated with 25 ml of 1, 2NH-BuLi, then at below zero temperature ($-10^\circ C$) it is processed with 0.1 mol of carbonyl compound. After relevant processing of reaction solution, I-IV compound is obtained.
2. Synthesis of carbinol derivatives of ferrocene under phase-transfer catalysis. For this purpose, first, immiscible diphasic system (water/petroleum ether) is created; the lower layer is inorganic, but upper layer is organic phase. Symmetrical and nonsymmetrical ketones are introduced into organic phase, but catalyst (H_2SO_4) and carrier (DTNat) is introduced into aqueous phase with ratio 2:1 correspondingly. After processing and neutralization of reaction mixture with $NaHCO_3$ we obtained corresponding carbinol ferrocenyl (I, III).
3. Preparation and use of nanocomposite solutions containing ferrocene (cymantrene) and their derivatives.

For preparation of relevant nanocomposite solution, first 0.1 mol of composite forming agent (ferrocene (cymantrene) or its derivatives) is dissolved in 30ml of solvating organic solvent and then 10ml of antioxidant is added to it, after that 70ml of diluent is added. Obtained homogeneous solution is mixed at speed of 3600rev/min. for an hour. The solution attained a light yellow color. In case of cymantrene and its derivatives, nanocomposite solution is stored in darkness or 3-5% of light-resistant stabilizer is added. Such solutions quickly become turbid and lose their catalytic activity.

Determination of exhaust was performed by using Bosch method on motor D-20. The method consists of transmission of certain amount of exhaust motor gases through filtering material and measurement by weighting, in mg, amount of furnace black in 1 l gas.

III. RESULTS AND DISCUSSION

It is considered that 0.5-1% (mass) of various additives are added into fuels to improve the combustion of hydrocarbon fuels and to decrease the amount of smoke in exhaust gases. Sulfates, sulfites, metal carbonates of 1st and 2nd group elements of periodic table (Li, K, Na, Ba, Ca and Cu) are used as such type additives. Barium containing additive 'CLD' (Belgium), additives "Lubrizon-565 (SVIA)" and "IKhP-706" of the institute of Chemistry of Additives of NAS of Azerbaijan are widely used as antismoke and carbon deposition additives.

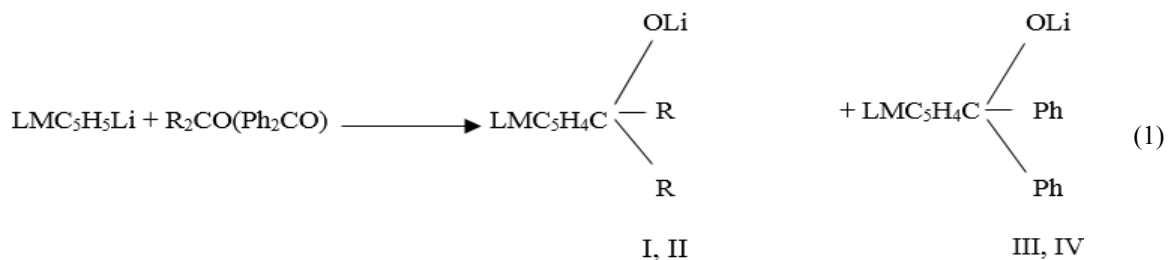
Antismoke effect of ferrocene and its methyl (ethyl) alkyl derivatives were compared to the effectiveness of above mentioned antismoke additives.

Results of experiments on sample of diesel fuel LDT in the work [11, 12] were compared to the above mentioned data (see table 1) [28].

Table 1. Smoke Reducing Effect of Ferrocene and its Derivatives.

No.	Fuel mixture	Amount of ferrocene or its derivatives, % mass	Decrease of smokiness, %
1	LDT	Without ferrocene and other additives, % mass	80
2	LDT + 0, 05% (mass)	ferrocene	55
3	LDT + 0, 1% (mass)	ferrocene	48
4	LDT + 0, 2% (mass)	ferrocene	50
5	LDT + 0, 05% (mass)	Methyl ferrocene	38
6	LDT + 0, 10% (mass)	Ethyl ferrocene	47
7	LDT + 0, 30% (mass)	Ethyl ferrocene	52
8	LDT + 0, 05% (mass)	1,1 dibutylferrocene	40
9	LDT + 0, 10% (mass)	1,1 dibutylferrocene	45
10	LDT + 0, 30% (mass)	1,1 dibutylferrocene	55
11	LDT + 0, 5% (mass)	“SLD”	50
12	LDT + 0, 5% (mass)	“Lubrizol 565”	50
13	LDT + 0, 5% (mass)	IKhP-706	47

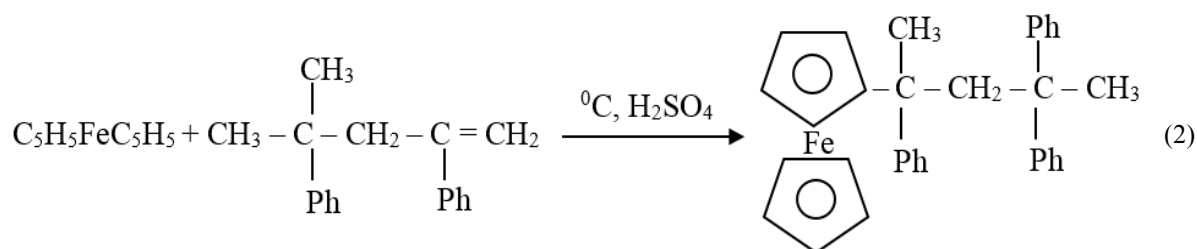
As table 1 shows, by adding LDT of 0.05% ferrocene to the composition, the amount of smoke is decreased by up to 50%, but for achieving 10 times more, antismoke additives “Lubrizol-565”, “SLD” and additive IKhP-706 must be used. Together with exhaust gases, tens of thousands of barium sulfate, as well as 25% of toxic carbonate inorganic compounds are thrown into atmosphere. However, in separate works it was noted that compared to ferrocene, ferrocenyl carbinol and amine group derivatives have universal smoke reducing and octane number increasing properties. They are more effective additives of both diesel and motor fuels. Therefore, recently, several methods have been developed for synthesis of carbinol derivatives of ferrocene and cymantrene. However, these methods are noted with the fact that used solvents and sorbents do not meet modern ecological standards [7-8]. We proposed new, more effective, ecologically pure and technologically marketable methods of producing carbinolate (I, III) and carbinol (II, IV) type derivatives of ferrocene and cymantrene. Carbinol $LMC_5H_4C(R_1R_2)OH$ (I, II), where $LMC_5H_4 = C_5H_5Fe$ (I), $(OC)_3Mn$ (II), and carbinolate $LMC_5H_4C(R_1R_2)O$ (III, IV), derivatives of ferrocene and cymantrene were obtained by the reaction (1) between lithic organometallic compounds of ferrocene $C_5H_5FeC_5H_4Li$ and cymantrene $(OC)_3MnC_5H_4Li$ obtained by method [10] with aliphatic R_2CO and aromatic Ph_2CO ketone compounds which depending on the conditions, the reaction was performed with relevant carbinolate (III, IV) or carbinol (I, II) derivatives.



Where $\text{LMC}_5\text{H}_4\text{Li}$, $\text{C}_5\text{H}_5\text{Fe}$ (I, III), $(\text{OC})_3\text{Mn}$ (I, IV), $\text{R} = \text{alk}$, $\text{Ph} = \text{CH}$.

The effect of carbonyl (carbonylate) radical introduced into cyclopentadienyl ring essentially changes basic physical and chemical properties of compounds I-IV, their solubility in different hydrocarbon solvents, antismoke and carbonization properties of diesel fuel L 0.5-40 prepared on GOST 500TU and bunker fuel of liquid black oil KT-40.

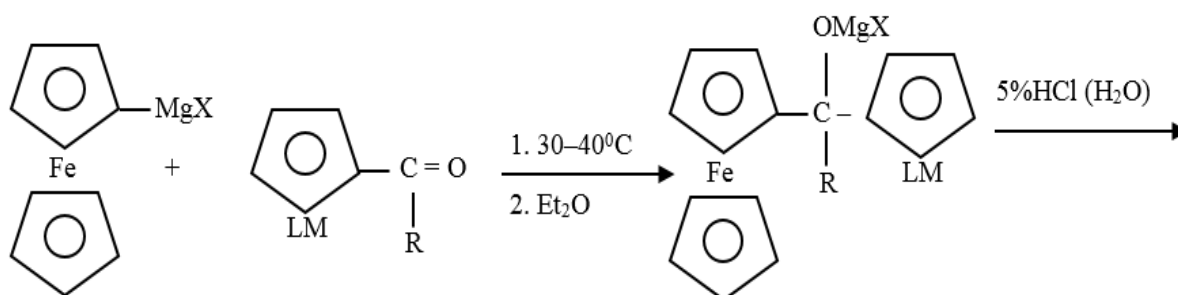
Nanocomposite solutions containing 0.01-0.1 mol/l of organometallic compounds were added into diesel fuel at 20°C and mixed 1000 rev. /min. for an hour. With the aim of developing new, more effective smoke reducing and octane – increasing nanocomposite solutions with minimum content of metals (Fe, Mn) in basic complexes, we worked out single-stage obtaining method of monoalkyl substituted derivatives of ferrocene based on the reaction (2) between dialphamethylstyrene (DAMS) and ferrocene catalyzed by H_2SO_4 at 0° temperature [8].

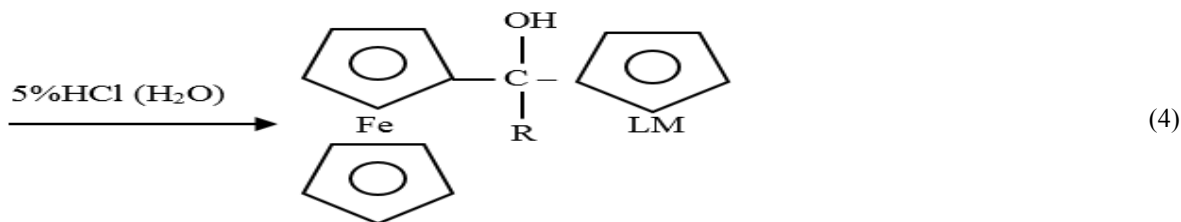


The yield of V-by reaction (5) is found to be 90-94%. Other derivatives of ferrocene, based on reaction (3), we have developed convenient method of producing polyalkyl substituted derivatives of ferrocene (VI) by direct alkylation with its pyrolysis products (pyrocondensate) containing 30-32 mass % of saturated hydrocarbons.



VI, polyalkyl ferrocene, In the reaction (3), as a catalyst we used diisopropylether solution containing 3-5% of non-aqueous AlCl_3 . Total yield of polyalkyl substituted derivative of ferrocene by proposed method makes 76-80% [14]. It must be stated that before our investigations, heterobinuclearoxyalkyl derivatives of ferrocene or cymantrene had not been described in literature. In order to produce these compounds, we first studied the reaction (4) between magnesium derivatives of ferrocene and acetyl (formyl) ferrocene or formylcymantrene [15].





Yield of derivatives VII by reaction (4) makes 94%, VII-80%. All obtained monoalkyl, polyalkyl and oxyalkyl derivatives are highly soluble in most hydrocarbon solvents. They do not have an exact melting temperature. Carbinol compounds under acidic conditions easily transforms into symmetric simple ethers $[\text{LMC}_5\text{H}_4]_2\text{O}$ [16].

Other practically valuable reaction direction is obtaining of ether derivatives of binuclear ferrocenyl and cymantrenyl compounds from the interaction of different alcohols of various nature and non-symmetric ethers $[\text{LMC}_5\text{H}_4\text{COR}]$.

By this method, we determined compositions, structures and some physical-chemical characteristics of newly synthesized carbinol (carbonilate) derivatives of ferrocene and cymantrene. We studied preparation of nanocomposite solutions based on ferrocene and cymantrene derivatives and use of them as neutralizers of exhaust gases for diesel fuels. Results of these studies are listed in table 2.

Nanocomposite samples prepared by us were tested for antismoke and anti-carbon deposition properties of carbinol and amine derivatives for diesel fuels.

Level of smokiness and anti-carbon deposition was determined by method [5] which consists of transmission of certain amount of exhaust gas through filtering material and we found unburned hydrocarbon residue (carbon black) by measuring it. As a result of systematic testing works, we found out that during operation of diesel motors, more effective neutralizer of exhaust gases are ferrocenyl carbinol derivatives, but for bunker fuels manganese-containing both carbinol and carbonilate metal complexes are more suitable. Consumption of manganese derivatives is lower than ferrocene derivatives for both diesel and bunker fuels. In table 2, we presented some exploitation parameters of diesel L 0.2-40 and KT-40 bunker fuel after introducing nanocomposite solutions (NCS), which contain ferrocene and its carbinol and amine derivatives.

Table 2. Presented Some Exploitation Parameters of Diesel L 0.2-40 and Kt-40 Bunker Fuel after Introducing Nanocomposite Solutions (NCS).

Compound	Consumption of NCS		Consumption of fuel	Smokiness. %	Carbon deposition of samples. %
	Limit	mol/l			
I. Diesel fuel – L0.2 – 40			0,542	88-90	28-32
1. $(\text{C}_6\text{H}_6)_2\text{Fe}$	Lower limit	0,002	0,7314	29	14
	Upper limit	0.006	0,685	17	10
2. $\text{C}_6\text{H}_6\text{FeC}_5\text{H}_4\text{-C}(\text{CH}_3)_2\text{OH}$	Lower limit	0,002	0,626	20	11
	Upper limit	0,006	0,696	12	8
3. $\text{C}_6\text{H}_6\text{FeC}_5\text{H}_4\text{-CH}_2\text{-NH}_2$	Lower limit	0,002	0,608	38	10
	Upper limit	0,006	0,644	24	10

4. $C_6H_6FeC_5H_4-N(CH_3)_2$	Lower limit	0,002	0,618	42	10
	Upper limit	0,006	0,602	33	7
II. Bunker fuel KT-40					
1. $(C_6H_6)_2Fe$	Lower limit	0,002		74	12
	Upper limit	0,006		36	10
2. $(OC)_3MnC_6H_6$	Lower limit	0,002		25	8
	Upper limit	0,006		14	6

As table 2 shows, by the introduction of 0.002-0.006 mol % mass of ferrocene (cymantrene) or their amine derivatives into L 0.2-40 diesel fuels, smokiness decreases in the range of 14-17% mass, but carbon deposition decreases 7-14% mass, that is 10 times less than alkyl ferrocenes «SLD», «Lubrizon 565» and IKhP-706, which creates a new possibility for using these compounds in practice. We developed obtaining method [17] of cyclopentadienyl manganese triple carbonyl and additive composition was prepared for motor fuels on the basis of it [18]. This additive composition allows us to increase octane number of motor fuels with lower octane numbers by 3-4 units. Obtaining method of dio-methylstyrene alkylation product of ferrocene – ferrocenyl 4-methyl 2, 4 diphenylpentylene was developed and this decreases Fe mass in molecule down to 13% and increases its application possibilities [19]. By using cluster MnX_2 and CoX_2 ($X = Cl, Br, J$), hetero binuclear compounds of ferrocene, distilled mercaptane was used for dimercaptanization of motor and diesel fuels [20, 21].

As mentioned above, ferrocene $(C_5H_5)_2Fe$ is a chemical product and is used as a raw material for obtaining derivatives of itself and other compounds.

Ferrocene and some of its derivatives are used in chemistry, petro-chemistry, defense, fuel energetic complexes as burning catalysts, medical preparations in anemia diseases, as radio protectors for effective absorption of γ -rays, obtaining of additive composite materials as reducers for diesel fuels.

During the work, we have developed a more advanced method by using a new reaction in order to obtain ferrocene.

The method consists of activation of monocyclopentadienyl with pyridine or any double (triple) amine by giving it ylide shape, and then obtaining of bistriscyclopentadienyl iron (ferrocene) by interacting it with $FeCl_2(Py)_2$ solvate salt under average polar solvent condition. As a result of this reaction, yield of ferrocene depends on several factors (purity degree of an activator, presence of water in $FeCl_2(Py)_2$ solvate salt and so on) and it was obtained with 75-90% yield. We have developed a non-waste method which enables us to obtain it with high purity. Ferrocene shows high solubility in hydrocarbon type solvents.

Use of reaction (5) equation allows us to create considerably profitable technology for developing new obtaining method of ferrocene. Reaction (5) can be considered to be a double stage reaction.

In the (I) stage, activation of it is made by converting to ylide intermediate complex with cyclic or aliphatic amines of organic ligand–monocyclopentadiene, $[C_5H_5Py]$.

In the (II) stage, conversion of $FeCl_2(Py)_2$ solvate salt to ferrocene is made by interacting it with $[C_5H_5Py]$ ylide intermediate complex.



Pyridine hydrochloride obtained by reaction equation can be returned back to the process by processing it with NaHCO_3 and neutralizing up to Py and NaCl .

Study of the reaction (I) showed that the use of calcinated FeCl_2 , instead of $\text{FeCl}_2(\text{Py})_2$ solvate salt for reaction, significantly affects purposeful product yield. During this reaction, FeCl_2 is very sensitive to water and during synthesis iron-carbon (Fe - C) chemical bond is hydrolyzed by water molecules. During the work, by using reaction (5), we determined and studied the main factors which influence the yield of product – ferrocene. Many methods for obtaining ferrocene and its compounds have a preparative significance for fire safety or availability of initial reagents. Thus, some of the main and necessary conditions of technological significance for synthesis of ferrocene are prevention of atmospheric injection of harmful impurities, recycling of auxiliary chemical reagents and compounds, possibility of using them in other chemical processes after relevant formations [22]. This is possible only by using exchange reactions, as a result of which neutral safe chemical compounds are formed. Interaction of non-aqueous iron dihalogenide with cyclopentadienate of alkali metals (Li, Na, K) can be related to such reactions and this leads to formation of ferrocene and relevant neutral halogenides of these metals [23].

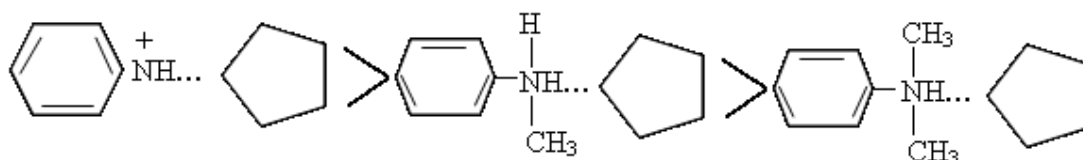
The other synthesis method of ferrocene is based on the reaction between FeO and C_5H_6 at 500°C . Obtained ferrocene and water do not cause ecological problem. However, when using other industrial synthesis methods of ferrocene, due to polycondensation and other conversions of cyclopentadiene together with basic product, a number of by-products are formed which require additional resources for their utilization [24, 25].

In one-step synthesis of ferrocene, one of the important experimental tasks is selection of such reaction conditions in which hydrogen chloride released in interaction of FeCl_2 and cyclopentadiene will be neutralized and the reaction directs towards formation of ferrocene. With this aim, for investigation, we selected the reaction between non-aqueous iron dichloride and cyclopentadiene activated with pyridine at absolute isopropanol.

It must be stated that cyclopentadiene by itself as a weak CH-acid (pK_a 15.5) in reaction with FeCl_2 does not allow to produce ferrocene. According to [26], for realization of this reaction, cyclopentadiene should have pK_a 22.

For obtaining ferrocene by reaction 910, we studied activation of cyclopentadiene with several amines. In literature, there is data on interaction of cyclopentadiene with amines like $(\text{CH}_3)_3\text{N}$, $\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$, $\text{C}_6\text{H}_5\text{NH}_2$, which leads to formation of intermediate active bipolar imide complex [24]. According to [25], chemical stability of formed cyclopentadienyl anions depends on electron-acceptance of substituents in nitrogen atom and decreases in the row: $\text{C}_6\text{H}_5\text{NH}_2 > \text{C}_6\text{H}_5\text{CH}_2\text{NH}_2 > (\text{CH}_3)_3\text{N}$. By using this property of substituted amines, we studied activation of cyclopentadiene with amines of industrial production. With this aim, we used diethylamine, triethylamine, methylamine, dimethylaniline and pyridine.

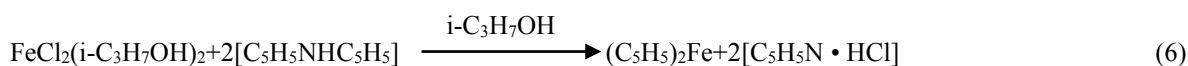
Studying spectra of NMR ^1N mixture of pyridine-cyclopentadiene showed only presence of two signals relating to protons of pyridine-cyclopentadienyl complex. One of them is in strong field and has chemical shift 0.75 m.d., but signal of protons of cyclopentadienyl anion is in weak field (δ 16.57 m.d.).



The highly activating property of pyridine compared to other aromatic amines is related to its structural feature, thus in aromatic ring nitrogen atom shows high basicity and forms more stable intermediate complex with cyclopentadiene than other amines.

On the other hand, above mentioned experimental data confirms assumption that in exothermal reaction conditions (5) more stable imide complex easily dissociate to initial compounds and cyclopentadiene is converted to dimer, trimer and polymer forms, and complicates separation of ferrocene from reaction mixture. Therefore, pyridine is a more effective activator of cyclopentadiene.

Obtained intermediate imide complex with pyridine was used for synthesis of ferrocene by interaction of solvated isopropanol with non-aqueous iron dichloride in absolute isopropanol at 30-40°C. After processing reaction mixture, the yield of pure ferrocene was more than 70%.



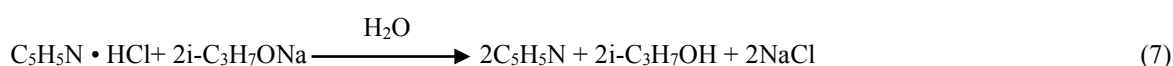
Release of ferrocene from reaction mixture was conducted by extraction method. As a reagent, we used light fraction of gasoline ($T_{\text{boil}} = 40-70^\circ\text{C}$).

For monomethylaniline, the yield of ferrocene reaches 37-43%, reaction mixture contains 10-15% cyclopentadiene dimer. When using pyridine intermediate complex, the yield of ferrocene exceeds 70%.

Thus, according to obtained data, on complexation ability of cyclopentadiene with studied amines, we established decrease of activity depending on nature of organic radical.

It was found out that after extraction of product, the residue contains pyridine hydrochloride $\text{C}_5\text{H}_5\text{N} \cdot \text{HCl}$, small amount of ferrocene, isopropyl alcohol, 1.2% pyridine and other non-identified compounds [27].

Neutralization of pyridine hydrochloride, its purification and recycling as an activator of cyclopentadiene in reaction (1) are of great interest. With this aim, we selected a neutralizer which allows us to conduct this reaction more selectively. As a neutralizer, the most traditional and economically useful reagent – NaOH can be used. However, using NaOH as a neutralizer for destruction of $\text{C}_5\text{H}_5\text{N} \cdot \text{HCl}$ turned to be impossible, since in the reaction (1), interaction with both $\text{C}_5\text{H}_5\text{N} \cdot \text{HCl}$ and mixtures of $\text{i-C}_3\text{H}_7\text{OH}$, $(\text{C}_5\text{H}_5)_2\text{Fe}$ and others complicates further purification of $\text{C}_5\text{H}_5\text{N}$. Therefore, for neutralization, we used $\text{i-C}_3\text{H}_7\text{ONa}$ (2). This helped to return neutralizer in the form of $\text{i-C}_3\text{H}_7\text{OH}$ to the reaction, secondly, excluded the possibility of decomposition of the remaining ferrocene and other compounds. As a result of reaction (6), only NaCl exists as a by-product.



Thus, we studied the reaction between non-aqueous iron dichloride in the form of solvated salt $\text{FeCl}_2(\text{i-C}_3\text{H}_7\text{OH})_2$ and cyclopentadiene, activated with pyridine in absolute isopropanol and showed possibility of

producing ferrocene with high yield. It was established that ferrocene is easily separated from pyridine hydrochloride and after neutralization of the latter with sodium isopropylate, pyridine can be recycled as an activator of cyclopentadiene and allows us to obtain ferrocene with ecologically pure and non-waste method.

Temperature Factor

According to results of study, when carrying out the reaction (5) in the range of $-5 \div +50^{\circ}\text{C}$, it was found that $-5 \div +10^{\circ}\text{C}$ temperature interval influences positively on the reaction, but $+20 \div +50^{\circ}\text{C}$ temperature interval influences negatively on the reaction and yield of the product was more than 15-20%.

Nature of Activator Factor

Selection of an activator and optimum condition for reaction (5) is very important. Being as a weak C – H carbonic acid C_5H_5 molecule conforms to $\text{P}k = 10-11$ acidic unit and enters to exchange reaction with FeCl_2 and by separating HCl shifts reaction equilibrium to the right. To obtain $(\text{C}_5\text{H}_5)_2\text{Fe}$, the pyridine activator which increases acidic unit of C_5H_6 up to $\text{P}k = 22-23$ unit is considered to be more expedient. Compared to aliphatic amines, cyclic amines C_5H_5 cyclic amines are more effective activators.

Water Factor

During obtaining of ferrocene with reaction (1), presence of water in the system does not allow us to produce the product by hydrolizing Fe – C (carbon-iron) chemical bond.

On the other hand, in order to obtain ferrocene from reaction mixture with high purity and non-waste method, we obtained biscyclopentadienyl iron with 80-87% yield and 98.2% purity by using liquid phase extraction method. According to results of elemental analysis $\text{C}_{10}\text{H}_{10}\text{Fe}$ conforms to Brutto formula.

As to recycling of activator after neutralization, as a result of relevant reaction $\text{A}\cdot\text{HCl}$ which was converted to hydrochloride can be recycled by processing it with 3-5% of NaHCO_3 and neutralizing till A and NaCl, and separating A from water.

The method which operates with ecologically more profitable technological circuit is proposed by reaction (5).

As a result of interaction of bispyridine iron chloride with mono-cyclopentadiene activated with cyclic and aliphatic amines, we developed a method which can obtain ferrocene with high yield. To obtain it from reaction mixture with high purity and non-waste method, we used liquid phase extraction method.

IV. CONCLUSION

1. The synthesis of ferrocene, cymantrene and their various carbonyl derivatives was carried out and some of their structural properties were determined.
2. Comparative analysis of smoke reducing properties of ferrocene, cymantrene and their various carbonyl derivatives in diesel fuels was carried out.

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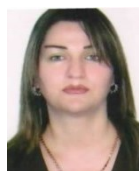
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