- 3. K. V. Topchieva, S. V. Kostikov, and A. Yu. Loginov, Vestn. Acad. Nauk Kaz SSR, No. 12, 53 (1977).
- 4. S. E. Spiridonov, A. Yu. Loginov, and K. V. Topchieva, Izv. Acad. Nauk Mold. SSR, Ser. Khim., No. 3, 48 (1982).
- 5. V. E. Shubin, V. A. Svets, K. Dyreck, K. Nocala, and V. B. Cazanskiy, React. Kinet. Catal. Lett., <u>14</u>, 239 (1980).
- 6. D. Cordishi, V. Indoirna, and M. Occhiuzzi, J. Chem. Soc. Faraday Trans. 1, <u>76</u>, 1147 (1980).
- K. V. Topchieva, S. É. (E.) Spiridonov, and A. Yu. Loginov, J. Chem. Soc. Chem. Comm., No. 8, 636 (1986).
- 8. D. L. Lazarov, G. St. Manev, and M. D. Strantcheva, Proceedings of the 5th International Symposium on Heterogeneous Catalysis, Varna (1983), Part 2, p. 91.
- 9. S. N. Vydrin, A. Yu. Loginov, and A. V. Bobolev, Izv. Akad. Nauk SSSR, Ser. Khim., 528 (1985).
- A. Yu. Loginov, S. É. Spiridonov, and K. V. Topchieva, Zh. Fiz. Khim., <u>56</u>, 1725, 2518 (1982).
- 11. K. V. Topchieva, A. Yu. Loginov, and V. A. Kreisberg, in: Contemporary Problems in Physical Chemistry [in Russian], Izd. MGU, Moscow (1975), Vol. 8, p. 272.
- 12. A. A. Davydov, Kinet. Katal., <u>26</u>, 157 (1985); IR Spectroscopy in the Chemistry of the Surface of Oxides [in Russian], Nauka, Novosibirsk (1984), p. 242.
- 13. V. A. Zasukha and L. M. Roev, Teor. Eksp. Khim., <u>6</u>, 608 (1970).
- 14. V. S. Vainer and A. I. Veinger, Fiz. Tverd. Tela, <u>19</u>, No. 3, 528 (1977).
- 15. W. Bücher, Helv. Chim. Acta, <u>49</u>, 907 (1966).

REACTIONS OF ALKYLATION, ISOMERIZATION, AND DEUTERIUM-HYDROGEN EXCHANGE ON CATALYSTS OF DISPROPORTIONATION OF OLEFINS

G. P. Startseva, P. E. Matkovskii, and Kh.-M. A. Brikenshtein

UDC 541.124:66.095.253:542.952.1: 541.128:547.313

Disproportionation of α -olefins in the presence of complex catalysts WCl₆-C₂H₅AlCl₂ and WCl₆-Sn (n-C₄H₉)₄ [1, 2] and metal oxide catalysts (M = Mo, W, Re) activated by Al(CH₃)₃ or Al(C₂H₅)₃ on carriers (SiO₂, Al₂O₃) [3] is accompanied by migration of double bonds. To elucidate the mechanism of this process and determine the nature of the active sites, we studied the reactions of alkylation, isomerization, and D-H exchange in the presence of models of catalysts of disproportionation of olefins.

EXPERIMENTAL

ShSK, KSM, S-3, and S-4 silica gels were ground in a ball mill before use and divided into narrow fractions by particle size on laboratory sieves. The fraction with a particle size smaller than 0.25 mm was used as the carrier. The best results for activity and selectivity were obtained with catalysts based on S-3 silica gel. A prepared weighed portion of silica gel was impregnated with an aqueous solution of ammonium p-molybdate while stirring at 293°K in an open porcelain beaker and the water was then evaporated in a water or sand bath while stirring. The catalyst obtained in this stage, in the form of a paste or powder, was dried and activated by calcination (4-6 h) in a muffle furnace at 823°K and was loaded hot into a specially prepared container, evacuated, and filled with dry N₂ or Ar. The MoO_3/Al_2O_3 , Re_2O_7/SiO_2 , and WO_3/SiO_2 catalysts were prepared similarly. The olefins were vacuum distilled over a Na wire and then stored in a special container in an atmosphere of inert gas.

N. D. Zelinskii Institute of Organic Chemistry, Academy of Sciences of the USSR, Moscow. I. M. Gubkin Oil and Gas Institute, Moscow. Translated from Izvestiya Akademii Nauk SSSR, Seriya Khimicheskaya, No. 3, pp. 499-504, March, 1987. Original article submitted July 5, 1985.

Disproportionation of α -olefins was conducted at 0.1 MPa in a special three-neck cell with a jacket for thermostatting and with an "inverter" for introduction of the components of the catalyst, mixing the reaction mass with an electromagnetic stirrer. The gaseous products formed were collected in a graduated gas holder. Alkylation of aromatic hydrocarbons by the olefins was studied on a high-pressure setup in static isothermal conditions with intense stirring.

The composition of the gaseous products was determined by GLC on a KhL-4 or LKhM-8MD chromatograph: 4×2000 mm column, A-1 activated by Al₂O₃ with a 0.25-0.50 mm particle diameter as the stationary phase, 293°K [4]. The products of disproportionation were analyzed on Tsvet-3, Khrom-4, and LMKh-8MD chromatographs with flame-ionization detectors [5], carrier gas (He) flow rate of 40, H₂ flow rate of 30, and air flow rate of 300 ml/min. The sample was introduced into the chromatograph with a microsyringe during attainment of an evaporator temperature of 573-623°K. Stainless steel columns (0.4 \times 70-0.4 \times 300 cm) packed with Chromaton NAWDMC with 30% OV-17 silicone or Chemasorb AW with 15% Apiezon L were used. During the quantitative analysis, the samples were chromatographed in the programmed temprature mode from 293 to 593°K with a temperature elevation rate of 8°K/min. The volume of the samples varied from 0.5 to 5.0 µl.

The products of the reaction containing the starting olefin, solvent, products of disproportionation of the olefins, and products of alkylation of the aromatic solvent by the olefins were analyzed similarly [5] and by IR spectroscopy [6-9] and separation of the reaction mass into fractions in a vacuum laboratory rectification column.

In addition to bands at 705 and 1495 cm^{-1} characteristic of monoalkyl aromatic hydrocarbons, the IR spectra of the products of alkylation of toluene by 1-hexene and 1-decene contained bands of o- (727 cm^{-1}), m- (757 and 783 cm^{-1}), and p- (847 and 1520 cm^{-1}) disubstituted alkyl aromatic hydrocarbons. Dialkylation of toluene was not observed. Monoalkylation of toluene was favored by the fact that the reaction took place to low degrees of conversion with respect to toluene.

The mass isotopic composition of the gaseous products was determined on a MI-1305 mass spectrometer using the results of mass spectrometric analysis of fragmentation of the individual compounds and mixtures [9, 10] and with an atlas of spectral data [11].

DISCUSSION OF THE RESULTS

In agreement with [12, 13], the data obtained indicate that WCL₆ containing $\sim 0.001\%$ water weakly and nonselectively catalyzes alkylation of benzene and toluene by α -olefins. Treatment of WCl₆ with ethylaluminum dichloride or Sn(n-C₄H₉)₄ significantly increases the rate of alkyla tion, which takes place parallelly with disproportionation.

The yield of products of disproportionation increases with an increase in the $Sn(n-C_4H_9)_4$ /WC16 molar ratio, and the yield of products of alkylation of toluene by the olefins decreases (Table 1). Based on this observation, it can be concluded that the cationic sites responsible for alkylation which arise from $WC1_6$ are deactivated by alkyl or carbene derivatives of tungsten which are formed in reactions of WCl_6 with $Sn(n-C_4H_9)_4$. In disproportionation of 1-decene on the $WCl_6-Sn(n-C_6H_9)_4$ system (1:2) in toluene at 348°K in the absence of ethylene, 1-decene is transformed into 9-octadecene [1]. The gaseous products contain ethylene, propylene, butenes, the reaction mass is greenish-black, and all of the catalyst remains in the solution. In contrast, in the disproportionation of 1-decene in the same conditions but in the presence of ethylene (2.5 MPa), propylene and butene are absent in the gas phase, the reaction mass is toally transparent and contains no W, and decyltoluenes are the basic product of transformation of 1-decene (91.6% conversion) [14]. Control experiments showed (Table 2) that WCl₆, apparently in a complex with impurities of water (0.001 wt. %), catalyzes alkylation of toluene by 1-decene (26.5% conversion). Disproportionation of 1-decene also takes place simultaneously with alkylation. Contact of 1-decene with WCl6 in toluene in the presence of ethylene (1.5 h at 348°K) increases the selectivity of alkylation to 100% (see Table 2). Ethylene probably destroys the active sites of disproportionation but does not react with the active sites of alkylation.

Under the effect of WCl_6 -Sn $(n-C_4H_9)_4$, MoO_3/SiO_2 -AlR₃, WO_3/SiO_2 -AlR₃, and Re_2O_7/SiO_2 -AlR₃ systems at 348-363°K, the symmetrically disubstituted olefins 5-decene, 7-tetradecene, and 9-octadecene are transformed into a mixture of olefins of the trans-vinylene type with a smaller and larger number of carbon atoms in the chain in comparison to the starting olefin.

TABLE 1. Effect of the $Sn(n-C_4H_9)_4/WCl_6$ Molar Ratio on the Yield (wt. %) of Products of Disproportionation of 1-Hexene (D) and Alkylation of Toluene (A) at 293°K on the $Sn(n-C_4H_9)_4-WCl_6$ System. WCl_6 0.028, 1-Hexene 1.4 mole/liter, Toluene 0.02 liter; 2 h

Product	$\operatorname{Sn}(n-\operatorname{C_4H_9})_4/\operatorname{WCl_6}$								
	0,5	1.0	2.0	3.0	4.0				
D A	4 30	10 12	26 8	$30 \\ 3$	30 0				

TABLE 2. Effect of Ethylene and the Sequence of Loading the Components into the Reactor on Transformation of 1-Decene (38 ml, 0.2 mole) at 348°K in Toluene (200 ml) under the Effect of the $WCl_6-Sn(n-C_4H_9)_4$ System. WCl_6 7.07 mmole/liter, Sn/W = 2.0

Sequence of loading components in reactor	_{РС2Н4} , МРа	Time, min	Conver- sion of 1-decene	Decyl- toluene g	9-Octa- decene, g
Toluene –1-decene- WCl_6 Toluene –1-decene- $WCl_6 - Sn(n-C_4H_9)_4$ Toluene – $WCl_6 - 1$ -decene – $Sn(n-C_4H_9)_4$ Toluene – $WCl_6 - C_2H_4$ – decene Toluene – $C_2H_4 - WCl_6$ – decene – $Sn(n-C_4H_9)_4$ Toluene – C_2H_4 – WCl_6 – decene – $Sn(n-C_4H_9)_4$ Toluene – C_2H_4 – WCl_6 – decene – $Sn(n-C_4H_9)_4$	$ \begin{array}{c} -\\ 2,5\\ 2,5\\ 2,5\\ 2,5\\ 2,5\\ 2,5\\ 2,5 \end{array} $	30 30 30 30 90 90 90	33,9 49,8 76,4 12,3 91,6 88,4 37,0	$\begin{array}{c} 13,6\\12,4\\3,65\\5,6\\49,3\\42,8\\17,2\end{array}$	1,3 6,5 19,2 - - -



Fig. 1. Semilogarithmic anamorphoses of the curves of the numerical distribution of the products of transformation of 5decene on the MoO₃ $(1.6\%)/SiO_2$ (S-3)- $A1(C_2H_5)_3$ system at 348°K in bulk (1) and in a mixture of 5-decene and toluene (1:1) (2). MoO₃/SiO₂ = 3.5 g; Mo 1.08\% (0.394 mmole); activator $A1(C_2H_5)_3$ (1.17 mmole); A1/Mo = 3.0; 5-decene 0.16 mmole; liquid phase 30 ml. TABLE 3. Effect of Concentration of $A1(CH_3)_3$ in Solution on the Activity and Selectivity of the $MoO_3/A1_2O_3-A1(CH_3)_3$ System during Disproportionation of 1-Nonene in Bulk. $MoO_3 \ 8.15\%/A1_2O_3 \ (r < 0.25) \ 3.5 \ g$, Mo 5.44% (0.19 g); 1nonene 40 ml (29.2 g); C=C/Mo = 117; 333°K

Al(CH ₃) ₃ , mmole/liter	Al/Mo	τ, min	S *, %	W _{max} , ml/min	Composition of gas phase, vol. percent			
					C_2H_4	C ₃ H ₆	C4H8	
8.37 15.0 39.0 59.75 119.5	$0,17 \\ 0,30 \\ 0.60 \\ 1,2 \\ 2.4$	130 83 80 77 35	3.25 71.4 76.0 66.0 9.3	14 102 92 70 50	94.5 80.3 84.7 91.6 98.1	5.2 19.2 14.7 7.9 1.6	$\begin{array}{c} 0.3 \\ 0.5 \\ 0.5 \\ 0.5 \\ 0.3 \end{array}$	

*S: conversion of 1-nonene into products of disproportionation, %.

Ethylene, propylene, and 1-butene are not present in the products of the reaction. The formation of these products can be represented by a scheme which includes positional isomerization of olefins and codisproportionation of the isomers formed. The products of transformation of the starting disubstituted olefins are characterized by complex asymmetric molecular weight distribution of the lower and higher homologs of the olefins.

Products with a larger and smaller number of C atoms than in the starting symmetrically disubstituted olefin are formed during the reaction, suggesting a step mechanism of isomerization

 $C_4 - CH = CH - C_4 \rightleftharpoons C_3 - CH = CH - C_5 \rightleftharpoons C_2 - CH = CH - C_6 \rightleftharpoons C_1 - CH = CH - C_7$

As the double bond is eliminated along the length of the chain with respect to its position in the starting olefin, the mole fraction of the corresponding homologs of the olefins monotonically decreases. The ascending and descending branches of the numerical distribution of the products of transformation of 5-decene or 9-octadecene along the length of the chain are linearized in semilogarithmic coordinates (Fig. 1), which indicates the exponential thermodynamically equilibrium character of the molecular weight distribution. The asymmetry of the numerical distribution with respect to the starting olefin can be explained by differences in the reactivity of the lower and higher homologs of the olefins in both the stage of isomerization and in the stage of disproportionation.

The most definite conclusions on the mechanism of these transformations were obtained for the MoO_3/Al_2O_3 -AlR₃ system, whose starting components are totally inactive in isomerization of olefins in the given conditions. Note that an antibatic relation is observed between the activity which is characterized by the maximum rate of liberation of gaseous products W_{max} , and the selectivity of this system in disproportionation, which can be judged by the composition of the gaseous products [1, 3, 5] (Table 3).

Contact of C_2H_4 and $C_2D_4 + C_2H_4$ mixtures with WCl_6 -SN $(n-C_4H_9)_4$, MoO_3/SiO_2 -AlR₃, and Re_2O_7/SiO_2 -AlR₃ systems (Tables 4 and 5) in decane medium at 293-343°K results in the formation of mixtures of tetra-, tri-, di-, and monodeuterated ethylenes [15, 16], which indicates that all of these systems catalyzed multiple D-H exchange.

The distribution of ethylenes by the degree of substitution of hydrogen by deuterium in the products is not monotonic. With high degrees of conversion, mixtures containing a large amount of dideuterated ethylene are formed, probably due to the formation of $C_2D_2H_2$ not only during D-H exchange, but also in codisproportionation of C_2D_4 with C_2H_4 .

Al(CH₃)₃-activated catalysts applied to SiO₂ or Al₂O₃, particularly Re₂O₇/SiO₂(S-3) + Al(CH₃)₃ exhibits the highest activity in D-H exchange. On the WCl₆-Pb(C₆H₅) system, which is one of the most selective catalyst of disproportionation of α -olefins [3], disproportionation of C₂H₄ with C₂D₄ and D-H exchange were not observed at 333-363°K. During contact of the WCl₆-Pb(C₆H₅)₄ system with the C₂H₄ + C₂D₄ mixture (1:1) at 348°K for 40 min, most of the active sites of disproportionation are quenched. After removal of the C₂H₄ + C₂D₄ mixture from the reactor, the total conversion of 1-decene into 9-octadedene and ethylene was 14.5% (C₁₁ 3.8; C₁₇ 1.15; C₁₈ 8.13; C₂H₄ 1.42; CH₂=CH 91.2 mole % + trans-CH=CH- 8.8 mole %).

TABLE 4. Composition of the Products of Reactions of C_2D_4 and Its Mixtures with C_2H_4 on the $WCl_6-Sn(n-C_4H_9)_4$ System in Toluene. Toluene 14 ml, $Sn(n-C_4H_9)_4$ 0.416; WCl_6 0.24 mmole (\sim 10 mmole/liter); Sn/W = 1.73

т., °К	$_{p,}$ mm Hg			Isotropic composition of starting mixtures and products of the reaction, mole percent						
	C_2H_4	C_2D_4	τ, min	C_2D_4	C_2D_3H	$C_2D_2H_2$	C_2DH_3	C_2H_4		
348	-	310	0 120	89,8 89,2	8.0 8.8	0	2.1 2.0	0		
348	132	198	0 120	$56 \\ 43.6$	4.8 9.9	$ \begin{array}{c} 0 \\ 3,7 \end{array} $	1.0 8,3	$36.9 \\ 33.4$		
348	165	215	0 60	75.5 35.7	10.3 7,5	0 9,9	3.1 10,1	8,9 34,3		
348	50	335	0 60	81.3 77,1	5,8 8,8	$0 \\ 4,9$	$\begin{array}{c} 0.9\\ 2.0\end{array}$	$\frac{10}{5}$		
363	47	295	0 90	75.1 21.4	10.9 6.3	0 30,1	$2.5 \\ 11.9$	9.2 29		

TABLE 5. Composition of the Products of the Reaction of C_2D_4 and its Mixtures with C_2H_4 on the Re_2O_7/SiO_2 (S-3)-A1(CH₃)₃ System in Decane (17 ml). T 348°K; A1/Re = 3.0

Be-0-/	Re, mmole	Re ₂ O ₇ ,	Al(CH ₃) ₃ , mmole	$C_2H_4++C_2D_4,$ mm Hg	τ, mín	Isotopic comp. of starting mixts. and products of reaction, mole %				
/SiO ₂ , g						C_2D_4	C ₂ D ₃ H	$\mathrm{C}_{2}\mathrm{D}_{2}\mathrm{H}_{2}$	$C_2 DH_3$	C_2H_4
8,0	0,428	1,0	1,28	270	$\begin{bmatrix} 0\\58\\60\end{bmatrix}$	89 51,2 49,7	7,3 33,1 33,6	0 9,9 8,8	$ \begin{array}{c c} 1,7 \\ 4,4 \\ 6,1 \end{array} $	0 0 0
8,0	0,428	1,0	1,28	362	$\begin{array}{c} 0\\ 60 \end{array}$	83,7 48,5	5,9 23,5	0 11	$1.0 \\ 8.2$	0
3,1	0,83	5,0	2,5	280	$\begin{array}{c} 0\\ 60 \end{array}$	$74,5 \\ 34,9$	$5.6 \\ 23,3$	$\begin{array}{c} 0 \\ 14,4 \end{array}$	1,3 11,8	$5,2 \\ 13.6$
3,1	0,83	5,0	2,5	340	0 58 60	$\begin{array}{c c} 41,2 \\ 11,7 \\ 11,9 \end{array}$	3,2 11,0 12,1	0 14,8 19,5	$2,3 \\ 23,4 \\ 26,8$	52,4 33,5 29,2
3,0 *	0,83	5,0	2,5	380	$ \begin{array}{c} 0 \\ 60 \\ 90 \end{array} $	34,5 15,4 8,2	$2.3 \\ 4.7 \\ 2.4$	$0 \\ 9,5 \\ 7,8$	$\begin{array}{c} 1,4\\26,7\\60,5\end{array}$	61,1 43,5 20,8
1,5 *	0,41	5,0	1,28	310	$ \begin{array}{c} 0 \\ 60 \\ 58 \end{array} $	$[\begin{array}{c} 28,8\\ 5,6\\ 7,2 \end{array}]$	$2,2 \\ 5,3 \\ 4,5$	0 14,8 13,0	1,8 46,6 43,6	$\begin{array}{c} 67,4\\27,5\\31,5\end{array}$

*In 5-decene medium (20 m1).

In addition to ethylene (83.7%), propylene (13.6%) and butenes (2.8%) were present in the gaseous products, which indicates a significant increase in the isomerizing capacity of the WCl₆-Pb(C₆H₅)₄ system after contact with the $C_2H_4-C_2D_4$ mixture. In a control experiment conducted with freshly prepared WCl₆-Pb(C₆H₅)₄ catalyst in the absence of $C_2H_4 + C_2D_4$, the conversion of 1-decene in the same conditions was 71.6% (C_2H_4 6.5; C_{11} 1.85; C_{12} 1.26, C_{13} 1.80, C_{14} 1.35, C_{15} 2.69, C_{16} 2.53, C_{17} 7.95, C_{18} 45.6%; CH_2 =CH 40.3, trans-CH=CH- 59.7 mole %).

These observations indicate that deactivation of $WCl_6-Pb(C_6H_5)_4$ during disproportionation on contact with ethylene is at least partially due to quenching of active sites in their reactions with C_2H_4 . Additional studies are necessary for determining the mechanism of this event. We will hypothesize that carbene hydride derivatives [16-18] of Mo, W, and Re whose origin can be represented by the following simplified scheme are responsible for all of the observed transformations

$$M_0O_3 \xrightarrow{A1(CH_3)_3} M_0O_2 \xrightarrow{AI(CH_3)_3} (CH_3)_2AIOM_0$$

 $M_0(IV)$ — $CH_3 \rightleftharpoons CH_2$ = $M_0(VI)$ —H

The absence of D-H exchange between C_2H_4 and C_2D_4 on the WCl₆-Pb(C₆H₅)₄ system is apparently due to the fact that the carbene hydride sites containing HW=CH₂ fragments are not formed in this system in the presence of ethylene.

The activity of WCl_6-MR_4 systems and AlR_3 -activated metal oxide catalysts in alkylation and isomerization reactions indicate the unusual nature of polarization of the M-H bond in carbene hydride derivatives of Mo, W, and Re. Like Co or Re hydrocarbonyls, these compounds are apparently proton donors, and the direction of transformations of olefins under the effect of these catalysts is determined by the part of the carbene hydride site with which the ethylene reacts. Most catalysts of double decomposition are probably bifunctional. The carbene and hydride forms of active site can function synchronously or independently and their ratio can be regulated with ethylene.

In conclusion, we note that the hypothesis on the carbene hydride form of active sites permits explaining all of the results obtained on disproportionation, alkylation, isomerization, and D-H exchange on complex organometallic and oxide catalysts of disproportionation of olefins without contradictions.

CONCLUSIONS

1. Soluble and heterogeneous, complex and oxide catalysts of the disproportionation of olefins containing molybdenum, tungsten, and rhenium activated by organoaluminum compounds cause alkylation of toluene, isomerization, and D-H exchange of olefins.

2. All of the catalysts of disproportionation studied are polyfunctional. It was hypothesized that the active sites of disproportionation, alkylation, and D-H exchange are carbene hydride derivatives of molybdenum, tungsten, or rhenium which are in dynamic equilibrium with the alkyl derivatives. A mechanism of their formation and function was proposed.

3. It was found that these forms of the active sites can function independently and that ethylene significantly alters their ratio.

LITERATURE CITED

- G. P. Startseva, M. P. Gerasina, Kh.-M. A. Brikenshtein, and P. E. Matkovskii, Complex Organometallic Catalysts of Polymerization of Olefins [in Russian], Redakts.-Izd. Otd. IKhF Akad. Nauk SSSR, No. 8, Chernogolovka (1980), pp. 23-26.
- 2. J. Berger, R. Sass, and G. Zimmermann, J. Prakt. Chem., <u>320</u>, 790 (1977); <u>320</u>, 283 (1978).
- 3. G. P. Startseva, S. V. Kir'yakova, P. E. Matkovskii, M. P. Gerasina, and Kh.-M. A. Brikenshtein, Neftekhim., 23, No. 1, 48 (1983).
- B. V. Aivazov, Principles of Gas Chromatography [in Russian], Vyssh. Shk., Moscow (1977), p. 183.
- 5. P. E. Matkovskii, G. N. Nesterenko, G. P. Startseva, L. N. Russiyan, V. N. Belova, A. A. Semenov, Kh.-M. A. Brikenshtein, and D. N. Sokolov, Vysokomol. Spedin., A19, 1836 (1977).
- 6. G. A. Beikhol'd, P. E. Matkovskii, Yu. V. Kissin, Kh.-M. A. Brikenshtein, and F. S. D'yachkovskii, Vysokomol. Soedin., <u>A13</u>, 131 (1971).
- P. E. Matkovskii, V. N. Belova, Kh.-M. A. Brikenshtein, F. S. D'yachkovskii, Z. A. Denisova, and Yu. V. Kissin, Vysokomol. Soedin., <u>A17</u>, 252 (1975).
- Z. G. Busheva, V. K. Golubev, and A. I. Polacheva, Neftekhim., <u>20</u>, No. 1, 71 (1980).
 L. A. Kozitsyna and N. B. Kupletskaya, Use of UV, IR, NMR and Mass Spectrometry in
- Organic Chemistry [in Russian], Izd. MGU, Moscow (1979), p. 237.
- 10. L. S. Golovkina, G. V. Rusinova, and Al. A. Petrov, Usp. Khim., <u>53</u>, 1493 (1984).
- 11. E. Stenhagen and S. Abrahamson, Atlas of Mass Spectral Data, Vol. 1, New York-London-Sidney-Toronto (1972).
- L. Hooks, A. J. Hubert, and Ph. Teyssie, Tetrahedron Lett., 3687 (1972); 2719 (1973); 877 (1974).
- Ichikawa Kazuaki, Watanabe Osamu, Takagi Toru, and Fukuzumi Kazuo, J. Catal., <u>44</u>, 416 (1976).
- 14. G. P. Startseva, Kh.-M. A. Brikenshtein, M. P. Gerasina, N. S. Enikolopov, F. S. D'yachkovskii, and P. E. Matkovskii, Method of Preparation of Higher Alkyl Aromatic Hydrocarbons, USSR Patent No. 941339; Byull. Izobr., No. 25, 107 (1982).
- N. S. Enikolopov, F. S. D'yachkovskii, G. P. Startseva, and P. E. Matkovskii, Dokl. Akad. Nauk SSSR, <u>250</u>, 627 (1980).
- 16. C. J. Lin, A. W. Aldag, and A. Clark, J. Catal., <u>45</u>, 287 (1977).
- 17. N. J. Cooper and M. L. H. Green, J. Chem. Soc. Chem. Commun., 761 (1974).
- 18. E. A. Lombardo, M. Houalla, and W. K. Hall, J. Catal., <u>51</u>, 256 (1978).