CATALYTIC CONVERSION OF TORCH GASES

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Abstract

Gas fractions of C_1-C_4 hydrocarbons with characteristics of paraffins and olefins currently do not have commercial applications and frequently vary. Sometimes they are used as a fuel in furnaces, but in most cases they're being burned in the torches in oil refineries, thus increasing the emission of greenhouse gases and possible carcinogenic substances in air. We investigated the possibility of catalytic transformation of torch gases into mixture of aromatic compounds. The influence of the catalytic transformation temperature on the total degree of torch gas conversion and content of benzene, toluene and xylene in the liquid product was investigated and determinated. A model of the catalytic transformation mechanism of torch gases into an aromatic hydrocarbons mixture on a composite zeolite catalyst was established. Obtained results provide sound basis for application of this process, that can not only create a profit, but also protect the environment

Introduction

The production of aromatic compounds such as benzene, toluene and xylene has exceptional economic and strategic importance. The actual world production of these three compounds is 5×10^6 tons per year with a further tendency to rise. A basic refinery's process for production of benzene, toluene and xylene (BTX) is the catalytic reforming of primary gasoline. Companies such as UOP and BP have developed the CYCLAR (1) process that catalytically transforms C_3-C_4 alkenes in aromatic compounds, with a high yield (55-65 mass %). Further growth of oil refining brings increasing secondary gases and heavy products quantity. Gas fractions of C_1-C_4 hydrocarbons (torch gases) currently do not have commercial applications and frequently vary. They were used as furnace fuels or were burned in a torch. In this paper the possibility of the catalytic transformation of gases for torch into aromatic compound mixtures was investigated.

Methods

Table 1 shows the hydrocarbon gas mixture composition used for burning in a torch.

Table 1: Hydrocarbon gas composition of gases for torch

	CH_4	ΣC_2	C_3H_8	C_3H_6	ΣC_4	H_2 + inert
Vol. %	11	12	10	20	17	30

The catalytic conversion of gases for torch utilizing composite zeolite catalysts (KAG 315 and KAG 705), synthesized by original procedures developed at the Department of Physical Chemistry, University of Belgrade (2) has been investigated. Table 2 shows the basic physical and chemical characteristics of these catalysts.

The catalytic conversion of gases for torch with the composite zeolite catalysts was investigated in our laboratory's stainless steel reactor (3). Experiments were carried out under a pressure of p=0.1 MPa, with a feed volume velocity of 1000 h^{-1} and temperatures between 573 and 823 K. The mass of the catalysts was 5 g for each experiment. Gaseous and liquid products of conversion were collected during 1 h of reaction time and were analyzed by standard gas chromatographic methods (4). The degree of conversion of gases for torch into aromatic hydrocarbons was determinated by appropriate methodology (5).

Table 2: Physical and chemical characteristics of the catalysts (KAG 315 and KAG 705)

Characteristics of the catalysts	KAG-315	KAG-705
Type of zeolite	ZSM-5	Substituted pentasil
Degree of crystallization of zeolite (%)	100	98
Average diameter of crystalloid (nm)	1.8	1.5
Content of zeolite (%)	68	60
Specific area, BET, (m^2/g)	250	280
Specific pore volume (m^3/g)	0.33	0.32
Average diameter of particles (nm)	0.8	0.8

Results

In table 3, the influence of reaction temperature on the total degree of conversion (Dc) of gases for torch into the liquid products (such as aliphatic hydrocarbons C_5-C_{10}, benzene (B), toluene (T) and xylene (X)) resulting from the catalytic reaction on catalyst KAG 315 is shown. The influence of the catalytic conversion temperature increase on the total degree of conversion and on the liquid products' content when catalyst KAG 705 is used is presented in table 4.

Table 3: Influence of catalytic reaction temperature on the total degree of conversion and composition of the resulting mixture (catalyst KAG 315)

Temperature (K)	Dc mass %	C_5-C_{10} mass %	Benzene mass %	Toluene mass %	Xylene mass %	Σ BTX mass %
573	13.2	81.3	2.7	8.4	7.1	18.2
673	56.7	19.2	5.2	35.1	36.5	76.8
773	36.5	9.1	12.7	43.2	32.1	88.0
823	40.1	9.8	18.7	40.7	30.0	89.4

Table 4: Influence of catalytic reaction temperature on the total degree of conversion and composition of the resulting mixture (catalyst KAG 705)

Temperature (K)	Dc mass %	C_5-C_{10}, mass %	Benzene mass %	Toluene mass %	Xylene mass %	Σ BTX, mass %
573	15.2	93.2	1.5	1.4	3.9	6.8
623	35.6	94.2	2.5	1.5	1.8	5.8
673	95.6	25	4.3	29.2	41.0	74.5
723	89.0	16.7	6.4	34.3	40.0	80.7
773	80.7	12.6	12.3	43.3	31.1	86.7
823	75.2	14.7	14.0	42.3	27.4	83.7

Discussion

From the results presented in table 3 it is clear that catalyst KAG 315 effectively converts gases for torch into a mixture of aromatic compounds. The degree of conversion and the yield of the individual products of catalytic conversion change with a reaction temperature. An increase in reaction temperature causes a rapid decrease in the aliphatic hydrocarbon content while the amount of benzene and total BTX increase. The degree of gas conversion changes complexly with a temperature increase and reaches a maximum at a temperature of T=673 K. At that temperature there is a maximal xylene content, while the amount of obtained toluene reaches its maximum at a temperature of T=773 K. From table 4, it can be seen that catalyst KAG 705, which contains substituted zeolite, converts gases into aromatic compounds more efficiently than catalyst KAG 315. An increase in conversion temperature changes the degree of conversion and content of liquid reaction products. By increasing the conversion temperature, the content of aliphatic hydrocarbons in the liquid products decreases while the benzene content increases. The largest degree of conversion and the biggest xylene content in the liquid reaction products are observed at a temperature of T=673 K, while the maximal toluene content and the largest total amount of BTX are noticed at T=773 K.

Presented results affirm the supposition that by choosing the combination of acid catalytic centers and catalytic centers for dehydrogenation correctly, it is possible, under appropriate reaction conditions, to perform catalytic transformations of aliphatic and olefinic hydrocarbons from gases for torch into an aromatic hydrocarbon mixture (BTX). At relatively low temperatures (T< 573 K), acid centers for cracking reaction and catalytic centers for dehydrogenation are relatively inactive and the degree of conversion is low. In addition, the content of aromatic compounds in the liquid products is low. Increase of reaction temperature activates acid centers for oligomerization and dehydrogenation, thus increasing degree of conversion and the content of aromatics in the liquid reaction products. At temperatures higher than T=773 K, cracking reactions have the main influence on catalytic conversion. They cause a decrease in the degree of conversion and in the BTX content of the liquid reaction products.

Conclusion

It is possible to get the mixture of aromatic hydrocarbons by catalytic conversion of torch gases under controlled conditions. The influence of the catalytic transformation temperature on the total degree of torch gas conversion and its influence on the BTX content in the liquid product is investigated and determinated. A model of the catalytic transformation mechanism of torch gases into an aromatic hydrocarbons mixture on a composite zeolite catalyst is established.

Literature

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