

Researches of Impact of Ionizing Radiation on Some Characteristics of Diesel Fuel

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To cite this article:

Lala Cabbarova, Islam Mustafayev. Researches of Impact of Ionizing Radiation on Some Characteristics of Diesel Fuel. *Journal of Energy, Environmental & Chemical Engineering*. Vol. 2, No. 3, 2017, pp. 41-45. doi: 10.11648/j.jeece.20170203.11

Received: June 7, 2017; Accepted: June 27, 2017; Published: July 27, 2017

Abstract: As the object of study used samples of diesel fuel from the oil of Azerbaijan. Laboratory studies conducted on Co^{60} gamma-source at dose rate of $P=0.18$ Gy/s at different absorbed doses $D=15-150$ kGy. The results of chromatographic, IR-spectroscopic studies are given. Concentrations, radiation-chemical yields of the obtained gases are established. Defined iodine number, viscosity, density before and after irradiation at various absorbed doses of fuel samples and measured their radiation resistance. The methods applied to determination of radiation stability are based on radiation of a product and the subsequent determination of the changes which happened in it. Impact of radiation on operational characteristics of fuels in static conditions on a regular technique before radiation was researched. Radiation oxidations of processes considered in the field of low temperatures when chain processes don't happen. The purpose of this work is the research of radiation firmness of fuels from oils of Azerbaijan. Results of such researches allow to estimate radiation stability of fuels, to find out influence of irradiation on general composition of fuels and possible changes of qualities of fuels.

Keywords: Fuel, Radiolysis, IR-Spectrum, Gases

1. Introduction

Diesel oil with a boiling temperature $180-360^{\circ}\text{C}$, density of $0.790-0.860$ g/cm³ is obtained from virgin oil followed by hydrotreating and dewaxing. The best diesel oil is considered light engine fuel with boiling temperature $230-350^{\circ}\text{C}$, consisting of 60% kerosene fractions boiling up to 300°C and 40% heavier – straw fractions boiling at the range of $290-350^{\circ}\text{C}$. The ability of fuel components to keep its chemical composition under operating conditions within temperature change, radiation, under metal influence is of important practical significance. Radiation influence can be accompanied by chemical transformations: break, displacement of chemical bonds, formation of free radicals, gas release, formation of double bonds and polymerization. The materials resistant to radiation influence must have the ability to absorb energy without excessive ionization.

Studied the effect of radiation on operational performance of diesel under static conditions in the usual manner before and after irradiation. Earlier, the results of experimental studies of radiation-chemical transformation of synthetic oil of oil-bituminous breed, effect of ionizing radiation on lube

oil fractions of heavy bituminous oils, radiation thermal refining of oil-bituminous rocks were presented [1-7].

The aim of the work is the study of radiation resistance of diesel oil from the oil of Azerbaijan. The results of such research allow estimating the radiation resistance of fuel, revealing the influence of irradiation on the overall composition of fuel and the possible changes in the quality of fuel.

2. Methodology

The samples of diesel oil in 1 ml placed in ampoules and sealed in vacuum were irradiated at room temperature on Co^{60} gamma-source at dose rate $P=0.18$ Gy/s at various absorbed doses: within $15-153$ kGy in vacuum for tracing the kinetics of the occurring processes. As an ionizing radiation it was used Co^{60} γ -radiation source of MPX γ -30 type. The influence of absorbed doses of radiation on the change of properties and some operational performance of diesel oil was studied.

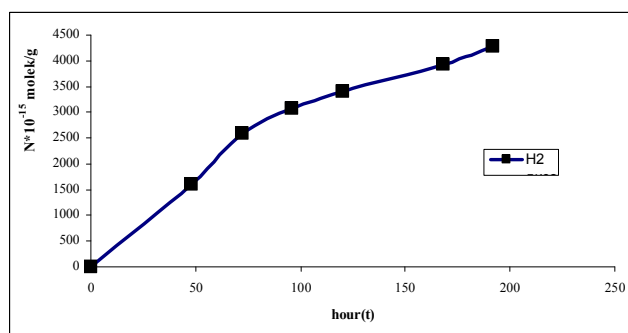
IR absorption spectra of the studied samples were recorded on the spectrometer VARIAN 640-IR (the Company of VARIAN) at the wavelength range ($4000-400\text{cm}^{-1}$). The samples were recorded in the form of film with thickness of $d=1$. Assignment of bands of the obtained spectra was carried

out as described in [8-9]. Gas products were analyzed by gas chromatography. Density was determined by a pycnometer in accordance with GOST 3900 - 85. Definition of viscosity was carried out in accordance with GOST 33-82, to it there corresponds ASTM D 445-88.

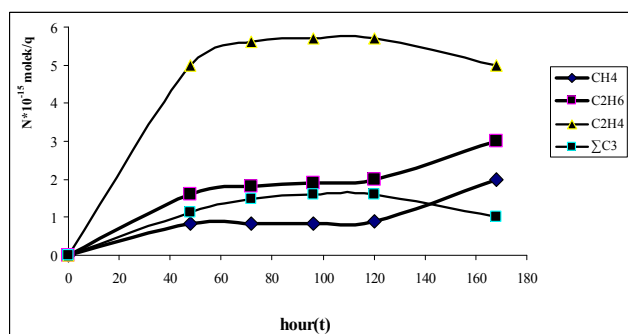
The method establishes definition of kinematic viscosity of oil products by the glass viscometer. Defined iodic numbers on BRUKER MPA spectrometer.

3. Experiments and Results

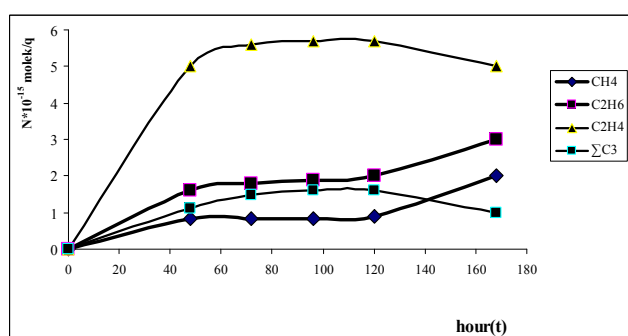
The kinetic curves of accumulation of gases at gamma-radiolysis of below diesel fuel are presented (figure 1).



(a)



(b)



(c)

Figure 1. (a, b, c). The kinetics of formation gases gamma radiolysis diesel.

The influence of absorbed radiation dose on the change of fuel density was studied. The change of density of diesel oil within radiation is given in figure 2.

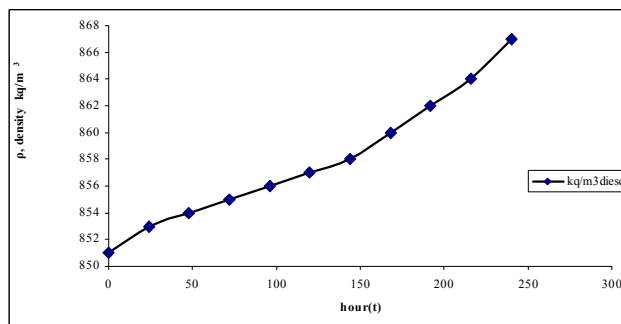


Figure 2. Change of density of diesel fuel in gamma radiolizes.

As it is seen from figure 2, fuel density increases with the increase of absorbed dose. Density indirectly characterizes the chemical properties, fraction composition and volatility of fuel. The more heavy fractions in the fuel, the higher its density. The fuel with high density falling to the bottom of piston and cylinder mirror promotes the increase in carbon-deposition and heat stress. The efficiency of purification from water in separators decreases in fuels with a density close to the unity.

At considerable viscosity of diesel fuels, especially at the depressed temperatures, the fine phase is defended slowly. Considerable content in fuel leads it to increase in wear of mechanical details of toplivkny system of the engine. Stability of fuel is defined by contents in them the unstable products estimated by the size of iodic number and the actual pitches. Almost for all light fuels the iodic number as an indicator of existence in them of the unsaturated hydrocarbons causing chemical instability of these products is normalized. Apparently from figure 3 at a gamma radiolize there is a change of viscosity of diesel fuel.

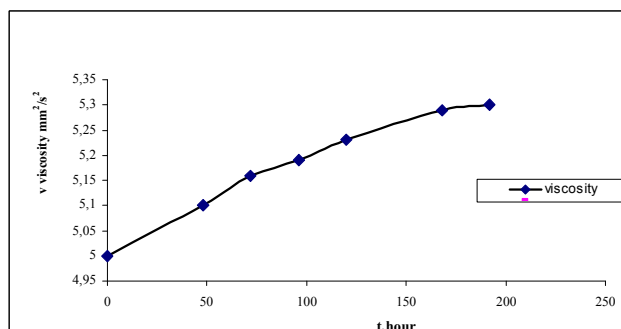


Figure 3. Change viscosity of diesel fuel in gamma radiolizes.

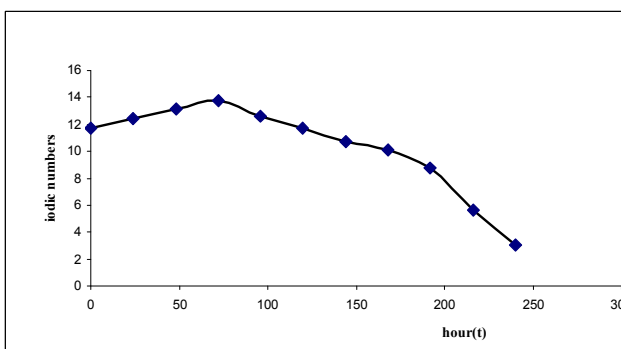


Figure 4. Change of iodic numbers of diesel fuel at the gamma radiation.

The results of IR-spectroscopic studies of samples are shown below in Figure 5 (a, b, c)

Under the influence of temperature, oxygen of air, effect of metals, light, etc. factors unsaturated hydrocarbons are

quickly oxidized and will be polymerized. It leads to an of fuels and deterioration in their operational properties. From figure 4 change of iodine numbers in diesel fuel under the influence of radiation is visible.

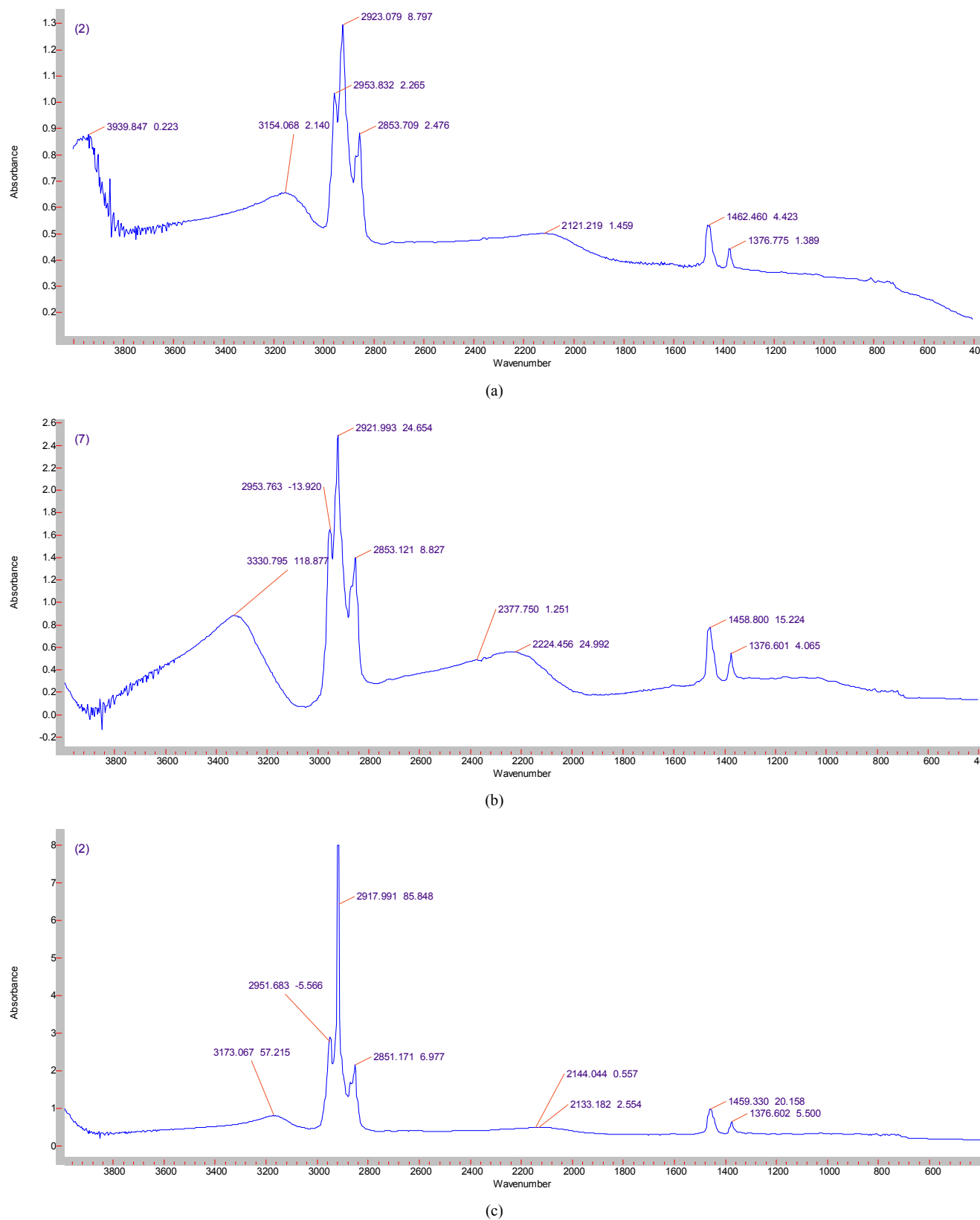


Figure 5. IR -spectra of original diesel fuel (a), IR -spectra of irradiated diesel fuel (b-120 hours, c- 240 hours irradiation).

Bands of deformation oscillation of $-\text{CH}_3$ ($1376\text{--}1380\text{ cm}^{-1}$) groups and oscillation of C-H bonds in alkanes ($1470\text{--}1435\text{ cm}^{-1}$) are observed in the original diesel fuel. Cumulated double $-\text{N}_3$ ($2160\text{--}2120\text{ cm}^{-1}$) bonds and an aldehyde $\text{C}=\text{O}$ ($2880\text{--}2650\text{ cm}^{-1}$) group attached to $-\text{CH}_3$ heteroatoms are observed. Significant valence oscillation of N-H groups (3154 cm^{-1}) -thiophene, furans and valence methylene $-\text{CH}_2-$ ($2940\text{--}2915\text{ cm}^{-1}$) oscillation are also observed.

After 120 hours irradiation (76 kGy), it is observed a 2 times increase in intensity of cycles (2920 cm^{-1}) of valence methylene $-\text{CH}_2-$ groups, and $\text{O}-\text{CH}_3$ groups attached to heteroatoms, as well as valence oscillation $-\text{CH}_3$ (2853 cm^{-1}).

($3400\text{--}3200\text{ cm}^{-1}$) - intra- and intermolecular H- bonds appear in the dimers and polymers. The intensity of valence oscillation of NH (primary amine $-\text{NH}_2$) is also increasing. There appears aryl nitrile (2224 cm^{-1}).

After 240 hours of irradiation (153 kGy), there occurs a sharp increase in cycles of valence methylene $-\text{CH}_2-$ (2917 cm^{-1}) groups by 8 times, and the intensity of the valence oscillation of $-\text{CH}_3$ - groups ($2860\text{--}2960\text{ cm}^{-1}$) by 2-3 times.

Radiochemical exit of gases is the characteristic of radiation stability of organic compounds which can be the main components of fuels. Values of radiochemical exits (molek/100 eV) gases of diesel fuel are given in table 1.

Table 1. Values of radiochemical exits (molek/100 eV) gases of diesel fuel at the absorbed doses $D=15\text{--}150\text{ kGy}$.

Gases	H_2	CH_4	C_2H_6	C_2H_4	ΣC_3	ΣC_4	ΣC_5	ΣC_6	ΣC_7
$D=15\text{--}150\text{ kGy}$	0.62	0.19	0.00048	0.0020	0.0005	0.0014	0.0045	0.0009	0.0006

4. Discussion of the Results

At big height hydrocarbonic fuel on planes can appear under the influence of space particles of big energy. However the processes which have arisen in connection with radiolysis can develop after the radiation termination for a long time that leads to change of composition of fuel. It is especially characteristic of the oxidizing processes which are followed by formation of peroxides. It is very important to keep thermal stability of jet fuels for supersonic planes at least at small doses of radiation. Every year use of organic materials - polymers of lubricants, fuels, heat carriers under operating conditions when they are affected by ionizing radiation, in operating conditions of atomic reactors, accelerators of electrons, in the conditions of space extends. Researches have shown that organic materials are sensitive to radiative effects, real terms of service of concrete technical products depend on their ability to keep initial properties in radiation fields.

All fuels are organic compounds, therefore different radiation lead to chemical degradation and formation of new chemical structures. Study of the irradiation influence on the composition of oil fuel, establishment of link between the demand for fuel composition and its radiation resistance is of practical importance. Unstable fuel are those which have unsaturated compounds and tar. Sunlight and radiation significantly increase the rate of tar formation in diesel oil. Within radiolysis of hydrocarbon mixtures the initial impact energy is rapidly absorbed by liquid and chemical changes occurring under radiation influence are caused by the effect of electrons with the energy less than 100 eV. As a result of γ -radiation in the irradiated medium fast electrons occur, which have high energy and are capable to change the chemical properties of molecules. In this case chemical bonds are broken and free radicals, ions are formed which have free valences and excess energy. Simultaneously with the low molecular compounds of fragmental character, dimers and polymers are formed as the products of recombination of radicals and ions as a result of cracking,

dehydrogenation, isomerization and polymerization of hydrocarbons. Radiolysis of alkanes leads to some of their dehydrogenating with disengagement of free hydrogen, radicals and ions. Secondary, especially tertiary and quaternary C-C bonds and secondary C-H bonds easily burst under radiolysis influence. The yield of gaseous products, including hydrogen is reduced within the irradiation of ethylenes. Total yield of radiolysis products, in which polymers are dominant, increases. More stable ones to radiation effect are polynuclear aromatic hydrocarbons, consisting of 2-4 rings, which were the basis to recommend this class of compounds for using as hydraulic fluid and lubricants working under the conditions of relatively high temperatures and radioactive radiation influence. Such compounds showed high radiation resistance even under intense γ -radiation [10-11].

5. Conclusion

Conducted studies showed that chemical processes, density change occur in diesel oil within the absorbed doses 15-153 kGy. The effect of radiation influence on hydrocarbons of fuel depends on chemical structure, fuel composition. Within the combustion the hydrocarbons are oxidized so fast that the radiation influence is negligible. When the formation of radicals slow down at low temperatures, a small amount of seal products are formed in hydrocarbon medium as a result of radiation. The processes occurring due to radiolysis can continue long after the termination of irradiation which leads to the change of fuel composition. As a result, the operating ability of oil fuel deteriorates at an ambient temperature. The negative effect of fuel irradiation which is in contact with atmospheric oxygen is more at higher temperatures. In the future, it will be able to select such composition of oil fuel which will withstand the effect of radioactive irradiation at high temperatures by changing hydrocarbon composition of oil products due to minor changes in the composition and introduction of additives.

References

- [1] I. I. Mustafaev, L. Y. Jabbarova, N. G. Gulieva., R. S. Rzaev., and S. F. Alieva. "Effect of Ionizing Radiation on Lube Oil Fractions of Heavy Bituminous Oils." M. «High Energy Chemistry», 2014, Vol. 48, No. 5, p. 315–320.
- [2] I. I. Mustafayev, L. Y. Jabbarova, Z. O. Nabizadeh, N. E. Ibadov. "Study of radiation-chemical transformation of synthetic oil from oil-bituminous rock". M. "High Energy Chemistry", 2013, № 6, p. 449-455.
- [3] I. I. Mustafaev, L. Y. Jabbarova., N. Q., Gulieva K. M. Yagubov. "Radiation thermal refining of oil-bituminous rocks". Journal of Radioanalytical and Nuclear Chemistry. Budapest, Akademia Kiado, 2004, vol. 262, №2, P. 509-511.
- [4] L. Y. Jabbarova, S. M. Aliev, S. Z. Melikova. "The impact of ionizing Radiation on Diesel fuel". Journal of Radiation Research. Volum 2, № 2, Baku, Azerbaijan, 2015, p. 71-7.
- [5] L. Y. Jabbarova., I. I. Mustafaev, Z. O. Nabizade, R. S. Rzaev S. F. Akhmadbayova. "Radiation Chemical Conversion of Oil Derived from Oil–Bitumen Rock." Chemistry Journal of Moldova. General, Industrial and Ecological Chemistry. 2014, 9(1), p. 80-84.
- [6] L. Y. Jabbarova, N. E. Ibadov. "Alternativ Energy Sources". Azerbaijan Chemikal. Journal, №3, 2010, p. 128-132.
- [7] I. I. Mustafaev., L. Y. Jabbarova, N. G. Gulieva K. M. Yagubov. "Radiation-thermal refining of organic parts of oil-bituminous rocks". Radiation Safety Problems in the Caspian Region. Kluwer Academic Publishers. Printed in the Netherlands. 2004, p. 141-146.
- [8] K. Nakanisi "Infra-red spectra and structure of organic compounds" M.: Mir, 1985 p. 210.
- [9] L. J. Bellami "Infra-red spectra of complex molecules." -M.: IL 1963, p. 592.
- [10] A. Svollou. "Radiation chemistry." Trans. from eng. -M.: Atomizdat, 1976. p. 278.
- [11] V. K. Milinchuk "Radiation resistance of organic materials": Handbook. M.: Energoatomizdat, 1986. 272.