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DECOMPOSITION OF HYDROGEN PEROXIDE IN THE PRESENCE
OF FULLERENE C₆₀ AND FULLERENE SOOTCorresponding Member of ANAS E.B.Zeynalov¹, E.R.Huseynov¹,
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The action of fullerene C₆₀ and fullerene soot on decomposition of hydrogen peroxide is considered for the first time. It has been established by kinetic methods that these carbon nanostructures (CNS) actively catalyze the decay with concomitant release of molecular oxygen. The catalytic activity of fullerene soot appears to be several times higher than that for fullerene C₆₀. The obtained results create a precedent for the use of CNS as active components of the peroxide oxidation of hydrocarbons.

Keywords: carbon nanostructures, fullerenes, hydrogen peroxide, fullerene soot, aerobic oxidation.

Introduction

One of the main directions of our research is to study the effect of various carbon nanostructures on the aerobic and peroxide oxidation of liquid hydrocarbons and polymeric materials. By a series of kinetic experiments conducted during last decades, we have shown that fullerenes C₆₀, C₇₀ and fullerene soot have a significant effect on the oxidation processes. The results were published and many of them were presented for the first time. They describe the antioxidant effect of fullerenes in oxidation of alkyl aromatic hydrocarbons (cumene, ethylbenzene, decahydronaphthalene), thermooxidative degradation of polyolefin compositions [1-3].

The ability of fullerenes and carbon nanotubes to actively transfer an electron has been also realized in systems with compounds containing metals of variable valence. These systems, under proper conditions, proved to be excellent catalysts for the aerobic oxidation of hydrocarbons [4-6].

In recent years, we have been conducting research to determine the effect of carbon nanostructures (CNS) on the processes of oxidation of hydrocarbons with hydrogen peroxide. These studies are situated at the initial stage and are carried out both in the aspect of studying the kinetic patterns of aerobic-peroxide oxidation of hydrocarbons, and the effects of different CNS on the yield and

selectivity of the final products as well [7-10].

Within framework of these studies, it is extremely important to know the rate of decomposition of hydrogen peroxide in the presence of CNS. The intensity of the thermal decomposition of hydrogen peroxide in aqueous solutions is characterized in the literature by various values and this is quite understandable, since peroxide is extremely sensitive to any, even smallest impurities that catalyze its decay.

There is even an indication that walls of glass reaction vessels have a weak catalytic effect on the decomposition of hydrogen peroxide. Thus, it seemed necessary to evaluate the systems of CNS + H₂O₂ under conditions under which we usually study the kinetic regularities of the process even before the hydrocarbon is involved in this process.

This article is devoted to the study of an effect of fullerene C₆₀ and fullerene soot on the decomposition of hydrogen peroxide. Among known papers of this scientific line, we can note the paper [11] where multi-walled carbon nanotubes (MWCNTs) were used for hydroxylation of aromatic hydrocarbons at temperatures 50-70°C.

It has been found that without the assistance of any solvent or additive, high selectivity was still obtained. The catalysts were characterized by X-ray powder diffraction, infrared spectra, Raman spectra, and transmission electronic micros-

copy. These results prove that MWCNT was a highly-active, highly-selective, and well-reproductive heterogeneous catalyst. The curved sp^2 -hybridized carbon surfaces of MWCNT played an important role in these selective catalytic reactions. The authors consider that reactions were proposed to occur via an oxene attacking process. The active oxygen species were generated through the interaction between the hydrogen peroxide and the MWCNTs and subsequently consumed by the aromatic hydrocarbons [11].

Experimental

As the objects of the study, a 30% aqueous solution of hydrogen peroxide was chosen. Fullerene C_{60} (98%) and fullerene soot (as pro-

duced), both provided by the “Sigma-Aldrich Chemicals”, were used. The fullerene soot contains fullerenes $\geq 7\%$, of which 76% C_{60} , 22% C_{70} , the rest are higher fullerenes.

To measure the decomposition of H_2O_2 in the presence of fullerenes, an operating temperature of $60^\circ C$ was employed. The decay rate of H_2O_2 was measured by the amount of the evolved gas (oxygen), according to the reaction $H_2O_2 + C_{60} \rightarrow H_2O + O_2$.

The gas evolution was fixed using gas metering unit, a schematic representation of which is given in Fig.1.

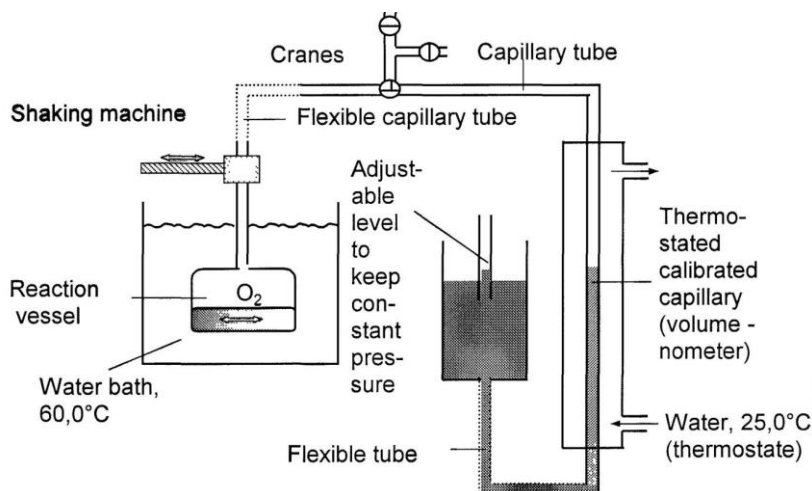


Fig.1. Schematic diagram of measuring equipment for a gas uptake or evolution

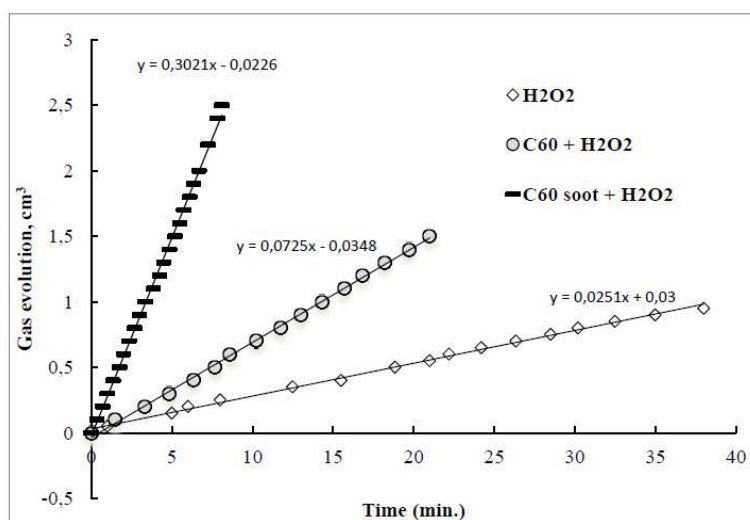


Fig.2. Kinetic dependencies of oxygen evolution during thermal decomposition of 30% aqueous solution of H_2O_2 in the presence of fullerene C_{60} and fullerene soot, $60^\circ C$

Before the experiments, the glass reaction vessels were thoroughly and consistently cleaned with a chrome mixture and ethanol.

Results of experiments and their discussion

Figure 2 represents the results of experiments on fixing the amount of oxygen released during the decomposition of a 30% aqueous solution of hydrogen peroxide in the presence of fullerenes.

It is seen from the results that the decomposition of hydrogen peroxide is catalyzed by fullerenes. Moreover, the catalytic activity of fullerene soot turns out to be 4 times higher than fullerene C₆₀.

If we consider the composition of fullerene soot, then it is characterized by a multilevel structure. Particles of soot, including fullerenes, aggregate with each other to form associates forming a spatial grid of fractal nanoclusters 40-80 nm in size. Nanoclusters are combined into aggregates, which in turn are part of the soot micro-particles [12, 13]. In addition, apparently fullerene soot also contains additional microimpurities that have an additional catalytic effect on the decomposition of hydrogen peroxide [14,15].

Conclusions

1. It has been inferred for the first time that fullerenes actively catalyze the decomposition of hydrogen peroxide with the concomitant release of gaseous products (oxygen).

2. Fullerene soot is a more active catalyst for the decomposition of hydrogen peroxide than fullerene C₆₀ – the catalytic activity of soot is 4 times higher than that of C₆₀.

3. The results obtained form the basis for the use of carbon nanostructures as catalysts for peroxide oxidation of hydrocarbons.

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FULLEREN DUDASI VƏ FULLEREN C_{60} -m İŞTİRAKI İLƏ HİDROGEN PEROKSİDİN PARÇALANMASI

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İlk dəfə olaraq fullerен C_{60} və fullerен dudasının hidrogen peroksidin parçalanma prosesinə təsiri öyrənilmişdir. Kinetik üsullarla təyin edilmişdir ki, qeyd edilən karbon nanoquruluşları (KNQ) molekulyar oksigenin ayrılması ilə parçalanma prosesini aktiv kataliz etməyə qadirdirlər. Fullerен dudasının katalitik aktivliyi fullerен C_{60} -dan bir neçə dəfə üstündür. Alınmış nəticələr karbon nanoquruluşlarından karbohidrogenlərin hidrogen peroksidin iştirakı ilə oksidləşmə proseslərində aktiv komponent kimi istifadə etməyə imkan yaradır.

Açar sözlər: karbon nanoquruluşları, fullerenlər, hidrogen peroksid, fullerен dudası, aerob oksidləşmə

РАСПАД ПЕРОКСИДА ВОДОРОДА В ПРИСУТСТВИИ ФУЛЛЕРЕНА C_{60} И ФУЛЛЕРЕНОВОЙ САЖИ

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Впервые рассмотрено действие фуллерена C_{60} и фуллереновой сажи на распад пероксида водорода. Кинетическими методами установлено, что указанные углеродные наноструктуры (УНС) активно катализируют распад с выделением молекулярного кислорода. Фуллереновая сажа по каталитической активности в несколько раз превосходит фуллерен C_{60} . Полученные результаты создают прецедент использования УНС в качестве активных компонентов пероксидного окисления углеводородов.

Ключевые слова: углеродные наноструктуры, фуллерены, пероксид водорода, фуллереновая сажа, аэробное окисление