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DISSOLUTION OF FULLERENES C_{60} AND C_{70} IN ORGANIC OILS

Victor I. Gerasimov*, Ilya A. Balay

[1]Department of Mechanics and Control Processes, St. Petersburg State Polytechnical University,

Polytekhnicheskaya 29, 195251, St. Petersburg, Russia

*e-mail: viger@rambler.ru

Abstract. In this paper we considered a group of oils (argan, apricot, macadamia, almond, and peach) based on oleic acid (ω-9) with the addition of fullerenes C_{60} and C_{70}. The following data are obtained: maximum solubility of fullerenes, time dependence of solubility and spectrophotometric data.

1. Introduction

Last few years, increasing attention is paid to the pharmaceutical and cosmetic solutions, oils and creams enriched with fullerenes. These particles are composed of carbon, so human body takes medicines based on fullerenes as "native". Fullerenes are a powerful antioxidant and antiseptic. As a part of medical and cosmetic products they activate biologically active substance composition, thereby accelerating regeneration rate of the skin [1]. Research [2] showed that the use of C_{60} enriched medicines instead of usual ones in the case of treatment and elimination of the consequences of external burn allow accelerate healing time in half, and avoid festering area near the burn.

For the manufacture of medicines with additives, it is necessary to study the process of dissolving nanoparticles in the basic substance (in this case – organic oils). Thus, the objectives of this work are:

1. Obtaining data for the maximum solubility of C_{60} and C_{70} in the basic oils based on oleic acid.
2. Obtaining data for the time dependence of the solubility of fullerenes C_{60} and C_{70} in the basic oils based on oleic acid.
3. Spectrophotometric data analysis to identify the presence or absence of pure C_{60} and C_{70} in solution.

2. Defining the maximum solubility of fullerenes C_{60} and C_{70}

First of all we need to know maximum solubility of fullerenes [3, 4<4, 5]. Based on the data for solubility in organic solvents [5<3], starting point was selected as concentration of 0.5 g/L. After the addition of a fullerene, the solution was stirred for two hours. Then the stirring was stopped, the solution was allowed to stand for one hour, thereafter it was examined for the presence of a precipitate. If the precipitate is present in the solution, this means that the fullerene is not completely dissolved. Then a certain amount of oil was added to the sample in order to reduce the concentration of fullerene and allow continuing dissolution. Otherwise, a certain amount of fullerene was added to the solution. After every step, the samples were stirring for one extra hour, and then were checked for the presence of a precipitate again. At each subsequent step, less extra fullerene or oil was added into solutions, thereby increasing accuracy of defining maximum solubility. Data of the maximum solubility are shown in Table 1.

Table 1. Maximum solubility of C_{60} and C_{70}.

Oil	Maximum solubility, g/L	
	C_{70}	C_{60}
Argana	0,3815±0,015	0,6904±0,014
Apricot	0,3066±0,002	0,6600±0,022
Macadamia	0,6625±0,007	0,5512±0,007
Almond	0,5976±0,014	0,4569±0,018
Peach	0,6612±0,012	0,5065±0,012

3. Time dependence of the solubility of fullerenes C_{60} and C_{70}

Discoloration (opacity) of the samples in the process of dissolution indicates interaction of fullerene molecules with components of oils. Each oil has its own incubation period, that is, the dissolution of the fullerene takes time. During the incubation period, solution color change recorded periodically. Opacity was evaluated by passing laser beam through the samples. The beam radius decreases due to scattering in solution. The opacity of source oil was taken as zero. Data on the time dependence of solubility are shown in Fig. 1. As we can see, the opacity change of oils with C_{70} takes place in one stage, that is, there is continuous darkening the solution to fully opaque. The process takes no more than two hours. In the samples with addition of C_{60} one observes three stages of color evolution: color change from source color to purple (purple color corresponds to C_{60} dissolved in solvents like benzole, toluene, xylene), solution remain purple for a long time (tens of hours), and the final stage – the transform into a saturated "cherry" color. The entire process takes few days, compared to few hours in the previous case.

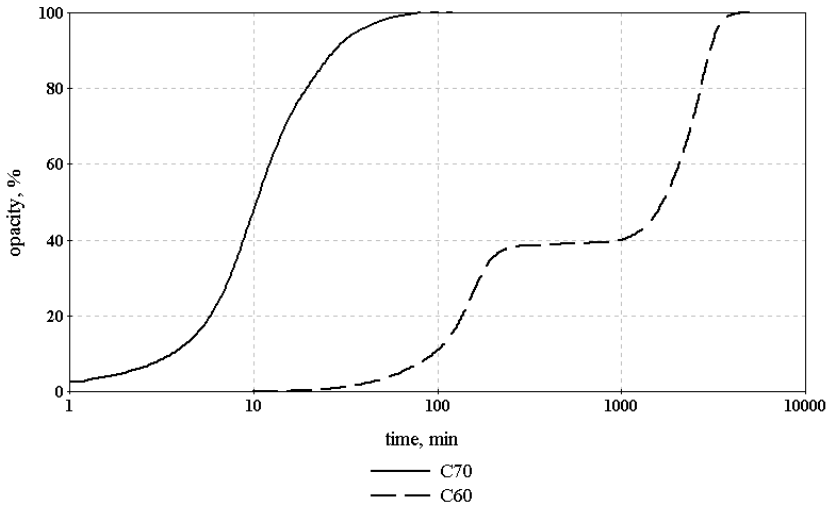

Fig. 1. Time dependence of solubility.

The time difference is caused by differences of C_{60} and C_{70} volumetric structure, which is represented in Fig. 2. Fullerene C_{60} has a structure close to spherical, and C_{70} has an ellipsoidal shape. Imagine a volume filled with fullerenes. Obviously, not all of it is filled with the fullerene molecules, there would be a free volume in which the oil components will penetrate into the fullerene clusters and tear them into individual molecules, thus starting process of dissolution. Because of its shape, the fullerene C_{70} has a larger free volume than the C_{60}. It means that the oil particles are better able for penetrating into the voids of the structure that directly affects the rate of dissolution.

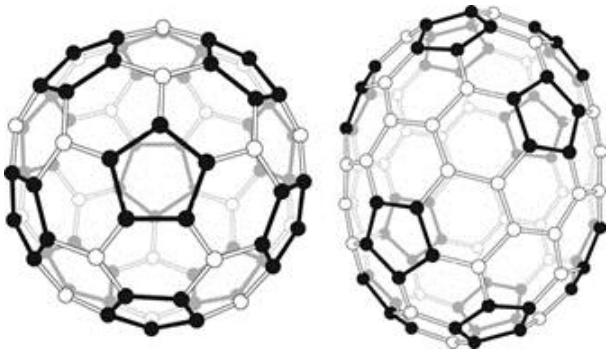

Fig. 2. Volumetric structure of C_{60} (left) and C_{70} (right).

Previously, the difference was justified for dissolution rates, and this rate directly affects the dissolution time. So, the higher dissolution rate we have, the less time is required to complete the dissolution. The high rate of dissolution, sponginess of a structure built of ellipsoidal fullerenes C_{70} let us suggest that one-stage color change for this substance seems legitimate. Fullerene clusters are quickly pulled apart and spread in oil as single molecules and immediately reacts with its components. However, for samples with C_{60} it is not so simple. The first stage, change from source oil color to purple, occurs in a few hours. Purple color stays stable from 5 to 20 hours; then the interaction between the fullerene molecules and oil components starts, whereby the color of the solution changes to the "cherry". That means that the preparation of fullerene molecules for interaction with oil components finishes, and the last stage of transformation starts. At this stage, attaching fatty acids to the outer surface of fullerene molecules occurs. Reaction is accompanied by the change of solution color – now it can be defined as "ripe cherry", the completion of the reaction leads to a further darkening of the solution.

4. Spectrophotometric data analysis

Assume that the interaction of fullerene with oil components leads to the formation of complexes where fatty acids attach to the outer surface of fullerene. So, on the spectrum of samples, peaks corresponding to the pure fullerene should disappear. That assumption is correct only if added fullerene consumed completely by reaction that creates complexes with fatty acids. As expected, none of the spectrum peaks correspond to the peak of pure C_{60} (Fig. 3).

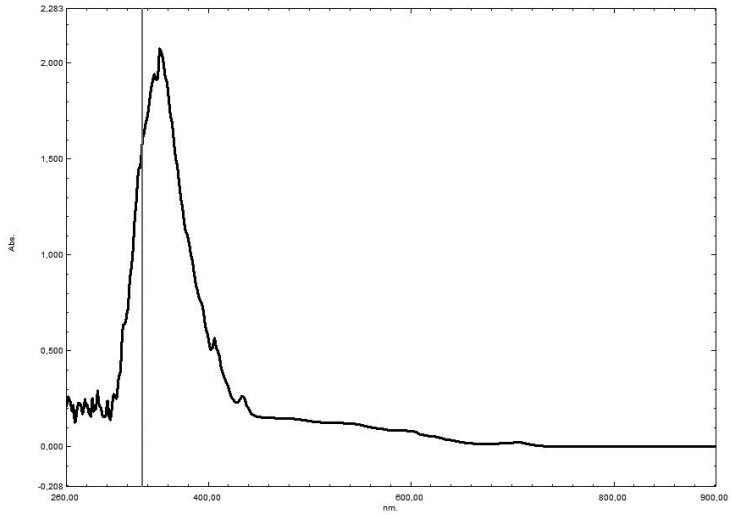

Fig. 3. Spectrum of Apricot oil with addition of C_{60}.

For C_{70} the situation almost the same excluding a sample of argana oil, where one of peaks corresponds to the peak of pure C_{70} (Fig. 4). The peaks of pure C_{60} and C_{70} are represented as a vertical line at 335 nm (for C_{60}) and 472 nm (for C_{70}) which is the wavelength of the peak.

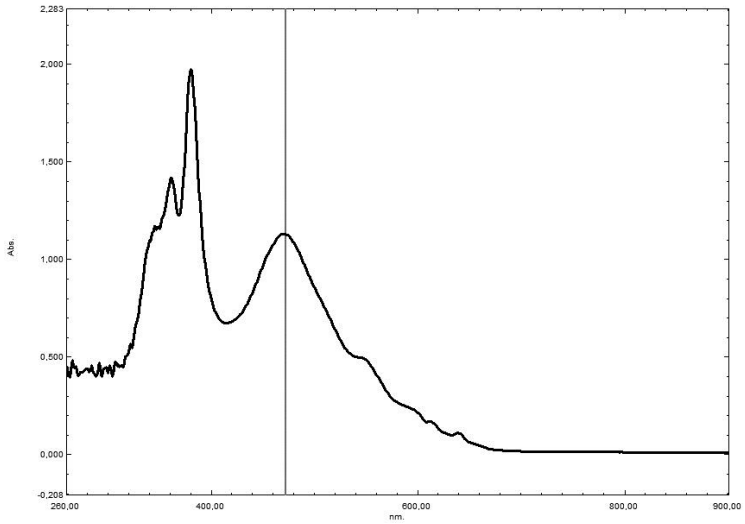

Fig. 4. Spectrum of Argana oil with addition of C_{70}.

5. Conclusions

The limit solubility of C_{60} and C_{70} in the studied group of organic oils was obtained. Based on these results, manufacturing method of organic oils with fullerenes for medicines and cosmetics was improved and optimized. Data for time dependence of the solubility of fullerenes were also obtained. The assumption that the fullerenes are completely dissolved in this organic group of oils is confirmed for the entire group excluding one: C_{70} do not dissolve completely in argana oil.

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