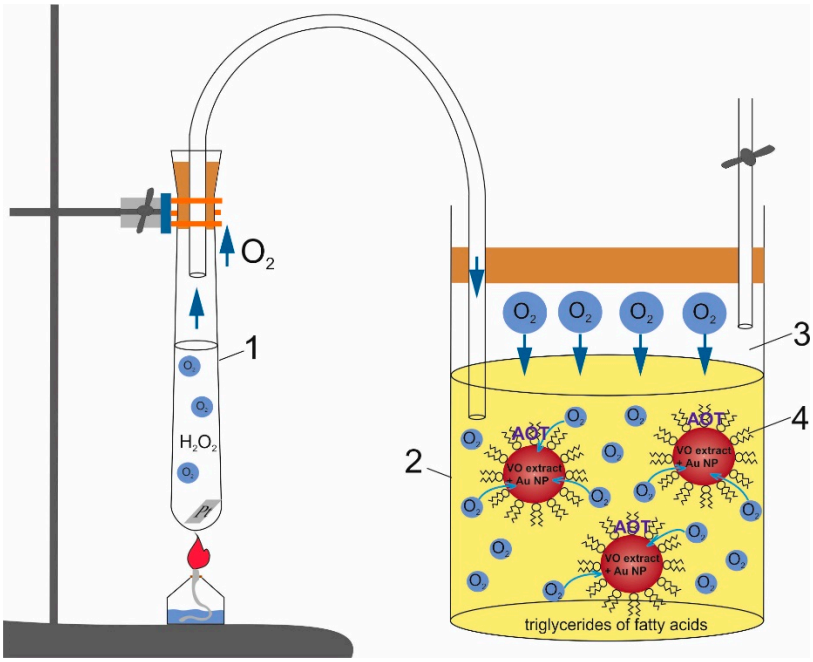
Supplementary Materials

Contents:

1. Scheme of oxygen saturation of the Viburnum opulus L. microemulsion



Scheme S1. The installation for oxygen generating and additional saturation of microemulsion (VO) with O_2: 1—an oxygen generator (a glass tube with a H_2O_2 solution and *Pt* plate); 2—a microemulsion with dissolved oxygen; 3—an air atmosphere with different partial pressure of O_2; 4—an AOT micelle containing a water–Eth extract of a Viburnum opulus L.

Atmospheric oxygen dissolves in the oil microemulsion in accordance with Henry's law. Saturation of the microemulsion with oxygen was performed by increasing the partial pressure of oxygen over the surface of the emulsion. For this purpose, hydrogen peroxide decomposition was performed according to the equation

$$2H_2O_2 \xrightarrow{t,\ Pt} 2H_2O + O_2.$$

By applying Henry's law, the following system of equations can be written:

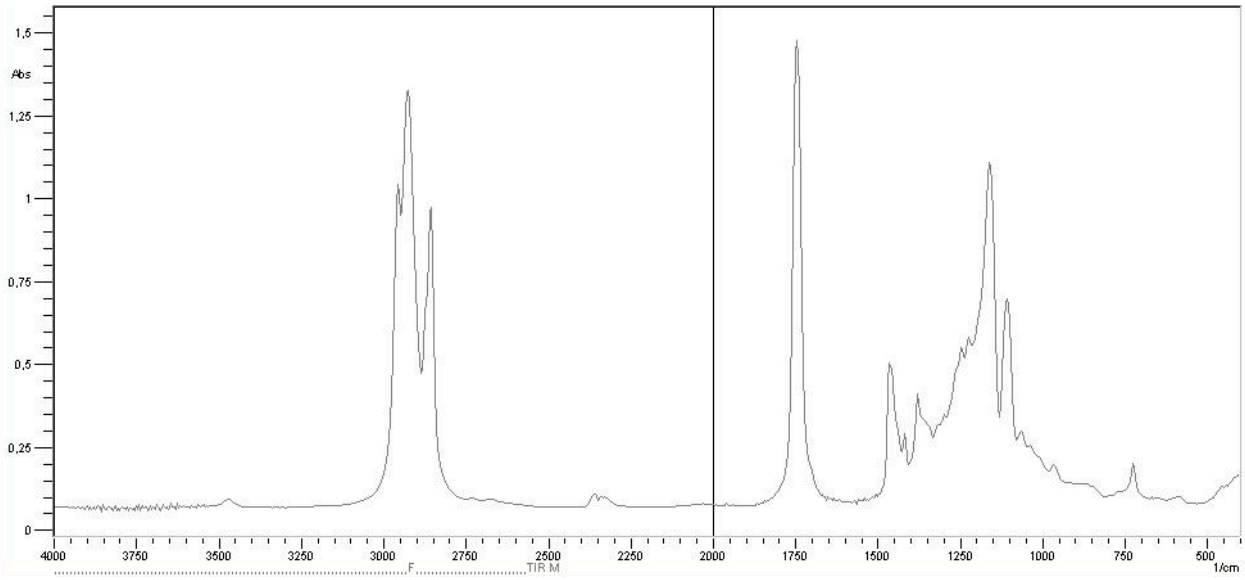
$$\left.\begin{matrix} S^0_{O_2} = kP^0_{O_2} \\ S_{O_2} = kP_{O_2} \end{matrix}\right\} \Rightarrow \frac{S_{O_2}}{S^0_{O_2}} = \frac{P_{O_2}}{P^0_{O_2}},$$

where S^0O_2 and SO_2 are the solubility of oxygen in the microemulsion (initial and after additional oxygen saturation, respectively). By substituting the PO_2 and P^0O_2 values, we obtained $SO_2/S^0O_2 = 4.7$. Thus, the O_2 concentration in the microemulsion increased 4.7 times at the partial pressure of oxygen equal to atmospheric pressure. Assuming that SO_2 (mic) = $t \cdot SO_2$(oil), where *t* is the coefficient of proportionality; SO_2(oil) denotes the oxygen solubility in oil; and SO_2(mic) is the oxygen solubility in micelle, where the last expression can be written as follows:

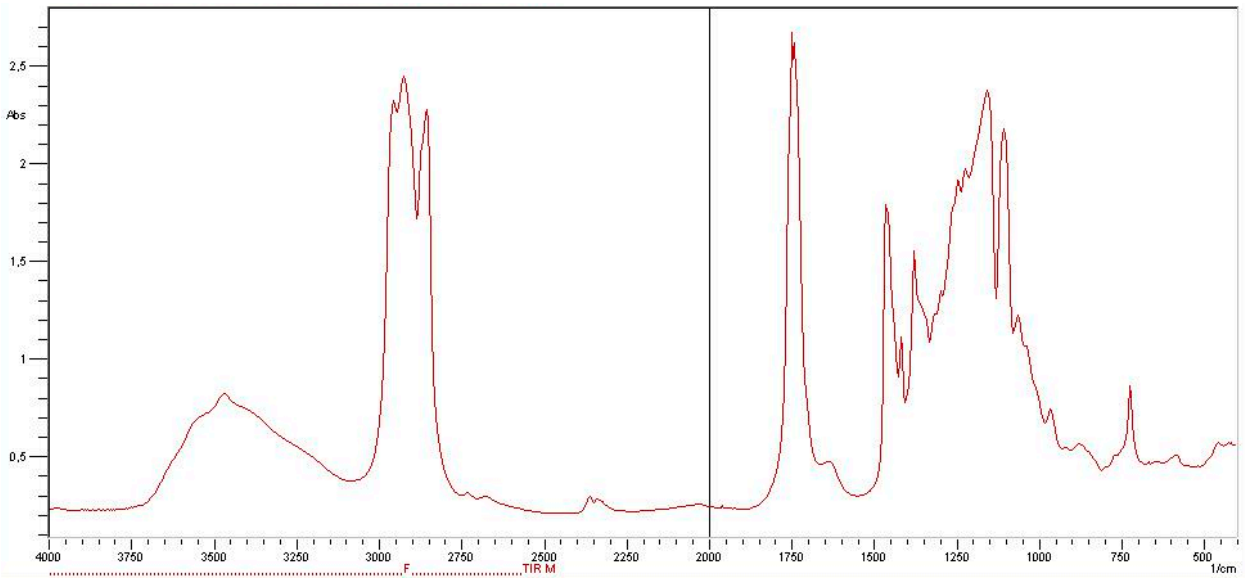
$$\frac{S_{O_2}(\text{mic})}{S^0_{O_2}(\text{mic})} = \frac{S_{O_2}(\text{oil})}{S^0_{O_2}(\text{oil})} \approx 4.7$$

Thus, the oxygen concentration in the micelle also increased 4.7 times and was $C_1=2\cdot10^{-4}$ M at oxygen partial pressure equal to atmospheric pressure. Adjusting the partial pressure of O_2 in the space above the microemulsion, different concentrations of oxygen in micelles were created. The oxygen pressure in the space above the emulsion was regulated by the reaction time (τ) and the oxygen concentration. C[O_2] grew linearly with an increase in pressure: at τ_1 = 5 min – p_1 = 0.25 atm ($C_1[O_2]= 2\times10^{-4}$ M); at τ_2 = 7 min – p_2= 0.65 atm ($C_2[O_2]= 3.5\times10^{-4}$ M); and at τ_1 = 12 min – p_3= 1 atm ($C_3[O_2]= 8.5\times10^{-4}$ M). The process of oxygen oversaturation of the microemulsion leads to the destruction of micelles and the precipitation of a pink sediment. This is due to oxidative processes leading to the destruction of double bonds in the triglycerides of fatty acids (oil).

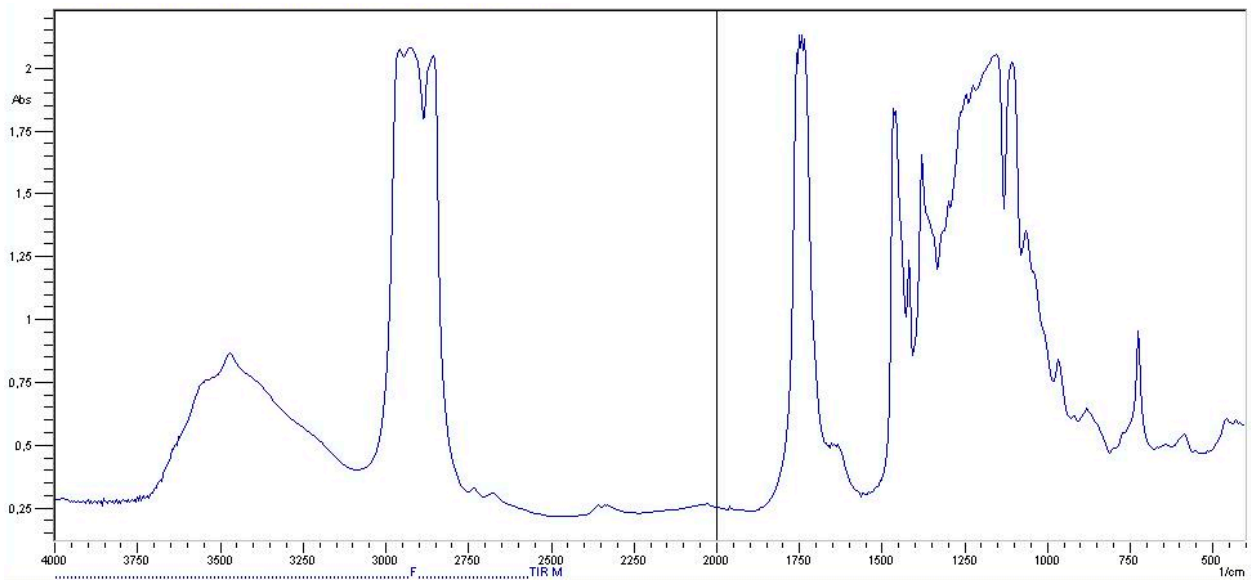
2. FTIR spectroscopy of the microemulsion with Au nanoparticles and oxygen molecules



(**a**)



(**b**)



(**c**)

Figure S1. IR spectra: microemulsion without Au NPs (**a**); microemulsion with Au NPs (**b**); microemulsion with oxygen molecules (**c**).

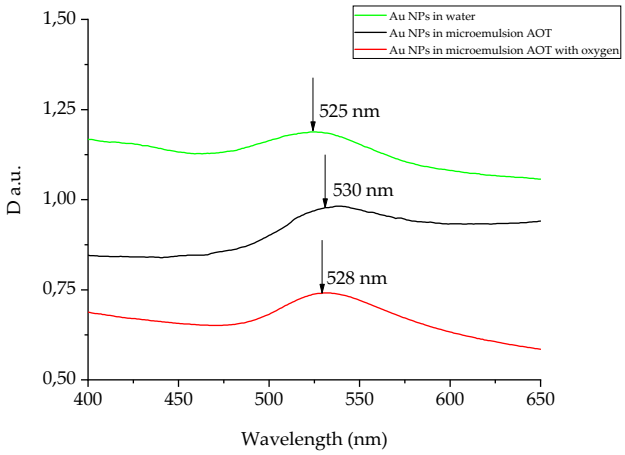
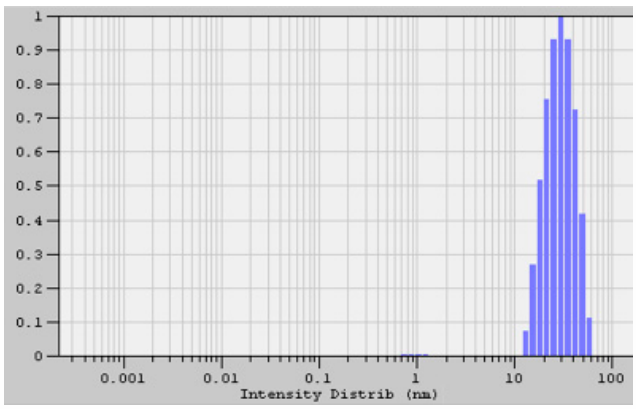
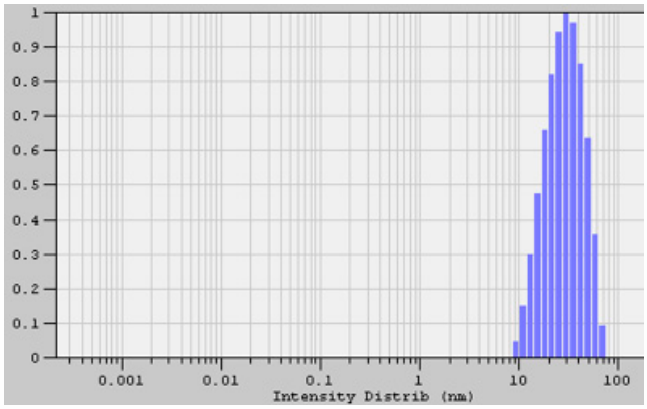


Figure S2. Absorption spectra: Au NPs in water solution; Au NPs in the microemulsion; Au NPs in the microemulsion with oxygen molecules.

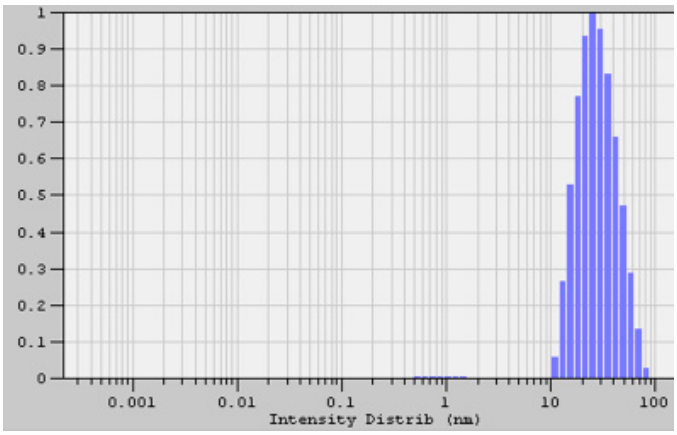
3. Size distribution and zeta potential results of gold nanoparticles



(**a**)



(**b**)



(**c**)

Figure S3. Size distribution of gold nanoparticles in water solution (**a**); in reverse micellar solution without oxygen molecules (**b**), and in reverse micellar solution with oxygen molecules (**c**).

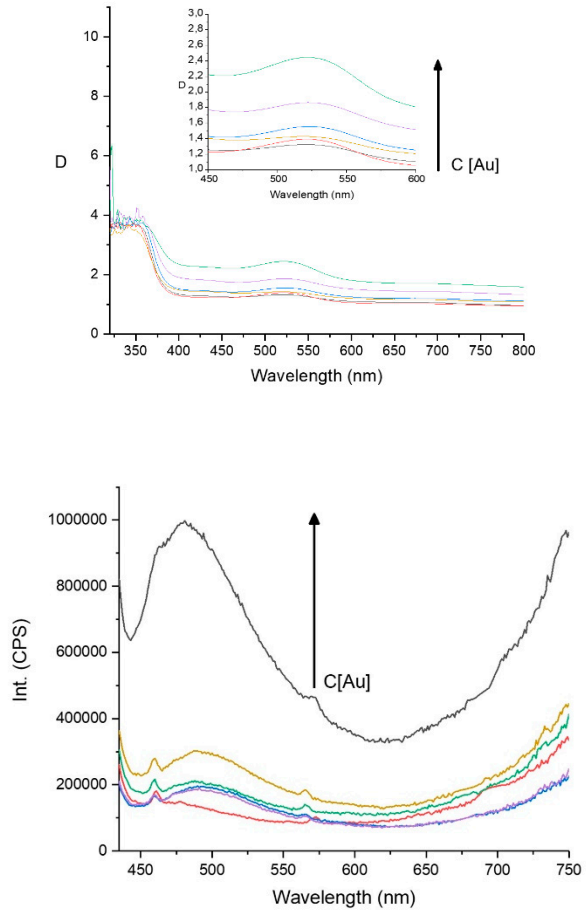
As can be seen from Figure S2, the size distribution and the average hydrodynamic radius did not change in the microemulsion AOT and in the presence of oxygen molecules.

Table S1. The results of the size distribution and zeta-potential measurements.

Sample	R (nm)	Z-potential (mV)
Colloidal water solution of Au NPs	30.27 ± 0.17	−15.65 ± 0.11
Microemulsion AOT with Au NPs without O_2 molecules	30.68 ± 0.12	−25.26 ± 0.34

Microemulsion AOT with Au NPs with O_2 molecules	28.86 ± 0.14	−22.88 ± 0.47

4. Absorption and luminescence spectra of microemulsions with water–ethanol Viburnum opulus L. extract and gold nanoparticles of various concentrations



(**a**) (**b**)

Figure S4. Absorption spectra (**a**) and luminescence spectra (**b**) of microemulsions with VO extract and gold nanoparticles of various concentrations. Au nanoparticle concentrations: $C_1 = 1\times10^{-10}$, $C_2 = 0.75\times10^{-10}$, $C_3 = 0.5\times10^{-10}$, $C_4 = 0.25\times10^{-10}$, $C_5 = 0.125\times10^{-10}$ M. Excitation wavelength was 400 nm.

5.Study of antioxidant activity of Viburnum opulus L. extract with gold nanoparticles

5.1. Determination of antioxidant activity by the Amperometric Method

The antioxidant activity of the extracts was determined by means of a Tsvet-Yauza-01-AA (NPO Himavtomatika, Russia) unit. The amperometric method for measuring the mass concentration of antioxidants is based on measuring the electric current strength that occurs during the oxidation of antioxidant molecules on the surface of the electrode at a certain potential, which after amplification is converted into a digital signal. Operating parameters of the device: constant current mode (BP), the potential of the working electrode (Up)—(+) 1.3 V,

the rate of eluent supply (orthophosphoric acid solution with a molar concentration of 0.0022 mole/dm^3) of the peristaltic pump—1.2 cm^3 / min.

The results are summarized in Table S2.

Table S2. The results of antioxidant activity obtained by amperometric method.

	Analytical signal (Peak area, nA*s)				
	Sample				
Sample no.	1-NPs Au	2-VO without NPs Au	3-VO with Au NPs (C_1)	4-VO with Au NPs (C_2)	5-VO Au NPs (C_3)
1	66	13,123	11,876	12,508	14,317
2	58	12,866	11,872	13,329	13,083
3	62	13,666	11,559	12,997	15,077
4	61	13,829	11,619	12,253	15,257
5	67	13,561	11,151	11,811	14,221
6	57	12,525	14,957	12,221	1,3087

Note: Au nanoparticle concentrations $C_1 = 1\times10^{-10}$, $C_2 = 0.5\times10^{-10}$, $C_3 = 0.25\times10^{-10}$ M.

5.2. Determination of Antioxidant Activity by the Spectrophotometric Method (FRAP Method)

The method is based on the assessment of antioxidant activity by restoring power in the interaction of antioxidants with the Fe(III)-2,4,6-tripyridyl-5-triazine (FRAP) complex. To determine the regenerating power of the extracts, a freshly prepared FRAP reagent was used (prepared by mixing 10 parts of 0.3 M acetate buffer (pH 3.6), one part of a 10 mM solution of 2,4,6-tripyridyl-5-triazine in 40 mM HCl, and one part of an aqueous 20 mM solution of ferric chloride $FeCl_3 \times 6H_2O$). The reaction was started by mixing 300 mL of FRAP reagent and 20 mL of the studied extract. The time reaction was 10 minutes at 37 °C in the dark. The optical density was measured at 595 nm (CLARIOstar, BMG Labtech, Germany). The results are presented in Table S3.

Table S3. The results of antioxidant activity obtained by FRAP method.

	Optical density				
	Sample				
№ sample	1- Au NPs	2-VO without Au NPs	3-VO with Au NPs (C_1)	4-VO with Au NPs (C_2)	5-VO with Au NPs (C_3)
1	0.028	0.337	0.359	0.359	0.345
2	0.032	0.366	0.375	0.347	0.368
3	0.03	0.383	0.396	0.369	0.378
4	0.036	0.356	0.37	0.375	0.335
5	0.025	0.346	0.367	0.336	0.341
6	0.041	0.375	0.377	0.356	0.378
7	0.026	0.35	0.382	0.376	0.378

Note: Au nanoparticle concentrations $C_1 = 1\times10^{-10}$, $C_2 = 0.5\times10^{-10}$, $C_3 = 0.25\times10^{-10}$ M.

5.3. Determination of Antioxidant Activity by the Spectrophotometry Method (DPPH Method)

The method is based on the ability of binding molecules of the reactive radical 2,2-diphenyl-1-picrylhydrazyl (DPH, DPPH) with antioxidants contained in the studied samples (VO extract solution with/without Au nanoparticles). Each portion of the extract (V = 20 mL) was mixed with 300 mL of a freshly prepared 0.1 mM solution of 2,2-diphenyl-1-picrylhydrazyl (DPH, DPPH) in ethanol. The sample was incubated for 60 minutes at room temperature in the dark. The decrease in optical density at 515 nm was measured by the spectrophotometry method (CLARIOstar, BMG Labtech, Germany).

The results are presented in Table S4.

Table S4. The results of antioxidant activity obtained by the DPPH method.

	Optical density				
	Sample				
Repeatability	1-Au NPs	2-VO without Au	3-VO with Au NPs (C_1)	4-VO with Au NPs (C_2)	5-VO with Au NPs (C_3)
1	0.0295	0.2186	0.2416	0.2346	0.2256
2	0.0261	0.2386	0.2326	0.2246	0.2426
3	0.0231	0.2426	0.2256	0.2336	0.2586
4	0.0171	0.2456	0.2416	0.2236	0.2016
5	0.0311	0.2296	0.2236	0.1886	0.2126
6	0.0231	0.2526	0.2166	0.2226	0.2276
7	0.0211	0.2466	0.2396	0.2306	0.2196
8	0.0321	0.2576	0.2576	0.2306	0.2356

Note: Au nanoparticle concentrations $C_1 = 1\times10^{-10}$, $C_2 = 0.5\times10^{-10}$, $C_3 = 0.25\times10^{-10}$ M.

5.4. Determination of Antioxidant Activity by the Spectrophotometry Method (ABTS Method)

The method is based on the binding ability of molecules of the reactive radical ABTS (2,2'-azino-bis(3-ethylbenzthiazolino-6-sulfonic acid). The ABTS radical was generated by mixing an aliquot of 2,2'-azino-bis(3-ethylbenztiazoline-6-sulfonic acid (7.0 mM) and 2.45 mM solution of potassium persulfate. To carry out the reaction, the volume of 300 μL of cation radical ABTS·+ was added to 20 μL of the extract (VO with/without Au NPs). The optical density was measured at 730 nm after incubation of the mixture for 15 min at 37 °C in the dark (CLARIOstar, BMG Labtech, Germany). The results are presented in Table S5.

Table S5. The results of antioxidant activity obtained by the ABTS method.

	Optical density				
	Sample				
N	1-Au NPs	2-VO without Au NPs	3-VO with Au NPs (C_1)	4-VO with Au NPs (C_2)	5-VO with Au NPs (C_3)
1	0.004	0.3508	0.3408	0.3048	0.2918
2	0.002	0.3398	0.3578	0.3458	0.3018
3	0.001	0.3588	0.3588	0.3198	0.3158
4	0.004	0.3198	0.3268	0.2948	0.3388
5	0.005	0.3228	0.3428	0.2988	0.2658
6	0.002	0.3478	0.2998	0.3088	0.3018
7	0.003	0.3618	0.3208	0.2968	0.3148

8	0.002	0.3748	0.3798	0.3298	0.2988

Note: Au nanoparticle concentrations $C_1 = 1\times10^{-10}$, $C_2 = 0.5\times10^{-10}$, $C_3 = 0.25\times10^{-10}$ M.

Based on the data presented in Tables S2–S5 it can be concluded that the water–ethanol extract of Viburnum opulus L. has an antioxidant activity and can form contact complexes with oxygen molecules (O_2). At the same time, the antioxidant activity of the extract can be increased or decreased depending on the concentration of gold nanoparticles in the solution.