Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Studying the effect of gold nanoparticles on mixture of surfactant of sodium dodecyl benzene sulfonate (SDBS) surfactant and folic acid

Liqaa Hussein Alwan[1*] and LAYLA A. AL JEBUR[2]

[1]*Department of Chemistry, College of Education, University of Samarra, Samarra, Iraq*

[2]*Department of Chemistry, College of Science, Tikrit University, Tikrit, Iraq*

Abstract

Gold nanoparticles were prepared from yeast dough via gold salt reduction and their effect on rheology of a mixture of folic acid and the surfactant of sodium dodecyl benzene sulfonate (SDBS) was studied. The results revealed that the highest viscosity (pa. s7.1232×10^2) was at a ratio of 2/8, a temperature of 10^{o}C and a concentration of 0.00004M of nano-gold. So, micelles growth is occurred by increasing nano-gold concentration. In the same manner, measuring the conductivity of the prepared solution revealed that there is a reverse proportion between conductivity and viscosity. Also, thermodynamic functions were calculated such as standard free energy (ΔGº), standard enthalpy (ΔH) and standard entropy (ΔSº) for the formed micelles together with calculating the micellization activation energy. Gold nanoparticles were prepared from yeast dough (Saccharomyces cerevisiae), via gold salt reduction, and the prepared nanoparticles were diagnosed by several techniques (UV-Vis.,x-ray, TEM, SEM), through which the results showed that the prepared gold particles have a purple colour at length (552nm) it has a spherical shape and is within the nano size that was specified by the Shearer equation. The effect of these prepared nanoparticles on the rheology of the mixture of folic acid and the surfactant of Sodium Dodecyl Benzene sulfonate was studied using different temperatures, as this study showed that the highest viscosity Its value was (pa. s7.1232×10 2) at the ratio (2/8) and at a temperature of 10Cº and when the concentration of nano-gold was 0.00004M. If these results indicate that the growth of micelles increases with the increase in the concentration of the prepared nano-gold. The conductivity measurement of the solutions prepared for the mixture was also studied, as it was found that the conductivity increases as the viscosity decreases in the presence of nano-gold particles, which leads to an increase in the growth of micelles. From calculating the thermodynamic functions, it was found that the standard free energy (ΔGº) is negative, the standard enthalpy (ΔH) is negative and the standard entropy (ΔSº) is negative for the formed micelles.

Keywords: Surfactant; Viscosity; thermodynamic; Folic Acid; Gold nano; micelles.

1. Introduction

Surfactant is a surface-active agent such as detergent that when used, reduces surface tension to increase its spreading and wetting properties. It has various applications in chemical and biological fields. Also, its structure is composed of two main parts; a polar hydrophilic head and a non-polar hydrophobic tail (1) (Figure 1). The worldwide consumption of surfactants now exceeds several million tons per annum [1, 2].

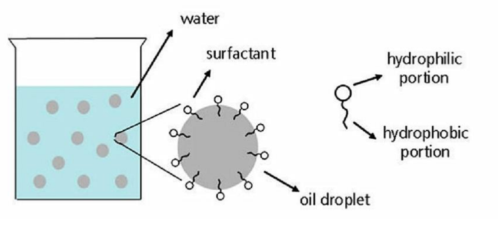

Figure 1: Surfactant structure

The binary structure of surfactant in the aqueous solution leads to aggregate and dispersed in a liquid to form colloidal suspension "Micelle"[3]. Typical micelles in H_2O form aggregations with

*Corresponding author e-mail: Liqaa.alsamarrai@gmail.com; (Liqaa Hussein Alwan).
EJCHEM use only: Receive Date: 28 August 2021, Revise Date: 02 September 2021, Accept Date: 05 September 2021 DOI: 10.21608/ejchem.2021.93005.4396

hydrophilic regions "head" in contact with the surrounding solvent, insulating hydrophobic single tail region micelle re-centre (Figure 2). This occurs at a critical concentration which is called critical micelle concentration (CMC) [4, 5].

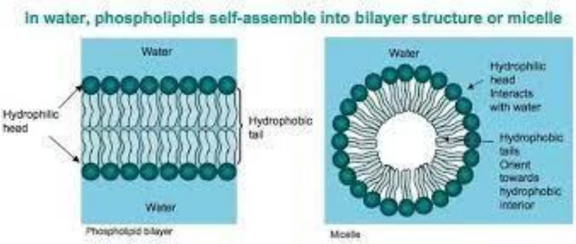

Figure 2: Micelle: mechanism of working

There are many types of surfactants: anionic, cationic, non-ionic or amphoteric [6]. The anionic molecule of surfactant is an active substance which is a long-chain anion such as soap (alkaline salts of fatty acid (RCOOM) and sulfonic acid salts (Laurecil + Na - Benzene Sodium Sulfonate C12). Surfactants have many applications; coatings to improve the wettability of surfaces [7], emulsifying agents to increase the stability of emulsions[8], and detergents to increase cleaning effectiveness[9], in addition to their use in cosmetics and the pharmaceutical industry [10].

Sodium dodecyl benzene sulfonate (SDBS) is one of the ionic surfactants that is used in many industrial applications such as inhibition of mild steel corrosion [11], an inhibitor for zinc corrosion [12], a solid sorbent for removal of diazinon[13], electrochemical properties [14, 15] (Figure 3).

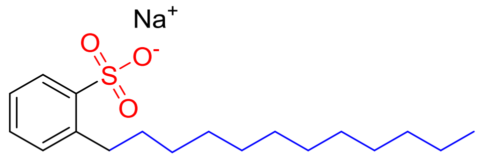

Figure 3: structure of Sodium dodecyl benzene sulfonate (SDBS)

As the growth of micelles increase, viscosity increase as it is a positive indicator of micelles formation in a dynamic combination [16] with no effect of concentration of electrolytes. Aggregation of surfactant has various forms: spherical, disk and filamentous, depending on the molecular structure, temperature and the accompanying ion [17, 18].

Micelle formation is necessary to many biological processes such as absorption of fat-soluble vitamins and complex lipids within the human body to facilitate absorption of fat into the appendage by the small intestine [19]. In the same manner, during milk curdling, protease acts on the soluble portion of the casein, resulting in an unstable micelle state that leads to clot formation. [20] also, micelles can be used for directed drug delivery [9] such as gold nanoparticles [21].

According to the above survey, our research aims to prepare gold nanoparticles with their characterization and studying there on some rheological properties of a mixture of Sodium dodecyl benzene sulfonate (SDBS) surfactant and folic acid (F.A).

2. Experimental

The devices used

The devices used: Table (1) shows the Devices used in the current study.

Table 1: Devices used in the current study

No.	the device name	Usage
1	Viscometer	The flow time was calculated through an Ostwald viscosity device, which measures the time of flow of a solution, which is a U-shaped glass tube.
2	Sensitive balance	Use the Sartorius BL 210S device to weigh a certain amount of materials according to the work requirements
3	Stopwatch	Calculate the descent time of the solution up to 100 milliseconds, with an accuracy of s± 0.15
4	Conductivity measuring device	(WTW) with an accuracy of µS.cm-1 ± 0.01.
5	Water bath	Type (HAKKE Nk22)) to control the temperature of solutions during the measurement of viscosity and conductivity.
6	Visible rays – ultraviolet (UV-Vis.)	To find out the highest wavelength of nano-gold
7	Scanning electron microscope (SEM)	Study of topography and pore sizes
8	transmission electron microscope (TEM)	Knowing the internal map of the sample

Chemicals used

In this study, the drug folic acid (FA) was used by the pharmaceutical factory in Samarra / Iraq SDI, in addition to the chemicals supplied by BDH company, which is Sodium Dodecyl Benzene Sulfonate (SDBS) with the regular name Sodium Dodecyl Sulfonate and its structural formula: $[CH_3(CH_2)_{10}CH_2C_6H_4SO_3Na]$.

Prepare nano-gold

A mixture of (25g) yeast dough and 100 ml of deionized water was stirred at 80°C, the extract was filtered using filter paper and the process was repeated several times, kept in the refrigerator until use. And prepare 1 ml mole of $HAuCl_4$, so (7 ml) of the extract was added to 70 ml of $HAuCl_4$ solution prepared at a concentration of (1 ml) mole by dissolving it in deionized water. Then it was placed on a stirrer magnetic plate hot heating device for 7 hours at a temperature of 100°C, and the magnetic stirrer was set at 3000 rpm. After 10-20 minutes of placing, it on the magnetic motor heater, a color change from reddish-brown to purple appeared. After leaving it was left overnight, the solution is placed in a centrifuge at 3500 rpm for 20 minutes, where the precipitate was collected at the end of the test tube for 12 hours. The sediment [13] was taken and placed onto Glass Watch, and then it was dried using an oven at 40°C.

Preparation of solutions

(100 ml) at a concentration of (2.0 wt%) was prepared as a stock solution from the SDBS by dissolving (2.00 g) in the smallest amount of distilled water for one time and then completing the volume to (100 ml) using a volumetric bottle, and from this solution is done Preparation of several different solutions with certain concentrations of a mixture of SDBS with Drug.

Water for conductivity measurement

High purity water was prepared by re-distilling distilled water twice with the addition of (2 g) of potassium permanganate and (0.2682g) of NaOH per liter of distilled water to obtain water of specific conductivity ranging between (3-4 μS.cm $^{-1}$).

Preparation of SDBS and Drug solutions in the presence of nano-gold

Various solutions were prepared for the mixture of Sodium Dodecyl Benzene Sulfonate and the drug in the presence of nano-gold with concentrations ranging between (0.000001-0.00004M) and at temperatures (10-40 ˚C).

Measurement of rheological properties

The Ostwald device was used to measure viscosity, as the viscosity measuring instrument containing the model to be measured (SDBS / Drug + Nanogold) was placed in the water bath so that the viscosity measuring instrument was almost completely submerged and left for (5) minutes with stirring from time to time. Then we start by measuring the time of the descent of the model from a starting point to an endpoint that was determined on the viscometer, and this measurement is done at four different temperatures. The same condition is for the SDBS/Drug mixture.

3. Results and Discussion

Gold nanoparticles concentration was determined via using various spectroscopic and analytical analyses such as Vis-UV spectroscopy, Transmission electron microscope (TEM) technology, Scanning Electron Microscope (SEM), with viscosity and conductivity. Vis-UV spectroscopy was used to determine the concentration of gold nanoparticles in a range of 400-800 nm. The absorption peak appeared at 552 nm in purple colour, depending on the type of extract that was used in the preparation of gold nanoparticles which represents the resonances plasmon surface (Figure 4) [22, 23].

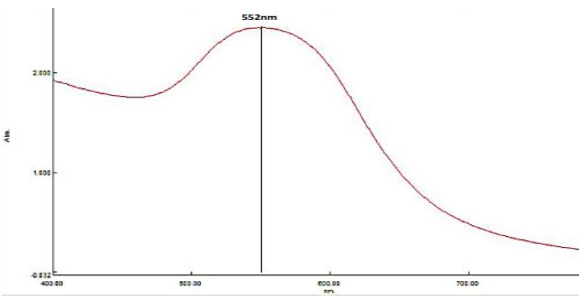

Figure 4: UV spectrum of the prepared nano-gold

The X-ray diffraction technique is one of the most important useful techniques that are used to determine the quality of the prepared material, whether it is crystalline or amorphous. That the material is not crystalline (166), as well as calculating the size of nanoparticles accurately using Debye Scherer Equation [24,25].

$D = K\lambda / \beta \cos\Theta$ ……………………………………(1)

Since:

D: the size of the nanoparticle

K: a constant value for the device being used, with a value of 0.9.

λ: the wavelength of X-rays is about 1.456 nm

B: average mid-total height of the beam

Cosθ: represents the cosine of an angle

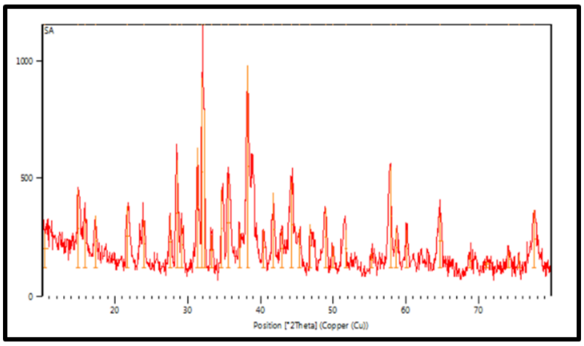

Figure 5: X-ray diffraction of gold nanoparticles.

Figure (5) represents the X-ray diffraction of the prepared gold particles, where it is observed that sharp and clear peaks appear at the main angles 2θ (10, 14, 15), respectively, from the Debye-Schirar equation (Equation 1) the size of the nanoparticles was calculated and from knowing the angle of incidence and the width of the top for one of the peaks Diffraction patterns, where it was found that the particulate size of the prepared gold is about (1.7 nm).

TEM technology was used to determine the shape and size of gold nanoparticles, its result showed that the particles were spherical in different sizes appearing in the form of dark spots and were within the nanoscale (Figure 6).

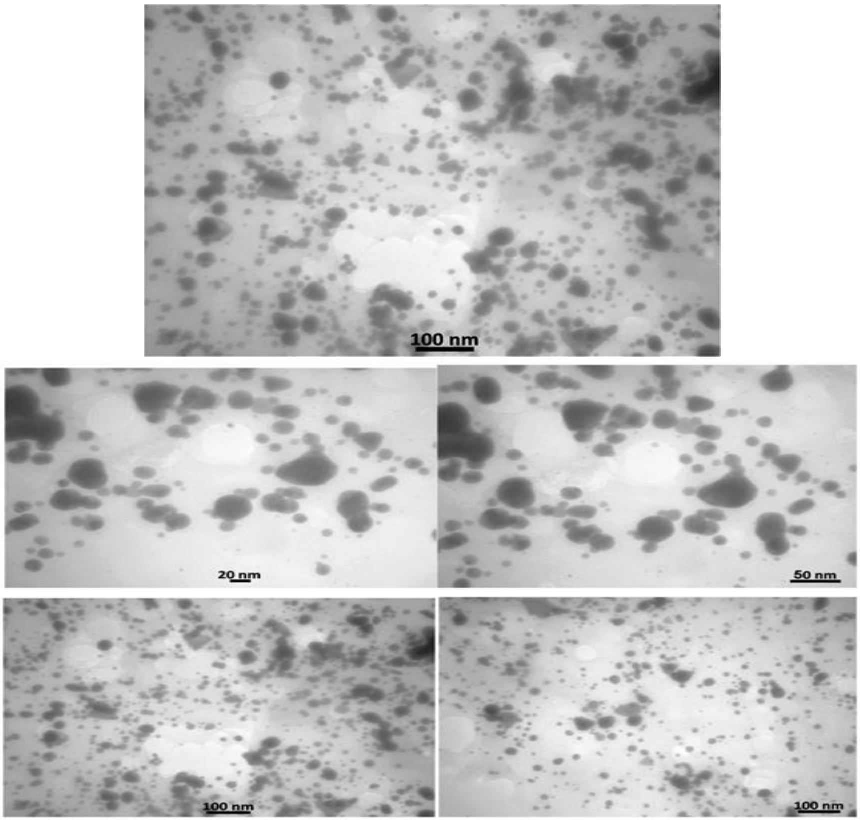

Figure 6: Gold nanoparticles under a transmission electron microscope (TEM)

In the same manner, SEM was used to determine the size and shape of prepared gold nanoparticles morphology. The results revealed that there are agree with TEM results that nanoparticle are spherical, and the gold nanoparticles AuNPs were distributed in the form of triangular and spherical assemblies, close in size and distributed in a compact manner and varying size proportions (Figure 7).

The effect of mixing ratios on the viscosity of the SDBS mixture was studied in the presence of the drug. The relationship between the viscosity and the percentage of SDBS was drawn in the presence of the drug at different temperatures, as shown in Figure (8). Where the viscosity was calculated by measuring the descent time of pure water and the descent time and density of the mixture formed at the different required temperatures and then using the following equation (2) [26-28].

$$= \frac{\sigma_1 \, t_1}{\sigma_2 \, t_2} \; \frac{\eta_1}{\eta_2} \text{ ....(2)}$$

Whereas η1, t1, and σ1 represent the density, descent time and viscosity of pure water, respectively, while η2, t2, and σ2 represent the density, descent time, and viscosity of the surfactant solutions and the drug to be measured, respectively.

The results in Table (2) indicate a rise in the viscosity values of the SDBS/Drug mixture, especially at the mixing ratio of 2/8 and 3/7 at the temperature of 10 C°, because the decrease in temperature leads to the process of forming micelles by providing energy kinetic (E_k), increases the chance of interference between the two materials SDBS/Drug due to the interactions and intermolecular forces. But increasing the temperature leads to an increase in the energy kinetic of the SDBS/Drug molecules, which leads to the difficulty of assembly and formation of micelles.

The results from Table (3) also show that the viscosity values increase for the SDBS/Drug mixture and in the presence of nanogold an irregular increase with the increase in the concentration of nanogold as in Figure (9). The reason for this is that nanogold is a material with a high surface area and will settle near the surface of micelles in addition to the possibility of forming large molecular interactions due to the presence of the unique nano-material in its physical and chemical properties.

Which in turn leads to an increase in the diffusion movement of the drug inside the solution and the presence of the surface-active substance, which increases the growth of filamentous micelles of the solution, as shown in Figure (9-a and b) (Image under transmission electron microscope (a) and scanning electron microscope (b)).

The mixture of sodium dodecyl benzene sulfonate (SDBS) negative ionic surfactant with the drug shows an increase in the dynamic viscosity curve and the ratio of 2/8 indicates the formation of wormy micelles. The results show that the presence of the benzene ring in SDBS causes a bad product towards the formation of the unidirectional assembly in contrast to what was previously studied [29-30]. The reason for this is also due to the nature of the surfactant, in addition to the presence of the ion accompanying the surfactant, which is bromide and also to the hydrophobic effect. The thermodynamic properties of the mixture were evaluated above, and the results were in good agreement with the rheological changes of the mixture [26]. To calculate the thermodynamic properties of micelles including free energy, enthalpy and standard entropy of the micelle formation, these thermodynamic variables were estimated using the following equations (3, 4, and 5)[31, 28].

$$\Delta G = -RT \, \text{In}(\eta/2*10^{-3}) \text{…………………....(3)}$$

$$d(\ln \eta/2*10^{-3})/d(1/T) = -\Delta H/R \text{ ....(4)}$$

$$\Delta S^{\circ} = \frac{\Delta H - \Delta G^{\circ}}{T} \text{ ....(5)}$$

Since (R) is the gas constant, and (T) is the absolute temperature. The relationship between ln η and the reciprocal of temperature 1/T was drawn to extract the value of ΔH from the slope. The change in the enthalpy sign indicates that the micellization process is exothermic [29, 32], and a negative ΔG° value is noted, indicating that the process is spontaneous, And the °ΔS is negative because the micellization process is random [30] (Table 3).

The electrical conductivity [33-35] of the prepared solutions was studied to detect the presence of wormlike micelles to obtain a relationship between this physical property with the viscosity of these solutions (Table 3).

It is noted from the results that increasing the temperature leads to a decrease in the specific conductivity (Table 4). This may be because increasing the temperature above the Krafft temperature with certain limits, leads to an increase in micelle formation and a decrease in the concentration of free molecules. Since the viscosity of the solutions was good in the presence of nano-gold, which leads to the ability to form wormy micelles, This contributed to maintaining solutions of ratios 2/8 and 3/7 containing different concentrations of nano-gold to show low specific conductivity values for the strength of the molecular interactions, that is, they have little kinetic energy compared to when they are alone without any addition, and there is no linear relationship between viscosity and specific conductivity shown in Figure (10).

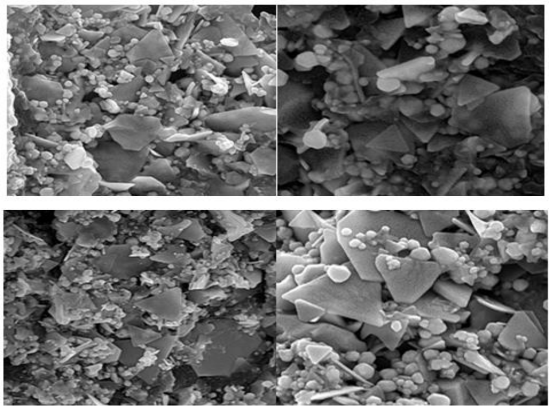

Figure 7: The results of the examination of gold nanoparticles using a scanning electron microscope (SEM)

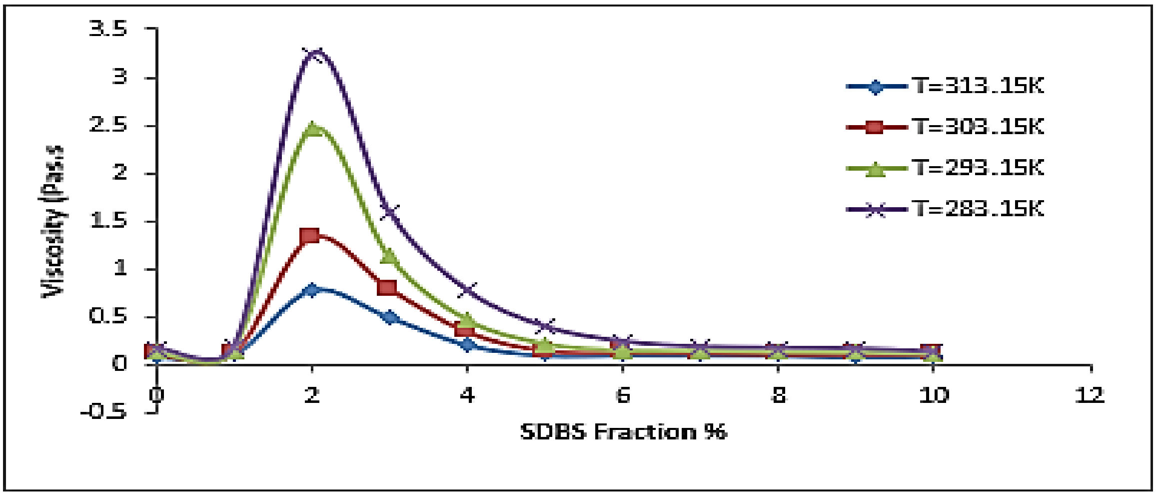

Figure 8: The relationship between viscosity and percentages of the mixture of SDBS and Drug at different temperatures

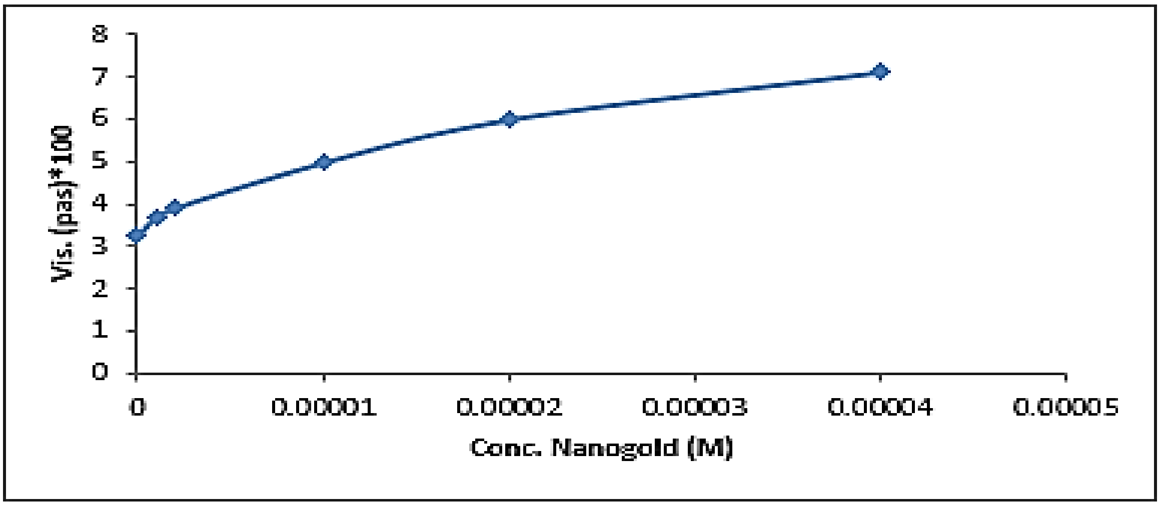

Figure 9: The relationship between the concentration of Nanogold and the viscosity of the mixture SDBS/Drug at the ratio 2/8 and a temp of 10° C.

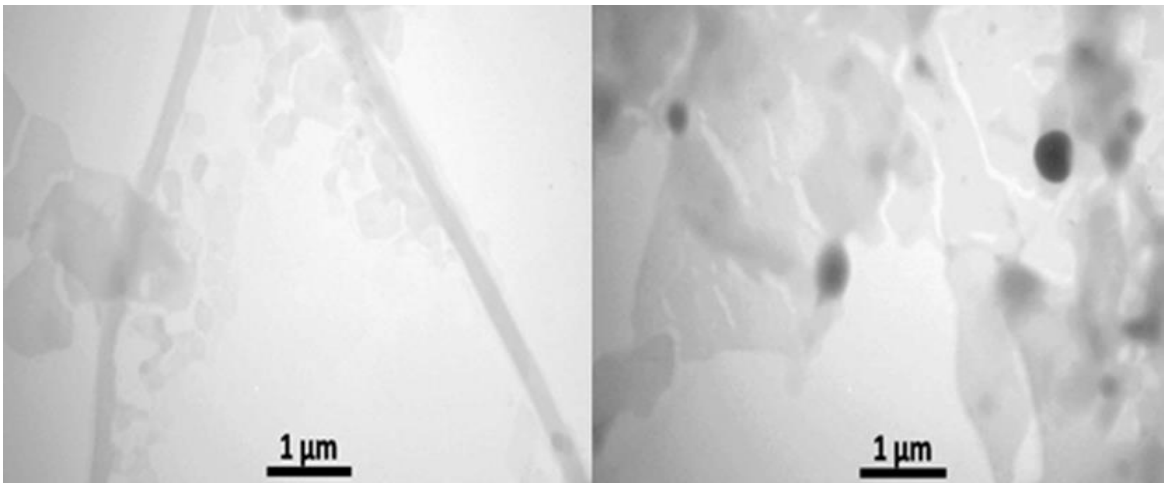

Figure 9-a: A transmission electron microscope image of the SDBS/Drug mixture in the presence of nano-gold.

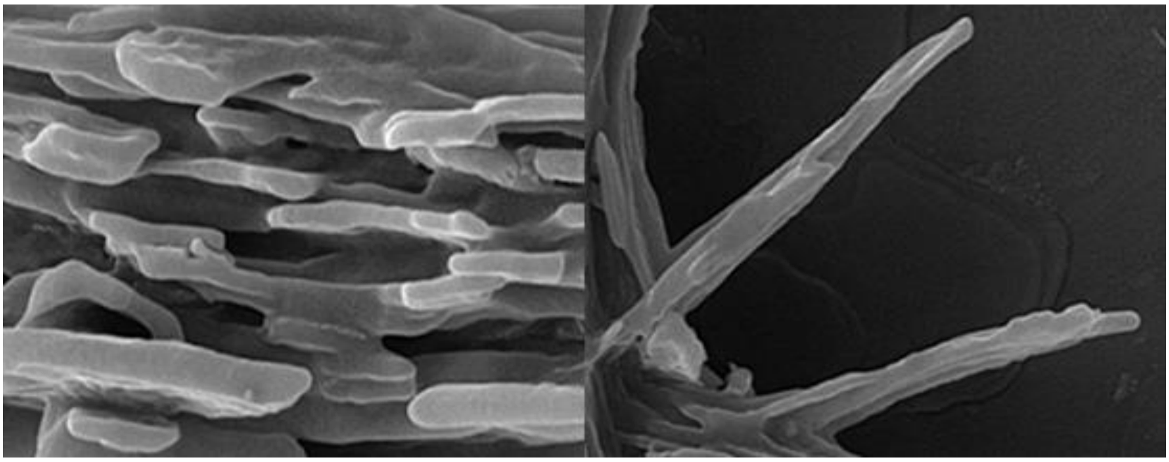

Figure 9-b: SIM of SDBS/Drug mixture in the presence of nano-gold

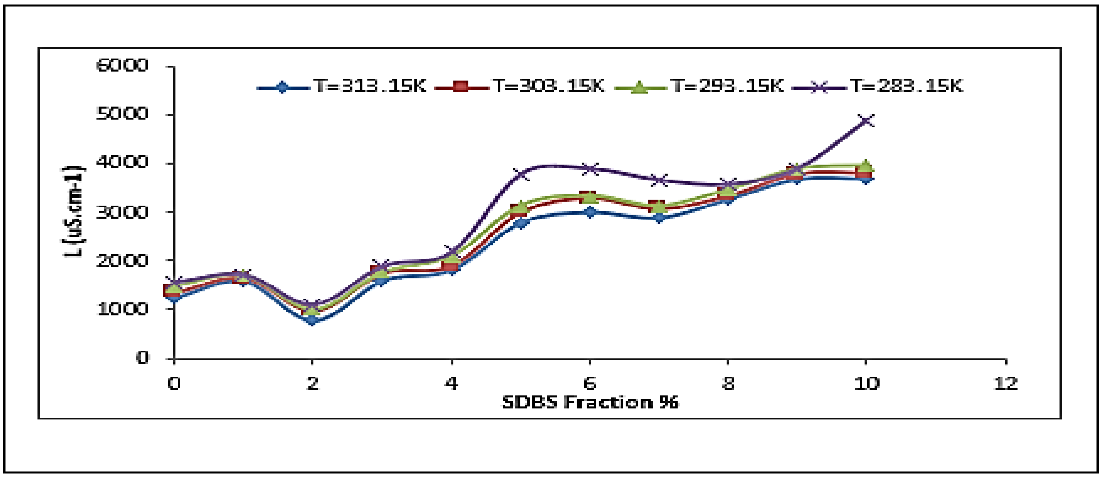

Figure 10: Relationship between conductivity and percentage of SDBS at different temperatures

Table 2: Viscosity values of the SDBS/Drug mixture at different mixing ratios and temperatures

SDBS	Drug	η×10²: (pas . s)			
		10Cº	20Cº	30Cº	40Cº
0	10	0.1690	0.1252	0.1000	0.0771
1	9	0.1716	0.1434	0.1201	0.1078
2	8	3.2346	2.4565	1.3128	0.7807
3	7	1.5897	1.1253	0.7891	0.4987
4	6	0.7674	0.4654	0.3412	0.2100
5	5	0.3893	0.2156	0.1467	0.1007
6	4	0.2334	0.1458	0.1278	0.1034
7	3	0.1790	0.1469	0.1233	0.1009
8	2	0.1678	0.1342	0.1099	0.0999
9	1	0.1589	0.1289	0.1100	0.0795
10	0	0.1278	0.1122	0.1110	0.0921

Table 3: Effect of nanogold at various concentrations of SDBS/Drug mixture on viscosity at different temperatures, thermodynamic function values, and micellization activation energy.

Nano gold(M)	***η: (Pa.s) x 10²,(ΔGº: kJ.mol⁻¹),[ΔSº: J.mol⁻¹.K⁻¹]***				***ΔH: kJ.mol⁻¹***	***Ea: J.mol⁻¹***
	10Cº	**20Cº**	**30Cº**	**40Cº**		
	2/8					
0	3.2346 (-6.5522) [-0.1036]	2.4565 (-6.1130) [-0.1016]	1.3128 (-4.7423) [0.1028]	0.7807 (-3.5456) [-0.1033]	-35.9081	627.7568
0.000001	3.6678 (-6.8481) [-8.8383]	2.7762 (-6.4112) [-11.8158]	1.5555 (-0.0223) [26.9762]	0.8895 (-0.0096) [-45.3786]	-35.4367	705.0272
0.000002	3.8943 (-6.9892) [-7.9536]	2.7860 (-6.4198) [-10.7131]	1.5777 (-0.0267) [-23.2304]	0.9121 (-0.0112) [-40.6413]	-36.1617	750.2553
0.00001	4.9671 (-7.5620) [-7.8591]	3.867 (-7.2191) [-11.1086]	2.0089 (-0.0302) [-24.1729]	1.0898 (-0.0128) [-41.8320]	-38.1679	994.6038
0.00002	5.9873 (-8.0018) [-3.4804]	4.6789 (-7.6834) [-4.5525]	3.8976 (-0.0496) [-12.5640]	2.0078 (-0.0208) [-23.1864]	-25.2895	934.2441
0.00004	7.1232 (-8.4107) [-3.8298]	5.0098 (-7.8499) [-5.0206]	3.2344 (-0.0901) [-8.0180]	1.9899 (-0.0383) [-15.5906]	-31.3412	1269.5478
Nano gold (M)	**3/7**					
0	1.5897 (-3.7423) [-0.0863]	1.1253 (-4.2103) [-0.0817]	0.7891 (-1.9888) [-0.0863]	0.4987 (-2.3788) [-0.0823]	-28.1803	266.7546
0.000001	1.8788 (-4.4229) [-0.0600]	1.4110 (-4.7617) [-0.0568]	1.0087 (-2.5423) [-0.0622]	0.7980 (-3.6027) [-0.0569]	-21.4218	269.7643
0.000002	2.2433 (-5.2809) [-0.0632]	1.4707 (-4.8627) [0.0624]	1.0065 (-2.5367) [-0.0680]	0.8980 (-3.9101) [-0.0615]	-23.1794	334.7964
0.00001	2.9999 (-7.0620) [-0.0701]	1.7897 (-5.3411) [-0.0736]	1.3997 (-3.5277) [-0.0772]	0.9656 (-4.0990) [-0.0729]	-26.9373	482.2036
0.00002	3.3721 (-7.9382) [-0.0510]	2.3453 (-6.0001) [-0.0559]	1.7811 (-4.4890) [-0.0590]	1.3444 (-4.9607) [-0.0556]	-22.3920	492.6377
0.00004	3.9917 (-9.3968) [--0.0391]	3.2078 (-6.7634) [-0.0468]	2.2113 (-5.5733) [-0.04922]	1.7877 (-5.7026) [-0.0472]	-20.4948	562.2508

Table 4: Conductivity values of the SBDS/Drug mixture at different temperatures

SDBS (2.0 Wt%)	Drug (2.0 Wt%)	[L [µS.cm^{-1}			
		10Cº	20Cº	30Cº	40Cº
0	10	1566	1478	1344	1261
1	9	1712	1698	1647	1589
2	8	1111	1009	978	789
3	7	1890	1769	1741	1601
4	6	2188	2105	1897	1823
5	5	3789	3136	3001	2790
6	4	3894	3331	3289	3001
7	3	3665	3128	3067	2889
8	2	3578	3464	3336	3269
9	1	3901	3888	3786	3679
10	0	4898	3955	3799	3685

4. Conclusions

Through the results obtained from the current study, it was found that:

1- The gold particles were nanoparticles, according to the internationally known range, and this is what was found through the size of the particles and the spherical shape of the Shearer equation and X-ray values. And other technologies

2- Through our study of gold nanoparticles on the mixture of folic acid and the active substance (sodium dodecylbenzene sulfonate) in terms of viscosity. It was found that the viscosity decreases with the increase in temperature and increases with the increase in the concentration of gold nanoparticles, which in turn leads to an increase in the growth of micelles.

3- It was concluded through the conductivity study of the prepared mixture that it increases with a decrease in viscosity in the presence of gold nanoparticles.

4- Through the results of the thermodynamic study, it was found that (ΔH) is negative values, meaning that the reaction is exothermic, (ΔGº) is negative, meaning that the reaction is spontaneous to occur on the surface, and (ΔSº) negative values reduce the random occurrence of the system and thus increase the regularity The drug and its mixing process with nanoparticles.

Conflicts of interest

"There are no conflicts to declare".

Formatting of funding sources

Self

References

[1] M.J. Rosen, J.T. Kunjappu, Surfactants and interfacial phenomena, John Wiley & Sons2012.

[2] Adeola O. Borode, Noor A. Ahmed1, and Peter A. Olubambi , Surfactant-aided dispersion of carbon nanomaterials in aqueous solution , Physics of Fluids 31, 071301 (2019).

[3] F.M. Menger, The structure of micelles, Accounts of Chemical Research 12(4) (1979) 111-117.

[4] A. McLachlan, K. Singh, M. McAlduff, D.G. Marangoni, S. Shortall, S.D. Wettig, msm cationic gemini and zwitterionic surfactants–a thermodynamic analysis of their mixed micelle formation, RSC Advances 10(6) (2020) 3221-3232.

[5] R.F. Jung, Oleic acid adsorption at the goethite-water interface, (1976).

[6] G. Hodges, C. Eadsforth, B. Bossuyt, A. Bouvy, M.-H. Enrici, M. Geurts, M. Kotthoff, E. Michie, D. Miller, J. Müller, A comparison of log K ow (n-octanol–water partition coefficient) values for non-ionic, anionic, cationic and amphoteric surfactants determined using predictions and experimental methods, Environmental Sciences Europe 31(1) (2019) 1-18.

[7] V.R. Gundabala, W.B. Zimmerman, A.F. Routh, A model for surfactant distribution in latex coatings, Langmuir 20(20) (2004) 8721-8727.

[8] Xiaoping Ni1 , Zhiheng Li and Yanbin Wang , Adsorption Characteristics of Anionic Surfactant Sodium Dodecylbenzene Sulfonate on the Surface of Montmorillonite Minerals, ORIGINAL RESEARCH article , Chem., 02 October 2018.

[9] D. Bajpai, Laundry detergents: an overview, Journal of oleo science 56(7) (2007) 327-340.

[10] N. Lourith, M. Kanlayavattanakul, Natural surfactants used in cosmetics: glycolipids, International journal of cosmetic science 31(4) (2009) 255-261.

[11] H. Luo, Y. Guan, K. Han, Inhibition of mild steel corrosion by sodium dodecyl benzene sulfonate and sodium oleate in acidic solutions, Corrosion 54(08) (1998).

[12] Y. Qiang, S. Zhang, L. Guo, S. Xu, L. Feng, I.B. Obot, S. Chen, Sodium dodecyl benzene sulfonate as a sustainable inhibitor for zinc corrosion in 26%

NH4Cl solution, Journal of Cleaner Production 152 (2017) 17-25.
[13] A. Sohrabi, M.R. Yaftian, L. Dolatyari, M.S.S. Dorraji, P. Soheili-Azad, Application of Mg–Al and Zn–Al layered double hydroxides modified with sodium dodecyl benzene sulfonate as a solid sorbent for removal of diazinon from water samples, Journal of the Iranian Chemical Society 17(6) (2020) 1411-1427.
[14] C. Li, Y. Ya, G. Zhan, Electrochemical investigation of tryptophan at gold nanoparticles modified electrode in the presence of sodium dodecylbenzene sulfonate, Colloids and Surfaces B: Biointerfaces 76(1) (2010) 340-345.
[15] Q. Xiao, G. Chen, Y.-H. Zhang, F.-Q. Chen, H.-F. Weng, A.-F. Xiao, Agarose Stearate-Carbomer940 as Stabilizer and Rheology Modifier for Surfactant-Free Cosmetic Formulations, Marine Drugs 19(6) (2021) 344.
[16] D.L. Pink, F. Foglia, D.J. Barlow, M.J. Lawrence, C.D. Lorenz, The Impact of Lipid Digestion on the Dynamic and Structural Properties of Micelles, Small 17(6) (2021) 2004761.
[17] R.J. Farn, Chemistry and technology of surfactants, John Wiley & Sons2008.
[18] K. Holmberg, D.O. Shah, M.J. Schwuger, Handbook of applied surface and colloid chemistry, Wiley-Blackwell2002.
[19] A. Kuksis, Absorption of fat-soluble vitamins, Fat absorption, CRC Press2018, pp. 65-86.
[20] D.J. McMahon, R.J. Brown, Enzymic coagulation of casein micelles: a review, Journal of Dairy Science 67(5) (1984) 919-929.
[21] H.M. Aliabadi, A. Lavasanifar, Polymeric micelles for drug delivery, Expert opinion on drug delivery 3(1) (2006) 139-162.
[22] S.S. Memon, A. Nafady, A.R. Solangi, A.M. Al-Enizi, M.R. Shah, S.T. Sherazi, S. Memon, M. Arain, M.I. Abro, M.I. Khattak, Sensitive and selective aggregation based colorimetric sensing of Fe3+ via interaction with acetyl salicylic acid derived gold nanoparticles, Sensors and Actuators B: Chemical 259 (2018) 1006-1012.
[23] K. Sebby, E. Mansfield, Determination of the surface density of polyethylene glycol on gold nanoparticles by use of microscale thermogravimetric analysis, Analytical and bioanalytical chemistry 407(10) (2015) 2913-2922.
[24] Mohammadyani D, Hosseini SA, Sadrnezhaad SK. Characterization of nickel oxide nanoparticles synthesized via rapid microwave-assisted route. In: International Journal of Modern Physics: Conference Series. World Scientific; 2012. p. 270–6.
[25]Alaa M. Abdullah, Liqaa H. Alwan, Abdulqader M. Abdulqader. Thermodynamic and kinetic studies of Eriochrome black adsorption on activated charcoal prepared from lemon leaves. This content was downloaded from IP address.2020. 128.123.44.24 on 16/01/2020 at 10:48**.**
[27] Ahmed Taha Yaseen , Liqa'a Hussein Alwan. Thermodynamic Study of Adsorption of Tamoxifen Drug on Activated Nano-Coal Particles prepared from Stem of Eucalyptus and its Diagnosis by different Techniques. IJDDT,2020; Vol(10) Issue 3.P.P.239-241.
[28] Rusul Rifat Jameel#1 & Liqaa Hussein Alwan2 ,"Preparation Of Graphene Oxide And Its Reduction By Lemon Peel To Graphene And Diagnosed By Several Techniques" , European Journal of Molecular & Clinical Medicine ISSN 2515-8260 Volume 07, Issue 09, 2020.
[29] H. Kong, Y. Li, D. Wang, H. Liu, H. Pan, Physicochemical parameters and thermodynamic behavior of aprepitant/HS15 micellar system at different temperatures: Effect of electrolytes concentration, Journal of Molecular Liquids 328 (2021) 115343.
[30] R.A. Khalil, L.H. Alsamarrai, The role of surfactants head group in the formation of self-assembled supramolecular aggregate, Arab J. Phys. Chem 2(1) (2015) 7-13.
[31] R.A. Khalil, F.J. Hammad, Critical Intermolecular Forces: A New Physical Insight for the Formation of Wormlike Micelles, Journal of the Chemical Society of Pakistan 36(2) (2014).
[32] J. Larsson, A. Sanchez-Fernandez, A.E. Leung, R. Schweins, B. Wu, T. Nylander, S. Ulvenlund, M. Wahlgren, Molecular structure of maltoside surfactants controls micelle formation and rheological behavior, Journal of colloid and interface science 581 (2021) 895-904.
[33] U.M. Savalli, The evolution of bird coloration and plumage elaboration, Current ornithology (1995) 141-190.
[34] S.R. Raghavan, G. Fritz, E.W. Kaler, Wormlike micelles formed by synergistic self-assembly in mixtures of anionic and cationic surfactants, Langmuir 18(10) (2002) 3797-3803.
[35] S. Krishna Prasad, K. Sandhya, G.G. Nair, U.S. Hiremath, C. Yelamaggad, S. Sampath, Electrical conductivity and dielectric constant measurements of liquid crystal–gold nanoparticle composites, Liquid crystals 33(10) (2006) 1121-1125.