Scientific paper

The Role of Ionic Surfactants on the Solubilization of Cyclohexenone Compounds in Aqueous Media

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Abstract

The solubilization and partitioning study of five newly synthesized organic compounds (Cyclohexenone Carboxylates) with ionic surfactants, sodium dodecylsulphate (SDS) and cetyltrimethylammonium bromide (CTAB) was studied using ultraviolet-visible absorption spectroscopy technique. The differential spectroscopic technique was employed to study the partition coefficient (K_x) of organic molecules between bulk water phase and the miceller phase. The values of partitioning coefficient were in the range 29.714×10^3 to 5.46×10^6. The standard free energy of partitioning (ΔG_p^o) was also determined, which was found out in the range of –25 to –38 kJ /mole and shows the stability of the system. The results show that the cyclohexenone carboxylate compounds have great interactions with CTAB as compared to SDS.

Keywords: Cyclohexenone carboxylates, synthesis, Ionic surfactants, solubilization, partitioning study

1. Introduction

Chalcones are known as carriers of different types of biological activity.[1,2] The key role of chalcones is the ability to act as activated unsaturated systems in Michael addition reactions of carbanions in basic media.[3,4] This reaction can be utilized for the preparation of 3,5-diaryl-6-carbethoxy-2-cyclohexenones *via* conjugated addition of ethyl acetoacetate. The mentioned cyclohexenones are effective intermediate in the syntheses of benzoselenadiazoles benzothiadiazoles, spirocyclohexanones, carbazole derivatives, fused isoxazoles and pyrazoles.[5]

The synthesis of 5-aryl-6-carbethoxy-2-cyclohexenones substituted in position 3 with a 2-furanyl moiety through Michael addition of ethyl acetoacetate to 3-aryl-1-(2-furanyl)-2-propenone has been already briefly described.[6] This paper presents the synthesis of some new 3,5-diaryl-2-cyclohexenones with various chemical functions, whose solubilization and partitioning study will be reported.

The surfactants are much familiar substances and are used in oil extraction, oil recovery from mud, ore extraction, food industries, bath room cleaners, cosmetics, shampoos and pharmaceuticals. Surfactants are compounds that lower the surface tension or interfacial tension between two liquids or between a liquid and a solid. Surfactants may act as detergents, wetting agents, emulsifiers, foaming agents, and dispersants. On the basis of their applications, surfactants have been classified as anionic, cationic, non ionic and zwitter ionic surfactants. Anionic surfactants contain anionic functional groups at their head, i.e. (sulphates, carbonates, phosphates, and sulphonates) e.g. sodium dodecylsulphate (SDS), sodium dodecylebenzensulfonate (SDBS), lithium dodecylsulphate (LDS) etc. Surfactants having positively charged head group are known as cationic surfactants e.g. cetyltrimethylammonium bromide (CTAB), dodicyltrimethyl ammonium bromide (DTAB), etc. Surfactants having no charge on their surface but exhibit some surfactant properties are known as nonionic surfactants e.g. TX-100, Tween-80, and poly- sorbates etc. They are used for ore extraction, oil recovery and removing grease and oil from metal surface and fabrics. Surfactants having both cationic and anionic centers attached to the same molecule are termed as zwitter ionic surfactants e.g. (3-[(3-Cholamidopropyl)dimethylammonio]-1-propanesulfonate).[7]

In pharmaceutical industries the surfactant role is very important, because it enhances the solubility of the

drug, increases the soaking and dissolution of the drug particles, diminishes the precipitation of the drug, modulates the release of drug, lowers the decomposition and loss of the drug, prevents harmful side effects, enhances drug bioavailability, facilitates drug uptake and similar many more functions are performed by the surfactants or micelles.[8] Micelles have been employed in drug delivery system owing to less viscosity, small aggregation number, small size, easy to prepare and long shelf life.[9]

The experimental model is very effective for investigating the interaction of biological system with solubilizate, drug career and drug release system.[10] Micelles of ionic surfactants combine electrostatically because of high charge densities on the surface of these aggregates and results in to powerful ionic dipole interactions.[11] Solubilization also takes care of separation of drug molecule with the aqueous bulk phase and miceller phase.[12] The separating properties of the drug molecule between the miceller and aqueous region are a sign of the lipophilic and hydrophilic balance of the molecules.[13]

The quantification of the degree of drug-micelle interaction which is represented as binding constant (K_b) and water/micelle partition coefficient (K_x) is determined as a result of these changes. The determination of these constants is very important for studying the interaction with biomembrane, as well as for structure-activity relationship of drugs.[14] The calculation of these constants has their own importance, when used in High Performance Liquid Chromatography for drug quality control.[15] The values of partition coefficient and free energy of solubilization and location of the solubilizate are mainly dependent on the structure of solubilizate and micelle of surfactants. In aqueous solution the solubilization of aliphatic alcohol[16] phenylalcohalic acid[17] and aromatic alcohol depends upon the hydrophobicity of the drugs. This hydrophobic interaction have been reported in the literature of cationic and zwitter ionic hemicynine dyes[18,19] with various surfactants micelle.

The amphiphilic hemicynine dyes have been investigated in aqueous solution with sodium dodecylebenzensulfonate (SDBS), whose solubilization is mainly dependent on the hydrophobic nature of these dyes. The interaction of three azo dyes has been studied with cationic surfactant (cetylpyridinium chloride) using potentiometric measurement until the CMC of the surfactant was observed.[20]

Like other drugs cyclohexenone compounds are also important from medical point of view, which have anticancer,[21] antitumor,[22] anti-HIV,[23] anti convulsant[24] and antitubercular[25] activities. Similarly newly synthesized organic compounds, known as cyclohexenoic long chain fatty alcohols are also prescribed for the treatment of neurological disorders.[26]

For the drug delivery to their target points different models have been proposed. In some model hydrophobic pathway is followed for the drug delivery to their targets. Ionic micelles have hydrophobic core region which lead to interaction with hydrocarbons and halogenated hydrocarbons groups of solutes. For determination of locus of solubilization the hydrophobic effect is often considered to be dominant.[27,28]

The critical micelle concentration (CMC) of CTAB in water and in the presence of drug was found out by plotting the surfactants concentration (C_s) versus the specific conductance. The CMC value decreases when an alkanol is added to ionic surfactant solution. The decrease in CMC becomes more remarkable by enhancing the number of carbon atoms in alkanol molecules. This decrease in CMC is due to solubilization of alkanol in surfactant micelle and increase in entropy of mixing in the micelle with alkanol molecules, where the alkanol is partitioned between the water-micelle bulk phases.[29]

Shah et al[30] investigated that self assembling of surfactant monomers are affected by organic additives. The effect of organic additives on CMC was studied by changing the concentration of additives. By the addition of additives to the surfactants the CMC was decreased in all the cases.

Due to the pharmacological importance of cyclohexenone family, an effort was made to use the five newly synthesized Cyclohexenone compounds for their solubilization and partitioning study using U/V Visible absorption spectroscopic technique. The names of these five synthesized compounds are as follows:

[Ethyl-4-(4-bromophenyl)-6-(chlorophenyl)-2-oxo-cyclohex-3-ene carboxylate ($4BC_2$), Ethyle-4-(4-bromophenyl)-6-(2-methoxyphenyl)-2-oxo-cyclohex-3-ene carboxylate ($4BM_4$), Ethyl-4-(4-chlorophenyl)-6-(3-methoxyphenyl)-2-oxo-cyclohex-3-ene-carboxylate ($3CM_3$), Ethyl-4,6-bis(4-chlorophenyl)-2-oxo-cyclohex-3-ene carboxylate ($3CC_4$), and Ethyl-4-(4-bromophenyl)-6-(4-methoxyphenyl)-2-oxo-cyclohex-3-ene carboxylate ($4BM_3$].

The main goal of this study is to extend the existing database on the partitioning study of cyclohexenone compounds between the water and micelle of SDS and CTAB and to present the thermodynamic feasibility of the drugs, using Differential absorption spectroscopic technique.

2. Experimental

2. 1. Materials

4'-Bromoacetophenone, 4'-Chloroacetophenone, 2-Chlorobenzaldehyde. 4-Chlorobenzaldehyde 3-Methoxybenzaldehyde, 4-Methoxybenzaldehyde, and Ethyl acetoacetate were procured from Sigma-Aldrich and were used as received. The solvents ethanol and acetone were dry distilled before using. The surfactants sodiumdodecyle sulphate (SDS) and cetyletrimethylammonium bromide (CTAB) were purchased from Merck and were utilized

without further purification. Experiments were performed using double distilled water.

2. 2. General Synthetic Method

Keeping in view the importance of cyclohexenones, the present work was carried out to synthesize this class of organic compounds with variable substituents to diversify the ring at position 4 and 6. As a result a variety of cyclohexenone derivatives were achieved in moderate to good yields.

To a solution of various substituted chalcone derivatives (3 mmol) in dry acetone was added dry potassium carbonate (12 mmol), and ethyl acetoacetate (6 mmol). The mixture was stirred for overnight. The reaction product was separated as solid filtrate and recrystallized from ethanol.

2. 3. Instrumentation

R_f values were determined by means of pre-coated silica gel aluminum backed plates Kiesel gel $60F_{254}$ Merck (Germany) using ethylacetate: pet-ether (1:4) as developing solvents. Melting points of the compounds were found out in open capillaries with Gallenkamp melting point apparatus and were un-corrected. The FTIR spectral data were obtained using Bio-Rad Merlin Spectrophotometer employing KBr discs. ^{1}H NMR spectra were recorded on Bruker (300 MHz) AM-250 spectrometer in $CDCl_3$ solution using TMS as internal standard. EIMS was recorded on Agilent mass spectrometer. Purity of each compound was determined by thin layer chromatography. The purification of synthesized compounds was accomplished by recrystallization technique or otherwise by employing solvent extraction or using preparative thin layer chromatography or column chromatography whenever required.

Double Beam Perkin Elmer 650 UV-Visible spectrophotometer was used for the absorption spectra of all the cyclohexenone carboxylate compounds. Mostly quartz cuvette were used in this technique because glass cuvette absorbs light below 350 nm and is used only for visible region but quartz cuvette can be used in both UV and visible regions. The cell used was a square cuvette with 1cm internal distance between the walls.

The stock solution of different cyclohexenone carboxylate compounds ($4BC_2$, $4BM_4$, $3CM_3$, $3CC_4$ and $4MB_3$) was prepared in 3% ethanol aqueous solution. The dilution was made up to the concentration when it obeys Beer- Lambert law. In differential absorption spectroscopy the concentration of cyclohexenone carboxylate compounds was kept constant (3×10^{-5} M) while the concentration of the surfactants i.e. SDS (6.3 mM to 14 mM) and CTAB (0.66 mM to 1.4 mM) was changed. The cyclohexenone carboxylate solution was kept in reference cell while cyclohexenone carboxylate solution containing surfactants varied was kept in sample cell.

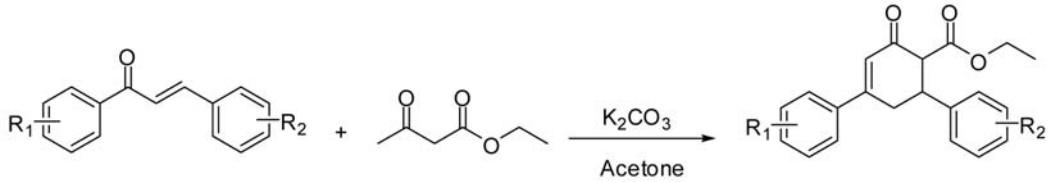
3. Results and Discussion

The reaction of chalcones with ethyl acetoacetate in the presence of basic condition went through Robinson annulation to generate cyclohexenones, as outlined in the following reaction scheme.

The formation of the newly synthesized cyclohexenones was confirmed by FT-IR and NMR spectral data. The appearance of stretching band around 1734–1738 cm^{-1} can be assigned to the ester functionality in the structure of cyclohexenones. Furthermore, another sharp strong absorption band at around 1655–1670 cm^{-1} assigned to the conjugated carbonyl group.

The ^{1}H-NMR spectra confirmed the results of the IR analysis. In the ^{1}H-NMR spectra, the ethyl protons resonated as triplet and quartet around 1.07 ppm and 4.07 ppm integrating for three and two protons respectively. The distinctive signal is however the singlet of the vinylic proton, that appears around 6.61 ppm integrating for one proton, which verifies the intramolecular cyclocondensation subsequent to the Michael addition. The signals due to methylene protons appear as doublet of doublets around 3.05 ppm, showing their diastereotropic nature. The remaining protons of the aryl and their substituents at position 3 and 5 of the cyclohexenone ring were in good agreement with the proposed structure.

The EI-MS analysis of the compounds in accord with the proposed structure indicated characteristic peaks; however, the molecular ion peak is absent, due to loss of ester functionality. The base peak is originated as a result of Retro-Diels-Alder fission of cyclohexene ring. The physical states, FTIR, ^{1}H NMR and EIMS data for these compounds are given below:



Scheme: Synthesis of Cyclohexenones derivatives.

Ethyl-4,6-bis(4-chlorophenyl)-2-oxo-cyclohex-3-ene carboxylate ($3CC_4$)
Yield 0.71g (61%); m.p.: 101–102 °C. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.07 (t, *J* = 7.2 Hz, 3H), 4.06 (q, *J* = 7.2 Hz, 2H), 3.04 (dd, J_1 = 2.2 Hz, J_2 = 17.5, 1H), 2.81–2.88 (m, 1H), 3.75 (dd J_1 = 3.1 Hz, J_2 = 7.1, 2H), 6.53 (s, 1H), 7.54 (d, *J* = 6.9 Hz, 2H), 7.08 (d, *J* = 7.08, 2H), 7.28 (d, *J* = 6.6 Hz, 2H), 7.30 (d, *J* = 6.7 Hz, 2H). IR (KBr, cm^{-1}): 755 (C-Cl), 1490 (C=C (Ar)), 1608 (C=C), 1655 (C=O (Keto)), 1738(C=O (Ester)), 2993 (C-H). EI-MS: *m/z* (%) = 316(30), 178(100), 150(20).

Ethyl-4-(4-chlorophenyl)-6-(3-methoxyphenyl)-2-oxo-cyclohex-3-ene carboxylate ($3CM_3$)
Yield 0.72g (63%); m.p.: 134–136 °C. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.08 (t, *J* = 7.1 Hz, 3H), 4.06 (q, *J* = 7.2 Hz, 2H), 3.04 (dd, J_1 = 2.3 Hz, J_2 = 17.5, 1H), 2.81–2.91 (m, 1H), 3.69 (dd J_1 = 3.0 Hz, J_2 = 6.9, 2H), 6.53 (s, 1H), 7.52 (d, *J* = 6.9 Hz, 2H), 7.07 (d, *J* = 6.9, 2H), 7.20 (m, 4H), 3.82 (s, 3H). IR (KBr, cm^{-1}): 765 (C-Cl), 1513 (C=C (Ar)), 1605 (C=C), 1670 (C=O (Keto)), 1734(C=O (Ester)), 2979 (C-H). EI-MS: *m/z* (%) = 312(20), 178(100), 150(10).

Ethyl-4-(4-bromophenyl)-6-(chlorophenyl)-2-oxo-cyclohex-3-ene carboxylate ($4BC_2$)
Yield 0.79g (61%); m.p.: 109–111 °C. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.07 (t, *J* = 7.1 Hz, 3H), 4.06 (q, *J* = 7.2 Hz, 2H), 3.04 (dd, J_1 = 2.3 Hz, J_2 = 17.0, 1H), 2.75–2.85 (m, 1H), 3.68 (dd J_1 = 3.0 Hz, J_2 = 6.9, 2H), 6.53 (s, 1H), 7.42 (d, *J* = 7.00 Hz, 2H), 7.04 (d, *J* = 6.9, 2H), 7.27 (m, 4H). IR (KBr, cm^{-1}): 756 (C-Cl), 677 (C-Br), 1483 (C=C (Ar)), 1605 (C=C), 1665 (C=O (Keto)), 1738(C=O (Ester)), 2976 (C-H). EI-MS: *m/z* (%) = 362(35), 222(100), 194(25).

Ethyle-4-(4-bromophenyl)-6-(2-methoxyphenyl)-2-oxo-cyclohex-3-ene carboxylate ($4BM_4$)
Yield 0.77g (60%); m.p.: 111–113 °C. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.08 (t, *J* = 7.1 Hz, 3H), 4.07 (q, *J* = 7.1 Hz, 2H), 3.05 (dd, J_1 = 2.4 Hz, J_2 = 16.5, 1H), 2.79–2.88 (m, 1H), 3.72 (dd J_1 = 2.9 Hz, J_2 = 7.0, 2H), 6.53 (s, 1H), 7.44 (d, *J* = 6.86 Hz, 2H), 7.02 (d, *J* = 6.9, 2H), 7.28 (d, *J* = 6.6 Hz, 2H), 7.23 (d, *J* = 6.7 Hz, 2H),. IR (KBr, cm^{-1}): 760 (C-Cl), 655 (C-Br), 1502 (C=C (Ar)), 1600 (C=C), 1670 (C=O (Keto)), 1736(C=O (Ester)), 2981 (C-H). EI-MS: *m/z* (%) = 362(35), 222(100), 194(20).

Ethyl-4-(4-bromophenyl)-6-(2-methoxyphenyl)-2-oxo-cyclohex-3-ene carboxylate ($4BM_3$)
Yield 0.72g (60%); m.p.: 121–123 °C. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.08 (t, *J* = 7.2 Hz, 3H), 4.06 (q, *J* = 7.2 Hz, 2H), 3.02 (dd, J_1 = 2.2 Hz, J_2 = 17.5, 1H), 2.81–2.89 (m, 1H), 3.71 (dd, J_1 = 3.1 Hz, J_2 = 7.0, 2H), 6.53 (s, 1H), 7.44 (d, *J* = 6.9 Hz, 2H), 7.20 (m, 4H), 3.81 (s, 3H). IR (KBr, cm^{-1}): 628 (C-Br), 1499 (C=C (Ar)), 1609 (C=C), 1660 (C=O (Keto)), 1738(C=O (Ester)), 2970 (C-H). EI-MS: *m/z* (%) = 358(20), 222(100), 194(18).

3. 1. Differential Absorbance Spectroscopic Study

In differential absorbance spectroscopic technique the reference cell contains the drug (cyclohexenone carboxylate) solution while the cyclohexenone solution along with surfactant is kept in the sample side. The following parameters were calculated by the differential spectroscopic technique.

3. 1. 1. Partition Coefficient (K_x)

Partition coefficient (K_x) is defined as "the ratio of the mole fraction concentration of the cyclohexenone compound (drug) in the micelle to that in the surrounding bulk aqueous part". The partition coefficient values depend upon the binding constant values (k_c) and its value gives significant information about the interaction of organic solubilizate with surfactant micelles and also locus of solubilizate with micelle. It is also an essential parameter not only for illumination the mechanism of solubilization but also understanding the biological membrane and anesthetics.[31]

Awan et al[32] studied the six amphiphilic hemicyanine dyes in which the sulphonate group of the hemicyanine dyes shows an electrostatic interaction with a positive head cluster of the CTAB micelles. In the process of solubilization the alkyl chain length have a foremost contribution and increases from di-methyl to di-hexyl in dyes. The partition coefficient (K_x) values increased with the increase in alkyl chain length and negative values of Gibbs free energy of partitioning (ΔG_p^o) also increases with K_x values. The hemicyanine dye is more polar if the alkyl chain length is shorter and transfer of hemicyanine dyes from water to non polar region is not easy. Similarly, this type of hemicyanine dyes has an interaction with surface region of the micelles and is more soluble in polar organic medium having less ΔG_p^o values, Hence we conclude that the solubilization depends upon the K_x value, greater the K_x value greater will be the solubilization and lesser the K_x value lesser will be the solubilization of cyclohexenone compound. Kawamura et al[33] suggested that the solubilized drug molecule in the micelle of the surfactants obey the Lambert-Beer Law and for this purpose they proposed an equation for water-micelle partition coefficient (K_x) which was also used in the current research work.

$$\frac{1}{\Delta A} = \frac{1}{K_c \Delta A_\alpha (C_a + C_s^{mo})} + \frac{1}{\Delta A_\alpha} \quad (1)$$

In the (Eq. 1), ΔA_α represents differential absorbance when surfactant concentration moves toward infinity, C_a shows the concentration of cyclohexenone, C_s^{mo} is equal to

(C_s - CMC) and CMC means critical micelle concentration of SDS and CTAB, where CMC of SDS is 8.4 mM and that of CTAB is 0.97 mM. K_c is binding constant. Slope in the above equation is $1/ K_c \Delta A_\alpha$ and intercept is $1/\Delta A_\alpha$.

3. 1. 2. Binding Constant

The binding constant (K_c) value is determined from the intercept and slope of plot $1/\Delta A$ vs $1/(C_a + C_s^{mo})$

3. 1. 3. Standard Gibbs Free Energy of Partition

Partition coefficient (K_x) is directly proportional to binding constant K_c values which is determined as

$$K_x \alpha K_c$$
$$K_x = n_w \times K_c \quad (2)$$

Where n_w = no of moles of water molecules, and is equal to 1000/18 = 55.5 moles/dm^3.

Standard Gibbs free energy for partitioning (ΔG_p^o) is directly depended upon the partition coefficient (K_x) and is determined by using the following Eq.

$$\Delta G_p^o = -RT \ln K_x \quad (3)$$

where "R" stands for gas constant, T for absolute temperature and K_x for partition coefficient.

3. 1. 4. Differential Absorption Spectra of Cyclohexenone Carboxylate Compounds in the Presence of Sodium Dodecylsulphate and Cetyltrimethylammonium Bromide

Differential Absorption spectroscopy is used to verify the solubility of the drug in aqueous solution to that of the micelle formation. The main aim of this technique is to calculate the partitioning of the drug in miceller phase and in the aqueous phase and thus to work out the capability of a given surfactant. The representative spectrum is given in (Fig. 1) and their related plot is also shown in (Fig. 2) for SDS system. The values in terms of binding constant (K_c), partition co-efficient (K_x), and standard Gibbs free energy of partitioning (ΔG_p^o) are shown in the Table 1.

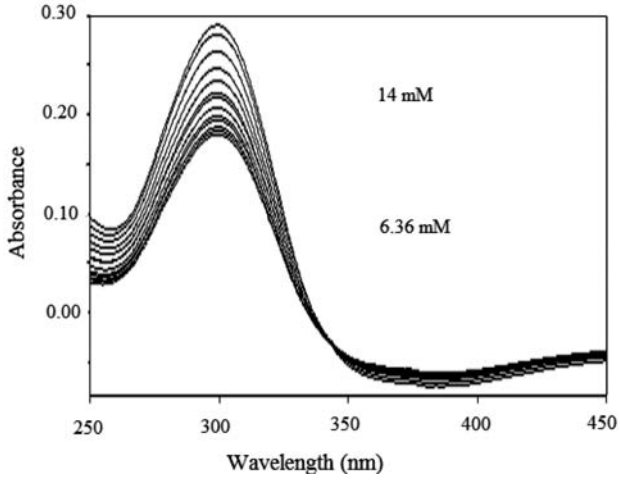


Fig. 1. Differential absorption spectra of SDS from 6.36×10^{-3} M to 14×10^{-3} M with 3% ethanol aqueous solution having 3×10^{-5}M $4BC_2$.

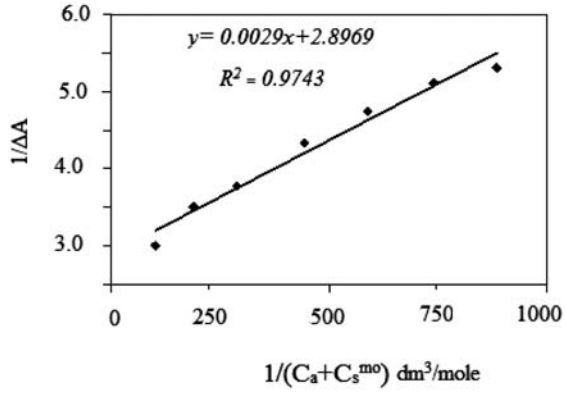


Fig 2. Inverse of differential absorbance ($1/\Delta A$) of $4BC_2$ Versus $1 / (C_a + C_s^{mo})$

Table 1. Calculations of K_c, K_x and ΔG_p^o values in case of SDS

Sample	K_c (dm^3/mole)	K_x	ΔG_p^o (kJmol^{-1})
$4BC_2$	998.930	55.441×10^3	–27.021
$4BM_4$	535.380	29.714×10^3	–25.474
$3CM_3$	945.350	52.467×10^3	–26.881
$3CC_4$	824.540	45.762×10^3	–26.542
$4BM_3$	1,153.94	64.045×10^3	–27.373

It is clear from the spectra that with increase in concentration of the surfactants, the differential absorbance spectra (ΔA) also increase which shows the penetration of drug molecules in to the micelles and this is in agreement with the literature studied.[17] After the incorporation of the drug molecules in to the micelle, a small increase in absorption is observed which indicates that the chromophores of their molecules are still oriented near the surface of the micelle and hence absorb light more proficiently than the bulk phase.[34,35] By increasing the concentration of SDS, a linear increase in absorption intensity was observed without any large shift in the wavelength. The values of binding constant (K_c), partition co-efficient (K_x) and standard Gibbs free energy of partitioning (ΔG_p^o) are given in Table 1 for cyclohexnone-SDS system. In Table 1 the ratio between Kc^{4BC2}/Kc^{4BM3} is 0.86, hence it is indicative of the fact that there is less interaction between SDS and drug molecule. Binding constant (K_c) value is an empirical constant and is calculated from (kawamura) model,[33] which is used to determine the partition co-efficient (K_x).

Partitioning will be higher if the K_x value is higher and the affinity of the drug molecule towards the miceller system is greater than the aqueous phase. The partitioning of cyclohexenone compound from polar (aqueous) to a non polar environment of the micelle is of similar magnitude to those reported in the literature.[36]

Standard Gibbs free energy of partitioning (ΔG_p^o) was determined to test the partitioning and stability of cyclohexenone compounds. Highly negative values conclude that the partitioning of the cyclohexenone compound from water to miceller environment is a spontaneous process and that cyclohexenone compound is more solubilized in micelle. These molecules go to that part of the system where they have more negative Gibbs free energy (ΔG_p^o) value and the system is more stable.[10]

To verify the partitioning of cyclohexenone compounds from polar to non polar (micelle) environment, differential spectroscopic technique was used. The same equation (Kawamura model) and same procedure was used as was used in case of SDS but here in this technique the cyclohexenone carboxylate sample was used in a reference cell. Partition co-efficient (K_x) gives the valuable and essential information regarding the interaction of cyclohexenone compound in polar and non polar phase and also to determine the solubilization efficiency of a given surfactant. The acquired spectra and its related plots are given in (Fig. 3 and 4), which shows the representative graphs. The spectra obtained in this case are very much similar as was discussed previously in SDS case. The differential absorbance (ΔA) increases with increase in surfactant concentration with no red or blue shift which shows the physical interaction (Van der Wall forces) of cyclohexenone carboxylate compounds with micellar core of CTAB. In some other cases the same behavior is observed.[33] The shift towards higher wavelength (red shift) shows the electrostatic interaction between the drug molecules and the negative π electron of surfactant.

Again this phenomenon is reorganized that though the cyclohexenone molecule are penetrated in to the micelle but the chromophore of these molecule are still oriented near the surface and absorb light more favorably than in the aqueous bulk phase.[9]

Here the maximum values of K_x and ΔG_p^o indicates the partitioning tendency of cyclohexenone compound from aqueous to micellar and also high spontaneity which is shown in Table 2. Looking at the table the ratio between Kc^{4BC2}/Kc^{4BM3} comes out to be 5.1; this shows greater interaction between CTAB and drug molecule. The Partitioning behavior of cyclohexenone compound between the two phases is due to hydrophobic nature. ΔG_p^o shows the stability between the cyclohexenone compound and surfactants, high the negative ΔG_p^o value high will be the stability and vice versa.

The data obtained from UV-Visible spectroscopy show that cyclohexenone is more attracted by CTAB as compared to SDS. This is because of the reality that micelles of SDS are negatively charged and cyclohexenone have conjugated π electrons which have electrostatic repulsions. Conversely, CTAB micelle has positively charged species so electrostatic attraction will appear along with hydrophobic interactions. Hence, we conclude that CTAB micelle has good interaction to get solubilized the cyclohexenone compounds as compared to SDS micelle.

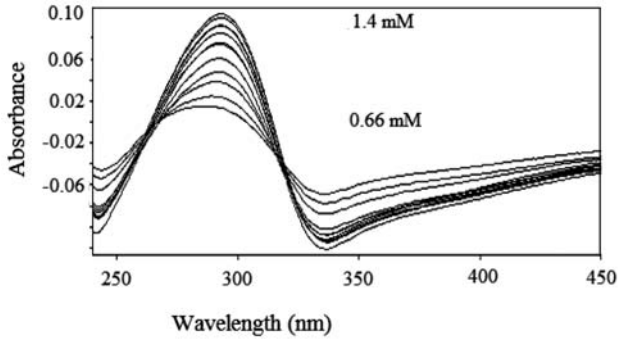


Fig. 3. Differential absorption spectra of CTAB from 0.66×10^{-3}M to 1.4×10^{-3} M with 3% ethanol aqueous solution having 3×10^{-5} M $4BC_2$.

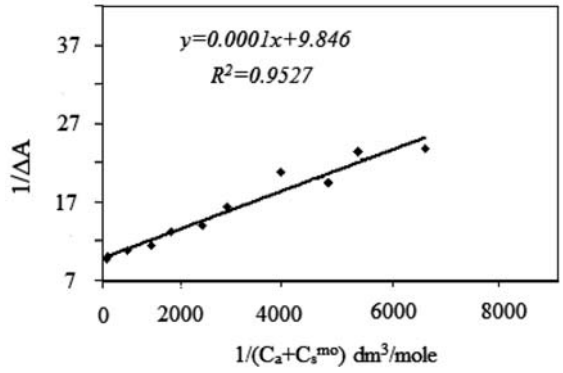


Fig. 4. Inverse of differential absorbance ($1/\Delta A$) of $4BC_2$ versus $1/(C_a + C_s^{mo})$

Table 2. Calculations of K_c, K_x and ΔG_p^o in case of CTAB

Sample	K_c (dm³/mole)	K_x	ΔG_p^o Value (kJmol⁻¹)
$4BC_2$	98.46×10^3	5.46×10^6	–38.372
$4BM_4$	5.35×10^2	1.07×10^6	–34.341
$3CM_3$	21.31×10^3	1.18×10^6	–34.585
$3CC_4$	16.27×10^3	0.90×10^6	–33.919
$4BM_3$	19.31×10^3	1.07×10^6	–34.342

4. Conclusions

It is evident from the differential data that the stability of cyclohexenone compounds is more in CTAB micel-

le as compared to SDS micelle. The reason is that micelles of SDS are negatively charged and cyclohexenone have conjugated π electrons which have electrostatic repulsions. On the other hand, CTAB micelle has positively charged species so electrostatic attraction appears along with hydrophobic interactions. Hence, we conclude that CTAB micelle has good interaction to get solubilized the cyclohexenone compounds as compared to SDS micelle.

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Povzetek

Z UV-VIS absorpcijsko spektroskopijo smo proučevali interakcije petih novih organskih spojin (cikloheksenon karboksilatov) z natrijevim dodecilsulfatom (SDS) in cetiltrimetilamonijevim bromidom (CTAB). Določili smo vrednosti porazdelitvenih koeficientov (K_x) organskih spojin med »bulk« vodno fazo in micelarno fazo, ki se gibljejo v mejah med 29.714×10^3 in 5.46×10^6. Vrednosti standardne proste energije porazdelitve (DG^o_p) so v območju med –25 in –38 kJ /mole in kažejo na dobro stabilnost sistema. Izkazalo se je, da so interakcije proučevanih cikloheksenon karboksilatov s CTAB močnejše kot pa z SDS.