ELECTROOPTICAL INVESTIGATIONS OF THE
POLY(ETHYLENE OXIDE)-SODIUM DODECYL SULFATE INTERACTIONS

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Abstract. So far different techniques have been applied to investigate the nature of the charged complexes in the system poly(ethylene oxide) (PEO)-sodium dodecyl sulfate (SDS) [1]. We have used the methods of static light scattering and viscometry to investigate PEO in the presence of ionic surfactant SDS in aqueous solution. The purpose was to demonstrate polyelectrolyte effects, which arise in PEO on formation of the charged complex between the components in solution in which small SDS micelles are incorporated into the flexible PEO coil [2]. The obtained results for the radius of gyration $R_g$ and relative viscosity showed changes as a function of the SDS concentration at given ionic strength of the medium.

1. Introduction

The charged complex formed between the ionic micelliforming SDS and neutral polymer PEO has received much attention in the literature. Similar complexes are formed between surfactants and other polymers [3-5] with interaction between the two species apparently being more favored the greater the hydrophobicity of the polymer. Recent reviews of the interactions between nonionic polymers and ionic surfactants have been given by Goddard [6], Sato [7], Hayakawa and Kwak [8], and Brown [9].

In the PEO/SDS system a number of different techniques have been employed to study the nature of the charged complex formed. In solutions of PEO containing sufficiently low concentrations of SDS such that a critical level is not exceeded, most of the surfactant molecules apparently exist freely in the solution. When the SDS concentration exceeds this level, termed the critical aggregation concentration (CAC) [10], complex formation occurs over a broad SDS range in which a substantial amount of SDS is bound in the form of micelles to the polymer chain, although a proportion of SDS will still be present in the free form. The amount of SDS bound to PEO remains in constant proportion to the PEO concentration [11]. The SANS measurements [11] show that the micelles which form on the PEO chains are probably small (of the magnitude 2 nm in radius) and polymer is associated with the interface between the hydrocarbon and water, i.e. the polymer is sited close to the surface of the SDS aggregates and the chain segments make an important amount to solubilization of segments. The critical micelle concentration (CMC) is in the free system and decreases strongly with the values are substantially lower than the POE has become saturated with SDS bulk solution as indicated by the phase coexists.

Light scattering techniques for investigating changes in the conform the system employed in this context. The present paper demonstrates the formation of the polyelectrolyte properties are imparted to the neutral complex in the presence of a simple polyelectrolyte properties of the concentration is thus used to estimate the radius molecular weight ($M_w$) has little or no value in this system in order to study the complex structure.

For preparation of the solution product of Aldrich Chem. Co., Brice Phoenix Photometer for scattered laser ($\lambda_0 = 514.5$ nm). The value of

In accordance to Rayleigh-Gans-Debye treatment of the results obtained form polymer-solvent system, so that the light scattering intensity $I$ is given by the following expression:

$$P_g^{-1} \Gamma_0$$

where $R_g$ is radius of gyration and $\Gamma_0$}

Experimentally, $P_g^{-1}$ can be calculated...
aggregates and the chain segments mainly interact in the surfactant head group region, this is tantamount to solubilization of segments of the flexible PEO chain in the SDS micelle. The critical micelle concentration (cnc) is approximately $0.23 \times 10^{-3} \text{ g/ml}$ for salt-free and polymer-free system and decreases strongly with increasing ionic strength. In presence of PEO, the cnc values are substantially lower than the cnc of pure SDS. Above the concentration at which the POE has become saturated with SDS micelles, the concentration of free micelles increases in the bulk solution as indicated by the phase diagram given by Cabane [11.

Light scattering techniques are highly sensitive and noninvasive methods for investigating changes in the conformation of the complex but, surprisingly, have been little employed in this context. The present communication utilizes light scattering techniques to demonstrate the formation of the PEO-SDS charged complex whereby polyelectrolyte properties are imparted to the neutral PEO chain, to elucidate the composition of the charged complex in the presence of a simple salt, and to investigate the modification of the polyelectrolyte properties of the complex when excess SDS is present. Static light scattering is thus used to estimate the radius of gyration. Although it is known that the polymer molecular weight ($M_\alpha$) has little or no influence on the aggregation number of SDS, it is convenient to use a large $M_\alpha$ in order to gain precision in determination of radii of gyration.

2. Experiment

For preparation of the solutions we used PEO ($M_\alpha = 5 \times 10^6$) sample, the commercial product of Aldrich Chem. Company. Static light scattering measurements were performed with Brice Phoenix Photometer for scattered angles range from 0° to 135°. The light source was Ar laser ($\lambda_0 = 514.5$ nm). The value of $(dn/dc) = 0.134$ ml/g for PEO was used [12].

In accordance to Rayleigh-Gans theory [13], Zimm method has been used for interpretation of the results obtained form the experimental measurements of scattered light in the polymer-solvent system, so that the scattering function ($I'_q$) for small scattering angles $\theta$, is given by the following expression:

$$P^{-1}_q = 1 + \frac{16 \pi^2 R_h^2 \sin^2 \theta}{3 \lambda_0^2} \left( \frac{M_\alpha}{M} \right)^{\frac{1}{2}}$$

(1)

where $R_h$ is radius of gyration and $n_0$ is refractive index of the solvent.

Experimentally, $P^{-1}_q$ can be calculated using the relation:

$$P^{-1}_q = \left[ \frac{Kc}{R_h} \right]_c \times \left[ \frac{Kc}{R_h} \right]_c^{\frac{1}{2}}$$

(2)
where $\frac{Kc}{R_0}$ is reduced scattering intensity. $R_0$ is estimated from the ratio of the slope angle of plots of angular dependence of $P_0^{-1}$ at given concentration of $c_{\text{SDS}} = 4 \times 10^{-3}$ g/ml as it is show for typical data in Figure 1.

3. Results and Discussion

Viscosity measurements on dilute solutions were made using an Ubbelohde capillary viscometer with SDS and LiCl presence in aqueous solvent. The relative viscosity is used here rather than the more usual reduced viscosity ($\eta_r/c$) since the concentration of the complex is unknown. Relative viscosities were determined at a fixed PEO concentration of $1.5 \times 10^{-4}$ g/ml as a function of $c_{\text{SDS}}$ at one concentration of simple salt (2mM LiCl). The data shown in Figure 2 demonstrate the strong coil expansion which reaches a maximum at $(c_{\text{SDS}}/c_{\text{SDS}}^{\text{m}}) \approx 6$. The maximum is broad on the $c_{\text{SDS}}$ scale, and this is in accordance with Figure 3.

![Figure 1](image1.png)

Figure 1. Angular dependence of $P_0^{-1}$ at the constant concentration $c_{\text{SDS}} = 4 \times 10^{-3}$ g/ml and 28 °C.

![Figure 2](image2.png)

Figure 2. Diagram of relative viscosity $\eta_{rel}$ versus concentration $c_{\text{SDS}}$ in 28 °C.

![Figure 3](image3.png)

Figure 3. Radius of gyration $R_g$ versus concentration $c_{\text{SDS}}$ at 28 °C.

Static light scattering measurements of different SDS concentrations in the properties of the polymer-SDS complex show it is necessary to make experiments thus prepared in the PEO concentration.

Figure 3 shows the results of the polymeric character of the PE/SDS weak but lies in the vicinity of $c_{\text{SDS}}^{\text{m}}$.

Static light scattering results show the effect, which is imparted to the neutron scattering from the ionic surfactant SDS. The strong increase in gyration and relative viscosity.


Static light scattering measurements have been made on solutions of PEO at series of different SDS concentrations in the presence of salt (LiCl). Since the polyelectrolyte properties of the polymer-SDS complex depend sensitively on the extent of binding of SDS, it is necessary to make experiments at different values of the ratio $c_{\text{SDS}}/c_{\text{PEO}}$. Solutions were thus prepared in the PEO concentration range $(0.5 \pm 2) \times 10^{-4}$ g/ml for each $c_{\text{SDS}}$ value.

Figure 3 shows the resulting $R_0$ data and these clearly demonstrate the polyelectrolytic character of the PEO-SDS complex. The maximum as a function of $c_{\text{SDS}}$ is weak but lies in the vicinity of $(c_{\text{SDS}}/c_{\text{PEO}}) \approx 6$.

4. Conclusion

Static light scattering results are used here to illustrate the pronounced polyelectrolyte effect, which is imparted to the neutral PEO chain on formation of a charged complex with the ionic surfactant SDS. The strong chain expansion is illustrated by changes in the radius of gyration and relative viscosity.

References
Abstract: Al$_2$TiO$_5$ precursors can be obtained using a flotation method—Dissolved Air Flotation (DAF)—separation/recovery of metallic ions from aqueous solutions. The insoluble hydroxyl-species with a tension of 10$^{-2}$ M at the air-water interface are concentrated in the foam, which is then separated from the solution.

The insoluble polymeric hydroxide solutions 10$^{-2}$ M after adding copper, aluminium, and titania powder. The final Al$_2$TiO$_5$ precipitates separated from the filtrate by centrifugation. X-ray diffraction (XRD) and scanning electron microscopy (SEM) investigations showed that the heating process revealed different size distributions. The samples having a higher tension of 10$^{-2}$ M yield a larger distribution (10 μm).

Simple or mixed oxide precursors can be obtained using a flotation method.

INTRODUCTION

Aluminium titanate oxide precursors can be obtained using non-conventional methods of Flotation, DAF—separation/recovery of metallic ions from aqueous solutions. This method allows the separation of the precipitate from the solution using the hydroxyl species with a tension of 10$^{-2}$ M at the air-water interface.

Applying the non-conventional method, Al$_2$TiO$_5$ precipitates can be obtained using a flotation method.

RESULTS AND DISCUSSION

Aluminium titanate oxide precursors were obtained by contacting for 20 minutes with an NH$_3$ 25% solution and the pH (laurylamine) was added in various concentrations. The thermal treatment of the samples led to Al$_2$TiO$_5$ precipitates.