Are Surfactant Molecules Really Oriented in the Interface?

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Surfactants are a versatile class of compounds that have diverse uses in the fields of chemistry, biochemistry, and pharmacy. From their early uses in cleaning of laundry, dispersing of paints, and frothing agents in ore flotation, surfactants have leapt forward to high technology regions such as electronic printing, magnetic recording, and microelectronics. Surfactants play a critical role to control interfacial behavior. Some articles published in this Journal demonstrate how interfacial tension, at liquid–air or liquid–liquid boundaries for example, can be changed by physical and chemical methods (1–3). Others discuss the structure and stability of a bubble and various uses (4–6). Reference 7 especially inspired us to devise this demonstration. All the above-mentioned articles have served the education community well, but we felt that it would be good to directly demonstrate that surfactant molecules are really oriented in the interfaces of a bubble.

This demonstration helps students visualize what happens on the submicroscopic level when a bubble is formed from an aqueous solution of surfactants, and it helps them visualize what basic spatial condition must be fulfilled for a reaction to have occurred. This demonstration can be used not only at the high school or introductory college level but also in the middle or junior high school to illustrate the ion-exchange reaction between cetyltrimethylammonium bromide and potassium ferricyanide and to introduce a class of compounds that possess amphiphilic properties. As a secondary theme, in high school or at introductory college level this demonstration would allow students to observe how the wetting efficiency (spreading coefficient) of a surfactant solution in air changes with the changes in the nature of solid surfaces.

The demonstration may be done on an overhead projector. It takes some practice to develop the technique necessary to carry it out successfully.

Experimental Procedure

First, a hole is drilled centrally and longitudinally in a #0 or #1 rubber stopper so that a glass tube, approximately 21 cm long, 3 mm i.d., and 7 mm o.d., fits snugly in the large end of the stopper. In the narrow end of the rubber stopper, the hole is sealed by gluing a 5-mm-thick rubber pad cut from another similar stopper. The length of the glass tube is not critical; shorter glass tubes work equally well. A hypodermic needle is pushed through the pad so that it enters the glass tube. Care is taken to make all the junctions leakproof.

Next, 0.04 M potassium hexacyanoferrate(III) solution is prepared and added to a large watch glass (diameter 12.5 cm) to give a pool about 8.5 cm in diameter. The watch glass can be supported on a cork ring. Alternatively, a petri dish may be used for overhead projection. This solution should be good for 8–12 trials, but should be discarded when foam or precipitate interferes with the experiment.

The bubble solution is prepared by adding 10 mL of water to a mixture of 0.4 g of cetyltrimethylammonium bromide (CTAB) and 0.512 g of polyoxyethylene sorbitan monooleate (Tween 80) in a 20-mL scintillation vial containing a 12-mm-long Teflon-coated magnetic stir bar. In this experiment double distilled water was used, and CTAB and Tween 80 were used without further purification. CTAB (A.R.) was from Qualigens Fine Chemicals (Glaxo India Limited, Mumbai) and Tween 80 was from LOBA Chemie (India). The CTAB sample should be colorless (no yellow discoloration). With occasional mild heating (never exceeding 50 °C) the mixture is slowly stirred magnetically for 30 minutes to obtain a clear solution with a minimum of foam.

The tube is dipped to the bottom of the vial of solution (31 °C) to wet it thoroughly up to about 5 cm from its end and form a thick film. The tube is then withdrawn vertically from the solution and allowed to drain until no more solution falls on its own. There should be no foam adhering to the tube. Next, a 10-mL hypodermic syringe with some enclosed air, approximate volume 5 mL, is placed in the needle socket, and a bubble (ca. 2–2.4 cm diam) is blown quickly by pushing the entire enclosed air. The tube and the attached syringe are rotated from the vertical to the horizontal and slightly further, so that the bubble end is slightly elevated. The bubble is allowed to slide down the tube until it no longer touches the end of the tube. Bubbles that do not easily slide downwards are discarded. Any foam adhering to the tube is removed with a tissue if necessary. Then the syringe is immediately removed from the needle socket, holding the tube in a horizontal position. The excess liquid at the bottom of the bubble is removed by
The stability of a bubble chiefly depends upon the extent of cohesion among the hydrophobic groups that are oriented in the air–solution interfaces \( \text{(8)} \). The cohesion imparts elasticity and mechanical strength to the bubble. For CTAB, this cohesion is good enough to form a stable bubble, since CTAB has one long, unbranched hydrophobic carbon chain. But, practically, it does not give a stable bubble when it is blown out at the end of a glass tube. This is due to the adsorption of CTA cation on the negatively charged glass surface, which forces the hydrophobic group of CTA\(^+\) to stay away from the glass surface, creating a hydrophobic layer. This hydrophobic layer on the glass surface repels water but attracts the hydrophobic group from the bubble, so the bubble collapses. To stop bubble rupture we use Tween 80, which has sufficient surface-wetting qualities to make a thin layer of water on the glass surface and repels the hydrophobic bubble surface; thus the bubble becomes stable. The other important factors that control bubble stability are surface tension, bulk viscosity of the solution, surface viscosity of the bubble, concentration of the surfactant solution, humidity, and temperature. Tween 80 sufficiently decreases the surface tension to form a bubble with a smaller internal pressure. The presence of Tween 80 makes the solution more viscous, and this raised viscosity resists the gravity drainage of solution in bubble. Drainage makes the bubble membrane thin, and the bubble bursts.

In addition to the critical micelle concentration \( \text{(cmc)} \) for both the surfactants, there is a critical concentration ratio of Tween 80 and CTAB, in a mixed solution, for which bubble life will be maximum. But we did not try to determine it exactly because the chosen solution worked well. On the basis of the rationale above, we can easily explain why the bubble moved easily onto a polyethylene surface when we tried to remove the excess liquid from the bottom of the bubble. Polyethylene is a low-energy surface that strongly attracts the hydrophobic part of surfactants and snatches the bubble from the glass tube; that is, our surfactant mixture acts as a wetting agent on the polyethylene surface.

After this demonstration a demonstrator can ask the following questions to arouse students’ interest. Can surfactant molecules resist water evaporation? Can they resist rust?

**Literature Cited**