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Predispersed Solvent Extraction

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COMMUNICATION

Predispersed Solvent Extraction

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Abstract

A novel method for solvent extraction from aqueous solution dispenses with a mixer-settler as the solvent is precomminuted in the form of aphrons which, after extraction, are buoyed to the surface by micrometer-sized bubbles. Extraction from solutions as dilute as a few parts per billion is possible in seconds.

Conventional solvent extraction suffers from two disadvantages. It needs a mixing-settling stage, which can be costly in capital and energy, and it requires a ratio of volume of solvent to volume of pregnant solution below which extraction is poor. Futhermore, because of the nature of the mixing, there is always the undesirable possibility of the formation of a third, little understood, colloidal phase which is difficult to eliminate. A new technique of predispersed solvent extraction avoids these problems because it eliminates the need for a mixing-settling stage. Consequently, it can even be used in large bodies of water such as contaminated ponds.

The technique depends upon two recent developments, both of which involve phases encapsulated in a soapy film, one of which consists of minute gas bubbles, called colloidal gas aphrons or CGA's (*1*), and the

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other a nonpolar liquid similarly encapsulated, a concentrate of which is called a polyaphron (*2*). The CGA bubbles are about 25 μm in diameter and can be made in concentrations up to 65% by volume of gas in water. Because of the encapsulating soap film and high pressure within due to the small radius, the bubbles do not coalesce, although they slowly grow in size by diffusion due to pressure differences. The liquid core aphrons, although similar in structure to the gas aphrons, can be made much smaller, extending from submicron to tens of microns in size, depending upon surfactant concentrations, but they have an extraordinary uniformity of size for any particular sample. They also have an energy barrier to coalescence, so concentrates of up to 96% dispersed in 4% water, which is actually a biliquid foam (*3*), are quite stable and can be stored for years. However, because water is the continuous phase, on dilution with water the individual aphrons separate, producing oil globules with a very large surface-area-to-mass ratio which makes them particularly suitable for solvent extraction.

In predispersed solvent extraction, the nonaqueous solvent is first comminuted into a polyaphron. This is achieved by first making a foam, either conventional or CGA, of the total aqueous phase containing sufficient surfactant dissolved in it to supply and stabilize the double surface of the soapy film needed to coat the aphrons. For example, to make 100 mL of kerosene polyaphron, 5 mL of water containing sodium dodecyl benzene sulfonate at a concentration of 4 g/L is foamed. Sometimes the solvent requires a small quantity of oil-soluble surfactant, such as a few drops of tergitol, 15-S-3, per 100 mL, to enable it to spread on the foam bubbles, a necessary step in the formation of aphrons. It is then added in small quantities to the foam with gentle shaking. As the aphrons build up, they provide surfaces for the additional production of aphrons, so the quantity of oil that can be added at one time progressively increases. At no time should there be more oil added than can be converted into aphrons by the available surface, because this would jeopardize production.

For extraction, the required quantity of solvent, which is preferably less dense than water, in the form of polyaphrons is introduced at the bottom of the extraction cell, which need not be more complicated than a simple cylinder, and which contains the aqueous pregnant solution (Fig. 1). Gentle stirring is all that is needed to disperse the aphrons immediately. Because the aphrons are so small, they rise to the surface rather slowly, so separation is assisted by buoying the aphrons to the surface by introducing some CGA. Aphrons tend to adhere to the film coating the CGA bubbles, and as these are considerably larger than the oil core

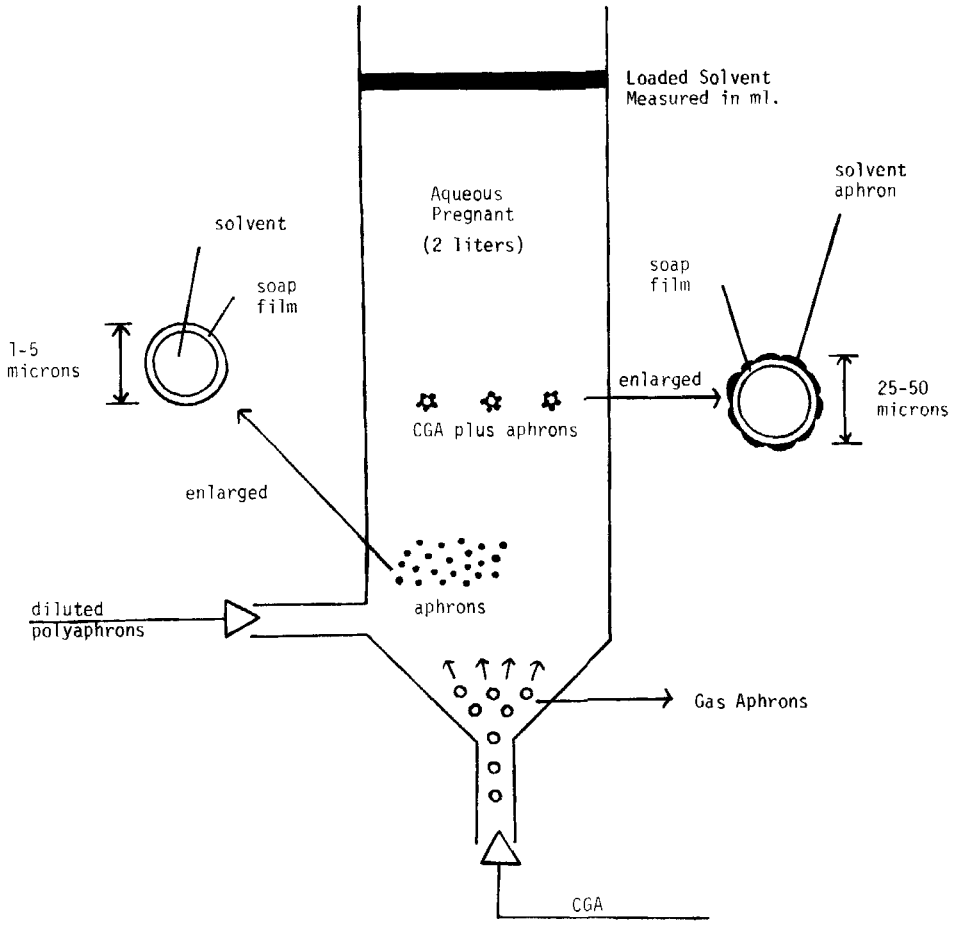

FIGURE 1.

aphrons, they rise to the surface within seconds. However, there are usually some aphrons which are so small that they remain colloidally dispersed. These can be collected by adding a few drops of a 10^{-2} *M* solution of aluminum sulfate, adjusting the pH to between 4 and 5, and then adding a CGA made of an anionic surfactant such as sodium dodecyl benzene sulfonate. This causes flocculation of an aluminum soap which entrains the bubbles as well as the very small aphrons. The entrained bubbles produce buoyancy, "bubble-entrained floc-flotation" (*4*), and in a few seconds the solvent containing the extracted solute

forms a liquid layer that floats on the surface, leaving a raffinate completely denuded of solute. There may be some froth produced, but this is destabilized by the oil and can easily be broken by, for example, playing steam on it.

The degree of extraction is remarkable. Two litres of aqueous solution containing a dye dispersed at a concentration of 2 ppb had all the dye concentrated into 1 mL of kerosene in seconds using this technique. Similarly, other organic solutes were removed from water in this way at low concentrations. By incorporating complexing agents in the kerosene, inorganic ions such as copper, can be concentrated, using a liquid ion exchanger, or uranium can be concentrated by using laurylamine dissolved in the kerosine. It appears that this technique offers a convenient, cheap way to remove hazardous substances from effluents prior to discharge. The quantity of surfactant (which could be biodegradable) needed is minimal, as is the quantity of solvent. It should be noted that the efficiency of extraction is enhanced by the fact that using the CGA to buoy up the aphrons makes this technique equivalent to an infinite stages extractor. Each aphron is, of course, limited in the amount of solute it can remove due to the distribution coefficient. However, when a droplet has reached this equilibrium, which is established very quickly because of its small size, it rises, leaving a solution slightly depleted of solute, which now reaches a new equilibrium with an oncoming droplet. In this way, complete extraction becomes possible at one pass. This contrasts with a mixing-settling process in which there is partition of solute between solvent and pregnant solution during the settling stage. Once the aphrons reach the surface, there is only a small interface across which equilibrium can be reestablished, the rate being diffusion controlled. The solvent can be removed from the system long before this happens.

This technique appears to have application not only for preliminary concentration from very dilute solutions for analytical purposes, or for biochemical concentration, but on a large scale in hydrometallurgy. As mentioned by Auten and Sebba (*4*), a new method for generating CGA which could be scaled up for industrial use has been developed.

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