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The formation of reverse vesicles and microdroplets

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It has been almost thirty years since the discovery that amphiphilic molecules, such as lecithin, could form approximately spherical, closed bilayer structures known as vesicles when dispersed in water. Reverse vesicles (RV), in contrast have only recently been described in the literature (Kunieda et al, 1991). RV differ from normal vesicles in that the surfactant head groups and any associated water form the core of the bilayer while the hydrophobic tails of the surfactant remain in contact with the continuous organic phase. Although a number of uses for RV have been suggested, such as enzyme entrapment during chemical reactions (Sanchez-Ferrer & Garcia-Carmona, 1994), to date they have not been widely exploited. We are currently investigating the ability of RV to act as drug delivery vehicles. During basic characterization work on RV we discovered that, in our systems, at certain compositions RV coexist with other particles we have named microdroplets (MD). These MD appear to be very small, stable droplets of water dispersed in the oil. The aim of the present study was to identify factors which influence the existence of these MD.

Identification and differentiation of RV and MD was simply and ingeniously effected by simultaneous use of polarising light microscopy and fluorescence microscopy. Under the influence of polarised light the RV appear as maltese crosses while the MD are invisible. Both MD and RV can be seen under fluorescence when the aqueous phase they entrap is labelled with the marker, calcein. Under these conditions the RV appear as concentric rings while the MD appear as solid circles. When both techniques are used simultaneously, RV appear as green maltese crosses, while the MD are seen as solid green circles, however when the fluorescent light was withdrawn the MD disappeared. Using this technique it was possible to count the numbers of RV and MD is any one sample. This experiment was performed for three surfactants $C_{12}E_4$, $C_{12}E_5$ and $C_{12}E_6$ (where E = OCH_2CH_2) a range of oils, namely hexane (C6), octane (C8), decane (C10), dodecane (C12) and hexadecane (C16).

The table shows the number of water molecules per mole of surfactant at which there are no MD detectable in the sample. At only very slightly higher amounts of water MD are clearly visible in the samples.

Number of moles of water per mole of surfactant required for vesicle formation

Oil	$C_{12}E_4$	$C_{12}E_5$	$C_{12}E_6$
C6	7.9	9.0	11.4
C8	7.9	9.0	11.4
C10	7.9	9.9	12.7
C12	7.9	9.9	13.1
C16	7.9	10.2	12.7

It can be seen that the length of head group affects the amount of water incorporated into the RV systems before MD formation occurs. In effect each surfactant can incorporate approximately 2 water molecules per E unit (just enough for head group hydration) before MD start to form. It is also noticeable that the nature of the oil does not have a big effect on the results.

In conclusion the results suggest that the amount of water required for RV formation is critical and that MD coexistence is a function of water concentration and head group length with the longer head group surfactants capable of suppresing MD formation at higher water concentrations than shorter head groups.

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