



# Microemulsion ; Essentials In Nanopore Synthesis And Its Benefits

*Microemulsion ; Utility for nanopore synthesis*

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**Abstract;** Microemulsions are a special type of colloidal system that have unique properties due to their high level of dispersion, tiny size, and ability to effectively control chemical reactions. In this study, researchers created calcium carbonate nano-powders using a reverse micro-emulsion method at room temperature, using Tween® 80 and Span® 80 as co-surfactants. To enhance the flow and distribution of the filler particles in polymer composites, they treated the surface of the CaCO<sub>3</sub> nano-particles with stearic acid. One key factor examined in the reverse micro-emulsion system, which includes Span 80, Tween 80, toluene, and water, was the  $\omega$ -value (the molar ratio of water to surfactant

**Index Terms** - Nanopores , sequencing , Mdna , ONT

## I. INTRODUCTION

The micro-emulsion method is a modern and effective way to create inorganic nanoparticles. When oil and water are mixed, they do not mix well and form two separate layers, each containing small amounts of the other. To blend these two layers, energy is needed to create an association between water and oil, replacing the connections between water and itself or oil and itself. The tension at the boundary between oil and water can be quite high, around 30-50 dynes/cm. This issue can be solved by using surfactants, which are special molecules that have parts that attract water (hydrophilic) and parts that attract oil (lipophilic). Because of this property, surfactants tend to gather at the water-oil boundary. When there are enough surfactant molecules, they organize themselves to form a barrier between the water and oil, reducing the interfacial tension .

An emulsion forms when a small amount of the right surfactant is mixed vigorously with oil and water, resulting in a two-phase mixture. In this mixture, one phase appears as tiny droplets coated with surfactant, which are scattered throughout the other phase. These emulsions look milky or unclear because the droplet sizes are between 0.1 to 1 micron , Generally, the type of surfactant used decides which phase will be the continuous one. If the surfactant is hydrophilic, the oil will form droplets in a continuous water phase. Conversely, if the surfactant is more lipophilic, the water will form droplets in a continuous oil phase. While emulsions are stable in terms of movement, they are not stable in terms of energy and will eventually start to separate back into their original layers. The droplets will combine, and the dispersed phases will settle.

Characteristics of Microemulsions

When a surfactant has a good balance of hydrophilic (water-attracting) and lipophilic (oil-attracting) qualities and is used at the correct concentration, it creates a unique oil and water mixture. This mixture remains an emulsion but has different features compared to the milky emulsions we talked about before. These new mixtures are called “microemulsions.” There are several differences between emulsions and microemulsions, including the tension between the phases, the energy needed to form them, the size of the droplets, and how they look. Water-in-oil microemulsions are also referred to as reverse micelles. They can dissolve both water-loving and oil-loving substances.

Microemulsions generally have low viscosities and show Newtonian flow properties, which means their flow stays steady even when different shear rates are applied. Some bicontinuous formulations might display a bit of non-Newtonian flow and plasticity. The viscosity of microemulsions is close to that of water, even with a high concentration of droplets. Their structure is constantly changing, making them very dynamic and allowing for reversible droplet merging. Various methods are used to analyze the different properties of microemulsions, including light scattering, X-ray diffraction, ultracentrifugation, electrical conductivity, and viscosity measurements.

### Types of Microemulsions

Microemulsions can be divided into four types based on their phase equilibrium. Winsor (1948) created a classification system for both micro and macro emulsions.

The first type, called Winsor-I, is oil-in-water (o/w) microemulsions. In this type, oil droplets are surrounded by a surfactant film, which may also include a co-surfactant, and these droplets are spread throughout water, the continuous phase.

The second type, Winsor-II, is water-in-oil (w/o) microemulsions, which exist in balance with an excess of water at the bottom. Typically, o/w microemulsions have a larger interaction volume compared to w/o microemulsions.

Water-in-oil microemulsions contain water droplets that are enclosed by an oil continuous phase and are often referred to as "reverse micelles."

The third type, known as Winsor-III, consists of middle-phase bicontinuous microemulsions that are in equilibrium with an excess of oil at the top and excess water at the bottom. These microemulsions may exhibit non-Newtonian flow and plasticity.

The primary focus of this study was on the Winsor II Type microemulsion system, which includes two phases where water-in-oil droplets are balanced with an excess water layer at the bottom.

### Microemulsion Formulation

The characteristics of the surfactant, oil, and water play a crucial role in creating microemulsions. If the actual formulation strays too far from the intended mix, it can lead to the breakdown of the microemulsion and result in an unstable macro-emulsion.

### Formulation Considerations

A microemulsion typically consists of four key components: a lipophilic phase, a hydrophilic phase, a surfactant, and a co-surfactant. The types of components used—such as oil, surfactant, co-surfactant, and water—along with temperature and pressure, influence the microemulsion systems. These factors are known as formulation variables. The amounts of each substance present can also alter the properties and are referred to as composition variables, which can be represented as weight, percentage, or proportion. To achieve low interfacial tension and effective solubilization, it is essential to formulate the microemulsions accurately. The creation of a microemulsion relies on several factors: (1) the ratio of oil to surfactant and surfactant to co-surfactant; (2) the type and concentration of the oil, surfactant, co-surfactant, and water; (3) pH levels; (4) temperature; and (5) the hydrophilic or lipophilic nature of the components. All these factors must be taken into account when formulating microemulsions. Additionally, it is vital to ensure that the oil, surfactant, or co-surfactant is compatible with the desired method of administration.

To analyze the phase behavior of simple microemulsion systems made up of surfactant, oil, and water under fixed pressure and temperature, researchers use ternary phase diagrams. Each corner of the ternary phase diagram shows 100% concentration of one component. When four or more components are involved, pseudo-ternary phase diagrams are used to illustrate these systems, with each corner representing binary mixtures of two components, such as surfactant/co-surfactant or surfactant/water.

### **Water Phase**

Depending upon the amount of water present in the system, water may form water pool or work as a dispersion medium in micro-emulsion systems .

### **Oil Phase**

The oil phase must be chosen appropriately, since it governs the selection of the other ingredients for the microemulsion and there are two main factors that need be considered before selecting the appropriate oil phase. Firstly, the solubilising potential of the oil for the selected substance must be seen and secondly, the chosen must be such that the microemulsion forming region is enhanced. Oils with shorter hydrocarbon chains are easier to micro-emulsify as compared to oils with long hydrocarbon chains. An oil's ability to solubilise lipophilic groups is directly proportional to the chain length of the oil. Thus, the selected oil should be such that it is capable of solubilising the API, and facilitating the formation of microemulsions with desired characteristics.

### **Surfactants in Microemulsions**

Surfactants are molecules that typically contain a polar head group and an apolar tail). They are surface-active and microstructure-forming molecules with a strong chemical dipole (Holmberg, 2002). They can be ionic (cationic or anionic), nonionic, or zwitterionic. Surfactant molecules self-associate due to various inter- and intra-molecular forces as well as entropy considerations. The surfactant molecules can arrange themselves in a variety of shapes. They can form spherical micelles, rod-shaped micelles, a hexagonal phase (consisting of rod-shaped micelles), lamellar (sheet) phases, reverse micelles, or hexagonal reverse micelles ). The structure change of micelle with size .

As with all things, microemulsions have advantages and disadvantages.

Microemulsions possess several advantages that make them suitable for making nano-particles. These include the following factors.

1. **Ease of Preparation:** Microemulsions form spontaneously at room temperature, and are easy to manufacture, when compared to liposomes and macroemulsions which require high pressure homogenization during preparation .
2. **Thermodynamic Stability:** The stability and shelf life of the formulation is improved due to the thermodynamic stability of the microemulsions.
3. **Ability to incorporate both hydrophilic and lipophilic therapeutic agents:** Microemulsions can form diverse microstructures which enable them to solubilise both hydrophilic and hydrophobic drugs, either alone or in combination
4. **As a template for the synthesis of nano-particles:** Microemulsions are thermodynamically stable, and consist of small droplets which possess large interfacial area. These characteristics facilitate their use in nanoparticle synthesis .

Microemulsions have some disadvantages as follows: Formation of microemulsions generally requires large amounts of surfactants and/or co-surfactants. All of these at high concentrations are generally irritating , Many external factors, such as temperature and pH, influence the stability of microemulsions as well.

### **Reverse Micelle**

There are some factors that affect the stability of an emulsion and further affect the morphology and size distribution of produced particles. These factors include type and amount of surfactant and co-surfactant, the concentration of precursor solution, the kind of oil phase, and the water-to-oil ratio. Micro-emulsion is generated by gradual addition of several drops of an agent as a non-continuous phase and the other material

as a continuous phase and rapid mixing of these two phases. Oil drops in the water is a good example of micro-emulsions Reverse micelles provide an example of organized self assemblies of surfactants

in solution and are most widely used as reaction media or templates for biomimetic synthesis of various inorganic nano-particles. The biomineralization process in nature uses organized aggregates of bio macromolecules to synthesize nano-particles with dimensional, morphological and architectural specificity and exercising full control over nucleation, growth and the patterns formed. The hydrophilic head and hydrophobic tail of surfactants in a polar solvent self assemble to give reverse micelles where the polar core contains the hydrophilic heads and the polar shell the hydrophobic chains. Water can be solubilized in the core forming water-in-

oil droplets (5 nm) which eventually become the w/o micro-emulsion as the water content increases (5 to 100nm). The water to surfactant molar ratio has a decisive influence on the diameter of the reverse micelles ). Reverse

micelles are generally characterized by the molar ratio of water to surfactant, Formation of Nano-particles in W/O Microemulsion System

In the present study pertaining to the synthesis of nano-particles (NPs), single phase w/o micro-emulsion with reverse micelles are required. Good dispersion of generated drops in the micro-emulsion is suitable for synthesis of nano-particles and it has good enough potential to control the chemical reaction that might occur in the micro-emulsion . surfactants. Because the exchange of aqueous contents between the microemulsion droplets or the intermicellar material exchange is closely related to the formation process of nanoparticles in reverse micelles, it is necessary to consider how the intermicellar exchange influences various aspects of the nanoparticle formation . It is generally accepted that the water contents of microemulsion droplets are exchanged rapidly through droplet collision and fusion, with the fusion step as the rate at the first route, reactant diffusion is taken place through oily phase into aqueous droplets including the second reactant. While the particles achieve their final size, molecules of surfactant stick to particles surface, and cause their durability, stability and maintenance in a certain level and prevent more growing of particles. On the other hand, reactant ions exchange may be occurred because of coalescence of two droplets with each other (second route). In this case, the contact of reactants and subsequent reaction can be regarded as a number of sequential steps:

1. Diffusion and convection to bring the emulsion droplets together,
2. Surfactant layer opening and coalescence,
3. Diffusion of the solubilize molecules in the temporary dimeric aggregate,
4. Reaction between solubilize molecules,
5. Nucleation and crystal growth of precursor particles, and
6. Decoalescence to return as smaller droplets.

#### **Factors Affecting the Size of Nano-particles in the Microemulsion**

The surface activated and stable micro-cavities produce cage-like effect and cause to limit growth nucleation and particles agglomeration. The size of micro-emulsion drops has a clear effect on the particles size. On the other hand, the size of micro-emulsion drops in turn, depends on their collisions and created interactions. These interactions are dependent on the viscosity of mixture. For a diluted dispersion of spherical droplets without interactions, the relative viscosity,  $\eta_r$  is expected to obey the Einstein-relation,

Where  $\eta_0$  is the viscosity of the solvent,  $\eta$  is the viscosity of the dispersion, and  $\Phi$  the volume fraction of droplets. For droplet volume fractions up to 0.2, a maximum relative viscosity  $\eta_r$  value of 1.5 is expected. A higher  $\eta_r$  indicates structural changes of the micro-emulsion . This is observed within the one-phase region approaching the lower phase boundary , show viscosity measurements within the one-phase region for micro-emulsions prepared from two different surfactants. In both systems a strong increase of viscosity is observed when decreasing the temperature and increasing the water concentration. This indicates

stronger droplet interactions or a higher degree of structural transformation when approaching the lower phase boundary. If the critical micro-emulsion concentration ( $c_{uc}$ ) is known, it is possible to calculate the size of spherical droplets from a simple geometric model. The second reason is that soluble water in the surface active agent and non-ionic micro-emulsion is as free and surrounded water. At low  $\omega$  ratios, more water molecules are surrounded with dissolution of the surface active agent and reactive components, while the number of free water molecules with the  $\omega$  ratio increases. When the water ratio is good enough high, free water molecules in the hydrophilic region are present and they are the major part of product size in these conditions which may decrease the interface membrane efficiency and increase the exchange rate of water droplets that is in turn helpful in increasing the flocculation of nucleation reported since the particle size in the micro-emulsions are

comparable with the size of micro-emulsion droplets, it can be found out that the level of water present in the micro-emulsion and the size of micro-emulsions droplets which is influenced by it, are controlling factor for particle size.

Other factors that are believed to be involved in the control of particles size are the nature of the surface active agent and concentration of aqueous reactants. To investigate the effect of surface active agent on the particles, Liyi and his colleagues obtained the nano-particles of  $\alpha$ -Al<sub>2</sub>O<sub>3</sub> in different amounts of surfactant and mix, while the rate of water and concentration of aqueous reactant were constant. They reported that an increase in the level of the surface active agent decreases the particle size.

Increasing the level of surface active agent causes decrease of  $\omega$  ratio and this makes the micro-emulsion stronger (more stable). Therefore, the level of surface active agent affects both the stability of the micro-emulsion and control of the particle size control.

Temperature is another effective factor on the particle size. As already

mentioned, it can affect the viscosity of the solution and finally can influence the particle size. Increase in temperature causes increase in the growth rate of particles.

Furthermore, at elevated temperatures, solubility of non-ionic surface active agent in water decreases due to less hydration of hydrophilic head-groups. In another way, at higher temperatures, solubility of surface active agent in oil phase increases, therefore, temperature management is necessary for particle size control. The particle size is also influenced by the stirring rate. During micro-emulsion formation, stirring stalls further growth of the droplets and this effect increases with increasing the stirring rate.

Therefore, the droplet size of micro-emulsion becomes small and consequently, the final produced particle size will be smaller.

### Surface Treatment

Surface treatment of calcium carbonate is an additional modification to enhance performance of the matrix-calcium carbonate interactions. It is also done to improve the fluidity and dispersion of the filler particles in polymer composites. Surface treatment of CaCO<sub>3</sub> reduces the inter particle interaction, enhances the polymer filler compatibility. Pronounced effect of

treatment is expected to be obtained by decreasing the filler size. Several methods can be used to surface-treat the CaCO<sub>3</sub> particles. In order to obtain the desired results, the type and mechanism of treatment must be chosen according to the chemical and physical properties of the components. The incompatibility of the high energetic hydrophilic surface of calcium carbonate with the low-energy surface of hydrophobic polymers is a particular problem that requires surface treatment of fillers).

Surface treatments can be reactive or non-reactive. Non-reactive surface

treatment, the oldest and most used modification, covers the filler with a small molecular weight organic compound (surfactant). A typical example is the surface treatment of calcium carbonate with stearic acid. Stearic acid is the most common surface modifier for calcite because of its low cost, Calcium

carbonate surface adsorbs the polar group of stearic acid by the formation of ionic bonds between stearic acid and the surface of calcium carbonate. It is really important to know the right amount of surfactant to use in order to obtain the desired properties. As a result of treatment, surface energy of the fillers

decreases dramatically, It is postulated that the stearic acid molecules interact with the calcium carbonate, with the carboxylate ion reacting with the surface and the organic chains sticking out normal from the surface. It is difficult to bind fillers to the matrix polymer by covalent bonds, especially polyolefins, because these do not possess reactive chemical groups. Non-reactive surface treatment modifies only the secondary forces between the surface of the filler and the matrix, The majority of treated calcium carbonates are post-treated on a separate production line at the end of the other processes. Surface treatment levels are usually determined by the mineral's surface area. Typically there will be a slight excess of treatment to insure complete encapsulation/reaction

#### IV. RESULTS AND DISCUSSION

Microemulsions are a unique class of colloidal systems having novel properties because of their high degree of dispersion, their very low size and good enough potential to control the chemical reaction.

- Micro emulsion properties are extremely varied. The extreme diversity of their practical applications is one consequence.
- One of their disadvantages is the large amount of surfactant required to stabilize them because of the small dispersion size.
- Although micro emulsion properties are beginning to be satisfactorily understood, especially the droplet structure, large research domains remain to be clarified.
- With evaluation of newer techniques of preparation, stabilization, rheological properties can serve as potential carrier for drugs, cosmetics, pharmaceutical agents

Multiple emulsions are complex polydispersed systems where both oil in water and water in oil emulsion exist simultaneously which are stabilized by lipophilic and hydrophilic surfactants respectively.

- The ratio of these surfactants is important in achieving stable multiple emulsions. Among water-in-oil-in-water (w/o/w) and oil-in-water-in-oil (o/w/o) type multiple emulsions; the former has wider areas of applications.

**Application** : Applications in Therapeutics & Cosmetics:

Multiple emulsion systems are finding unlimited uses because of their vesicular structure with innermost phase closely similar to that of liposomal vesicles and the selective permeability characteristic of liquid membrane.

- In cancer therapy.
- In herbal drugs.
- In taste masking.
- In food industry.
- In drug overdose treatment.
- In inverse targeting

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