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## Chemistry 101

### Emulsion Optimization by use of Phase Inversion Temperature (PIT)

One of the best methods available for choosing emulsifiers is the Phase Inversion Temperature (PIT) system developed by Shinoda. Before we can discuss how this system works or how to apply it, we must first understand ethoxylated emulsifiers and their properties. Let's begin with a simple question: why are ethoxylated fatty materials soluble in water? The answer is hydrogen bonding between the epoxide (as it was once) oxygen of ethylene oxide and the hydrogen of water. Many have questioned the reverse cloud point seen with ethoxylated materials. It is well known that, as temperature is increased, ethoxylated surfacants become less water-soluble. This some-what surprising observation is easily

explained by considering that, as the temperature increases, the molecules exhibit more movement/vibration. Thus, hydrogen bonding is inhibited, the ethoxylate loses its water solubility and cloudiness results.

Now, back to emulsifiers and PIT. Let's take a typical emulsion (o/w) based on ethoxylated emulsifiers. We heat each phase to 75°C and add the oil phase to the water phase. The temperature is still 75°C, and the hydrogen bonding is nowhere to be found. Thus, emulsifiers that normally, at room temperature, have an HLB of 12 now have an HLB of 5. They want to form a water-in-oil (w/o) emulsion and, in fact, do. As the emulsion cools, the hydrogen bonding and the HLB of the emulsifier increase. There is a temperature, the PIT, at which the emulsion now inverted from w/o to o/w. When this happens, the particle size decreases and the distribution of particles narrows. Both conditions make for a good emulsion. If the PIT is at least 20°C above the typical storage temperature (25°C), then we can be quite confident that the emulsion will exhibit excellent stability.

**Determining PIT:** PIT can be determined in several ways, including observation with the naked eye. Above the PIT, the emulsion is thin, watery and generally ugly. Below the PIT, it is white, opaque, glossy and thickened. Above the PIT, the pH is unstable; below the PIT, the pH is quite stable. Keep in mind that, above the PIT, we are trying to measure the pH of an oil phase, which, of course, is silly! In order to measure a pH you must have ionic strength and conductivity; oils have neither. In a like manner, we can monitor the PIT by measuring the conductivity.

**Using PIT:** Suppose your emulsion has a PIT of 40°C, and you would like to raise it to at least 50°C. Alter the ratio or the concentration, even change emulsifiers and

emollients to see the effect on the PIT and, thus, the particle size and final stability! This system is particularly useful because it takes into account the entire emulsion and not just the oil phase components. A drawback of the PIT system is that it does not work for w/o emulsions. The emulsifiers will continue to orient towards forming w/o emulsions (low HLB) at increased temperatures. Formula 1 is an example of a sunscreen moisturizer that will exhibit a clear PIT. Try making it, and vary the emulsifier concentration to see how it affects the PIT. If you cut the concentration in half, and the PIT does not significantly drop, you just saved some money while reducing the irritation potential. You can also substitute an anionic emulsifier for one of the nonionics and watch the PIT dramatically rise.

**Happy formulating!**