Agitated Vegetable Oil Settling Slowly on Top of Water

I originally wanted to create an image of a vortex within a clear acrylic tube. After several failed attempts I brainstormed quite a bit and ended up experimenting a bit with the dynamics of an oil-water interface. Hundreds of pictures were taken with about a dozen different setups with no decent images created. After dimming the lights and adding external lighting in the form of a flashlight, decent images started appearing. But agitating the vegetable oil to get a picture of the flow in fast motion didn't result in a good image, and I took a half hour break. Upon returning, I found the once uniform layer of bubbles in the oil had deteriorated into a fascinating shape as the bubbles started to accrete into each other. The final image represents a top-down view of this stage in the flow, as the oil is slowly returning from an opaque layer of bubbles to back to a homogeneous and clear layer of oil.

The flow was entirely contained in a wine glass. It was about 2/3 full, with a layer of oil about 1.5 inches thick and a layer of dyed-red water about 2.5 inches thick. The diameter of the glass is about 3 inches at the top. The setup is shown in Figure 1, with the middle picture of the three representing the state of the fluids when the picture was taken. The initial agitation was by method of stirring with a spoon until the entirety of the layer of oil consisted of tiny bubbles

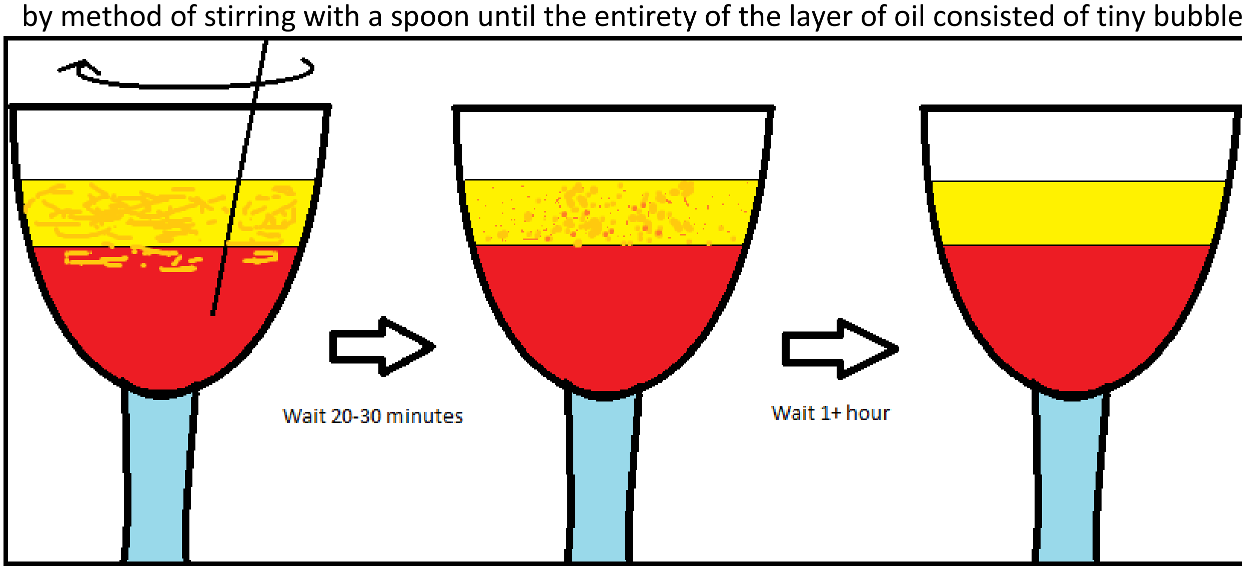

Figure 1: Schematic of Flow Setup

of oil and perhaps some water. The only force acting on the flow after the agitation is gravity, which causes the two fluids to naturally separate due to density. The density of water and the density of vegetable oil are about 1.00 g/cm^3 and 0.91 g/cm^3, respectively at room temperature.[1] This drives the water particles in the oil downward and the oil particles in the water upward due to buoyancy from gravitational forces on the molecules. This happens quickly, and as little as a minute after agitation there was a clear, solid boundary between the oil and the water. At this point the water had no bubbles in it, but the oil was almost pure bubbles. Although the fluid is technically in motion, the average velocity of the oil molecules is low enough to estimate the Reynolds's number to be very low, approximately 0. The dispersion and accretion of the bubbles into each other and the surrounding oil isn't well documented online, and it's hard to find accurate literature on the process and reasons why they formed such a complicated pattern as they dispersed into the liquid.

Color was added to the water substrate in the form of cherry Kool-Aid. This contrasted well with the yellow vegetable oil on top. The experiment was performed at a friend's house, and the specific type of vegetable oil was not documented. The temperature of the liquid was equal to the temperature of the room (about 22 degrees Celsius), as the water had been sitting for quite some time after being extracted from the faucet. The water was poured into a container that held about 1.5 liters, and 4 packets of Kool-Aid powder were added. The water was then poured into a wine glass, filling it to about 3/5 of its maximum capacity. Vegetable oil was then poured into the glass on top of the water until the glass was about 4/5 of the way full. The water and oil mix was then stirred violently with a spoon for about thirty seconds. The lights in the room were turned off and a standard MAGLITE flashlight was held about 2 feet away from the edge of the glass, lighting it from the side. The camera was then positioned above the glass, the flash turned off, and pictures were captured. Many different flashlight positions were used, but the best image was caught when the main beam of light shone orthogonally to the edge of the glass, straight through the layer of oil.

The field of view of the image is only about 3 inches by 3 inches in the plane of the oil-air interface at the top of the glass. The camera was held quite close to the oil, and the lens was only about 2 to 3 inches above the aforementioned interface. The focal length of the lens was 6 mm. The camera used was a digital PENTAX X90 model with 12.1 megapixels and 26X optical zoom. The original image was 3000 pixels tall and 4000 pixels wide, and the left side was cropped off for a more symmetric framing; the final width was 3754 pixels. The shutter speed used was 0.25 seconds due to the very low lighting. Good focus was achieved from the cameras built in image-stabilization software, however in the future I would use a more powerful flashlight and decrease the shutter speed to achieve even better focus. The aperture was f8.0, and the ISO setting was 80. To be honest, the only thing I remembered about the ISO was that at high values image noise could occur, so I tried to use a low ISO value to minimize this effect. The highest aperture was used to absorb as much light as possible during exposure. These properties were experimented with minimally, and the final values used were estimations of the best settings tried. No post processing was used other than simple cropping of one edge.

The image reveals a physical process that happens so slowly it's rarely thought about in every day terms. A few days after I took and submitted the picture, I jumped in a puddle of water on the ground, and stepped away as I watched the bubbles on the interface between the water and air slowly disperse back into the water. The physical process that governs when those bubbles pop and how they collect on the top of the water is probably very much the same as the process that governs how and when the bubbles in the oil disperse back into their original medium. The physics are shown decently well in the picture; however a lot more data needs to be taken to obtain an accurate picture of what happens. In three dimensions, the shapes formed by the bubbles were even more spectacular, although pictures from the side showing the vertical orientation of the bubbles in the oil did not depict the physical orientation well at all. A high definition time-lapse video of the dispersion of the bubbles would be a much better representation of the physical process

References:

[1] http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1016&context=chemeng_biomaterials