

Physical Properties of Solutions

Colloids

Colloid Formation and Flocculation Page [1 of 2]

Take some sand, throw it in a glass of water. In this case, I've got a beaker of sand here. We'll stir it up and what you're seeing is something I'm sure you've seen before, that we can mix the sand up but very quickly after I stop mixing, the sand settles to the bottom under the influence of gravity, the sand simply drops. And if I come back in fifteen minutes or so, that solution is going to be completely clear again. This is an example of a suspension. We can see particles with our naked eye here. They are under the influence of gravity. They are large enough that they get pulled down to the bottom very quickly. On the other extreme are what we've been talking about for the last few units and that is solutions. An example of a solution being salt and water. We know that if we dissolve salt and water, and let it dissolve, that the particle size of these ions in this case, in solution, is sufficiently small, that we do not collect, once it all dissolves, it is not sufficiently large to scatter any light off of it and so the solution appears to us absolutely clear. Well, in between these two extremes of suspension and solution, are colloids. Colloids are a very large class of mixtures. Again, the key word here is that this is another example of a mixture but it is a mixture where the particle size is sufficiently large that it can scatter light off of it and so it appears cloudy to us, but it is sufficiently small that the particle size is not under the influence of gravity enough to pull them down to the bottom. In other words, the thermal motion in the solution, just random motions and random currents, what are called convection currents, are sufficient to keep the particles suspended because they are not that large that they are again dropped to the bottom. But, if we waited for fifteen years and came back, indeed where nature ultimately would take this system is that, in fact, all the colloids would be collected together and dropped down at the bottom of the beaker. So there is something keeping a colloid in this suspended state and we'll get to that in a moment. But, again, what characterizes a colloid from a physical sense is that it appears cloudy to us and it can be considered small particles that are sufficiently large to scatter light, so we can see them, but we can't actually make out the individual particles, but we can see the light scattered off of them. But not sufficiently large that they drop down to the bottom of the solution readily. Now there are all kinds of colloids around us in nature. There are aerosols; those are examples of colloids. That would be a liquid that is dispersed in a gas. So, an example of that actually would be fog, for instance. You're all familiar with fog; again, very tiny droplets of water suspended in air. Other types of examples of aerosols would be a solid aerosol, that's where we have solid dispersed in a gas. Smoke would be a common example of that type of an aerosol. We have foams, whether the foam is whipped cream, for instance, and you've all experienced whip cream before, that's an example of a gas that is dispersed within a liquid, in this case, the gas is dispersed into the cream. Fire extinguishers, many fire extinguishers are foam based that contain foam when you spray them on a fire. That is again a gas dispersed within a liquid. Emulsions are examples of liquids dispersed in other liquids, so milk for instance would be a classic example of an emulsion. And you have sols. Now sols are examples of solids that are dispersed in either liquids or solids. An example of a solid dispersed in a liquid would be paint, and again you can leave a can of paint for a long period of time without the particulate matter dropping to the bottom, at least if it's a good pain. And then there are there are solid sols where you have a solid that is dispersed in another solid. An example of which might be the tiger's eye in my ring for instance, where again we have impurities dissolved in other minerals, and so we get this mixture of different things, but again, everything is in the solid state in this case. So, lots of examples of colloids.

Now, what I want to show you is one of the characteristic features of many colloids, and in particular aerosols, whether we have a liquid dissolved in a gas or a solid dissolved in a gas, or also emulsions, a liquid dissolved in another liquid. This is something called the Tyndall Effect and actually, let me show you that here. I have just a container of water in this case and I'm going to take a flashlight and just simply, let me focus the beam real quick, and if we could turn out the lights please, I just want you to look at what happens here and basically, you should see nothing, pretty much. The light beam is passing through the liquid in this case and aside from a stray dust particle or something, you really should see no indication of scattered light at all. In fact, all the light comes through and you can see it coming through by the indication of my hand here. Now, go ahead and leave the lights out. I'm going to add one drop of cream to this. We'll stir that up and we'll do the same thing again. And now you see a big difference, that although the solution almost looks clear if we were bring up the house lights, you can clearly see now where the beam is passing. You can see if I move the orientation of the flashlight, very clearly where that beam is. A lot of the light is still making it through to my hand, but not as much as before. And, again, you can see very, very clearly now. I can't see, even with my nose right up in it, the individual particles that are scattering the light, but I certainly can see the light coming off in my direction in that I can see where that beam is. Now, if I add a lot more, now we get to a point where there is enough scattering that I can almost not even see where that beam is going now. There is so much scattering going on in this mixture, that light is just bouncing every which way and, in fact, the whole mixture seems to be glowing now as a result. We talked about opaque materials having this basic characteristic, that the light is scattered throughout the material. So if we could bring up the lights please, again, that was the Tyndall Effect and that is again one of the characteristics of an emulsion or also of an aerosol that you can see those individual particles.

Physical Properties of Solutions

Colloids

Colloid Formation and Flocculation Page [2 of 2]

So what is it that causes this type of thing? Well, there are two very, very common types, not the only two, but two of the most common types of colloids in aqueous solution are fat globules in which case we have nonpolar molecules that tend to stick together. Remember, we talked about the hydrophobic effect and the notion that nonpolar molecules don't like to interact with water very well. And remember the real reason is that water tends to form these cage structures around them and that is bad as far as entropy goes. So we have this hydrophobic effect and the bottom line is that nonpolar things tend to stick together and form these little globules. We also have something called micelles that very often are formed, in particular with things like soaps. Now the characteristic feature of a soap or a detergent molecule is that it has both a hydrophobic side, this hydrocarbon chain again, and a hydrophilic or water-loving side. Usually, this is an ionic group or at least a very polarized group on the other side. And what happens is, in a micelle, all of the tails, the nonpolar portions of the micelle tend to clump together in the middle, leaving the polarized head groups on the outside to interact with the water. So, again, that forms a particle size that is much larger than the individual molecules that make it up. Proteins again also are examples of colloids and they tend to again lump together in such a way that the hydrophobic sides are kind of buried within the protein and the hydrophilic sides are on the outside. So, again, some of the most common examples of colloids.

Well the last question we want to ask is if nature ultimately would like to get to a point where all of these got together and precipitated out a solution, why doesn't that happen faster? Well, the reason is that colloids very often will collect charge – they could be ionic charge or straight electrostatic charges – so I show you just schematically here. Let's suppose that this colloid particle collected some positive ions on the surface. Well, those will be accompanied by the complimentary negative ions so overall, that particle is indeed neutral. But, the point is on the outside surface, there is a negative charge presented. When that comes up to another particle with a similar charge makeup, it's got the outside shell with negative charges, there is a repulsion between those two colloid particles and so they tend to stay away from each other. You also can have the colloids where you have a net positive outer shell that comes in contact with the positive outer shell. Both kinds exist. But the point is that because of this charge buildup, there ends up being a repulsion between these particles. So, when you heat these materials, very often that supplies enough kinetic energy that those repulsive forces can be overcome and the colloids can get together and the oil droplets, let's say, are micelles. The other thing that you can do is to add an electrolyte, like salt for instance. And that will break down some of the charge problems here, help neutralize this charge shell and that allows the system to more easily overcome that repulsion barrier and you get what is referred to as flocculation, when then hastens the precipitation of the colloid. So again, anything you can do to minimize that repulsion, either by heating it up to get them to collide together with more energy or adding ions to help neutralize this. So, again, colloids are just one more example of mixtures found in nature all over the place, especially in biochemical systems, as well as everywhere else in nature. One other example, just while I'm thinking of it, where flocculation in fact occurs, is at river deltas. Rivers pick up a large amount of mud that becomes suspended in the water and it's not until it dumps out into the ocean where it encounters high ion concentrations of salt water and then flocculation occurs and the mud particles coagulate and then eventually drop out, giving you huge amounts of sediment in the river bed, or again, at the delta.

So, anyway, once again, in between the two extremes of the suspension or the solution, are colloids. They are all over the place. And remember that a colloid is a kinetic state. It is a metastable state. Its nature on its way to going to some final resting stop but it has gotten stuck in the middle trying to get there. And so, again, methods people use to hasten that would be heating it up to help get it there faster, or adding electrolytes to break down this charge that keeps them apart. So that would conclude, then, our discussion of mixtures of different substances.

Physical Properties of Solutions

Colloids

CIA Demonstration: Tyndall Effect Page [1 of 1]

This is a cute little demonstration called the sunset demonstration. It's an example of the Tyndall Effect, where it's sodium thiosulphate and hydrochloric acid, which combine to form a sol. Remember a sol is a colloid and it's a solid dispersed in a liquid. In this case, the liquid is water inside this aquarium. What we're going to do is we're going to mix the ingredients inside the aquarium and we'll shine a light through. Remember the Tyndall Effect is the scattering of light off the particles that are in the solution. They are not fully dissolved. They are starting to precipitate and just as the sunset turns progressively redder, as the sun goes down, what we're going to see is something along those lines. I won't give away too much.

So, here are the solutions. We're going to pour them into the aquarium. We're going to give it a quick stir and then I'm going to set up some nice sunset music and let you all enjoy it.

I hope you enjoyed that. As the particles of our sol grew larger and larger, it was only the very longest wavelengths of light that were not scattered and so what happens is that we start with white light coming out of our light source and the appearance is more and more red as the sunset progresses because only the longest wavelengths make it through. And that explains why sunsets look red.