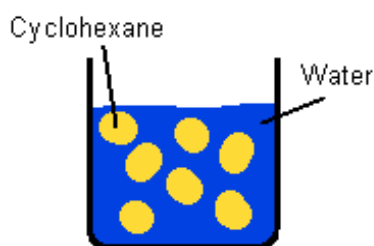


Nanoparticle and Colloid Science Assignment

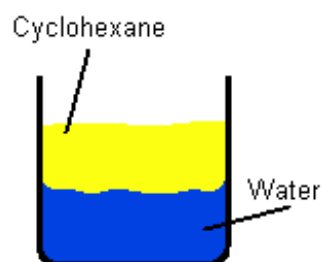
Question 1

Cyclohexane (C₆H₁₂) is a molecule comprising of 6 carbons, linked in a ring by single bonds. Despite its name however, the typical physical structure is not a ring, but a ‘chair’ arrangement, as this is the lowest energy state for it. The bond angles involved mean that a simple ring is almost never the conformation.



Cyclohexane is not soluble in water (H₂O), so we do not get a cyclohexane solution. Instead, the cyclohexane forms a dispersion through the water, (or vice versa if there is a greater quantity of cyclohexane than water) known as an emulsion.

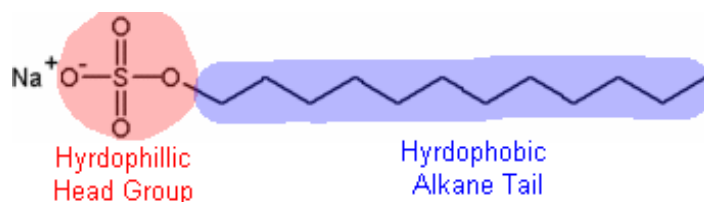
Now, the energy of particles on the interface between the water and the cyclohexane have a higher energy than those in either bulk. So when two particles of cyclohexane come together, through Brownian motion, they act so as to reduce their surface, thus moving to a lower energy state.



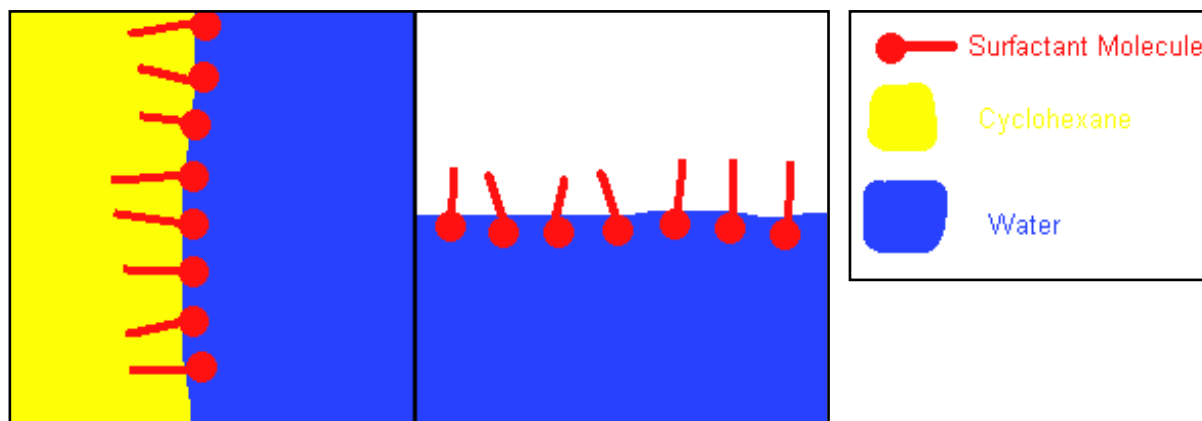
In addition, the smaller the droplet, the greater the vapour pressure – the tendency for molecules to leave the droplet for the surrounding environment – this leads to a flow of molecules from smaller particles to larger particles. The eventual result of both these processes is the separated dispersions seen after leaving the mixture or stand. Because cyclohexane is less dense than water, it forms a layer on the surface.

The dispersion can be recreated by mixing, this will break up the bulk cyclohexane and water into a particulate dispersion again. Here the mixing is the energy needed to be input to create the additional water-cyclohexane surface. This energy is given by the equation $dW = \gamma dA$ where W is the work done, A is the surface area and γ is the interfacial tension, in this case between cyclohexane and water. The amount of energy input by the mixing process will determine the amount of surface created, and hence the size of the cyclohexane colloids created.

A ‘typical’ surfactant consists of a hydrophilic ‘head’, and a hydrophobic, typically alkane, ‘tail’. A common example of an ionic surfactant is Sodium dodecyl sulphate (SDS, [CH₃\(CH₂\)₁₁OSO₃Na](#)).



Surfactants like this will adsorb to interfaces between water and other phases. They will act upon the air-water interface, and the cyclohexane-water interface in this situation.



Here we see the surfactant molecules adsorbed to the interfaces. This has two major implications for the stability of our colloidal cyclohexane in water. The interfacial tension between the cyclohexane and the water is reduced – this means that less energy is needed to create the additional surface involved in the colloidal dispersion.

The surfactant layer also prevents the droplets of cyclohexane from actually coming into contact with each other – in fact if an ionic surfactant is used, there is likely to be a weak coulombic repulsion between the droplets. If the particles cannot come into contact, then they will be unable to lower their energy by bringing more material into bulk and having less as surface material.

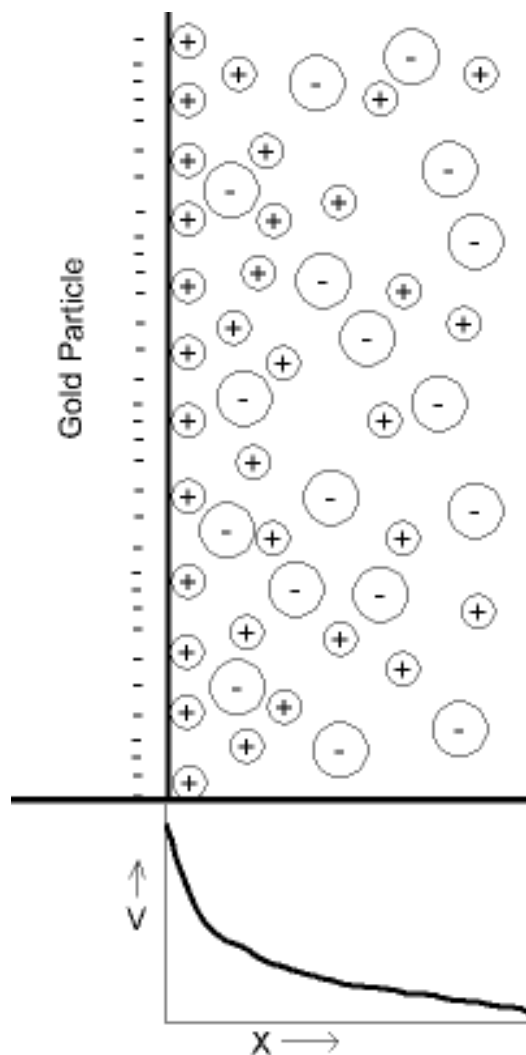
Overall, as the stability of colloids is all related to surface behaviour, even small amounts of surface active materials, as seen here, can have a major effect on the behaviour and nature of the colloid.

Question 2

The gold sol is a formation of close-packed gold (Au) atoms. The energy of gold atoms at the surface of the particle is higher than that of those in the bulk, so there is a desire in the gold to form into bulk gold. The red colour of the solution, is not the colour of bulk gold, but caused by the light scattering from the sub-microscopic particles in the solution.

This solution is however charge stabilised – the particles are kept apart, initially by coulombic repulsion between the individual colloids keeps them separate.

Upon addition of the salt to the solution, it separates into its individual ions and acts as an electrolyte, with positive and negative charges in solution. The positive (in this case) ions are attracted to the surface of the nanoparticles, but Brownian motion and repulsion between the positive charges means that the charge is not completely neutralised. This influx of positive ions drags negative ions behind it, and then the charge of the particle bring in more positive ions, so that the charge of the particles is neutralised over a certain distance in solution. This is known as the electrical double layer.



If the particles come together, with their surrounding double layers, there is initially no interaction (save van-der-waals forces). However, as their electrical double layers overlap, there is a build up of electrolyte in the overlap. This concentration imbalance causes a rush of solute into the area. This kinetically repels the particles from each other.

As more salt is added however, the amount of ions flocking to the surface to neutralise the charge increases, and the degree of repulsion from the rest of solution on the ions increases. As a result, the double-layer is “compressed” – that is to say the extent into solution is reduced. Now, when the particles approach each other, they are much closer before any repulsive effects take place, often to the extent that the repulsive forces are insufficient to overwhelm the attractive forces between the particles at such close distances. As expressed before, the gold particles desire to decrease their energy by forming larger particles with less surface area.

The colour change observed from red to blue is a result of the light no longer being scattered by the small gold nanoparticles, but larger agglomerates. The point at which this coagulation occurs is known as the critical coagulation concentration – the concentration of salt needed to shield the particles influence from each other to the degree that there is no repulsive effect until the attractive effects overcome it. The transition from a finely dispersed colloid with a red colour to a less fine with blue colouring takes time, as it relies on the kinetics of the particles encountering each other.

The different salts show different efficiencies in achieving the change due to the different charges on the ion. The greater charge has an influence, not equivalent to the charge value, but to the charge squared. This influence is so extreme for the increase in charge for a variety of reasons. Of course, the fact that each ion has twice the charge means that only half the amount of ions would be needed. This is then added to by the fact that the greater charge means there can be more separation between ions adsorbed to the gold surface for the same amount of charge neutralisation. In effect, more ions can adsorb to the surface for the same concentration.