Charged Colloids in Water

Colloidal interactions 1

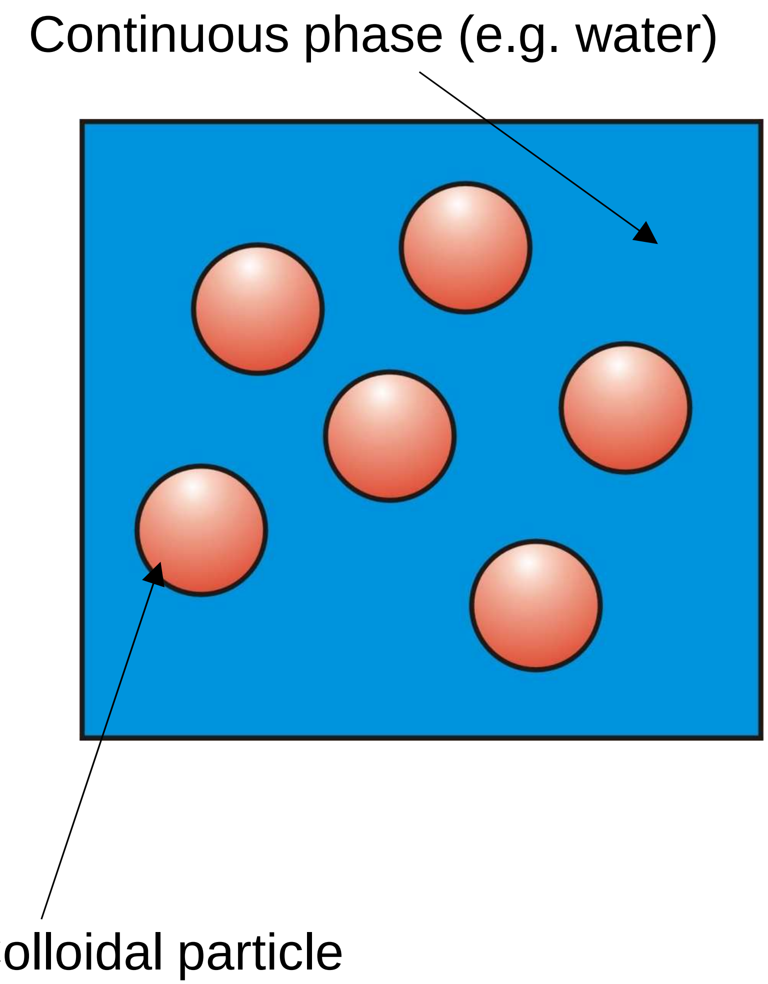
In this lecture…

1. What are Colloids and why are they important?
2. Colloidal stability
3. Interactions between charged surfaces in solutions
4. Osmotic pressure

Colloids and nanoparticles

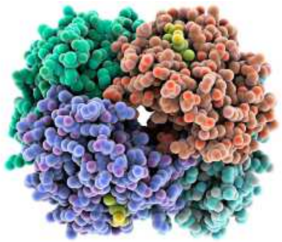
Colloids are mixtures where small particles (<1 μm in diameter) of one substance are **suspended** in a second medium or **continuous phase**

They are not solutions! The material is not completely dispersed, but exists as discrete particles

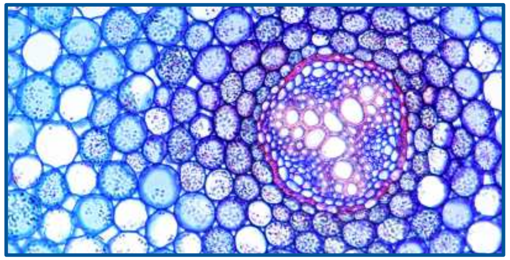


Why are colloids important?

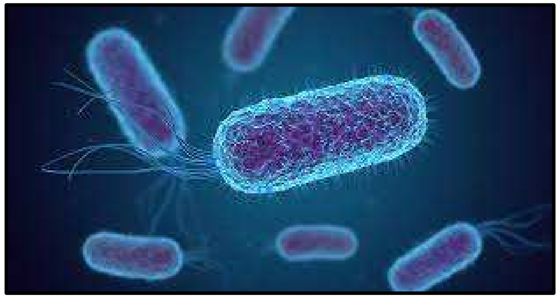
Colloidal interactions in aqueous environments are really important



Proteins

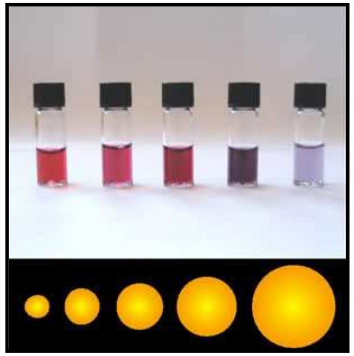


Cells



Microbes

Quantum dots (CdSe)



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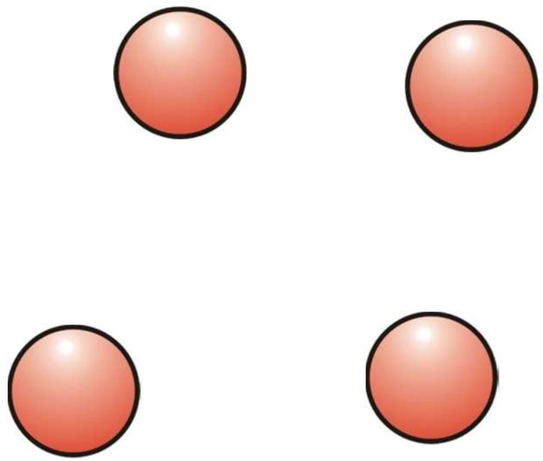
Key challenge in manufacturing colloidal dispersions

When materials are dispersed in particulate form they have a very large surface area.

Their natural tendency is to stick together or *flocculate* to form an aggregate (more on aggregation in a later lecture)

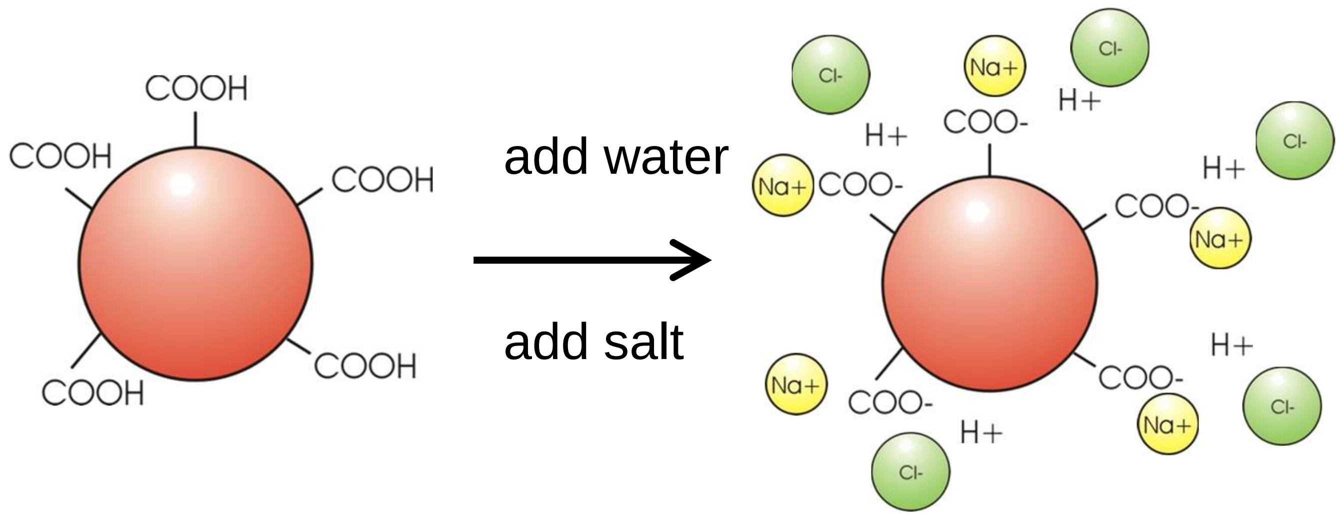


We have already seen that dispersion forces result in a mutual attraction between particles. These can drive the flocculation of even very dilute systems.

How do we stop things sticking together?

We need to introduce a short range repulsion force to keep particles apart.

In water, this is often done by decorating the surface of the particles with charged groups and adding a small amount of salt



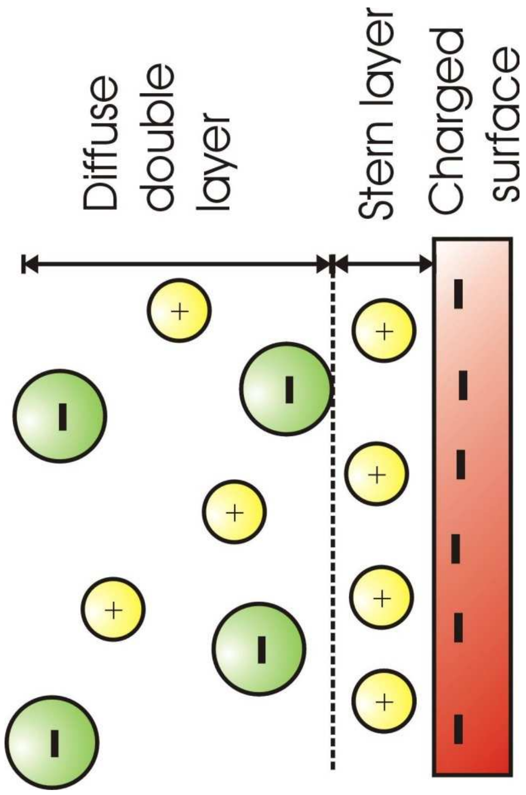
But the reason why the particles repel is not purely electrostatic…

Charged surfaces in electrolytes

The added salt is often referred to as an *electrolyte*

In practice the electrolyte concentration is much higher than the concentration of ions due to dissociated groups

Some of the charged ions from the salt form layers at the particle surfaces, ensuring that charge neutrality is maintained

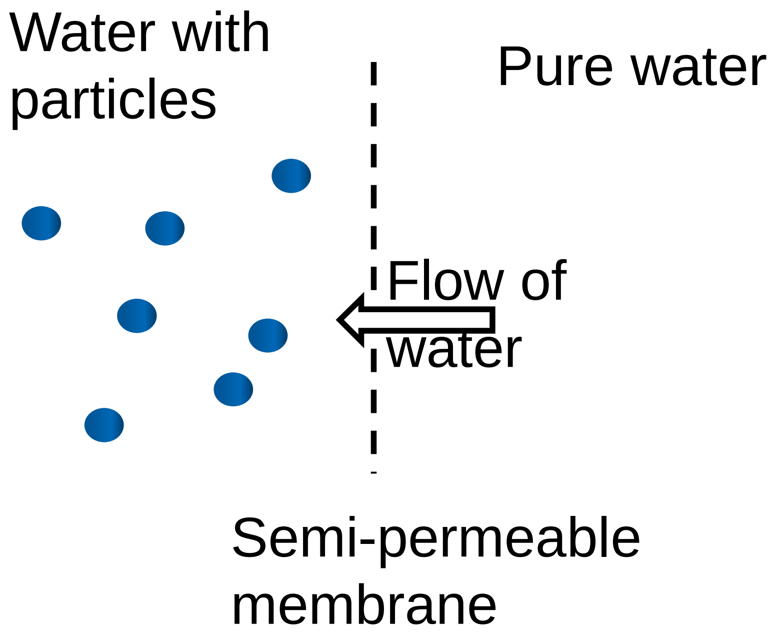


So if everything is charge neutral, how do the particles repel one another?

Osmotic Pressure

A concentration difference results in a chemical potential.

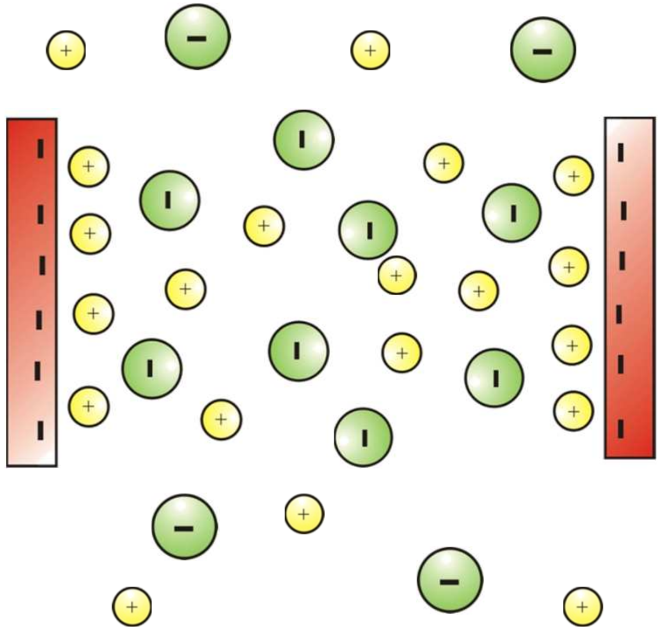
This creates a pressure difference that causes water to flow such that the concentration difference is minimised.



Repulsive forces between charged surfaces in an electrolyte

When two charged surfaces are brought close together the counter-ion concentration between the surfaces is larger than outside this region.

This results in an **osmotic pressure**, Π, which pushes the surfaces apart and tries to restore a uniform concentration.



$$\Pi = (n_+ + n_- - 2n_0)k_B T$$

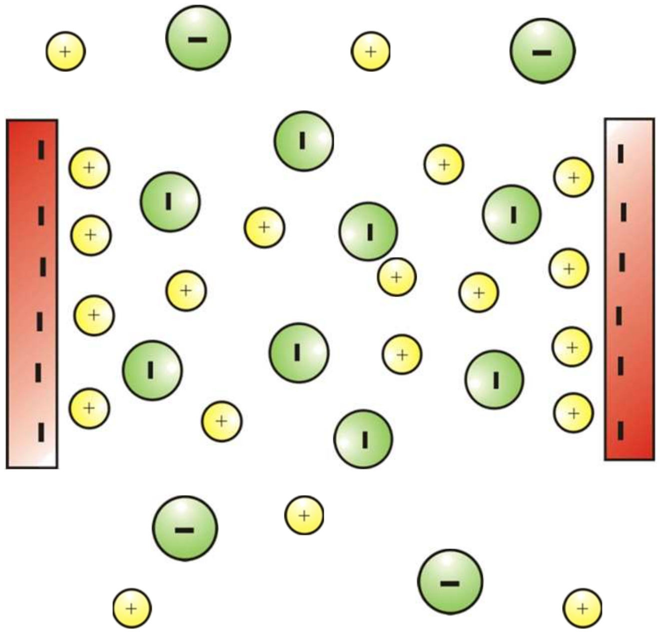
Where n+ and n- are number densities of positive and negative ions in gap

Calculating the Osmotic Pressure in terms of the Potential

$$\Pi = 2n_0 k_B T \left[\cosh\left(\frac{zeV(x)}{k_B T}\right) - 1\right]$$

However, in the limit of small potentials $\quad \dfrac{zeV(x)}{k_B T} << 1$

$$\Pi \approx \left(\frac{n_0}{k_B T}\right)\left(zeV(x)\right)^2$$



Key points

Colloids are small particles in a liquid which diffuse due to thermal fluctuations

The interaction of charged particles in a liquid is **not** direct repulsion since free ions shield the particles

A concentration difference between two regions of fluid results in an **osmotic pressure** that acts to try and equalise the concentration.