Key Concepts for section IV (Electrokinetics and Forces)

1: Debye layer, Zeta potential, Electrokinetics

2: Electrophoresis, Electroosmosis

3: Dielectrophoresis

4: **Inter-Debye layer force**, Van-Der Waals force

5: Coupled systems, Scaling, Dimensionless Numbers

Goals of Part IV:

(1) Understand electrokinetic phenomena and apply them in (natural or artificial) biosystems

(2) Understand various driving forces and be able to identify dominating forces in coupled systems

Motion of (bio) Particles in Electric and Magnetic field

Electrophoresis

Motion of charged particles in an electric field

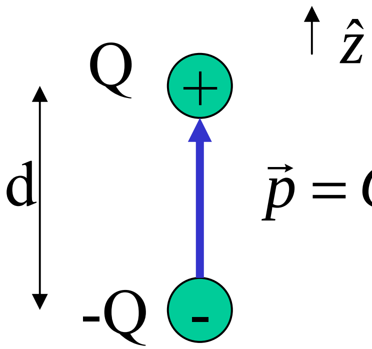
Dielectrophoresis

Motion of (neutral) particles in an electric field gradient

Magnetophoresis

Motion of magnetic particles (with magnetic dipole) in a magnetic field

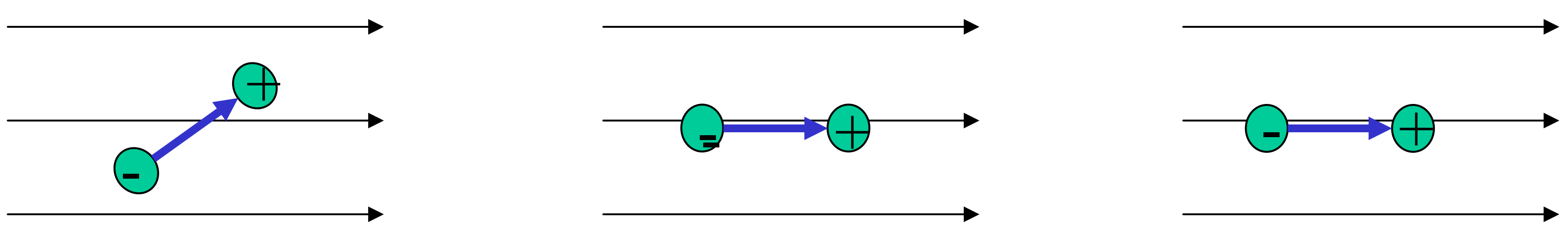
Electric dipole



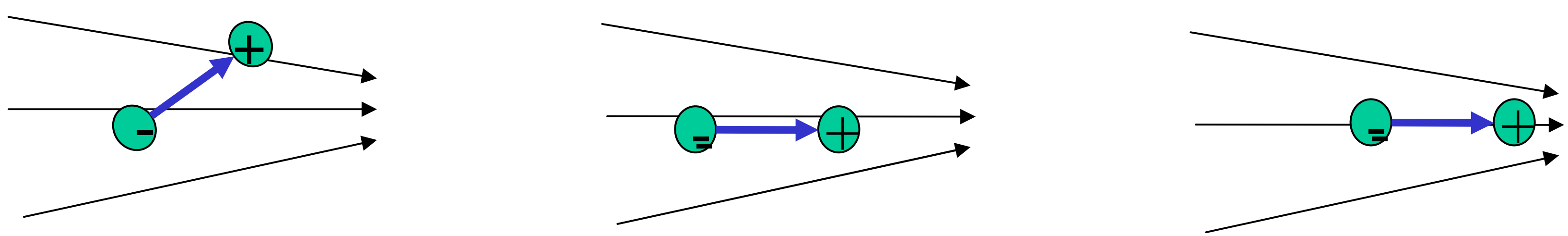
$\vec{p} = Qd\hat{z}$

$$Q_{net} = 0, \quad \Phi(\vec{r}) = \frac{\vec{r} \cdot \vec{p}}{4\pi\varepsilon r^3} \qquad (r >> d)$$

Dipole in uniform electric field



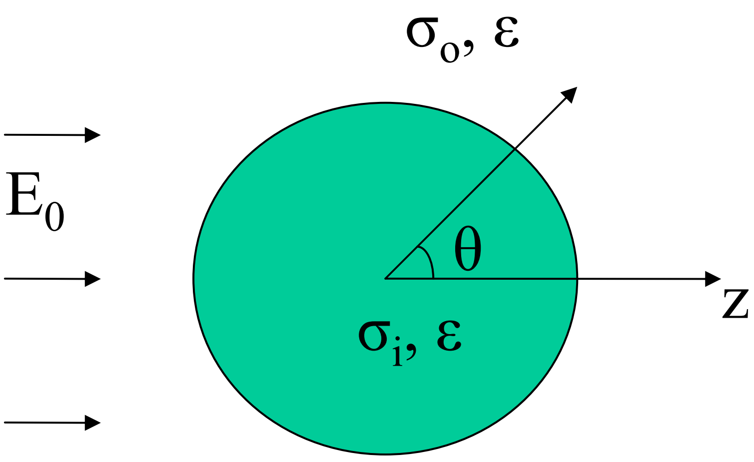
Dipole in non-uniform electric field



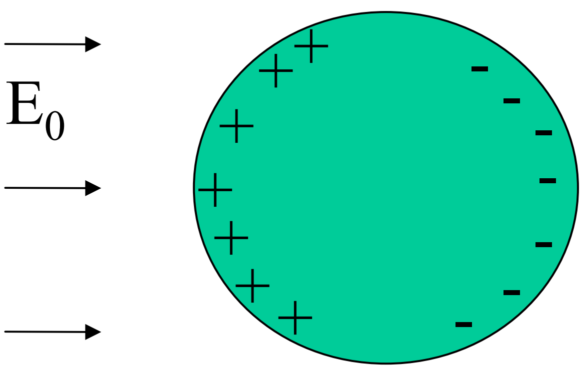
Induced dipole by external field

$$\Phi_{in} = -E_0\left(\frac{3\sigma_0}{\sigma_i + 2\sigma_0}\right)z$$

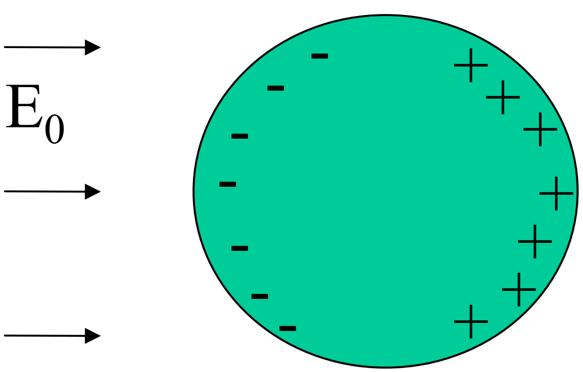
$$\Phi_{out} = \underbrace{-E_0 z}_{\text{external field}} + \underbrace{\frac{E_o R^3}{r^2}\left(\frac{\sigma_i - \sigma_0}{\sigma_i + 2\sigma_0}\right)\cos\theta}_{\text{induced dipole field}}$$



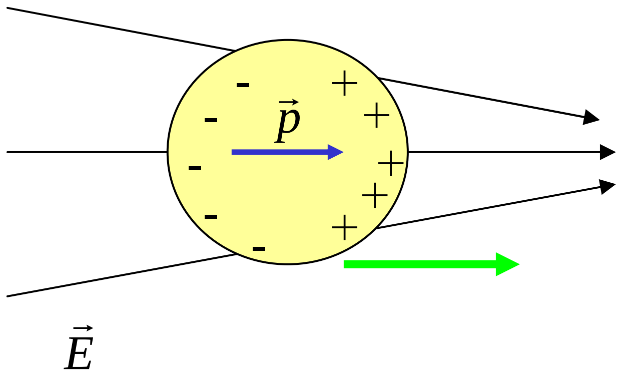
$\sigma_o > \sigma_i$



$\sigma_o < \sigma_i$

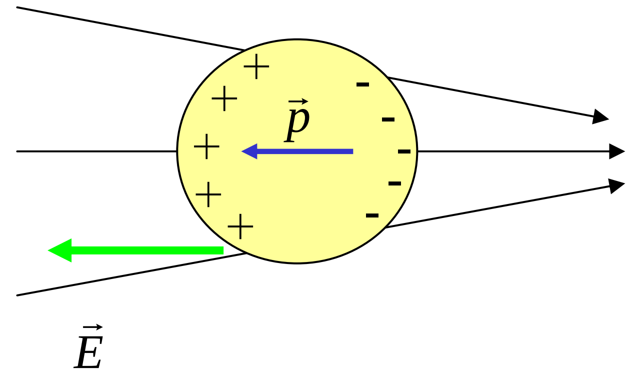


Positive DEP $(\sigma > \sigma_0)$



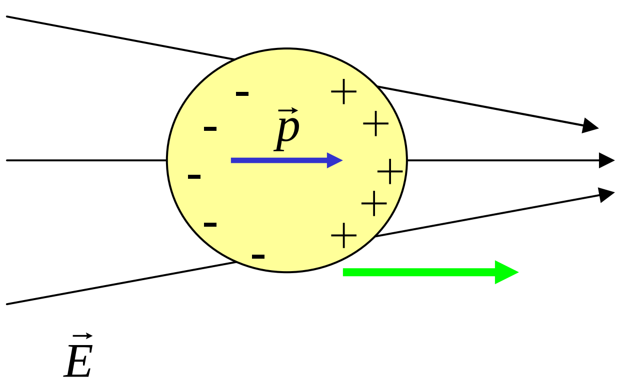
Particle moves toward the high field region.

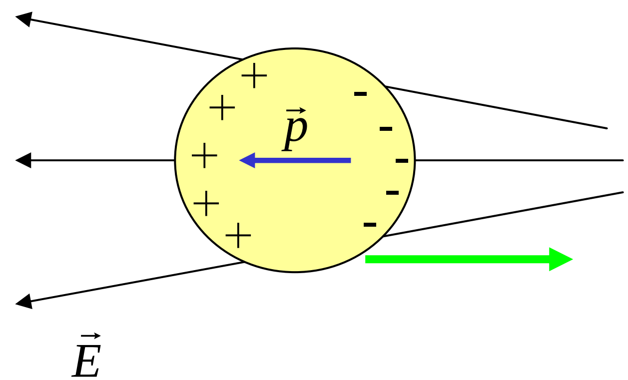
Negative DEP $(\sigma < \sigma_0)$



Particle moves away from the high field region.

DEP force is independent of the direction of the field.





Nanoparticles : Emerging tools for Bioengineering

Image removed due to copyright restrictions.
Photo of EviDots (TM) vials - 490nm to 680nm.

From www.eviddenttech.com (Evident Technology)

Nanoparticles : Emerging tools for Bioengineering

Image removed due to copyright restrictions.
Electron microscope photo of Qdot core-shell nanocrystals.

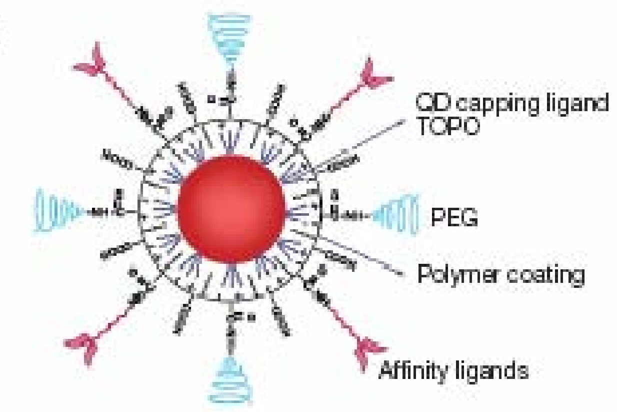
From www.qdots.com (Quantum Dots Corporation)

In vivo cancer targeting and imaging with semiconductor quantum dots

Xiaohu Gao,[1] Yuanyuan Cui,[2] Richard M Levenson,[3] Leland W K Chung[2] & Shuming Nie[1]

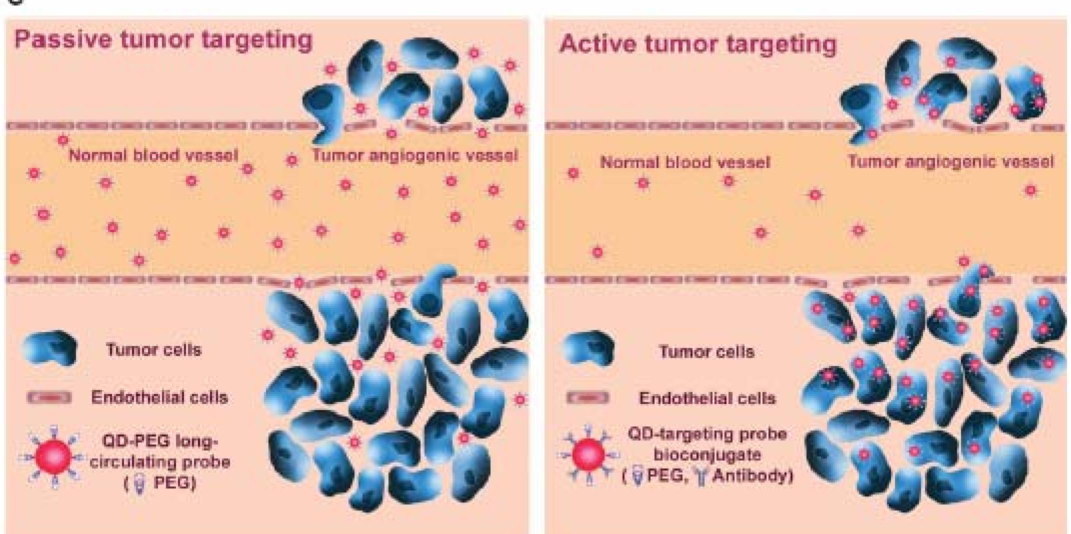
We describe the development of multifunctional nanoparticle probes based on semiconductor quantum dots (QDs) for ca
ing and imaging in living animals. The structural design involves encapsulating luminescent QDs with an ABC triblock co
and linking this amphiphilic polymer to tumor-targeting ligands and drug-delivery functionalities. *In vivo* targeting studie
prostate cancer growing in nude mice indicate that the QD probes accumulate at tumors both by the enhanced permeabi
retention of tumor sites and by antibody binding to cancer-specific cell surface biomarkers. Using both subcutaneous inj
QD-tagged cancer cells and systemic injection of multifunctional QD probes, we have achieved sensitive and multicolor f
imaging of cancer cells under *in vivo* conditions. We have also integrated a whole-body macro-illumination system with w
resolved spectral imaging for efficient background removal and precise delineation of weak spectral signatures. These res
new possibilities for ultrasensitive and multiplexed imaging of molecular targets *in vivo*.

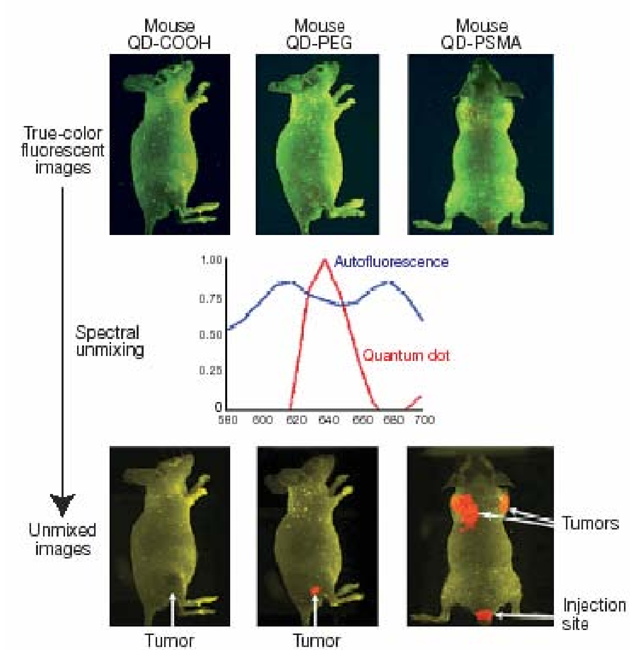
a



Gao, Cui, Levenson, Chung and Nie, Nature Biotechnology **22**, 969 (2004)

c





The problem of colloid (nanoparticle) stability

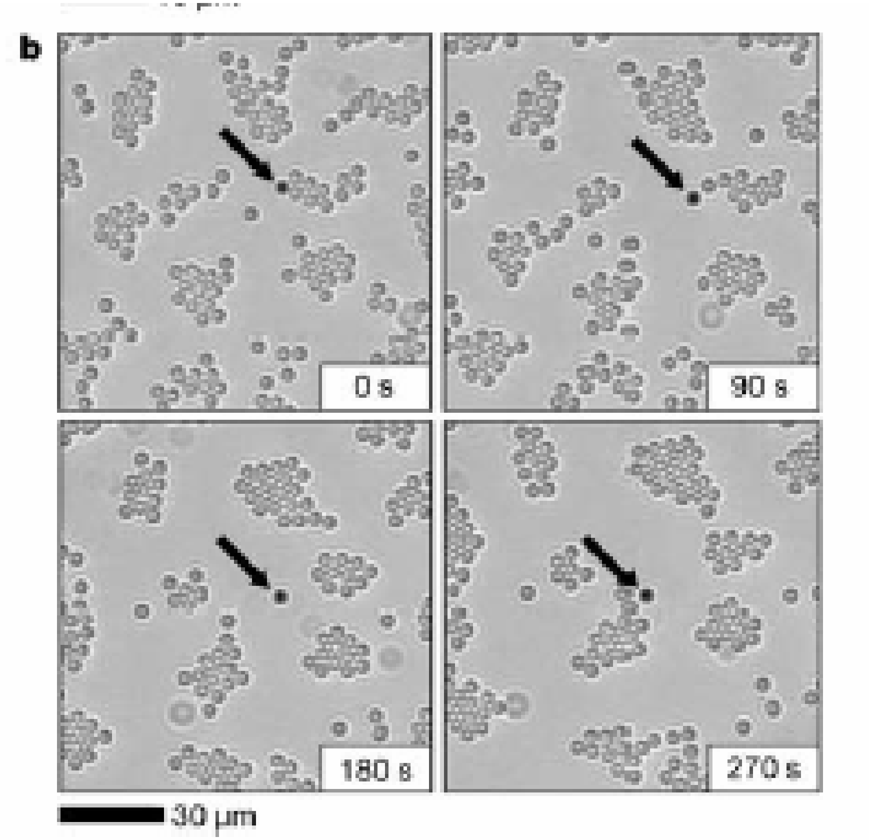
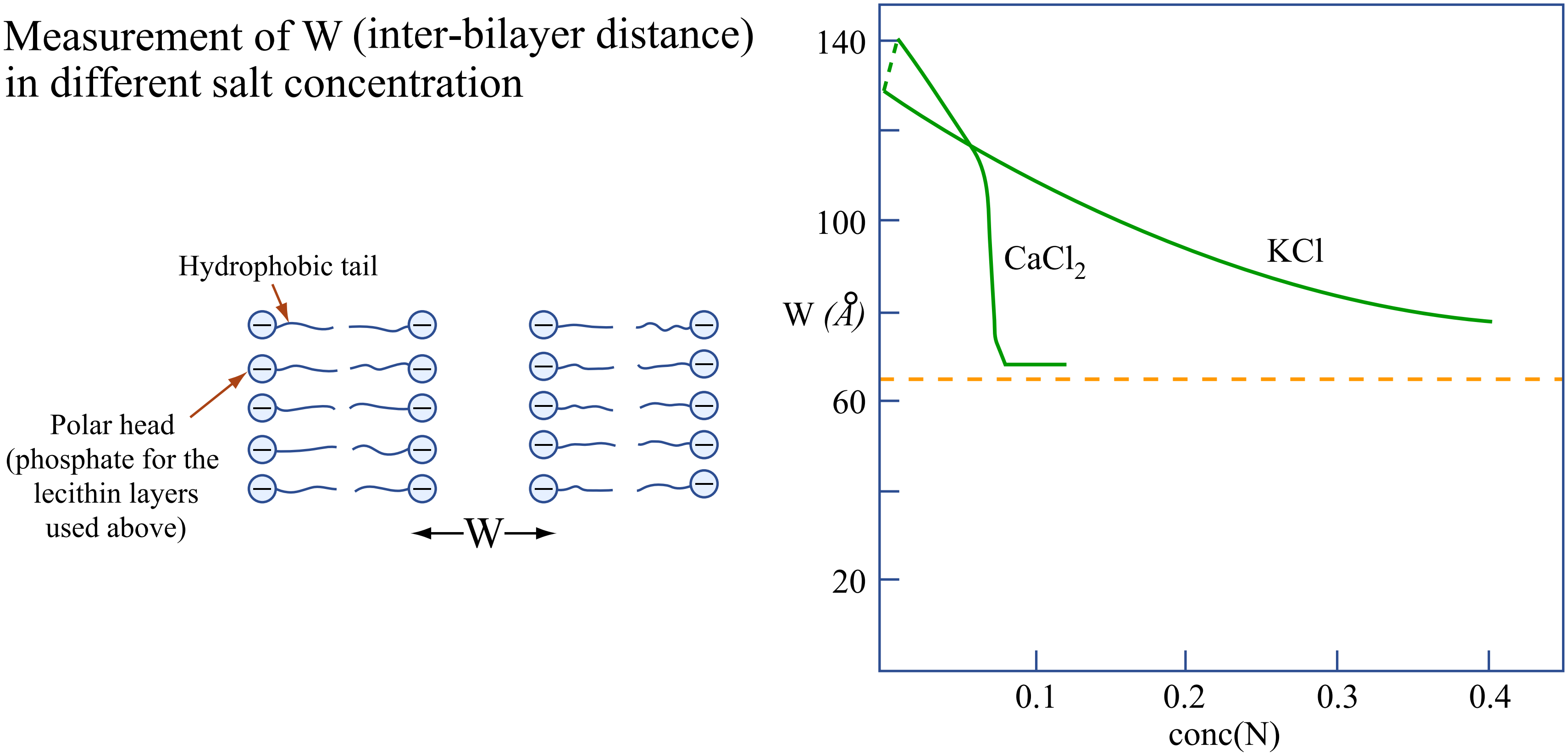


Image removed due to copyright restrictions.
Figure 4 in A. Yethiraj and A. van Blaaderen. *Nature* **421**, 513 (2003)

M. M. Baksh, M. Jaros, J. T. Groves, *Nature* **427**, 139 (2004)

Coagulation / Flocculation

Measurement of W (inter-bilayer distance) in different salt concentration



Interlayer distance in lipid layers, separated by aqueous solution containing varying amounts of electrolyte as determined by K.J. Palmer and F.O. Schmitt.

Figure by MIT OCW.

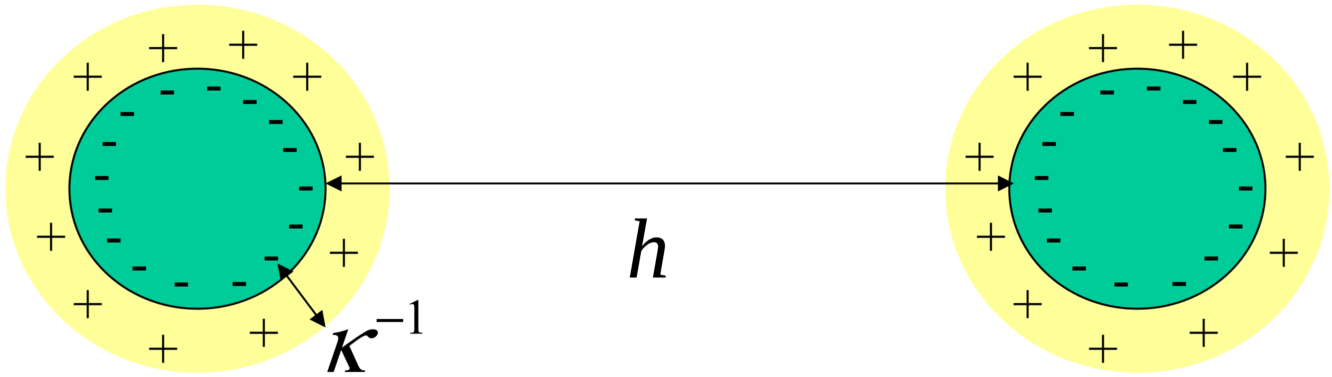
Schulze-Hardy Rule

Critical coagulation concentrations for hydrophobic solutions (millimoles per dm^3)					
As_2S_3 (-ve sol)		*AgI (-ve sol)*		*Al_2O_3 (+ve sol)*	
LiCl	58	$LiNO_3$	165	NaCl	43.5
NaCl	51	$NaNO_3$	140	KCl	46
KCl	49.5	KNO_3	136	KNO_3	60
KNO_3	50	$RbNO_3$	126		
K acetate	110	$AgNO_3$	0.01		
$CaCl_2$	0.65	$Ca(NO_3)_2$	2.40	K_2SO_4	0.30
$MgCl_2$	0.72	$Mg(NO_3)_2$	2.60	$K_2Cr_2O_7$	0.63
$MgSO_4$	0.81	$Pb(NO_3)_2$	2.43	K_2 oxalate	0.69
$AlCl_3$	0.093	$Al(NO_3)_3$	0.067	$K_3[Fe(CN)_6]$	0.08
$\frac{1}{2}\,Al_2(SO_4)_3$	0.096	$La(NO_3)_3$	0.069		
$Al(NO_3)_3$	0.095	$Ce(NO_3)_3$	0.69		

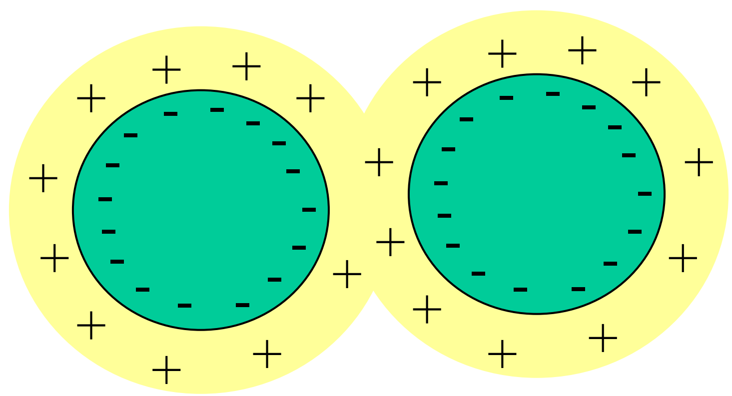
Figure by MIT OCW.

Source: “Introduction to Colloid and Surface Chemistry”
By Duncan J. Shaw (Butterworth Heinemann)

Electrostatic interaction within electrolyte solution

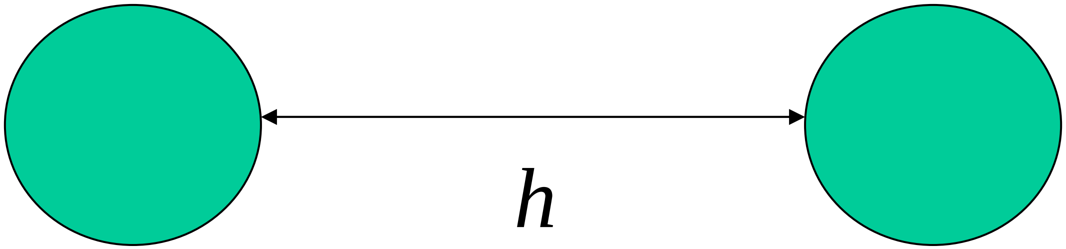


weak or no interaction



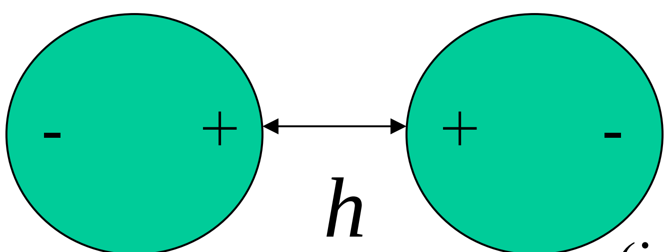
significant repulsive interaction
(inter-Debye layer repulsion)

Van der Waals Forces (attractive forces)
London Dispersion Forces (F. London, 1930)



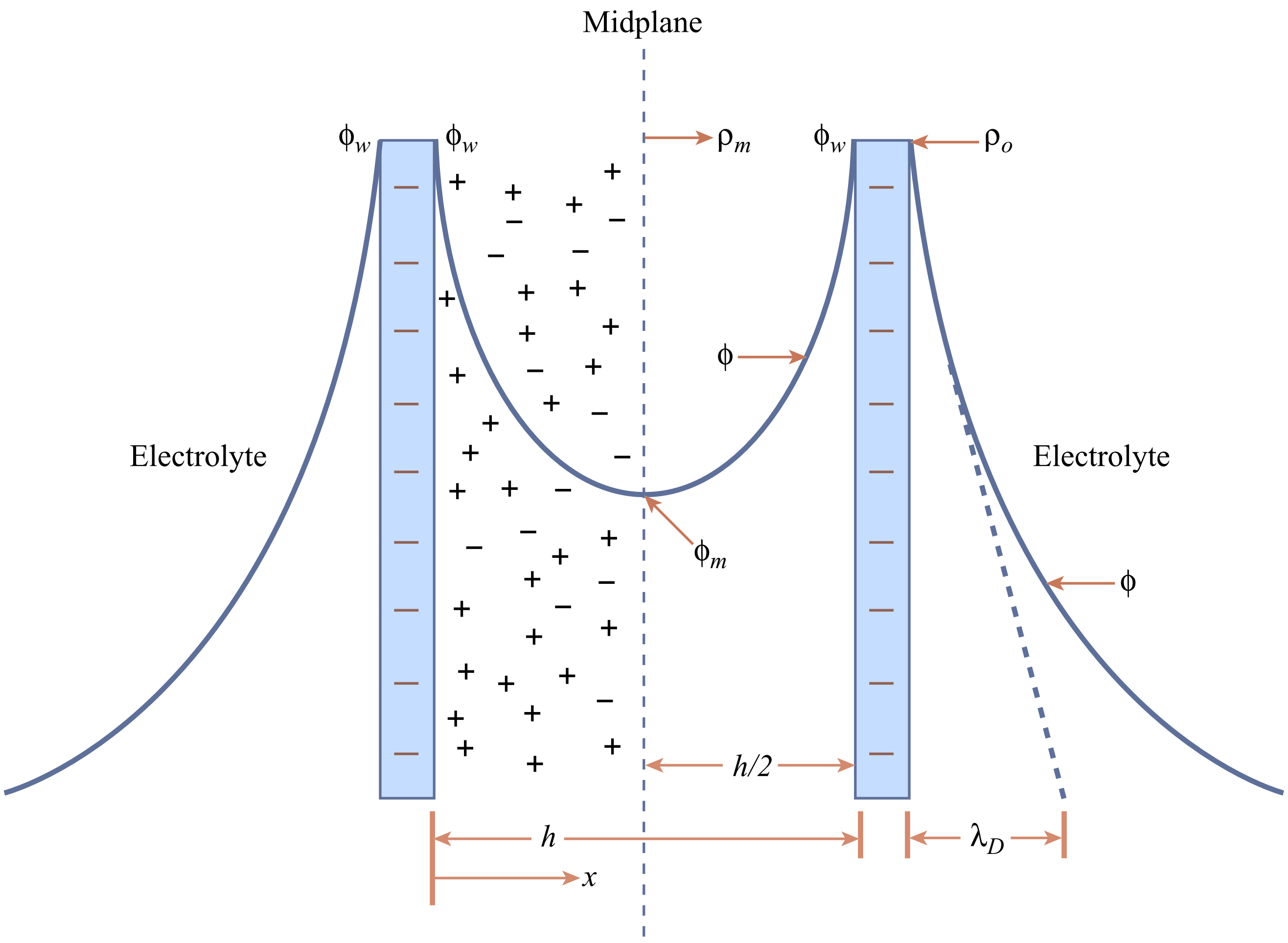
Non-polar molecules

weak or no interaction



(induced dipole)

Attractive interaction



Potential distribution resulting from the overlap of double layers from opposing plates.

Figure by MIT OCW.