

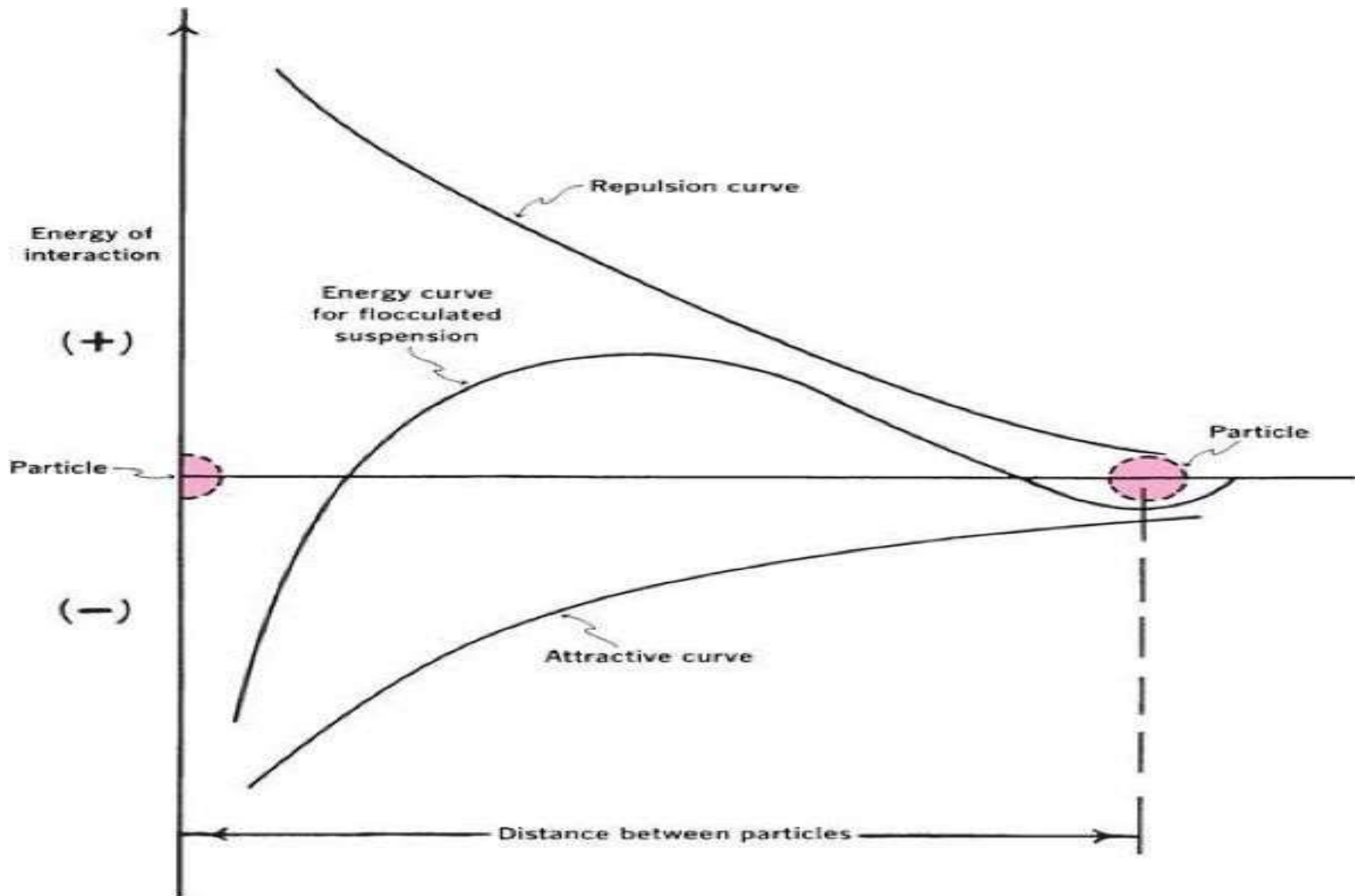
INTERFACIAL PROPERTIES OF SUSPENDED PARTICLES

- Work must be done to reduce a solid to small particles and disperse them in a continuous medium.
- The large surface area of the particles that results from the comminution is associated with a surface free energy that makes the system *thermodynamically unstable*, by which we mean that the particles are highly energetic and tend to regroup in such a way as to decrease the total area and reduce the surface free energy.
- The particles in a liquid suspension therefore tend to *flocculate*, that is, to form light, fluffy conglomerates that are held together by weak van der Waals forces.
- Under certain conditions—in a compacted cake, for example—the particles may adhere by stronger forces to form what are termed *aggregates*.
 - *Caking often occurs by the growth and fusing together of crystals in the precipitates* to produce a solid aggregate.

- The formation of any type of agglomerate, either flocules or aggregates, is taken as a measure of the system's tendency to reach a more thermodynamically stable state.
- An increase in the work, W , or surface free energy, ΔG , brought about by dividing the solid into smaller particles and consequently increasing the total surface area, ΔA , is given by
 - $\Delta G = \gamma_{SL} \cdot \Delta A$
- where γ_{SL} is the interfacial tension between the liquid medium and the solid particles.

- To approach a stable state, the system tends to reduce the surface free energy; equilibrium is reached when $\Delta G = 0$. *This condition can be accomplished, as seen from equation .*
- ***By a reduction of*** interfacial tension, or it can be approached by a decrease of the interfacial area.
- The latter possibility, leading to flocculation or aggregation, can be desirable or undesirable in a pharmaceutical suspension.
- The interfacial tension can be reduced by the addition of a surfactant but cannot ordinarily be made equal to zero.
- A suspension of insoluble particles, then, usually possesses a finite positive interfacial tension, and the particles tend to flocculate.

- The forces at the surface of a particle affect the degree of flocculation and agglomeration in a suspension.
- Forces of attraction are of the London–van der Waals type; the repulsive forces arise from the interaction of the electric double layers surrounding each particle.
- The formation of the electric double layer deals with interfacial phenomena.
- The potential energy of two particles is plotted in Figure as a function of the distance of separation.
- Shown are the curves depicting the energy of attraction, the energy of repulsion, energy, which has a peak and two minima, and the net



- When the repulsion energy is high, the potential barrier is also high, and collision of the particles is opposed.
- The system remains deflocculated.
- When sedimentation is complete, the particles form a close-packed arrangement with the smaller particles filling the voids between the larger ones.
- Those particles lowest in the sediment are gradually pressed together by the weight of the ones above; the energy barrier is thus overcome, allowing the particles to come into close contact with each other.

- To resuspend and redisperse these particles, it is again necessary to overcome the high-energy barrier
- Because this is not easily achieved by agitation, the particles tend to remain strongly attracted to each other and form a hard cake.
- When the particles are flocculated, the energy barrier is still too large to be surmounted, and so the approaching particle resides in the second energy minimum, which is at a distance of separation of perhaps 1000 to 2000 Å.
- This distance is sufficient to form the loosely structural flocs.

- These concepts evolve from (DLVO) theory for the stability of lyophobic sols.
- To summarize, flocculated particles are weakly bonded, settle rapidly, do not form a cake, and are easily resuspended.
- Deflocculated particles settle slowly and eventually form a sediment in which aggregation occurs with the resultant formation of a hard cake that is difficult to resuspend.