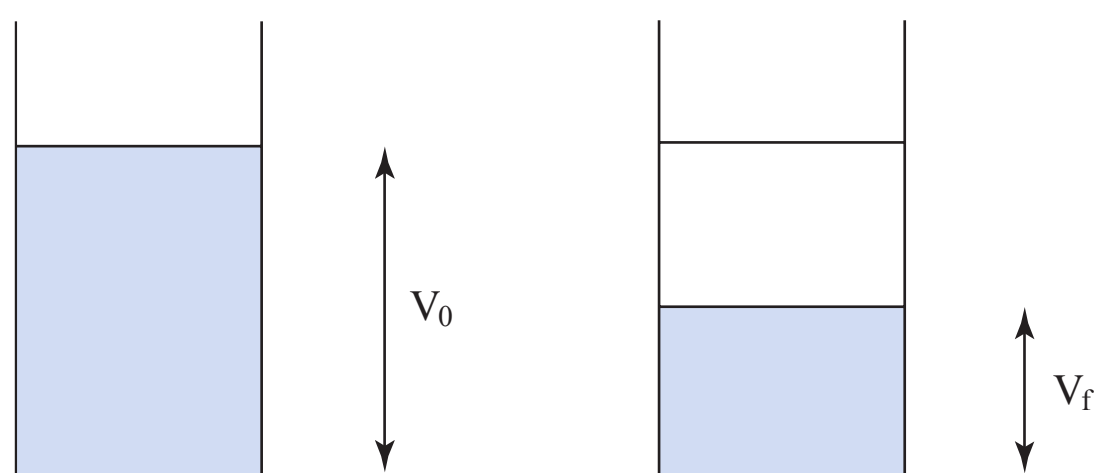


behaviour. Repeated cyclical variations in temperature will lead to Ostwald ripening, a deleterious effect, which will be discussed later.

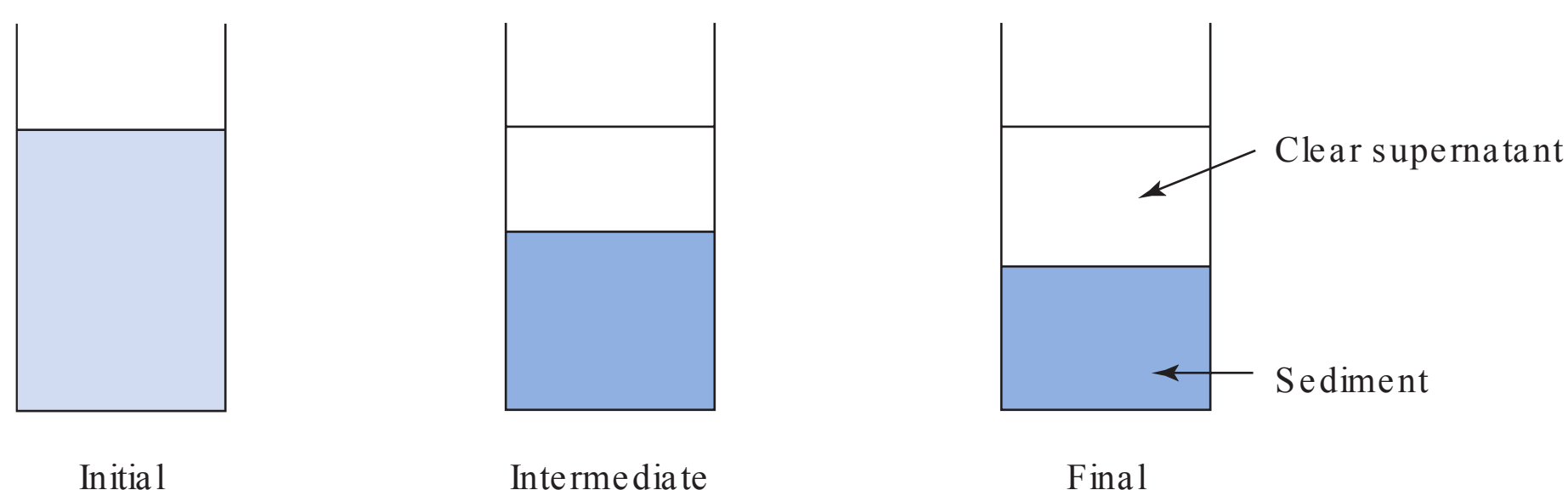
## Measuring particle movement

It is not straightforward to measure diffusion in a suspension formulation, but bulk sedimentation is very easy to observe. A known volume of the suspension with the solid particles dispersed as optimally as possible is placed in a graduated cylinder and left to stand, allowing sedimentation to occur. At certain time intervals, the volume of sediment is measured and the sedimentation volume ratio,  $F$ , calculated, as shown in Equation 26.4; the value of  $F$  is in the range of 0 to 1. Figure 26.5 illustrates this diagrammatically. The speed and extent of sedimentation can be observed visually and used to assess the behaviour of the formulation.

$$F = \frac{V_f}{V_o} \quad (26.4)$$



**Fig. 26.5** • Calculation of the sedimentation volume ratio for a suspension. Blue colouration indicates a suspension, no colouration indicates an optically clear medium.



**Fig. 26.6** • The sedimentation behaviour of a flocculated suspension. Pale blue colouration indicates the initial suspension, dark blue the resulting sediment, and no colouration indicates an optically clear medium.

where  $F$  is the sedimentation volume.  $V_o$  is the initial volume of suspension before settling and  $V_f$  is the final volume of sediment.

The sedimentation patterns of flocculated and deflocculated systems are different. In a flocculated system, the particles are arranged in loose aggregates or flocs, which behave as large, porous individual particles. These flocs will begin to sediment quickly, generally within a period of minutes, leaving a clear supernatant, and sedimentation will reach a maximum within a few hours or days. The sediment formed is loose and fluffy and can be easily redispersed by shaking, as both the individual floc and the bulk sediment formed has the solvent medium incorporated into it. A high volume of sediment is observed, with calculated values of the sedimentation volume ratio,  $F$ , being up to 0.6. Figure 26.6 illustrates this, showing the initial condition, an ‘intermediate’ condition after a short period of time and the ‘final’ condition after a prolonged period.

Deflocculated systems show a different pattern of sedimentation. As the particles behave independently, they will sediment slowly, reflecting their small size. Sedimentation takes some time, measured in days and weeks rather than minutes. In the initial stages of sedimentation, a small amount of compact sediment is observed at the base of the cylinder, with no, or limited clear supernatant being observed. Subsequently, the volume of sediment and the volume of clear supernatant both increase. The sediment formed is dense and compacted, described as being ‘caked’. Redispersion of the caked sediment is difficult, as little, if any, of the solvent medium can penetrate into it. A low final volume of sediment is observed, with calculated values of the sedimentation volume ratio,  $F$ , being as low as 0.1. Figure 26.7 illustrates this, showing the initial condition, an ‘intermediate’ condition after a short period of time (although longer than for flocculated