of the protein solution, η, can be related to the solvent viscosity, η_0, and the protein concentration, c, by a power series (Cantor & Schimmel, 1980):

$$\eta = \eta_0 \left(1 + k_1 c + k_2 c^2 + \cdots\right) \tag{9.3}$$

where k_1 is related to the contribution from the individual protein molecules, and k_2 and higher order coefficients are related to interactions of two, three, or more protein molecules. The parameter k_1 has been termed the intrinsic viscosity, [η] but has units of mL/g, and can be determined experimentally by extrapolating to zero protein concentration so that

$$[\eta] = \lim_{c_{A0}} \left(\eta_{sp}/c\right) \tag{9.4}$$

where

$$\eta_{sp} \text{ is } (\eta - \eta_0)/\eta_0 \tag{9.5}$$

The intrinsic viscosity is dependent on the protein shape and size and can be related to the partial specific volume of the hydrated protein, V (size) and a parameter, ν, that is related to shape by the equation (Van Holde, 1971, pp. 141–157):

$$[\eta] = V\nu \tag{9.6}$$

Einstein determined for spherical particles $\nu = 5/2$ (Einstein, 1911), whereas for prolate (football-shaped) and oblate (disc-shaped) objects the parameter ν is related to the ratio of the minor and major axis and has been termed the Simha parameter (Mehl, Oncley, & Simha, 1940). At higher concentrations the higher order coefficients will begin to dominate and will significantly contribute to the viscosity.

How is viscosity measured experimentally?

Glass capillary viscometry

One of the oldest techniques for measuring viscosity of solutions is the glass capillary viscometer. This method involves determining the time for a fluid to move a specified distance through a capillary tube immersed in a constant-temperature water bath. The most precise and accurate measurements require times not less than 200 s and not more than 1000 s. For a Newtonian fluid the kinematic viscosity is

$$\eta_k = 10^6 \pi g D^4 Ht/(128\, VL) \tag{9.7}$$

where D is the capillary diameter, L the capillary length, H the distance the fluid with volume V travels in time t, and g is the acceleration due to gravity. The kinematic viscosity has units of cm^2/s also called Stokes so that