The accuracy and precision expected from dynamic light scattering measurements

Introduction

Dynamic light scattering (DLS) is a non-invasive technique used for characterizing macromolecules in solution and particles in suspension [1]. The technique measures the time-dependent fluctuations in the intensity of scattered light that occur because the particles are undergoing Brownian motion. The velocity of this Brownian motion is measured and is called the translational diffusion coefficient D. This diffusion coefficient can be converted into a hydrodynamic diameter (D_H) using the Stokes-Einstein equation.

$$D_H = \frac{kT}{3\pi\eta D}$$

where:-

D_H = hydrodynamic diameter
k = Boltzmann's constant
T = absolute temperature
η = viscosity
D = translational diffusion coefficient

This technical note discusses the accuracy and precision expected from dynamic light scattering (DLS) measurements. The factors influencing the accuracy and precision will be highlighted.

Definitions of Accuracy and Precision

The accuracy of a DLS measurement can be defined as how close the result obtained is to the actual value of the parameter being measured.

The precision of DLS is defined as how close a repeat number of measurements are to one another.

Factors Affecting Accuracy and Precision

There are several factors that will influence both the accuracy and the precision of dynamic light scattering measurements and this section will discuss the impact of these various factors on the results obtained.

In general, for a well designed and built system, the precision of measurements is usually limited by the quality of the sample preparation, rather than the system itself.

The accuracy however, will depend on the system, and latex standards are used as a final check of build quality.

Temperature

From the Stokes-Einstein equation, the accuracy of the hydrodynamic diameter obtained from a measurement is directly proportional to the accuracy of the temperature. The temperature has a direct effect on the viscosity of the sample and hence on the diffusion speed of the particles being measured. It can be theoretically calculated that for aqueous dispersions measured at a temperature close to 25°C, every 1^o error in the temperature will result in a 2% error in the size obtained. For a measurement taken at a temperature of 5°C, a 1°C error in the temperature equates to an error in size of 3.2%. Measurements taken at a temperature of 100^o will have a 1.07% error for every 1^o error. This relationship is due to the effect of temperature on the viscosity of the dispersant.

From a practical perspective, the accuracy of the temperature will depend on the capabilities of the instrument both in terms of reaching and maintaining the requested temperature and in reading the temperature back correctly. The Zetasizer Nano series of instruments has a standard temperature range of 2 to 90°C, which is controlled through a Peltier. The temperature precision of the instrument is 0.1°C with an accuracy of 0.2°C. This is equivalent to an error of 0.4% in the size for aqueous samples, which is more than accurate enough for any application of the instrument.

Sample Stability

There are polystyrene latex size standards available from Duke Scientific that are NIST traceable [2]. Each standard has a quoted size range (hydrodynamic size range). The International Standard on DLS, ISO13321, states that the result obtained from a measurement should be within 2% of the stated size (i.e. the accuracy should be within 2%) and repeatability should be better than 2% (i.e. the precision should be within 2%) [3].

The stability of the sample during the measurement is paramount to the accuracy and precision achievable. If the sample contains particles that are slowly sedimenting, aggregating, creaming or dissolving during the measurement, the accuracy and

precision obtained will obviously be compromised.

The sample needs to be well dispersed and stable and the only motion of the particles detected being Brownian motion. If these criteria are met, both the accuracy and precision of the measurements should be within 2%.

Instrument Quality

The quality of the data obtained from the measurement will have an obvious impact on the accuracy and precision of the results obtained. Apart from the suitability of the sample, there are several other instrument factors will affect the data quality obtained. These will depend upon the quality of the components used in the instrument and will include the stability of the laser, the stability of the detector and the stability of the optical path. The Zetasizer Nano series uses the finest components available, and the stability tested rigorously, to ensure that the errors in the accuracy and precision of the measurements are negligible.

One other instrument factor that has to be considered is the effect of the any error in the detection angle on the accuracy of the measurement. There are 2 detection angles available in the Zetasizer Nano series, 90^{o} (Nano S90 or ZS90) and 173^{o} (Nano S or ZS) respectively. The measurement errors involved with a 1^{o} error in detection angle can be theoretically calculated to be 1.8% error for a 90^{o} system and 0.1% for a 173^{o} system. Therefore, any errors in the detection angle of a Nano S or ZS become insignificant.

Conclusions

This technical note has highlighted the main factors that influence the accuracy and precision expected from dynamic light scattering measurements.

Taking all of these factors into consideration, it can be concluded that for a sample that is suitable for measurement by dynamic light scattering, the accuracy and precision expected from the technique should be better than 2% for a suitably well designed system such as the Zetasizer Nano.

References

[1] Dynamic Light Scattering: An Introduction in 30 Minutes, Technical Note available from www.malvern.co.uk

[2] Duke Scientific website www.dukesci.com

[3] International Standard ISO13321 Methods for Determination of Particle Size Distribution Part 8: Photon Correlation Spectroscopy, International Organization for Standardization (ISO) 1996.

Malvern Instruments Ltd

Enigma Business Park • Grovewood Road • Malvern • Worcestershire • UK • WR14 1XZ
Tel: +44 (0)1684 892456 • Fax: +44 (0)1684 892789

Malvern Instruments Worldwide

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