

When the determination is made by weighing, the buoyancy of air is disregarded, which may introduce an error of 1 unit in the 3<sup>rd</sup> decimal place. When using a density meter, the buoyancy of air has no influence.

*Oscillating transducer density meter.* The apparatus consists of:

- a U-shaped tube, usually of borosilicate glass, which contains the liquid to be examined;
- a magneto-electrical or piezo-electrical excitation system that causes the tube to oscillate as a cantilever oscillator at a characteristic frequency depending on the density of the liquid to be examined;
- a means of measuring the oscillation period ( $T$ ), which may be converted by the apparatus to give a direct reading of density, or used to calculate density using the constants  $A$  and  $B$  described below.

The resonant frequency ( $f$ ) is a function of the spring constant ( $c$ ) and the mass ( $m$ ) of the system:

$$f^2 = \frac{1}{T^2} = \frac{c}{m} \times \frac{1}{4\pi^2}$$

Hence:

$$T^2 = \left( \frac{M}{c} + \frac{\rho \times V}{c} \right) \times 4\pi^2$$

$M$  = mass of the tube,

$V$  = inner volume of the tube.

Introduction of 2 constants  $A = c / (4\pi^2 \times V)$  and  $B = M/V$ , leads to the classical equation for the oscillating transducer:

$$\rho = A \times T^2 - B$$

The constants  $A$  and  $B$  are determined by operating the instrument with the U-tube filled with 2 different samples of known density, for example, degassed *water R* and air. Control measurements are made daily using degassed *water R*. The results displayed for the control measurement using degassed *water R* shall not deviate from the reference value ( $\rho_{20} = 0.998203 \text{ g cm}^{-3}$ ,  $d_{20}^{20} = 1.000000$ ) by more than its specified error. For example, an instrument specified to  $\pm 0.0001 \text{ g cm}^{-3}$  shall display  $0.9982 \pm 0.0001 \text{ g cm}^{-3}$  in order to be suitable for further measurement. Otherwise a re-adjustment is necessary. Calibration with certified reference materials is carried out regularly. Measurements are made using the same procedure as for calibration. The liquid to be examined is equilibrated in a thermostat at 20 °C before introduction into the tube, if necessary, to avoid the formation of bubbles and to reduce the time required for measurement.

Factors affecting accuracy include:

- temperature uniformity throughout the tube,
- non-linearity over a range of density,
- parasitic resonant effects,
- viscosity, whereby solutions with a higher viscosity than the calibrant have a density that is apparently higher than the true value.

The effects of non-linearity and viscosity may be avoided by using calibrants that have density and viscosity close to those of the liquid to be examined ( $\pm 5$  per cent for density,  $\pm 50$  per cent for viscosity). The density meter may have functions for automatic viscosity correction and for correction of errors arising from temperature changes and non-linearity.

Precision is a function of the repeatability and stability of the oscillator frequency, which is dependent on the stability of the volume, mass and spring constant of the cell.

Density meters are able to achieve measurements with an error of the order of  $1 \times 10^{-3} \text{ g cm}^{-3}$  to  $1 \times 10^{-5} \text{ g cm}^{-3}$  and a repeatability of  $1 \times 10^{-4} \text{ g cm}^{-3}$  to  $1 \times 10^{-6} \text{ g cm}^{-3}$ .

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## 2.2.6. REFRACTIVE INDEX

The refractive index of a medium with reference to air is equal to the ratio of the sine of the angle of incidence of a beam of light in air to the sine of the angle of refraction of the refracted beam in the given medium.

Unless otherwise prescribed, the refractive index is measured at  $20 \pm 0.5$  °C, with reference to the wavelength of the D-line of sodium ( $\lambda = 589.3 \text{ nm}$ ); the symbol is then  $n_D^{20}$ .

Refractometers normally determine the critical angle. In such apparatus the essential part is a prism of known refractive index in contact with the liquid to be examined.

Calibrate the apparatus using certified reference materials.

When white light is used, the refractometer is provided with a compensating system. The apparatus gives readings accurate to at least the third decimal place and is provided with a means of operation at the temperature prescribed. The thermometer is graduated at intervals of 0.5 °C or less.

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## 2.2.7. OPTICAL ROTATION

Optical rotation is the property displayed by chiral substances of rotating the plane of polarisation of polarised light.

Optical rotation is considered to be positive (+) for dextrorotatory substances (i.e. those that rotate the plane of polarisation in a clockwise direction) and negative (–) for laevorotatory substances.

The specific optical rotation  $[\alpha_m]_{\lambda}^t$  is the rotation, expressed in radians (rad), measured at the temperature  $t$  and at the wavelength  $\lambda$  given by a 1 m thickness of liquid or a solution containing 1 kg/m<sup>3</sup> of optically active substance. For practical reasons the specific optical rotation  $[\alpha_m]_{\lambda}^t$  is normally expressed in milliradians metre squared per kilogram ( $\text{mrad m}^2 \text{ kg}^{-1}$ ).

The Pharmacopoeia adopts the following conventional definitions.

The *angle of optical rotation* of a neat liquid is the angle of rotation  $\alpha$ , expressed in degrees (°), of the plane of polarisation at the wavelength of the D-line of sodium ( $\lambda = 589.3 \text{ nm}$ ) measured at 20 °C using a layer of 1 dm; for a solution, the method of preparation is prescribed in the monograph.

The *specific optical rotation*  $[\alpha]_D^{20}$  of a liquid is the angle of rotation  $\alpha$ , expressed in degrees (°), of the plane of polarisation at the wavelength of the D-line of sodium ( $\lambda = 589.3 \text{ nm}$ ) measured at 20 °C in the liquid substance to be examined, calculated with reference to a layer of 1 dm and divided by the density expressed in grams per cubic centimetre.

The *specific optical rotation*  $[\alpha]_D^{20}$  of a substance in solution is the angle of rotation  $\alpha$ , expressed in degrees (°), of the plane of polarisation at the wavelength of the D-line of sodium ( $\lambda = 589.3 \text{ nm}$ ) measured at 20 °C in a solution of the substance to be examined and calculated with reference

to a layer of 1 dm containing 1 g/ml of the substance. The specific optical rotation of a substance in solution is always expressed with reference to a given solvent and concentration.

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In the conventional system adopted by the Pharmacopoeia the specific optical rotation is expressed by its value without units; the actual units, degree millilitres per decimetre gram [ $(^\circ)\text{ml}\cdot\text{dm}^{-1}\cdot\text{g}^{-1}$ ] are understood.

The conversion factor from the International System to the Pharmacopoeia system is the following:

$$[\alpha_m]_\lambda^t = [\alpha]_\lambda^t \times 0.1745$$

In certain cases specified in the monograph the angle of rotation may be measured at temperatures other than 20 °C and at other wavelengths.

The polarimeter must be capable of giving readings to the nearest 0.01°. The scale is usually checked by means of certified quartz plates. The linearity of the scale may be checked by means of sucrose solutions.

**Method.** Determine the zero of the polarimeter and the angle of rotation of polarised light at the wavelength of the D-line of sodium ( $\lambda = 589.3$  nm) at  $20 \pm 0.5$  °C, unless otherwise prescribed. Measurements may be carried out at other temperatures only where the monograph indicates the temperature correction to be made to the measured optical rotation. Determine the zero of the apparatus with the tube closed; for liquids the zero is determined with the tube empty and for solids filled with the prescribed solvent.

Calculate the specific optical rotation using the following formulae.

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For neat liquids:

$$[\alpha]_{\text{D}}^{20} = \frac{\alpha}{l \cdot \rho_{20}}$$

For substances in solution:

$$[\alpha]_{\text{D}}^{20} = \frac{1000\alpha}{l \cdot c}$$

where  $c$  is the concentration of the solution in grams per litre.

Calculate the content  $c$  in grams per litre or the content  $c'$  in per cent  $m/m$  of a dissolved substance using the following formulae:

$$c = \frac{1000\alpha}{l \cdot [\alpha]_{\text{D}}^{20}} \quad c' = \frac{100\alpha}{l \cdot [\alpha]_{\text{D}}^{20} \cdot \rho_{20}}$$

- $\alpha$  = angle of rotation in degrees read at  $20 \pm 0.5$  °C;  
 $l$  = length in decimetres of the polarimeter tube;  
 $\rho_{20}$  = density at 20 °C in grams per cubic centimetre. For the purposes of the Pharmacopoeia, density is replaced by relative density (2.2.5).

## 2.2.8. VISCOSITY

The *dynamic* viscosity or *viscosity coefficient*  $\eta$  is the tangential force per unit surface, known as *shearing stress*  $\tau$  and expressed in pascals, necessary to move, parallel to the sliding plane, a layer of liquid of 1 square metre at a rate ( $v$ ) of 1 metre per second relative to a parallel layer at a distance ( $x$ ) of 1 metre.

The ratio  $dv/dx$  is a speed gradient giving the *rate of shear*  $D$  expressed in reciprocal seconds ( $s^{-1}$ ), so that  $\eta = \tau/D$ .

The unit of dynamic viscosity is the pascal second (Pa·s). The most commonly used submultiple is the millipascal second (mPa·s).

The *kinematic viscosity*  $\nu$ , expressed in square metres per second, is obtained by dividing the dynamic viscosity  $\eta$  by the density  $\rho$  expressed in kilograms per cubic metre, of the liquid measured at the same temperature, i.e.  $\nu = \eta/\rho$ . The kinematic viscosity is usually expressed in square millimetres per second.

A capillary viscometer may be used for determining the viscosity of Newtonian liquids and a rotating viscometer for determining the viscosity of Newtonian and non-Newtonian liquids. Other viscometers may be used provided that the accuracy and precision is not less than that obtained with the viscometers described below.

## 2.2.9. CAPILLARY VISCOMETER METHOD

The determination of viscosity using a suitable capillary viscometer is carried out at a temperature of  $20 \pm 0.1$  °C, unless otherwise prescribed. The time required for the level of the liquid to drop from one mark to the other is measured with a stop-watch to the nearest one-fifth of a second. The result is valid only if two consecutive readings do not differ by more than 1 per cent. The average of not fewer than three readings gives the flow time of the liquid to be examined.

Calculate the dynamic viscosity  $\eta$  (2.2.8) in millipascal seconds using the formula:

$$\eta = k\rho t$$

- $k$  = constant of the viscometer, expressed in square millimetres per second squared,  
 $\rho$  = density of the liquid to be examined expressed in milligrams per cubic millimetre, obtained by multiplying its relative density ( $d_{20}^{20}$ ) by 0.9982,  
 $t$  = flow time, in seconds, of the liquid to be examined.

The constant  $k$  is determined using a suitable viscometer calibration liquid.

To calculate the kinematic viscosity ( $\text{mm}^2\cdot\text{s}^{-1}$ ), use the following formula:  $\nu = kt$ .

(1) The European Pharmacopoeia describes the system proposed by the International Organisation for Standardisation (ISO).