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Title: Dispersion, light sources and Abbe Number

What is Dispersion?

Dispersion is the term given to the effect of the wavelength of a light source on the Refractive Index, i.e. the RI of a substance will be different when light sources of different wavelength (colour) are used with a refractometer.

Light Sources

The light source used most widely in refractometry is that of the yellow sodium D line (589.3 nm). Other common light sources tend to emit at more than one wavelength and therefore are not as convenient to use as sodium. The most common alternative sources are mercury, cadmium and hydrogen, although the latter is not used often nowadays because hydrogen lamps are considered dangerous. The following table is a useful reference list of spectral sources and emission lines.

Wavelength (nm)	Spectral Line	Designation	Element
2325.4	Infrared mercury line		Hg
1970.1	Infrared mercury line		Hg
1529.6	Infrared mercury line		Hg
1060.0	Neodymium glass laser		Nd
1014.0	Infrared mercury line	t	Hg
852.1	Infrared cesium line	s	Cs
706.5	Red helium line	r	He
656.3	Red hydrogen line	C	H
643.8	Red cadmium line	C'	Cd
632.8	Helium neon gas laser		He-Ne
589.3	Yellow sodium line	D	Na
587.6	Yellow helium line	d	He
546.1	Green mercury line	e	Hg
486.1	Blue hydrogen line	F	H
480.0	Blue cadmium line	F'	Cd
435.8	Blue mercury line	g	Hg
404.6	Violet mercury line	h	Hg
365.0	Ultraviolet mercury line	i	Hg
334.1	Ultraviolet mercury line		Hg
312.6	Ultraviolet mercury line		Hg
296.7	Ultraviolet mercury line		Hg
280.4	Ultraviolet mercury line		Hg
248.3	Ultraviolet mercury line		Hg

When light sources with multiple emission lines (e.g. mercury) are used with a refractometer, a number of borderlines will be observed from a testy sample. Each borderline corresponds to a different emission line wavelength. This is confusing to the user who normally only

requires one measurement at a single wavelength. An eyepiece filter is used to eliminate all unwanted wavelengths and to allow the user to observe the one borderline of interest or software for a PC may be used to help identify the correct line for measurement.

Sodium Light

When measuring refractive index (RI) it is necessary to use a light of a single wavelength. Sodium emits an almost pure light of 589.3 nm (sodium 'D' line). In actual fact, sodium emits a pair of spectral lines at 589.1 and 589.6 nm, the latter being the stronger. However, these lines are so close together that, for practical purposes, it can be regarded as a pure source with average wavelength 589.3 nm. This is why sodium has been adopted as the principal light source in refractometry and RI usually refers to this source. In books and tables of physical constants, the RI of a substance is often denoted by the symbol n with subscript to denote wavelength. Thus n_D means the RI at the sodium D line (=589.3 nm).

Measuring Dispersion (Abbe Number)

It is sometimes necessary to measure dispersion by measuring the effect of wavelength on RI. This is sometimes required by scientists for studies into the fundamental properties of materials. A good example of an industrial application is in the manufacture of optical glass.

In most cases, a number of wavelengths are selected, usually utilising one or more of the light sources shown in the above table. Results are then expressed in the form of a dispersion coefficient (simple gradient), dispersion number or Abbe number, definitions of which vary.

Traditionally, the Abbe Number (V_d) was defined as follows:

$$V_d = (n_d - 1) / (n_F - n_C)$$

where:

n_D	=	RI at helium red (587.6 nm)
n_F	=	RI at hydrogen blue (486.1 nm)
n_C	=	RI at hydrogen red (656.3 nm)

To perform these measurements it is necessary to have a hydrogen source (e.g. Balmer spectral hydrogen lamp) which is no longer readily available for reasons of safety and its low luminance.

An alternative Abbe Number is based on a different set of wavelengths from mercury and cadmium sources as follows:

$$V_e = (n_e - 1) / (n_{F'} - n_{C'})$$

where:

n_e	=	RI at mercury green (546.1 nm)
$n_{F'}$	=	RI at cadmium blue (480.0 nm)
$n_{C'}$	=	RI at cadmium red (643.8 nm)