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Title: ***Refractometers - what are they? what do they do?*** **what are they used for?**

Introduction

Many people in industry and academia around the world are using refractometers for a variety of purposes. Refractometers are generally quite easy to use and a result can be obtained without any need to understand the underlying principles. However, lack of understanding can also lead to problems and often a user may not understand the exact meaning of a measurement. Sometimes an instrument is faulty but often the problem is associated with the sample type or a misuse of the equipment.

The purpose of this document is to provide the reader with a quick appreciation of the principles of refractometry, the use of modern refractometers and their limitations. It should not be regarded in any way as a comprehensive treatise. It may serve as a useful guide to someone contemplating using refractometry for a particular purpose or wanting to purchase or replace an instrument.

What is refraction and what does a refractometer actually do?

Light travels through different media at different speeds. When crossing the boundary between two different media, such as air and water, the light changes direction and is said to be refracted. The magnitude of this direction change, or angle of refraction, can be equated to the change in light speed. The refractive index (RI) of a substance is defined as the ratio of the speed of light in the substance divided by the speed of light in a vacuum. The RI is therefore a unique and characteristic number for any substance.

Light speed and hence RI depends on the temperature of the medium and the wavelength of the light. As the temperature increases RI generally falls; similarly RI increases with decreasing wavelength. Measurements of RI have historically been standardised with regards to both temperature and wavelength. 20 °C and sodium light (589.3 nm) give the most commonly applied condition with RI then being denoted as n_D. The n_D for water is 1.3329 at 20 °C and for most liquids the value falls within the range 1.2 to about 2.0.

Changes to a medium, for example the presence of dissolved substances in the water, are accompanied by changes in light speed and hence RI. A relationship between concentration of dissolved substance and RI can be established thus enabling a measure of RI to be used to determine the concentration of dissolved substances. This is by far the most common type of application.

Refractometers

A refractometer is a precision optical instrument designed to measure the RI of different substances. Commercially available instruments range from optical-mechanical devices (hand-held or higher precision laboratory bench or 'Abbe' models) to digital automatic instruments with multi-purpose software. The type of refractometer used will depend upon the precision and flexibility required coupled to the price the customer is prepared to pay for the instrument.

The fundamental scale of a refractometer is RI. However there are many established relationships between RI and the concentration of a dissolved substance from which special scales can be derived and built into a refractometer. The most widely used scales are those based on sugar in water and the Brix scale is by far the most popular. The Brix scale is a sucrose scale and based on the relationship between RI (589.3 nm-sodium) and weight % sucrose in water at 20 °C. Provided the substance is truly dissolved, a concentration scale can be established for any two-component system.

Refractometers can therefore be equipped with one or more different scales. Hand-held instruments usually have one scale, e.g. sugar % or % sodium chloride. Sometimes the instrument graticule has more than one scale, for example, an antifreeze refractometer may have a scale in % ethylene glycol or % propylene glycol or indeed a scale showing 'degrees centigrade protection'. The latter will be based on a relationship between RI and the freezing point of a glycol water concentration. Electronic refractometers can benefit from software that enables the user to switch between pre-programmed scales such as Brix or RI or indeed which allows the user to create his own scale from measured data.

Hand held instruments are favoured because of their low cost and portability. Thus they can be used in all situations from agricultural uses outdoors (fruit, honey, silage) to factory and laboratory testing. Large-scale manufacturers tend to prefer electronic digital instruments for their high precision, ease of use and flexibility. Abbe type refractometers are therefore less common these days in many industrial applications but are still often favoured in R&D or academic laboratories. Abbe refractometers do of course cost less than equivalent digital automatic refractometers and some models have special features such as an extended RI scale. These are also important reasons why Abbe refractometers are still sometimes preferred.

Practical Applications of Refractometry

There are actually hundreds if not thousands of actual practical applications of refractometry, mainly involving the measurement of concentrations of one substance dissolved in another. Most of these are in the food, agricultural and beverage industries where sugar(s) is usually the dissolved component, but there are also many applications in the chemical, pharmaceutical and oil industries.

The Brix scale is used extensively and in most cases the dissolved species is sugar, but not necessarily so and often not pure sucrose. I such cases, the reading obtained is not accurate or meaningful in a scientific sense, but nevertheless can still be a reliable parameter for the purpose of quality control. The Brix scale is a universally recognised scale against which many food products have been assigned a specification. The Brix value (more correctly termed 'apparent Brix' for non-sucrose based products) gives a

measure of the total dissolved solids (mainly/all sugars) in a product.

The Brix scale is usually given as 0 – 95 Brix or % sugar, despite the fact that sucrose is not soluble to this extent in water. Other sugars can be more soluble in water than sucrose and the scale is often used for various sugar syrups in confectionery and soft drink concentrate preparation. There are also examples where high Brix readings are taken on super-saturated sugar solutions.

For the purist, other sugar scales have been established. The most common ones are glucose and fructose and invert sugar. However, most applications are in quality control/assurance and for this purpose, the Brix scale is usually preferred. In quality control the important requirement is for precision (repeatability) and reproducibility rather than absolute accuracy.

Non sugar applications in the food industry would include salt solutions and extensive variety of uses with oils and fats, for example vegetable oil blending for use in cooking oils and margarines.
It is difficult to generalise on uses in other industries because of the variety, but chemists make use of refractometers for numerous purposes. Some examples are:

- characterisation of pure liquids and distillation fractions (oil industry)
- two component blending operations (e.g. mixing antifreeze fluids, solvent blending, adhesive preparations etc)
- following changes in chemical reactions.