Application Note
ANTCREFRACT0311

The Importance of Temperature Control with Abbe Refractometers

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Key Words:

- Refractometry
- Refractive index
- Liquid density
- Temperature control

Abstract

Refractometry is an important tool used to detect, identify, and quantify substances in solution and is widely used in food & beverage, agricultural, medical, and industrial applications. Natural temperature variations in the samples being measured could result in grossly inaccurate readings. Accurate refractometric results can only be achieved by stabilizing the sample temperature of the solution during measurement. Stabilizing the solution temperature typically requires the use of a refrigerated bath circulator or laboratory chiller. Selecting the best temperature control equipment will not only improve the accuracy of the measured refractive index, but offer efficient operation and limited workspace.

Introduction

Refractometers are a simple cost effective optical tool used to measure the amount of dissolved substances in solution or to help identify unknown substances. This is accomplished by determining the refractive index of the solution, i.e., measuring the ratio of the speed of light through the solution compared to the speed of light in a vacuum (which is a physical constant).

In solutions, the density will typically decrease as the temperature increases. As a result, the speed of light passing through will also increase as the solution becomes less dense, thus altering the refractive index. In order to accurately measure the refractive index, it is imperative that the temperature of the solution be kept at a constant, typically 20°C.

ABBE-3L Refractometer

How Refractometers Work

A refractometer has an illuminating prism, a refracting prism, and a light source. It works by placing a thin layer of solution between the refractometer's prisms and reading the angle at which the light changes direction. The angle will vary depending on the physical properties of the solution.

Whenever light changes speed as it crosses a boundary from one medium into another its direction of travel also changes, i.e., it is refracted. The relationship between lights speed in the two mediums is the refractive index.

It is not necessary to measure the speed of light in a sample in order to determine its refractive index. Instead, by measuring the refraction (change in direction of the light) of the solution, and knowing the index of refraction of the layer that is in contact with (refracting prism), it is possible to accurately determine the refractive index of the solution. Nearly all refractometers utilize this principle, but may differ in their optical design.

Benefits of Tight Temperature Control

The speed of light in a substance is slower than in a vacuum since the light is being absorbed and remitted by the atoms in the sample. Since the density of a liquid usually decreases with temperature, it is not surprising that the speed of light in a liquid will normally increase as the temperature increases. Thus, the index of refraction normally decreases as the temperature increases for a liquid. For many organic liquids the index of refraction decreases by approximately 0.0005 for every 1°C increase in temperature. Most of the refractive index measurements are determined at 20 or 25 °C. Variations in temperature between measurements can result in great variation in the index of refraction reported (Table 1).

Many refractometers are equipped with a thermometer to indicate the sample temperature. Because they are coarsely graduated, this can cause a different interpretation between users, so achieving an accurate reading is difficult.

These same refractometers are often equipped to circulate temperature controlled water allowing for control and stabilization of the sample temperature. The result is a highly accurate refractive index reading without the need of an applying a correction factor to the refractometer reading. This can be achieved by using a temperature control device such as the Thermo Scientific Accel 250 LC laboratory chiller.

Index of Refraction of Water, Alcohol, and Carbon Bisulfide Relative to Air for sodium light, $\lambda = 0.5893$*

Temp. (°C)	Pure Water	99.8% Ethyl Alcohol	Carbon Bisulfide
20	1.33299	1.36048	1.62546
22	1.33281	1.35967	1.62387
24	1.33262	1.35885	1.62226
26	1.33241	1.35803	1.62064
28	1.33219	1.35721	1.61902
30	1.33192	1.35639	1.61740
32	1.33164	1.35557	1.61577
34	1.33136	1.35474	1.61413
36	1.33107	1.35390	1.61247
38	1.33079	1.35306	1.61080
40	1.33051	1.35222	1.60914

Table 1: Effect of temperature fluctuation on the index of refraction

** Information in this table was obtained from the Handbook of Chemistry and Physics, 59th Edition, CRC Press, 1979.*

Accel 250 LC Laboratory Chiller

Conclusion

When utilizing a refractometer for testing samples, the most effective and consistent results are obtained by removing variables from the process. Liquid temperature control improves the reliability of the results by removing inconsistencies such as correction factors and rounding errors from the process.

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