Reminder: These notes are meant to supplement, not replace, the laboratory manual.

Refractive Index

History and Application:

The type of refractometer instrument you are using today [i] has been commercially available since the early 1940's. These instruments are easy to use, reliable and rugged. Different types of refractometers are routinely used to monitor the wine and beer making process [ii] and many other commercial food and industrial processes[iii]. Refractometers are especially adept at measuring the sugar content in juices, jellies and other liquids.

Here is some terminology on the subjects of this experiment.

Refractive index: The ratio of the velocity of light in a vacuum to the velocity of light in a sample. Since it is a ratio of two velocities, it is dimensionless (that is, it has no units).

Refractometer: Instrument used to measure the refractive index of a compound.

1. The refractive index changes with the wavelength of light used in the refractometer; most literature values of refractive indexes are taken using a wavelength emitted by sodium called the D line. The refractive index also changes with the temperature; many literature values (not all) are reported at 20° C. Finally, the presence of impurities can change a refractive index.

Light has a fixed speed in a perfect vacuum 3.0 x 10^8 m/s. The speed of light drops when traveling through all other substances.

The index of refraction (n) is a measurement of that change in the speed of light when passing through particular substances.

$$n = \frac{velocity\ of\ light\ in\ vacuum}{velocity\ of\ light\ in\ test\ medium}$$

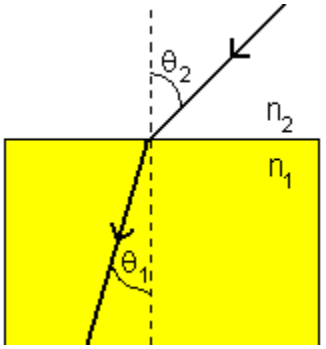
Since the speed of light is slower (smaller velocity), the value for n will always be greater than 1.0000.

2. Directly measuring the speed of light is not easy. One result of the changing velocity of light is that when light enters a material, the angle of incidence of that light changes.

We regularly see this without thinking about why it has happened. Look at any object sticking out of a glass of water. The object appears to shift and break at the surface. In fact this is just the light bending slightly as it goes from air to water.

 [iv]

If we measure the change in the angle of incidence, we can indirectly measure the change in the speed of ligt. This relationship is pictured and mathematically described below[v]. It is much easier to measure the change in the angle of incidence and calculate the change in the velocity in light, than it is to directly measure the velocity of light. The refractometer measures the change in the angle of incidence.



$$n_1 = \frac{n_2 \sin\theta_2}{\sin\theta_1}$$

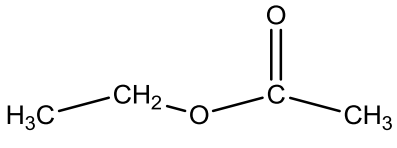
3. When using the refractometer, a thin film of liquid sample is sandwiched between two glass panes. Light is passed through. The change in the angle of incidence is measured as the light passes through the sample. The value for n for your sample is measured.

4. The value for n is called the index of refraction or the refractive index. It is a physical characteristic of that substance. Other physical characteristics of substances include density, melting point, boiling point, conductivity and viscosity.

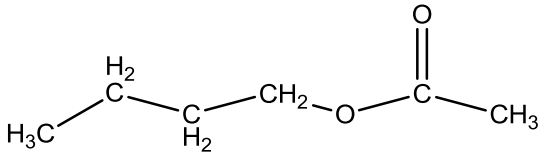
5. Pure materials have known and set refractive indexes. Identities of unknown pure compounds can be ascertained by comparing the measured index of refraction to a table of known refractive indexes.

Mixtures of two materials will have index of refraction between that of the two pure compounds. If the identities of the two materials making up the mixture are known, the composition of the mixture can be determined by measuring the refractive index of the mixture. This is what we are doing today.

5. The compounds being used are ethyl acetate and butyl acetate. They are both esters. These esters have a moderately low toxicity. They both are highly flammable. The refractive index is given.[vi]



Ethyl acetate, n= 1.3723



Butyl acetate, n = 1.3941

6. Determining the composition of a mixture is the refractive indexes of the two pure materials are known.

Pure ethyl acetate has a refractive index of 1.3723. Pure butyl acetate has a refractive index of 1.3941.

The observed refractive index of your mixture will be a weighted average of the two refractive index values. For example if your mixture is made up of 27% of ethyl acetate and 73 % of butyl acetate the observed refractive index will be:

27 % of 1.3723 + 73 % of 1.3941 = (0.27x1.3723) + (0.73x1.3941) = 1.3882

If a value for the mixture is known, the composition can be calculated.

$$\frac{\text{Observed value-smaller pure value}}{\text{Larger pure value- smaller pure value}} \times 100\% = \text{percentage of larger in mix}$$

Percentage of smaller material is equal to 100%- % of larger in mix.

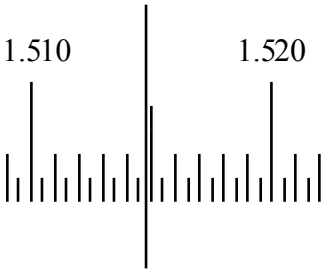
If an unknown mixture of ethyl acetate and butyl acetate was found to have a refractive index of 1.3804, what is the composition?

$$\frac{1.3804-1.3723}{1.3941-1.3723} \times 100\% = 37\ \%\ \text{butyl acetate}$$

100%- 37% = 63 % of ethyl acetate

This can be checked by doing the math:
(0.63x 1.3723) + (0.37 x 1.3941) = 1.3804 check

7. Measuring the refractive Index. Your professor will show you how to use and read the refractometer. The scale must be read one decimal place past the value of the line. Correct readings have 4 decimal places. What is this refractive index?



Important considerations: You must give four significant figures to the right of the decimal point, and interpolate between the two closest lines rather than reading the closest line only. The refractive index here is 1.5148.

Each machine may be slightly off. To correct for slight variations, the refractive index of a known material is taken. This is used to calibrate the machine. An offset is applied. To calculate a corrected refractive index, you need three pieces of information: the observed refractive index (RI) of your mixture, the observed RI of water, and the literature RI of water (which is 1.3330). First measure water on your machine. Find the difference between the measurement for water and the literature value for water. (1.3330). This difference is the correction factor or the machine offset.

	Measured value	1.3342	1.3321
-	Literature value	1.3330	1.3330
-	Offset or correction factor	0.0012	-0.0009

Decide if the machine is reading artificially high (first example) or artificially low (second example).

Next measure the refractive index for your sample Say the sample was 1.5148.

If the machine is reading high, you know the corrected value must be lower than the measured value, so the offset must be subtracted. If the machine is reading low (second example), the corrected value must be higher than the measured value so the absolute value of the offset must be added (or the actual value must be subtracted. Subtracting a negative is the same as adding.)

1.5148	1.5148
-0.0012	+ 0.0009
1.5136	1.5157

6. Sample problem: You determine the refractive index (RI) of your unknown using a refractometer, and it is 1.4414. Your observed RI of water is 1.3337. The literature RI of water is 1.3330. What is the corrected refractive index of your unknown?

Note: If your observed RI of water is higher than the literature value, the observed RI of your unknown will be higher than the corrected value, and vice versa. Both of the observed values will be higher (or they'll both be lower); no crossovers.

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[i] History of ATAGO, (February 9, 2011) http://www.atago.net/english/history.html

[ii] Topac. Instruments for research , production and quality control (February 9,2011) http://www.topac.com/to02000.html

[iii] Pocket Digital Refractometers Meet Diverse Application Needs in the Food Industry By Charles Smith, Reichert, Inc., http://www.fishersci.com/wps/portal/CMSTATIC?href=Scientific/researchAnalytical/ProductsServices/Food_Diagnostics/food_beverage_newsletter_refractometers.jsp&store=Scientific&segment=researchAnalytical

[iv] Refractive Index Determination of an unknown liquid (February 9, 2011) http://www.chemistryland.com/CHM151Lab/Lab03IDliquid/Lab03Help.html

[v] A. Hudson, R. Nelson, *University Physics,* Harcourt Brace Javanovich, Inc, New York, *1982* pp755759-

[vi] *CRC Handbook of Chemistry and Physics*, 65th Ed., CRC press, 1984, p C-71, C-73