Experiment 4:
Refractive Index

Objectives

This experiment is designed to

1. illustrate the use of refractive index as a criterion of purity.

2. demonstrate the use of refractive index in estimating the composition of a mixture of two liquids.

Introduction to Refractive Index

As we learned in the previous three experiments, we can increase the purity of a solid or liquid compound by recrystallization or distillation, respectively. While the purity of a solid compound can be assessed by melting point, the characteristic refractive index can be used for liquids by comparing the observed refractive index with the published literature value for that compound.

Theory

The refractive index of a liquid is a physical property that can often be used to assist in the identification of an unknown liquid. The property arises from the fact that light travels at a different velocity in a liquid than it does in air. We can define the refractive index, n, of a substance as the velocity of light in air, V_{air}, divided by the velocity of light in the liquid in question, V_{liq}. However, what we actually measure is not the velocity of light in the two media, but the ratio of the sine of the angle of incidence, sin i, to the sine of the same angle of refraction, sin r. The angle of incidence corresponds to the angle at which the light strikes the surface of the liquid, and the angle of refraction is the angle to which the light is refracted within the liquid (see Figure 4.1).

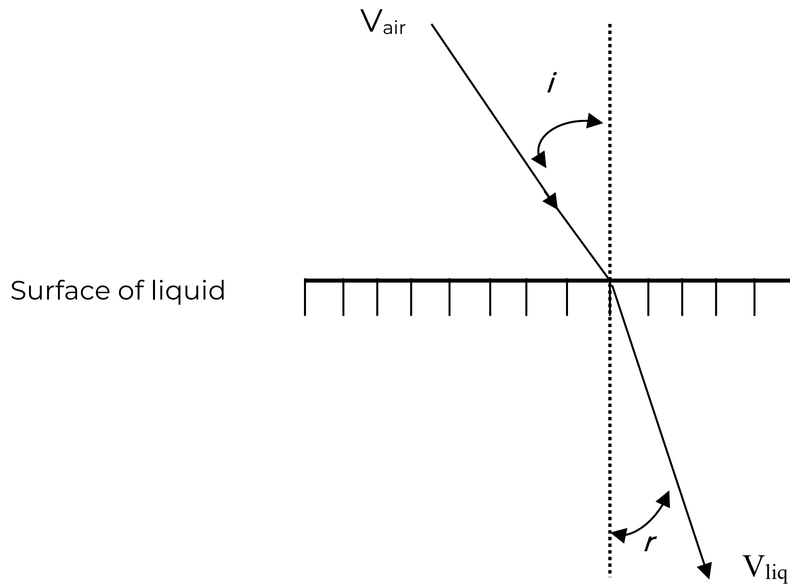

Figure 4.1. Light is refracted as it passes from air into a liquid.

That is,

$$n = \frac{V\text{air}}{V\text{liq}} = \frac{\sin i}{\sin r}$$

Refractive index is dependent on two factors: temperature and the wavelength of the incident light. Normal practice is to report refractive indices measured at 20° C using the so-called "sodium D line" (i.e., the yellow light of wavelength 589 nm given off by sodium lamps). The symbol used to represent such a refractive index is n_D^{20}. If a refractive index is measured at a temperature other than 20° C, the value obtained can be corrected to 20° C using a correction factor of 0.00045° C^{-1}. Note that the refractive index decreases with increasing temperature. Thus, if a certain compound has a n_D of 1.5506 at 25° C, the value of n_D^{20} would be:

$$1.5506 + ((25°\text{C} - 20°\text{C}) \times 0.00045°\text{C}^{-1}) = 1.5506 + 0.0022 = 1.5528 = n_D^{20}$$

(Equation for Temperature Correction of Refractive Index Readings)

To this point, we have only been concerned with the refractive indices of pure liquids. Most literature values of refractive index are quoted to four decimal places, and n_D is considered to be a very precise physical constant for a given substance. However, small amounts of impurity present in a substance can have a major effect on the measured refractive index. We can take advantage of this sensitivity to the presence of impurities by using refractive index as a means of determining the approximate composition of a two-component mixture of liquids. In a mixture of two liquids, A and B, having refractive indices of n_A and n_B, respectively, the observed refractive index of the mixture, n_{mix}, is related to the molar composition of the 'fraction mixture' or 'mole fraction' by the following relationship:

$$\text{mol\% B} = \frac{n_{\text{mix}} - n_A}{n_B - n_A} \times 100\%$$