

## **WHAT IS PERMEATION?**

Graham's Colloidal Diffusion illustrates the three-step process of permeation through a material. The first step is the sorption of the permeant into the material. Next, the permeant diffuses through the material followed by the final step where it is desorbed from the other side. This entire process is driven by a concentration difference or gradient. Molecules will permeate from the high concentration side of the material to the low concentration side. This will continue until both sides are at equal concentration levels.

Permeation measurement is generally a straight-forward concept. However, terminology surrounding permeation and its measurement is often used incorrectly. Permeation rate and transmission rate are used interchangeably but are, in fact different properties. The rate at which the permeant goes through a material of a specific area is evaluated to give the transmission rate. The units of transmission rate have the dimensions of volume of permeant per unit area per time.

Transmission rate is a measurement specific to the actual material tested, permeant and conditions such as temperature and relative humidity (RH). When more general results are required, the permeation rate is calculated from the measured transmission rate data. Permeation rates take into account the material thickness and the driving force or concentration gradient of the permeant. Permeation rate provides more of a material property as it can be used for any given material thickness or permeant driving force. To obtain the permeation rate, the measured transmission rate results are multiplied by the thickness of the material tested and divided by the partial pressure gradient of the permeant. Of course, many instruments automatically calculate the permeation rate and provide it as one of the outputs.

## **MEASUREMENT TECHNIQUES:**

Most common techniques for transmission rate measurement of sheets include challenging one side of the material with the permeant (test gas) while the other side is swept with a carrier gas. The material is placed in a diffusion cell, separating it into two chambers. The inner chamber is flushed with nitrogen carrier gas and the outer chamber contains the permeant. Molecules of permeant diffuse through the film to the inside chamber and are carried to the sensor by the carrier gas. The computer monitors the increase in water vapor or gas concentration in the carrier gas and it reports that value as the transmission rate. This process is perfectly illustrated in the transmission rate units shown above; amount of permeant per unit area per time. Although the typical test sample size is only 50 cm<sup>2</sup> it is normalized to either 1 m<sup>2</sup> or 100 in<sup>2</sup> for purposes of the units.

A variety of permeant-specific sensors are used to analyze the concentration in the carrier gas stream. Different sensors can be used depending on the sensitivity required due to barrier level as well as the accuracy desired.

Transmission rate data from flat samples is extremely useful in initial material evaluations, research and development applications and ranking potential materials as candidates for a given package. However, final package configurations can and should also be analyzed. Testing the transmission rate of packages provides insight into the stresses incurred in the packaging process. Full package testing is typically recommended when developing shelf life predictions.

## **IMPORTANT FACTORS IN PERMEATION MEASUREMENT:**

While concentration gradient is the driving force behind permeation, other factors play an important role.

Temperature has a large effect on permeation rates as the permeation rate increase 5-7% per degree C. Correct temperature control and measurement is crucial to obtaining accurate results. Package testing can be especially susceptible to temperature variation as many packages are tested in ambient air and the temperature in many

labs can fluctuate several degrees in a 24-hour period. Relative humidity (RH) can also impact permeation results. Obviously when testing WVTR, the proper RH generation, control and monitoring are crucial as the water vapor serves as the test gas. However, the presence of moisture can also greatly impact the permeation rates of oxygen and other gasses in certain materials. It shows the effect of moisture on the OTR of some key materials used in the packaging industry. Proper RH generation and control during an OTR test provides an accurate indication of how the material will truly perform under those conditions. Other factors to consider when testing transmission rates include sheet thickness variation, equilibrium time, barometric pressure and proper test gas generation.

## **CONCLUSION**

This article provides a brief overview of permeation, its measurement and its importance in package design. While other factors such as marketing and cost also play significant roles in the development of package, product protection through permeation measurement is crucial to creating a functional, cost-effective package that meets the product's shelf-life. More in-depth information regarding permeation test methods, instrumentation and theory is available.

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