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SYNTHETIC FUSED SILICA CAPILLARY TUBING: A DISCUSSION OF DIFFUSION

Synthetic fused silica capillary tubing is commonly used as the preferred substrate for chromatographic separation columns. In limited instances the absorption and diffusion of molecules into and through the fused silica deserves consideration.

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INTRODUCTION

Synthetic fused silica capillary tubing is the substrate of choice for chromatography columns around the world. The inertness, tight i.d/o.d. tolerances, and the ease of use make it an invaluable tool for a broad array of applications. In many cases, it acts as the conduit for gas transfer lines or as the base material for chromatographic columns. Understanding its interaction with commonly used gases can be important.

MATERIALS

Synthetic fused silica is Silicon dioxide in an amorphous state which is produced through a chemical deposition and sintering process. The resulting product is a fully consolidated, high purity silica glass with a density of ~2.2 g/cc (1). According to Doremus the typical interstitial diameter within the amorphous structure is ~3 Å (2). The interstice is small enough to prevent most molecules from permeating the material. Molecules such as Helium, Neon, and Hydrogen will diffuse into and out of the glass due to their small size; their molecular diameters are 2.0Å, 2.4 Å, and 2.5 Å, respectively (2). In fact, these small molecules are considered to actually be soluble in the glass as they can occupy the “free space” within the glass structure. Although data is available on the small molecules mentioned, our discussion will focus on Hydrogen due to its interest across a range of applications and the diminishing availability of Helium.

DISCUSSION

Gas permeability is a measure of the rate at which a volume of gas will diffuse through a volume of a substrate and is often expressed as the corresponding diffusion coefficient under a set of experimental conditions. The diffusion coefficients of Hydrogen in silica glass have been determined under varying temperatures and are shown in Table I (3). The diffusion coefficients in Table I were determined using fused silica with a wall thickness of 200µm, thus providing a fair representation of a typical Polymicro capillary.

Table 1: Diffusion Coefficients of H_2 in Fused Silica

Temperature °C	Constant, cm^2 / sec. X 10^{-6}
400	0.5
600	1.5
700	2
800	3

Gas solubility of Hydrogen in fused silica was described by Doremus as the gas concentration in the glass divided by the gas concentration in the surrounding gas phase; he reported this ratio to be 0.028. Increasing the temperature to 1000°C and the pressure to 850 atm increased the concentration ratio only slightly. The data suggests that ~25% of the total “free volume” within the fused silica is available to be occupied. The displacement of a resident soluble gas within the fused silica can alter the diffusion rate of another gas, as described by Williams, et.al. (4). Thus the exposure history of the glass is important to consider.

It is important to note the volumes of gas which permeate through the glass wall are extremely low. Typical maximum operating temperatures used in gas chromatography are around 400°C. At this temperature, the diffusion coefficient is 0.5 X $10^{-6}cm^2$/sec. Given this low molecular diffusion, the gas lost through the column wall is negligible. The permeability of the polyimide coating to these common gases is significantly higher than that of the fused silica; the fused silica is the limiting factor with respect to diffusion.

CONCLUSION

Synthetic fused silica is a dense material with an interstice of ~3 Å. Although this is not porous enough to allow permeation of large molecules, many molecules, such as Hydrogen and Helium, can diffuse into the glass. An understanding of how to determine the actual volumes of these small gases that diffuse through fused silica is important. Contact a Polymicro Technical Sales Representative for any questions about the physical properties of Synthetic Fused Silica Capillary Tubing or to discuss your specific application.

REFERENCES

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