UNIVERSITY OF TORONTO SCARBOROUGH

3D Printed Flow-Through Cuvette

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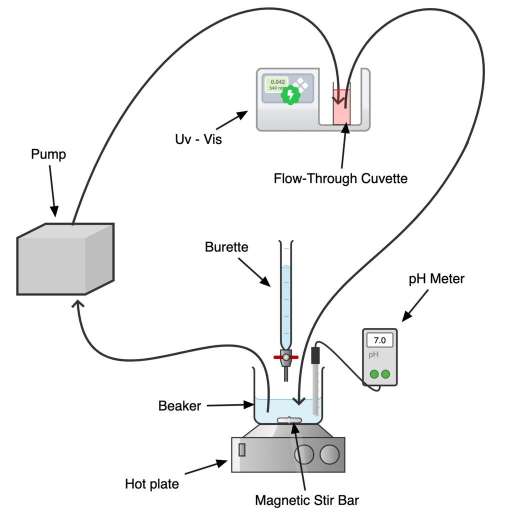
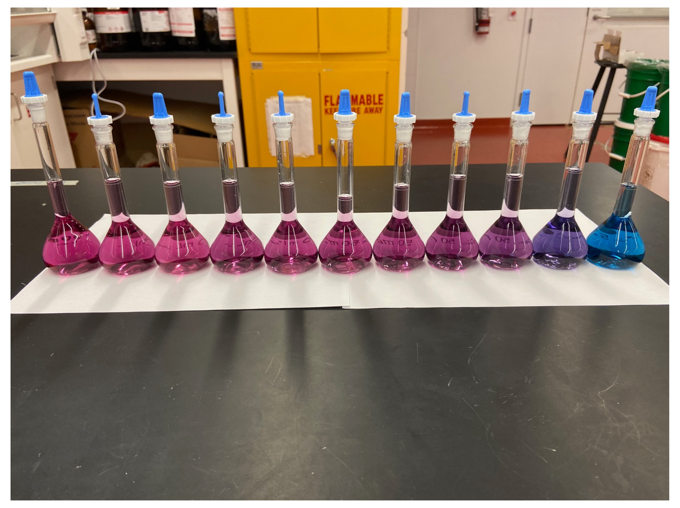
Introduction

Cuvettes are small containers that hold liquid samples with the dimension of 12.5 x 12.5 x 45mm (L x W x H). The liquid in the cuvette can be exposed to light in the ultraviolet and visible regions, resulting interactions between light and molecules (UV-Vis spectroscopy). This enables chemists to conduct qualitative and quantitative experiments on samples. The flow-through feature allows researchers to monitor reactions real-time without having to disturb a system and prepare new samples at time points of interest. A flow-through cuvette allows a sample to be continuously measured by UV-Vis spectroscopy by forming a closed-circuit loop between a cuvette (where a measurement is taken) and a larger reaction vessel through incorporation of tubing, pumps, and other equipment. This setup can improve the efficiency of analyzing a system as the user only requires a single cuvette to monitor a reaction at time points of interest while reducing errors associated with manually preparing and filling cuvettes at various time points.



Real-World Application

The flow-through cuvette allows for a broad range of chemical analyses. For example, measuring the "hardness" of water (which is the amount of various ions in water), is important for understanding aquatic ecosystems, human health, as well as minimizing damage to our household plumbing. We can add chemicals into our drinking water which will turn it from colorless to pink. As we start to add some other chemicals continuously, the sample will turn from pink to purple and finally to blue. These color changes enable us to determine the hardness of water. To more accurately quantify this process, we can measure the color changes via UV-Vis spectroscopy at various point in a closed-circuit testing environment with the flow-through cuvette.

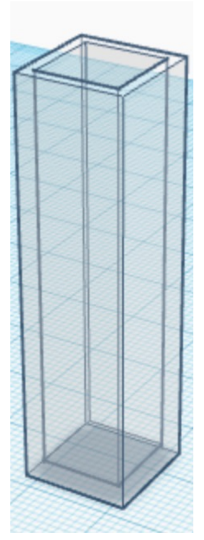


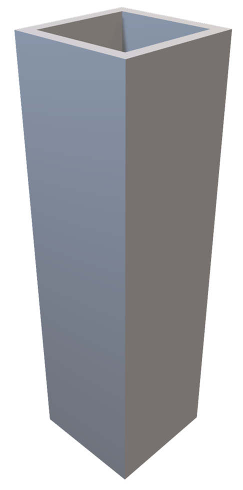
Motivation

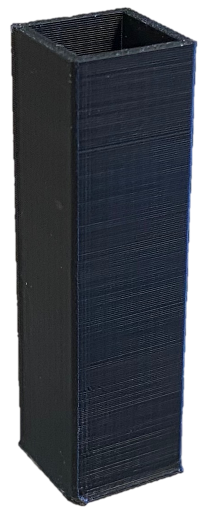
Applying flow-through titration with UV-Vis Spectroscopy is a versatile approach that can provide an equivalent, or more accurate, result in comparison to a traditional titration method. However, a commercial flow-through cuvette can be upwards of $1300 per unit. It is too expensive and inaccessible to be used in undergraduate courses. So my goal is to dramatically reduce the cost to less than $5 per unit by designing and 3D-printing a new flow-through cuvette.

Prototype 1

My first prototypes start from printing a standard cuvette with transparent PETG and black ABS material to test the applicability of each material. The model with transparent PETG after printing is unexpected because of its cloudy white appearance and there is no visible improvement after trying different methods of polishing like sanding and chemical vapour. So, we switch the material to black ABS and comes to my second design.

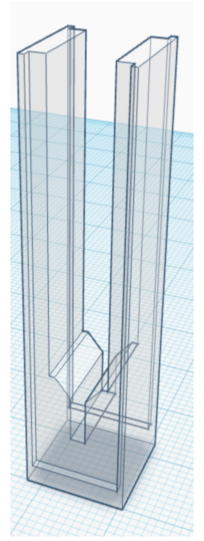


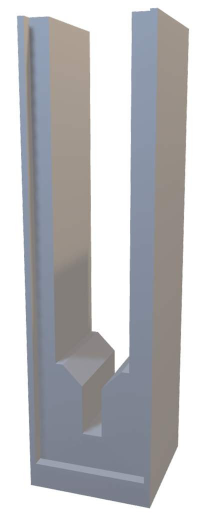




Prototype 2

Considering the black ABS will absorb the visible light that is supposed to pass through the cuvette, the second prototype was prepared by leaving two sides of the cuvette open to adhere glass (which is more transparent to visible light). This second prototype was tested on the UV-Vis spectrophotometer. The cuvette transmitted light effectively and its performance was similar to a commercial cuvette and paved the way for the following flow-through cuvette design.

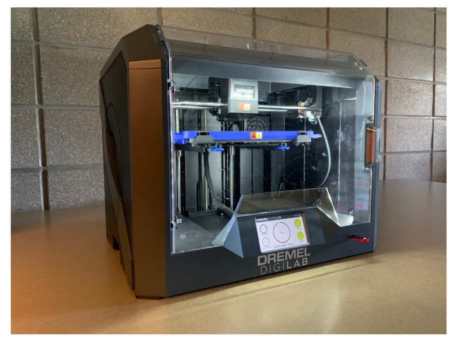


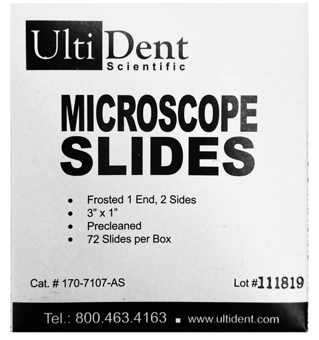


Software, Material & Printer

Printer model: Dremel 3D45 3D printer
3D design software: Tinker Cad
Materials:
Black ABS (Acrylonitrile Butadiene Styrene)
Transparent PETG (Polyethylene terephthalate glycol)
Ulti Dent Microscope Slide

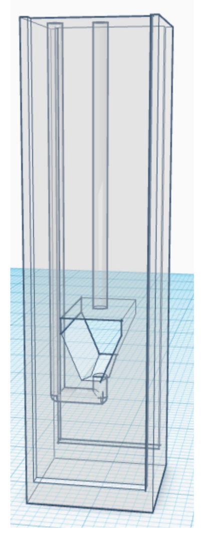
TIN KER CAD

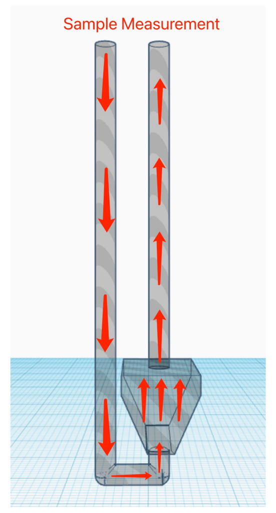


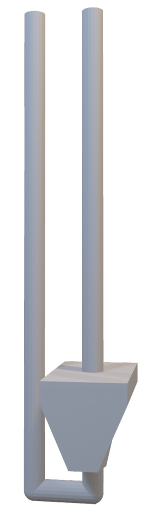


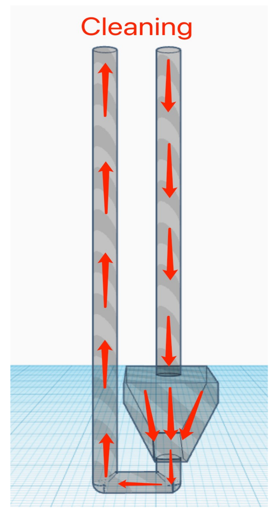
Prototype 3

The solution holding chamber was upgraded to a "V" shape in prototype 3 for a better liquid flow in the chamber. In addition, one pipeline was altered to form a "U"-shaped design connected to the bottom of the chamber. This allows for a solution to be "drained" upon completing an experiment. This design allows the cuvette to be more easily cleaned.



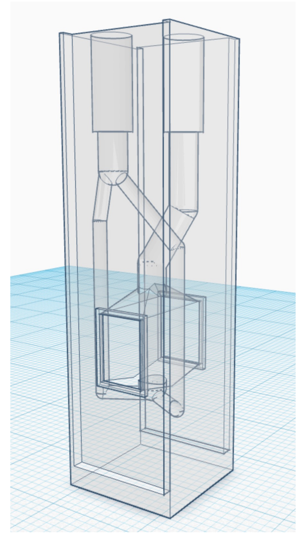


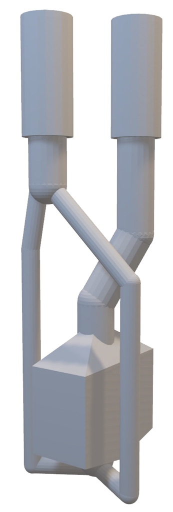




Prototype 4

To satisfy the demand of a larger flow rate, the inner structure was designed as a double "U". The entrance/exit section of the pipelines are designed to fit a connector between the cuvette and the external tubing for a better seal. A small frame was added to the sides around the chamber to minimize contamination of the glue (used to adhere the glass to the cuvette) on the inside of the solution holding chamber.





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