Practical Problem-Solving through Design Projects

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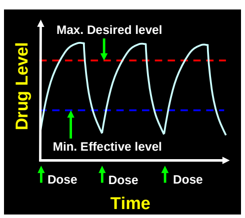
Introduction

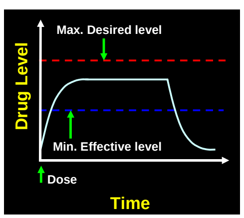
The Science Framework for the National Assessment of Educational Progress repeatedly stresses the importance of teaching "practical problem-solving that involves design, use of materials, and weighing risks in relation to benefits".[1] A student survey indicated that a significant proportion of students strongly hold serious misconceptions about heat transfer.[2] Several nanoconcepts or "Big Ideas in Nanoscience" as well as student misconceptions are associated with *Size and Scale*.[3,4] An approach to training students in these nanoconcepts while clearing up misconceptions is to use project-based learning.[1,5] This motivates the development of experimental design projects that will help clear up these misconceptions while teaching nanoconcepts.

Objective

Development of two experimental design projects concerning "size and scale" to help clear up misconceptions while teaching nanoconcepts.

The first is a design project on drug delivery which is an important applications area for nanotechnology.

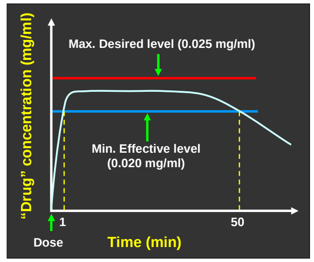




The second is a design project on the application of phase-change materials such as paraffin wax for thermal energy storage.[6]

Controlled "Drug"-Delivery Design Project

Design the "drug"-delivery Profile as shown below

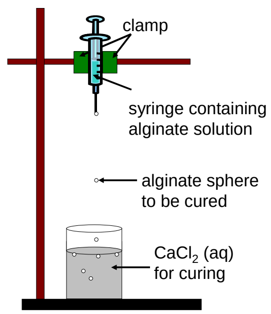


Students design a desired "drug" release profile by using different sizes of sodium alginate polymer spheres with dye as the "drug." The given uptake rate of "drug" by the body is 0.01 mg/min.

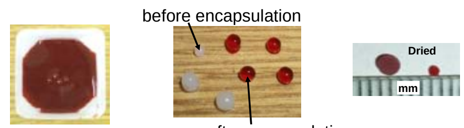
The goal is to attain the desired "drug" concentration within 1 minute, maintain the "drug" level within a desired concentration range and to drop below the minimum effective concentration in ~50 minutes.

Experiment Setup & Results

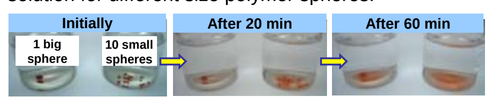
Formation of Alginate Polymer Spheres using External Method:



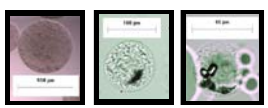
"Drug" (dye) encapsulation:



Comparison of "drug" release rate in sodium citrate solution for different size polymer spheres:



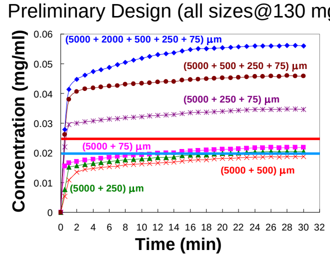
Formation of Micro/Nano Polymer Spheres using Internal Method:



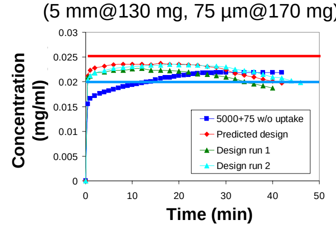
Micro/Nano polymer spheres are produced using emulsification/internal method.[7]

Design Result: Plot of "Drug" Release vs. Time

Preliminary Design (all sizes@130 mg)



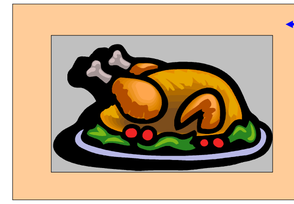
Designed Profile (5 mm@130 mg, 75 µm@170 mg)



Left: Preliminary results students might obtain by investigating release rates of different size spheres. Right: A possible design that satisfies the desired profile.

Phase-Change Material Design Project

Design a pot vessel to keep food warm around 50°C

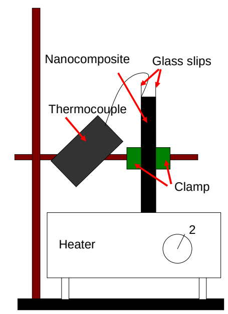


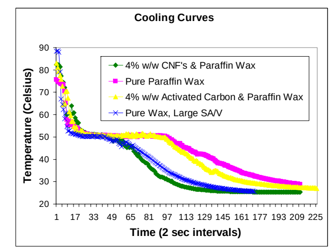
Pot vessel containing molten paraffin wax at 60°C.

As temperature drops, the wax solidifies around 50°C and the large amount of latent heat released by the wax keeps the food warm.

Students will design a phase-change material (PCM) by adding various carbon nano-particles and changing the SA/V of the wax so as to optimize the heat release rate from the PCM.

Experimental Set-up & Preliminary Results





- Paraffin wax containing carbon nanofibers (CNFs) has the fastest latent heat release rate.
- Crashed paraffin wax has higher surface-area-to-volume ratio (SA/V) demonstrates almost equally fast heat release rate.
- Latent heat release can hence be optimized by adding CNFs and by increasing the SA/V of the paraffin wax.

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