Solution Calorimetry as a Tool to Assess Swelling of Polymer Blends and Hydrogels

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Directly measuring the swelling characteristics of polymeric drug delivery systems (DDS) is fraught with difficulties but is desirable because it allows quantitative structure activity relationships (QSARs) to be constructed. Conventional methods, such as those based on optical microscopy, require the DDS to be removed from the dissolution medium for measurement which means that, as well as being invasive, they are not suitable for microparticulate systems. Since swelling is accompanied by a change in heat, calorimetry has the potential to monitor swelling non-invasively and in real time. An additional benefit is that the physical form of the sample is irrelevant, meaning that even microparticulate systems are amenable to study.

Here we report the use of solution (ampoule-breaking) calorimetry to study the swelling of polymer blends (various HPMC grades with NaCMC) and hydrogels (cross-linked PEG400) and show how the data can be interpreted to recover swelling parameters. Samples (up to 16 mg) were dispersed into dissolution medium (15 mL) in a 2265 microsolution ampoule (Thermometric AB) at 25^{o}C. The power-time trace obtained, which represented all of the events occurring during swelling (hydration, swelling, gelation and, at least in the case of the HPMC and NaCMC samples, dissolution) was converted to cumulative heat versus time and analysed using[1];

$$qt/Q = kt^{n}$$

where qt is the heat released up to time t, Q is the total amount of heat released (and hence qt/Q is a term analogous to the fraction of swelling), k is a constant and n is a parameter the value of which indicates the mechanism of swelling. Thus, by plotting log qt/Q versus log t linear relationships were obtained, the slope of which gave the value of n directly.

For HPMC blends, values of n were always greater than 1. This indicates that there was no rate limiting step caused by the geometry of the system and dissolution occurred immediately following polymer hydration, a result of the small particle size of the polymers used. An effect of particle size was noted, which supports this hypothesis. However, the values of n were significantly different between polymer blends, which substantiates the notion that solution calorimetry data could form the basis of QSARs. For the hydogels a biphasic response was noted. This has been seen previously [2] for PEG-based hydrogels; the first phase is mainly associated with water uptake into the polymeric network and the second phase to the swelling of the whole hydrated structure. The data indicate that solution calorimetry has the potential to be a useful tool to understand and predict the behavior of polymeric materials used as functional recipients in drug delivery systems.

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