Experimental report

04/08/2016

Proposal: 5-25-244 **Council:** 10/2014

Title: SANS Studies of the Structural Evolution of Para-Aminobenzoic Acid during Solution Crystallisation and Phase Transformations

Research area: Chemistry

This proposal is a new proposal

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Samples: ethanol-d6
Para-Aminobenzoic Acid

Instrument	Requested days	Allocated days	From	To
D22	2	2	16/10/2015	18/10/2015

Abstract:

Crystallisation of materials is a key step in chemical synthesis as a means of purification and phase separation. However, the initial stage of crystallisation, involving nucleation of molecules to form molecular clusters from a supersaturated solution is not fully understood. The results from this work will elucidate the thermodynamics and kinetics associated with such processes and the effect this has on the crystal properties, e.g. polymorphic form, and growth rate. This experiment will build on SAXS data using para aminobenzoic acid as a representative material, to probe the structural evolution of single molecules to molecular clusters through to nano-sized crystallites. SAXS results suggested a mechanism involving progression from monomer through dimers to more extended structures.
SANS will be used to probe both the low-Q region which could not be elucidated from SAXS data and also the high-Q region where evidence suggesting the presence of pre-nucleation clustering, which have been previously predicted and are critical to fully elucidating the crystallisation mechanism. SANS will be used to elucidate the structure/ dynamics of such intermediate systems.

ILL Experimental Report

Experiment 5-22-44 D22

SANS Studies of PABA Nucleation from Super-Saturated Ethanol Solutions

Introduction

The nucleation process is not fully understood from a structural perspective; however progress has been made recently using a variety of techniques including dynamic light scattering[1], small angle X-ray scattering[2], nuclear magnetic resonance spectroscopy[3] and ultracentrifugation[4]. The structural pathway to nucleation is particularly important in understanding polymorph selection; particle size distributions and crystal quality during a crystallisation process. Glycine in particular has been the subject of much study into the structure of possible pre-nucleation clusters which form during crystallisation from aqueous solutions[5]. Recent X-ray scattering studies of PABA nucleation reveal the formation of large liquid-like clusters of PABA, >40nm, in the under-saturated state[6]. These Nano-scale assemblies increase in size and structural ordering, indicated by an increase in fractal dimensionality from 1 – 2 as a function of supersaturation driving force. There has been much debate as to whether such pre-nucleation assemblies represent the molecular packing of the final macroscopic crystalline phase or whether nucleation proceeds through a liquid-like cluster during concentration fluctuations in the solution, from which the crystalline phase nucleates. These questions were the focus of the present experiment with the aim of exploring the structural pathway from single molecule to cluster formation during the crystallisation of PABA from supersaturated ethanolic solutions. These particular experiments focused on the previously reported large disordered nano-assemblies present during cooling crystallisations from ethanol and in particular the low q region.

Experimental Details

Solutions of alpha PABA in d-ethanol at a concentration of 247 g/kg and 300g/kg, saturation concentration at 50°C and 60°C, were prepared. The solutions were heated to 5°C above saturation temperature in a sealed laboratory bottle with screw cap in a pre-heated oven. Syringes, for transfer of the solutions to the sample cell,

were also preheated to the same temperature to prevent unwanted crystallisation of the solution before reaching the sample cell. Samples were run at two detector positions, with temperature steps of 2°C and 15 minute equilibrations times until crystallisation was observed.

Results

The scattering patterns were collected as a function of specified isothermal holding temperature within the meta-stable zone to induce the nucleation process. The scattering patterns collected at 55, 50 and 40°C, which focused on the low q region and hence larger solute aggregations, are presented in Figure 1. Analysis of the scattering patterns indicates an increase in intensity and a slight increase in slope of the scattered intensity below 0.01 $Å^{-1}$ as a function of increasing solution supersaturation. This is consistent with the presence of large aggregations of solute present in the sample and is in agreement with previous scattering studies on supersaturated solutions of PABA[6].

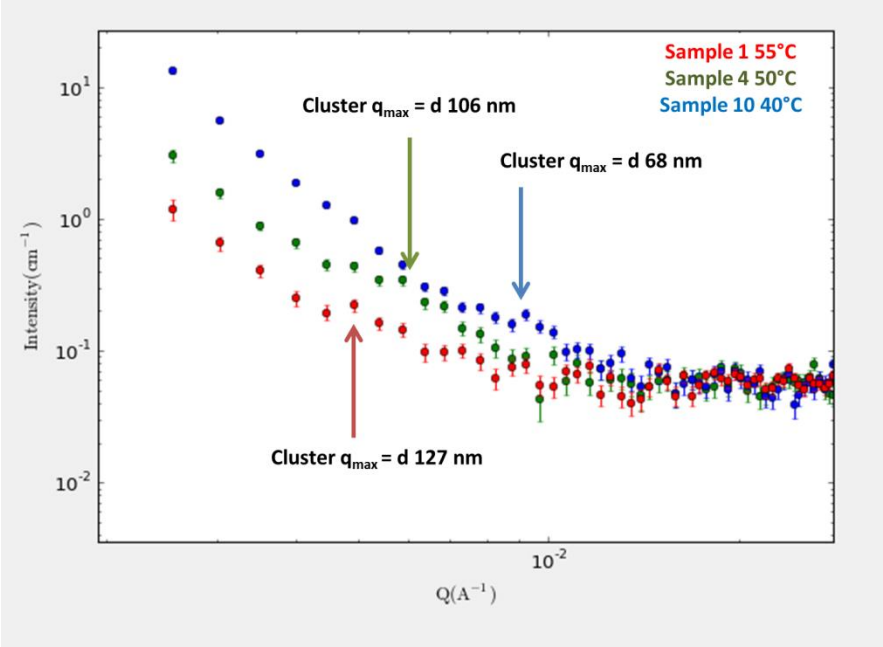

Figure 1 Scattering intensity of the low q region recorded for a cooling crystallisation at set isothermal temperature points of 55, 50 and 40°C, indicating an observed q_{max} region of a small peak relating to molecular clusters

The appearance of a smaller shoulder peak, initially at 4.9×10^{-3} $Å^{-1}$ at 55°C was observed to shift to higher *q* space. This peak is likely to indicate a population of molecular clusters of PABA, where the increase in the value of cluster q_{max} relates to

a decreasing size as a function of increasing solution supersaturation. Calculation of the related d-spacing from the values of q_{max}, Figure 2, provides an estimate to the size parameter of these nano-scale assemblies. An initial size of ~120nm is observed which upon reaching the metastable zone gradually decreases to ~70nm with experimental time. This can be interpreted as de-supersaturation of the large molecular assemblies of PABA with time, as mass transport of solute to the nuceli/crystal facilitates the crystal growth process in the supersaturated solution.

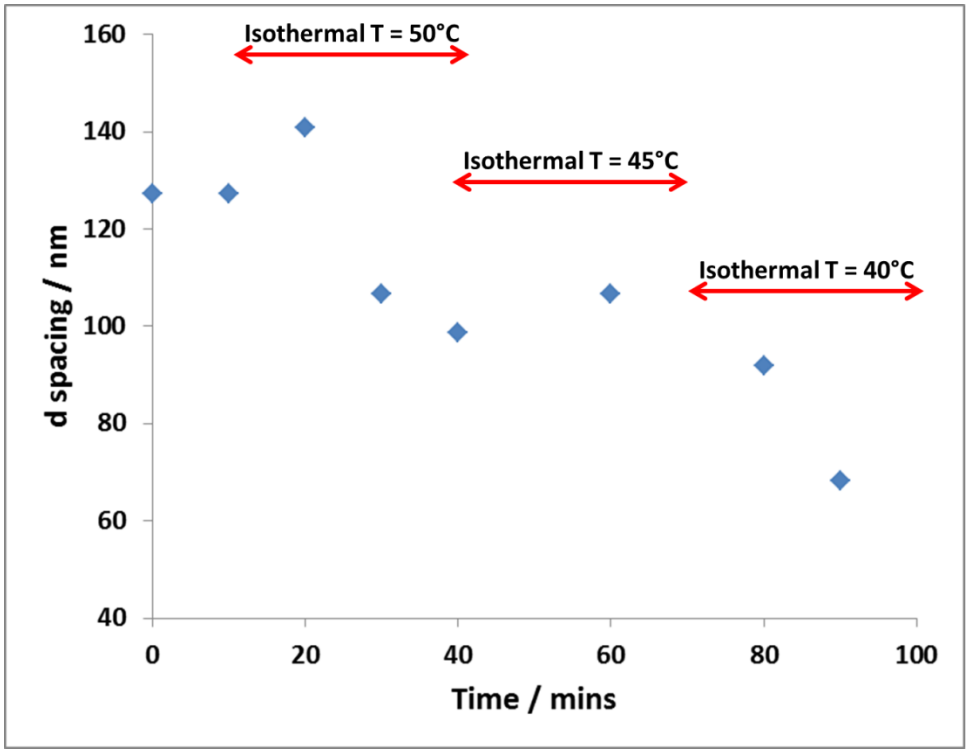

Figure 2 Calculated values of d-spacing for the time dependant shoulder peaks at positions of *cluster* q_{max}

References

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