SMALL ANGLE NEUTRON SCATTERING BY POLYMER SOLUTIONS

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1. INTRODUCTION

The small angle scattering (close to the incident direction$^1$) reveals correlations at large distances inside the sample, as typically exhibited in polymer solutions. Earlier, small angle scattering experiments on dilute solutions using electromagnetic radiations were performed for the purpose of polymer characterization.$^2$ Small angle neutron scattering (SANS) is an experimental technique introduced about ten years ago for observing polymer conformations in all concentration ranges from dilute solution to the melt.$^3-6$
In what follows, we will mainly be concerned with conditions necessary for the observation of small angle scattering. After a brief review (Section 2) of the elementary relations between scattering amplitude, index of refraction, and scattered intensity, we will discuss in detail two concepts related to this last quantity, the contrast (Section 3) and the pair correlation function (Section 4).

Experimental results obtained by SANS have been extensively reviewed in many general articles. We have limited our review to atactic polystyrene (and sulfonated polystyrene) in solution. This polymer is taken as a prototype of the flexible coil. As an example of a problem studied by SANS, we consider polymer coil shape as a function of polymer concentration. Using light or X-rays, experimentation could only observe the coil configuration in dilute solutions. But with use of neutron scattering, investigation of the coil configuration in other environments such as semi-dilute and concentrated solutions becomes possible. We briefly recall the findings of the SANS by semi-dilute polymer solutions.

(1) Neutron, light scattering, and osmotic pressure data could all be interpreted in terms of a single length $\xi$;

(2) Characteristic domains of variation were found in the temperature concentration diagram. Results are mostly expressed in terms of power laws. A major experimental problem is the determination of the characteristic exponents and the spatial range over which a given power law holds true (cross over).

Another typical problem investigated by SANS is the nature of strong polyelectrolye solutions. The scattering pattern is similar to the one associated with a long range ordered structure. However, experimenters are more and more convinced that the correct interpretation leads to a disordered structure.

In all these examples the polymer chain is in the equilibrium state. This state has been extensively studied for the last ten years. A new problem now is the study of polymer conformations in non-equilibrium states such as the stretched polymer chain. Neutron scattering in real experimental conditions are difficult because the scattered intensity is very low. These studies require new experimental approaches. One is described in Section 4.

2. ELEMENTARY RELATIONS

The experimental analysis of SANS is based on elementary relations.