030404 Quiz 1 Polymer Physics

The Gaussian approximation is used in most of Flory's work describing polymer properties such as the Flory-Rehner Theory for gels, Flory's rubber elasticity expressions, osmotic pressure for polymer solutions and the Flory expression for the free energy of a polymer blend.

1) What is the Gaussian function and what does it describe? What assumptions does it involve?

2) How does it relate to a single polymer coil and a Brownian walk for a pollen grain?

3) What is the mean end to end distance for a polymer coil, (R)? Is this a good measure of size?

4) From neutron scattering (a static technique) it was found that the mass fractal dimension of a randomly crosslinked Gaussian network was 2.5 (a network of Gaussian chains that are randomly connected together). Quasi-elastic neutron scattering (a dynamic technique) showed that the connectivity dimension was 2.8. Are these values reasonable? Explain first if each of the values are independently reasonable and then if the two values are compatible for a single structure.

5) What are the values of d_f and C for: Sphere, Rod, Disk, Gaussian Coil.

ANSWERS

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1)

$$P_G(R,n)\,dR = 4\pi R^2 \left(\frac{2\pi}{3} n b^2\right)^{-3/2} \exp\left[-\frac{3}{2}\left(\frac{R}{b\sqrt{n}}\right)^2\right] dR$$

The function describes the differential probability that a random chain will have an end to end distance of R if the chain is composed of n steps of length b. The assumption is that each step is completely random, for instance the chain can backtrack over itself and there is no interaction between chain units of any kind, no excluded volume no net enthalpic or entropic interactions. It is inherently assumed that n approached infinity since there is a probability for any R. In the most general form $nb^2 = \sigma^2$, where σ is the standard deviation of the distribution.

2) For a polymer coil $\sigma^2 = nb^2$, as described above. For a Brownian walk $\sigma^2 = tb^2/\tau$, where t is time and τ is a characteristic time for diffusion of the particle. R is the distance traveled by the Brownian particle.

3) <R> = 0 since the Gaussian walk is random and reflects a symmetric probability function about 0. <R> is not a good measure of size since it has a value of 0 for all Gaussian chains.

4) The random network must have a dimension greater than 2 since it has more mass than a Gaussian coil, it must be less than 3 since it does not fill space, so 2.5 is reasonable. The connectivity dimension should be greater than 1 since the chain is not linear, but less than 3 since the chain is not 3-d so alone the connectivity dimension seems high but could be accurate. In combination, it is not mathematically possible to have a connectivity dimension greater than the mass dimension. That is, there is no structure for which the minimum path, L_{min}, that is shorter than the end to end distance, R.

5)

	Sphere	Rod	Disk	Gaussian Coil
d_f	3	1	2	2
C	3	1	2	1