September 15, 2016 Quiz 1 Polymer Properties

1) This weeks Friday seminar deals with flame-made nanoparticles. Many people try to make nanoparticles through careful wet chemical synthesis mechanisms such as salt (silver halide) decomposition to make silver nanoparticles. Synthesis can take up to several weeks by these careful wet chemical processes.

a) Why would you think that you could effectively make controlled ceramic nanoparticles in less than a millisecond in a 2000°C flame? Is there an equation mentioned in class that can support this proposition?

b) Would you expect to see nanoparticle synthesis in engine exhaust where you have similar flame processes occurring?

c) Sketch a plot of the melting point of alkanes of increasing molecular weight. Why does this plot display a plateau?

2) It is observed that a bubble in shampoo takes the shape of a teardrop. Shampoo contains worm-like micelles that are long cylindrical structures about 10 μm in contour length (path length along the chain) and about 4 nm in diameter that are convoluted and subject to thermally driven motion similar to a polymer in solution.

a) Explain why the bubble takes a tear drop shape rather than a spherical shape by sketching a drawing of the bubble and showing the forces acting on the bubble with arrows. Explain the origin of these forces.

b) A typical shampoo contains 30 volume percent worm-like micelles that display a Kuhn length of about 100 nm. Calculate the size $<R^2>^{1/2}$ for a worm-like micelle.

c) Calculate the volume fraction within an isolated coil of a worm-like micelle (occupied cylinder volume/(coil volume)). Comparing this with the shampoo volume fraction what can you say about the micelles?

d) If the concentration were reduced to below the isolated micelle concentration what shape would the bubbles take?

e) If the micelles were spherical micelles at 30 volume percent what shape would the bubbles take?

3) In economics the price of a stock (security) is said to fluctuate about an "intrinsic" value following a random walk. That is, people will bid for a stock about some average, and these bids are sometimes higher and sometimes lower than the actual "intrinsic" value of the stock. Economists can keep track of these bids and use this information to guide their own bids.

a) How would you determine if fluctuations in a stock price are random, that is that they reflect a random walk? What is the average fluctuation for a random walk? What is the root mean square fluctuation?

b) If the "intrinsic" value of a stock increased, due to changes in the portfolio of the company, the fluctuations about the original "intrinsic" value would not be random. Give a plan for how you would judge that the "intrinsic" value had changed.

c) How would you determine if you should offer a higher or a lower price for a stock?

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1)

a*) Why would you think that you could effectively make controlled ceramic nanoparticles in less than a millisecond in a 2000°C flame? Is there an equation mentioned in class that can support this proposition?*

The important feature of any process for synthesis of nanoparticles is being far from equilibrium and rapidly quenching the structure before it can coalesce or mature into larger particles. This is manifest in the Gibbs-Thompson Equation,

$r = 6\sigma T_\infty/(\Delta H\, \Delta T)$

where ΔT is the quench depth (thermal distance from the equilibrium temperature).

b) Would you expect to see nanoparticle synthesis in engine exhaust where you have similar flame processes occurring?

Yes, engines produce nanoparticles of carbon, especially diesel engines.

c) Sketch a plot of the melting point of alkanes of increasing molecular weight. Why does this plot display a plateau?

Chain folding leads to the plateau at degree of polymerization above about 100.

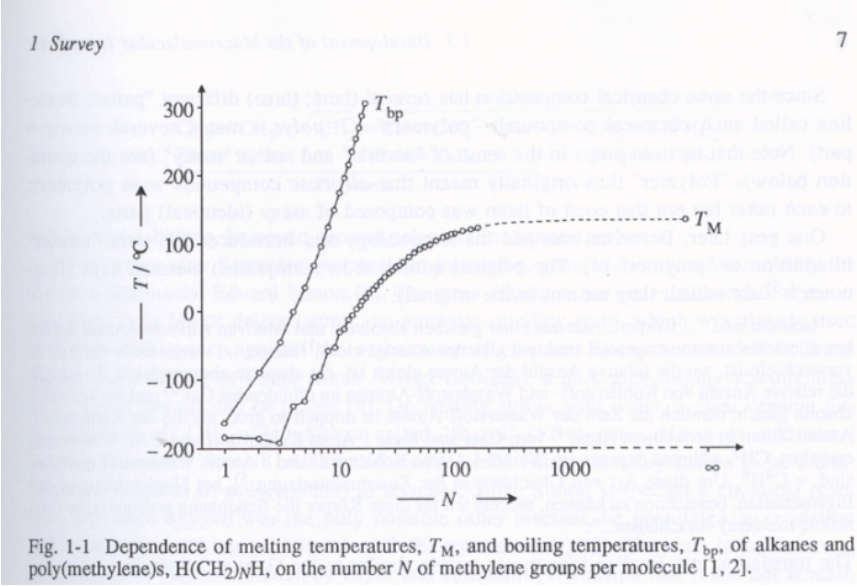
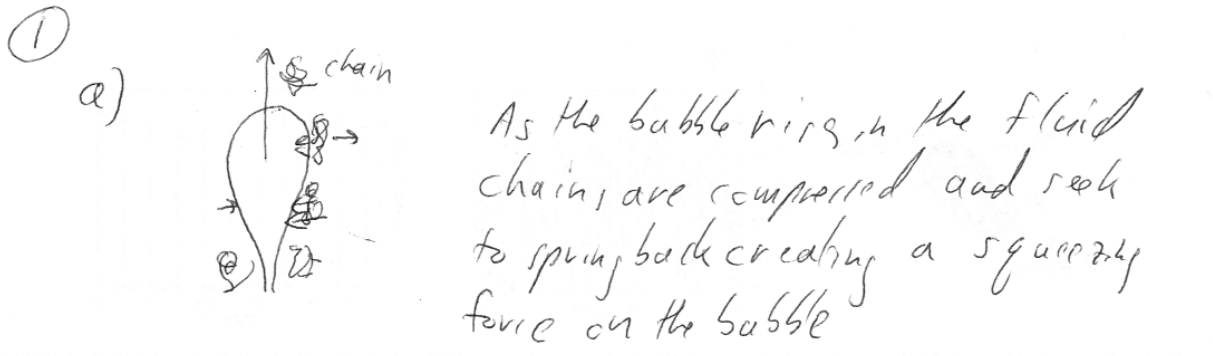


Fig. 1-1 Dependence of melting temperatures, T_M, and boiling temperatures, T_{bp}, of alkanes and poly(methylene)s, $H(CH_2)_NH$, on the number N of methylene groups per molecule [1, 2].

2) a)



b) The chains contain $10^4/10^2 = 100$ Kuhn units = N_k. $\langle R^2 \rangle^{1/2} = N_k^{1/2} l_k \sim 1\mu m$.
c) $V_{coil} = 4/3\ \pi R^3 = 4.2$ e 9 nm^3. $V_{occupied} = \pi R^2 L = 5.0$ e 5 nm^3. So $\phi_v = 0.01\%$. The micelles are highly overlapped and entangled at 30 %.
d) At extremely low concentration the bubbles would be spherical since the fluid would be Newtonian.
e) If the micelles were spherical the fluid would also be Newtonian and the bubbles would be spherical.

3)

a) How would you determine if fluctuations in a stock price are random, that is that they reflect a random walk? What is the average fluctuation for a random walk? What is the root mean square fluctuation?

The fluctuations should have an average value of 0 and the standard deviation should be proportional to roughly the $(|\text{maximum fluctuation}|/|\text{minimum fluctuation}|)^{1/2}$ if you explore a high number of stock purchases. The standard deviation is equal to this number times the stock volatility.

b) If the "intrinsic" value of a stock increased, due to changes in the portfolio of the company, the fluctuations about the original "intrinsic" value would not be random. Give a plan for how you would judge that the "intrinsic" value had changed.

Plot the average value and see if it shifts. Calculate the predicted random standard deviation of stock price following part "a". If the actual standard deviation differs then the intrinsic value has changed.

c) How would you determine if you should offer a higher or a lower price for a stock?

If the mean value is increasing and the standard deviation is larger than your calculation then you should offer a higher price. If it is lower you should offer a lower price.