CME 300 Properties of Materials

Homework 6 October 31, 2011

1) Outline a computer program to create a random walk structure similar to the program on the web site: http://zeus.plmsc.psu.edu/~manias/MatSE443/Study/7.html The input is n and the output are a series of n x, y and z positions for a random walk and the root mean square end-to-end distance. What do you expect to be the relationship between R and n from this program?

2) Polymers in solution do not follow a random walk due to "excluded volume".
   -Give the scaling law followed by polymers in solution,
   -comment on the average size difference for a chain of 100,000 units of step length 5Å in solution and in the melt,
   -explain what you think "excluded volume" means and
   -propose why polymers in the melt or solid state follow a random configuration.

3) The ideal rubber law states that the retractive force on a stretched chain is proportional to the absolute temperature. Compare this functionality with the ideal gas law (using P = F/A). What is the connection between an ideal gas and an ideal rubber/polymer chain in terms of the thermal response? In what way is increasing the chain molecular weight similar to reducing the gas atom density (n/V)?

4) How can a disk be distinguished from a random-walk polymer chain using fractal scaling laws? Is a disk self-similar? ("Self-similarilty" means that the object "looks the same" at different magnifications. Mass-fractal objects display self-similarity.)

5) How does the overlap concentration change for a chain of 10,000 units and a step length of 5Å to a chain of 100,000 units with a similar step length if the chain is in a solution (d_f = 5/3)?

6) The space shuttle Challenger exploded 73 seconds after takeoff in January 28, 1986.
   "Disintegration of the entire vehicle began after an O-ring seal in its right solid rocket booster (SRB) failed at liftoff. The O-ring failure caused a breach in the SRB joint it sealed, allowing pressurized hot gas from within the solid rocket motor to reach the outside and impinge upon the adjacent SRB attachment hardware and external fuel tank. This led to the separation of the right-hand SRB's aft attachment and the structural failure of the external tank. Aerodynamic forces promptly broke up the orbiter."

The morning of take-off the temperature was close to freezing. Explain how this low temperature could effect a rubber o-ring to cause this disaster. Use a plot of elastic modulus versus temperature and a plot of elastic modulus versus frequency (rockets vibrate at high frequency) in your explanation.

7) Sketch the storage modulus versus frequency and storage modulus versus temperature plots for a crosslinked and uncrosslinked polymer through the glass transition region. Explain the mechanical properties below the glass transition, at the glass transition and above the glass transition temperature.

8) There are two main types of polymerization reactions used to produce synthetic polymers. Give one example of each of these and sketch out the reaction scheme for both.

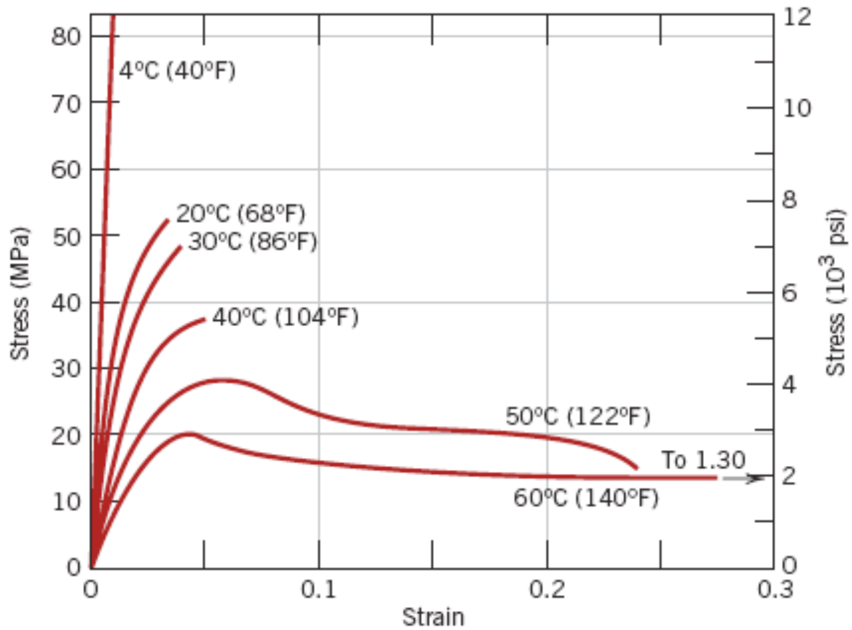
9) A commercial polyethylene has a PDI = M_w/M_n of 16 and M_w = 120 kDa. $M_z/M_w = 2$. A similar polymer has the same PDI and M_w but $M_z/M_w = 3.5$. Do you expect dramatically different viscosity from the second polymer? Why or Why not? What feature in the molecular weight distribution could account for the difference between these two polymers?

10) Triad tacticity is classified as isotactic, syndiotactic and heterotactic. Using polypropylene show Newman projections that show racemic and meso diads then explain how these are used to produce the three types of triads. In terms of r and m describe an atactic polymer. In terms of iso, syndio and hetero describe an atactic polymer. Would atactic polypropylene be of commercial use? Why?

14.12 Sketch cis and trans structures for **(a)** butadiene, and **(b)** chloroprene.

14.15 Sketch the repeat structure for each of the following alternating copolymers: **(a)** poly (ethylene-propylene), **(b)** poly(butadiene-styrene), and **(c)** poly(isobutylene-isoprene).

15.1 From the stress–strain data for poly(methyl methacrylate) shown in Figure 15.3, determine the modulus of elasticity and tensile strength at room temperature [20°C (68°F)], and compare these values with those given in Table 15.1.



15.3 For some viscoelastic polymers that are subjected to stress relaxation tests, the stress decays with time according to

$$\sigma(t) = \sigma(0)\exp\left(-\frac{t}{\tau}\right) \qquad (15.10)$$

where $\sigma(t)$ and $\sigma(0)$ represent the time-dependent and initial (i.e., time = 0) stresses, respectively, and t and τ denote elapsed time and the relaxation time; τ is a time-independent constant characteristic of the material. A specimen of some viscoelastic polymer with the stress relaxation that obeys Equation 15.10 was suddenly pulled in tension to a measured strain of 0.5; the stress necessary to maintain this constant strain was measured as a function of time. Determine $E_r(10)$ for this material if the initial stress level was 3.5 MPa (500 psi), which dropped to 0.5 MPa (70 psi) after 30 s.