Polymer Processing
Quiz 2 1/23/2001

a) **-Write** the total stress tensor and its two component tensors
-noting the number of independent terms in each tensor.
-Write and expression that relates these three tensors.

b) Explain why $\tau_{12} = \tau_{21}$ by,
-Drawing a box with Cartesian axis 1, 2 and 3 centered at one corner.
-Consider $\boldsymbol{\tau_{12} = F_1/A_2}$ where a force vector in the "1" direction is applied to the surface made by the 1 and 3 axes. **Sketch this** and the corresponding force vector from τ_{21}.
-If the torque on the box edge opposite the 3 axis edge is 0 (no rigid body rotations) explain why $\tau_{12} = \tau_{21}$.

c) **-Sketch** the viscosity of a typical polymeric fluid (high molecular weight and an oligomeric fluid (low molecular weight) as a function of shear rate.
-Define the "Newtonian plateau viscosity" in this sketch.
-Give a constitutive equation that describes the flow behavior of a polymer at high rates of strain.
-Show where De<<1, De=1 and De>>1 on this plot for both materials. (De is the Deborah Number which is the ratio of relaxation time to experimental time.)

d) **-How does** the viscosity of water change with temperature? Give a function.
-How does the viscosity of a polymer change with temperature? Give a function.
-What is the similarity between these two functions?

e) **-Write** the total velocity gradient tensor and its two component tensors
-noting the number of independent terms in each tensor.
-Write an expression that relates these three tensors.

Answers Quiz 2 Polymer Processing 1/23/01

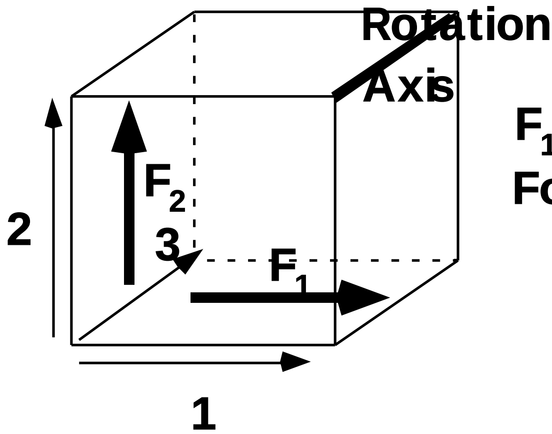
a)

$$\pi = \begin{pmatrix} P+\tau_{11} & \tau_{12} & \tau_{13} \\ \tau_{21} & P+\tau_{22} & \tau_{23} \\ \tau_{31} & \tau_{32} & P+\tau_{33} \end{pmatrix}$$

$\pi = P\delta + \tau$

6 1 5 Components.

b)



$F_1 = F_2$

For No Rotation

c)

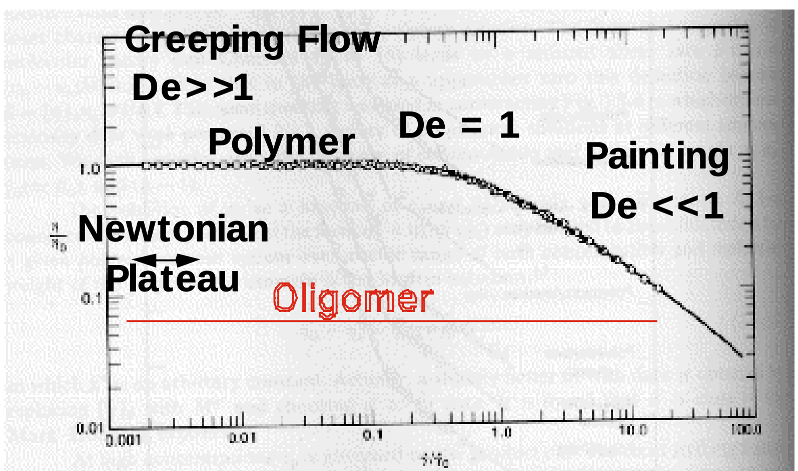


FIGURE 3.6-5. Composite plot of dimensionless viscosity η/η_0 versus dimensionless shear rate for several different concentrated polystyrene–n-butyl benzene solutions. Molecular weights varied from 1.6×10^5 to 2.4×10^6, concentrations from 0.255 to 0.55 g/cm^3, and temperatures from 303 to 333 K. [W. W. Graessley, *Adv. Polym. Sci.*, **16**, 1-179 (1974).]

$\eta = m\,(dv_x/dy)^{P-1}$ at high rates of strain.

d) See Notes:

Arrhenius for water:

$\eta/\eta_S = \exp(C/T)$

WLF

$\log(a_T) = C_1(\Delta T)/\{C_2+\Delta T\}$ or $\eta/\eta_S = \exp(C_1(\Delta T)/\{C_2+\Delta T\})$

$a_T = \eta/\eta_S$

-The two functions show similar behavior away from T_0.

e)

$$\nabla v = \begin{pmatrix} \frac{\partial v_1}{\partial x_1} & \frac{\partial v_2}{\partial x_1} & \frac{\partial v_3}{\partial x_1} \\ \frac{\partial v_1}{\partial x_2} & \frac{\partial v_2}{\partial x_2} & \frac{\partial v_3}{\partial x_2} \\ \frac{\partial v_1}{\partial x_3} & \frac{\partial v_2}{\partial x_3} & \frac{\partial v_3}{\partial x_3} \end{pmatrix}$$

Del v = 1/2(dγ/dt +del ω)

9 6 3 Components

del ω is the difference between **del v** and its transpose.

the rate of strain is the sum of **del v** and its transpose.