Aalto University
School of Chemical
Technology

KE-100.3410 Polymer properties

Exam 9.12.2012

1. a) Describe viscoelasticity.

   b) Draw a viscosity-shear rate picture for a typical pseudo plastic polymer.

   c) Define Williams-Landel-Ferry -equation

2. If you had access to the following characterization methods but were only allowed to use two of the methods, which would you use when asked to identify an unknown thermoplastic sample? FTIR, UV, GPC, DSC, TGA, ^{13}C-NMR and SEM. Explain how you would conduct your study, what is the principle of the chosen measurement, what information you can obtain and why did you choose it?

3. What is optimal operating temperature for semi-crystalline polymer, amorphous thermoplastic polymer, elastomer (rubber), and thermoset? How would you alter the operating temperature, give one example for each polymer type?

4. Polymers A and B are monodisperse polystyrenes. Molecular weight of Polymer A is three times the molecular weight of polymer B. Polymer C is polydisperse PS with $M_w = 2.0\times10^5$ g/mol. Mixture containing 25 g of polymer A, 50 g of polymer B and 25 g of polymer C was measured with light scattering and molecular weight obtained was 112 500 g/mol. With osmotic pressure the molecular weight was determined to be 60 000 g/mol. Estimate the number average molecular weight M_n of the polymer C.

5. Polypropylene PP rod attached to the ceiling (length 200 mm, width 25.0 mm, thickness 3.0 mm) is loaded with 30 kg´s. How much will the polymer creep in two minutes when the creep compliance $J(t)$ follows the equation (t is time in minutes)?

   $J(t) = 1.5 - \exp(-t/6\text{min})\ \text{GPa}^{-1}$

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EQUATIONS

$n = \frac{m}{M}$ $\quad c = \frac{n}{V}$ $\quad \rho = \frac{m}{V}$ $\quad V_m = \frac{V}{n} = \frac{M}{\rho}$ $\quad pV = nRT$ $\quad k = Ae^{-\frac{E}{RT}}$

$\bar{M}_n = M_0 \bar{X}_n$ $\quad p = 1 - \frac{[M]}{[M]_0}$ $\quad \sigma = \frac{F}{A}$ $\quad \varepsilon(t) = \frac{\Delta l}{l_0} = J(t) \times \sigma$ $\quad Q = \frac{P \times A \times t \times \Delta p}{l}$

Molecular weight:

$$\bar{M}_n = \frac{\sum n_i M_i}{\sum n_i} = \frac{\sum w_i}{\sum n_i} \qquad \bar{M}_w = \frac{\sum w_i M_i}{\sum w_i} = \frac{\sum n_i M_i^2}{\sum n_i M_i} \qquad PD = \frac{\bar{M}_w}{\bar{M}_n}$$

Viscosity:

$$\eta_r = \frac{\eta}{\eta_0} \approx \frac{t}{t_0} \qquad \eta_{sp} = \frac{\eta - \eta_0}{\eta_0} \approx \frac{t - t_0}{t_0} \qquad \eta_{red} = \frac{\eta_{sp}}{c} \qquad \eta_{inh} = \frac{\ln \eta_r}{c} \qquad [\eta] = \lim_{c \to 0}\left(\frac{\eta_{sp}}{c}\right)$$

$\eta_{red} = [\eta] + k_H [\eta]^2 c$ (Huggins) $\qquad [\eta] = k \times M_v^{\alpha}$ (Mark-Houwink)

$\log \frac{\eta}{\eta_s} = \frac{-8.86(T - T_s)}{101.6 + T - T_s} = \log a_T$ (WLF) $\qquad \eta = k \times \exp\left(\frac{E}{RT}\right)$

Constants:

$R = 8.3145$ J/(K mol) $\quad N_A = 6.022 \times 10^{23}$ mol^{-1} $\quad g = 9.80665$ m/s^2

0°C = 273.15 K $\quad$ 1 bar = 10^5 Pa

Molar masses (g/mol):

H	1.008	C	12.011	N	14.007	O	15.999
Al	26.982	Cl	35.453	Ti	47.867	Zr	91.224