Aalto University
School of Chemical
Technology

KE-100.3410 Polymer properties

Exam 18.2.2015

1. a) Draw the isotactic, syndiotactic and atactic structures of polypropylene

   b) What is the difference between homogenous and heterogeneous nucleation in crystallization?

   c) What is the optimal operating temperature of a semi-crystalline polymer, amorphous thermoplastic polymer, elastomer (rubber) and thermoset?

2. How could you determine whether a polymer sample consisted any **ceramic filler**? Chose **two** of the following methods: DSC, FTIR, UV, GPC, TGA, ^{13}C-NMR and SEM, and explain:
   - The operating principle of the method
   - What data you can obtain from it
   - Why you chose the method

3. Draw a typical flow curve obtained from DMA (Storage modulus vs. Temperature) for an amorphous polymer. Mark in the figure how the curve would differ if the material is crosslinked or semi-crystalline. Explain the five main regions found in a typical flow curve.

4. A sample of polystyrene is composed of a series of fractions of different sized molecules

a) Calculate the number average and weight average molecular weights of this sample as well as the PDI.

b) How would adding styrene oligomer change the average molecular weights? The added amount is 5wt.% of polymer mass and M=1000g/mol.

Table 1. PS fractions.

Fraction	weight fraction	Molecular weight [g/mol]
A	0.130	11000
B	0.300	14000
C	0.400	17000
D	0.170	21000

5. There is a novel polymer available for the production line with the following properties: melt viscosity at 140 °C is 1×10^5 Pa×s, glass transition temperature 110 °C but some decomposition starts at 160 °C. The production line is tailored for polymer viscosity 2×10^2 Pa×s running at 160 °C. What would the processing temperature have to be for the novel polymer grade in order to have viscosity in the range appropriate for the production line? How could the decomposition temperature of the polymer be altered (increased)?

EQUATIONS:

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

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

$\log\frac{\eta}{\eta_s} = \frac{-17{,}44\times(T-T_g)}{51{,}6+(T-T_g)}$ (Williams-Landel-Ferry) $\quad \eta = k\times\exp\left(\frac{E}{RT}\right)$ (Arrhenius)

$\bar{M}_n = M_0\bar{X}_n$ $\quad T_{g,oligomer} = T_g^{\infty} - \frac{K}{\bar{M}_n}$ (Fox-Flory) $\quad \frac{1}{T_g} = \frac{w_1}{T_{g,1}} + \frac{w_2}{T_{g,2}}$

Constants:

$R = 8.3145$ J/(K mol) $\quad N_A = 6.022\times10^{23}$ mol^{-1} $g = 9.80665$ 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

Polypropylene structure