Textbook Sample Exam

1) Choose an appropriate answer (20).

i. Choose the method that provides relative molecular weight rather than absolute.
   a. Osmotic pressure
   b. Light scattering
   c. NMR end-group analysis
   d. Intrinsic viscosity
   e. Freezing point depression

ii. Choose the polymer obtained from a difunctional monomer
   a. Network polymer
   b. Star polymer
   c. Dendrimer
   d. Linear
   e. Hyperbranched

iii. Choose a liquid crystalline polymer that is used for LC display such as a computer screen
   a. Cholesteric LC
   b. Nematic LC
   c. Smectic LC
   d. Atropic LC

iv. Choose the process that is not part of the Tromsdorff-Norrish effect.
   a. As the content of large polymer molecules increases with reaction time and the polymer solution eventually gels, the viscosity of the solution dramatically increases.
   b. The large molecular weight polymers produced suddenly form branched molecules.
   c. The small monomer molecules can easily diffuse to the polymer free radicals as well as the usual initiator free radicals.
   d. Thus, from the overall rate equation, a reduction in k, increases both Rp and Xn.
   e. The mobility of the polymer chain radicals nearly halts and hence ki is reduced substantially due to the low diffusion rates of the polymer free radicals in such viscous media. In the meantime, the initiator molecules continue to split. Thus, the steady-state condition no longer holds.

v. Disproportionation termination
   a. Two polymer free radicals combine to form even larger dead polymer
   b. A free radical transfers to a non-free radical partner molecule and continues to grow from these newly produced free radicals.
   c. Two polymer free radicals exchange an electron and proton to form two dead polymers.
   d. A block copolymer formation with a disproportionate composition of the block A and B.

vi. Choose one that is not part of Flory-Huggins theory assumptions
    a. The placement of N2 polymer chains in N1 lattice units, W(N1, N2), provides the entropy of mixing, ΔS, according to the Boltzmann equation shown below:
    $$\Delta S = k\, log(W(N1, N2))$$
    b. Polymer chains that are entangled will be excluded from the consideration.
    c. The lattice units have equal size, and each lattice unit can be occupied either by a solvent molecule or the chemical repeat unit.
    d. The number of neighboring chemical repeat units is called the valence number.
    e. A polymer solution can be regarded as chemical repeat units of the polymer chain occupying each lattice unit.

vii. Gordon-Tayler Equation
    a. An equation to calculate Tg of an immiscible blend by considering Tg and weight fraction of polymer components
    b. An equation to calculate G'
    c. An equation to calculate Tg of a miscible blend by considering Tg and weight fraction of the polymer components
    d. An equation to calculate Tg, of a miscible blend by considering Tg, thermal expansion coefficient and concentration of the polymer components
    e. An equation to calculate Tg, of an immiscible blend by considering Tg, thermal expansion coefficient and concentration of the polymer components

viii. G" in dynamic mechanical analysis
    a. It is a strain to failure in a shear experiment
    b. It is the dynamic strain in a tensile experiment
    c. It is the enthalpic relaxation in a polymer that froze in the thermal history
    d. It corresponds to the recoverable energy that was stored as elastic strain
    e. It corresponds to the irrecoverable energy that dissipates as heat

ix. Voigt Model
    a. A model that explains time-temperature superposition principle
    b. A model that explains creep behavior
    c. A model that evaluates the conversion of the gel effect
    d. A model that is made up with two dashpots in a parallel manner
    e. A model that is made up with a spring and dashpot in a series manner

x. Preform
    a. It is a formation of a laminate using an automated fabrication method
    b. A reversible formulation methods
    c. Previously formulated resin is painted on a reinforcing glass fiber cloth
    d. Unwoven chopped glass or carbon fibers are formed into a skeletal product shape and it is placed into an empty mold prior to resin injection
    e. A special matched metal die to direct the most efficient resin injection process.

2) You are asked to manufacture the following composite or polymer products.

i. A xylophone bar with the dimension of 5 cm (width) x 30 cm (length) x 1 cm (thickness). This is to be distributed to the nation's primary schools and thus million parts per month production is desired. The glass fiber content of the continuous filament should be very high (minimum of 50 vol%)

ii. A high density polyethylene pipe filled with 20% talc for gas pipe application (3cm diameter, 500m long)

iii. A jet ski that is on water 24hr a day

iv. A 15m long submersible glass fiber composite ship (simple submarine) that is to be used for underwater sightseeing (5 m underwater). Due to the water pressure, the rivet and adhesive use are highly discouraged.

v. A roof of a very light weight electronic car. The size is approximately 1.25m (wide) x 2.5 m (long) * 0.54 cm (thick). It is a concave rectangular shape. Monthly production rate is 5000. (The matrix to be chosen is polypropylene.)

Choose **<u>one technique</u>** out of:

A. Spray-up molding;
B. Compression molding;
C. Extrusion;
D. Reaction injection molding;
E. Thermoforming
F. Hand lay-up molding;
G. Vacuum-assisted Resin Transfer molding;
H. Transfer molding;
I. Pultrusion,
J. Filament winding.
K. Blow molding
L. Injection molding
M. Centrifugal molding

for the above products. Do not choose the product for the technique, but choose the technique for the product. You may choose the same technique more than once for different products if necessary. However, if you choose more than one technique for a particular product, you will receive zero points (10)

3) Answer the following T/F questions.

i. *Fourier transform infrared spectroscopy (FTIR)*

FTIR uses a device called Michelson interferometer to obtain the signal instead of the traditional dispersive element such as a prism or grating. Michelson interferometer has two mirrors, one is stationary and the other moving. The modulated signal is obtained as a function of time, which is then mathematically converted into a frequency domain spectrum through the operation called inverse Fourier transformation. Thus, the name Fourier transform infrared spectroscopy is used.

ii. *Size exclusion chromatography*

Size exclusion chromatography uses crosslinked polystyrene that is full of voids. The molecules with different sizes go in and out of those voids and thus develop differences in residence time. The small molecular comes out of the column first and thus appears in the chromatogram first, followed by the large molecule.

iii. *Reptation theory*

It is the theory proposed by Professor Pierre du Genne of France who later received a Nobel prize. This theory tries to explain the low power dependence of the relationship between the molecular weight and viscosity. This theory can also predict the properties as a function of time. Therefore, it can be used for the accelerated test and predict the properties for a product that is to have 100 year life time.

iv. *Nuclear magnetic resonance spectroscopy (NMR)*

This technique is ideal in determining detailed chemical structures of liquid samples. Using the chemical shift concept, the chemical structure of a molecule can relatively easily be deduced. However, one cannot determine the number of components in unknown samples.

v. *Solubility parameter*

The solubility parameter can be used to evaluate an appropriate solvent to dissolve a polymer. The molar contribution approach can be used to calculate the solubility parameter once the molecular structure of the polymer is known. The larger the difference in solubility parameter between the polymer and solvent, the more difficult it is to dissolve the polymer in this solvent.

vi. *Thermogravimetric analysis (TGA)*

TGA uses an extremely accurate balance to monitor the change of weight of a sample as the micro-furnace temperature is linearly increased. At a certain temperature, the sample starts degrading and reduces the weight. Under an inert atmosphere, some material does not completely disintegrate even at 800oC. The residual weight for this sample at this temperature is called "char yield" and is a measure of the ease of carbonization.

vii. *Living polymerization*

Termination of polymerizing species creates the molecular weight distribution. Thus, the more termination mechanisms, the wider the PDI. However, using ionic polymerization, the rate of polymerization is extremely fast and one can afford using sub-zero temperature. effectively eliminates the chain transfer termination mechanism. Along with the intrinsic lack of combination termination mechanism, there is practically no termination mechanism. This polymerization is thus called living polymerization and can be used to produce polymers with PDI very close to 2.00.

viii. *Staudinger's proposed concept on macromolecules*

Staudinger's initial proposal on the macromolecular concept received heavy criticism due to the fact that he did not use large molecules for his experiment. Even detrimentally, he used a colligative property that is more sensitive to small molecules than a large molecule. He continued experimenting for nearly 10 years using a similar approach that did not allow him to overcome those criticisms. Eventually, he used the light scattering method that is the absolute molecular weight determination method and more importantly sensitive to large molecular weight. Finally, therefore, he successfully overcame the opposition by the colloidal scientist and the entire world accepted the concept of macromolecules. He is the first Nobel laureate in polymer science.

ix. *Rubber elasticity theory*

According to the rubber elasticity theory, an ideal rubber will decrease the entropy upon stretching. This expectation leads to the experimentally observed phenomenon called "strain-induced crystallization." The theory further predicts the increased strength or modulus as the temperature increases. In reality, the increase is not observed. However, the modulus of the rubbery material above the Tg does not decrease as the temperature increases. This is used as a strong support for the existence of crosslinking.

x. *Differential scanning calorimetry (DSC)*

This technique uses flow of heat as the detection scheme. Any phenomenon that accompanies heat flow can be studied using DSC. Thus, phenomena, such as Tg,

polymerization exotherm, crystallization endotherm, are all studied extensively using DSC.

4) Choose an appropriate answer (20).

i. Choose one wrong statement.
   a. Transfer molding effectively eliminates the production of flash.
   b. Filament winding produces a high performance composite, but is poor in productivity. Thus, it is typically used for products with high performance, expensive resins.
   c. Pultrusion is the only continuous composite processing technique that can be used for continuous fibers
   d. Reaction injection molding is so fast and versatile. Many known thermoplastic resins can be molded using this processing method.
   e. Spray-up molding is more labor intensive than compression molding, but less labor intensive than hand lay-up molding.

ii. Chemical shift in NMR spectroscopy
   a. It is the shift caused by optical interaction
   b. It is the shift caused by chemical reaction
   c. It is the shift caused by local magnetic field environment
   d. It is the shift caused by fluctuation of NMR superconducting magnet
   e. It is the shift caused by fluctuation of temperature of the magnet

iii. What can you learn from dynamic mechanical analysis?
   a. Intrinsic viscosity of a random copolymer
   b. Tan δ
   c. Polymerization enthalpy
   d. Crystallization exotherms
   e. Strength of material

iv. What is not the property of condensation polymerization?
   a. Disproportionation termination mechanism
   b. Monomer concentration rapidly reduces as a function of reaction time
   c. Towards the end of conversion, the molecular weight rapidly increases.
   d. Relatively slow rate of polymerization

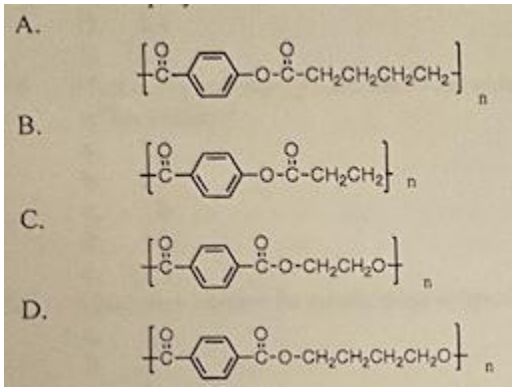
v. I have an unknown polymer sample with a total weight of 1.284 g. What is the most appropriate technique to determine the glass transition temperature of this polymer?
   a. Proton nuclear magnetic resonance spectroscopy (H NMR)
   b. Size exclusion chromatography (SEC)
   c. Thermogravimetric analysis (TGA).
   d. Time of flight, matrix assisted laser desorption ionization mass spectroscopy (MALDI-TOFF).
   e. Dynamic mechanical analysis (DMA).

vi. The Fox Equation
   a. It is the equation to calculate the molecular weight using the intrinsic viscosity.
   b. It is the equation to determine the polymer chain/solvent interaction energy.
   c. It is the equation to predict the Tg of a miscible blend
   d. It is the equation to predict the Tg of an immiscible blend considering thermal expansion coefficient.
   e. It is the equation to predict the Tg of a miscible blend considering thermal expansion coefficient.

vii. Radius of gyration
   a. It is a chain rotation under zero gravity
   b. It is the volume shrinkage under hydrostatic pressure
   c. It is the volume expansion under the chain rotation
   d. It is the experimentally determinable size of the molecule that relates to the end-to-end distance and is smaller than the end-to-end distance.
   e. It is the experimentally determinable size of the molecule that relates to the end-to-end distance and is larger than the end-to-end distance.

viii. What is not the advantage of composite materials?
   a. It combines the advantages of both components. Sometimes, synergism can also be observed.
   b. It offers improved dimensional stability
   c. By adding inexpensive extender, the total cost of the composite can be reduced
   d. It is much easier to process than homopolymer, thus is less expensive than non-composite polymeric products.
   e. It can produce a light weight and extremely strong material.

ix. Which polymer shown below is the correct poly(ethylene terephthalate)?



x. Inhibitor
    a. It is an additive that is used to stop the polymerization reaction. Thus, we can save the unused resin for a future use.
    b. It is an additive that decreases the viscosity of the resin
    c. It is an additive that works based on the radical scavenger mechanism
    d. It is an additive that works based on the intra-molecular chain transfer mechanism
    It is an additive that works based on the inter-molecular chain transfer mechanism

5) Choose an appropriate answer (20).

i. Poisson's ratio of an ideal rubber..
   a. 0.01
   b. 0.5
   c. 5.0
   d. 10

ii. A solvent is called the Θ-solvent when the Flory-Huggins & parameter of the solvent for the polymer of interest is:
   a. 2000
   b. 200
   c. 50
   d. 5
   e. 0.5

iii. Tg of a thermodynamically miscible polymer blend made of 50:50 weight ratio of polymer A with Tg =250K and polymer B with Tg = 500K
   a. below 300K
   b. between 310 and 340K
   c. 375K
   d. between 380 and 410K
   e. above 420K

iv. Tg is an iso-free volume concept. What is the volume fraction of the free volume at Ig?
   a. 2.5%
   b. 5%
   c. 0.025
   d. 0.05
   e. 0.1

v. The molecular weight dependence of the viscosity below the entanglement molecular weight in a log-log plot (slope of the straight line)
   a. 0.1
   b. 1
   c. 1.4
   d. 3.4
   e. 4.1

vi. What is the number of carbons of the side chains that is most favorably produced as a result of backbiting?
   a. 2.5
   b. 5
   c. 16
   d. 1
   e. 2

vii. A polymer cannot be synthesized when the number of functionality is:
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

viii. An equal number fraction of three different molecular weight polymers are mixed. When the PDI is 3, what is the weight average molecular weight of the blend if polymer A, B and C has molecular weight of 30,000, 60,000 and 90,000, respectively.
   a. 30,000
   b. 60,000
   c. 120,000
   d. 180,000
   e. 380,000

ix. When Material A has a modulus of 24.6 MP a and strain to break is 1020% while Material B has a modulus of 6 GPa and strain to break is 3.02%, Material A is:
   a. stronger than B
   b. more rigid than B
   c. more flexible than B
   d. more viscous than B
   e. more brittle than B

x. Two polymers are readily miscible when the Flory-Huggins x parameter is:
   a. 1.02
   b. 0.66
   c. -0.01
   d. 0.68
   e. 0.51

6) State if the following materials fit the definition of a composite material or not (10).

i. A precipitated silica (average diameter of the primary particle is 32.5 m, though they are expected to be agglomerated) fillers colored, styrene-butadiene rubber tires. The color of the tire is a deep Prussian blue.
    a. Composite
    b. Non-composite

ii. A Kevlar bullet proof jacket with a thickness of 22.3 mm. The fiber diameter is 35 um. The product is designed to stop a bullet of 44 Remington Magnum handgun.
    a. Composite
    b. Non-composite

iii. An exfoliated laponite filled polybenzoxazine. The laponite filler is made of a synthetic silicate with the primary particle of the thickness of 1 nm, and a diameter of 25 nm. It is a circular disc shape. The filler content is 4.65% by weight.
    a. Composite
    b. Non-composite

iv. A mica filler and polypropylene powder mixture. The mica filler has an average diameter of 159 um, and the thickness of 9.58 um. The polypropylene has a rather narrow distribution of particle size around 96 um. Due to the close proximity of the particle sizes, the mixing is expected to be rather homogeneous.
    a. Composite
    b. Non-Composite

v. A rigid-rod polymer with the number average molecular weight of 34,000 is melted with a coiled, amorphous transparent polymer with the number average molecular weight of 145,000 at 280°C. This mixture is then cooled to room temperature to mold a solid product with the rod molecule content of 1.37 % by weight. The solid material upon cooling is relatively transparent.
    a. Composite
    b. Non-Composite