**MSE 214**
**Practice Exam**
**(~1/2 the length of the full exam)**
**17th Dec 2025**

**Part A: Multiple Choice Questions (20 pts)**
**Instructions: Circle the correct answer or answers; no negative marking**

**Q1. What is the correct definition of Degree of Polymerization?**

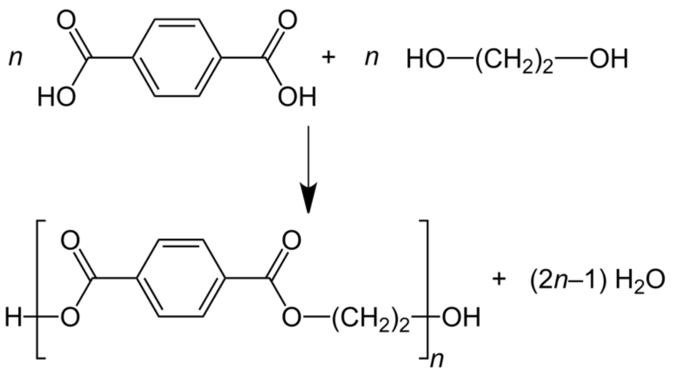
a) Average number of repeat units in each polymer chain

b) Average number of monomeric units in each polymer chain

c) The total number of monomers consumed at time *t*.

d) The fraction of monomers consumed at time *t*.

**Q2: For the polymerization reaction shown, which of the terms below can be used to classify it? <u>Circle all that are correct.</u>**




a) Homopolymer

b) Copolymer

c) Chain-growth polymerization

d) Step-growth polymerization

e) Condensation polymerization

f) Addition polymerization

**Q3: For a chain-growth radical polymerization with bimolecular termination, the polymer produced contains an average of 1.44 initiator fragments per polymer molecule. Assuming no chain transfer occurred, what percentage of polymer chains terminated by coupling?**

a) 39%

b) 61%

c) 50%

d) 26%

**Q4: Circle <u>all</u> statements that are true.**

a) A chemically crosslinked polymer in a good solvent will dissolve.

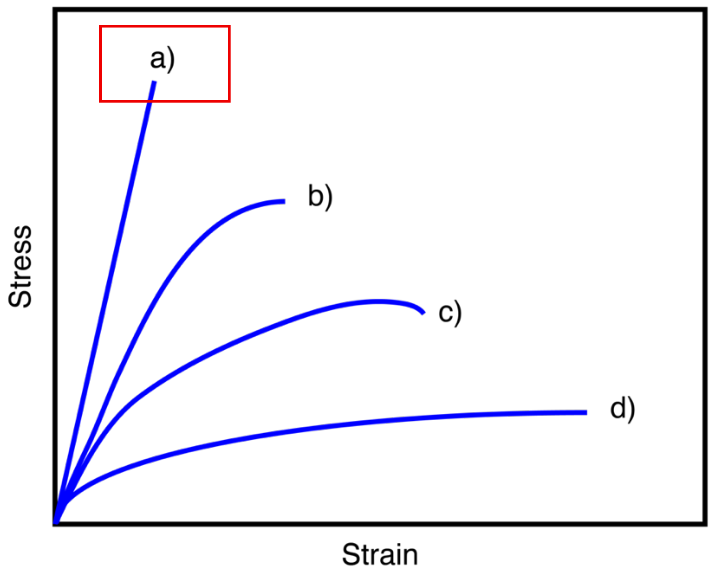
b) A physically crosslinked polymer in a good solvent will dissolve.

c) Chemically crosslinked polymers are generally stronger than physically crosslinked polymers.

d) Only chemical crosslinks can contribute to the mechanical strength of polymers.

e) Physically crosslinked polymers often have higher thermal stability than chemically crosslinked polymers.

**Q5: The stress-strain curves shown below all correspond to the same polymer tested at the same temperature, but at different strain rates. Which tensile test was most likely performed at the highest strain rate? <u>Circle the option in the graph.</u>**



**Q6: Which of the following are commonly used methods to prevent corrosion in metals? Circle all that are correct.**

a) Applying a protective coating, such as paint or a polymer layer.

b) Using cathodic protection, i.e. coupling the metal to a sacrificial metal at the anode.

c) Using anodic protection, i.e. coupling the metal to a sacrificial metal at the cathode.

d) Alloying the metal with elements like chromium to improve their corrosion resistance.

e) Heating the metal to high temperatures to eliminate corrosion.

**Q7: How does alloying impact the mechanical properties of a metal?**

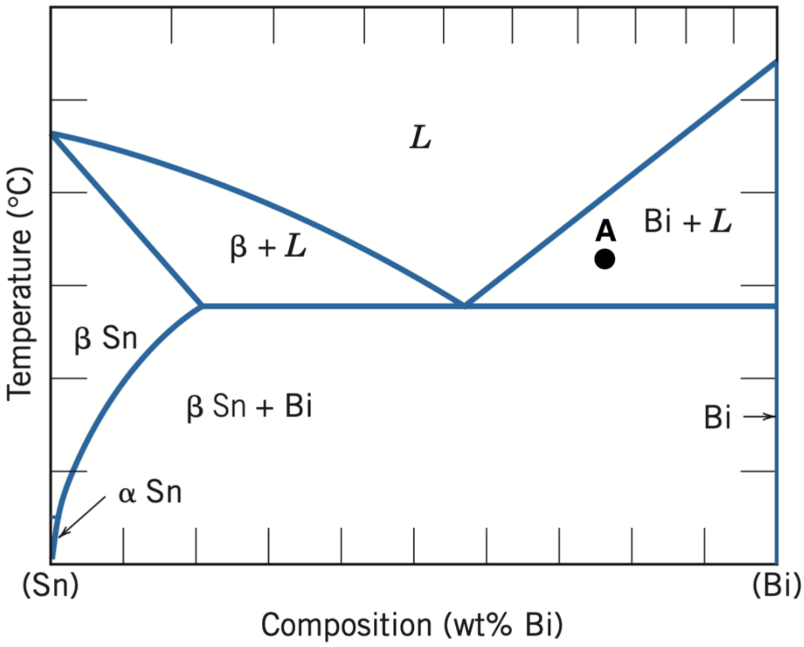
a) Alloying introduces new dislocations, which reduces the strength of the metal.

b) Alloying creates lattice distortions that impede dislocation motion, which increases the strength of the metal.

c) Alloying eliminates dislocations from the metal, which increases the strength of the metal.

d) Alloying increases dislocation mobility, which reduces the strength of the metal.

**Q8: The Sn-Bi phase diagram is shown below. At point A, approximately what percentage of the alloy is liquid by mass?**



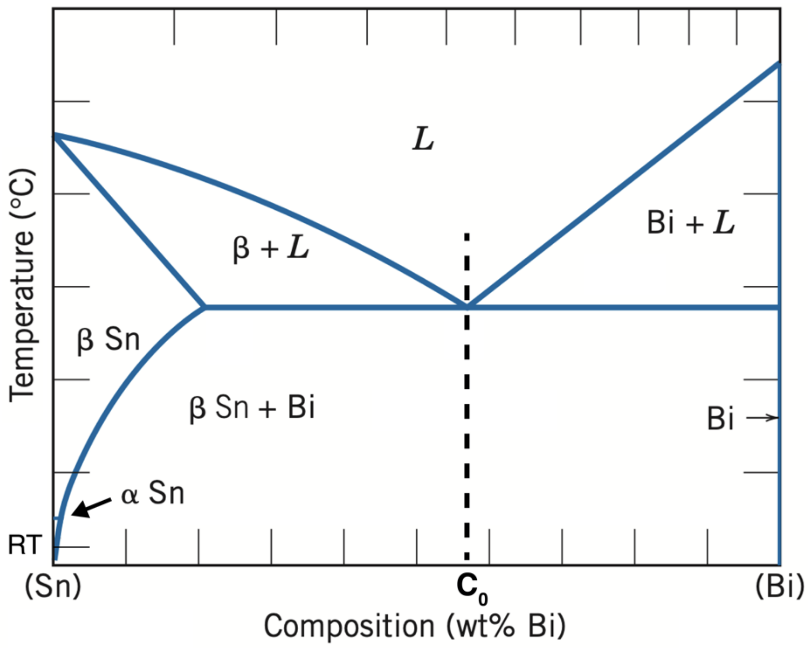

a) 68%

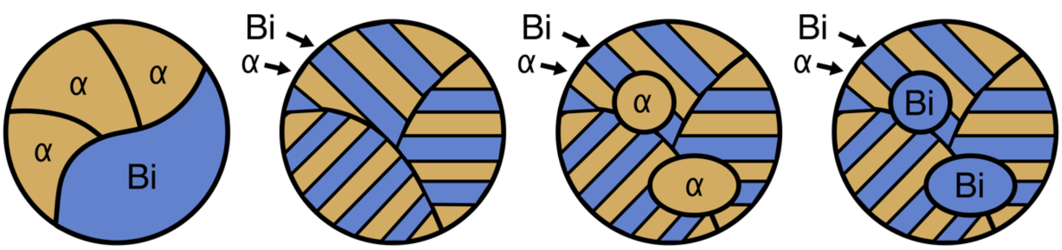
b) 32%

c) 50%

d) 75%

**Q9: The Sn-Bi phase diagram is shown below. An alloy with composition $C_0$ was cooled slowly from the melt to room temperature (RT). Assuming an equilibrium microstructure, what microstructure does this alloy have?**




a) b) c) d)

**Q10: A part made of a steel alloy with a $K_{IC}$ value of 60 MPa$\sqrt{m}$ has a surface crack that is 1 mm long. What is the maximum amount of stress that the part can tolerate before it fractures? Assume Y = 1.**

a) 33 MPa

b) 60 MPa

c) 1071 MPa

d) 1897 MPa

**Part B: Short Open-Ended Questions (24 pts)**

**Q11: A sample of polystyrene is composed of multiple groups of different sized molecules (see table below).**

a) **Calculate the number average molecular weight, the weight average molecular weight, and dispersity of this polymer sample. Show how you obtained your answer. (3 pts)**

| Group | Number of moles | Molar mass (g/mol) |
|---|---|---|
| 1 | 0.20 | $5.0 \times 10^3$ |
| 2 | 0.25 | $7.5 \times 10^3$ |
| 3 | 0.20 | $1.0 \times 10^4$ |
| 4 | 0.15 | $1.4 \times 10^4$ |
| 5 | 0.12 | $2.0 \times 10^4$ |
| 6 | 0.08 | $2.6 \times 10^4$ |
| 7 | 0.05 | $3.4 \times 10^4$ |

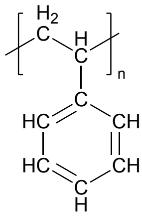
$$M_n = \frac{\sum N_x M_x}{\sum N_x} = 12529 \text{ g/mol}$$

$$M_w = \frac{\sum N_x M_x^2}{\sum N_x M_x} = 17358 \text{ g/mol}$$

$$D = \frac{M_w}{M_n} = 1.38 = 1.4$$

**b) What is the degree of polymerization of the polystyrene sample described in part a)? Show how you obtained your answer. (2 pts)**

**The structure of polystyrene is shown below. If needed, the atomic weights of carbon and hydrogen are 12 g/mol and 1 g/mol respectively.**




Molar mass of monomeric unit ($M_0$) = 104
Degree of polymerization = $M_n/M_0$ = 12529 / 104 = 120

**Q12: a) Explain why semi-crystalline polymers are often translucent/opaque. (1 pt)**

The crystalline domains scatter light and reduce light transmission

**b) Some semi-crystalline polymers with a high degree of crystallinity (the wt% of crystalline phases) are transparent. Explain how this is possible. (1 pt)**

The crystalline domains are smaller than the wavelength of light

**Q13: What is one unintended consequence of recycling polymers? (1 pt)**

Any one of these:

The release of microplastics into the environment

Mixing of polymers leading to changes in properties

Chemical contaminants from recycled plastics

**Q14: Why are polymers lightweight? (2 pts)**

Typically made of light elements (carbon, oxygen, hydrogen)

Low density since polymers do not pack well

**Q15: List two advantages that additive manufacturing has over injection molding. (2 pts)**

Any of these two:

Design flexibility
Low startup cost
Capable of small-medium production volume
Rapid prototyping

**Q16: A helicopter blade is made of a laminated composite of epoxy and high strength carbon fibres.**

**a) Express the relationship between the tensile centrifugal load on the blade during operation and all the possible deformations of the blade. (1 pt)**

$$[N] = [A][\varepsilon^0] + [B][K]$$

$$N_x = A_{11}\varepsilon_x^0 + A_{12}\varepsilon_y^0 + A_{16}\gamma_{xy}^0 + B_{11}K_x + B_{12}K_y + B_{16}K_{xy}$$

**b) Without changing the weight fraction of the filler phase, state one possible strategy to further increase the stiffness of the blade. (1 pt)**

Use a sandwich structure with the laminate as skins

Use high modulus carbon fibres

**Q17: Using band theory, explain why metals can be electrically conductive even at 0K. (2 pts)**

Metals do not have a band gap between the valence and conduction band

Thus, even in the absence of thermal energy, an applied electric field can cause electrons to flow, and result in conductivity

**Q18: With respect to metal processing, what is one major limitation of phase diagrams? (1 pt)**

Any variant of these:

Non-equilibrium phases do not appear on the phase diagram

The phase diagram does not provide any information about the kinetics of phase formation

**Q19: A turbine blade is fabricated from an alloy that has a fracture toughness ($K_{IC}$) of 35 MPa$\sqrt{m}$. The blade fractures at a stress of 250 MPa when the maximum internal crack length is 2.0 mm. For this same component and alloy, will fracture occur at a stress level of 325 MPa when the maximum internal crack length is 1.0 mm? Show how you obtained your answer. (2 pts)**

We first need to determine Y

**From Case 1: 250 MPa, 2a = 2.0 mm**
Internal crack length = 2a = 2.0mm

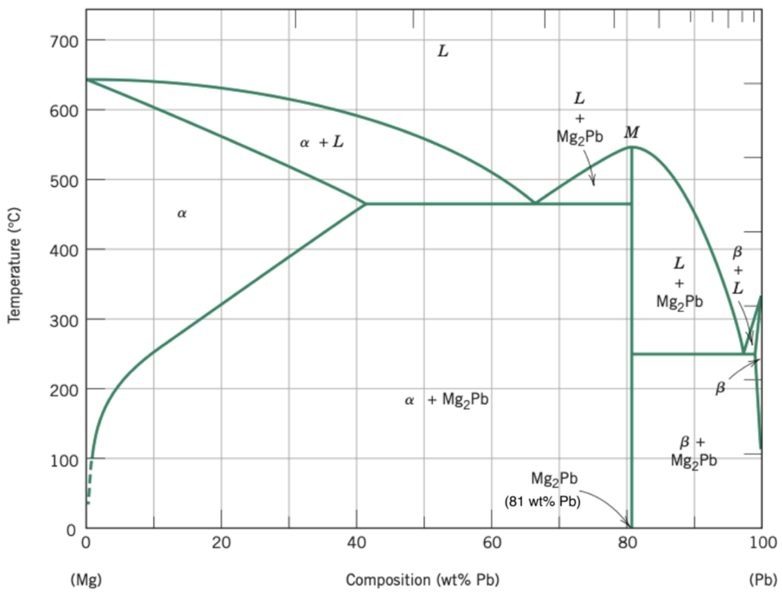
$K_{IC} = \sigma Y \sqrt{\pi a}$

$$Y = \frac{K_{IC}}{\sigma\sqrt{\pi a}} = \frac{35}{250\sqrt{\pi(0.001)}} = 2.50$$

Then can either determine K and compare to $K_{IC}$, or determine $\sigma_c$ and compare to $\sigma$. In the former, K = 32, which is less than KIC of 35. For the latter, $\sigma_c$ is 353 which is less than the applied $\sigma$ of 325.

Fracture will not occur under the second loading conditions.

**Q20: The Mg-Pb phase diagram is shown below. A 50 wt% Pb – 50 wt% Mg alloy is slowly cooled from 700˚C to 400˚C.**




**a) What temperature does the first solid phase form? (0.5 pt)**

560˚C (accept to within +- 10˚C)

**b) What is the composition of this first solid phase? (0.5 pt)**

21wt% Pb – 79wt% Mg (accept to within +- 1wt% Pb)

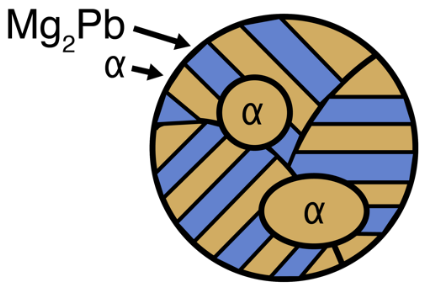
**c) What temperature does the last liquid phase solidify? (0.5 pt)**

465˚C (accept to within +- 10˚C)

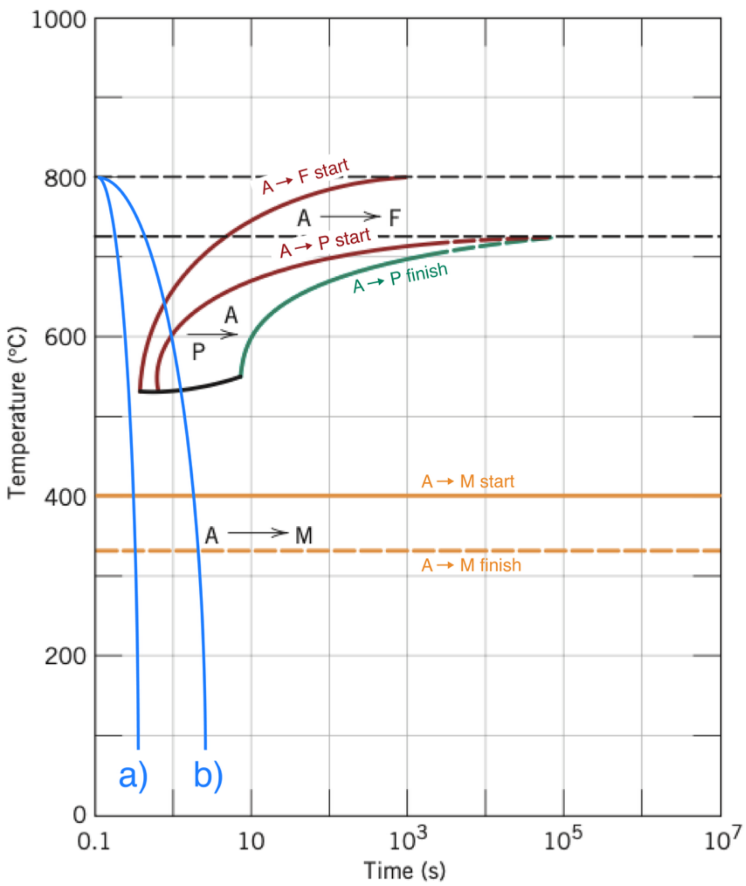
**d) What is the composition of the last liquid phase before it solidifies? (0.5 pt)**

67wt% Pb – 33wt% Mg (accept to within +- 1wt% Pb)

**e) Sketch the microstructure of the alloy at 400˚C. Please label the phases appropriately. (1 pt)**



**Q21: The continuous cooling transformation (CCT) diagram for a 0.35 wt% C iron-carbon alloy is shown below. Three different cooling curves (in blue; labeled a), b), and c)) are superimposed onto the CCT diagram. At 800˚C, the alloy is completely in the A phase.**




a) **State what phases you would expect if the alloy was cooled via cooling curve a). Use the letters in the diagram, e.g. A + M or M + P, etc. (1 pt)**

M

b) **State what phases you would expect if the alloy was cooled via cooling curve b). Use the letters in the diagram, e.g. A + M or M + P, etc. (1 pt)**

M + F + P