No notes, books, or information stored in calculator memories may be used. Cheating will be punished severely. All of your work must be written on these pages and turned in. Mark your answer on this paper first, and then copy onto the answer sheet at the end of the test. Use #2 pencil to mark the answer sheet.

Multiple choices (3 points each):

C 1. Shown on the right is
   A. an ethylene molecule
   B. an ethylene monomer
   C. a vinyl molecule
   D. a vinyl monomer

B 2. Shown on the right is
   A. polyethylene
   B. a vinyl polymer
   C. a vinylidene polymer

B 3. Polymerization involves the following 3 steps
   A. Radical generation, monomer reaction, and polymer molecule growth
   B. Initiation, propagation, and termination
   C. Catalyst reaction, monomer reaction, and entanglement
   D. None of the above

A 4. \( R \rightarrow O \rightarrow O \rightarrow R \rightarrow 2R \rightarrow O \) represents
   A. A reaction to produce free radicals
   B. Initiation of polymerization
   C. Dissociation of hydroxide
   D. Propagation

B 5. \( R \rightarrow O' + C \rightarrow C \rightarrow R \rightarrow O \rightarrow C \) represents
   A. A reaction to produce free radicals
   B. Initiation of polymerization
   C. Dissociation of hydroxide
   D. Propagation

B 6. ABBABABBBAAAAABA represents
   A. A homopolymer
   B. A random polymer
   C. An alternating polymer
D. A block polymer  
E. A graft polymer

**A** 7. In the right figure, \( T_m \) represents the

A. melting temperature of a partly crystalline polymer  
B. melting temperature of noncrystalline polymer  
C. glass transition temperature of a partly crystalline polymer  
D. glass transition temperature of noncrystalline polymer

**D** 8. The formula on the right represents the

A. natural rubber  
B. styrene-Butadiene rubber  
C. nitrile rubber  
D. polychloroprene rubber  
E. silicone rubber

**A** 9. The formula on the right represents the

A. natural rubber  
B. styrene-Butadiene rubber  
C. nitrile rubber  
D. polychloroprene rubber  
E. silicone rubber

**B** 10. The figure on the right represents

A. elastic deformation  
B. elastic or plastic deformation  
C. plastic deformation

**B** 11. Below the glass transition temperature, \( T_g \), a thermoplastic polymer

A. can deform plastically  
B. can only deform elastically  
C. will be brittle  
D. will melt

**B** 12. A thermoset polymer

A. can deform plastically above the glass transition temperature  
B. can only deform elastically  
C. will melt above the melting temperature  
D. none of the above

**B** 13. Above the melting temperature, \( T_m \), a partially crystalline thermoplastic polymer

A. will melt partially
B. will melt totally
C. none of the above

D. 14. The following can strengthen a thermoplastic except

A. increasing molecular weight
B. adding side groups
C. increasing crystallinity
D. mixing with a plasticizer

C. 15. A copolymer consists of 15 wt% of PVA and 85% PVC. Determine the mole fraction of PVC. The mass of a PVA mer is 86 g/mol. The mass of a PVC mer is 62.5 g/mol.

A. 0.113 B. 0.174 C. 0.887 D. 1.36

Let the mole fraction of PVC = x. Assume there are a total of 100 g of copolymer. The weight of the PVA is 15 g and the weight of PVC is 85 g.

The mole # of PVA is M(PVA) = 15g/86 g/mole = 0.1744 mole
The mole # of PVC is: M(PVC) = 85g/62.5 g/mole = 1.36 mole
The mole fraction of PVC = 1.36/(1.36+0.1744) = 0.887

D. 16. Determine the mole fraction of PVA in a PVA+PVC copolymer, which has a molecular weight of 10520 g/mol and a degree of polymerization of 160. The mass of a PVC mer is 62.5 g/mol. The mass of a PVA mer is 86 g/mol.

A. 0.113 B. 0.174 C. 0.86 D. 0.14

Let the fraction of PVA as x
10520 = [86x +(1-x)62.5]*160, x= 0.14

C. 17. A stress of 1100 psi is applied to an elastic rubber at a constant strain. After 40 days at 20°C, the stress decreases to 700 psi. What is the stress after 60 days at the same temperature?

A. 300 psi B. 500 psi C. 559 psi D. 437 psi

700 = 1100 exp(-40/τ) τ = 88.5 days
σ = 1100 exp(-60/88.5) = 559 psi

A. 18. An ABS copolymer consists of 25 wt% of polyacrylonitrile, 30 wt% polybutadiene, and 45 wt% polystyrene. The mass of acrylonitrile mer is M_n = 53 g/mol; the mass of butadiene mer is M_b = 54 g/mol; the mass of styrene mer is M_s = 104 g/mol. The mole fraction of polyacrylonitrile is

A. 0.322 B. 0.384 C. 0.294 D. 0.423

Assuming that there are 25 g of polyacrylonitrile, 30 g polybutadiene, and 45 polystyrene.
Fraction polyacrylonitrile = (25/53)/(25/53 + 30/54 + 45/104) = 32.2%

B. 19. An ABS copolymer consists of 25 wt% of polyacrylonitrile, 30 wt% polybutadiene, and 45 wt% polystyrene. The mass of acrylonitrile mer is M_n = 53 g/mol; the mass of butadiene mer is M_b = 54 g/mol; the mass of styrene mer is M_s = 104 g/mol. The mole fraction of polybutadiene is

A. 0.322 B. 0.384 C. 0.294 D. 0.423
Assuming that there are 25 g of polyacrylonitrile, 30 g polybutadiene, and 45 polystyrene.

Fraction of butadiene = \( \frac{30/54}{25/53 + 30/54 + 45/104} \) = 0.381

__A__ 20. A stress of 100 MPa is applied to an elastomer at 27 °C, and after 25 days the stress is reduced to 75 MPa. At 50 °C, the stress is reduced to 40 MPa. Calculate the activation energy. R=8.314 J/(mol K).

\begin{align*}
\text{A. } 41 \text{ kJ/mol} & & \text{B. } 235 \text{ kJ/ml} & & \text{C. } 98 \text{ kJ/mol} & & \text{D. } 148 \text{ kJ/mol}.
\end{align*}

\[
\ln \left( \frac{1}{\tau_1} - \ln \frac{1}{\tau_2} = -\frac{Q}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \right), \quad Q = 41 \text{ KJ/mol}
\]

__A__ 21. A tensile stress of 50 MPa is applied to an elastomer at 27 °C, and after 5 minutes the stress is reduced to 25 MPa. Calculate the relaxation time. R=8.314 J/(mol K).

\begin{align*}
\text{A. } 7.21 \text{ minutes} & & \text{B. } 2.0 \text{ minutes} & & \text{C. } 5.0 \text{ minutes}.
\end{align*}

\[
\ln \left( \frac{\sigma}{\sigma_0} \right) = -\frac{t}{\tau}, \quad \tau = 7.21 \text{ min}.
\]

__C__ 22. A tensile stress of 50 MPa is applied to an elastomer at 27 °C, and after 5 minutes the stress is reduced to 25 MPa. Calculate the load after 30 minutes. R=8.314 J/(mol K).

\begin{align*}
\text{A. } 72.2 \text{ MPa} & & \text{B. } 3.2 \text{ MPa} & & \text{C. } 0.78 \text{ MPa}.
\end{align*}

\[
\ln \left( \frac{\sigma}{\sigma_0} \right) = -\frac{t}{\tau}, \quad \tau = 7.21 \text{ min}. \quad \sigma_2 = \sigma_0 e^{\frac{30}{7.21}} = 0.78 \text{ MPa}
\]

__B__ 23. An elastomer can be made stiffer (the modulus can be increased) by

A. heating it above the Tg
B. increasing the amount of cross-linking
C. decreasing the amount of cross-linking
D. none of the above

__C__ 24. A ceramic compound has a coordinate of 4, the ratio \( r_{\text{cation}}/r_{\text{anion}} \) is

\begin{align*}
\text{A. } r_{\text{cation}}/r_{\text{anion}} & \geq 0.732
\text{B. } 0.414 & \leq r_{\text{cation}}/r_{\text{anion}} < 0.732
\text{C. } 0.225 & \leq r_{\text{cation}}/r_{\text{anion}} < 0.414
\text{D. } 0.155 & \leq r_{\text{cation}}/r_{\text{anion}} < 0.225
\text{E. } r_{\text{cation}}/r_{\text{anion}} & \leq 0.225
\end{align*}

__D__ 25. A ceramic compound has a coordinate of 3, the ratio \( r_{\text{cation}}/r_{\text{anion}} \) is
26. In the ZrO₂, the electronegativity difference is 2.3. The % ionic character of Zr-O bond is
   A. 73%, B. 27% C. 32% D. 68%

27. The figure on the right represents this crystal structure
   A. CsCl B. NaCl C. CaF₂ D. ZnS

28. The figure on the right represents this crystal structure
   A. CsCl B. NaCl C. CaF₂ D. ZnS

29. Ceramics typically have
   A. high tensile strength B. high compressive strength C. high ductility D. high toughness

30. A covalently bonded ceramics under compressive load may
   A. fracture in brittle mode if it is a single crystal B. deform in plastic mode if it is a single crystal C. fracture in brittle mode if it is polycrystalline D. fracture in plastic mode if it is polycrystalline E. Both A and C F. Both B and D

31. An ionic bonded ceramics under compressive load may not
   A. fracture in brittle mode if it is a single crystal B. deform in plastic mode if it is a single crystal C. fracture in brittle mode if it is polycrystalline D. fracture in plastic mode if it is polycrystalline

32. A large ceramic part
   A. is weaker than a small ceramic part B. has the same strength as a small ceramic part C. is likely weaker than a small ceramic part
likely has the same strength as a small ceramic part

33. The toughness of a ceramic materials can be described as $K_{IC} = Y\sigma_f\sqrt{a}$, where $Y$ is the geometry factor, $a$ is the crack length
   A. $K_{IC}$ changes with the geometry factor $Y$
   B. $K_{IC}$ changes with applied stress
   C. $K_{IC}$ changes with crack length
   D. All of above
   E. None of the above

34. In the CsCl compound, the ionic radii of Cs+ and Cl- are 0.170 nm and 0.181 nm, respectively, the coordination number should be
   A. 3,  B. 4,  C. 6,  D. 8

35. In the NaCl compound, the ionic radii of Na+ and Cl- are 0.102 nm and 0.181 nm, respectively, the coordination number should be
   A. 3,  B. 4,  C. 6,  D. 8

36. In the CsCl compound, the ionic radii of Cs+ and Cl- are 0.170 nm and 0.181 nm, respectively. Calculate the packing factor
   A. 0.68,  B. 0.74,  C. 0.63,  D. 0.48

37. In the Zinc blende (ZnS) compound, the ionic radii of Zn$^{2+}$ and S$^{2-}$ are 0.060 nm and 0.174 nm, respectively, and their atomic masses are 65.37 g/mol and 32.06 g/mol, respectively. Avogadro’s constant $N_A = 6.023 \times 10^{23}$ mol$^{-1}$. Calculate its density in g/cm$^3$:

38. A Kevlar-epoxy composite contains 60% by volume Kevlar. The densities of Kevlar and epoxy are 1.48 g/cm$^3$ and 1.20 g/cm$^3$, respectively. The weight% of Kevlar is
   A. 64.9%,  B. 35.1%,  C. 60.0%,  D. 40.0%

39. A glass-epoxy composite contains 60% by volume glass fiber. The Young’s modulus of glass fiber and epoxy are 10.5 GPa and 0.45 GPa, respectively. The strengths of glass fiber and epoxy are 350 MPa and 9 MPa, respectively. Calculate the strength of the composite:
   A. 289 MPa,  B. 350 MPa,  C. 214 MPa,  D. 9 MPa

40. The coordination of the cation in an ionic ceramic structure depends on
   A. the density
   B. the charges on the ions
C. the ratio of the cation to the anion radii
D. none of the above

Equation sheet

\[ \sigma = \sigma_0 e^{-\frac{t}{\tau}}, \quad 1/\tau = Ce^{Q/RT} \]
Avogadro’s constant \( Na = 6.023 \times 10^{23} \) mol\(^{-1}\).

\[ R = 8.314 \text{ J/(mol K)} \]

\[ K_{IC} = Y \sigma_f \sqrt{\pi a} \]

\[ \frac{1}{E_c} = \frac{V_f}{E_f} + \frac{V_m}{E_m} \]

\[ \% = \left[ 1 - e^{-\frac{(x_A-x_B)^2}{4}} \right] \times 100\% \]

Keys:
1C 2B 3B 4A 5B; 6B, 7A, 8A, 9D, 10A;
11B, 12B, 13B, 14D, 15C; 16D, 17C, 18A, 19B, 20A
31D, 32C, 33E, 34D, 35C; 36A, 37D, 38A, 39C, 40C