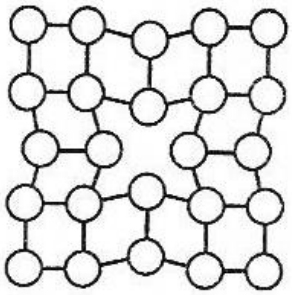
Modern Materials Design and Application
Entrance exam for second-cycle studies - academic year 2023/2024

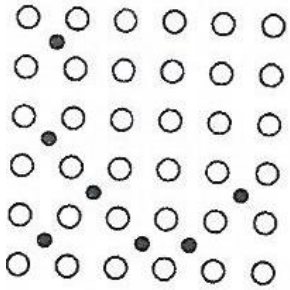
The student has to answer 50 questions (35 specialist knowledge questions and 15 additional ones) – they can score 2 points for each correct answer.

Questions related to the student's major area of study– 35 questions are drawn from a pool of 150 questions.

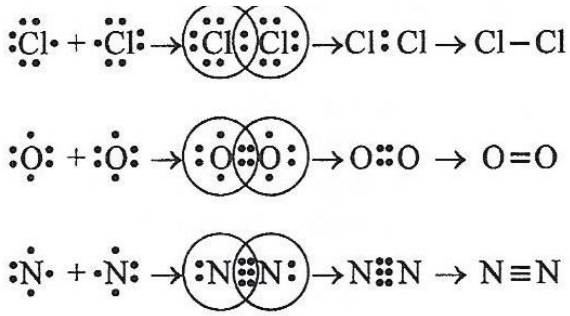
1. What kind of lattice defect is shown in the figure below:



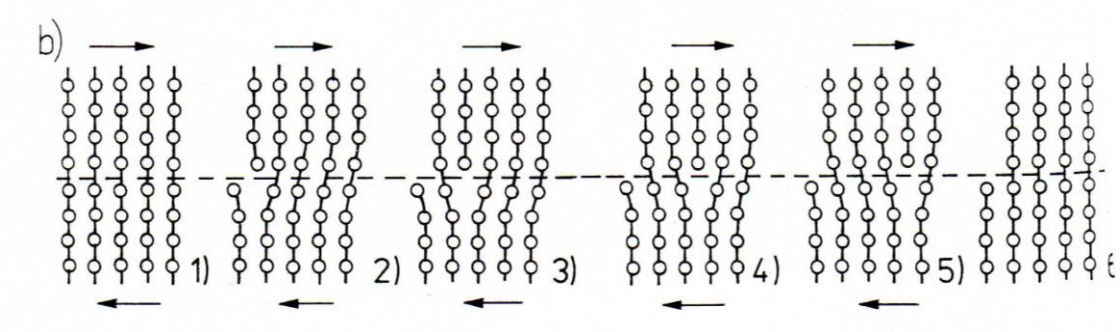
2. What type of solid solution is presented in the figure below:



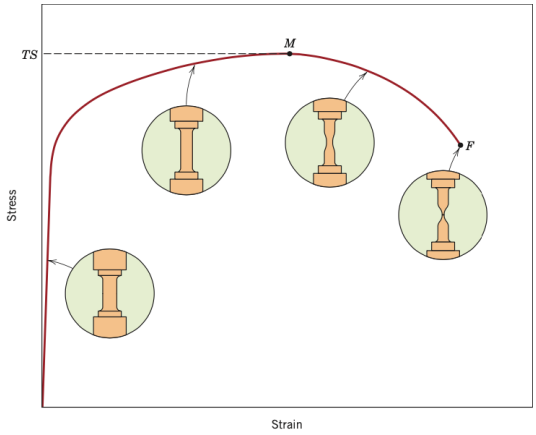
3. What is allotropy:
4. The unit of stress is:
5. Hooke's law states that in many materials the strain value is directly proportional to the stress in the case of:
6. What type of bond is shown in the figure below?



7. A hardness tester with a pyramid-shaped indenter leaving a square-imprint is a hardness tester using:
8. The creep of a material is:
9. The figure below shows the mechanism of:

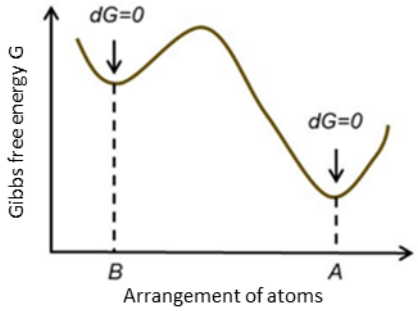


10. The figure below shows:

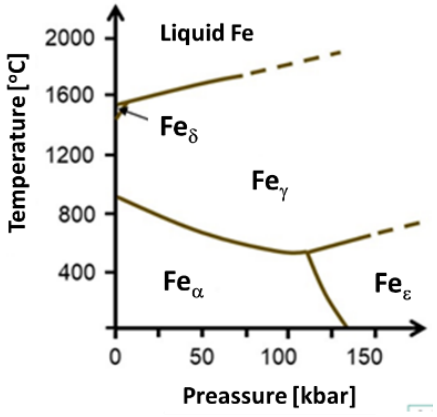


11. Hydroxides with amphoteric properties dissolve in aqueous solutions of:
12. Copper (II) sulfate (VI) cannot be obtained in the following reaction:
13. Indicate the oxidation/reduction (redox) reaction:
14. The oxidation state of sulfur in sodium thiosulfate (VI) with the formula $Na_2S_2O_3$ is:
15. Isotopes include:
16. In a reaction tank, the state of the chemical equilibrium of the reaction $2HCl_g + I_{2g} \rightleftarrows 2HI_g + Cl_{2g}$ (T - const) has been developed. In what direction will the equilibrium state of the reaction move upon increasing the overall pressure of the reaction mixture?
17. The ammonia synthesis $N_{2g} + 3H_{2g} \rightleftarrows 2NH_{3g}$ is an exothermic reaction. An increase in the efficiency of this process can be achieved by:
18. The atomic number of aluminum in the periodic table of elements is 13, whereas the atomic mass of this element is 26.982 u. This means that the number of electrons in an Al atom is:
19. The principal quantum number (n) describes:
20. A polarized covalent bond occurs in:
21. The elementary cell is:
22. The elementary cell of a rhomboid system is described using the following parameters:
23. In crystallography, a set of symmetrically equivalent directions is denoted as:
24. The atomic packing factor for a regular face-centered (FCC) structure is:

25. Properties that are particularly defect-prone include:
26. Dislocation is a crystalline lattice defect classified as:
27. A low-angle boundary occurs when the misorientation angle between the grains is:
28. A weak AB electrolyte (1:1 type) with the total concentration c and the degree of dissociation α undergoes dissociation in accordance with the general equation $AB \rightleftarrows A^+ + B^-$. What is the concentration of the undissociated molecules in the equilibrium state?
29. If the PH of a solution is 2, the concentration of hydrogen ions is:
30. The process of electrolytic dissociation according to the Brönsted-Lowry theory is described by the following equation:
31. The ionic reaction formula $CO_3^{2-} + H_2O \rightleftarrows H_2CO_3 + OH^-$ corresponds with the process of:
32. The equilibrium constant of the process denoted by the equation $BaSO_4 \downarrow \rightleftarrows Ba^{2+} + SO_4^{2-}$ is:
33. The oxidation state of cobalt in the $[Co(NH_3)_5Br]SO_4$ complex is:
34. What is the SEM value of the $Zn|Zn^{2+} || Ni^{2+}| Ni$ cell if the equilibrium potentials of the electrodes are equal to $E_{o,Zn/Zn2+} = -0,76V$ and $E_{o,Ni/Ni2+} = -0,26V$?
35. During the electrolysis of an aqueous solution of copper (II) sulfate (VI), the following process takes place on a graphite anode:
36. The figure presents a change in the Gibbs free energy of a system in relation to the configuration of the atoms. The arrangement of the atoms in the B configuration means that the system is at:

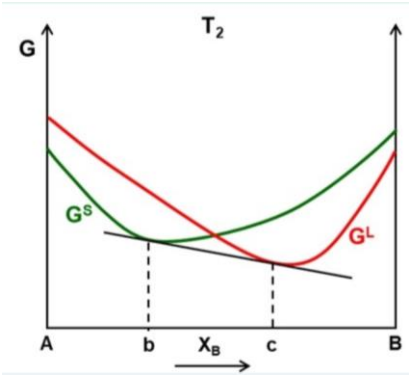


37. Phase transformation will occur when:
38. The figure shows the stability regions of the allotropic forms of iron in relation to the temperature and pressure. Answer, which Fe phase ehxibits the highest density:

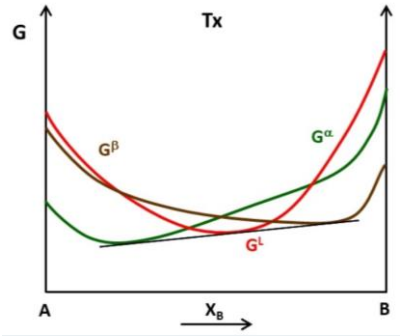


39. The figure presents the dependence of the Gibbs free energy on the composition of the solid phase G^S (the green curve) and the liquid phase G^L (the red curve) of a given

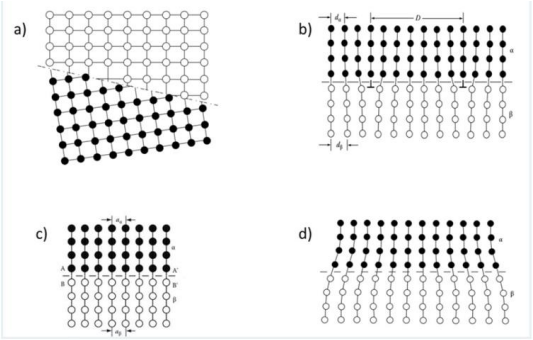
system at a constant temperature T_2. Based on this, it can be concluded that for alloys with compositions in the range between points b and c, the stable (equilibrium) phase is:



40. At a certain temperature T_x, it is possible to plot a line tangent to each of the curves depicting the dependence of the Gibbs free energy on the chemical composition of the liquid phase G^L (the red curve) and two solid phases G^α and G^β (the green and the brown curve, respectively). This means that T_x is the temperature of the following phase transformation:

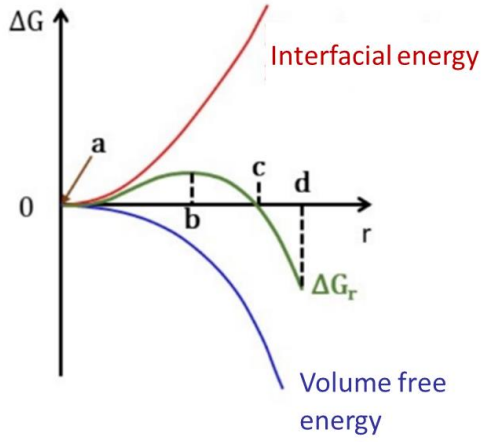


41. In the figure, different interphase boundaries are schematically presented. Which of these boundaries represent a partially coherent (semi-coherent) boundary?

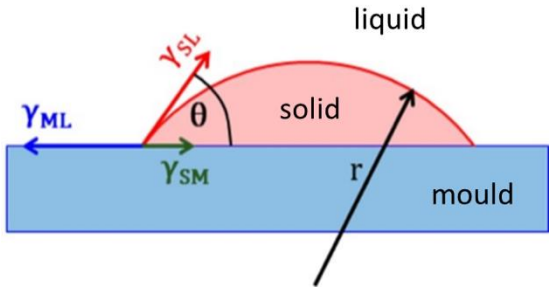


42. The figure shows (among other things) the dependence of radius of a homogenously nucleating spherical particle on the free energy change (the green curve). An important

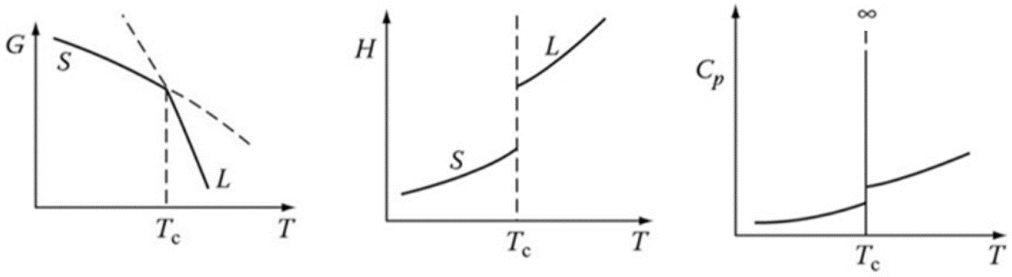
parameter during nucleation is critical radius, which in the figure can be seen at the point:



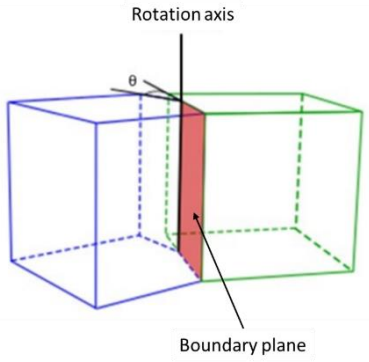
43. The figure schematically shows the nucleus of the solid phase that is heterogeneously nucleating on the surface of the mould. The activation energy of the nucleation will be lower (nucleation will be "easer"), when the wetting angle θ will be:



44. The figure shows the dependence of the Gibbs free energy G, enthalpy H and specific heat C_p on the temperature T. Based on these graphs, it can be concluded that the phase transition at the temperature T_c is:

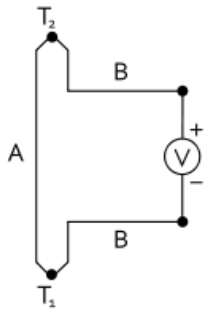


45. The figure schematically shows a grain boundary for which the rotation axis is parallel to the boundary plane. Such boundary is called:



46. Indicate the false relationship between the elastic constants:
47. The symmetricity of the stress tensor origins from:
48. Which of the following equations of the equilibrium of forces with respect to the axis x_1 is incorrect?
49. Which of the following equations of the elastic strain energy density represent correct formula?
50. The principal strain values $\varepsilon_1 = -1$, $\varepsilon_2 = 2$ and $\varepsilon_3 = 8$ are given. Indicate the correct form of the pure strain deviator tensor.
51. Which of the following strain tensors represent a uniaxial deformation state?
52. Which of the following Hooke's relationships for an isotropic material is incorrect?
53. An isotropic material with a yield strength of $\sigma_{pl} = 100$ MPa is subjected to a combined load so that the principal stresses are: $\sigma_1 = 50$ MPa, $\sigma_2 = 20$ MPa, $\sigma_3 = -50$ MPa. Which of the following answers is incorrect?
54. A metallic lattice can be built with sequences of orientations of particular crystallographic planes. Which of the following sequences of crystallographic planes orientation is incorrect?
55. A regular crystallographic body-centered lattice has been subjected to a simple shear of $\sqrt{6}$ in the slip system of (110)[1-11]. Which form of the deformation matrix is correct?
56. Which of the reactions describing the formation of a Lomer-Cotrell dislocation in materials with a face-centered lattice is incorrect?
57. In which of the following deformation systems of the FCC lattice (K_1 – the twinning plane, η_1 – the twinning direction) mechanical twinning will not occur due to the polar nature of twinning?
58. The principal stress is:
59. Maximum principal stress or major principal stress is:
60. A material with a yield point of $\sigma_{pl} = 400\,MPa$ was subjected to a flat stress state described by: $\sigma_1 = 300$ MPa and σ_3. Determine what value of σ_3 should be for a material to pass into the plastic state in accordance with the Tresca criterion.
61. In which of the following processes a force is applied to the tool?
62. The total elongation A_{200} in a tensile stress test means that:
63. Which group of properties includes the yield point:
64. In a tensile (or compressive) strength test, it is possible to determine the Young's modulus on the basis of the following characteristic:
65. Performing a temperature measurement with a pyrometer, care should be taken to set correctly one of the parameters which is material dependent. This parameter is:

66. With the Matthiessen rule in mind, select those characteristics that affect the resistivity of the tested material:
67. Materials hardness testing can be performed using:
68. In the Vickers hardness test, the indenter is:
69. During a Charpy impact test, a hammer arm is raised to a certain height h. How does the form of energy change at the moment the hammer is lowered in order to break the sample?
70. The measuring gauge length of the standardized sample prepared for a tensile test is calculated from the equation:
71. The temperature measurement using a thermocouple is based on the Seebeck effect, involving the measurement of the electromotive force at the ends of cables made of different materials A and B at the contact points at different temperatures, T_1 and T_2, as shown in the figure below.



If these contact points have different temperatures, then the potential difference between them is expressed by the equation:

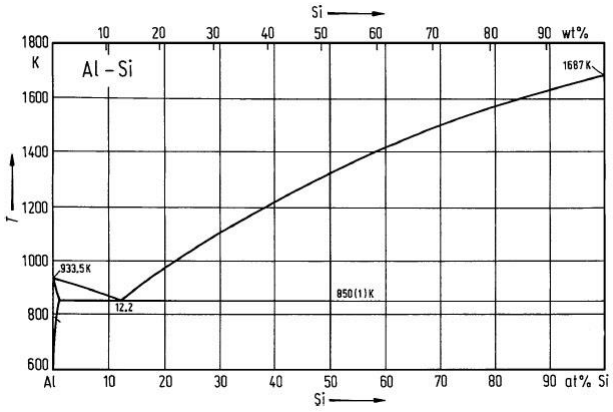
72. In order to construct a thermocouple, the following have to be used:
73. The piezoelectric effect consists in:
74. The ability of electrons to penetrate matter depends on:
75. When preparing thin foil for TEM analysis using the ion polishing method the sample is:
76. Do observations in polarized light enable examining the chemical composition?
77. The EDS method enables:
78. Secondary electrons (SE) in SEM:
79. Microhardness is:
80. Using the Poldi hammer for establishing hardness, the obtained result is given in:
81. The resolution limit of a microscope is specified by:
82. A Scanning Tunelling Microscope can work in:
83. When preparing thin foil for TEM analysis using the electropolishing method the sample is:
84. The blade of the ice axe is made of:
85. Teflon seals can work properly in the temperature range of:
86. The material used to make springs should exhibit:
87. Materials suitable for manufacturing climbing equipment are aluminum alloys of:
88. A radiator is a component or an assembly that should be characterized by:
89. A smooth surface reflecting light is:
90. A material that is often used for making pistons is an alloy of aluminum and:

91. Today, in photovoltaics, the most commonly used material is:
92. Pistons in combustion engines are most frequently:
93. The term "thermomechanical processing" is understood as:
94. For the manufacturing of the drawing charge in the form of a copper rod or aluminum rod, the commonly used system is:
95. The industrial speed range for manufacturing copper wires with diameters of below 100 micrometers is:
96. The most advantageous tolerance of geometric dimensions of the products is obtained in the process of:
97. The most effective methods for minimizing the inhomogeneity of the chemical composition and structure across the entire volume of cast ingots include the processes of:
98. In order to obtain products characterized by a high tensile strength and also by a high electrical conductivity, it is necessary to apply the processes of:
99. The annealing of the charge at a temperature high enough to relieve the stresses, with subsequent slow cooling to remove or reduce the residual stress, without any significant changes in the structure and properties obtained by previous processing - this is the definition of:
100. The correct sequence of stages in the production process of aluminum packaging is:
101. Which of the elements listed below has a melting point of 1083°C:
102. The density of aluminum is:
103. An example of an interstitial solid solution is:
104. Which of the following equations expresses the Gibbs phase rule under a constant pressure:
105. What is the difference between an ore and a concentrate?
106. Floatation is the process of:
107. Metal oxide reduction processes require the use of a reducing agent that:
108. Which of the following reactions describes the reversible reaction of the thermal decomposition of carbonate (calcination):
109. The process of electrolytic refining of copper is described by the following reactions:
110. Aluminum is obtained in the process of aluminum electrolysis in molten cryolite. The temperature of this process is:
111. During the production process of aluminum by molten salt electrolysis:
112. Which of the following reactions is related to the electrolytic process of obtaining magnesium from molten salts:
113. In heterogenous type of nucleation:
114. In a eutectic reaction:
115. In die casting method:
116. The strength and hardness of some metal alloys may be enhanced by the formation of extremely small uniformly dispersed particles of a second phase within the original phase matrix. This process is called:
117. Indicate the most common plastic forming operations:
118. In direct extrusion process:
119. Drawing proces can be described as:
120. The major alloying element in 5xxx series alumnium alloy is:

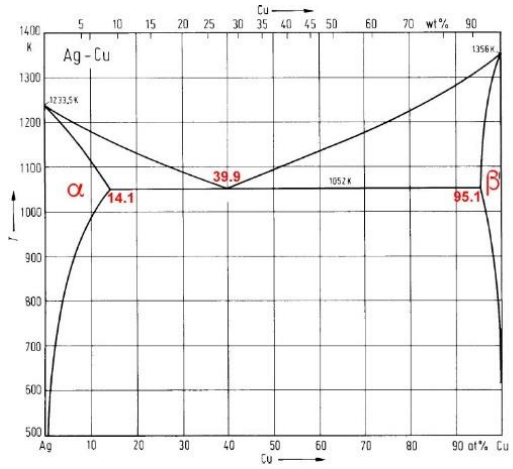
121. Indicate the series of heat treatable aluminium alloys:
122. Rod, wire, and tubing products are commonly fabricated by:
123. Indicate typical extrusion products:
124. Precipitation hardening is accomplished by:
125. Artificial ageing is carried out at:
126. Unit cell presented below shows:
127. Indicate a metal which experiences an allotropic transformation:
128. Close-packed planes for FCC metals are:
129. Grain boundaries, twin boundaries, stacking faults, phase boundaries are classified as:
130. For substitutional solid solutions, appreciable solubility is possible only when:
131. Which of the following parametr has a most profound influence on the coefficients and diffusion rates:
132. Hooke's law is represented by the following relationship:
133. Some of the characteristics of metallic bonds include:
134. How many elastic constants fully desribe the elastic properties of potassium crystals?
135. How many elastic constants fully desribe the elastic properties of magnesium crystals?
136. Three elastic constants, i.e: C_{11}, C_{12} and C44 describe elastic properties of:
137. Which of the following equations represent Huber-Mises-Hancy (HMH) yielding criterion?
138. The ability of electrons to penetrate matter depends on:
139. Polycrystalline solids on a much larger scale than the grain size and possessing no texture, and amorphous solids with no principal processing direction, have uniform properties in all directions and are referred to as:
140. Shear transformations in crystals constitute an alternative to slip for inelastic deformation. These transformations include:
141. Strain hardening, alternatively referred to as work hardening, results from the:
142. A regular face-centered lattice has undergone a simple shear of $\sqrt{3}/\sqrt{2}$ in the slip system (111) [0-11]. Which of the following lattice vectors will not retain its length and crystallographic direction?
143. In a eutectoid reaction:
144. The image seen with a transmission electron microscope (TEM) is formed by an electron beam that:
145. A typical material property is often specified in terms of an average value $\bar{x}$ while magnitude of scatter may be expressed as:
146. A diagram to identify and eliminate unnecessary movement of people and products in work processes is:
147. Interstitial type of diffusion occurs:
148. Which of the following expressions means an excessive load of machines and people?
149. The concept of delivering the components necessary to produce products or services in exactly the amount they are needed and at the exact time they are needed is called:
150. Engineering strain ε is defined as:

The remaining questions (General knowledge questions): 15 questions are drawn from a pool of 100 questions.

1. According to the Act on industrial property law, an invention is considered to be new if:
2. Patents are granted for:
3. The material scope of the patent is determined by the patent claims included in this document:
4. For a utility model to be introduced into the appropriate register shall be considered as:
5. The impact test is based on the following:
6. The physical quantity measured during an impact test using the Charpy hammer is:
7. A device enabling the measurement of the absolute value of temperature is:
8. A clear yield point observed during the static tensile test of some materials is characterized by:
9. A hardness test using the Rockwell method consists in:
10. A flat sample with a gauge length of l_0 = 50 mm is stretched at a traverse speed of v = 6 mm/min. The tensile speed for this sample is:
11. During a static tensile test conducted at an elevated temperature, single or multiple stress oscillations can be observed in the plastic flow of a material. The plastic flow instabilities may originate from:
12. The bulk density of powders is:
13. Powders obtained by grinding in ball and impact mills are characterized by:
14. The granular composition of powders is tested with:
15. Copper powders may be obtained using:
16. In powder metallurgy compact is defined as:
17. Based on the criterion of the location of the solute atom in the solvent lattice, solid solutions can be divided into:
18. The non-equilibrium crystallization of continuous solid solutions can lead to the following non-equilibrium changes:
19. According to the aluminum-silicon binary phase diagram given below, the Al-Si alloy with the chemical composition of 12.2 at.% of Si and 87.8 at.% Al is characterized by:



20. The disorder-order transformation:
21. According to the Al-Cu binary phase diagram system, alloys with a composition higher than 39.9 at.% Cu, are:



22. Intermetallic phases are:
23. Phase transformations that can take place without nucleation and the growth of nuclei are:
24. α-phase CuZn alloys contain:
25. The major alloying element in 2xxx series aluminum alloys is:
26. The maximum effect of precipitation hardening in binary Al-Cu alloys is observed when the precipitates are:
27. The magnesium alloy denoted as AZ61A contains:
28. Adding Pb to brasses leads to:
29. Dendritic microsegregation in Cu-Sn alloys is characterized by:
30. The modification of Al-Si alloys is:
31. Titanium alloys with the α-phase structure are titanium alloys with a content of:
32. The element used as a deoxidizing agent for Cu is:
33. Based on the type of matrix composites can be classified as:
34. An "in situ" metal matrix composite is:
35. An aluminum alloy-based composite contains 35% vol. of directionally oriented fibers. The Young's modulus for the fibers is E = 390 GPa and for the aluminum alloy E = 70 GPa. The matrix density is 2.7 g/cm^3, the reinforcement density is 1.95 g/cm^3. Determine the density of the composite (ρ) and the Young's modulus (E) of the composite when the applied stress is parallel to the fiber axis.
36. The wettability in a metal matrix-fiber system can be improved by:
37. The basic function of the reinforcement in composite materials is:
38. The lowest obligatory standard of fineness for gold and silver products in Poland is:
39. The equivalent of an 18-carat gold alloy is the fineness of:
40. Which of the following precious metals is characterized by the highest density:
41. "Fineness" is defined as:
42. The most frequently introduced elements into a gold alloy in order to obtain the so-called "white gold", are:

43. The strength properties of the popular 925 silver-copper alloy can be significantly improved by applying:
44. Metal texture is defined as:
45. Texture measurements were performed by using and X-ray diffractometer equipped with a cobalt radiation (Co Kα) with a wavelength of 1.789 Å. The diffraction conditions for tested crystallographic plane were met for an angle of $2\Theta = 88.833^{o}$. Calculate the spacing of the diffracting plane d.
46. The methods for measuring and determining the texture are:
47. Characteristic X-rays are emitted:
48. Metal texture is not formed during:
49. The allotropic transformation of iron α into iron γ occurs at a temperature of:
50. For the iron-carbon (cementite) system at 727°C and for a carbon content of 0.77%, the following phase transformation occurs:
51. During recrystallization, the mechanical properties that were changed as a result of cold working are:
52. The martensitic transformation is:
53. What does the TTT diagram represent?
54. Which of the following sentences is not true for Ni-based alloys:
55. Which of the following statements is/are correct:
56. Choose the correct statement:
57. Recycling is a comprehensive method of environmental protection because:
58. Using eddy-current precipitators, it is possible to separate:
59. One of the methods of recycling silver from scrap metal is to dissolve it in an HNO_3-H_2O solution. To precipitate silver chloride from such a solution, the following should be used:
60. The fly ash during the process of re-melting the battery paste from the disassembly of used car batteries acts as:
61. Which of the following solutions dissolves gold from scrap material:
62. The metallic phase, called "black copper", which is the product of melting low-copper scrap in a shaft furnace contains:
63. The recycling of used lead-acid car batteries is currently:
64. Homogenous nucleation takes place when:
65. The most important heat treatment operations include:
66. The martensite is:
67. The Hume-Rothery rules are satisfied for:
68. With respect to the type of chemical influence on the heated surfaces of certain metal materials, the atmospheres in heat treatment furnaces are divided into:
69. Typical homogenization process:
70. Recovery process leads to:
71. Ferrite is:
72. Metal-diamond tools for cutting hard materials usually consist of:
73. Which of the following tool materials has the lowest density?
74. Diamond is an allotrope of:
75. The hardest known material is:
76. Which of the following parameters does not affect the morphology of the second phase distribution in two-phase monocrystals:

77. Factors that may affect the growth of metal whiskers are:
78. The Griffiths theory of brittle fracture relies on the postulate that:
79. According to most theories of microcrack nucleation:
80. A comparison of the theoretical strength of a material with the experimentally determined tensile strength values indicates that the actual strength is:
81. Material fatigue is the process of:
82. The most favorable conditions for plastic deformation, due to the stress state and deformation of a material, occur during the process of:
83. The Lankford coefficient (also called Lankford value, R-value, or plastic strain ratio) is:
84. Which of the following alloys are not used as a biomaterials in dentistry?
85. Diffusion mechanism which involves the interchange of an atom from a normal lattice position to an adjacent vacant lattice site or vacancy is called:
86. Vacancies and self-interstitialas are considered as:
87. Engineering stress is defined by the relationship:
88. Hardness of metallic materials can be defined as:
89. Annealing treatment of cold worked metals and alloys may induce the following structural changes:
90. Which of the following is the preferred slip system for the face-centered crystal (FCC) structure?
91. Tensile strength of metallic materials:
92. Recrystallization temperaturę is defined as:
93. Welding is:
94. Which group of metals is considered as "critical metals":
95. Brass is an alloy of:
96. Plastic deformation of a metal above its recrystallization temperature is termed as:
97. During recrystallization:
98. Critical resolved shear stress (CRSS) is:
99. Indicate the criterion for "soft soldering" and "hard soldering":
100. In a peritectic reaction: