Board Exam Desk

Metallurgical Engineering Reviewer

Metallurgical Engineering Licensure Examination | PRC | 120 original questions

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Original board-style practice questions with an answer key.

Practice questions

Mineral Processing

1. A copper rougher-cleaner circuit treats ore assaying 1.20% Cu and produces a concentrate of 24.0% Cu and a tailing of 0.15% Cu. Using the two-product formula, what is the copper recovery?

A. 84.0%
B. 92.5%
C. 87.5%
D. 88.1%

4. For a circuit with feed 1.20% Cu, concentrate 24.0% Cu and tailing 0.15% Cu, what is the ratio of concentration (tonnes of feed per tonne of concentrate)?

A. 20.0
B. 22.7
C. 25.4
D. 18.6

7. An ore with a Bond work index of 14 kWh/t is ground from an F80 of 12,000 um to a P80 of 150 um. What specific energy does Bond's equation predict?

A. 11.43 kWh/t
B. 12.69 kWh/t
C. 10.15 kWh/t
D. 8.12 kWh/t

10. A ball mill draws 1,500 kW at the pinion while grinding 120 t/h from F80 = 2,000 um to P80 = 106 um. What is the operating work index?

A. 16.7 kWh/t
B. 12.5 kWh/t
C. 12.9 kWh/t
D. 18.4 kWh/t

13. A grinding line must process 200 t/h of ore requiring 10.15 kWh/t by Bond's equation. What net mill power is required?

A. 2707 kW
B. 2031 kW
C. 1523 kW
D. 203 kW

16. A ball mill has an internal diameter of 3.6 m. If it runs at 75% of critical speed (Nc = 42.3/sqrt(D), D in m), what is the operating speed?

A. 22.3 rpm
B. 8.8 rpm
C. 16.7 rpm
D. 30.3 rpm

19. In a closed ball mill-cyclone circuit, the percent passing 75 um is 45% in the cyclone feed, 80% in the overflow and 30% in the underflow. What is the circulating load?

A. 233%
B. 43%
C. 333%
D. 70%

22. A pulp has a density of 1.45 t/m3 and the dry solids have a specific gravity of 2.8. What is the percent solids by weight?

A. 25.0%
B. 31.0%
C. 55.5%
D. 48.3%

25. A cyclone feed stream carries 100 t/h of solids (SG 2.7) at 40% solids by weight. What is the volumetric flow rate of the pulp?

A. 250 m3/h
B. 150 m3/h
C. 187 m3/h
D. 137 m3/h

28. Using Stokes' law, what is the terminal settling velocity in water (viscosity 0.001 Pa.s) of a 50 um quartz particle of density 2,650 kg/m3?

A. 3.61 mm/s
B. 2.25 mm/s
C. 1.12 mm/s
D. 8.99 mm/s

31. What is the concentration criterion for separating free gold (SG 19.3) from quartz (SG 2.65) in water?

A. 7.3
B. 11.1
C. 6.3
D. 6.9

34. A plant evaluates gravity concentration of cassiterite (SG 7.0) from quartz gangue (SG 2.65) in water. What is the concentration criterion?

A. 2.64
B. 1.64
C. 3.64
D. 2.26

37. Batch settling tests give a unit area of 0.25 m2 per t/d of solids. What thickener diameter is needed for 1,200 t/d of concentrate?

A. 9.8 m
B. 95.5 m
C. 7.8 m
D. 19.5 m

40. A screen receives 100 t/h of feed containing 60% undersize. The undersize product, essentially free of oversize, is 54 t/h. What is the screen efficiency based on undersize recovery?

A. 54%
B. 90%
C. 85%
D. 60%

43. A flotation bank follows first-order kinetics with ultimate recovery 95% and rate constant 0.5 per min. What recovery is expected after 6 minutes of flotation?

A. 37.4%
B. 90.3%
C. 95.0%
D. 73.8%

46. A rougher flotation bank receives 250 m3/h of pulp and needs 12 minutes residence time. If only 85% of nominal cell volume is effective pulp volume, what total nominal cell volume is required?

A. 50.0 m3
B. 42.5 m3
C. 66.7 m3
D. 58.8 m3

49. A thickener receives 1,000 t/d of solids at 30% solids and discharges underflow at 60% solids. Assuming a clear overflow, how much water reports to the overflow?

A. 1,667 t/d
B. 2,333 t/d
C. 667 t/d
D. 1,333 t/d

52. A lead-zinc plant treats feed assaying 5.0% Pb and 7.0% Zn. The lead concentrate assays 65% Pb, 5% Zn; the zinc concentrate 1.5% Pb, 55% Zn; the tailing 0.4% Pb, 0.6% Zn. What is the lead recovery to the lead concentrate?

A. 6.9%
B. 76.6%
C. 90.1%
D. 92.0%

55. For a feed of 1.2% Cu upgraded to a 24% Cu concentrate, what is the enrichment ratio?

A. 22.7
B. 4.4
C. 20
D. 28.8

58. A jaw crusher accepts feed with a top size of 600 mm and is set to discharge a product with a top size of 120 mm. What is its limiting reduction ratio?

A. 4.0
B. 6.0
C. 5.0
D. 0.2

61. In sulfide flotation, what is the main role of a xanthate collector?

A. It stabilizes the froth by lowering surface tension
B. It adsorbs on the sulfide surface and makes it hydrophobic
C. It raises the pulp pH to depress iron sulfides
D. It disperses slimes by charging gangue particles

64. A flotation operator adds MIBC to the cells. Which function does this reagent primarily serve?

A. Collector for oxidized copper minerals
B. Frother that produces small, stable bubbles
C. Depressant for pyrite in alkaline circuits
D. Activator for sphalerite surfaces

67. In a copper-zinc sulfide flotation circuit, why is copper sulfate added before the zinc flotation stage?

A. To depress chalcopyrite remaining in the pulp
B. To activate sphalerite so xanthate can float it
C. To flocculate fine gangue in the zinc rougher
D. To lower pulp pH and dissolve iron hydroxides

70. A copper concentrator raises the rougher pulp pH to about 11 using lime. What is the main metallurgical purpose of this?

A. To activate quartz for reverse flotation
B. To depress pyrite while floating copper sulfides
C. To dissolve chalcopyrite surface oxidation films
D. To increase the solubility of the frother

73. A gravity plant must recover fine free gold from a cyclone underflow stream. Which device is best suited because it applies a high centrifugal force?

A. Spiral classifier
B. Low-intensity drum magnet
C. Centrifugal bowl concentrator
D. Rake thickener

76. Which separator is most suitable for recovering magnetite from a crushed and ground iron ore?

A. High-tension electrostatic separator
B. Low-intensity wet drum magnetic separator
C. Froth flotation with fatty acid collector
D. Heavy medium cyclone using magnetite

79. In a mineral sands plant, which pair can be separated by high-tension electrostatic separation?

A. Magnetite from ilmenite
B. Ilmenite from zircon
C. Quartz from feldspar by size
D. Gold from silver

82. A coal or ore dense medium separation plant commonly prepares its medium from which material?

A. Bentonite clay suspended in kerosene
B. Concentrated sulfuric acid solution
C. Sodium silicate dissolved in water
D. Finely ground ferrosilicon or magnetite in water

85. Which comminution law states that energy consumed is proportional to the new surface area produced, and is most applicable to fine grinding?

A. Rittinger's law
B. Kick's law
C. Bond's third theory
D. Stokes' law

88. Compared with a ball mill, why might a plant choose a rod mill ahead of a gravity or magnetic separation stage?

A. It achieves a much finer final product size
B. It consumes less steel per tonne of ore at all sizes
C. It gives a narrower product size with less overgrinding
D. It requires no water and operates fully dry

91. A hydrocyclone overflow becomes too coarse after maintenance. Which change would most likely have caused this?

A. Reducing the feed percent solids
B. Increasing the feed pressure
C. Installing a larger vortex finder
D. Installing a smaller-diameter cyclone

94. A hydrocyclone underflow discharges as a dense rope rather than an umbrella-shaped spray. What does this usually indicate?

A. The vortex finder is too short
B. The apex is too small for the solids load
C. The feed is too dilute for classification
D. The feed pressure is far too high

97. An ore sample shows that 72% of the chalcopyrite occurs as free grains at the grind size. What does this figure describe?

A. The recovery of chalcopyrite to concentrate
B. The degree of liberation of chalcopyrite
C. The enrichment ratio of the circuit
D. The grade of the final concentrate

100. Heavy-liquid sink-float tests on crushed ore at several densities are mainly used to determine what?

A. The Bond work index for ball milling
B. The flotation rate constant of sulfides
C. The amenability of the ore to gravity separation
D. The thickener unit area requirement

103. When an additional cleaner stage is added to a flotation circuit treating the same feed, what is the typical effect?

A. Higher recovery with a lower concentrate grade
B. Higher grade and higher recovery together
C. No change in grade but a higher mass pull
D. Higher concentrate grade with some loss of recovery

106. Fine iron ore concentrate is balled with a small amount of bentonite and indurated in a furnace. What process is this?

A. Sintering
B. Briquetting with tar
C. Nodulizing in a kiln
D. Pelletizing

109. A mineral has a large contact angle with water at the solid-air-water interface. What does this indicate about its flotation behavior?

A. It is hydrophilic and remains in the pulp
B. It requires an activator before any collector
C. It is hydrophobic and readily attaches to bubbles
D. It will act as a natural frother in the cell

112. For a very large tonnage operation treating hard run-of-mine ore, which primary crusher is usually preferred?

A. Hammer mill
B. Roll crusher
C. Cone crusher in short-head form
D. Gyratory crusher

115. A sample of ground ore is passed through a riffle splitter before assaying. What is the main purpose?

A. To divide the sample into representative portions
B. To remove the fine fraction before assay
C. To separate heavy minerals from light ones
D. To dry the sample before weighing

118. If the copper concentrate in a two-product balance is 4.4% of the feed mass and assays 24% Cu with feed at 1.2% Cu, what fraction of the feed copper reports to concentrate?

A. 4.4%
B. 95%
C. 80%
D. 88%

Extractive Metallurgy

2. Using the Elsner equation 4Au + 8NaCN + O2 + 2H2O = 4NaAu(CN)2 + 4NaOH, what minimum mass of NaCN is needed to dissolve 1.0 kg of gold?

A. 0.25 kg
B. 0.50 kg
C. 1.00 kg
D. 0.37 kg

5. A gold ore assays 3.20 g/t and the leach residue assays 0.28 g/t. Assuming no change in solids mass, what is the leach extraction?

A. 8.8%
B. 88.5%
C. 94.1%
D. 91.3%

8. A copper electrowinning tankhouse runs at 30 kA for 24 hours with 92% current efficiency. How much copper is deposited?

A. 854 kg
B. 393 kg
C. 785 kg
D. 1571 kg

11. Copper is electrowon at a cell voltage of 2.0 V with 90% current efficiency. What is the specific DC energy consumption?

A. 1,687 kWh/t
B. 937 kWh/t
C. 1,875 kWh/t
D. 281 kWh/t

14. A Hall-Heroult pot line cell operates at 300 kA with 94% current efficiency. How much aluminum does one cell produce per day?

A. 2,416 kg
B. 3,407 kg
C. 1,514 kg
D. 2,271 kg

17. A zinc electrowinning circuit operates at a total current of 50 kA and 90% current efficiency. What is its daily zinc output?

A. 1,464 kg
B. 659 kg
C. 1,216 kg
D. 1,317 kg

20. During copper electrorefining, where do most of the gold and silver in the anode copper report?

A. To the anode slimes
B. To the cathode copper
C. Dissolved in the electrolyte
D. To the cell off-gas

23. Why does copper electrorefining need a much lower cell voltage than copper electrowinning?

A. The electrolyte has no sulfuric acid
B. Refining cells operate at much higher temperature
C. The cathodes in refining are made of lead
D. The anode reaction is copper dissolution, not oxygen evolution

26. One tonne of iron ore contains 80% Fe_2O_3 by mass. If all the hematite is reduced to metallic iron, what mass of iron is produced?

A. 800 kg
B. 280 kg
C. 699 kg
D. 560 kg

29. In the iron blast furnace, which reaction regenerates CO from CO_2 at high temperature in the presence of coke?

A. Water-gas shift, $CO + H_2O = CO_2 + H_2$
B. Calcination, $CaCO_3 = CaO + CO_2$
C. Boudouard reaction, $C + CO_2 = 2CO$
D. Indirect reduction, $FeO + CO = Fe + CO_2$

32. A blast furnace slag analyzes 42% CaO and 35% SiO_2. What is its basicity expressed as CaO/SiO_2?

A. 1.20
B. 0.83
C. 1.42
D. 0.77

35. An ore contributes 100 kg of SiO_2 per tonne. To reach a slag basicity (CaO/SiO_2) of 1.2 using pure $CaCO_3$ as flux, what mass of limestone is required?

A. 120 kg
B. 67 kg
C. 178 kg
D. 214 kg

38. Pure sphalerite is dead-roasted by ZnS + 1.5O2 = ZnO + SO2. How much SO2 is generated per tonne of ZnS?

A. 329 kg
B. 492 kg
C. 657 kg
D. 835 kg

41. An acid plant converts all the sulfur captured from a smelter off-gas to H2SO4. What mass of acid is produced per tonne of sulfur fixed?

A. 3.06 t
B. 1.00 t
C. 2.00 t
D. 2.50 t

44. One tonne of limestone containing 95% CaCO3 (rest inert) is fully calcined. What mass of CaO is formed?

A. 560 kg
B. 950 kg
C. 418 kg
D. 532 kg

47. A smelter treats 1,000 t of concentrate assaying 28% Cu and makes a 60% Cu matte, recovering 98% of the copper to matte. What mass of matte is produced?

A. 457 t
B. 467 t
C. 274 t
D. 392 t

50. A matte consisting only of Cu2S and FeS assays 50% Cu. What is its Cu2S content by mass?

A. 50.0%
B. 37.4%
C. 71.5%
D. 62.6%

53. In a Peirce-Smith converter, what happens during the first (slag-forming) blow on copper matte?

A. Cu2S is oxidized directly to blister copper
B. FeS is oxidized and the iron is slagged with silica flux
C. Sulfur is added to raise the matte grade
D. Copper oxide is reduced by coke to metal

56. A reaction has dH = +180 kJ and dS = +150 J/K, both assumed constant. Above what temperature does it become thermodynamically favorable?

A. 1200 C
B. 600 C
C. 927 C
D. 1473 C

59. A reduction reaction has a standard Gibbs energy change of -40 kJ at 1,000 K. What is its equilibrium constant at that temperature?

A. 8
B. 123
C. 0.0081
D. 44

62. For 2Ni + O2 = 2NiO, the standard Gibbs energy change at 1,200 K is -300 kJ per mol O2. What is the equilibrium oxygen partial pressure for Ni/NiO coexistence?

A. 3.0e-07 atm
B. 2.1e-06 atm
C. 2.1e-16 atm
D. 8.7e-14 atm

65. Given standard enthalpies of formation of -824.2 kJ/mol for Fe2O3 and -1,675.7 kJ/mol for Al2O3, what is the enthalpy change of 2Al + Fe2O3 = Al2O3 + 2Fe?

A. -2499.9 kJ
B. 851.5 kJ
C. -851.5 kJ
D. -425.8 kJ

68. The standard potential of Cu2+/Cu is +0.34 V. What is the electrode potential at 25 C in a solution with Cu2+ activity of 0.01?

A. 0.222 V
B. 0.281 V
C. 0.399 V
D. 0.340 V

71. For FeO + CO = Fe + CO2 at a certain temperature, K = pCO2/pCO = 0.40. What minimum CO percentage in a CO-CO2 gas is needed to reduce wustite?

A. 40.0%
B. 28.6%
C. 71.4%
D. 60.0%

74. How much heat is needed to raise 500 kg of copper from 25 C to its melting point of 1,083 C and melt it? Use cp = 0.385 kJ/kg.K and latent heat 205 kJ/kg.

A. 306 MJ
B. 204 MJ
C. 311 MJ
D. 409 MJ

77. Hydrogen dissolved in liquid steel obeys Sieverts' law. If vacuum treatment lowers the hydrogen partial pressure from 1.0 atm to 0.04 atm, the equilibrium hydrogen content becomes what fraction of the original?

A. 0.04
B. 0.20
C. 0.02
D. 0.40

80. On an Ellingham diagram, the line for Al2O3 lies well below that for Cr2O3. What does this imply?

A. Chromium can reduce Al2O3 to aluminum metal
B. Al2O3 is less stable than Cr2O3 at all temperatures
C. Both oxides need carbon to be reduced
D. Aluminum can reduce Cr2O3 to chromium metal

83. What information does a Pourbaix (potential-pH) diagram provide for a hydrometallurgical system?

A. The stable species as functions of potential and pH
B. The reaction rate constants at each temperature
C. The phase fractions of an alloy upon cooling
D. The heat released by each leaching reaction

86. In copper solvent extraction, how is copper transferred from the loaded organic phase to the electrowinning electrolyte?

A. Contacting the organic with fresh alkaline leach liquor
B. Stripping with strongly acidic spent electrolyte
C. Adding zinc dust to precipitate copper
D. Heating the organic to evaporate the diluent

89. In a carbon-in-pulp plant, how is gold usually removed from the loaded activated carbon?

A. Washing with cold dilute hydrochloric acid
B. Burning the carbon in an open hearth
C. Elution with hot caustic cyanide solution
D. Grinding the carbon and floating the gold

92. Before zinc dust is added in the Merrill-Crowe process, the pregnant cyanide solution is deaerated. Why?

A. Dissolved oxygen would redissolve gold and consume zinc
B. Oxygen is needed for gold to precipitate
C. Deaeration raises the solution temperature
D. Air bubbles would float the zinc dust away

95. In bacterial leaching of copper sulfides, what is the main role of iron-oxidizing bacteria?

A. Regenerating ferric ions that oxidize the sulfides
B. Producing cyanide that complexes copper
C. Reducing cupric ions to metallic copper
D. Neutralizing sulfuric acid in the heap

98. In the Kroll process for titanium, which reductant converts $TiCl_4$ to titanium sponge?

A. Molten magnesium
B. Carbon monoxide gas
C. Hydrogen at high pressure
D. Molten aluminum

101. In the Bayer process, bauxite is digested in which reagent to form a soluble aluminate?

A. Concentrated sulfuric acid
B. Hot sodium hydroxide solution
C. Molten cryolite
D. Dilute hydrochloric acid

104. In the Pidgeon process, magnesium is produced by reducing calcined dolomite with which material under vacuum?

A. Ferrosilicon
B. Coke breeze
C. Aluminum powder only
D. Natural gas

107. Which refining method purifies nickel by forming a volatile carbonyl that is later decomposed?

A. Parkes process
B. Zone refining
C. Mond process
D. Betts process

110. In basic oxygen steelmaking, how is most of the carbon in the hot metal removed?

A. Absorption into the lime slag as carbide
B. Oxidation to CO gas by blown oxygen
C. Reaction with silicon to form SiC
D. Vaporization as elemental carbon

113. Which slag condition most favors sulfur removal from molten iron or steel?

A. High basicity with low oxygen potential
B. Acidic slag with high FeO content
C. Low temperature with high silica
D. High oxygen potential and low CaO

116. In a gas-based direct reduction shaft furnace, what mainly reduces the iron oxide pellets?

A. Molten carbon-saturated iron
B. Liquid slag containing FeO
C. Pulverized coal injected with oxygen
D. Reformed natural gas rich in H2 and CO

119. Zone refining relies on which characteristic of an impurity to purify a metal bar?

A. Its distribution coefficient k is less than 1
B. Its melting point is higher than the metal's
C. It forms a volatile chloride
D. It is more noble than the base metal

Physical and Mechanical Metallurgy

3. A 0.40 wt% C plain carbon steel is slowly cooled to just below the eutectoid temperature. Using 0.022% C for ferrite and 0.76% C for the eutectoid, what is the mass fraction of pearlite?

A. 51.2%
B. 48.8%
C. 52.6%
D. 5.7%

6. What is the total mass fraction of cementite in a slowly cooled 1.0 wt% C steel just below the eutectoid temperature (ferrite 0.022% C, Fe3C 6.70% C)?

A. 4.0%
B. 17.9%
C. 14.6%
D. 85.4%

9. A 1.2 wt% C steel is slowly cooled from the austenite field. What mass fraction of proeutectoid cementite forms (eutectoid at 0.76% C, Fe3C at 6.70% C)?

A. 17.6%
B. 92.6%
C. 9.9%
D. 7.4%

12. A Cu-35 wt% Ni alloy is held in the two-phase region where the liquid contains 31.5% Ni and the solid contains 42.5% Ni. What is the mass fraction of solid?

A. 31.8%
B. 68.2%
C. 82.4%
D. 90.0%

15. Copper is FCC with an atomic radius of 0.128 nm and atomic mass 63.55 g/mol. What is its theoretical density?

A. 4.45 g/cm3
B. 8.17 g/cm3
C. 6.58 g/cm3
D. 8.90 g/cm3

18. Alpha iron is BCC with an atomic radius of 0.1241 nm. What is its lattice parameter?

A. 0.2866 nm
B. 0.3510 nm
C. 0.2482 nm
D. 0.2808 nm

21. X-rays of wavelength 0.1542 nm diffract from planes with spacing 0.2027 nm in first order. At what 2-theta angle does the peak appear?

A. 44.7 deg
B. 22.4 deg
C. 66.0 deg
D. 99.1 deg

24. A cubic metal has a lattice parameter of 0.3615 nm. What is the interplanar spacing of its (111) planes?

A. 0.2556 nm
B. 0.1205 nm
C. 0.2087 nm
D. 0.1807 nm

27. The energy for vacancy formation in a metal is 0.90 eV. What is the equilibrium fraction of vacant lattice sites at 1,000 K?

A. 5.4e-03
B. 5.8e-07
C. 2.9e-05
D. 2.7e-04

30. A 0.20% C steel is gas carburized with surface carbon held at 1.00%. Diffusivity is 1.6e-11 m2/s. How long until the carbon reaches 0.60% at 0.6 mm depth? (erf 0.4769 = 0.50)

A. 1.7 h
B. 6.9 h
C. 13.7 h
D. 6.2 h

33. Carbon diffusion in austenite has D0 = 2.3e-5 m2/s and Q = 148 kJ/mol. What is the diffusion coefficient at 900 C?

A. 5.9e-12 m2/s
B. 5.9e-14 m2/s
C. 3.2e-08 m2/s
D. 5.9e-11 m2/s

36. A steel obeys Hall-Petch with friction stress 70 MPa and k = 0.74 MPa.m^0.5. What is the yield strength for an average grain diameter of 25 um?

A. 73 MPa
B. 148 MPa
C. 296 MPa
D. 218 MPa

39. A tensile specimen with a 12.5 mm diameter carries an axial load of 45 kN. What is the engineering stress?

A. 367 MPa
B. 92 MPa
C. 733 MPa
D. 288 MPa

42. A 250 mm long steel bar (E = 200 GPa) is loaded elastically to 300 MPa. What is its elongation?

A. 0.375 mm
B. 0.150 mm
C. 0.750 mm
D. 3.75 mm

45. During a tensile test before necking, a specimen shows engineering stress 400 MPa at engineering strain 0.12. What is the true stress?

A. 448 MPa
B. 357 MPa
C. 400 MPa
D. 453 MPa

48. A tensile specimen of initial diameter 12.8 mm fractures with a neck diameter of 8.0 mm. What is the percent reduction in area?

A. 60.9%
B. 37.5%
C. 39.1%
D. 48.8%

51. A 50 mm gauge length is marked on a tensile bar. After fracture the pieces are fitted together and the gauge length measures 62.5 mm. What is the percent elongation?

A. 20%
B. 12.5%
C. 80%
D. 25%

54. A Brinell test with a 3,000 kgf load and 10 mm ball leaves an impression 4.2 mm in diameter. What is the Brinell hardness number?

A. 217 HB
B. 207 HB
C. 165 HB
D. 258 HB

57. A steel plate has a fracture toughness of 50 MPa.m^0.5 and is stressed to 400 MPa. Taking Y = 1.0 in K = Y sigma sqrt(pi a), what is the critical crack length a?

A. 15.62 mm
B. 4.97 mm
C. 2.49 mm
D. 5.61 mm

60. A shaft steel has an endurance limit of 300 MPa and a tensile strength of 800 MPa. By the Goodman relation, what alternating stress amplitude is allowed with a mean stress of 200 MPa?

A. 300 MPa
B. 250 MPa
C. 175 MPa
D. 225 MPa

63. A heat-resistant alloy ruptures after 1,000 h at 900 K. With C = 20, what is its Larson-Miller parameter?

A. 18,000
B. 20,700
C. 20,900
D. 27,000

66. A single crystal is loaded in tension at 60 MPa. The slip plane normal makes 40 deg and the slip direction makes 55 deg with the tensile axis. What is the resolved shear stress?

A. 22.1 MPa
B. 46.0 MPa
C. 30.0 MPa
D. 26.4 MPa

69. A copper rod is cold drawn from 15 mm to 12 mm diameter. What is the percent cold work?

A. 36%
B. 20%
C. 64%
D. 25%

72. A spring steel has a yield strength of 350 MPa and E = 200 GPa. What is its modulus of resilience?

A. 0.613 MJ/m3
B. 0.306 MJ/m3
C. 0.875 MJ/m3
D. 0.153 MJ/m3

75. A 10 mm diameter rod with Poisson's ratio 0.30 is loaded elastically to an axial strain of 0.0015. What is the change in diameter?

A. -0.0045 mm
B. -0.0150 mm
C. +0.0045 mm
D. -0.0050 mm

78. A steel contains 0.20% C, 1.20% Mn, 0.10% Cr, 0.05% Mo, 0.10% Ni and 0.15% Cu. What is its IIW carbon equivalent?

A. 0.40
B. 0.52
C. 0.31
D. 0.45

81. A steel coupon (density 7.87 g/cm3, area 50 cm2) loses 4,850 mg in 720 h of immersion. Using CPR = 87.6W/(rho A t), what is the corrosion rate?

A. 0.15 mm/y
B. 3.00 mm/y
C. 0.90 mm/y
D. 1.50 mm/y

84. A eutectoid steel is quenched rapidly from austenite to room temperature. What is the nature of the martensite that forms?

A. A supersaturated BCT phase formed by diffusionless shear
B. An equilibrium mixture of ferrite and cementite
C. Fine spheroidal carbides in a ferrite matrix
D. A FCC phase stabilized by dissolved carbon

87. What property of a steel is measured by the Jominy end-quench test?

A. Ultimate tensile strength
B. Impact toughness
C. Hardenability
D. Creep resistance

90. A quenched steel part is too brittle for service. What does tempering it at an intermediate temperature accomplish?

A. Raises hardness and lowers ductility further
B. Converts all martensite back to austenite
C. Raises toughness while lowering hardness somewhat
D. Increases the carbon content of the surface

93. A steel is quenched into a salt bath above the Ms temperature and held until transformation is complete. Which microstructure results?

A. Martensite
B. Coarse pearlite
C. Bainite
D. Retained austenite only

96. A type 304 stainless steel weld fails by intergranular corrosion in the heat-affected zone. What is the most likely cause?

A. Formation of martensite in the weld metal
B. Hydrogen absorption from the shielding gas
C. Chromium carbide precipitation at grain boundaries
D. Excess nickel segregated to the surface

99. Galvanized steel sheet is scratched through to the base metal and exposed to seawater. What happens at the scratch?

A. Steel corrodes faster than if uncoated
B. Both metals become passive and stop corroding
C. Iron deposits onto the zinc coating
D. Zinc corrodes sacrificially and protects the steel

102. For precipitation hardening of an Al-Cu alloy, what is the correct sequence of heat treatment steps?

A. Age, quench, then solution treat
B. Quench, solution treat, then age
C. Solution treat, quench, then age
D. Anneal, slow cool, then quench

105. Why is deformation of pure lead at room temperature regarded as hot working?

A. Lead has a BCC structure with few slip systems
B. Lead work hardens rapidly at room temperature
C. Room temperature is above lead's recrystallization temperature
D. Lead undergoes a phase change near 25 C

108. How many slip systems of the {111} plane, 110-direction type does an FCC crystal have?

A. 8
B. 24
C. 48
D. 12

111. Charpy tests on a low-carbon structural steel show a sharp drop in absorbed energy below about -20 C. Why is this behavior expected?

A. FCC metals become brittle at low temperature
B. BCC steels exhibit a ductile-to-brittle transition
C. Charpy specimens are too small for low temperatures
D. Carbon precipitates as graphite on cooling

114. Adding small amounts of magnesium or cerium to molten cast iron before casting produces which type of iron?

A. Gray cast iron with flake graphite
B. Ductile (nodular) cast iron
C. White cast iron with massive cementite
D. Malleable iron directly from the mold

117. For a binary alloy at constant pressure, how many degrees of freedom exist at the eutectic point where three phases coexist?

A. 1
B. 0
C. 2
D. 3

120. An inspector must check an austenitic stainless steel weld for fine surface-breaking cracks. Which NDT method is most appropriate?

A. Liquid penetrant testing
B. Magnetic particle testing
C. Eddy current wall thickness gauging
D. Hardness traverse testing

Answer key

Metallurgical Engineering

1. D. 88.1%

R = c(f - t)/[f(c - t)] = 24.0(1.05)/[1.20(23.85)] = 25.2/28.62 = 88.1%.

2. B. 0.50 kg

2 mol NaCN per mol Au: 1000/196.97 x 2 x 49.01 g = 498 g = 0.50 kg.

3. A. 51.2%

Wp = (0.40 - 0.022)/(0.76 - 0.022) = 0.378/0.738 = 51.2%.

4. B. 22.7

F/C = (c - t)/(f - t) = 23.85/1.05 = 22.7; 20.0 is the enrichment ratio c/f, not the ratio of concentration.

5. D. 91.3%

Extraction = (3.20 - 0.28)/3.20 = 2.92/3.20 = 91.25%, or about 91.3%.

6. C. 14.6%

W(Fe3C) = (1.0 - 0.022)/(6.70 - 0.022) = 0.978/6.678 = 14.6%.

7. C. 10.15 kWh/t

W = Wi(10/sqrt(P80) - 10/sqrt(F80)) = 14(0.8165 - 0.0913) = 10.15 kWh/t.

8. C. 785 kg

m = ItM/(nF) x CE = 30000(86400)(63.546)/(2 x 96485) x 0.92 = 785 kg.

9. D. 7.4%

W = (1.2 - 0.76)/(6.70 - 0.76) = 0.44/5.94 = 7.4%.

10. A. 16.7 kWh/t

W = 1500/120 = 12.5 kWh/t; Wio = 12.5/(10/sqrt(106) - 10/sqrt(2000)) = 12.5/0.7477 = 16.7 kWh/t.

11. C. 1,875 kWh/t

E = VnF/(M x CE) = 2.0(2)(96485)/(63.546 x 0.90) J/g = 6748 J/g = 1,875 kWh/t.

12. A. 31.8%

Ws = (C0 - CL)/(CS - CL) = (35 - 31.5)/(42.5 - 31.5) = 3.5/11 = 31.8%.

13. B. 2031 kW

Power = 200 t/h x 10.15 kWh/t = 2031 kW.

14. D. 2,271 kg

m = ItM/(3F) x CE = 300000(86400)(26.98)/(3 x 96485) x 0.94 = 2,271 kg.

15. D. 8.90 g/cm3

a = 2sqrt(2)r = 0.3620 nm; rho = 4(63.55)/[6.022e23 x (3.620e-8 cm)^3] = 8.90 g/cm3.

16. C. 16.7 rpm

Nc = 42.3/sqrt(3.6) = 22.29 rpm; 0.75 x 22.29 = 16.7 rpm.

17. D. 1,317 kg

m = 50000(86400)(65.38)/(2 x 96485) x 0.90 = 1,317 kg.

18. A. 0.2866 nm

In BCC, atoms touch along the body diagonal: a = 4r/sqrt(3) = 4(0.1241)/1.732 = 0.2866 nm.

19. A. 233%

CL = (o - f)/(f - u) = (80 - 45)/(45 - 30) = 35/15 = 2.33, or about 233% of new feed.

20. A. To the anode slimes

Noble metals do not dissolve at the anode potential and fall to the cell bottom as anode slimes, which are treated for precious metals.

21. A. 44.7 deg

sin(theta) = 0.1542/(2 x 0.2027) = 0.3804, theta = 22.36 deg, so 2-theta = 44.7 deg.

22. D. 48.3%

Cw = rho(s)(rho(p) - 1)/[rho(p)(rho(s) - 1)] = 2.8(0.45)/[1.45(1.8)] = 48.3%.

23. D. The anode reaction is copper dissolution, not oxygen evolution

In refining the anode and cathode reactions are nearly reverse of each other, so only ohmic and overpotential losses remain.

24. C. 0.2087 nm

d = a/sqrt(h^2 + k^2 + l^2) = 0.3615/sqrt(3) = 0.2087 nm.

25. C. 187 m3/h

Water = 100(60/40) = 150 m3/h; solids volume = 100/2.7 = 37.0 m3/h; total = 187 m3/h.

26. D. 560 kg

Fe = 800 kg x (2 x 55.845/159.69) = 800 x 0.6994 = 560 kg.

27. C. 2.9e-05

Nv/N = exp(-Qv/kT) = exp(-0.90/(8.617e-5 x 1000)) = exp(-10.44) = 2.9e-05.

28. B. 2.25 mm/s

v = g d^2 (rho(s) - rho(f))/(18 mu) = 9.81(50e-6)^2(1650)/(0.018) = 2.25e-03 m/s = 2.25 mm/s.

29. C. Boudouard reaction, C + CO2 = 2CO

The Boudouard (solution loss) reaction converts CO2 back to CO, which is the main gaseous reductant.

30. B. 6.9 h

(Cx - C0)/(Cs - C0) = 0.5, so erf(z) = 0.5 and x/(2sqrt(Dt)) = 0.4769; t = (0.0006/0.9538)^2/1.6e-11 = 24732 s = 6.9 h.

31. B. 11.1

CC = (19.3 - 1)/(2.65 - 1) = 18.3/1.65 = 11.1; values above about 2.5 indicate easy gravity separation.

32. A. 1.20

Basicity = 42/35 = 1.20.

33. A. 5.9e-12 m2/s

D = 2.3e-5 exp(-148000/(8.314 x 1173)) = 2.3e-5 x exp(-15.18) = 5.9e-12 m2/s.

34. C. 3.64

CC = (7.0 - 1)/(2.65 - 1) = 6.0/1.65 = 3.64.

35. D. 214 kg

CaO needed = 1.2 x 100 = 120 kg; CaCO3 = 120 x 100.09/56.08 = 214 kg.

36. D. 218 MPa

sigma(y) = 70 + 0.74/sqrt(25e-6) = 70 + 0.74/0.005 = 218 MPa.

37. D. 19.5 m

Area = 0.25 x 1200 = 300 m2; D = sqrt(4 x 300/pi) = 19.5 m.

38. C. 657 kg

SO2 = 1000/97.47 kmol x 64.07 = 657 kg.

39. A. 367 MPa

A = pi(12.5)^2/4 = 122.7 mm2; sigma = 45000/122.7 = 367 MPa.

40. B. 90%

Efficiency = undersize recovered / undersize in feed = 54/60 = 90%.

41. A. 3.06 t

H2SO4/S = 98.08/32.06 = 3.06 t per tonne of sulfur.

42. A. 0.375 mm

delta = sigma L/E = 300(250)/200000 = 0.375 mm.

43. B. 90.3%

R = 95(1 - e^(-0.5 x 6)) = 95(1 - 0.0498) = 90.3%.

44. D. 532 kg

CaO = 950 x 56.08/100.09 = 532 kg.

45. A. 448 MPa

sigma(T) = sigma(1 + e) = 400(1.12) = 448 MPa, valid up to the onset of necking.

46. D. 58.8 m3

V = 250 x 12/60 / 0.85 = 50.0/0.85 = 58.8 m3.

47. A. 457 t

Cu to matte = 0.98 x 280 = 274.4 t; matte = 274.4/0.60 = 457 t.

48. A. 60.9%

%RA = [1 - (8.0/12.8)^2] x 100 = (1 - 0.3906) x 100 = 60.9%.

49. A. 1,667 t/d

Feed water = 1000(70/30) = 2,333 t/d; underflow water = 1000(40/60) = 667 t/d; overflow = 2,333 - 667 = 1,667 t/d.

50. D. 62.6%

Cu2S = 50 x 159.16/(2 x 63.55) = 62.6%.

51. D. 25%

%EL = (62.5 - 50)/50 x 100 = 25%; 20% would wrongly divide by the final length.

52. C. 90.1%

Solving the three-product mass balance gives a lead concentrate mass of 6.93% of feed; Pb recovery = 6.93(65)/5.0 = 90.1%.

53. B. FeS is oxidized and the iron is slagged with silica flux

Iron sulfide oxidizes preferentially; FeO combines with SiO2 to form fayalite slag, leaving white metal (Cu2S).

54. B. 207 HB

HB = 2P/[pi D (D - sqrt(D^2 - d^2))] = 6000/[pi(10)(10 - 9.075)] = 207.

55. C. 20

Enrichment ratio = concentrate grade/feed grade = 24/1.2 = 20.

56. C. 927 C

dG = 0 at T = dH/dS = 180000/150 = 1200 K = 927 C; above this dG is negative.

57. B. 4.97 mm

a = (K/(Y sigma))^2/pi = (50/400)^2/pi = 0.015625/3.1416 = 0.00497 m = 4.97 mm.

58. C. 5.0

Reduction ratio = feed size/product size = 600/120 = 5.0.

59. B. 123

K = exp(-dG/RT) = exp(40000/(8.314 x 1000)) = exp(4.811) = 123.

60. D. 225 MPa

sigma(a) = Se(1 - sigma(m)/Su) = 300(1 - 200/800) = 300(0.75) = 225 MPa.

61. B. It adsorbs on the sulfide surface and makes it hydrophobic

Xanthates chemisorb on sulfide surfaces, rendering them hydrophobic so they attach to air bubbles.

62. D. 8.7e-14 atm

pO2 = exp(dG/RT) = exp(-300000/(8.314 x 1200)) = exp(-30.07) = 8.7e-14 atm.

63. B. 20,700

LMP = T(C + log t) = 900(20 + 3) = 20,700 (T in K, t in hours).

64. B. Frother that produces small, stable bubbles

MIBC is an alcohol-type frother that lowers surface tension, forming fine bubbles and a stable froth.

65. C. -851.5 kJ

dH = -1675.7 - (-824.2) = -851.5 kJ; the reaction is strongly exothermic (thermite).

66. D. 26.4 MPa

tau = sigma cos(phi) cos(lambda) = 60(0.766)(0.574) = 26.4 MPa.

67. B. To activate sphalerite so xanthate can float it

Cu2+ ions exchange onto the sphalerite surface, forming a copper-sulfide-like layer that responds to xanthate.

68. B. 0.281 V

E = 0.34 + (0.05916/2)log(0.01) = 0.34 - 0.059 = 0.281 V.

69. A. 36%

%CW = [1 - (12/15)^2] x 100 = (1 - 0.64) x 100 = 36%; 20% uses diameters instead of areas.

70. B. To depress pyrite while floating copper sulfides

At high pH, hydroxide and calcium species coat pyrite and suppress xanthate adsorption, improving copper selectivity.

71. C. 71.4%

%CO = 1/(1 + K) x 100 = 1/1.40 = 71.4%; any higher CO content drives reduction.

72. B. 0.306 MJ/m3

Ur = sigma(y)^2/(2E) = 350^2/(2 x 200000) = 0.306 MPa = 0.306 MJ/m3.

73. C. Centrifugal bowl concentrator

Centrifugal concentrators apply many times gravitational acceleration, improving recovery of fine dense particles such as gold.

74. A. 306 MJ

Q = 500[0.385(1058) + 205] = 500(407.3 + 205) kJ = 306 MJ.

75. A. -0.0045 mm

Lateral strain = -0.30 x 0.0015 = -0.00045; change = -0.00045 x 10 = -0.0045 mm.

76. B. Low-intensity wet drum magnetic separator

Magnetite is strongly ferromagnetic and is readily recovered by low-intensity drum magnets.

77. B. 0.20

Sieverts' law: [H] is proportional to sqrt(pH2); sqrt(0.04/1.0) = 0.20.

78. D. 0.45

CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15 = 0.20 + 0.20 + 0.03 + 0.017 = 0.45.

79. B. Ilmenite from zircon

Ilmenite and rutile are conductors that lose charge on a grounded roll, while zircon is a non-conductor that stays pinned.

80. D. Aluminum can reduce Cr2O3 to chromium metal

A lower line means a more negative dG of formation, so aluminum can reduce oxides lying above it (aluminothermic reduction).

81. D. 1.50 mm/y

CPR = 87.6(4850)/(7.87 x 50 x 720) = 1.50 mm/y.

82. D. Finely ground ferrosilicon or magnetite in water

Ferrosilicon or magnetite suspensions give adjustable medium densities and are recovered magnetically for reuse.

83. A. The stable species as functions of potential and pH

Pourbaix diagrams map thermodynamically stable phases and ions against electrode potential and pH at a given temperature.

84. A. A supersaturated BCT phase formed by diffusionless shear

Martensite forms without diffusion, trapping carbon in a body-centered tetragonal lattice.

85. A. Rittinger's law

Rittinger's law relates energy to new surface created, and fits fine grinding better than coarse crushing.

86. B. Stripping with strongly acidic spent electrolyte

High acidity reverses the extraction equilibrium, releasing Cu2+ into the aqueous strip liquor for electrowinning.

87. C. Hardenability

The Jominy test records hardness versus distance from a quenched end, indicating depth of hardening (hardenability).

88. C. It gives a narrower product size with less overgrinding

Rods grind preferentially on coarse particles, producing a more uniform size distribution with fewer slimes.

89. C. Elution with hot caustic cyanide solution

Hot alkaline cyanide (often under pressure) desorbs the gold cyanide complex; acid washing only removes scale.

90. C. Raises toughness while lowering hardness somewhat

Tempering precipitates fine carbides and relieves stresses, trading some hardness for improved toughness.

91. C. Installing a larger vortex finder

A larger vortex finder lets more flow and coarser particles exit through the overflow, raising the cut size d50.

92. A. Dissolved oxygen would redissolve gold and consume zinc

Removing oxygen prevents re-dissolution of precipitated gold and wasteful oxidation of zinc.

93. C. Bainite

Isothermal holding above Ms (austempering) transforms austenite to bainite.

94. B. The apex is too small for the solids load

Roping occurs when the apex cannot pass the coarse solids, so coarse particles misreport to the overflow.

95. A. Regenerating ferric ions that oxidize the sulfides

Bacteria oxidize Fe2+ back to Fe3+, the oxidant that attacks sulfide minerals, sustaining the leach.

96. C. Chromium carbide precipitation at grain boundaries

Sensitization depletes chromium next to grain boundaries; low-carbon or Ti/Nb-stabilized grades prevent it.

97. B. The degree of liberation of chalcopyrite

Degree of liberation is the percentage of a mineral present as free particles at a given size.

98. A. Molten magnesium

$TiCl_4 + 2Mg = Ti + 2MgCl_2$ in an inert atmosphere; the $MgCl_2$ is recycled by electrolysis.

99. D. Zinc corrodes sacrificially and protects the steel

Zinc is anodic to steel in the galvanic series, so it corrodes preferentially and cathodically protects exposed steel.

100. C. The amenability of the ore to gravity separation

Sink-float (washability) data show how mass and value distribute by density, indicating gravity separation potential.

101. B. Hot sodium hydroxide solution

Hot caustic soda dissolves gibbsite and boehmite as sodium aluminate, leaving iron oxides in red mud.

102. C. Solution treat, quench, then age

Solutionizing dissolves Cu, quenching retains a supersaturated solid solution, and aging forms strengthening precipitates.

103. D. Higher concentrate grade with some loss of recovery

Extra cleaning rejects more entrained gangue, raising grade, but some valuable particles are also lost, lowering recovery.

104. A. Ferrosilicon

Silicothermic reduction with ferrosilicon at high temperature and vacuum releases Mg vapor, which is condensed.

105. C. Room temperature is above lead's recrystallization temperature

Lead's low melting point puts its recrystallization temperature near or below room temperature, so it does not strain harden.

106. D. Pelletizing

Pelletizing rolls moist fine concentrate with a binder such as bentonite into balls that are then fired for strength.

107. C. Mond process

In the Mond process Ni reacts with CO to form Ni(CO)4, which decomposes at higher temperature to pure nickel.

108. D. 12

Four {111} planes each contain three 110-type close-packed directions, giving 12 slip systems.

109. C. It is hydrophobic and readily attaches to bubbles

A large contact angle means the surface is poorly wetted by water, favoring bubble attachment.

110. B. Oxidation to CO gas by blown oxygen

Oxygen jets oxidize dissolved carbon to CO, which leaves as gas and stirs the bath.

111. B. BCC steels exhibit a ductile-to-brittle transition

BCC iron's yield stress rises steeply as temperature falls, causing a ductile-to-brittle transition; FCC metals do not show this.

112. D. Gyratory crusher

Gyratory crushers handle large feed and very high throughput continuously, making them standard for big primary duties.

113. A. High basicity with low oxygen potential

Desulfurization (S + O2- = S2- + O) is promoted by abundant free CaO and reducing conditions.

114. B. Ductile (nodular) cast iron

Mg or Ce causes graphite to grow as spheroids, giving ductile iron with much higher ductility than gray iron.

115. A. To divide the sample into representative portions

A riffle splitter divides a dry sample into equal, representative fractions for reducing sample mass.

116. D. Reformed natural gas rich in H2 and CO

Natural gas is reformed to H2 and CO, which reduce pellets in the solid state to direct reduced iron.

117. B. 0

Condensed phase rule F = C - P + 1 = 2 - 3 + 1 = 0; the eutectic is invariant.

118. D. 88%

Recovery = (C/F)(c/f) = 0.044 x 24/1.2 = 0.88, or 88%.

119. A. Its distribution coefficient k is less than 1

If k = Cs/Cl < 1, the impurity concentrates in the molten zone and is swept toward one end of the bar.

120. A. Liquid penetrant testing

Austenitic stainless is non-ferromagnetic, so magnetic particle testing will not work; penetrants reveal surface-open cracks.

Topics to review

• Mineral processing and metal extraction

- Phase diagrams, microstructures and heat treatment
- Mechanical testing and failure analysis
- Corrosion, process control and safety

Online question banks and study resources

Metallurgical Engineering - Pass Harbor (Question bank)

Official PRC board information

Current PRC exam programs

Independent study material prepared by Board Exam Desk.