2007

MT: Metallurgical Engineering

Duration : Three Hours Maximum Marks :150

Read the following instructions carefully.

1. This question paper contains 85 objective type questions. Q.1 to Q.20 carry **one** mark each and Q.21 to Q.85 carry **two** marks each.
2. Attempt all the questions.
3. Questions must be answered on **O**bjective **R**esponse **S**heet (**ORS**) by darkening the appropriate bubble (marked A, B, C, D) using HB pencil against the question number on the left hand side of the **ORS**. **Each question has only one correct answer.** In case you wish to change an answer, erase the old answer completely.
4. Wrong answers will carry NEGATIVE marks. In Q.1 to Q.20, **0.25** mark will be deducted for each wrong answer. In Q.21 to Q.76, Q.78, Q.80, Q.82 and in Q.84, **0.5** mark will be deducted for each wrong answer. However, there is no negative marking in Q.77, Q.79, Q.81, Q.83 and in Q.85. More than one answer bubbled against a question will be taken as an incorrect response. Unattempted questions will not carry any marks.
5. Write your registration number, your name and name of the examination centre at the specified locations on the right half of the **ORS**.
6. Using HB pencil, darken the appropriate bubble under each digit of your registration number and the letters corresponding to your paper code.
7. Calculator is allowed in the examination hall.
8. Charts, graph sheets or tables are NOT allowed in the examination hall.
9. Rough work can be done on the question paper itself. Additionally blank pages are given at the end of the question paper for rough work.
10. This question paper contains **20** printed pages including pages for rough work. Please check all pages and report, if there is any discrepancy.

S/121 Food/06–MT–1A

Useful Data

1 poise = 0.1 Pa s
Universal Gas Constant, $R = 8.314\ \text{J mol}^{-1}\ \text{K}^{-1}$
Boltzmann's constant, $k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
Acceleration due to gravity, $g = 9.8\ \text{m s}^{-2}$

Atomic Mass
H = 1
C = 12
N = 14
O = 16

Q. 1 – Q. 20 carry one mark each.

Q.1 The number of boundary conditions required to solve a steady-state two-dimensional diffusion equation ($\nabla^2 C = 0$) is

(A) 1 (B) 2 (C) 3 (D) 4

Q.2 The determinant of the matrix $\begin{bmatrix} 1 & 3 & 2 \\ 2 & 6 & 4 \\ -5 & 3 & 1 \end{bmatrix}$ is

(A) -10 (B) -5 (C) 0 (D) 5

Q.3 With ε = true plastic strain and n = strain-hardening coefficient, necking in a cylindrical tensile specimen of a work-hardening metal occurs when

(A) $\varepsilon = n$ (B) $\varepsilon = 2n$ (C) $\varepsilon = n^{0.5}$ (D) $\varepsilon = n^2$

Q.4 A perfectly plastic metal piece, with 4 mm × 4 mm cross-section and 25 mm length, is stretched to 100 mm. What is the deformed cross-section?

(A) 1 mm × 1 mm (B) 2 mm × 2 mm (C) 3 mm × 3 mm (D) 4 mm × 4 mm

Q.5 Loading in Mode I fracture refers to

(A) Opening mode (B) Sliding mode (C) Tearing mode (D) Twisting mode

Q.6 Cyclones are primarily used for

(A) Comminution
(B) Concentration
(C) Dewatering
(D) Classification

Q.7 A typical collector used in sulphide mineral flotation is

(A) Pine oil
(B) Potassium ethyl xanthate
(C) Oleic acid
(D) Polyacrylamide

Q.8 In a three component system at constant pressure, the maximum number of phases that can coexist at equilibrium is

(A) 2 (B) 3 (C) 4 (D) 5

Q.9 Which metal is extracted by leaching?

(A) Iron (B) Aluminum (C) Lead (D) Gold

Q.10 In a niobium micro-alloyed steel joined by fusion welding the most likely cause of loss of strength in the heat affected zone (HAZ) is

(A) precipitate coarsening and grain growth
(B) coarse pearlite and grain boundary precipitation
(C) tempered martensite and grain boundary carbide
(D) formation of bainite

Q.11 The primary source of heat in cupola melting is provided by the reaction:

(A) $C + O_2 \rightarrow CO_2$
(B) $C + H_2O \rightarrow CO + H_2$
(C) $C + CO_2 \rightarrow 2CO$
(D) $CaCO_3 \rightarrow CaO + CO_2$

Q.12 A solder wire does NOT work-harden at room temperature, even upon bending back and forth several times. This is because

(A) the dislocations become immobilized during the bending process
(B) the grains grow preferentially in the direction of deformation
(C) the recrystallization temperature is below room temperature
(D) the grains have a preferred orientation

Q.13 A typical cooling rate for metal substrate powder atomization is of the order of

(A) $10^{-4}\ Ks^{-1}$ (B) $1\ Ks^{-1}$ (C) $10^{4}\ Ks^{-1}$ (D) $10^{8}\ Ks^{-1}$

Q.14 In foundry practice, the fluidity of an alloy does NOT increase with increasing

(A) superheat
(B) channel size
(C) flow velocity
(D) heat transfer coefficient

Q.15 In a polymer with a large quantity of relatively small chains, the mass-averaged molecular weight is

(A) greater than the number-averaged molecular weight
(B) smaller than the number-averaged molecular weight
(C) equal to the number-averaged molecular weight
(D) unrelated to the number-averaged molecular weight

Q.16 Which one of the following alloy systems exhibits complete solid solubility?

(A) Cu-Ni
(B) Fe-Cu
(C) Pb-Sn
(D) Cu-Zn

Q.17 A small amount of thoria is doped into tungsten filament wires used in light bulbs. This is because thoria particles

(A) decreases solute diffusivity
(B) enhance the mobility of grain boundary
(C) increases solute segregation to the grain boundary
(D) are effective in limiting grain growth

Q.18 Liquid steel is in equilibrium with a graphite crucible. The activity of carbon (with graphite as the reference state) in liquid iron is

(A) 0.5 (B) 0.85 (C) 1.0 (D) 1.5

Q.19 In one FCC unit cell, there are

(A) 4 tetrahedral and 8 octahedral sites
(B) 8 tetrahedral and 4 octahedral sites
(C) 12 tetrahedral and 4 octahedral sites
(D) 4 tetrahedral and 4 octahedral sites

Q.20 The dimension of thermal conductivity in terms of mass (M), length (L), time (T), and temperature (θ) is

(A) $M L^2 T^{-3} \theta^{-1}$ (B) $M T^{-3} \theta^{-1}$ (C) $L^2 T^{-1}$ (D) $M L T^{-3} \theta^{-1}$

Q. 21 to Q. 75 carry two marks each.

Q.21 The configurational entropy, S_c in an ideal solid solution is given by: $S_c = -R\left[x \ln x + (1-x)\ln(1-x)\right]$, where x is the mole fraction of solute. The limit of S_c, as x tends to zero ($\lim_{x\to 0} S_c$) is

(A) ∞ (B) $R \ln 2$ (C) R (D) 0

Q.22 The [100] and [110] directions in a cubic crystal are coplanar with

(A) [101] (B) [001] (C) [120] (D) [111]

Q.23 In a RH degasser, the hydrogen mass balance is governed by the following equation:

$$-W\frac{dC_H}{dt} = R(C_H - C_{H,eq}),$$

where W is the capacity of the degasser in tons, C_H is the hydrogen concentration at any time t, and $C_{H,eq}$ is the equilibrium hydrogen concentration in liquid steel. R is the circulation rate in tons per minute. In order to bring down the hydrogen content from 5 ppm to 1 ppm in 20 minutes, the circulation rate, R, should be (Given: $C_{H,eq} = 0.5$ ppm, $W = 150$ tons)

(A) 10.05 tons/min (B) 12.51 tons/min (C) 14.73 tons/min (D) 16.48 tons/min

Q.24 If $\mathbf{V} = \left(4xy - 3z^3\right)\mathbf{i} + 2x^2\,\mathbf{j} - 9xz^2\,\mathbf{k}$, the divergence of $\mathbf{V}$ is

(A) $(4xy - 18z)$ (B) $(4y^2 - 9xz)$ (C) $(4y - 18xz)$ (D) $(2xy + 18z^2)$

Q.25 The carbon concentration profile $C(x,t)$ during decarburization is given by:

$$C(x,t) = L + M\,\mathrm{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

where x is the distance from the surface, t is time, D is the diffusion coefficient of carbon in austenite, and L and M are constants. If the furnace atmosphere is free of carbon and maintained at 927°C, approximately how long does it take for a steel with an initial carbon concentration of 1.2 % to attain a carbon concentration of 0.8 % at a distance of 0.5 mm below the surface?

[Given: $D = 1.28 \times 10^{-11}\ \mathrm{m^2\,s^{-1}}$ at 927 °C;
$\mathrm{erf}(0) = 0$; $\mathrm{erf}(0.65) = 0.64$; $\mathrm{erf}(0.69) = 0.667$; $\mathrm{erf}(0.7) = 0.678$; $\mathrm{erf}(\infty) = 1$]

(A) 30 hours (B) 3 hours (C) 3 minutes (D) 30 seconds

Q.26 The probability distribution function, $p(x)$, for a random variable, x, is given by:

$$p(x) = \frac{1}{\sqrt{\pi}}\exp\left(-x^2\right).$$

The probability that x lies between $x_1 = 0.6$ and $x_2 = 0.8$ is
[Use single-step trapezoidal rule]

(A) 0 (B) 0.069 (C) 0.138 (D) 0.560

Q.27 In the TTT diagram for the eutectoid carbon steel, the nose of the characteristic C-curve is at 550 °C; this C-shape implies delayed transformation both above and below 550 °C. The delay at lower temperatures is due to low diffusivity. The delay at higher temperatures is due to

(A) low driving force for transformation
(B) low mobility of dislocations
(C) low concentration of vacancies
(D) low diffusivity

Q.28 A cylindrical specimen of an isotropic metal (Young's modulus, $E = 200$ GPa) is elastically deformed in tension. Length of this cylinder before deformation is 100 mm and the diameter is 10 mm. After the deformation, they are 100.1 mm and 9.996 mm, respectively. The shear modulus, G, of this metal is
[Given: $E = 2\,G\,(1+\nu)$]

(A) 71.43 GPa (B) 76.92 GPa (C) 83.33 GPa (D) 100.00 GPa

Q.29 By means of chemical modifications, surface energy of a highly brittle material is doubled without changing the elastic modulus. The approximate percent increase in fracture strength of the material is

(A) 100 (B) 73 (C) 50 (D) 41

Q.30 Match the fracture processes in group I to the fracture surface morphologies in group II.

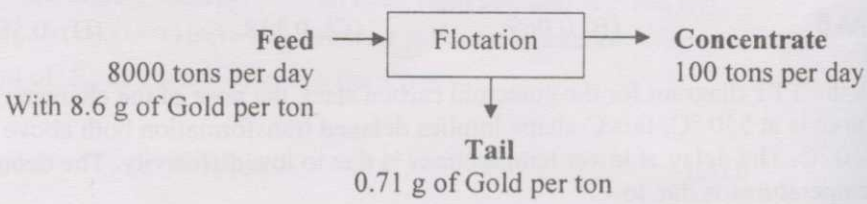
Group-I	Group-II
(P) Ductile fracture	(1) Cleavage
(Q) Brittle fracture	(2) Dimples
(R) Fatigue fracture	(3) Striations
	(4) Veins

(A) P-4, Q-2, R-3
(B) P-2, Q-1, R-3
(C) P-2, Q-3, R-1
(D) P-4, Q-3, R-2

Q.31 The settling velocity of a 0.5 micron diameter particle (density = 4900 kg m^{-3}) in water (density = 1000 kg m^{-3}) under laminar flow conditions is
[Given: viscosity of water = 1 centipoise]

(A) 53.08×10^{-9} m s^{-1}
(B) 40×10^{-9} m s^{-1}
(C) 53.08×10^{-8} m s^{-1}
(D) 106.16×10^{-9} m s^{-1}

Q.32 The recovery of gold in the following operation is



(A) 8.25% (B) 22.26 % (C) 85.80% (D) 91.80%

Q.33 What is the volume % solids in a pulp containing 65 wt % solids? Average specific gravity of solids is 2.70

(A) 72.9% (B) 65% (C) 59.3% (D) 40.7%

Q.34 The conditions necessary for superplastic deformation in an alloy are

(P) extremely fine and uniform grain size
(Q) high homologous temperature
(R) high strain rate
(S) coarse non-uniform grains

(A) P,Q
(B) Q, R, S
(C) P, Q, R
(D) Q, R

Q.35 For ingot breakdown by hot rolling, the rolls are generally grooved parallel to the roll axis in order to

(P) increase the angle of bite
(Q) decrease the rolling load
(R) achieve larger reduction
(S) decrease roll flattening

(A) P, Q
(B) Q, R
(C) P, R
(D) Q, S

Q.36 An induction furnace with a holding capacity of 20 tons is used for melting 5 tons of white iron charge. The maximum available power is 5 MW. The energy required to melt 1-ton of charge is 530 kWh. Assuming no heat loss, the maximum melting rate in tons/hour is approximately

(A) 18.4
(B) 15.8
(C) 9.4
(D) 1.8

Q.37 The pressure required to maintain flow during indirect extrusion

(P) decreases with decreasing length of the billet
(Q) increases with increasing extrusion ratio
(R) is independent of the length of the billet
(S) is independent of extrusion ratio

(A) P, Q
(B) Q, R
(C) R, S
(D) P, S

Q.38 Match the forming methods in group-I with the defects in group-II.

Group-I	Group-II
(P) Extrusion	(1) Flash cracking
(Q) Closed die forging	(2) Fir-tree cracking
(R) Rolling	(3) Alligatoring
	(4) Earing

(A) P-1, Q-2, R-3
(B) P-4, Q-3, R-1
(C) P-3, Q-1, R-4
(D) P-2, Q-1, R-3

Q.39 Match the additions to the flux cover in a welding rod in group-I with their functions in group-II.

Group-I	Group-II
(P) Boron, Niobium	(1) De-oxidizer
(Q) Aluminium, Silicon	(2) Grain refiner
(R) Sodium Oxide, Potassium Oxide	(3) Arc stabilization
	(4) Protection of weld metal

(A) P-1, Q-2, R-3
(B) P-2, Q-1, R-3
(C) P-3, Q-1, R-4
(D) P-1, Q-3, R-4

Q.40 For better resistance welding, the metal must have

(P) high electrical resistivity and low melting point
(Q) high thermal conductivity
(R) high electrical resistivity and high melting point
(S) low thermal conductivity

(A) P, Q
(B) P, S
(C) R, Q
(D) R, S

Q.41 The atomic packing factor for the diamond cubic structure is

(A) 0.74
(B) 0.68
(C) 0.34
(D) 0.25

Q.42 The maximum amount of proeutectic austenite that can form in an iron-carbon alloy containing 3.5% carbon is
[Given: The maximum solubility of carbon in γ-iron is 2.11%]

(A) 24.80%
(B) 36.53%
(C) 67.87%
(D) 72.52%

Q.43 Identify the **incorrect** statement with reference to LD steel making

(A) The temperature of the LD furnace is maintained at around 1600 °C.
(B) The basicity of slag is maintained at around unity.
(C) Dephosphorization and decarburization should proceed simultaneously.
(D) High silicon hot metal may lead to slopping.

Q.44 Match each process in group I with a product in group II.

Group-I	Group-II
(P) Czochralski process	(1) single crystal of GaAs
(Q) Calendaring	(2) hypoeutectic Al-Si alloy
(R) Pultrusion	(3) vinyl floor tile
(S) Thixocasting	(4) polymer matrix composite containing continuous fibres

(A) P-1, Q-2, R-3, S-4
(B) P-4, Q-1, R-3, S-2
(C) P-1, Q-3, R-4, S-2
(D) P-4, Q-3, R-1, S-2

Q.45 Match each application in group I with a material in group II.

Group-I	Group-II
(P) Cores for electric motors	(1) $\gamma - Fe_2O_3$ particles
(Q) Stripe on credit cards	(2) barium titanate
(R) Permanent magnet	(3) Co_5Sm intermetallic compound
(S) Multilayer capacitors	(4) grain-oriented silicon steel

(A) P-3, Q-1, R-2, S-4
(B) P-4, Q-1, R-3, S-2
(C) P-4, Q-1, R-2, S-3
(D) P-2, Q-1, R-3, S-4

Q.46 Match each phase in group I with a description in group II.

Group-I	Group-II
(P) ε - Carbide	(1) a three-component eutectic of iron, iron-carbide, iron-phosphate found in cast iron
(Q) Sigma phase	(2) an embrittling compound found in ferritic stainless steels
(R) δ – Ferrite	(3) obtained on tempering of hardened steels
(S) Steadite	(4) responsible for causing the weld-deposit on austenitic stainless steels to be slightly magnetic

(A) P-1, Q-3, R-4, S-2
(B) P-1, Q-2, R-4, S-3
(C) P-3, Q-2, R-1, S-4
(D) P-3, Q-2, R-4, S-1

Q.47 Match each material in group I with a bond-type in group II.

Group-I	Group-II
(P) Silicon	(1) Metallic bonding
(Q) Copper	(2) Covalent bonding
(R) Sodium chloride	(3) Ionic bonding
	(4) Van der Waals bonding

(A) P-2, Q-1, R-4
(B) P-1, Q-3, R-1
(C) P-4, Q-1, R-3
(D) P-2, Q-1, R-3

Q.48 The activation energy for a reaction is 100 kJ/mole. The approximate increase in temperature required for doubling the rate of reaction, from that at 25 °C, is

(A) 5 °C (B) 10 °C (C) 15 °C (D) 20 °C

Q.49 The standard free energy change for the reaction,
$2Fe(s)+\frac{3}{2}O_2(g)=Fe_2O_3(s)$, is $0.258\,T-820.89$ kJ mol^{-1}, where T is the temperature in K. The approximate pressure for the dissociation of Fe_2O_3 at 1100°C is

(A) 1.0×10^{-20} atm (B) 1.46×10^{-12} atm (C) 2.3×10^{-7} atm (D) 3.55×10^{-15} atm

Q.50 Identify the **incorrect** statement with reference to unit processes in extractive metallurgy.

(A) Selective distillation is a purification technique used in extractive metallurgy
(B) Coking of coal is carried out in a shaft furnace
(C) Precipitation is a hydrometallurgy route of purification
(D) Predominance area diagram is used to select the operating conditions of roasting

Q.51 Identify the **correct** statement with reference to blast furnace iron making.

(A) Hematite is reduced to magnetite in the lower part of the shaft
(B) Coke rate cannot be improved by oil injection through tuyer
(C) High exit gas temperature may be an indication of "channeling"
(D) Pressure drop in blast furnace cannot be improved by proper burden distribution

Q.52 Match the process in group I to its description in group II.

Group-I	Group-II
(P) COREX process	(1) decarburization of liquid steel
(Q) OBM process	(2) steelmaking using oxygen
(R) Carbonyl process	(3) nickel refining
(S) AOD process	(4) alternative route of liquid iron production

(A) P-4, Q-2, R-3, S-1
(B) P-3, Q-1, R-2, S-4
(C) P-1, Q-4, R-3, S-1
(D) P-2, Q-1, R-3, S-4

Q.53 The process of cementation involves

(A) separation of the desired metal by adding a more reactive metal
(B) elimination of a more reactive metal from molten metal by preferential oxidation
(C) refining by preferential dissolution of the desired metal in an organic solvent
(D) extraction by selective dissolution of the desired metal in an inorganic solvent

Q.54 Identify the **incorrect** statement.

(A) A concentration gradient in the electrolyte may lead to the formation of a galvanic cell
(B) Chromium is added to improve the oxidation resistance of stainless steels
(C) Cathodic protection can be provided by applying a coating
(D) A steel bolt or nut is permissible on a large copper vessel

Q.55 Nanoparticles derive some of their interesting properties due to the large value of f_s, the fraction of surface atoms, compared to f_b, the fraction of atoms in the bulk. The ratio (f_s/f_b) varies with the particle size, r, as

(A) r^{-3}
(B) r^{-2}
(C) r^{-1}
(D) r^{2}

Q.56 A dislocation free single crystal of aluminium has a theoretical shear strength of about
[Given: Shear Modulus, G = 28 GPa]

(A) 28.0 GPa
(B) 4.5 GPa
(C) 0.56 GPa
(D) 0.07 GPa

Q.57 The equilibrium vacancy concentration in copper is 588 ppm at 1000°C and 134 ppm at 800°C. The molar enthalpy of vacancy formation is

(A) 49 kJ mol^{-1}
(B) 84 kJ mol^{-1}
(C) 168 kJ mol^{-1}
(D) 243 kJ mol^{-1}

Q.58 In a cubic crystal with lattice parameter a, the dislocation reaction that is vectorially correct **and** energetically feasible is

(A) $\frac{a}{2}[1\bar{1}\bar{1}]+\frac{a}{2}[111] \rightarrow a[100]$

(B) $\frac{a}{2}[110]+\frac{a}{2}[110] \rightarrow a[110]$

(C) $\frac{a}{6}[101]+\frac{a}{6}[121] \rightarrow \frac{a}{3}[111]$

(D) $\frac{a}{2}[011] \rightarrow \frac{a}{6}[211]+\frac{a}{6}[12\bar{1}]$

Q.59 The mechanical response of an elastomer (such as rubber) is characterized by

(P) an increase in elastic modulus with increasing temperature
(Q) large recoverable strains
(R) a decrease in elastic modulus with increasing temperature
(S) an adiabatic decrease in temperature on stretching

(A) Q, S
(B) P, S
(C) Q, R
(D) P, Q

Q.60 Which of the following statements are **true** about edge dislocations?

(P) Edge dislocations do not have an extra half plane associated with them
(Q) The Burgers vector is perpendicular to the line direction
(R) Edge dislocations can avoid obstacles by cross-slip
(S) Depending on geometry, parallel edge dislocations of opposite sign can attract or repel one another

(A) R
(B) P, Q, S
(C) Q, S
(D) Q, R

Q.61 A structural component in the form of a very wide 10 mm thick plate is to be fabricated from 4340 steel. If the design stress level for the component is 50% of the yield strength, the critical flaw size is
[Given: Yield Strength = 1515 MPa; K_{Ic} = 60.4 MPa $\sqrt{m}$; Geometry factor, Y = 1]

(A) 1.0 mm
(B) 2.0 mm
(C) 3.0 mm
(D) 4.0 mm

Q.62 The tensile yield strength of a ductile metal is 100 MPa. If the material is subjected to tensile stresses of $\sigma_2 = \sigma_3 = 50$ MPa along the second and third principal directions, the material yields when

(A) σ_1 = 50 MPa in compression *or* 150 MPa in tension
(B) σ_1 = 50 MPa in compression *or* 50 MPa in tension
(C) σ_1 = 100 MPa in tension
(D) σ_1 = 0

Q.63 A pure low-angle tilt boundary may be equivalently represented by

(A) an array of jogs on an edge dislocation
(B) a cross grid of screw dislocations
(C) a dislocation pileup consisting of both edge and screw dislocations
(D) an array of edge dislocations perpendicular to the slip plane

Q.64 Match the energy gaps in group-I with the materials in group-II.

Group I	Group II
(P) Diamond	(1) 0.1 eV
(Q) Silicon	(2) 0.7 eV
(R) Gray Tin	(3) 1.1 eV
	(4) 6.0 eV

(A) P-1, Q-3, R-4
(B) P-2, Q-4, R-1
(C) P-3, Q-1, R-2
(D) P-4, Q-3, R-1

Q.65 Match the terms from group I to their descriptions in group II.

Group I	Group II
(P) Hall-Petch Effect	(1) Solute-dislocation interaction
(Q) Bauschinger Effect	(2) Dislocation multiplication
(R) Cottrell atmosphere	(3) Grain boundary strengthening
	(4) Barrelling under compression
	(5) Mechanical hysteresis during plasticity

(A) P-3, Q-5, R-1
(B) P-1, Q-4, R-3
(C) P-5, Q-1, R-2
(D) P-3, Q-4, R-2

Q.66 Enthalpy of formation at 298 K, ΔH^0 of CO_2 and PbO are -393 kJ mol^{-1} and -220 kJ mol^{-1}, respectively. The enthalpy change for the reaction $2PbO + C \rightarrow 2Pb + CO_2$ is

(A) -173 kJ
(B) 15 kJ
(C) 47 kJ
(D) 440 kJ

Q.67 In normalized hypoeutectoid plain carbon steels, how do the fraction of proeutectoid ferrite (f) and yield strength (σ_y) change with increasing carbon content?

(A) f increases and σ_y decreases
(B) both f and σ_y increase
(C) both f and σ_y decrease
(D) f decreases and σ_y increases

Q.68 Identify the **correct** statement about manganese in steels from the following.

(A) it decreases hardenability
(B) it makes the steel susceptible to hot-shortness
(C) it is a strong austenite stabilizer
(D) it decreases hardness of martensite

Q.69 When one mole of copper is quenched from 1000 K to 300 K, the amount of heat released is
[Given: the specific heat capacity of copper in J K^{-1} mol^{-1}
$C_p = 22.68 + 6.3 \times 10^{-3}$ T, where T is temperature]

(A) 9.37 kJ (B) 15.87 kJ (C) 18.74 kJ (D) 22.68 kJ

Q.70 A suitable technique for monitoring a growing crack in an alloy is

(A) acoustic emission
(B) radiography
(C) magnetic particle technique
(D) liquid penetrant test

Common Data Questions

Common Data for Questions 71,72,73:

A Blast Furnace makes pig iron containing 3.6% C, 1.4% Si, 95% Fe. The ore is 80% Fe_2O_3, 12% SiO_2 and 8% Al_2O_3. The coke rate is 1 kg of coke per kg of pig iron, and it contains 90%C, and 10% SiO_2. The flux rate is 0.4 kg per kg of pig iron, and it is pure $CaCO_3$. The blast furnace gas contains 28% CO and 12%CO_2. Assume that there is no iron loss through slag. The atomic mass of Fe, Si and Ca are 56, 28 and 40, respectively.

Q.71 The weight of the ore used per ton of pig iron is

(A) 3.0 tons (B) 1.7 tons (C) 1.0 tons (D) 0.5 ton

Q.72 The weight of the slag made per ton of pig iron is

(A) 821 kg (B) 735 kg (C) 633 kg (D) 450 kg

Q.73 The volume (at NTP) of the blast furnace gas produced per ton of pig iron is

(A) 3789 m^3 (B) 4256 m^3 (C) 5797 m^3 (D) 7234 m^3

Common Data for Questions 74, 75:

Metal M melts at 1000 K with an enthalpy of fusion of 10 kJ mol^{-1}. The specific heat capacity of solid and liquid M are, respectively, $C_p^{(S)} = 20$ J K^{-1} mol^{-1} and $C_p^{(L)} = 30$ J K^{-1} mol^{-1}.

Q.74 The enthalpy change, $\Delta H^{L\rightarrow S}$, associated with the liquid-to-solid transformation at 900 K is

(A) -9 kJ mol^{-1} (B) -10 kJ mol^{-1} (C) -12 kJ mol^{-1} (D) -15 kJ mol^{-1}

Q.75 The entropy change, $\Delta S^{L\rightarrow S}$, associated with the liquid-to-solid transformation at 900 K is

(A) 4.97 J K^{-1} mol^{-1} (B) 0 J K^{-1} mol^{-1}
(C) -5.34 J K^{-1} mol^{-1} (D) -8.95 J K^{-1} mol^{-1}

Linked Answer Questions: Q.76 to Q.85 carry two marks each.

Statement for Linked Answer Questions 76 & 77:
The free energy change $\Delta G(r)$ accompanying the formation of a spherical cluster of radius r of solid from a liquid is given by

$\Delta G(r) = 4\pi r^2\gamma + \frac{4}{3}\pi r^3 \Delta G_v$, where γ is the interfacial energy and $\Delta G_v < 0$ is the free energy change per unit volume for the liquid-to-solid transformation.

Q.76 The size r^*, of the critical cluster is given by:

(A) $-2\gamma / \Delta G_v$ (B) $-\Delta G_v / 2\gamma$ (C) $-\pi \cdot \gamma / \Delta G_v$ (D) $-\gamma / (\pi \cdot \Delta G_v)$

Q.77 If $\Delta G_v = 3.0 \times 10^7$ J m^{-3}, and $\gamma = 3.3 \times 10^{-2}$ J m^{-2}, the number of atoms in the critical cluster is approximately
(Given: the solid is an FCC crystal with a lattice parameter of 0.495 nm)

(A) 95 (B) 550 (C) 1470 (D) 20700

Statement for Linked Answer Questions 78 & 79:
A fibre reinforced composite consists of Nylon 6,6 matrix with aligned and continuous carbon fibres. Their properties are:
Young's modulus of Nylon 6,6 = 3 GPa; Specific gravity of Nylon 6,6= 1.14
Young's modulus of carbon fibre = 403 GPa; Specific gravity of carbon fibre = 1.90

Q.78 The composite exhibits a Young's modulus of 103 GPa in the longitudinal direction (parallel to the fibre orientation). The volume fraction of the fibre is

(A) 5% (B) 10% (C) 25% (D) 40%

Q.79 The *specific* Young's modulus of the same composite in the transverse direction (perpendicular to the fibre orientation) is

(A) 3 GPa (B) 4 GPa (C) 10 GPa (D) 403 GPa

Statement for Linked Answer Questions 80 & 81:
The density of α-iron (BCC) is 7882 kg m^{-3}. The atomic weight of iron is 55.847 g/mol. A powder diffraction pattern is taken using X-rays of wavelength, $\lambda = 1.54$ Å

Q.80 The lattice parameter of α−iron is

(A) 0.204 nm (B) 0.287 nm (C) 0. 404 nm (D) 0.574 nm

Q.81 The X-ray diffraction angle (2θ, in degrees) for the (110) set of planes is

(A) 22.3° (B) 35.5° (C) 44.6° (D) 63.3°

Statement for Linked Answer Questions 82 & 83:
The overall reaction for electrolysis of Al_2O_3 is:

$$\frac{2}{3}Al_2O_3 + C = \frac{4}{3}Al + CO_2$$

The standard free energy change for this reaction at 1273 K is $\Delta G^0_{1273} = 452$ kJ.
[Given: Faraday's Number = 96.5 kJ V^{-1} $eq.^{-1}$]

Q.82 The standard EMF of the cell is

(A) -1.17 V (B) -1.21 V (C) -1.36 V (D) +1.56 V

Q.83 When the activity of alumina is 0.1, the EMF of this cell is

(A) -1.17 V (B) -1.21 V (C) -1.36 V (D) +1.21 V

Statement for Linked Answer Questions 84 & 85:
A single crystal of copper is oriented such that the tensile axis is parallel to the zone axis of the planes $(\bar{1}10)$ and $(\bar{1}\bar{1}1)$. The critical resolved shear stress for slip on the {111}<110> slip system is 1 MPa.

Q.84 The zone axis is

(A) [112] (B) [111] (C) [001] (D) [110]

Q.85 If a tensile stress of 3 MPa is applied, slip will occur on which of the following slip systems?

(A) $(1\bar{1}\bar{1})[0\bar{1}1]$ (B) $(1\bar{1}\bar{1})[110]$ (C) $(111)[10\bar{1}]$ (D) $(1\bar{1}\bar{1})[101]$

END OF THE QUESTION PAPER