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Metallurgical Engineering

TIME : **3** HOURS

MAXIMUM MARKS : **300**

INSTRUCTIONS :

1. *All questions are **compulsory**.*
2. *Question Paper may be divided into **4 (four)** Sections from **Section-A** to **Section-D** and carry marks as under :*
   - a. ***Section - A** - Total **3** Questions having **two** parts, i.e. **(a) and (b)** each questions carries **12** marks × 3 Questions = Total **36** Marks.*
   - b. ***Section - B** - Total **3** Questions having **two** parts, i.e. **(a) and (b)** each questions carries **20** marks × 3 Questions = Total **60** Marks.*
   - c. ***Section - C** - Total **3** Questions having **two** parts, i.e. **(a) and (b)** each questions carries **28** marks × 3 Questions = Total **84** Marks.*
   - d. ***Section - D** - Total **3** Questions having **two** parts, i.e. **(a) and (b)** each questions carries **40** marks × 3 Questions = Total **120** Marks.*

SECTION - A

(Each question is of **12** marks and each sub part **(a)** and **(b)** are of **6** marks each)

1 (a) Which is the most abundant metal in earth ? State its ore and how do we extract it ?

(b) Sketch a unit cell of an FCC crystal and calculate the effective number of atoms in it.

2 (a) Define electrometallurgy. What is a half-cell reaction, and give an example of a half-cell reaction.

(b) Give two examples each of zero, one and two-dimensional defects in a crystalline solids.

3 (a) 10,000 cubic meters per hour of a gas analyzing 45% Zn(g), 55% CO are fed at 1600°C and 1.8 atm absolute pressure to a splash condenser. The splash condenser removes all the zinc, turning it into liquid zinc, which is tapped from the bottom of the condenser. The specific gravity of Zn (*l*) is 6.79. Molar mass of Zinc is 65.37 g/mol. How many cubic meters of liquid zinc are produced per hour ?

(b) Draw a schematic engineering stress-engineering strain diagram for uniaxial tensile test of a ductile metal. Indicate how Young's modulus, yield strength, ultimate tensile strength and toughness can be determined from this diagram.

SECTION - B

(Each question is of **20** marks and each sub part **(a)** and **(b)** are of **10** marks each)

4 (a) State three functions of coke in Blast furnace. What is the approximate coke consumption per ton of hot metal and state four ways to reduce the coke rate requirements.

(b) Draw a simple cubic unit cell and show (110) plane and $[1\,\bar{1}0]$ (one, bar one, zero) direction in it. Clearly indicate your axes and origin for each.

5 (a) What is the electrochemical potential of a solution containing 0.0001 M Fe^{+2} with 0.0001 M Fe^{+3} assuming only those ions are involved and unit activity coefficients ?

(b) Draw a standard creep curve of a sample tested at constant stress and temperature. Make the different stages. Add to your diagram another curve for the same sample tested at a higher stress.

6 (a) Why do we need ore comminution ? State different modes of fracture and which size reduction units are they used in ?

(b) Draw a schematic S-N curve for a plain carbon steel tested in fatigue. Superimpose on the same drawing a curve for aluminium. Indicate the meaning of S and N.

SECTION - C

(Each question is of **28** marks and each sub part **(a)** and **(b)** are of **14** marks each)

7 (a) A slurry of barium carbonate (density = 4.43 g/cm^3) in water with a slurry specific gravity of 1.31 is filtered to produce a filter cake containing 85% $BaCO_3$ by weight. How many kilograms of filter cake will be obtained per cubic meter of slurry ?

(b) Draw a schematic microstructure of 1% C steel labeling various microconstituents. Carbon concentrations in ferrite, austenite and cementite are 0.02, 0.8 and 6.67 wt% respectively at the eutectoid temperature.

8 (a) Why copper making consists of two steps smelting and converting?

(b) A zinc single crystal (HCP) is oriented with normal to the basal plane making an angle of 60^o with the tensile axis. The three slip directions X_1, X_2, X_3, lying in the plane make angles 38^o, 45^o and 85^o respetively with the tensile axis. Find which of the three slip directions has initiated slip and at what value of the yield stress. [Critical Resolved Shear Stress (CRSS) = 1 MPa]

9 (a) Determine the equilibrium concentration of Ag^+ and the equilibrium pH when 0.05 moles of $AgNO_3$ are added to 1000 g of water with an initial pH of 12.3, assuming the only product is Ag(OH). Assume I = 0.1.

$$Ag^+ + OH \leftrightarrow Ag(OH)$$

$$\Delta G^o Ag(OH) = -91,970\ J/mole$$

$$\Delta G^o Ag^+ = 77,100\ J/mole$$

$$\Delta G^o OH^- = -157,328\ J/mole$$

(b) Draw a TTT diagram for plain carbon eutectoid steel (0.8% C) labeling all boundaries and phase fields. On your diagram superimpose the cooling curves for the following heat treatments : (i) Annealing (ii) Normalising (iii) Quenching (iv) Austempering and (iv) Martempering. Name the final microstructure obtained in each of these heat treatments.

SECTION - D

(Each question is of **40** marks and each sub part **(a)** and **(b)** are of **20** marks each)

10 (a) A lead ore sample, with a weight of 8 kg, contains 15% Cu as $CuFeS_2$ (Chalcopyrite). The mean densities of the chalcopyrite and gangue minerals are 4.2 g/cm^3 and 2.6 g/cm^3, respectively. If a suspension with 45 wt % of mineral (chalcopyrite + gangue) was pumped to a flotation cell, calcualte the volume % of mineral phase in the suspension and the specific gravity (pulp density) of the suspension. Assume the mineral phases are liberated.

(b) First 4 peaks in a powder x-ray diffraction pattern from a cubic crystal occur at 2θ values of 38.70^{o}, 45.4^{o}, 65.7^{o} and 78.8^{o} when CuK_{α} radiation was used. Find the d-spacing and index of each peak and determine the Bravais lattice. Also determine the lattice parameter based on the highest angle peak. [Wavelength of CuK_{α} radiation is $1.54\,\overset{\circ}{A}$]

11 (a) What is the source of phosphorous in steelmaking ? State five operating parameters desirable for dephosphorization of steel and summarize the dephosphorization mechanism in oxygen steelmaking.

(b) Match the strengthening mechanisms listed in the left column to relevant concepts listed in the column at the right.

(A) Solid solution hardening	(1) Martensite
(B) Strain hardening	(2) Hall-Petch relation
(C) Grain size hardening	(3) Solute atoms
(D) Age hardening	(4) Dislocations
(E) Hardening of steel by quench	(5) Precipitates

The yield strength of an iron sample with average grain diameter of $50\,\mu m$ is 135 MPa and at a grain diameter of $8\,\mu m$ it is 260 MPa. Determine the grain diameter to obtain any yield point of 205 MPa.

12 (a) Consider a blast furnace which is charged with iron ore coke and flux of the following composition :

Iron ore (weight %) :	$Fe_2O_3 = 78$, $SiO_2 = 8.4$, $MnO = 0.6$, $Al_2O_3 = 5.0$, $P_2O_5 = 1.7$ $MgO = 1.2$ and $H_2O = 5.1$
Coke (weight %) :	$C = 88$, $SiO_2 = 9$, $Al_2O_3 = 1$ and $H_2O = 2$
Flue :	$CaCO_3 = 96\%$, $MgCO_3 = 2\%$ and $SiO_2 = 2\%$

Pig iron analyses wt% Fe=92.7, C=4, Si=2, P=0.9, Mn=0.4. The coke rate is 900 kg/ton of pig iron. During smelting 99.5% of Fe is reduced and 0.5% is slagged. The CO/CO_2 ratio in the top gas is 2/1.

Calcualte

Weight of iron ore

Weight and composition of slag

Volume of air required

Volume and % composition of exit gas.

(b) Determine the time required to case carburize a steel with an initial carbon concentration of 0.2% to 1% at a depth of 0.2mm. The steel is exposed to a carburizing atmosphere at 900°C, which gives a constant surface concentration of 1.4 wt% C. The carbon concentration $C\left(x,t\right)$ in steel as a function of depth x from the surface and time t of carburization is given by the solution to Fick's diffusion equation for this condition as

$$C\left(x,t\right) = C_s - \left(C_s - C_0\right)\text{erf}\left(\frac{x}{\sqrt{Dt}}\right)$$

where, C_s is the surface concentration and C_0 is the initial concentration of steel and D is the diffusion coefficient. The error function is given in the table below :

z	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
$erf(z)$	0.1125	0.2227	0.3268	0.4284	0.5205	0.6039	0.6778	0.7421

The diffusion coefficient of C in steel is given as function of absolute temperature T as

$$D = D_0 \exp\left(-\frac{Q}{RT}\right)$$

where, the preexponentional factor $D_0 = 0.7 \times 10^{-4} m^2 s^{-1}$, the activation energy $Q = 157\ kJ\ mol^{-1}$ and the gas constant $R = 8.314\ J\ mol^{-1}\ K^{-1}$.