National Exams December 2019

10-Met-A3, Metal Extraction Processes

3 hours duration

NOTES:

1. Answer only **five** questions. Any five questions (out of seven) constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.

2. All questions are of equal value (20 marks each out of 100).

3. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.

4. Candidates may use one of two calculators, the Casio or Sharp approved models. This is a closed book exam.

5. The exam consists of 3 pages.

Question 1: (a) 2, (b) 2, (c) 2, (d) 2, (e) 2, (f) 2, (g) 2, (h) 2, (i) 2, (j) 2
Question 2: (a) (i) 5, (a) (ii) 5, (b) (i) 5, (b) (ii) 5
Question 3: (a) 2, (b) 4, (c) 2, (d) 2, (e) 2, (f) 8
Question 4: (a) 10, (b) 10
Question 5: (a) 8, (b) 6, (c) 6
Question 6: 20
Question 7: (a) 5, (b) 5, (c) 5, (d) 5

Problem No. 1 (20 marks): Mineral Processing

Explain the meaning of the following terms:

(a) Gravity concentration (2 marks)
(b) Dense media separation (2 marks)
(c) High tension separation (2 marks)
(d) Direct flotation (2 marks)
(e) Reverse flotation (2 marks)
(f) Froth flotation (2 marks)
(g) Selective flocculation (2 marks)
(h) Concentrate (2 marks)
(i) Middlings (2 marks)
(j) Tailings (2 marks)

Problem No. 2 (20 marks): Mass Balance

(a) A slurry stream containing a solid ore is flowing at the rate of 10 m^3/h. The pulp density of the slurry is 1,250 kg/m^3. The density of solid ore is 2,850 kg/m^3.

(i) Calculate the % solids by weight. (5 marks)

(ii) Calculate the flow rate of solid (kg/hr) within the slurry. (5 marks)

(b) A pump is fed by two slurry streams. First slurry stream is flowing at the rate of 15 m^3/h and contains 15 % solids. Second slurry stream is flowing at the rate of 25 m^3/h and contains 25 % solids. The density of solid ore in both streams is 2,700 kg/m^3.

(i) Calculate the % solids in the combined stream. (5 marks)

(ii) Calculate the tonnage of dry solids pumped per hour. (5 marks)

Problem No. 3 (20 marks): Pyrometallurgical processes

a) What is roasting? (2 marks)

b) Give two examples of roasting by writing balanced chemical reactions. (4 marks)

c) What is dead roasting? (2 marks)

d) What is chloridizing roasting? (2 marks)

e) Give an example of chloridizing roasting by writing a balanced chemical reaction. (2 marks)

f) ZnS is roasted with 25 % excess air. Calculate the composition of roast gas in volume %. (8 marks)

Problem No. 4 (20 marks): Pyrometallurgical processes/Refining

a) With the help of a phase diagram, explain the process of zone refining. (10 marks)

b) With the help of appropriate chemical reactions and thermodynamic considerations, explain the process of vacuum refining. (10 marks)

Problem No. 5 (20 marks): Magnesium production

(a) Describe the silicothermic magnesium process (Pidgeon process) with the aid of chemical reactions. (8 marks)

(b) Describe the magnatherm process for the production of magnesium. (6 marks)

(c) Describe the electrolytic process for the production of magnesium. (6 marks)

Problem No. 6 (20 marks): Heat balance

Given the following thermodynamic data, calculate the change in enthalpy when 55.85 kg of iron is heated from 160°C to 1735°C. (20 marks)

Solid α-Fe: $C_p = 17.5 + 24.8 \times 10^{-3}T$ J/(K mol)
α-β transformation at 760°C: $\Delta H_{trf} = 2{,}760$ J/mol
Solid β-Fe: $C_p = 37.7$ J/(K mol)
β-γ transformation at 910°C: $\Delta H_{trf} = 920$ J/mol
Solid γ-Fe: $C_p = 7.7 + 19.5 \times 10^{-3}T$ J/(K mol)
γ-δ transformation at 1400°C: $\Delta H_{trf} = 1180$ J/mol
Solid δ-Fe: $C_p = 44$ J/(K mol)
Melting point at 1535°C: $\Delta H_m = 15{,}680$ J/mol
Liquid Fe: $C_p = 42$ J/(K mol)
Atomic weight of Fe = 55.85

Problem No. 7 (20 marks): Electrometallurgy

Consider a galvanic cell based on the following reaction:

$$Zn\,(s) + Cd^{2+}\,(aq) \longrightarrow Zn^{2+}\,(aq) + Cd\,(s)$$

(a) Calculate the standard cell potential (E°) at 25 °C. (5 marks)

(b) Calculate the standard free energy (ΔG°) for the cell at 25 °C. (5 marks)

(c) Calculate the equilibrium constant for the redox reaction at 25 °C. (5 marks)

(d) Calculate the cell potential (E) at 25 °C if concentration of Cd^{2+} is 0.5 M and concentration of Zn^{2+} is 1.5 M. (5 marks)

Given: Standard reduction potentials at 25 °C for half reactions:

$Zn^{2+} + 2e^- \longrightarrow Zn$ -0.76 V
$Cd^{2+} + 2e^- \longrightarrow Cd$ -0.40 V