National Exams December 2016

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, (ii) 5; (b) (i) 5, (ii) 5
Question 3: (a) 2, (b) 4, (c) 2, (d) 2, (e) 6, (f) 4
Question 4: (a) 10, (b) 10
Question 5: (a) 2, (b) 2, (c) 2, (d) 2, (e) 4, (f) 4, (g) 2, (h) 2
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) Recovery (2 marks)
(e) Comminution (2 marks)
(f) Tailing (2 marks)
(g) Middlings (2 marks)
(h) Froth flotation (2 marks)
(i) Selective flocculation (2 marks)
(j) Hydrophobicity (2 marks)

Problem No. 2 (20 marks): Mass Balance

(a) A slurry stream containing a solid ore is flowing at the rate of 15 m^3/h. The pulp density of the slurry is 1,500 kg/m^3. The density of solid ore is 3,000 kg/m^3.
(i) Calculate the % solids by weight. (5 marks)
(ii) Calculate the flow rate of solid within the slurry. (5 marks)

(b) A pump is fed by two slurry streams. First slurry stream is flowing at the rate of 20 m^3/h and contains 20 % solids. Second slurry stream is flowing at the rate of 30 m^3/h and contains 30 % solids. The density of solid ore in both streams is 3,000 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): Iron and steelmaking

(a) What are three major feed materials for the production of iron in a blast furnace? (2 marks)
(b) What is the function of coke in the production of iron in a blast furnace? (4 marks)
(c) What is the function of limestone in the production of iron in a blast furnace? (2 marks)
(d) What are the products in the production of iron in a blast furnace? (2 marks)
(e) Describe the advantages of using oxygen instead of air in steelmaking. (6 marks)
(f) Which metals are used for deoxidation of steel and why? (4 marks)

Problem No. 4 (20 marks): Light metals production

(a) Describe the Silicothermic magnesium process (Pidgeon process) with the aid of chemical reactions. (10 marks)
(b) Describe the Hall-Heroult process for the production of aluminum with the aid of chemical reactions. (10 marks)

Problem No. 5 (20 marks): Hydrometallurgy

Answer the following:

a) What is an amphoteric substance? (2 marks)
b) Give an example of an amphoteric substance. (2 marks)
c) What is a buffer solution? (2 marks)
d) What is neutralization? (2 marks)
e) What is VAT leaching? (4 marks)
f) What is pulp leaching? (4 marks)
g) What is an autoclave? (2 marks)
h) What is hydrolysis? (2 marks)

Problem No. 6 (20 marks): Heat balance

Given the following thermodynamic data, calculate the change in enthalpy when 5 kg of iron is heated from 60°C to 1635°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)

Problem No. 7 (20 marks): Electrometallurgy

Consider a galvanic cell based on the following reaction:

$$Fe\ (s) + Cu^{2+}\ (aq) \longrightarrow Fe^{2+}\ (aq) + Cu\ (s)$$

(a) Calculate the standard cell potential (E^o) at 25 °C. (5 marks)
(b) Calculate the standard free energy (ΔG^o) 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 Cu^{2+} is 0.5 M and concentration of Fe^{2+} is 1.5 M. (5 marks)

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

$Fe^{2+} + 2\ e^- \longrightarrow Fe$ -0.44 V
$Cu^{2+} + 2\ e^- \longrightarrow Cu$ 0.34 V