



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

**ECE 5107 - EXTRACTIVE METALLURGY 1A /
TCE 5107 - ADVANCED MINERALS ENGINEERING IA**

Final Examination Paper

December 2024

This examination paper consists of **four** pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Periodic Table of Elements

INSTRUCTIONS

1. Answer **ALL** questions in **SECTION A**
2. Answer **ANY THREE** questions in **SECTION B**
3. Each question carries 20 marks
4. Use of calculators is permissible

MARK ALLOCATION

QUESTION	MARKS
A1	20
A2	20
B1	20
B2	20
B3	20
B4	20
TOTAL ATTAINABLE MARK	100

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SECTION A

ANSWER ALL QUESTIONS

QUESTION A1

- a) Briefly describe the five classes of unit processes in pyrometallurgy. [10]
- b) What is calcination? Give two examples of industrial scale calcination processes. [5]
- c) In a copper ore, chalcopyrite is 34%, pyrite is 30% and silica is 36%. Determine the percentages of iron, copper and sulphur in the ore. [5]

QUESTION A2

- a) Coke is an essential raw material in Blast Furnace iron making, identify the functions of coke in the blast furnace. [5]

b) Steel Inc. is an integrated Iron and Steel making plant located in Kwekwe. The hot metal from the blast furnace is transported using torpedo cars to the steel making section where it is charged into a Basic Oxygen Furnace. Scrap metal is also charged into the steelmaking furnace at a ratio of 1:4 to the hot metal. Given the following information:

Hot metal composition: 4% C; 1% Si; 1% Mn; 0.3% P and the rest is Fe

Flux composition: 2% SiO₂; 3% MgO and the rest is CaO

Oxygen of 99% purity is blown into the furnace for refining.

The gas leaving the converter has a ratio of P_{CO}:P_{CO₂} = 1:1

2% of the Fe charged is lost in the slag as FeO and Fe₂O₃, the ratio of the two oxides is 1:2

Steel composition: 0.2% C; 0.2% Mn and the rest is Fe.

Assume that the scrap metal contains 100% Fe, slag contains 50% CaO and that oxygen utilisation is 92%.

Calculate the following per tonne of steel produced:

- (i) Weight of hot metal and scrap metal charged into the furnace. [4]
- (ii) The volume of oxygen blown into the furnace in m³ @STP [7]
- (iii) Weight of flux charged into the furnace. [3]
- (iv) Weight of slag produced. [1]

SECTION B

ANSWER ANY THREE QUESTIONS

QUESTION B1

a) Aluminium is a silvery-white, light weight metal which is used to make a variety of products. Aluminium is produced by the electrolysis of anhydrous alumina (Al_2O_3) which is a product of the calcination of $\text{Al}(\text{OH})_3$ at 1700K in a rotary kiln. The feed to the kiln is a damp filter cake analysing 60% $\text{Al}(\text{OH})_3$ and 40% H_2O , and this is calcined to give pure Al_2O_3 as a solid product.

The fuel consumption in the rotary kiln is approximately 0.2kg per kg of alumina, fuel composition is; 84% C and 16% H. Air for combustion is 25% in excess of the theoretical air required. Assuming complete combustion, calculate;

- (i) Weight of damp filter cake required to produce 1000kg of Al_2O_3 . [3]
- (ii) The volume of gases (@1atm and 1700K) leaving the kiln per 1000kg of Al_2O_3 produced. [4]
- (iii) Percentage composition by volume of the dry flue gas. [3]

b) The iron making blast furnace interior is divided into three regions, briefly describe the operating conditions in each region and state the refractory material used to line the steel shell in each region. [6]

c) State four uses of steel and four uses of copper. [4]

QUESTION B2

a) Give a detailed description of the production of copper-rich matte from copper concentrate in the Outokumpu flash furnace. The description should include;

- (i) Clearly labelled diagram of the furnace. [3]
- (ii) Process operation [4]
- (iii) Reactions [3]
- (iv) Products [2]

b) A copper ore has the following analysis (weight %); Cu_2S – 25%, FeS_2 – 50%, SiO_2 – 25%
It is smelted in a flash furnace using limestone of the following composition (weight %);
 CaCO_3 – 93%, SiO_2 – 7% as flux. The slag has 38% FeO and 20% CaO .
Assume no loss of copper to the slag phase all the Cu_2S reports to the matte phase.
Using a basis of 1000 kg of ore, calculate;

- (i) Weight of slag, limestone and matte. [5]
(ii) Matte grade. [3]

QUESTION B3

a) A Blast Furnace produces pig iron of the following composition:

Fe – 94%, Si – 2%, Mn – 0.5%, C – 3.5%, by reduction smelting of iron ore, coke and limestone.

The analysis of the raw materials is as follows:

Iron ore: Fe₂O₃ – 78%, SiO₂ – 8%, Al₂O₃ – 5%, MnO – 2%, H₂O – 7%

Coke (Charged at 600kg per tonne of pig iron): C – 86%, SiO₂ – 10%, Al₂O₃ – 4%

Limestone: CaCO₃ – 100%

The slag produced has 45% CaO

During smelting 99.5% of Fe is reduced and 0.5% is slagged

Calculate:

- (i) Weight of iron ore charged per tonne of pig iron produced. [2]
(ii) Weight of slag produced per tonne of pig iron. [4]
(iii) Percentage composition of slag (w/w%) [2]
(iv) Percentage of SiO₂ and MnO reduced in the furnace. [2]

b) Converting of molten Cu-Fe-S matte to molten blister copper is normally done in a Peirce-Smith converter. With the aid of a well labelled diagram give a detailed description, including reactions, of the batch converting process. [10]

QUESTION B4

a) Highlight the differences between the following processes:

- (i) oxidising roasting and sulphating roasting, give examples of each process [4]
(ii) outokumpu flash furnace and inco flash furnace [4]
(iii) basic oxygen steel making and electric arc steel making [4]
(iv) pig iron and sponge iron [2]

b) Discuss the negative effects of pyrometallurgy on the environment, suggest possible technical solutions to these challenges. [6]

(END)

IUPAC Periodic Table of the Elements

1 H hydrogen 1.0080 ± 0.0002																	2 He helium 4.0026 ± 0.0001
3 Li lithium 6.94 ± 0.06	4 Be beryllium 9.0122 ± 0.0001											13 B boron 10.81 ± 0.02	14 C carbon 12.011 ± 0.002	15 N nitrogen 14.007 ± 0.001	16 O oxygen 15.999 ± 0.001	17 F fluorine 18.998 ± 0.001	18 Ne neon 20.180 ± 0.001
11 Na sodium 22.990 ± 0.001	12 Mg magnesium 24.305 ± 0.002											13 Al aluminium 26.982 ± 0.001	14 Si silicon 28.085 ± 0.001	15 P phosphorus 30.974 ± 0.001	16 S sulfur 32.06 ± 0.02	17 Cl chlorine 35.45 ± 0.01	18 Ar argon 39.95 ± 0.16
19 K potassium 39.098 ± 0.001	20 Ca calcium 40.078 ± 0.004	21 Sc scandium 44.956 ± 0.001	22 Ti titanium 47.867 ± 0.001	23 V vanadium 50.942 ± 0.001	24 Cr chromium 51.996 ± 0.001	25 Mn manganese 54.938 ± 0.001	26 Fe iron 55.845 ± 0.002	27 Co cobalt 58.933 ± 0.001	28 Ni nickel 58.693 ± 0.001	29 Cu copper 63.546 ± 0.003	30 Zn zinc 65.38 ± 0.02	31 Ga gallium 69.723 ± 0.001	32 Ge germanium 72.630 ± 0.008	33 As arsenic 74.922 ± 0.001	34 Se selenium 78.971 ± 0.008	35 Br bromine 79.904 ± 0.003	36 Kr krypton 83.798 ± 0.002
37 Rb rubidium 85.468 ± 0.001	38 Sr strontium 87.62 ± 0.01	39 Y yttrium 88.906 ± 0.001	40 Zr zirconium 91.224 ± 0.002	41 Nb niobium 92.906 ± 0.001	42 Mo molybdenum 95.95 ± 0.01	43 Tc technetium [97]	44 Ru ruthenium 101.07 ± 0.02	45 Rh rhodium 102.91 ± 0.01	46 Pd palladium 106.42 ± 0.01	47 Ag silver 107.87 ± 0.01	48 Cd cadmium 112.41 ± 0.01	49 In indium 114.82 ± 0.01	50 Sn tin 118.71 ± 0.01	51 Sb antimony 121.76 ± 0.01	52 Te tellurium 127.60 ± 0.03	53 I iodine 126.90 ± 0.01	54 Xe xenon 131.29 ± 0.01
55 Cs caesium 132.91 ± 0.01	56 Ba barium 137.33 ± 0.01	57-71 lanthanoids	72 Hf hafnium 178.49 ± 0.01	73 Ta tantalum 180.95 ± 0.01	74 W tungsten 183.84 ± 0.01	75 Re rhenium 186.21 ± 0.01	76 Os osmium 190.23 ± 0.03	77 Ir iridium 192.22 ± 0.01	78 Pt platinum 195.08 ± 0.02	79 Au gold 196.97 ± 0.01	80 Hg mercury 200.59 ± 0.01	81 Tl thallium 204.38 ± 0.01	82 Pb lead 207.2 ± 1.1	83 Bi bismuth 208.98 ± 0.01	84 Po polonium [209]	85 At astatine [210]	86 Rn radon [222]
87 Fr francium [223]	88 Ra radium [226]	89-103 actinoids	104 Rf rutherfordium [267]	105 Db dubnium [268]	106 Sg seaborgium [269]	107 Bh bohrium [270]	108 Hs hassium [269]	109 Mt meitnerium [277]	110 Ds darmstadtium [281]	111 Rg roentgenium [282]	112 Cn copernicium [285]	113 Nh nihonium [286]	114 Fl flerovium [290]	115 Mc moscovium [290]	116 Lv livermorium [293]	117 Ts tennessine [294]	118 Og oganeson [294]

Key:
atomic number
Symbol
name
abridged standard
atomic weight



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57 La lanthanum 138.91 ± 0.01	58 Ce cerium 140.12 ± 0.01	59 Pr praseodymium 140.91 ± 0.01	60 Nd neodymium 144.24 ± 0.01	61 Pm promethium [145]	62 Sm samarium 150.36 ± 0.02	63 Eu europium 151.96 ± 0.01	64 Gd gadolinium 157.25 ± 0.03	65 Tb terbium 158.93 ± 0.01	66 Dy dysprosium 162.50 ± 0.01	67 Ho holmium 164.93 ± 0.01	68 Er erbium 167.26 ± 0.01	69 Tm thulium 168.93 ± 0.01	70 Yb ytterbium 173.05 ± 0.02	71 Lu lutetium 174.97 ± 0.01
89 Ac actinium [227]	90 Th thorium 232.04 ± 0.01	91 Pa protactinium 231.04 ± 0.01	92 U uranium 238.03 ± 0.01	93 Np neptunium [237]	94 Pu plutonium [244]	95 Am americium [243]	96 Cm curium [247]	97 Bk berkelium [247]	98 Cf californium [251]	99 Es einsteinium [252]	100 Fm fermium [257]	101 Md mendelevium [258]	102 No nobelium [259]	103 Lr lawrencium [262]

For notes and updates to this table, see www.iupac.org. This version is dated 4 May 2022.
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