NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

ADVANCED MINERALS ENGINEERING IA

TCE 5107

Supplementary Examination Paper

August 2024

This examination paper consists of **three** pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Periodic Table of Elements

INSTRUCTIONS

1. Answer **ALL** questions
2. Each question carries 20 marks
3. Use of calculators is permissible

MARK ALLOCATION

QUESTION	MARKS
1	**20**
2	**20**
3	**20**
4	**20**
5	**20**
TOTAL	**100**

QUESTION 1

a) State and justify the **three** main advantages of using pyro metallurgical methods to extract metals. **[8]**

b) Describe the three main branches of extractive metallurgy. **[9]**

c) Give examples of **three** metals which are extracted using pyro metallurgy. **[3]**

QUESTION 2

a) A pyritic ore is reduced with hydrogen according to the following reaction:

$FeS_2\ (s) + 2H_2\ (g) \leftrightarrow Fe\ (l) + 2H_2S\ (g)$

The ore contains 15% inert solid (gangue). 25% excess hydrogen is used, and the cinder (solid residue) remaining contains 5% FeS_2 by weight.

Calculate the volume of furnace gases in m^3 (at 400°C and 1 atm) per 100 kg of ore charged. **[8]**

b) Differentiate between the following:

(i) roasting and calcination. **[4]**

(ii) matte smelting and reduction smelting **[4]**

(iii) pig iron and sponge iron **[4]**

QUESTION 3

a) Limestone mixed with coke is calcined in a kiln. An average analysis of the limestone is $CaCO_3$ 85%, $MgCO_3$ 12% and the rest are inerts. The coke contains 76% C, 21% ash and 3% moisture. The calcinations of $CaCO_3$ and $MgCO_3$ are 95% and 90% complete respectively. The C in coke is completely burnt to carbon dioxide. The kiln is fed with 1 kg of coke per 5kg of limestone. Calculate the weight percent of each product leaving the kiln. Assume that the moisture in the feed is completely vaporized. **[10]**

b) An annealing furnace uses a fuel oil containing 20% H, the fuel is burnt with 20% excess air. Calculate the flue gas analysis, assuming complete combustion. **[4]**

c) The basic oxygen furnace and the electric arc furnace are the two main furnaces used in modern day steel making. Compare and contrast the two processes. **[6]**

QUESTION 4

a) A copper ore has the following analysis (weight %); Cu_2S – 20%, FeS_2 – 56%, SiO_2 – 24%
It is smelted in a flash furnace using pure limestone as flux. The slag has 36% FeO and 21% 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]**

b) The blast furnace is essentially a continuous counter-current reactor in which the descending charge is heated and reacted with ascending gases, derived from combustion of carbon at the tuyere. The charge consists of iron ore (hematite), coke and limestone.

Give a detailed description of reactions and conditions occurring in the lower zone of the blast furnace. **[12]**

QUESTION 5

a) A copper ore contains 5% Cu and 38% S. The copper mineral is chalcopyrite $CuFeS_2$ and S is also present as iron pyrite (FeS_2). The rest of the ore is gangue containing no Cu, S and Fe.

The ore is roasted until all the sulphur is removed; the following reactions are taking place:

$$4FeS_2 + 11O_2 \leftrightarrow 2Fe_2O_3 + 8SO_2$$
$$4CuFeS_2 + 13O_2 \leftrightarrow 4CuO + 2Fe_2O_3 + 8SO_2$$

Calculate the following;

(i) Weight of chalcopyrite and iron pyrite in 1000 kg of ore **[4]**

(ii) Air required in m^3 **[3]**

(iii) Weight of Fe_2O_3 **[3]**

b) In Blast Furnace Ironmaking the lining life determines the duration of a non-stop campaign.

(i) Identify the <u>**six**</u> major causes of lining failure in Blast Furnace operation. **[3]**

(ii) For each zone in the blast furnace identify the appropriate lining material required to line the steel shell. **[3]**

c) State <u>**four**</u> uses of copper. **[4]**

(END OF PAPER)

IUPAC Periodic Table of the Elements

Key: atomic number / **Symbol** / name / abridged standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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											5 **B** boron 10.81 ± 0.02	6 **C** carbon 12.011 ± 0.002	7 **N** nitrogen 14.007 ± 0.001	8 **O** oxygen 15.999 ± 0.001	9 **F** fluorine 18.998 ± 0.001	10 **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** oganesson [294]

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]

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