PROGRAM	:	NATIONAL DIPLOMA *EXTRACTION METALLURGY*
SUBJECT	:	**PYROMETALLURGY III**
CODE	:	**MYP3111**
DATE	:	SUMMER EXAMINATION 2016 26 NOVEMBER 2016
DURATION	:	(SESSION 2) 12:30 - 15:30
WEIGHT	:	40:60
TOTAL MARKS	:	100

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NUMBER OF PAGES	:	4 PAGES AND 3 ANNEXURES	

INSTRUCTIONS

1. ANSWER ALL QUESTIONS
2. CALCULATORS ARE PERMITTED

QUESTION 1

You are in charge of conditioning the concentrates before it is fed in the smelter. It is suggested that the moisture coming in the furnace should not exceed 50 kg. You receive from the concentrator 9t of wet iron ore concentrate (assume to be 100% hematite) containing 30% moisture. It is also stated that you should use methane to remove water and meet the requirements as per statement above (50kg of water is the max acceptable in the furnace). Calculate:

1) The amount of water to remove (5)

2) The cost of the drying process assuming that air was pre-heated to 150°C before using for the combustion reaction. The drying temperature is 120°C and 1kg of methane cost 100.00R (5)

3) The volume of the gas released during the drying process (3)

4) The percentage of CO_2 in the off-gas (2)

5) If you had to use coke (500R/ t), which fuel should you recommend? (5)

[20]

QUESTION 2 [20]

The mine feeding your hydrometallurgical plant mines chalcopyrite. Partial roasting is suggested to minimize sulfuric acid consumption. The reaction being:

$CuFeS_2 + 4O_2 \rightarrow CuSO_4 + FeSO_4$. Calculate:

1) The mass of the feed of the roasting section if the mass of the calcine is 25t/hour. Assuming that copper sulfates is 65% of the mass of the calcine. (7)

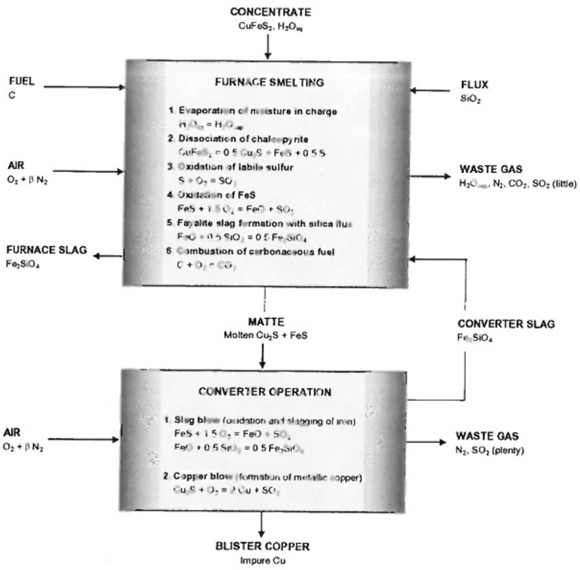
2) The total volume of air blown in the roaster daily if 10% air excess is needed for more efficient process (5)

3) If instead of roasting chalcopyrite, ZnS is deadly roasted in a fluid-bed roaster. The mass fed is 41t of ZnS, given the density of ZnS (4100kg/m^3) and the pressure drop being 80 kPa. Design the luid-bed roaster (in other words calculate its diameter). Consider g=9.81 m/s^2 (8)

4) A part from acid consumption in 1), another aspect is pollution. Discuss environmental issues if instead of partial roasting dead roasting was conducted. Be more explicative. (5)

[25]

QUESTION 3



The flowsheet above provides the route for the production of copper blister from chalcopyrite. You have been assigned to establish the heat balance over the converter. However, the feed of the converter is the matte from the reverberatory furnace. It is stated that 100t of wet concentrate contains 60% chalcopyrite, 15% moisture, 10% silica and 15% pyrrhotite. The matte produced is directly conveyed to the Pierce Smith converter at a temperature of 1100°C. The operating temperature in the converter is 1250 °C. It is sated that they blow normal air with 10% excess of air needed.

3.1 Establish the heat balance over the converter (7)

3.2 Calculate the total volume of gas released during the iron slagging step (4)

3.3 Calculate the volume percentage of SO_2 in the off-gas. (3)

3.4 Discuss the environmental issues, how you could avoid penalties based on the results obtained in 3.3. Be more specific. (6)

Cu	M_{Cu}	=	63.5	g/mol
$CuFeS_2$	M_{CuFeS2}	=	183.5	g/mol
Cu_2S	M_{Cu2S}	=	159.1	g/mol
FeS	M_{FeS}	=	87.9	g/mol
Fe_2SiO_4	$M_{Fe2SiO4}$	=	203.8	g/mol

[20]

QUESTION 4

You are working for RBM and are supposed to oversee the titania slag cooling section. It is said that the cooling rate of the slag is important to avoid the precipitation of some undesirable phases into the slag. It is therefore requested that a water dame be designed in order to avoid any low level water crisis. If the slag is assumed to be only made of TiO_2 and 40t of slag are tapped every 8 hours on a daily basis:

4.1 Calculating the theoretical minimum amount of water that the dam should store

4.2 If the surface available to you is $200m^2$, how minimum deep should the dam be?

[14]

Hint: The slag is tapped at 1600°C and should be cooled down to 200 °C

QUESTION 5

You have passed S4 with distinctions in all subjects and have been selected for BTech. You have been given a project on studying possible (theoretical) ways of producing aluminum from alumina using a pure metal. With the use of the Ellingahm diagram discuss the above based on thermodynamics to support your decision on your choice. Also make use of equilibrium constant, oxygen partial pressure as well as free energy.

[12]

QUESTION 6

You are operating a roasting process. It is alleged that As_2O_3 is present in the fumes which must be removed and condensed in a pure form. The fumes leave the furnace at 450°C. Design a gas cleaning device that would remove the above.

[9]

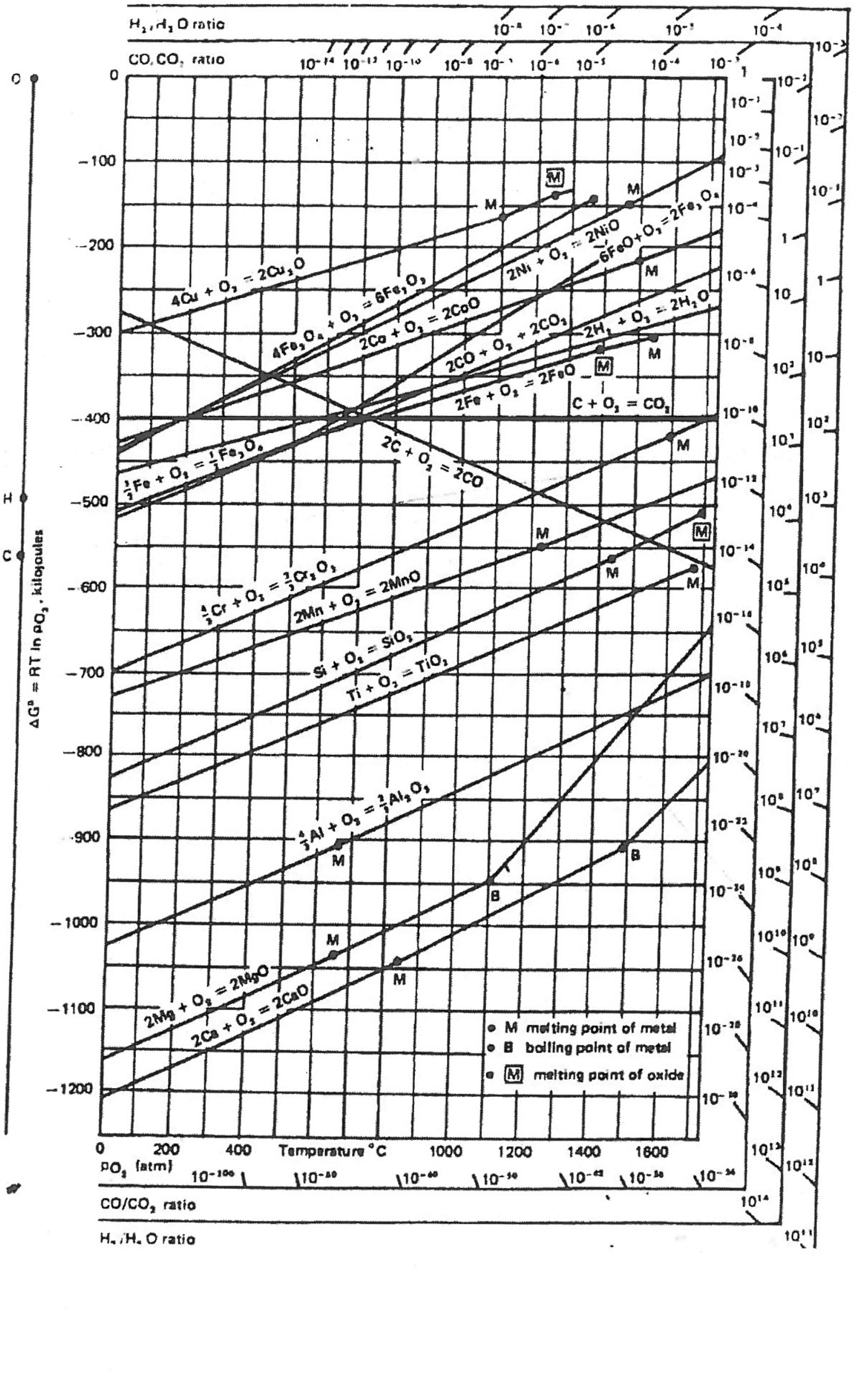
TOTAL MARKS 100

Substance				Enthalpy	Entropy	Temperature	Heat Capacity		
			Mol Mass	H^o_{298}	S^o_{298}	Range	$C = a + b\,10^{-3}\,T$		*Mean*
Name	Formula	State	g/mol	J/mol	J/(mol K)	K	J/(mol K)		
							a	b	
Acetylene	C_2H_2	gas	26.0	226 731	201.0	298 - 3000	50.2	14.2	
Aluminium	Al	sol	27.0		28.3	298 - 933	33.0	-20.7	
	Alliq	liq		10 711	11.5	933 - 2790	31.7		
Aluminium Oxide, *alumina*	Al_2O_3	sol	102.0	-1675 274	50.9	298 - 800	58.2	83.5	
Cadmium	Cd	sol	112.4		51.8	298 - 594	22.3	12.2	
	Cdliq	liq		6 192	10.4	594 - 1038	29.7		
	Cdgas	gas		111 796	167.7	1038 - 2000	20.8		
Cadmium Carbonate	$CdCO_3$	sol	172.4	-751 865	92.5	298 - 600	43.1	131.8	
Cadmium Oxide	CdO	sol	128.4	-258 990	54.8	298 - 1500	42.5	10.1	
Calcium Oxide, *lime*	CaO	sol	56.1	-635 089	38.1	298 - 3200	46.0	6.0	*56.3*
Ca-Carbonate, *calcite*	$CaCO_3$	sol	100.1	-1206 921	92.9	298 - 1200	74.8	50.2	*110.4*
Carbon, *graphite*	C	sol	12.0		5.7	298 - 1100	4.9	17.2	*16.3*
Carbon Monoxide	CO	gas	28.0	-110 541	197.7	298 - 3000	28.7	2.6	*29.7*
Carbon Dioxide	CO_2	gas	44.0	-393 505	213.8	298 - 5000	51.9	3.0	*60.9*
Chromium	Cr	sol	52.0		23.6	298 - 2130	20.3	12.1	*30.0*
	Crliq	liq		16 900	8.0	2130 - 2945	39.3		
Chromium(III) Oxide	Cr_2O_3	sol	152.0	-1139 701	81.2	298 - 2603	114.8	11.2	
Copper	Cu	sol	63.5		33.2	298 - 1358	22.0	7.4	
	Culiq	liq		13 138	9.7	1358 - 2843	32.8		
Copper(I) Oxide, *cuprite*	Cu_2O	sol	143.1	-170 707	92.3	298 - 1517	56.4	25.8	
	Cu2Oliq	liq		64 768	42.7	1517 - 2000	99.9		
Copper(II) Oxide	CuO	sol	79.5	-156 063	42.6	298 - 1397	40.8	13.9	
Chalcopyrite	$CuFeS_2$	sol	183.5	-190 372	125.0	298 - 830	78.6	63.6	
Cu(I)sulfide, *Chalcocite*	Cu_2S	sol	159.1	-81 170	116.2	298 - 1400	47.9	97.2	
	Cu2Sliq	liq		12 845	9.2	1400 - 2000	89.7		
Cu(II)sulfide, *Covellite*	CuS	sol	95.6	-53 095	66.5	298 - 1300	44.4	11.0	
Hydrogen	H_2	gas	2.0		130.7	298 - 5000	28.2	2.7	
Iron	Fe	sol	55.8		27.3	298 - 1809	17.4	25.0	
	Feliq	liq		13 807	7.6	1809 - 3158	40.9	1.7	*45.0*
Iron Oxide, *wüstite*	FeO	sol	71.8	-267 270	57.6	298 - 1650	47.9	10.7	
		liq		24 058	14.6	1650 - 3687	68.2		
Iron Oxide, *magnetite*	Fe_3O_4	sol	231.5	-1118 383	146.1	298 - 1870	75.5	240.1	*205.0*
	Fe3O4liq	liq		138 072	73.8	1870 - 2000	213.4		
Iron Oxide, *hematite*	Fe_2O_3	sol	159.7	-824 248	87.4	298 - 1700	78.1	99.8	
Iron Carbonate, *siderite*	$FeCO_3$	sol	115.9	-740 568	92.9	298 - 800	48.7	112.1	
Iron Sulfide, *pyrrhotite*	FeS	sol	87.9	-105 441	60.8	298 - 598	35.8	49.6	
Iron Sulfide, *pyrite*	FeS_2	sol	120.0	-171 544	52.9	298 - 1000	56.0	27.8	
Lead	Pb	sol	207.2		64.8	298 - 600	24.2	8.7	
	Pbliq	liq		4 770	7.9	600 - 1200	32.5	-3.1	
Lead Oxide, *litharge*	PbO	sol	223.2	-218 062	68.7	298 - 1159	41.8	16.1	
	PbOliq	liq		25 522	22.0	1159 - 2000	65.0		
Lead Sulfide, *galena*	PbS	sol	239.3	-98 634	91.3	298 - 1386	46.6	9.5	
	PbSliq	liq		18 828	13.6	1386 - 2000	66.9		
Lead Sulfate, *anglesite*	$PbSO_4$	sol	303.3	-923 137	149.5	298 - 1139	66.5	110.0	
Magnesium	Mg	sol	24.3		32.7	298 - 922	21.4	11.8	
	Mgliq	liq		8 954	9.7	922 - 1361	32.6		
	Mggas	gas		146 440	148.6	1361 - 2000	20.8		
Mg-Carbonate, *magnesite*	$MgCO_3$	sol	84.3	-1095 798	65.7	298 - 700	47.8	99.0	
Mg-Oxide, *periklase*	MgO	sol	40.3	-601 241	26.9	298 - 3105	42.8	6.0	

THERMODYNAMIC DATA

Substance				Enthalpy	Entropy	Temperature	Heat Capacity		
Name	Formula	State	Mol Mass g/mol	H^o_{298} J/mol	S^o_{298} J/(mol K)	Range K	$C = a + b\ 10^{-3} T$ J/(mol K) a	b	*Mean*
Manganese	Mn	sol	54.9		32.0	298 - 1360	20.7	18.7	
Manganese Carbonate	$MnCO_3$	sol	114.9	-894 100	85.8	298 - 700	58.1	85.4	
Manganese Oxide	MnO	sol	70.9	-385 221	59.7	298 - 1500	42.9	10.9	
Mercury (Quicksilver)	Hg	liq	200.6		75.9	298 - 630	28.4	-2.1	
	Hggas	gas		61 291	174.8	630 - 3000	20.8		
Mercury Oxide, red mercury	HgO	sol	216.6	-90 789	70.3	298 - 800	36.6	27.6	
Mercury Sulfide, *cinnabar*	HgS	sol	232.7	-53 346	82.4	298 - 1096	43.8	15.6	
	HgSgas	gas		127 194	254.2	1096 - 2000	36.6	0.5	
Methane	CH_4	gas	16.0	-74 873	186.2	298 - 1000	19.6	54.1	
Nickel	Ni	sol	58.7		29.9	298 - 500	19.1	23.5	
Nickel Carbonyl	$Ni(CO)_4$	gas	170.8	-602 910	410.6	298 - 2000	152.7	29.1	
Nitrogen	N_2	gas	28.0		191.6	298 - 1600	28.0	3.1	*30.8*
Oxygen	O_2	gas	32.0		205.1	298 - 5000	31.9	2.5	*38.3*
Palladium	Pd	sol	106.4		37.8	298 - 1400	24.2	6.4	
Palladium Oxide	PdO	sol	122.4	-115 478	38.9	298 - 1200	21.0	34.7	
Platinum	Pt	sol	195.1		41.6	298 - 2045	24.3	5.4	
	Ptliq	liq		19 665	9.6	2045 - 4096	34.7		
Silicon	Si	sol	28.1		18.8	298 - 1687	22.8	3.9	
	Siliq	liq		50 208	29.8	1687 - 3504	27.2		
Silica	SiO_2	sol	60.1	-910 857	41.5	298 - 1996	29.2	56.8	*65.0*
	SiO2liq	liq		9 565	7.8	1996 - 3000	85.8		
Silver	Ag	sol	107.9		42.7	298 - 1234	24.3	2.5	
	Agliq	liq		11 297	9.2	1234 - 2433	33.5		
Slag, *calcium ortho silicate*	Ca_2SiO_4	sol	172.2	-2315 216	120.8	298 - 1121	145.9	40.8	
	Ca2SiO4liq	liq		71 100	29.6	2403 - 2800	209.2		
Slag, *fayalite*	Fe_2SiO_4	sol	203.8	-1479 902	145.2	298 - 1490	125.5	60.6	
	Fe2SiO4liq	liq		92 174	61.9	1490 - 1700	240.6		
Sulfur	S	sol	32.1		32.1	298 - 368	16.8	20.1	
	Sliq	liq		1 720	4.4	368 - 882	30.0	6.8	
	Sgas	gas		128 599	228.2	882 - 5000	35.2	1.9	
Sulfur Dioxide	SO_2	gas	64.1	-296 813	248.2	50 - 500	30.8	31.9	*39.0*
	SO2hi				0.0	500 - 5000	52.5	3.0	*60.7*
Heat of Fusion	Ice	sol	*5 980*						
Water	H_2O	liq	18.0	-285 830	69.9	298 - 373	59.7	23.0	*75.5*
	H2Ogas	gas		-241 827	188.8	373 - 1600	30.1	10.4	*38.5*
Zinc	Zn	sol	65.4		41.6	298 - 693	22.2	10.5	
	Znliq	liq		7 322	10.6	693 - 1 180	31.4		
	Zngas	gas		130 415	161.0	1 180 - 2 000	20.8		
Zinc Carbonate	$ZnCO_3$	sol	125.4	-812 780	82.4	298 - 500	38.9	138.1	
Zinc Oxide, *zincite*	ZnO	sol	81.4	-350 460	43.6	298 - 2248	41.4	9.5	*53.3*
Zinc Sulfide, *sphalerite*	ZnS	sol	97.4	-201 669	57.7	298 - 1293	44.7	10.6	*52.8*

Temperature	K	=	273 + °C
Universal gas constant	R	=	8.31 J/(mol K)
Mol volume of gases	V_{mol}	=	22.4 L/mol
Oxygen in air	oav	=	21.0% by vol
Power	1 W	=	1 J/s



H_2/H_2O ratio
CO/CO_2 ratio
$\Delta G° = RT \ln p_{O_2}$, kilojoules
0
−100
−200
−300
−400
−500
−600
−700
−800
−900
−1000
−1100
−1200
O
H
C
$4Cu + O_2 = 2Cu_2O$
$4Fe_3O_4 + O_2 = 6Fe_2O_3$
$2Ni + O_2 = 2NiO$
$6FeO + O_2 = 2Fe_3O_4$
$2Co + O_2 = 2CoO$
$2CO + O_2 = 2CO_2$
$2H_2 + O_2 = 2H_2O$
$2Fe + O_2 = 2FeO$
$C + O_2 = CO_2$
$\frac{3}{2}Fe + O_2 = \frac{1}{2}Fe_3O_4$
$2C + O_2 = 2CO$
$\frac{4}{3}Cr + O_2 = \frac{2}{3}Cr_2O_3$
$2Mn + O_2 = 2MnO$
$Si + O_2 = SiO_2$
$Ti + O_2 = TiO_2$
$\frac{4}{3}Al + O_2 = \frac{2}{3}Al_2O_3$
$2Mg + O_2 = 2MgO$
$2Ca + O_2 = 2CaO$
M melting point of metal
B boiling point of metal
[M] melting point of oxide
0
200
400
Temperature °C
1000
1200
1400
1600
p_{O_2} (atm)
CO/CO_2 ratio
H_2/H_2O ratio