UNIVERSITY OF JOHANNESBURG

PROGRAM	: NATIONAL DIPLOMA *EXTRACTION METALLURGY*	
SUBJECT	: **PYROMETALLURGY III**	
CODE	: **MYP3111**	
DATE	: SUMMER EXAMINATION 2015 12 NOVEMBER 2015	
DURATION	: (SESSION 1) 08:30 - 11:30	
WEIGHT	: 40:60	
TOTAL MARKS	: 100	

EXAMINER	: MR KALENGA	082009303
MODERATOR	: MR T.MUKONGO	5055
NUMBER OF PAGES	: 5 PAGES AND 2 ANNEXURES	

INSTRUCTIONS

1. ANSWER ALL QUESTIONS
2. CALCULATORS ARE PERMITTED

QUESTION 1

You have to supply 500 t of MgO monthly to Umoya Plant in the Katanga province. You are mining its carbonates. From your laboratories, the analysis show that the carbonates are twice hydrated (chemically bound). From the passed data of your plant, it is stated that the carbonates only 95% of the carbonates fed get decomposed. If we assume that the working temperature for the process is 400^{O}C and that heat loss is equivalent to 11% of the heat leaving with the products, calculate:

1.1 The mass of the feed daily. Assume that the plant is operating 24 hours a day

1.2 Heat balance over the process. (Use the heat capacity mean where provided or calculate it if not provided). Assume that you are using methane as fuel and normal air for combustion

1.3 The monthly mass of fuel needed

1.4 The cost of the process if 1kg of methane is 1ZAR

1.5 The volume of the gas released every month

[20]

QUESTION 2

You are part of the pyrometallurgist team busy designing a furnace in the Research and development division. A rotary hearth furnace must be used to heat up iron up to 1300°C. The heating capacity has to be 0.245 kWh/kg. You are also provided with the following data:

-Diameter, outer wall: 4700mm	- Diameter, inner wall: 1650 mm
- Height: 1525 mm	- Roof insulation Li: 300 mm
- Width of door opening: 1800 mm	- Line voltage: 400/230v
- Control: Thyristor	- Weigh of steel billets: 1500 kg

If $\eta = 0.6$, Calculate:

2.1	The power needed according to the actual charge of 1500kg	(6)
2.2	The heated area according to the data provided above to you	(6)
2.3	The heating zone length	(6)

[18]

QUESTION 3

The Umoya plant in question 1 has trippled its capacity and has requested that the eliveries be done once a month. The Trucks used for transport can only carry 30 t each. It is said that the rainfall is high before you reach the plant, 20mm rain. Also knowing that from the chemical analysis, it has shown that the carbonate is twice hydrated. Also assuming that the physical moisture before rain is 20%:

3.1 Estimate the amount of water that needs to be removed if all the moisture must be removed before the carbonates get decomposed. Assume that even the chemically bound water is removed at this stage (6)

3.2 Calculate the cost of the process if coke is used and that normal air is used for Combustion. 1 t of coke is 50US$ (6)

3.3 Calculate the mass and volume of gas released during the process (6)

[18]

QUESTION 4

An example of the roasting under oxidizing conditions of vanadium-bearing magnetite in the presence of soda ash. In this magnetite, found in the Bushveld Igneous Complex, V(III) substitutes for Fe(III). The process is carried out at some 1250°C in coal- or gas-fired long rotary kilns. Magnetite is oxidized to hematite, Fe_2O_3; vanadium is liberated from its host lattice and oxidized to V(V) which then combines with soda ash to form sodium vanadate:

$$Fe^{II}\,[(Fe^{III},V^{III})_2\,O_4] + Na_2CO_3 + 1.25\,O_2 = 1.5\,Fe_2O_3 + 2\,NaVO_3 + CO_2$$

If the daily feed vanadium-bearing magnetite is 1000t, calculate:

4.1 The monthly (30 days) amount of sodium carbonate

4.2 Assuming that enriched air (with 30% oxygen) is used, calculate the hourly volume of air

[12]

QUESTION 5

You are currently working at a furnace (reverberatory) producing copper matte. Knowing the reaction taking place in the furnace, the off-gas assessment reveals that the off-gas contains hot solids coarse and fines. It is also said that the analysis of the feed shows an amount of moisture in the feed. Design a plant with one or more cleaning gas equipment that will allow you to recover the heat, get rid of coarse solids as well as fines, etc...

[10]

QUESTION 6

With energy crisis increasing in Africa, in your company it was decided to choose amongst different fuels. It is suggested to choose between CH_4 and coke. Assuming that you are running your test with enriched air (40% Oxygen) to determine the best fuel that generates more heat. Assuming that you are using 1 t for each fuel, make a decision on which fuel to go for.

[10]

QUESTION 7

During the sintering of hematite for pig-iron production, you have decided to increase the temperature to 1350°C. In the mixture, carbon has been added as fuel and enriched air (30% Oxygen) has been used for combustion purposes. The off-gas analysis shows that $CO/(CO + CO_2)$ is higher than 0.5. During the strategic production meeting the above information is provided. It is also reported to you that these analysis reflect what happened during the last three months and that the sinters exported to China were returned to RSA due to bad quality. Make a decision as to what should be done to ensure good sinter products. Elaborate with the use of Boudouard reaction.

[12]

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	

Substance Name	Formula	State	Mol Mass g/mol	**Enthalpy** H^{o}_{298} J/mol	**Entropy** S^{o}_{298} J/(mol K)	**Temperature Range** K	**Heat Capacity** $C = a + b\ 10^{-3}T$ 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