UNIVERSITY OF JOHANNESBURG

PROGRAM	:	**B-ENG TECH METALLURGY**
SUBJECT	:	**METALLURGICAL THERMODYNAMICS 2B**
CODE	:	**MTDMTB2**
DATE	:	**EXAMINATION A 2019**
DURATION	:	3 HOURS
WEIGHT	:	40 : 60
TOTAL MARKS	:	**78**

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NUMBER OF PAGES	:	3 PAGES AND 2 ANNEXURES	

INSTRUCTIONS :

- First read carefully through all questions.
- Answer all questions in any sequence.
- Please start answering each question on a new page.
- You must clearly demonstrate how you arrived at a given answer.
- Calculators permitted, but nothing else because all data required for calculations are provided in the Annexure.

NOTE: THIS EXAM PAPER FORMATIVELY EVALUATES AND ASSESS STUDENTS ON GA 2 AND GA 5 ON ALL QUESTIONS.

QUESTION 1 [10]

A silver coin (10 g of pure silver)) is heated up to 600°C and then dropped into a beaker containing 50 mL of water at 18°C.

Calculate the increase in water temperature. (10)

QUESTION 2 [16]

Consider production of calcium oxide and carbon dioxide from calcite.

2.1 Formulate the overall balanced reaction. (2)

2.2 Calculate the change in enthalpy of the reaction at standard temperature condition. (3)

2.3 Calculate the change in entropy of the reaction at standard temperature condition. (3)

2.4 Calculate the change in Gibbs free energy of the reaction at standard temperature condition. (3)

2.5 Calculate the equilibrium pressure of carbon dioxide over lime rock at 890°C. (5)

QUESTION 3 [34]

Millions of tons of iron metal are produced worldwide by the reduction of iron oxides with coke.
Consider the reduction of magnetite:

3.1 Write the stoichiometric reaction (assume coke to be carbon) (2)

3.2 Calculate, in respect to 1 t of magnetite, the stoichiometric amount of;

3.2.1 Carbon that is required for reduction (in t) (3)

3.2.2 Iron metal that is produced (in t) (3)

3.2.3 Carbon monoxide that is produced (in m^3) (3)

3.3 Calculate the heat of reaction (enthalpy change ΔH^o_{298}) for the above reduction reaction.

Express the result in MJ/t of magnetite (3)

3.4 State whether the reaction is exothermic or endothermic, and give a reason (s). (2)

3.5 Calculate the change in entropy of the reaction at standard temperature condition. (3)

3.6 Is the reaction feasible? Why? Determine (Calculate) at what the temperature at which the reaction becomes feasible. (5)

3.7 If the produced carbon monoxide would be used as a fuel and be completely combusted (reacted with oxygen),

3.7.1 Formulate the overall balanced reaction. (2)

3.7.2 Calculate the heat of CO combustion in MJ/t of magnetite (3)

3.7.3 Calculate the ratio of ΔH_{o298} (for CO combustion, as calculated above) / ΔH_{o298} (for magnetite reduction, as calculated above) and comment on the result. (5)

QUESTION 4 [13]

A British power station burns natural gas (assume this to be pure methane) at a rate of 57 m^3/min with the required stoichiometric amount of air.

4.1 Formulate the overall balanced reaction. (2)

4.2 Calculate the ratio of ΔH^o_{298} (3)

4.3 Estimate the generated thermal power in MW (5)

4.4 Estimate the amount of combustion gas that is produced, in m^3/min. (3)

QUESTION 5 [5]

Consider the following reaction, calculate the heat of reaction for the same reaction where water is a gaseous product instead of a liquid; (5)

$$N_2H_{4(\ell)} + O_{2(g)} \text{--->} N_{2(g)} + 2H_2O_{(\ell)} \quad \Delta H = -622.2 \text{ kJ}$$

Substance				Enthalpy	Entropy	Temperature Range	Heat Capacity		
			Mol Mass	H^o_{298}	S^o_{298}		$C = a + b\ 10^{-3}\ T$		*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	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	0	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	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	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	
Chromite	$FeCr_2O_4$	sol	223.8	-1458 124	142.0	298 – 2123	140.1	35.5	
Copper	Cu	sol	63.5	0	33.2	298 – 1358	22.0	7.4	*28.0*
	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	0	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	0	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 Dioxide	PbO_2	sol	239.2	-274 470	71.8	298 – 1200	58.9	20.4	
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	0	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	

Manganese	Mn	sol	54.9	0	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	
Mn Dioxide, *pyrolusite*	MnO_2	sol	86.9	-520 029	53.0	298	–	800	35.1	66.0	
Mercury (Quicksilver)	Hg	liq	200.6	0	75.9	298	–	630	28.4	-2.1	
	Hggas	gas		61 291	174.8	630	–	3000	20.8		
Hg-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	–	1098	43.8	15.6	
	HgSgas	gas		127 194	254.2	1098	–	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	0	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	
Nickel Oxide	NiO	sol	74.7	-239 701	38.0	565	–	2228	48.2	7.3	
Nitrogen	N_2	gas	28.0	0	191.6	298	–	1600	28.0	3.1	*30.8*
Oxygen	O_2	gas	32.0	0	205.1	298	–	5000	31.9	2.5	*38.3*
Palladium	Pd	sol	106.4	0	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	0	41.6	298	–	2045	24.3	5.4	
	Ptliq	liq		19 665	9.6	2045	–	4096	34.7		
Silicon	Si	sol	28.1	0	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	0	42.7	298	–	1234	24.3	2.5	
Heat of Fusion	Agliq	liq	*6 200*	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	0	32.1	298	–	388	16.8	20.1	
	Sliq	liq		1 720	4.4	388	–	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	hi			0.0	500	–	5000	52.5	3.0	*60.7*
Sulfuric Acid	H_2SO_4	liq	98.1	-813 989	156.8	298	–	610	81.1	193	*168*
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	0	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	V_{mol}	=	22.4 L/mol				
Oxygen in air	oav	=	21.0% by vol	oam	=	23.2% by mass	