University of Fort Hare
Together in Excellence

PAC 123 F

Supplementary Examinations: January 2019

Subject: DESCRIPTIVE CHEMISTRY

Time: 3 hours **Marks: 100**

This question paper consists of SEVEN pages

ANSWER ALL FOUR QUESTIONS

Each question carries 25 marks

ALL COMPUTATIONS MUST BE ROUNDED-OFF TO THE CORRECT NUMBER OF SIGNIFICANT FIGURES

Examiners:

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Question 1

Spontaneity, Entropy, and Free Energy

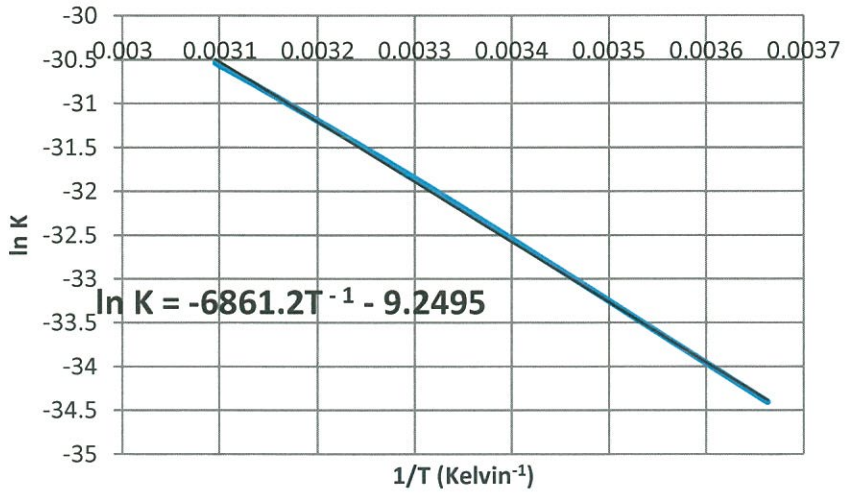
1. Tetraphenylgermane $(C_6H_5)_4Ge$ has a melting point of 232.5 ° C and its enthalpy increases by 106.7 J/g during fusion. Calculate the molar enthalpy of fusion and molar entropy of fusion of tetraphenylgermane. [5]

2.
   a. Calculate the standard entropy change at 25 ° C for the reaction
   $$N_2H_4\ (l) + 3O_2\ (g) \rightarrow 2NO_2\ (g) + 2H_2O\ (l)$$
   b. Supposed the hydrazine (N_2H_4) is in the gaseous state, rather than the liquid state. Will the entropy change for its reaction with oxygen be higher or lower than the one calculated in reaction a? [5]

3. Tungsten (VI) oxide can also be reduced to tungsten by heating with carbon in an electric furnace
   $$2WO_3\ (s) + 3C\ (s) \rightarrow 2W\ (s) + 3CO_2\ (g)$$
   a. Calculate standard free energy change (ΔG°) for this reaction, and comment on the feasibility of the process under these conditions
   b. What must be done to make the process thermodynamically feasible, assuming ΔH° and ΔS° are independent of temperature? [5]

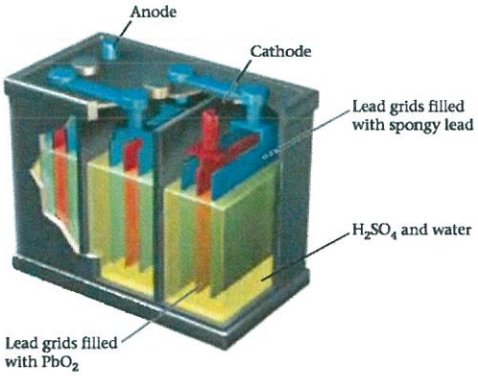
4. Consider the reaction
   $$N_2\ (g) + 3F_2\ (g) \rightleftharpoons 2NF_3\ (g)$$
   An equilibrium mixture contains the following partial pressures:
   $$P_{N_2} = 0.021\ \text{atm}, \qquad P_{F_2} = 0.063\ \text{atm}, \qquad P_{NF_3} = 0.48\ \text{atm}$$
   Calculate ΔG° for this reaction at 800. K. [4]

5. Use the following plot to determine ΔH°, ΔS° and K at 25 ° C for the autoionization of water. [6]
   $$2H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + OH^-\ (aq)$$



Question 2

Electrochemistry



1. A standard galvanic cell is constructed so that the overall reaction is

$$2Al^{3+}(aq) + 3M(s) \rightarrow 3M^{2+}(aq) + 2Al(s)$$

where M is an unknown metal. If $\Delta G^{o} = -411$ kJ for the overall cell reaction. Identify the metal used to construct the standard cell. [5]

2. The Edison storage cell is symbolized:

$$Fe(s)|FeO(s)|KOH(aq)||Ni_2O_3(s)|NiO(s)|Ni(s)$$

$$E°(cathode) = 0.40\ V,\ E°(anode) = -0.87\ V$$

   a. What are the half-cell reactions?
   b. What is the cell reaction?
   c. Calculate the cell potential.
   d. How does the cell potential depend on the concentration of KOH? [5]

3. Consider a galvanic cell in which the following reaction takes place [6]

$$PbO_2(s) + H_2SO_3(aq) \rightarrow PbSO_4(s) + H_2O(l)$$

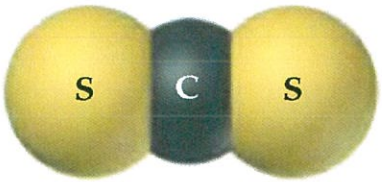
   a. Calculate E^{o}_{cell}
   b. Calculate K at 25 ° C
   c. Calculate E_{cell} when $[H_2SO_3] = 0.050$ M

4. Gold is produced electrochemically from an aqueous solution of $Au(CN)_2^-$ containing an excess of CN^-. Gold metal and oxygen gas are produced at the electrodes. What amount (moles) of O_2 gas will be produced during the production of 1.00 mol of gold? [4]

5. How many hours will it take to deposit 35.3 g of Cr from a solution of $Cr_2(SO_4)_3$ at a current of 6.00 A? [5]

Question 3

Representative Elements



1. Write the formulas for each of the following compounds:
   a. Lithium phosphide b. Potassium bicarbonate c. Rubidium selenide
   d. Sodium hypochlorite e. Hydrogen peroxide [5]

2. Aluminium hydroxide is amphoteric and dissolves in both acidic and basic solutions. Write balanced chemical equations representing each process. [4]

3. Complete and balance each of the following reactions.
   a. The decomposition of solid ammonium nitrate.
   b. The reaction between aqueous ammonia and aqueous sodium hypochlorite. [5]

4. Although nitrogen trifluoride (NF_3) is a thermally stable compound, nitrogen triiodide (NI_3) is known to be a highly explosive compound. NI_3 can be synthesized according to the equation:

$$BN\ (s) + 3IF\ (g) \rightarrow BF_3\ (g) + NI_3\ (g)$$

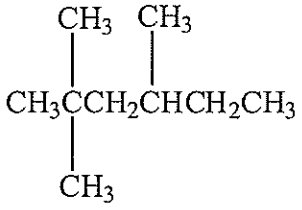
   a. What is the enthalpy of formation of NI_3 (s) is given the enthalpy of reaction (– 307 kJ) and the enthalpies of formation for BN (s) (– 254 kJ/mol), IF (g) (– 96 kJ/mol), and BF_3 (g) (– 1136 kJ/mol)?
   b. It is reported that when the synthesis of NI_3 is conducted using 4 mol IF for every mol BN, one of the by-products isolated is $[IF_2]^+[BF_4]^-$. What are the molecular geometries of the species in this by-product and what are the hybridizations of the central atoms in each species? [6]

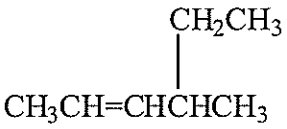
5. For the molecule XeF_4, write Lewis structure, predict the molecular structure (including bond angles), and give the expected hybridization of the central atom. [5]

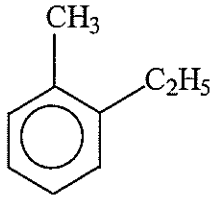
Question 4

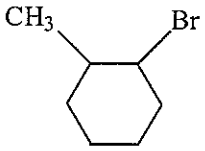
Organic and Biological Molecules

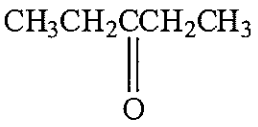
1. Name each of the following:

a. 

b. 

c. 

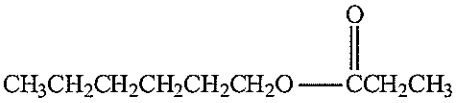
d. 

e. 

[5]

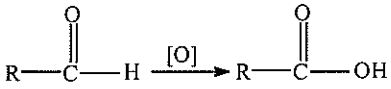
2. How would you synthesize the following esters? [5]

a. *n*-Octylacetate

b. 

3. Draw structural formulas for each of the following alcohols. Indicate whether the alcohol is primary, secondary, or tertiary.
   a. 1-Butanol b. 2-Methyl-1-butanol c. 2-Butanol d.2-Methyl-2-butanol
   [5]

4. Oxidation of an aldehyde yields a carboxylic acid:



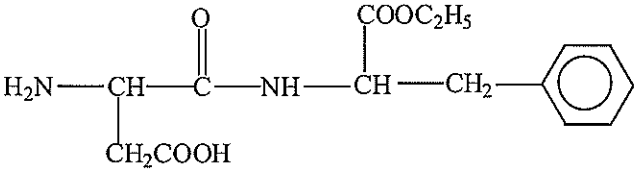
Draw the structures of the products of the following reactions:

a. Propanal $\xrightarrow{[O]}$

b. 2,3-Dimethylpentanal $\xrightarrow{[O]}$

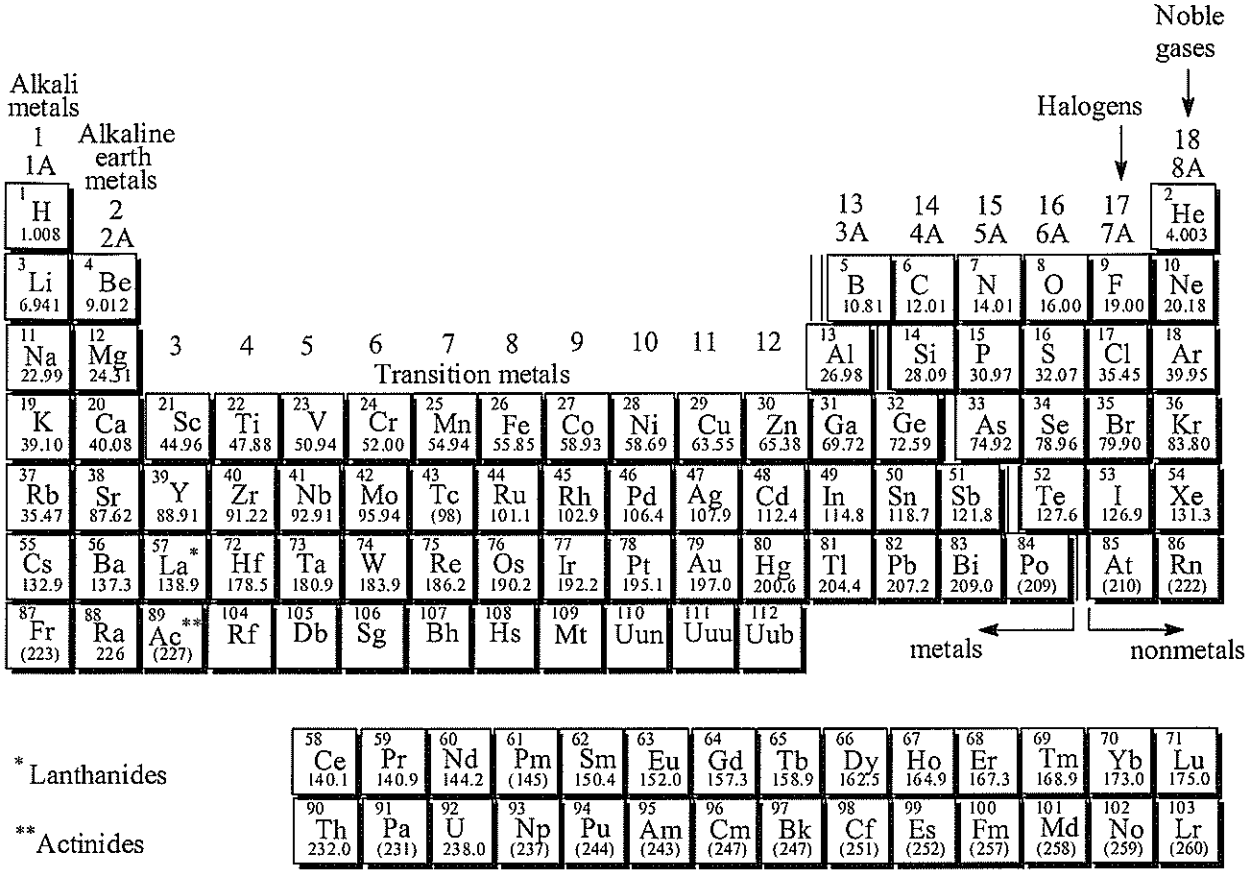
c. 3-Ethylbenzaldehyde $\xrightarrow{[O]}$ [6]

5. Aspartame is a methyl ester of a dipeptide:



What two amino acids are used to prepare aspartame? [4]

PERIODIC TABLE OF ELEMENTS



Important constants

$$R = 8.314\ J/mol \cdot K = 0.08206\ L \cdot atm/mol \cdot K$$

$$F = 96485\ C/mol$$

Important Formulas

$$\Delta G^\circ = -RT \ln K$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$E^\circ_{cell} = [E^\circ(\text{cathode}) - E^\circ(\text{anode})]$$

$$E_{cell} = E^\circ_{cell} - \frac{0.0257}{n} \ln K$$

$$m = \frac{tIM}{nF}$$

Standard Reduction Potentials at 25°C (298 K) for Many Common Half-Reactions

Half-Reaction	$\mathscr{E}°$ (V)	Half-Reaction	$\mathscr{E}°$ (V)
$F_2 + 2e^- \rightarrow 2F^-$	2.87	$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	0.40
$Ag^{2+} + e^- \rightarrow Ag^+$	1.99	$Cu^{2+} + 2e^- \rightarrow Cu$	0.34
$Co^{3-} + e^- \rightarrow Co^{2-}$	1.82	$Hg_2Cl_2 + 2e^- \rightarrow 2Hg + 2Cl^-$	0.27
$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$	1.78	$AgCl + e^- \rightarrow Ag + Cl^-$	0.22
$Ce^{4+} + e^- \rightarrow Ce^{3+}$	1.70	$SO_4^{2-} + 4H^+ + 2e^- \rightarrow H_2SO_3 + H_2O$	0.20
$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$	1.69	$Cu^{2+} + e^- \rightarrow Cu^+$	0.16
$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$	1.68	$2H^+ + 2e^- \rightarrow H_2$	0.00
$2e^- + 2H^+ + IO_4^- \rightarrow IO_3^- + H_2O$	1.60	$Fe^{3+} + 3e^- \rightarrow Fe$	−0.036
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	1.51	$Pb^{2+} + 2e^- \rightarrow Pb$	−0.13
$Au^{3+} + 3e^- \rightarrow Au$	1.50	$Sn^{2+} + 2e^- \rightarrow Sn$	−0.14
$PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$	1.46	$Ni^{2+} + 2e^- \rightarrow Ni$	−0.23
$Cl_2 + 2e^- \rightarrow 2Cl^-$	1.36	$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$	−0.35
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	1.33	$Cd^{2+} + 2e^- \rightarrow Cd$	−0.40
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	1.23	$Fe^{2+} + 2e^- \rightarrow Fe$	−0.44
$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$	1.21	$Cr^{3+} + e^- \rightarrow Cr^{2+}$	−0.50
$IO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2}I_2 + 3H_2O$	1.20	$Cr^{3+} + 3e^- \rightarrow Cr$	−0.73
$Br_2 + 2e^- \rightarrow 2Br^-$	1.09	$Zn^{2+} + 2e^- \rightarrow Zn$	−0.76
$VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$	1.00	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	−0.83
$AuCl_4^- + 3e^- \rightarrow Au + 4Cl^-$	0.99	$Mn^{2+} + 2e^- \rightarrow Mn$	−1.18
$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	0.96	$Al^{3+} + 3e^- \rightarrow Al$	−1.66
$ClO_2 + e^- \rightarrow ClO_2^-$	0.954	$H_2 + 2e^- \rightarrow 2H^-$	−2.23
$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	0.91	$Mg^{2+} + 2e^- \rightarrow Mg$	−2.37
$Ag^+ + e^- \rightarrow Ag$	0.80	$La^{3+} + 3e^- \rightarrow La$	−2.37
$Hg_2^{2+} + 2e^- \rightarrow 2Hg$	0.80	$Na^+ + e^- \rightarrow Na$	−2.71
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.77	$Ca^{2+} + 2e^- \rightarrow Ca$	−2.76
$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$	0.68	$Ba^{2+} + 2e^- \rightarrow Ba$	−2.90
$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	0.56	$K^+ + e^- \rightarrow K$	−2.92
$I_2 + 2e^- \rightarrow 2I^-$	0.54	$Li^+ + e^- \rightarrow Li$	−3.05
$Cu^+ + e^- \rightarrow Cu$	0.52		

Species	Name	Enthalpy $\Delta H_f°$ (kJ/mol)	Gibbs energy $\Delta G_f°$ (kJ/mol)	Entropy $S°$ (J/mol·K)
CO_2 (g)	Carbon Dioxide	-393.51	-394.36	213.74
O_2 (g)	Oxygen gas	0	0	205.07
N_2H_4 (*l*)	Hydrazine	50.63	149.45	121.52
NO_2 (g)	Nitrogen Dioxide	33.1	51.23	240.04
H_2O (*l*)	liquid water	-285.83	-237.15	69.95
WO_3 (s)	Tungsten (VI) oxide	-842.87	-764.08	75.90
W(s)	Tungsten metal	0	0	32.6
C(s)	Carbon (s)	0	0	5.74