UNIVERSITY
OF
JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY
DIPLOMA: ENGINEERING METALLURGY
DIPLOMA: EXTRACTION METALLURGY

MODULE CET1AM2
METALLURGICAL CHEMISTRY 2

CAMPUS **DFC**

JUNE EXAMINATION

DATE: 05/06/2018 **SESSION: 12:30 – 15:30**

ASSESSOR **DR J RAMONTJA**

INTERNAL MODERATOR **MR A PP MONAMA**

DURATION 3 HOURS **MARKS 140**

NUMBER OF PAGES: 11 PAGES, INCLUDING 2 ANNEXURES

INSTRUCTIONS:

ANSWER SECTION A (THE MULTIPLE CHOICE QUESTIONS) AND SECTION B (LONG QUESTIONS) IN SEPARATE ANSWER SCRIPTS.

FOR SECTION A, CLEARLY SHADE THE LETTER CORRESPONDING TO THE ANSWER OF CHOICE.

CONSULT THE DATA SHEET AND THE PERIODIC TABLE FOR ALL SUPPLEMENTARY INFORMATION.

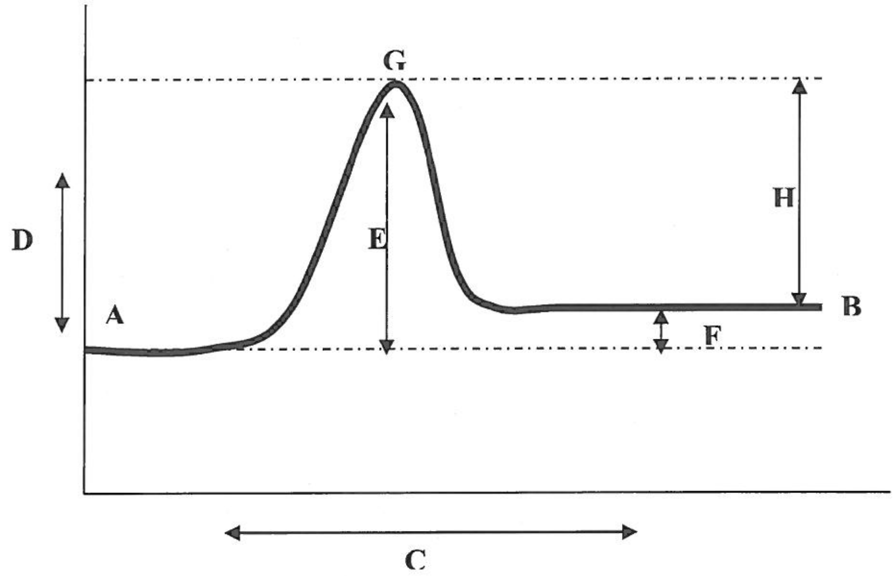
NON-PROGRAMMABLE CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT).
GIVE ALL NUMERICAL ANSWERS TO THE CORRECT NUMBER OF SIGNIFICANT FIGURES AND WITH APPROPRIATE UNITS.

REQUIREMENTS: 2 ANSWER SCRIPT (INCLUDING MULTIPLE CHOICE).

/2…

SECTION A

1. Consider the diagram below and then use it to answer the questions that follow:



The labels E, F and G in the diagram above are best described as:

A. Activation energy of the reverse reaction, enthalpy of the forward reaction and activated complex
B. Enthalpy of the reverse reaction, activation energy of the forward reaction, and intermediate
C. Activation energy of the forward reaction, enthalpy of the forward reaction and deactivated complex
D. Enthalpy of the forward reaction, activation energy of the reverse reaction, and activated intermediate
E. Activation energy of the forward reaction, enthalpy of the forward reaction and activated complex

2. If the reaction represented by the diagram above were conducted at temperatures T_1 and T_2 (where $T_1 < T_2$), then the Boltzmann distribution for the reaction conducted at temperature T_2 would reflect:

A. a curve with the same area, but higher peak height than for T_1
B. a curve with higher area than, but the same activation energy as T_1
C. a curve with lower area and lower activation energy than at T_1
D. a curve with the same area, but lower peak height than for T_1
E. a curve with the same area, but higher activation energy than at T_1

3. Each of the following is a factor which affects the rate that a reaction occurs except:

A. Particle size
B. Total pressure
C. Ambient temperature
D. Reactant concentration
E. Enthalpy

4. The decomposition of NO_2 is a second order process:

$$2NO_2(g) \rightarrow 2NO(g) + O_2(g)$$

The rate constant for the decomposition at 300°C is 0.543 M^{-1} s^{-1}.Suppose we start with 0.0250 mol of NO_2 in a volume of 500 mL, how many moles of NO_2 will remain after 1 minute and 45 seconds?

A. 0.0103 mol
B. 0.0129 mol
C. 0.00649 mol
D. 0.0148 mol
E. 0.00740 mol

5. How many seconds will it take for the quantity of NO_2 for the reaction in **Question 4** to drop to 0.0150 mol?

A. 14.5 seconds
B. 16.3 seconds
C. 8.16 seconds
D. 29.4 seconds
E. 24.6 seconds

6. What is the half-life of NO_2 for the reaction in **Question 4**?

A. 128 seconds
B. 123 seconds
C. 92.0 seconds
D. 36.8 seconds
E. 184 seconds

7. A certain first-order reaction has a rate constant of 2.520 x 10^{-5} s^{-1} at 189.7°C. The activation energy for the reaction is 160.1 kJ. mol^{-1}. Determine the rate constant at 230.3°C. [R = 8.31451 $J.K^{-1}.mol^{-1}$].

A. 2.528 x 10^{-5} s^{-1}
B. 7.218 x 10^{-4} s^{-1}
C. 8.798 x 10^{-7} s^{-1}
D. 2.512 x 10^{-5} s^{-1}
E. 4.509 x 10^{-1} s^{-1}

/4...

8. Which one of the following statements is **correct**?

A. A catalyst that is present in the same phase as the reacting molecules is a heterogeneous catalyst.
B. Elementary steps involving the simultaneous collision of two molecules are bimolecular.
C. Absorption refers to the binding of molecules to a surface.
D. Because the fast step limits the overall reaction rate, it is called the rate-determining step.
E. A balanced chemical equation details the individual steps that occur in the course of a reaction.

9. Given the following reaction: $2\ DC(g) + C_2(g) \rightarrow 2\ DC_2(g)$

If the mechanism below was proposed, then this implies that:

$DC(g) + DC(g) \rightarrow D_2C_2(g)$...(1)
$D_2C_2(g) \rightarrow DC(g) + DC(g)$......(2) (SLOW)
$D_2C_2(g) + C_2(g) \rightarrow 2\ DC_2(g)$......(3)

A. the formation of $DC(g)$ is the rate determining step
B. the rate of formation of $DC_2(g)$ is slower than that of $DC(g)$
C. the intermediate is $DC(g)$
D. the rate of formation of $D_2C_2(g)$ is less than that of $DC(g)$
E. the overall reaction order is three

10. Propanone can be made from propan-2-ol.

$C_3H_8O(g) \rightleftharpoons C_3H_6O(g) + H_2(g)$ $K_c = 0.0100$

In an experiment, 6.00 moles of $C_3H_8O(g)$, 0.150 mole of $C_3H_6O(g)$ and 0.100 mole of $H_2(g)$ are placed in a 1.00 dm^3 container and allowed to establish equilibrium.

Which of the following change(s) will occur as the system proceeds towards equilibrium?

A. $[C_3H_6O(g)]$ increases while $[H_2(g)]$ decreases.
B. $[C_3H_6O(g)]$ and $[H_2(g)]$ both increase.
C. $[C_3H_8O(g)]$ and $[H_2(g)]$ both increase.
D. $[C_3H_8O(g)]$ and $[C_3H_6O(g)]$ both decrease.
E. None of the above

11. Given the following reaction: A $\rightarrow$ 2B

Time (min):	[A] mol/L
0	0.200
5	0.140
10	0.0800
15	0.0200

What is the reaction rate (in mol/L.s) for the production of B?

A. 2.00×10^{-4}
B. 1.00×10^{-4}
C. 2.40×10^{-2}
D. 1.20×10^{-2}
E. 4.00×10^{-4}

12. Adding an ion common to a saturated solution of a sparingly soluble salt in water:

A. has no effect on the solution
B. reduces the quantity of the sparingly soluble salt dissolved in solution
C. increases the solubility of the other ions of the sparingly soluble salt in solution
D. increases the quantity of sparingly soluble salt in solution
E. reduces the concentration of water in solution

13. Consider the following equilibria:
$SO_2(g) + \frac{1}{2} O_2(g) \rightleftharpoons SO_3(g)$ K_1
$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$ K_2
Which one of the following is true?

A. $K_2 = K_1^2$
B. $K_2^2 = K_1$
C. $K_2 = K_1$
D. $K_2 = 1/K_1^2$
E. $K_2 = 1/K_1$

14. Calculate the pOH of a 0.135 M solution of ammonia, given that the K_b for ammonia is 1.50×10^{-5}.

A. 2.85
B. 11.2
C. 8.98
D. 5.02
E. None of the above

15. Which of the following buffer compositions can withstand the greatest addition of a 0.025 mol. dm^{-3} solution of sodium hydroxide before collapsing?

A. 0.121 M H_2S and 0.121 M $Ba(HS)_2$
B. 0.242 M H_2S and 0.121 M NaHS
C. 0.242 M $Ca(HS)_2$ and 0.121 M H_2S
D. 0.121 M KHS and 0.121 M H_2S
E. 0.242 M H_2S and 0.242 M $Mg(HS)_2$

16. 10 g of a sparingly soluble salt (X_3Y_2) with a solubility constant of 1.0×10^{-16} is placed into 1 L of water. If the salt produces $X^{2+}(aq)$ and $Y^{3-}(aq)$ ions, then calculate its molar solubility.

A. 4.47×10^{-9}
B. 4.08×10^{-9}
C. 1.24×10^{-3}
D. 2.47×10^{-4}
E. None of the above

17. Which transformation can take place at the cathode of an electrochemical cell?

A. $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq)$
B. $MnO_2(s) + 4H^+(aq) \rightarrow Mn^{2+}(aq) + 2H_2O(l)$
C. $Br^-(aq) + 2OH^-(aq) \rightarrow BrO^-(aq) + H_2O(l)$
D. $ClO_3^-(aq) + 2OH^-(aq) \rightarrow ClO_4^-(aq) + H_2O(l)$
E. None of the above

18. For any reaction at equilibrium it is always true to say that...

A. the speed that products form is greater than the speed that reactants react
B. the speed that reactants react is greater than the speed that products form
C. the reaction rates for both directions are non-equivalent
D. the speed that both reactants react and products form are equivalent
E. None of the above

19. The two electrodes $Al(s)/ Al^{3+}(aq)$ (0.350 $mol.dm^{-3}$) and $Co(s)/Co^{2+}(aq)$ (0.100 $mol.dm^{-3}$) were combined to produce a spontaneous electrochemical reaction. The cell potential for this reaction at 25.00°C is:

A. +1.38 V
B. +1.36 V
C. −1.38 V
D. −1.36 V
E. −1.37 V

20. One of the main reasons why the molar conductivity of a strong electrolyte decreases as its concentration increases is because:

A. the electrophoretic effect increases as the concentration of the strong electrolyte increases
B. with less water there are less hydronium and hydroxide ions to conduct electricity
C. the fraction of ions formed in a solution of a strong electrolyte is directly proportional to its volume
D. the asymmetric effect on a solution of a strong electrolyte decreases as the volume of water decreases
E. the dissociation of a solution of a strong electrolyte is inversely proportional to its volume

[20 x 3 = 60]

SECTION B

QUESTION 1

Consider the following equilibrium for which $\Delta H = +26.38$ kJ/mol:

$SnBr_2(s) + H_2(g) \rightleftharpoons Sn(s) + HBr(g)$ **(unbalanced)**

When 5.98 moles of each $SnBr_2$ and H_2 were placed into an evacuated 21.5 dm^3 container at 758 K and the reaction reached equilibrium the pressure in the container was 1.88×10^4 torr. A certain amount of moles of H_2 was then carefully added to the mixture in the container and the reaction was allowed to reach equilibrium for the second time. The pressure in the container is found to be 2.21×10^4 torr at the second equilibrium.

1.1 Calculate the **additional number of moles** of H_2 that was introduced into the container at 758 K. (19)

1.2 Use the data provided in this question to predict what would happen if the **volume** of the container were **fixed** and the **temperature doubled**. Give all details. (5)

[23]

QUESTION 2

A buffer solution of pH of 9.50 contains **P** mol of a weak base and 0.100 mol of a salt of its conjugate acid. When 100 cm^3 of a 0.0600 $mol.dm^{-3}$ solution of hydrochloric acid was added to this buffer solution the pH changes by 0.200 pH units. Use this information to calculate the value of K_b for the weak base.

[12]

QUESTION 3

A mixture is first made of 320 cm^3 of a 0.0175 $mol.dm^{-3}$ solution of silver nitrate and **y** cm^3 of a 6.75 $mol.dm^{-3}$ solution of ammonia. Thereafter, 440 cm^3 of a 0.0148 $mol.dm^{-3}$ solution of sodium bromide is added to this mixture and the resulting solution is diluted to 1.60 dm^3. Calculate the value of **y** that *will just prevent the precipitation* of silver bromide.

[14]

/9...

QUESTION 4

An ore sample collected near the Zambezi river was treated so that the resulting 50.0 dm^3 solution contained 0.00120 mol dm^{-3} of $Ni^{2+}(aq)$ ions and 0.0240 mol dm^{-3} of $Fe^{2+}(aq)$ ions. The solution was kept saturated with an aqueous solution of 0.300 mol dm^{-3} H_2CO_3. The pH was then carefully adjusted to selectively precipitate the first metal ion (as a metal carbonate) from the second. The first precipitate was filtered off from the remaining solution, dried and reduced to its pure metal form. The pH of the remaining solution was then carefully adjusted for the second time until the entire concentration of the second metal ion, together with a trace concentration of the first metal ion, were co-precipitated as metal carbonates. This co-precipitate was also filtered off, dried and reduced to the metal form. Based upon this information and that in the data sheet, calculate:

4.1 The pH at which maximum separation of the two metal ions was achieved. (9)

4.2 The mass % impurity of the metal that was obtained from the reduction of the last precipitate. (7)

[15]

QUESTION 5

5.1 Define or describe each of the following:

5.1.1 Bimolecular reaction. (3)

5.1.2 Liquid junction. (3)

5.1.3 Limiting molar conductivity. (3)

5.2 Balance the following reaction and construct an electrochemical cell that represents this reaction by using the correct cell notation and an appropriate junction:

Oxidation of Zn to ZnO_2^{2-} with SbO_3^- to SbO_2^- (alkali medium) (14)

[23]

DATA

Avogadro's number: N = 6.02 x10^{23}

0^oC = 273.15 K

Standard pressure = 1 atm = 101.325 kPa = 760 mmHg = 760 torr = 1.01325 bar

R = 8.31451 L.kPa .K^{-1}.mol^{-1}
= 8.31451 J.K^{-1}.mol^{-1}
= 8.31451 x10^{-2} L.bar .K^{-1}.mol^{-1}
= 8.20578 x10^{-2} L.atm .K^{-1}.mol^{-1}
= 62.364 L.torr .K^{-1}.mol^{-1}

F = 9.6485 x 10^4 C.mol^{-1}

V = J.C^{-1}

Equilibrium constants (T = 25.0°C)

K_{sp} (Silver bromide, AgBr) = 5.30 x 10^{-13}

K_f ($Ag(NH_3)_2^+$) = 1.70 x 10^7

K_{a1} (Carbonic acid, H_2CO_3) = 4.30 x 10^{-7}

K_{a2} (Carbonic acid, H_2CO_3) = 5.60 x 10^{-11}

K_a (Chlorous acid, $HClO_2$) = 1.10 x 10^{-2}

K_{sp} (Iron(II) carbonate, $FeCO_3$) = 2.10 x 10^{-11}

K_{sp} (Nickel(II) carbonate, $NiCO_3$) = 1.30 x 10^{-7}

K_{sp} (Silver chloride, AgCl) = 1.80 x 10^{-10}

Standard reduction potentials (T = 25.0 °C)

E^o red (Al^{3+}/ Al) = –1.66 V

E^o red (Cd^{2+}/ Cd) = –0.403 V

E^o red (Co^{2+}/ Co) = –0.277 V

E^o red (Ni^{2+}/ Ni) = –0.280 V

UNIVERSITY OF JOHANNESBURG
Department of Applied Chemistry

Atomic Number		Atomic Weight
2	He	4.0026

1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.179
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.064	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.88	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.03	89 **Ac** 227.03															

58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92	62 **Sm** 150.36	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	94 **Pu** (244)	95 **Am** (234)	96 **Cm** (247)	97 **Bk** 247	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)