UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF CHEMICAL SCIENCES
DEGREE: BACHELOR OF ENGINEERING TECHNOLOGY(METALLURGY)

MODULE CETM1B1
ENGINEERING CHEMISTRY 1B

CAMPUS **DFC**

MAIN EXAMINATION

DATE: **21/11/2019** **SESSION:** **08:30 – 11:30**

LECTURER **PROF J RAMONTJA**

INTERNAL MODERATOR **MR PP MONAMA**

DURATION **3 HOURS** **MARKS 120**

NUMBER OF PAGES: **7 PAGES, INCLUDING 2 ANNEXURES**

INSTRUCTIONS: **ANSWER SECTION A (THE MULTIPLE CHOICE QUESTIONS) AND SECTION B (LONG QUESTIONS) IN THE SAME ANSWER SCRIPT.**

FOR SECTION A, CLEARLY INDICATE THE QUESTION NUMBER AND THE LETTER CHOICE. FOR EXAMPLE 27 = E.

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

ONLY ONE CALCULATOR PER STUDENT IS PERMITTED

GIVE ALL NUMERICAL ANSWERS TO THE CORRECT NUMBER OF SIGNIFICANT FIGURES AND WITH APPROPRIATE UNITS.

REQUIREMENTS: **1 ANSWER SCRIPT.**

SECTION A

1. Consider the formation of ammonia (NH_3):

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

If the rate of appearance of NH_3 at a particular instant in a reaction vessel is 3.33×10^{-3} M.s^{-1}, what is the rate of disappearance of H_2?

A. 3.33×10^{-3} M.s^{-1}
B. 9.99×10^{-3} M.s^{-1}
C. 1.11×10^{-3} M.s^{-1}
D. 5.00×10^{-3} M.s^{-1}
E. 2.22×10^{-3} M.s^{-1}

2. 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.

3. Which one of the following statements is **incorrect**?

A. The equilibrium constant of a reaction equation where the coefficients have been multiplied throughout by a number is the equilibrium constant raised to a power equal to that number.
B. Reducing the volume of a gaseous equilbrium mixture causes the system to shift in the direction that increases the number of moles of gas.
C. If a pure solid is involved in a heterogeneous equilibrium, its concentration is not included in the equilibrium-constant expression for the reaction.
D. The reaction quotient (Q) will equal the equilibrium constant (K_C) only if the system is at equilibrium.
E. A catalyst increases the rate at which equilibrium is achieved, but it does not change the composition of the equilibrium mixture.

4. What is **primarily** responsible for the high solubility of ammonia in water?

A. Dispersion forces
B. Ionic bonds
C. Covalent bonds
D. Hydrogen bonds
E. London forces

5. In cold countries, ethylene glycol is added to water in car radiators during winter. This results in:

A. Reducing viscosity
B. Reducing latent heat
C. Reduction of boiling point
D. Reduction of freezing point
E. None of above

6. Consider the following reaction at equilibrium at 577 K:

$A_2C_2(g) \rightleftharpoons 2A(g) + C_2(g)$ …………$K_c = 0.00402$

If the same reaction was conducted at 977 K and the new equilibrium constant was found to be one – third that of the value of K_c, this would imply that:

A. the forward reaction is exothermic
B. an equilibrium constant is inversely proportional to temperature
C. the reverse reaction is exothermic
D. an equilibrium constant is directly proportional to temperature
E. the forward reaction is endothermic

7. A 0.0500 M solution of a weak base B is dissociated by 8.50%. The pH of the solution and the K_b for the weak base are:

A. 12.9 and 1.36×10^{-1}
B. 11.6 and 3.61×10^{-4}
C. 12.7 and 3.71×10^{-4}
D. 12.9 and 3.40×10^{-4}
E. 11.6 and 3.95×10^{-4}

8. The pH of 0.0155 $mol.dm^{-3}$ solution of carbonic acid (H_2CO_3) is:

A. 1.81
B. 4.09
C. 2.95
D. 9.91
E. 12.2

9. Which of the following substances will produce an alkaline solution when dissolved in water?

A. HCl
B. Na_2CO_3
C. NH_4Cl
D. CO_2
E. H_2SO_4

10. 15.0 mg of a sparingly soluble salt ($X_3Y_2(s)$) with a solubility product constant of 1.50×10^{-21} is placed into 100 cm^3 of water. If the salt produces $X^{2+}(aq)$ and $Y^{3-}(aq)$ ions, then its molar solubility is:

A. 6.84×10^{-5}
B. 1.58×10^{-11}
C. 4.96×10^{-5}
D. 2.25×10^{-20}
E. 2.68×10^{-5}

[10 x 3 = 30]

SECTION B

QUESTION 1

1.1 Compute the vapor pressure of an ideal solution containing 92.1 g of glycerin, $C_3H_5(OH)_3$, and 184.4 g of ethanol, C_2H_5OH, at 40 °C. The vapor pressure of pure ethanol is 0.178 atm at 40 °C. Glycerin is essentially nonvolatile at this temperature. (8)

1.3 What concentration of NaCl in water is needed to produce an aqueous solution isotonic with blood (π = 7.70 atm at 25^{o}C). (6)

1.4 When a 4.25 g sample of solid NH_4NO_3 dissolves in 60.0 g of water in a calorimeter, the temperature drops from 21.0°C to 16.9°C. Calculate the energy involved in the dissolving of the NH_4NO_3. (Specific Heat Capacity of water: 4.18 J/g.̊C) (4)

1.5 The decomposition of hydrogen peroxide (H_2O_2) is a first order process:

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

1.5.1 At 24.2^{o}C, the half-life for this reaction is 15.0 minutes and 36.6 seconds. What is the rate constant at this temperature? (3)

1.5.2 If, at 24.2^{o}C, we begin with 0.0250 mol of H_2O_2 in a volume of 350 cm^3, how long will it take for the number of moles of H_2O_2 to drop by 36.0%? (6)

1.6 The activation energy of a first order reaction is 60.4 kJ/mol at 25^{o}C. At what temperature will the rate constant triple? (5)

[32]

QUESTION 2

A concentration (***P***) of gaseous hydrogen peroxide ($H_2O_2(g)$) was placed into an evacuated container of fixed volume that was kept at 855 K. At this temperature some of the gaseous hydrogen peroxide decomposed to form gaseous hydrogen ($H_2(g)$) and gaseous oxygen ($O_2(g)$) until an equilibrium was established. The pressure in the container was measured to be 2.88 x 10^3 mmHg. The equilibrium constant (K_c) was measured to have a value of 0.176.
A concentration (***Q***) of gaseous hydrogen peroxide was then carefully removed from the mixture in the container and the reaction was allowed to reach a new equilibrium. At the new equilibrium, the concentration of gaseous hydrogen was found to be 32.6% less than it was at the initial equilibrium.

Calculate the concentration of gaseous hydrogen peroxide (***Q***) that was removed from the container to cause the concentration of hydrogen at the new equilibrium to be 32.6% less than it was initially.

[18]

/5…

QUESTION 3

A buffer solution of pH of 8.96 contains **X** mol of a weak base and **Z** mol of a salt of its conjugate acid. When 144 cm^3 of a 0.0212 $mol.dm^{-3}$ solution of hydrochloric acid was added to this buffer solution the pH changes by 0.250 pH units. If the K_b value for the weak base is 1.66×10^{-5}, calculate the values of **X** and **Z**.

[14]

QUESTION 4

A mass of 200.00 g of an ore was acid leached so that the resulting 2.0 dm^3 solution contained 0.0140 mol dm^{-3} of Cu^{2+}(*aq*) ions and 0.205 mol dm^{-3} of Co^{2+}(*aq*) ions. This solution was then, slowly made alkaline by adding a solution of hydroxide ions to it in order to selectively precipitate these metal ions. Finally, each of the dry precipitates was reduced in the presence of gaseous hydrogen to form a pure metal. Based upon this information, calculate:

4.1 The pH at which maximum separation of the two metal ions was achieved. (10)

4.2 The percentage mass impurity of the metal that was obtained from the reduction of the last precipitate. (8)

[18]

QUESTION 5

5.1 Distinguish between the terms "salt bridge" and "liquid junction". (4)

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:

Reduction of CrO_4^- to $Cr(OH)_3$ with Al to $Al(OH)_3$ (alkali medium) (14)

[18]

DATA SHEET

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^oC)

(Carbonic acid, H_2CO_3)	K_{a1} = 4.30 x 10^{-7}
(Carbonic acid, H_2CO_3)	K_{a2} = 5.60 x 10^{-11}
(Hydrocyanic acid, HCN)	K_a =1.49 x 10^{-10}
(Hydrosulphuric acid, H_2S)	K_{a1} = 1.10 x 10^{-7}
(Hydrosulphuric acid, H_2S)	K_{a2} = 1.00 x 10^{-14}
$Cu(OH)_2$	K_{sp} = 2.2 x 10^{-20}
$Co(OH)_2$	K_{sp} = 2.5 x 10^{-16}
($Cu(CN)_4^{2-}$)	K_f = 1.00 x 10^{25}

Standard reduction potentials (T = 25.0 ^oC)

E^o red (Al^{3+}/ Al) = –1.66 V

E^o red (Cu^{2+}/ Cu) = +0.337 V

E^o red (H^+/ H_2) = 0.000 V

/7…

UNIVERSITY OF JOHANNESBURG

Department of Chemical Sciences

Atomic Number

2 **He** *4.0026*

Atomic Weight

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)*