UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY
B. ENG. TECH. IN CHEMICAL ENGINEERING
B. ENG. TECH. IN ELECTRICAL ENGINEERING

MODULE CETE1A1
ENGINEERING CHEMISTRY (CHEMICAL/ELECTRICAL) 1A

CAMPUS **DFC**

MAIN EXAMINATION

DATE: 04/06/2018 **SESSION: 12:30 – 15:30**

ASSESSORS: **DR D NKOSI**
DR C ZVINOWANDA

INTERNAL MODERATOR: **MR P MONAMA**

DURATION: 3 HOURS **MARKS: 145**

NUMBER OF PAGES: 10 PAGES, INCLUDING A DATA SHEET AND PERIODIC TABLE.

INSTRUCTIONS: ANSWER SECTION A ON THE MULTIPLECHOICE ANSWER SHEET.

ANSWER SECTION B IN THE TWO ANSWER BOOKLETS PROVIDED:
ANSWER QUESTION 1 TO 4 IN ANSWER BOOKLET 1
AND QUESTION 5 AND 6 IN ANSWER BOOKLET 2.

CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT).

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

REQUIREMENTS:

SECTION A: **MULTIPLE CHOICE ANSWER SHEET**

SECTION B: **2 ANSWER BOOKLETS:**

SECTION A

ANSWER THIS SECTION ON THE MULTIPLE-CHOICE ANSWER SHEET

1. Which one of the following statements is not correct about matter?

   A. Chemistry is the study of the properties and behavior of atoms in matter only.
   B. Matter is anything that has mass and takes up space.
   C. Atoms are the building blocks of matter.
   D. Each element is made of a unique kind of atom.
   E. A compound is made of two or more different kinds of elements.

2. Which one of the following statements is correct about some of the properties of matter?

   A. Physical Properties can *only* be observed when a substance is changed into another substance
   B. Intensive Properties depend upon the amount of the substance present.
   C Chemical Properties can be observed without changing a substance into another substance.
   D. Another name for a homogeneous mixture is solution.
   E. Extensive Properties are independent of the amount of the substance that is present.

3. Determine the mass-percentage of carbon in ethane (C_2H_6).

   A. 69.75%
   B. 85.25%
   C. 68.85%
   D. 79.85%
   E. 90.35%

4. How many protons (p), neutrons (n), and electrons (e^-) are in an atom of strontium-90?

   A. 90p; 38e^-; 38n
   B. 38p, 90e^-; 90n
   C. 38p; 38e^-; 52n
   D. 52p, 52e^-; 38n
   E. 38p, 38e^-; 38n

5. Naturally occurring chlorine is 75.78% ^{35}Cl (atomic mass 34.969 amu) and 24.22% ^{37}Cl (atomic mass 36.966 amu). Calculate the atomic weight of chlorine.

   A. 35.550
   B. 35.453
   C. 35.968
   D. 34.451
   E. 35.620

6. Which one of the following statements is not correct about ionic compounds.

A. Ionic compounds are generally formed between metals and nonmetals.
B. Electrons are transferred from the metal to the nonmetal.
C. The oppositely charged ions attract each other.
D. Only empirical formulas are written.
E. Electrons are shared by the atoms involve in making ionic compound.

7. Which of the ions formed by elements in Period number 2 has the largest ionic radius?

A. O^{2-}
B. Li^{+}
C. Be^{2+}
D. B^{3+}
E. C^{4+}

8. Which one of the following statements is correct?

A. Nitrate salts are insoluble in water
B. Compounds formed between metals and non-metals tend to be covalent
C. Substances containing only non-metals are ionic
D. Most non-metal oxides are basic
E. Metal oxides tend to be basic

9. The outermost electron in gallium (Ga) is found in $4p^1$. Which one of the following sets of quantum numbers correctly describe this electron?

A. $n = 4; l = 0;\ m_l = -1, 0, +1; m_s = +1/2$
B. $n = 4; l = 2;\ m_l = -1, 0, +1; m_s = +1/2$
C. $n = 4; l = 1;\ m_l = -1, 0, +1; m_s = +1/2$
D. $n = 2; l = 2;\ m_l = -2, -1, 0, +1, +2; m_s = +1/2$
E. $n = 2; l = 1;\ m_l = -1, 0, +1; m_s = +1/2$

10. Which one of the following equations illustrate correctly the third ionisation energy of aluminium (Al)

A. $Al(g) \rightarrow Al^{+}(g) + e^{-}$
B. $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^{-}$
C. $Al^{+}(g) \rightarrow Al^{2+}(g) + e^{-}$
D. $Al(g) \rightarrow Al^{3+}(g) + 3e^{-}$
E. $Al^{+}(g) \rightarrow Al^{3+}(g) + 2e^{-}$

11. The formation of molecular geometry can be explained using hybridisation and formation of degenerate orbitals. Which one of the following hybrid orbitals are associated with octahedral shape?

A. sp
B. sp^2
C. sp^3
D. p
E. s

12. Which one of the following statements is not correct about lattice energy?

A. The energy required to completely separate a mole of a solid ionic compound into its gaseous ions.
B. Lattice energy is the energy change accompanying the addition of an electron to a gaseous atom.
C. Lattice energy increases with decreasing size of ions
D. Lattice energy increases with the charge on the ions.
E. The energy associated with electrostatic interactions is governed by Coulomb's law.

13. The following statements describe some of the characteristics of gases except which one?

A. Expand to fill their containers
B. Are highly compressible
C. Have extremely low densities
D. Gases consist of large numbers of molecules that are in continuous, random motion
E. Attractive and repulsive forces between gas molecules are significant

14. What is the oxidation number of iron (Fe) in the oxyanion ferrate (FeO_4^{3-})?

A. +5
B. +3
C. –3
D. +6
E. +4

15. Which one of the following of the statements does not correctly describe what is happening in the equation: $Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

A. Zinc is acting as an oxidising agent
B. Hydrogen ion is an oxidising agent
C. Zinc is oxidised
D. Hydrogen ion is reduced
E. Zinc is a reducing agent

16 The equilibrium constant for the gas phase reaction

$$NH_3(g) \rightleftharpoons N_2(g) + 3\,H_2(g)$$

is $K_c = 230$ at 300 °C. At equilibrium, _____.

A. products predominate
B. reactants predominate
C. roughly equal amounts of products and reactants are present
D. only products are present
E. only reactants are present

17. The value of K_c for the equilibrium

$$H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$$

is 794 at 25 °C. At this temperature, what is the value of K_c for the equilibrium below?

$$HI(g) \rightleftharpoons \tfrac{1}{2}\,H_2(g) + \tfrac{1}{2}\,I_2(g)$$

A. 1588
B. 28
C. 397
D. 0.035
E. 0.0013

18. Which one of the following will change the value of an equilibrium constant?

A. adding other substances that do not react with any of the species involved in the equilibrium
B. varying the initial concentrations of reactants
C. varying the initial concentrations of products
D. changing the volume of the reaction vessel
E. changing temperature

19. The reaction below is exothermic:

$$2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g)$$

Le Chatelier's Principle predicts that _____will result in an increase in the number of moles of $SO_3(g)$ in the reaction container.

A. decreasing the pressure
B. increasing the temperature
C. removing some oxygen
D. increasing the pressure
E. increasing the volume of the container

20. The conjugate base of HSO_4^- is _____.

A. OH^-
B. H_2SO_4
C. SO_4^{2-}
D. HSO_4^+
E. $H_3SO_4^+$

21. The magnitude of K_w indicates that _____.

A. water autoionizes very slowly
B. water autoionizes very quickly
C. water autoionizes only to a very small extent
D. the autoionization of water is exothermic
E. none of the above

22. The K_a for HCN is 4.9×10^{-10}. What is the value of K_b for CN^-?

A. 2.0×10^{-5}
B. 4.0×10^{-6}
C. 4.9×10^{4}
D. 4.9×10^{-24}
E. 2.0×10^{9}

23. A Brønsted-Lowry base is defined as a substance that _____.

A. increases $[H^+]$ when placed in H_2O
B. decreases $[H^+]$ when placed in H_2O
C. increases $[OH^-]$ when placed in H_2O
D. acts as a proton acceptor
E. acts as a proton donor

24. Of the acids in the table below, _____ is the strongest acid.

Acid	K_a
HOAc	1.8×10^{-5}
$HCHO_2$	1.8×10^{-4}
HClO	3.0×10^{-8}
HF	6.8×10^{-4}

A. HOAc
B. $HCHO_2$
C. HClO
D. HF
E. HOAc and $HCHO_2$

25. In a solution, when the concentrations of a weak acid and its conjugate base are equal,

A. pH = 7.00
B. pH > pK_a
C. pH = PK_a
D. pH < pK_a
E. pH = 14

[25 x 2 = 50]

SECTION B

ANSWER QUESTION 1 TO 4 IN THE ANSWER BOOK 1.
GIVE ALL NUMERICAL ANSWERS TO THE CORRECT NUMBER OF SIGNIFICANT FIGURES AND WITH APPROPRIATE UNITS.

QUESTION 1

1.1 Briefly describe and explain the variation of bonding atomic radius

1.1.1 from left to right across the row. (2)
1.1.2 from top to bottom of the column. (2)
1.1.3 Given that $C - H$ bond length is 1.14 Å and the H bonding atomic radius is 0.37 Å, calculate the carbon bonding atomic radius. (2)

1.2. Arrange Mg^{2+}, Ca^{2+}, and Ca in order of decreasing radius (3)

1.3 Write the condensed electron configuration of the following ions

1.3.1 Ca^{2+} (2)
1.3.2 Co^{3+} (2)
1.3.3 S^{2-} (2)

[15]

QUESTION 2

2.1 Describe the following basic chemical bonds

2.1.1 Metallic (1)
2.1.2 Ionic (1)
2.1.3 Covalent (1)

2.2 Briefly describe all the electrostatic interactions involved in a typical covalent bond such as in a hydrogen molecule $(H - H)$. (3)

2.3 How many valence electrons should appear in the Lewis structure for:

2.3.1 CH_2Cl_2 (2)
2.3.2 Draw the Lewis structure of CH_2Cl_2 (1)

2.4 Methane is a molecule with a typical regular tetrahedral shape with bond angle of 109.5^0. With an aid of a diagram briefly explain how the bond angle will vary in the following molecules.

2.4.1 Chloromethane (CH_3Cl) (2)
2.4.2 Ammonia (NH_3) (2)
2.4.2 Water (H_2O) (2)

[15]

QUESTION 3

3.1 Describe the three characteristics of gases which make them distinguishable from liquids and solids. (3)

3.2 Boyle's Law describes the relationship between the pressure and volume of a given amount of gas.

3.2.1 State the Boyle's Law on gases (1)

3.2.2 A volume of 7.8 L of a gas in trapped in a frictionless piston of plunger pump at 1 atm. The piston is pushed in to reduce the volume of a gas to 3.9 L. Calculate the new pressure of the gas. (3)

3.3 An unknown gas composed of homonuclear diatomic molecules effuses at a rate that is 0.355 times the rate at which O_2 gas effuses at the same temperature. Calculate the molar mass of the unknown and identify it. (4)

3.4 A mixture of 6.00 g $O_2(g)$ and 9.00 g $CH_4(g)$ is placed in a 15.0-L vessel at 0 °C. What is the partial pressure of each gas, and what is the total pressure in the vessel? (4)

[15]

QUESTION 4

4.1 The dichromate reacts with chloride acid according to the following redox reaction:

$$Cr_2O_7^{2-}(aq) + 8K^+(aq) + 14H^+(aq) + 7SO_4^{2-}(aq) + 6Cl^-(aq) \rightarrow 2Cr^{3+}(aq) + 7SO_4^{2-}(aq) + 8K^+(aq) + 7H_2O(l) + 3Cl_2(g)$$

Identify the following in the given reaction:

4.1.1 The oxidising agent, (1)

4.1.2 The reducing agent, and (1)

4.1.3 The spectator ions. (2)

4.2 Determine the oxidation number of the following;

4.2.1 Bromine (Br) in the bromate ion, BrO_3^- (1)

4.2.2 Sulphur (S) in the tetrathionate ion, $S_4O_6^{2-}$ (2)

4.3 Use the given half-cell reactions to answer the following questions.

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l);\ E^0 = +1.51\ V$$
$$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq);\ E^0 = +0.77\ V$$

4.3.1 Write a balanced reaction equation for the preceding half-cell reaction. (2)

4.3.2 Calculate the e.m.f (standard cell potential) of the half-cell reactions (1)

4.3.3 Explain the significance of a positive or a negative cell potential in terms of the feasibility of a redox reaction. (2)

4.5 Calculate the number of grams of aluminum produced in 1.00 h by the electrolysis of molten $AlCl_3$ if the electrical current is 10.0 A. (3)

[15]

QUESTION 5

5.1 At a temperature of 800 °C, steam passed over coke, reacts to form CO and H_2:

$$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$$

5.1.1 The equilibrium constant (K_p) for this reaction is 14.1. What are the equilibrium partial pressures of H_2O, CO and H_2 in the equilibrium mixture at this temperature if we start with solid carbon and 0.200 mol of H_2O in a 1500 mL vessel? (8)

5.1.2 Predict what will happen to the equilibrium partial pressure of CO when the volume of the container is reduced to 750 mL? (3)

5.1.3 At 25 °C the value of K_p for this reaction is 1.7×10^{-21}. Is this reaction exothermic or endothermic? Explain. (2)

[13]

QUESTION 6

6.1.1 Distinguish between Arhenius acid and a Lowry Bronsted acid. (2)

6.2 Calculate the pH of a solution obtained by mixing 400 mL of a 0.200 M acetic acid solution and 100 mL of a 0.300 M sodium hydroxide solution.
[K_a of acetic acid (CH_3COOH) = 1.8×10^{-5}] (12)

6.3 A solution is made up of 0.15 M $NH_3(aq)$

6.3.1 Calculate the pH of the $NH_3(aq)$ [$K_b = 1.8 \times 10^{-5}$] (6)

6.3.2 Calculate the percentage ionization of $NH_3(aq)$ (2)

[22]

DATA

Avogadro's number: $N = 6.02 \times 10^{23}$

Plank constant, $k = 6.626 \times 10^{-34}$ J-s

0 °C = 273.15 K

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

$R = 8.31451$ L.kPa $.K^{-1}.mol^{-1}$
$= 8.31451$ $J.K^{-1}.mol^{-1}$
$= 8.31451 \times 10^{-2}$ L.bar $.K^{-1}.mol^{-1}$
$= 8.20578 \times 10^{-2}$ L.atm $.K^{-1}.mol^{-1}$
$= 62.364$ L.torr $.K^{-1}.mol^{-1}$

$F = 9.6485 \times 10^4$ $C.mol^{-1}$
$V = J.C^{-1}$

UNIVERSITY OF JOHANNESBURG

Department of Applied Chemistry

Atomic Number | 2 **He** *4.0026* | Atomic Weight

																2 **He** *4.0026*	
								5 **B** *10.811*	6 **C** *12.011*	7 **N** *14.007*	8 **O** *15.999*	9 **F** *18.998*	10 **Ne** *20.179*				
								13 **Al** *26.982*	14 **Si** *28.086*	15 **P** *30.974*	16 **S** *32.064*	17 **Cl** *35.453*	18 **Ar** *39.948*				
								31 **Ga** *69.723*	32 **Ge** *72.61*	33 **As** *74.922*	34 **Se** *78.96*	35 **Br** *79.904*	36 **Kr** *83.80*				
								49 **In** *114.82*	50 **Sn** *118.71*	51 **Sb** *121.75*	52 **Te** *127.60*	53 **I** *126.90*	54 **Xe** *131.29*				
								81 **Tl** *204.38*	82 **Pb** *207.2*	83 **Bi** *208.98*	84 **Po** *(209)*	85 **At** *(210)*	86 **Rn** *(222)*				
	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*										
42	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*										
06	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*										
95																	

	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*
91												

Potential (V)	Reduction Half-Reaction
+2.87	$F_2(g) + 2\,e^- \longrightarrow 2\,F^-(aq)$
+1.51	$MnO_4^-(aq) + 8\,H^+(aq) + 5\,e^- \longrightarrow Mn^{2+}(aq) + 4\,H_2O(l)$
+1.36	$Cl_2(g) + 2\,e^- \longrightarrow 2\,Cl^-(aq)$
+1.33	$Cr_2O_7^{2-}(aq) + 14\,H^+(aq) + 6\,e^- \longrightarrow 2\,Cr^{3+}(aq) + 7\,H_2O(l)$
+1.23	$O_2(g) + 4\,H^+(aq) + 4\,e^- \longrightarrow 2\,H_2O(l)$
+1.06	$Br_2(l) + 2\,e^- \longrightarrow 2\,Br^-(aq)$
+0.96	$NO_3^-(aq) + 4\,H^+(aq) + 3\,e^- \longrightarrow NO(g) + 2\,H_2O(l)$
+0.80	$Ag^+(aq) + e^- \longrightarrow Ag(s)$
+0.77	$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$
+0.68	$O_2(g) + 2\,H^+(aq) + 2\,e^- \longrightarrow H_2O_2(aq)$
+0.59	$MnO_4^-(aq) + 2\,H_2O(l) + 3\,e^- \longrightarrow MnO_2(s) + 4\,OH^-(aq)$
+0.54	$I_2(s) + 2\,e^- \longrightarrow 2\,I^-(aq)$
+0.40	$O_2(g) + 2\,H_2O(l) + 4\,e^- \longrightarrow 4\,OH^-(aq)$
+0.34	$Cu^{2+}(aq) + 2\,e^- \longrightarrow Cu(s)$
0 [defined]	$2\,H^+(aq) + 2\,e^- \longrightarrow H_2(g)$
−0.28	$Ni^{2+}(aq) + 2\,e^- \longrightarrow Ni(s)$
−0.44	$Fe^{2+}(aq) + 2\,e^- \longrightarrow Fe(s)$
−0.76	$Zn^{2+}(aq) + 2\,e^- \longrightarrow Zn(s)$
−0.83	$2\,H_2O(l) + 2\,e^- \longrightarrow H_2(g) + 2\,OH^-(aq)$
−1.66	$Al^{3+}(aq) + 3\,e^- \longrightarrow Al(s)$
−2.71	$Na^+(aq) + e^- \longrightarrow Na(s)$
−3.05	$Li^+(aq) + e^- \longrightarrow Li(s)$