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**

SUPPLEMENTARY EXAMINATION

DATE: XX/06/2018 **SESSION: 08:30 – 11:30**

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

INTERNAL MODERATOR: **MR P MONAMA**

DURATION: **180 MINUTES** **MARKS: 140**

NUMBER OF PAGES: **13 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 when classifying matter?

   A. The two types of substances are elements and compounds.
   B. An element is a substance which cannot be decomposed to simpler substances.
   C. A substance has distinct properties and a composition that does not vary from sample to sample
   D. A compound is a substance which *can* be decomposed to simpler substances.
   E. The two types of substances are elements and mixtures.

2. Which one of the following best describe a physical change?

   A. Production of colourful light from fireworks
   B. Hydrogen burning in air with a popping sound
   C. Formation of rust in a tin containing water
   D. Freezing of carbon dioxide on the moon surface
   E. A breathalyser surface turning yellow when exposed to alcohol

3. A vanadium (III) isotope has a mass number of 50 and atomic number of 23. Which one of the following is correct about the vanadium ion (V^{3+})?

   A. Proton number is 23
   B. Electron number is 18
   C. Neutron number is 50
   D. Neutron number is 23
   E. Proton number is 20

4. Choose the oxyanion correctly named according to oxyanion nomenclature.

   A. SO_3^{2-} : sulphate
   B. MnO_4^- : permanganate
   C. ClO_4^- : chlorate
   D. IO_3^- : iodide
   E. NO_3^- : nitrite

5. Three isotopes of silicon occur in nature: ^{28}Si (92.23%), atomic mass 27.97693 amu; ^{29}Si (4.68%), atomic mass 28.97649 amu; and ^{30}Si (3.09%), atomic mass 29.97377 amu. Calculate the atomic weight of silicon.

   A. 28.109
   B. 28.085
   C. 28.225
   D. 28.115
   E. 28.128

6. Which one of the following statements is in line with Pauli's exclusion principle

A. For degenerate orbitals, the lowest energy is attained when the number of electrons with the same spin is maximized.
B. For degenerate orbitals, the lowest energy is attained when the number of electrons with the same spin is minimized.
C. The "spin" of an electron describes its magnetic field, which affects its energy.
D. Two electrons in the same atom can have identical sets of quantum numbers.
E. No two electrons in the same atom can have exactly the same energy.

7. Which one of the ions formed by elements in Period number 3 has the lowest ionic radius?

A. Na^+
B. Mg^{2+}
C. Al^{3+}
D. S^{2-}
E. Cl^-

8. Why is silicon dioxide (SiO_2) soluble in concentrated sodium hydroxide and not in concentrated sulphuric acid?

A. Silicon dioxide is an oxide of a non-metal, thus is acidic and will react with sodium hydroxide which is a base.
B. Sodium hydroxide is a good solvent/
C. Sulphuric acid is a power solvent.
D. Concentrated sulphuric acid is not a strong acid
E. The compound formed between silicon dioxide and sulphuric acid is insoluble.

9. Which of the following set of quantum numbers correctly describe an electron in $5s^1$?

A. $n = 0, l = 1, \ m_l = 1, \ m_s = -1/2$
B. $n = 3, l = 0, m_l = 0, m_s = +1/2$
C. $n = 4, l = 1, m_l = 0, m_s = 0$
D. $n = 5, l = 0, m_l = +1/2, m_s = 0$
E. $n = 5, l = 0, m_l = 0, m_s = +1/2$

10. Which one of the following equations illustrate correctly the fifth ionisation energy of manganese (Mn)

A. $Mn(g) \rightarrow Mn^+(g) + e^-$
B. $Mn^{2+}(g) \rightarrow Mn^{3+}(g) + e^-$
C. $Mn^{3+}(g) \rightarrow Mn^{4+}(g) + e^-$
D. $Mn^{4+}(g) \rightarrow Mn^{5+}(g) + e^-$
E. $Mn^{5+}(g) \rightarrow Mn^{6+}(g) + e^-$

11. A typical polar covalent compound can be represented by:

A. Carbon dioxide (CO_2)
B. hydrogen chloride (HCl)
C. Methane (CH_4)
D. Carbon tetrachloride (CCl_4)
E. Acetylene (C_2H_2)

12. What is the maximum number of Lewis resonance structures can be obtained from a nitrate (NO_3^-)

A. 2
B. 4
C. 5
D. 3
E. 1

13. Using the valence-shell electron-pair repulsion (VSEPR) model which molecule is correctly matched to the shape.

A. AsF_3 – trigonal planar
B. BF_3 – trigonal pyramid
C. NH_3 – trigonal planar
D. ICl_3 – trigonal pyramid
E. ICl_4^- – square planar

14. Which one of the following hybrid orbitals is correctly matched to the geometry they form?

A. sp – linear
B. sp^2 – trigonal bi-pyramidal
C. sp^3 – octahedral
D. sp – trigonal bi-pyramidal
E. sp^3 – square planar

15. Which one of the following of the statements correctly describe what is happening in the equation: $Cu^{2+}(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + Cu(s)$

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

16. Which of the following statements with regard to a chemical reaction at equilibrium is **incorrect**?

A. A large value of the equilibrium constant indicates that the equilibrium mixture contains more products than reactants.
B. Catalyst affect the rate at which an equilibrium is reached but do not affect the value of the equilibrium constant.
C. For an endothermic reaction, a decrease in temperature shifts the equilibrium to the left.
D. If a reactant or product is added to a system at equilibrium, the equilibrium will shift to consume the added substance.
E. For an exothermic reaction, a decrease in temperature shifts the equilibrium to the left.

17. The K_c for the equilibrium below is 7.52×10^{-2} at 480.0°C.

$$NO(g) + O_3(g) \rightleftharpoons NO_2(g) + O_2(g)$$

What is the value of K_C at this temperature for the following reaction?

$$NO_2(g) + O_2(g) \rightleftharpoons NO(g) + O_3(g)$$

A. 0.0752
B. –0.0752
C. 5.66×10^{-3}
D. 0.150
E. 13.3

18. Consider the following chemical reaction:

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

At equilibrium in a particular experiment, the concentrations of SO_3, O_2, and SO_2 were 0.15 M, 0.033 M and 0.55 M respectively. The value of K_c for this reaction is _____.

A. 111
B. 6.7×10^{-2}
C. 23
D. 3.9×10^{-3}
E. 6.1

19. The reaction below is endothermic:

$$2\ H_2S(g) \rightleftharpoons 2\ H_2(g) + S_2(g)$$

Le Chatelier's Principle predicts that _____ will result in a decrease in the number of moles of $H_2S(g)$ in the reaction container.

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

20. Given the following reaction at equilibrium at 300 K:

$$NH_4I\ (s) \rightleftharpoons NH_3(g) + HI\ (g)$$

If $P_{NH3} = P_{HI} = 0.111$ atm, K_p = _____.

A. 4.99×10^{-4}
B. 1.11×10^{-1}
C. 1.23×10^{-2}
D. 8.12×10^{-2}
E. 5.66×10^{-3}

21. When any acid is dissolved in water, _____ will be true for the solution that is formed.

A. $[H_3O^+] = [OH^-]$
B. $[H_3O^+] > [OH^-]$
C. $[H_3O^+] = 0$ M
D. $[OH^-] > 7.00$
E. $[H_3O^+] < [OH^-]$

22. Determine the pH of a 0.15 M aqueous solution of $Ca(OH)_2$.

A. 2.2
B. 2.0
C. 1.9
D. 0.52
E. 2.1

23. A 0.10 M solution of _____has a pH of 7.0:

A. Na_2S
B. KF
C. KNO_3
D. NH_4Cl
E. NaF

24. What is the concentration (M) of KCl in a solution made by mixing 25.0 mL of 0.200 M KCl with 50.0 mL of 0.100 M KCl?

A. 0.300
B. 0.0500
C. 0.133
D. 0.0333
E. 0.0250

25. The concentration of H^+ ions in a solution of pH 3.50 at 25.0°C is _____.

A. 5.44×10^{-1}
B. -5.44×10^{-1}
C. 3.35×10^{-4}
D. 3.16×10^{-4}
E. 2.76×10^{-4}

[25 x 2 = 50]

SECTION B

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

QUESTION 1

1.1 Describe fully the following major regions of the atom

1.1.1 Nucleus of an atom (3)
1.1.2 Electron Cloud (2)

1.2 The following table gives the abundances of the major isotopes of carbon.

Isotope	Symbol	Composition of the nucleus	% in nature
Carbon-12	^{12}C	6 protons 6 neutrons	98.89%
Carbon-13	^{13}C	6 protons 7 neutrons	0.11%

Calculate the average atomic mass of carbon. (4)

1.3 Describe the following properties of matter giving three examples of each.

1.3.1 Intensive properties (2)
1.3.2 Extensive properties (2)

1.4 Name the two states of matter, with the lowest and highest densities respectively (2)

[15]

QUESTION 2

2.1 Write the chemical reaction between the sodium (Na) atom and chlorine (Cl) in using Lewis structure format. (3)

2.2 Which one of the following bonds is more polar: B—Cl or C—Cl? Indicate in each case, which atom has the partial negative charge. (4)

2.3 Define the following terms

2.3.1 Ionisation energy (2)
2.3.2 Lattice energy (2)
2.3.3 Electron affinity (2)
2.3.4 Electronegativity (2)

[15]

QUESTION 3

3.1 Explain the Boyle's Law in terms of molecular view. (3)

3.2 A volume of 7.8 L of a gas in trapped in a frictionless piston of plunger pump at 4.5 atm. The piston is pushed out to increase the volume of a gas to 12.5 L. Calculate the new pressure of the gas. (3)

3.3 How can one determine the absolute temperature using the principles of Charles' Law? (3)

3.4 A gas has a volume of 15.6 L at T °C. Calculate the initial temp, T of the gas if its final volume and temperature (°C) are 23.5 L and 120 °C respectively and conditions are changed according to Charles' Law? (3)

[12]

QUESTION 4

4.1 The nickel-cadmium (nicad) battery, a rechargeable "dry cell" used in battery-operated devices, uses the following redox reaction to generate electricity:

$Cd(s) + NiO_2(s) + 2H_2O(l) \rightarrow Cd(OH)_2(s) + Ni(OH)_2(s)$.

Identify the following substances from the redox reaction.

4.1.1 Oxidising agent and substance oxidised (2)
4.1.2 Reducing agent and the substance reduced (2)
4.1.3 the spectator species. (2)

4.2 Determine the oxidation number of the following;

4.2.1 Iodine (I) in the periodate ion, IO_4^- (1)
4.2.2 Iron (Fe) in the magnetite formula weight, Fe_3O_4 (1)

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

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$; $E^0 = +1.51\,V$
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$; $E^0 = -1.66\,V$

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)

4.4 Calculate the number of grams of copper produced in 3.00 h by the electrolysis of molten CuO(l) if the electrical current is 10.0 A. Given the reaction:
$Cu^{2+} + 2e^- \rightarrow Cu(s)$ (3)

[15]

QUESTION 5

5.1 Consider the following equilibrium:

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

When 0.200 mol of C and 0.200 mol of H_2O are placed into a 500 cm^3 container at 920 K and the reaction reached equilibrium, the equilibrium molar concentration of CO is 0.0300 $mol.dm^{-3}$.
Calculate the value of K_C. (10)

5.2 If 0.0272 mol NH_3, 0.0150 mol N_2 and 0.0840 mol H_2 were placed in a 5.00 L container where the following reaction occurs,

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $K_c = 400$ at 325°C

Determine by calculation:

5.2.1 Whether or not the mixture is at equilibrium. (6)
5.2.2 Whether more or less NH_3 will be formed in order to achieve equilibrium. (1)

[17]

QUESTION 6

6.1 Distinguish between a strong acid and a weak acid, and give one example of each. (4)

6.2 Calculate the pH of the following solutions:

6.2.1 A 0.128 M HCl. (1)
6.2.2 A mixture of 100.00 mL of a 0.255 M HCl solution and 100.00 mL of a 0.125 M $Ba(OH)_2$ solution, basing your answer on a balanced reaction equation. (9)

6.3 The percentage dissociation of a 6.25×10^{-3} M solution of a monoprotic weak acid is 15.25%. Calculate its K_a value. (6)

[20]

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 $.K^{-1}.mol^{-1}$

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

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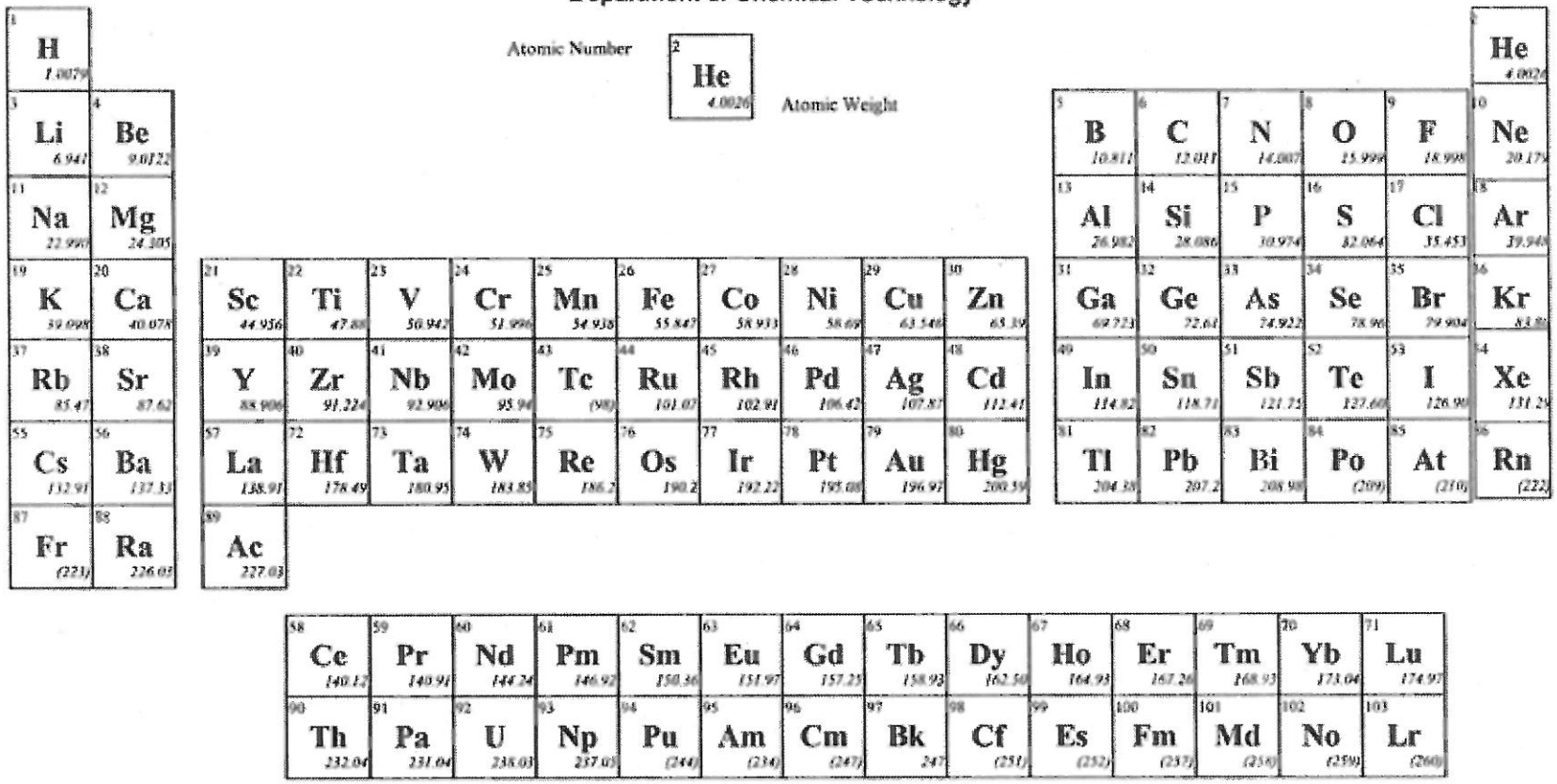

Potential (V)	Reduction Half-Reaction
+2.87	$F_2(g) + 2\,e^- \longrightarrow 2\,F^-(aq)$
+1.51	$MnO_4^-(aq) + 8\,H^+(aq) + 5\,e^- \longrightarrow Mn^{2+}(aq) + 4\,H_2O(l)$
+1.36	$Cl_2(g) + 2\,e^- \longrightarrow 2\,Cl^-(aq)$
+1.33	$Cr_2O_7^{2-}(aq) + 14\,H^+(aq) + 6\,e^- \longrightarrow 2\,Cr^{3+}(aq) + 7\,H_2O(l)$
+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	$Li^+(aq) + e^- \longrightarrow Li(s)$