**GWANDA STATE UNIVERSITY**

**FACULTY OF ENGINEERING AND THE ENVIRONMENT**

**CHEMISTRY FOR ENGINEERS / INTRODUCTION TO CHEMISTRY**

**EMG (N) 1104**

**PART 1 EXAMINATION PAPER**

**SEPTEMBER 2024**

This examination paper consists of 5 printed pages

**Time Allowed: 3 hours**

**Total Marks: 100**

**Examiner : Mrs S Maphosa**

**INSTRUCTIONS**

**1. Answer any 4 questions**

**2. Each question carries 25 marks**

**3. Use of calculators is permissible**

**QUESTION 1**

a) Predict the geometry of each of the following species:
   i. $PO_4^{3-}$ [2]
   ii. $PCl_5$ [2]
   iii. $CCl_4$ [2]
   iv. $NH_3$ [2]

b) What are the basic postulates of VSEPR theory? Predict the shape of $SF_6$ and molecule using this theory. Show Lewis dot structure in your answer. [4]

c) An investigation of the reaction between magnesium oxide and hydrogen chloride gas showed that an intermediate product was formed with the composition by mass Mg, 31.65%; O, 20.84%; H, 1.31% and Cl, 46.20%. Calculate the empirical formula of this intermediate compound [3]

d) You work in a semiconductor production plant that relies on several chlorofluorocarbons in its manufacturing process. One day, you find an unlabeled gas cylinder, and you are assigned to figure out what is in the tank. First you fill a 1.000-L flask with the gas. At a pressure of 250.0 torr and a temperature of 25.00°C, you determine that the mass of the gas in the flask is 2.2980 g. Then you send the flask to an outside lab for elemental analysis, and they report that the gas contains 14.05% C, 44.46% F, and 41.48% Cl only by mass. Find the molecular formula of this gas. [5]
   NB: 1 torr =133.322Pa

e) Silicon carbide, an abrasive, is made by the reaction of silicon dioxide with graphite (solid carbon).

$$SiO_2 + C \xrightarrow{\text{heat}} SiC + CO$$

   i) Write the balanced equation [1]
   ii) We mix 150.0 g of $SiO_2$ and 101.5 g of C. If the reaction proceeds as far as possible, which reactant is left over? How much of this reactant remains? [4]

**QUESTION 2**

a) The Solvay process is important in the commercial production of sodium carbonate ($Na_2CO_3$), which is used in the manufacture of most glass. The last step in the Solvay process is the conversion of $NaHCO_3$ (sodium bicarbonate, or baking soda) to $Na_2CO_3$ by heating. The equation is below.

$$2\,NaHCO_3(s) \xrightarrow{\text{heat}} Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

In a laboratory experiment, a student heats 42.0 g of $NaHCO_3$ and determines that 22.3 g of $Na_2CO_3$ is formed. What is the percentage yield of this reaction? [5]

b) Mining engineers often have to deal with gases when planning for the excavation of coal. Some of these gases, including methane, can be captured and used as fuel to support the mining operation. For a particular mine, 2.4 g of $CH_4$ is present for every 100. g of coal that is extracted. If 45.6% of the methane can be captured and the daily production of the mine is 580 metric tons of coal, how many moles of methane could be obtained per day? [5]

c) Many metals react with halogens to give metal halides. For example, iron reacts with chlorine to give iron(II) chloride, $FeCl_2$.

$$Fe(s) + Cl_2(g) \rightarrow FeCl_2(s)$$

Beginning with 10.0 g iron, what mass of $Cl_2$, in grams, is required for complete reaction? What quantity of $FeCl_2$, in moles and in grams, is expected? [6]

d) State the four assumptions of the Kinetic Theory of gases [4]

e) A gas is either $CH_4$ or $C_2H_6$. A 1.00-g sample of this gas produces 1.80 g of water when combusted in excess $O_2$. Assuming complete combustion to $CO_2$ and $H_2O$, which gas is it? [5]

**QUESTION 3**

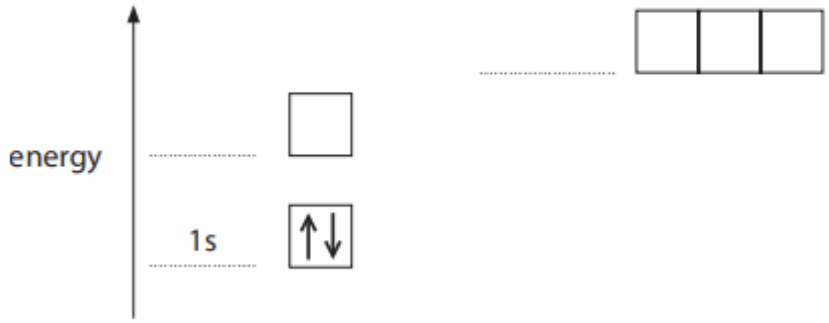
a) Sketch each of the orbitals listed below. For each orbital, use a set of axes to clearly show its orientation.

i) $2p_z$ [2]

ii) 2s [2]

iii) $3d_{yz}$ [2]

b) The energy diagram below shows the 8 electrons present in an oxygen atom. Complete the diagram by adding labels to show the names of the orbitals and arrows to show how the remaining electrons are distributed in the orbitals




[4]

c) Use the periodic table to:

i) Determine the electron configuration of tungsten (W), which is used in the filaments of most incandescent lights. [2]

ii) Using the periodic table write the ground state electronic configuration for B, Ba, Be, and Bi, [4]

d) What is effective nuclear charge and how does it influence the size of an orbital? [3]

ii) Depict two ways to place electrons in the 2p orbitals for a nitrogen atom. Which depiction is correct according to Hund's rule? [3]

ii) How does the charge of electrons provide some rationale for Hund's rule? [3]

**QUESTION 4**

a) An unidentified solid is dissolved in water to produce a clear, colourless solution, and this solution conducts electricity. A second solution is added, and a precipitate forms. Once the precipitate has settled, the liquid above it does not conduct electricity perceptibly. What does this experiment tell you about the bonding in the initial solid and in the precipitate, and how does it tell you that? [4]

b) Describe the difference between a covalent bond and an ionic bond. [4]

c) Explain with the help of i) dot and cross diagrams, ii) ionic equations the formation of the following compounds

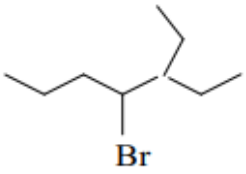
1. Calcium Oxide [3]
2. Magnesium chloride [3]
3. Carbon dioxide [3]

d) Lead selenide nanocrystals may provide a breakthrough in the engineering of solar panels to be efficient enough to be an economical source of electricity. Selenium is generally considered a nonmetal while lead is considered a metal. Is this distinction enough to suggest that this compound should be ionic? Explain your answer [4]

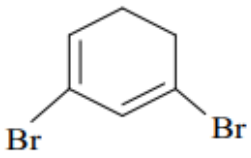
e) One important physical property of metals is their malleability. How does the sea of electrons model account for this property? [4]

**QUESTION 5**

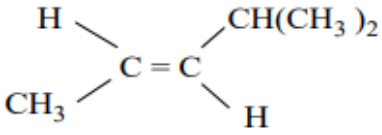
Give the correct IUPAC name for the following structures




(a)




(b)




(c)

[6]

d)Draw the displayed formula for the organic compounds below

(A) $CH_3CH_2CH_2CH_2CH_2CH_3$ (B) $(CH_3)_2CHCH_2CH_2CH_3$

(C) $(CH_3)_3CCH_2CH_3$ (D) $(CH_3)_2CHCH(CH_3)_2$

[8]

e) Give the balanced symbol equations for:

i) The complete combustion of heptane, $C_7H_{16}$, giving carbon dioxide and water [2]

ii) The incomplete combustion of methane, $CH_4$, giving carbon monoxide and water [3]

f) Alkanes are saturated hydrocarbons.

i) Explain the words saturated and hydrocarbons. [2]

ii) Methane, ethane, and propane are also hydrocarbons, but they are not major components of gasoline. What prevents them from being part of this mixture?

[4]