THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES
DEPARTMENT OF CHEMISTRY
2022/23 ACADEMIC YEAR
TERM II TEST ONE
CHEMISTRY (CH 11O)

TIME ALLOWED: Two (2) Hours.

DATE: 06 / 04 / 2023

INSTRUCTIONS:

(i) Attempt all the four questions, each question carries 25 Marks.
(ii) All calculated quantities must have units and reported to the correct number of significant figures.
(iii) Do not open till instructed to do so.

IMPORTANT DATA:

Physical Constants		
Constant	Symbol	Value
Atomic mass unit	*Amu*	1.660554×10^{-27}kg
Avogadro's number	N_A	6.02214×10^{23} mol^{-1}
Gas constant	R	8.31451 J K^{-1} mol^{-1}
		0.08206 L atm K^{-1} mol^{-1}
1 atm = 760mmHg = 1.0132×10^5 Nm^{-2} = 1.0132×10^5Pa		

QUESTION ONE (INTRODUCTION TO GENERAL CHEMISTRY) [25 marks]

a) Define each of the following terms applied in the scientific method:
   (i) Hypothesis (ii) theory (iii) law [3]

b) Use exponential notation to express the number 101.325 to:
   (i) One significant figure. [1]
   (ii) Five significant figures. [1]

c) State the difference between precision and accuracy. [2]

d) Perform the following mathematical operations, and express each result to the correct number of significant figures.
   (i) $(9.04 - 8.23 + 21.954 + 81.0) \div 3.1416$ [2]
   (ii) $\frac{0.470}{0.623} + \frac{80.705}{0.4326} - \frac{2.526}{3.1}$ [2]

e) Show your understanding of metric prefixes by giving the name to the unit that equals the following:
   (i) 10^{-9} gram (ii) 10^{+9} gram (iii) 10^{-15} metre [3]

f) Convert each of the following temperatures from degrees Celsius to Kelvin:
   (i) –38.9 °C (ii) 119.3 °C [4]

g) State the chemical formula of each of the following compounds:
   (i) Perchloric acid (ii) Phosphorus pentachloride [4]

h) Europium has two isotopes whose relative abundances are 48 % and 52 %. Given that the average atomic mass of Europium is 151.96 amu and the mass of an isotope with relative abundance of 52 % is 152.92 amu. Determine the mass of the isotope whose relative abundance is 48%. [3]

QUESTION TWO (STOICHIOMETRY AND MOLE CONCEPT) [25 marks]

Compound A (Fe_xO_y) comprises of 30.02% oxygen.

a) Determine the actual value of x and y [4]
b) Write down the systematic name of compound A [1]
c) If 50.0 g of compound A reacts with 40.0 g of carbon monoxide to produce iron metal and carbon dioxide gas, prove that compound A is a limiting reagent in this reaction. [10]
d) 0.658 g of a compound containing only carbon, hydrogen and oxygen is burned in excess oxygen gas, 1.285 g of carbon dioxide and 0.658g of water are produced. If the molar of the compound is determined to be 90g/mol. Determine the molecular formula. [10]

QUESTION THREE (REACTION IN AQUEOUS SOLUTION) [25 Marks]

a) Predict whether mixing each pair of the following solutions will result in the formation of a precipitate. If so, identify the precipitate.
[5]

i. $KOH_{(aq)}$ and $H_3PO_{4(aq)}$
ii. $K_2CO_{3(aq)}$ and $BaCl_{2(aq)}$
iii. $Ba(NO_3)_{2(aq)}$ and $Na_2SO_{4(aq)}$

b) Calculate the oxidation state of each of the following:
i. Cr in $Cr_2O_7^{2-}$ [2]
ii. S in H_2SO_4 [2]

c) Given the following reaction:

$$CuS(s) + NO_3^-{}_{(aq)} \rightarrow Cu^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} + NO_{(g)}$$

i. Identify the oxidizing and reducing agents [4]
ii. Write the two half reaction equations specifying which one is the oxidation half reaction and which one is the reduction half reaction. [4]
iii. Balance each of the two half reaction equations. [4]
iv. Considering that the reaction is taking place in acidic medium, write the overall balanced equation for this redox reaction. [4]

QUESTION FOUR (GASES) [25 marks]

a) Gas laws help us to understand the behaviour of gases under different conditions of temperature, pressure, and volume.
i. State Boyle's Law
[1]
ii. Sketch a graph of pressure against volume for the law in (i) [1]

b) If 22.5 L of nitrogen at 748 mm Hg are compressed to 725 mm Hg at constant temperature.
i. What is the new volume?
[2]
ii. What is the Volume in litres at STP of 50 g of nitrogen (N_2)? [2]
iii. State the gas laws applied in (i) and (ii) above.
[2]

c) A mole of a gas at 450 K has a density of 1.41 g/dm^3 at 2.0 atm. What is the density of the gas at STP?
[4]

d) Dalton, a renowned scientist talked about partial pressures in the atmosphere.
i. State the Dalton's law of partial pressures. [2]
ii. What is the partial pressure in the atmosphere? [2]

e) At -18 °C, a 2L mixture of helium, nitrogen, and neon has a total pressure of 815 mmHg. What mass of neon is present in the mixture if the partial pressure of helium is 201 mmHg and the partial pressure of nitrogen is 351 mmHg? [9]

THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY (CH 110) TERM III, TEST TWO

DATE: **28 / 06 / 2023** DURATION: **2 hours.**

INSTRUCTIONS: Answer **Any three of the four questions.**

Each question carries **25 Marks.**

QUESTION ONE (THERMOCHEMISTRY) [25 marks]

a) State Hess's Law. [2]

b) Consider the following reaction:

$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$ $\Delta H = -1204$ kJ.

(i) Calculate the amount of heat transferred when 2.4 g of $Mg_{(s)}$ reacts at constant pressure. [3]

(ii) How many grams of $MgO_{(s)}$ are produced during an enthalpy change of 96.0 kJ? [3]

(iii) How many kilo joules of heat are absorbed when 7.50 g of $MgO_{(s)}$ are decomposed into $Mg_{(s)}$ and $O_{2\,(g)}$ at constant pressure. [3]

c) Identify each process as endothermic or exothermic and indicate the sign of ΔH. [3]

a. Sweat evaporating from skin
b. Water freezing in a freezer
c. Wood burning in a fire

d) From the following enthalpies of reaction;

$H_{2\,(g)} + F_{2\,(g)} \rightarrow 2HF_{(g)}$ $\Delta H = -537$ kJ

$C_{(s)} + 2F_{2\,(g)} \rightarrow CF_{4\,(g)}$ $\Delta H = -680$ kJ

$2C_{(s)} + 2H_{2\,(g)} \rightarrow C_2H_{4(g)}$ $\Delta H = -52.3$ kJ

Calculate the ΔH for the reaction of $C_2H_{4(g)}$ with $F_{2(g)}$ to make $CF_{4(g)}$ and $HF_{(g)}$. [6]

e) When a 6.50 g sample of solid NaOH dissolves in 100.0g of water in a coffee-cup calorimeter, the temperature rises from 21.6°C to 37.8°C. Calculate the ΔH (in kJ/mol NaOH) for the solution process. (Assume the specific heat of the solution formed is 4.18 J/g-K) [5]

$NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

QUESTION TWO (ATOMIC STRUCTURE AND PERIODICITY) [25 marks]

a) Suppose you were de Broglie and you had just devised your formula. A friend points out that the world obviously isn't wavelike. Maybe you should check whether your formula has worrying consequences for everyday objects. Calculate the wavelength of a particle of mass 1 g traveling at 1 ms^{-1}. [2]

b) Calculate the wavelength of a photon (in nanometers) emitted during a transition from the $n_i = 5$ state to the $n_f = 2$ state in the hydrogen atom and identify the spectral line series. [5]

c) What is wrong with each of the following quantum number designation and/or sublevel names?

S. No.	n	l	m_l	Name
(i)	1	1	0	1p
(ii)	4	3	+1	4d
(iii)	3	1	-2	3p

[6]

d) Arrange each set of ions in order of decreasing size, and explain your answer

(i) Ca^{2+}, Sr^{2+}, Mg^{2+} [2]
(ii) K^+, S^{2-}, Cl^- [2]
(iii) Au^+, Au^{3+} [2]

e) Write electron configuration of each transition metal ions, and predict whether it is paramagnetic or diamagnetic.

(a) Mn^{2+} (b) Cr^{3+} (c) Hg^{2+} [6]

QUESTION THREE (ORGANIC CHEMISTRY) [25 Marks]

a) Draw the structural formula for each of the following compounds: [3]

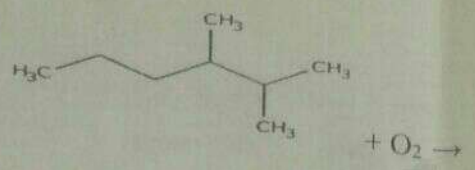
i) Cis-3, 4-dimethyl-3-hexene ii) 6, 6-Dimethyl-2, 4-nonadiene iii) Methyl Ethanoate

b) Draw any two possible structures for each of the following molecules: [4]

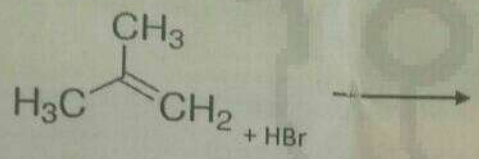
i) C_5H_{12} ii) C_5H_8

c) Predict and draw the major products of the following reactions: [5]

(i)



ii)



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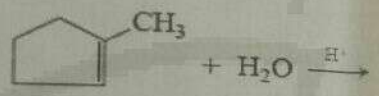

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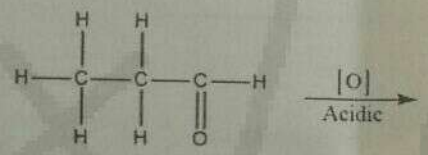

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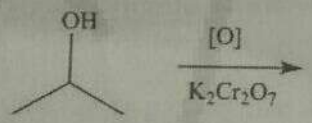


d) Complete the following reaction: [1]

$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-OH + CH_3-OH \xrightleftharpoons{[H^+]}$$

a) What name is given to the type of reaction mentioned above? [1]

b) State the IUPAC name of the product formed [1]

c) State the IUPAC names of the reactants used [2]

e) Draw and name the structure of the compound with four carbon atoms that belongs to each of the following families of organic compounds: [8]

i) Aldehydes ii) Ketones iii) Carboxylic acids iv) Ester

QUESTION FOUR (CHEMICAL BONDING) [25 Marks]

a) Answer the following short answer questions:

i. Which of the following elements, Be, B, C, and N has the lowest ionization energy? [1]

ii. Which of these elements Li, O, Ne, & Na has the largest atomic radius? [1]

iii. ___ is the energy change associated with the addition of an electron to a gaseous atom. [1]

iv. The _____ is the change in energy that takes place when separated gaseous ions are packed together to form an ionic solid. [1]

b) Complete the following table by indicating whether the given molecules are polar or non-polar. Further, indicate what intermolecular forces exist in each given substance.

Substance	Polarity	Intermolecular force
Carbon dioxide		
Ammonia		
Silicon tetrachloride		
Sulfur dioxide		

[4]

c) Consider the cyanate ion, NCO^-

i. Draw all the possible Lewis structures for the cyanate ion [6]

ii. Among the possible Lewis structures you have drawn, identify the best structure. Justify your choice. [3]

iii. What is the molecular geometry of the cyanate ion? [2]

d) Answer the following question based on strontium chloride

a. Draw the Born-Haber cycle for the formation of strontium chloride. [3]

b. Use the following data to calculate the enthalpy of formation of strontium chloride. You must write all thermochemical equations for the steps of the cycle. [3]

The enthalpy of sublimation of strontium	+ 164 kj/mol
First ionization energy for strontium	+ 549 kj/mol
Second ionization energy for strontium	+ 1064 kj/mol
The enthalpy of dissociation of chlorine, Cl_2	+ 243 kj/mol
The electron affinity of chlorine, Cl	- 349 kj/mol
Lattice energy of strontium chloride	- 2150 kj/mol

====THE END====

Physical Constants		
Constant	Symbol	Value
Atomic mass unit	*amu*	1.660554×10^{-27} kg
Avogadro's number	N_A	6.02214×10^{23} mol^{-1}
Bohr radius	a_0	5.292×10^{-11} m
Boltzmann's constant	k	1.38066×10^{-23} J K-1
Charge of an electron	e	1.60218×10^{-19} C
Faraday's constant	F	96,485 C mol^{-1}
Gas constant	R	8.31451 J K^{-1} mol^{-1}
		0.08206 L atm K^{-1} mol^{-1}
Mass of an electron	m_e	9.10939×10^{-31} kg
		5.48580×10^{-4}amu
Mass of a neutron	m_n	1.67493×10^{-27} kg
		1.00866 amu
Mass of a proton	m_p	1.67262×10^{-27} kg
		1.00728 amu
Rydberg constant	R_E (or A in Joules) or	2.18×10^{-18} J
	R_H	109678 cm^{-1}
Planck's constant	h	6.62608 x 10-34 J s
Speed of light	c	2.99792458×10^{8} m s^{-1}
1 atm = 760mmHg = 1.0132×10^{5} Nm^{-2} = 1.0132×10^{5}Pa		

THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

SESSIONAL EXAMINATION 2022/23

TITLE OF PAPER: GENERAL CHEMISTRY

COURSE NUMBER: CH110/CH120/FO130

TIME: THREE (3) HOURS

INSTRUCTIONS:

- **There are seven (7) questions in this paper. Each question is worth 20 marks**
- **Answer ANY five (5) questions only**
- **A periodic table is attached**
- **A table of physical constants and conversion factors is attached**
- **Electronic calculators may be used, provided that they cannot store text**

DO NOT OPEN THIS PAPER UNTIL PERMISSION TO DO SO HAS BEEN GRANTED BY THE CHIEF INVIGILATOR.

QUESTION ONE (Introduction and Atomic Structure) [20 marks]

a) An automobile runs for 10 minutes and burns 47 g of gasoline. The gasoline combined with oxygen from air and formed 132 g of carbon dioxide and 34 g of water. How much oxygen was consumed in the process? Name the law applied to solve above problem? [3]

b) Gallium has two naturally occurring isotopes: Ga-69 with mass 68.9256 amu and a natural abundance of 60.11%, and Ga-71 with mass 70.9247 amu and a natural abundance of 39.89%. Calculate the atomic mass of gallium. [3]

c) How many protons, neutrons, and electrons are in:

i) $^{41}_{20}R$

ii) $^{131}_{53}S$

iii) What element symbol do R and S represent? [4]

d) Calculate the wavelength (in nm) and the wave number of red light emitted by a barcode scanner that has a frequency of $4.62 \times 10^{14}\ s^{-1}$. [3]

e) Write a set of four quantum numbers for the eighth electron of the Cl atom. [2]

f) Given the following systematic names, write the formula for each compound: [5]

i) Sodium hydrogen carbonate $NaHCO_3$

ii) Cesium perchlorate

iii) Sodium hypochlorite

iv) Sodium selenate

v) Barium hydroxide octahydrate

moles = C.V

0.15 moles

QUESTION TWO (Stoichiometry and Aqueous Solutions). [20 Marks]

mol = C.V

a) Calculate the volume of 16.0 M H_2SO_4 that must be used to prepare 1.5 L of a 0.10 M H_2SO_4 solution? [4]

b) Balanced the following reaction ionic in basic media. [8]

0.009375

$$MnO_4^- + I^- \longrightarrow MnO_2 + I_2$$

c) Aqueous barium nitrate is added to dilute sulfuric acid to form a barium sulphate precipitate plus aqueous nitric acid. For this reaction:

i) Write the balanced chemical equation [3]

ii) Write the net ionic equation [3]

d) Determine the oxidation state of each of the following:

i) Mn in $KMnO_4$

ii) O in Na_2O_2 [2]

$E = h\nu$

$1nm = 10^{-9} m$

$c = \lambda \nu$

$6.49 \times 10^{-7} m$

$c = \lambda \nu$

Chlorine

QUESTION THREE (Gases) [20 marks]

a) List three properties of an ideal gas. [3]

b) A mole of a gas at 450 K has a density of 1.41 g/dm³ at 2.0 atm. What is the density of the gas at STP? [4]

c) At 0 °C and 760 mm mercury pressure, a gas occupies a volume of 100 cm³. The kelvin temperature of the gas is increased by a fifth of the initial, while pressure is increased by one and half times.

i) Calculate the final volume of the gas [6]

ii) Which gas law(s) is being applied in the solution to (i) above? [2]

d) At 25°C, a 4.0 L container is filled with 2.0 g neon and 8.0 g helium. What is the total pressure of the mixture? [5]

QUESTION FOUR (Thermochemistry) [20 marks]

a) State whether the following statements are **true** or **false**. [4]

i) An isothermal process is when thermal contact between a closed and open system is at constant temperature while the change takes place

ii) work is positive (w>0) if the system performs work

iii) Energy, heat and work are all state functions of a system

iv) Heat is positive (q>0) if heat is added to the system

b) Identify each process as endothermic or exothermic and indicate the sign of ΔH. [4]

i) Chemical explosion

ii) Photosynthesis

iii) Vaporization of water

iv) Cooking an egg

c) How much energy is released during the formation of 98.7 g of Fe, according to the reaction below?

$$Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow Al_2O_{3(s)} + 2Fe_{(s)} \quad \Delta H^o = -852\ kJ$$ [3]

d) Find the standard enthalpy change ΔH, of the reaction;

$$P_{4(g)} + 10Cl_{2(g)} \rightarrow 4PCl_{5(s)}$$

Given the following;

$$PCl_{5(g)} \rightarrow PCl_{3(g)} + Cl_{2(g)} \quad \Delta H = 157\ kJ$$

$$P_{4(g)} + 6Cl_{2(g)} \rightarrow 4PCl_{3(g)} \quad \Delta H = -1207\ kJ$$ [4]

e) A 10 g sample of a metal at 88.0 °C is submerged in 30 mL of water at 25 °C. The final temperature of water is measured to be 36.0 °C. Assuming no heat is lost to the surroundings, what is the approximate specific heat capacity of the metal? (C_{H_2O} = 4.184 J/g °C). **[5]**

QUESTION FIVE (Chemical Bonding and Molecular Geometry) [20 marks]

a) Define the following periodic properties:

i. Ionization energy

ii. Electronegativity **[2]**

b) Arrange the following bonds in order of increasing ionic character giving reason. **[2]**

N – H, F – H, C – H and O – H.

c) Draw all the possible lewis structures of each of the following ions and determine the formal charge on each atom involved:

i) CO_3^{2-} ii) NO_2 **[6]**

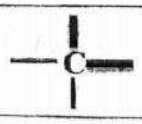
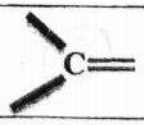
d) Draw the lewis structure and predict the geometry of each of the following molecules:

i) BF_3 ii) NH_3 iii) PCl_5 **[6]**

e) Between water (H_2O) and 1,2,3-Propanetriol ($CH_2OHCHOHCH_2OH$) which one would you expect to have a higher boiling point? Justify your answer. **[4]**

QUESTION SIX (Organic Chemistry) [20 marks]

a) Carbon forms single, double and triple bonds to achieve a filled octet as shown in the first row of the table below. Copy the table in your answer book and complete. **[12]**

Carbon bonding combination				
Number of i) sigma bonds ii) Pi bonds	4 0	3 1	2 2	2 2
iii) Carbon atom bond angles	90°	180.5°	180°	180°

b) Give the structural formula of: **[3]**

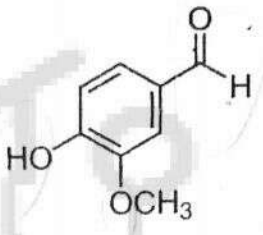
i) An aldehyde that is an isomer of acetone

ii) An ether that is an isomer of 1-propanol

iii) 2-chloro pentanoic acid

c) Draw the structural formula of the compound formed by the condensation reactions between ethanoic acid and a phenol [2]

d) Identify the **three** functional groups in the molecule of vanillin shown below. [3]



QUESTION SEVEN (Chemical Equilibria and Acids and Bases) 3 **[20 marks]**

a) Acids may be classified as strong or weak:

i) Define a strong acid and give one example of a strong acid [2]

ii) Define a weak acid and give one example of a weak acid. [2]

b) Consider the decomposition equilibrium reaction of methanol to carbon monoxide and hydrogen: $CH_3OH_{(g)} \rightleftharpoons CO_{(g)} + 2H_{2(g)}$

(i) Calculate K_p for the reaction given that $P_{CH_3OH} = 6.10 \times 10^{-4}$atm, $P_{CO} =$ 0.387 atm and $P_{H_2} = 2.68$ atm. [2]

(ii) Derive the expression that relates K_c and K_p for this reaction [4]

c) The average pH of normal arterial blood is 7.40. At normal body temperature (37 °C), $K_w = 2.4 \times 10^{-14}$. Calculate $[H^+]$, $[OH^-]$ [redacted] for blood at this temperature. [5]

d) Given that the K_a of acetic acid (CH_3COOH) is 1.8×10^{-5}. Determine the pH of a solution containing 0.50 M acetic acid and 0.50 M sodium acetate (CH_3COONa) [5]

3.4×10^{-8} M

pOH = 6.6

$[H^+][OH^-] = 2.4 \times 10^{-14}$

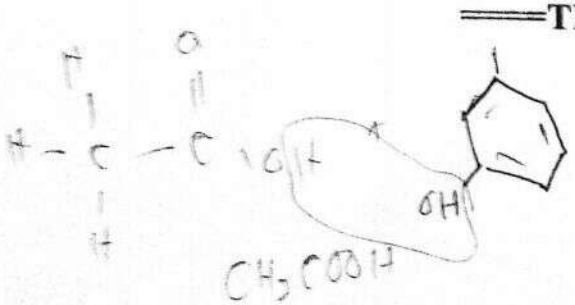
2.51×10^{-7} M

$CH_3COOH + CH_3COONa$

6.02

THE END

pOH = 6.22



13.62

6.02×10^{-7} M

THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

DEPARTMENT OF CHEMISTRY

Test One for 2021/2022

DATE: May 2022

COURSE: GENERAL CHEMISTRY

COURSE CODE: CH 110

TIME ALLOWED: Two (02) HOURS

TRUCTIONS TO CANDIDATES:

. This paper comprises **FOUR** questions
. Candidates are expected to attempt **ALL** questions.
. Each question carries **TWENTY FIVE** marks.
Candidates are reminded to **CLEARLY PRESENT** their answers.

Start answering each new question on a new page.

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[25 MARKS]

QUESTION 1: INTRODUCTION

a) Fill each blank space with an appropriate word in the sentences that follow; [5]

Energy is a by-product of many chemical processes.

When considering nuclear energy, _____ [i] is a proven large scale energy source but has radioactive waste problems. _____ [ii] can help to devise better ways of disposing nuclear waste.

Energy production and energy utilization can negatively affect our environment. For example, burning fossil fuels gives off _____ [iii] which is a greenhouse gas along with _____ [iv] and _____ [v] which result in acid rain. However, new technologies are being introduced to reduce harmful emissions and improve air quality.

b) Fill in the Table below for units of measurements. [6]

Table 1: Table of Units of Measurement

	Base Quantity	Name of Unit	Symbol
1	Mass	Kilogram	kg
2			
3			
4			
5			
6			
7			

c) What is the collective term used for the units in question (b)? [1]

d) In Table 1, correctly list the three parameters that uniquely identify an isotope in the nuclide symbol ${}^{A}_{Z}X$. [3]

Table 2: Parameters that uniquely describe an isotope

Parameter	Meaning of parameter
A	
X	
Z	

e) For a nuclide, two of its components give the same value. Which are these two? [1]

f) A certain isotope X^{+} contains 54 electrons and 78 neutrons. Write the nuclide of this isotope. [3]

g) Complete the table below on the three fundamental chemical laws that you learnt in the introductory topic of General Chemistry. [6]

Table 3: List of three Fundamental Chemical Laws

No.	Name of Fundamental Chemical Law	Discoverer of Law
1		
2		
3		

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QUESTION 2: STOICHIOMETRY

[25 MARKS]

a) Zinc (Zn) is a silvery metal that is used in making brass (with copper) and in plating iron to prevent corrosion. How many moles of Zn are there in 45.9 g of Zn? [2]

b) Sulfur (S) is a nonmetallic element that is present in coal. When coal is burned, sulfur is converted to sulfur dioxide and eventually to sulfuric acid, which gives rise to the acid rain phenomenon. How many atoms are in 25.1 g of S? [2]

c) Lithium carbonate (Li_2CO_3) was the first "mood-stabilizing" drug approved by the FDA for the treatment of mania and manic-depressive illness, also known as bipolar disorder. Calculate the percent composition ~~by mass of lithium carbonate.~~ each element in Lithium Carbonate. [3]

d) Iron (Fe), the main component of steel, is the most important metal in industrial society. How many Fe atoms are in 95.8 g of Fe? [3]

e) During excessive physical activity, lactic acid (Molar mass = 90.08 g/mol) forms in muscle tissue and is responsible for muscle soreness. Elemental analysis shows that this compound contains 40.0 mass % C, 6.71 mass % H, and 53.3 mass % O. [10]

   i. Determine the empirical formula of lactic acid.
   ii. Determine the molecular formula.

f) When potassium chromate (K_2CrO_4) is added to a solution containing 0.500 g silver nitrate ($AgNO_3$), solid silver chromate (Ag_2CrO_4) is formed. Write a balanced chemical equation and find the percent yield if 0.455 g of silver chromate is obtained. [5]

QUESTION 3: REACTIONS IN SOLUTION

[25 MARKS]

a) A redox reaction is defined as a reaction in which oxidation and reduction take place simultaneously. Identify the following changes as either oxidation or reduction: [6]

   (i) BiO_3^- to Bi^{3+}
   (ii) N_2O_4 to N_2O
   (iii) SO_2 to SO_3

b) Identify the oxidizing and reducing agents in each of the following reactions [4]

   (i) $I_2O_5 + 5CO \rightarrow 5CO_2 + I_2$
   (ii) $2Fe^{2+} + H_2O_2 + 2H^+ \rightarrow 2Fe^{3+} + 2H_2O$

c) One litre of solution is prepared by dissolving 125.6 g of NaF in it. If you took 180.0 mL of that solution and diluted it to 500 mL determine the molarity of the resulting solution [5]

d) Sodium chloride, NaCl, reacts with lead (II) nitrate, $Pb(NO_3)_2$, to form lead (II) chloride, ($PbCl_2$) and sodium nitrate, $NaNO_3$. For this reaction write [10]

   (i) Balanced molecular Equation,
   (ii) Complete Ionic Equation
   (iii) Net Ionic Equation:

Assume all reactions occur in aqueous solution. Include states of matter in your equations

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QUESTION 4: GASES **[25 MARKS]**

a) State each of the following gas laws:

(i) Avogadro's law [1]

(ii) Charles' law [1]

(iii) Boyle's law [1]

(iv) Graham's law on diffusion of gases [2]

b) Given that one mole of a gas at 450 K has a density of 1.41 gdm^{-3} at 1520 mm Hg. What is the density of the gas at rtp? [3]

c) Determine the molar mass of a gas whose density is 1.50 gdm^{-3} at a temperature of 25°C and pressure of 760 torr. [3]

d) Three gases were added to the same container of volume 20 litres to give a total pressure of 150 kPa at 25°C. If the mixture contained 8.0 g of O_2, 8.0g of CO_2 and an unknown mass of N_2.

(i) Define the term partial pressure [2]

(ii) Calculate the partial pressure of each gas [3]

(iii) Calculate the more fraction of each gas [3]

(iv) Determine the mass of N_2 in the container [3]

e) Give any three postulates of the kinetic theory of gases [3]

$\frac{PV}{RT} = n$

$PV = nRT$

$PV = \frac{m}{mr}RT$

$\frac{mrPV}{V} = \frac{mrT}{V}$

$mrP = dRT$

$d = \frac{mrP}{RT}$.

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THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

Test Two for 2021/2022

DATE: August 2022

COURSE: GENERAL CHEMISTRY

COURSE CODE: CH 110

TIME ALLOWED: Two (02) HOURS

INSTRUCTIONS TO CANDIDATES

1. This paper comprises **FOUR** questions
2. Candidates are expected to attempt **ALL** questions.
3. Each question carries **TWENTY FIVE** marks.
4. Candidates are reminded to **CLEARLY PRESENT** their answers.
5. **Start answering each new question on a new page**

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(25 MARKS)

QUESTION 1: THERMOCHEMISTRY

a) An LP gas tank in a home barbeque contains 13.2 kg of propane, C_3H_8. Calculate the heat (in kJ) associated with the complete combustion of all of the propane in the tank. **(5 marks)**

$$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g) \quad \Delta H_{rxn} = -2044 \text{ kJ}$$

(5 marks)

b) Find ΔH_{rxn} for the reaction:

$$3C(s) + 4H_2(g) \longrightarrow C_3H_8(g)$$

Use these reactions with known ΔH's:

(i) $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g)$ $\Delta H = -2043$ kJ

(ii) $C(s) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H = -393.5$ kJ

(iii) $2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$ $\Delta H = -483.6$ kJ

$n = \frac{PV}{RT}$

nRT

c) Identify each process as endothermic or exothermic and indicate the sign of ΔH. **(3marks)**

(i) sweat evaporating from skin
(ii) water freezing in a freezer
(iii) wood burning in a fire

d) A gas, while expanding, absorbs 25 J of heat and does 243 J of work. What is ΔE for the gas? **(2 marks)**

e) Write thermochemical equations corresponding to the following descriptions. **(6 marks)**

(i) The standard enthalpy of formation of iron (III) oxide at 298 K is -824.2 kJ/mol.

(ii) The standard enthalpy change at 298 K for the reaction between gaseous phosphorus trichloride and chlorine gas to give gaseous phosphorus pentachloride is -84.3 kJ.

(iii) The standard enthalpy of combustion of liquid ethanol is -1368 kJ/mol.

f) Glucose is the primary sugar in your bloodstream, supplying energy to your body. Dieticians are therefore very interested in the energy resource that it represents and need to investigate the enthalpy changes that accompany its reactions. A constant-volume calorimeter showed that the heat generated by the combustion of 1.000 mol glucose molecules in the reaction

$$C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + H_2O(g)$$ is 2559 kJ at 298 K, $\Delta E = -2559$ kJ. What is the change in enthalpy for the same reaction? (R=8.314J/K/mol).

(4 marks)

QUESTION 2: ATOMIC STRUCTURE AND PERIODICITY

(25 MARKS)

a) Determine the wavelength of light emitted when the electron in a hydrogen atom undergoes transition from energy level n = 4 to the level n= 2. **(4 marks)**

b) In the electronic configuration representation $3d^5$;

(i) What does each of the numbers 3 and 5 represent? **(2 marks)**

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(ii) Which quantum number is represented by the symbol "d"? **(2 marks)**

c) Copper is the 29th element in the periodic table of elements, for copper:

(i) Give the ground state electronic configuration **(3 marks)**

(ii) Draw the orbital diagrams for the electronic configuration in c(i) above, **(3 marks)**

(iii) Give the set of the four quantum numbers for the 3rd electron in the ground state of copper. **(2 marks)**

(iv) Which electron in the ground state of copper has the following set of the four quantum numbers; (3, 0, 0, -½). **(2 marks)**

d) Calculate the;

(i) Energy difference in joules between n=1 and n=5 principal energy levels of a hydrogenic atom. **(3 marks)**

(ii) de Broglie wave length of a boy of mass 10.5 Kg experiencing translational motion at 18 km/h. **(4 marks)**

QUESTION 3: CHEMICAL BONDING AND MOLECULAR GEOMETRY

(25 MARKS)

a) Some plant fertilizer compounds are $(NH4)_2SO_4$, $Ca_3(PO_4)_2$, K_2O, P_2O_5, and KCl. Which of these compounds contain both ionic and covalent bonds? **(2marks)**

b) Draw three resonance structures for CO_2. Which resonance structure is best from a formal charge standpoint? **(3marks)**

c) Draw Lewis structure of the following compounds. **(6marks)**

(i) NF_3 (ii) HNO_2 (iii) H_2SO_4

d) Predict the empirical formulas of the ionic compounds formed from the following pairs of elements. Name each compound. **(4marks)**

(i) Li and N (ii) Ga and O

e) Using the bond energies listed in Table-2, calculate ΔH for the reaction of methane with chlorine and fluorine to give Freon-12 (CF_2Cl_2). **(5marks)**

$$CH_4(g) + 2Cl_2(g) + 2F_2(g) \longrightarrow CF_2Cl_2(g) + 2HF(g) + 2HCl(g)$$

f) Predict the geometry of the following molecules and ion using the VSEPR model: **(5marks)**

(i) CH_3I
(ii) ClF_3
(iii) H_2S
(iv) SO_3
(v) SO_4^{2-}

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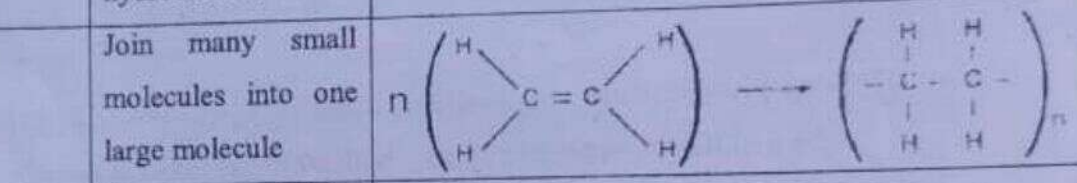
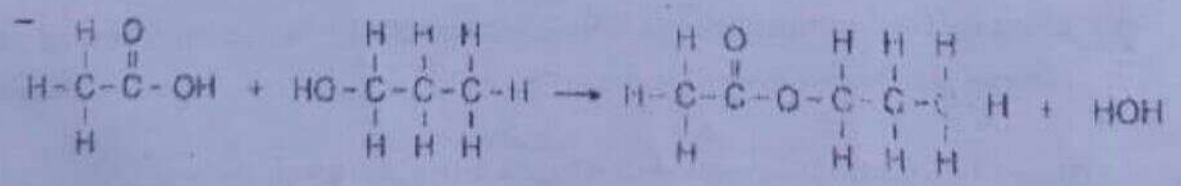
(25 MARKS)

QUESTION 4: ORGANIC CHEMISTRY

a) Answer this question by numbering your responses according to the numbering of the questions in the table. For the number with two questions, differentiate them by adding (a) and (b). E.g. (i)(a) and (i)(b). Be sure to complete the example reaction as well as fill in all other blanks. Ensure that you are very clear in your answers. **(7marks)**

S/No	ORGANIC REACTION	DESCRIPTION	EXAMPLE
i.	Addition		$CH_2{=}CH_2 + Cl_2 \rightarrow$
ii.		A halogen replaces a hydrogen on a saturated hydrocarbon.	$CH_3CH_2CH_3$ + ____ → $CH_3\overset{I}{C}HCH_3$ + HI
iii.		Join many small molecules into one large molecule	
iv.		An exothermic reaction in which something reacts with oxygen.	$C_3H_8 + O_2 \rightarrow$

b) Base your answers to questions (i) through (iii) on the information below. Many artificial flavorings are prepared using the organic reaction: **(3 marks)**



Reactant 1 Reactant 2 Product1 Product 2

i. What is the name of this organic reaction?

ii. To what class of organic compounds does reactant 2 belong?

iii. Draw the structure of an isomer of reactant 2

c) Draw the structure of any two isomers for C_6H_{14} and give each structure an IUPAC name.

(4 marks)

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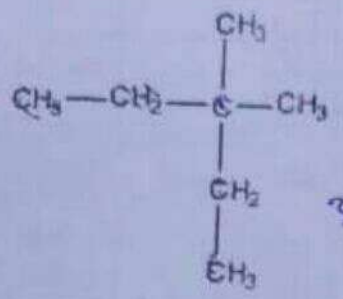
d) What is the IUPAC name of the following compounds?

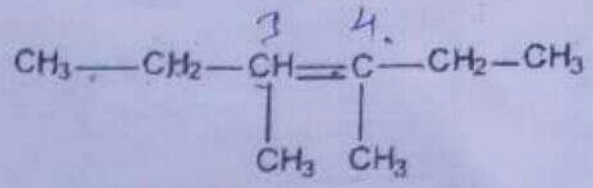
(2 marks)

(i)



3,3 di

(ii)



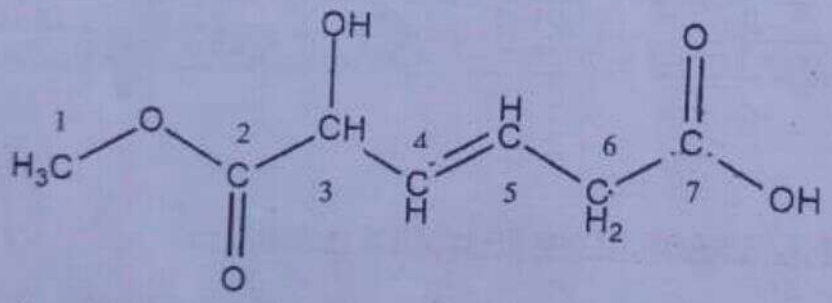
e) Draw the structure of the following compounds. **(4 marks)**

(i) 2,3,3-trimethylhexane

(ii) 3-methyl-2-pentene

f) Answer the following question based on the structure of an organic compound below. Copy the structure in your answer sheet.

(5 marks)



i. Circle and name all the functional groups in this compound.

ii. What is the hybridization of the carbon atom labeled 7?

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TABLE-1 FUNDAMENTAL CONSTANTS

Quantity	symbol	Value	Power of ten	Units
Speed of light	C	2.9979	10^{8}	$m\ s^{-1}$
Elementary charge	E	1.602	10^{-19}	C
Faraday's constant	$F=N_Ae$	9.6485	10^{4}	$C\ mol^{-1}$
Boltzmann's constant	K	1.380 65	10^{-23}	$J\ K^{-1}$
Gas constant	$R=N_Ak$	8.314 47 8.314 47 8.205 74 6.236 37	 10^{-2} 10^{-2} 10 ..	$J\ K^{-1}\ mol^{-1}$ $L\ bar\ K^{-1}\ mol^{-1}$ $L\ atm\ K^{-1}\ mol^{-1}$ $L\ Torr\ K^{-1}\ mol^{-1}$
Planck's constant	H	6.626 08	10^{-34}	Js
Avogadro's constant	N_A	6.022 14	10^{23}	mol^{-1}
Atomic mass unit	M_u	1.660 54	10^{-27}	Kg
Mass Electron Proton neutron	 m_e m_p m_n	 9.109 38 1.672 62 1.674 93	 10^{-31} 10^{-27} 10^{-27}	 K g K g kg
Rydeberg constant	R_H	1.097 37	10^{7}	m^{-1}
1 atm = 760 mmHg = 760 Torr = $1.01325 \times 10^5\ Nm^{-2}$ = 1.01325×10^5 Pa= 1.01325 bar				

TABLE-2- AVERAGE BOND ENERGIES (kj/mol)

		Single Bonds				Multiple Bonds	
H—H	432	N—H	391	I—I	149	C=C	614
H—F	565	N—N	160	I—Cl	208	C≡C	839
H—Cl	427	N—F	272	I—Br	175	O=O	495
H—Br	363	N—Cl	200			C=O*	745
H—I	295	N—Br	243	S—H	347	C≡O	1072
		N—O	201	S—F	327	N=O	607
C—H	413	O—H	467	S—Cl	253	N=N	418
C—C	347	O—O	146	S—Br	218	N≡N	941
C—N	305	O—F	190	S—S	266	C≡N	891
C—O	358	O—Cl	203			C=N	615
C—F	485	O—I	234	Si—Si	340		
C—Cl	339			Si—H	393		
C—Br	276	F—F	154	Si—C	360		
C—I	240	F—Cl	253	Si—O	452		
C—S	259	F—Br	237				
		Cl—Cl	239				
		Cl—Br	218				
		Br—Br	193				

*C=O(CO_2) = 799

H-F

$E = 2.18 \times 10^{-18}\left(1 - \frac{1}{5^2}\right)$

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The Periodic Table of Elements

6	Atomic Number = Number of Protons = Number of Electrons
C	Chemical Symbol
CARBON	Chemical Name
12	Atomic Weight = Number of Protons + Number of Neutrons*

NON-METALS

METALS

1 H HYDROGEN 1																	2 He HELIUM 4
3 Li LITHIUM 7	4 Be BERYLLIUM 9											5 B BORON 11	6 C CARBON 12	7 N NITROGEN 14	8 O OXYGEN 16	9 F FLUORINE 19	10 Ne NEON 20
11 Na SODIUM 23	12 Mg MAGNESIUM 24											13 Al ALUMINUM 27	14 Si SILICON 28	15 P PHOSPHORUS 31	16 S SULFUR 32	17 Cl CHLORINE 35	18 Ar ARGON 40
19 K POTASSIUM 39	20 Ca CALCIUM 40	21 Sc SCANDIUM 45	22 Ti TITANIUM 48	23 V VANADIUM 51	24 Cr CHROMIUM 52	25 Mn MANGANESE 55	26 Fe IRON 56	27 Co COBALT 59	28 Ni NICKEL 59	29 Cu COPPER 64	30 Zn ZINC 65	31 Ga GALLIUM 70	32 Ge GERMANIUM 73	33 As ARSENIC 75	34 Se SELENIUM 79	35 Br BROMINE 80	36 Kr KRYPTON 84
37 Rb RUBIDIUM 85	38 Sr STRONTIUM 88	39 Y YTTRIUM 89	40 Zr ZIRCONIUM 91	41 Nb NIOBIUM 93	42 Mo MOLYBDENUM 96	43 Tc TECHNETIUM 98	44 Ru RUTHENIUM 101	45 Rh RHODIUM 103	46 Pd PALLADIUM 106	47 Ag SILVER 108	48 Cd CADMIUM 112	49 In INDIUM 115	50 Sn TIN 119	51 Sb ANTIMONY 122	52 Te TELLURIUM 128	53 I IODINE 127	54 Xe XENON 131
55 Cs CESIUM 133	56 Ba BARIUM 137		72 Hf HAFNIUM 178	73 Ta TANTALUM 181	74 W TUNGSTEN 184	75 Re RHENIUM 186	76 Os OSMIUM 190	77 Ir IRIDIUM 192	78 Pt PLATINUM 195	79 Au GOLD 197	80 Hg MERCURY 201	81 Tl THALLIUM 204	82 Pb LEAD 207	83 Bi BISMUTH 209	84 Po POLONIUM 209	85 At ASTATINE 210	86 Rn RADON 222
87 Fr FRANCIUM 223	88 Ra RADIUM 226		104 Rf RUTHERFORDIUM 263	105 Db DUBNIUM 268	106 Sg SEABORGIUM 271	107 Bh BOHRIUM 270	108 Hs HASSIUM 270	109 Mt MEITNERIUM 278	110 Ds DARMSTADTIUM 281	111 Rg ROENTGENIUM 281	112 Cn COPERNICIUM 285	113 Nh NIHONIUM 286	114 Fl FLEROVIUM 289	115 Mc MOSCOVIUM 289	116 Lv LIVERMORIUM 293	117 Ts TENNESSINE 294	118 Og OGANESSON 294

57 La LANTHANUM 139	58 Ce CERIUM 140	59 Pr PRASEODYMIUM 141	60 Nd NEODYMIUM 144	61 Pm PROMETHIUM 145	62 Sm SAMARIUM 150	63 Eu EUROPIUM 152	64 Gd GADOLINIUM 157	65 Tb TERBIUM 159	66 Dy DYSPROSIUM 163	67 Ho HOLMIUM 165	68 Er ERBIUM 167	69 Tm THULIUM 169	70 Yb YTTERBIUM 173	71 Lu LUTETIUM 175
89 Ac ACTINIUM 227	90 Th THORIUM 232	91 Pa PROTACTINIUM 231	92 U URANIUM 238	93 Np NEPTUNIUM 237	94 Pu PLUTONIUM 244	95 Am AMERICIUM 243	96 Cm CURIUM 247	97 Bk BERKELIUM 247	98 Cf CALIFORNIUM 251	99 Es EINSTEINIUM 252	100 Fm FERMIUM 257	101 Md MENDELEVIUM 258	102 No NOBELIUM 259	103 Lr LAWRENCIUM 262

KEY

- = Solid at room temperature
- = Liquid at room temperature
- = Gas at room temperature
- = Radioactive
- = Artificially Made

* The atomic weights listed on this Table of Elements have been rounded to the nearest whole number. As a result, this chart actually displays the **mass number** of a specific isotope for each element. An element's complete, unrounded atomic weight can be found on the It's Elemental website: http://education.jlab.org/itselemental/

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THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

SESSIONAL QUESTION PAPER for 2021/2022

SEPTEMBER 2022

COURSE: GENERAL CHEMISTRY

COURSE CODE: CH 110

TIME ALLOWED: THREE (03) HOURS

***INSTRUCTIONS TO CANDIDATES*:**

1. This paper comprises **SEVEN** questions printed on pages 2 to 6.
2. Page 6 also has useful constants while page 7 has the Periodic Table
3. Candidates are expected to attempt **ANY FIVE** questions.
4. Each question carries **TWENTY** marks.
5. Candidates are reminded to **CLEARLY PRESENT** their answers.
6. All the parts of a question should be answered **IN CONTINUATION.**
7. Start answering every new question on a new page.

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QUESTION 1: INTRODUCTION TO CHEMISTRY & CHEMICAL EQUILIBRIA

[20 Marks]

a) Describe how the equilibrium constant for an overall reaction is related to the equilibrium constants for the individual reactions that yield the overall reaction. **[2]**

b) What role does a catalyst play in a reversible chemical reaction? How does a catalyst affect the value of the equilibrium constant for a reaction? **[2]**

c) A closed system initially containing 1.0×10^{-3} M H_2 and 2.0×10^{-3} M I_2 at 448 °C is allowed to reach equilibrium. Analysis of the equilibrium mixture shows that the concentration of HI is 1.87×10^{-3} M.

   i) Write a balanced chemical equation with state symbols for the above reaction **[1]**

   ii) Calculate K_c at 448 °C for the reaction taking place. **[6]**

d) Fill each blank space with an appropriate word in the sentences that follow.

   i) _____ is a set of tested hypotheses that gives an overall explanation of natural phenomenon **[1]**

   ii) _____ is a summary of repeatable measurable behavior. **[1]**

   iii) _____ is a possible explanation for an observation. **[1]**

e) As a group, what do the above statements in (d) compose of? **[2]**

f) Complete the names of the anions and acids whose chemical formulae are given in the table below. **[4]**

Table 1: Names of anions and acids

No.	Acid's chemical formula	Acid's anion	Acid's name
1	H_2S		
2	$HClO_2$		
3	$HBrO_3$		
4	HIO_4		

QUESTION 2: ATOMIC STRUCTURE AND PERIODICITY

[20 Marks]

a) Define the following periodic properties and explain their variation in the periodic table:

   i) Ionization energy **[2]**

   ii) Electron affinity **[2]**

   iii) Electronegativity **[2]**

b) State the Pauli exclusion principle **[2]**

c) Chromium is the 24th element in the periodic table of elements, for chromium:

   i) Give the ground state electronic configuration **[2]**

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ii) Draw the ground state orbital diagrams for the electronic configuration [2]

iii) Give the set of the four quantum numbers for the 24th electron in ground state of chromium [2]

iv) Write down the three sets of quantum numbers that define the 3p atomic orbitals. [3]

d) Determine the wavelength of the light emitted when an electron in a hydrogen atom under goes transition from energy level n=6 to the level n=2. [3]

3: REACTIONS IN AQUEOUS SOLUTIONS & STOICHIOMESTRY [20 Marks]

a) The oxidation number of an element is the "charge" the element would have if all of its bonds were completely ionic, that is, if the electron pairs of each bond were transferred to the more electronegative atom. Determine the oxidation state of: [2]

i) Chromium in $K_2Cr_2O_7$

ii) Lead in $Pb(OH)_4^{2-}$

b) Identify the oxidizing and reducing agent in the following reaction [2]

$$2Fe^{2+} + H_2O_2 + 2H^+ \rightarrow 2Fe^{3+} + 2H_2O$$

c) Nickel nitrate, $Ni(NO_3)_2$ reacts with sodium hydroxide (NaOH) to produce sodium nitrate ($NaNO_3$) and a solid nickel (II) hydroxide, $Ni(OH)_2$ Write balanced *molecular*, *ionic*, and *net ionic* equations for the reaction. Assume all reactions occur in aqueous solution. Include states of matter in your balanced equation. [6]

d) Solid sodium and iron (III) oxide are involved in a reaction that is one of many reactions responsible for inflating a car airbag. [10]

$$6Na + Fe_2O_3 \rightarrow 3Na_2O + 2Fe$$

If 100.0 g Na and 100.0 g Fe_2O_3 are used, determine:

i) limiting reactant

ii) moles excess reactant

iii) mass of solid iron produced

iv) mass of excess reactant left over

v) what is the percent yield if 58.8 g of solid iron were produced?

QUESTION 4: THERMOMETRY [20 Marks]

a) Consider the Thermochemical equation below. Based on this equation, what is the standard enthalpy of formation of Fe_2O_3: [2]

$$2Fe_2O_3(s) \rightarrow 4Fe(s) + 3O_2(g) \quad \Delta H^o = 1644\ kJ$$

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b) Given the following

$$CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l) \quad \Delta H = -890kJ$$

i) Balance the given thermochemical equation. [1]

ii) Is the reaction exothermic or endothermic? [1]

iii) How much heat is given off by the reaction of 3.5 moles of CH_4? [2]

iv) How much heat is given off by the reaction of 40.0g of O_2? [2]

v) How many grams of CH_4 are needed to release 2000J of heat? [2]

c) The equation for the combustion of ~~ethane~~ ethene is shown. [8]

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g) \quad \Delta H_c = -1387kJmol^{-1}$$

Using this and values of the average bond enthalpies in the table to calculate the average bond enthalpy of $C-H$

Bond	$C=C$	$O=O$	$C=O$	$O-H$	$C-H$
Bond energy (kJ/mol)	614	495	799	465	x

d) Write the equation that corresponds to the standard molar enthalpy change for the [2]

i) Formation of magnesium carbonate

ii) Formation of ethanol

QUESTION 5: ORGANIC CHEMISTRY [20 Marks]

a) Given the organic compound C_2H_4,

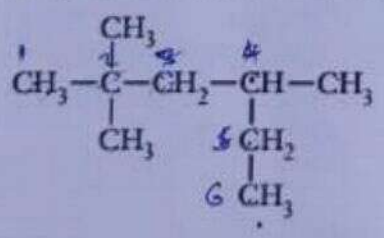
i. Write its structural formula [1]

ii. Identify how many sigma and pi bonds are formed by each carbon atom. [2]

iii. What is the hybridization on each carbon atom? [1]

iv. Name the type of reaction this compound undergoes when it reacts with bromine. [1]

b) Consider a molecule with the following structural formula:



2,2,methyl,4 methyl hexane

2,2,4-Trimethyl hexane

Write the IUPAC name of the molecule. [2]

c) Answer the following question based on aromatic compounds.

i) identify the important characteristics of an aromatic compound [2]

ii) What is the major product given the reagents below? [2]

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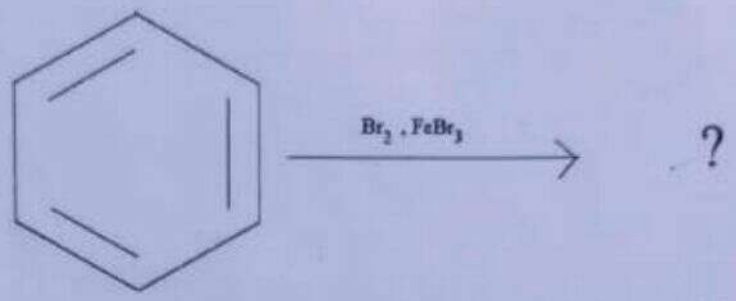

d) 4-methyl-2-pentene can exist as either of two geometric isomers. Draw the structurers of the two geometric isomers and name them using the IUPAC system. [4]

e) Propene reacts with HBr to give two possible products.

   i) Write the structure and the IUPAC name of the major product when propene reacts with HBr. [2]

   ii) Identify and state the rule that gives guide to the major product in this reaction. [3]

QUESTION 6: CHEMICAL BONDING & MOLECULAR GEOMETRY [20 Marks]

a) Arrange the ions Se^{2-}, Br^{-}, Rb^{+}, and Sr^{2+} in order of decreasing size and explain the reason. [2]

b) The cyanate ion, OCN^{-}, forms a number of stable salts, but many fulminates, CNO^{-}, are explosive. Draw resonance Lewis structures (including formal charges) for the two anions, and on the basis of these, explain the difference in stability. [7]

c) Describe the bonding and hybridization in the ammonia (NH_3) molecule using the localized electron model. [5]

d) The N_2O molecule is linear and polar.

   i) On the basis of this experimental evidence, which arrangement, NNO or NON, is correct? Explain your answer. [3]

   ii) On the basis of your answer to part (i), write the Lewis structure of N_2O (including resonance forms). Give the formal charge on each atom and the hybridization of the central atom. [3]

1 ## QUESTION 7: GASES ✓ [20 Marks]

a) The pressure needed to make synthetic diamonds from graphite is 8×10^4 atm. Express this pressure in

   i) Pascal ii) Torricelli [2]

b) A container of total volume 1.5 dm^3 contains 6.0 g of helium gas at 25°C. Calculate the pressure in atmospheres exerted by helium assuming it behaved as:

   i) an ideal gas [2]

   ii) A van der waals gas with van der waals constants **a** and **b** of values 4.20 $L^2atm\ mol^{-2}$ and 0.052 $Lmol^{-1}$ respectively. [4]

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c) Given that the composition of a 100.0 g sample of dry air at sea level is 75.5 g nitrogen, 23.2 g oxygen, and 1.3 g argon, what is the partial pressure of each component at 100 kPa total pressure? **[10]**

d) State the two special features of an ideal gas. **[2]**

TABLE OF USEFUL CONSTANTS

Quantity	Symbol	Value	Power of ten	Units
Speed of light	C	2.9979	10^{8}	$m\ s^{-1}$
Elementary charge	E	1.602	10^{-19}	C
Faraday's constant	$F=N_Ae$	9.6485	10^{4}	$C\ mol^{-1}$
Boltzmann's constant	k	1.380 65	10^{-23}	$J\ K^{-1}$
Gas constant	$R=N_Ak$	8.314 47 8.314 47 8.205 74 6.236 37	 10^{-2} 10^{-2} 10	$J\ K^{-1}\ mol^{-1}$ $L\ bar\ K^{-1}\ mol^{-1}$ $L\ atm\ K^{-1}\ mol^{-1}$ $L\ Torr\ K^{-1}\ mol^{-1}$
Planck's constant	h	6.626 08	10^{-34}	Js
Avogadro's constant	N_A	6.022 14	10^{23}	mol^{-1}
Atomic mass unit	m_u	1.660 54	10^{-27}	Kg
Mass				
Electron	m_e	9.109 38	10^{-31}	Kg
Proton	m_p	1.672 62	10^{-27}	Kg
Neutron	m_n	1.674 93	10^{-27}	Kg
Rydeberg constant 1	R_H	1.097 37	10^{7}	m^{-1}
Rydberg constant 2	R_Y	2.178	10^{-18}	J
1 atm = 760 mmHg = 760 Torr = $1.01325 \times 10^{5}\ Nm^{-2}$ = 1.01325×10^{5} Pa= 1.01325 bar				

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The Periodic Table

Atomic Number

Element

Atomic Mass

1	2											3	4	5	6	7	0
1 **H** 1.01																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.71	29 **Cu** 63.55	30 **Zn** 65.37	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.91	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.40	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
55 **Cs** 132.91	56 **Ba** 137.34	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.21	77 **Ir** 192.22	78 **Pt** 195.09	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.19	83 **Bi** 208.98	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 ‡ **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)	113 **Nh** (284)	114 **Fl** (289)	115 **Mc** (288)	116 **Lv** (291)	117 **Ts** (Unknown)	118 **Og** (294)

58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	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)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

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THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

Test One for 2020/2021

DATE: 10TH MARCH 2021

COURSE: GENERAL CHEMISTRY

COURSE CODE: CH 110

TIME ALLOWED: TWO (02) HOURS

INSTRUCTIONS TO CANDIDATES:

1. This paper comprises **FOUR** questions
2. Candidates are expected to attempt **ALL** questions.
3. Each question carries **TWENTY FIVE** marks.
4. Candidates are reminded to **CLEARLY PRESENT** their answers.
5. **Start answering each new question on a new page.**

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QUESTION 1: INTRODUCTION

[25 MARKS]

a) Fill each blank space with an appropriate word in the sentences that follow. [3]

(i) _____ is a set of tested hypotheses that gives an overall explanation of natural phenomenon [1]

(ii) _____ is a summary of repeatable measurable behavior. [1]

(iii) _____ is a possible explanation for an observation. [1]

b) As a group, what do the above statements compose of? [2]

c) Complete the names of the anions and acids of the acids whose chemical formulae are given in the table below. [4]

Table 1: Names of anions and their acids

No.	Acid's chemical formula	Acid's anion	Acid's name
1	H_2S		
2	$HClO_2$		
3	$HBrO_3$		
4	HIO_4		

d) Fill in the blank spaces using a word for each space [6]

(i) _____ is the estimate in a measurement that depends on the precision of the measuring device. [1]

(ii) The term _____ is agreement of a particular value with a true value. [1]

(iii) _____ is the degree of agreement among several measurements of the same quantity. [1]

(iv) These terms are encountered when doing the opposite of qualitative observations, that is, _____ observations which have two parts, namely, _____ and _____. [3]

e) Mixtures have variable compositions. Using two very short sentences of less than 10 words, distinguish a homogeneous mixture from a heterogeneous mixture. [2]

f) Which of the listed substances is a homogeneous mixture? [2]

(i) Pure water

(ii) Clean air

(iii) Petrol

(iv) Soil

(v) Copper wire

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g) Complete the table below on the three fundamental chemical laws that you learnt in the introductory topic of General Chemistry. [6]

Table 2: List of three Fundamental Chemical Laws

No.	Fundamental Chemical Law's	
	Name	Definition
1		
2		
3		

QUESTION 2: STOICHIOMETRY

[25 MARKS]

a) Ammonia (NH_3) reacts with fluorine (F_2) to produce dinitrogen tetrafluoride (N_2F_4) and hydrogen fluoride (HF). In an experiment 4.0 g of NH_3 and 14.0 g of F_2 are combined.

i) Write a balanced chemical equation for the reaction [2]

ii) Which reactant is the limiting reactant? [6]

iii) How many grams of N_2F_4 can theoretically be prepared from this experiment? [4]

iv) If 4.80 g N_2F_4 are obtained from this experiment, what is the percentage yield? [3]

b) When 12.10 g of tert-butyl ether (a compound of C, H, and O) are completely burned in an apparatus, 30.1 g of CO_2 and 14.8 g of H_2O are formed. What is the empirical formula of the compound? [10]

QUESTION 3: REACTIONS IN SOLUTION

[25 MARKS]

a) In the table below, indicate the solubility of the given species. Giving your answer as; Soluble, insoluble or slightly soluble.

Specie (s)	Solubility
NO_3^-	
NH_4^+	
AgCl	
SO_4^{2-}	
CO_3^{2-}	

[5]

b) A standard solution is prepared by dissolving 10 g of NaCl in 500 mL of water.

i. Calculate the molar concentration of the standard solution, [5]

ii. From the standard solution, calculate volume required to prepare a dilute solution with a concentration of 0.05 M in a 100 mL volumetric flask. [3]

c) In the reaction;

$$CuSO_4\ (aq) + Zn\ (s) \rightarrow ZnSO_4\ (aq) + Cu\ (s)$$

Give the reduction and oxidation half equations. [2]

d) Balance the following redox equation in acidic solution;

$$SO_3^{2-}{}_{(aq)} + MnO_4^-{}_{(aq)} \rightarrow SO_4^{2-}{}_{(aq)} + Mn^{2+}{}_{(aq)}$$ [10]

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QUESTION 4: GASES

[25 MARKS]

a) Write down the mathematical expressions of the following gas laws: [2]

i) Boyle's law

ii) Charles' law

b) Consider a mixture of two gases A and B, confined in a closed vessel. A quantity of a third gas, C, is added to the same vessel at the same temperature. State whether each of the following will increase, decrease, or remain the same. [3]

i) The partial pressure of gas A

ii) The total pressure in the vessel

iii) The mole fraction of gas B

c) A diver releases a bubble of air which rises to the surface of the sea. The volume of the bubble increases from 4.0 cm^3 to 10.0 cm^3 during this process.

i) Why does the bubble expand as it rises? [1]

ii) Just below the surface, the pressure acting on the bubble is 1.0 atm. What is the pressure (in atm) acting on it before it starts to rise? [4]

iii) Which gas law is being applied in your calculation in c(ii) above? [1]

d) An aerosol spray can with a volume of 250 ml contains 2.30 g of propane gas (C_3H_8) as a propellant.

i) If the can is at 23^0C, what is the pressure in the can? [5]

ii) What volume would the propane occupy at STP? [4]

iii) The can's label says that exposure to temperatures above 130^0F may cause the can to burst. What is the pressure in the can at this temperature? [5]

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TABLE OF FUNDAMENTAL CONSTANTS

Quantity	symbol	Value	Power of ten	Units
Speed of light	c	2.9979	10^{8}	$m\ s^{-1}$
Elementary charge	e	1.602	10^{-19}	C
Faraday's constant	$F=N_A e$	9.6485	10^{4}	$C\ mol^{-1}$
Boltzmann's constant	k	1.380 65	10^{-23}	$J\ K^{-1}$
Gas constant	$R=N_A k$	8.314 47 8.314 47 8.205 74 6.236 37	 10^{-2} 10^{-2} 10	$J\ K^{-1}\ mol^{-1}$ $L\ bar\ K^{-1}\ mol^{-1}$ $L\ atm\ K^{-1}\ mol^{-1}$ $L\ Torr\ K^{-1}\ mol^{-1}$
Planck's constant	h	6.626 08	10^{-34}	Js
Avogadro's constant	N_A	6.022 14	10^{23}	mol^{-1}
Atomic mass unit	m_u	1.660 54	10^{-27}	Kg
Mass Electron Proton Neutron	 m_e m_p m_n	 9.109 38 1.672 62 1.674 93	 10^{-31} 10^{-27} 10^{-27}	 Kg Kg Kg
Rydberg constant	R_H	1.097 37	10^{7}	m^{-1}
1 atm = 760 mmHg = 760 Torr = $1.01325 \times 10^{5}\ Nm^{-2}$ = 1.01325×10^{5} Pa = 1.01325 bar				

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THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

SESSIONAL EXAMINATIONS 2020/2021

DATE: 14th OCTOBER 2021

COURSE: GENERAL CHEMISTRY

COURSE CODE: CH 110

TIME ALLOWED: THREE (03) HOURS

INSTRUCTIONS TO CANDIDATES:

1. This paper comprises **seven** questions printed on pages 2 to 6.
2. Candidates are expected to attempt any **five** questions.
3. Each question carries **twenty** marks.
4. Candidates are reminded to **clearly present** their answers.
5. All the parts of a question should be answered **strictly in continuation.**

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QUESTION 1: INTRODUCTION & ATOMIC STRUCTURE

[20 MARKS]

a) Does each of the following describe a physical change or a chemical change? [3]

i. The helium gas inside a balloon tends to leak out after a few hours.

ii. A flashlight beam slowly gets dimmer and finally goes out.

iii. Frozen orange juice is reconstituted by adding water to it.

b) Express the following numbers as decimals: [2]

(i) 1.52×10^{-2} (ii) 7.78×10^{-8}

c) How many significant figures are there in each of the following? [3]

(i) 0.006 L (ii) 0.0605 dm^3 (iii) 60.5 mg

d) Venus, the second closest planet to the sun, has a surface temperature of 7.3×10^2 K. Convert this temperature to °C and °F. [2]

e) Give the maximum number of electrons in an atom that can have the following quantum numbers: [3]

(i) n = 4 (ii) n = 5, $m_l = +1$ (iii) n = 5, $m_s = +\frac{1}{2}$

f) Give a possible set of values of the four quantum numbers for all the electrons in a boron atom and a nitrogen atom if each is in the ground state. [5]

g) For each of the following pairs of elements [2]

(C and N) (Ar and Br) pick the atom with

i. more favorable (exothermic) electron affinity.

ii. higher ionization energy.

7.3×10^2

730 K

$1s^2 2s^2 2$

QUESTION 2: REACTIONS IN AQUEOUS SOLUTIONS

[20 MARKS]

a) Assign oxidation numbers to the elements whose atoms are underlined in each of the following compounds or ions:

$C = \frac{5}{9}(F - 32)$

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$1 + x + (-2 \times 3) = 0$
$1x - 6 = 0$
$x = 5$

Compound/ion	Element: Oxidation Number
$K\underline{N}O_3$	N:
$\underline{Al}H_3$	Al:
$\underline{N}H_4^+$	N:
$H_2\underline{P}O_4^-$	P:

$2BrCl_2 \rightarrow Br_2 + 2Cl_2$

[4]

b) Bromine tri~~fluoride~~ chlride ($BrCl_3$) is a strong ionizing inorganic solvent. It is also used for manufacturing uranium hexafluoride (UF_6) while processing and reprocessing nuclear fuel.

i. Write a balanced chemical equation for the dissociation of liquid Bromine trifluoride to form chlorine and bromine in solution, [2]

ii. If 3.54 moles of $BrCl_3$ reacts according to the equation, how many moles of Cl_2 will be formed? How many moles of Br_2 will be formed? [4]

iii. To ensure stability of uranium hexafluoride (UF_6), an 8.19 g compound of C, H, and O is burned in a cylinder. From this, 20.3 g of CO_2 and 10.1 g of H_2O are formed. What is the empirical formula of the compound? [10]

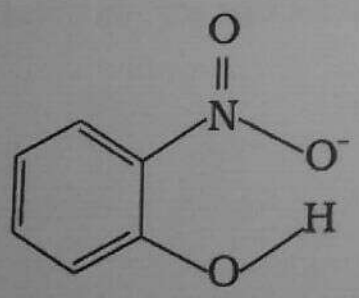
QUESTION 3: CHEMICAL BONDING & MOLECULAR GEOMETRY [20 MARKS]

a) Structures of molecules of two compounds are given below :

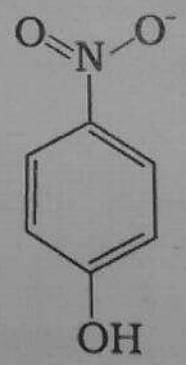
$x + (1 \times 4) = +1$
$x + 4 = 1$
$x = -3$

$x + (3 \times 1) = 0$
$x + 3 = 0$
$x = -3$

$2 + x - 8 =$
$x = 8 - 1$
$x =$



(I)



(II)

i. Which of the two compounds will have intermolecular hydrogen bonding and which compound is expected to show intramolecular hydrogen bonding? [2]

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5.5419
1.1312

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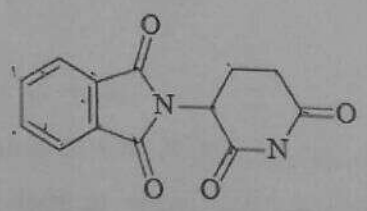
ii. The melting point of a compound depends on, among other things, the extent of hydrogen bonding. On this basis explain which of the above two compounds will show higher melting point. **[1]**

iii. Solubility of compounds in water depends on power to form hydrogen bonds with water. Which of the above compounds will form hydrogen bond with water easily and be more soluble in it? **[1]**

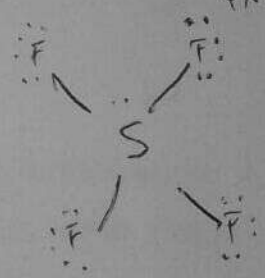
b) Match the species in Column I with the type of hybrid orbitals in Column II. **[4]**

Column I	Column II
(i) SF_4	(a) sp^3d^2
(ii) IF_5	(b) d^2sp^3
(iii) NO_2^+	(c) sp^3d
(iv) NH_4^+	(d) sp^3
	(e) sp

c) Thalidomide ($C_{13}H_{10}N_2O_4$) is a sedative and antiemetic that was widely prescribed during the 1950s, although not in the United States, for pregnant women suffering from morning sickness. Its use was largely discontinued when it was determined to be responsible for thousands of devastating birth defects. The structure of Thalidomide is shown below. Determine the number of carbon-carbon sigma bonds and the total number of pi bonds in thalidomide. **[4]**



Thalidomide



d) For each of the following molecules: NF_3 and SeF_6

(i) Draw the Lewis Structure. **[2]**

(ii) Determine the molecular structure. **[2]**

(iii) Predict the expected hybridization. **[2]**

(iv) Indicate if the molecule is polar or non-polar. **[2]**

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QUESTION 4: GASES AND CHEMICAL KINETICS [20 MARKS]

a) Whose gas law describes the following: [2]

i. The relationship between volume and temperature.

ii. The relationship between pressure and volume

b) Under what conditions will the assumptions of the kinetic molecular theory of gases most likely be incorrect? [2]

c) Two flasks are connected with a stopcock. Flask 1 has a volume of 2.5 L and contains oxygen gas at a pressure of 0.70 atm. Flask 2 has a volume of 3.8 L and contains hydrogen gas at a pressure of 1.25 atm. When the stopcock is between the two flasks is opened and the gases are allowed to mix, calculate:

i. The pressure of oxygen [2]

ii. The pressure of hydrogen [2]

iii. The total pressure of the gas mixture [2]

d) Consider the following reaction:

$O_3 \rightarrow O_2 + O$ (Fast)

$O_3 + O \rightarrow 2O_2$ (Slow)

i. Write the overall balanced equation [1]

ii. Identify any intermediate(s) within the mechanism [1]

iii. What is the order with respect to each reactant? [2]

iv. Write the rate law for the overall reaction. [2]

e) Consider the reaction: $2B \rightarrow C + 3D$

In one experiment, it was found that at 300K, the rate constant is 0.134 L/mol.s. A second experiment showed that at 450K, the rate constant was 0.569 L/mol.s. Determine the activation energy for the reaction. [4]

$P = \frac{nRT}{V}$

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QUESTION 5: THERMOCHEMISTRY

[20 MARKS]

Propane is a clean-burning alternative fuel whose uses include home and water heating, cooking and refrigerating food, clothes drying etc.

a) The thermochemical equation for the combustion of propane is

$$C_3H_8\,(g) + 5O_2 \rightarrow 3CO_2 + 4H_2O \qquad \Delta H^0_{rxn} = -2220\ \text{kJ mol}^{-1}$$

i) What is the enthalpy change in kJ of heat released when 0.50 mole of propane reacts? [2]

ii) What is the enthalpy change (how much heat is released) when 88.2 g of propane reacts? [2]

b) The standard enthalpy of formation (ΔH^0_f) of ammonia (NH_3) is -46.1 kJ/mole.

i) Write a thermochemical equation for the standard enthalpy of formation of ammonia. [2]

ii) What is the enthalpy change (ΔH^0_{rxn}) for the following reactions?

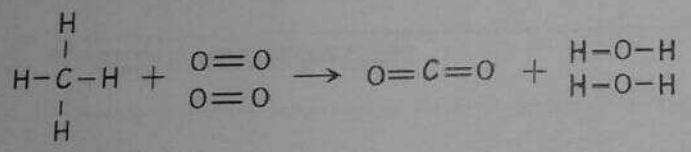
a) $N_2(g) + 3H_2\,(g) \rightarrow 2NH_3(g)$ [2]

b) $2NH_3(g) \rightarrow N_2\,(g) + 3H_2\,(g)$ [2]

c) Methane burns in oxygen to form carbon dioxide and water. The data book gives the enthalpy of combustion of methane as $-891\ \text{kJ mol}^{-1}$. The balanced chemical equation for the combustion of methane is

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

and the skeletal structures for the reactants and products are:



Bond	Bond Energy kJ mol^{-1}
H − O	458
C = O	798
O = O	497
C − H	414

i) Use the mean bond enthalpy data given to calculate the energy needed to break the bonds in the reactants [4]

ii) Calculate the energy released to form the bonds in the products [4]

iii) Hence, calculate the enthalpy change for this reaction using bond enthalpies. [2]

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QUESTION 6: ORGANIC CHEMISTRY **[20 MARKS]**

(a) Copy the list of compounds below and write the class of each compound after its chemical formula [5]

(i) C_4H_9OH

(ii) $CH_3OC_2H_5$

(iii) C_2H_5CHO

(iv) C_6H_5COOH

(v) CH_3NH_2

(b) When a mixture of methane and bromine vapour is exposed to light, the following reaction occurs slowly:

$$CH_4(g) + Br_2(g) \rightarrow CH_3Br(g) + HBr(g)$$

In two sentences, suggest a mechanism for this reaction and in the third sentence, from the types of organic chemistry reactions learnt in CH 110, state the name of the type of a chemical reaction observed here. *[Hint: Bromine vapour is deep red, methane is colourless].* [5]

(c) Copy the table below in your answer booklet and give the names of the organic compounds and their chemical formulae in the last two columns. [5]

Organic compound	Name	Chemical formula
1. Marsh gas		
2. Grain alcohol		
3. Wood alcohol		
4. Mothballs		
5. Vinegar's main ingredient		

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(d) Given these data

$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2 + 2H_2O(l)$ $\Delta H^o = -1411\ kJ/mol$ Equation 1

$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2 + 2H_2O(l)$ $\Delta H^o = -2599\ kJ/mol$ Equation 2

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H^o = -285.3\ kJ/mol$ Equation 2

Calculate the heat of hydrogenation of acetylene [5]

$C_2H_2(g) + H_2(g) \rightarrow C_2H_4(g)$ $\Delta H_4 = ?\ kJ/mol$ Equation 4

QUESTION 7: CHEMICAL EQULIBRIUM, ACIDS & BASES [20 MARKS]

(a) What is meant by a Bronsted-Lowry base? Write the acid-base equilibrium reaction of the hydroxide ion and the ammonium ion and identify the Bronsted-Lowry acids and the Bronsted-Lowry bases of your reaction [5]

(b) Amines are Bronsted-Lowry bases. The unpleasant smell of fish is due to the presence of certain amines. Explain why cooks often add lemon juice to suppress the odour of fish (in addition to enhancing the flavor). [5]

(c) Fill in the appropriate word for each blank space in the sentence that follows. Chemical equilibria reactions that involve a single phase are termed _____ equilibrium reactions while those that involve different phases are termed _____ equilibrium reactions. [2]

(d) Consider the equilibrium reaction of two gaseous substances like that of $N_2O_4 \rightleftharpoons 2NO_2$ represented by the general chemical equation $aA(g) \rightleftharpoons bB(g)$.

(i) Write the two expressions of the equilibrium constant involving molar concentrations (K_c) and partial pressures (K_p) of the reactants and products, respectively. [2]

(ii) Derive the relationship between the two equilibrium constants [6]

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THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

SESSIONAL QUESTION PAPER for 2019/2020

DATE: 9th October, 2020

COURSE: GENERAL CHEMISTRY

COURSE CODE: CH 110

TIME ALLOWED: THREE (03) HOURS

INSTRUCTIONS TO CANDIDATES:

1. This paper comprises **SEVEN** questions printed on pages 2 to 7.
2. Page 8 has useful constants while page 9 has the Periodic Table
3. Candidates are expected to attempt **ANY FIVE** questions.
4. Each question carries **TWENTY** marks.
5. Candidates are reminded to **CLEARLY PRESENT** their answers.
6. All the parts of a question should be answered **IN CONTINUATION.**

QUESTION 1: INTRODUCTION & ATOMIC STRUCTURE AND PERIODICITY [20 Marks]

a) What is matter? State the difference between homo and heterogeneous mixture. [2]

b) What are the 4 points of Dalton's Atomic Theory? [2]

c) Carry out the following mathematical operations, and give each result with the correct number of significant figures.

i. $1.05 \times 10^{-3} \div 6.135$ [2]

ii. $21 - 13.8$ [2]

iii. As part of a lab assignment to determine the value of the gas constant (R), a student measured the pressure (P), volume (V), and temperature (T) for a sample of gas, where

$$R = \frac{PV}{T}$$

The following values were obtained: $P = 2.560$, $T = 275.15$ and $V = 8.8$. Calculate R to the correct number of significant figures. [2]

d) Use the details of modern atomic theory to explain each of the following experimental observations.

i. Within a family such as the alkali metals, the ionic radius increases as the atomic number increases. [2]

ii. The radius of the chlorine atom is smaller than the radius of the chloride ion, Cl^-. (Radii : Cl atom = 0.99Å; Cl^- ion = 1.81Å) [2]

iii. The first ionization energy of aluminium is lower than the first ionization energy of magnesium. (First ionization energies: 12Mg = 7.6 ev; 13Al = 6.0 ev) [2]

iv. For magnesium, the difference between the second and third ionization energies is much larger than the difference between the first and second ionization energies. (Ionization energies for Mg: 1st = 7.6 ev; 2nd = 14 ev; 3rd = 80 ev) [2]

e) What is the difference between an emission spectrum and an absorption spectrum? Explain why the absorption spectrum of atomic hydrogen at room temperature has only the lines of the Lyman series. [2]

$R = \frac{PV}{T}$

QUESTION 2: GASES [20 Marks]

Must · 2.560 ×

a) (i) What is pressure? [1]

(ii) What is the atmospheric pressure when the height of the mercury column in a barometer is 756 mm? [1]

b) (i) The kinetic Molecular Theory of a gas is based on four assumptions. State any two of these assumptions [2]

(ii) What is the difference between a real gas and an ideal gas [1]

c) State the following gas laws mathematically (using formulas)

(i) Charles' law [1]

(ii) Boyle `s law [1]

(ii) Gay-Lussac`s law [1]

d) (i) A gas at 110 KPa and 30.0°C fills a flexible container with an initial volume of 2.00L. If the temperature is raised to 80.0°C and the pressure increased to 440KPa, what is the new volume of the gas? [2]

(ii) What volume will 1.07g of carbon dioxide (CO_2) gas occupy at 48°C and 740mmHg?[3]

(iii) The mass of a definite volume of a gas is referred to as the density of the gas. What is the density of C_2H_2 gas at STP? [1]

e) (i) John Dalton, the English chemist who proposed the atomic theory, also made an important contribution to the study of mixtures of gases. He stated the law of partial pressures. What is partial pressure? [1]

(ii) A mixture of 50.0g of oxygen gas and 50.0 g of methane, CH_4, gas is placed in a container under a pressure of 600 mmHg. What is the partial pressure of the oxygen gas in the mixture? [2]

f) (i) Thomas Graham, a Scottish chemist carried out a series of experiments on the rate of effusion of gases. His observation is now known as Graham`s law of effusion. State Graham's law of effusion [1]

(ii) Compare the rate of effusion of hydrogen and oxygen at the same temperature and pressure [2]

QUESTION 3: THERMOMETRY [20 Marks]

Answer the following questions

a) Identify each of the following processes as endothermic or exothermic and indicate the sign of ΔH. [3]

i. Sweat evaporating from the skin
ii. Water freezing in a freezer
iii. Wood burning in a fire

b) Consider the reactions: [2]

$A \longrightarrow 2B \quad \Delta H_1$

$A \longrightarrow 3C \quad \Delta H_2$

Which of the following represents ΔH for the reaction $2B \longrightarrow 3C$?

$-\Delta H_1$

C_3H_8 ×(-1)

$2B$ $A \rightarrow 2B$ ΔH_1

$A \rightarrow 3C$ ΔH_2

$2B \rightarrow 3C$

A. $\Delta H_1 + \Delta H_2$
B. $\Delta H_1 - \Delta H_2$
C. $\Delta H_2 - \Delta H_1$
D. $2 \times (\Delta H_1 + \Delta H_2)$

c) Calculate the standard heat of formation of propane (C_3H_8) if its heat of combustion is -2220.2kJ mol^{-1}. The heats of formation of $CO_2(g)$ and $H_2O(l)$ are -393.5 and -285.8 kJ mol^{-1} respectively. [8]

d) Define standard enthalpy of formation. [1]

e) When 1 mole of methane (CH_4) is burnt at constant pressure, 890 kJ of energy is released as heat. Calculate ΔH for a process in which a 5.8g sample of methane is burned at constant pressure. [2]

f) Calculate ΔH for the reaction: [4]

$CH_4(g) + 4Cl_2(g) \longrightarrow CCl_4(g) + 4HCl(g)$

Using the following reactions and given ΔH values.

$C(s) + 2H_2(g) \longrightarrow CH_4(g)$ $\Delta H = -74.6$ kJ

$C(s) + 2Cl_2(g) \longrightarrow CCl_4(g)$ $\Delta H = -95.7$ kJ

$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$ $\Delta H = -92.3$ kJ

ΔH for O_2

3c

QUESTION 4: ORGANIC CHEMISTRY [20 Marks]

a) Explain the properties of carbon that led to the formation of large number of organic compounds. [2]

b) What do you mean by alkyl groups? [2]

c) Draw the structural formula for each of the following. [6]

i. 3-isobutylhexane

ii. 2,2,4-trimethylpentane, [also called isooctane].

iii. 2-*tert*-butylpentane

d) What is wrong with the following names? Give the correct name for each compound. [8]

i. 2-ethylpropane

ii. 5-iodo-5,6-dimethylhexane

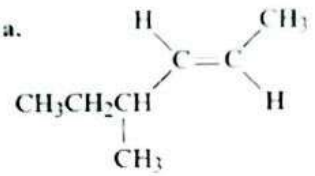
iii. cis-4-methyl-3-pentene

iv. 2-bromo-3-butanol

3C

e) Name each of the following molecules. [2]

a.



b. $CH_3CH_2C{\equiv}CCHCH_2CH_3$
$\quad\quad\quad

QUESTION 5: CHEMICAL BONDING & MOLECULAR GEOMETRY [20 Marks]

a) Answer the following TRUE/FALSE questions. [2]

i. A nonpolar covalent bond results from the unequal sharing of a pair of electrons between atoms in a molecule.
ii. The shape of a water molecule is linear.
iii. The Lewis structure for $CHCl_3$ has 9 lone electron pairs.
iv. The size in a series of isoelectronic ions increases as the nuclear charge increases

b) Predict which of the following compounds are ionic and which are covalent based on the location of their constituent atoms in the periodic table. [2]

i. MnO
ii. Cl_2CO
iii. IBr
iv. $CoBr_2$

c) From their position in the periodic table, arrange the atoms in each of the following series in order of increasing electronegativity. [2]

i. Ba, H, N, O
ii. C, N, Si, P
iii. Cs, F, Na, K
iv. Al, Na, O, P

d) P_2, a diatomic molecule, is an unstable form of phosphorus found in high-temperature phosphorus vapor. Write the Lewis structure of P_2. [2]

e) Copy and complete the following table based on the VSEPR theory. [12]

Substance	Lewis structure	Bonding electron pairs	Non-bonding electron pairs	Electron geometry	Molecular geometry
NH_3					
CO_2					
XeF_4					

QUESTION 6: CHEMICAL EQUILIBRIA & ACIDS AND BASES [20 Marks]

(a) Briefly distinguish between an acid and a base by completing the table below summarizing models of acids and bases [6]

Model	Definition of Acid	Definition of Base
1. Arrhenius		
2. Bronsted-Lowry		
3. Lewis		

(b) Give the conjugate acid for the conjugate bases in the table below [4]

Conjugate Base	Conjugate Acid
1. Br^-	
2. NH_3	
3. ClO^-	
4. CO_3^{2-}	

(c) Using the equation: $aA_{(g)} + bB_{(g)} \rightleftharpoons cC_{(g)} + dD_{(g)}$

(i) Write the expressions you would use to calculate the values of equilibrium constants K_c and K_p of the above gaseous reaction. [2]

(ii) The relationship between K_c and K_p is $K_p = K_c(RT)^{\Delta n}$ where Δn is the change in number of moles of gaseous substances in the reaction equation. For the reaction given above, specify whether $\Delta n = (c + d) - (a + b)$ is TRUE or FALSE. [1]

(iii) At 20 °C, the vapour pressure of water is 0.0231 atm. Calculate the K_p and K_c for the process: $H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$ [2]

(d) At 200 °C phosphorus penta-chloride dissociates according to the following reaction:

$PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$ $\Delta H = +124$ kJ

A pure sample of PCl_5 was introduced into an evacuated vessel at 200°C. At equilibrium, the concentration of PCl_5 was found to be 0.5×10^{-1} mol dm^{-3}.

Calculate the equilibrium concentration of PCl_3, Cl_2 and the initial concentration of PCl_5 (K_c = 8.0×10^{-3}mol dm^{-3}) [5]

[Hint use the ICE table below and substitute the ICE table terms to define the equilibrium constant.

	$PCl_{5(g)}$	$\rightleftharpoons$	$PCl_{3(g)}$ +	$Cl_{2(g)}$	$\Delta H = +124$ kJ
Initial Conc:	Y		0	0	
Change in Conc:	-x		+x	+x	
Equilibrium Conc:	y-x		x	x	

$y - x = 0.5\times10^{-1}$

$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{x^2}{y - x}$$

This gives the equation where the only unknown is x^2]

QUESTION 7: REACTIONS IN SOLUTION & STOICHIOMESTRY [20 Marks]

a) In a reaction between iron, Fe, and hydrochloric acid, HCl, two products, $FeCl_2$ and H_2, can be formed according to the equation

$$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

In an experiment, 22.40 g Fe and 27.38 g HCl are reacted

i) Which one is the limiting reactant? [2]

ii) How much H_2 in grams is produced? [2]

iii) How many grams of the reactant in excess will remain after the reaction has topped? [2]

iv) How many grams of $FeCl_2$ would be produced after the reaction has stopped? [2]

v) If 27.20 g of $FeCl_2$ were formed, calculate the percentage yield for this reaction. [2]

b) A sample of a compound is found to contain 64.80 % carbon, 13.62 % hydrogen, and 21.58 % oxygen by weight.

i) What is the empirical formula for this compound? [6]

ii) The molecular weight for this compound is 74.14 g/mol. What is its molecular formula? [4]

Fe or HCl

$C_4H_{10}O$ — 4 x 16

10 x 1.01

4 x 12.01

= 16 + 10.1 + 48.04

$n = \frac{M}{Mr}$

TABLE OF FUNDAMENTAL CONSTANTS

Quantity	Symbol	Value	Power of ten	Units
Speed of light	C	2.9979	10^{8}	$m\ s^{-1}$
Elementary charge	E	1.602	10^{-19}	C
Faraday's constant	$F=N_Ae$	9.6485	10^{4}	$C\ mol^{-1}$
Boltzmann's constant	k	1.380 65	10^{-23}	$J\ K^{-1}$
Gas constant	$R=N_Ak$	8.314 47 8.314 47 8.205 74 6.236 37	 10^{-2} 10^{-2} 10	$J\ K^{-1}\ mol^{-1}$ $L\ bar\ K^{-1}\ mol^{-1}$ $L\ atm\ K^{-1}\ mol^{-1}$ $L\ Torr\ K^{-1}\ mol^{-1}$
Planck's constant	h	6.626 08	10^{-34}	Js
Avogadro's constant	N_A	6.022 14	10^{23}	mol^{-1}
Atomic mass unit	m_u	1.660 54	10^{-27}	Kg
Mass Electron Proton Neutron	 m_e m_p m_n	 9.109 38 1.672 62 1.674 93	 10^{-31} 10^{-27} 10^{-27}	 Kg Kg kg
Rydeberg constant	R_H	1.097 37	10^{7}	m^{-1}
1 atm = 760 mmHg = 760 Torr = $1.01325 \times 10^{5}\ Nm^{-2}$ = 1.01325×10^{5} Pa= 1.01325 bar				

THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

Test One for 2018/2019 Academic Year

DATE: 28th FEBRUARY 2019

COURSE: GENERAL CHEMISTRY

COURSE CODE: CH 110

TIME ALLOWED: TWO (02) HOURS

INSTRUCTIONS TO CANDIDATES:

1. This paper comprises **FOUR** questions printed on pages 2 to 5.
2. Candidates are expected to attempt **ALL** questions.
3. Each question carries **TWENTY-FIVE** marks.
4. Candidates are reminded to **CLEARLY PRESENT** their answers.
5. All the parts of a question should be answered **IN CONTINUATION.**

QUESTION 1: INTRODUCTION **[25 MARKS]**

(a) Copy Tables 1 and 2 into your answer book and complete the missing information.

(i) Fill in the names of the compounds [3]

Table 1: Compounds and their names

Number	Compound	Name of Compound
1	$CaHPO_4$	
2	S_2Cl_2	
3	N_2O_5	

(ii) Fill in the chemical formulae and the common names of the compounds. [3]

Table 2: Chemical formulae of named compounds and their common names

#	IUPAC Compound Name	Formula	Common Name
1	Dihydrogen dioxide		
2	Dinitrogen monoxide		
3	Nitrogen trihydride		

(b) Most elements occur in nature as mixtures of isotopes. Calculate the average relative atomic mass of chlorine given that naturally occurring chlorine is 75.78% ^{35}Cl (atomic mass 34.969 amu) and 24.22% ^{37}Cl (atomic mass 36.966 amu). [4]

(c) Copy Table 3 into your answer book and complete the missing isotopic information for which you will get 1 mark for each correctly completed cell. [6]

Table 3: Information on chlorine and iron isotopes

Isotope	Nucleon number	Neutron number	Electron number
^{35}Cl			
^{55}Fe			

(d) What are the commonly used alternative terms for nucleon number and electron number for an element? [2]

(e) The Table 4 below relates to separation of substances. Copy the table into your answer book and complete the missing items for ½ a mark for each correctly filled cell. [3]

Table 4: Separation of matter

S/No	Separation method	Description of method
1		Select components by particle size
2		Select components by density
3	Crystallisation	
4	Extraction	
5		Select components by boiling point
6		Select components by affinity for a 'stationary phase'

(f) Carry out the following mathematical operations, and give each result with the correct number of significant figures.

(i) $1.05 \times 10^{-3} \div 6.135$ [1]

(ii) $21 - 13.8$ [1]

(f) Copy the table below in your answer book and fill in the order in which the elements in (e) are drawn into a magnetic field. Start with the least drawn element as the first one and end with the most drawn element as the last or fourth one. You will get ½ a mark for each correctly filled cell. [2]

Table 7: Order of elements attraction in a magnetic field.

Order being drawn in magnetic field	1	2	3	4
Element				

(g) Mendeleev is one the first scientists to organise elements into the first periodic table. Explain the difference in how his periodic table and the modern periodic table are organised. [2]

1. Noble gases only in modern periodic table
2. Mendeleev based on atomic mass, modern based on atomic number

QUESTION 3: CHEMICAL EQUILIBRIUM **[25 MARKS]**

(a) (i) What do you understand by the term "chemical equilibrium"? [1]

(ii) State three factors that affect the chemical equilibrium [3]

(b) A mixture of 0.10 mol of NO, 0.050 mol of H_2 and 0.10 mol of H_2O is placed in a 1.0 L vessel at 300 K. The following equilibrium is established.

$$2NO_{(g)} + 2H_{2(g)} \rightleftharpoons N_{2(g)} + 2H_2O_{(g)}$$

At equilibrium, the concentration of NO is 0.062M

(i) Calculate the equilibrium concentration of H_2, N_2 and H_2O [9]

(ii) Calculate the equilibrium constant K_C and show its units [3]

(iii) Then, calculate the equilibrium constant, K_c for the reaction below

$$N_{2(g)} + 2H_2O_{(g)} \rightleftharpoons 2NO_{(g)} + 2H_{2(g)}$$ [3]

(c) (i) State Le chatellier's principle [1]

(ii) For the reaction, $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$, $\Delta H = -93KJ$.

An equilibrium mixture of $PCl_3(g)$, $Cl_2(g)$ and PCl_5 is in a container.

If chlorine gas is added to the container:

What is the effect on the quantity of $PCl_3(g)$ and what is the effect on the equilibrium constant, K_p ? [2]

(iii) If the temperature for the reaction in (ii) above is increased, what is the effect on the quantity of $PCl_3(g)$, *and* PCl_5? and what is effect on the equilibrium constant, K_p? [3]

(iii) As part of a lab assignment to determine the value of the gas constant (R), a student measured the pressure (P), volume (V), and temperature (T) for a sample of gas, where

$$R = \frac{PV}{T}$$

The following values were obtained: P = 2.560, T = 275.15, and V = 8.8. (Since gases will be discussed in detail later on in the course, do not be concerned at this time about the units for these quantities.) Calculate R to the correct number of significant figures. [2]

QUESTION 2: ATOMIC STRUCTURE AND PERIODICITY [25 MARKS]

(a) Complete the first column of the table of the series of electromagnetic lines of atomic spectra of a hydrogen atom. [5]

Table 5: Electromagnetic line series of hydrogen atom

Series	n_1	n_2
	1	2, 3, 4, ...∞
	2	3, 4, 5 .....∞
	3	4, 5, 6 .....∞
	4	5, 6, 7, ...∞
	5	6, 7, 8 .....∞

(b) One application of the wave-particle duality of matter is electron diffraction, which is used to determine the distances between atoms in crystalline solids. Experimentally, this is done by accelerating a beam of electrons to the point where the wavelength of the electron beam is of the same order of magnitude as the distance between atoms (roughly 0.1 – 0.5 nm). How fast would an electron need to be travelling in order to have a wavelength of 0.1 nm? [6]

(c) What is the energy of a photon of light, with a wavelength of 515 nm? [2]

(d) Use the Rydberg equation to explain the electron transition (or give n_1 and n_2) that leads to the emission of the spectral line mentioned in (c) assuming the emission is of a hydrogen atom. [2]

(e) Copy the table below in your answer book and complete it for ¾ of mark per correctly filled cell. [6]

Table 6: Abbreviated electron configuration and number of unpaired valence elements for given elements.

Element	Electron configuration	Unpaired valence shell electrons
Zn		
V		
Cr		
Mn		

$\lambda = \frac{hc}{|\Delta E|}$

$\lambda = \frac{h}{mv}$

$c = \lambda \times v$

$\Delta E = \frac{R_H}{n^2}$

$|\Delta E| = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$|E| = h\nu$

$|\Delta E| = \frac{hc}{\lambda}$

$\nu = \frac{c}{\lambda}$

QUESTION 4: CHEMICAL BONDING AND MOLECULAR GEOMETRY [25 MARKS]

a) From their positions in the periodic table, arrange the atoms in each of the following series in order of increasing electronegativity: [3]

i) C, F, H, N, O
ii) Br, Cl, F, H, I
iii) F, H, O, P, S

b) Identify the most polar bond in each of the following pairs of bonds: [3]

i) HF or HCl
ii) NO or CO
iii) PCl or SCl

c) In the Lewis structures listed here, M and X represent various elements in the third period of the periodic table. Write the formula of each compound using the chemical symbols of each element: [2]

i) $\left[M^{3+}\right]_2\left[:\ddot{\underset{\cdot\cdot}{X}}:\right]^{2-}_3$ ii) $\left[M^{+}\right]_2\left[:\ddot{\underset{\cdot\cdot}{X}}:\right]^{2-}$

d) For each of the following, CNO and CON

i) Draw the Lewis structures [3]
ii) Calculate the formal charge for each element [3]
iii) Determine the best structure based on the formal charges. Explain. [2]

e) Copy the following table on your answer sheet and complete the blank spaces. The first one is already done for you:

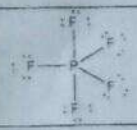
Molecule/Ion	Electron geometry	Molecular geometry	Number of lone pairs of electrons	Lewis structure
i) PF_5	Trigonal bipyramidal	Trigonal bipyramidal	0	
ii) NH_3				
iii) IF_4^-				
	[2]	[2]	[2]	[3]

TABLE OF FUNDAMENTAL CONSTANTS

Quantity	symbol	Value	Power of ten	Units
Speed of light	c	2.9979	10^{8}	$m\ s^{-1}$
Elementary charge	e	1.602	10^{-19}	C
Faraday's constant	$F=N_Ae$	9.6485	10^{4}	$C\ mol^{-1}$
Boltzmann's constant	k	1.380 65	10^{-23}	$J\ K^{-1}$
Gas constant	$R=N_Ak$	8.314 47		$J\ K^{-1}\ mol^{-1}$
		8.314 47	10^{-2}	$L\ bar\ K^{-1}\ mol^{-1}$
		8.205 74	10^{-2}	$L\ atm\ K^{-1}\ mol^{-1}$
		6.236 37	10	$L\ Torr\ K^{-1}\ mol^{-1}$
Planck's constant	h	6.626 08	10^{-34}	Js
Avogadro's constant	N_A	6.022 14	10^{23}	mol^{-1}
Atomic mass unit	m_u	1.660 54	10^{-27}	Kg
Mass				
Electron	m_e	9.109 38	10^{-31}	Kg
Proton	m_p	1.672 62	10^{-27}	Kg
Neutron	m_n	1.674 93	10^{-27}	kg
Rydeberg constant	R_H	1.097 37	10^{7}	m^{-1}
1 atm = 760 mmHg = 760 Torr = $1.01325 \times 10^{5}\ Nm^{-2}$ = 1.01325×10^{5} Pa= 1.01325 bar				

$\frac{J/s}{n}$

J/s/n

515×10^{-9}

The Periodic Table

Atomic Number
Element
Atomic Mass

1	2											3	4	5	6	7	0
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.71	29 Cu 63.55	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.34	57 † La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.21	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 ‡ Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 Nh (284)	114 Fl (289)	115 Mc (288)	116 Lv (291)	117 Ts (Unknown)	118 Og (294)

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	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)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CH 110 : GENERAL CHEMISTRY

TEST 2 : SEPTEMBER 2019

INSTRUCTIONS

1. TIME ALLOWED : TWO (02) HOURS
2. ANSWER ANY THREE (03) QUESTIONS

DO NOT TURN THIS PAPER UNTIL TOLD TO DO SO!

$H_2O + H_2O$

Protons donor acid
Proton acceptor base

QUESTION ONE

(a) Define acids and bases as per
   (i) Arrhenius [2]
   (ii) Bronsted and Lowry [5]

(b) (i) Write the equation that represents the solution of an acid in water and name the products. [4]
   (ii) Then give the equilibrium expression for the reaction at b (i) [4]

(c) Calculate $[H^+]$ or $[OH^-]$ for the following solutions and indicate whether the solution is neutral, acidic or basic
   (i) 1.0×10^{-5} M OH^- [2]
   (ii) 1.0×10^{-7} M OH^- [2]

(d) At 60 °C the value of K_w *is* 1×10^{-13}
   Use Le Chatelier's principle to predict whether the reaction
   $2H_2(l) \rightleftharpoons H_3O^+(aq) + HO^-(aq)$ is exothermic or endothermic [2]

$2H_2O \rightleftharpoons H_2O$

(e) Arrange the following or species in order of their strengths as bases:
   H_2O, F^-, Cl^- *and* CN^- [4]

$\frac{g}{1000} = kg$

QUESTION TWO [25 MARKS]

Chlorine

STOICHIOMETRY

a) Carbon dioxide in the air of a spacecraft can be removed by reacting it with lithium hydroxide to give lithium carbonate and water. On average, a person will exhale about one kilogram of CO_2 per day.
   i) Write a balanced equation for the reaction. [2]
   ii) If you react the given amount of carbon dioxide with 1.5 kg of lithium hydroxide, identify the limiting reagent. [3]
   iii) How many kgs of lithium carbonate do you expect from the quantities of the reactants given? [3]
   iv) If 1,259.20 g of lithium carbonate is produced, calculate the percentage yield of lithium carbonate. [3]
   v) How much in moles is the excess reagent? [3]
   vi) Calculate the percentage composition of each element in lithium carbonate. [3]

$g = kg \times 1000$

Chloride

$HCl + H_2O \rightarrow Cl^- + H_3O^+$

$HCl(aq) \rightarrow Cl^- + H^+$

Cl 6

2: OH

31.31

+ 2 → +

b) Nicotine, an alkaloid in the nightshade family of plants that is mainly responsible for the addictive nature of cigarettes, contains 74.02% C, 8.710% H, and 17.27% N. If 40.57 g of nicotine contains 0.2500 mol nicotine, what is the molecular formula of nicotine? [5]

c) Dianabol is one of the anabolic steroids that has been used by some athletes to increase the size and strength of their muscles. It is similar to the male hormone testosterone. Some studies indicate that the desired effects of the drug are minimal, and the side effects, which include sterility and increased risk of liver cancer and heart disease, keep most people from using it. The molecular formula of Dianabol, which consists of carbon, hydrogen, and oxygen, can be determined using the data from two different experiments. In the first experiment, 14.765 g of Dianabol is burned, and 43.257 g CO_2 and 12.395 g H_2O are formed. In the second experiment, the molecular mass of Dianabol is found to be 300.44 g/mol. What is the molecular formula for Dianabol? [6]

QUESTION THREE **[25 MARKS]**

REACTIONS IN AQUEOUS SOLUTIONS

(a) A solution is prepared by dissolving 36.4 g CaI_2 in 750 mL of water. What is the molarity of the solution?

(b) Identify each of the following changes as either oxidation or

Reduction. Recall that e- is the symbol for an electron.

(i) $I_2 + 2e^- \rightarrow 2I^-$ (ii) $Fe^{2+} \rightarrow Fe^{3+} + e^-$

(c) Identify what is oxidized and what is reduced in the following process.

$$2Ce + 3Cu^{2+} \rightarrow 3Cu + 2Ce^{3+}$$

(d) Identify the oxidizing agent and the reducing agent in the above process. Explain your answer.

(e) Use the oxidation number method to balance the following redox reaction.

$$Cu + HNO3 \rightarrow Cu(NO_3)_2 + NO_2 + H_2O$$

QUESTION FOUR **[25 MARKS]**

ORGANIC CHEMISTRY

(a) Hydrocarbons form the base from which the huge numbers of known organic compounds are assumed to have been derived. State two natural sources of hydrocarbons.

X(b) Write IUPAC names for the following hydrocarbon:

(i) (ii) (iii) (iv)

(c) Write balanced equations for the combustion of each of the following hydrocarbons. Assume that each is converted completely.

(i) Hexane (ii) 2-Methylpentane

(d) Bromine (brown in colour) is used to test for unsaturation in hydrocarbons. Show, by way of a sufficiently labelled chemical reaction of ethene with bromine, how this is possible.

(e) Identify the families of organic compounds to which the following molecules belong:

(i) $CH_3\ CH_2{-}O{-}CH_2\ CH_3$ (ii) (iii) (iv) $CH_3\ CH_2\ CH_2\ NH_2$

C_2H_6BO Ether $-\overset{O}{\overset{\|}{C}}-$ Amide

Lyman	1
Balmer	2
Pasichen	3
Brackt	4
P-fund	5

CH_4 $\cdot\dot{C}^-$

C_nH_{2n+2} $(6\times2)+12$

C_6H_{14} C_2H_4

$+\ O_2$ ethene C_nH_{2n}

C 12.01

O 16.00

L 6.91

H 1.008

N 14.01

I 126.9

C 40.0

12
14
26

13

$C_6H_{14} + 14O_2 \rightarrow 6CO_2 + 7H_2O$

$12 + 7$ 19

2

12 14 24

$24 + 14$ 38

126.
14
20
19
39

THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

MCH 110 (General Chemistry) Date: Friday, 14th June 2019

Instructions to candidates: Time: Two (02) hours

1. This test comprises of 2 printed pages
2. Candidates are expected to attempt **ALL** questions.
3. Candidates are reminded to **CLEARLY PRESENT** their answers.
4. All the parts of a question should be answered **IN CONTINUATION**

---

1. Show that the equilibrium data obtained at 298 K , for the reaction

$$PCl_5\,(g) \rightleftarrows PCl_3\,(g) + Cl_2(g)$$

Experiment	$[PCl_5]$	$[PCl_3]$	$[Cl_2]$
1	0.0023	0.23	0.055
2	0.010	0.15	0.37
3	0.085	0.99	0.47
4	1.00	3.66	1.5

a. Demonstrate the consistency of the mass action expression for a system at equilibrium [2]

b. What is Kc for this reaction? [1]

c. What is Kp for this reaction [2]

2. A pure nitrogen dioxide, NO_2, sample reacts at 1000 K, If at 1000 K the equilibrium partial pressure of O_2 is 0.25 atm, what are the equilibrium partial pressures of NO and NO_2, given that K_p is 158?

$$NO_2(g) \rightleftarrows NO(g) + O_2(g)$$ [4]

3. For the following reaction: $H_3BO_3 + H_2O \rightleftarrows H_3O^+ + H_2BO_3^-$

a. identify the conjugate acid/base pair(s) [2]

b. Calculate the pH of 0.020 M H_3BO_3 [4]

c. What is the percent ionization of H_3BO_3? [2]

4. A 1.000 g sample of a compound containing **C**, **H**, and **O** is combusted in excess oxygen to produce 2.492 g of CO_2 and 0.6495 g of H_2O.
   a. Determine the empirical formula of the compound. [6]
   b. Given that its molar mass is 388.46 g/mol, determine the compound's molecular formula. [2]
   c. Calculate the % composition of each of the element in the compound [3]

5. In an experiment, a student allowed benzene, C_6H_6, to react with excess bromine, Br_2, in an attempt to prepare bromobenzene, C_6H_5Br. This reaction also produced, as a by-product, dibromobenzene, $C_6H_4Br_2$. On the basis of the equation below,

   $C_6H_6 + Br_2 \rightarrow C_6H_5Br + HBr$

   a. What is the maximum quantity of C_6H_5Br that the student could have hoped to obtain from 15.0 g of benzene, C_6H_6? [2]
   b. In this experiment, the student obtained 2.50 g of dibromobenzene, $C_6H_4Br_2$. How much benzene, C_6H_6, was *not* converted to bromobenzene, C_6H_5Br? [2]
   c. What was the student's actual yield of bromobenzene, C_6H_5Br? [2]
   d. Calculate the percentage yield for this reaction. [2]

6. Aluminum reacts with sulfuric acid to produce aluminum sulphate and hydrogen gas according, to the equation: $Al + H_2SO_4 \rightarrow Al_2(SO_4)_3 + H_2$

   If 20.0 g of Aluminum are put into solution containing 115 g of sulfuric acid

   a. Which is the limiting reactant? [2]
   b. How many moles of H_2 will be formed? [2]
   c. How many grams of aluminum sulphate will be formed? [2]
   d. How many grams of the reactant in excess will be left over? [2]

7. A 1.00 g of sample of an iron ore containing Fe_2O_3 was dissolved in an acid and all the iron converted to Fe^{2+}. The solution was titrated with 90.40 cm^3 of 0.0200 M to give Fe^{3+} and Mn^{2+} among the products.

   $Fe^{2+} + MnO_4^- \rightarrow Mn^{2+} + Fe^{3+}$

   a. Balance the equation using the ion-electron method [2]
   b. Calculate the mass of Fe_2O_3 in the sample [2]
   c. What percent of the ore was Fe_2O_3? [2]

Useful data

H_3BO_3 ($Ka = 3.8 \times 10^{-10}$) *$R = 0.08206$ L atm mol^{-1} K^{-1}*

Relative Atomic Masses: C = 12.0, H = 1.01, O = 16.0, Br = 79.9, Al, = 26.9,

S = 32.0, Fe = 55.8, Mn = 54.9, B = 10.8, Cl = 35.45, P = 30.9,

THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

SESSIONAL EXAMINATIONS 2018/2019

DATE: 7 OCTOBER 2019

COURSE: GENERAL CHEMISTRY

COURSE CODE: CH 110

TIME ALLOWED: THREE (03) HOURS

INSTRUCTIONS TO CANDIDATES:

1. This paper comprises **seven** questions printed on pages 2 to 6.
2. Candidates are expected to attempt any **five** questions.
3. Each question carries **twenty** marks.
4. Candidates are reminded to **clearly present** their answers.
5. All the parts of a question should be answered **strictly in continuation.**

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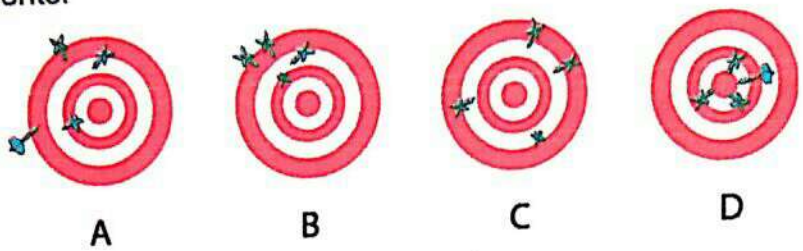
QUESTION 1: INTRODUCTION AND STOICHIOMETRY [20 MARKS]

(a) Four students weigh an item using different scales. These are the values they report:

(i) 20.03 g
(ii) 20.0 g
(iii) 0.2003 kg
(iv) 20 g

How many significant figures should be assumed in each measurement? [2]

(b) The following archery targets show marks that represent the results of four sets of measurements.



Which target shows:

(i) a set of measurements that is both precise and accurate?
(ii) a set of measurements that is neither precise nor accurate?
(iii) a precise but inaccurate set of measurements?
(iv) an accurate but imprecise set of measurements? [2]

(c) A piece of iron (5.59 g) is ignited in a vessel containing 1.60 g of oxygen gas to form Fe_3O_4.

(i) Write a balanced equation for the reaction [1]
(ii) Deduce which reactant is in excess [2]
(iii) For the reactant in excess calculate the amount in moles by which it is in excess. [2]
(iv) Using the limiting reagent, determine how much of the product you would expect. [2]
(v) If the actual mass of the product obtained is 4.64g, calculate the percentage yield. [2]

(d) A compound contains carbon and hydrogen only. On combustion, 0.150 g of the compound gives 0.488 g CO_2 and 0.150 g H_2O. The molar mass is found to be 52.0g.

(i) What is the mass percentage of each element in the compound? [3]
(ii) Calculate the empirical formula of the compound. [2]
(iii) Calculate the molecular formula of the compound. [2]

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+1 -2
HNO_3
$+1 + x + 3(-2) = 0$
$1 + -6 + x = 0$
$-5 + x = 0$
$x = +5$

$x + 3 = 0$
$x = -3$

$2x - 2 = 0$
$\frac{2x}{2} = \frac{2}{2}$
$x = +1$

$1 + x + 2(-2) = 0$
$1 + x - 4 = 0$
$x - 3 = 0$
$x = +5$

$x - 4 = 0$
$x = +4$

QUESTION 2: REACTIONS IN SOLUTIONS [20 MARKS]

(a) Order the following molecules from lowest to highest oxidation state of the nitrogen atom: HNO_3, NH_4Cl, N_2O, NO_2, $NaNO_2$. [2.5]

(b) List the three important types of solution reactions. [½ mark/correct answer] [1.5]

(c) Which of the following statements is (are) true? For the false statements, correct them. [1 mark per correct answer]

(i) A concentrated solution in water will always contain a strong or weak electrolyte.

(ii) A strong electrolyte will break up into ions when dissolved in water.

(iii) An acid is a strong electrolyte.

(iv) All ionic compounds are strong electrolytes in water. [4]

(d) A 1.42 g sample of a pure compound, with formula M_2SO_4, was dissolved in water and treated with an excess of aqueous calcium chloride, resulting in the precipitation of all the sulphate ions as calcium sulfate. The precipitate was collected, dried, and found to weigh 1.36 g. Determine the atomic mass of M, and identify M. [5]

(e) What volume of 0.100*M* HCl will react with 50.00mL of 0.200*M* NaOH? [3]

(f) Metallurgy, the process of producing a metal from its ore, always involves redox reactions. In the metallurgy of galena (PbS), the principal lead-containing ore, the first step is the conversion of lead sulphide to its oxide (a process called *roasting*):

$$2PbS(s) + 3O_2(g) \longrightarrow 2PbO(s) + 2SO_2(g)$$

The oxide is then treated with carbon monoxide to produce the free metal:

$$PbO(s) + CO(g) \longrightarrow Pb(s) + CO_2(g)$$

$C = \frac{n}{V}$

For each reaction, identify the atoms that are oxidized and reduced, and specify the oxidizing and reducing agents. [4]

QUESTION 3: ATOMIC THEORY AND PERIODICITY [20 MARKS]

(a) Blue colour in fireworks is achieved by heating Copper (I) Chloride (CuCl) to a temperature of about 1200^{0}C. This compound then emits blue light having a wavelength of 450 nm, what is the increment of energy (quantum) that is emitted at 4.50×10^2 nm by CuCl? [3]

(b) Wave-particle duality of matter can be applied in electron diffraction, it is usually used to determine the distances between atoms in crystalline solids. Experimentally, this is done by accelerating a beam of electrons to the point where the wavelength of the electron beam is of the same order of magnitude as the distance between atoms (roughly 0.1 – 0.5 nm). How fast would an electron need to be travelling in order to have a wavelength of 0.1 nm? [6]

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(c) Hydrogen can be excited from level n=1 to level n=2, for this action to take off energy is required. Calculate the energy required and wavelength of light that must be absorbed by a hydrogen atom in its ground state to reach the excited state. [4]

(d) Using the Aufbau Principle, write the electronic configuration of the following atoms. [3]

(i) Sulphur (S) (ii) Gallium (Ga) (iii) Radium (Ra)

(e) Consider atoms with the following electronic configuration.

(i) $1s^2 2s^2 2p^6$ (ii) $1s^2 2s^2 2p^6 3s^1$ (iii) $1s^2 2s^2 2p^6 3s^2$

Which atom has the largest first ionization energy, and which one has the smallest second ionization energy? Explain your choices. [2]

(f) Predict the trend in radius for the following ions starting with the smallest: Be^{2+}, Mg^{2+}, Ca^{2+} and Sr^{2+}. [2]

QUESTION 4: CHEMICAL BONDING & MOLECULAR GEOMETRY [20 MARKS]

(a) (i) The four common types of chemical bonds are covalent, ionic, metallic and intermolecular. Under which of these types would you place a coordinate or dative bond? Give a reason for your answer. [2]

(ii) Which type of chemical bonding would you ascribe to two group 4 elements that bond together. Explain why the bonding type you have mentioned would **not** be ionic bonding. [2]

(b) Electronegativity plays a major role in chemical bonding as it has a bearing on the type of bonding that will occur between combining elements. From their positions in the periodic table, arrange the atoms in each of the following series in order of increasing electronegativity:

(i) As, H, N, P, Sb (ii) Cl, H, P, S, Si [5]

(c) Write Lewis structures for the following:

(i) SbH_3 (ii) PCl_5 [6]

(d) (i) According to the VSEPR model, what are the arrangements (geometry) of ***two, three, four, five, and six*** valence-shell electron pairs about an atom? [2.5]

(ii) In deciding the molecular geometry of a molecule or ionic species using the VSEPR model, why is a lone pair expected to occupy an equatorial (horizontal) position instead of an axial (vertical) position in the ***trigonal bipyramidal*** arrangement? [2.5]

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QUESTION 5: ORGANIC CHEMISTRY **[20 MARKS]**

(a) Draw a structural formula for each of the following compounds [2]

(i) 2-methyl propane [2]

(ii) 2,2-dimethyl heptane [2]

(iii) 2,2,4-trimethyl pentane [2]

(b) The following organic compounds cannot exist why? [2]

(i) 2-methyl-2-propanone [2]

(ii) 1,1–dimethyl benzene [2]

(c) Name each of the following compounds [2]

(i) $CH_2 = CH–CH_2–CH_3$ [2]

(ii) $CH_3\ CH_2CH_2CH_2CCl_3$ [2]

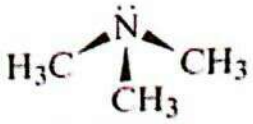
(d) Give the structure for 2–methyl–3–octene [2]

(e) Complete the following reactions:-

(i) $CH_3\,CH = CHCH_3 + H_2 \xrightarrow{Pt}$ [2]

(ii) $CH_3\ CH_2\ C \equiv CH + 2HBr \longrightarrow$ [2]

QUESTION 6: ACIDS AND BASES **[20 MARKS]**



Trimethylamine

(a) For a dilute solution for trimethylamine, write the equation for its acid-base equilibrium and specify the conjugate base and the conjugate acid of this reaction. [6]

(b) Using the given list of salts, identity those that produce a neutral, acidic and basic solution. $NaC_2H_3O_2$, NaCl, NaF, $AlCl_3$, KNO_3 and $Al_2(SO_4)_3$ [3]

(c) In this problem of a salt as weak acid, calculate the pH of a 0.10 M NH_4Cl solution. The K_b value for NH_3 is 1.8×10^{-5}. [6]

(d) Copy and complete the table below to give the various definitions of acids and bases. [3]

Type of definition	Acid	Base
Arrhenius		
Bronsted-Lowry		
Lewis		

(e) Give two examples of polyprotic acids [2]

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QUESTION 7: CHEMICAL EQULIBRIUM **[20 MARKS]**

(a) What is chemical equilibrium? [1]

(b) Write the concentration equilibrium constant (K_c) expressions for each of the following chemical reactions.

(i) $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$

(ii) $Ni(s) + 4CO(g) \rightleftarrows Ni(CO)_4(g)$

(iii) $CaCO_3(s) \rightleftarrows CaO(s) + CO_2(g)$ [6]

(c) (i) What does Le Ch^atelier's principle state about the effect of an addition of NH_3 on a mixture of N_2 and H_2 before it attains equilibrium? [2]

(ii) Write an "equation" for the addition of heat to a water-ice mixture at 0°C to produce more liquid water at 0°C. Which way does the equilibrium shift when you try to lower the temperature? [2]

d) Calculate the value of the equilibrium constant in the following reaction if 1.50 mol of A and 2.50 mol of B are placed in 1.00 L of solution and allowed to come to equilibrium. The equilibrium concentration of C is found to be 0.45 *M*. [4]

$$A + B \rightleftarrows C + D$$

(e) A mixture of 0.500 mol H_2 and 0.500 mol I_2 was present in 1 litre flask at 430 °C. Calculate the concentrations of H_2, I_2 *and* HI at equilibrium. The equilibrium constant for the reaction at this temperature is 54.3 [5]

$$H_2(g) + I_2(g) \rightleftarrows 2HI(g)$$

– END –

$(0.5-x)(0.5-x)$

$0.25 - 0.5x - 0.5x$

$0.25 - x + x^2$

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TABLE OF FUNDAMENTAL CONSTANTS

Quantity	symbol	Value	Power of ten	Units
Speed of light	c	2.9979	10^{8}	$m\ s^{-1}$
Elementary charge	e	1.602	10^{-19}	C
Faraday's constant	$F=N_Ae$	9.6485	10^{4}	$C\ mol^{-1}$
Boltzmann's constant	k	1.380 65	10^{-23}	$J\ K^{-1}$
Gas constant	$R=N_Ak$	8.314 47 8.314 47 8.205 74 6.236 37	 10^{-2} 10^{-2} 10	$J\ K^{-1}\ mol^{-1}$ $L\ bar\ K^{-1}\ mol^{-1}$ $L\ atm\ K^{-1}\ mol^{-1}$ $L\ Torr\ K^{-1}\ mol^{-1}$
Planck's constant	h	6.626 08	10^{-34}	Js
Avogadro's constant	N_A	6.022 14	10^{23}	mol^{-1}
Atomic mass unit	m_u	1.660 54	10^{-27}	Kg
Mass Electron Proton neutron	 m_e m_p m_n	 9.109 38 1.672 62 1.674 93	 10^{-31} 10^{-27} 10^{-27}	 Kg Kg kg
Rydeberg constant	R_H	1.097 37	10^{7}	m^{-1}
1 atm = 760 mmHg = 760 Torr = $1.01325 \times 10^{5}\ Nm^{-2}$ = 1.01325×10^{5} Pa= 1.01325 bar				

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Atomic Number

Element

Atomic Mass

1	2											3	4	5	6	7	0
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.71	29 Cu 63.55	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.34	57 † La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.21	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 ‡ Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (291)	117 Uus (Unknown)	118 Uuo (294)

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	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)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

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THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

DEPARTMENT OF CHEMISTRY

2017/2018 ACADEMIC YEAR

CHEMISTRY CH 110 TEST ONE

TIME ALLOWED: Two (2) Hours.

DATE: 04/ 12/ 2017

INSTRUCTIONS:

(i) Attempt all the four questions, each question carries 25 Marks.
(ii) All calculated quantities must have units and reported to the correct number of significant figures.
(iii) Do not open till instructed to do so.

IMPORTANT DATA:

Physical Constants		
Constant	**Symbol**	**Value**
Planck's constant	h	6.626×10^{-34} J s
Speed of light (vacuum)	c	2.998×10^{8} m s^{-1}
Rydberg constant	R_H	$1.097 \times 10^{7} m^{-1}$
Rydberg energy	R_E	2.179×10^{-18} J
Atomic mass unit	*Amu*	1.660554×10^{-27}kg
Avogadro's number	N_A	$6.02214 \times 10^{23} mol^{-1}$
Gas constant	R	8.31451 J $K^{-1} mol^{-1}$
		0.08206 L atm$K^{-1} mol^{-1}$
1 atm = 760mmHg = 1.0132×10^{5} Nm^{-2} = 1.0132×10^{5}Pa		

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QUESTION 1 — 25 MARKS

(a) If the earth's oceans contain approximately 1.36×10^{21} L of water.

i) Calculate this volume in cubic kilometres. [3]

ii) Use the appropriate prefix to write the value of 1.36×10^{9} L without exponents. [1]

(b) Copperbelt University (CBU) is situated in the town of Kitwe in Zambia whose temperature on 25 October 2017 at 14:23 hours was 30°C. What is this temperature reading in

i) Fahrenheit [1]

ii) Kelvin [1]

(c) By referring to the periodic table provided, reproduce the table below and correctly fill in the third and fourth column. *(Hint: The first row is an example of how to complete the table; 0.5 marks for each correctly filled cell)* [5]

Number	Element Symbol	Element class (metal, non-metal or metalloid)	Element group
1	He	Non-metal	Noble gas
2	Se	Non-metal	6A
3	Cu	metal	Transitional (11B)
4	Cs	Metal	Alkali metal (1A
5	Br	non-metal	7A (Halogens)
6	As	metalloid	5A

(d) What is the nuclide symbol for a nucleus that contains 38 protons and 50 neutrons? [2]

(e) Chromium, Cr, has the following isotopic masses and fractional abundances

Mass Number	Isotopic Mass (amu)	Fractional Abundance
50	49.9461	0.0435
52	51.9405	0.8379
53	52.9407	0.0950
54	53.9389	0.0236

What is the atomic mass of chromium? [2]

(f) Give the answers to the following questions

i) State the laws of definite proportions and conservation of matter. [2]

ii) Name the two types of properties commonly used to characterize or identify substances [2]

(g) Perform the following calculations and round the answers to the correct number of significant figures (units of measurement have been omitted) [4]

(i) $\frac{2.568 \times 5.8}{4.186}$ (ii) $5.41 - 0.398$ (iii) $3.38 - 0.31$ (iv) $4.18 - 58.16 \times (3.38 - 3.01)$

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QUESTION 2 **25 MARKS**

(a) The percentage composition of caffeine is 49.5% C, 5.15% H, 28.9% N, and 16.5% O.

i) What is the empirical formula of caffeine? [2]

ii) Determine the molecular formula of caffeine if its molar mass is 195g/mol [2]

(b) A solution containing 3.5 g of sodium phosphate is mixed with a solution containing 6.4 g of barium nitrate.

i) Write a balanced equation for the reaction taking place [2]

ii) Write the complete ionic equation for the reaction taking place [2]

iii) Write the net ionic equation for the reaction taking place [2]

iv) Calculate the number of moles for each reactant [3]

v) Determine the limiting reagent for this reaction [2]

vi) For the reagent in excess, calculate the mass that remains after the reaction [3]

vii) Calculate the mass of barium phosphate formed in this reaction [3]

(c) In an experiment, 5.50 g of $SOCl_2$ was obtained from the reaction of 5.80 g of SO_2 with excess PCl_5 according to the following reaction equation:

$$SO_2(l) + PCl_5(l) \rightarrow SOCl_2(l) + POCl_3(l)$$

i. What is the theoretical yield of $SOCl_2$? [2]

ii. Determine the percentage yield of $SOCl_2$ [2]

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QUESTION 3 **25 MARKS**

(a) Name three examples of nonelectrolytes apart from sugar and alcohol. [3]

(b) Spanner Zulu, from Mutenguleni University made 10.0 L of 1.2 M Sobo drink. What was the initial molarity of the Sobo drink if he used only 2.5 L of it? [2]

(c) What volume in mL of 0.250 M potassium hydroxide solution is needed to react completely with a solution containing 1.00 g of phosphoric acid? [4]

(d) Kombe Chileshe from Lubushi University in Kasama was asked to prepare an insoluble salt called calcium phosphate from the reaction of calcium chloride and sodium phosphate.

i) What name is given to the type of reaction above? [1]

ii) Write the balanced chemical equation for the formation of calcium phosphate [2]

iii) Write the net ionic equation to show the formation of calcium phosphate [2]

(e) Identify the species that are reducing and oxidizing agents in each of the following reaction.

i) $2Al + 3Cu^{2+} \rightarrow 2Al^{3+} + 3Cu$ [2

ii) $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ [2

$x + (-6) = 6$ $x + (2 \times 2) =$

(f) Consider the redox reaction below

$$Cr_2O_7^{2-}(aq) + HNO_2(aq) \rightarrow Cr^{3+}(aq) + NO_3^-(aq)$$

i) Write the balanced oxidation half reaction of the equation above

ii) Write the balanced reduction half reaction of the equation above

iii) Write the balanced overall reaction in basic medium of the equation above

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QUESTION 4 **25 MARKS**

(a) Complete information on a shell with n = 5

i) What is the total number of sub-shells in this level? 5 [1]

ii) Name the sub-shells [2.5]

iii) What is the maximum number of electrons that can be held by this shell? $2n^2 = 50$ [1]

iv) In relation to the number of electrons in each sub-shell for elements in the ground state, what is your comment on the last sub-shell in question 4a (iii) above? [0.5]

v) Give the name of the first element found in the periodic table for each sub-shell in 4a(iii) in the first column of the table below and give the element's condensed electronic configuration. [4]

Sub-shell	Element	Condensed electronic configuration

(b) Complete information on a sub-shell with n = 5 and l =3

i) Write the electronic configuration of sulphur, Z=16.

ii) Draw the orbital diagram for sulphur

iii) How many unpaired electrons does sulphur atom posses?

(c) Take sulphur as a case study

i) Draw the orbital diagram for the electron configuration of sulphur Z=16

ii) How many unpaired electrons does sulphur atom possess? ~~Which principle is used in this case~~?

iii) Which pricimple is used in this case

(d) Ionization energy is a vital parameter properties of elements

Element	I1	I2	I3	I4
Na	495	4562		
Mg	738	1451	7733	
Al	578	1817	2745	11,577

i) Define ionization energy (IE)?

ii) Explain the trend observed in IE values from the s to p block elements in the periodic table.

iii) There is drastic leap in the 4th IE of aluminum element. Explain the reasons for this observation

(e) Answer True or False for of the following statements

i) Blue light has a greater wavelength than red light. F

ii) Red light has a lower frequency than blue light T

iii) A red light photon has lower energy than a blue light photon. T

(f) Consider the hypothetical atom X that has one electron like the H atom but has different energy levels. The energies of an electron in an X atom are described by the equation

$$E_{X,n} = -\frac{R_H}{n^3}$$

where R_H is the same as for the hydrogen atom (2.179×10^{-19}J).

i) True or False: X atom would require more energy than the H atom to completely remove its electron.

ii) Explain your answer in 4f (i) above.

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THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

CH 110: GENERAL CHEMISTRY

TEST 2, 2017/18 ACADEMIC YEAR

TIME ALLOWED: TWO (02) HOURS

INSTRUCTIONS TO CANDIDATES:

1. *This paper comprises 4 questions, and is printed on 10 pages. Candidates are expected to attempt **any 3** questions.*
2. *Each question carries **twenty five (25)** marks.*
3. *Candidates are to **present their answers clearly**.*
4. *The answers to all the parts of a question should be **in strict continuation**.*
5. *Start answering a new question on a new page of the answer booklet.*

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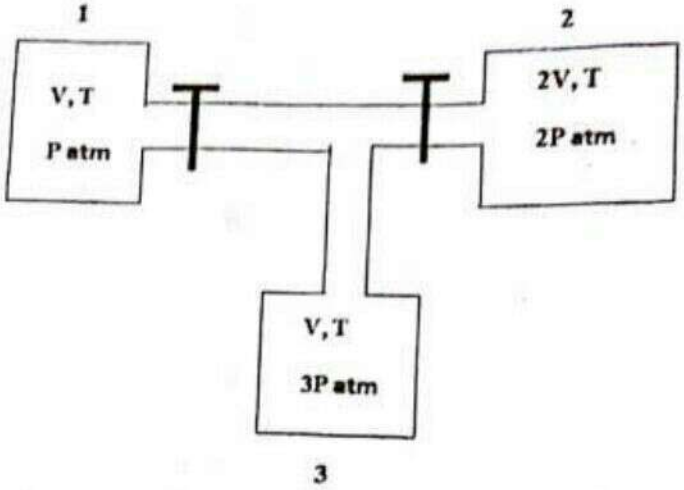
QUESTION 1: GASES

a) When we open the valves given in the picture below, state whether the pressure of the gas will increase, decrease, or remain constant in each container. [5]



b) State whether each of the following statements is true or false. [4]

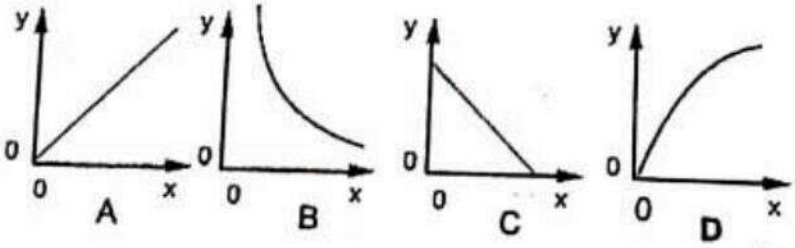
(i) According to Charles Law, if you have a balloon inside a car at noon during a hot summer day the balloon molecules inside will increase in pressure.

(ii) A good example of Charles Law is when a piece of metal expands in the heat.

(iii) You drove continuously from Kitwe to Lusaka and you observed that the pressure in your tires increased. This is because of the increased temperature outside the tire caused by friction.

(iv) Charles' law is involved when a balloon bursts when you sit on it.

c) Answer the following questions based on the graphs below: [3]



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(i) Which graph shows the variation in **volume** (y) of a fixed mass of ideal gas at constant pressure with **absolute temperature** (x)?

(ii) Which graph shows the variation in volume (y) of a fixed mass of ideal gas at constant temperature with pressure (x)?

(iii) Which gas law is being shown graphically in (ii) above? [1]

d) (i) What is an ideal gas? [1]

(ii) State one reason why ammonia gas deviates from an ideal behavior. [1]

(iii) State one condition under which the deviation of ammonia from ideal behavior will be more pronounced. [1]

e) A small quantity of the volatile organic solvent propanone (C_3H_6O) evaporates at room temperature and pressure. Assuming that propanone is an ideal gas, calculate the volume, in litres, of propanone vapour formed when 0.29 g of liquid propanone evaporates taking room temperature as 20^0C and room pressure as 101kPa. [4]

f) Carbon dioxide gas (1.00 mol) at 373 K occupies 536 mL at 50.0 atmosphere pressure. What is the calculated value of the pressure using:

(i) Ideal gas equation [2]

(ii) Van der Waals equation? [3]

(iii) Give one reason why the two values are different [1]

[Data: Van der Waals constants for carbon dioxide: $a = 3.61\ L^2\ atm\ mol^{-2}$; $b = 0.0428\ Lmol^{-1}$; $R = 8.314 J.K^{-1}mol^{-1}$ or $0.08206\ L.atm.mol^{-1}.K^{-1}$]

QUESTION 2 – THERMOCHEMISTRY

a) The enthalpy change for the reaction

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$$

is −891 kJ for the reaction *as written.*

(i) What quantity of heat is released for each mole of water formed? [2]

(ii) What quantity of heat is released for each mole of oxygen reacted? [2]

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b) Consider the following reaction:

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H = -891 \text{ kJ}$$

Calculate the enthalpy change for each of the following cases:

(i) 1.00 g methane is burned in excess oxygen. [3]

(ii) 1.00×10^3 L methane at 740 torr and 25°C is burned in excess oxygen. [3]

c) It takes 585 J raise the temperature of 125.6 g mercury from 20.0°C to 53.5°C. Calculate the specific heat capacity and the molar heat capacity of mercury. *Hints: specific heat or* $s = \frac{q}{m \times \Delta T}$ *and molar specific heat or* $s_{molar} = \frac{q}{m \times \Delta T} \times M_r = s \times M_r$ [4]

d) Calculate ΔH^o_{rxn} for reactions below using the data in Appendix 4. *Hint: Use the equation* $\Delta H^o_{rxn} = (sum\ of\ n_{products} \times \Delta H^o_{f,prodcuts}) - (sum\ of\ n_{reactants} \times \Delta H^o_{f,reactants})$.

(i) $4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$ [3]

(ii) $2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$ [3]

(iii) $2Na(s) + CO_2(g) \longrightarrow 2Na_2O(s) + CO(g)$ [3]

(iv) Explain why a water or carbon dioxide fire extinguisher might not be effective in putting out a sodium fire. [2]

QUESTION 3 – CHEMICAL BONDING

a) Hot and spicy foods contain molecules that stimulate pain-detecting nerve endings. Two such molecules are piperine and capsaicin:

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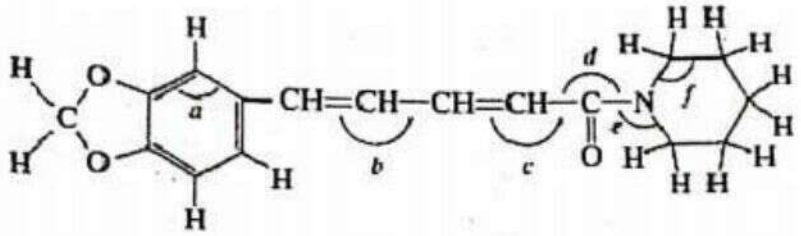
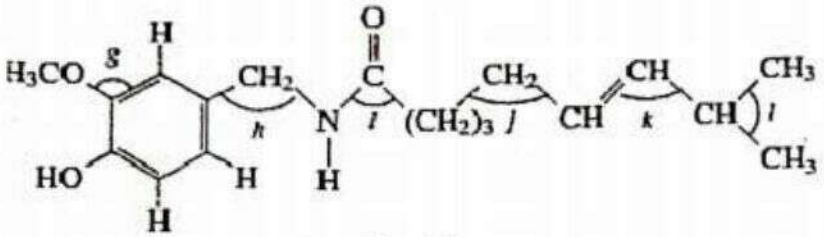


Piperine



Capsaicin

Piperine is the active compound in white and black pepper, and capsaicin is the active compound in chili peppers. The ring structures in piperine and capsaicin are shorthand notation. Each point where lines meet represents a carbon atom.

(i) On a single page and writing your answer in landscape mode of your paper, complete the Lewis structure for piperine and capsaicin showing all lone pairs of electrons. [4]

(ii) Copy the table below and use it to show how many carbon atoms are sp, sp^2, and sp^3 hybridized in each molecule? [6]

Number of carbon atoms with specified hybrid orbitals	Piperine	Capsaicin
sp		
sp^2		
sp^3		

(iii) Copy the table below and use it to indicate the hybrid orbitals used by the nitrogen atoms in each molecule? [2]

Molecule	Piperine	Capsaicin
Hybrid orbitals used by nitrogen atoms		

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(iv) Copy the table below and complete it by filling in the approximate values for the bond angles marked *a* through *l* in the above structures. [6]

Piperine Molecule		Capsaicin Molecule	
Angle number	Angle Value	Angle number	Angle Value
a		g	
b		h	
c		i	
d		j	
e		k	
f		l	

b) Predict the type of bond (ionic, covalent, or polar covalent) one would expect to form between the following pairs of elements. [3]

(i) Rb and Cl (ii) S and S (iii) C and F (iv) Ba and S (v) N and P (vi) B and H

c) (i) Order the following species with respect to carbon–oxygen bond length (longest to shortest). [1]

CO, CO_2, CO_3^{2-}, CH_3OH

(ii) What is the order from the weakest to the strongest carbon–oxygen bond? (CH_3OH exists as $H_3C{-}OH$.) [1]

d) ClF_5, is a compound whose central atom does not follow the octet rule. Draw the Lewis structure for this compound. [1]

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QUESTION 4: ORGANIC CHEMISTRY

a) (i) What do the terms "*saturated*" and "*unsaturated*" mean when applied to hydrocarbons? [2]

(ii) Give an example of a saturated and an unsaturated hydrocarbon. [2]

b) Suggest two chemical tests that would help you distinguish between $CH_3CH_2CH_2CH_2CH_3$ and $CH_3CH_2CH_2CH{=}CH_2$ [2]

c) Draw the structures and write the name of each structure for all the distinct chloropentanes, $C_5H_{11}Cl$ that could be produced in the direct chlorination of n-pentane, $CH_3CH_2CH_2CH_2CH_3$ [6]

d) Copy the following table in your answer booklet and classify each of the molecules as alcohol, aldehyde, ketone, carboxylic acid, amine, or ether. Suggest the name for each molecule: [6]

MOLECULE	CLASSIFICATION
$CH_3{-}O{-}CH_2{-}CH_3$	
$CH_3{-}CH_2{-}NH_2$	
$CH_3{-}CH_2{-}C(=O){-}H$	
$CH_3{-}C(=O){-}CH_2{-}CH_3$	
$H{-}C(=O){-}OH$	
$CH_3{-}CH_2CH_2{-}OH$	

d) Write structures for the following compounds: [3]

i) 1-bromo-3-methyl hexane

ii) 1-chloro-2-propyl-4-hexene

iii) 1,2,3,4-tetramethyl benzene

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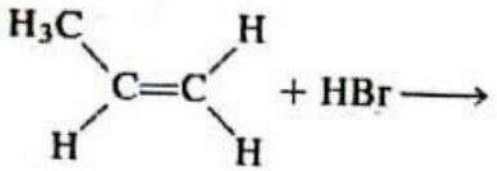
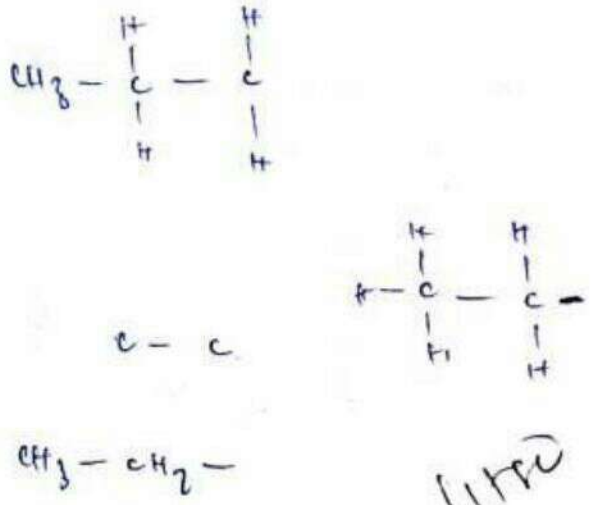
e) (i) Draw structures of the possible products of the following reaction [2]



propene

(ii) In reality, which one of the structures you have drawn in e(i) above is actually formed? [2]



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THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

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CHEMISTRY DEPARTMENT

SESSIONAL EXAMINATIONS 2017/2018

DATE: 13 AUGUST 2018

COURSE: GENERAL CHEMISTRY

COURSE CODE: CH 110

TIME ALLOWED: THREE (03) HOURS

INSTRUCTIONS TO CANDIDATES:

1. This paper comprises **eight** questions printed on pages 2 to 8.
2. Candidates are expected to attempt any **five** questions.
3. Each question carries **twenty** marks.
4. Candidates are reminded to **clearly present** their answers.
5. All the parts of a question should be answered **strictly in continuation.**

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QUESTION 1: ACIDS AND BASES

[20 MARKS]

(a) Answer the following questions

(i) What is the Arrhenius definition of an acid? Give an example of an acid according to this theory. [2]

(ii) What is the Arrhenius definition of a base? Give an example of a base according to this theory. [2]

(b) When ethanoic acid is added to water, it reacts reversibly to give ethanoate ions and hydroxonium ions.

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

Use this reaction to explain the meaning of the terms conjugate acid and conjugate base, clearly picking out the conjugate pairs. [4]

(c) Which of the following conditions indicate a *basic* solution at 25°C? [2]

(i) $pOH = 11.21$

(ii) $pH = 9.42$

(d) Use the following equations to help you to explain what is meant by the statement that "water is amphoteric". [2]

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$
$$HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$$

(e) Answer the following questions

(i) Define the terms Lewis acid and Lewis base. [2]

(ii) Draw a dots-and-crosses diagram of a molecule of aluminium chloride, $AlCl_3$, showing outer electrons only. Would you expect this to behave as a Lewis acid, a Lewis base, or neither, or both? Explain your answer. [3]

(f) Calculate the concentration of acetic acid, CH_3COOH, whose pH and K_a are 3.40 and 1.7×10^{-5}, respectively. [3]

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QUESTION 2: THERMOCHEMISTRY

(a) Answer the following questions **[20 MARKS]**

(i) What is thermochemistry? [1]

(ii) State first law of thermodynamics [1]

(b) Copy the table of state functions below into your answer booklet and complete its second and third columns as shown for (i) [5]

State function	The function is an extensive one (True or False)	Its S.I. units are
(i) Volume	True	m^3
(ii) Density		
(iii) Internal Energy		
(iv) Molar Internal Energy		
(v) Enthalpy		
(vi) Molar Enthalpy		

(c) Answer the following questions relating to Hess's Law

(i) State Hess's Law [1]

(ii) The enthalpy of combustion of N_2 are given in the reaction equations below

$$\tfrac{1}{2}N_2(g) + \tfrac{1}{2}O_2 \longrightarrow NO(g) \qquad \Delta H_f^o = 90\ kJ/mol$$
$$\tfrac{1}{2}N_2(g) + O_2 \longrightarrow NO_2(g) \qquad \Delta H_f^o = 33.18\ kJ/mol$$

Use these equations to derive and calculate the heat of combustion of the reaction $NO(g) + \tfrac{1}{2}O_2 \longrightarrow NO_2(g)$. [4]

(iii) The enthalpy of combustion of solid carbon to form carbon dioxide is −393.7 kJ/mol carbon, and the enthalpy of combustion of carbon monoxide to form carbon dioxide is −283.3 kJ/mol CO. Use these data to calculate ΔH for the reaction [3]

$$2C(s) + O_2(g) \longrightarrow 2CO(g)$$

(iii) The bombardier beetle uses an explosive discharge as a defensive measure. The chemical reaction involved is the oxidation of hydroquinone by hydrogen peroxide to produce quinone and water:

$$C_6H_4(OH)_2(aq) + H_2O_2(aq) \longrightarrow C_6H_4O_2(aq) + 2H_2O(l)$$

Calculate ΔH for this reaction from the following data [5]

$$C_6H_4(OH)_2(aq) \longrightarrow C_6H_4O_2(aq) + H_2(g) \qquad \Delta H = +177.4\ kJ$$
$$H_2(g) + O_2(g) \longrightarrow H_2O_2(aq) \qquad \Delta H = -192.2\ kJ$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(g) \qquad \Delta H = -241.8\ kJ$$
$$H_2O(g) \longrightarrow H_2O(l) \qquad \Delta H = -43.8\ kJ$$

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QUESTION 3: ATOMIC THEORY AND PERIODICITY [20 MARKS]

(a) Which metal in each of the following sets will be drawn into a magnetic field the most? [4]

(i) Zn Mn V (ii) Ca Cu Cd (iii) Sc Cu V (iv) Ti Tl Ga

(b) What is wrong with each of the following ground state configurations? [4]

(i) $1s^2\,2p^6\,3d^{10}\,4f^{14}$ (ii) $1s^2\,2s^2\,2p^4\,3s^2\,3p^6$ (iii) $[Xe]\,6s^2\,5d^{10}\,4f^{15}$

(iv) $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^{14}$

(c) How many unpaired electrons are present in the ground state of an atom if there are five electrons in each of the following subshells? There are no other unpaired electrons. [3]

(i) 3*p* subshell (ii) 3*d* subshell (iii) 4*f* subshell

(d) Identify the element from each of the following *partial* configurations of neutral atoms: [2]

(i) $\ldots 3d^{10}\,4p^5$ (ii) $\ldots 7s^2\,6d^1\,5f^{14}$

(e) Calculate the energy of a photon of light of wavelength 4.340×10^{-7} m, corresponding to a line in the visible spectrum of hydrogen. [3]

(f) Answer each the following questions using one sentence only:

(i) What is the difference, if any, between an *s* subshell and an *s* orbital? [2]

(ii) What is the difference, if any, between a *p* subshell and a *p* orbital? [2]

QUESTION 4: CHEMICAL BONDING & MOLECULAR GEOMETRY [20 MARKS]

(a) Xenon can react with oxygen and fluorine to form compounds such as XeO_3 and XeF_4. Draw the complete Lewis electron-dot diagram for each of these molecules.

(i). XeO_3 [2] (ii) XeF_4 [2]

(b) On the basis of the Lewis electron-dot diagrams you drew for part (a), predict the following:

(i) The geometric shape of the XeO_3 molecule. [1]

(ii) The geometric shape of the XeF_4 molecule. [1]

(i) The hybridization of the valence orbitals of xenon in XeO_3 [1]

(iv) The hybridization of the valence orbitals of xenon in XeF_4. [1]

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(c) Predict whether the XeO_3 molecule is polar or nonpolar. Justify your prediction. [3]

(d) Explain why the CH_2F_2 molecule is polar, whereas the CF_4 molecule is not. [2]

(e) Calculate the formal charges of atoms in;

(i) XeO_3 [2] (ii) XeF_4 [2]

(f) List the three possible molecular geometries which have sp^3 hybridized orbitals. [3]

QUESTION 5: ORGANIC CHEMISTRY

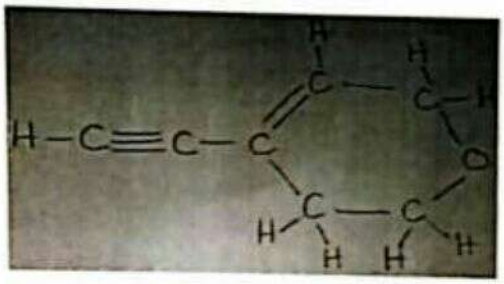
[20 MARKS]

(a) State whether each of the following statements is true or false [2]

(i) 3-propyl heptane and n-decane are structural isomers

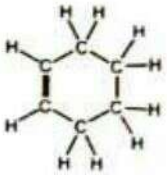
(ii) A series of compounds whose structures differ from each other by a specific structural unit is called a homologous

(b) Copy the following molecule in your answer booklet and label all the sp and sp^2 hybridized carbon atoms. [4]



(c) Answer the following questions based on the structures of organic compounds given below:

P



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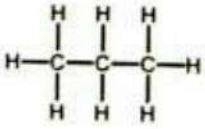

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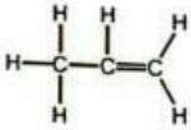

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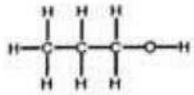

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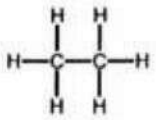

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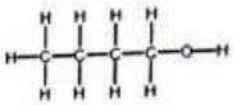

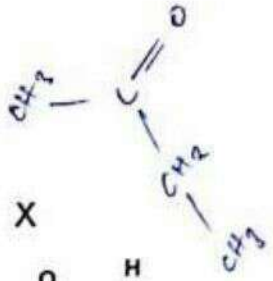

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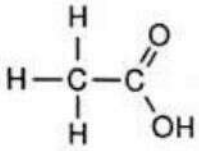

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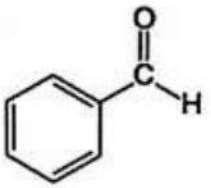

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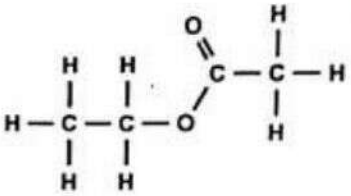


(i) Which **two** of these compounds are alcohols? [2]

(ii) Which **two** of these compounds are saturated hydrocarbons? [2]

(iii) Identify any **two** of these compounds that are not hydrocarbons? [2]

(iv) Which **one** of these compounds is a ketone? [1]

(v) Suggest the name of the main product when compound R reacts with hydrogen bromide [2]

(vi) Suggest the names of the products when compound Q completely reacts with oxygen [2]

(d) Write down the structural formula and the name of an aldehyde that is an isomer of acetone (propanone) [1]

(e) Draw the structures of the following organic molecules [2]

(i) 2-methyl-3-ethyl heptane

(ii) 1,2-dimethyl benzene

HBr

CH_3C

C_nH_{2n}

$C_3H_6 + HBr$

C_nH_{2n+2}

C_2H

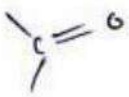
QUESTION 6: REACTIONS IN SOLUTION [20 MARKS]

(a) Define the following

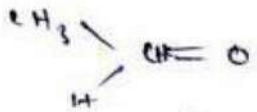
C_3H_8

(i) Titrant [1]

(ii) Standard solution [1]



$CH_3-CH_2-CH_3$



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(b) Answer the following questions

(i) What is the difference between an end point and the equivalence point in a titration? [2]

(ii) What is the difference between a direct titration and a back titration? [2]

(c) Answer the questions below

(i) Calculate the molarity of silver nitrate solution when 117.40 g of silver nitrate is dissolved in a litre of solution. [3]

(ii). Calculate the amount of sodium hydroxide in milligrams for a 0.500 mol/L sodium hydroxide solution whose volume is 100 mL. [3]

(d) A 0.500 g sample containing sodium dihydrogen phosphate is titrated with sodium hydroxide:

$$OH^- + H_2PO_4^- \longrightarrow HPO_4^{2-} + H_2O$$

If 23.06 mL of 0.0985 M sodium hydroxide is required for the titration, what is the percentage of NaH_2PO_4 in the sample? [4]

(e) A 0.3147 g sample of primary standard grade $Na_2C_2O_4$ was dissolved in dilute H_2SO_4 and titrated with a solution of $KMnO_4$. The end point was observed after the addition of 31.67 mL of the titrant. Use the unbalanced reaction in acidic media is given below to write the balance redox reaction. [4]

$$C_2O_4^{2-} + MnO_4^- \longrightarrow Mn^{2+} + CO_2 + H_2O$$

QUESTION 7: GASES [20 MARKS]

(a) The pressure of a gas is measured as 49 torr. Represent this pressure in both atmospheres and pascals. [4]

(b) State the two gas laws below, give each law's mathematical representation and sketch a graphical plot of the mathematical relation that you give for each law. [6]

(i) Boyle's Law (ii) Avogadro's Law

(c) Quicklime (CaO) is produced by thermal decomposition of calcium carbonate ($CaCO_3$). Calculate the volume of carbon dioxide (CO_2) at STP produced from the decomposition of 152 g of $CaCO_3$. [6].

(d) Answer the following questions on Dalton's Law.

(i) The partial pressure of oxygen was observed to be 156 torr in air with a total atmospheric pressure of 743 torr. Calculate mole fraction of O_2 present. [2]

(ii) The mole fraction of nitrogen in the air is 0.7808. Calculate the partial pressure of N_2 in air when the atmospheric pressure is 760 torr. [2]

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QUESTION 8: CHEMICAL EQUILIBRIUM

[20 MARKS]

(a) Calculate the value of the equilibrium constant, K_c at 127 ^oC for the reaction given below. [2]

$$\frac{1}{2}N_2\,(g) + \frac{3}{2}H_2\,(g) \rightleftharpoons NH_3\,(g)$$

where $[NH_3] = 3.1 \times 10^{-2}$ mol/L
$[N_2] = 8.5 \times 10^{-1}$ mol /L
$[H_2] = 3.1 \times 10^{-3}$ mol /L

(b) For the reaction for the formation of nitrosyl chloride: $2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$ the pressures were:

P_{NOCl} = 1.2 atmospheres
$P_{NO} = 5.0 \times 10^{-2}$ atmosphere
$P_{Cl2} = 3.0 \times 10^{-1}$ atmosphere

(i) Calculate K_p at 25^oC [2]

(ii) Using K_p calculated at (i), obtain the value of K_c at 25^oC for the reaction $2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$ [2]

(c) Answer the questions below.

(i) Write the reaction quotient for the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ [2]

(ii) For the synthesis of ammonia at 500 ^oC, $K_c = 6.0 \times 10^{-2}$. Predict the direction in which the system will shift to reach equilibrium in the following cases:-

(1) $[NH_3]_O = 1.0 \times 10^{-3}$ M; $[N_2]_0 = 1.0 \times 10^{-5}$ M; $[H_2]_0 = 2 \times 10^{-3}$ M [1]
(2) $[NH_3]_O = 2.0 \times 10^{-4}$ M; $[N_2]_0 = 1.50 \times 10^{-5}$ M; $[H_2]_0 = 3.54 \times 10^{-1}$ M [1]
(3) $[NH_3]_O = 1.0 \times 10^{-4}$ M; $[N_2]_0 = 5.0$ M; $[H_2]_0 = 1.0 \times 10^{-2}$ M [1]

(d) The reaction for the formation of gaseous hydrogen fluoride from hydrogen and fluorine has

$K_c = 1.1 \times 10^2$ at a certain temperature. In one experiment, 3 moles of each component was added to the 1.5 litre flask. Calculate the equilibrium concentrations of all species. [6]

(e) Answer the questions below.

(i) State Le Chaterlier's Principle. [1]

(ii) Arsenic can be extracted from its ores, first reacting the ore with oxygen (called roasting) to form $As_4\,0_6$ which is then reduced by carbon:

$$As_4O_6(s) + 6C(s) \rightleftharpoons As_4(g) + 6CO\,(g)$$

In which direction will the equilibrium position shift in response to the following conditions

(1) Addition of carbon monoxide [1]
(2) Addition or removal of carbon or tetra arsenic hexoxide (As_4O_6) [1]
(3) Removal of gaseous arsenic (As_4) [1]

1.25 x 9

2HF

$H_2 + F_2 \rightarrow 2HF$

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THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

DEPARTMENT OF CHEMISTRY

2016/17 ACADEMIC YEAR

CHEMISTRY (CH 110/FO 130) TEST TWO

TIME ALLOWED: Two (2) Hours.

DATE: 17 / 03/ 2017

INSTRUCTIONS:

(i) Attempt all the three questions that carry specified marks.

(ii) All calculated quantities must have units and reported to the correct number of significant figures.

(iii) Do not open till instructed to do so.

IMPORTANT DATA:

Physical Constants		
Constant	**Symbol**	**Value**
Planck's constant	h	6.626×10^{-34} J s
Speed of light (vacuum)	c	2.998×10^{8} m s^{-1}
Rydberg constant	R_H	1.097×10^{7} m^{-1}
Rydberg energy	R_E	2.179×10^{-18} J
Atomic mass unit	*amu*	1.660554×10^{-27}kg
Avogadro's number	N_A	6.02214×10^{23} mol^{-1}
Gas constant	R	8.31451 J K^{-1} mol^{-1}
		0.08206 L atm K^{-1} mol^{-1}
1 atm = 760 mm Hg = 1.0132×10^{5} Nm^{-2} = 1.0132×10^{5}Pa		

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QUESTION ONE (THERMOCHEMISTRY) [33 marks]

a) Indicate whether the following statements are true or false; the internal energy can be increased by

(i) transferring heat from the surroundings to the system
(ii) transferring heat from the system to the surroundings
(iii) doing work on the system [3]

b) Indicate whether the following process is endothermic or exothermic
(i) ice melting (ii) boiling soup (iii) condensation of water vapor [3]

c) An 8.29 g sample of calcium carbonate [$CaCO_3$ (s)] absorbs 50.3 J of heat, upon which the temperature of the sample increases from 21.1 °C to 28.5 °C. What is the specific heat of calcium carbonate? [4]

d) Write a thermochemical equation for each of the following processes:

(i) The enthalpy of combustion of liquid benzene (C_6H_6) is -3268 kJ/mol.
(ii) When solid boron reacts with oxygen gas to form one mole of solid diboron trioxide 1274 kJ heat is released.
(iii) The enthalpy of formation of liquid methanol (CH_3OH) is -239 kJ/mol. [6]

e) For the reaction: $HgO(s) \rightarrow Hg(l) + \frac{1}{2}O_2$ $\Delta H = +90.7$ kJ

(i) What quantity of heat is required to produce 3 moles of mercury by this reaction?
(ii) What quantity of heat is required to produce 1 mol of oxygen gas by this reaction?
(iii) What quantity of heat would be released in the following reaction as written?
$2\,Hg(l) + O_2(g) \rightarrow 2HgO(s)$ [6]

f) Given the following data

i) $2ClF(g) + O_2(g) \rightarrow Cl_2O(g) + F_2O(g)$ $\Delta H = -447$ kJ
ii) $2ClF_3(g) + 2\,O_2(g) \rightarrow Cl_2O(g) + 3F_2O(g)$ $\Delta H = 341.4$ kJ
iii) $2\,F_2(g) + O_2(g) \rightarrow 2F_2O(g)$ $\Delta H = -43.4$ kJ

Calculate ΔH for the reaction

$ClF(g) + F_2(g) \rightarrow ClF_3(g)$ [6]

g) A meal containing a burger, chips, and a milkshake contains 53.0 grams of fat, 38.0 grams of protein, and 152 grams of carbohydrate. The respective fuel values for protein, fat, and carbohydrate are 17, 38, and 16 kJ/g, respectively. If swimming typically burns 1100.0 kJ/hour, how many minutes of swimming are required to completely burn off the meal? [5]

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QUESTION TWO (ATOMIC STRUCTURE AND PERIODICITY) [33 marks]

a) Green light has a wavelength of 535 nm. Calculate the energy of a photon of green light. [3]

b) Calculate the wavelength of an infrared transition of the hydrogen atom in the Paschen series from the n = 4 level to n = 3 level. [3]

c) Calculate the number of photons that reached the detector when 3.928×10^{-18} J of blue light of wavelength 4.552×10^{-7} meters reached the detector. [5]

d) Calculate the speed of an electron with mass 9.1×10^{-31} kg and the de Broglie wavelength is 1.46×10^{-10} m. [3]

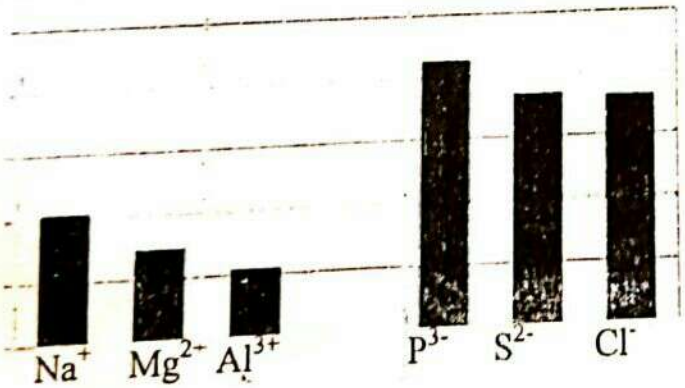
e) During an American football match called the Super Bowl, the uncertainty in the momentum (Δp) of a football thrown by Tom Brady is 16×10^{-6} kg ms^{-1}. What is its uncertainty in position Δx? [2]

f) Write down the quantum numbers that define the three P (3p) atomic orbital [3]

g) Write the full electron configuration, compressed electron configuration, and valence electron configuration of the following;
   (i) Rubidium [3]
   (ii) Sulphur [3]
   (iii) Titanium [3]

h) Write the orbital diagram for a phosphorus atom. Is the phosphorus atom paramagnetic or diamagnetic? [2]

i) The bar chart below shows the relative radii of the ions of the elements in the third period.



   (i) The ions Na^+, Mg^{2+} and Al^{3+} are said to be what? [1]
   (ii) Which of the following ions above has the shortest ionic radius? [1]
   (iii) Which of the following ions above has the longest ionic radius? [1]

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QUESTION THREE(CHEMICAL BONDING AND GEOMETRY) [34 Marks]

(a) Appropriately answer the following questions

(i) **True or false:** An ionic bond is a chemical bond formed by the electrostatic attraction between ions of different positive charges. [1]

(ii) **True or false:** A Lewis electron-dot formula and a Lewis electron-dot symbol can both be defined as; A formula using dots to represent valence electrons. [1]

(iii) Use Lewis electron-dot symbols to represent the transfer of electrons from calcium to chlorine atoms to form ions with noble-gas configurations. [2]

(b) **For the PO_4^{3-} ion:**

(i) Draw the Lewis structure [2]

(ii) Assign the formal charges to each atom [2]

(iii) State the geometry of the ion [2]

(c) Use the data provided below to calculate the lattice energy of NaCl. [4]

Electron affinity of Cl = −394kJ/mol

1st ionization energy of Na = 496 kJ/mol

Bond energy of Cl_2 = 242kJ/mol

Sublimation energy of Na = 108kJ/mol

ΔH_f [NaCl (s)] = − 411kJ

(d) Answer the following questions:

(i) Arrange the following compounds in order of increasing lattice energy NaCl, $MgCl_2$, and MgO. [3]

(ii) Arrange the NO_2^- and NO_3^- ions in order of increasing N−O bond length. [2]

(iii) Draw the two possible resonance structures for NCO^- [3]

(e). Indicate the molecular geometry of the following molecules and state for each whether they are polar or non-polar. [4]

(i) $BeCl_2$ [4]

(ii) IF_5 [4]

(iii) PF_5

====THE END ====

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THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

2016/2017 SESSIONAL EXAMINATION

TITLE OF PAPER: GENERAL CHEMISTRY

COURSE CODE – CH 110 /CH 120/ FO 130

TIME ALLOWED: THREE (03) HOURS

INSTRUCTIONS TO CANDIDATES:

1. This paper comprises 7 questions.
2. Candidates are expected to attempt any **five (05)** questions only.
3. Each question carries **twenty (20)** marks.
4. Candidates are reminded of the need for **clear presentation** of their answers.
5. All calculated quantities must have units and be reported to the correct number of significant figures.
6. All the parts of a question should be answered **strictly in continuation**.
7. A data sheet and periodic table are provided
8. Non-programmable electronic calculators may be used.

DO NOT OPEN UNTIL PERMISSION HAS BEEN GRANTED TO DO BY THE CHIEF INVIGILATOR

Question 1 [20 MARKS]

1 (a). Define the following terms

(i) Aqueous solution

(ii) Spectator ions

(b). What is the molarity of a solution of potassium chloride that is prepared by diluting of 855 ml of a 0.475M solution to a volume of 1.25L? [3]

(c). A 25.0 ml of 0.350 M NaOH is mixed with 45.0 ml of 0.125 M copper (II) sulfate solution to produce solid copper (ii) sulphate.

(i) Write a balanced chemical equation for the reaction

(ii) Write the net ionic equation for the reaction

(iii) What is the name of this type of chemical reaction

(iv) How many grams of copper (II) hydroxide will precipitate? **[3]**

(d). Determine the oxidation state for the underlined atom in each of the following

(i) $Na\underline{S}_4O_6^{3-}$

(ii) $\underline{P}O_4^{3-}$

(e). Using half reactions, Balance the equation below in acidic medium. **[6]**

MnO_4^- (aq) + Cl^- (aq) → Cl_2 (g) + Mn^{2+} (aq)

Question 2 (20 marks)

a) The pressure of a gas is measured as 49 Torr, represent this pressure in:

(i) atm [1]

(ii) Pa [1]

(iii)Bar [1]

(iv)mmHg [1]

b) Taking pressure P, volume V, temperature T, and mole n for a system consisting of the initial state[i] to a final state [f], write a mathematical expression for;

(i) Boyle's law [1]

(ii) Charles's law [1]

(iii)Avogadro's law [1]

(iv)Using the ideal gas equation, show that $V_f = \frac{P_i V_i T_f}{P_f T_i}$ [1]

c) Sodium azide, the explosive compound in automobile air bags, decomposes according to the following equation:

$$\mathbf{2NaN_{3(s)} \rightarrow 2Na_{(s)} + 3N_{2(g)}}$$

What mass of sodium azide is required to provide the nitrogen to inflate a 75.0 L bag to a pressure of 1.3 atm at 25 °C? [4]

d) Consider the combustion of nitric oxide **(NO)** to produce nitrogen dioxide **(NO_2)** as follows:

$$2NO_{(g)} + O_{2\,(g)} \longrightarrow 2NO_{2\,(g)}$$

A 5.00L flask is charged with 10.0g of **NO** $_{(g)}$ and $10.0_{(g)}$ of $O_{2(g)}$ and the reaction proceeds until one of the reagents is completely consumed. After the reaction is complete, the temperature was 3978K.

(i) What is the partial pressure of NO_2 (g)? [6]

(ii) A sample of NO_2 (g) effuses from a container in 42.0 seconds. How long will it take the same amount of gaseous NO to effuse from the same container under identical conditions? [2]

Question 3 (20 Marks)

a) Write an equation that expresses the first law of thermodynamics in terms of heat and work. What is the change in the internal energy, ΔE, when a system absorbs 105 kJ of heat from its surroundings while doing 29 kJ of work on the surroundings? [4]

b) Write the thermochemical equations for the following processes

(i) The standard enthalpy of formation of solid copper(I) oxide is +64.8 kJ/mol.

(ii) The standard enthalpy of combustion of solid phenol, C_6H_5OH, is -3054 kJ/mol [4]

c) Calculate the enthalpy change of the reaction

$P_4(s) + 10Cl_2(g) \rightarrow 4\,PCl_5(s)$

from the following reactions

$P_4(s) + 6\,Cl_2(g) \rightarrow 4\,PCl_3(l) \quad \Delta H^\theta = -1278.8\,kJ$

$PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s) \quad \Delta H^\theta = -124\ kJ$ [4]

d) Calculate the heat evolved from a reaction of a mixture of 50.0 g of iron(III) oxide and 25.0 g of aluminium in the thermite reaction:

$Fe_2O_3(s) + 2\,Al(s) \rightarrow Al_2O_3(s) + 2\,Fe(s) \quad \Delta H^\theta = -851.5\,kJ$ [8]

Question 4 (20 marks)

a) Consider a hydrogen atom in its ground state absorbing a photon of wave length 94.96nm.

(i) Deduce the final level of the electron in the atom [2]

(ii) Calculate the energy of the photon absorbed [2]

b) Consider the reaction below:

$$\mathbf{Mg_{(s)} + 1/2O_{2(g)} \rightarrow MgO_{(s)}}$$

(i) Write the orbital diagram for both magnesium and chlorine atoms? [2]

(ii) State which one is diamagnetic and paramagnetic [1]

(iii) Write down the four quantum numbers that define sixth electron in a magnesium and oxygen atom [4]

(iv) Show that Mg^{+2} and O^{2-} are isoelectronic. [2]

(v) Given the following information:

Electron affinity for oxygen	$\Delta H = +737kJ$
Ionization energy for Mg atom to form Mg^{2+}	$\Delta H = +2180kJ$
Bond dissociation of Oxygen	$\Delta H = +247kJ$
Sublimation energy of **Mg** (s)	$\Delta H = +150kJ$
The heat of formation of **MgO** (s)	$\Delta H^{o}_{rxn} = -602kJ$

Calculate the lattice energy of **MgO** (s) [4]

The thermo chemical equations are as follows:

d. Chlorine triflouride **(ClF_3)** is an inter halogen mainly used as a high-energy fluorinating agent or incendiary material.

(i) Draw the Lewis structure of the compound [2]

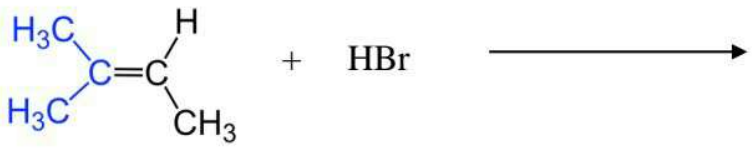
(ii) From the Lewis structure indicate the geometry of the molecule [½]

(iii) Is the **ClF_3** molecule Non-polar or polar? [½]

Question 5 (20 marks)

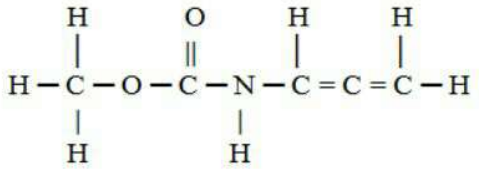
a) Write the structural formula and the name of the major product in the following reaction: [3]

(i)



(ii) Name the rule that guided you in identifying the product of this reaction?

b) Examine the compound below and answer the questions that follow: [3]



(i) How many sigma (σ) bonds are present in this molecule?

(ii) How many pı (π) bonds are present in this molecule?

(iii)Indıcate the number of sp^2, and sp^3 hybridized atoms present in this molecule.

c) For each of the following reactions, write a balanced equation, draw the structural formula, and name the products. [6]

(i) Methane reacting with enough chlorine in the presence of ultra-violet light.

(ii) 2-butene reacting with hydrogen (with nickel used as a catalyst).

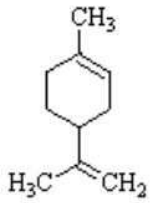
d) Draw the structural formulae of the following: [3]

(i) 2,3,4 – trimethyl hexane.

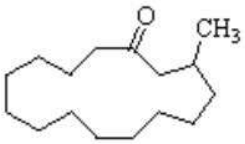
(ii) 1,2,3 – trimethyl cyclohexane

(iii)trans – 3 – hexane

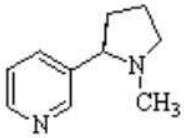
e) The compounds whose structures are shown below incorporate a variety of functional groups. Examine the compounds and answer the questions that follow.



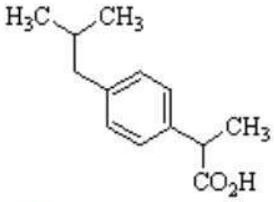
1. limonene



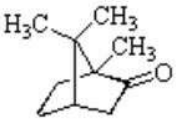
2. muscone



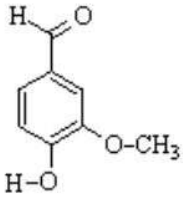
3. nicotine



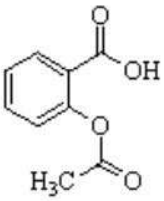
4. ibuprofen



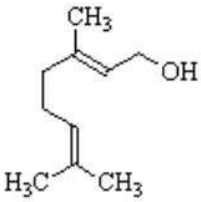
5. camphor



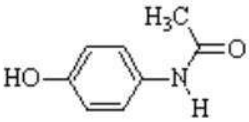
6. vanillin



7. aspirin



8. geraniol



9. acetaminophen

Write the names of the compounds that have the following functional groups: [5]

(i) Alcohol group

(ii) Ester group

(iii) Aldehyde group

(iv) Aromatic rings

QUESTION SIX (CHEMICAL KINETICS) [20 marks]

a) State whether each of the following statements is TRUE or FALSE. **[3]**

(i) In kinetics we study the rate at which a chemical process occurs.

(ii) Rates of reactions can be determined by monitoring the change in concentrations of products as function of time.

(iii) If a reaction is monitored over time, it is found that the average rate decreases as the reaction proceeds because as the reaction goes forward, there are fewer collisions between reactant molecules.

b) List 3 factors that can affect the rate of a reaction **[3]**

c) Answer the three question below about a reaction coordinate diagram (or the energy profile) of a chemical reaction: What is the

(i) high point on the diagram called? [1]

(ii) species present at the high point called? [1]

(iii) energy gap between the reactants and high point called? [1]

d) The initial rate data at 298 K are listed in the table for the reaction of the ammonium and nitrite ion: $NH_{4\,(aq)}^{+} + NO_{2\,(aq)}^{-} \longrightarrow N_{2\,(g)} + 2H_2O_{(l)}$. **[4]**

Experiment	$[NH_{4\,(aq)}^{+}]_0$	$[NO_{2\,(aq)}^{-}]_0$	Initial rate $\times 10^{-6}$ $(\frac{mol}{L} \cdot s)$
1	0.24	0.10	7.2
2	0.12	0.10	3.6
3	0.12	0.10	5.4

(i) What is the rate law? [4]

(ii) What is the value of the rate constant? [1]

(iii) What is the value of rate constant when the concentrations are $[NH_{4\,(aq)}^{+}] = 0.39$ M and $[NO_{2\,(aq)}^{-}] = 0.052$ M? [1]

e) The rearrangement of methyl isonitrile (CH_3NC) to acetonitrile (CH_3NC) is a first-order reaction, $CH_3 - N \equiv C \longrightarrow CH_3 - C \equiv N$, has a rate constant of $5.11 \times 10^{-5} s^{-1}$ at 472 K.. If the initial concentration of CH_3NC is 0.0340 M:

(i) What is the molarity of CH_3NC after 2 hours? [3]

(ii) What is the half-life (in hours) of this reaction? [2]

Question 7 (20 marks)

(a) Write the expression for the equilibrium constant, K_p, for each of the following reactions:

i. $3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$

ii. $2NH_3(g) \rightleftharpoons 3H_2(g) + N_2(g)$

iii. $3/2H_2(g) + ½N_2(g) \rightleftharpoons NH_3(g)$ [3]

(b) An equilibrium mixture at a certain temperature for the reaction

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

has 2.00 atm pressure of H_2S, 0.400 atm H_2 and 1.60 atm S_2. What is K_p for this reaction? [4]

(c) Given the following equilibrium constants:

i. $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$ $K_1 = 0.62$

ii. $FeO(s) + H_2(g) \rightleftharpoons Fe(s) + H_2O(g)$ $K_2 = 0.42$

Find the equilibrium constant, K, at the same temperature for the reaction:

$FeO(s) + CO(g) \rightleftharpoons Fe(s) + CO_2(g)$ [4]

(d) K_c has a value of 12.9 for the following reaction at a temperature of 1550K.

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

What is the value of K_P for this reaction? [5]

(e) In which direction will each of the following reactions shift after the specified stress is applied?

i. $N_2O_4(g) \rightleftharpoons 2NO(g)$
The total pressure is decreased by increasing the volume

ii. $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$
An increase in the concentration of CO_2

iii. $2Cl_2(g) + 2H_2O(g) \rightleftharpoons 4HCl(g) + O_2(g)$ $\Delta H^o = +113$ kJ
An increase in temperature

iv. $FeO(s) + CO(g) \rightleftharpoons Fe(s) + CO_2(g)$
Amount of Fe(s) is increased [4]

THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

DEPARTMENT OF CHEMISTRY

TEST 2: CH 110/FO 130: General Chemistry

AY 2015/16

Duration: 2 hours.

Date: 22nd January, 2015.

INSTRUCTIONS:

(i) Attempt all **three questions**, each question carries 20 Marks.
(ii) All calculated quantities must have units and reported to the correct number of significant figures.
(iii) Do not open till instructed to do so.

Non-programmable calculators can be used.

Table of Physical quantities:

Physical Constants		
Constant	**Symbol**	**Value**
Atomic mass unit	*Amu*	1.660554×10^{-27} kg
Avogadro's number	N_A	6.02214×10^{23} mol^{-1}
Gas constant	R	8.31451 J K^{-1} mol^{-1}
		0.08206 L atm K^{-1} mol^{-1}
1 atm = 760mmHg = 1.0132×10^5 Nm^{-2} = 1.0132×10^5 Pa		

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QUESTION ONE (THERMOCHEMISTRY) [20 marks]

a) State the difference(s) between a state and a non-state function [1]

b) A chemical reaction occurs in a container of cross-sectional area 100 cm^2. As a result of the reaction, a piston is pushed out against an external pressure of 1.0 atm and does work of-1. Calculate the distance (in meters) through which the piston is pushed. [3]

c) A sample of Ar under standard conditions occupies a volume of 33.6 L. It is expanded isothermally to a volume of 67.05 L. Calculate the work done if the expansion is:

(i) Freely, [2]

(ii) Against a constant external pressure equal to the final pressure of the gas. [3]

d) When 2.00 mole of H_2 gas and 1.00 mole of O_2 gas at 100 °C and 1 atm, react to produce 2.0 mole of gaseous water at 100 °C and 1 atm, a total of 484.5 KJ are evolved. In this reaction, the production of a single mole of $H_2O_{(g)}$ determine:

(i) The change in enthalpy (ΔH) [2]

(ii) The change in internal energy (ΔE) [3]

$W = -P\Delta V$

$\Delta H =$

e) Calculate the lattice enthalpy of SrI_2 from the following data: [3]

Process	ΔH/(kJ mol^{-1})
Sublimation of $Sr_{(s)}$	+164
Ionisation of $Sr_{(g)}$ to $Sr^{2+}_{(g)}$	+1626
Sublimation of $I_{2(s)}$	+62
Dissociation of $I_{2(g)}$	+151
Electron attachment to $I_{(g)}$	-304
Formation of $SrI_{2(s)}$ from $Sr_{(s)}$ and $I_{2(s)}$	-558

f) Calculate the standard enthalpy of formation of N_2O_5 from the following data: [3]

$2NO_{2(g)} \longrightarrow 2NO_{(g)} + O_{2(g)}$ $\Delta H° = +114.1$ kJ mol^{-1}

$4NO_{2(g)} + O_{2(g)} \longrightarrow 2N_2O_{5(g)}$ $\Delta H° = -110.2$ kJ mol^{-1}

$N_{2(g)} + O_{2(g)} \longrightarrow 2NO_{(g)}$ $\Delta H° = +180.5$ kJ mol^{-1}

$\Delta H°$

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QUESTION TWO (CHEMICAL BONDING AND MOLECULAR GEOMETRY) [20 marks]

a) Predict the type of bond formed by each of the following pairs of atoms. [2]

(i) Rb and Cl (ii) C and F (iii) B and H (v) Ba and S

b) Arrange the following atoms in order of increasing periodic property mentioned in the question: [2]

(i) Ionization energy: Na, Rb, K

(ii) Electron affinity: N, P, As

(iii) Electronegativity F, Cl, Br

(iv) Ionic size Na^+, Mg^{2+}, Al^{3+}

c) Oxidation of the cyanide ion produces the stable cyanate ion (OCN^-).

(i) Write all possible Lewis structures for the cyanate ion. [3]

(ii) Assign formal charges to each of the atoms in the Lewis structures for cyanate ion. [3]

(iii) Based on the formal charges, which of the three structures you have drawn for the cyanate ion is the best structure. [1]

d) Complete the following table: [6]

Compound	Lewis structure	Molecular geometry
NH_3		
PCl_5		
SF_6		
XeF_4		

e) Identify the type of intermolecular forces existing between molecules in the following molecules.

(i) CO_2 (ii) SO_2 (iii) HF (iv) CH_4 [2]

f) For each set below, indicate which bond would be the most polar: [1]

(i) C – F, N – F, or O – F

(ii) Si – F or C – F

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QUESTION THREE(ATOMIC STRUCTURE AND PERIODICITY) [20 Marks]

a) Give the three primary characteristics of waves. Write the expression of their mathematical relationship. [2]

b) Give the mathematical relationship of kinetic energy of a photoelectron to the incident light particle in the photoelectric effect with a clear explanation of the terms of the equation. [5]

c) (i) Who was the scientist who postulated that *matter has a dual nature?* [1]

(ii) Write the mathematical expression he formulated alongside his postulate? [2]

d) (i) Given the sublevels $E_{n_s}, E_{n_p}, E_{n_d}, E_{n_f}$ of a polyelectronic atom, state whether these are degenerate or not. [1]

(ii) If they are not degenerate, show how the quantum levels of the orbitals vary in energy. [1]

e) In the table below, complete the missing information in the last three columns. [6]

n (Principal quantum No.)	l (Angular mom. quantum No.)	Sublevel designation	Element with first electron in the sublevel		
			Electron configuration	Name of element	Element group Name
3	0	3s	$[Ne]3s^1$	Sodium (Na)	Group 1
	1	3p	$[Ne]3s^2, 3p^1$	Aluminum (Al)	Group 3
	2	3d	N	Zinc (Zn)	Transition metal

f) Periodic trends in atomic properties - Atomic radius

Arrange the following groups of atoms in order of increasing size. [2]

(i) Te, S, Se

(ii) Ba, Si, Fe

matter 13 [Ne]

Plank's constant = 6.63×10^{-34} J.S

(b) $K = \frac{1}{2}mv^2$ $C = \lambda\nu$ $\lambda = \frac{h}{mv}$

1s

2s 2p

3s 3p 3d

4s 4d 4p 4f

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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
												3	4	5	6	7	
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 20.180
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.409	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
37 Rb 85.468	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 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-71	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	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)	89-103	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (271)	111 Rg (272)							

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	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
89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

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THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

SESSIONAL EXAMINATION 2015/16

TITLE OF PAPER: GENERAL CHEMISTRY

COURSE NUMBER: CH110/CH120/FO130

TIME: THREE (3) HOURS

INSTRUCTIONS:

There are seven questions, each worth 20 marks. Answer any five (5) questions.

All calculated quantities must have units and be reported to the correct number of significant figures otherwise marks will be deducted.

A data sheet and a periodic table are provided

Non-programmable electronic calculators may be used.

DO NOT OPEN THIS PAPER UNTIL PERMISSION TO DO SO HAS BEEN GRANTED BY THE CHIEF INVIGILATOR.

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Question 1 (20 marks)

(a) A 100.0ml aliquot of 0.200 M aqueous potassium hydroxide is mixed with 100.0 ml of 0.200 M aqueous magnesium nitrate.

i) Write the balanced chemical, ionic and net ion equation for the reaction [3]

ii) What precipitate is formed from this reaction? [1]

iii) Calculate the mass of the precipitate formed [3]

(b) Specify which of the following is a redox reaction. For the redox reaction, identify the reducing agent, the oxidizing agent, the substance oxidized, and the substance reduced

i) $2H^+(aq) + 2CrO_4^{2-}(aq) \rightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$

ii) $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$ [3]

(c) Balance the following Redox reaction equation below using oxidation numbers

$Rh^{3+}(aq) + Ni(s) \rightarrow Rh^{2+}(aq) + Ni^{2+}(aq)$ [2]

(d) Consider the unbalanced chemical equation for the combustion of pentane (C_5H_{12}) given as $C_5H_{12}(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$. If 20.4 g of pentane are burned in excess oxygen, what mass of water can be produced, assuming 100% yield? [4]

(e) The empirical formula of styrene is CH; the molar mass of styrene is 104.14 g/mol. What number of H atoms are present in a 2.00-g sample of styrene? [4]

Question 2 (20 marks)

(a) $KClO_3$ is decomposed by the following reaction:

$$KClO_3(s) \rightarrow KCl(s) + O_2(g) \quad \text{(not balanced)}$$

The O_2 produced was collected by the displacement of water at 22 °C at a total pressure of 760 torr. The volume of gas collected was 1.20 liters, and the vapour pressure of water at 22°C is 21 torr.

(i) Define the term partial pressure [1]

(ii) Calculate the partial pressure of O_2 in the gas collected and the mass of $KClO_3$ in the sample that was decomposed [3]

(b) Incandescent light bulbs "burn out" because their tungsten filament evaporates, weakening the thin wire until it breaks. Argon gas is added inside the bulbs to reduce the rate of evaporation. (Argon is chosen because, as a noble gas, it will not react with the components of the bulb, and because it is easy to obtain in significant quantities. It is the third most abundant element in air).

(i) At what temperature would 0.0315 g of Ar in a 25.0-mL incandescent light bulb have a pressure of 952 mmHg? [3]

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(ii) What would be the density of argon gas in an incandescent bulb at 79.9 °C and 129.8 kPa? [3]

(c) In the study of gases in CH110, it is important that undergraduate students understand ideal and real gases with respect to the conditions surrounding these two types of gases.

(i) Define the term ideal gas and explain how it differs from a real gas. [3]

(ii) Calculate the pressure exerted by 1.00 mol ammonia when it is confined at 25 °C in 500 cm^3 (a = 4.169 atm dm^6 mol^{-2}, b = 3.71 x 10^{-2} dm^3 mol^{-1}) behaving as:

1) an ideal gas; [2]
2) a van der Waals gas. [5]

Question 3 (20 marks - alternative)

(a) Define a system and state the three types of systems [2]

(b) Write thermochemical equations corresponding to the following descriptions.

(i) The standard enthalpy of formation of iron(III) oxide at 298 K is -824.2 kJ/mol.

(ii) The standard enthalpy change at 298 K for the reaction between gaseous phosphorus trichloride and chlorine gas to give gaseous phosphorus pentachloride is -84.3 kJ.

(iii) The standard enthalpy of combustion of liquid ethanol is -1368 kJ/mol. [6]

(c) The reaction between a metal and an acid yields a salt and hydrogen gas. 50 g of iron is reacted with excess hydrochloric acid.

(i) Write a balanced equation for the above reaction [2]

(ii) State the equation employed in calculating the work done by the surrounding on a system. [1]

(iii) Calculate the work done if the reaction takes place in a closed vessel [2]

(iv) Calculate work done if the reaction takes place in an open beaker at 25°C. [3]

(d) Given the following thermochemical equations:

$4NH_{3(g)} + 3O_{2(g)} \rightarrow 2N_{2(g)} + 6H_2O_{(l)}$ $\Delta H_1 = -848KJ$

$N_2O_{(g)} + H_{2(g)} \rightarrow N_{2(g)} + H_2O_{(l)}$ $\Delta H_2 = -367KJ$

$H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta H_3 = -285.9KJ$

Calculate the value of ΔH for the reaction;

$2NH_{3(g)} + 3N_2O_{(g)} \rightarrow 4N_{2(g)} + 3H_2O_{(l)}$ $\Delta H = ?$

[4]

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Question 4 (20 marks)

(a) In the quantum mechanical model of an atom

(i) When given the sublevels $E_{4_s}, E_{4_p}, E_{4_d}, E_{4_f}$ of a polyelectronic atom, state whether these are degenerate or not. [1]

(ii) If they are not degenerate, show how the quantum levels of the orbitals vary in energy. [1]

(b) For each Subshell above, copy the table below and fill the last column [4]

Subshell	Element with final Subshell electron configuration given as	Element name or symbol
E_{4_s}	$4s^2$	
E_{4_p}	$4p^6$	
E_{4_d}	$4d^{10}$	
E_{4_f}	$4f^{14}$	

(c) Classify the elements in the last column of the table of (b) into following element groups

(i) main group elements [1]

(ii) alkali metals [1]

(iii) alkaline earth metals [1]

(iv) transition metals [1]

(v) actinides and [1]

(vi) noble gas [1]

(d) Wave particle duality: Neutron diffraction is used in determining the structures of molecules. Calculate the de Broglie wavelength of a neutron moving at 1.00% of the speed of light. [5]

(e) Photoelectric Effect: At the conclusion of the study of the photoelectric effect, the phenomenon of the **dual** *nature of light* was demonstrated. Explain what is meant by this phenomenon. What was the name of the scientist who demonstrated the dual nature of light using the photoelectric effect? [3]

Question 5 (20 marks)

(a) Predict the order of increasing electronegativity in each of the following groups of elements: [2]

(i) Si, Ge, Sn

(ii) Tl, Cl, Ge

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(iii) B, O, Ga

(iv) S, O, F

(b) Identify the noble gas that has the same electron configuration as each of the ions in the following compounds: [3]

(i) Strontium fluoride

(ii) Calcium nitride

(iii) Cesium bromide

(c) Arrange the following atoms/ions in order of increasing size: [2]

(i) Ni^{2+}, Pd^{2+}, Pt^{2+}

(ii) Cu, Cu^{+}, Cu^{2+}

(iii) O, O^{-}, O^{2-}

(iv) Cs^{+}, K^{+}, Rb^{+}

(d) Arrange the bonds in order of increasing ionic character in the molecules: LiF, K_2O, N_2, SO_2 and ClF_3. [1]

(e) For each of the following molecules: PF_3 and $COCl_2$:

(i) Draw the Lewis Structure. [2]

(ii) Determine the geometry of the molecule. [2]

(iii) Sketch the molecule to show the dipoles. [2]

(iv) Indicate if the molecule is polar or non polar. [1]

(v) What intermolecular force exists in each of them? [1]

(vi) Determine the number of lone pairs of electrons on each central atom. [1]

(f) Given the following molecules: C_2H_2, H_2, $C(CH_3)_4$, N_2.

(i) Identify the type of intermolecular force present in each molecule. [1]

(ii) Are the molecules polar or non polar? [1]

(iii) Arrange the molecules in order of increasing intermolecular force. [1]

Question 6 (20 marks)

(a) Give the condensed structural formula and name of a hydrocarbon **containing five carbon** atoms that is

(i) an alkane (ii) a cycloalkane (iii) an alkene (iv) an alkyne [8]

(b) Using condensed structural formulas, write a balanced chemical equations for each of the following reactions. In each case name the products.

(i) hydrogenation of 2-butene

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(ii) addition of H_2O to 2-pentene using H_2SO_4 as a catalyst (two products)

(c) Give the condensed structural formula of [6]

(i) an aldehyde that is an isomer of acetone

(ii) an ether that is an isomer of 1-propanol

(iii) 2-choro-pentanoic acid

[3]

(d) Draw the structural formula of the compound formed by the condensation reactions between

(i) ethanoic acid and methylamine

(ii) ethanoic acid and phenol

[3]

Question 7 (20 marks)

(a) Given the following general reaction,

$$3A + 2B \rightarrow 4C$$

Write down the instantaneous rate for each of the reactants and products. [2]

(b) Study the following experimental data for the reaction below which was conducted at 25 °C and answer the questions below:

$$NO(g) + NO_2(g) + O_2(g) \rightarrow N_2O_5(g)$$

Run	$[NO]_o$	$[NO_2]_o$	$[O_2]_o$	Initial Rate, Ms^{-1}
1	0.10 M	0.10 M	0.10 M	2.1×10^{-2}
2	0.20 M	0.10 M	0.10 M	4.2×10^{-2}
3	0.20 M	0.30 M	0.20 M	1.26×10^{-1}
4	0.10 M	0.10 M	0.20 M	2.1×10^{-2}

(i) Deduce the order of reaction with respect to each reactant and determine the overall order of reaction. [6]

(ii) Write down an expression for the rate law for the above reaction and calculate the value of the rate constant for the reaction. [3]

(c) Derive an expression for the half life of a first order reaction and use this result to show that in a first order reaction the time taken for the reactant concentration to drop by three quarters of its initial value is double that for the initial concentration to drop by one half.

[5]

(d) Consider the reaction: $2B \rightarrow C + 3D$. In one experiment it was found that at 300 K the rate constant was 0.134 L/ (mol.s). A second experiment showed that at 450 K, the rate constant was 0.569 L/ (mol.s). Determine the activation energy for the reaction.

[4]

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Table of fundamental constants

Quantity	symbol	Value	Power of ten	Units
Speed of light	c	2.9979	10^{8}	$m\ s^{-1}$
Elementary charge	e	1.602	10^{-19}	C
Faraday's constant	$F=N_A e$	9.6485	10^{4}	$C\ mol^{-1}$
Boltzmann's constant	k	1.380 65	10^{-23}	$J\ K^{-1}$
Gas constant	$R=N_A k$	8.314 47 8.314 47 8.205 74 6.236 37	 10^{-2} 10^{-2} 10	$J\ K^{-1}\ mol^{-1}$ $L\ bar\ K^{-1}\ mol^{-1}$ $L\ atm\ K^{-1}\ mol^{-1}$ $L\ Torr\ K^{-1}\ mol^{-1}$
Planck's constant	h $\hbar=h/2\pi$	6.626 08 1.054 57	10^{-34} 10^{-34}	Js Js
Avogadro's constant	N_A	6.022 14	10^{23}	mol^{-1}
Atomic mass unit	m_u	1.660 54	10^{-27}	Kg
Mass Electron Proton neutron	 m_e m_p m_n	 9.109 38 1.672 62 1.674 93	 10^{-31} 10^{-27} 10^{-27}	 Kg Kg kg
Rydeberg constant	$R=\frac{m_e e^4}{8h^3 c\varepsilon_0^2}$	1.097 37	10^{5}	cm^{-1}

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THE PERIODIC TABLE OF ELEMENTS

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
Period 1	1 H 1.008																	2 He 4.003
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.9	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.01	25 Mn 54.9	26 Fe 55.85	27 Co 58.71	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.7	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.91	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 91.22	42 Mo 95.94	43 Tc 98.9	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	71 Lu 174.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 196.9	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 208.9	84 Po 210	85 At 210	86 Rn 222
7	87 Fr 223	88 Ra 226.0	103 Lr 257	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une									

NON-METALS

METALLOIDS

METALS

Lanthanides	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm 146.9	62 Sm 150.9	63 Eu 151.3	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0
Actinides	89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.1	94 Pu 239.1	95 Am 241.1	96 Cm 247.1	97 Bk 249.1	98 Cf 251.1	99 Es 254.1	100 Fm 257.1	101 Md 258.1	102 No 255

Numbers below the symbol indicates the atomic masses; and the numbers above the symbol indicates the atomic numbers.

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QUESTION ONE

(a) Define acids and bases as per [2]

(i) Arrhenius [5]

(ii) Bronsted and Lowry

(b) (i) Write the equation that represents the solution of an acid in water and name the products. [4]

(ii) Then give the equilibrium expression for the reaction at b (i) [4]

(c) Calculate $[H^+]$ or $[OH^-]$ for the following solutions and indicate whether the solution is neutral, acidic or basic

(i) 1.0×10^{-5} M OH^- [2]

(ii) 1.0×10^{-7} M OH^- [2]

(d) At 60 ^{O}C the value of Kw *is* 1×10^{-13}

Use Le Chatelier's principle to predict whether the reaction

$2H_2O(l) \rightleftharpoons H_3O^+(aq) + HO^-(aq)$ is exothermic or endothermic [2]

$2H_2O \rightleftharpoons$

(e) Arrange the following or species in order of their strengths as bases:

H_2O, F^-, Cl^- *and* CN^- [4]

CO_3^{2-} L OH^-

QUESTION TWO **[25 MARKS]**

STOICHIOMETRY

Li

a) Carbon dioxide in the air of a spacecraft can be removed by reacting it with lithium hydroxide to give lithium carbonate and water. On average, a person will exhale about one kilogram of CO_2 per day.

i) Write a balanced equation for the reaction. [2]

ii) If you react the given amount of carbon dioxide with 1.5 kg of lithium hydroxide, identify the limiting reagent. [3]

iii) How many kgs of lithium carbonate do you expect from the quantities of the reactants given? [3]

iv) If 1,259.20 g of lithium carbonate is produced, calculate the percentage yield of lithium carbonate. [3]

v) How much in moles is the excess reagent? [3]

vi) Calculate the percentage composition of each element in lithium carbonate. [3]

1.5 kg+ 100

b) Nicotine, an alkaloid in the nightshade family of plants that is mainly responsible for the addictive nature of cigarettes, contains 74.02% C, 8.710% H, and 17.27% N. If 40.57 g of nicotine contains 0.2500 mol nicotine, what is the molecular formula of nicotine? [5]

c) Dianabol is one of the anabolic steroids that has been used by some athletes to increase the size and strength of their muscles. It is similar to the male hormone testosterone. Some studies indicate that the desired effects of the drug are minimal, and the side effects, which include sterility and increased risk of liver cancer and heart disease, keep most people from using it. The molecular formula of Dianabol, which consists of carbon, hydrogen, and oxygen, can be determined using the data from two different experiments. In the first experiment, 14.765 g of Dianabol is burned, and 43.257 g CO_2 and 12.395 g H_2O are formed. In the second experiment, the molecular mass of Dianabol is found to be 300.44 g/mol. What is the molecular formula for Dianabol? [6]

QUESTION THREE **[25 MARKS]**

REACTIONS IN AQUEOUS SOLUTIONS

(a) A solution is prepared by dissolving 36.4 g CaI_2 in 750 mL of water. What is the molarity of the solution?

(b) Identify each of the following changes as either oxidation or

Reduction. Recall that e- is the symbol for an electron.

(i) $I_2 + 2e^- \rightarrow 2I^-$ (ii) $Fe^{2+} \rightarrow Fe^{3+} + e^-$

(c) Identify what is oxidized and what is reduced in the following process.

$$2Ce + 3Cu^{2+} \rightarrow 3Cu + 2Ce^{3+}$$

(d) Identify the oxidizing agent and the reducing agent in the above process. Explain your answer.

(e) Use the oxidation number method to balance the following redox reaction.

$$Cu + HNO3 \rightarrow Cu(NO_3)_2 + NO_2 + H_2O$$

QUESTION FOUR **[25 MARKS]**

ORGANIC CHEMISTRY

(a) Hydrocarbons form the base from which the huge numbers of known organic compounds are assumed to have been derived. State two natural sources of hydrocarbons.

(b) Write IUPAC names for the following hydrocarbon:

(i) (ii) (iii) (iv)

(c) Write balanced equations for the combustion of each of the following hydrocarbons. Assume that each is converted completely.

(i) Hexane (ii) 2-Methylpentane

(d) Bromine (brown in colour) is used to test for unsaturation in hydrocarbons. Show, by way of a sufficiently labelled chemical reaction of ethene with bromine, how this is possible.

(e) Identify the families of organic compounds to which the following molecules belong:

(i) $CH_3\ CH_2{-}O{-}CH_2\ CH_3$ (ii) (iii) (iv) $CH_3\ CH_2\ CH_2\ NH_2$

FRANK MWALE

THE COPPERBELT UNIVERSITY

SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

SESSIONAL EXAMINATION 2014/15

TITLE OF PAPER: GENERAL CHEMISTRY

COURSE NUMBER: CH110/CH120/FO130

TIME: THREE (3) HOURS

INSTRUCTIONS:

There are seven questions in two sections, A and B. Each question is worth 20 marks.
Answer a total of five (5) questions with at least two(2) questions from each section.

All calculated quantities must have units and be reported to the correct number of significant figures otherwise marks will be deducted.

A data sheet and a periodic table are provided

Non-programmable electronic calculators may be used.

DO NOT OPEN THIS PAPER UNTIL PERMISSION TO DO SO HAS BEEN GRANTED BY THE CHIEF INVIGILATOR.

SECTION A: ANSWER AT LEAST TWO QUESTIONS FROM THIS SECTION

Question 1 (20 Marks)

(a) Explain the following key terms in the study of chemical equilibrium,

(i) Law of mass action [1]

(ii) Reaction quotient [1]

(b) Write the equilibrium expression for each of the following reactions

(i) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ [1]

(ii) $S_8(g) \rightleftharpoons 8S(g)$ [1]

(iii) $Cl_2O_7(g) + 8H_2(g) \rightleftharpoons 2HCl(g) + 7H_2O(g)$ [1]

(c) Consider the decomposition equilibrium reaction of methanol to carbon monoxide and hydrogen: $\mathbf{CH_3OH(g) \rightleftharpoons CO(g) + 2H_2(g)}$.

(i) Calculate K_p for the reaction given that $P_{CH_3OH} = 6.10 \times 10^{-4}$atm, $P_{CO} = 0.387$ atm and $P_{H_2} = 2.68$ atm. [2]

(ii) Derive the expression that relates K_c and K_p for this reaction [4]

(d) The average pH of normal arterial blood is 7.40. At normal body temperature (37 °C), $K_w = 2.4 \times 10^{-14}$. Calculate $[H^+]$, $[OH^-]$ and pOH for blood at this temperature. [5]

(e) Lactic acid ($HC_3H_5O_3$) has one acidic hydrogen atom. A 0.10 M solution of lactic acid has a pH of 2.44. Calculate its K_a. [4]

Question 2 (20marks)

(a) List four factors that affect reaction rates. [2]

(b) The rate law for a reaction is $rate = [A][B]^2$. What is the order with respect to [A], with respect to [B] and the overall order? [3]

(c) Consider the combustion of ethylene,

$$C_2H_4(g) + 3\,O_2(g) \rightarrow 2\,CO_2(g) + 2\,H_2O(g)$$

If the concentration of C_2H_4 is decreasing at the rate of 0.37 M/s, what are the rates of change in the concentration of CO_2 and O_2? [4]

(d) The first order rate constant for the decomposition of N_2O_5,

$$N_2O_5(g) \rightarrow 2\,NO_2(g) + O_2(g),$$

at 70 °C is 6.82×10^{-3} s^{-1}. Suppose we start with 0.0250 mol of $N_2O_5(g)$ in a volume of 2.0 L. (First order rate law $[A]_t = [A]_0 e^{-kt}$)

(i) How many moles of N_2O_5 will remain after 2.5 min? [2]

(ii) How many minutes will it take for the quantity of N_2O_5 to drop to 0.010 mol? [2]

(iii) What is the half-life of N_2O_5 at 70 °C? [2]

$-\log(2.0 \times 10^{-4})$ 0.1M $\frac{K_a K_b}{K_a} = \frac{K_w}{K_a}$ $K_b =$

(e) A certain first order reaction has a rate constant of $2.75 \times 10^{-2}\ s^{-1}$ at 20 °C. What is the value of k at 60 °C if the E_a = 75.5 kJ/mol. (Arrhenius equation $k = Ae^{-E_a/RT}$) [5]

Question 3 (20 marks)

(a) Naphthalene, $C_{10}H_8$, is a solid aromatic compound often sold as mothballs. The complete combustion of this substance to $H_2O(l)$ and $CO_2(g)$ at 25 °C yields 5154 kJ/mol. Write a thermo-chemical equation for the combustion of $C_{10}H_8$. [2]

(b) Consider the combustion of liquid methanol, $CH_3OH(l)$

$$CH_3OH(l) + 3/2O_2(g) \rightarrow CO_2(g) + 2\,H_2O(l) \qquad \Delta H = -726.5\ kJ$$

(i) What is the enthalpy change for the reverse reaction? [1]

(ii) Balance the forward reaction with whole-number coefficients. What is ΔH for the reaction represented by this equation? [2]

(iii) Which is more likely to be thermodynamically favoured, the forward reaction or the reverse reaction? Explain. [2]

(iv) If the reaction were written to produce $H_2O(g)$ instead of $H_2O(l)$, would you expect the magnitude of ΔHto increase, decrease, or stay the same? Explain. [2]

(c) From the enthalpies of reaction

$H_2(g) + F_2(g) \rightarrow 2\,HF(g)$ ΔH = -537 kJ
$C(s) + 2\,F_2(g) \rightarrow CF_4(g)$ ΔH = -680 kJ
$2\,C(s) + 2\,H_2(g) \rightarrow C_2H_4(g)$ ΔH = +52.3 kJ

Calculate ΔH for the reaction of ethene with F_2:

$$C_2H_4\,(g) + 6F_2(g) \rightarrow 2\,CF_4(g) + 4\,HF(g)$$ [5]

(d) Given that standard enthalpy of formation, ΔH_f^θ, of HCN(g) is 135 kJ/mol and the standard entropy values in the table below:

Compound	$H_{2(g)}$	$N_{2(g)}$	$C_{(s)}$	$HCN_{(g)}$
S^o J K^{-1} mol^{-1}	218	413	716	202

(i) Write the thermo-chemical equation corresponding ΔH_f^θ of HCN(g). [1]

(ii) Calculate the value of the Gibbs energy of formation, ΔG_f^θ, in kJ mol^{-1} at 25°C of HCN. [3]

(iii) Determine the temperature above or below which the reaction is spontaneous. [2]

$C_{10}H_8 + 12O_2 \rightarrow 10CO_2 + 4H_2O$

$\Delta G^\circ = \Delta H - \Delta S^\circ T$

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SECTION B: ANSWER AT LEAST TWO (2) QUESTIONS FROM THIS SECTION

Question 4 (20 Marks) (GASES,NON QUOTA)

(a) A 200 mL sample of hydrogen chloride at 690 Torr and 20.0°C is dissolved in 100 mL of water. The solution was titrated to the stoichiometric point with 15.7 mL of sodium hydroxide solution.

(i) Write a balanced equation for the titration reaction. [1]

(ii) What is the molar concentration of the NaOH solution? (4)

(b) The analysis of a hydrocarbon revealed that it was 85.7% C and 14.3% H by mass. When 1.77 g of the gas was stored in a 1.500 L flask at 17 °C, it exerted a pressure of 508 Torr. Determine

(i) the empirical formula of the hydrocarbon [3]

(ii) the molar mass of the hydrocarbon [3]

(iii) the molecular formula of the hydrocarbon? [1]

(c) Iron pyrite, FeS_2, is the form in which much of the sulphur occurs in coal. In the combustion of the coal, oxygen reacts with iron pyrite to produce iron(III) oxide and sulphur dioxide.

(i) Write a balanced equation for the reaction of iron pyrite with oxygen. [2]

(ii) Calculate the mass of Fe_2O_3 that is produced from the reaction of 75.0 L of oxygen at 2.33 atm and 150. °C with an excess of iron pyrite. [4]

(iii) If the sulphur dioxide that is produced is dissolved to form 5.00 L of aqueous solution, what is the molar concentration of the resulting sulphurous acid, H_2SO_3, solution? [2]

OR

Question 4 (20 Marks)(BIOCHEMISTRY, NATURAL RESOUCES)

(a) (i) Draw the mirror images of the words MUM and DAD. [1]

(ii) Define chirality and apply your definition to these two words. [3]

(iii) Give the molecular formula and draw the Fischer projections of the simplest carbohydrates and their enantiomers. Name them all and indicate, with an asterisk, the chiral center in each structure. Apply your earlier definition of chirality to these molecules. [6]

(iv) What in meant by an *optically active compound*? Exemplify. [2]

(b) Describe the structure of DNA, including reference to:

- The components of a nucleotide
- The pairing of bases
- The type and number of bonds between the bases. [3]

(c) Deduce the structures of the two dipeptides that can be formed from one molecule of the amino acids alanine and cysteine for which -R is -H and $-CH_2SH$ respectively.How different are the two dipeptides? [3]

(d) Explain briefly why:

(i) Phospholipids are amphipathic [1]

(ii) Amino acids are amphoteric [1]

Question 5 (20 Marks)

(a) Consider the following elements: magnesium, carbon, and chlorine.

(i) Write the ground state electron configuration of each element. [3]

(ii) Use an appropriate pair of the above elements and their Lewis symbols to illustrate covalent bond formation. [2]

(iii) Use an appropriate pair of the above elements and their Lewis symbols to illustrate ionic bond formation. [2]

(b) Consider the following molecules: CF_4 and SF_4

(i) Write the Lewis structure of each. [3]

(ii) Predict the shape of each molecule using VSEPR model. [2]

(iii) Predict whether molecule is polar or non-polar. [2]

(c) For the molecule N_2O

(i) Write the Lewis structures that contribute to its resonance hybrid. (skeleton is N-N-O) [2]

(ii) Calculate the formal charges on all atoms in the above structures. [3]

(iii) Select the structure that is likely to make a dominant contribution to the resonance hybrid. [1]

Question 6 (20 marks

(a) Write the structure of the following hydrocarbons;

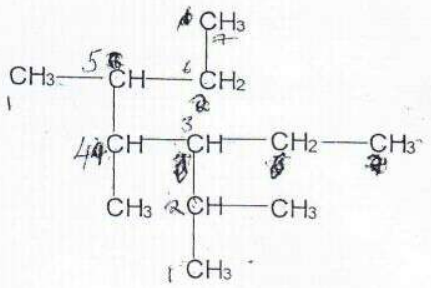
(i) 2-methylpentane

(ii) 2,3-dimethyl-2-butene

(iii) 3,3,4-trimethyl-1-pentyne [3]

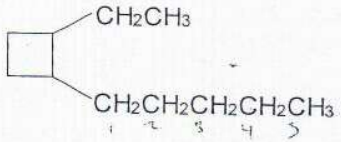
(b) Give **IUPAC names** for the following molecules C-C-C-C-C

(i)

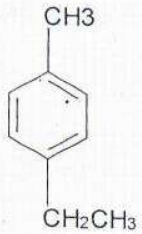


3-ethyl-2, 4, 5, trimethyl-heptane

(ii)

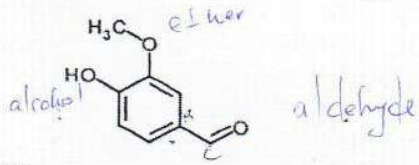


(iii)



(c) A compound has the molecular formula C_3H_8O. Draw the full structural formulas of the **three** possible isomers and give their names. [3]

(d) Identify three **functional groups** found in this molecule of vanillin: [3]



Vanillin (vanilla bean)

(e) Complete the following reactions in hydrocarbons: [3]

(i) $C_{37}H_{76} + \frac{113}{2}O_2 \longrightarrow 37CO_2 + 38H_2O$

(ii) $CH_3CH{=}CH_2 + HCl \longrightarrow$

(iii) + H_2 ⟶ [3]

(f) (i) Draw the structure of **3-methylhexane.** [1]

(ii) The molecule contains a **chiral** carbon. Define chiral carbon and identify such a carbon in this molecule. [2]

(iii) Draw the 2 structural **enantiomers** of this molecule [2]

Question 7 (20 Marks)

(a) Assign oxidation numbers to underlined elements in the following compounds and ions,

(i) $\underline{Cs_2}O$ (ii) $H_3\underline{As}O_3$ (iii) $\underline{Mo}O_4^{2-}$ (iv) $\underline{Cl}F_3$ [2]

(b) Classify the following reactions according to the types of aqueous reactions you learnt in this course

(i) $Cl_2(g) + 2OH^-(aq) \longrightarrow Cl^-(aq) + ClO^-(aq) + H_2O(l)$ [1]

(ii) $Ca^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow CaCO_3(s)$ [1]

(iii) $NH_3(aq) + H_3O^+(aq) \longrightarrow NH_4^+(aq) + H_2O(l)$ [1]

(c) A 60.00 mL 0.513 M glucose ($C_6H_{12}O_6$) solution is mixed with 120 mL of 2.33 M glucose solution. What is the concentration of the final solution? *(Assume additive volumes)* [4] $a_2 + NaOH$

(d) Balance the following reaction occurring in acidic solution

$NO_2^-(aq) + Cr_2O_7^{2-}(aq) \rightarrow Cr^{3+}(aq) + NO_3^-(aq)$ [4]

(e) A voltaic cell consists of a silver strip placed in a solution of $AgNO_3(aq)$ and an iron strip immersed in $FeCl_2(aq)$ solution. The overall cell reaction is

$Fe(s) + 2\,Ag^+(aq) \rightarrow Fe^{2+}(aq) + 2\,Ag(s)$

(i) Write the half reactions that occur in the two electrode compartments. [2]

(ii) Which electrode is the anode and which the cathode? [2]

(f) A voltaic cell that uses the reaction

$Tl^{3+}(aq) + 2\,Cr^{2+}(aq) \rightarrow Tl^+(aq) + 2Cr^{3+}(aq)$

has a measured standard cell potential of +1.19 V. Given that $E^o_{red}(Cr^{2+}/Cr^{3+}) = -0.41$ V, determine E^o_{red} for reduction of $Tl^{3+}(aq)$ to $Tl^+(aq)$. [3] 0.78

$2x + 7(-2) = -2$
$2x = -2 + 14$
$2x = +12$
$+6$

$Ag^+ + e^- \rightarrow Ag$
$Fe \rightarrow Fe^{2+} + 2e^-$

Physical Constants		
Constant	Symbol	Value
Atomic mass unit	*amu*	1.660554×10^{-27} kg
Avogadro's number	N_A	6.02214×10^{23} mol^{-1}
Bohr radius	a_o	5.292×10^{-11} m
Boltzmann's constant	k	1.38066×10^{-23} J K-1
Charge of an electron	e	1.60218×10^{-19} C
Faraday's constant	F	96,485 C mol^{-1}
Gas constant	R	8.31451 J K^{-1} mol^{-1}
		0.08206 L atm K^{-1} mol^{-1}
Mass of an electron	m_e	9.10939×10^{-31} kg
		5.48580×10^{-4} amu
Mass of a neutron	m_n	1.67493×10^{-27} kg
		1.00866 amu
Mass of a proton	m_p	1.67262×10^{-27} kg
		1.00728 amu
Planck's constant	h	6.62608 x 10-34 J s
Speed of light	c	2.99792458×10^{8} m s^{-1}
1 atm = 760mmHg = 1.0132×10^{5} Nm^{-2} = 1.0132×10^{5}Pa		