NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCES

DEPARTMENT OF APPLIED CHEMISTRY

FUNDAMENTALS OF CHEMISTRY

SCH 1117

SPECIAL EXAMINATION QUESTION PAPER

AUGUST 2024

This examination paper consists of 10 printed pages

Time Allowed:	3 hours
Total Marks:	100
Special Requirements:	1) Physical constants & formulae (included – page 9)
	2) Periodic table of the elements (included – page 10)
Internal Examiner:	Dr. M. Moyo
External Examiner:	Dr. G. Mehlana

INSTRUCTIONS & INFORMATION

1. Answer **all five** questions.
2. Where appropriate, answers should be presented in **essay or continuous writing** form. Importance should be attached to accuracy, clarity of expression and legibility of handwriting, NOT LENGTH.
3. Unless stated otherwise, all numerical answers should be expressed to **three significant figures**.

MARK ALLOCATION

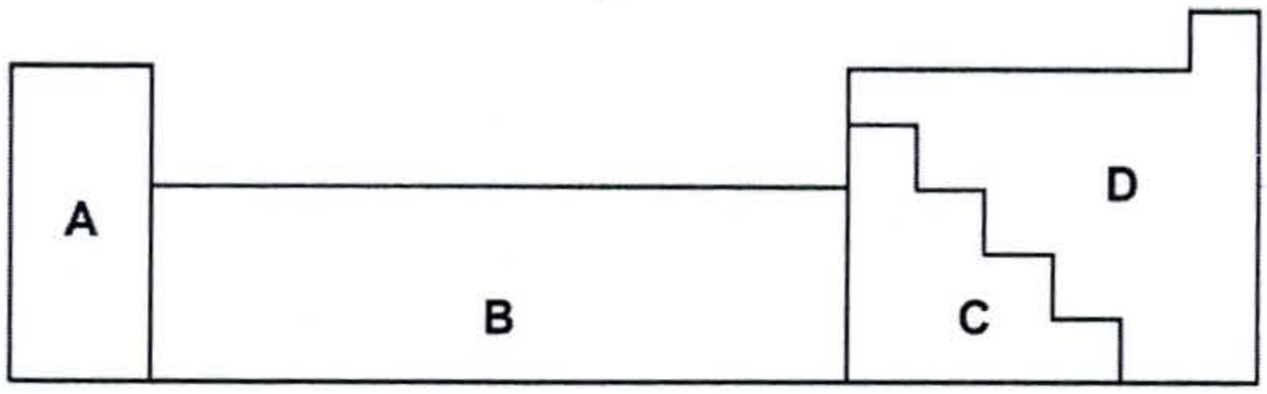
QUESTION	MARKS
1.	20
2.	20
3.	20
4.	20
5.	20
TOTAL POSSIBLE MARKS	**100**

QUESTION 1

Only write the question number and the letter (A – D) corresponding to your answer.

1.1 The diagram below shows an outline of part of the periodic table.

Figure 1



Element Q is a dull solid with a melting point of 44 °C and does not conduct electricity.

Element R, an electrical conductor, reacts violently with water, forming ions of formula R^+.

(a) Which section of the depicted periodic table is most likely to contain element Q?

[1 mark]

(b) Which section of the depicted periodic table is most likely to contain element R?

[1 mark]

1.2 Palladium (Pd) is in Period 4 of the periodic table. It has six stable isotopes, ^{102}Pd, ^{104}Pd, ^{105}Pd, ^{106}Pd, ^{108}Pd, and ^{110}Pd.

(a) How many neutrons are there in a ^{106}Pd atom?

A 106 **B** 46 **C** 60 **D** 152

[1 mark]

(b) How many shells does each isotope of palladium have?

A 2 **B** 3 **C** 4 **D** 5

[1 mark]

(c) Which palladium isotope contains the most electrons?

A ^{102}Pd **B** ^{104}Pd **C** ^{106}Pd **D** None of them

[1 mark]

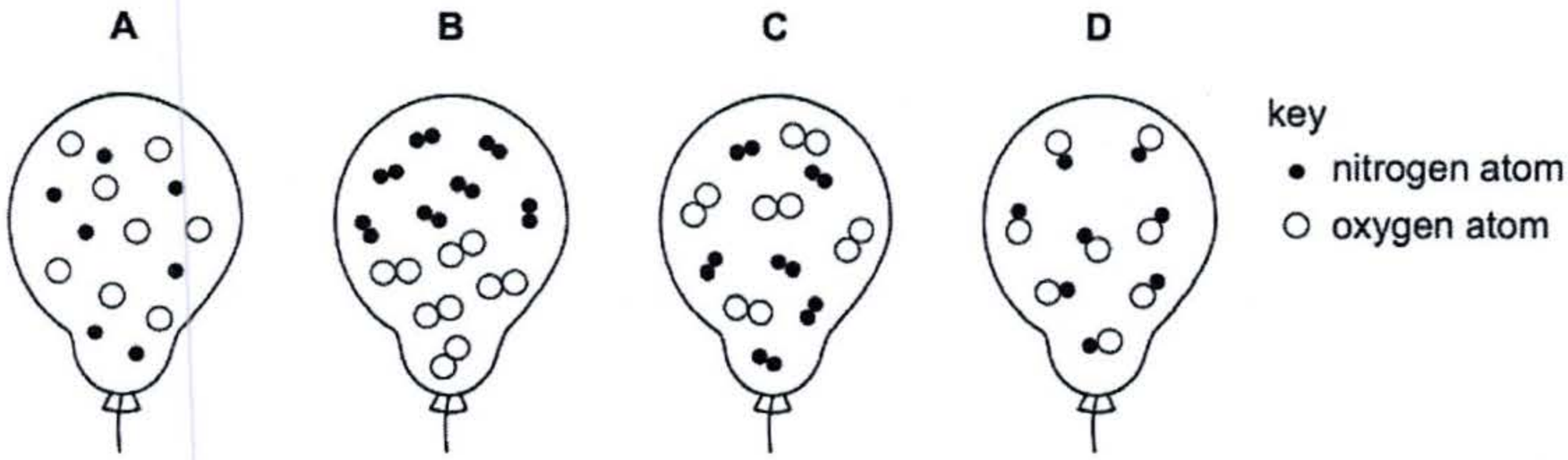
1.3 How many of the diatomic molecules shown below contain only **two(2)** covalent bond?

Cl_2	H_2	HCl	N_2	CO

A 0 **B** 1 **C** 2 **D** 3

[1 mark]

1.4 Which diagram shows the arrangement of particles inside a balloon containing a mixture of the gases nitrogen and oxygen?



[2 marks]

1.5 Some metals and the compounds in their ores are shown.

Metal	Al	Ca	Pb	Na	Fe	Mg
Compound in ore	Al_2O_3	$CaCO_3$	PbS	NaCl	Fe_2O_3	$MgCO_3$

Which type of reaction occurs in the extraction of each of these metals from their ore?

A decomposition by heat **B** oxidation **C** reduction **D** precipitation

[2 marks]

1.6 Solutions containing chlorate(I) ions are used as household bleaches and disinfectants decompose on heating as follows:

$$3C\ell O^- \rightarrow C\ell O_3^- + 2C\ell^-$$

Which oxidation states are shown by chlorine in these three ions?

	$C\ell O^-$	$C\ell O_3^-$	$C\ell^-$
A	+1	+3	–1
B	–1	+3	+1
C	+1	+5	–1
D	–1	+5	+1

[2 marks]

1.7 One mole of which of the following alkanes will produce **five(5)** moles of *products* upon undergoing complete combustion?

A CH_4 **B** C_2H_6 **C** C_3H_8 **D** C_4H_{10}

[2 marks]

1.8 The formation of liquid water from hydrogen and oxygen may occur in three stages.

1. $2H_2(g) + O_2(g) \rightarrow 4H(g) + 2O(g)$
2. $4H(g) + 2O(g) \rightarrow 2H_2O(g)$
3. $2H_2O(g) \rightarrow 2H_2O(\ell)$

Which stages would be endothermic?

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

[2 marks]

1.9 A medal has a total surface area of 150 cm^2. It is evenly coated with silver by electrolysis. Its mass increases by 0.216 g.

How many atoms of silver are deposited per cm^2 on the surface of the medal?

A 8.0×10^{18} **B** 1.8×10^{19} **C** 8.7×10^{20} **D** 1.2×10^{21}

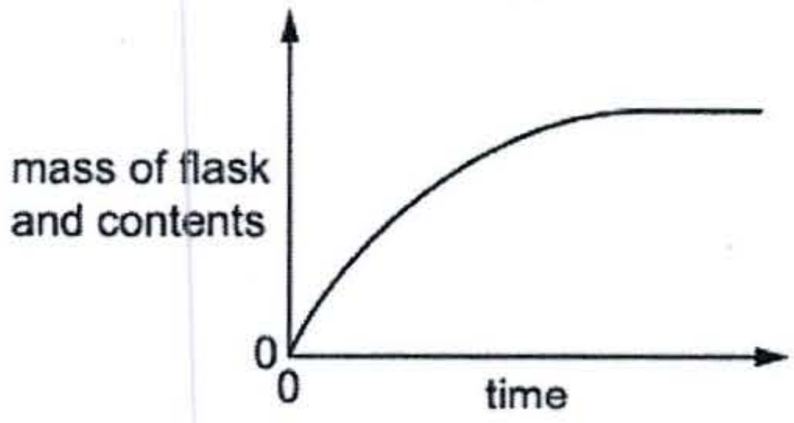
[2 marks]

1.10 When sodium carbonate granules are dropped into a flask containing hydrochloric acid an exothermic reaction occurs. The equation for the reaction is:

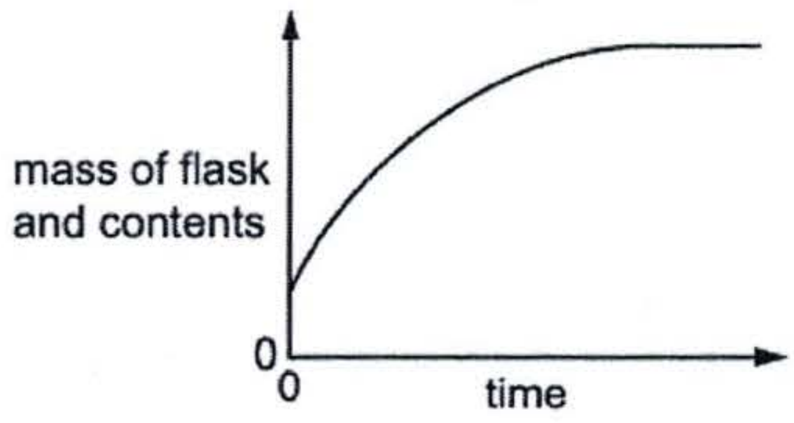
$$Na_2CO_3(s) + 2HC\ell(aq) \rightarrow 2NaC\ell(aq) + CO_2(g) + H_2O(\ell)$$

Which graph correctly shows the change in the mass of the flask and contents with time?

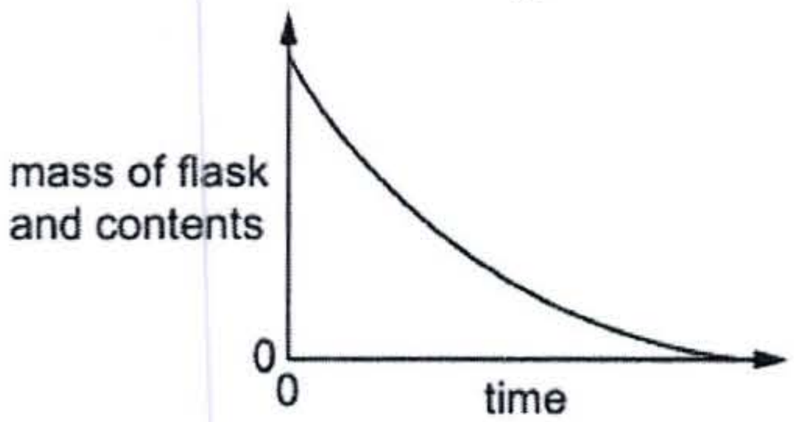
A



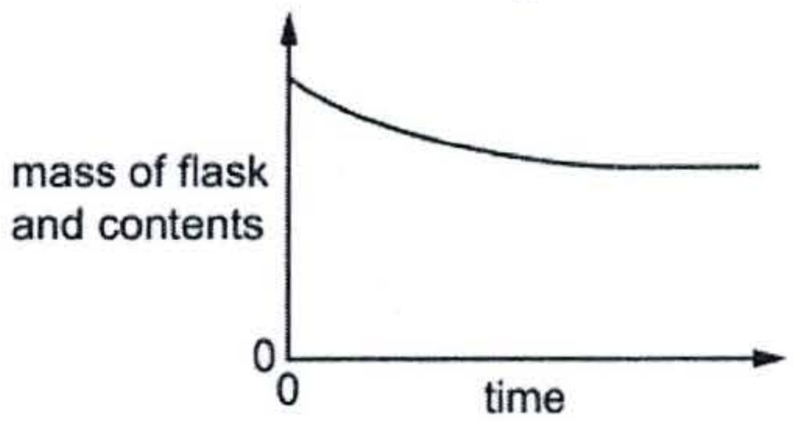
B



C



D



[2 marks]

End of Question 1

QUESTION 2

Carbon and silicon are elements in Group 14. C_{60} sublimes (turns directly from solid to gas) at approximately 800 K according to $C_{60}(s) \rightarrow C_{60}(g)$. Diamond also sublimes but only above 3800 K according to: $C_{diamond}(s) \rightarrow C(g)$.

2.1 (a) Describe in simple terms the structure of solid C_{60}.

[3 marks]

(b) Explain why diamond sublimes at such a high temperature in comparison to C_{60}.

[4 marks]

2.2 0.144 g of C_{60} is placed in a 100 cm^3 container of hydrogen gas at a temperature of 20 °C and a pressure of 1.00×10^5 Pa. The container is heated to make the C_{60} and hydrogen gas react. The reaction occurs as shown in the equation.

$$C_{60}(s) + xH_2(g) \rightarrow C_{60}H_{2x}(s)$$

After the reaction, the container is allowed to cool to 20 °C. The pressure decreases to 2.21×10^4 Pa. All of the C_{60} has reacted.

(a) Name the type of reaction that occurs. Explain your answer.

[2 marks]

(b) Calculate the amount, in moles, of C_{60} that reacts.

[2 marks]

(c) Calculate the amount, in moles, of hydrogen gas that reacted with the C_{60}.

[3 marks]

(d) Use your answers from (b) and (c) to deduce the molecular formula of the hydrocarbon, $C_{60}H_{2x}$.

(If you were unable to calculate the amount of hydrogen gas, assume that 0.00240 mol of hydrogen gas reacts. This is **not** the correct value.)

[3 marks]

2.3 Silicon, which shows the same type of bonding and structure as diamond, reacts with magnesium to form Mg_2Si. Solid Mg_2Si reacts with dilute hydrochloric acid to form gaseous SiH_4 and a solution of magnesium chloride.

Construct an equation for Mg_2Si–Hydrochloric acid reaction. Include state symbols.

[3 marks]

End of Question 2

QUESTION 3

3.1 Give the balance form of the following equations, indicate the **specific** pattern-based type of reaction, and provide an explanation for your choice of the type of reaction:

(a) $CH_4\,(g) + Cl_2\,(g) \longrightarrow CCl_4\,(l) + HCl\,(g)$

(b) $Mg\,(s) + N_2\,(g) \longrightarrow Mg_3N_2\,(s)$

[6 marks]

3.2 One of the steps in the commercial process for converting ammonia to nitric acid is the conversion of NH_3 to NO represented by:

$$4NH_3\,(g) + 5O_2\,(g) \longrightarrow 4NO\,(g) + 6H_2O\,(g)$$

In a certain experiment, 2.04 g of NH_3 is sealed in a vessel containing 4.00 g of O_2.Using one or more calculations:

(a) Show, by calculation, that O_2 is the *limiting* reactant.

[5 marks]

(b) Determine the quantities of NO and H_2O formed, in **moles** and in **grams**.

[4 marks]

(c) Determine the quantities of excess reagent that remained after the limiting reactant was completely consumed, in **moles** and in **grams**.

[3 marks]

(d) Show that your calculation in (b) and (c) are consistent with the law of conservation of mass.

[2 marks]

End of Question 3

QUESTION 4

4.1 Copy and complete the following table to give the corresponding details of the listed pure substances:

Table 1

Substance	Formula	Name(s) of particle(s)	Dominant interparticle force
Hydrogen gas			
Copper			
Gold(I) dihydrogen phosphate			
Water			
Nitrogen triiodide			
Argon			
Graphite			

[12 marks]

4.2 (a) Outline the meaning of the term *mixture*.

[3 marks]

(b) Using a table that cites **one (1)** example of each, name and distinguish between the two types of mixtures.

[6 marks]

End of Question 4

QUESTION 5

5.1 Xenon and radon are noble gases in Group VIII. Representations of two different atoms of radon are shown below.

$$^{220}_{86}Rn \qquad\qquad ^{222}_{86}Rn$$

(a) What collective name is given to atoms of this nature?

[1 mark]

(b) Give **one (1)** difference and **two (2)** similarities in the structure of the two atoms.

[3 marks]

(c) Xenon forms a compound that contains only xenon, oxygen and fluorine. The compound contains 22.1% oxygen by mass and 17.5% fluorine by mass.

Calculate the empirical formula of this compound

[6 marks]

5.2 When bromine water reacts is combined with aqueous methanoic acid (HCO_2H), hydrobromic acid is formed and carbon dioxide is evolved.

(a) Construct a balanced equation to represent the reaction of bromine water with aqueous methanoic acid. Include state symbols.

[3 marks]

(b) Copy and complete the following table to show the oxidation numbers of the atoms in the reactant and product species involved in the reaction.

	Oxidation number	
	In reactants	In products
Bromine		
Hydrogen		
Carbon		
Oxygen		

[4 marks]

(c) Identify the oxidising agent in this reaction. Explain your reasoning with reference to oxidation numbers.

[3 marks]

End of Question 5

LIST OF PHYSICAL CONSTANTS & FORMULAE

PHYSICAL CONSTANTS

Name	Symbol	Value
Standard temperature	T^{θ}	273 K (25 °C)
Standard pressure	p^{θ}	1.013×10^5 Pa (1 atm)
Molar gas constant	R	8.31 J K^{-1} mol^{-1}
Molar gas volume at STP	V_m	22.4 dm^3 mol^{-1}
Avogadro's constant	N_A	6.02×10^{23} mol^{-1}

FORMULAE

$n = \frac{m}{M}$	$n = \frac{N}{N_A}$	$n = \frac{V}{V_A}$
$c = \frac{n}{V}$	$pV = nRT$	$pH = -\log[H^+]$

PERIODIC TABLE OF THE ELEMENTS

						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 Aluminium 27	14 Si Silicon 28	15 P Phosphorous 31	16 S Sulphur 32	17 Cl Chlorine 35.5	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	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 Caesium 133	56 Ba Barium 137	57-71 La	72 Hf Hafnium 178	73 Ta Tantalum 181	74 W Tungsen 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	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radius	89-103 Ac	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seabrgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoid series	57 La Lanthanum 139	58 Ce Cerium 140	59 Pr Praseodymium 141	60 Nd Neodymium 144	61 Pm Promethium	62 Sm Samarium 150	63 Eu Europium 152	64 Gd Gadolinium 157	65 Tb Terbium 159	66 Dy Dysprosium 162	67 Ho Holmium 165	68 Er Erbium 167	69 Tm Thulium 169	70 Yb Ytterbium 173	71 Lu Lutetium 175
Actinoid series	89 Ac Actinum 227	90 Th Thorium 232	91 Pa Protactinium	92 U Uranium 238	93 Np Neptunium	94 Pu Plutonium	95 Am Americum	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

End of question paper