



**PAMIBIA UNIVERSITY**  
OF SCIENCE AND TECHNOLOGY

**FACULTY OF ENGINEERING**

**InSTEM**

<b>QUALIFICATION: INTRODUCTION TO SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS</b>	
<b>QUALIFICATION CODE: 04STEM</b>	<b>LEVEL: 4</b>
<b>COURSE CODE: ICH402S</b>	<b>COURSE NAME: INTRODUCTION TO CHEMISTRY B</b>
<b>SESSION: NOVEMBER 2019</b>	<b>PAPER: N/A</b>
<b>DURATION: 3 HOURS</b>	<b>MARKS: 100</b>

<b>FIRST OPPORTUNITY EXAMINATION QUESTION PAPER</b>	
<b>EXAMINER(S)</b>	<b>Mr Victor Uzoma</b>
<b>MODERATOR:</b>	<b>Prof Habauka M Kwaambwa</b>

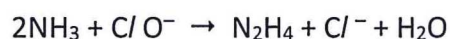
<b>INSTRUCTIONS</b>
<ol style="list-style-type: none"><li>1. Answer all questions.</li><li>2. Write all the answers in ink.</li><li>3. No books, notes, correction fluid (Tippex) or cell phones allowed.</li><li>4. Pocket calculators are allowed.</li><li>5. You are not allowed to borrow or lend any equipment or stationary.</li><li>6. All <b>FINAL ANSWERS</b> must be rounded off to <b>TWO DECIMAL PLACES</b> unless otherwise stated.</li><li>7. Periodic table on page 9.</li></ol>

**THIS QUESTION PAPER CONSISTS OF 9 PAGES (Excluding this front page)**

**Question 1**

**[9]**

1.1 Chlorate(I) ions undergo the following reaction under aqueous conditions:



A series of experiments was carried out at different concentrations of  $\text{ClO}^-$  and  $\text{NH}_3$ . The table below shows the results obtained:

experiment	$[\text{ClO}^-] / \text{mol dm}^{-3}$	$[\text{NH}_3] / \text{mol dm}^{-3}$	initial rate / $\text{mol dm}^{-3} \text{s}^{-1}$
1	0.200	0.200	1.025
2	0.400	0.200	2.05
3	0.400	0.400	8.20

1.1.1 Use the data in the table to determine the order with respect to each reactant,  $\text{ClO}^-$  and  $\text{NH}_3$ . Show your reasoning. (2)

1.1.2 Write the rate equation for this reaction. (1)

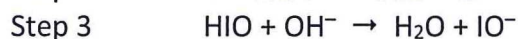
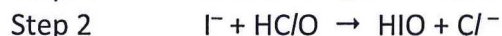
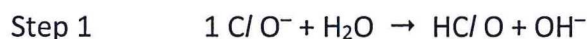
1.1.3 Use the results of experiment 1 to calculate the rate constant,  $k$ , for this reaction. Include the units of  $k$ . (1)

1.1.4 Redraw the axes and sketch a graph to show how the value of  $k$  changes as temperature is increased. (1)

1.2 In another experiment, the reaction between chlorate(I) ions and iodide ions in aqueous alkali was investigated. A solution of iodide ions in aqueous alkali was added to a large excess of chlorate(I) ions and  $[\text{I}^-]$  was measured at regular intervals.

1.2.1 Describe how the results of this experiment can be used to confirm that the reaction is first-order with respect to  $[\text{I}^-]$ . (2)

1.2.2 A three-step mechanism for this reaction is shown:



Use this mechanism to deduce the overall equation for this reaction. (1)

1.2.3 In the three step mechanism in 1.2.2, Identify a step that involves a redox reaction. Explain your answer. (1)

**Question 2****[12]**

Entropy changes and free energy changes can be used to predict the feasibility of processes.

2.1 Three processes are given below. For each process, predict and explain whether the entropy change,  $\Delta S$ , would be positive or negative. (3)

- The melting of iron.
- The reaction of magnesium with dilute sulfuric acid.
- The complete combustion of ethane:  $2\text{C}_2\text{H}_6(\text{g}) + 7\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l})$

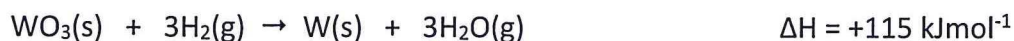
2.2 Ammonia can be oxidised as shown in the equation below:



At  $450^\circ\text{C}$ ,  $\Delta H = -907 \text{ kJ mol}^{-1}$  and  $\Delta G = -1041 \text{ kJ mol}^{-1}$ . Calculate the standard entropy change,  $\Delta S$ , in  $\text{J K}^{-1} \text{ mol}^{-1}$ , for this reaction. Show all your working. (2)

2.3 A reaction is not feasible at low temperatures but is feasible at high temperatures. Deduce the signs of  $\Delta H$  and  $\Delta S$  for the reaction and explain why the feasibility changes with temperature. (3)

2.4 The metal tungsten is obtained on a large scale from its main ore, wolframite. Wolframite contains tungsten(VI) oxide,  $\text{WO}_3$ . Tungsten is extracted from wolframite by reduction with hydrogen:



Standard entropies are given in the table below:

Substance	$\text{WO}_3(\text{s})$	$\text{H}_2(\text{g})$	$\text{W}(\text{s})$	$\text{H}_2\text{O}(\text{g})$
$S^\ominus/\text{JK}^{-1}\text{mol}^{-1}$	76	131	33	189

2.4.1 Calculate the free energy change,  $\Delta G$ , in  $\text{kJmol}^{-1}$ , for this reaction at  $25^\circ\text{C}$ . (2)

2.4.2 Calculate the minimum temperature, in K, at which this reaction becomes feasible. (Show your working) (2)

**Question 3****[16]**

This question is about acids, bases and buffers solutions.

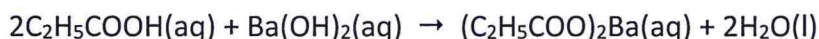
3.1 Barium hydroxide,  $\text{Ba}(\text{OH})_2$ , is a strong Brønsted–Lowry base. A student prepares  $250.0 \text{ cm}^3$  of  $0.1250 \text{ mol dm}^{-3}$  barium hydroxide.

3.1.1 Explain what is meant by the term *Brønsted–Lowry base*. (1)

3.1.2 Calculate the mass of  $\text{Ba}(\text{OH})_2$  that the student would need to weigh to two decimal places to prepare  $250.0 \text{ cm}^3$  of  $0.1250 \text{ mol dm}^{-3}$   $\text{Ba}(\text{OH})_2$ . (3)

3.1.3 Calculate the pH of a  $0.1250 \text{ mol dm}^{-3}$  solution of  $\text{Ba}(\text{OH})_2$ . Give your answer to two decimal places. (3)

3.2 The student attempts to prepare a buffer solution by mixing  $200 \text{ cm}^3$  of  $0.324 \text{ mol dm}^{-3}$   $\text{C}_2\text{H}_5\text{COOH}$  with  $100 \text{ cm}^3$  of the  $0.1250 \text{ mol dm}^{-3}$   $\text{Ba}(\text{OH})_2$  prepared in (3.1). The equation for the reaction that takes place is shown below:



Explain whether the student was successful in preparing a buffer solution. Include all reasoning and any relevant calculations. (4)

3.3 Blood contains a mixture of carbonic acid,  $\text{H}_2\text{CO}_3$ , and hydrogen carbonate ions,  $\text{HCO}_3^-$ . Explain how the carbonic acid–hydrogen carbonate mixture acts as a buffer. *In your answer include the equation for the equilibrium in this buffer solution and explain how this equilibrium system is able to control blood pH* (5)

**Question 4****[12]**

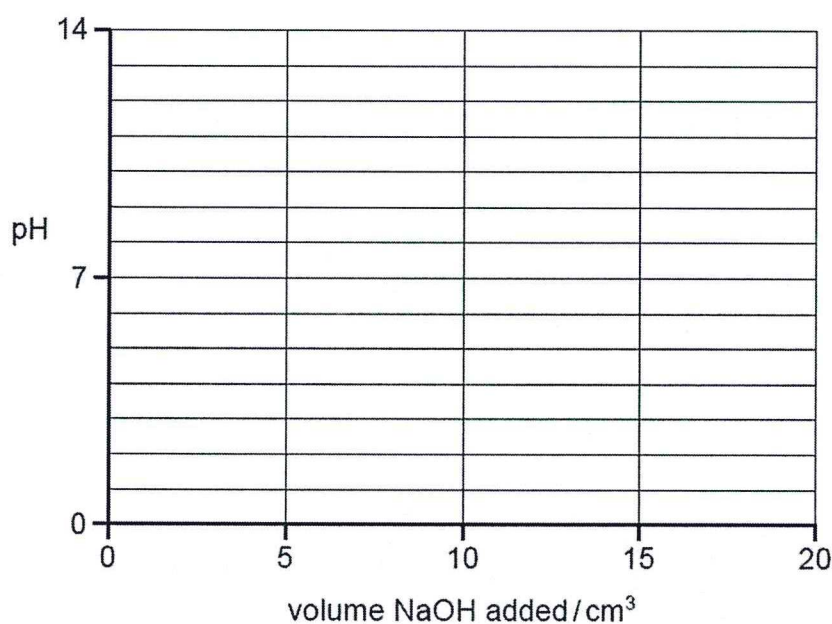
4.1 20.0 cm<sup>3</sup> of 0.100 mol dm<sup>-3</sup> NaOH were slowly added to a 10.0 cm<sup>3</sup> sample of 0.100 mol dm<sup>-3</sup> ethanoic acid, and the pH was measured throughout the addition.

4.1.1 Calculate the number of moles of NaOH remaining at the end of the addition. (2)

4.1.2 Calculate the [OH<sup>-</sup>] at the end of the addition. (3)

4.1.3 Using the expression  $K_w = [H^+][OH^-]$  and your value in 4.1.2, calculate [H<sup>+</sup>] and the pH of the solution at the end of the addition. (3)

4.2 Draw similar axes as below in your answer book, sketch how the pH will change during the addition of a total of 20.0 cm<sup>3</sup> of 0.100 mol dm<sup>-3</sup> NaOH. Mark clearly where the endpoint occurs. (3)



4.3 From the following list of indicators, which one is most suitable for this titration? (1)

Indicator	pH
Malachite green	0 - 1
Thymol blue	1 - 2
Bromophenol blue	3 - 4
Phenolphthalein	9 - 10

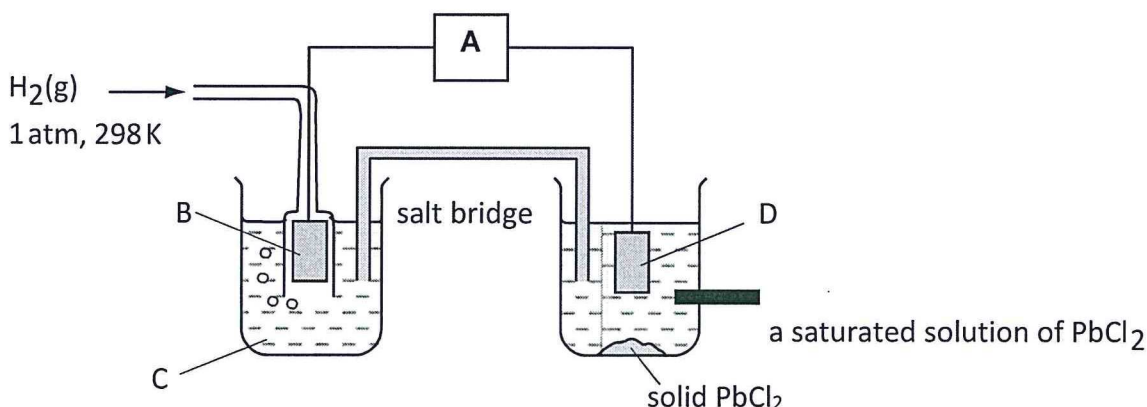
**Question 5**

**[12]**

Lead(II) chloride,  $\text{PbCl}_2$ , can be used in the manufacture of some types of coloured glass.  $\text{PbCl}_2$  is only sparingly soluble in water. The  $[\text{Pb}^{2+}]$  in a saturated solution of  $\text{PbCl}_2$  can be estimated by measuring the cell potential,  $E_{\text{cell}}$ , of the following cell.

Table of cell potential values:

Half-reaction	Cell potential/ $E^\ominus$ (V)
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-$	1.36
$\text{I}_2(\text{s}) + 2\text{e}^- \rightleftharpoons 2\text{I}^-$	0.53
$2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Pb}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$	-0.14



5.1 State what the four letters A-D in the above diagram represent. (2)

5.2 In a saturated solution of  $\text{PbCl}_2$ , The concentration  $[\text{PbCl}_2(\text{aq})] = 3.5 \times 10^{-2} \text{ mol dm}^{-3}$ .

5.2.1 The  $E^\ominus$  for the  $\text{Pb}^{2+} / \text{Pb}$  electrode is  $-0.13\text{V}$ . Predict the potential of the right-hand electrode in the diagram above, choosing from the box in the table below:

Electrode potential / V
-0.1
-0.13
-0.09
-0.00

Explain your answer. (2)

5.2.2 Write an expression for the solubility product,  $K_{\text{sp}}$ , of  $\text{PbCl}_2$ . (1)

5.2.3 Calculate the value of  $K_{\text{sp}}$ , including units. (2)

- 5.3 The behaviours of  $\text{PbI}_2$  and  $\text{SnCl}_2$  towards reducing agents are similar, but their behaviours towards oxidising agents are very different.

Table of some electrode potentials:

Half-reaction	Electrode potential (V)
$\text{Zn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Zn(s)}$	-0.76
$\text{Fe}^{2+} + 2\text{e}^- \rightleftharpoons \text{Fe(s)}$	-0.44
$\text{Pb}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pb}$	-0.13
$\text{Sn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sn}$	-0.14
$2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2$	0.00
$\text{Sn}^{4+} + 2\text{e}^- \rightleftharpoons \text{Sn}$	0.15
$2\text{I}^- + 2\text{e}^- \rightleftharpoons \text{I}_2$	0.54
$\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag}$	0.80
$\text{Br}_2(\text{l}) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-$	1.07
$2\text{Cl}^- + 2\text{e}^- \rightleftharpoons \text{Cl}_2$	1.36
$\text{Pb}^{4+} + 2\text{e}^- \rightleftharpoons \text{Pb}^{2+}$	1.69

- 5.3.1 Illustrate this comparison by quoting and comparing relevant  $E^\circ$  values shown in the table above for the two metals and their ions. Explain what the relative  $E^\circ$  values mean in terms of the ease of oxidation or reduction of these compounds. (3)
- 5.3.2 Writing a balanced molecular or ionic equation in each case, suggest a reagent to carry out each of the following reactions: (2)



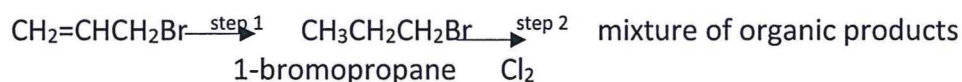
**Question 6****[25]**

Allyl bromide,  $\text{CH}_2=\text{CHCH}_2\text{Br}$ , is used in the production of polymers.

- 6.1 Part of the C=C double bond in allyl bromide is called a  $\pi$ -bond. Draw a labelled diagram to show the formation of the  $\pi$ -bond. (2)
- 6.2 Allyl bromide is a member of a homologous series. Compounds in this series have the same general formula.
- 6.2.1 What is meant by the term homologous series? (2)
- 6.2.2 What is the general formula of the homologous series that has allyl bromide as a member? (1)
- 6.2.3 Give the systematic name for allyl bromide. (1)
- 6.3 Reaction mechanisms use curly arrow and can involve electrophiles and nucleophiles.
- 6.3.1 What does a curly arrow represent in mechanisms? (1)
- 6.3.2 What is meant by the term nucleophile? (1)
- 6.4 Allyl bromide  $\text{CH}_2=\text{CHCH}_2\text{Br}$ , reacts with aqueous sodium hydroxide.
- 6.4.1 Outline the mechanism of this reaction. Include curly arrows, relevant dipoles and final product(s). (3)
- 6.4.2 Name the type of mechanism. (1)
- 6.5 Allyl bromide,  $\text{CH}_2=\text{CHCH}_2\text{Br}$ , reacts with bromine,  $\text{Br}_2$ .
- 6.5.1 Outline the mechanism of this reaction. Include curly arrows, relevant dipoles and the intermediate and final product(s). (4)
- 6.5.2 Name the type of mechanism. (1)



6.6 Allyl bromine is reacted as shown below:



6.6.1 State the reagents and conditions for step 1. (1)

6.6.2 In step 2, 1-bromopropane reacts with chlorine by radical substitution. Outline the mechanism for the monochlorination of 1-bromopropane. In your mechanism, you can show the formula of 1-bromopropane as  $\text{C}_3\text{H}_7\text{Br}$ . Include the names of the three stages in this mechanism, state the essential conditions and all termination steps. (5)

6.6.3 Radical substitution produces a mixture of organic products. Suggest two reasons why. (2)

**Question 7 [14]**

7.1 Write the equations for the following decay processes:

7.1.1 The beta decay of uranium -237 (2)

7.1.2 Positron emission from silicon-26 (2)

7.2 The radioisotope fluorine-21 had an initial mass of 80 milligrams. 20 milligrams of sample remained unchanged after 8.32 s. What is the half life of F-21? (2)

7.3 If  $1.000 \times 10^{-12}$  mol of Cs-135 emits  $1.390 \times 10^5$  beta-particles in 1.00 year, what is the decay constant? (4)

7.4 A chemist determines that a sample of petrified wood has a carbon-14 decay rate of 6.00 counts per minute per gram. What is the age of the piece of wood in years? The decay rate of carbon-14 in fresh wood today is 13.6 counts per minute per gram, and the half life of carbon-14 is 5730 years. (4)

**THE END**

# Periodic Table of the Elements

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	1 1.00794 <b>H</b>	2 4.00260 <b>He</b>																	
2	3 6.941 <b>Li</b>	4 9.01224 <b>Be</b>																	
3	11 22.989769 <b>Na</b>	12 24.30409 <b>Mg</b>																	
4	19 39.0983 <b>K</b>	20 39.0983 <b>Ca</b>	21 78.9724 <b>Sc</b>	22 47.88 <b>Ti</b>	23 50.9415 <b>V</b>	24 51.9961 <b>Cr</b>	25 54.9380 <b>Mn</b>	26 55.845 <b>Fe</b>	27 58.9332 <b>Co</b>	28 58.9332 <b>Ni</b>	29 63.546 <b>Cu</b>	30 65.38 <b>Zn</b>	31 69.723 <b>Ga</b>	32 72.64 <b>Ge</b>	33 74.9216 <b>As</b>	34 75.94 <b>Se</b>	35 78.96 <b>Br</b>	36 79.904 <b>Kr</b>	
5	37 85.4678 <b>Rb</b>	38 85.4678 <b>Sr</b>	39 132.905 <b>Y</b>	40 88.906 <b>Zr</b>	41 90.905 <b>Nb</b>	42 90.905 <b>Mo</b>	43 95.94 <b>Tc</b>	44 101.07 <b>Ru</b>	45 101.07 <b>Rh</b>	46 106.32 <b>Pd</b>	47 106.32 <b>Ag</b>	48 107.868 <b>Cd</b>	49 112.411 <b>In</b>	50 114.818 <b>Sn</b>	51 127.60 <b>Sb</b>	52 127.60 <b>Te</b>	53 127.60 <b>I</b>	54 132.905 <b>Xe</b>	
6	55 132.905 <b>Cs</b>	56 137.327 <b>Ba</b>	57 138.905 <b>La</b>	58 174.967 <b>Hf</b>	59 178.49 <b>Ta</b>	60 180.948 <b>W</b>	61 183.84 <b>Re</b>	62 186.207 <b>Os</b>	63 188.906 <b>Ir</b>	64 193.224 <b>Pt</b>	65 197.04 <b>Au</b>	66 200.59 <b>Hg</b>	67 204.38 <b>Tl</b>	68 207.2 <b>Pb</b>	69 208.98 <b>Bi</b>	70 208.98 <b>Po</b>	71 208.98 <b>At</b>	72 208.98 <b>Rn</b>	
7	87 223.019 <b>Fr</b>	88 226.025 <b>Ra</b>	89 227.027 <b>Ac</b>	90 232.0377 <b>Th</b>	91 231.03688 <b>Pa</b>	92 238.02891 <b>U</b>	93 237.04817 <b>Np</b>	94 237.04817 <b>Pu</b>	95 244.06422 <b>Am</b>	96 244.06422 <b>Cm</b>	97 244.06422 <b>Bk</b>	98 244.06422 <b>Cf</b>	99 244.06422 <b>Es</b>	100 244.06422 <b>Fm</b>	101 244.06422 <b>Md</b>	102 244.06422 <b>No</b>	103 244.06422 <b>Lr</b>		

**KEY**

Atomic Mass → 12.011  
Symbol → **C**  
Atomic Number → 6  
Electron Configuration → 2-4

Selected Oxidation States  
-4  
+2  
+4

Relative atomic masses are based on <sup>12</sup>C = 12.000

Note: Mass numbers in parentheses are mass numbers of the most stable or common isotope.

\*\*Denotes the presence of (2-8-) for elements 72 and above

\*The systematic names and symbols for elements of atomic numbers above 109 will be used until the approval of trivial names by IUPAC.