NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

InSTEM

QUALIFICATION: INTRODUCTION TO SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS	
QUALIFICATION CODE: 04STEM	**LEVEL:** 4
COURSE CODE: ICH402S	**COURSE NAME**: INTRODUCTION TO CHEMISTRY B
SESSION: JANUARY 2020	**PAPER:** N/A
DURATION: 3 HOURS	**MARKS:** 100

SECOND OPPORTUNITY EXAMINATION QUESTION PAPER	
EXAMINER(S)	**Mr Victor Uzoma**
MODERATOR:	**Prof Habauka M Kwaambwa**

INSTRUCTIONS

1. Answer all questions.
2. Write all the answers in ink.
3. No books, notes, correction fluid (Tippex) or cell phones allowed.
4. Pocket calculators are allowed.
5. You are not allowed to borrow or lend any equipment or stationary.
6. All **FINAL ANSWERS** must be rounded off to **TWO DECIMAL PLACES** unless otherwise stated.
7. Periodic table on page 9.

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

Question 1 **[9]**

1.1 Nitrogen(II) oxide reacts with hydrogen according to the equation below:

$$2NO\ (g) + 2H_2\ (g) \rightarrow N_2\ (g) + 2H2O\ (g)$$

A suggested mechanism for this reaction is:

Step 1: $NO + H_2$ Ý X fast

Step 2: $X + NO \rightarrow Y + H_2O$ slow

Step 3: $Y + H_2 \rightarrow N_2 + H_2O$ fast

1.1.1 Identify the rate-determining step. (1)

1.1.2 A student hypothesized that the order of reaction with respect to H_2 is 2. Evaluate this hypothesis by finding the orders with respect to hydrogen and nitrogen oxide and write the rate expression for this reaction. (show all working) (3)

1.2.1 Determine the orders of reaction with respect the reactants and the overall rate expression for the reaction between 2-bromobutane and aqueous sodium hydroxide using the data in the table below: (2)

Experiment	**[NaOH] / mol dm^{-3}**	**[C_4H_9Br] / mol dm^{-3}**	**Rate / mol dm^{-3}s^{-1}**
1	1.00	1.00	1.66×10^{-3}
2	0.50	1.00	8.31×10^{-4}
3	0.25	0.25	1.02×10^{-4}
4	1.00	0.50	8.29×10^{-4}

1.2.2 Determine the rate constant, *k*, with its units, using the data from experiment 3. (2)

1.2.3 Identify the molecularity of the rate-determining step in this reaction. (1)

Question 2 **[8]**

2.1 Iron (III) oxide is the main source of iron but the decomposition of $Fe_2O_3(s)$ into its elements is extremely difficult due to a large positive value of $\Delta G^\ominus$. Consider the following reactions:

$$Fe_2O_3\ (s) \rightarrow 2Fe(s) + \frac{3}{2}O_2(g) \qquad \Delta G^\ominus = +742\ \text{kJ mol}^{-1}$$

$$CO\ (g) + \frac{1}{2}O_2\ (g) \rightarrow CO_2\ (g) \qquad \Delta G^\ominus = -257\ \text{kJ mol}^{-1}$$

Suggest, with a reason, whether it is possible to produce iron by reacting Fe_2O_3 with CO. (2)

2.2 The thermite reaction is one of the most exothermic reactions:

$$Fe_2O_3\ (s) + 2Al\ (s) \rightarrow 2Fe\ (l) + Al_2O_3\ (s) \qquad \Delta H^\ominus = -825.2\ \text{kJ}$$

Species	$S^\ominus$/ J K^{-1}mol^{-1}	$\Delta G_f^\ominus$/ kJ mol^{-1}
Al(s)	+28.3	0
Al_2O_3 (s)	+50.9	-1582
Fe (l)	+34.8	+10.0
Fe_2O_3 (s)	+87.5	-742

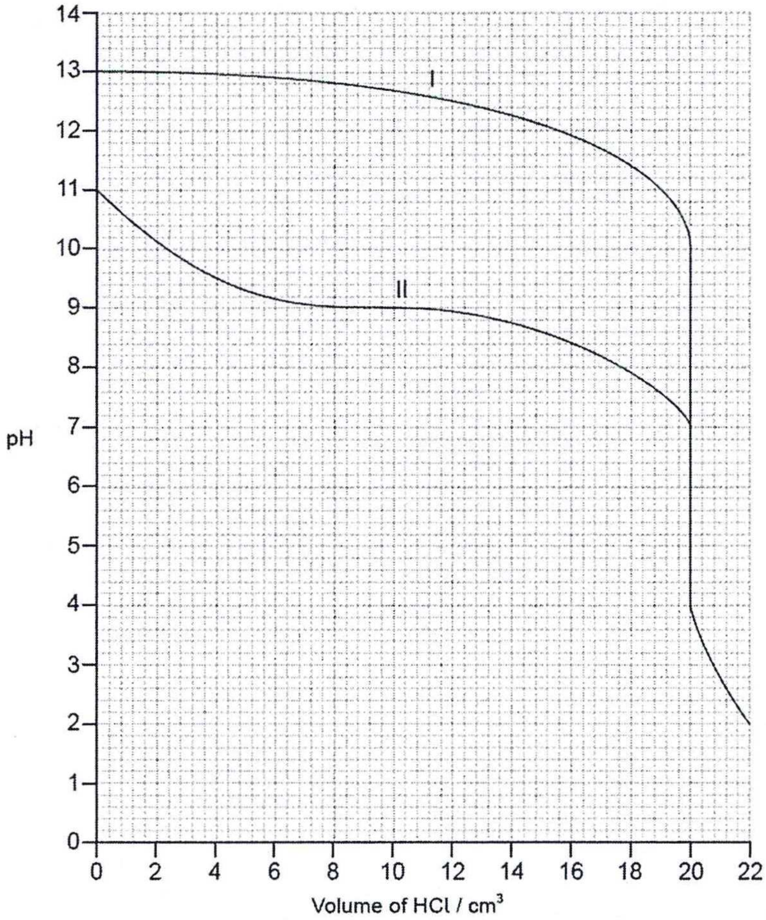
2.2.1 Calculate the standard free energy change, $\Delta G^\ominus$, in kJ mol-1, by using values of the standard free energy change of formation, ΔG_f, from the table above. (2)

2.2.2 Calculate the standard entropy change, ΔS, in J K^{-1} mol^{-1}, by using values of standard entropy, $S^\ominus$, from the table. (2)

2.2.3 Calculate the standard free energy change, $\Delta G^\ominus$, for the reaction using $\Delta H^\ominus$ and $\Delta S^\ominus$ values at 25°C. (2)

Question 3 **[21]**

3.1 20.0 cm^3 aqueous solutions of two bases, each with a concentration of 0.100 mol dm^{-3} were separately titrated with 0.100 mol dm^{-3} hydrochloric acid, HCl (aq), and the following graph was obtained.



3.1.1 Deduce the pH at the equivalence points for base I and base II. (2)

3.1.2 Suggest why the titration curve for base I is different from base II. (1)

3.1.3 State the formulas of two possible bases which could be used as base I. (1)

3.1.4 Calculate, using data from the graph, the dissociation constant, K_b, of base II, showing your working. (3)

3.1.5 Table of Common Acid-Base Indicators:

Indicator	**pH Range**	**Acid**	**Base**
Thymol Blue	1.2-2.8	red	yellow
Pentamethoxy red	1.2-2.3	red-violet	colorless
Methyl red	4.4-6.2	red	yellow
Bromcresol purple	5.2-6.8	yellow	purple

Suggest an indicator from the table above, that can be used for both titrations. (1)

3.2.1 State what is meant by the term buffer solution. (2)

3.2.2 Calculate the pH of a solution prepared by mixing 40.0 cm^3 of 0.200 mol dm^{-3} NH_3 (aq) and 40.0 cm^3 of 0.100 mol dm^{-3} HCl (aq), showing your working.
(pK_b NH3 = 4.75 at 298 K) (3)

3.3 The equations of two acid-base reactions are given below:

Reaction A H_2CO_3(aq) + H_2O(l) Ý HCO_3^-(aq) + H_3O (aq)

Reaction B HCO_3^-(aq) + H_2O(l) Ý CO_3^{2-}(aq) + H_3O^+(aq)

3.3.1 Explain whether HCO_3^-(aq) behaves as an acid or a base in each of the reactions A and B. (1)

3.3.2 Deduce two conjugate acid-base pairs from reactions A and B. (2)

3.4 Nitric acid, HNO_3, and nitrous acid, HNO_2, are described as strong and weak acids respectively.

3.4.1 Distinguish between *strong* and *weak* acids. (1)

3.4.2 A 1.00 g sample of solid magnesium carbonate, MgCO3, is added to separate solutions of HNO_3 and HNO_2 of the same concentration and temperature. State one similarity and one difference in the observations made in these reactions. (2)

3.4.3 A solution of HNO_3 has a pH of 1, while a solution of HNO_2 has a pH of 5. Determine the ratio of the hydrogen ion concentration in HNO_3:HNO_2. (1)

Question 4 [13]

Iodine monobromide, IBr, has a permanent dipole. Alkenes react with IBr in a similar way to the reactions of alkenes with HBr.

4.1 Propene reacts with IBr to make two possible organic products. One of these products is 2-bromo-1-iodopropane.

4.1.1 Using the curly arrow model, complete the mechanism to make 2-bromo-1-iodopropane. (3)

4.1.2 What is the name of this mechanism? (1)

4.1.3 Draw the structure of the possible organic product of the reaction of propane with IBr. (1)

4.2 Methane reacts with IBr to form many products. Two of these products are Iodomethane and hydrogen bromide.

4.2.1 Suggest the essential condition needed for this reaction. (1)

4.2.2 The mechanism of this reaction involves three steps, of which one is called termination. Describe the mechanism of the reaction that forms iodomethane and hydrogen bromide. Your answer must include:

The name of the mechanism
The names of the other two steps of the mechanism
Equations for these two steps of the mechanism
The type of bond fission
One equation for a termination step. (7)

Question 5 **[9]**

The electrons transferred in redox reactions can be used by electrochemical cells to provide energy. Some electrode half-equations and their standard electrode potentials are shown in the table below:

Half-equation	**E / V**
$Cr_2O_7^{2-}$ (aq) + 14H (aq) + 6e → 2Cr (aq) + H_2O (l)	+1.33
Fr^{3+} (aq) + e^- → Fe^{2+} (aq)	+0.77
$2H^+$ (aq) + $2e^-$ → H_2 (g)	0.00
Fe^{2+} (aq) + $2e^-$ → Fe (s)	-0.44
Li^+ (aq) + e^- → Li (s)	-0.304

5.1 Describe a standard hydrogen electrode. (4)

5.2 A conventional representation of a lithium cell is given below. This cell has an e.m.f. of +2.91 V.

$$Li(s) \mid Li^+(aq) \mid\mid Li^+(aq) \mid MnO_2(s), LiMnO_2(s) \mid Pt(s)$$

Write a half-equation for the reaction that occurs at the positive electrode of this cell. Calculate the standard electrode potential of this positive electrode, and the change in gibbs free energy for the cell. Is the reaction feasible or not, explain why. (5)

Question 6 [25]

6.1 Electrolysis of an aqueous solution of copper(II) sulfate, $CuSO_4$, can be carried out using platinum electrodes.

6.1.1 State an equation for the half-reaction occurring at the positive electrode (anode) and one observation that could be made as a result. (2)

6.1.2 State an equation for the half-reaction occurring at the negative electrode (cathode). (2)

6.1.3 Describe two changes or observations in the electrolyte as result of these half-reactions. (2)

6.1.4 Determine the relative amount, in moles, of products formed at each electrode. (1)

6.1.5 Identify another compound which will form the same products at the positive and negative electrodes. (1)

6.1.6 The same process is carried out using copper electrodes instead of the platinum electrodes. Describe the changes or observations that take place at both the electrodes and in the electrolyte. (3)

6.2 Identify two factors that affect the quantity of copper produced during the electrolysis of an aqueous copper(II) sulfate solution. (1)

6.3 Consider the following half cell reactions and their standard electrode potentials:

Ni^{2+} (aq) + 2e– Ý Ni(s) $E^{\ominus} = -0.2$ V
MnO_4^- (aq) + $8H^+$ (aq) +$5e^-$ Ý Mn^{2+} (aq) + $4H_2O$ (l) $E^{\ominus} = +1.51$ v

6.3.1 State the conditions needed for the electrode potentials to be described as standard.(1)

6.3.2 Deduce a balanced equation for the overall reaction which will occur spontaneously when the two half cells are connected. (2)

6.3.3 Identify the reducing agent in the above reaction and determine the change in oxidation number for the oxidizing agent. (2)

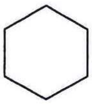
6.3.4 Determine the cell potential when the two half cells are connected. (1)

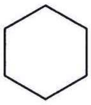
6.3.5 Draw and label a diagram of the voltaic cell from part 6.3. Indicate the anode, cathode, the direction of the electron movement and ion flow. (5)

6.3.6 Outline two differences between an electrolytic cell and a voltaic cell. (2)

Question 7 **[15]**

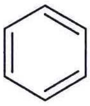
7.1 Crude oil is a source of many hydrocarbons. The skeletal formulae of some of these hydrocarbons are shown below:


A


B

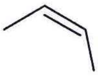

C

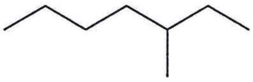

D


E


F


G


H


I

7.1.1 Explain why compound A is both saturated and a hydrocarbon. (2)

7.1.2 What is the empirical formula of compound C? (1)

7.1.3 Give the letters, of two hydrocarbons that are structural isomers of each other. (2)

7.1.4 Explain why hydrocarbon D has a higher boiling point than hydrocarbon C. (2)

7.1.5 Hydrocarbons G and H are stereoisomers of each other. What is meant by the term stereoisomerism? (2)

7.1.6 Construct the equation for the complete combustion of hydrocarbon C. (2)

7.1.7 Compound I does not contain a functional group.

7.1.7.1 What is meant by the term functional group? (1)

7.1.7.2 Give the IUPAC name for the structure. (1)

7.1.7.3 Compound I reacts with chlorine in the presence of ultraviolet radiation to give several structural isomers of $C_8H_{17}Cl$. How many structural isomers could be formed in this reaction? (1)

7.1.7.4The mechanism of the reaction involves radicals. What is meant by the term radical? (1)

THE END

Periodic Table of the Elements

KEY

Atomic Mass → 12.011

Symbol → **C**

Atomic Number → 6

Electron Configuration → 2-4

-4 +2 +4 ← Selected Oxidation States

Relative atomic masses are based on $^{12}C = 12.000$

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

Period	Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1.00794 +1 -1 **H** 1 1																	4.00260 0 **He** 2 2
2	6.941 +1 **Li** 3 2-1	9.01218 +2 **Be** 4 2-2											10.81 +3 **B** 5 2-3	12.0111 -4 +2 +4 **C** 6 2-4	14.0067 -3 -2 -1 +1 +2 +3 +4 +5 **N** 7 2-5	15.9994 -2 **O** 8 2-6	18.998403 -1 **F** 9 2-7	20.179 0 **Ne** 10 2-8
3	22.98977 +1 **Na** 11 2-8-1	24.305 +2 **Mg** 12 2-8-2											26.98154 +3 **Al** 13 2-8-3	28.0855 -4 +2 +4 **Si** 14 2-8-4	30.97376 -3 +3 +5 **P** 15 2-8-5	32.06 -2 +4 +6 **S** 16 2-8-6	35.453 -1 +1 +3 +5 +7 **Cl** 17 2-8-7	39.948 0 **Ar** 18 2-8-8
4	39.0983 +1 **K** 19 2-8-8-1	40.08 +2 **Ca** 20 2-8-8-2	44.9559 +3 **Sc** 21 2-8-9-2	47.88 +2 +3 +4 **Ti** 22 2-8-10-2	50.9415 +2 +3 +4 +5 **V** 23 2-8-11-2	51.996 +2 +3 +6 **Cr** 24 2-8-13-1	54.9380 +2 +3 +4 +7 **Mn** 25 2-8-13-2	55.847 +2 +3 **Fe** 26 2-8-14-2	58.9332 +2 +3 **Co** 27 2-8-15-2	58.69 +2 +3 **Ni** 28 2-8-16-2	63.546 +1 +2 **Cu** 29 2-8-18-1	65.39 +2 **Zn** 30 2-8-18-2	69.72 +3 **Ga** 31 2-8-18-3	72.59 -4 +2 +4 **Ge** 32 2-8-18-4	74.9216 -3 +3 +5 **As** 33 2-8-18-5	78.96 -2 +4 +6 **Se** 34 2-8-18-6	79.904 -1 +1 +5 **Br** 35 2-8-18-7	83.80 0 +2 **Kr** 36 2-8-18-8
5	85.4678 +1 **Rb** 37 2-8-18-8-1	87.62 +2 **Sr** 38 2-8-18-8-2	88.9059 +3 **Y** 39 2-8-18-9-2	91.224 +4 **Zr** 40 2-8-18-10-2	92.9064 +3 +5 **Nb** 41 2-8-18-12-1	95.94 +3 +6 **Mo** 42 2-8-18-13-1	(98) +4 +6 +7 **Tc** 43 2-8-18-14-1	101.07 +3 **Ru** 44 2-8-18-15-1	102.906 +3 **Rh** 45 2-8-18-16-1	106.42 +2 +4 **Pd** 46 2-8-18-18	107.868 +1 **Ag** 47 2-8-18-18-1	112.41 +2 **Cd** 48 2-8-18-18-2	114.82 +3 **In** 49 2-8-18-18-3	118.71 +2 +4 **Sn** 50 2-8-18-18-4	121.75 -3 +3 +5 **Sb** 51 2-8-18-18-5	127.60 -2 +4 +6 **Te** 52 2-8-18-18-6	126.905 -1 +1 +5 +7 **I** 53 2-8-18-18-7	131.29 0 +2 +4 +6 **Xe** 54 2-8-18-18-8
6	132.905 +1 **Cs** 55 2-8-18-18-8-1	137.33 +2 **Ba** 56 2-8-18-18-8-2	138.906 +3 **La** 57 2-8-18-18-9-2	178.49 +4 **Hf** 72 **18-32-10-2	180.948 +5 **Ta** 73 -18-32-11-2	183.85 +6 **W** 74 -18-32-12-2	186.207 +4 +6 +7 **Re** 75 -18-32-13-2	190.2 +3 +4 **Os** 76 -18-32-14-2	192.22 +3 +4 **Ir** 77 -18-32-15-2	195.08 +2 +4 **Pt** 78 -18-32-17-1	196.967 +1 +3 **Au** 79 -18-32-18-1	200.59 +1 +2 **Hg** 80 -18-32-18-2	204.383 +1 +3 **Tl** 81 -18-32-18-3	207.2 +2 +4 **Pb** 82 -18-32-18-4	208.980 +3 +5 **Bi** 83 -18-32-18-5	(209) +2 +4 **Po** 84 -18-32-18-6	(210) **At** 85 -18-32-18-7	(222) 0 **Rn** 86 -18-32-18-8
7	(223) +1 **Fr** 87 -18-32-18-8-1	226.025 +2 **Ra** 88 -18-32-18-8-2	227.028 +3 **Ac** 89 -18-32-18-9-2	(261) **Rf** 104	(262) **Db** 105	(263) **Sg** 106	(264) **Bh** 107	(265) **Hs** 108	(268) **Mt** 109	(269) **Uun**	(272) **Uuu** 111	(277) **Uub** 112		(285) **Uuq** 114				

**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.

140.12 +3 +4 **Ce** 58	140.908 +3 **Pr** 59	144.24 +3 **Nd** 60	(145) +3 **Pm** 61	150.36 +2 +3 **Sm** 62	151.96 +2 +3 **Eu** 63	157.25 +3 **Gd** 64	158.925 +3 **Tb** 65	162.50 +3 **Dy** 66	164.930 +3 **Ho** 67	167.26 +3 **Er** 68	168.934 +3 **Tm** 69	173.04 +2 +3 **Yb** 70	174.967 +3 **Lu** 71
232.038 +4 **Th** 90	231.036 +4 +5 **Pa** 91	238.029 +3 +4 +5 +6 **U** 92	237.048 +3 +4 +5 +6 **Np** 93	(244) +3 +4 +5 +6 **Pu** 94	(243) +3 +4 +5 +6 **Am** 95	(247) +3 **Cm** 96	(247) +3 +4 **Bk** 97	(251) +3 **Cf** 98	(252) **Es** 99	(257) **Fm** 100	(258) **Md** 101	(259) **No** 102	(260) **Lr** 103