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Physical Sciences Preliminary Examination

Paper II – Chemistry

Monday 7 September 2020

Form V

Marks: 200

Examiner: C Adelaar

Time: 3 hours

Examination number: _____

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 17 pages, a yellow answer sheet of 3 pages (i-iii) and a green data sheet of 3 pages (i-iii). Please make sure that your question paper is complete.
2. Remove the data and answer sheets from inside this question paper. **Write your examination number on the answer sheet and question paper.**
3. **Please complete the multiple choice question on your answer sheet:**
There is only one correct answer for each of the multiple choice questions. The letter corresponding to the answer you think is correct should be marked with a cross, thus:

A	B	C	D
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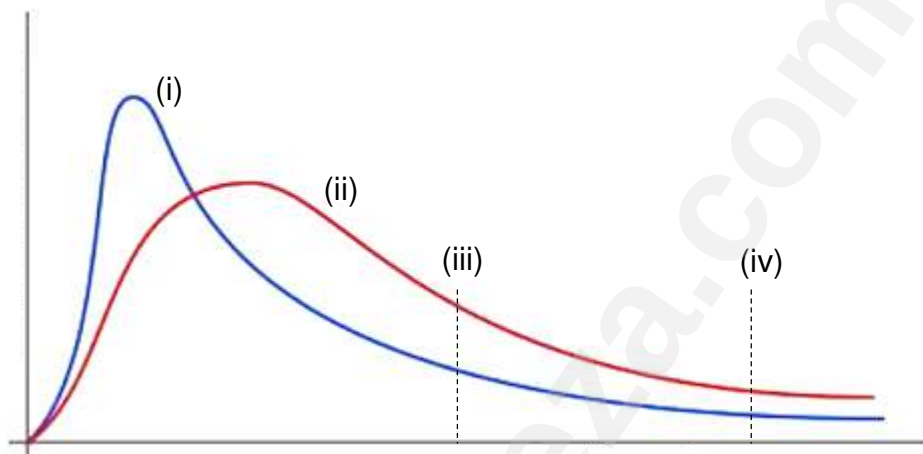
Here, C is the answer

4. Start each question on a new page, but please write on both sides of the paper.
5. Use the data and formulae whenever necessary.
6. Show all of the necessary steps in calculations.
7. Where appropriate, take your answers to 2 decimal places, unless instructed otherwise. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
8. It is in your own interest to write legibly and to present your work neatly. Please ensure that you number your answers as the questions are numbered.
9. When you hand in your exam, place the yellow answer sheet in the **front** of your answer book and your question paper booklet and green data sheets at the **back** of your answer book.

QUESTION 1

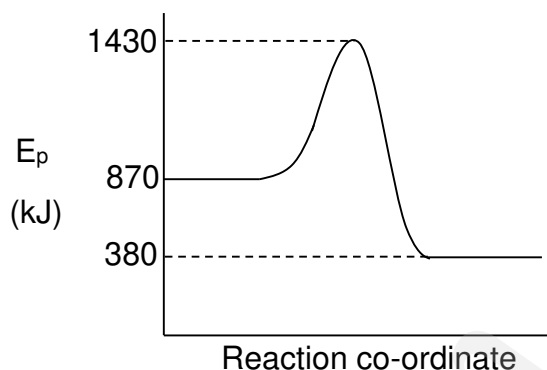
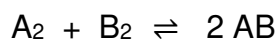
Answer questions 1.1 – 1.10 on the grid provided on your ANSWER SHEET. There is only one correct answer for each of the multiple choice questions. Place a cross over the letter that represents the most correct answer.

Questions 1.1 and 1.2 refer to the following Maxwell-Boltzmann distribution curve for particles involved in a chemical reaction.



- 1.1 Which one of the following CANNOT be the label for the x-axis of the graph?
- A kinetic energy
 - B velocity
 - C number of particles
 - D temperature
- 1.2 Which statement below is TRUE?
- A The rate of the chemical reaction with particles from curve (i) will be the fastest.
 - B Curve (ii) represents the catalysed reaction.
 - C Line (iii) represents the average temperature of the substance.
 - D Line (iv) indicates that the reaction rate will be slow.
- 1.3 Which of the following is a closed system?
- A Zinc metal reacts with hydrochloric acid
 - B Endothermic dissolution of potassium iodide
 - C Combustion of petrol
 - D Decomposition of copper chloride

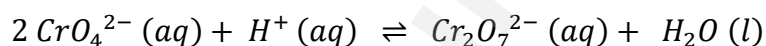
1.4 The energy profile for the following reaction is given.



What is the activation energy for the reverse reaction?

- A 1430 kJ
- B 715 kJ.mol^{-1}
- C 560 kJ
- D 525 kJ.mol^{-1}

1.5 The following chemical equilibrium is established in a beaker and the solution is a mid-orange colour.



yellow

orange

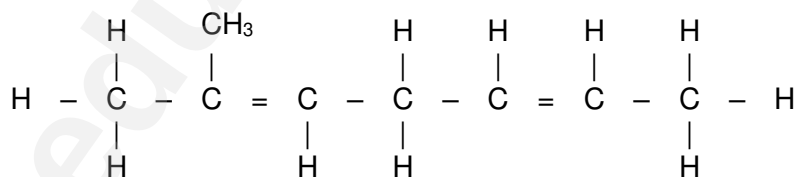
Which statement is FALSE?

- A The addition of water to the beaker will cause the solution to turn yellow.
- B Bubbling NH_3 through the solution will cause the solution to turn yellow.
- C Adding crystals of potassium chromate to the system will cause the colour to deepen.
- D The addition of FeCl_2 (aq) will cause a redox reaction to occur and the colour will darken.

1.6 Which one of the following substances will have a very weak conjugate base?

- A H_2O
- B KOH
- C HSO_4^-
- D HCO_3^-

- 1.7 Which one of the following reactions will NOT result in a change to the pH of the solution?
- A $\text{Cl}^- (\text{aq}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{HCl} (\text{aq}) + \text{OH}^- (\text{aq})$
- B $\text{NH}_4^+ (\text{aq}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{NH}_3 (\text{aq}) + \text{H}_3\text{O}^+ (\text{aq})$
- C $\text{CH}_3\text{COOLi} (\text{s}) \xrightarrow{\text{H}_2\text{O}} \text{Li}^+ (\text{aq}) + \text{CH}_3\text{COO}^- (\text{aq})$
- D $\text{HNO}_3 (\text{aq}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{H}_3\text{O}^+ (\text{aq}) + \text{NO}_3^- (\text{aq})$
- 1.8 When the standard hydrogen electrode is connected to a $\text{Zn}|\text{Zn}^{2+}$ half cell, which one of the following statements is CORRECT?
- A Zn is the oxidising agent.
- B H^+ is the oxidising agent.
- C H_2 is oxidised.
- D Zn^{2+} is reduced.
- 1.9 Which one of the following statements about recovery of aluminium from bauxite is FALSE?
- A Cryolite reduces the running costs of the cell.
- B Carbon dioxide is produced during the process.
- C The aluminium produced in the cell is molten.
- D The graphite cathode is corroded during operation.
- 1.10 What is the IUPAC name for the organic compound shown below?



- A 2-methylhept-2,5-diene
- B 2-methylhepta-2,5-diene
- C 2-methylheptan-2,5-diene
- D 6-methylhepta-2,5-diene

(10 x 2) [20]

QUESTION 2

2.1 Refer to the following substances and answer the questions that follow.

A	water
B	carbon dioxide
C	hydrogen fluoride
D	silver bromide
E	diamond
F	ammonia
G	sodium fluoride
H	nitrogen
I	methane
J	graphite

Use one letter (letters may be used more than once or not at all) for each question in order to identify a substance which:

2.1.1 contains a double covalent bond.

2.1.2 has the greatest electronegativity difference in a covalent bond.

2.1.3 exhibits electrostatic forces of attraction.

2.1.4 would make a good electrolyte.

2.1.5 has the highest melting point.

2.1.6 conducts electricity as a solid.

2.1.7 has a volume of $22,4 \text{ dm}^3$ at STP.

(7)

2.2 Consider the table below, which shows the boiling points of the halogens.

Halogens	F_2	Cl_2	Br_2	I_2
Boiling point ($^{\circ}\text{C}$)	-188	-35	59	184

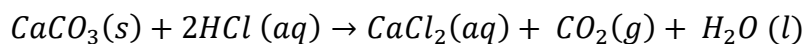
2.2.1 Name the **specific** type of intramolecular bond that occurs between the atoms in a chlorine molecule. (2)

2.2.2 The table shows that the boiling point of the halogens increases from F_2 to I_2 . Explain this trend by referring to the relevant intermolecular force between the halogen molecules and the factors influencing its strength. (4)

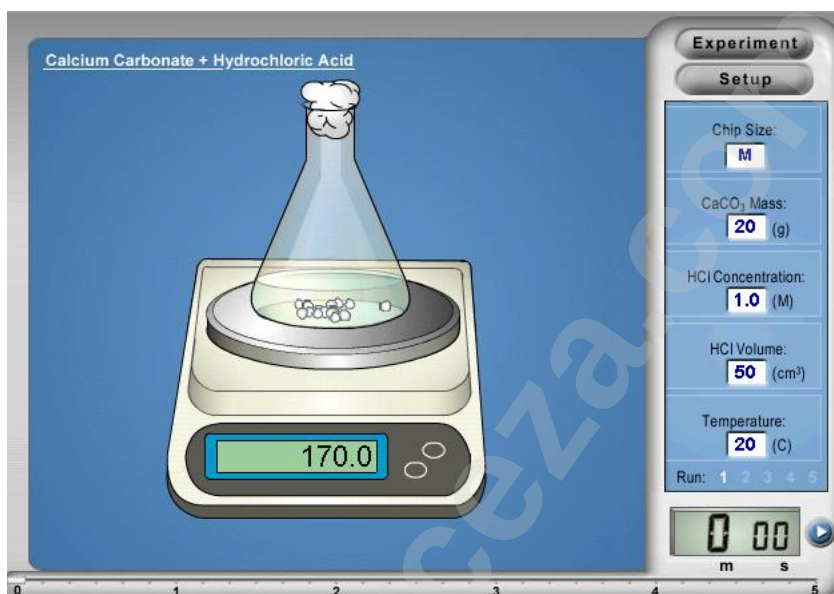
[13]

QUESTION 3

Calcium carbonate and hydrochloric acid react according to the following balanced chemical equation:



The following experimental set-up is used to investigate various aspects of the rate of this reaction. The cotton wool only allows gases to escape.



- 3.1 20 g of calcium carbonate react with 50 cm³ of 1 mol.dm⁻³ hydrochloric acid solution. Prove that the hydrochloric acid is the limiting reactant. (7)

The data collected in this experiment at a temperature of 40 °C is recorded in the table below.

Time (s)	Reading on electronic scale (g)
0	170,0
15	169,7
30	169,5
45	169,4
60	169,3
75	169,2
90	169,1
105	169,1
120	169,0
135	169,0
150	169,0
165	169,0
180	169,0

- 3.2 Determine the percentage yield of carbon dioxide for this chemical reaction based on the data provided. (6)

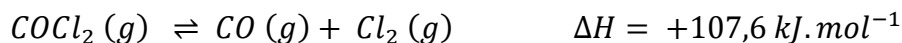
Answer questions 3.3 – 3.6 on the ANSWER SHEET provided.

- 3.3 A graph showing the collected data has been plotted on the ANSWER SHEET. Complete this graph by providing all the missing information and drawing a line of best fit. (4)
- 3.4 **From your graph**, determine the average rate of the reaction over the first minute in g.s^{-1} . Express your answer in scientific notation. (3)
- 3.5 A second set of data is recorded for the same reaction conducted at a temperature of $60\text{ }^{\circ}\text{C}$. The reaction reaches completion at 75 seconds. On the same graph on the ANSWER SHEET, add a line to indicate the progress of this reaction. Label this line: 3.5. (2)
- 3.6 In the final experiment, the concentration of hydrochloric acid is doubled, but remains the limiting reactant. On the same graph on the ANSWER SHEET, add a line to indicate the progress of this reaction. Label this line: 3.6. (2)
- 3.7 Instead of small granules, large lumps of the same mass of calcium carbonate are used in the reaction. State and explain in terms of collision theory what happens to the rate of the reaction. (4)

[28]

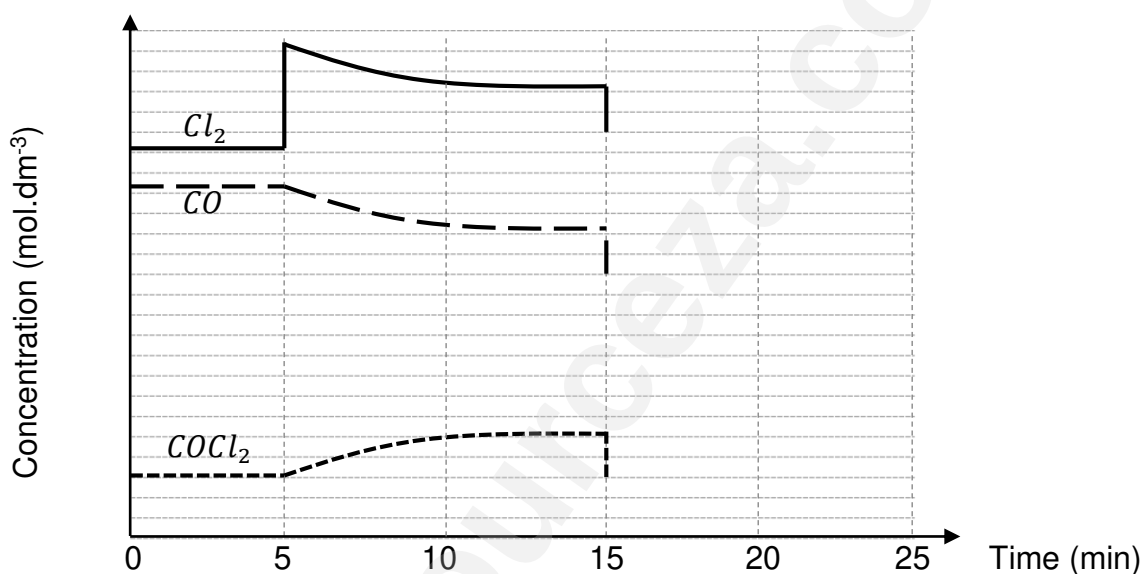
QUESTION 4

Phosgene gas, COCl_2 , exists in equilibrium with carbon monoxide and chlorine gas in a container with a variable volume. The equilibrium is represented by the following balanced equation:



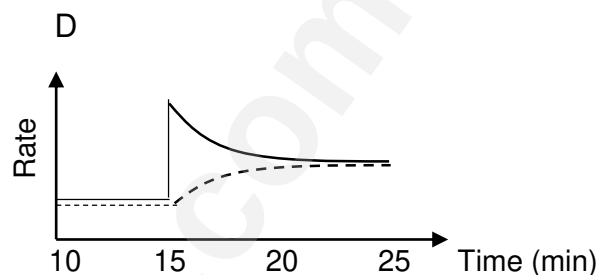
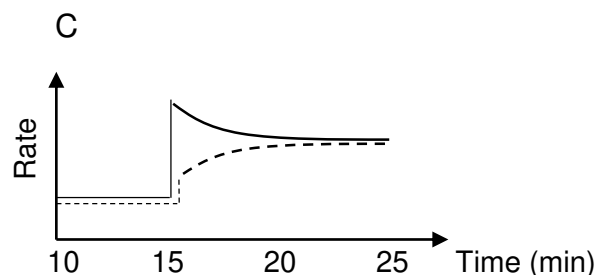
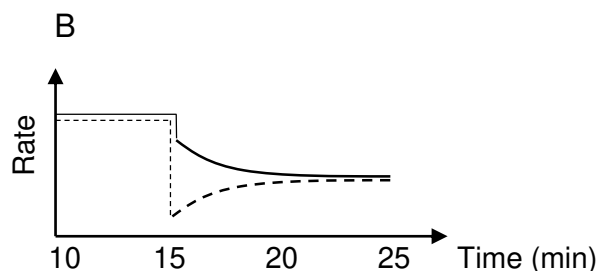
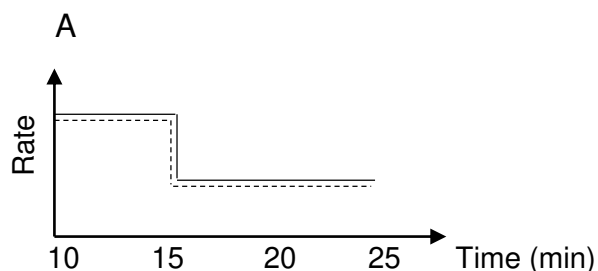
The K_c value for this reaction at 395°C is $1,2 \times 10^3$.

The graph below shows the substances already at equilibrium at $t = 0$ minutes.



- 4.1 Identify the stress that occurred at 5 minutes. (1)
- 4.2 Use Le Châtelier's Principle to explain the changes that occurred between 5 and 10 minutes on the graph. (3)
- 4.3 Define *concentration*. (2)
- 4.4 Identify the disturbance to the equilibrium that occurred at 15 minutes. Explain your answer. (3)
- 4.5 On the ANSWER SHEET, complete the graph given in order to show the changes to the concentration of each substance allowing for the equilibrium to be re-established at 20 minutes. (4)

- 4.6 Which one of the following rate versus time graphs is the most correct for the period between 10 and 25 minutes? Write down only the letter that represents the correct answer.



(2)

- 4.7 At 25 minutes a further stress acted on the system and once equilibrium had been re-established, the new equilibrium concentrations were as follows:

$$[COCl_2] = 0,009 \text{ mol. dm}^{-3}$$

$$[CO] = 0,40 \text{ mol. dm}^{-3}$$

$$[Cl_2] = 0,52 \text{ mol. dm}^{-3}$$

- 4.7.1 Calculate the K_c for the reaction at the new equilibrium. (4)

- 4.7.2 Use your answer from 4.7.1 above to identify the exact nature of the stress that acted on the system at 25 minutes. Explain your answer fully. (5)

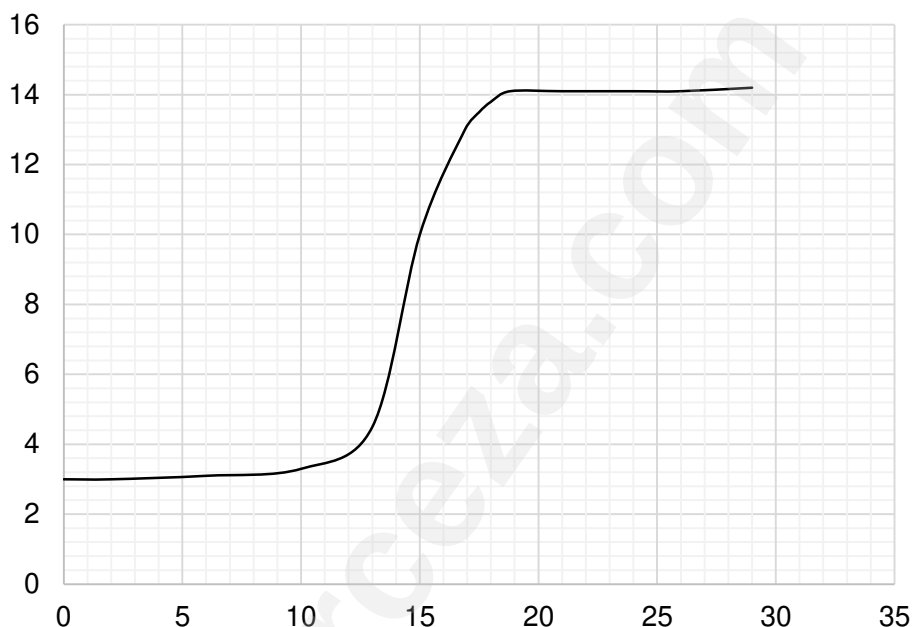
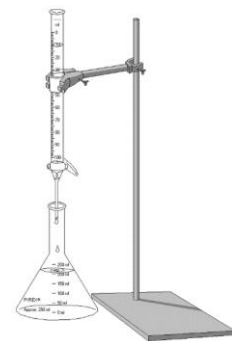
[24]

QUESTION 5

- 5.1 A titration between an acid and a base is completed using the apparatus shown alongside.

All readings were taken throughout the titration using a probe placed in the conical flask.

The following titration curve was drawn from the data.



- 5.1.1 Provide the label for the y-axis of the graph above. (1)

- 5.1.2 Define the *equivalence point* for a titration. (2)

- 5.1.3 From the graph, determine the equivalence point for this titration. Rewrite and complete the following sentence:

The equivalence point is reached at a pH of _____ when (number and unit) of acid/base (select the correct one) has been added to the conical flask. (3)

The acid originally placed in the flask is represented by the formula HX (with X being the negative ion).

- 5.1.4 Write a balanced chemical equation for the ionisation of acid HX (aq). Phase labels are not required. (2)

- 5.1.5 The concentration of the acid solution, HX (aq), in the flask is $0,17 \text{ mol}\cdot\text{dm}^{-3}$ while the hydroxide ion concentration in the flask is $1 \times 10^{-11} \text{ mol}\cdot\text{dm}^{-3}$.

- (a) Determine the K_a value for this acid. (8)
- (b) Is this acid strong or weak? Explain by referring to the K_a value. (2)
- (c) Suggest an identity for X in the formula of the acid, HX. (1)

5.2 Sodium bicarbonate (NaHCO_3) [Scientific name: sodium hydrogen carbonate] is a white, crystalline powder that is commonly used as a pH buffering agent. You can find it in most kitchen cupboards.

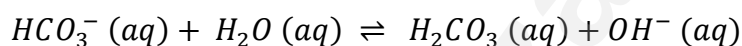
5.2.1 Define *hydrolysis of a salt*. (1)

5.2.2 Give the names of the acid and the base that could have reacted to produce the sodium bicarbonate salt. (2)

5.2.3 When the salt is placed in water and dissolves, will the solution be neutral, acidic or basic? (1)

A buffer is an aqueous solution that resists changes in pH upon the addition of an acid or a base.

The following equation can be used to explain the buffering action of the bicarbonate ion in solution.



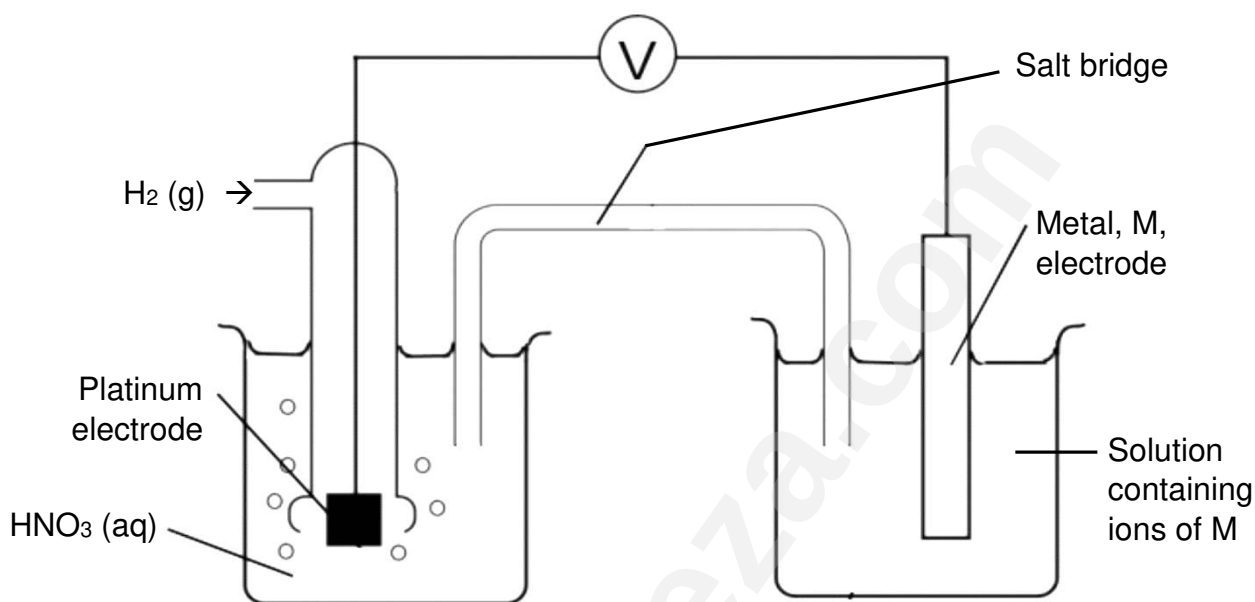
5.2.4 Refer to the equation above and Le Châtelier's Principle to explain how buffering is achieved when a solution of hydrochloric acid is added to the buffer solution. (4)

[27]

QUESTION 6

The Standard Hydrogen Electrode (SHE) can be used to determine the identity of any other half cell to which it is connected.

6.1 The following diagram shows the SHE connected to an unknown metal M.



- 6.1.1 Define an *anode*. (1)
- 6.1.2 State the conditions under which standard electrode potentials are determined. (3)
- 6.1.3 The reading on the voltmeter is +0,80 V. On the diagram on the ANSWER SHEET, provide labels as noted below:
- Label the positive and negative side of the voltmeter according to its connection to the SHE. (1)
 - Identify the metal, M. (3)
 - Label the metal electrode as anode or cathode. (1)
 - Give the chemical formula for an appropriate electrolyte in the salt bridge. (4)
- 6.1.4 Write the cell notation for the SHE half of the cell shown above, up to and including the salt bridge. Standard conditions are not required, but phase labels must be included. (3)
- 6.1.5 Describe how the salt bridge performs its function in this specific cell. (2)
- 6.1.6 Assuming that the identity of metal M in the cell remains unchanged, how will an increase in the concentration of $\text{HNO}_3(\text{aq})$ affect the reading on the voltmeter? Answer with INCREASES, DECREASES or STAYS THE SAME and explain your answer. (3)

- 6.2 The following substances are provided to a student in order to create a galvanic cell with an emf of +0,84 V. Standard conditions have been met for all substances.

Fe	$FeSO_4$	$Fe(NO_3)_3$	Ag	$AgNO_3$	KNO_3
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- 6.2.1 Use the Table of Standard Electrode Potentials and the substances given above to determine which two half reactions must occur in the cell in order to generate an emf of +0,84 V. Answer using the format below **and include a relevant calculation** to support your answer.

Oxidation half reaction:

Reduction half reaction: (6)

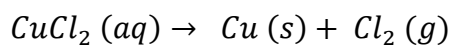
- 6.2.2 Hence derive the balanced overall ionic reaction for the spontaneous cell. (2)

[24]

QUESTION 7

- 7.1 A student wishes to observe simple electrolysis of a salt solution. She prepares a solution of copper chloride and inserts two graphite electrodes into the solution. She connects these electrodes to a power supply.

The following balanced equation shows the predominant reaction that occurs:



- 7.1.1 At which electrode, anode or cathode, will chlorine gas be produced? (1)

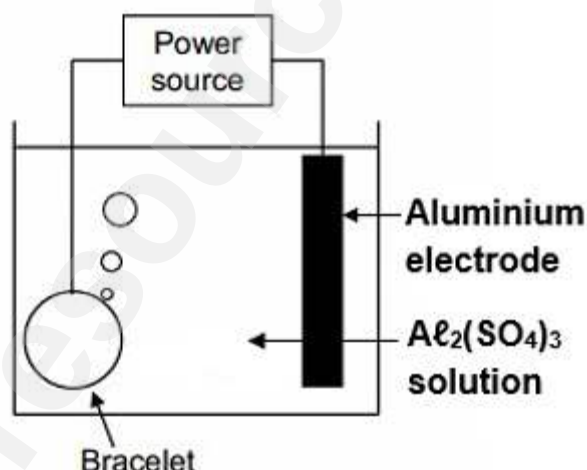
- 7.1.2 What must the student do to ensure that chlorine, rather than oxygen is the predominant gas formed at the electrode in 7.1.1? Explain your answer and support your argument with reference to appropriate half-reactions. (4)

Over a period of 10 minutes 0,011 mol of copper metal is formed in the cell.

- 7.1.3 Determine the current supplied to this cell in order for the reaction to occur. (6)

- 7.1.4 What volume of chlorine gas is formed at STP while the cell runs for 10 minutes? (4)

- 7.2 In an attempt to electroplate a bracelet with **aluminium metal**, a technician uses an aqueous solution of aluminium sulfate in a cell as shown below.



When the technician connects the power source, she notices that there is no shiny plating of aluminium metal appearing on the bracelet. Instead, there is a stream of colourless bubbles forming.

- 7.2.1 Over time, what will be observed at the aluminium electrode? (1)
- 7.2.2 Give the name of the gas being produced at the bracelet. (1)
- 7.2.3 Explain why this gas is produced at the bracelet instead of solid aluminium as the technician had hoped. Write down the relevant half-reaction occurring at the bracelet in your answer. (3)

[20]

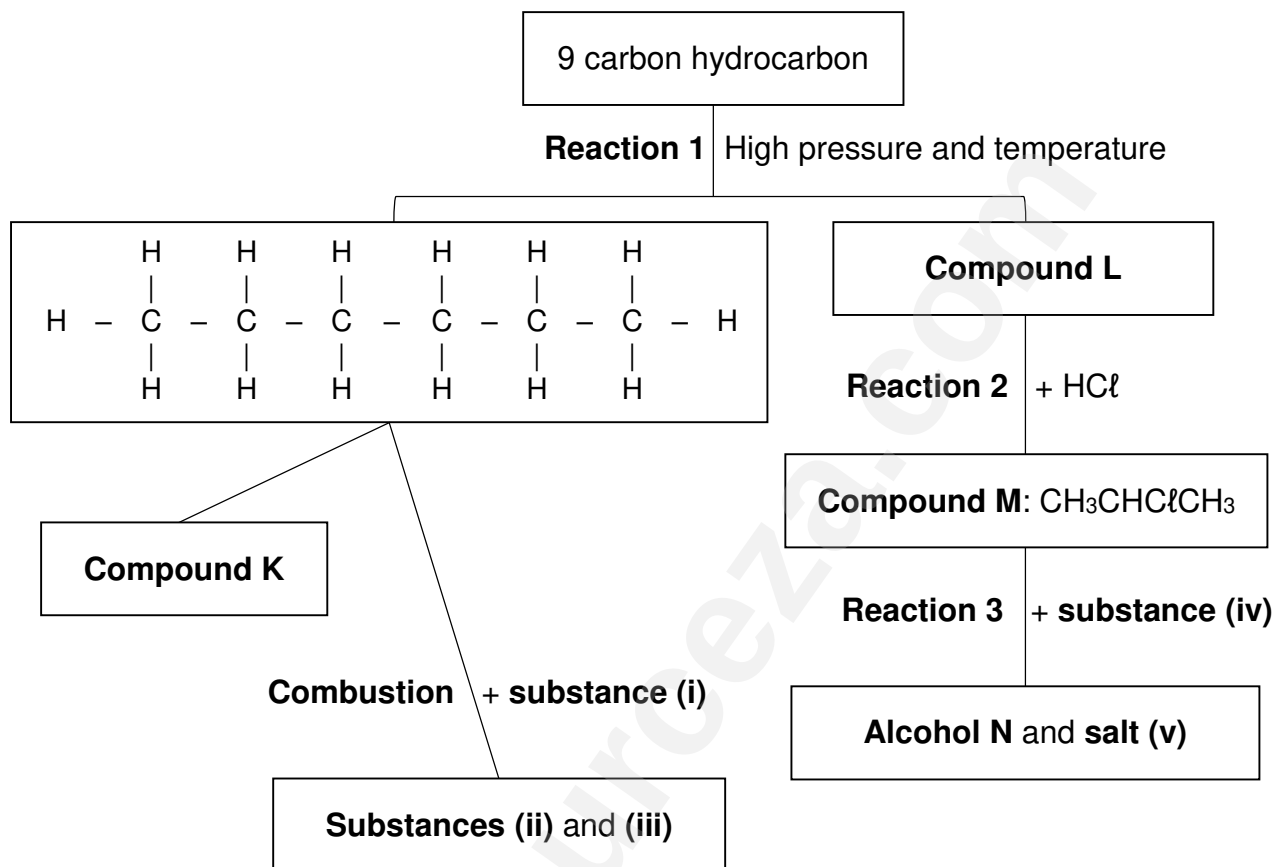
QUESTION 8

- 8.1 Define a *functional group*. (2)
- 8.2 Draw the structural formula for the functional group of a carboxylic acid. (2)
- 8.3 Define an *unsaturated compound*. (2)
- 8.4 Name the homologous series of hydrocarbons which are all saturated compounds. (1)
- 8.5 To which homologous series does the functional isomer of hexanoic acid belong? (1)
- 8.6 Butyl ethanoate is formed through the process of esterification.
- 8.6.1 Give the IUPAC names of the two reactants required to produce butyl ethanoate. (3)
- 8.6.2 One of the conditions for the formation of butyl ethanoate is heating. Describe a safe way to do this in a laboratory and state why it is necessary. (2)
- 8.6.3 What other condition must be met in order for esterification to occur? (2)
- 8.6.4 Name the other product of esterification. (1)

[16]

QUESTION 9

A long chain hydrocarbon containing 9 carbons undergoes **reaction 1** to produce hexane and **compound L**. Further reactions of each substance are shown in the diagram below.



- 9.1 For **reaction 1**, identify both the GENERAL type of reaction and SPECIFIC type of reaction that has occurred. (2)
- 9.2 Write the balanced **combustion** reaction for hexane hence identifying **substances (i)–(iii)**. Use molecular formulae. Phase labels are not required. (3)
- 9.3 **Compound K** is a structural isomer of hexane.
 - 9.3.1 Define *structural isomers*. (2)
 - 9.3.2 What specific type of isomerism is shown by these two isomers? (1)
 - 9.3.3 Give the IUPAC name for a possible isomer of hexane. (2)
- 9.4 Give the IUPAC name for **compound L**. (1)
- 9.5 Refer to **reaction 2**.
 - 9.5.1 Identify the SPECIFIC type of reaction that took place. (1)
 - 9.5.2 What specific condition must be met for this reaction to take place? (1)

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- 9.6 Refer to **reaction 3** which produces an alcohol and a salt.
- 9.6.1 Identify the GENERAL type of reaction that took place. (1)
- 9.6.2 Draw the structural formula for **alcohol N**. (3)
- 9.6.3 Identify **substance (iv)** and **salt (v)**. (2)
- 9.6.4 State the conditions required for this reaction to occur. (2)
- 9.7 Consider **compounds L, M and N**.
- 9.7.1 Rank these compounds in increasing order of boiling points. (2)
- 9.7.2 Identify the type of intermolecular forces present in each of the compounds. (3)
- 9.7.3 Explain your choice of compound with the highest boiling point by referring to relative strengths of intermolecular forces. (2)
- [28]**

TOTAL: 200 MARKS

Sources: Acknowledgements and Thanks:

Question 1: 1.1 and 1.2 curve from: <http://www.entropy-book.com/maxwell-boltzmann-distribution/>
Question 2.2: From Woodridge College Prelim paper II 2019
Question 3: Image: Multimedia Science School
Question 5: Titration image: <http://acidsandbasesfordummieschem.weebly.com/titration.html>
Question 6: Image adapted from: <https://www.thestudentroom.co.uk/showthread.php?t=5922384>
Question 7: 7.2 From Woodridge College Prelim paper II 2019