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Physical Sciences Preliminary Examination

Paper II – Chemistry

Wednesday 25 September 2019

Form V

Marks: 200

Examiner: M Blair

Time: 3 hours

Examination number: _____

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 17 pages, a yellow answer sheet of 2 pages (i-ii) 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. Place a cross in the appropriate block for each question.

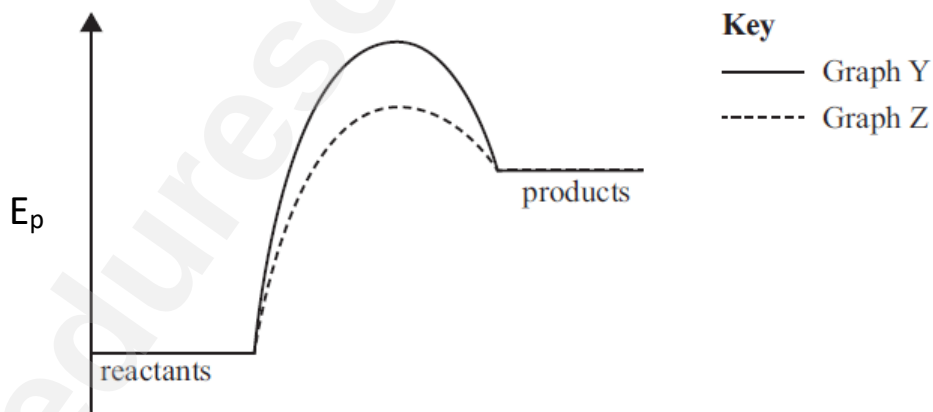
1.1 Which of the following has the most polar covalent bond?

- A silicon dioxide
- B hydrogen fluoride
- C hydrogen phosphide
- D carbon tetrachloride

1.2 Identify the INCORRECT definition below:

- A Electronegativity is *a measure of the tendency of an atom to attract a pair of electrons*
- B A covalent bond is *a sharing of at least one pair of electrons by two non-metal atoms*
- C An intermolecular force is *a weak force of attraction between molecules, ions, or atoms of noble gases*
- D An intramolecular bond is *a bond which occurs between atoms within molecules*

1.3 In the diagram below, Graph Y represents the energy profile for the reaction between two gases in a sealed container. The experiment was repeated and one change was made to the reaction conditions. Graph Z represents the energy profile under the new conditions.

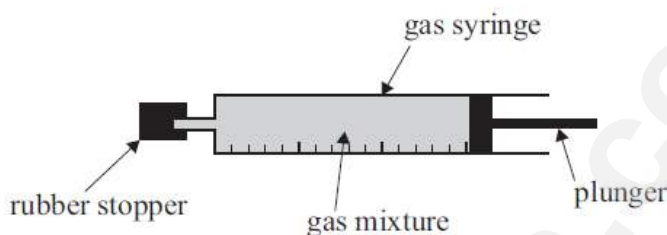


Which one of the following possible changes to the reaction conditions would result in the change in the energy profile from Graph Y to Graph Z?

- A The initial temperature of the gases was higher.
- B An inert gas was added to the reaction container.
- C The volume of the reaction container was decreased.
- D A catalyst was added to the reaction container with the gases.

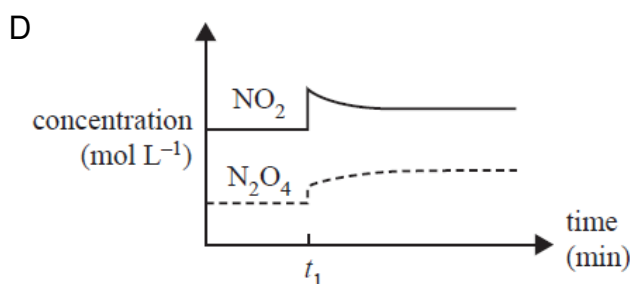
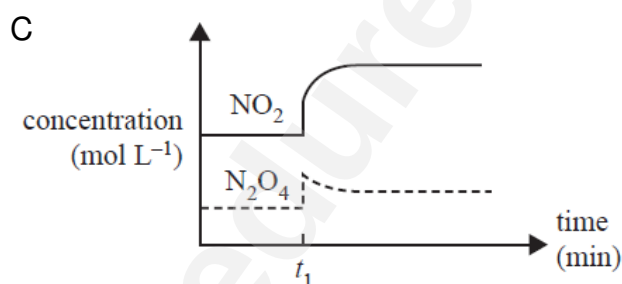
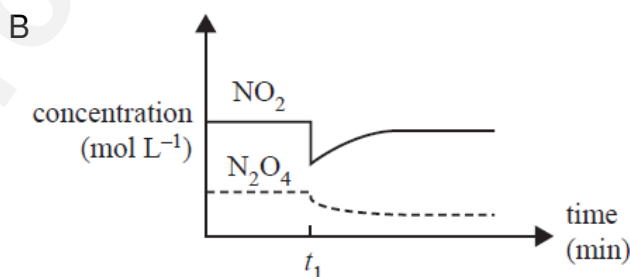
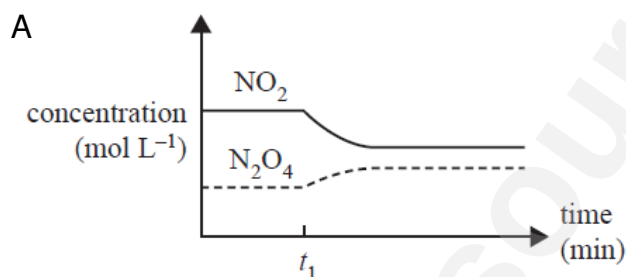
- 1.4 The rate at which equilibrium is established in a system can be lowered by increasing the:
- A temperature of the reaction mixture at a constant volume.
 - B total volume of the reaction vessel at a constant temperature.
 - C concentration of the reactants at a constant temperature.
 - D pressure in the reaction vessel at a constant temperature.

A sealed gas syringe contains an equilibrium mixture of brown nitrogen dioxide gas, NO_2 , and colourless dinitrogen tetroxide gas, N_2O_4 . This is shown in the diagram below.



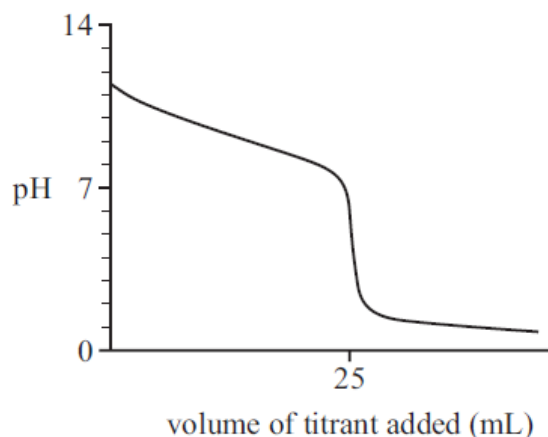
The equation for this equilibrium reaction is $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ $\Delta H = +57.20 \text{ kJ}\cdot\text{mol}^{-1}$

Questions 1.5 and 1.6 refer to the information above and the following concentration-time graphs A – D.



- 1.5 Which graph above (A, B, C, or D) best represents the change that occurs in a scenario where the only change is that the system is cooled at time t_1 ?
- 1.6 Which graph above (A, B, C, or D) best represents the change that occurs in a scenario where the plunger is suddenly pushed in at time t_1 so that the volume of the system is decreased (and the temperature of the gas is kept constant)?

1.7 The diagram below represents a particular acid-base titration.



Which one of the following statements about this titration is correct?

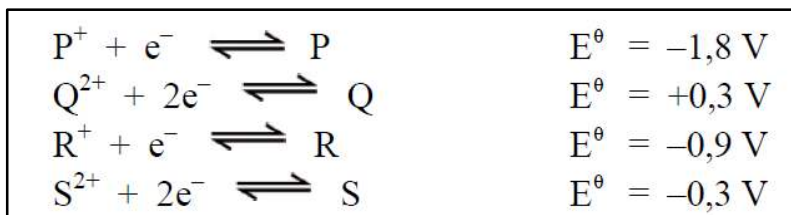
- A At the equivalence point, the pH of the solution is close to 4.5.
- B A solution of a strong base has been delivered by the burette.
- C A strong acid is in the conical flask.
- D A solution of a weak acid has been delivered by the burette.

1.8 Strips of the metals, Fe, Zn, and Ag, were placed in separate beakers, each containing $1,0 \text{ mol.dm}^{-3} \text{ NiSO}_4$, solution at 25°C .

What is expected to occur over time?

- A Ni will be deposited in all of the beakers.
- B Ni will not be deposited in any of the beakers.
- C A reaction will occur only in the beaker containing Ag.
- D A reaction will occur only in the beakers containing Fe and Zn.

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- 1.9 The emf of a galvanic cell is found to be 1,2 V under standard conditions. The following half-reactions and standard electrode potentials are provided:



Which of the substances P, Q, R and S will act as the anode and cathode respectively?

- A P and R
- B R and Q
- C R and S
- D P and S
- 1.10 Pentane, hexane, heptane and octane are non-branched alkanes.
- Which one of the following statements gives a valid comparison?
- A Octane has a greater viscosity and a higher boiling point than hexane.
- B Pentane has a greater viscosity and a lower boiling point than octane.
- C Heptane has a lower viscosity and a higher boiling point than octane.
- D Heptane has a lower viscosity and a lower boiling point than pentane.

[10 x 2 = 20]

- 2.1 Complete the table below in your answer book by writing the question number and your answer: (2)

Formula	Name
2.1.1	Iron (II) ethanoate
$\text{Na}_2\text{S}_2\text{O}_3$	2.1.2

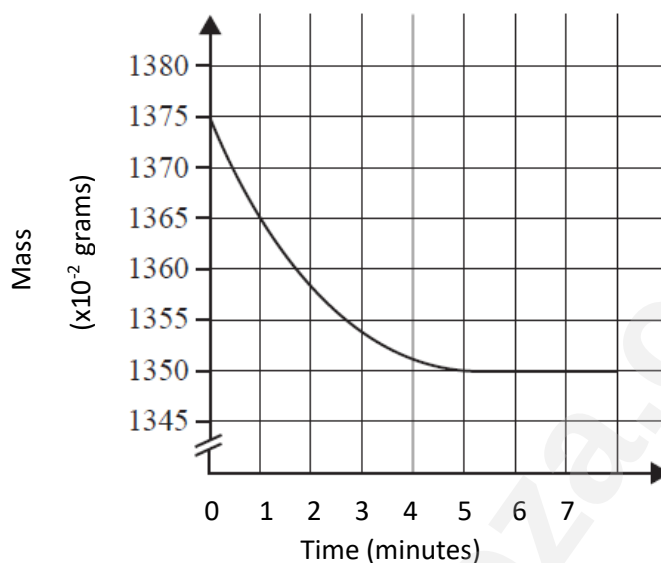
- 2.2 Consider the following substances and then answer the questions that follow.

Diamond	Dry ice (solid CO_2)	Zinc	Chlorine
CO_2 gas	NaCl	Graphite	Iodine

- 2.2.1 Which two substances are allotropes of each other? (1)
- 2.2.2 Select a substance that forms a molecular lattice **at room temperature**. (1)
- 2.2.3 Which solid substance is an example of an atomic lattice? (1)
- 2.2.4 Which substance's particles consist of positive kernels and a sea of delocalised electrons? (1)
- 2.2.5 Which substance would conduct electricity in a solution? (1)
- 2.2.6 Which solid substance would conduct electricity but would not conduct heat? (1)
- 2.3 Discuss why iodine's melting point is much higher than chlorine's melting point. (4)

[12]

Soda water is made by dissolving pressurised carbon dioxide, CO_2 , in water. In a rates of reaction investigation, a bottle of soda water was placed on an electronic balance. The cap was removed and placed on the electronic balance alongside the bottle. The graph below shows the change in mass as the CO_2 comes out of solution and escapes. The experiment was conducted at STP.



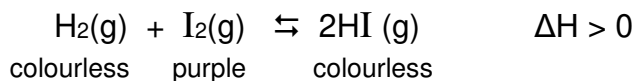
- 3.1 Define *reaction rate*. (2)
- 3.2 State the dependant variable in this investigation. (2)
- 3.3 Calculate the average reaction rate between 0 and 1 minute in centigrams per second. Show your working. (2)
- 3.4 Is the rate of the reaction between 1 and 2 minutes faster or slower than your answer in 3.3? (1)
- 3.5 What is the purpose of the double lines that cut the y-axis in the graph above? (2)
- 3.6 Assuming CO_2 was the only gas given off, calculate the volume of CO_2 that was released over 5 minutes. (5)

[14]

Question Four

25 marks

When colourless hydrogen gas and purple iodine vapour are mixed at high temperatures, they react to form an equilibrium mixture of colourless hydrogen iodide. The equation for the reaction is shown below.



A chemist injects equal amounts of $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ into an insulated, evacuated and sealed $1,0 \text{ dm}^3$ container to which a temperature probe is attached. Both gases and the container have an initial temperature of 250°C . The chemist's observations over the next hour are shown in the table below.

Observations:

Time from the moment of mixing (min)	Temperature ($^\circ\text{C}$)	Colour of gas mixture
0	250	dark purple
15	239	purple
30	232	pale purple
45	232	pale purple (no further change)
60	232	pale purple (no further change)

- 4.1 Explain why the temperature decreases and the initial dark-purple colour of the gas mixture lightens to pale purple and then remains unchanged as the first equilibrium is being established. (3)
- 4.2 Identify **one** change that could be made to the original reaction conditions so that equilibrium is reached at a faster rate. Justify your answer by referring to the collision theory. (4)

- 4.3 The chemist performs three tests to observe how the equilibrium mixture responds to change.
Predict the effect of each of the following changes on the colour of the gas mixture as it was after 60 minutes.

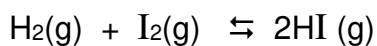
- 4.3.1 The gas mixture was heated to a constant 280 °C. Assume the volume remained constant.
Predict the effect on the colour of the gas mixture by stating only: DARKER, LIGHTER or UNCHANGED. (2)
- 4.3.2 The temperature of the gas mixture was restored to 232 °C. The volume of the container is now changed to 1,5 dm³ at a constant temperature of 232 °C.
Predict the effect on the colour of the gas mixture by stating only: DARKER, LIGHTER or UNCHANGED. (2)
- 4.3.3 The volume of the container was restored to 1,0 dm³. Some HI_(g) was injected into the container at a constant temperature of 232 °C.
(a) Predict the effect on the colour of the gas mixture by stating only: DARKER, LIGHTER or UNCHANGED. (1)
(b) Explain your choice in (a). (3)

- 4.4 Complete this whole question on your ANSWER SHEET.

The container is now at 1,0 dm³ and filled with 0,03 mol of hydrogen and 0,03 mol of iodine. The container is heated to a temperature of 350 °C and allowed to reach equilibrium.

- 4.4.1 Determine expressions for the equilibrium concentrations of all three gases by completing the table on your ANSWER SHEET. (5)
- 4.4.2 Write the expression for the equilibrium constant for the reaction. (1)
- 4.4.3 Calculate the equilibrium concentrations of all three gases if the equilibrium constant for the reversible reaction is 45. (4)

The equation has been repeated below for your convenience.



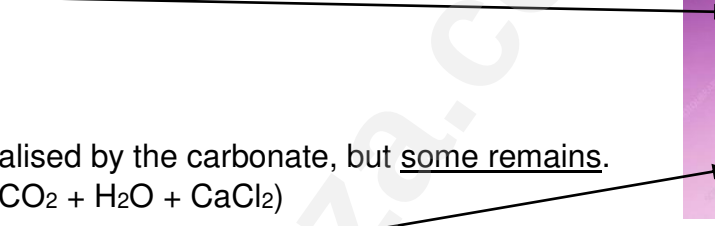
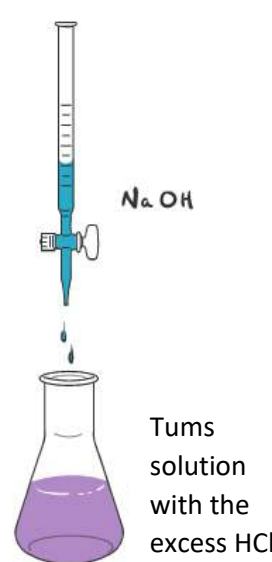
[25]

Antacids are medication that neutralize stomach acid (HCl) to cut down on heartburn, acid indigestion, and stomach upset. Three common antacids are calcium carbonate (the active ingredient in Tums tablets), magnesium hydroxide (as found in milk of magnesia) and aluminium hydroxide.

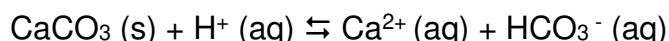
- 5.1 Write down and balance the chemical reaction between aluminium hydroxide and hydrochloric acid (phase labels are not required). (3)

A student conducts the following titration using Tums and HCl:

Experiment:

- In order to determine the ability of the Tums antacid to neutralize acid, a tablet of Tums was dissolved in an excess amount of hydrochloric acid of known concentration. 
- Some of the HCl** is neutralised by the carbonate, but some remains. (excess $2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{CaCl}_2$) 
- A titration of the solution (from point 1) with NaOH was performed to figure out the amount of excess acid that was not neutralised by the Tums tablet. 
- Then, from this, the amount of acid that reacted with the antacid was calculated.
- This method of analysis is called a back-titration. The reactions below are reversible, which means that CO_2 dissolved in water will produce some carbonic acid. It is important to boil the initial solution when the carbonate reacts with acid, to remove CO_2 as a gas.

HCl is neutralised by CaCO_3 as illustrated by the following equations:



- 5.2 Why is it important to remove the carbon dioxide gas in this experiment? (2)
- 5.3 Write an aim for the experiment. (2)
- 5.4 State two ways to ensure accuracy when performing a titration. (2)

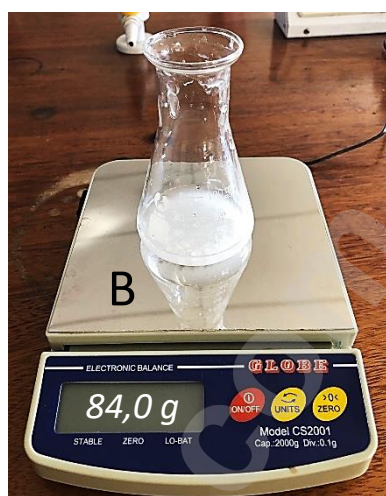
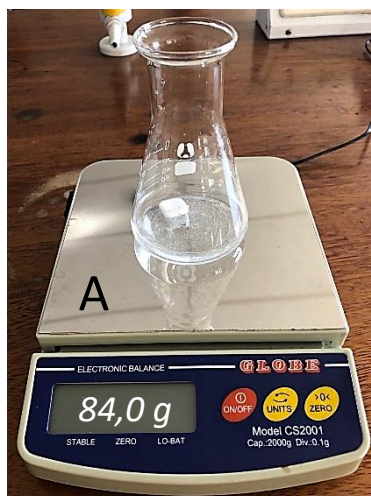
- 5.5 The table of results below for the titration is incomplete. Complete the table by writing the question number and your answer in your answer book. Question numbers are in bold for clarity. (4)

	Trial 1	Trial 2
Volume of HCl added to Tums (dm ³)	0,05	0,05
Final volume of burette (cm ³)	26,6	27,2
Initial volume of burette (cm ³)	0,0	0,4
Volume of NaOH dispensed (cm ³)	5.5.1	5.5.2
Volume of NaOH (dm ³)	5.5.3	5.5.4
Average volume of NaOH (dm ³)		5.5.5

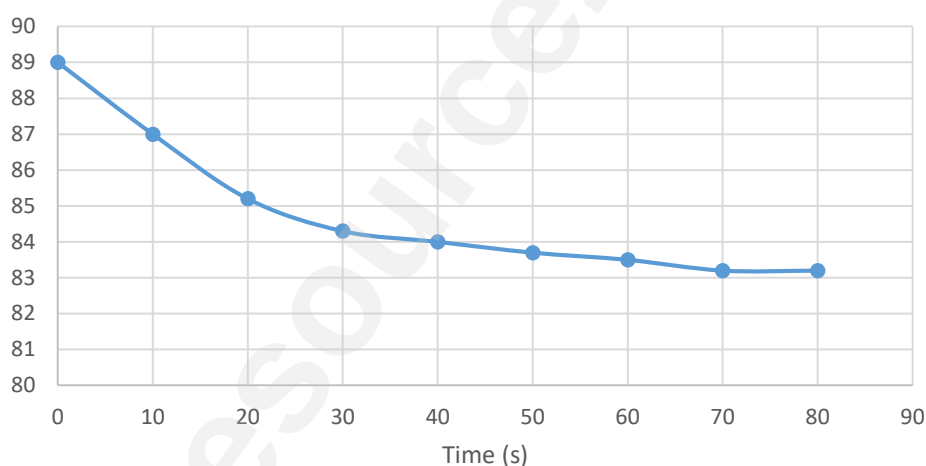
- 5.6 The concentration of HCl in the stomach is 0,16 mol.dm⁻³. Calculate the number of moles of acid in the 0,05 dm³ used at the start to dissolve the Tums tablet. (3)
- 5.7 Using the average volume of NaOH in the table, calculate the number of moles of NaOH of concentration 0,1 mol.dm⁻³ used to neutralise the remaining HCl in the titration. (3)
- 5.8 Hence state the number of moles of HCl required to neutralise this NaOH considering that they react in a ratio of 1:1. (1)
- 5.9 Hence calculate the number of moles of HCl that was neutralised by the **Tums tablet** when it was dissolved in the acid. (2)
- 5.10 Use your answer in 5.9 to calculate the volume of HCl that will be neutralised by a Tums tablet. (3)
- 5.11 A Tums tablet has a mass of 1,3 g. The mass of CaCO₃ in each tablet is 0,265 g. Calculate the percentage purity of the CaCO₃ in the Tums tablet. (3)

QUESTION 5 CONTINUES ON THE NEXT PAGE

Tums tablets are usually chewed before they reach the stomach. Into two conical flasks (labelled A and B), the pupils placed the volume of HCl calculated previously in question 5.10 with a tums tablet. In flask A they used a whole tablet and in B they used a crushed tablet. Each flask was placed on an electronic scale as shown below.



They measured the rate of the reaction and their data produced the following graph for flask A:

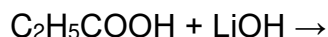


- 5.12 Provide a suitable label for the y-axis of this graph. (1)
- 5.13 Using the graph (that is identical to the one above) on your ANSWER SHEET draw a line to represent the data that you would expect for flask B. Label the line flask B. (2)

[31]

Questions 6.1 to 6.5 below relate to the reaction of $\text{C}_2\text{H}_5\text{COOH}$ with LiOH .

- 6.1 Complete and balance the equation below (phase labels are not required). (2)



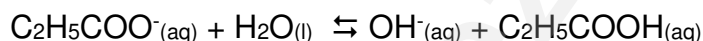
- 6.2 Define a salt. (2)

- 6.3 Predict whether the resulting salt in the equation above is ACIDIC or BASIC or NEUTRAL. (1)

- 6.4 Define the K_w for water at 25°C . (1)

- 6.5 The concentration of H_3O^+ ions in the solution at equilibrium is $5,6 \times 10^{-10} \text{ mol.dm}^{-3}$. Calculate the concentration of OH^- ions in the solution. (3)

- 6.6 The hydrolysis reaction of the salt is as follows:



- 6.6.1 Identify the conjugate acid of $\text{C}_2\text{H}_5\text{COO}^-$ and state whether it is a strong or weak acid. (2)

- 6.6.2 Identify a strong base in the reaction. Is its conjugate acid weak or strong? (2)

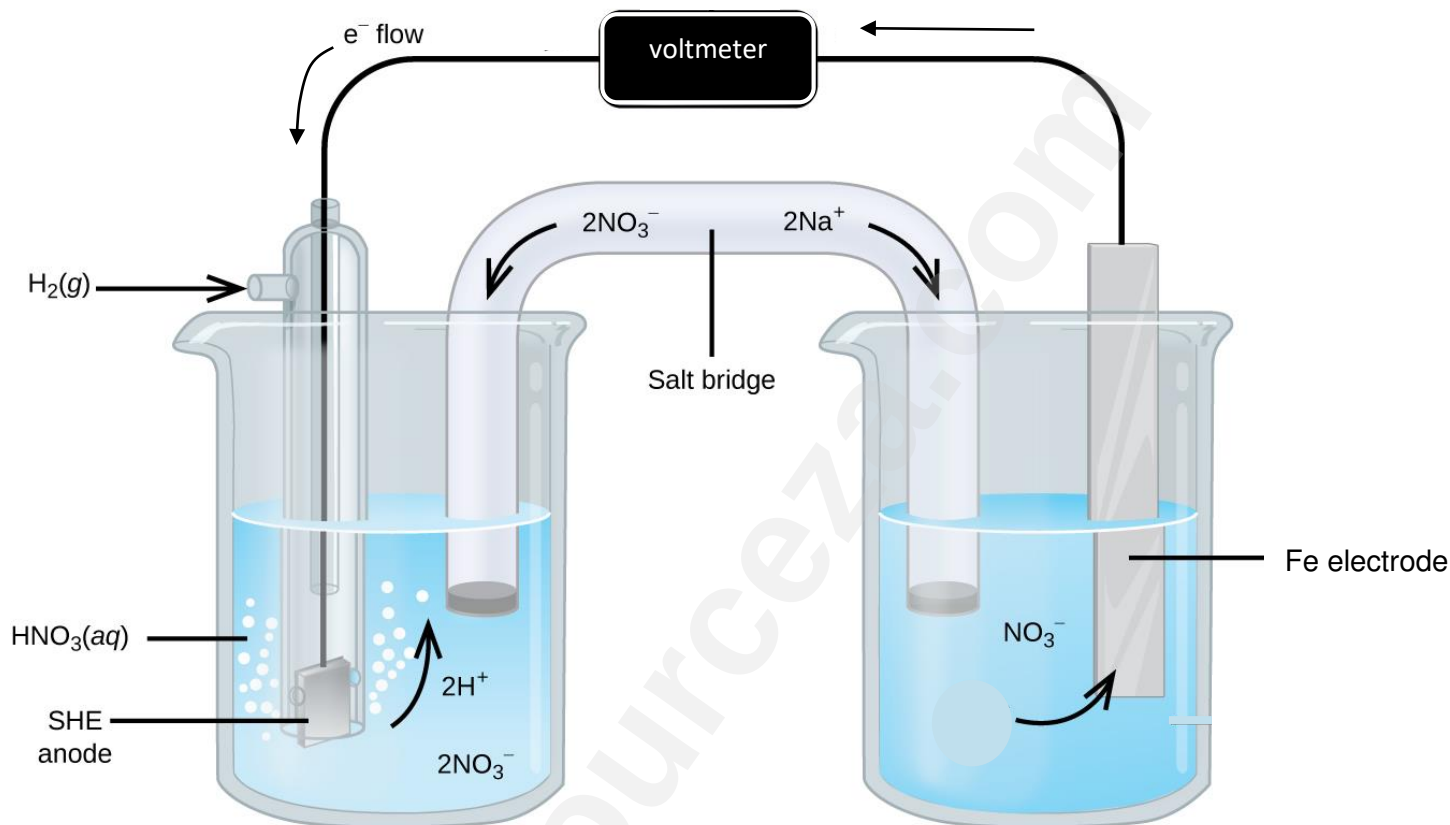
- 6.7 Define the *hydrolysis of a salt*. (2)

- 6.8 Explain why the $\text{C}_2\text{H}_5\text{COO}^-$ ion undergoes hydrolysis. You can use reaction equations to help you if you wish. (4)

- 6.9 Predict the approximate pH of the resulting solution. (1)

[20]

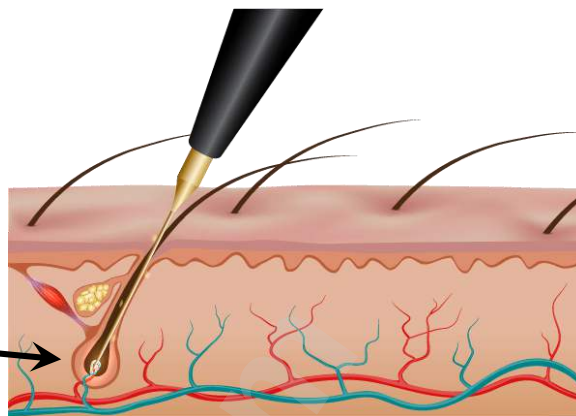
The SHE (standard hydrogen electrode) connected in a galvanic cell can be used to determine the standard reduction potential of Fe^{2+} . The SHE on the left in the diagram below is the anode and assigned a standard reduction potential of zero.



- 7.1 Why is the standard hydrogen electrode always considered to be the anode? (1)
- 7.2 Give the cell notation for this cell as connected, at 25 °C. Include standard conditions in the brackets. (4)
- 7.3 Write down the half reactions and the nett ionic reaction for the spontaneous process in this cell. (3)
- 7.4 Calculate the reading on the voltmeter. (3)
- 7.5 With reference to the reactants and products, state what would cause the voltage of this cell to decrease over time. (2)
- 7.6 What does it mean when the potential difference of the cell is zero? (2)

[15]

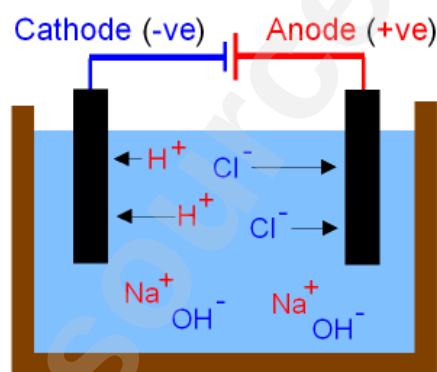
Electrolysis is a method that can be used to permanently remove individual hairs from the face or body. During electrolytic hair removal a thin probe is inserted into the hair follicle, which is a natural opening of the skin.



The application of direct electrical current to a solution of salt water (which naturally occurs in our body) produces a reaction that causes the salt and the water to break into their constituent parts. The new substances that are formed are sodium hydroxide (NaOH), hydrogen gas (H_2), and chlorine gas (Cl_2).

It is the sodium hydroxide (NaOH), which is very caustic that causes the destruction of the hair follicle.

The process mirrors that which happens in the chloro-alkali industry except that the cathode is the needle probe and the anode is the person's body.



- 8.1 Write down the half reactions that take place at the anode and the cathode. (2)
- 8.2 Write down the nett ionic reaction for this process. (2)
- 8.3 Why are the sodium ions not reduced at the cathode? (2)
- 8.4 The current in the probe is 3 mA and each hair requires 10 seconds of electricity until the follicle is destroyed.
- 8.4.1 Convert 3 mA to A. (1)
- 8.4.2 Calculate the amount of charge required to destroy one follicle. (3)
- 8.4.3 Calculate the number of moles of OH^- ions that are produced in each hair follicle. (5)
- 8.4.4 How many grams of NaOH is made in each hair follicle? (4)
- 8.5 Hence, 360 hairs could potentially be removed in an hour. If a person wanted their facial hair removed, what is the minimum amount of hours it would take if the average beard contains 15 000 hairs? (2)

[21]

9.1 Provide the IUPAC names for the following two organic molecules.



9.2 Butan-1-ol, $\text{C}_4\text{H}_9\text{OH}$, can react with acidified permanganate ions, MnO_4^- , to produce butanoic acid, $\text{C}_3\text{H}_7\text{COOH}$.

The half reaction that produces butanoic acid from butan-1-ol is as follows:



9.2.1 Use the half reaction from the table of reduction potentials for the reduction of MnO_4^- and determine the net ionic equation for the full reaction of butan-1-ol and permanganate ions. (4)

9.2.2 $\text{C}_3\text{H}_7\text{COOH}$ reacts with an alcohol in the presence of sulphuric acid to form ethyl butanoate. Name the alcohol that reacted and write down its molecular formula. (2)

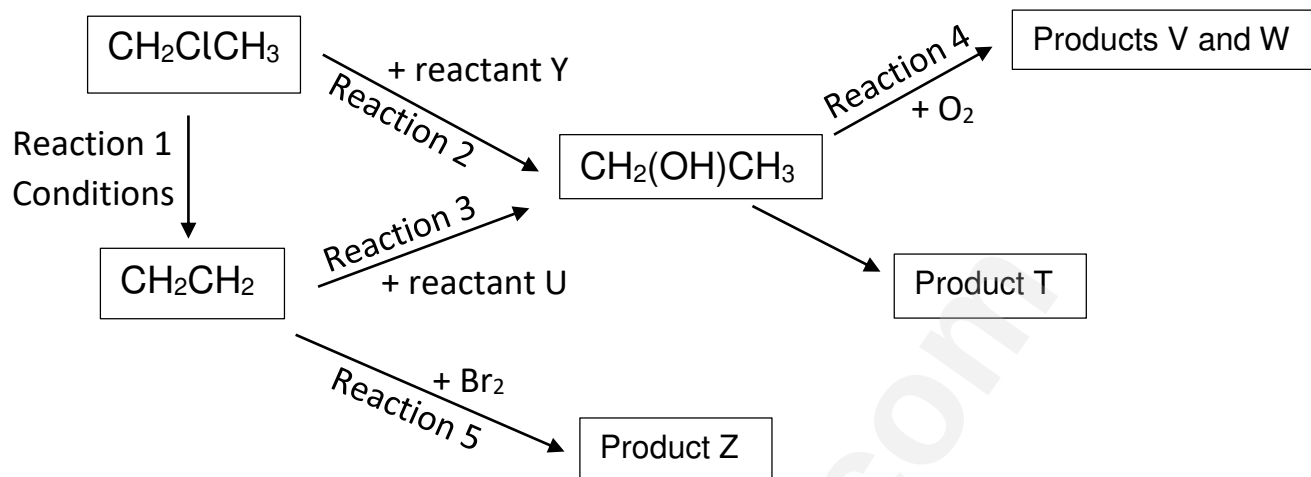
9.2.3 In terms of the strength of the intermolecular forces, rank $\text{C}_3\text{H}_7\text{COOH}$, the alcohol in 9.2.2 and the ester ethyl butanoate in increasing order of intermolecular force strength. (2)

9.2.4 Explain your order choice in 9.2.3 with respect to the alcohol and the carboxylic acid, $\text{C}_3\text{H}_7\text{COOH}$. (2)

9.2.5 Name a positional isomer of the ester formed in 9.2.2. (2)

9.2.6 Draw and name the structural formula of a functional isomer of the ester formed in 9.2.2. (3)

- 9.3 The following flow diagram illustrates a number of organic chemical reactions. Consult the flow diagram and answer the questions that follow:



- 9.3.1 Define the term *hydrocarbon* and identify one in the diagram above. (3)
- 9.3.2 Reaction 1, which forms ethene and another product, is an elimination reaction. What is the name of the specific type of reaction? (1)
- 9.3.3 State the reaction conditions that are required in order for ethene to be formed in reaction 1. (4)
- 9.3.4 $\text{CH}_2(\text{OH})\text{CH}_3$ can be formed in two different reactions (Reaction 2 or Reaction 3). Name reactant Y and name reactant U. (2)
- 9.3.5 In Reaction 2, reactant Y is added to CH_2ClCH_3 forming $\text{CH}_2(\text{OH})\text{CH}_3$ along with product T. Write the formula for product T. (1)
- 9.3.6 Products V and W are formed in Reaction 4. Name the type of chemical reaction that forms products V and W and write down the balanced chemical equation for the reaction. (4)
- 9.3.7 Reaction 5 forms product Z. Name this general type of reaction. (1)
- 9.3.8 Draw the structural formula of product Z. State and explain what observations will be made during Reaction 5. (5)

[42]

TOTAL = 200 MARKS

Sources:

MCQ 1.3; 1.5 – 1.7: Adapted from Victoria certificate of education Chemistry written exam 2017

MCQ 1.8 & 1.10: Adapted from Victoria certificate of education Chemistry written exam 2018

Question 3 diagram taken from Victoria certificate of education Chemistry written exam 2017

Question 4 data used from Victoria certificate of education Chemistry written exam 2018

Q 4.4 adapted from IEB KZN regional user group conference notes 2018 (Sue Murray)

Question 5 diagrams: <https://www.sciencephoto.com/media/141027/view/tums-reacting-in-hydrochloric-acid> & <https://www.khanacademy.org/test-prep/mcat/chemical-processes/titrations-and-solubility-equilibria/a/acid-base-titration-curves>

Question 7 diagram: https://chem.libretexts.org/@api/deki/files/66461/CNX_Chem_17_03-GalvanAg.jpg?revision=1&size=bestfit&width=633&height=469

Question 8 information: <https://elegantlooks.com/electrolysis/>

Question 8 diagrams: <https://myrevive.co.uk/electrolysis/> & <https://www.2passclinic.com/permanent-hair-removal/electrolysis-hair-removal/galvanic-electrolysis/>

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