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Physical Sciences Preliminary Examination

Paper II – Chemistry

Monday 11 September 2017

Form V

Marks: 200

Examiner: C Adelaar

Time: 3 hours

Examination number: _____

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 21 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.

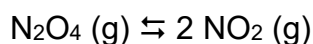
QUESTION 1

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 one of the following substances contains the most polar covalent bond?

- A NaF
- B HCl
- C H₂O
- D CH₄

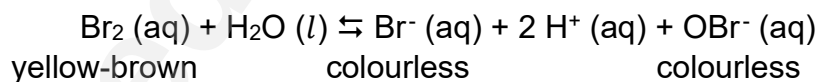
1.2 1 mole of N₂O₄ (g) was placed in an empty 1 dm³ container and allowed to reach equilibrium according to the following equation:



At equilibrium, x mole of N₂O₄ (g) had converted into NO₂ (g). What is the value of the equilibrium constant, K_c , at the temperature of the experiment?

- A $\frac{2x}{(1-x)}$
- B $\frac{2x}{(1-x)^2}$
- C $\frac{2x^2}{(1-x)}$
- D $\frac{4x^2}{(1-x)}$

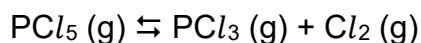
1.3 The following equilibrium exists in aqueous bromine:



The addition of a few drops of which one of the following concentrated solutions would result in the yellow-brown colour of aqueous bromine fading?

- A HCl
- B KBr
- C AgNO₃
- D NaOBr

- 1.4 $\text{PCl}_5(\text{g})$ decomposes to form $\text{PCl}_3(\text{g})$ and $\text{Cl}_2(\text{g})$ according to the equation:



At equilibrium at a specific temperature, the equilibrium constant, K_c , for the reaction is determined to be 0,4.

While the temperature remains constant, the equilibrium is disturbed and before equilibrium is re-established, concentrations of each gas are measured and the value of the mass action expression is determined to be 0,225.

Based on these values, in which option are both statements true and the second statement is a correct explanation of the first statement?

	First statement	Second statement
A	The rate of the forward reaction is greater than the rate of the reverse reaction.	The position of the new equilibrium has shifted to the left.
B	The rate of the forward reaction is greater than the rate of the reverse reaction.	The equilibrium is shifting to the right to re-establish equilibrium.
C	The rate of the reverse reaction is greater than the rate of the forward reaction.	The position of the new equilibrium has shifted to the left.
D	The rate of the reverse reaction is greater than the rate of the forward reaction.	The equilibrium is shifting to the right to re-establish equilibrium.

- 1.5 Which one of the following is a weak polyprotic acid?

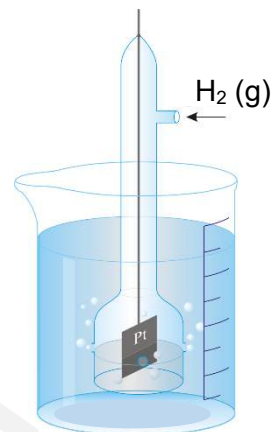
- A H_2SO_4
- B H_3PO_4
- C NH_3
- D CH_3COOH

- 1.6 Which one of the following statements about the extraction of aluminium from alumina is false?

- A Oxide ions are reduced at the graphite electrodes.
- B Alumina dissolves in molten cryolite reducing the energy cost of running the smelter.
- C Carbon dioxide is a by-product of the extraction process.
- D Aluminium is formed at the negative electrode through the process of reduction.

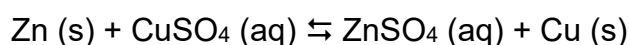
1.7 Which statement about the standard hydrogen electrode is true?

- A Hydrogen gas is supplied at a pressure of 1 kPa.
- B The acid solution in the beaker has a concentration of 1 mol.cm^{-3} .
- C The cell operates at a temperature of 0°C .
- D The oxidation or reduction takes place on the platinum electrode.



Source: <http://glossary.periodni.com/glossary.php?en=standard+hydrogen+electrode>

1.8 Consider the following balanced chemical redox reaction. The forward reaction is spontaneous.



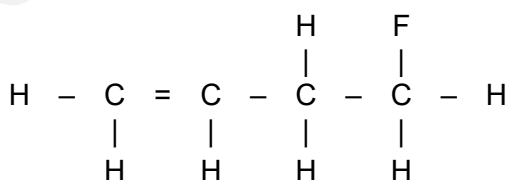
Which one of the following changes will increase the emf generated by the spontaneous forward reaction?

- A Decrease the concentration of $\text{ZnSO}_4 \text{ (aq)}$
- B Decrease the concentration of $\text{CuSO}_4 \text{ (aq)}$
- C Increase the concentration of $\text{ZnSO}_4 \text{ (aq)}$
- D Increase the mass of the Zn electrode

1.9 In which option, do all the compounds belong to the same homologous series?

- A ethane, ethene, ethyne
- B dimethylpropane, methylbutane, pentane
- C propan-1-ol, propan-1,2,3-triol, propanoic acid
- D ethylmethanoate, methylethanoate, propanoic acid

1.10 What is the correct IUPAC name for the following compound?



- A but-1-ene
- B fluorobutene
- C 4-fluorobut-1-ene
- D 1-fluorobut-3-ene

QUESTION 2

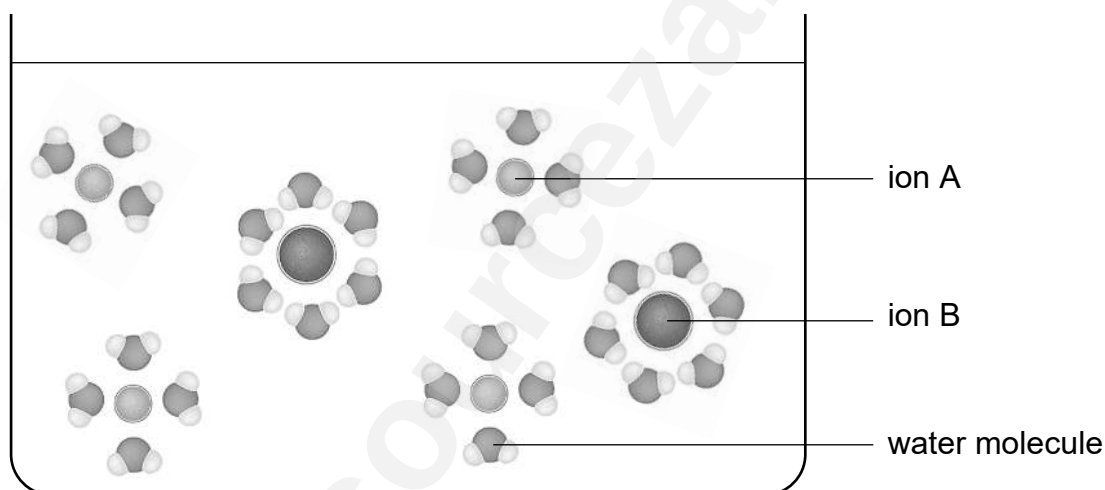
QUANTITATIVE CHEMISTRY AND CHEMICAL BONDING

- 2.1 A standard solution of $\text{Mg}(\text{OH})_2$ is made up so that it will have a volume of $0,25 \text{ dm}^3$ and a concentration of $0,5 \text{ mol} \cdot \text{dm}^{-3}$.

The standard solution is made up using distilled water.

- 2.1.1 **Name** the solute used to make this solution. (2)
- 2.1.2 Calculate the mass of solid $\text{Mg}(\text{OH})_2$ required to make up the standard solution. (6)

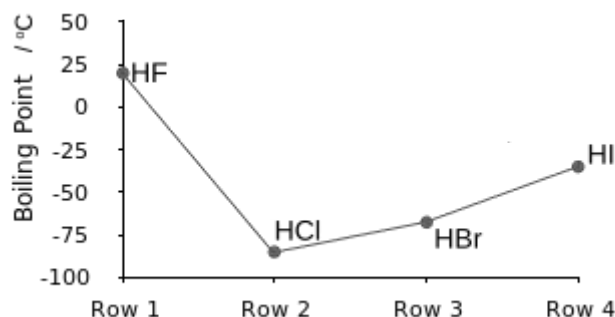
The diagram below shows ions of $\text{Mg}(\text{OH})_2$ dissolved in water.



Source: Adapted from: <http://www.cntdtf.com/Pure%20Water%20Equipment/Lab%20Water.htm>

- 2.1.3 Name the **specific type** of force that holds the solid $\text{Mg}(\text{OH})_2$ crystal together before dissolution. (1)
- 2.1.4 Name the **specific type** of force between the ions and the water molecules. (1)
- 2.1.5 Give the formula for ion B. Explain your answer. (3)

2.2 Consider the following graph showing the hydrides of the halogens.



Source: https://en.wikipedia.org/wiki/Fluorine#/media/File:Boiling-points_Chalcogen-Halogen.svg

2.2.1 By referring to appropriate specific intermolecular forces, explain why the boiling point of hydrogen fluoride (HF) is so much higher than that of hydrogen chloride (HCl). (4)

When hydrogen chloride gas (HCl) is bubbled through water, ionisation of HCl occurs.

2.2.2 Write down the balanced chemical equation for the ionisation of hydrogen chloride in water. Phases need not be shown in your equation. (3)

2.3 A salt can be formed when $\text{Mg}(\text{OH})_2$ reacts with hydrochloric acid.

2.3.1 Write down the balanced chemical equation for this reaction. Phase labels need not be shown in your equation. (2)

2.3.2 If the concentration of the hydrochloric acid is 4 mol.dm^{-3} , determine the volume of the acid required to exactly neutralise the entire volume of the standard solution prepared in 2.1 on the previous page. (4)

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QUESTION 3

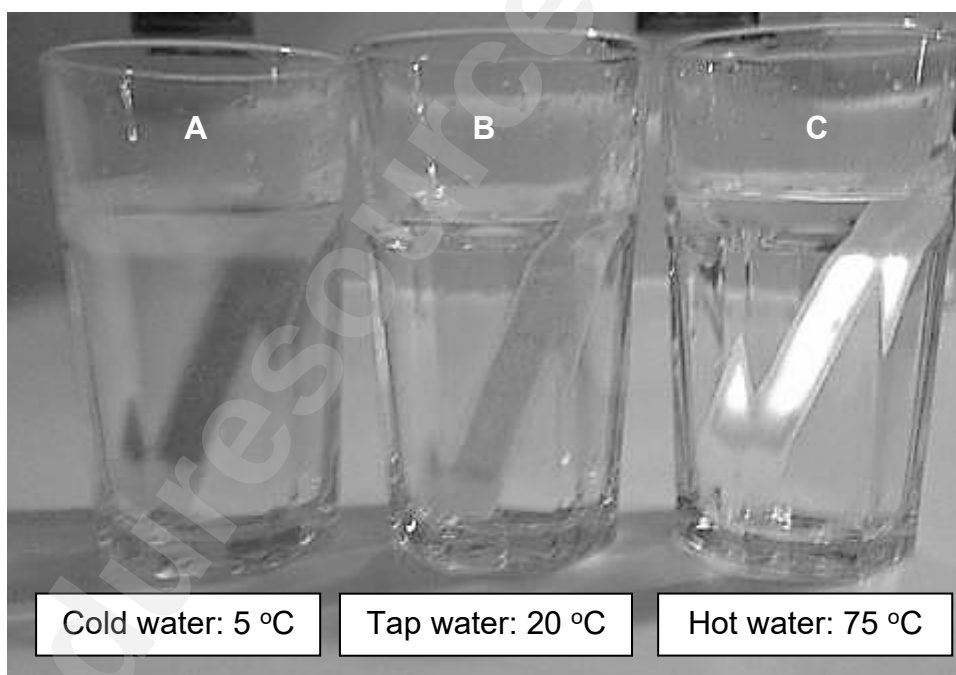
- 3.1 Glow sticks emit light when two chemicals are mixed. The sticks consist of a tiny, brittle container within a flexible outside container. Each container holds a different solution. When the outer container is bent, the inner container breaks, allowing the solutions to combine, causing the necessary chemical reaction. After breaking, the tube is shaken to thoroughly mix the two components.

Source: https://en.wikipedia.org/wiki/Glow_stick



<https://science.wonderhowto.com/how-to/make-your-own-homemade-glow-sticks-0146580/>

An experiment was conducted in which identical glow sticks were simultaneously cracked and placed into water of three different temperatures as shown in the picture below.



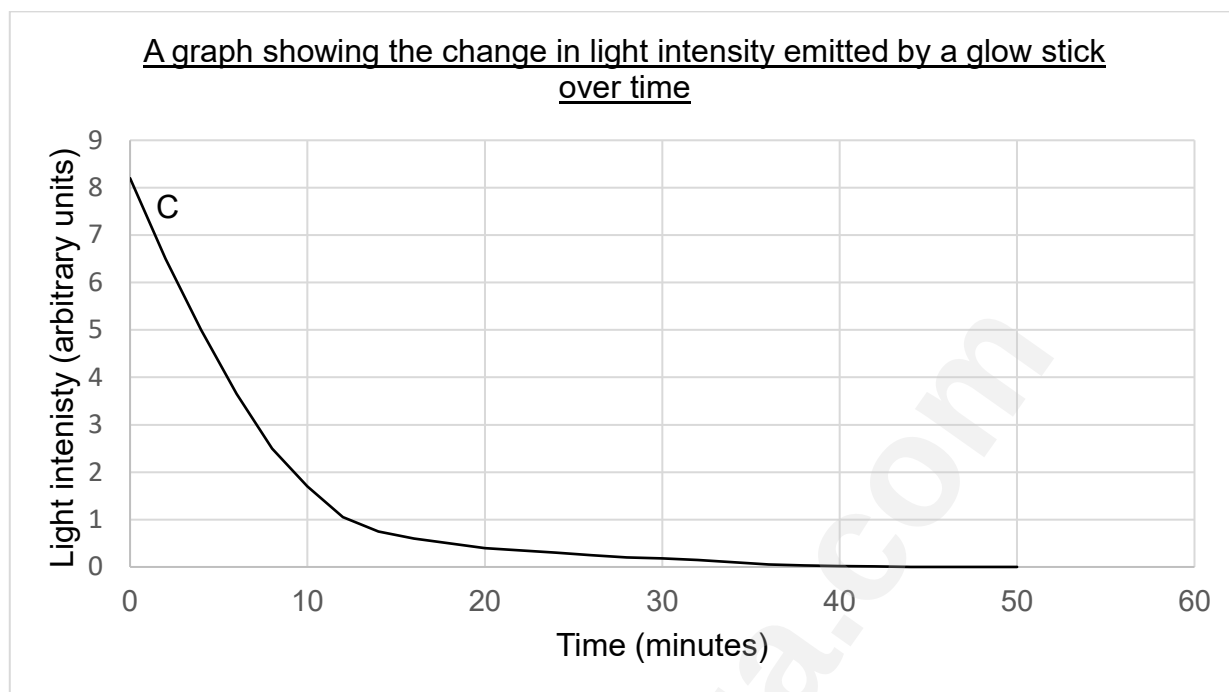
Source: <http://www.discoveryexpresskids.com/blog/the-science-behind-glow-sticks-how-does-temperature-affect-the-glow-intensity>

The light intensity of the glow sticks varied based on the glass of water into which they were placed. The glow stick in the cold water (A) glowed dimly for the greatest amount of time and the glow stick in hot water (C) glowed brightly for the least amount of time.

3.1.1 Identify the independent variable in this investigation. (1)

3.1.2 Identify two fixed variables in this investigation. (2)

The following graph was plotted from data recorded for the glow stick in the hot water (C).



3.1.3 On the ANSWER SHEET provided, draw in a possible line indicating the progress of the reaction for the glow stick in the cold water (A). Ensure that you think about all aspects of the line. Label your line 'A'. (2)

3.1.4 Use kinetic and collision theory to explain how an increase in the temperature of the water affects the rate of the reaction in the glow stick. (3)

An **alternative method** for measuring the rate of this reaction is to determine how long it takes for the light intensity of each glow stick to fade to a certain light intensity level in water of different temperatures.

3.1.5 On the set of axes provided on the ANSWER SHEET, indicate what variables should be plotted on each axis for this **alternative method**. Include a line on your graph to indicate the type of relationship between the variables plotted. (3)

- 3.2 The test for the presence of a carbonate anion in a salt involves the addition of dilute nitric acid to the salt. If a carbonate is present, bubbling or fizzing will be observed. The balanced chemical equation for such a reaction is given below.



An investigation was completed to determine how quickly the reaction proceeds when various variables are altered. The following data points were collected.

In each experiment, the nitric acid was in excess.

Exp	Concentration of HNO_3 (mol.dm^{-3})	Volume of HNO_3 (cm^3)	Mass of solid Na_2CO_3 (g)	Form of solid Na_2CO_3	Time to reach completion (seconds)
A	0,5	100	1,2	Powder	270
B	0,5	100	1,2	Chip	500
C	0,6	200	1,5	Powder	300
D	0,7	200	1,5	Chip	530
E	0,8	100	1,6	Powder	310
F	0,9	100	1,2	Powder	160
G	1,0	100	1,2	Powder	95

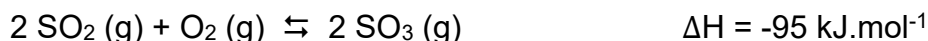
- 3.2.1 Calculate the volume of carbon dioxide gas at STP that was produced in experiment A. (7)
- 3.2.2 Which experiments (if any) could be used to provide **valid** data (from a fair test) to show the effect of:
- (a) surface area on the rate of a reaction? List only the letters of the relevant experiments.
 - (b) mass of the reactant on the rate of a reaction? List only the letters of the relevant experiments.
 - (c) concentration on the rate of a reaction? List only the letters of the relevant experiments.

(4)

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QUESTION 4

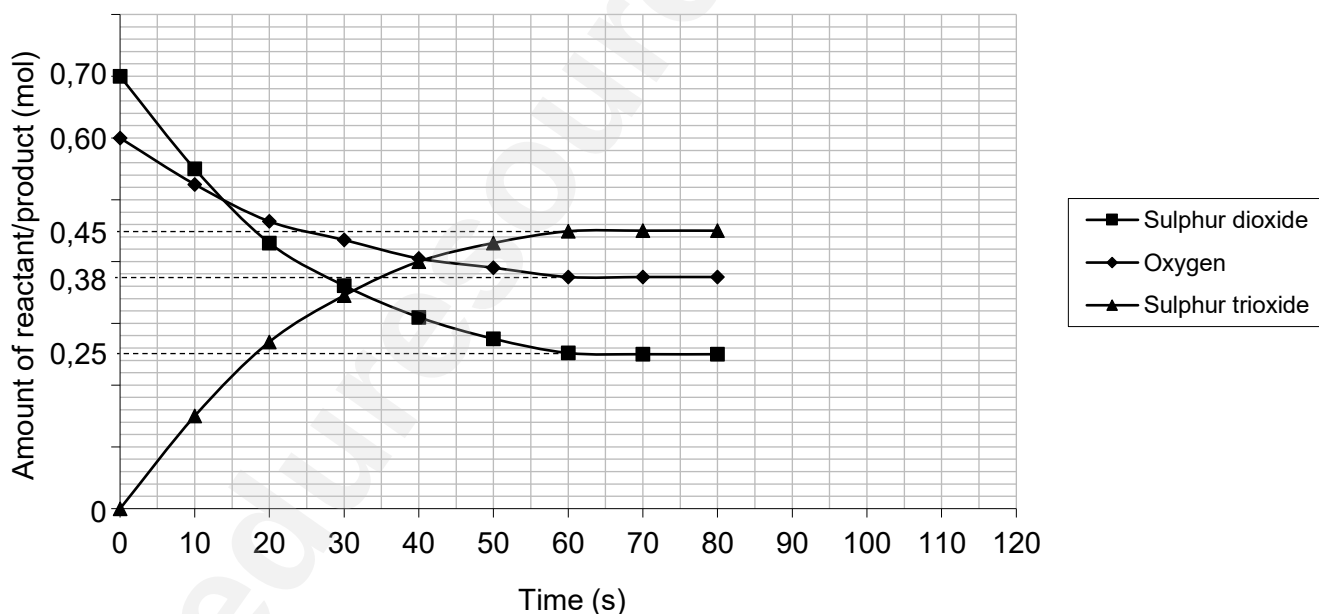
The critical step in the manufacture of sulphuric acid industrially, is the following equilibrium reaction:



- 4.1 On the set of axes on the ANSWER SHEET, sketch the potential energy graph for the forward reaction given above. Certain aspects of the graph have been included already. Include the following labels on your graph: products, activation energy, activated complex and heat of reaction. (4)

This particular reaction is catalysed by vanadium pentoxide.

- 4.2 Define a *catalyst*. (2)
- 4.3 Explain why a catalyst is needed in this particular industrial chemical reaction. (3)
- 4.4 The following graph shows how a dynamic chemical equilibrium is established between SO_2 (squares), O_2 (diamonds) and SO_3 (triangles) in the reaction above. The reaction takes place at a fixed temperature of 450°C in a 4 dm^3 container.

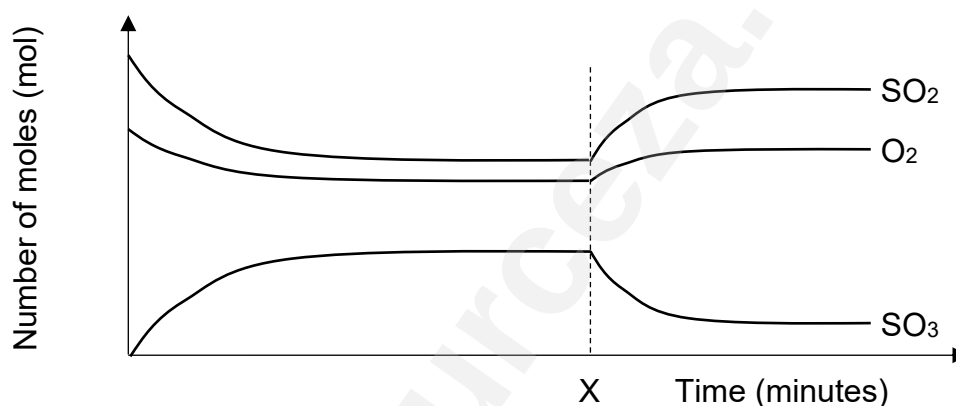
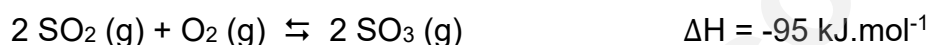


- 4.4.1 Define the term *dynamic chemical equilibrium*. (2)
- 4.4.2 At what time is equilibrium reached? Explain your answer. (2)
- 4.4.3 Calculate the equilibrium constant for this reaction at 450°C . (6)

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At $t = 80\text{s}$, $0,1\text{ mol}$ of SO_2 gas is injected into the system. A new equilibrium is established 20s later and is maintained for a further 20s .

4.4.4 On the graph on the ANSWER SHEET, show the approximate effect of an increase in the number of moles of SO_2 on the amounts of SO_2 , O_2 and SO_3 for the time period $80 - 120\text{s}$. Pay attention to the **relative change** in number of moles of each substance. (4)

4.5 Consider the following sketch graph which represents a disturbance to the chemical equilibrium at time X. Numerical values have been omitted on each axis, but would be available in an experiment where this data could have been collected.



4.5.1 With reference to the graph and any associated numerical values, state how you could determine if the disturbance at X was due to a change in pressure or temperature. Explain your answer. (2)

4.5.2 If the graph above was obtained by changing the pressure of the system at time X, state whether the volume of the container was increased or decreased in order to achieve this disturbance. Explain your answer by referring to Le Chatelier's Principle. (4)

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QUESTION 5

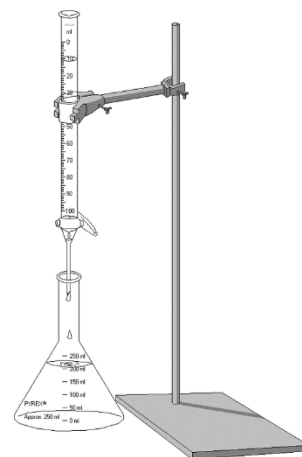
- 5.1 Define an *acid* in terms of the Lowry-Brønsted model. (1)
- 5.2 Explain the difference between a weak base and a dilute base. (3)
- 5.3 In separate beakers, solutions of three different substances are prepared.

	Solution 1: HNO ₃ (aq)	Solution 2: H ₂ SO ₄ (aq)	Solution 3: NH ₃ (aq)
Concentration	1 mol.dm ⁻³	1 mol.dm ⁻³	1 mol.dm ⁻³
volume	0,5 dm ³	0,5 dm ³	0,5 dm ³

- 5.3.1 Which solution will have the lowest pH? Explain fully. (3)
- 5.3.2 State which solution will have the lowest conductivity? (1)

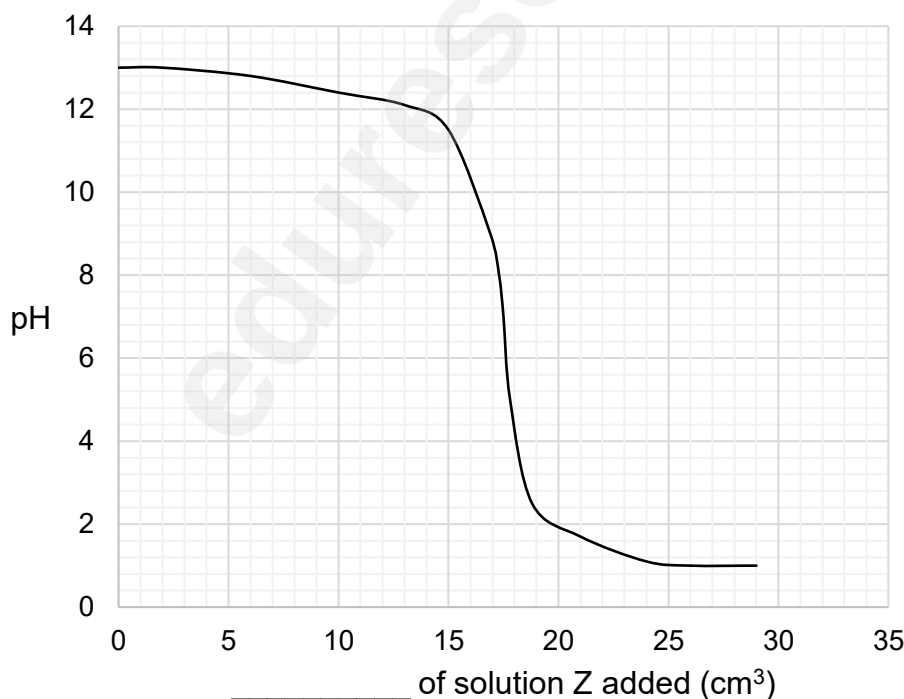
- 5.4 A titration between an acid and a base is completed using the apparatus shown alongside.

The pH of the solution in the conical flask was measured throughout the titration and a graph was created using the pH data.



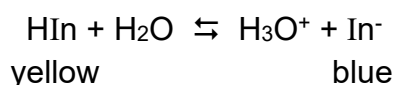
Source: <http://acidsandbasesfordummieschem.weebly.com/titration.html>

Graph showing the change in pH of a solution in a titration



Look at the graph on the previous page and answer the following questions.

- 5.4.1 What substance was placed in the conical flask? Select only **one** of the following options in order to describe the substance fully:
acid; base; strong acid; weak acid; strong base; weak base (2)
- 5.4.2 Provide the correct axis label for the x-axis of the graph. Provide the missing word and replace “solution Z” with the word “acid” or “base”. (2)
- 5.4.3 Define the *equivalence point* for a titration. (2)
- 5.4.4 From the graph, determine how much of solution Z must be added to the conical flask in order for neutralisation to occur. (1)
- 5.4.5 Consider the balanced chemical equation for the indicator used in this titration. The indicator (HIn) is a weak acid with a yellow colour.

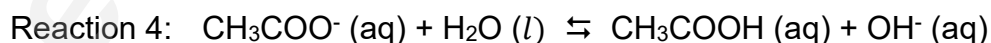
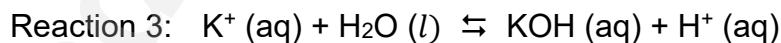
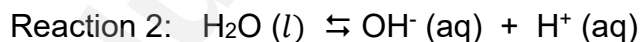
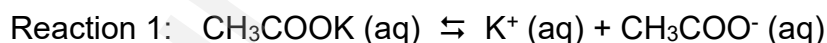


Based on the graph given, what colour would this indicator be at the start of the titration? Explain your answer by applying Le Chatelier's Principle. (4)

- 5.4.6 In practice, it turns out that the indicator changed colour to green at a pH of 10. The titration was repeated three times and the same colour change occurred at a pH of 10 in each repeat. If the results of the experiment were based on colour change rather than the graph given on the previous page, would the experimental outcome be considered valid? Explain by referring to one or more of the following factors: reliability, precision, accuracy and fair test. Justify your answer. (3)

- 5.5 In a different titration, the salt potassium ethanoate (CH_3COOK) is formed. The pH of the salt in solution is basic.

Consider the following reactions and then answer the questions that follow.



- 5.5.1 Name the process that happens in order for the salt solution to be basic. (1)
- 5.5.2 Identify one reaction from reactions 1-4 that will have no effect on the pH of the salt in solution. (1)
- 5.5.3 Refer to any or all of the reactions above (refer to the appropriate reaction number/s in your answer) in order to explain why the solution of the CH_3COOK salt is basic. (3)

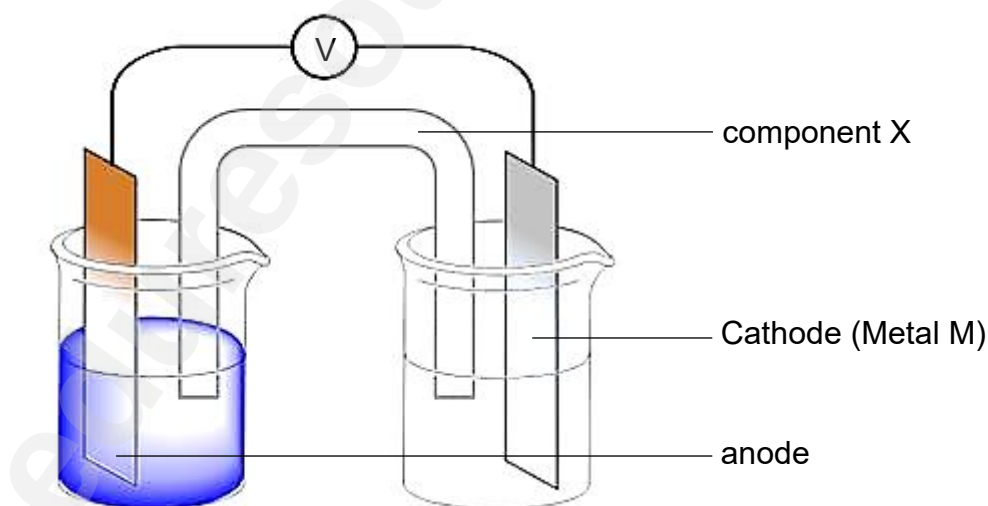
QUESTION 6

The following galvanic cell is set up under standard conditions using copper as the anode and an unknown metal, M as the cathode. A voltmeter connected across the electrodes reads 0,46 V.



Source: Adapted from: http://wps.prenhall.com/wps/media/objects/602/616516/Media_Assets/Chapter18/Text_Images/FG18_02.JPG

The schematic diagram below represents the same cell in a simplified format. The copper anode is drawn on the left.



Source: <http://drfus.com/electrochemistry-lab-experience>

- 6.1 In which direction do electrons tend to flow in this cell? (1)
- 6.2 Determine the identity of metal M for this galvanic cell. Show your working. (5)
- 6.3 Give the cell notation for this cell. Phases and standard conditions need not be shown. (3)

6.4 Consider component X which completes the circuit in the galvanic cell.

6.4.1 Which (if any) of the following electrolytes is **unsuitable** for use in component X in this cell? Give only the letter/s that represent the correct answer/s.

A KNO_3

B CH_3COONa

C KCl (1)

6.4.2 Component X performs another vital function in this chemical cell. Briefly and specifically explain what it does and how it accomplishes this purpose. (3)

6.4.3 Component X is modified and is made longer. Which of the following is/are impacted by this modification? Give only the letter/s that represent the correct answer/s.

A emf of the cell

B cell's capacity to deliver current

C internal resistance of the cell

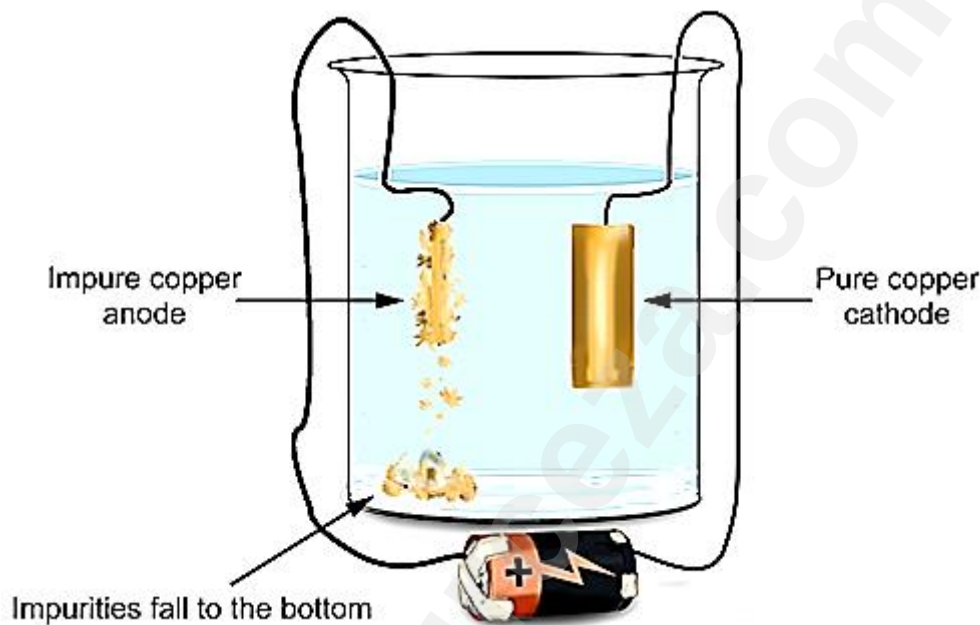
D conductivity of the electrolyte (2)

[15]

- 7.1 In an electro-refining process, the anode is the impure metal and the impurities must be lost during the passage of the metal from the anode to the cathode during electrolysis.

Impure copper metal, also called blister copper, can be refined in this way.

The impurities contained in blister copper can include: zinc, nickel, silver, gold and platinum.



Source: <http://www.mammothmemory.net/chemistry/electrolysis/how-did-electrolysis-start-example-2.html>

- 7.1.1 Write down the half reaction taking place at the:

- (a) anode. (2)
- (b) cathode. (2)

- 7.1.2 Give the chemical formula for a suitable electrolyte for this process. (2)

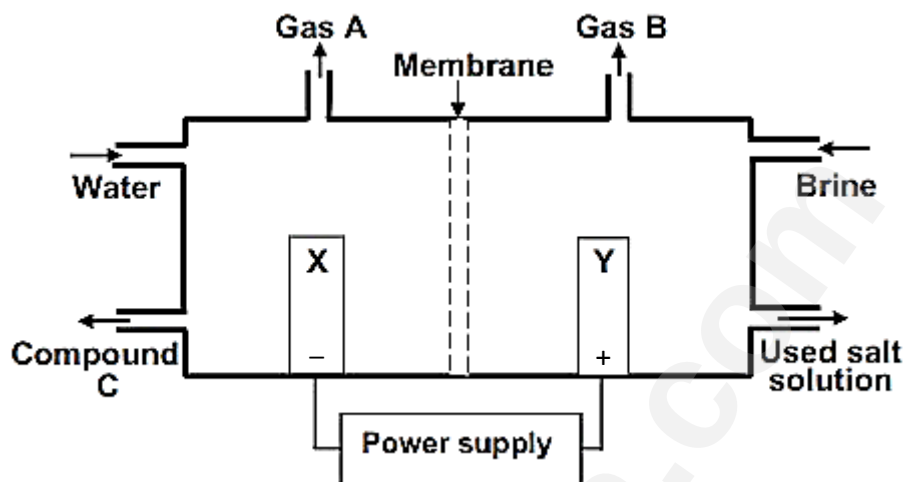
- 7.1.3 Calculate the current required to plate 0,1 mol of copper on to the cathode in a period of 60 minutes. (6)

- 7.1.4 From the list of impurities above, identify one metal found in blister copper that will not react at the anode and will instead sink to the bottom of the cell (1)

- 7.1.5 Explain why this metal will not react at the anode. (2)

- 7.2 The following diagram shows a membrane cell used in the industrial process for the production of chlorine from brine (concentrated sodium chloride solution).

Gas A, gas B and compound C are the major products formed during this process.



Source: <http://www.smartlearner.mobi/science/VideoPastPapers/Chloralkali/Chloralkali.htm>

7.2.1 Describe the conversion of energy in this cell. (2)

7.2.2 Which gas, A or B, is chlorine gas? Explain your choice of answer. (2)

Consider the following half reactions that could possibly take place in a cell of this kind:

Half reaction:	$E^\circ/\text{volt}:$
$\text{Na}^+ + \text{e}^- \rightleftharpoons \text{Na}$	-2,71 V
$2 \text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons \text{H}_2 (\text{g}) + 2 \text{OH}^-$	-0,83 V
$\text{O}_2 + 4 \text{H}^+ + 4 \text{e}^- \rightleftharpoons 2 \text{H}_2\text{O}$	+1,23 V
$\text{Cl}_2 + 2 \text{e}^- \rightleftharpoons 2 \text{Cl}^-$	+1,36 V

7.2.3 Write down the half reaction taking place at the cathode of this cell. (1)

7.2.4 Identify the two other products of this cell (the other gas and compound C). (2)

7.2.5 A diaphragm cell produces the same products as the membrane cell. Identify one disadvantage of the diaphragm cell in comparison to the membrane cell. (1)

[21]

QUESTION 8

Consider the various 5-carbon compounds and their boiling points given in the table below and answer the questions that follow.

Compound	Name or structural formula	Boiling point (°C)
A	pentanoic acid	187
B	<pre> H H H H H - C - C - C - C - H H C H H </pre>	-161
C	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$	139
D	$\text{CH}_3\text{CH}_2\text{CH}_2\text{COOCH}_3$	102
E	<pre> H H H H H H - C - C - C - C - C - H H H H O H H </pre>	119
F	<pre> H H H H H H - C - C - C - C - C - H H H H H H </pre>	-130
G	<pre> H H O H H H H - C - C - C - C - C - H H H H H H </pre>	119

- 8.1 Define the term *functional group*. (2)
- 8.2 Draw the structural formula for the functional group found in compound A. (2)
- 8.3 To which homologous series does compound D belong? (1)
- 8.4 Give the IUPAC name of compound E. (2)
- 8.5 From the compounds in the table on the previous page, select all the positional isomers of compound E. Give only the letter/s of the correct compound/s. (1)
- 8.6 From the compounds in the table on the previous page, select two compounds that are functional isomers of each other. Give only the letters of the correct compounds. (2)
- 8.7 Explain why compounds B and F are chain isomers of each other. (3)
- 8.8 Explain why compound B has a lower boiling point than compound F. Include reference to specific intermolecular forces in your answer. (4)
- 8.9 Draw the structural formula for an unbranched **unsaturated** hydrocarbon containing **four** carbon atoms. Give the IUPAC name for this compound. (4)

[21]

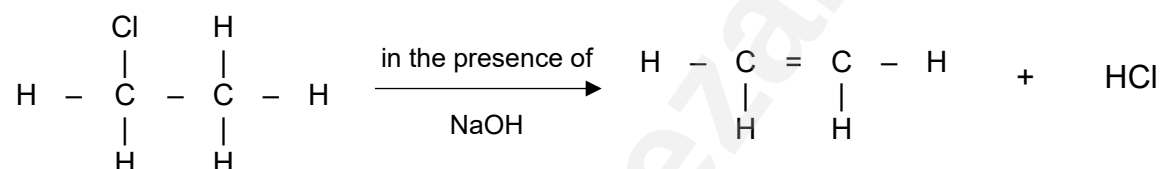
Consider the following reactions. Unidentified compounds are labelled with letters W, X and Y within boxes. Not all of the relevant conditions have been included in the reactions.

Reactions A and B:

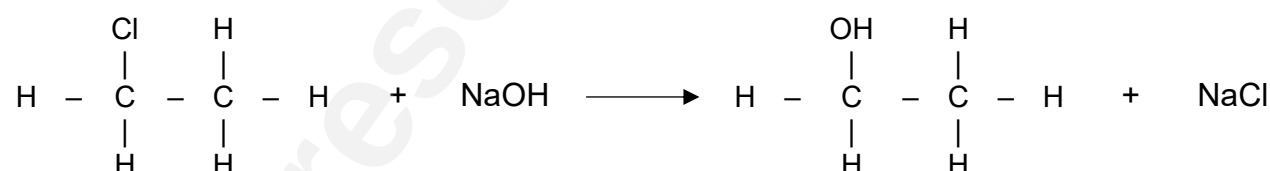
Under different conditions, a haloalkane will either react to form an alkene or an alcohol. Both reactions require the presence of a strong base such as sodium hydroxide to allow each reaction to take place.

Reaction A:

A haloalkane can be converted into ethene according to the following reaction:

**Reaction B:**

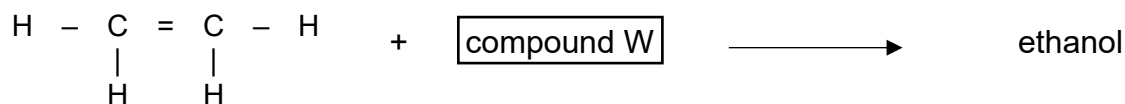
A haloalkane can alternatively be converted into an alcohol according to the following reaction:



- 9.1 What type of reaction is Reaction A? (1)
- 9.2 What type of reaction is Reaction B? (1)
- 9.3 Reaction A produces two gaseous products, ethene and hydrogen chloride. Suggest a practical way to separate these two products from each other and explain why it is a suitable method. (3)
- 9.4 Which reaction will happen (Reaction A or Reaction B) when the sodium hydroxide is in the form of a dilute aqueous solution? (1)

Reaction C:

Ethene further reacts in a hydration reaction to form ethanol according to the following reaction:

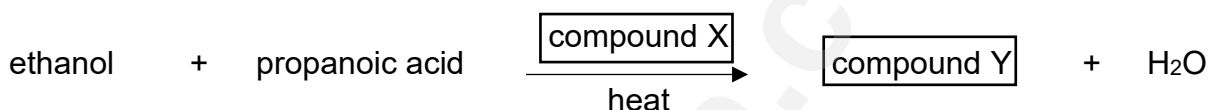


9.5 Reaction C is a hydration reaction, what general type of reaction is this? (1)

9.6 Give the formula for compound W. (1)

Reaction D:

Ethanol further reacts with propanoic acid forming compound Y according to the following reaction:

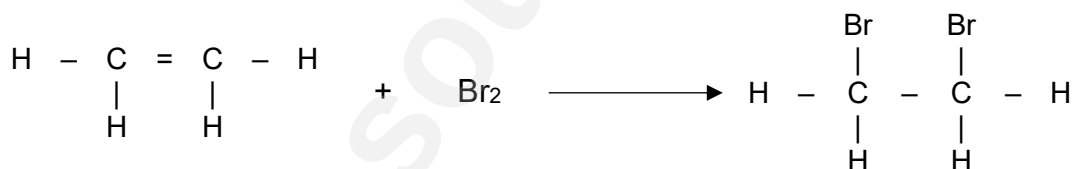


9.7 Give the IUPAC name of compound Y. (2)

9.8 Identify compound X which is needed for Reaction D to form compound Y. (1)

Reaction E:

In another reaction, ethene is bubbled through liquid bromine and a reaction takes place according to the following equation:



9.9 What observations can be made when Reaction E takes place? (2)

9.10 Give the IUPAC name for the product of Reaction E. (3)

Reaction F:

Ethene will also burn in the presence of oxygen. It is considered to be a fossil fuel.

9.11 Give the balanced chemical equation for the combustion of ethene. Use molecular formulae for all substances in the reaction. Phases need not be shown. (3)

[19]

TOTAL: 200 MARKS