Kennedy Baptist College

CHEMISTRY
UNITS 3 & 4
2019

Name: _____

TIME ALLOWED FOR THIS PAPER
Reading time before commencing work: ten minutes
Working time for the paper: three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:
This Question/Answer Booklet
Multiple-choice Answer Sheet
Chemistry Data Book

To be provided by the candidate:
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, eraser, correction tape/fluid, ruler, highlighters

Special items: up to three non-programmable calculators approved for use in the WACE examinations

IMPORTANT NOTE TO CANDIDATES
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	50	/50	/25
Section Two: Short answer	8	8	60	/70	/35
Section Three: Extended answer	5	5	70	/80	/40
					/100

Instructions to candidates

1. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write your answers in this Question/Answer Booklet.

2. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

4. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

5. The Chemistry Data Book is **not** handed in with your Question/Answer Booklet.

See Next Page

Section One: Multiple-choice **25% (50 marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

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1. The following system is at equilibrium.

$$HCN(aq) + SO_3^{2-}(aq) \rightleftharpoons HSO_3^-(aq) + CN^-(aq) + \text{heat}$$

Which imposed change would result in a higher concentration of $HSO_3^-(aq)$, when compared to the original system?

(a) Addition of a few drops of 1.5 mol L^{-1} NaCN(aq).
(b) Increasing the external pressure on the system.
(c) Precipitation of $CN^-(aq)$ by addition of $Cu^+(aq)$ ions.
(d) Gently warming the solution.

2. The reaction sequence below illustrates the production of dithionic acid ($H_2S_2O_6$).

Step 1: $2\ Fe(OH)_3 + 3\ SO_2 \rightarrow Fe_2(SO_3)_3 + 3\ H_2O$
Step 2: $Fe_2(SO_3)_3 \rightarrow FeSO_3 + FeS_2O_6$
Step 3: $FeS_2O_6 + Ba(OH)_2 \rightarrow BaS_2O_6 + Fe(OH)_2$
Step 4: $BaS_2O_6 + H_2SO_4 \rightarrow H_2S_2O_6 + BaSO_4$

Which step in the production of dithionic acid is a redox process?

(a) Step 1
(b) Step 2
(c) Step 3
(d) Step 4

3. Which of the following molecules does **not** exhibit cis-trans (geometric) isomerism?

(a) 2,3-dichloro-3-methylpent-2-ene
(b) 2,3-dichloro-4-methylpent-2-ene
(c) 3,4-dichloro-2-methylpent-2-ene
(d) 4,5-dichloro-4-methylpent-2-ene

4. Of the following tertiary structures that could form between the amino acids asparagine and aspartic acid, which would be the **least** significant?

(a) dispersion forces
(b) dipole-dipole forces
(c) hydrogen bonds
(d) ionic bonds

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Questions 5, 6 and 7 relate to the equilibrium system below.

An equal number of moles of carbon dioxide and hydrogen gas were placed in a reaction chamber which was maintained at 400 °C. The value of K_c is equal to 1.44×10^3 at this temperature.

$$CO_2(g) + 4\ H_2(g) \rightleftharpoons CH_4(g) + 2\ H_2O(g)$$

5. The system was allowed to established equilibrium. Therefore

   (a) the partial pressure of H_2 would be greater than that of CO_2.
   (b) the partial pressure of CO_2 would be half that of H_2O.
   (c) the partial pressure of CH_4 would be greater than that of CO_2.
   (d) the partial pressure of all four gases would be equal.

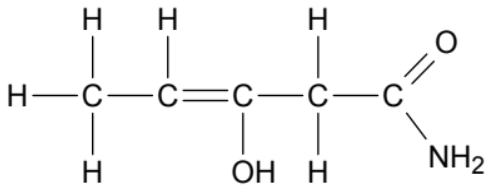
6. The value of K_c at 400 °C indicates that

   (a) the reaction proceeds very quickly.
   (b) the reaction is exothermic.
   (c) the reaction mixture contains a high ratio of products to reactants.
   (d) the reaction mixture contains almost no reactants.

7. The partial pressure of CH_4 is decreased by selectively removing it from the reaction chamber. The resultant equilibrium shift would be caused by

   (a) the forward reaction rate increasing more than the reverse reaction rate.
   (b) the reverse reaction rate increasing more than the forward reaction rate.
   (c) the forward reaction rate decreasing less than the reverse reaction rate.
   (d) the reverse reaction rate decreasing less than the forward reaction rate.

8. Which functional groups are present on the molecule below?



   (i) alcohol
   (ii) alkene
   (iii) ketone
   (iv) amine
   (v) amide

   (a) (i), (ii) and (iv) only
   (b) (ii), (iii) and (iv) only
   (c) (i), (ii) and (v) only
   (d) (i), (ii), (iii) and (iv) only

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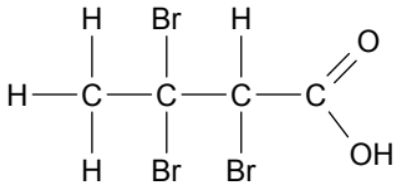
Questions 9, 10 and 11 relate to the following four organic compounds.

A



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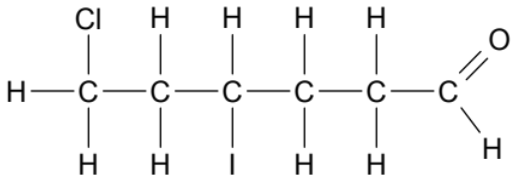
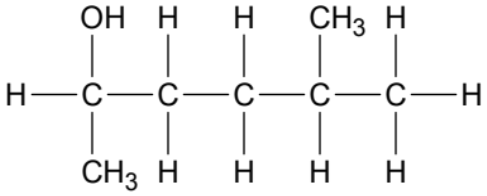
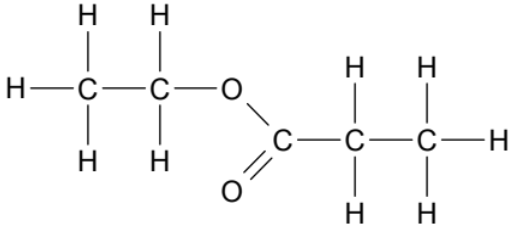


C



D



9. The correct IUPAC name for

(a) A is 2,2,3-tribromobutanoic acid.
(b) B is 6-chloro-4-iodohexanal.
(c) C is 1,4-dimethylpentan-1-ol.
(d) D is propyl ethanoate.

10. Which compound would have the highest solubility in each of the solvents, water and kerosene (a mixture of alkanes, C_{10} to C_{16})?

	Water	**Kerosene**
(a)	A	C
(b)	C	D
(c)	C	B
(d)	A	D

11. Which substance could most easily be distinguished from the other three, by adding a small amount of solid Na_2CO_3?

(a) A
(b) B
(c) C
(d) D

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12. Two groups of chemistry students were setting up the Daniell cell under standard conditions, to see if they could replicate the EMF value predicted from the standard reduction potential table. The Daniell cell consists of the $Cu(s)/Cu^{2+}(aq)$ and $Zn(s)/Zn^{2+}(aq)$ half-cells.

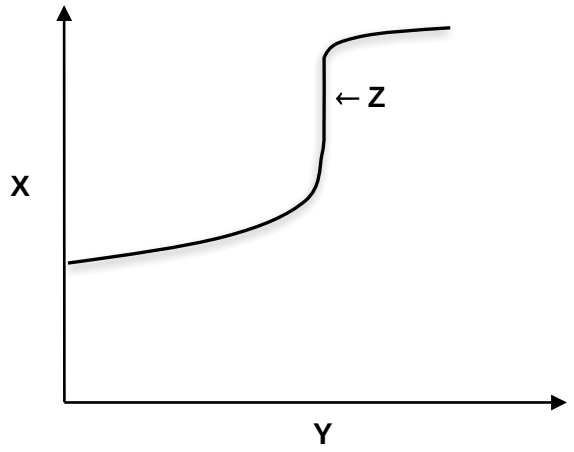
Each group carried out 4 trials and measured the EMF each time. The results of the two groups are shown in the table below.

	Trial 1	Trial 2	Trial 3	Trial 4
Group A	0.98	0.97	0.97	0.97
Group B	1.13	1.08	1.07	1.12

Which statement is **correct**?

(a) The results of group A are the most accurate.
(b) The results of group B suggest no sources of error were present.
(c) The results of group B are the most precise.
(d) The results of group A suggest a source of systematic error.

13. Consider the titration curve shown below.



Which of the following **correctly** identifies the labels represented by X, Y and Z?

	X	**Y**	**Z**
(a)	concentration	volume of acid added	equivalence point
(b)	pH	volume of base added	indicator end point
(c)	pH	volume of acid added	equivalence point
(d)	pH	volume of base added	equivalence point

14. Excess sodium bromide solution is added to a beaker containing some iodine water. The reagents were mixed thoroughly and allowed to sit on the benchtop for 10 minutes. Which species would **not** be present in the beaker?

(a) $I_2(aq)$
(b) $Br^-(aq)$
(c) $Br_2(aq)$
(d) $Na^+(aq)$

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15. An increase in the level of atmospheric $CO_2(g)$ has a strong correlation with an increase in

(a) global surface temperatures.
(b) ocean pH.
(c) the rate of calcification in marine organisms.
(d) the size of the hole in the ozone layer.

Questions 16 and 17 refer to the information below.

A $Cd(s)/Cd^{2+}(aq)$ half-cell was set up by placing a cadmium electrode in a solution of cadmium nitrate. This was then coupled to a half-cell of unknown identity, consisting of a silvery-grey coloured metal electrode submerged in a green solution. Both half-cells were set up under standard conditions. The EMF recorded was +0.34 V.

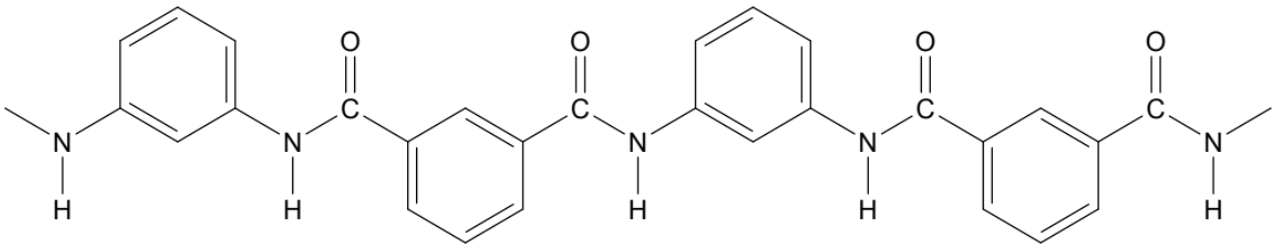
16. Which of the following correctly identifies the unknown half-cell, as well as the designation of the cadmium electrode?

	Identity of half-cell	**Cadmium is the…**
(a)	$Ni(s)/Ni^{2+}(aq)$	anode
(b)	$Ni(s)/Ni^{2+}(aq)$	cathode
(c)	$Cr(s)/Cr^{3+}(aq)$	anode
(d)	$Cr(s)/Cr^{3+}(aq)$	cathode

17. Which of the following is the strongest oxidising agent, under standard conditions?

(a) $Ni^{2+}(aq)$
(b) $Ni(s)$
(c) $Cr^{3+}(aq)$
(d) $Cr(s)$

18. The diagram below shows a section of the polymer Nomex, which is used in flame-resistant materials.



This is an example of

(a) an addition polymer.
(b) a polyester.
(c) a polyamide.
(d) a polypeptide.

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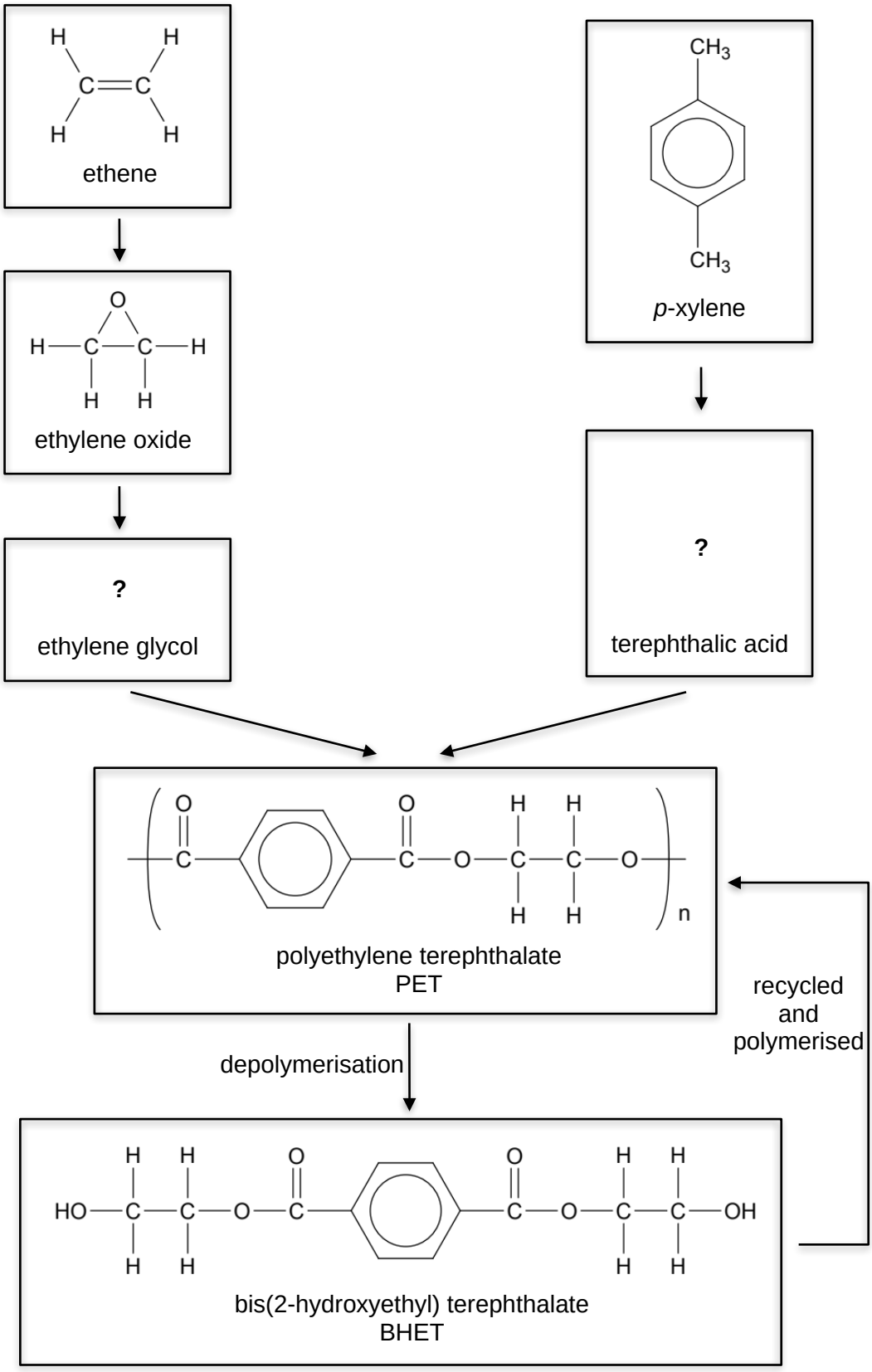
Questions 19, 20 and 21 refer to the information below.

Polyethylene terephthalate (PET) is a synthetic, non-biodegradable polymer. The following **partially** completed reaction sequence shows the main steps involved in the chemical synthesis and subsequent recycling, of PET. Recent studies have determined a simple, sustainable, solvent-free, catalysed process to 'depolymerise' discarded PET into a molecule called bis(2-hydroxyethyl) terephthalate (BHET). This can then be recycled and turned back into PET.



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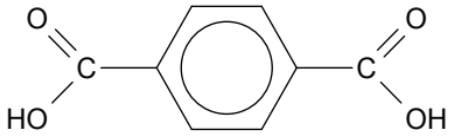
19. The two monomers, ethylene glycol and terephthalic acid, used to produce PET are

(a)



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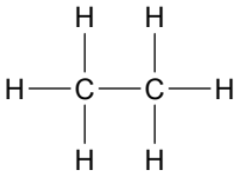
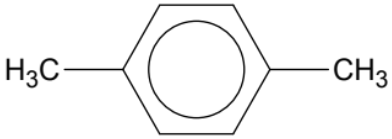


(b)



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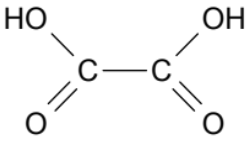
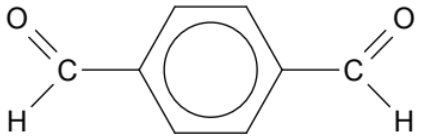


(c)



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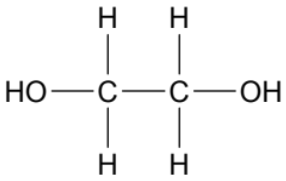
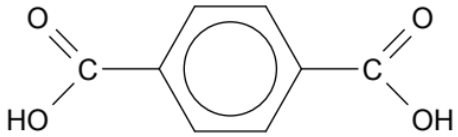


(d)



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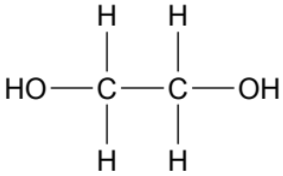

20. Which of the principles of green chemistry is **most clearly** being upheld in this chemical synthesis process?

(a) Preventing waste.
(b) Less hazardous chemical syntheses.
(c) Use of renewable feedstocks.
(d) Increase in energy efficiency.

21. PET molecules have an average of 100 repeating units. The average molecular mass of a strand of PET is therefore closest to

(a) 10 000 g mol^{-1}.
(b) 20 000 g mol^{-1}.
(c) 30 000 g mol^{-1}.
(d) 40 000 g mol^{-1}.

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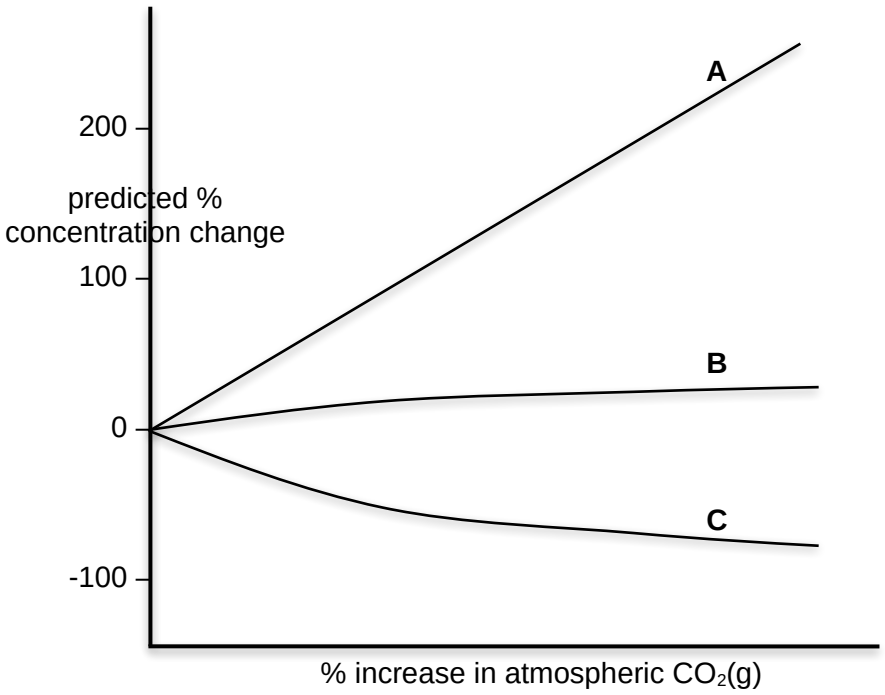
22. Consider the redox reaction below.

$$3\ HCOOH(aq) + 2\ NO_3^-(aq) + 2\ H^+(aq) \rightarrow CO_2(g) + 2\ NO(g) + 4\ H_2O(l)$$

Which of the following statements is **correct**?

(a) HCOOH(aq) is the oxidising agent.
(b) $NO_3^-(aq)$ is the oxidant.
(c) $H^+(aq)$ is the reducer.
(d) Electrons are transferred to HCOOH(aq).

23. Scientific models were used to produce the graph below, which shows future estimates of the percentage concentration change in the upper oceans of the three ions, $HCO_3^-(aq)$, $CO_3^{2-}(aq)$ and $H_3O^+(aq)$, with respect to a continued increase in atmospheric $CO_2(g)$ levels.



Choose the correct labels for lines A, B and C.

	A	**B**	**C**
(a)	$H_3O^+(aq)$	$CO_3^{2-}(aq)$	$HCO_3^-(aq)$
(b)	$H_3O^+(aq)$	$HCO_3^-(aq)$	$CO_3^{2-}(aq)$
(c)	$HCO_3^-(aq)$	$CO_3^{2-}(aq)$	$H_3O^+(aq)$
(d)	$HCO_3^-(aq)$	$H_3O^+(aq)$	$CO_3^{2-}(aq)$

24. The value of K_w at 50 ˚C is 5.48×10^{-14}. What is the pH of a 0.5 mol L^{-1} sodium chloride solution that has been warmed to 50 ˚C?

(a) 6.63
(b) 7.00
(c) 2.31
(d) 9.68

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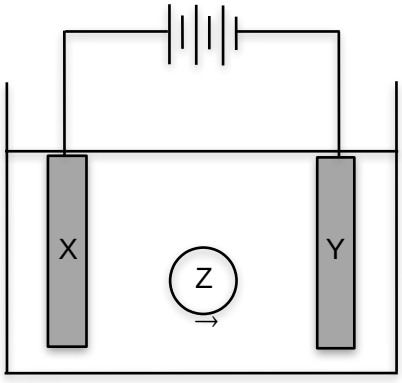
25. A chemist set up an electrolytic cell for metal plating. The diagram below illustrates the set up the chemist used.



Correctly identify X, Y and Z.

	X	**Y**	**Z**
(a)	plating metal	anode	cations
(b)	plating metal	object to be plated	anions
(c)	anode	object to be plated	cations
(d)	cathode	plating metal	anions

End of Section One

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Section Two: Short answer **35% (70 marks)**

This section has **8** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

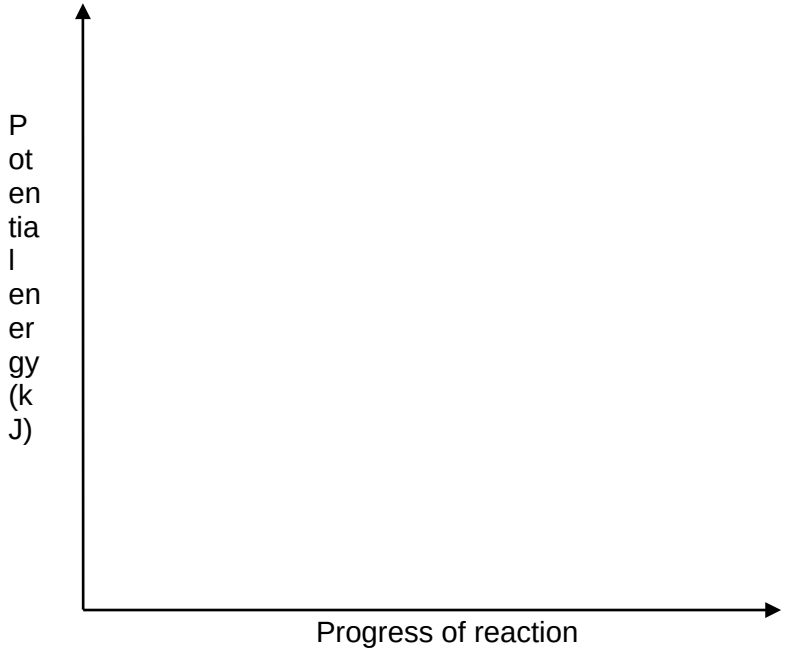
Question 26 **(12 marks)**

The production of ethanol by fermentation of glucose in the presence of the enzyme *zymase* can be represented by the chemical equation below.

$$C_6H_{12}O_6(s) \xrightarrow{zymase} 2\ C_2H_5OH(l) + 2\ CO_2(g) + 68\ kJ$$

The activation energy for this reaction is 109 kJ.

(a) Sketch a labelled energy profile diagram for this reaction. Label the heat of reaction and the activation energy. (3 marks)



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(b) What is an enzyme? Briefly describe the function of an enzyme in terms of the collision theory. (3 marks)

An alternate method for producing ethanol involves the addition reaction of an alkene. This reaction is reversible and exothermic in the forward direction.

(c) Write a balanced chemical equation for this reaction. Use full structural formula for any organic substances and include the heat of reaction. (3 marks)

Industrially, the addition reaction that produces ethanol is carried out under acidic conditions, in the presence of phosphoric acid.

(d) Considering the principles of green chemistry, state one advantage of using an enzyme catalyst rather than a phosphoric acid catalyst. (1 mark)

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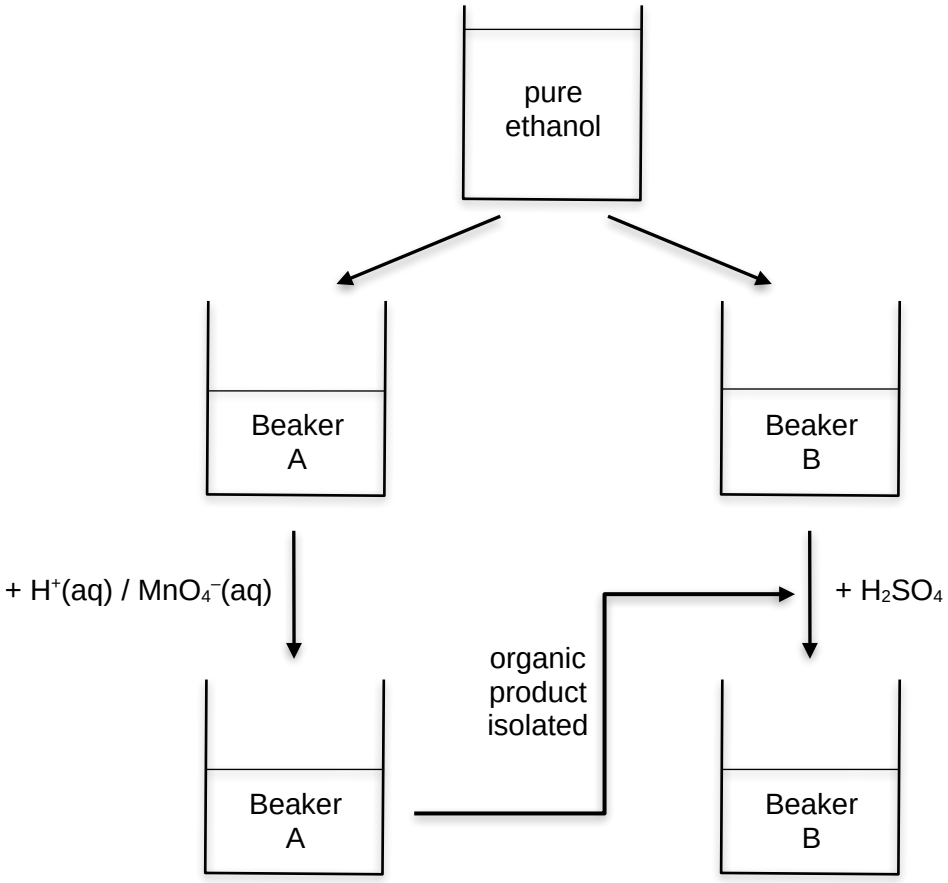
A sample of pure ethanol was collected and divided into two beakers, A and B.



Some acidified potassium permanganate was added to Beaker A and the reaction was allowed to proceed to completion. The organic product from this reaction was then isolated and added into Beaker B along with a few drops of concentrated sulfuric acid. Beaker B was gently warmed.

(e) Write a balanced chemical equation for the reaction occurring in beaker B. (2 marks)

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Question 27 **(6 marks)**

Polyethene is the world's most common plastic and accounts for approximately one third of the total plastic produced globally each year.

(a) Discuss the polymerisation process by which polyethene forms. Include a chemical equation in your answer. (3 marks)

Equation:

The melting points of two common forms of the polymer, low density polyethene (LDPE) and high density polyethene (HDPE), are shown below.

	LDPE	HDPE
Melting point range	105 – 115 ˚C	120 – 180 ˚C

(b) Explain the difference in melting point of LDPE and HDPE. (3 marks)

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Question 28 **(12 marks)**

Consider the data regarding the four hydrohalic acids in the table below.

Hydrohalic acid	Formula	K_a
Hydrofluoric acid	HF(aq)	6.6×10^{-4}
Hydrochloric acid	HCl(aq)	approx. 1.0×10^{6}
Hydrobromic acid	HBr(aq)	approx. 1.0×10^{9}
Hydroiodic acid	HI(aq)	approx. 1.0×10^{10}

(a) Write the K_a expression for hydroiodic acid. (1 mark)

(b) Considering all of the K_a values given in the table, classify HI as a strong or weak acid. Justify your answer. (3 marks)

All of the hydrohalic acids are classified as monoprotic acids.

(c) Define the term ‘monoprotic’. (1 mark)

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(d) Select an appropriate acid from the table and describe how a buffer solution could be produced using this acid. Your answer should include; (7 marks)

- the definition of a buffer solution
- a brief description of how the buffer solution would be made
- the chemical equation for the buffer solution
- a brief description, using Le Chatelier's principle, of how the buffer solution would respond to the addition of a small volume of 0.1 mol L^{-1} nitric acid (noting that equations are not required).

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Question 29 **(7 marks)**

Write balanced chemical equations which represent each of the procedures described below. Include state symbols, i.e. (s), (l), (g) and (aq), in your answer.

(a) A few drops of acidified sodium dichromate solution are added to a test tube containing colourless propan-2-ol. (2 marks)

(b) A sample of solid potassium phosphate was dissolved in a beaker of distilled water. When 2 drops of universal indicator were added the solution turned a blue colour. (3 marks)

(c) A piece of nickel metal was placed into a beaker containing a solution of zinc nitrate. (2 marks)

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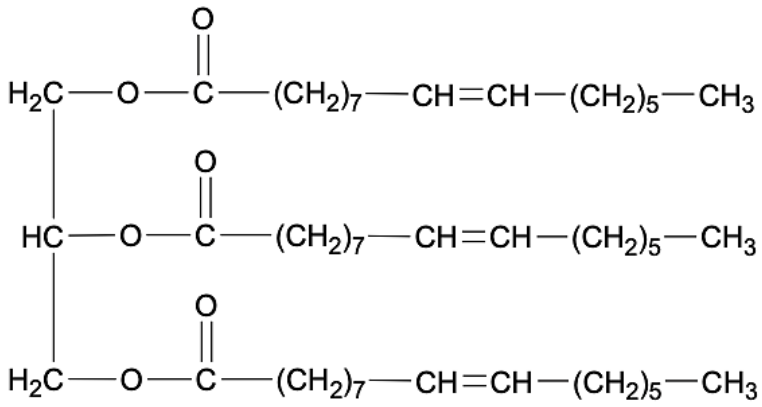
Question 30 **(6 marks)**

Consider the triglyceride shown below.



(a) Complete the table below, showing how this triglyceride can be converted into soap. Give the name or formula of the reactant that can be added to the triglyceride to form soap and draw the structure of the resulting soap formed. (3 marks)

Name or formula of reactant to be added	
Structural diagram of soap	

(b) Complete the table below, showing how this triglyceride can be converted into biodiesel. Give the name or formula of the reactant that can be added to the triglyceride to form biodiesel and draw the structure of the resulting biodiesel formed. (3 marks)

Name or formula of reactant to be added	
Structural diagram of biodiesel	

See Next Page

Question 31 **(12 marks)**

Consider the following closed system which is at equilibrium.

$$5\ O_3(g) + 4\ H_2S(aq) \rightleftharpoons S(s) + O_2(g) + H_2O(l) + 6\ H^+(aq) + 3\ SO_4^{2-}(aq)$$

(a) Write the equilibrium constant expression for this reaction. (2 marks)

(b) When changes are imposed to this equilibrium system, describe and justify how the direction of the equilibrium shift could be **visibly observed**. (2 marks)

(c) Consider the effect of imposing the following changes on the system. Complete the table below by stating;
- in which direction, if any, an equilibrium shift would occur, and
- how the forward reaction rate will differ from the original equilibrium once the new equilibrium has been re-established. (4 marks)

	Equilibrium shift (left, right, no change)	Rate of forward reaction (increase, decrease, no change)
distilled H_2O is added to the system		
volume of system is decreased (at constant temperature)		

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A small volume of 2 mol L^{-1} sodium sulfate, Na_2SO_4, solution was added to the original equilibrium.

(d) Explain, in terms of the collision theory and reaction rates, the effect this change would have on the equilibrium position. (4 marks)

Question 32 **(6 marks)**

When solid red phosphorus, P(s), is mixed with sodium chlorite solution, $NaClO_2(aq)$, this results in the formation of the aqueous salt disodium pyrophosphate, $Na_2H_2P_2O_6$, in addition to hydrochloric acid.

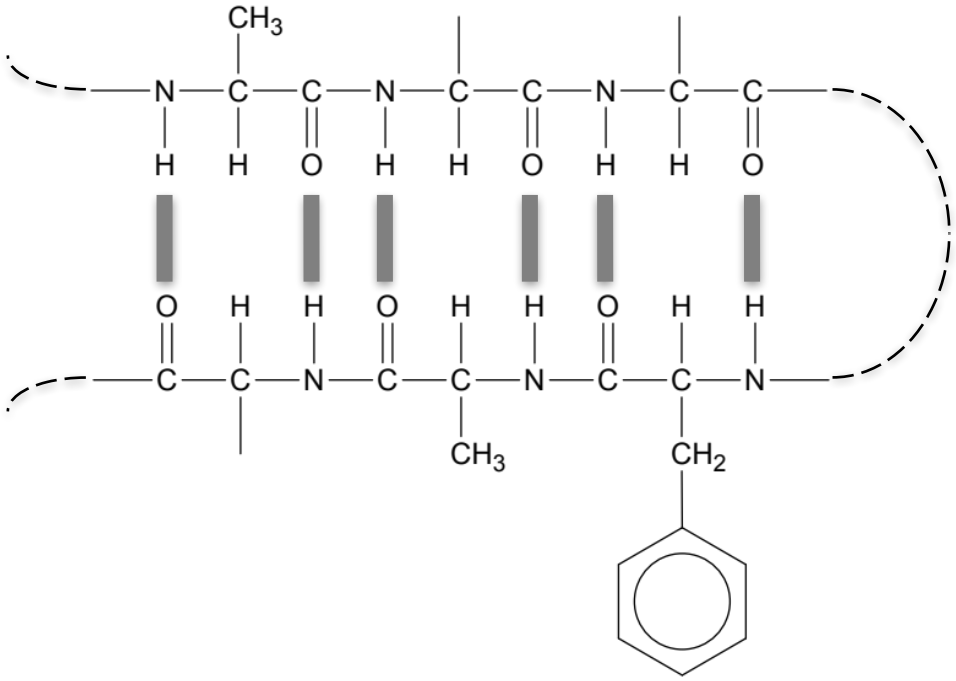
Write the oxidation and reduction half-equations, and an overall balanced redox equation for this reaction.

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

See Next Page

Question 33 **(9 marks)**

Consider the **partially** drawn protein fragment below.



(a) The **partially** completed primary sequence of this protein fragment is given below. Complete the primary sequence. (3 marks)

_____ – leu – gly – - - - - - - - - – _____ – _____ – cys

(b) Complete the drawing of the protein fragment in the diagram above. (3 marks)

Part of the structure of this protein is formed because of the bonds represented by ▬ on the diagram above.

(b) Do these bonds represent a secondary or tertiary structure? Justify your answer. (3 marks)

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End of Section Two

See Next Page

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Section Three: Extended answer **40% (80 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

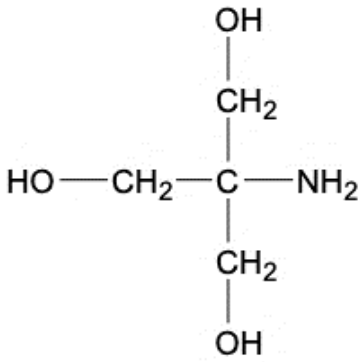
- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

Question 34 **(18 marks)**

The compound tris(hydroxymethyl)aminomethane is generally referred to by its common name 'Tris'. It is a white, crystalline, water-soluble powder.

The molecular formula for Tris is $C_4H_{11}NO_3$ and the structural formula is shown below.



Tris is a primary amine and therefore a weak base. It is frequently found as a component of buffers used in molecular biology labs.

Tris can also function as a primary standard in acid-base titrations.

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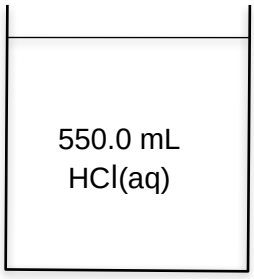
Some chemistry students found a large beaker on the bench in their laboratory. The beaker contained 550.0 mL of solution and was labelled HCl(aq). The students decided to determine the concentration of the acid by titrating it against a standardised solution of 0.08482 mol L^{-1} Tris.



The students took a 20.00 mL sample of the HCl(aq) and diluted it to 250.0 mL in a volumetric flask. They then titrated 25.00 mL aliquots of the diluted HCl(aq) solution and found an average titre of 32.47 mL of Tris was required for equivalence.

The titration equation is given below.

$$C_4H_{11}NO_3(aq) + HCl(aq) \rightarrow C_4H_{12}NO_3Cl(aq)$$

(a) Name an appropriate indicator for use in this titration. Justify your choice using a relevant chemical equation to support your answer. (3 marks)

(b) Calculate the concentration of the undiluted HCl(aq) in the beaker. State your answer to the appropriate number of significant figures. (6 marks)

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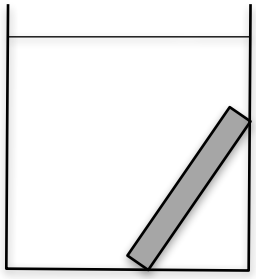
After talking with the laboratory technician, the students learned that the original beaker of acid had **previously been used to dissolve and remove the scale, $CaCO_3(s)$**, off a small section of pipe. The pipe had been soaked in the acid for 3 hours to remove all traces of scale, according to the reaction below.



$$CaCO_3(s) + 2\,H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$$

By weighing the pipe before and after it was soaked in the acid, the laboratory technician was able to determine that the mass of scale removed from the pipe was 12.730 ± 0.010 g.

(c) Calculate the **maximum** concentration of the original $HCl(aq)$, before the pipe had been placed into the solution. You may assume the entire mass of the scale was composed of $CaCO_3(s)$ and the volume of the acid remained constant at 550.0 mL throughout. (6 marks)

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The laboratory technician knew that the build-up of scale in the water pipes at school was most likely caused by hard water.

(d) Define ‘hard water’ and explain why detergents are used in preference to soaps when cleaning in hard water (note that chemical equations are not required). (3 marks)

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Question 35 **(15 marks)**

Galena is one of the most common lead-containing ores. It is comprised of a large proportion of the mineral lead (II) sulfide, PbS, as well as small amounts of other metals such as silver, zinc, copper, bismuth, cadmium and antimony.

The extraction of lead from galena ore can be represented by the following equations.

Roasting: $2\ PbS(s) + 3\ O_2(g) \rightarrow 2\ PbO(s) + 2\ SO_2(g)$

Smelting: $2\ PbO(s) + C(s) \rightarrow 2\ Pb(s) + CO_2(g)$

The first step involves roasting the crushed galena in the presence of oxygen gas over a lengthy period of time, which results in conversion of lead (II) sulfide to lead (II) oxide. Following this, the lead (II) oxide is smelted to produce lead metal.

A particular sample of galena ore was found to contain 89.3% lead (II) sulfide. An 8.62×10^6 g quantity of this ore was crushed and roasted in a furnace where the pressure and temperature were maintained at 470.0 kPa and 540.0 $^\circ$C respectively. Air was injected into the chamber at a rate of 1.75×10^5 L per hour, for a period of 18 hours. The air was comprised of 21.0% oxygen gas.

(a) Determine the limiting reagent for the 'roasting' step. (8 marks)

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If 5.91 tonnes of lead metal was produced from this sample of galena;

(b) Calculate the percentage yield of the overall process for this particular sample of ore. (4 marks)

The waste sulfur dioxide gas produced by the roasting of galena ore can be used to make sulfuric acid via the Contact process. The process of converting sulfur dioxide gas into sulfuric acid can be represented by three chemical equations, one of which is given in the table below.

(c) Write two (2) balanced chemical equations to complete the series of steps, illustrating the conversion of sulfur dioxide to sulfuric acid. (3 marks)

Step 1	
Step 2	
Step 3	$H_2S_2O_7(l) + H_2O(l) \rightarrow 2\ H_2SO_4(l)$

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Question 36 **(19 marks)**

The nickel-iron battery was developed by Thomas Edison in the early 1900s. It is a rechargeable battery that was originally designed for use in electric vehicles. Though not common today, it is still used in some railway vehicles found in the London Underground and the New York City Subway.

The nickel-iron battery contains a nickel oxide-hydroxide electrode and an iron electrode. The relevant half-equations for the **discharge** of the cell are shown below.

Reduction: $NiOOH(s) + H_2O(l) + e^- \rightarrow Ni(OH)_2(s) + OH^-(aq)$

Oxidation: $Fe(s) + 2\ OH^-(aq) \rightarrow Fe(OH)_2(s) + 2e^-$

The nickel-iron battery contains an alkaline electrolyte composed of a mixture of 240.0 g L^{-1} KOH(aq) and 50.0 g L^{-1} LiOH(aq).

(a) Calculate the pH of the electrolyte used in the nickel-iron battery. Assume a 1.00 L volume. (6 marks)

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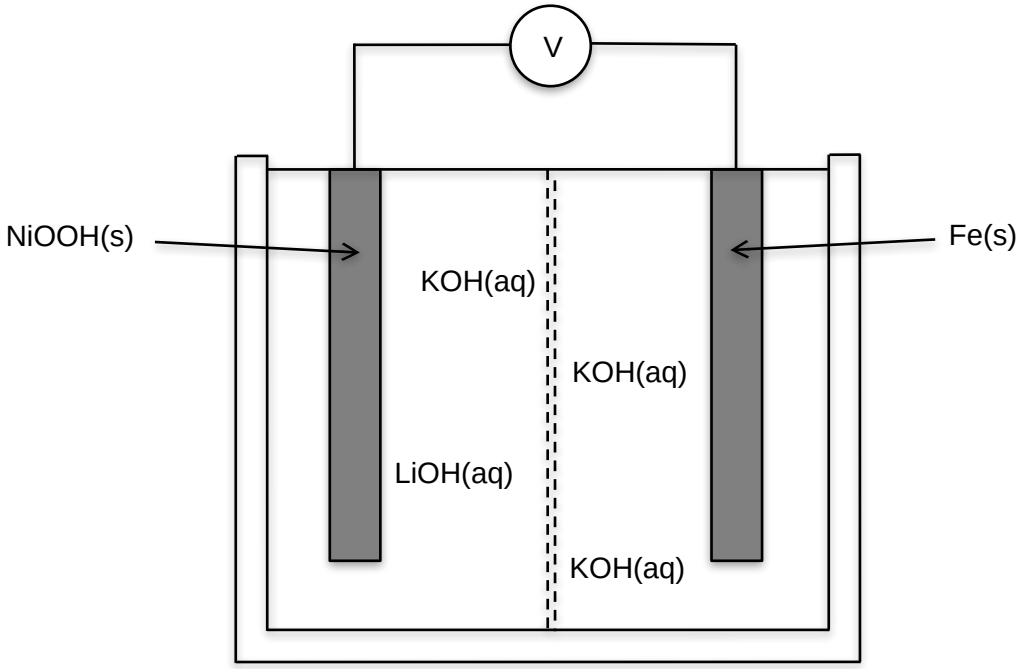
Consider the following diagram of the nickel-iron battery.



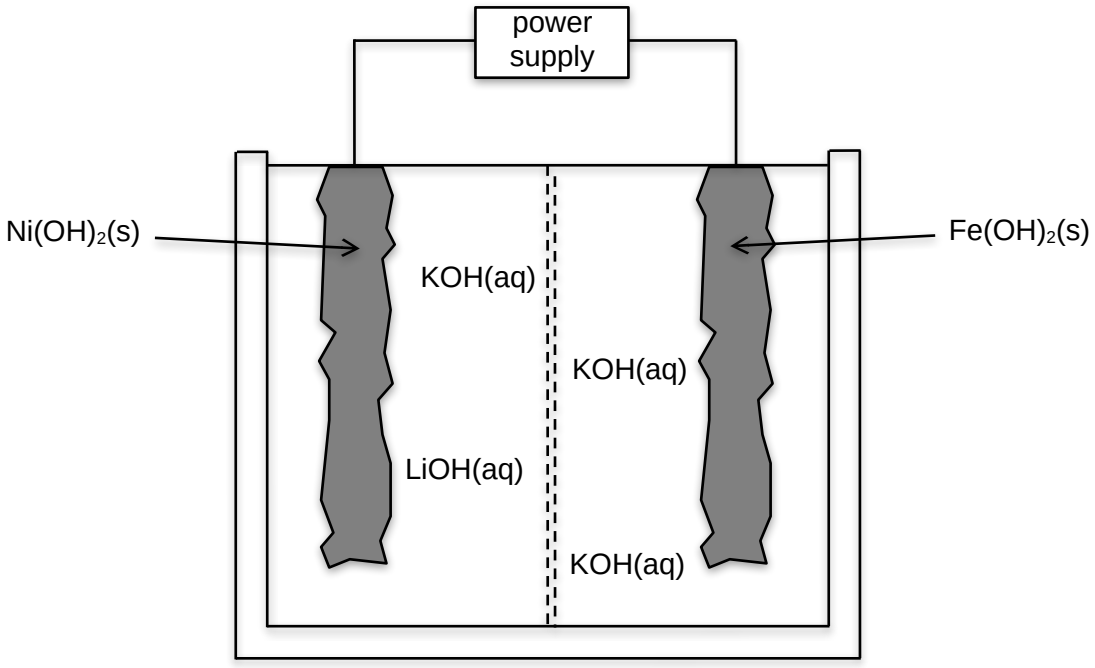
(b) Label the
- anode and cathode
- polarity (sign) of each electrode
- direction of electron flow (3 marks)

As mentioned, the nickel-iron battery is rechargeable. One of the main modern uses of the nickel-iron battery is to store surplus electricity produced by solar panels and wind turbines. The surplus electricity causes the nickel-iron battery to recharge and the energy is then stored as chemical potential energy until required.

(c) Write the overall equation for the recharging process. (2 marks)

See Next Page

Consider the following diagram of the nickel-iron battery, during the **recharging process**.



(d) Label the
- anode and cathode
- polarity (sign) of each electrode
- direction of anion flow (3 marks)

Recent research has investigated the use of nickel-iron batteries as “battolysers”. This name refers to the ability of the cell to function as both a battery (galvanic cell) and an electrolyser (electrolytic cell).

(e) Briefly describe the difference between a ‘galvanic cell’ and an ‘electrolytic cell’ in terms of the redox processes occurring. (2 marks)

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Once the nickel-iron battery is fully recharged, the overcharging process results in electrolysis of the water present in the electrolyte, producing hydrogen and oxygen gases. The half-equations for the production of hydrogen and oxygen gas are shown in the table below.

(f) Complete the table, by naming the electrode (NiOOH or Fe) where each of these 'overcharging' reactions take place. (1 mark)

Half-equation	**Electrode (NiOOH or Fe)**
$2\ H_2O(l)\ +\ 2\ e^-\ \rightarrow\ H_2(g)\ +\ 2\ OH^-(aq)$	
$4\ OH^-(aq)\ \rightarrow\ O_2(g)\ +\ 2\ H_2O(l)\ +\ 4\ e^-$	

The ability of the nickel-iron battery to be discharged, recharged and produce hydrogen and oxygen gas by electrolysis, has resulted in research into its potential use in fuel cell cars.

(g) State **two** differences between fuel cells and primary/secondary cells. (2 marks)

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_____

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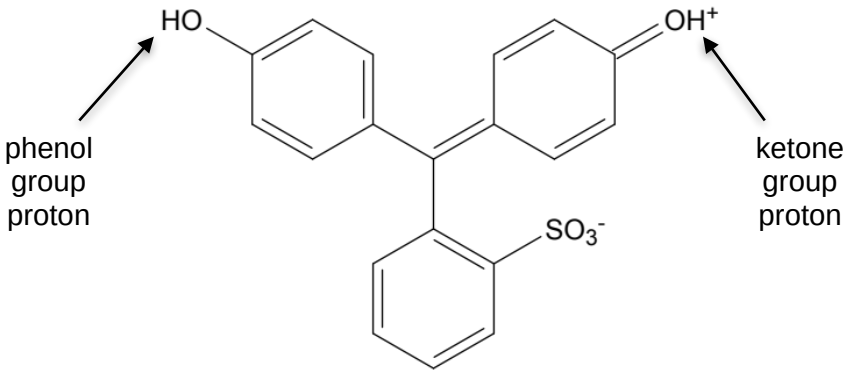
Question 37 **(15 marks)**

Phenol red is a pH indicator commonly used in molecular biology laboratories. When found as a crystalline solid, the molecular formula of phenol red is $C_{19}H_{14}O_5S$ and the structure is shown below.



When solid and in solution below pH 1.2, phenol red exists in zwitterion form, as shown in the diagram above. In this case, the compound appears as red crystals or an orange-red solution.

Once the pH of a solution containing phenol red rises above 1.2, the proton from the ketone group is lost and the colour of the solution becomes yellow.

If the pH is raised higher still, to a level greater than 7.7, a second proton is lost from the phenol group. This causes the colour of the indicator to change again, to a bright pink (fuchsia).

(a) What is a 'zwitterion'? State how the physical appearance of phenol red, as a crystalline solid, is related to its existence in zwitterion form. (2 marks)

(b) Use the information given to complete the table below regarding the three forms of phenol red indicator. (2 marks)

	Molecular formula
pH < 1.2	$C_{19}H_{14}O_5S$
1.2 < pH < 7.7	
pH >7.7	

See Next Page

One of the three forms of phenol red was isolated and analysed as follows.

A 1.232 g sample of the indicator was combusted in pure oxygen and produced 2.908 g of carbon dioxide gas and 0.4385 g of water vapour. A **separate** 2.198 g sample of the indicator was treated to convert all the sulfur to sulfur dioxide gas. This produced 170.0 mL of sulfur dioxide, which was collected at a pressure of 132.0 kPa and temperature of 435.15 K.

(c) Determine the empirical formula of this sample. **Identify which form** of phenol red has been isolated and state the colour it would appear in solution. Full working must be shown. (11 marks)

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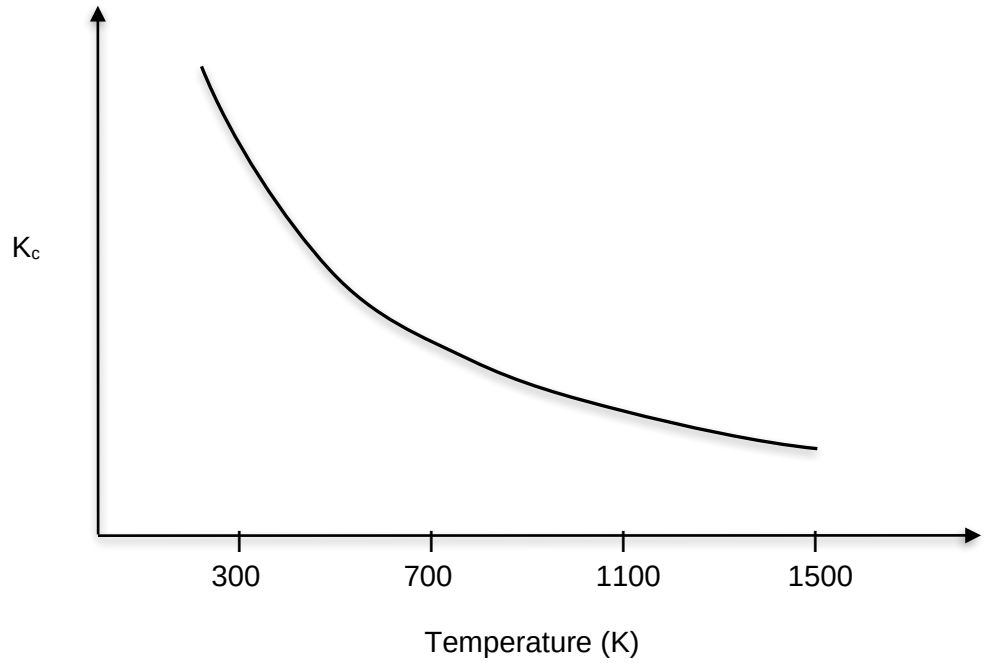
Question 38 **(13 marks)**

The 'water-gas shift reaction' or just 'shift reaction' is a common and extremely important industrial process used to manufacture hydrogen. The hydrogen produced is used in many ways, such as the production of ammonia via the Haber-Bosch process.

The shift reaction is an equilibrium process and can be represented by the following equation.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

The graph below shows the relationship between temperature and K_c for the shift reaction.



(a) Using the information provided in the graph, state whether the forward reaction is exothermic or endothermic as written. Justify your answer. (4 marks)

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On an industrial scale, the shift process utilises two stages. The first is a 'high temperature shift' which is carried out at 310 – 450 ˚C. This is then followed by a 'low temperature shift' which occurs at temperatures of 200 – 250 ˚C.

(b) Briefly explain the main advantage of using a; (4 marks)

(i) high temperature shift.

(ii) low temperature shift.

A pressure of 10 – 20 atmospheres is used in the shift process. This is considered to be **relatively low** in industrial terms.

(c) By referring to reaction rate, equilibrium yield and operating cost, explain why this choice of relatively low pressure is preferred over using a much higher pressure. (5 marks)

End of Exam

Spare answer page

Question number: _____

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Question number: _____