CHEMISTRY

UNITS 3 & 4

Semester 2, 2016

Name: _____

Teacher: ELIAS   HARVEY   POLAND   SMITHIES

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	10	10	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 questions 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 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.

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.

1.   Old fashioned 'smelling salts' are made of ammonium carbonate crystals, which decompose in an endothermic reaction to produce the pungent-smelling ammonia gas. The decomposition equation is shown below.

$$(NH_4)_2CO_3(s) \rightleftharpoons 2\,NH_3(g) + CO_2(g) + H_2O(g)$$
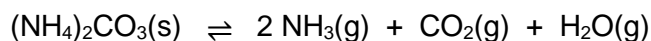
Which of the following statements regarding this equilibrium is **not** correct?

(a)   The reverse reaction rate would increase if the volume of the system was decreased.
(b)   The forward reaction would be favoured by having more finely divided ammonium carbonate crystals.
(c)   The reverse reaction rate would be increased on a warmer day.
(d)   More ammonia would be produced on a warmer day.

2.   The five (5) substances named below were dissolved in water and the pH of each was determined by adding a few drops of universal indicator. For which of these substances is the observed pH **unable** to be explained by the Arrhenius theory of acids and bases?

(i)   Hydrochloric acid, HCl
(ii)   Ethanoic acid, CH_3COOH
(iii)   Ammonia, NH_3
(iv)   Calcium carbonate, $CaCO_3$
(v)   Sodium hydroxide, $NaOH$

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

3.   Consider the incomplete chemical equation shown below.

$$Cr(s) + ClO_3^-(aq) + H^+(aq) \rightarrow Cr^{3+}(aq) + HClO_2(aq) + H_2O(l)$$
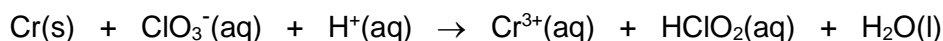
When this redox reaction is completed and balanced correctly (using whole numbers), the coefficient in front of $H^+(aq)$ will be;

(a)   1
(b)   3
(c)   6
(d)   9

SEE NEXT PAGE

Questions 4 and 5 refer to the information below.

Consider the following five (5) organic compounds.

| (i)	(ii)	(iii)	(iv)	(v)
CH_3CH_3	CH_3COOH	CH_3CHO	CH_3CONH_2	CH_3CH_2OH

4.   Which of the following lists contain compounds that **all** have the ability to form hydrogen bonds?

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

5.   Which of the following statements regarding the five compounds is **not** correct?

      (a) CH_3CONH_2 is water-soluble.
      (b) CH_3COOH is miscible with CH_3CH_2OH.
      (c) CH_3CH_3 has the highest boiling point.
      (d) CH_3CHO is able to form dipole-dipole forces.

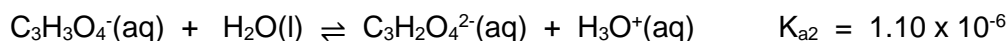6.   The equation below shows the key step involved in the Contact process.

$$2\ SO_2(g)\ +\ O_2(g)\ \rightleftharpoons\ 2\ SO_3(g) \qquad \Delta H = -198\ kJ\ mol^{-1}$$
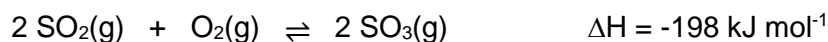
      Which of the following sets of conditions would increase both the rate and yield of $SO_3(g)$?

	Increased rate	**Increased yield**
(a)	High temperature	Low pressure
(b)	High pressure	Low temperature
(c)	Low temperature	High pressure
(d)	Low pressure	High temperature

7.   Considering only the information given below, which reaction is **most likely** to proceed quickly in the reverse direction?

	ΔH(forward) (kJ mol^{-1})	**E_a(forward) (kJ mol L^{-1})**
(a)	+850	875
(b)	+120	645
(c)	-95	730
(d)	-545	90

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8. Consider the information below, relating to malonic acid ($C_3H_4O_4$), which is a weak, organic, diprotic acid.

$$C_3H_4O_4(aq) + H_2O(l) \rightleftharpoons C_3H_3O_4^-(aq) + H_3O^+(aq) \qquad K_{a1} = 1.48 \times 10^{-3}$$

$$C_3H_3O_4^-(aq) + H_2O(l) \rightleftharpoons C_3H_2O_4^{2-}(aq) + H_3O^+(aq) \qquad K_{a2} = 1.10 \times 10^{-6}$$
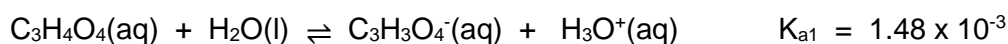
Which of the following statements is **true** regarding **diprotic** acids?

(a) They have only 2 hydrogen atoms per molecule.
(b) They have a lower pH than monoprotic acids of the same concentration.
(c) They are all weak acids.
(d) The value of K_{a1} is always greater than the value of K_{a2}.

9. Rank the following substances in order of increasing **nitrogen** oxidation number (i.e. from species with nitrogen in lowest oxidation state to highest oxidation state).

$$NO_3^- \qquad N_2O \qquad HNO_2 \qquad NH_4^+ \qquad N_2$$

(a) NH_4^+ < N_2 < N_2O < HNO_2 < NO_3^-
(b) NO_3^- < N_2O < HNO_2 < N_2 < NH_4^+
(c) NH_4^+ < HNO_2 < N_2 < NO_3^- < N_2O
(d) N_2 < NH_4^+ < NO_3^- < N_2O < HNO_2

10. For which of the following organic molecules does the structural diagram match the correct IUPAC name given?

(i)	(ii)	(iii)
2-methylpentan-4-one	1,2,3-trichloropropene	aminoethanal

(a) (i) only
(b) (i) and (ii) only
(c) (ii) only
(d) (ii) and (iii) only

11. Consider 0.25 mol L^{-1} aqueous solutions of the following salts;

$$NaHSO_4 \qquad K_3PO_4 \qquad Ca(NO_3)_2$$
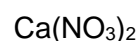
Rank these three (3) solutions in order of decreasing pH (i.e. highest to lowest).

(a) K_3PO_4 > $Ca(NO_3)_2$ > $NaHSO_4$
(b) $Ca(NO_3)_2$ > $NaHSO_4$ > K_3PO_4
(c) $NaHSO_4$ > $Ca(NO_3)_2$ > K_3PO_4
(d) $NaHSO_4$ > K_3PO_4 > $Ca(NO_3)_2$

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Questions 12, 13 and 14 relate to the equilibrium system below.

At temperatures greater than 1000 °C, gaseous octasulfur (S_8) can undergo an endothermic decomposition to form gaseous disulfur (S_2) as shown in the equation below.

$$S_8(g) \rightleftharpoons 4 S_2(g)$$
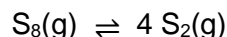
Some $S_8(g)$ was placed in an empty rigid container and allowed to establish equilibrium at 1052 °C. At this temperature the value of K for this equilibrium system is 324.

12.   Once the system has established equilibrium, which of the following statements are **correct**?

       (i)   The total pressure inside the container will be constant.
       (ii)   The pressure inside the container will be higher than initially.
       (iii)   The colour of the gaseous mixture will be constant.
       (iv)   The rates of the forward and reverse reactions will be equal.
       (v)   The concentration of S_8 and S_2 will be equal.

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

13.   Which of the following statements regarding K for this equilibrium system is **correct**?

(a)   At equilibrium there is a higher concentration of $S_8(g)$ present than $S_2(g)$.
(b)   If the temperature of the system was decreased the value of K would increase.
(c)   The equilibrium constant expression can be written $K = \dfrac{[S_8]}{[S_2]}$
(d)   The equilibrium constant expression can be written $K = \dfrac{[S_2]^4}{[S_8]}$

14.   Once the system had established equilibrium, various changes were imposed on the system and the effects of these changes were predicted using Le Chatelier's principle. Which of the following is **not** correct (i.e. the predicted effect on the equilibrium position does **not** match the imposed change stated)?

	Imposed change	Effect on equilibrium position
(a)	Pressure increase	←
(b)	Removal of S_2	←
(c)	Temperature increase	→
(d)	Addition of S_8	→

Questions 15 and 16 refer to the information below.

There are several different types of fuel cells, which mostly differ in terms of the fuel being utilised. One of the most common fuel cells is the hydrogen / oxygen fuel cell. A partially completed sketch of an hydrogen / oxygen fuel cell operating with an acid electrolyte is shown in the diagram below. The only overall chemical product of the hydrogen / oxygen fuel cell is water.
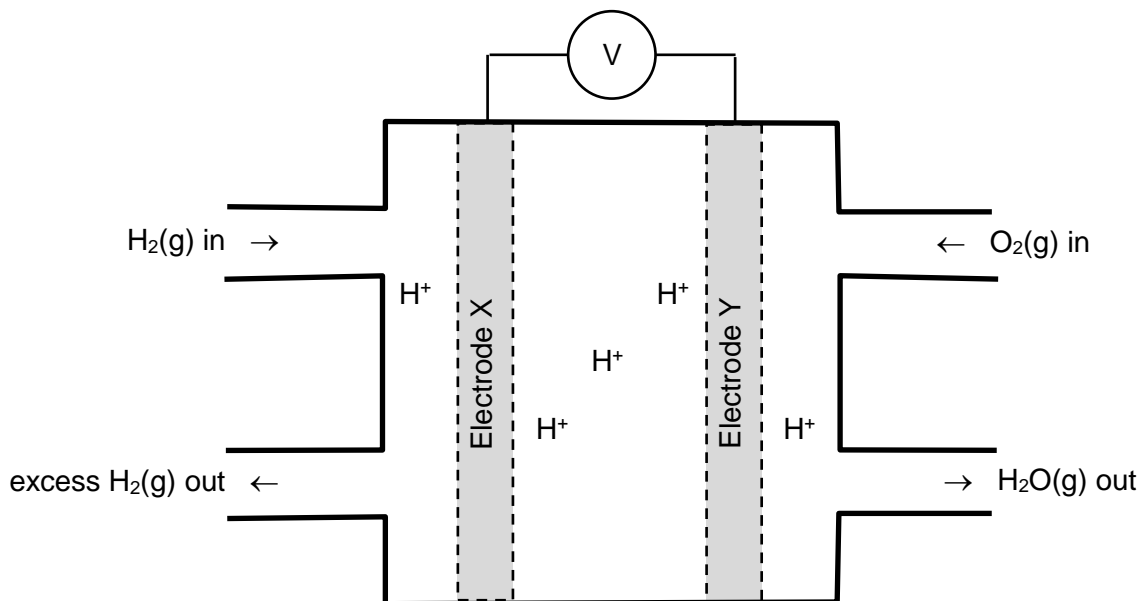
15.   Which of the following statements are **correct**, regarding **fuel cells in general**?

         (i)   Fuel cells involve a redox reaction.
         (ii)   Fuel cells require continuous input of reactants to operate.
         (iii)   Fuel cells are a type of galvanic cell.
         (iv)   Fuel cells are a type of secondary cell.
         (v)   Fuel cells do not produce any sources of pollution.

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

16.   Which of the following statements is **correct,** regarding the **hydrogen/oxygen fuel cell** shown in the diagram above?

    (a)   Reduction occurs at X.
    (b)   Electrons move from Y to X.
    (c)   Cations move towards Y.
    (d)   The EMF of this cell under standard conditions is 1.15 volts.

17. The partially completed equations below show the various chemical reactions involved in the synthesis of ethyl ethanoate.

Equation 1: CH_2CH_2 + **A** $\overset{D}{\rightleftharpoons}$ CH_3CH_2OH

Equation 2: $3\ CH_3CH_2OH$ + **B** $Cr_2O_7^{2-}$ + $16\ H^+$ → 3 **C** + $4\ Cr^{3+}$ + $11\ H_2O$

Equation 3:   **C** + CH_3CH_2OH $\overset{D}{\rightleftharpoons}$ $CH_3COOCH_2CH_3$ + **A**
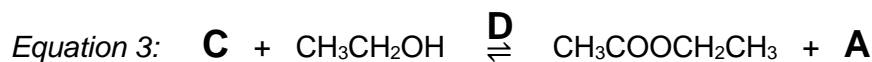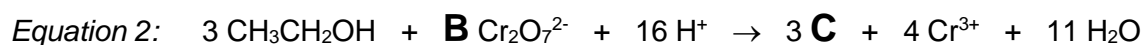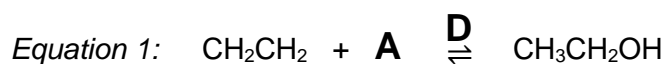
Which of the following correctly identifies the unknowns A, B, C & D?

	A	**B**	**C**	**D**
(a)	H_2O	2	CH_3COOH	H^+
(b)	H_2O	1	CH_3COOH	catalyst
(c)	H_2O	2	CH_3CHO	H^+
(d)	H^+	4	CH_3CHO	H_2O

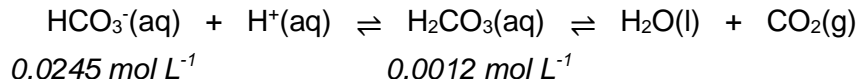18. The hydrogencarbonate / carbonic acid buffering system in blood helps to maintain our blood at a pH of 7.4. Carbon dioxide (CO_2) can be exhaled by the lungs and hydrogen ions (H^+) can be excreted by the kidneys to help maintain the delicate balance of our blood chemistry. The equations for this buffer system are shown below, along with the concentration of the two main buffer components.

$$HCO_3^-(aq) + H^+(aq) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H_2O(l) + CO_2(g)$$
$$0.0245\ mol\ L^{-1} \qquad\qquad 0.0012\ mol\ L^{-1}$$

Which of the following statements regarding this buffer system is **not** correct?

(a) H_2CO_3/HCO_3^- are a conjugate acid-base pair.
(b)   The buffering capacity is greater for a rise in H^+ concentration than for a fall in H^+ concentration.
(c)   A rise in H^+ concentration in the blood would shift the equilibrium to the right.
(d)   Increased breathing would decrease the pH of blood.

19. Name the polymer described in the paragraph below.
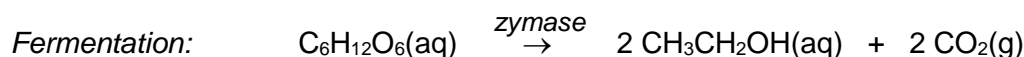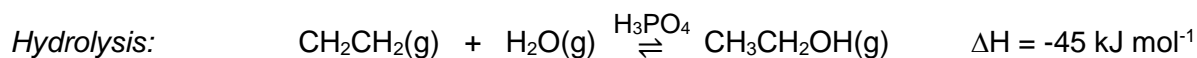
"This addition polymer is one of the most commonly used plastics and can be easily recycled. Depending on the manufacturing conditions chosen, it can be used to make plastic milk containers, cling film, toys, shopping bags or even form part of knee and hip replacement joints."

(a)   Polyethene
(b)   Polytetrafluoroethene
(c)   Nylon
(d)   Polyethylene terephthalate

Questions 20 and 21 refer to the following information.

There are two main methods for the industrial production of ethanol; fermentation of glucose and hydrolysis of ethene. The chemical equations for each process are shown below.

Hydrolysis: $\qquad$ $CH_2CH_2(g) + H_2O(g) \overset{H_3PO_4}{\rightleftharpoons} CH_3CH_2OH(g)$ $\qquad$ $\Delta H = -45$ kJ mol^{-1}

Fermentation: $\qquad$ $C_6H_{12}O_6(aq) \overset{zymase}{\rightarrow} 2\ CH_3CH_2OH(aq) + 2\ CO_2(g)$

20.   Which of the following statements is **not** correct, regarding the hydrolysis of ethene to produce ethanol?

(a)   An increased pressure increases the forward reaction rate.
(b)   An increased pressure increases the ethanol yield.
(c)   An increased temperature increases the forward reaction rate.
(d)   The H_3PO_4 catalyst increases the ethanol yield.

21.   Which of the following statements is **not** correct, regarding the fermentation method of ethanol production?

(a)   It is performed at a lower temperature than the hydrolysis method.
(b)   It is performed at a lower pressure than the hydrolysis method.
(c)   It is a less sustainable method than the hydrolysis method.
(d)   The *zymase* enzyme provides an alternative reaction pathway with a lower activation energy.

22.   The equation for the autoionisation of water is shown below, along with two values for K_w at two corresponding temperatures.

$$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

$$K_w = 1.0 \times 10^{-14} \text{ at } 25\ ^\circ C$$
$$K_w = 2.9 \times 10^{-14} \text{ at } 40\ ^\circ C$$

Considering the information provided, which of the following statements is **not** correct?

(a)   The autoionisation of water is an endothermic process.
(b)   The concentration of H_3O^+ in water at 40 °C is higher than water at 25 °C.
(c)   The pH of water at 40 °C is lower than water at 25 °C.
(d)   The water at 40 °C is slightly more acidic than water at 25 °C.

23.   Which of the following halogen displacement reactions would **not** occur under standard conditions?

(a) $Cl_2(aq) + 2\ Br^-(aq) \rightarrow 2\ Cl^-(aq) + Br_2(aq)$
(b) $I_2(aq) + 2\ Br^-(aq) \rightarrow 2\ I^-(aq) + Br_2(aq)$
(c) $Cl_2(aq) + 2\ I^-(aq) \rightarrow 2\ Cl^-(aq) + I_2(aq)$
(d) $Br_2(aq) + 2\ I^-(aq) \rightarrow 2\ Br^-(aq) + I_2(aq)$

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24.   A sample of ethanoic acid was placed in a beaker and several drops of universal indicator
       were added. To the beaker, aqueous sodium carbonate was added dropwise until it was in
       excess. Which of the following statements is **not** correct regarding the reaction that would
       have taken place?

       (a)   A colourless, odourless gas would have been produced.
       (b)   The colour of the solution would have changed from pink to green to blue.
       (c)   A neutralisation reaction would have taken place.
       (d)   A solid white salt would have been produced.

25.   Consider the section of polymer shown below.
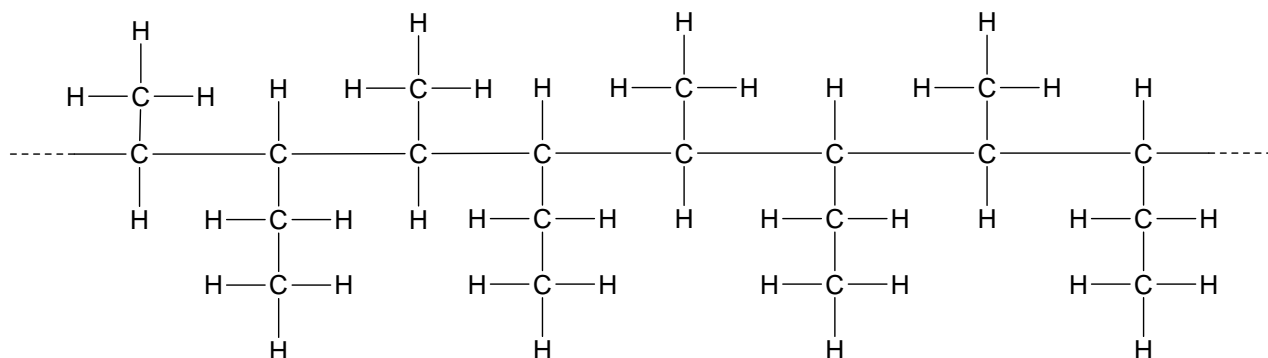
       Which of the following monomers could be used to produce this polymer?

       (a) CH_3

                  H_2C-CH_2

                     H_2C-CH_3

       (b)   H   H

                  $H_3C-C=C-CH_2-CH_3$

       (c) H_3C

                  $H_2C=C-CH_2-CH_3$

       (d) H_3C

                  $H_3C-CH-CH_2$

                           CH_3

                              End of Section One

                              SEE NEXT PAGE

Name: _____   Teacher: _____

Section Two: Short answer   35%   (70 marks)

This section has **10** 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.

Suggested working time: 60 minutes.

Question 26   (8 marks)

Tuftsin is a tetrapeptide (a molecule consisting of four amino acid residues) which is produced by the spleen. It has been found that people with low levels of tuftsin in their bodies are susceptible to repeated frequent infections of the skin, lymph nodes and lungs. Low tuftsin levels can be inherited genetically or can be the result of a spleen operation. The tuftsin tetrapeptide molecule is shown below.
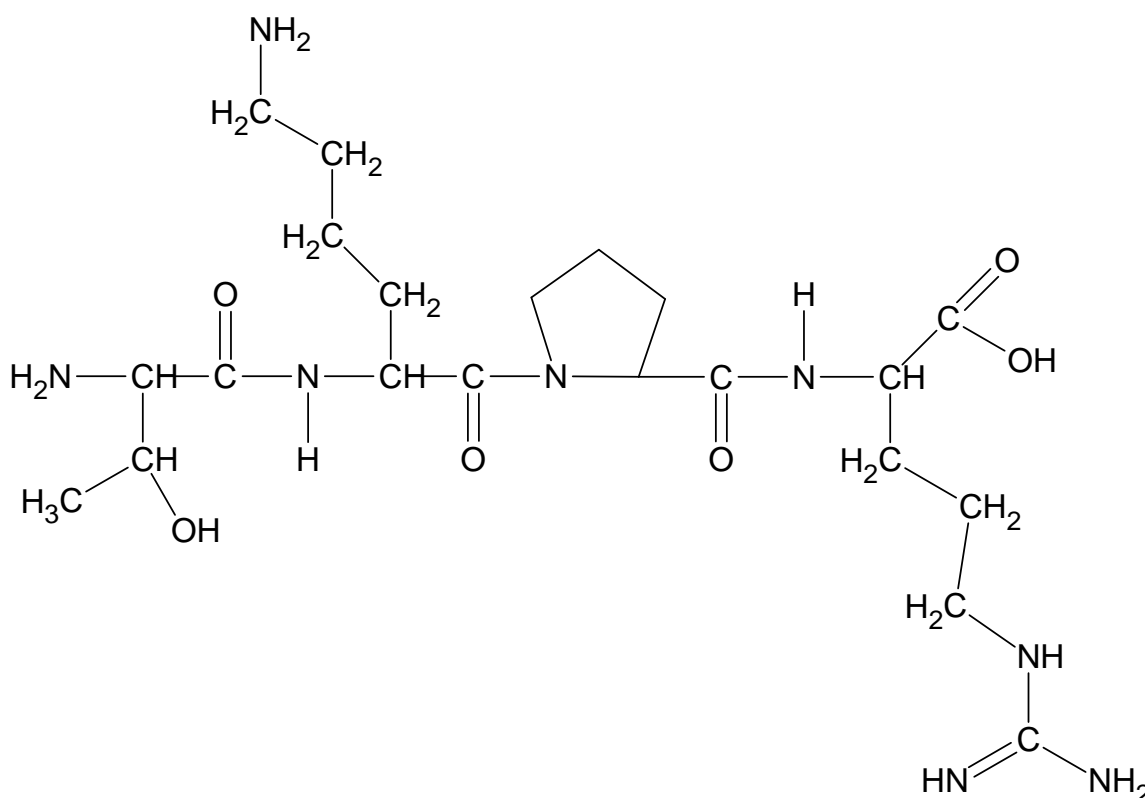
(a)   On the diagram above, circle the peptide bonds and then complete the primary sequence of tuftsin below using the standard three letter abbreviations.   (3 marks)

thr – lys – _____ – _____

One medical study has shown that some people have a genetic mutation which causes the lysine residue in tuftsin to be replaced with a glutamic acid residue instead.

(b)   Draw a diagram of glutamic acid in zwitterion form and use this example to explain what a zwitterion is.   (2 marks)

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In the mutated form of tuftsin, the primary sequence of the tetrapeptide has been changed, altering its function.

(c)   In general terms, explain how alteration of the primary sequence of a protein can affect its secondary and tertiary structures.   (3 marks)

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Question 27   **(8 marks)**

Consider the equation for the following reversible chemical system. Gaseous hydrogen and bromine were injected into an empty flask and allowed to establish equilibrium at 25 °C.

$$H_2(g) \ + \ Br_2(g) \ \rightleftharpoons \ 2 \, HBr(g) \qquad\qquad \Delta H = -104 \text{ kJ mol}^{-1}$$
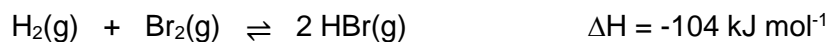
The activation energy for this reaction is 188 kJ mol $^{-1}$. The value of K_c for this reaction at 25 °C is 2.0×10^{19}.

(a)   Does this question refer to an open or closed system? Explain.   (2 marks)

_____

_____

_____

(b)   What information does the value of K_c provide about the;   (2 marks)

     (i)   equilibrium position?

_____

_____

     (ii)   rate of reaction?

_____

_____

(c)   Draw an energy profile diagram for this reaction. Label the activation energy and the enthalpy change.   (4 marks)

Potential energy (kJ)

Progress of reaction

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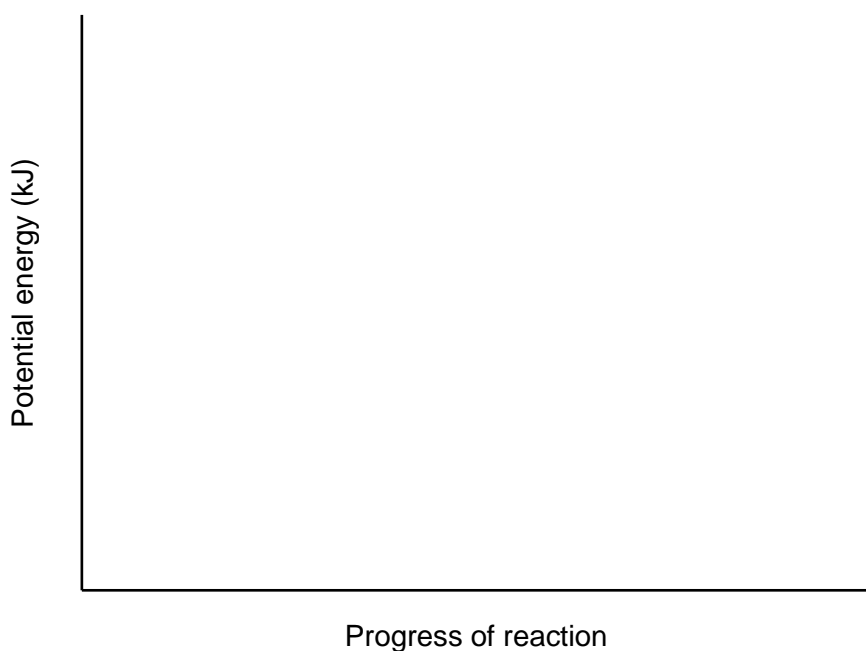
Question 28   **(7 marks)**

Bromocresol green is an indicator that can be used in biological laboratories when growing microorganisms as well as for titrations or as a tracking dye. It displays two colours, yellow and blue, as shown in the diagram below.
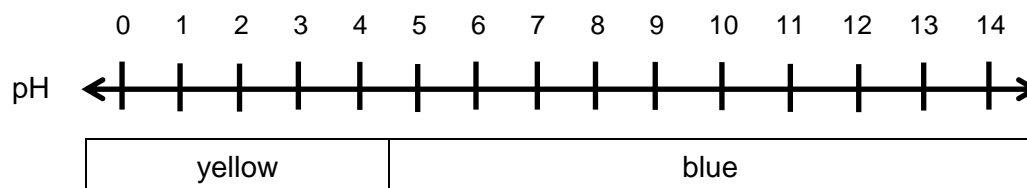
(a)   What types of substances are acid-base indicators?   (2 marks)

_____

_____

_____

_____

_____

(b)   What colour would the following aqueous solutions turn, if a few drops of bromocresol green was added to each? Use a chemical equation to support your answer where appropriate.   (3 marks)

Solution	Colour	Chemical equation
$Mg(NO_3)_2$(aq)		
Na_2SO_3(aq)		

A standardised solution of hydrochloric acid, HCl(aq), was being used in a titration with a sodium hydrogencarbonate solution, $NaHCO_3$(aq), of unknown concentration.

(c)   Would bromocresol green be an appropriate indicator for this titration? Explain your answer.   (2 marks)

_____

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Name: _____ Teacher: _____

Question 29 **(6 marks)**

Tin is a metallic element located in Group 14 of the periodic table. It is used to make many different alloys such as bronze and solder, as well as finding application in the plating of steel to produce 'tin cans' for storage.

A chemistry student had 1.0 mol L^{-1} solutions of the following four substances;

$Ni(NO_3)_2$ $Zn(NO_3)_2$ $Pb(NO_3)_2$ $Mg(NO_3)_2$
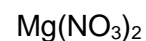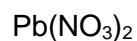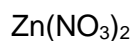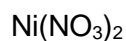
(a)   Which of these solutions could **not** be stored in a tin container? Explain your answer using a relevant chemical equation.   (3 marks)

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When tin metal is placed in an acidified solution containing the weak acid hydrogen chromate ($HCrO_4^-$) a deep green solution containing chromium(III) ions is formed, and the tin metal dissolves producing tin(II) ions.

(b)   Write the oxidation and reduction half-equations and the overall redox equation for this reaction.   (3 marks)

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

Question 30   **(7 marks)**

Consider the various organic molecules shown below.

(a)   Circle and name the three (3) remaining functional groups on the molecule below. (One
       functional group has been circled for you.)   (3 marks)

**benzene
ring**
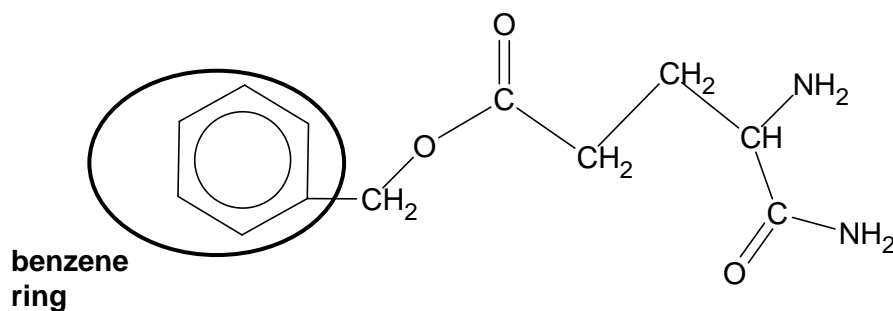
(b)   Give the IUPAC names for the following organic molecules.   (2 marks)

Name:	Name:

(c)   If the two substances shown in part (b) were mixed together and warmed in the presence of
       sulfuric acid;   (2 marks)

       (i)   name the type of reaction that would occur.

       _____

       (ii)   draw the structure of the organic product that would form.

Question 31 **(7 marks)**

Ammonium carbamate can decompose in a reversible, endothermic reaction, according to the chemical equation shown below.

$$NH_4COONH_2(s) \ \rightleftharpoons \ 2\,NH_3(g) \ + \ CO_2(g)$$
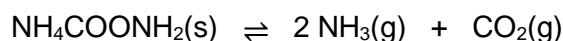
(a)   If the total volume of the system was decreased, state the effect this would have on the equilibrium position and note an observation. (2 marks)

equilibrium position: _____

_____

observation: _____

_____

(b)   If the temperature of the system was decreased, explain the effect this would have on the equilibrium in terms of reaction rates. (3 marks)

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(c)   One of the products of this decomposition reaction is carbon dioxide gas. Write two (2) chemical equations that illustrate how increasing atmospheric CO_2 levels may contribute to ocean acidification. (2 marks)

| 1. |
| 2. |

Question 32   **(6 marks)**

Hydrofluoric acid, HF(aq), is a colourless, highly corrosive solution, used in the manufacture of many pharmaceuticals. Hydrofluoric acid has a K_a value of 6.76×10^{-4}.

(a)   Write an equilibrium constant (K_a) expression for the ionisation of HF in water and explain what information the value of K_a provides.   (2 marks)

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A student was given 0.500 L of a 0.250 mol L^{-1} hydrofluoric acid solution and instructed to produce a buffer.

(b)   What substance could the student add to the HF(aq) to produce a buffer? Explain your answer.   (2 marks)

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(c)   Write a chemical equation for the buffer system that would be formed and label the conjugate acid-base pairs.   (2 marks)

_____

Question 33   **(5 marks)**

Consider the electrochemical cell shown below.
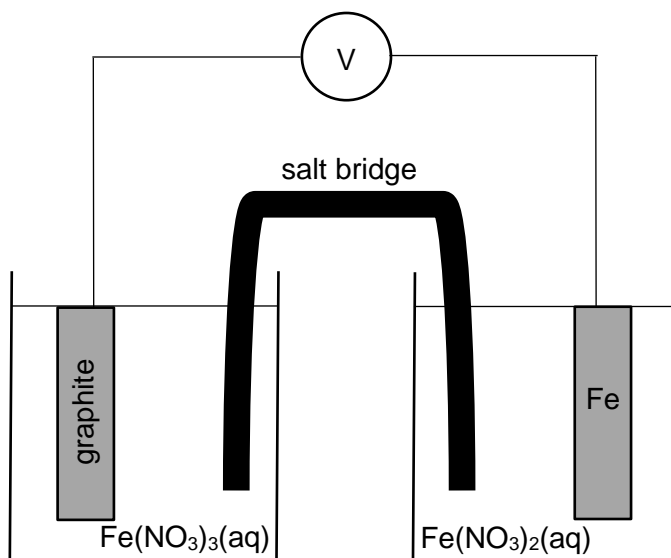
(a)   Determine the half-equations occurring at each electrode.   (2 marks)

Cathode	
Anode	

(b)   Calculate the EMF of this cell under standard conditions.   (1 mark)

_____

(c)   Note an observation for each electrode.   (2 marks)

Cathode	
Anode	

Question 34   **(9 marks)**

But-2-ene is produced from crude oil and its main use is in the production of petrol.

(a)   Explain why but-2-ene exhibits *cis-trans* (geometric) isomerism while but-1-ene does not.

(3 marks)

but-1-ene   *but-2-ene*

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A chemistry fact sheet about but-2-ene stated, *"But-2-ene is often used to produce the solvent butanone via hydration to butan-2-ol followed by oxidation"*.

(b)   Elaborate on this statement, by giving a brief description of the reaction processes involved and using chemical equations to illustrate the reaction sequence described.   (6 marks)

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Question 35   **(7 marks)**

The structure of a detergent molecule called 'branched dodecylbenzene sulfonate' is shown below.

(a)   Note one similarity and one difference between the structure of this detergent molecule and
        a soap molecule.   (2 marks)

Similarity	
Difference	

(b)   Describe the cleaning action of detergents. Include in your answer a discussion of the
        advantage detergents have over soaps when used in hard water.   (5 marks)

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End of Section Two

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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 36   (17 marks)

Hydrogen sulfide (H_2S) is a poisonous, colourless gas with the distinctive odour of rotten eggs. It is found in some types of rock salt, as well as volcanic gas and natural gas. Some sources of spring water with high hydrogen sulfide levels are used as medicinal baths, and there is evidence to suggest that H_2S may have some anti-ageing properties.

When hydrogen sulfide gas dissolves in water, it ionises as shown in the equations below to produce the following equilibria, which is comprised of the three sulfur-containing species (H_2S, HS^- and S^{2-}).

$$① \qquad H_2S(aq) + H_2O(l) \rightleftharpoons HS^-(aq) + H_3O^+(aq)$$
$$② \qquad HS^-(aq) + H_2O(l) \rightleftharpoons S^{2-}(aq) + H_3O^+(aq)$$
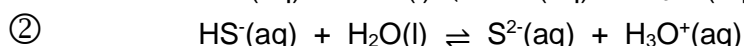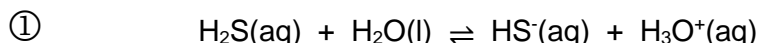
Scientists noted that the percent of each sulfur-containing species (H_2S / HS^- / S^{2-}) present in a given aqueous sample was dependent upon the pH of the solution. An investigation was conducted to examine how the concentrations of each of these sulfur-containing species changed with respect to pH. The results of the investigation are displayed in the graph below.

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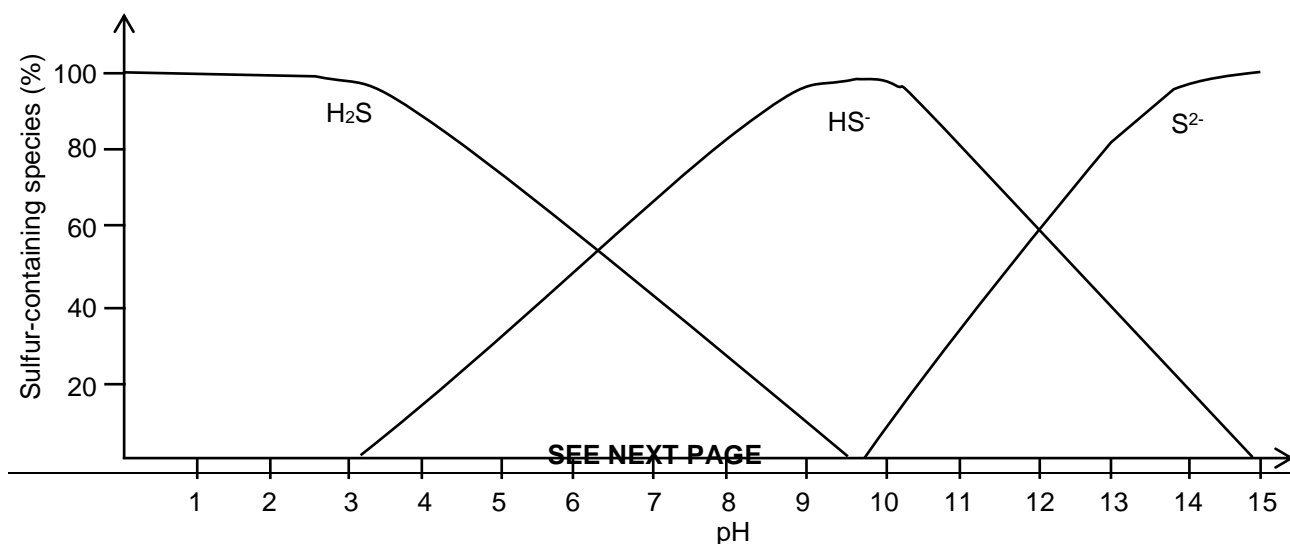
(a) State each of the variables for the investigation described above.   (3 marks)

Independent	
Dependent	
Controlled	

(b) Using your knowledge of collision theory and chemical equilibrium, explain the results displayed in this graph.   (4 marks)

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Hydrogen sulfide is often found in sources of drinking water, as it is produced by the decomposition of organic matter. It can cause the water to have an unpleasant smell and taste when present in as little as 0.05 mg L^{-1} concentrations. Hydrogen sulfide can be removed from water sources by the addition of chlorine gas, which reacts according to the equation below.

$$H_2S(aq) + 4\,Cl_2(g) + 4\,H_2O(l) \rightarrow 10\,H^+(aq) + SO_4^{2-}(aq) + 8\,Cl^-(aq)$$
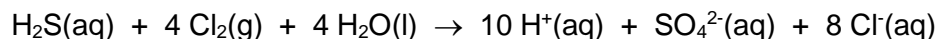
(c) Use oxidation numbers to demonstrate that this is a redox reaction. State which substance is oxidised and reduced in this process.   (2 marks)

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A 2000 L tank of water contaminated with hydrogen sulfide at a concentration of 0.173 mg L^{-1} was to be treated with chlorine gas. If the chlorine was stored under a pressure of 395 kPa and at a temperature of 20.0 °C;

(d)   Calculate the volume of chlorine gas that would be required to remove all the hydrogen sulfide from the water. (You may disregard the presence of other sulfur-containing species and assume all the chlorine gas added will dissolve in the water).   (5 marks)

(e)   Calculate the final pH of the water in the tank after the chlorination process was complete and all the hydrogen sulfide had been removed. (You may disregard the presence of other sulfur-containing species and assume that the original pH of the water was 7).   (3 marks)

Question 37   **(15 marks)**

Ammonia (NH_3) is produced industrially by the Haber process. Ammonia is an important chemical, particularly in the agricultural industry, where it is used to produce many different types of fertilisers. The Haber process involves the reaction between gaseous nitrogen and hydrogen to produce ammonia. The nitrogen gas is extracted from air, whilst the hydrogen gas is produced via the 'shift' and 'steam reforming' processes, using methane from natural gas.

The two equations below can be used to summarise the chemical processes involved in industrial ammonia production. Step 1 represents the overall process that produces hydrogen gas from methane, and Step 2 shows the subsequent reaction with nitrogen gas to produce ammonia.

$$① \qquad CH_4(g) + 2 H_2O(g) \rightleftharpoons 4 H_2(g) + CO_2(g)$$
$$② \qquad N_2(g) + 3 H_2(g) \rightleftharpoons 2 NH_3(g)$$
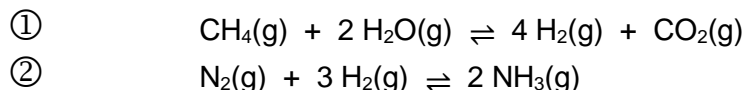
The conditions for Step 2 are optimised for both rate and yield of ammonia production. A pressure of between 100-350 atm is maintained and a moderate temperature of 350-550 °C is used, in conjunction with an Fe_3O_4 catalyst. Using these conditions, a yield of 20-30% is obtained for each reaction cycle, but the overall yield is much closer to 100% due to the continuous cycling of unreacted materials back through the chamber.

If 311 tonnes of nitrogen gas and 71.0 tonnes of hydrogen gas are injected into a reaction chamber with a 25 000 kL capacity;

(a)   Calculate the initial pressure inside the reaction chamber if the temperature was maintained at 450 °C.   (4 marks)

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(b)   Determine the limiting reagent.   (2 marks)

After one reaction cycle, the yield of ammonia was determined to be 25.7%. This ammonia was removed from the chamber, liquefied and pumped into cylinders that each hold 400 kg of ammonia. These cylinders are used to store or transport the ammonia.

(c)   How many cylinders would you need to store the ammonia produced from one reaction
        cycle?   (4 marks)

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If 150 tonnes of methane gas was used to produce the 71.0 tonnes of hydrogen used in this reaction;

(d)   Calculate the yield of Step 1.   (3 marks)

(e)   Give two (2) reasons that may have contributed to the yield of Step 1 being lower than 100%.   (2 marks)

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Question 38   **(20 marks)**

Biodiesel is commonly manufactured by a transesterification reaction between oil and methanol. There are many different types of oils that can be used in this process, providing great scope for the range of sources from which biodiesel can be manufactured.

(a)   Explain why biodiesel is considered a more sustainable 'green' alternative to traditional fuels such as petrol.   (2 marks)

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An example of the biodiesel-producing transesterification reaction is shown below using the oil *triolein*, which is one of the triglycerides commonly found in olive oil.

$$H_2C - O - \overset{\displaystyle O}{\overset{\|}{C}} - (CH_2)_7CH=CH(CH_2)_7CH_3$$

$$HC - O - \overset{\displaystyle O}{\overset{\|}{C}} - (CH_2)_7CH=CH(CH_2)_7CH_3 \quad + \quad 3\ CH_3OH$$

$$H_2C - O - \overset{\displaystyle O}{\overset{\|}{C}} - (CH_2)_7CH=CH(CH_2)_7CH_3$$

triolein   *methanol*

NaOH

3		+	
biodiesel		*glycerol*	

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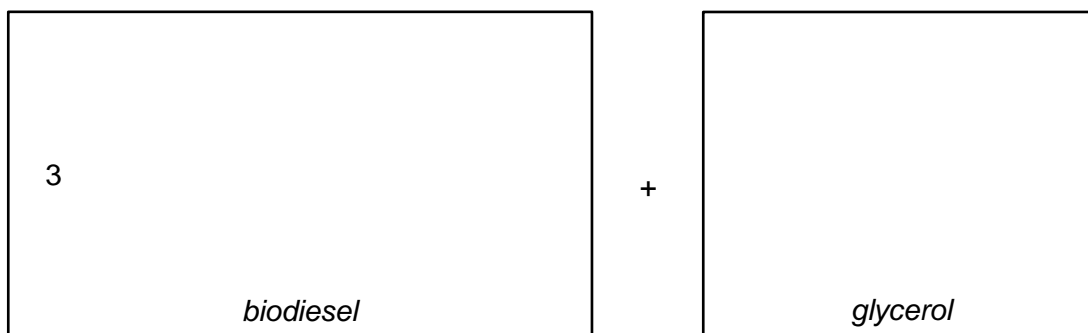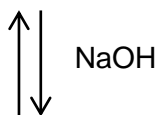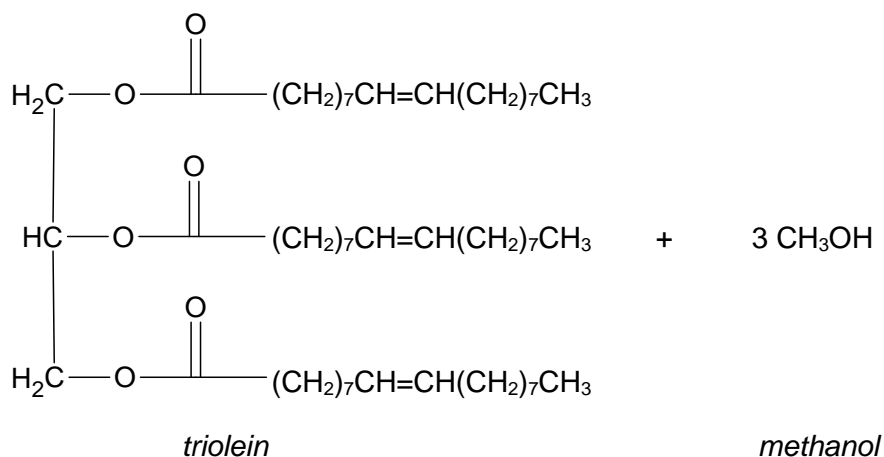
(b)   Complete the reaction above by filling in the boxes.   (2 marks)
Due to the slow rate of the transesterification reaction, a sodium hydroxide (NaOH) catalyst is used
and a temperature of around 60 °C is maintained.

(c)   Explain how each of these factors increases the rate of reaction.   (4 marks)

NaOH catalyst	
Temperature of 60 °C	

During the manufacture of biodiesel, an unwanted side-reaction occurs where soap is produced.
This is problematic as it reduces the purity of the biodiesel product and requires further refining to
be performed before the biodiesel can be used or sold.

(d)   Explain how this soap-producing reaction can occur. (Chemical equations are **not** required
         in your answer).   (2 marks)

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To ensure that the levels of soap in commercial biodiesel are not too high, a 'soap test titration' is
performed once a batch of biodiesel is produced. An acceptable level of purity requires the soap
content of the biodiesel to be no higher than 41 ppm (parts per million).

To perform this titration, a sample of biodiesel is dissolved in pure isopropyl alcohol. Bromophenol
blue indicator is added and a blue colour should be observed. The biodiesel is then titrated against
a standard solution of hydrochloric acid (HCl) until a colour change from blue to yellow is observed.

The titration equation is given below.

$$C_{17}H_{33}COONa(aq) \;+\; HCl(aq) \;\rightarrow\; C_{17}H_{33}COOH(aq) \;+\; NaCl(aq)$$

         soap present in biodiesel

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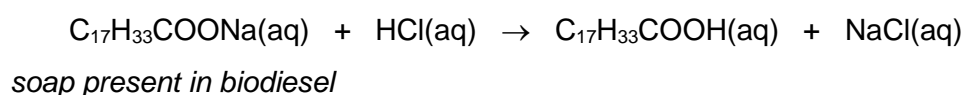
A 60.00 mL sample of a particular batch of biodiesel was taken and made up to 150.0 mL with pure isopropyl alcohol. 35.00 mL aliquots were then titrated against a standard 1.65×10^{-4} mol L^{-1} hydrochloric acid solution, requiring an average of 8.83 mL for equivalence. If the density of the biodiesel is 0.833 g mL^{-1};

(e)   Determine the soap content of this biodiesel sample in parts per million (ppm) and state whether or not the soap content is at an acceptable level for sale.   (6 marks)

Current research is focussing on alternate catalysts for biodiesel manufacture, and one of the most promising candidates is the enzyme *lipase*. When *lipase* is used to catalyse the transesterification reaction, this prevents the alternate soap-producing pathway from occurring.

(f)   Describe what an enzyme is and explain why enzymes are able to minimise the occurrence of unwanted side reactions.   (4 marks)

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Question 39   **(15 marks)**

'Nylon 4/6' is a polymer which can be obtained as a fibre, film, rod or sheet. It has wide ranging applications owing to its high heat and chemical resistance in comparison with other nylons. It is most often used for electrical and electronic components, in particular those that must withstand high temperatures for a long period of time.

A segment of nylon 4/6 is shown in the diagram below.

$$—N—CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2—N—\overset{\overset{\displaystyle H}{\vert}}{}—\underset{\underset{\displaystyle O}{\parallel}}{C}—CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2—\underset{\underset{\displaystyle O}{\parallel}}{C}—N—CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2—N—$$

(a)   Nylons have the ability to form hydrogen bonds between polymer strands. How does this bonding affect the physical properties of nylon polymers?   (2 marks)

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(b)   Draw the two (2) monomers from which nylon 4/6 is composed.   (2 marks)

(c)   Name and briefly describe the process by which these monomers are able to form this nylon polymer.   (2 marks)

_____

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A pure sample of an amine (containing only the elements carbon, hydrogen and nitrogen) was analysed to determine its composition. The amine was combusted in oxygen and produced 6.43 g of carbon dioxide, 3.93 g of water and 2.04 g of nitrogen gas.

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(d)   Calculate the empirical formula of the amine.   (7 marks)

(e)   Did this analysis provide sufficient information to identify whether this amine is one of the
        monomers used to produce nylon 4/6? Explain.   (2 marks)
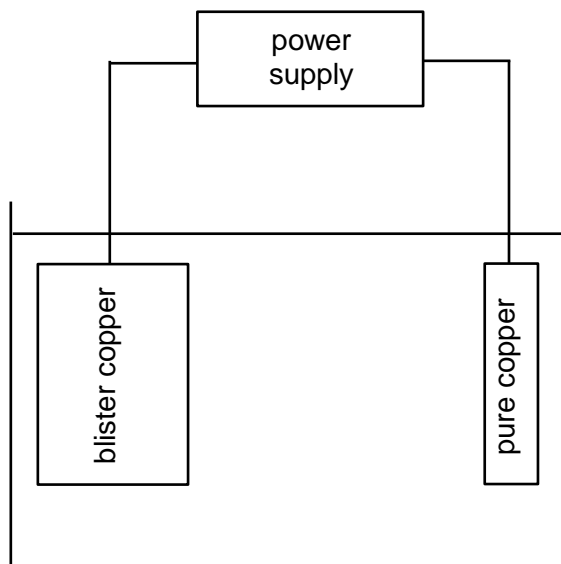
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Question 40 **(13 marks)**

A group of chemistry students set up an experiment to replicate the electrolytic refining of copper metal. They obtained some impure 'blister copper' as well as a thin piece of pure copper and set up an electrochemical cell as shown in the diagram below.

(a)   Explain the chemical principles of an electrolytic cell.   (2 marks)

_____

_____

_____

_____

(b)   On the diagram above label;   (4 marks)

     (i)   the anode and cathode
     (ii)   the sign of each electrode
     (iii)   the direction of cation flow
     (iv)   the direction of electron flow

(c)   State two (2) safety considerations the students would have to take into account when conducting this experiment.   (2 marks)

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The students recorded the mass of the blister copper and pure copper electrodes before allowing the cell to run for a period of time. They then recorded the mass of each electrode again. Their results are shown in the table below.

	Blister copper	Pure copper
Initial mass (g)	65.8	11.9
Final mass (g)	52.3	25.1

(d)   Calculate the percent purity of the blister copper.   (3 marks)

(e)   What factors or problems with an experiment can cause;   (2 marks)

(i)   random error?   _____

_____

(ii)   systematic error?   _____

_____

End of questions

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