ATAR CHEMISTRY

UNITS 3 & 4

2021

Name: _____

Teacher: _____

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	/ 25	/ 25
Section Two: Short answer	10	10	60	/ 82	/ 35
Section Three: Extended answer	5	5	70	/ 89	/ 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.

Section One: Multiple-choice   **25%   (25 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.   Consider a chemical reaction with the following characteristics.

         (i)   The reaction is exothermic.
         (ii)   The reaction occurs spontaneously at room temperature.
   (iii)   The reaction is very difficult to reverse.

        Which energy profile diagram most accurately represents this reaction? Assume the scale on each set of axes is identical.
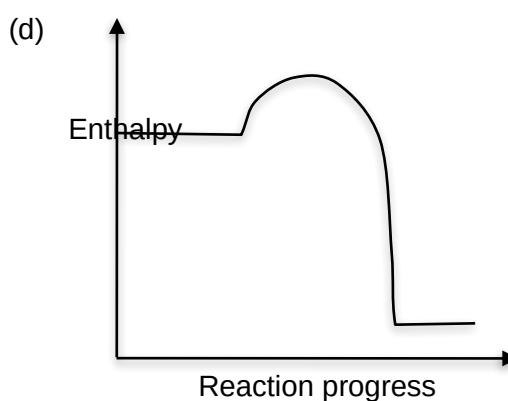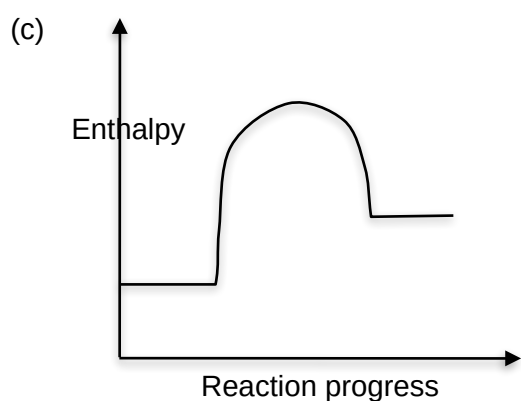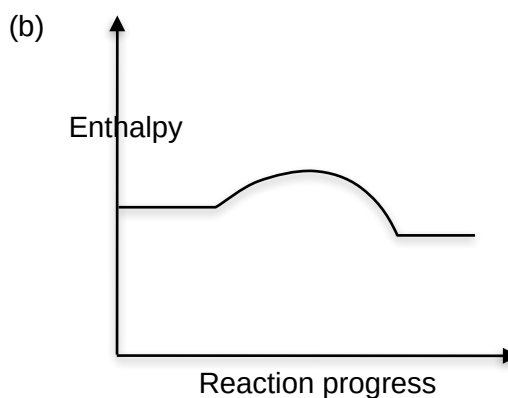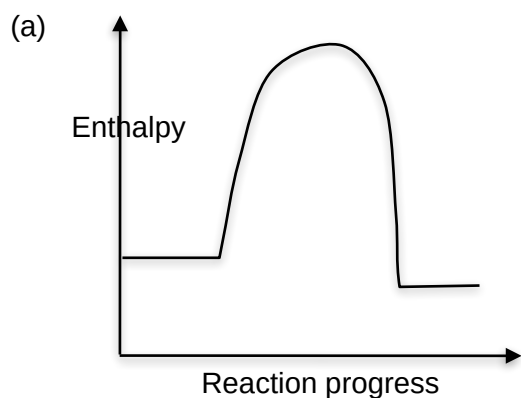
2.   Which of the following ranks the compounds in order of increasing oxidation number (oxidation state) for chlorine?

         (a) NH_4Cl $HClO_3$ Cl_2O_7
         (b) $HClO_3$ Cl_2O_7 NH_4Cl
         (c) Cl_2O_7 $HClO_3$ NH_4Cl
         (d) NH_4Cl Cl_2O_7 $HClO_3$

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3.   Consider the following organic compound.
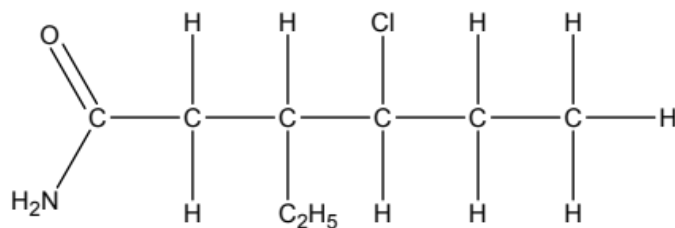

The correct IUPAC name for this substance is

(a)   1-amino-4-chloro-3-ethylhexanal.
(b)   4-chloro-3-ethylhexanamide.
(c)   3-ethyl-4-chlorohexanamide.
(d)   1-amino-3-ethyl-4-chlorohexanal.

Questions 4 and 5 refer to the following equilibrium system.

A sample of liquid dinitrogen trioxide, N_2O_3, is placed in a sealed glass tube where the temperature of the system is maintained at -15 $°C$. The N_2O_3 begins to decompose and eventually establishes equilibrium, as shown in the chemical equation below.

$$N_2O_3(l) \rightleftharpoons NO(g) + NO_2(g)$$

The following rate graph illustrates the establishment of equilibrium in this system at Time E1.
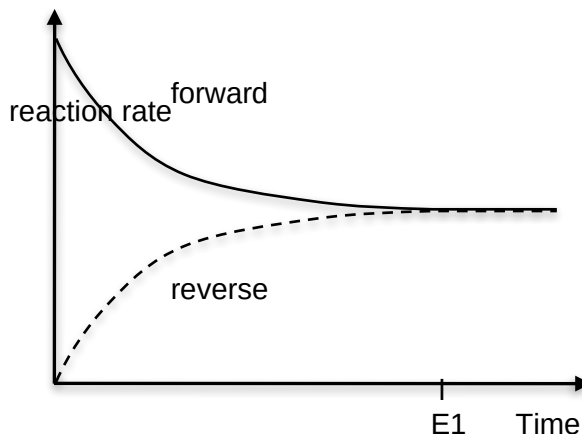
4.   Which of the following statements is **not** correct?

(a)   Before Time E1, the forward reaction rate is decreasing.
(b)   Before Time E1, the forward reaction rate is faster than the reverse reaction rate.
(c)   At Time E1, the forward and reverse reaction rates both become zero.
(d)   At Time E1, the forward and reverse reaction rates become equal.

5.   At Time E1, the NO(g) and $NO_2(g)$ present in the system would **not** have the same

(a)   number of moles.
(b)   mass.
(c)   partial pressure.

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(d)   concentration.

6.   Three separate test tubes contain three different 0.5 mol L^{-1} aqueous salts. Several drops of universal indicator were added to each test tube; one turned pink, one turned green and one turned blue.

Which of the following lists three solutions that would produce these observations?

	pink	green	blue
(a)	KNO_3	Na_2SO_4	$CaCO_3$
(b)	$NaHSO_4$	KCl	LiF
(c)	NH_4Cl	$Mg(NO_3)_2$	NaH_2PO_4
(d)	$LiHCO_3$	CaF_2	$BaCl_2$

7.   A piece of silver-coloured metal was placed into a beaker containing nickel chloride solution. Over time, the green colour of the solution faded. The identity of the metal is

(a)   silver.
(b)   chromium.
(c)   tin.
(d)   zinc.

8.   Consider the segment of polypeptide shown below.
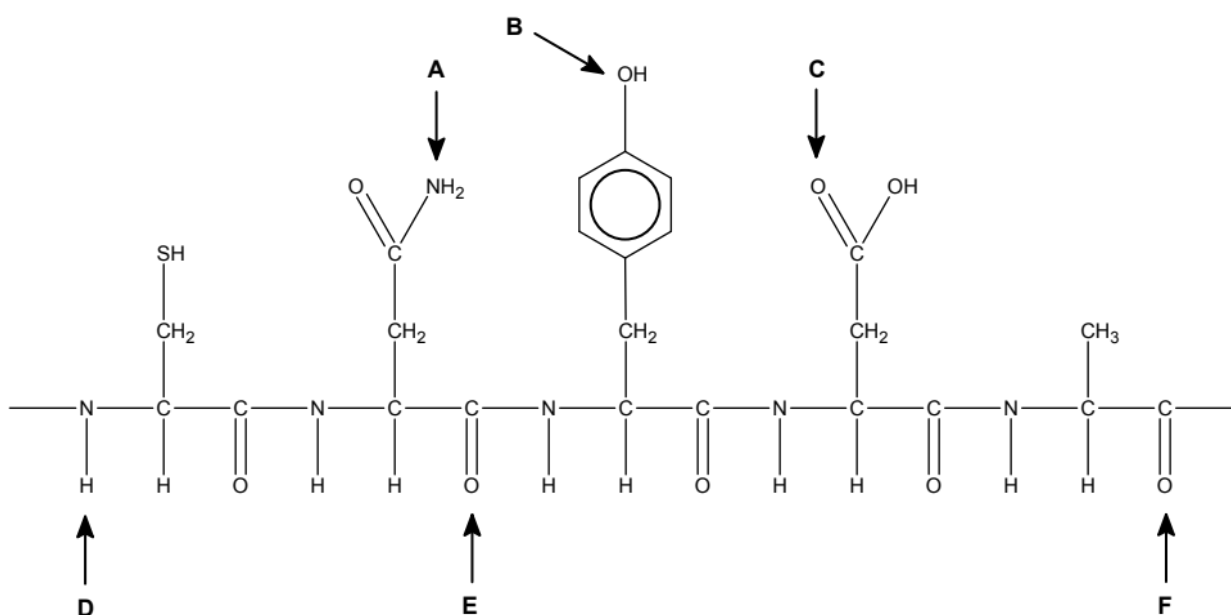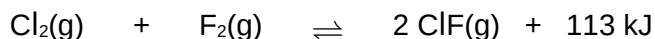

Bonds contributing to the secondary structure of this protein could form between sites

(a)   A and C.
(b)   B and F.
(c)   A and E.
(d)   D and F.

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Questions 9 and 10 refer to the following equilibrium system.

Consider the following chemical reaction that has been allowed to establish equilibrium in a closed system.

$$Cl_2(g) \quad + \quad F_2(g) \quad \rightleftharpoons \quad 2\,ClF(g) \quad + \quad 113\ kJ$$

Two different changes were imposed on the system at Time T1 and T2. In each case the system was allowed to re-establish equilibrium. The graph below illustrates the changes that occurred in the system.
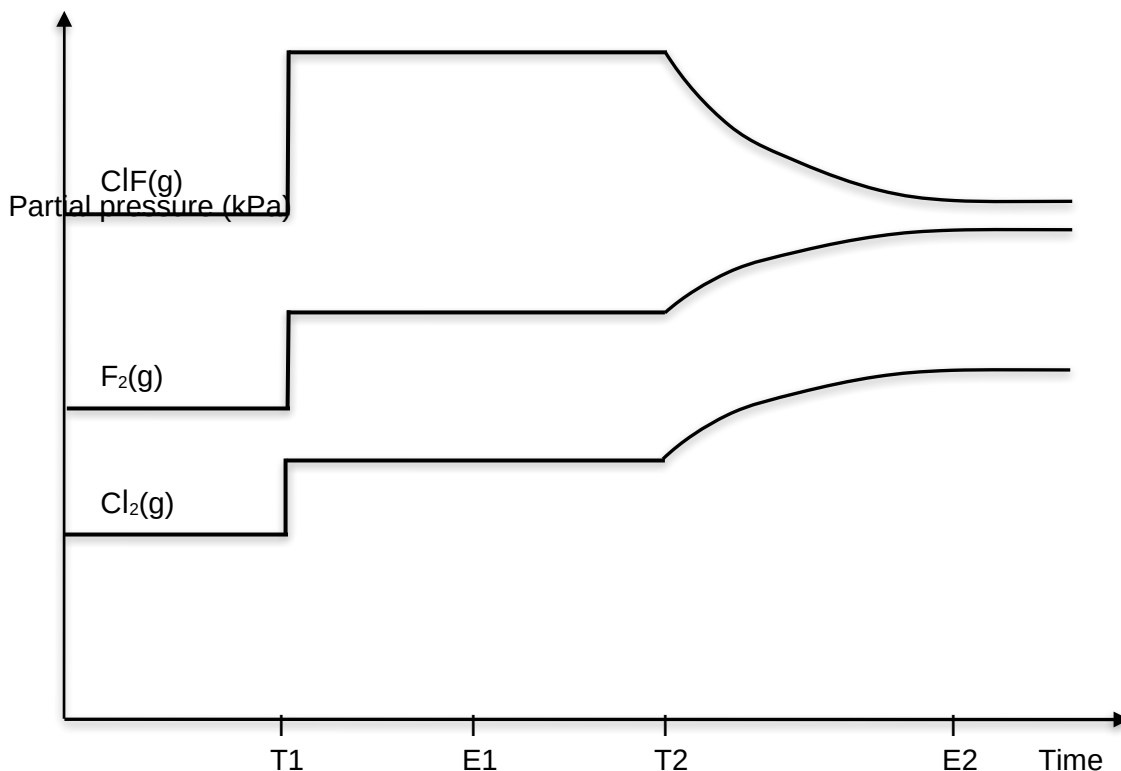
9.   Identify the changes imposed on the system at Times T1 and T2.

	T1	**T2**
(a)	Increased volume	Increased temperature
(b)	Increased volume	Decreased temperature
(c)	Decreased volume	Increased temperature
(d)	Decreased volume	Decreased temperature

10.   Compare the rate of forward reaction and the value of the equilibrium constant at Time E1 and Time E2. Which of the following correctly describes these characteristics at Time E2?

	Rate of forward reaction	**Value of K_c**
(a)	Higher than E1	Higher than E1
(b)	Higher than E1	Lower than E1
(c)	Lower than E1	Higher than E1
(d)	Lower than E1	Lower than E1

SEE NEXT PAGE

11.   Which of the following are weak, monoprotic acids?

        (i) $CH_3COOH(aq)$
        (ii) $HF(aq)$
        (iii) $H_2C_2O_4(aq)$
        (iv) $HCl(aq)$
        (v) $NH_3(aq)$

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

12.   Consider the reaction represented by the chemical equation below.

$$2\ Cu(CN)_3^{2-}(aq)\ +\ 6\ H^+(aq)\ +\ S^{2-}(aq)\ \rightleftharpoons\ Cu_2S(s)\ +\ 6\ HCN(aq)$$
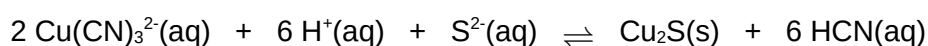
The equilibrium constant expression for this reaction is

(a)
$$K\ =\ \frac{[Cu(CN)_3^{2-}]^2\ [H^+]^6\ [S^{2-}]}{[HCN]^6}$$

(b)
$$K\ =\ \frac{[Cu_2S]\ [HCN]^6}{[Cu(CN)_3^{2-}]^2\ [H^+]^6\ [S^{2-}]}$$

(c)
$$K\ =\ \frac{[HCN]^6}{[Cu(CN)_3]^{2-}\ [H]^+\ [S]^{2-}}$$

(d)
$$K\ =\ \frac{[HCN]^6}{[Cu(CN)_3^{2-}]^2\ [H^+]^6\ [S^{2-}]}$$

13.   Consider the industrial conditions used in the Haber process during the manufacture of ammonia. Which of the following reaction conditions presents a conflict between the rate of reaction and the equilibrium yield of ammonia?
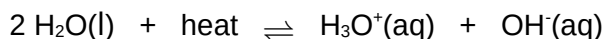
    (a)   High concentration of reactants.
    (b)   High pressure.
    (c)   High temperature.
    (d)   Addition of an Fe_3O_4 catalyst.

14.   Identify the strongest reducing agent.

    (a) $F_2(g)$
    (b) $F^-(aq)$
    (c) $K^+(aq)$
    (d) $K(s)$

15.   The following chemical equation represents the autoionisation of water.

$$2\ H_2O(l)\ +\ heat\ \rightleftharpoons\ H_3O^+(aq)\ +\ OH^-(aq)$$

As a sample of pure water is cooled from 25 ˚C to 4 ˚C, the

(a)   concentration of $H_3O^+(aq)$ increases.
(b)   concentration of $OH^-(aq)$ increases.
(c)   pH increases.
(d)   value of K_w increases.

16.   Consider the incomplete series of equations below, representing the chemical reactions occurring in the Contact process.

$$S(l)\ +\ O_2(g)\ \rightarrow\ \textbf{X}(g)$$
$$\textbf{X}(g)\ +\ O_2(g)\ \rightleftharpoons\ \textbf{Y}(g)$$
$$\textbf{Y}(g)\ +\ H_2SO_4(l)\ \rightarrow\ \textbf{Z}(l)$$
$$\textbf{Z}(l)\ +\ H_2O(l)\ \rightarrow\ 2\ H_2SO_4(aq)$$
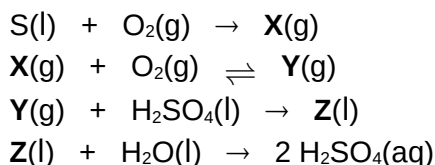
Identify the substances represented by X, Y and Z.

	X	**Y**	**Z**
(a)	SO_2	SO_3	$H_2S_2O_7$
(b)	SO_3	S_7O_2	H_2SO_4
(c)	SO_2	SO_3	H_2SO_4
(d)	SO_3	S_7O_2	$H_2S_2O_7$

Questions 17 and 18 refer to atmospheric carbon dioxide levels.

An increased level of atmospheric $CO_2(g)$ is resulting in various negative environmental consequences.

17.   Which of the following environmental impacts is **not** caused by an increase in atmospheric $CO_2(g)$?

(a)   Deforestation.
(b)   Global warming.
(c)   Ocean acidification.
(d)   Rising sea levels.

Due to the Covid-19 pandemic, the level of global $CO_2(g)$ emissions was reduced by 6% in 2020.

18.   Which of the following sources is **least** likely to have contributed to this fall in $CO_2(g)$ emissions?

(a)   The aviation industry.
(b)   Cars, trucks and other vehicles.
(c)   Commercial electricity.
(d)   Residential electricity.

19.   The diagram below represents the molecular structure of a segment of the polymer named poly-3-hydroxyvalerate (PHV).
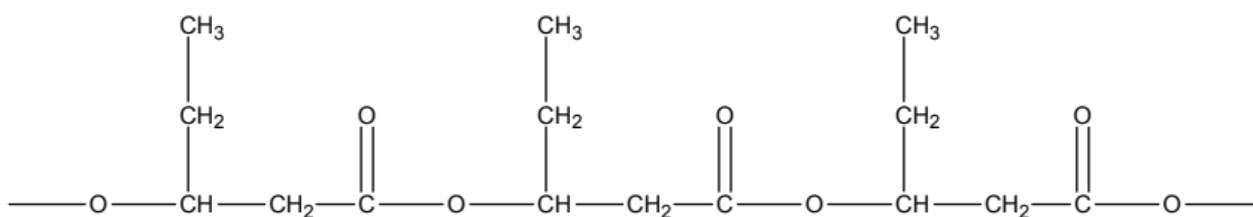
Identify the PHV monomer(s).

(a)

and

(b)

and

(c)

(d)

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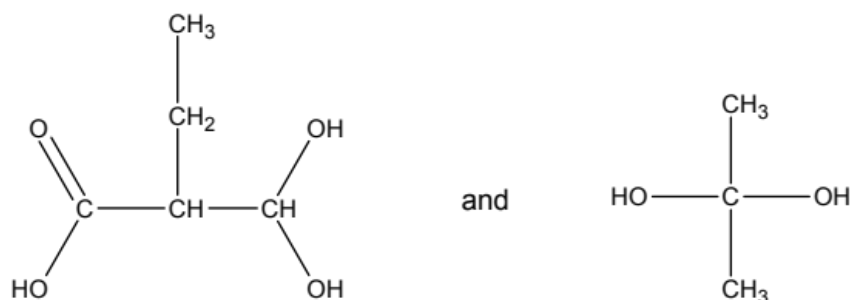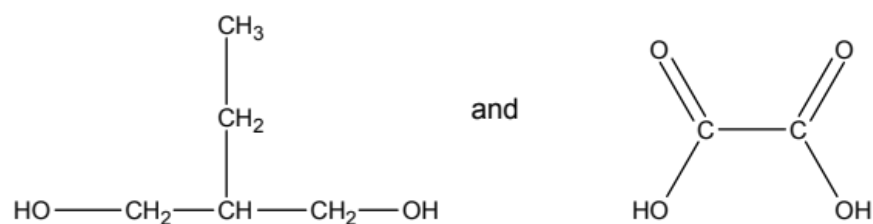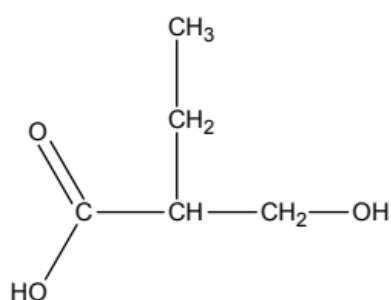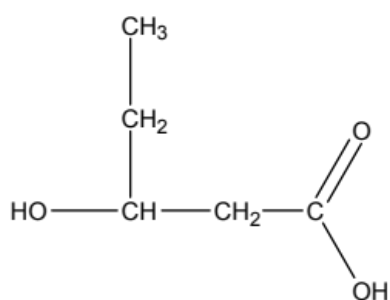
20.   The chemical equation below shows the combustion of butane in a limited oxygen supply.

$$C_4H_{10}(l) \ + \ 4\,O_2(g) \ \rightarrow \ 3\,CO(g) \ + \ C(s) \ + \ 5\,H_2O(g)$$

Identify the correct statement.

(a)   Carbon atoms are oxidised.
(b)   Carbon atoms are reduced.
(c)   Some carbon atoms are oxidised whilst others are reduced.
(d)   Oxygen atoms are oxidised.

Questions 21 and 22 refer to the galvanic cell below.

The following cell was set up under standard conditions.
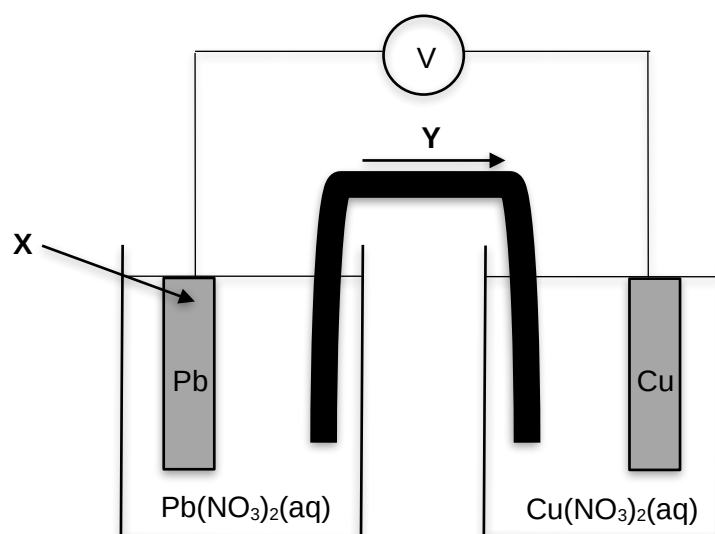
21.   Correctly identify X and Y, as labelled in the diagram above.

	X	**Y**
(a)	anode	anion movement
(b)	anode	cation movement
(c)	cathode	anion movement
(d)	cathode	cation movement

22.   Which of the following changes to the cell above, would result in a greater EMF being produced? Assume all changes maintain standard conditions.

(a)   Change the Pb/Pb^{2+} half-cell to Ag/Ag^+.
(b)   Change the Cu/Cu^{2+} half-cell to Fe/Fe^{2+}.
(c)   Change the Cu/Cu^{2+} half-cell to Cr/Cr^{3+}.
(d)   Change the Cu/Cu^{2+} half-cell to Co/Co^{2+}.

SEE NEXT PAGE

23.   When compared to high density polyethene, low density polyethene has

        (a)   a higher melting point.
        (b)   lower tensile strength.
        (c)   stronger dispersion forces.
        (d)   lower transparency.

24.   Identify the conjugate base of glutamic acid.

        (a) CH_2——CH_2——COOH
                              |
                H_3N^+——CH——COO^-

        (b) CH_2——CH_2——COOH
                              |
                H_3N^+——CH——COOH

        (c) CH_2——CH_2——COOH
                              |
                H_2N——CH——COO^-

        (d) CH_2——CH_2——COO^-
                              |
                H_2N——CH——COO^-
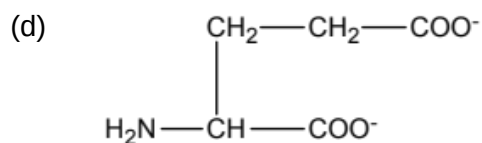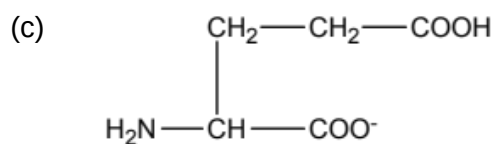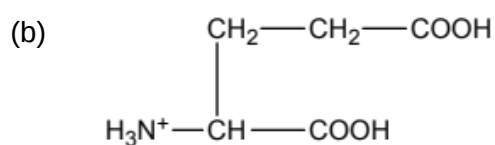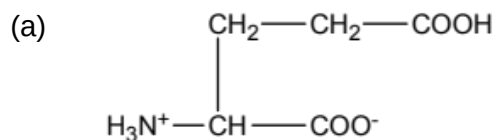
25.   Which of the amino acids below would have the highest melting point?

        (a)   Alanine.
        (b)   Glycine.
        (c)   Leucine.
        (d)   Valine.

End of Section One

Section Two: Short answer   **35% (82 marks)**

This section has 10 questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

Question 26   **(13 marks)**

A 0.7707 g sample of purified amino acid, containing only the elements carbon, hydrogen, oxygen and nitrogen, was analysed to determine its composition. When completely combusted, the water vapour collected at 122 kPa and 197 °C occupied a volume of 822.3 mL. The sample was also found to contain 0.2641 g of carbon. The percent by mass of nitrogen in the amino acid was known to be 13.33%.

(a)   Determine the empirical formula of the amino acid.   (7 marks)

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(b)   If the molecular mass of the amino acid is 105.1 g mol^{-1}, determine its identity.   (3 marks)

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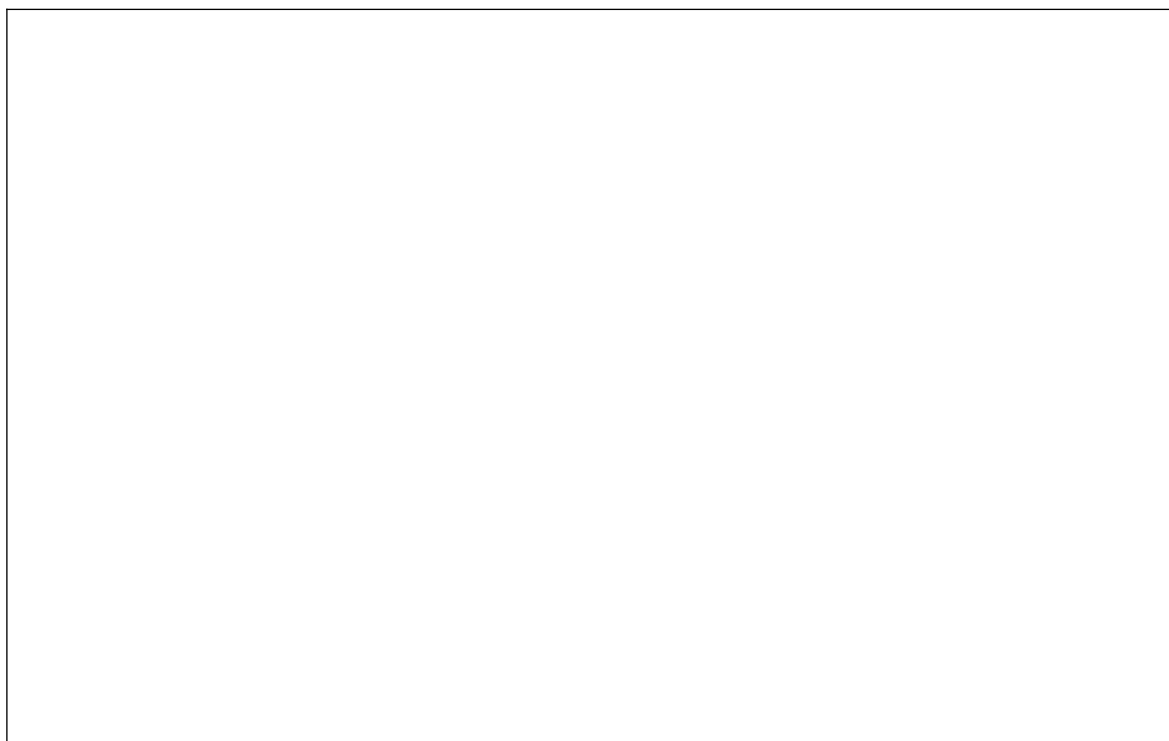
(c)   When the amino acid is dissolved in water, ion-dipole forces form. Draw a diagram
        illustrating the arrangement of these forces.   (3 marks)

Question 27   **(9 marks)**

Write balanced ionic equations for any reactions occurring between the following substances and describe the observation(s).

(a)   A few drops of bromine water were added to a test tube containing sodium iodide solution, and the mixture was briefly shaken.   (3 marks)

Equation
Observation(s)

(b)   Excess nitric acid was poured over zinc carbonate powder.   (3 marks)

Equation
Observation(s)

(c)   A few drops of acidified sodium dichromate solution were added to a sample of propan-2-ol, and the mixture was gently warmed.   (3 marks)

Equation
Observation(s)

Question 28 **(5 marks)**

A sealed glass vial contained the following gaseous equilibrium at room temperature. The appearance of the mixture was pale brown.

$$SO_2(g) \quad + \quad NO_2(g) \quad \rightleftharpoons \quad SO_3(g) \quad + \quad NO(g)$$

colourless   *brown*   *colourless*   *colourless*
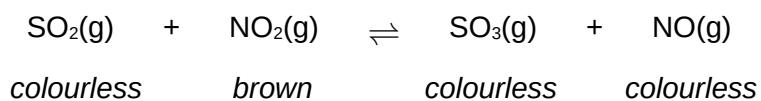
Describe how you could experimentally determine whether this reaction, as written, is endothermic or exothermic. Include the observations that would allow you to reach this conclusion and justify your answer using Le Chatelier's principle.

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Question 29   **(9 marks)**

Consider the information in the table below, regarding ethanoic acid and several of its derivatives.

Name	Formula	K_a at 25 °C
ethanoic acid	CH_3COOH	1.74×10^{-5}
chloroethanoic acid	$CH_2ClCOOH$	1.38×10^{-3}
dichloroethanoic acid	$CHCl_2COOH$	0.0513
trichloroethanoic acid	CCl_3COOH	0.224

(a)   Identify the strongest acid. Justify your answer.   (2 marks)

_____

_____

_____

_____

Consider now, the **potassium salts** of each of these acids;

   $CH_3COOK(aq)$ $CH_2ClCOOK(aq)$ $CHCl_2COOK(aq)$ $CCl_3COOK(aq)$

Separate 0.1 mol L^{-1} aqueous samples of these salts each had three drops of cresol red indicator added to them. The endpoint of cresol red is pH 7.2 – 8.8 and the associated colour changes are shown in the diagram below.
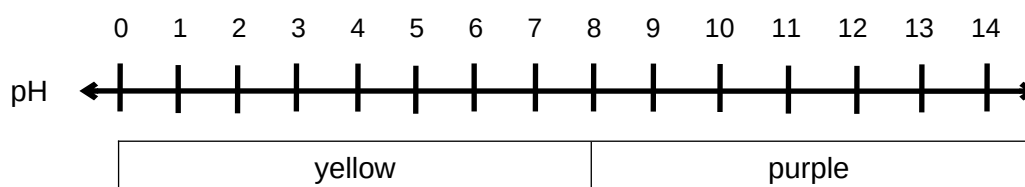
Three of the salt solutions turned purple, whilst one turned yellow.

(b)   Which salt solution is likely to have turned yellow? Justify your answer.   (3 marks)

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(c)   Explain why the CH$_2$ClCOOK(aq) solution turned purple. Use a relevant chemical equation
to support your answer.   (3 marks)

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_____

Equation

Cresol red indicator can exist as either of the two structures shown below.
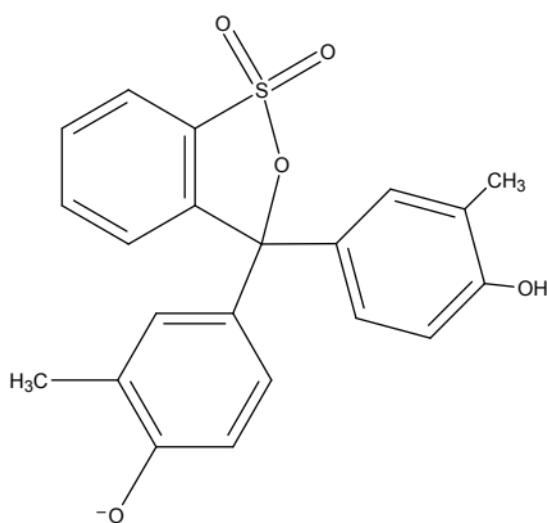
Structure A   Structure B
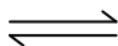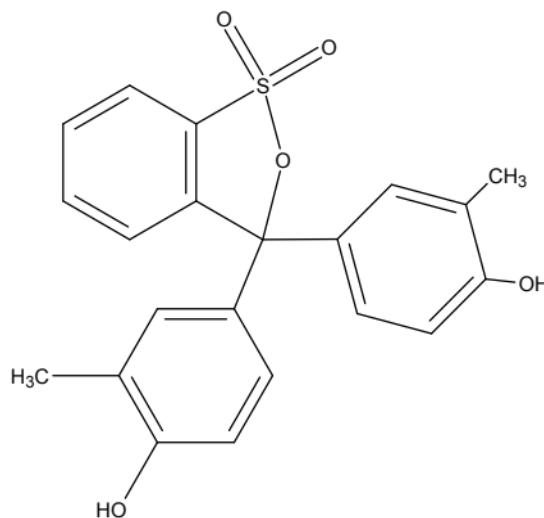
(d)   When cresol red was added to the CH$_2$ClCOOK(aq) solution, which of these would have
been the predominant indicator structure present?   (1 mark)
(circle your choice)

Structure A   **or**   Structure B

_____

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Question 30   **(5 marks)**

The following equation represents the overall chemical process involved in the corrosion of iron.

$$4 \, Fe(s) \; + \; 3 \, O_2(g) \; + \; 2 \, H_2O(l) \; \rightarrow \; 2 \, Fe_2O_3.H_2O(s)$$
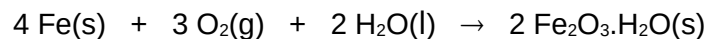
(a)   Identify the oxidant and reductant in this process, using oxidation numbers to support your answer.   (2 marks)

	Species	Oxidation number change
oxidant (oxidising agent)		
reductant (reducing agent)		

(b)   Complete the following table, by giving a brief description of how each method results in a reduced rate of iron corrosion.   (3 marks)

	How is rate of iron corrosion reduced?
Appling a coat of paint to a steel structure such as the Eiffel Tower.	
Connecting the negative terminal of a DC power supply to an underground gas pipeline, and the positive terminal to a protective electrode.	

Question 31 (10 marks)

Complete the table below, by drawing the structural formulae for the organic compounds that match each of the descriptions.

	Structural formula
The *cis* isomer of 1-fluorobut-2-ene.	
The tertiary alcohol with molecular formula $C_5H_{12}O$.	
The compound with IUPAC name '6-hydroxyhexanamide'.	
The organic compound produced from the oxidation of 2-methylpropanal by acidified permanganate solution.	
The organic compound formed from the catalysed reaction between butan-1-ol and methanoic acid.	

Question 32   **(11 marks)**

Consider the following chemical reaction, which has been allowed to establish equilibrium in a closed system.

$$NH_4OCONH_2(s) \; + \; heat \; \rightleftharpoons \; 2\,NH_3(g) \; + \; CO_2(g) \qquad K = 2.9 \times 10^{-3} \text{ at } 25\,^{\circ}C$$
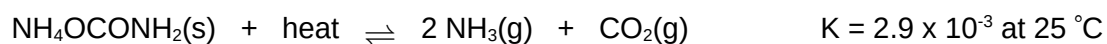
(a)   State how the following changes would affect the rate of the forward reaction, once equilibrium had been re-established.   (3 marks)

	Rate of forward reaction ('increased', 'decreased', 'no change')
Increasing the volume of the system.	
Decreasing the temperature of the system.	
Increasing the partial pressure of $NH_3(g)$.	

(b)   State how the following changes would affect the position of equilibrium.   (2 marks)

	Position of equilibrium ('shift left, 'shift right, 'no change')
Increasing the state of subdivision of $NH_4OCONH_2(s)$.	
Injecting $CO_2(g)$ into the system.	

(c)   Using collision theory, explain the equilibrium shift caused by injecting $CO_2(g)$ into the system in part (b).   (4 marks)

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(d)   State how the following changes would affect the value of K.   (2 marks)

	Value of K ('increased', 'decreased', 'no change')
Decreasing the temperature of the system.	
Decreasing the volume of the system.	

Question 33   **(6 marks)**

Many brands of shampoo contain both citric acid ($C_6H_8O_7$) and sodium citrate ($NaC_6H_7O_7$). These ingredients produce a buffer with a pH of between 5.6 and 6.2, depending on the concentrations used. In shampoo, the purpose of this buffer is to counteract the basicity of the detergent ingredients present.

(a)   Write an equation for the buffer that would be formed when a small amount of shampoo is mixed with water.   (2 marks)

(b)   Explain how this buffer maintains its mildly acidic pH, despite the presence of a small concentration of $OH^-(aq)$ being produced by the detergents in the shampoo.   (4 marks)

Question 34 **(8 marks)**

Hypophosphorus acid (H_3PO_2) is a weak, monoprotic acid. When it is mixed with silver nitrate solution, phosphonic acid (H_3PO_3) is formed, in addition to solid silver metal.

(a)   Write balanced oxidation and reduction half-equations, as well as an overall equation for this chemical reaction. (5 marks)

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

The silver produced by this reaction was collected and melted to form a solid silver electrode, which was then used as part of an electrolytic cell. The cell was used to silver-plate a fork, as shown in the diagram below.
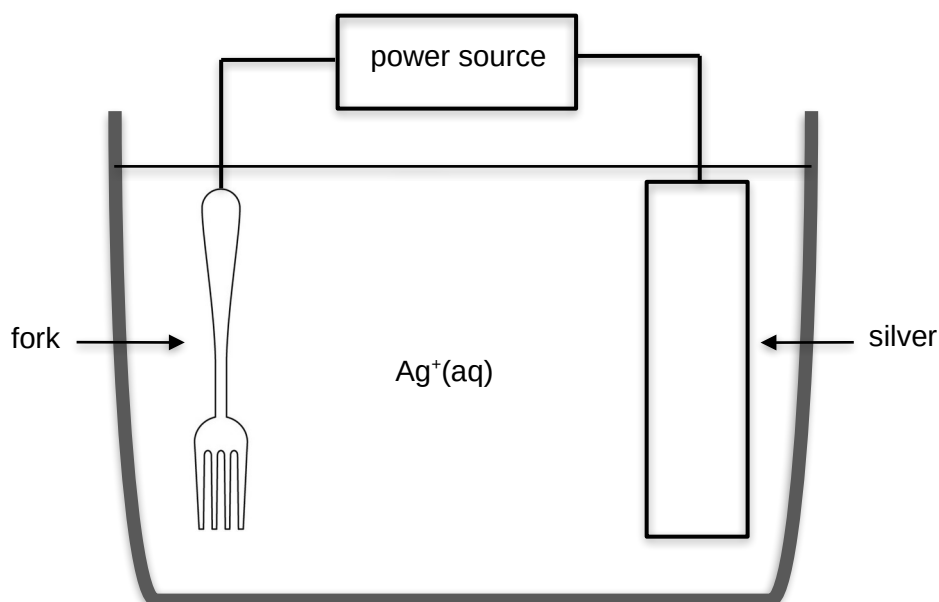
(b)   On the diagram above, label (3 marks)
- the direction of electron flow through the wire,
- the cathode and the anode, and
- the polarity (sign) of the electrodes.

SEE NEXT PAGE

Question 35   **(6 marks)**

Sodium dodecyl sulfate (SDS) is an anionic detergent used in many cleaning products such as liquid hand wash. SDS can be represented by the formula $CH_3–(CH_2)_{11}–SO_4^-\ Na^+$.

One of the simple, yet effective ways that people can prevent transmission of the Covid-19 virus, is by frequently washing their hands. This process enables detergents such as SDS to destroy the virus particles through breaking apart the oily lipid molecules, as illustrated in the diagram below.
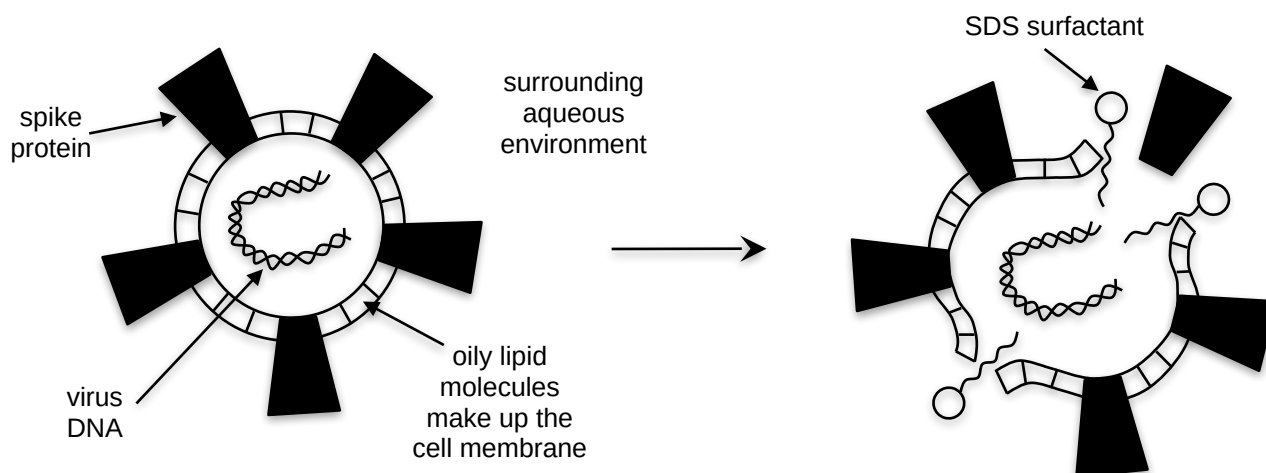
(a)   Explain, in terms of intermolecular forces, how SDS is able to break apart and destroy these coronavirus particles.   (4 marks)

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(b)   Explain why liquid hand wash containing SDS is equally effective in both hard and soft water.   (2 marks)

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End of Section Two

SEE NEXT PAGE

Section Three: Extended answer   **40%   (89 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.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes.

Question 36   **(18 marks)**
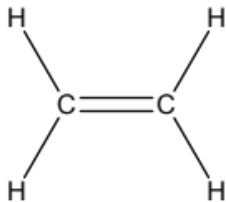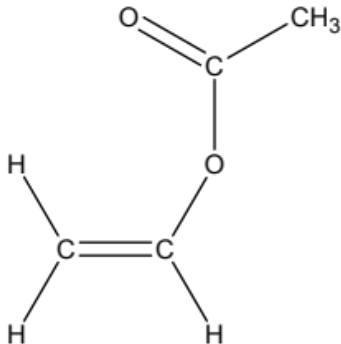
Polyethylene vinyl acetate (PEVA) is a copolymer made from the monomers ethylene and vinyl acetate. There are several different types of PEVA, and these differ in the relative amount of each monomer used in the polymerisation process. Some of the most common uses of PEVA are listed in the table below.

Uses of polyethylene vinyl acetate (PEVA)
• foam art and craft stickers • toys • shower curtains • soles of flip flops/thongs, slippers and other shoes • hockey pads • foam floor mats • mattress protectors • gloves

(a)   Considering the uses above, suggest three (3) physical properties that PEVA is likely to have.   (3 marks)

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SEE NEXT PAGE

PEVA is produced by polymerising two monomers; ethylene and vinyl acetate. The table below provides information regarding the composition of the most common form of PEVA.

	Monomer 1	Monomer 2
Name	Ethylene / Ethene	Vinyl acetate / Ethenyl ethanoate
Structure		
Proportion of reaction mix	23 – 25%	75 – 77%

(b)   State whether PEVA is made by addition or condensation polymerisation. Justify your answer.   (2 marks)

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(c)   Draw a segment of PEVA comprised of four (4) monomer units. Your diagram should take into account the percentage composition of the monomers.   (3 marks)

PEVA is a 'thermoplastic' polymer. This means it will soften when heated, and then harden again once cooled. However, the properties of PEVA can be greatly altered by crosslinking. Crosslinked-PEVA is classified as a 'thermosetting' polymer, which means it has been irreversibly hardened and will not melt, even at high temperatures.

Crosslinked-PEVA is proving to be of great use in the manufacture of solar cells, due to its increased mechanical and thermal stability, as well as its optical transparency. It is stable, long lasting and prevents cracking and overstressing of the solar cells, as well as providing electrical insulation.

(d)   Explain, in terms of structure and bonding, why crosslinked-PEVA is stronger and has a higher melting point, than regular PEVA .   (4 marks)

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To keep up with the demand for PEVA, a plentiful supply of the monomers is required. Vinyl acetate is prepared industrially by the vapour phase reaction of ethene, ethanoic acid and oxygen, in the presence of a palladium catalyst.

$$2\ CH_2=CH_2(g)\ +\ 2\ CH_3COOH(g)\ +\ O_2(g)\ \xrightarrow{Pd}\ 2\ CH_3COOCH=CH_2(g)\ +\ 2\ H_2O(g)$$

ethene   +   ethanoic acid   +   oxygen   →   vinyl acetate   +   water

388 kg of ethene and 471 kg of ethanoic acid were placed in a reactor, in the presence of excess oxygen gas and a palladium catalyst.

(f)   Calculate the maximum volume of gaseous vinyl acetate, measured at 195 °C and 855 kPa, that could be produced. State your final answer to the appropriate number of significant figures.   (6 marks)

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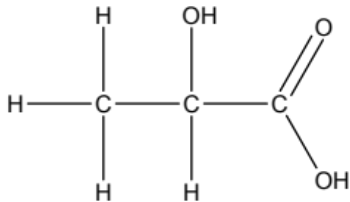_____

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Question 37 (18 marks)

Cow's milk is composed primarily of water and protein, as well as fats, minerals and lactose (a type of sugar found only in milk).

Fresh cow's milk has a relatively short shelf life and must be kept refrigerated. This is due to the presence of bacteria which ferment the lactose in milk, forming lactic acid. This increased acidity causes milk to sour and eventually curdle. This curdling causes the lumpy texture of 'off' milk.

Some information on lactic acid is given in the following table.

Formula	Structure	Molar mass
$CH_3CHOHCOOH$		90.078 g mol^{-1}

Fresh cow's milk usually has a pH of 6.6 and a very low concentration of lactic acid. As milk ferments, the concentration of lactic acid increases and the pH will fall. Once the pH reaches 4.6, the milk curdles.

The table below provides a comparison between fresh and sour milk.
(Note: You may assume lactic acid is the only acidic substance present in the milk.)

	Concentration of lactic acid	pH	Appearance
Fresh milk	1.8 g L^{-1}	6.6	opaque, white liquid with a low viscosity
Sour milk	8.1 g L^{-1}	4.6	liquid becomes more viscous and contains clumps of white solid

A sample of **fresh** milk was analysed by titration, to assess its quality and determine its lactic acid content. A 25.00 mL aliquot of the fresh milk was placed in a conical flask, and a few drops of phenolphthalein were added.
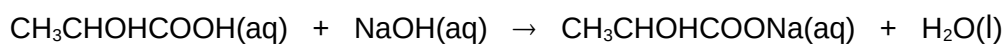
The chemist performing the titration had three (3) bottles of standardised sodium hydroxide solution, NaOH(aq), available for use. They were labelled as follows.

0.01012 mol L^{-1} NaOH(aq)	0.02073 mol L^{-1} NaOH(aq)	0.03141 mol L^{-1} NaOH(aq)

SEE NEXT PAGE

The equation for the titration reaction is given below.

$$CH_3CHOHCOOH(aq) \; + \; NaOH(aq) \; \rightarrow \; CH_3CHOHCOONa(aq) \; + \; H_2O(l)$$

"In this titration, NaOH(aq) is used as the standard solution, however it is not a primary standard."

(a)   Explain this statement, including two (2) reasons why sodium hydroxide is **not** an
        appropriate primary standard.   (4 marks)

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(b)   Determine which of the standard NaOH(aq) solutions would be most appropriate for use in
        this titration. Show all workings.   (3 marks)

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        The chemist should use; (circle your choice)

        0.01012 mol L^{-1} **or**   0.02073 mol L^{-1} **or**   0.03141 mol L^{-1}
            NaOH(aq)   NaOH(aq)   NaOH(aq)

An open bottle of milk, that had been sitting in a refrigerator for five days, was then analysed. A 50.00 mL sample of the milk was placed in a 100.0 mL volumetric flask and diluted with water. 25.00 mL aliquots of the dilute milk were titrated against the 0.03141 mol L^{-1} NaOH(aq) solution. An average titre of 22.13 mL was required to reach the phenolphthalein end point.

The titration equation is shown again below.

$$CH_3CHOHCOOH(aq) \ + \ NaOH(aq) \ \rightarrow \ CH_3CHOHCOONa(aq) \ + \ H_2O(l)$$
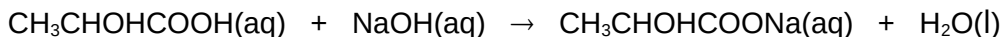
(c)   Calculate the concentration of lactic acid in the open milk sample, in grams per litre, and thus determine whether the milk would be classified as 'sour' or not.   (7 marks)

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Has the milk become sour? (circle your choice)

YES   **or**   NO

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Milk is an excellent source of protein as it contains all nine essential amino acids. Approximately 82% of the proteins in cow's milk are 'casein' proteins.

The curdling observed in sour milk is due to the denaturation of these proteins. This occurs because the decrease in pH disrupts the tertiary structures in the casein proteins, resulting in them clumping together.

(d)   Define the 'tertiary structure' of a protein.   (2 marks)

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Consider the effect of pH on the tertiary structures that the amino acids aspartic acid and lysine are able to form.

(e)   Complete the polypeptide segments in the following table by filling in the blank boxes, to show how the **tertiary structures** formed by these amino acids may be disrupted by pH changes.   (2 marks)

	Low pH	High pH
Aspartic acid	[box] CH$_2$ ----N----C----C---- 　 | 　 | 　 || 　 H 　 H 　 O	[box] CH$_2$ ----N----C----C---- 　 | 　 | 　 || 　 H 　 H 　 O
Lysine	[box] (CH$_2$)$_4$ ----N----C----C---- 　 | 　 | 　 || 　 H 　 H 　 O	[box] (CH$_2$)$_4$ ----N----C----C---- 　 | 　 | 　 || 　 H 　 H 　 O

Question 38 **(20 marks)**

Diesel fuels can generally be classified as either 'petrodiesel' or 'biodiesel'. Petrodiesel is a non-renewable diesel made from fossil fuels. Biodiesel is a renewable form of diesel fuel made from animal fats or plant oils (triglycerides). Over 80% of the biodiesel produced in the US is made from soybean oil, and is often referred to as 'soy biodiesel'.

The production and use of biodiesel is continually advancing and increasing, in efforts to reduce our reliance on petrodiesel. A major advantage of biodiesel is that it can be used in place of petrodiesel, without the need for modifying existing vehicle engines and other infrastructure.

(a) Explain why combustion of biodiesel results in overall lower carbon emissions than petrodiesel. (2 marks)
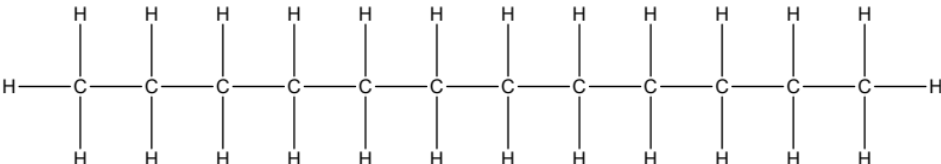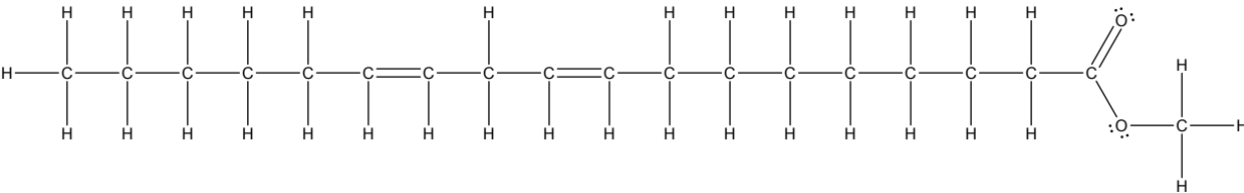
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An important factor when assessing the quality and usefulness of diesel fuels is their 'cloud point'. The cloud point is the temperature where the fuel begins to freeze, and small wax crystals start to form throughout the liquid. This causes the fuel to appear cloudy.

A low cloud point generally corresponds to a lower boiling point and a more desirable fuel. One of the disadvantages of biodiesel, is that it usually has a higher cloud point than petrodiesel.

Consider the information provided in the tables below.

Petrodiesel	
Major component: dodecane, $C_{12}H_{26}$	Cloud point -9 $^\circ$C

Soy biodiesel	
Major component: methyl linoleate, $C_{19}H_{34}O_2$	Cloud point 1 $^\circ$C

SEE NEXT PAGE

(b)   Explain, in terms of intermolecular forces, why the cloud point of soy biodiesel is higher
        than that of petrodiesel.   (5 marks)

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The cloud point of biodiesel will depend on the triglycerides from which it is made. For example, palm oil biodiesel has a cloud point of 17 °C, resulting in a much narrower range of applications.

To a large extent, the cloud point is determined by the percentage of saturated and unsaturated fatty acids comprising the triglycerides used to manufacture the biodiesel. The tables below compare the fatty acid composition of the triglycerides found in soybean oil and palm oil.

Soybean oil fatty acid content	% of oil	Type of fatty acid
linoleic acid	55	polyunsaturated
oleic acid	18	monounsaturated
linolenic acid	13	polyunsaturated
palmitic acid	10	saturated
stearic acid	4	saturated

Palm oil fatty acid content	% of oil	Type of fatty acid
palmitic acid	44	saturated
oleic acid	41	monounsaturated
linoleic acid	10	polyunsaturated
stearic acid	5	saturated

(c)   State the relationship between the percentage of unsaturated fatty acid present in the
        component triglycerides, and the cloud point of a biodiesel.   (1 mark)

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(d)   Explain the relationship stated in part (c), in terms of intermolecular forces. Your answer
       should include a definition of 'unsaturated fatty acids'.   (4 marks)

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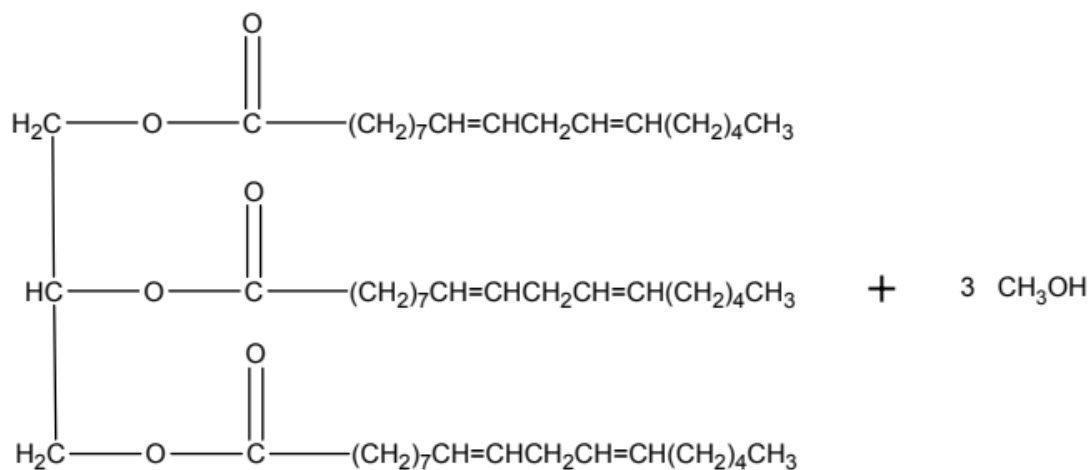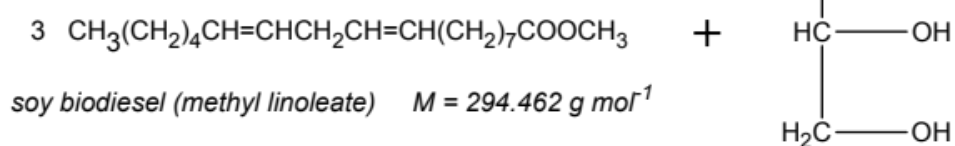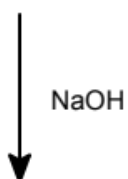
Biodiesel is made by a transesterification reaction between triglycerides and methanol, in the
presence of a sodium hydroxide catalyst. The equation below represents a simplified version of the
production of soy biodiesel.

$$H_2C-O-\overset{\overset{O}{\|}}{C}-(CH_2)_7CH=CHCH_2CH=CH(CH_2)_4CH_3$$

$$HC-O-\overset{\overset{O}{\|}}{C}-(CH_2)_7CH=CHCH_2CH=CH(CH_2)_4CH_3 \quad + \quad 3 \; CH_3OH$$

$$H_2C-O-\overset{\overset{O}{\|}}{C}-(CH_2)_7CH=CHCH_2CH=CH(CH_2)_4CH_3$$

soybean oil (trilinolein) $M = 879.354 \; g \; mol^{-1}$

NaOH

$3 \; CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7COOCH_3 \quad + $

soy biodiesel (methyl linoleate) $M = 294.462 \; g \; mol^{-1}$

$$H_2C-OH$$
$$HC-OH$$
$$H_2C-OH$$

A particular batch of soybean oil was treated, and this resulted in the production of 7545 L of soy biodiesel. The density of the soy biodiesel was measured to be 0.882 kg L^{-1}.

(e)   If the yield of this process was 92.1%, calculate the mass of soybean oil that reacted.

(6 marks)

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The reaction above can also be carried out using lipase enzymes in place of sodium hydroxide.

(f)   Identify two (2) reasons why 'the use of enzymes' is one of the twelve principles of green chemistry.   (2 marks)

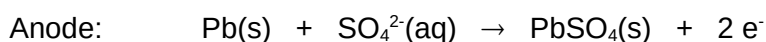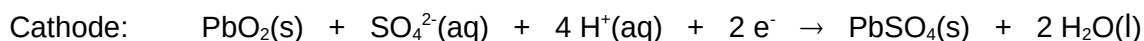|	
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Question 39 **(19 marks)**

The lead-acid battery was invented by Gaston Planté in 1859 and was the first rechargeable battery to be developed. Well over a century later, lead-acid batteries are still used as the starter battery in most vehicles, due to their relatively low cost and ability to produce high currents.

The lead-acid battery consists of six (6) individual cells which are connected in series to increase the overall voltage. Each cell contains a lead(IV) oxide cathode and a lead anode, submerged in a sulfuric acid electrolyte.

A diagram of a typical lead-acid battery is shown below.
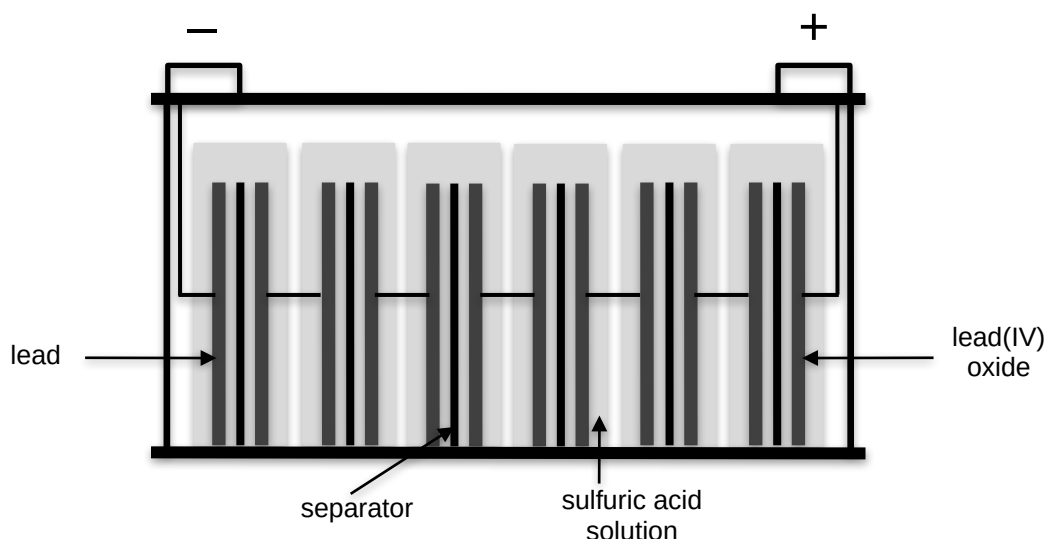
When discharging, the lead-acid battery is functioning as a galvanic cell. The chemical equations for the discharge reactions occurring in the lead-acid battery are;

Cathode: $PbO_2(s) + SO_4^{2-}(aq) + 4 H^+(aq) + 2 e^- \rightarrow PbSO_4(s) + 2 H_2O(l)$

Anode: $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2 e^-$

(a) Explain, in terms of the chemical processes occurring, how a galvanic cell is able to produce an electrical current. (4 marks)

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(b)   Calculate the electrical potential difference produced by a **single** lead-acid cell under
        standard conditions.   (1 mark)

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As the lead-acid battery operates, the lead(IV) oxide cathode reacts to become lead(II) sulfate.
Since this process consumes H^+(aq) ions, the pH of the electrolyte solution will rise as the cell
discharges.

A single lead-acid cell was tested by a mechanic. The cell contained 500.0 mL of electrolyte
solution, which had an initial pH of 0.800. After several hours of use, the electrolyte pH was
measured again, and found to be 3.50.

(c)   Calculate the mass of $PbSO_4$(s) that would have formed at the cathode.   (7 marks)

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(d)   If the initial mass of the PbO$_2$(s) cathode was 695 g, calculate its final mass.   (3 marks)

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The lead-acid battery is a secondary cell and thus is capable of being recharged. During this process it functions as an electrolytic cell.

(e)   Explain, in terms of the chemical processes occurring, how a secondary cell becomes recharged. Include the overall balanced redox equation for the recharging reaction occurring in the lead-acid battery.   (4 marks)

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Question 40 (14 marks)

Ethyl ethanoate ($CH_3COOCH_2CH_3$) is a colourless liquid with a sweet smell. It is a commonly used solvent due to its low cost and low toxicity. Ethyl ethanoate is used in nail polish remover, perfume, varnishes, paints, column chromatography and the production of decaffeinated coffee and tea.

Ethyl ethanoate can be manufactured on an industrial scale using several different methods. One such method is summarised by the reaction sequence shown in the diagram below.

ethene

Reaction A

ethanol

Reaction B

ethanoic acid

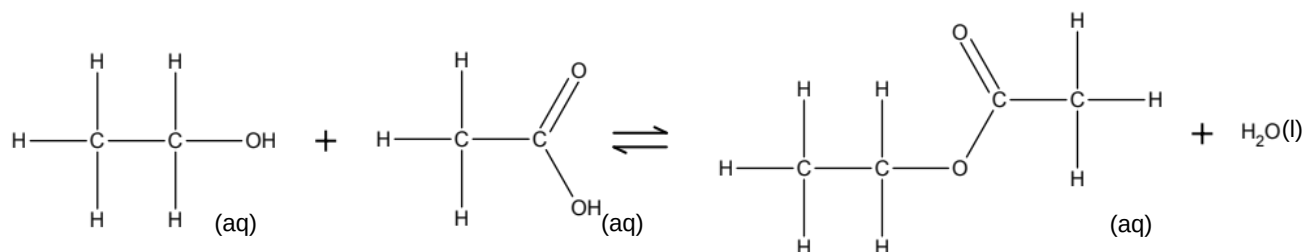Reaction C

ethyl ethanoate
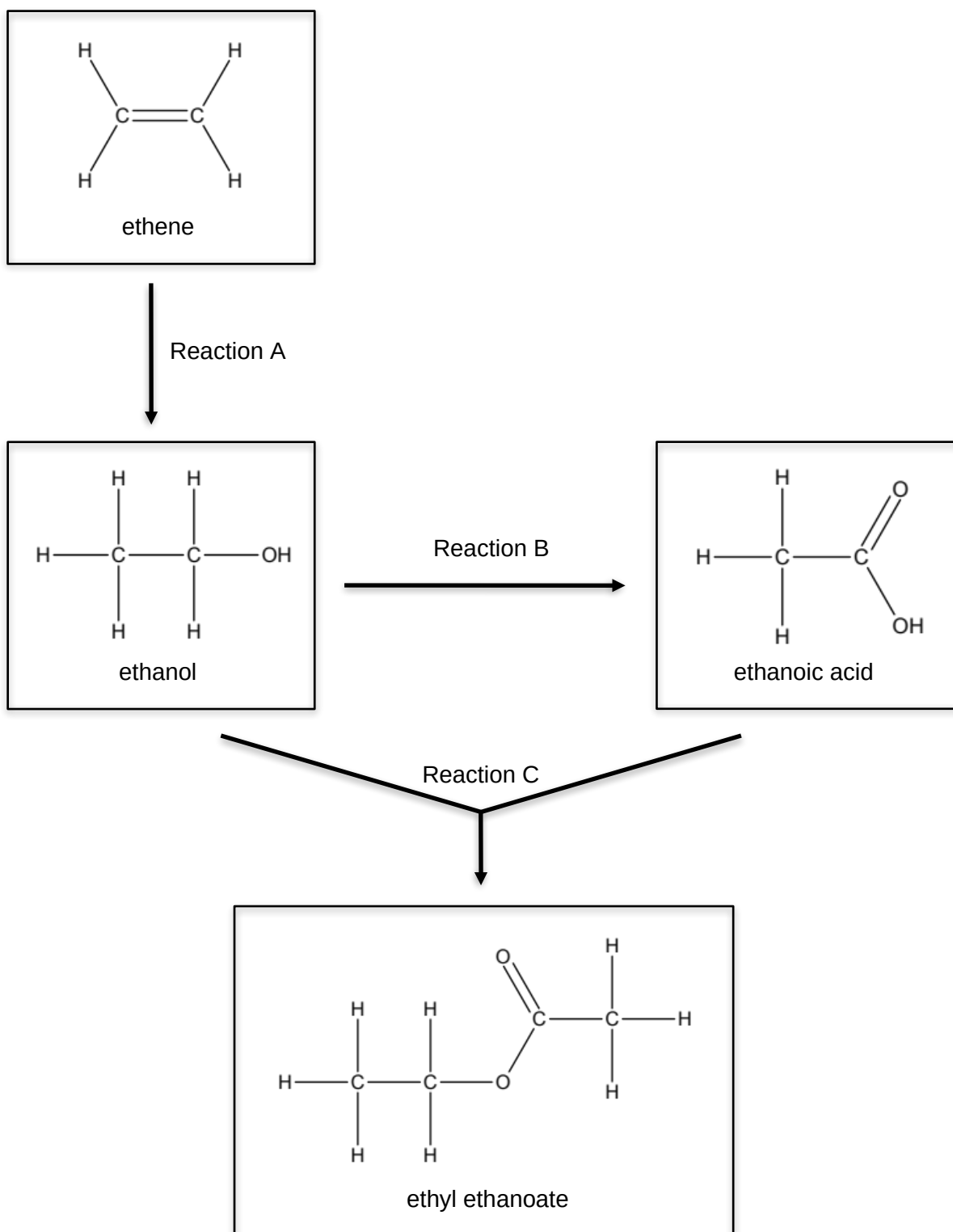
(a)   Complete the table below, regarding each step of this reaction sequence, by identifying;

-    the name or formula of any additional reactant(s) required,
-    the name or formula of any catalyst required, and
-    the type of reaction occurring.   (7 marks)

	Additional reactant(s) required	Catalyst	Type of reaction
Reaction A			
Reaction B			
Reaction C			

The chemical process represented by Reaction C is reversible, as shown below.

All the compounds in this reaction mixture are miscible and form a single solution. This represents a homogeneous equilibrium system with the following equilibrium constant expression;

$$K = \frac{[CH_3COOCH_2CH_3]}{[CH_3CH_2OH]\,[CH_3COOH]}$$

At room temperature this reaction occurs slowly, and the value of the equilibrium constant is 3.38.

(b)   State what information the value of K provides about this equilibrium system.   (1 mark)
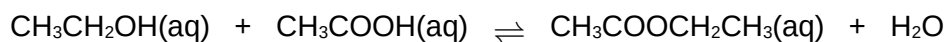
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The equation for Reaction C is shown again below.

$$CH_3CH_2OH(aq) + CH_3COOH(aq) \rightleftharpoons CH_3COOCH_2CH_3(aq) + H_2O$$

When optimising the industrial conditions used in Reaction C, it was found that the yield of ethyl ethanoate could be greatly increased by;

      (i)   incorporating additional ethanol into the reaction mixture, and

      (ii)   using a dehydrating agent to remove half of the water from the entire system.

(c)   On the axes below, sketch graphs showing the effect of each of these changes on both the forward and reverse reaction rates, from the time of the imposed change until equilibrium is re-established. Consider each change in isolation.   (6 marks)

      (i)   Addition of ethanol at Time T1.

reaction rate

forward

reverse

T1   E1   Time
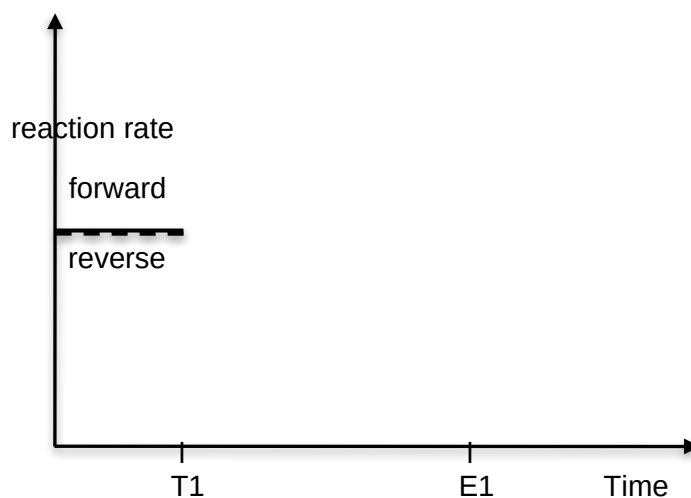
      (ii)   Removal of half of the water from the entire system at Time T2.

reaction rate

forward

reverse

T2   E2   Time
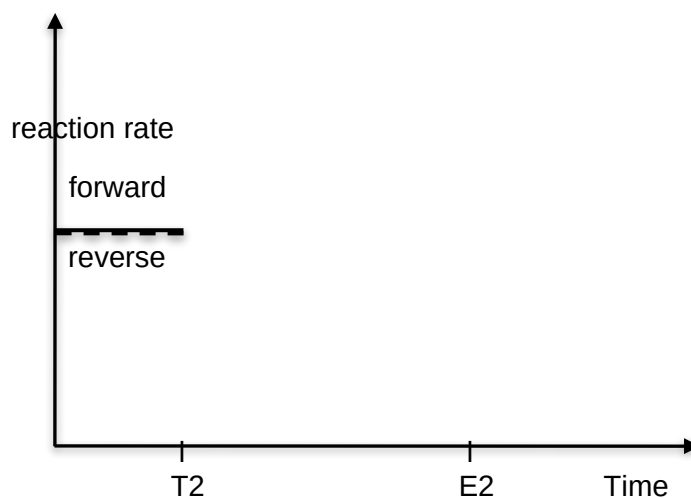
End of questions

Spare answer page

Question number: _____