Kennedy Baptist College

ATAR CHEMISTRY

UNITS 3 & 4

2021

Sue Lutions

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

Section One: Multiple-choice (25 marks)

1	☐ a	☐ b	☐ c	☐ d
2	■ a	☐ b	☐ c	☐ d
3	☐ a	■ b	☐ c	☐ d
4	☐ a	☐ b	■ c	☐ d
5	☐ a	■ b	☐ c	☐ d
6	☐ a	■ b	☐ c	☐ d
7	☐ a	☐ b	☐ c	☐ d
8	☐ a	☐ b	☐ c	☐ d
9	☐ a	☐ b	■ c	☐ d
11	■ a	☐ b	☐ c	☐ d
12	☐ a	☐ b	☐ c	■ d
13	☐ a	☐ b	■ c	☐ d
14	☐ a	☐ b	☐ c	■ d
15	☐ a	☐ b	■ c	☐ d
16	■ a	☐ b	☐ c	☐ d
17	■ a	☐ b	☐ c	☐ d
18	☐ a	☐ b	☐ c	☐ d
19	☐ a	☐ b	☐ c	■ d
21	☐ a	■ b	☐ c	☐ d
22	☐ a	☐ b	■ c	☐ d
23	☐ a	■ b	☐ c	☐ d
24	☐ a	☐ b	■ c	☐ d
25	☐ a	☐ b	■ c	☐ d

(1 mark per question)

10	a ☐ b ■ c ☐ d ☐
20	a ■ b ☐ c ☐ d ☐

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.

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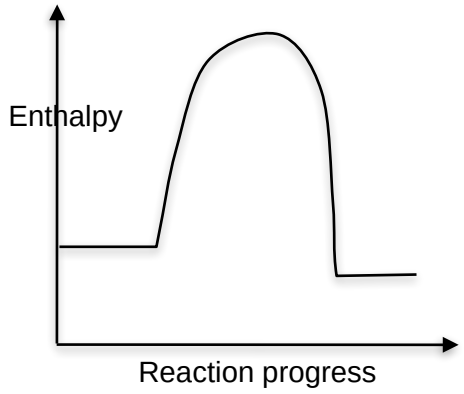
1. Consider a chemical reaction with the following characteristics.

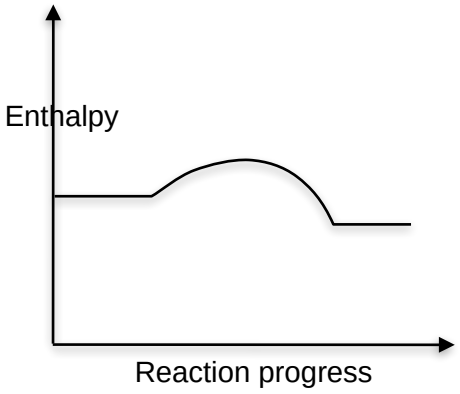
   (i) The reaction is exothermic.
   (ii) The reaction occurs spontaneously at room temperature.
   (iii) The reaction is very difficult to reverse.

   Which energy profile diagram most accurately represents this reaction? Assume the scale on each set of axes is identical.

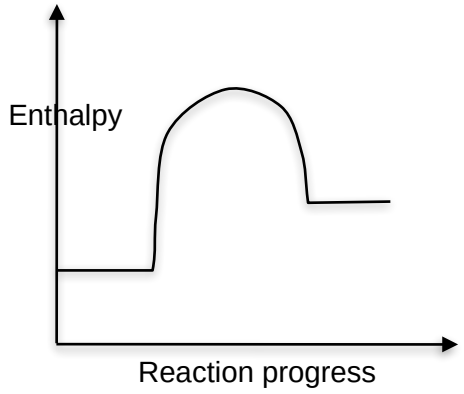
(a)



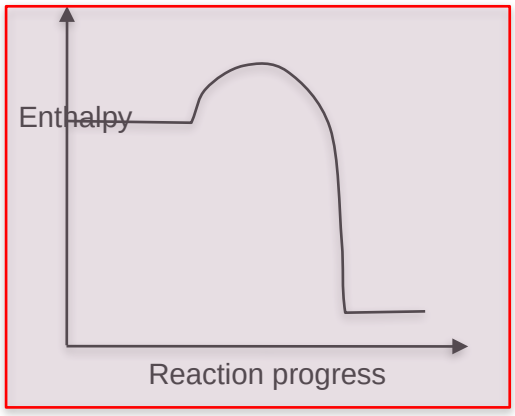
(b)



(c)



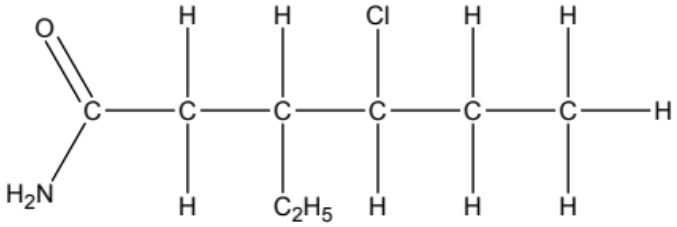
(d)



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	$HClO_3$

3. Consider the following organic compound.



The correct IUPAC name for this substance is

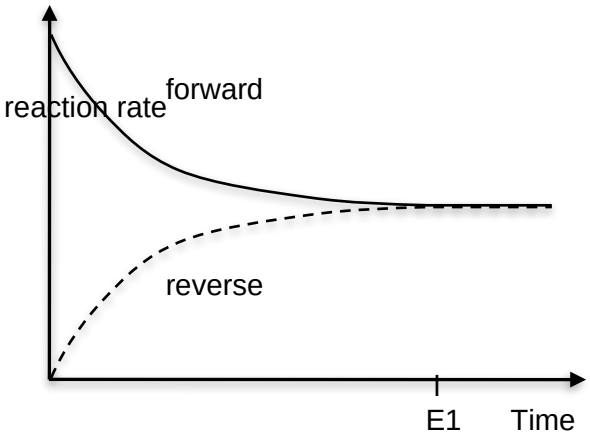
(a) 1-amino-4-chloro-3-ethylhexanal.
(b) 4-chloro-3-ethylhexanamide.
(c) 3-ethyl-4-chlorohexanamide.
(d) 1-amino-3-ethyl-4-chlorohexanal.

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.

(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.

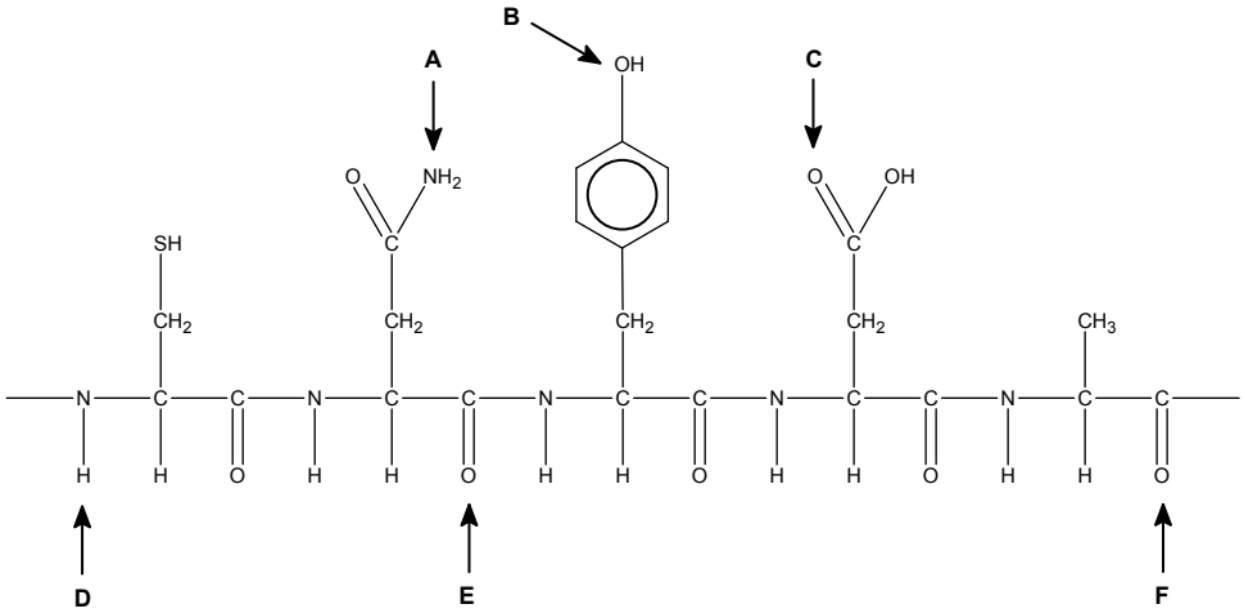
Which of the following lists three solutions that would produce these observations?

	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

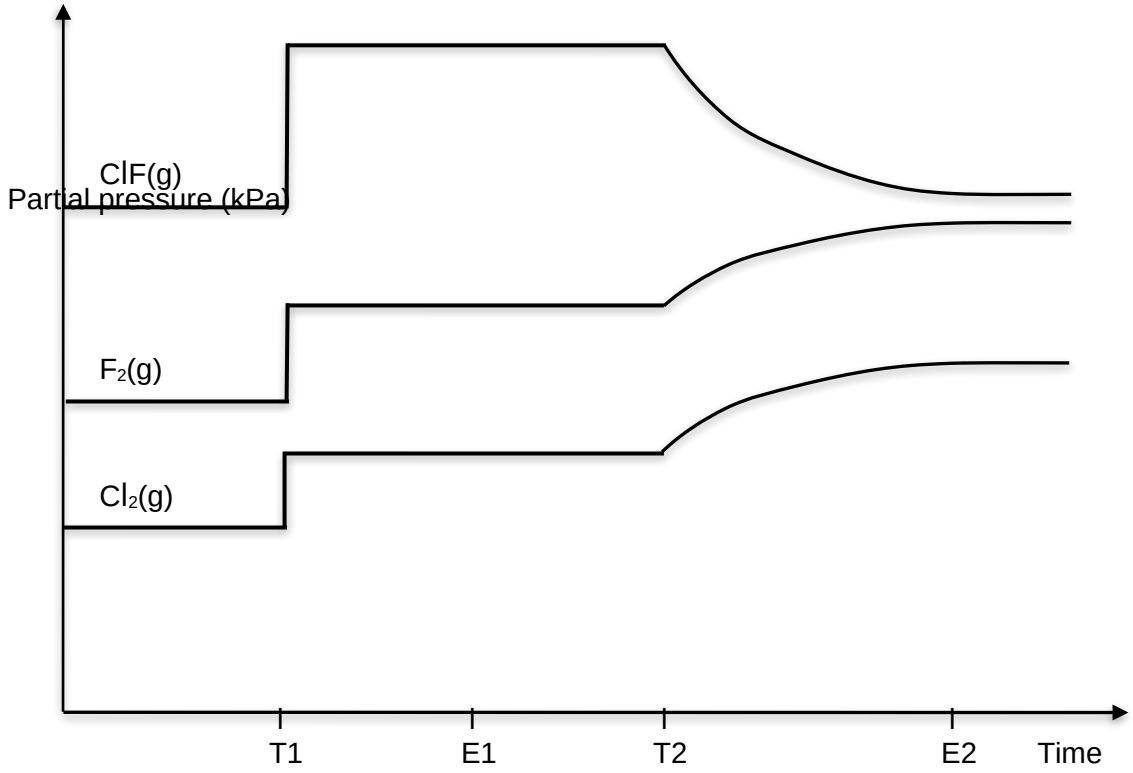
(a) A and C.
(b) B and F.
(c) A and E.
(d) D and F.

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.

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

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

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

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

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

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

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.

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

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.

$$S(l) + O_2(g) \rightarrow \mathbf{X}(g)$$
$$\mathbf{X}(g) + O_2(g) \rightleftharpoons \mathbf{Y}(g)$$
$$\mathbf{Y}(g) + H_2SO_4(l) \rightarrow \mathbf{Z}(l)$$
$$\mathbf{Z}(l) + H_2O(l) \rightarrow 2\ H_2SO_4(aq)$$

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 $CO_2(g)$?

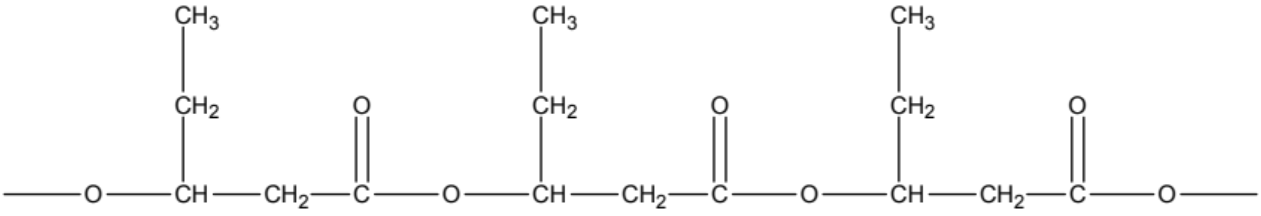
(a) Deforestation.
(b) Global warming.
(c) Ocean acidification.
(d) Rising sea levels.

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

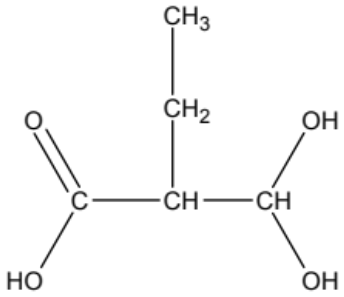
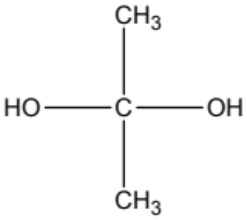
18. Which of the following sources is **least** likely to have contributed to this fall in $CO_2(g)$ emissions?

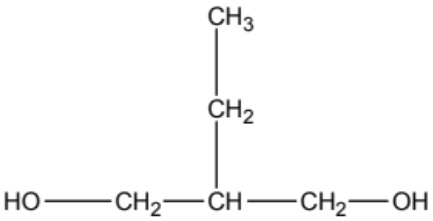
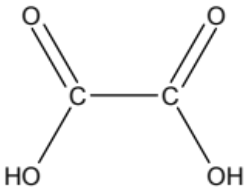
(a) The aviation industry.
(b) Cars, trucks and other vehicles.
(c) Commercial electricity.
(d) Residential electricity.

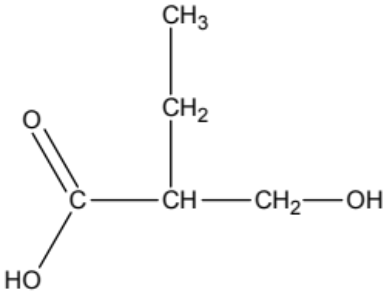
19. The diagram below represents the molecular structure of a segment of the polymer named poly-3-hydroxyvalerate (PHV).

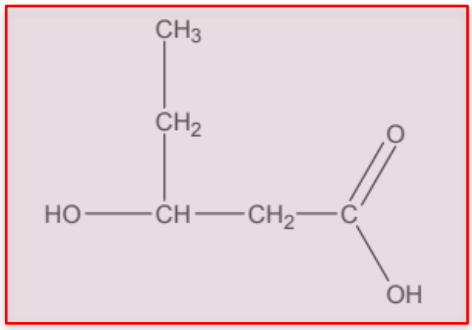


Identify the PHV monomer(s).

(a)  and 

(b)  and 

(c) 

(d) 

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

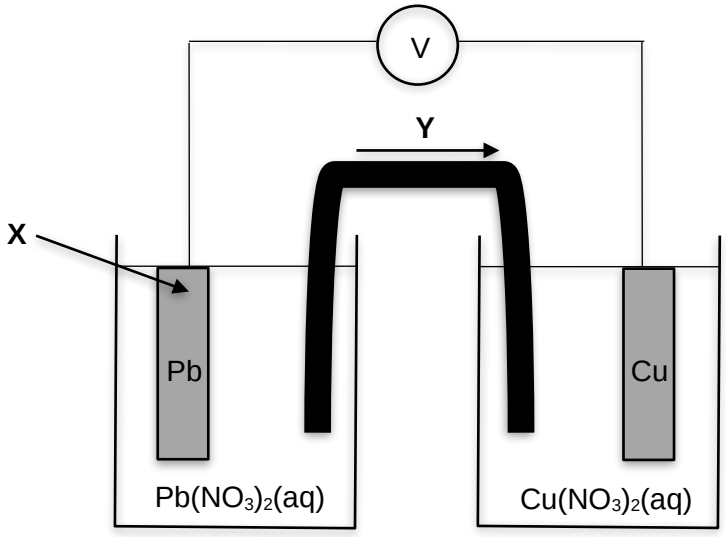
$$C_4H_{10}(l) + 4\ O_2(g) \rightarrow 3\ CO(g) + C(s) + 5\ H_2O(g)$$

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

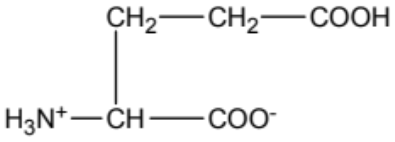
22. Which of the following changes to the cell above, would result in a greater EMF being produced? Assume all changes maintain standard conditions.

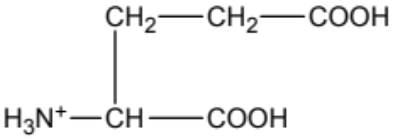
(a) Change the Pb/Pb^{2+} half-cell to Ag/Ag^{+}.
(b) Change the Cu/Cu^{2+} half-cell to Fe/Fe^{2+}.
(c) Change the Cu/Cu^{2+} half-cell to Cr/Cr^{3+}.
(d) Change the Cu/Cu^{2+} half-cell to Co/Co^{2+}.

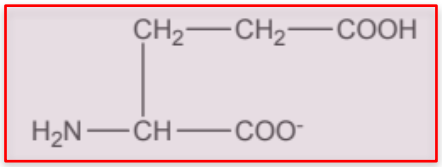
23. When compared to high density polyethene, low density polyethene has

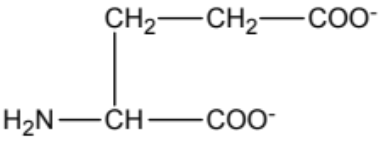
(a) a higher melting point.
(b) lower tensile strength.
(c) stronger dispersion forces.
(d) lower transparency.

24. Identify the conjugate base of glutamic acid.

(a) 

(b) 

(c) 

(d) 

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)

Description	Marks
Calculating moles of H	1
Calculating % of H	1
Calculating % of C	1
Calculating % of O	1
Calculating moles of C/N/O	1
Determining simplest ratio by dividing all by moles of N	1
Writing empirical formula as $C_3H_7NO_3$	1
Total	**7**

Example of a seven mark response

n(H) = 2 x n(H_2O) = (122 x 0.8223) / (8.314 x 470.15) = 0.05133 mol
m(H) = 0.05133 x 1.008 = 0.05174 g %(H) = (0.05174/0.7707) x 100 = 6.713 %

%C (0.2641/0.7707) x 100 = 34.27 %

%(O) = 100 – (%C + %H + %N)
= 100 – 54.31 = 45.69 %

	C	H	N	O
mass in 100 g(g)	34.27	6.713	13.33	45.69
moles (mol)	34.27 / 12.01 = 2.853	6.713 / 1.008 = 6.660	13.33 / 14.01 = 0.9515	45.69 / 16.00 = 2.856
ratio	2.853 / 0.9515 = 3.00	6.660 / 0.9515 = 7.00	0.9515 / 0.9515 = 1.00	2.856 / 0.9515 = 3.00
	3	7	1	3

Empirical formula is $C_3H_7NO_3$

Description	Marks
Calculating moles of H	1
Calculating mass of H	1
Calculating mass of N	1
Calculating mass of O	1
Calculating moles of C/N/O	1
Determining simplest ratio by dividing all by moles of N	1
Writing empirical formula as $C_3H_7NO_3$	1
Total	**7**

Example of a seven mark response

n(H) = 2 x n(H_2O) = (122 x 0.8223) / (8.314 x 470.15) = 0.05133 mol
m(H) = 0.05133 x 1.008 = 0.05174 g

	C	H	N	O
mass (g)	0.2641	0.05174	(13.33/100) x 0.7707 = 0.10273	0.7707 – (0.2641 + 0.05174 + 0.10273) = 0.35213
moles (mol)	0.2641 / 12.01 = 0.02199	0.05133	0.10273 / 14.01 = 0.00733	0.35213 / 16.00 = 0.02201
ratio	0.02199 / 0.00733 = 2.999	0.05133 / 0.00733 = 7.000	0.00733 / 0.00733 = 1	0.02201 / 0.00733 = 3.002
	3	7	1	3

Empirical formula is $C_3H_7NO_3$

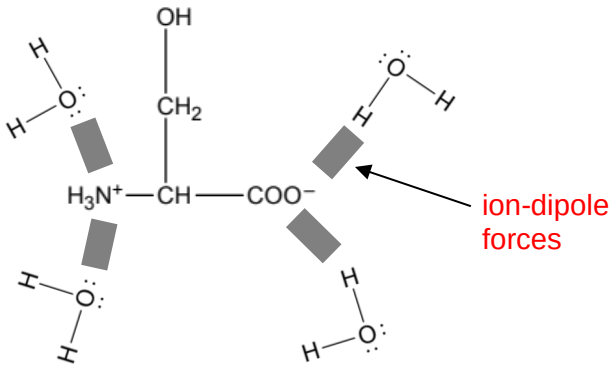
(b) If the molecular mass of the amino acid is 105.1 g mol^{-1}, determine its identity. (3 marks)

Description	Marks
M(EF) = 105.096 g mol^{-1}	1
therefore MF = EF	1
Serine	1
Total	**3**

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

Description	Marks
Serine (or other amino acid) drawn in zwitterion form	1
Correct orientation of water around positive charge	1
Correct orientation of water around negative charge	1
Total	**3**

Example of a three mark response



Note:
Award mark for correct zwitterionic structure of **any follow on** amino acid.

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)

Description	Marks
Equation $Br_2(aq) + 2\ I^-(aq) \rightarrow I_2(aq) + 2\ Br^-(aq)$	
Correct species	1
Correct balancing	1
Observations (minus 0.5 for any wrong/missing) Orange and colourless solutions mix to form a brown solution.	1
Total	**3**
Note: State symbols are not required for full marks. Also accept formation of 'purple solid' as observation.	

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

Description	Marks
Equation $ZnCO_3(s) + 2\ H^+(aq) \rightarrow Zn^{2+}(aq) + CO_2(g) + H_2O(l)$	
Correct species	1
Correct balancing	1
Observations White solid dissolves in a colourless solution (to form a colourless solution) and a colourless (odourless) effervescence (gas) is produced.	1
Total	**3**
Note: State symbols are not required for full marks.	

(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)

Description	Marks
Equation $3\ CH_3CHOHCH_3(l) + Cr_2O_7^{2-}(aq) + 8\ H^+(aq) \rightarrow 3\ CH_3COCH_3(aq) + 2\ Cr^{3+}(aq) + 7\ H_2O(l)$	
Correct species	1
Correct balancing	1
Observations Orange and colourless solutions mix to form a deep green solution.	1
Total	**3**
Note: State symbols are not required for full marks. Award one mark if a correctly balanced oxidation half-equation is given.	

Question 28 **(5 marks)**

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

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

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.

Description	Marks
Increase the temperature of the glass vial.	1
According to Le Chatelier's principle, the equilibrium will shift to counteract the imposed change (increased temperature).	1
An increase in temperature will favour the endothermic direction in order to use up the heat / decrease the temperature.	1
If the mixture becomes darker brown then the reverse reaction is favoured and the equation is exothermic as written.	1
If the mixture becomes paler brown then the forward reaction is favoured and the equation is endothermic as written.	1
Total	**5**

Alternate response:

- Decrease the temperature of the glass vial.
- According to Le Chatelier's principle, the equilibrium will shift to counteract the imposed change (decreased temperature).
- A decrease in temperature will favour the exothermic direction in order to produce more heat / increase the temperature.
- If the mixture becomes darker brown then the reverse reaction is favoured and the equation is endothermic as written.
- If the mixture becomes paler brown then the forward reaction is favoured and the equation is exothermic as written.

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

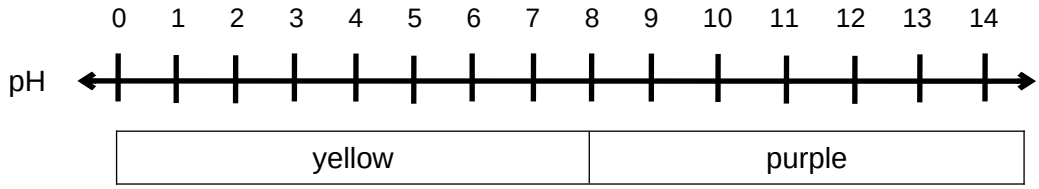
(a) Identify the strongest acid. Justify your answer. (2 marks)

Description	Marks
CCl_3COOH	1
It has the highest K_a value, indicating the ionisation of the acid occurs to the greatest extent. **or** It has the highest K_a value, indicating the highest ratio of product to reactant concentration.	1
Total	**2**
Note: Do not accept 'has the highest K_a value' as only justification.	

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)

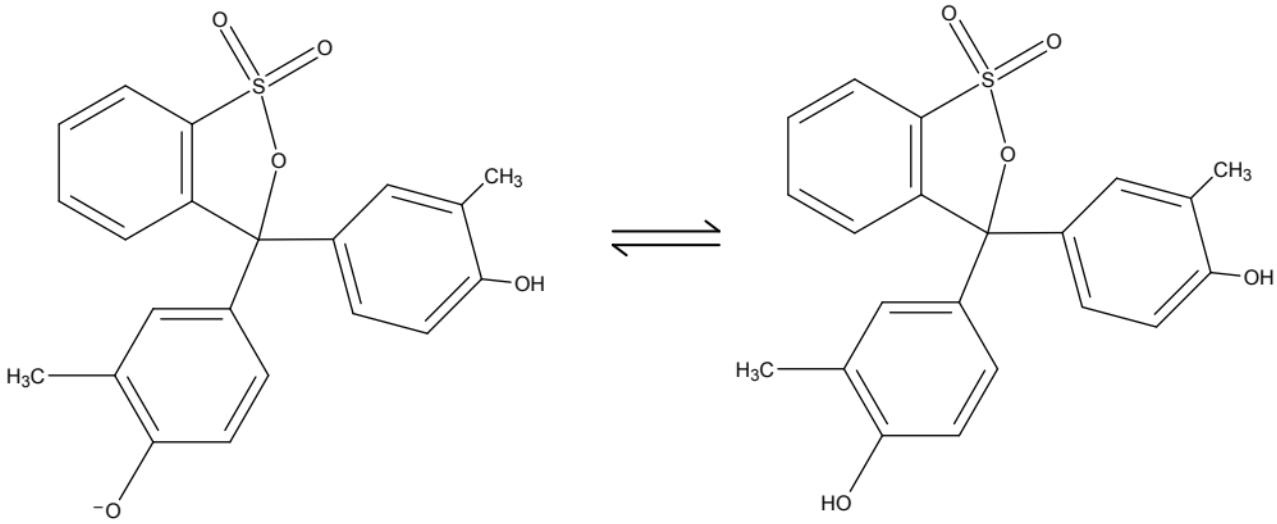
Description	Marks
CCl_3COOK	1
The stronger the acid, the weaker the conjugate base. **or** Anions derived from strong acids have little tendency to hydrolyse.	1
Therefore the $[OH^-]$ is less and so pH is likely to be the closest to 7 (and thus yellow).	1
Total	**3**

(c) Explain why the $CH_2ClCOOK(aq)$ solution turned purple. Use a relevant chemical equation to support your answer. (3 marks)

Description	Marks
$CH_2ClCOO^-(aq) + H_2O(l) \rightleftharpoons CH_2ClCOOH(aq) + OH^-(aq)$	2
Therefore $[OH^-] > [H_3O^+]$ and solution will be basic / turn purple.	1
Total	**3**
Note: State symbols are not required for full marks. No penalty for incorrect arrows.	

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 $CH_2ClCOOK(aq)$ solution, which of these would have been the predominant indicator structure present? (1 mark)
(circle your choice)

Structure A **or** Structure B

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)

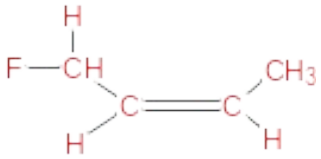
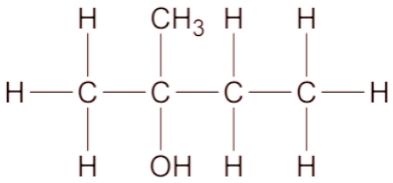
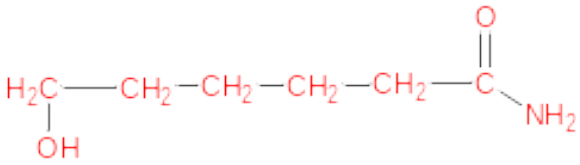
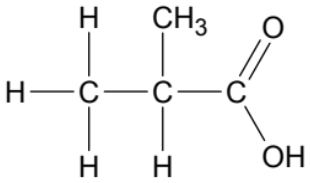
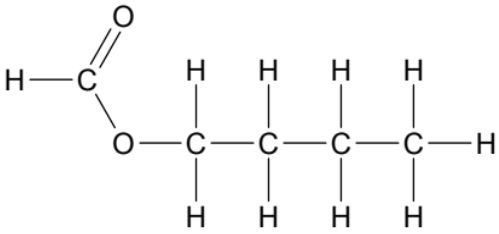
Description			Marks
Oxidant	$O_2(g)$	(0) to (-2)	1
Reductant	Fe(s)	(0) to (+3)	1
		Total	**2**
Note: Award one mark if species and oxidation numbers are correct but answers have been given the wrong way around i.e. do not correspond to 'oxidant' and 'reductant'.			

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

Description		Marks
Appling a coat of paint to a steel structure such as the Eiffel Tower.	Prevents oxygen and water from coming into contact with the iron.	1
Connecting the negative terminal of a DC power supply to an underground gas pipeline, and the positive terminal to a protective electrode.	• The pipeline is held at a negative potential/supplied with electrons which prevents oxidation. • The protective electrode is oxidised preferentially / oxidation occurs at the protective electrode.	2
	Total	**3**

Question 31 **(10 marks)**

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

Description	Marks
	2
	2
	2
	2
	2
Total	**10**

Note:
In each case, one mark may be awarded if structure includes minor error (ie one H missing).
Accept either full or semi-structural formulae.

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 $\rightleftharpoons$ $2\ NH_3(g)$ + $CO_2(g)$ $K = 2.9 \times 10^{-3}$ at 25 °C

(a) State how the following changes would affect the rate of the forward reaction, once equilibrium had been re-established. (3 marks)

Description		Marks
Increasing the volume of the system.	decreased	1
Decreasing the temperature of the system.	decreased	1
Increasing the partial pressure of $NH_3(g)$.	increased	1
Total		**3**

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

Description		Marks
Increasing the state of subdivision of $NH_4OCONH_2(s)$.	no change	1
Injecting $CO_2(g)$ into the system.	shift left	1
Total		**2**

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

Description	Marks
Adding $CO_2(g)$ increases partial pressure of $CO_2(g)$ ($[CO_2]$).	1
This decreases the distance between $CO_2(g)$ and $NH_3(g)$ (product) particles.	1
This increases the frequency of successful collisions.	1
This increases the rate of the reverse reaction relative to the forward reaction (and so equilibrium shifts left).	1
Total	**4**
Note: State symbols are not required for full marks. No penalty for incorrect arrows.	

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

Description		Marks
Decreasing the temperature of the system.	decreased	1
Decreasing the volume of the system.	no change	1
Total		**2**

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)

Description	Marks
$C_6H_8O_7(aq) + H_2O(l) \rightleftharpoons C_6H_7O_7^-(aq) + H_3O^+(aq)$ **or** $C_6H_8O_7(aq) + OH^-(aq) \rightleftharpoons C_6H_7O_7^-(aq) + H_2O(l)$ *	
Correct species	1
Double arrow	1
Total	**2**
Note: Do not award mark for 'double arrow' if equation is incorrect. State symbols are not required for full 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)

Description	Marks
Adding $OH^-(aq)$ (neutralises and thereby) decreases the $[H_3O^+]$.	1
The reverse reaction rate is decreased, relative to the forward reaction rate.	1
As the forward reaction is now at a greater rate than the reverse reaction, the equilibrium shifts right.	1
The $[H_3O^+]$ is returned to close to the original concentration, maintaining pH.	1
Total	**4**
Alternate response (if students have given buffer equation with $OH^-(aq)$ in part (a)*): • The increased concentration of $OH^-(aq)$ increases the frequency of collisions between the reactants. • The forward rate is increased, relative to the reverse reaction rate. • This results in the equilibrium position shifting to the right. • The $[OH^-]$ is thus decreased close to original concentration, maintaining pH. Alternate response: • The $OH^-(aq)$ will react with the conjugate acid buffer component ($C_6H_8O_7$). • $C_6H_8O_7(aq) + OH^-(aq) \rightleftharpoons C_6H_7O_7^-(aq) + H_2O(l)$ • The additional $OH^-(aq)$ is therefore neutralised, forming water. • Since the [OH-] is restored to a similar level, the pH is maintained by the buffer.	

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)

Description	Marks
Oxidation $H_3PO_2(aq) + H_2O(l) \rightarrow H_3PO_3(aq) + 2\ H^+(aq) + 2\ e^-$	
Correct species	1
Correct balancing	1
Reduction $Ag^+(aq) + 1\ e^- \rightarrow Ag(s)$	
Correct species and balancing	1
Overall $H_3PO_2(aq) + H_2O(l) + 2\ Ag^+(aq) \rightarrow H_3PO_3(aq) + 2\ H^+(aq) + 2\ Ag(s)$	
Correct species	1
Correct balancing	1
Total	**5**
Note: State symbols are not required for full marks. If oxidation and reduction equations around the wrong way -1 mark.	

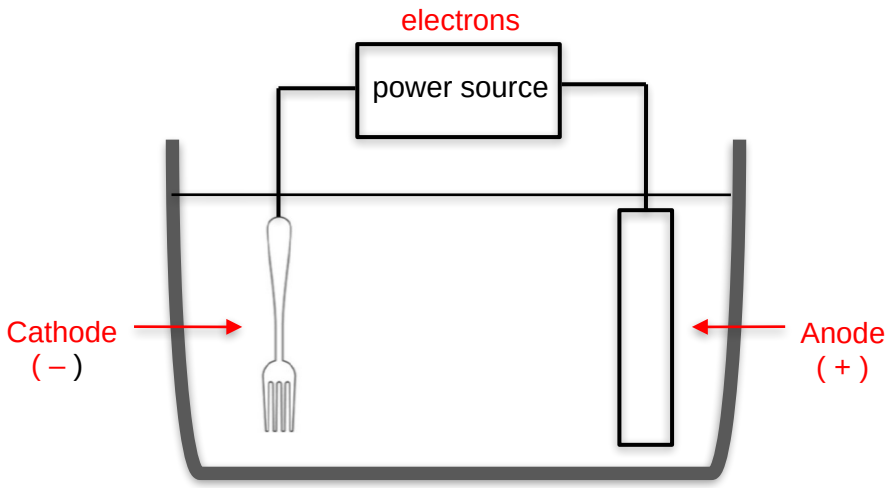
The silver produced by this reaction was collected and melted to form a solid silver electrode, which was then used as part of an electrolytic cell. The cell was used to silver-plate a fork, as shown in the diagram below.

(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.

Description	Marks
Electron flow (right to left) labelled	1
Cathode (left) and anode (right) correctly labelled	1
Negative (left) and positive (right) correctly labelled	1
Total	**3**

Example of a three mark response

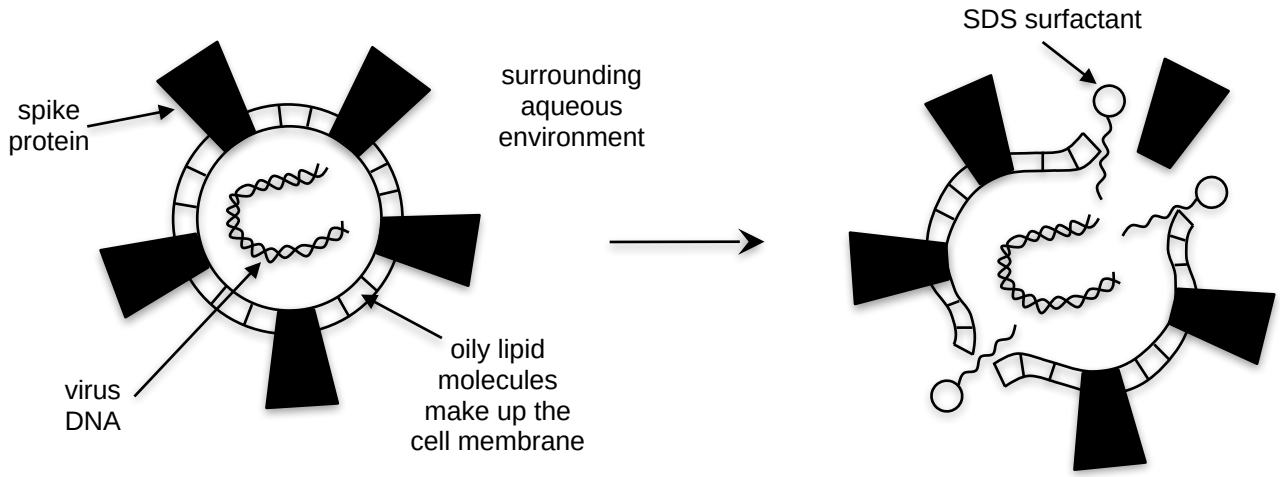


Note:
If electron flow incorrect, follow through possible for two marks.

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)

Description	Marks
SDS has both an anionic (hydrophilic) head and a non-polar (hydrophobic) tail.	1
Both the non-polar tail and the cell membrane interact (primarily) through dispersion forces.	1
The anionic head is able to interact with the surrounding aqueous environment / water through ion-dipole forces.	1
This allows the SDS to embed in the cell membrane and disrupt / break apart the virus particles.	1
Total	**4**

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

Description	Marks
SDS will not precipitate / form a scum with Ca^{2+} and/or Mg^{2+} ions in hard water (as it is a detergent).	1
Therefore, the surfactant ions will still be able to perform their corona virus destroying / cleaning function (equally well in both soft and hard water).	1
Total	**2**

End of Section Two

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)**

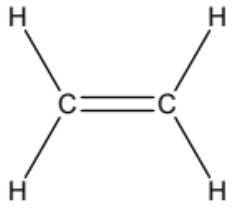
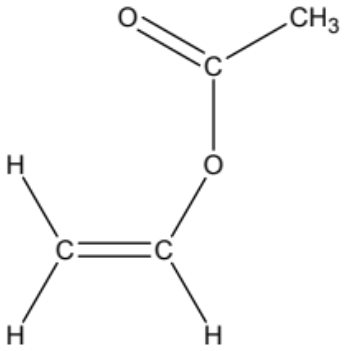
Polyethylene vinyl acetate (PEVA) is a copolymer made from the monomers ethylene and vinyl acetate. There are several different types of PEVA, and these differ in the relative amount of each monomer used in the polymerisation process. Some of the most common uses of PEVA are listed in the table below.

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)

Description	Marks
Any three of the following: • light weight • flexible / durable / moldable / elastic • soft • able to be coloured • waterproof / water repellent / low water solubility • moderate to high melting point • moderately chemically resistant • insulating	3
Total	**3**

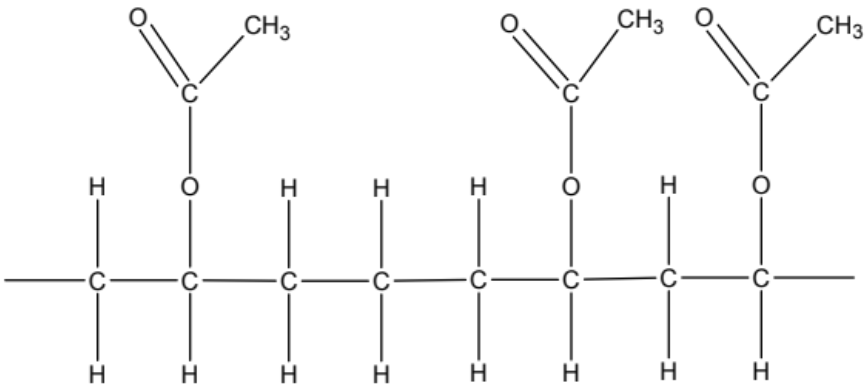
PEVA is produced by polymerising two monomers; ethylene and vinyl acetate. The table below provides information regarding the composition of the most common form of PEVA.

	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)

Description	Marks
Addition polymerisation.	1
Both monomers contain double carbon-carbon bonds / an alkene group.	1
Total	**2**

(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)

Description	Marks
	
Polymer segment shows at least one unit of ethylene (monomer 1) drawn correctly	1
Polymer segment shows at least one unit of vinyl acetate (monomer 2) drawn correctly	1
Segment shows 4 units with a 1:3 ratio of ethylene:vinyl acetate	1
Total	**3**

Note:
Accept the four monomers joined and oriented in any order.
Marks not deducted for terminating ends or inclusion of brackets at ends.

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)

Description	Marks
Crosslinking increases the size / length of the polymer chains.	1
This decreases the mobility of the polymer chains / ability of polymer chains to slide past one another (thus making the polymer stronger).	1
The increased M / number of molecular electrons increases the strength of the dispersion forces. OR Greater number of bonds to overcome.	1
Therefore, a greater amount of heat is required to disrupt the bonding (resulting in a higher melting point).	1
Total	**4**

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)

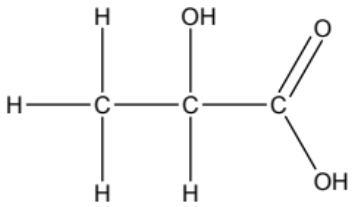
Description	Marks
$n(CH_2CH_2) = (388 \times 10^3) / 28.052 = 13831.46$ mol $n(CH_3COOH) = (471 \times 10^3) / 60.052 = 7843.20$ mol Mole comparison $n(CH_2CH_2) = 13831.46 / 2 = 6915.73$ mol $n(CH_3COOH) = 7843.20 / 2 = 3921.60$ mol	1
CH_3COOH is limiting reagent as there is less present on a mole-to-mole basis	1
$n(\text{vinyl acetate}) = 2 \times n(CH_3COOH) = 7843.20$ mol	1
195 ˚C = 468.15 K	1
$V(\text{vinyl acetate}) = (7843.20 \times 8.314 \times 468.15) / 855 = 35704$ L	1
$= 3.57 \times 10^4$ L **or** 35.7 kL (3 SF)	1
Total	**6**
Note: Other methods of calculating limiting reagent are acceptable but must make Chemistry-sense and include a sentence of justification commensurate with method.	

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)

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)

Description	Marks
The sodium hydroxide is a standard solution because it has an accurately known concentration.	1
Sodium hydroxide is not a primary standard because the solid cannot be accurately weighed and dissolved in water to produce a standard solution.	1
Any two of the following: • Sodium hydroxide is deliquescent • Sodium hydroxide is hygroscopic • The molar mass of sodium hydroxide is too low • Sodium hydroxide reacts with $CO_2(g)$ in the air • Sodium hydroxide is difficult to obtain in pure form / with known purity	2
Total	**4**

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

Description	Marks
c(lactic acid in fresh milk) = 1.8 g L^{-1} Therefore c(lactic acid) = 1.8 / 90.078 = 0.01998 mol L^{-1}	1
Since the acid and base are reacting in a 1:1 stoichiometric ratio, it is desirable that they have similar concentrations.	1
The chemist should use **0.02073 mol L^{-1}** NaOH(aq) (circled)	1
Total	**3**

The chemist should use; (circle your choice)

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

Description			Marks
n(NaOH)	=	0.03141 x 0.02213	1
	=	0.0006951 mol	
n(lactic acid in 25 mL)	=	0.0006951 mol	1
n(lactic acid in 100 mL)	=	0.0006951 x (100/25)	1
	=	0.0027804 mol	
	=	n(lactic acid in 50 mL milk)	1
m(lactic acid in 50 mL milk)	=	0.0027804 x 90.078	1
	=	0.25045 g	
c(lactic acid in 50 mL milk)	=	0.25045 / 0.050	1
	=	5.009 g L^{-1} (i.e. less than 8.1 g L^{-1})	
No, the milk is not sour (circled)			1
		Total	**7**

OR

Description			Marks
n(NaOH)	=	0.03141 x 0.02213	1
	=	0.0006951 mol	
n(lactic acid in 25 mL)	=	0.0006951 mol	1
n(lactic acid in 100 mL)	=	0.0006951 x (100/25)	1
	=	0.0027804 mol	
	=	n(lactic acid in 50 mL milk)	1
c(lactic acid in mol L^{-1})	=	0.0027804/ 0.05	1
	=	0.055608 mol L^{-1}	
c(lactic acid in g L^{-1})	=	0.055608 x 90.078	1
	=	5.009 g L^{-1} (i.e. less than 8.1 g L^{-1})	
No, the milk is not sour (circled)			1
		Total	**7**

Has the milk become sour? (circle your choice)

YES **or** NO

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.

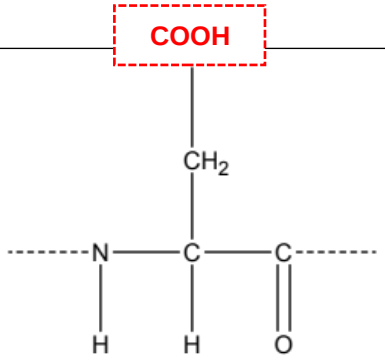
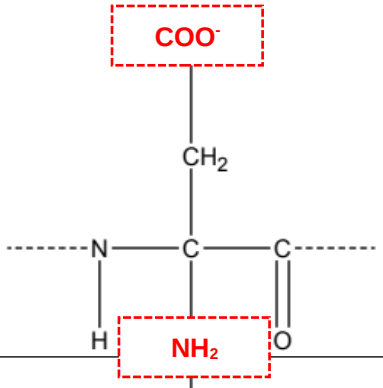
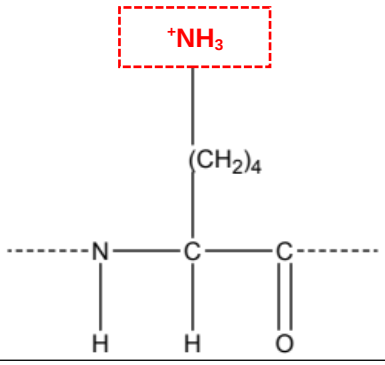
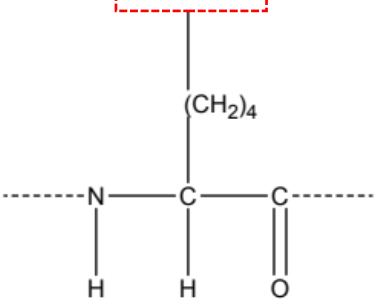
The curdling observed in sour milk is due to the denaturation of these proteins. This occurs because the decrease in pH disrupts the tertiary structures in the casein proteins, resulting in them clumping together.

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

Description	Marks
The folding of the polypeptide chain to produce the overall protein shape.	1
Created by the bonds and interactions between the amino acid side chains.	1
Total	**2**

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)

		High pH
Aspartic acid		
Lysine		

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.

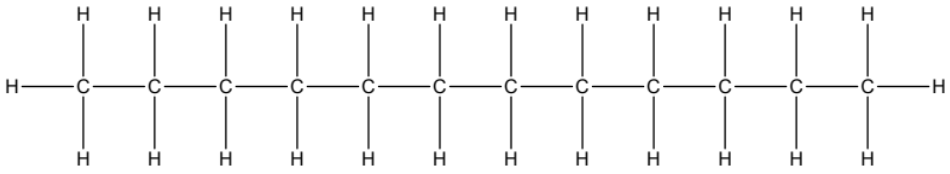
(a) Explain why combustion of biodiesel results in overall lower carbon emissions than petrodiesel. (2 marks)

Description	Marks
The carbon in biodiesel comes from renewable sources / plant material.	1
Plants have taken CO_2 out of the atmosphere, therefore less overall carbon emissions than diesel from non-renewable fossil fuels. OR The CO_2 emitted equals the CO_2 taken out the atmosphere during plant growth (photosynthesis) so no net emissions.	1
Total	**2**

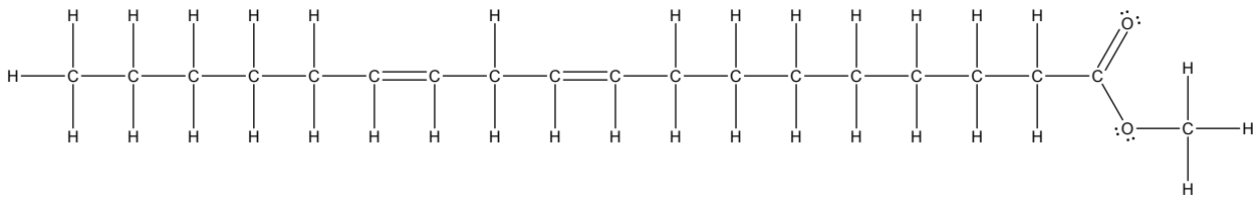
An important factor when assessing the quality and usefulness of diesel fuels is their ‘cloud point’. The cloud point is the temperature where the fuel begins to freeze, and small wax crystals start to form throughout the liquid. This causes the fuel to appear cloudy.
A low cloud point generally corresponds 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 ˚C



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



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

Description	Marks
Petrodiesel only exhibits dispersion forces.	1
Biodiesel exhibits dispersion forces of greater strength due to its larger M.	1
Biodiesel also has a polar ester group and therefore exhibits some dipole-dipole forces.	1
The sum total of intermolecular forces in biodiesel is greater than petrodiesel.	1
Therefore, a greater amount of energy would be required to overcome the intermolecular forces in biodiesel (resulting in a higher cloud point).	1
Total	**5**

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

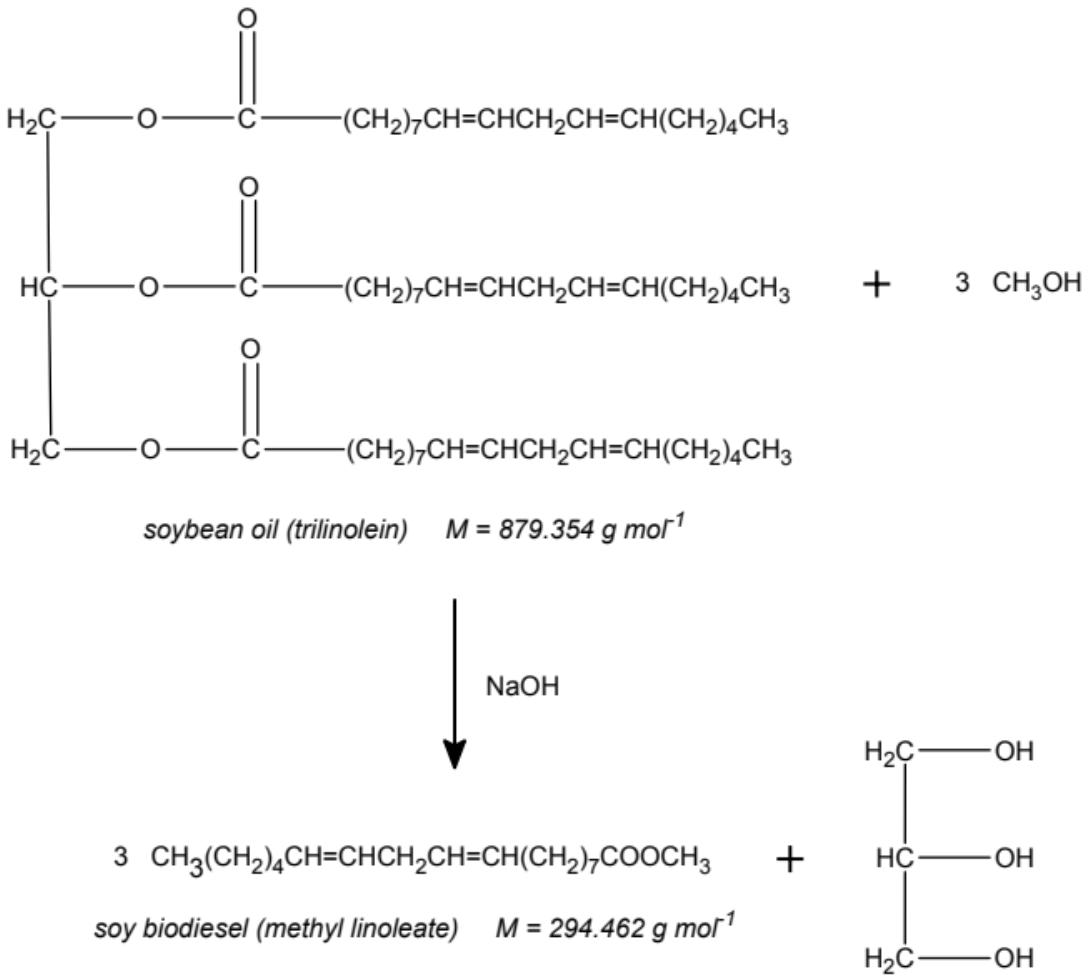
(c) State the relationship between the percentage of unsaturated fatty acid present in the component triglycerides, and the cloud point of a biodiesel. (1 mark)

Description	Marks
The higher the percentage of unsaturated fatty acids, the lower the cloud point of the biodiesel. OR The lower the percentage of unsaturated fatty acids, the higher the cloud point of the biodiesel.	1
Total	**1**

(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)

Description	Marks
Unsaturated fatty acids have one or more double carbon-carbon bonds.	1
This makes it harder for the molecules to pack together / reduces the surface area in contact between the molecules / reduces interactions between the molecules.	1
Therefore, resulting in weaker dispersion forces.	1
Less energy is then required to overcome weaker dispersion forces (and thus a lower cloud point).	1
Total	**4**

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.



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)

Description			Marks
m(soy biodiesel)	=	0.882 x 7545	1
	=	6654.69 kg	
	=	6654690 g	1
n(soy biodiesel)	=	6654690 / 294.462	1
	=	22599.5 mol	
n(soybean oil)	=	22599.5 / 3	1
	=	7533.16 mol	
n(soybean oil inc. yield)	=	7533.16 x (100/92.1)	1
	=	8179.33 mol	
m(soybean oil)	=	8179.33 x 879.354	1
	=	7192526 g	
	=	7.19 x 10^6 g (7.19 t)	
		Total	**6**

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)

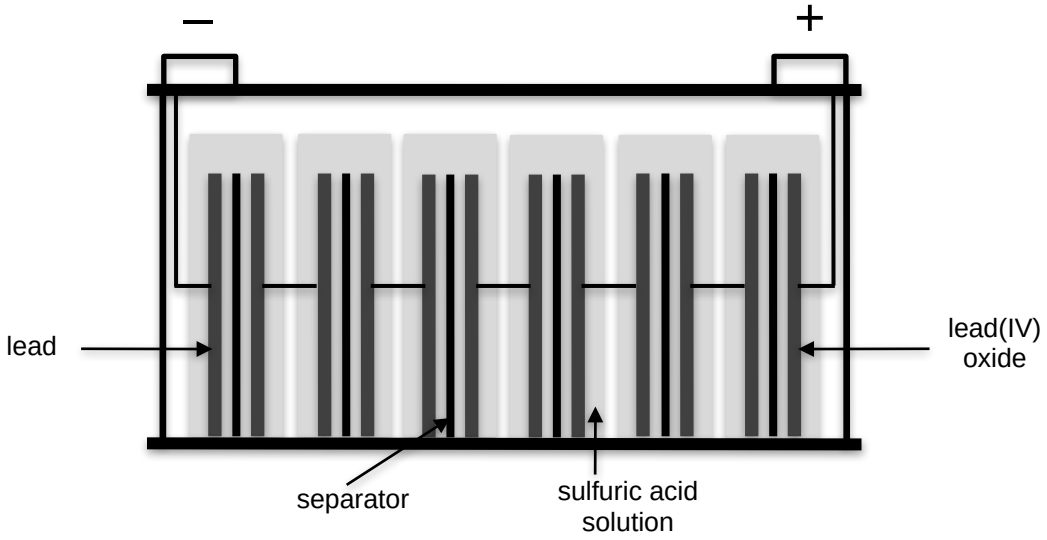
Description	Marks
Any two of the following: • Allows use of lower temperature and / or pressure • Aligns with less harmful synthesis / use of milder conditions • Less toxic / corrosive / harmful • Able to operate at a less dangerous pH • Reduces derivatives produced • Purer product formed / less refining required • Results in a lower energy input	2
Total	**2**

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)

Description	Marks
Galvanic cells make use of a spontaneous redox reaction.	1
Oxidation occurs at the anode, where electrons are lost.	1
Reduction occurs at the cathode, where electrons are gained.	1
The electrons travel via an external pathway from anode to cathode, generating an electric current.	1
Total	**4**

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

Description	Marks
E°cell = 1.69 + (+0.36) = (+) 2.05 V	1
Note: Working not necessary	
Total	**1**

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)

Description			Marks
$[H^+$ at start$]$	=	$10^{-0.80}$ 0.15849 mol L^{-1}	1
$n(H^+$ at start$)$	=	0.15849 x 0.5 0.079245 mol	1
$[H^+$ at end$]$	=	$10^{-3.5}$ 0.00031623 mol L^{-1}	1
$n(H^+$ at end$)$	=	0. 00031623 x 0.5 0.00015811 mol	1
$n(H^+$ used$)$	=	0.079245 – 0.00015811 0.079097 mol	1
$n(PbSO_4$ formed$)$	=	0.079097 / 4 0.019772 mol	1
$m(PbSO_4$ formed$)$	=	019772 x 303.26 5.996 g 6.00 g	1
Total			**7**

(d) If the initial mass of the $PbO_2(s)$ cathode was 695 g, calculate its final mass. (3 marks)

Description			Marks
$n(PbO_2$ used up)	=	$n(PbSO_4$ formed)	1
	=	0.019772 mol	
$m(PbO_2$ used up)	=	0.019772 x 239.2	1
	=	4.7295 g	
Final cathode mass	=	695 – 4.7295 + 5.9960	1
	=	696.3 g	
	=	6.96×10^2 g	
		Total	**3**

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)

Description	Marks
A voltage / electric current is applied to the cell.	1
Thereby forcing a non-spontaneous redox reaction to occur.	1
This reverses the oxidation and reduction processes. **or** This converts the products of the discharge reaction back into reactants.	1
$2\ PbSO_4(s) + 2\ H_2O(l) \rightarrow PbO_2(s) + Pb(s) + 2\ SO_4^{2-}(aq) + 4\ H^+(aq)$	1
Total	**4**

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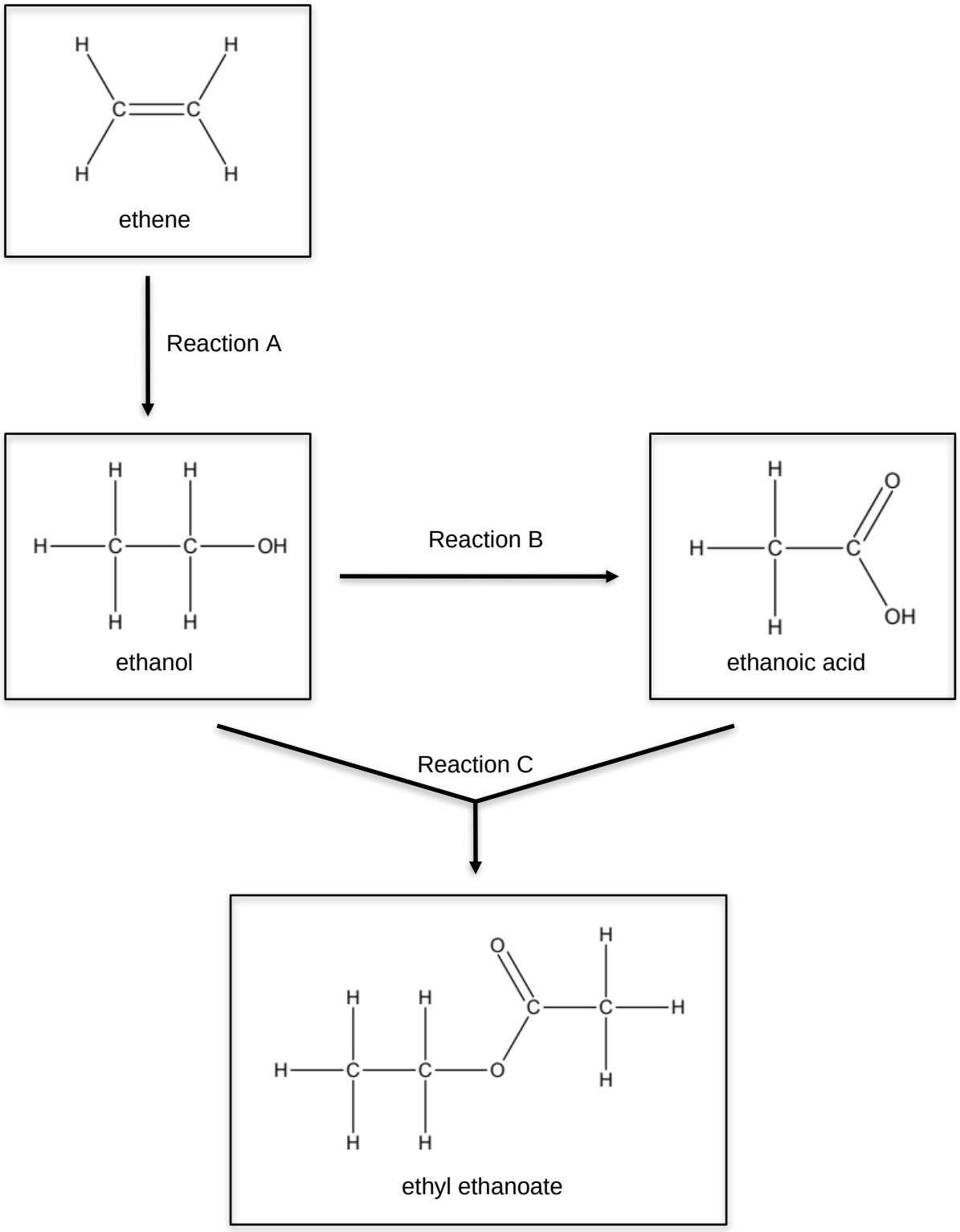
Question 40 **(14 marks)**

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.

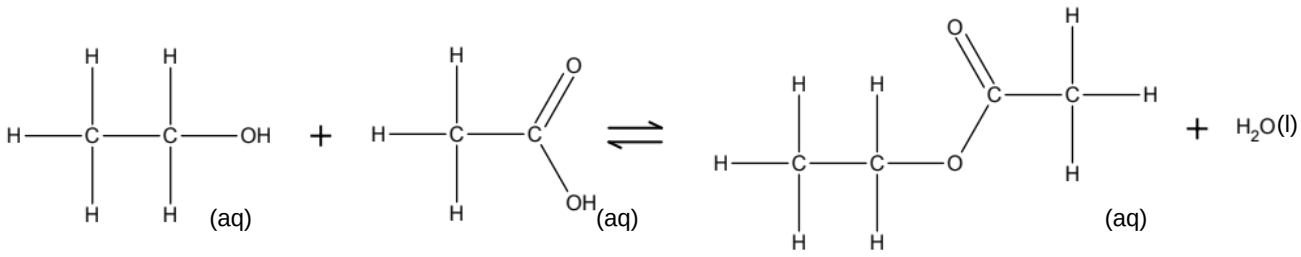


(a) Complete the table below, regarding each step of this reaction sequence, by identifying;

- 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)

Description				Marks
A	H_2O	H_2SO_4 **or** H_3PO_4	addition **or** hydration	3
B	(Acidified) $KMnO_4/H_2SO_4$ **or** (Acidified) $Na_2Cr_2O_7/H_2SO_4$		oxidation **or** redox	2
C		H_2SO_4	esterification **or** condensation	2
			Total	**7**

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)

Description	Marks
A (slightly) greater concentration of products than reactants is present at equilibrium.	1
Total	**1**

The equation for Reaction C is shown again below.

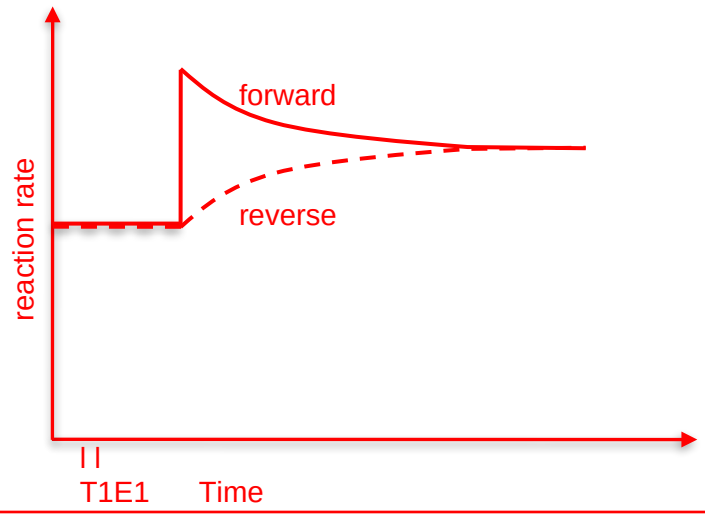
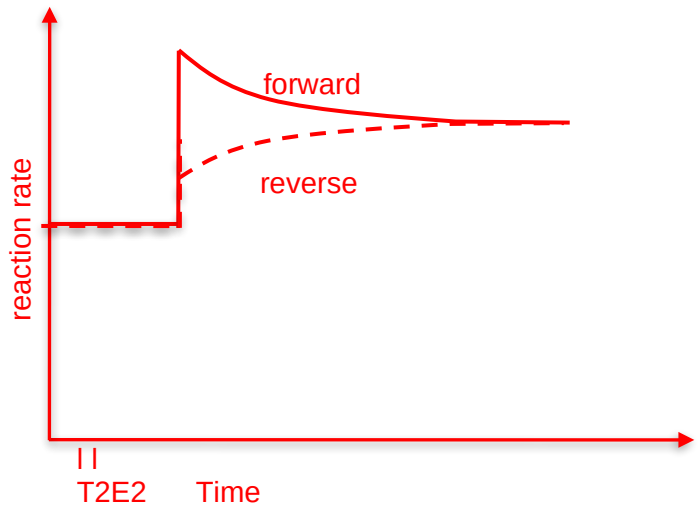
$$CH_3CH_2OH(aq) + CH_3COOH(aq) \rightleftharpoons CH_3COOCH_2CH_3(aq) + H_2O$$

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)

Description	Marks
(i) Addition of ethanol at Time T1 	
Shape of curves between T1 and E1	1
Forward and reverse correctly labelled	1
Curves merge and become horizontal at E1	1
(ii) Removal of water at Time T2 	
Shape of curves between T2 and E2	1
Forward and reverse correctly labelled	1
Curves merge and become horizontal at E2	1
Total	**6**

End of questions

Spare answer page

Question number: _____