Q1. The table below gives some values of standard enthalpy changes. Use these values to answer the questions.

Name of enthalpy change	ΔH° /kJ mol^{-1}
Enthalpy of atomisation of chlorine	+121
Electron affinity of chlorine	−364
Enthalpy of atomisation of silver	+289
First ionisation enthalpy of silver	+732
Enthalpy of formation of silver chloride	−127

(a) Calculate the bond enthalpy of a Cl–Cl bond.

    121 × 2 = 242 kjmol⁻¹

atomisation is when one mole of atoms formed. Here we would get 2 moles!!

(1)

(b) Explain why the bond enthalpy of a Cl–Cl bond is greater than that of a Br–Br bond.

    In Cl–Cl bond is shorter as Cl is a smaller atom and therefore the attraction between the nucleus and bond pair is stronger. *smaller atoms = stronger bonds.*
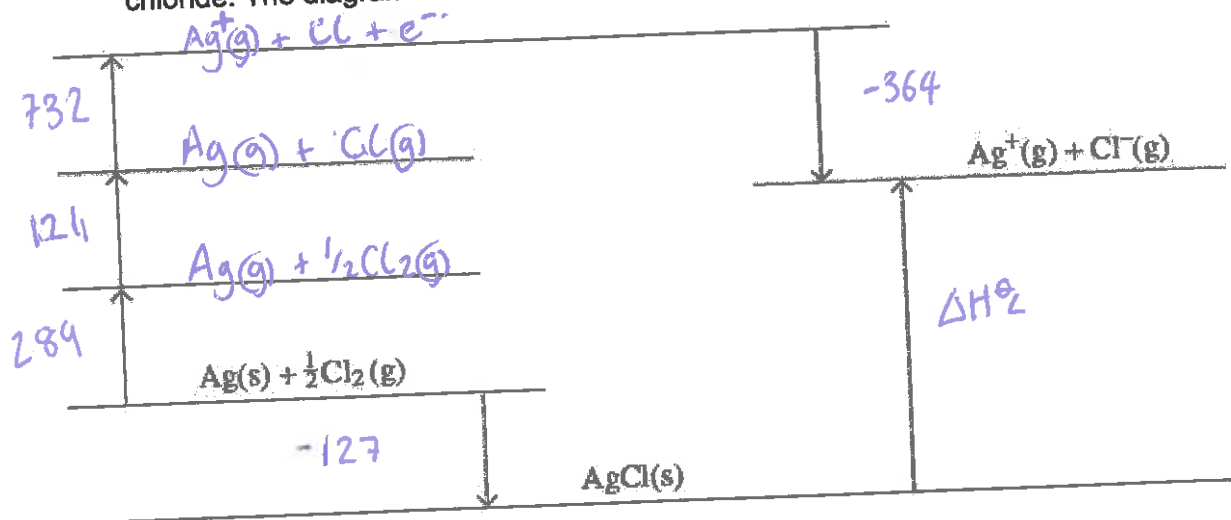
(2)

(c) Suggest why the electron affinity of chlorine is an exothermic change.

    There is an overall attraction between the chlorine nucleus and the extra electron *opposites attract*

(1)

Page 1

(d) The diagram below is an incomplete Born–Haber cycle for the formation of silver chloride. The diagram is not to scale.

$Ag^+(g) + Cl + e^-$

732

$Ag(g) + Cl(g)$

−364

$Ag^+(g) + Cl^-(g)$

121

$Ag(g) + \frac{1}{2}Cl_2(g)$

$\Delta H^{\ominus}_L$

289

$Ag(s) + \frac{1}{2}Cl_2(g)$

−127

$AgCl(s)$

(i) Complete the diagram by writing the appropriate chemical symbols, with state symbols, on each of the three blank lines. **(3)**

✓✓✓

(ii) Calculate a value for the enthalpy of lattice dissociation for silver chloride.

Remember all the ups minus all the downs!

$(127 + 289 + 121 + 732) - 364 = \Delta H^{\ominus}_L$

$\Delta H^{\ominus}_L = +905\ kJmol^{-1}$

(2)

(e) The enthalpy of lattice dissociation for silver chloride can also be calculated theoretically assuming a perfect ionic model.

(i) Explain the meaning of the term *perfect ionic model*.

Ions are point charges

(1)

(ii) State whether you would expect the value of the theoretical enthalpy of lattice dissociation for silver chloride to be greater than, equal to or less than that for silver bromide. Explain your answer.

Theoretical lattice enthalpy for silver chloride ...Greater...

Explanation ...chloride ions are smaller than bromide so therefore attracted more strongly to silver ions.
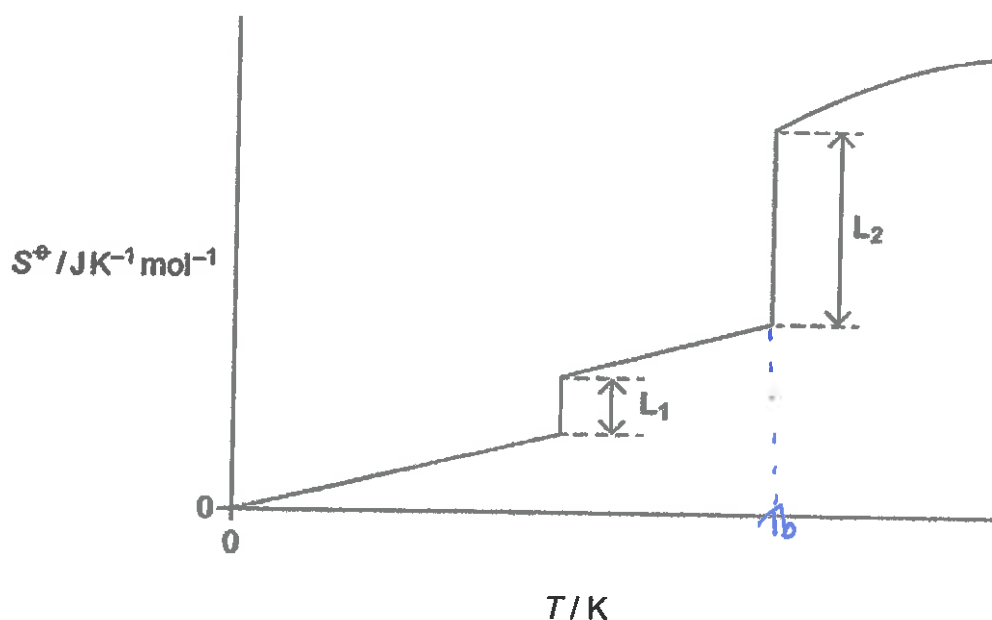
(3)

(iii) Suggest why your answer to part (d) (ii) is greater than the theoretical value for the enthalpy of lattice dissociation for silver chloride.

AgCl has covalent character which makes the bond stronger than expected.

(2)
(Total 15 marks)

Q2.(a) Figure 1 shows how the entropy of a molecular substance **X** varies with temperature.

Figure 1

(i) Explain, in terms of molecules, why the entropy is zero when the temperature is zero Kelvin.

At absolute zero particles are stationary, they do not vibrate. This means there is perfect order / No disorder.

(Extra space) ....

....

(2)

(ii) Explain, in terms of molecules, why the first part of the graph in **Figure 1** is a line that slopes up from the origin.

As T increases the particles gain energy and start to vibrate. This means that disorder has increased.

(Extra space) ....

....

(2)

(iii) On **Figure 1**, mark on the appropriate axis the boiling point (T_b) of substance **X**.

✓

(1)

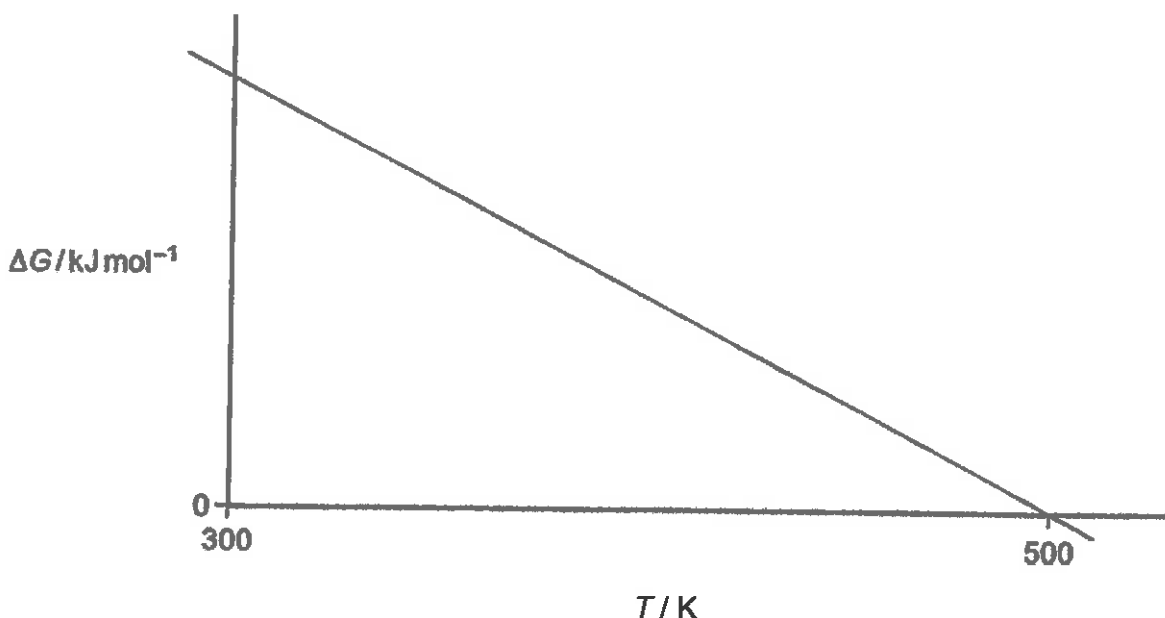(iv) In terms of the behaviour of molecules, explain why L_2 is longer than L_1 in **Figure 1**.

L1 is melting (solid to liquid) where as L2 is boiling (liquid to gas). There is a greater entropy change for L2/bigger change in disorder.

(Extra space) ....

....

(2)

(b) **Figure 2** shows how the free-energy change for a particular gas-phase reaction varies with temperature.

Figure 2

(i) Explain, with the aid of a thermodynamic equation, why this line obeys the mathematical equation for a straight line, $y = mx + c$.

$\Delta G = \Delta H - T\Delta S$

$\Delta H = c$ $\Delta S = m$
    ↖ x intercept   ↖ gradient

(2)

(ii) Explain why the magnitude of ΔG decreases as T increases in this reaction.

As T increases ΔS becomes more positive hence $-T\Delta S$ becomes more negative.

(1)

(iii) State what you can deduce about the feasibility of this reaction at temperatures lower than 500 K.

NOT FEASIBLE

Don't fall into the trap. Lower than 500K is left of 500 and hence ΔG becomes positive so NOT FEASIBLE!

(1)

(c) The following reaction becomes feasible at temperatures above 5440 K.

$$H_2O(g) \longrightarrow H_2(g) + \frac{1}{2}O_2(g)$$
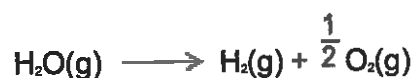
The entropies of the species involved are shown in the following table.

	$H_2O(g)$	$H_2(g)$	$O_2(g)$
S / J K^{-1} mol^{-1}	189	131	205

(i) Calculate the entropy change ΔS for this reaction.

131 + 102.5 = 233.5   233.5 − 189 = +44.5 J K^{-1} mol^{-1}

(1)

(ii) Calculate a value, with units, for the enthalpy change for this reaction at 5440 K.

(If you have been unable to answer part (c)(i), you may assume that the value of the entropy change is +98 J K^{-1} mol^{-1}. This is **not** the correct value.)

$\Delta G = \Delta H - T\Delta S$

@ Zero ΔG $\Delta H = T\Delta S$

$\Delta H = 5440 \times 44.5$

$\Delta H = 242080$ J mol^{-1} or 242 kJ mol^{-1}

(3)
(Total 15 marks)

Q3.   A reaction mechanism is a series of steps by which an overall reaction may proceed. The reactions occurring in these steps may be deduced from a study of reaction rates. Experimental evidence about initial rates leads to a rate equation. A mechanism is then proposed which agrees with this rate equation.

Ethanal dimerises in dilute alkaline solution to form compound **X** as shown in the following equation.

$$2CH_3CHO \rightarrow CH_3CH(OH)CH_2CHO$$

X
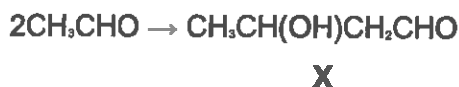
A chemist studied the kinetics of the reaction at 298 K and then proposed the following rate equation.

$$Rate = k \, [CH_3CHO][OH^-]$$

(a)   Give the IUPAC name of compound **X**.

3-hydroxybutanal

(1)

(b)   The initial rate of the reaction at 298K was found to be 2.2×10^{-3} mol dm^{-3} s^{-1} when the initial concentration of ethanal was 0.10 mol dm^{-3} and the initial concentration of sodium hydroxide was 0.020 mol dm^{-3}.

Calculate a value for the rate constant at this temperature and give its units.

Calculation $K = \dfrac{Rate}{[CH_3CHO][OH^-]}$ $k = \dfrac{2.2 \times 10^{-3}}{0.10 \times 0.020}$ $\dfrac{mol\,dm^{-3}s^{-1}}{mol\,dm^{-3} \times mol\,dm^{-3}}$
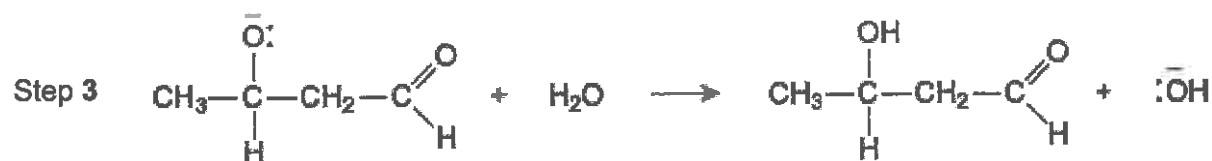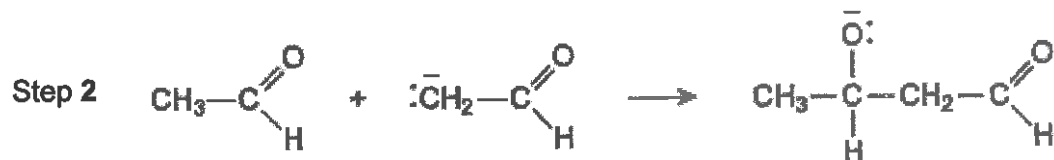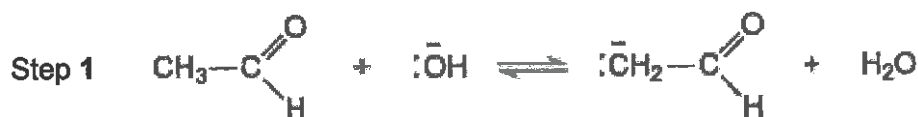
Units $K = 1.1 \ mol^{-1} dm^3 s^{-1}$

(3)

(c)   The sample of **X** produced consists of a racemic mixture (racemate). Explain how this racemic mixture is formed.

As the C=O is planar then there is equal probability of attack from above and below.

H
C=O   CH⁻
R

(2)

Page 7

(d) A three-step mechanism has been proposed for this reaction according to the following equations.

Step 1 CH_3-CHO + :$\overline{O}H$ $\rightleftharpoons$:$\overline{C}H_2-CHO$ + H_2O

Step 2 CH_3-CHO + :$\overline{C}H_2-CHO$ $\longrightarrow$ $CH_3-\overset{\overset{\displaystyle \overline{O}:}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-CH_2-CHO$

Step 3 $CH_3-\overset{\overset{\displaystyle \overline{O}:}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-CH_2-CHO$ + H_2O $\longrightarrow$ $CH_3-\overset{\overset{\displaystyle OH}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-CH_2-CHO$ + :$\overline{O}H$

(i) Using the rate equation, predict which of the three steps is the rate-determining step. Explain your answer.

Rate-determining step .....*Step 1*...

Explanation .....*Species are in the rate equation,*.....

....

(2)

It's donating a H+ to the OH:

(ii) Deduce the role of ethanal in Step **1**.
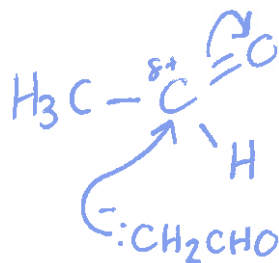.....*A Bronsted Lowry acid (Proton donor)*............

(1)

(iii) Use your knowledge of reaction mechanisms to deduce the type of reaction occurring in Step **2**.
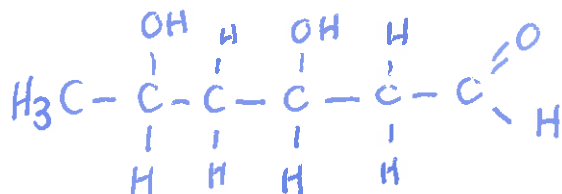.....*Nucleophilic addition*.....................................

(1)

(iv) In the space below draw out the mechanism of Step **2** showing the relevant curly arrows.

$$H_3C - \overset{\delta^+}{C} \overset{}{\underset{\diagdown H}{\overset{\diagup O}{=}}}$$

$$:CH_2CHO$$

(2)

(e) In a similar three-step mechanism, one molecule of **X** reacts further with one molecule of ethanal. The product is a trimer containing six carbon atoms.
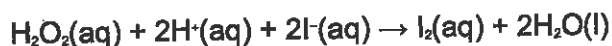
Deduce the structure of this trimer. → three identical or very similar units bonded together.

$$H_3C - \underset{\underset{H}{|}}{\overset{\overset{OH}{|}}{C}} - \underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}} - \underset{\underset{H}{|}}{\overset{\overset{OH}{|}}{C}} - \underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}} - C\overset{\diagup O}{\underset{\diagdown H}{}}$$

(1)
(Total 13 marks)

Q4. Hydrogen peroxide is a powerful oxidising agent. Acidified hydrogen peroxide reacts with iodide ions to form iodine according to the following equation.

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2H_2O(l)$$

The **initial rate** of this reaction is investigated by measuring the time taken to produce sufficient iodine to give a blue colour with starch solution.

A series of experiments was carried out, in which the concentration of iodide ions was varied, while keeping the concentrations of all of the other reagents the same. In each experiment the time taken (t) for the reaction mixture to turn blue was recorded.

The initial rate of the reaction can be represented as $\left(\dfrac{1}{t}\right)$, and the initial concentration of iodide ions can be represented by the volume of potassium iodide solution used.

A graph of $\log_{10}\left(\dfrac{1}{t}\right)$ on the y-axis against $\log_{10}$ (volume of KI(aq)) is a straight line. The gradient of this straight line is equal to the order of the reaction with respect to iodide ions.

The results obtained are given in the table below. The time taken for each mixture to turn blue was recorded on a stopclock graduated in seconds.

Expt.	Volume of KI(aq) / cm³	log₁₀ (volume of KI(aq))	Time / s	$\log_{10}\left(\dfrac{1}{t}\right)$
1	5	0.70	71	−1.85
2	8	0.90	46	−1.66
3	10	1.00	37	−1.57
4	15	1.18	25	−1.40
5	20	1.30	19	−1.28
6	25	1.40	14	−1.15

(a)   Use the results given in the table to plot a graph of $\log_{10}\left(\dfrac{1}{t}\right)$ on the y-axis against $\log_{10}$ (volume of KI(aq)).

Draw a straight line of best fit on the graph, ignoring any anomalous points.
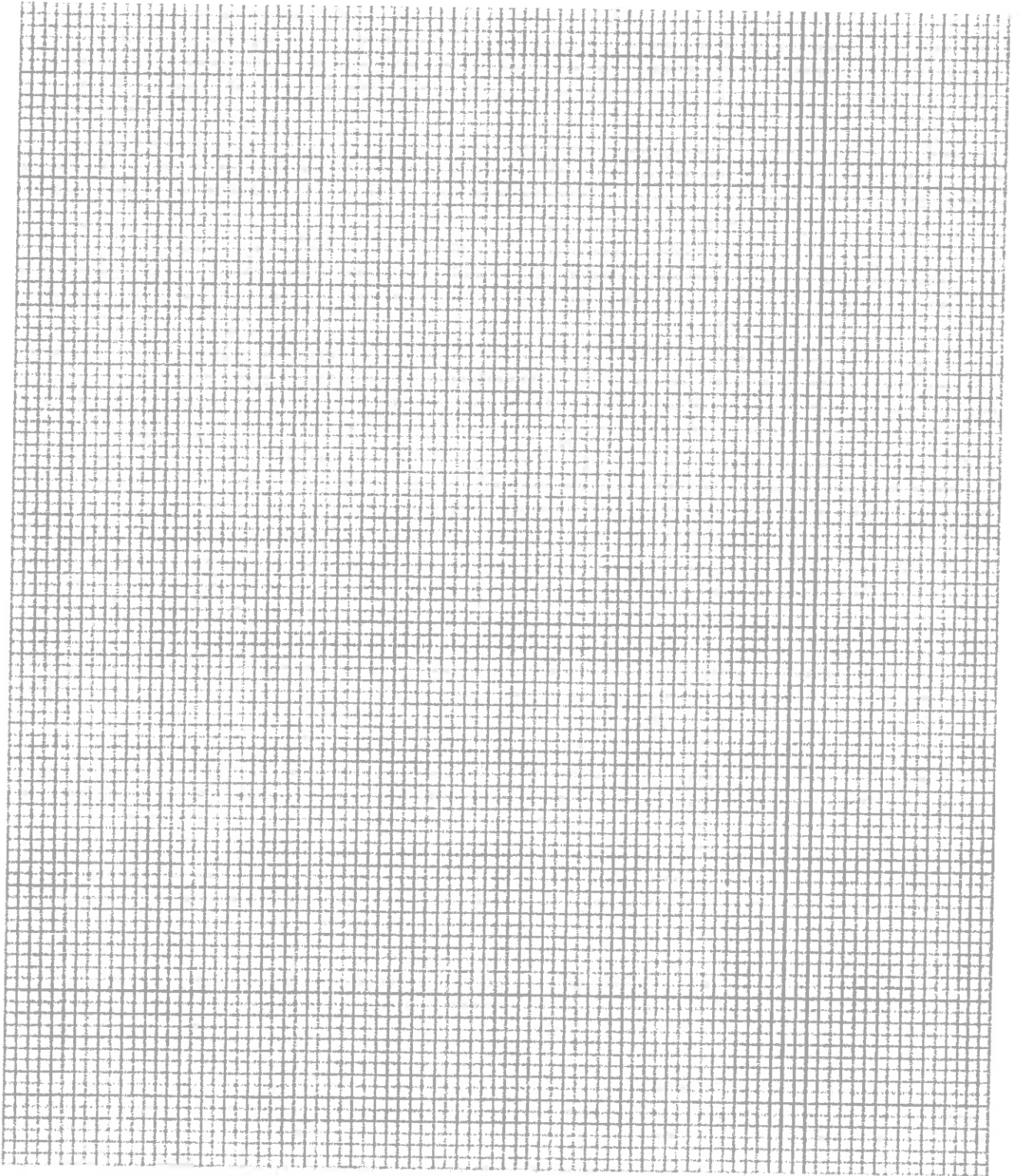
(5)

(b)   Determine the gradient of the line you have drawn. Give your answer to two decimal places. Show your working.

....

....

....

(3)

(c)   Deduce the order of reaction with respect to iodide ions.

....

(1)

(d)   A student carried out the experiment using a flask on the laboratory bench. The student recorded the time taken for the reaction mixture to turn blue. State **one** way this method could be improved, other than by repeating the experiment or by improving the precision of time or volume measurements. Explain why the accuracy of the experiment would be improved.

Improvement ....

....

Explanation ....

....

(2)
(Total 11 marks)

Q5. Many chemical processes release waste products into the atmosphere. Scientists are developing new solid catalysts to convert more efficiently these emissions into useful products, such as fuels. One example is a catalyst to convert these emissions into methanol. The catalyst is thought to work by breaking a H–H bond.
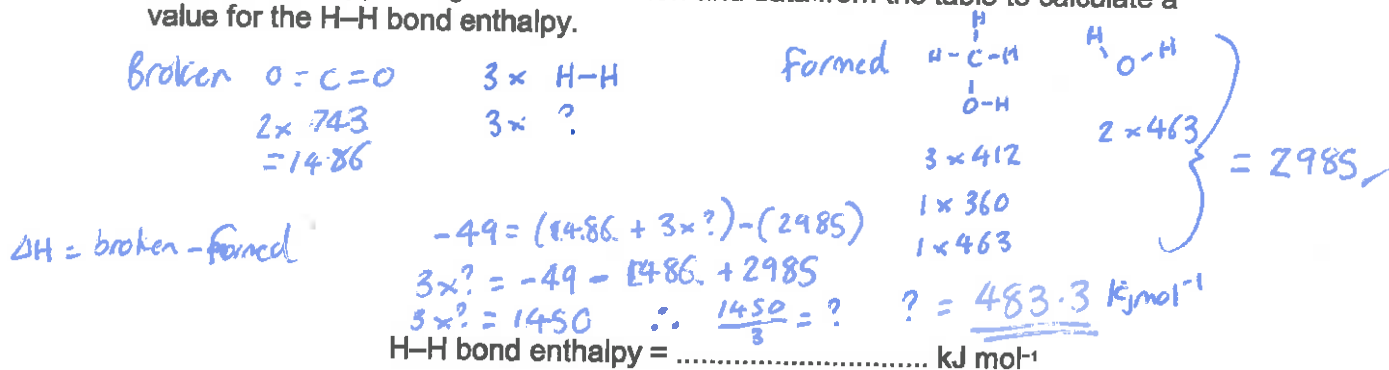
An equation for this formation of methanol is given below.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \quad \Delta H = -49 \text{ kJ mol}^{-1}$$
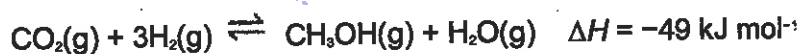
Some mean bond enthalpies are shown in the following table.

Bond	C=O	C–H	C–O	O–H
Mean bond enthalpy / kJ mol^{-1}	743	412	360	463

(a) Use the enthalpy change for the reaction and data from the table to calculate a value for the H–H bond enthalpy.

Broken $O=C=O$ $3 \times$ H–H   Formed   H–C–H   H O–H

2×743 $3 \times$?   O–H

$= 1486$ 2×463

3×412 $\Big\}= 2985$ ✓

$\Delta H =$ broken – formed $-49 = (1486 + 3 \times ?) - (2985)$ 1×360

$3 \times ? = -49 - 1486 + 2985$ 1×463

$3 \times ? = 1450$ $\therefore$ $\dfrac{1450}{3} = ?$ $? = 483.3 \text{ kJmol}^{-1}$

H–H bond enthalpy = ... kJ mol⁻¹

(3)

(b) A data book value for the H–H bond enthalpy is 436 kJ mol⁻¹.

Suggest **one** reason why this value is different from your answer to part (a).

uses mean bond enthalpies which are not the same as actual bond enthalpies – they have been averaged over a wide range of compounds

(1)

(c) Suggest **one** environmental advantage of manufacturing methanol fuel by this reaction.

The carbon dioxide produced by the combustion of methanol was used in the process of creating it.

(1)

(d) Use Le Chatelier's principle to justify why the reaction is carried out at a high pressure rather than at atmospheric pressure.

There are 4 moles of gas on the reactants side and 2 on the products. A high pressure causes the position of the equilibrium to shift to the right to oppose this. This would therefore increase the yield of methanol.

(3)

(e) Suggest why the catalyst used in this process may become less efficient if the carbon dioxide and hydrogen contain impurities.

Impurities in the compounds of sulfur could block the active sites of the catalyst.

(1)

(f) In a laboratory experiment to investigate the reaction shown in the equation below, 1.0 mol of carbon dioxide and 3.0 mol of hydrogen were sealed into a container. After the mixture had reached equilibrium, at a pressure of 500 kPa, the yield of methanol was 0.86 mol.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Calculate a value for K_p
Give your answer to the appropriate number of significant figures.
Give units with your answer.

	CO_2	$3H_2$ $\rightleftharpoons$	CH_3OH	H_2O
Initial	2.0	3.0	0	0
eqm	$1-0.86 =$ 0.14	$3-(3 \times 0.86)$ $= 0.42$	0.86	0.86

$0.14 + 0.42 + 0.86 + 0.86 = 2.28$ total moles of gas.

partial pressures $= \frac{mol}{fraction} \times total$

$\therefore$ $CO_2 = 0.14 \times \left(\frac{500}{2.28}\right) = 30.7$

$H_2 = 0.42 \times \left(\frac{500}{2.28}\right) = 92.1$

$CH_3OH = 0.86 \times \left(\frac{500}{2.28}\right) = 188.6$

$H_2O = 0.86 \times \left(\frac{500}{2.28}\right) = 188.6$

$kp = \dfrac{P_{CH_3OH} \times P_{H_2O}}{P_{CO_2} \times (P_{H_2})^3}$

$kp = \dfrac{188.6^2}{30.7 \times 42.1^3}$

$kp = 1.48 \times 10^{-3}$

$K_p =$ .....1.5×10^{-3}..... Units = ...kPa^{-2}.....

(7)
(Total 16 marks)

UNITS = $\dfrac{kPa \times kPa}{kPa \times kPa \times kPa \times kPa} = \underline{\underline{kPa^{-2}}}$

Q6. Water dissociates slightly according to the equation:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$
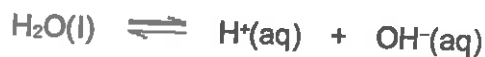
The ionic product of water, K_w, is given by the expression

$$K_w = [H^+][OH^-]$$

K_w varies with temperature as shown in the table.

Temperature / °C	K_w / mol² dm⁻⁶
25	1.00×10^{-14}
50	5.48×10^{-14}

(a) Explain why the expression for K_w does **not** include the concentration of water.

Concentration of H₂O is huge compared to [H+] and [OH⁻]. This means that it effectively a constant.

(2)

(b) Explain why the value of K_w increases as the temperature increases.

Bond breaking is endothermic when Temp increases then equilibrium will shift to the enothermic side (Right) to oppose the increase of Temp.

(2)

(c) Calculate the pH of pure water at 50 °C.
Give your answer to 2 decimal places.

$$K_w = (H^+)(OH^-)$$
$$5.48 \times 10^{-14} = (H^+)^2$$
$$\sqrt{5.48 \times 10^{-14}} = (H^+) \qquad -\log H^+ = 6.63$$

(3)

(d) Calculate the pH of 0.12 mol dm^{-3} aqueous NaOH at 50 °C.
Give your answer to 2 decimal places.

$K_w = [H^+][OH^-]$ $5.48 \times 10^{-14} = [H^+][0.12]$

$$\frac{5.48 \times 10^{-14}}{0.12} = 4.566 \times 10^{-13} \quad -\log 4.566 \times 10^{-13}$$

$$= 12.34$$

(3)
(Total 10 marks)

Q7. The acid dissociation constant, K_a, for ethanoic acid is given by the expression

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$$

The value of K_a for ethanoic acid is 1.74×10^{-5} mol dm^{-3} at 25 °C.

(a) A buffer solution is prepared using ethanoic acid and sodium ethanoate. In the buffer solution, the concentration of ethanoic acid is 0.186 mol dm^{-3} and the concentration of sodium ethanoate is 0.105 mol dm^{-3}.

Calculate the pH of this buffer solution.
Give your answer to 2 decimal places.

$$\frac{K_a \times (CH_3COOH)}{(CH_3COO^-)} = (H^+) \quad \frac{1.74 \times 10^{-5} \times 0.186}{0.105} = [H^+]$$

$[H^+] = 3.08 \times 10^{-5}$ $-\log(H^+) = 4.51$

(3)

(b) In a different buffer solution, the concentration of ethanoic acid is 0.251 mol dm^{-3} and the concentration of sodium ethanoate is 0.140 mol dm^{-3}.

A sample of hydrochloric acid containing 0.015 mol of HCl is added to 1000 cm^3 of this buffer solution.

Calculate the pH of the buffer solution after the hydrochloric acid has been added. You should ignore any change in total volume. Give your answer to 2 decimal places.

$$0.251 + 0.015 = 0.266 \quad HA$$

$$0.140 - 0.015 = 0.125 \quad A^-$$

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]} \qquad \frac{K_a \times [CH_3COOH]}{[CH_3COO^-]}$$

$$\frac{1.74 \times 10^{-5} \times 0.266}{0.125} = [H^+] = 3.7 \times 10^{-5}$$

$$-\log H^+ = 4.43$$

(5)
(Total 8 marks)

Q8. Titration curves, labelled **E, F, G** and **H**, for combinations of different aqueous solutions of acids and bases are shown below.

All solutions have concentrations of 0.1 mol dm^{-3}.
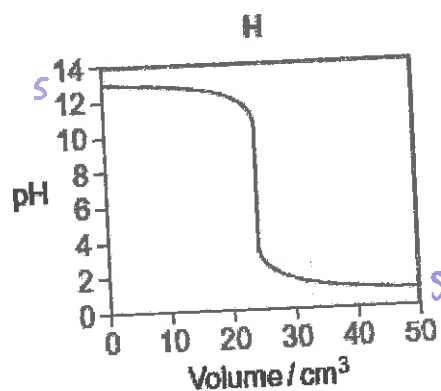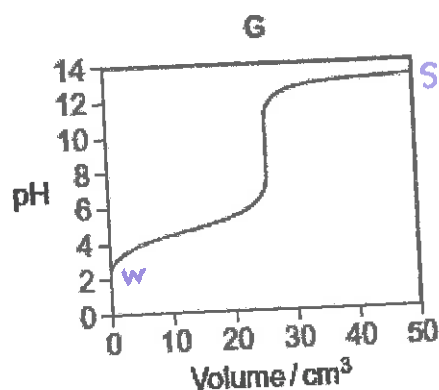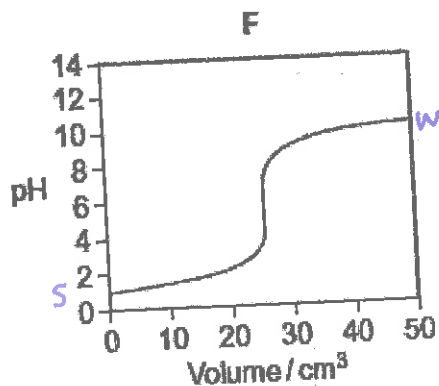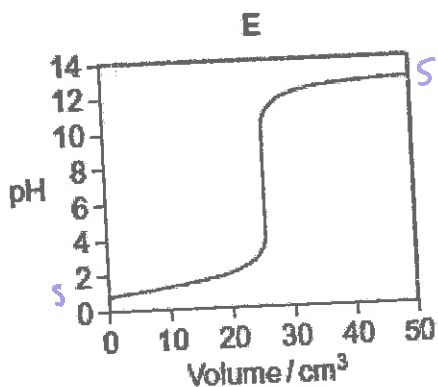
(a) In this part of the question, write the appropriate letter in each box.

From the curves **E, F, G** and **H**, choose the curve produced by the addition of

(i) sodium hydroxide to 25 cm^3 of ethanoic acid

w to S

G

(1)

(ii) ammonia to 25 cm^3 hydrobromic acid

S to w

F

(1)

(iii) hydrochloric acid to 25 cm^3 of potassium hydroxide

S to S

H

(1)

(b) The table shows information about some acid-base indicators.

Indicator	pH range	Lower pH colour (Acid)	Higher pH colour (Basic)
pentamethoxy red	1.2–3.2	violet	colourless
naphthyl red	3.7–5.0	red	yellow
4–nitrophenol	5.6–7.0	colourless	yellow
cresol purple	7.6–9.2	yellow	purple

(i) Which indicator in the table could be used for the titration that produces curve **E** but **not** for the titration that produces curve **F**?

Tick (✓) **one** box.

pentamethoxy red ☐

naphthyl red ☐

4–nitrophenol ☐

cresol purple ✓

(1)

(ii) Give the colour change at the end point of the titration that produces curve **H** when naphthyl red is used as the indicator.

.... yellow to red ....

(1)

(iii) A beaker contains 25 cm³ of a buffer solution at pH = 6.0
Two drops of each of the four indicators in the table are added to this solution.

State the colour of the mixture of indicators in this buffer solution.
You should assume that the indicators do **not** react with each other.

.... yellow ....

(1)
(Total 6 marks)

Q9. Ibuprofen is a drug used as an alternative to aspirin for the relief of pain, fever and inflammation. The structure of ibuprofen is shown below.
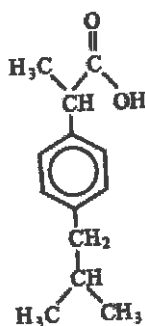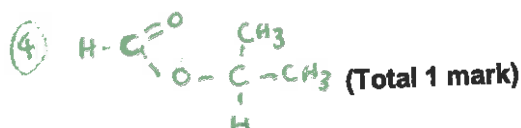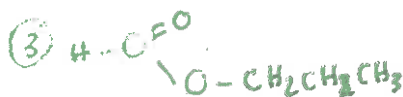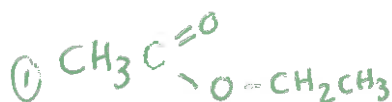
(handwritten) COOH group cannot be oxidised

Which one of the following statements is **not** correct?

A   It has optical isomers.

B   It liberates carbon dioxide with sodium carbonate solution.

D   It undergoes esterification with ethanol.

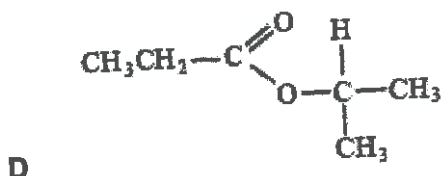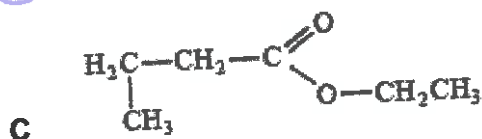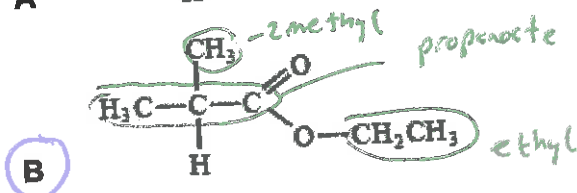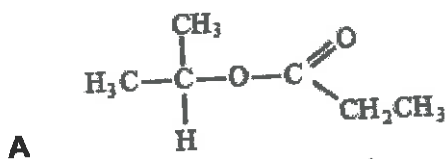(D)   It undergoes oxidation with acidified potassium dichromate(VI).   **(Total 1 mark)**

Q10. How many structural isomers, which are esters, have the molecular formula $C_4H_8O_2$?
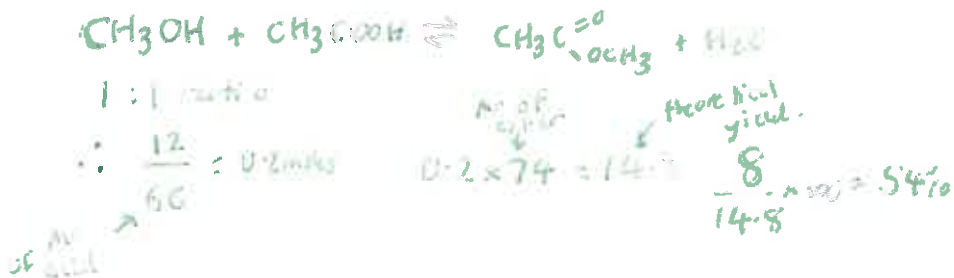
A   2

B   3

(C)   4

D   5

(handwritten structures)
① $CH_3C{\overset{O}{\underset{O-CH_2CH_3}{\diagup}}}$ ② $CH_3CH_2C{\overset{O}{\underset{O-CH_3}{\diagup}}}$

③ $H-C{\overset{O}{\underset{O-CH_2CH_2CH_3}{\diagup}}}$ ④ $H-C{\overset{O}{\underset{O-C-CH_3}{\diagup}}}$ with CH_3 and H **(Total 1 mark)**

Q11. The structural formula of ethyl 2-methylpropanoate is

A
$$H_3C-\underset{\underset{H}{|}}{\overset{\overset{CH_3}{|}}{C}}-O-C{\overset{O}{\underset{CH_2CH_3}{\diagup}}}$$

B
(handwritten: -2methyl propanoate)
$$H_3C-\underset{\underset{H}{|}}{\overset{\overset{CH_3}{|}}{C}}-C{\overset{O}{\underset{O-CH_2CH_3}{\diagup}}}$$ *ethyl*

C
$$H_3C-CH_2-C{\overset{O}{\underset{O-CH_2CH_3}{\diagup}}}$$ with CH_3

D
$$CH_3CH_2-C{\overset{O}{\underset{O-\underset{\underset{CH_3}{|}}{\overset{\overset{H}{|}}{C}}-CH_3}{\diagup}}}$$

(Total 1 mark)

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Q12. An excess of methanol was mixed with 12 g of ethanoic acid and an acid catalyst. At equilibrium the mixture contained 8 g of methyl ethanoate. The percentage yield of ester present was
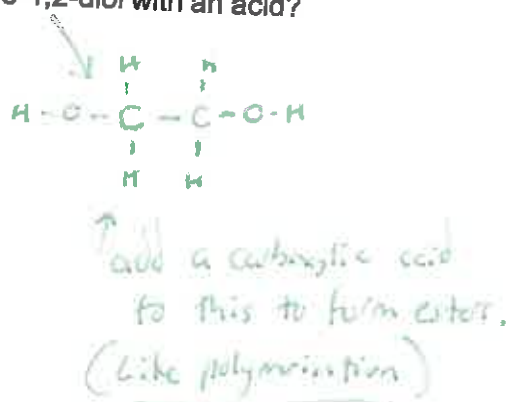
A   11

B   20

C   54

D   67

(handwritten working:) $CH_3OH + CH_3COOH \rightleftharpoons CH_3C\overset{=O}{\underset{OCH_3}{}} + H_2O$

1 : 1 ratio

$\frac{12}{60} = 0.2$ moles

$0.2 \times 74 = 14.8$ theoretical yield

$\frac{8}{14.8} \times 100 = 54\%$

(Total 1 mark)

Q13. Which compound is formed by the reaction of ethane-1,2-diol with an acid?

A $H-\overset{O}{\overset{\|}{C}}-CH_2-\overset{O}{\overset{\|}{C}}-CH_3$

B $H-\overset{O}{\overset{\|}{C}}-O-CH_2CH_2-O-\overset{O}{\overset{\|}{C}}-H$

C $H_3C-\overset{O}{\overset{\|}{C}}-O-\overset{O}{\overset{\|}{C}}-CH_3$

D $CH_3CH_2-O-CH_2CH_2OH$

(handwritten:) $H-O-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-O-H$

add a carboxylic acid to this to form ester.

(Like polymerisation)

(Total 1 mark)

Q14. Butan-1-ol was converted into butyl propanoate by reaction with an excess of propanoic acid. In the reaction, 6.0 g of the alcohol gave 7.4 g of the ester. The percentage yield of ester was
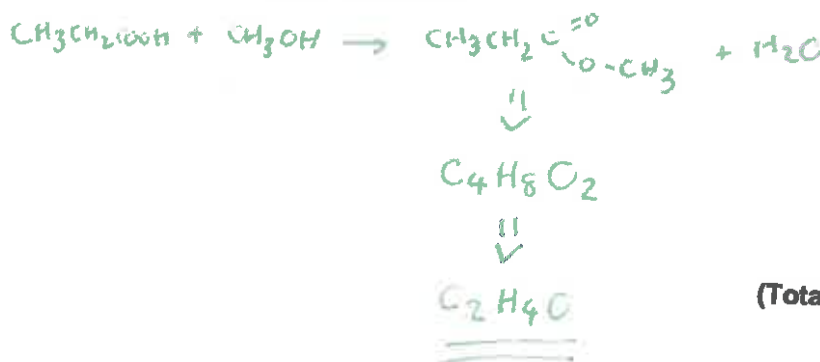
A   57

B   70

C   75

D   81

(handwritten:) $CH_3CH_2CH_2CHOH + CH_3CH_2COOH \rightarrow CH_3CH_2C\overset{=O}{\underset{O-CH_2CH_2CH_2CH_3}{}} + H_2O$

1 : 1 ratio!

Mr $\frac{6}{72} = 0.082$ moles $0.082 \times 130 = 10.66$ theoretical yield

$\frac{7.4}{10.66} \times 100 = 69.4$ // 70%
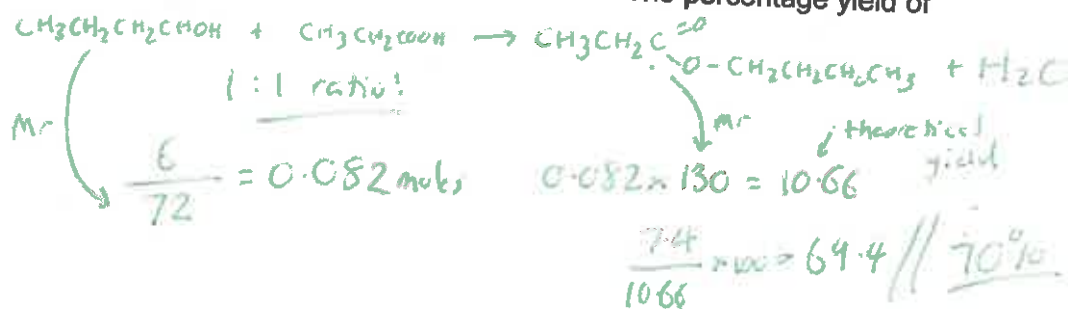
(Total 1 mark)

Q15. Propanoic acid reacts with methanol in the presence of a small amount of concentrated sulphuric acid. The empirical formula of the ester formed is
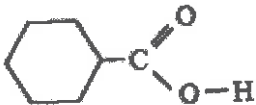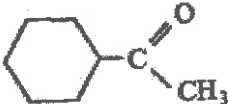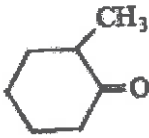
A CH_2O

B $C_2H_6O_2$

C $C_2H_4O_2$

D C_2H_4O

(handwritten:) $CH_3CH_2COOH + CH_3OH \rightarrow CH_3CH_2C\overset{=O}{\underset{O-CH_3}{}} + H_2O$

$C_4H_8O_2$

C_2H_4O

(Total 1 mark)

Q16. The compound lithium tetrahydridoaluminate(III), $LiAlH_4$, is a useful reducing agent. It behaves in a similar fashion to $NaBH_4$. Carbonyl compounds and carboxylic acids are reduced to alcohols. However, $LiAlH_4$ also reduces water in a violent reaction so that it must be used in an organic solvent.

Which one of the following can be reduced by $LiAlH_4$ to a primary alcohol?

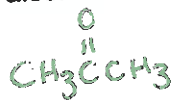A *(cyclohexanone structure with =O)*

B *(cyclohexane with C=O and O–H group, circled)*

carboxylic acids are reduced to primary alcohols.

C *(cyclohexane with C=O and CH₃ group)*

all the rest were ketones

D *(cyclohexane with CH₃ and =O)*

(Total 1 mark)

Q17. Propanone can be reduced to form an alcohol. A functional group isomer of the alcohol formed is

$CH_3\overset{\overset{O}{\parallel}}{C}CH_3$ ← 6 hydrogens.
so cant be A.

A $CH_3CH_2CH_2OH$ ✗

ketones form secondary alcohols
so not B. and D is just propanone!!

B CH_3CH_2CHO

Ⓒ $CH_3OCH_2CH_3$

D CH_3COCH_3

(Total 1 mark)

Q18. Which alcohol could **not** be produced by the reduction of an aldehyde or a ketone?

A   2-methylbutan-1-ol   ☐

Ⓑ   2-methylbutan-2-ol   ☐

C   3-methylbutan-1-ol   ☐

D   3-methylbutan-2-ol   ☐

(structure drawn: H–C–C–C–C–H with OH and CH₃ branches)
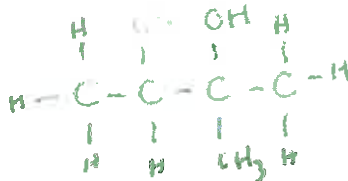
B is a tertiary alcohol.
Cannot be formed from reduction of aldehyde or ketone.

(Total 1 mark)

Q19. Which compound forms optically active compounds on reduction?

A $CH_3CH_2C(CH_3)=CHCH_3$ ☐

B $CH_3CH_2C(CH_3)=CH_2$ ☐

C CH_3COCH_3 ☐

(D) $CH_3CH_2COCH_3$ ☐

(handwritten: planar carbonyl – equal attack above + below plane – will give rise to chiral carbon.)

(handwritten: $CH_3CH_2 \overset{O}{\overset{||}{C}}-CH_3$)

(Total 1 mark)

Q20.

Summarised directions for recording responses to multiple completion questions			
A (i), (ii) and (iii) only	**B** (i) and (iii) only	**C** (ii) and (iv) only	**D** (iv) alone

Isomers of the ester $HCOOCH_2CH_2CH_3$, include   *(handwritten: 4 carbons)*

(i)   ethyl ethanoate   *(handwritten: 4)*

(ii)   methyl propanoate   *(handwritten: 4)*

(iii) butanoic acid   *(handwritten: 4)*

(iv)   butyl methanoate   *(handwritten: ← 5 carbons (cannot be iv!))*

(Total 1 mark)

Q21.

Summarised directions for recording responses to multiple completion questions			
A (i), (ii) and (iii) only	**B** (i) and (iii) only	**C** (ii) and (iv) only	**D** (iv) alone

Products from the acid hydrolysis of the ester $CH_3CH_2COOCH_2CH_3$ include

(i) CH_3CH_2COOH *(handwritten: propanoic ✓)*

(ii) CH_3COOH *(handwritten: ✗)*

(iii) CH_3CH_2OH *(handwritten: ethanol ✓)*

(v) $CH_3CH_2CH_2OH$ *(handwritten: ✗)*

(handwritten: $CH_3CH_2C \overset{O}{\underset{O-CH_2CH_3}{}}$ made from propanoic acid and ethanol)

(Total 1 mark)