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Draw a cross through the box (☒) if you have NOT written in this booklet

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 3 Chemistry 2024

91391 Demonstrate understanding of the properties of organic compounds

Credits: Five

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of the properties of organic compounds.	Demonstrate in-depth understanding of the properties of organic compounds.	Demonstrate comprehensive understanding of the properties of organic compounds.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

A periodic table and other reference material are provided in the Resource Booklet L3–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area. This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

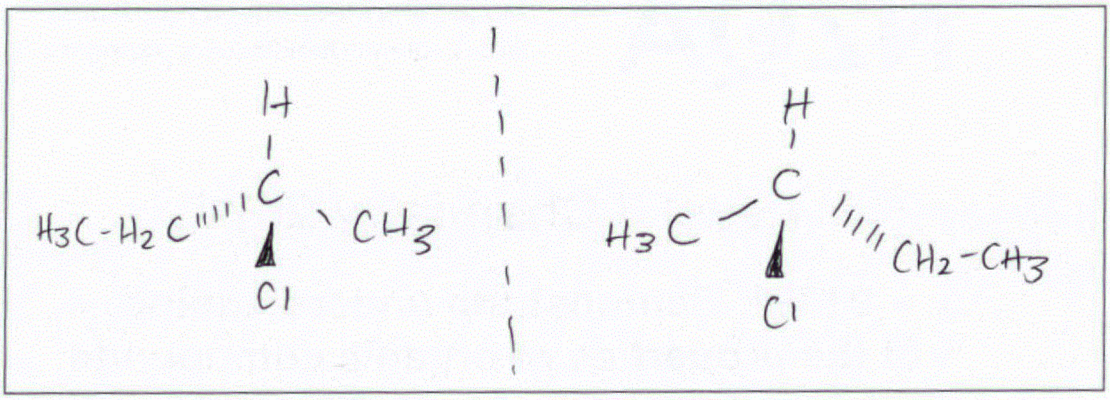
TOTAL 19

QUESTION ONE

(a) 2-chlorobutane exists as enantiomers (optical isomers).

$$CH_3-CH_2-\underset{\displaystyle Cl}{\underset{|}{C}}H-CH_3$$

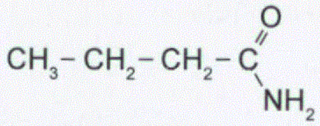
(i) Draw the enantiomers of 2-chlorobutane in the box below.



(ii) Explain why 2-chlorobutane can exist as enantiomers.

2-chlorobutane can exist as enantiomers due to the presence of an asymmetric carbon — a carbon with 4 different groups attached to it, making it chiral.

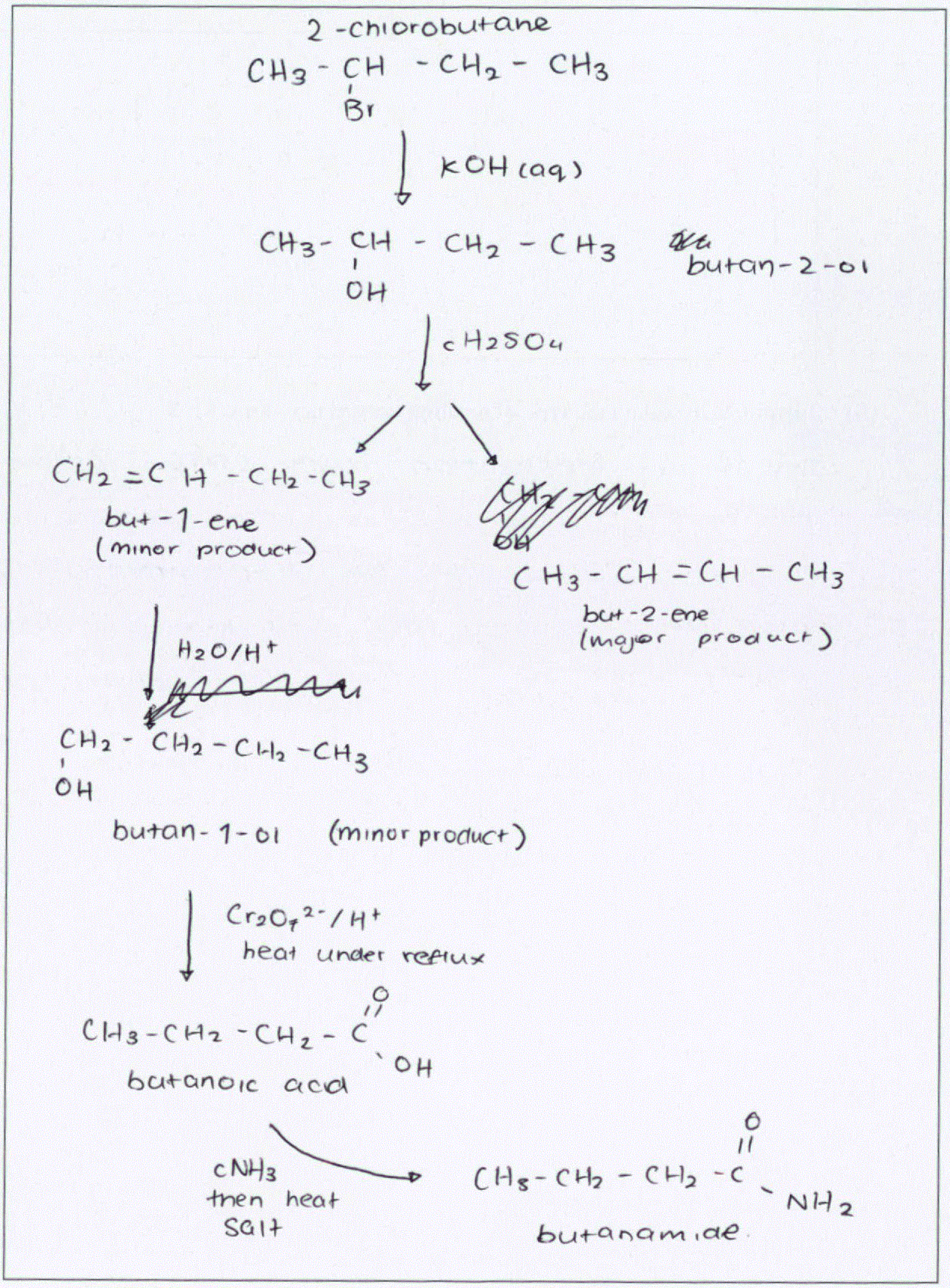
(iii) Devise a reaction scheme to convert 2-chlorobutane into butanamide.



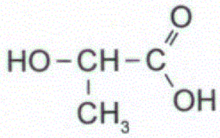
butanamide

For each step include:

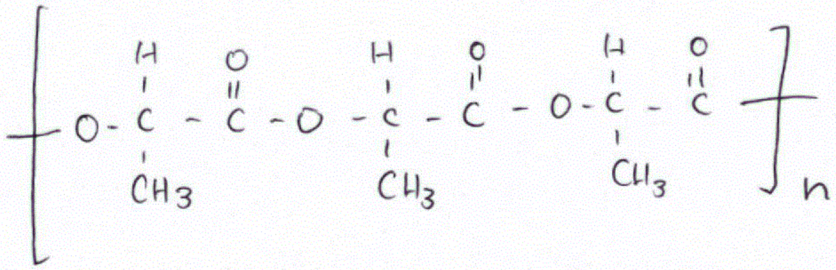
- the reagents
- the structural formula of the organic product after each step.



(b) Polylactic acid (PLA) is a polyester with various uses, including medical implants, tissue engineering, and 3D printing. It is made from lactic acid, shown below:



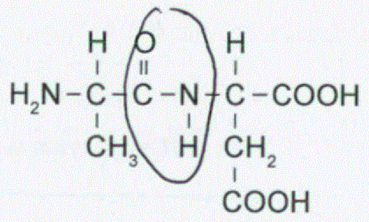
(i) In the box below, draw a section of the PLA chain to show THREE repeating units.



(ii) Identify and explain the type of reaction occurring to form PLA.

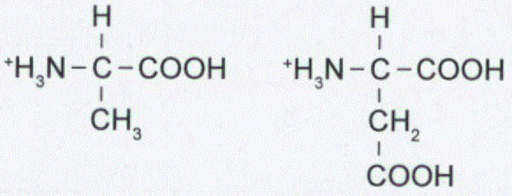
This is a condensation polymerisation, as small monomers join together to create a longer polymer chain, and one H_2O molecule is produced / released per ester link (an OH from COOH and an H from COH) hence 'condensation'.

(c) Below is the structural formula of a dipeptide:



(i) Circle the amide (peptide) linkage on the dipeptide above.

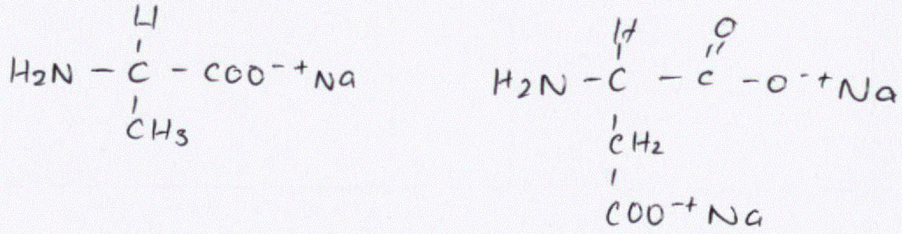
(ii) The dipeptide can undergo a chemical reaction to form the following products:



Identify and justify the type of chemical reaction that has occurred to form the above products.

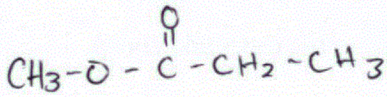
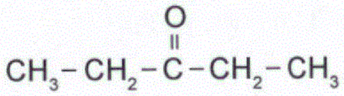
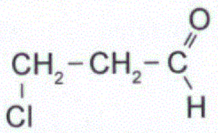
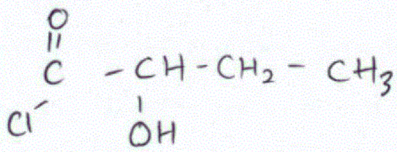
This is acidic hydrolysis. Hydraysis reactions split the dipeptide at the amide link using one H_2O molecule to form 2 amino acids. An OH is added to C=O to form $\overset{O}{\overset{\|}{C}}$–OH, and an H is added to N–H to form NH_2. Under acidic conditions, (ie using dil H_2SO_4), ~~a~~ the NH_2 is protonated to form NH_3^+, as in the amino acids shown above. These reactions require dil ~~HCl~~ acid, and heat under reflux.

(iii) Draw the structural formulae of the organic products formed when the dipeptide is heated under reflux with sodium hydroxide solution.

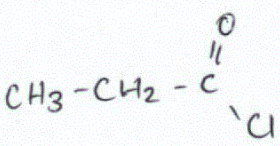
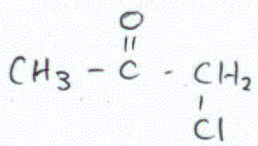
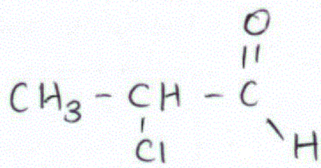


QUESTION TWO

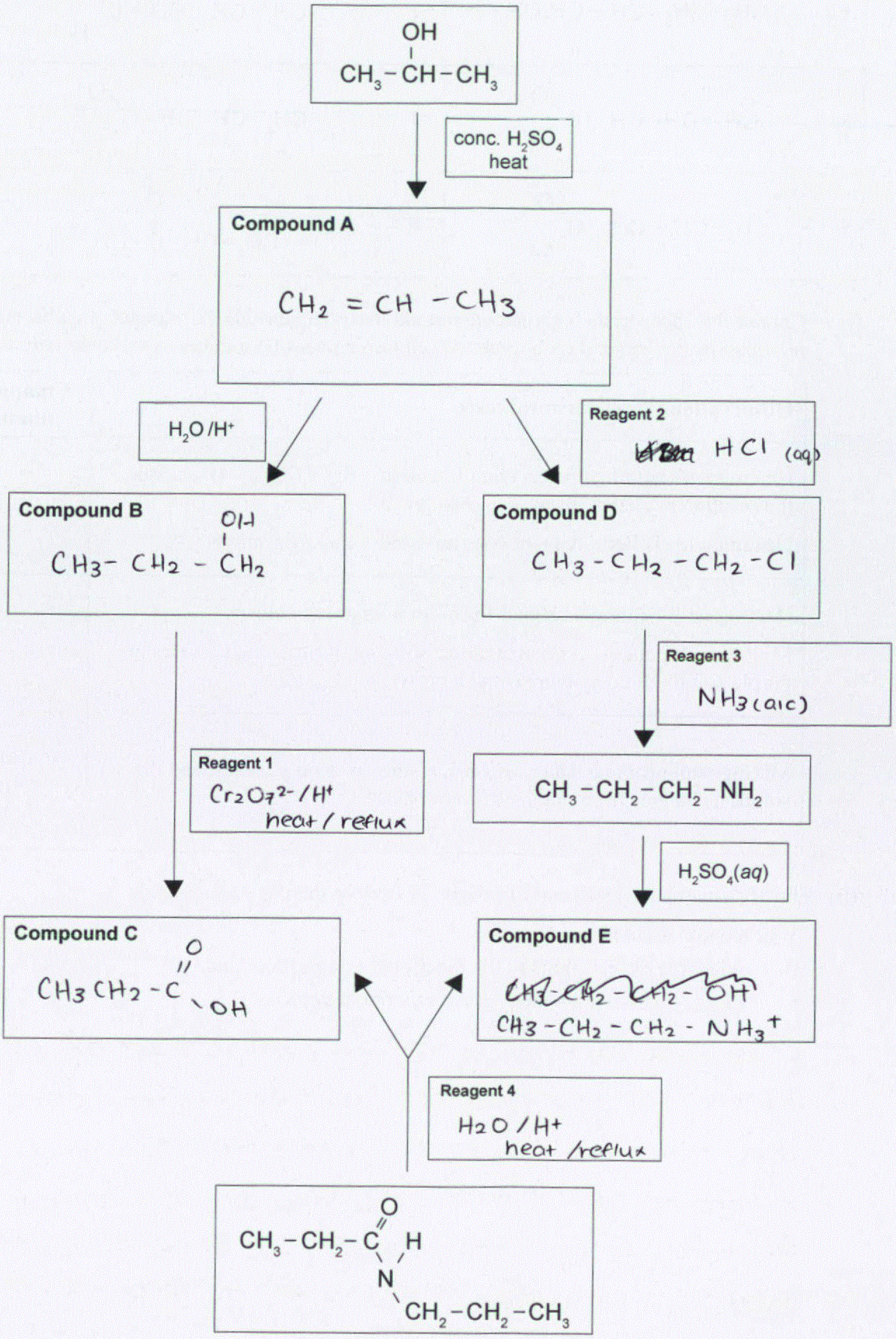
(a) (i) Complete the table below to show the structural formula or the IUPAC (systematic) name for each compound.

Compound	Structural formula	IUPAC (systematic) name
A		methyl propanoate
B		pentan-3-one
C		3-chloropropanal
D		2-hydroxybutanoyl chloride

(ii) Draw THREE constitutional (structural) isomers of **Compound C** that contain a carbonyl group (C=O). C_3H_5OCl

(b) Complete the flowchart below by drawing the structural formulae for **Compounds A**, **B**, **C**, **D**, and **E**, and identifying **Reagents 1**, **2**, **3**, and **4**.



(c) The following table lists the structural formulae for six different organic compounds.

1	$CH_3-CH_2-CH_2-CH_2OH$	**2**	$CH_3-CH_2-CH_2-C(=O)H$
3	$CH_2=CH-CH_2-C(=O)H$	**4**	$CH_3-CH=CH-C(=O)Cl$
5	$CH_3-CH_2-CH_2-C(=O)Cl$	**6**	$CH_2=CH-C(=O)-CH_3$

(i) Choose the appropriate organic compounds from the table above to match the observations recorded from chemical tests. Enter the chosen compound number in the table below.

Observations from chemical tests	**Compound number**
Heating with acidified potassium dichromate, $K_2Cr_2O_7(aq)/H^+$, causes the solution to change from orange to green. [illegible]. Heating with Tollens' reagent does not produce a silver mirror.	6
Heating with Fehling's reagent forms an orange-red solid. Mixing with potassium permanganate solution, $KMnO_4(aq)$, causes the purple solution to decolourise and a brown solid to form.	3
Mixing with bromine water, $Br_2(aq)$, results in steamy fumes, and the solution changes from orange to colourless.	4

(ii) Justify your chosen structural formula for each of the three compounds.

Your answer should:

- relate the observations to the functional groups identified
- identify and explain the types of reaction involved.

~~Compound~~ The first compound must ~~have an~~ be a ketone, as these cannot further oxidise, thus do not react with Tollen's reagent. This must be compound 6. Compound 6 also has an alkene functional group, allowing it to oxidise with heat + acidified dichromate to produce a diol, and turning ~~from~~ acidified dichromate from

orange to green.
The second compound must be an aldehyde to further oxidise and react with Fehling's reagent in an oxidation reaction to a carboxylic acid & turning blue solution to an orange-red solid. This may be compound 2 or 3. However, it must also be able to ~~oxidise~~ undergo oxidation with $KMnO_{4(aq)}$, compound 3 has an alkene group allowing it to be oxidised to a diol and go from a purple solution to a brown solid. Compound 3 must mix with Br_2 water to change from orange to colourless & produce steamy white fumes. This must be compound 4. Compound 4 has an alkene double bond that undergoes an addition reaction with Br_2 to rapidly decolorise it from orange to colourless, ~~dd~~ and one Br atom is added to each C across the double bond. It must also produce steamy white fumes, which occurs when ~~the~~ the acid chloride group on compound 4 reacts with water (bromine water) to ~~be~~ undergo a substitution reaction to produce a carboxylic acid & steamy white fumes of HCl gas.

QUESTION THREE

(a) A student followed the procedure outlined below to prepare a pure sample of ethyl propanoate in the laboratory:

Step 1: Add propanoic acid, ethanol, and concentrated H_2SO_4 to a round-bottomed flask.

Step 2: Heat the reaction mixture under reflux for 30 minutes.

Step 3: Add sodium carbonate until the bubbling stops.

Step 4: Add water and separate the layers.

Step 5: Add a drying agent to the organic layer.

Step 6: Distill the organic layer to purify the ethyl propanoate.

(i) Describe the function of the concentrated H_2SO_4 added in step 1.

Provides acidic conditions so that the propanoic acid & the ethanol can undergo a rapid condensation/ esterification where an H_2O molecule is removed.

(ii) Give TWO reasons to explain why the reaction mixture was heated under reflux in step 2.

(1) Heating the reaction under reflux speeds up the rate of reaction and ensures the reaction is gone to completion. Volatile chemicals that vaporise are condensed and drop back into the flask via gravity so that all products are fully reacted.

(2) Also increases the yield of the product as it ensures that no reactant or product is lost ~~[illegible]~~ due to vaporisation and the ~~[illegible]~~ yield of the product increases.

(iii) Why was sodium carbonate added in step 3?

~~To change the ester~~ The sodium carbonate reacts with the H_2SO_4 in an acid-base reaction to neutralise the sample & produce water & a neutral salt. ~~[illegible]~~ ~~[illegible]~~ ~~$Na_2CO_3 + H_2SO_4 \rightarrow Na + CO_2 + H_2O$~~

(iv) Explain how distillation was used in step 6 to purify the ethyl propanoate from the organic layer.

Your answer should refer to relevant boiling point(s) from the table below.

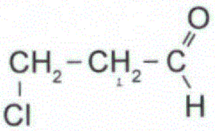
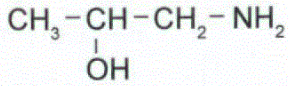
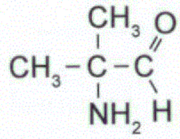
Compound	Boiling point / °C
Propanoic acid	141
Ethanol	78.3
Ethyl propanoate	99.1

Distilation is used to separate (purify) a substance from a mixture. As the mixture is heated, the compound with the lowest bp will vaporise first ☆ and enter the condensor. ~~As ethyl propanoic acid is polar & does not create a layer with H_2O, only the ethanol & ethyl propanoate are present in the organic layer.~~ As the organic layer is distilled, the ethanol will vaporise first & enter the condensor, where it is condensed back into a liquid & ~~dropped~~ falls into a separate flask. Ethanol has a lower bp of 78.3, so all of the ethanol will be removed before the ethyl propanoate, leaving only ethyl propanoate ~~in the flask and thus purifying the~~ ~~(and propanoic acid in the flask. The distillation can then be used to vaporise the ethyl propanoate which has a lower b.p than propanoic acid)~~ will remain in the flask, thus purifying it.

☆ Only ethanol and ethyl propanoate will be present in the organic layer as they ~~do not mix~~ are not soluble in water.

Question Three continues on the next page.

(b) (i) Consider Compounds A, B, and C, shown below:

Compound A	**Compound B**	**Compound C**
		

Choose the ONE compound that has ALL the following properties:

- cannot exist as enantiomers (optical isomers)
- forms a silver mirror when heated with Tollens' reagent
- turns damp red litmus paper blue.

Compound (A, B, or C): C

Explain your choice.

Compound C does not contain a chiral carbon (carbon with 4 different groups attached) due to the two methyl (CH_3) groups attached to it, so it cannot form enantiomers.

Compound C also has an aldehyde group, which is able to oxidise with Tollen's to form a silver mirror.

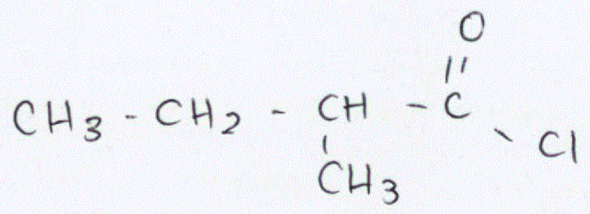
It also has an amine group attached to it, giving it ~~acidic~~ basic properties and thus it can undergo an acid-base reaction ~~with~~ ~~it~~ and turn damp red litmus blue.

Cannot be compound A as it contains a chiral carbon.

Cannot be compound B as it cannot react with Tollen's reagent to form a silver mirror.

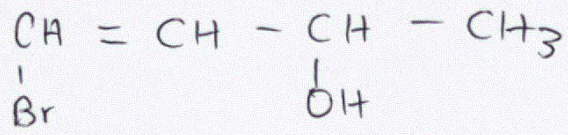
(ii) Draw the structural formula for the constitutional (structural) isomer of C_5H_9OCl that has the following properties:

- exists as enantiomers (optical isomers)
- branched carbon chain
- produces steamy fumes upon addition of water.



(iii) Draw the structural formula for the constitutional (structural) isomer of C_4H_7OBr that has the following properties:

- exists as cis-trans (geometric) isomers
- straight chain arrangement
- causes a colour change of orange to green when heated with acidified potassium dichromate to produce an organic product that does not react with Benedict's solution.



Excellence

Subject: Chemistry

Standard: 91391

Total score: 19

Q	Grade score	Marker commentary
One	E7	To gain E8 the candidate would need to have included the carboxylic acid to acyl chloride step with reagent $SOCl_2$.
Two	M5	To gain E7 or E8 the candidate would need to have all reagents correct in reaction scheme. And selected three correct compounds with all functional groups linked to observations and reaction types explained for 2 compounds with a minor error in the third.
Three	E7	To gain E8 the candidate would need to have recognised that heating a solution under reflux increases the rate of reaction and used data to support the distillation explanation.