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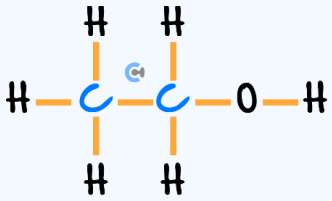
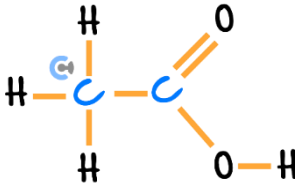
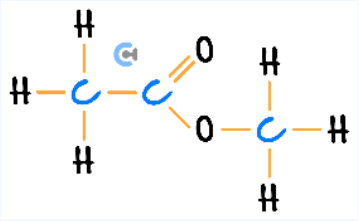
VCE Chemistry ½
Functional Groups in Organic Chemistry [0.19]
Workshop Solutions

Error Logbook:

New Ideas/Concepts	Didn't Read Question
Pg / Q #: _____ Notes:	Pg / Q #: _____ Notes:
Algebraic/Arithmetic/ Calculator Input Mistake	**Working Out Not Detailed Enough**
Pg / Q #: _____ Notes:	Pg / Q #: _____ Notes:

Section A: Recap

Learning Objective: [2.7.1] - Apply IUPAC Conventions to Identify, Draw & Write IUPAC Names of Straight-Chained & Branched Carboxylic Acids

Structural Formula	Functional Group	Class of Molecule	Prefix / Suffix
	Hydroxyl	Alcohol	Hydroxy- or -ol
	Carboxyl	Carboxylic acid	-oic acid
	Ester		N/A

- As carboxyl groups must always be at the end, numbers [do] / [do not] need to be specified!
- **Multiple Functional Groups Naming Steps:**

1. **Find** the **primary functional group** first (highest on the table in the databook).
2. Primary functional group assigned: [Prefix] / [Suffix] naming.
3. Other functional groups assigned: [Prefix] / [Suffix] naming.

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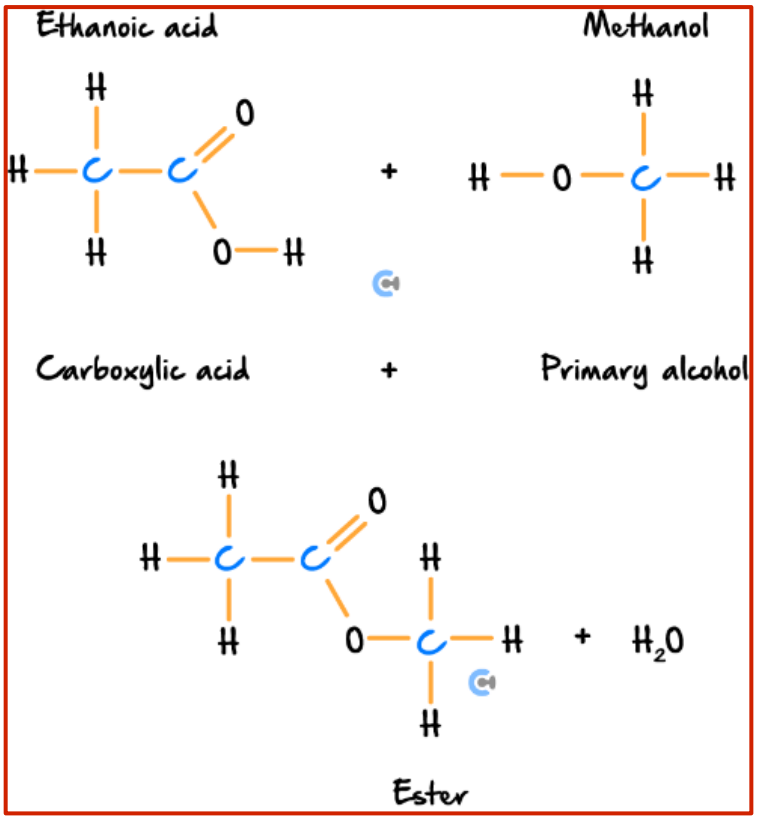
Learning Objective: [2.7.2] - Write Condensation Reactions for the Formation of Esters & Relevant Catalysts / Conditions

- Condensation Reaction Produces: ____ H_2O ____



- Ester Name: _____ Methyl ethanoate _____

Learning Objective: [2.7.3] - Apply IUPAC Conventions to Identify, Draw & Write IUPAC Names of Straight-Chained Esters

- **Naming Esters:**

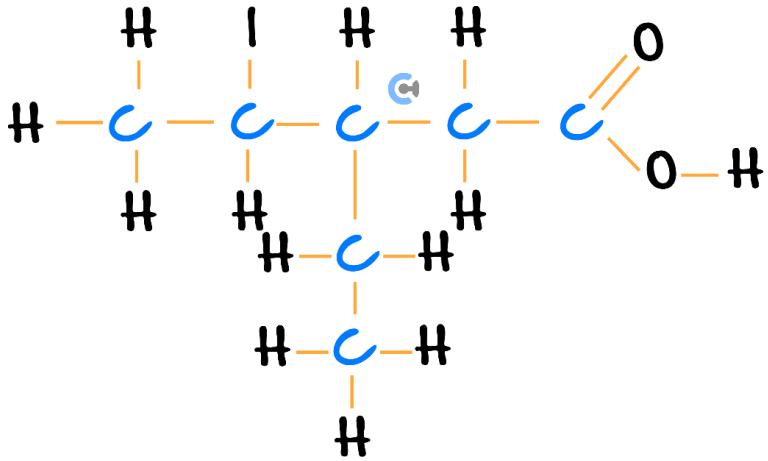
Main Chain	Side Chain
Originally [carboxylic acid] / [alcohol] end	Originally [carboxylic acid] / [alcohol] end
Naming: [Prefix] / [Suffix] of ___ '-oate' ___	**Naming:** [Prefix] / [Suffix] like alkyl groups

Drawing Esters from Name:

Beginning Portion of name ending with '-yl'	Ending Portion of name ending with '-oate'
[Main] / [Side] chain	[Main] / [Side] chain
Attached to side with [C = O] / [−O −]	Attached to side with [C = O] / [−O −]

Question 1 Walkthrough.

Name the following molecule.



3-ethyl-4-iodopentanoic acid

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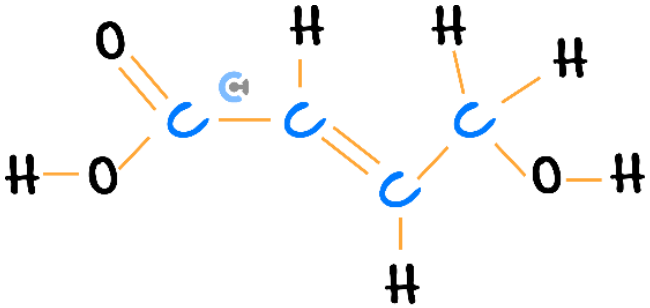
Question 2 Walkthrough.

Name the following molecule.



4-hydroxybut-2-enoic acid

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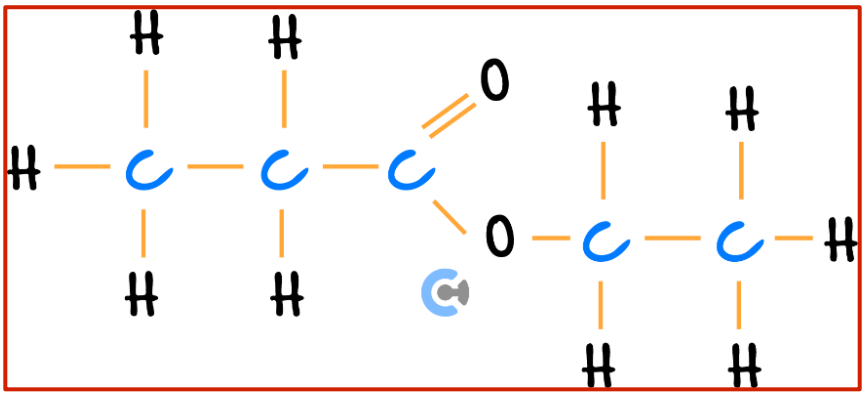
Question 3 Walkthrough.

Larry knows that a particular ester is ethyl propanoate.

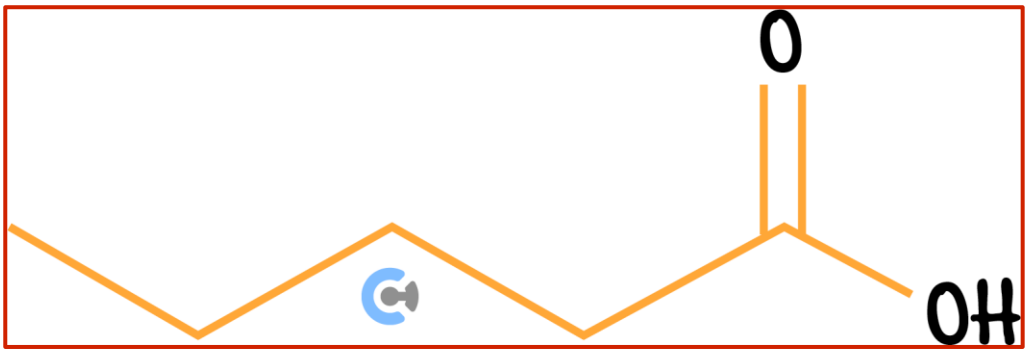
a. Draw the structural formula of ethyl propanoate.



b. Write the semi-structural formula for the reaction between an alcohol and carboxylic acid to form ethyl propanoate.

$$CH_3CH_2COOH + CH_3CH_2OH \rightarrow CH_3CH_2COO\,CH_2CH_3 + H_2O$$

c. Draw the skeletal formula for the functional isomer of ethyl propanoate.



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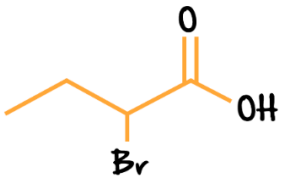
Section B: Warm Up (14 Marks)

INSTRUCTION: 14 Marks. 9 Minutes Writing.

Question 4 (5 marks)

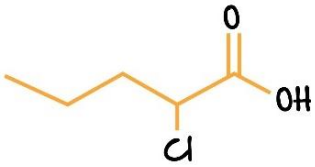
Provide the IUPAC name for the following molecules:

a. (1 mark)



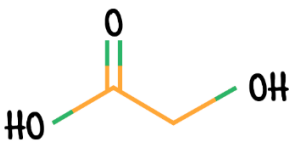
2-bromobutanoic acid

b. (1 mark)



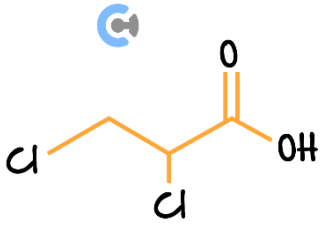
2-chloropentanoic acid

c. (1 mark)



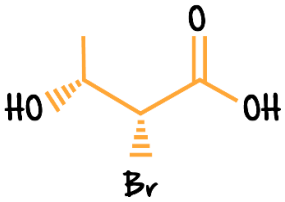
Hydroxyethanoic acid

d. (1 mark)



2,3-dichloropropanoic acid

e. (1 mark)

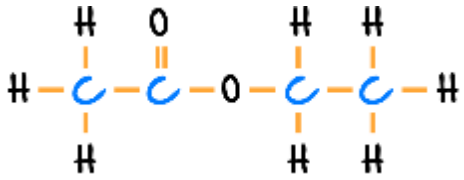


2-bromo-3-hydroxybutanoic acid

Question 5 (1.5 marks)

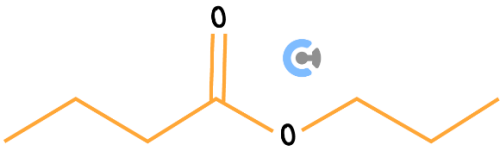
For the following esters, identify the reactants which were used to produce them.

a. (0.5 marks)



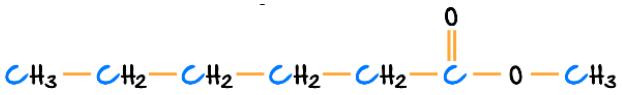
Ethanol and Ethanoic acid

b. (0.5 marks)



Propanol and Butanoic acid

c. (0.5 marks)



Methonol and Hexanoic acid

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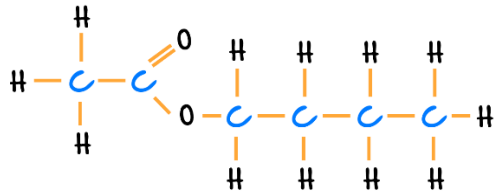
Question 6 (1.5 marks)

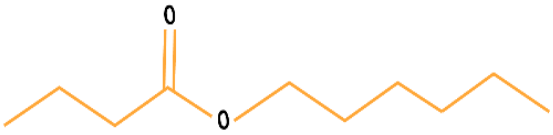
Provide the IUPAC name for the following esters.

a. (0.5 marks)



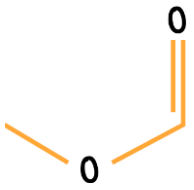
Butyl ethanoate

b. (0.5 marks)



Hexyl butanoate

c. (0.5 marks)



methyl methanoate

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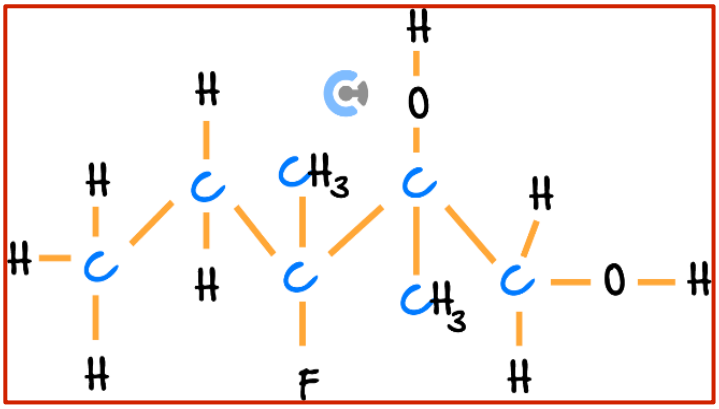
Question 7 (6 marks)

For the following molecules, draw their structural formula and give the semi-structural formula.

a. 3-fluoro-2,3-dimethylpentane-1,2-diol.

i. Structural formula. (1 mark)

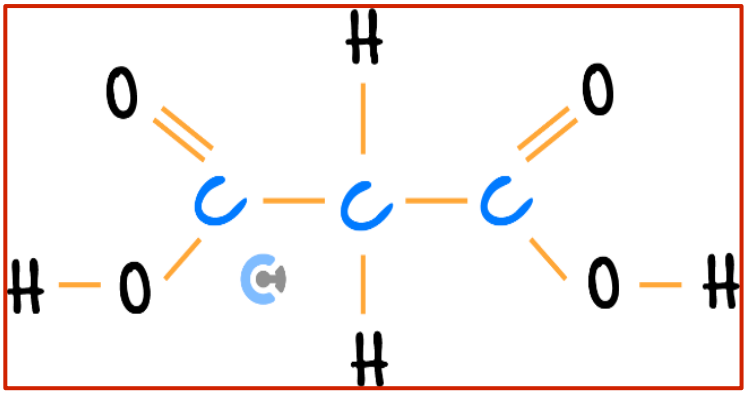


ii. Semi-structural formula. (1 mark)

$CH_3CH_2CF(CH_3)COH(CH_3)CH_2OH$

b. Propanedioic acid.

i. Structural formula. (1 mark)

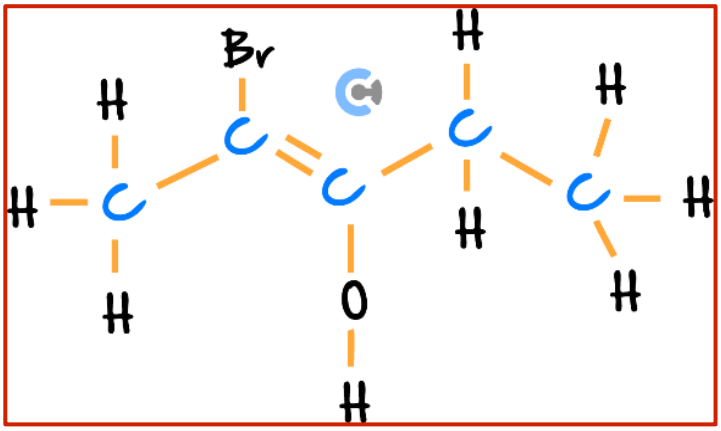


ii. Semi-structural formula. (1 mark)

$HOCOCH_2COOH$

c. 2-bromopent-2-en-3-ol.

i. Structural formula. (1 mark)



ii. Semi-structural formula. (1 mark)

$CH_3CBrCOHCH_2CH_3$

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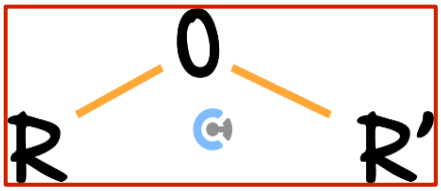
Section C: Ramping Up (13 Marks)

INSTRUCTION: 13 Marks. 10 Minutes Writing.

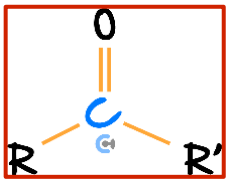
Question 8 (8 marks)

Janita is interested in the molecular structure and arrangement of different chemical compounds, especially those in organic chemistry. Of these structures, she particularly wishes to investigate functional groups.

a. Draw an ether functional group. (1 mark)



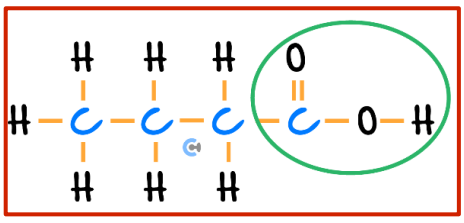
b. Draw a carbonyl functional group. (1 mark)



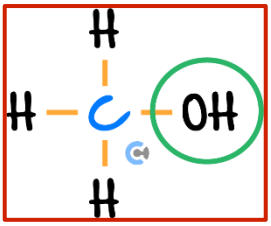
c. Why can oxygen not be bound to 3 different atoms? Explain with reference to the valence number. (2 marks)

Oxygen has a valence number of 6, which means it needs only 2 more electrons to form a full outer shell. If it binds to 3 atoms, it will gain 3 extra electrons, which exceeds the number it needs to form a stable outer shell.

d. Draw a molecule of butanoic acid, circling the primary functional group. (2 marks)



e. Draw a molecule of methanol, circling the primary functional group. (2 marks)



Question 9 (5 marks)

Adya is investigating the isomerism of organic compounds such as esters and wishes to take a look at a few specific examples.

a. Explain the difference between a structural and functional isomer. (2 marks)

A structural isomer has a different structural formula with the same functional group. A functional isomer has a different functional group, whilst maintaining the same molecular formula.

b. List all of the functional isomers of butanoic acid with an ester functional group. (2 marks)

Methyl propanoate
Ethyl Ethanoate
Propyl Methanoate

c. Adya finds another molecule which is not an acid or an ester but has the same formula as butanoic acid. What type of functional group could this molecule have? (1 mark)

Hydroxyl (would need two)

Space for Personal Notes

Section D: Getting Trickier I (9 Marks)

INSTRUCTION: 9 Marks. 7 Minutes Writing.

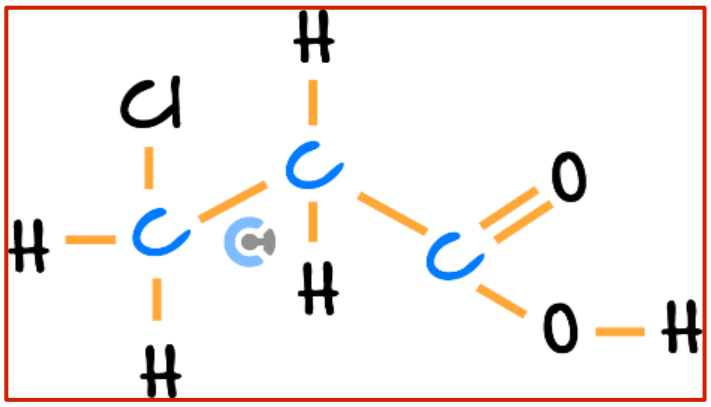
Question 10 (9 marks)

Consider the carboxylic acid 3-chloropropanoic acid.

a. State the **two** functional groups that make up the carboxyl group. (1 mark)

Hydroxyl and Carbonyl

b. Draw the structural formula of the carboxylic acid. (1 mark)



c. Given that structure drawn in **part b.**, certain assumptions can be made using your prior knowledge of intermolecular bonding.

i. List the type(s) of intermolecular bonding can 2-chloro-2-methylbutanoic acid form. (2 marks)

Dispersion forces, dipole-dipole interaction and hydrogen bonding.

ii. Is it likely that when this carboxylic acid is mixed with water, it will dissolve? Justify your answer. (3 marks)

Yes, it is likely that it will dissolve in water because the molecule contains the $-COOH$ group which can form hydrogen bonds with water molecules, hence allowing the carboxylic acid to be surrounded by water and hence, dissolve.

iii. The chlorine atom is then replaced with a hydrogen atom, resulting in the molecule turning into propanoic acid. State the impact would this have on the intermolecular bonding exerted by the molecule. (2 marks)

This would make the molecule less polar, since chlorine is a polar group, however, since chlorine cannot form hydrogen bonds and the $-COOH$ is intact, the molecule will remain largely polar and would be able to exert the same intermolecular bonding since, hydrogen bond is merely a stronger form of dipole-dipole interaction.

Space for Personal Notes

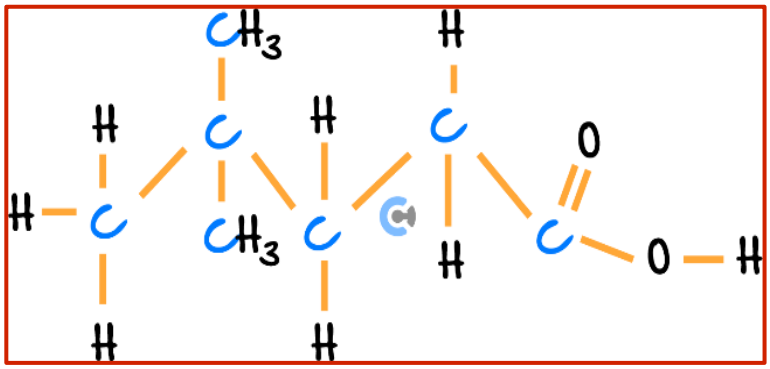
Section E: Getting Trickier II (10 Marks)

INSTRUCTION: 10 Marks. 9 Minutes Writing.

Question 11 (10 marks)

Consider organic molecules that fall under the category of carboxylic acids.

a. Draw the structural formula for a molecule of 4,4-dimethylpentanoic acid. (1 mark)



b. Write out the semi-structural formula for the molecule above and circle the primary functional group of the structural formula. (1 mark)

$CH_3C(CH_3)_2CH_2CH_2COOH$

c. Explain why the carboxyl group is always at the end of the organic molecule and never in the centre. (2 marks)

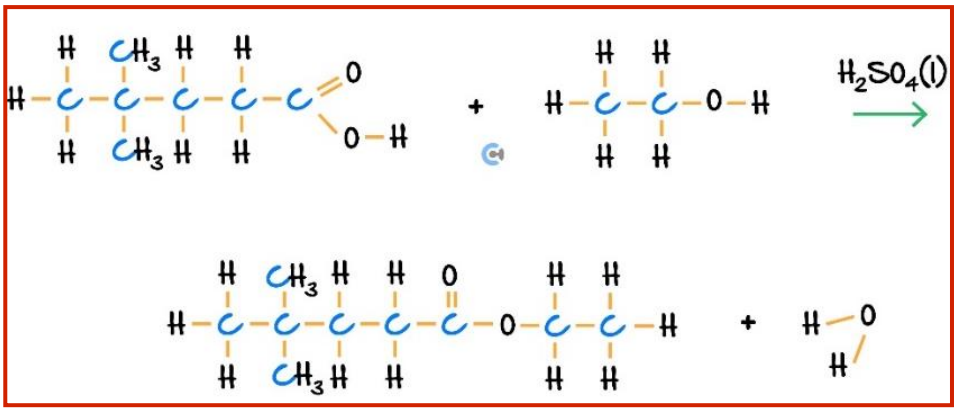
The carboxyl group is always at the end of the molecule because the carbon that is a part of the carboxyl has already had 3 of its 4 bonds taken up, so it only can form one more single bond. Hence, it will always be bonded to only one carbon and the only configuration that allows this is to be at the end of the molecule.

d. Consider when a molecule of 4,4-dimethylpentanoic acid reacts with ethanol.

i. Name the type of reaction. (1 mark)

Esterification

ii. Write out the structural formula of the reaction, showing all bonds. (3 marks)



iii. What is the percentage composition of oxygen in the resulting ester? (2 marks)

Molar mass $= 108 + 17 + 32 = 157\ g\ mol^{-1}$
$\% = 32/157 \times 100 = 20.38\%$

Let's take a BREAK!

Space for Personal Notes

Section F: VCAA-Level Questions I (10 Marks)

INSTRUCTION: 10 Marks. 30 Seconds Reading. 10 Minutes Writing.

Question 12 (10 marks)

Esters are widely used for scents on a global scale, being mass-produced in factories for specialised smells which are then sent to companies for specific purposes. One of the main esters produced is that of propylethanoate.

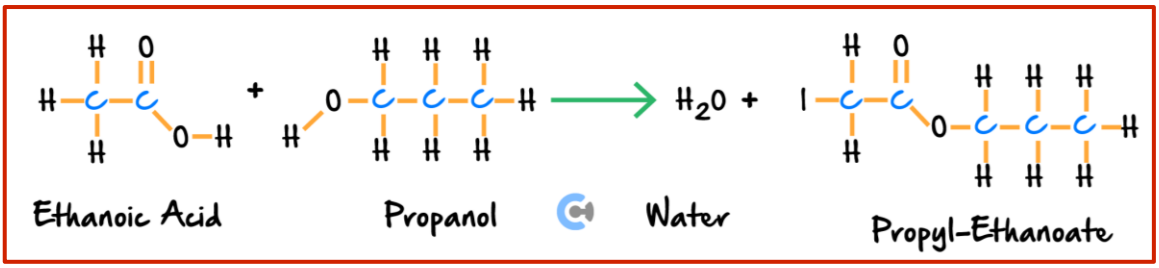
a. Identify the reactants required to produce this ester. (1 mark)

Propanol and ethanoic acid.

b. Identify the conditions required to produce this ester. (1 mark)

There needs to be concentrated sulfuric acid.

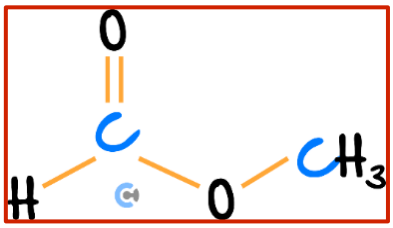
c. Draw the structural equation of the formation of this ester. (2 marks)



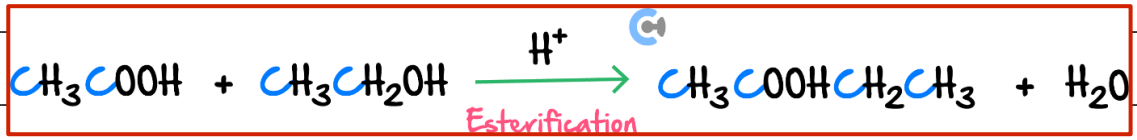
d. How many other structural isomers of this ester exist? (1 mark)

6

e. Draw a functional isomer of ethanoic acid. (1 mark)



f. Another ester which is also commonly produced, is formed by mixing ethanol and ethanoic acid. Write the semi-structural formula for this reaction. (2 marks)



g. Name the ester produced in this reaction. (1 mark)

Ethylethanoate

h. Explain what a catalyst is and why one is required for this reaction. (1 mark)

A catalyst increases the rate of reaction.
It is needed as this reaction does not occur spontaneously.

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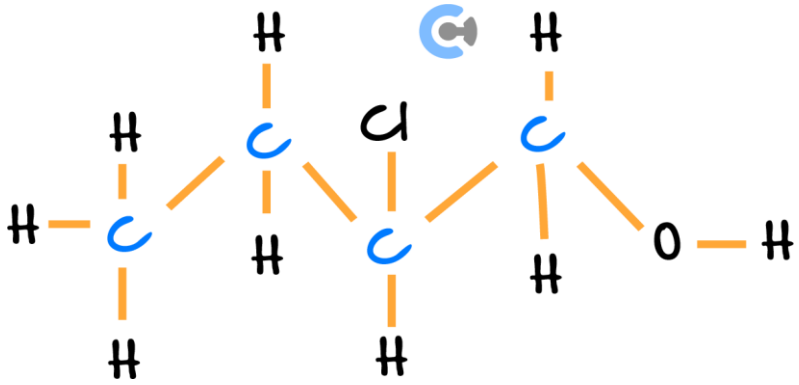
Section G: Multiple Choice Questions (10 Marks)

INSTRUCTION: 10 Marks. 10 Minutes Writing.

Question 13 (1 mark)

What is the IUPAC name for the following molecule?



A. 2-chlorobutan-1-ol

B. 3-chlorobutan-4-ol

C. 1-chlorobutan-2-ol

D. 2-chlorobutanol

Question 14 (1 mark)

In organic molecules, how many double bonds can oxygen form?

A. 0

B. 1

C. 2

D. 3

Space for Personal Notes

Question 15 (1 mark)

Which one of the following molecules contains a carbonyl group?

A. $CH_3CH(CH_3)OCH_2CH_3$

B. CH_3CH_2OH

C. $CH_3CH_2OCH_2CH_3$

D. $CH_3COCH_2CH_3$

Question 16 (1 mark)

Which one of the following semi-structural formulae correctly represents the molecule of methylpropanoic acid?

A. $CH_3CH_2CH_2COOH$

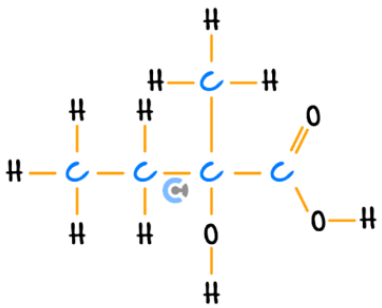
B. CH_3CH_2COOH

C. $CH_3CH_2(CH_3)COOH$

D. $CH_3CH_2CH_2(CH_3)COOH$

Question 17 (1 mark)

What is the IUPAC name for the following organic molecule?



A. 2-hydroxy-2-methylpropanoic acid

B. 2-hydroxy-2-methylbutanoic acid

C. 2,2-methylhydroxybutanoic acid

D. 2-methyl-2-hydroxybutanoic acid

Question 18 (1 mark)

What is the name of the product that is formed between ethanol and propanoic acid in an esterification reaction?

A. Propyl propanoate

B. Ethyl propanoate

C. Propyl ethanoate

D. Ethyl ethanoate

Question 19 (1 mark)

Which one of the following details the reaction that produces the ester propyl methanoate as a result?

A. $CH_3CH_2CH_2OH + HCOOH \rightarrow HCOOCH_2CH_2CH_3$

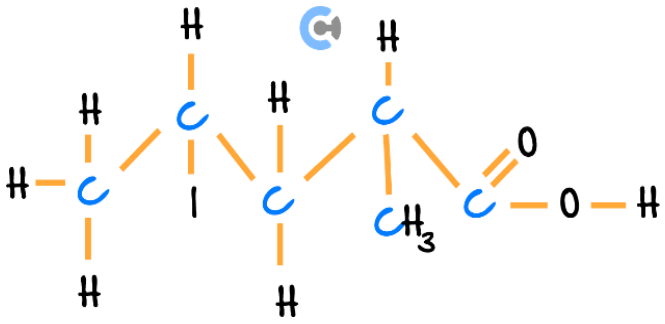
B. $CH_3CH_2OH + HCOOH \rightarrow HCOOCH_2CH_3 + H_2O$

C. $CH_3CH_2CH_2OH + HCOOH \rightarrow HCOOCH_2CH_2CH_3 + H_2O$

D. $CH_3OH + CH_3CH_2COOH \rightarrow CH_3CH_2COOCH_3 + H_2O$

Question 20 (1 mark)

What is the IUPAC name for the following organic molecule?



A. 3-iodo-3-methylpentanoic acid

B. 4-iodo-2-methylpentanoic acid

C. 2-iodohexanoic acid

D. 2-iodo-4-methylpentanoic acid

Question 21 (1 mark)

Which one of the following is **not** necessary for an esterification reaction to occur?

A. Concentrated sulfuric acid catalyst.

B. High-pressure environment.

C. High-temperature environment.

D. The presence of an alcohol and a carboxylic acid.

Question 22 (1 mark)

What is the semi-structural formula for pentyl propanoate?

A. $CH_3(CH_2)_4CH_2CH_2CH_3$

B. $CH_3CH_2CH_2CH_2COOHCH_2CH_2CH_3$

C. $CH_3CH_2COOCH_2CH_2CH_2CH_3$

D. $CH_3(CH_2)_2COOHCH_2(CH_2)_3CH_3$

Space for Personal Notes

Section H: VCAA-Level Questions II (9 Marks)

INSTRUCTION: 9 Marks. 30 Seconds Reading. 9 Minutes Writing.

Question 23 (9 marks)

The analysis of a certain organic molecule that contains 54.5% carbon, 36.4% oxygen and the remainder is hydrogen.

a. The identity of the molecule is required before any further analysis can be done.

i. Determine the empirical formula for the molecule. (2 marks)

$54.5/12 = 4.54/2.275 \sim 2$
$36.4/16 = 2.275/2.275 \sim 1$
$12.1/1 = 12.1/2.275 \sim 6$
Hence, empirical formula is $C_3H_6O_2$.

ii. The molecule has a molar mass of 74 $g\ mol^{-1}$. State the molecular formula. (1 mark)

$C_3H_6O_2$

iii. From this molecular formula, is it possible to determine the presence of any specific functional groups? Explain your answer. (2 marks)

No, it isn't because it is possible the molecule can contain any of the functional groups that have oxygen in them, i.e. carboxylic acid, ester, carbonyl, alcohol, ether. This is because the molecular formula doesn't tell us about arrangement, it merely tells us what is in the molecule itself.

b. Given your answer to **part a.**, information has been provided that the molecule is an unbranched ester.

i. State all possible names for the ester. (2 marks)

Methyl ethanoate or ethyl methanoate.

ii. Draw the semi-structural esterification reaction for the ester that is produced from ethanoic acid. (2 marks)

$CH_3OH + CH_3COOH \rightarrow CH_3COOCH_3 + H_2O$ (with H_2SO_4 catalyst).

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Section I: Extension Questions (10 Marks)

Question 24 (10 marks)

The way that an organic molecule is structured, especially with the addition of certain functional groups, relates directly to their observed properties.

a. Suggest a reason as to why in organic chemistry, it's preferred to use semi-structural formulas over structural formulas and molecular formulas. (2 marks)

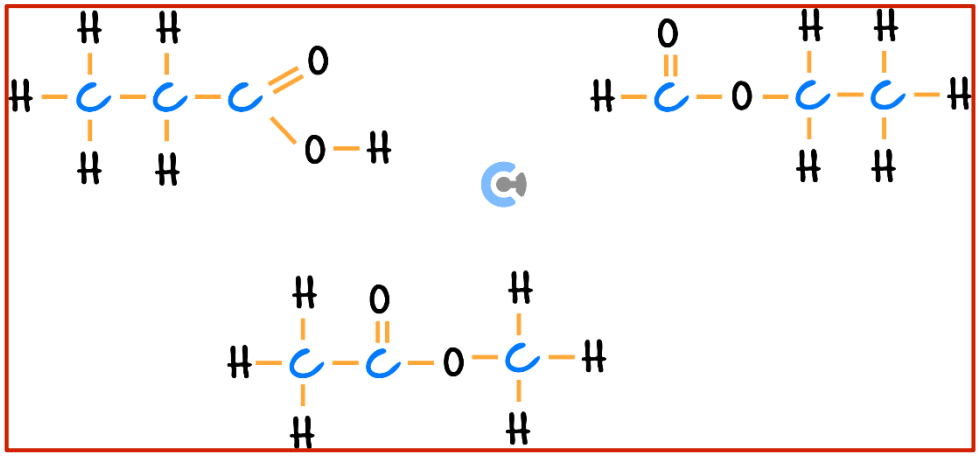
It's preferable to use semi structural formula over structural formula because a lot of organic molecules are repetitive in nature and writing them out fully would be inconvenient so this is faster. In addition to that, semi-structural provides information on what functional groups are present and how they are arranged whereas molecular formula does not.

b. Given the molecular formula of $C_3H_6O_2$, multiple isomers can be considered.

i. What type of functional groups can this be attributed to? (2 marks)

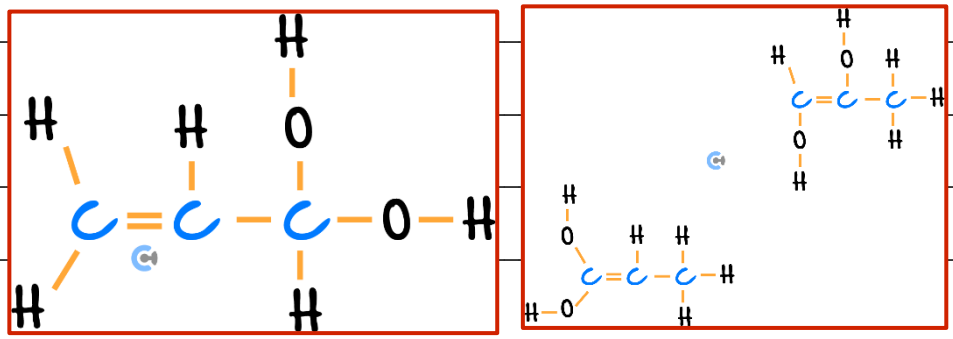
Ester, carboxyl group, carbonyl, hydroxyl(s), etc.

ii. Draw out the structural formulae of all the possible isomers of $C_3H_6O_2$ that are either a carboxylic acid or an ester. (3 marks)



iii. Could the molecular formula be an isomer for an alcohol? Justify your answer with relevant structural formulae. (3 marks)

Yes



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